We AEM P07 - *Advanced Processing of Airborne FDEM Data for Improved Imaging of Karst Conduits*

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The Survey

The survey area is located at the south-east coast of the Yucatan peninsula near the town of Tulum and scientificely embedded in an extended Karst water study including also ground geophysical surveys and cave exploration. Goal is to provide aero/ground-geophysical data for an innovative hydrological modeling approch developed by the Swiss partner at the University of Neuchatel - Center for Geothemics and Hydrogeology. All freshwater is flowing underground in an extended hidden conduit network.

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 (see flightlines below – vertical: 2015, horizontal: 2007 and 2008). First data proved that Karst conduits deliver signal but considerably covered with stochastic texture caused by karst geology as well as by measurement noise (see red signatures above yellow in 2007/2008 survey, blue: cave survey stick line data of from cave explorers).

The Austrian airborne geophysical measurement system integrates a four channel FDEM sensor, a caesium type magnetometer, gamma ray spectrometry with 78l NaJ crystals, IR-camera and a laser altimeter. The helicopter for the mexican surveys was provided by the Mexican Marina. The bird is flown approx. 50 meters above ground and performs 1 sounding every 3 metres averaged.

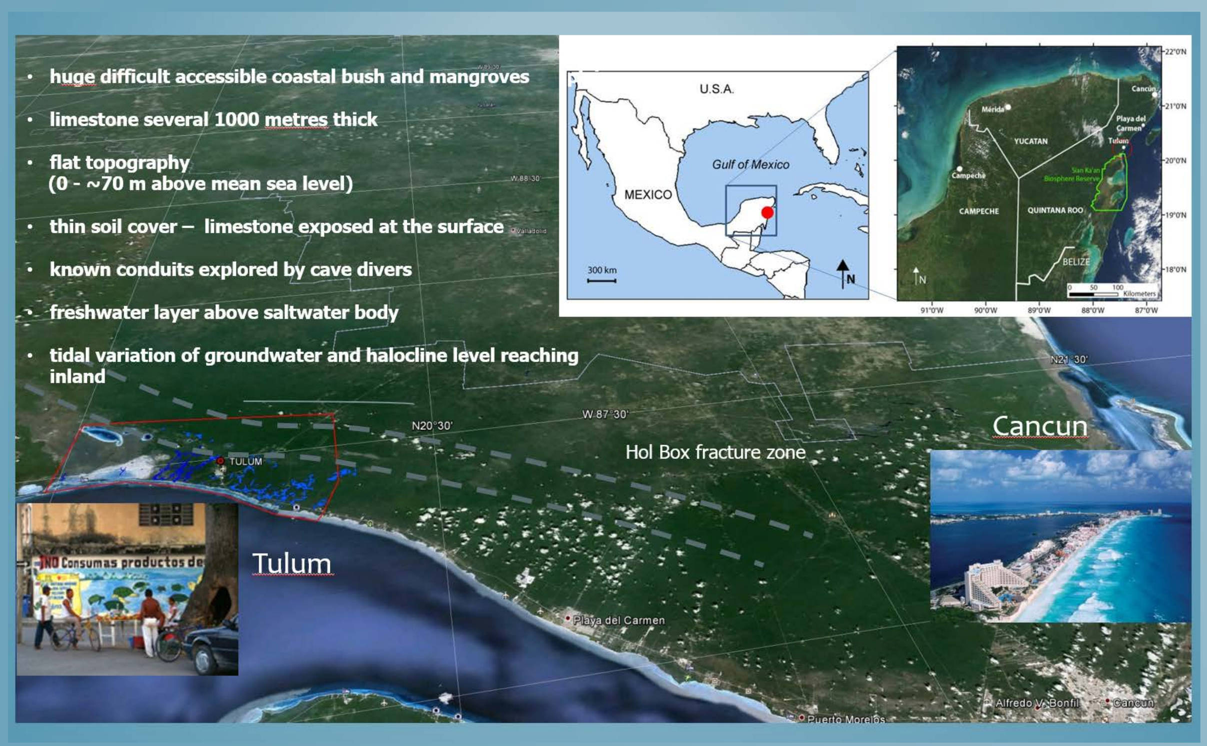

Fig.1 – situation of survey area

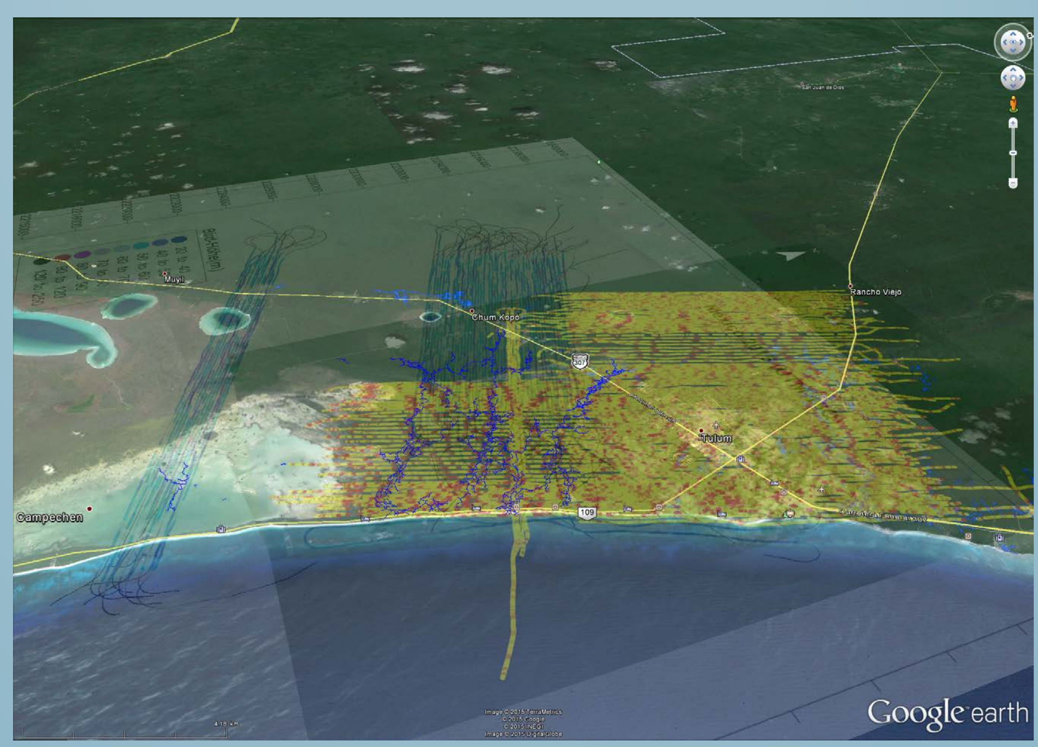

Fig.2, flight lines 2007-2015 and raw ppm data of 2007/8 (f2_in).

