IPA

SOUTHCOP

4–14 DECEMBER 2019

QUEENSTOWN, NEW ZEALAND

1st SOUTHERN HEMISPHERE CONFERENCE ON PERMAFROST

CONFERENCE HANDBOOK

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CONFERENCE COMMITTEE WELCOME

Nau mai, Haere mai, Welcome

As convenor of the first ever International Permafrost Association Southern Hemisphere Regional Conference on Permafrost, I am delighted to welcome you to Queenstown, Aotearoa - New Zealand. The bringing together of permafrost researchers from all over the world is an exciting event for us, so I thank you for the effort you have made to travel here to join us in our far corner of the world. I am looking forward to your participation, an experience that I am sure will be fulfilling and enjoyable for all, both scientifically and socially.

The picturesque setting of Queenstown is truly stunning, with landscapes formed as a result of our location on the boundary of the Pacific and Australian tectonic plates, overprinted with the effects of the last glaciation. We have an environment unique to New Zealand, and the world, with a blend of natural beauty, productive land uses, and adventure tourism. We hope to share some understanding of our landscapes through the conference fieldtrips. Even if you are not planning on coming on a fieldtrip I do hope you will join us, for a public lecture on Monday from 4.30 to 5.30pm, in the Millenium Hotel, that will give you an understanding of the landscape, geological, and climate, history of the area that surrounds you here.

Finally, I wish to thank the IPA executive, our conference steering committee, our fieldtrip leaders who have freely given thier time and shared thier expertise, On-Cue – our conference organisers, and especially you, the participants, for making the conference a reality. Have a safe and enjoyable trip. I hope you return home a little wiser, with some new insights into our planet, and inspired to continue with your important work in improving our understanding of permafrost, cryosols, and the global environment.

Ngā mihi nui

Dr Megan Balks

CONFERENCE STEERING COMMITTEE

- Megan Balks, *New Zealand – Chair*
- Hanne Hvidtfeldt Christiansen, *Norway*
- Sarah Strand, *Norway*
- Megan Balks, *New Zealand*
- Peter Almond, *New Zealand*
- Tanya O'Neill, *New Zealand*
- Fiona Shanhun, *New Zealand*
- Annette Carshalton, *New Zealand*
- Mauro Guglielmin, *Italy*
- Gonçalo Vieira, *Portugal*
- Ian Meiklejohn, *South Africa*
- Shelley Macdonell, *Chile*
- Carlos Schaefer, *Brazil*
- Britta Sannel, *Sweeden*
- Fujun Niu, *China*
- Marc Oliva, *Spain*
- Lea Boodee, *New Zealand*

CONFERENCE SPONSORS

Thank you to all our sponsors. This conference is made possible only through the commitment of many individuals and groups.

Antarctica New Zealand

remote sensing

GENERAL INFORMATION

Registration Desk

If you require any assistance throughout the conference please see the conference organisers at the Registration Desk on Level 1.

A Conference Notice Board will be placed at the Registration Desk and will be used to display conference information, programme changes, announcements and messages. Please check the board regularly.

Internet

Wireless internet broadband is provided free to conference delegates in the Millennium hotel, **the password is Permafrost19**

Name Tags

Delegates are requested to wear their name badges to all sessions and social functions. Delegates have navy blue lanyards and student helpers will be wearing green lanyards, please ask them for any assistance.

Cell Phones

Please ensure that cell phones are turned off, or on silent, during all presentations.

No Smoking

There is no smoking allowed inside the venue.

Parking

Car parking is limited, please check with the hotel for availability. You can park in the surrounding streets, please observe the signposted time limits.

Road Crossing

Please cross between hotels using the traffic island and take care - this is a busy road.

Taxis

Queenstown Blue Bubble Taxis
Phone: +64 3 450 3000

Super Shuttle
Phone: +64 9 522 5100

The Queenstown Airport is approx. 15–20 minutes' drive from the Millennium Hotel.

Public Transport

You can go anywhere on the Queenstown bus network for just $2 with a GoCard. You can get a GoCard from your bus driver, at the Queenstown Airport Paper Plus or at the Stanley Street kiosk for $5. The minimum top up for GoCards is $10. GoCards can be topped up anywhere that they're sold.

You don't need a GoCard to take the bus, you can pay for your fare with cash. However, a cash fare is $5 per trip for an adult and $4 for a child – and for trips that begin or end at the airport, the cash fare is $10. It's cheaper with GoCard.

To see a map and timetable of Queenstown bus services, visit: orc.govt.nz/public-transport/queenstown-buses

Public Transport Accessability

All Queenstown buses have extra space for wheelchairs and prams/pushchairs. If you use a wheelchair, buses have the ability to kneel close to the kerb to make it easy for you to board. Because accessibility can differ from stop to stop and bus to bus, the driver may have to set up a wheelchair ramp to help you board.

If you have a motorised wheelchair, please note that size can also be a factor for access on the bus. There is a maximum weight limit of 300 kg and a maximum width of 700 mm wide.

Please contact Ritchies Queenstown for more information on wheelchair access.
Phone: +64 3 441 4471

Meals

All conference catering will be served in Galaxy III, if you have advised us of your special dietary requirements, these have been forwarded to the caterers and will be available on a separate table individually marked.

At the Conference Dinner, please make yourself known to the waiting staff and they will make the necessary arrangements for your special meal. If you have any dietary requirements that we are not aware of, please see the Conference Organisers at the Registration Desk on arrival at the conference.

GENERAL INFORMATION

Conference Contact Number

For assistance during the conference, please call Lea Boodee from On-Cue Conferences on **+64 21 117 0916**

Loading Presentations

Please load your presentation at the Registration Desk – this should be done at least two sessions prior to your scheduled presentation session time.

Poster Presentations

Posters must be displayed before 10am on Sunday 8 December. Poster boards are in the Galaxy III Room – velcro dots will be provided.

Session Chairs

Please can all session chairs be in their room at least 10 minutes prior to the start of the session. Please familiarise yourself with the AV equipment. If you have any questions, locate the student helper or AV technician, who will be close by. It is very important that presentations do not run over their allocated total of 15 minutes so please ensure presenters start and finish on time. If people want to move rooms during sessions they should do so at the start of the 3-minute question/discussion part of the presentation.

MEDICAL INFORMATION

New Zealand Emergency Services

Ambulance, Fire and Police. Dial 111 from any public, private telephone or mobile phone in New Zealand.

Queenstown Police

Phone: +64 3 441 1600 from within Queenstown. The police station is located at 11 Camp Street, Queenstown.

Queenstown Hospital

Phone: +64 3 441 0015
The Lakes District Hospital: 20 Douglas Street, Frankton.

Doctors & Medical Centres

Queenstown Medical Centre:
9 Isle Street, Queenstown & Remarkables Park.
Phone: +64 3 441 0500

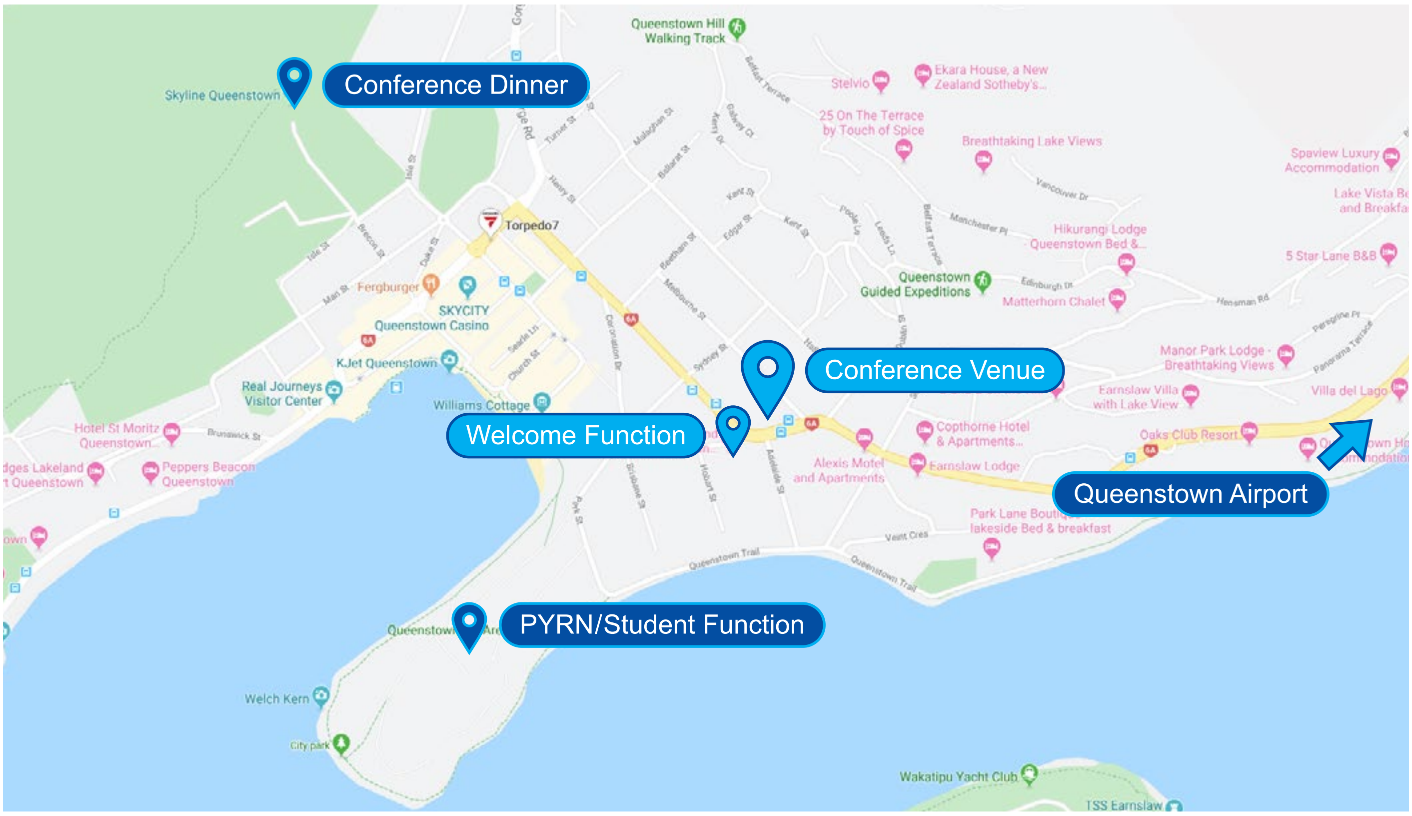
Arrowtown Surgery:
Berkshire Street, Arrowtown.
Phone: +64 3 442 1215

Wakatipu Medical Centre:
11 McBride Street, Frankton.
Phone: +64 3 442 2288

Chemist/Pharmacy

Unichem Wilkinson's Pharmacy:
The Mall – Queenstown Ballarat Street & Rees Street, Queenstown.
Phone: +64 3 442 7313
Hours: 8.30am – 10pm every day

QUEENSTOWN CITY MAP



CONFERENCE VENUE

Millennium Hotel Queenstown

32 Frankton Road, Queenstown

Welcome Function

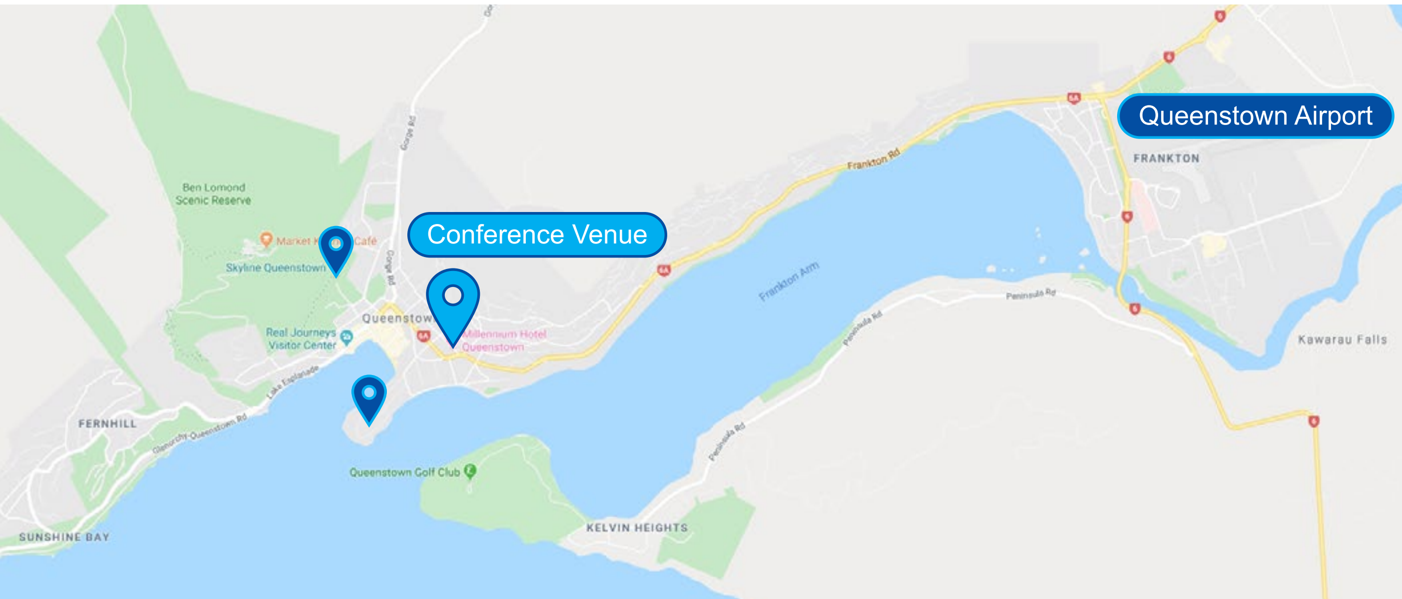
Copthorne Hotel and Resort,
Corner Frankton Road & Adelaide Street,
Queenstown

PYRN/Student Function

Queenstown Bowling Club,
Queenstown Gardens,
19 Park Street, Queenstown

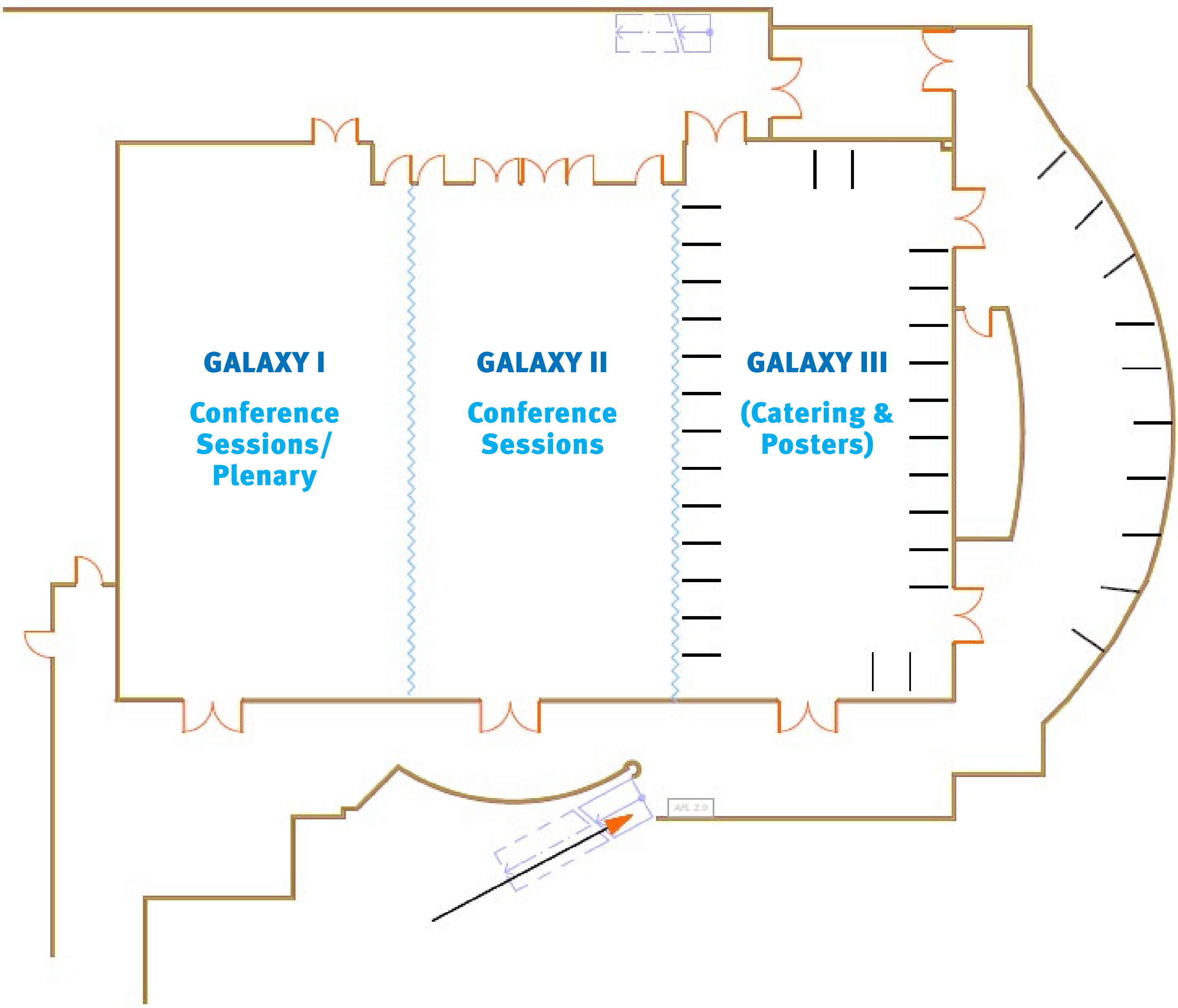
Conference Dinner

Skyline Queenstown,
Brecon Street, Queenstown



CONFERENCE VENUE FLOOR PLAN

MILLENNIUM HOTEL – LEVEL ONE CONFERENCE ROOMS



EMERGENCY INFORMATION

In the event of an emergency you will hear an alarm at the hotel, please follow staff instructions, evacuate the building and assemble outside. In the event of an earthquake, stop, drop and cover. When the shaking stops make your way out of the building to the assembly point.

This information will be covered each day in conference housekeeping, preceeding the Keynote presentation.

SOCIAL FUNCTIONS

WELCOME FUNCTION

Time: Saturday 7 December, 5pm–7pm
Location: Impressions Bar, Copthorne Hotel and Resort (opposite Millennium Hotel)
Additional Tickets: $35
Dress: Casual

Renew old friendships and make new acquaintances as we welcome you to Queenstown. This function is included in the registration fee (excluding day registrations). Additional tickets may be purchased for guests.

PYRN/STUDENT FUNCTION

Time: Sunday 8 December, 5:30pm–8pm
Location: Queenstown Bowling Club, Queenstown Gardens, 19 park Street

This function is open to PYRN members and students.
Pizza and 1x drink is included.

CONFERENCE DINNER

Time: Monday 9 December, please arrive no later than 6:45pm
Location: Skyline Gondola Queenstown, Brecon Street
Additional Tickets: $120
Ticket Includes: 3-course meal and some beverages (then cash bar)
Dress: Semi-formal

The Conference Dinner will be the premier event of the conference and is not to be missed by delegates and guests. The Conference Dinner is by ticket only.

Please make your own way to the Gondola.

PUBLIC LECTURE–MON 9 DECEMBER

We invite you to attend two talks that provide an insight into the geological and climate history of the region and the landscape you will see about you in Queenstown and on the conference field trips

AN INTRODUCTION TO THE GEOLOGY AND TECTONICS OF THE SOUTHERN ALPS

Speaker: Simon Cox (Principal Scientist, GNS Science Dunedin)
Time: Monday 9 December, 4.30pm–5.30pm
Location: Millennium Hotel

Dr Simon Cox is a Principal Scientist at GNS Science in Dunedin, with professional expertise in the fields of geological mapping and tectonics. Simon graduated with a PhD from University of Otago in 1993, then developed consulting experience in the mineral industry. Simon now sits in GNS Science's Natural Hazards Division, where his work involves: fault and earthquake research in the South Island; the mapping of rock avalanches, earthquake-induced landslides and alluvial fan flooding hazards; and building a digital geological map dataset of Antarctica. He has led immediate earthquake response, was part of the Alpine Fault Drilling Project, run experiments on Southern Alps hot springs, and an Earthquake Hydrology project that demonstrates liquefaction damage during the 2010-2011 Canterbury earthquakes was exacerbated by leakage and release of groundwater from artesian aquifers. As a regular recipient of national geoscience awards, he is well respected in the New Zealand earth science community. Widely recognised as a public speaker and communicator of science, Simon also maintains close ties with local iwi/Māori, supervises research students, collaborates internationally and is cited globally, and has a wide-network to science end-users.

SOUTHERN ALPS GLACIERS, GEOMORPHOLOGY AND HISTORY OF CLIMATE CHANGE

Speaker: David Barrell (Senior Scientist, GNS Science Dunedin)
Time: Monday 9 December, 4.30pm–5.30pm
Location: Millennium Hotel

David Barrell is a general practitioner in the fields of geology and geomorphology. Since graduating from the Engineering Geology programme at the University of Canterbury in 1989, David has worked mainly in the central and southern South Island, on a variety of research and consultancy projects. He was part of the geological team involved in landslide remediation for the Clyde Dam in the early 1990s, before joining the GNS Science regional geological mapping team. With a particular interest in landforms, surficial geological processes and natural hazards, David has worked extensively on earthquake geology investigations of active faults, and the assessment of landslide and liquefaction hazards. He was involved in immediate science responses following the 2010-2011 Canterbury and Christchurch earthquakes, and more recently, the 2016 Kaikoura Earthquake. For the past 15 years, David has been part of an international research team mapping and dating glacial landforms in the Southern Alps to obtain a chronology of past climate change in the New Zealand sector of the Southern Hemisphere. He is the lead author of an award-winning geomorphological map of the glacial landforms of the central South Island. David's expertise on the geology and landforms of southern New Zealand is nationally recognised, and his advice is widely sought.

OPTIONAL FIELD TRIPS – TUESDAY 10 DECEMBER: QUEENSTOWN OR DOUBTFUL SOUND

Option 1: Rock and roll: geology, geomorphology and natural hazards in western Otago
Cost: $75 per person
Includes: Transport and a packed lunch
Time: Departs from the Millennium Hotel at 8.30am
Returning: Returning to the Millennium Hotel at 5:30pm

Join local geologists David Barrell and Simon Cox (GNS Science) on a one-day bus tour that will examine the geology, landforms and active tectonic and geomorphic processes on the circuit from Queenstown, through Cromwell, Wanaka, Hawea, Clyde and returning to Queenstown. Highlights include the structure and origins of Mesozoic-age schist bedrock, and its significance in the evolution of the Zealandia continent, glacially-scoured mountain landscapes; ice-age moraines and outwash terraces; paleoclimate history; range and basin tectonic geomorphology; surface expression of active faults; landslides and alluvial fans; hydroelectric power and engineering for the Clyde Dam; and historic gold mining.

This field trip is currently sold out, if you are interested in attending please ask at the Conference Registration Desk to be included on a waitlist.

Option 2: Doubtful Sound Trip
Cost: $335 per person
Includes: Deluxe Picnic Lunch
Time: A Real Journeys coach will depart the Millennium Hotel at 7:40am
Return: Returning to the Millennium Hotel at 8:15pm

This trip is organised and run by local operators, Real Journeys.

Travel to the heart of Fiordland National Park and take in the beauty and vastness of remote Doubtful Sound on our Wilderness Cruise. It will take your breath away as you experience its deep wilderness.

A 3-hour cruise of Doubtful Sound, exploring beautiful waterways on our way to meet the Tasman Sea. Commentary by their knowledgeable onboard nature guide. Wildlife viewing, including dolphins, fur seals and even occasionally penguins.

Start with a cruise across Lake Manapouri, followed by a coach trip over the epic Wilmot Pass through Fiordland's rainforest and into the Sound.

To book, please ask at the Conference Registration Desk.

For more information, visit:
www.realjourneys.co.nz/en/experiences/cruises/doubtful-sound-wilderness-cruises/

Clyde Dam

Doubtful Sound

PROGRAMME

PRE-CONFERENCE FIELD TRIP, 3–6 DEC

Travel from Christchurch to Queenstown via Mt Cook National Park

WELCOME FUNCTION, SAT 7 DEC

3:00pm – 5:30pm	Pre Conference Registration (Millennium Hotel)
3:30pm – 5:30pm	**PYRN Networking Session** at the Copthorne Hotel
5:00pm – 7:00pm	**Welcome Function** at the Copthorne Hotel

DAY 1 – SUN 8 DEC, 8AM–10:40AM

8:00am	Registration Desk Opens
9:00am – 9:15am	Mihi/Welcome Chair: Megan Balks, Conference Convenor IPA Welcome, Hanne Hvidtfeldt Christiansen, IPA President Room: Galaxy I
9:15am – 10:15am	*Plenary Speakers* **Professor Antoni Lewkowicz,** *University of Ottawa,* "The Impermanence of Permafrost" **Dr Fiona Shanhun,** *Acting Chief Scientific Advisor – Antarctica New Zealand,* "Looking South: The New Zealand Antarctic Programme" Chair: Hanne Christiansen Room: Galaxy I
10:15am – 10:40am	Morning Tea

DAY 1 – SUN 8 DEC, 10:40AM–1:25PM

Room	Galaxy I	Galaxy II	Galaxy III
Session number/ name	1. Permafrost Engineering	2. Analogy between terrestrial Martian and remote-sensed data	Poster Sessions
Session Chair	Adrian McCallum and Dongqing Li	Anshuman Bhardwaj and Javier Martin-Torres	
10:40am – 11:00am	*Session Keynote* Applicability evaluation of cast-in-place bored pile in permafrost regions **Zhi Wen** *State Kay Laboratory of Frozen Soil Engineering*	*Session Keynote* Sublimation in the CRREL permafrost Tunnel- implications for ice-loss landforms on Mars **Thomas Douglas** *Cold Regions Research and Engineering Laboratory*	
11:00am – 11:15am	Analysis of cooling effect on a concrete thermal pile in permafrost regions **Yunhu Shang** *State Key Laboratory of Frozen Soil Engineering, Chinese Academy of Sciences*	Morphological analogies between ice-debris complexes on Mars and in Himalaya: First results of a high-resolution basin-scale inventory **Lydia Sam** *Luleå University of Technology*	
11:15am – 11:30am	Thermal behavior of a novel crushed-rock embankment for expressway in permafrost regions **Minghao Liu** *Northwest Institute of Eco-environment And Resources, Chinese Academy of Sciences*	Analyzing Change in Russian Arctic Urban Areas using Multiple Remote Sensing Data Sources **Ryan Engstrom** *The George Washington University*	
11:30am – 11:45pm	Effect of temperature controlled ventilated embankments under the Qinghai-Tibet Expressway **Zhenyu Zhang** *Northwest Institute of Eco-environment And Resources, Chinese Academy of Sciences*	Post-wildfire surface deformation at Batagay, Eastern Siberia, detected by L-band and C-band InSAR **Kazuki Yanagiya** *Hokkaido University*	
11:45am – 12:00pm		Application of the mathematical morphology of landscapes in Cryolithozone research **Olga Trapeznikova** *Sergeev Institute Of Environmental Geoscience of RAS*	
12:00pm – 12:15pm		Monitoring ice-free areas in the South Shetland Islands using advanced remote sensing techniques **Thomas Schmid** *CIEMAT*	
12:15pm – 1:25pm	Lunch		

DAY 1 – SUN 8 DEC, 1:25PM–3:25PM

Room	Galaxy I	Galaxy II	Galaxy III
Session number/ name	3. Permafrost Engineering continued	4. Rock Glacier identification, dynamics, and hydrological importance	Poster Sessions
Session Chair	Adrian McCallum and Zhemin You	Shelley MacDonell and Nicole Schaffer	
1:25pm – 1:45pm	*Session Keynote* Cooling performance of crushed-rock embankments and their application in permafrost regions **Mingyi Zhang** *Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences*	*Session Keynote* IPA Action Group - Rock glacier inventories and kinematics (2018-2020): ongoing work and first results **Chloé Barboux** *Department of Geosciences - Geography. University of Fribourg. Switzerland*	
1:45pm – 2:00pm	Artificial Ground Cooling using Solar Paneled Thermosyphons **Anna Wagner** *U.S. Army Cold Regions Research and Engineering Laboratory*	Using geophysical techniques to identify the presence of ice, aiding optical imagery interpretation of rock glaciers and periglacial landforms **Nicole Schaffer** *Centro De Estudios Avanzados En Zonas Áridas*	
2:00pm – 2:15pm	Field observations on thermal performance of air-convection embankment affected by surface water ponding in permafrost zones **Yanhu Mu** *State Key Laboratory of Frozen Soil Engineering, Chinese Academy of Sciences*	Mapping rock glaciers in the Southern Alps of New Zealand with Sentinel-1 InSAR **Christophe Lambiel** *University of Lausanne*	
2:15pm – 2:30pm	Settlement Problems of Land-bridge Piles in the Qinghai-Tibet Railway and Inspiration from its Treatment **Ji Chen** *Northwest Institute of Eco-environment And Resources, Cas, China*	Decadal-scale variability of polar rock glacier dynamics: Accelerating due to warming? **Norikazu Matsuoka** *University of Tsukuba*	
2:30pm – 2:45pm		Rock glaciers in the central Andes (Chile) **Cedomir Marangunic** *Geoestudios, Chile*	
2:45pm – 3:25pm	Afternoon Tea		

DAY 1 – SUN 8 DEC, 3:25PM–8PM

Room	Galaxy I	Galaxy II	Galaxy III
Session number/ name	5. ANTPAS: Antarctic permafrost, soils and ground ice	6. Rock Glacier identification, dynamics, and hydrological importance – continued	Poster Sessions
Session Chair	Marjolaine Verret and Ian Meiklejohn	Shelley MacDonell and Nicole Schaffer	
3:25pm – 3:45pm	*Session Keynote* Pan-Antarctic modelling of permafrost temperatures at 1 km scale **Jaroslav Obu** *University of Oslo*	*Session Keynote* The hidden ice of the Andes – quantifying rock glacier water storage capacities **Lothar Schrott** *University of Bonn, Department of Geography*	
3:45pm – 4:00pm	Ice table depth, ground ice and its δD-δ18O composition in cold-dry soils **Denis Lacelle** *University of Ottawa*	Rock glacier degradation and instability in the Tianshan Mountains, China: A case study **Yu Zhou** *Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences*	
4:00pm – 4:15pm	Origin of ground-ice in miocene sediments, friis hills, Antarctica **Marjolaine Verret** *Antarctic Research Centre, Victoria University of Wellington*	Hydrological processes at rock glacier using historical data of observations (Suntar-Khayata Ridge, Eastern Siberia) **Nataliia Nesterova** *St. Petersburg State University*	
4:15pm – 4:30pm	Constraining the age of ice-free permafrost environments in the South Shetland Islands **Marc Oliva** *Universitat de Barcelona*	Modeling ground temperatures to investigate potential water sources in ice-rich rock glaciers **Luisa Pruessner** *ETH Zurich*	
4:30pm – 4:45pm	Ground Temperatures in the Ahlmannryggen, Western Droning Maud Land Antarctica **Ian Meiklejohn** *Rhodes University*	Debris-covered glacier and rock glacier kinematics in the Andes (30°S), documented by 64 years of remote sensing and field observations **Sebastián Vivero** *University of Lausanne*	
5:30pm – 8:00pm	**PYRN Function** – Queenstown Bowling Club Queenstown Gardens, 19 Park Street, Queenstown		

DAY 2 – MON 9 DEC, 8AM–1:10PM

8:00am	Registration Desk Opens		
8:45am – 9:45am	Welcome *Plenary Speakers* **Thomas Schmid**, *CIEMAT*, "Soils influenced by periglacial processes in the Northern Antarctic Peninsula region" **Tanya O'Neill**, *University of Waikato*, "Soils and permafrost in the Ross Sea region of Antarctica: an overview" **Alexey Lupachev,** *Institute of physico-chemical and biological problems in soil science, Russian Academy of Sciences, Russian Federation*, "Soils and soil-like bodies of coastal Antarctica: Genesis, spatial diversity, temperature regime, age, ecological functions" Chair: Ian Meiklejohn Room: Galaxy I		
9:45am – 10:30am	Poster Session One: 1 Minute Flash Talks Chair: Megan Balks		
10:30 – 10:55am	Morning Tea		
Room	**Galaxy I**	**Galaxy II**	**Galaxy III**
Session number/ name	7. Permafrost and periglacial environments/ Sub-Antarctic Islands – sentinels of change	8. Methods to measure, monitor, and sample cryosols and permafrost/ Past environments in permafrost regions	Poster Sessions
Session Chair	Anna Liljedahl and Annette Carshalton	Marc Oliva and Jaroslav Obu	
10:55am – 11:15am	*Session Keynote* Changes in hydraulic connections in the Source Area of the Yellow River (SAYR) using isotope tracing techniques **Huijun Jin** *State Key Lab Frozen Soils Eng, Cas*	*Session Keynote* Ground thermal variability within a subarctic peat plateau landscape **Britta Sannel** *Stockholm University*	
11:15am – 11:30am	Glacier-permafrost-interaction at a thrust moraine complex in the Val Muragl, Swiss Alps **Christof Kneisel** *University of Wuerzburg, Institute of Geography and Geology*	An experimental method for obtaining transverse stress of the freezing direction in frozen soil samples **Zheng Hao** *Faculty of Engineering*	
11:30am – 11:45pm	The vegetation in the forefield of glacier in the Uj-su valley (Eastern Pamir, Tajikistan **Łukasz Chachulski** *Warsaw University of Life Sciences*	Digital soil mapping of functional soil properties of the McMurdo Dry Valleys Pierre Roudier **Manaaki Whenua - Landcare** *Research*	
11:45am – 12:00pm	Using Topography to Establish Holocene Glaciation and Volcanism on Sub-Antarctic Marion Island **Ian Meiklejohn** *Rhodes University*	Geochronology of Cryoplanation Terraces in the Yukon-Tanana Upland, Alaska **Kelsey Nyland** *Michigan State University*	
12:00pm – 12:15pm	Characteristics of ground surface temperatures at Chalaping, the source area of the Yellow River, Northeastern Qinghai-Tibet Plateau **Dongliang Luo** *Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences*	Long-term spatially distributed monitoring of thaw subsidence on Alaska's North Slope **Dmitry Streletskiy** *GWU*	
12:15pm – 1:10pm	Lunch		

DAY 2 – MON 9 DEC, 1:10PM–3:30PM

Room	Galaxy I	Galaxy II	Galaxy III
Session number/ name	9. Mountain permafrost	10. Permafrost and climate change at high latitudes	Poster Sessions
Session Chair	Sarah Strand and Song Zhang	Britta Sannel, Bernd Etzelmüller and Florence Magnin	
1:10pm – 1:30pm	*Session Keynote* Identification of water-sources in permafrost-affected catchment (33°s;70°3'w) **Sebastian Ruiz** *Instituto De Geografía, Catholic University of Chile*	*Session Keynote* Late Holocene increase in atmospheric greenhouse gas forcing due to permafrost aggradation in a subarctic peatland, NE European Russia **Minna Väliranta** *Helsinki Institute of Sustainability Science*	
1:30pm – 1:45pm	Soil thermal and moisture regime along a climosequence at the Bolivian Altiplano-Amazon watershed, Cordillera Real, Bolivia **Senra Eduardo**	High Arctic Permafrost Biogeochemistry Under Climate Change **Eleanor Jones** *University of Sheffield*	
1:45pm – 2:00pm	2D thermal modelling of unstable rock walls in Norway: Examples from Mannen and Gámanjunni **Justyna Czekirda** *Department of Geosciences, University of Oslo*	Conceptual model of formation and evolution of gas emission craters on Yamal peninsula **Yury Dvornikov** *Earth Cryosphere Institute of Tyumen Scientific Center SB RAS*	
2:00pm – 2:15pm	Collapse and regeneration of Aparejo Glacier, central Chile **Felipe Ugalde** *Geoestudios*	Evaluation of biogeophysical feedbacks in ice-wedge degradation through field measurements, remote sensing, and modelling **Anna Liljedahl** *University of Alaska Fairbanks*	
2:15pm – 2:30pm	Modelling Thermal Regime of an Intrapermafrost Talik in Central Yakutia, Siberia **Nikita Tananaev** *Melnikov Permafrost Institute SB RAS*	Microbial survival and metabolism across a pan-Arctic study of North American and Siberian permafrost **Rachel Mackelprang** *California State University Northridge*	
2:30pm – 2:45pm	Hydrological processes of thermokarst lake in the Tibet Plateau, China **Zeyong Gao** *State Key Laboratory of Frozen Soil Engineering, Chinese Academy of Sciences, China*	A simple algorithm of active layer freeze-thaw processes at the watershed scale in the Qinghai-Tibet plateau **Kewei Huang** *Institute of Mountain Hazards and Environment, Chinese Academy of Sciences*	
2:45pm – 3:30pm	Afternoon Tea		

DAY 2 – MON 9 DEC, 3:30PM–7PM

Room	Galaxy I	Galaxy II	Galaxy III
Session number/ name	11. Mountain permafrost – continued	12. Permafrost and climate change at high latitudes – continued	Poster Sessions
Session Chair	Thomas Schmid and Brianna Rick	Britta Sannel and Florence Magnin	
3:30pm – 3:45pm	Permafrost is a crucial factor for paraglacial landscape modifications in glaciated mountain regions **Bernd Etzelmüller** *University of Oslo*	Which climatic changes affect permafrost and periglacial landforms the most? **Hanne Hvidtfeldt Christiansen** *The University Centre In Svalbard, Unis*	
3:45pm – 4:00pm	Permafrost has support of run-off in a semiarid region, Chile: “Cochiguaz” river sub-basin rock glaciers, warming & mining impact **Francisco Ferrando** *Universidad De Chile*	Multi-scale characterization of polar permafrost landscapes, Yukon and Northwest Territories, Canada **Christof Kneisel** *University of Wuerzburg, Institute of Geography and Geology*	
4:00pm – 4:15pm	Recent Acceleration of Thaw Slump Activity in the Permafrost Region of the Qinghai-Tibet Plateau **Jing Luo** *Tate Key Laboratory of Frozen Soil Engineering, Northwest Institute of Eco-environment And Resources*		
4:30 – 5:30pm	**Public Lecture** Location: Millennium Hotel, Room: Galaxy I **Simon Cox,** *Principal Scientist, GNS Science Dunedin,* “An introduction to the geology and tectonics of the Southern Alps” And **David Barrell,** *Senior Scientist, GNS Science Dunedin*, “Southern Alps glaciers, geomorphology and history of climate change”		
7:00pm	**Conference Dinner** – Skyline Gondola Brecon Street, Queenstown Please make your own way to the gondola foyer by 6.45pm		

FIELD TRIPS, DAY 3 – TUES 10 DEC

7:40am – 8:30pm	**Doubtful Sound Wilderness Cruise** – The Real Journeys coach will collect you from the Bus Stop directly outside the Millennium Hotel. Please be ready by 7.30am. Real Journeys phone 03 249 6000
8:30am – 5:30pm	**Queenstown and Surrounds Tour** with David Barrell and Simon Cox – Johnston’s coach will collect you from the Millennium Hotel

DAY 4 – WED 11 DEC, 8AM–1:10PM

8:00am	Registration Desk Opens		
8:30am – 9:30am	*Plenary Speakers* **Fujun Niu**, "Changes of Chinese Cold Regions and the Adaptation Measures for Linear Engineering" **Michael Krautblatter**, "Future destabilisation of high-mountain permafrost rockwalls: detection, anticipation and modelling" **Vicki Singleton**, *Antarctica New Zealand* & **Jamie Lester**, *WSP*, "Scott Base Redevelopment: Cold Climates & Construction" Chair: Hanne Hvidtfeldt Christiansen Room: Galaxy I		
9:30am – 10:15am	Poster Session Two: 1 Minute Flash Talks Chair: Hanne Hvidtfeldt Christiansen		
10:15am – 10:40am	Morning Tea		
Room	**Galaxy I**	**Galaxy II**	**Galaxy III**
Session number/ name	13. Cryogenic Soils of Arctic and Antarctica	14. Living with permafrost/ Training through research for international educational	Poster Sessions
Session Chair	Alexey Lupachev and Eleanor Jones	Vladislav Isaev and Anna Klene	
10:40am – 11:00am	*Session Keynote* Links between increased summer and winter precipitation and enhanced seasonal thaw of permafrost across a variety of Alaskan ecosystems **Thomas Douglas** *Cold Regions Research and Engineering Laboratory*	*Session Keynote* Sustainable Development in Yakutia: Economic, Environmental and Innovative Aspects **Anisiia Lazareva** *North-Eastern Federal University*	
11:00am – 11:15am	Soil climate and active layer depth monitoring, from 1999-2018, and relationship to regional climate drivers, Ross Sea Region, Antarctica **Annette Carshalton** *University of Waikato*	Russian-Norwegian Research-based education in Cold Regions Engineering **Vladislav Isaev** *Lomonosov Moscow State University*	
11:15am – 11:30am	Stability and biodegradability of soil organic matter in North-Western Siberia, Russian Arctic **Ivan Alekseev** *Saint Petersburg State University*	Developing a rock glacier management plan in Northern Chile **Shelley MacDonell** *Centro De Estudios Avanzados En Zonas Áridas*	
11:30am – 11:45pm	The Preliminary Analysis of the Polychemical Pollution of Cryogenic Soils and Upper Permafrost in Russia **Alexey Lupachev** *Institute Of Physico-chemical And Biological Problems In Soil Science, RAS*	Traditional and Nontraditional Permafrost Infrastructure and Climate Change: Examples from Alaskan and Russian Arctic **Nikolay Shiklomanov** *The George Washington University*	
11:45am – 12:00pm		Urban Safety and Sustainable Development in Northeast China's Permafrost Regions **Wenbing Yu** *College of Civil Engineering, Chongqing Jiaotong University*	
12:00pm – 12:15pm		Study of cryopegs phase composition under the frame of internship **Artem Shimanov** *Lomonosov Msu*	

DAY 4 – WED 11 DEC, 1:10PM–3:15PM

12:15pm – 1:10pm	Lunch		
Room	**Galaxy I**	**Galaxy II**	**Galaxy III**
Session number/ name	15. Cryosols and permafrost at high altitudes in Asia	16. GTN-P Global terrestrial network for permafrost	Poster Sessions
Session Chair	Fujun Niu and Sebastian Ruiz Pereira	Dmitry Streletskiy and Ivan Alekseev	
1:10pm – 1:30pm	*Session Keynote* Spatial variation of active layer thickness in a mountainous area of the eastern Tibetan Plateau **Defu Zou** *Northwest Institute of Eco–Environment and Resources, Chinese Academy of Sciences*	*Session Keynote* Climate change warms and degrades permafrost in European mountains **Bernd Etzelmuller** *University of Oslo*	
1:30pm – 1:45pm	Content and distribution of non-silicate iron forms along depth of hydrogenic soil profiles from the Eastern Pamir (Tajikistan) **Malgorzata Suska Malawska** *Faculty of Biology At University of Warsaw*	Elevation impacts on mountain permafrost temperatures, Yukon, Canada **Antoni Lewkowicz** *University of Ottawa*	
1:45pm – 2:00pm	The characteristics of ground ice isotopes in the permafrost regions of the Central Qinghai-Tibetan Plateau **Tonghua Wu** *Northwest Institute of Eco-environment And Resources,chinese Academy Of Sciences*	Active layer thickening and controls on interannual variability at Nordic CALM sites **Sarah Strand** *The University Centre In Svalbard*	
2:00pm – 2:15pm	Permafrost distribution pattern nearby Zonag Lake in the Qinghai-Tibet Plateau, China **Changwei Xie** *Cold And Arid Regions Envioronmental And Engineering Research Institute, Chinese Academy of Sciences*	20-years of permafrost monitoring in Switzerland: lessons learned and key messages **Cécile Pellet** *University of Fribourg*	
2:15pm – 2:30pm	Properties of soils developed under cushion plants in glacier forefield in the Eastern Pamir, Tajikistan. **Marcin Sulwinski** *University of Warsaw, Faculty of Biology, Biological And Chemical Research Centre*	CALM I-V: A Quarter-Century of Observations at Alaskan Active Layer Monitoring Sites **Frederick Nelson** *Michigan State University*	
2:30pm – 3:15pm	**Conference Close** Awards, 2020, 2021 & 2022 IPA Conferences and Farewell Chair: Megan Balks Room: Galaxy I		

PLENARY SPEAKERS

In order of presentation time

ANTONI LEWKOWICZ

Antoni Lewkowicz is Professor in the Department of Geography, Environment and Geomatics at the University of Ottawa. He has worked for more than 40 years across northern Canada on permafrost distribution, geomorphology and hydrology. He obtained his B.Sc. in Geography from the University of Southampton, and his MA and PhD from the University of Ottawa. He worked for an engineering consulting company for two years, and then became a professor at the University of Toronto for 12 years before moving back to Ottawa in 1994. He edited the journal Permafrost and Periglacial Processes (2006-2012), and was President of the International Permafrost Association (2012-2016). He is currently Chair of the IPA's International Advisory Committee and is the first President of the Canadian Permafrost Association.

