Assessment of Current Global and Regional Mean Sea Level Estimates Based on the TOPEX/Poseidon, Jason1&2 Climate Data Record

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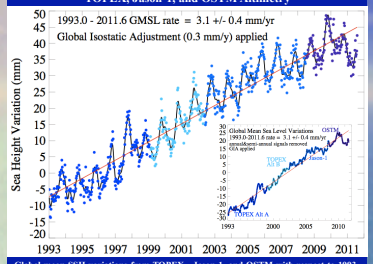
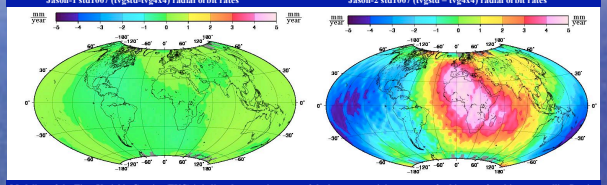
Abstract: Recent developments in Precise Orbit Determinations (POD) due to in particular to revisions to the terrestrial reference frame realization and the time variable gravity (TVG) continues to provide improvements to the accuracy and stability of the PO directly affecting mean sea level (MSL) estimates. Long -term credible MSL estimates require the development and continued maintenance of a stable reference frame, along with vigilant monitoring of the performance of the independent tracking systems used to calculate the orbits for altimeter spacecrafts. The stringent MSL accuracy requirements of a few tenths of a mm/yr are particularly essential for mass budget closure analysis over the relative short time period of Jason-1&2, GRACE, and Argo coincident measurements. In an effort to adhere to cross mission consistency, we have generated a full time series of experimental orbits (GSFC std1110) for TOPEX/Poseidon (TP), Jason-1, and OSTM based on an improved terrestrial reference frame (TRF) realization (ITRF2008), revised static, and time variable gravity field (Eigen6s). In this presentation we assess the impact of the revised precision orbits on inter-mission bias estimates, and resultant global and regional MSL trends. Tide gauge verification results are shown to assess the current stability of the Jason-2 sea surface height time series that suggests a possible discontinuity initiated in early 2010. Although the Jason-2 time series is relatively short (~ 3 years), a thorough review of the entire suite of geophysical and environmental range corrections is warranted to maintain the fidelity of the record.

Global Mean Sea Level Estimated from TOPEX, Jason-1, and OSTM Altimetry



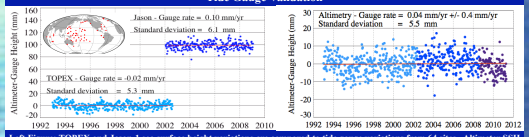
Global mean SSH variations from TOPEX, Jason-1, and OSTM with respect to 1993 - 2002 mean are plotted every 10 days. The solid black line is the sea surface height variation with a 60-day Hanning filter applied revealing the annual cycle. Inset Image: The global mean sea level rate is estimated from linear fit (bold red line) after removal of annual and semi-annual signal. The MSL rate over the entire time span is 3.1 ± 0.41 mm/yr. SSH values throughout entire series are based on consistent GSFC std1007 (ITRF2008) replacement orbit, and most current radiometer calibrations. MSL rate error reported above is the root-square sum of the tide gauge precision and the variance of the global mean SSH variations about the linear fit.

Experimental GSFC Replacement Orbits based on revised Time Variable Gravity



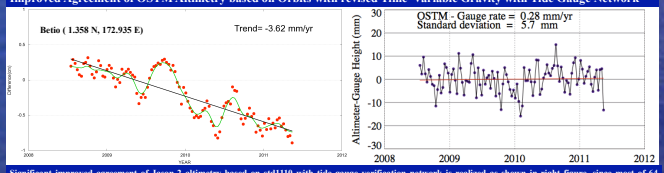
Modeling of the Time Variable Gravity (TVG) is believed to constitute one of the largest remaining sources of orbit error for altimeter satellite Precise Orbit Determination (POD). We have generated a an experimental series of orbits that span the T/P, Jason-1&2 missions based on a TVG model that incorporates more recent GRACE and GOCE data (see Zelensky et al poster). Although the GSFC operational TVG model can be applied at anytime, there may be long-term variations not captured by these linear models, and more importantly the linear models may not be consistent with more recent surface mass trends due to global climate change. Rates of the radial orbit differences between std1007 and std1110 shows minimal impact on Jason-1 (left figure) as compared to significant rate changes observed by Jason-2 right figure) caused by possible inadequacy of current operational TVG model for Jason-2 forecasts.

