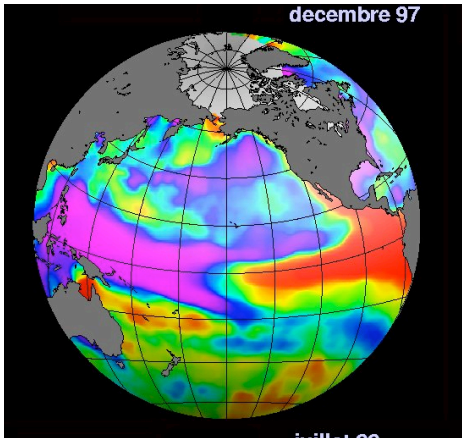
Interannual global mean sea level: Link with ENSO and the global water cycle

Anny Cazenave, Benoit Meyssignac, Olivier Henry,
Simon Munier, Hindu Palanisamy and William Llovel*
LEGOS-CNES, Toulouse, France
(*now at JPL, USA)

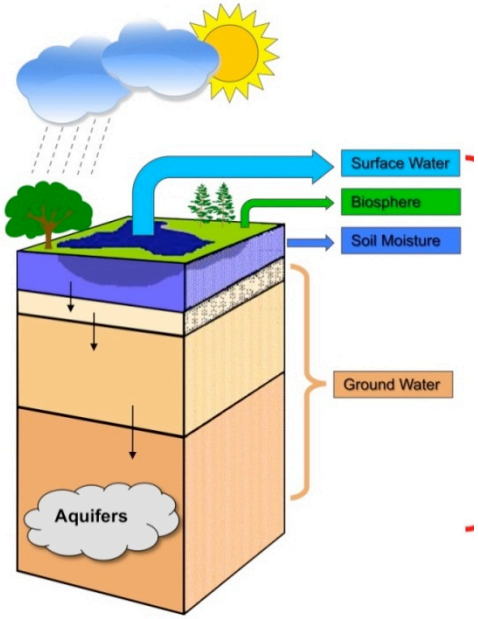
WCRP OSC
Denver Oct. 2011

ENSO

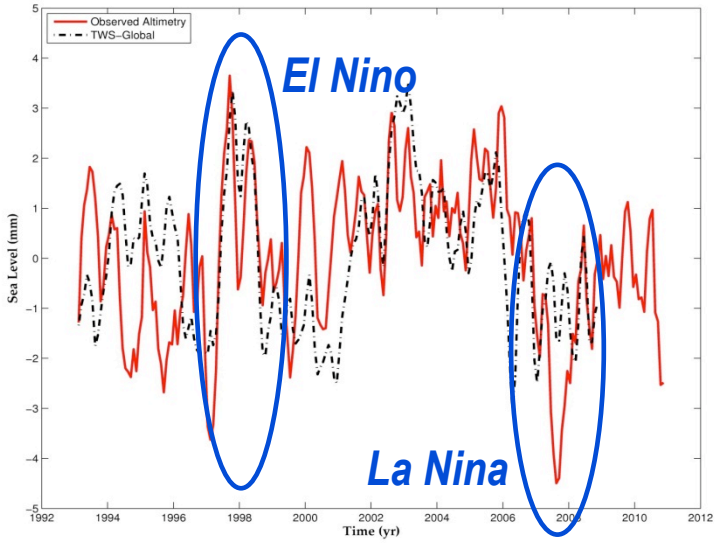


GLOBAL WATER CYCLE

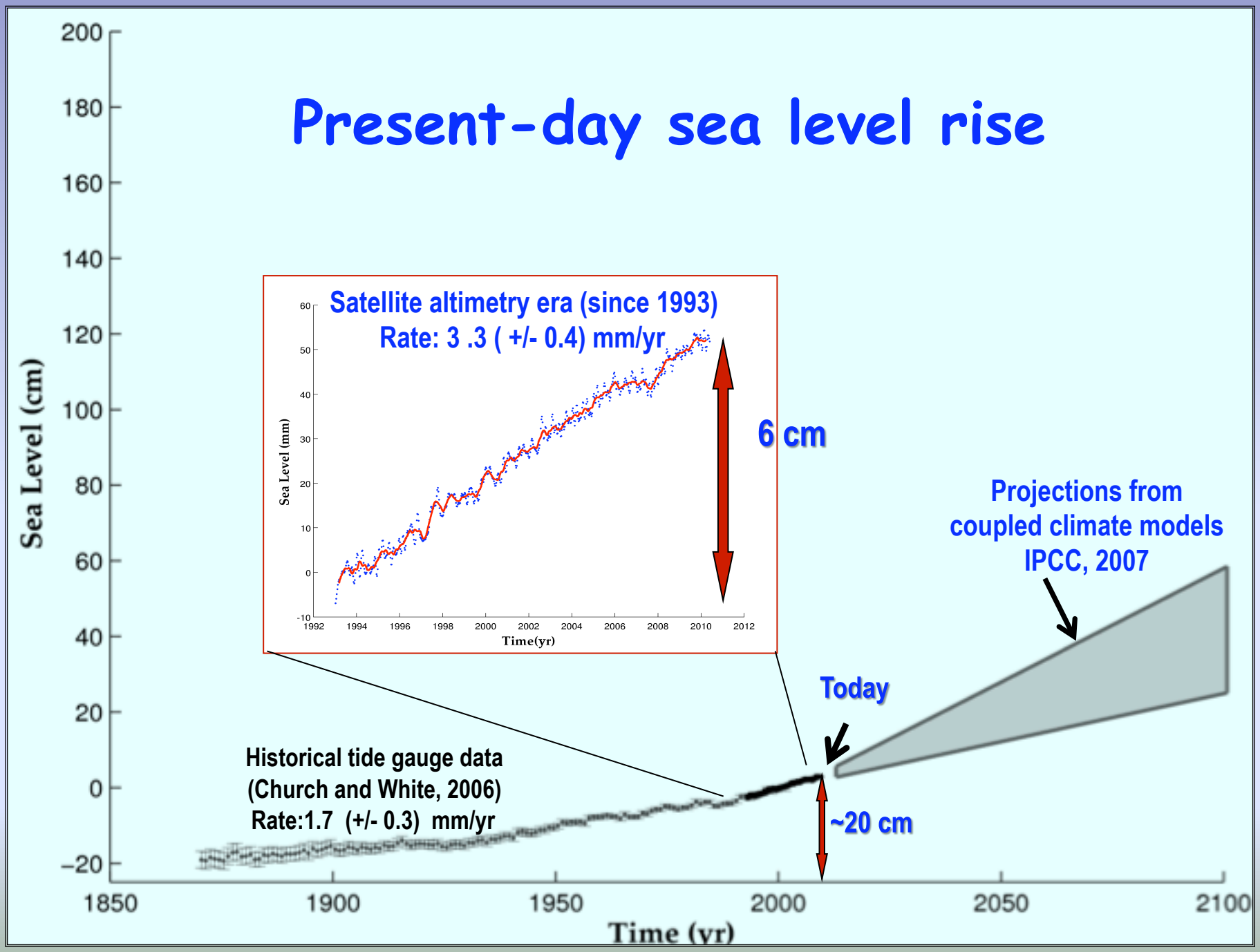
Land water storage



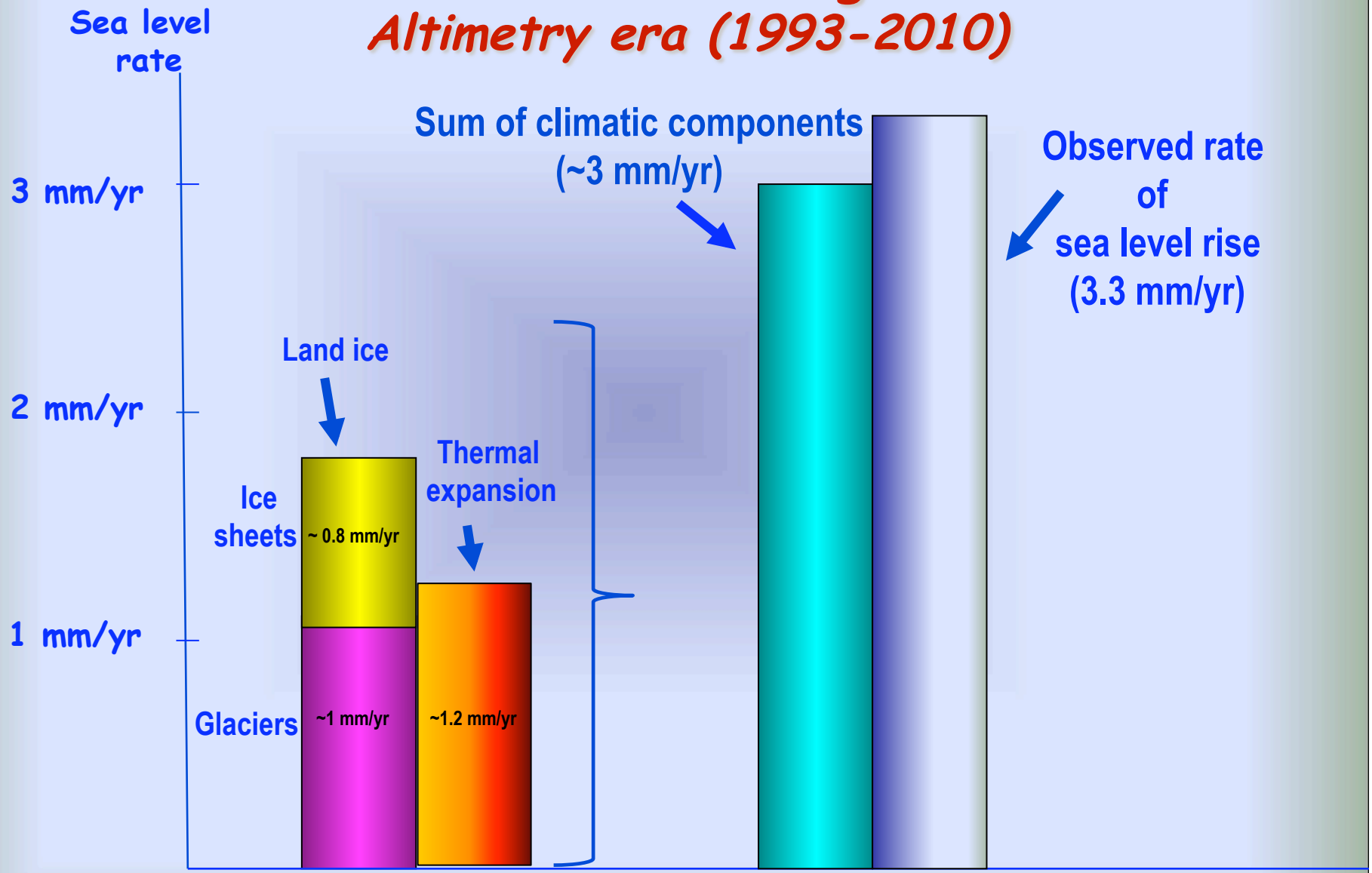
Global mean sea level (red curve)



