H. PRECISION ORBIT DETERMINATION OF ALTIMETRIC SATELLITES

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The ability to determine accurate global sea level variations is an important contributor to both the detection and understanding of changes in the climate patterns. Sea level variability occurs over a wide spectrum of both temporal and spatial scales, and precise global measurements are only recently possible with the advent of spaceborne satellite radar altimetry missions. One of the inherent requirements for the accurate determination of absolute sea surface topography is that the altimetric satellite orbits be computed with sub-decimeter accuracy within an accurately defined terrestrial reference frame. The significance of SLR tracking in support of precision orbit determination (POD) of altimetric satellites has been well established. Recent examples are the use of SLR as the primary tracking systems for TOPEX/Poseidon and for ERS-1 precision orbit determination. The current radial orbit accuracy for TOPEX/Poseidon is estimated to be around 3-4 cm, with geographically correlated orbit errors around 2 cm [Tapley et al., 1994]. The significance of the SLR tracking system is its ability to allow altimetric satellites to obtain absolute sea level measurements and thereby provide a link to other altimetry measurement systems for long-term sea level studies. SLR tracking allows the production of precise orbits which are well centered in an accurate terrestrial reference frame. With proper calibration of the radar altimeter instrument, these precise orbits, along with the altimetric measurements, provide long-term absolute sea level measurements. As an example, the U.S. Navy's Geosat mission is equipped with only Doppler beacons and without laser retroreflectors. The orbits computed using a decimated Tranet and Opnet tracking network have a reported radial accuracy of 20-40 cm [Shum et al., 1990; Haines et al., 1993]. However, these orbits, and even the Geosat orbits computed using the available full 40-station Tranet tracking network, yield orbits with significant north-south shifts with respect to the IERS terrestrial reference frame. The resulting Geosat sea surface topography will be tilted accordingly, making interpretation of long-term sea level variability studies difficult. Figure 1 shows two cases of altimeter residuals, or inverse sea levels, displayed geographically for Geosat orbits computed with and without the additional use of direct altimeter data (top and bottom pictures, respectively) in orbit determination. A significant north-south tilt (+/-50 cm) of the sea surface is observed for the orbit computed without using the direct altimeter to constrain the z-component of the orbit [Kozel, 1992]. However, the use of direct altimeter data for orbit determination has the potential to alias oceanographic features into the orbit and should be avoided, if possible. Without the benefit of global laser tracking, the use of Geosat measurements for the study of long-term or broad-scale sea level variations should be done with caution.

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SLR is the most accurate absolute-ranging instrument among existing tracking systems. Because of this, SLR has demonstrated the capability to provide additional support in the verification of possible ambiguities in other tracking systems, such as DORIS and the GPS receiver on TOPEX/Poseidon. Examples include the verification of the time bias offset in the DORIS tracking system, the center-of-mass correction offset in the GPS tracking system, and other ambiguities such as the geocentric positioning offset along the Earth's spin axis which have been obtained by some radiometric tracking systems. Figure 2 shows the time history of DORIS measurement time tag bias compared to SLR for Cycles 1-9 of TOPEX/Poseidon. The large offsets seen in the original analysis were corrected and considerably reduced in a subsequent re-release of the DORIS data. Thus, SLR provides an independent verification tool for calibration of a radiometric tracking system.

Figure 3 shows a comparison between TOPEX/Poseidon Cycle 10 orbits computed using SLR tracking data and using GPS tracking data by JPL. A significant radial offset on the order of 6 cm was observed initially during the verification time period of the TOPEX/Poseidon GPS Demo experiment. This offset appears to have been caused by an error in the correction of the GPS receiver phase center to the center of mass of the TOPEX/Poseidon spacecraft. This offset is now routinely estimated as part of the GPS orbit solution, so it is no longer a problem. Without SLR tracking, the GPS tracking system would not have the benefit of an independent calibration device to achieve absolute ranging accuracy. Results of detailed comparisons between the SLR/DORIS orbits and the GPS reduced-dynamic orbits for TOPEX/Poseidon indicate that there is a z-axis offset on the order of 2-3 cm [Tapley et al., 1994]. The cause of this offset is still under investigation. The advantage of the SLR tracking system enhances the ability to identify and correct ambiguities of tracking systems.