IMPERMANENT PERMAFROST: DIFFERING PATHWAYS, TIMESCALES AND CONSEQUENCES OF PERMAFROST THAW AT TUNDRA, FOREST AND MOUNTAIN SITES

Sunday 8 December, 9:15am
Location: Galaxy I

Researchers in the field know that permafrost is not defined as permanently frozen, but as perennially frozen earth materials. The difference between these terms is becoming increasingly evident as the climate warms. Thaw has been observed at the southern margin of latitudinal permafrost and at the lower elevation bound of mountain permafrost, in both cases in regions where permafrost is already warm and discontinuous. The impacts of these changes include accelerating rock glaciers, changes in hydrology, the expansion of thermokarst terrain, and the release of previously frozen organic material for bacterial breakdown. More unexpectedly, thaw is occurring in the upper horizons of cold, continuous permafrost leading to near-surface degradation of polygon networks and the initiation of thaw-induced landslides on slopes. These can be caused by individual warm or wet summers that trigger changes which may continue for years after the initial disturbance. The combination of regular episodic extremes superimposed on warming trends means that all permafrost zones are vulnerable to impacts, and that where the ground is ice-rich, many will be irreversible.

FIONA SHANHUN

Fiona Shanhun is the Acting Chief Scientific Advisor for Antarctica New Zealand. She has been involved in Antarctic research for 15 years, leading and contributing to teams studying soils, permafrost, ecosystems and biodiversity, and has a PhD in soil science. Fiona has led field expeditions with both the New Zealand and Australian Antarctic programmes. She now leads the Antarctica New Zealand science team, which supports the delivery of a high-quality, internationally-recognised science programme. As well as playing an integral role in the establishment of the Antarctic Science Platform, Fiona works closely with the science community and communicates the value and relevance of the research that Antarctica New Zealand supports. Fiona was a finalist in 2019 Women of Influence Awards (Science, Health and Innovation) and is a former Scientific Committee on Antarctic Research (SCAR) fellow.

LOOKING SOUTH: THE NEW ZEALAND ANTARCTIC PROGRAMME

Sunday 8 December, 9:15am

New Zealand has been undertaking research in the Ross Sea region of Antarctica since the International Geophysical Year in 1957. Together with international partners, New Zealand supports a collaborative, multidisciplinary science programme, underpinned by a unifying theme of global change. Researchers contribute to our collective understanding of Antarctic and Southern Ocean environments through a range of studies, from ice dynamics in a warming world, to biological resilience and adaptation to change, to Antarctica's connectivity with the rest of the world and future projections of change.

The Ross Sea region of Antarctica is unique. The ocean extends to nearly 85°S beneath the Ross Ice Shelf – Antarctica's largest floating ice shelf – and is some of the world's least explored. Its interaction with the overlying ice shelf is thought to be a critical element in the potential future loss of the West Antarctic Ice Sheet.

Along the western part of the Ross Sea region, the Transantarctic Mountains extend from Cape Adare to the South Pole. Covering nearly 20° of latitude, studies of Antarctica's changing environments and the associated management challenges are conducted in a wide range of marine and terrestrial environments. The Dry Valleys in the southern Victoria Land section of the Transantarctic Mountains are the largest contiguous ice-free area in Antarctica, and present opportunities to investigate soils and permafrost, along with terrestrial biodiversity.

The Ross Sea region Marine Protected Area provides an international imperative to monitor and assess the effectiveness of its conservation measures. Studies of marine biodiversity, coastal interactions and the changing influence of the Southern Ocean on top predators in the Ross Sea contribute to our understanding of this vast and important marine protected area.

THOMAS SCHMID

Thomas Schmid is employed as a senior researcher at the Soil Conservation and Remediation Research Unit in the Environment Department of the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT). He has undertaken 3 trips to the Northern Antarctic Peninsula and his work focuses on mapping the spatial distribution of periglacial, glacial and morpho-structural features within ice-free areas by applying advanced remote sensing techniques and studying recent morphological changes in soils due to degradation processes.

SOILS INFLUENCED BY PERIGLACIAL PROCESSES IN THE NORTHERN ANTARCTIC PENINSULA REGION

Monday 9 December, 8:45am

The Northern Antarctic Peninsula region includes a number of ice-free areas in which soil formation occurs and periglacial processes are predominant. Conditions found within these ice-free areas, in particular in the South Shetland Islands, are characteristic of the so-called maritime Antarctica. The region has the largest warming trends recorded in Antarctica over the past sixty years and the alterations in the regional climate, especially oscillations around the freezing point of water, cause important changes in biological activity, chemical and physical weathering, hydrology and geomorphic processes. Periglacial environments are frequently marginal to the glaciers, and are subject to cycles of freezing and thawing. The presence of permafrost is closely related to the periglacial environment and has a variable distribution and continuity with an altitudinal trend. Furthermore, the ice-free areas are key nesting grounds for birds and mammals and therefore the soils receive an important input of nutrients. This is the basis of soil formation and a high pedodiversity within this region. However, the soils are often shallow and fragile and are subject to degradation due to natural causes as well as the high presence of international research stations and tourism activities.

TANYA O'NEILL

Tanya O'Neill has a PhD in soil science and is a researcher and lecturer in soil and environmental sciences at the University of Waikato in New Zealand. Tanya's main research focus is investigating the impacts of human activities on Antarctic terrestrial environments and rates of soil recovery following disturbance. She has had six trips to Antarctica and is currently working on a number of national and international Antarctic-related collaborations. Tanya has contributed to policy decisions on environmental management issues, and is currently involved in an effort to undertake a baseline survey of the Scott Base environment before the major redevelopment of the New Zealand base. Tanya is an APECS member and an executive committee member of the New Zealand Society of Soil Science. Her work has had her visit various permafrost-affected regions including Alaska, Tibet, the Ross Sea Region of Antarctica and the Antarctic Peninsula.

SOILS AND PERMAFROST IN THE ROSS SEA REGION OF ANTARCTICA: AN OVERVIEW

Monday 9 December, 8:45am

Terrestrial ice-free areas constitute approximately 0.18% of the Antarctic land area, but represent the most biologically active, historically rich, and environmentally sensitive sites. Soils in the Ross Sea region of Antarctica are among the oldest, coldest, and driest soils on Earth and have some unusual pedological features. All ice free areas in the Ross Sea Region are underlain by permafrost with mean annual temperatures ranging from about -18°C to -24°C. Soil formation is extremely slow due to the frigid climate and lack of moisture, as evaporation exceeds precipitation, forming a "cold desert" environment over much of the region. Slow pedogenesis and extremes in climate give rise to soil features such as varnished and ventifacted desert pavements, cavernous weathering, surface salt crusts and thick salt horizons at depth. Ross Sea region soils generally comprise a surface desert pavement and a seasonally thawed active layer over permafrost. Most soils are formed on regolith such as glacial till or colluvium. The active layer ranges in depth from minimal in higher altitude, colder sites, to near 1 m deep at warmer coastal sites in the northern part of the region. The underlying permafrost may be ice-cemented, or dry with no ice cement. In some areas ice-cored moraine occurs where there is a large body of ice within the subsoil permafrost. Soils in the region are diverse ranging from ornithogenic Typic Haplorthels in penguin colonies such as Cape Hallet, to dry Typic Anhyorthels in the southernmost Beardmore Glacier region. The soil-permafrost environment in the Ross Sea region is more dynamic the previously recognised with short-lived erosion and depositional events, due to occasional warmer than average summers, increased snowfall, or human disturbances. Such perturbations can lead to melt of sub-surface ice, and surface slumping until sufficient mineral material accumulates to insulate the underlying ice and a new stable equilibrium is attained.

ALEXEY LUPACHEV

PhD in soil science, senior researcher at the Soil Cryology Laboratory of the Institute of Physico-Chemical and Biological Problems in Soil Science, Russian Academy of sciences since 2005. Main research interests are in studying of genesis and ecological functions of permafrost–affected soils in high latitudes and also at high altitudes, their structure and genesis, soil-permafrost interaction, cryoconservation of biota, nutrients and contaminants.

Regular fieldsites are Kola Peninsula, Bolshezemelskaya Tundra, Polar Urals, North Jakutia, Baikal region, Kamchatka Peninsula, Antarctica, and some others. PYRN and APECS member. Co-chair of the Cryosol Working Group (cryosols.org) of the International Union of Soil Sciences since 2017. Personal website: a-lupachev.com

SOILS AND SOIL-LIKE BODIES OF COASTAL ANTARCTICA: GENESIS, SPATIAL DIVERSITY, TEMPERATURE REGIME, AGE, ECOLOGICAL FUNCTIONS

Monday 9 December, 8:45am

Despite the initial investigation of parent rock weathering processes and possible soil formation in Antarctica was conducted by Soviet scientists in 1958, regular and extensive studying of the Antarctic soils and permafrost simultaneously began only in the late 2000-s by the teams of geocryologists and pedologists from Puschchino headed by David Gilichinsky and from St.-Petersburg headed by Dmitry Vlasov. The spatial coverage of the Russian Antarctic Expedition's research stations is the world's most dense with 5 wintering, 2 seasonal and 4 irregularly visited abandoned stations. This allowed conducting long-term investigations of soils, parent rocks and soil-like bodies and monitoring of the permafrost active layer in coastal and trans-ice-shelf oases around the Antarctic continent as well as on the Subantarctic islands.

Following the WRB for soil classification, the most widely distributed soils with well-expressed profile organization are Leptosols and Cryosols. The significant areas are occupied by the soils with ornithogenic (2-5% of the whole territory of given oases) and technogenic (5-15%) impact. At the same time, rocks are inhabited by epi-, hypo- and endolithic communities, which demonstrate diverse set of organo-mineral interactions and are capable to produce soil-like profiles at the microscale level. The preliminary study shows that in some cases the organic carbon pool in "ahumic" soil-like bodies with no vegetation cover is comparable to the relatively well-developed soils under the mosses or lichens. The carbon dioxide emission during the austral summers varied from 0.8-2 to 28 mg C-CO2 m^{-2} $hour^{-1}$ with the highest values recorded in moss rich soils of the wind shelters reaching 117 mg C-CO2 m^{-2} $hour^{-1}$. According to the ^{14}C analysis the topsoil organic matter is relatively young (< 500 yr BP) mainly due to the disturbances caused by various types of erosion. The average residence time of carbon in the material of soils, soil-like bodies and cryoconites (organo-mineral soil-like bodies on the surface of the ice) in Antarctica ranges from 1500 to 2500 ^{14}C-years.

In the geographical aspect, all the studied regions may be referred to two soil-geographical divisions - Low-Antarctic humid barrens (e.g. King George Island) and Mid-Antarctic snow-patch barrens (e.g. Larsemann Hills) - barren landscapes with contrast hydrological regime where strong paludification caused by thawing snow patches in one places is in combination of soil dryness of other snowless places. The soil cover of the largest oasis of East Antarctica (Bunger Hills) is characterized by transitional combination of soil features between snow-patch barrens and cold deserts, including salinization and calcification. The main feature of Antarctic soil geography is that it has no manifested soil zones but only "islands of pedosphere" in glaciers. These fragments of soil cover do not strongly depend on the latitude and macroclimate but mostly are controlled by local factors – topography, parent rocks, wind direction and speed, sea bird's rookeries etc.

The results of the 10-year monitoring of the mean depth of the active layer as a part of CALM-S and GTN-P programs show the relatively stable soil temperature regime with no significant signs of active layer depth increasing. Authors underline that the time period of the monitoring is still too short to identify trends.

The investigation of the anthropogenically impacted soils and Antarctic Technosols themselves have shown that a significant part of them can be identified as "moderately polluted" and "significantly polluted" by the concentrations of local (oil and polyaromatic hydrocarbons, heavy metals) and global (pesticides and organochlorines) pollutants.

The long-term study was logistically supported by Russian Antarctic Expedition and funded by several projects of Russian Foundation for Basic Researches (incl. current 18-04-00900a) and Russian Scientific Foundation.

DR. FUJUN NIU

Dr. Fujun Niu is a professor in civil engineering at the State Key Laboratory of Frozen Soil Engineering, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, with a focus on permafrost engineering, environment and geo-hazards. He has been undertaking research woks on some major cold region projects, such as the Qinghai-Tibet Railway and the Qinghai-Tibet Highway in the Qinghai-Tibet Plateau, Haerbing-Dalian High-speed Railway in North-east China. He has published over 200 publications on permafrost and cold region engineering, and has gotten many awards from the government, the Geological Society and Geographic society of China.

CHANGES OF CHINESE COLD REGIONS AND THE ADAPTATION MEASURES FOR LINEAR ENGINEERING

Wednesday 11 December, 8:30am

In view of that the area affected by seasonally frozen soil and permafrost accounts for about 70% of the land area of China, so it is significant to study the changes of Chinese cold regions in the context of climate change. The permafrost area of China is about 2.15 ×106 km2. In recent years, the permafrost is undergoing degradation because of climate warming and increasing human activities. For example, a) from 1980 to 2010, the region with stable degradation in China is 101.21 ×104 km2, the degraded area of the transitional zone between permafrost and seasonally frozen soil is 12.68 ×104 km2, accounting for 13% of the total degraded area; b) the permafrost area of the Qinghai-Tibetan Plateau decreased from 174.76 ×104 km2 to 133.1 ×104 km2 during 1960's-2000's. In addition, the active layer thickness of Qinghai-Tibetan Plateau increased 0.15-0.50 m during 1996-2001, and still increased by 7.5 cm/year in recent years; c) the permafrost of northeast China degraded rapidly in the southern limit and island permafrost area, along with the deepening of the permafrost table, such as that the observed data indicates the depth of permafrost table of Jagdaqi in 1964 was 1.7m, but it increased to 6.0m in 1974. The permafrost degradation will lead to grassland degradation and desertification; besides, it will cause the frequent occurrence of thermal hazards, such as thaw settlement, thawing slumping and thermokarst lake.

Furthermore, the seasonally frozen soil also has a degradation trend. The result shows the seasonal freezing depth of seasonally frozen soil in the east of China has decreased in the past 40 years and its southern limit moves northward. Especially since the late 1980s, the degradation trend of seasonally frozen soil has been notable. Mann-Kendall method indicates the change year was about 1987. Meanwhile, the change of seasonally frozen soil is closely related to the activity of East Asian winter monsoon.

All the changes happened in the cold regions have significant influences on in local infrastructure, causing settlement problem, as a major hazard to infrastructures in the permafrost regions, and freezing-thawing induced problems in seasonal frozen ground. For reason of large scale, linear engineering was mainly studied searching for effective adaptation measures in the cold regions. The objective of the measures is to mainly cool down the subgrade soils in the permafrost regions for preventing thawing settlement; and prevent frost heaven through decreasing frozen depth, using non-frost susceptive soils and waterproofing and drainage measures in seasonal frozen ground. All the measures have been tested and practically applied, and their effectiveness, along with the deficiencies have been evaluated with the monitored data.

MICHAEL KRAUTBLATTER

Michael Krautblatter is a professor at the Technical University of Munich and the head of the Landslide Research Group. He has worked for 15 years on the mechanics of degrading permafrost, on geophysical techniques in permafrost and the geomorphological processes response in permafrost-affected and other rock walls. He studied in Passau (D) and Durham (UK) and Erlangen (D) and obtained his MSc in Geography and Geology in 2004, started working with geophysical methods during a research visit at the Rock Breakdown Group in Oxford (UK) and finished his PhD in Bonn (D) in 2009 on the destabilisation of permafrost-affected bedrock. He became lecturer in Bonn (2009-12) and was then appointed to the Chair of Landslide Research in Munich in 2012. His research works combines laboratory experiments, field monitoring and mechanical modelling of destabilisation effects of permafrost affected landforms. Michael has served as Chair of the GAPHAZ working group and as Permafrost Science Officer of the EGU and is presently the speaker of the German Working Groups on Permafrost and Geomorphology and is a member of the IPA executive committee.

FUTURE DESTABILISATION OF HIGH-MOUNTAIN PERMAFROST ROCKWALLS: DETECTION, ANTICIPATION AND MODELLING

Wednesday 11 December, 8:30am

High-mountain permafrost-affected rockwalls have been reported to have caused unprecedented frequencies and magnitudes of rockfall in many mountain ranges worldwide. In addition, infrastructure in permafrost-affected mountains faces significant problems due to enhanced rates of subsidence, exposure to rockfalls, enhanced rates of debris flows, enhanced creep and accelerated rock glacier movements. This talk aims at analysing the underlying processes and mechanics of permafrost-related destabilisation of rockwalls, which we need to anticipate these phenomena in the foreseeable future. Modelling instable permafrost bedrock is a key requirement to anticipate magnitudes and frequency of rock slope failures in a changing climate but also to forecast the stability of high-alpine infrastructure throughout its lifetime.

We propose a conceptual rock-ice mechanical model that incorporates enhanced driving forces in terms of elevated hydrostatic and cryostatic pressure and reducing resisting forces due to decreasing rock mechanical strength, weakening of ice and rock-ice interfaces. This talk presents strategies how to obtain relevant (i) rock mechanical parameters such as compressive and tensile strength and fracture toughness (lab), (ii) ice- and rock-ice interface mechanical parameters (lab), (iii) cryostatic forces in low-porosity alpine bedrock (lab and field) and (iv) hydrostatic forces in perched water-filled fractures above permafrost (field).

We demonstrate first benchmark mechanical models that rely on frozen/unfrozen parameter testing in the lab and field. Continuum mechanical models (no discontinuities) can be used to demonstrate permafrost rock wall destabilization on a valley scale over longer time scales, as exemplified by progressive fjord rock slope failure in the Lateglacial and Holocene. Discontinuum mechanical models including rock fracture patterns can display rock instability induced by permafrost degradation on a singular slope scale, as exemplified for recent a recent ice-supported 10.000 m³ preparing rock at the Zugspitze (D). Discontinuum mechanical models also have capabilities to link permafrost slope stability to structural loading induced by high-alpine infrastructure such as cable cars and mountains huts, as exemplified for the Kitzsteinhorn Cable Car and its anchoring in permafrost rocks (A).

This talk shows benchmark approaches to develop mechanical models based on a rock-ice mechanical model for degrading permafrost rock slopes. Modelling instable permafrost bedrock is a key requirement to anticipate magnitudes and frequency of rock slope failures in a changing climate but also to forecast the stability of high-alpine infrastructure throughout its lifetime.

VICKI SINGLETON & JAMIE LESTER

Vicki is originally from the United Kingdom, having moved to New Zealand only 20 months ago to work with Antarctica New Zealand. She studied Civil & Structural Engineering, and Geotechnical Engineering before gaining Chartership as a Geotechnical Engineer. She subsequently moved into construction project management, working with the UK and US military before joining the British Antarctic Survey. She currently works as the Design Integration Manager for the Scott Base Redevelopment Project, overseeing all elements of the design work.

Jamie is a Technical Principal with WSP with 14 years' experience in the design of building structures. He has a passion for resilient design, and enjoys working on complex projects as part of a collaborative team. This has been demonstrated by his involvement in award-winning, innovative projects such as the Trimble Navigation building using post-tensioned engineered timber, Christchurch Central Library and The WSP Christchurch office which utilises viscous dampers. Jamie is currently leading the civil and structural aspects of the Scott Base Redevelopment for WSP as part of a global design team delivering this "once in a generation" project for Antarctica New Zealand.

SCOTT BASE REDEVELOPMENT: COLD CLIMATES & CONSTRUCTION

Wednesday 11 December, 8:30am

The presentation will give a whistle-stop tour of the design for the Scott Base Redevelopment project, looking specifically at the challenges of constructing in the permafrost on Pram Point, Antarctica.

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Remote Sensing and Modelling of Terrestrial and Martian Permafrost

Guest Editors:

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Deadline for manuscript submissions:
31 May 2020

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Message from the Guest Editors

Studying planetary permafrost has implications for understanding the regional and global climate shifts, ecosystems, hydrology, water cycle, carbon cycle, and methane influx into the atmosphere. Considering the widespread presence of permafrost in inaccessible or hostile environments, using remote sensing and modeling approaches becomes imperative for inventorying and observing the state and change of this essential component of the cryosphere.

This topical collection derives its title and origin from the special session of the SouthCOP Conference to be held in Queenstown, New Zealand in December 2019. We solicit manuscripts that use the multitude of remote sensors available for describing permafrost characteristics and dynamics. We welcome submissions that focus on multiple spatiotemporal scales as well as the integration of permafrost region field studies with remotely sensed data. A special invitation is extended to the Mars research community on submitting their works pertaining to Martian permafrost.

The topics can be related to the use of remote sensing for identifying/mapping permafrost, periglacial geomorphology, thermokarst lakes, and permafrost-related geohazards.

Special Issue

POSTER LIST

In order of presenter's last name last name

POSTER SESSIONS

Last Name	First Name	Organization	Paper Title	Poster #	Session Time
Alekseev	Ivan	*Saint Petersburg State University*	Ornithogenic soils of King George and Ardley Islands, South Shetland Islands, Maritime Antarctica	**1**	Monday 9 Dec: 9.45am – 10.30am
Barboux	Chloé	*Department of Geosciences - Geography. University of Fribourg. Switzerland*	Regional trend of rock glacier kinematics derived from DInSAR data	**2**	Monday 9 Dec: 9.45am – 10.30am
Czekirda	Justyna	*Department Of Geosciences, University Of Oslo*	Evaluation of rock glacier dynamics in Northern Iceland using spaceborne radar interferometry and image correlation techniques	**3**	Monday 9 Dec: 9.45am – 10.30am
Dvornikov	Yury	*Earth Cryosphere Institute Of Tyumen Scientific Centre Sb Ras*	GPR-based mapping of active layer depth within catchments of freshwater lakes in Larsemann Hills oasis (East Antarctica)	**4**	Monday 9 Dec: 9.45am – 10.30am
Etzelmuller	Bernd	*University Of Oslo*	Towards a national inventory of continuous rock glaciers movement in Norway based on InSAR	**5**	Monday 9 Dec: 9.45am – 10.30am
Fröjd	Christina	*Inst Physical Geografy, Stockholm University*	Soil organic carbon storage in periglacial landforms of the Patagonian Andes	**6**	Monday 9 Dec: 9.45am – 10.30am
Fröjd	Christina	*Inst Physical Geografy, Stockholm University*	Recent periglacial studies on rock glaciers of the Central Andes, Mendoza, Argentina	**7**	Monday 9 Dec: 9.45am – 10.30am
Harada	Koichiro	*Miyagi University*	Frost depth measuring program in Japan	**8**	Monday 9 Dec: 9.45am – 10.30am
He	Binbin	*Northwest Institute Of Eco-environment And Resources, Chinese Academy of Sciences*	Analysis of the Embankment Stability in Permafrost Regions based on Strength Reduction Finite Element Method	**9**	Monday 9 Dec: 9.45am – 10.30am
Khomutov	Artem	*Earth Cryosphere Institute Tyumen Scientific Centre SB RAS*	Remote Sensing Data and Field-based Methods of Cryogenic Processes Monitoring Along Kara Sub-latitudinal Transect, Russia	**10**	Monday 9 Dec: 9.45am – 10.30am
Klene	Anna	*University of Montana*	Rock glaciers of the Beartooth and northern Absaroka ranges, Montana, USA	**11**	Monday 9 Dec: 9.45am – 10.30am
Krautblatter	Michael	*Technical University Of Munich*	Towards benchmark mechanical models for warming permafrost rock slopes	**12**	Monday 9 Dec: 9.45am – 10.30am
Lambiel	Christophe	*University Of Lausanne*	Rapid degradation of permafrost and ground ice in an ice-cored moraine, Swiss Alps	**13**	Monday 9 Dec: 9.45am – 10.30am
Li	Guoyu	*State Key Laboratory Of Frozen Soil Engineering, Chinese Academy Of Sciences*	Cooling performance of mitigative measures on permafrost under the China-Russia Crude Oil Pipeline	**14**	Monday 9 Dec: 9.45am – 10.30am
Li	Dongqing	*Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences*	Effect of freeze-thaw on pore structure characteristics of cement-stabilized soil	**15**	Monday 9 Dec: 9.45am – 10.30am
Lupachev	Alexey	*Institute Of Physico-chemical And Biological Problems In Soil Science, Ras*	Influence of Environmental Factors on Microfauna Communities in Arctic Cryosols	**16**	Monday 9 Dec: 9.45am – 10.30am

Last Name	First Name	Organization	Paper Title	Poster #	Session Time
Lupachev	Alexey	*Institute Of Physico-chemical And Biological Problems In Soil Science, Ras*	Late Pleistocene Paleosols and Permafrost of a periglacial area of the East-European plain	**17**	Monday 9 Dec: 9.45am – 10.30am
MacDonell	Shelley	*Centro De Estudios Avanzados En Zonas Áridas*	Catchment scale analysis of rock glacier velocities and elevation changes	**18**	Monday 9 Dec: 9.45am – 10.30am
Magnin	Florence	*Edytem Lab. Cnrs, Université Savoie Mont Blanc*	Modelling water-related processes in rock wall permafrost	**19**	Monday 9 Dec: 9.45am – 10.30am
Magnin	Florence	*Edytem Lab. Cnrs, Université Savoie Mont Blanc*	What can we learn from ice collected in high mountain rockfall scars? Three examples from the Mont Blanc massif (France)	**20**	Monday 9 Dec: 9.45am – 10.30am
Matsuoka	Norikazu	*University Of Tsukuba*	Differential frost heave on incipient sorted patterns in the Japanese Alps: a multi-method monitoring	**21**	Monday 9 Dec: 9.45am – 10.30am
Nelson	Frederick	*Michigan State University*	Geomorphometry of “Cryoplanated Uplands”: An Exploratory Analysis in Unglaciated Beringia	**22**	Monday 9 Dec: 9.45am – 10.30am
Nyland	Kelsey	*Michigan State University*	Long-Term Erosion Rates by Nivation, Cathedral Massif, Northwestern British Columbia	**23**	Wednesday 11 Dec: 9.30am – 10.15am
Obu	Jaroslav	*University Of Oslo*	Sorted patterned ground in karst caves: development and potential for permafrost research	**24**	Wednesday 11 Dec: 9.30am – 10.15am
Obu	Jaroslav	*University Of Oslo*	Modelling peatland and permafrost dynamics across pan-Arctic	**25**	Wednesday 11 Dec: 9.30am – 10.15am
O’Neill	Tanya	*Waikato University*	Scott Base Redevelopment Environmental Monitoring Programme	**26**	Wednesday 11 Dec: 9.30am – 10.15am
Pellet	Cécile	*University of Fribourg*	Standardized data management and storage for mountain permafrost data	**27**	Wednesday 11 Dec: 9.30am – 10.15am
Peng	Chenyang	*Northwest Institute Of Eco- Environment And Resources, Chinese Academy Of Sciences*	Simulation of permafrost distribution in Mountain Qilian	**28**	Wednesday 11 Dec: 9.30am – 10.15am
Plaesken	Regina	*Technical University of Munich*	Numerical representation of temperature-dependent failure criteria for ice-filled permafrost rock discontinuities	**29**	Wednesday 11 Dec: 9.30am – 10.15am
Rick	Brianna	*Colorado State University*	Rock glaciers as climate resilient cold-water reservoirs in alpine basins within the Colorado Rocky Mountains	**30**	Wednesday 11 Dec: 9.30am – 10.15am
Ruiz Pereira	Sebastian	*Geography Institute, Catholic University Of Chile*	Identification and Monitoring of Rock Glacier Units (31°-33°S)	**31**	Wednesday 11 Dec: 9.30am – 10.15am
Saito	Kazuyuki	*Jamstec*	Three-dimensional temperature variations measured with fibre-optic sensors and boreholes at a boreal permafrost site in Interior Alaska	**32**	Wednesday 11 Dec: 9.30am – 10.15am

POSTER SESSIONS

Last Name	First Name	Organization	Paper Title	Poster #	Session Time
Şerban	Mihaela	*State Key Laboratory Of Frozen Soils Engineering, Northwest Institute Of Eco-environment And Resources*	Active layer dynamics under two distinct vegetation covers along the China–Russia Crude Oil Pipeline	**33**	Wednesday 11 Dec: 9.30am – 10.15am
Şerban	Raul-David	*State Key Laboratory Of Frozen Soils Engineering, Northwest Institute Of Eco-environment and Resources*	Surface water bodies mapping using different remote sensing methods in a small permafrost landscape	**34**	Wednesday 11 Dec: 9.30am – 10.15am
Streletskiy	Dmitry	*George Washington University*	Permafrost Monthly Alerts (PMA) Program	**35**	Wednesday 11 Dec: 9.30am – 10.15am
Sun	Zhizhong	*Cold And Arid Regions Environmental And Engineering Research Institute, Chinese Academy Of Sciences*	Characteristics of permafrost change under natural field along the Qinghai-Tibet Railway during the year of 2006-2015	**36**	Wednesday 11 Dec: 9.30am – 10.15am
Trapeznikova	Olga	*Sergeev Institute Of Environmental Geoscience Of Ras*	Agricultural suitability of the ice age periglacial and postglacial zones in the Russian North	**37**	Wednesday 11 Dec: 9.30am – 10.15am
Vivero	Sebastián	*Institute Of Earth Surface Dynamics (IDYST), University Of Lausanne*	Rock glacier kinematics derived from UAV surveys: validation and accuracy assessment	**38**	Wednesday 11 Dec: 9.30am – 10.15am
You	Zhemin	*Cold And Arid Regions Environmental And Engineering, Research Institute, Chinese Academy Of Sciences*	Microscopic failure mechanism of saline soil considering salt transport and phase change under freeze-thaw cycles	**39**	Wednesday 11 Dec: 9.30am – 10.15am
Zhang	Song	*Shijiazhuang Tiedao University*	Influence of Heat Dissipation of Shield Tunnel Segment on Temperature Field and Design Optimization	**40**	Wednesday 11 Dec: 9.30am – 10.15am
Zhang	Xiyan	*Northwest Institute of Eco- Environment and Resources, Chinese Academy of Sciences*	A review of tangential heave force on piles in permafrost	**41**	Wednesday 11 Dec: 9.30am – 10.15am
Zhao	Yonghua	*Northwest Institute Of Eco-environment And Resources,chinese Academy Of Sciences*	Soil moisture dominate alpine meadow carbon balance in the permafrost region of the Qinghai-Tibetan Plateau	**42**	Wednesday 11 Dec: 9.30am – 10.15am
Liljedahl	Anna	*University of Alaska Fairbanks*	Making permafrost big imagery products discoverable for knowledge-generation by scientists & the public	**43**	Wednesday 11 Dec: 9.30am – 10.15am

ORAL ABSTRACTS

In order of presenter's last name

STABILITY AND BIODEGRADABILITY OF SOIL ORGANIC MATTER IN NORTH-WESTERN SIBERIA, RUSSIAN ARCTIC

Ivan Alekseev,[1] **Evgeny Abakumov**[1]

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On-going global climate change raises many environmental problems especially in highly sensitive ecosystems, e.g. polar and subpolar environments. Arctic region provide many crucial ecosystem services: carbon sequestration and greenhouse gas cycle regulation, water quality and biodiversity levels control. On-going climate change, which is expressed in many aspects, e.g. Arctic warming, may cause degradation of vulnerable polar and sub-polar ecosystems and components, which would lead to further degradation of ecosystems benefits. Investigation of biotic and abiotic environments and their interactions is vital for development of strategies for sustainable environmental management in response to anthropogenic disturbances and climate change. Polar soils play a key role in global carbon circulation and stabilization as they contain maximum stocks of soil organic matter (SOM) within the whole pedosphere. Cold climate and active layer dynamics result in the stabilization of essential amounts of organic matter in soils, biosediments, and grounds of the polar biome. Chemical composition of soil organic carbon (SOC) determines its decomposability and may affect soil organic matter stabilization (SOM) rate (Beyer, 1995). This is quite important for understanding variability in SOC pools and stabilization rate in context of changes in plant cover or climate (Rossi et al. 2016). 13C nuclear magnetic resonance spectroscopy, which provides detailed information on diversity of structural composition of humic acids and SOM, may also be used to study the SOM dynamics under decomposition and humification proceses (Kogel-Knabner, 1997; Zech et al., 1997). This study aims to characterize molecular organization of the humic acids, isolated from various permafrost-affected soils of Yamal region and to assess the potential vulnerability of soils organic matter in context of possible mineralization processes. Organic carbon stocks for studied area were 7.85 ± 2.24 kg m-2 (for 0-10 cm layer), 14.97 ± 5.53 kg m-2 (for 0-30 cm), 23.99 ± 8.00 kg m-2 (for 0-100 cm). Results of solid-state 13C-NMR spectrometry showed low amounts of aromatic components in studied soils. All studied humic powders are characterized by predominance of aliphatic structures, and also carbohydrates, polysaccharides, ethers and amino acids. High content of aliphatic fragments in studied humic acids shows their similarity fulvic acids. Low level of aromaticity reflects the accumulation in soil of lowly decomposed organic matter due to cold temperatures. Our results provide further evidence of high vulnerability and sensitivity of permafrost-affected soils organic matter to Arctic warming. Consequently, these soils may play a crucial role in global carbon balance under effects of climate warming.
This study was supported by the grant of Saint Petersburg State University "Urbanized ecosystems of the Russian Arctic: dynamics, state and sustainable development" and the Government of the Yamalo-Nenets Autonomous District.

Keywords

Cryogenic soils, soil organic matter, permafrost, Arctic, climate change.

IPA ACTION GROUP - ROCK GLACIER INVENTORIES AND KINEMATICS (2018-2020): ONGOING WORK AND FIRST RESULTS

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Rock glaciers are best expressing the creep of mountain permafrost and constitute an essential geomorphological heritage of the mountain periglacial landscape. Their dynamics is largely depending on climatic factors and may locally interact with human activities (e.g. debris flow initiated from a rock glacier snout). Observing changes in rock glacier kinematics provide clue information on the climatic impact and has the potential to become a key parameter of the cryosphere monitoring in mountain regions.

Initiatives have risen for decades in many high-altitude regions for inventorying rock glaciers as a proxy for permafrost occurrence, but also for instance in the perspective of ice (water) storage estimation, geohazards management as well as climate reconstruction. However, these efforts often rely on different methodologies based on the unequal availability of source datasets and on variable local skills and institutional support. In a context where open access to high-quality remotely sensed data is constantly increasing, there is a need for the scientific community to promote international cooperation and develop standard guidelines.

An International Permafrost Association (IPA) Action Group on Rock glacier inventories and kinematics has been launched for 2 years at EUCOP5 2018 in Chamonix. At the time of writing this abstract (Apr. 2019), the Action Group is gathering more than 80 researchers supporting the idea of organizing and managing a network (open-access database) dedicated to rock glacier mapping (inventorying) and monitoring (kinematics) in all relevant mountain regions on Earth including the definition of the necessary standards. The Action Group activities are divided into three main tasks: 1) definition of widely accepted standard guidelines for inventorying (mapping) rock glaciers in mountain permafrost regions, including indications on the activity rate; 2) preparation of products which could serve in the long run for monitoring rock glacier kinematics as a future associated parameter of the GCOS-defined ECV (Essential Climate Variable) Permafrost; 3) operational development of a database / web platform.

The proposed presentation intends to report on the main collective decisions that will arise from the Action Group Workshop to be held in Switzerland in September 2019 and focusing on Task 1. They will concern mainly the formulation of a “working definition” of rock glaciers, including essential attributes to be observed (e.g. definition of key attributes, activity rate, genetic category, etc.) and practical guidelines for inventorying, considering the wide diversity of environmental contexts where rock glaciers are developing or had done so.

SOIL CLIMATE AND ACTIVE LAYER DEPTH MONITORING, FROM 1999-2018, AND RELATIONSHIP TO REGIONAL CLIMATE DRIVERS, ROSS SEA REGION, ANTARCTICA

Annette Carshalton,[1] Megan Balks,[1] Karin Bryan,[1] Tanya O'Neill,[1] Cathy Seybold[2]

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[2] United States Department of Agriculture, Lincoln, United States of America

The depth of seasonal thaw (the active layer), integrates a range of soil and atmospheric climate variables and has the potential to provide a clear signal of a changing climate. Nine soil climate monitoring stations were established between 1999-2012 and are currently operating in the McMurdo Dry Valleys. The stations range in altitude between 1700 m a.s.l. at Mt Fleming and 4.5 m a.s.l. at Granite Harbour, with four of the other stations located with in the Wright and Victoria Valleys, and three stations situated along the coast. At each monitoring station, soil temperatures are measured at a range of depths down to 120 cm. Atmospheric data are measured every 10 seconds, and soil temperature every 20 minutes, with hourly means recorded. Data are manually downloaded annually. Data validation has been carried out through the comparison of multiple sensors and has given confidence in the data-set.

Between site establishment and 2018 the mean active layer depth was 8 cm at Mt Fleming, 38 cm at the Wright Valley South Wall, 37 cm at the Wright Valley North Wall, 23 cm at Victoria Valley, 49 cm at the Wright Valley floor, 50 cm on the coast at Marble Point, 29 cm at Minna Bluff, 33 cm at Scott Base, and 86 cm at Granite Harbour. All sites show between-year variability, but no warming or cooling trends are evident.

Regression analysis was used to create a model that could predict active layer depth using more readily available above-ground climate variables. Mean summer air temperature, total summer solar radiation, altitude, and ground surface temperature were found to have the greatest effect on active layer depth ($p < 0.0001$). Multiple regression analysis was undertaken with differing number variables using both step-wise and restricted maximum likelihood (REML) methods, which gave significant results (Adj $R^2 > 0.5$).

Three potential drivers of temperature within the soil climate monitoring network were tested, the Southern Oscillation Index, the relative central Amundsen Sea Low pressure and the Southern Annular Mode. A strong relationship is found between the Amundsen Sea Low and the soil climate network at a 3-4-year cycle with significant events occurring between 2001-2006, 2011-2012 and in 2016. There is a weak relationship between the monitoring network with both the Southern Annular Mode and Southern Oscillation Index, with a return period of 6-8 years.

The database comprises approximately 123 million data points, collected from both soil and atmospheric sensors, and becomes more valuable with time as the record gets longer. The soil climate monitoring network is a useful baseline and a key resource in understanding the changing global climate.

