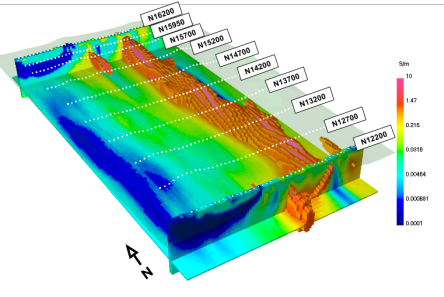


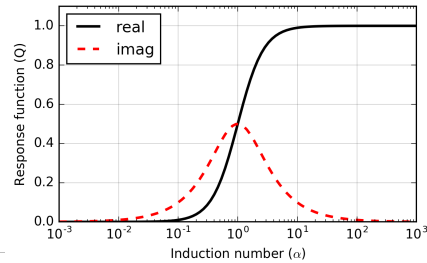
Summary and the Future



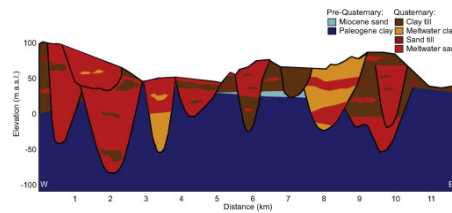
What have we covered?



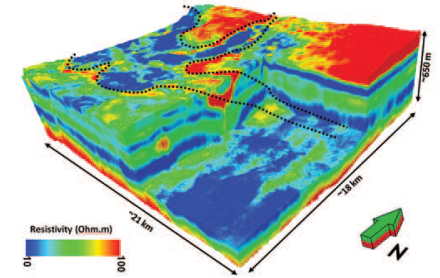
Mt. Isa, Australia:
Mineral Exploration



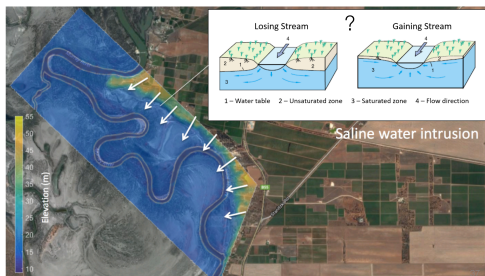
EM Fundamentals



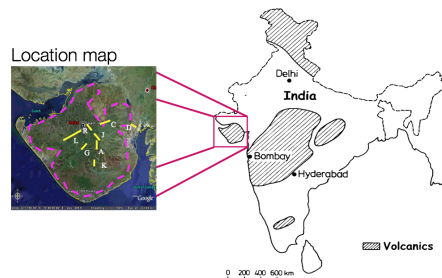
Kasted, Denmark:
mapping
paleochannels



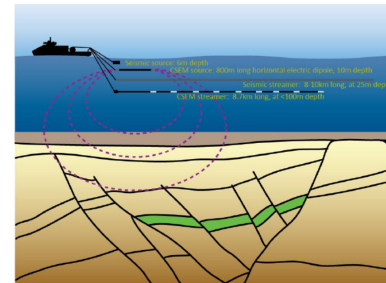
Wadi Sahba, Saudi
Arabia: using EM to
improve seismic imaging



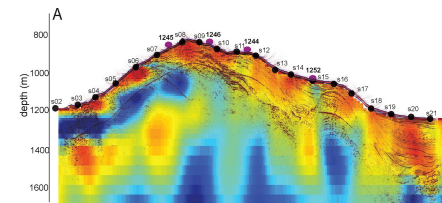
Bookpurnong, Australia:
diagnosing river
salinization



Deccan Traps, India:
mapping sediment
beneath basalt

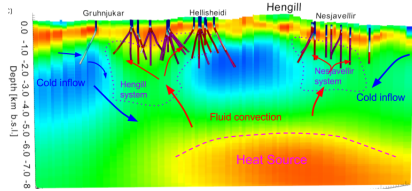


Barents Sea:
Hydrocarbon de-
risking

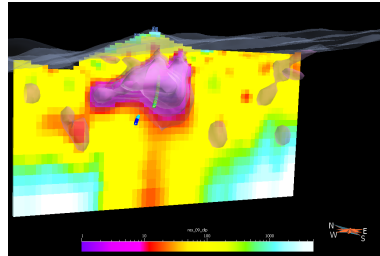


Oregon, USA:
Methane Hydrates

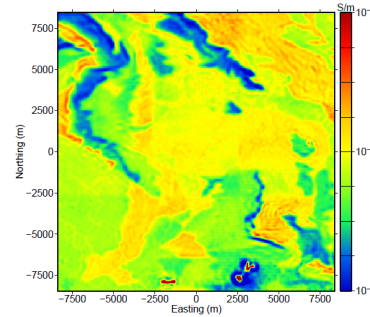
What have we covered?



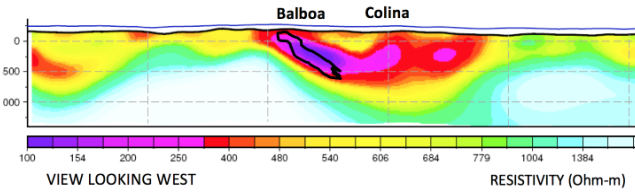
Iceland: characterizing geothermal systems



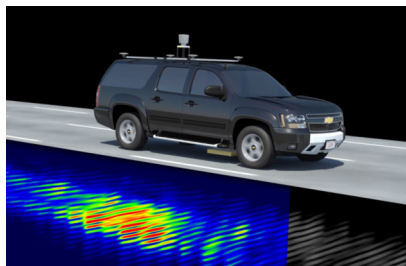
Santa Cecilia, Chile: Mineral Exploration



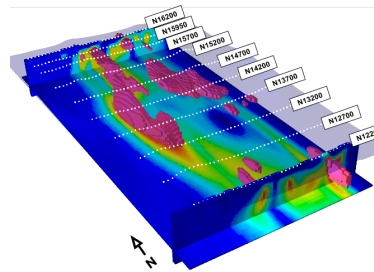
Noranda, Canada: Geologic Mapping



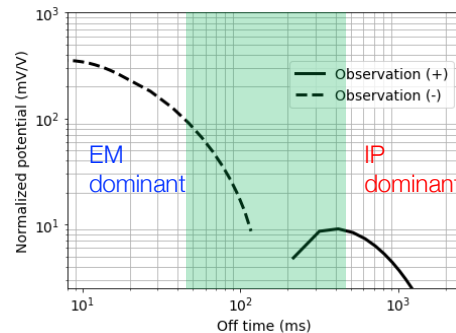
Balboa, Panama: Mineral Exploration



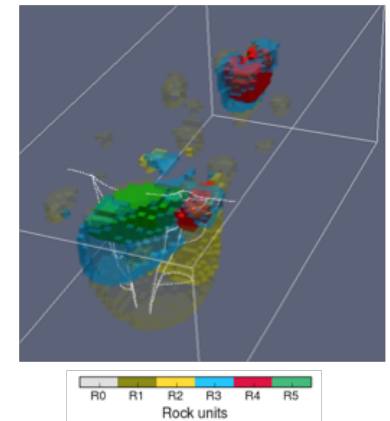
USA: Self-driving vehicles



Mt. Isa, Australia: Mineral Exploration



EM decoupling



TKC, Canada: Mineral Exploration

What does the future hold?

What does the future hold?

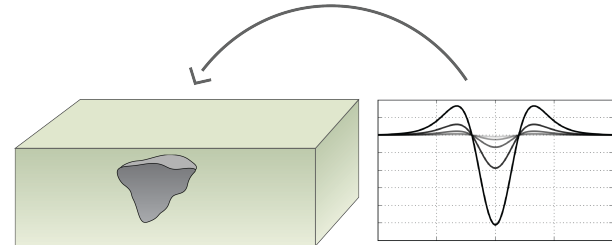


What does the future hold?

