Apollo 17

December 1972

Climate Science in the Space Age

Gary Lagerloef

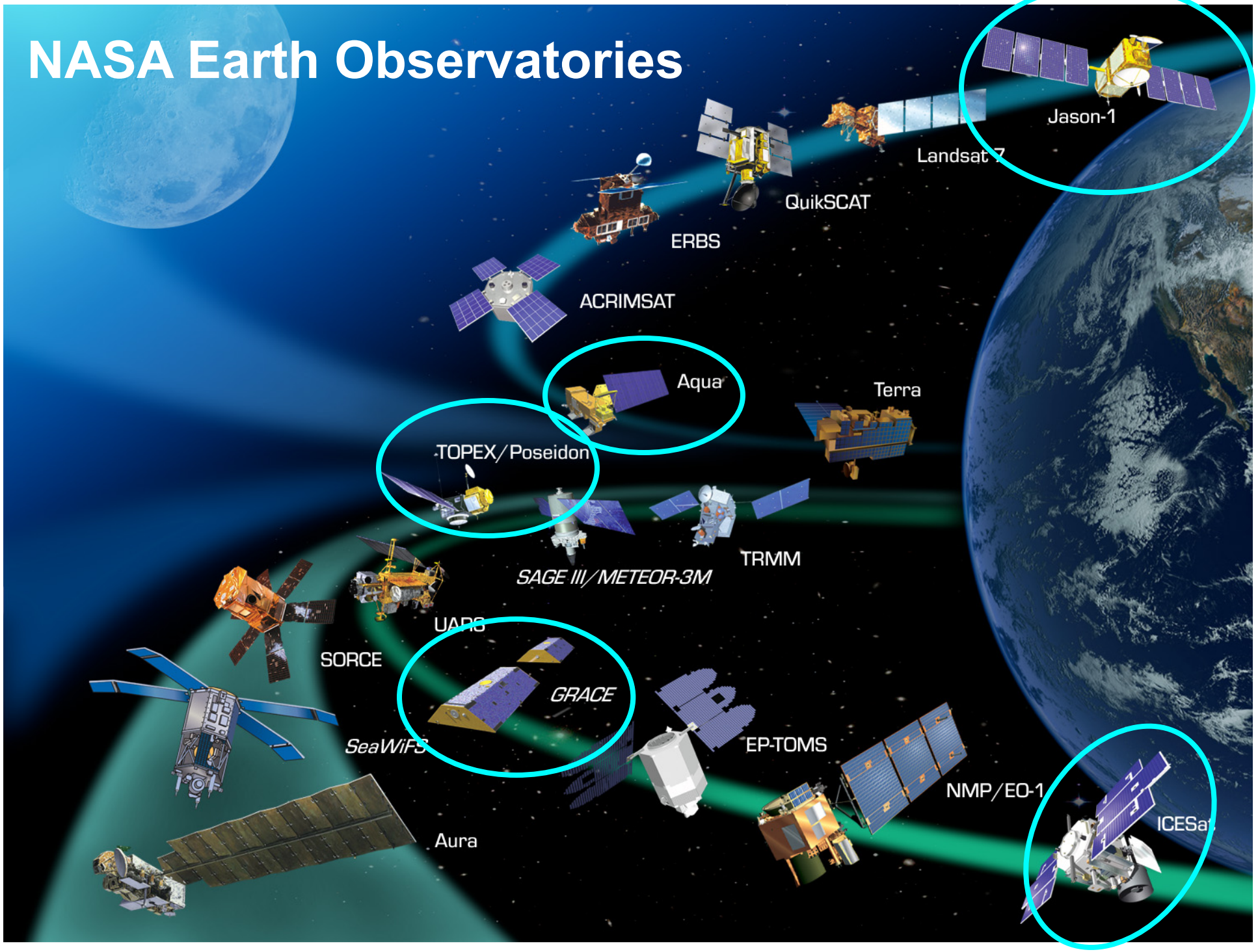
Oceanographer & Climate Scientist

Earth & Space Research

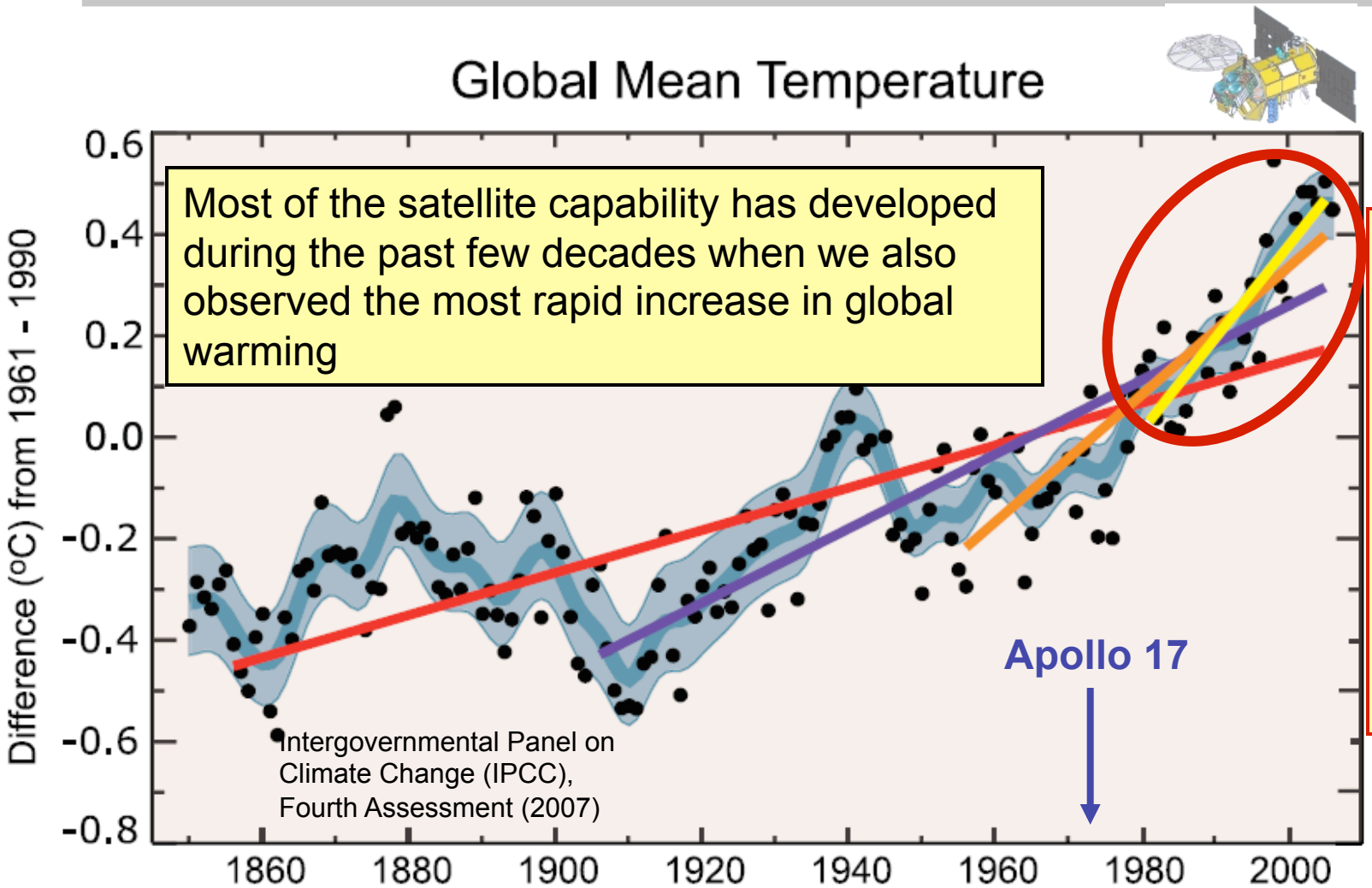
Bainbridge Science Open Mic

4 November 2010

NASA Earth Observatories



The Warming of Earth's Climate



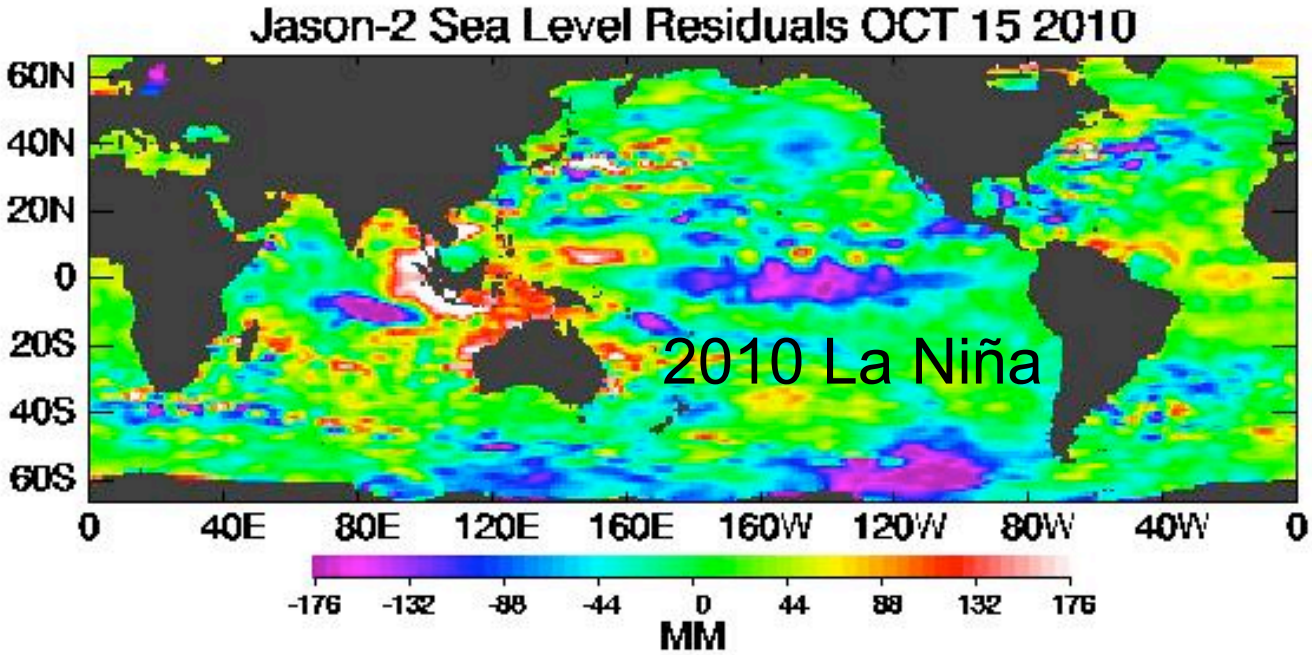
Temperature rise during the past 25 years is about 0.18°C (0.32° F) per decade.

