Barotropic high-frequency sea level signals and the Jason-1 altimeter mission

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Atmospheric surface fields, particularly winds and pressure, drive significant sea level variability at frequencies not well resolved by the Jason-1 altimeter sampling. Such rapid signals can thus hamper the interpretation of the altimeter records. Our Jason-1 investigation focuses on determining the sea level response to high frequency atmospheric forcing using a combination of numerical modeling, data analysis, and state estimation techniques. Efforts will lead to improved knowledge of rapid sea level signals, their dynamics and relation to atmospheric forcing, and to estimates of such signals that can be used to improve the processing and analysis of altimeter observations and extend their range of applications.

With its repeat cycle of about 10 days, Jason-1 will poorly resolve sea level (ζ) signals at periods shorter than about 20 days. Analyses of in-situ tide gauge and bottom pressure data show a substantial amount of variance over these time scales. Recent model results and comparisons with data indicate that wind-forced high frequency (HF) signals can be a source of large aliasing in the altimeter records, particularly at mid and high latitudes. Signals forced by pressure (p_a) can also add to the problem. In particular, the HF ζ response to p_a does not follow the “inverted barometer” (IB) model æthe isostatic ζ adjustment to p_a at a rate of approximately -1 cm/hPa that holds at longer time scales. Our general goal is to move closer to a full determination of the atmospherically forced HF ζ signals and a better understanding of their dynamics and relation to forcing. Focus is on signals driven by surface winds and p_a. By improving current knowledge of these atmospheric forcing fields and by developing the necessary modeling and optimization tools, we seek to estimate the HF ζ signals as best as possible. Such estimates should provide for the removal of some of the HF noise in the Jason-1 records, leading to cleaner data products that can benefit the general altimeter user.

To arrive at useful estimates of the HF ζ signals, one needs to know well the relevant atmospheric forcing fields and their error statistics. In this regard, comparisons among the different forcing products provided by various weather centers are useful (figure 1). Our assessment of the forcing fields also involves comparisons with independent data (e.g., island pressure stations) and combined analysis with altimeter data (e.g., checking the effects of IB corrections based on different pa fields). Improved representation of the forcing fields can lead directly to improved altimeter data processing (e.g., better p_a fields yield better environmental corrections), as well as to better estimates of HF ζ signals obtained from combined model and data analysis.

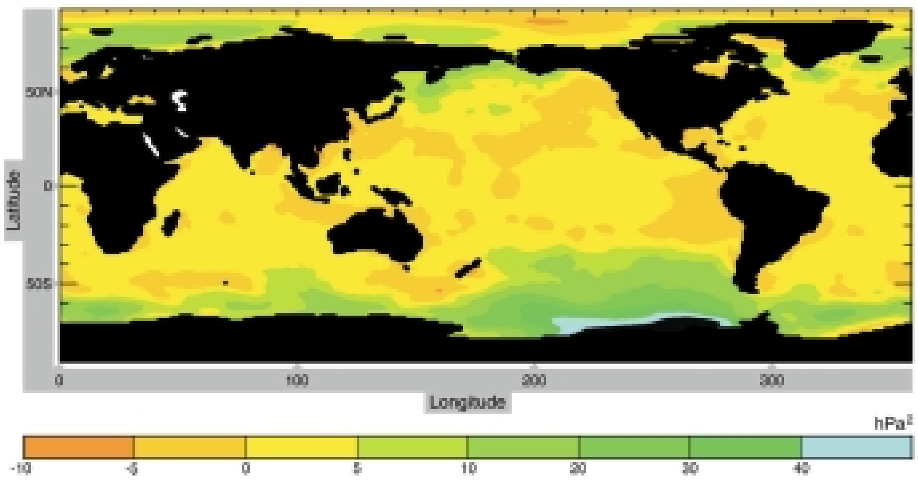

Figure 1: An estimate of the difference between the error variance in operational NCEP and ECMWF p_a fields (hPa²). Positive values denote larger errors in NCEP fields. Notice the apparent smaller errors in ECMWF fields over most regions and especially in southern mid and high latitudes.

Given the HF and large scales of interest, modeling work focuses on the use of simple barotropic (constant density) models. Modeling efforts include an evaluation of effects of different forcing fields on the sea level response, assessment of sensitivity of results to different parameterizations of bottom friction, and implementation of increasingly smaller grid spacing to improve the representation of coastal geometry and bottom topography (figure 2). Comparisons of different numerical models are intended to check for inconsistencies and learn about the various factors affecting the realism of the numerical solutions.

Straightforward model comparisons with data (mostly altimeter but also tide gauge) should provide a measure of their consistency and lead to model improvements. Ultimately, the goal of achieving an “optimal” estimate of HF ζ signals related to atmospheric forcing is best approached through estimation schemes that combine model and data in an optimal fashion. Part of our investigation is devoted to the development of assimilation techniques that combine barotropic models and altimeter data to provide dynamically based estimation of atmospherically driven signals over the global ocean. Such estimates of HF ζ signals can be used to “correct” the altimeter data, just as tide models are currently applied to remove the large HF tidal signals from the records. Sorting out the variability in the records due to HF winds and p_a forcing will allow a better analysis of other less understood components.

In addition, analyses of the model results and estimated HF ζ fields carried out during our investigation will shed light on many scientific issues of current importance in oceanography. Specific topics of study include: the validity of the IB approximation as a function of location and time; the relative importance of winds and p_a as forcing mechanisms for HF oceanic variability; the relevant dissipation mechanisms for HF barotropic motions in the ocean and appropriate ways of parameterizing such processes in numerical models; and the influence of topography on HF dynamics. In summary, our efforts will lead to significant improvements in current understanding of the sea level response to HF atmospheric forcing, while providing for more precise analysis and interpretation of the altimeter signals and moving us closer to meeting the 1-cm accuracy challenge for Jason-1.

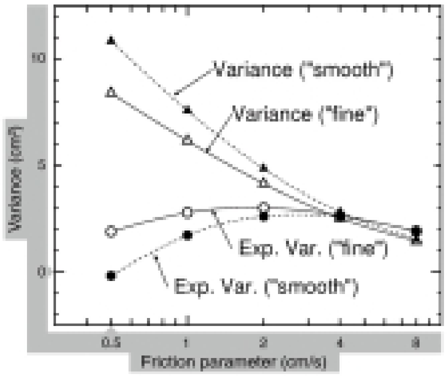

Figure 2: Globally-averaged z variance calculated by a barotropic model forced by winds and pa, and TOPEX/ POSEIDON variance explained by the model, as a function of bottom friction parameter. The curves labeled “smooth” and “fine” refer to model results obtained with smooth and fine resolution topography, respectively. (From [Hirose, 2001])

References

Hirose, Fukumori, V. Zlotnicki, R.M. Ponte, 2001: High-frequency barotropic response to atmospheric disturbances: Sensitivity to forcing, topography, and friction, *J. Geophys. Res.* (submitted).

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