

Mexican Collaborations - Projects XPLORE, XIBALBA, and XIB_TCS ^{22/09/2017}

Extended Karst Studies with Innovative Methods in Area of Tulum/Mexico

Aerogeophysics – hydr. Modeling – 3d Laserscanning – Laser Flux Imaging – TCS-Monitoring



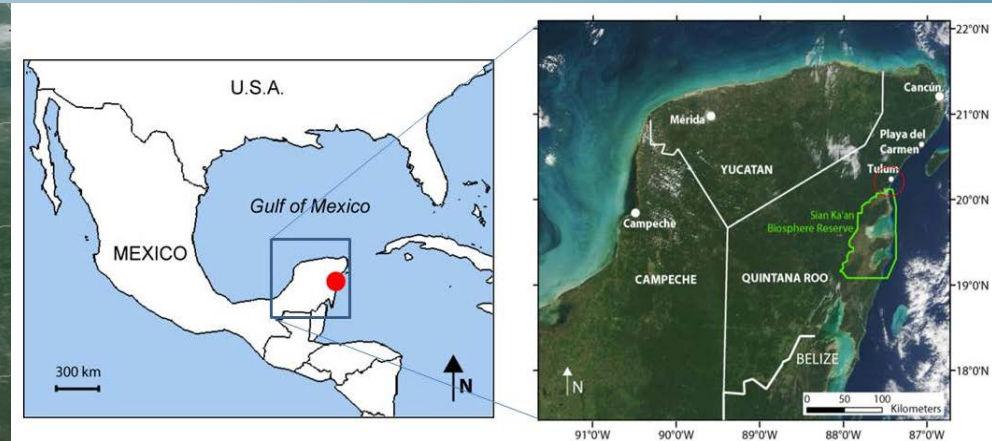
Arnulf Schiller



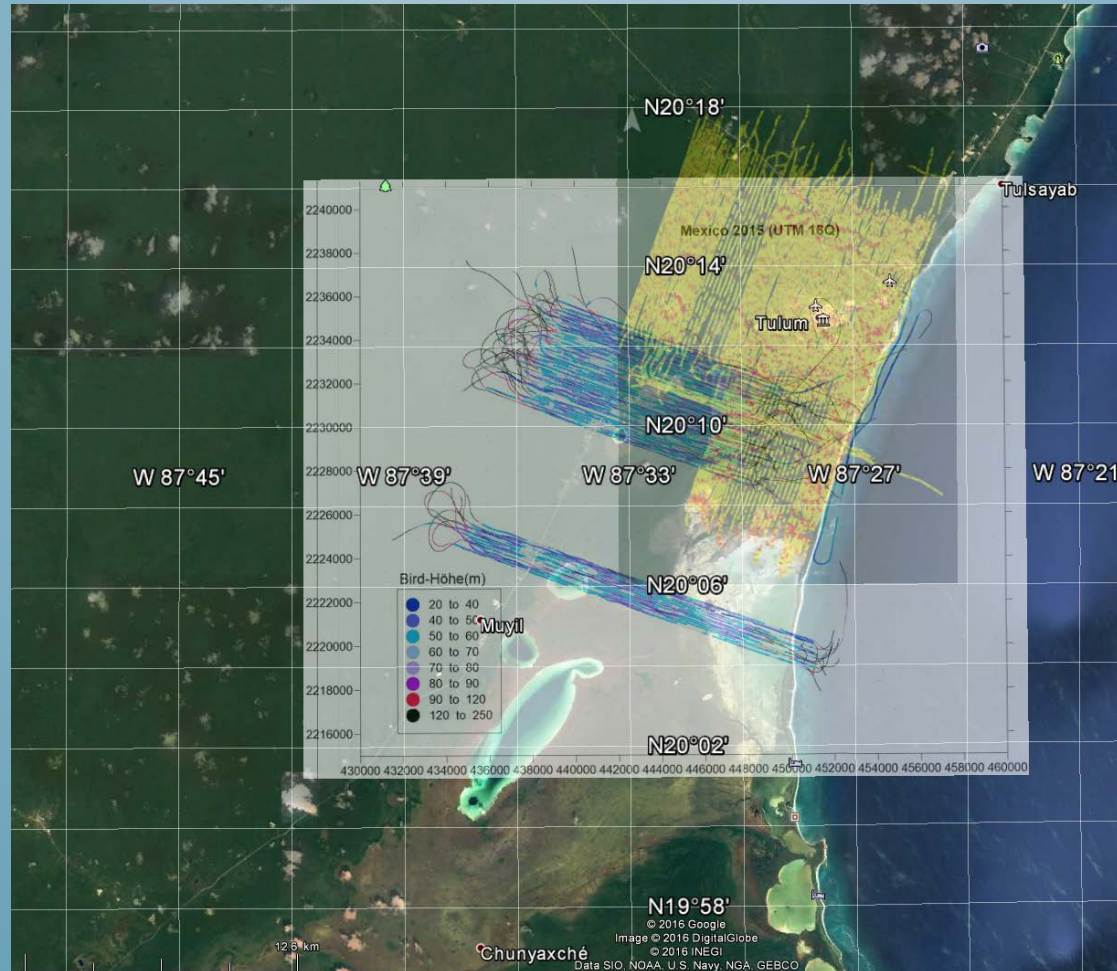
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The Survey Area – Tulum Karst Plain

- huge and difficult accessible coastal karst plain covered with forests, mangroves and lagoons
- variably consolidated limestones several 1000 metres thick.
- thin soil cover – limestone exposed at the surface
- flat topography (0 - ~50 m above mean sea level)
- known conduits/caves system explored by cave divers
- freshwater layer above saltwater body
- tidal variation of groundwater and halocline level reaching inland
- socio-economic impact due to urban development and increasing water demand
- climate change



AEM Surveys Tulum 2007, 2008 and 2015: approx. 250 km²



- Can **AEM** map the underground conduit system?
- Can a Karst water regime be modelled by **combining aerogeophysical and hydrogeological** input data?

