21th Century Sea-Level change

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13

Sea Level Change

Coordinating Lead Authors:
John A. Church (Australia), Peter U. Clark (USA)

Lead Authors:
Anny Cazenave (France), Jonathan M. Gregory (UK), Svetlana Jevrejeva (UK), Anders Levermann (Germany), Mark A. Merrifield (USA), Glenn A. Milne (Canada), R. Steven Nerem (USA), Patrick D. Nunn (Australia), Antony J. Payne (UK), W. Tad Pfeffer (USA), Detlef Stammer (Germany), Alakkat S. Unnikrishnan (India)

Contributing Authors:
David Bahr (USA), Jason E. Box (Denmark/USA), David H. Bromwich (USA), Mark Carson (Germany), William Collins (UK), Xavier Fettweis (Belgium), Piers Forster (UK), Alex Gardner (USA), W. Roland Gehrels (UK), Rianne Giesen (Netherlands), Peter J. Gleckler (USA), Peter Good (UK), Rune Grand Graversen (Sweden), Ralf Greve (Japan), Stephen Griffies (USA), Edward Hanna (UK), Mark Hemer (Australia), Regine Hock (USA), Simon J. Holgate (UK), John Hunter (Australia), Philippe Huybrechts (Belgium), Gregory Johnson (USA), Ian Joughin (USA), Georg Kaser (Austria), Caroline Katsman (Netherlands), Leonard Konikow (USA), Gerhard Krinner (France), Anne Le Brocq (UK), Jan Lenaerts (Netherlands), Stefan Ligtenberg (Netherlands), Christopher M. Little (USA), Ben Marzeion (Austria), Kathleen L. McInnes (Australia), Sebastian H. Mernild (USA), Didier Monselesan (Australia), Ruth Mottram (Denmark), Tavi Murray (UK), Gunnar Myhre (Norway), J.P. Nicholas (USA), Faezeh Nick (Norway), Mahé Perrette (Germany), David Pollard (USA), Valentina Radić (Canada), Jamie Rae (UK), Markku Rummukainen (Sweden), Christian Schoof (Canada), Aimée Slangen (Australia/Netherlands), Jan H. van Angelen (Netherlands), Willem Jan van de Berg (Netherlands), Michiel van den Broeke (Netherlands), Miren Vizcaíno (Netherlands), Yoshihide Wada (Netherlands), Neil J. White (Australia), Ricarda Winkelmann (Germany), Jianjun Yin (USA), Masakazu Yoshimori (Japan), Kirsten Zickfeld (Canada)

Review Editors:
Jean Jouzel (France), Roderik van de Wal (Netherlands), Philip L. Woodworth (UK), Cunde Xiao (China)

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21th Century Sea-Level change

Paleo sea level records from warm periods during the last 3 million years indicate that global mean sea level has exceeded 5 m above present (very high confidence)[1] when global mean temperature was up to 2°C warmer than pre-industrial (medium confidence).

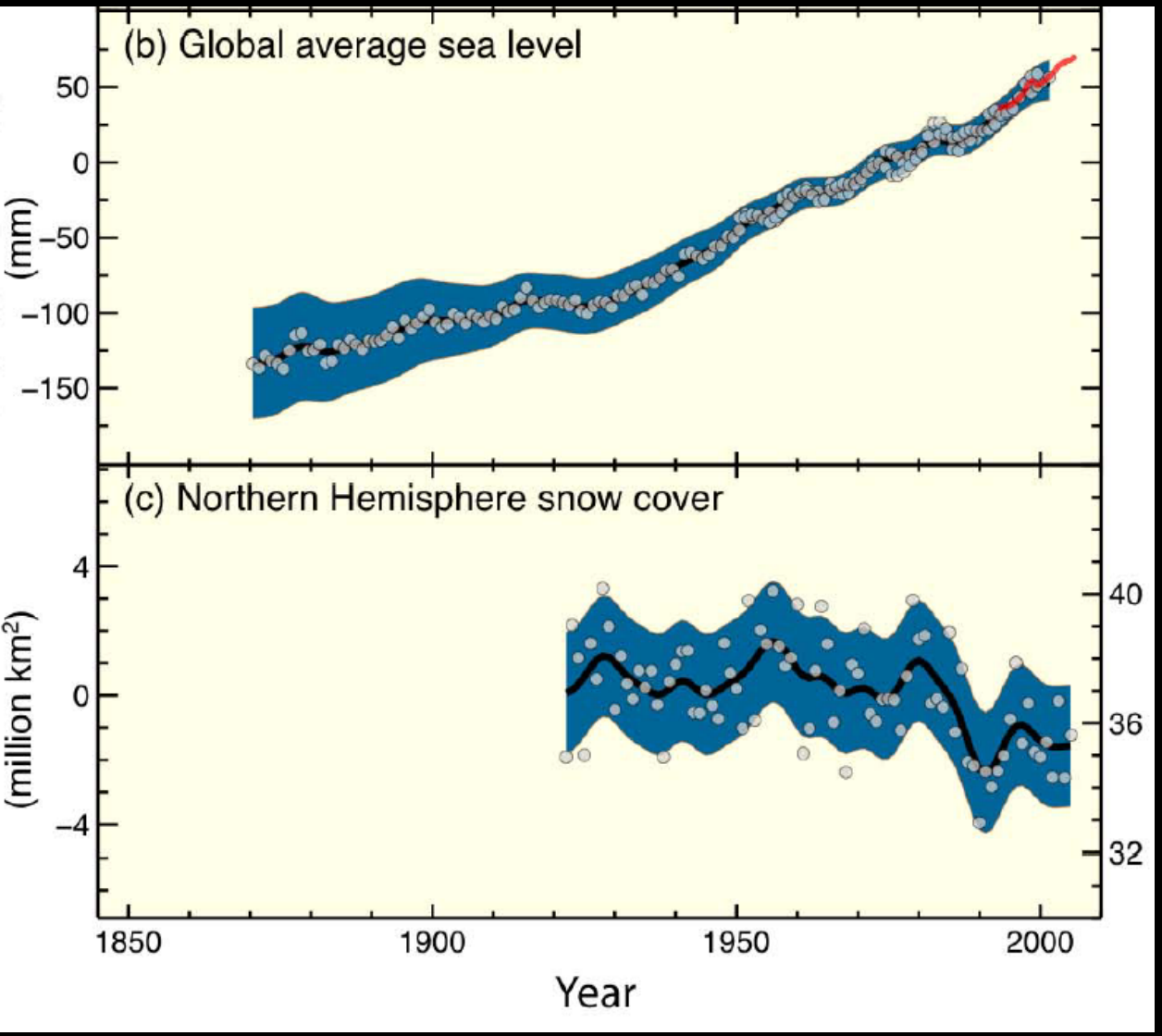
Proxy and instrumental sea level data indicate a transition in the late 19th century to the early 20th century from relative- ly low mean rates of rise over the previous two millennia to higher rates of rise (high confidence). It is likely[2] that the rate of global mean sea level rise has continued to increase since the early 20th century, with estimates that range from 0.000 [–0.002 to 0.002] mm yr^{-2} to 0.013 [0.007 to 0.019] mm yr^{-2}.

Ocean thermal expansion and glacier melting have been the dominant contributors to 20th century global mean sea level rise.

There is high confidence in projections of thermal expansion and Greenland surface mass balance, and medium confidence in projections of glacier mass loss and Antarctic surface mass balance.

The sum of thermal expansion simulated by Coupled Model Intercomparison Project phase 5 (CMIP5) Atmosphere–Ocean General Circulation Models (AOGCMs), glacier mass loss computed by global glacier models using CMIP5 climate change simulations, and estimates of land water storage explain 65% of the observed global mean sea level rise for 1901–1990 and 90% for 1971–2010 and 1993–2010 (high confidence).

The uncertain sea level future



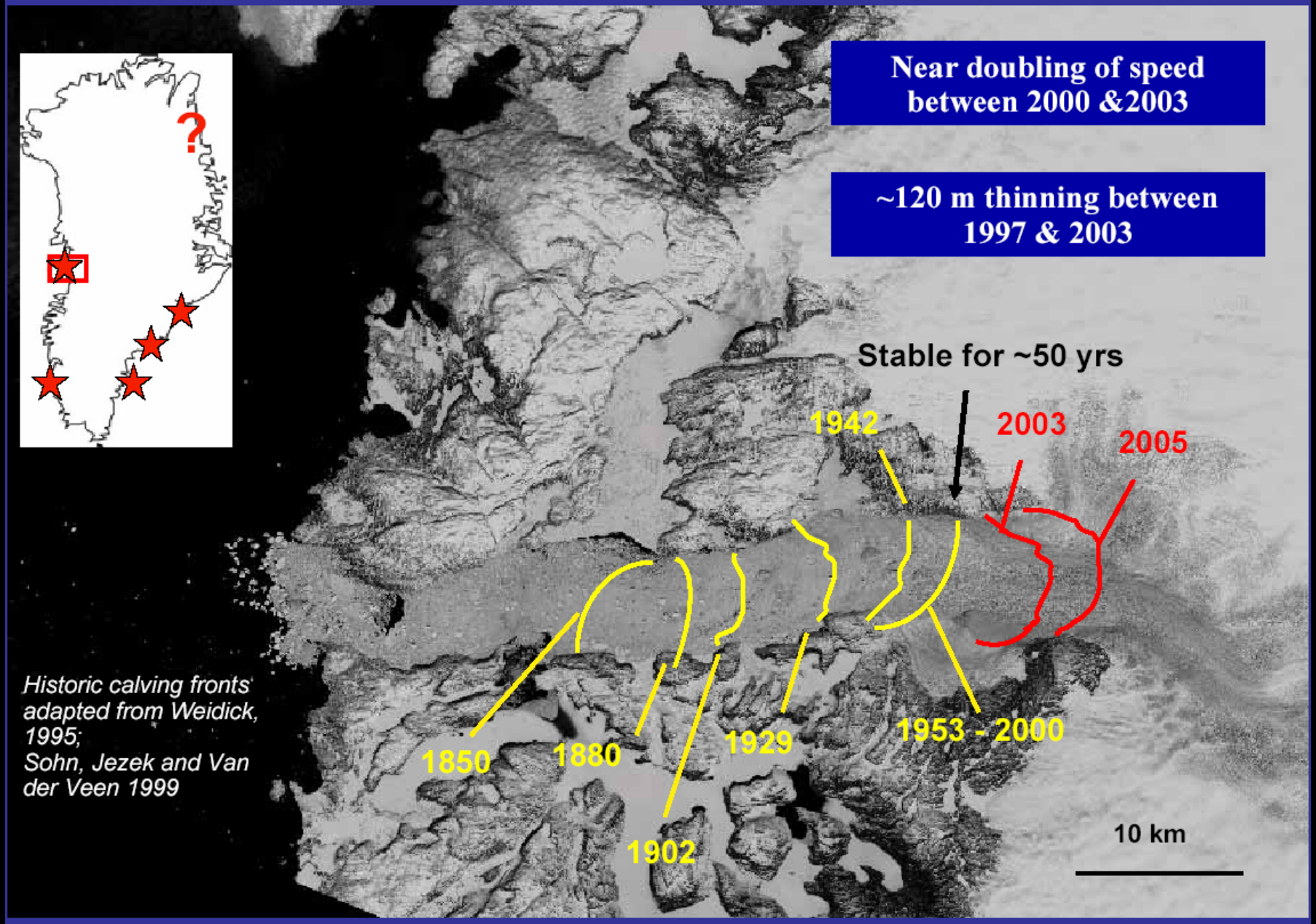
The Earth's ice is melting, sea level has increased
~3 inches since 1960
~1 inch since 1993

