Ocean wave impacts on altimetry

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The upcoming Jason-1 and ENVISAT altimeter data sets present new challenges and opportunities related to optimal altimeter range correction for the sea state bias (SSB). The lack of accurate and collocated information on changing ocean surface wave dynamics remains as a key roadblock to further refinement of the SSB algorithm. Strategies to acquire and utilize new information on long wave dynamics are outlined here. Improved surface information should also support ongoing studies into precise altimeter wind estimation and anomalously high radar signal levels encountered under light wind conditions.

SSB range correction

Mean sea level is the ultimate derivative from a satellite altimeter's range measurement over the ocean. To obtain this estimate, range corrections are applied for known atmospheric, orbital, oceanic, and geoid-related factors. The prime task for this research group is optimal correction for range error attributed to changes in the overall shape of the ocean waves that reflect the impinging altimeter signal.
This range correction is termed the sea state bias and its description is summarized in Chelton et al. [2001]. The ocean's geometry is constantly altered due to changing winds and to swell that arrives from distant storms. These changes affect both the total power and time-dependence of the altimeter ocean reflection. The most current SSB algorithm [Gaspar and Florens, 1998] provides the best range correction based on the surface wind speed and ocean wave height (SWH) derived directly from the altimeter. This globally-derived routine was developed using a non-parametric estimation technique that removes the need to assume a functional form for the two dependent variables. The error left after correction remains at a level of about 1% of SWH. Over much of the ocean this implies a remaining 1-3 cm range error attributed to wave dynamics.

The basic task for future research, as affirmed by recent empirical and theoretical studies [e.g. Elfouhaily et al., 2000; Millet et al., 2001], is to provide additional long wave information beyond that of simply SWH. Two empirical studies towards this end are planned. First, Météo-France has agreed to provide one year of global wave model data at fine grid and every six hours for collocation with the TOPEX and/or Jason-1 crossover data used in SSB model work. This data set will support the first large-scale test of WAM fidelity for use in SSB refinement. The initial long-wave parameter of interest will be the wave orbital velocity (i.e. heave) variance. Second, global analysis of the Jason-1 radar altimeter waveforms will be performed using an approach designed to relate the fit residual to changing wave dynamics. This latter method was impeded by TOPEX waveform imperfections but may prove worthwhile for Jason-1.

Wind speed estimation

Wind speed near the ocean's surface controls the growth or decay of ocean waves. This variation of wave roughness (mostly small wavelets) with the wind provides the means to estimate the wind speed using a satellite altimeter [see Chelton et al., 2001]. Basically, the level of reflected signal is inversely proportional to the surface roughness and hence to wind speed. This first-order physical rule is the basis for the empirical relationship of wind speed and the radar's roughness estimate, the normalized radar cross section (NRCS).
Our recent research [Gourrion et al., 2000] has shown that a more accurate altimeter wind speed estimate is obtained by correcting for long wave (e.g. swell) contributions to the NRCS that are not well correlated with the local wind field. The new algorithm maps altimeter-measured NRCS and H_5 to wind speed and provides an improvement of roughly 10-15% in the overall accuracy as compared to use solely of the NRCS. This new wind speed model will be applied to Jason-1 and validated against NASA's QuikScat scatterometer wind speed data on a global basis. In addition we will assess the C-band NRCS data from the POSEIDON-2 altimeter for use in dual-frequency radar wind

estimates following the approach of Elfouhaily et al. [1998]. A similar study will performed using the new S-band data from ENVISAT.
This lower frequency channel provides a new opportunity to focus on slightly longer waves of the scale of 0.5 to 1 m in length.

Sigma naught anomalies

Roughly 5% of TOPEX over-ocean data are contaminated by a phenomenon we have designated as the “sigma naught bloom”.
Here sigma naught is the Ku-band NRCS. These TOPEX measurements are always characterized by unusually high radar return signal levels, and usually occur during low sea state conditions. A bloom is not a small km-scale event; it can extend over tens of seconds (50-200 km) along the TOPEX ground track.
In addition to the high power level, the return signal shapes vary significantly from those used to develop the altimeter’s range measurement algorithm. During an extreme bloom situation the range tracker can lose lock, degrading sea surface height and sea state information. However, there are also bloom cases where the tracker indicates valid geophysical data when this may not be true. The global bloom data set shows significant and repeatable seasonal and regional patterns.

This study addresses the characterization, modeling, and proper data flagging of sigma naught bloom data. Initial attempts to classify these waveforms proved difficult as they are extremely varied, but it is hoped that modeling efforts may eventually provide the capability to extract accurate range and sea state information from these data.
From an empirical perspective, a procedure has been defined to find possible sigma naught blooms within

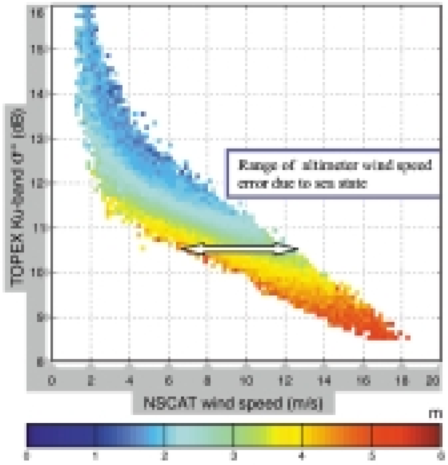

Figure 1: This globally-derived information on the variation of TOPEX altimeter NRCS versus a “true” scatterometer wind speed, and versus sea state for a given wind speed, provides the basis for the algorithm developed in Gourrion et al. [2000].

the TOPEX GDR data, characterizing a bloom by its $\sigma°$ peak, and width (i.e., time duration in the data), and by the bloom’s average geographical position, time, and SWH. This detection procedure has been run for the entire TOPEX data set from launch to date, and we are in the process of correlating the observations with relevant climatological and satellite datasets. We expect that sigma naught bloom data are associated with very calm, light wind conditions. Initial findings suggest this is the case, but not exclusively so.

The bloom-finding procedure also collects information about how much bloom-contaminated data remain in the TOPEX set even after contaminated samples have been supposedly eliminated by using the editing criteria described in the MGDR-B User’s Handbook.
The experience with the TOPEX data will be used as a guide to the development of proper sigma naught bloom flagging for the Jason-1 GDR.

References

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