Advanced airborne electro-magnetics for capturing hidden conduits and hydrological parameters by helicopter over the Ox Bel Ha karst conduit system (Quintana Roo, México)

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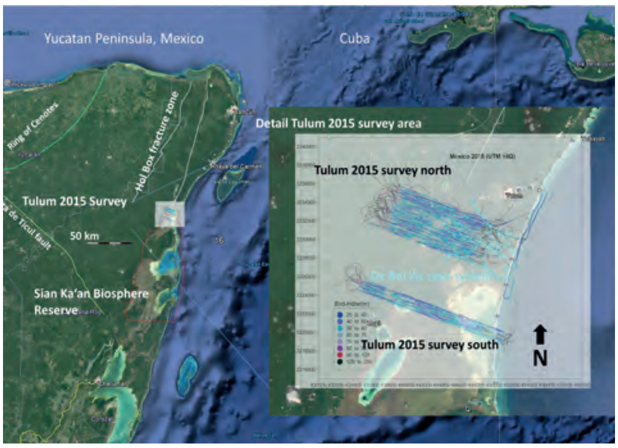
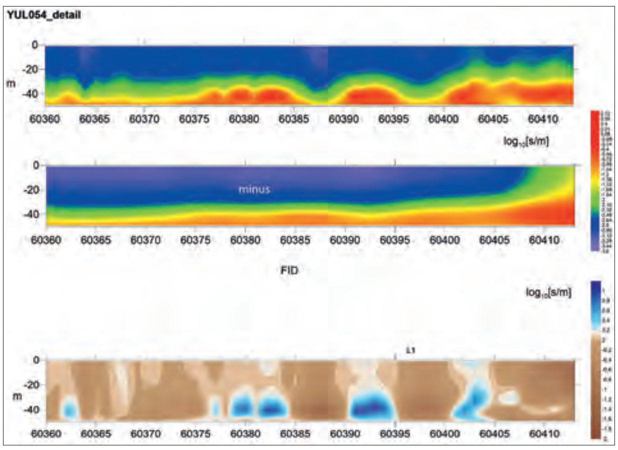
The Ox Bel Ha karst system (Quintana Roo, México) with over 250 kilometers of explored underwater tunnels is significant part of a vast, in large part still non-explored complex conduit network at the Caribbean coast around Tulum. It represents the main freshwater resource of the city of Tulum, stressed by increasing tourism and urban development. The Geological Survey of Austria (GBA) and Amigos de Sian Ka'an, a local NGO dedicating numerous projects to preservation of the unique biodiversity as well as Mayan tradition in the region, initiated together with European partners, particularly the Center of Hydrogeology and Geothermics, University of Neuchâtel, a scientific collaboration with the target to study structure, dynamics, and development of this karst groundwater system. One main goal is to develop a hydrological model for estimating the impact of the current situation as well as different possible future scenarios addressing urban/touristic or climate development. In several field campaigns extended surveys and monitoring/logging were conducted including electrical resistivity tomography, borehole geophysics, groundwater level monitoring, tracer tests and chemical analysis as well as acquisition of the karst conduits geometry and flow velocity data using new developed laser devices, and airborne electromagnetics (AEM; Text-Fig. 1). The acquired data serves for setting up the flow and solute transportation models.

The frequency domain-AEM method applied in this study is, concerning the hardware, very common. The instrument consists of a tuned four frequency coil transmitter (400, 3,200, 7,200, 29,000 Hz) and corresponding tuned receiver circuits mounted into a 6 m long torpedo-shaped 'bird' which hangs 30 m below helicopter/50 m above ground during flight. It transmits a primary EM-field into the underground which generates eddy currents. The receiver senses primary field and the secondary field caused by eddy currents. With adapted hardware design and data preprocessing the pure secondary field strength is extracted which – after inversion of the data – gives the apparent electrical conductivity distribution in the underground. The hydrological situation

Text-Fig. 1.
Survey area with flight paths of 2015 survey.
Google earth; © 2016 INEGI, Image Landsat / Copernicus.
Data SIO, NOAA, U.S. Navy, NGA, GEBCO-



Text-Fig. 2.
Principle of cave detection in AEM sections.