-signs of accelerating melting are now clear

-land ice particularly striking, poles more complicated

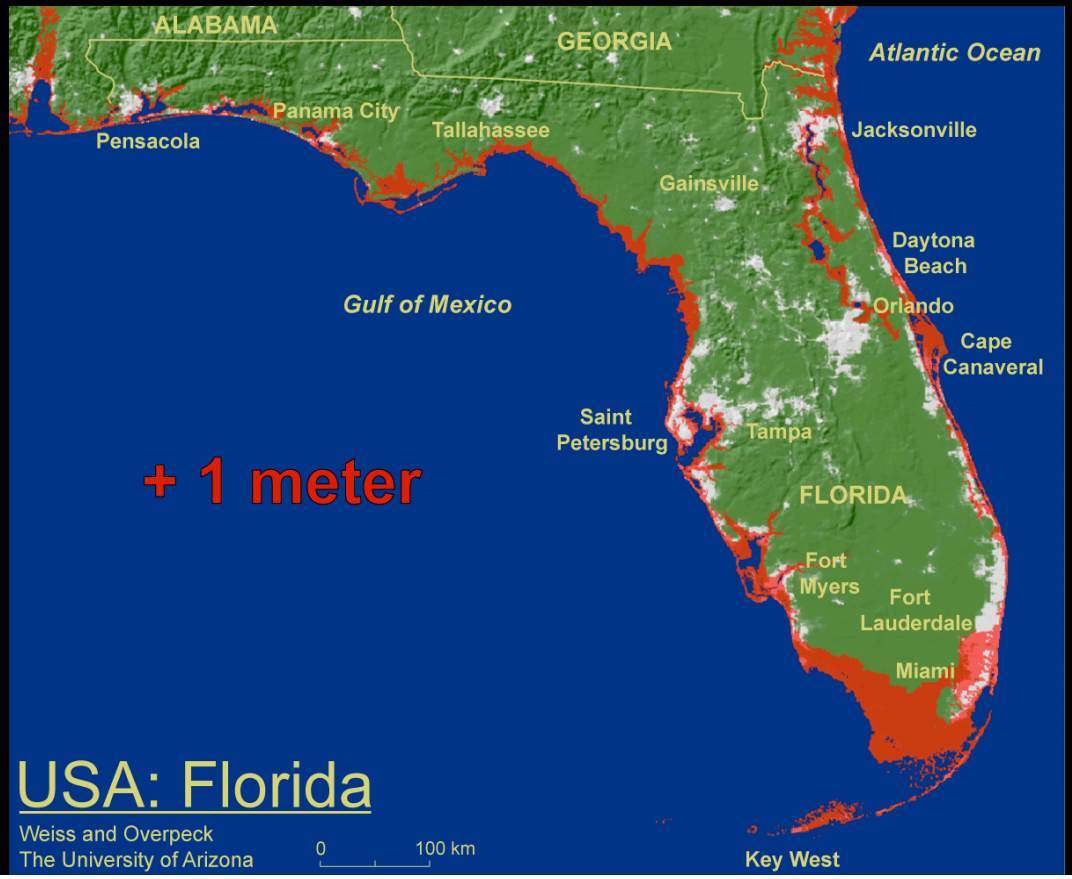
-IPCC estimates project current trends forward i.e. LOWER estimate using no acceleration

Retreat of the Jakobshavn Ice Stream



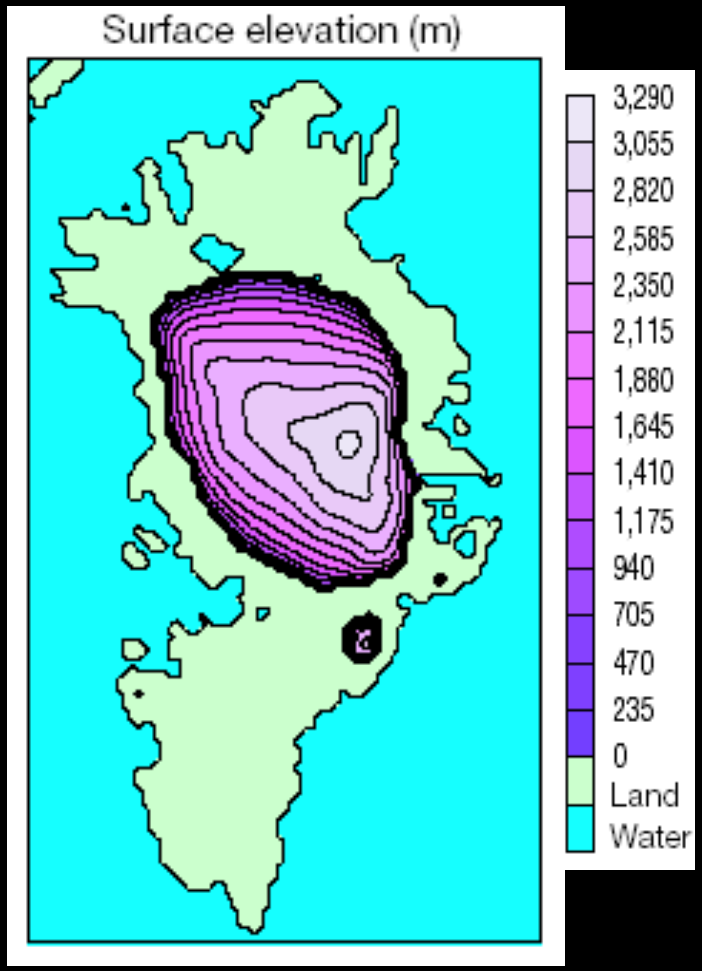
Sea level rise:
IPCC says 7” to 22” by 2100,
much more if rapid ice sheet collapse occurs

most scientists would go on record for 1m rise (30 inches)

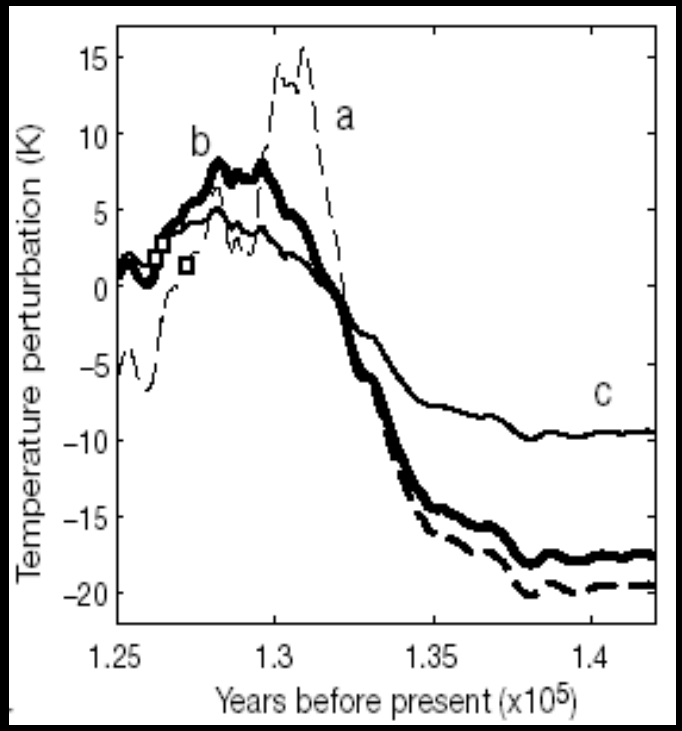


http://www.geo.arizona.edu/dgesl/index.html

During the last interglacial, temperatures were warmer than pre-industrial (by 5ºC), and sea level was higher by 5-6m



Cuffey and Marshall, 2000

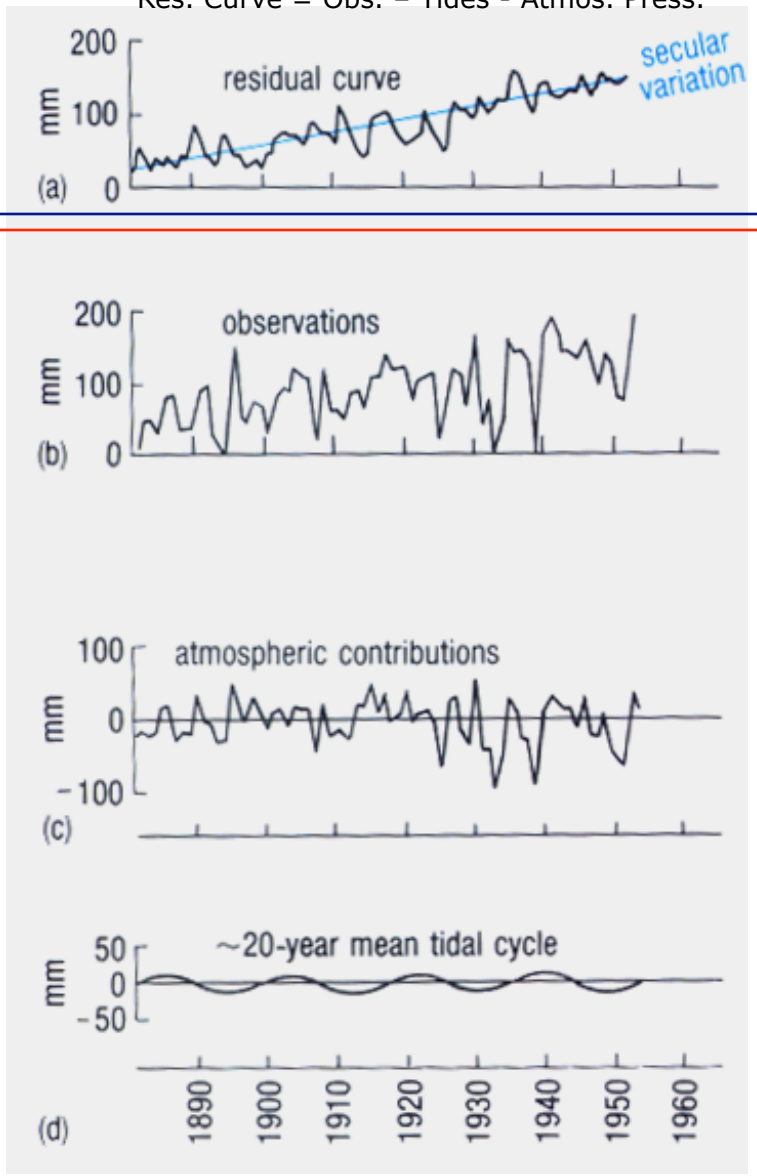


Location	Volume (km^3)	Potential sea-level rise (m)
East Antarctic ice sheet	26,039,200	64.80
West Antarctic ice sheet	3,262,000	8.06
Antarctic Peninsula	227,100	.46
Greenland	2,620,000	6.55
All other ice caps, ice fields, and valley glaciers	180,000	.45
Total	32,328,300	80.32

Greenland + West Antarctic = 14m

Sea Level Change based on tidal gauges

Res. Curve = Obs. – Tides - Atmos. Press.



