



# Ice Sheets and Future Sea Level

**Dr. Robert Bindschadler**

Chief Scientist

Hydrospheric and Biospheric Sciences Laboratory

NASA Goddard Space Flight Center

[Robert.A.Bindschadler@nasa.gov](mailto:Robert.A.Bindschadler@nasa.gov)

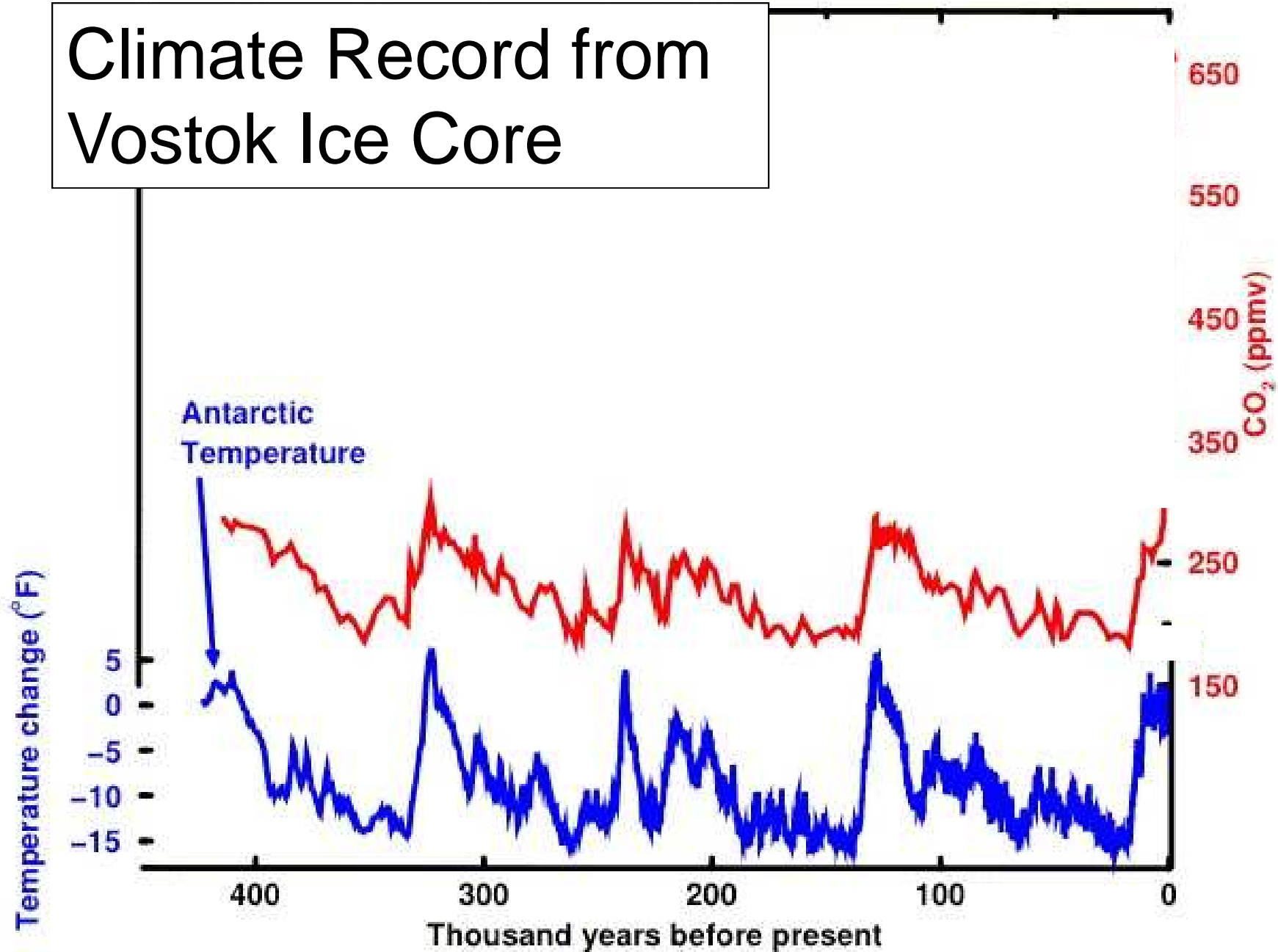
**CLEAN**  
AIR



