

# Observations of sea level rise

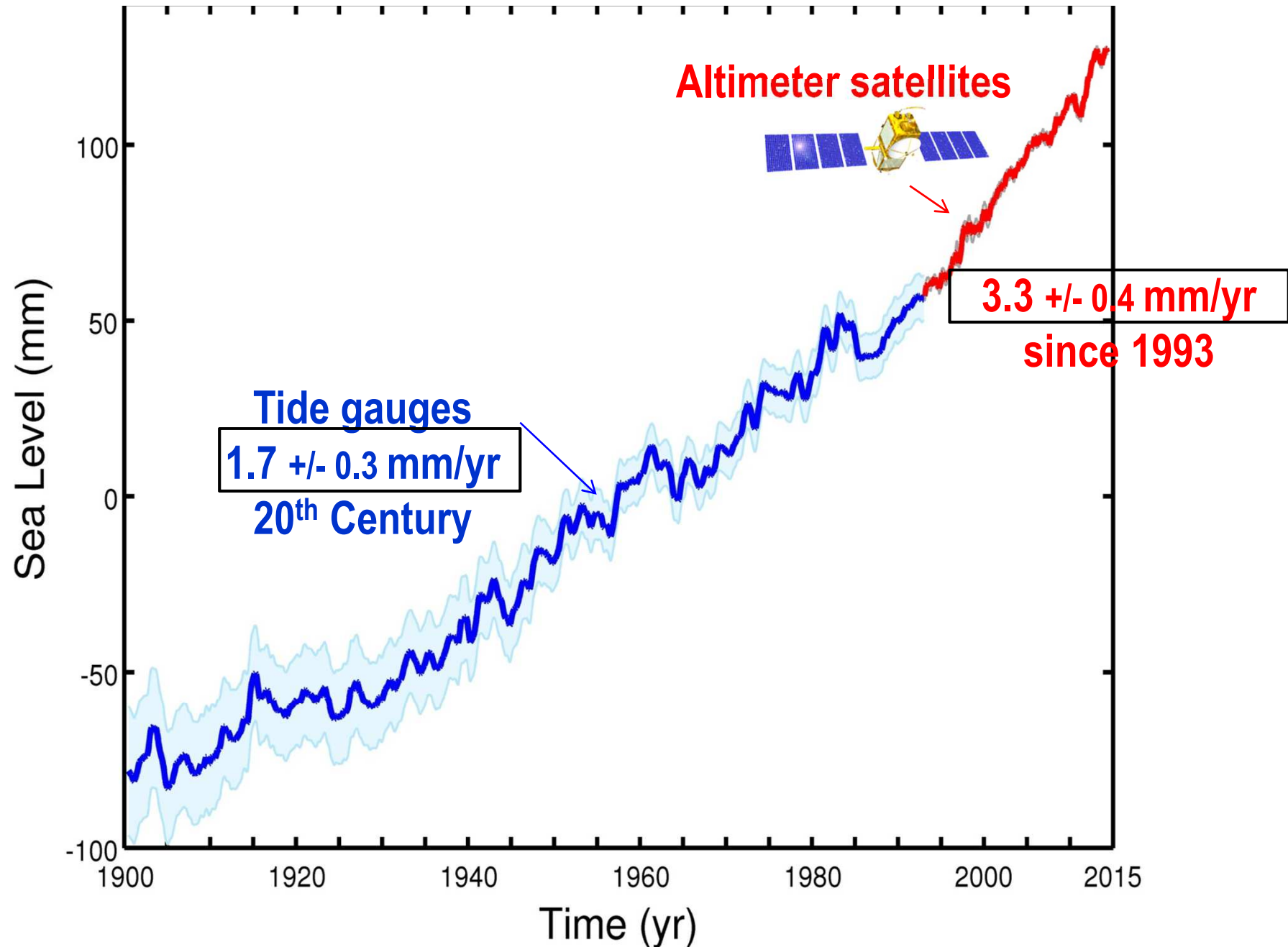
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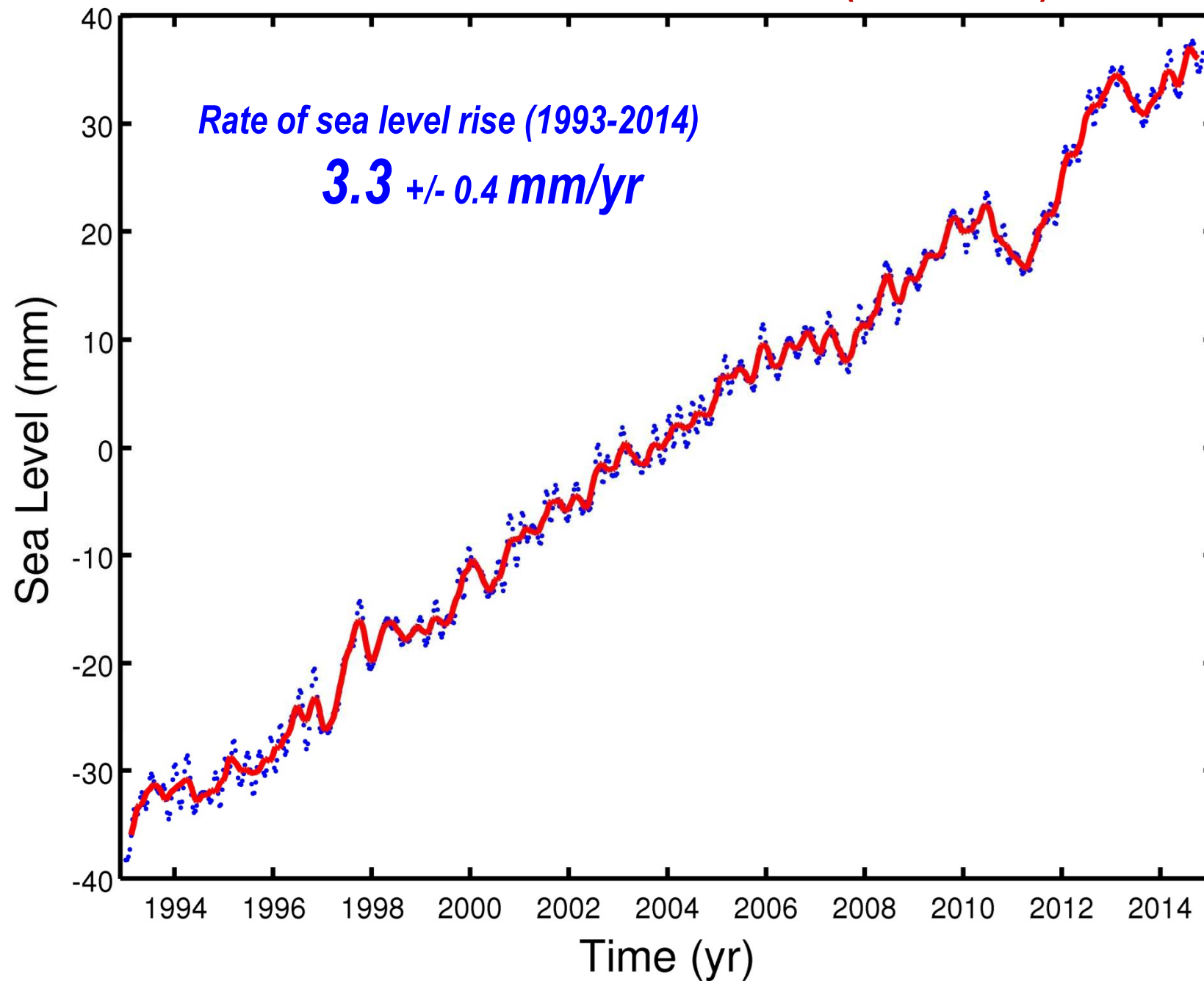
**ECRA**  
***New Knowledge for Risk Reduction***  
***25/26 March 2015***



