The impacts of ENSO/PDO on regional sea level change: After 20 years, are we finally seeing a change in the pattern of Pacific sea level change?

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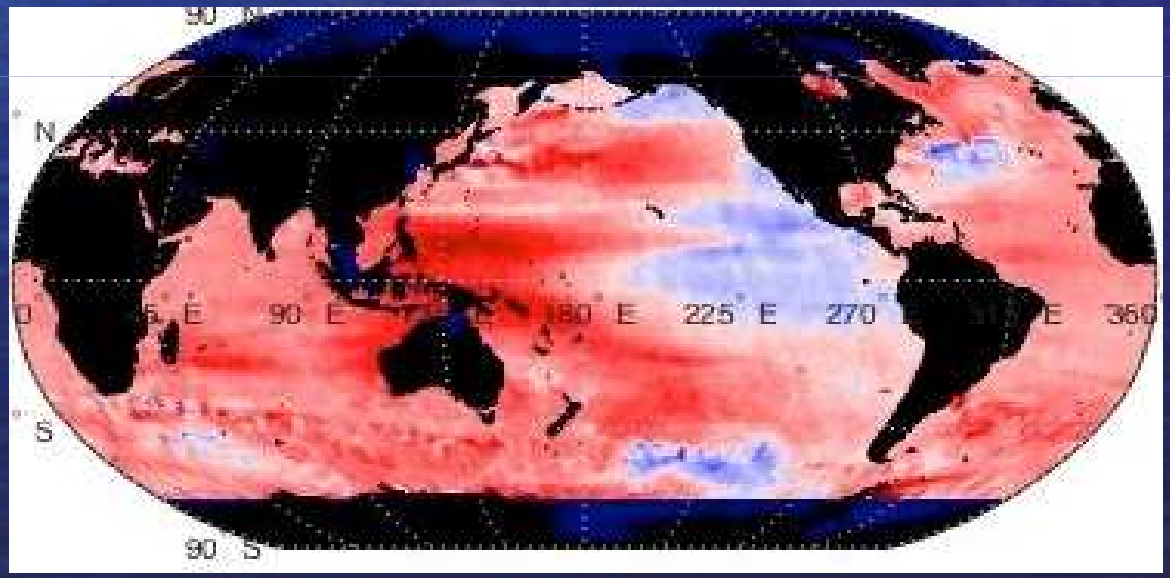
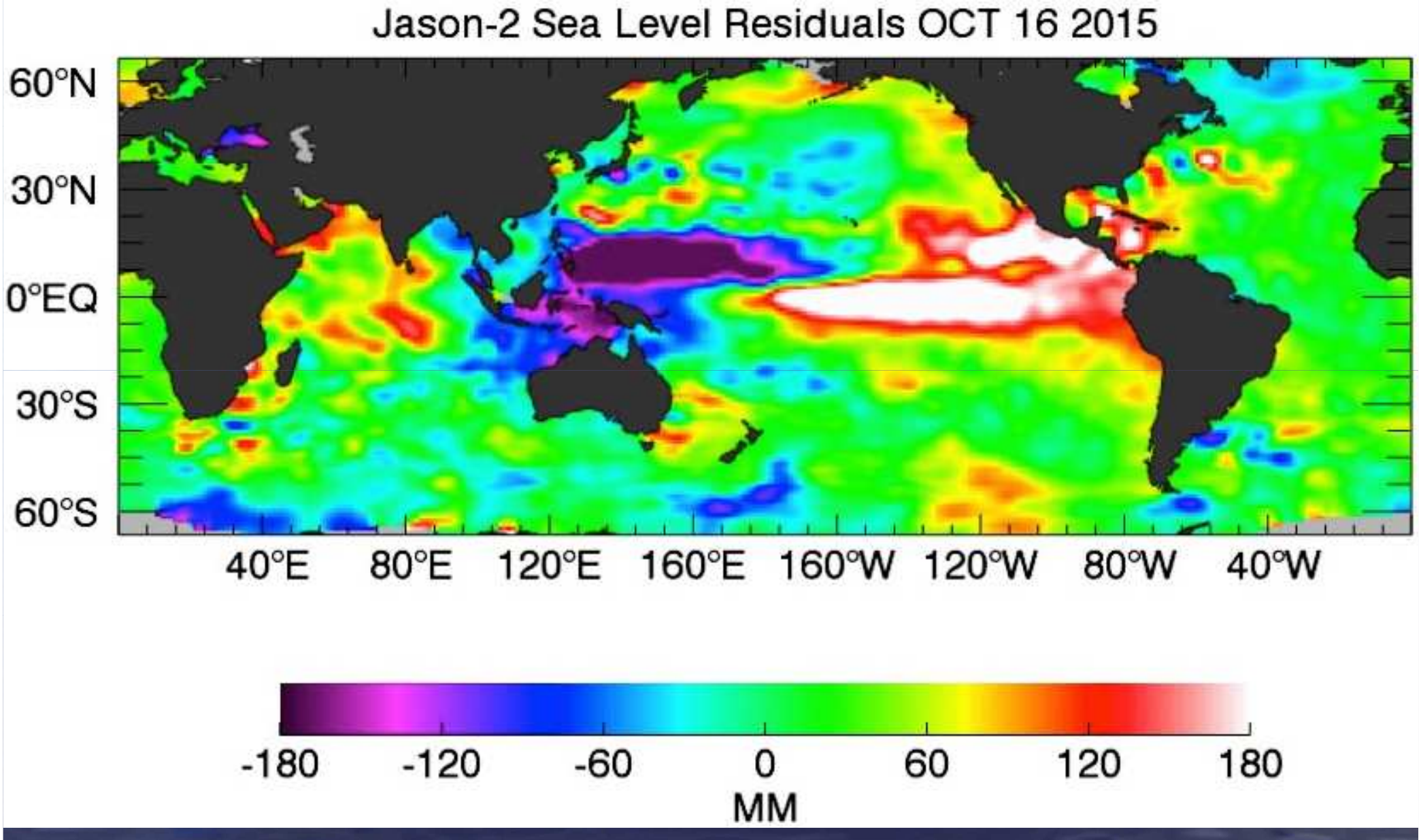
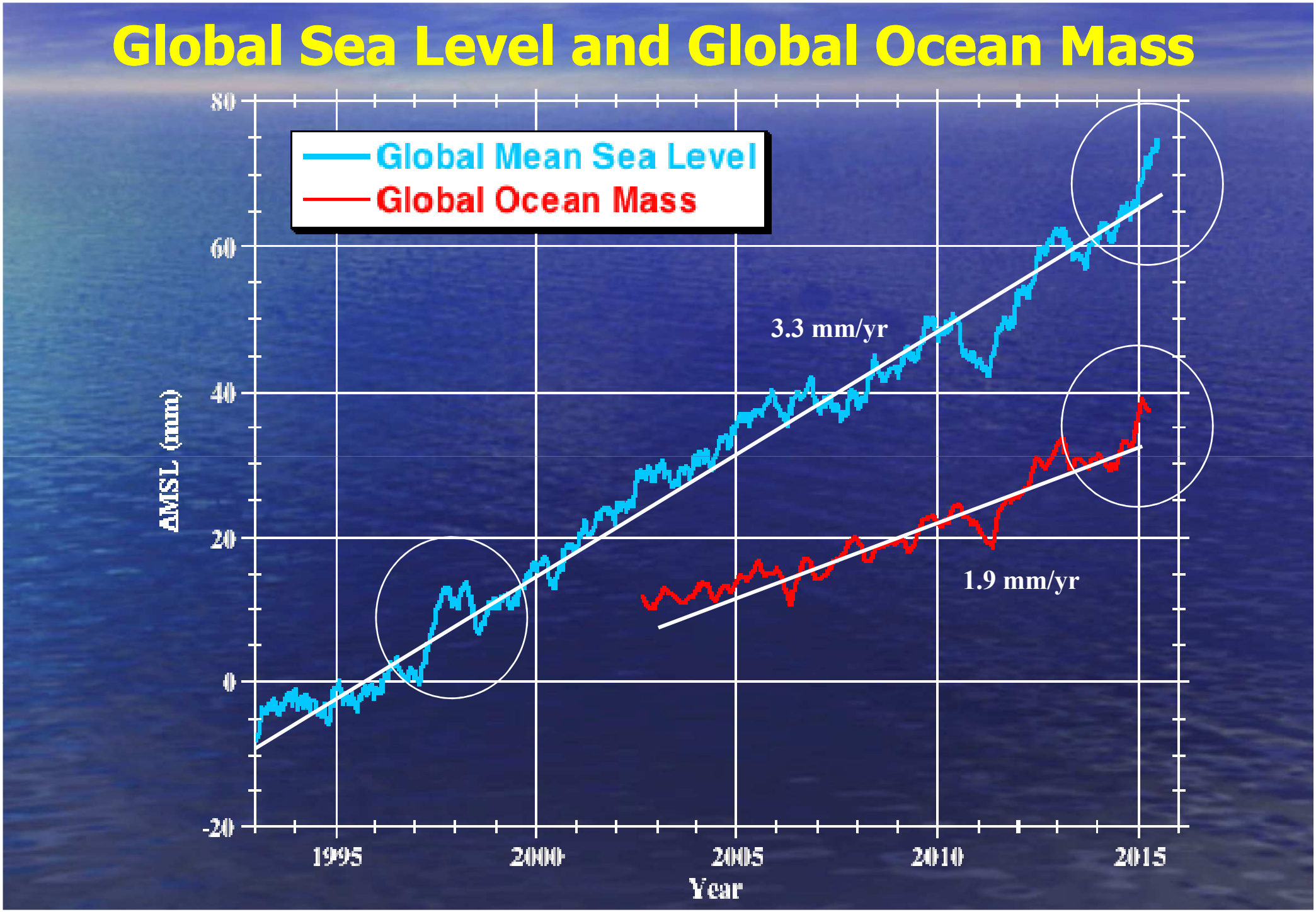


OSTST Meeting, October 20-23, 2015
Reston, Virginia

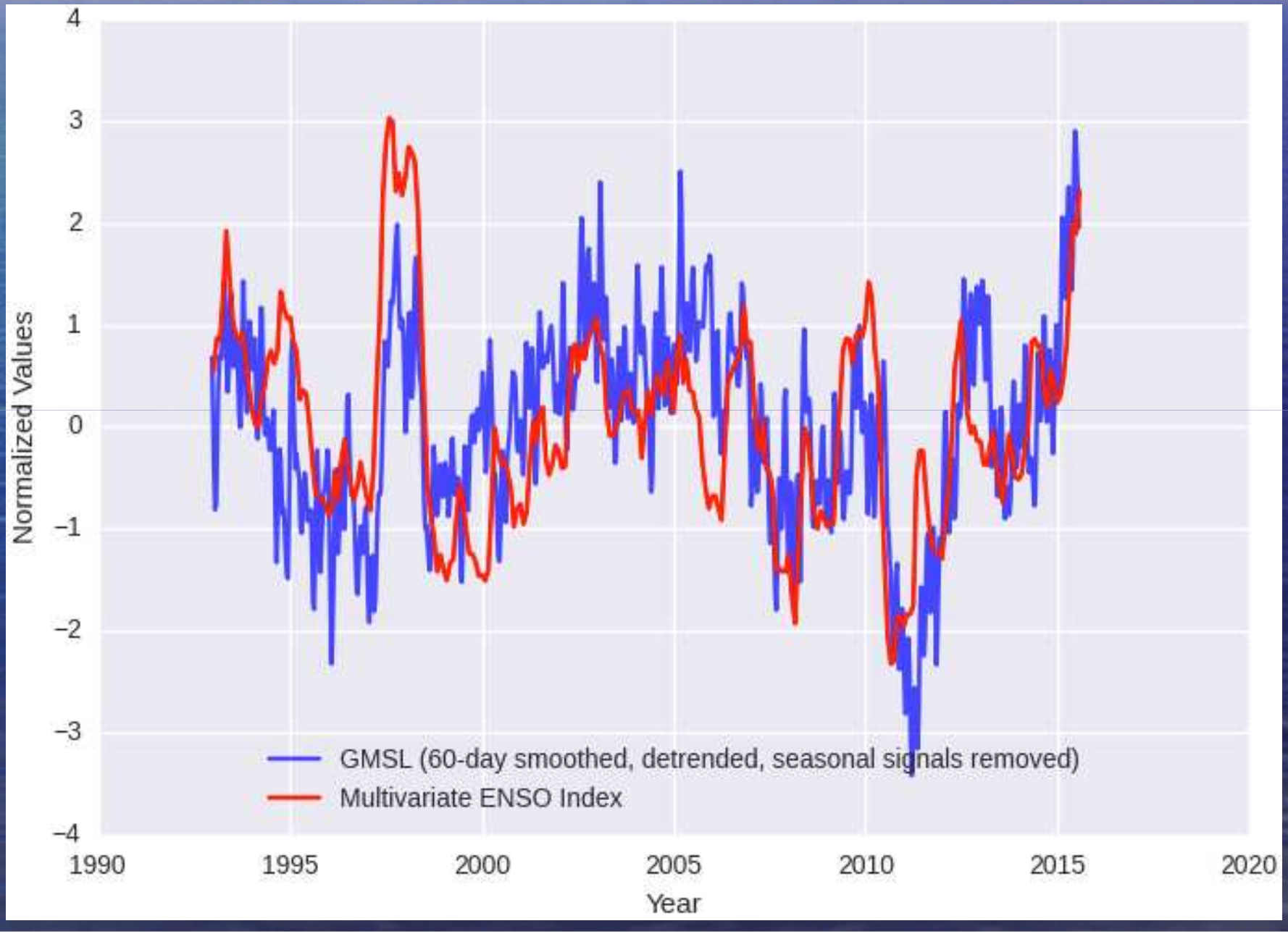
ENSO is here!


