Polarity Preserving Chirp Sub-bottom Profiler

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Goals

The goal of the project is to develop an acoustic imaging system to investigate the shallow subsurface of the seafloor in areas with gaseous sediments.

BACKGROUND

Chirp sub-bottom profilers use a high frequency sweep signal to produce high-resolution images of the seabed subsurface. The images produced by the chirp sub-bottom profiler are seismic profiles displaying reflections from the subsurface discontinuities due to changes in the physical properties of the sediments. When this project began none of commercially available chirp systems preserved the polarity of the reflections (positive versus negative). It is important to retain the polarity of the signal because it can be used to discriminate changes of the acoustic impedance of the sediments and then calculate the physical properties of the sediments on the seafloor.

Density is one property that can have a significant effect on the strength of the signal recorded at the receiver. If there is a strong density difference between two sediment layers, then there will be a strong reflector in the data. Furthermore, density differences are to be expected due to compaction of buried sediments with depth and\or significant differences in the lithology (sand versus clay, soft sediments versus hard rocks etc.). The presence of gas in the subsurface can decrease the density and produce a strong reflector as well. Fortunately, we can begin to distinguish between these two situations because the preserved polarity of the signal provides us insight into the direction of the density change (either increasing or decreasing). The capability to map the presence of gas in the shallow sediments is very important in many areas of ocean geological investigation, such us: natural and man-made hydrocarbon seeping, seafloor stability, geo-hazard assessment, benthic habitat mapping.

To achieve our goal we developed a set of specifications for a system that would preserve the polarity of the signal and challenged industry to produce an instrument that could meet our needs. Several industry leaders vied for the option but only Geo Acoustics, Ltd. provided convincing information that their system would indeed preserve the polarity.

AUV INTEGRATION

MMRI maintains a close working relationship with the Undersea Vehicle Technology Center at the University of Southern Mississippi and their survey class Autonomous Underwater Vehicle (AUV) Eagle Ray was identified as a suitable test bed for the new system (Fig 1). Mounting the hardware in the vehicle was relatively straight forward but integrating the system operations with the AUV mission software proved more challenging. Even though Geo Acoustics has years of experience with ship mounted and tow-body systems, this was the first unit for AUV application they had produced. AUV engineers Max Woolsey and Roy Jarnagin worked closely with Geo Acoustic engineers to work through the bugs in the software.

Figure 1. The Eagle Ray Autonomous Underwater Vehicle has a large payload capacity making it a suitable test bed for the development of new sensors and instruments.

SYSTEM SPECIFICATIONS

- 2000m depth rating
- Raw and match filter data recorded
- 40 to 50 m penetration
- 1.5 to 16 kHz frequency sweep
- 100kHz sample rate
- 24bit dynamic range
- Configured to operate from different platforms (AUVs)

FIELD TESTING

The polarity preserving chirp SBP was initially field tested as a payload of the Eagle Ray AUV in July of 2011. The resulting profiles indicated that changes in operations protocol were necessary and they provided data, albeit noisy, that were used to study processing techniques. During its missions in 2012, 2013 (Fig.2-3), and 2014, Eagle Ray acquired multibeam and subbottom profiles at various sites in the Gulf of Mexico, including regions containing natural oil seeps and methane gas hydrate formation. Using a converter developed in-house, the files logged by the SBP in GeoAcoustics condensed format (.gcf) are merged with vehicle log files and exported in a variant of the SEG-Y (.sgy) geophysical data format. This allows additional processing to be carried out using standard seismic

