SEA LEVEL RISE

Regional and global trends

OCEANOBS 2009 Plenary Paper

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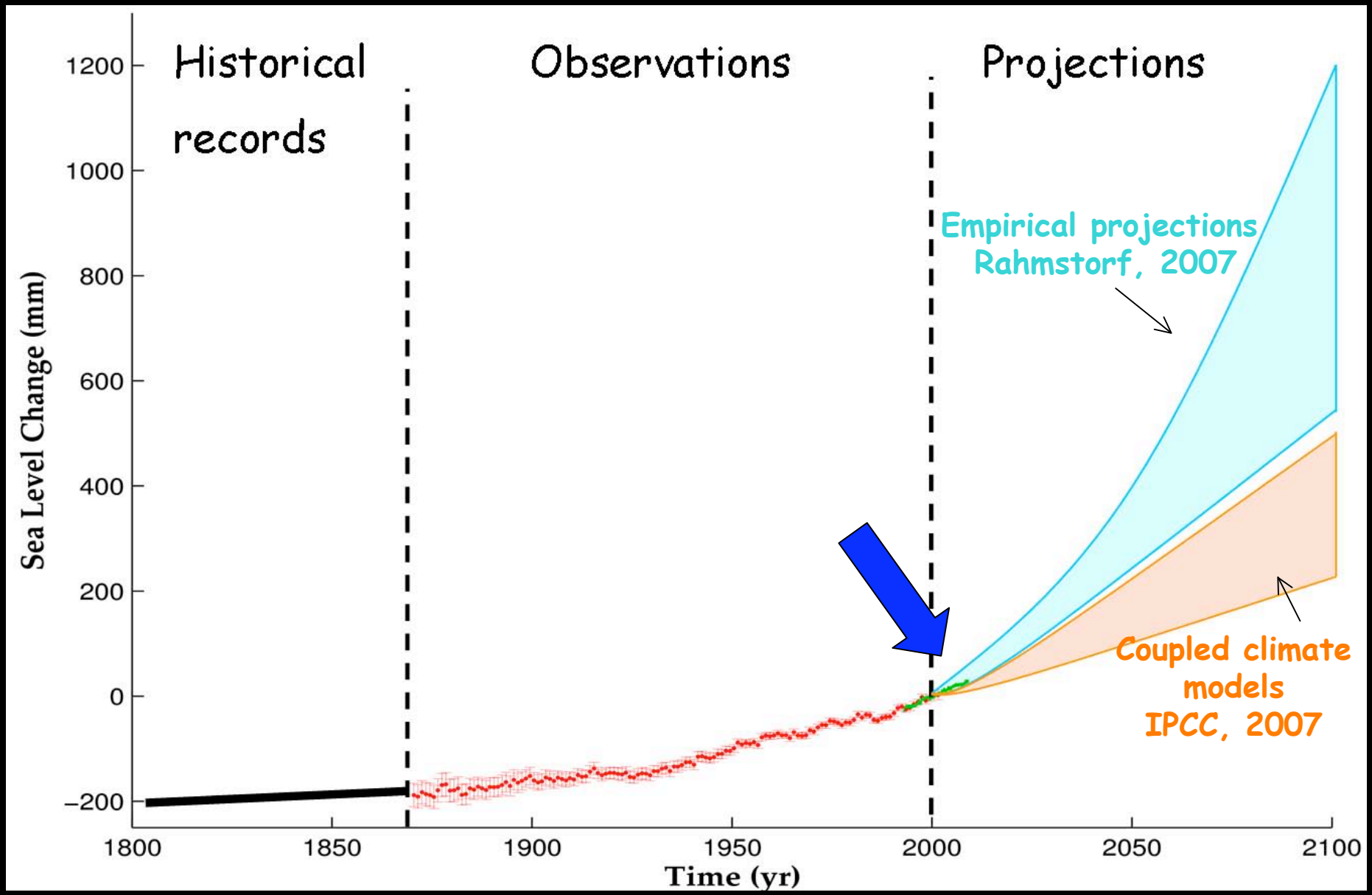
Global mean sea level evolution since 1800



Importance of sea level studies:

- Major consequence of global warming
- Numerous coastal regions under threat in the coming decades if sea level rise accelerates
- Sea level rise: a global problem involving the whole climate system and the solid Earth

Main recommandations

I. Continuity of observations (multi-decade-long records)
(Altimetry/sea level; Argo/Temperature & salinity; GRACE/mass changes)

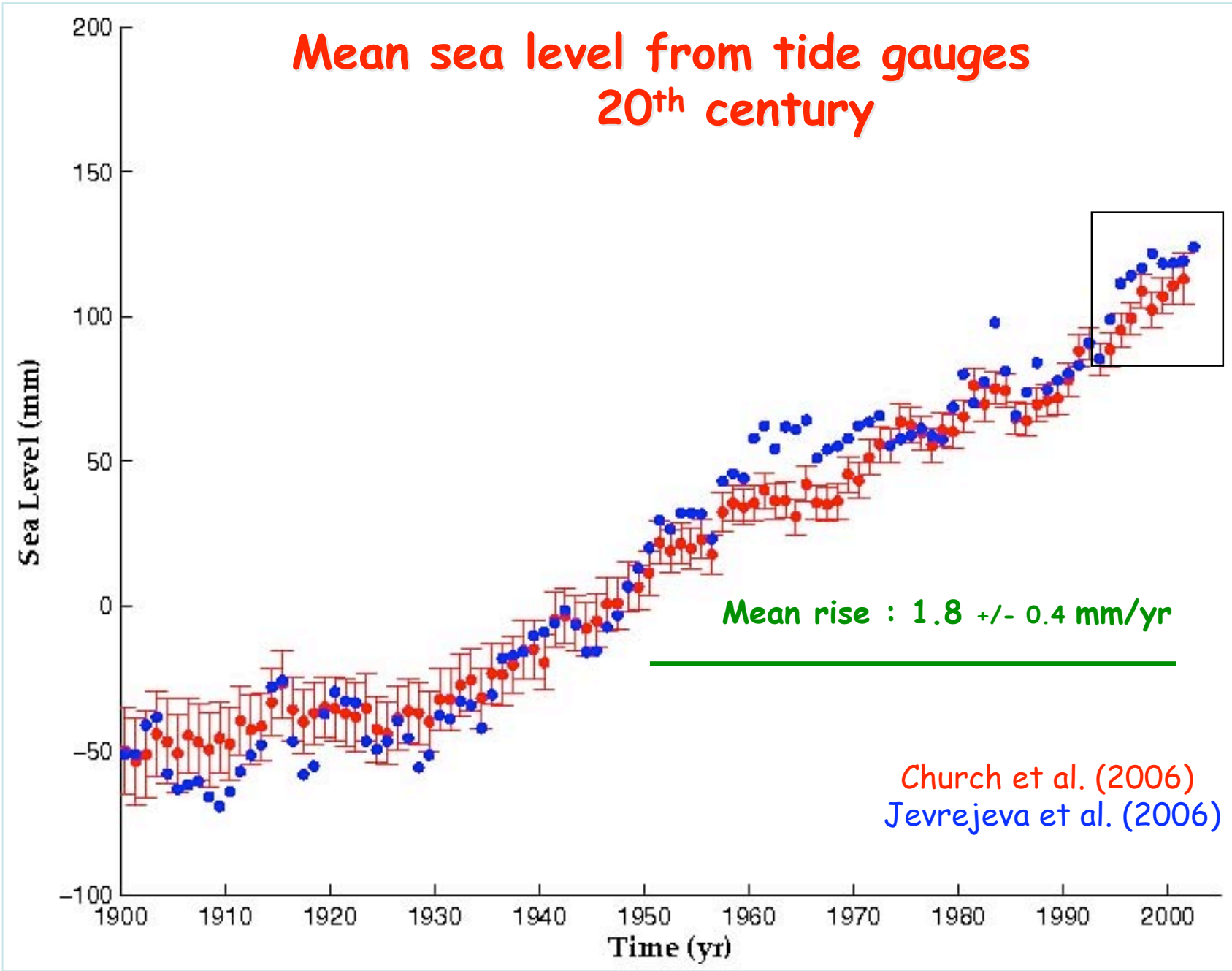
II. Accuracy (sea level rate → 0.1 mm/yr):
Calibration (altimetry→ tide gauges; Argo→CTD)

III. Modeling efforts

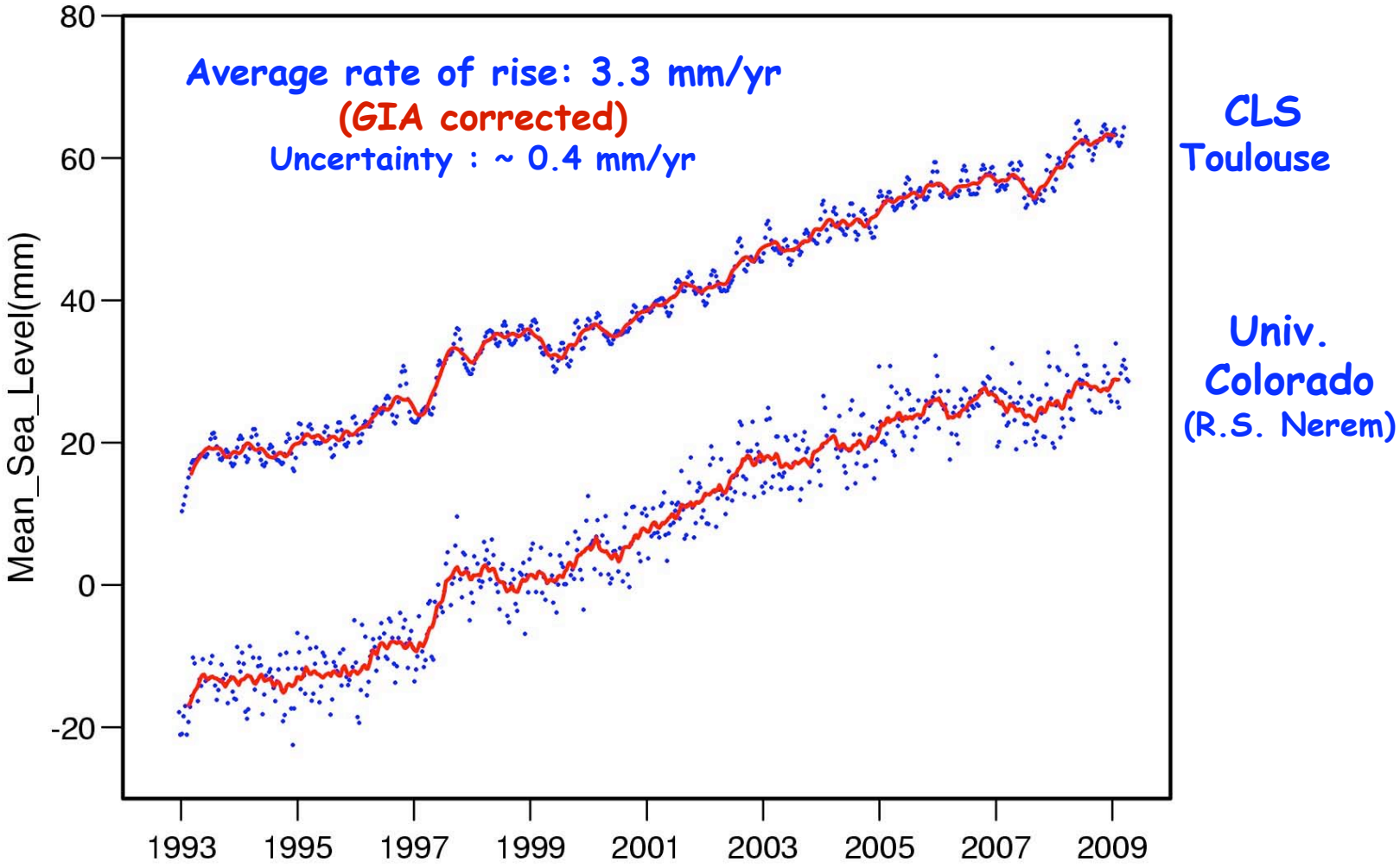
- Integrated sea level studies (2-D; past decades)
- Coupled climate model projections (21st century)
  - Ice sheet dynamics
  - Regional/decadal variability


