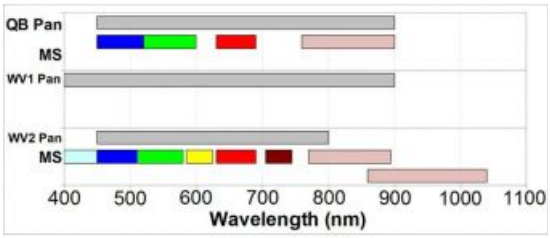
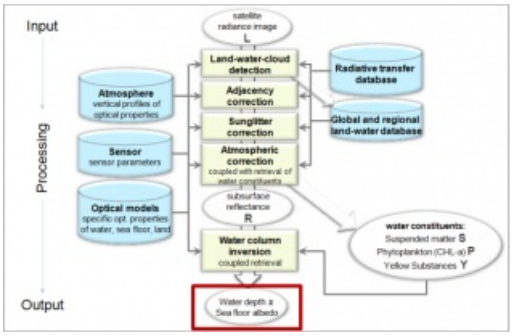
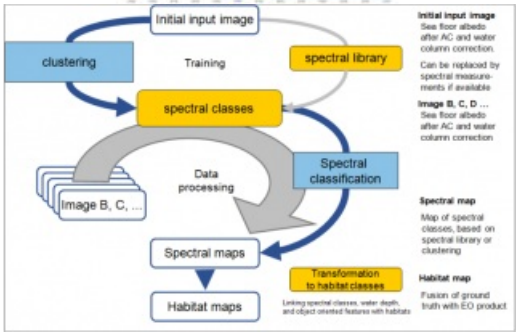
UKHO SPONSORS PILOT FOR SATELLITE IMAGERY-BASED SURVEY IN MEDITERRANEAN

Imagery-derived Bathymetry and Seabed Classification Validated







Proteus FZC, EOMAP and DigitalGlobe have formed a partnership to bring satellite-derived bathymetry and seabed classification to the hydrographic community. A pilot conducted by UKHO in the Mediterranean confirms that the satellite-based process yields depth and seafloor information faster and more safely than traditional hydrographic survey methods in the shallow-water environment.

In summer 2012, the United Kingdom Hydrographic Office (UKHO) contracted the Proteus-led team in a pilot trial of satellite-derived bathymetry and seabed classification to assess the quality and the potential for satellite-derived bathymetry as a data gathering technique in the very shallow-water or nearshore environment. The UKHO are interested in using new techniques to enable them to update charts in remote areas more frequently and more efficiently than solely relying on waterborne methods.

Two project sites, one comprising a 50-km stretch of coastline (Area A) and another about half that size (Area B) were identified in the Mediterranean for the pilot. Per instructions from UKHO, the Proteus team was required to work entirely remotely with no access to horizontal and vertical ground truthing data and to achieve depths from the zero contour or surf zone to the maximum depth possible.

Coastal Blue Band Makes the Difference

This project and the process tested were made possible by the launch of DigitalGlobe's WorldView 2 satellite. This high-resolution satellite captures eight multispectral bands of imagery, and most notably includes the coastal blue band, see Figure 1. All bands are utilised for bathymetry and determining seabed type through seabed classification extraction, however, the introduction of the coastal blue band starting at 400nm has significantly improved this technology and brought this methodology as an alternative solution to the hydrographic sector.

DigitalGlobe has a vast library of multispectral imagery providing global coverage to the hydrographer. For this project, participants decided to task the satellite by capturing a new image for the two survey areas. Dedicated tasking parameters were calculated and assigned to the project. The angle of the satellite camera is an important variable when capturing an image for bathymetry applications, so team members tasked the satellite to acquire images with a maximum incidence angle of 30° from nadir.

Suitable imagery was captured for the areas with minimal cloud cover and favourable environmental conditions. For this type of application, desired conditions include little or no wind so as to minimise turbidity in the shallow waters near the shore. The satellite images a total coastline length of over 100 kilometres with a survey time of less than 10 seconds.

New Processing Technique

Imagery was downloaded from the satellite within 6-24 hours of capture and delivered to EOMAP for processing. The imagery was quickly assessed for quality and suitability for hydrographic purposes. In this instance, excess cloud cover obscured the northern section of Area A which required acquisition of another image.

The UKHO chose to apply tidal corrections itself using tidal gauge data available over the internet. This required the project technicians to deliver bathymetric results for the time collected. This actual tidal data improved the vertical accuracy of the measurements.

EOMAP has developed an in-house processing suite called the Modular Inversion and Processing system, or MIP. This proprietary program extracts seafloor reflectance and converts this into water depth and seabed classification measurements. MIP is designed for the physical based recovery of hydro-biological parameters from multi- and hyperspectral remote sensing data and used for environmental mapping of aquatic shallow and deep water of inland waters, coastal zones and wetlands.

