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Problems in Determining Sea Surface Topography

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Abstract. Anticipated problems for determining ocean dynamics signals from sea surface topography are discussed. The needs for repeated tracks are listed if oceanic tides or ocean turbulence are to be determined.

People want to observe sea surface topography for many reasons and I would like to discuss the ocean dynamics aspects, in contrast to the geodynamics aspects which I feel have been presented by others.

Geodesists and geophysists are interested in things that are shown in Figure 1, which I will call oceanographic noise. This is presented as a function of typical wavelength. Approximate amplitudes are also given. In the middle we see the footprint size of SEASAT represented as a footprint. Features smaller than the footprint lie outside our interests. A big signal of amplitude 40 meters or so comes from trenches. The various global highs and lows are not particularly related to surface tectonics in any clearly understood way that I know of. They are up to 100 meters in amplitude. Ridge systems give a very small signal but they do apparently affect the second derivatives very strongly.

I'm not really concerned with the geophysical signal here. What I'm interested in telling you about is shown in Figure 2, entitled Geodesists and Geophysists noise.

In this figure we present the deviation of the ocean surface from the geoid as a function of length scale. The span of such wavelengths is represented by a horizontal line and I caution you that this is meant to be very crude. Equally crude estimates of amplitudes are included. Starting on the left we see capillary waves, spray, foam, and seaweed in the millimeter to centimeter range. Next come wind waves in the 10^{-1} to 10^{3} meter range and as we know, these are very variable both spatially and temporally. Amplitudes vary from a tenth of a meter to ten meters. We believe there is a fairly good sized minimum (we're not really sure) in the wavelength range from about a kilometer to roughly 50 km. In this range lies the footprint size of SEASAT, represented as a footprint. Above 50 km or so we get a strong contribution from oceanic eddies. These are low frequency events with periods of weeks or longer and with amplitudes from 20 cm to one meter. There are stationary counterparts to these in various frontal zones near the Gulf Stream, the current that goes around Antarctica, and so forth. From 1000 to 5000 km lie tides, which are really shallow water gravity waves, influenced by rotation of the earth, and with easily identified, sharp frequencies of various sorts. Equatorial currents and the non-frontal aspects of the big ocean currents appear to be at most a few thousand km. Little is known of any structures of 10,000 km, but there may be some long basin modes (periods up to about 30 hours).

First, let us note that the wind-driven waves contribute the most height and lie below the footprint size. This causes me as much worry as anything, although I've been assured that empirical corrections can be made down to the 10 cm level of SEASAT. One additional feature is that

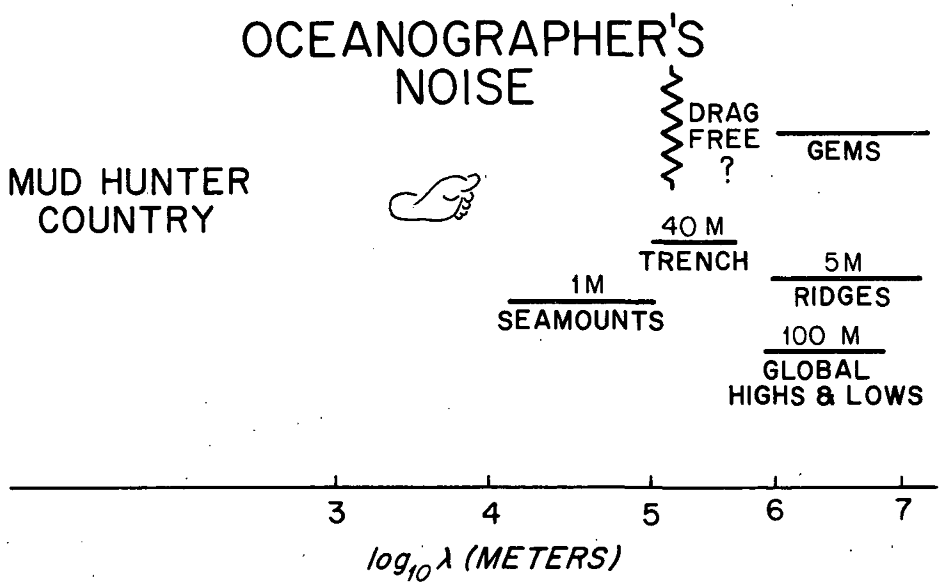

Fig. 1. Oceanographer's noise.

