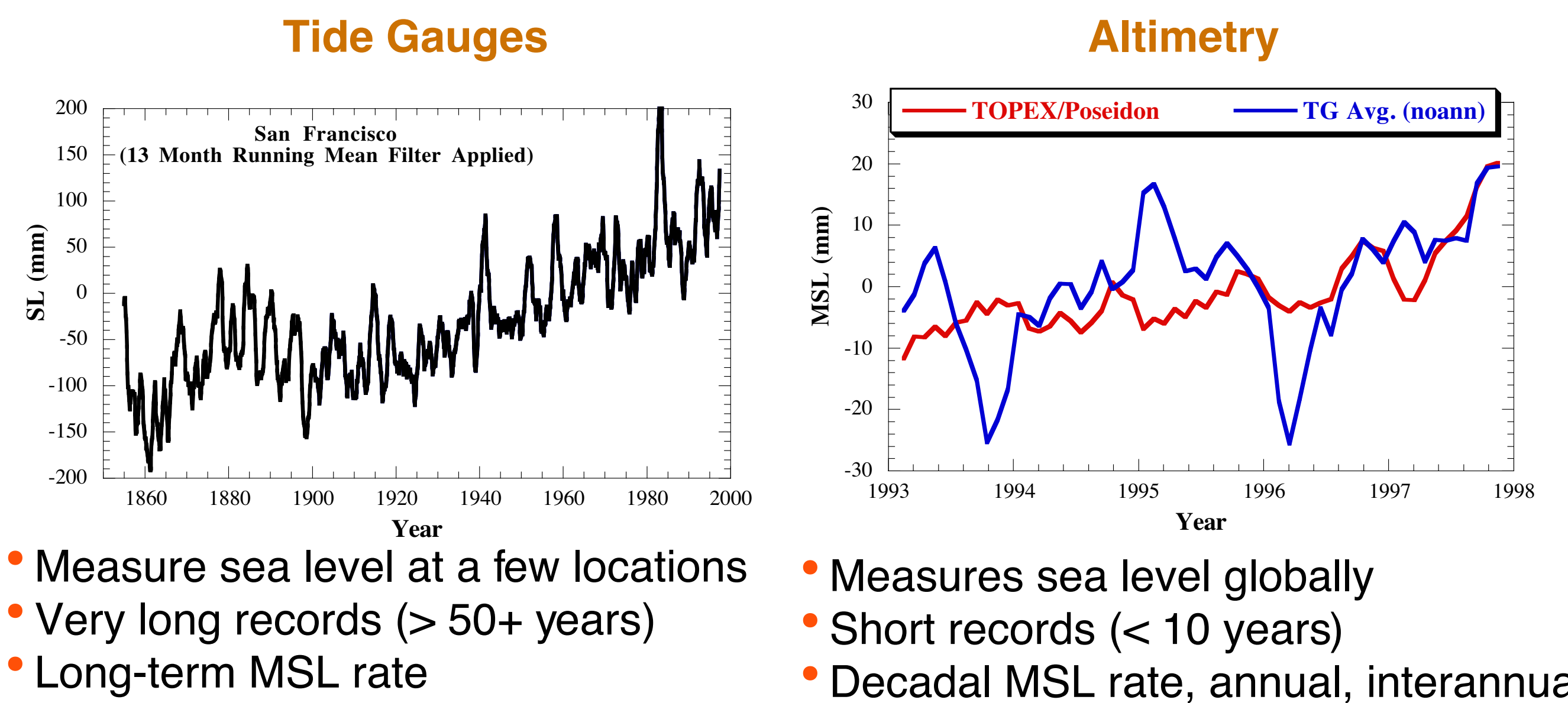


Low Frequency Variations in Global Mean Sea Level: 1950-2000

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1. Measuring Sea Level

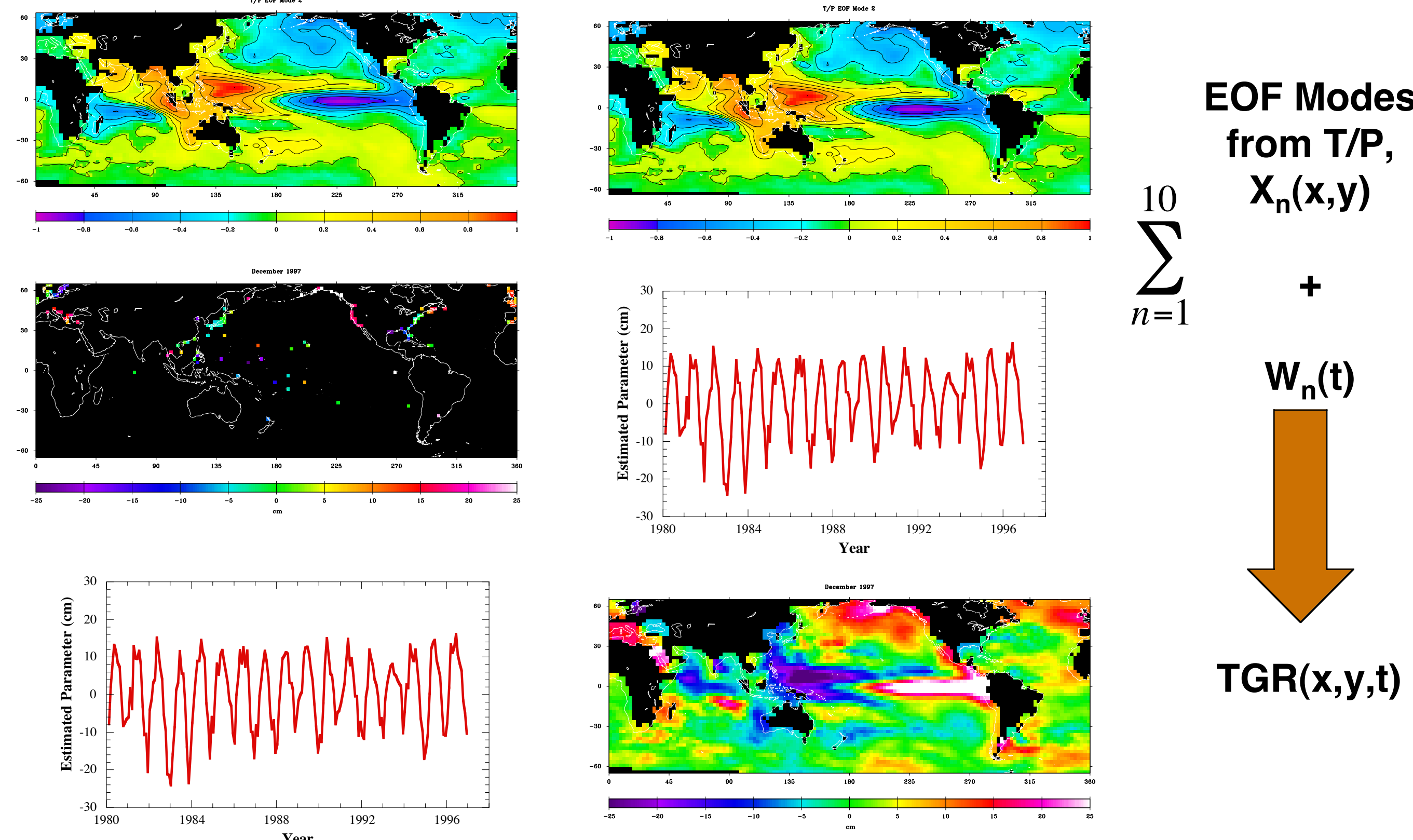


Can one compute a MSL time-series from tide gauges with enough accuracy to determine low-frequency variability before 1993?