THE VEGETATION IN THE FOREFIELD OF THE GLACIER IN THE UJ-SU VALLEY (EASTERN PAMIR, TAJIKISTAN)

Łukasz Chachulski[1]

[1] Warsaw University Of Life Sciences

The development of the vegetation of the Uj-su glacier valley is strongly limited by low temperatures, small precipitation and strong erosion caused by glacier activity and a low nutrient level of initial soil. In July 2018, 131 relevés were done along 4 transects located across the valley at different distances from the glacier (0, 1, 4 and 8 km). The results of a cluster analysis by the TWINSPAN method showed that there are 8 plant communities with different species composition. A map of the relief of the studied section of the valley was made. It was shown that the arrangement of the plant associations is well correlated to the relief. The structure of the plant cover of fluvial terraces, rock glacier, talus slope and talus cone was significantly different. The newest river terrace, T1, has almost no vegetation. Fluvioglacial processes in the river-bed are not conducive to the development of vegetation due to strong erosion. The plant cover of older terraces (T2 and T3) consists of patches of cushy plants most of which belong to the *Acantholimon*, *Astragalus* and *Oxytropis* genuses. The richest plant associations are located along the rock glacier's remains stretched along the margin of the valley. They are dominated by plants belonging to the *Kobresia*, *Poa* and *Astragalus* genuses and have relatively the highest biodiversity index (H). The succession of the vegetation of the fluvial terraces is interrupted by aeolian processes. The lowest investigated part of the valley is covered by semi-shrub vegetation named *Krashennikovia* deserts. The main factor behind the development of plant cover is the accumulation of sand and dust.

The important result of this work is the description of glacier foreground vegetation that is unique to East Pamir mountains and has not been mentioned in literature. It is shown that the plant succession in Pamir glaciers is quite different than in other regions described in literature. The distance from the glacier front affects the vegetation structure considerably. Important factors that strongly affect the plant cover are relief and the way of supplying water.

Funding: This work was supported by the Polish National Science Centre Grant No 2017/25/B/ST10/00468.

SETTLEMENT PROBLEMS OF LAND-BRIDGE PILES IN THE QINGHAI-TIBET RAILWAY AND INSPIRATION FROM ITS TREATMENT

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Land-bridge of 1401 milestone in the Qinghai-Tibet railway is located in the permafrost area of Tanggula Mountains. After the railway went into service, serious settlement problems occurred in the bridge and did big harm to the line. Monitoring data from 2009 showed that the rise of permafrost temperature and base resulting from warm season, climate warming and leakage of deep artesian sub-permafrost groundwater was the main reason of settlement problem. Complicated and long treatment process implied that thermal disturbation of countermeasures must be considered before it was adopted in the pile problems. It is suggested that the land-bridge settlement should be monitored periodically. Earlier detection, earlier prevention and earlier treatment should be more welcome.

Keywords
Land Bridge Pile, Settlement Problems, Thermal Stability, Permafrost, Qinghai-Tibet Railway.

WHICH CLIMATIC CHANGES AFFECT PERMAFROST AND PERIGLACIAL LANDFORMS THE MOST?

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The ongoing rather large climatic warming of the high Arctic landscape in Svalbard has been 3.7°C over the last 118 years of observations in the Longyearbyen airport area, which is three times the global average. The largest increase in air temperatures has occurred during the autumn and winter seasons, while summers warmed much less, and springs warmed moderately.Precipitation has recently increased to around 300 mm annually. Both air temperatures and precipitation are predicted to continue increasing towards 2100, with more extreme rain events in autumn. A network of permafrost monitoring boreholes in different periglacial landforms, which have been operated for a decade since the IPY, and a CALM grid that has been operated for two decades, allow us to study to which extent the prolonged autumn thawing periods affect the ground thermal regime, and how winter warming might affect active layer thickness and dynamics. Autumn rainstorms as late as mid October in 2016 caused extensive landsliding around the settlement of Longyearbyen, when the active layer had not yet refrozen. New real-time permafrost borehole instrumentation is being installed as part of the Svalbard Integrated Arctic Earth Observing System, SIOS, to allow for better direct use of permafrost thermal observations for research, education and societal preparedness, particularly during extreme rain events.

2D THERMAL MODELLING OF UNSTABLE ROCK WALLS IN NORWAY: EXAMPLES FROM MANNEN AND GÁMANJUNNI 3

Justyna Czekirda,[1] **Sebastian Westermann**,[1] **Bernd Etzelmüller**[1]

[1] **Department Of Geosciences, University Of Oslo, Oslo, Norway**

Recent rock wall temperature data and modelling studies indicate that many rock walls in Norway are underlain by permafrost. During ongoing atmospheric warming, permafrost in such steep slopes will warm to critical temperatures, at which the shear strength of the ground materials decreases drastically, possibly leading to slope destabilization and eventually rock-slope failures.

In this study, we model the temporal and spatial distribution of rock wall permafrost using a two-dimensional thermal heat flow model CryoGrid 2D (Myhra et al., 2017), where lateral heat fluxes can be modelled along a transect. The model is implemented with the Dirichlet boundary conditions at the upper boundary and is forced with observational or modelled climate data. We will present the results of CryoGrid 2D simulations from two unstable rock slopes in Norway that are currently monitored due to the risk they pose to population or infrastructure within the estimated runout zones. The “Veslemannen” unstable rock slope in southern Norway comprises a volume of c. 120 000-180 000 m^3. The rock slab shows a seasonal increase in the movement rates, even up to 1 m d-1 during autumn 2018. Another slope in northern Norway, Gámanjunni 3, is a slowly creeping rockslide of c. 26 million m^3 that moved on average ~28 mm yr^{-1} during the last 5.3 ky based on results of cosmogenic 10Be dating technique or up to 54 mm yr^{-1} during the recent years based on the differential global navigation satellite system (dGNSS) surveys (Böhme et al., 2019). The dynamics of the two slopes might potentially be related to the ground thermal regime, hence the interplay between these factors should be investigated in detail.

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LINKS BETWEEN INCREASED SUMMER AND WINTER PRECIPITATION AND ENHANCED SEASONAL THAW OF PERMAFROST ACROSS A VARIETY OF ALASKAN ECOSYSTEMS

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Recent studies have reported increases in summer wet precipitation at northern latitude sites as a result of climate warming. In some locations warming is projected to also lead to deeper snowpacks despite a shorter winter season. Changes in wet precipitation and snowpacks are known to affect the thermal state of permafrost though some aspects of heat transfer (latent heat) are better studied and understood than others (advective heat transport). The ramifications of deeper snowpacks in winter and increased wet precipitation in summer on top-down thaw of permafrost and active layer processes are not understood. Further, though it is well established that different ecosystem types provide stronger thermal insulation and protection of permafrost than others, there is little information on how precipitation-thaw relationships may be controlled by above ground vegetation structure. Between 2014 and 2018 we made more than 3,200 repeat active layer depth measurements and more than 10,000 snow depth measurements at sites representing a range of permafrost and vegetation characteristics at four sites in Interior Alaska. These surveys represented the first and third wettest summers (2014, 2016) in the 90-year meteorological record for the area and three summers with wet precipitation close to mean historical values. The winter of 2017-2018 was anomalously warm and had a significantly deeper snowpack than typical winters. As such, our measurements provide insight into how winter and summer precipitation affect seasonal thaw and active layer development. Increased rainfall led to deeper seasonal thaw across all sites and ecotypes. For every 10 cm increase in rainfall active layer depth increased by an average of 7 ± 1 cm. Disturbed and wetland sites were the most vulnerable to rain-induced thaw with almost 10 cm deeper active layer for each 10 cm of additional rain. Permafrost in tussock tundra, mixed forests, and conifer forests was less sensitive to rain-induced thaw. We collected SIPRE cores at some of our sites following the winter of 2017-2018 and identified numerous locations where the winter freeze only reached half of the previous year's active layer. The taliks that were created represented a variety of permafrost ice contents and included sites representing multiple ecotypes. Our results demonstrate that enhanced seasonal thaw and deeper active layers result from increasing soil wetness and deeper than normal snowpacks. Our work shows the projected conditions of increased summer precipitation and deeper snowpacks will favor increased thaw of permafrost.

CONCEPTUAL MODEL OF FORMATION AND EVOLUTION OF GAS EMISSION CRATERS ON YAMAL PENINSULA

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[2] Tyumen State University, Tymen, Russia

We have studied gas emission craters (GEC) on Yamal and Gydan peninsulas through three years (2015-2018). Based on the results of these studies and related sub-marine analogues, we propose a conceptual model for GEC formation and evolution. Such model may also help to determine potential scenarios of future landscape development in the permafrost regions. In the terrestrial and near-shore environment, methane originates from shallow intra-permafrost gas occurrences or relic gas hydrate reservoirs (Yakushev 2009) within the relic gas hydrate distribution zone (RGHDZ) deeper than 70 mbsl in the continuous permafrost. This gas might further migrate and be accumulated within cryotic layer of saline sediments that can be often observed at 25 – 35 mbsl on Yamal (Streletskaya and Leibman 2002). This is also supported by the documented gas blowouts from depths 70-120 m (Skorobogatov et al. 1998) during drilling of boreholes in Central Yamal, mainly from sandy coastal-marine deposits (Are et al. 1990). Gas flows can create a pressure in areas with the distribution of tabular ground ice in clay – sand interface (Streletskaya and Leibman 2002) which results in the development of mound predecessor in the terrestrial environment and pingo-like features in the near-shore environment (Portnov et al. 2013). Abnormally warm summer season in the Arctic in 2012 has increased the active layer thickness in Yamal (Leibman et al. 2015). This weakened the upper frozen layer which further led to GEC formation (Leibman et al. 2014). GEC was further infilled with collapsed sediments from the crater walls. This new >50 m thick sediment layer probably re-freeze preventing further gas release from permafrost.

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SOIL THERMAL AND MOISTURE REGIME ALONG A CLIMOSEQUENCE AT THE BOLIVIAN ALTIPLANO-AMAZON WATERSHED, CORDILLERA REAL, BOLIVIA

Senra Eduardo, Carlos Ernesto Schaefer, Márcio Rocha Francelino, Roberto Ferreira Michel

High tropical mountains host the most sensitive cryosphere of the three poles, and witness the vanishing of the last tropical mountain glaciers, snowpacks and mountain permafrost, due to accelerated global changes. It possesses high variability in local climates and topographic attributes, accompanied by highly contrasting environmental features. At the central Andes of Cordillera Real, Bolivia, three climatic sectors have five main types of vegetation: Puna, Páramo, Tundra, Scrub and Sub-tropical highland rainforests. Pedoclimatic monitoring is key to understand the dynamics of high mountain ecosystems and occurrence of permafrost of tropical high mountain. Soil climate patterns define the occurrence of permafrost, weathering, organic carbon and vegetation dynamics. This study analyzed the annual pedoclimatic monitoring of a high mountain along an east-west transect in Cordillera Real, Bolivia and its relationship with environmental and pedological characteristics. In each of the three climatic sectors (Altiplano, High Mountain and Amazon Slope), two sites of soil thermal monitoring were installed. At 5cm, 20cm and 50cm depth and 1 air temperature sensor (50cm above ground). Moisture was also monitored at different depths (10cm, 30cm, 50cm and 100cm) in the central part of High Mountain. To analyze the soil thermal behavior at each sector, four parameters were calculated: freezing and thawing days (FTD); thawing days (TWD); freezing days (FD) and isothermal days (ISO). These parameters reveal predominantly TWD conditions at all sectors and show an absence of permafrost in this central Andes high mountain sector. The Altiplano is the driest sector with annual rainfall of 300mm and mean air temperatures of 6.30C, covered with Dry Puna, herbaceous vegetation. The High Mountain sector has a transitional climate with annual rainfall of 800mm and the lowest averages of air temperature (2.40C and 3.60C). In the Amazonian Slope there is an increase of moisture resulting from adiabatic cooling followed by condensation of humid air masses coming from the Amazon basin. The thermal regimes were classified as Isofrigid, Cryic and Isomesic at Altiplano, High Mountain and Wet Slope sectors, respectively. The pedoclimate data indicate large variations along the climosequence, related to climatic effects on a regional scale and variations in the local conditions of the terrain, accompanied by changes in the vegetation. On the Amazonian-facing slope slightly higher temperatures, translates in higher intensity of weathering and organic matter mineralization rate at the surface soil. The high mountain sector is absent of permafrost below 5000 a.s.l. and suggest a periglacial landscape in strong unbalance.

ANALYZING CHANGE IN RUSSIAN ARCTIC URBAN AREAS USING MULTIPLE REMOTE SENSING DATA SOURCES

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The Arctic environment and areas underlain by permafrost in particular are not conducive to urban development because of the extreme temperatures, engineering requirements, and long periods of darkness. In spite of these conditions, there are numerous urban areas within the Russian Arctic. Over the last 50 years, development in the Russian Arctic has undergone significant change ranging from intensive development in Northwest Siberia, stagnation in Northern Central Siberia, and decay and abandonment in the Northern Far East. Understanding and documenting these changes in development and how it has impacted Arctic urban areas and their future sustainability is part of a larger, NSF funded Partnership for International Research and Education (PIRE) project. Our focus in this study is to determine if we can use a combination of remotely sensed data to map the changes within six urban areas that span a range of development areas and are located in both permafrost and non-permafrost areas including Murmansk, Norilsk, Arkhangelsk, Vorkuta, Yakutsk and Anadyr.

In order to do this we are using a wide array of remotely sensed data including declassified, KH-9 Hexagon and Corona high spatial resolution imagery from the 1960s to 1980s, DMSP-OLS Night Time Lights (NTL) imagery, global products derived from remotely sensed data, including the Global Urban Footprint (GUF) and the Global Human Settlements Layer (GHSL), and current high spatial resolution satellite imagery. This study aims to answer the following questions: 1) What are the changes over time of the built-up areas in the cities? 2) How well do the global datasets, Global Urban Footprint, Global Human Settlements Layer, and Night Time Lights represent these urban areas and what are the differences between the datasets? 3) Do the data from the global datasets show a trend over time and how does it compare to the data from the high resolution imagery both current and historical? 4) What does the NTL data imply about these cities in terms of economic and urbanization trends?

For each of the urban areas, a high spatial resolution satellite photo was acquired from the National Geospatial Intelligence agency. The imagery is either from the Corona program or the Hexagon program depending on the availability of imagery and cloud cover. The first step was visually identify the built up area and delineate the borders using heads up digitizing. The next step was to find the most recent, freely available high spatial resolution image that we could legally digitize the boundary for. From this we are able to calculate the change in the built up area over the 40-50 year period for each urban area. Next, these polygons were used to clip the global data sets GUF, GHSL, and NTL to determine both their ability to depict these small urban areas and in the cases of GHSL and NTL, examine changes over time. The GHSL data the built up and population values from 1975, 1990, 2000, and 2014 are examined, while the NTL data is used to determine if any notable change from 1992-2014. Preliminary results indicate that there are substantial changes within all of the urban areas in terms of urban extant there are significantly different trajectories for some of the cities.

CLIMATE CHANGE WARMS AND DEGRADES PERMAFROST IN EUROPEAN MOUNTAINS

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Since the 18th century, permafrost has been known to be an important geomorphological factor governing certain landform development, and producing geotechnical problems for construction. Relatively recently, permafrost has been related as a major store for certain greenhouse gasses, which can be released if permafrost thaws, and a possible major component for the stability of steep rock walls or other slope covers in mountain environments. Permafrost or ground thermal regime seems also to be an important factor modulating geomorphological process rates and ultimately landscape development.

With the EU-funded PACE project in the turn of this century, several deep boreholes (100 m +) were drilled in European mountain sites, including mainland Norway, Svalbard and Sweden. During other projects from c. 2004 and the IPY period in 2006/07, several additional boreholes were drilled in different sites, including Iceland, measuring temperatures along both altitudinal and latitudinal gradients. In addition, at most sites multi-temporal geophysical soundings are available using seismic and ERT. In Iceland, four boreholes exist since 2004, three of them drilled in permafrost. Finally, daily gridded data sets of meteorological parameters such as air temperature, precipitation and associated snow cover is available back to 1957 for all areas, allowing the evaluation of climate-ground thermal regime relation along regional gradients.

This study focus on the development of ground temperatures in mainland Norway and Iceland, and compare them to the PACE boreholes in Svalbard, Sweden and the Alps. We document the development of taliks in both Norway and Iceland in response to climate variations during the last 20 years. The presentation further discusses the major drivers for these changes and possible future paths of development.

PERMAFROST IS A CRUCIAL FACTOR FOR PARAGLACIAL LANDSCAPE MODIFICATIONS IN GLACIATED MOUNTAIN REGIONS

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Ground temperatures in steep slopes are a well-recognized factor for slope stability. In rock walls, cold permafrost tends to be stable due to additional cohesion provided by ice bonds. A warming of such rock faces influences the ice rheology in rock joints, and decreases tensile and compressive stresses in rock masses.

During the transitions between glaciation and inter-glaciation, many steep mountain slopes encounter repeatedly strong cooling and warming, leading to permafrost aggradation and degradation over relatively short time periods depending on regional deglaciation patterns. We hypothesize that this dynamic is a major factor for slope instabilities after deglaciation in addition and in concert to debutressing.

To test this hypothesis, we have employed a 2D heat flow model over glacial-interglacial cycles, which subsequently has been input into a thermo-mechanical stability model. In addition, emerging sliding planes and deposits from major rock slide events were dated using cosmogenic nuclides. The results indicate the development of progressive instability modulated by permafrost development that acts to transiently influence the mechanical stability of bedrock. Therefore, permafrost dynamics may be an overlooked factor for understanding valley forming and modifying processes during glacial-interglacial transitions, while at the same time influencing present-day rock fall processes in deglaciated areas.

PERMAFROST HAS SUPPORT OF RUN-OFF IN A SEMIARID REGION, CHILE: “COCHIGUAZ” RIVER SUB-BASIN ROCK GLACIERS, WARMING & MINING IMPACT

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At the Cochiguaz river sub-basin, an Andean tributary of the Elqui River, Coquimbo Region of the north of Chile, inhabitants remember that from many decades the run-off have maintained enough water for supply the needs of agriculture and pecuary activities and the people consumption, even during severe drought periods (how the last mega-drought 2010-2015), or because the impact of the local mountain warming tendency. How reference, the increase in the Central Chilean Andes during last 4 decades was more or less 1ºC (0.25º C/decade) (Ferrando, 2012; Falvey & Garreau,2009).

An ongoing research about the founts of the Cochiguaz run-off revealed two facts: The first is that because the altitude, in the sub-basin exist conditions for the presence of different types of classic permafrost, principally on shadow slopes (southern exposition). That means sporadic or seasonal permafrost between 3500 and 4000 m. asl; isolated between 4000 and 4500 m. asl; discontinuous between 4500 y 5000 m. asl; also continuous permafrost in some summits over 5000 m. asl (Barsh, 1978 & IPA, 2010). The other fact is the existence of many rock glaciers of different types and, according to them, different percentage of ice and water equivalent too. About them, there was no information before 2018 (Pino, 2018; Merino et als, 2018).

The recognition by satellite images revealed the existence of 46 rock glaciers, and many morrenic deposits. Considering glacigenic origin, there are a little one semi covered glacier, 12 active rock glaciers, 14 semi-active rock glaciers, 10 boulder rock glaciers, and 2 fossil rock glaciers. From cryogenic origin was founded 4 rampart and 3 talus rock glaciers.

Applying the maximal and minimal proportion of ice stablished for Ferrando, Janke and Bellisario (2014) for different types of rock glaciers, and the 80% how water equivalent (20% of sediments), the results indicate a very high variation of the total hydrological reserves at this sub-basin. That means a minimal quantity of water equivalent to 25.800.200 m^3, and a maximal of 58.303.200 m^3.

From the point of view of a water management plan, this information is not enough but, from the other side, it brings a basic scenery about the existence of these ice reserves that, form always, have provided the water for rivers and the underground in the valley.

Because of this, the need of more investigation about his existence, the real situations of them in a scenery of mountain warming, a more accuracy mount of water equivalent determination, the fusion velocity, his mass balance and the possible effects of mining projects, is clearly necessary. Also, warming tendency at the Andean mountains of the Coquimbo Region must be determinated.

Into this scenery, and the necessary preservation of these ice reserves for insure the life and the continuity of the activities of the people who lives and works in this valley, a lineal oasis, two new mining projects were recently submitted to the corresponding authorities of Chile, both at the Cochiguaz river sub basin.

These projects are seen how a big hazard by the inhabitants because they know what is happening in another Andean valleys of the North of Chile, specifically Atacama Region, and also in the Metropolitan Region of Santiago, the capital city. His execution means a real threat for the maintenance of these “water towers”, also for the ecosystem, the human activities and all forms of life that exist there.

With the new knowledge of this research and the academic support, the governance exercise by them have more tools and arguments for a better defense of his right to live in a place free of contamination and maintaining better conditions for a good quality of life, now and for the next generations.

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HYDROLOGICAL PROCESSES OF THERMOKARST LAKE IN THE TIBET PLATEAU, CHINA

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Themokarst lakes are widespread in the permafrost region. In recent years, the scale and number of thermokarst lakes are significantly increasing in the Tibet Plateau under the background of climate warming and wetting. The evolution of thermokarst lake are expect to release greenhouse gas, accelerate the water cycles, and reshape the permafrost landscape. However, the regime of hydrological cycles remains unclear in the high-altitude permafrost region. To fill the gap, the supra-permafrost water, sub-permafrost water, lake water level were systematically monitored in a typical thermokarst lake. The results showed that the thermokarst lake originated from multiple sources, such as precipitation and its caused supra-permafrost water, permafrost melting water, and the contribution of sub-permafrost water to thermokarst lake is tiny in the Tibet Plateau. Moreover, the isotope mass model revealed that the water loss caused by evaporation is almost half of inflow in the ice-free season, and the sublimation process is the main factor to lead water loss in the ice-covered season. Finding demonstrate that the thermokarst lake will be continued expansion with the climate changing.

AN EXPERIMENTAL METHOD FOR OBTAINING TRANSVERSE STRESS OF THE FREEZING DIRECTION IN FROZEN SOIL SAMPLES

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In this study, an innovative frost heave cell is designed to investigate the characteristics of stress in the radial direction of freezing. The frost heave cell is divided into several independent rings connected by silicone sheets, which can reduce the deformation influence of the frozen part on the unfrozen part. The circumferential strain is measured by strain gauges on the surface of frost heave cell. In order to transfer this circumferential strain into stress in the radial direction, we adopt the thick-walled cylinder theory. Then, we conducted some freezing tests to investigate the characteristics of radial stress during freezing. The results suggest that the radial stress caused by frost heave increases rapidly when the temperature drops from 0 ºC to -2 ºC. However, as the temperature decreases below -2 ºC, the radial stress gradually increases. When the temperature approaches -10 ºC, the radial stress plateaus and does not increase further. These findings indicate the unique characteristics of radial stress and suggest the need for further research on this topic. As more complicated applications of artificial freezing method in underground space of urban area are expected, the influence on the surrounding structures brought by three-dimensional freezing shows its significance. Our research is aiming to investigate the mechanism of freezing phenomenon of soil in three-dimensional space and then promote the application of artificial freezing method in a wide area.

Keywords

Frost heave; radial stress; freezing direction; thick-walled cylinder theory.

A SIMPLE ALGORITHM OF ACTIVE LAYER FREEZE-THAW PROCESSES AT THE WATERSHED SCALE IN THE QINGHAI-TIBET PLATEAU

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The shortage of both land surface temperature and soil moisture information in high latitudes or altitudes places a major limitation on permafrost modeling, especially at the watershed scale. A simple model composed of the revised High Resolution Simplified Surface Energy Balance (HRES-SEB) model, the S-curve model and the bidirectional freezing Stefan algorithm was thus developed to simulate the freeze-thaw processes of active layer underlain by permafrost. The HRES-SEB model was revised for the transfer of air temperature to land surface temperature, replacing the n-factor, and an S-curve model was established to obtain soil moisture via the S-curve relationship between soil moisture and land surface temperature. To apply the combined model in the Fenghuoshan (FHS) watershed, a typical permafrost watershed located in the central Qinghai-Tibet plateau (QTP), the model was validated with observation data at sites with different elevations, slope aspects and vegetation coverages, with the mean RMSE of 0.20m and R^2 of 0.93. The simulation results showed large spatial-temporal variation in the active layer freeze-thaw processes over the FHS watershed, with a thickness variation of 1.73~2.17m, a thawing duration variation of 151~208 days, and a freezing duration variation of 49~107 days. At the watershed scale, the slope aspect most influenced active layer thickness (ALT), followed by vegetation coverage, and the impact of elevation was the smallest. The average variation rates of ALT were -3.0 cm/100 m in shady slopes, and -7.0 cm/100 m on a sunny slope. Air temperature, vegetation coverage and slope aspects were found to be particularly sensitive to freeze-thaw processes, which indicates that the combined model could identify the impacts of topography and vegetation conditions on the freeze-thaw processes at the watershed scale. The simple model proposed in this study is not only an optional approach with high-precision for freeze-thaw process simulation of active layer, but could also be easily integrated with watershed hydrological models and regional ecological models in permafrost region.

Keywords

Active layer; Freeze-thaw process; Stefan algorithm; Revised HRES-SEB model; S-curve.

RUSSIAN-NORWEGIAN RESEARCH-BASED EDUCATION IN COLD REGIONS ENGINEERING

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As known the northern part of Europe is becoming more important from an economical standpoint. However, sustainable development of this region require from engineers a better understanding of the mechanics and geodynamics associated to frost. MSU and NTNU have long history of research cooperation on Arctic and cold region engineering, providing better education to students at both universities (NTNU reports (Isaev et al., 2017)). Throughout this cooperation, the students from both universities gain better understanding of the scientific culture and traditions in Russia and Norway.

Keywords

International educational program; geocryological surveys; Arctic polar regions.

Introduction

The two main activities in the framework of the RuNoCORE project are to arrange indoor intensive course for exchange students from Russia and Norway at NTNU and MSU respectively, and to enroll Norwegian students to fieldworks in the north European Russia. Such courses and fieldworks will assure an excellent educational basis for engineers focusing in cold climates. A significant part of funding is allocated for student scholarships and travel expenses. The RuNoCORE project is building on the strong foundation of science, promoting student involvement in research activities. Administrative staff from both sides is involved in facilitating student mobility, giving the students a better understanding of two educational systems and helping to solve administrative hindrances. This project is essential to establish an effective platform for student mobility and, when up and running, will further facilitate funding search for future student mobility and cooperation efforts.

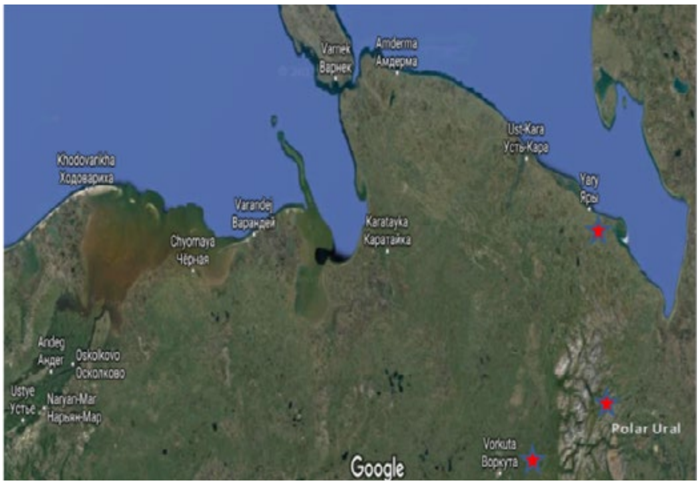

Figure 1: Field work sites location. (https://earth.google.com/web/)

Engineer-geocryological scientific-educational fieldwork campaigns of Moscow State University masters students in the European Russian Arctic were lunched in 2012 and were since based on integrated research program using classical field geocryological methods (Melnikov & Spesivcev, 1995).

The key research sites were chosen in the vicinity of the Vorkuta city, and at the coastal site Yary on the Baydara Bay coast, Kara sea. In 2014 the field work program was changed and the main focus switched to exercises in geocryological mapping of differential periglacial landscapes. Subsequently, several new sites became available for researchers (Fig.1):

- The Hanovey railway station area on the coastal zone of Vorkuta river located in Bolshezemlskaya tundra (N67.283598,E 63.661332);
- The 110 km railway station area on the coastal zone of the Sob' river in Polar Ural mountain area (N67.051180, E65.351926);
- A 6,5 km long section of the western coast zone of the Baydara Bay, Kara sea (N68.908657, E66.501391).

The content of the training tasks corresponds to the methodologies that were developed during the implementation of famous international projects. In particular, the experience of the World Meteorological Organization's GTN-P – GCOS project was used.

Figure 2: Cryological mapping during field course for international students team with field teachers (Alla Bezdelova&Pavel Kotov).

Figure 3: Geophysical survey (ERA) by Norwegian PhD students (Karlis Riekst&Vadim Simonsen) with Russian railway engineering staff (Alexander Kekelev) supervised by MSU geophisist (Oleg Komarov).

In 2018, PhD students from Norwegian University of Science and Technology (NTNU, Trondheim, Norwey), supported by the RuNoCORE collaboration project, have participated on the main field activities at Hanovey educational area (Fig.2), in an individual survey at the Nikita railway station (N67.054186,E 63.772885) in the Polar Ural mountain area (Fig.3), and then joined to the MSU research group on the coast of the Baydara Bay (Fig.4).

Figure 4: DGPS&LIDAR mapping of Kara sea coastal line (Isaev et al., 2019) by Norwegian student (Vadim Simonsen) supervised by MSU&ArtGeo specialists (Ruslan Amangurov&ArtGeo).

Figure 5: Safety training at UNIS with MSU students (Anton Agapov, Maria Kalabina, Frantz Shevchik, Maria Kozlova).

From the other side, the MSU students had the opportunity to get acquainted with new approaches to teaching on the example of the Norwegian higher education (University Center Svalbard-UNIS) from 19/09/2018 to 19/10/2018 with intensive lecture courses, field work & excursion, and final examination. (Fig. 5)

UNIS is a joint stock company owned by the Norwegian Ministry of Education and Research. UNIS was established in 1993 to provide university education in the field of Arctic research, to conduct high-quality research, and to promote the development of Svalbard as an international research platform.

The geographical position of UNIS gives it a unique advantage, allowing students and teachers to use nature as a laboratory, an arena for observation and data collection. The constituent council includes four Norwegian Universities: Oslo, Bergen, Trondheim and Tromso. UNIS works closely with other universities and UNIS courses are designed to complement university teaching. The student community, faculty and support staffs are international (https://www.unis.org/).

Conclusions

The RuNoCORE project is active since 2018, with already a one year history of successful joint fieldworks and exchanges. The main expected outcomes are as following:

1. The collaboration is supported between the universities in Norway and Russia connecting education with research activities;
2. The partnership will support joint bilateral efforts in the development, quality assurance and integration of two research-based courses in cold regions engineering and geocryology;
3. Joint educational materials for new and ongoing courses at NTNU, provided in English, will be partly based on the translation of Russian literature, promoting it on the European level;
4. Bilateral knowledge transfer between students and academic staff in the field of cold climate engineering between NTNU and MSU;
5. Increase the mobility of students and staff between participating institutions is supported by dedicated funding for scholarships and both short- and long term stays at partner institutions;
6. Increase the involvement of both students and academic staff in joint ongoing research activities through joint supervision of bachelor/master/PhD students;
7. Improve intercultural competence among students, academic staff and administration in the partner institutions through guest lectures, workshops and joint activities;
8. Encourage multidisciplinary and international academic programs at partner institutions and promote the engagement of public authorities, industry and research institutions in such programs.

Acknowledgments

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the SAMCoT WP6 https://www.ntnu.edu/web/samcot/home

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CHANGES IN HYDRAULIC CONNECTIONS IN THE SOURCE AREA OF THE YELLOW RIVER (SAYR) USING ISOTOPE TRACING TECHNIQUES

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Hydraulic connections have changed greatly in the Source Area of the Yellow River (SAYR) on the northeastern Qinghai-Tibet Plateau, SW China, affecting hydrological processes. Isotope tracing techniques have provided the crucial support for studying dynamic changes in permafrost-controlled, coupled flow systems. This program aims at studying the spatiotemporal distribution of and changes in isotopes, such as ^{222}Rn, δD and $\delta^{18}O$, in various waters in the five carefully-chosen zones with varied stages of degrading permafrost in the SAYR, in order to evaluate changes in hydraulic connections due to the degrading permafrost. Since the initiation of this program, the team have conducted research on the following four aspects: 1) Qualitative analysis of hydraulic connections in the SAYR by using stable oxygen and hydrogen isotopes; 2) Studying impacts of seasonal freeze-thaw processes on runoff generation and flow-paths by using Radon isotopes; 3) Research on the resident time of groundwater and ground-ice and hydraulic connections by using radioactive isotopes, and; 4) Comprehensive analyses on hydraulic connections by integrating the spatiotemporal distribution of isotopes. The program achieved in the following four aspects. 1) Experimental studies on changes in runoff generation and flow-paths resulting from degrading discontinuous permafrost in the SAYR. Hydrological experimental studies were conducted in the Shuangchagou and Wanlong Worma rivers experimental watersheds, Tangchama Piedmont Plain and SAYR by monitoring hydrothermal and hydro(geo)logical processes, using the isotope tracing, and by deploying hydrogeological and geophysical explorations. These studies have revealed changing features on and trends for dynamics of surface and subsurface waters, and mutual supplies and discharge relationships. 2) Some hydrological and geocryological observations were conducted in experimental valleys under varied degrees of permafrost degradation. Models for interactive exchanges of surface and subsurface waters were established on the basis of radioactive isotopes for analyzing hydrological impacts from degrading permafrost; 3) Hydraulic connections between frozen ground and river/lake taliks were studied by using isotopic dating, and; 4) Differences in hydrological processes and water resources in various zones of frozen ground were evaluated by establishing quantitative lake/river isotope models. Supplies from ground-ice meltwater and groundwater from taliks and the supra-permafrost water are important in the SAYR hydrological processes, and permafrost degradation has already resulted in marked hydrological impacts. Hydraulic changes due to degrading permafrost are evidenced mainly by deepening flow generation depths and elongating flow-paths, enhanced groundwater storage, as well as dramatic changes in most aspects of water balance. However, better quantitative evaluation of hydrological impacts from degrading permafrost awaits more in-depth and detailed analyses.

Key words

Permafrost degradation, coupled flow systems, Isotope hydrology, permafrost hydrogeology, changes in hydraulic connections.

HIGH ARCTIC PERMAFROST BIOGEOCHEMISTRY UNDER CLIMATE CHANGE

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Permafrost active layer depths are predicted to increase in response to rising air temperatures in the High Arctic. This will liberate formerly frozen organic carbon and nutrients for microbial metabolism. Past and present environmental and sediment parameters exert a powerful influence on the amounts of methane and carbon dioxide generated as this organic carbon is decomposed. To determine the dominant biogeochemical processes leading to greenhouse gas production, we studied the active layer and permafrost of High Arctic low- and high-centred ice-wedge polygons in two contrasting sedimentary environments: inter-beach ridge sediments and fjord valley infill sediments in Svalbard. We extracted the porewaters of replicate cores and measured the aqueous and solid phase chemistry. Our results show that high organic carbon content and water saturation at one fjord valley site were conducive to iron and sulphate reduction, with the products forming pyrite and siderite. In addition, the low redox environment of this site was ideal for methanogenesis, with the porewater methane concentrations reaching almost 200 µmol l-1. In contrast, the well-drained fjord valley site was low in organic carbon and was dominated by pyrite oxidation. This led to high concentrations of aqueous iron and sulphate in the cores from this site, as well as negligible methane. Finally, ice-wedge polygon degradation in the inter-beach ridge sediments led to: i) a well-drained, aerobic polygon centre, ii) negligible pyrite and siderite formation, despite a high organic carbon content, and iii) an absence of methane in the active layer porewaters. Although ice-wedge polygons in Svalbard have yet to experience widespread degradation, it is predicted that permafrost thaw will cause poorly-drained, low-centred polygons to degrade to well-drained, aerobic, high-centred polygons. The low-centred polygons established in the fjord valley infill sediments are vulnerable in the long-term to altered hydrology by polygon degradation. These polygons could transition from methanogenesis to aerobic respiration, leading to rapid decomposition of organic carbon, increased carbon dioxide emissions and major changes in the redox chemistry of iron and sulphur.

GLACIER-PERMAFROST-INTERACTION AT A THRUST MORAINE COMPLEX IN THE VAL MURAGL, SWISS ALPS

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The genesis of thrust moraines in high alpine environments like the European Alps is still poorly explored. Several studies indicate the existence of an interaction between glacier and permafrost and have verified the presence of polygenetic ground ice in several moraine complexes in the European Alps by geophysical surveying. The presence of massive polygenetic ground ice within the large thrust moraine complex of the upper Val Muragl (Swiss Alps) was confirmed some years ago. However, so far no other structures indicating an interaction of the glacier and sub- and proglacial permafrost were detected inside this moraine complex. Aim of the study was to detect the internal structure and composition of the moraine complex in order to develop a conceptual model of moraine formation including the impact of permafrost and potential pre-existing glacier-permafrost relationships. A combination of 2D electrical resistivity imaging and ground penetrating radar surveys have been applied. The GPR surveys were performed using a PulseEKKO Pro system with two unshielded 50 MHz antennas. The ERT surveys we conducted using a Syscal Pro Switch resistivity imaging system with 36 electrodes and an electrode spacing of 5 m.

The results of the ERT measurements enabled the delineation of the extent of a massive ice core and showed a zone of very high electrical resistivity values in the central and proximal part of the moraine body. The high electrical resistivity values reach more than 1 MOhm and give evidence of a polygenetic origin of the ice core. GPR-data show a lot of linear reflectors, which dip into the proximal side of the moraine complex. Their extent, disposal and dipping direction suggest that they correspond to the shear planes during moraine formation.

The combination of ERT and GPR surveying could contribute to a better understanding of the internal structure of the moraine complex. The geophysical data make the presence of a polygenetic massive ice core likely and indicate as well substrate boundaries inside the moraine body that can be interpreted as shear planes. These shear planes give additional evidence of a glacier-permafrost-interaction during the formation of the moraine complex because of the mainly brittle deformation of the sub- and proglacial sediments.

MULTI-SCALE CHARACTERIZATION OF POLAR PERMAFROST LANDSCAPES, YUKON AND NORTHWEST TERRITORIES, CANADA

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In the Arctic, a significant increase of the mean air and ground temperatures has been observed during the last decades. Impacts on the geo- and ecosystem of permafrost landscapes are already recognizable such as the proliferation of shrub lands, or the increase of the active layer thickness.

The aim of our project is the identification of interconnections between surface properties detectable by remote sensing instruments and subsurface properties characterizing the state of permafrost landscapes. The selected investigation areas are located in the Yukon and Northwest Territories (Mackenzie Delta region and adjacent Peel Plateau), Canada and exhibit different permafrost dominated ecosystems.

To reach our goal to characterize the different permafrost landscapes and investigate different typical landforms in this continuous permafrost zone in order to analyze possible interconnections of the different parameters we apply a multi-scale and multi-method approach to map the surface and subsurface parameters characterizing the geosystem based on in-situ, airborne and satellite borne measurements. The in-situ measurements comprise geophysical surveying, active layer thickness measurements, vegetation height mapping and the continuous recording of the near-surface temperature and soil moisture. Especially the vegetation characteristics and surface morphology and therewith the local drainage system is of particular importance for the subsurface conditions and for the development of the landforms. Therefore, we investigate the internal structures of the landforms but also the catchment area to assess the hydrological system connected to the landforms.

First results of the geophysical measurements (electrical resistivity imaging and ground penetrating radar) indicate heterogeneous subsurface conditions with a considerable small-scale variability of the permafrost characteristics to an extent that could not be expected for an at first sight homogeneous landscape. The comparison of the surface and subsurface data point to a complex linkage between surface and subsurface characteristics. For example, the first results clearly show that the relationship between active layer thickness and vegetation height appears to be more complex than it is often assumed.

We hypothesize that the relation of subsurface geophysical data and surface parameters captured by imaging remote sensing sensors allows the area wide recognition, identification and quantification of interactions between the different components of the periglacial system. The findings of our project will be used to delineate conceptual models illustrating the surface and sub-surface interconnections during the development of the characteristic periglacial landforms and explain the landscape dynamics, evolution and future development with a view to the impact of recent and ongoing climate change.

ICE TABLE DEPTH, GROUND ICE AND ITS δD-δ¹⁸O COMPOSITION IN COLD-DRY SOILS

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In the ultraxerous region of the Dry Valleys of Antarctica, the very cold and arid climate ensure that dry soils overlie icy permafrost; a characteristic unique to this region. Here, we present a summary of our work in University Valley, in the upper Dry Valleys. In University Valley, mean annual air temperature approximates mean annual ground surface temperature (ie, surface offset ~ 0°C); however, mean annual relative humidity (45.5 ± 14%) is much lower than mean annual ground surface relative humidity (varying from 100 to ~ 85%ice). The ice table depth increase with distance from the glacier: from < 1 cm to ~ 60 cm, indicating that despite being a cold and dry region, ground ice is pervasive and active. Excluding two bodies of buried glacier ice, the volumetric ice contents ranged from 0 to 93%. These high ice contents suggest the cold temperatures and low precipitation in the upper Dry Valleys are likely not limiting factors to the development of ice-rich permafrost. Based on D18O measurements for all ice bodies, the ground ice has different origins, including: vapor deposition, freezing of evaporated snow meltwater or burial of glacier ice. We modeled the net water vapour flux, ice table depths and D18O of ground ice using the conditions measured in the valley. When ground surface conditions are used (instead of those measured in the atmosphere), our modeling predicts that the measured ice table depths in the valley are likely in equilibrium with contemporary conditions.

