Assessment of Jason-1 and OSTM Global Verification Phase Sea Surface Height Collinear Residuals

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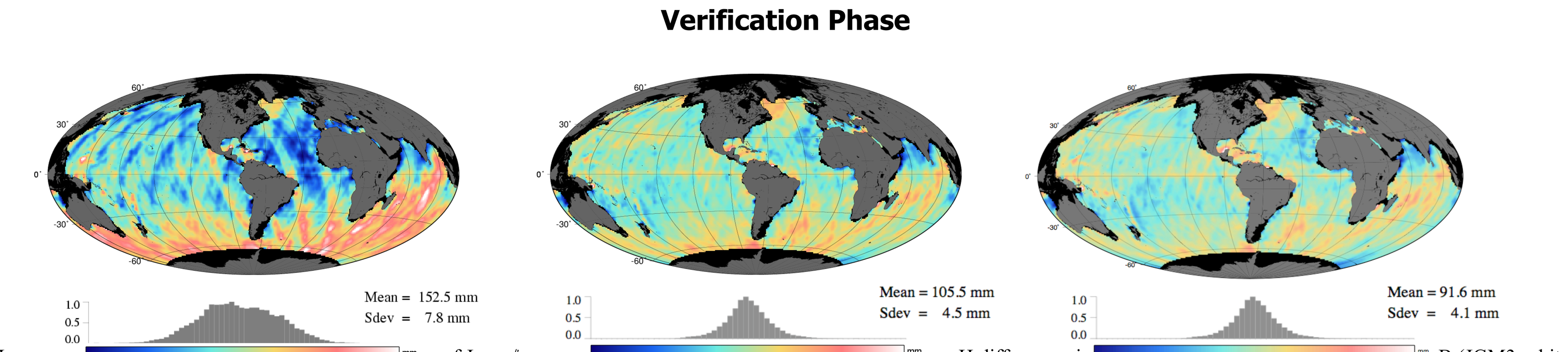
The measurement of mean sea-level change from satellite altimetry requires extreme stability of the altimeter measurement system. In particular, the orbit and reference frame within which the altimeter measurements are situated, as well as the associated altimeter corrections, must be stable and accurate 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.

