Operational and Precise Orbit Determination for Geosat Follow-On Altimetry

Fall 2001 AGU Poster G22A-0202

John L. Lillibridge[1], Nikita P. Zelensky[3], Frank G. Lemoine[2], David D. Rowlands[2], Douglas S. Chinn[3] and Brian D. Beckley[3]

[1] *NOAA Laboratory for Satellite Altimetry, 1315 East-West Hwy. #3620, Silver Spring, MD 20910-3282*

[2] *Space Geodesy Branch, Code 926, NASA Goddard Spaceflight Center, Greenbelt, MD 20771*

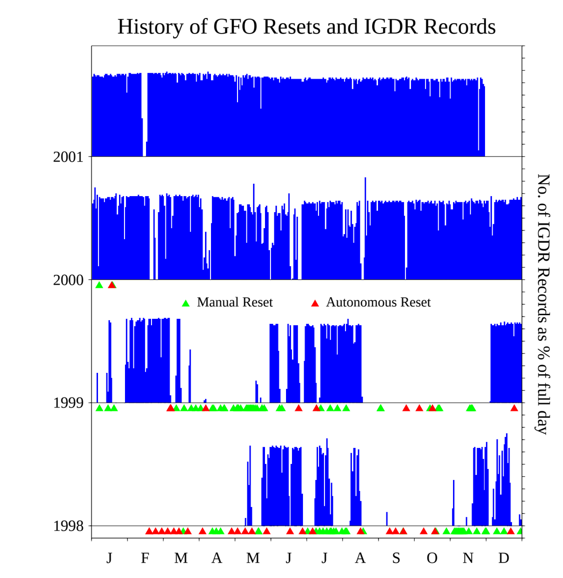
[3] *Raytheon ITSS Corporation, Greenbelt, MD 20771*

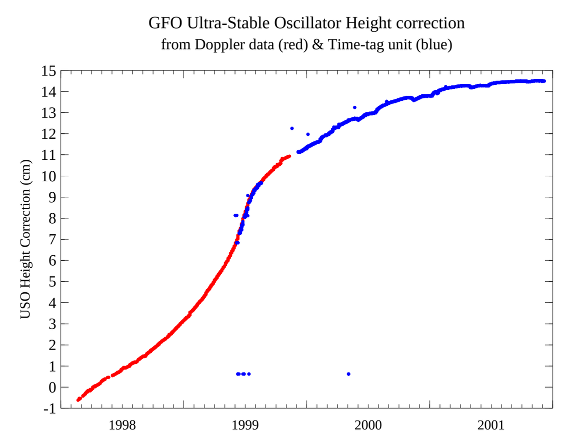
ABSTRACT - The U.S. Navy's GEOSAT Follow-On spacecraft, launched in early 1998, began continuous radar altimeter coverage of the oceans in 2000. After an extensive series of calibration campaigns in 1999 and 2000, the satellite was accepted by the Navy on November 29, 2000. GFO can supplement the altimetry data from TOPEX/POSEIDON and ERS-2 (and their successors JASON-1 and ENVISAT), by providing a different synoptic sampling of the oceans with its 17-day ground track repeat cycle.

Altimeter crossover analysis suggests that GFO is capable of "cm-class" altimetry, with orbit errors remaining the largest contributor to the sea surface height error budget. Satellite laser ranging (SLR), especially in combination with altimeter crossover data, offers the only means of high-quality precise orbit determination, due to the failure of the GPS tracking system on board GFO. SLR tracking is augmented by the operational Doppler (Tranet style) tracking system. These data have been used to tune the gravity field model and satellite macro-model (a 3-D representation of the spacecraft geometry and surface properties) used in the orbit determination software.

Near real-time medium precision orbits (MOEs) are generated at GSFC within 72 hours and (in the absence of maneuvers) have radial orbit errors of 10 cm or less. These preliminary orbits are suitable for mesoscale studies where short-arc orbit error removal doesn't severely impact the sea surface height signals. Beginning on August 9, 2001 GSFC began releasing Precision Orbit Ephemeris (POE) data for use on the science-quality NOAA GDR and NASA Pathfinder Project. The POE orbits are more accurate than the MOEs, with orbit errors of 5 cm or less. In order to characterize the POE errors, these orbits are evaluated using tracking data residual analysis, GFO altimeter crossover and collinear analyses, dual-satellite altimeter crossovers, and direct orbit comparisons.

