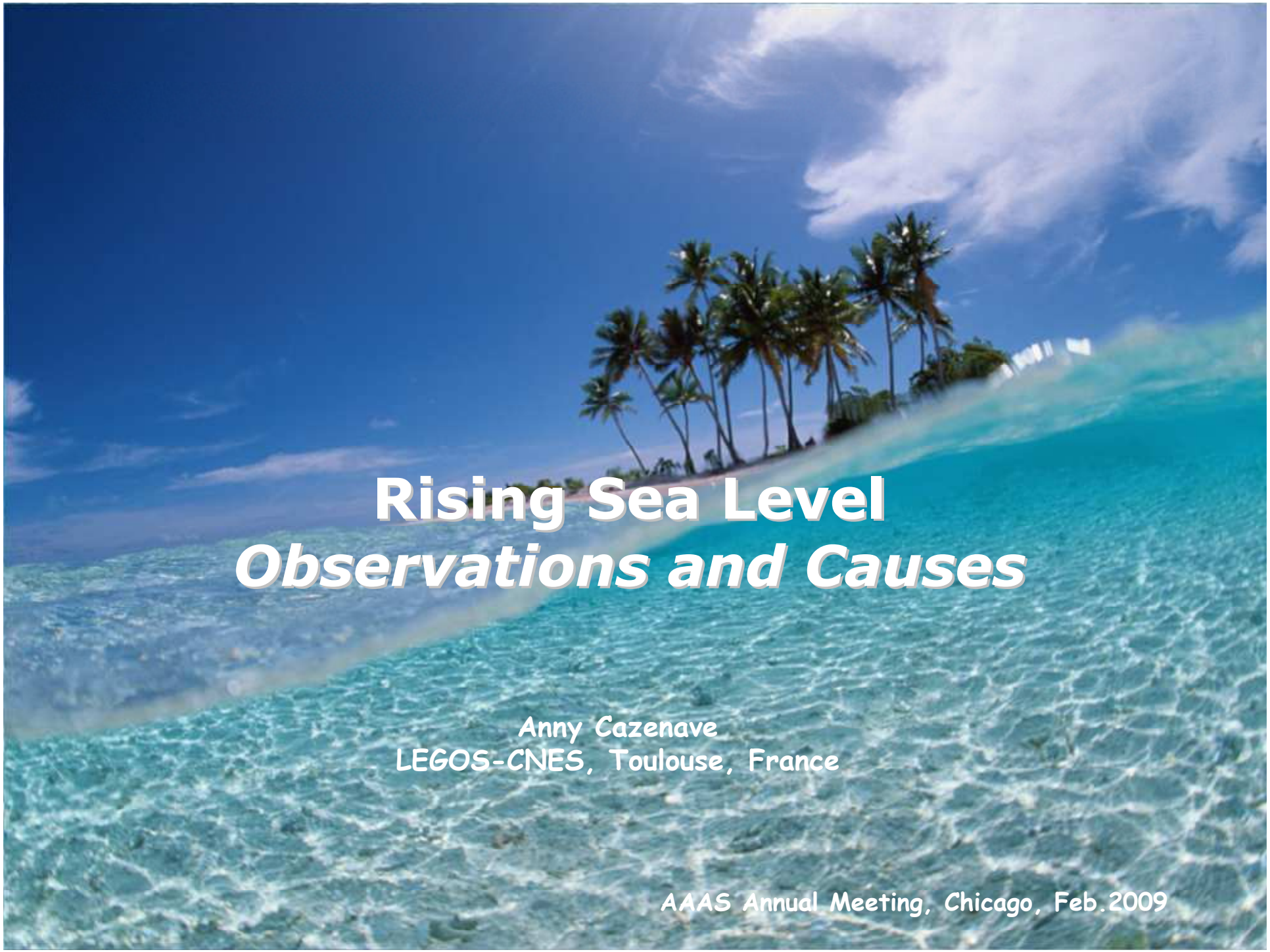


Rising Sea Level
Observations and Causes

Anny Cazenave
LEGOS-CNES, Toulouse, France

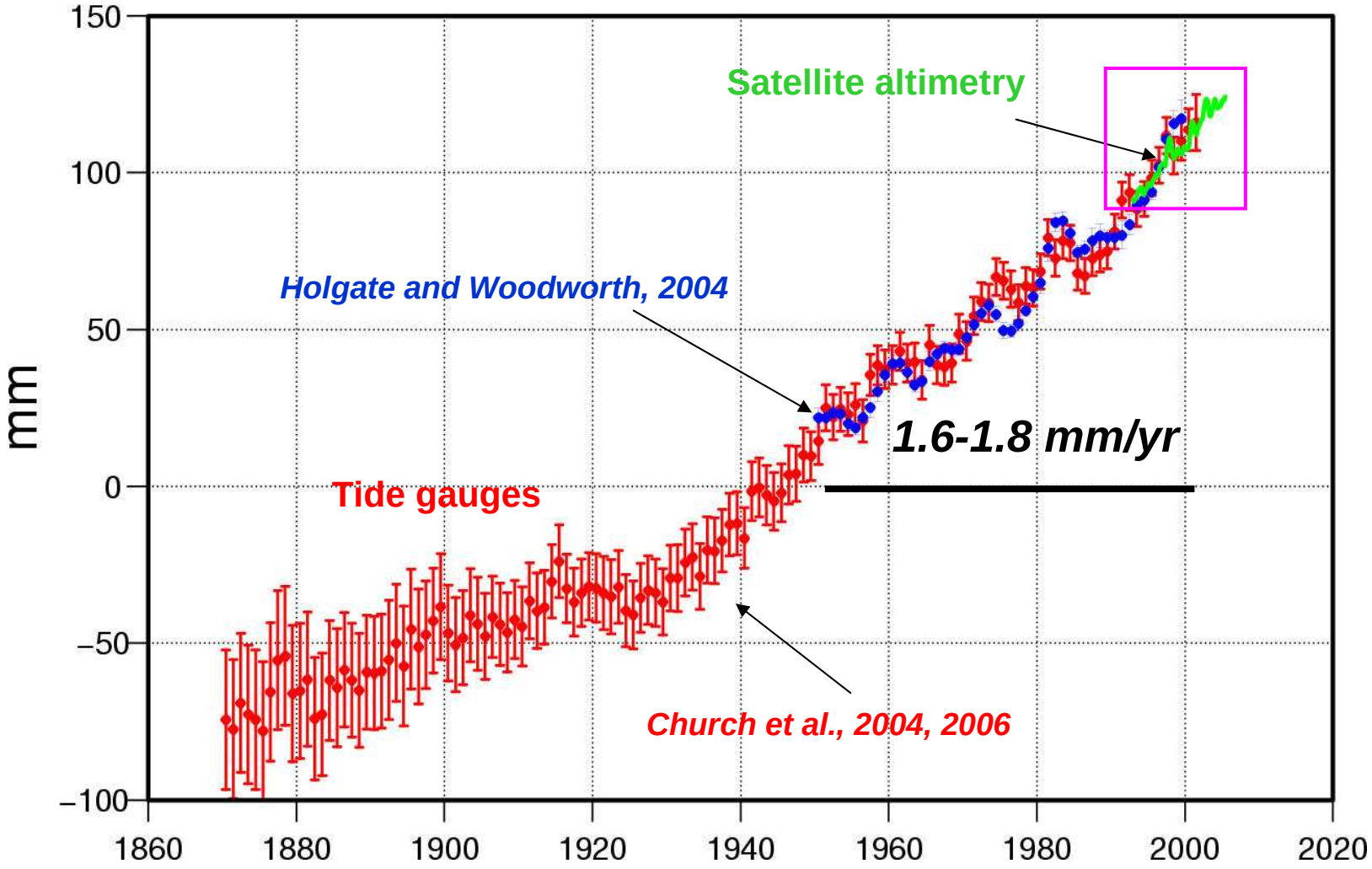
AAAS Annual Meeting, Chicago, Feb.2009

Sea Level budget:

Comparison between observed sea level and sum of climate contributions (thermal expansion, land ice, land waters)

- 1993-2003: IPCC AR4
- 2003-2008: New

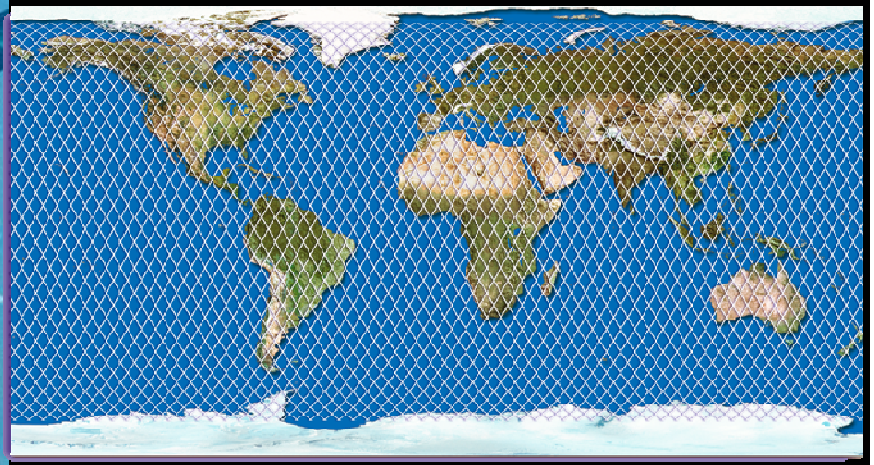
Global mean sea level rise during the 20th century



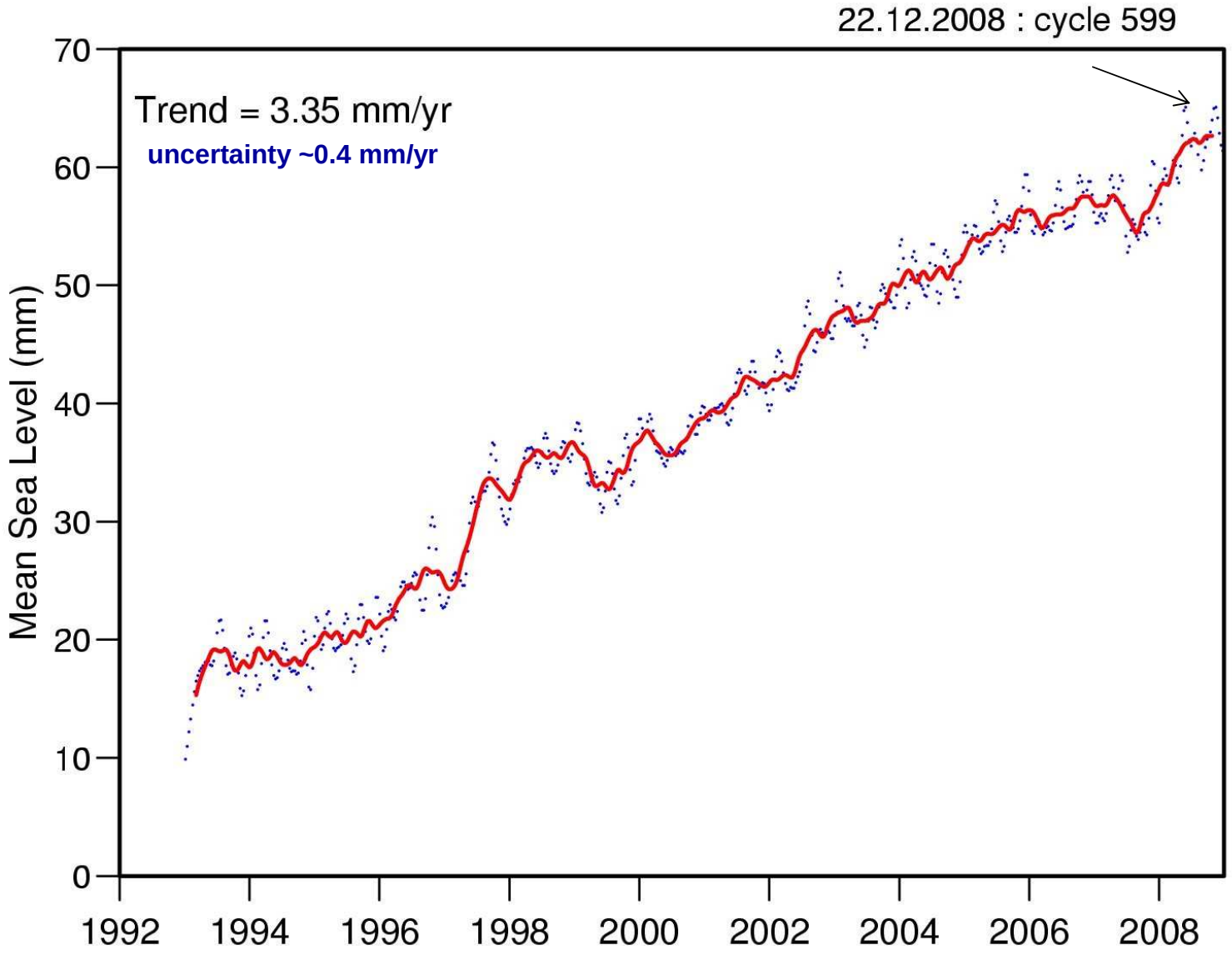
Satellite altimetry

Topex/Poseidon
(1992-2006)