Methodology:

Pilot surveys, simulation of measurement situation – estimation of expected measurement signal

AEM-Survey

electrical conductivity in the subsurface (through 1D-inversion)

El. Conductivity



*lateral and vertical distribution of **hydrogeological relevant structures** (due to distribution of porosity, water saturation, ion concentration, permeability, GWL, halocline) – Map of potential conduits.*

Structural information from AEM and underwater cave surveys



Groundwater model (UNINE)

Archie's law (Archie 1942)

Calibration of AEM-measurements and groundwater model by ground survey data (ERT, bore hole geophysics, piezometry, GPR)

$$\rho_e = a\phi^{-m}S^{-n}\rho_w$$

2.28

ρ_e ... spezifischer elektrischer Widerstand der Formation

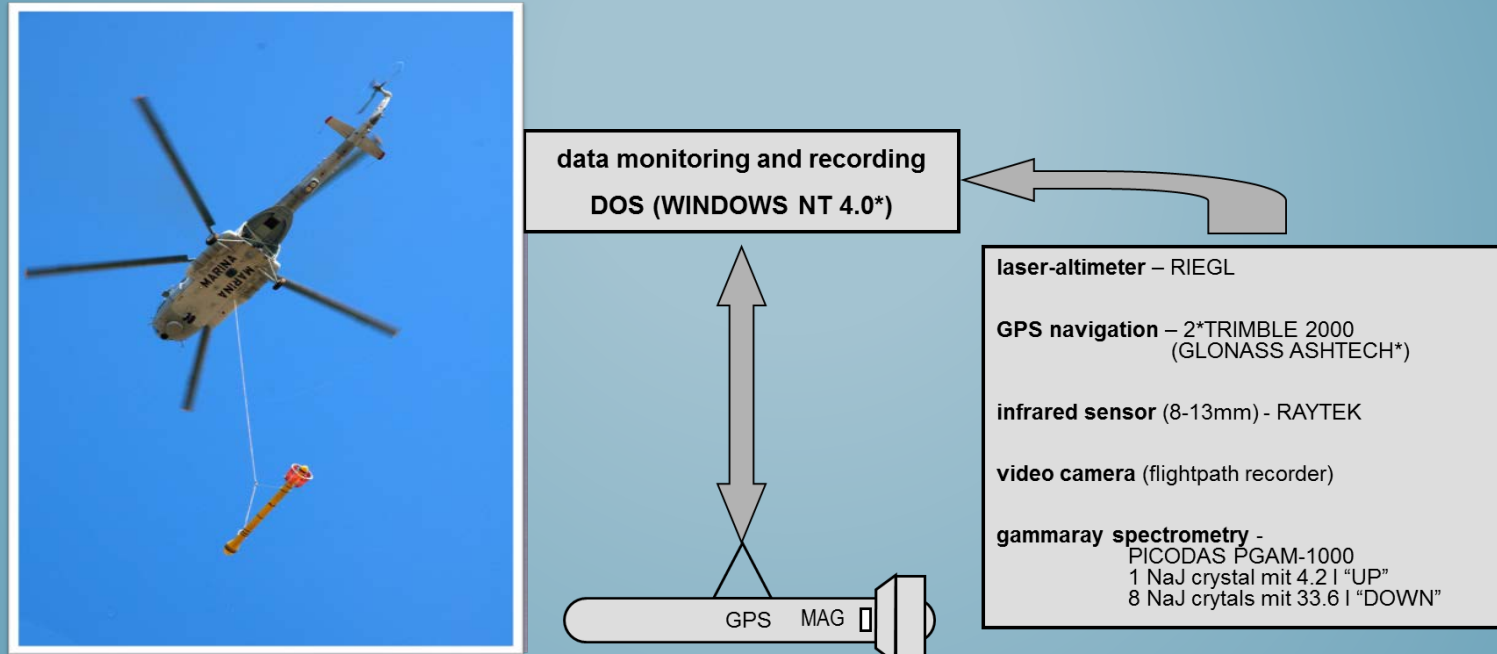
ρ_w ... spezifischer elektrischer Widerstand der Porenflüssigkeit (zumeist Wasser)

ϕ ... Porosität

S... Sättigung (Anteil des Porenvolumens das mit Flüssigkeit gefüllt ist)

a, m, n... empirisch bestimmte Konstanten

The measurement system



AIRBORNE SENSOR - HUMMINGBIRD

4 frequency electromagnetic system

- $f_1 = 340$ Hz horizontal coplanar loops
- $f_2 = 3200$ Hz vertical coaxial loops
- $f_3 = 7190$ Hz horizontal coplanar loops
- $f_4 = 28850$ Hz vertikal koaxial loops

Cesiumtype magnetometer Scintrex CS-2

**The Austrian
Airborne System**

Helicopter provided by the Mexican Marina (MilMi - 8)





