Evaluation of the Geosat Follow-On Precise Orbit Ephemeris

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ABSTRACT

The GEOSAT Follow-On spacecraft (GFO), launched in 1998, began continuous radar altimeter coverage of the oceans in 2000. After an extensive series of calibration campaigns in 1999 and 2000, the spacecraft was finally accepted by the US Navy on November 29, 2000. By providing high quality altimeter data, GFO can supplement Jason, TOPEX/POSEIDON(T/P), and Envisat, providing a different synoptic sampling of the oceans with its 17-day ground track repeat cycle. Altimeter crossover analysis suggests GFO is capable of POSEIDON class altimetry, with orbit error the largest contributor to the GFO altimeter error budget. Satellite laser ranging (SLR) data, especially in combination with altimeter crossover data, offer the only means of determining high-quality precise orbits. SLR tracking is also augmented by Doppler (Tranet style) beacons. These data were used to tune the gravity field and macromodel (3D representation of the spacecraft geometry and surface properties). Beginning with January 2000 GSFC has produced a 3.8 year span of the Precision Orbit Ephemeris (POE) intended for use on the GFO GDR. The current GFO gravity field (pgs7727) has been re-tuned using CHAMP data and an additional 2-years of GFO SLR/Doppler/Crossover data (pgs7777b). The pgs7777b shows significant improvement in POD performance over all other gravity fields. All previous orbits for GFO have been re-processed and the new orbits now use pgs7777b. Orbit accuracy is evaluated using GFO tracking data and altimeter crossover and collinear sea surface height residuals, and analysis of coefficients used to adjust GFO data into the TOPEX frame.

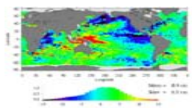
4-5 cm GDR orbit error relative to TOPEX and Jason

GFO Adjustment to TOPEX Reference Network

T/P-GFO altimeter crossover data is used to adjust GFO to the T/P frame removing GFO instrumental and orbit effects

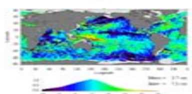
TOPEX SSH anomaly wrt GSFC MSS

January 2001



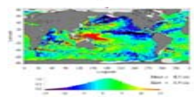
GFO SSH anomaly wrt GSFC MSS

January 2001



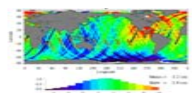
GFO SSH anomaly wrt GSFC MSS adjusted using TP-GFO crossovers

January 2001



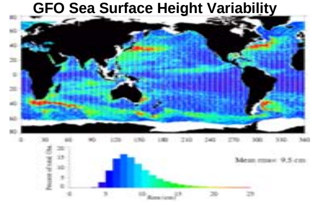
GFO Correction (mostly orbit error)

January 2001

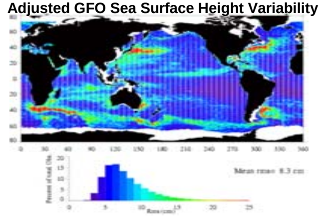


4-5 cm GFO orbit error relative to TOPEX inferred from the improvement in the mean rms of the Adjusted GFO SSH variability

GFO Sea Surface Height Variability

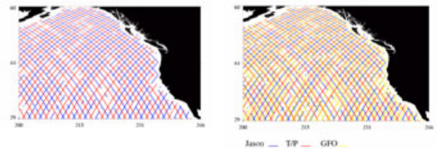


Adjusted GFO Sea Surface Height Variability



GFO Adjustment to Jason/TOPEX Tandem Reference Network

An adjustment reference network from TOPEX+Jason provides four times the number of crossovers allowing a crossover time constraint of two days to further preserve oceanographic signals during the adjustment of GFO. To maximize Tandem Mission benefits, discrepancies between Jason/TOPEX should be minimized (see Beckley et.al. poster)

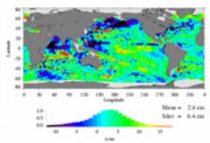


Jason reference with 5 day crossover time difference constraint

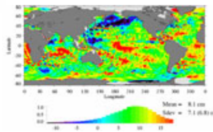
crossover type	number crossovers	rms (cm)
GFOxJason	9696	9.9
GFOxGFO before adjustment	8267	9.5
GFOxGFO after adjustment	8267	7.1

Jason/TP reference with 2 day crossover time difference constraint

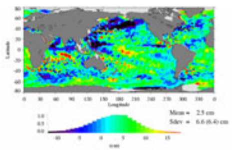
crossover type	number crossovers	rms (cm)
GFOxJason/TP	9481	8.8
GFOxGFO before adjustment	8267	9.5
GFOxGFO after adjustment	8267	7.0



TOPEX + Jason sea surface height anomalies with respect to GSFC00.1 MSS for Jason cycle 37 (January 07-17, 2003.)



