

# TOPEX/Poseidon Precision Orbit Determination Using Combined GPS, SLR and DORIS

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TOPEX/Poseidon ("T/P") is a joint spaceborne oceanographic mission of U.S. NASA and France CNES design launched August 10, 1992. The satellite has a variety tracking systems for both operational and precision orbit determination. Three precise tracking systems: Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), and Global Positioning System (GPS) provide high quality measurements essential for reconstructing the T/P orbital height with centimeter precision. This paper presents results of simultaneously processing all three data types to exploit the inherent strength of each in a combined solution, SLR and DORIS are routinely combined to provide orbit solutions for the T/P *science* team. GPS orbit solutions are produced as part of the first demonstration flight of a high quality spaceborne GPS receiver. Coordinate frame and software system differences between the combined SLR/DORIS orbits and the GPS orbits induce orbital height differences of 2 to 3 centimeters. Combining the three data types within a single software system permits removal of software system differences while obtaining coordinate frame calibration information. These calibrations will aid future spaceborne GPS missions that are not complemented with SLR and/or DORIS.

## INTRODUCTION

The TOPEX/Poseidon (T/P) satellite carries a high precision Global Positioning System (GPS) receiver as part of a proof-of-concept precision orbit determination experiment. Resulting orbit solutions yield height accuracies below 3 centimeters ( $1\sigma$ ) [Bertiger, *et al.*, 1994]. At a similar accuracy level are independently determined orbit solutions derived from Satellite Laser Ranging, (SLR) and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) observations [Tapley, *et al.*, 1994].

Comparisons between these orbit solutions consistently yield height agreements below 3 centimeters but with a bias in the Earth-Fixed Z-component. This “Z-shift”, as it will be referred to in this paper, is believed to be associated with a reference frame misalignment between the GPS defined frame and that of the SLR and DORIS systems. The intent of this paper is to combine observations from the three tracking systems in a single solution to obtain a better understanding of the Z-shift and to calibrate the GPS reference frame relative to the SLR and DORIS frames.

## SOLUTION STRATEGY

We use the reduced-dynamic [Wu, *et al.*, 1991] filtering technique for the combined orbit determination solutions. In addition to estimating all of the GPS space vehicle states simultaneously with the T/P state, the Earth-Fixed geocenter offsets to the GPS station positions are adjusted. These geocenter offsets apply only to the GPS stations and give the translational contribution of the GPS to SLR/DORIS frame tie.

Reference station locations for use in processing the GPS ground observations are derived from a fiducial free adjustment of a global network of about 50 stations for the years 1991 to 1995. These station positions and velocities are closely related to the International Terrestrial Reference Frame (ITRF) of 1993. They are referred to as: JPL95P02 and are the submission from JPL to the International Earth Rotation Service (IERS) ITRF94 solution. SLR and DORIS station locations, also closely tied to ITRF93, are from solutions computed at the University of Texas Center for Space Research (UTCSR). The SLR station coordinates (CSR95L01) are based on LAGEOS and LAGEOS-2 observations between 1976 and 1992. DORIS positions (CSR95D02) are derived from T/P data from 1992-1994.

Observations weights are unchanged from the uncombined solutions. Table 1. gives the weight for each observation type.

Table 1. observation Weights

<u>Observation Type</u>	<u>Weight</u>
GPS Spaceborne Carrier Phase	0.02 m
GPS Spaceborne Psuedorange	2 m
GPS Ground Carrier Phase	0.01 m
GPS Ground Psuedorange	1 m
SLR Ground	0.01 - 100 m
DORIS Ground	3.2 mm/s

## ORBIT COMPARISONS

Five ten day cycles have been processed with virtually no change to the orbital height differences with respect to the GPS only solutions. Figs. 1. and 2. show the height and Z-shift orbit differences for the uncombined solutions. Also, little change is seen in the Z-shift when comparing the combined solutions. This is believed to be the result of the GPS observations dominating the combined solution due. to the abundance of observations and overweighting relative to the SLR and DORIS data.

## ALTIMETER CROSSOVER COMPARISONS

Altimeter crossover differences for the uncombined solutions are shown in Fig. 3. A noticeable correlation is observed between the T/P beta prime angle (angle related to the Earth/Sun position and the T/P orbit plane) and the altimeter crossovers. This suggest some sort of dynamic mis-modelling in one of the orbit solutions. For the combined solutions, the improvement in the altimeter crossover variances computed is small compared to the GPS only solution. Fig. 4. shows the resulting crossover variances for various combinations of observations during groundtrack repeat cycle 43.