20th century sea level rise:
What tide gauges and satellite altimetry have told us?

Mean sea level from tide gauges
20th century

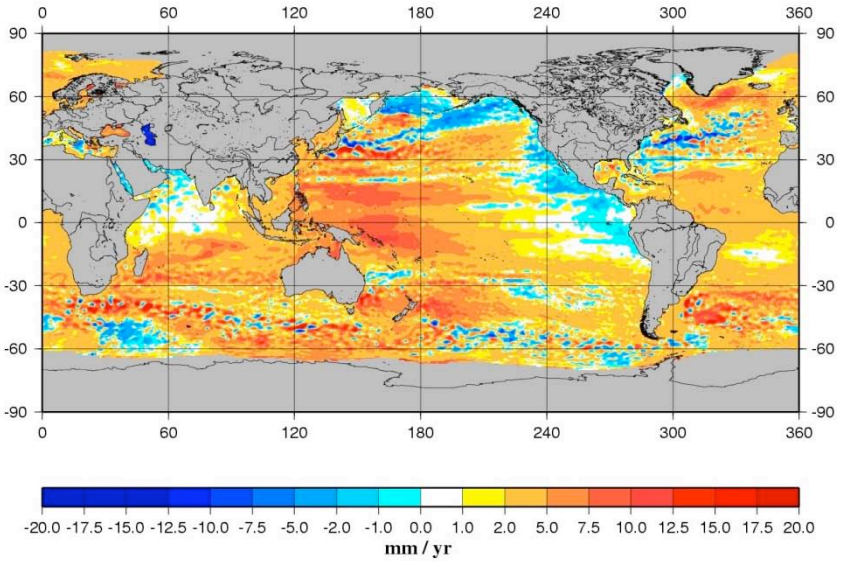


Global mean sea level (1993 to 2008)
Topex/Poseidon and Jason-1/2 satellites

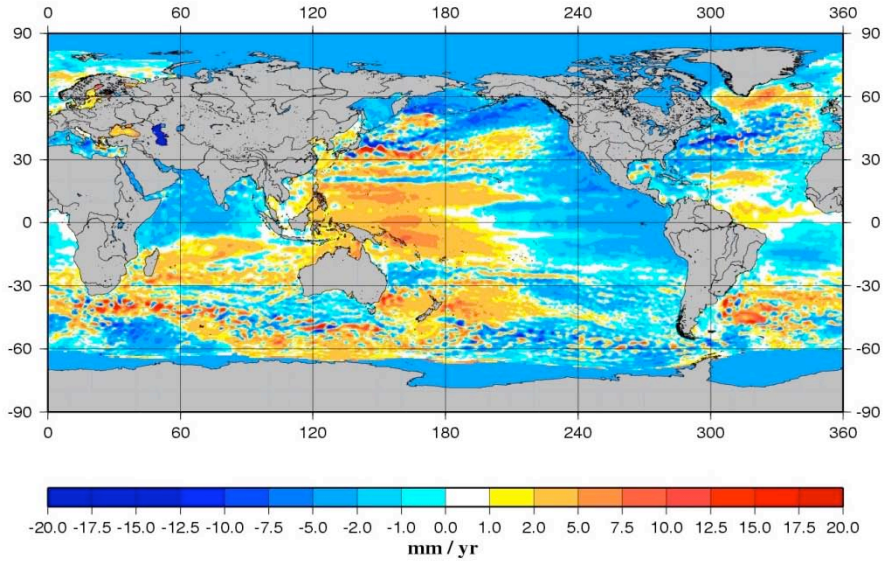


Regional variability in sea level trends

Observed spatial trend patterns from satellite altimetry 1993-2008



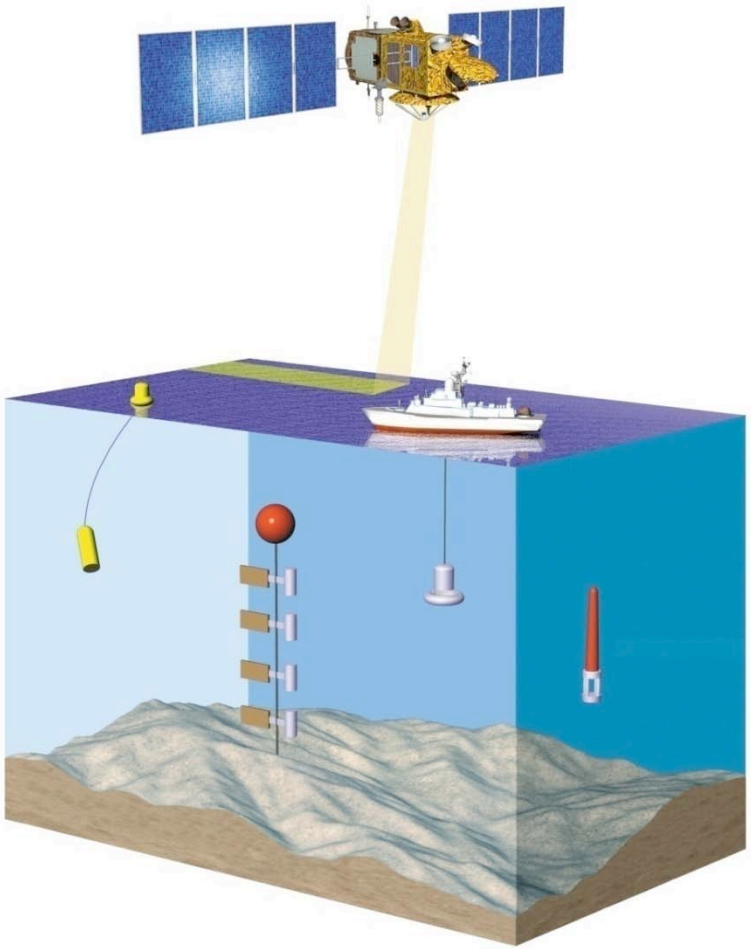
With uniform mean trend
(3.3 mm/yr)

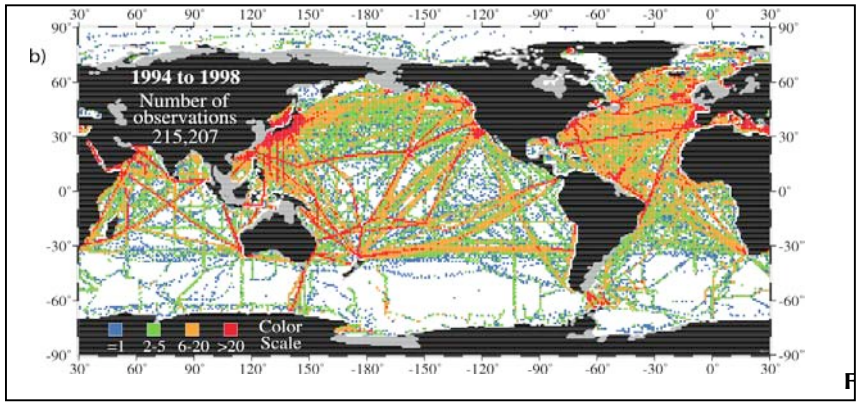


Without uniform mean trend

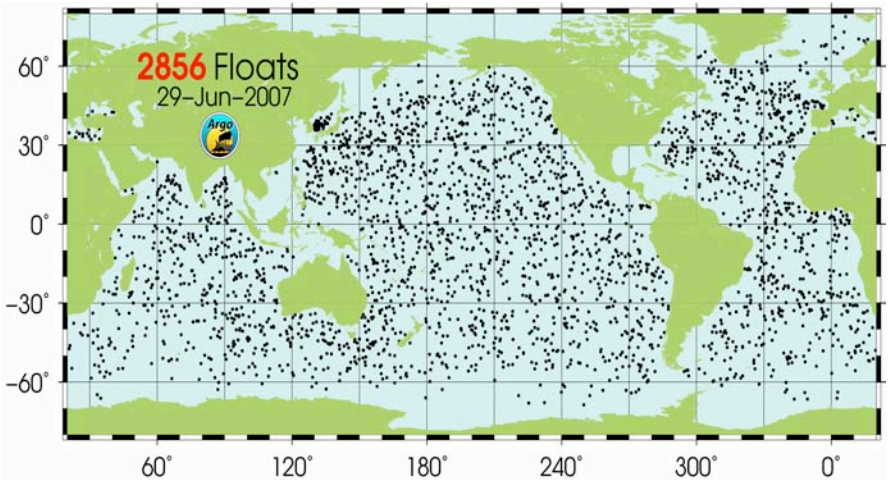

What have we learned
about the causes of sea level rise
at global & regional scale?