# Observed global mean sea level rise since 1900

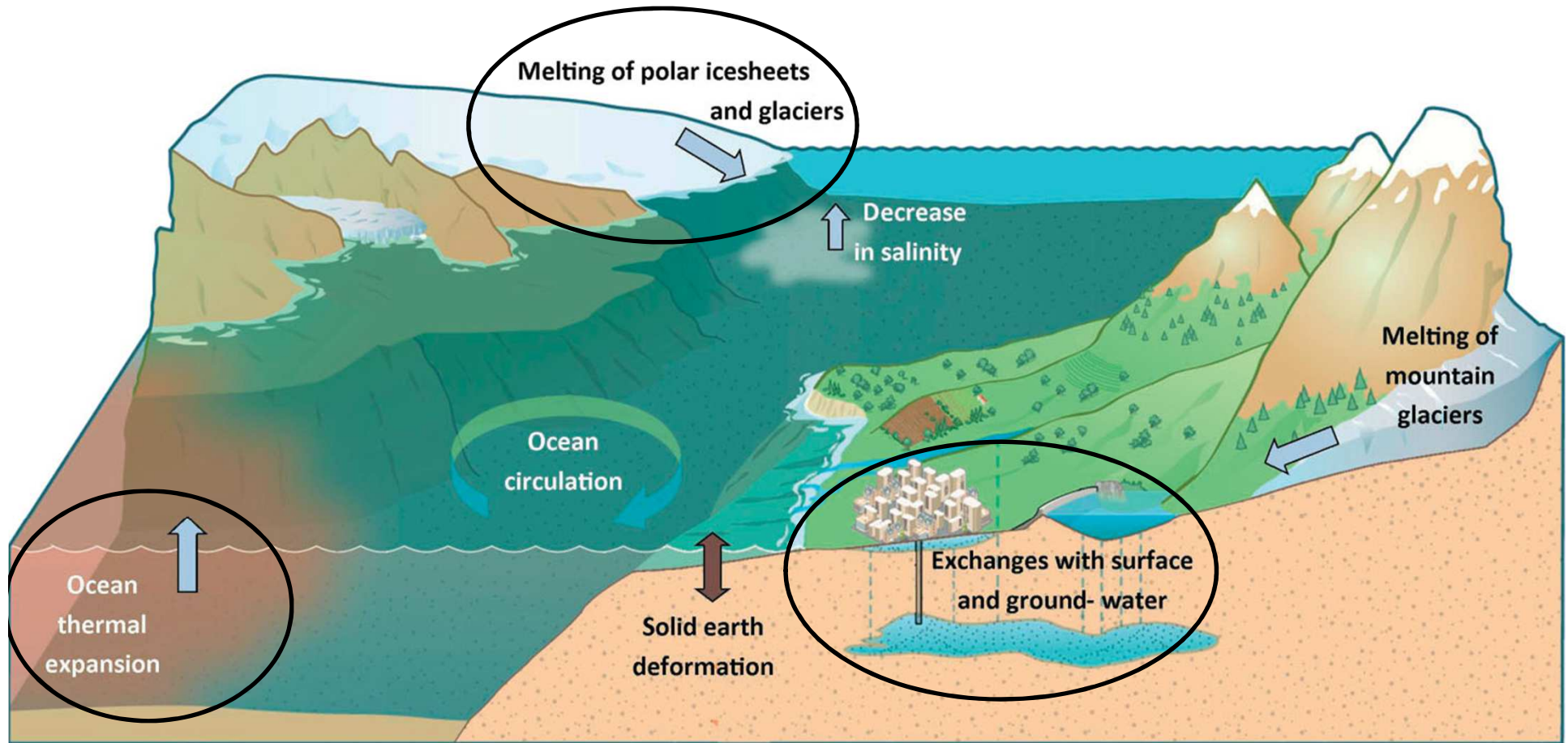


## Global mean sea level evolution (1993-2014)



# Causes of the global mean sea level rise

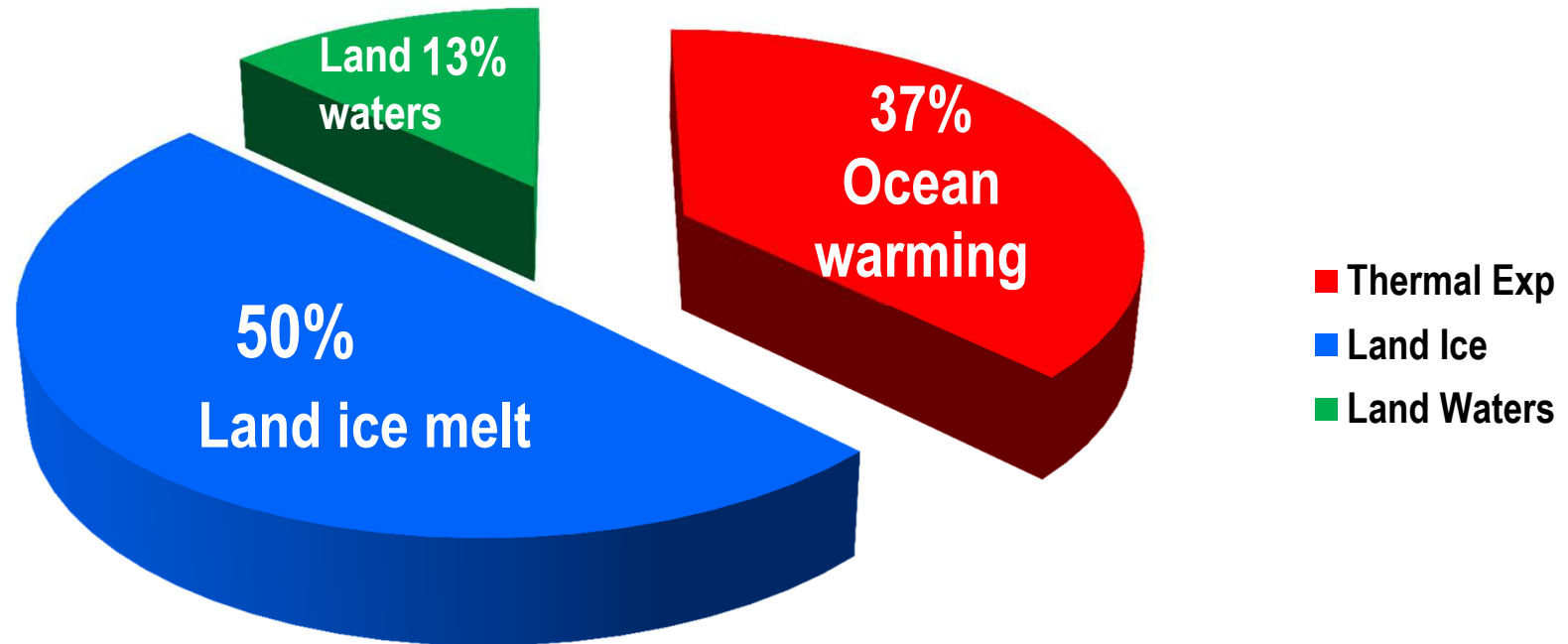
- Ocean warming (thermal expansion) → steric sea level
- Land ice melt (glaciers + ice sheets)