22/09/2017



load specialist

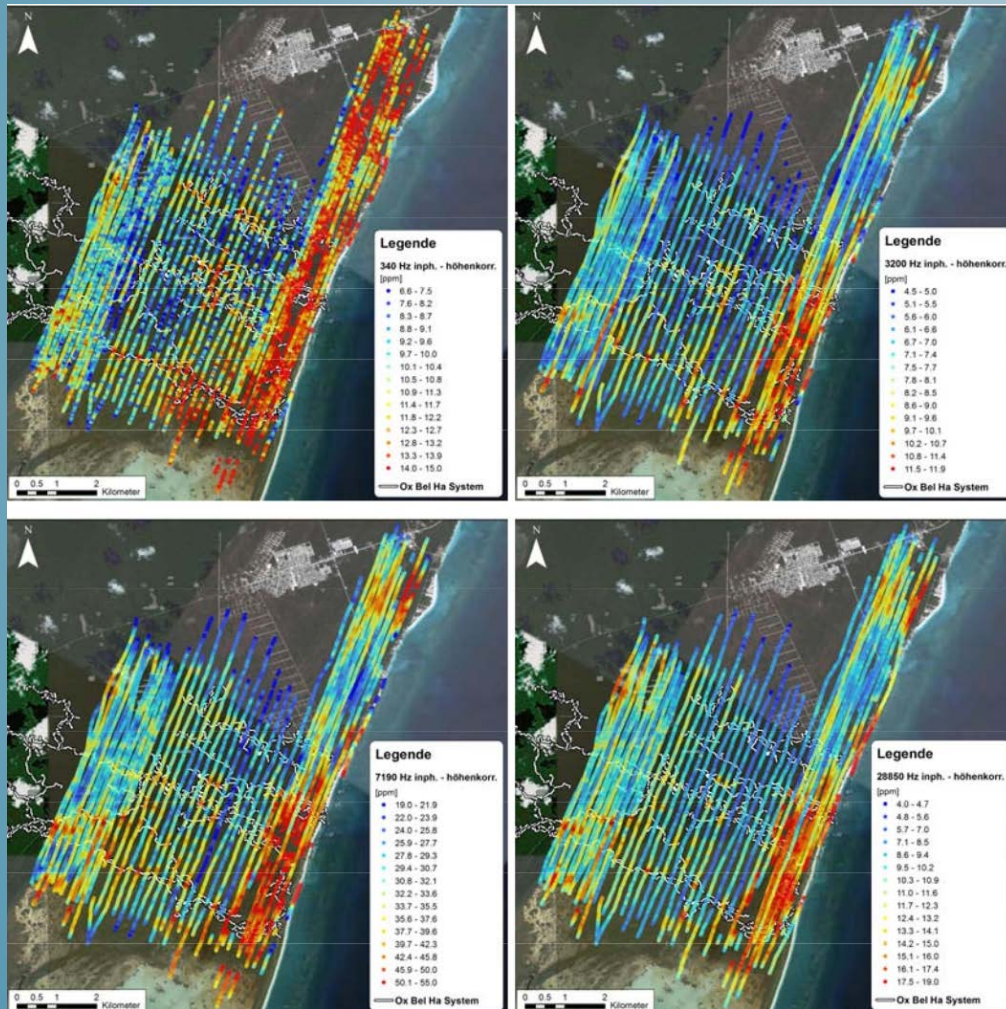


Bird 30 m below the helicopter

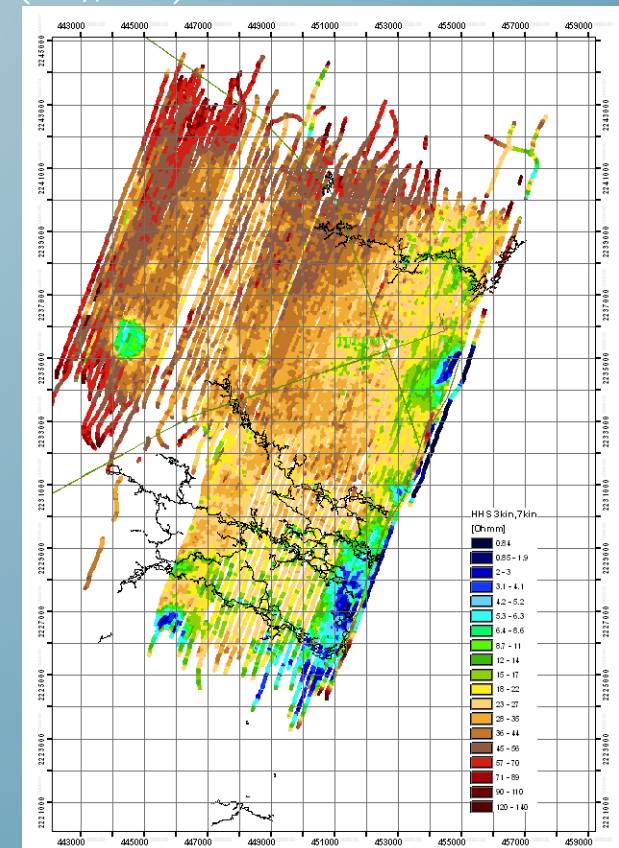
The 2007/2008 AEM surveys –first results

known caves are detected – some indication of further conduits

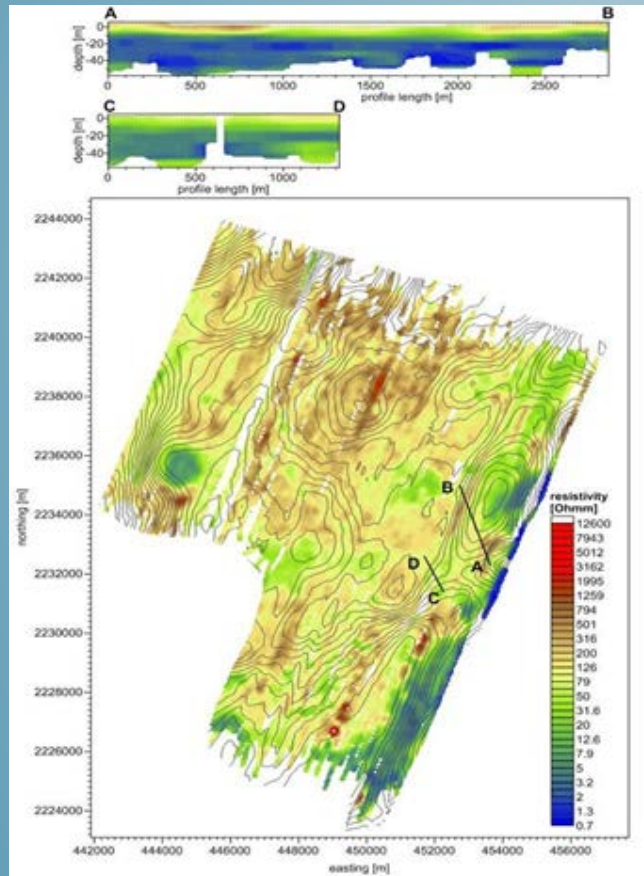
Edited and height reduced raw signal (ppm) of all inphase components (2007)