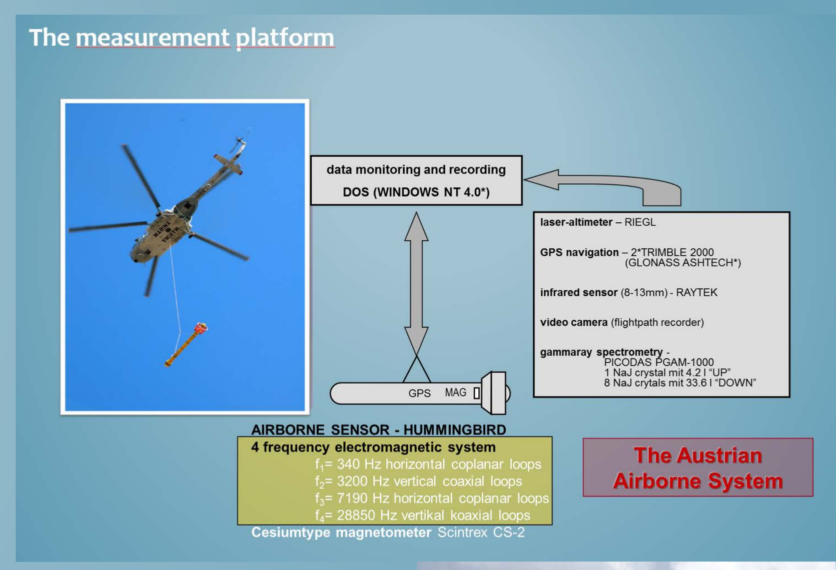

Fig.3 – the Austrian Airborne geophysics System.

Data Processing

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

1) ***In line nulling***: Soundings conducted above a certain height limit are supposed to deliver near null signal. So the drift-offset can be estimated in line.
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 with an effective novel de-stripping scheme which approaches the basic strip-free model and reduces strips significantly (fig 4.: synthetic test).

Reduction of dominant background in inversion results:
The special 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 weakly indicated. After modeling and reducing the governing gradient field caused by the deeper saltwater body potential conduits show up clearly (Fig.5,7).

Enhancing linear structures:
In the de-stripped ppm 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 (Figs. 6, 9). First of all this is an interpretational support tool.

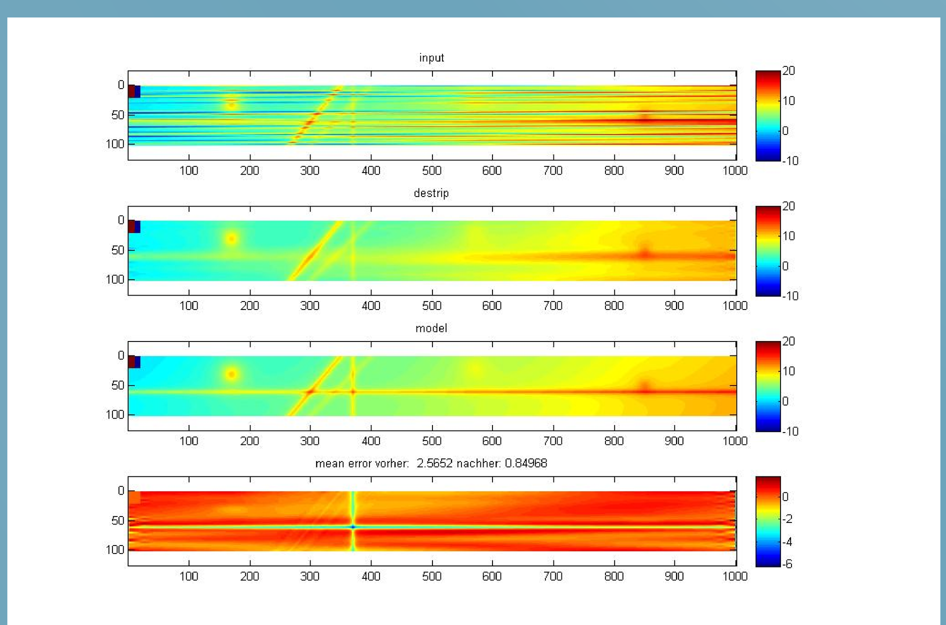

Fig.4 – Test of de-stripping scheme.