Ocean temperature and salinity measurements



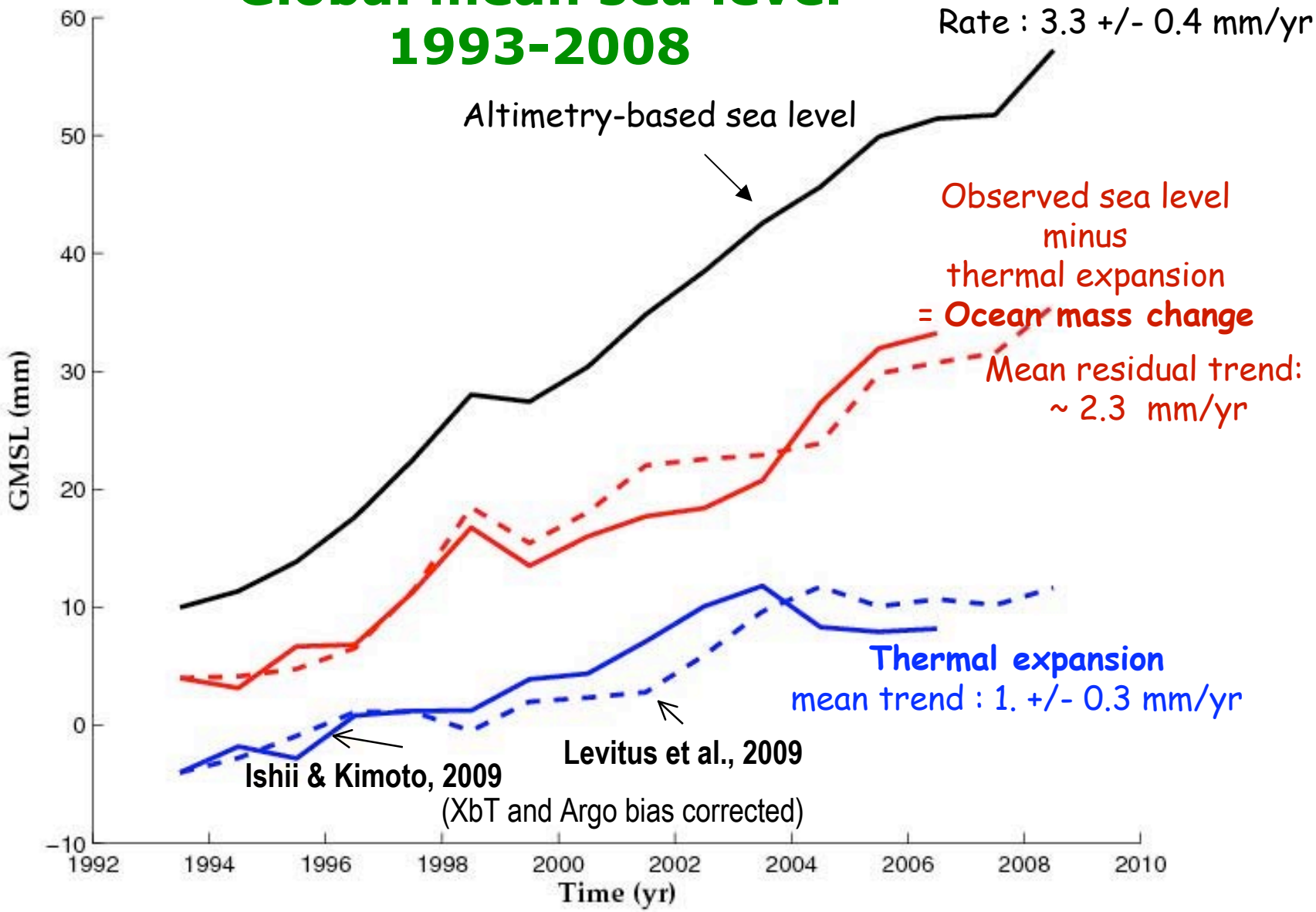


Until ~ 2003

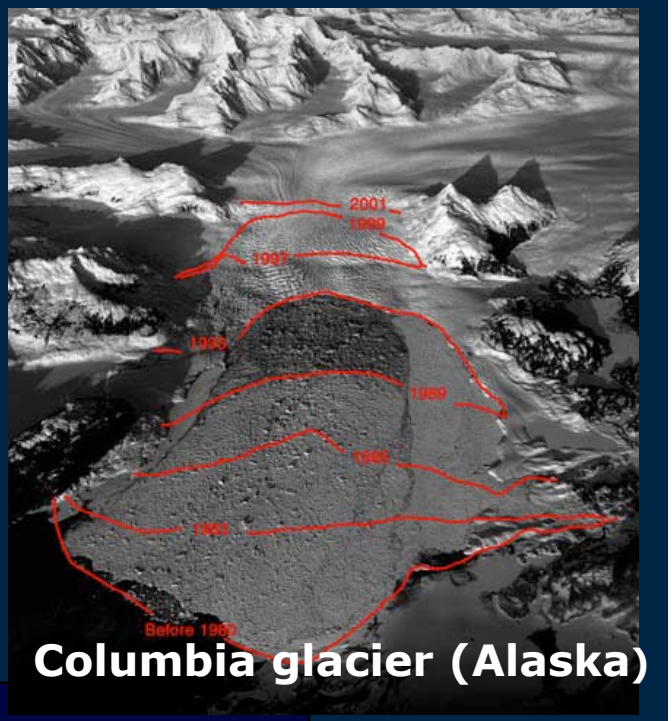


Since ~2003: Argo

Global mean sea level 1993-2008



Land Ice Loss

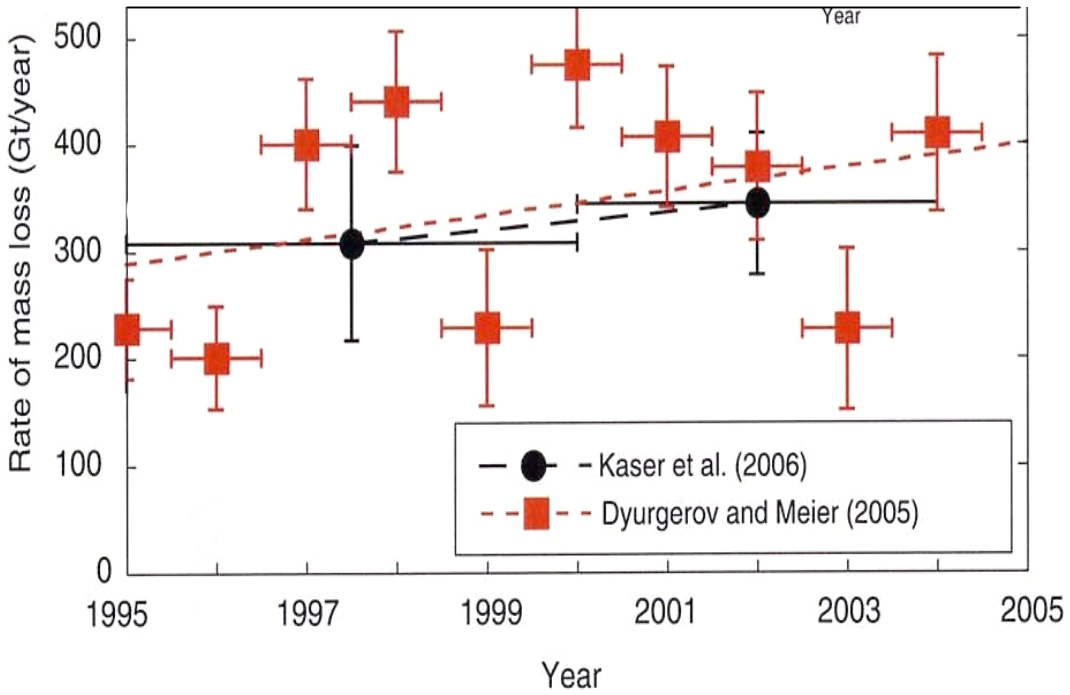


Columbia glacier (Alaska)

Contribution of glacier melting to sea level rise

Ice mass loss by glacier melting (Gt/year)

From Meier et al.(2007)



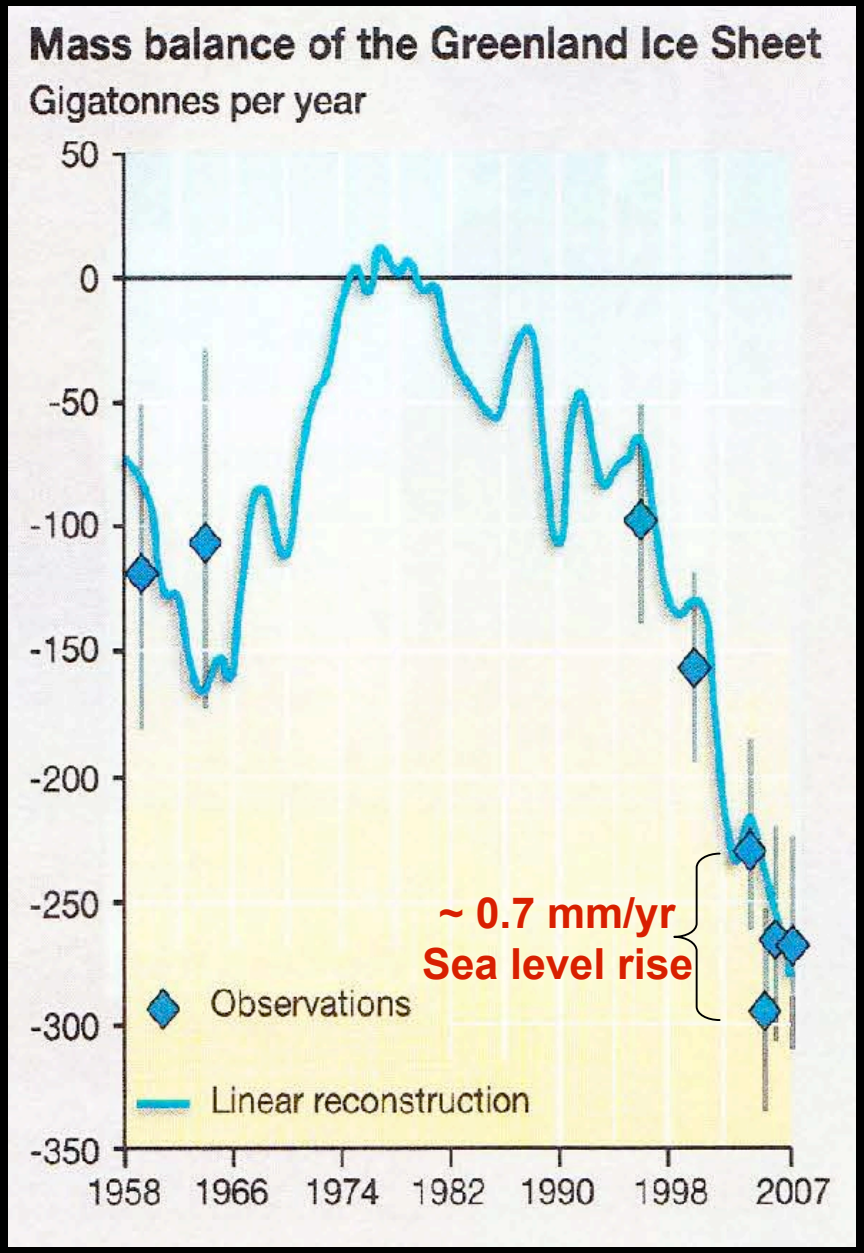
300 Gt/yr ice loss = 0.85 mm/yr sea level rise

