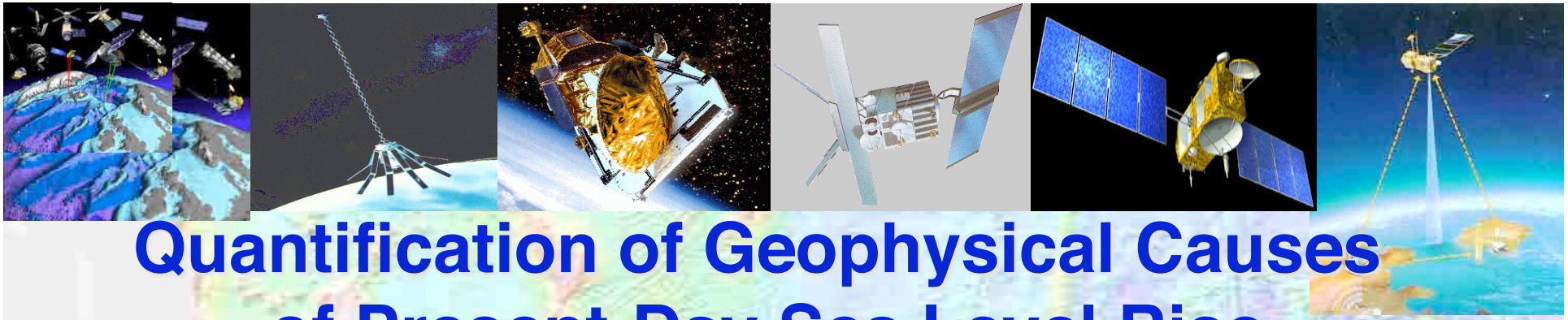

Quantification of Geophysical Causes of Present-Day Sea Level Rise

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AAAS Annual Meeting
Session 180–040
Global Sea Level Rise: Observation, Causes, and Prediction

Chicago, Illinois
12–16 February 2009

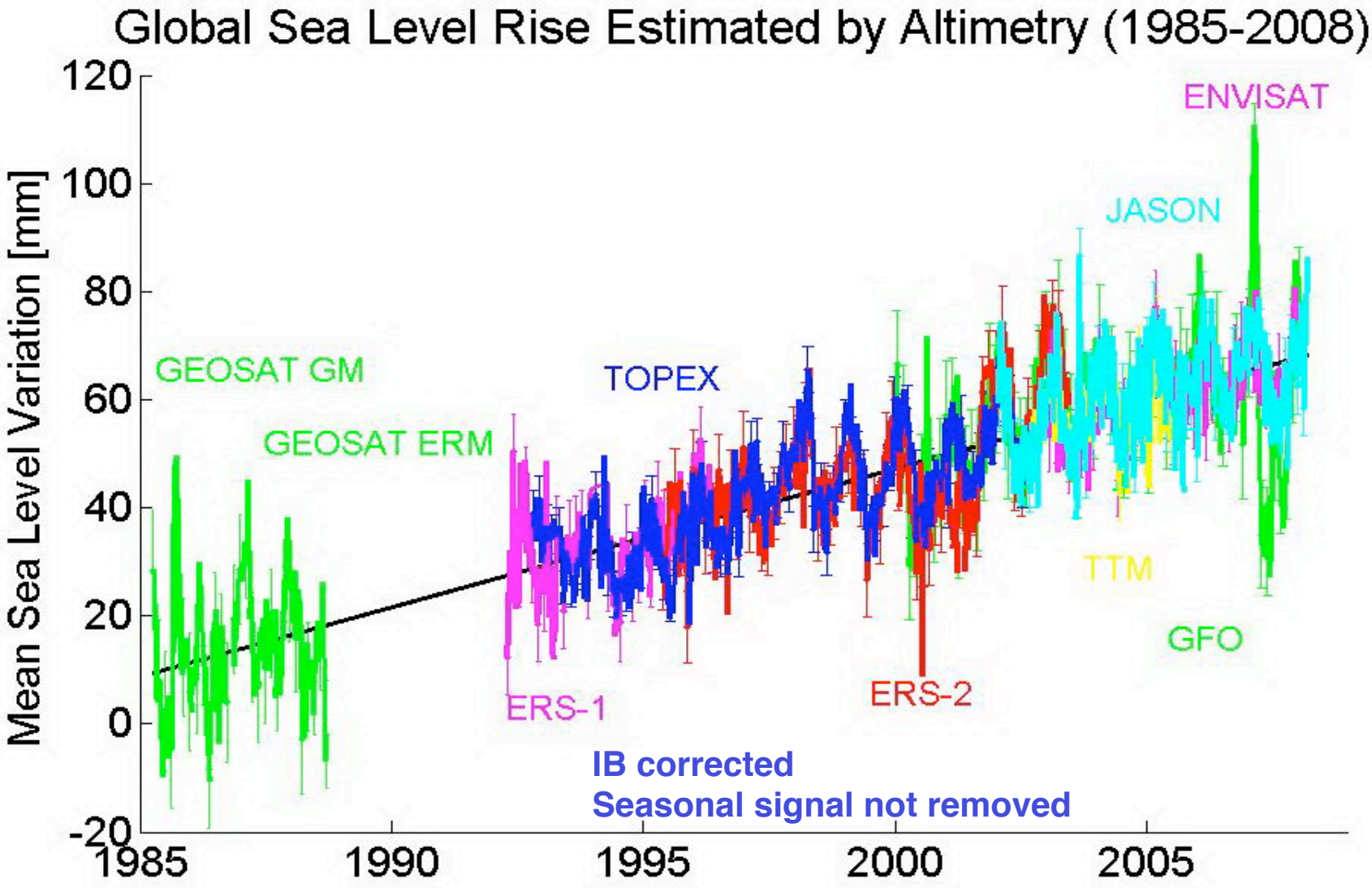
THE OHIO STATE UNIVERSITY School of Earth Sciences www.earthsciences.osu.edu

AAAS ADVANCING SCIENCE, SERVING SOCIETY

Global Sea Level Rise Observed By Satellite Altimetry (1985–2008)

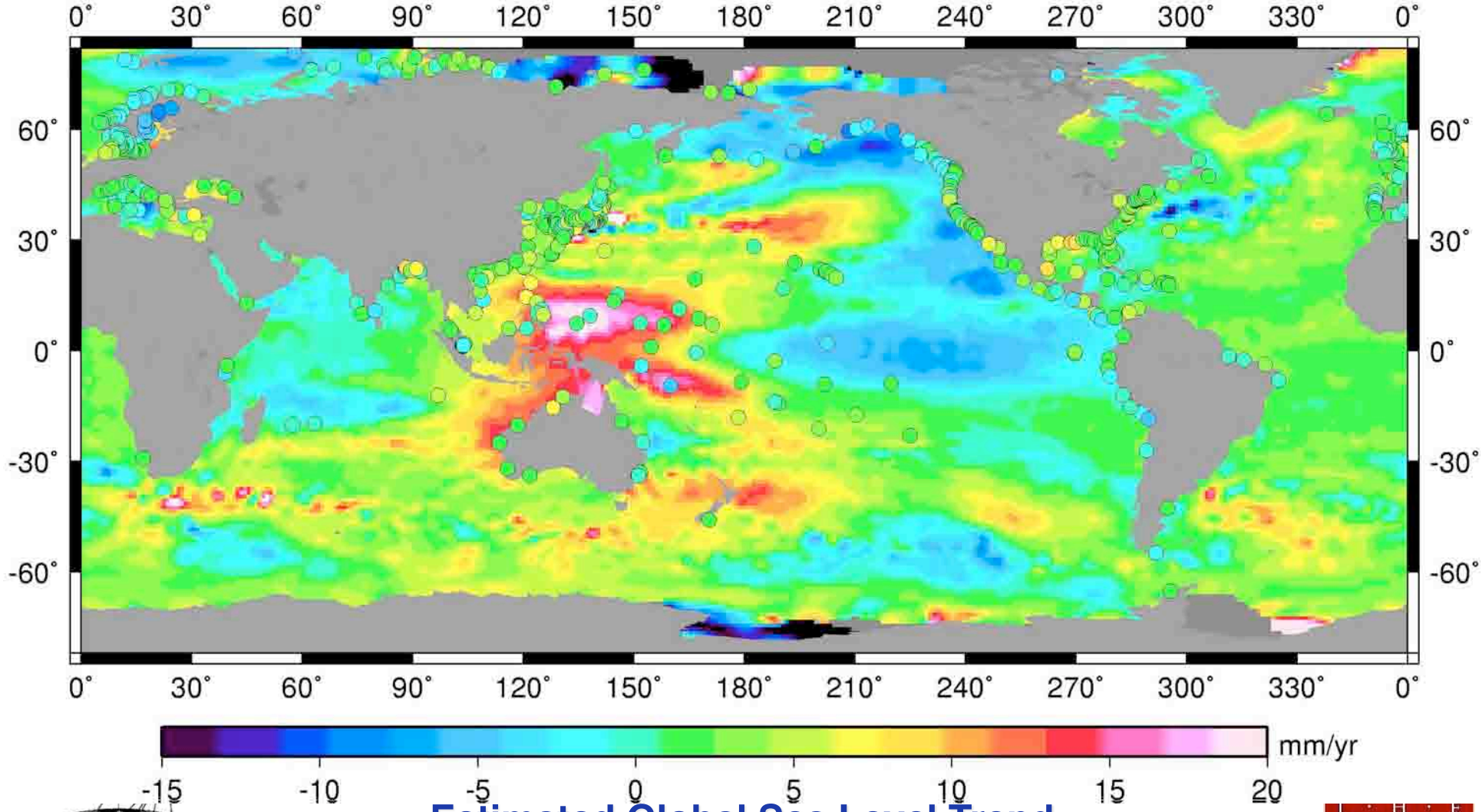
Estimated sea level trend (1985–2008): 2.6±0.4 mm/yr

