Climate Change, the Oceans and Sea Level Rise

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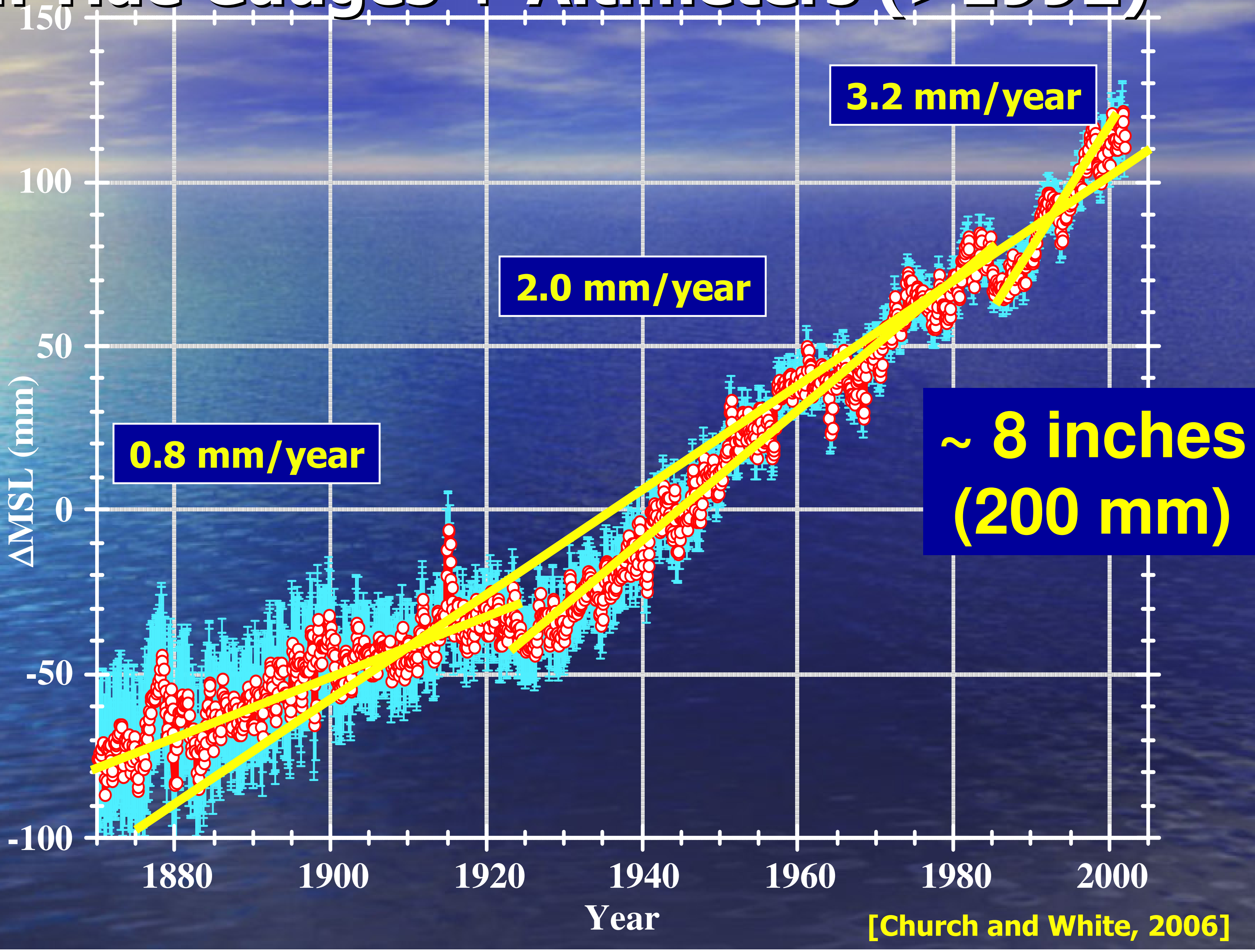
NOAA Satellite & Information Service

Round Table 2:
Contribution of Space Systems to Understanding and Forecasting Climate

IAF Symposium on Earth Observation Satellites and Climate Change
UN Committee on Peaceful Uses of Outer Space
Vienna, 9 February 2009

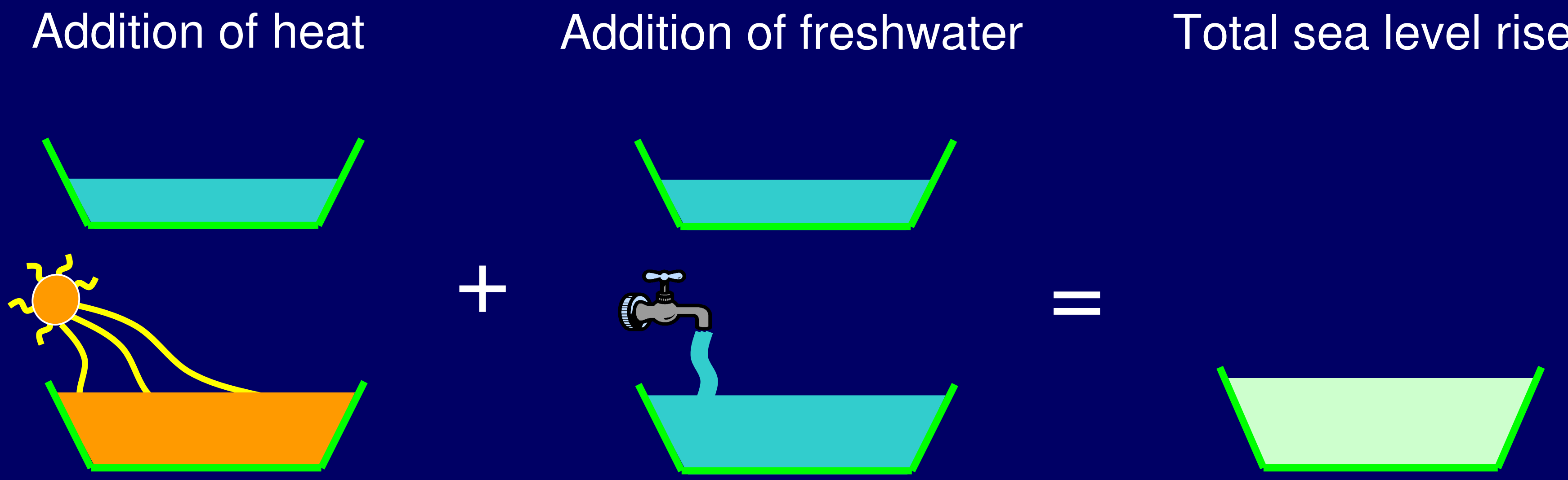
What is the most obvious oceanic impact of the Earth’s warming climate?

Global Sea Level from Tide Gauges + Altimeters (>1992)



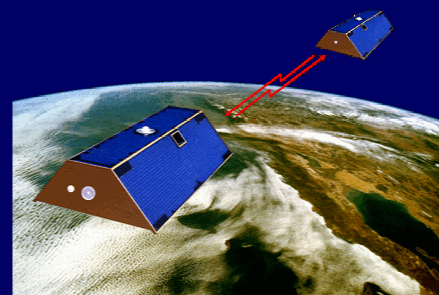
How well do we understand global sea level rise?