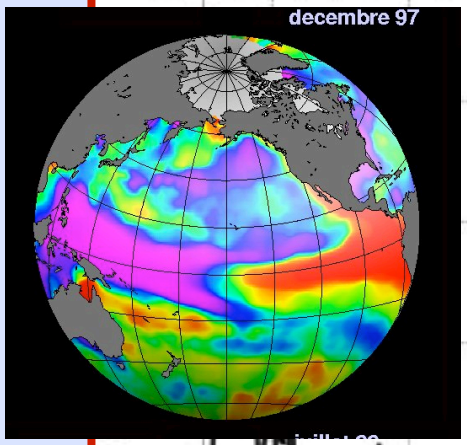
Present-day sea level rise

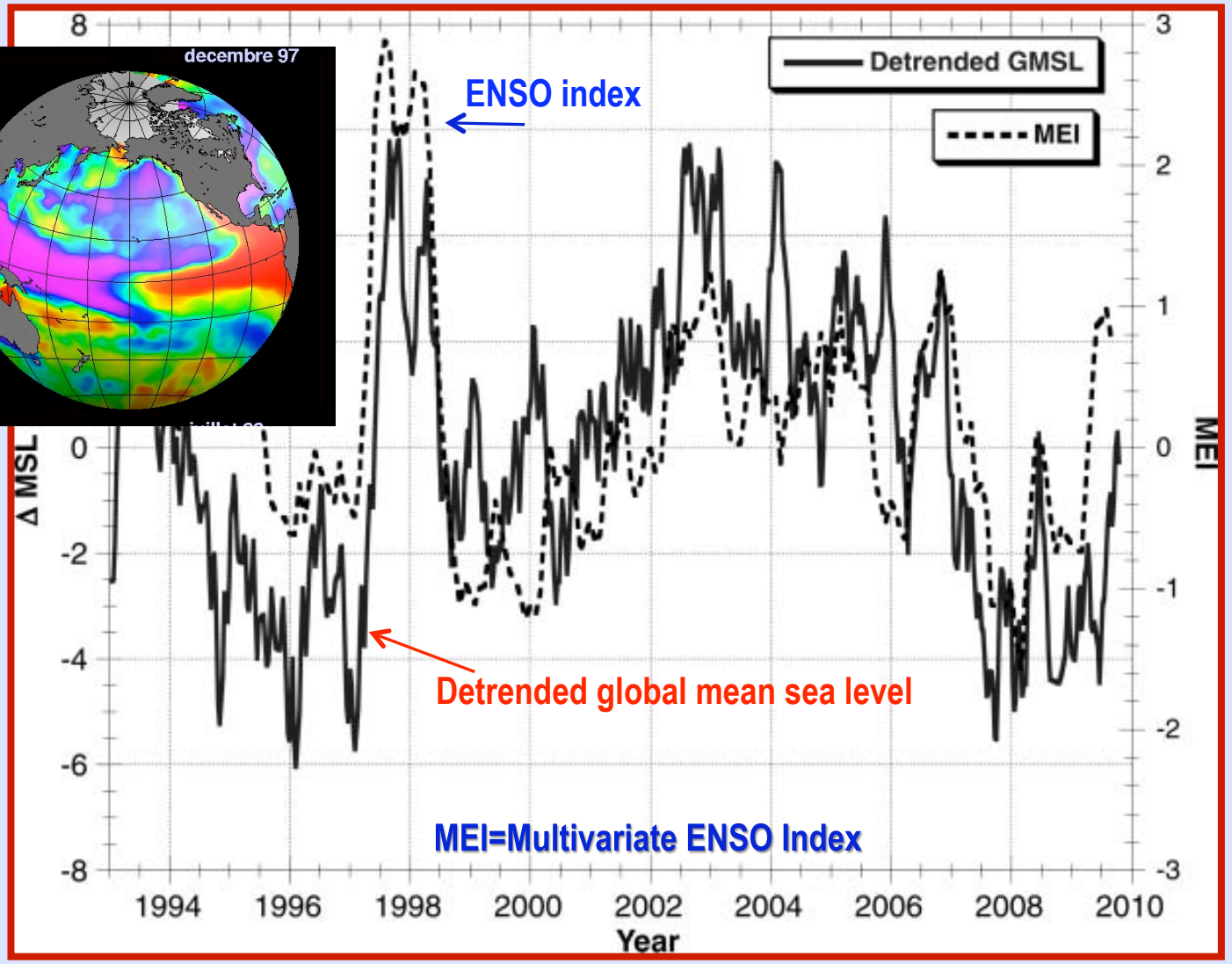


Sea Level Budget:
Altimetry era (1993-2010)



Interannual global mean sea level (1993-2010)



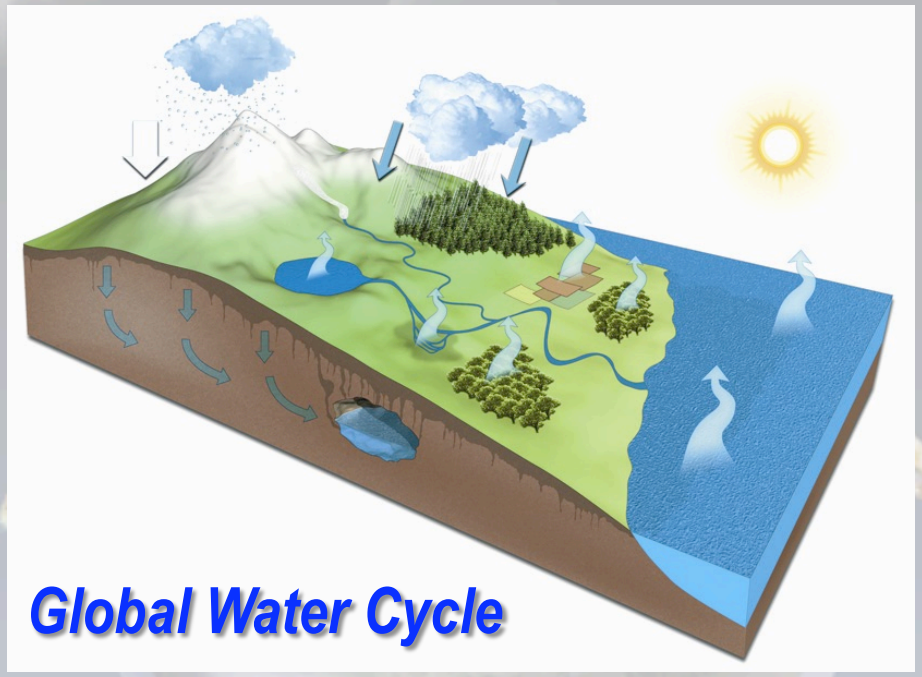


Nerem et al. (2010)

What is the cause of the observed correlation between interannual global mean sea level and ENSO?:

-Ocean heat content?
→thermal expansion anomaly?

-Land water storage?
→ocean mass anomaly?

