Calibration/Validation Results for Geosat Follow-On

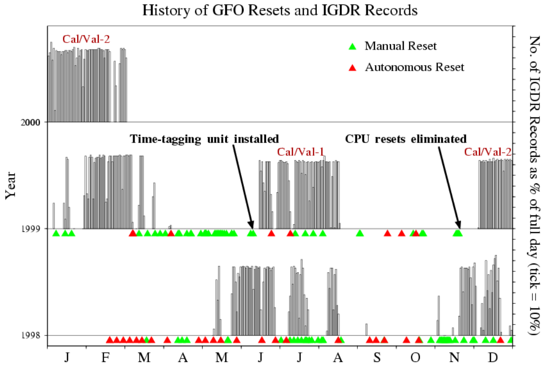
John L. Lillibridge [1], C.-K. Shum [2], Robert E. Cheney [1], and Changyin Zhao [2]

[1] *NOAA Laboratory for Satellite Altimetry*
1315 East-West Highway
Silver Spring, MD 20910 USA
http://ibis.grdl.noaa.gov/SAT

[2] *Department of Civil and Environmental Engineering*
and Geodetic Science
The Ohio State University
Columbus, OH 43210 USA
http://geodesy.eng.ohio-state.edu

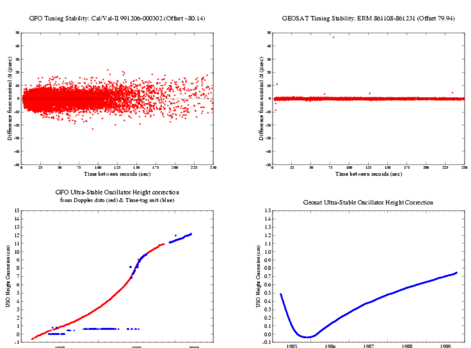
Mission History and Status

History of GFO Resets and IGDR Records

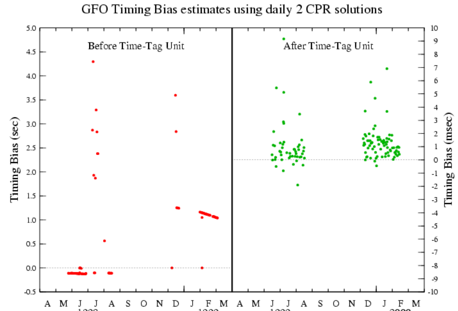


- Launched from Vandenberg AFB on February 10, 1998 - nominal 8-year lifetime
- Ku-band single-frequency altimeter; dual-frequency radiometer; Doppler beacon; four GPS receivers; laser retroreflector; fixed solar array; solid state data storage
- CPU resets of both on board processors hampered operations until software patched successfully in November, 1999.
- GPS receivers fail to lock onto GPS constellation due to hardware defect; software workarounds have been unsuccessful
- Loss of GPS affects both precise orbit determination AND time-tagging of data
- Precision timing now provided by ground-based time-tagging unit, installed in June 1999

Timing Issues



GFO Timing Bias estimates using daily 2 CPR solutions



- Nominal 1-Hz spacing between data records varies by +/- 10 microseconds for GFO; by comparison Geosat has much greater datation stability
- Ultra-stable oscillator frequency (provided by Doppler beacon) is drifting at a rate ~ 10 times greater than Geosat
- USO correction from time-tagging unit has outliers due to bookkeeping errors, unrelated to oscillator frequency
- Timing biases (between the altimeter and orbit determination "clocks") are primarily manifested as twice per revolution orbit error
- Prior to installation of the time-tagging unit in June 1999 large timing biases, on the order of seconds, are observed; current Cal/Val data exhibit timing biases of around 1 +/- 1 millisecond
- Data prior to time-tag unit installation can be salvaged

GFO-1 ORBIT DETERMINATION AND ANALYSIS

- Averaged statistics for OSU orbit, RA time bias, range bias, sea state bias

SLR rms	Crossover rms	RA rms	Time bias* (ms)	RA bias**	SSB
3.8 cm	7-9 cm	14 cm	-1 to +2	-5 cm	4.3% SWH

*June 16-Aug. 19, 1999 Data ** Relative to T/P MSS, negative: RA short

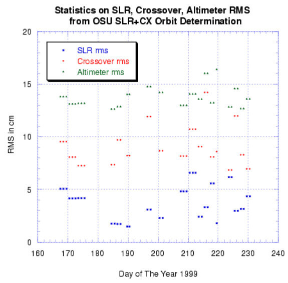
- Selected orbit (6-day arcs) comparison (gravity models, different Orbits)