After sea floor basin "geoid" GIA correction (ICE4G): Trend = 2.9 mm/yr



School of Earth Sciences

Global Sea Level Observed by Tide Gauges (1900-2006) & Altimetry (1985-2008)



Estimated Global Sea Level Trend:

Tide gauges (1900–2006) = 1.6±0.4 mm/yr

Multiple radar altimetry (1985–2008) = 2.6±0.4 mm/yr

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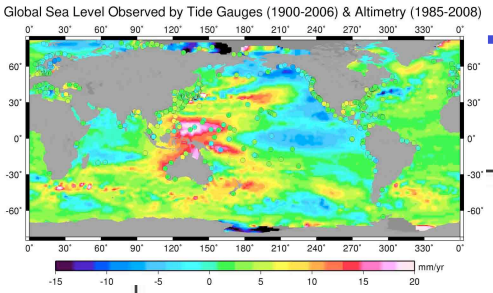
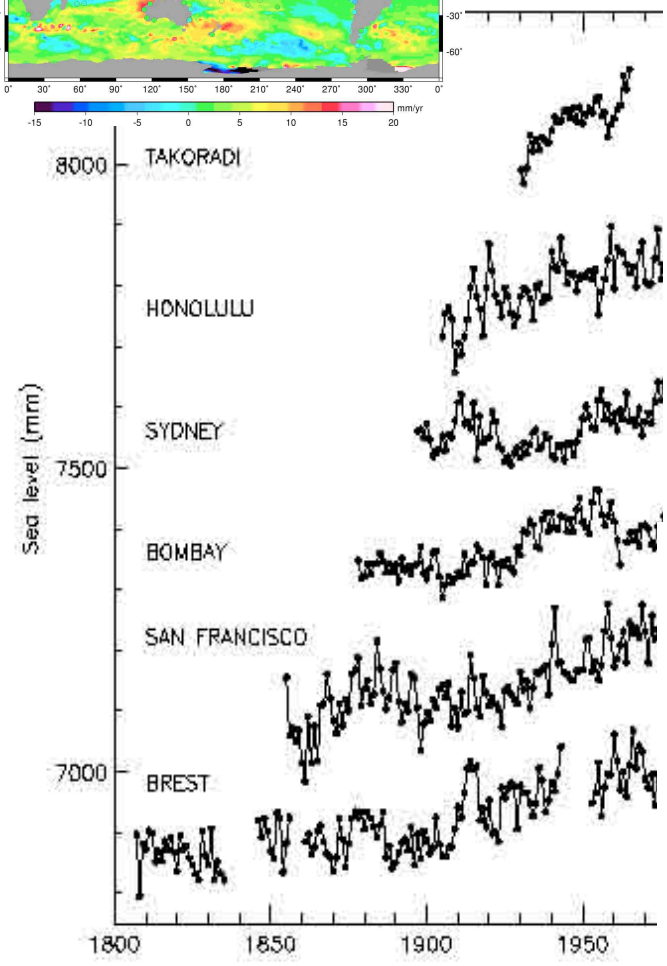
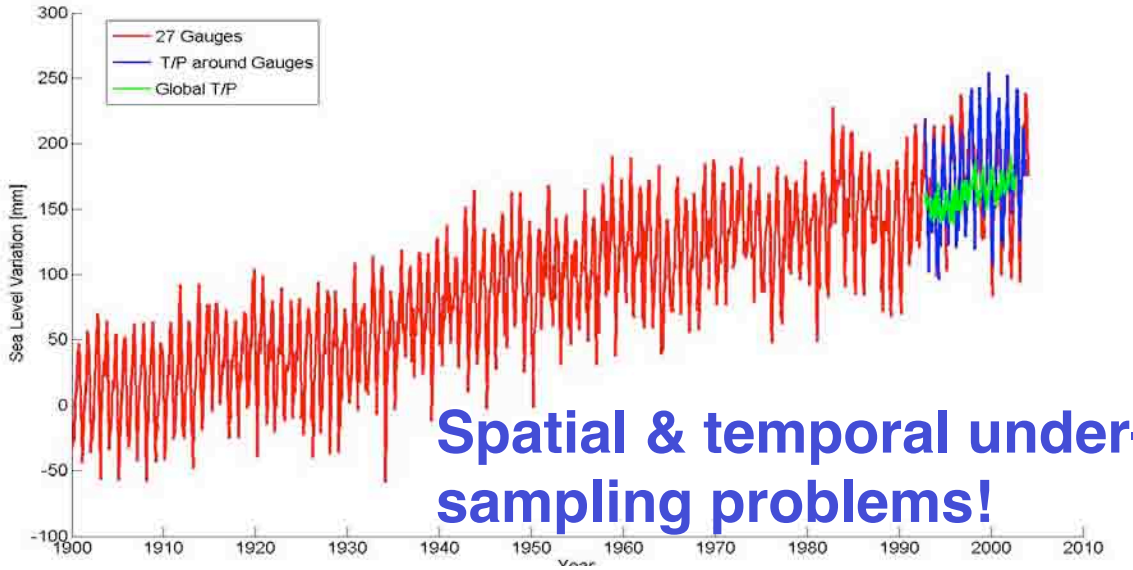
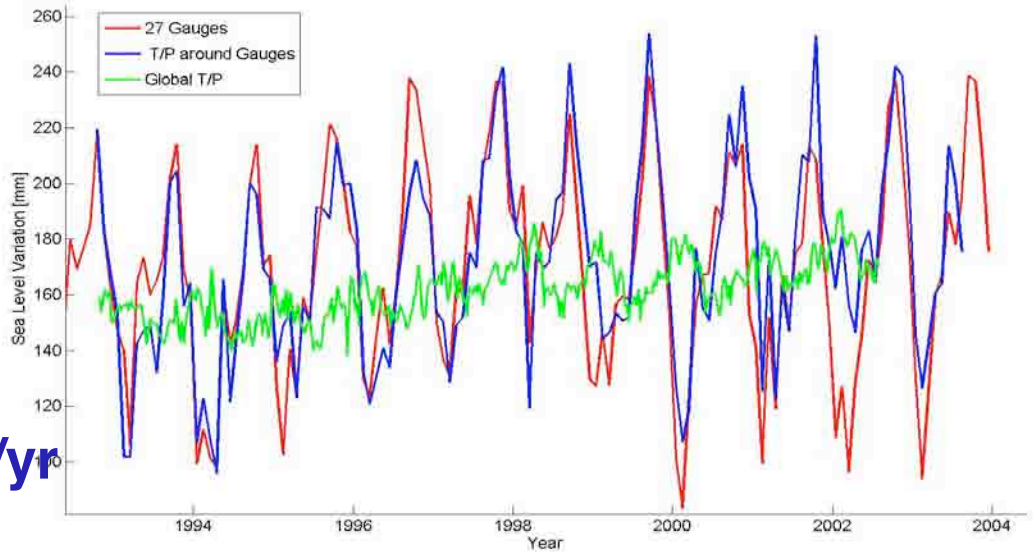
Tide Gauge vs Altimetry Observed Sea Level





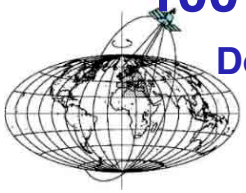


Spatial & temporal under-sampling problems!



Sea level rise: ~ 1.6–1.8 mm/yr
100–200 year records

Douglas, 2001; Church et al. [2006]