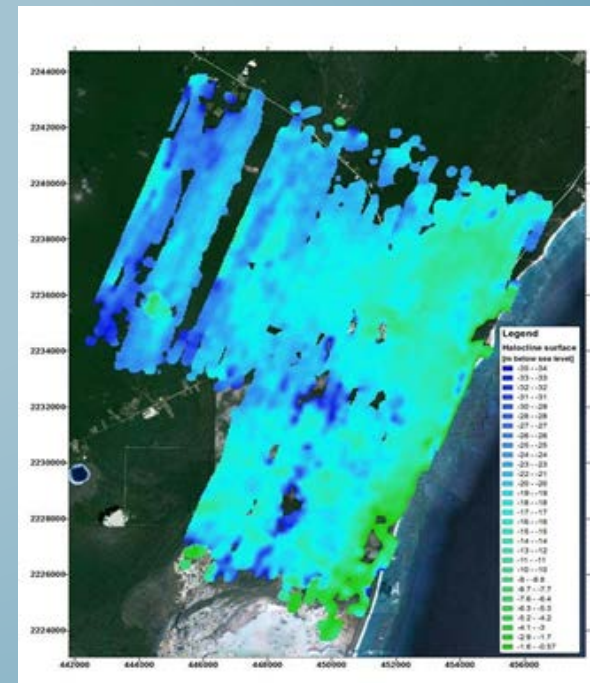
Halfspace inversion from 3k_in, 7k_in – phases (2007/2008)



AEM-data inversion
surface layer and two sections
(software: UBC EM1DFM)



Estimated topography of
halocline



Resistivity ranges found:
Above halocline: 10 to 200 Ohmm
Below halocline 0.7-50 Ohmm

Seawater: 0.2-0.25 Ohmm
Freshwater: around 4 Ohmm
Brakish water: around 1 Ohmm

How to get out more information?

adapting AEM pre/post-processing for enhancing signals of possible conduits

* Pre-Inversion-Processing (on raw/ppmdata)

- 1) System drift analysis
- 2) Automatic drift correction
- 3) Estimation and correction of residual drift by analysis of vertical field gradient.
- 4) De-stripping (type of levelling)
- 5) Qualitycontrol/editing

* 1D-Inversion (UBC EM1DFM)

* Processing of inversion results:

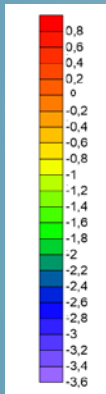
- De-stripping (type of levelling).
- Reduction of vertical gradient



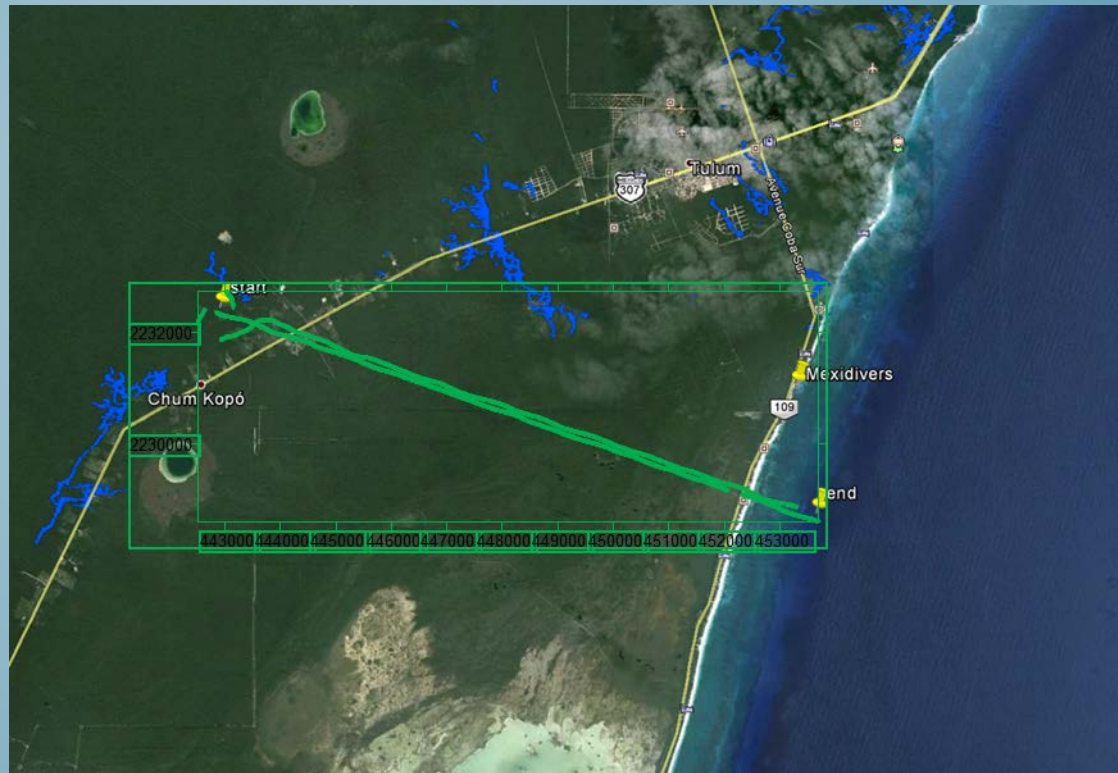
2007/2008 f3_in , reduced to 40 meters above ground, meanfree.