- Exchange of water with continental reservoirs (ground water pumping)





# Causes of the global mean sea level rise (1993-2010)

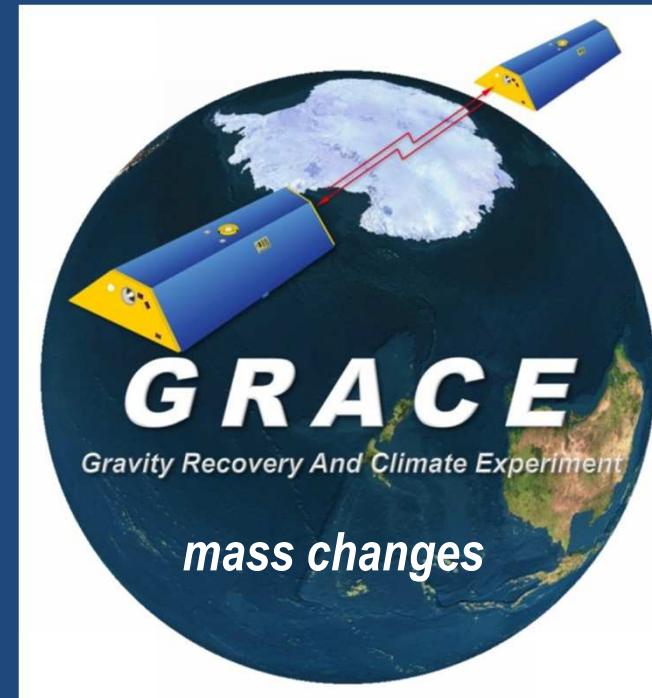
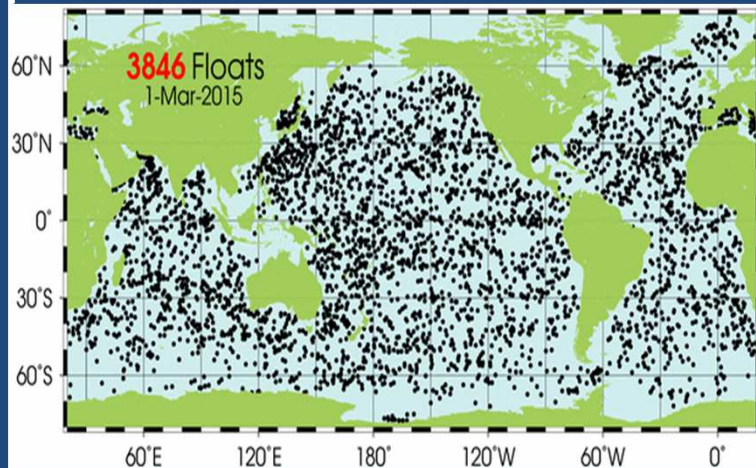
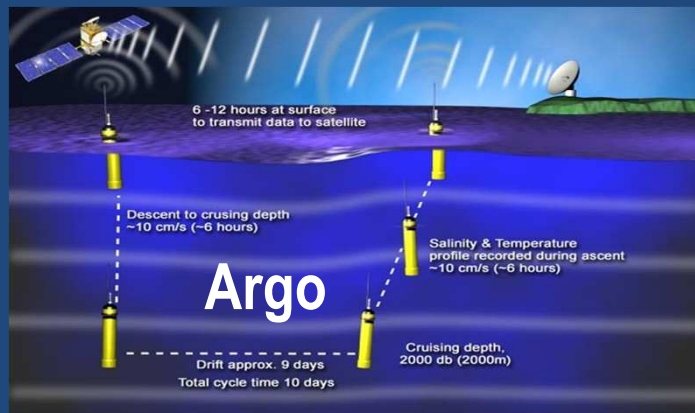
*Individual contributions (in % of the observed rate of rise)*



