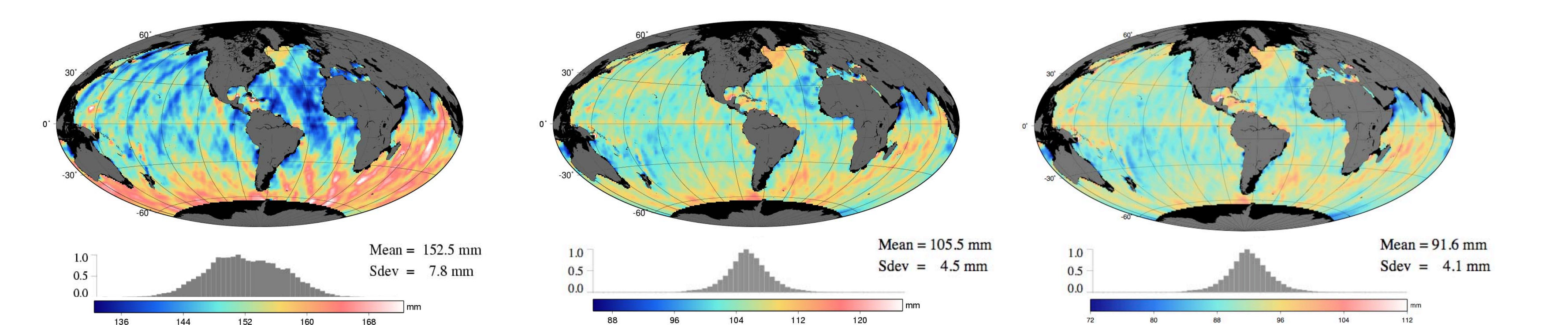
Extending the Sea Surface Height Climate Data Record with OSTM Altimetry

B. Beckley, N. Zelensky, S. Holmes - SGT, Inc.
F. Lemoine, S. Luthcke, R. Ray – NASA/GSFC
S. Desai, S. Brown – JPL
G. Mitchum – Univ. of S. Florida
S. Labroue - CLS

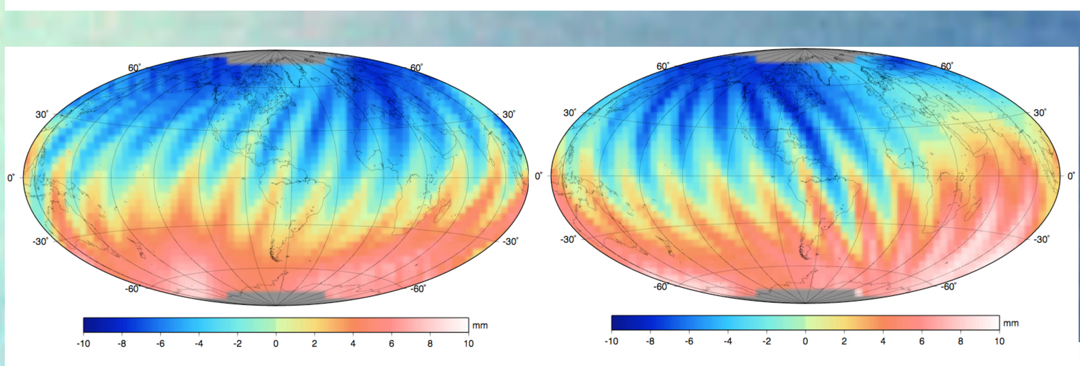
The measurement of mean sea-level change from satellite altimetry requires extreme stability of the altimeter measurement system. In particular, the orbit and reference frame within which the altimeter measurements are situated, as well as the associated altimeter corrections, must be stable and accurate enough to permit robust mean sea level (MSL) estimates over an extended time period. The terrestrial reference frame is linked inseparably to the measurement of global mean sea level estimates from satellite altimetry and provides the context for the interpretation of the causes of current mean sea level trends. Dramatic improvements foreseen in gravity field models anticipated from the GRACE Mission are currently being realized, further offering a very significant reduction in orbit error, including those which are of special concern given they are geographically correlated, yet mission specific. In an effort to adhere to cross mission consistency, we have generated the full time series of orbits for TOPEX/Poseidon (TP) ,Jason-1, and OSTM through reduced dynamic methods based on the Eigen_g104s GRACE derived gravity field within a consistent well defined ITRF2005 terrestrial reference frame. The recent release of the Jason-1 Geophysical Data Record Version C and recalibration of the TOPEX and Jason microwave radiometers also require the further re-examination of TP/Jason-1 consistency issues. Here we present an assessment of these recent improvements to the accuracy of the TP/Jason-1/OSTM sea surface height time series, and evaluate the subsequent impact on global and regional mean sea level estimates.