The SLR tracking system has also proven to be invaluable in the event of failure of the primary radiometric tracking system, as in the case of ERS-1. Without the SLR tracking, the failure of the PRARE system would have severely degraded the scientific return of the mission. The current ERS-1 radial orbit accuracy achieved using SLR tracking is below the 15-cm level [Shum et al., 1993]. The SLR system can also serve as a complement to other tracking systems, especially during data outages. In the case of TOPEX/Poseidon, DORIS data outages and loss of GPS data due to anti-spoofing or other system problems may occur.

References:

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Fig. 1. GEOSAT Altimeter Residuals from Orbits Computed With and Without Direct Altimeter Data

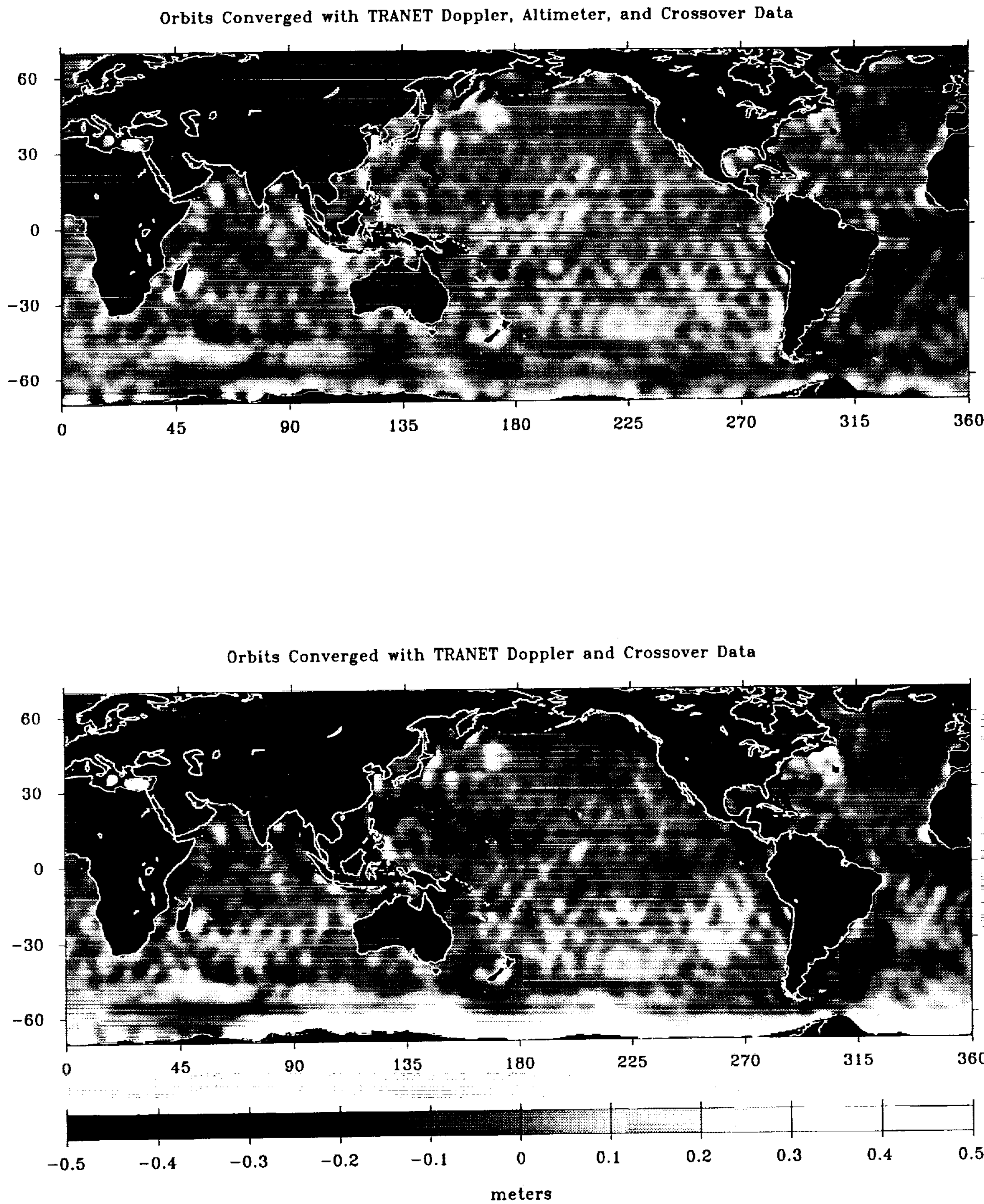

Figure 2. DORIS/SLR Time Bias vs. Time for Cycles 1–9

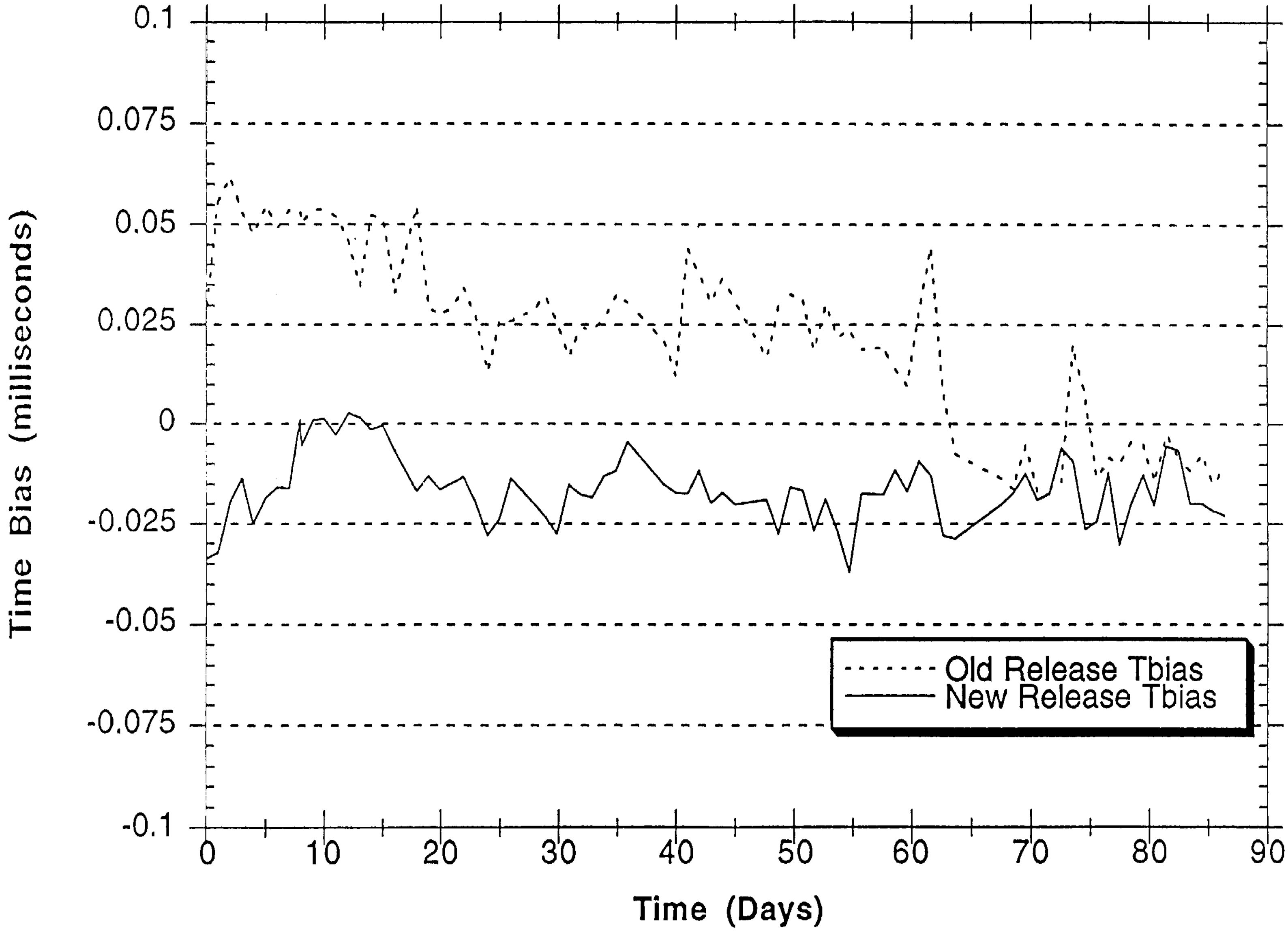

Figure 3. TOPEX Cycle 10: Radial Orbit Difference vs. Time
UT/CSR Slr vs. JPL GPS