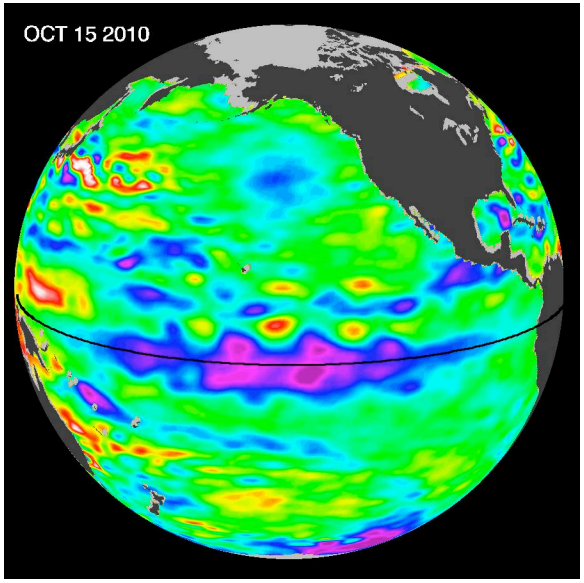
This is about 4X faster than the past 150 years

Mapping Sea Level with Satellites

Very accurate satellite radar altimeters can measure changes in sea level with an accuracy of about 2 cm (less than an inch) from 800 miles (1350 km) high.

Sea water expands as it warms.





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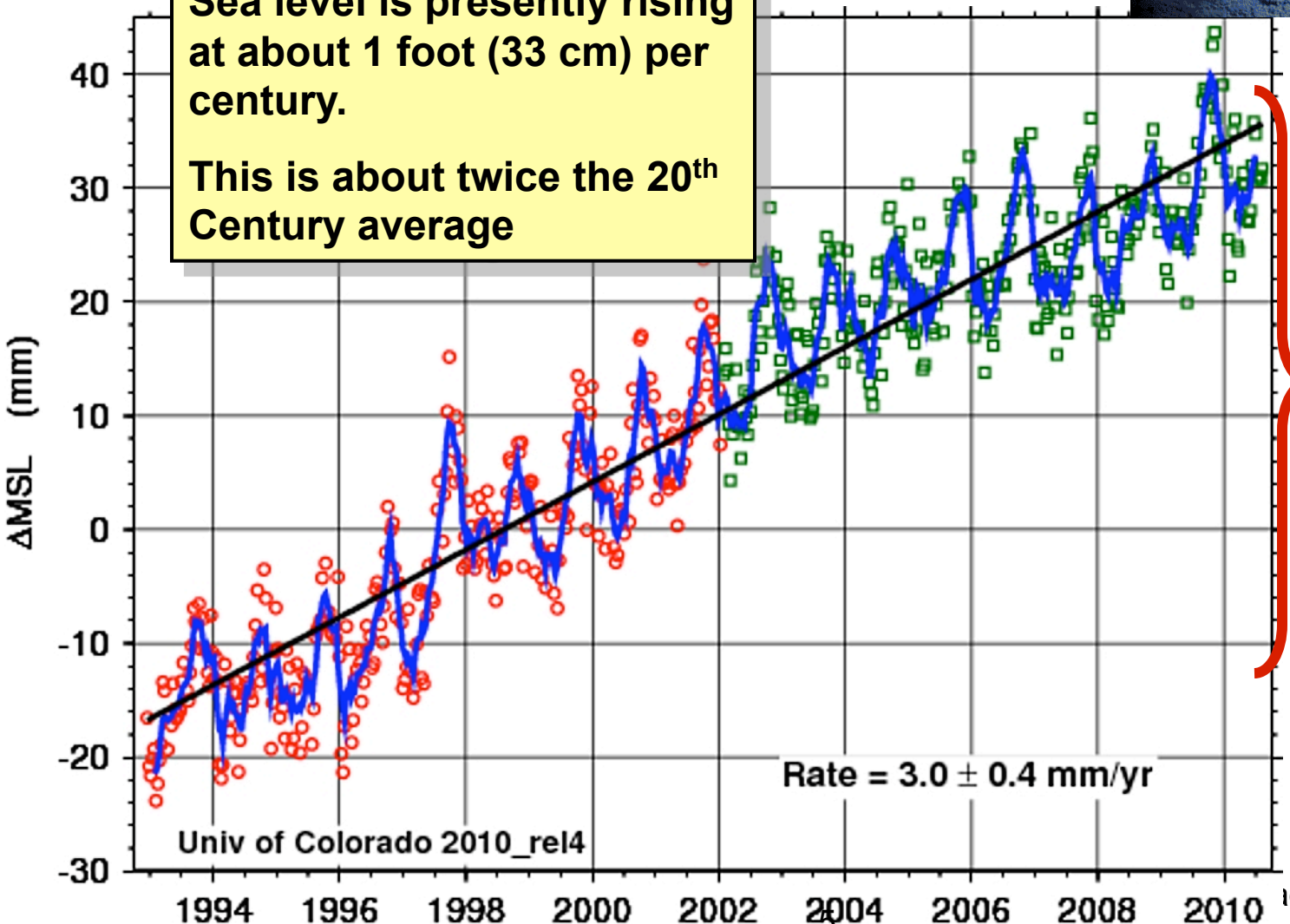
Satellite Radar Altimeter Global Average Sea Level Rise

Sea level is presently rising at about 1 foot (33 cm) per century.

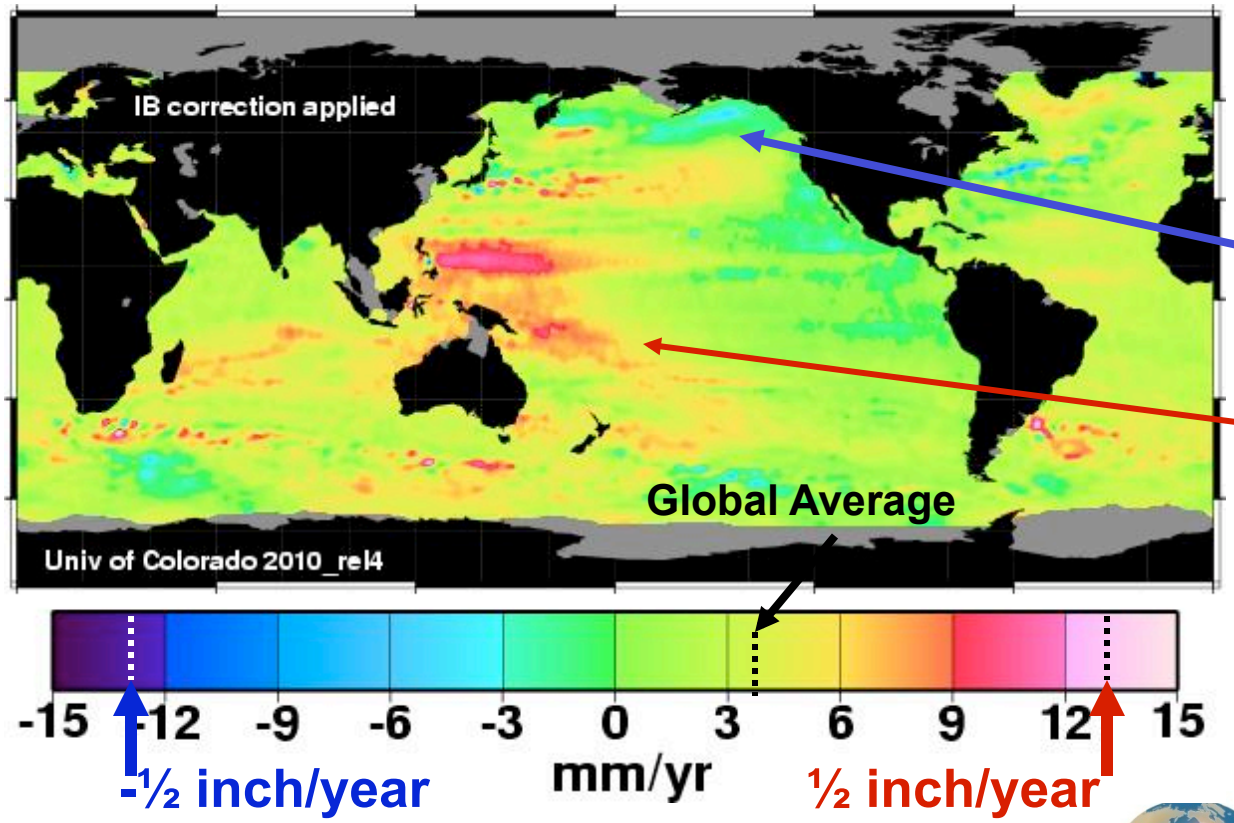
This is about twice the 20th Century average



About half the sea level rise is due to expansion as the ocean warms, and the other half is water added to the ocean from melting land ice.

Mapping Sea Level with Satellites

This map shows the time average rate of sea level change from Fall 1992 through 2010 (15 years).



- The patterns reflect differential rates of ocean heating and cooling.
- Cooling has occurred in the eastern North Pacific (PDO pattern).
- Warming has been concentrated in western tropical Pacific.
- Most of the ocean area is rising at about the global average rate (pale green color).

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IceSat Surface Elevation Changes