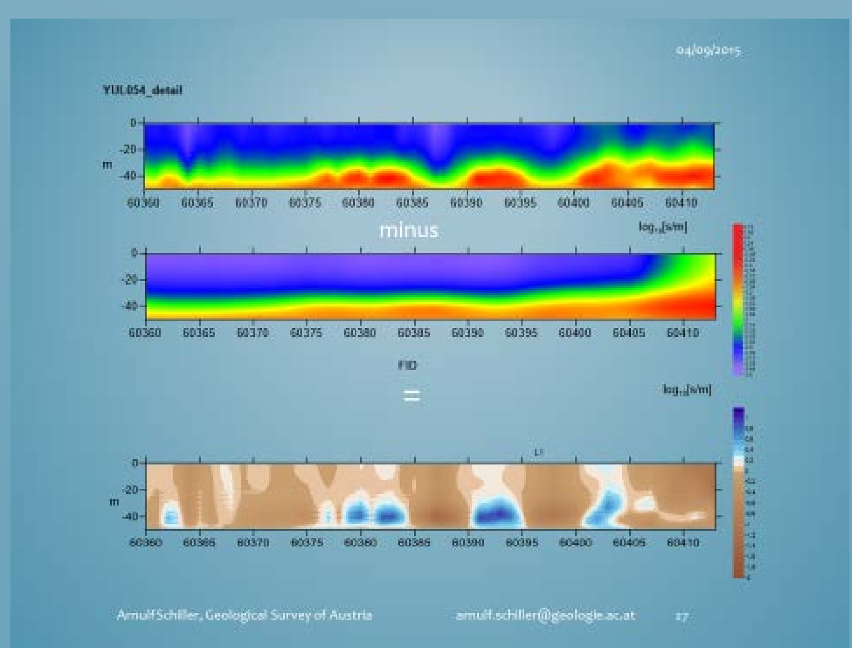

Fig.5 – vertical section. Top: raw inversion result. Middle: Gradient field. Bottom: residual anomalies.

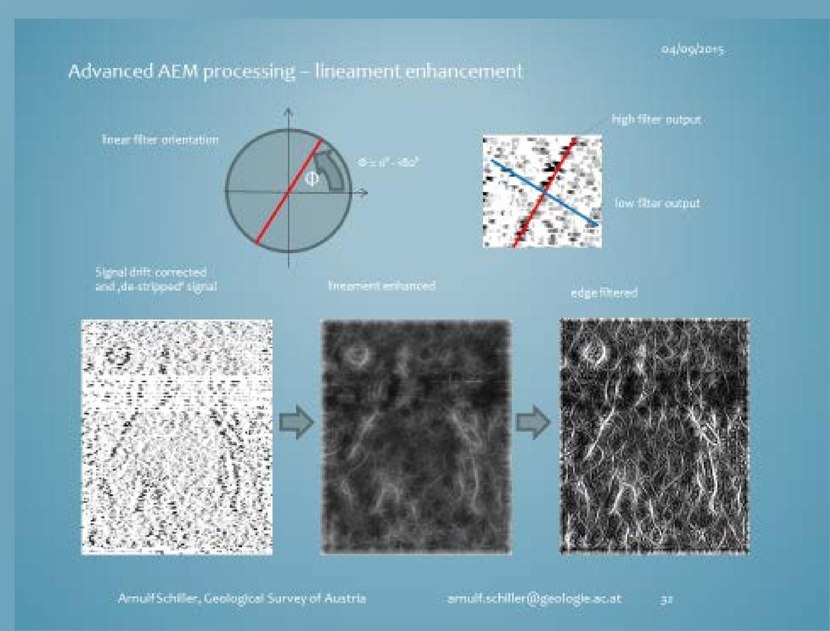

Fig.6 – linear feature enhancement in noisy data.