Observations of Sea Level

II

Atmospheric Pressure

+

Tides

21th Century Sea-Level change

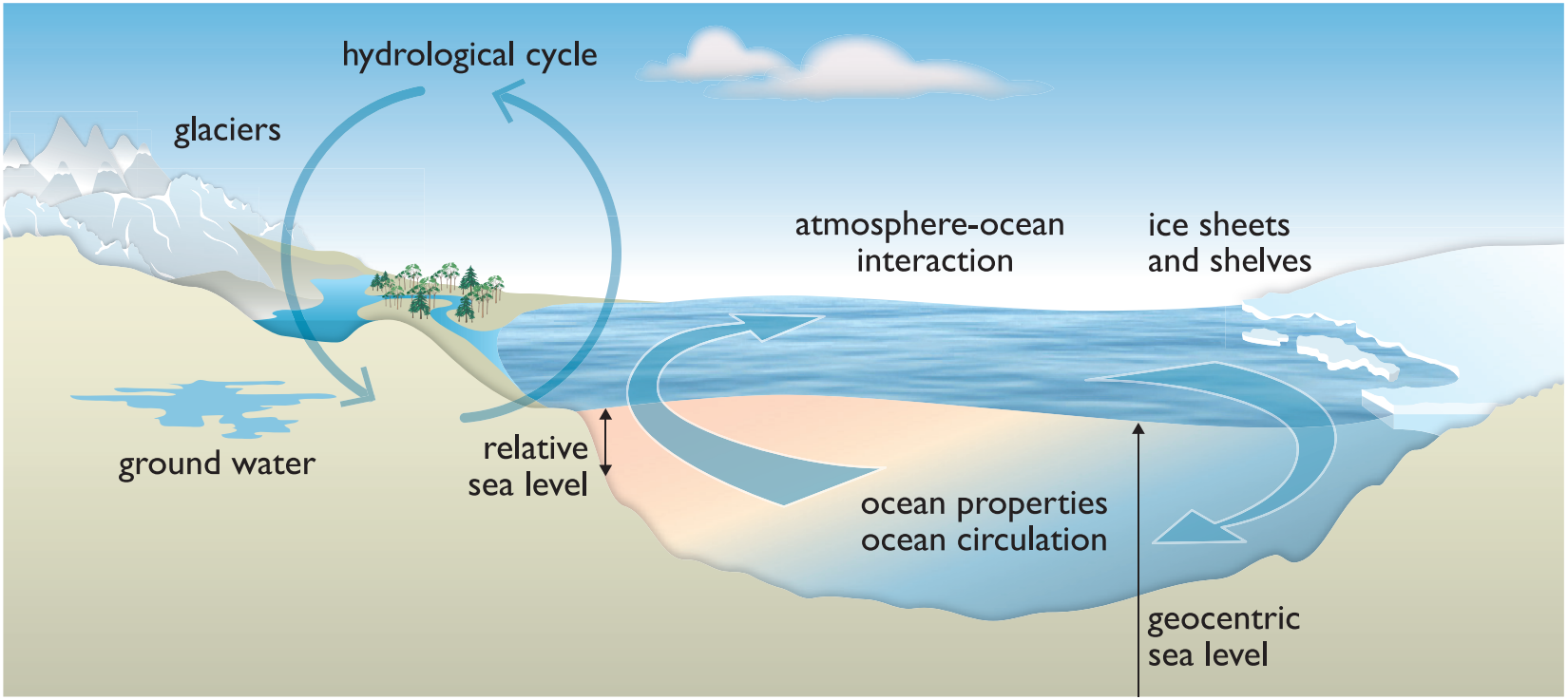


Figure 13.1 | Climate-sensitive processes and components that can influence global and regional sea level and are considered in this chapter. Changes in any one of the components or processes shown will result in a sea level change. The term 'ocean properties' refers to ocean temperature, salinity and density, which influence and are dependent on ocean circulation. Both relative and geocentric sea level vary with position. Note that the geocenter is not shown.

Measuring sea level changes in time:

1. Tide gauges

Located at coastal stations, they measure the relative change in sea level.

2. Satellite altimetry

Satellites in orbit around the planet use radar altimetry to measure the height of the sea level (accuracy of 2 cm).

Attribution of observed changes:

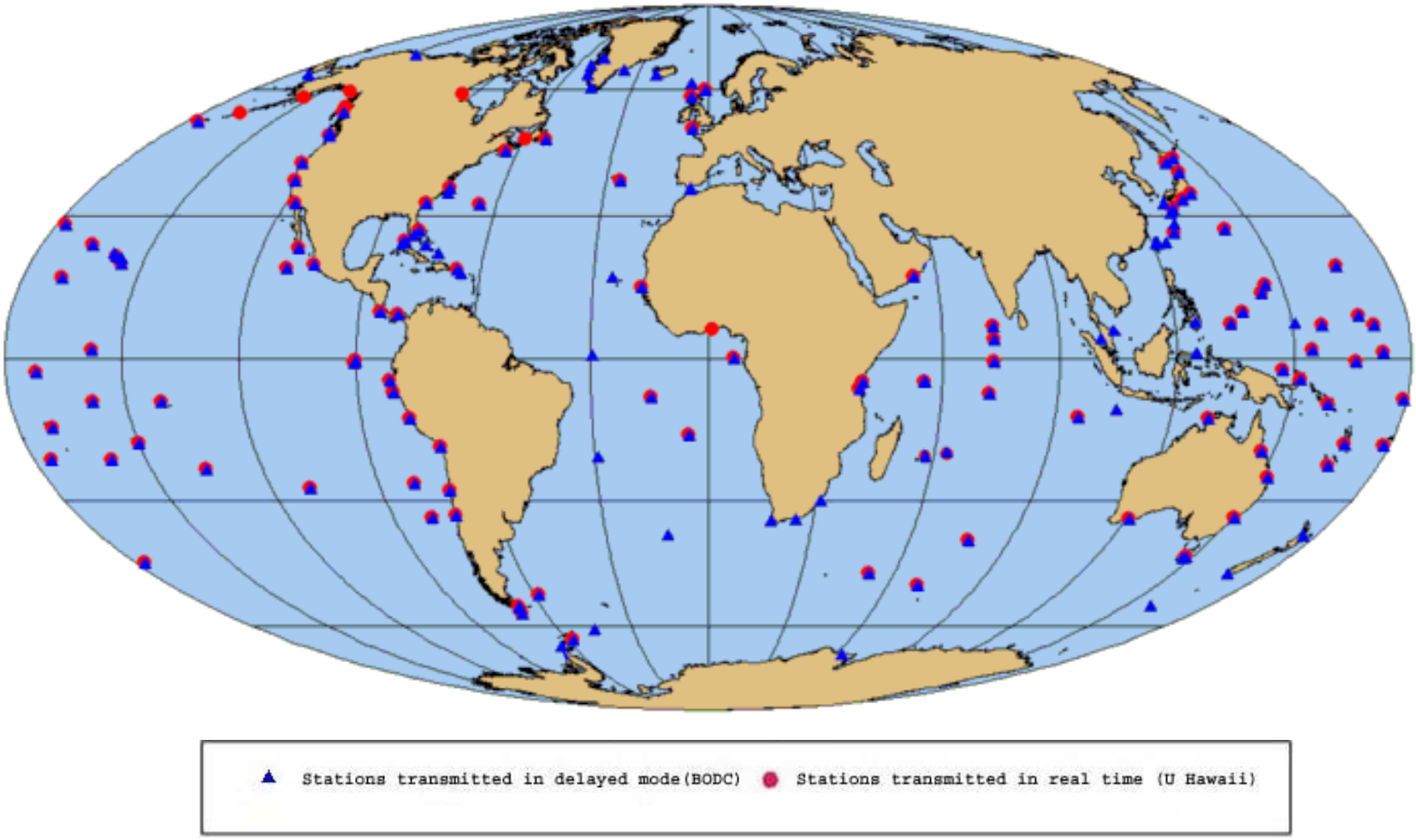
1. Ocean heating and thermal expansion (steric effect)

Requires detailed measurements of ocean heat content

2. Melting of land ice (eustatic effect)

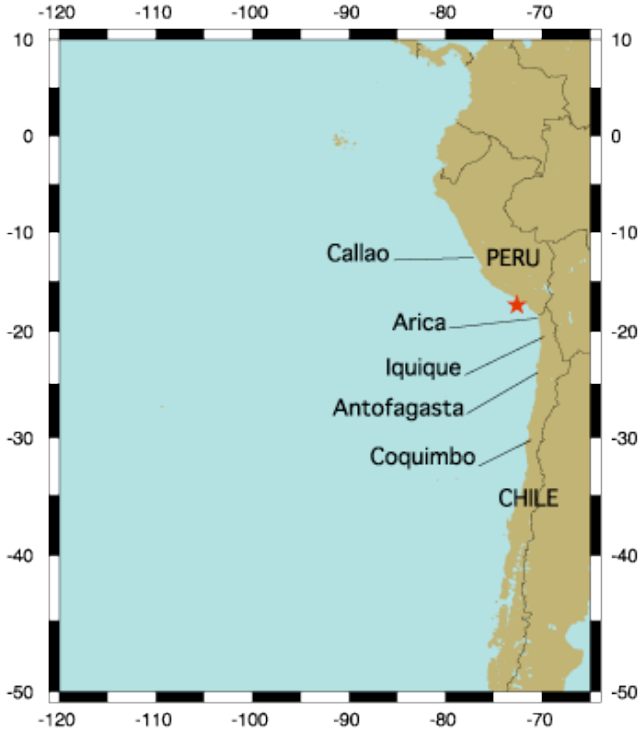
Difficult to measure directly: indirect measurements include area extent of glaciers and snow-covered regions, and changes in global ocean salinity

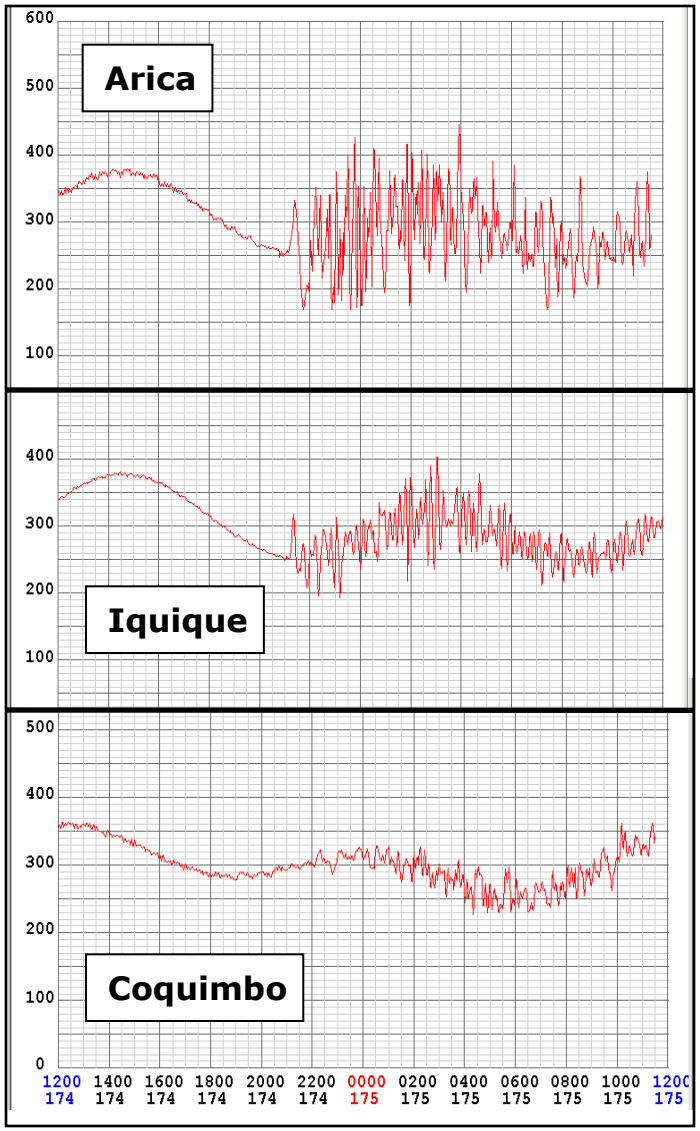
WOCE Sea Level Stations as of February 2000 (from Tidal Gauges)



WOCE is the World Ocean Circulation Experiment → http://woce.nodc.noaa.gov/wdiu/

What can we say about these tide gauges record?