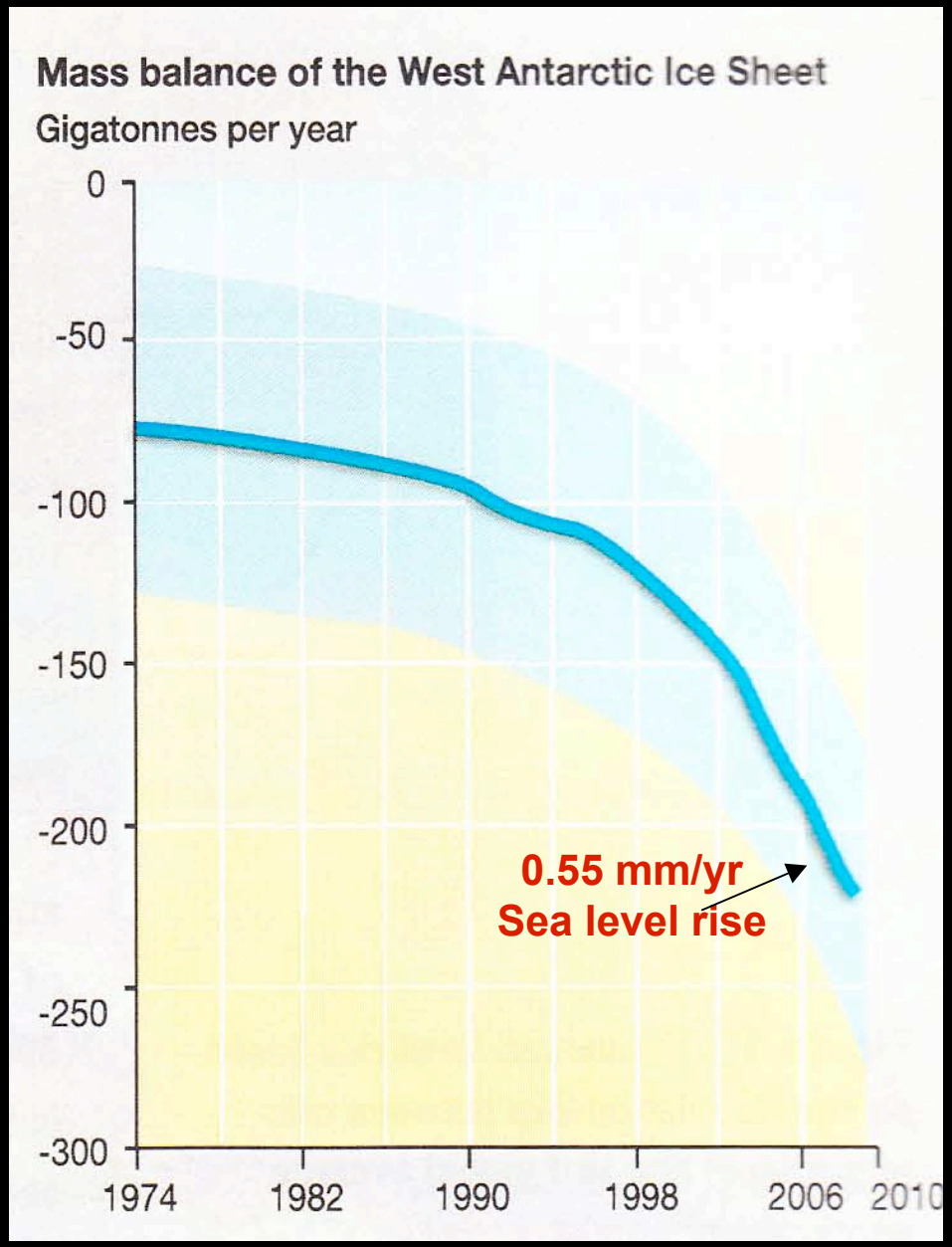
Sea level equivalent

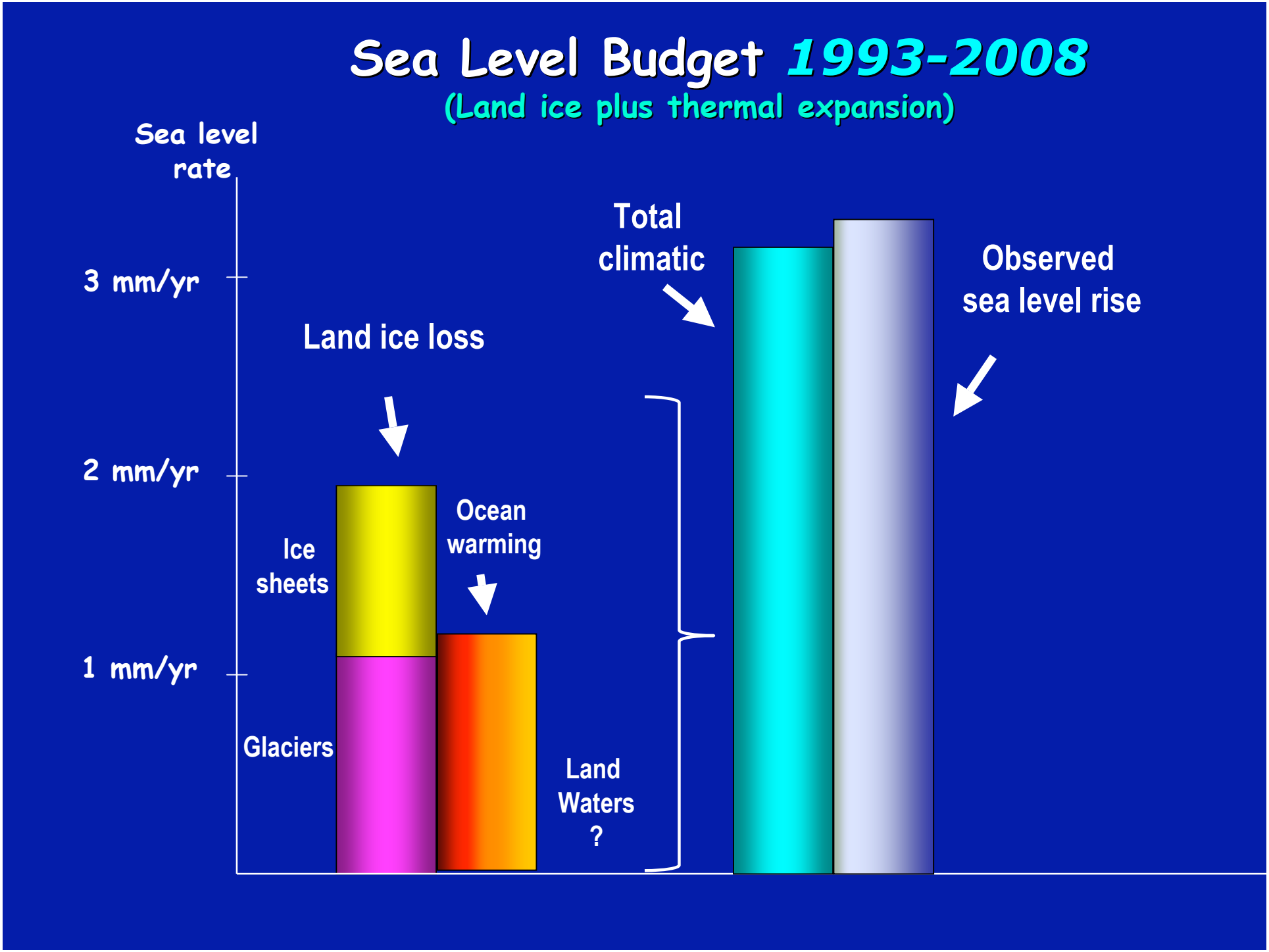
- 1993-2003: 0. 8 +/- 0.11 mm/yr (IPCC AR4)
- 2001-2004 : 1. +/- 0.2 mm/yr (Kaser et al. , 2006)
- 2001-2005: 1.1-1.4 mm/yr (Cogley, 2009)
- 2006: 1.1 +/- 0.24 mm/yr Meier et al. (2007)

