Exploring Differences in Global Mean Sea Level Time Series

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Abstract

Satellite radar altimeters, beginning with the TOPEX/Poseidon in 1992, and continuing through the present day with Jason-1 and Jason-2, have allowed estimation of the time series of global mean sea level (GMSL). A number of different research institutions independently produce a GMSL time series, and each of these time series generally show the same linear trend in global mean sea level over the 19-year data record. But the different GMSL time series are each produced using varying techniques and different corrections, and subsequently the time series exhibit different higher-order signals and sensitivity to interannual cycles, such as the ENSO. In this work, we compare the GMSL time series produced by these groups and explore the differences among them. We also compare the various techniques and the applied corrections used by each institution to understand how these affect the differences among the GMSL time series. We find that the various GMSL time series follow the same general trend and computed linear rates once high frequency noise and seasonal signals are removed. Along-track versus gridded means show unexplained differences that may be due to smoothing of interannual signals in the latter. Our goal is to continue to identify improvements in our own GMSL time series so that it can better be used by the science community as a climate data record.

Processing Differences

Each institution applies different corrections, limits, and processing algorithms in producing their GMSL estimates. The most significant differences are highlighted in RED the table below. These include the SSB corrections applied to TOPEX/Poseidon and the choice of algorithm (along-track or gridded) and spatial/temporal resolution in computing the means.

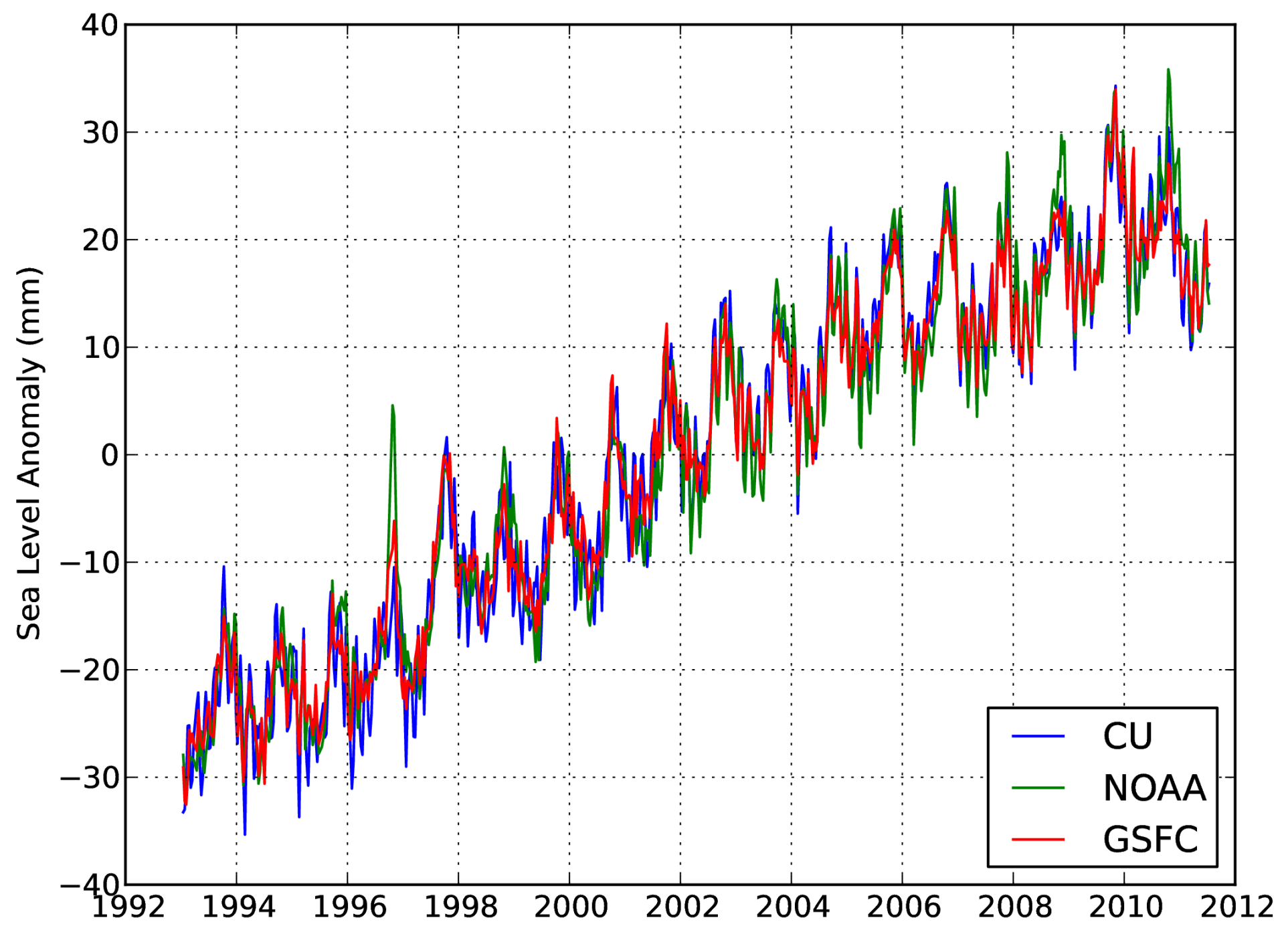
