Precise orbit determination for GEOSAT and GEOSAT Follow-On

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ABSTRACT

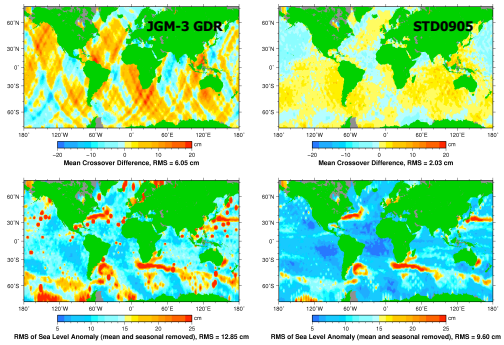
The U.S. Navy GEOSAT mission provided the first long-term altimetric record for studies of ocean circulation, marine gravity/bathymetry and continental ice, from early 1985 through 1989. The GEOSAT Follow-On spacecraft (GFO), launched in 1998, began continuous radar altimeter coverage of the oceans in 2000 and was terminated in late 2008. By providing high quality altimeter data, GEOSAT delivered the first and only altimetric measurements over the 1980's. GFO supplements 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 and GEOSAT are capable of Poseidon class altimetry, both showing crossover residuals averaging below 7.5 cm, with 5-cm orbit error the largest contributor to the altimeter error budget. This study evaluates improvements to the recently released GEOSAT GGM02C GDR orbits and current GFO GDR orbits. The POD model improvements include application of standards consistent with the latest generation of GSFC reprocessed T/P, Jason-1, and Jason-2 MEaSURES orbits, such as the LPOD2005 set of SLR station coordinates, the EIGEN-GL04S1 gravity model, and improved modeling of the time-varying geopotential using GRACE data and the GOT4.7 ocean tide model. In addition the Doppler station coordinates have been re-estimated. In this presentation we summarize the quality of the orbits and the status of our research effort.

GEOSAT orbit improvement

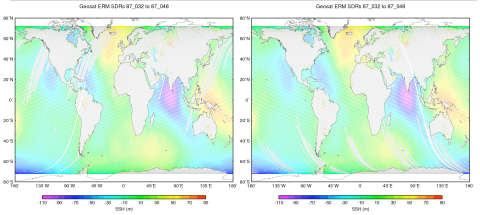
GEOSAT POD model improvements

Version	GDR (1997)	GGM02C (2007)	EIGEN_GL04S (2009)
Gravity (static)	JGM3 (70x70)	GGM02C (120x120)	EIGEN_GL04S (120x120)
Gravity (time-variable)	C20dot, C21dot, S21dot	C20dot, C21dot, S21dot + 20x20 annual terms from GRACE	same
Atmospheric gravity	Not applied	NCEP, 50x50 @6 hrs	ECMWF, 50x50 @6 hrs
Ocean Tides	Schwiderski + GEMT3X	GOT00.2 (20x20)	GOT4.7 (20x20)
Solid Earth Tides	k2= 0.300; k3=0.093 + special handling for FCN	IERS2003	same
Albedo/IR	Knocke & Ries, 1988	same	same
Atmospheric drag	MSIS86	same	same
Data	Doppler-only	Doppler + Altimeter Crossovers	same
Parameterization	Cd/day + Cr + once-per-rev/arc	Cd/8 hrs + once-per-rev along +cross-track/day	+ Constrained Drag / 25 min (high solar activity option)
Doppler station coordinates	JGM2	pgs7727 (post-EGM96: used all ERM & GM Doppler data)	eigen_gl04s (4 years Doppler/ crossover data)

Mean crossover differences (top) and RMS sea surface variability (bottom) ERM (11/86 - 12/89)

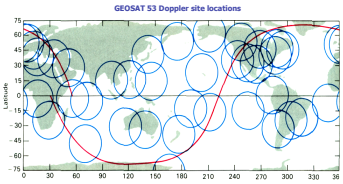


Example validation of recovered SDR ERM data, based on range-orbit values which reflect the marine geoid height with a range of -110 to +90 m as expected



In 2009 NOAA completed a major data rescue effort to recover the original Geosat Sensor Data Records (SDR) for the Exact Repeat Mission. 1098 daily SDR tapes were successfully recovered, with a loss of only 8 tape blocks totaling 2m 32s of data. Eleven SDR tapes could not be located, resulting in a total success ratio of 99.2% for the entire ERM. This year the SDRs will be merged with their companion Waveform Data Records, to enable retracking of the complete Geosat mission, application of the improved orbits described here, and enhancements to the previous correction fields.

