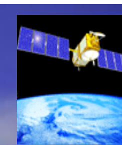

Monitoring Jason-3 Sea Surface Height Stability for Global and Regional Sea Level Estimates

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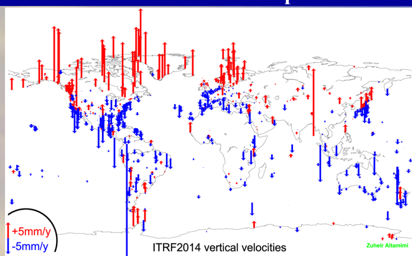
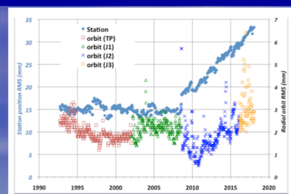
Abstract: The terrestrial reference frame is the foundation for analysis and interpretation of Earth science observations, especially for data from ocean radar altimeter satellites. The accuracy of the coordinates as well as the consistency of the technique solutions within an ITRF affect the accuracy with which orbits are computed, and map into the accuracy of the estimates for global mean sea level (GMSL). The launch of Jason-3 offers the possibility of continuing GMSL monitoring well into the next decade. In an effort to provide a consistent TOPEX/Jason altimeter sea surface height (SSH) time series and seamless transition to Jason-3, we have generated orbits for the entire time span based on the revised ITRF2014 terrestrial reference frame, improved gravity field and solar-radiation models. We report the efficacy of precise orbits from several centers, and evaluate the subsequent impact on current global and regional mean sea level estimates.

Improved Orbit Determinations based on ITRF2014 for TOPEX/Poseidon, Jason-1, 2, & 3 Altimetry



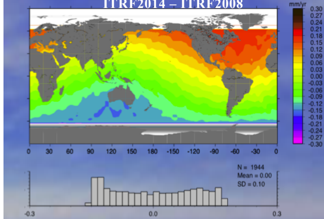
Revised preliminary GSFC replacement orbits (std1808a) have been generated for the Jason-2&3 altimetric time series based on a new release of the International Terrestrial Reference Frame ITRF2014. Improvements over the prior ITRF2008 is realized by the "extended observation history of the four space geodetic techniques VLBI, SLR, GNSS, and DORIS" (*Altamimi et al., 2016*). Image above left (from *Altamimi et al., 2016*) show the tracking stations vertical velocities with formal error less than 0.2 mm/y.



Station position degradation begins upon extrapolation past the ITRF solution end date, degrading the orbit. POD standards must be updated with each new ITRS realization, available every ~5-years.

Sea Level Rate Differences (1993 – 2017)

ITRF2014 – ITRF2008



For altimetric satellite POD outside the "station solution interval" (1979 to 2008 for ITRF2008), the tracking station coordinates must be extrapolated. It is in this "extrapolation period" that we can see increasing degradation in tracking data fits and the resultant orbits based on ITRF2008, which can include potential drift error. We have evaluated ITRF2014 and compared its performance to ITRF2008 (*Zelensky et al., 2017*). We see an improvement in the Satellite Laser Ranging Data RMS of fits per 10-day arc of 1-2 mm for ITRF2014 after 2010. The right image (note ± 0.3 mm/y color scale) shows expected regional sea level trend differences over the 1993-2017 period when orbits are based on ITRF2014 versus ITRF2008. A standard deviation of 0.1 mm/y provides a stability metric for the most recent ITRF (*Zelensky et al., 2017*).

