

**Present-day global mean sea level rise:
Observations and causes
a brief review**

Anny Cazenave

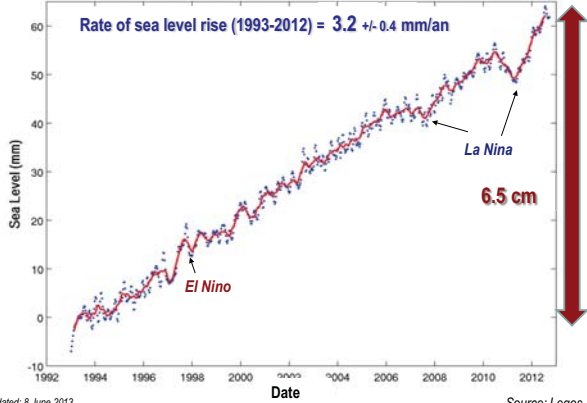
Collège de France & LEGOS, Toulouse

with contributions from E. Berthier, H. Boubacar Dieng, O. Henry, B. Meyssignac, H. Palanisamy – LEGOS- & W. Llovel (JPL), J. Wahr (Univ. Colorado)

Since the early 1990s, sea level is precisely and globally measured by altimeter satellites



Global mean sea level from satellite altimetry

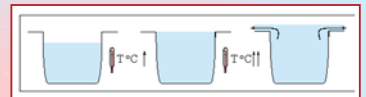


Updated: 8 June 2013

Source: Legos-CLS

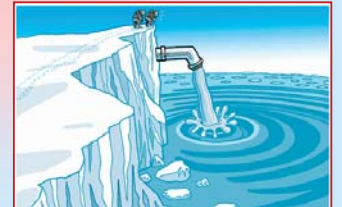
2 causes ...

-Ocean thermal expansion changes



-Ocean mass changes

- **Glaciers**
- **Ice sheets**
- **Land waters**
- **Atmospheric water vapour**

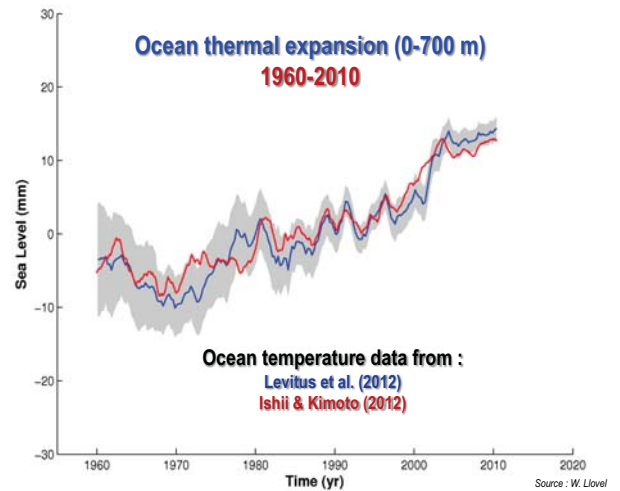


Since 1-2 decades, different observing systems for estimating these contributions

Thermal expansion changes

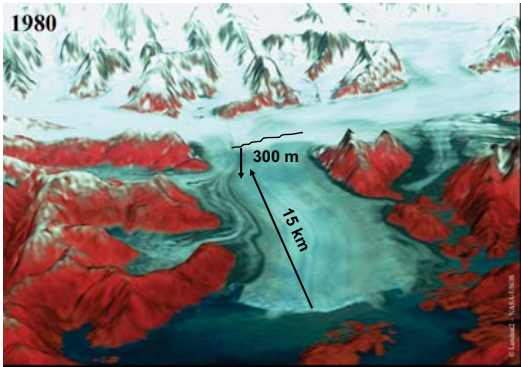
Mass changes

**Ocean thermal expansion (0-700 m)
1960-2010**



Source: W. Llovel

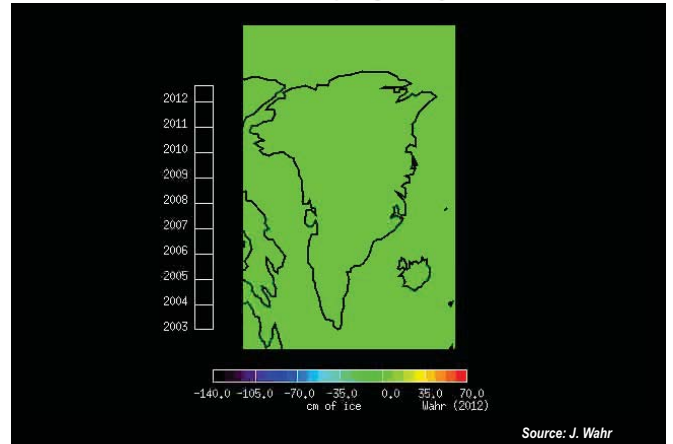
Retreat and thinning of glaciers estimated by satellite imagery



Columbia glacier (Alaska) in 1980 and 2007

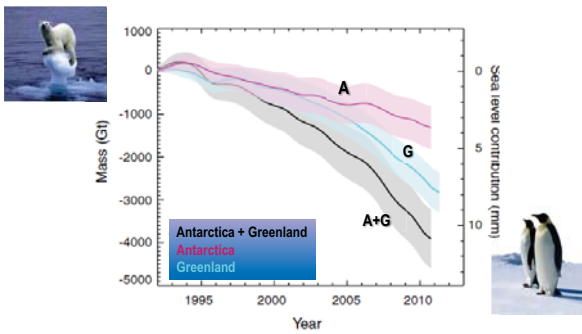
Berthier et al. 2010

Ice mass loss from the Greenland ice sheet between 2003 and 2012 (blue-violet-dark) from GRACE space gravimetry



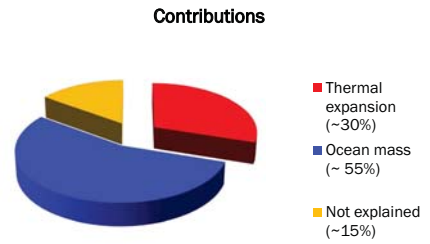
Source: J. Wahr

Ice sheet mass loss measured by different space techniques since 1992 (in Gigatons)



Recent update from Shepherd et al., 2012

Components of the global mean sea level (1993-2012)



Sources: Church et al., 2011, Hanna et al., 2013, LEGOS studies, etc.