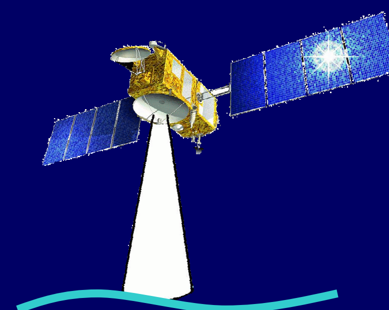
Causes of Sea Level Rise



Measuring the Global Oceans

Addition of heat + Addition of freshwater = Total sea level rise

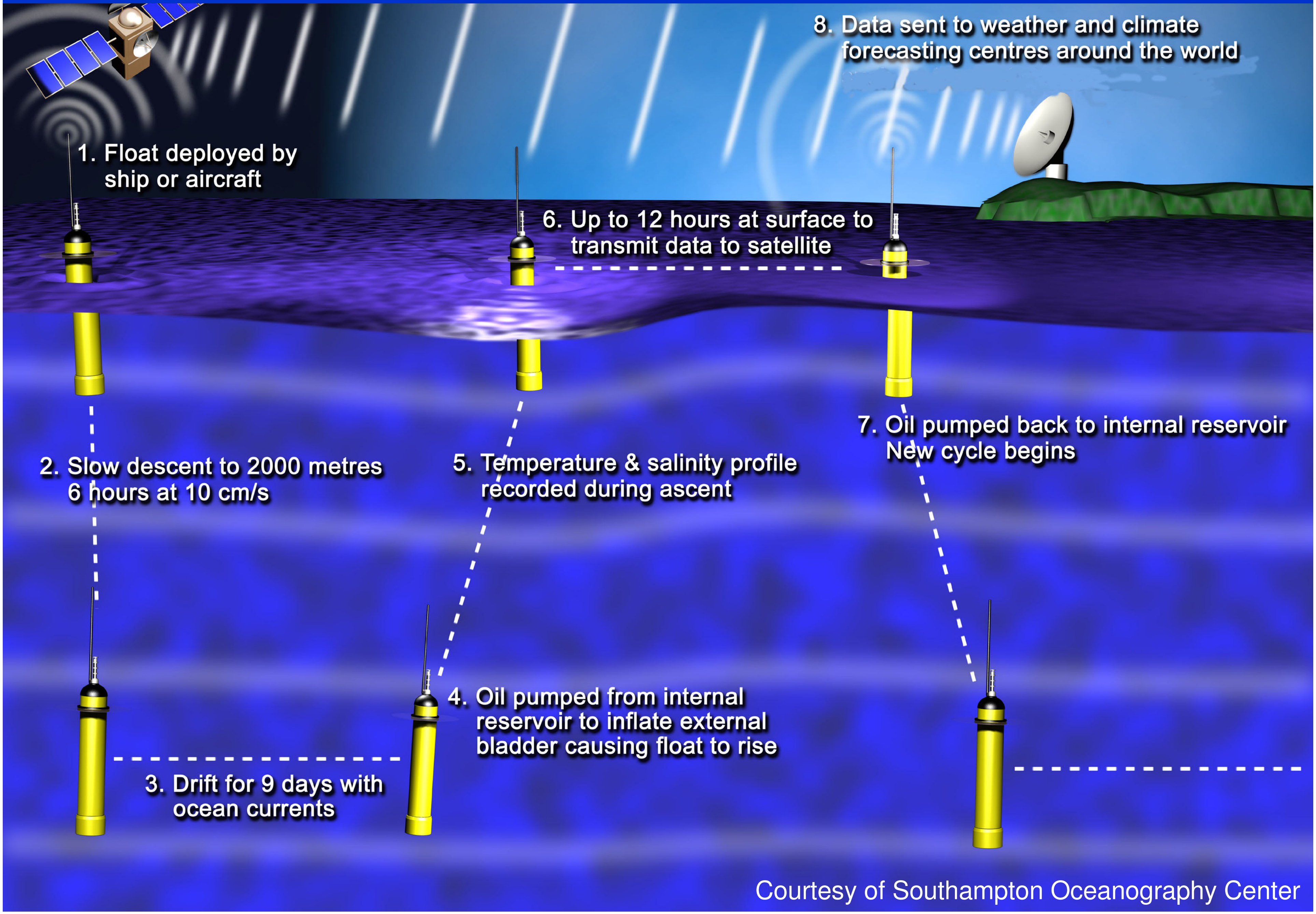




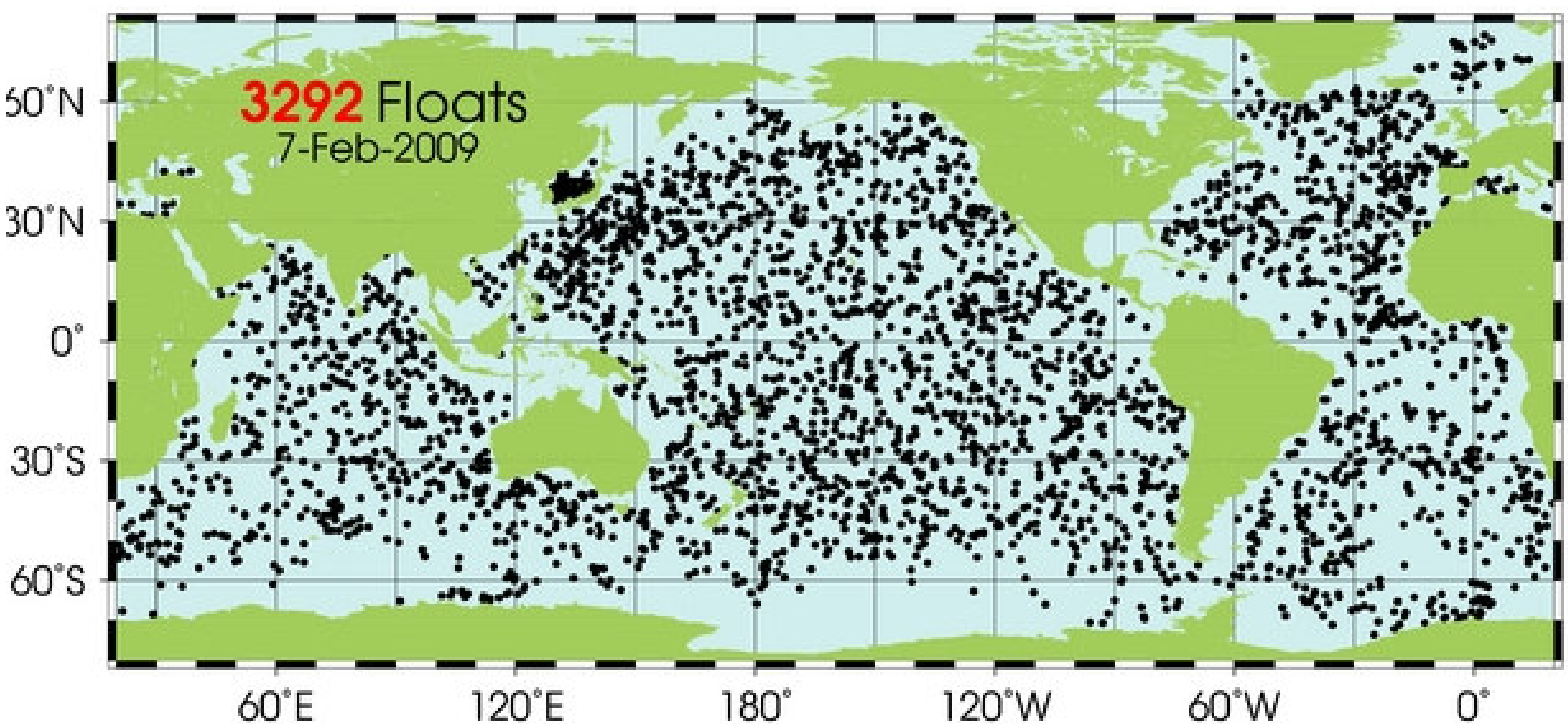
Argo **GRACE** **Jason**

Measuring the addition of heat

How is the oceanic heat distribution measured?



Having achieved global coverage in Nov 2007, Argo is resolving for the first time the global distribution of heat in the upper ocean*



*** ice-free oceans**

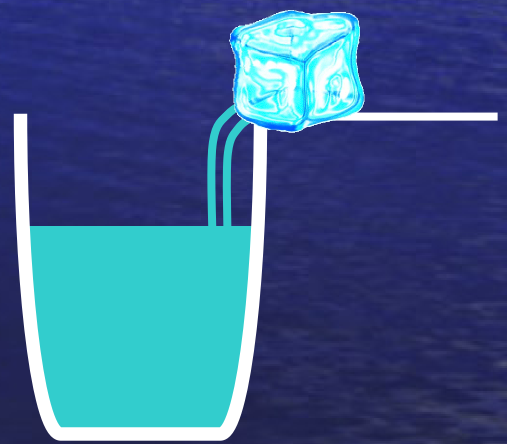
Courtesy of Mathieu Belbeoch, Argo Information Center and the 20+ Participating countries

Measuring the addition of fresh water

Addition of Water from Melting Ice

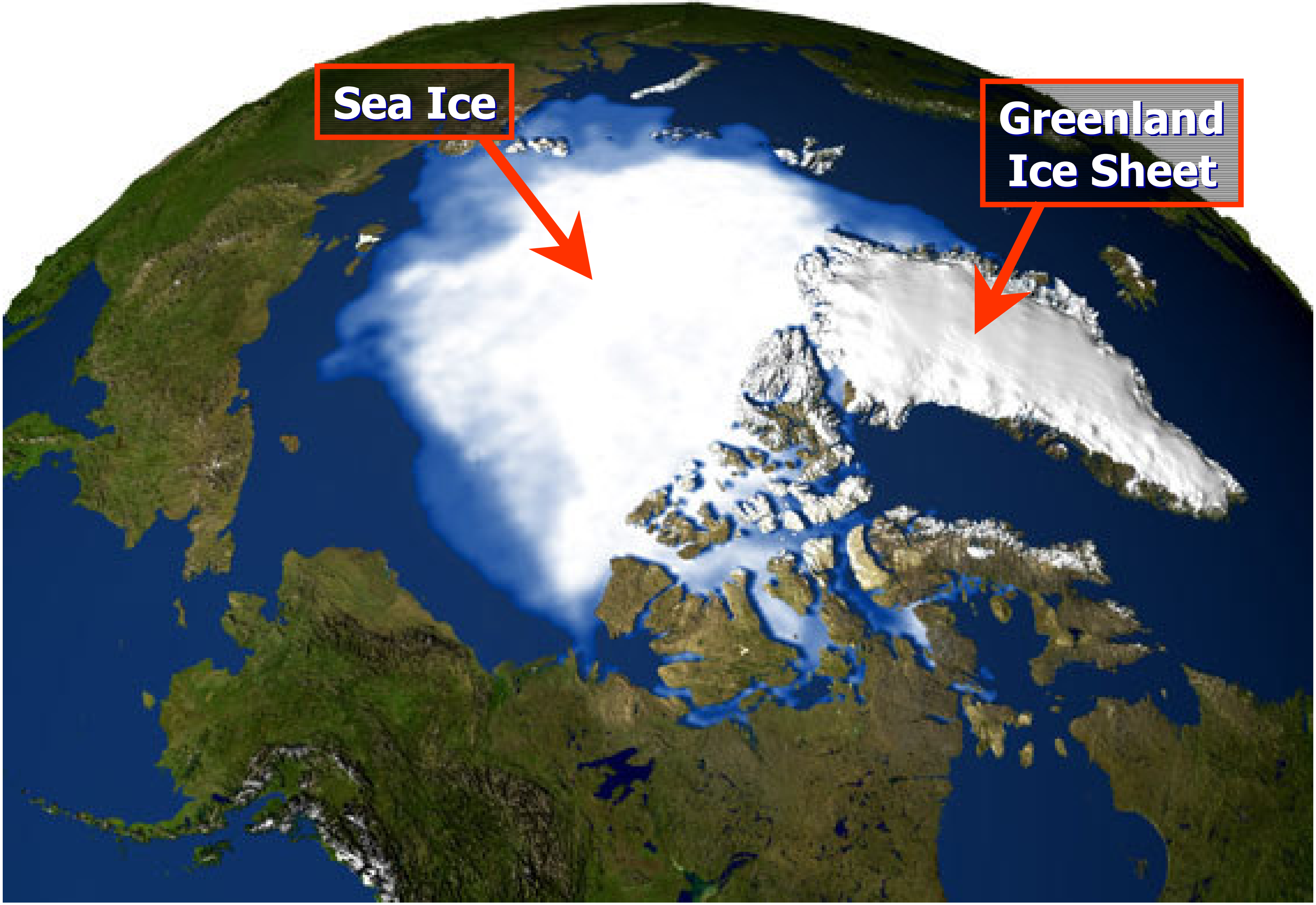
Melting *Land* ice does!