**IPCC AR5**

Since ~ 2003/05, Argo + GRACE → steric sea level (upper ocean) + ocean mass

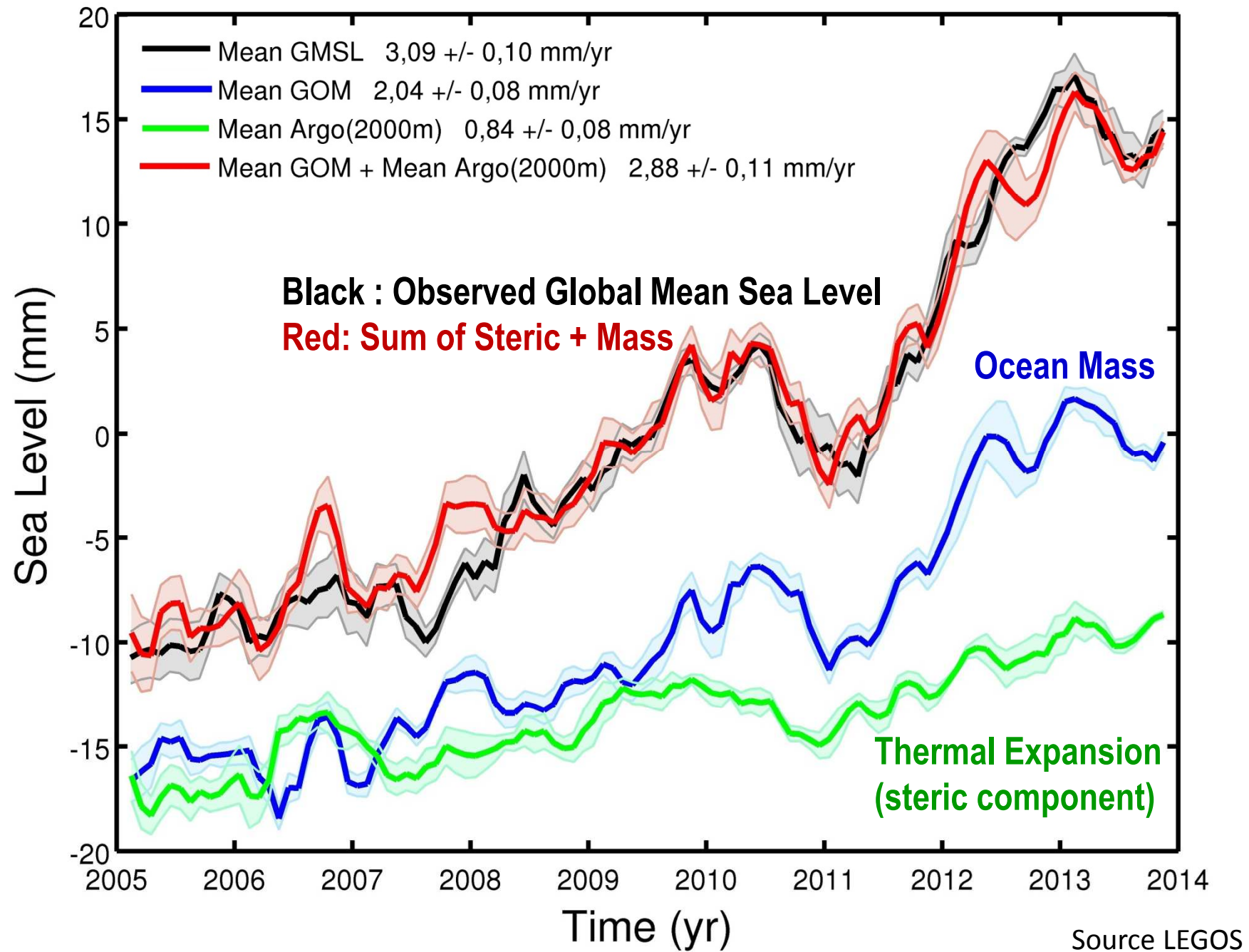
*Thermal expansion + salinity  
of the upper ocean  
(0-2000 m)*