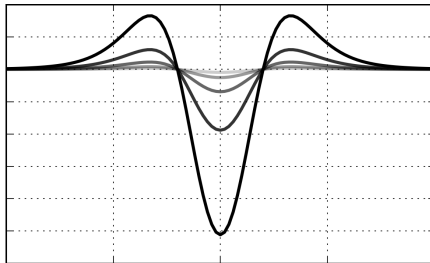
Problems



Inversion capabilities



High quality data



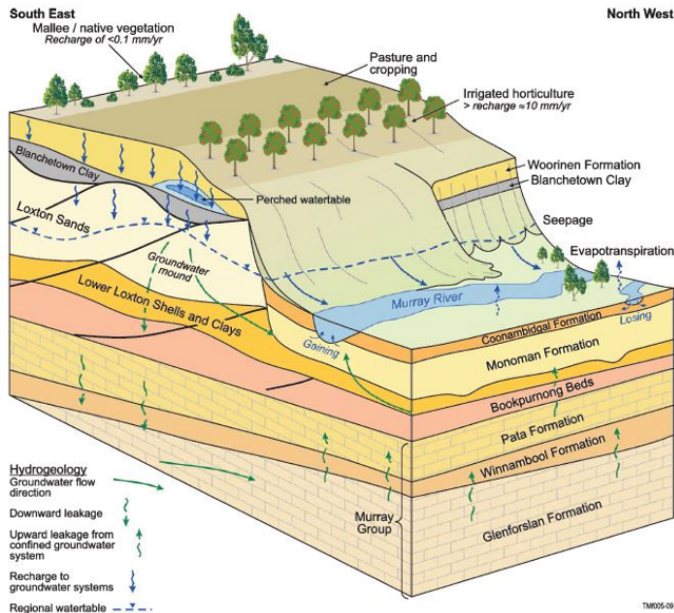
Web tools to
communicate



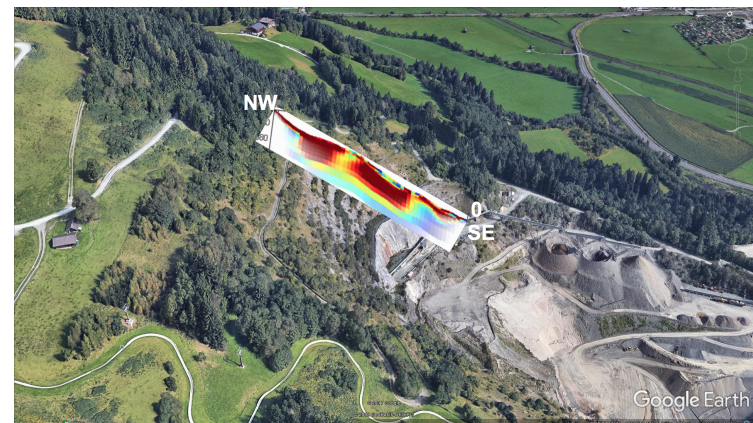
The Future: Monitoring

- Dam integrity
- Slope stability
- Aquifers
- Coal seam gas
- Enhanced oil recovery

Mt. Polly tailings dam collapse



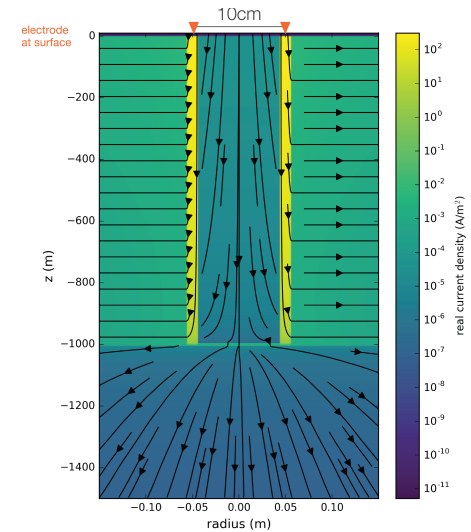
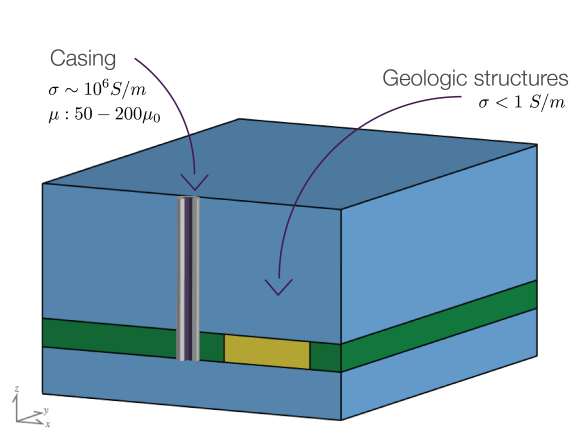
Water infiltration and slope stability



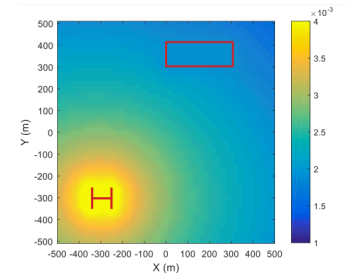
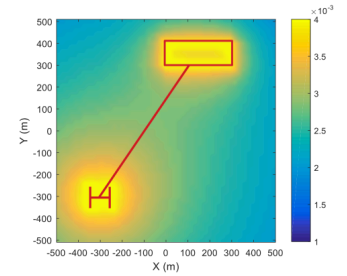
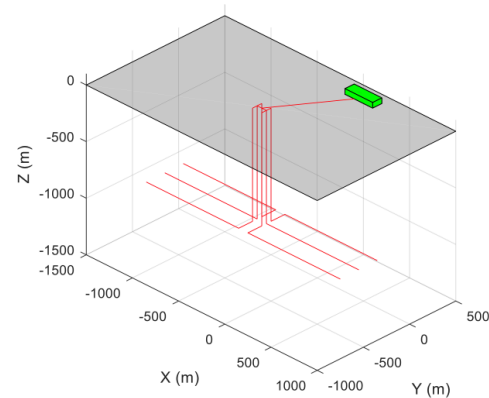
Florian Bleibinhaus

The Future: Large Contrasts

- Conductivity contrasts
- Permeability contrasts
- eg. Steel Casing
 - Mechanism for getting current to depth
 - Challenges:
 - Scales
 - Physical properties



Corrosion

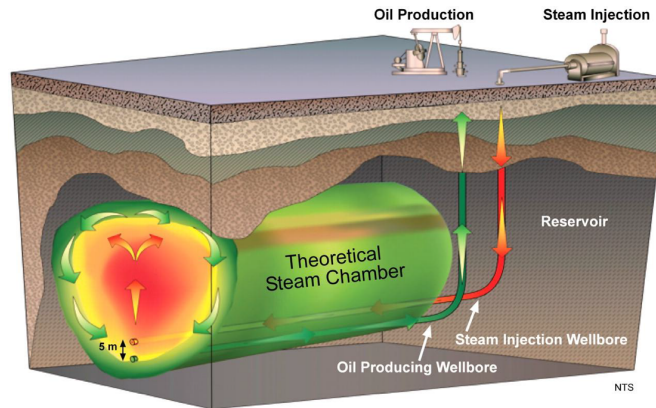


eg. Sudbury basin

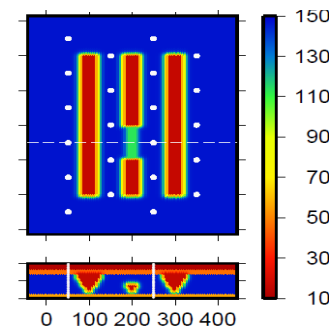
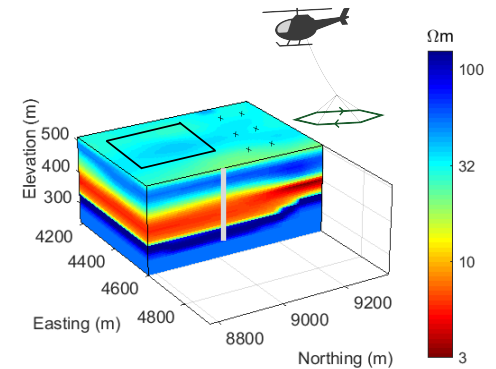
Monitoring: Choosing the appropriate survey