MAPPING ROCK GLACIERS IN THE SOUTHERN ALPS OF NEW ZEALAND WITH SENTINEL-1 INSAR

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In the Southern Alps of New Zealand, around 150 rock glaciers have been classified as active or inactive by Sattler et al. (2016) based on aerial photographs. All of them are located at the East side of the Main Divide, were glaciers are more reduced. Besides, only little attention has been paid to the dynamics and evolution of rock glaciers (e.g Brazier et al. 1998; Winkler & Lambiel 2018). Therefore, their rate of activity remains largely unknown. To address the lack of knowledge on rock glacier activity in the Southern Alps of New Zealand, we have started a study aiming at 1) inventorying moving landforms located in the periglacial belt and 2) estimating their rate of activity with the support of Sentinel-1 InSAR data.

The radar interferometric analysis was performed with a series of about 30 Sentinel-1 images acquired between 2014 and 2018. A topographic reference was prepared with the 8m Digital Elevation Model (DEM) originally created by Geographx (geographx.co.nz) from January 2012 LINZ Topo50. We only employed images acquired during the snow free period, between February and April. A total of 23 differential SAR interferograms – 12 in the ascending mode and 11 in the descending one –, with time interval from 6 days to about two years, were produced for this study.

The analysis of the differential SAR interferograms coupled with orthoimages permitted to detect not only active rock glaciers, but also debris-covered glaciers and large landslides, mainly in the Two Thumb, the Liebig and the Ben Ohau Ranges. Rock glacier velocities are generally lower than 30 cm/y and in most cases around 10-20 cm/y. The InSAR data were validated by differential GNSS data acquired on two selected rock glaciers of the Irishman valley (Ben Ohau Range). These velocities are low compared to what is usually observed in the European Alps. Such low velocities are probably explained by the related climatic control on rock glacier creep. Sattler et al. (2016) have indeed shown that the permafrost lower limit is unusually low compared to the European Alps, which is due to the maritime climate and moderate summer temperatures.

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SUSTAINABLE DEVELOPMENT IN YAKUTIA: ECONOMIC, ENVIRONMENTAL AND INNOVATIVE ASPECTS

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Sources of regional development are becoming critical in Yakutia, the biggest Russian region with enormous amounts of natural resources. After the 1990s, Yakutia focused mainly on the extraction and export of oil and gas. However, this resource-dependent development is no longer sustainable due to changes in federal tax law regulations (2013) and the current environmental situation. Currently, there are no sources for sustainable development of Yakutia, and the federal funding is inadequate to support the regional infrastructure development. This decline affects every aspect of living in Yakutia. It is time to focus on new development advantages and possibilities in the region. Therefore, we need to create a Sustainable Development Initiative in Yakutia with a focus towards creative economics that will be implemented through the special state policies and will be based on the results of conducted interdisciplinary research.

ELEVATION IMPACTS ON MOUNTAIN PERMAFROST TEMPERATURES, YUKON, CANADA

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Previous studies have shown that air temperature lapse rates in regions of discontinuous permafrost in the Yukon vary spatially with continentality. The extent to which these air temperature trends translate into ground temperatures has not been investigated. Such knowledge is needed to predict potential hazards such as landslides and rockfalls associated with thawing mountain permafrost.

We present results from 13 sites where ground temperatures in boreholes (median depth 7 m, range 1.6-42.9 m) and air temperatures have been monitored for periods of 1-13 years. The boreholes are located in pairs or clusters at elevations from 320 m to 765 m asl in valley bottoms and from 1190 to 2080 m asl in mountains, extending west to east from Kluane Lake to Macmillan Pass, and south to north from Whitehorse to Dawson. The ten sites above treeline are the only high elevation boreholes currently being monitored in the region.

Mean annual air temperature (MAAT) at the ten mountain permafrost sites varies from -2.1°C to -6.2°C, while mean ground temperature (MGT) at or close to the depth of zero annual amplitude ranges from -0.2°C to -4.3°C. The average MAAT to MGT offset is 2.6°C, but is as low as 1.6°C at windblown sites where little snow accumulates. The depth of zero annual amplitude is only 3 m at the warmest site in fine sediment but >20 m in bedrock. The base of permafrost, inferred from electrical resistivity tomography ranges from 7 m to >65 m (maximum depth of investigation). The sites with longer records show warming that averages 0.1°C/decade since 2004 but twice this rate has been observed in the past 5 years. Rates of change in air and ground temperature with elevation show little correlation and can even exhibit differing signs, indicating the challenge of modelling ground temperatures in this region.

EVALUATION OF BIOGEOPHYSICAL FEEDBACKS IN ICE-WEDGE DEGRADATION THROUGH FIELD MEASUREMENTS, REMOTE SENSING, AND MODELING

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Ice-wedge degradation is documented at many locations across the Arctic region in recent decades through field and remote sensing observations. Initial thaw may be abrupt, responding to an unusual warm summer, while the subsequent processes could either enhance or reverse continued thaw. Here, we are assessing the prevalence and rates of biogeophysical processes that initially promote and then quickly stabilize ice-wedge degradation through studies at Prudhoe Bay and the Arctic National Wildlife Refuge, northeast Alaska, with field observations spanning over a decade. We find ground subsidence associated with melting of the top of ice-wedges during the last four decades to have become areas of productive growth of aquatic vegetation and organic soil accumulation, which in turn caused permafrost aggradation and therefore partially recovered topography. Vegetation growth and accumulation of organic soils above previously degraded wedges result in decreased active layer thickness and subsequent accumulation of ground ice and formation of a protective perennially frozen soil layer. Thickness of the protective layer above stabilized wedges is usually two to three times greater than above undegraded wedges. Active ice-wedge degradation initially forms isolated pits followed by integration of surface channels in the trough network. More advanced trough drainage networks show a history of draining trough-ponds, as seen through remote sensing imagery time series. New and older trough drainage networks are visible with increased greenness. Nitrogen availability in surface waters increases with ice-wedge degradation, but then is reduced with the subsequent increase in aquatic vegetation, presumably due to plant uptake of nitrogen. Submergent aquatic mosses may be suppressing heat transfer into the pond sediment, potentially acting as a threshold variable in promoting permafrost aggradation in ponds too deep for sedges to populate. Also, many ice-wedge ponds are actively expanding laterally. The landscape shows active aggradation and degradation happening side by side, with both processes appearing even within the same pond. Over time, the biogeophysical processes promote a landscape more resilient to thaw due to the response in vegetation productivity and organic soil accumulation. However, the alterations to the surface topography appear to imprint irreversible hydrological changes in lateral surface flow pathways, which follow the ice-wedge patterns that are developed over millennia.

THERMAL BEHAVIOR OF A NOVEL CRUSHED-ROCK EMBANKMENT FOR EXPRESSWAY IN PERMAFROST REGIONS

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The planned Qinghai-Tibet Expressway (QTE) will traverse the largest plateau permafrost region in China, and it is expected to play an important role in promoting the economic development of Tibet. Although a crushed-rock embankment has been successfully adopted in construction of the Qinghai-Tibet Railway (QTR) to maintain the road foundation stability on the plateau, the current embankment structure may not be sufficient to cool the expressway roadbed because of the strong heat absorption of the wide and dark-colored asphalt pavement surface. Thus, there has been concern that the QTE will face more severe permafrost degradation problems than the QTR, especially under the impacts of a warming climate in the plateau. To satisfy the higher cooling requirement of expressways, a novel crushed-rock interlayer structure, which especially focuses on enhancing the cooling performance on the embankment core, is presented. A numerical heat transfer model was developed to investigate the thermal behavior of a full-scale embankment section with the new design built in Huashixia, the Qinghai-Tibet Plateau. The numerical results indicate that the new structure has a significant cooling performance and especially plays an effective role in lowering the permafrost temperature beneath the centerline of the expressway. Moreover, the new structure eliminates the thermal asymmetry induced by the Qinghai-Tibet Plateau's prevalent wind direction. Therefore, the new structure is an effective method to prevent permafrost degradation under expressways and can ensure the long-term thermal stability of embankments under the climate warming. The study provides guidance for expressway design and construction in permafrost regions, such as the planned QTE.

Keywords

Thermal behavior; crushed-rock embankment; expressway; permafrost.

RECENT ACCELERATION OF THAW SLUMP ACTIVITY IN THE PERMAFROST REGION OF THE QINGHAI-TIBET PLATEAU

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Thaw slump activity has increased in the permafrost region of the Qinghai-Tibet Plateau (QTP) in recent years, which not only influences the stability of the local infrastructure but also impacts the global biogeochemistry and climate cycle. Utilizing satellite image interpretation, this study presents changes in retrogressive thaw slumps in the Beiluhe Region, which is an area on the QTP where thaw slumps have widely developed over the last ten years. The results indicate that thaw slump activity has increased rapidly from 2008 to 2017, with the total number of thaw slumps increasing by 253.23% and the total affected area increasing by 617.30%. This study determined that the intensification of thaw slumps in the study region did not occur evenly in each year, but they were concentrated in the specific years of 2010 and 2016. This was mainly attributed to the anomaly of high warm season air temperature as well as abundant precipitation in those two years. Future thaw slump initiation on the QTP will likely be linked to changing trends in anomalous weather events and general climate warming.

CHARACTERISTICS OF GROUND SURFACE TEMPERATURES AT CHALAPING, THE SOURCE AREA OF THE YELLOW RIVER, NORTHEASTERN QINGHAI-TIBET PLATEAU

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Permafrost in at high altitudes such as the Qinghai-Tibet Plateau is a product of cold climates interplayed with complex surface hydrothermal processes and energy balance. To success in modeling or mapping the permafrost distribution, the parameterization between the near-surface air and ground surface temperatures at local-, meso-, or macro-scales should be an ongoing practice. Here, we conducted a long-term experimental observation concerning the difference between the near-surface air and ground surface temperature at a local scale with 21 observational sites for more than eight years (November 2010 to August 2018). Results demonstrate that the GST varies greatly even within a short distance. The mean annual ground surface temperature (MAGST) ranges from -0.60 to -2.62 °C and is averaged at -1.34±0.62 °C, despite within 1 km^2 of the plot with elevations about 4,700 m above sea level; while the surface offset, the difference between mean annual air temperature (MAAT) and the MAGST varies from 1.31 to 3.45 °C and is averaged at 2.76±0.69 °C. The difference between monthly air temperature and monthly ground surface temperature decreases from 4.64±2.09 °C in January to 1.09±1.34 °C in July and then gradually increases to 5.61±2.53 °C in November (Figure 1). The thermal state of permafrost at Chalaping was modeled for details in considerations of the surface characteristics, soil textures, in situ observations of GST, and TTOP model. The modelled results showed that the permafrost temperature at the depth of zero annual amplitude ranges -0.6 °C to -2.2 °C and is averaged at -1.34 °C. This study may facilitate the parameterization of upper thermal boundary condition of permafrost-climate systems.

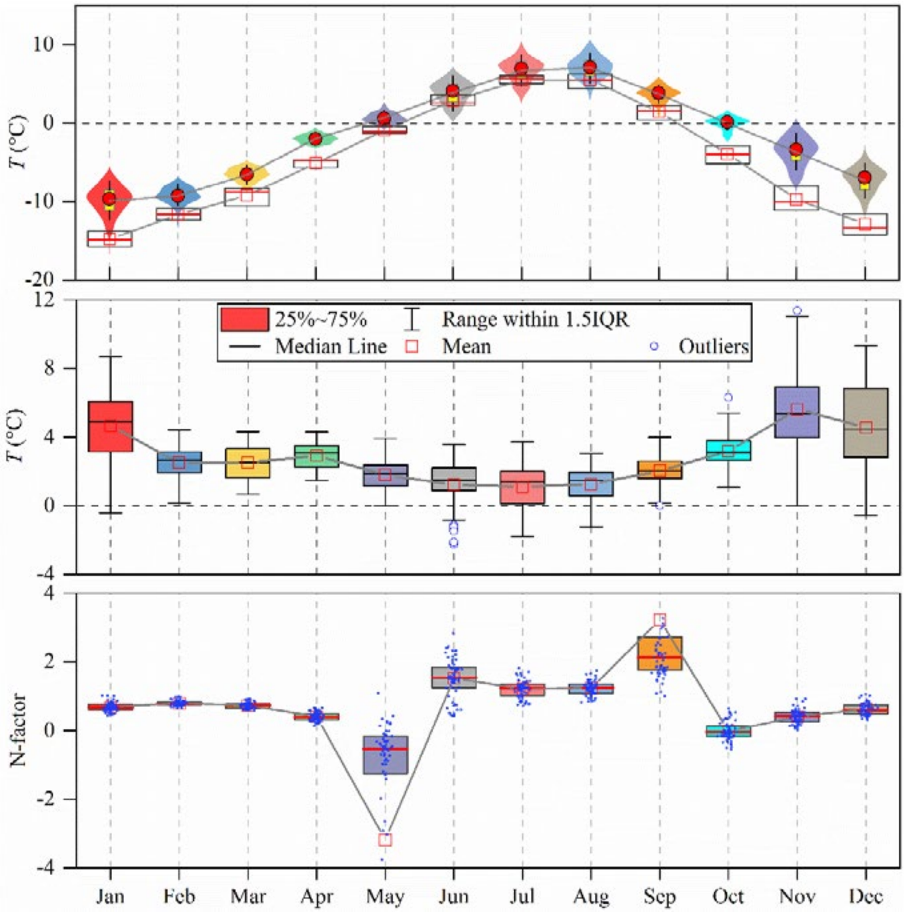

Figure 1: Variations of monthly air temperature and ground surface temperature (a) and their differences (b), and the N-factors related to near-surface air and ground surface temperature.

THE PRELIMINARY ANALYSIS OF THE POLYCHEMICAL POLLUTION OF CRYOGENIC SOILS AND UPPER PERMAFROST IN RUSSIA

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Nowadays Russia experiences the new wave of increasing exploration in the Arctic: oil and gas production, coal mining, military objects, Arctic Ocean sea-pass development. All this activities are strongly connected with hydrocarbon consumption and environmental pollution due to high rate of risks. In some cases, the ecological damage can be partly eliminated by bioremediation and recultivation actions. Still unknown is the fate of large part of pollutants' volume which can potentially migrate downwards due to the active processes of cryogenic mass-exchange then laterally redistribute over the surface of permafrost and even penetrate into it. Geochemical evolution of these contaminants in polar ecosystems under global climate change and local impacts is poorly studied.

The reaction of soil-permafrost complex to the environmental changes results in changing of thickness of the active layer of permafrost, intensity of cryogenic mass-exchange, cryolithological structure of the upper permafrost. In some cases (at the construction sites, road building, soil insulation etc.), the decreasing of the active layer thickness is often obtained. It results in cryoconservation of pollutants in the upper permafrost. Later, after the environmental and climate change these layers of permafrost can thaw again and can be included into the biogeochemical cycle.

Besides the local pollutants (e.g. anthropogenic hydrocarbons), the supertoxicants can be accumulated in polar ecosystems: persistent organic pollutants, heavy metals, polyaromatic hydrocarbons, radionuclides etc. Some of them migrate via atmosphere, some via trophic chains. However, the same as local pollutants, these toxicants' fate in cryogenic soils, upper permafrost and in polar ecosystems themselves is very poorly studied. Arctic region became the depo of global pollutants from other regions of the planet.

The special case of Arctic exploration is the ecological damage from nuclear testing which led to the accumulation of Cs, U, Pu, Sr artificial isotopes.

The complex concept of assessment and forecast of polychemical pollution of soil-permafrost complex and future decreasing of negative technogenic impact is of high importance in terms of governmental and social requests.

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DEVELOPING A ROCK GLACIER MANAGEMENT PLAN IN NORTHERN CHILE

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During the last century, northern Chile has experienced difficulties with water availability. This situation is related to both the decrease in precipitation during this period, and the increase in the demand for water from various sectors, including agriculture, mining and for domestic use. At present, there is limited information available to quantify hydrological contribution from different natural water sources (snow, glaciers, rock glaciers, rain, fog, and dew) to the local hydrological system. The contribution and importance of each of these elements varies annually due to climate variability, which is largely driven by ENSO cycles. In this context, we know that the primary water source comes from the cordillera, and that snow is the dominant source. However, during the summer months, and periods of drought, glaciers and rock glaciers play an important role, especially for maintaining basal flow. Over the last decade, both scientific and public interest in the existence and role of glaciers and rock glaciers in the Chilean Andes has increased, leading to the initial development of legislation aiming to give protection to ice bodies along the length of Chile. The development of this legislation has run parallel to a strengthening of the Environmental Impact Assessment system, which as of 2013 includes specific clauses relating to glacier and rock glacier evaluation. Due to the relatively recent awareness of glacier processes in the semiarid Andes, there is currently limited information and available methods to analyse the hydrological role and behaviour of rock glaciers in this area. The aim of this presentation is to outline a strategy to develop a rock glacier management plan for the Coquimbo Region, by diagnosing the current state of information, and methodologies available, before outlining steps required to address current knowledge gaps. From our analysis of the public sector, we have determined that 35 ministries and/or departments have a direct connection with glaciers, and that several rank highly in terms of both interest and influence. Of those institutions, all confirmed a lack of an efficient system to disseminate information, and in general a low level of knowledge with regards to glaciers. From this analysis based on questionnaires, interviews and working groups we are currently developing strategies to efficiently and sustainably manage rock glaciers in the region, as a socialeconomic resource.

MICROBIAL SURVIVAL AND METABOLISM ACROSS A PAN-ARCTIC STUDY OF NORTH AMERICAN AND SIBERIAN PERMAFROST

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Permafrost is an extreme habitat, yet it hosts microbial communities that remain active over geologic timescales. To determine how physicochemical conditions drive microbial functional potential, we conducted a large pan-Arctic study with over 100 samples of microbial communities from Siberian and North American permafrost. Large-scale metagenomic sequencing combined with physicochemical measurements and high resolution characterization of dissolved organic carbon (DOC) via FTICR-MS revealed that DOC, percent carbon, percent nitrogen, and age drove functional potential, while pH and continental origin did not affect the abundance of functional genes. Genes related to carbon characteristics included those involved in the degradation of plant polysaccharides such as starch and cellulose. We also found changes in aromatic hydrocarbon degradation genes, indicating the ability to metabolize recalcitrant carbon and nitrogen substrates such as lignin.

Permafrost age appeared to affect the characteristics of dissolved C and N pools. Over time, microbial metabolism appeared to change the molecular composition of DOC. The number of identifiable carbon compounds declined, as did the nominal oxidation state of carbon (NOSC). Fermentation intermediates such as acetate and formate increased in older permafrost, which was coupled with an increase in genes involved in fermentation of these products.

Together, these data demonstrate a complex relationship between physicochemistry, age, and the metabolism of active microbial populations. This differs from non-permafrost soils, where pH is the primary driver of microbial community composition. We present a conceptual model of microbial metabolism in permafrost based on fermentation of OC and the buildup of organic acids that helps explain the unique chemistry of permafrost soils. These data are relevant to climate change, which will expose frozen organic matter and the associated microbial communities to above-freezing temperatures. The metabolic strategies of permafrost microorganisms enabling survival through geologic time is also relevant to the field of astrobiology. Permafrost may act as a model for survival on other icy worlds such as Mars or Europa.

ROCK GLACIERS IN THE CENTRAL ANDES (CHILE)

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Twenty rock glaciers have been explored and are monitored since 1998 in the Maipo and Aconcagua river basins in the mountains of central Chile. This monitoring includes drill holes, internal temperature and water level, geophysical exploration, mass and energy balances, glacier surface and internal velocities, and stress controls. Different aerial and satellite images have also been used. The area of the explored and monitored glaciers is from 1.3 to 49.6 ha.

Over 110 drill holes (ODEX and coring) to the glacier bed provide information on composition and thickness, in addition to geophysical exploration, pits, trenches and mining cuts; all glaciers have ice cores, and most have full debris cover from tens of centimeters to several meters thick. Where exposed, ice and firn is less than 6% of total glacier area.

All are temperate glaciers, as per temperature measured in drill holes and pits, and have very variable internal water levels. Average Mass Balance, geodetic from aerial photos and satellite images, and glaciological (including temperature gradient and thermal conductivity measurements in the debris cover) is -0.15 m a^{-1} of ice, of which 3% to 6% is due to basal ice melting because of geothermal and frictional heat; main surface heat source is, by far, solar radiation.

Surface velocities, measured with geodetic instruments and assessed by feature-tracking techniques, range from about two tens of cm a^{-1} to slightly over 1 m a^{-1}, and summer time velocities are 29% to 74% larger than annual velocities. Basal velocities, measured with inclinometer on drill holes, are 38% to 57% of surface velocities.

Longitudinal surface stresses are mostly compressive in the lower part of the glaciers and extensive in the upper part. Two of the monitored glaciers were debris covered glacier as per 1955 aerial photography and have transformed to rock glaciers a decade ago.

One of the glaciers advanced slightly four decades ago, while the rest show stable fronts. Glacier bed material is mostly rock under the upper part of the glaciers, and from few % to 100% extent of till under the lower part of the glaciers, percentage changes in an apparent relation to surface inclination.

A best fit between area and thickness of the glaciers is $H = 0.06165 \times Area^{0.48585}$ meters. Glacier flow can be replicated assuming all deformation occurs in the ice present in the ice core and the basal moraine, considering the debris present in the ice at various depths, and using ice flow equation (Cuffey and Paterson, 2010) with B and n values of 0.164 and 3.

DECADAL-SCALE VARIABILITY OF POLAR ROCK GLACIER DYNAMICS: ACCELERATING DUE TO WARMING?

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Whereas dynamics of active rock glaciers in mid-latitude and subpolar mountains have been well documented, a research gap still exists in cold, polar rock glaciers. We conducted 13 years (2005-2018) of multi-method monitoring of a small valley-side rock glacier (called Huset RG) in Svalbard. The programme include (1) automated monitoring of ground temperature with thermistors installed at different depths down to 15 m and internal deformation with inclinometers installed at depths of 5, 9, 13 m, (2) annual Real-Time Kinematic GPS surveys of surface benchmarks and (3) Synthetic Aperture Radar Interferometry (InSAR) analysis of surface movements using TerraSAR-X and Sentinel-1 images. The combined data highlight the effect of interannual climate variability on the activity of polar rock glacier.

During 13 years, annual mean air temperature fluctuated significantly between −0.9 and −4.3°C with an overall warming trend. The average warming rates were 0.13°C/yr in the atmosphere, 0.12°C/yr at the ground surface and 0.05 to 0.10°C/yr at depths of 1 to 15 m. Annual GPS surveys of 13 benchmarks indicated downslope movements at an average velocity of 3.4 cm/yr (2.4 to 5.0 cm/yr) in the observed nine years (2009-2018), which is comparable with InSAR analysis showing downslope velocities of 5 to 6 cm/yr at the frontal part of the Huset RG. The benchmark movements showed small but overall acceleration at an average increment of ~0.2 cm/yr. The interannual variation in the surface velocity generally correlates with annual mean ground temperatures at depths of 5 to 15 m. The subsurface inclinometers steadily tilted downslope at average rates of 0.005 to 0.01° per year, with largest tilting at 5 m depth. The downslope tilting showed slight acceleration over 13 years but lacked seasonal variation. The largest tilting at 5 m depth corresponds to the presence of an ice-rich layer at 5 to 10 m depth, which was confirmed by both drilling and electrical resistivity tomography. The interannual variation in downslope tilting also correlates well with annual mean ground temperatures at the same depths. Integration of these data shows that permafrost creep induces slow but steady movements of polar rock glaciers with near-surface temperatures below −3°C, and predicts that the surface velocity could rise by two times in 10–20 years on the assumption of continuous warming.

GROUND TEMPERATURES IN THE AHLMANNRYGGEN, WESTERN DRONING MAUD LAND ANTARCTICA

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Ground temperatures were measured in eight shallow boreholes in the Ahlmannryggen of Western Droning Maud Land between 2007 and 2017. The active layer depth was found to approximately 70 cm at Robertskollen an altitude of 450 m.a.s.l., 50 km from the coastal margin of the Fimbul ice shelf and decreased to 10 cm at Slettfjel, at 1230 m.a.s.l., and 190 km from the coast. As altitude (R^2 = 0.94), latitude (R^2 = 0.90) and the distance from the coast (R^2 = 0.87) increased, the average annual ground temperature at 60cm depth decreased from -16 °C to -20 °C. A seasonal variation, with warm summers and cold winters is clear. In the Austral Summer season (October through to March), diurnal cycles dominated the ground thermal regime, whereas, in winter, synoptic-scale weather systems had the greatest impact. All eight sites, covering an area of greater than 4 000 km², showed similar responses to both synoptic-scale and seasonal variations, albeit with cooling as latitude, altitude and the distance from the coast increased. Larger scale systems are argued to be responsible for temperature increases, or reduced rates of cooling, in autumn. Similarly, decreases in temperature, or slower rates of increase are evident in spring. The systems responsible are linked, to continent-wide oscillations or changes in sea ice. Recent increases in snowfall are argued to be responsible for a slight decrease in ground temperature at all the sites monitored in 2016 and 2017, despite increases air temperatures recorded at the SANAE IV Base. The thermal regime has provided valuable contributions that represent the only ground thermal data for a large part of the Antarctic continent. Additionally, these data are now being utilised to modify the monitoring system to reduce the number of stations, but to provide a regionally representative coverage for long term monitoring, and to include deeper measurements in the permafrost, where the temperature is isothermal.

USING TOPOGRAPHY TO ESTABLISH HOLOCENE GLACIATION AND VOLCANISM ON SUB-ANTARCTIC MARION ISLAND

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Deglaciation has been identified as a trigger for volcanism in the late Pleistocene and early Holocene on Sub-Antarctic Marion Island. While previous research has presented arguments for significant erosion following volcanism, a new interpretation is presented that suggests that the observed scarps are the boundaries of lava flows, rather than the edges of eroded surfaces. Holocene volcanism has built up some of the interior of the Island and has been responsible for the infilling of valleys. Other than early Holocene glaciation, erosion has been limited in the Epoch. Currently the Island is free of permafrost, but the ground in at altitudes above 1 000 m is frozen to a depth of 15 cm for much of the year. Scoria, which comprises much of the Island's interior, was moulded around the edge of glacial ice. With the ground remaining frozen, the sharp topographical breaks at glacial edges have remained and allow identification of previous ice levels. Current ice is covered by scoria and depicts many collapsed features that are observed elsewhere. Using topographical indicators, it has been possible to identify where glacial ice existed previously. Holocene glaciation was dominated by an ice-cap that occupied a basin in the centre of the Island Marion Island that has been reduced in area from 107 Ha in 1966 to only 5 Ha in 2018, losing in excess of 50 million m^3 of ice. Elsewhere, ice was found in sheltered locations protected from wind and solar radiation. The glacial and volcanic history is critical, and has been used to understand biological distributions and colonisation of Marion Island.

FIELD OBSERVATIONS ON THERMAL PERFORMANCE OF AIR-CONVECTION EMBANKMENT AFFECTED BY SURFACE WATER PONDING IN PERMAFROST ZONES

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Air-convection embankment (ACE) constructed with crushed rocks has proven to be an effective measure to maintain and cool the permafrost subgrade in the context of climate warming. However, thermal performance of an ACE can be affected by many factors during its operation. In this paper, impacts of surface water ponding on thermal performance of an embankment modified from a traditional earthen embankment to an ACE were evaluated through field observation from 2003 to 2016. The observed results showed that an interesting thermal regime developed in and beneath the embankment after its construction in 2003. A layer with soil temperatures close to 0 °C (zero curtain layer, ZCL) all year round developed within the embankment filling and the original active layer below. The thermal interaction between the seasonally freezing/thawing layer above and the permafrost subgrade below were almost impeded totally by the ZCL. The crushed rock revetments installed four years after the embankment construction also could not exert any cooling on the underlying permafrost subgrade. After drainage of the ponded water taken in 2012, the thermal performance of the embankment changed significantly. The soil temperatures within the ZCL decreased rapidly and the permafrost table rose up and reached to the maximum seasonally thawing depth. Over the observation period, the ponded water did not lead to considerable permafrost degradation beneath the embankment. Moreover, after the drainage, the deep permafrost warming induced by climate warming slowed down under the cooling effect of the crushed rock revetments. This study confirms the great thermal impacts of surface water ponding on roadway embankment over permafrost. Finally, a new structure was proposed to prevent thaw slump of drainage ditches in permafrost zones.

CALM I-V: A QUARTER-CENTURY OF OBSERVATIONS AT ALASKAN ACTIVE LAYER MONITORING SITES

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The Circumpolar Active Layer Monitoring (CALM) program is a network of sites at which data on active-layer thickness (ALT) and dynamics are collected. CALM was established in the early 1990s to observe and detect the long-term response of the active layer and near-surface permafrost to changes and variations in climatic conditions. In this study we used 25 years (1995-2019) of extensive, spatially oriented field observations at CALM sites in northern Alaska to examine landscape-specific spatial and temporal trends in active-layer thickness. On Alaska's North Slope there are 25 CALM sites representative of local and/or landscape level environmental conditions (e.g., topography, vegetation, soils). This landscape approach facilitates spatial analyses of active-layer patterns and temporal trends at a range of spatial scales. Sites consist of 1 km2 grids, representative of generalized landscape conditions, and 16 1 ha plots, established in relatively homogenous landscape categories. These sites are arranged in two parallel north-south transects along the regional bioclimatic gradient spanning the Arctic Coastal Plain and Arctic Foothills physiographic provinces. Active layer thickness (ALT) is measured by mechanical probing at 100 m intervals across the km2 grids and 5 m intervals across hectare plots at least once per summer. The date of maximum annual thaw can vary from year to year and between sites, making it difficult to detect the maximum annual active-layer thickness by mechanical probing. To insure consistency, annual thaw depth measurements for each site are performed during the same week of each year. The specific time of observations varies between sites but falls within the period from mid-August to early September, when thaw depth nears its maximum. Additionally, all sites are outfitted with data loggers for monitoring air and ground surface temperatures. Long-term active-layer thickness observations averaged over the Arctic Coastal Plain and the Arctic Foothills physiographic provinces show increasing trends in ALT over the 25-year period in response to climatic warming, as indicated by higher total degree days of thaw. Despite relatively similar degree-day trends for all areas considered in this analysis, the rate of ALT change is variable by site. The highest rate of ALT increase of 0.5 cm/yr was observed at the Atqasuk site, representing the southern Coastal Plain in the western transect. The northern Coastal Plain showed the smallest rate (0.1 cm/yr) of ALT increase. The differences in ALT trends are attributable primarily to variability in surface and subsurface conditions.

HYDROLOGICAL PROCESSES AT ROCK GLACIER USING HISTORICAL DATA OF OBSERVATIONS (SUNTAR-KHAYATA RIDGE, EASTERN SIBERIA)

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Hydrological processes at rock glacier using historical data of observations (Suntar-Khayata Ridge, Eastern Siberia).

Rock glaciers are widely distributed in the mountainous regions of Siberia. 540 rock glaciers were identified at the Suntar- Khayata Ridge in the Indigirka River basin which is located in the zone of continuous permafrost. Distribution density of rock glaciers is estimated as 8.4 objects/100 km2 (Lytkin, Galanin, 2016). The hydrological impact of rock glaciers is not fully understood in this remote Arctic region. Lack of observed data could partly be compensated by hydrological modelling. The purpose of this study is to estimate the runoff from the landscape where rock glaciers are widely found based on detailed historical dataset and hydrological model.

The Suntar river basin (7680 km2) was selected as the study object. The high-altitude Suntar-Khayata station, which was located at the altitude of 2067 m in rocky talus landscape, was operating in the Suntar river basin in 1957-1959 under the program of the International Geophysical Year. The observations (glaciological, geomorphological, geocryological, etc.) are unique for the high-mountain areas of the Eastern Siberia and North-East of Russia.

The process-based hydrological Hydrograph model was used in the study as it describes hydrological processes in different permafrost environments. The level of model complexity is suitable for a remote, sparsely gauged region such as Eastern Siberia as it allows for a priori assessment of the model parameters. Based on the observations the model parameters were estimated for main landscapes, including rocky talus where rock glaciers are found. Verification of the model was carried out based on the observational data of ground temperature at different depths, snow cover characteristics and evaporation at the rocky talus landscape at the Suntar-Khayata station.

The runoff modelling with initially assessed parameters was carried out during 1957-1964. The distribution of water balance among main landscapes was evaluated. Rocky talus landscape with rock glacier complex covers about 7% of the catchment but provides about 20% of total streamflow of the Suntar river, and the runoff coefficient reaches 0,92. Tundra is the largest contributor to the runoff formation at the Suntar river catchment – 49 % of the total streamflow, with a runoff coefficient – 0.74. The total runoff from the sparse larch and riparian forest landscapes, which take 56% of the territory, is around 31%.

The contribution of the rocky talus landscape increases in dry years when it may amount up to 30% of streamflow (for example, in 1963 the total annual streamflow was just 130 mm, while the calculated one for rocky talus complex – 513 mm). Thus, rocky talus containing rock glacier and mountain tundra are the main sources of runoff formation at the mountain watersheds in studied mountainous permafrost zone.

GEOCHRONOLOGY OF CRYOPLANATION TERRACES IN THE YUKON-TANANA UPLAND, ALASKA

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Cryoplanation Terraces (CTs) are erosional landforms reminiscent of giant staircases with alternating shallow sloping treads (<10° spanning tens to hundreds of meters) and steep scarps (15-40° tens of meters high) leading to extensive flat summits. CTs are associated with periglacial environments and are found in elevated positions on ridges and hill slopes. Despite identification and discussion in geomorphic literature for more than a century, a consensus still has not been reached on the processes involved in CT formation. Two hypotheses continue to receive support: (1) CTs are dominantly controlled by geologic structure, and (2) CTs are dominantly controlled by climate through nivation – the erosion process suite associated with late-lying snowbanks.

This presentation details spatial statistical analysis of relative weathering indices and the first absolute surface exposure ages and erosion rates from cryoplanation terraces obtained from terrestrial cosmogenic nuclides (TCN) in surface boulders. Statistically significant differences in relative weathering indices (fracture counts, Cailleux roundness, Cailleux flatness, Krumbein sphericity, rebound, and weathering rind thickness) detected through chi-square and multiple-comparison procedures indicate that material is less weathered closer to scarps, i.e., that these areas were more recently exposed than those distant from the scarp. Absolute ages include six ^{10}Be TCN ages from two terrace treads near Eagle Summit and six ^{36}Cl ages from two terrace treads on Mt. Fairplay, in the Yukon-Tanana Upland, Alaska. Calculated ages confirm scarp retreat last active around the time of the Last Glacial Maximum. Boulder exposure ages and distances between sample locations were also used to estimate erosion rates across these four terrace treads. Based on these findings, a refined model of time-transgressive cryoplanation terrace development through nivation-driven scarp retreat is proposed. This new qualitative model addresses the removal of weathered material from terrace treads down side slopes through piping and gravity-driven mass-wasting processes.

PAN-ANTARCTIC MODELLING OF PERMAFROST TEMPERATURES AT 1 KM SCALE

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Permafrost occupies almost all of the Antarctic's ice-free areas, however, permafrost borehole measurements are mostly limited to the vicinity of research stations and well accessible areas. Little is known about spatial variations of permafrost properties and its general picture in the Antarctic. We use a TTOP model to estimate permafrost temperature at 1 km^2 during 2000-2017 for all the ice-free areas of Antarctic mainland and Antarctic Islands.

The TTOP is equilibrium model that calculates temperature at the top of the permafrost based on freezing and thawing degree days and adjustment n_f- and r_k-factors. The freezing and thawing degree days were calculated using remotely-sensed land surface temperatures from MODIS sensor on board of Terra and Aqua satellites and were gap-filled with ERA-Interim reanalysis. N_f-factors were estimated based on snowfall that was calculated using downscaled ERA-Interim precipitation and r_k-factors were set to vary randomly according to the values reported in literature.

Permafrost temperatures were the most commonly modelled between -18 and -23 °C for mountainous areas rising above the Antarctic Ice Sheet, but temperatures below -30 °C were modelled in the highest parts of Transantarctic Mountains. Coastal parts are usually characterised with permafrost temperatures between -14 and -8 °C and approaching 0 °C on Antarctic Peninsula. The results were validated using measurements from 40 permafrost boreholes and soil climate stations from the major Antarctic ice-free regions. The average accuracy (RMSE) is 1.9 °C but varies significantly among borehole sites. The difference is smaller than 1 °C for more than 80 % of the sites, but can reach up to 5 °C.

The greatest differences between modelled and measured permafrost temperatures occur where the used snow model didn't successfully simulate snow conditions. These sites are exposed to strong wind-driven redistribution of snow at nunataks of Queen Maud Land and Hobs Coast in Marie Byrd Land. Considerable difference can be found also at sites with microclimate and ground properties that are not representative for the modelled 1 km^2 pixel. The improved information on snow cover and ground properties together with extended network of borehole measurements can significantly improve future permafrost modelling efforts in the Antarctic.

CONSTRAINING THE AGE OF ICE-FREE PERMAFROST ENVIRONMENTS IN THE SOUTH SHETLAND ISLANDS

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Permafrost is widespread in ice-free environments in the Maritime Antarctica. In the northernmost tip of the Antarctic Peninsula, as well as in surrounding islands, the occurrence of permafrost is conditioned by the altitude, glacier-temperature regime and calendar of deglaciation. This is the case of the South Shetland Islands, where the retreat of polythermal glaciers since the Last Glacial Maximum has exposed the land surface and favoured the existence of permafrost. However, our knowledge of the timing of deglaciation is crucial to better understand the geomorphological and climatic meaning of the current distribution of permafrost conditions in this archipelago.

To provide insights into the deglaciation process, we have applied surface exposure dating methods using the in situ cosmogenic nuclide ^{36}Cl to the deglaciated polished surfaces, as these surfaces are shaped on basaltic rocks. 26 samples were collected in January 2017 from three old volcanic plugs that constituted nunataks during the deglaciation (Chester, Cerro Negro and Clark). They are distributed across the central plateau of Byers Peninsula, South Shetland Islands, the largest ice-free area (60 km^2) in this archipelago. To date, our understanding of the spatio-temporal pattern of deglaciation of this peninsula was only based on a few radiocarbon dates from lacustrine sediments and geomorphic evidence.

The data suggest that glacial shrinking already started during the Last Glacial Maximum, with the summit surfaces of nunataks becoming deglaciated between 26 and 19 ka. A first phase pulse of rapid deglaciation occurred until 17-16 ka followed by a relative stability of the ice cap until 12-11 ka. Subsequently, there was another stage of massive glacier retreat that exposed the land surface of the central plateau of Byers by 8-5-7.5 ka. This is also confirmed by lake records that revealed that the Chester and Cerro Negro hills were no longer isolated nunataks by that time. The rapid shrinking, which occurred during this stage, favoured the development of currently inactive permafrost-related landforms, such as block streams in Cerro Negro, indicating much colder climate conditions than nowadays. Although the eastern slope of nunatak Clark is still surrounded by the Rotch dome glacier, the deglaciation here followed a similar pattern, with its western fringe being deglaciated by 7.5 ka. Small glacier advances were recorded during the Late Holocene, although of much lesser magnitude and always constrained within the limits of the polygenic moraine systems.

These new data confirm that the first ice-free areas in the Antarctic Peninsula appeared much earlier than known to date, which has major implications for understanding permafrost distribution and vegetation colonization in Antarctica. These nunataks acted as biodiversity hotspots during the Late Pleistocene and throughout the Holocene. This research will be complemented with ongoing studies from other enclaves of the South Shetland Islands to infer the calendar of glacial oscillations since the Last Glacial Maximum.

20-YEARS OF PERMAFROST MONITORING IN SWITZERLAND: LESSONS LEARNED AND KEY MESSAGES

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Permafrost was classified as an essential climatic variable (ECV) by the Global Climate Observing System (GCOS) because of its sensitivity to changes in climatic conditions and is monitored worldwide. The Swiss Permafrost Monitoring Network PERMOS was founded in the year 2000. It plays a pioneer role regarding the structure and organization of an operational national permafrost observation network as well as regarding the number of monitoring elements, sites and available data.

The systematic long-term documentation of the state of permafrost and its changes in the Swiss Alps has evolved during two decades with continuous adaptation and evaluation. Today, the mountain permafrost monitoring is based on three observation elements: (1) ground-surface and subsurface temperatures, (2) changes in relative ice content, and (3) permafrost creep velocities. These three elements complement each other to capture not only the effects changing climate conditions but also the influence of topography and different landforms. Currently the PERMOS network includes 16 sites where permafrost temperature as well as GST are continuously measured, 15 sites where permafrost creep velocities are observed annually and 5 sites where annual electrical resistivity tomography (ERT) surveys are performed.

All three observation elements indicate the same general warming trend of mountain permafrost over the past 20 years. Borehole temperatures show a clear warming trend at 10 and 20 m depth throughout the Swiss Alps, especially between 2009 and 2016. This trend is more pronounced at cold sites like the rock glacier Murtèl, where an increase of +0.5°C has been observed at 20 m over the past 30 years. For permafrost temperatures close to 0°C, warming effects do not result in significant temperature increase but are “masked” by phase changes and latent heat effects. The latter however result in significant changes in electrical resistivity. At Schilthorn, for example, repeated ERT measurements show an overall decreasing trend of resistivity since 1999 pointing to a substantial decrease in ice-water ratio in the subsurface, which is not captured by the temperature measurements. Generally increasing creep rates of Alpine rock glaciers further corroborate the warming trend. The creep rates follow an exponential relationship with ground temperatures. In this contribution, we present and discuss the 20 years long time series of continuous monitoring in mountain permafrost collected within the PERMOS network.