IceSat is a NASA Laser Altimeter that measures ice sheet elevation changes

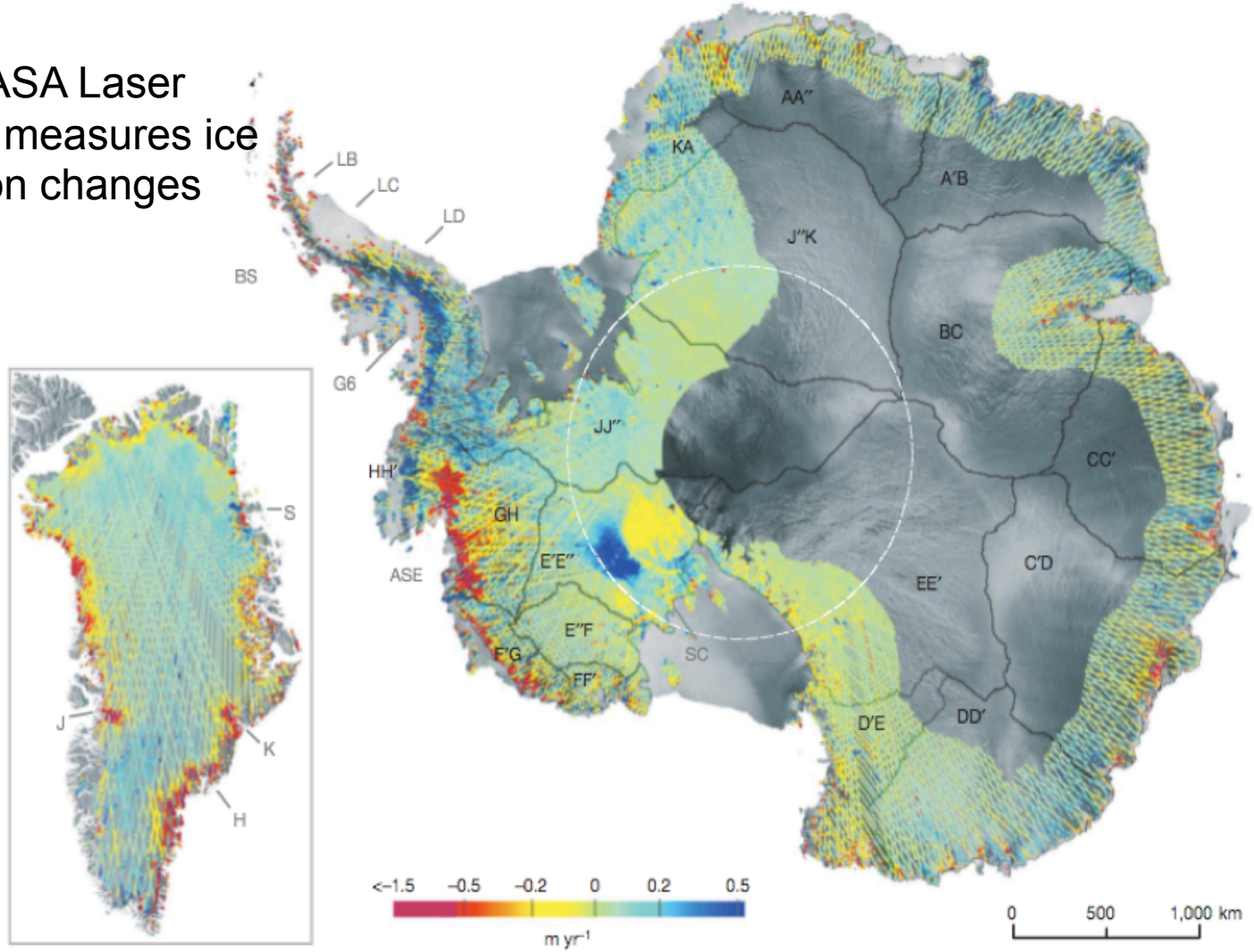
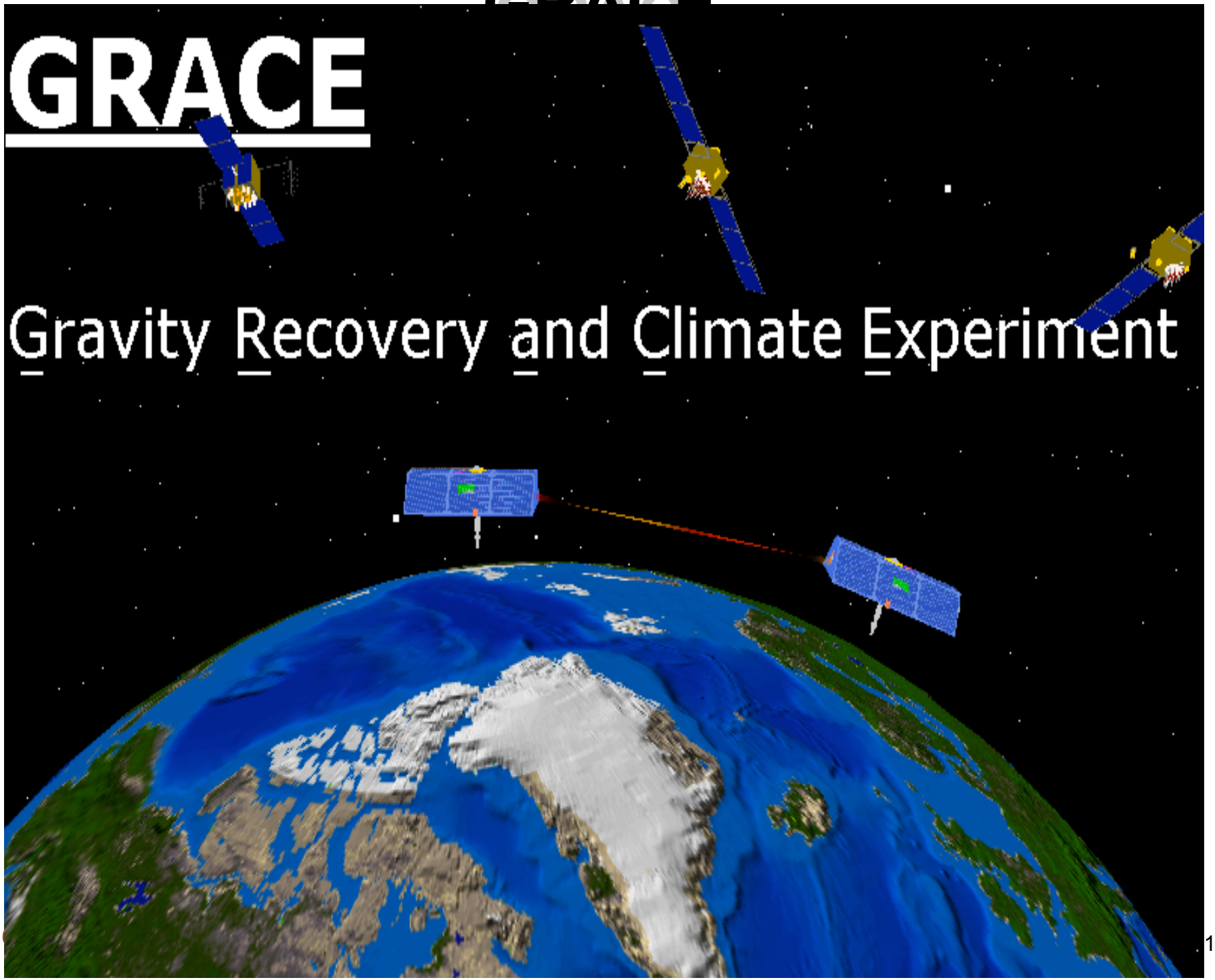


Figure 2 | Rate of change of surface elevation for Antarctica and Greenland. Change measurements are median filtered (10-km radius), spatially averaged (5-km radius) and gridded to 3 km, from intervals (Δt) of at least 365 d, over the period 2003–2007 (mean Δt is 728 d for Antarctica and 746 d for Greenland). East Antarctic data cropped to 2,500-m altitude. White dashed line (at 81.5° S) shows southern limit of radar altimetry measurements. Labels are for sites and drainage sectors (see text).

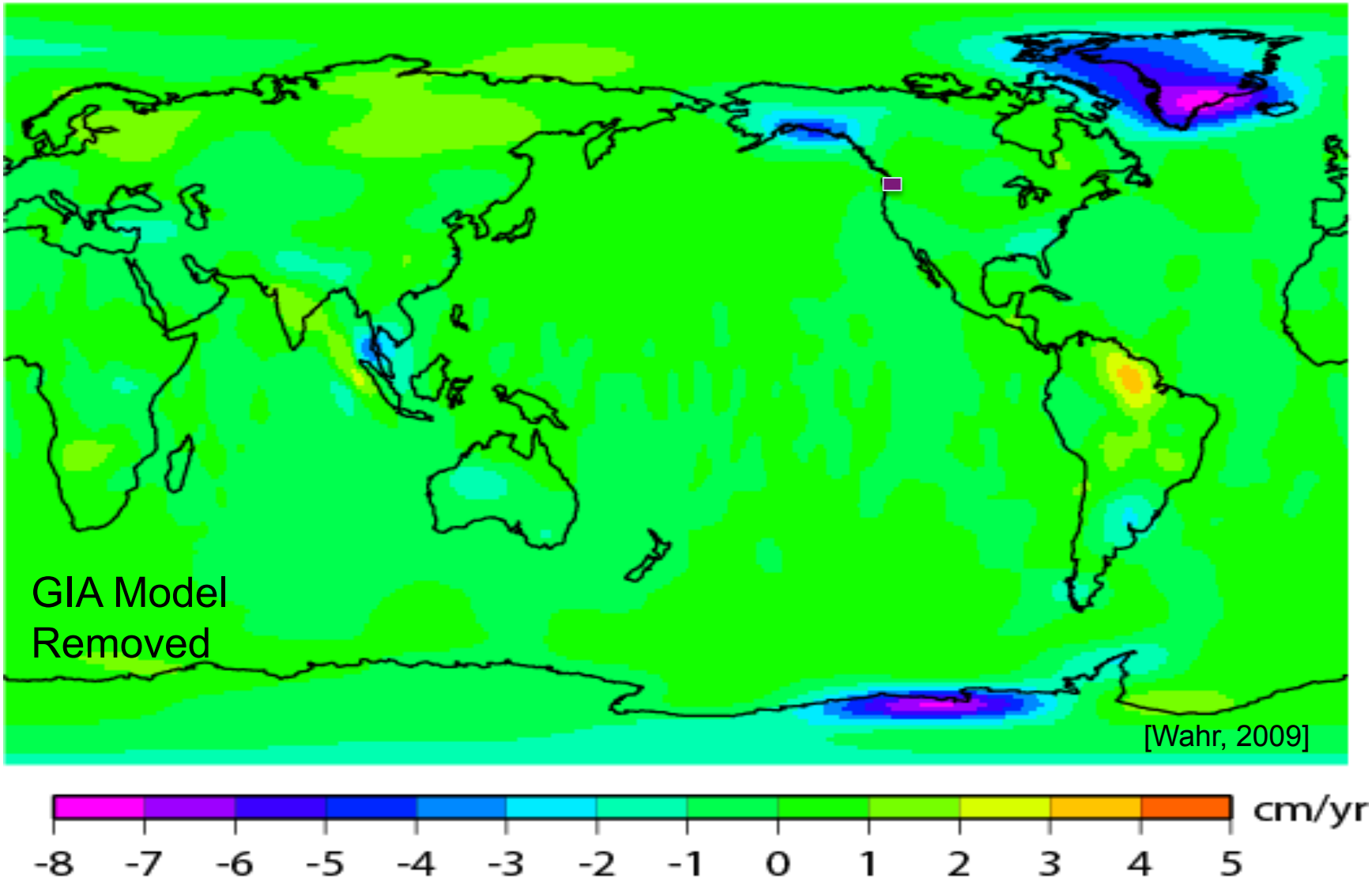
[Pritchard et al., 2009]

GRACE



GRACE can measure the change in mass at the Earth's surface that is equivalent to a layer of water just 1 cm thick spread over an area about the size of the State of Washington (i.e. about 450 km square)