Results

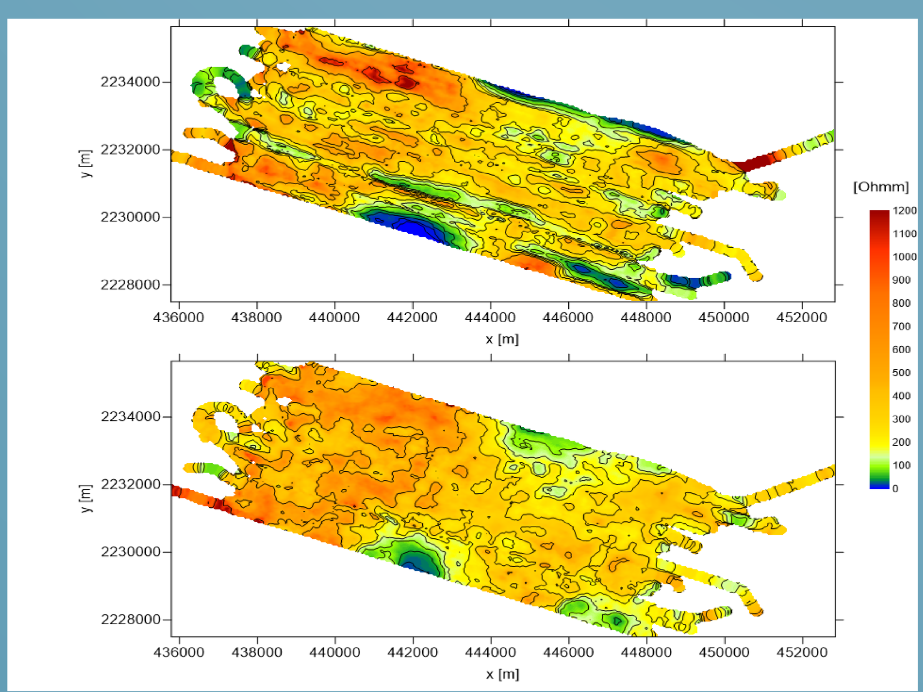

Fig.7 – Tulum 2015 survey – north part. Inversion result of upper layer (0-3 m). Top: raw ppm data input, bottom: de-stripped ppm data input.

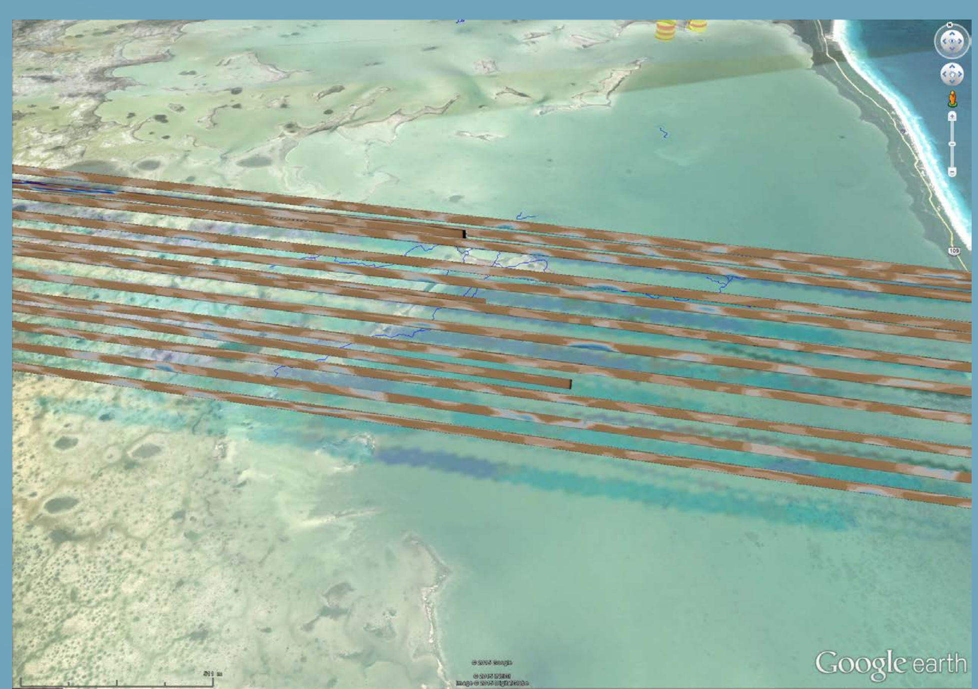

Fig.8 – Tulum 2015 survey - south part. Vertical sections after background reduction (50 m depth).