Use "models" to aid spatial Interpolation

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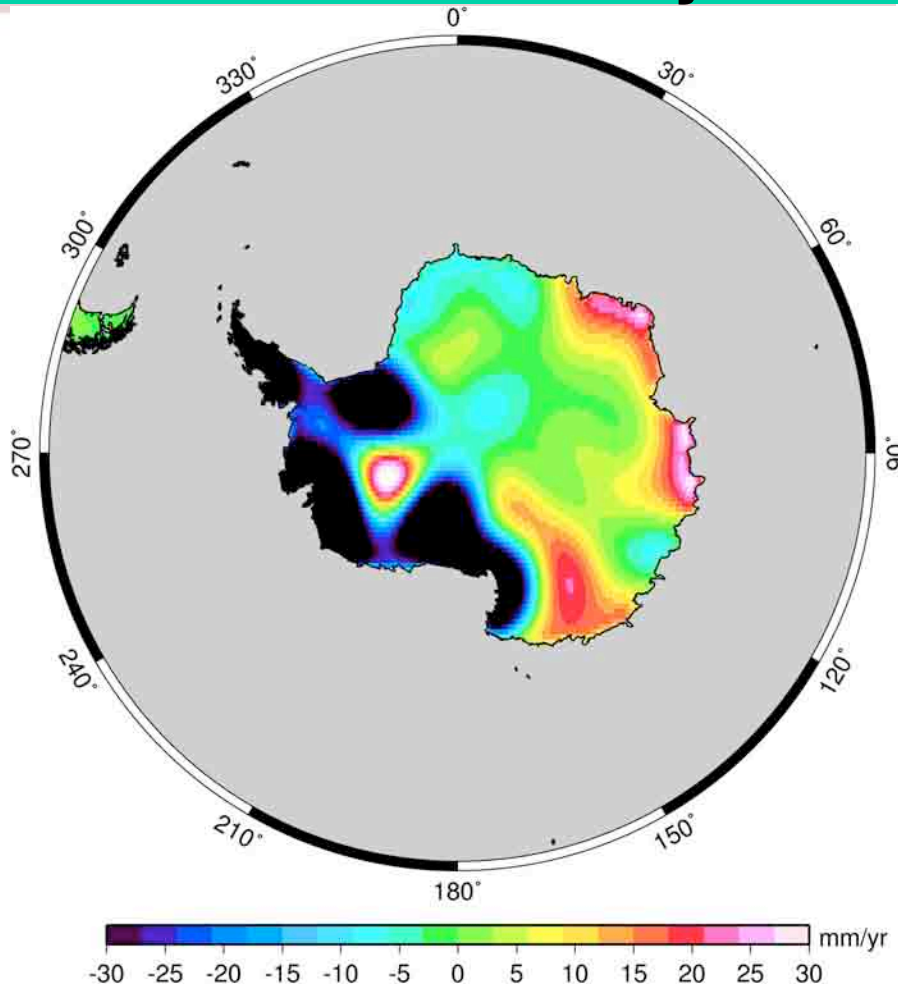
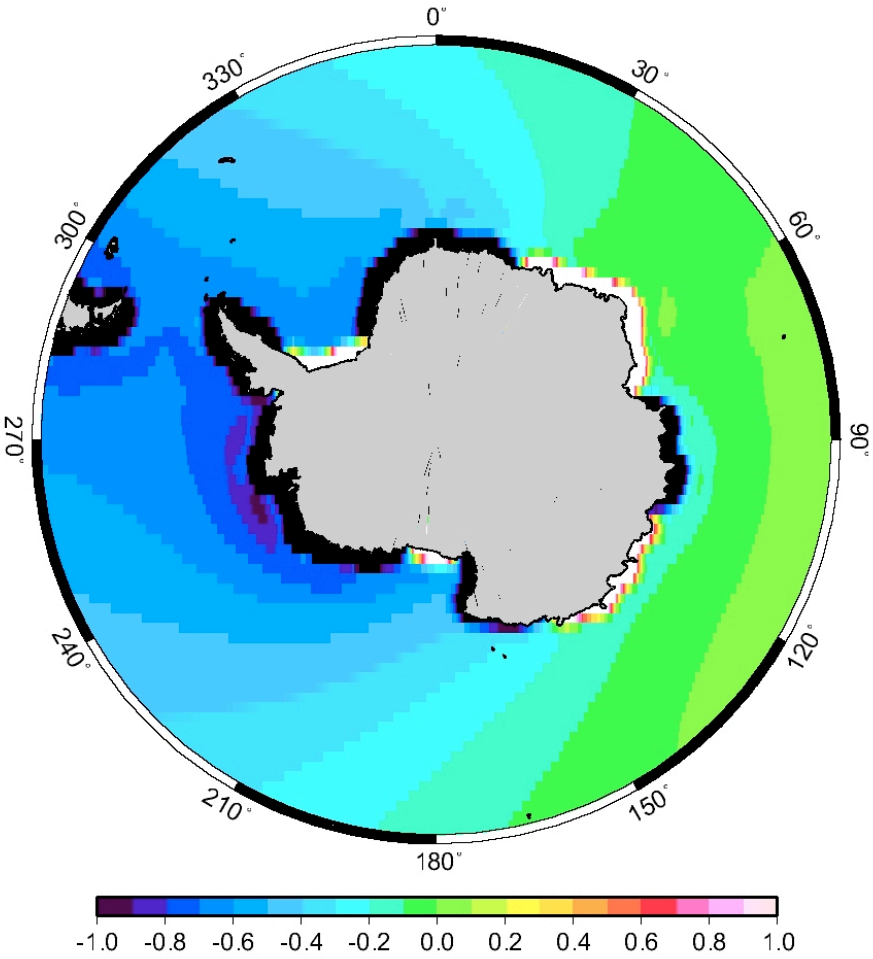
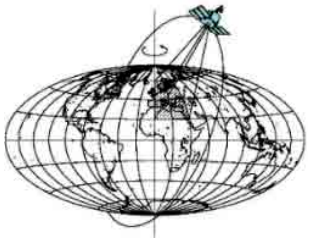
Predicted Sea Level Change Due to Elastic Loading of Present-Day Antarctica Ice Sheet Melt







GRACE observed water thickness trend (mm/yr) (2002–2008)

Predicted sea level change as a result of ice-ocean mass change assuming elastic loading (mm/yr)

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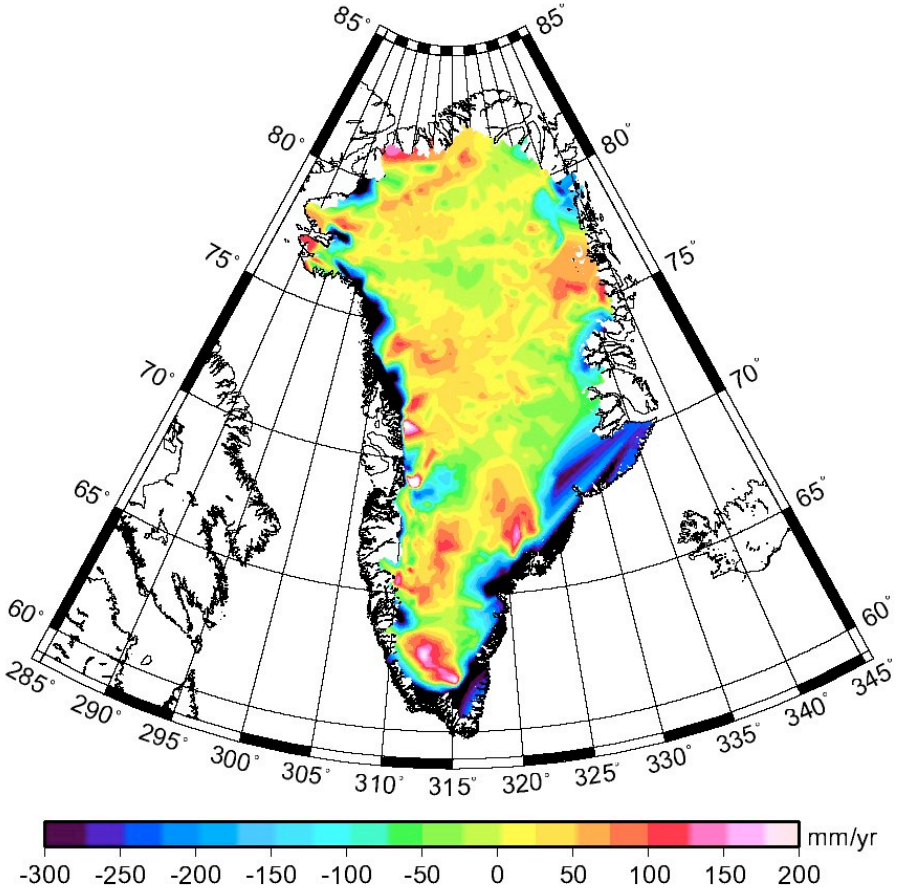
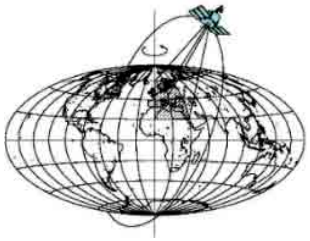
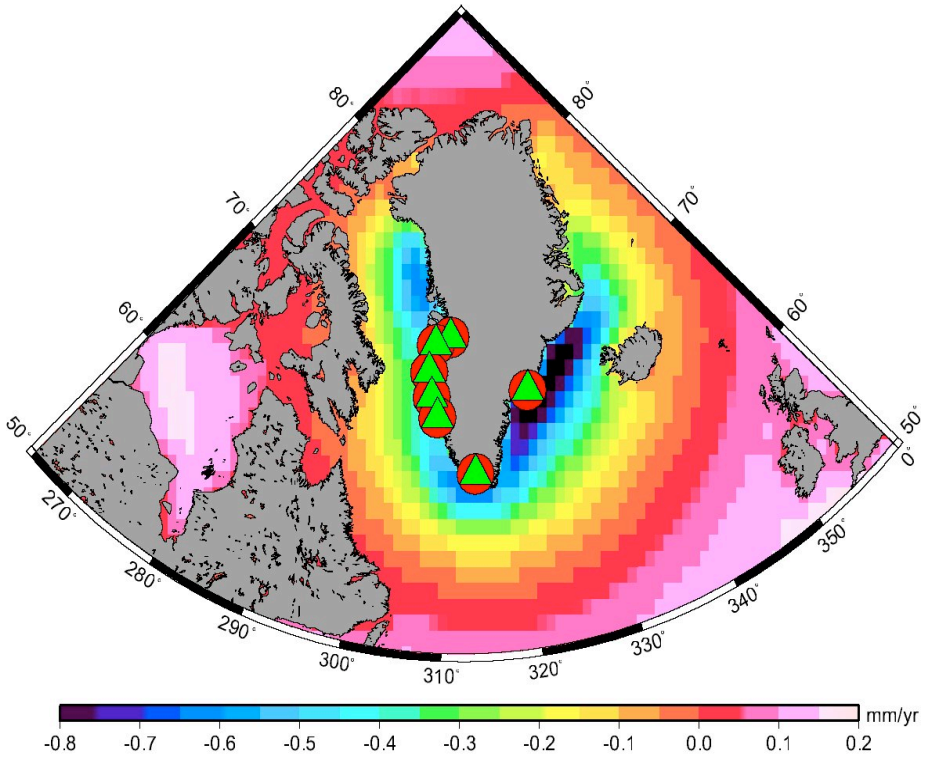
Predicted Sea Level Change Due to Elastic Loading of Present-Day Greenland Ice Sheet Melt