Jason-2 Sea Level Residuals OCT 16 2015
60°N
30°N
0°EQ
30°S
60°S
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
-180
-120
-60
0
60
120
180
MM

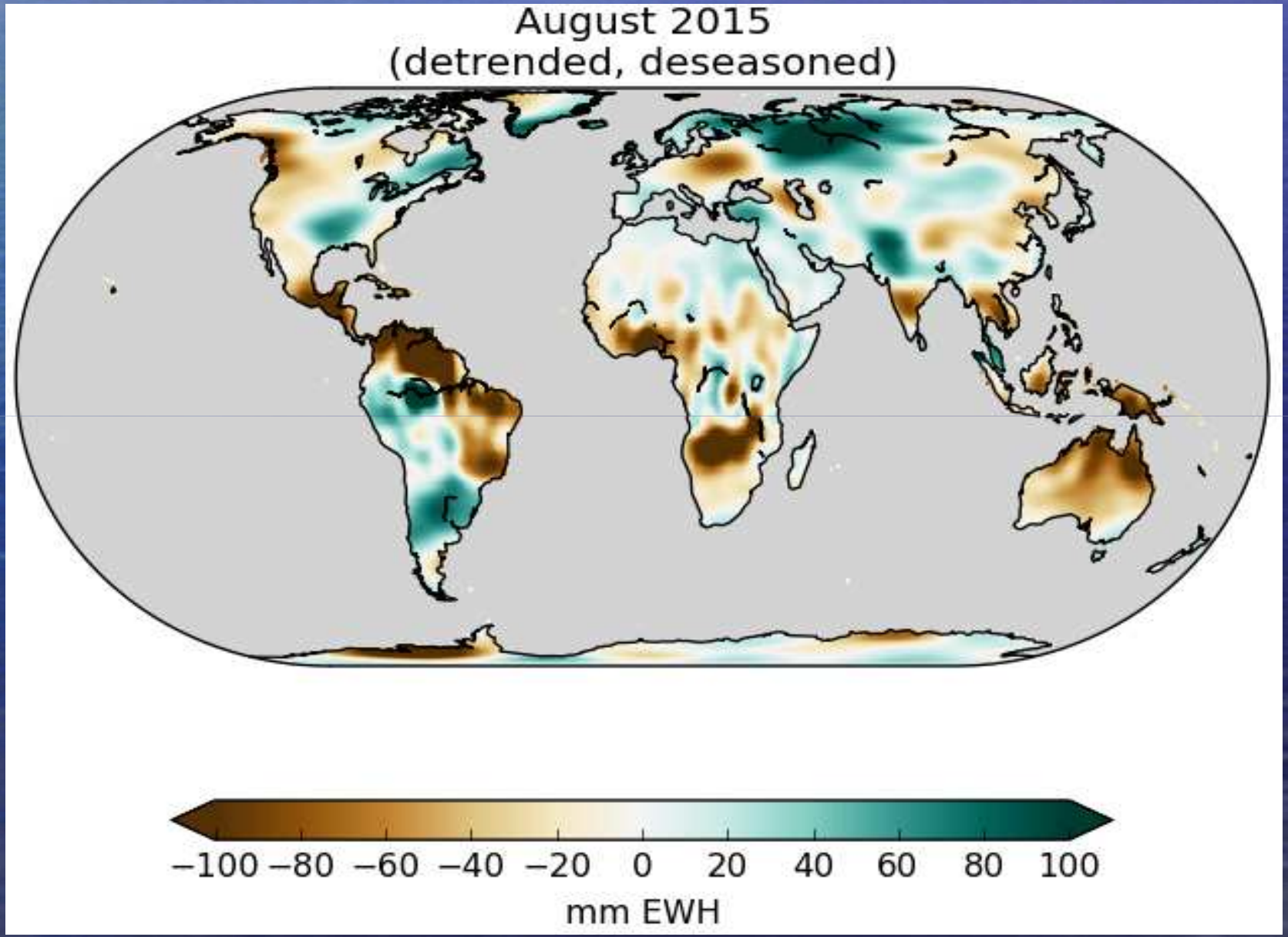
Global Sea Level and Global Ocean Mass



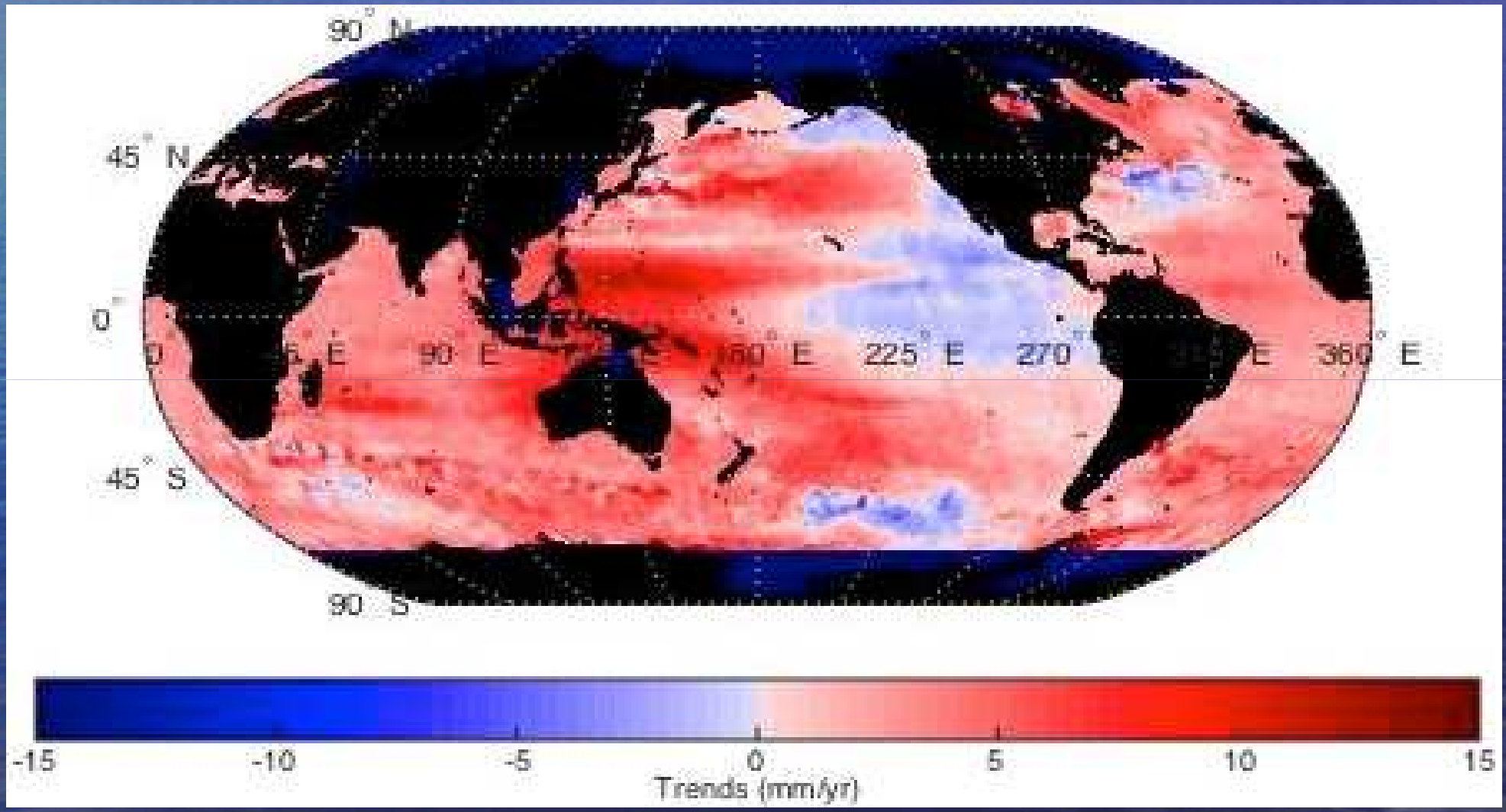
GMSL versus MEI



GRACE Surface Mass Anomalies



Sea Level Trends: 1993.0-2013.0



Western Pacific Sea Level

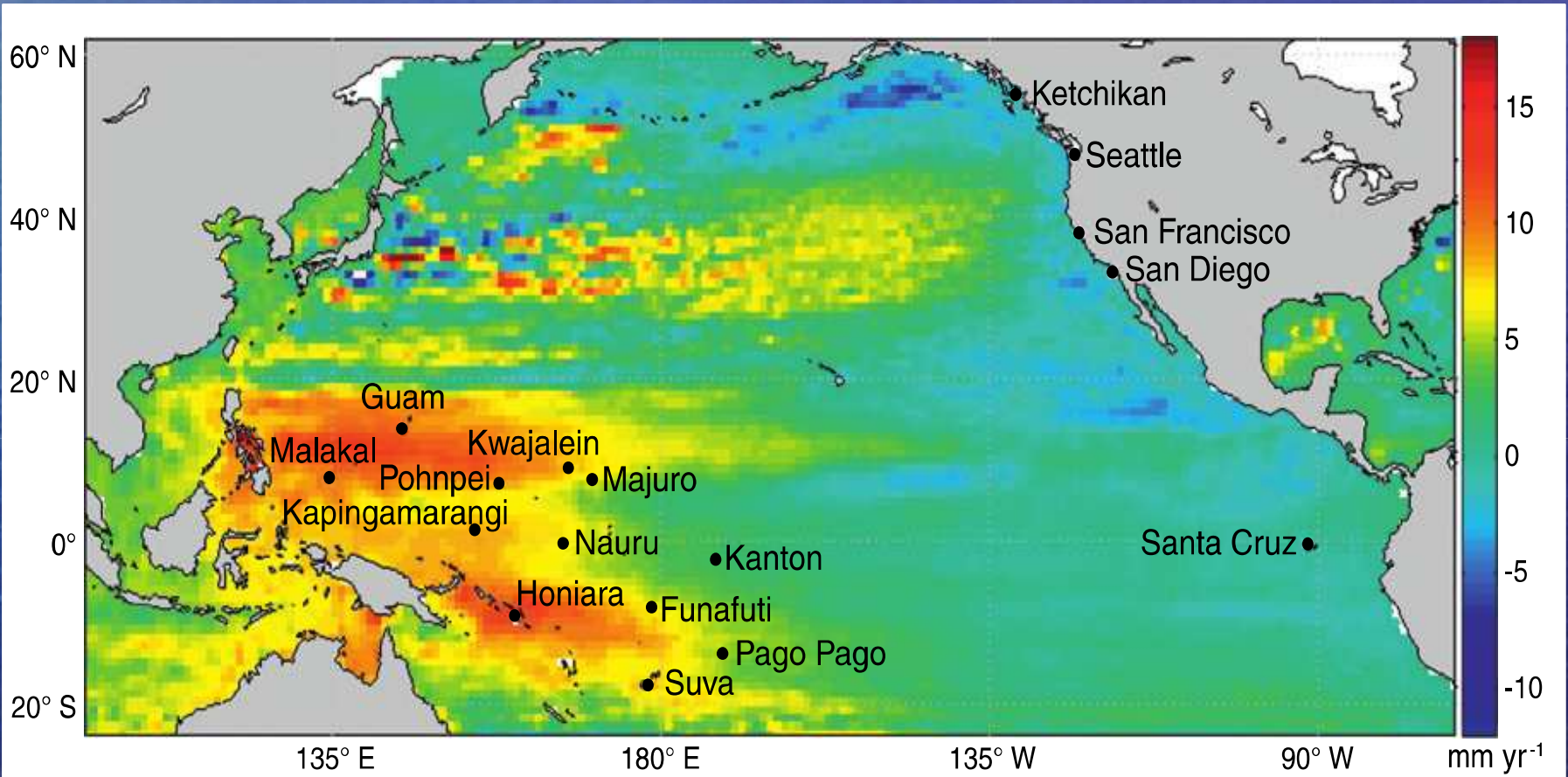


FIG. 3. Map of SSH trends for 1993–2009 with the locations of tide gauge stations.