2. EOF Reconstruction

$$\Delta\eta(x, y, t) = \sum_{n=1}^{10} X_n(x, y)W_n(t)$$

Estimation Reconstruction



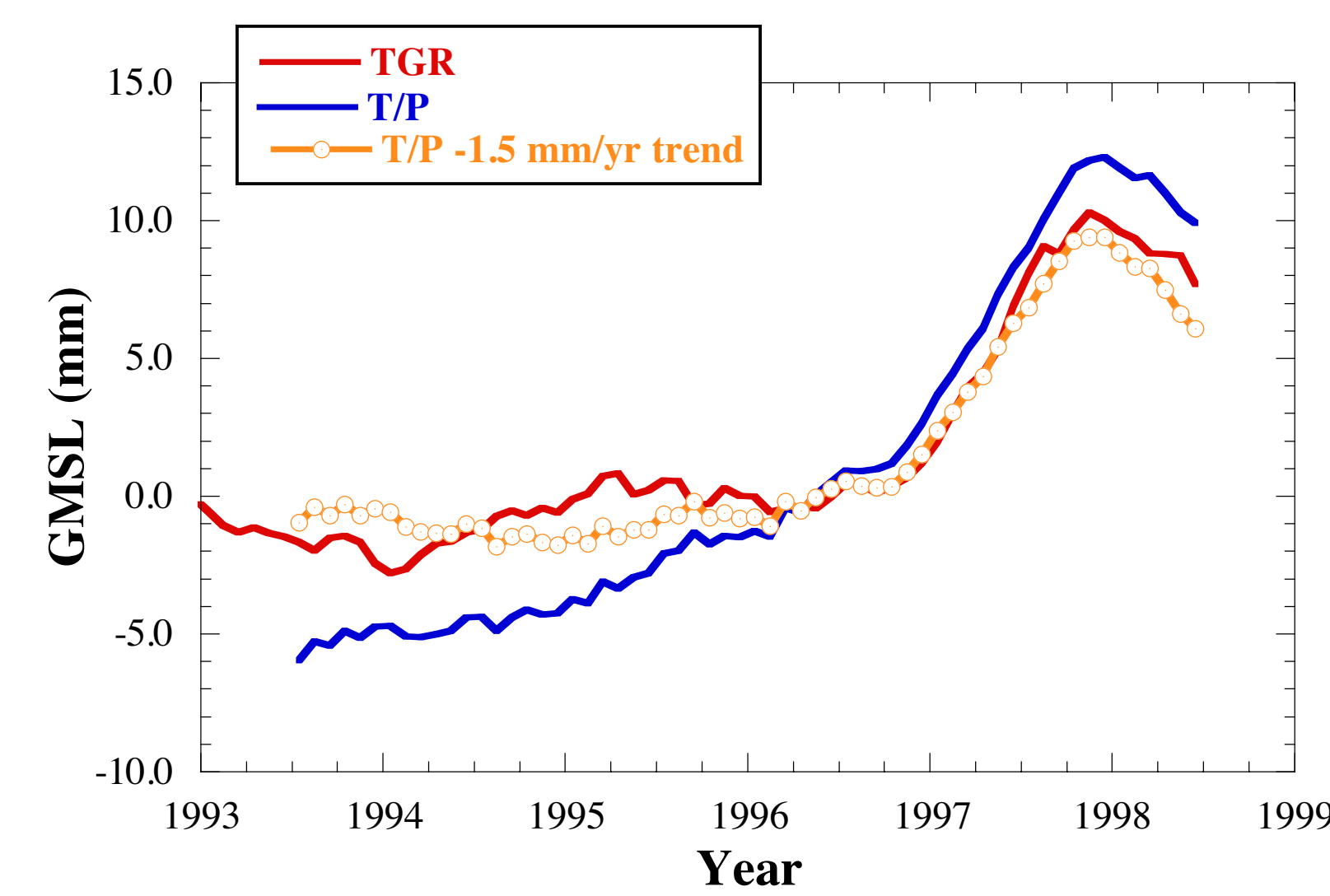
3. Data Processing

- Monthly data from Permanent Service for Mean Sea Level (PSMSL) through December 1998; Revised Local Reference (RLR) data - data corrected to common datum at each site
- TOPEX altimeter data with standard corrections (January 1993 - December 1998); no inverted barometer correction
- In this study, we are most interested in interannual variations, not trends
 - » Estimate and remove bias + trend from all tide gauge data using an epoch of 1950. Use only sites with > 25 years of observations; reduces PGR, uplift/subsidence errors
 - » **Results will not have a secular trend**
- Grid data into 2.5° x 2.5° monthly grids, smooth T/P with a long-wavelength filter
- Compute EOFs with T/P data between January 1993 and December 1998. Use 10 EOF modes in reconstruction