The architecture of the program binds a set of general and transferable computational schemes in a chain, connecting bio-physical parameters with the measured sensor radiances. The schemes include a number of algorithms to extract the depth information from the imagery. Atmospheric, sun glitter, water surface and underwater bidirectional effects of the underwater light field are all accounted for, as depicted on Figure 2.

The flow line incorporates a number of correction factors. The multispectral signals are subject to refraction and absorption through the atmosphere and water column. These need to be accounted for to establish seafloor reflectance value before converting reflectance into depth and seabed classification data.

The bathymetry processing flow line is sensor independent, allowing different hyperspectral and multi spectral imagery to be used. WorldView-2 multispectral imagery has a resolution of 2m and the eight-band multispectral bands provide better vertical accuracy and depth penetration than previously seen.
The seabed classification processing line is based on either supervised or unsupervised classification methods. For this project no ground truth data was made available for either bathymetry or seabed classification, and hence extraction was undertaken on an unsupervised basis.
In contrast to the land classification, the satellite input image was not only corrected to atmospheric influences, but also to the effects of sun reflectance on the sea surface and the effects of the water column. This unique semi-automatic approach was developed and maintained by EOMAP and implemented in MIP. The program processed radiance satellite imagery and outputs a bottom reflectance image, which represent the reflectance of the sea-surface bottom without the effects of water column and atmosphere, see Figure 3.

Faster, Safer Results

Proteus delivered bathymetry and seabed classification mapping, high-resolution satellite imagery, quality mapping, metadata and technical reporting to the UKHO where they undertook a comprehensive review of the results. The UKHO used historical single beam data from acoustic devices to compare the results.

Bathymetry covered nearly 100% seafloor coverage, with the exception of surface objects e.g. vessels and navigation marks. Objects with the size of greater than 4m were detected and mapped. Despite the no ground control restrictions required by the UKHO vertical accuracies achieved were 10 – 15% of water depth and a positional accuracy of 10m CEP 90% were seen. However, a small amount of ground truthing data would have comfortably seen an accuracy improvement to 10% of depth and 6.5m 90% CEP would have been achievable. Seabed classification was also successful, with four seabed types being identified; sand, rock/debris, vegetation and mixed seafloor (mainly vegetation). The 2m resolution seafloor mapping supported and corresponded with the bathymetry and provided essential information for hydrography, scientific or engineering applications. Figure 4 shows the bathymetry results, with depths ranging from 0.1m to 10m, after 10m the turbidity of the water column slightly reduced the overall accuracy, but still provided results acceptable for this application. Figure 5 shows the seafloor classification for the same area. With four seabed types being identified and mapped to a high resolution, these being sand, rock/debris, vegetation and mixed seafloor (mainly vegetation).

In areas where the turbidity exceeded the tolerances of the processing system the depths recorded aired on the side of safety. When the satellite depths were compromised by the environmental conditions then the system reported shoal depths, thus erring on the side of safety.

A crucial metric used in judging the pilot’s success was timeliness. The entire project, even with re-acquisition of some imagery, was completed in eight weeks. The same project would have taken months if it had been undertaken with traditional acoustic

hydrographic surveys, which have inherent dangers operating in the shallow, near-shore environment of the Mediterranean

Lessons Learned

- Project participants learned several lessons during the course of this pilot in the Mediterranean.
  Using multiple satellite images would increase the point density and enable a shoal bias product to be created. This would increase the cost of the product; however, it would also increase the safety element for survey or engineering applications. An average depth value is suitable for environmental/ engineering and marine resources planning applications, however, for some advanced applications a shoal depth is required.
- Stationary surface objects provide valuable information for this application, however, moving objects e.g. vessels would prefer to be removed from the bathymetry and reported separately on their characteristics, size; direction and speed of vessel.

Satellite tasking parameters are location and time dependent. They are important for survey planning and considered when trying to produce the highest degree of vertical accuracy.

Conclusion

Without the use of ground control data for horizontal and vertical referencing – as dictated by the project guidelines – the results are reliable and consistent to 10-11m water depths throughout all of the areas of interest where environmental conditions have allowed. Quality mapping is an essential deliverable for users when viewing and working with the deliverables.
For the purpose of survey reconnaissance and survey planning, this technique has delivered results good enough for serious consideration as a rapid, cost effective alternative to airborne and waterborne survey techniques in many environments. Being able to survey considerable volume areas quickly and remotely is a cost-effective and safe solution.

DigitalGlobe's archive of recent imagery, EOMAP's technology and Proteus's expertise enables bathymetry and seabed classification data to be produced within weeks. In the event of tasking the satellite for new imagery, the project life cycle is extended, but this process is still faster and has considerable advantages over traditional methods.

More Information

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