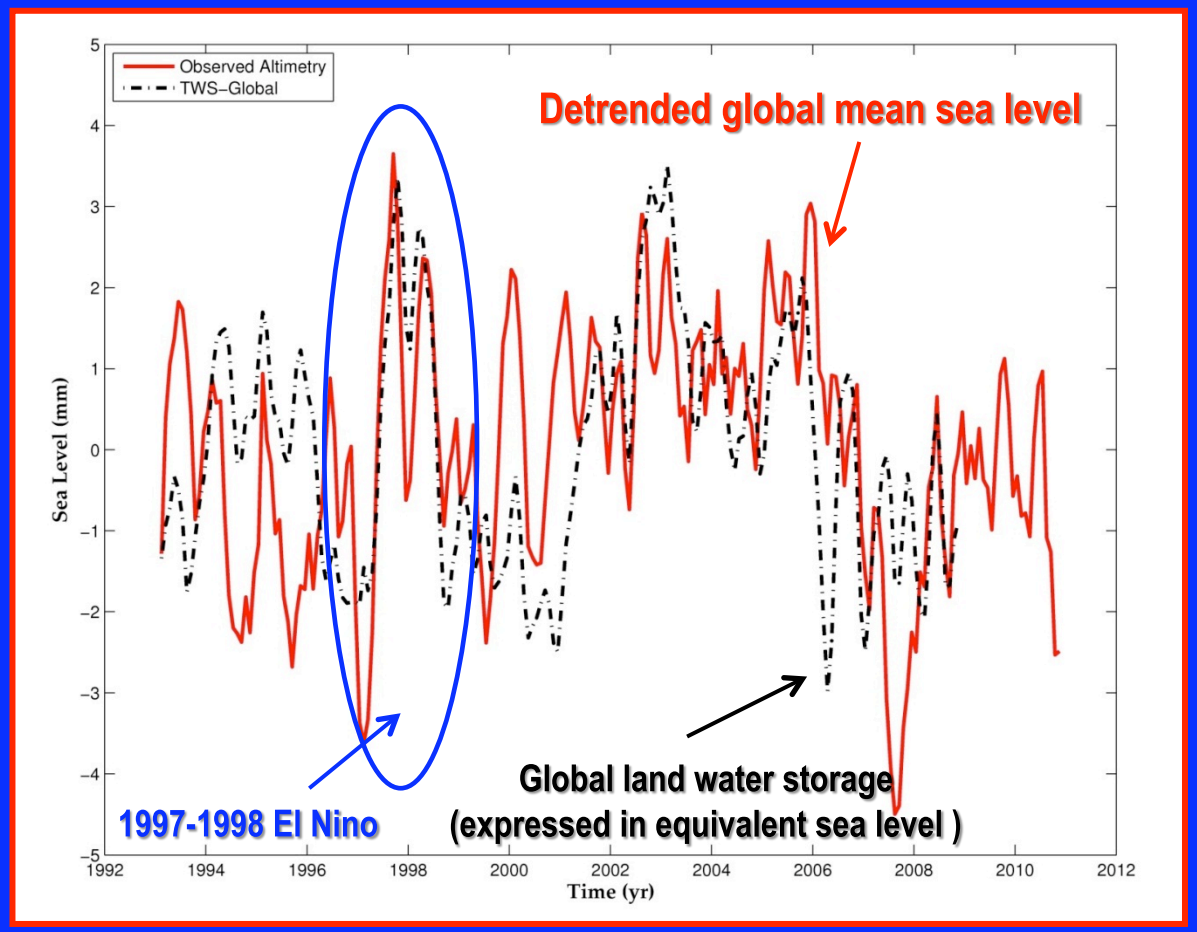


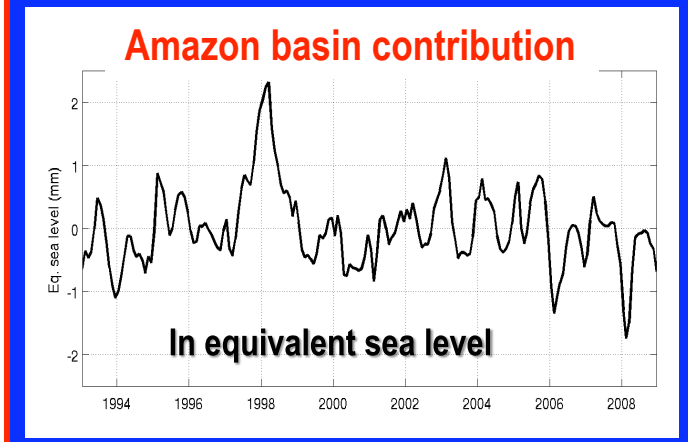
Water mass conservation in the climate system

$$\Delta M_{ocean} + \Delta M_{land} = 0$$

ΔM : change in water mass
Atmospheric reservoir neglected

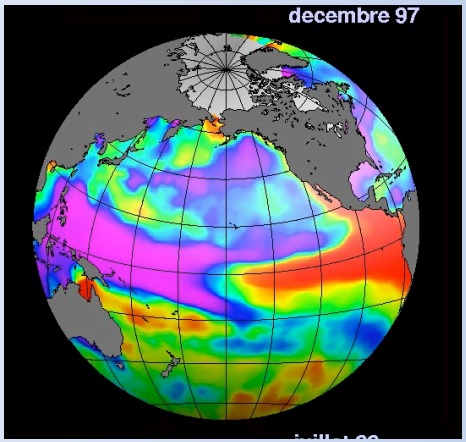
Detrended global mean sea level and total land water storage (based on the MeteoFrance hydrological model)





Update of Llovel et al. (2011)' study

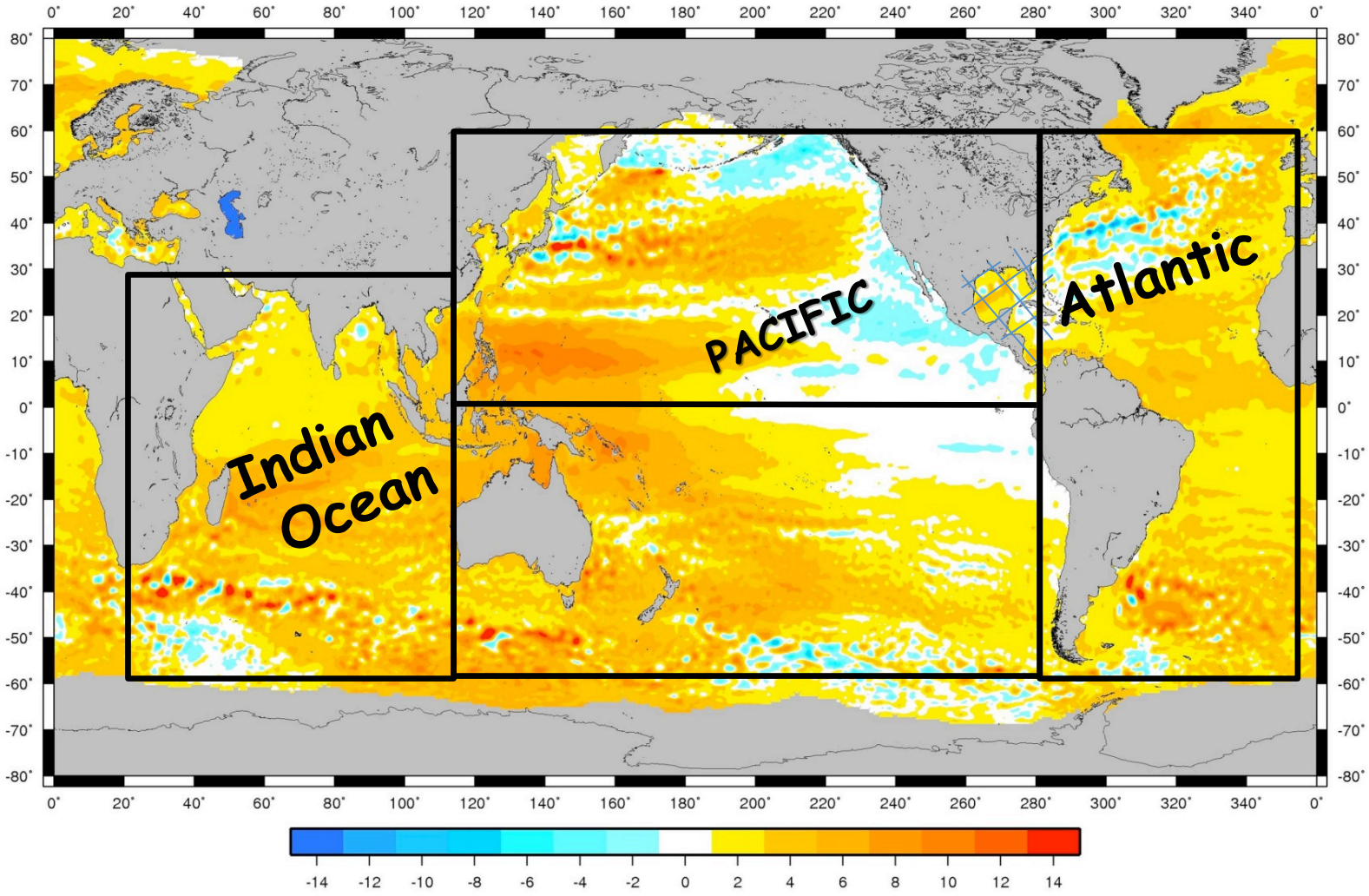
- What process is causing the >0 anomaly seen in the global mean sea level during El Nino?