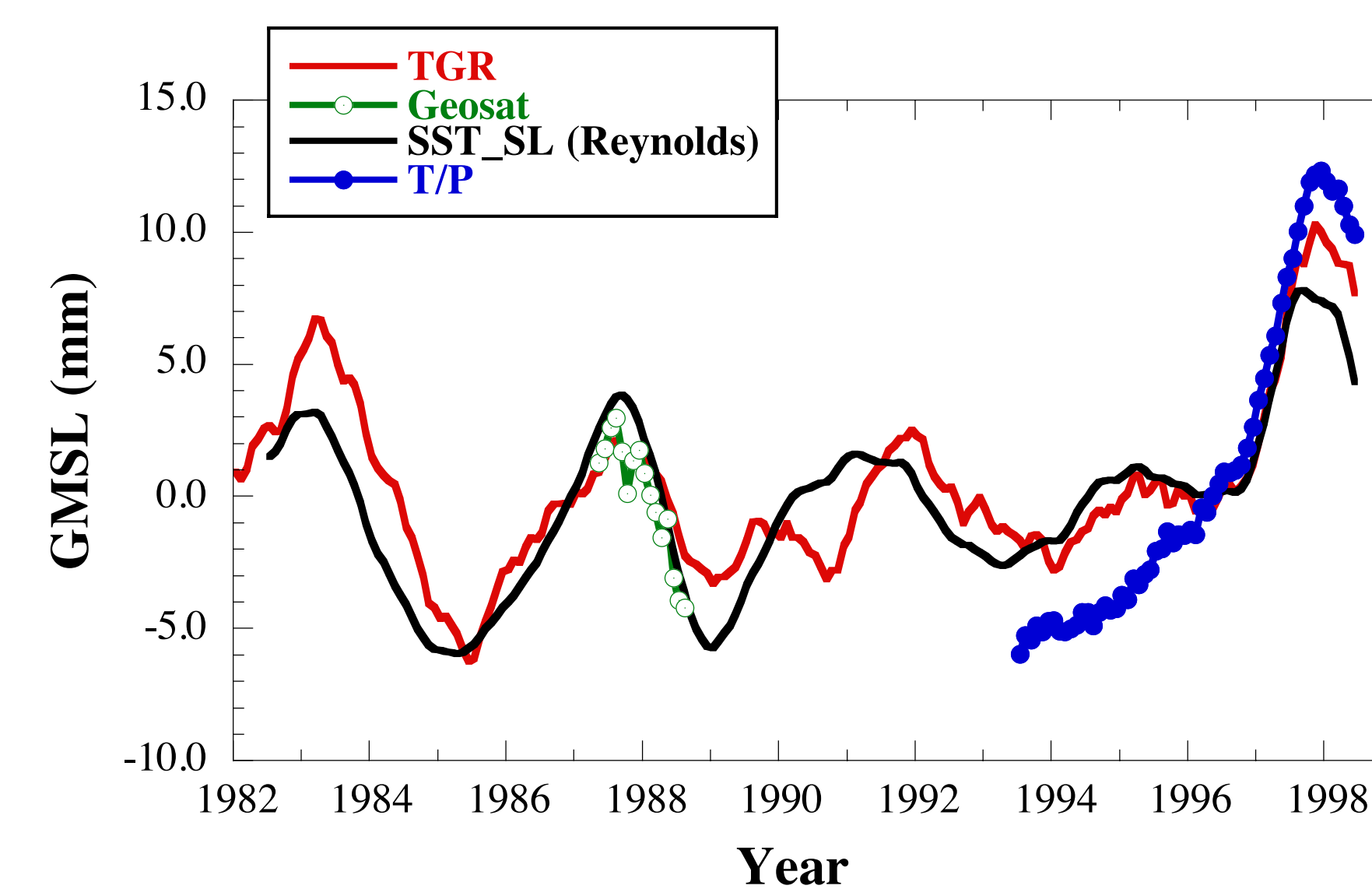
4. Verification of TGR GMSL

- 1993-1998
 - » GMSL from tide gauge reconstruction (TGR) compared to T/P
- 1987-1989
 - » Geosat GMSL
- 1950-1993
 - » Sea surface temperature (SST) measurements
 - » 1982 - present: Reynolds and Smith [1994] interpolation of satellite measurements
 - » 1950 - 1981: Smith et al. [1996] reconstruction of in situ measurements