New Doppler station positions



7-parameter Helmert transform estimated for pgs7727-to- eigen_gl04s station coordinates (1987.0 epoch)

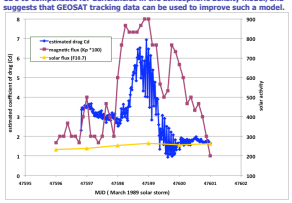
translation (mm)			scale (ppb)	rotation (mas)		
x	y	z		Rx	Ry	Rz
-28.1	54.3	26.5	-4.4	-1.8	-1.0	0.5

Evaluation of new Doppler coordinates using independent 1989 data

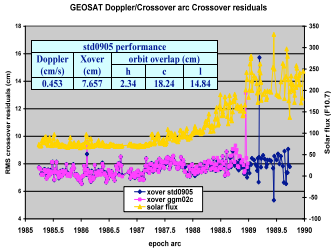
station complement	Doppler (cm/s)	Xover (cm)
pgs7727 (a-priori)	0.6408	8.242
eigen_gl04s (new)	0.6288	8.123

Solar Storm

An intense solar storm occurred March 1989. The figure below illustrates the efficacy of estimating a time series of closely spaced but constrained Cd's to compensate for deficiencies in the atmospheric density model, and suggests that GEOSAT tracking data can be used to improve such a model.



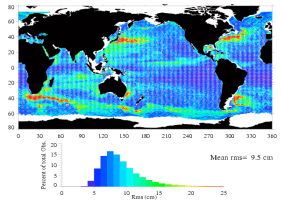
GEOSAT Doppler/Crossover arc Crossover residuals



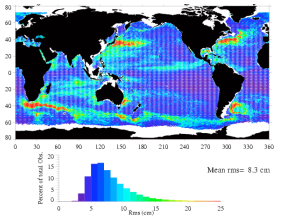
GFO GDR orbit (pgs7727) 5-cm error relative to TOPEX

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

GFO Sea Surface Height Variability



Adjusted GFO Sea Surface Height Variability

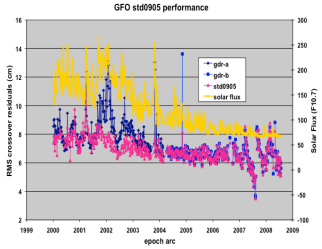


GFO orbit improvement

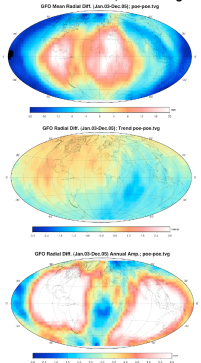
GFO POD model improvements

Orbit	gdr-a (to Apr 8 '04) (2001)	gdr-b (from Apr 9 '04) (2004)	std0905 (2009)
Gravity (static)	PGS7727 (70x70)	PGS7777b (110x110)	EIGEN_GLO4S (120x120)
Gravity (time-variable)	C20dot, C21dot, S21dot	same	C20dot, C21dot, S21dot + 20x20 annual terms from GSFC GRACE solutions
Atmospheric gravity	Not applied	not applied	ECMWF, 50x50 @6 hrs
Ocean Tides	Ray99 (T/P) + PGS7727 resonant	Ray99 (T/P) + PGS7777b resonant	GOT4.7 (T/P) (20x20)
Solid Earth Tides	k_2= 0.300; k_3=0.093 + special handling for FCN.	same	IERS2003
Parameterization and arc span	Cd/8 hrs + opr along+cross track/day; 6-day arc	same	Constrained Drag / 25 minutes for high solar activity
SLR stations	ITRF2000 with ocean loading	same	LPOD2005
Doppler stations	adjusted to the SLR CSR95L02 frame	same	added velocities, re- tuned to ITRF2000
LRA offset	tuned with 2-months SLR tracking data	same	phase center correction, re-tuned
precession	IAU1976	same	IAU2000
nutation	IAU1980+ corrections	same	IAU2000

GFO std0905 performance



Time varying gravity radial signal modeled in std0905, but not in gdr



summary orbit solutions 2000 - 2008	radial overlap (cm)	SLR (cm)	Xover (cm)	estimated radial error
gdr	2.09	4.71	7.31	4 - 5 cm
std0905 (ITRF2005)	1.56	2.63	6.91	3 - 4 cm
std1007 (ITRF2008)	1.53	2.48	6.89	3 - 4 cm

Summary and future work

Since the GDR release the orbits for GFO and especially for GEOSAT have seen dramatic improvement. Reasons for the improvement include use of GRACE-derived gravity fields, a POD approach tailored for periods of increased atmospheric density, and the use of altimeter crossovers for GEOSAT. The presence of 2-cm mean crossover residuals suggests remaining GEOSAT orbit error, possibly due to mis-alignment of the Doppler stations with the current ITRF2005 realization. We plan to re-estimate the Doppler stations using TOPEX/GEOSAT crossover for a better tie to the current TRF. ITRF2008 SLR complement (std1007) shows an improvement over ITRF2005 for GFO. The std1007 POD standards are also consistently applied across the TOPEX and Jason-1/2 missions

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