Sea Ice Melt

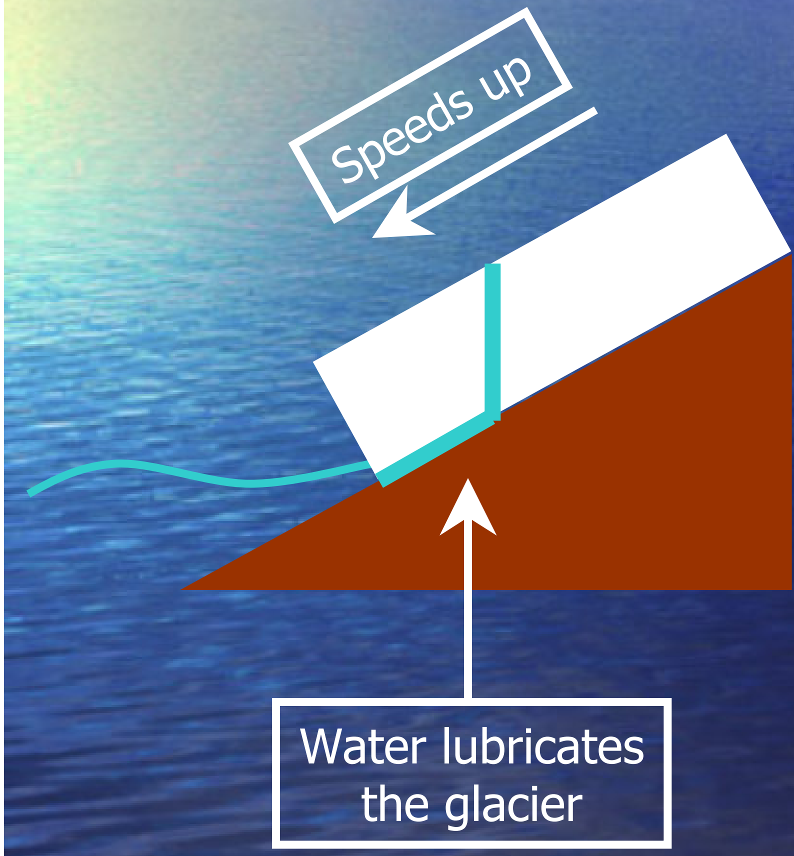


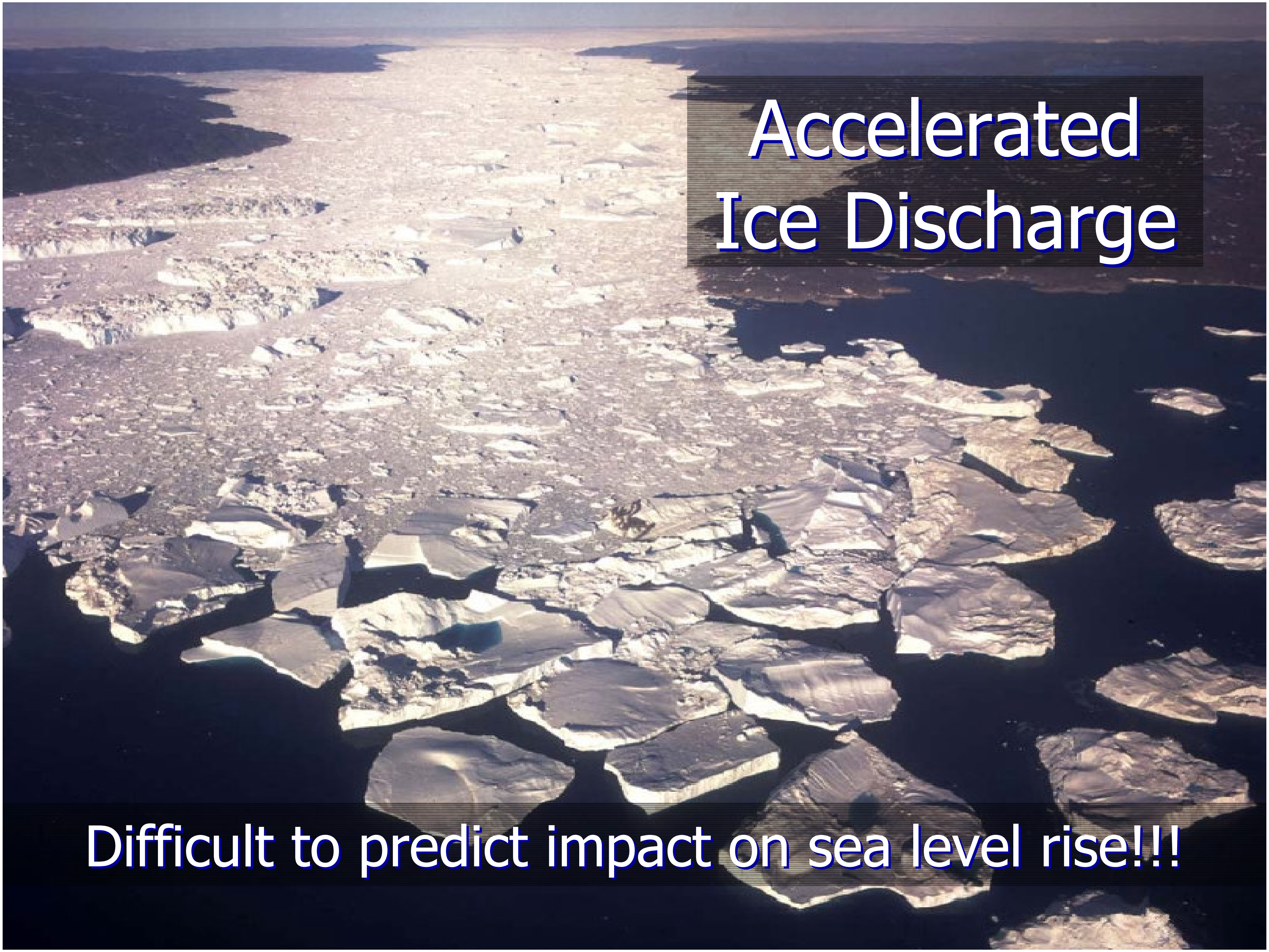
Does NOT raise sea level

So does iceberg calving


Sea Ice
Greenland Ice Sheet

Ice Sheet Melting



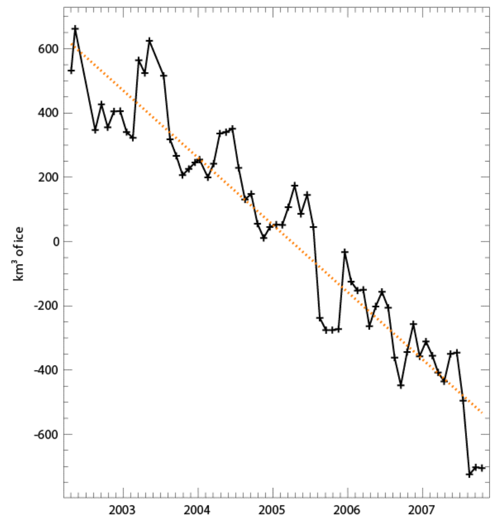

Accelerated
Ice Discharge
Difficult to predict impact on sea level rise!!!

Changes in Gravity from NASA's GRACE Satellite

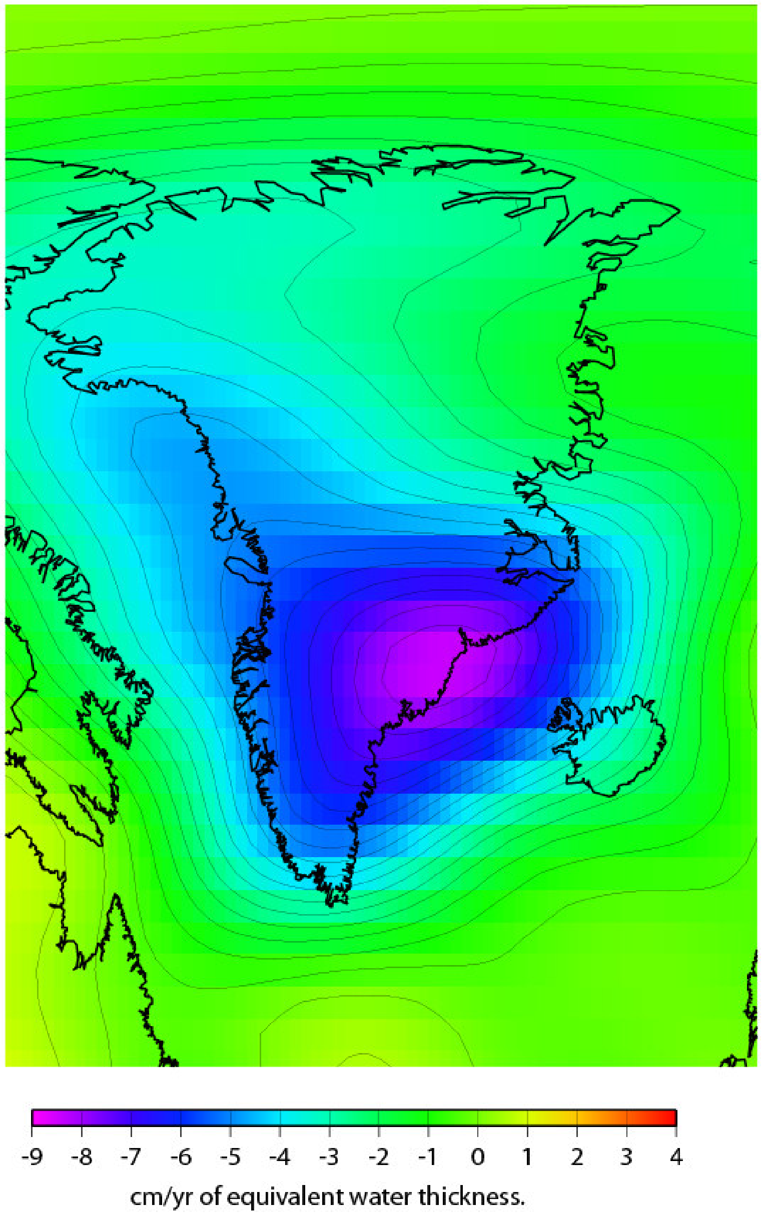
Apr 2002 – Oct 2007
(400 km smoothing)