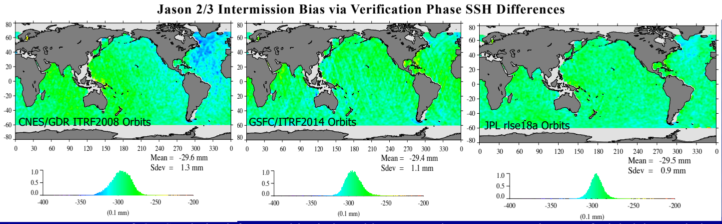
GSFC POE Description (changes)

model	dpod2014v04	std1808a
	(Previous, 2017)	(New, 2018)
GEODYN version	1612	1802
gravity	GOCO02S + 5x5 GSFC	GOCO05S
atmospheric gravity	ECMWF 50x50, 6-hour	GFZ 90X90, 3-hour
mean pole	IERS2010	IERS2014 (linear)
integration step size	30 s	15 s
SRP	old TSI, Cr=0.945	new TSI, tuned SA+, X-, + adjust Cr/arc
DPOD2014	Version 0.4	Version 2.0
LRA phase center	constant correction	constant + elevation correction
SLR bias template	gsfc2014 (ILRS_Data_Handling_File _2010.snx	gsfc2018 (ILRS_Data_Handling_File_ 2018-05-04.snx)
estimate C31+S31/ arc	yes	no

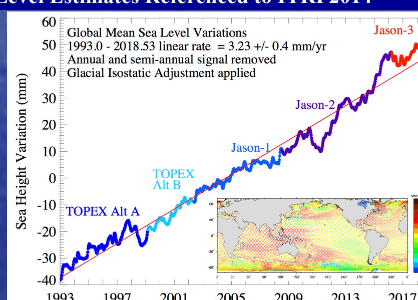
The primary revisions to the GSFC replacement orbits shown above; for details see Lemoine et al., and Zelensky et al., oral presentations at the POD splinter.

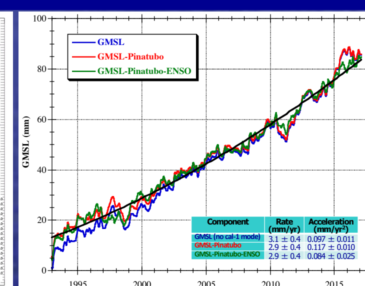
Global and Regional Mean Sea Level Estimates Referenced to ITRF2014

Jason 2/3 Intermission Bias via Verification Phase SSH Differences



Accurate measures of GMSL derived from multi-mission altimetry requires accurate estimates of global inter-mission biases. As seen in the Jason-2/Jason-3 SSH residuals during the Jason-3 verification phase, the revised GSFC orbits based on ITRF2014 further reduce geographically correlated errors, when compared to the CNES GDR_E ITRF2008-based orbits. The recently released jpl18a orbits further reduces the standard deviation about the mean bias to less than 1 mm.

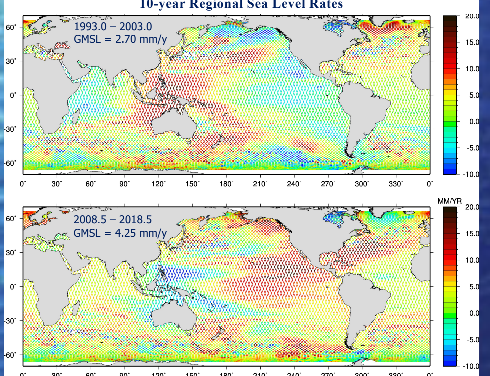




Component	Rate (mm/yr)	Acceleration (mm/yr²)
GMSL (no cal-1 mode)	3.1 ± 0.4	0.097 ± 0.011
GMSL-Pinatubo	2.9 ± 0.4	0.117 ± 0.010
GMSL-Pinatubo-ENSO	2.9 ± 0.4	0.084 ± 0.025

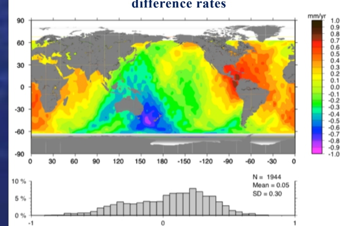
Left figure: Global mean sea level variations from 1993 to mid 2018 are estimated from NASA MEaSUREs v4.2 altimetry based on ITRF2014 using SLR & DORIS-based std1808a orbits. The red line is the linear fit to the SSH variations after removal of annual and semi-annual signal and application of GIA. Note, the TOPEX cal-1 mode range correction is not applied. The inset image shows the regional sea level trends over the same period. Right figure: Recent work by *Nerem et al. (2017)* have isolated the climate-driven acceleration of GMSL change by accounting for the impacts of the Mount Pinatubo volcanic eruption and ENSO events.