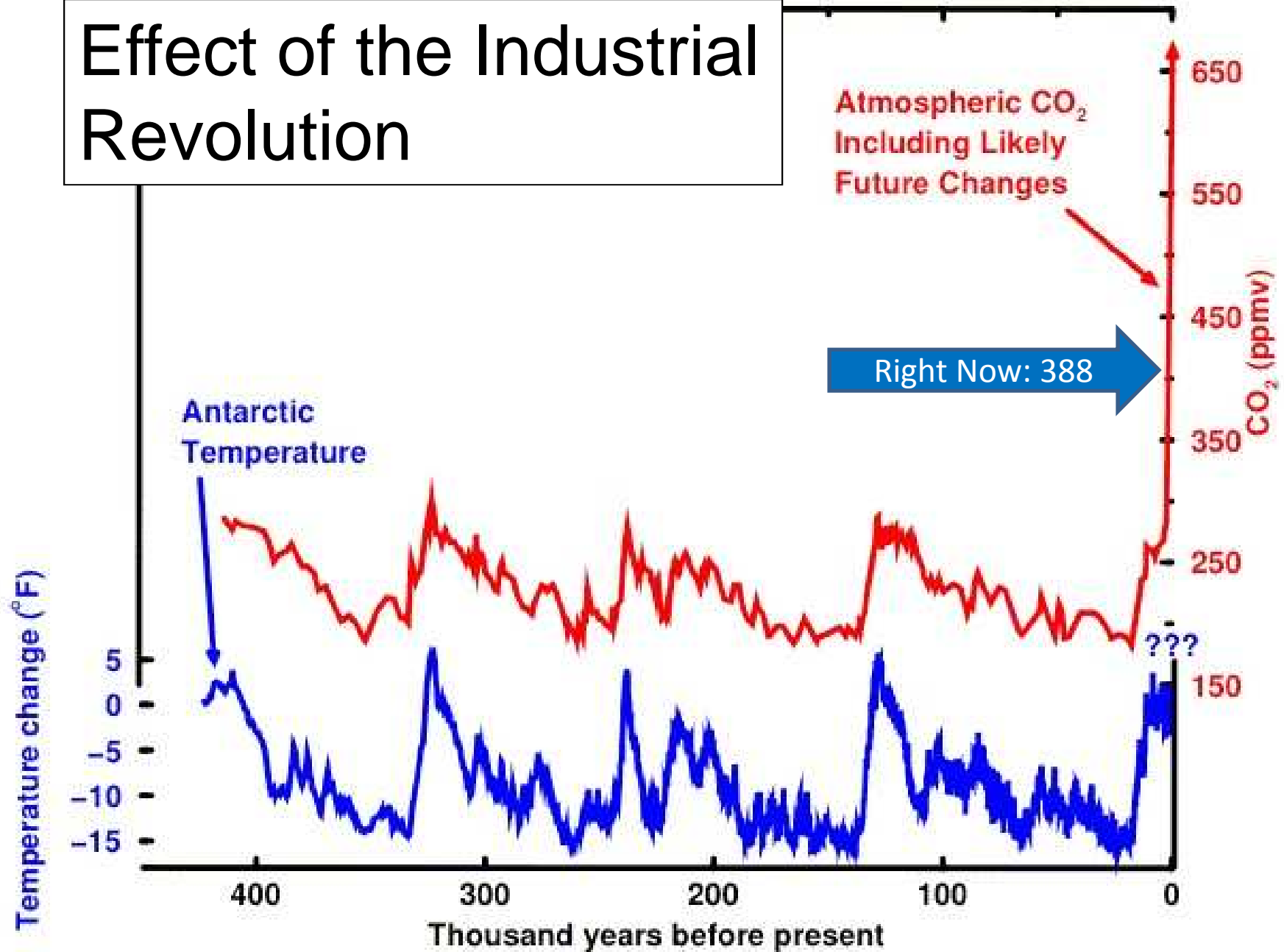
**COOL**  
PLANET



# Climate Record from Vostok Ice Core

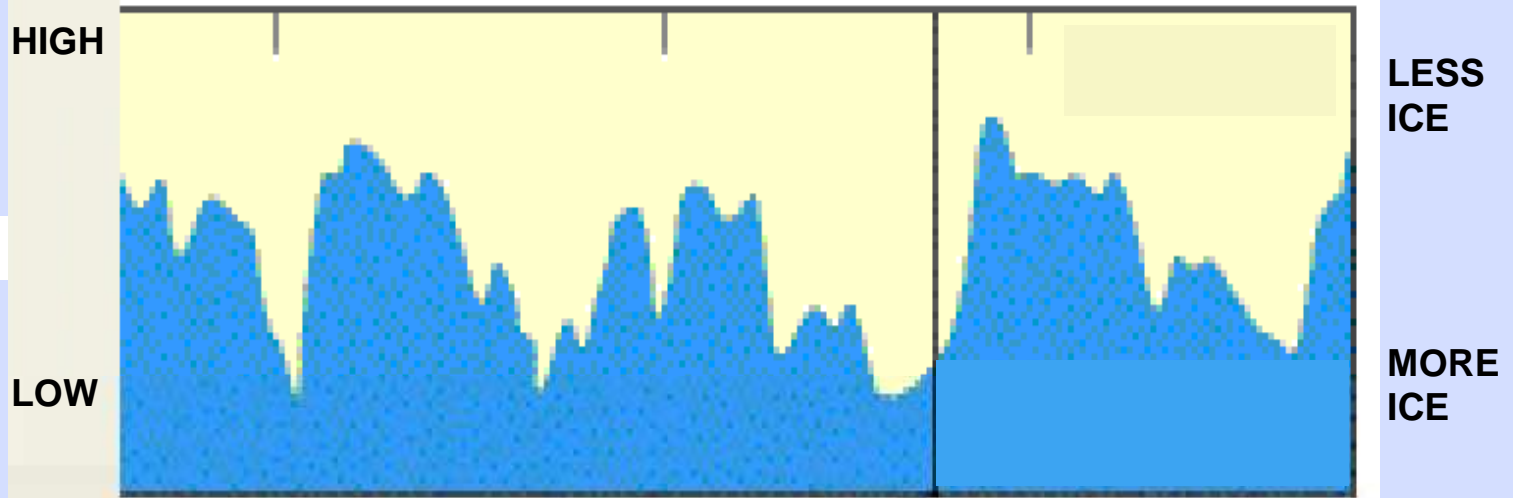


# Effect of the Industrial Revolution

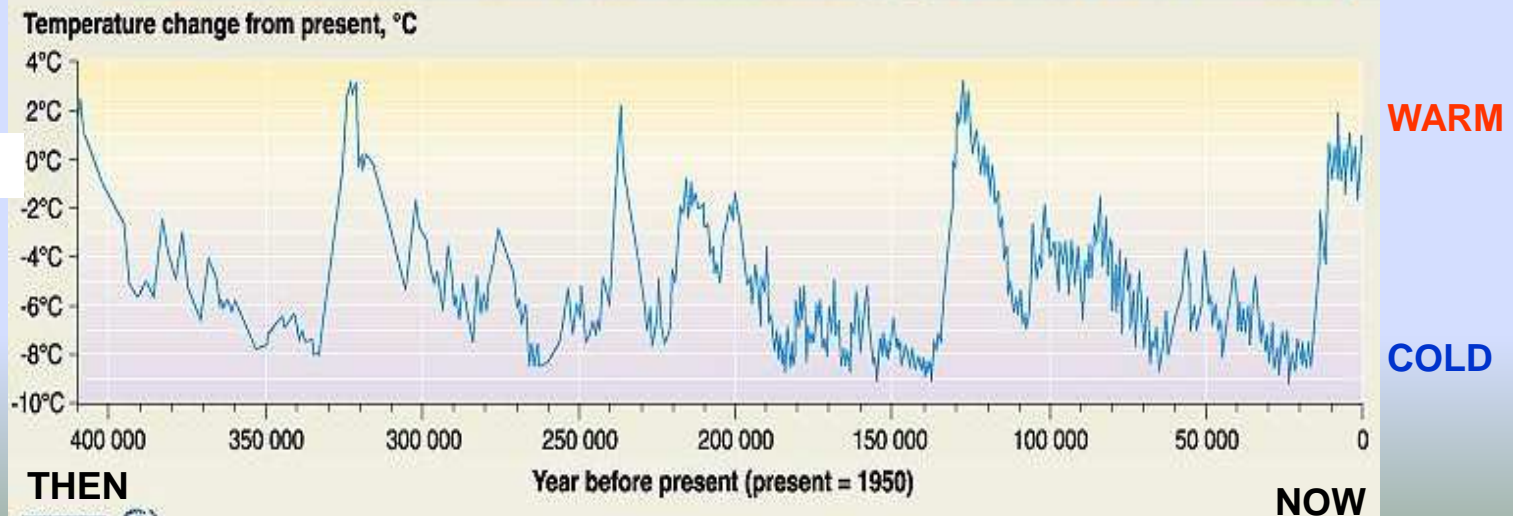


# Less ice in warmer climates

SEA LEVEL



TEMPERATURE



THEN

Year before present (present = 1950)