Airborne laser altimeter Observed Greenland ice thickness trend (dh/dt data courtesy, Bill Krabill)



Predicted sea level change as a result of ice-ocean mass change assuming elastic loading (mm/yr, green triangle, tide gauge locations)

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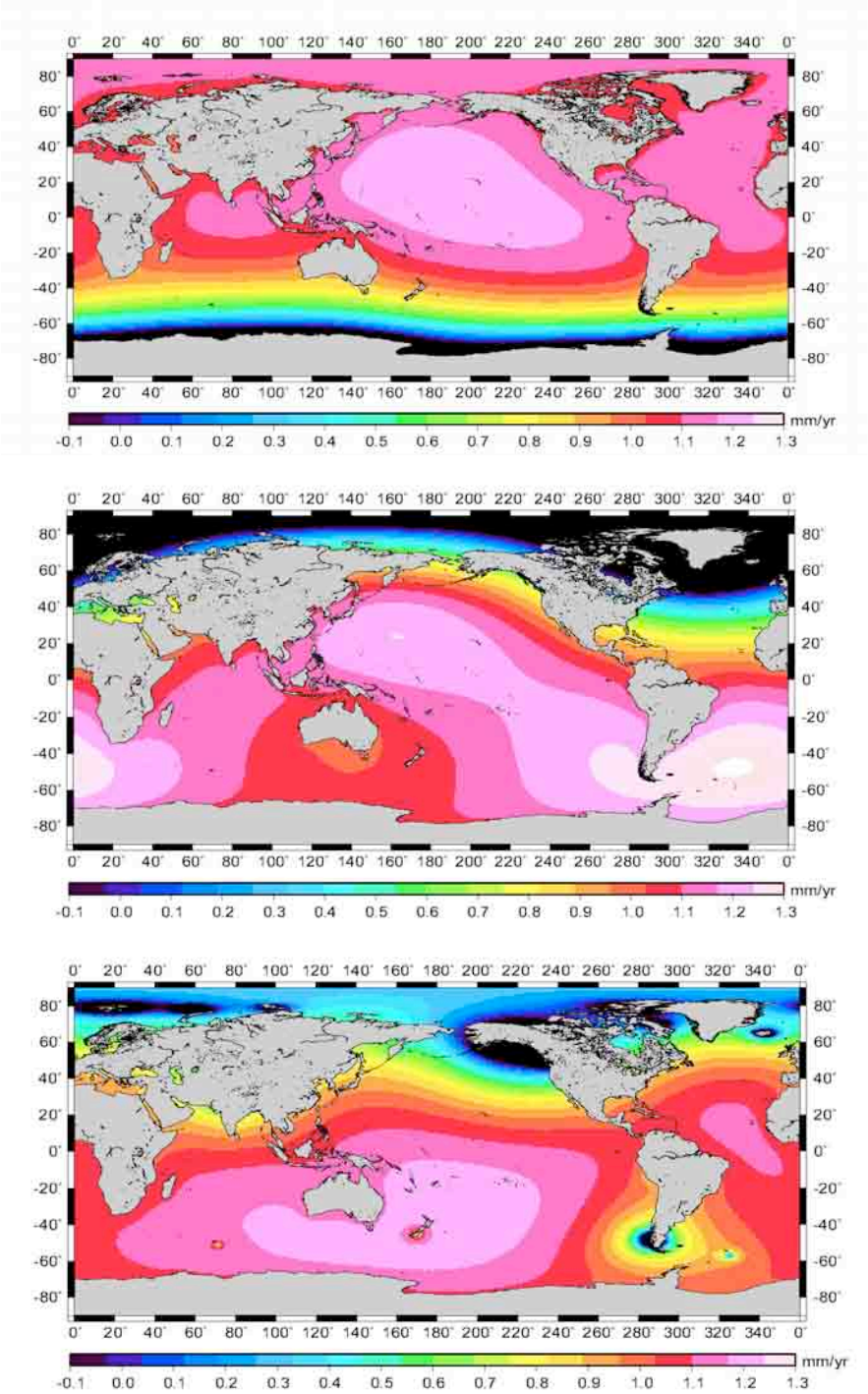
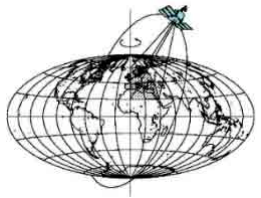


Sea level change "patterns" computed using elastic loading theory of geoid change from present-day melt water "loading" from Antarctica (top), Greenland (middle), and mountain glacier (bottom) ice melt [Plag, 2001, Mitrovica et al., 2001, Kuo & Shum, 2006]:

$$S_T(\theta_j,\varphi_j) = V_O \times S_O^n(\theta_j,\varphi_j) + V_A \times S_A^n(\theta_j,\varphi_j)$$
$$+V_G \times S_G^n(\theta_j,\varphi_j) + V_M \times S_M^n(\theta_j,\varphi_j)$$

S_T=GIA corrected sea level from tide gauges; S^n are maps of sea level variation patterns; V_A, V_G, V_M are scale factors of S^n due to the 3 ice systems, and V_0 is for are other contributions, e.g., oceanic thermal expansion



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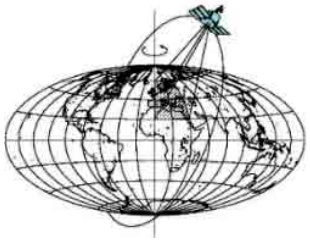
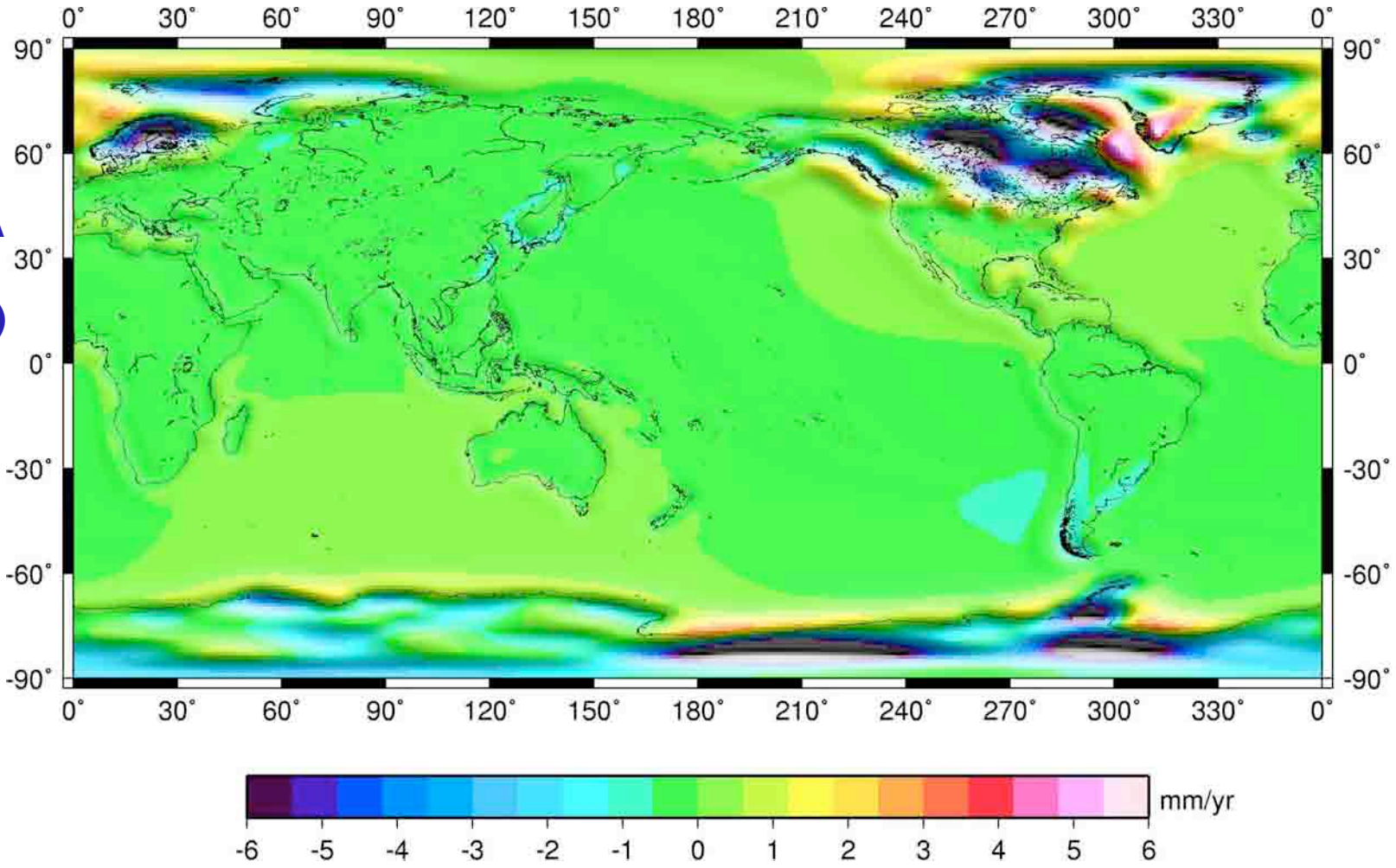
Glacial Isostatic Adjustment

The phenomena of solid Earth visco-elastic rebound due to deglaciation from the last Ice Age (LGM: ~18,000 yBP).