Contributions to sea level rise

- *All Greenland: 0.60 mm/yr*
- *South: 0.45*
- *North: 0.15*



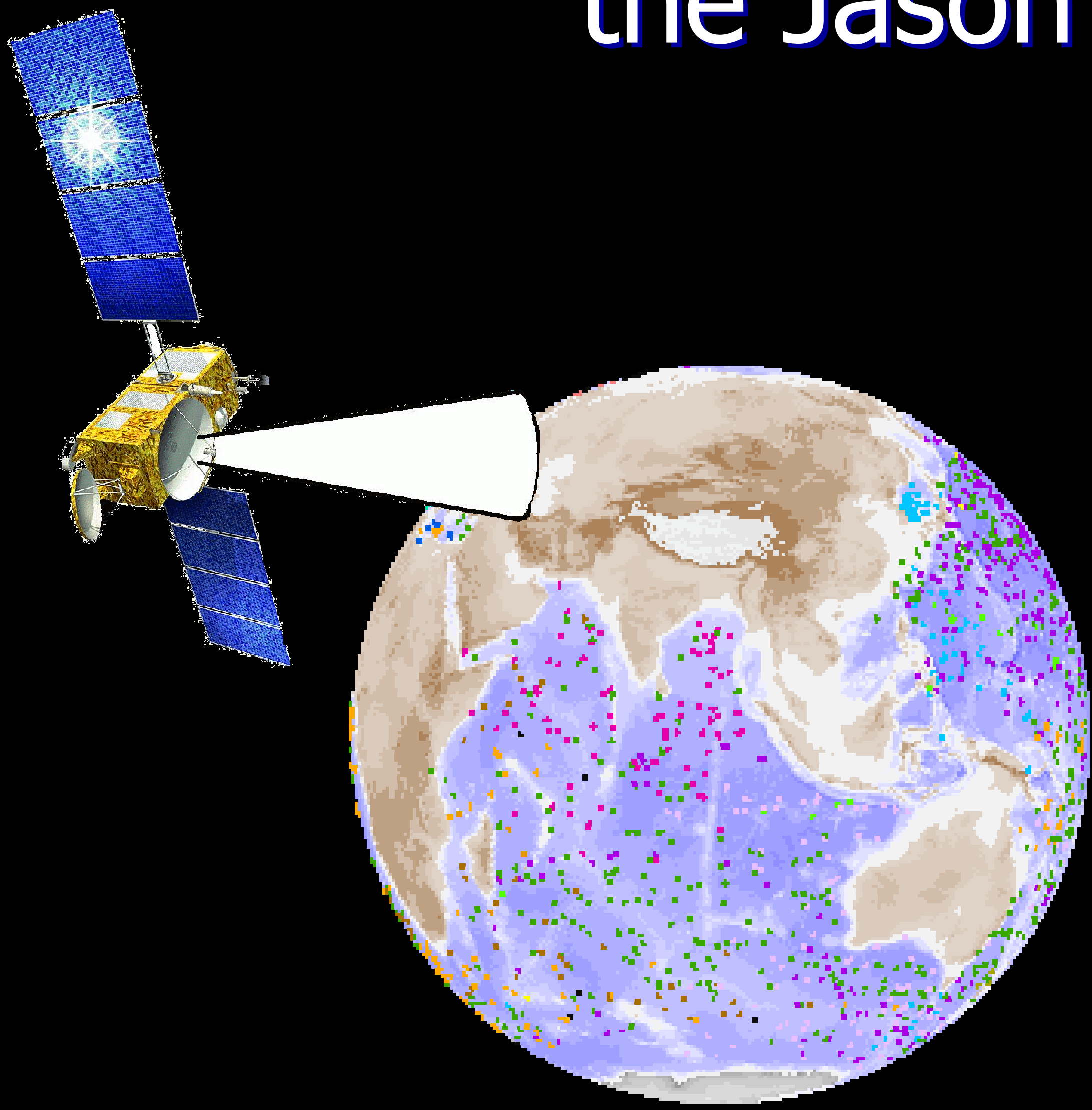
Greenland ice is equivalent to a ~7-m (23-ft) rise in global sea level



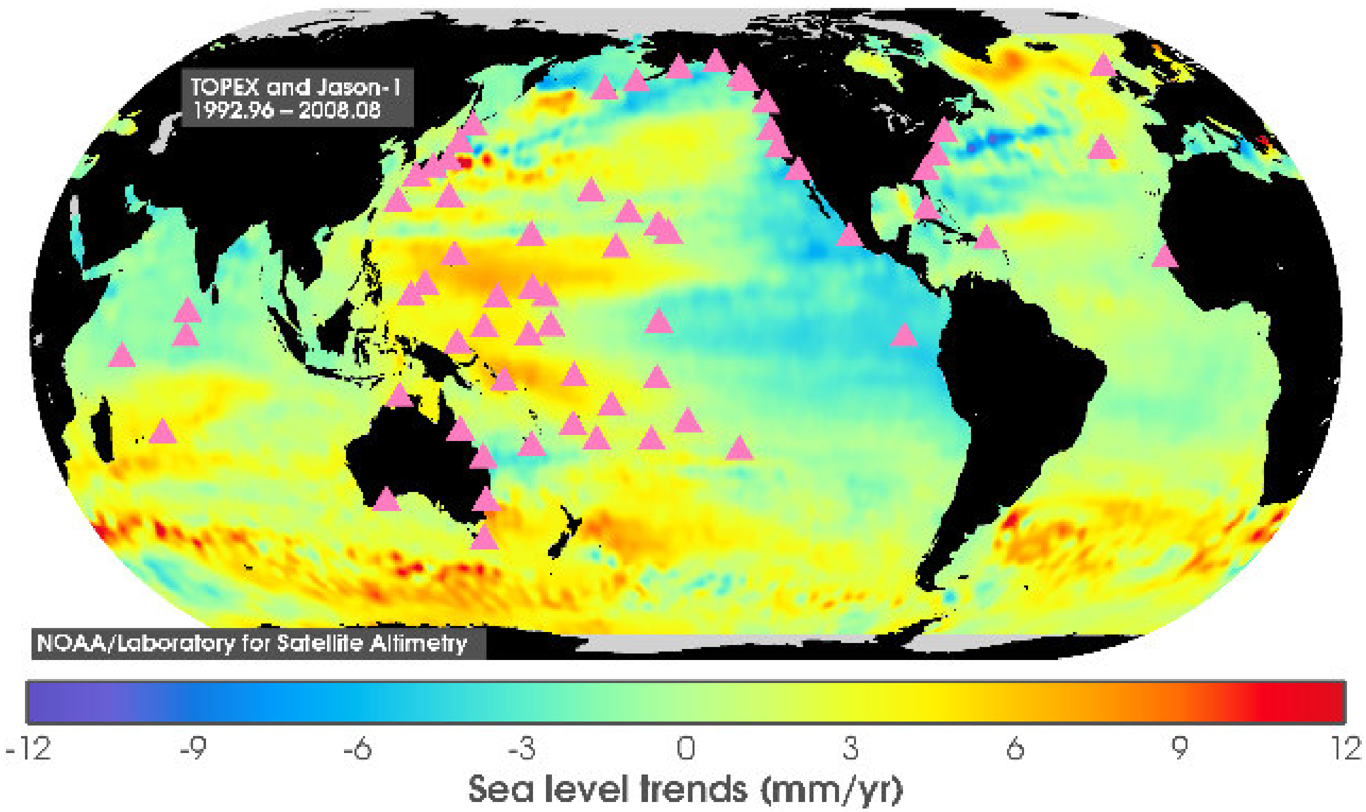
Courtesy of John Wahr and Isabella Velicogna, 2008

Measuring total sea level rise

Measuring total sea level with the Jason satellite



Sea level rise is not uniform



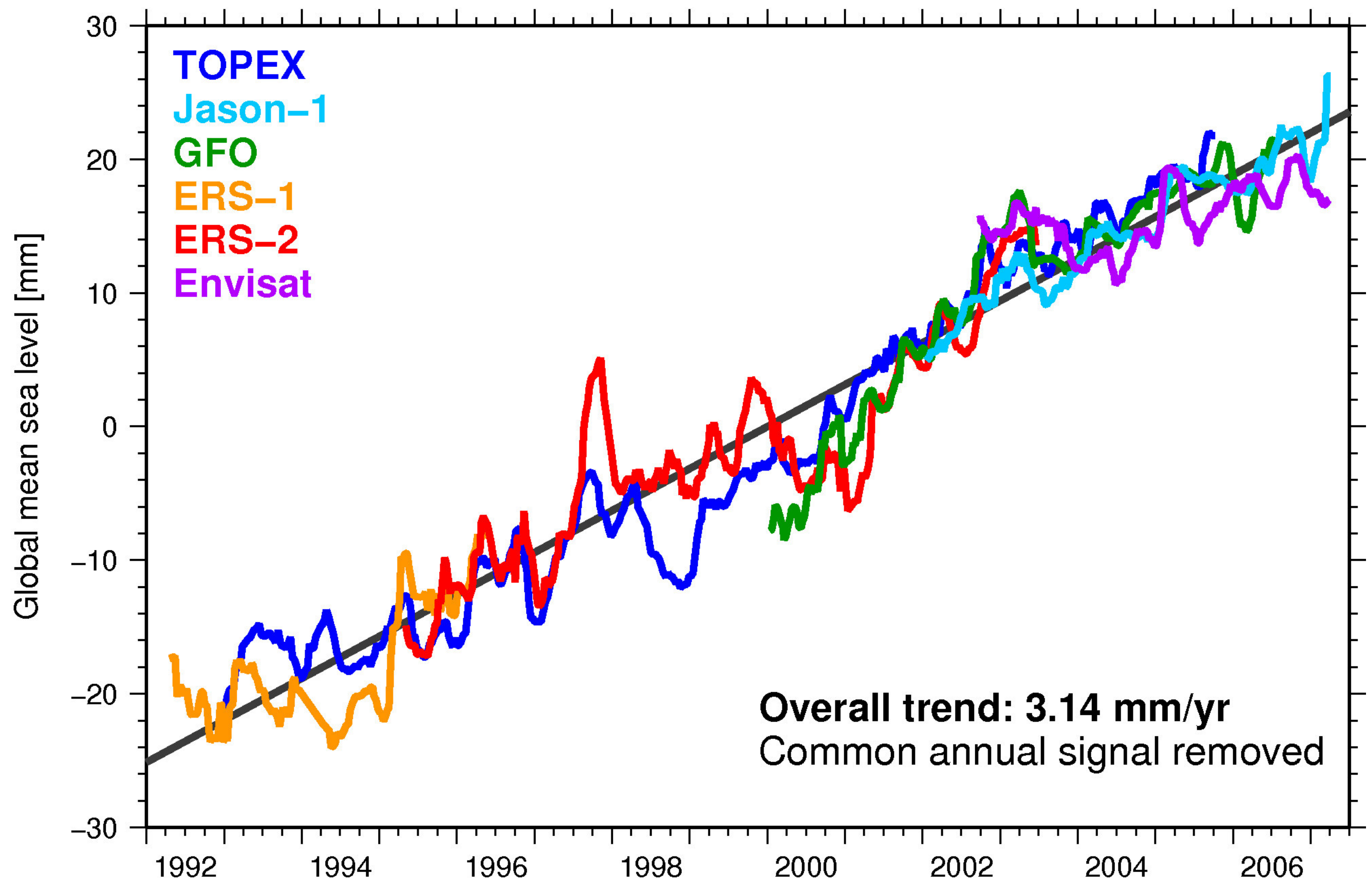
From NASA/CNES TOPEX/Poseidon & Jason missions from 1993 to 2008