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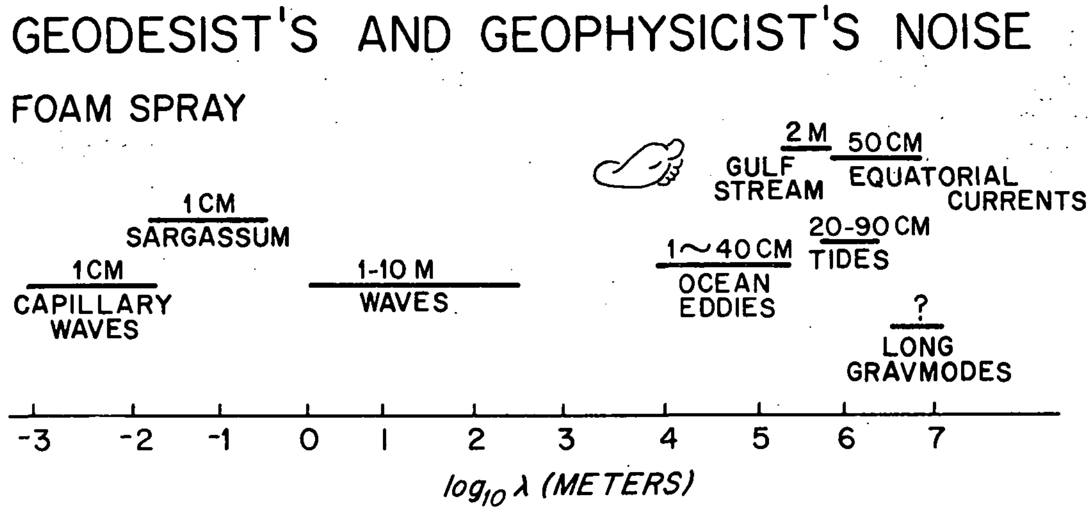

Fig. 2. Geodesists' and Geophysicists' noise.

patches of waves (under storms) are from 100 km to 1000 km in size generally, and thus overalp ocean eddies.

Ocean eddies, of the size 100 km or so, have been observed by standard oceanographic methods for the past ten years. Figure 3 (from MODE Atlas (1977)) shows estimated pressure at 150 meters depth from float and hydrographic data, in units of equivalent centimeters of head. The region encompasses a 300 × 300 km region and the eddies are of order 100 km. The amplitude peak to peak is about 25 centimeters. To see how this signal stands up against the geoidal deflection, Figure 4 shows a sketch of the GEOS altimeter output for the region. There is change in depth of the geoid of about 2 to 3 meters. It is obvious from this that the oceanic turbulence is going to be a small relative signal indeed and we would really need to take continuous tracks for intervals of well over a month in order to get the signal.

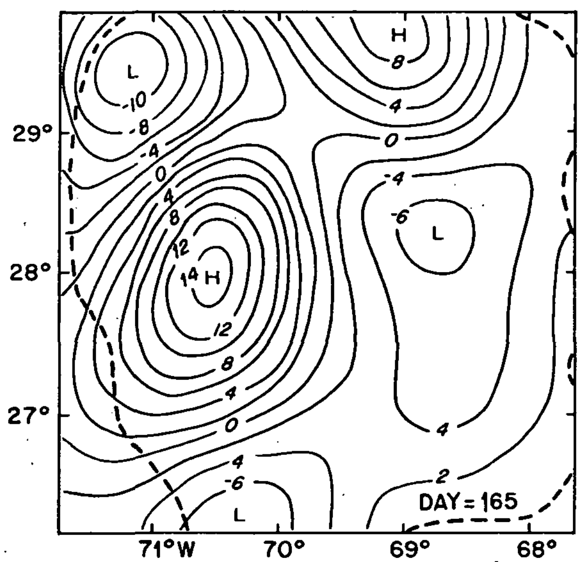

Fig. 3. Pressure in units of equivalent centimeters of head, as deduced from float and density data. Contour interval is 1 cm. Source: MODE Atlas, p. 131.