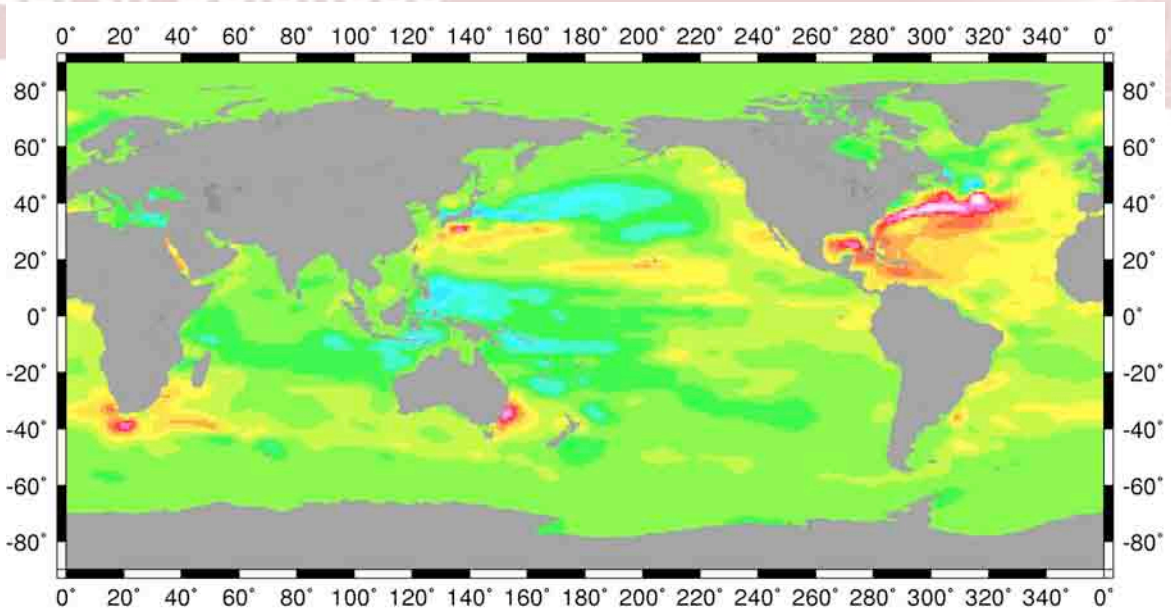
GIA changes land and ocean basins to which instrument (tide gauge & altimetry) are based and referenced.

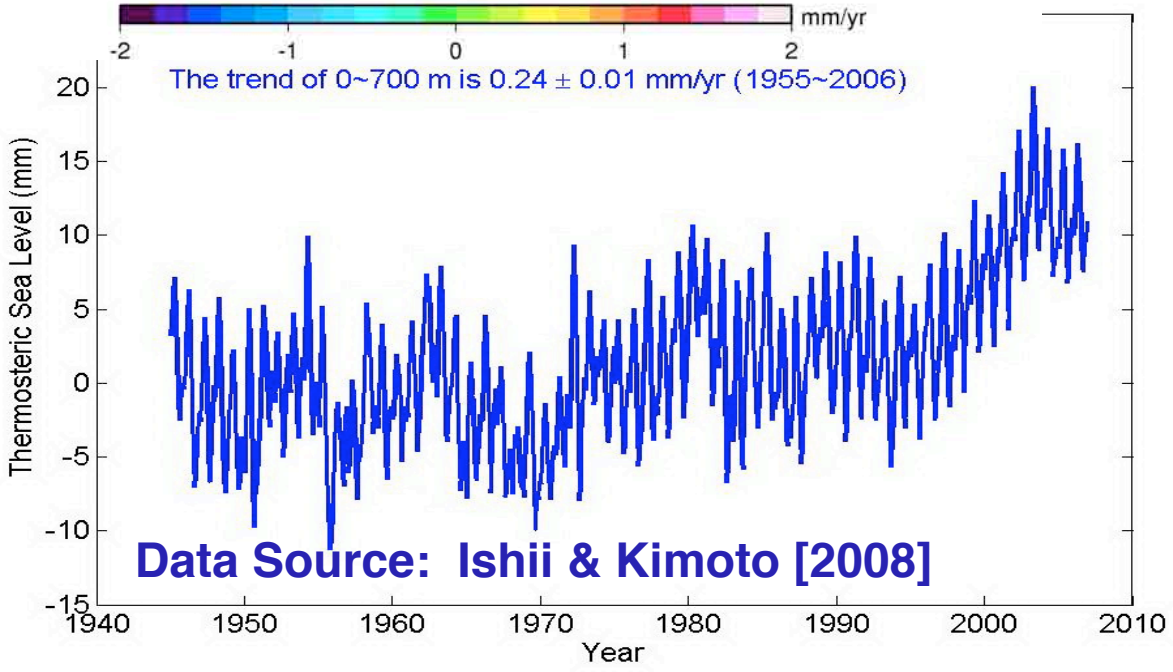
ICE-5G (VM2) predicted GIA "sea level" (geoid –uplift) [Peltier, 2004]



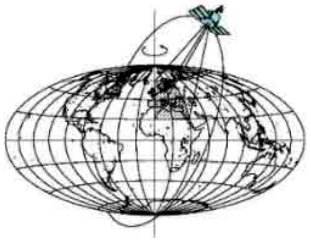


Thermosteric Sea Level (1945–2006)





Historic data coverage extremely sparse in the Southern Ocean (improved with ARGOS)



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Sea Level Adjustment and Quantifications Using Tide Gauges & Satellite Altimetry

Observation Equations [Kuo & Shum, 2006]:

$$y_T(\theta_j,\varphi_j) = V_O \times S_O^n(\theta_j,\varphi_j) + V_A \times S_A^n(\theta_j,\varphi_j)$$

$$+V_G \times S_G^n(\theta_j,\varphi_j) + V_M \times S_M^n(\theta_j,\varphi_j) + V_{GIA} \times GIA(\theta_j,\varphi_j)$$

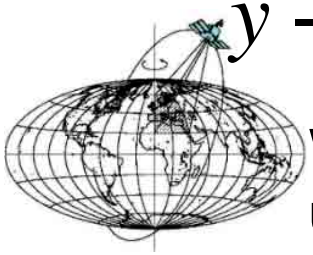
$$y_V(\theta_j,\varphi_j) = V_{GIA} \times \dot{u}(\theta_j,\varphi_j)$$

Where S are normalized spatial functions of sea level trend contributed by ocean (thermal), Antarctica, Greenland, and mountain glaciers, and GIA is pattern (radial motion+geoid) due to GIA, y_T and y_v are the sea level (tide gauge trends), and the crustal vertical motion observations (combining tide gauge and altimetry), respectively. *V* are unknown scale factors. $\dot{u}$ is the crustal vertical motion due to GIA.