GFO cycle 102 SSH anomalies with respect to GSFC00.1 MSS (January 11-27, 2003)

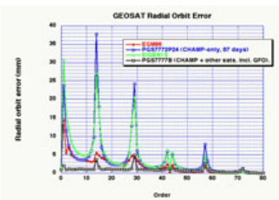


Adjusted GFO cycle 102 SSH anomalies with respect to GSFC00.1 MSS

pgs7777b – a new tuned gravity field for GFO

Pgs7777b is superior to all other gravity fields for GFO POD, including the latest fields from Grace. Pgs7777b was , computed from pgs7727 (the EGM9-derived GDR standard) using 87 days of Champ data and tracking data from GFO (SLR/Crossovers), TOPEX (SLR/DORIS), Jason (GPS), Envisat (SLR/DORIS), and other SLR data.

Covariance projections



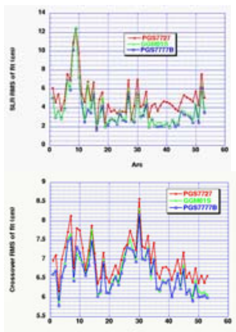
GEOSAT & GFO Radial Orbit Error:

JGM2:	65.2 mm
JGM3:	49.8 mm
EGM96:	26.2 mm
PGS7727:	13.2 mm
GRIM5C1:	57.0 mm
EIGEN1S:	61.9 mm
PGS7772p24:	62.8 mm
PGS7777B:	10.0 mm

Performance results

GFO POD Gravity Model Test Summary
average RMS over 53 arcs July '00 – August '01

gravity model (red: combination; blue: satellite only)	SLR (cm)	Crossovers (cm)
OSU03A	7.70	11.19
EIGEN1S	9.98	10.50
GRIM5C1	7.14	10.49
EIGEN2	5.98	7.87
EIGEN3p	5.36	6.92
GGM01C	3.98	6.69
GGM01S	3.87	6.67
PGS7727	5.07	7.00
PGS7777B	3.62	6.63
PGS7777B +new GFO macromodel	3.59	6.60



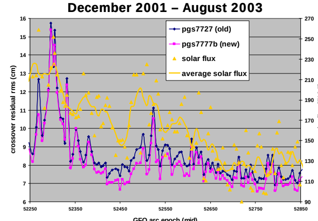
GFO GDR (pgs7727) and Reprocessed (pgs7777b) orbits

The table and plot below show the pgs7777b offer a significant and consistent improvement over the pgs7727 orbits. All new orbits since Feb 2004 have been determined with pgs7777b. The plot also shows error due to atmospheric drag dominates the orbit over periods of high solar activity.

Orbit performance summary
rms residuals (cm)

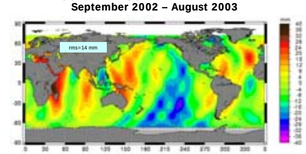
orbit	jan 4, 2000 – feb 18, 2004 slr	jan 4, 2000 – feb 18, 2004 xover	jan 1, 2003 – feb 18, 2004 slr	jan 1, 2003 – feb 18, 2004 xover
pgs7727	6.831	8.779	6.367	7.501
pgs7777b	5.539	8.330	4.771	7.124

**Crossover residuals and solar activity
December 2001 – August 2003**

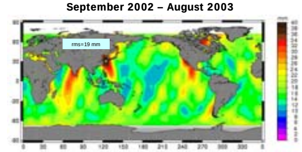


The mean orbit difference (figure C1) and standard deviation about that mean (figure C2) indicate geographically correlated and geographically anti-correlated error in the orbits It is believed most of the error is in the pgs7727 orbits.

**C1. pgs7777b – pgs7727 radial orbit mean
September 2002 – August 2003**

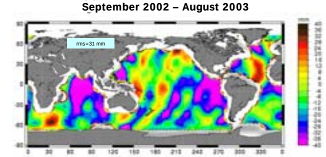


**C2. standard deviation about radial orbit mean
September 2002 – August 2003**



The average altimeter crossover residuals maps (figures C3 and C4) indicate anti-correlated gravity orbit error. Notice the reduction in this error as we move from pgs7727 to pgs7777 (C3 to C4). Also notice the resemblance between the orbit difference standard deviation (C2) and the pgs7727 mean crossover map (C3).

**C3. pgs7727 crossover residuals mean
September 2002 – August 2003**



**C4. pgs7777b crossover residuals mean
September 2002 – August 2003**