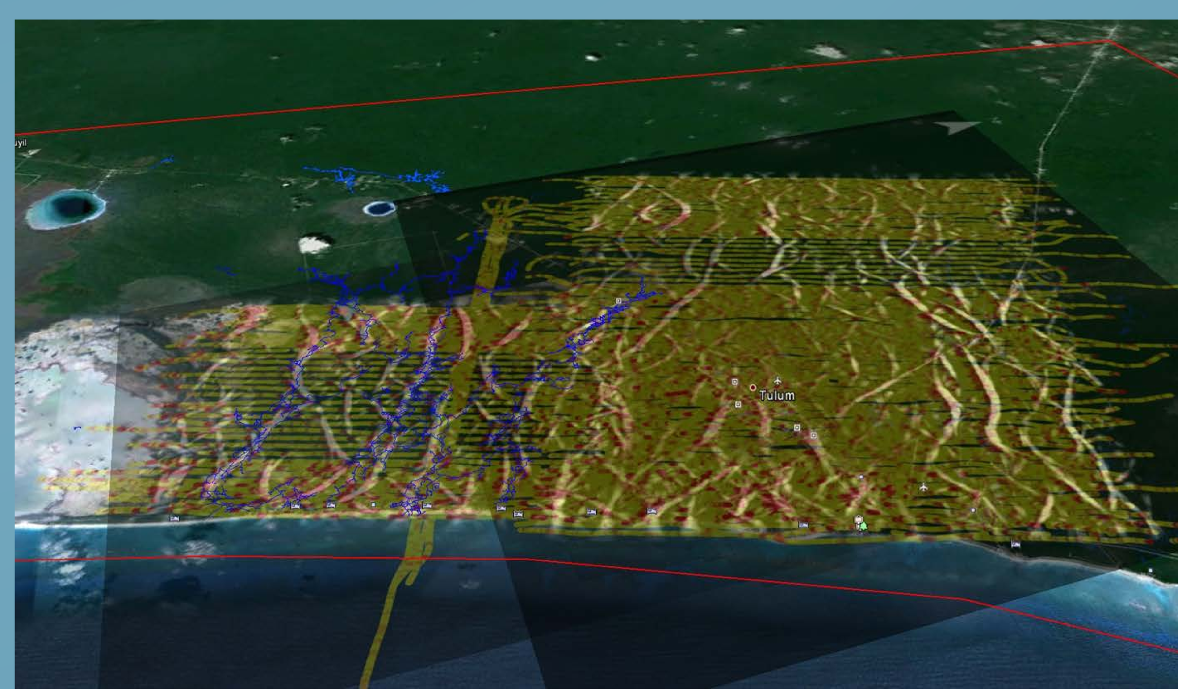

Fig.9 – Tulum 2007/8 survey – imaging of conduit network by means of lineament enhancement.

Conclusion

The presented processing sequence 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. However, drift estimation and correction techniques (de-stripping) as well as inversion data processing and linear feature enhancement improve the imaging capability of a common HEM system significantly – no hardware adaptions have been conducted yet. Advanced processing combined with an advanced sensor could achieve even more for studies in Karst ground-water regimes, permafrost till to ocean studies (imaging of sea water conductivity layering for estimation of temperature and salinity down to depths of several 10 metres). This could result into a valuable tool for investigating polar ice melting, arctic estuaries, fresh water lenses, ocean-atmospheric heat balance in storm regions as well as permafrost thawing.
It is the only tool capable to scan in-depth over large/inaccessible areas in short time. Further development is in progress, collaboration is highly appreciated.

Acknowledgement: We want to thank the supporting cave explorers of Tulum providing us important stick line data as ground truth.

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