Elementwise Weighted Total LS (EW-TLS) [Premoli & Rastello, 2002]:

$$y - e = (A + E_A)\xi \qquad E\{[E_A, e]\} = 0; C\{[E_A, e]\} = 0$$

$$D\{e\} = \sigma_{iy}^2 \qquad D\{E_A\} = \sigma_{ij}^2$$



Where *y* are observations (tide gauge & altimetry); ξ are unknown scale factors of spatial functions, *S and GIA*

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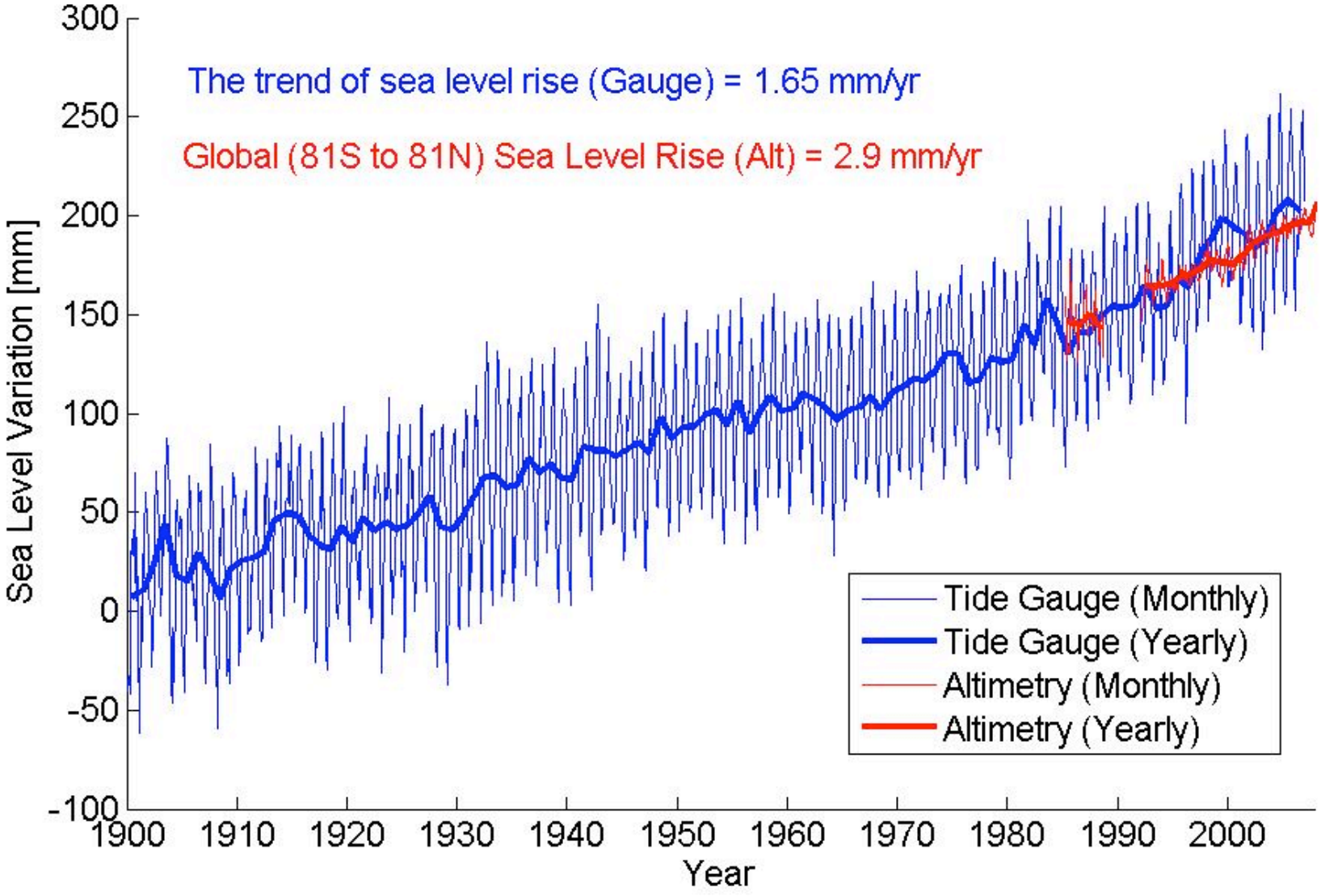
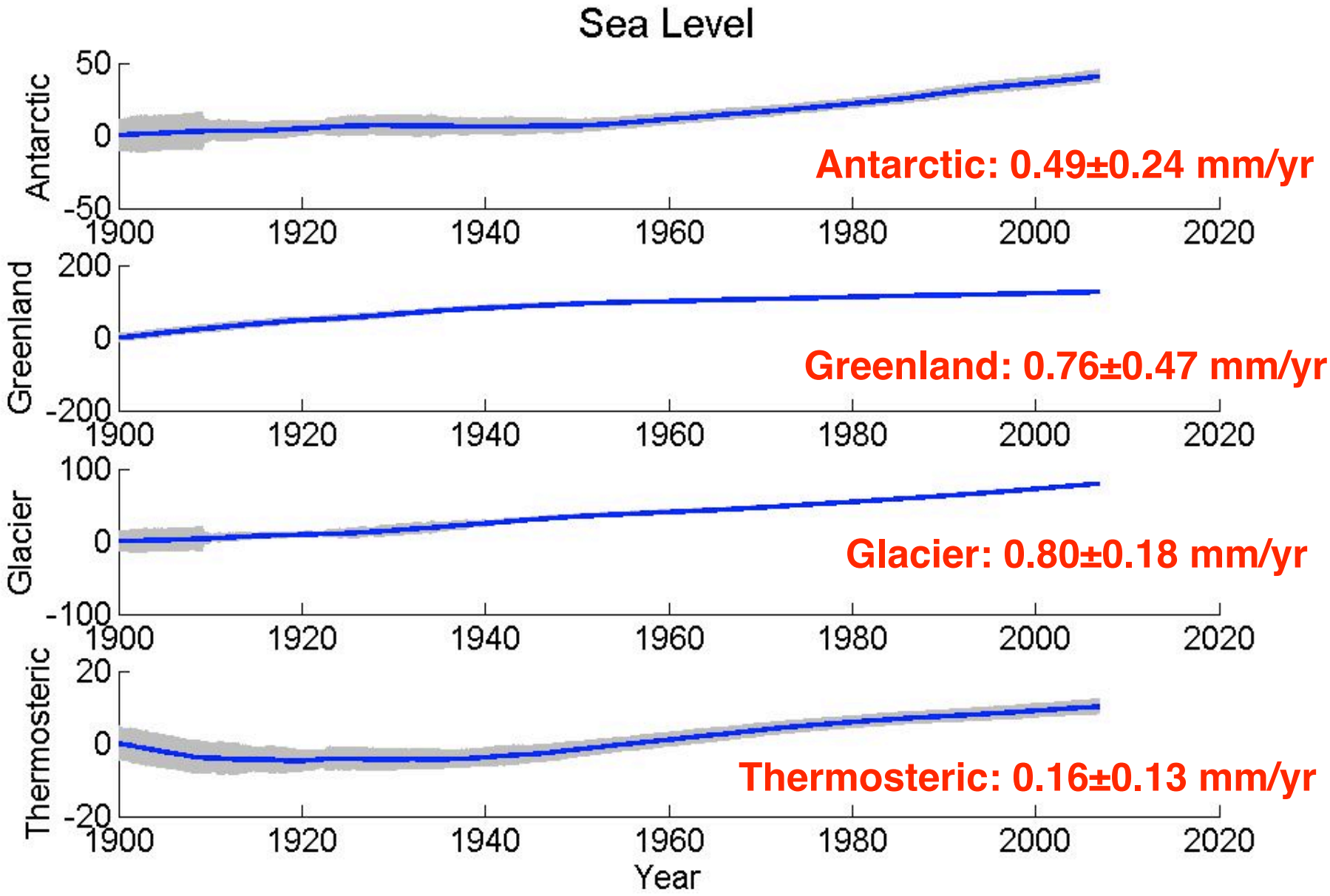
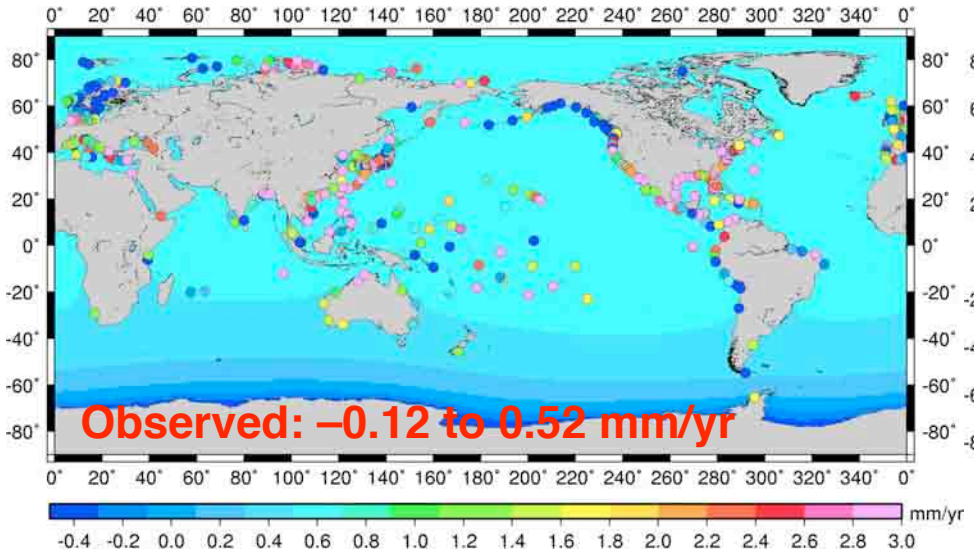
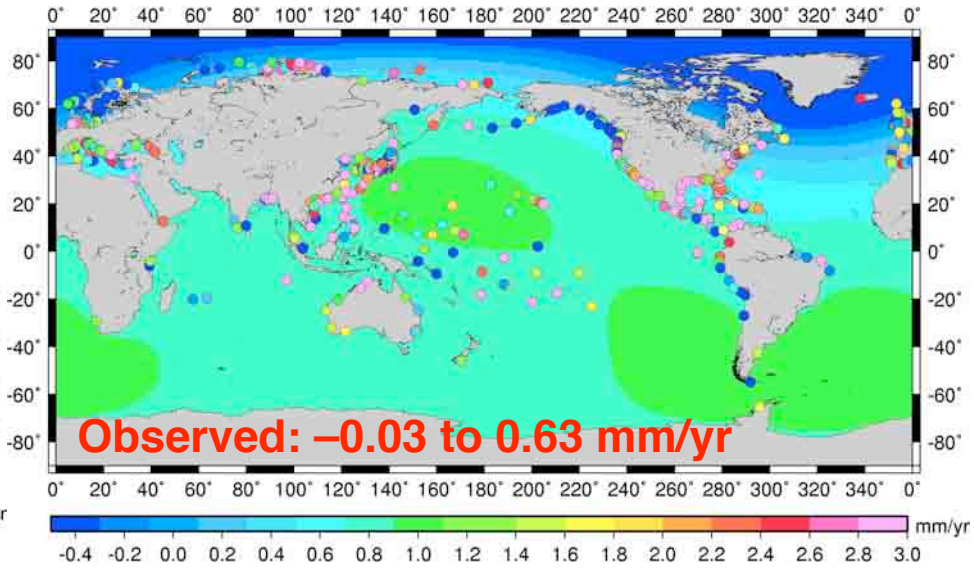