MODELING GROUND TEMPERATURES TO INVESTIGATE POTENTIAL WATER SOURCES IN ICE-RICH ROCK GLACIERS

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Due to ongoing climate change mountain permafrost and periglacial features are undergoing changes. While clean-ice glaciers have been studied extensively, rock glaciers are less well understood, especially when it comes to their role as potential sources of water. This requires modeling at the catchment scale and beyond. Due to their coarse blocky surface layer, rock glaciers are thought to be more resilient to climate change. Thus, requiring an emphasis on long-term modeling.

In the present study we extend the empirical-based, distributed glacier runoff model GERM (Glacier Evolution Runoff Model) to allow for the inclusion of rock glaciers. We compare model results with the 1D physics-based model SNOWPACK. The addition to GERM involves a 1D permafrost module, which solves the diffusion equation for the temperature in the ground and in the snow cover. Melting, freezing and ventilation effects are accounted for but lateral effects are not. The new model component was tested for the Murtel rock glacier (Eastern Swiss Alps) for a past period of approximately 20 years. Overall the GERM results-show good agreements with measured data. However, particularly low ground temperatures are less well represented when compared to the SNOWPACK model.

The model is applied and calibrated for two further sites in the Swiss Alps (Ritigraben and Schafberg) and the results are compared to SNOWPACK. Finally, GERM is employed to study the thermal evolution and runoff potential at the three sites under future climate scenarios provided by the CH2018 initiative, giving hints as to whether rock glacier ice melt will increase in the coming decades.

DIGITAL SOIL MAPPING OF FUNCTIONAL SOIL PROPERTIES OF THE MCMURDO DRY VALLEYS

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Antarctica is the most arid continent in the world. A range of extreme environmental conditions combine to create a harsh, cold desert environment: extremely low and fluctuating temperatures, very little water in an accessible form, and high salinity. Despite the extreme environmental conditions encountered in ice-free areas, soils have do harbour life. A range of organisms (viruses, bacteria, but also larger animals like nematodes or collembollas) are distributed throughout soils of the region.

The McMurdo Dry Valleys system is the largest ice-free region in Antarctica, covering about 6 900 km^2 . It is a designated Antartcic Specially Managed Area (ASMA), and home to the Onyx River, the largest and longest river in Antarctica. Soils in the McMurdo Dry Valleys are predominantly developed in glacial drift, colluvium, alluvium, or re-worked aeolian deposits.

While microbiologists face a wide range of questions concerning the biodiversity of the terrestrial systems in these valleys, a major hurdle is the sparse coverage of soil information. The spatial distribution of these microbiological communities has been shown to be strongly influenced by soil attributes such as water content, salinity, organic carbon, and pH. But while pedological maps have been published for various ice-free regions across the continent, the spatial distribution of those soil attributes themselves is largely unknown.

Antarctic research is very costly: considering the operational costs, it is important not only to make the most of the existing legacy data, but also to maximise the amount of data collected in the Dry Valleys each season. The use of digital soil mapping (DSM) has been tested to address this lack of soil attributes information: local soil observations can be combined with a range of spatial layers reflecting different factors of soil formation using a machine learning model, in order to predict the spatial distribution of soil attributes measured at those locations.

In this project, we are collating and harmonising data from different soil surveys in order to investigate the spatial distribution of pH, one of the soil properties that are critical for understanding the distribution of life in Antarctic soils. Since other parameters of interest are also measured, this opens an opportunity to extend this soil information system to other important soil properties for the region, such as electrical conductivity, or organic carbon content.

The application of those digital soil mapping techniques can (i) be a tool to understand and predict where microbial habitats occur, and (ii) has the potential to generate base layers for researchers outside the soil science community (in particular the fields of microbiology and climate change).

IDENTIFICATION OF WATER-SOURCES IN PERMAFROST-AFFECTED CATCHMENT (33°S;70°3'W)

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Fresh water is scarce in Central Chile, especially in the context of reduced precipitation in the 21st century due to climate change. Identification and quantification of all hydrological resources is therefore a priority for adaptation strategies of the region. Above 3600masl, perennially frozen ground is present in the semi-arid Andes. As temperatures are rising in the region, the thawing of permafrost could potentially contribute to subsurface hydrology. Here, we study for the first time a permafrost region in Central Chile to estimate its potential as a hydrological resource.

The study-site, *Monos de Agua* (upper) catchment (Fig. 1) is located close to Santiago de Chile, at 33°S; 70°16W. In the last 60 years, it lost almost 30% of glacierized surface, leaving behind rock-glacier type deposits and surface subsidence throughout the valley, as well as ice-cored moraines in the less sun-exposed slopes.

With a mean annual air temperature of -2 ± 2°C and having >100 freeze-thaw cycles per year, the upper-catchment is assumed to contain permafrost.

In order to identify frozen-ground water sources, we produce residence-time distributions from different water sources (glaciers, streams and springs) using a lumped parameter method. We collected water samples in Spring and Autumn and measured water isotopes (18O, 2H, 3H) and anthropogenic gases (CFC, SF6). In addition, we measured temperature variability in our research area throughout the year to account the change of hydraulic properties.

Using the estimated residence time, we quantify the volume of frozen groundwater sources by modeling aquifer geometries and flow-path lengths. Our results suggest for the first time the presence of a significant volume of frozen groundwater in a Central Chile catchment area. We expect similar findings in other catchments throughout the central Chilean region, which would represent an additional (finite) hydrological resource that has not been considered in current and projected budgets or even legislation.

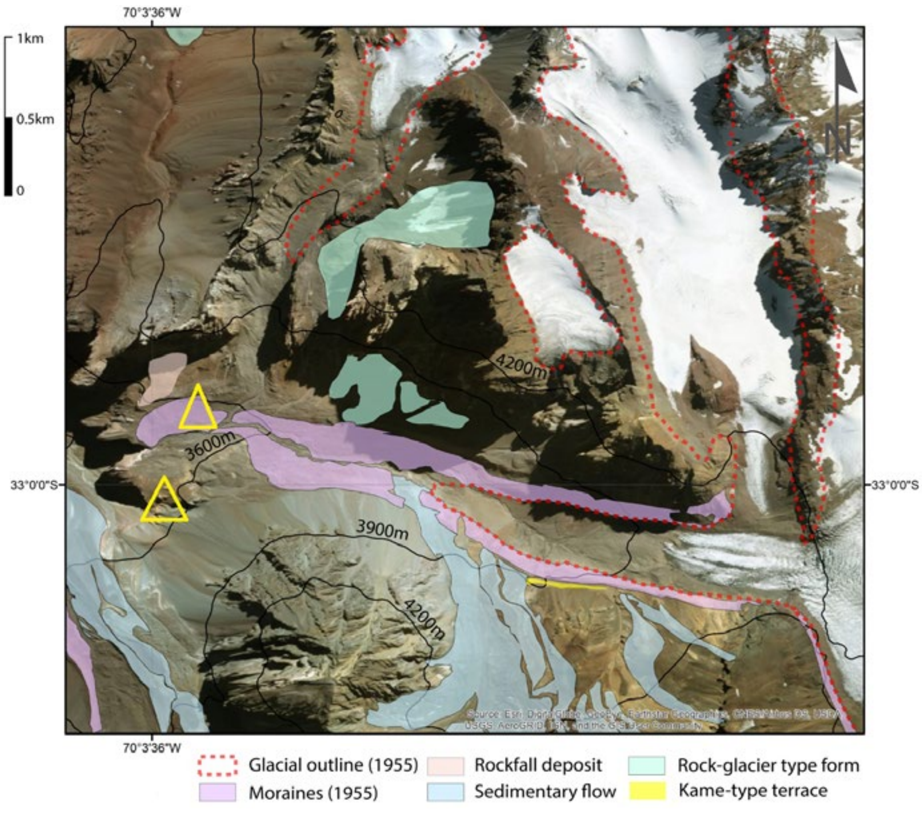

Figure 1: Monos de Agua upper catchment in the Central Andes. The study-site is located 70km north-east from Santiago de Chile. Glacier outlines and moraine limits are drawn from Hycon 1955 aerial images and georeferenced historical maps. Yellow triangles represent water-sampling locations.

Keywords

Andes, Permafrost, Deglacierization, Residence times.

MORPHOLOGICAL ANALOGIES BETWEEN ICE-DEBRIS COMPLEXES ON MARS AND IN HIMALAYA: FIRST RESULTS OF A HIGH-RESOLUTION BASIN-SCALE INVENTORY

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The ancient continental-scale glaciation (Budd et al., 1986) on Mars explains the presence of several geomorphological forms of ice-debris complexes (Bhardwaj et al., 2016a) and other permafrost landforms. These ice-debris complexes, also known as glacier-like forms (GLFs), and permafrost landforms are present in a widespread region of Mars' subpolar latitudes (Bhardwaj et al., 2016a). Our understanding of the ongoing glacial and periglacial processes in Martian subpolar latitudes is still majorly incomplete, mainly due to the absence of full and repeat coverage of these latitudes at high spatial resolutions. However, GLFs show significant analogy with the terrestrial ice-debris complexes, thus allowing for the scope of comparative inferences. In the past couple of decades, there has been a significant influx of high-resolution remotely-sensed images of Mars (Bhardwaj et al., 2019). Another encouraging fact is that these images are freely available to researchers. Using similar resolution images available on Google Earth for the ice-debris complexes or permafrost landforms in high-altitude and high-latitude terrain on Earth can give us a starting point to study the morphological analogies.

In the present research, we have taken a classic geomorphologic approach (Hamilton et al., 1995; Humlum, 1982) for identifying and characterising several of such GLFs in the subpolar Martian latitudes using recent HiRISE images and in the Himalaya using Google Earth images. The presence of permafrost in general and ice-debris complexes in particular in the Himalayan mountains is still one of the least explored topics. A careful observation of high-resolution images confirms a widespread and widely unreported presence of periglacial landforms such as rock glaciers and other ice-debris complexes in these mountains. To establish any geomorphological analogy, well-preserved and undisturbed terrestrial specimens are preferable and high Himalayan terrain encompasses such landscapes in ample, away from any anthropogenic interference (Bhardwaj et al., 2016b). We generated the first complete basin-scale inventory of such ice-debris complexes in the Western Himalaya for the 1100 km2 Baspa River basin and observed the striking geomorphologic analogy between terrestrial and Martian GLFs. We identified and mapped 73 ice-debris complexes or periglacial features covering a wide area of ~15.17 km2 (>8% of total glacier area in the basin). In addition to typical lobate rock glaciers, we also identified several protalus ramparts in both Martian as well as Himalayan images.

A similar approach was adopted for Swedish Arctic mountain permafrost observations and monitoring. We identified solifluction lobes on the mountain slopes with similar dimensions and morphologies as the ones observed on the HiRISE images of Martian subpolar latitudes. We performed visual and thermal observations on these landforms to provide a first-hand information on their qualification as a Martian analogue.

As the future scope, we intend to include Digital Terrain Model (DTM) derivatives and morphometry, and feature tracking to our analyses of these landforms on Mars and on Earth. Such studies are relevant to: (i) model Martian landscape evolution, (ii) understand and predict the presence and phase state of water on Mars, and (iii) understand the past climatic shifts.

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GROUND THERMAL VARIABILITY WITHIN A SUBARCTIC PEAT PLATEAU LANDSCAPE

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Subarctic permafrost peatlands cover extensive areas and store large amounts of soil organic carbon, that can be remobilized as active layer deepening and thermokarst is expected to increase in a future warmer climate. Since most permafrost peatlands are located in the southern parts of the permafrost region they are already near thawing and very sensitive to the projected climate change. These ecosystems are characterized by a complex mosaic of different landforms including dry surface peat plateaus and palsas uplifted above the surrounding wetlands by frost heave, and collapse features such as fens and thermokarst lakes formed as a result of ground-ice melt. The overall topography in these landscapes is relatively flat, but there is considerable microtopography with mounds and hollows of various sizes (sometimes filled with water) which makes the local hydrology, and possibly also the ground thermal regime very variable. In a peat plateau complex in Tavvavuoma, northern Sweden, ground temperatures and snow depth have been monitored within six different landscape units; on the peat plateau, in a depression within the peat plateau, along the peat plateau edge (close to a thermokarst lake), at the thermokarst lake shoreline, in the lake sediments and in a fen. Permafrost is present in all landscape units on the peat plateau itself, also close to the thermokarst lake, and the mean annual ground temperature (MAGT) at 2 m depth is around -0.3 °C. In low-lying and saturated landscape units such as fens and thermokarst lakes, and along lake shorelines taliks are present and the MAGT at 1 m depth is 1.0-2.7 °C. Microtopography appears to be a key parameter for ground thermal patterns in this landscape affecting both soil moisture and local snow depth. Wind redistribution of snow creates a variable snow depth pattern between elevated and low-lying landscape units. Permafrost is present in peat plateaus where the mean December-April snow cover is shallow (<20 cm), whereas snow depths >40 cm mostly result in absence of permafrost. In a small depression on the peat plateau permafrost exists despite a 60-80 cm mean December-April snow cover, but here the active layer is almost 1 m deeper (~1.5 m) than in the surroundings and permafrost thaw is extensive. This landscape unit has possibly experienced active layer deepening and ground subsidence in recent years, and can be considered to represent the initial transition phase between a peat plateau and a thermokarst lake in this dynamic and climate-sensitive landscape.

Keywords
Permafrost, peatland, microtopography, landscape units, thermokarst, Sweden.

USING GEOPHYSICAL TECHNIQUES TO IDENTIFY THE PRESENCE OF ICE, AIDING OPTICAL IMAGERY INTERPRETATION OF ROCK GLACIERS AND PERIGLACIAL LANDFORMS

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Rock glaciers and periglacial landforms likely play an important hydrological role in the semiarid Andes (SA; 27º-35ºS). They supplement streamflow when water is needed most, especially during dry years in the late summer months. The national glacier inventory, which includes rock glaciers, provides an indication of the hydrological importance of the cryosphere in the region. This inventory is currently being updated, as many landforms that may contain ice were not previously included, and these could collectively represent an important amount of stored water. Here, we present a case study of one such landform in Estero Derecho (~30˚S), in the upper Elqui River catchment, Chile. Two geophysical methods (ground-penetrating radar (GPR) and electrical resistivity tomography) were combined to detect the presence of ice and understand the internal structure of the landform. While the geomorphology does not suggest movement, a steep frontal slope and high electrical resistivity values imply the presence of ice. Both techniques estimate the landform depth to be 17.5 m, with a high density of pebbles and/or boulders inferred from the GPR radargram. These results strongly suggest that such landforms contain ice, are therefore important to include in future inventories and should be considered when evaluating the hydrological importance of a particular region.

MONITORING ICE-FREE AREAS IN THE SOUTH SHETLAND ISLANDS USING ADVANCED REMOTE SENSING TECHNIQUES

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A small percentage of the land in the South Shetland Islands is ice-free which amounts to approximately 470 km^2 of the terrestrial surface. However, these areas are of importance as they contain fragile ecosystems that are sensitive to environmental changes and are located within a region particularly affected by global climate change. Periglacial, glacial, fluvial, and coastal processes and landforms are dominant and permafrost is present except in the lowest areas. As a consequence, there are exposed complex surface covers that represent the past and present dynamic conditions. Access is often limited to ice-free areas due to logistical reasons. Therefore remotely sensed satellite systems with sensors that operate in the optical and microwave range offer an ideal alternative to identify and monitor relief landscape features and changes in areas for which little or no data are available. A clear advantage is associated with synthetic aperture radar (SAR) data that are acquired in all weather conditions. The objectives of this work was to determine the spatial distribution and changes in the surface cover of complex periglacial features within Fildes Peninsula, King George Island, using remotely sensed SAR and optical multispectral (MS) data. An integrated methodology was developed in order to use SAR RADARSAT2 and SENTINEL1 data (single and fully polarized), and MS LANDSAT8 data. Pre-processing of the SAR data included radiometric correction, using a speckle noise filter, developed specifically within the team for both SAR single channel images and fully polarimetric images. A digital terrain model (DEM) was used to carry out

the terrain and geometric corrections. Only a fine geometric correction was needed to improve the georeferencing of the MS data. Supervised classifications were carried out using Random Forest (RF), a decision tree-based classifier using the different SAR, MS and DEM data. A calibration and verification of the datasets and results was carried out with ground observations and field measurements from several expeditions carried out by our group in the last decade. This includes rock, sediment and soil sampling for laboratory analysis and a site specific spectral library that is being compiled using reflectance spectroscopy data (ASD FieldSpec3). RF results with SAR data detected surface texture differences that are related to the complex surface covers such as slope and other deposits and periglacial landforms. The MS classification emphasised the lithological units and sparse vegetation cover. Glacier fronts as well as water bodies were clearly identified and are well correlated in both the SAR and MS data. Again SAR information was able to identify the abrupt textural changes of buildings and other structures within stations and their vicinity. The synergetic use of multiple sensor data enhances the identification and spatial distribution of the different surface covers encountered in the studied area.

THE HIDDEN ICE OF THE ANDES – QUANTIFYING ROCK GLACIER WATER STORAGE CAPACITIES

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Recent regional assessments suggest that rock glaciers are important water stores in the periglacial zones of arid mountain regions, such as the central Andes of Argentina. However, field based studies quantifying the hydrological significance of rock glaciers and their contribution to river discharge are still rare in these environments.

Here we try to fill this research gap by quantifying the water storage capacities of three rock glaciers including talus and morainic derived features as well as one large rock glacier complex in the arid to semiarid Andes of Argentina. We investigated subsurface material compositions based on several kilometres of complementary ERT and RST profiles that were carried out at different elevations from the root zones towards positions on lower tongues. By means of a petrophysical model, called Four-Phase-Model, the absolute and relative material compositions of air, ice, rock and water were modelled. Furthermore, we monitored vertical and horizontal surface changes for a three-year period using high resolution digital elevation models (DEMs) derived from structure from motion (SfM) techniques based on aerial pictures taken by a drone. Vertical changes of the rock glacier surface indicate annual changes of subsurface ice, but can also be caused by the horizontal movement of surface features. Horizontal velocities were used to check independently potential rock glacier bulk densities based on Glen's ice flow equation. Thus, we estimated the relative water and ice content and the potential ranges of annual water equivalents stored or released from different rock glaciers.

High water contents and saturated subsurface conditions are identified underneath surface depression and furrows indicating effective water pathways. Increased active layer depths, dissected permafrost bodies, and thermokarst show local influences of thermal erosion on the internal hydrologic structure of all rock glaciers. Ice-oversaturated permafrost and massive ground ice with ice contents of 70 up to 90 % could only be found in the root zones and the middle part of debris rock glaciers and rock glacier complexes. Volumetric ice contents decrease towards the rock glaciers fronts partly to 30-50 %. Talus rock glaciers contain lower mean and maximum volumetric ice contents compared to debris rock glaciers. However, annual vertical surface changes of talus rock glaciers indicate annual storage and release capacities up to 50 mm/a, which constitutes a significant amount to runoff or ground water recharge in the dry Andes with annual precipitation rates <200mm/a. Thus, rock glaciers constitute an important seasonal and annual hydrological buffer and a significant long-term water store in the Central and Desert Andes of Argentina. In the light of rising temperatures, the hydrological buffer and storage function of permafrost landforms might gain importance in the Central Andes, even exceeding glacial water storage in very dry regions.

ANALYSIS ON COOLING EFFECT OF A CONCRETE THERMAL PILE IN PERMAFROST REGIONS

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The bearing capacity of pile is significantly sensitive to the thermal regime in permafrost regions. The stability of pile foundation will face with grave challenges under the scenarios of permafrost degradation. To address the problem, it is necessary to adopt active measures to control the ground temperature around piles. However, few available researches focus on the approach to cool the pile foundation in permafrost regions. Studies have shown that two phase closed thermosiphon (TPCT) performs well in cooling permafrost engineering. In this study, we innovatively put forward the concrete thermal pile, which consists of a concrete pile and TCPTs, to control the temperature of the pile shaft. And an experiment is conducted to analyze the cooling effect of concrete thermal pile. The influence of length of the condenser section on cooling effect is discussed based on a 3 D heat transfer model of thermal pile. The experiment results show that the concrete thermal pile can effectively cool the foundation soils around it and the cooling rate of the thermal pile can reach 2.5 times that of the pile without TPCT. The numerical results suggest the optimal length of condenser section should be 44% of the total length of TPCT in thermal pile. The conclusions summarized from this paper will provide the valuable references and lessons to the design of the pile foundation in permafrost regions.

TRADITIONAL AND NONTRADITIONAL PERMAFROST INFRASTRUCTURE AND CLIMATE CHANGE: EXAMPLES FROM ALASKAN AND RUSSIAN ARCTIC

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Changes in permafrost affect human population indirectly, through changes in hydrology (e.g. soil storage capacity, regional drainage pattern) and vegetation but also have a direct impact on socio-economic system through its effect on human infrastructure. Interactions between human society and permafrost are related to traditional, Indigenous livelihoods and nontraditional urban and industrial activities. This presentation provides examples of research aimed at identifying and quantifying societal impacts of permafrost degradation on rural Alaskan and urban Russian communities.

In Alaska we focus on the ways in which traditional communities utilize permafrost. Ice cellars, or sigḷuaq in Iñupiaq, are excavated into permafrost to provide easily accessible cold storage for large quantities of subsistence hunted meats. In terms of ice cellars, permafrost provides both a cultural and regulatory ecosystem service to coastal Arctic peoples, but ice cellars are failing. Catastrophic flooding and collapses, among other issues have been related to the warming climatic conditions and development. Presented here are results of ice cellar temperature monitoring program in Utqiaġvik (formerly Barrow), Alaska. Three of the five monitored cellars have significantly increasing mean annual internal temperatures. Additionally, one cellar has flooded and partially collapsed, while another has been abandoned due to sloughing walls. Our results indicate that while climatic changes contribute to the deteriorating conditions of the ice cellars, land-cover/land-use changes associated with urban development exert considerable influences and require further investigations.

Russia represents an unprecedented case of massive urban and industrial construction in the permafrost regions of the Arctic. This can be attributed to the development and proliferation of engineering practices that maintained the thermal stability of permafrost. However, climate-induced warming and degradation of permafrost have contributed to a widespread deformation of structures throughout Russia. Here we provide quantitative estimates of potential changes in stability of Russian urban and industrial infrastructure in response to climate change and their potential economic impacts. According to our results, significant portion of Russian Arctic urban infrastructure will be negatively affected by permafrost warming and degradation by the mid-21st century. Mitigation of negative impact of permafrost degradation will impose additional economic stress on regional and the national Russian economies.

Examples provided in this presentation indicate a clear need for integrative assessment of the climate change impacts on permafrost infrastructure in the context of Arctic traditional and nontraditional socio-economic systems in order to develop adequate and cost-effective adaptation and mitigation strategies for diverse Arctic communities.

Keywords
Permafrost; infrastructure; traditional and urban communities; climate change.

STUDY OF CRYOPEGS PHASE COMPOSITION UNDER THE FRAME OF INTERNSHIP

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International energy company Total S.A. provides unique opportunity for students to have a 6-months traineeship in Paris and Moscow offices. The range of performing tasks varies from bibliographical review to calculations of frozen soils properties. The main research was analysis of frozen soil phase and chemical composition in the temperature range of up to -35oC. This study gives findings on chemical, physical properties of cryopegs such as unfrozen water content, freezing temperature and ions concentration.

Introduction

During the 6-months internship at Total S.A. several tasks were performed:

- Review of fiber optics application in permafrost;
- Analysis of new equipment and new measurement methods for thermal characteristics of frozen soils (thermal conductivity, heat capacity) and phase composition (freezing and thawing temperature, unfrozen water content);
- Analysis of gas saturation of permafrost;
- Study of cryopegs phase composition.

The phase composition of solutions, for example, cryopegs was investigated in details. Cryopegs is a geohazard for the regions of saline frozen soils distribution. It reduces bearing capacity of the foundations, complicates of its design, and operation. The improvement of the calculating method on the phase composition of cryopegs is presented in this publication.

Method and Results

The phase composition was investigated using thermodynamic modeling method [Komarov, Mironenko, Kiyashko, 2012]. The calculation method is based on the Pitzer model. The algorithm includes the calculations of cryopegs chemical and phase composition (unfrozen water content), freezing temperature. The cryopegs are mainly characterized by (table 1):

- Higher mineralization (45-68 g/l);
- Presence of organic matter (444-2838 mg/l);
- Low temperatures (-3,2…-4.8oC).

Table 1: Characteristics of studied cryopegs

Cryopeg	Depth, m	Mineralization, g/l	Organic matter, mg/l	Temperature, oC
1	16.4-16.5	67,8	451	-4,8
2	10.3-10.6	52,7	444	-3,9
3	10.7-12.3	44,9	2838	-3,2

Unfrozen water content of cryopegs is about 50-80% at temperatures -3…-5 oC. The content is gradually decreasing till 20%, reaching a temperature of -23 oC (fig.1). Higher unfrozen water content of cryopeg 1 caused by higher mineralization.

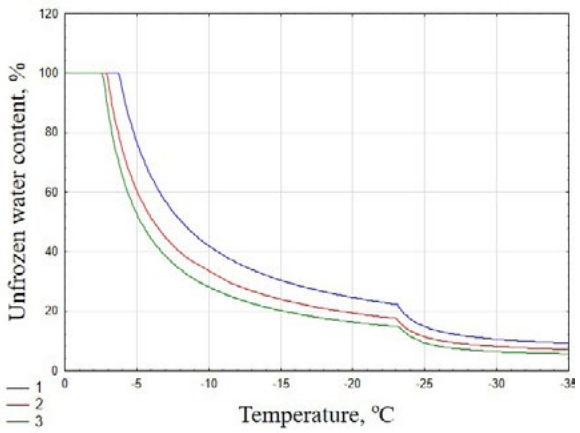

Figure 1: Unfrozen water content of cryopegs (lines of different colors)

The calculated ions concentration (Cl- and Na+) is drastically increases at lowering the temperature of -5oC (fig.2). But at temperature of -23oC the ion of Na+ is fallen, withal the ion of Mg2+ and Cl- are continuing increase. Higher content of ion Cl- of cryopeg 1 caused by higher mineralization. Increased magnesium content in cryopeg 3 caused by the initial solution chemical composition.

The increasing ions content solution leads to corrosiveness of cryopeg to concrete and reduction of the bearing capacity of pile foundations.

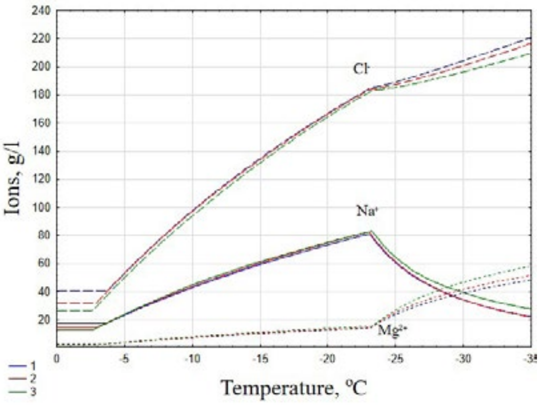

Figure 2: Concentration of ions in cryopegs (lines of different colors)

Conclusions

The calculated unfrozen water content and chemical composition of cryopegs are applicable as regional parameters for cryopegs in the studied area and for evaluation of aggressiveness to pile foundations. As the temperature of the cryopegs decreases, the concentration of ions increases. This fact should be taken into account during design of pile foundations. This calculation method can be improved by taking into account of organic matter content and gas saturation. The obtained results are unique, because they are not listed in geotechnical surveys, but are necessarily for a design.

Keywords

Cryopegs, unfrozen water content, ion concentration, aggressiveness, internship.

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ACTIVE LAYER THICKENING AND CONTROLS ON INTERANNUAL VARIABILITY AT NORDIC CALM SITES

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Manual active layer probing in northern Sweden, northeast Greenland, and central Svalbard reveals active layer thickening has occurred since Circumpolar Active Layer Monitoring (CALM) sites were established at these locations. Interannual variability in active layer thickness (ALT) is unique to each site. Depending on the specific subsite near Abisko, northern Sweden (68°N), ALT has increased by approximately 20-50 cm since 1978. ALT in 2017 was 73 cm at the Storflaket subsite and 91 cm at the Heliport subsite. Lowland permafrost disappearance is also occurring in this area of discontinuous and sporadic permafrost, where permafrost occurs at high elevations and in peat mires. In Zackenberg, northeast Greenland (74°N), the grids ZEROCALM1 and ZEROCALM2 have been monitored since 1996. Interannual changes in ALT are similar in the two grids, though ZEROCALM2 exhibits a consistently thinner active layer due to an overlying snowdrift, whereas ZEROCALM1 is flat with average snow cover for the landscape. From 1996 to 2017, ALT increased 1 cm per year at ZEROCALM1 and 0.7 cm per year at ZEROCALM2, estimated via linear regression. In 2017, ALT was 83 cm at ZEROCALM1 and 71 cm at ZEROCALM2. Thaw progression and ALT measurements at a loess-covered terrace in Adventdalen, central Svalbard (78°N), show an increase in ALT since 2000 of approximately 0.7 cm per year. Since 2006, ALT has been 1 m or greater, and was 103 cm in 2018. The variability in estimated annual ALT increase is 0.6-1 cm per year among the Nordic sites. The comparison of ALT at the presented sites with meteorological parameters (e.g. air temperature, precipitation, and timing and depth of snow cover) indicates that the meteorological influence on ALT is location- and site-dependent. For example, ALT in central Svalbard does not correlate with thawing degree days (TDD), whereas ALT and TDD in northern Sweden and northeast Greenland do exhibit this relationship. Winter conditions better explain measured ALT in Svalbard, as ALT correlates with freezing degree days during the preceding winter.

LONG-TERM SPATIALLY DISTRIBUTED MONITORING OF THAW SUBSIDENCE ON ALASKA'S NORTH SLOPE

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Thaw subsidence and frost heave are common phenomena in permafrost regions. The freezing of moisture within the active layer leads to upward movement of the surface as a result of water migration to the freezing front and development of segregation ice. Development of the active layer in the summer and melting of ground ice leads to downward movement of the soil. The variability of soil properties, moisture content, and microtopography results in spatial heterogeneity of frost heave and thaw subsidence over small areas with relatively uniform climatic and vegetation conditions. Under progressively warmer climatic conditions, the overall downward movement of the ground surface due to progressive melting of ground ice may lead to landscape differentiation, thermokast development, and inundation in low-lying areas along Arctic coasts. Spatial assessments of thaw subsidence by radar interferometry are growing, but there is a shortage of locations where thaw subsidence is monitored on the ground. This study evaluates long-term trends in thaw subsidence at three sites on Alaska's North Slope. Two of the sites were installed on the Arctic Coastal Plain (CALM sites U1 Barrow and U5 West Dock) and one in the Arctic Foothills (U32A Sagwon Hills) in 2003. The Barrow site has historical data available back to the 1960s. A detailed description of the sites is available at the CALM site: (www.gwu.edu/~calm).

During the 2004-2018 period, field surveys were conducted at all three sites at least once each year during the second half of August, when thaw depth is near its maximum. Each plot was surveyed using the Rapid Static technique at 32 spatially distributed points marked with acrylite targets. The transparent acrylite targets were designed to minimize disturbance. Each target was surveyed for at least 10 min using Trimble 4700/5700/R7 Differential Global Positioning System (DGPS) units. Monitoring of the vertical position of the ground surface at each point was accompanied by a probed active-layer measurement using a graduated steel rod, according to CALM's measurement protocol.

The observations of the ground surface position, taken at the end of the thawing period during 2004-2018, show a relatively small trend of continuing subsidence at three sites, resulting in total subsidence of 5 to 10 cm over the entire observational period. The years with extremely warm summers were responsible for the most subsidence during this period.

PROPERTIES OF SOILS DEVELOPED UNDER CUSHION PLANTS IN GLACIER FOREFIELD IN THE EASTERN PAMIR, TAJIKISTAN

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Occurrence of vascular plants at the early stages of pedogenesis has an important role for substrate stabilization and formation of soil organic matter, especially in initial soils containing low amounts of carbon and nitrogen and developed in the forefield of glacier. The effect of vegetation on soil formation was well documented for example in Arctic and Alps, where soils located further from glacier had typically denser plant cover and higher organic matter content.

The Ujsu glacier is located in the Eastern Pamir Mountains, Tajikistan, Central Asia. This region belongs to the high mountain permafrost zone and is characterized by low mean annual temperatures (-4oC) and precipitation (80 mm). In the valley originating from Ujsu glacier, plant growth is strongly limited by water deficiencies, thus even at the long distance from the glacier, soils remain in initial state, plant cover is sparse and cushion plants are dominant species.

Cushion plants are typical for areas with harsh climate, such as polar or high mountain alpine zones. Cushion plants have short, densely distributed shoots forming mats or domes. Thanks to their growth form, these plants have positive effect on soil properties. Soil under cushions usually contains more water, organic matter and nutrients However it is known that in very dry climate, nutrient content under cushions may be lower than in the nearby bare soil. It may be a result of low rate of soil organic decomposition and nutrient release, which may be slower than uptake by plants.

The aim of presented study was to assess the influence of cushion plants on carbon sequestration and nitrogen accumulation in initial soils in arid mountains of the Eastern Pamir. We chose 3 cushion species characterized by different growth form: (1) Acantholimon hedinii, forming hemispherical domes; (2) Oxytropis immersa, forming thin, flat mats; and (3) Oxytropis poncissi, forming thick flat mats. We took soil samples under the cushions (depth 0-5 cm and 5-10 cm) and, accordingly, from the nearby located bare soil. We took samples in a distance gradient (12 m – 9000 m) from the glacier terminus, within elevation gradient from 4400 m.a.s.l to 4200 m.a.s.l.

Soil samples, taken in July 2018, were very dry, some of them gained weight after week of air drying, which indicates absorption of air moisture. Soils without plant cover had low total nitrogen and organic carbon content (mean 0.04% and 0.35% respectively). As a general pattern, soil under cushions had higher values of measured parameters (i.e. nitrate and ammonia ions, organic C, total C, EC) than control bare soil and differences were more clear in samples taken from 0-5 cm than from 5-10 cm layer. A. hedinii had relatively small influence on soil properties, while influence of both Oxytropis species was clearly visible. For example, soil under A. hedinii had on average 2.2 times more total N than bare soil, under O. immersa 4.8 times more and under O. poncissi 22.4 times more. Similarly, phosphates content was respectively 1.6, 10.1 and 28.6 times higher under cushions. Soil pH was lower under cushions, possibly as the effect of humic acids accumulation. There was no clear relationship between soil characteristics and a distance from the glacier terminus.

The results show, that in dry conditions of the Eastern Pamir cushion plants play crucial role in pedogenesis by increasing content of organic matter and nutrients availability.

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CONTENT AND DISTRIBUTION OF NON-SILICATE IRON FORMS ALONG DEPTH OF HYDROGENIC SOIL PROFILES FROM THE EASTERN PAMIR (TAJIKISTAN)

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Soil development is closely related to weathering processes, the course of which depends on local environmental conditions. Redox-induced transformation of iron is a key biogeochemical process during water table fluctuations in wetlands, which involves carbon and nitrogen mobilisation/stabilisation over time. The place of this process in the soil profile depends on the type of soil and on climatic and hydrogenic (redox) conditions. Driven by numerous soil parameters, the iron oxides are formed under a certain timeframe which consist of pedogenic (free), well-crystallised iron oxides, hydroxides and oxyhydroxides (Fe_d), metalorganic compounds and organically bound iron (Fe_p). These Fe oxides are characterised by specific degrees of crystallisation, which can be quantified by particular extraction methods. Hydrogenic soils of the Eastern Pamir are formed under specific climatic conditions, including presence of permafrost and cryogenic processes, and slow rate of mineralization of organic material.The main goals of our study are (1) assessment of non-silicate iron content in permafrost soils of high-mountain wetlands, (2) finding a connection between physical and chemical properties of different soil profiles and the content of various iron forms, as a result of the reductive environment influence on iron transformations.

The peat/soil profiles were collected from wetlands developed in surroundings of lakes and rivers in the Eastern Pamir. In all the collected soil samples the following parameters were measured: (1) basic soil features, i.e. soil moisture, pH, TC, TN, TOC, (2) isotopic ratios:$\delta^{15}N$ and $\delta^{13}C$, (3) non-silicate iron forms as follows: metalorganic compounds and organically bound iron (Fe_p), pedogenic (free), iron (Fe_d), (4) total iron (Fe_t), according to the dithionite method.

Our results showed that peat soil samples (TOC>12%) differ significantly from mineral soil samples (TOC>6%) in soil moisture ($p<0.0001$), soil pH ($p<0.0001$); soil salinity (ECe) ($p<0.0001$), TC and TN ($p<0.00001$), and C/N ($p<0.002$). Considering $\delta^{15}N$ and $\delta^{13}C$ of soil samples, it we found significant differences between semi-mineral soil samples (6%<TOC<12%) and peat soil samples ($p<0.0001$). All studied soils differed significantly in Fet content ($P<0.0001$). Peat soils contained significantly higher Fep than mineral soils (average values 880 and 630 mg/kg respectively; $p<0.0003$) and significantly higher Fep than semi-mineral soils (average values 680 mg/kg; $p<0.0003$). In case of peaty soils, we foundpositive correlation between Fet and Fed, and soil moisture ($r^2 = 0.72$, $p<0.0003$; $r^2 =0.48$; $p<0.03$ respectively); and negative correlations between Fet and TN and TC ($r^2=-0.90$; $p<0.0001$ and $r^2=0.89$; $p<0.00001$, respectively), and Fed and TC and TN ($r^2 = -0.63$, $p<0.002$; $r^2 = -0.57$, $p<0.008$, respectively). The Spearman correlation coefficients for metalorganic compounds and organically bound iron (Fe_p) and TC were much lower comparing to other iron forms in peaty soils ($r^2 =-0.44$; $p<0.03$). No correlations were found between studied soil parameters and non-silicate iron forms in mineral and semi-mineral soil samples.

We concluded that the observed differences in Fet and Fep may result from disturbances in wetland hydrology, caused by thawing of ground ice, especially in organic soils developed in Bulunkul lake peatlands.

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Keywords

Hydrogenic soils, cryogenic processes, non-silicate iron, Eastern Pamir Mts.

MODELLING THERMAL REGIME OF AN INTRAPERMAFROST TALIK IN CENTRAL YAKUTIA, SIBERIA

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Intrapermafrost taliks widely occur in sandy deposits of the Lena River alluvial terraces on the right bank of the Lena River, in central Yakutia. Most such talik strata host intrapermafrost groundwaters, discharging in small creeks cutting the valley sides and feeding multiple icings throughout winter. While the source areas of the groundwater flow can be traced at most locations, the question of the origin of non-frozen intrapermafrost layers remains open. Are they a product of the current climate, or of the warmer Holocene optimum conditions? In both cases, is there a significant thermal imprint from the groundwater flow capable of maintaining the non-frozen state of the deposits? Our study aimed at addressing these questions with the means of heat transfer modelling.

Our study site is the well-studied Ulakhan-Taryn valley, at the right bank of the Lena River ca. 50km from Yakutsk. Local geology is fine to medium sands from the surface Boreholes and ERT surveys provide sufficient details on the permafrost distribution: a topmost frozen layer from surface to 16m, a top of permafrost at ca. 80m, and an intrapermafrost talik between the two. Mean monthly ground temperatures vary from -18.6ºC (January) to +16.8ºC (August) at the ground surface, from -9.3ºC (January) to +9.8ºC (August) at 1m, and are slightly positive at zero annual amplitude depth (18m). The active layer depth averages 2.8m.

Our modelling exercises involved two numerical models, QFrost (Moscow State University) and PFLOTRAN (Sandia National Laboratories, USA), both open-source and distributed under GNU GPL license. QFrost is a conductive heat transfer model with phase changes, and PFLOTRAN is a fully coupled convective-conductive heat and water transfer model. At the current stage of our study, only 1D calculations were performed and only conductive heat transfer was accounted for in both models. Initial conditions were assigned based on borehole descriptions and published thermal properties of central Yakutian sands. Calibration and verification runs were used to test and adjust, if necessary, the major input parameters, of which the most important were the thermal properties of local sands in both frozen and non-frozen state. A uniform temperature distribution (1ºC) was applied, and geothermal flux was neglected in both model settings, based on previous studies.

The variations in thermal properties of frozen and non-frozen sands were found to control the thermal regime of the upper part of the cross-section. Calibration runs have proven that the ‘positive temperature shift’ effect controls ground temperature distribution in the active layer, where the thermal conductivity in non-frozen state exceeds that of the frozen sands. Our preliminary results from a series of 1D simulations in QFrost, running for 100y, show that under current climate, permafrost develops to a depth at least 40m in an initially non-frozen profile of sandy deposits. In PFLOTRAN, however, the bottom of permafrost depth limits to ca. 20m, but further freezing is expected in longer model runs. Therefore, a certain thermal impact from groundwater flow may be assumed sustaining the intrapermafrost talik in its present dimensions.

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APPLICATION OF THE MATHEMATICAL MORPHOLOGY OF LANDSCAPES IN CRYOLITHOZONE RESEARCH

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The aim of the report to discuss the efficiency of the mathematical morphology of landscapes in different aspects of Cryolithozone research. The mathematical morphology of landscapes is a branch of the Earth science dealing with the quantitative laws for the Earth surface mosaics, which are formed by natural units like bogs or aeolian hills, and mathematical methods for their analysis. One of the most important results of the mathematical morphology of landscapes is the concept of mathematical models of landscape patterns. A mathematical model for a landscape pattern is a set of mathematical dependences which reflects the essential geometric characteristics of a landscape. The theory of random process is the most successful basis for developing these models.