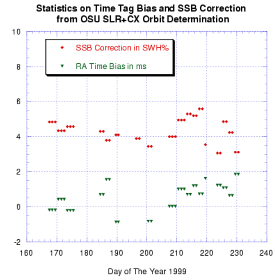
		TEG3	EGM96	IGDR (NASA Orbit)
Jun 16-21 1999	SLR rms	4.75cm	4.78cm	
	CX rms	8.03cm	8.60cm	12.74cm
July 26-31 1999	SLR rms	6.84cm	7.70cm	
	CX rms	8.49cm	9.19cm	8.40cm

Estimated GFO Radial Orbit Error

$$xover_{rms}^2 = \sigma_{orbit}^2 + \sigma_{nonorbit}^2 = (8cm)^2$$

For GFO: $\sigma_{nonorbit} \approx 6cm \Rightarrow \sigma_{orbit} \approx 5cm$

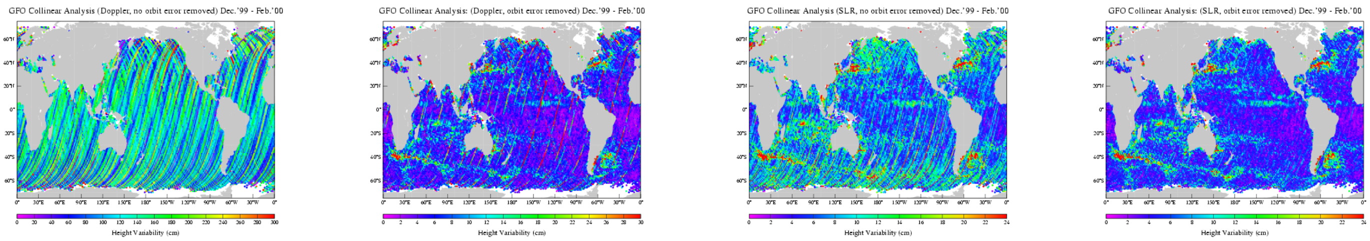


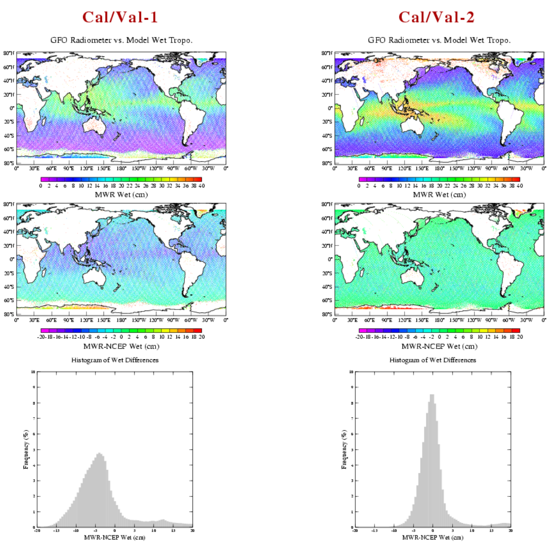


Precise Orbit Determination

- Orbit error analysis performed at OSU indicates GFO laser orbits contain residual errors of only 5 cm rms
- Range bias of 5 cm in Cal/Val-1 due to radiometer (see below)
- Timing biases confirmed at ~ 1 +/ 1 millisecond
- Sea-state bias estimated between 3 - 4.5% of SWH
- Operational Doppler orbits have orbit errors on the order of one meter or more; even after removal of once and twice per revolution error there is significant trackiness
- Sea surface height variability shows expected oceanic current regimes when laser orbits are utilized, even before correcting for orbit error

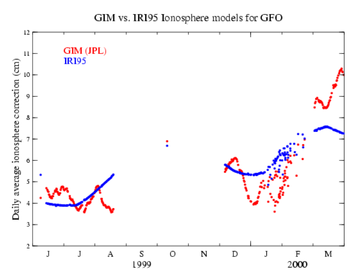
Doppler orbits vs. precision laser orbits





Environmental Corrections

- Radiometer algorithm error, prior to second Cal/Val period, causes 5 cm bias in wet troposphere height correction
- Ionosphere corrections from IRI95 and GIM models differ by a few cm, which can lead to unrealistic trends in sea level - GIM iono correction appears more reasonable



Summary

- Significant problems with CPU resets & time-tagging have been solved
- Timing biases are now at the millisecond level
- Laser orbits with 5 cm accuracy are achievable, perhaps in near real-time
- The 5 cm bias due to a radiometer algorithm error has been eliminated
- Work is needed on the ionosphere correction, USO height correction, and SSB estimation