Jason - TOPEX Mean Sea Surface Height

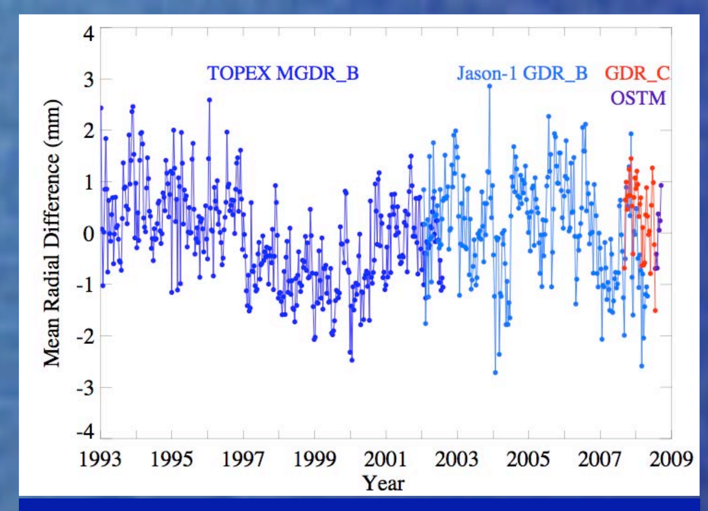
Verification Phase



Images above show progressive improved agreement of Jason/TOPEX mean SSH during the verification phase. SSH differences in left image are based on TOPEX MGDR_B (JGM3 orbits, CSR95 terrestrial reference frame), and Jason GDR_A (JGM3 orbits, ITRF2000). In the middle image the SSH is based on GSFC ITRF2000 (GGM02c) replacement orbits for both TOPEX and Jason GDR_A. In the right image the SSH is based on GSFC ITRF2005 (GGM02c) replacement orbits for both TOPEX and Jason GDR_B. Improved agreement has been realized with recently developed GSFC std0809 orbits with POD standards more consistent with GDR_C (See Lemoine, et al., poster SB.5-043).

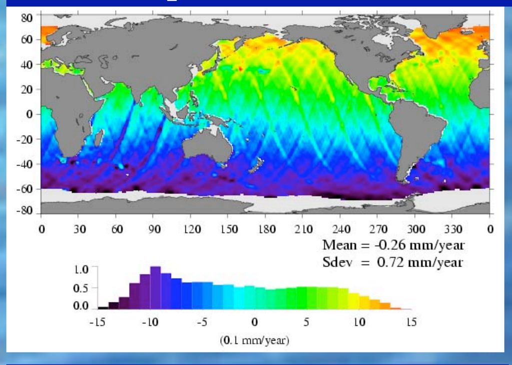


TOPEX orbit differences between GSFC JGM3 reduced dynamic replacement orbits based on ITRF2000 and GDR JGM3 orbits based on CSR95 terrestrial reference frame are shown for ascending and descending passes during the Jason verification phase. The source of the dominant hemispherical Jason/TOPEX mean sea surface height difference in above figure is due primarily to the terrestrial reference frame inconsistency that existed between Jason-1 initial GDR_A and TOPEX MGDR_B (Geophysical Data Record) based orbits.

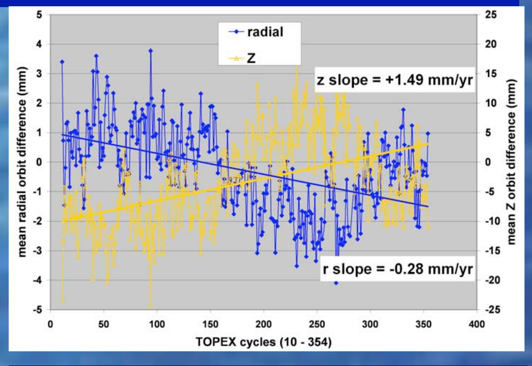


Global mean radial differences between GSFC ITRF2005 (Eigen_g104s) replacement orbits and project GDR based orbits are shown in above figure. The sign convention of the differences are such that the above long wavelength signature maps directly into the global MSL estimate as a result of the orbit inconsistencies with regard to the terrestrial reference frame and gravity field.