The most exciting results of the mathematical morphology of landscapes include:

- The laws of spatial patterns and development of Crylithozone landscapes,
- Exogenous hazard prognosis;
- Natural risks assessment for engineering structures in the Cryolithozone.

Thermokarst plains are amongst the studied areas of the mathematical morphology of landscapes. We revealed the following laws governing their development, which were empirically tested in different natural environments but within isotropic key sites using remote sensing data:

- The emergence and arrangement of the thermokarst depressions (lakes) obey the Poisson distribution;
- Size distribution of the thermokarst lakes obeys the lognormal distribution.

Thermokarst plains with fluvial erosion were studied for the prognosis of their development including natural exogenous hazards. These plains develop through two contrasting processes:

1. Thermokarst lakes appearing and increasing in size,
2. Drainage of the lakes through fluvial erosion and their transformation into khasireis (drained thermokarst depressions).

Our research includes both the theoretical substantiation of the mathematical model and its empirical testing on the basis of single and repeated high-resolution space imagery. Thus, we have found that following after a long period of development the spatial pattern of thermokarst plains with fluvial erosion may achieve a state of dynamic balance which characterizes with certain limit distributions:

- Rayleigh distribution for the size distribution of the drained thermokarst depressions;
- The integral exponential distribution for the size of the thermokarst lakes.

The developed mathematical models give us theoretical bases for assessing the impact probability for human-made structures from natural hazards. In particular, we analyzed the laws of human-provoked thermokarst along linear structures (roads, pipelines) in Cryolithozone and detected:

- The lognormal distribution of the projections of thermokarst depressions (ponds) both on a linear structure and the direction perpendicular to the structure;
- The exponential distribution of projection distances between the centers of thermokarst depressions onto the linear structure.

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COLLAPSE AND REGENERATION OF APAREJO GLACIER, CENTRAL CHILE

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On March 1st, 1980, a catastrophic slide resulted in the sudden removal of an ice volume of 7.2 Mm^3 of Aparejo Glacier, located 60 km east of Santiago de Chile, which was 1.2 km long and 200 m wide in average, with an area of 15 ha. The slide affected 85% of the total volume of the glacier. The event caused the sudden mobilization of the sliding mass 3.7 km down valley with an estimated speed of 110 km/h, causing remarkable geomorphological changes, including the obliteration of most of the glacier and a thick ice-rock debris deposit downstream.

The abundance of glacier meltwater has been proposed as a cause of the event, which would have acted as a trigger due to enhanced water pressure at the bed and reduction of basal drag. This hypothesis is supported by witnesses of the event, who noted supraglacial lakes on the glacier surface, with a thin (2-3 cm) snow layer at the melting point. The glacier detached from its bergschrund (with a fracture 20 m wide) and started to slide as a block flow, with an ondulating movement over its bed, progressively accelerating down valley. First, the glacier preserved its initial morphology, sliding down with a Southeast direction. Once it reached the main valley, the ice climbed 70 meters upslope before disintegrating with a cloud of ice and dust and progressed down valley as a turbulent flow. The event lasted 2 minutes approximately.

Field inspection at 12th March 1980, showed that a major part of the glacier basin was ice-free, with the lower bed in the 2/3 of the lower basin composed of till. The upper third of was composed mostly of bare rock of poor geotechnical quality with a slope of 32º. The remnant ice (about 15% of the original glacier volume) was preserved mostly on the upper reaches of the basin. The slide deposit downstream covered an area of 55 ha with an ice and rock debris depth of some 17 m. The volume of the deposit was estimated as $8.1x10^6$ m^3, equals to the original volume of the detached glacier with a swelling volume of 11%. Within the slide path not covered by debris, furrows and striae with a maximum depth of 2 m could be observed.

GNSS and GPR surveys, performed between 2015 and 2016, confirmed the existence of a new glacier occupying the same basin after the 1980 collapse. The current glacier is 1.1 km long with a surface area of 0.12 km^2, and a maximum ice depth of 40 m after the GPR survey.

We propose the hypothesis that most of the remnant ice after the 1980 event was preserved and became part of the actual Aparejo Glacier. This is likely, considering that the glacier is located on a low temperature site, with south exposure and low solar radiation, conditions proper for glacier preservation. The remnant ice probably flowed, then slipped and fell through avalanches to the glacier's mid and lower portion of the basin. Also it is likely that the snow accumulation, coming from the steep slopes at both sides of the glacier, could have filled quickly and partially the glacial basin. Then, the transformation of snow into firn, and then into ice, would have occurred in a couple of decades. The latter is probably considering that during the 80' and 90' decades there were several particularly humid years, related to a higher frequency of El Niño events.

A negative ice thickness has been identified on the lower and mid-section of the glacier, pointing out to decreasing conditions, according to climatological regional tendencies. This trend allows us to estimate as very unlikely the risk associated to a new catastrophic slide, particularly in view of future warmer scenarios.

LATE HOLOCENE INCREASE IN ATMOSPHERIC GREENHOUSE GAS FORCING DUE TO PERMAFROST AGGRADATION IN A SUBARCTIC PEATLAND, NE EUROPEAN RUSSIA

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Impact of the peatland permafrost development on greenhouse gas (GHG) dynamics is scarcely studied. We applied palaeoecological methods, namely plant macrofossils and radiocarbon dating, to study permafrost peatland dynamics in Seida, NE European Russia. We combined palaeoecological data with on-site GHG measurements to model past radiative forcing (RF). Our palaeoecological study shows a prominent landscape-level change from an early Holocene forested minerotrophic fen to a late Holocene subarctic permafrost peatland. This resulted in a distinctive increase in GHG emissions to the atmosphere. Paradoxically, it seems that permafrost initiation triggered by late Holocene cooling climate generated a positive, i.e. warming RF impact. This is especially driven by increase in CO_2 emissions. While we evidently need more studies investigating links between permafrost peatland dynamics and atmospheric forcing, the current study highlights importance of Arctic peatlands for atmospheric GHG dynamics.

ORIGIN OF GROUND-ICE IN MIOCENE SEDIMENTS, FRIIS HILLS, ANTARCTICA

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The high elevation (>1000 m) McMurdo Dry Valleys of Antarctica (MDV) have remained frozen under a hyper-arid polar climate since 13.8 Ma. Ground ice is ubiquitous in subsurface sediments at these high elevations; however, some sublimation models predict that this ice should not last more than several hundred thousand years. The presence and origin of ground ice at high elevations is not fully understood and presents a major challenge in understanding the paleoclimate of the MDV.

During the 2016 Friis Hills Drilling Project (77°45′S, 161°30′E), three sediment cores were retrieved and provide a well-preserved record of Antarctic environmental changes from approximately 15 million years ago, which was the last time global climate averaged 3 – 5°C warmer than present and tundra-like ecosystems were present in Antarctica. These cores contain a unique cryostratigraphic assemblage with ground ice present to depths of 50 m, providing a rare opportunity to study ground ice constrained within Miocene-aged sediments. To provide information on the source and genesis of ground ice at Friis Hills, we have analyzed stable isotopes and soluble ions in water from the core samples. We also made a high-resolution stratigraphic log of the first 5 m using grain-size and XRF data. Irrespective of sedimentological facies, results show that these cores contain two types of ground ice with unique geochemical characteristics: (1) samples from the upper-meter of ice-cemented permafrost have an evaporative signature, which is enriched in heavy isotopes (avg. dD: -197.1‰, d18O: -16.7‰ VSMOW) with exceptionally low d-excess values (avg. -63.6‰ VSMOW) and high soluble salt concentrations, and (2) samples retrieved from depths below 30 m, which have low soluble salt concentrations and an isotopic signature similar to snow/ice in the MDV (avg. dD: -269.8‰, d18O: -34.6‰ VSMOW). Samples between 5 and 30 m lack ground ice throughout all cores, corresponding to 3 – 15 % gravimetric water content. This demonstrates there may be more than one process responsible for the ground ice in the sediments of Friis Hills.

DEBRIS-COVERED GLACIER AND ROCK GLACIER KINEMATICS IN THE ANDES (30°S), DOCUMENTED BY 64 YEARS OF REMOTE SENSING AND FIELD OBSERVATIONS

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In the Dry Andes of Chile and Argentina, debris-covered glacier and rock glacier assemblages represent complex cases of glacier-permafrost interactions. However, the lack of systematic and continuous measurements of these features has precluded a better understanding of their response to changes in environmental conditions. The Tapado Glacier system is a composite assemblage of uncovered, debris-covered and rock glaciers located at the head of the Elqui basin, Coquimbo Region, between 4330 and 5536 m a.s.l.

Here we use aerial photographs, satellite imagery, UAV and in situ surveys obtained between 1955 and 2019 to track changes in motion and geomorphology on the Tapado debris-covered glacier and rock glacier assemblage in the Dry Andes of Chile. A semi-automatic feature tracking procedure between a series of orthorectified and co-registered images was employed to calculate surface velocities on the debris-covered glacier and the two rock glaciers. A large and widespread network of ca. 50 differential GNSS points on superficial rocks measured between 2010 and 2019 revealed a good agreement between in situ and image-derived velocities. The results indicate larger velocities for the upper debris-covered glacier (up to 4 m/y) than for the most active rock glacier (~1 m/y). Nevertheless, the lower debris-covered glacier has very low velocities (< 1 m/y), surface collapse features (downwasting), thermokarst depressions, and supraglacial ponds and lakes. Our findings suggest that, while the lower debris-covered glacier is locally collapsing and becoming stagnant, the active rock glacier shows evidence of horizontal movement and terminus advance. The multi-method monitoring since 1955 provides a unique times series documenting the surface kinematics of creeping mountain permafrost and debris-covered ice in the Southern Hemisphere.

ARTIFICIAL GROUND COOLING USING SOLAR PANELED THERMOSYPHONS

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Thermosyphons have been used extensively in arctic and sub-arctic locations to create or maintain frozen ground below buildings, pipelines, and road features. They are increasingly being used at locations where ground disturbance or changes in local climate require additional ground cooling. Passive thermosyphons extract heat from the ground with a two-phase working liquid. The fluid vaporizes and rises upward to a condenser where the working fluid condenses. The cooled fluid then gravitates to the bottom of the pipe (the evaporator) bringing cold thermal mass with it. When pressurized carbon dioxide is used as the working fluid, the heat extraction only works when there is a temperature gradient between the pipe and the ground (colder at the condenser than at the evaporator) and ambient air temperatures are below freezing. Passive thermosyphons cease operation when air temperatures are warmer than ground temperatures. Active thermosyphons use mechanical refrigeration to chill the working fluid and thus they can promote cooling and extract heat at all air temperatures. However, active thermosyphons require energy to function. Hybrid thermosyphons function passively when air temperatures are sufficiently cold and they use power and refrigerant when air temperatures are above ground temperatures. Passive thermosyphons are the cheapest to maintain because they function independently and can be part of a resilient energy system. For locations where power is limited or costly there is a need to develop a self-maintained system that can function without being connected to an electrical source. A promising new technology for thermosyphon application would consist of hybrid systems that use solar power when the passive system is not functioning because ambient air temperatures are too warm. This could expand the potential ground cooling periods, particularly during the early fall and late spring shoulder seasons when passive systems are not operating but there is 12 or more hours of sunlight available to power the solar panels. We are developing a hybrid system where solar panels will power a refrigeration unit coupled to a battery system. This expands the timeframe of when the thermosyphons can cool the ground. These systems could also be used in warmer climate or remote locations. We are developing a prototype system at the Fairbanks Permafrost Experiment Station, Fairbanks, Alaska, United States. The system will consist of a solar paneled refrigeration unit that will activate a hybrid thermosyphon when air temperatures are above freezing and when solar gain is sufficient to power the refrigerant part of the hybrid system.

APPLICABILITY EVALUATION OF CAST-IN-PLACE BORED PILE IN PERMAFROST REGIONS

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In recent years, cast-in-place bored piles have been widely used in engineering constructions. The performance of piles depends on many aspects. Permafrost surrounding the pile has a pernicious influence on the development of concrete strength in a negative-temperature curing environment. To evaluate the applicability of bored pile constricted by the loss of concrete strength in the cold curing environment of permafrost, we developed a temperature-tracking concrete hydration model to clarify the refreezing process of the bored pile. Based on an initial refreezing time (IRT) on the pile side of at least 30 days, the applicability of cast-in-place bored pile in permafrost regions was discussed. The results show that the IRT increases with the increasing of the mean annual ground temperature (MAGT), the ice content of frozen soil, the molding temperature of concrete, and the pile diameter. The applicability of the bored pile can be expanded by increasing the diameter of the bored pile as well as the molding temperature. Particularly, the influence of diameter is more obvious than that of the molding temperature. The simulations indicate that the bored pile is not recommended to be adopted in perennially cryotic ground where the MAGT is lower than −3.5 °C. The IRT should be adjusted to guarantee both pile quality and schedule. Significant heave force is expected due to the existence of extensive frost susceptible soils and cold weather. Besides, to provide reasonable suggestions for design and construction, a safety coefficient calculation which involves with the frost penetration, frost heave force, freezing strength as well as loads is conducted. The results show that the spread-type footing has more excellent performance to resist uplift loads than drilled shaft. To improve the safety of foundations, antiheave measures including non-frost susceptive soil backfill, bevel foundation design, surface treatment and two-phase closed thermosyphon, etc were proposed and applied in the construction of the Qinghai-Tibetan grid project. The advantages and applicability of anti-heave technical solutions are described.

THE CHARACTERISTICS OF GROUND ICE ISOTOPES IN THE PERMAFROST REGIONS OF THE CENTRAL QINGHAI-TIBETAN PLATEAU

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The thawing of ground ice in permafrost under climate changes could have great impacts on the local and regional hydrological and biogeochemical cycles. It is of great significance to reveal the characteristics of ground ice and their impacting factors for understanding the moisture migration between the permafrost and active layer during the freezing thawing processes in the context of climate change. Until now the characteristics of ground ice and their impacting factors were still not well understand because of less observations. The stable isotopic measurement provides an effective tool to figure out the characteristics of ground ice and their impacting factors. In this study, we examined spatial distributions and controlling factors of ground ice isotopes using data of eight soil profiles surveyed in the permafrost regions of the Qinghai Tibet Plateau (QTP). Isotopic values (δD and $\delta^{18}O$) of water components are variable as the geographic locations of the sampling sites change. The spatial distribution of isotopes was complicated. Isotopes generally decreased with depth within the soil profile, implying a general isotope depth gradient across different permafrost affected regions. It is discovered that the water source, evaporative and freeze-out fractionation, and cryoturbation are four dominant factors to the soil water isotopes. The statistical analysis showed that δD and $\delta^{18}O$ in soil water were positively related to air temperature and soil temperature, while negatively related to soil moisture, depth, active layer thickness, vegetation coverage, elevation, and precipitation. Both the elevation and soil depth are dominant impacting factors of spatial characteristics for ground ice isotopes. A conceptual framework on soil moisture cycling during the freezing thawing processes has been presented. The results could provide a new insight into soil moisture movement and cycling during freeze thaw process in the permafrost region of the QTP, which is helpful to understand subsurface water cycle mechanism in the context of permafrost dynamics

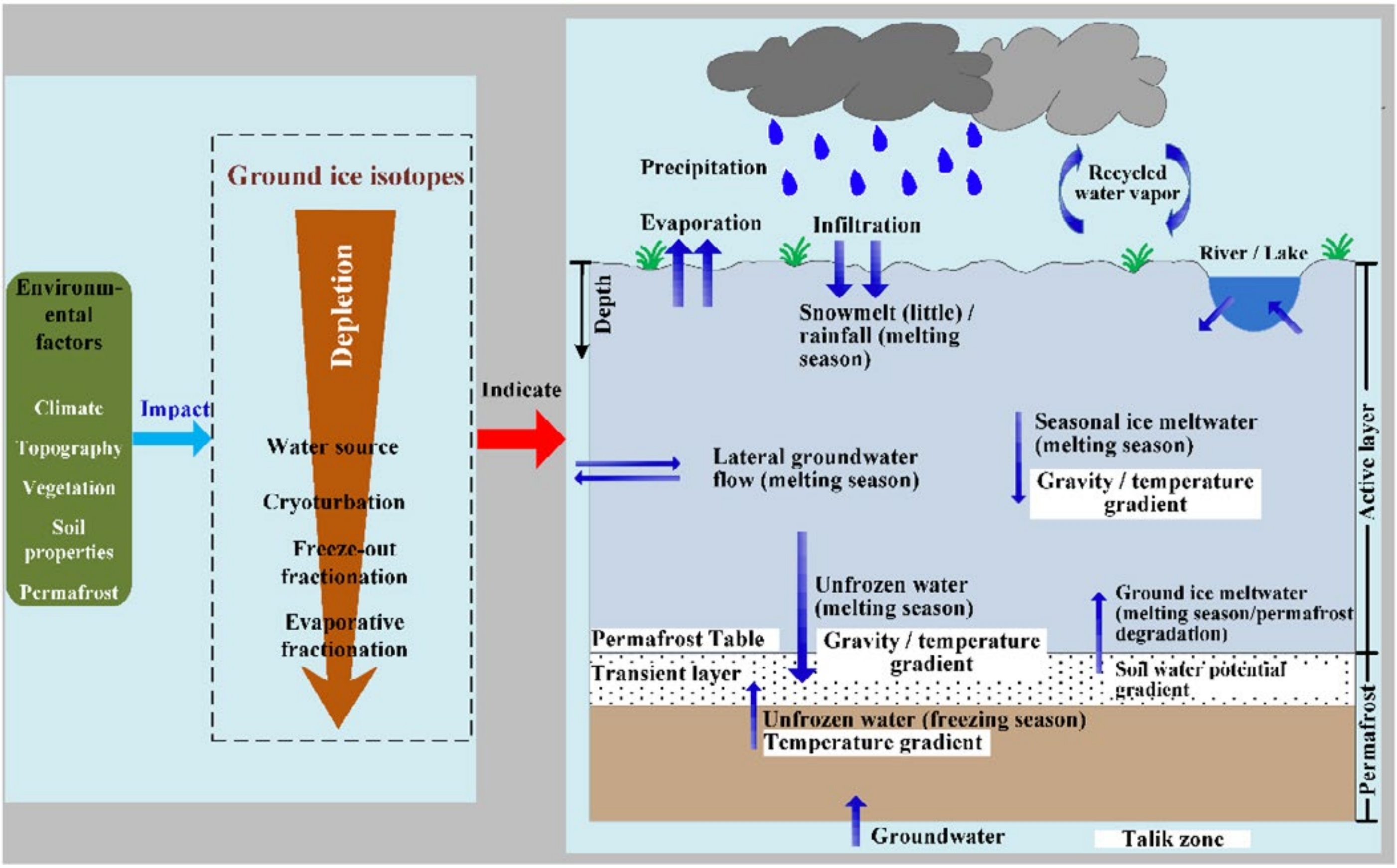

Figure 1: The conceptual diagram of soil moisture cycling during freezing-thawing process in the permafrost regions of the Central QTP.

PERMAFROST DISTRIBUTION PATTERN NEARBY ZONAG LAKE IN THE QINGHAI-TIBET PLATEAU, CHINA

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The QTP possesses the largest areas of permafrost in the mid-and low latitude regions of the world. According to the latest statistics, permafrost area of the QTP is about 1.06 million square kilometers. The QTP also possesses large number and area of lakes. The total area of lakes in the QTP is about 36,899 km, accounting for 45.2% of the total lake area in China. Zonag Lake (35° 33' 23", 91° 56' 8") is located in HohXil regions. It is a famous lake for Tibetan antelope breeding here every spring. The climate is cold and dry too in this region. Average annual temperature is about -5.0 °C and annual precipitation is about 150-300 mm. In September 2011, Zonag Lake burst after the water level had risen for several years. Zonag Lake shrank from 270 km^2 to 156 km^2 and lakebed was partially exposed after the lake outburst. In April 2012, 6 boreholes were drilled at the south of Zonag Lake. The ZN-1 borehole is located on the exposed lakebed with a distance of 200m from the old lakeshore. The ZN-2 borehole was located just on the old lakeshore. ZN-3, ZN-4 and ZN-5 are distributed vertically in the south of old lakeshore with distance of 200 m, 350 m and 1500 m, respectively. Geophysical exploration was conducted on several sections in this region and an Automatic Weather Station was set up closed to ZL-5 borehole in October 2013.

During the drilling work in April, permafrost was found in all six boreholes nearby Zonag Lake. In ZN-1 borehole, permafrost base was found at about 4.5 m depth, which shows that the frozen soil in this region was formed after the outburst of the lake and there was a penetrating melting zone under Zonag Lake. Due to the cold climate in Zonag Lake region, permafrost has developed rapidly on the bottom of the lake after the lake outburst in 2011. At ZN-1 site, observation data indicated that the permafrost base increased to 5.4m and 5.7m in 2013 and 2014. Simulation results show that the annual growth rate of permafrost thickness will decrease with the increase of depth and it will need 200 years for the frozen layer to reach 30m. The ground temperatures in ZN-3, ZN-4 and ZN-5 holes are basically close, ground temperatures at 8.0 m depth were lower than -1.0 °C and the ground temperature curves are nearly coincident. The temperature curves of permafrost under the same ground conditions at different distances are close, which indicates that the lake water has little effect on the thermal condition of permafrost in these region. Comparing the ground temperature curves of all the five boreholes, it can be concluded that there was a talic under lake water and the heating effect of lake water on the surrounding permafrost may be limited in less than 100 m..

POST-WILDFIRE SURFACE DEFORMATION AT BATAGAY, EASTERN SIBERIA, DETECTED BY L-BAND AND C-BAND INSAR

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Observing thaw-induced ground subsidence by InSAR (Interferometric Synthetic Aperture Radar) can tell us the state of permafrost with high spatiotemporal resolution. Some previous studies have been conducted in a part of Alaska, Canada and lowland Siberia where it is relatively easy to compare with field observations (Liu et al. 2010; Short et al. 2011; Iwahana et al. 2016; Antonova et al. 2018).

Our study area is around Batagay (67’39N, 134’39E), Sakha Republic, Russia. At ~10 km southeast of Batagay, there is a well-known and one of the largest slump terrains caused by thawing of permafrost (Murton et al. 2017). Processing ALOS and ALOS2 InSAR images, we detected deformation signals due to a wildfire occurred in 2014 at the hill to the 20 km northwest of Batagay. Loss of surficial vegetation layer by wildfire accelerates permafrost thawing, and the degradation continues for several years to decades after a fire (Yoshikawa et al. 2002). Furthermore, given the fact that the frequency and intensity of wildfires are increasing in the Arctic region with global warming (Alexander et al. 2018; Gibson et al. 2018; Masrur et al. 2018), it is important to reveal the spatiotemporal variation of the ground deformation in the post-wildfire area.

Besides L-band ALOS2 SAR images, we also used C-band Sentinel-1 images to examine short-term deformation. Seasonal deformation from 2017 to 2018 is detected from both satellites data, whose magnitude and spatial patterns of subsidence and uplift were consistent in both satellites. In particular, Sentinel-1 short-term InSAR images revealed detailed temporal changes from the start of thawing to the end of freezing. Long-term deformation was detected by ALOS2 data. Although some data were affected by ionospheric and topography-correlated tropospheric phase delay, we corrected them by removing long-wavelength phase trend and fitting with DEM on the assumption that the deformation signal over the post-wildfire area is uncorrelated with other noises. The results indicated that thawing subsidence reached up to 15cm in the satellite line of sight direction and were continuing even 2-3 years after the fire. We also used our detected frost heave signals to estimate the thickness of active layer after the fire, using the model by Liu et al (2012). InSAR-based quality deformation maps can contribute to our understanding of thermokarst processes.

KEY EXPRESSWAY CONSTRUCTION ISSUES IN CHINESE PERMAFROST REGIONS

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In view of the highway construction planning and demand in permafrost region in China, this paper analyzes some key issues from the aspects of the heat transfer process of embankment, the main influencing factors, and cooling efficiency of engineering measures during the expressway construction in permafrost regions. The research showed that, the heat absorption intensity of the expressway embankment will be doubled, and more heat will be gathered in the central part of the subgrade and difficult to diffuse, resulting in the increase of the degradation rate and scope of the permafrost compared with the Qinghai-Tibet railway and the Qinghai-Tibet ordinary highway in Qinghai-Tibet Plateau. The application of existing typical engineering measures to protect permafrost has the problems of insufficient cooling efficiency, difficulty in overall and uniform cooling, and to cause longitudinal cracks and uneven settlement other engineering diseases in the condition of expressway. It is found that the keyway to solve these problems is the adoption of separate building or the research of new effective engineering measures.

URBAN SAFETY AND SUSTAINABLE DEVELOPMENT IN NORTHEAST CHINA'S PERMAFROST REGIONS

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Mohe County, northernmost China, is one of the densely populated areas in permafrost regions. The urban population has grown from about 25 000 residents in 1992 to more than 41 000 in 2011. The climate warming tendency rate at Mohe County is 0.357 oC decade -1 during the past 50 years. This paper adopted drilling, ground penetration radar, and ground temperature monitoring to investigate the permafrost in the urban area of Mohe County. The results show that the permafrost table is much lower in the urban area of Mohe County because of the surface disturbance of construction, space heating in winter, cultivation etc. The permafrost table in the natural area and at the edge of the urban area is 1.65 - 2.0 m and 2.63 - 3.70 m, respectively. In the urban area, the artificial permafrost table has exceeded 15 m. The mean annual ground temperature in the natural area and the edge of the urban area, which is at the 15 m depth, is -2.75 oC and -1.0 – -1.33 oC, respectively. At the same depth, the ground temperature is 0.18 - 1.16 oC in the urban area. Evidences outline a clear distribution rule that, from the edge to the center of the urban area of Mohe County, the permafrost table goes deeper and deeper, which states that the cumulative impact of the climate warming and urbanization have significant influence on permafrost degradation. The degradation of permafrost in the urban area in turn has been affecting the residents' lives, such as water supply and stability of buildings.

Urban Permafrost degradation adds significantly to social costs in northeast China. Additional investments are being made to strengthen and repair buildings and roads damaged by permafrost degradation. Spending in 2016 accounted for a third of the region's GDP. Due to environmental protection, the local government has stopped deforestation and reduced coal mining. As a result, the income of the local residents and the governments has been greatly reduced, and the sustainable development of the region is facing severe challenges. The emerging tourism industry and wild blueberries grown in permafrost wetlands are an important resource for sustainable development. But wild blueberry yields are affected by climate change. Permafrost has caused losses to the society under climate change, but permafrost can be developed as a unique tourism resource to attract more tourists from the south of China. At the same time, as the climate warming, the permafrost degrades, leading to the thickening of active layer in summer and the increase of ground temperature, which provides feasible conditions for local agriculture. In addition, a small number of breeding industries are emerging in this area. But more research is needed by now. The authors provide the utilization plan of permafrost tourism resourcelization and the technical path to realize it.

COOLING PERFORMANCE OF CRUSHED-ROCK EMBANKMENTS AND THEIR APPLICATION IN PERMAFROST REGIONS

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Crushed-rock embankments have been widely used to increase the thermal stability of railways/highways in permafrost regions, e.g., the Qinghai-Tibet Railway and Highway in China, the Alaska Taylor Highway in the USA and the Baikal-Amur Railway in Russia. The cooling performance of the crushed-rock embankments in permafrost regions has been evaluated using laboratory test, in-situ observation, and numerical simulation. The research results indicate that the cooling performance of the crushed-rock embankments in practical applications is determined by factors that include particle size, thickness, configuration, and ambient condition and so on. Even with optimization, the single measure, e.g. crushed-rock interlayer embankment, crushed-rock revetment embankment and U-shaped (interlayer and revetment) embankment, can only ensure the thermal stability of narrow (<10m) embankments in permafrost regions, and is insufficient for wider embankments under climate warming. The cooling performance of crushed-rock embankments can be improved by combining them with other thermal protection methods such as two-phase closed thermosyphons, ventilation ducts, and insulation. Typical composite embankments have been developed, such as crushed-rock interlayer embankments with ventilated ducts, and crushed-rock revetment embankments with two-phase closed thermosyphons and insulation. It is found that the composite embankments can effectively protect the underlying permafrost from degradation. These works can provide the basis for highway/railway embankment design and construction in permafrost regions, such as the Qinghai-Tibet Plateau and the Arctic region. Future work will focus on further studies of the thermo-mechanical behavior of the crushed-rock embankments in permafrost regions under different scenarios for climate change.

Keywords

Cooling performance, application, crushed-rock embankment, permafrost region.

EFFECT OF TEMPERATURE CONTROLLED VENTILATED EMBANKMENTS UNDER THE QINGHAI-TIBET EXPRESSWAY

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The temperature controlled ventilated embankment (TCVE) is an engineering measure that is an improvement of the duct-ventilated embankment (DVE). TCVE can control the heat exchange of embankment with outside according to ambient air temperature, which conducts heat transfer in the cold season but prevents it in the warm season with auto temperature-controlled wind doors installed in duct nozzle. In this way, the cold energy storage is promoted, and embankment stability is strengthened. To confirm the cooling effect of TCVE, we installed auto temperature-controlled wind doors at the ventilation ducts nozzles of the original DVE in Qinghai-Tibet Plateau. After the door's installation, the field observational data from the testing section indicated that the permafrost temperature further decreased under the embankment and the embankment deformation tends to be stable. The results revealed that the mean temperature of the air inside the duct was decreased by 46% in the warm season and the thawing index decreased obviously in ventilation ducts after the wind door installation. The results also showed that the annual net heat release was 1.4 times than that before installing the doors nearby the permafrost table and the time of heat absorbing reduced about one month after installation of the doors. Comparison of ground temperature of the embankment profiles, the artificial permafrost table lifted to the original natural surface and sunny–shady slope effect decreased after installation of the doors. This study has important guiding significance for the application of cooling measures in expressway construction in permafrost regions.

SPATIAL VARIATION OF ACTIVE LAYER THICKNESS IN A MOUNTAINOUS AREA OF THE EASTERN TIBETAN PLATEAU

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The active layer plays an important role in permafrost regions due to most ecological, hydrological and biochemical activities take place within it. The active layer thickness (ALT) in mountainous areas can be spatially highly variable, which substantially influenced by the interaction of various local factors (e.g. slope, vegetation, soil texture and moisture). A systematic survey in a wet mountain of eastern Tibetan Plateau was conducted by using ground-penetrating radar (GPR). Meanwhile, the unmanned aerial vehicle (UAV) was employed to detect the micro topography of all GPR profiles, and the soil and biomass samples also were collected. The influence of local factors on ALT were analyzed, and results indicate that: 1) GPR performed well in detecting active layer in this area, the derived ALTs are in high agreement with the survey data with a positive bias ~0.14 m (R^2=0.94), the MAE and RMSE were ~0.15 m (10.2%) and ~0.18 m (12.4%), respectively; 2) The ALTs in the study area ranged from 1.0 to 4.1 m, with the average 1.9 m (the CV was ~42.2%); 3) The ALTs were sensitive to spatial scales of different terrain factors, the first three primary local factors are terrain, soil bulk density/moisture and NDVI, with a total contribution account for ~70% of ALTs distribution in this region. The results could be helpful to improve the ALT modelling in mountainous region on the Tibetan Plateau.

Keywords

Tibetan Plateau, Mountain permafrost, Active layer thickness, Local factors.

POSTER ABSTRACTS

In order of presenter's last name

ORNITHOGENIC SOILS OF KING GEORGE AND ARDLEY ISLANDS, SOUTH SHETLAND ISLANDS, MARITIME ANTARCTICA

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In severe climatic conditions of Antarctica birds play an important role in transportation of organic matter to the coastal landscapes. This study is aimed to investigation of ornithogenic factor in soil formation on King George and Ardley islands (South Shetland Islands). Our work revealed that redistribution of guano components affects significantly the speed of soil cover spatial development and formation of new polypedons of soils in environments of rookeries. Analysis of mesomorphological organization of soil aggregates showed different rates of association between guano remnants and mineral grains in humus horizons, which is caused by variability in both fine earth content and guano decomposition rate. Our work revealed that redistribution of guano components affects significantly the speed of soil cover spatial development and formation of new polypedons of soils in environments of rookeries. Analysis of mesomorphological organization of soil aggregates showed different rates of association between guano remnants and mineral grains in humus horizons, which is caused by variability in both fine earth content and guano decomposition rate. In this study, 13C-NMR spectroscopy was performed to analyze soil organic matter of Ornithosols, Post-Ornithosols and Cryosols not affected by bird activity. We found that the humic acids (HAs) of the cryoturbated, buried areas had lower amounts of alkyl aromatic and protonized aromatic compounds. In contrast, the HAs from the surface layers contain less alkyl carbon components. Our data showed that the portion of aromatic compounds is little higher in soils under materials transported by birds compared to soils under mono species of bryophyta or lichens communities. This is probably caused by the fact that birds use mainly remnants of Deschampsia antarctica (which contains increased portion of phenyl-propanous organic precursors) for nest building. The free-radical content was higher in the surface layers than in the buried layers due to the presence of fresh organic remnants in superficial soil samples Permafrost table depth in studied soils was determined using vertical electrical resistivity sounding and ranged from 89 to 100 cm at studied sites. The electrical resistivity profiles of ornithogenic soils (under guano) are more homogenous which can be related to the less pronounced turbic processes within the soil profile. This study was supported by RFBR, grant 18-04-00900 “Ornithogenic soils of Antarctica: formation, geography, biogeochemistry and bioindication”.

Keywords

Ornithogenic soils, Antarctica, guano, soil formation

REGIONAL TREND OF ROCK GLACIER KINEMATICS DERIVED FROM DINSAR DATA

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The kinematics of rock glaciers closely depend s on the temperature profile between the surface and the main shearing horizon at depth: the closer to 0°C it is, the faster the rock glacier is moving. Rock glaciers have been observed to develop a landform specific but repetitive intra annual behavior displaying a ratio between minimal and maximal velocities ranging from close to 1:1 to 1:10 and have a concomitant regiona l behavior at the (pluri --)annual to (pluri --)decennial time scale. Nevertheless, some rock glaciers may accelerate or decelerate abnormally. Therefore, it is important to use a relatively large set of rock glaciers for performing a regional trend analysis.

Development in remote sensing technologies and the greater availability of appropriate satellite imagery have recently permitted to include more detailed kinematic information into rock glacier inventories. Observing or deriving a rock glacier kinematic variable at regional or even global scale seems technically feasible using remote sensing techniques.

The presented study shows the potential of Differential SAR Interferometry (DInSAR) to derive a rock glacier kinematic variable on a regional scale. The Bas Valais (Swiss Alps , 46°N 7.4°E covers an area of typical high mountain terrain with predominantly continental climate which one third (~ 600km 2) is located above the lower regional permafrost limit (~ 2500 m.a.s.l). The area encompasses 437 identified moving rock glaciers, for most of them at a velocity in the order of 0.1 to 2 m/yr. Among them, several tens rock glaciers have experienced over the last decades very strong changes in their kinematical behavior and morphology. These features, displaying velocities up to 10 m/yr (exceptionally higher) and often showing distinct cracks as well as significant changes at their front, have been called destabilized. Annual regional trend over the last decade have been performed using DInSAR data on about one hundred of rock glaciers, which are not destabilized. This study is based on a unique large data set of about 140 DInSAR scenes computed from summer TerraSAR-X, ALOS-1 PALSAR-1, Cosmo-SkyMed, ALOS-2 PALSAR-2 and Sentinel-1 a cquisitions from 2010 to 2018. As differential GNSS campaigns are systematically repeated twice per year for about ten active rock glaciers in this region and permanent GNSS stations are also operating on some of them, comparison with in-situ measurements is feasible.

A rock glacier kinematics variable has the potential to become a key parameter for the monitoring of the cryosphere in mountain regions. It provides a unique validation dataset for climate models, where direct permafrost (thermal state) measurements are mostly lacking. A proper rock glacier kinematics variable derived from Earth Observation (EO) products could be integrated as a new associated parameter to the Essential Climate Variable (ECV) permafrost in the monitoring strategy of international programs, in addition to the observation of the Thermal State of Permafrost and the Active Layer Thickness already available on the Global Terrestrial Network on Permafrost (GTN-P). This is one of the main objectives of the *IPA Action Group Rock glacier inventories and kinematics*, supported by the International Permafrost Association (IPA). Launched in summer 2018, this Action aims, in its second phase to develop prototypes of EO products for the monitoring of rock glacier related ECV Permafrost. In this context, the ongoing work of the Action will also be presented

A GEOELECTRIC SURVEY TO STUDY THE GROUND STATE BENEATH THE FACILITIES OF THE PERUVIAN ANTARCTIC STATION MACHU PICCHU

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Under the framework of the Project Hydrotomo, funded by the Foundation for Science and Technology of the ministry of Higher Education of Portugal, and the Peruvian Polar Program and the Portuguese Polar Program a geoelectrical survey using electrical resistivity tomographies was carried out in January 2019 under the facilities of the Peruvian Antarctic Station Machu Picchu. The station is located in the Admiralty Bay of King George Island of the South Shetland Islands archipelago. The main objective of the survey was to try to estimate the depth and lateral extent of the permafrost that was found beneath the main building of the Machu Picchu station during maintenance works performed in the antarctic summer of 2018. Two rectangular shaped buildings of the Machu Picchu Antarctic Station were chosen to measure the ground electrical resistivity beneath them. In the biggest building (the main building) the electrical profiles crossed 14 m beneath it along its smallest dimension; in the other (a refuge) the electrical profile crossed 7 m beneath the building also along its smallest dimension. To carry out the geoelectrical profiles 40 active electrodes were used in a Wenner configuration; 1 m and 2 m distance between adjacent electrodes were used for different profiles. After processing of the raw electrical data (apparent electrical resistivity pseudosections), real electrical resistivity sections of the ground beneath the two buildings were obtained. The preliminary interpretation of those electrical resistivity profiles indicate that in both buildings there is a layer of permafrost, which has been detected by thermometers, installed in 2018, as well as by eye inspection after digging a small hole to install new thermometers. However, beneath the permafrost layer, coinciding with the area of both buildings, a low electrical resistivity layer about 1 to 2 m thick, with electrical resistivity values as low as 20 Ω.m was found. The interpretation of this low electrical resistivity layer is still a challenge and several hypotheses and explanations are being tested.

GEOELECTRIC STRUCTURE OF THE AQUIFER THAT PROVIDES WATER TO THE PERUVIAN ANTARCTIC STATION OF MACHU PICCHU

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Under the framework of the Project Hydrotomo, and the Peruvian Polar Program, the Portuguese Polar Program, and the Uruguayan Antartic Program, a geoelectrical survey using electrical resistivity tomographies was started in January 2018 near the Peruvian Antarctic Station of Machu Picchu, located in the Admiralty Bay of King George Island of the South Shetland Islands archipelago. The main objective of the survey was to try to delineate the geoelectrical structure of the aquifer that provides water for domestic use to the station; in particular, we were interested in finding the aquifer's lateral and depth extensions so that a water volume could be estimated and a better exploration and exploitation plan could be devised; furthermore, since the station is located a few meters from the cost, the work also aimed at identifying areas of possible saline intrusion. As a matter of fact, Machu Picchu Station is a temporary station that is open during the antarctic summer only; however, there are plans to transform it in the future into a permanent station which implies a more rigorous aquifer management. The study area (about 90,000 m^2) presents glacial, alluvial-glacial, alluvial, alluvial-fluvial, and marine sediments (mostly sandy gravels with some silty gravel layers); the area where the aquifer is believed to exist was covered by several electric resistivity tomographies with lengths that varied from 100 to 300 m long. Hydrogeologic data were obtained from piezometers located within the area where electrical resistivity tomographies were carried out; water samples from the piezometers have electrical resistivity values ranging from 25 to 50 Ω.m. Preliminary processing of the geoelectric data (apparent electrical resistivity pseudosections) obtained along different directions indicates that several tomographic profiles crossed the aquifer which appears to be several meters deep; the bedrock is deeper than 60 m. The aquifer formation presents electrical resistivity values that range from about 100 to 400 Ω.m.

GPR-BASED MAPPING OF ACTIVE LAYER DEPTH WITHIN CATCHMENTS OF FRESHWATER LAKES IN LARSEMANN HILLS OASIS (EAST ANTARCTICA)

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This work is done in framework of 62 seasonal Russian Antarctic Expedition (RAE) to Larsemann Hills oasis. Measurements of the active layer depth in catchments of freshwater lakes were a part of hydroecological research program of the station Progress, as lakes are the main water source for several Antarctic station in this area. In addition, we monitored the dynamic of snow patches located in lake catchments in order to assess potential water inflow into lakes due to snow melt through summer season and influence of snow patches on active layer depth. To map active layer depth, we applied geophysical technics – ground penetrating radar (GPR) with antennas 270 and 900 MHz with different settings. In total, we made 14 profiles with a length of 30-250 meters within catchments of three lakes. Active layer depth varied in a range between 0.07 and 4 meters depending on the landscape. In addition, measurements were done on a CALM site 50x50 m for validation of results.

TOWARDS A NATIONAL INVENTORY OF CONTINUOUS ROCK GLACIERS MOVEMENT IN NORWAY BASED ON INSAR

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Creeping permafrost landforms in Norway are widely distributed over the country. While in southern Norway features originated from ice-cored moraines dominate in high elevation, northern Norway has clusters of both active and relict rock glaciers derived mainly from talus slope deposits. Mapping of these features was mainly based on interpretation of aerial photos of varying quality and resolution, which opens for misinterpretation of both type and activity status, along with lacking observations. E.g., in the northern part of Finnmark in Northern Norway, a group of rock glaciers exists close to sea level, and has been mapped as relict features in our inventory. Since 2015, we have investigated one of these rock glaciers (Ivarsfjord rock glacier) more closely using high resolution (10 cm) SfM, DEM comparison and ERT surveys, revealing a significant displacement pattern indicating an active rock glacier.