Sections

Detection of fresh water layer, mixing zone and salt water saturated limestone



Electrical Conductivity Log₁₀[S/m]



Line YUK001, 2008-survey

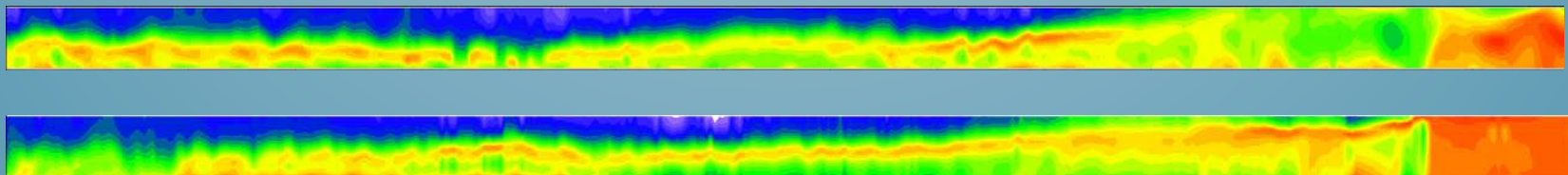
Fresh water layer (blue)

~ 10 km

Low wet land

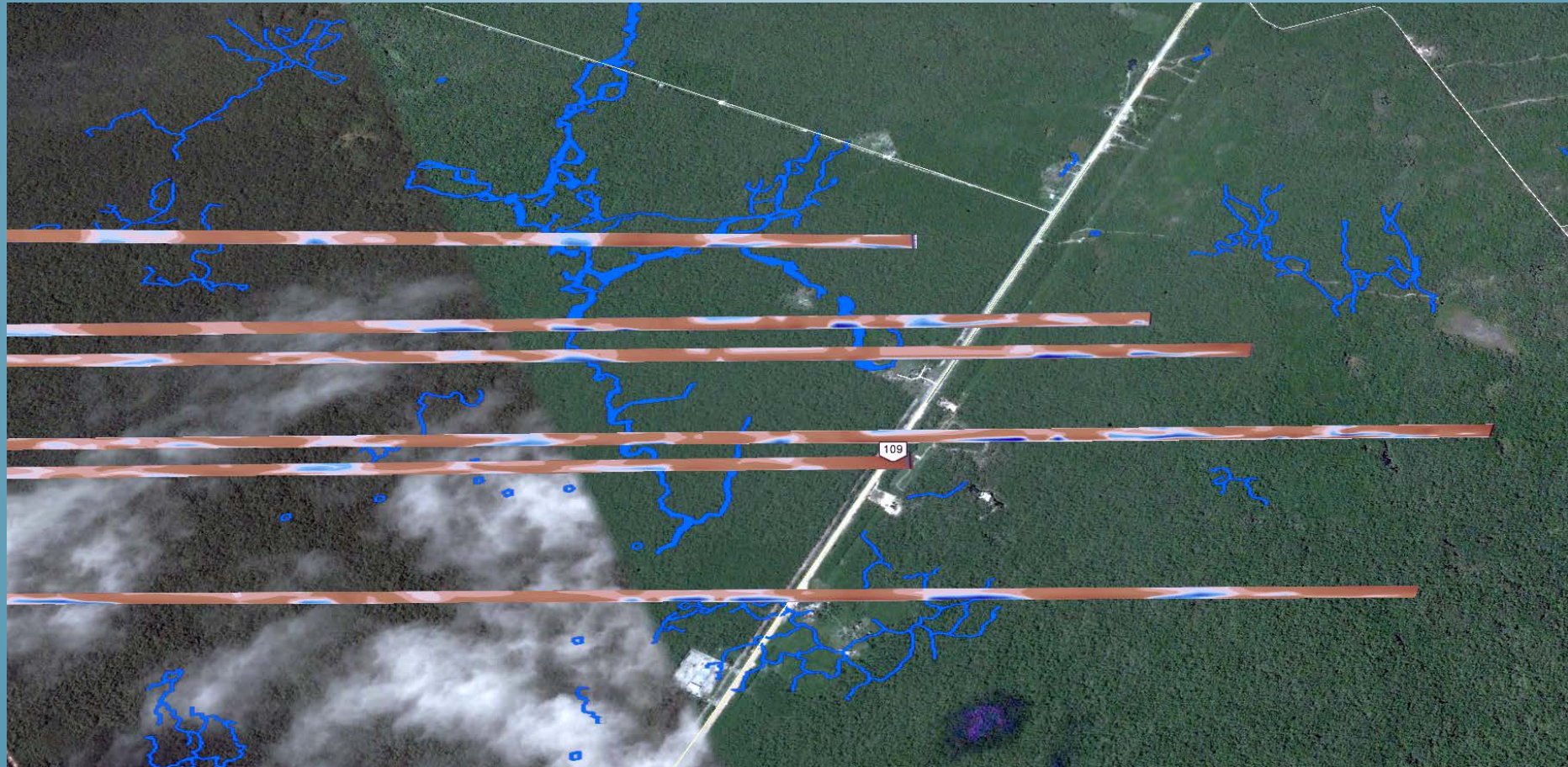
reef

50 m depth

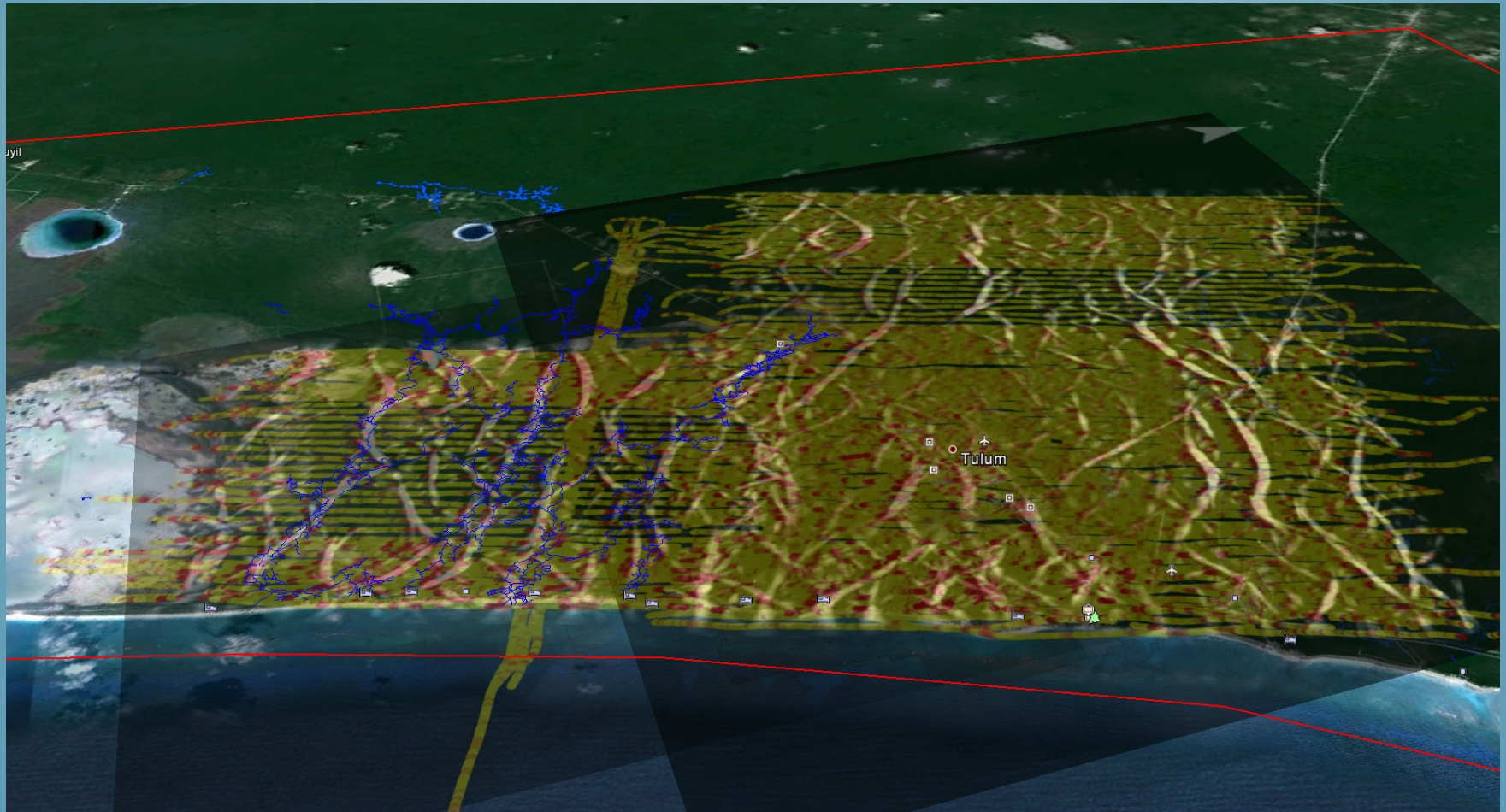


Salt water body (yellow-red)