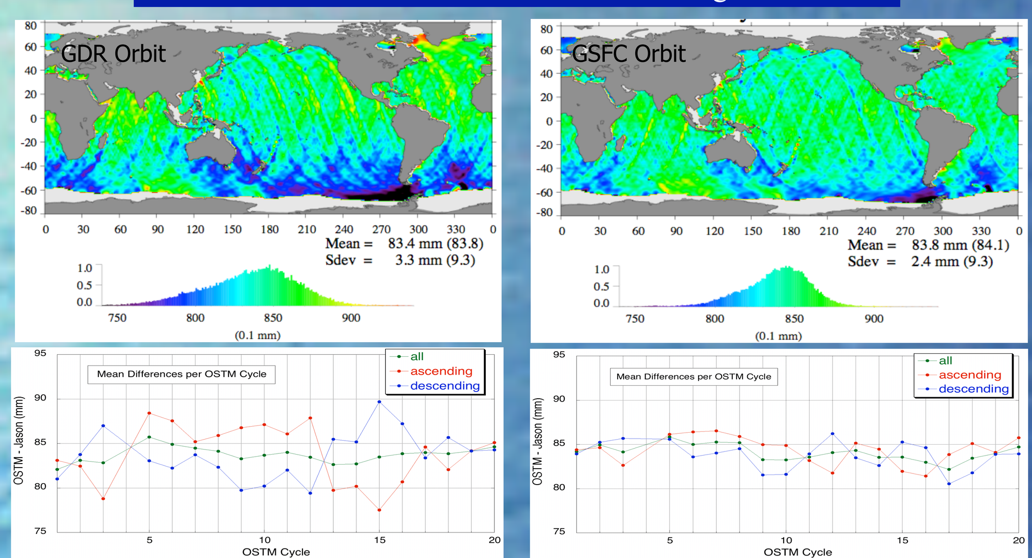
Jason - TOPEX Mean Sea Surface Height

Verification Phase



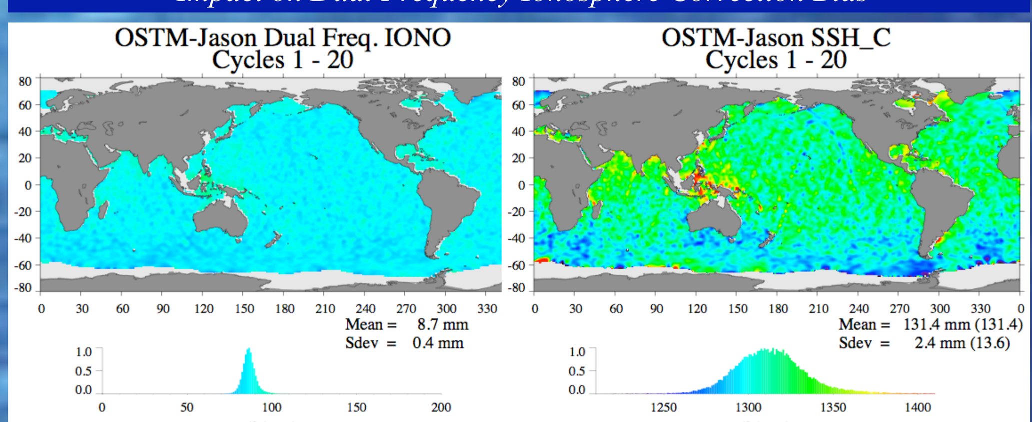
In [...] f Jason/[...] H differences i[...] B (JGM3 orbits, CSR95 terrestrial reference frame), and Jason GDR_A (JGM3 orbits, ITRF2000). In the middle image the SSH is based on GSFC ITRF2000 (GGM02c) replacement orbits for both TOPEX and Jason GDR_A. In the right image the SSH is based on GSFC ITRF2005 (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).

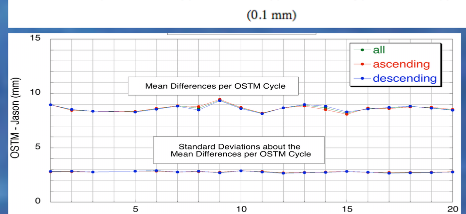
Inter-Mission Orbit Consistency
OSTM – Jason-1 Sea Surface Height



Ku band range bias between OSTM and Jason-1 is estimated from collinear SSH residuals during verification phase when near coincident sampling takes place. Standard deviation of mean differences are less than 1 cm for both the project GDR orbit and the GSFC Std0905 orbit. Agreement is largely due to inter-mission consistency in the terrestrial reference frame (ITRF2005) and static gravity field (Eigen -Gl04s).

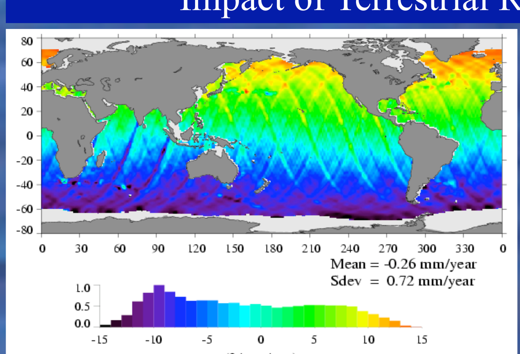
Ku / C Band Range Bias
Impact on Dual Frequency Ionosphere Correction Bias



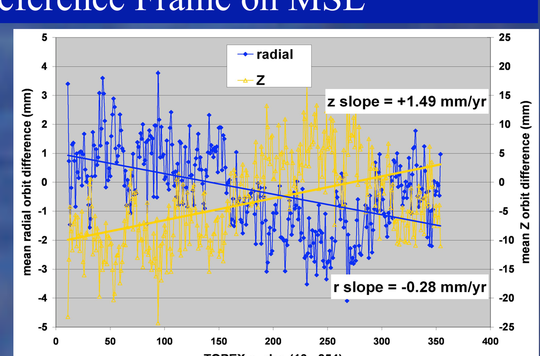


Ionosphere SSH correction bias =
$0.1798 * (R_{Ku}\text{ bias}) - (R_C\text{ bias}) =$
$0.1798 * ((-83.4\text{mm}) - (-131.4\text{mm})) = 8.6\text{ mm}$
OSTM Iono = J1 Iono + 8.6 mm