The Geological Survey of Norway (NGU) has recently published a nationwide database of radar interferometry measurements (InSAR; https://insar.ngu.no/). The data is collected from the Sentinel 1-satellites, part of the EU Copernicus program, and data exist from October 2014, with a temporal resolution of up to 6 days during the snow-free season. The database is openly available, and has until now be used to identify unstable rock slope areas and vertical movement of buildings and infrastructure.

To evaluate the activity of Norwegian rock glaciers we systematically compared the InSAR database to our existing rock glacier inventory. The high correspondence between the existence of rock glaciers and large ground displacement verifies the inventory interpretations. The field measurements from the Ivarsfjord rock glacier correspond to a large degree to the InSAR-derived displacements. Further, areas of large displacement in the InSAR dataset were investigated more closely, and in this way several areas of rock glaciers previously not mapped were discovered. Here we will present the result of our dataset comparison in terms of activity classification, flow velocities and their variations in time and space in Norway.

RECENT PERIGLACIAL STUDIES ON ROCK GLACIERS OF THE CENTRAL ANDES, MENDOZA, ARGENTINA

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Different periglacial studies related to mountain permafrost were carried out in the Central Andes of Mendoza, Argentina, in the last years. These studies were made especially on rock glaciers. Most important research included monitoring of soil temperatures in active layers and the determination of the top and base mountain permafrost to observe climatic changes as well as the impact of global warming on the Andean cryospheric system. Other studies have involved hydrochemistry and an overview of how groundwater interacts with cryoforms. Hydrological studies in Mendoza are considered strategic because the region is semiarid and needs to improve the management of the resource water for human activities in the oasis as well as for drinking water in a changing environment. Expanding Andean wetlands at high altitudes are studied in order to analyse the C storage. The region corresponds to the most southern part of the Dry Andes. Important investigated valleys with permafrost are located in the basin of the Vallecitos river with a surface of 44.95 km². The basin belongs to the Cordón del Plata mountain range, Cordillera Frontal (32˚57' S, 69˚22' W). Sub-basins show > 60% of periglacial environment with possible permafrost occurrence from ~3600 m asl on upwards. The heads of the valley are occupied by debris-covered glaciers. At present, the glacier area has decreased considerably, or even vanished. Thermokarst are also present in the covered glacier area but also in some parts of the rock glaciers indicating ice degradation and at the same time the occurrence of subterranean glacial ice. At the Morenas Coloradas rock glacier, regional studies were carried out between 1989 and 1992, where the terminal part has been monitored continuously since 1999. This rock glacier showed different temperature characteristics at three monitoring sites in active layers, Balcón I (3560 m asl), Balcón I Superior (3590 m asl) and Balcón II (3770 m asl). As a consequence of the thermal changes of the active layers, the rock glacier shows abrupt movements, particularly in its terminal part. Thus geodesic measurings were made and resulted in different speeds and directions. At the monitoring area of Balcón I Superior, which lies on a superimposed lobe, the geodesic measuring points revealed significant kinematic activity in the period May 2015 – February 2016, when the largest displacement was approximately 2 m to the South, developing an advance of the front over Balcón I. At Balcón II however, the points moved much less, in the order of 0.30 m/yr. On the other hand, at the Stepanek rock glacier a seasonal hydrochemical monitoring was carried out between 2013 and 2017. The objective was to explain groundwater and surface water flow, hydrochemistry and to understand the interaction between groundwater and the rock glacier. The Stepanek rock glacier fills the valley and its permafrost affects the water flow. The isotopic results of the water samples strongly indicate that there is an intra-permafrost water influence from the rock glacier, in response of the degradation of permafrost and melting of ground ice. Due to lithological factors, the Andean periglacial environment may indicate altitudinal differences in the hydrogeochemical results. Elevated values of Ni^{2+}, Cd^{2+} and Zn^{2+} were detected in the meltwater runoff. The hydrogeochemical and isotopic research allows the interpretation of different water paths across the rock glacier. It is expected that this becomes more important in the future due to further global warming.

SOIL ORGANIC CARBON STORAGE IN PERIGLACIAL LANDFORMS OF THE PATAGONIAN ANDES

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This study is part of a project that investigates soil organic carbon (SOC) storage in the periglacial zone of the Andes of South America, in order to assess whether this region will represent a source or sink of carbon (positive or negative feedback) under conditions of future global warming. In January 2019 we conducted field SOC inventories in two study areas located at latitudes 43-44 °S in the Patagonian Andes (Argentina). In total 27 soil profiles were collected along altitudinal and landscape gradients, which are in the process of being analysed for geochemical properties (dry bulk density, coarse fraction, %C, C/N ratios, and stable isotopes). The two mountain areas show a similar altitudinal zonation, with the Nothofagus treeline located at c. 1400-1500 m, and patches of alpine dwarfshrub and grassland extending up to c. 1700-1800 m. Above these elevations, plant cover becomes very sparse, with peaks at c.1900 and c. 2100 m having barren surfaces. Stabilized solifluction terraces on gentle slopes between c. 1500-1700 m are most often characterized by high plant cover, relatively deep soil profiles and (in some cases) evidence of buried organic layers. At higher elevations small but active solifluction lobes, sorted circles and stripes become prominent, with plant cover becoming sparse and soil profiles shallow. Permafrost terrain is restricted to active rock glaciers (with predominantly southern aspects) and the highest peaks (>2000 m), with very sparse or no vegetation/soil development. Once geochemical analyses are completed (summer 2019), the SOC storage for each profile, the mean SOC storage for each of the major land cover and landform classes, and the mean SOC storage for the study areas as a whole, will be calculated. Upscaling from point observations to study area will be based on remotely sensed land cover and landform classifications corroborated by ground-truth points collected during the field season. Finally, we will evaluate the consequences of an upward shift of vegetation/soil belts under global warming. Preliminary observations suggest that the periglacial and permafrost zones in these mountain areas are characterized by very sparse plant cover with very low SOC storage. A future upward shift of plant life zones will most likely represent a net total ecosystem carbon sink and, therefore, a negative feedback on global warming.

FROST DEPTH MEASURING PROGRAM IN JAPAN

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In Japan, frost depths have been measured as an outreach program since 2011 winter season. Frost depths were measured at schools in Hokkaido, northern part of Japan, where seasonal ground freezing occurs in winter, in order to emphasis their interest for earth sciences. At schools, using the frost tube, measurements were conducted directly once a week by students or teacher during ground freezing under no snow-removal condition. A lecture was made in class and a frost tube was set at schoolyard, as the same tube and protocol as UAF's Permafrost Outreach Program, using clear tube with blue-colored water.

In 2011 winter season, we started measurements at three schools, and the number of school extended to 35 in 2018-2019 season, 29 elementary schools, 5 junior high schools and one high school. We visited schools before frost season to talk about the method of measurement, and measurements by students started just after ground freezing. After the end of frozen period, we visited schools again to explain results of each school or another schools in Japan, Alaska, Canada or Russia.

The measured frost depths in Hokkaido ranged widely, from only a few centimeter to more than 50 cm. However, some schools had no frost depth due to heavy snow. We confirmed that the frost depth strongly depends on air temperature and snow depth. The lecture was made to student why the frost depth ranged widely, and the effect of snow was explained by using the example of igloo.

In order to validate the effect of snow and to compare frost depths, we tried to measure frost depths under snow-removal and no snow-removal conditions at the same elementary school. At the middle of December, depths had no significant difference between these conditions, and the frost depth reached to 55 cm under the snow-removal condition difference, while only 28 cm in no snow-removal condition. After these measurements and lectures, students noticed snow has a role as insulator and affects the frost depth.

ANALYSIS OF THE EMBANKMENT STABILITY IN PERMAFROST REGIONS BASED ON STRENGTH REDUCTION FINITE ELEMENT METHOD

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With the rapid development of economy, a large number of infrastructures, including bridges, roads and railways, are built in permafrost regions. According to the demand of road construction and maintenance in permafrost areas, it is extremely urgent to study on the embankment stability in permafrost regions. This paper describes the impact of the external environmental factors, internal factors of permafrost, and engineering factors on embankment stability in permafrost regions, and analyzes the mechanism of the impact on the embankment stability under various factors. Considering various factors based on finite element method to analyze temperature field of embankment under different conditions in permafrost regions. Analyzing the stress-strain field and the stability of embankment under different conditions in permafrost regions based on the finite element double strength reduction method. The main contents and conclusions are as follows:

1. In terms of the characteristics of embankment in permafrost regions, simulating the calescence of climate at a speed of 0.022 °C · a-1 constantly, different direction and different altitude of permafrost underlie the embankment during 50a operating period based on numerical methods, it can conclude that the area of thawing plate underlying embankment, the lowest position of the thawing plate, and the distance deviating from the center line of embankment are the biggest at east-west, 45°to the second, north-south minimized. And with the growth of the operating time, the depth and the distance deviating from the center line of embankment and area of the thawing plate are bigger. With the increase of embankment height, the upper limit of permafrost decrease, the area of the thawing plate increases in both horizontal and vertical.
2. Using double strength reduction finite element method to calculate the simplified mechanical model of thawing plate, it can conclude that the stability safety factor of embankment has a turning point with the increases of embankment height under the condition of the given calculation. When embankment is under the height correspond to the point , the safety factor of stability increases with the embankment elevated gradually, when over this height correspond to the point, the safety factor of stability decreases with the embankment elevated gradually.
3. By comparing with the existence of the underlying embankment thawing plate, it can conclude when considering thawing plate the safety factor of stability is lower than the thawing plate is not considered under the condition of the same calculation. By analyzing the state of bilateral and unilateral thawing of the embankment, it can conclude that the safety factor of stability of the bilateral melting is lower than the unilateral melting of the embankment.
4. By analyzing longitudinal deeper development of the thawing plate area, it can conclude that the longitudinal deeper has only impact on the embankment surface with the scale of longitudinal cracks, but has no impact on its position. The deeper longitudinal dimension of thawing plate, the smaller the safety factor of embankment stability. The horizontal extended length of thawing plate area of embankment are different, the location and size of longitudinal cracks of the embankment surface are different. There is a critical length in different transverse extended length, then the embankment has the largest cracks.

Keywords

Permafrost regions; Double strength reduction; Temperature field; Stress-strain field; Thawing plate; The stability of embankment

REMOTE SENSING DATA AND FIELD-BASED METHODS OF CRYOGENIC PROCESSES MONITORING ALONG KARA SUB-LATITUDINAL TRANSECT, RUSSIA

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Climatic fluctuations in the Arctic over the past decade significantly affected the increase of cryogenic processes activity in area of continuous permafrost distribution. In particular, central parts of Yamal and Gydan Peninsulas are characterized by tabular ground ice distribution. Deepening of the active layer and exposure of tabular ground ice on some slopes leads to active thermal denudation: thawing of icy permafrost or pure ice and removal of the thawed material by gravitation. Gas-emission craters found in the North of West Siberia in 2014 also occur in an area of wide tabular ground ice distribution. Furthermore, permafrost areas have widespread polygonal relief formed by a system of frost fractures with the formation of ice wedges – another type of ground ice. Peatlands with ice wedges could degrade under the influence of combination of natural and technogenic factors due to ice wedges thaw, especially on the southern limits of continuous permafrost. Study methods of above listed processes are based on combining remote sensing (optical and radar sensors) and field methods of cryogenic processes monitoring. Remote sensing data is interpreted and verified in key sites along the Kara Sub-latitudinal Transect from the coast of the Yugorsky Peninsula through Yamal and Gydan peninsulas to western Taimyr. These activities are carried out to assess the impact of climatic changes and the associated dynamics of landscapes and thermal state of the permafrost on the activation of cryogenic processes in the Arctic. Observation of processes resulting from climate and landscape changes and thermal state of permafrost aims at the creation of a more general theory of cryogenic processes associated with ground ice thaw along the Kara Sub-latitudinal Transect, and the changes caused by these processes in the relief of the Arctic plains. This research was funded by RFBR grants ##18-05-60222, 18-45-890013, by RSF grant #16-17-10203 and ESA DUE GlobPermafrost.

ROCK GLACIERS OF THE BEARTOOTH AND NORTHERN ABSAROKA RANGES, MONTANA, USA

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Six-hundred and sixty rock glaciers in the northern Absaroka and Beartooth Ranges of south-central Montana were digitized and evaluated using geographic information systems technology and an array of topographic and environmental parameters. Beartooth rock glaciers are larger, occur at higher elevations, receive more precipitation, and are subject to colder temperatures than northern Absaroka rock glaciers. Elevation is strongly correlated with rock glacier activity. Comparative analysis of these adjacent mountain ranges indicates that Beartooth geomorphic landscapes are shifting from predominantly glacial to periglacial regimes, and that the northern Absarokas have largely completed this transition. Because glaciers are declining in response to climatic warming, rock glaciers could soon become the most important source of ice in the region.

TOWARDS BENCHMARK MECHANICAL MODELS FOR WARMING PERMAFROST ROCK SLOPES

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This paper discusses mechanical modelling strategies for instable permafrost bedrock. Modelling instable permafrost bedrock is a key requirement to anticipate magnitudes and frequency of rock slope failures in a changing climate but also to forecast the stability of high-alpine infrastructure throughout its lifetime.

High-alpine rock faces witness the past and present mechanical limit equilibrium. Rock segments where driving forces exceed resisting forces fall of the cliff often leaving a rock face behind which is just above the limit equilibrium. All significant changes in rock mechanical properties or significant changes in state of stress will evoke rock instability which often occurs with response times of years to 1000 years. Degrading permafrost will act to alter (i) rock mechanical properties such as compressive and tensile strength, fracture toughness and most likely rock friction, (ii) warming subcero conditions will weaken ice and rock-ice interfaces and (iii) increased cryo- and (iv) hydrostatic pressures are expected. Laboratory experiments provide estimations of the serious impact of thawing and warming rock and ice-mechanical properties (ad i and ii), which often lose 25-75% of their strength between -5°C and -0.5°C. Approaches to calculate cryostatic pressure (ad iii) have been published and are experimentally confirmed. However, the importance and dimension of extreme hydrostatic forces (ad iv) due to perched water above permafrost-affected rocks has been assumed but has not yet been quantitatively recorded.

This paper presents data and strategies how to obtain relevant (i) rock mechanical parameters (compressive and tensile strength and fracture toughness, lab), (ii) ice- and rock-ice interface mechanical parameters (lab), (iii) cryostatic forces in low-porosity alpine bedrock (lab and field) and (iv) hydrostatic forces in perched water-filled fractures above permafrost (field).

We demonstrate mechanical models that base on the conceptual assumption of the rock ice mechanical (Krautblatter et al. 2013) and rely on frozen/unfrozen parameter testing in the lab and field. Continuum mechanical models (no discontinuities) can be used to demonstrate permafrost rock wall destabilization on a valley scale over longer time scales, as exemplified by progressive fjord rock slope failure in the Lateglacial and Holocene. Discontinuum mechanical models including rock fracture patterns can display rock instability induced by permafrost degradation on a singular slope scale, as exemplified for recent a recent ice-supported 10.000 m³ preparing rock at the Zugspitze (D). Discontinuum mechanical models also have capabilities to link permafrost slope stability to structural loading induced by high-alpine infrastructure such as cable cars and mountains huts, as exemplified for the Kitzsteinhorn Cable Car and its anchoring in permafrost rocks (A).

Over longer time scales the polycyclicity of hydro- and cryostatic forcing as well as material fatigue play an important role. We also introduce a mechanical approach to quantify cryo-forcing related rock-fatigue. This paper shows benchmark approaches to develop mechanical models based on a rock-ice mechanical model for degrading permafrost rock slopes.

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RAPID DEGRADATION OF PERMAFROST AND GROUND ICE IN AN ICE-CORED MORAINE, SWISS ALPS

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Lateral moraines located in permafrost environments often preserve large amounts of both glacier and permafrost ice. To understand how such ice-cored moraines are evolving in the current context of rapid atmospheric warming, we have investigated the Col des Gentianes moraine since 2002. This moraine is located at 2900 m a.s.l. on the orographic left side of the Tortin glacier (Swiss Alps), where large ski facilities have been deployed.

Ground temperatures recorded in a 20 m deep borehole have increased from -0.54°C in 2002 to -0.2°C in 2018 at 20 m depth. Meanwhile, the active layer thickness has risen from -1.4 m to -4.5 m.

Ten electrical resistivity profiles (ERT) made of 24 or 48 electrodes with a 4 m spacing were carried out on the moraine in 2009. The data show strong heterogeneity of the ground, with large amounts of glacier ice in the inner flank of the moraine, permafrost ice present on the back of the moraine and several sectors free of ground ice. The repetition of the surveys on five ERT profiles in 2018 indicate strong degradation of ground ice. Where glacier ice is present, the decrease of resistivities can reach more than 100 %, while it is generally lower than 50 % for sectors with permafrost ice.

We performed also 14 terrestrial laser-scanning measurement campaigns between 2007 and 2018 on the inner flank of the moraine and two UAV flights in 2017 and 2018. Resulting comparison of the subsequent 3D models allowed to qualitatively and quantitatively analyze the morphological evolution of the moraine. The comparisons indicate a very high geomorphic activity of the moraine including large areas affected by downslope movements of blocks and 10 landslides with a volume between 20 and 1100 m^3. Data also indicates a very strong ice melt with a loss of ice thickness locally reaching 18 m on the adjacent debris-covered glacier.

These results indicate both a pronounced degradation of the permafrost conditions as well as ground ice melt and warming in the landform, which leads to an intense morphodynamics activity. They point out the rapid evolution of ice-cored moraines and push-moraines in high alpine environments and the potential risks for the ski facilities built on these landforms.

EFFECT OF FREEZE-THAW ON PORE STRUCTURE CHARACTERISTICS OF CEMENT-STABILIZED SOIL

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The method of artificial ground freezing is widely used in the underground construction; however, this method is limited by frost heave and thawing settlement. The freeze-thaw will change the soil pore structure characteristics, and further change the soil properties, such as permeability, strength, compressibility, etc. In this study, the unimproved soil and the cement stabilized soil were subjected to the freeze-thaw tests and the mercury intrusive porosimetry (MIP) tests to found out the effect of freeze-thaw on the pore structure characteristic. Except the pore size distribution obtained by the MIP tests, the pore fractal dimension was also used to describe the pore structure characteristic. The pore fractal dimension represents the roughness of the pore structure, which was calculated using the Menger sponger model and the thermodynamic model by means of the MIP tests. Afterwards, the fractal permeability model was used to calculate the permeability of samples, then the effect of freeze-thaw on permeability was also analyzed. The conclusions can be drawn as:

1. The pore size distribution curves of the cement stabilized soil after different freeze-thaw cycles show a significant bimodal characteristic; the first peak with a larger diameter is smooth and broad, while the second peak with a smaller diameter is sharp and narrow.

2. The first peak of the cement stabilized soil increases with the freeze-thaw cycles and then tend to be stable, while the second peak increases all the time; for the unimproved soil, the first peak increases with the freeze-thaw cycles and then decrease, while the second peak decreases first and then increases, which indicates that the two peaks changes differently with freeze-thaw; the freeze-thaw cycles have a significant influence on the pore zone the peak located in, including small pore zone (0.04~0.4μm), medium pore zone (0.4~4μm) and large pore zone (4~20μm), and have almost no effect on the micro pore zone (<0.04μm) and macro pore zone (>20μm); the influence of freeze-thaw cycles on the first peak is less than the second peak; moreover, the freeze-thaw cycles just alter the bimodal value and location.

3. Compared with unimproved soil, the cement stabilized soil has much more smaller pores and fewer larger pores, which leads to a reduction of permeability; the pore structure of the cement stabilized soil is more stable than the unimproved soil after the first freeze-thaw cycle.

4. The value of the Menger fractal dimensions and the thermodynamic fractal dimensions of samples after freeze-thaw are all in the range of 2~3, which indicates that the pore space have a fractal nature and the pore fractal dimension could be used to describe the pore characteristic of the soil sample; the Menger pore fractal dimension is larger than thermodynamic pore fractal dimension due to the Menger sponger structure cant not match well with the actual structure of the soil; the pore fractal dimension of cement stabilized soil is larger than the unimproved soil due to the hydration of the cement increases the complexity and irregularity of the pore structure of the cement stabilized soil, which leads to the decrease of permeability of cement stabilized soil; the pore size dimensions of the unimproved soil increase and then decrease with freeze-thaw cycles, and subsequently tend to be stable at about 10 freeze-thaw cycles; but for cement stabilized soil, the pore size dimension increases first with freeze-thaw cycles and then decreases all the time; The results show that the pore characteristic is affected by the freeze-thaw cycles obviously.

5. Compared with the unimproved soil, the permeability of the cement stabilized soil decreases by 2~3 orders of magnitude; after freeze–thaw, the permeability of the cement stabilized soil increased by 1~2 orders of magnitude; the variation trend of the permeability is same as that of the lager pore of samples; the larger pore size plays a key role in affecting the permeability.

COOLING PERFORMANCE OF MITIGATIVE MEASURES ON PERMAFROST UNDER THE CHINA-RUSSIA CRUDE OIL PIPELINE

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The permafrost under the China-Russia Crude Oil Pipeline (CRCOP) is degrading due to warm oil, construction disturbance, controlled burn each autumn and climate warming. The process of permafrost warming under the CRCOP and cooling performance of its mitigative measures were studied based on air and ground temperatures monitoring and ERT surveys at two study sites. Results show that: (1) mean annual air temperature (MAAT) in permafrost regions along the CRCOP increased at a rate of 0.21–0.40 °C/10a during the past decades; (2) the mean annual ground temperature (MAGT) of undisturbed permafrost increased at 0.33°C/10a from 2012 to 2018 and the natural permafrost table remained unchanged due to zero-curtain effect; (3) During 2012–2017, the MAGT and the artificial permafrost table, 2 m away from the pipeline centerline, increased at rates of 0.63 °C/10a and 1.0 m/a respectively. The thaw bulb develops around the oil pipe and exhibits a faster lateral expansion; (4) Thermosyphons and U-shaped air-ventilated pipes can cool the soils surrounding the oil pipe and effectively minimize thawing of underlying permafrost depending on its number, spacing and working duration.

Keywords

China-Russia Crude Oil Pipeline; Permafrost degradation; Climate change; Thermosyphon; U-shaped air-ventilated pipe.

LATE PLEISTOCENE PALEOSOLS AND PERMAFROST OF A PERIGLACIAL AREA OF THE EAST-EUROPEAN PLAIN

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The results of the morphology, stratigraphic position and genesis of the cryogenic phenomena of the end of middle and late Pleistocene in the periglacial zone of the East-European Plain are examined in this work. The features related to the continuous and discontinuous permafrost and deep seasonal freezing are described, and the relationships are shown between the paleocryogenic features and paleosols. Seven cryogenic horizons were identified: Dnepr, Seim, Mlodat', Selikhovdvor, Tuskar', Vladimir and Yaroslavl'. They have the stratigraphic importance, and reflect the coldest phases of the climatic rhythms of the middle and late Pleistocene within the studied region. Climatic conditions were reconstructed for these cryogenic periods. Polygonal-blocky relief was formed during Moscow late glacial. Later, after the ice-melting, it was subjected to erosion and preserved in the form of cryoerosional meso- and microrelief (periglacial gullies, dells, holes). The second half of the Mikulino interglacial combined with a climate cooling resulted in the conditions favoring the deep seasonal freezing of soils. The complicated history of cryogenic processes was found for the Valdai glaciation. The first permanent features of permafrost appeared since the first stade (MIS 5d). The second stade of the early Valdai was less cold (MIS 5b), but permafrost definitely existed during the final third stage of the early Valdai (MIS 4). In a course of the middle Valdai the conditions for soil and rock freezing appeared at least twice. The late Valdai period was the most cold. The investigation has shown more complex structure of early and middle Valdai intervals for the periglacial zone of East-European Plain, than in the commonly accepted schemes. It was indicated by the increased number of warm periods with paleosols formation, as well as by cold periods with the formation of cryogenic horizons.

The most detailed study of cryogenic deformation was carried out for the Bryansk paleosol (MIS 3) located in the Alexandrov quarry at the centre of the Russian Plain. This paleosol is strongly deformed, broken by pseudomorphs along ice wedges (the Vladimir cryogenic horizon of LGM). The typical appearance of the Bryansk geosol has the humus horizons A and AB concentrated in large cryogenic wedge structures. The carbonate horizon rises in the space between wedges. Our radiocarbon investigations showed that the Bryansk paleosol was on the surface until the maximum of glacial (LGM), about 24-22 ka BP or even before the start of degradation of last glaciations (LGT), about 17-15 ka BP. Approximately in the range of 17-15 ka BP this paleosol began to be buried under new loess within the studied area. Due to that the Bryansk paleosol was deformed by cryogenic processes in the most degree in comparison with other paleosols of the end of middle and late Pleistocene in the periglacial zone of the East-European Plain.

CATCHMENT SCALE ANALYSIS OF ROCK GLACIER VELOCITIES AND ELEVATION CHANGES

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The Laguna Catchment is situated in at the upper reaches of the Elqui river basin within the Semi-Arid Andes of Chile and contains an assortment of rock glaciers as well as small amounts of clean ice and debris-covered ice. The water released from these rock glaciers is an important hydrological contribution, especially during the dry season and in times of drought. The catchment also contains Tapado Glacier, approximately 1.2 km^2, which appears to be transitioning from a clean ice glacier into a debris-covered glacier into a rock glacier.

We derived velocity fields from feature tracking very-high resolution satellite imagery (GeoEye and Pléiades) between 2010/2012 and 2019. Both images were orthorectified using temporally coindent 1 m DEMs derived using Semi-Global Matching (SGM) of the tri-stereo imagery. In order to account for slight differences in illumination and different sensor parameters, feature tracking was performed on orientation images. Velocity vectors were filtered using a combination of the signal to noise ratio, as well as by examining local variations in magnitude and direction.

In addition to the DEMs generated from the tri-stereo satellite imagery, we also generates DEMs from aerial photography from 1956, 1978, and 2000 which covered Tapado Glacier as well as some of the surrounding rock glaciers. These datasets were also processed using SGM and were all co-registered to the 2019 DEM.

The velocity result show a range in the rates of deformation of rock glaciers in the catchment. While some rock glaciers are deforming at over 1 ma^{-1} in places, others are flowing at rates as low as 0.25 ma^{-1}. Interestingly, when the velocity fields are compared with the national inventory of rock glaciers for Chile, there are clear discrepancies, either rock glaciers that have either partly or fully excluded from the inventory, but in other locations the area of individual rock glaciers were overestimated.

Elevation change results show that Tapado Glacier has been thinning by as much as 1 ma^{-1} over it’s clean ice section, while the boundary between the debris-covered and rock-glacier sections becomes more apparent when elevation changes are examined. Losses are also higher within the vicinity of supraglacial ponds and ice cliffs. While some rock glaciers show noticeable patterns of thinning, most show a slight thickening at the terminus while parts upglacier showed only minor changes in elevation.

MODELLING WATER-RELATED PROCESSES IN ROCK WALL PERMAFROST

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Rock wall permafrost has been increasingly regarded since the early 2000s in reason of the growing frequency and magnitude of bedrock failures from mountain permafrost areas. One of the main current challenges to better assess its degradation and the failure mechanisms is the quantification of hydric processes, *i.e.* water infiltration and circulation in the fractures. Indeed, since the pioneer studies, the thermal and mechanical behavior of saturated frozen rock media has been deeply investigated *(e.g.* Noetzli *et al*., 2007; Krautblatter *et al*., 2013; Mamot *et al*., 2018), allowing a better understanding of the mid- to long-term (decadal to millennial) permafrost evolution and rupture of ice-filled joints. However, thermal and mechanical processes acting on the short term (seasonal to pluri-annual) remain poorly understood due to the lack of consideration for hydric processes acting into non-saturated bedrock fractures. However, these processes have been evidenced by the presence of water alongside ice bodies in several rock fall scars worldwide.

In this communication, we will present a first attempt to model hydric processes in high-alpine bedrock permafrost. This entails designing a new modelling approach accounting for heterogeneous (fractures) and non-saturated areas in the rock media. We use the Finite Element simulation system Feflow (DHI-WASY) to model variably saturated flow and advective-conductive heat transports combined with phase change processes. We simulate heat transports in a 2D geometry (vertical cross-section) reflecting the Aiguille du Midi settings (3842 m a.s.l., Mont Blanc massif, European Alps), where heat conduction models in similar geometry have been already successfully applied to reconstruct and predict permafrost evolution since the Little Ice Age to the end of the 21st century (Magnin et al., 2017). The water circulation is enabled in the upper part of the model geometry through a partially saturated domain, whereas the lower part is saturated. Water circulation in unfrozen zones is allowed by two outlets on each side of the cross section, one of them being under the Géant glacier (accumulation zone of the Mer de Glace), and by active layer thawing when the hydraulic conductivity is sufficient. Finally, the fractures intersection is also necessary to allow water circulation considering that massive rocks have low permeability also at positive temperature. We test two numerical approaches to design this fracture network and implement the related heat transports, applying the Richards equation and the Hagen-Poiseuille laws.

These novel modelling approaches bear strong potential to address thermal and mechanical effects of water infiltration (from snow melting and rain) and circulation in the frozen bedrock, and to draw hypotheses on the periglacial processes and paraglacial slope adjustment affecting steep bedrock slopes.

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WHAT CAN WE LEARN FROM ICE COLLECTED IN HIGH MOUNTAIN ROCKFALL SCARS? THREE EXAMPLES FROM THE MONT BLANC MASSIF (FRANCE)

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The study of the ice (cryostructures, cryostratigraphy, types and age) that partly fills the fractures in rockwall permafrost is necessary to better understand the increasing frequency/volume of rockfalls in the high alpine rockwalls.

Typically inaccessible, this ice is visible only when a rockfall occurs, exposing previously hidden ice. Over the past two years in the Mont Blanc massif, the two largest rockfalls of the decade and a smaller one allowed to start the documentation of the rockwall permafrost ice.

The first one (44,387 m^3) occurred at the Tournier spur in the north face of the Aiguille du Midi (3842 m a.s.l.), above the Pélerins glacier, on Sept. 29, 2017. A collapse of about 10,000 m^3 had already occurred in this sector in 2007. Following the 2017 event, massive ice was observed in the upper part of the scar. Ice observations and sampling were carried out with a sling-helped drop by a helicopter in the upper part of the scar. The sampled area formed a 15-m-high and 1-m-thick overhanging ice wall characterized by a horizontal bedding of very varied layers of ice in terms of type (translucent, white, bulky, with or without rock debris) and thickness. First results on dating indicate an ice age (micro-^{14}C) of several thousand years.

The second collapse (42,433 m^3) occurred in the steep SE face of the Trident du Tacul (3639 m a.s.l.) in the Géant glacier basin on Sept. 26, 2018. Massive ice was here also largely present in the upper part of the scar after the collapse. Sampling was done by abseiling down the face to a 15-m-large and high ice wall. From a cryostructure point of view, dozens of pluri-decimetric layers of white ice interspersed with dark beds producing very varied schemes with inclined parallel layers in some places, and developed folds in others.

A last rockfall of about 7000 m^3 occurred on Dec. 4, 2018 at the foot of the east face of the Tour Ronde (3793 m a.s.l.), in the Géant glacier basin too. A 45-m-high pillar collapsed along a vertical rock plan that remained for several weeks largely covered with massive ice. Sampling took place at the top and bottom of the scar, where a 6-m-high, 4-m-wide and 30-cm-thick ice wall was characterized by thick bands of translucent to white ice, interspersed with three thin layers of brown-yellow colored ice.

These three cases show the wide variety of ice in permafrost rockwalls, possibly with very different origins and formation processes that we intend to elucidate through ice dating, cryostructure and cryostratigraphy analyses.

DIFFERENTIAL FROST HEAVE ON INCIPIENT SORTED PATTERNS IN THE JAPANESE ALPS: A MULTI-METHOD MONITORING

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Although sorted patterned ground has been the best-known periglacial feature, its origin is still not well documented in the field. This study presents the results of 5-year monitoring of differential frost heaving and associated hydro-thermal factors on an incipient sorted feature produced on a mountain-top bare ground in the Japanese Alps. The monitoring programme include frost heaving on coarse-grained (stony) and fine-grained (granular) surfaces with extensometers and a time-lapse camera, air and soil temperatures, precipitation and soil moisture recorded at subdaily intervals (cf. Matsuoka, 2014). The time-lapse images are also used to estimate snow depth.

The sorted ground experienced frequent diurnal frost heave activity supported by shallow and short-lived snow cover, while seasonal heave was minimum due to thin fine soil confined within the top 10 cm. Detectable heave (>0.1 mm) occurred 35-67 times on the granular surface and 30-64 times on the stony surface. Interannual variability of frost heave activity mainly originated from the duration of snow cover (2−5 months). The heave amounts were generally a few mm and rarely in excess of 6 mm. The granular surface showed slightly larger cumulative heave amount (66-129 mm/yr) than the stony surface (61-117 mm/yr). The slight differences in both the frequency and cumulative heave between the two surfaces mainly resulted from small-scale heaving due to superficial needle-ice activity which was lacking on the stony surface. The differential heave mainly resulting from needle-ice activity is considered a major driver of superficial sorting, which coincides with laboratory simulations (cf. Yamagishi and Matsuoka, 2015).

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GEOMORPHOMETRY OF "CRYOPLANATED UPLANDS": AN EXPLORATORY ANALYSIS IN UNGLACIATED BERINGIA

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Cryoplanation terraces (CTs) are large landforms characterized by alternating series of treads, risers, and summit flats, giving the impression of giant staircases ascending ridgecrests and hillsides. CTs are well developed and ubiquitous in unglaciated Beringia. Although disagreement exists in the literature about the origin of CTs, the dominant hypothesis is that they form through the actions of localized weathering and transportation processes associated with late-lying snowcover. The concept of a distinct periglacial landscape has often been referred to in periglacial studies. This project explores how geomorphometry can be used to formulate an objective definition of an upland periglacial landscape, in which CTs are a dominant landform. Here, we contribute to periglacial geomorphometry through (1) semi-automated identification of CTs; and (2) use of hypsometric analysis to discern between periglacial, glacial, and warm-desert environments. Our CTAR ("Cryoplanation Terrace Automated Recognition") methodology identified 90% or more of previously delimited CTs in several study areas in central and western Alaska. Hypsometric curves of cryoplanated uplands in Alaska's Yukon-Tanana Upland physiographic province, part of easternmost Beringia, indicate that this region displays a distinctively periglacial signature. We conclude that an objectively defined "characteristic periglacial (geomorphic) landscape" does indeed exist in the uplands of unglaciated Beringia.

LONG-TERM EROSION RATES BY NIVATION, CATHEDRAL MASSIF, NORTHWESTERN BRITISH COLUMBIA

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Recent literature has brought increasing recognition about the importance of running water in periglacial environments. Sorted stripes are prominent upland features on “Frost Ridge” atop the Cathedral Massif in northwestern British Columbia. Nivation hollows (incipient cryoplanation terraces), are present near the summit of Frost Ridge. Marginal drainage channels are preserved on the north-facing flank at lower elevations and on the opposite, south-facing valley wall. This paper examines features on Frost Ridge to estimate long-term denudation attributable to nivation processes active since the Last Glacial Maximum. This work also evaluates the efficacy of coarse stripes to operate as channels or pipes for sediment-laden rivulets, providing a mechanism for removal of eroded sediment. Frost Ridge presents a highly unusual opportunity for addressing long-term nivation erosion rates, by virtue of its east-west orientation and deglaciation history. Minimized solar radiation on the steep north-facing wall (Frost Ridge) allowed snowbanks accumulated in marginal drainage scars to persist and nivation processes to erode the slope. Elsewhere on Frost Ridge, complete meltout of what until recently were perennial snowbanks has revealed the existence of well-developed sorted stripes, indicating that these features form rapidly after snowmelt, or develop even beneath snowpatches. Using an unmanned aerial vehicle (UAV), a high-resolution survey was conducted, and the volumes of unmodified marginal drainage channels and the much larger incipient cryoplanation terraces were compared.

SORTED PATTERNED GROUND IN KARST CAVES: DEVELOPMENT AND POTENTIAL FOR PERMAFROST RESEARCH

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One of the most distinctive periglacial landscape landforms is patterned ground. Although usually found in mountains or in polar regions, it has also been reported from several karst caves in Slovenian Dinaric Mountains and Alps, Swiss Jura Mountains and West Carpathian Mountains in Slovakia but never studied in detail.

Ledenica pod Hrušico ice cave lies on a karst plateau at an elevation of about 800 m. It consists of a spacious 20 m deep shaft, debris cone and two small passages. One of the passages contains fine sediments, which are mixed with limestone debris. Sorted stripes are present on an inclined slope of this passage. Twelve 20-50 cm wide stripes of coarse limestone debris developed on fine cave sediment. The grain size of the fine sediment is predominantly silty (80 %), which makes it very susceptible to frost heaving. A geoelectrical survey and drilling revealed one metre sediment thickness. Several freeze-thaw cycles occur at the sediment ground surface in winter due to cave temperature fluctuations. Cave air temperature measurements show that surface air enters the cave only when its temperature drops below the cave air temperature, which results in preferentially cold and oscillating winter temperatures and the formation of a cool air pool in the summer.

Karst caves can contain significant amounts of silty sediments that accumulated during flood events when the cave was situated in the floodwater zone or can originate from fine rock weathering. Frost shattering of parent bedrock is a potential source for coarse debris. The cold climatic conditions that result from cave morphology sustain low ground temperatures in summer and cause freeze-thaw cycles in winter, which result in frost heaving that causes sediment sorting.

Barka Cave lies close to Snežnik Mountain at an elevation of 1100 m. It is a 20 m deep and 50 long oval collapse doline with locally overhanging walls. Sorted patterned ground developed on vegetation free floor under these walls. Especially characteristic are sorted circles with diameters ranging between 40 to 70 cm. Frost heave and needle ice length up to 10 cm were observed during freezing conditions. A wide grain size range of sediment (gravel and sand) present on sorted circles enables tracking of ground movements with surface from motion technique. Absence of snow and vegetation makes karst caves unique places for monitoring of ground movements caused by ground freezing. Sorted patterned ground in karst caves can thus help to reveal cryoturbation mechanisms that are responsible for large organic carbon storage in soils underlain by permafrost..

MODELLING PEATLAND AND PERMAFROST DYNAMICS ACROSS PAN-ARCTIC

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The majority of northern peatlands were initiated during the Holocene around 8–12 thousand years ago[1]. Owing to their mass imbalance, they have sequestered huge amounts of carbon in the terrestrial ecosystem[2]. Distribution of soil organic carbon is widespread and uneven across the pan-Arctic[3]. Recent syntheses have filled some existing gaps[2, 4]; however, the extent and remoteness of many locations pose challenges to develop a reliable regional carbon accumulation estimate. In this work, we combined three published peat basal age datasets[1, 5, 6] with some independent measurements[2, 4, 7] to form a most up-to-date peat basal age surface for the pan-Arctic region which we then used to constrain the model in order to reduce the current and future uncertainties related to the northern peatlands carbon cycle. We employed an individual– and patch– based dynamic global vegetation model (LPJ–GUESS)[7, 8] with dynamic peatland and permafrost functionality to quantify the long-term carbon accumulation rates and to assess the effects of historical and projected climate change on peatland carbon balance. We divided our analysis into two parts– the carbon accumulation changes detected within observed peatland boundary[9] and at pan-Arctic scale under two contrasting scenarios (RCP8.5 and RCP 2.6). Our results are largely consistent with published long-term carbon accumulation rates. We found that peatlands would continue to act as carbon sink under both scenarios but their sink capacity would substantially reduce under RCP8.5 scenario after 2050. The 286 sites within the observed boundary showed similar behaviour as pan-Arctic scale but their carbon sink capacity would be further strengthened under RCP 2.6. Additionally, areas where peat production was initially hampered by permafrost and low productivity would accumulate more carbon because of the initial warming, moisture rich environment due to permafrost thaw, higher precipitation and elevated CO_2 levels. On the other hand, areas which experience reduced precipitation rates and without permafrost will lose more carbon in the near future, particularly, peatlands located in the European region and between 45-55°N latitude.

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SCOTT BASE REDEVELOPMENT ENVIRONMENTAL MONITORING PROGRAMME

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Scott Base, New Zealand's permanent station in Antarctica, was officially opened on January 20, 1957. It was originally designed for a short life – as the Ross Island base for the British Trans-Antarctic Expedition and New Zealand's contribution to the International Geophysical Year. Situated on a low volcanic headland called Pram Point at the Southern End of Ross Island, Scott Base is 3650 kms south of Queenstown, 1350 kms from the South Pole and 3kms away from McMurdo station

The Scott Base Redevelopment (SBR) is the largest project ever undertaken by New Zealand in Antarctica. It is a requirement of the Environmental Protocol to the Antarctic Treaty and New Zealand's Antarctica (Environmental Protection) Act (1994) that an environmental impact assessment be completed prior to any activity taking place in Antarctica. A Comprehensive Environmental Evaluation (CEE) of the project is being completed in order to support decision-making with an assessment of predicted environmental impacts linked with the redevelopment. A comprehensive monitoring programme was set up to verify the accuracy of the environmental impact assessment presented in the CEE and to detect unforeseen impacts or impacts that are more significant than expected.