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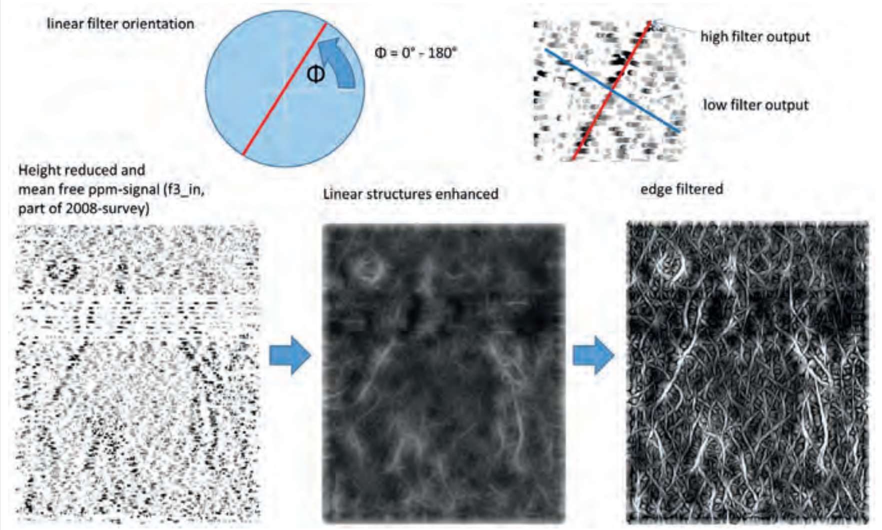
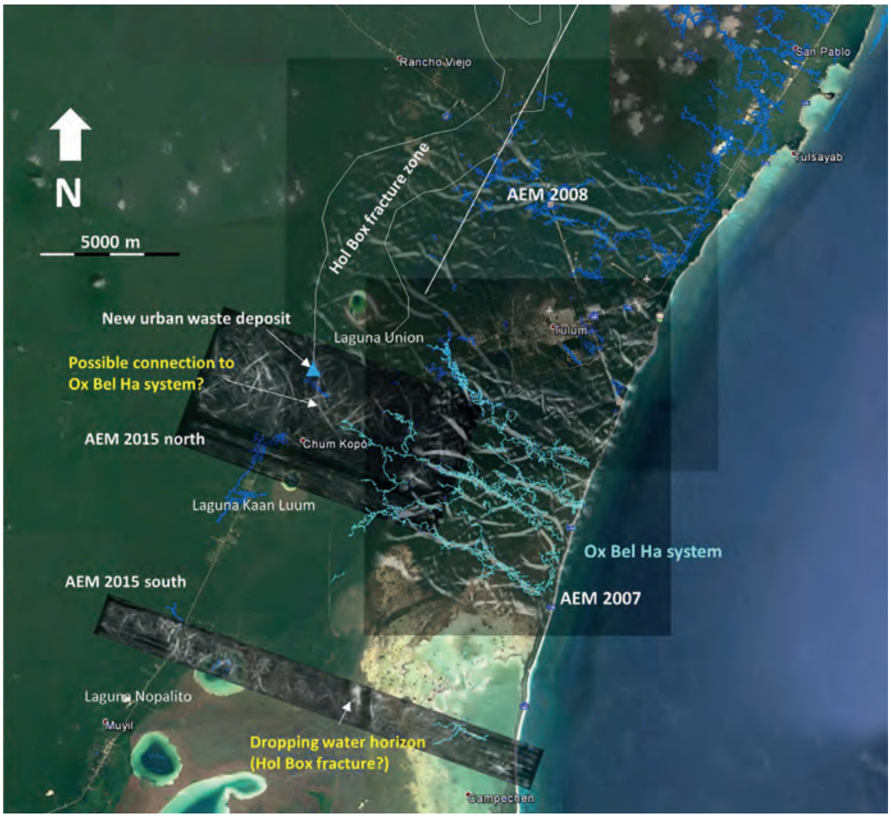


Text-Fig. 3.
Principle of enhancing conduit signatures in noisy data.

concerning water saturation, water salinity, porosity of the matrix, and presence of conduits maps more or less distinct into the electrical conductivity image so relevant parameters principally can be derived. However, AEM-data is usually corrupted by different kind of external and internal interference producing artefacts and degrading resolution. In course of the studies, new automatic data processing techniques have been developed for reducing significantly noise and system drift (Text-Figs. 2, 3). These comprise 3-stage automatic drift correction (spline, height correlation, de-stripping) and reduction of vertical gradient field in the inversion result caused by strong saltwater response. Furthermore, a new 2-dimensional circular noise filtering technique was developed for enhancing connected linear structures (as conduits) in the case of weak signal/noise ratio. The improved results give a clearer image of already known as well as unknown conduits in vertical sections as well as maps revealing the true extension of the vast conduit network (Text-Fig. 4). Furthermore, a complex halocline table shows up clearly in gradient field with vertical resolution in meter range. Altogether, it is proven that, supported by advanced data processing methods, a common AEM-system can deliver crucial hydrogeological information about a karst ground water regime over a wide and nearly non-accessible area in short time with near-optimum resolution down to depths of 50 m in the presence of saltwater.



Text-Fig. 4.
Enhanced conduit signatures (light gray) compared with known caves (blue, turquoise. Google earth; © 2016 Google, © 2016 INEGI.
Data SIO, NOAA, U.S. Navy, NGA, GEBCO.
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