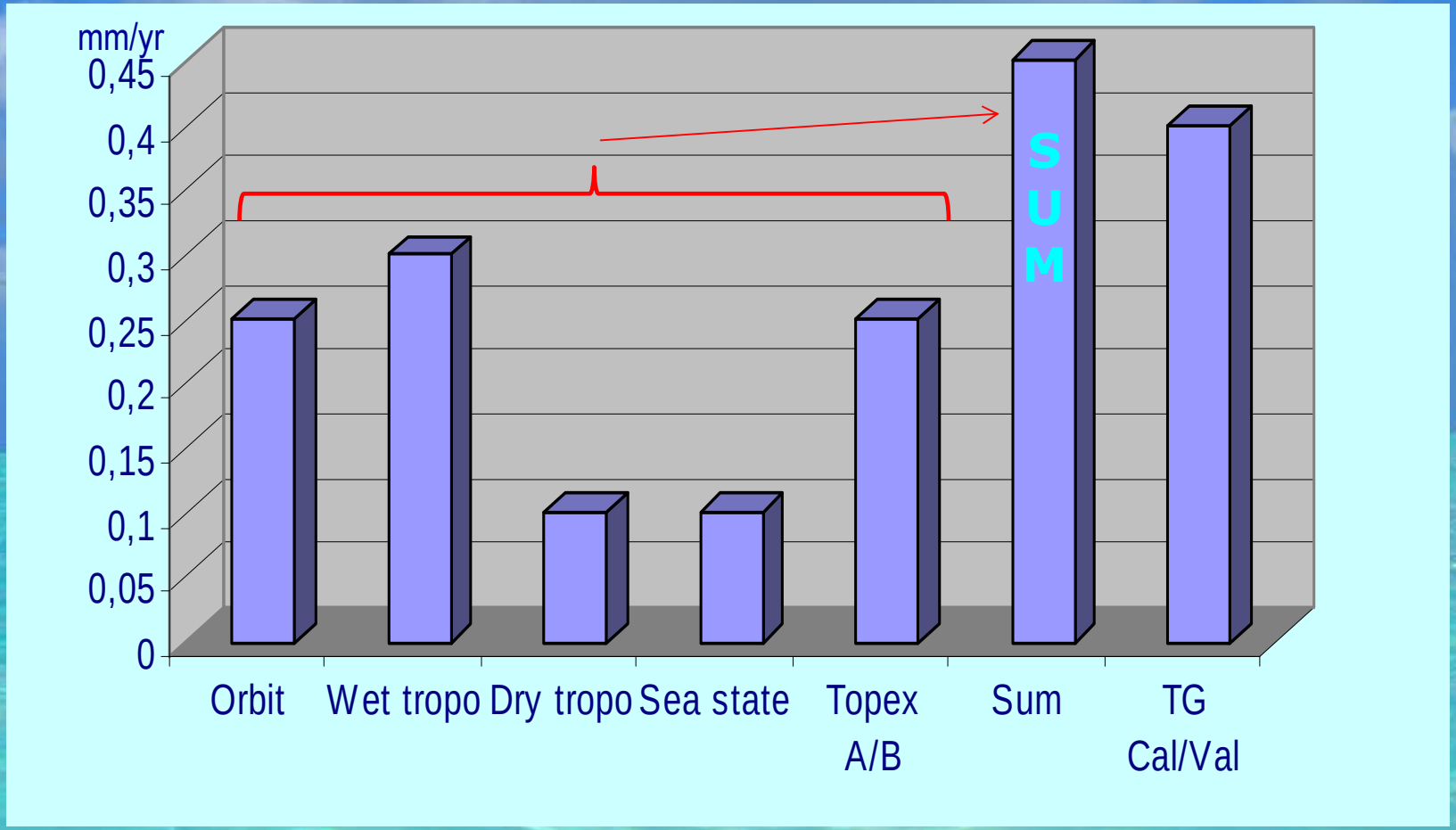
Jason-1
(2001-)



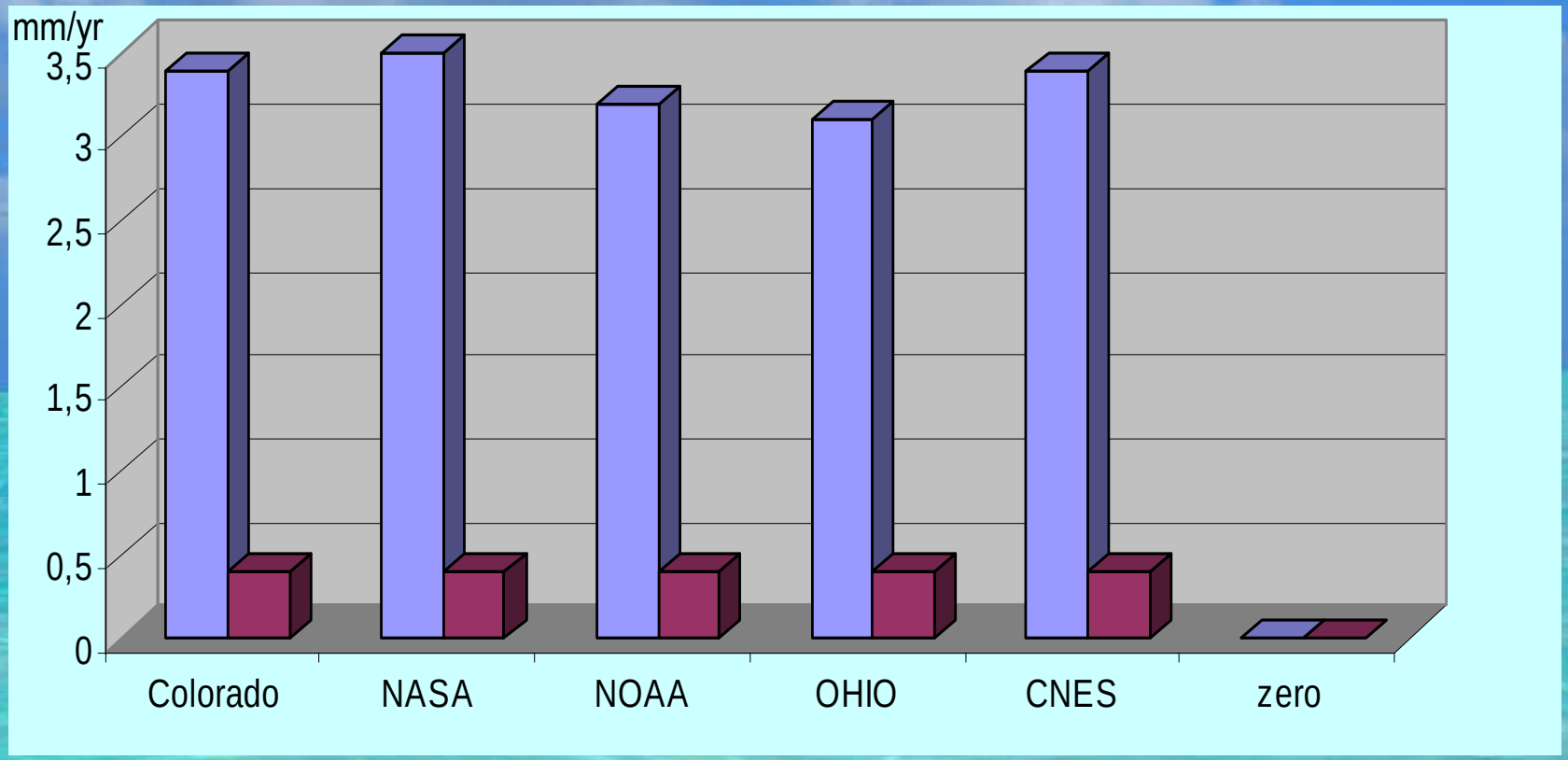
Global mean sea level between 1993 and 2008 (Topex/Poseidon and Jason-1 satellites)



Global mean sea level trend: error budget



Recent estimates of altimetry-based sea level rise (1993-2008)



Present-day Sea Level Rise:

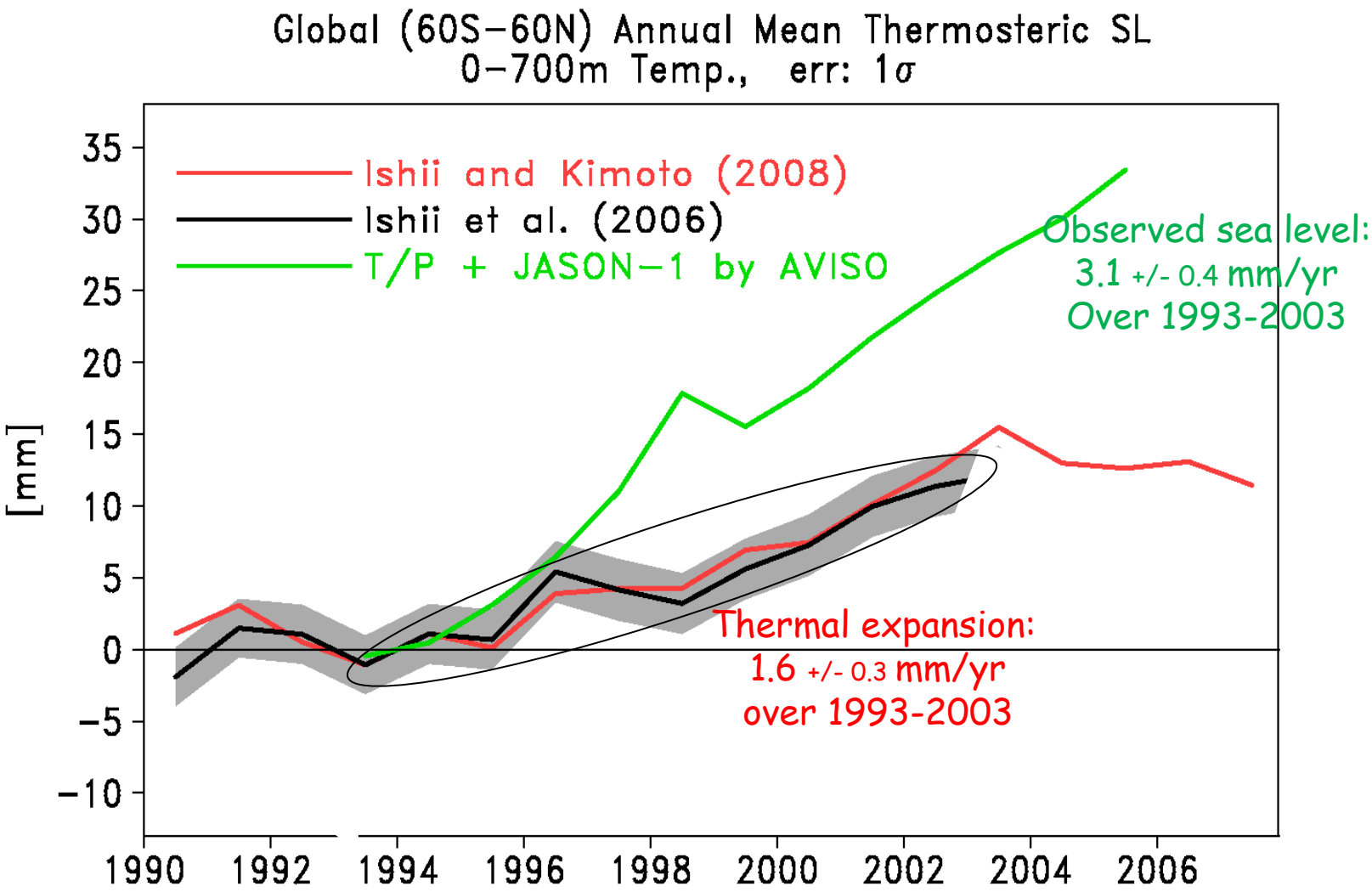
1950-2000: 1.7-1.8 mm/yr
1993-2008: 3.0-3.5 mm/yr

Acceleration?
Decadal fluctuation?