## GPS STATION COORDINATE ALIGNMENT

Geocenter estimates for the GPS ground station network produce an average 2 centimeter Z-shift. Fig. 5, shows geocenter estimates from two time periods in 1993 and 1995. The 1995 solutions incorporate improved GPS space vehicle attitude modelling during Earth shadow events. Estimates of the X and Y geocenter offsets compare well with values deter-mined with GPS ground observations only (i.e., no T/P data). However, the Z-component estimates appear to much better determined when including the T/P observations.

## CONCLUSIONS

Preliminary results of combining GPS, SLR and DORIS observations show that small improvements in the altimeter crossover variance can be obtained and an average 2 centimeter geocenter offset in the Z-component of the GPS station coordinates is observed. Future study will involve processing more observations and optimizing the relative data weights.

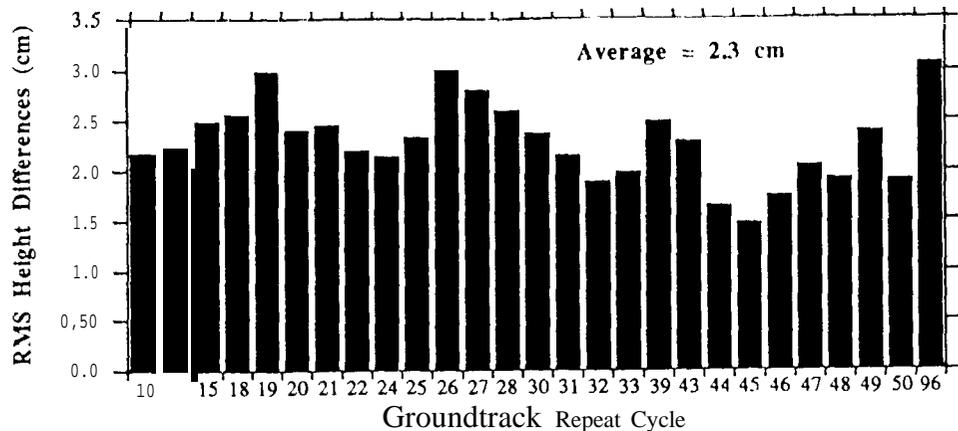


Fig. 1. Orbit Height Comparisons (S LR+DORIS minus GPS)