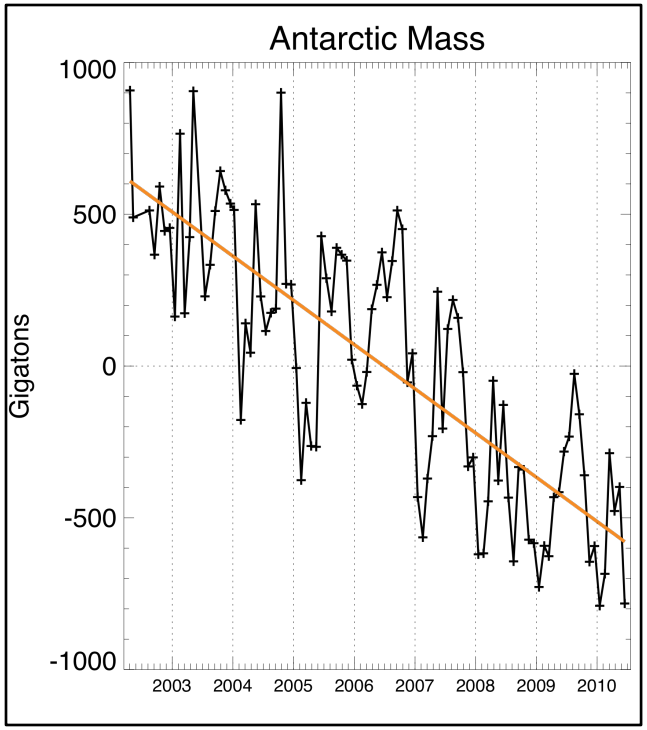
GRACE Secular Trends (2002-2009)



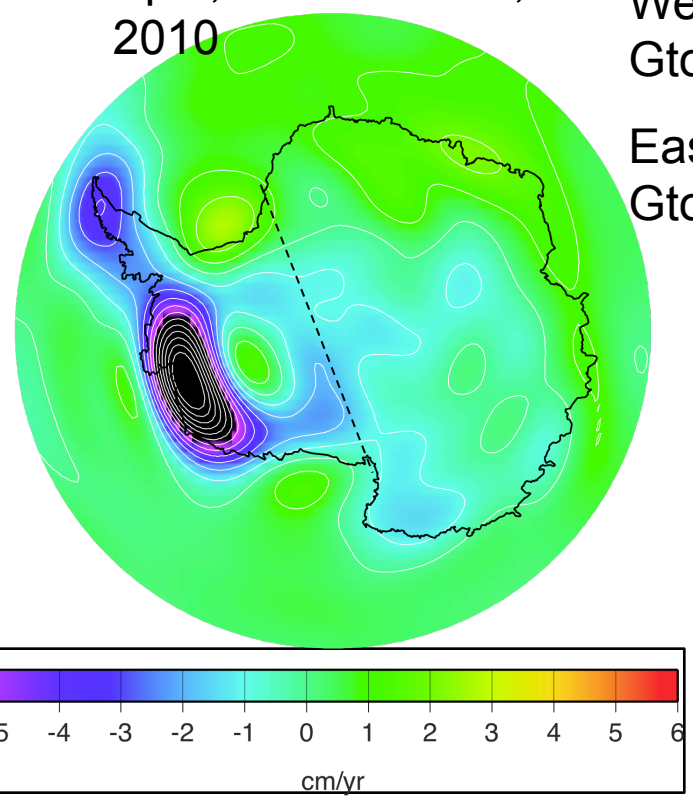
Antarctica Ice Mass Variations from GRACE

Total Antarctic ice mass

(noisy because of atmospheric pressure errors)



April, 2002 – June, 2010



[Wahr, 2010]

Rate of ice mass change:

All Antarctica: -143 Gton/yr

West Antarctica: -155 Gton/yr

East Antarctica: +15 Gton/yr

Uncertainty of GIA correction:

All Antarctica: ± 80 Gton/yr

West Antarctica: ± 20 Gton/yr

East Antarctica: ± 55 Gton/yr

-143 Gton/yr = 0.40 mm/yr sea level rise

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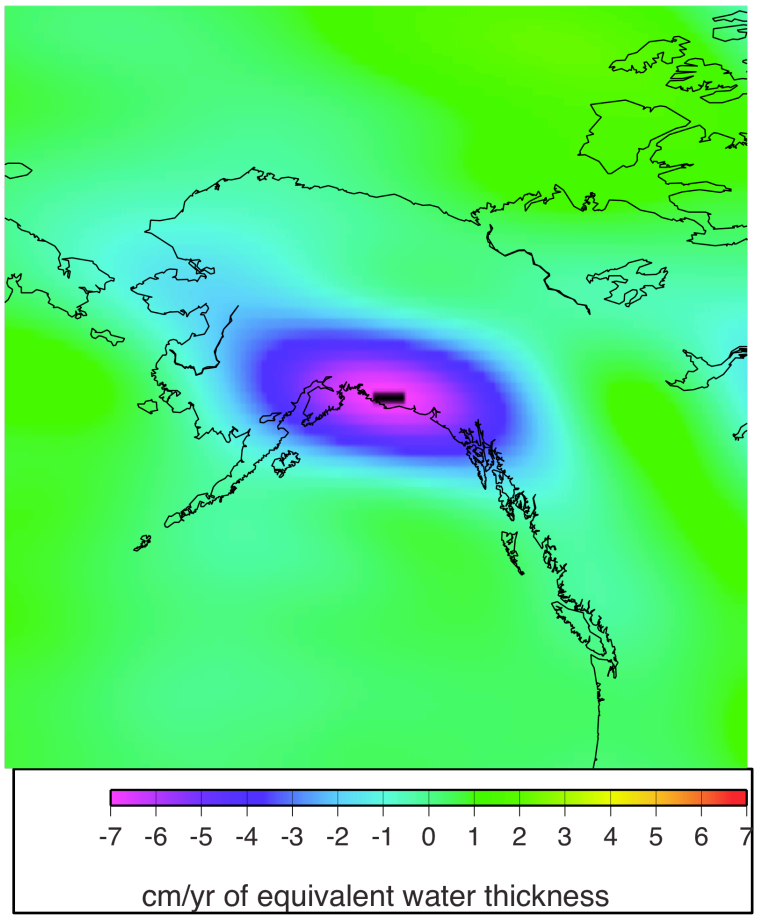
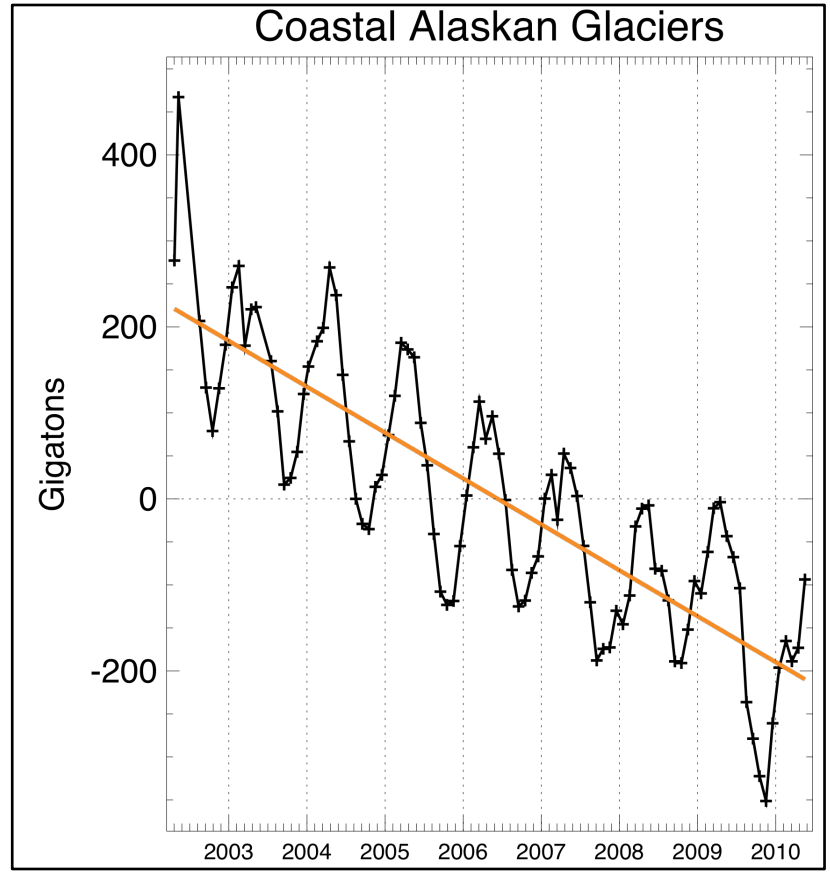
Alaskan Glaciers from GRACE

Rate of mass change between April, 2002 and May, 2010





Rate of mass change: -55 Gton/yr = 0.15 mm/yr sea level rise

[Wahr, 2010]

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Greenland Ice Mass Changes from GRACE

April, 2002 – June, 2010

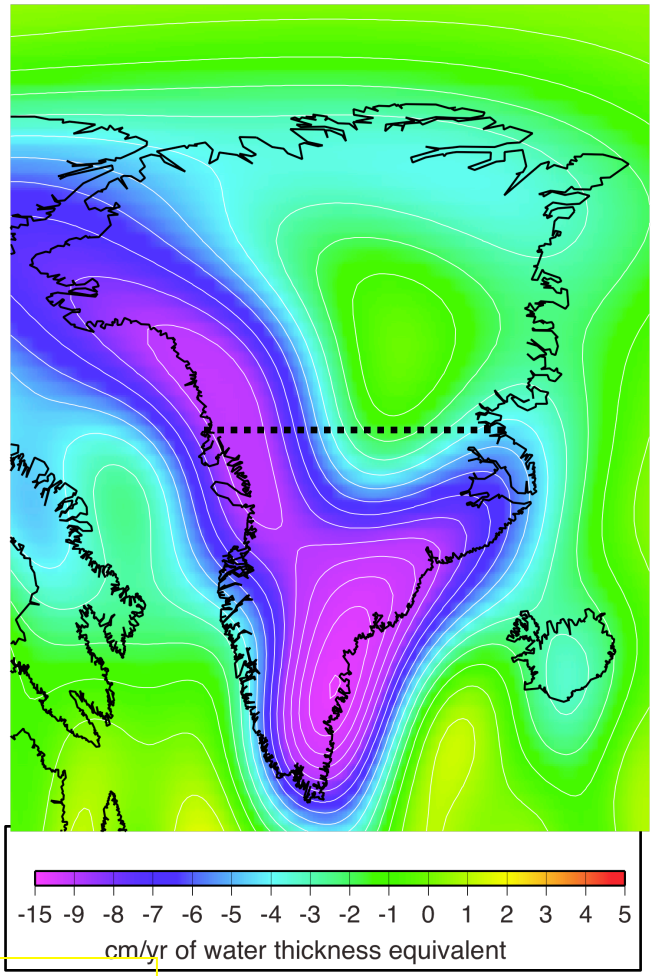
Rate of Ice mass change:

All Greenland: -239 Gton/yr

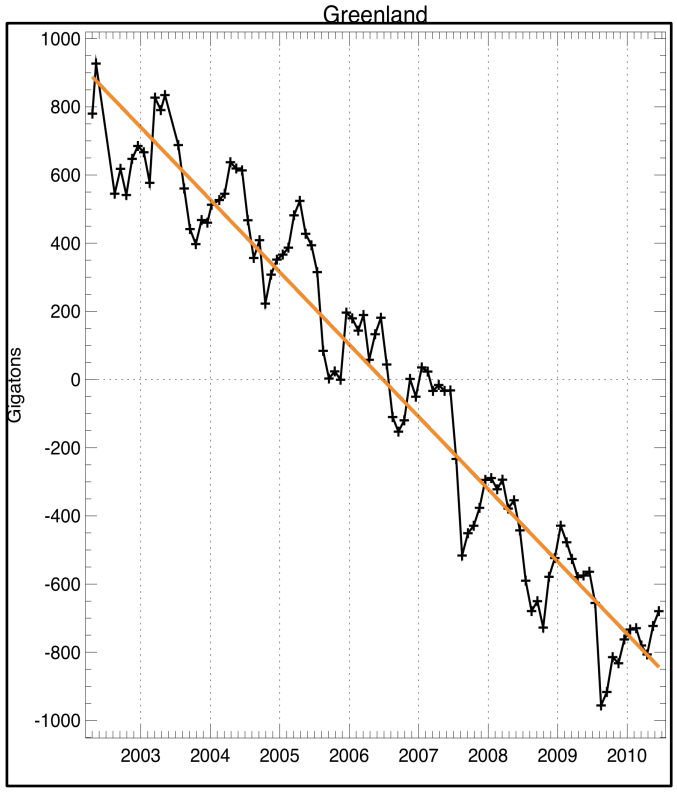
South Greenland: -162 Gton/yr

North Greenland: -77 Gton/yr

(1 Gton = 1 km^3 of water)



Total Greenland ice volume



[Wahr, 2010]

-239 Gton/yr = 0.66 mm/yr sea level rise

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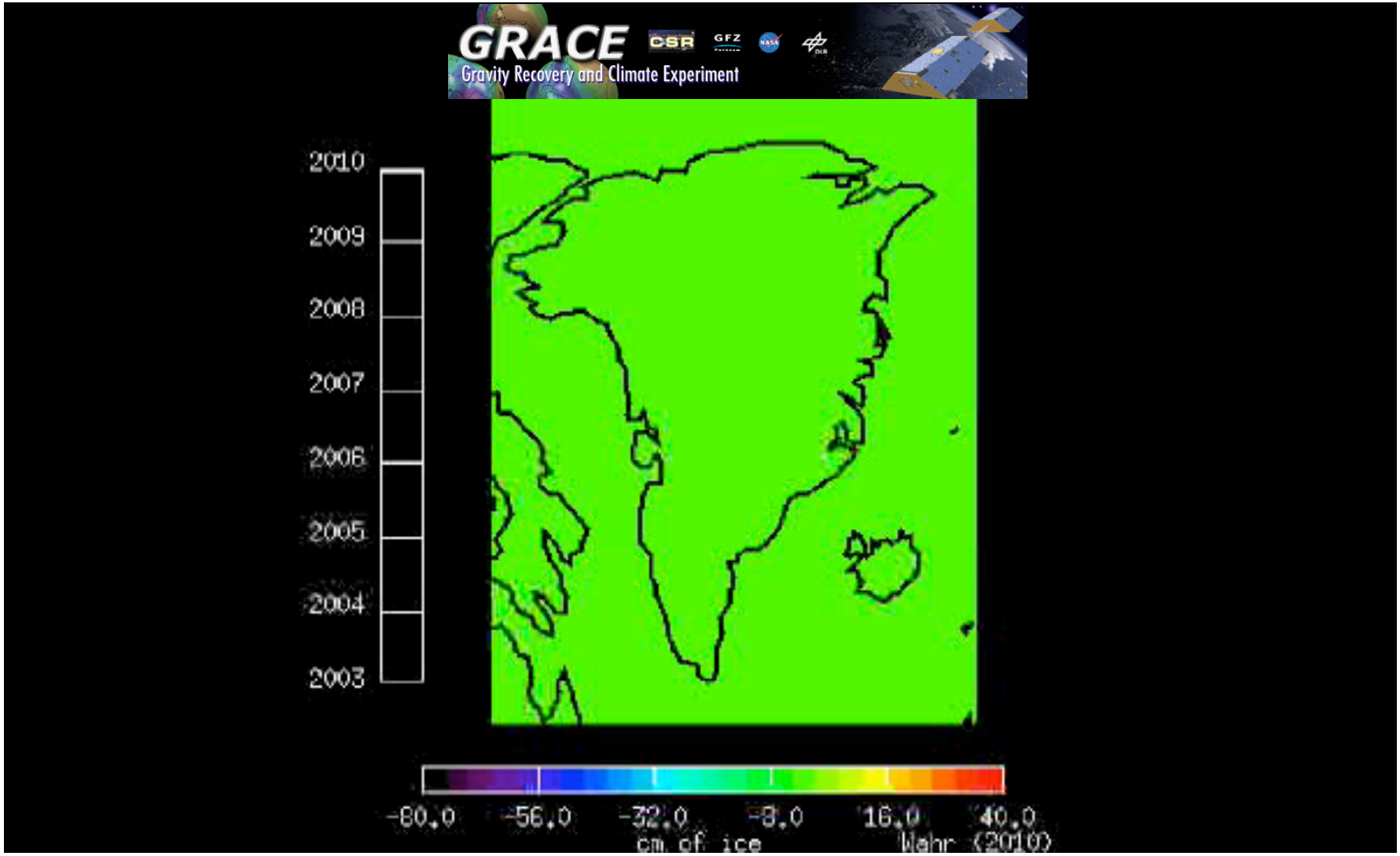
Greenland Ice Loss Animation



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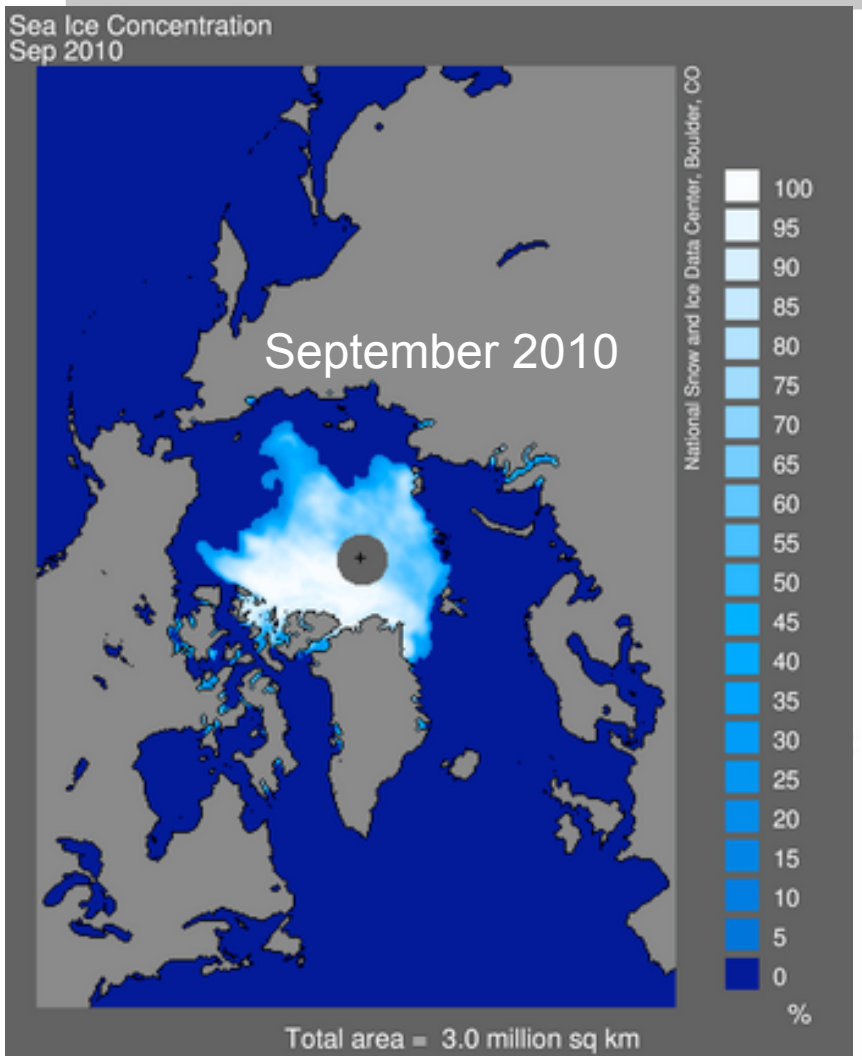
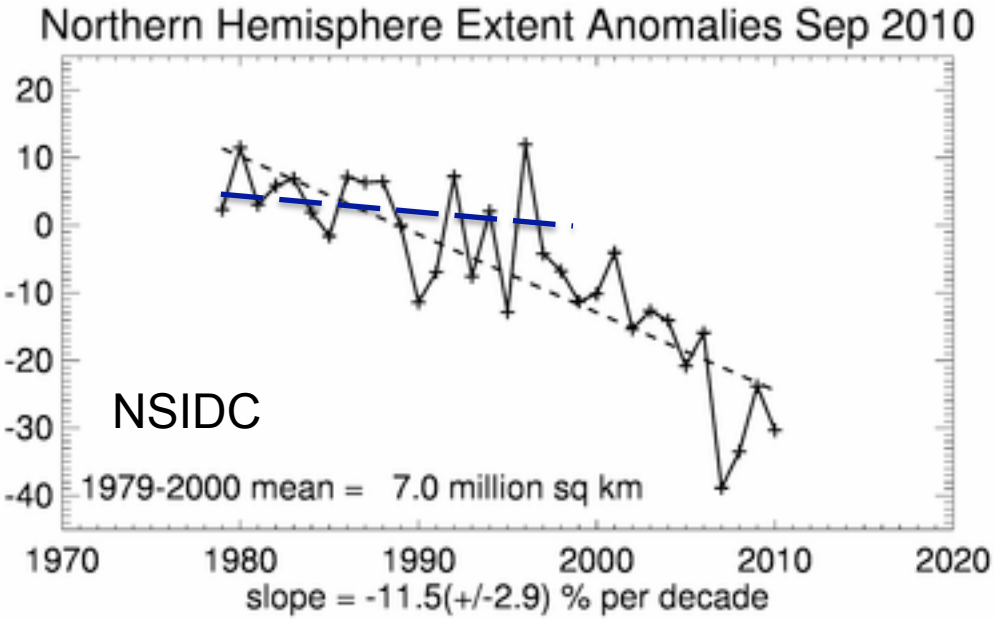
Arctic Sea Ice Cover is Shrinking



Sea ice concentration and sea ice extent are measured from a number of satellites operated by the Air Force (DMSP) and NASA (Aqua) and compiled by the National Snow and Ice Data Center (NSIDC)