Over the summers of 2018/19 and 2019/20 a multidisciplinary team will undertake two field seasons to establish an environmental baseline against which future natural changes and changes attributable to SBR can be measured. During the 2018/19 summer the focus was on the terrestrial environment with 25 monitoring plots established in the wider Scott Base operational area. These sites were selected by stratified sampling, drawing on a suite of variables describing the variations in environmental conditions. At each of the 25 plots soil samples were taken for chemical, spectroradiometry, and microbial DNA analysis in addition to surveys of invertebrate and vegetation abundance. Additionally, 3 cameras were installed to count seals, along with 12 dust collectors to investigate baseline dust transport around the base vicinity. A high-resolution multispectral imagery drone survey was also carried out to capture vegetation and surface disturbance. The baseline work will continue in 2019/20 summer where a marine survey, aerial and ground-based LiDAR surveys are planned in addition to a resurvey of the plots.

The draft CEE and findings from the field seasons will be presented and discussed at the Committee for Environmental Protection to the Antarctic Treaty meeting in 2020. The SBR project and the CEE process are opportunities for New Zealand to deliver on its purpose to support world-leading science and environmental protection and to demonstrate environmental best practice and leadership in the Antarctic Treaty community.

STANDARDIZED DATA MANAGEMENT AND STORAGE FOR MOUNTAIN PERMAFROST DATA

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The 10th of the GCOS climate monitoring principle states that data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems. The Swiss Permafrost Monitoring Network PERMOS systematically documents the state of mountain permafrost in the Swiss Alps and its and changes by delivering reliable, robust and comparable measurements over decades. This very challenging task requires respective standardization of the instrumentation and maintenance of the stations as well as a well-defined data flow from the logger through data processing and to archiving, visualisation, and analysis.

PERMOS started as an unconsolidated network of sites taken from research, which progressively grew in size and diversified observation elements. Over the past two decades, the network has continuously been converted to the needs and structure of an operational long-term monitoring network by developing automatized and standardized procedures and processing as well as a data management system for the systematic storage, access and visualisation of data and related products.

The relational PERMOS Data Base includes data from three observation elements from most of the Swiss permafrost research sites with time series up to more than 30 years. For each observation element, a unique database structure was developed to calculate and store not only the final data products – such as aggregations or derived parameters like active layer thickness or creep velocities – but also the raw data and the relevant meta-information of the sites, methods and/or individual surveys. The centralised database enables a timely access to the data and is directly linked to online data browsing, which facilitate data control, quality checks as well as the dissemination of data to the scientific community or any other user of the data.

In this contribution, we present the structure and organisation of the operational PERMOS data management, including the database structure, the data flows as well as data browsers, reports and DOIs.

SIMULATION OF PERMAFROST DISTRIBUTION IN MOUNTAIN QILIAN

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Mountain Qilian is located in the northeast edge of Qinghai-Tibet plateau, across Gansu and Qinghai provinces. It is the birthplace of Heihe river, Shule river, Datong river and other river systems. The change of permafrost in the source region plays an important role in regulating the runoff process and water distribution. At present, the research on the distribution of permafrost in Qilian Mountains is mainly concentrated in the sub-collection of the research on the distribution of permafrost on the Qinghai-Tibet plateau. The source area of the Qilian Mountain where geographic coordinates between about 93 ° 30 'E ~ 39 ° 50' 103 ° 03 'E, N ~ 35 ° 50' N elevation above 3 000m was chosen as the study area. Based on the second comprehensive scientific investigation of the Qinghai-Tibet plateau, road surveying and drilling points, as well as the elevation data of permafrost lower limit height obtained from previous literatures, this paper regress to obtain the formula of permafrost lower limit height elevation. With the help of ArcGis platform and DEM data, the permafrost distribution in the Qilian Mountain with a resolution of 100 meters was simulated. In this paper, the lowest elevation point of permafrost is defined as the initial elevation point of island permafrost, the lowest elevation point of permafrost continuously distributed is defined as the initial elevation point of permafrost generally developed, and the region between island development and general development is defined as the transition zone. The conclusions are drawn as follows:

1. The lower limit height of permafrost distribution in Qilian Mountain has a very good zonal rule, which shows that the lower limit height decreases with the increase of latitude and decreases with the increase of longitude
2. When the latitude increases by 1 degree, the lower limit height of generally developed permafrost decreases by about 113m and the longitude increases by 1 degree, and the lower limit height of generally developed permafrost decreases by about 78m.
3. The difference between the elevation value of the lower limit height of the island developed permafrost and that of the generally developed permafrost is the smallest in the northwest of Qilian Mountain, about 145m, and the largest in the southeast of Qilian Mountain, about 162m.
4. The permafrost in the Qilian Mountain shows a distribution pattern with Hala lake as the center and spreading around. The permafrost area of Qilian Mountain is about 80,300 km^2, and the transition area from the permafrost generally developed area to the seasonal permafrost area is about 16,400 km^2.

ROCK GLACIERS AS CLIMATE RESILIENT COLD-WATER RESERVOIRS IN ALPINE BASINS WITHIN THE COLORADO ROCKY MOUNTAINS

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Many countries with alpine environments have well-established methods for monitoring permafrost and periglacial landforms, however, the contiguous US has relatively few. Although the Rocky Mountains contain less permafrost than the European Alps or the Himalayas, recent studies have identified rock glaciers as an often-overlooked component of the water budget in alpine basins. In Colorado specifically, rock glaciers vastly outnumber traditional ice glaciers (3877:20) and have a larger spatial extent, suggesting that the former contain a significantly larger volume of ice than glaciers themselves. In certain basins, the reduced climate sensitivity of rock glaciers and their sustained cold-water input to mountain streams might help mitigate the predicted habitat loss of endemic mountain species such as cutthroat trout. Located in the Never Summer Mountain Range of northern Colorado, the Lake Agnes rock glacier is 700 m long, active (~1 m/yr), and situated between 3260 and 3520 m asl. This study uses bottom temperature of snow, ground penetrating radar, refraction seismics, and electrical resistivity tomography collected in 2019 to identify the internal structure of the rock glacier, including total thickness, active layer depth, and internal ice distribution. Although the lower portion of the rock glacier (~3260 – 3380 m asl) has little to no horizontal displacement, inactive rock glaciers can still have a cooling effect on groundwater, producing a potential cold-water refuge for aquatic species in a warming climate.

IDENTIFICATION AND MONITORING OF ROCK GLACIER UNITS (31°-33°S)

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“Monos de Agua” catchment is located at 33°S; 70°16W in the Juncal sub-basin (Central Andes, Chile). In the last 60 years, it lost a 27±3% of glacierized surface. A ratio of covered /uncovered glaciers in the sub-basin is of 24%. Several rock glacier geoforms were mapped and represent 8.18km2 within Juncal sub-basin.

Nowadays, above 3600m ASL, “Monos de Agua” catchment presents several rock glacier deposits and surface subsidence throughout the valley as well as ice-cored moraines in the less sun-exposed slopes. Further, with a mean annual air temperature of -2 ± 2°C and having >100 freeze-thaw cycles per year, the upper-catchment is assumed as being affected by permafrost occurrence.

At the “Monos de Agua” catchment, a sub-metric DEM was obtained (Fig. 1a) by aerial photography which resembles the same geoform as in 1955 (Hycon aerial image, 1m resolution), without noticeable changes in motion or edges. Results point-out that a critical frozen volume may be present in mountain catchments at determined circumstances in the form of rock glacier flows which coalesce with moraines and solifluction lobes. Such sources may configure a part of the basin’s input yet not in the current and projected water budgets.

In the Argentine Central Andes, the active layer of “Candidato” rock glacier (Fig. 1b) is monitored since March 2018. SMT100 soil temperature and volumetric water content, as well as iButtons DS1922L temperature sensors, where installed at 0, 25, 50 and 70 cm depth. Soil density, porosity, moisture, bulk thermal conductivity, thermal diffusivity, heat capacity and latent heat where calculated from in situ soil samples, in three trenches above 4000 m ASL.

Results indicate that moisture saturation in the active layer reached up to 40% at 50 cm depth, after the delayed winter snow precipitation during year 2018 and, during the first months of the warm season (November-December). Since January to July, the uppermost soil levels of the active layer remain almost dry (5-15% moisture) (Figure 1c).

First findings support updated water-resource baselines for future legislations and water-planning in water scarce region of developing countries.

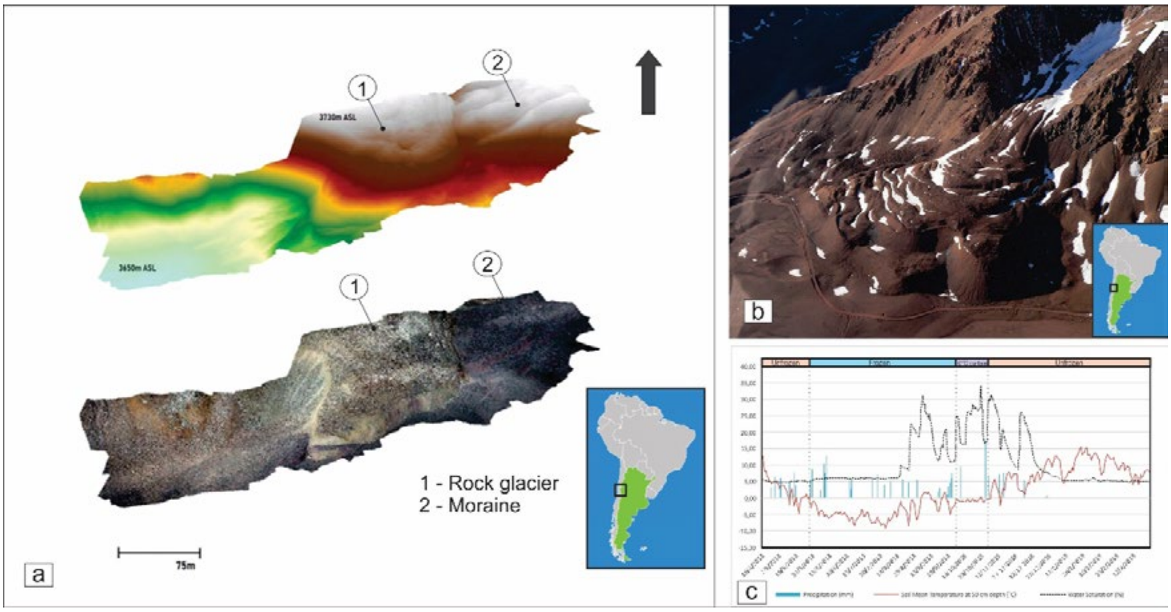

Figure 1: a) Analyzed geoforms located at 32°59'44.71"S; 70° 2'53.70"W within “Monos de Agua” catchment, Aconcagua Basin, Chile. b) Monitored “Candidato” rock glacier located at 31°53’S and 70°11’W, Central Andes, Argentina. c) Soil temperature and volumetric water content during 2018 at 50 cm depth in 4030 m ASL.

Keywords

Central Andes, Rock glaciers, Deglacierization, Mountain permafrost.

THREE-DIMENSIONAL TEMPERATURE VARIATIONS MEASURED WITH FIBRE-OPTIC SENSORS AND BOREHOLES AT A BOREAL PERMAFROST SITE IN INTERIOR ALASKA

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A DTS (distributed temperature sensing) system using fibre-optic cable as a sensor, based on the Raman-scattering optical time domain reflectometry, was deployed to monitor a research site (Poker Flat Research Range) in the boreal forest of interior Alaska. Surface temperatures range between in winter and in summer at this site. A fibre-optic cable sensor system (multi-mode, GI50/125, dual core; 3.4 mm) monitored ground surface temperatures across the landscape at high resolution (0.5m intervals at every 30 min). The total cable ran 2.7 km with about 2.0 km monitoring a horizontal surface path on a flat area (loop1), and another 5.5 km that covers four 30-m quadrats and hill slope (loop2). Sections of the cable sensor were deployed in vertical coil configurations (1.2m high) to measure temperature profiles from the ground up at 5mm intervals.

Measurements were made continuously over two separated periods; a 2-year period from October 2012 to October 2014 (loop1), and a 32-month period from July 2016 and February 2019 (loop1 and loop2). Vegetation at the site consists primarily of black spruce underlain by permafrost, but shows large heterogeneity. We classified land cover types within the study area into six descriptive categories: relict thermokarst lake (including bare ground), open moss, shrub (both tall and dwarf), deciduous-evergreen mixed forest, sparse conifer forest, and dense conifer forest. The measured horizontal temperature data exhibited spatial and temporal changes within the diurnal and seasonal variations, and showed different characteristic behaviours for specific land cover type. Differences in snow pack evolution and insulation effects also co-varied with the land cover types. The hill-slope measurements illustrated the development of the atmospheric boundary layer. The apparatus used for monitoring the vertical temperature profiles generated high-resolution (ca. 5 mm) data for air column, snow cover, and ground surface, to deduce the distribution and seasonal changes in thermal diffusivity of the snow pack and the upper soil layer.

This research also identified several technical challenges in deploying and maintaining a DTS system under subarctic environments.

ACTIVE LAYER DYNAMICS UNDER TWO DISTINCT VEGETATION COVERS ALONG THE CHINA–RUSSIA CRUDE OIL PIPELINE

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The diversity of ecosystems along the China-Russia Crude Oil Pipeline (CRCOP), successional changes during construction and operation of the pipeline, and climate warming, require significant knowledge on active-layer thickness dynamics and permafrost distribution. To address this complexity, we established a system of permafrost observatories that included more boreholes drilled along the pipeline in order to investigate the effects and interaction between pipeline and permafrost. Only two of the established boreholes will be analysed in this study. This work analyses the active layer thermal regime of two adjacent boreholes (T1 and T2) located under the same study area but with different changes in surface conditions. Both boreholes are established in one of the four cross sections, perpendicular to the CROP-1 line, in MDS391 site, an area with sporadic permafrost. T1 borehole is located on the right-of-way (on-ROW) 2 m away from the center of the oil pipeline, while T2 is located in a natural and undisturbed site, approximately 17 m off-ROW. The monitoring system consists of soil temperatures probes connected to a data logger that recorded data at every 2 hours between October 2017 and September 2018. We calculated the number of isothermal days (ID), freezing days (FD), thawing days (TD), freezing degree days (FDD), thawing degree days (TDD), and number of freeze-thaw days (FTD). The two boreholes show significant differences of the mean annual ground surface temperature (MAGST) ranging from 3.5°C (T1) to 0°C (T2). Moreover, the mean annual ground temperature at 0.5-8 m depths recorded higher positive values varying between 0.3°C and 3.4°C for T1, comparing with lower values from -0.5°C to 0°C recorded on T2. The thermal regime of the 9 m depth (T1) indicates that the permafrost is very close, due to the fact that events with maximum temperatures higher than 0°C are rare along the entire monitoring period. The soil thermal regime at natural and undisturbed site T2 showed less variability than in T1. Here, the maximum daily amplitudes of soil temperature reached 0.7°C (0 m) and 0°C (2.5-20 m). At T2 site, the near surface sensor froze on 08 November 2017, and the frost expanded in 13 days to 1.5 m depth. Deeper layers (2-20 m depth) remained frozen during the entire monitoring period. Active layer thickness was approximately 10 m for T1 and around 2 m for T2 site. Long-term monitoring of the ground temperature will improve the understanding of the effects of CRCOP on permafrost degradation.

Keywords

Soil thermal regime, Active layer, China-Russia Crude Oil Pipeline, permafrost.

SURFACE WATER BODIES MAPPING USING DIFFERENT REMOTE SENSING METHODS IN A SMALL PERMAFROST LANDSCAPE

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One of the most sensitive areas to climate change is the Qinghai-Tibetan Plateau (QTP), with areal extent of lakes at about 40,000 km². However, only the lakes larger than 1 km² were generally mapped on regional studies on the QTP, while ponds (water bodies with surface areas smaller than 0.01 km²) have been omitted. Recently, ponds have attracted wide attention, especially because they have been acknowledged as hotspots in biogeochemistry, ecology, hydrology and geocryology. Lately, many remote sensing methods were developed for mapping surface water bodies, which reported close accuracy ranging from 89% to 95%. However, an extensive application of a specific method at different sites remains a challenge. Ponds and lakes are abundant in the Headwater Area of the Yellow River (HAYR, above Huang'heyan Hydrological Station near Madoi, Qinghai Province, Southwest China), as permafrost warming, thawing and subsidence are held responsible for increased surface extent of water bodies. Thereby, this study aims at assessing the accuracy of different classification techniques of water bodies on a local scale at Chalaping in south-central HAYR (150 km²). Water body inventory was conducted on a Sentinel-2 satellite image with 10 m spatial resolution from 23 November 2015. Based on correlation matrix, several wide-used mapping methods were compared as: normalized difference water index (NDWI), supervised and unsupervised classifiers (K-means, Maximum Likelihood Classification - MLC), and machine learning algorithms (Random Forest). Supervised classifications show the highest overall accuracies (>95%) but revealed large misclassification with overestimations of water bodies >10 km². The method of NDWI shows the lowest misclassification, with a high accuracy (90%), and can identify water bodies also in shadow areas. Unsupervised classification (K-means) reports the second less misclassification and is useful when the purpose is to identify more classes (e.g. grass, ice, etc.). Based on NDWI in the test area of 150 km², 528 water bodies were identified with a total water surface of 3.82 km². Ponds smaller as 400 m² (4 Sentinel-2 pixels) were correctly detected. Ponds are dominating up to 89% of individual water bodies and contribute with 32% to the total water surface. Using a higher spatial resolution, even smaller ponds can be inventoried. Results from this study will provide baseline information for the sustainable management of water resources and wetland protection in the HAYR permafrost environment, the core of the Sanjiangyuan (Three-river source) National Park of China.

Keywords

Qinghai-Tibetan Plateau, classification, remote sensing, permafrost, lakes and ponds.

PERMAFROST MONTHLY ALERTS (PMA) PROGRAM

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The U.S. Permafrost Association (USPA) and the American Geosciences Institute (AGI) have jointly provided a monthly catalog of the world-wide, permafrost literature since 2012. The Permafrost Monthly Alert (PMA) program produces professionally reviewed reference material on a regular monthly schedule and results are made available in multiple locations. The monthly-updates portion of the PMA program are available through the USPA web site (http://uspermafrost.org). The current collection includes over 85 monthly updates with a total of 6,000 citations. The references have abstracts and are organized into four major categories: journals, conferences, theses and reports. The monthly accessions are uploaded by AGI to the Bibliography of Cold Regions Science and Technology (COLD), a searchable database that includes more than 29,000 permafrost references.

Bibliographic references on the USPA website are easily searchable with internet search engines. An example using “Antarctic” and “permafrost” gives more than a hundred references. The number of different search engines that index the USPA website exceeded 20 for each of the last four years. For 2017, the total search engine hits exceeded 90,000. Google search routines exceeded 6,000 hits each year since 2012. Content matters as much as reference age. As an example, the March 2012 PMA monthly reference listing is in the top four viewed monthly pages over a five-year period. Average annual usage of the service exceeds 10,000 inquiries (views by readers) in the last three years, with over 55,000 views since 2012.

In addition to serving academic communities, the PMA is a valuable resource to industry, private institutions, engineering firms, government agencies and K-12 education programs. By providing current and historical sources of information, the PMA program is a readily available mechanism for conveying scientific information to decision-makers and the public. Future improvements to the PMA program will include efforts to increase engineering topics and reference sources, evaluations for using various search engines and improving applications for K-12 education programs.

CHARACTERISTICS OF PERMAFROST CHANGE UNDER NATURAL FIELD ALONG THE QINGHAI-TIBET RAILWAY DURING THE YEAR OF 2006-2015

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The Qinghai–Tibet Railway (QTR), about 1952 km long in total, is the longest railway with highest altitude in permafrost regions on the Qinghai–Tibet Plateau (QTP), and it crosses approximately 550 km of continuous permafrost regions. Among these regions, the permafrost with high temperature [mean annual ground temperature (MAGT)>−1.0 °C] and high ice content (volumetric ground ice content greater than 20%) is widespread. Permafrost changes under natural fields along the Qinghai-Tibet Railway were investigated based on the ground temperature monitored during the year of 2006 to 2015. Thirty observation sites, with boreholes depth of 18 m in natural ground, were used to monitor ground temperature along the railway. The ground temperatures were acquired by the thermistors installed at intervals of 0.1, 0.2, 0.4, 0.8, 1.2, 1.6 and 2.0 m from the surface to 2 m deep, and at intervals of 0.5 m from 2 m to 18 m in depth, respectively. These thermistors, with a precision of ±0.05 °C, were made by the State Key Laboratory of Frozen Soil Engineering (SKLFSE) in China. The ground temperatures were automatically collected daily by the DT500 series Datalog made in Australia, and were manually downloaded by well-trained technicians every 3 months. Under the effect of climate warming, the results showed that the permafrost along the railway degraded gradually in total. Among these sites, the mean permafrost table is 3.54 m, with a range of 0.88 m to 9.14 m. Among the sites with declining permafrost table, the mean declining of permafrost table was 0.51 m, with a range of 0.05m to 2.22 m; and the mean declining rate of permafrost table was 0.07 m/a, with a range of 0.01 m/a to 0.25 m/a. The declining amplitude and the declining rate of permafrost table in high temperature regions were 0.47 m and 0.06 m/a greater than those in low temperature regions, respectively. In general, the ground temperatures at permafrost table and 15 m depth presented rising tendency. The mean rising of ground temperature at permafrost table was 0.16 °C, with a range of 0.01 °C to 0.60 °C; and the mean rising rate of ground temperature at permafrost table was 0.018 °C/a, with a range of 0.001 °C/a to 0.067 °C/a. The rising amplitude and the rising rate of ground temperature at permafrost table in low temperature regions were 0.12 °C and 0.014 °C/a greater than those in high temperature regions, respectively. The mean rising of ground temperature at 15 m depth was 0.10 °C, with a range of 0.01°C to 0.48 °C; and the mean rising rate of ground temperature at 15 m depth was 0.011 °C/a, with a range of 0.002 °C/a to 0.054 °C/a. The rising amplitude and the rising rate of ground temperature at 15m depth in low temperature regions were 0.11 °C and 0.012 °C/a greater than those in high temperature regions, respectively. The rising of permafrost table and the decreasing of ground temperature were observed under several sites, which may be caused by the effect of local factor such as paludification on the ground surface.

Key words

Qinghai-Tibet Plateau; Permafrost; Permafrost table; Ground temperature; Permafrost change.

AGRICULTURAL SUITABILITY OF THE ICE AGE PERIGLACIAL AND POSTGLACIAL ZONES IN THE RUSSIAN NORTH

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The agriculture of the Russian North (the forest zone of the East European plain) is dependent on the climate and, in particular, the microclimate because the entire territory suffers from cold temperatures. Annually, these range between 1.5 C and 4.0 C. At that, the microclimate differentiation has similar amplitudes, and it depends on geology and topography.

The natural environment of the East European plain is the result of the recent geological history which includes a series of Pleistocene glacials. At its peak the Scandinavian ice sheet covered almost all the modern forest zone of the plain except for the south-eastern tip. The most recent ice cover (Wurm-Wisconsin-Valday) occupied only the northwest part of the plain. Following the last glaciation we now have three natural zones called the postglacial, periglacial, and non-glacial zones. These differ by the age of the landscape which has developed since they became free of ice. Strange as it may seem, the agricultural suitability of the natural environment correlates with its age. The ancient landscapes of the south-east have a platform of clay and limestone which creates rather fertile soil. They also have a dense river network with well-developed valleys and a warm microclimate which is more suitable for farming than that of the highlands.

In contrast the young western landscapes of the postglacial zone have poor young soil covering the glacial clay and sand. Despite the rugged moraine topography and the highest altitudes of the entire plain the river valleys are usually so shallow, narrow and bogged that they cannot be tilled. Despite this, there are many glacial lakes surrounded by areas with a warm microclimate and fertile soil. The intermediate periglacial zone is characterized by rather flat and gentle areas amongst well-developed broad river valleys but the majority of lakes are already drained or boggy.

Thus we arrive at the geological trend which runs from the north-west through to the south-east across the entire forest zone of the East European plain. This trend shows a natural change over time which led to the natural areas evolving distinctly based on their distance from the center of the Pleistocene glaciation located in Scandinavia. The spatial pattern of the agricultural landscapes in turn generally result from this trend and each of these geographical zones is characterized with its own unique farming landscapes. These include "porechia" in the non-glacial zone (a Russian term meaning near river areas), "poozeria" (meaning near lake areas) and "sush" (meaning a drained area) within the postglacial zone. In the intermediate periglacial zone we see the greatest variety of farmland spatial patterns in the Russian North.

ROCK GLACIER KINEMATICS DERIVED FROM UAV SURVEYS: VALIDATION AND ACCURACY ASSESSMENT

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Active rock glaciers are the manifestation of mountain permafrost creep. They are a distinctive component of the cryosphere, where favourable climatic and topographic factors allow their growth and development. Rock glacier surface displays sequences of compression and extension features such as furrows and ridges, reflecting their past and current dynamics. The novel progresses in the field of Unmanned Aerial Vehicles (UAV) systems and digital photogrammetry are providing an improvement of high-resolution data, together with the enhancement of image processing and acquisition protocols. These new developments, however, have not been thoroughly tested and validated in high alpine terrain.

This study introduces a rigorous procedure to quantify rock glacier kinematics and their associated uncertainties derived from sequential UAV surveys. This procedure is applied to five consecutive UAV surveys of Tsarmine rock glacier, Valais Alps, Switzerland. This tongue-shaped rock glacier is about 500 m long and spans an elevation range of 2460–2680 m a.s.l. Since 2004, around 50 blocks are measured biannually with a differential GNSS equipment, reaching an overall uncertainty of ca. 2 ± cm horizontally. In 2016, we started UAV surveys with a SenseFly eBee RTK device concomitant with the terrestrial geodetic surveys. Sequences of orthomosaics and Digital Elevation Models (DEM) with pixel sizes of 5 cm were produced for Tsarmine and its environs using a SfM-photogrammetry processing procedure. Co-registration and image cross-correlation methods were performed on the multitemporal orthomosaics.

Thanks to the high-resolution customised UAVs surveys, rock glacier geometric changes can be studied in detail. Results indicate a good overall fitness between in-situ and UAV-derived displacements, where the flow structure of Tsarmine shows a regular profile of increasing velocities towards the terminus (up to 7 m/y). Furthermore, the general assessment of the 3D-models allows quantifying not only horizontal displacements but also vertical changes with a good level of confidence. UAV monitoring approaches can be advantageous for accessing remote and difficult terrain, as they can be easily customised to provide high resolution and frequency of observations in comparison with other remote sensing or ground survey techniques.

MICROSCOPIC FAILURE MECHANISM OF SALINE SOIL CONSIDERING SALT TRANSPORT AND PHASE CHANGE UNDER FREEZE-THAW CYCLES

Zhemin You

Numerous engineering problems including frost heave and thaw settlement, as well as salt heave and dissolve settlement caused by temperature change and salt transport occur commonly when constructions build in seasonal saline frozen soil regions. Microstructure transformation is thought substantially to be reason for the failure mechanism of saline soil. Focused on the saline soil with sodium sulfate in seasonal frozen regions, the proposal utilizes a comprehensive approach that combines macroscopic and microscopic, experimental and theoretical methods. Based on freeze-thaw cycles, CT scanning, MIP and SEM tests, water and salt transport characteristics and the mesoscopic damage evolution law of saline soil are obtained. The pore size distribution characteristics are analyzed to calculate crystallization pressure and induced effective stress and then the model of crystallization pressure of saline soil is established. According to the microstructural characteristics, the particles' contact and sliding model is formed considering freeze-thaw cycles and salt transport, and it is used to calculate the macro deformation, and predict the variations of salt and frost heave. The objective of this project is to provide theoretical guidance to the design of bearing capacity and the measurements of preventing subgrades from salt and frost heave in seasonal saline frozen soil districts.

Keywords
Saline soil; freeze-thaw cycles; salt transport and phase change; salt crystallization model; microstructure model.

INFLUENCE OF HEAT DISSIPATION OF SHIELD TUNNEL SEGMENT ON TEMPERATURE FIELD AND DESIGN OPTIMIZATION

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The artificial ground freezing (AGF) method is widely used in cross-passage of metro shield tunnel in China. It can provide artificially frozen curtain which increases the strength of the ground around the cross-passage and makes the project impervious to water seepage. However, the thickness of the frozen curtain close to segment is far less than the design value in many projects. As a result, the project must face a lot of engineering risk than design. This is largely due to heat dissipation of segment and air in the tunnel. The purpose of this paper is to study the influence of the heat dissipation on temperature field and optimization of the design of AGF method.

In order to research the temperature field, a 3D model for the AGF project is set up (Fig.1). Firstly, it set the size of the model to 5×5×10 m, and the distance of freeze pipes to L (a variable). Secondly, set the infinite element domain of 0.5m thickness around the model which can represent a soil of 500m. In order to simplify the numerical model, the freeze pipes set to parallel and the distance of them is a fixed value along the length. In order to verify the reliability of the model, the comparison of field testing temperature and simulation temperature in the active process was carried out. Overall, the actual temperature at different timewas basically consistent with the value obtained from numerical analyses at the corresponding point.

Fig.2 show the result on the end of the active freezing period, the thickness of frozen curtain close to segment is about 30% of normal thickness (distance from segment more than 3m). It pointed out that this effect can't be ignored in the length of 1m which calculated from frozen curtain thickness curve based on FEM calculation and in-suit test.

The results of different parameter L show that the thickness of frozen curtain gradually decreases as the 'L'increases. So, the riskiest area in an AGF cross-passage project is the soils close to the segment opposite the freezing station and most freeze pipes. By comparing different calculation results, covering insulation, not covering insulation, partial time coverage insulation, it can get the conclusion that the use of effective insulation can improve the frozen curtain thickness about 1.05m. However, the insulation layer is often damaged by other essential work or eroded by water during the project.Therefore, we proposed a new production process of the segment, which set a layer of insulation inside the segment. And the comparison of temperature filed shown in Fig.3. In the end, it uses an influence coefficient to describe the influence of heat dissipation for temperature field, which shows in equation (1). And get the different spatial distribution curves show in Fig.4.

$$\eta(x,t) = 1 - \frac{\xi(x,t)}{\xi_{\max}(t)} \qquad (1)$$

From the study, we can get that, (1) it got the temperature field close to the segment by numerical calculation and pointed out the influence range of heat dissipation; (2) the most dangerous locations are pointed out by the result of different parameter 'L', and the effect of effective insulation is proposed; (3) a new design of segment was proposed for AGF project which can effectively increase the thickness of frozen curtain.

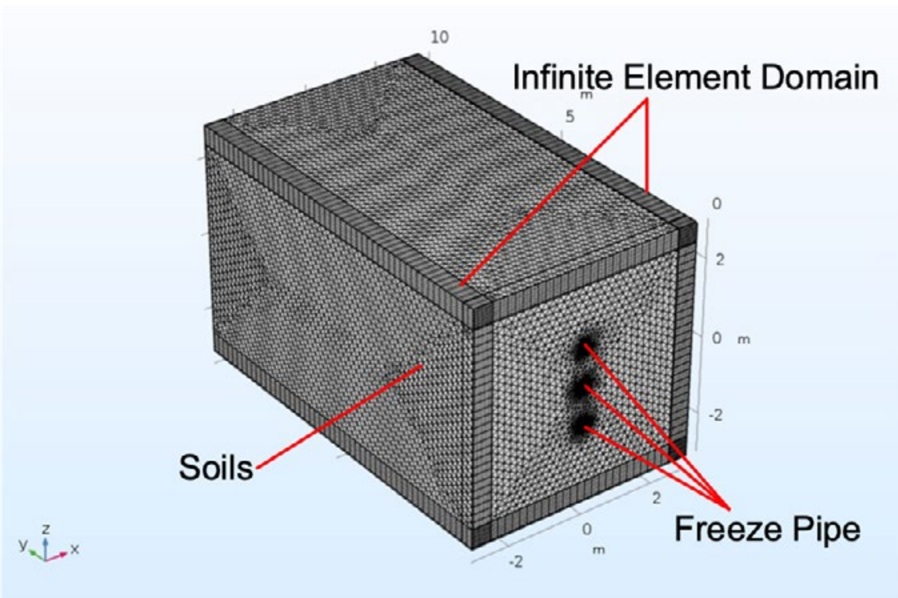

Figure 1: The 3D model of temperature field

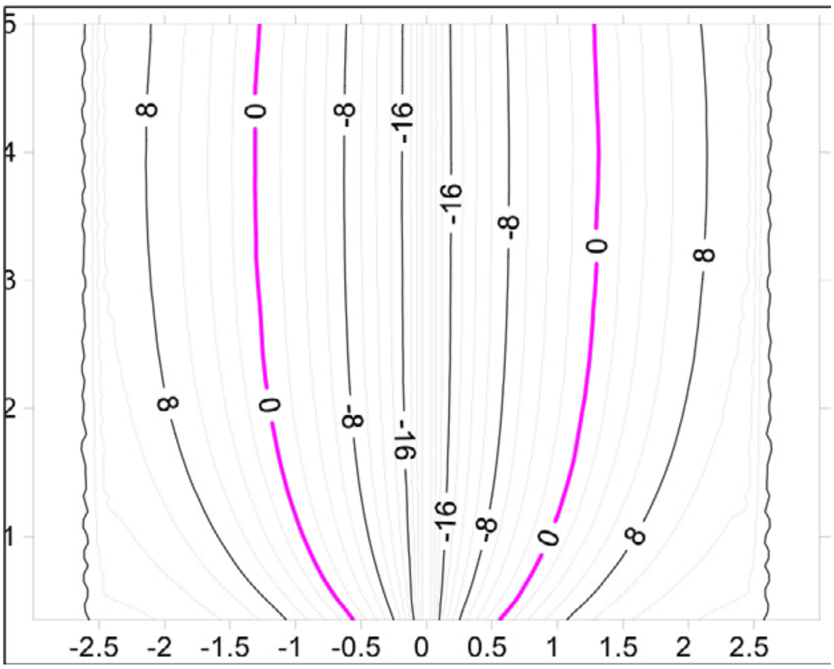

Figure 2: Temperature field after 40d

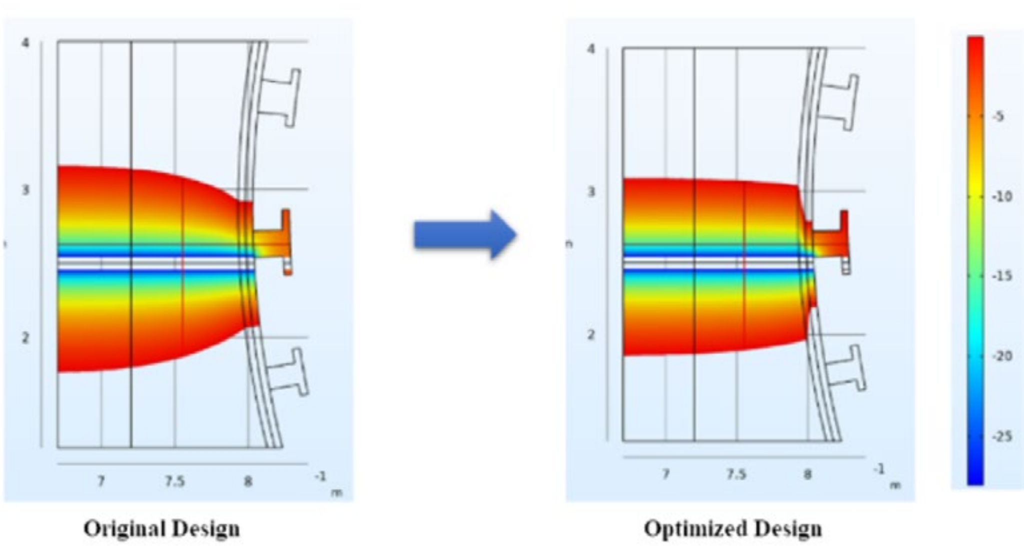

Figure 4: Temperature field of segment design

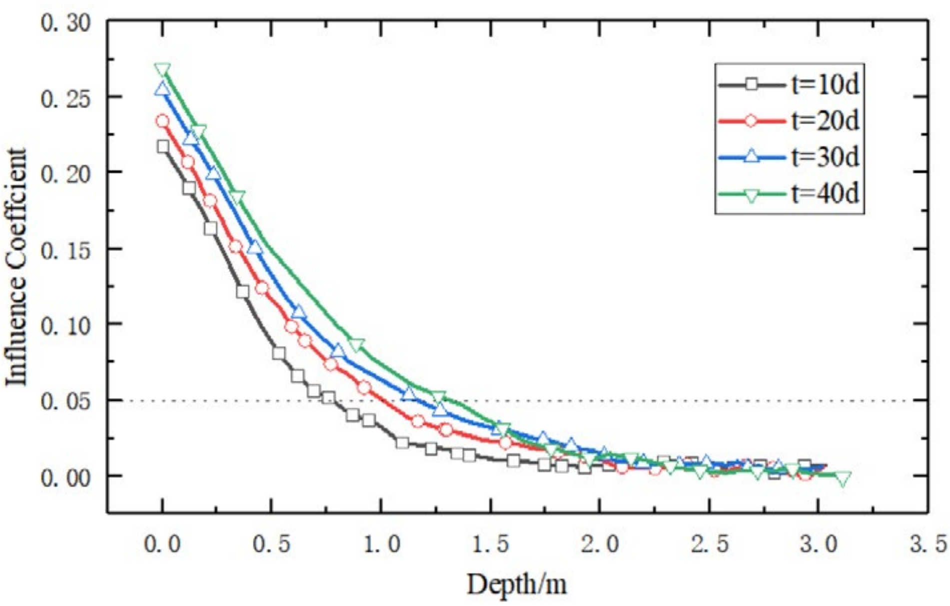

Figure 5: Influence coefficient distribution

SOIL MOISTURE DOMINATE ALPINE MEADOW CARBON BALANCE IN THE PERMAFROST REGION OF THE QINGHAI-TIBETAN PLATEAU

Yonghua Zhao,[1] Lin Zhao,[1] jimin Yao,[1] Yao Xiao,[1] Guangyang Yue,[1] Yanhui Qin,[1] Yongping Qiao[1]

[1] Cryosphere Research Station on the Qinghai-Tibet PlaCryosphere Research Station on the Qinghai-Tibet Plateau, State Key Laboratory of Cryospheric Sciences, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, China

The Qinghai–Tibet Plateau (QTP) is the most extensive high-altitude permafrost distributing regions in the world with a permafrost area of $1.5\times10^6 km^2$, occupy for 74.5% of the high-altitude permafrost, or 8% of permafrost in the northern hemisphere. So the carbon balance in permafrost region of QTP is important to evaluate permafrost roles in the global terrestrial carbon cycle. Here, we compiled a 4-year eddy CO_2 flux and environmental factors field observation from January 2008 to December 2011 over the Tanggula (TGL, 91°56'E, 33°04'N, 5133 m asl) and Xidatan (XDT, 94°07'E, 35°43'N, 4538 m asl) monitoring sites of the alpine meadow ecosystems to help deepen the understanding of carbon balance from the permafrost region of the QTP. Analysis of 4 four years of data revealed that both TGL and XDT alpine meadow ecosystems seasonal variations in CO_2 flux exhibited a bimodal pattern with strong emission in both spring and autumn, weak absorption in summer, and weak emission in winter. We found that CO_2 absorptive period was shorter(from July to September) and the maximum uptake rate was weaker (0.04 $mg^{-2}s^{-1}$)from TGL alpine meadow ecosystem than from XTD (from May to September with the maximum uptake rate 0.09 $mg^{-2}s^{-1}$). Further, cumulative CO2 flux shown that XDT alpine meadow was a net sink for atmospheric CO2 with the mean uptake rate of 32.1 $gm^{-2}yr^{-1}$(21.8-47.1 $gm^{-2}yr^{-1}$) , but TGL alpine meadow was a net source with the mean emitted rate of 142.3 gm-2yr-1 (112-164.4 gm-2yr-1). Carbon uptake in XDT was likely caused by high soil moisture content, which increased the vegetation coverage and photosynthetic intensity in XDT alpine meadow ecosystem. In turn, carbon release in TGL was due to dry soil reduced vegetation coverage and photosynthetic intensity in TGL alpine meadow ecosystem. Our results suggest that the soil moisture content was the dominant factor controlling alpine meadow carbon balance in the permafrost region of the QTP.

DELEGATE LIST

In order of delegate last name

DELEGATE LIST

Alekseev	Ivan	*Saint Petersburg State University*
Almond	Peter	*Lincoln University*
Anyuan	Li	*Shaoxing University*
Balks	Megan	*University of Waikato*
Barboux	Chloé	*Department of Geosciences - Geography. University of Fribourg. Switzerland*
Barrell	David	*GNS Science*
Bhardwaj	Anshuman	*Luleå University Of Technology*
Carshalton	Annette	*University Of Waikato*
Chachulski	Łukasz	*Warsaw University Of Life Sciences*
Chowdhury	Akm Foiz Billah	*Public Resources And Services Foundation*
Christiansen	Hanne Hvidtfeldt	*The University Centre In Svalbard*
Cox	Simon	*GNS Science*
Czekirda	Justyna	*Department Of Geosciences, University Of Oslo*
Deng	Yousheng	*Cold And Arid Regions Environmental And Engineering Research Institute, Chinese Academy Of Sciences*
Dvornikov	Yury	*Earth Cryosphere Institute Tyumen Scientific Centre SB RAS*
Engstrom	Ryan	*George Washington University*
Etzelmuller	Bernd	*University Of Oslo*
Feng	Wenjie	*Cold And Arid Regions Environmental And Engineering Research Institute, Chinese Academy Of Sciences*
Ferrando	Francisco	*Ex-university Of Chile*
Fröjd	Christina	*Inst Physical Geografy, Stockholm University*
Gross	Julian	*Technical University Of Munich*
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