Different EM surveys needed to answer different questions

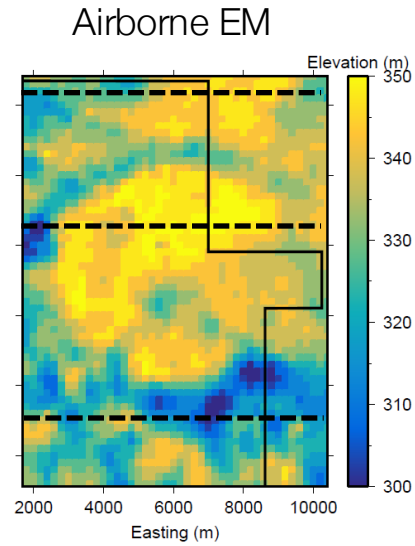
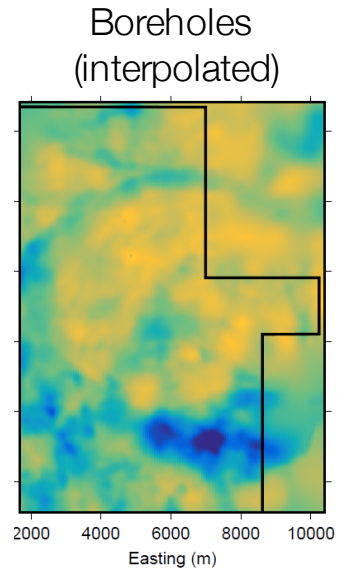
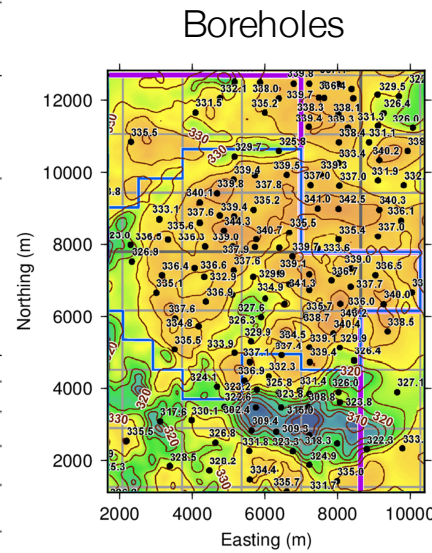
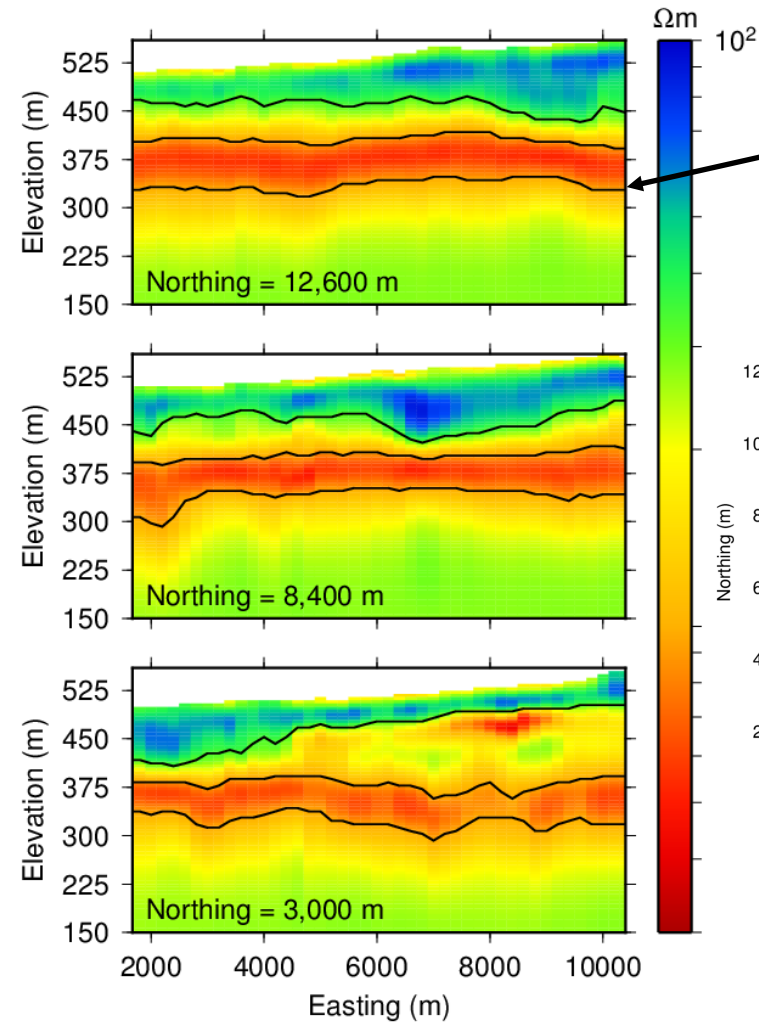
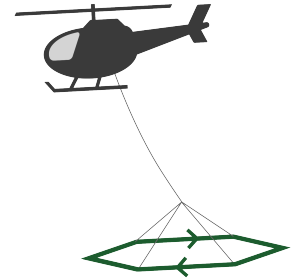
SAGD (Injection and monitoring steam flooding)



- Stage 1: Airborne reconnaissance survey
- Stage 2: Surface and borehole for pre-injection
- Stage 3: Monitoring array

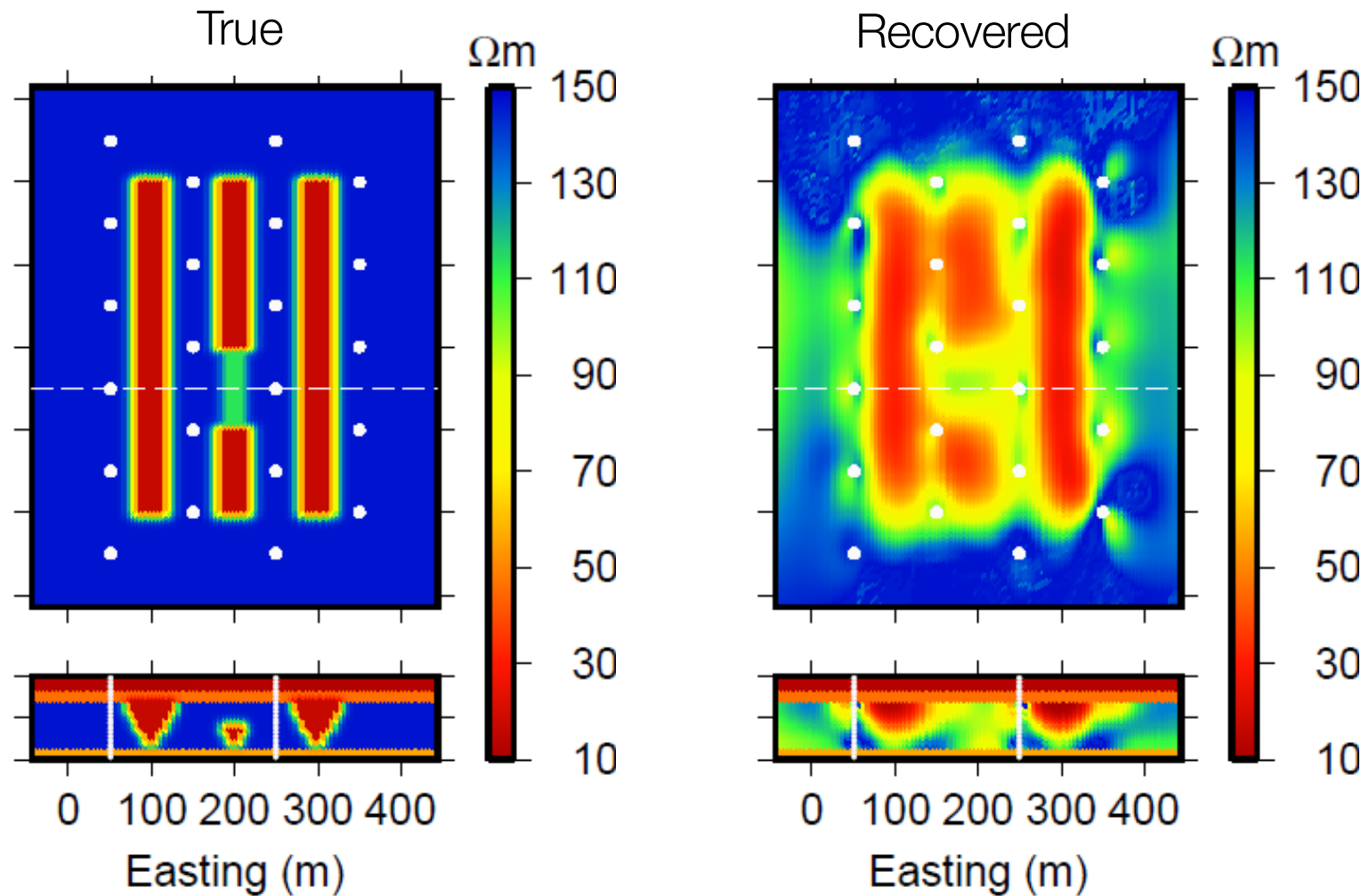


Large scale reconnaissance (SAGD)