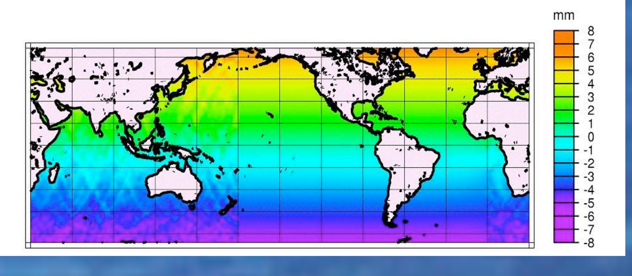
Impact of Terrestrial Reference Frame on MSL



Regional TOPEX (1993-2002) SSH trend differences from direct impact of the ITRF2005 (GGM02C) minus CSR95 (JGM3) orbit differences.

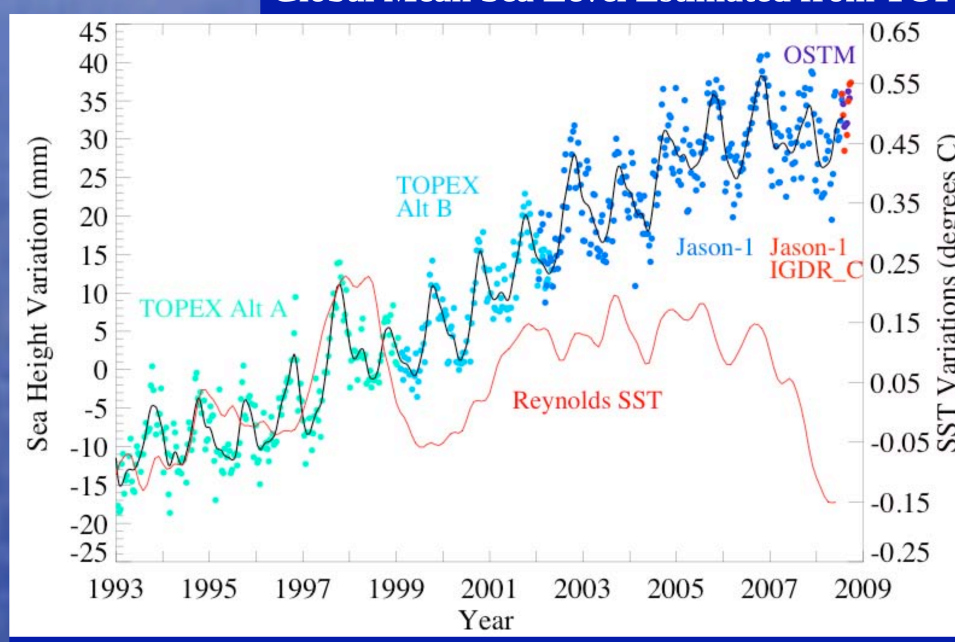


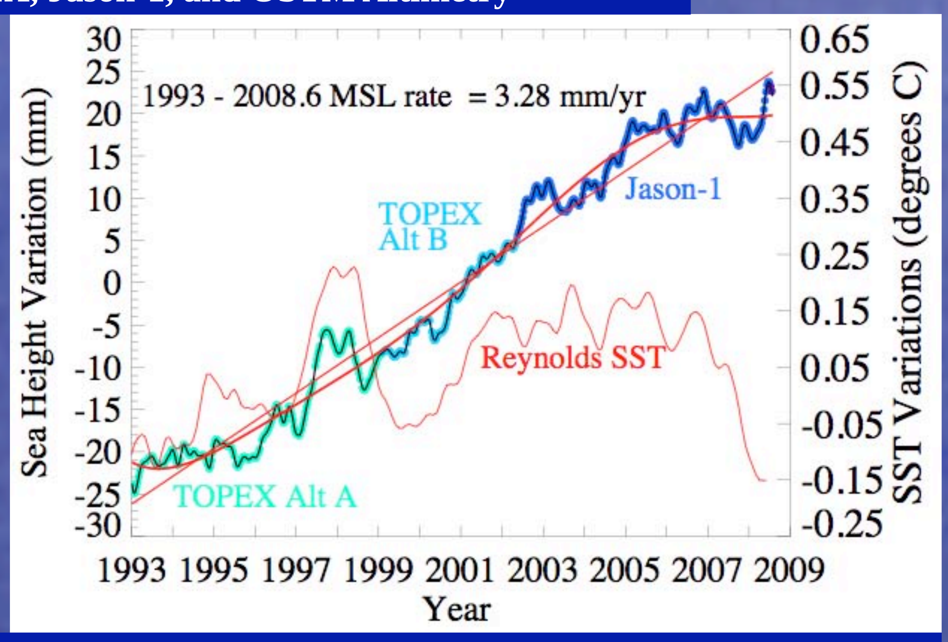
R slope / Z slope = -0.28 mm/yr / 1.49 mm/yr
MSL rate error = - 0.19 x TZ (mm/yr)
Where TZ is the mean orbit rate error in Z.



Regional mean sea level errors resulting from a 10 mm Z-translation of the Terrestrial Reference Frame (DORIS station coordinates). *From Morel L., and Willis, P., 2005.*
Mean sea level= -0.12 x TZ (mm)