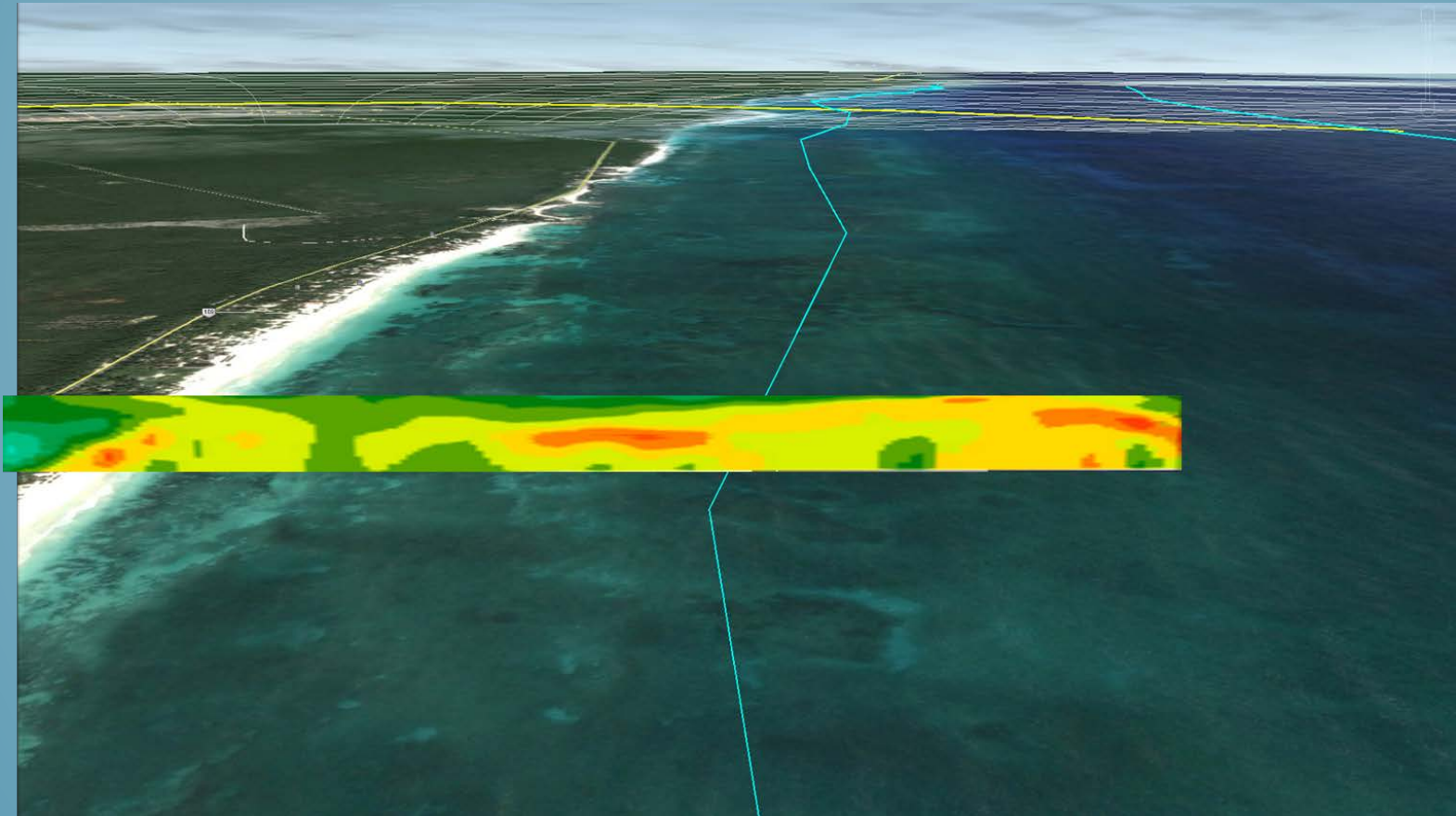
Background reduced sections crossing surveyed cave system



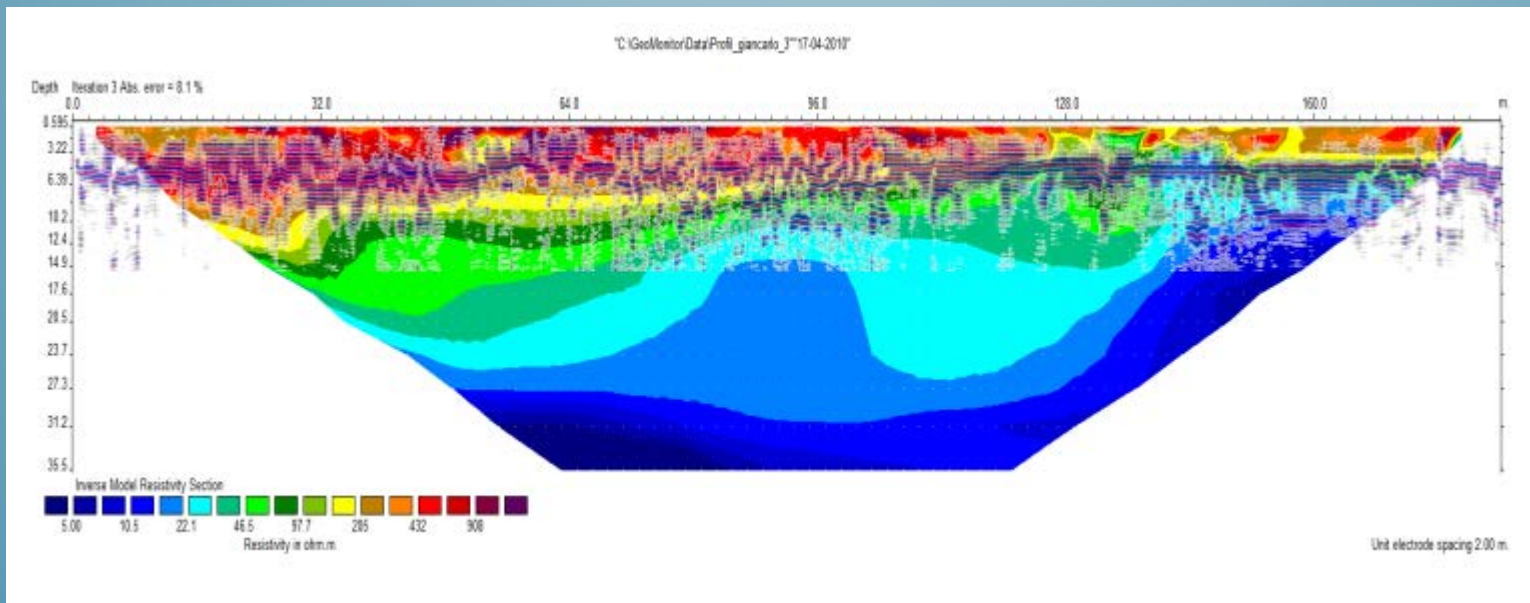