 - » Regress against 1993-1998 data against T/P sea level to create a proxy sea level (SST_SL), accounting for lags
 - » Compare statistics for TGR/SST_SL from earlier decades with TGR/SST_SL from 1993-1998.

5. 1993-1998



6. 1982-1998

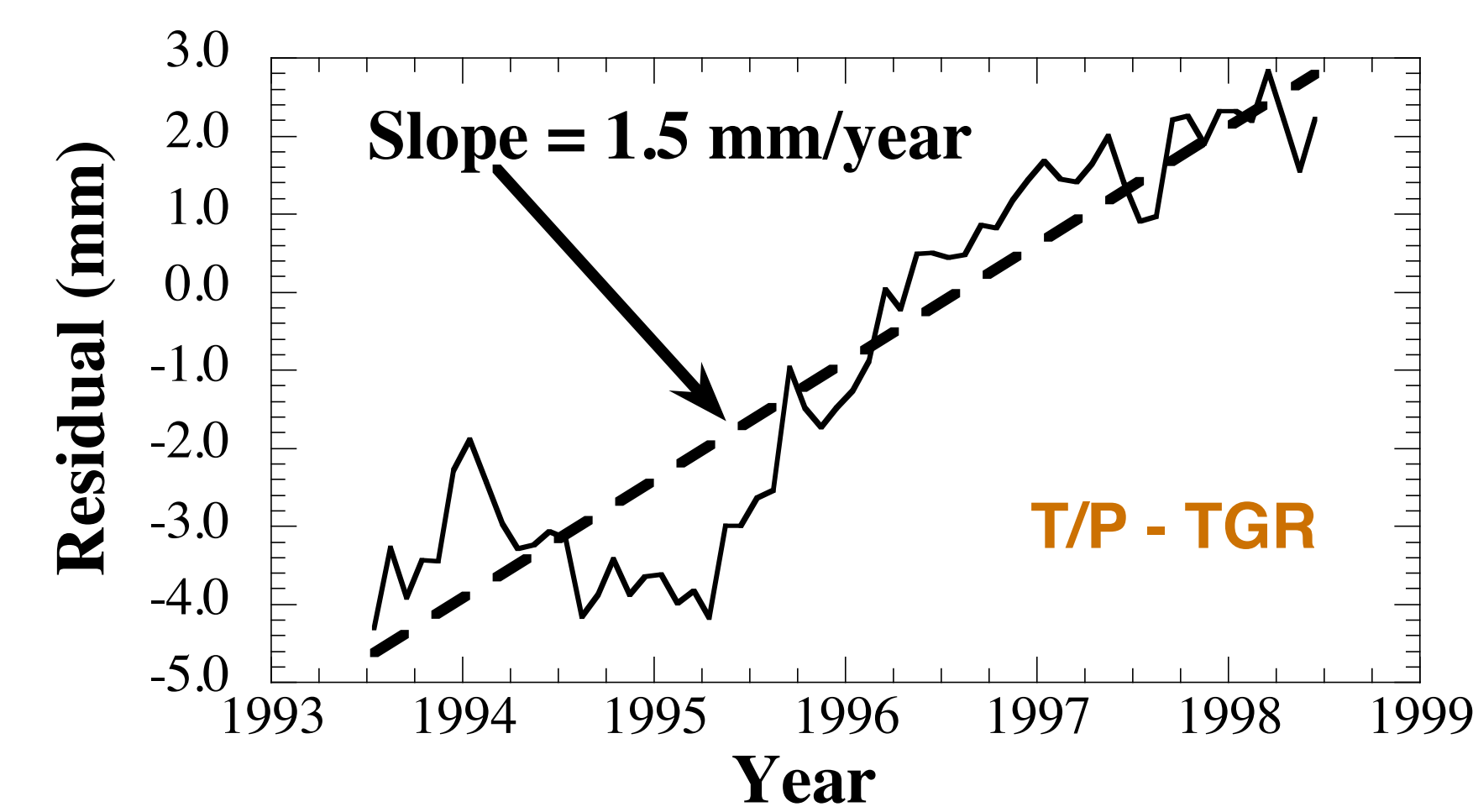
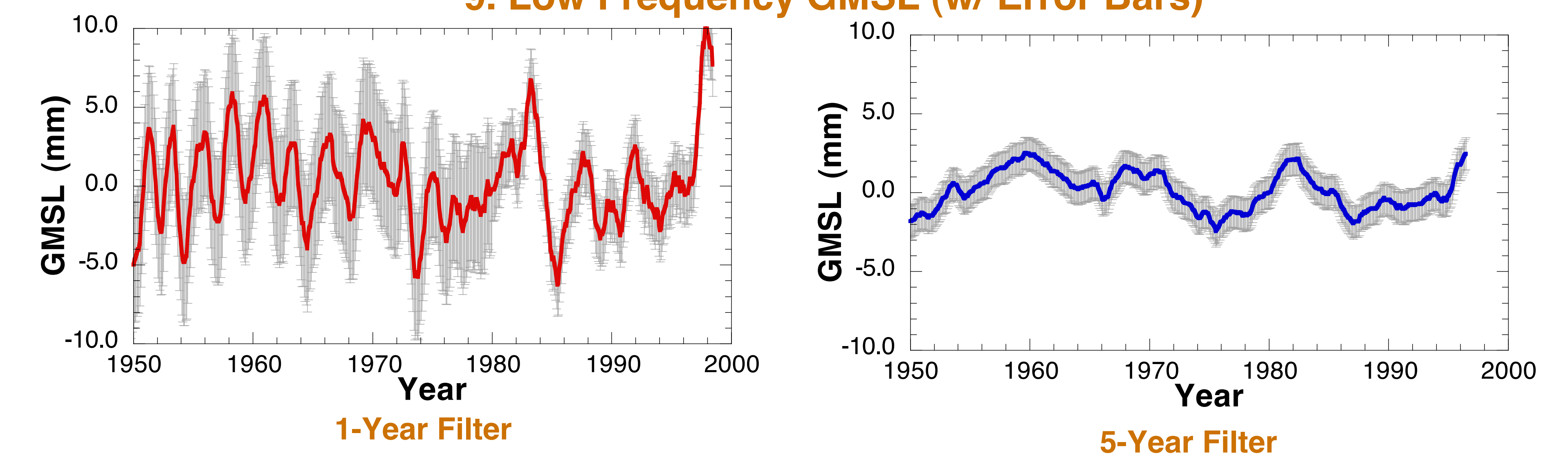