where TZ is the TRF error in Z.

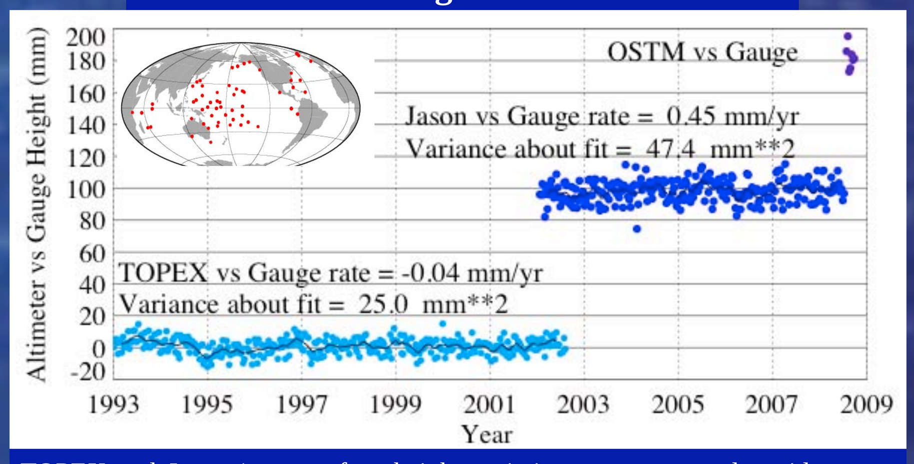
Global Mean Sea Level Estimated from TOPEX, Jason-1, and OSTM Altimetry





Left Image: 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. The red line is monthly mean sea surface temperature variations from Reynolds climatology. ***Right 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 **3.28 ± 0.41 mm/yr**. SSH values throughout entire series are based on consistent ITRF2005 (Eigen_g104s) orbit, recent recalibration of TMR and JMR, MOG2d barometric correction applied. 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.