Parameter	**TOPEX/Poseidon**	**Jason-1**	**Jason-2**
Cycles	AVISO, GSFC uses Poseidon cycles; all others use TOPEX only		
Orbit	CSIRO uses MGDRB orbit; all others use new GSFC STD orbits	CU, GSFC use GSFC STD orbits; all others use GDR	CU, GSFC use GSFC STD orbits; all others use GDR
Range & Corrections			
Dry Troposphere	NOAA corrects for S1/S2 tides		
Wet Troposphere	CSIRO uses MGDRB; all others use TMR replacement	NOAA uses Enhanced JMR; CSIRO uses GDR; all others use JMR replacement	NOAA uses Enhanced AMR; all others use GDR-T
Ionosphere	CU does not smooth along-track		
Sea State Bias	CU, AVISO: CLS Collinear v. 2009 (CU does not use updated SWH/wind); NOAA: CLS Collinear v. 2006 w/ SWH (Queffeulou, 2004) & wind speed (Gourrion, 2002); GSFC: revised parametric BM4 (Beckley, 2010); CSIRO: MGDRB	CU, NOAA: CLS Collinear v. 2009; GSFC, AVISO, CSIRO: GDR	CU, NOAA: CLS Collinear v. 2009; GSFC, AVISO, CSIRO: GDR
Mean Sea Surface & Corrections			
Mean Sea Surface	CU, AVISO: CLS01; NOAA, GSFC: DNSC08, CSIRO: GDR	CU, AVISO: CLS01; NOAA, GSFC: DNSC08, CSIRO: GDR	CU, AVISO: CLS01; NOAA, GSFC: DNSC08, CSIRO: GDR
Ocean Tide & Loading Tide	CSIRO uses GDR; all others use GOT4.7	CSIRO uses GDR; all others use GOT4.7	CSIRO uses GDR; all others use GOT4.7
Atmospheric Pressure (Inverted Barometer)	CU, NOAA, AVISO: DAC; GSFC, CSIRO: GDR IB + hf fluctuations	CU, NOAA, AVISO: DAC; GSFC, CSIRO: GDR IB + hf fluctuations	CU, NOAA, AVISO: DAC; GSFC, CSIRO: GDR IB + hf fluctuations
Processing Corrections			
Minimum Ocean Depth	CU, GSFC: 120 m; NOAA, AVISO, CSIRO: 0 m	CU, GSFC: 120 m; NOAA, AVISO, CSIRO: 0 m	CU, GSFC: 120 m; NOAA, AVISO, CSIRO: 0 m
Outlier Removal	CU > 2 m; NOAA > 1 m; Others: ?	CU > 2 m; NOAA > 1 m; Others: ?	CU > 2 m; NOAA > 1 m; Others: ?
Processing Algorithm:			
CU, GSFC: along-track, per-cycle means; NOAA gridded 3°x1°, per-cycle means; AVISO: gridded 2°x2°, per-cycle means; CSIRO: 1° grid, monthly means			