8. Statistics

Decade	RMS (mm)
90s (T/P)	2.5
90s (T/P - 1.5) mm/year	1.0
90s (SST_SL)	1.5
80s (Geosat)	1.5
80s (SST_SL)	2.1
70s (SST_SL)	4.1
60s (sample)	2.6
50s (sample)	3.6

- Estimate error in GMSL from TGR (1-year filter) to be
 - » ± 2 mm (1980 - present)
 - » ± 4 mm (1950-1980)
- Error for 5-year GMSL estimated to be about half this

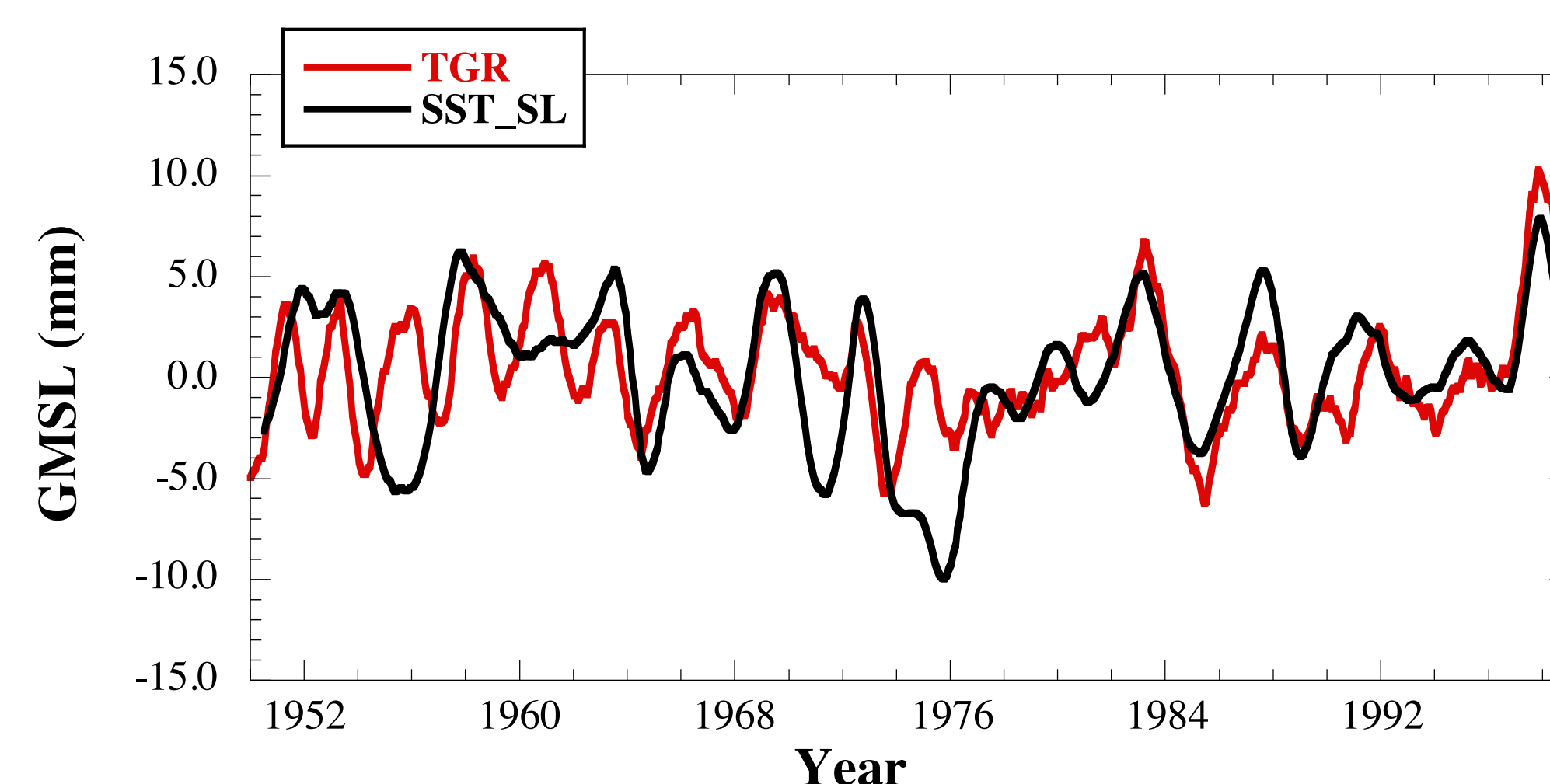
9. Low Frequency GMSL (w/ Error Bars)



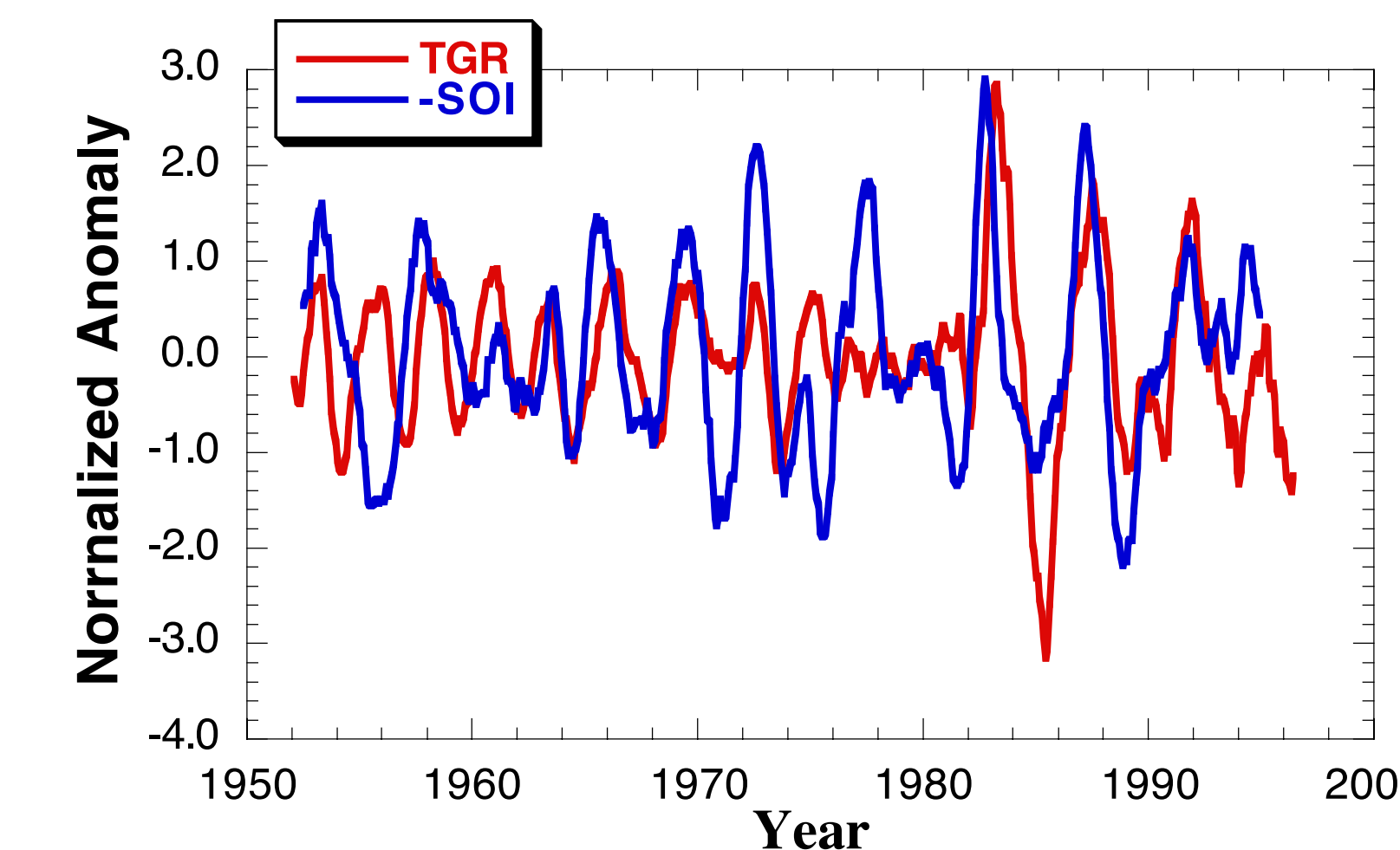
If TGR really determines interannual GMSL signal without the secular trend, then the residual (T/P - TGR) should be the long-term trend in GMSL rise. We note the rate of the residual is 1.5 mm/year, which is in the middle of current estimates.