Merrifield [2011]

Western Pacific Sea Level from Tide Gauges

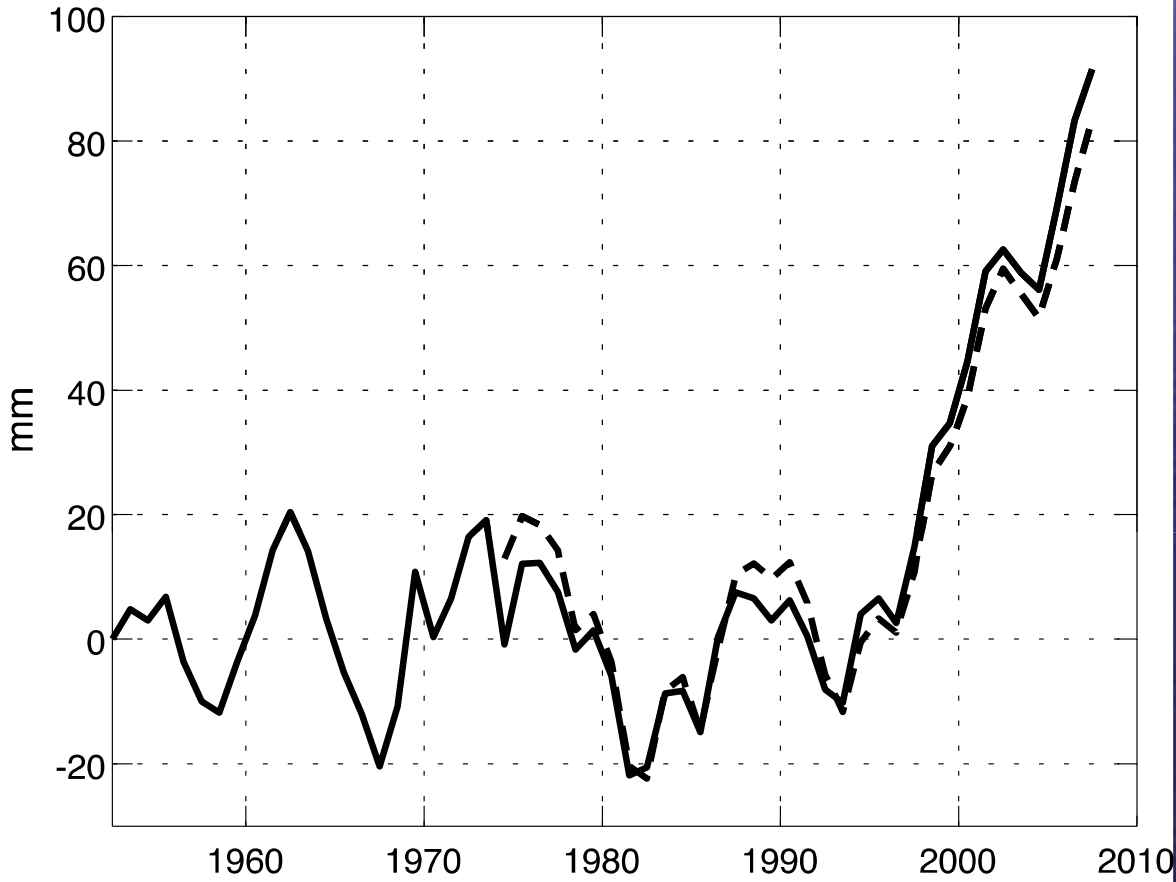
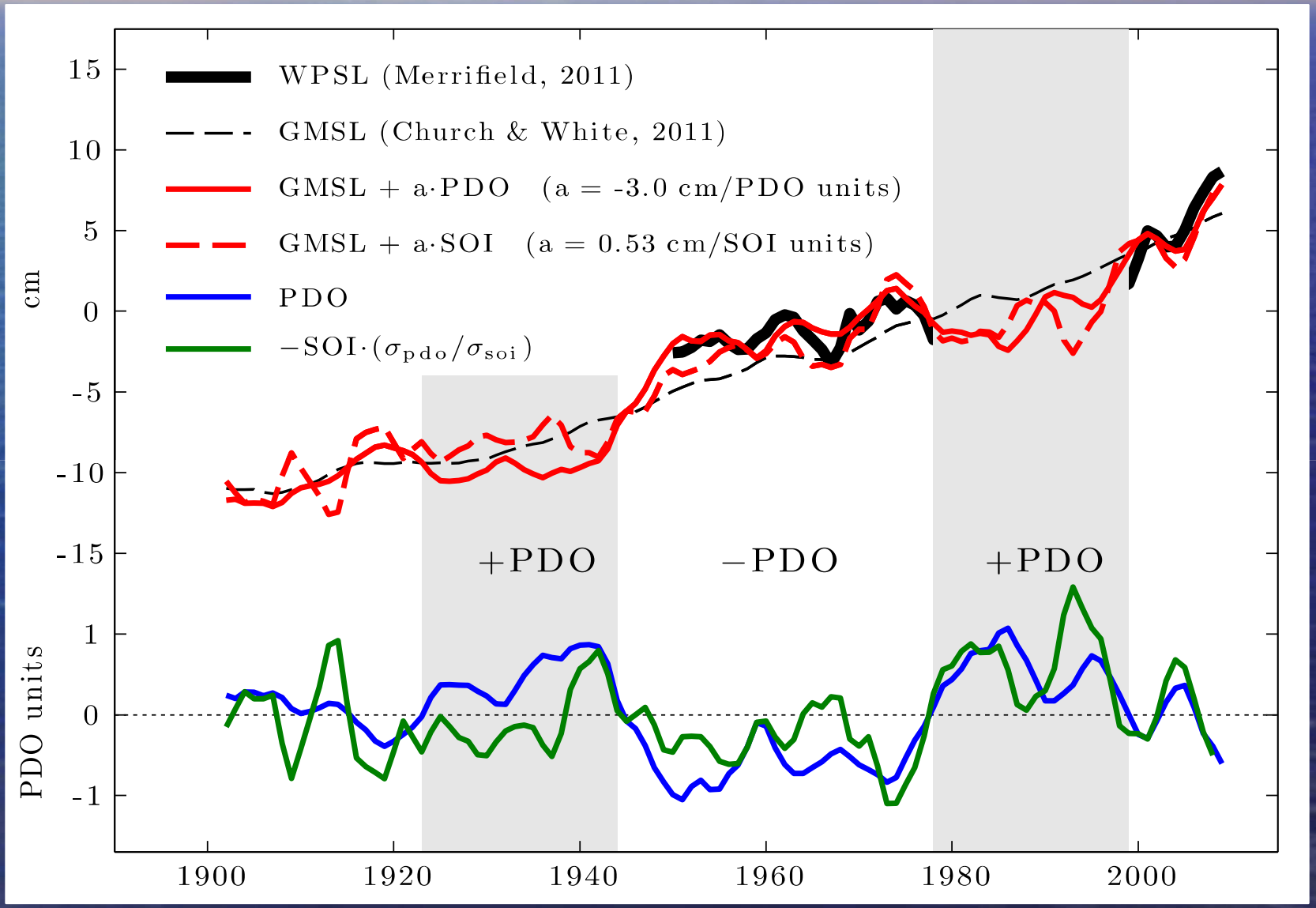


FIG. 6. The average sea level in the WTP computed from the tide gauge records in Fig. 5. The solid curve is the average of all records. Prior to the mid-1970s, only Guam, Kwajalein, and Pago Pago contribute to the mean. The dashed curve is the average of all the records except Guam, Kwajalein, and Pago Pago.

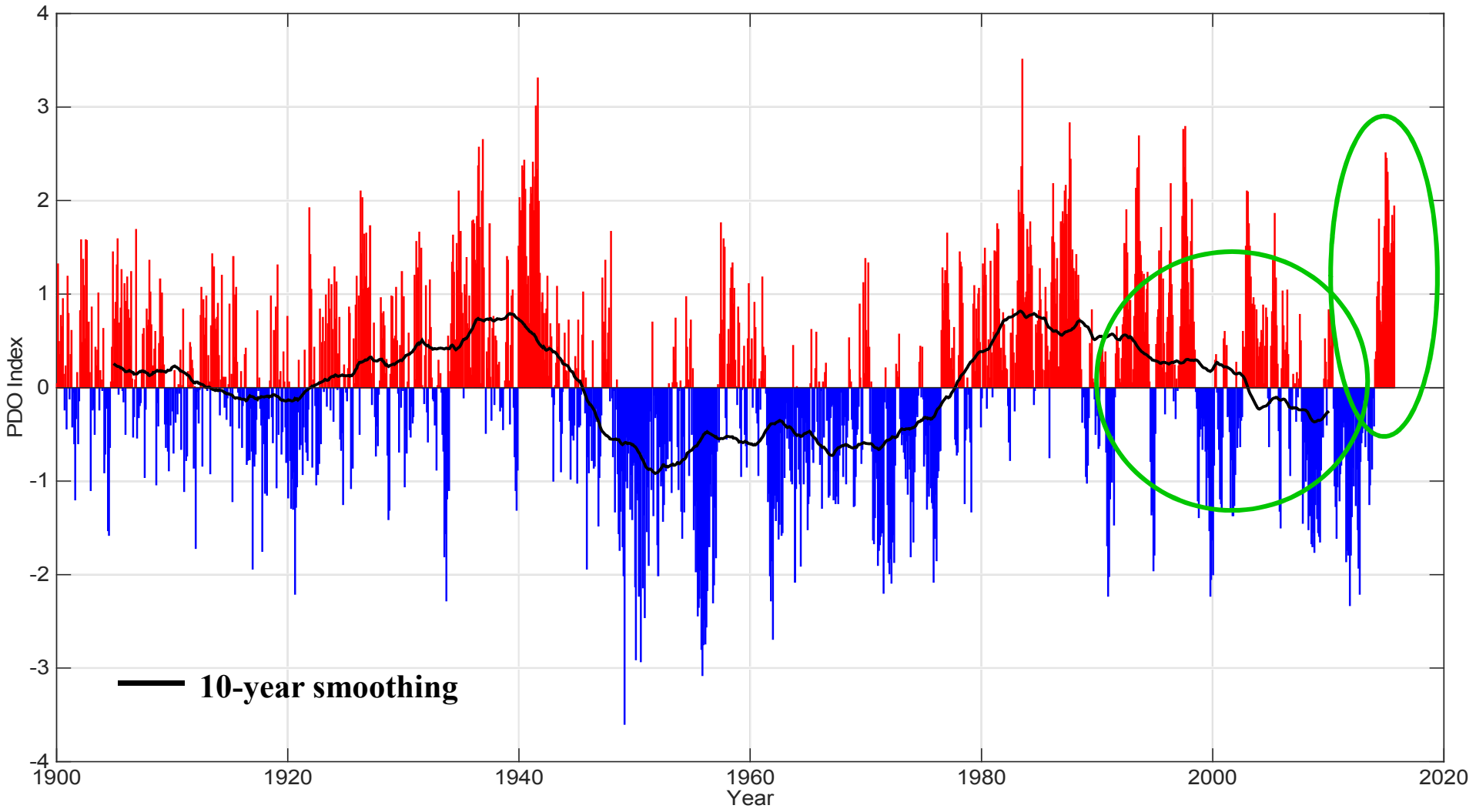
Merrifield [2011]