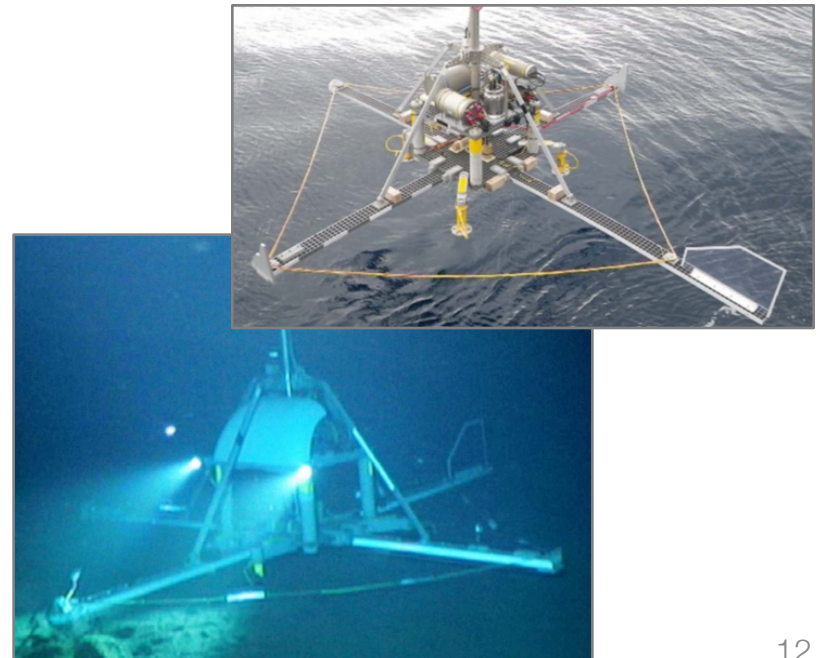
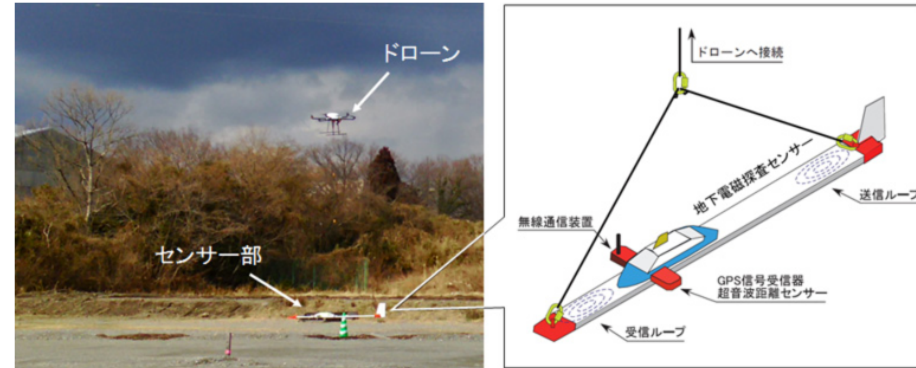
Multi-stage EM for monitoring

Post-injection: surface sources, borehole receivers



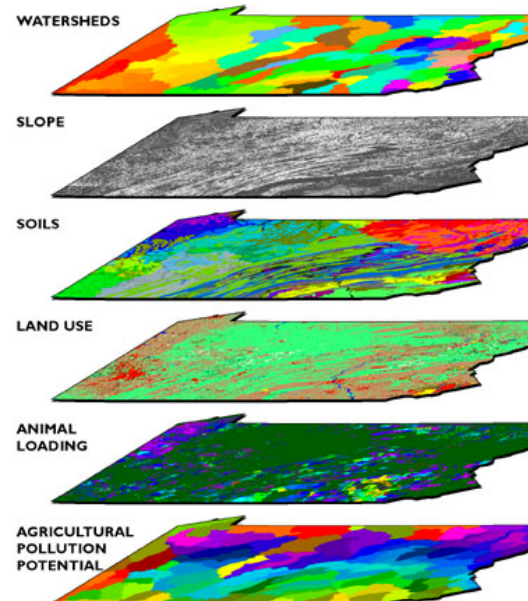
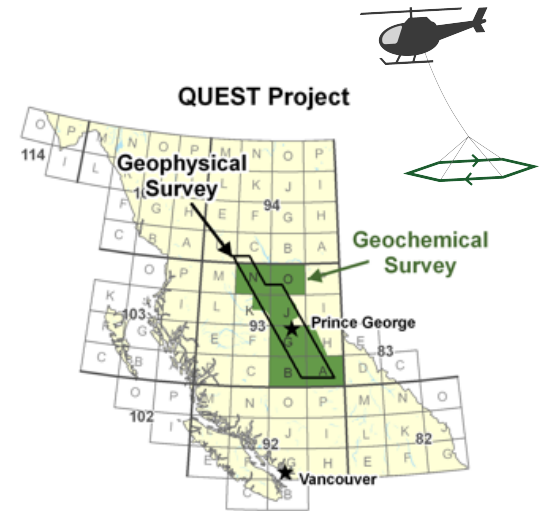
The Future: High Quality Data

- Improved instrumentation
 - Lower noise
 - More power
 - Better control on transmitters and receivers
 - Current waveform
 - Filtering parameters
 - Position and orientation
 - Higher sampling rates
 - ...
- Data collection
 - Drones
 - AUVs
 - ROVs
- Mathematical modelling requires that we know all the details.



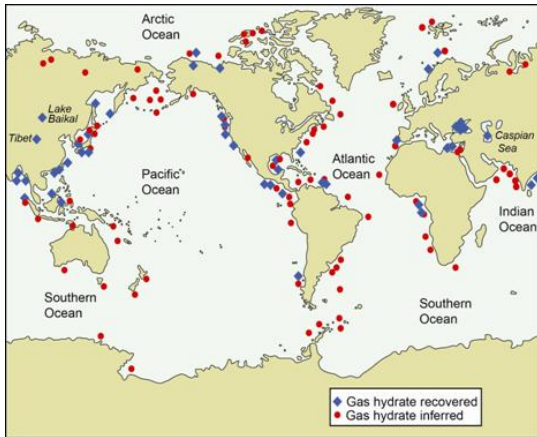
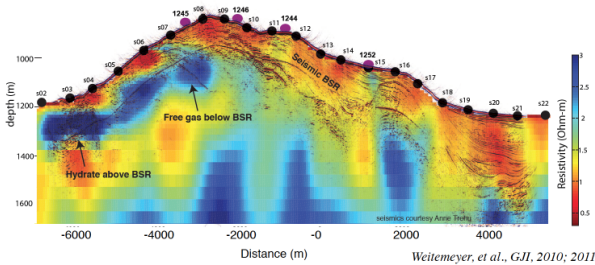
The Future: Lots of Data

- Big data
 - Multicomponent receivers
 - Many transmitters, receivers
 - High sampling rates
 - Large areas
- Multiple types of data
 - geophysical surveys
 - Physical properties
 - Geochemistry
 - Geology
 - ...
- Machine learning

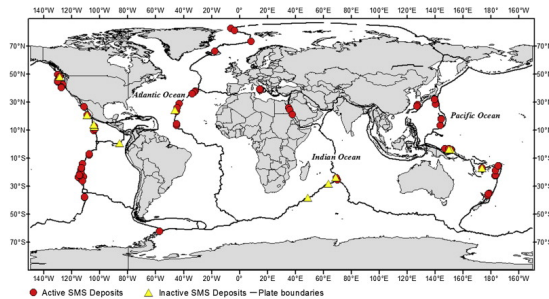
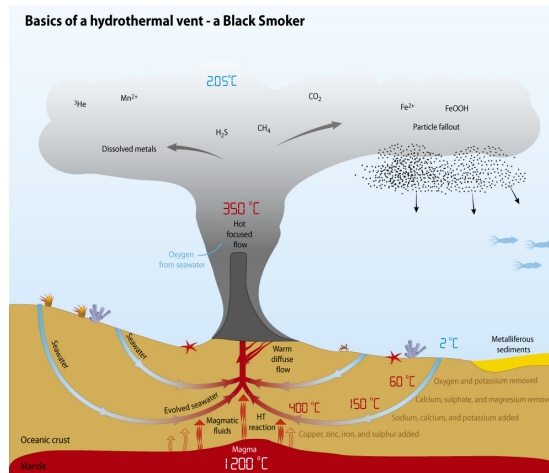