Note: A 13 month running mean boxcar filter has been applied to all time-series

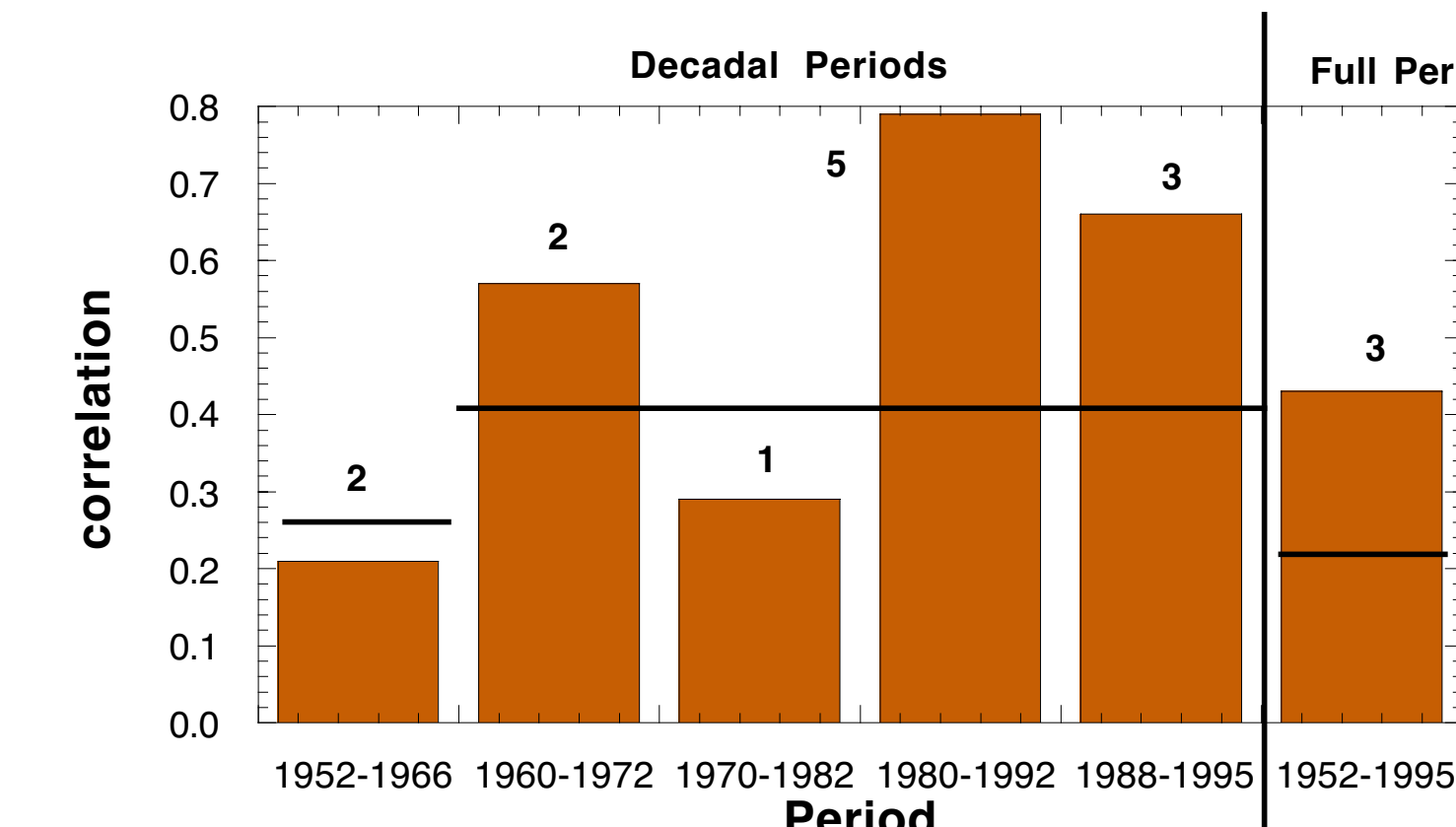
7. 1950-1998



10. GMSL and ENSO

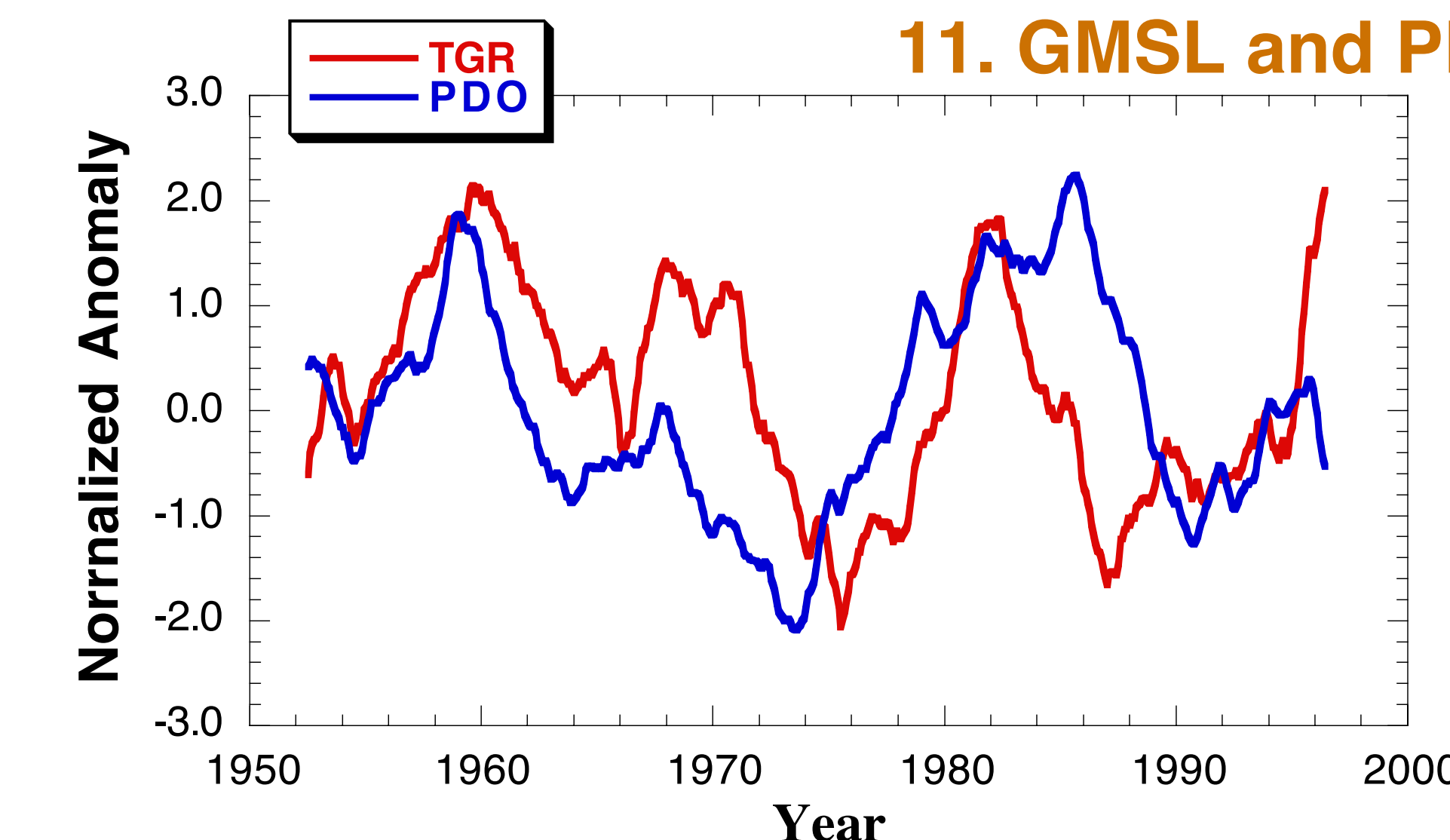


- Use Southern Oscillation Index (SOI) as proxy for El Niño/La Niña.
- Remove 5-year running mean to remove low-frequency signals



- » Black lines are 90% confidence levels based on equivalent degrees of freedom
- » Numbers are lag in months for maximum correlation

11. GMSL and PDO



12. Conclusions

- Low frequency global mean sea level (MSL) variations can be determined from tide gauge data and altimeter EOF modes with an accuracy of 2-4 mm to 1950.
- Significant changes in low-frequency and interannual GMSL as far back as 1950.
- Variations correlated with most El Niño/Southern Oscillation events and Pacific Decadal Oscillation.
- An article describing this research in more detail is currently in press in JGR-Oceans