Advanced Processing of Airborne FDEM Data for Improved Imaging of Karst Conduits in Tulum, Mexico

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The Survey

The survey area is located at the south-east coast of the Yucatan peninsula near the mexican town of Tulum and part of an extended Karst water study including ground geophysical surveys and cave exploration. General goal is to provide aero/ground-geophysical data for innovative hydrological modeling approaches developed by the Swiss partner at the University of Neuchâtel - Center for Geothermics and Hydrogeology (Vuilleumiere 2012, Kaeser 2016). The only significant freshwater resource is confined in a thin groundwater top layer floating on salt water intruding from the sea, both moving through an extended hidden conduit network.

Airborne electro-magnetic (AEM) surveys have been conducted in 2007, 2008 and 2015 in cooperation of Geological Survey of Austria, Amigos de Sian Ka'an and Mexican Marina. First data proved that Karst conduits deliver signal but covered by stochastic texture caused by karst structures as well as by measurement noise. Advanced data processing techniques, however, revealed the picture of a vast conduit network and processible data for hydrological modeling. The 2015 AEM survey focused on imaging possible extension of the Hol Box fault zone south of Tulum, so the flight line orientation was chosen perpendicular to the coast (optimizing sensitivity). The methods capability above wetland, laggons and sea was investigated.

The Austrian airborne geophysical measurement system integrates a four channel FDEM sensor (,bird'), a caesium type magnetometer, gamma ray spectrometry with 78l NaJ crystals, IR-camera and a laser altimeter. The helicopter was provided by the Mexican Marina. The sensor is flown approx. 50 meters above ground and performs 1 sounding every 3 metres averaged.
In the 2015 survey electro-magnetics and radiometry has been applied.

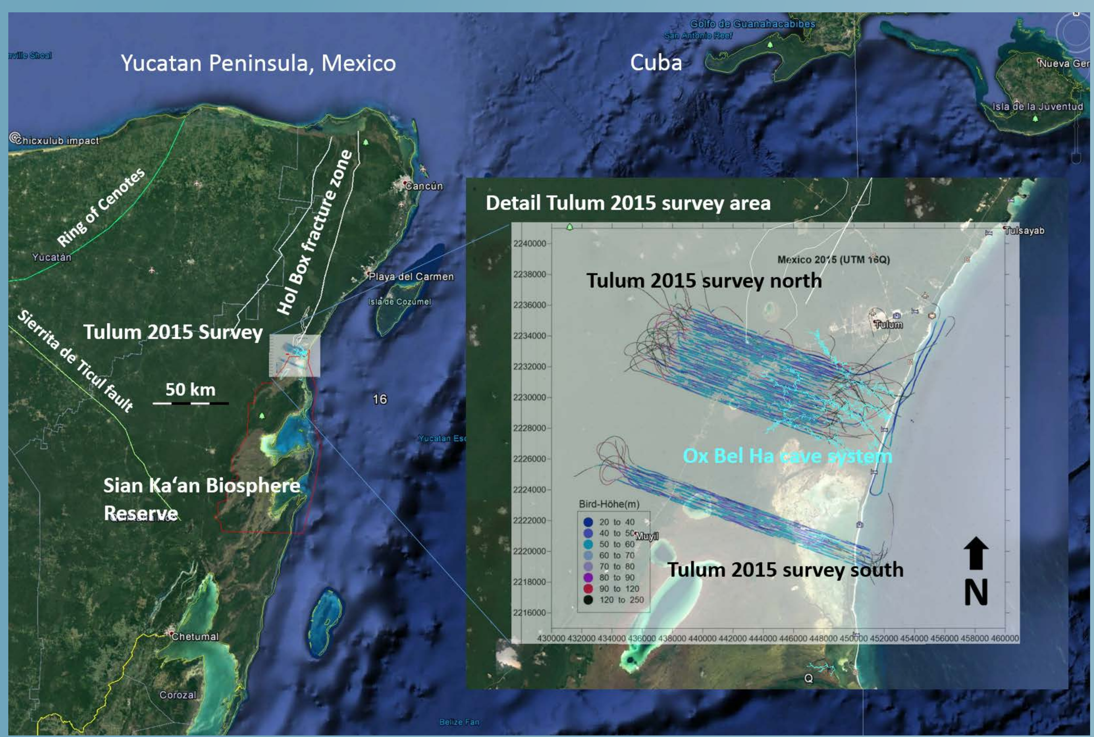

Fig.1 – survey area south of Cancun with flight lines. Coordinates UTM 16N.