NOW

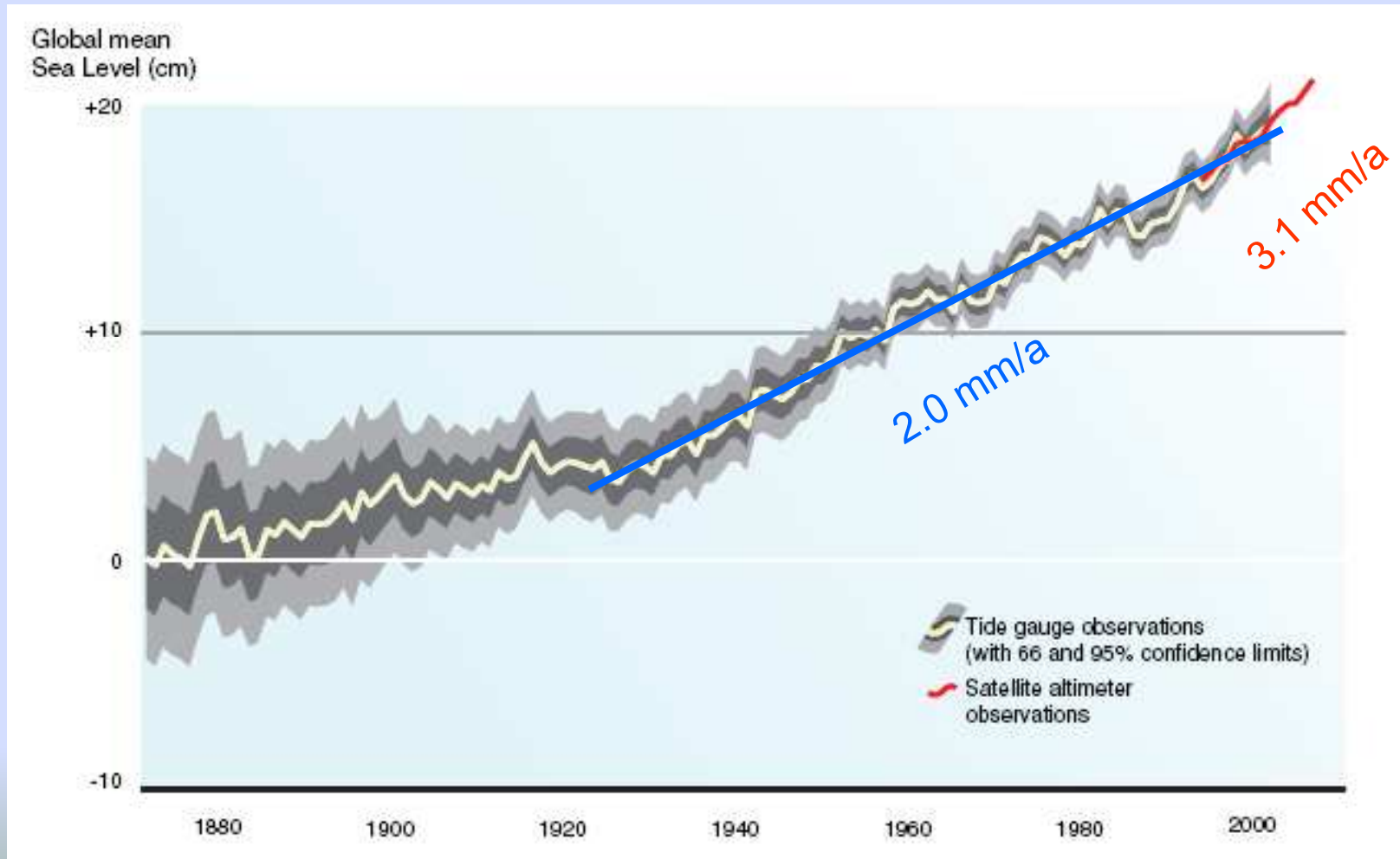
Time



When the earth warms, ice sheets and glaciers shrink and sea level rises

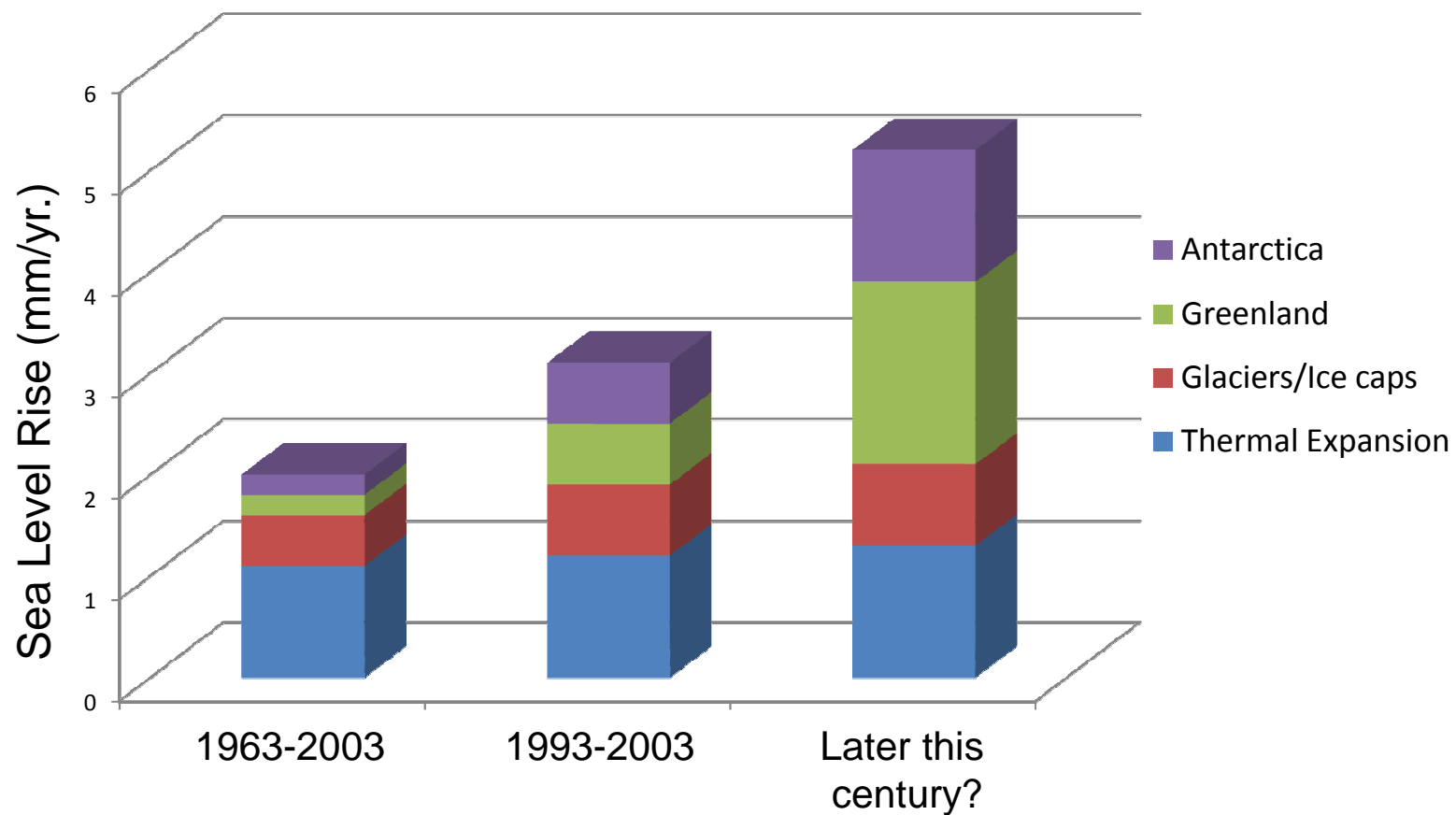
- Earth's temperature has been increasing
- Sea level has been rising