6/23/2001

6/24/2001

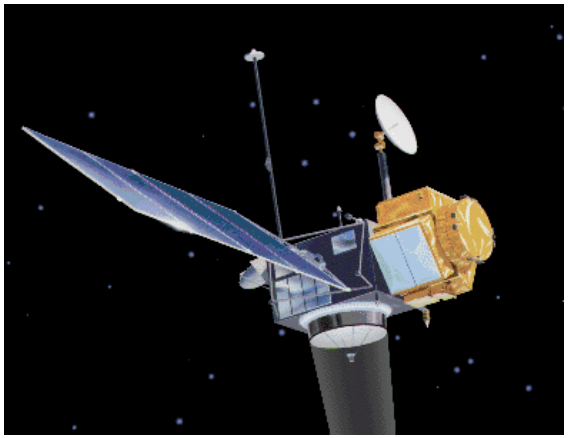
Sea Level trend based on Tidal Gauges

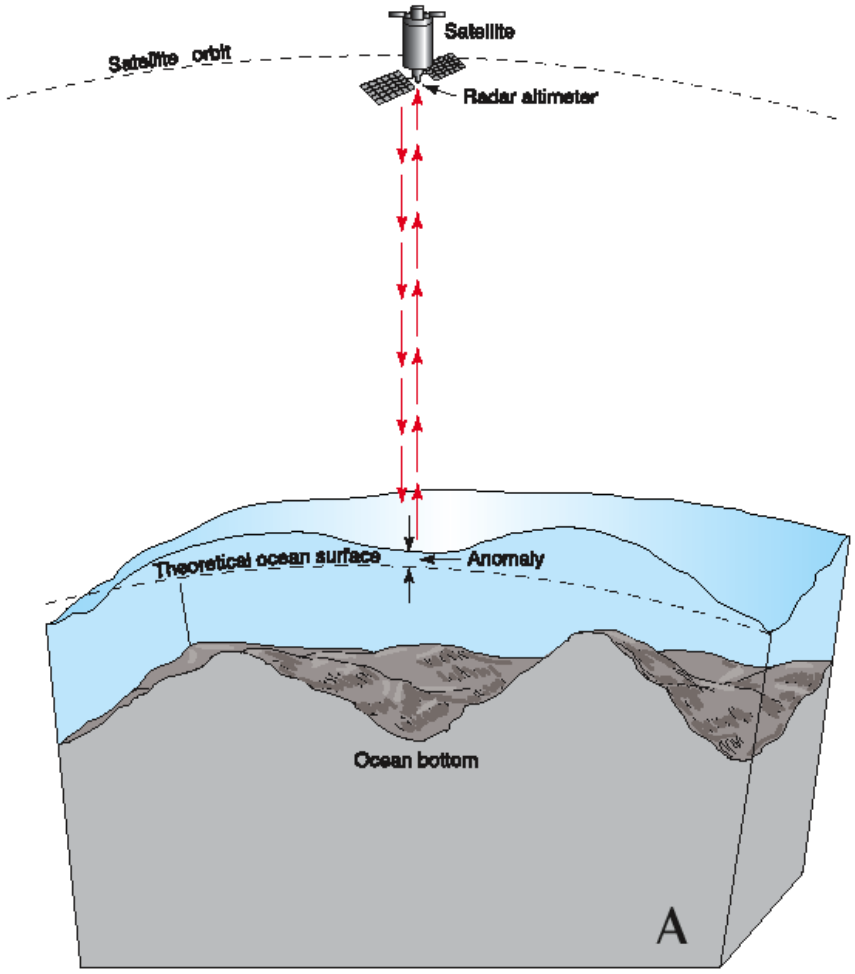
Investigation	Rate (mm/year)	Note
Peltier and Tushingham [1989]	2.4 ± 0.9	Global
Barnett [1990]	1-2	Global
Nakiboglu and Lambeck [1990]	1.15 ± 0.38	Global
Trupin and Wahr [1990]	1.75 ± 0.13	Global
Douglas [1991]	1.8 ± 0.1	Global
Shennan and Woodworth [1992]	1.0 ± 0.15	Europe
Unal and Ghil [1995]	1.62 ± 0.38	Global
Davis and Mitrovica [1996]	1.5 ± 0.3	U.S. East Coast
Peltier and Jiang [1997]	1.8 ± 0.2	U.S. East Coast
Douglas [1997]	1.8 ± 0.1	Global

altimetry

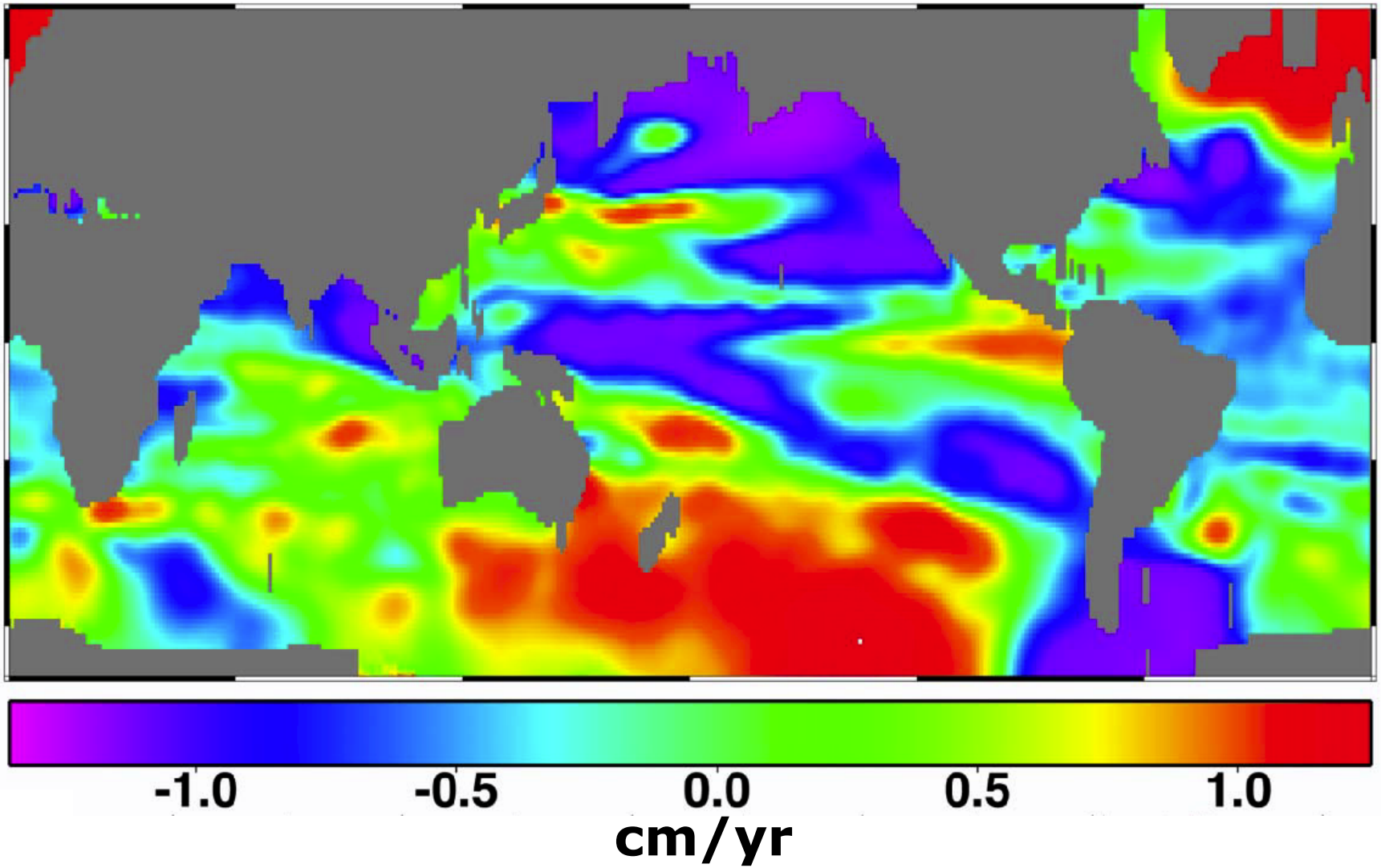
Satellites in orbit around the planet use radar altimetry to measure the height of the sea level (accuracy of 2 cm).

http://www.ecco-group.org/animations_iter21/TP_ps21.mpeg



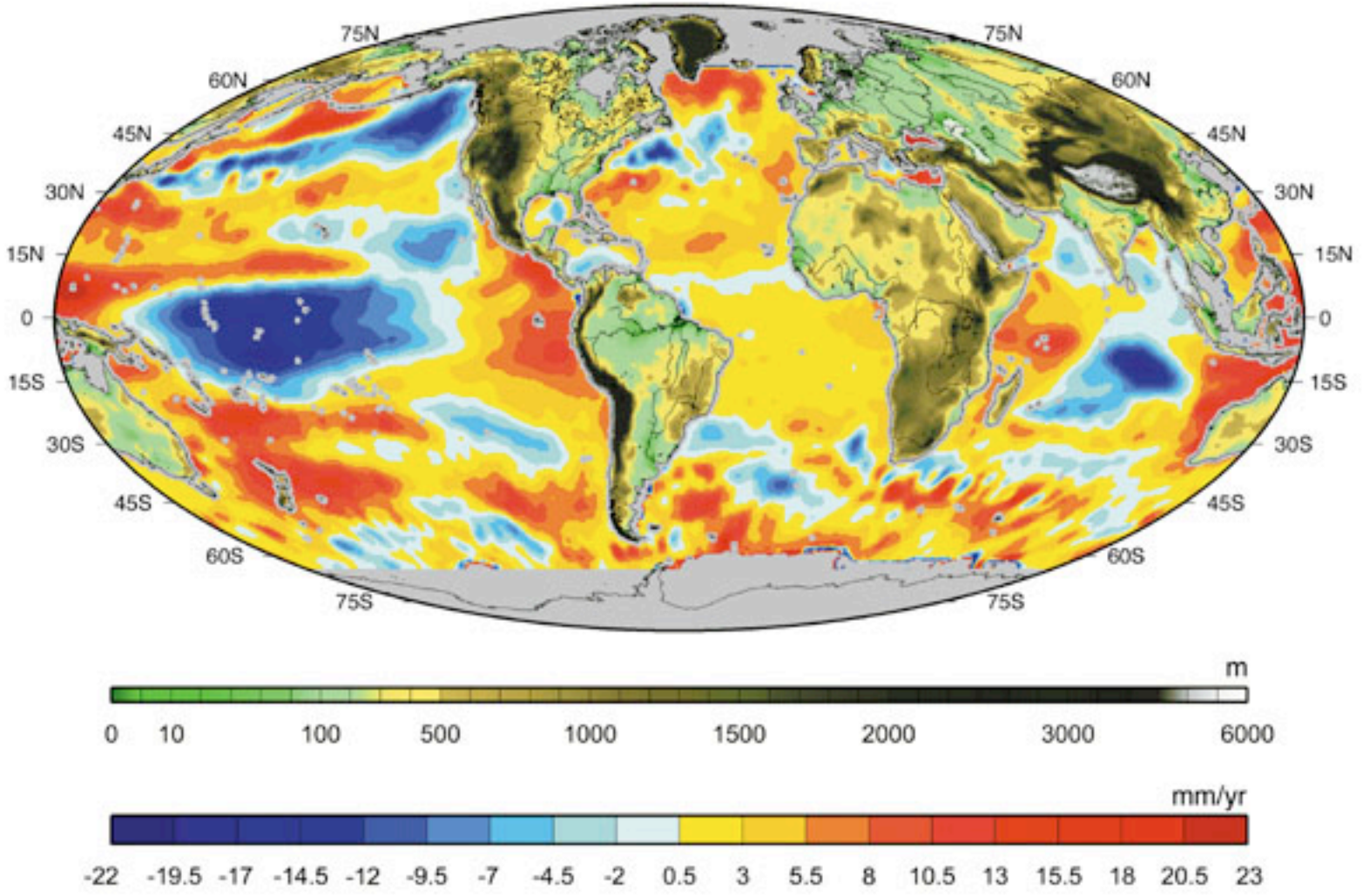


Spatial pattern of sea level change 1993-2003 (from Satellite)