The Future: Marine EM

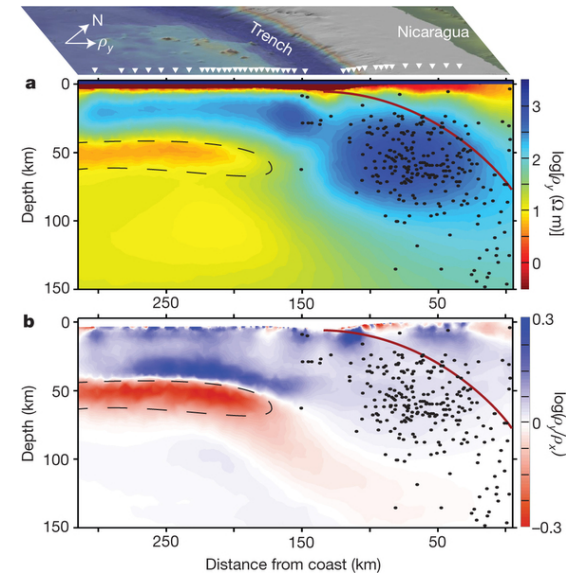
Gas hydrates



Seafloor massive sulfides



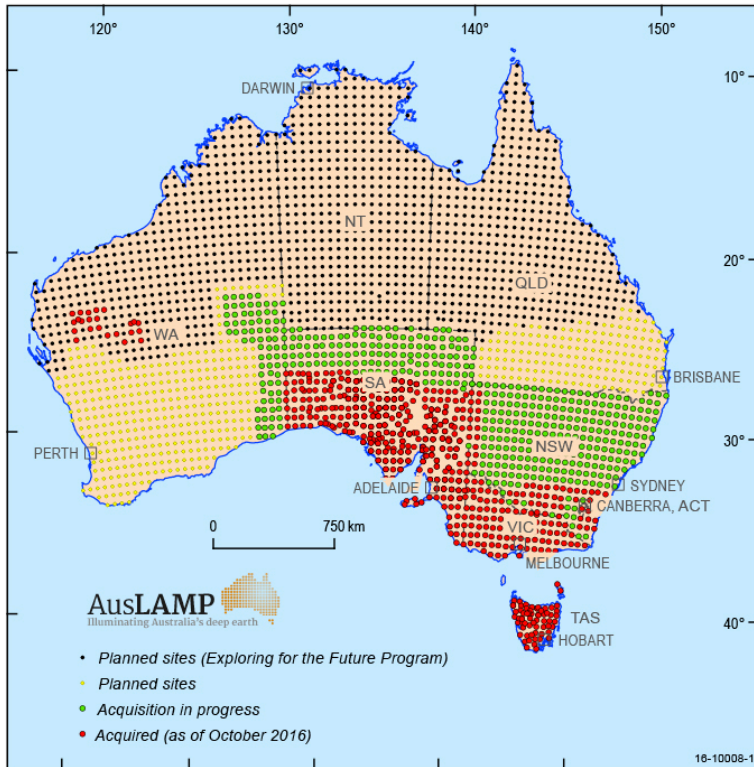
Tectonic studies, natural hazards



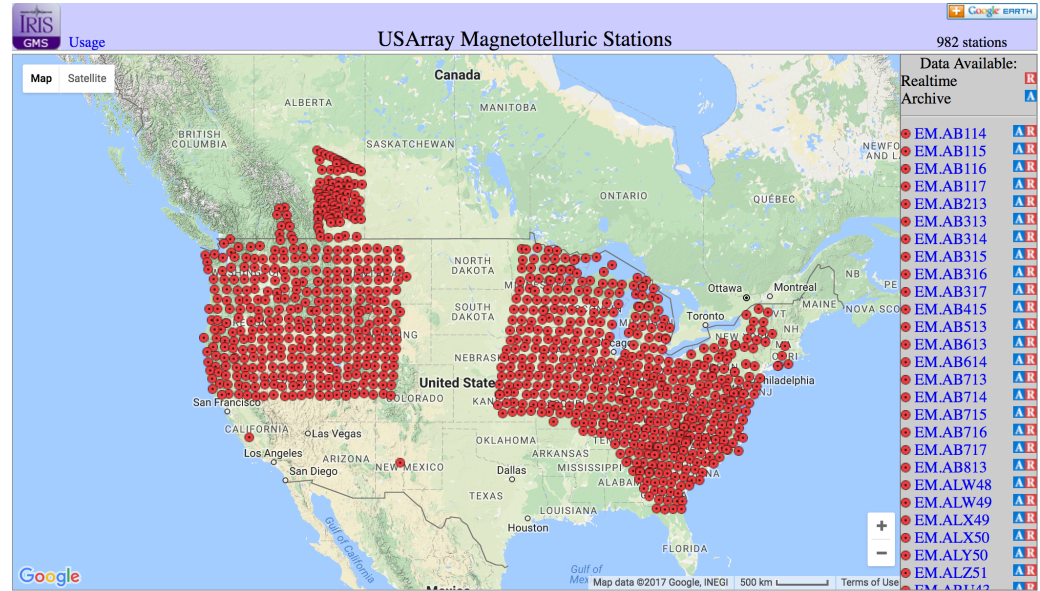
Naif et al., 2013

The Future: Large Scale EM

AusLamp

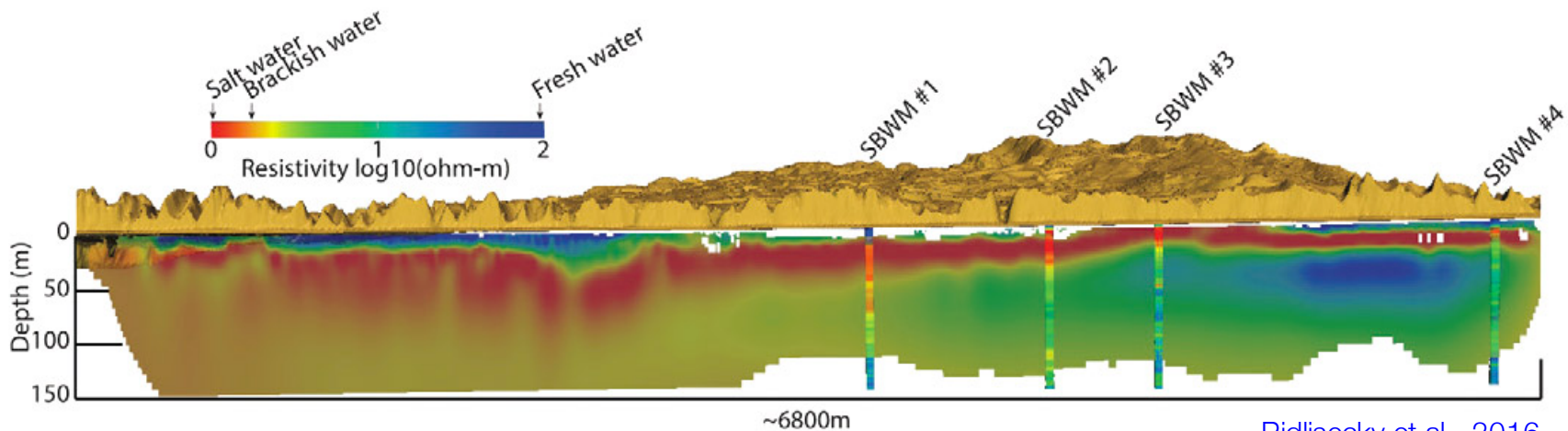
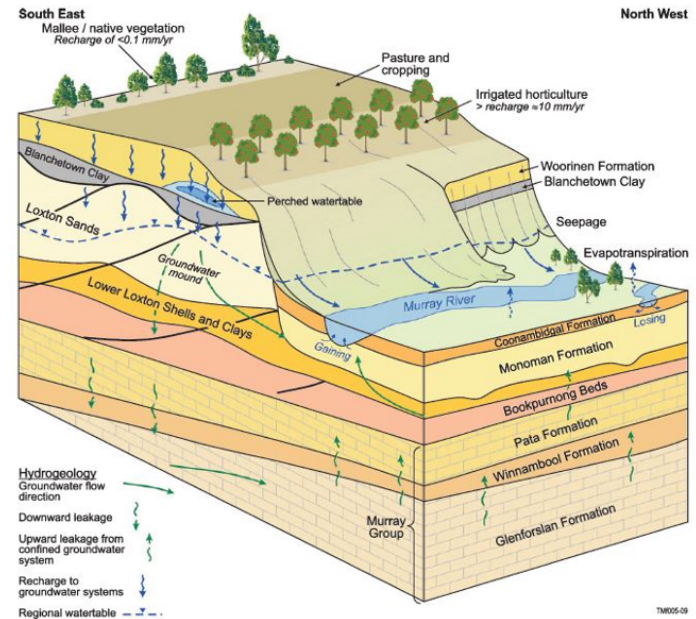


Earth scope



The Future: Water

- Finding and delineating water
- Aquifer monitoring and management
- Salt water intrusions
- Pollutants

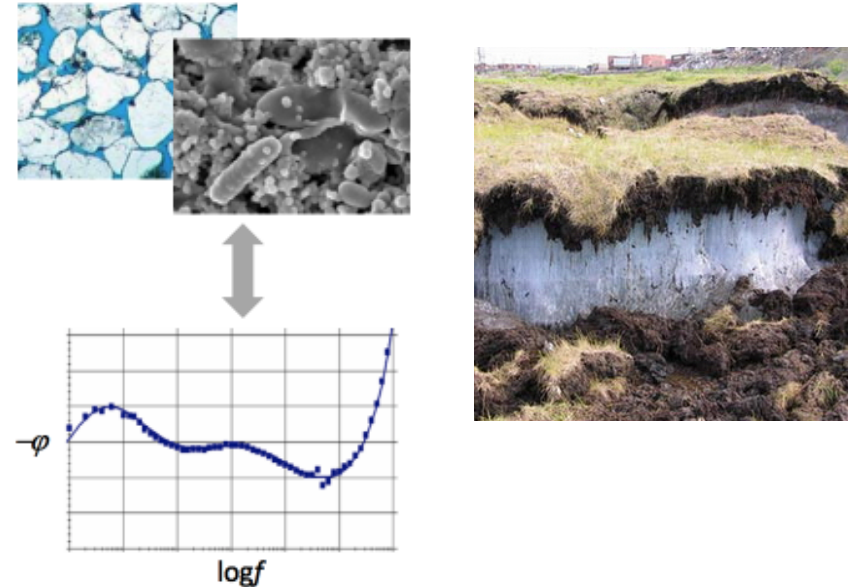


[Pidlisecky et al., 2016](#)