Western Pacific Sea Level



Changes in western tropical Pacific sea level are well explained by global sea-level rise plus a combination of slowly varying trade wind fluctuations captured by dominant climate indices for the tropical Pacific (SOI, PDO). **[Merrifield et al., 2012]**

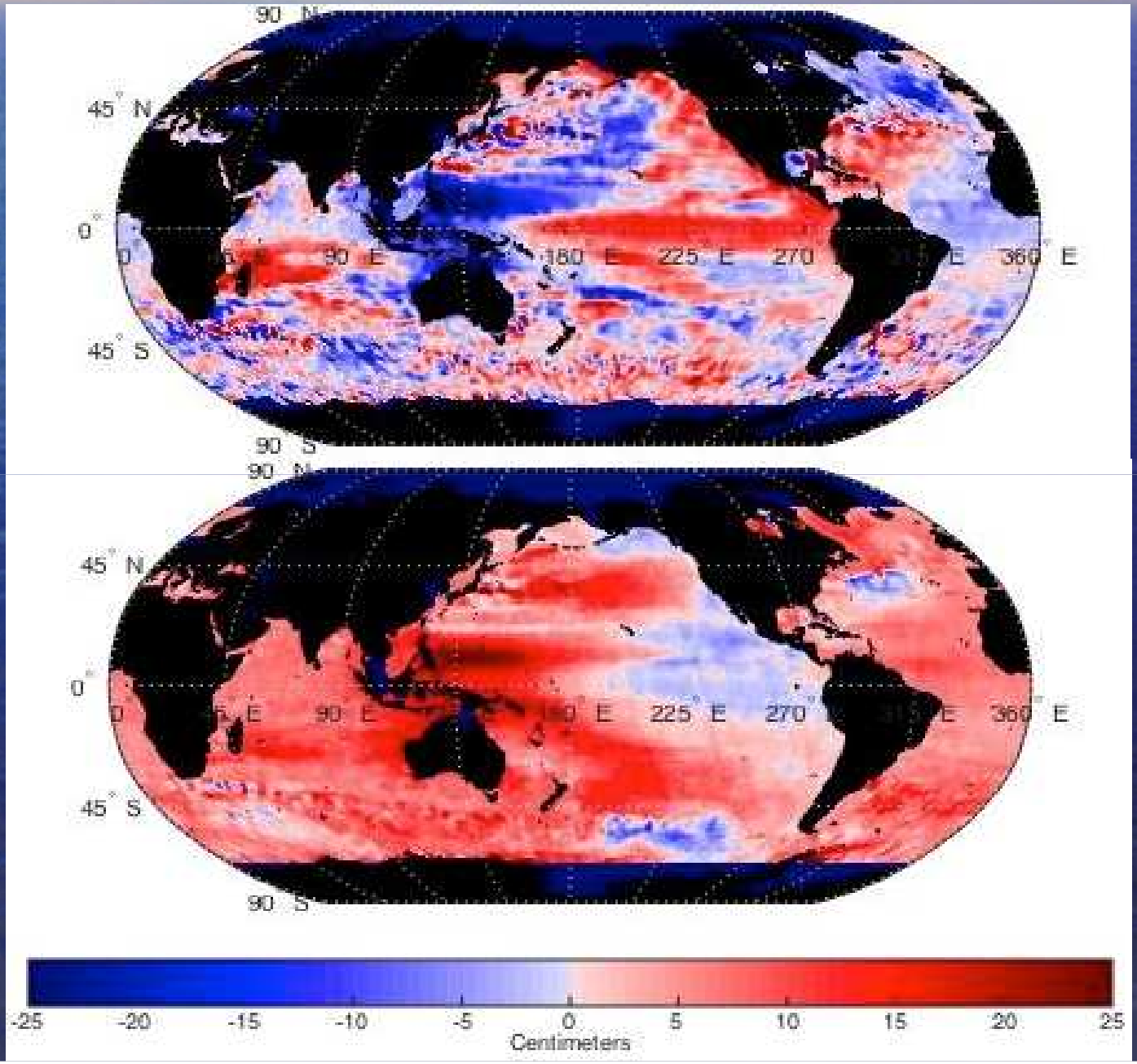
PDO Index


PDO Index
Year
10-year smoothing
4
3
2
1
0
-1
-2
-3
-4
1900
1920
1940
1960
1980
2000
2020

Discussion

- Changes in western tropical Pacific sea level are well explained by global sea-level rise plus a combination of slowly varying trade wind fluctuations captured by dominant climate indices for the tropical Pacific (SOI, PDO).
- During most of the altimeter record, the PDO has been shifting from its positive to its negative phase, which has caused the observed pattern of trends in Pacific sea level.
- But, the PDO index has turned positive since the beginning of 2014. Is this just because of ENSO, or is the PDO really switching phase?
- Big ENSOs tend to occur when the PDO is in its positive phase (e.g. 82-83, 97-98)
- What's going to happen next? Big La Nina? Switch of the PDO? What does the altimeter data tell us?

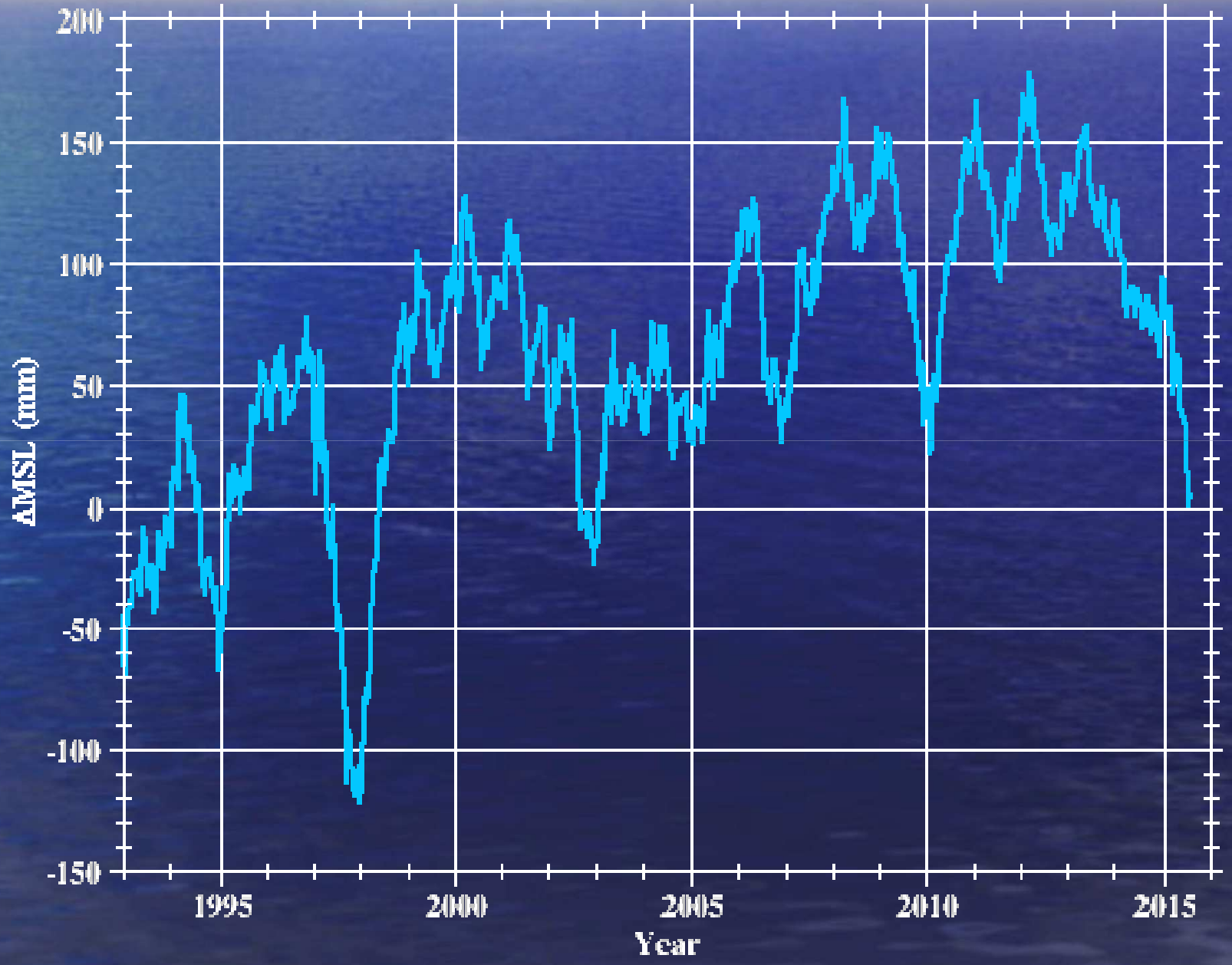
Average Sea Level Change (trend x Δt)



