A GEOPAUSE SATELLITE SYSTEM CONCEPT

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Abstract. The forthcoming 10 cm range tracking accuracy capability holds much promise in connection with a number of Earth and ocean dynamics investigations. These include a set of earthquake-related studies of fault motions and the Earth's tidal, polar and rotational motions, as well as studies of the gravity field and the sea surface topography which should furnish basic information about mass and heat flow in the oceans.

The state of the orbit analysis art is presently at about the 10 m level, or about two orders of magnitude away from the 10 cm range accuracy capability expected in the next couple of years or so. The realization of a 10 cm orbit analysis capability awaits the solution of four kinds of problems, namely, those involving orbit determination and the lack of sufficient knowledge of tracking system biases, the gravity field, and tracking station locations.

The Geopause satellite system concept offers promising approaches in connection with all of these areas. A typical Geopause satellite orbit has a 14 hour period, a mean height of about 4.6 Earth radii, and is nearly circular, polar, and normal to the ecliptic. At this height only a relatively few gravity terms have uncertainties corresponding to orbital perturbations above the decimeter level. The orbit, in this sense, at the geopotential boundary, i.e., the geopause. The few remaining environmental quantities which may be significant can be determined by means of orbit analyses and accelerometers.

The Geopause satellite system also provides the tracking geometery and coverage needed for determining the orbit, the tracking system biases and the station locations. Studies indicate that the Geopause satellite, tracked with a 2 cm ranging system from nine NASA affiliated sites, can yield decimeter station location accuracies. Five or more fundamental stations well distributed in longitude can view Geopause over the North Pole. This means not only that redundant data are available for determining tracking system biases, but also that both components of the polar motion can be observed frequently. When tracking Geopause, the NASA sites become a two-hemisphere configuration which is ideal for a number of Earth physics applications such as the observation of the polar motion with a time resolution of a fraction of a day.

Geopause also provides the basic capability for satellite-to-satellite tracking of drag-free satellites for mapping the gravity field and altimeter satellites for surveying the sea surface topography. Geopause tracking a coplanar, drag-free satellite for two months to 0.03 mm per second accuracy can yield the goeoid over the entire Earth to decimeter accuracy with 2.5° spatial resolution. Two Geopause satellites tracking a coplanar altimeter satellite can then yield ocean surface heights above the goeoid with 7° spatial resolution every two weeks. These data will furnish basic boundary condition information about mass and heat flows in the oceans which are important in shaping weather and climate.

1. Introduction

The prospect of developing laser and electronic ranging systems and VLBI instrumentation capable of decimeter accuracy opens up the possibility of conducting a number of Earth physics and oceanographic investigations which are expected to be scientifically important and of practical value from the applications standpoint as well. Phenomena associated with the Earth's dynamical and crustal motions and its sea surfaces are all of interest in connection with the emerging programs which are intended to exploit these new scientific and applications capabilities.

The present state of the art is one or two orders of magnitude away from the pro-
jected instrumental accuracy levels. This is due largely to limitations in our knowledge of the Earth's gravitational field and figure, and the need for the solution of problems involving orbit determination and tracking system biases. (Cf. [1–23].)

The purpose of this discussion is to indicate ways in which the Geopause spacecraft system concept can contribute to the achievement of the Earth physics and oceanographic goals which the instrumentation technology appears to have placed nearly within our grasp.

The scientific and applications aspects of the program are described in more detail in reports of the National Academy of Sciences and NASA [24–26].

Portions of these documents which are of special interest here are briefly reviewed in the following discussion.

In the area of Earth dynamics there is interest in observing tectonic plate motions of more than one type. The gross motions of the tectonic plates with respect to one another, such as the continental drifts, are important for the understanding of the continuing evolution of the Earth's crustal surface. Fault zone regions of the type which are found at the interfaces between two tectonic plates are of special interest in connection with earthquakes. More detailed information about the deformations of the tectonic plates in the neighborhood of a fault zone can be used to estimate the amount of energy stored in the region. Such data may one day form the basis for earthquake risk predictions.

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The study of these types of tectonic plate motions calls for observational capability in the decimeter range, since the annual motions involved are estimated to be of the order of a few centimeters to somewhat over a decimeter.

Evidence for correlations between earthquakes and anomalies of the polar motion has been found by Smylie and Mansinha [27]. These studies are currently limited by the fact that polar motions are normally observed in terms of five day means with accuracies of the order of a meter or so. The ability to observe polar motions with decimeter accuracy over time intervals of the order of a day or less would clearly be of real value here.

The capability for observing crustal motions at the decimeter level carries with it the ability to observe solid Earth tides. Amplitudes of the solid Earth tides are of the order of a third of a meter. They may vary from place to place on a tectonic plate. The nature of any correlations which may exist between tidal processes and earthquakes has been a subject of investigation and discussion for some time. Additional observational data may shed light on this important question. Observations of tidal motions at points near fault zones may be of special interest in this connection, for example. These could be made in conjunction with the fault zone plate deformation measurement program indicated above.

These studies all involve the observation either of the relative motions of points on the Earth's surface, or of the dynamical motions of the Earth as a whole, with uncertainties on the order of a decimeter.

Satellite altimeters capable of decimeter accuracy are expected to open up the possibility of observing many phenomena of great interest to oceanographers. For