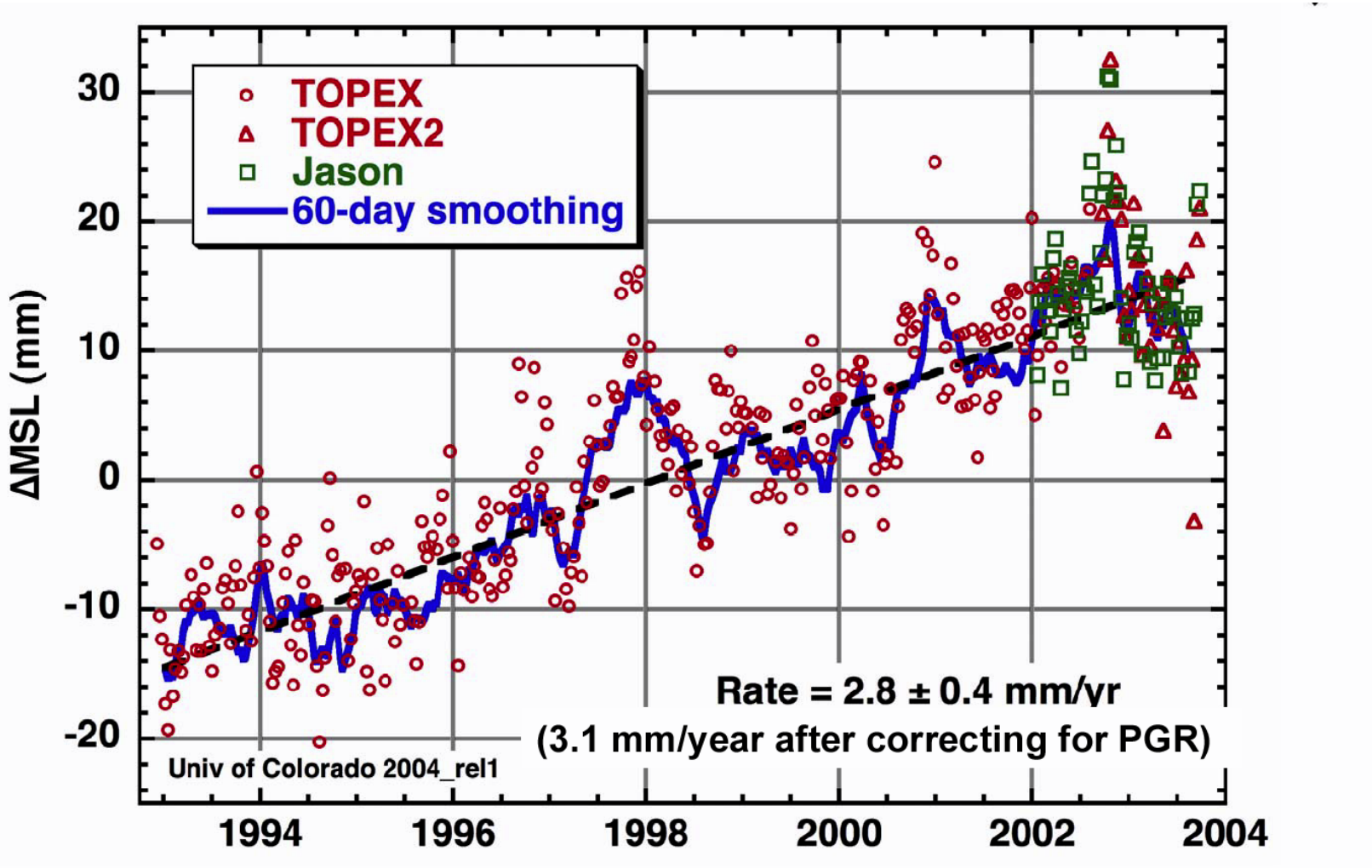


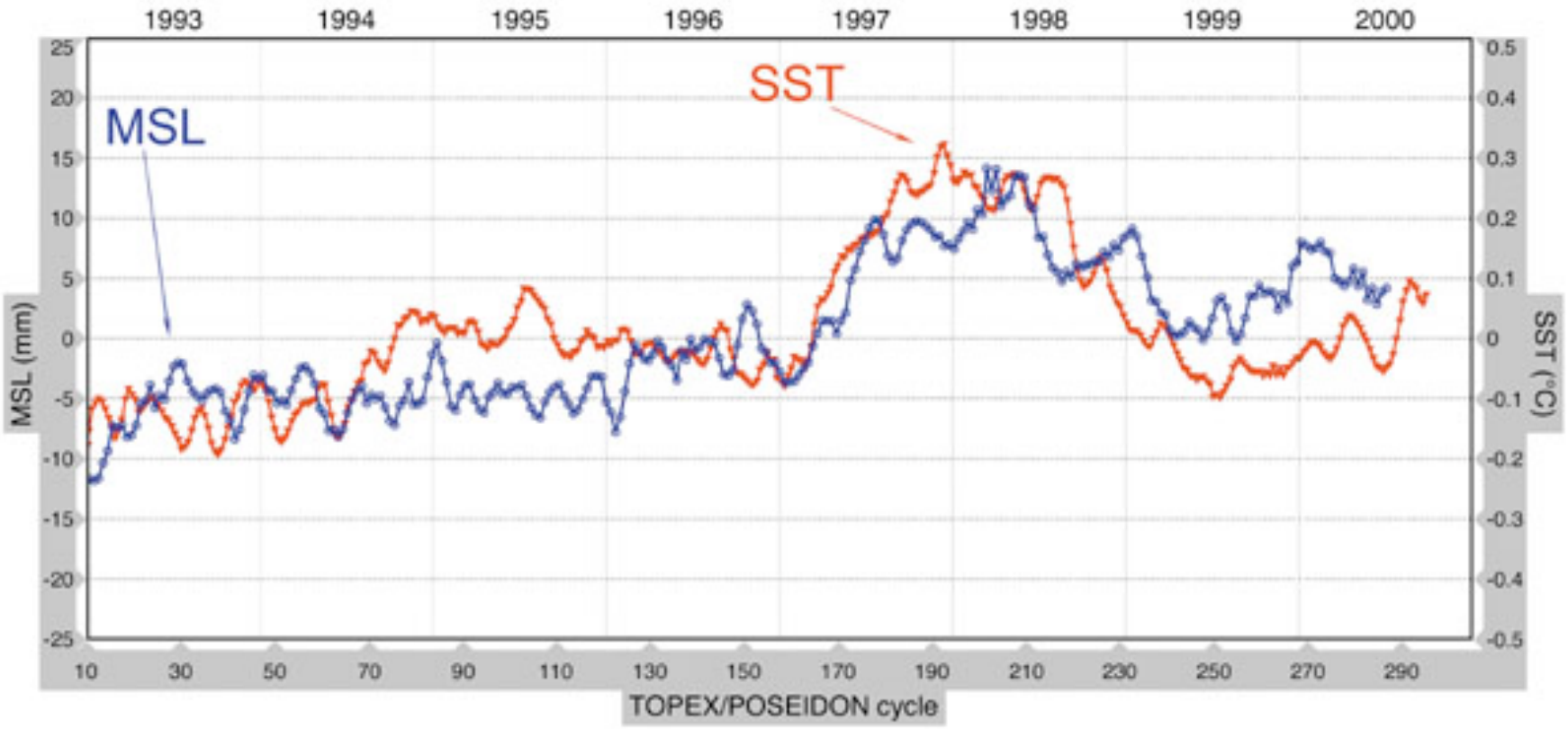
Geographical distribution of sea level trends (in mm/yr)

computed from **TOPEX/POSEIDON altimetry** between January 1993 and December 1999. Yellow and red colors correspond to sea level rise, while blue color corresponds to sea level drop.



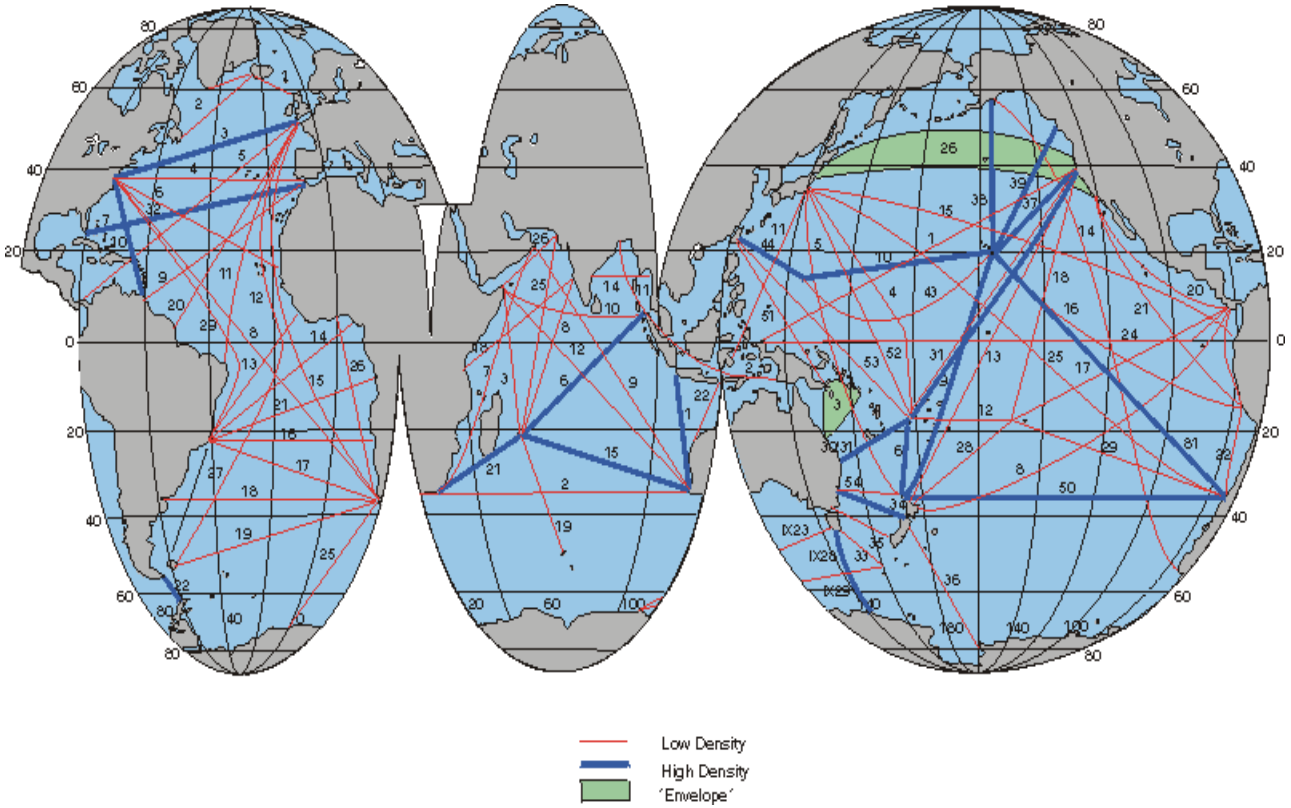
Sea Level Change in the last 20 yr (from Satellites)




1993
1994
1995
1996
1997
1998
1999
2000
MSL
SST
MSL (mm)
SST (°C)
25
20
15
10
5
0
-5
-10
-15
-20
-25
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
TOPEX/POSEIDON cycle

An example of Temperature measurements:

Expendable Bathythermograph (XBT) Lines



XBT

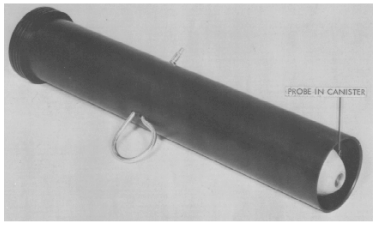
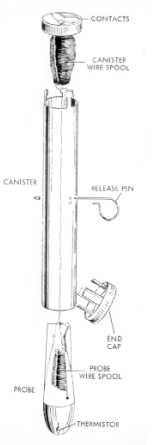
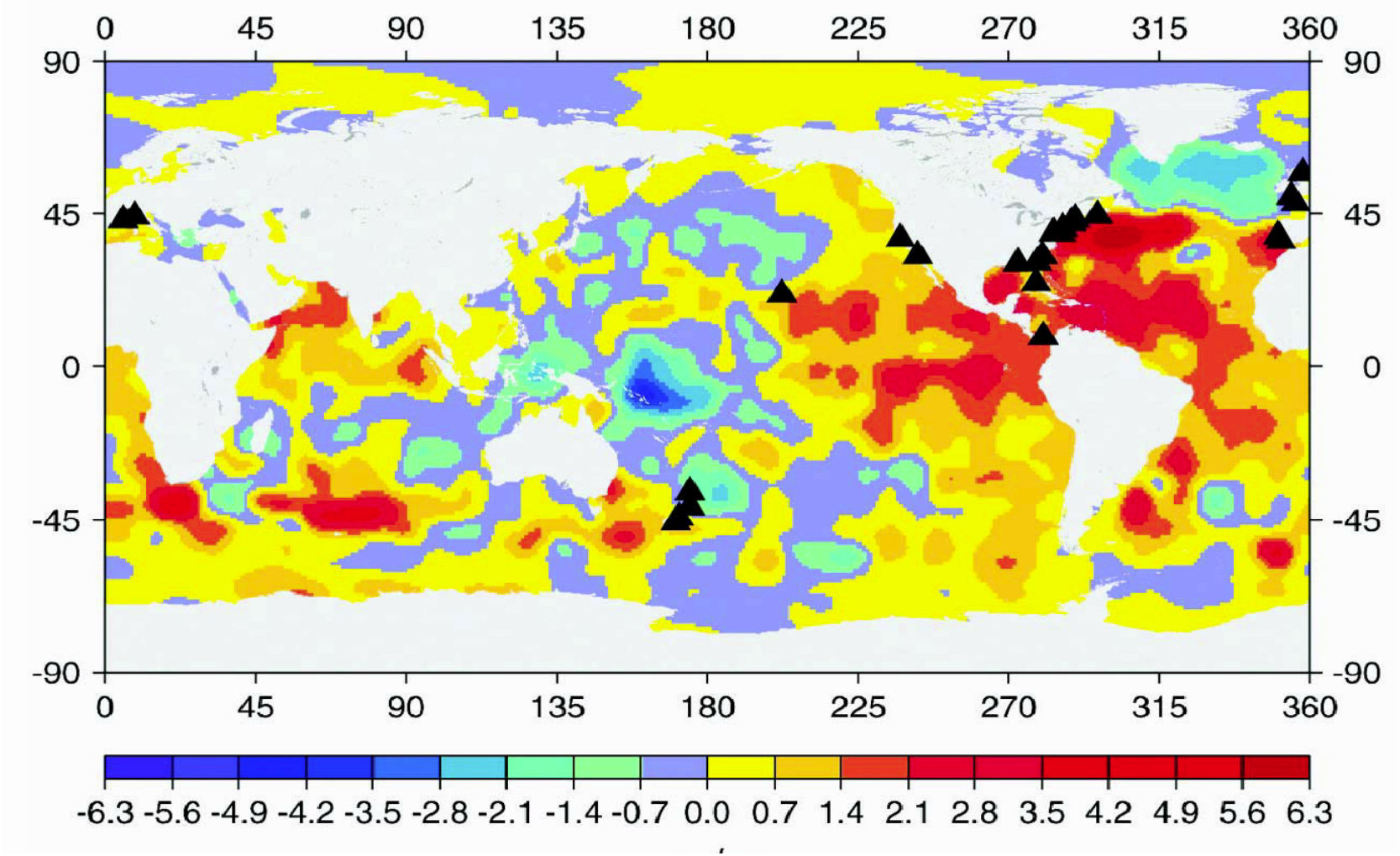


Fig. 1: XBT diagrams: Bathythermograph (probe) and exploded view.



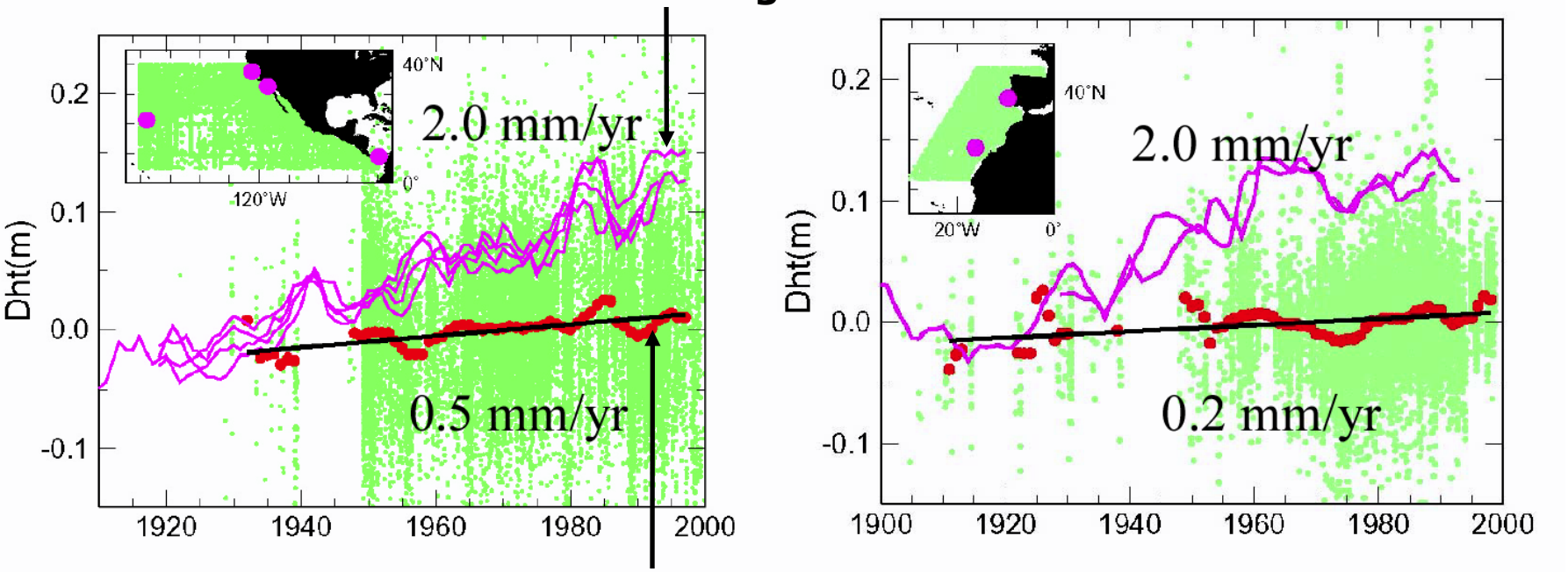
Steric sea trend changes 1955-1996



Closer look at Sea Level Change in the last 100 yr

from Tidal Gauges and Dynamic Height (=thermal expansion of oceans)

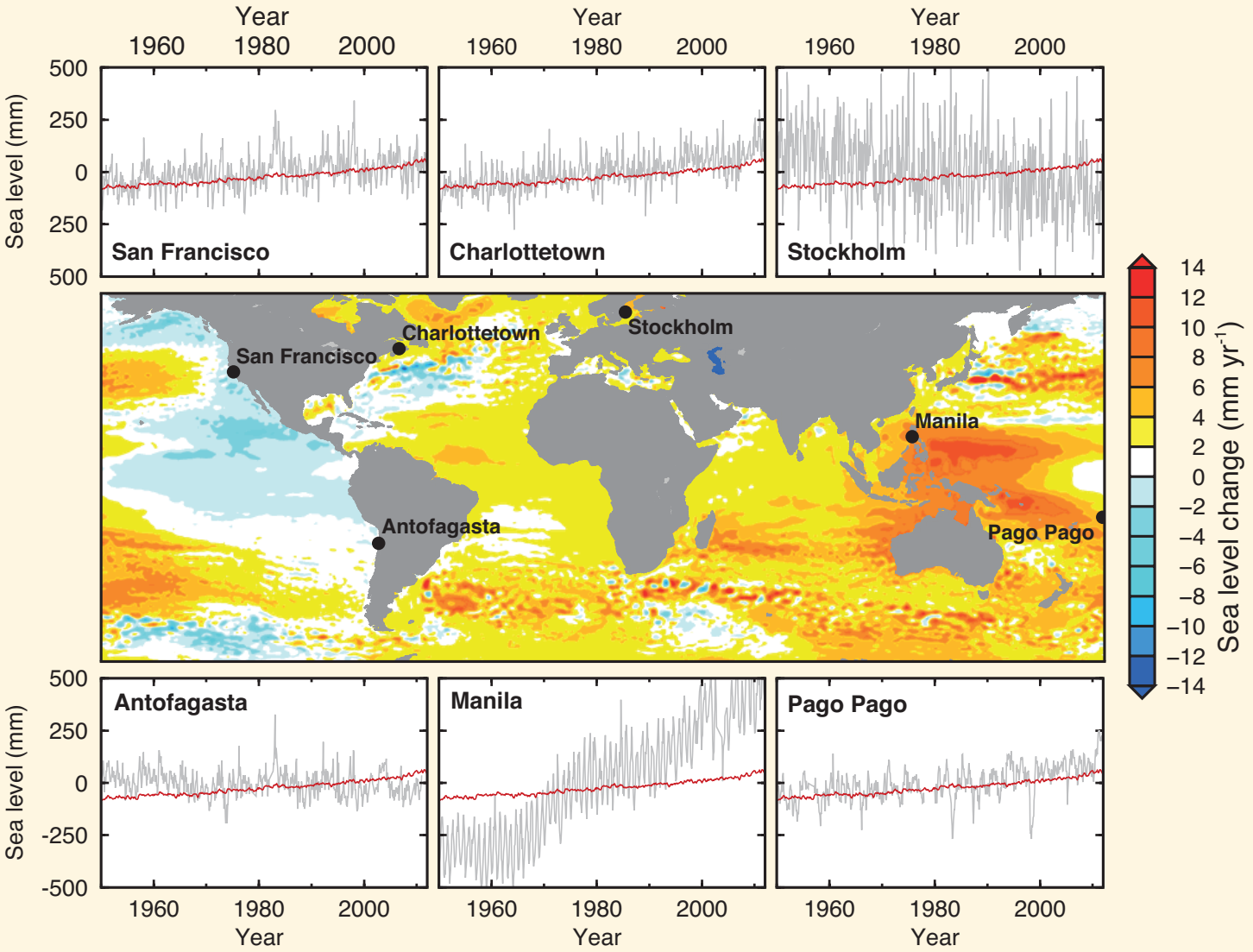
Tidal Gauges



Ocean temperature & Salinity obs (green and red)

