SATELLITE ALTIMETRY APPLICATIONS

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Abstract

This paper provides the brief background of precision satellite altimetry. A description of satellite altimetry concepts and instrumentation is presented. The parameters measured, supporting data and techniques, as well as physical limitations, are discussed. In addition, results are shown and a variety of applications are emphasized.

Digest

Introduction and Background

Satellite altimetry is primarily devoted to active sensing of the topography of the ocean surface which is then utilized for geodetic and oceanographic studies.

The long term objectives of satellite altimetry were stated in the 1969 Williamstown study on Solid Earth and Ocean Physics[1] and the 1972 Earth and Ocean Physics Applications Program (EOPAP) report. These studies call for development of a 10 cm accurate synoptic satellite altimeter with at least 1° (100 km) spacial resolution.

Satellite Altimetry Concept

The basic idea behind altimetry is to utilize the highly stable platform provided by a satellite as a moving reference system from which vertical measurements to the ocean surface are made (see fig. 1). The altimeter measures to the instantaneous electromagnetic mean sea level (IEMSL) averaged over the spacial footprint of the instrument.

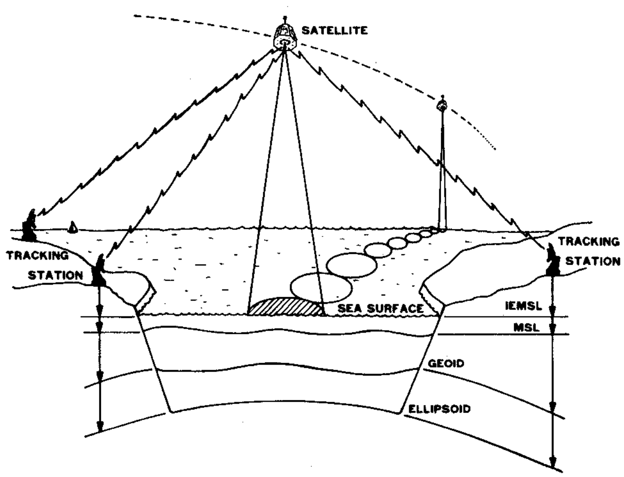

Figure 1 Satellite Altimetry Geometry

Instrumentation

Present altimeters are basically conventional tracking radars which track in range only. The instrumentation utilized on Skylab and planned for GEOS-C, makes measurements applicable to determination of altitude, ocean wave height, pointing and returned signal strength. Following, the salient points of some of these quantities are discussed.

The time interval from transmit time to the half power point of the leading edge of the return is proportional to altitude. These transit times are measured with a closed loop tracking system with bandwidths of a few hertz to follow the dynamics of the ocean surface. It should be noted that the pulsewidth or sea state (depending on which represents the larger time spread to the altimeter) determines the footprint size.[2] This footprint[3] acts as a spacial filter that has to be considered in detecting surface features (see fig. 2).

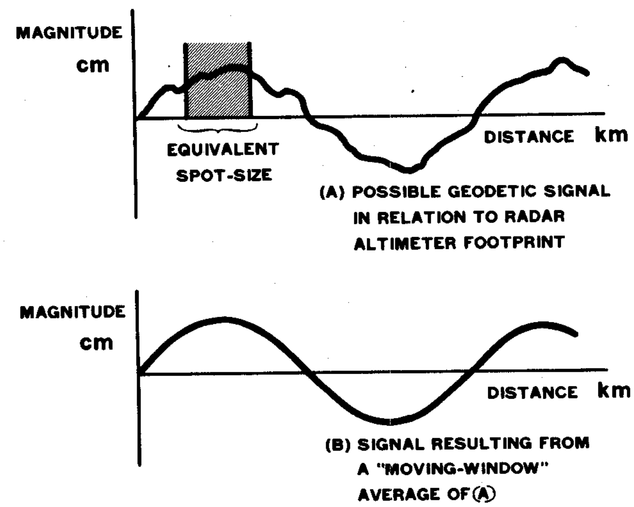

Figure 2

Techniques and Limitations

To support satellite altimetry some special new techniques have had to be developed, which include the orbit determination, instrument calibration, determination of satellite pointing and data corrections. In addition, while the instrumentation techniques required have not been entirely new, they have had to be applied to altimetry and made compatible with a spacecraft environment. Some challenging developments have been made in pulse compression, pulse stretch, maximum likelihood processing and high voltage power supplies.