The Future: Physical Properties

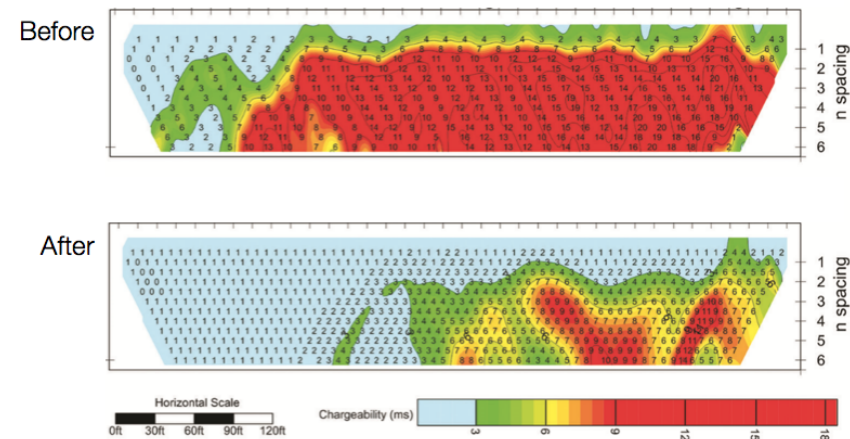
Dispersive Conductivity (IP)

- Ice / water, permafrost
- Organic materials
- Bioremediation
- Hydraulic permeability
- Characterizing materials based on spectral IP response



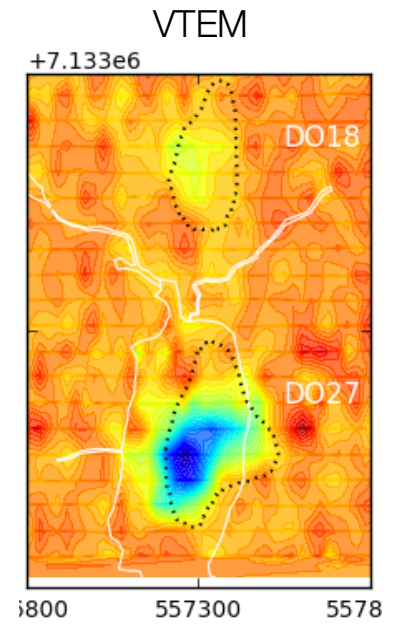
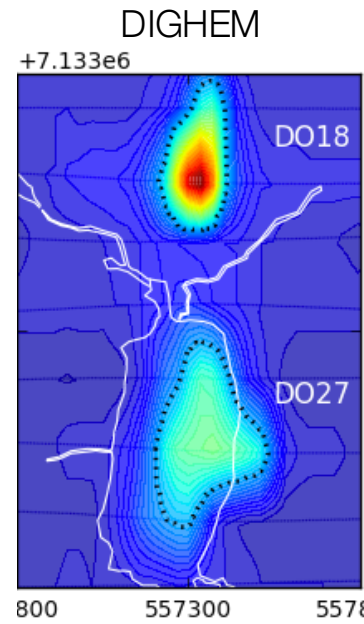
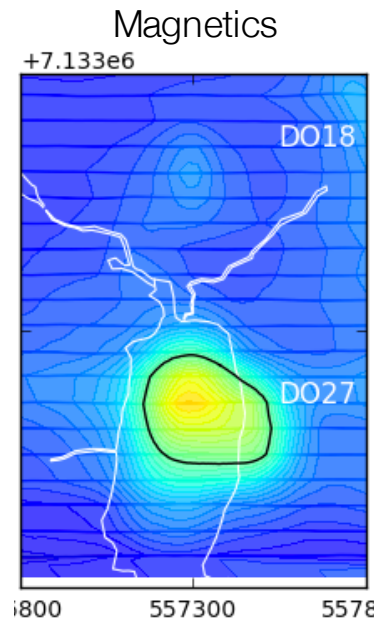
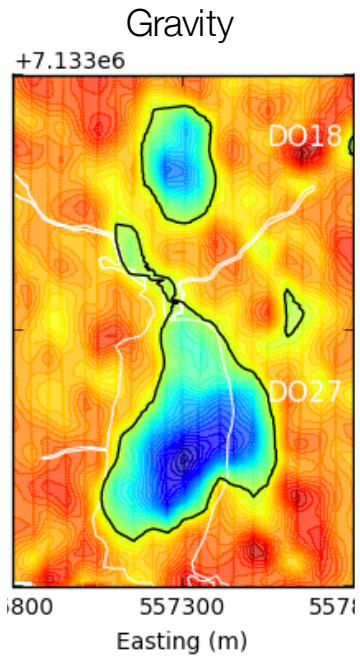
Dispersive Magnetic Permeability (Viscous Remanent Magnetization)

- Soils
- Bioremediation (?)

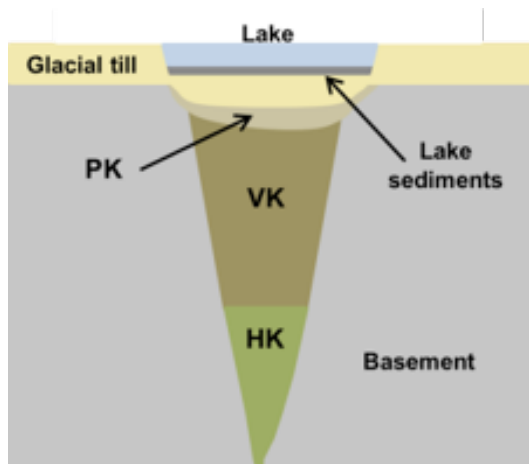


Numerical Modelling

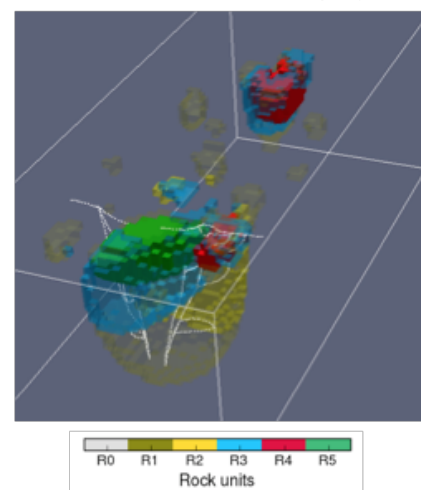
The Future: Data Integration & Multi-physics



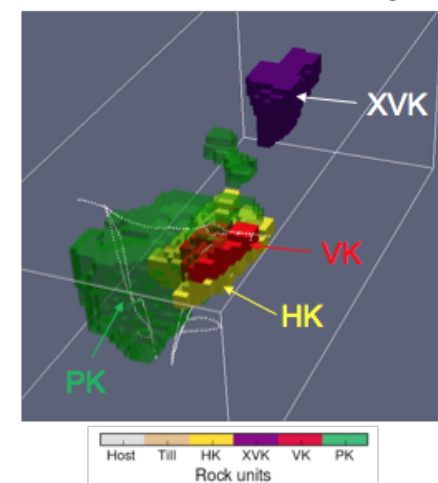
Kimberlite Model



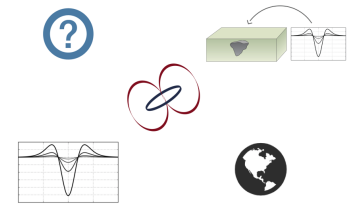
Rock Model from Geophysics



Rock Model from Drilling



The Future: Modelling and Inversion

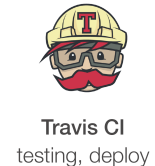
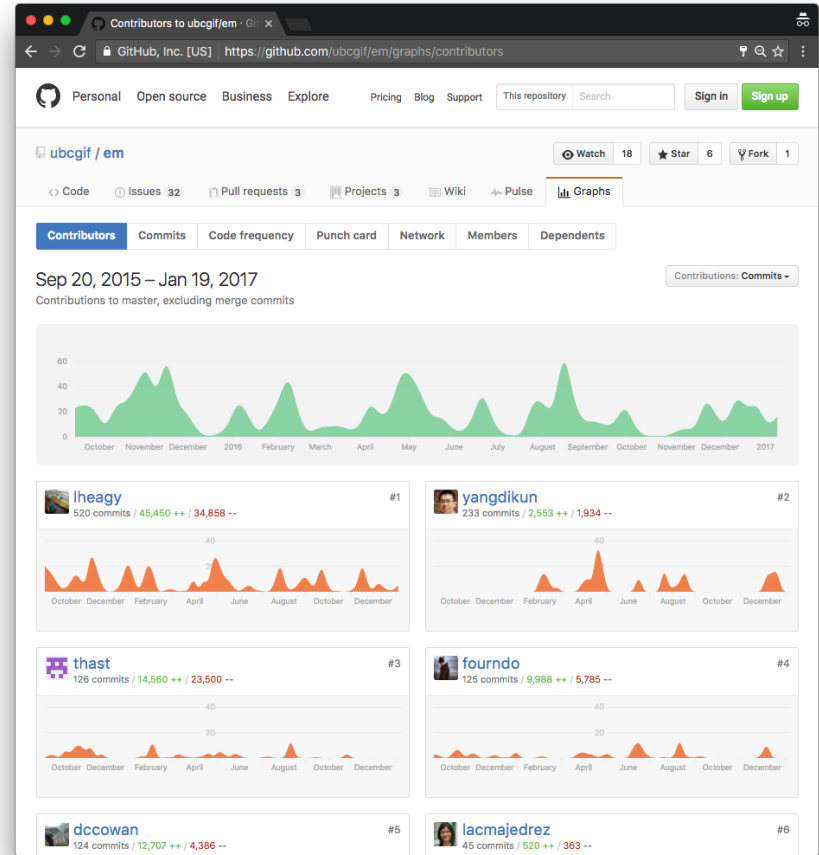