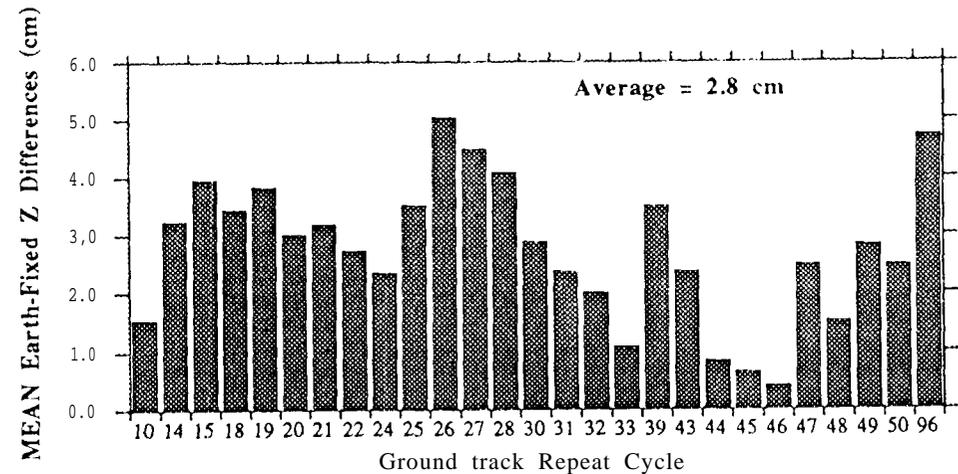


Fig. 2. Z-Shift

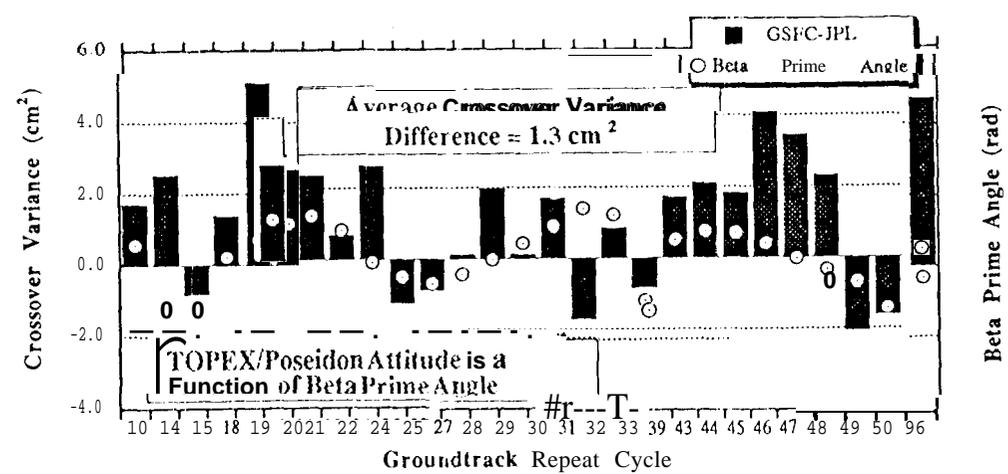


Fig. 3. Altimeter Crossover Comparisons (S LR+DORIS minus GPS)

Groundtrack Repeat Cycle 43 (93nov13 to 93nov23)

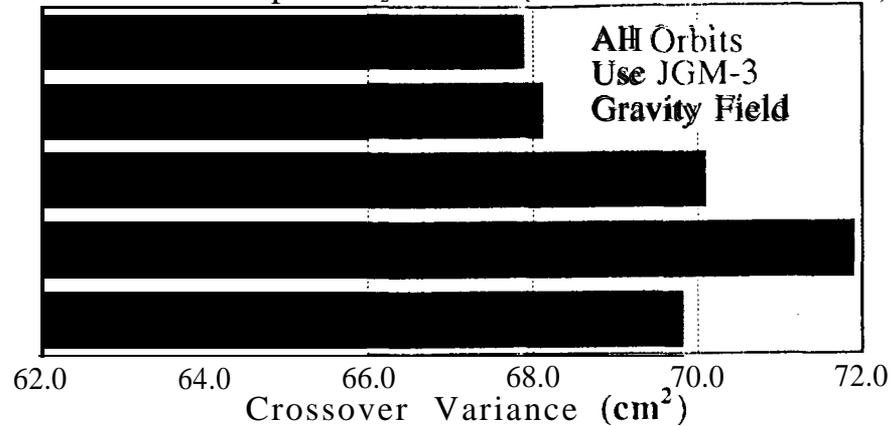


Fig. 4. Altimeter Crossover Results

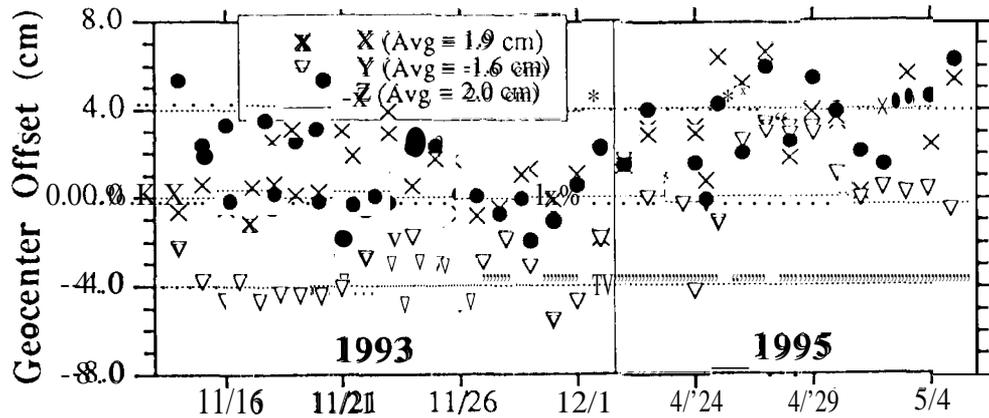


Fig. 5. Geocenter Estimates

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REFERENCES

Bertiger, W., et al., GPS precise tracking of TOPEX/POSEIDON: Results and implications, *J. Geophys. F/es.*, 99, 24449-24464, 1994.  
 Tapley, B., et al., Precision orbit determination for TOPEX/POSEIDON, *J. Geophys. Res.*, 99, 1994.  
 Wu, S. C., et al., Reduced-dynamic technique for precise orbit determination of low Earth satellites, *J. Guid., Control and Dynamics.*, 14, 24-30, 1991.