These areas of technology development also are the major areas that limit altimetry. For example, the pulse width determines the footprint which limits the spacial resolution and also limits the measurement of wave heights. Likewise, the orbit accuracy limits altimetry accuracy for mapping the broad scale ocean topography (see Table 1).

	SKYLAB Uncorrected	Corrected
1. Instrument Errors		
Systematic	up to 30 meters	< 2 meters
Random	.6 meters (over 1 sec.)	.6 meters
2. Pointing	up to 60 meters	< 5 meters
3. Ocean Surface	Up to .75 meters	< .75 meters
4. Atmospheric		
Tropospheric (dry) (wet) }	< 3 meters	< .6 meters
Ionospheric		using fixed 2.79 m
5. Orbit	< 100 meters (JSC)	< 10 meters (WFC)
System Capability for Global Mapping	< ± 100 meters	< ± 10 meters

TABLE 1

Altimeter Applications

Geoid Determination

Since the water surface of the ocean has the unique property of seeking an equilibrium with the equipotential gravity forces, and since the satellite altimeter provides a direct measurement of the shape of this ocean surface (fig. 3), the altimeter measurements over ocean surfaces are almost direct geoid measurements.[4]

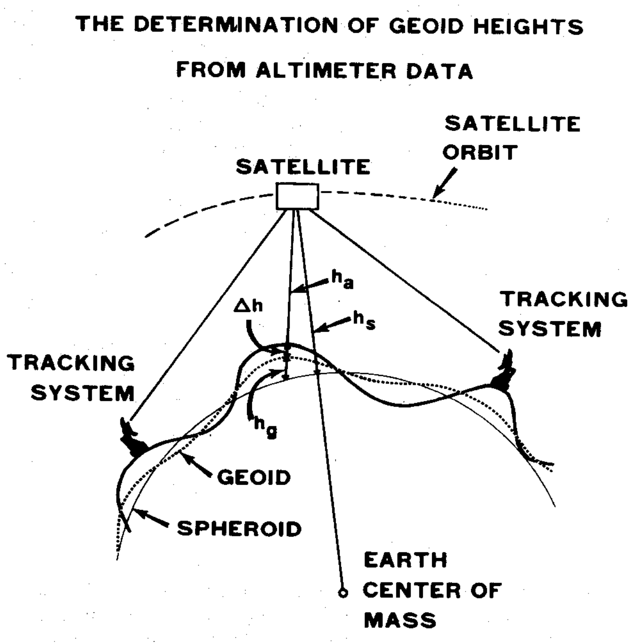

Figure 3

Probably the most significant results of satellite altimetry are in the detection of short wave length features such as trenches, seamounts, ridges and caps. Since the orbit of the satellite acts like a low pass filter, and doesn't respond to short wave length features, the orbit is not a significant error source in mapping the shape of short wave length features. Figure 4 shows a comparison of altimeter data and the Marsh-Vincent (GEM 6) geoid over the Puerto Rico trench area.

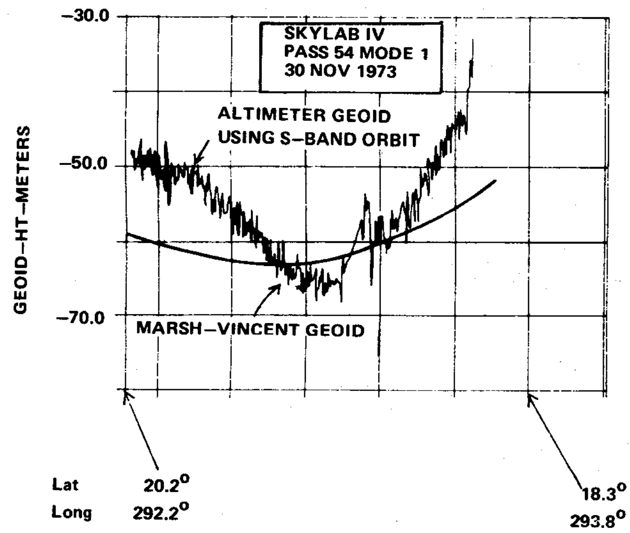

Figure 4

Correlation with Ocean Floor Topography

During the early phase of the Skylab program, the data recorded in the overwater passes off Charleston, S.C., showed abrupt changes in mean sea level which were not immediately obvious in existing geoidal data. Figure 5 illustrates this effect: note the 8 meter change which occurs near time $17^h\ 12^m\ 22^s$, also note the Marsh-Vincent geoidal contour. The geoidal data available to use was computed using a 1° x 1° grid.[5] Therefore, to place the altimeter and geoid contours on a comparative basis, the altimeter data was smoothed beyond that required for minimum-mean square error considerations and to a degree which simulates a 1° x 1° resolution. One can easily see that the altimeter has the resolution to detect features that are caused by local topography. Therefore, the altimeter can be used to determine when, where and how to consider local topography in geoid models. In this manner, a large quantity of topographic data can be utilized to improve immediately the resolution of the geoid and might later be used to fill in gaps between satellite altimeter geoid measurements. In addition, in areas where the topography is not well known, the altimeter could contribute to the improved mapping of these features.