# Rising Sea Level

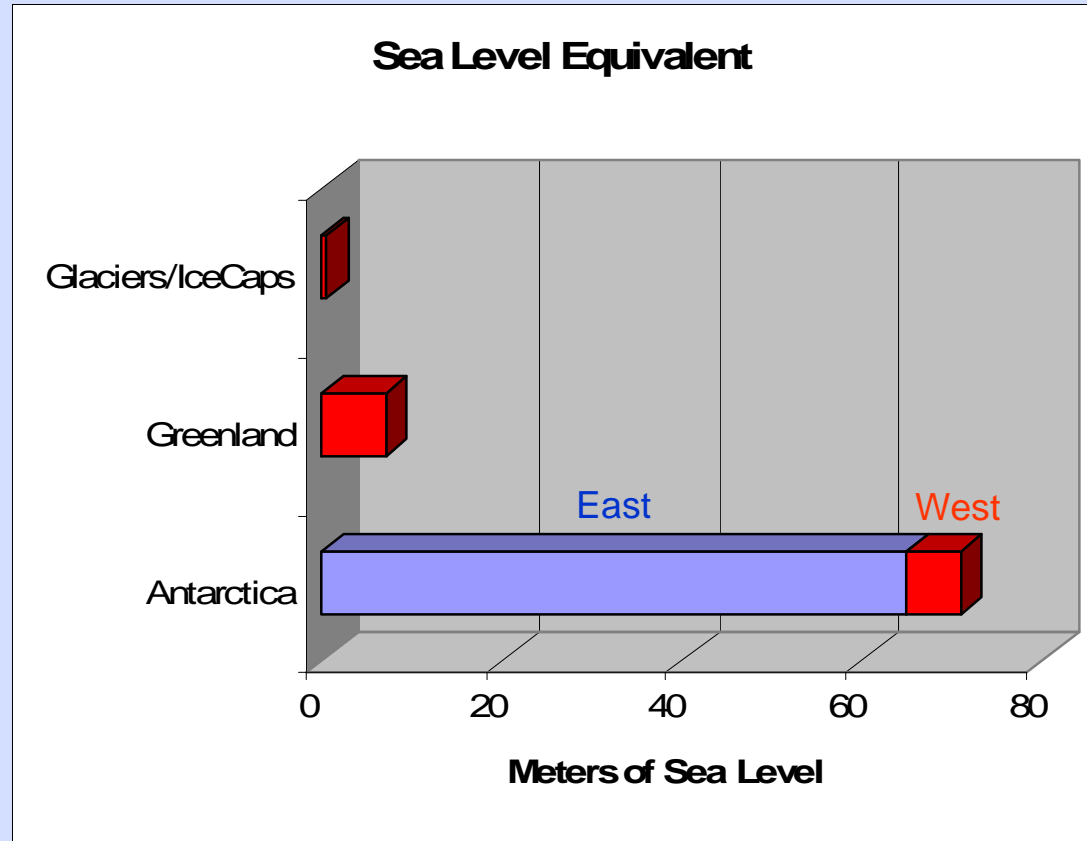


From Church and White, 2006

# Sea Level Rise Components

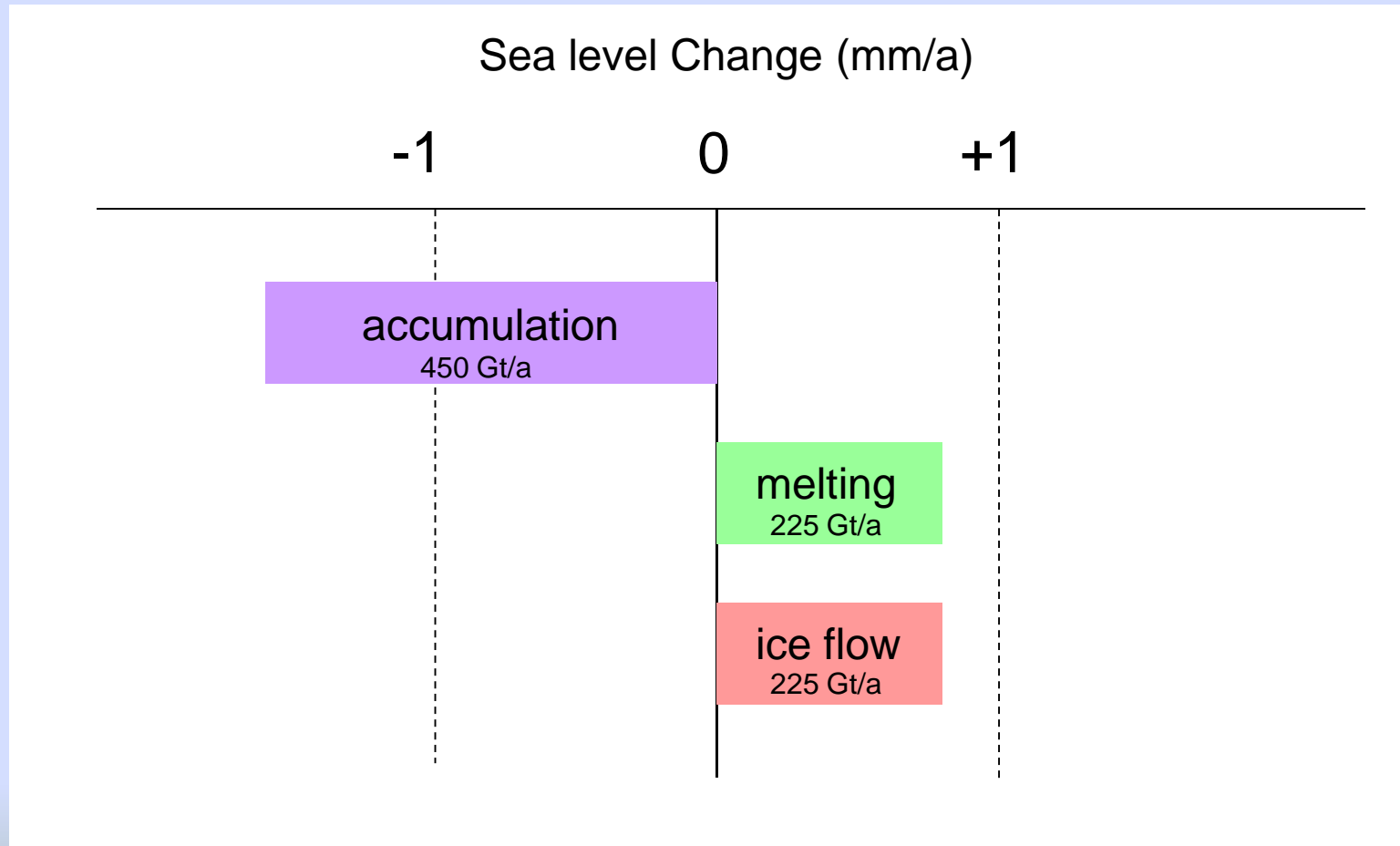


# Where is the Ice?



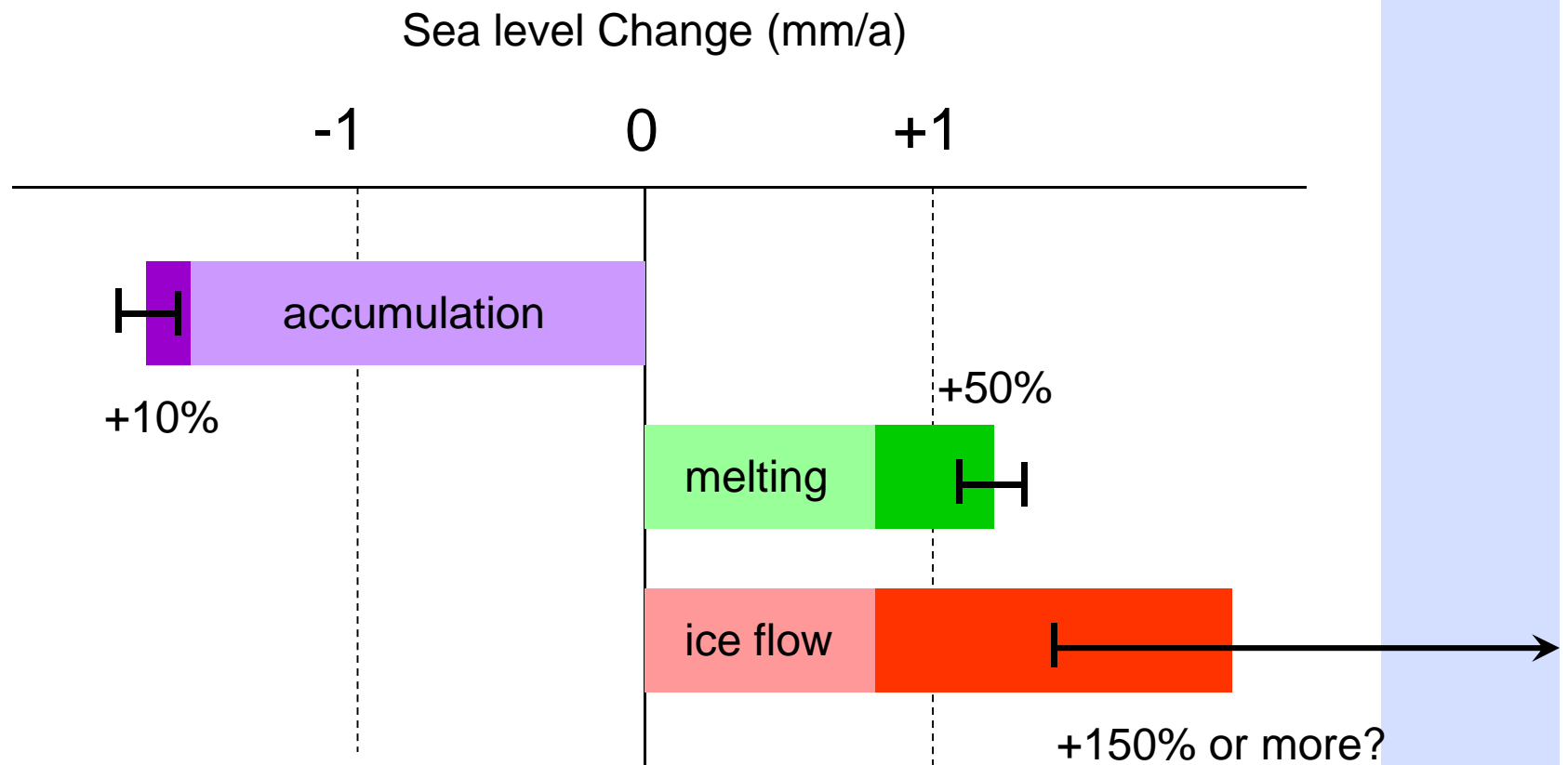
2-6% of all water on Earth  
70-80% of all fresh water on Earth