10-year Regional Sea Level Rates

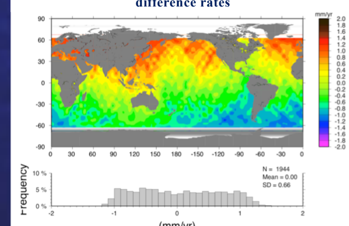


Regional sea level rates based on GSFC std1808a orbits are shown above (left) for the first and last 10-years of the T/P, Jason-1, 2, and 3 sea surface height time series. Two signatures of note are the reversal of the Pacific Decadal Oscillation (PDO) bringing significantly higher sea level rates to the U.S. west coast, and the rate reversal along southern Greenland coast as a result of ice mass loss post gravitational attraction effects. The estimation of accurate regional sea level rates warrants improvements to the time variable gravity (TVG) modeling in the POD process. The upper right figures show geographically correlated errors at the 1 mm/y level due primarily to TVG mismodeling.

Jason-2/3 GSFC std1808a – JPl18a radial orbit difference rates

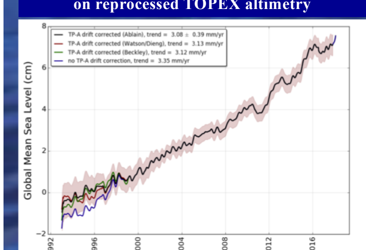


Jason-3 (JPL18a – CNES POE_F) radial orbit difference rates

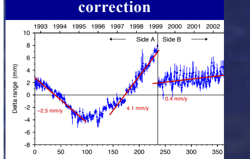


Even for the latest orbits, which agree to 4mm, radial drifts exceed 1 mm/year in some regions - Time varying gravity remains the largest source of POD error

Revised estimates of GMSL based on reprocessed TOPEX altimetry

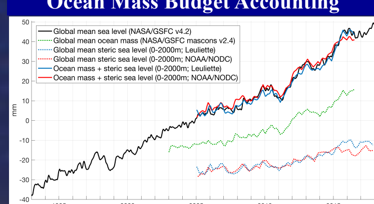


TOPEX cal-1 mode range correction



(Top left): Figure 2 from Cazenave et al., 2018: Evolution of ensemble mean GMSL time series (average of the 6 GMSL products from AVISO/CNES, SL_cci/ESA, University of Colorado, CSIRO, NASA/GSFC, and NOAA). On the black, red, and green curves, the TOPEX-A drift correction is applied respectively based on Ablain et al., 2017b, Watson et al., 2015, and Beckley et al., 2017 (cal-1 mode correction not applied). Annual signal removed and 6-month smoothing applied; GIA correction also applied. Uncertainties (90% confidence interval) of correlated errors over a 1-year period are superimposed for each individual measurement (shaded area). Top right: TOPEX cal-1 mode range correction.

Ocean Mass Budget Accounting



NASA MEaSUREs v4.2 GMSL variations based on GSFC std1808a orbits are compared to sum total of ocean mass+steric variations in an accounting towards mass budget closure. The above image shows the total ocean mass variations derived from GRACE GSFC Mascons v2.3 (*Luthcke et al., 2015*) and the steric component derived from two separate ARGO processing sources. The standard deviation of the GMSL minus (mass+steric) residuals is 1.52 mm. A "hybrid GMSL" estimate with Jason-2&3 based on JPL rlse18a orbits yields a standard deviation of 1.32 mm.

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