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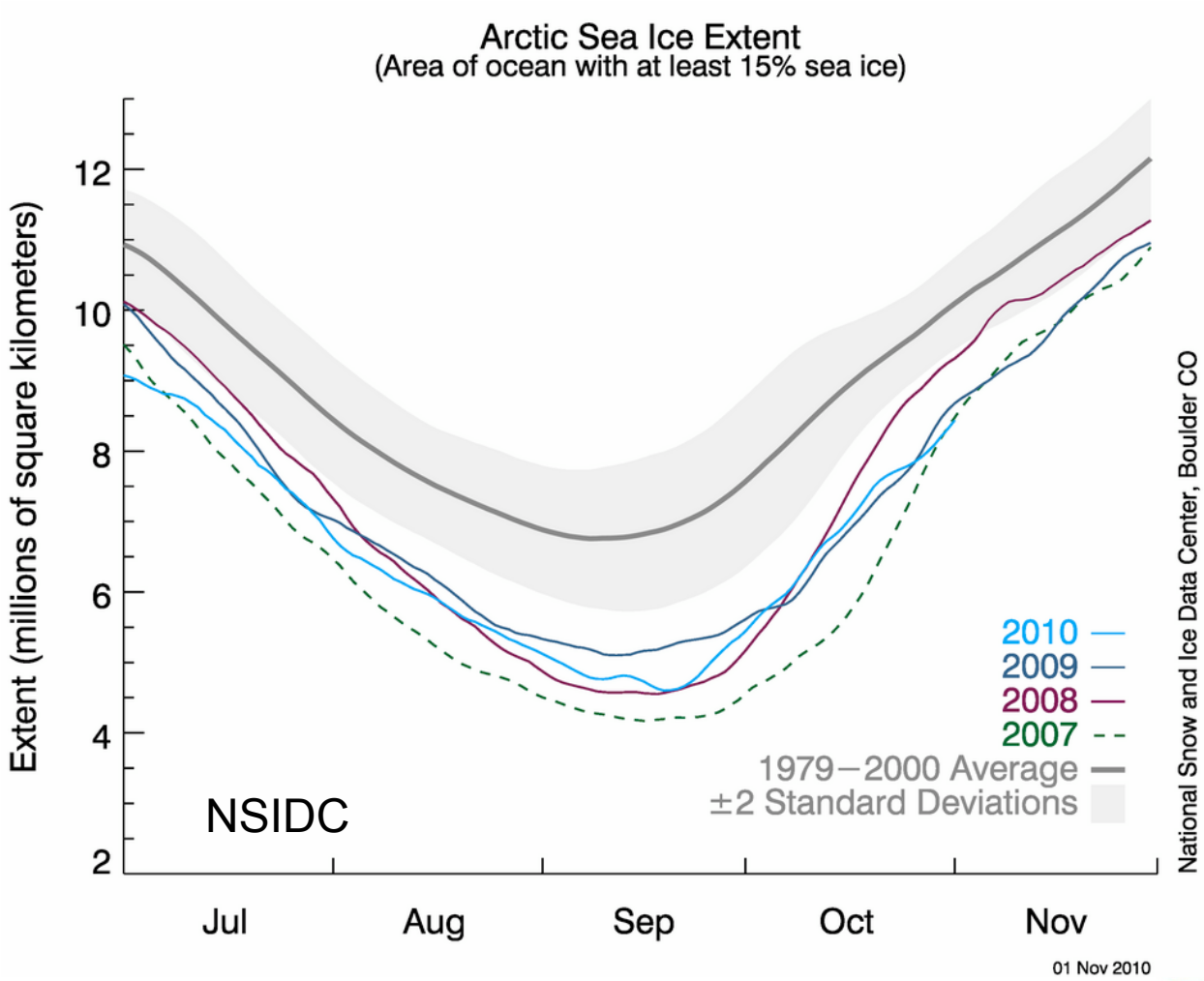
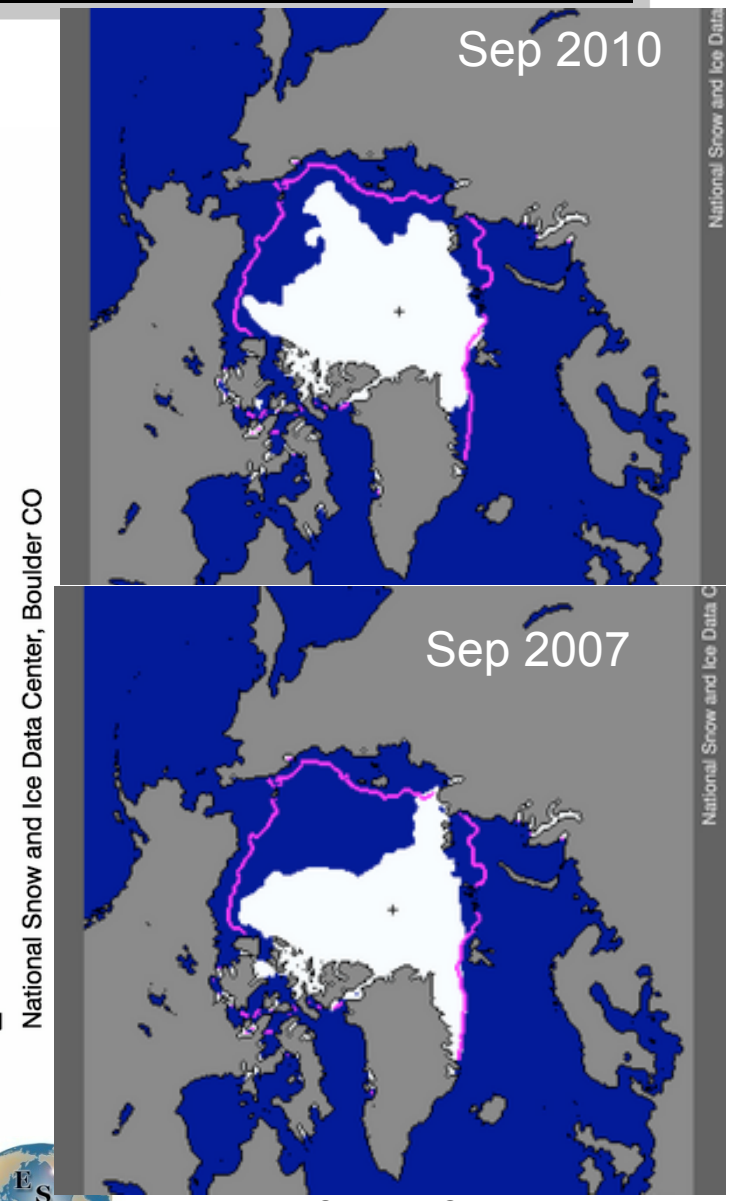
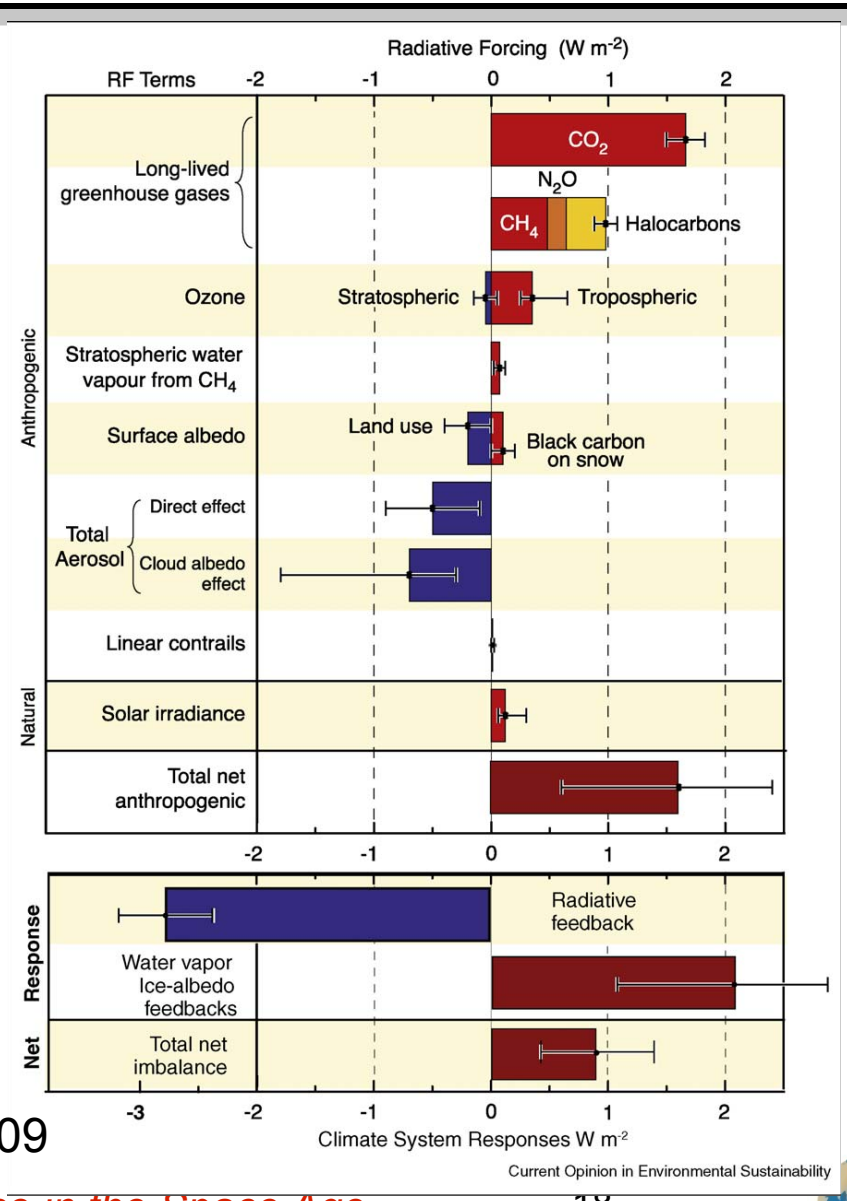
Recent Ice Minima Years 2007-2010





Arctic Sea Ice Video from 2007

Net Anthropogenic heating ~1 W/m^2

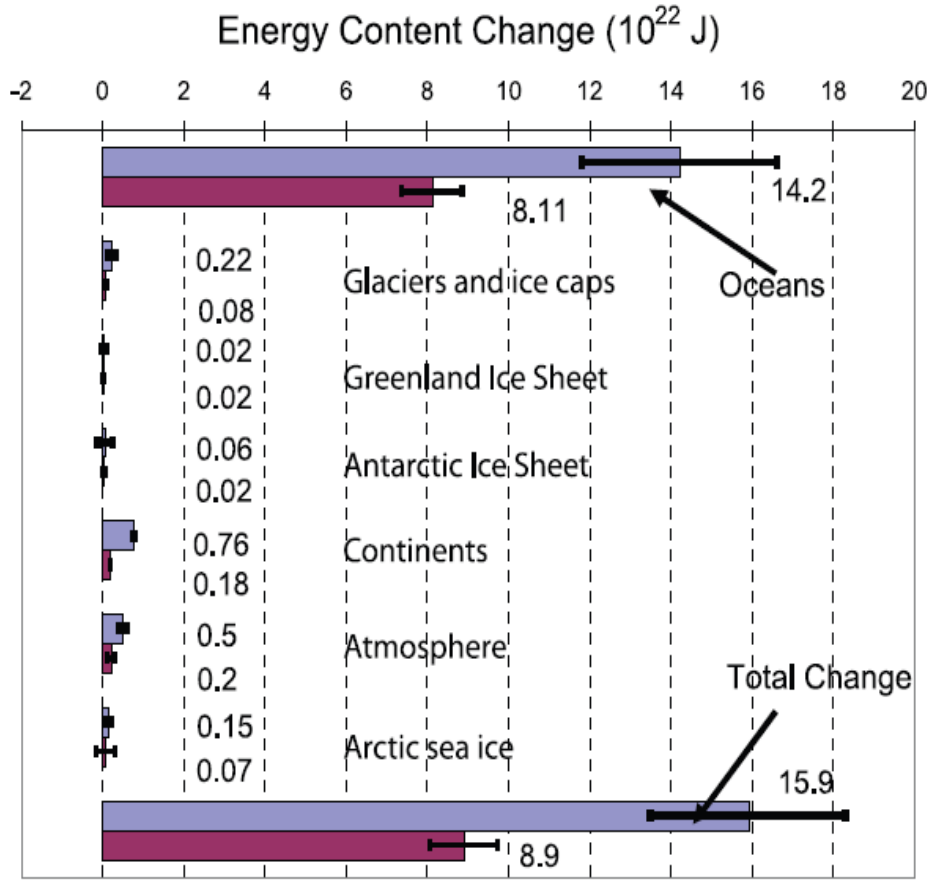


Net Anthropogenic radiative forcing ~1.5 W/m^2

With feedbacks ~1 W/m^2

Trenberth 2009

How much energy to warm the planet ?