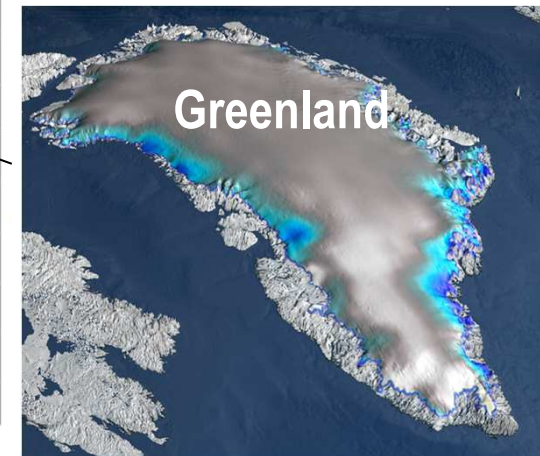
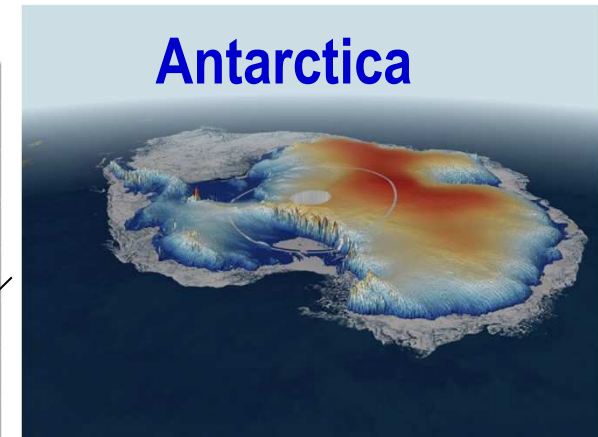
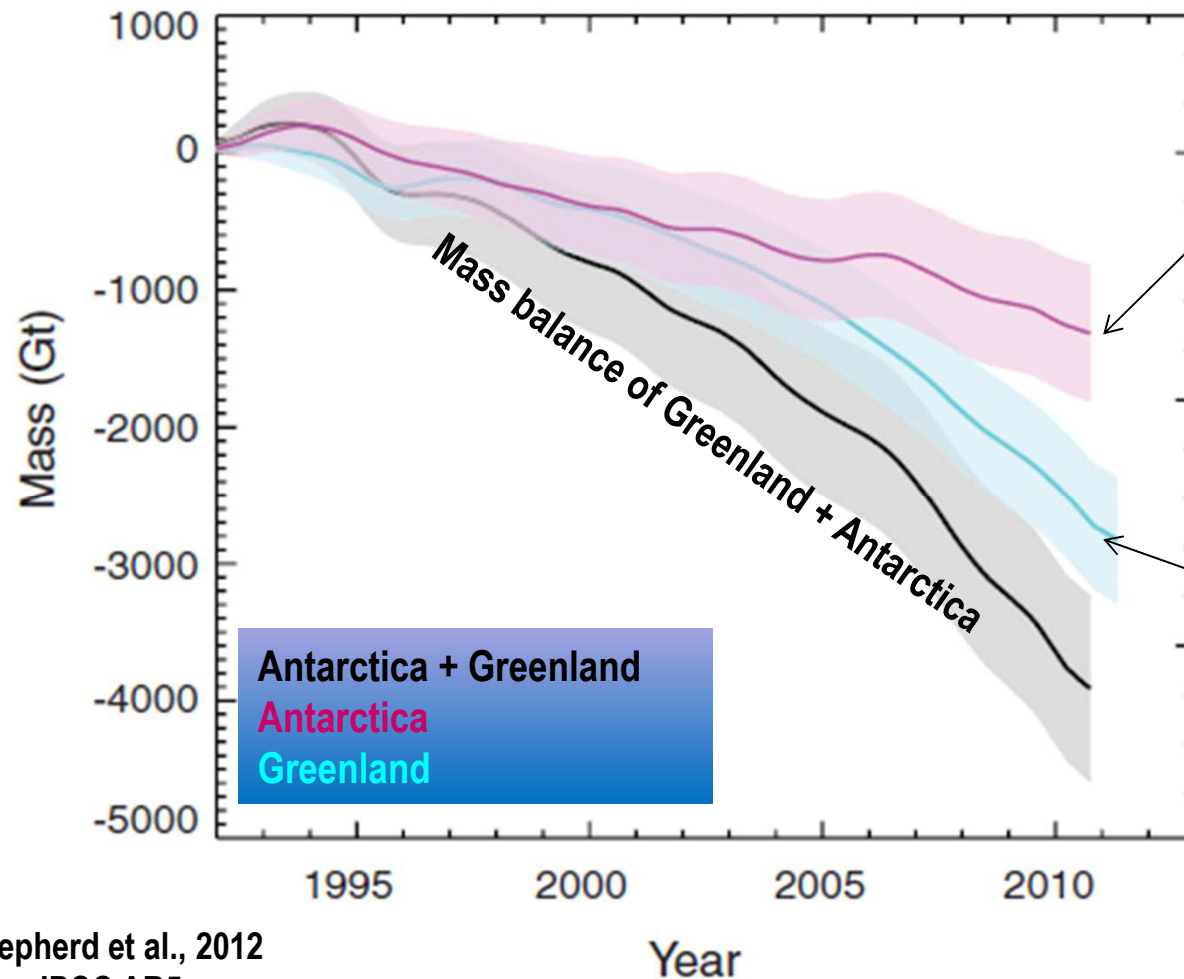
ocean mass

glaciers, ice sheets,  
land waters

## Global Mean Sea Level budget over 2005-2013

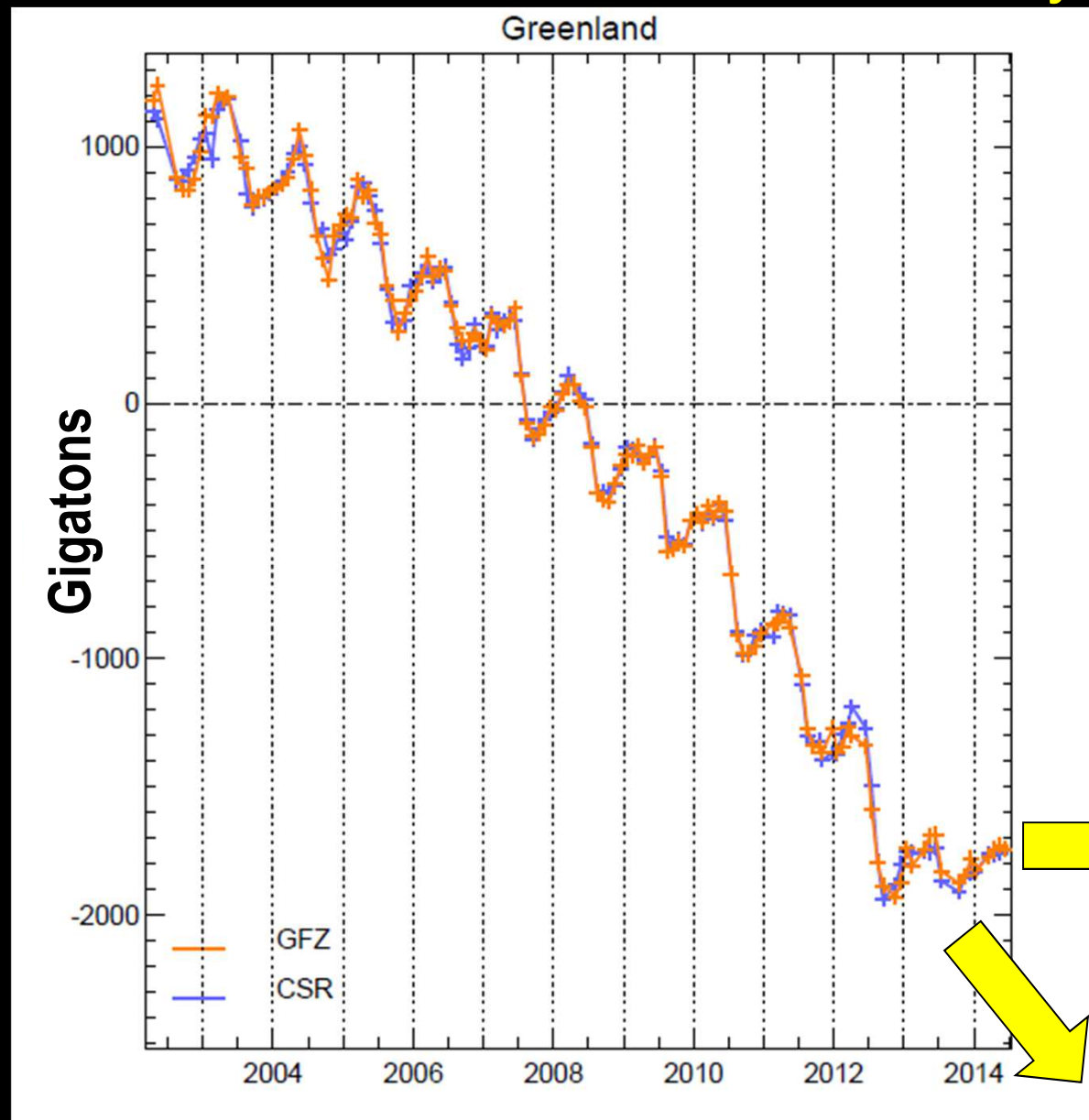


***Ice mass loss from Greenland and Antarctica  
measured by space techniques  
since 1990 (in Gt) → mass loss acceleration during the last decade***