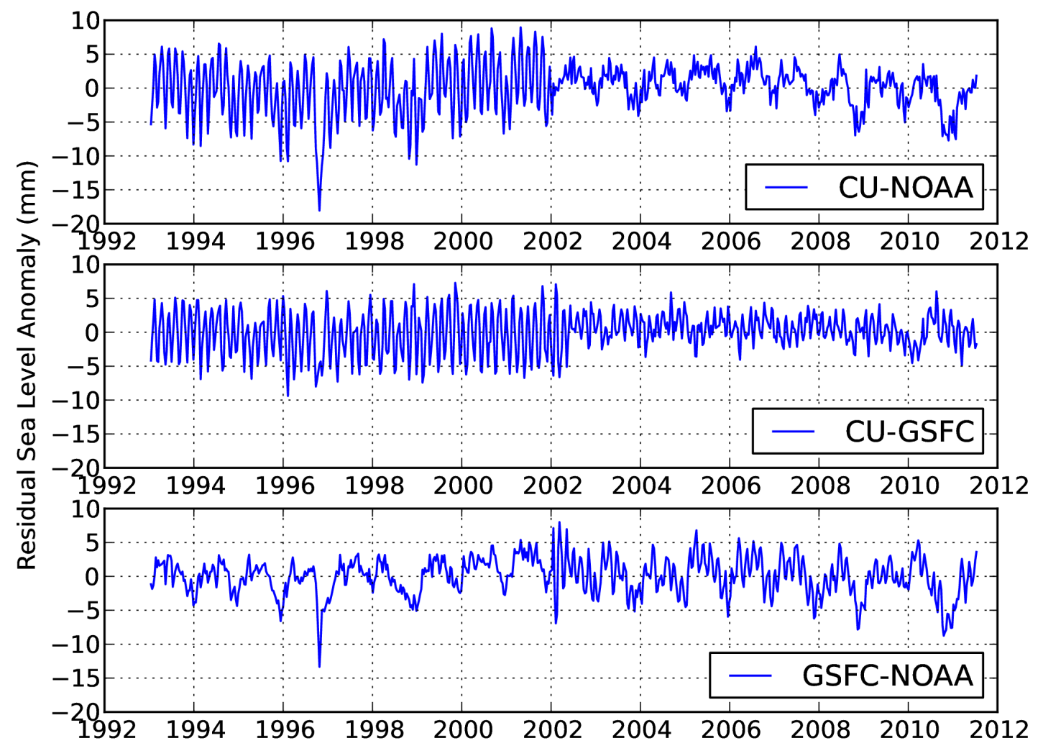
Comparing Unfiltered Time Series

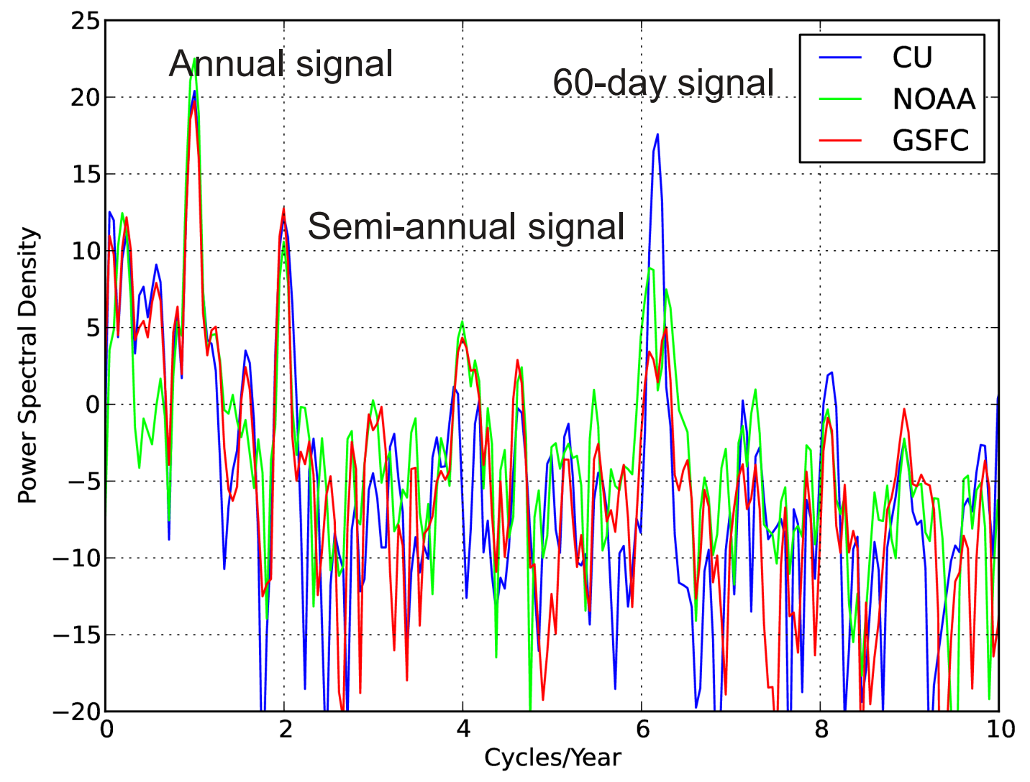
Time series which were available at native resolution (10-day repeat cycle), which included CU, NOAA, and GSFC, were compared before standard 60-day and annual signal filtering (right).

Differences in these raw time series were computed (bottom left). These raw differences show that the CU GMSL suffers a large 60-day signal during T/P compared to the NOAA and GSFC estimates. This is most likely due to using the CLS v. 2009 SSB in TOPEX without upgrading the SWH and wind estimates from GDR values. The plots also show that the CU and GSFC differences do not have seasonal component that is evident in the differences with NOAA. This is most likely due to the use of along-track means (CU, GSFC) versus gridded means (NOAA).