2013.0 – 2015.0

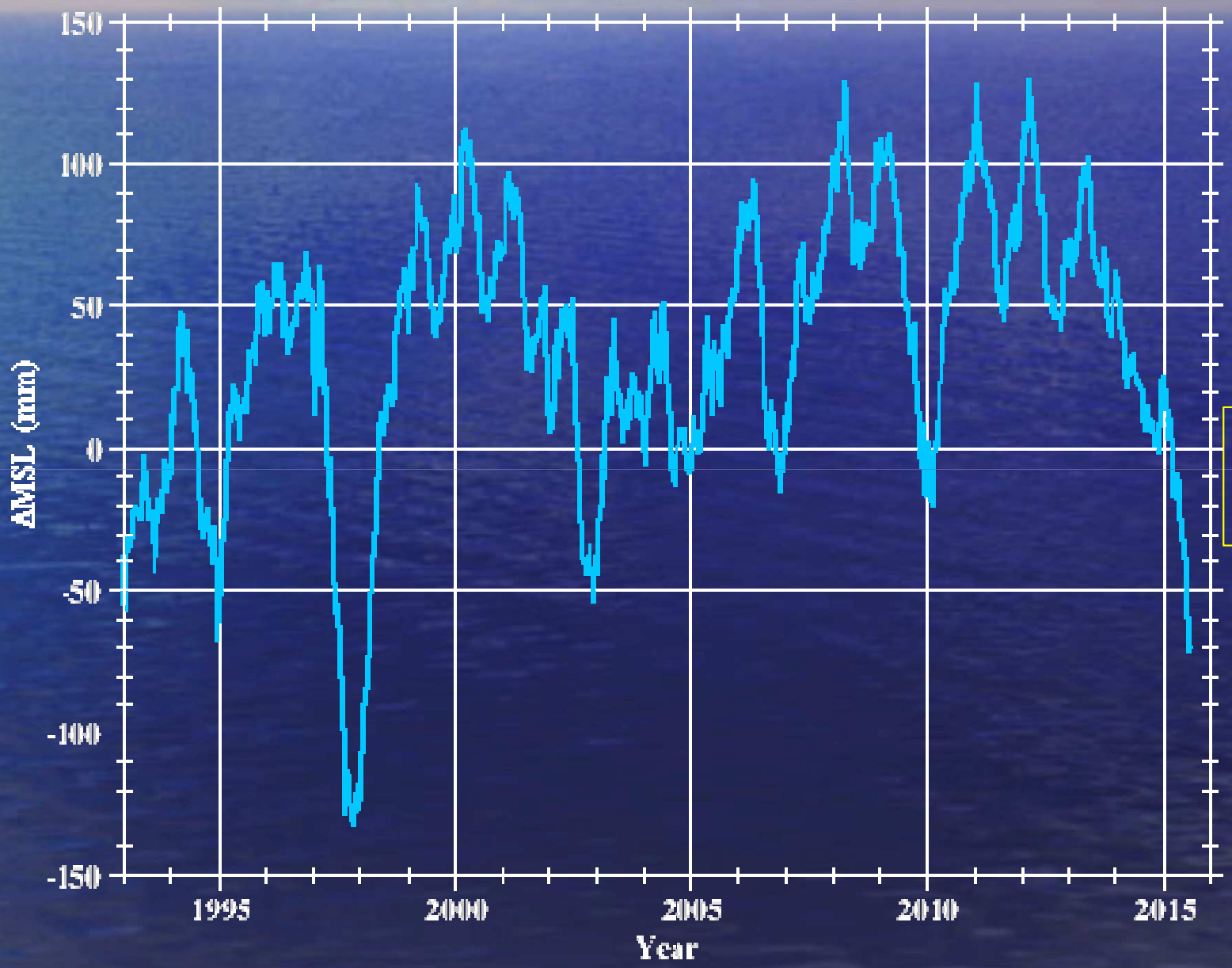
1993.0 – 2013.0

Western Pacific Mean Sea Level

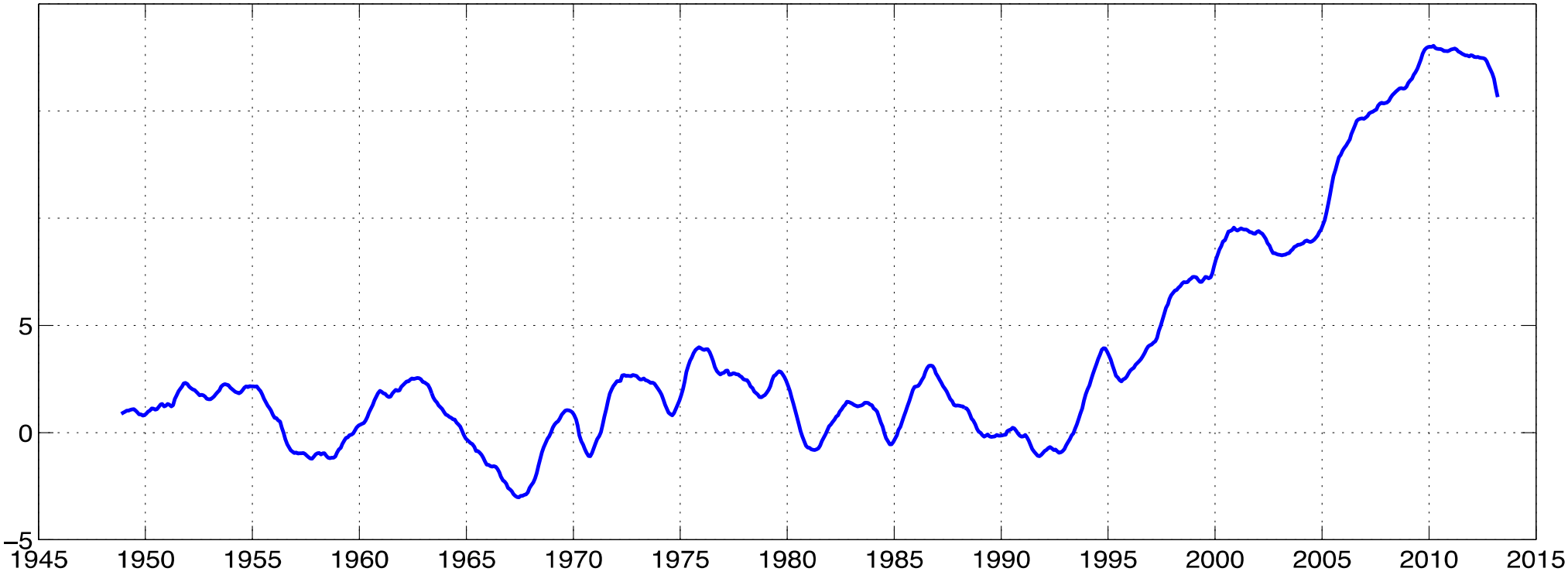


Lat: ±18°
Long: 115° E-
180° E

Western Pacific Mean Sea Level minus GMSL

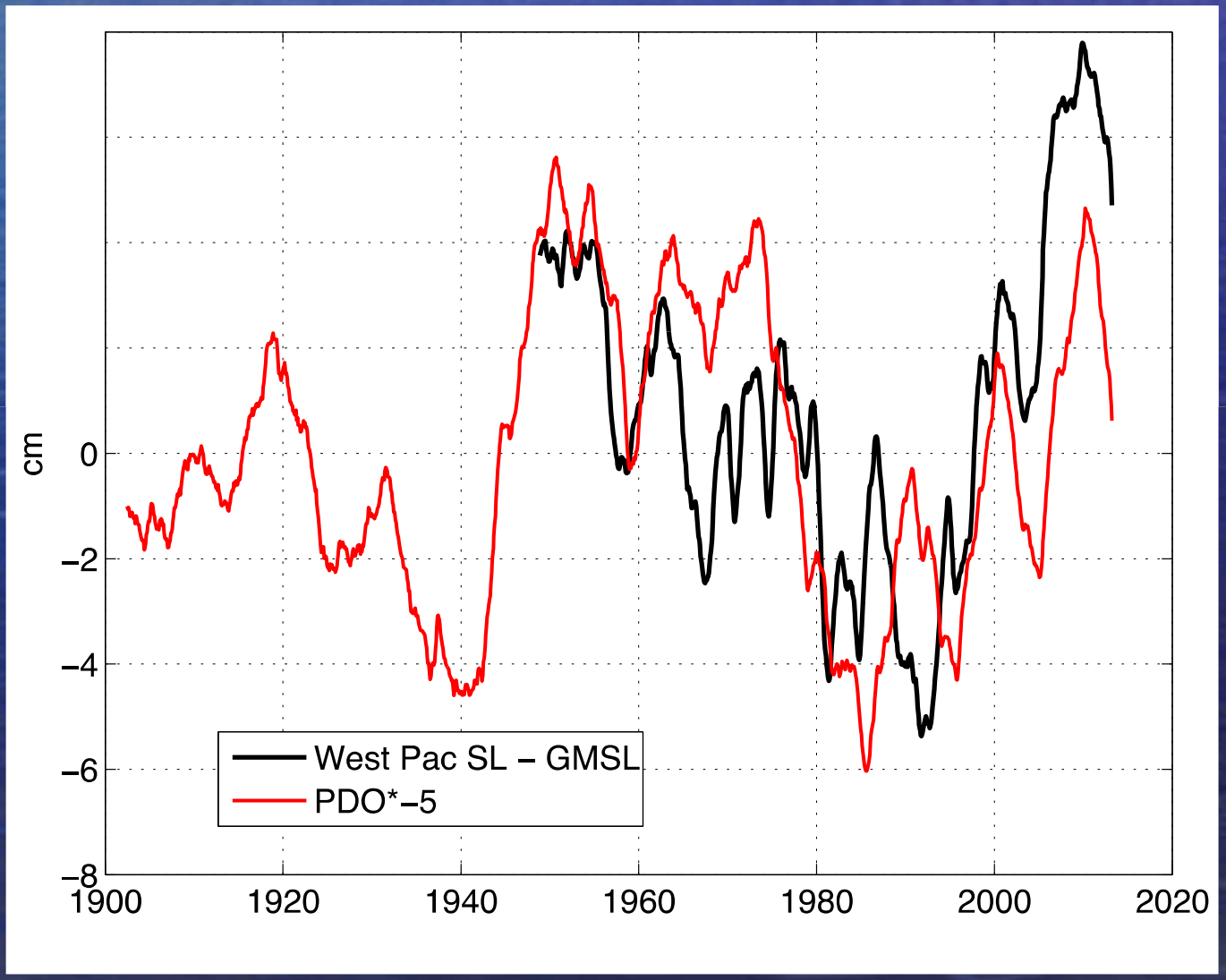


Western Tropical Pacific Sea Level (Guam + Kwajalein)



5 year smoothing

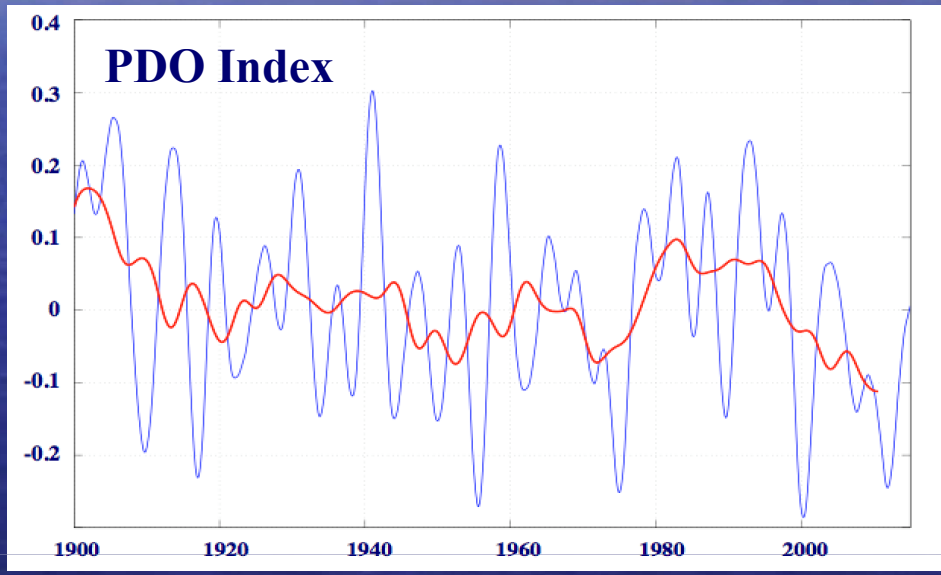
Western Tropical Pacific Sea Level minus GMSL (Guam + Kwajalein)