## Ice mass loss from the Greenland ice sheet observed by GRACE



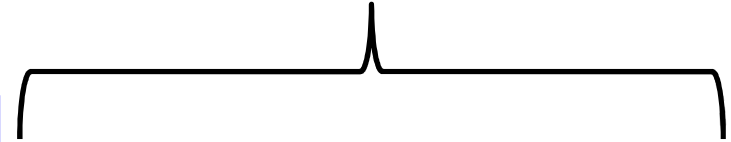
Courtesy: Frank Flechtner, GFZ

## Sea level budget : can inform on missing components



$$\text{Global Mean Sea Level} = \text{Ocean mass} + \text{Steric (0-2000m)} + \text{Deep Ocean (>2000m)} + \text{data errors}$$

Residual



*The residual term includes the deep ocean contribution plus data errors*



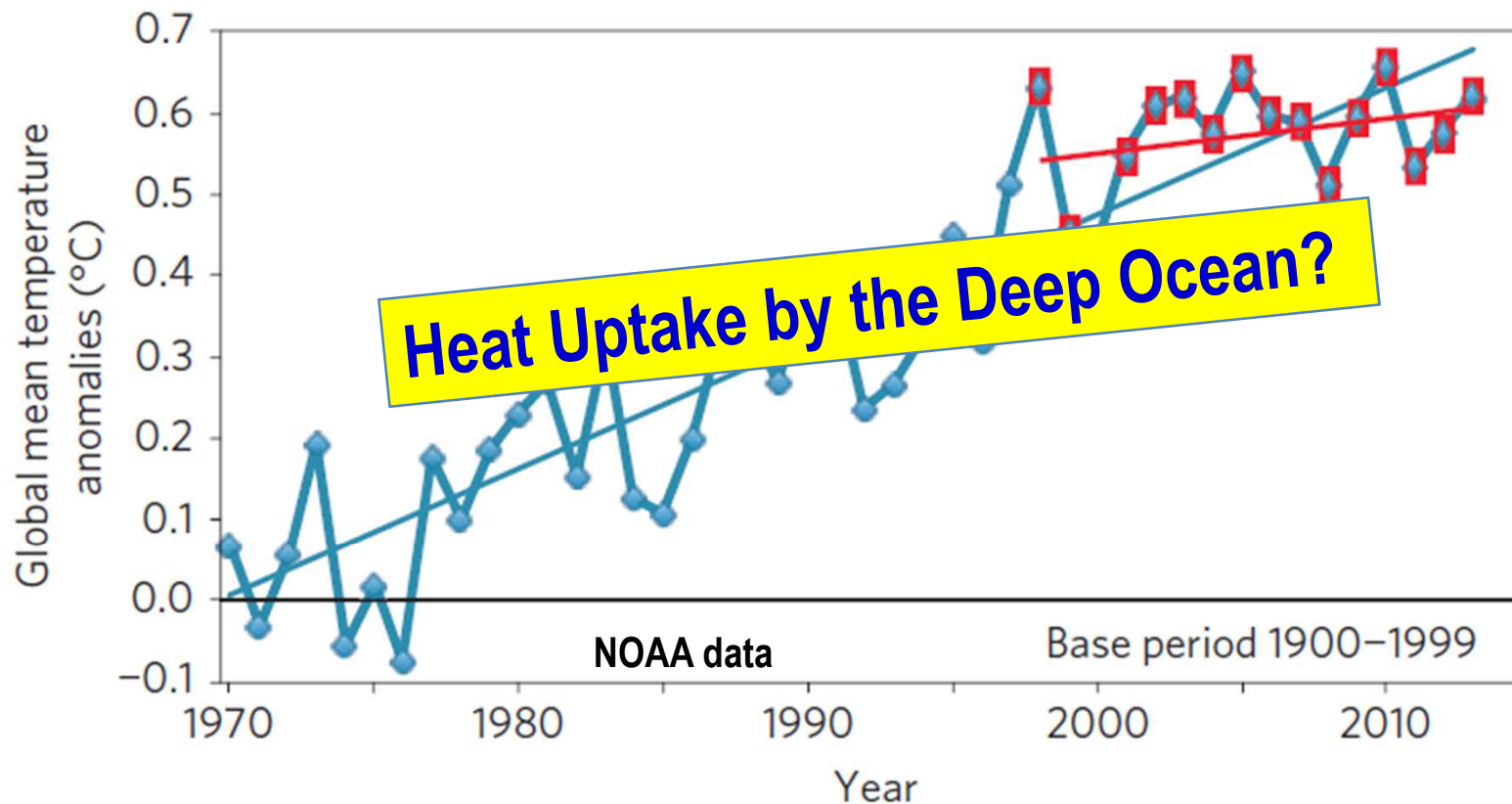
Deep ocean warming?