Jason-class satellite altimetry is required to resolve the spatial variability of sea level rise in determining accurate global means

While tide gauges [▲] are poorly distributed, they are critical for calibration

Courtesy of Laury Miller, NESDIS

Since 1992, the mean rate from satellite altimetry has been ~3.1 mm/yr

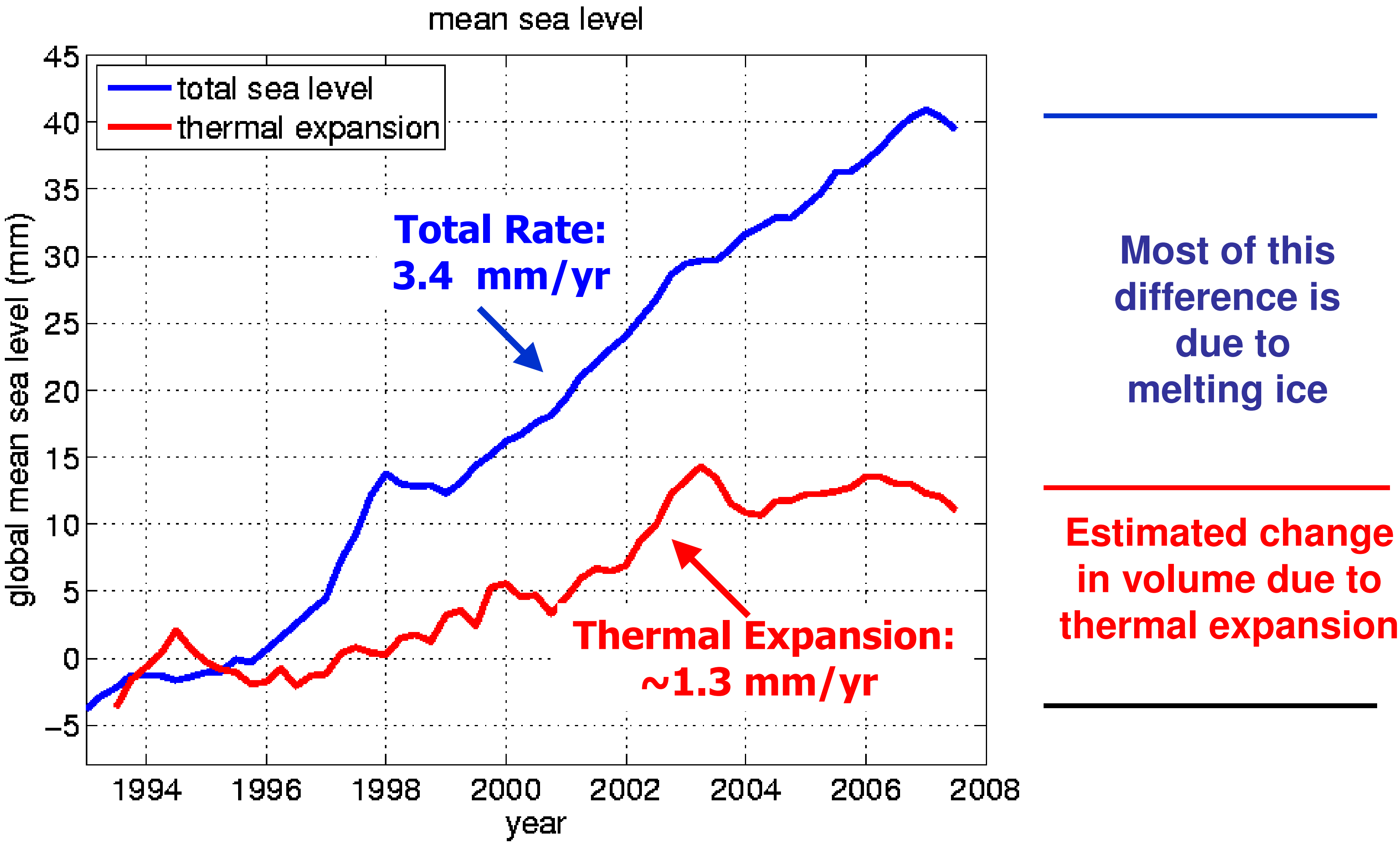


While data from all satellite altimeters were used, the high-accuracy T/P & Jason missions were critical to *calibrate* the others.

Courtesy of Remko Scharroo, NOAA/NESDIS

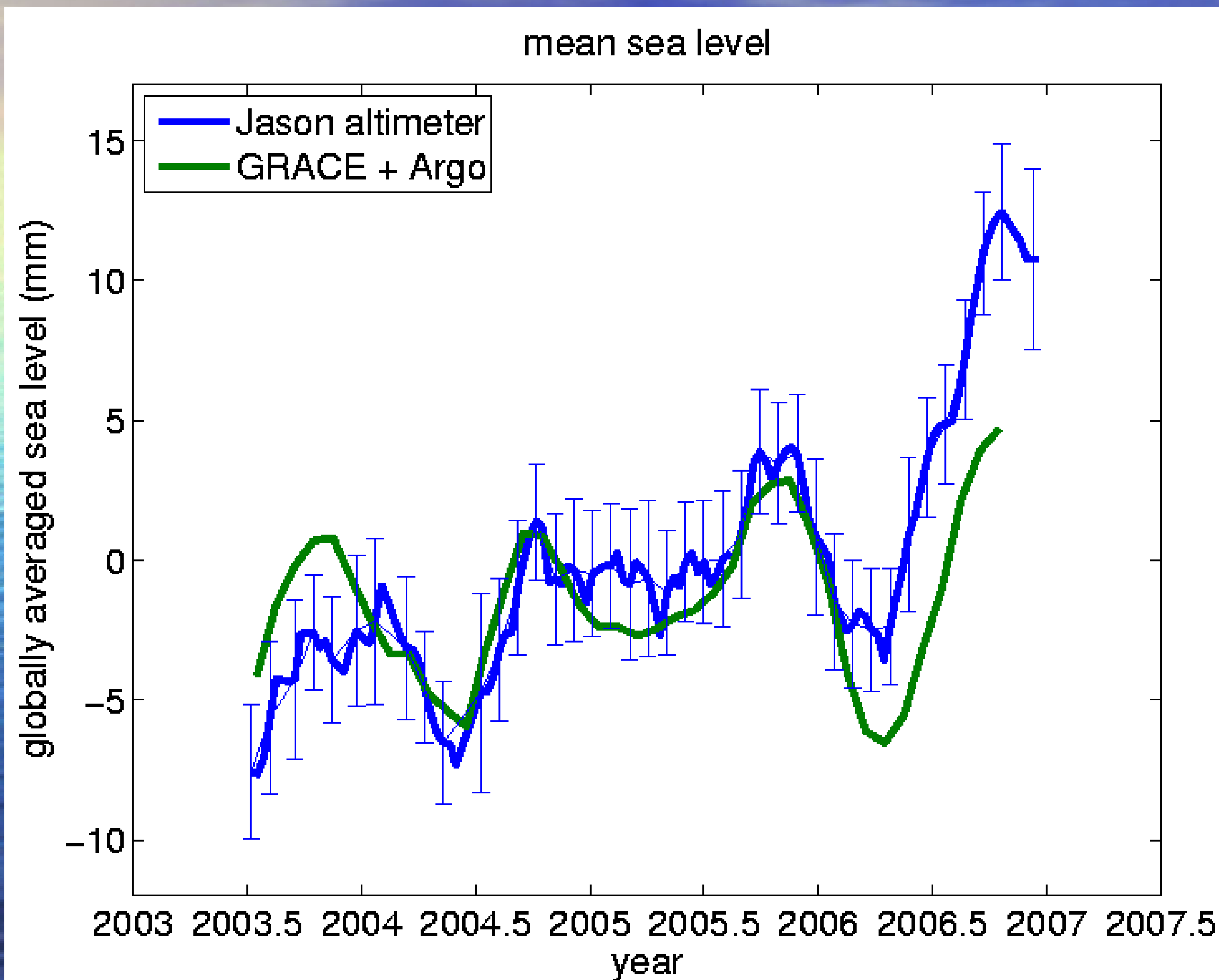
How well do we understand sea level rise?