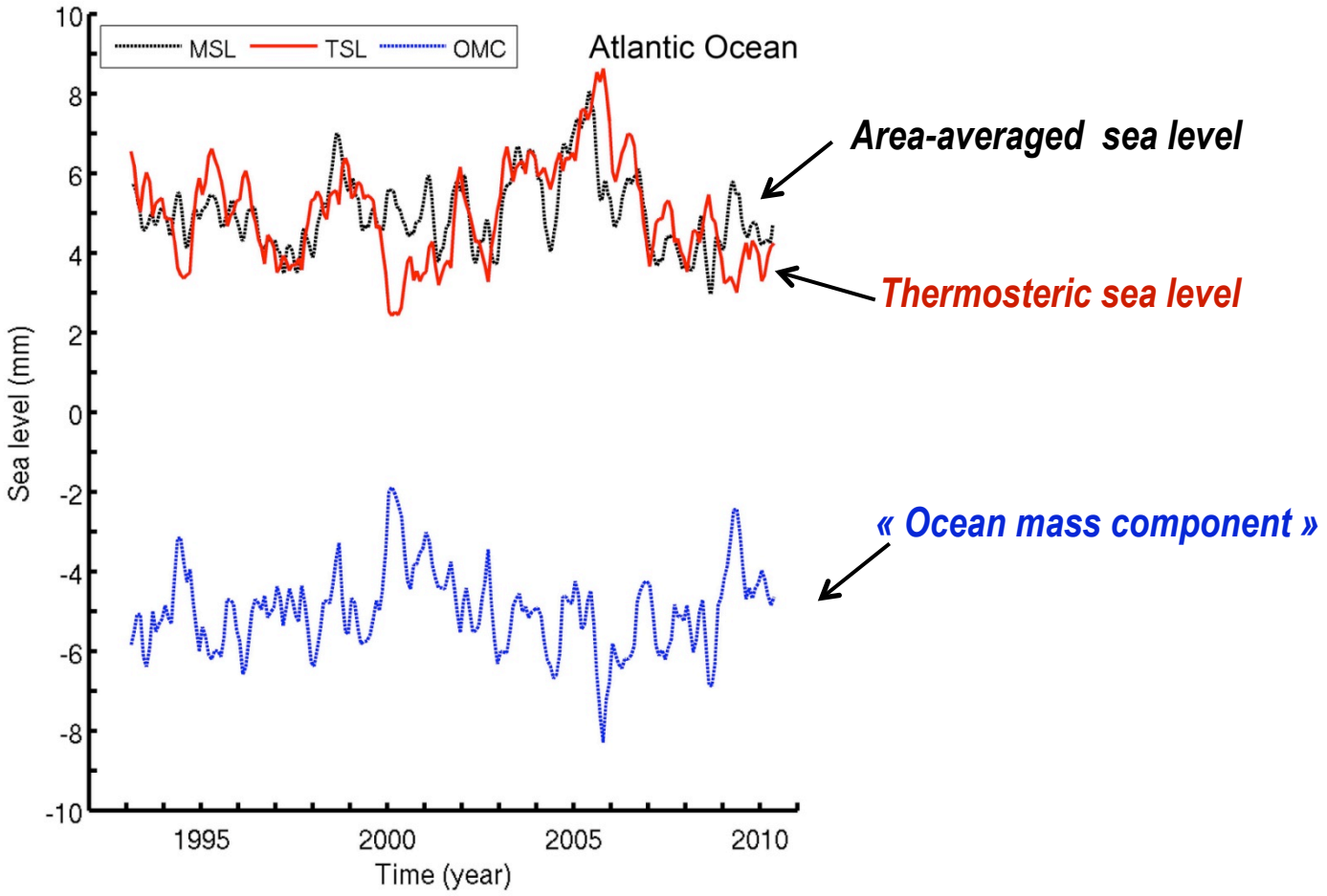
El Nino → More rain over oceans
Less rain over land

- Which ocean basin is responsible?
  → (is the whole ocean concerned or is it a localized effect?)