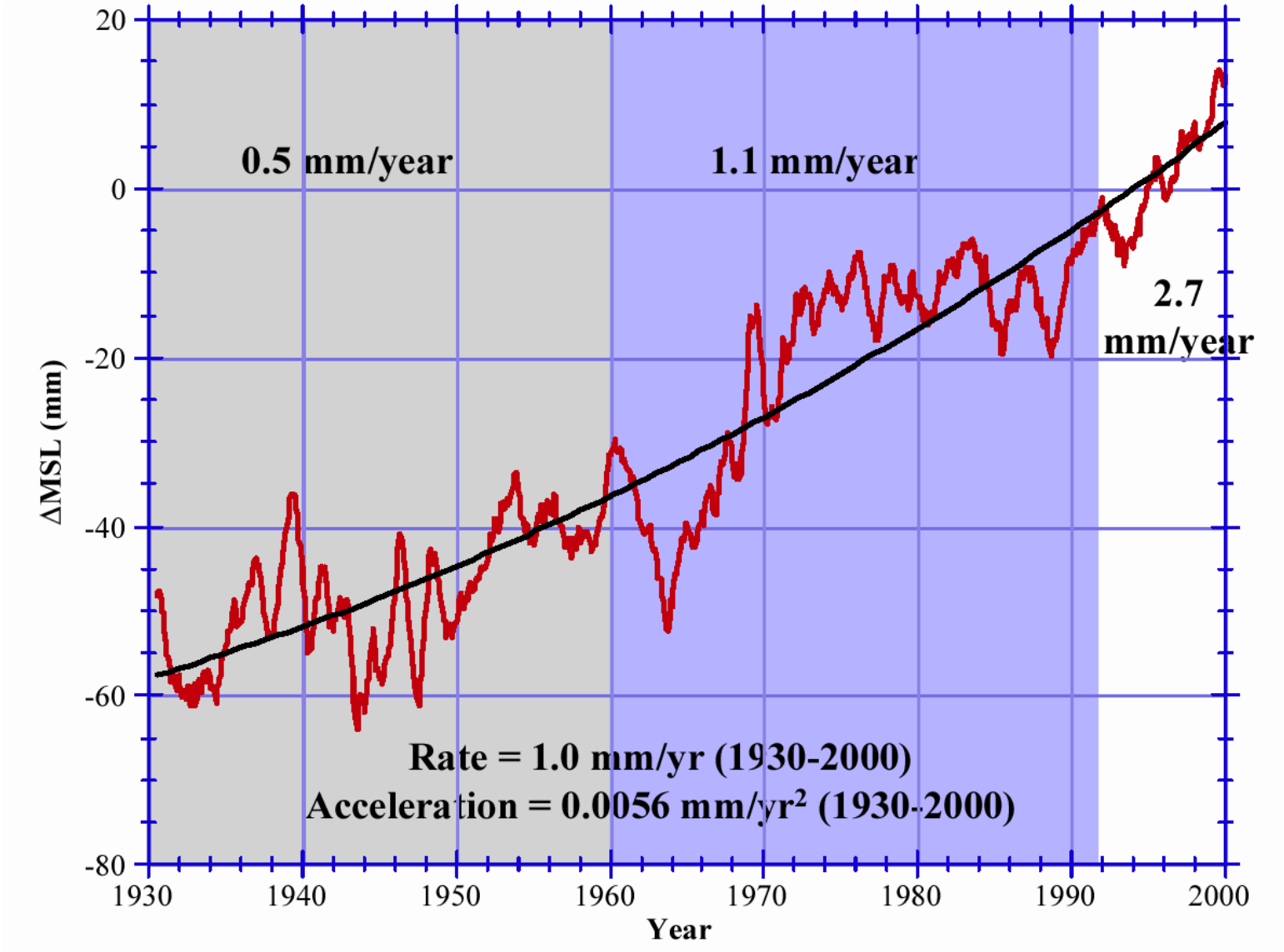
Miller and Douglas, 2004

FAQ 13.1 | Why Does Local Sea Level Change Differ from the Global Average?



FAQ13.1, Figure 1 | Map of rates of change in sea surface height (geocentric sea level) for the period 1993–2012 from satellite altimetry. Also shown are relative sea level changes (grey lines) from selected tide gauge stations for the period 1950–2012. For comparison, an estimate of global mean sea level change is also shown (red lines) with each tide gauge time series. The relatively large, short-term oscillations in local sea level (grey lines) are due to the natural climate variability described in the main text. For example, the large, regular deviations at Pago Pago are associated with the El Niño-Southern Oscillation.

Reconstruction of MSL using all data sources

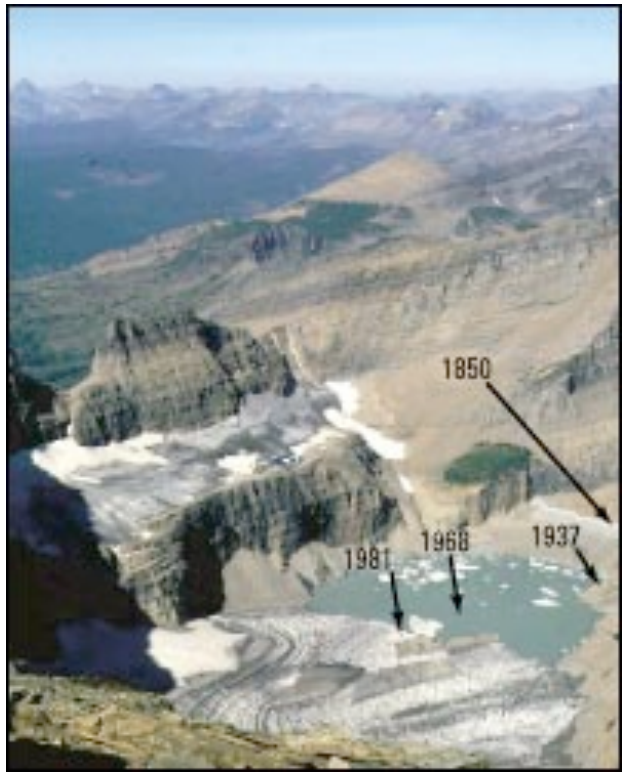


The Earth's climate has warmed about 1°C (1.8°F) during the last 100 years.

(the warming follows the Little Ice Age (19th century) → 1-2 mm/yr sea level rise)

thermal expansion of ocean water

reduction in volume of ice caps, ice fields, and mountain glaciers



IMPACTS of HUMAN on SEA LEVEL:

Increase in greenhouse-gas emissions:
→ Global Warming → expansion of oceans
☒ many of the world's mountain glaciers will disappear
☒ sea level rise acceleration

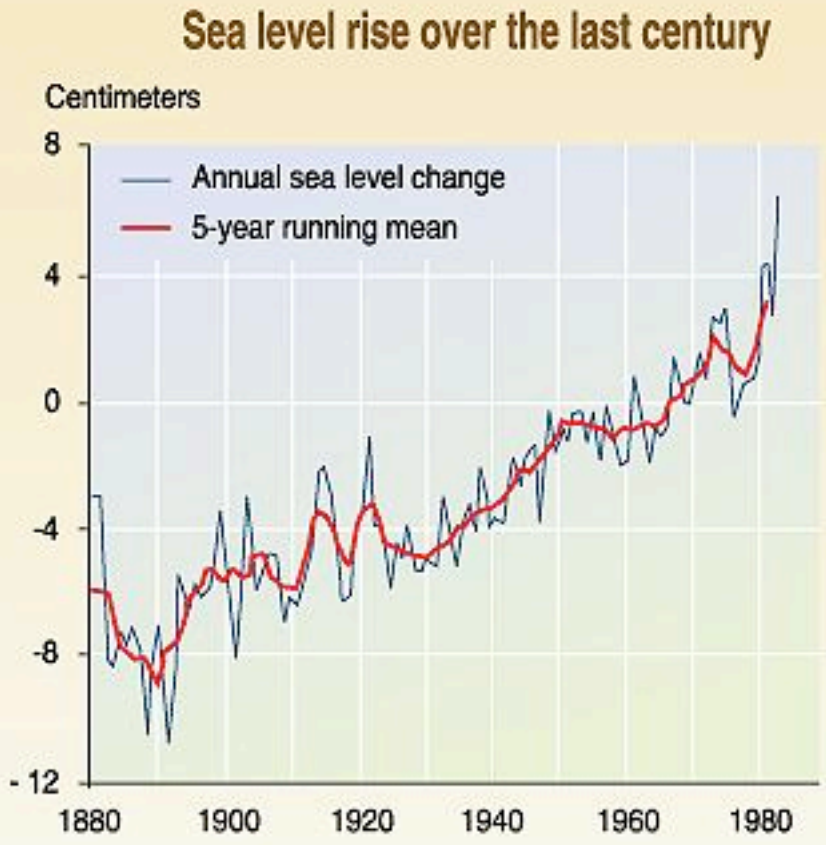
FUTURE:

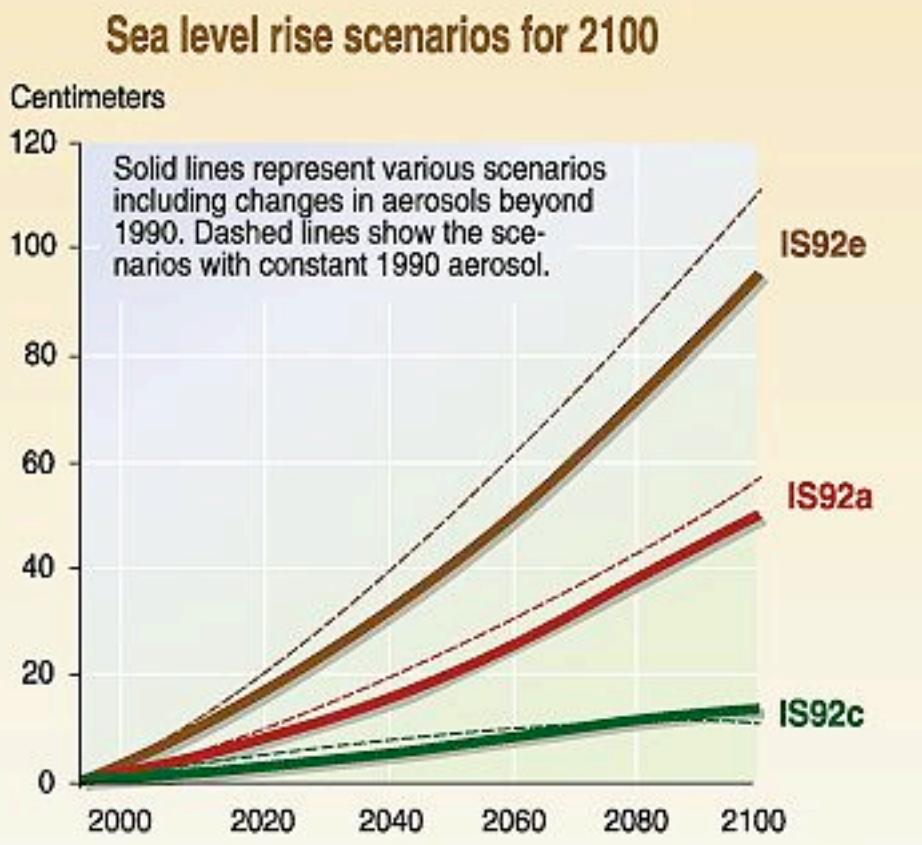
Numerical models of the Climate System

can be used to predict future changes in Sea Level?

END of Lecture

Sea level rise due to global warming



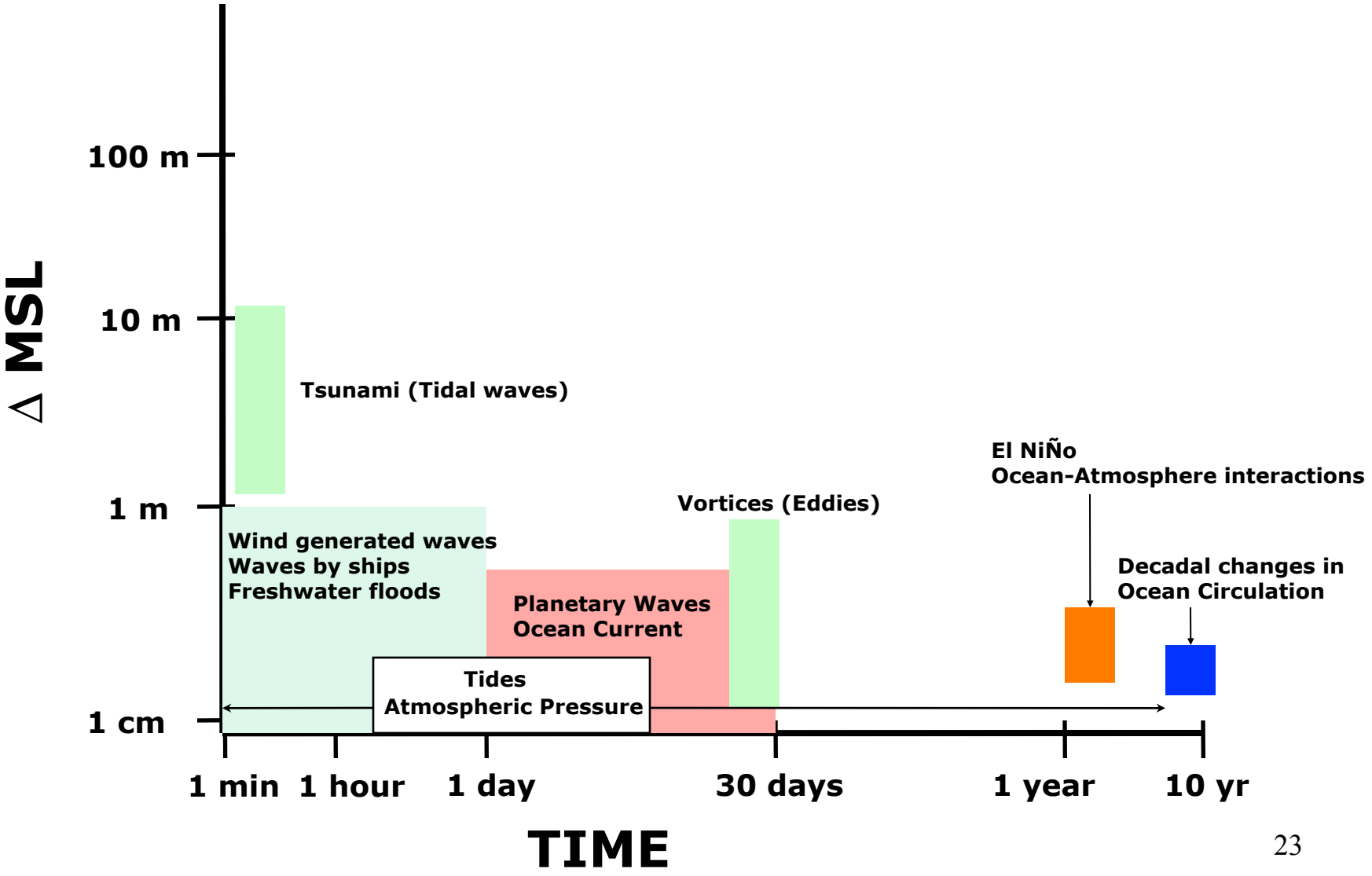


GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996; Sea level rise over the last century, adapted from Gornitz and Lebedeff, 1987.