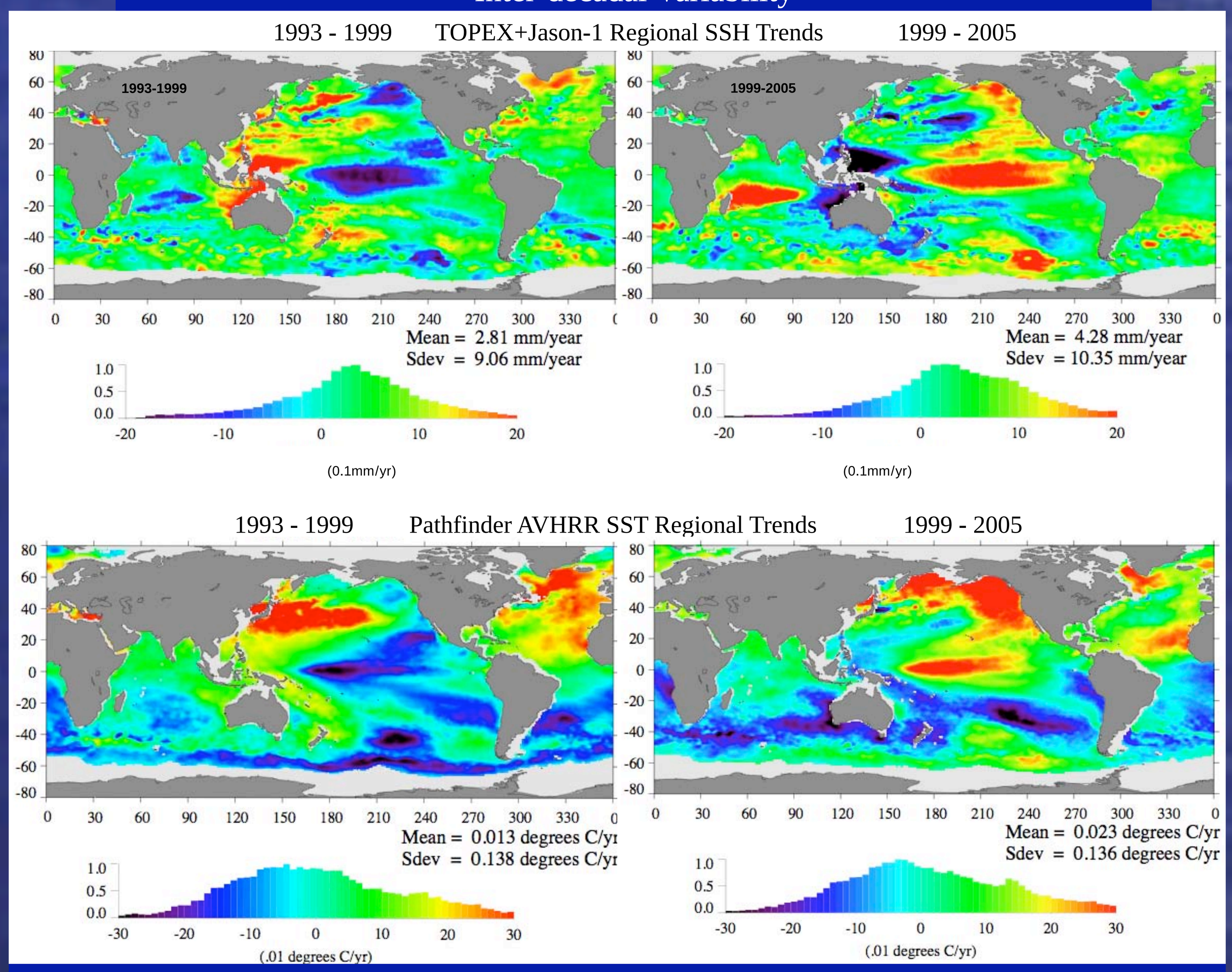
Tide Gauge Validation



TOPEX and Jason-1 sea surface height variations are compared to tide gauge variations from 64 sites. Altimeter SSH values are based on GSFC ITRF2005 (Eigen_g104s) 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.