Since ~ 2003, Argo + GRACE → upper ocean thermal expansion + ocean mass

Thermal expansion of the upper ocean (0-1500 m)

Argo

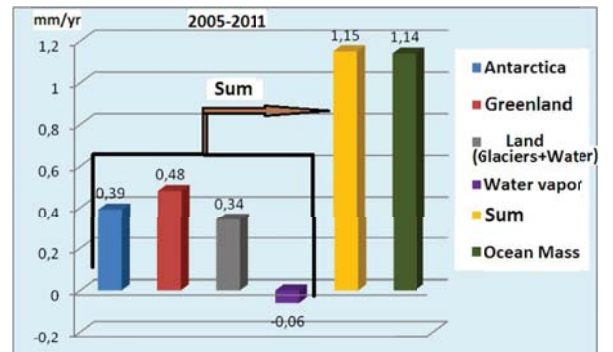
GRACE
Gravity Recovery And Climate Experiment

mass changes

ocean mass

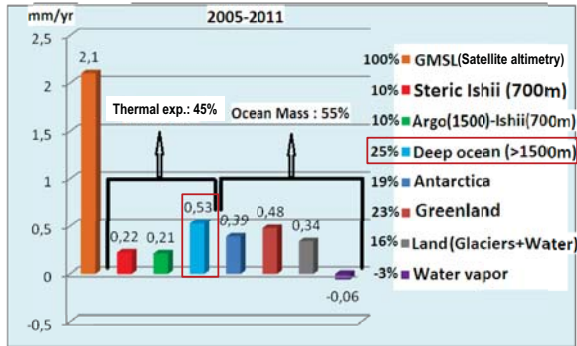
Glaciers, ice sheets, land waters

2005-2011: Ocean mass change from GRACE and individual components



From H. Boubacar Dieng, LEGOS

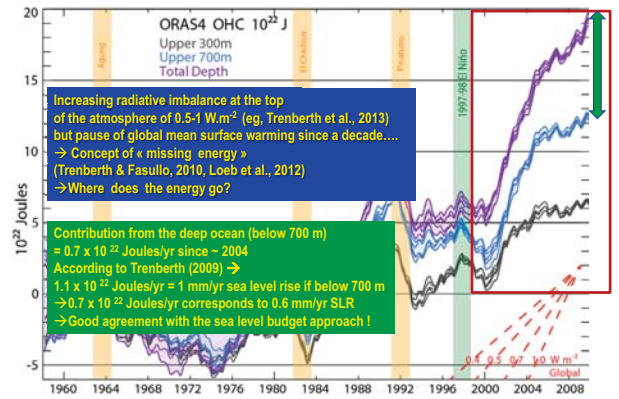
2005-2011: Observed global mean sea level rise and estimated individual contributions from Argo, GRACE and other data



→ Allows estimating the (unknown) contribution from the deep ocean

From H. Boubacar Dieng, LEGOS

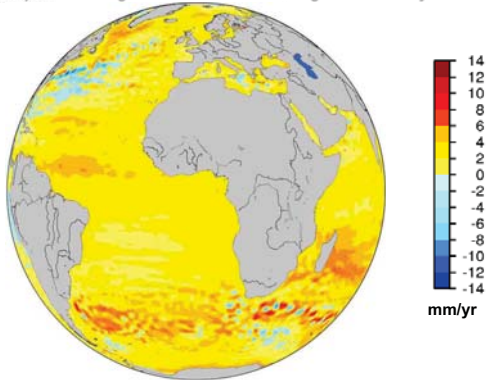
Ocean Heat Content from the ORAS4 reanalysis



Balmaseda et al., 2013

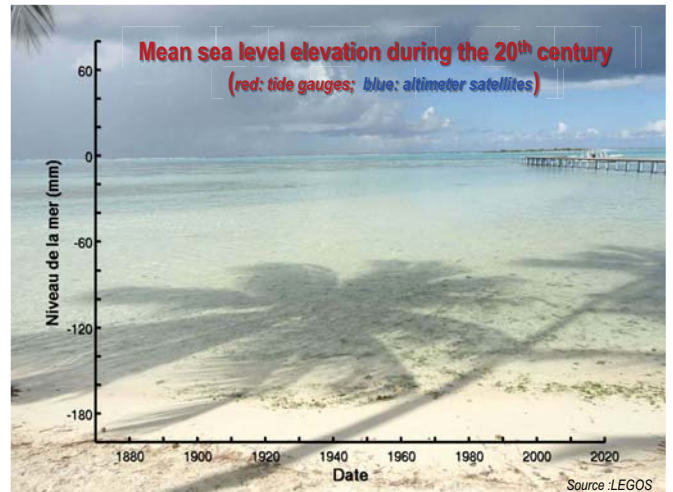
Spatial trend patterns in sea level from satellite altimetry (1993-2012)

Superimposed to the global mean sea level → regional variability



Source: O. Henry, LEGOS

Mean sea level elevation during the 20th century
(red: tide gauges; blue: altimeter satellites)



Source :LEGOS