# 20<sup>th</sup> Century Greenland Ice Sheet



Approximately in "mass balance"

# 21<sup>st</sup> Century Greenland Ice Sheet



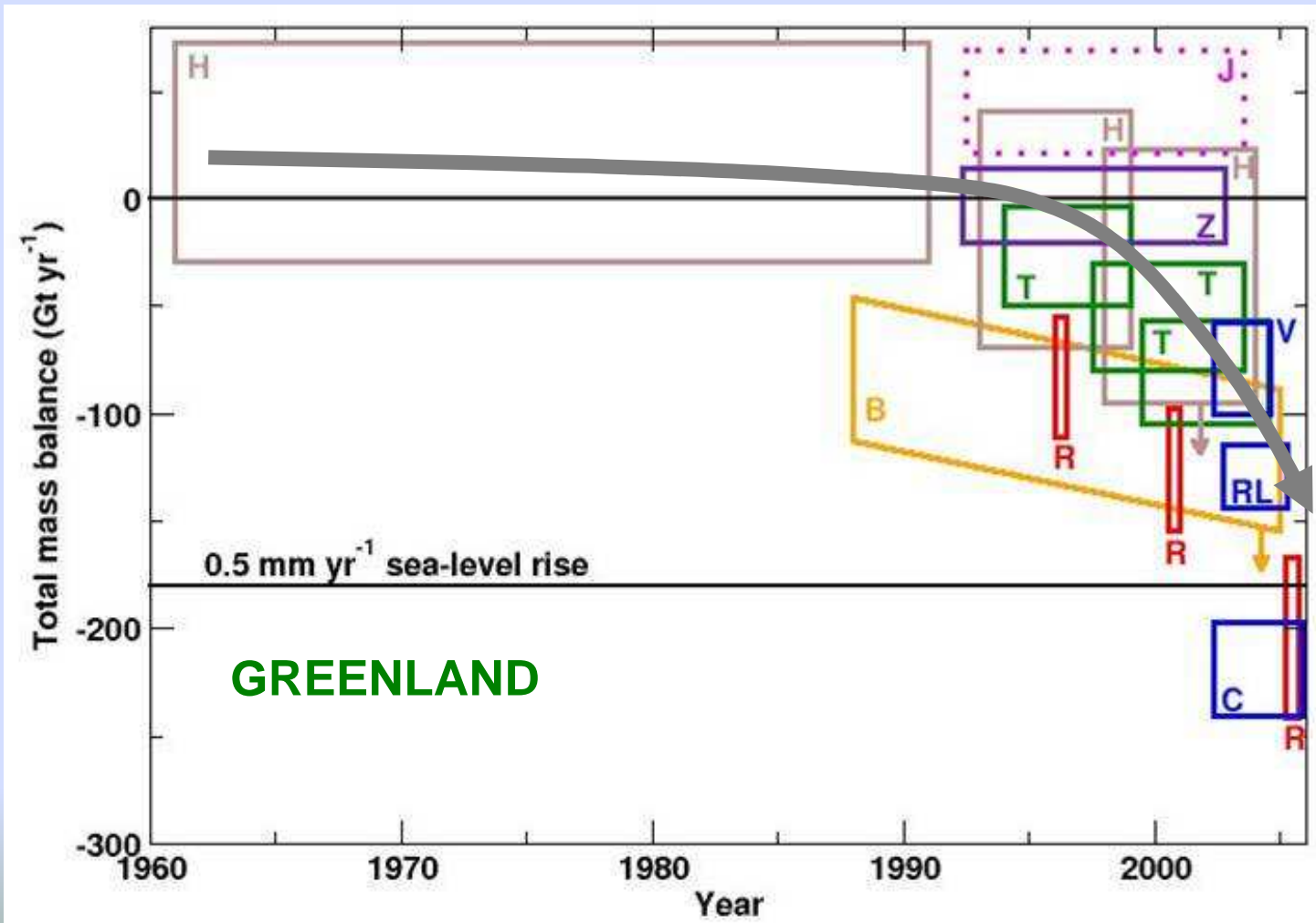
Things could get a little better or a lot worse  
Increased ice flow will dominate the future rate of change

# Greenland Ice Sheet is Shrinking



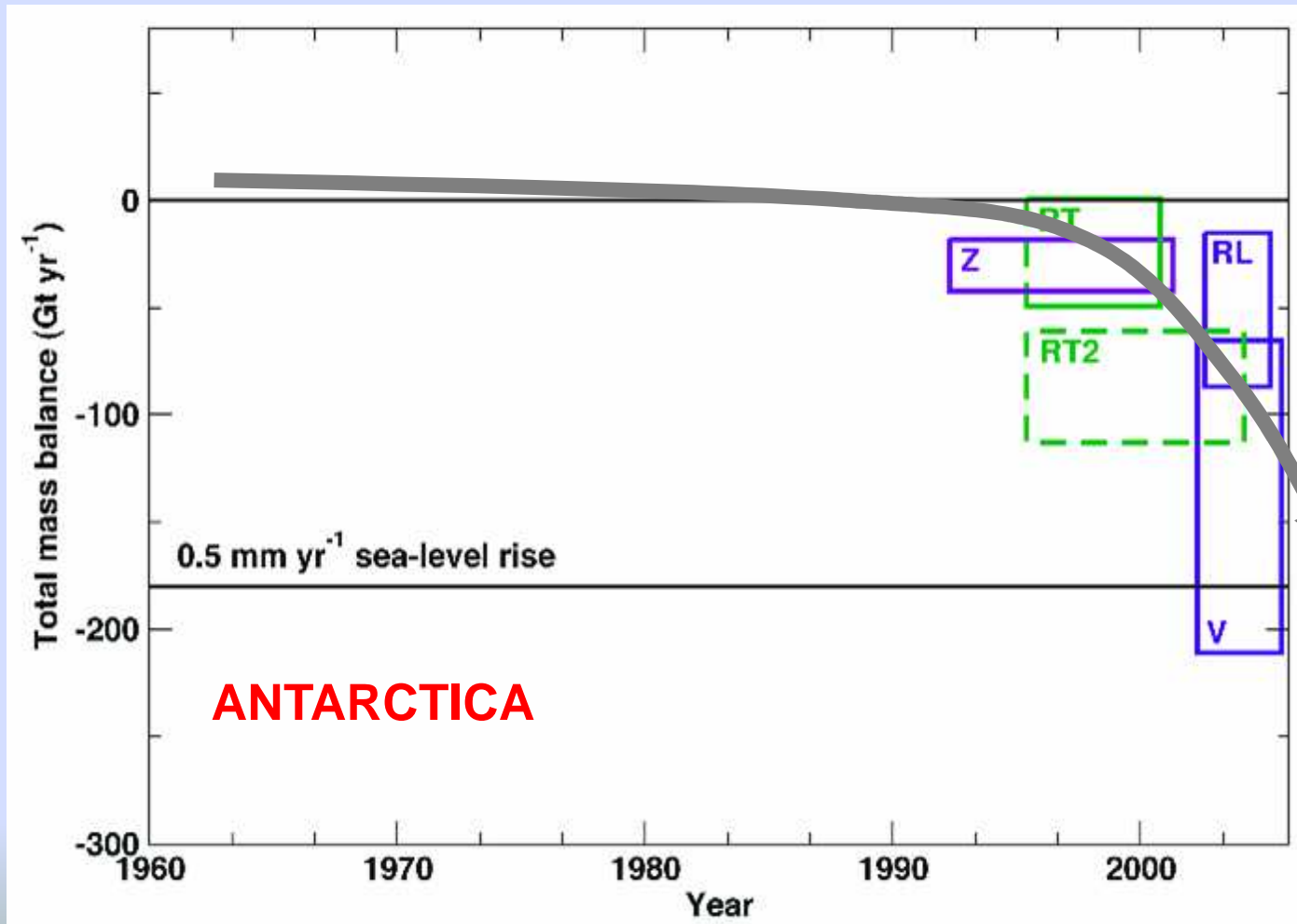
(Source: Luthcke et al., unpub.)