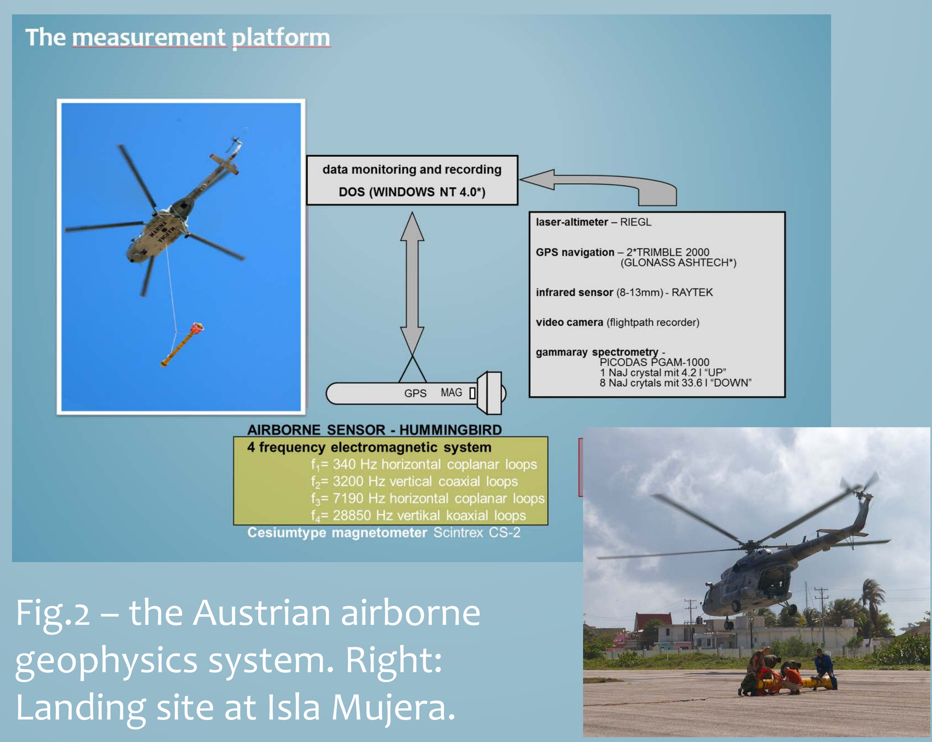

Fig.2 – the Austrian airborne geophysics system. Right: Landing site at Isla Mujera.

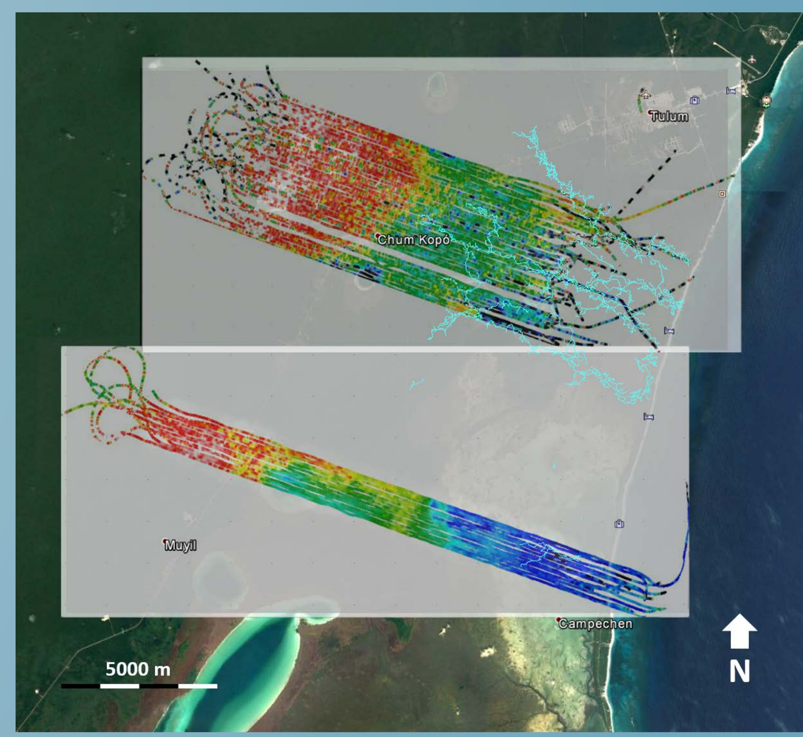

Fig.3 – raw signal, strip reduced: red: low response related to dry rock. Blue: high response related to wetland and lagoons.