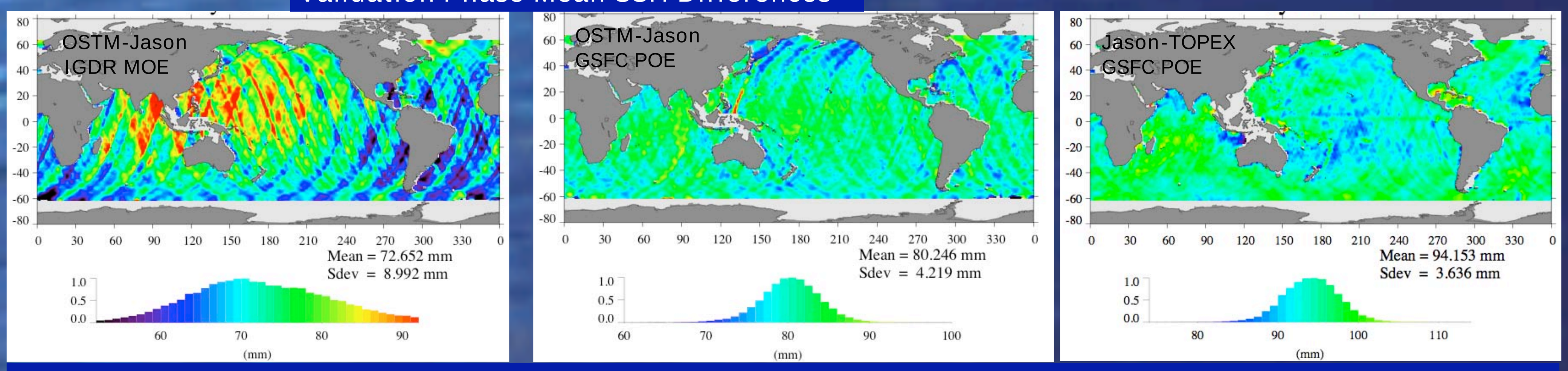
TOPEX +Jason-1 Global and Regional Mean Sea Level Rates

Inter-decadal Variability



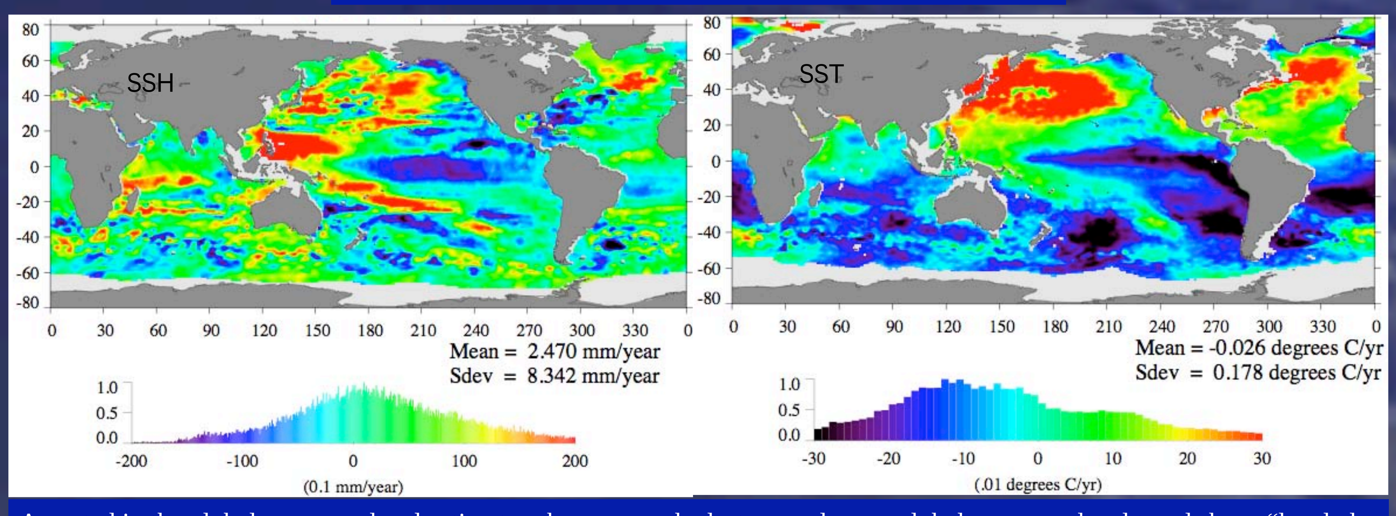
Regional sea surface height trends from TOPEX+Jason-1 altimetry (upper image), and sea surface temperature trends from AVHRR are computed over the seven year time spans of 1993-1999 and 1999-2005 (overlap in 1999). The most apparent correlated features exhibited in both the SSH and SST regional trends is the basin scale polarity (particularly in the tropical and North Pacific) between the two time frames revealing pronounced inter-decadal variability modulated by the strong ENSO event in the late nineties.