Impact of Terrestrial Reference Frame on MSL

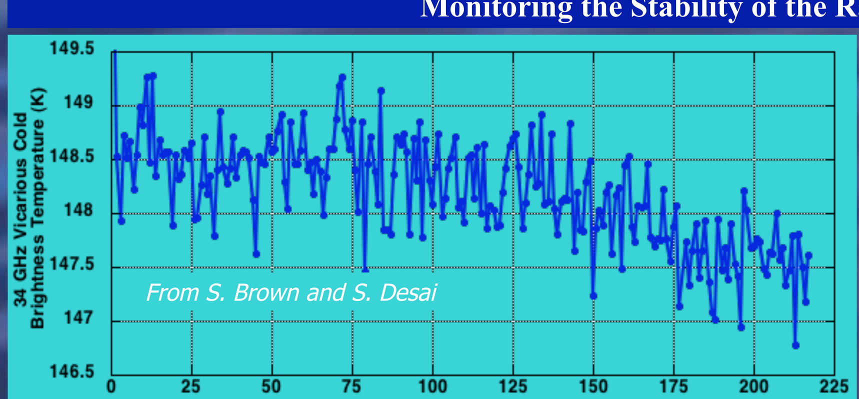


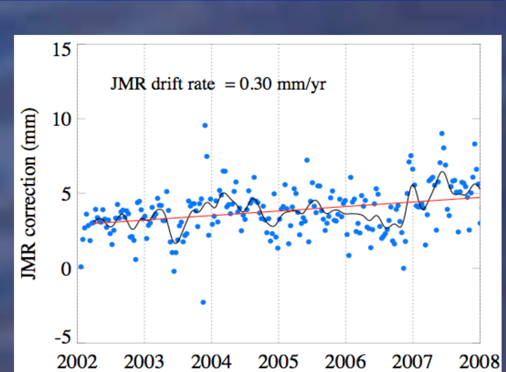
Regional TOPEX (1993-2002) SSH trend differences from direct impact of the ITRF2005 (GGM02C) minus CSR95 (JGM3) orbit differences.



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.

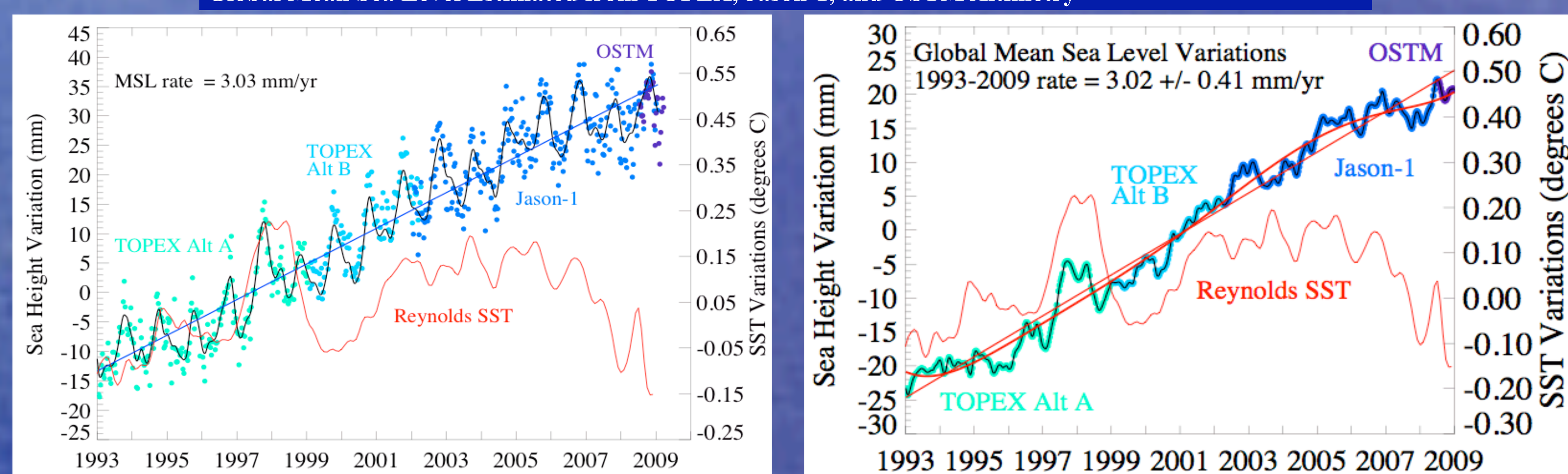
Monitoring the Stability of the Radiometer