# Greenland Ice Sheet Mass Balance



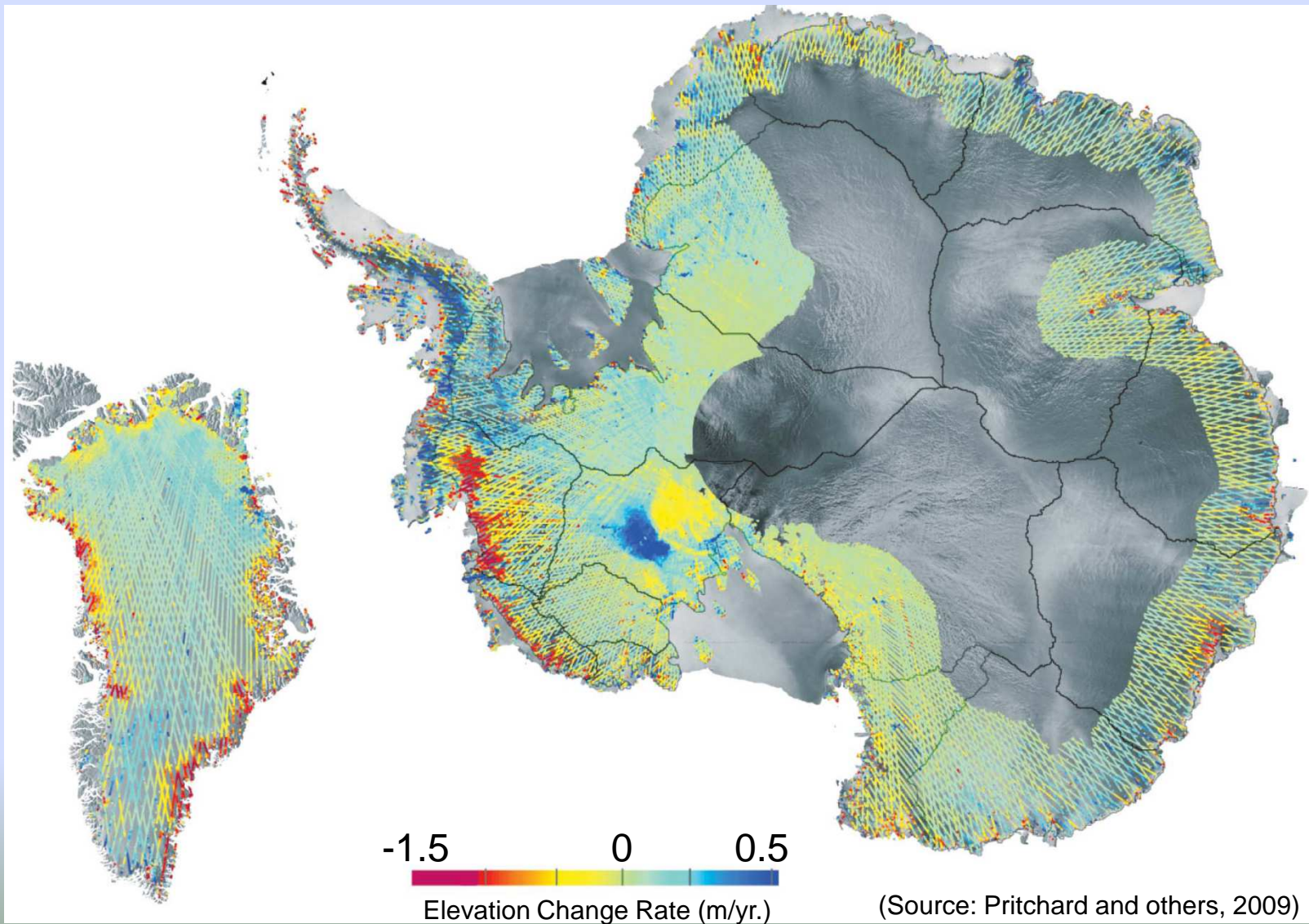
(Source: IPCC FAR)

# Antarctic Ice Sheet Mass Balance

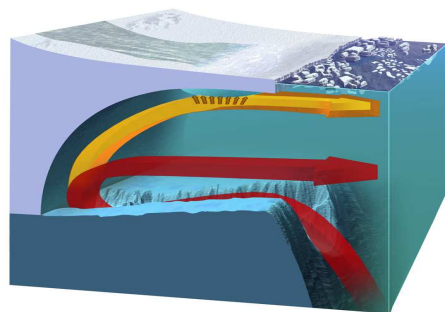
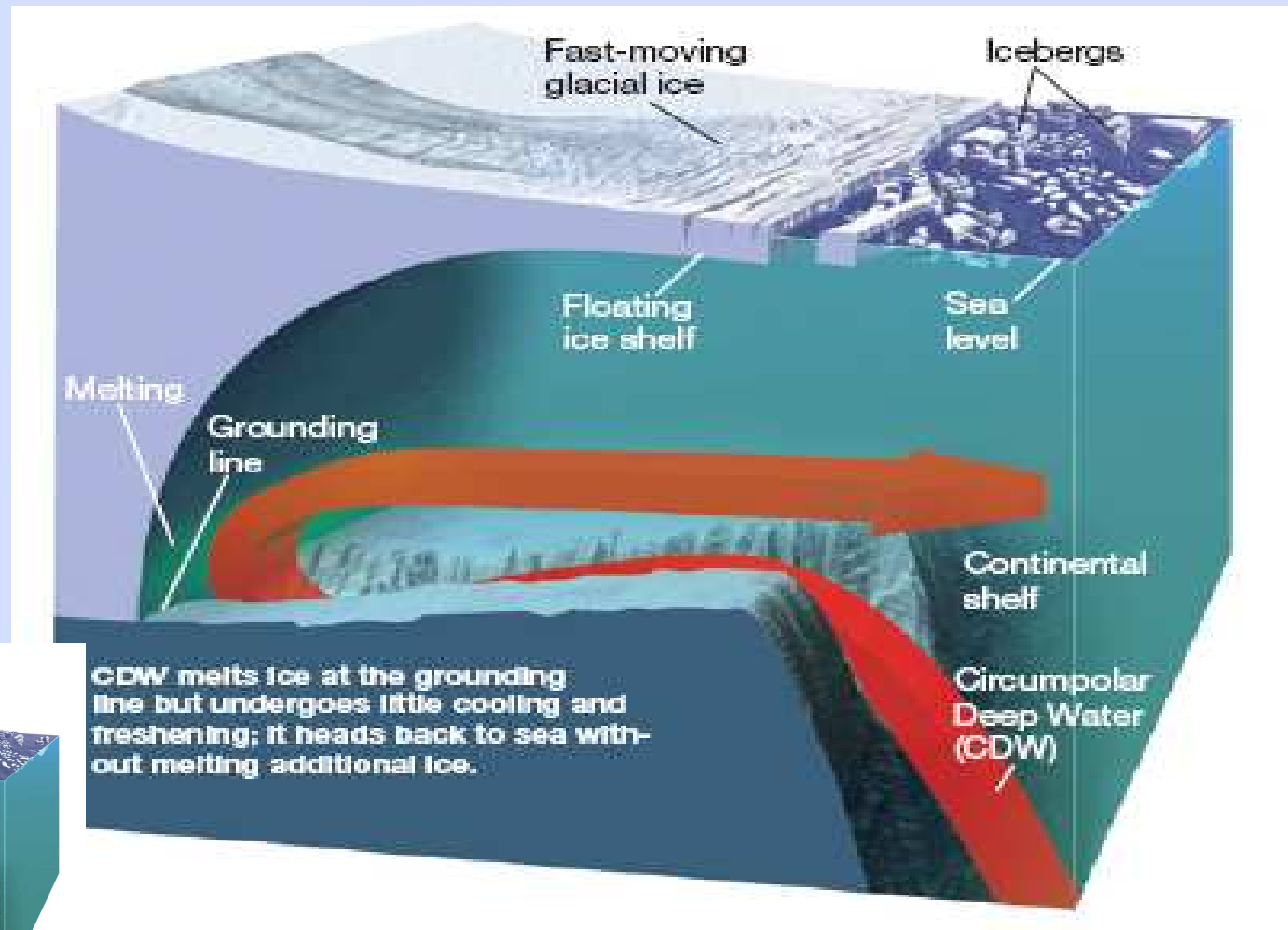