The trend of sea level rise (Gauge) = 1.65 mm/yr
Global (81S to 81N) Sea Level Rise (Alt) = 2.9 mm/yr
Sea Level Variation [mm]
300
250
200
150
100
50
0
-50
-100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Year
Tide Gauge (Monthly)
Tide Gauge (Yearly)
Altimetry (Monthly)
Altimetry (Yearly)

Estimated Sea Level Contributions (1900–2007)

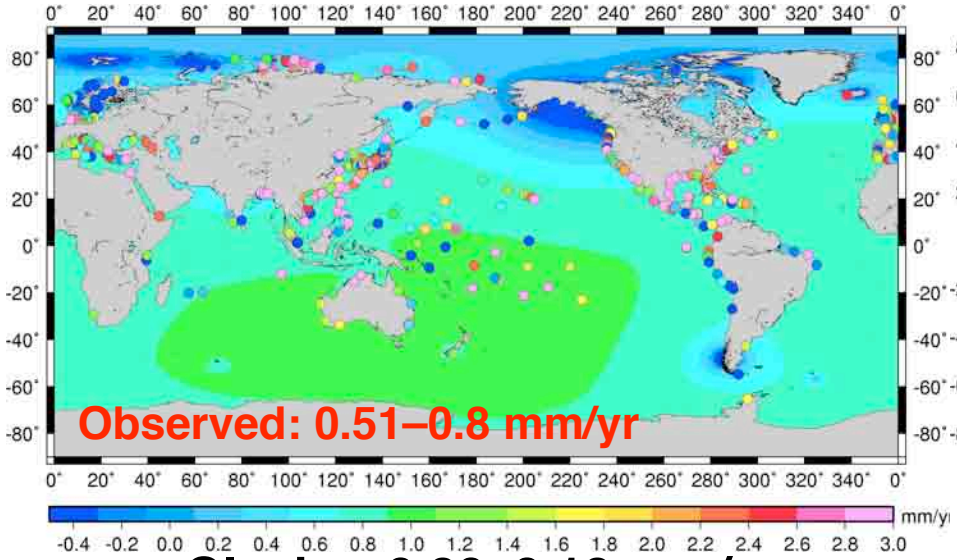




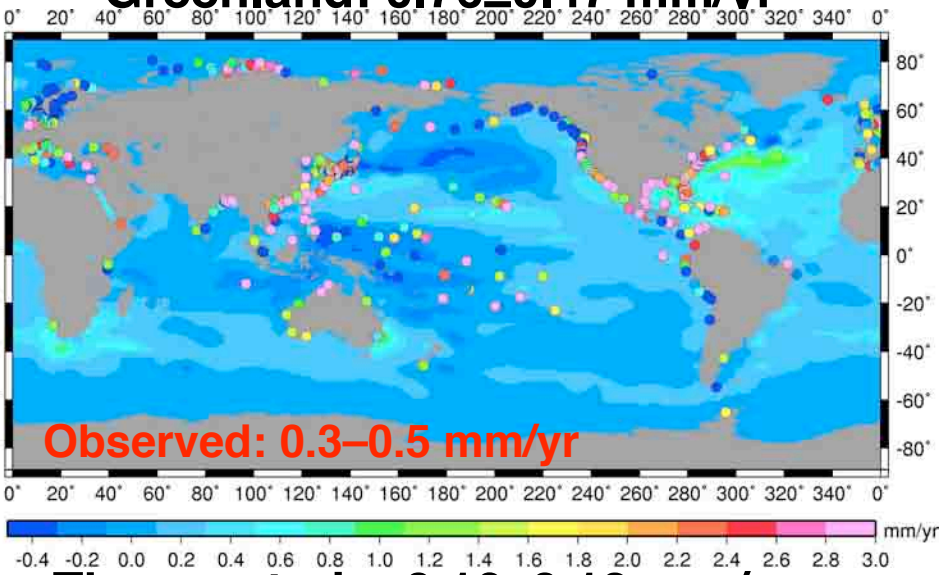
Antarctic: 0.49±0.24 mm/yr



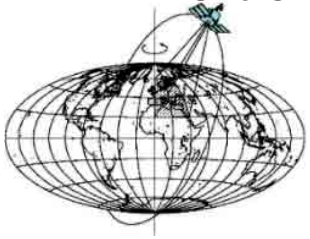
Greenland: 0.76±0.47 mm/yr



Glacier: 0.80±0.18 mm/yr



Thermosteric: 0.16±0.13 mm/yr



Estimated Global Sea Level Rise, 1900–2006, Using Tide Gauges (590 sites) & Altimetry (1984–2007)

*No IB correction; tide gauges before 1948 down-weighted

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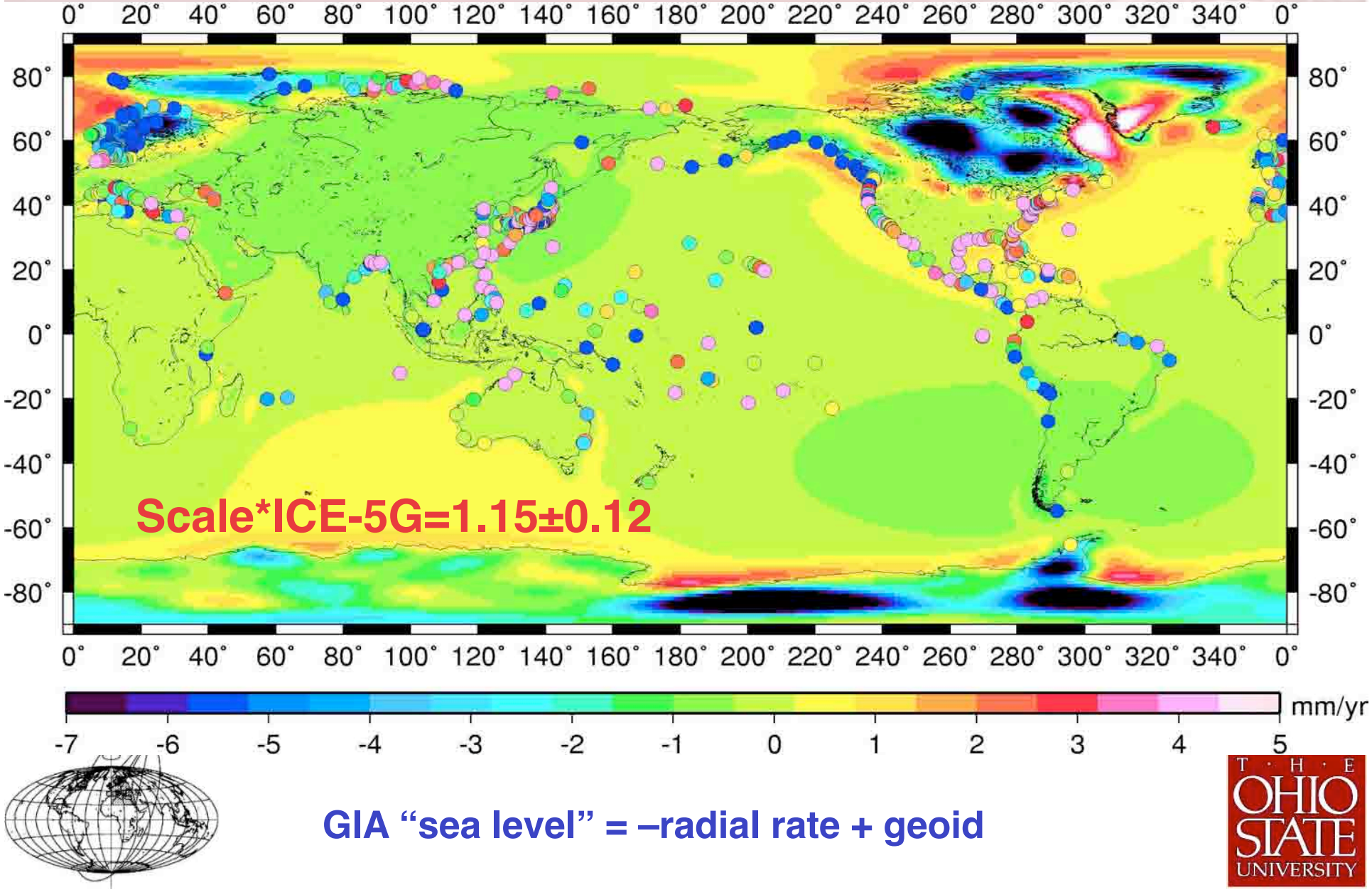
Estimated Scale to ICE-5G Sea Level* (1900–2007)