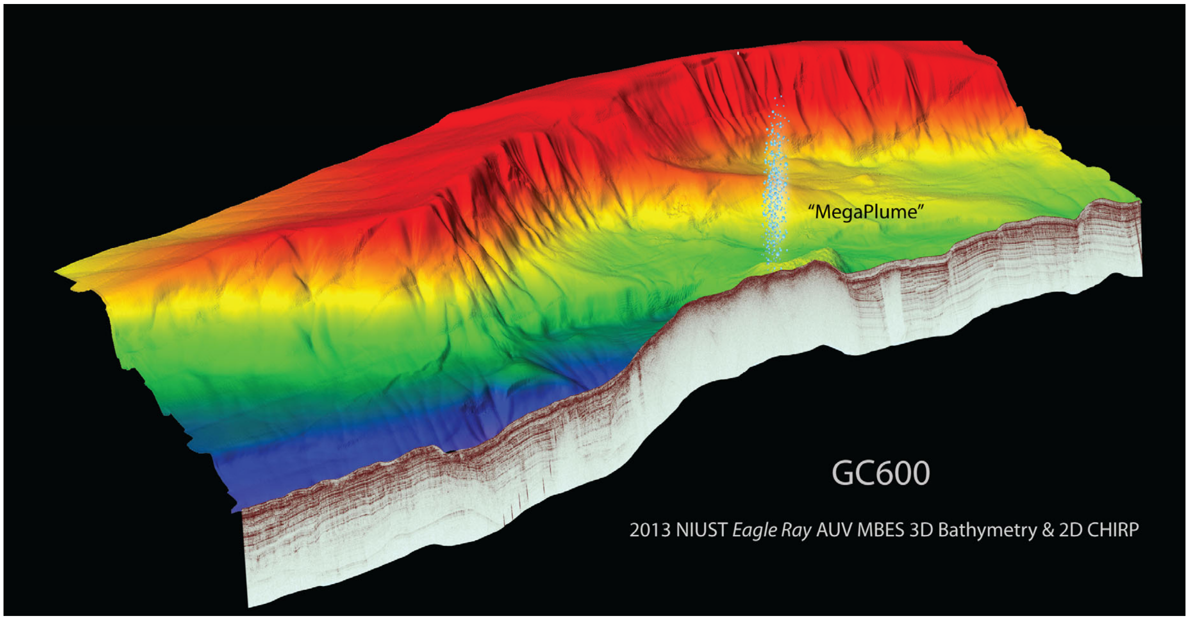

Figure 2. High-resolution bathymetric 3D image of GC600, Gulf of Mexico, acquired by the Eagle Ray AUV in 2013. Note the acoustic wipeout in the shallow sub seafloor under the gas expulsion features on the sea floor.

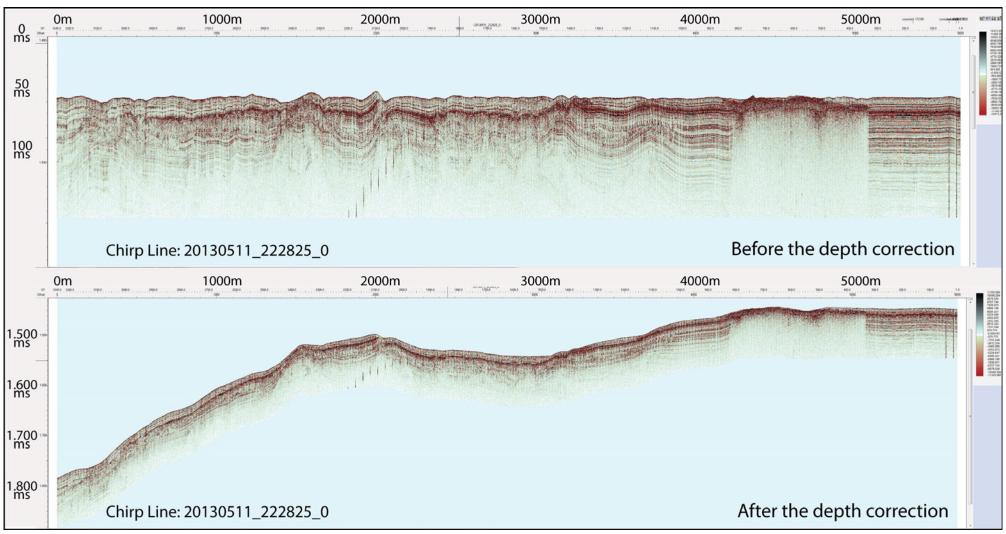

Figure 3. Depth correction of a SBP profile.

tools, thereby allowing for analysis of sediment elastic properties and, eventually, the creation of pseudo-3D volumes. Integrating the SBP records with other AUV data products is beneficial during this post processing phase. The SBP data reveal the structure along the nadir path of the vehicle, while the multibeam bathymetry indicates the surface expression of some of these structures over a wide area of the seafloor. Thus subtle features observed from one source can often be explained with the added dimension of the complementary sensor.

Future Work and Continued Development

Surveys using chirp sub-bottom profilers are common today because they are a proven tool for mapping faults and fractures in the subsurface. Our new system expands the usefulness of chirp surveys with an evaluation of the potential for natural gas accumulation and migration along these fracture zones. The presence of gas in fracture systems is significant because it affects the stability of the seafloor and can help promote the formation of gas hydrates.

Collaborators

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