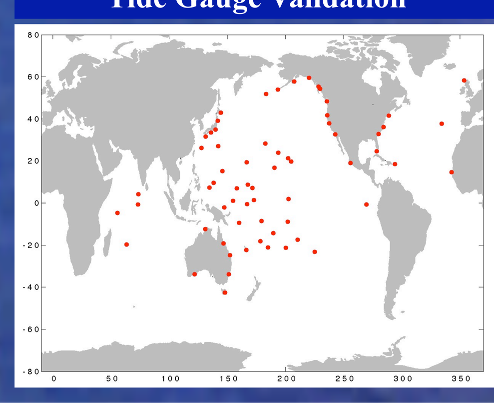
Left Figure: JMR 34 GHz brightness temperatures had drifted ~ 1K from initial GDR_B re-calibration (from cycle 127-212). Impact is ~ **+0.9 mm/yr drift** in JMR wet path delay measurements since cycle 127. ***Middle Figure***: Mean 1Hz JMR differences averaged per cycle between GDR_B and current recalibration for GDR_C (*S. Brown and S. Desai, 2008*). ***Right Figures:*** Mean OSTM – Jason-1 wet troposphere differences during the verification phase, showing improved agreement of the recently released GDR_C JMR replacement product for cycles 228-259 with the OSTM Advanced Microwave Radiometer (AMR).

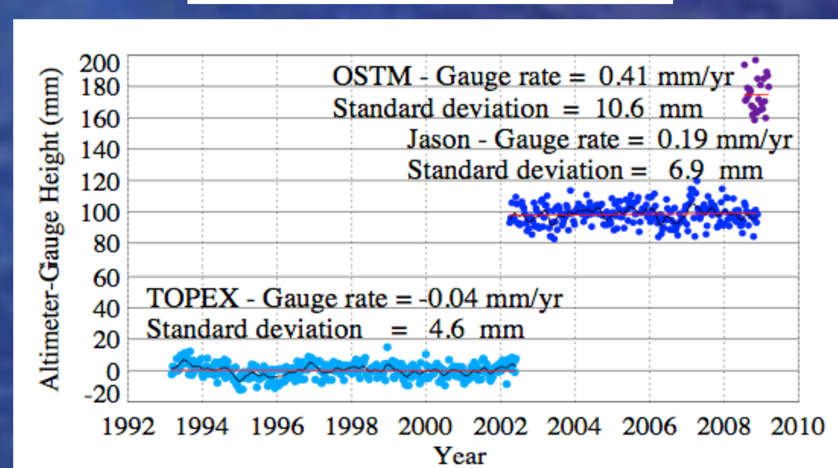
Global Mean Sea Level Estimated from TOPEX, Jason-1, and OSTM Altimetry

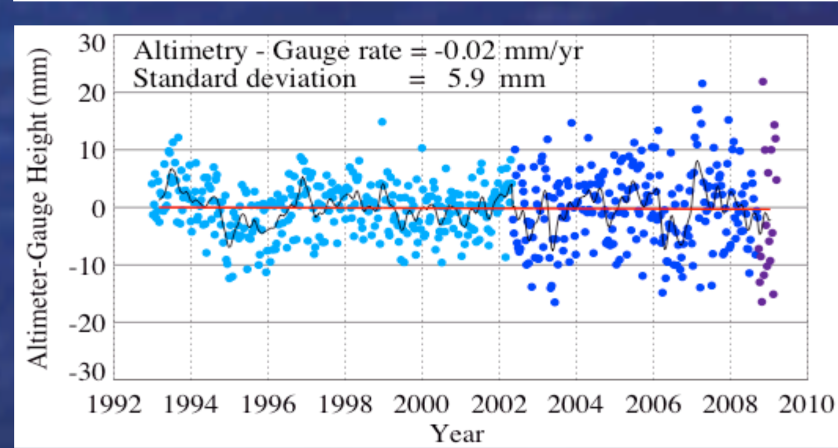


Left Image: Global mean SSH variations from TOPEX, Jason-1, and OSTM with respect to 1993 – 2002 mean are plotted every 10 days. The solid black line is the sea surface height variation with a 60-day Hanning filter applied revealing the annual cycle. The red line is monthly mean sea surface temperature 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 **3.02 ± 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