Trenberth, et al 2010

Figure 1. Energy content changes in different components of the Earth system for two periods (1961–2003 and 1993–2003). Blue bars are for 1961 to 2003, burgundy bars for 1993 to 2003. From [6].

Most of the energy is being absorbed by the ocean.

The top 3.5 m of the ocean hold as much energy as the whole atmosphere.

Blue bar: 1961-2003 (42 yrs)
Red bar: 1993-2003 (10 yrs)
1961-2003: 0.25 W/m^2
1993-2003: 0.55 W/m^2

The net greenhouse forcing is 1 W/m^2, which is more than enough to account for the changing energy content to warm the climate in recent decades.

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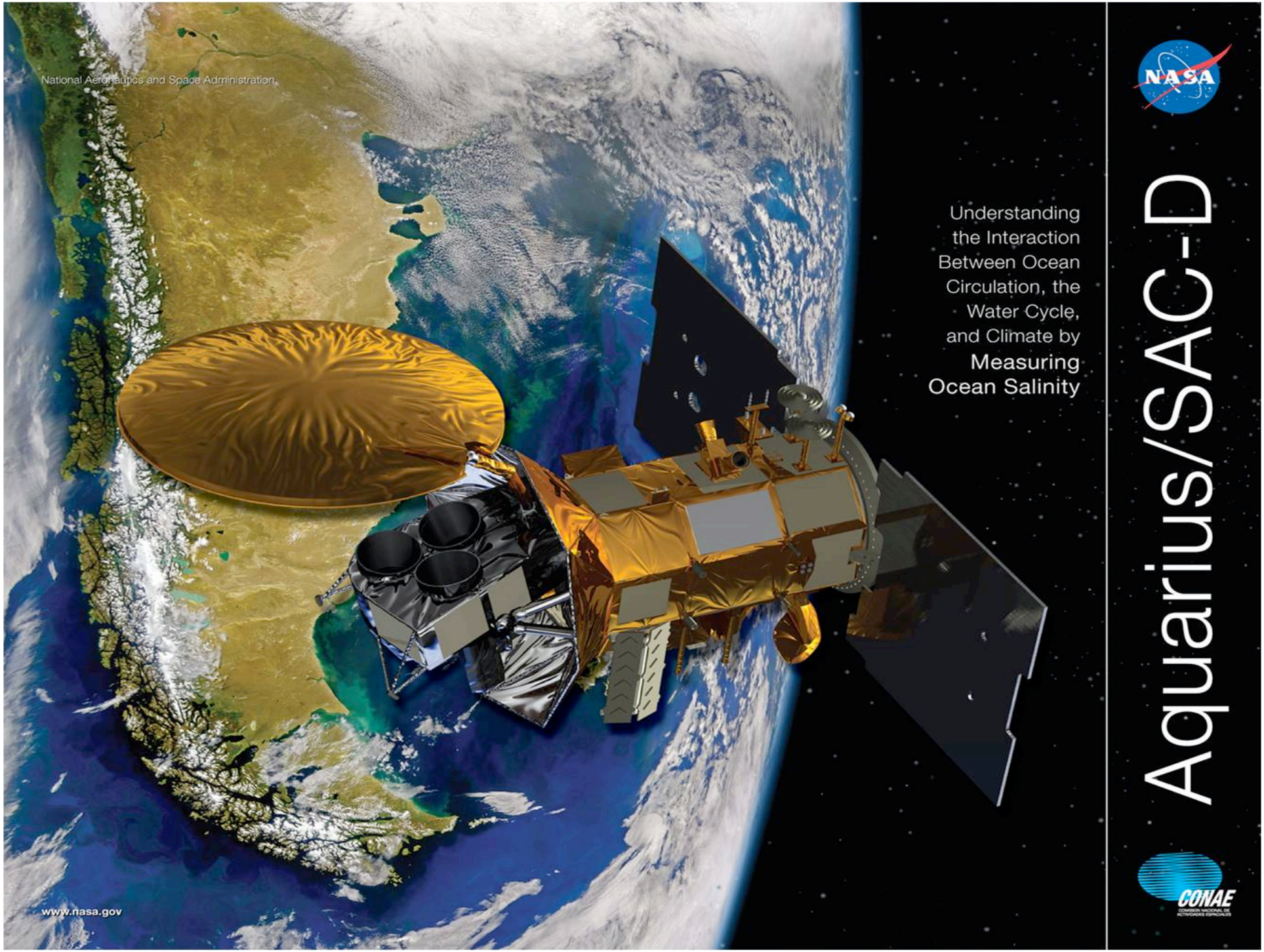
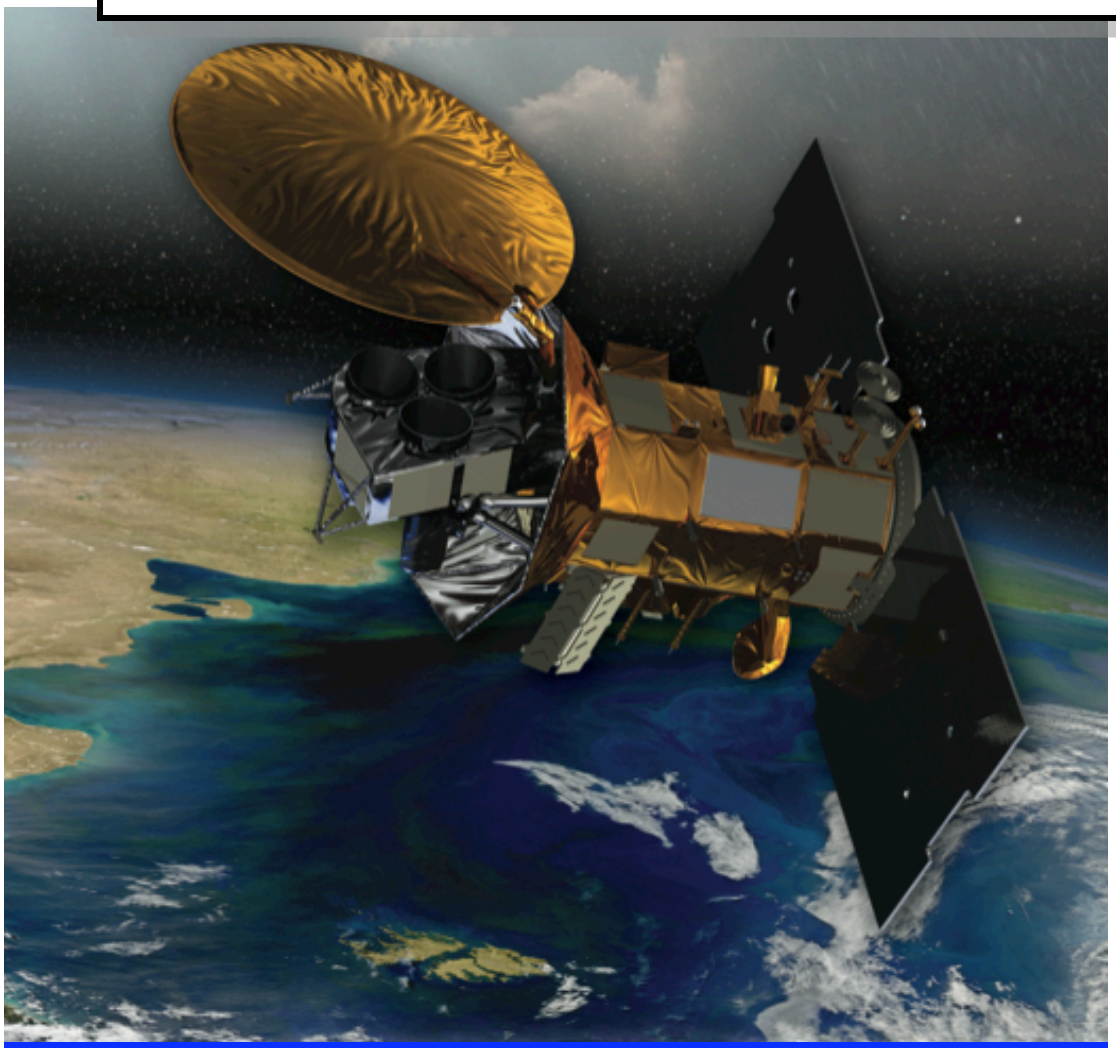

National Aeronautics and Space Administration
www.nasa.gov
Understanding the Interaction Between Ocean Circulation, the Water Cycle, and Climate by Measuring Ocean Salinity
Aquarius/SAC-D
NASA
CONAE

Aquarius Elevator Speech



Understanding the Interactions Between the Ocean Circulation, Global Water Cycle and Climate by Measuring Sea Surface Salinity

Climate Science in the Space Age

Water Cycle
(rainfall, evaporation, rivers, ice freeze/melt)

↓

Salinity

↓

Density

↓

Ocean Circulation

↓

Ocean heat transport and exchange with the Atmosphere

↓

Water Cycle

Coupled System

and we need to map the sea surface salinity variability over the whole ocean in order to understand these interactions.