Area-averaging of altimetry-based sea level data

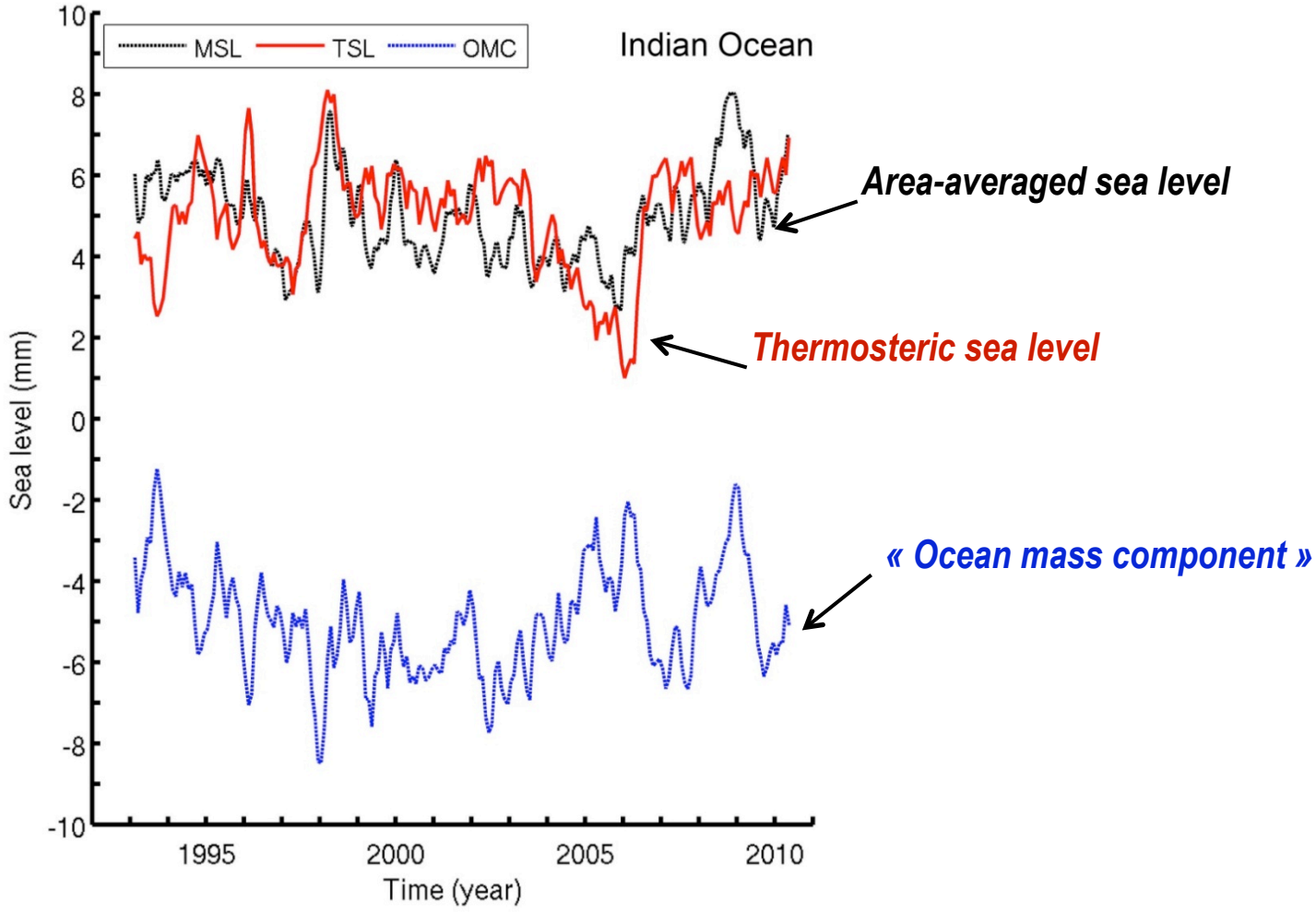


Atlantic Ocean



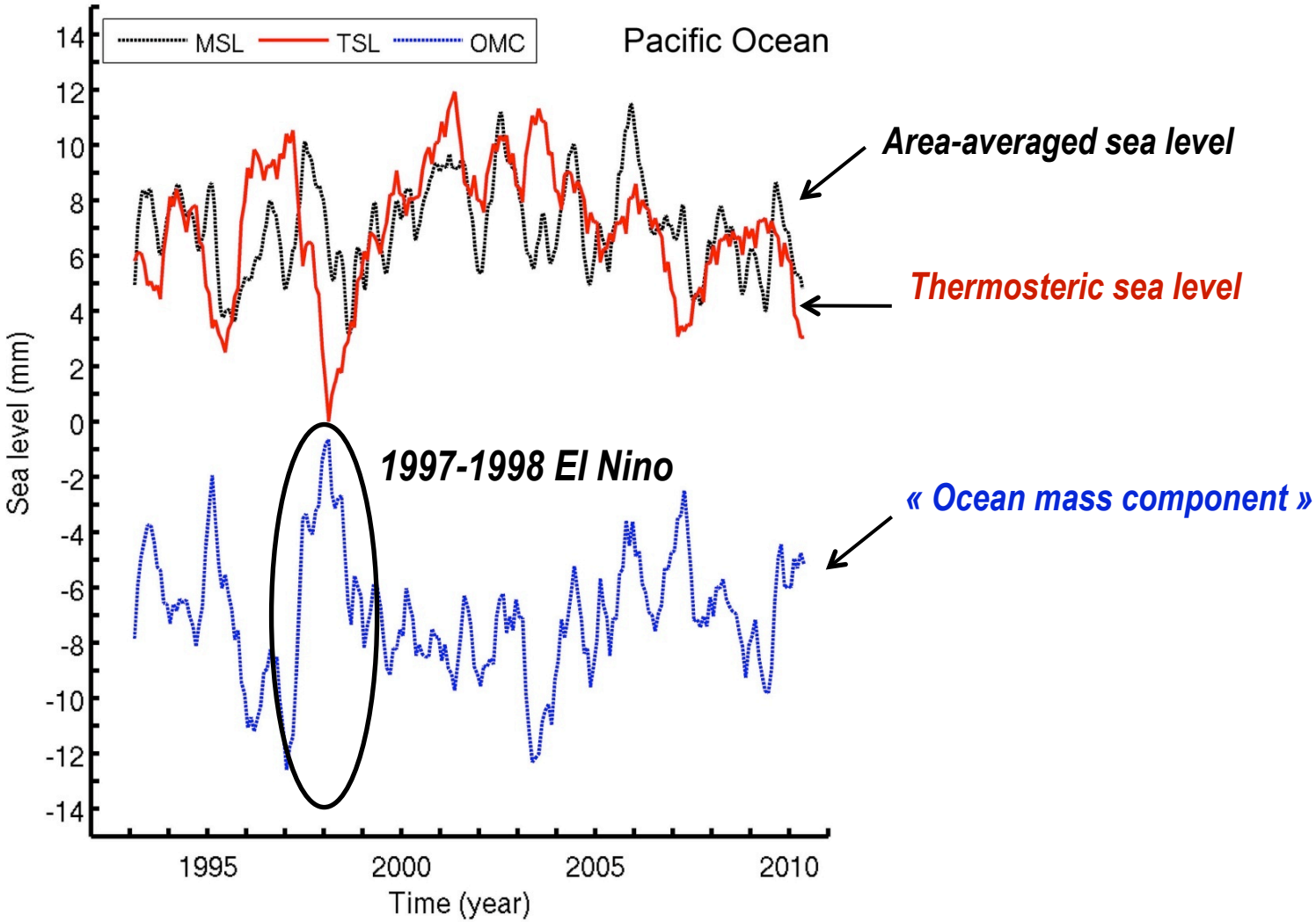
Weighting by the ratio of the averaging area to the total ocean surface