(Source: IPCC FAR)

# Dynamic Thinning at Ice-Sheet Margin



# Warm ocean water is attacking the edges of ice sheets



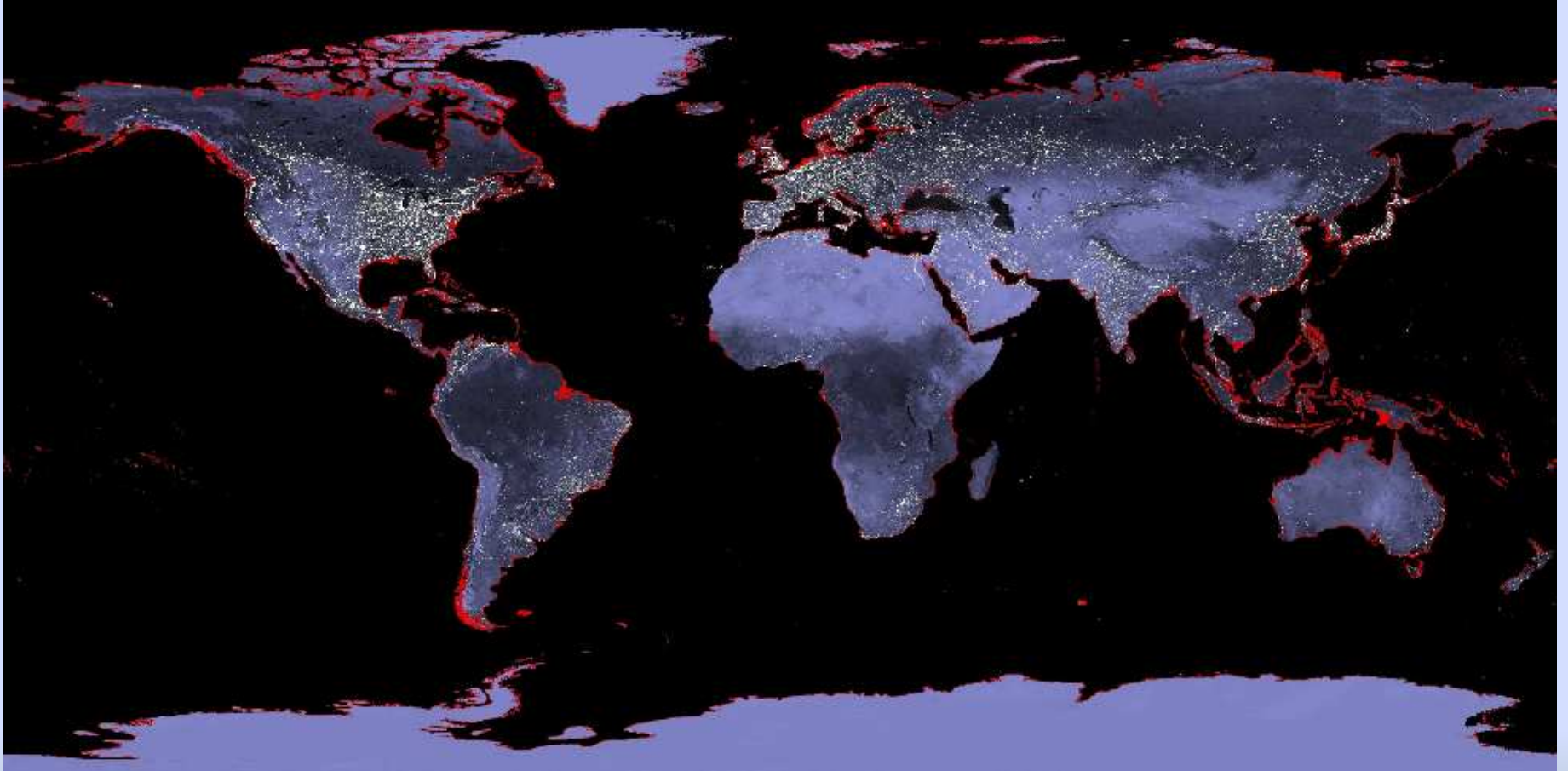
(illustration (c) Frank Ippolito)

# Sea Level Prediction

Easy part: Ice sheets will shrink faster and accelerate sea level rise

Hard part: How much and how fast?