Not all eddies have such a small amplitude. Figure 5 shows some typical sections of isotherms in relatively quiet regions of the ocean. The undulations in the isotherms are due to such turbulence as we saw on the previous slide with estimated surface deflections of 10 cm. However, Figure 6 shows a section further north, where there is evidence of very much stronger eddy activity. These may get up to 50 or 60 centimeters surface deflection.

One should be able to take advantage of the time dependence of these eddies to filter out some of their contributions to "geodesists noise." Steady counterparts to these eddies such as the edge of the Gulf Stream or the Antarctic circumpolar front won't be so easily isolated except that, fortunately, they tend to wiggle about. There will be no way to determine the gravity field to 10 centimeters in the 100 km wavelength region in my opinion short of extensive ship surveys, and handling this "wiggle of streams" problem is essential if those currents are to be resolved.

Tides are another feature whose time dependence may aid in their analysis, especially since

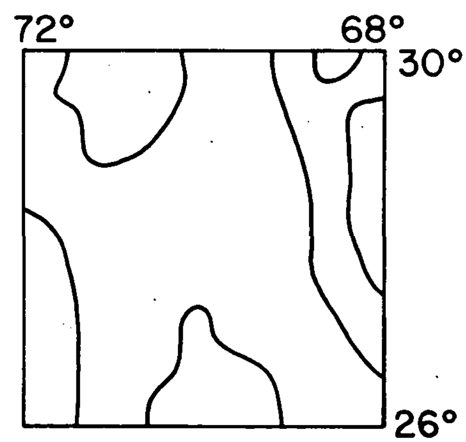

Fig. 4. Geoidal variation as seen from the GEOS-3 satellite of the MODE area. Contour interval 1 meter.

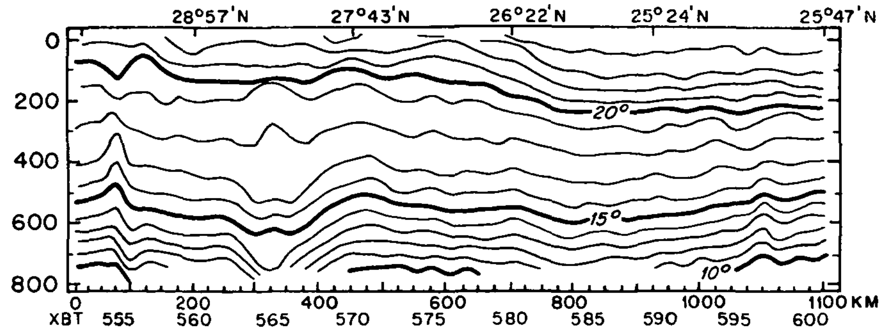

Fig. 5. Section of isotherms of Atlantic Ocean at approximately 30° north.

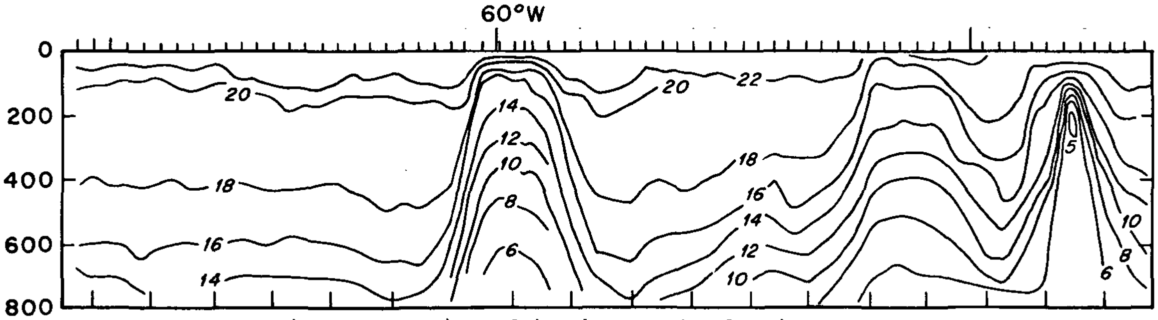

Fig. 6. Section of isotherms of Atlantic Ocean at approximately 50° north. There is evidence of much stronger eddy activity.