Indian Ocean



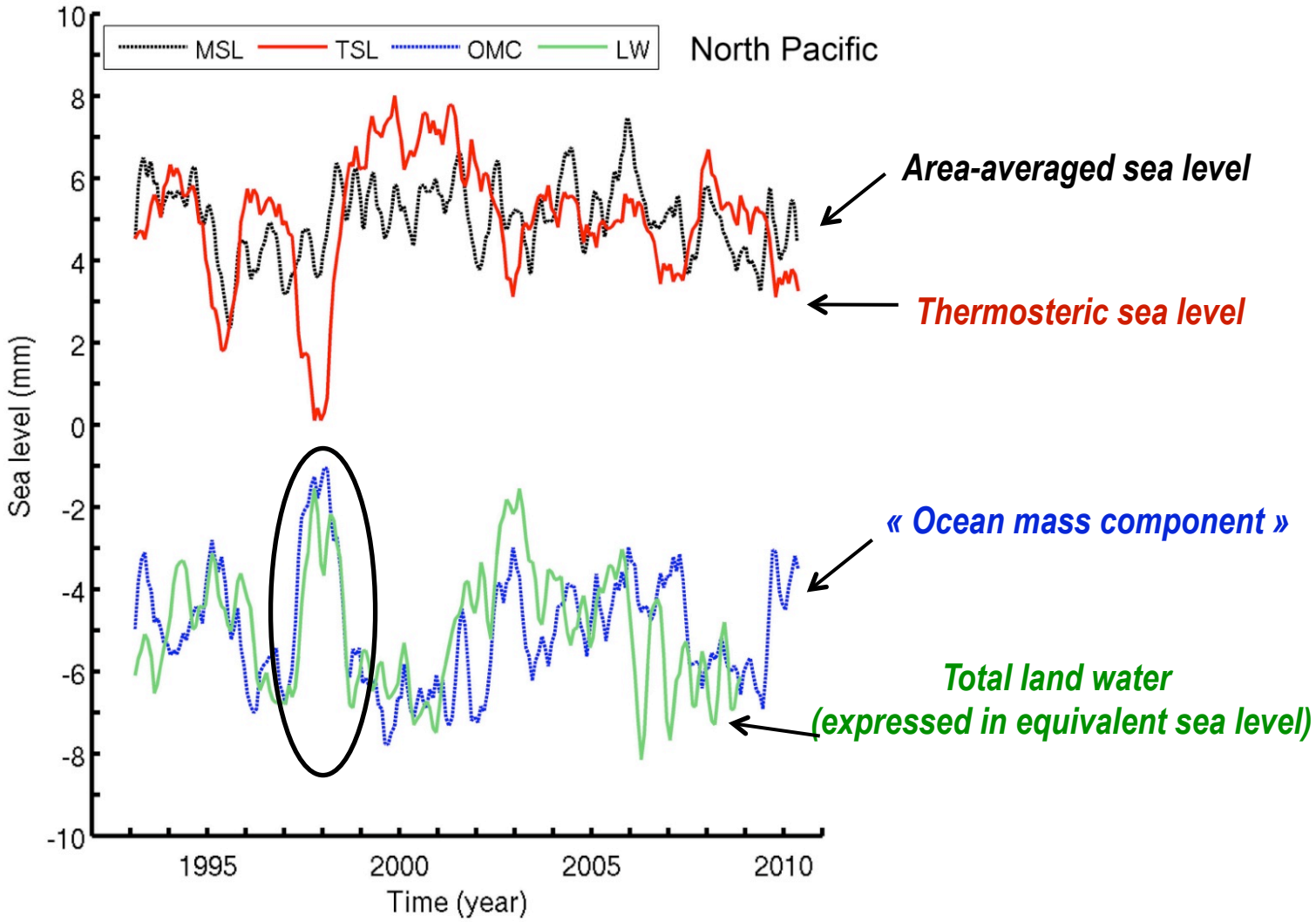
Weighting by the ratio of the averaging area to the total ocean surface

Pacific Ocean



Weighting by the ratio of the averaging area to the total ocean surface

North Pacific Ocean



Weighting by the ratio of the averaging area to the total ocean surface

North Pacific water budget

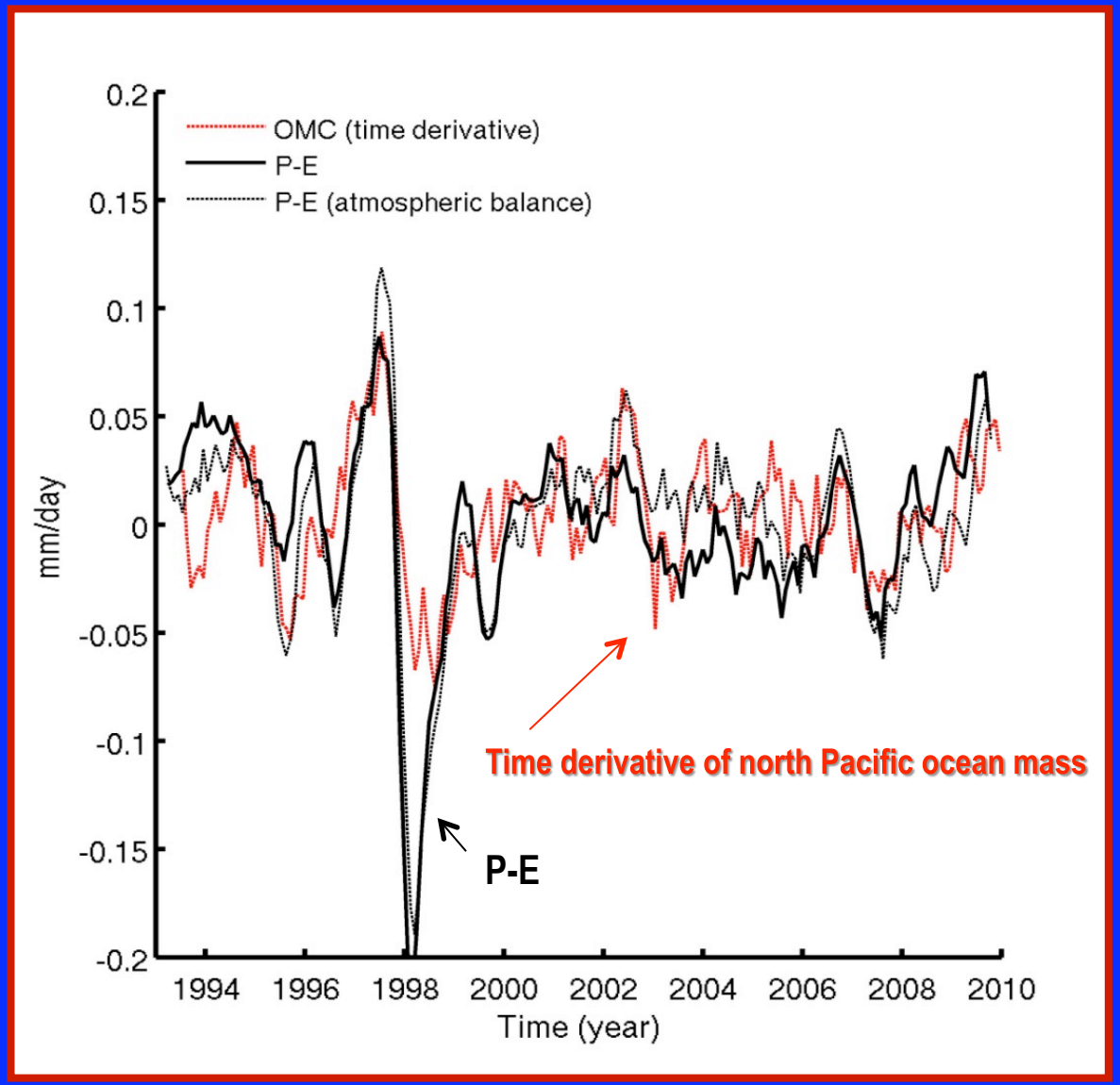
- $dM_{nP}/dt = P-E+\cancel{R}$ oceanic water balance