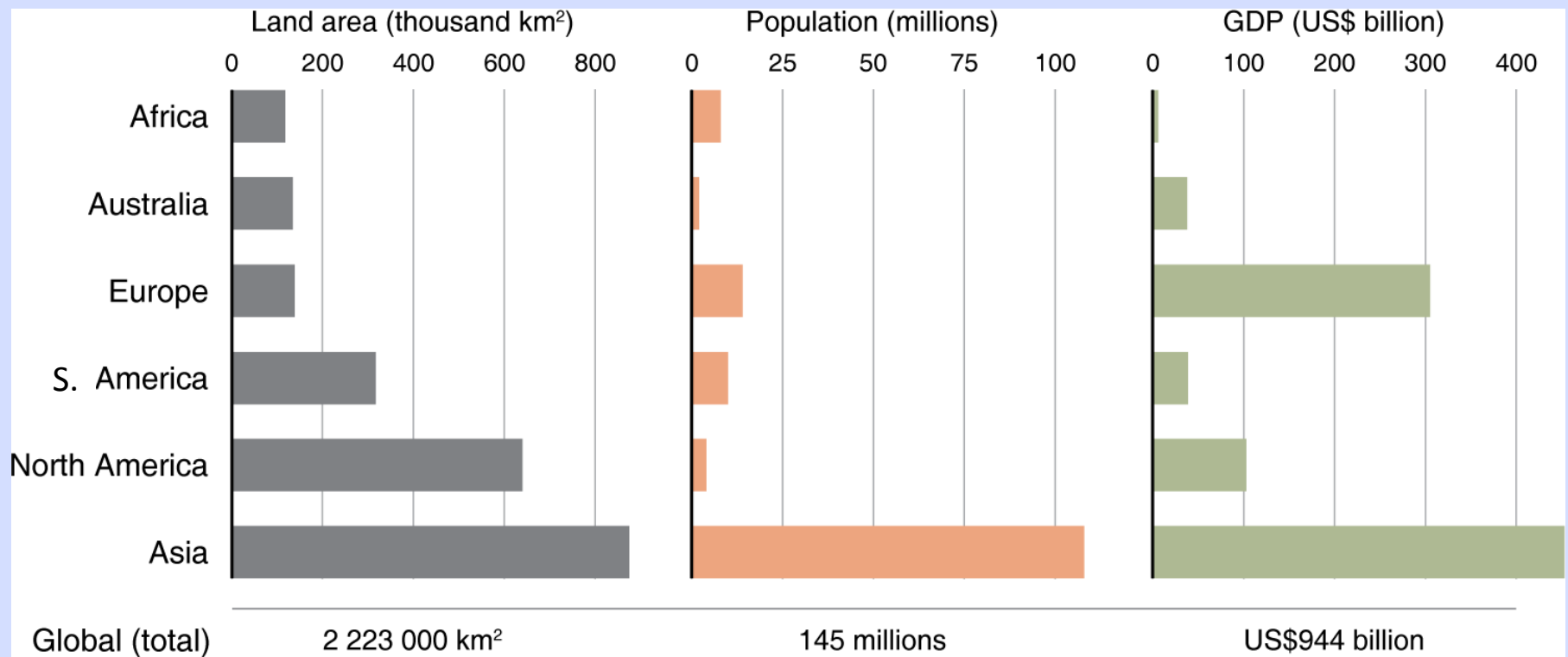
# Ice Sheets matter Globally



Source: CReSIS and NASA

**Land area lost by 1-meter rise in sea level**

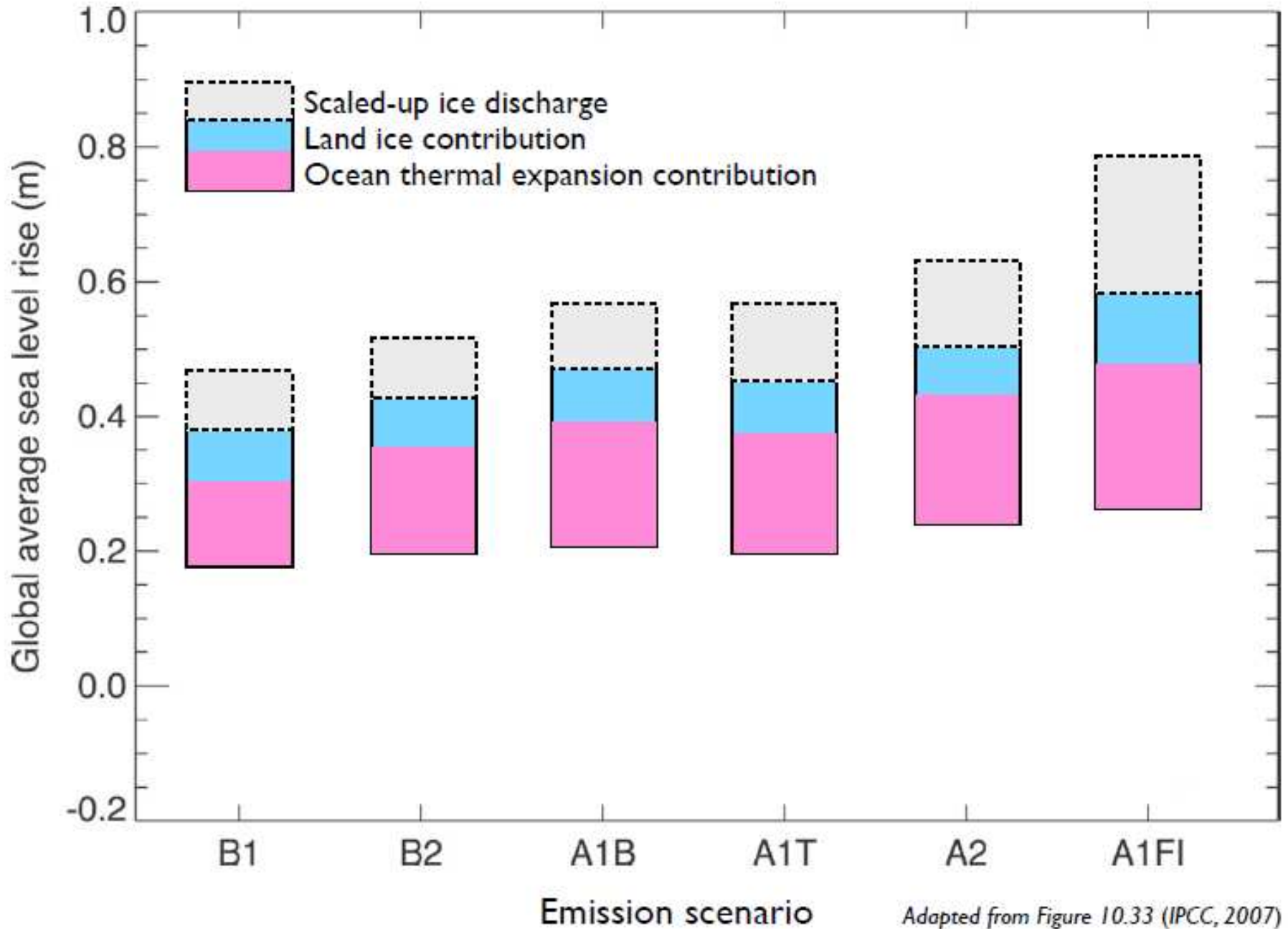
# Impact of 1-meter sea level rise:



From Anthoff et al., 2006



# Sea level projections for the 21st century



# Extrapolation

Table 3. SLR projections based on kinematic scenarios. Thermal expansion numbers are from (22).

	SLR equivalent (mm)		
	Low 1	Low 2	High 1
<i>Greenland</i>			
Dynamics	93	93	467
SMB	71	71	71
Greenland total	165	165	538
<i>Antarctica</i>			
PIG/Thwaites dynamics	108		394
Lambert/Amery dynamics	16		158
Antarctic Peninsula dynamics	12		59
SMB	10		10
Antarctica total	146	128	619
<i>Glaciers/ice caps</i>			
Dynamics	94		471
SMB	80		80
GIC total	174	240	551
Thermal expansion	300	300	300
<b>Total SLR to 2100</b>	<b>785</b>	<b>833</b>	<b>2008</b>

## Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise

W. T. Pfeffer,<sup>1\*</sup> J. T. Harper,<sup>2</sup> S. O'Neel<sup>3</sup>

5 SEPTEMBER 2008 VOL 321 SCIENCE www.sciencemag.org

1. Observed glacier accelerations were applied to additional glaciers
2. Additional accelerations were applied to already fast-moving glaciers

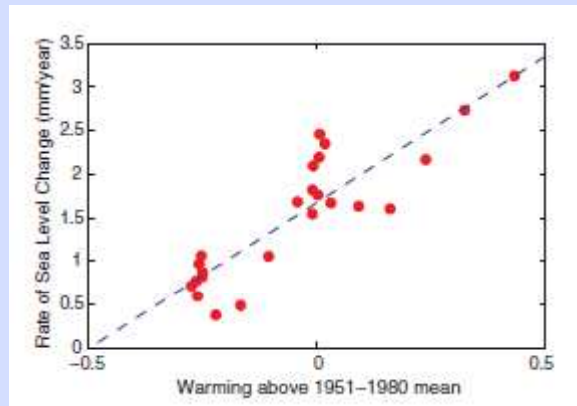
Range of sea level by 2100:  
0.8 to 2.0 m

# Proxies

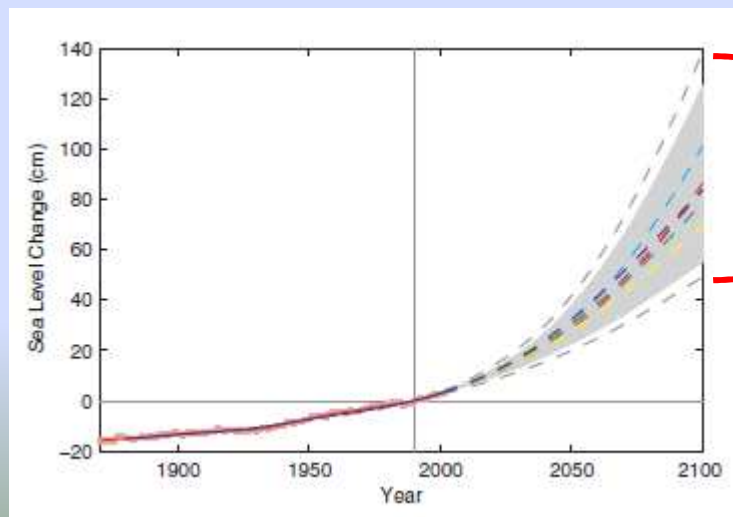
## A Semi-Empirical Approach to Projecting Future Sea-Level Rise

Stefan Rahmstorf

19 JANUARY 2007 VOL 315 SCIENCE www.sciencemag.org



1. Rate of sea level rise empirically related to global temperature
2. Relationship applied to predicted future temperatures



Range of sea level by 2100:  
0.5 to 1.4 m

# Global Warming and Sea Level

- Global warming
  - is a fact and is observed
  - is not a “theory” or a “belief”
  - is caused by human burning of fossil fuels
    - CO<sub>2</sub> well beyond natural variation
- Sea level
  - will continue to increase and accelerate
  - 1 m by 2100 is likely
  - Just the beginning
    - eventual level dependent on future CO<sub>2</sub> emissions

# Thank you!



Photo: I. Joughin

# Questions?