- HPC, Cloud computing
- Collaborative development
- Open source

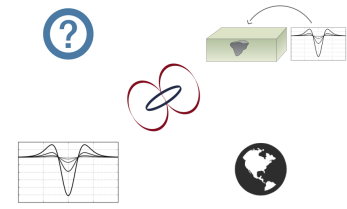


Simulation and Parameter Estimation in Geophysics

<http://simpeg.xyz>



The Future: Modelling and Inversion



- Interactive computing
- Visualization

$$\nabla \times \mathbf{e} = - \frac{\partial \mathbf{b}}{\partial t}$$



$$\nabla \times \mathbf{h} = \mathbf{j} + \frac{\partial \mathbf{d}}{\partial t}$$



The screenshot shows a Jupyter Notebook window titled "HarmonicDipoleWidget_MD". The code cell contains the following Python code:

```
In [10]: dwidget = DipoleWidgetFD()
Q1 = dwidget.InteractiveDipoleBH(nRx=Q0.kwarg["nRx"], plane=Q0.kwarg["Pla
```

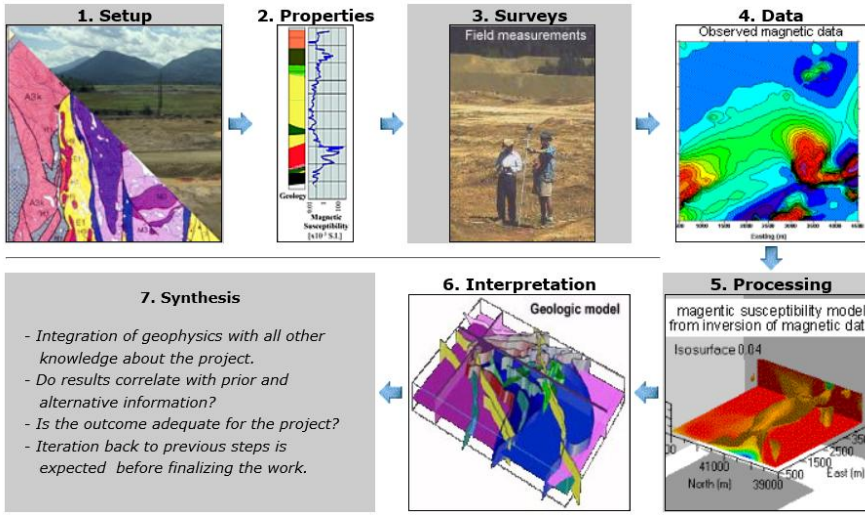
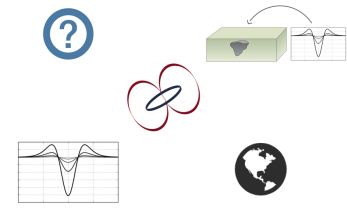
The output of the code is an interactive widget with the following controls:

- Field: E, H, J (selected)
- AmpDir: None, Amp, Direction (selected)
- Comp.: x, y, z (selected)
- Complex Number: Re, Im, Amp, Phase (selected)
- f (Hz): 0
- σ (S/m): 0.01
- Offset: 50
- Scale: log, linear (selected)
- Slider: FreqLog (-3.00), SigLog (-3.00)

Two plots are displayed below the widget:

- Vector H-field from MD:** A 2D vector field plot showing magnetic field lines in the Y-Z plane. The Y-axis ranges from -40 to 40 m, and the Z-axis ranges from -40 to 40 m. A color bar on the right indicates the magnitude of the magnetic field in A/m, ranging from $10^{-6.5}$ to $10^{-6.2}$.
- EM data at Rx hole:** A line plot showing the A-B profile of the magnetic field. The Y-axis is labeled "A-B profile (m)" and ranges from -40 to 40. The X-axis is labeled "|H|-field field (A/m)" and ranges from -40 to 40. The plot shows a smooth, bell-shaped curve centered at zero.

The Future: Collaboration



Edit on GitHub

Case Histories

Case histories provide the context for our development of educational and research materials presented in em.geosci. Each case history focuses upon a particular problem to be solved and provides the motivation for working with particular surveys and shows the effectiveness of electromagnetics in answering the posed questions. For many people, a case history will be the entry point to this site. To facilitate transfer of knowledge we have developed a common framework (Seven Step Process) in which each case history is presented. Links are provided so that a reader can investigate fundamental aspects of EM, the survey, or interpretation. In some cases we are able to provide data sets and analysis/inversion software to enhance the user experience and to address important issues regarding reproducibility. Case histories for our initial launch of em.geosci are those that have been developed by past and present students at the Geophysical Inversion Facility. The titles, and EM systems used are provided below.

Gallery

Mt. Isa

- **Contributors**
 - author: Dom Fournier
- **Tags**
 - geophysical survey: DC, IP
 - application: Mining
 - location: Australia

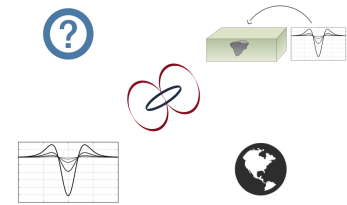
Bookpurnong

- **Contributors**
 - author: Dikun Yang
- **Tags**
 - geophysical survey: Airborne FDEM, Airborne TDEM
 - application: Groundwater
 - location: Australia



<http://slack.geosci.xyz>

Goals for the DISC



- Inspire
 - See the variety of potential applications
 - Illustrate effectiveness using case histories
- Build a foundation
 - Basic principles of EM
 - Exploration and visualization with interactive apps
 - Open source resource: <http://em.geosci.xyz>
- Set realistic expectations
- Promote development of an EM community
 - Open source software
 - Capturing case histories world-wide

Resources

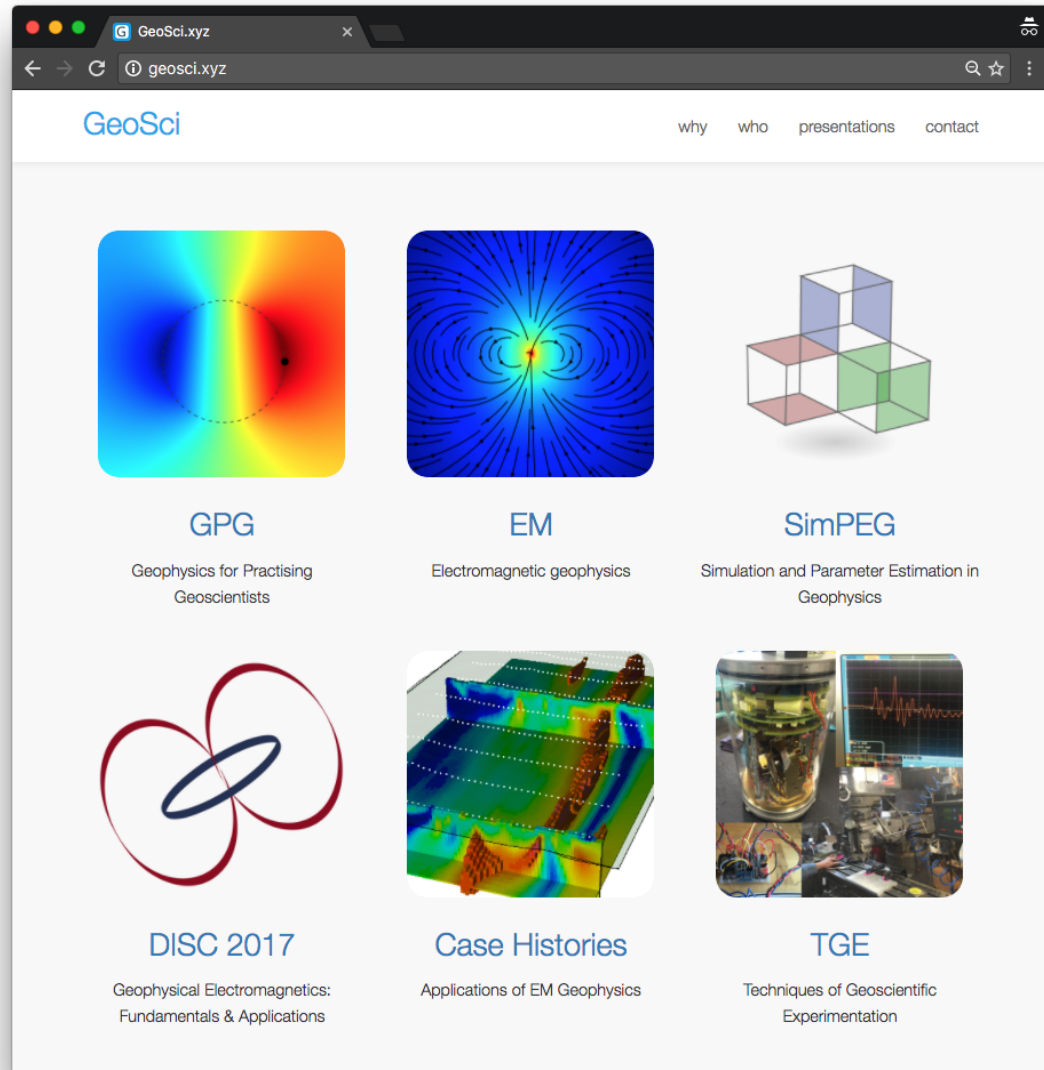
- GeoSci

<http://geosci.xyz>

- Web-textbooks
- Software
- Apps

- Apps:

<http://em.geosci.xyz/apps.html>



GIF DISC Team



doug



lindsey



seogi

UBC GIF Team



Thibaut



Patrick



Rowan



Devin



Kris



Sarah



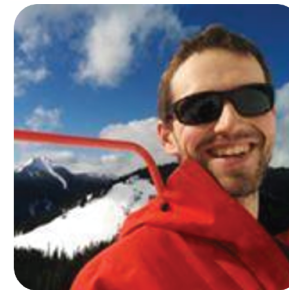
Dom



Mike



Mike



Gudni



Dikun

Join us tomorrow at DISC Lab

- Tell us what you are doing
- How EM is (or could!) play a role in the solution
- Continue the conversations
- Connect with other geoscientists
- Contribute to the development of a community

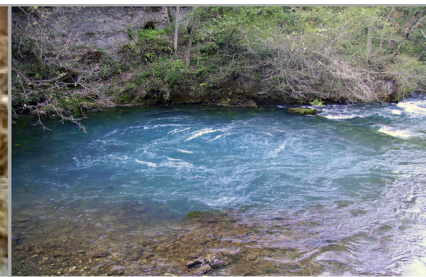
<http://disc2017.geosci.xyz>



minerals



contaminants



water



geothermal



geotechnical



slope stability



hydrocarbons



unexploded ordnance

Thank You!

<http://disc2017.geosci.xyz>



minerals



contaminants



water



geothermal



geotechnical



slope stability



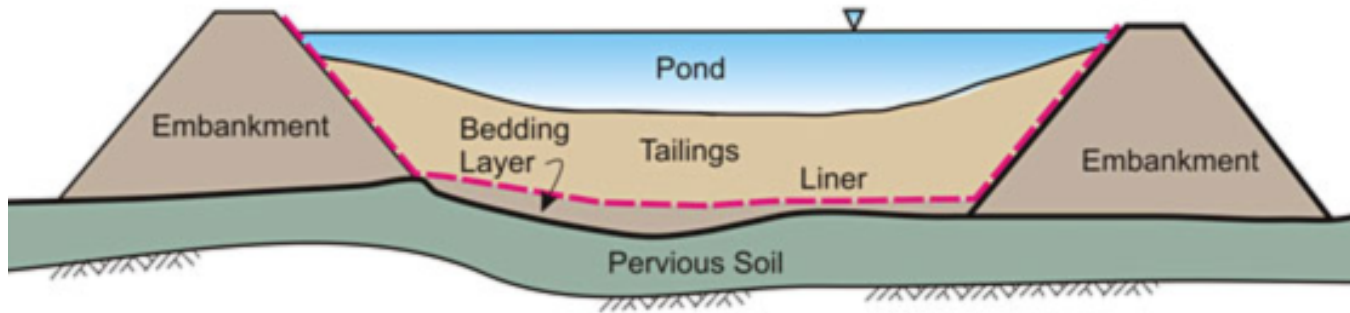
hydrocarbons



unexploded ordnance

The Future: Monitoring

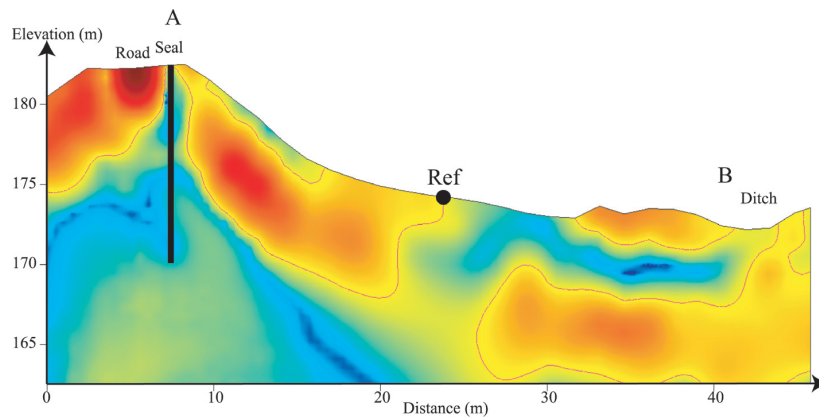
- Tailings Dam: How do we monitor?



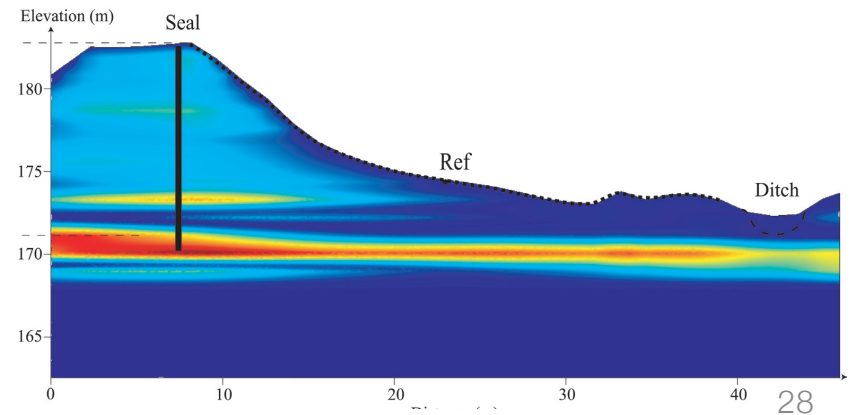
From the GARD Guide

- Self-potential and DC for monitoring Dam integrity

Conductivity

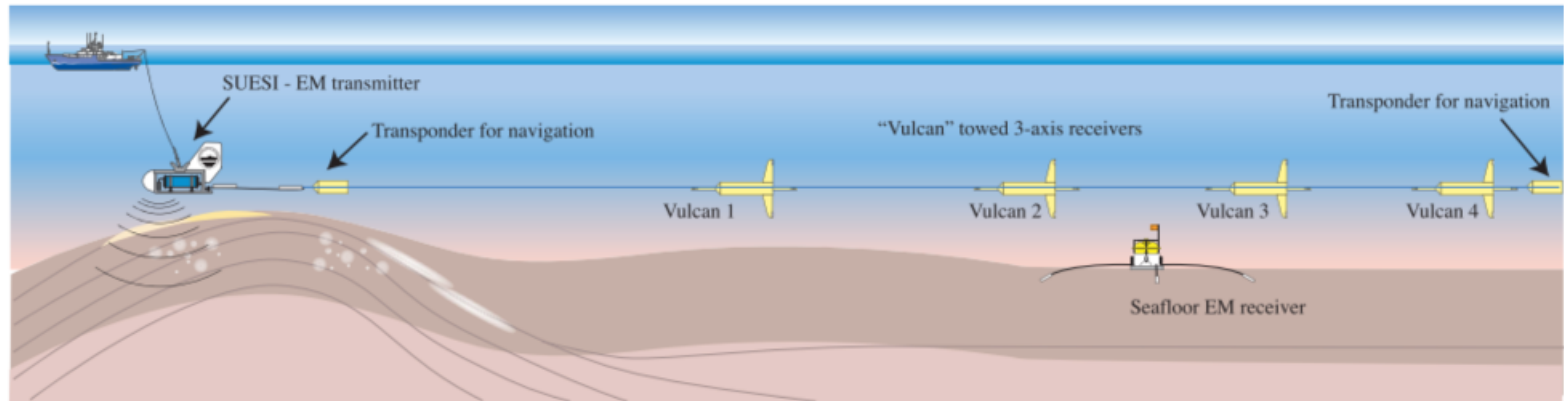


Streaming current



The Future: Marine EM

- Grounded source:
 - E.g. Vulcan system (towed + ocean bottom receivers)



Constable et al., 2016

- Inductive source:
 - E.g. Waseda Univ. (towed coincident loop; similar to AEM)