Sea Level budget:

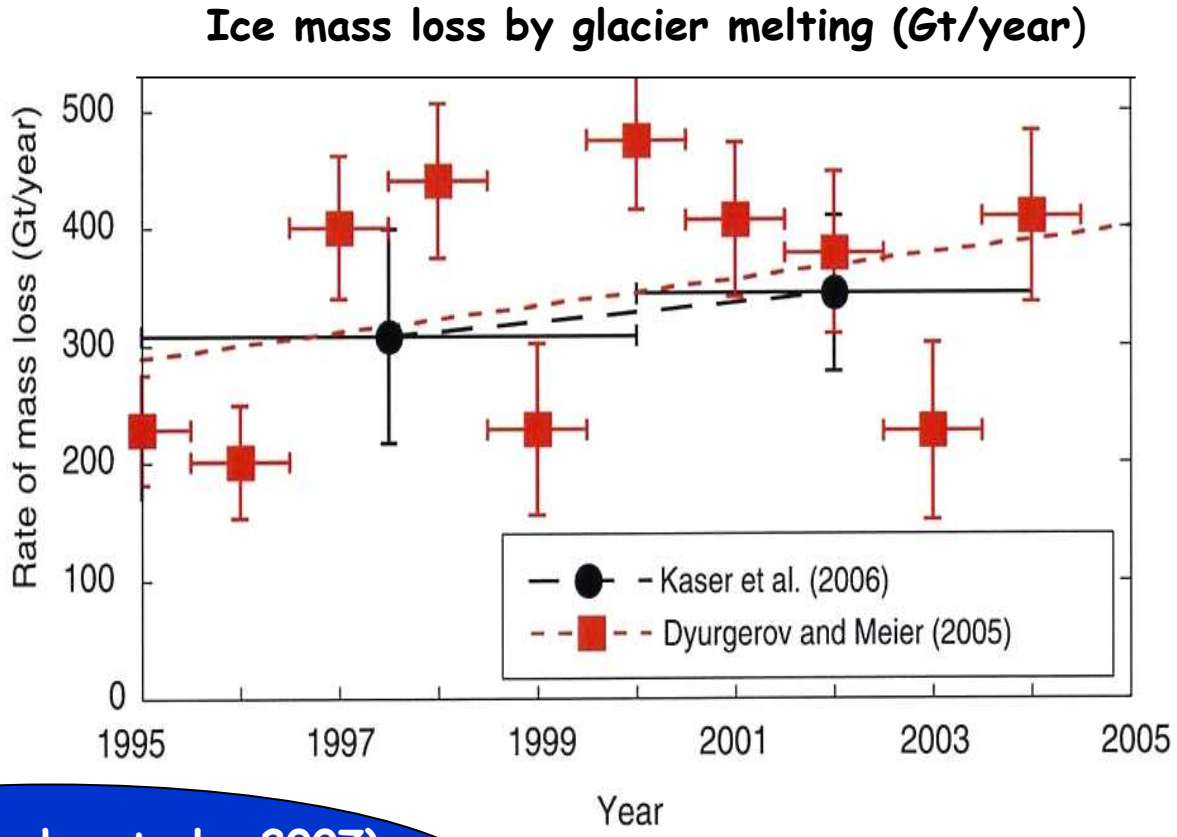
Comparison between observed sea level and sum of climate contributions (thermal expansion, land ice, land waters)

- 1993-2003: IPCC AR4



Courtesy M. Ishii

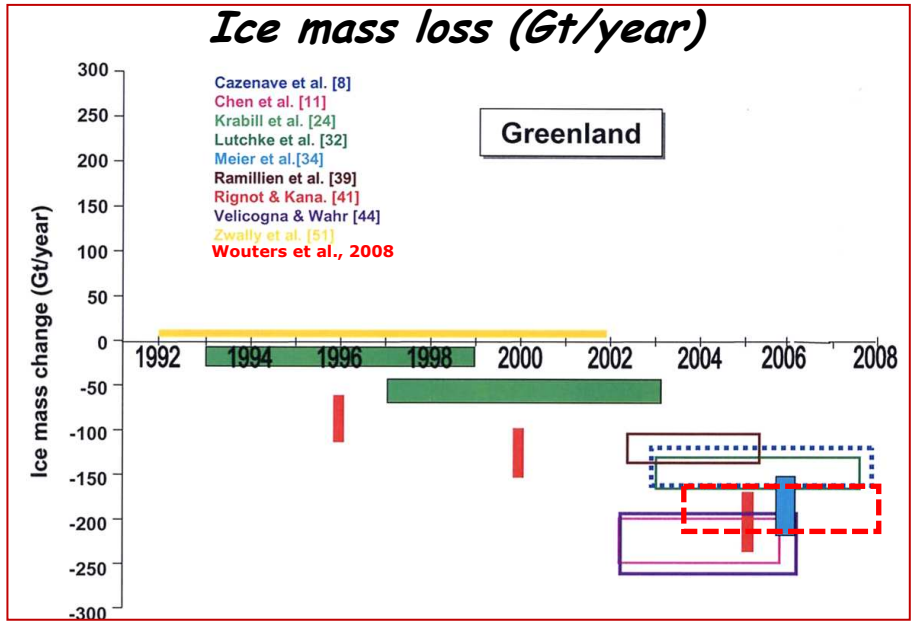
Contribution of glacier melting to sea level rise



IPCC AR4 (Lemke et al., 2007)
Contribution to sea level :
0.77 +/- 0.1 mm/yr (1993-2003)

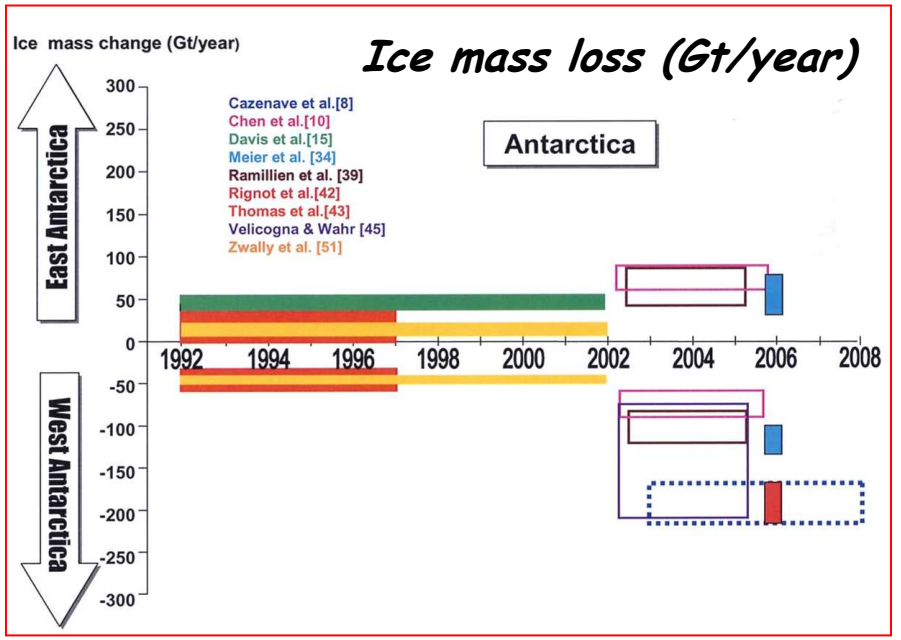
Meier et al.(2007)

Greenland and Antarctica mass balance



Greenland contribution to sea level rise (1993-2003) : 0.21 +/-0.04 mm/yr (IPCC AR4)

Antarctica contribution to sea level rise (1993-2003) : 0.21 +/-0.18 mm/yr (IPCC AR4)

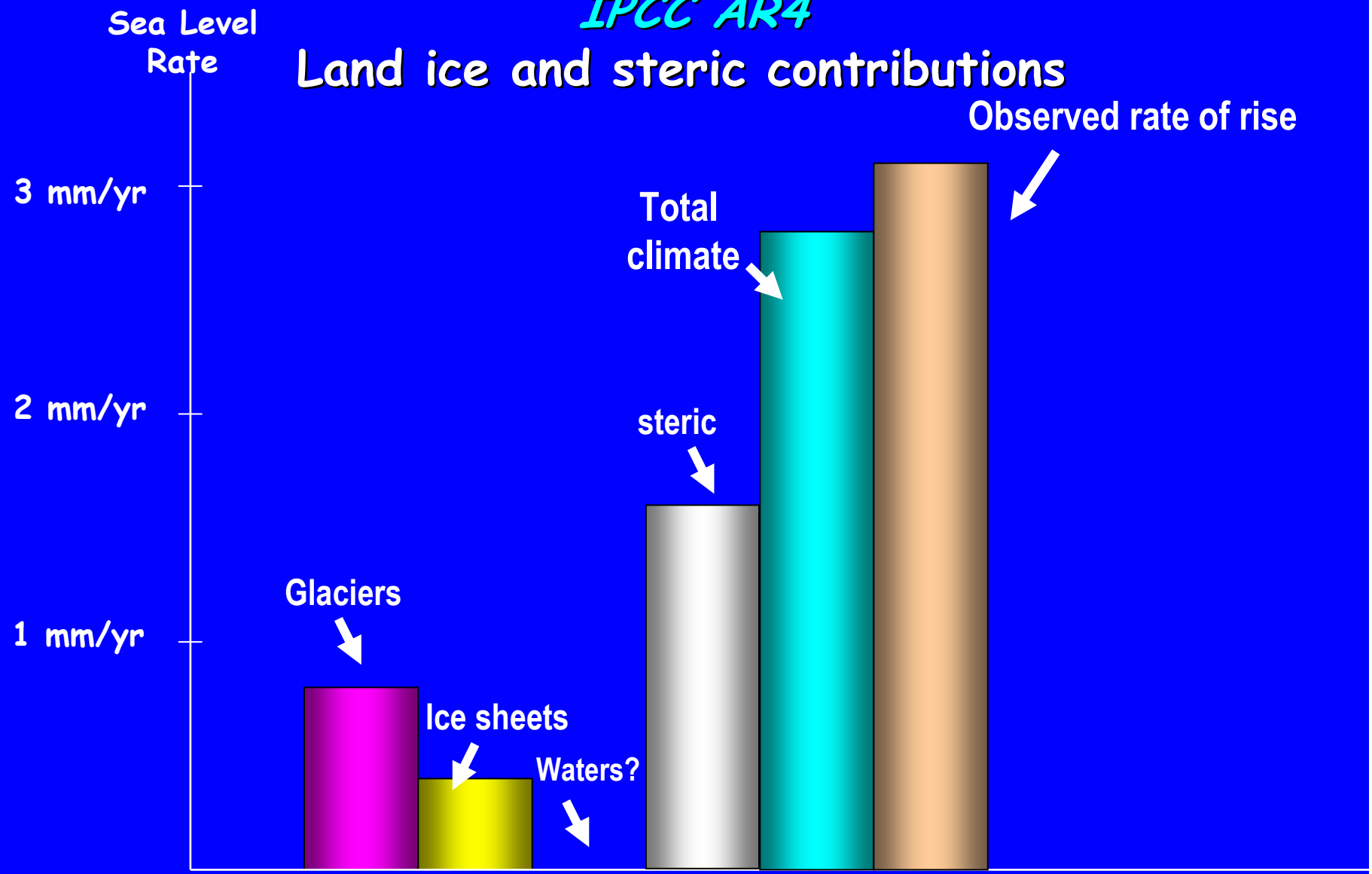


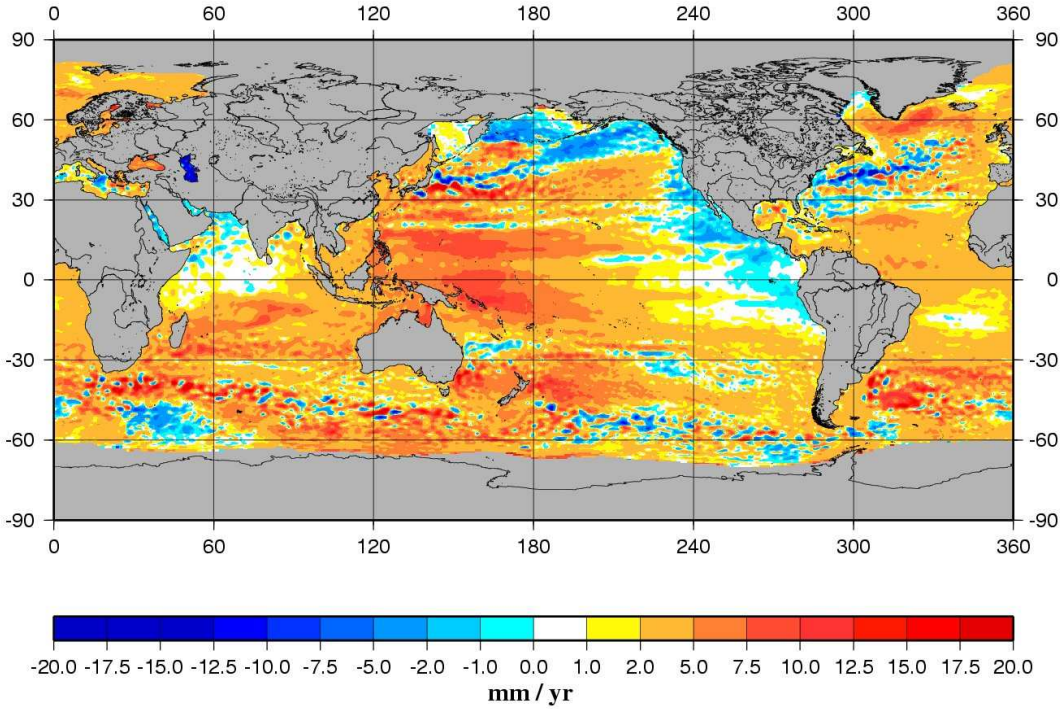
Ice mass loss measured by remote sensing techniques