Mission History and Status



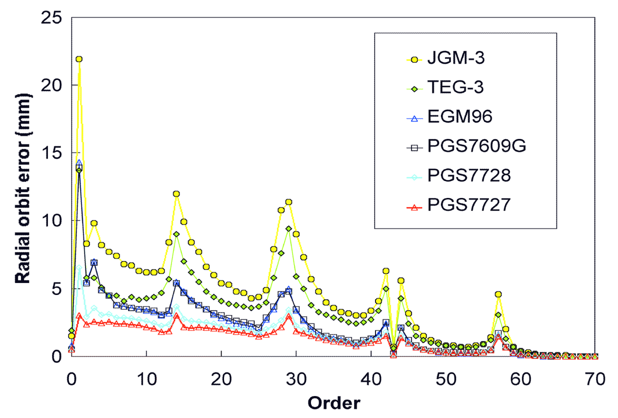


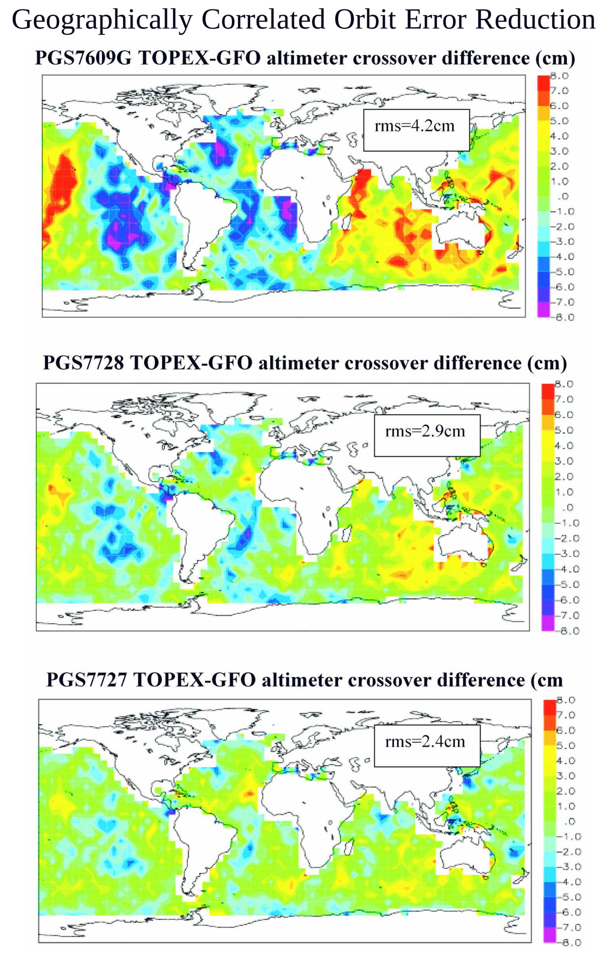
- Launched from Vandenberg AFB in February, 1998: nominal 8-year lifetime
- Ku-band single-frequency altimeter; dual-frequency radiometer; Doppler beacon; laser retroreflector; fixed solar array; solid state data storage; four GPS receivers - unable to track GPS constellation
- CPU resets of both on board processors hampered operations until software patched successfully in November, 1999
- Loss of GPS affects precise orbit determination AND time-tagging of data
- Precision timing now provided by ground-based time-tagging unit, installed at NAVSOC in June, 1999
- Large initial drift in Ultra-Stable-Oscillator has stabilized greatly in 2001
- Navy acceptance on November 29, 2000 - high data coverage during most of years 2000 and 2001.
- NOAA GDRs are in production for most of 2000 and all of 2001, based upon NASA POE orbits, with state-of-the-art corrections and model fields

Gravity Field & Satellite Macro Modelling

GFO Gravity Orbit Error Covariance (to 70x70) Projection

Gravity Field	GFO Orbit Error (cm) geographically correlated Radial	Radial	Cross-Track	Along-Track
JGM3	4.53	4.97	23.80	42.61
TEG3	3.30	3.48	21.42	42.76
EGM96	2.35	2.61	8.94	17.72
PGS7609G	2.35	2.61	8.93	16.44
PGS7728	1.49	1.66	8.57	14.84
PGS7727	1.16	1.31	8.42	14.40





GFO Macro Model Approximation

Anticipate 70-90% pre-tune accuracy

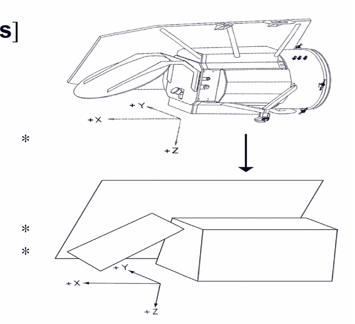
Acceleration due to radiation pressure on a flat plate:

$$\Gamma = -\frac{\Phi A\cos\theta}{Mc}\left[2(\delta/3+\rho\cos\theta)\mathbf{n}+(1-\rho)\mathbf{s}\right]$$

where

Γ	=	acceleration (m/s^2)	
Φ	=	radiation flux from source	
A	=	surface area of flat plate (m^2)	*
θ	=	incidence angle (surface normal to source)	
M	=	satellite mass (m)	
c	=	speed of light (m/s)	
δ	=	diffuse reflectivity	*
ρ	=	specular reflectivity	*
$\mathbf{n}$	=	surface normal unit vector	
$\mathbf{s}$	=	source incidence unit vector	