Mass balance of Greenland and West Antarctica

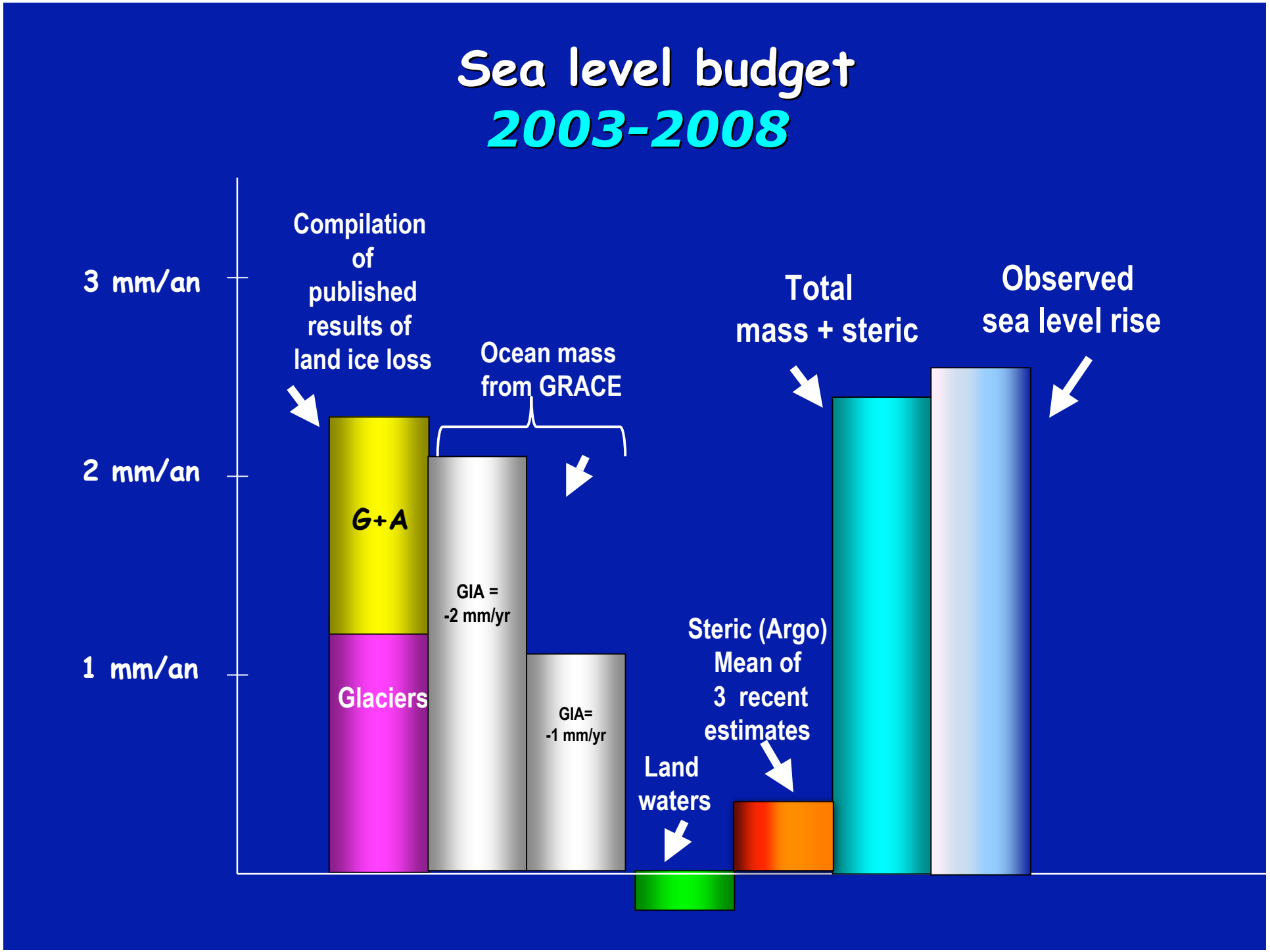
after Rignot et al. 2008a,b

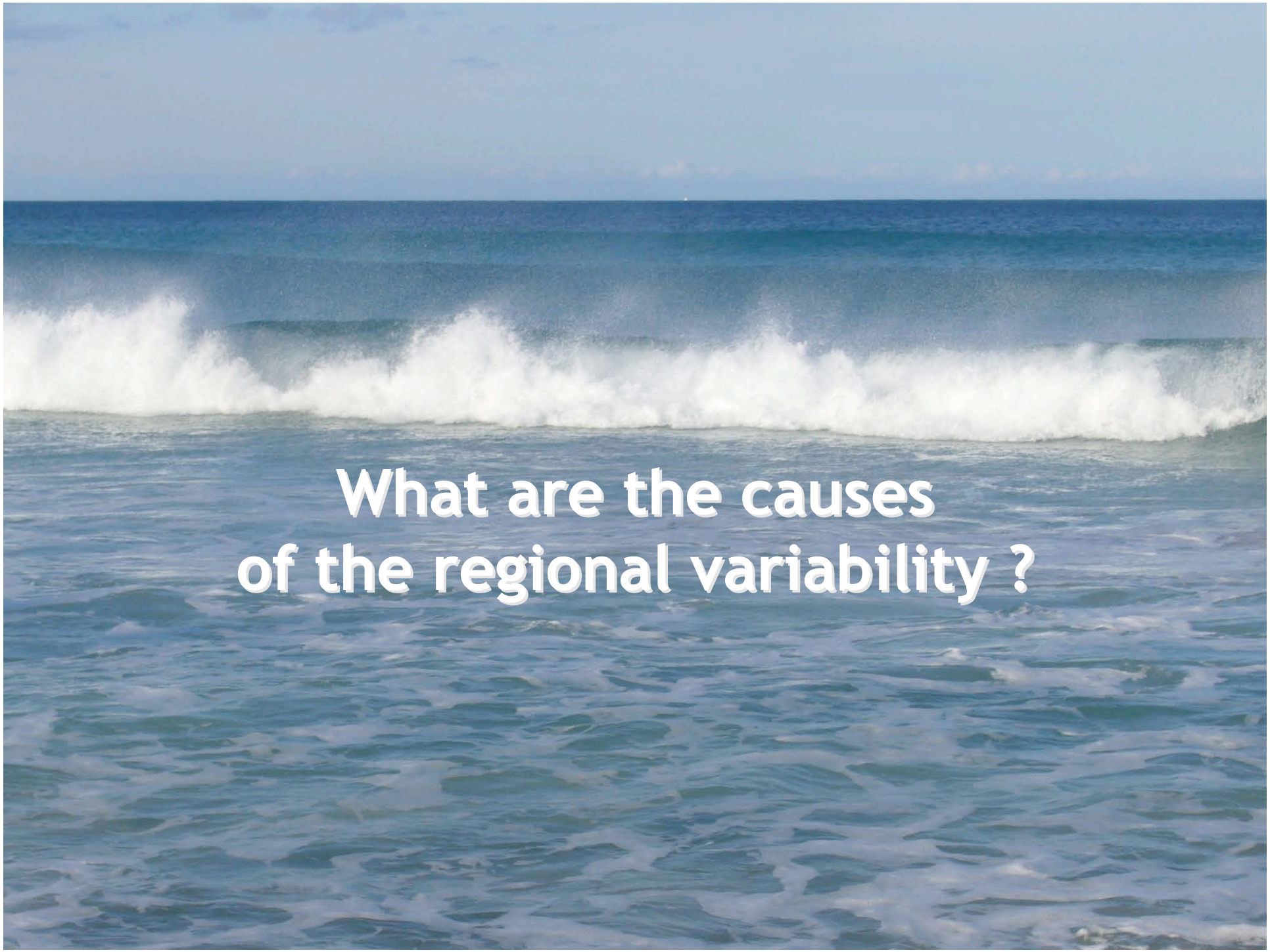




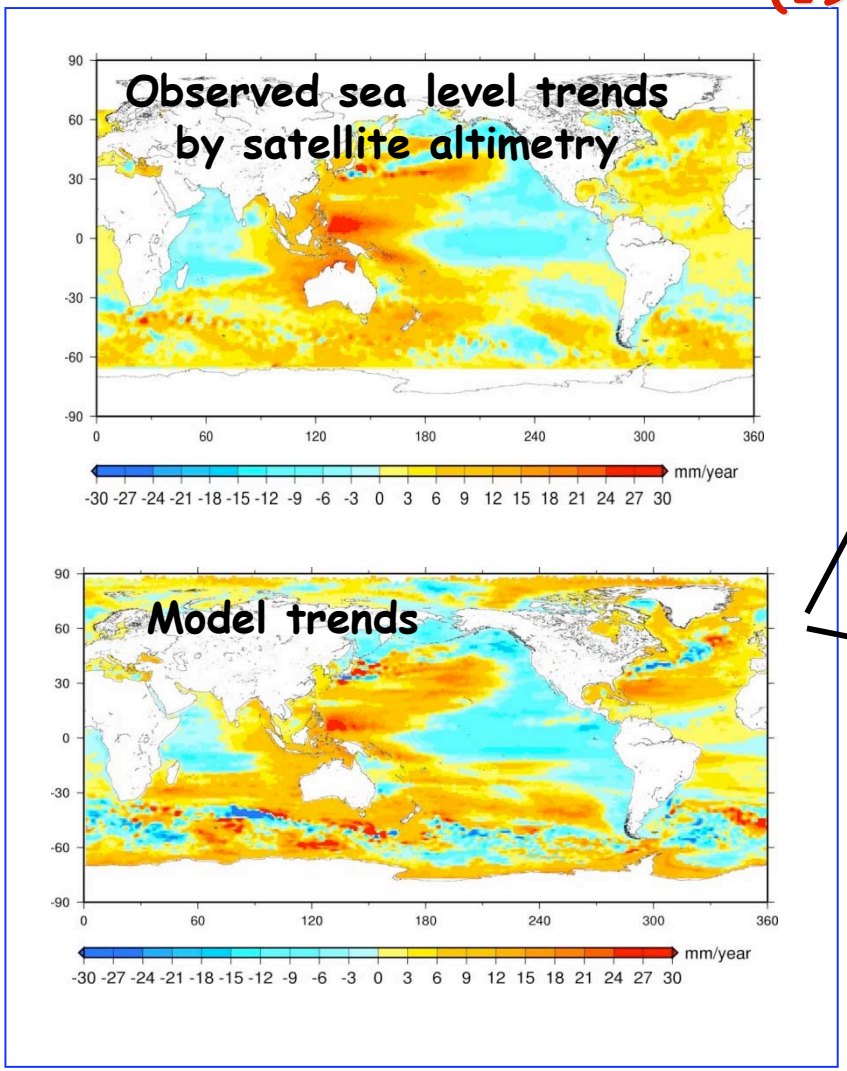

Sea Level Budget 1993-2008
(Land ice plus thermal expansion)
Sea level rate
3 mm/yr
2 mm/yr
1 mm/yr
Land ice loss
Ice sheets
Glaciers
Ocean warming
Land Waters ?
Total climatic
Observed sea level rise