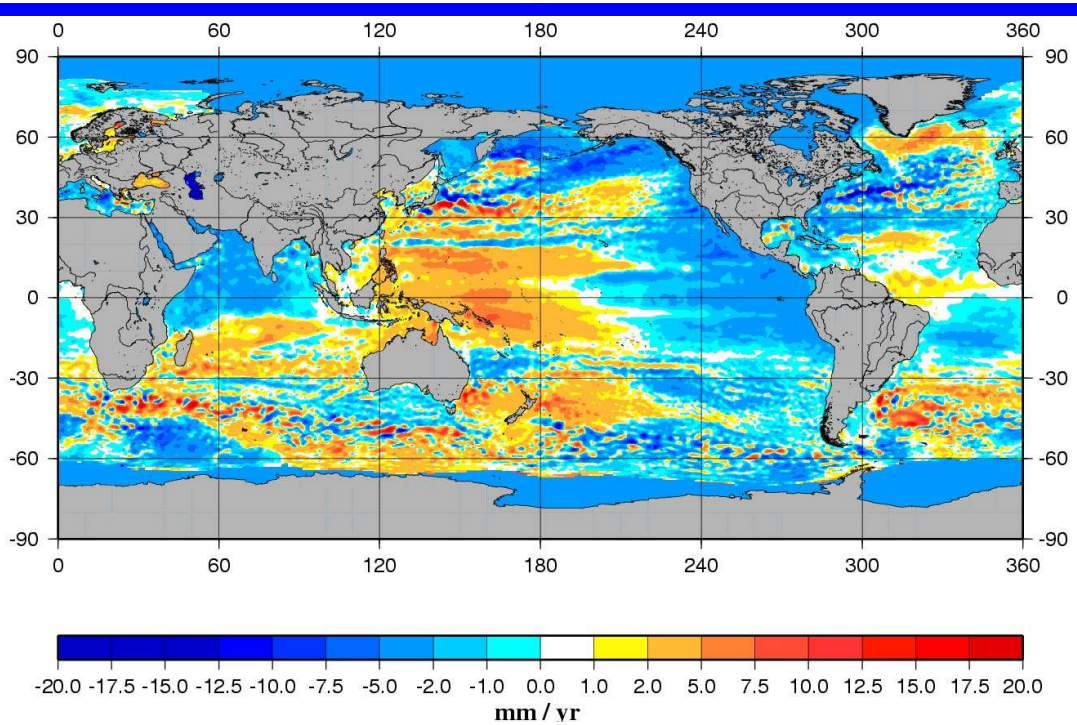
Sea Legel Budget 1993-2003

IPCC AR4

Land ice and steric contributions





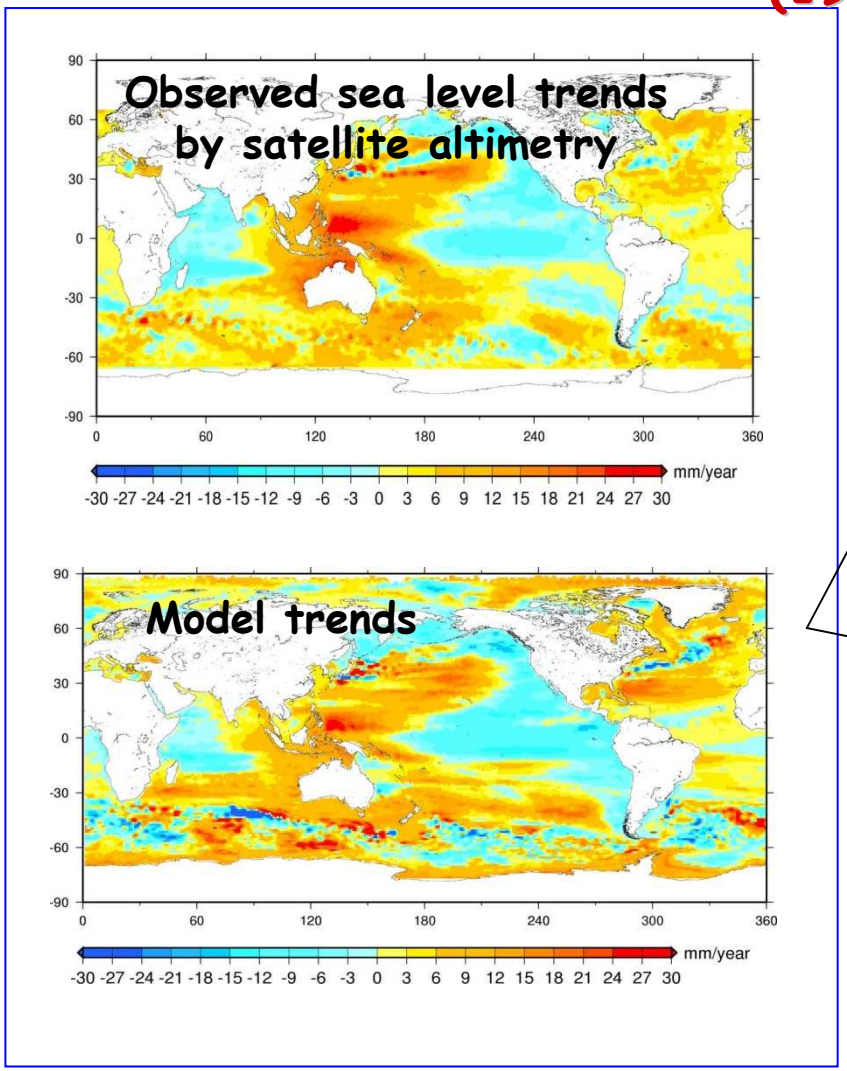


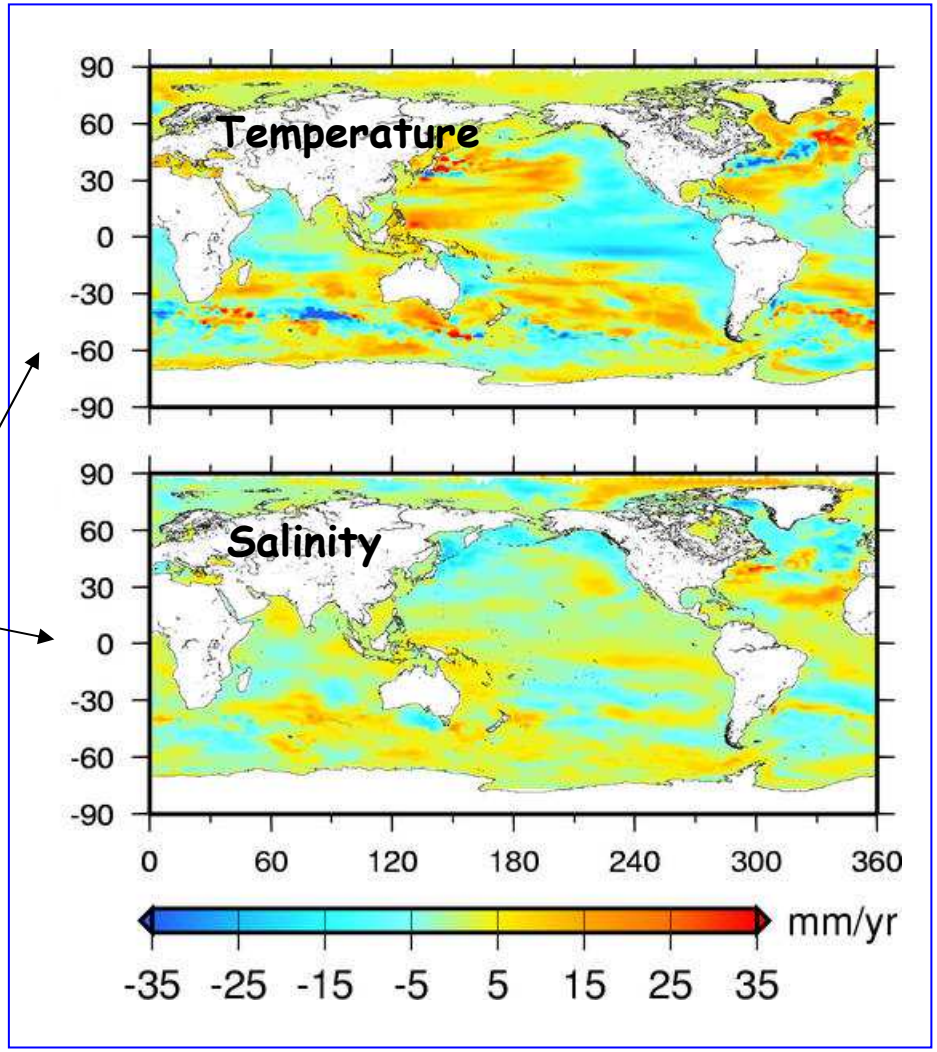
Regional distribution of sea level trends 1993-2008

Observed by satellite altimetry

Uniform trend (of 3.3 mm/yr) removed

Comparison between spatial patterns in sea level trends observed by satellite altimetry and estimated by the ORCA ocean circulation model (no assimilation) (1993-2001)

