IMPROVED ORBITS AND REFERENCE FRAME STABILITY FROM GPS TRACKING OF TOPEX/POSEIDON TO SUPPORT BASIN-SCALE SEA LEVEL STUDIES

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The TOPEX/POSEIDON (T/P) mission has contributed significantly to our understanding of the large scale variability of sea surface height. To satisfy the mission science objectives, tight restrictions have been placed on the knowledge of the radial component of the T/P orbit. Meeting these restrictions requires both precise modeling and estimation of the dynamic forces acting on the spacecraft as well as stability of the reference frame in which the orbits are expressed.

Introduction

For T/P, a combination of satellite laser ranging (SLR) and DORIS Doppler data has provided the orbits and defined the reference frame in which to study sea surface variations. However, T/P also carries a precise Global Positioning System (GPS) receiver which has operated well under non-Anti-Spoofing conditions. There is some evidence that the GPS orbits provide slightly better radial orbit knowledge as measured by altimeter crossovers and overlaps [Bertiger et al., 1994]. There has been, however, an unexplained translational offset in these precise GPS ephemerides relative to those of SLR/DORIS , which corresponds to a shift along the terrestrial z-axis (along the Earth92s rotation axis) of several centimeters. There is also some variability about the mean value of this translation. This offset and its variations can degrade both estimates of large-scale circulation and sea-level variability. Particularly sensitive are observations of the change in global mean sea level and estimates of basin and hemispheric-scale variations in sea level stemming from seasonal steric or geostrophic changes. Since GPS tracking is potentially superior otherwise, and will likely be a significant or primary tracking type for future altimetric satellites, understanding the source of this reference frame uncertainty is important. We propose that a major cause of this z-shift is the poor sensitivity of GPS to the location of the z-axis due to the estimation of real-valued phase ambiguities for all satellite-station pairs. The work proposed has two main thrusts. The first will examine the effect of ground-GPS phase ambiguity resolution for reducing the observed z-shifts, an approach which has met with partial success in preliminary tests. The second effort will be to resolve phase ambiguities directly for the T/P-GPS links.

GPS carrier phase ambiguity resolution

Recall that the primary observables from the GPS are one-way time of flight (pseudorange) and carrier phase on two L-band frequencies. The carrier phase is a biased measurement, and a real-valued bias, representing the number of integer wavelengths to be added to the phase to describe the satellite-receiver range, must be adjusted during the estimation process. This data type can be strengthened by determining the actual integer number of wavelengths, as opposed to the real-valued approximation. In practice, this can only be done for double differenced ambiguities in order to remove small transmitter and receiver specific non-integer delays. Methods for this carrier phase ambiguity resolution (sometimes referred to as bias fixing) have been described in some detail in a number of references including Melbourne [1985] and Blewitt [1989]. These methods rely on widelane ambiguity (the phase difference between L1 and L2) resolution either from ionospheric constraints or pseudorange data, combined with accurate narrowlane (ionosphere-free linear combination of L1 and L2) estimates. As the baseline length between the two sites (or one site and a low-Earth orbiter such as T/P) increases, one must rely either on increasingly sophisticated ionosphere models or utilize fairly precise pseudorange data to resolve the widelane ambiguity. Modern receivers are of sufficient quality to frequently satisfy this requirement, even under Anti-Spoofing conditions with arcs of reasonable length. Separate solutions for L1 and L2 phase ambiguities are obtained by combining the widelane ambiguity with the ionosphere-free ambiguity directly estimated as a real valued parameter in a global solution. The small wavelength of the ionosphere-free combination places tight constraints on the accuracy of the dynamic and measurement models used in the global solution in order to resolve ambiguities.

Ambiguity resolution involving TOPEX/POSEIDON

Resolution of phase biases between two ground receivers and GPS s/c ambiguities strongly improves the reference frame stability of the GPS s/c orbits [Watkins et al., 1997]. However, an additionally powerful improvement would be to resolve carrier phase biases involving one ground site, T/P itself, and two GPS s/c. This is challenging for two reasons. First, due to a design error in the application specific integrated circuit (ASIC) for the T/P GPS receiver, numerical truncation noise is added to the T/P pseudorange that makes widelaning difficult, particularly during the short spans of continuous tracking available to T/P and any specific ground site. The second major limitation is the shortness of the phase connected arcs are available to a particular ground site and T/P. This severely limits the precision of the ionosphere-free phase bias, and makes ambiguity resolution challenging even if the right widelane is obtained. Should this type of ambiguity resolution be successful, the T/P orbit would be much more firmly connected to the GPS terrestrial reference frame than ever previously achieved. As an added benefit, we could also increase the process noise for the T/P orbit and obtain excellent quality kinematic solutions for additional study and comparison with dynamic orbits.

References :

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