GIA "sea level" = –radial rate + geoid

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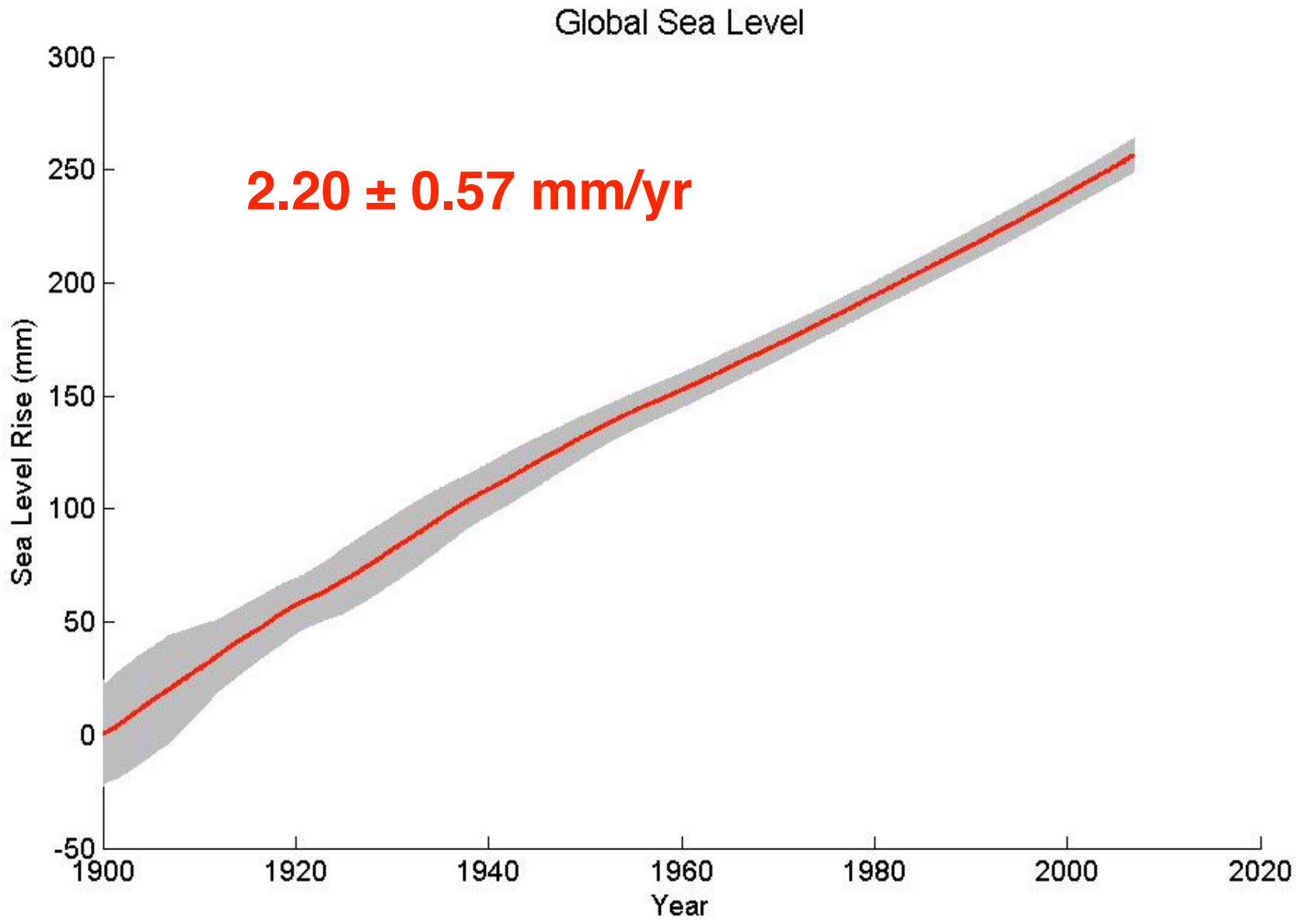
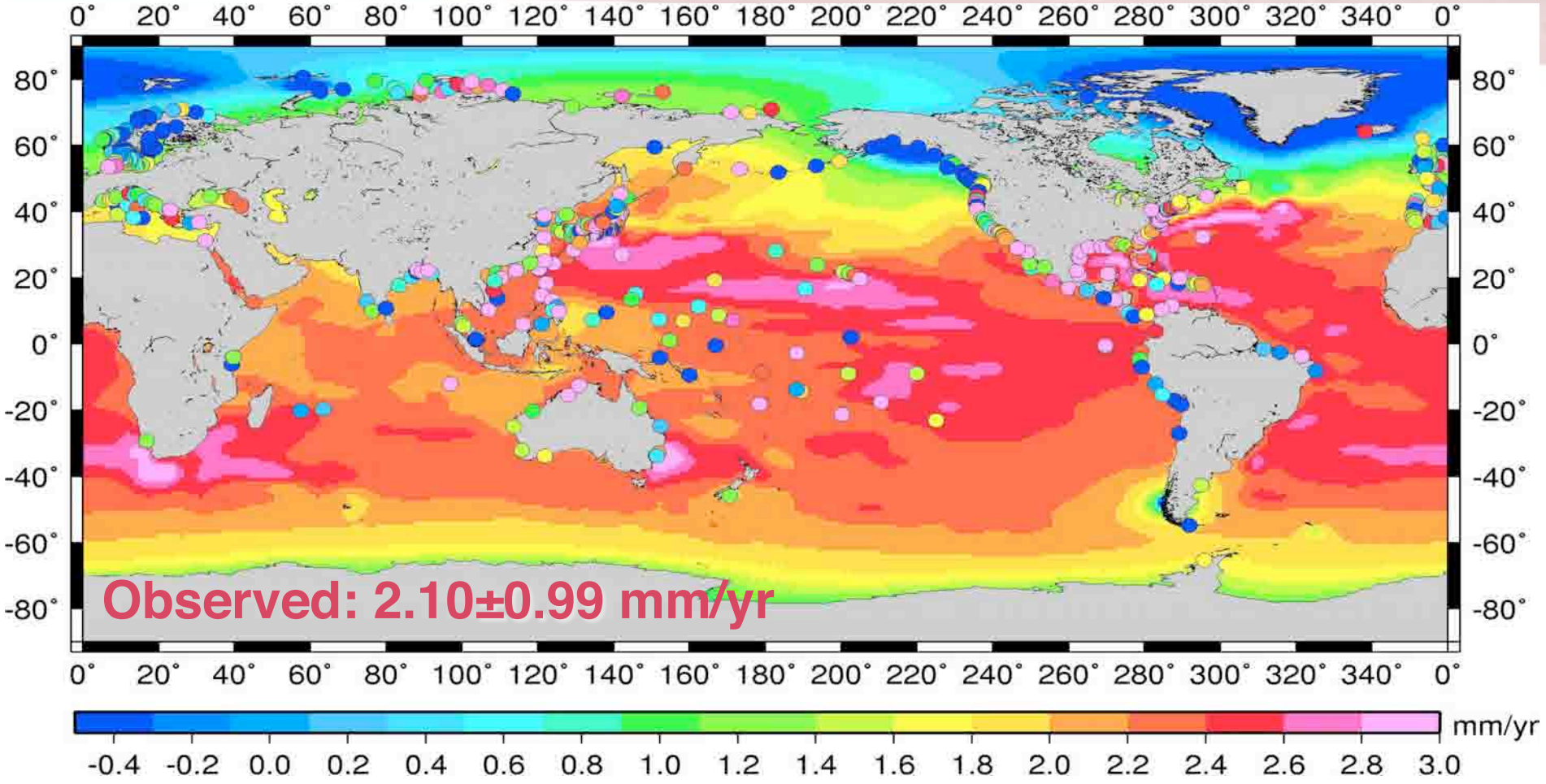
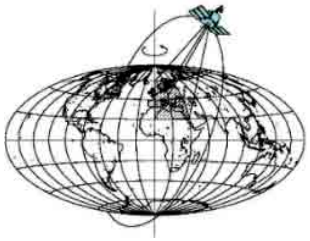
Estimated Total Sea Level Rise, 1900–2007



Estimated Global Sea Level Rise Using Tide Gauges and Satellite Altimetry (1900–2007)





Estimated Sea Level Rise = 2.20±0.57 mm/yr

590 selected tide gauges, multiple satellite altimetry used

Assuming geographical patterns of sea level change due to glacier/ice sheet melt, thermal expansion, and GIA known

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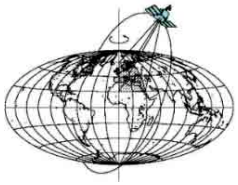
CONCLUSIONS

- 20th century (1900–2007) global sea level (SL) rise is estimated to be 2.20±0.57 mm/yr (2.18±0.28 mm/yr for 1948–2007, results not shown), based on a sea level adjustment assuming known SL change patterns based on geophysical modeling, and using tide gauge and satellite altimetry data

- The estimated contribution from geophysical sources are dominated by mountain glacier and ice sheet (Greenland and Antarctica) ablation, followed by thermal expansion



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