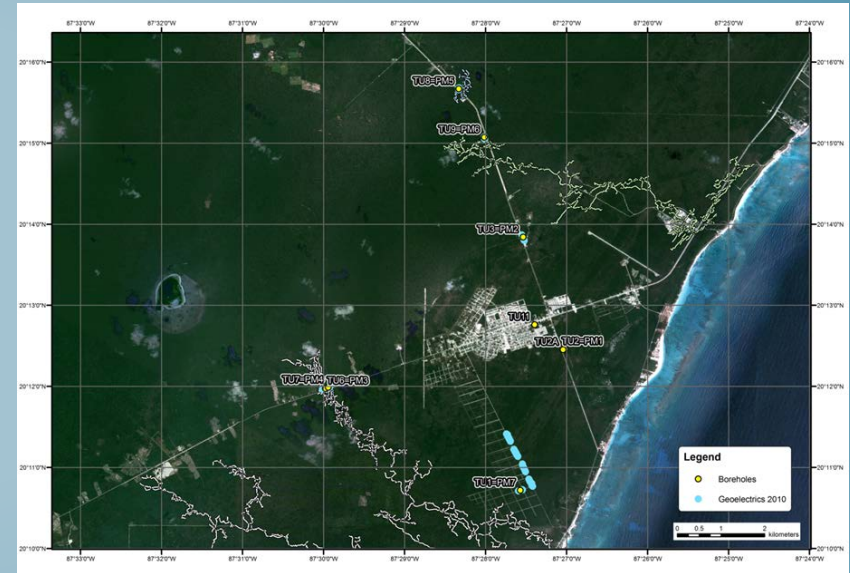
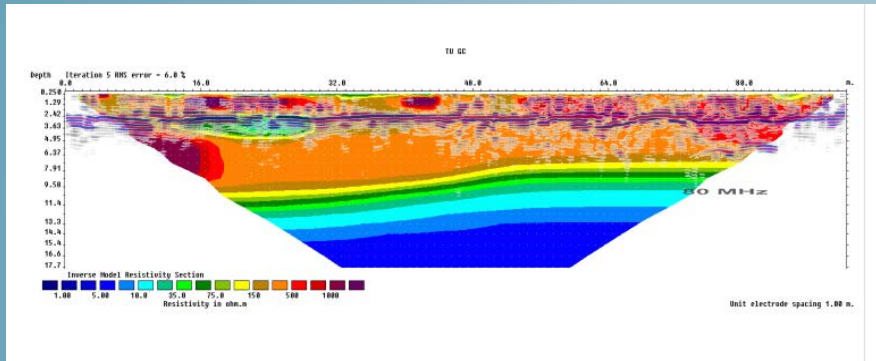
Results: Overview of conduit network (from 2007 and 2008 AEM data)