Validation Phase Mean SSH Differences



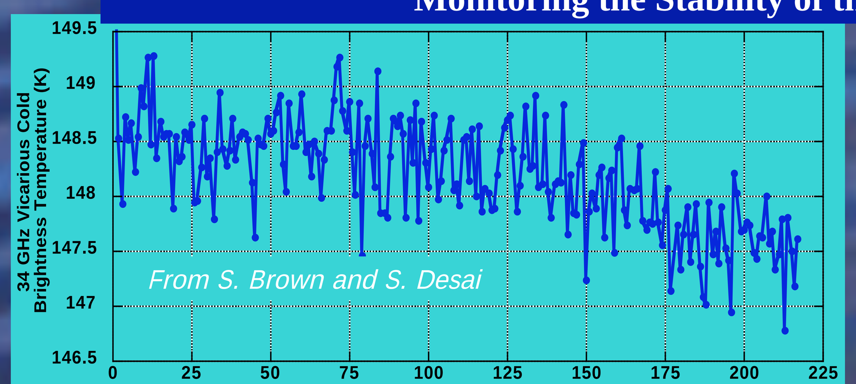
Left Figure: Mean sea surface height differences derived from OSTM IGDR cycles 1-7 minus Jason-1 IGDR_C (corresponding cycles 240-246). The medium precision orbits on the IGDR data create an obstacle to accurately define a global OSTM instrument bias due to the pronounced geographically correlated orbit error.
Middle Figure: Improved agreement is realized with GSFC POE orbit replacement on both the OSTM and Jason-1 IGDR product. In particular the absence of any significant differences in the southern ocean implies there exists little or no tracker bias between OSTM and Jason-1. ***Right Figure***: Similar improvement is also realized for Jason-1/TOPEX agreement.

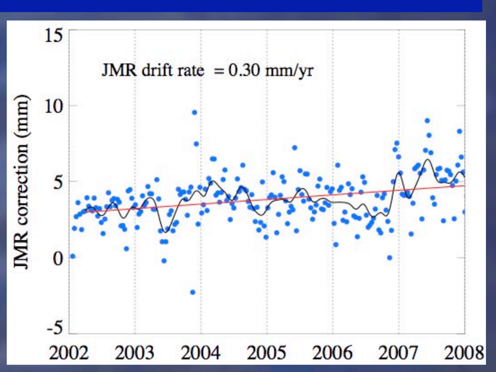
Recent Mean Sea Level and SST Trends 2003 - 2008

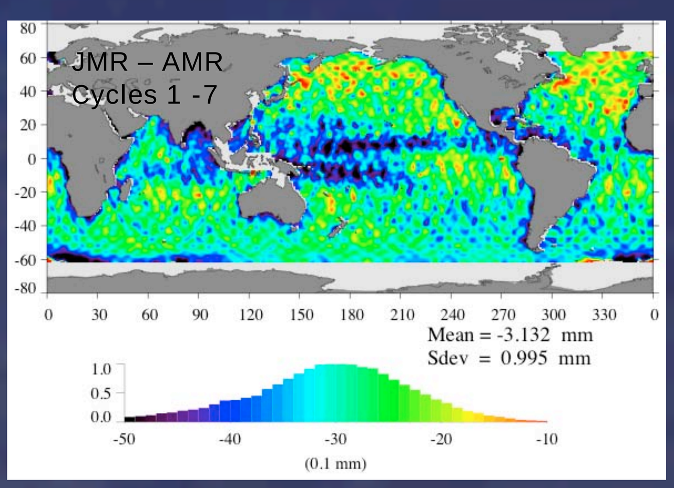


As noted in the global mean sea level estimates above, over the last several years global mean sea level trends have "leveled off" due in part due an extended La Nina period, with a negative global mean SST trend.

Monitoring the Stability of the Radiometer







Left Figure: JMR 34 GHz brightness temperatures have drifted ~ 1K from last GDR_B re-calibration (from cycle 127-212). Impact is **~ +0.9 mm/yr drift** in JMR wet path delay measurements since cycle 127. ***Middle Figure***: Mean 1Hz JMR differences averaged per cycle between GDR_B and proposed JMR recalibration for GDR_C (*S. Brown and S. Desai, 2008). **Right Figure**:* Mean Jason – OSTM wet troposphere over first seven cycles of IGDR. Reduction of mean to 1mm is expected for GDR.

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.