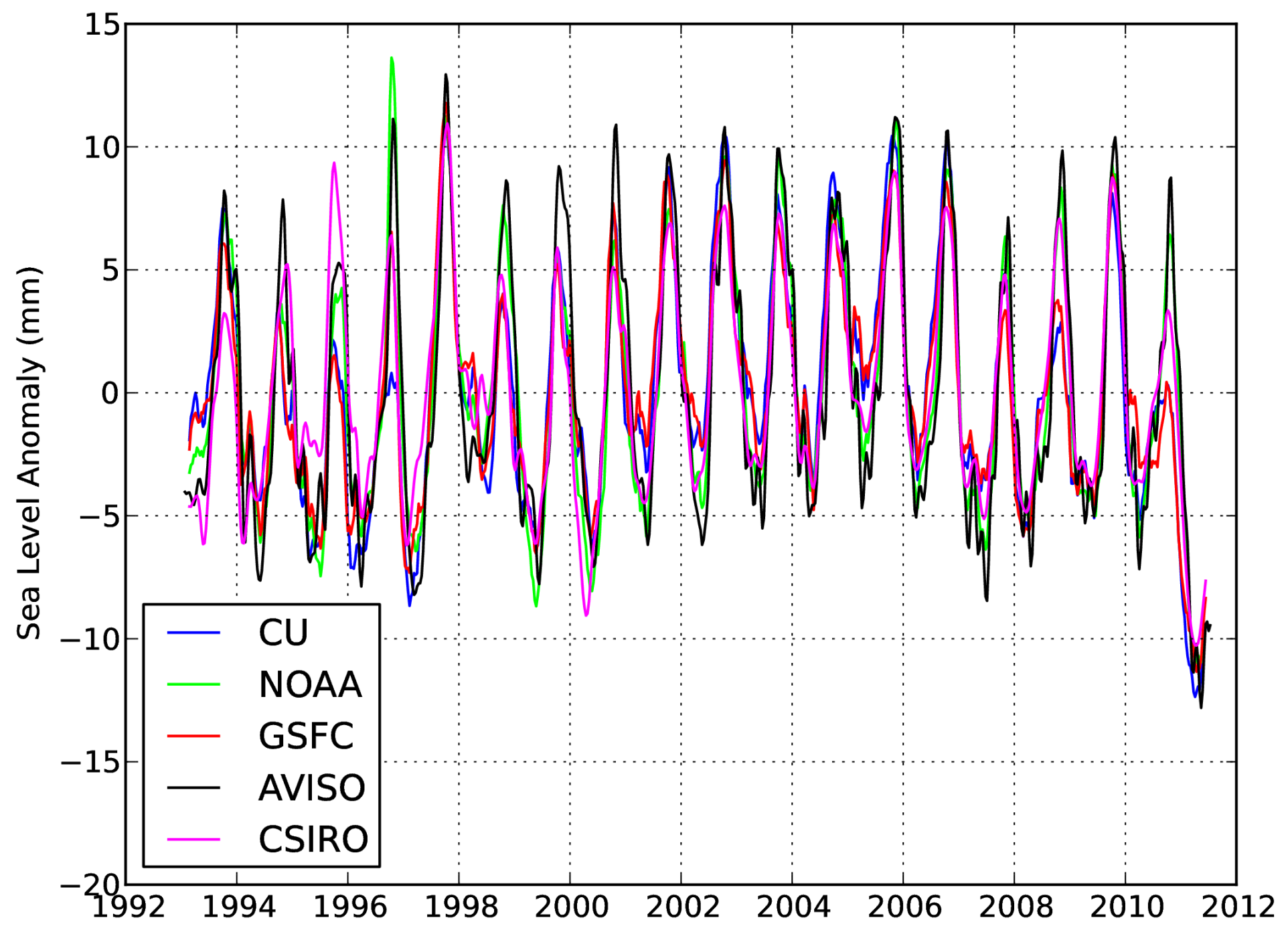
The PSD plot (bottom right) show the annual signal is largest in the NOAA series, while the CU series has the anomalous 60-day signal.