Observed Mean Sea Level Rise and that portion due to Changes in Volume



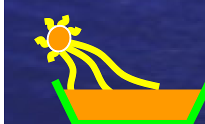
Courtesy of Josh Willis, JPL

Beginning to put it all together



Total sea level rise from Jason over the past 3 years should equal:

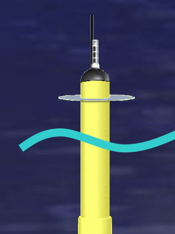
addition of heat



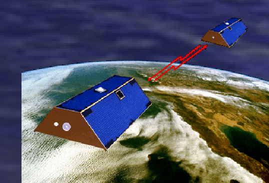
+

addition of freshwater

Argo



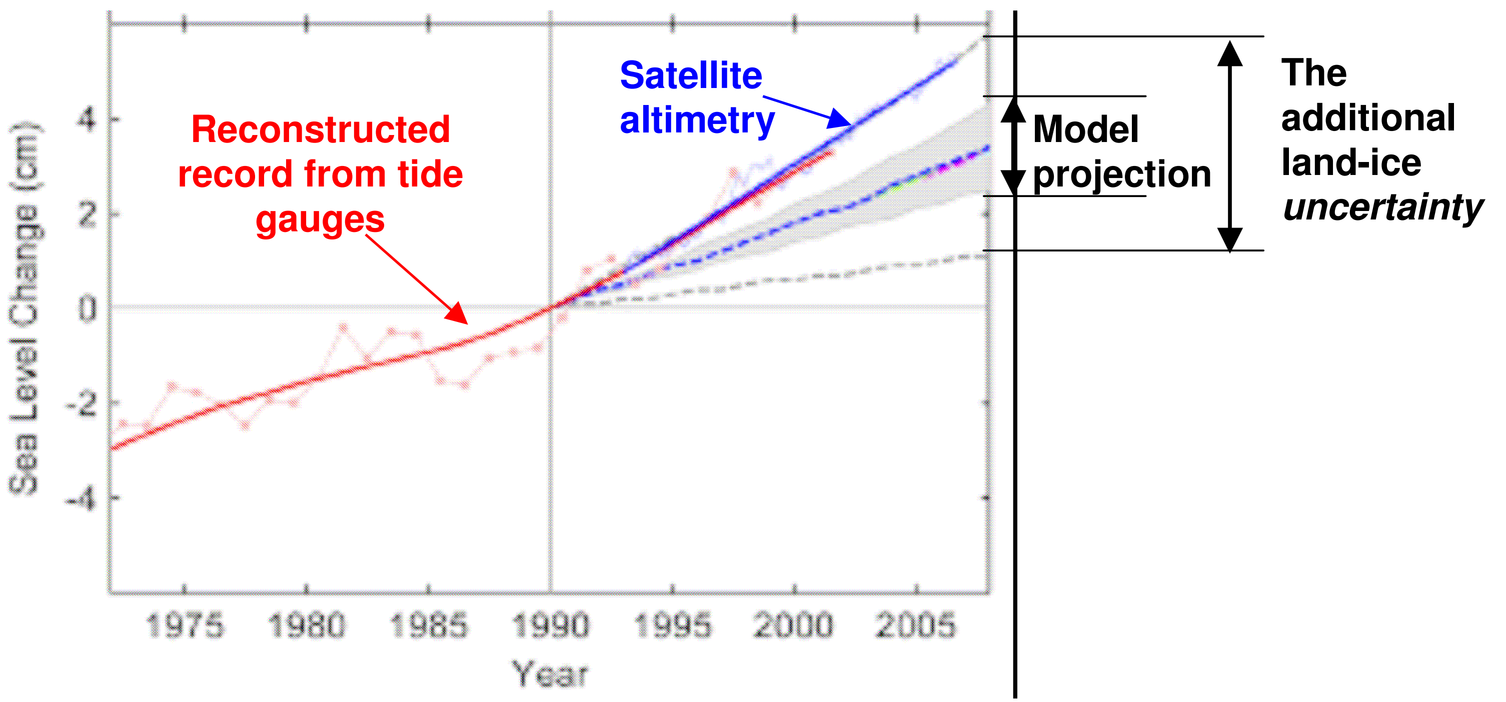
GRACE



From *Willis et al.*, in prep.

How good are the current projections of sea level rise?

Intergovernmental Panel on Climate Change projects sea level to rise ~30-80 cm by 2100*



But the observed sea level is rising at the upper limit of the earlier IPCC projection!

** 4th Assessment Report*

Rahmstorf et al., Science, 2007

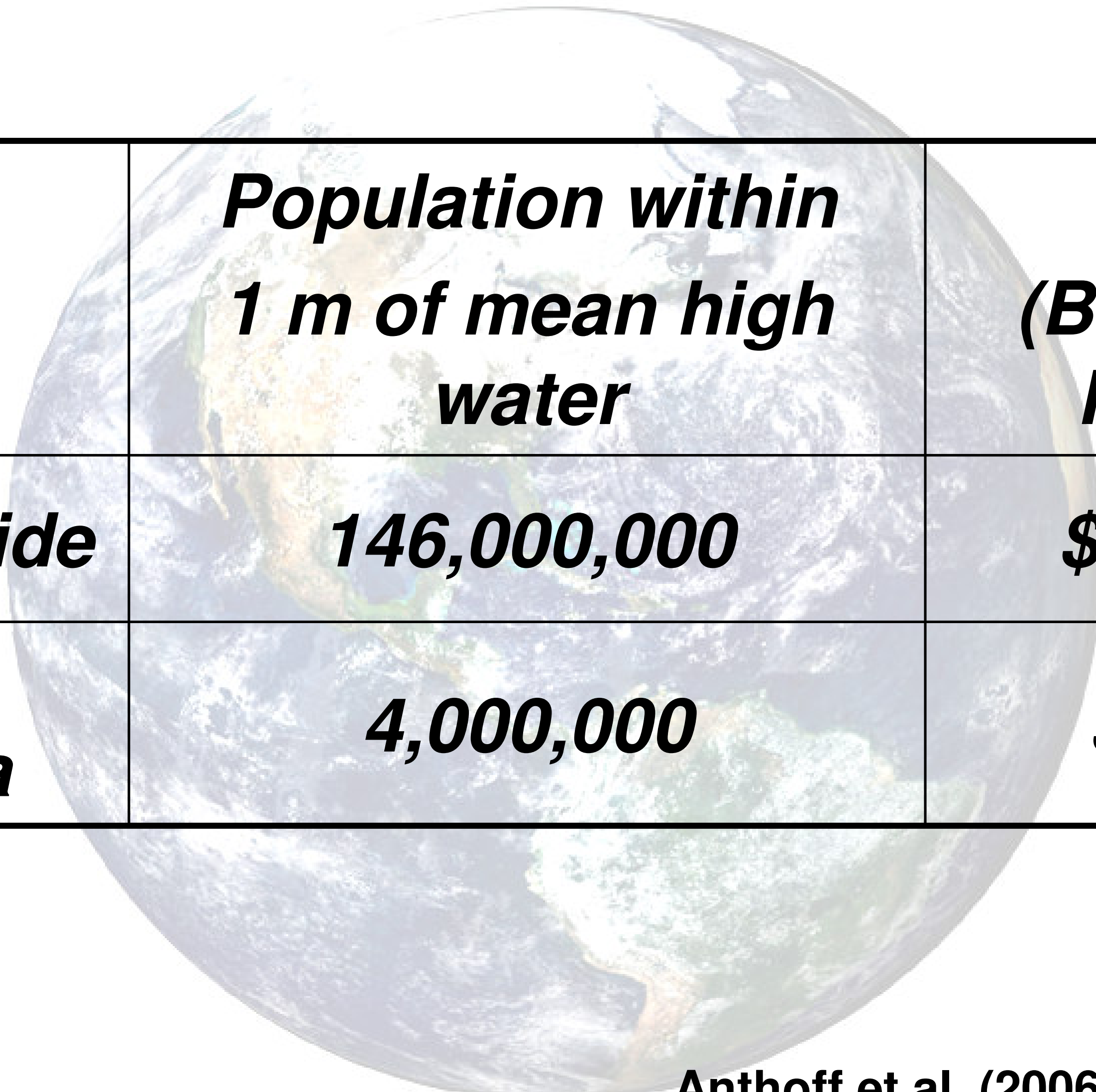
Uncertainties in IPCC Projections*

- Reading the fine print in the Synthesis Report that concerns the land-ice uncertainty:

  "…the upper values of the ranges given are not to be considered upper bounds for sea level rise"!

** 4th Assessment Report*

Why are accurate projections important?



	Population within 1 m of mean high water	GDP (Billions, MER)
Worldwide	***146,000,000***	***$1,119***
North America	***4,000,000***	***$140***

Anthoff et al. (2006)
Prepared for: *Stern Report on the Economics of Climate Change*

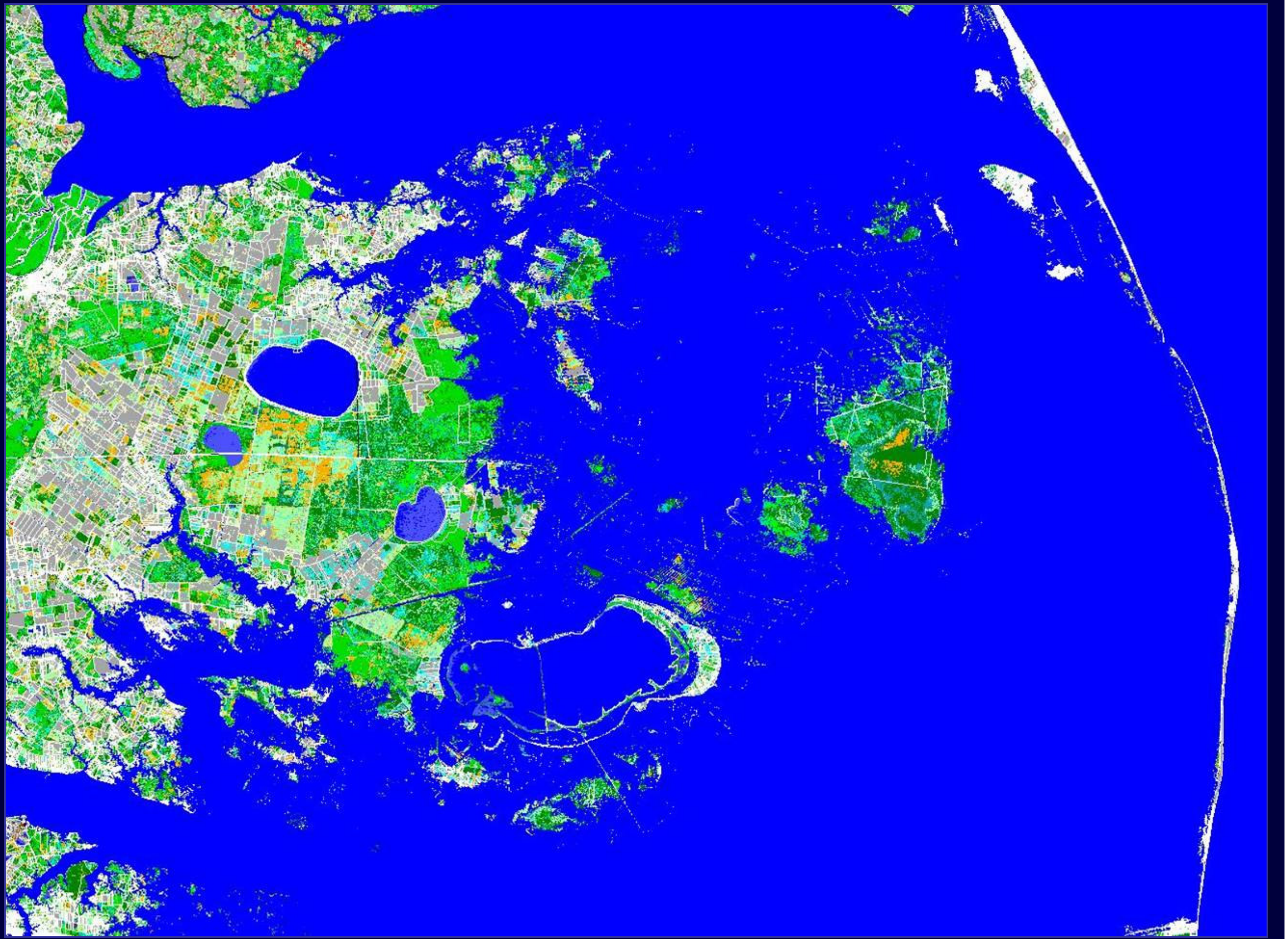
The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH

What will North Carolina's Albemarle Peninsula look like in 2100?

Global sea level is currently predicted to increase from 30 to 80 cm by 2100 (AR4)

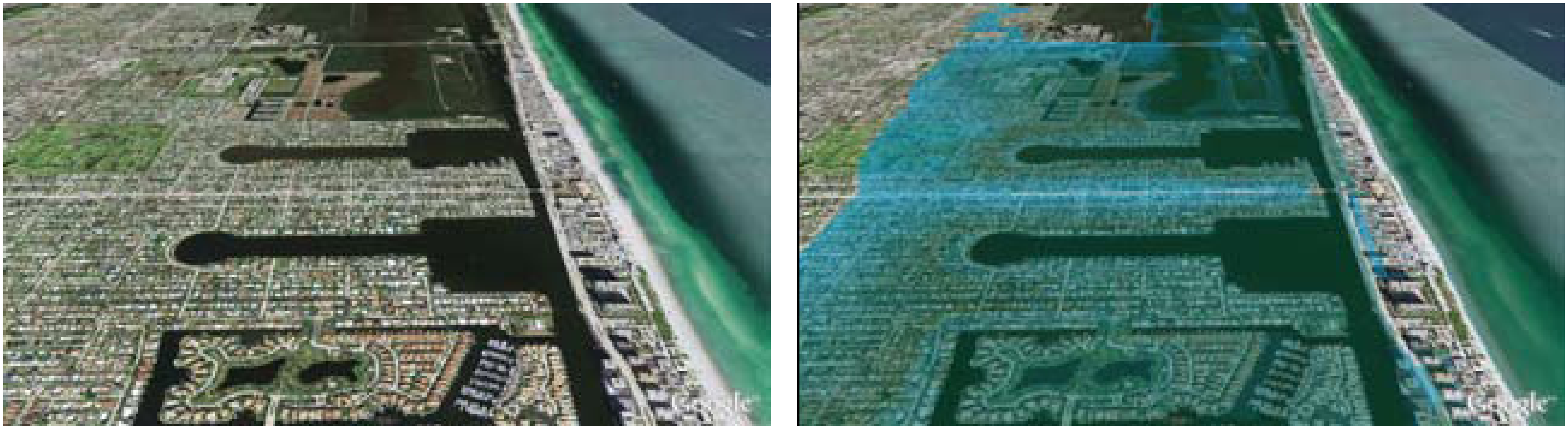
In this simulation, sea-level rise ranges from 10 to 80 cm