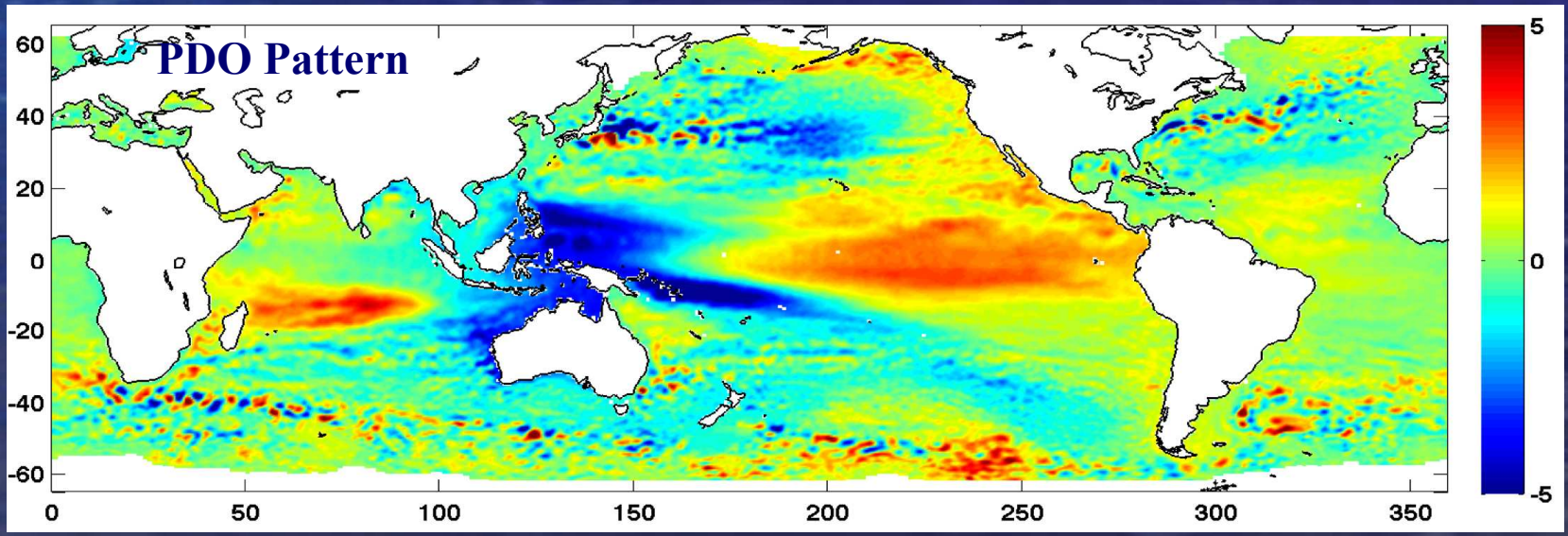


5 year smoothing

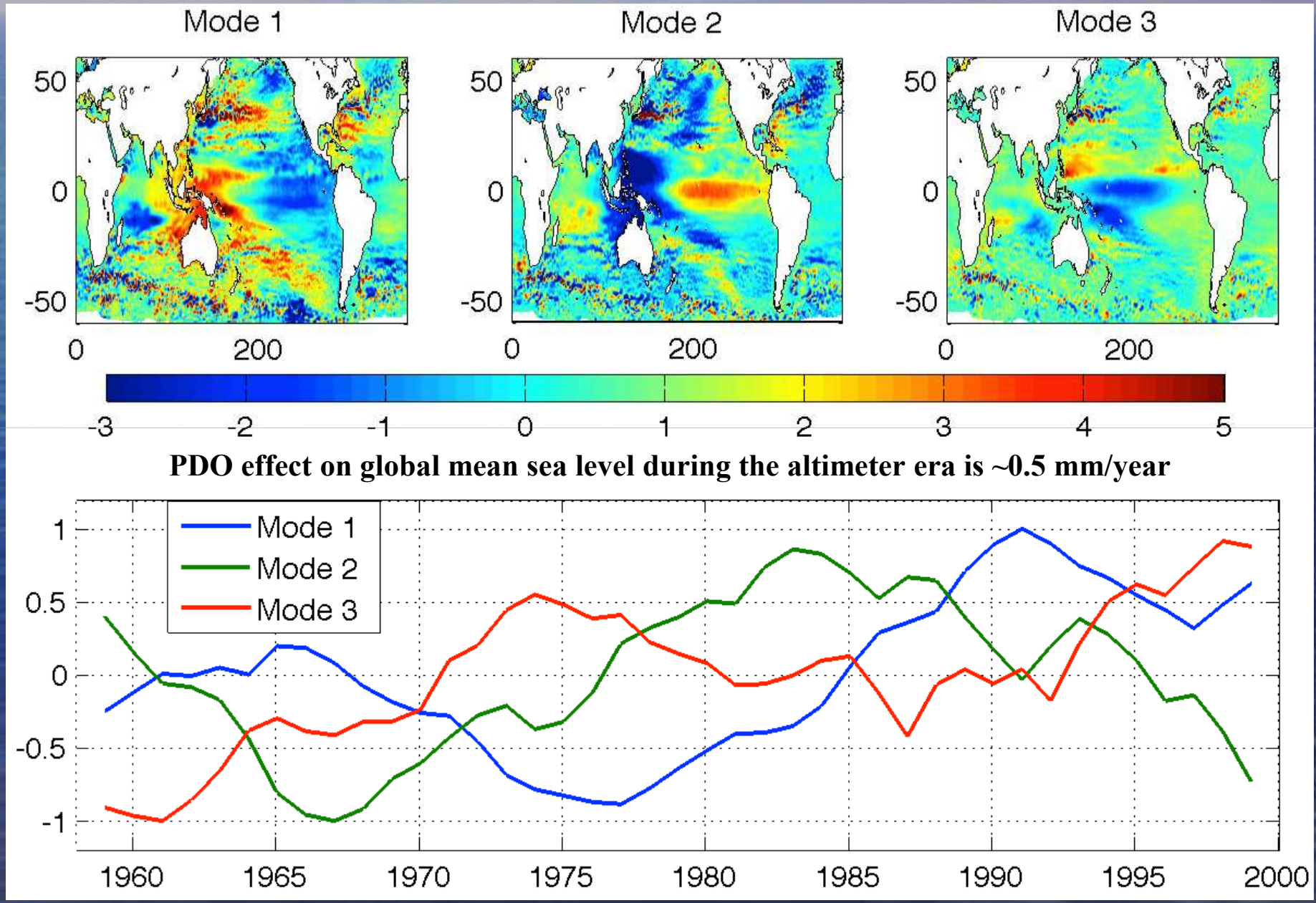
Pacific Decadal Oscillation

Hamlington et al. identified the PDO pattern in the altimetry and then used tide gauges to reconstruct the PDO mode back in time.



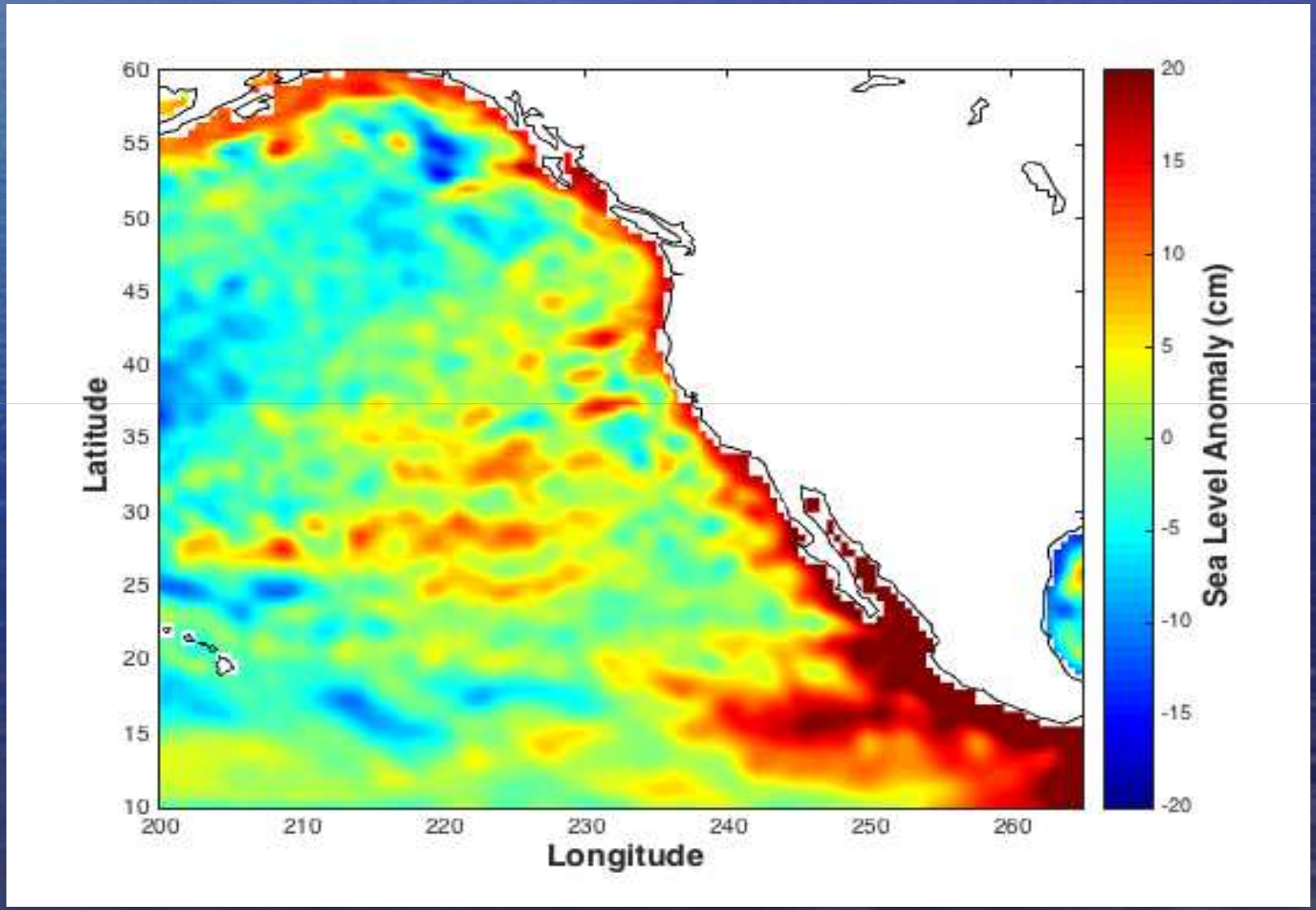


EOFs of Reconstructed Sea Level Trends



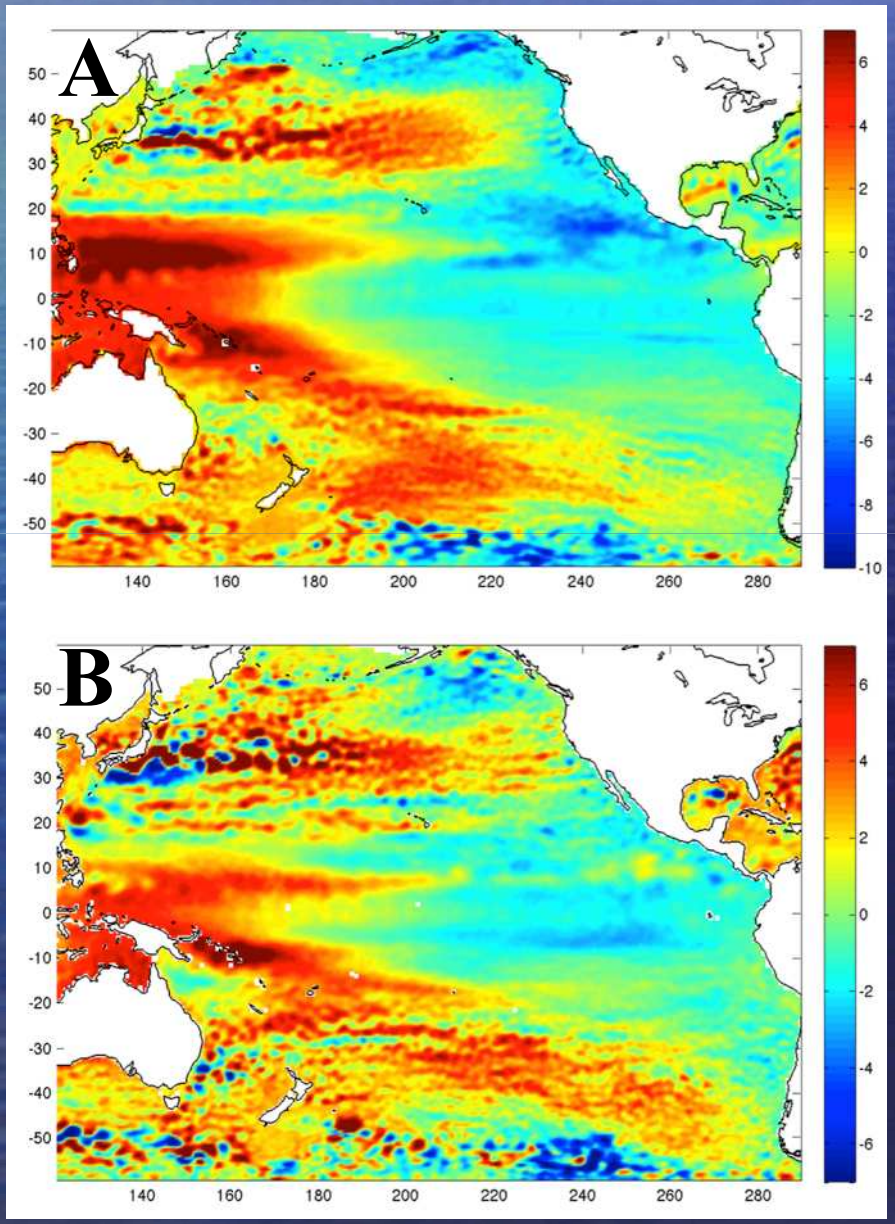
[Hamlington et al., 2013]

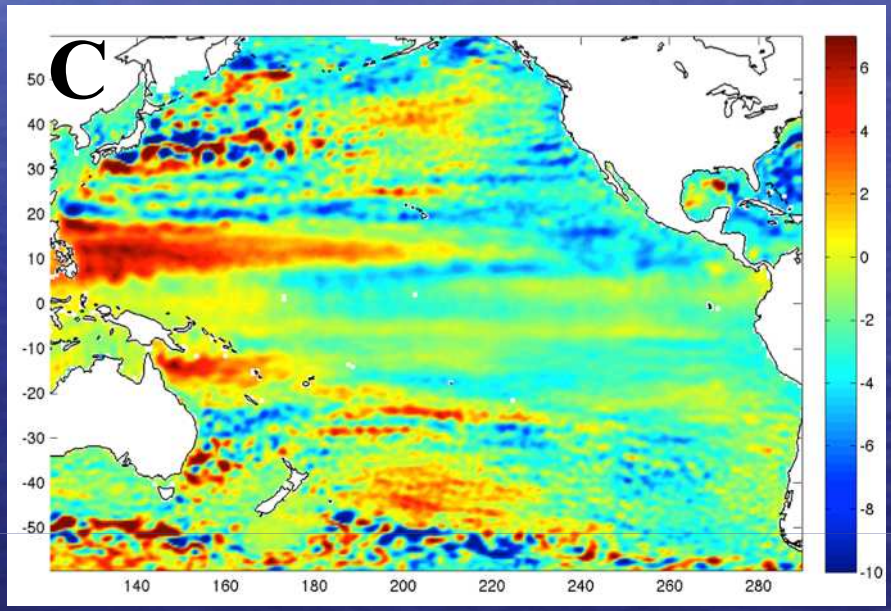
PDO + ENSO Sea Level Anomalies for 2016?