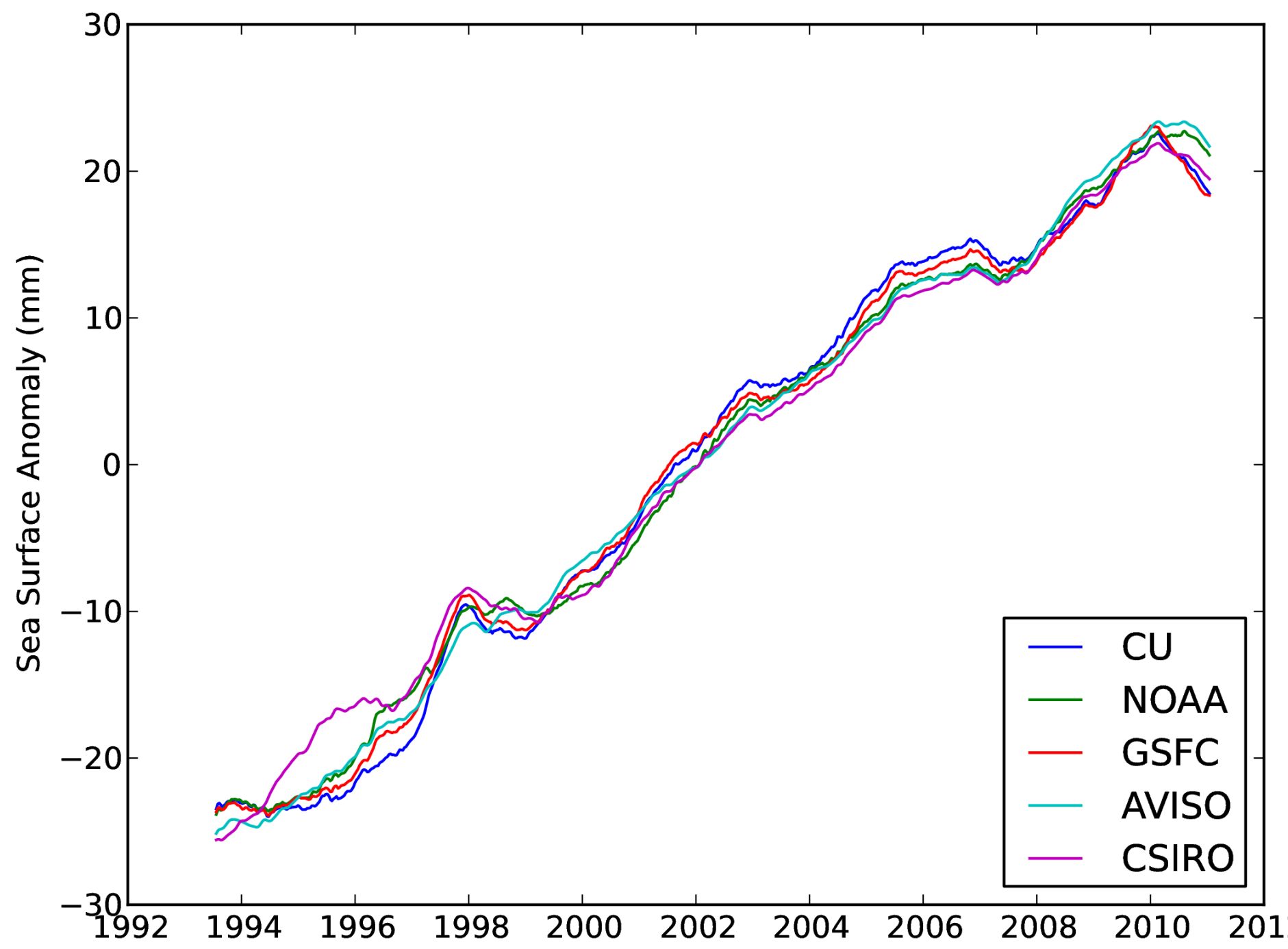






Comparing Filtered Time Series

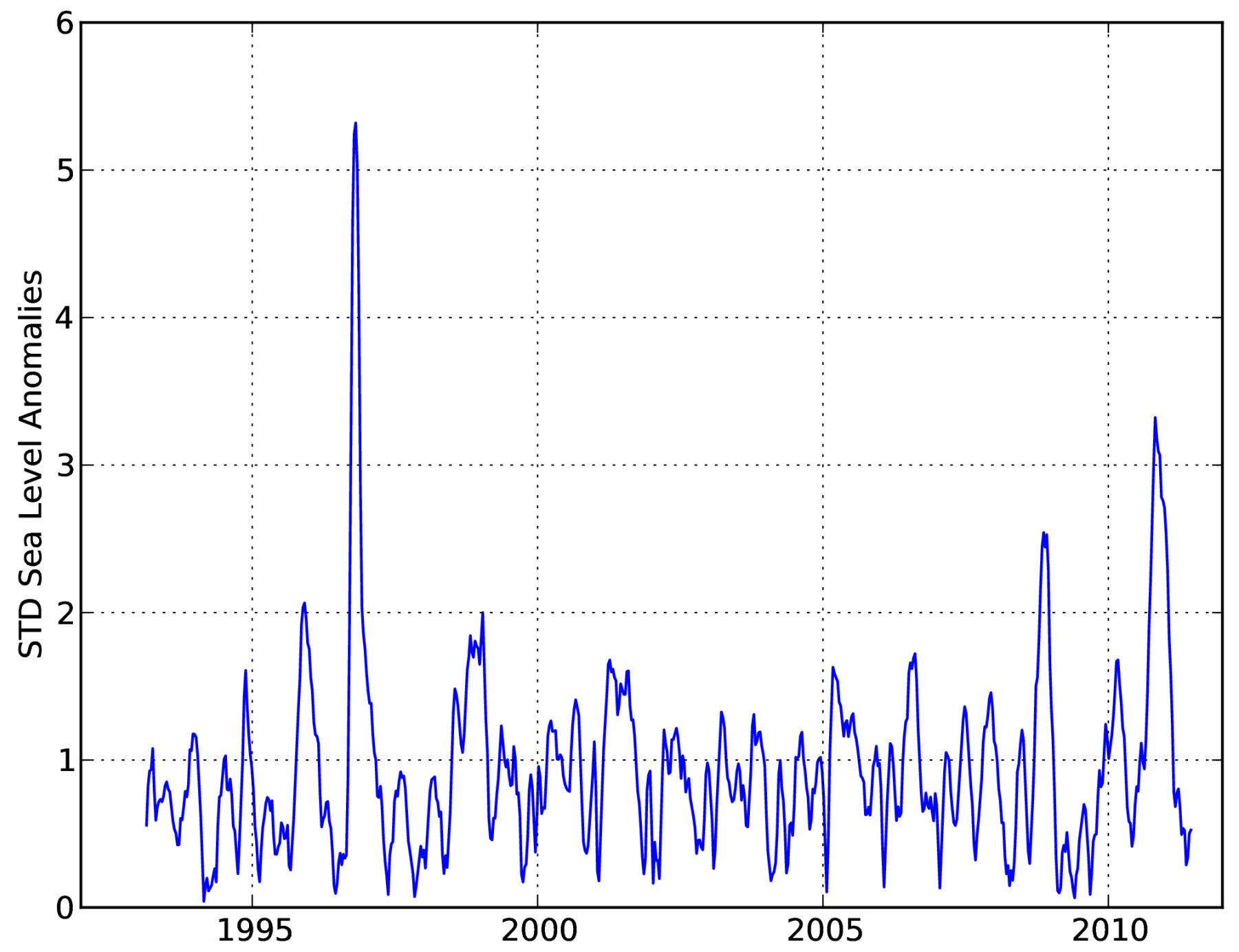


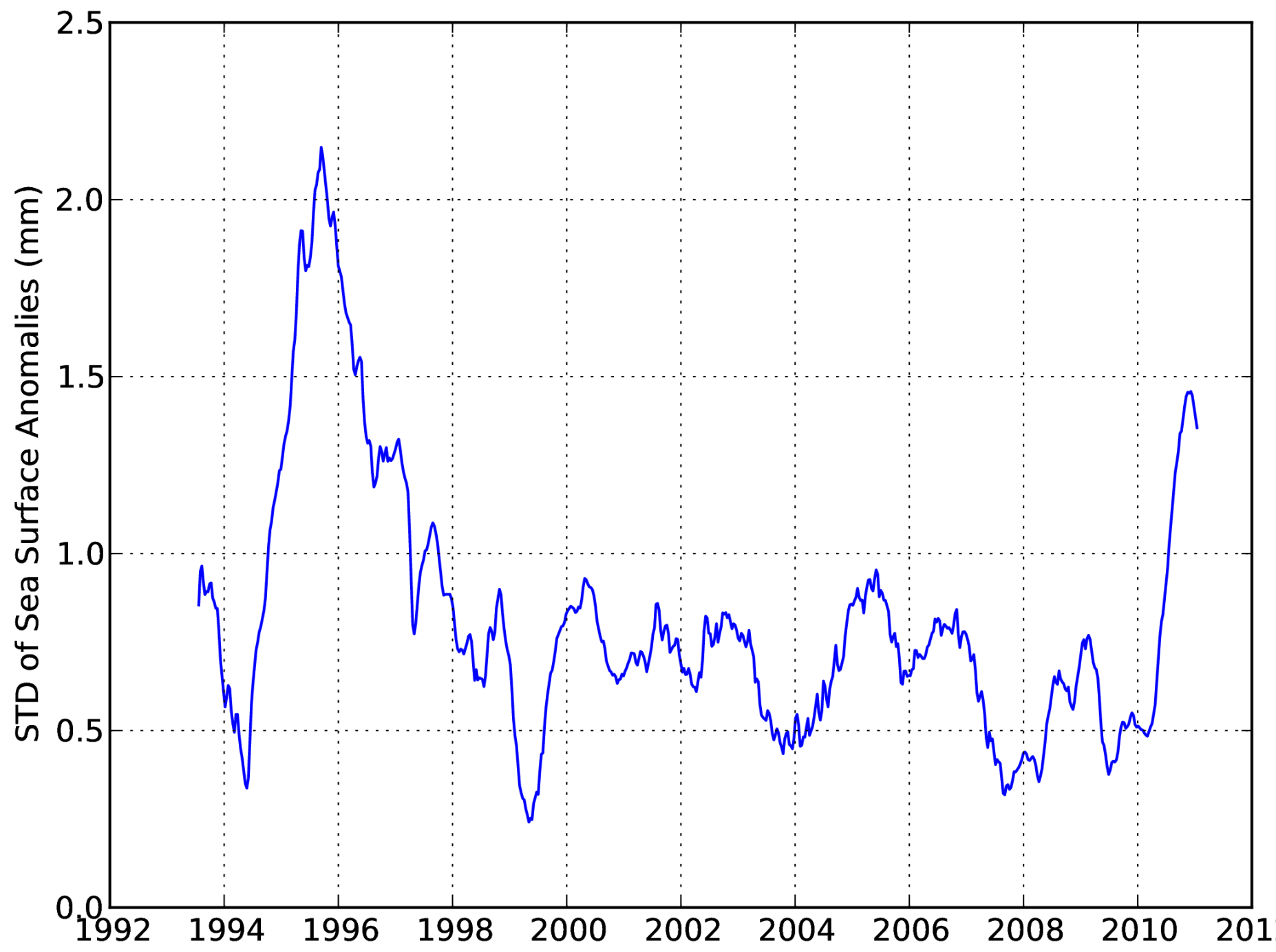


The seasonal (after removing the 60-day filtered and detrending) series are shown in the top left. To highlight time s where the seasonal signals disagree, the standard deviations of the time series is plotted below (bottom left). The largest differences occur during strong ENSO variations, such as in 1997/1998 El Nino and the recent strong La Nina in 2010. The NOAA and AVISO series show the strongest signals in 1997/1998.