Inversion line YUK001 (2008) – section of reef structure?



Example: Geoelectrics and GPR

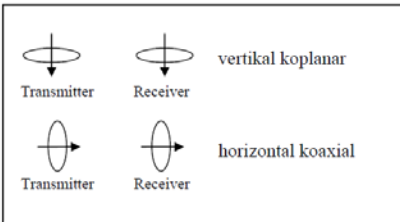


Gracias!

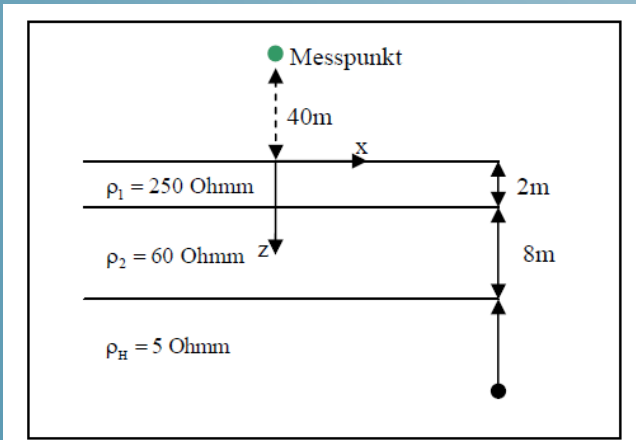


System

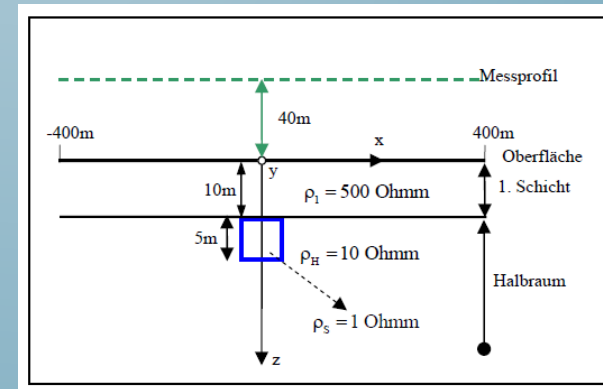
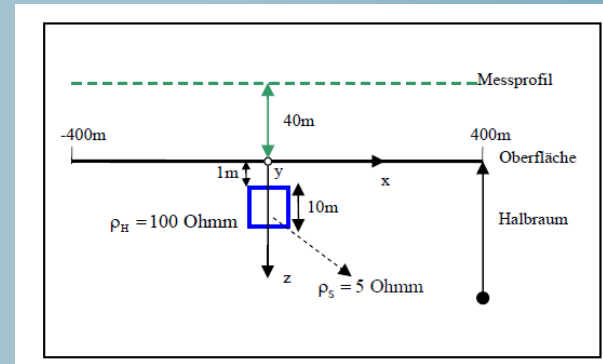
	Frequenz [Hz]	Konfiguration	Abstand (Tx-Rx) [m]
Messwert 1 (f1)	340	vertikal koplanar	4.53
Messwert 2 (f2)	3200	horizontal koaxial	4.53
Messwert 3 (f3)	7190	vertikal koplanar	4.49
Messwert 4 (f4)	28850	horizontal koaxial	4.66



Layered halfspace



Halfspace with conduits



Emigma, 1d