Other processes contributing to Mean Sea Level on shorter Timescales and on local spatial scales.



Spatial pattern of sea level change 1993-2003
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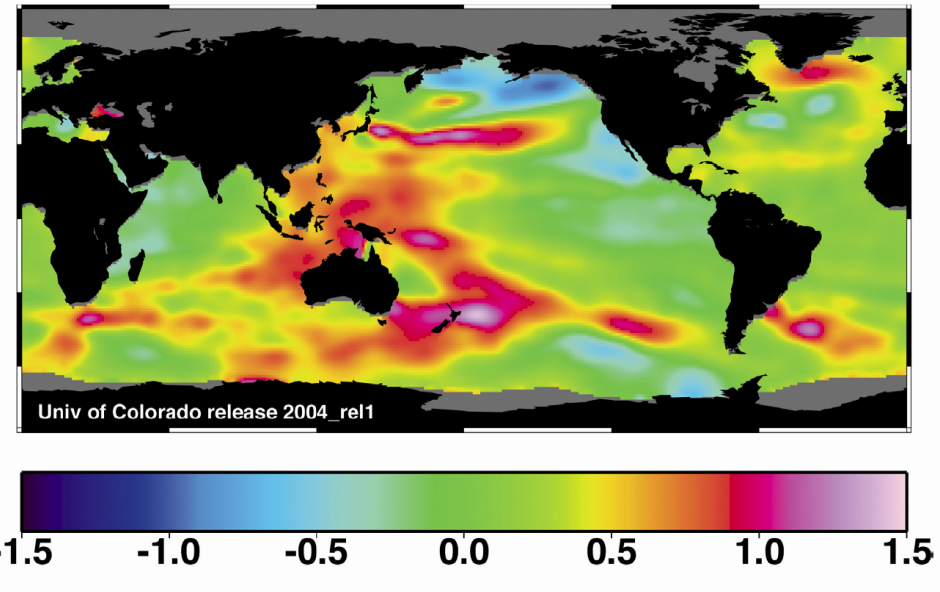
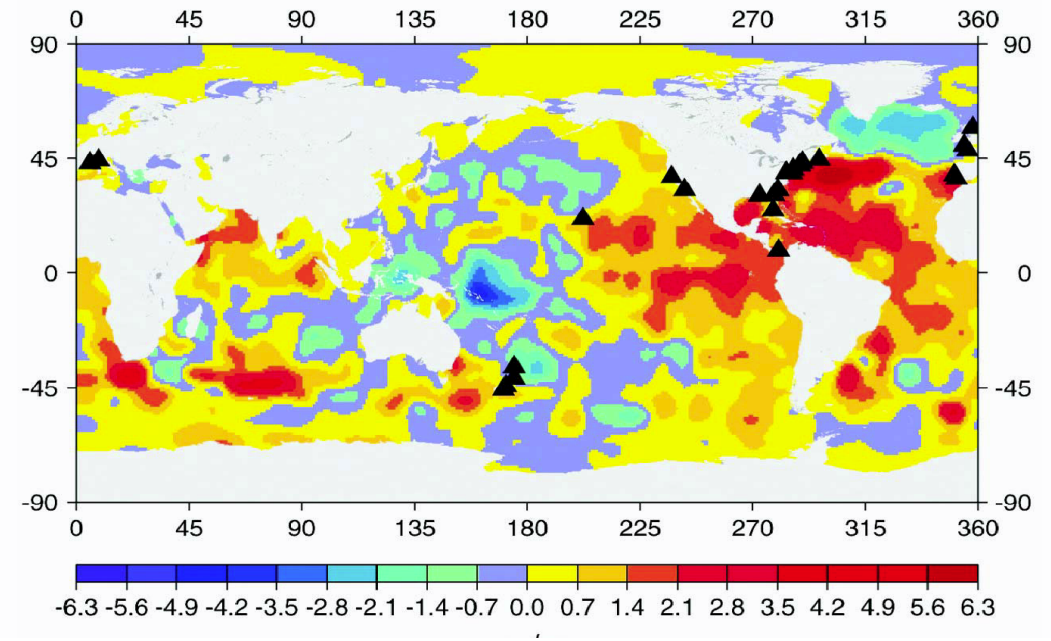


Steric sea trend changes 1955-1996
(from ocean temperatures)

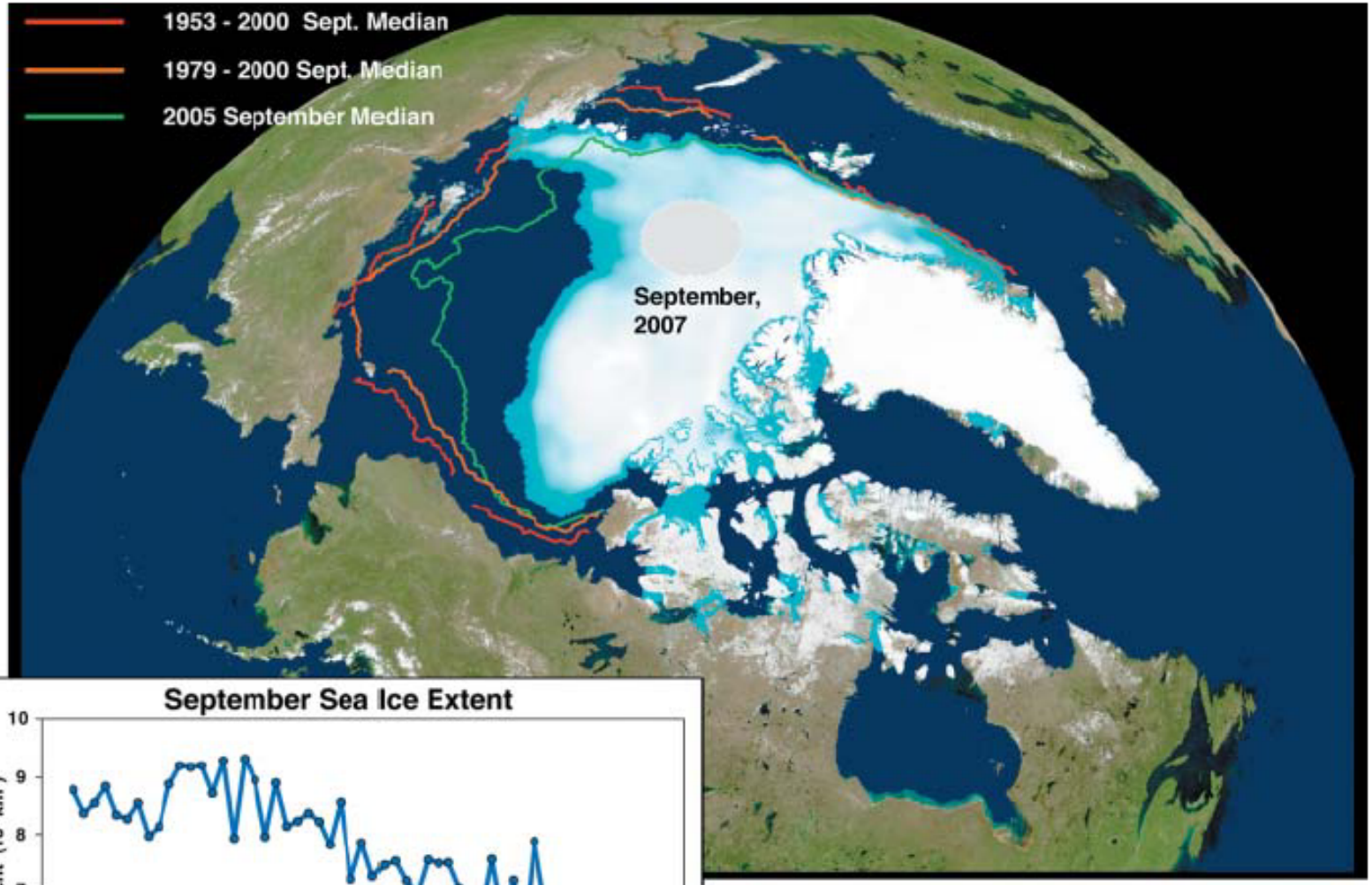


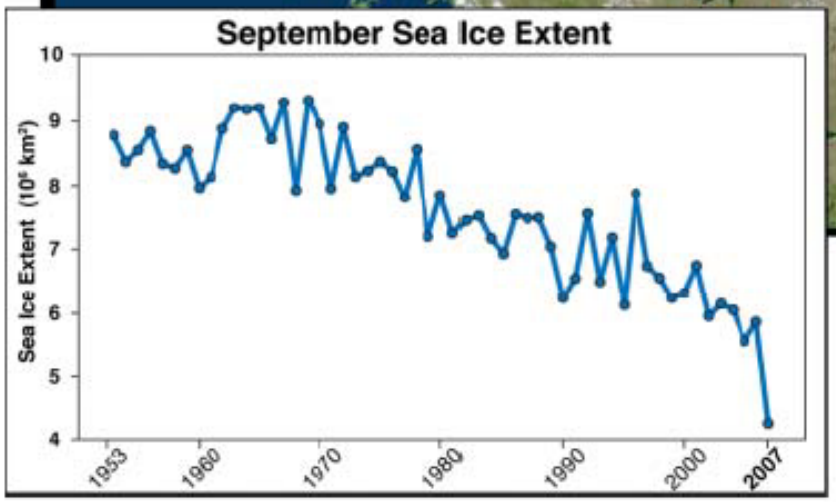
ol. 294. no. 5543, pp. 840 - 842
DOI: 10.1126/**science**.1063556
Reports

Sea Level Rise During Past 40 Years Determined from Satellite and in Situ Observations

Cecile Cabanes, Anny Cazenave, Christian Le Provost

The 3.2 ± 0.2 millimeter per year global mean sea level rise observed by the Topex/Poseidon satellite over 1993-98 is fully explained by thermal expansion of the oceans. For the period 1955-96, sea level rise derived from tide gauge data agrees well with thermal expansion computed at the same locations. However, we find that subsampling the thermosteric sea level at usual tide gauge positions leads to a thermosteric sea level rise twice as large as the "true" global mean. As a possible consequence, the 20th century sea level rise estimated from tide gauge records may have been overestimated.





Stroeve et al, 2008