The residual trend after removing the seasonal signals and means from each series is shown in the top right. An obvious feature is the early rise in TOPEX SLA for the CSIRO series. This is most likely due to use of the MGDRB orbits which have been updated in all other series.

Additionally, the recent strong La Nina in 2010, resulted in a much steeper drop in SLA for the CU and GSFC series than the NOAA and AVISO series. This may be due to the along-track algorithm or the use of GRACE gravity fields in the GSFC orbits.

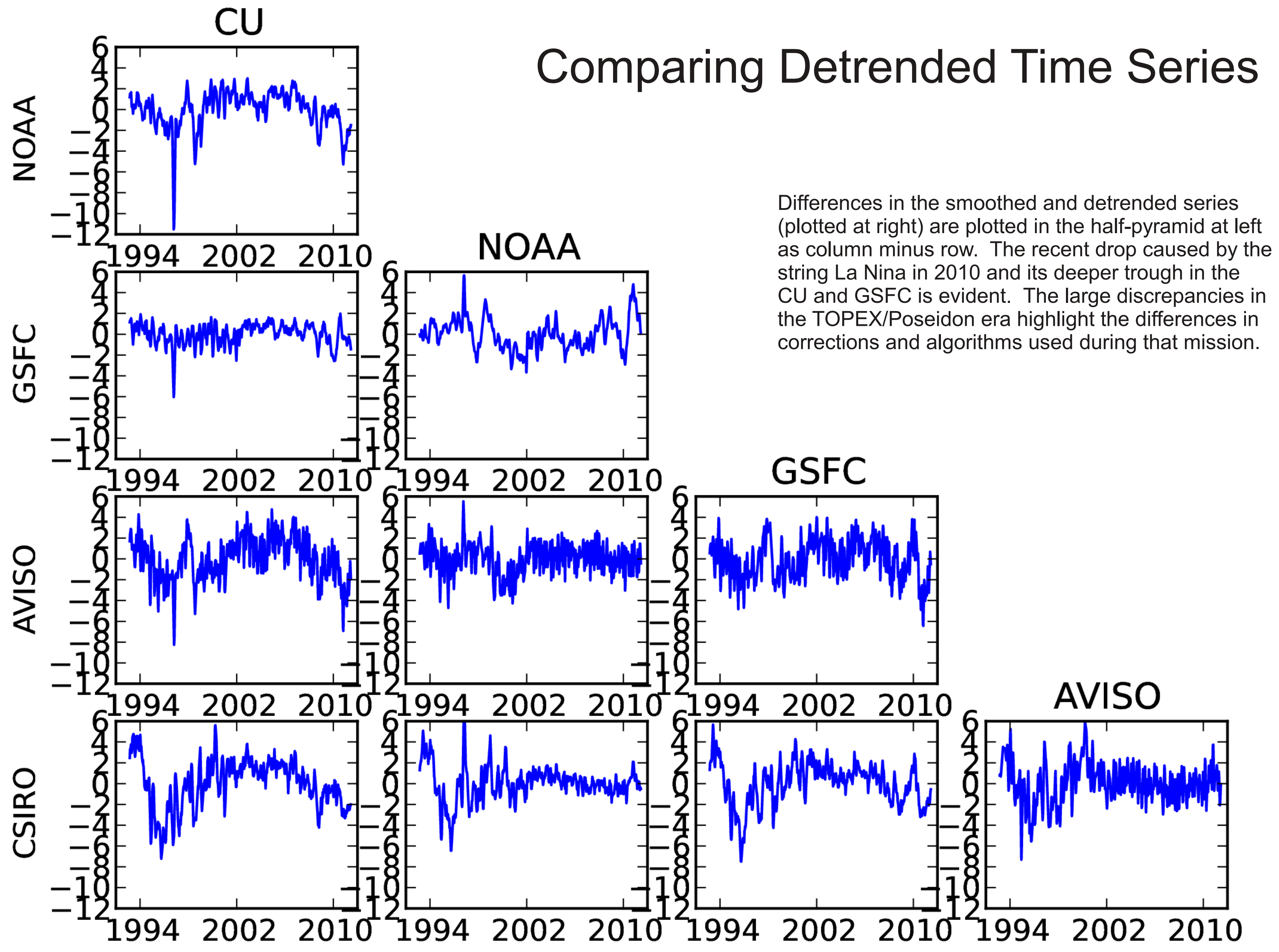




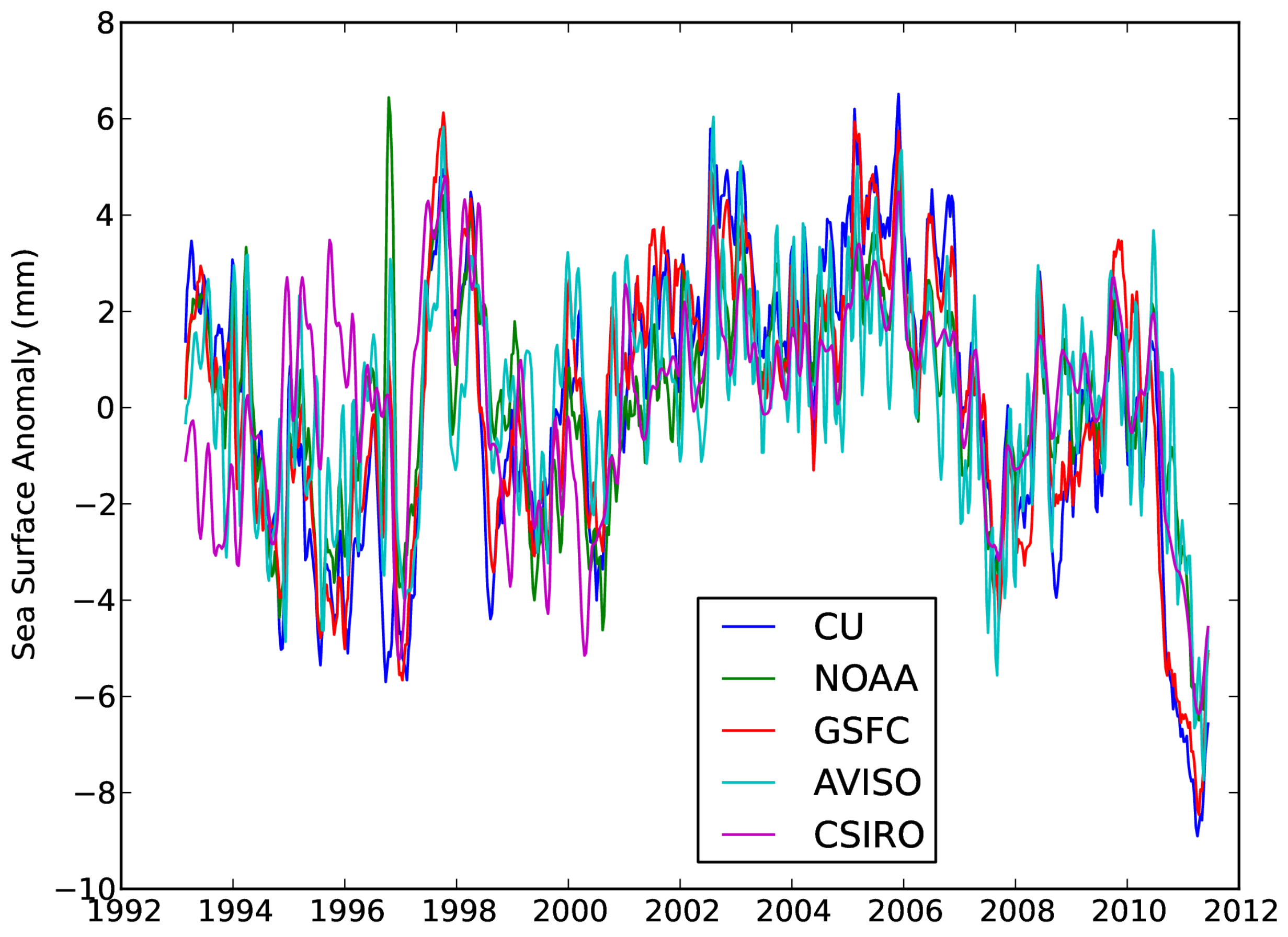
	Annual Amplitude (mm)	Annual Phase (deg)	Linear Trend (mm/yr)
CU	4.7	261	2.88
NOAA	5.9	246	2.84
GSFC	4.2	258	2.82
AVISO	6.5	241	2.91
CSIRO	5.0	257	2.71

The annual signal amplitude and phases are shown in the table above. Larger amplitudes and offset phases are noted in both the NOAA and AVISO series, and this is mot likely due to inclusion of shallow water estimates in these series. CU and GSFC series both use a minimum 120 m depth cut-off.

Comparing Detrended Time Series



Differences in the smoothed and detrended series (plotted at right) are plotted in the half-pyramid at left as column minus row. The recent drop caused by the string La Nina in 2010 and its deeper trough in the CU and GSFC is evident. The large discrepancies in the TOPEX/Poseidon era highlight the differences in corrections and algorithms used during that mission.



Future Work

This investigation has illuminated differences in the GMSL series produced by different institutions. Some errors, such the orbits used in the CU and GSFC series should be corrected, as well as updating the SWH and wind inputs when computing new SSB models (CU). Sensitivity to interannual variations seem to be affected as well by choice of algorithm (along-track versus gridded). Continued efforts to understand these effects and reach consensus is important for establishing confidence in a sea level climate data record.