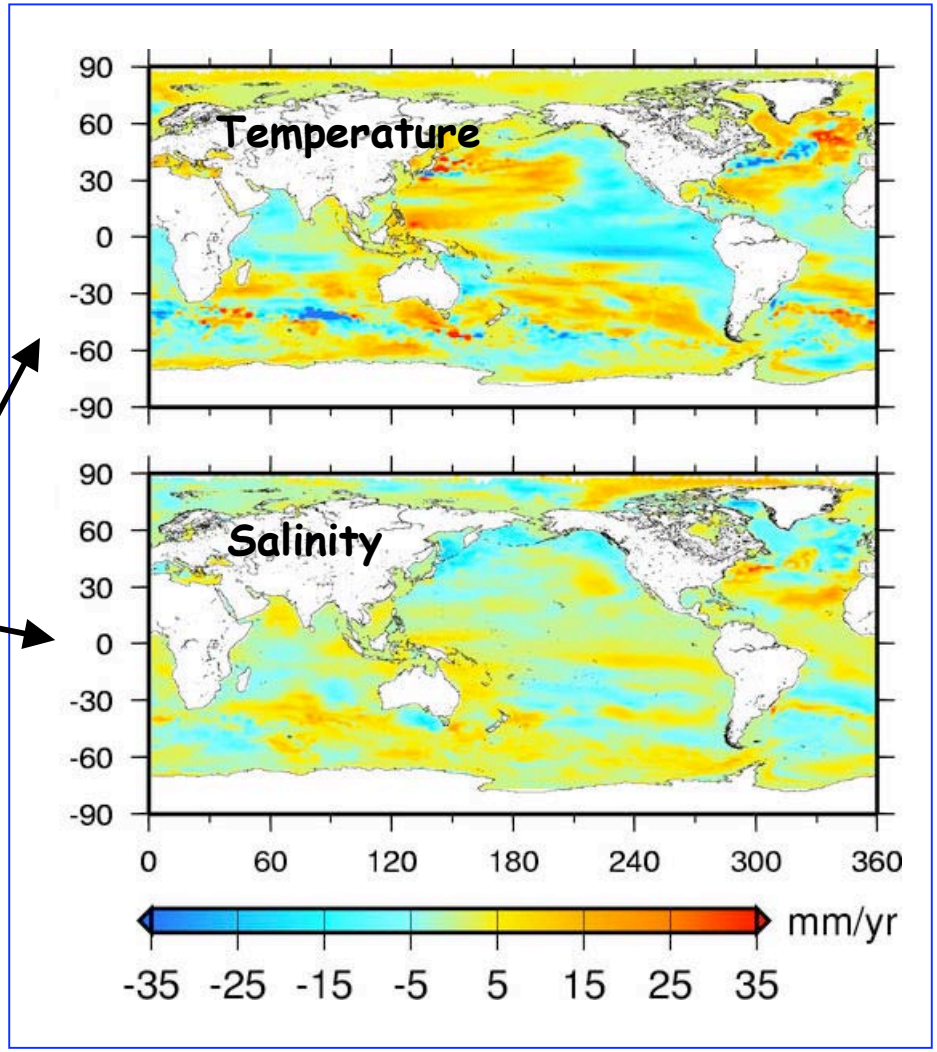
Sea level budget
2003-2008




What are the causes
of the regional variability ?

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

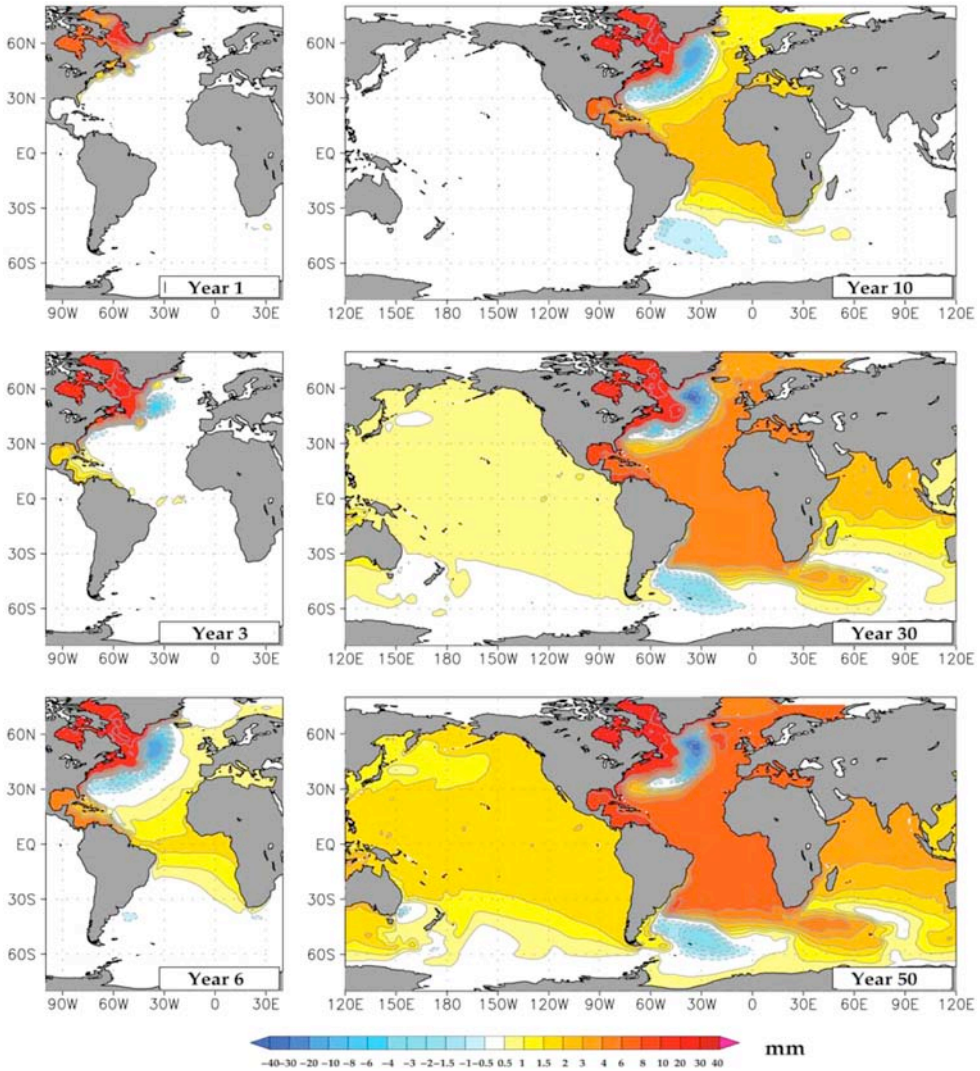




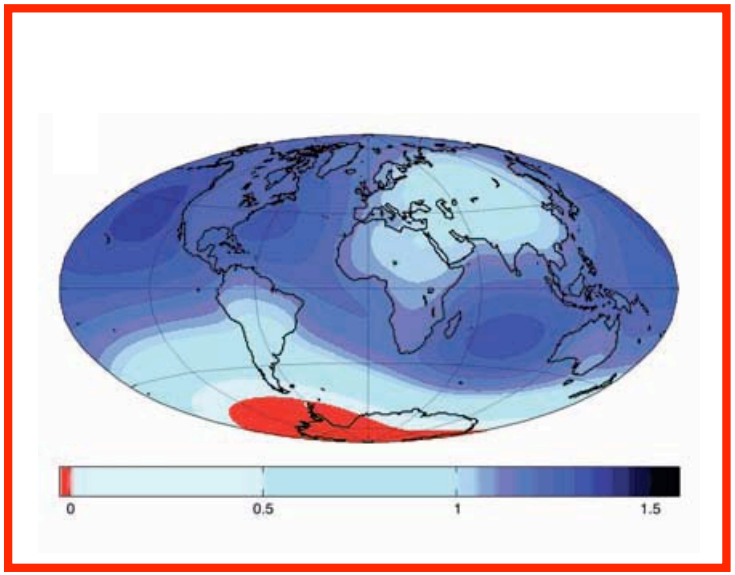
Wunsch et al. 2007; Kohl & Stammer 2008; Lombard et al. 2009

Other processes cause regional variability in sea level

Dynamical effect of circulation changes in response to Greenland melting; *Stammer, 2008*