[Hamlington et al., 2015]

Contribution of PDO to Regional Sea Level

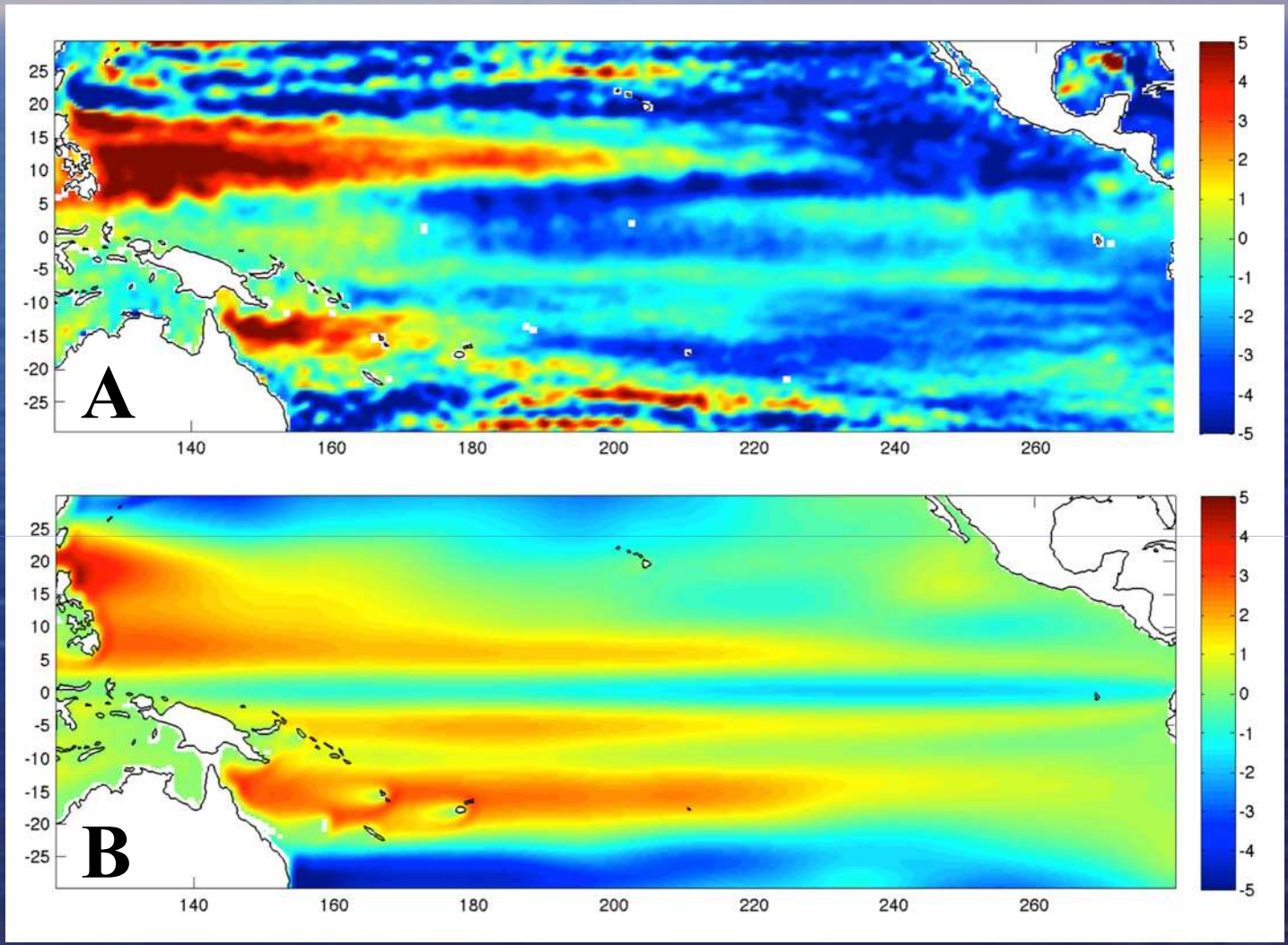




Sea level trends (mm/year) from 1993 to 2010 for:
(A)AVISO altimeter data.
(B) PDO contribution estimated by EOF analysis of sea level reconstruction.
(C) AVISO minus the PDO contribution.

[Hamlington et al., 2014]

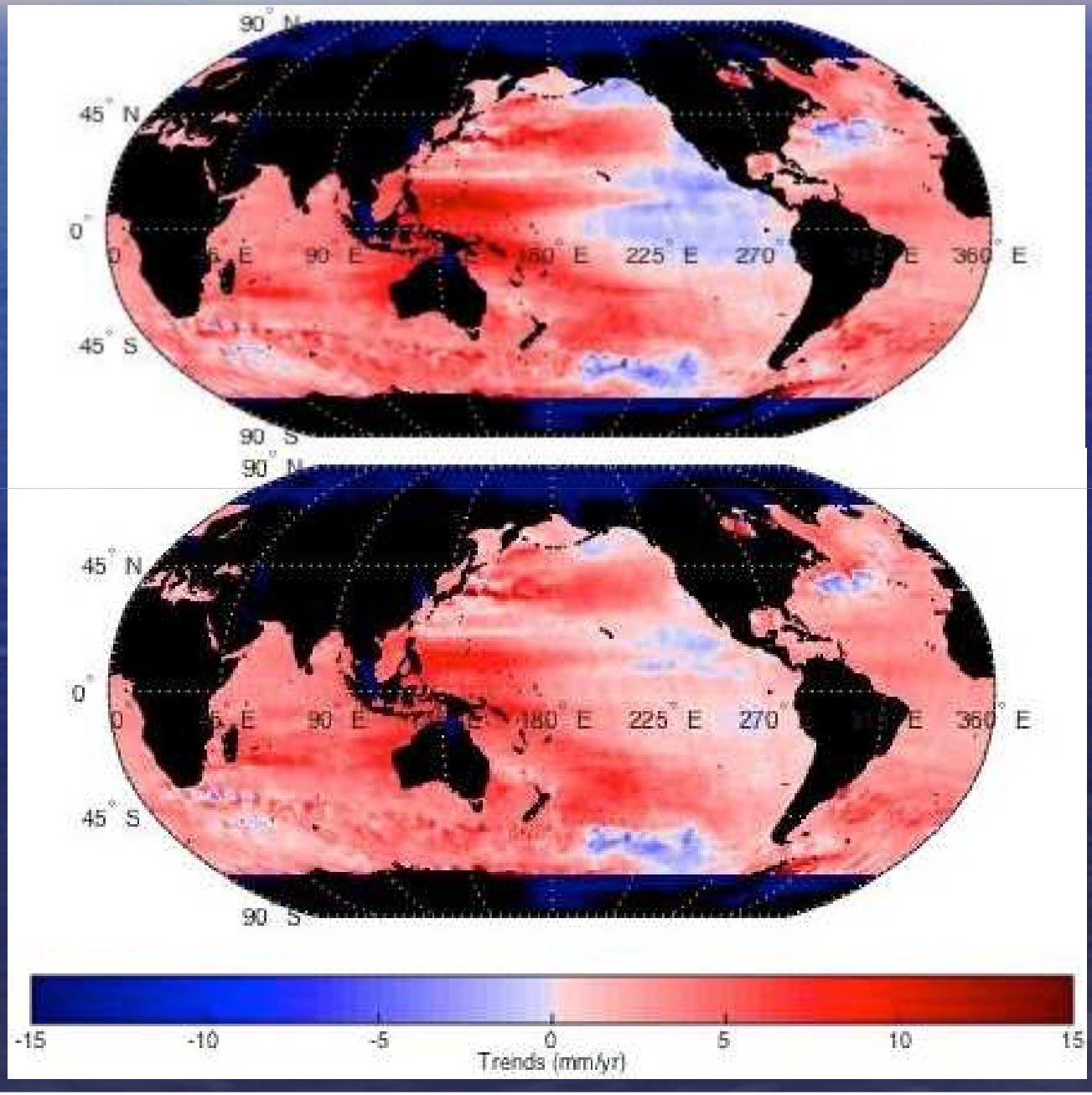
Contribution of PDO to Regional Sea Level



Sea level trends (mm/year) in Western Tropical Pacific from (A) AVISO data minus PDO contribution and (B) model result obtained from 0.5° C Tropical Indian Ocean warming.

[Hamlington et al., 2014]

Sea Level Trends from Altimetry



1993.0 - 2013.0

1993.0 – 2015.5

Summary

- The pattern of decadal sea level change in the tropical Pacific that has been dominate for 20+ years appears to be changing.
- Whether this represents the ongoing ENSO or also a switch in the PDO phase won't be known for a few years.
- If the latter, we can expect the rates of sea level rise along the coast of California to increase dramatically over the next decade as it recovers from an ~7 cm sea level deficit.
- If the PDO switches phase and we begin to average out decadal variability in Pacific sea level, there will likely be a residual pattern of sea level change due to climate change.