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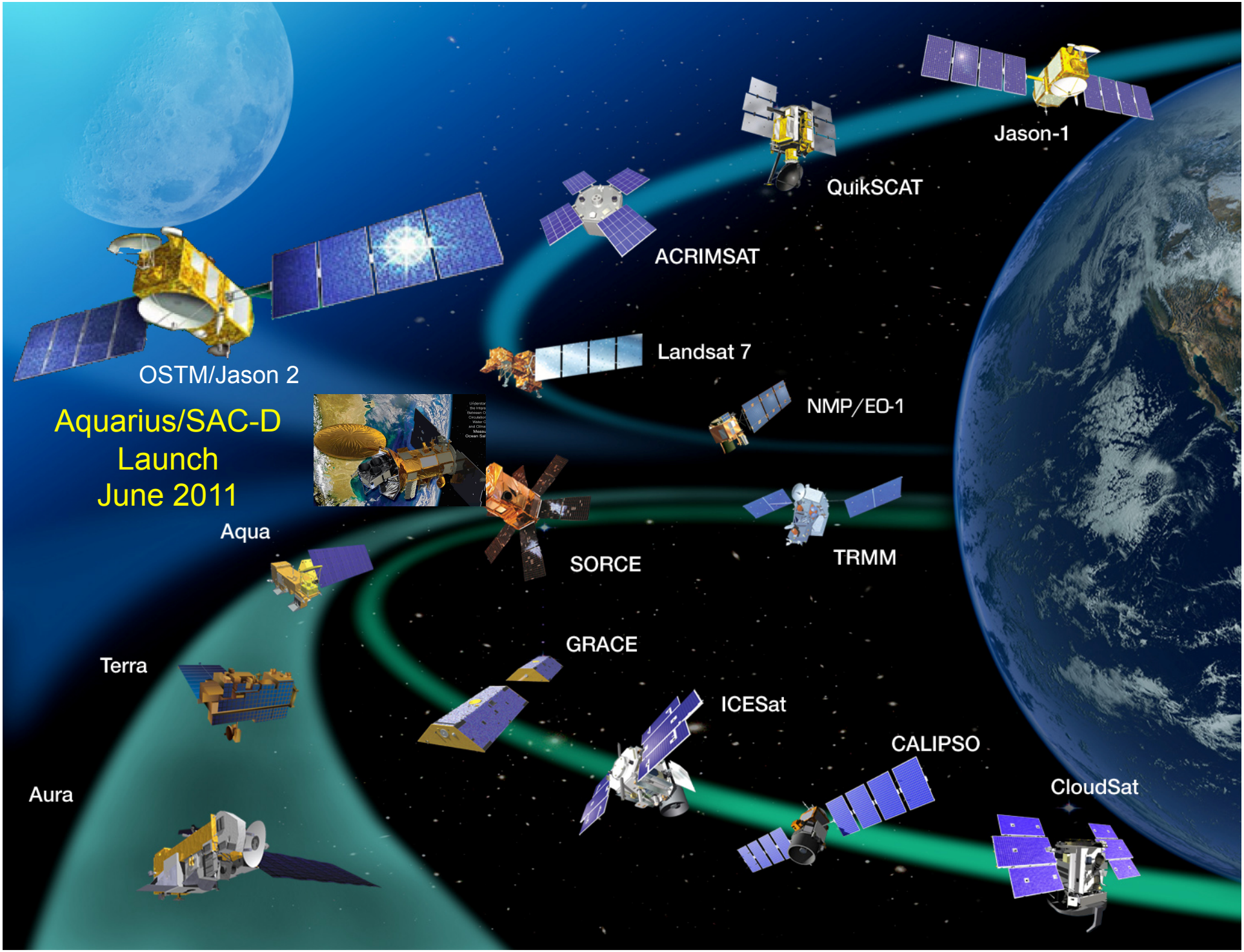
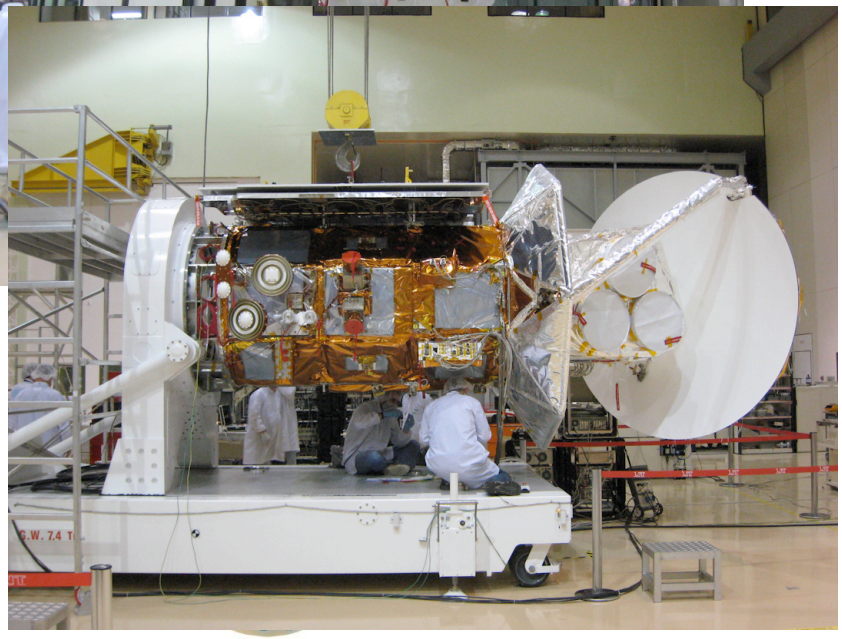
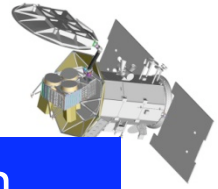

Jason-1
QuikSCAT
ACRIMSAT
OSTM/Jason 2
Landsat 7
NMP/EO-1
Aquarius/SAC-D
Launch
June 2011
Aqua
SORCE
TRMM
GRACE
Terra
ICESat
CALIPSO
Aura
CloudSat

Recent photos – September 2010

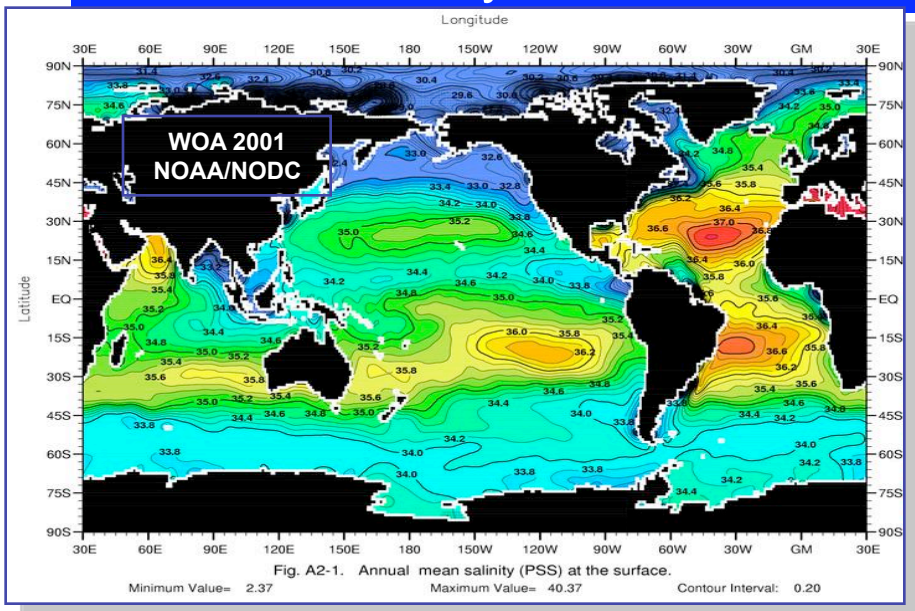


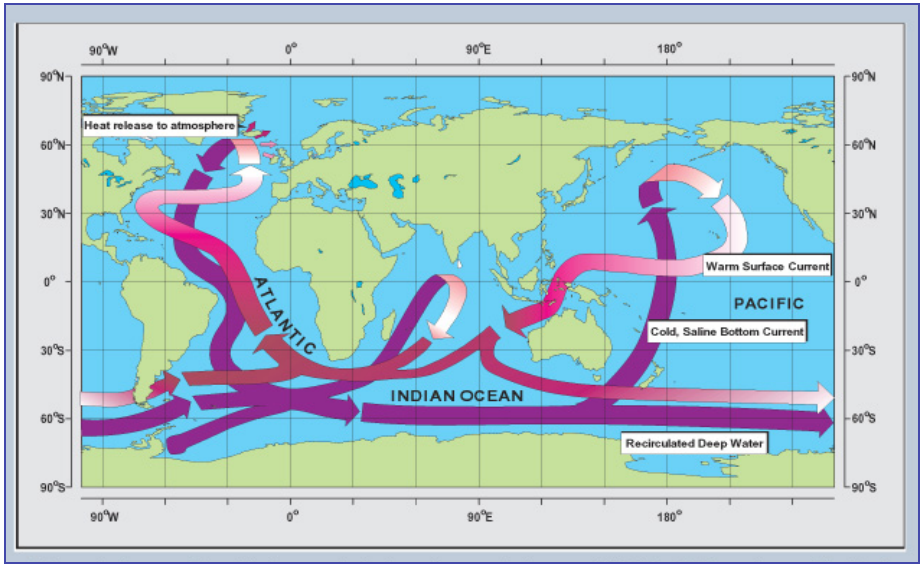
AQUARIUS/SAC-D

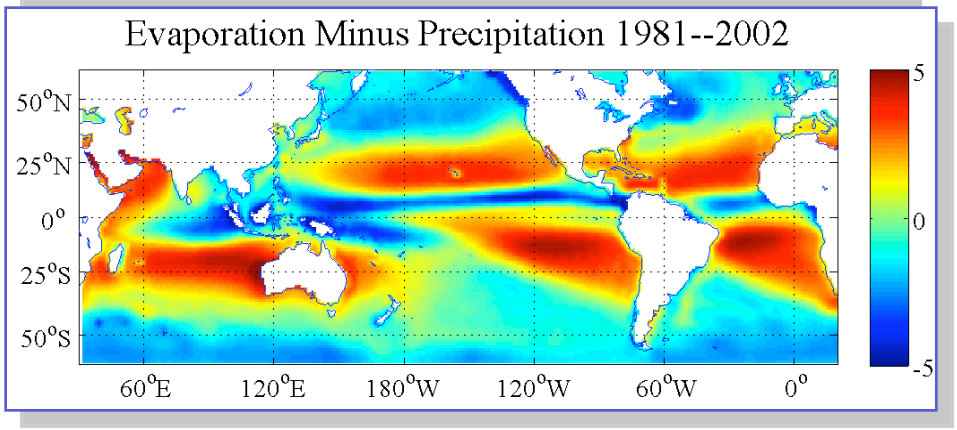
Ocean Salinity; the Next Challenge



Understanding the Interactions Between the Ocean Circulation, Global Water Cycle and Climate by Measuring Sea Surface Salinity







Global salinity patterns are linked to rainfall and evaporation

Salinity affects seawater density, which in turn governs ocean circulation and climate

The higher salinity of the Atlantic sustains the oceanic deep overturning circulation

Salinity variations are driven by precipitation, evaporation, runoff and ice freezing and melting

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