## Evolution of the global mean Earth' surface temperature since 1970

*Since the early 2000s ( $0.05^{\circ}\text{C}/\text{decade}$ )*

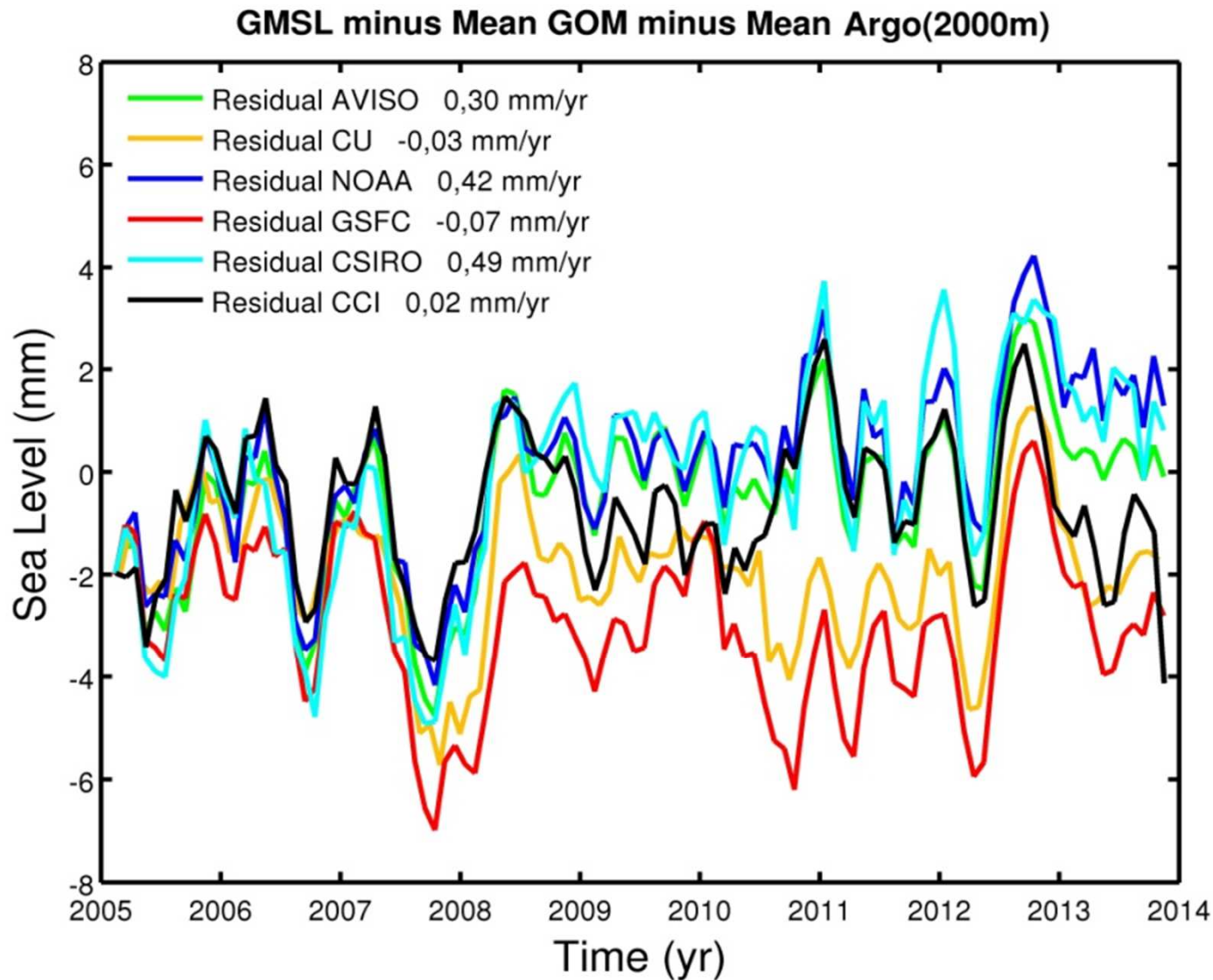
*→ 2 times less than the average rate since 1950 ( $0.12^{\circ}\text{C}/\text{decade}$ )*

What is the cause of the 'Pause' (also called 'Hiatus')?



## Residuals computed with different satellite altimetry products

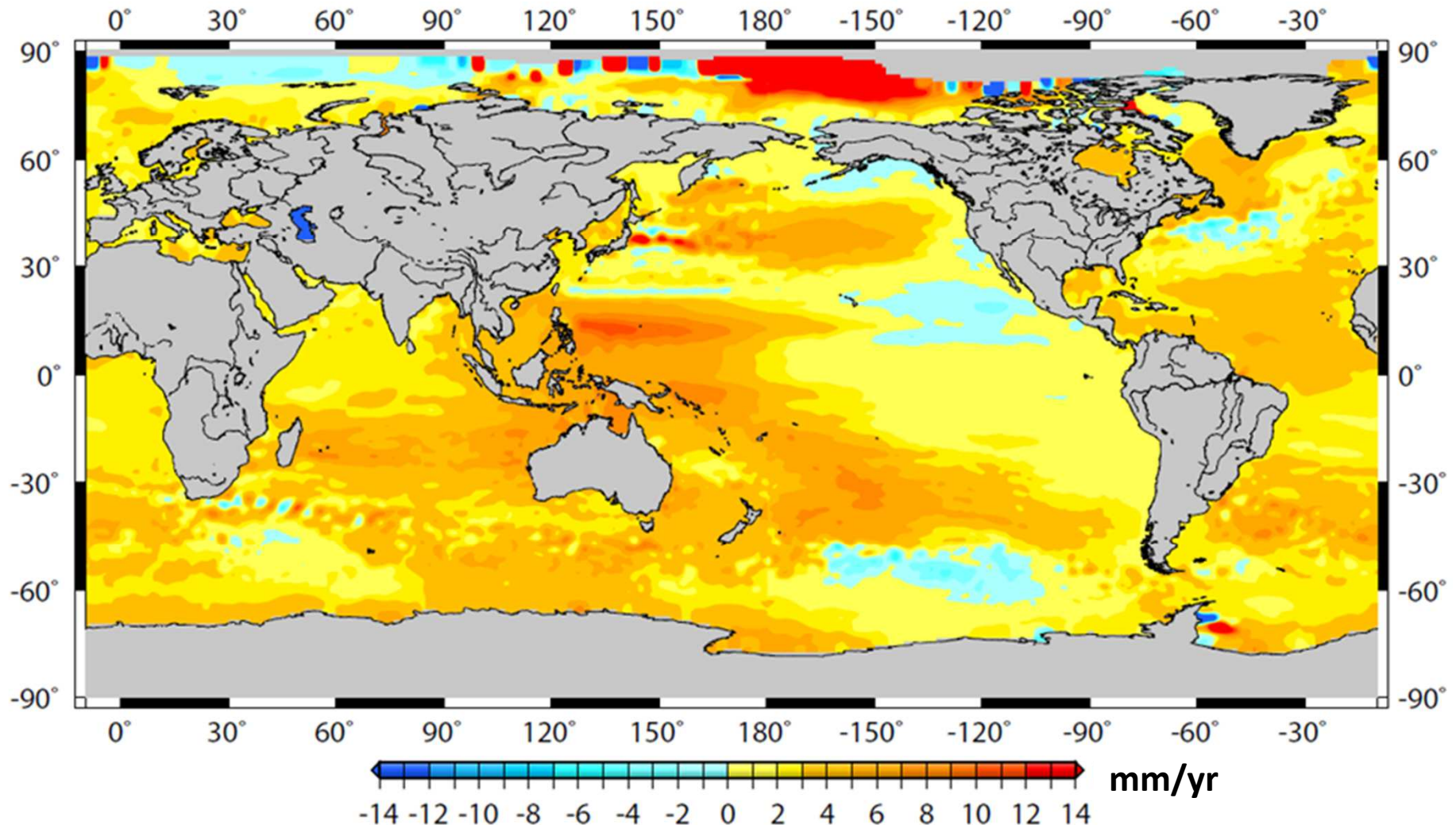
Global mean sea level minus ocean mass (GRACE) minus steric sea level (Argo → 2000 m)