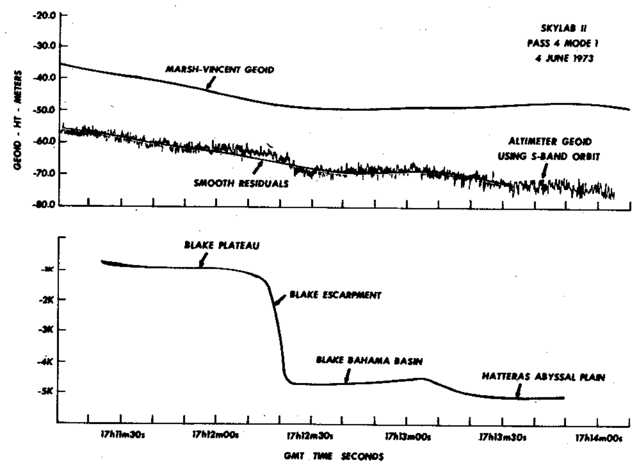

Figure 5

Geological Structure

The underwater topography doesn't always correlate with the altimeter measured ocean topography. In fact, since the equipotential gravity field is being measured, the subsurface structure can cause the surface topography to vary significantly from the subsurface topography. This effect has been seen off the east coast of the United States and in the Gulf of Mexico.

These areas and similiar ones can be geologically important for plate tectonics and geological age studies. In areas where the structure is unknown the altimeter data can be used to test an inferred structure model.

Distribution of Wave Heights

Ocean wave height data is obtained by analyzing the leading edge of the average return signal waveforms. The higher sea states effectively give both earlier and later returns to the altimeter such that the average risetime is rounded and resloped. If the transmitted pulse shape is known and narrow, and if the altitude tracker noise is comparably low, it is possible to de-convolve the whole distribution of wave heights from the leading edge.[6]

Current Detection

All three parameters (height, waveforms and radar-cross-section) measured by radar altimeters are important for the sensing of currents. The slope of the sea surface perpendicular to the flow for north-south currents should be detectable in the altitude data. The Gulf Stream, for example, has a rise of 1 meter over distances of 50 to 100 km.

Land Topography

The mapping of land topography has on some occasions been extremely good. For example, in fig. 6, an overland pass over the Eastern Shore of Virginia, the altimeter appeared to follow the topography extremely well. This particular pass over areas with heavy vegetation, which together with the 4 nautical mile footprint, makes the analysis very difficult. However, the potential for mapping these areas can be visualized, and applications to forestry surveys and even growth rate studies can be predicted for the future. It should be noted that water bodies serve as good height reference points for the data analysis.

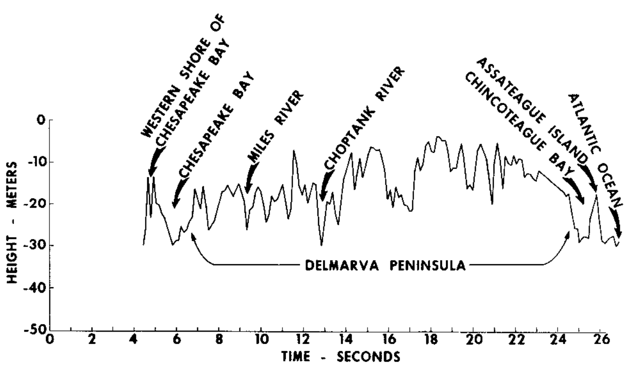

Figure 6

Conclusions

Satellite altimetry offers the physical scientists an important new source of measurements. These measurements are sufficiently unique to provide all-weather, independent observations of global topographic features. The combination of the altitude, AGC and waveform data, together with data from other remote sensing instruments, can contribute to the accurate mapping of underwater features, detection of ocean currents, modeling of geological structure, measurement of distribution of wave heights, rain and rain rate mapping, and surveying of forest heights.

In addition, altimeter data can supply precise satellite pointing information and surface reflectivity data. This information is valuable for calibrating the altimeter and other satellite radars and for design of future radar systems.

References

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