Tide Gauge Validation



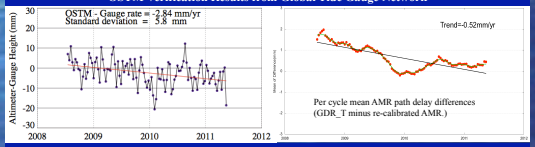
Left Figure: TOPEX and Jason-1 sea surface height variations are compared to tide gauge variations from 64 sites. Altimeter SSH values are based on GSFC std1007 (ITRF2008) orbits, and most recent recalibrated TMR and JMR wet troposphere range corrections. Estimated instrument bias derived from tide gauge comparisons are consistent with global mean collinear differences during the verification phases. Right Figure: Resultant per cycle comparisons of altimeter derived SSH variations with height variations from 64-site tide gauge network after application of inter-mission biases to form a single adjusted SSH Climate Data Record verifies the stability of the 18-year record (note reduced scale). TOPEX cycles 11-355 are indicated by light blue dots, Jason-1 cycles 13-239 by dark blue dots, and Jason-2 cycles 1-113 by purple dots.

Improved Agreement of OSTM Altimetry based on Orbits with revised Time Variable Gravity with Tide Gauge Network



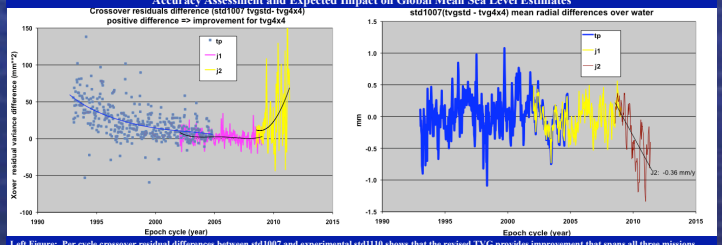
Significant improved agreement of Jason-2 altimetry based on std1110 with tide gauge verification network is realized as shown in right figure, since most of 64 verification gauges are located in the tropical Pacific where rates of orbit differences are at a maximum. Left figure shows typical differences of tide gauge comparisons with Jason-2 based on std1007 and std1110 orbits for such stations.

OSTM Verification Results from Global Tide Gauge Network



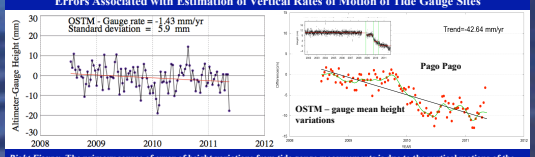
Left Figure: OSTM (cycles 1-105) altimeter derived sea surface height variations are compared to global tide gauge network. OSTM altimetry is based on GSFC std1007 orbit and latest AMR recalibration (right figure, Brown, 2011). With over three years of OSTM data, this negative drift causes concern in maintaining the fidelity of the Climate Data Record. Right Figure: Mean path delay differences between the re-calibrated AMR replacement product and the AMR currently on GDR_T.

Accuracy Assessment and Expected Impact on Global Mean Sea Level Estimates



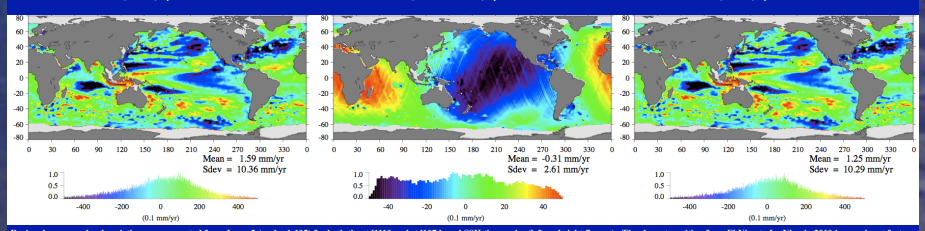
Left Figure: Per cycle crossover residual differences between std1007 and experimental std1110 shows that the revised TVG provides improvement that spans all three missions. Right Figure: Mean radial orbit differences over water (200 meter mask) between std1007 and std1110 shows subsequent impact on GMSL estimate.

Errors Associated with Estimation of Vertical Rates of Motion of Tide Gauge Sites



Right Figure: The primary source of error of height variations from tide gauge measurements is due to the vertical motions of the sites. Many of the sites are currently equipped with GPS receivers to monitor this motion. The inset figure shows such a GPS time series and reveals sharp discontinuity due to severe tectonic activity in early 2010. *Left Figure:* After editing corrupt Pago Pago gauge data (after September 29, 2009) from the global mean solution the level of agreement improves but still exceeds 1 mm/yr. Interrogation of additional sites in the vicinity of active tectonic motion is warranted.

Jason-2 Regional Mean Sea Level Estimates



Regional mean sea level variations are computed from Jason-2 (cycles 1-105) for both the std1110 and std107 based SSH time series (left and right figures). The sharp transition from El Nino to La Nina in 2010 is prominent feature in eastern tropical Pacific. As expected the global mean sea level variation difference between the two solutions is the same magnitude and sign as the above orbit differences and show the same geographical distribution (center figure).

The authors acknowledge the University of Hawaii Sea Level Center for providing the most recent tide gauge data for comparisons against OSTM. This work is supported by NASA OSTM Science Working Team and MEaSURE's funding.