# Spatial trend patterns in sea level observed by satellite altimetry over 1993-2014

Sea level trends from satellite altimetry (Jan 1993 - Sept 2014 ; LEGOS/CLS)

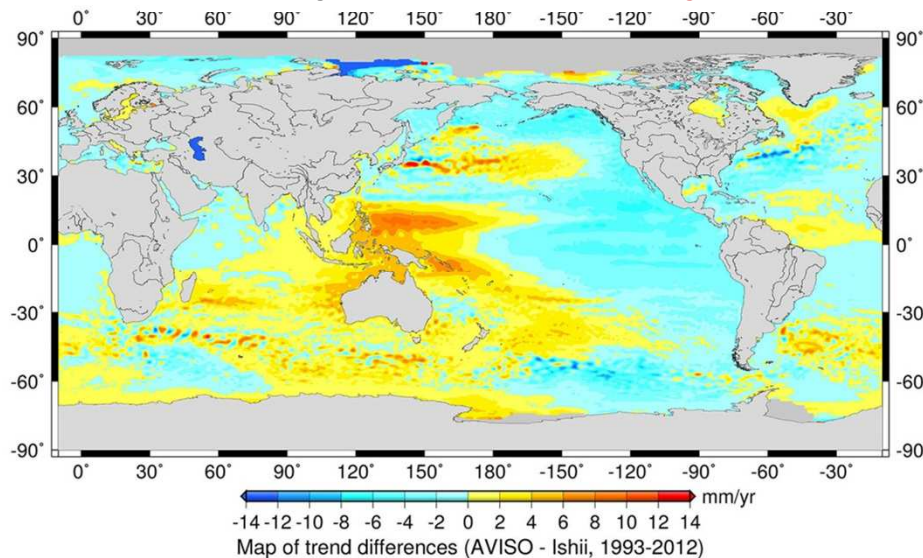


# Regional sea level trends over 1993-2013

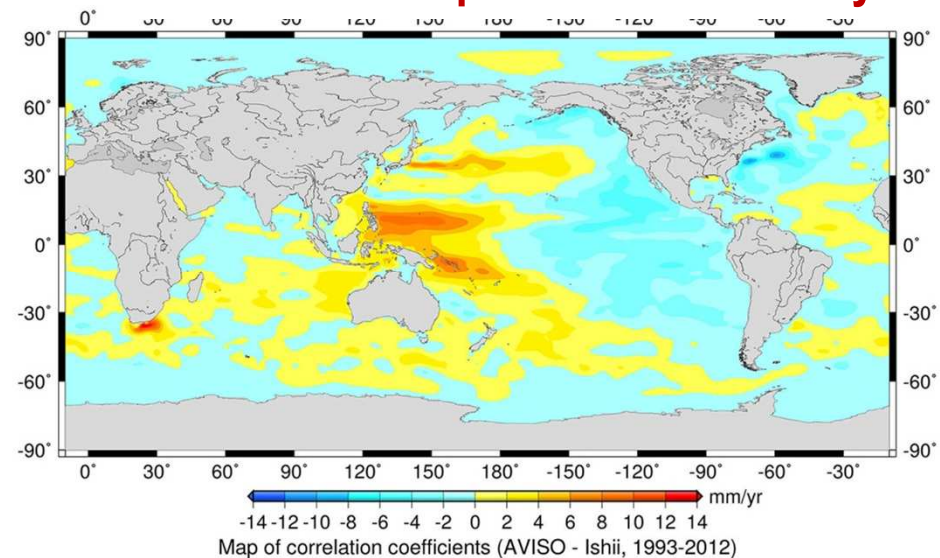
(global mean rise removed) →

Spatial trend patterns mainly caused by non uniform thermal expansion  
(& to a lesser extent to salinity variations)

Observed spatial trend patterns  
by **satellite altimetry**



Spatial trend patterns  
from **thermal expansion and salinity**



*Can we detect other phenomena causing regional variability in sea level (e.g., Glacial Isostatic Adjustment/GIA)?*

## A few examples of important issues related to regional variability in sea level

- *Are the observed spatial trend patterns in sea level due to the natural/internal variability only? Or Is the anthropogenic forcing signal already detectable?*
- *Can we accurately reconstruct the regional variability in sea level before the altimetry era? (→ understand/reduce differences observed between available ocean reanalyses, and past sea level reconstructions as well)*
- *Can we estimate the **total relative sea level** at the coast (i.e., in addition to the altimetry-based regional sea level, estimate local vertical crustal motions + other processes acting at the coast)?*
- *What is the contribution of past few decades (total relative) sea level rise to coastal erosion reported along shorelines worldwide?*
- *.....*

# Challenges related to sea level observations

- ★ Sea level data contain information on several components (land ice melt, land waters, steric sea level, GIA, etc.)
  - The sea level budget approach allows cross validation of different types of observations & observing systems, and validation of model results (e.g., GIA, land hydrology, ...).
- ★ The sea level budget (last decade) can be used to constrain 'missing' contributions (e.g. deep ocean and its role in the current 'hiatus'); However errors in all components first need to be reduced
- ★ Long, accurate records of (global & regional) sea level and components are crucial → important to identify new processes, constrain missing contributions & validate climate models used for projections.