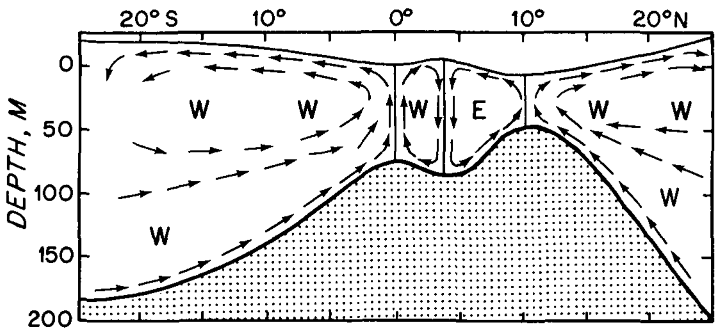

Fig. 7. Hypothesized north-south section of the equatorial ocean. The surface deflection has never been measured.

their frequencies are so sharp. It would appear that there are some interesting spatial-temporal biasing problems connected with the tides since the basic coarse grid for SEASAT takes three days to get established. The problem of observing the tides is old and fascinating, but according to the most recent survey (Hendershott (1977)) deep ocean tides all over the world are not known.

There has been a lot of debate over whether it is necessary to subtract out a geoid which is accurate to ten centimeters. The present planning is for SEASAT to cover the entire earth oceans twice in the first year, hence the geoid plus the steady oceanic currents could be reasonably well determined. My view is that, although it would be desirable to know the orbit of SEASAT to an accuracy of 10 cm, it does not appear to be crucial, since the orbit is extremely smooth for short wavelengths. Although the orbit may bump around at long wavelengths (over 1000 km) we have good spherical harmonic gravity models such as the GEM series to determine this orbit correction. By an appropriate least squares fitting, slow changes of the orbit, which I understand will be less than 10 cm per orbit, will contribute to only the lowest orders of the apparent gravity field, and can therefore be easily subtracted.

Lastly I would like to tell of possible long wavelength features such as long basin-filling sloshing modes with periods up to 30 hours or so. We know little about them and they should be relatively easy to pick out with the assistance of a good gravity model. They might be less than ten centimeters in amplitude, and if so the basic problem will be the usual one of separating a weak signal from the noise.

In terms of stationary long modes, Figure 7 shows an oceanographer's view of the tropics from the famous Sverdrup, Johnson, and Fleming (1942) textbook. The anticipated surface deflection is schematically sketched in and spectral components of the geoid should be known to sufficient accuracy to aid in observing such a surface. To assist in such an endeavor, however, one could look for a banded structure in an east-west direction. This is absent in the gravitational field as far as we know.

There are many more ocean surface features which haven't been mentioned, many possessing their own particular challenges. Some examples are the sea level adjustment on shelf areas, level changes across straits such as Gibraltar, sea level changes between Pacific and Atlantic, and the response of an oceanic surface during an earthquake event.

References

Hendershott, Myrl C., in The Sea, Vol. 6, E. D. Goldberg, I. N. McCave, J. J. O'Brien, and J. A. Steele, Eds., John Wiley and Sons, New York, 1048 p, 1977.

MODE Atlas, Valery Lee and Carl Wunsch, Eds. Atlas of the Mid-Ocean Dynamics Experiment. POLYMODE Office 54-1417, Massachusetts Institute of Technology, Cambridge, MA 02139, 274 p, 1977.

Sverdrup, H. V., Martin W. Johnson, and Richard H. Fleming, The Oceans. Prentice Hall, Inc. Englewood Cliffs, NJ, 1087 p, 1942.