Backup

Western Pacific Sea Level

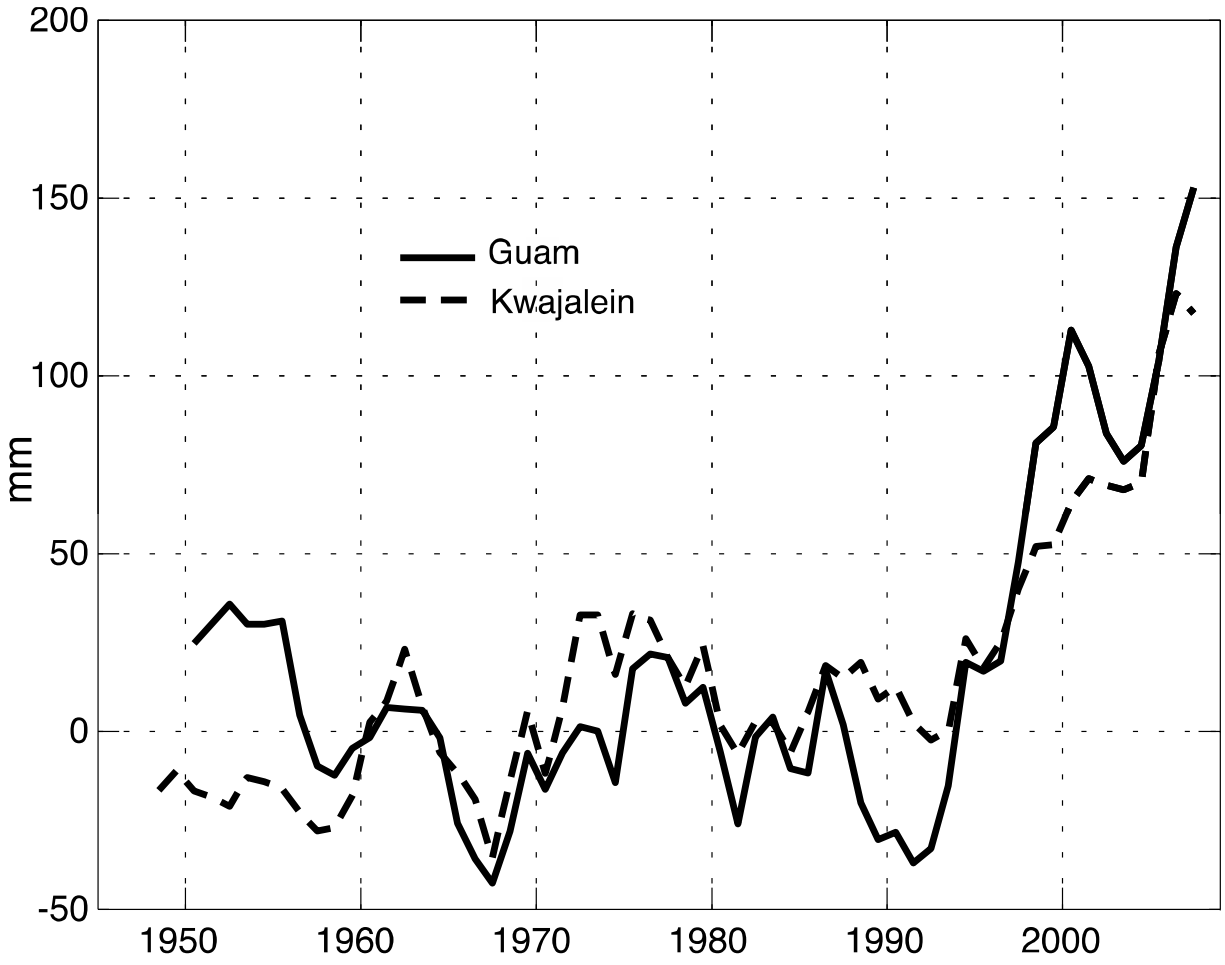
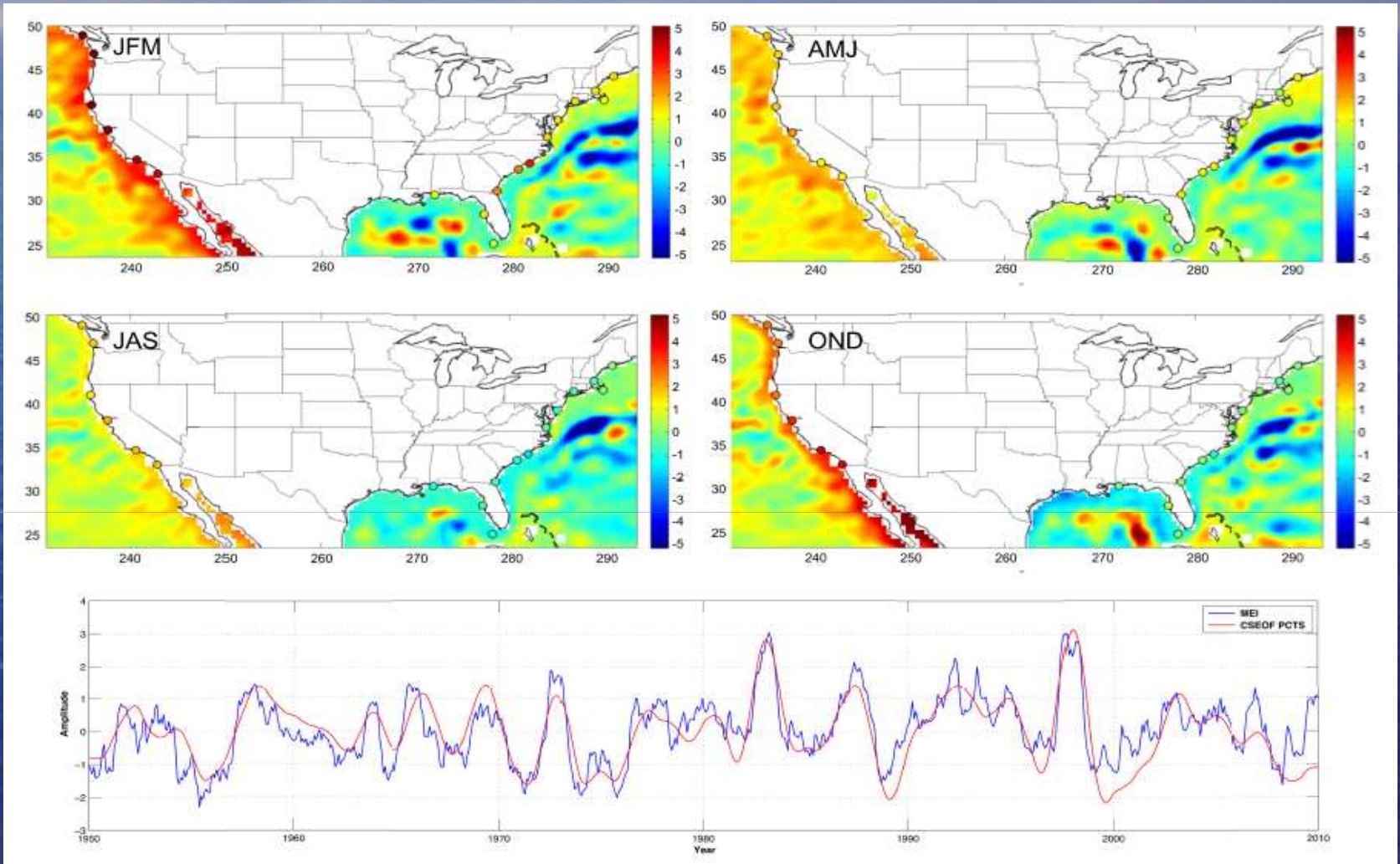


FIG. 4. The 5-yr mean sea level from the Guam and Kwajalein tide gauges. The data are presented relative to the mean of each record computed through 1992.

Merrifield [2011]

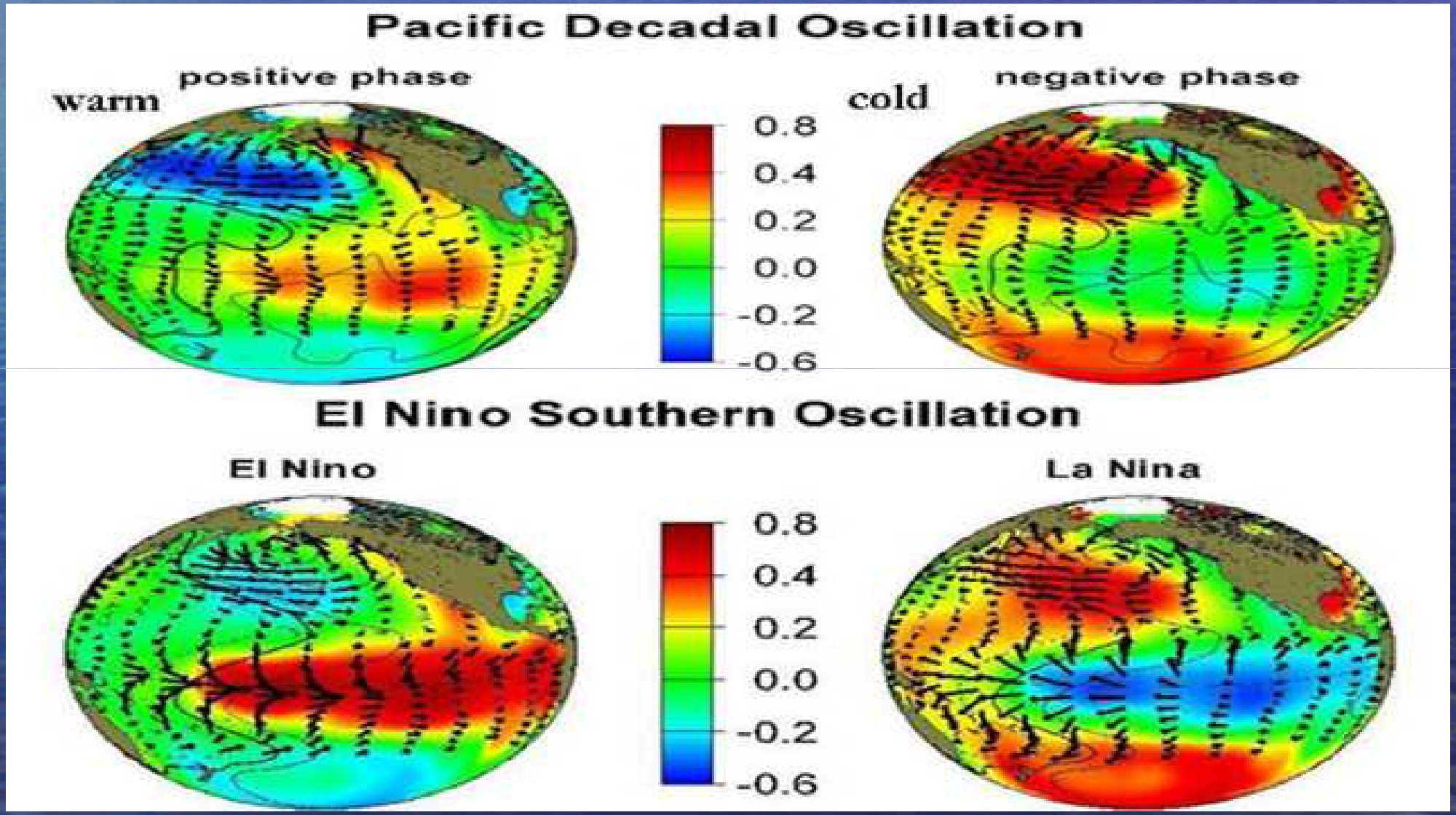
ENSO/PDO Effects on Coastal Sea Level



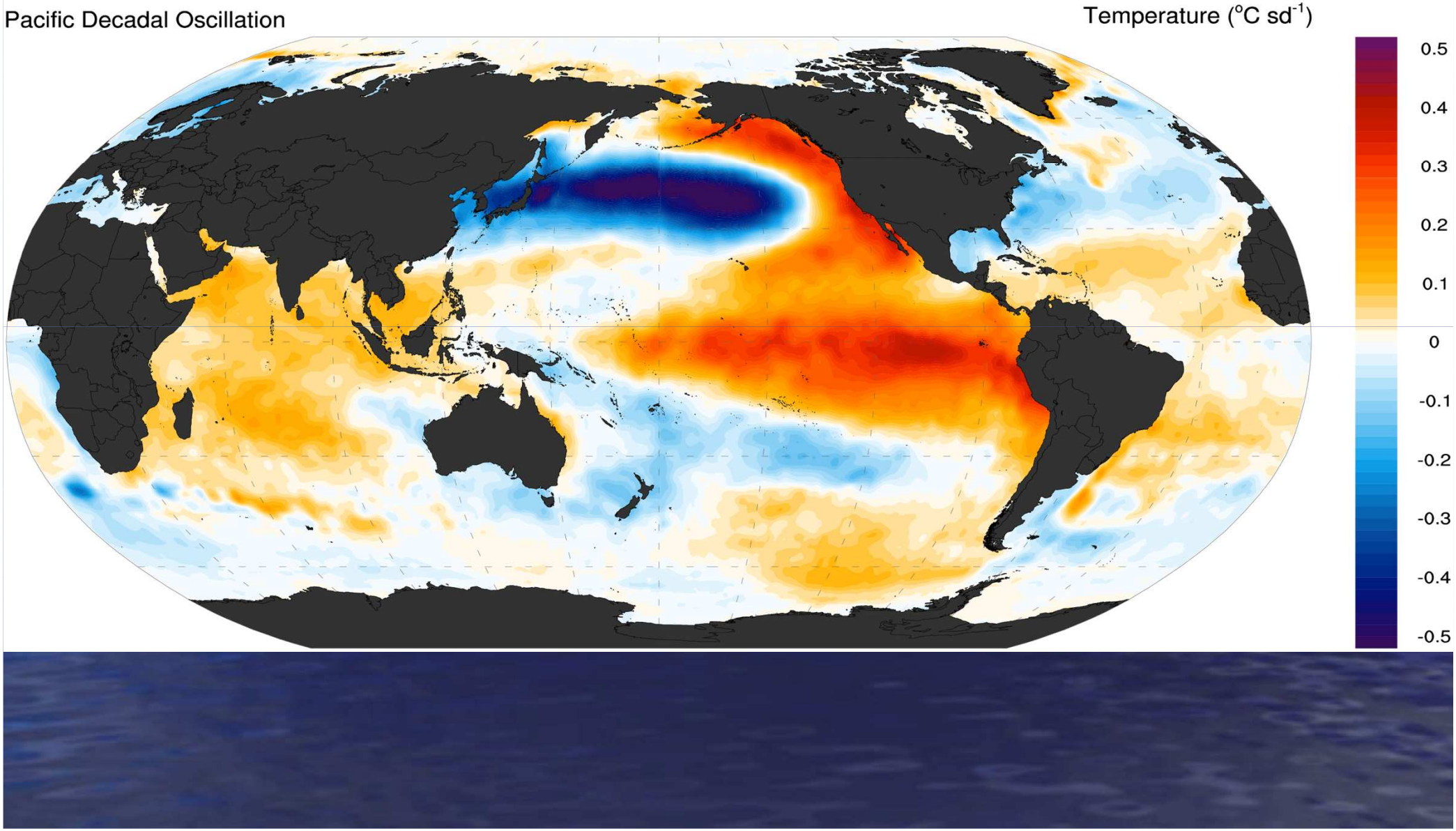
ENSO CSEOF mode (units of centimeters by combining time series and spatial patterns) obtained using a one-year decomposition of the sea level reconstruction (background) and U.S. coastal tide gauge data (overlaying filled circles). Seasonally averaged spatial patterns are provided in the top panel with corresponding time series in bottom panel (red). MEI is shown for comparison (blue).

[Hamlington et al., 2015]

PDO and ENSO Patterns



PDO Pattern


Pacific Decadal Oscillation
Temperature (°C sd-1)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5