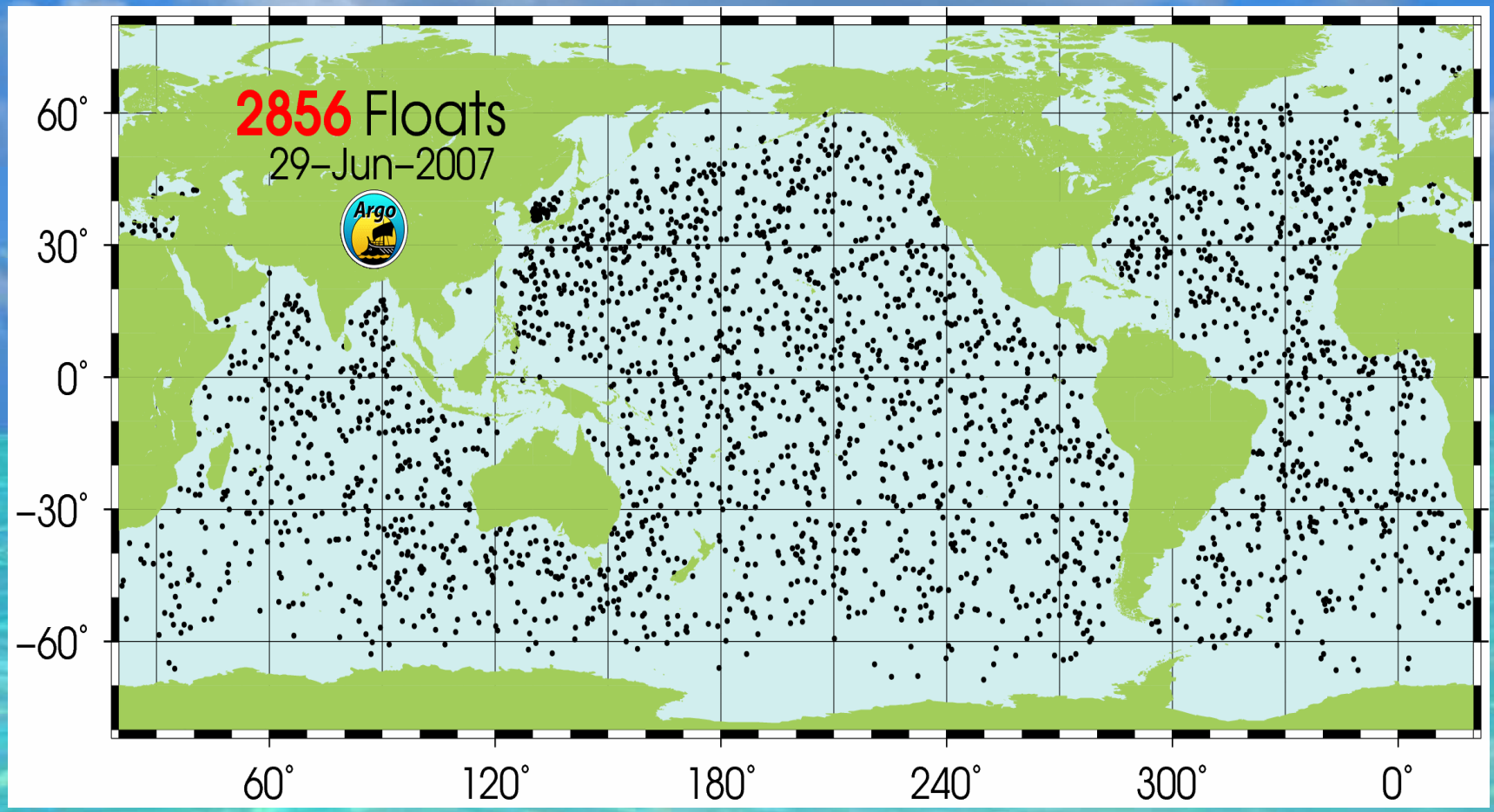


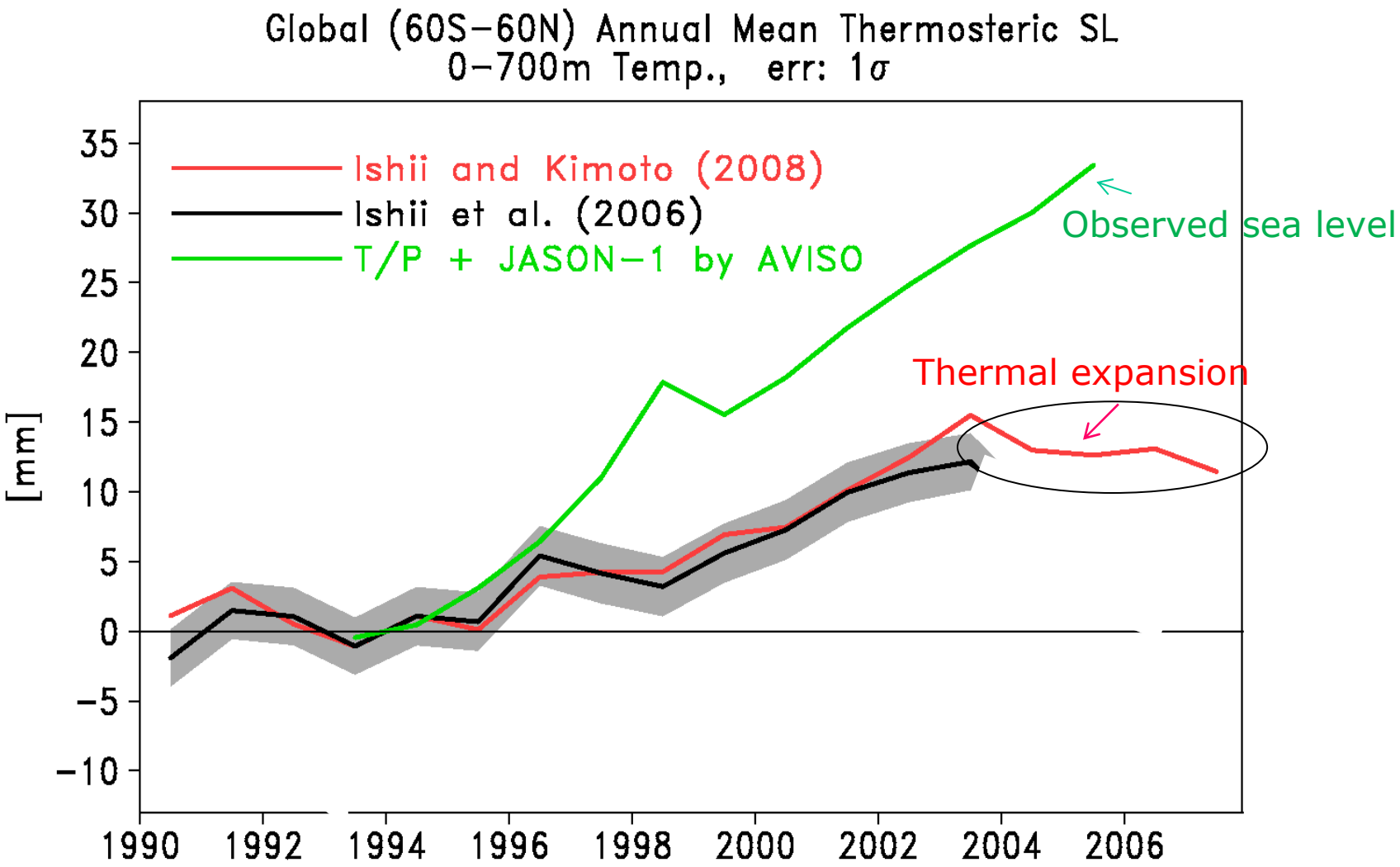


Wunsch et al. (2007);Kohl & Stammer (2008); Lombard et al. (2009)


Sea Level budget:
Comparison between observed sea level
and sum of climate contributions
(thermal expansion, land ice, land waters)
2003-2008
Surprises!

Steric sea level now estimated by Argo

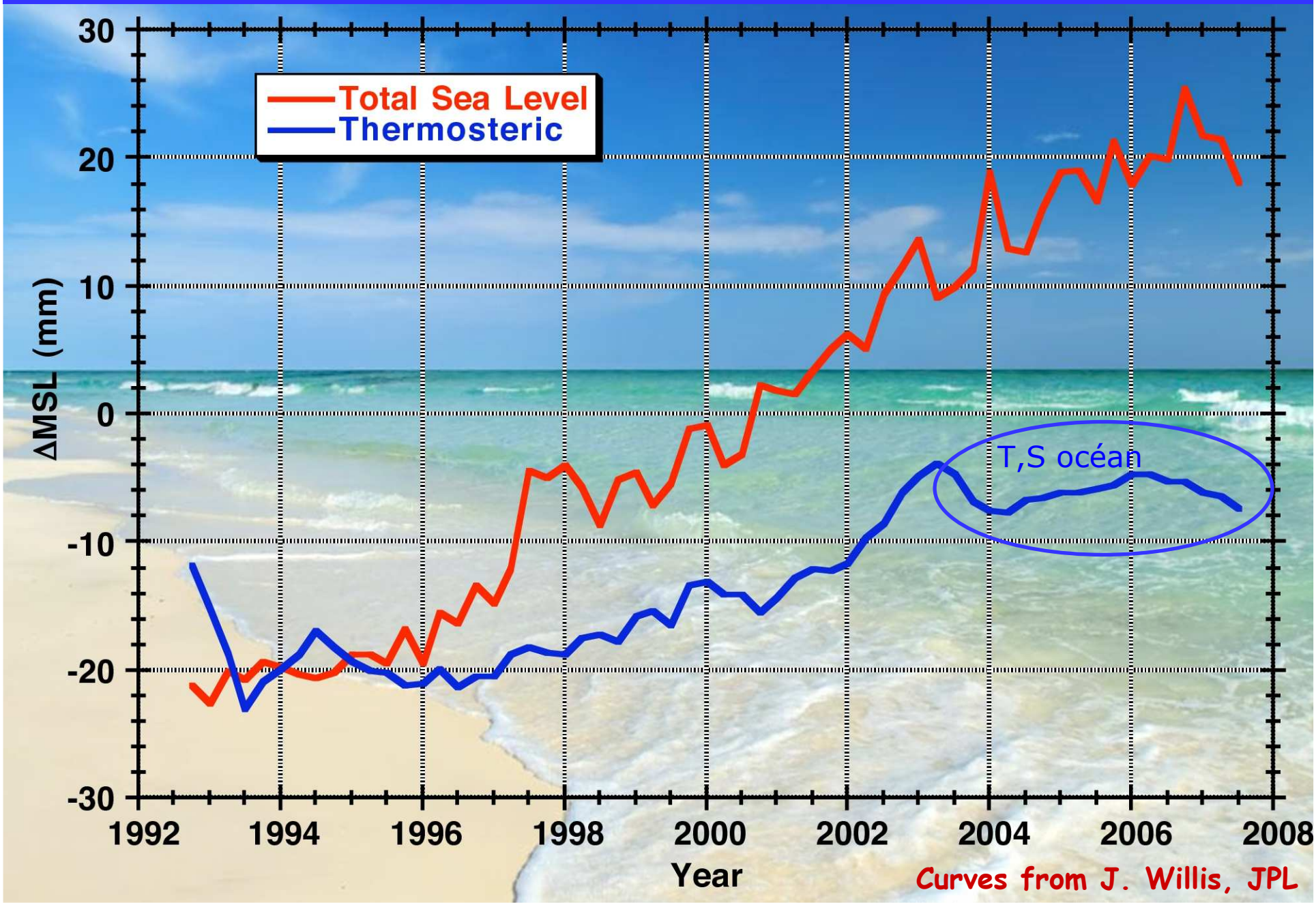




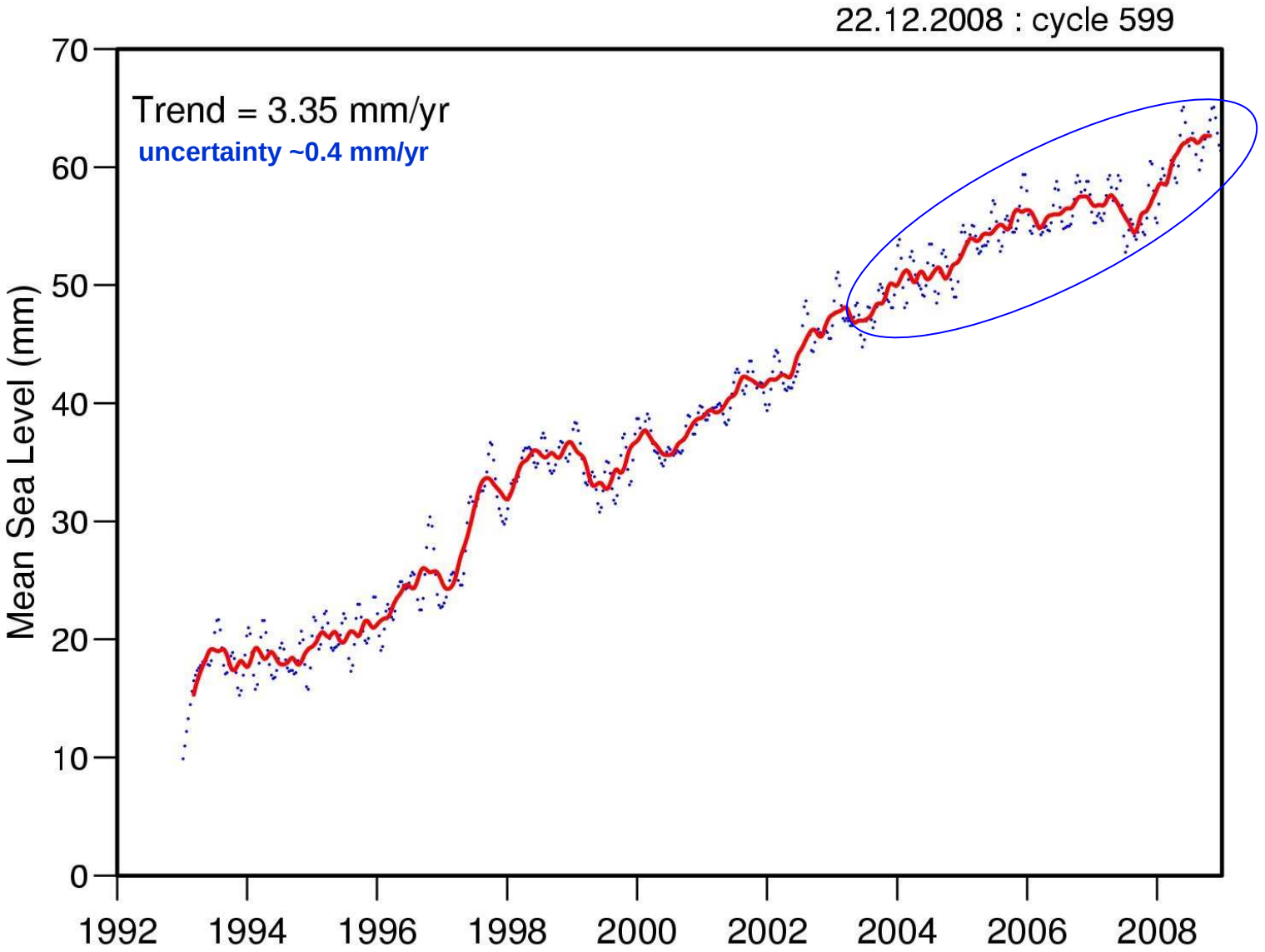
Recent thermosteric sea level change (Ishii and Kimoto, 2008)

Courtesy M. Ishii

Observed and thermosteric sea level (2003-2008)



Global mean sea level between 1993 and 2008 (Topex/Poseidon and Jason-1 satellites)