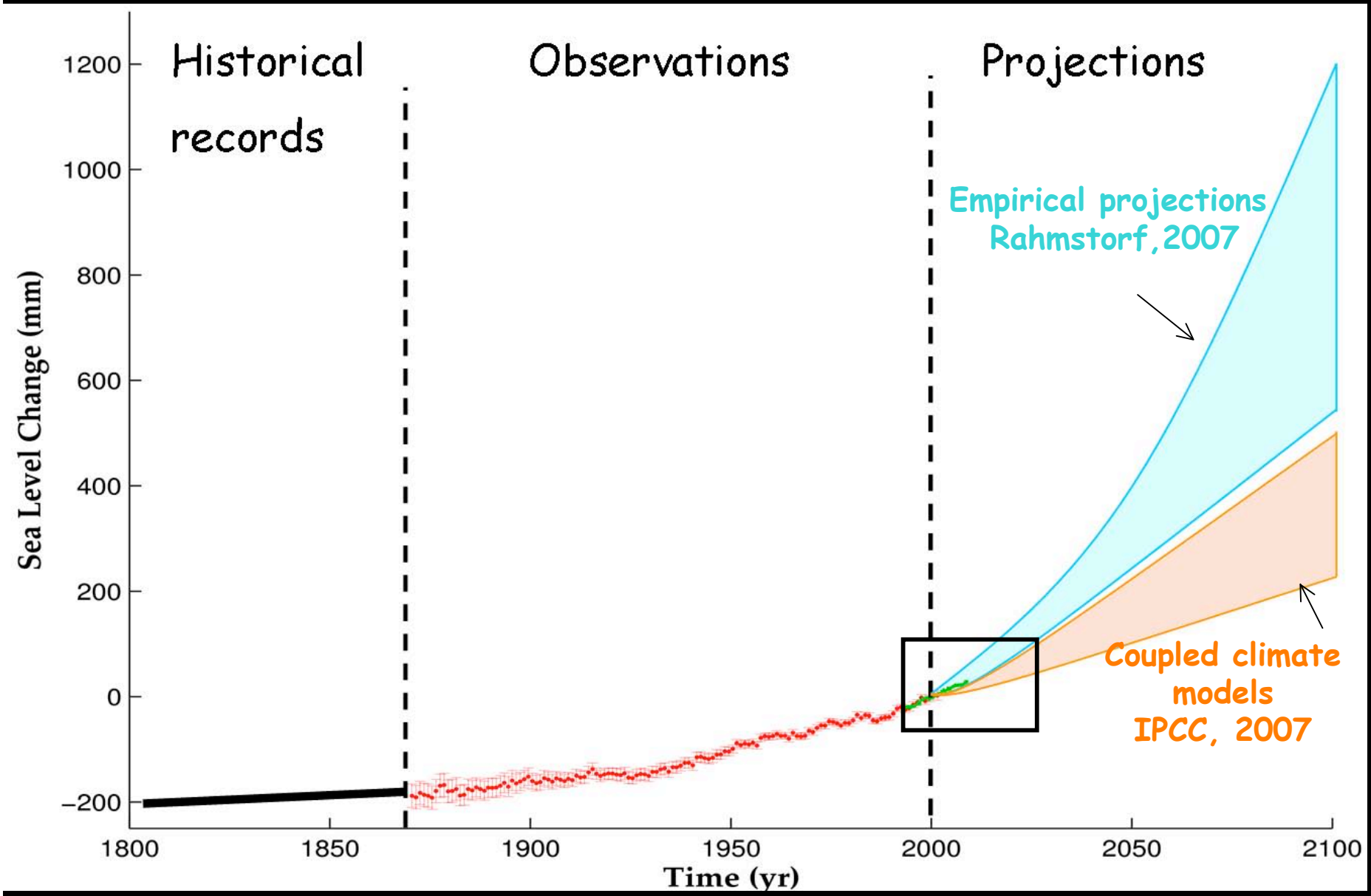


Gravitational fingerprint of West Antarctica collapse
Mitrovica et al 2009




What are the great challenges
in the coming decade?

Global mean sea level evolution since 1800



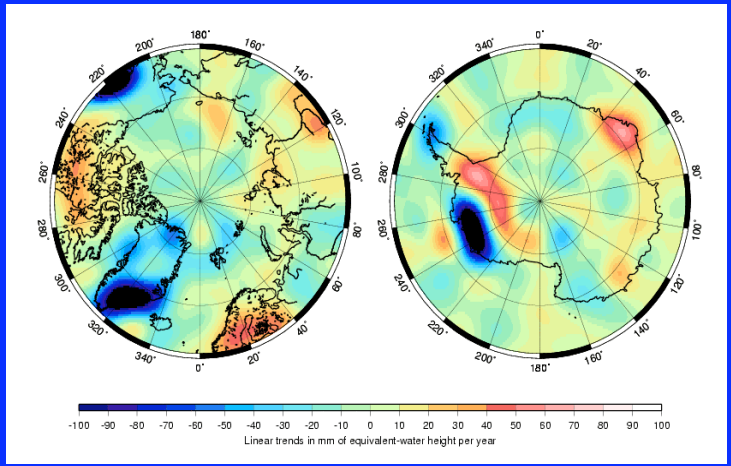
Main recommandations

I. Continuity of observations

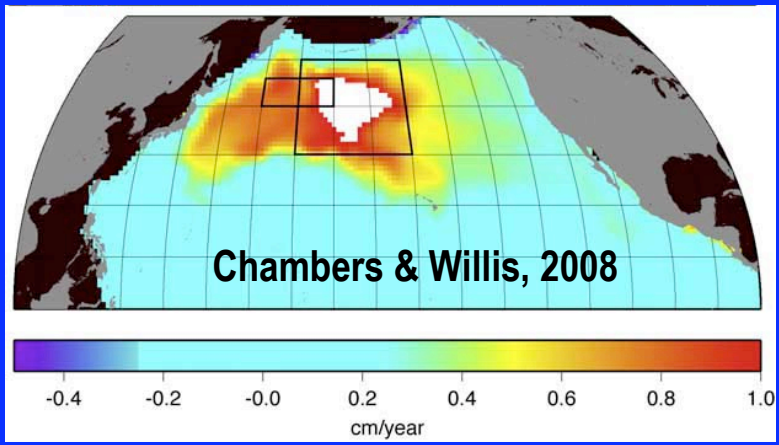
- Multi-decade-long sea level observations by satellite altimeters (global and regional scales)
- Network of good quality tide gauges with GNSS precise positioning (e.g., GLOSS core network plus additional stations)
- Long-term maintainance of the Argo network in its optimal configuration for ocean T, S measurements
- Continuity of GRACE-type space gravimety observations for ice sheet mass balance, ocean mass and land water change estimates: a GRACE-2 mission critically needed

GRACE (2002- 2011 ?)

No mission currently planned
to take over GRACE-1 →
Data gap of 5 to 10 years very likely



Ice sheet mass balance
and
Glacier melting



Ocean mass change

Land water changes

Main recommandations

II. Measurement accuracy & calibration

1. Sea level : 0.1 mm/yr (rate)

- Precise orbits at the 1 cm level (multiple tracking networks and perenity of geodetic infrastructures)
- Terrestrial Reference Frame at 1 mm accuracy and 0.1 to 0.5 mm/yr stability
- Onboard radiometrers stable at 0.1 mm/yr
- Dedicated tide gauge network (with GNSS) for altimeter system calibration

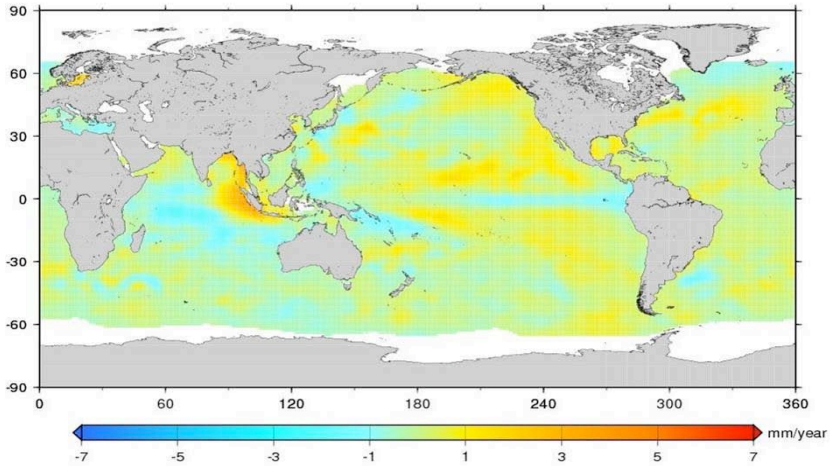
2. Ocean Temperature and salinity

- Shipboard CTD measurement program for absolute calibration of Argo and other data
- Reanalyses of historical temperature and salinity data

Observe, understand, reproduce past decades regional variability and its dominant modes of temporal change using all available resources

Sea level trend maps (~1950-2000)