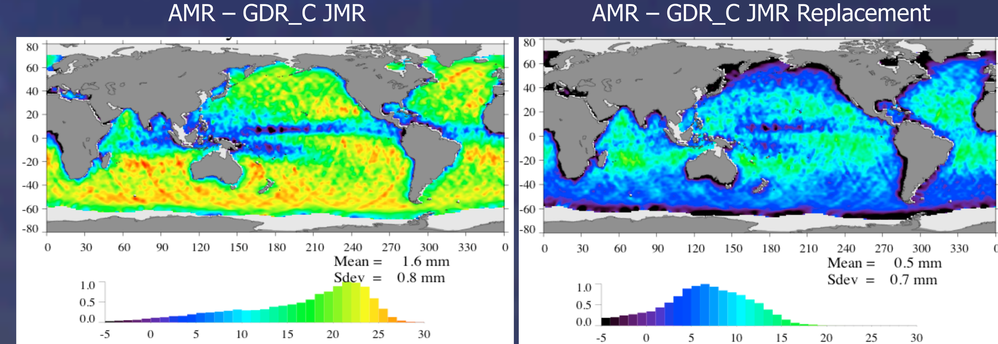


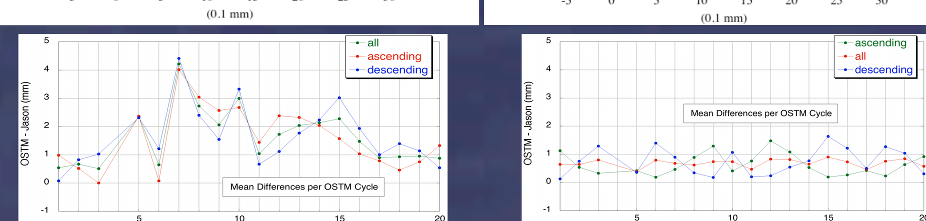




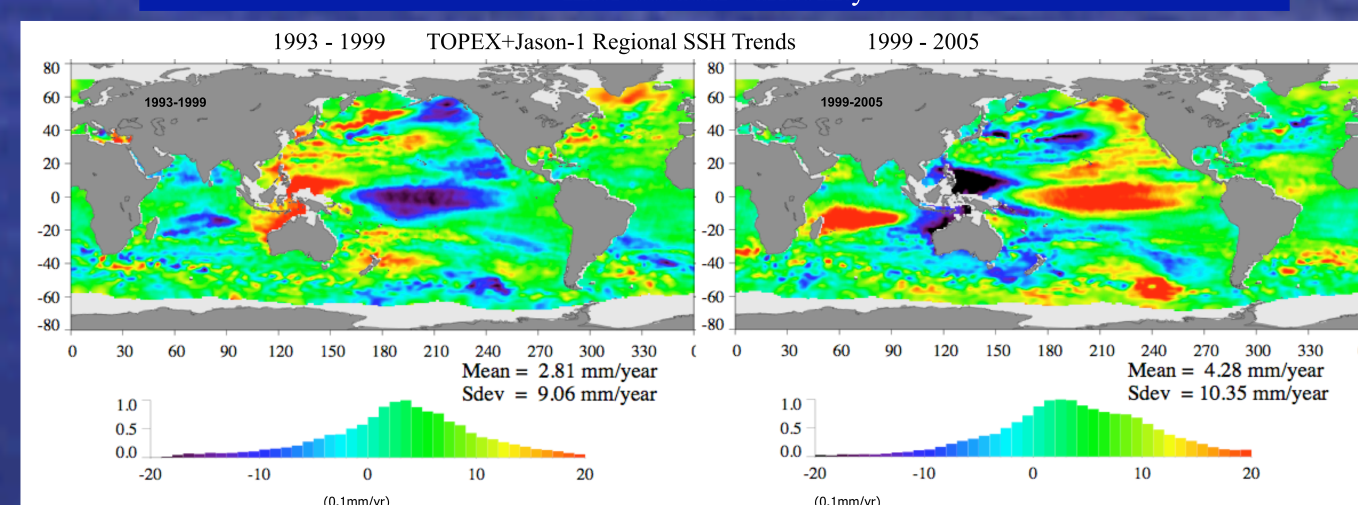
TOPEX, Jason-1, and OSTM sea surface height variations are compared to tide gauge variations from 64 sites. Altimeter SSH values are based on GSFC Std0905 ITRF2005 (Eigen_g104s) orbits, and most recent recalibrated TMR and JMR wet troposphere range corrections. Estimated instrument bias derived from tide gauge comparisons are consistent with global mean collinear differences during the verification phases.