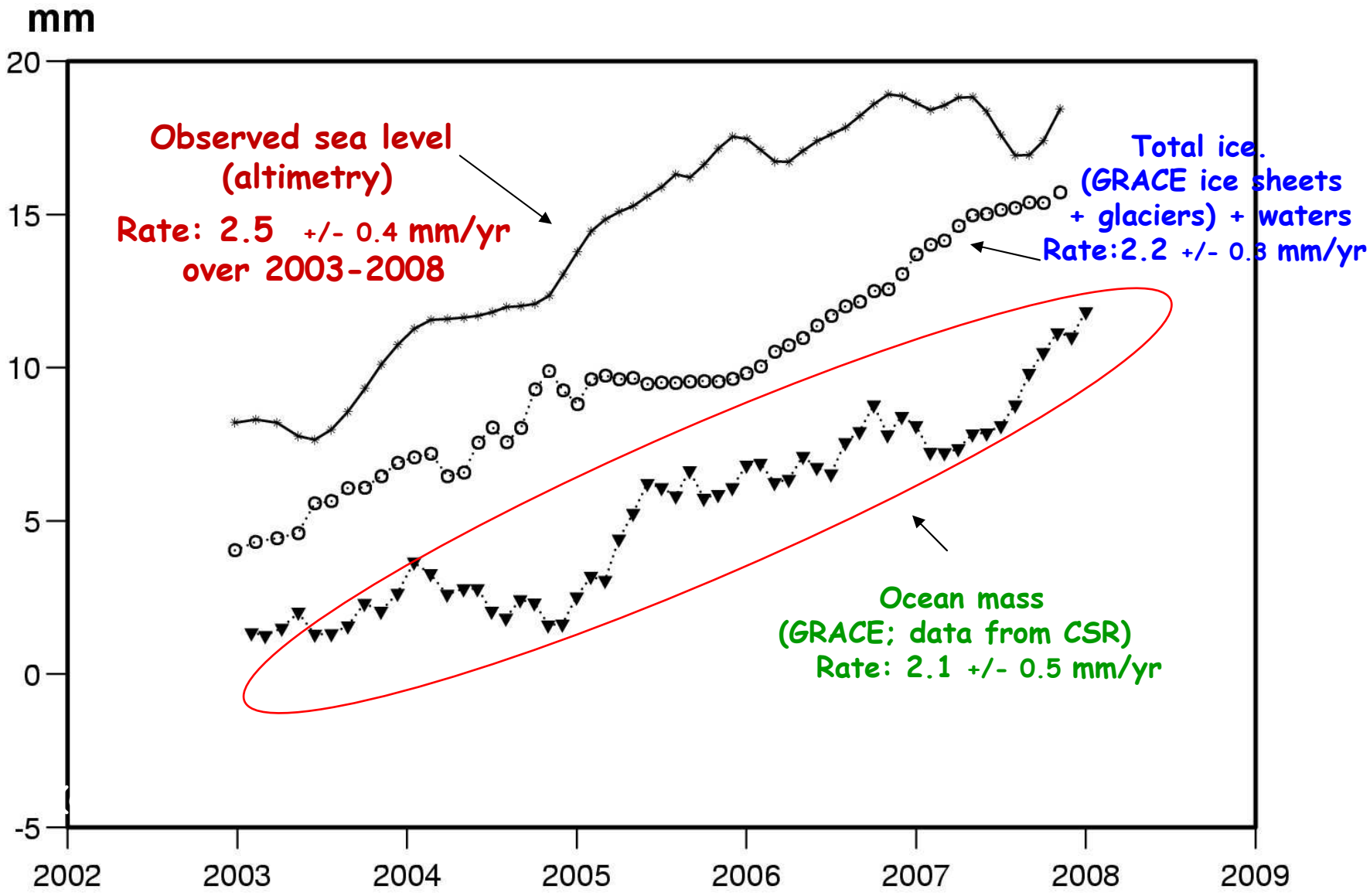

Can we explain recent sea level rise
by land ice loss only?

Space gravimetry mission « GRACE » (2002-)

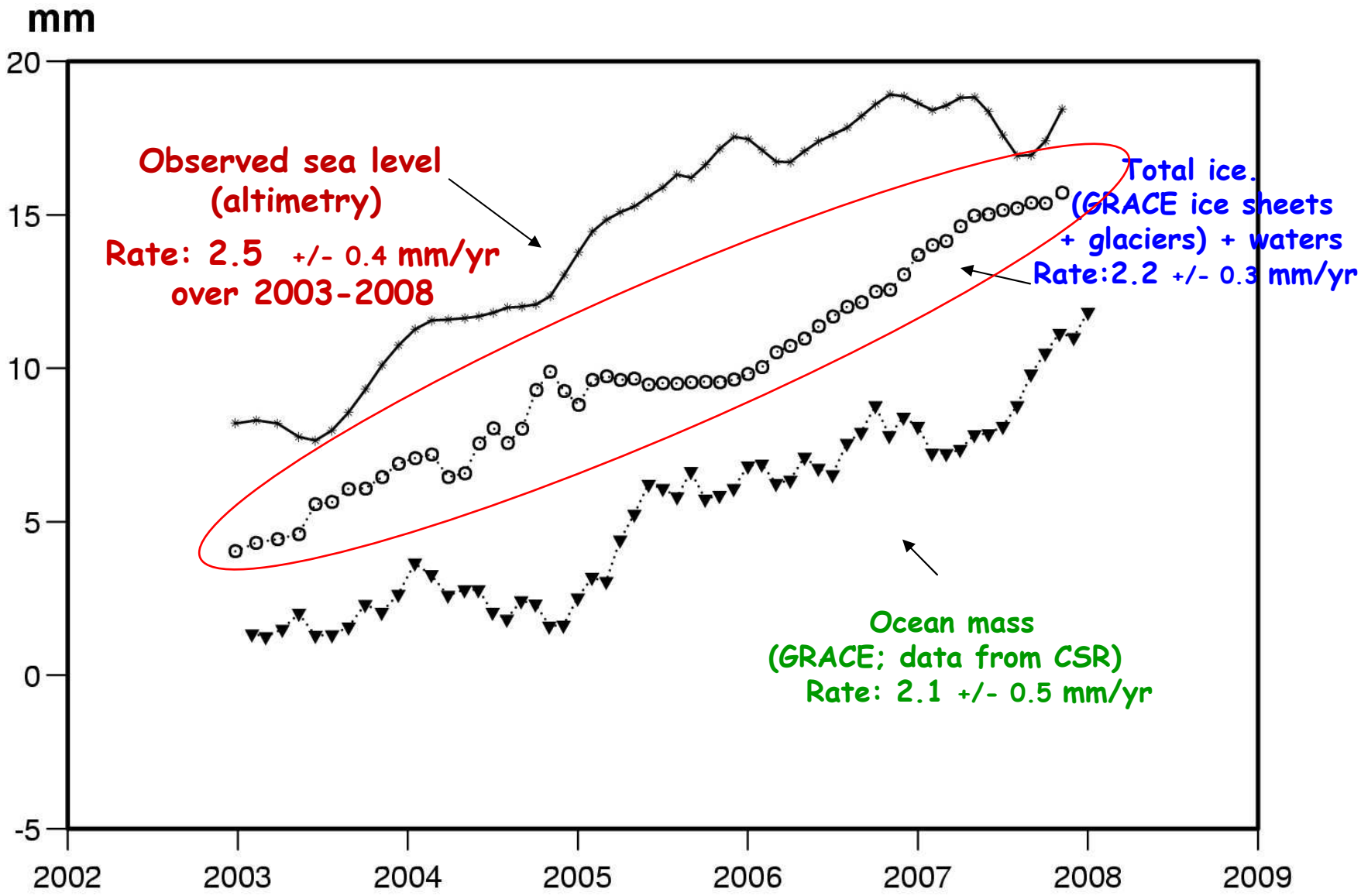
→Temporal variations of the gravity field

→ Mass redistribution inside and at the surface of the Earth

Sea Level Rise since 2003



Sea Level Rise since 2003



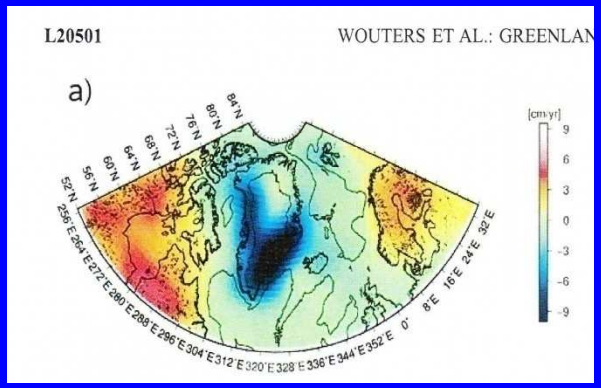
Contribution of glacier melting to sea level rise (recent years)

-Glaciers (2001-2004): 1.0 +/- 0.19 mm/yr
Kaser et al. (2006)

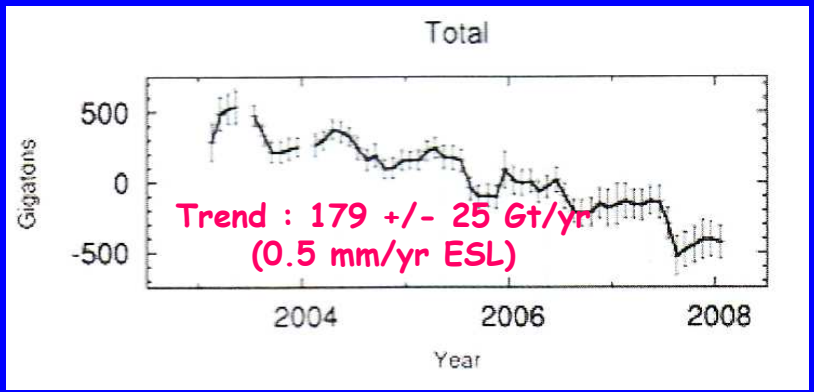
-Glaciers (2001-2005): 1.1-1.4 mm/yr
Cogley (2009)

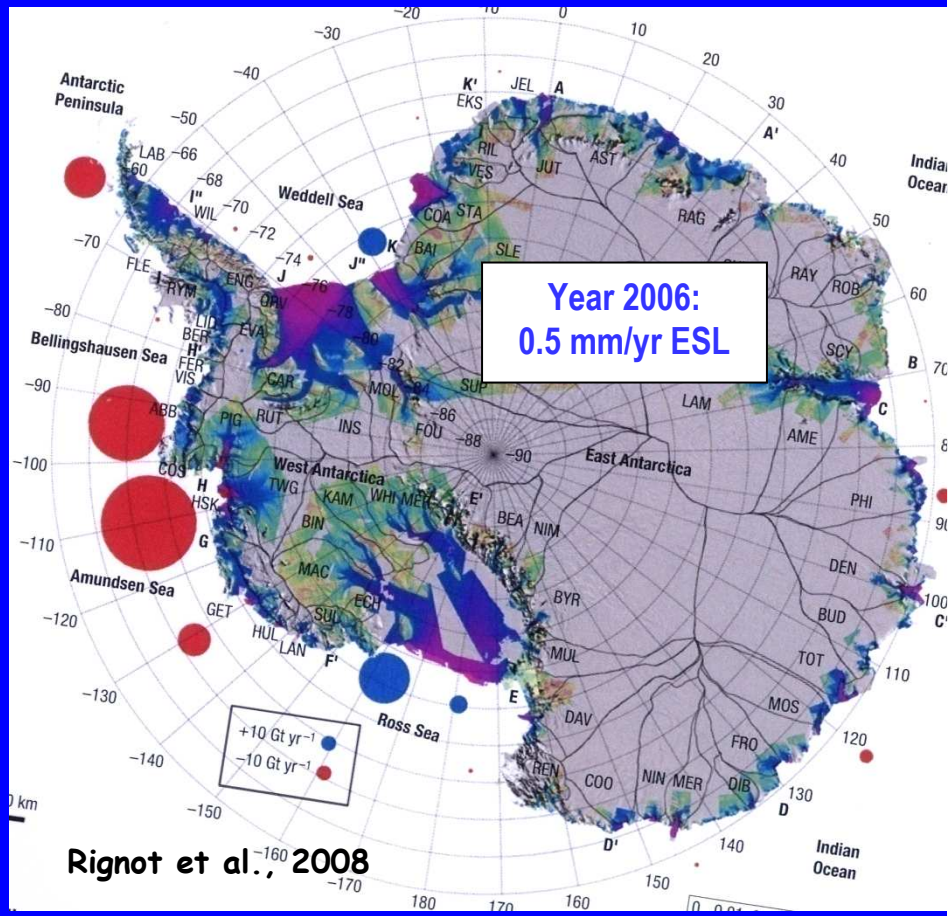
-Glaciers (2006): 1.1 +/- 0.24 mm/yr
Meier et al. (2007)