Advanced AEM-Data Processing

Reduction of signal drift:
The raw AEM-data is corrupted by different types of drift and noise, mainly temperature/tuning - caused. For drift correction three methods have been applied:

1) ***In-line nulling***: Soundings conducted above a certain height limit are assumed to deliver near zero signal. Hence the drift-offset can be estimated during measurement.
2) ***Signal-height correlation***: The height decay of the signal is fitted by a model and extrapolated to infinity. From that the residual drift offset can be estimated.

3) De-stripping: residual drift causes strip artefacts in ppm-data and inversion results. This can be overcome by an effective de-stripping scheme which approaches the basic strip-free model and reduces strips significantely.

Reduction of dominant background in inversion results:
One problem in this case study was to image the conduit network, so small anomalies had to be captured. In the raw inversion results conduits are poorly indicated. After modeling and reducing the governing gradient field caused by the deeper saltwater body potential conduits show up clearly (Figs.6,7).

Enhancing linear structures:
In the de-stripped raw data and inversion maps conduits are indicated but covered by stochastic variations caused by geology and system noise. Based upon the assumption the conduits building a connected network of linear structures a filter has been designed which is able to enhance possible connections significantly (Fig. 5). First of all this is an interpretational support tool.

Results

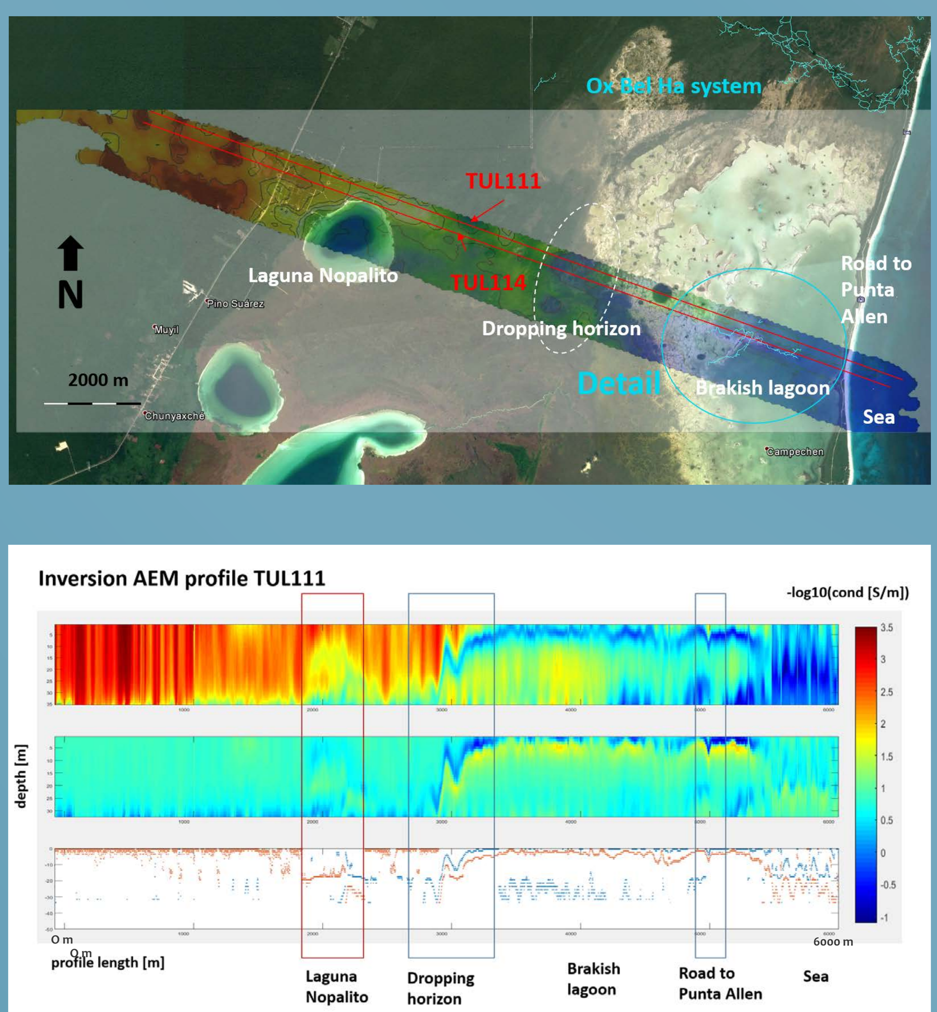

Fig.4 – top: South survey: Inversion map for 25 m depth layer with lines TUL 111 and 114. Overlay with satellite imagery (Google Earth). Bottom: South survey: inversion result – depth section of line TUL111 - top: conductivity. Middle: vertical gradient. Bottom: horizons extracted from vertical gradient.