- $P-E = -(dP_{water}/dt + divQ)$ atmospheric water balance

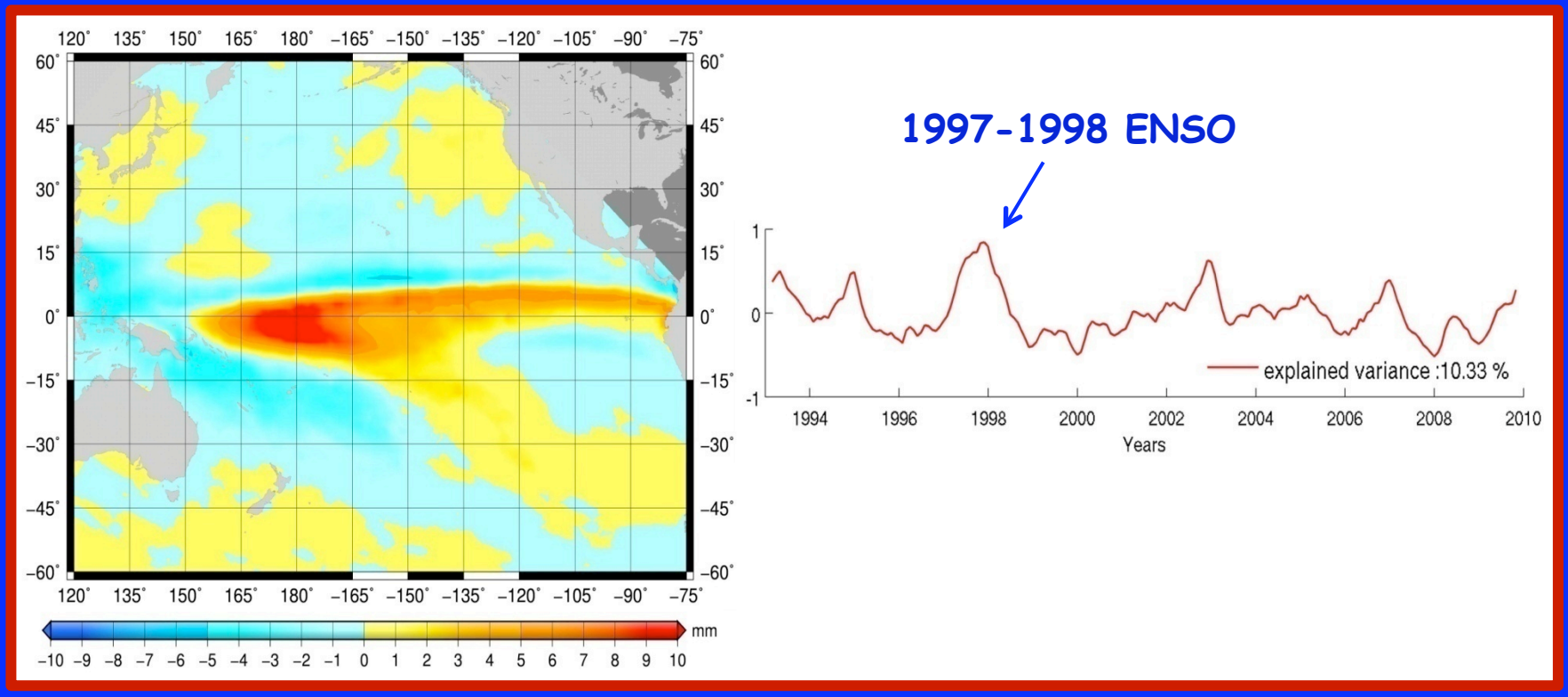
M_{nP} : north Pacific ocean mass
P : precipitation, E : evaporation; R : runoff
P_{water} : precipitable water
divQ : moisture flux divergence

Data from ERA-Interim

Time derivative of the North Pacific ocean mass and P-E



1st mode of the EOF decomposition of P-E over the Pacific



Conclusions

- Interannual variability of the global mean sea level directly related to ENSO-driven changes in the global water cycle
- The positive anomaly of the global mean sea level seen during El Nino essentially due to (tropical) north Pacific ocean mass increase
- North Pacific ocean mass increase during El Nino correlates well with net precipitation (P-E) increase in that region
- Positive (P-E) anomaly asymmetrical wrt equator during El Nino
- But several unsolved questions remain →
  - Why does the north Pacific alone contribute to the global mean sea level anomaly and almost perfectly balance total land water storage changes?
  - What are the effects of fresh water input and salinity changes in the NP?
  - What is the role of wind stress?
  - Are there circulation-driven mass redistributions?
  - ……


Thanks for your attention