Title: Mapping ocean currents with IKONOS
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Technical areas: 4.9 Remote Sensing – Space Systems

One of the methods of remote sensing and mapping ocean currents is based on the motion of gravity waves. In the absence of a current waves propagated at a known "wave dispersion" velocity ($v = 1.25k^{-1/2}$, where k is the wavenumber). The usual practice is to analyze a sequence of ocean surface images with 3-dimensional Fourier transform where the wave energy is concentrated on a “dispersion curve” manifold and the location of the manifold is a direct measurement of the current. There have been successful implementations of this idea with marine radars (e.g., Young et al., 1985) and aerial video (Dugan et al., 2001). In this paper we describe our implementation with commercial high resolution satellite images.

Of the number of commercial satellites now in operation, the IKONOS satellite offered several advantages which will be explained in the paper. We’ll also discuss the options for using the other commercial satellites.

The IKONOS satellite provides a sequence of 4-5 images at ~10 s intervals during the overpass over the area to be mapped. This is much less data than used in the aforementioned Young and Dugan systems (where there are typically ~100 frames at 1 frame/s), but adequate for current measurements. With the satellite there is also a choice of using panchromatic images at 1 m GSD or multispectral images (Near IR, Red, Green, and Blue bands) at 4 m GSD. The panchromatic resolves shorter waves which in turn provide greater current measurement accuracy. However, the multispectral images are better for discriminating ocean wave pixels from breaking waves, surfactant slicks, and other image artifacts that can contaminate the data reduction. We have used both separately, but the best results are with an algorithm that fuses the panchromatic and multispectral.

The satellite image data will usually be obtained by a special satellite tasking order for some future date/time. In scheduling the satellites there are two important considerations: wind waves and sun angle. The data must be taken when and where there are wind waves. Suitable conditions can generally be found on coastlines open to the sea or where there is a large wind fetch. The precise time of collection should be coordinated with wind and wave forecasts. The optimum sun angle for taking images of the ocean is just outside the sun glint cone where the SNR of waves is greatest but without glint distortions.

There is also a need to co-register the sequence of images. A mis-registration translates into biases in the current estimation. The required co-registration accuracy is greater than normally provided in satellite data products. We use land features (if the area is near a coastline and some land is included in the image area) to improve the registration.

Figure 1 shows the results of processing IKONOS images of the ocean area just outside the San Diego harbor inlet. The "X current" panel shows a ½ to 1 m/s outflow current from the inlet area. The outflow current dissipates further out. The accuracy of current measurements is 5 cm/s or better over most of the water area in this image. Notable exceptions are areas without sufficient wind waves: the kelp forest area off Pt. Loma where waves are damped and an area near the inlet where a jetty obstructs the waves (these areas are dark in the Figure 1). The paper goes into further detail on factors affecting the accuracy.

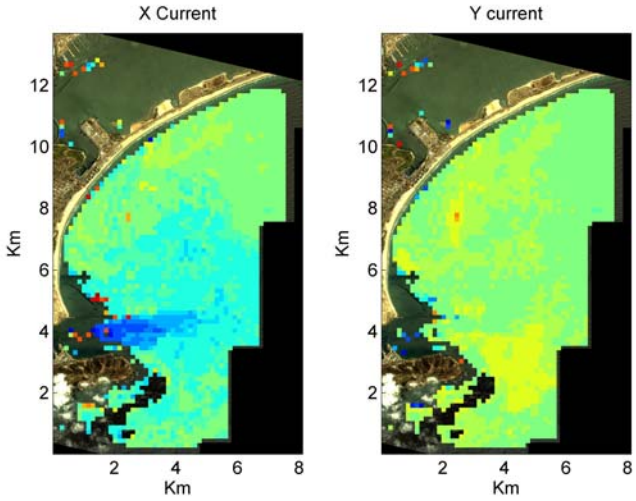

Figure 1 Estimated current overlay on image of area off San Diego inlet. The Silver Strands beach is visible in the upper left. Current is indicated by color code from dark blue (-1 m/s) to red (+1 m/s)

The current estimation method described here is closely related to a method of determining shallow water bathymetry. Bathymetry results were also reported by the Dugan group, by a number of European research groups that followed Young et al. work with radar imaging, and by this author with satellite images (Abileah, 2005).

References

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Abileah, R., 2006, Mapping Shallow Water Depth from Satellite, ASPRS 2006 Annual Conference, Reno, Nevada May 1-5, 2006