Space gravity mission GRACE (2002-)
→ Longer mass balance time series



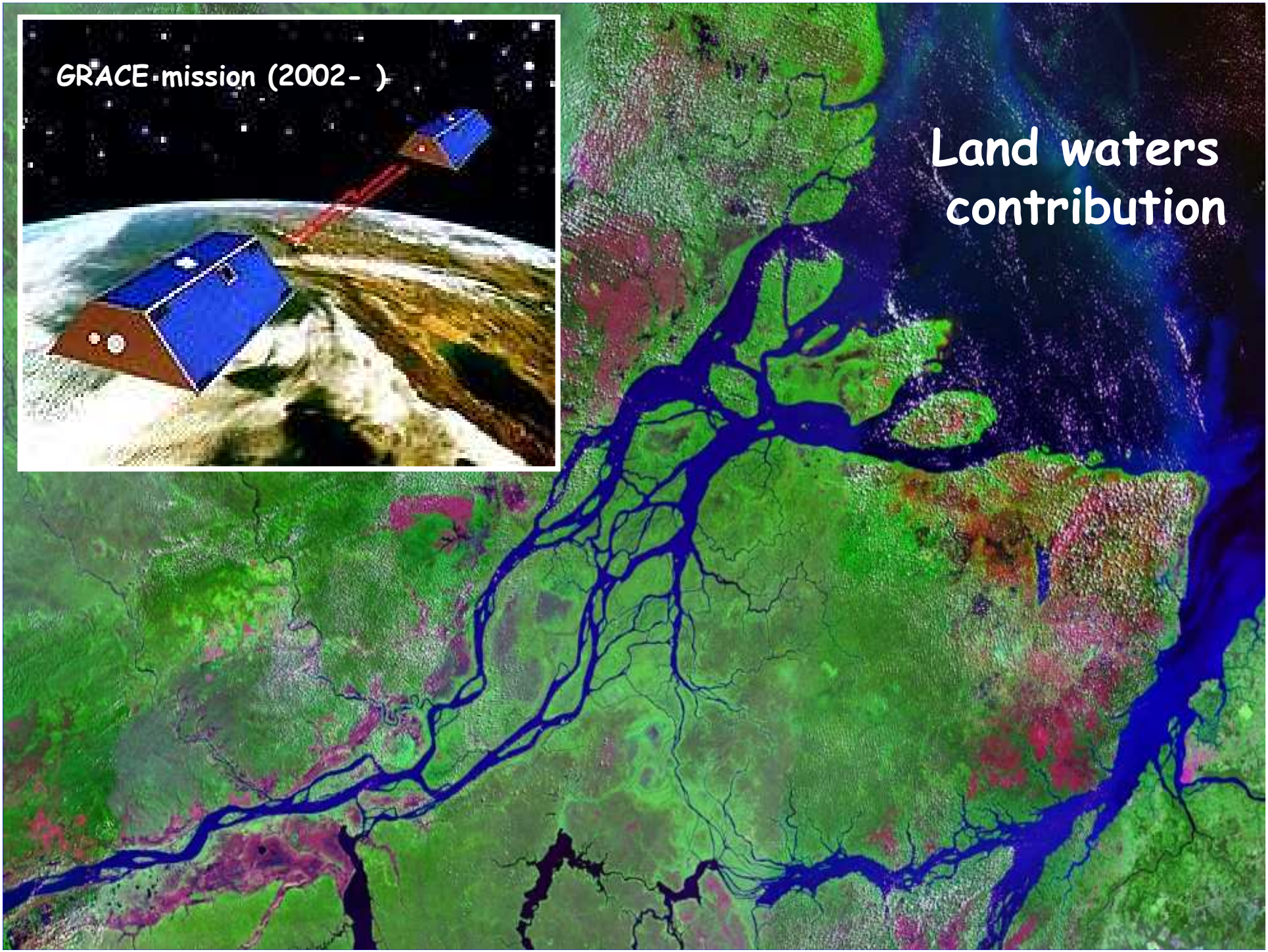
Wouters , Chambers, Schrama (2008)



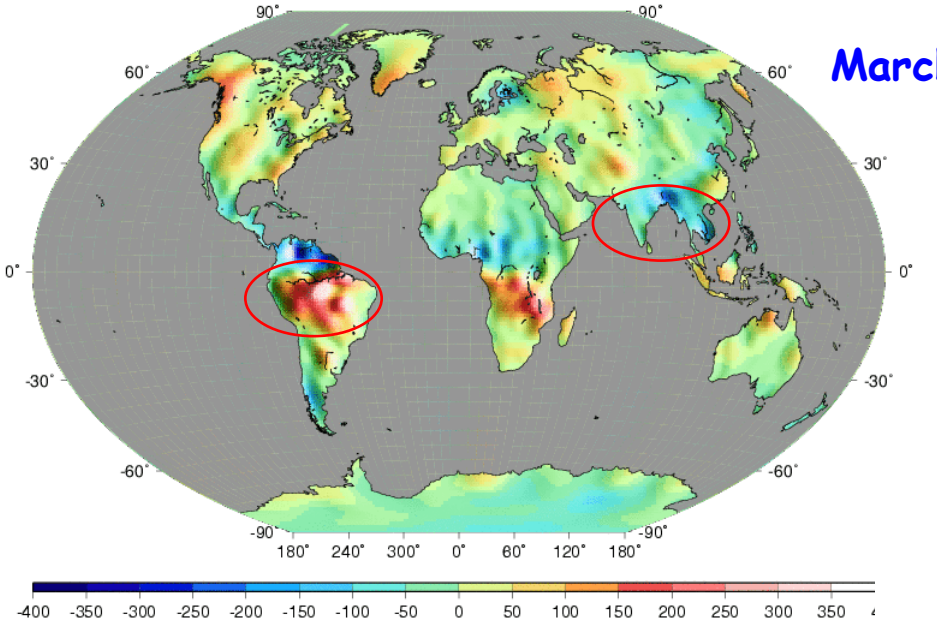


→ Ice mass loss

New results for Greenland and Antarctica ice mass loss : ~1 mm/yr over 2003-2008


GRACE-mission (2002-)
Land waters contribution

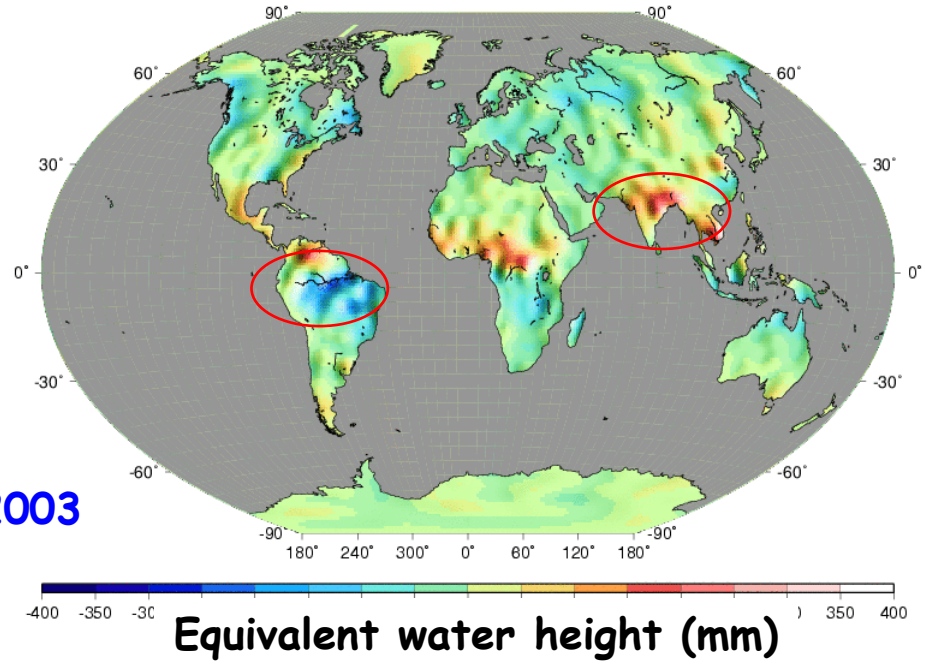
Change in land water storage from GRACE



March 2003

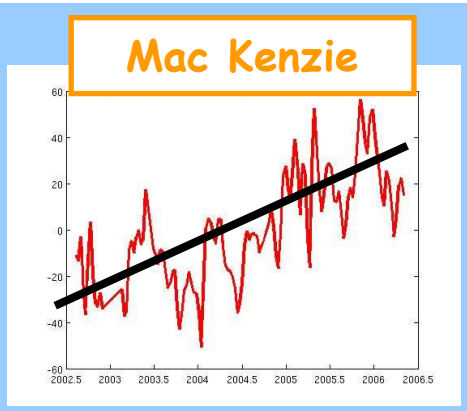
Equivalent water height (mm)

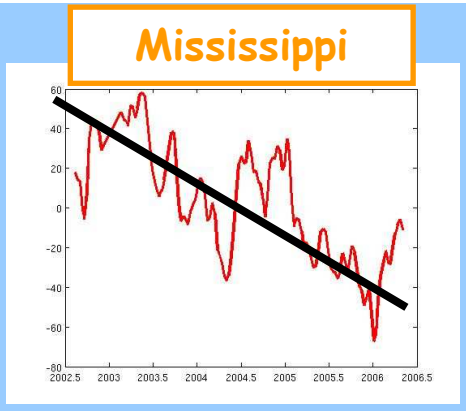
Red: water excess
Blue : water deficit

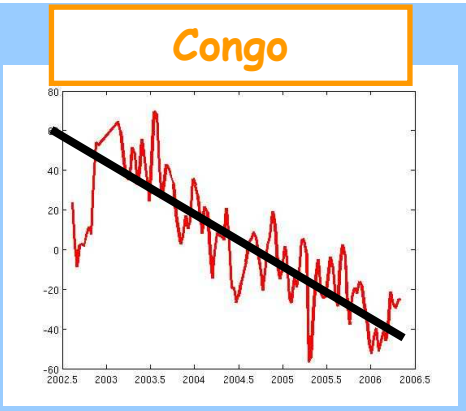


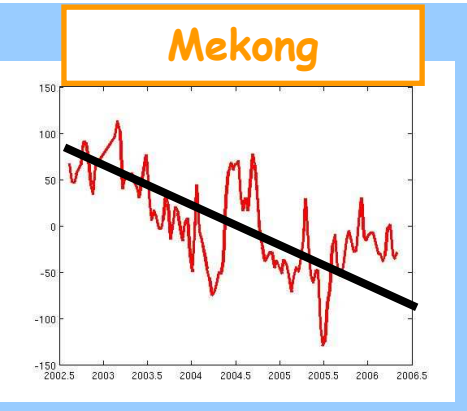
September 2003

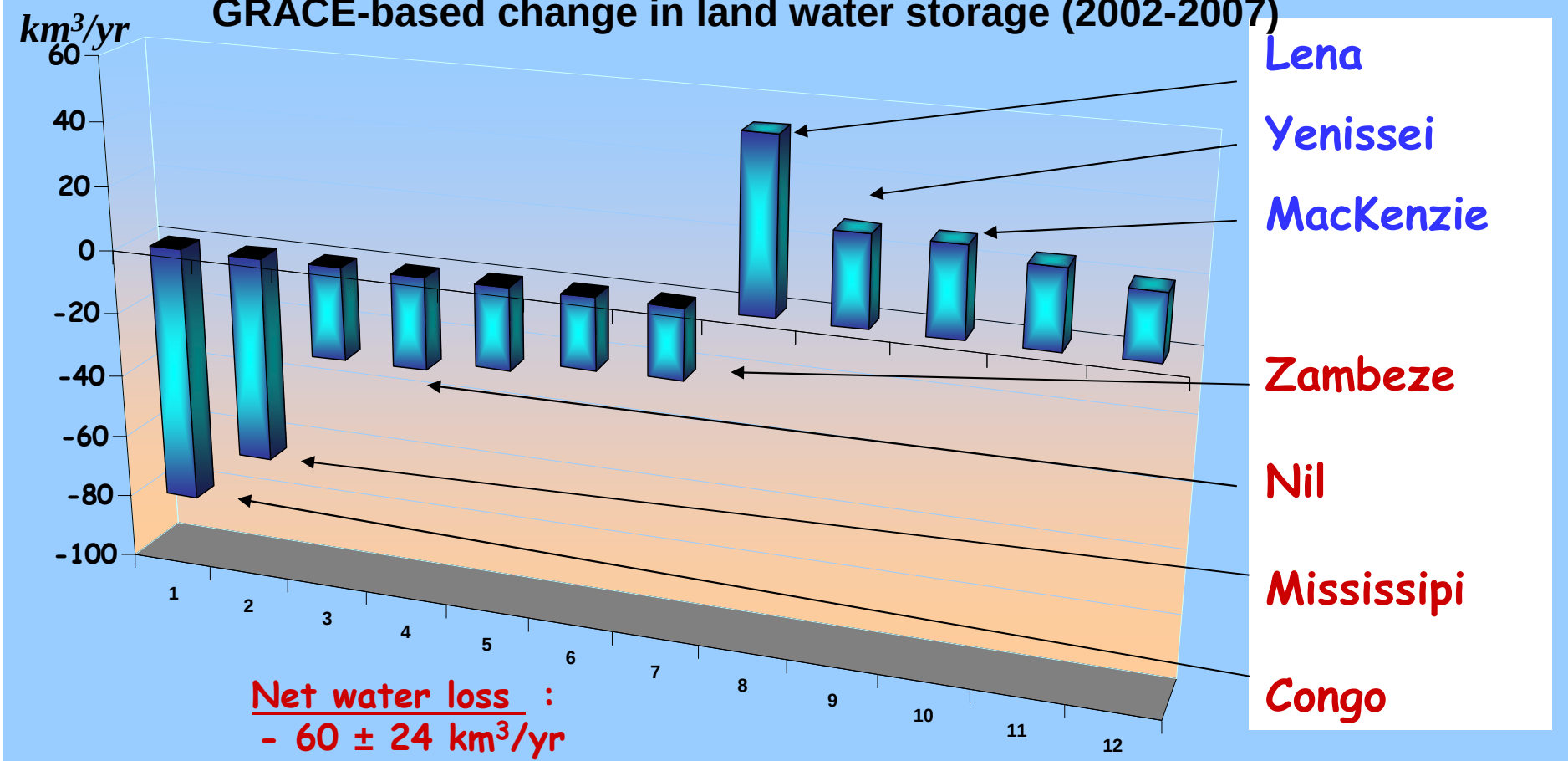
Equivalent water height (mm)