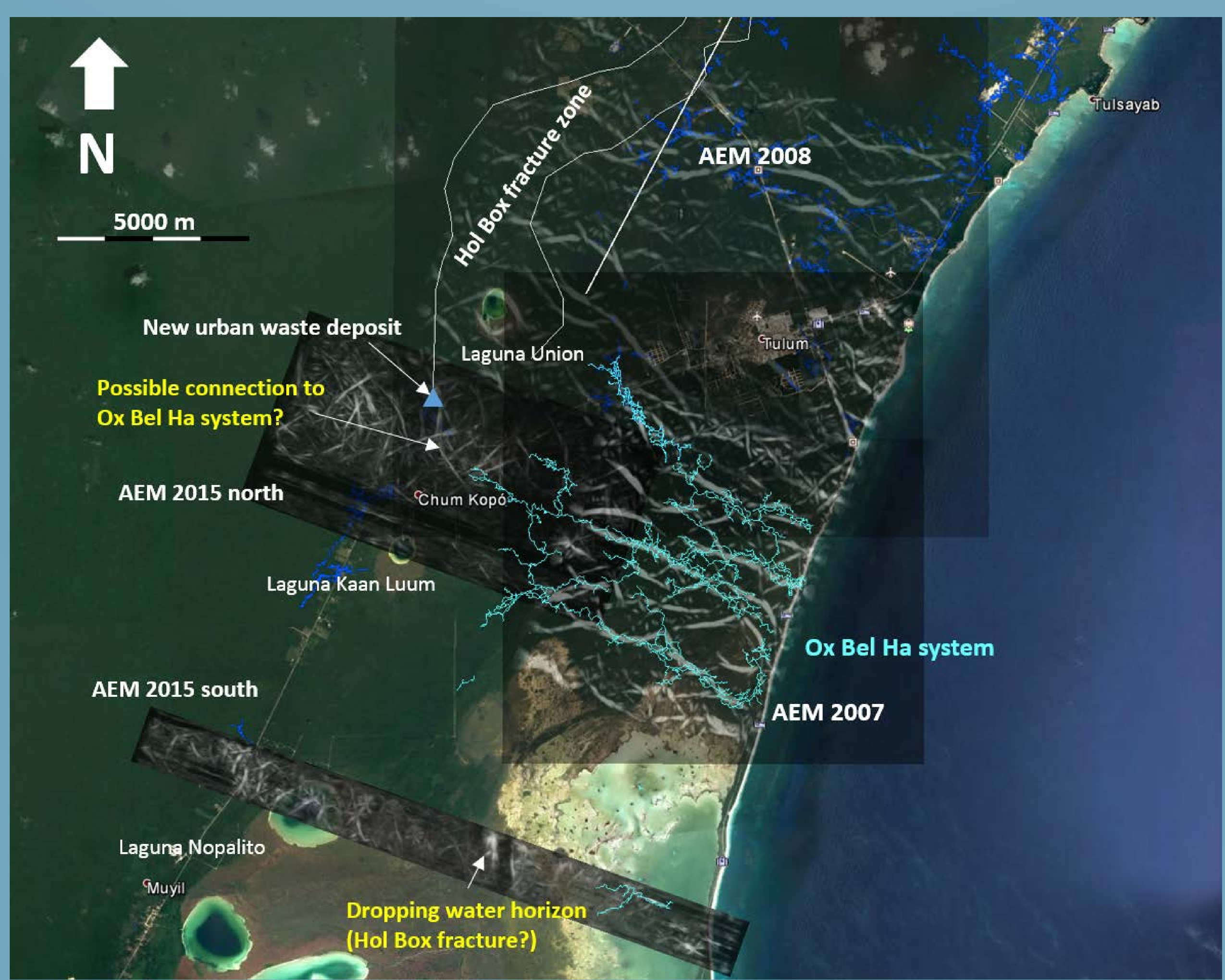

Fig.5: Combined conduit maps of 2007, 2008 and 205 surveys revealing a possible conduit near the new waste deposit connecting to the Ox Bel Ha system. In the south part a structure shows up correlating with the dropping water horizon in Fig. 4. This may refer to an inclining fault of the Hol box fracture zone.