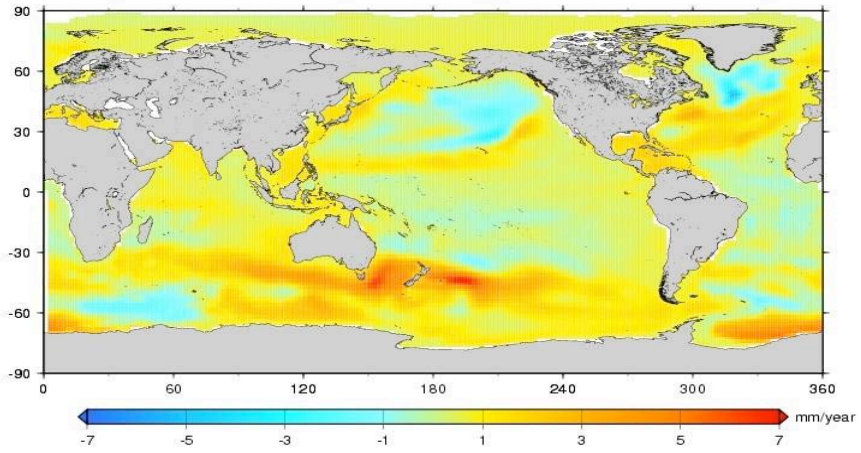
cm/yr



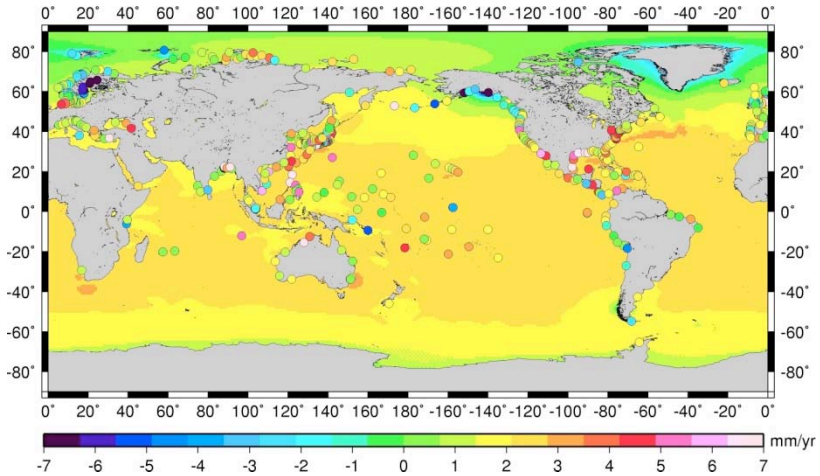
1962-2001

Reconstruction (Tide gauges + altimetry-based EOFs)
Church et al. 2004

OGCM (GECCO with assimilation) Kohl and Stammer, 2008

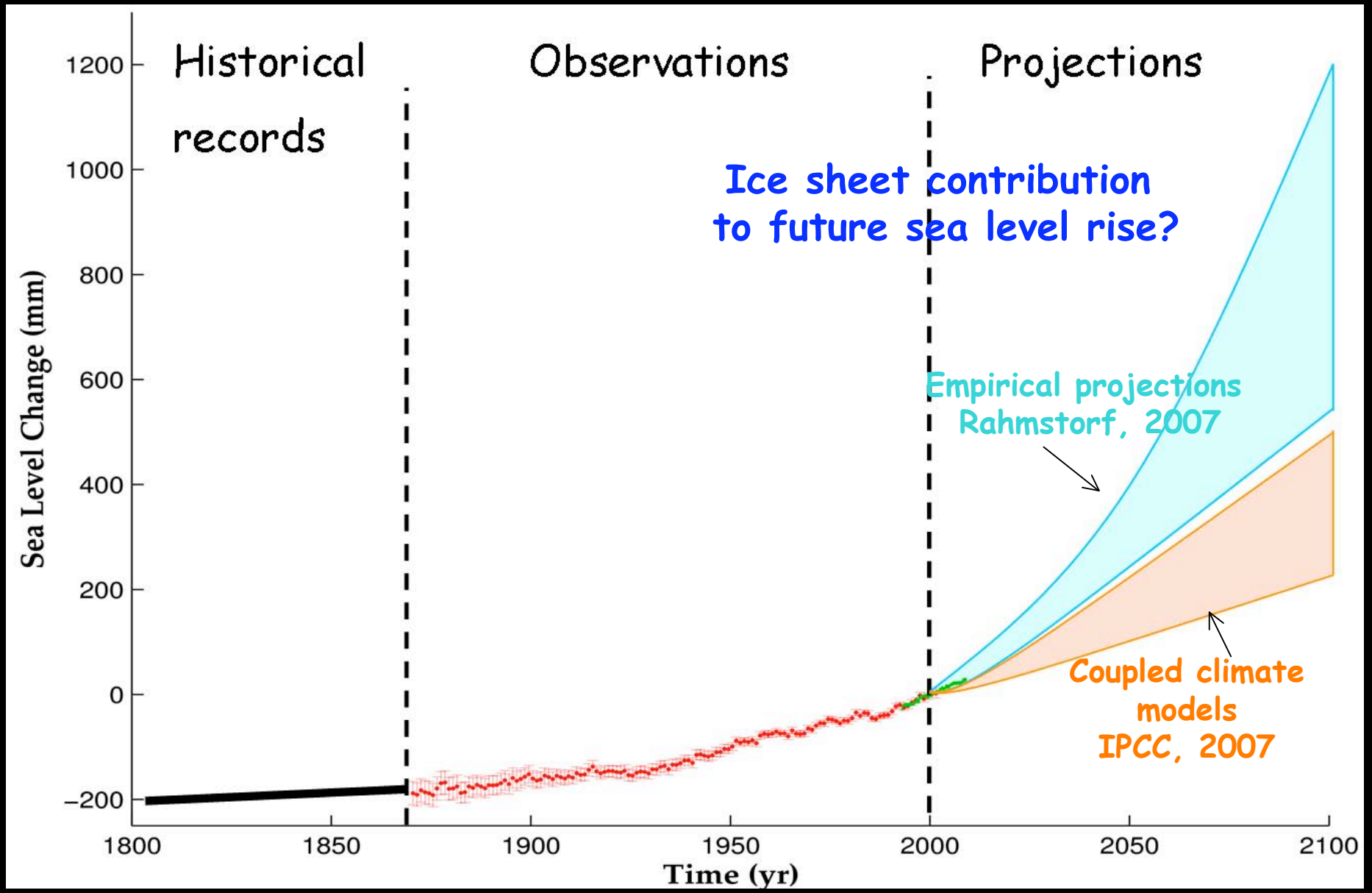


Coupled Climate model (CNRM/CM3)



Data (TG, alti, steric, …) + modeling (e.g. GIA)
Shum et al. 2009

Global mean sea level evolution since 1800



Main recommandations

III. Modeling efforts

- Sea level rise projections from coupled climate models :
  - realistic modeling of ice sheets dynamics
  - regional and decadal variability

- Integrated sea level studies (last century)
  - sea level reconstructions & ocean reanalyses
  - attribution studies that account for all factors (climate, human-induced changes in hydrology, GIA, etc.): Global/regional

- Consensus results for GIA corrections needed to interpret altimetry, tide gauges, GRACE

Impacts

Adverse effects of sea level rise in coastal regions

- Permanent inundation & recurrent flooding associated with storm surges
- Shoreline erosion
- Wetland loss
- Saltwater intrusion in aquifers
- Rising water tables

Amplify other natural & anthropogenic factors

- Ground subsidence due to water withdrawal, hydrocarbon extraction, natural processes
- Decreased fluvial sediment deposition in river deltas (dam building)
- Change in coastal currents

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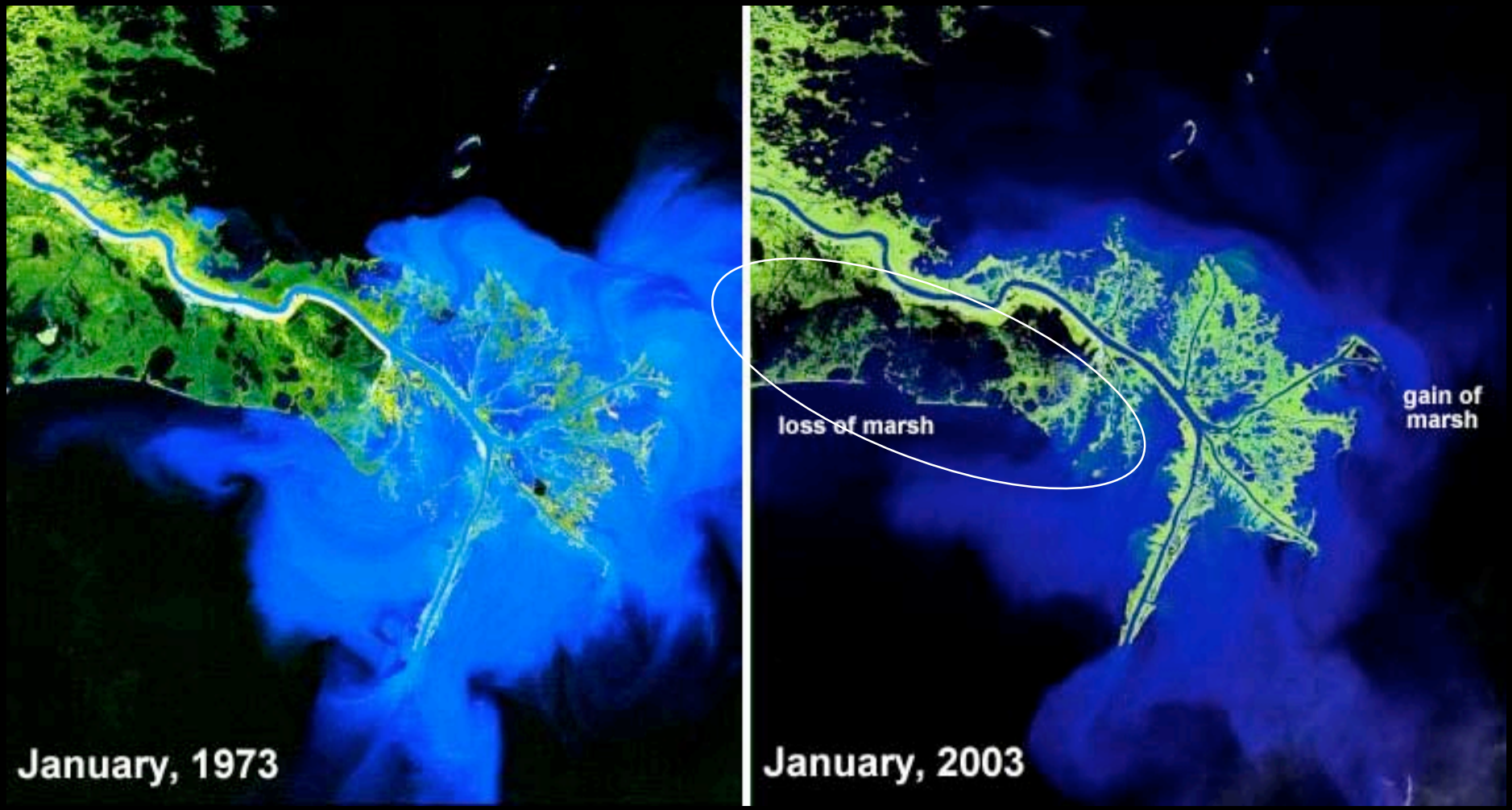
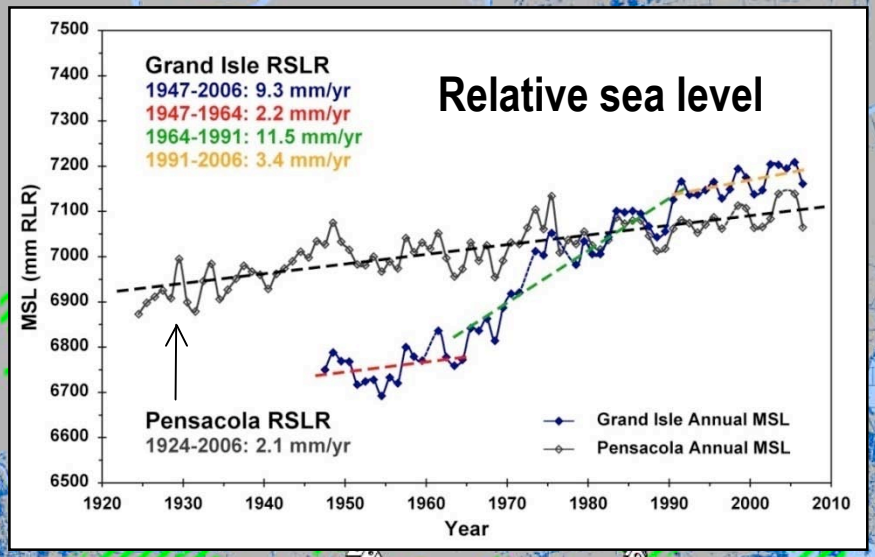
Mississipi River Delta



Source : USGS

Source: Bernier & Morton (2008)

Delta-Plain Oil-and-Gas Fields



Grand Isle tide gauge

benchmark | oil-and-gas field | 1932-2006 land loss

0 12.5 25 50 km

Main recommandations

IV. Coastal Impacts

- Multidisciplinary studies of past shoreline retreat (sea level rise, oceano processes, ground subsidence, etc.)
- Local surveying (tide gauges + GNSS, satellite imagery, coastal altimetry/SWOT mission)
- Sea level change projections at local scale, integrating climate change processes + non climate factors


Thank you!