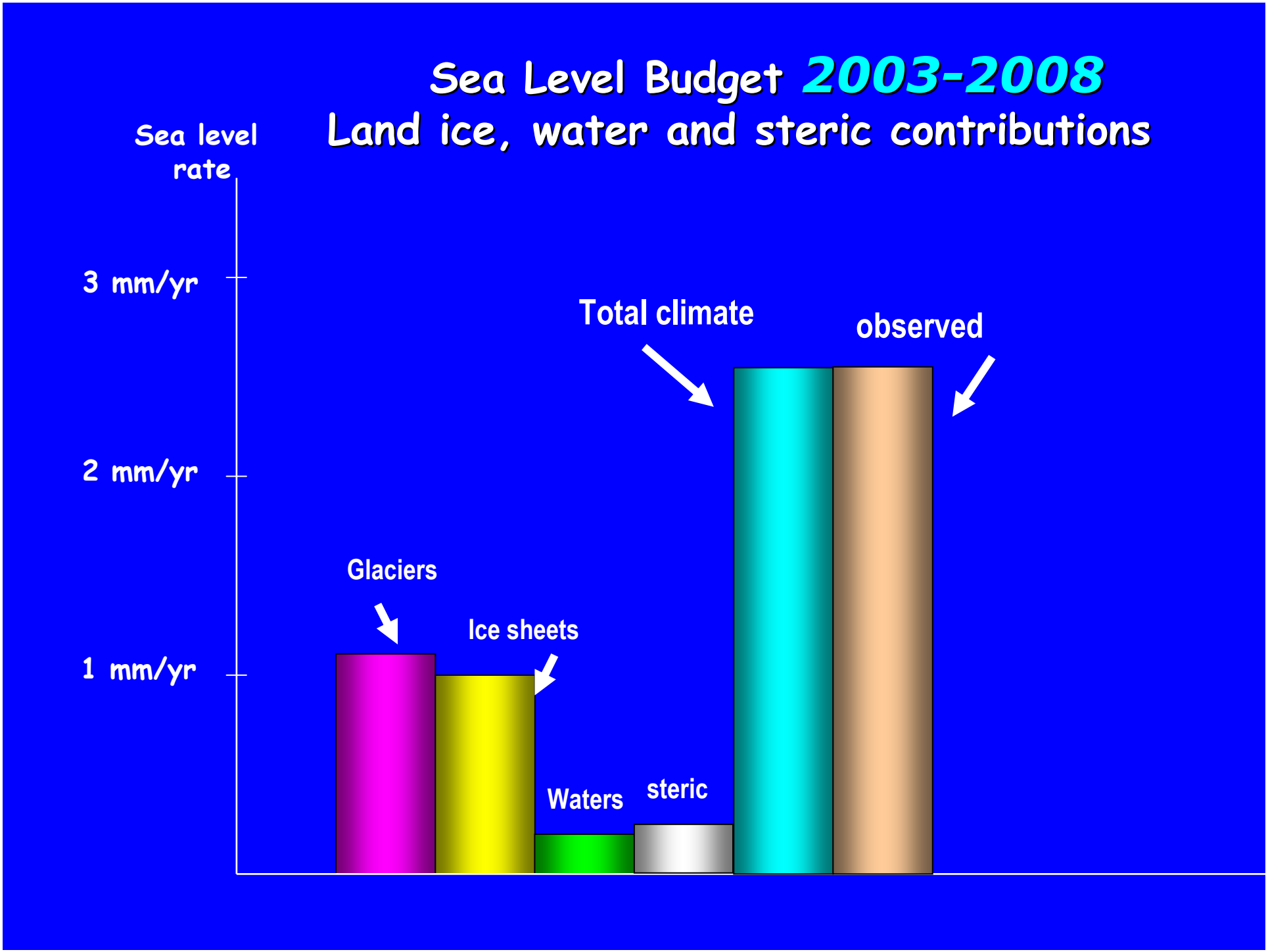






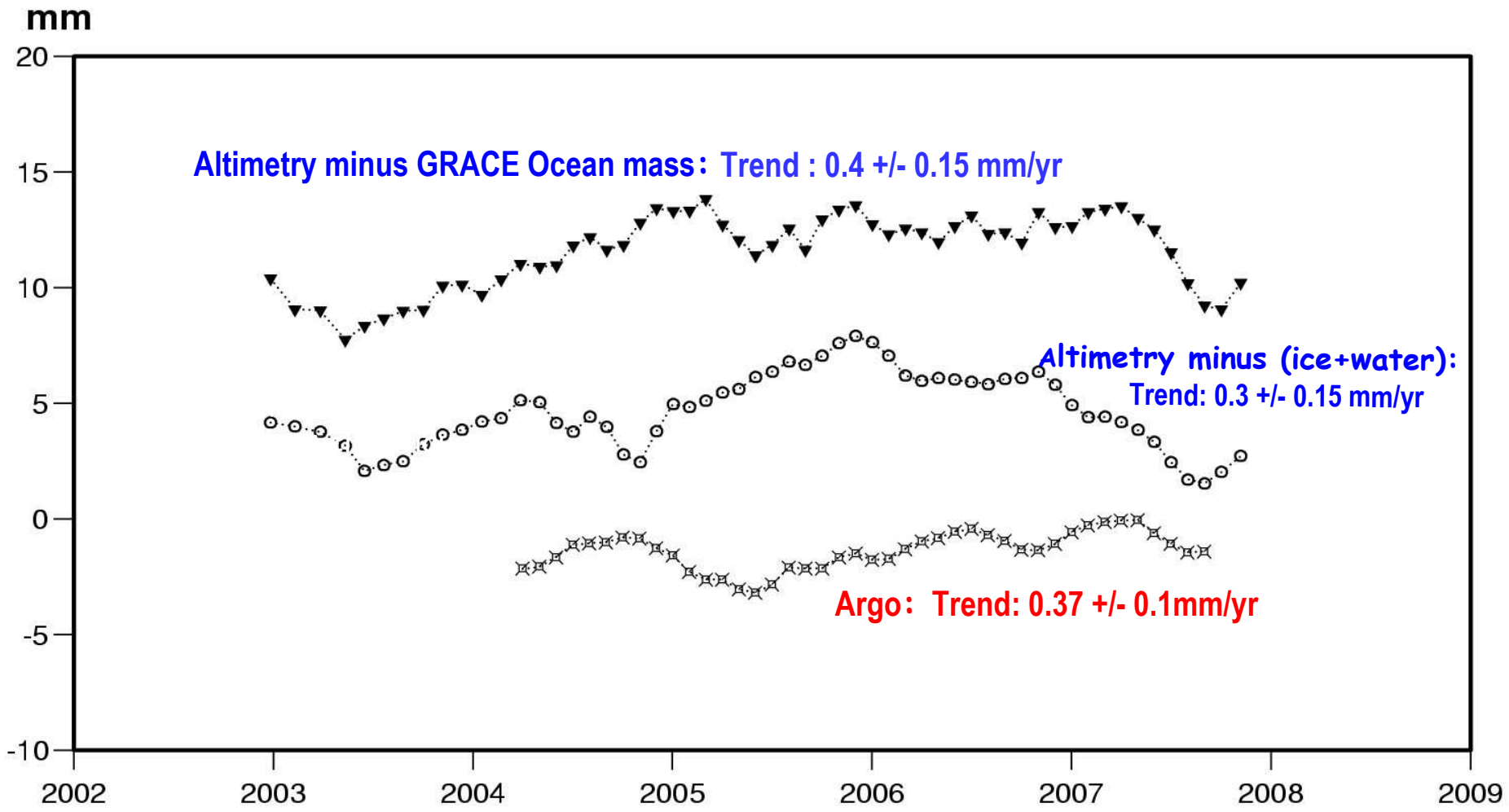
Ramillien et al. (2008)

Sea Level Budget 2003-2008
Land ice, water and steric contributions

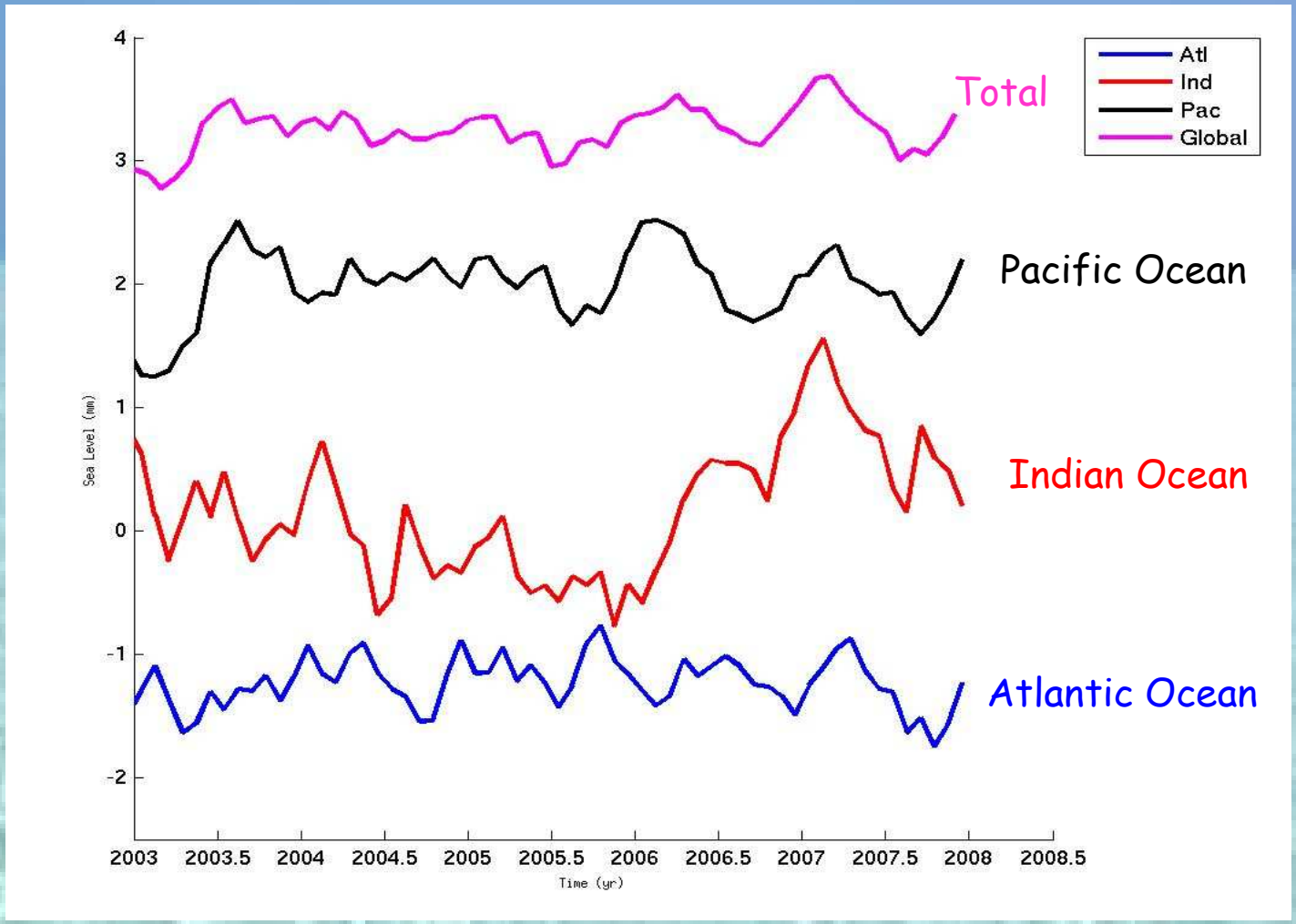


Steric Sea Level (2003-2008)

(sum of ocean temperature and salinity)



Steric Sea Level (2003-2008): contribution of each ocean



Concluding remarks

Sea level is still rising but causes are different:

1993-2003 : Ocean thermal expansion 50%
Land ice 40%

2003-2008 : Land ice 80%!
Ocean thermal expansion: <20%


End
CRDS
SRI
IYYAN
RSPR
OLIC RELIEF SERVICES