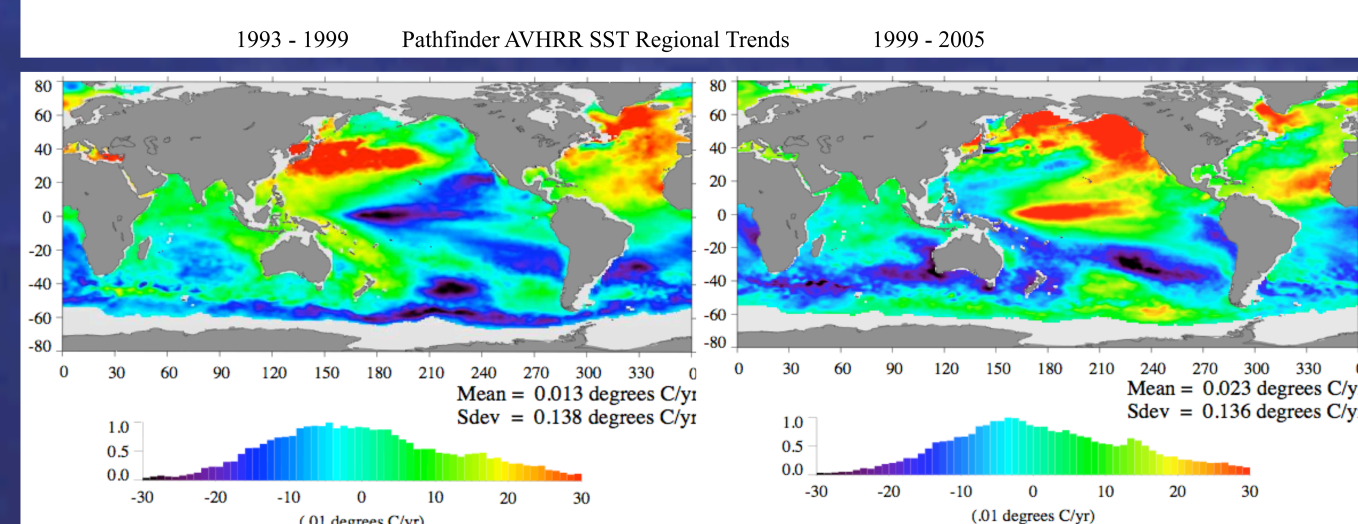
JMR GDR_C Replacement Product





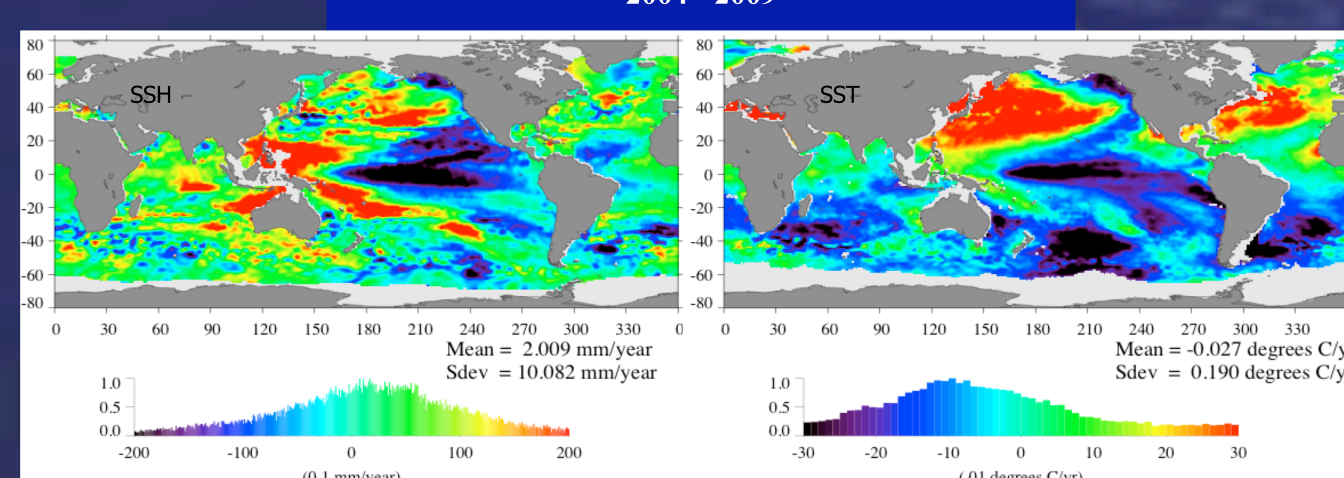
TOPEX +Jason-1 Global and Regional Mean Sea Level Rates
Inter-decadal Variability





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.

Recent Mean Sea Level and SST Trends
2004 - 2009



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. The global mean sea level trend over the past five years is estimated at 2.01 mm/yr (no GIA applied).

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