* are the adjustable macro model parameters

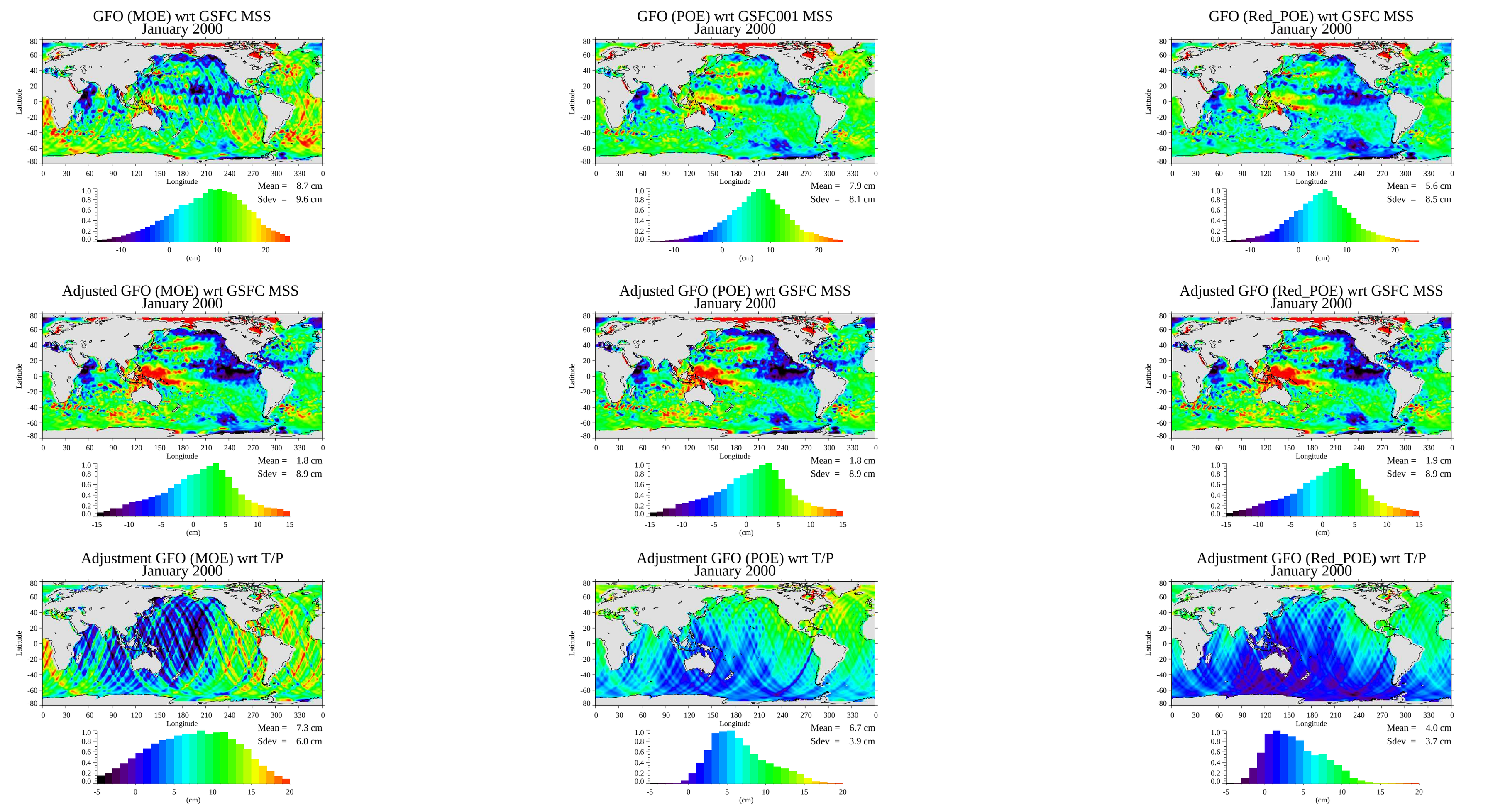


GFO Macro model Tuning

Spacecraft Surface Model	Solar Array (SA) Reflectivity Coefficient	SLR Fits Over 32 Dependant Arcs (cm)	SLR Fits Over 57 Independent Arcs (cm)	SLR Fits Over 80 Arcs Total[2] (cm)
Cannonball	----	13.23	12.88	12.99
A-priori macro model	.160	13.11	12.89	12.95
Tuned SA macro model[1]	.144	13.04	12.80	12.87

[1] Tuned using 23 SLR+Doppler and 8 SLR+Dopple+Crossover arcs spanning 980522-000206
[2] 80 consecutive arcs spanning 980422-990603

GFO Orbit Improvement: MOE - POE - Reduced Dynamic



Summary

- Tuning of the gravity field model has reduced GFO orbit errors significantly with respect to Topex/Poseidon
- A macro model for GFO has been tuned to further reduce orbit errors by better modelling of non-conservative forces
- Near real-time Medium Orbit Ephemeris solutions are adequate for operational mesoscale analyses, but the final Precise Orbit Ephemeris on the NOAA GDRs reduces residual orbit error to 5 cm or better
- The combination of NASA POE orbits, precision time-tagging, and the best environmental model corrections yields true "cm-class" altimetry from Geosat Follow-On