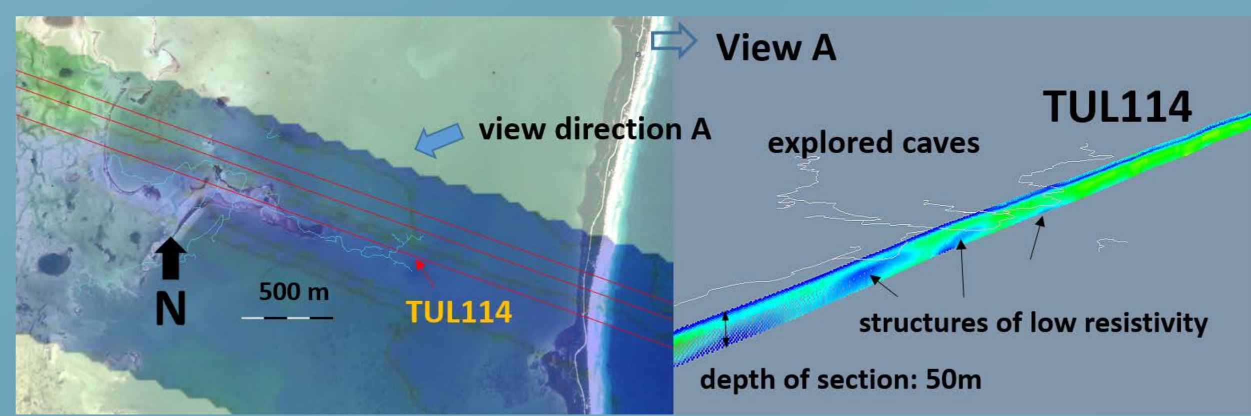

Fig.6 – examples of vertical sections. top: Detail of line TUL114 in the lagoon - top right: perspectivic view to section cutting known caves.

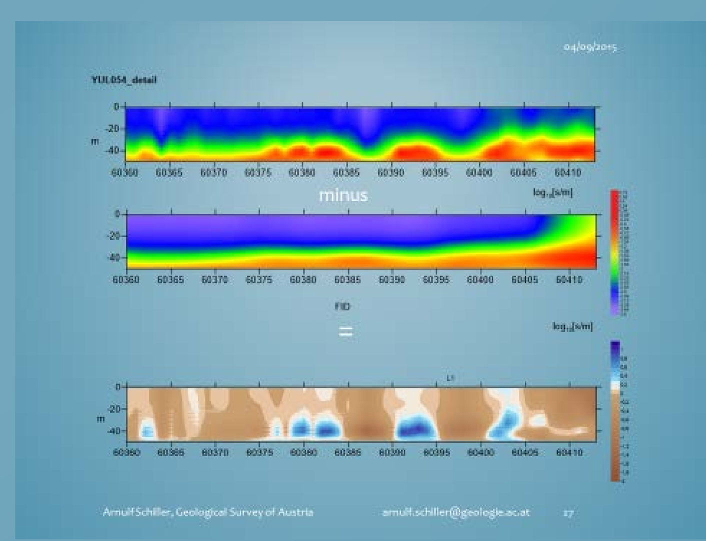

Fig.7 - top: example of raw inversion result.
Right-middle: Gradient field.
Right-bottom: Residual anomalies with interpretation - blue: conduits, brown: Limestone matrix. Actually the plots show pure electrical conductivity, whereas high values indicate higher concentration of water.

Conclusion

Advanced AEM data processing provides automatic and effective damping of noise and drift artefacts while approaching a realistic underlying underground model. It has been developed in the context of a special problem statement which combines aerogeophysics with novel hydro-geologic modelling methods. It improves the imaging capability of a common AEM configuration significantly, so AEM can serve as a useful tool in karst studies especially in hardly accessible coastal regions with moderate topography. The Mexcian revealed significant flight line sensitivity of the method providing completing information. Low conductive fresh water gives similar signal as water saturated limestone, so low contrast. Saltwater aquifers give a strong signal. Stochastic representation of the karst structures partially overlap with system noise.
The Tulum surveys for the first time imaged a complex karst conduit network by AEM and increased the extractible information content of AEM-data in order to support innovative Karst studies.

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Reference:

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