~15 miles

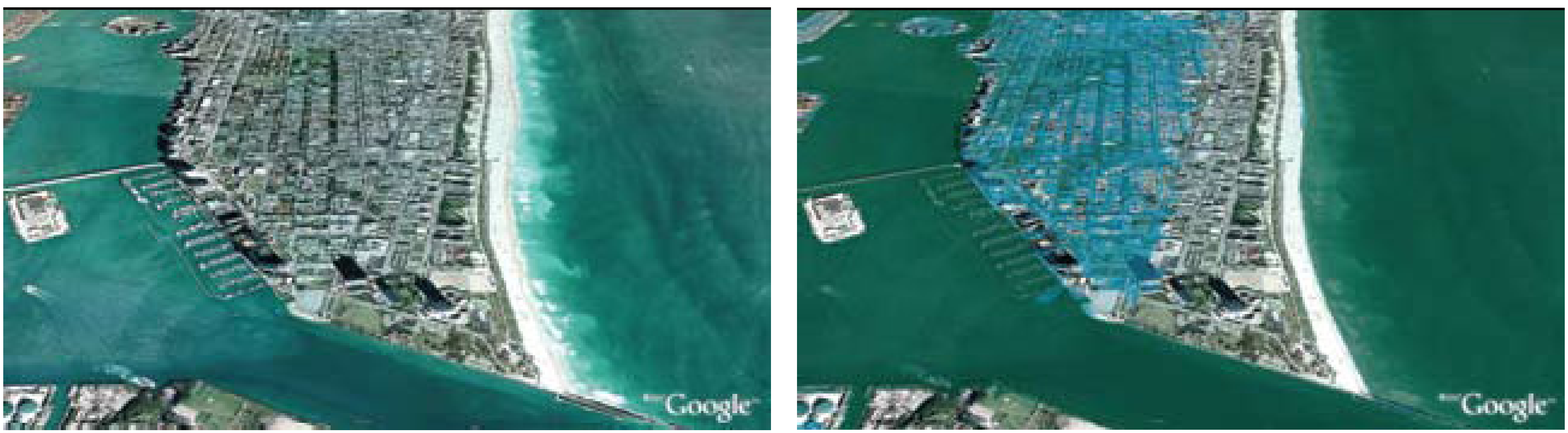


Impact of a 1 Meter Rise above Mean Higher-High Water

Guerin, Thorp & Thompson (2007) www.architecture2030.org



Hollywood, FL – Population Impacted 140,000

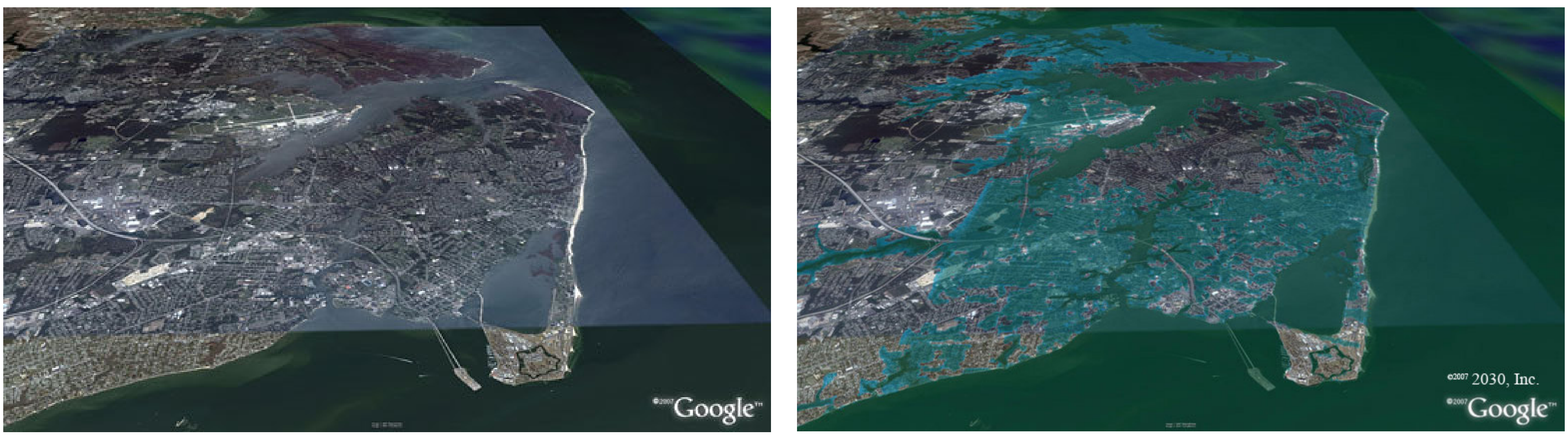


Miami Beach – Population Impacted 88,000

Impact of a 1 Meter Rise above Mean Higher-High Water

Guerin, Thorp & Thompson (2007) www.architecture2030.org

Point Pleasant, NJ – Population Impacted 19,000

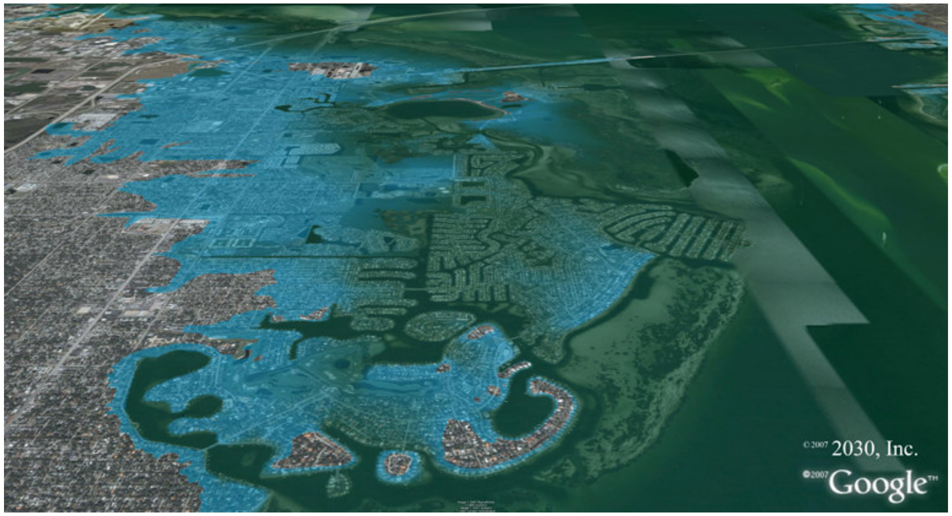


Hampton, VA – Population Impacted 146,000

Impact of a 1.25 Meter Rise above Mean Higher-High Water

Guerin, Thorp & Thompson (2007) www.architecture2030.org

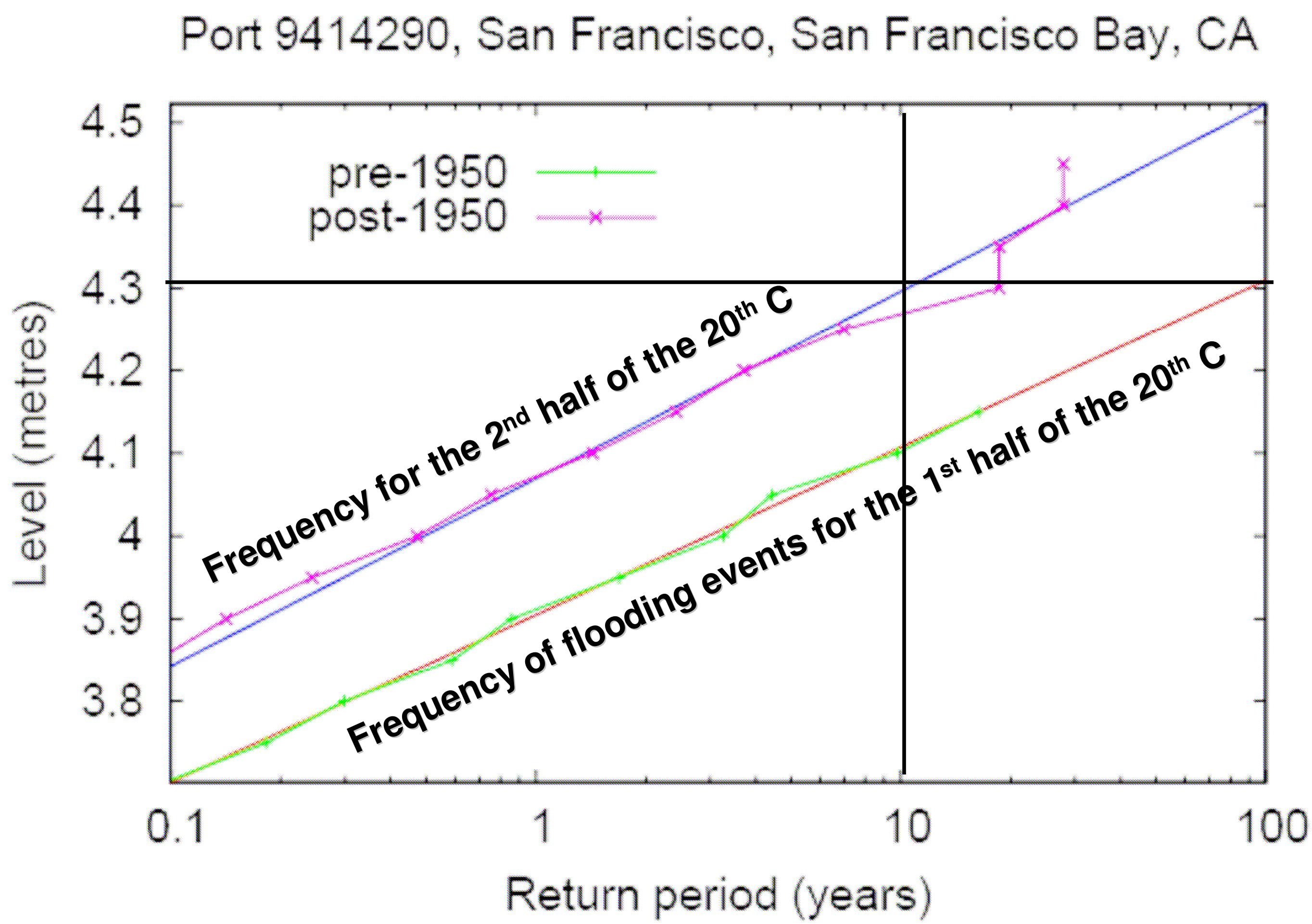
Foster City/San Mateo, CA – Population Impacted 23,000



St. Petersburg, FL – Population Impacted 248,000

How will sea level rise impact storm surges?

Changes in mean sea level result in changes in the frequency of flooding events



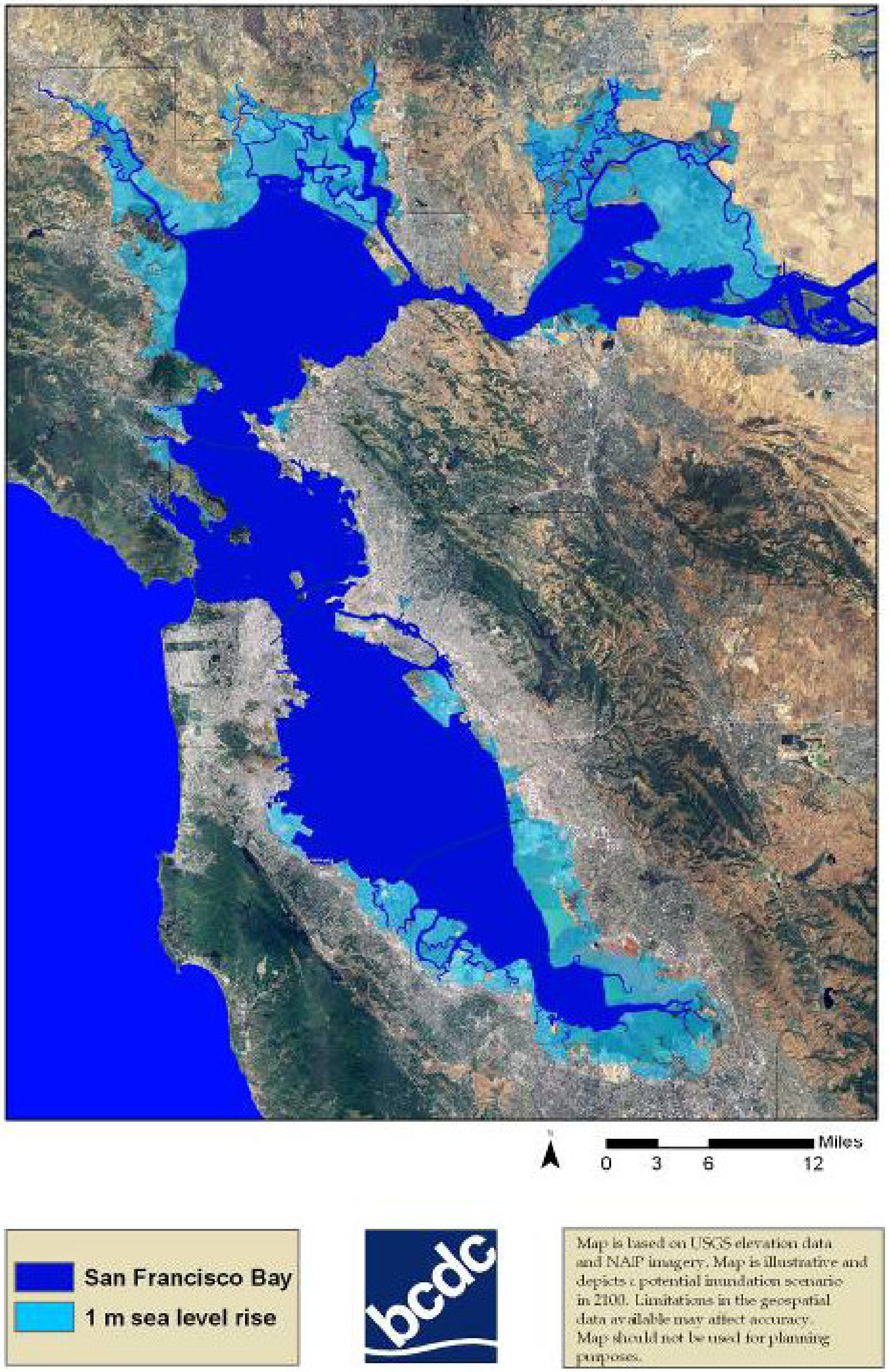
<u>For San Francisco, a 1-in-100 year flooding event has become a 1-in-10 year event!</u>

Courtesy of John Hunter, CSIRO Hobart

Flooding and storm damage in New Orleans

How is the public sector responding?

An example…



A water level rise in San Francisco Bay of nearly one meter by 2100 would inundate ~200 square miles of land and development worth ~$100 billion.

San Francisco
Bay Conservation and
Development Commission
http://www.bcdc.ca.gov

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Oakland, CA 94607-4756
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tedd@abag.ca.gov
www.abag.ca.gov/jointpolicy

- **Goal of the Bay Area Climate Protection Program:**
  - ***To be a model for California, the nation and the world***

- **Develop a vision for San Francisco Bay to accommodate projected sea level rise and protect the most significant resources from flooding while continuing to enhance the productivity of the estuary**
  - **Determine economic value of all resources…to be impacted**
  - **Estimate the cost of protecting these resources**
  - **Decide whether to remove/relocate or protect them**

How is the private sector responding?

An example…

Coastal Communities and Climate Change: Maintaining Future Insurability

A Report by Lloyd's in partnership with Risk Management Solutions

- ***If no action is taken, losses from coastal flooding for high risk properties could double by 2030.***
  - ***While reducing greenhouse gas emissions is the only effective way to mitigate, adaptation is vital given the potential future rate of climate change.***
- ***With an effective adaptation strategy, future losses can be reduced to below current levels.***
  - ***Adaptation could reduce most losses resulting from climate change in the 2030s to less than that today.***
  - ***Losses for high-risk properties could be reduced by 70% through the use of flood defences and flood resilient & resistant measures.***

Coastal Communities and Climate Change: Maintaining Future Insurability

A Report by Lloyd's in partnership with Risk Management Solutions

- ***Adaptation strategies must be tailored to individual locations and circumstances***
  - ***There is no single solution to manage coastal flood risk for all future situations.***
  - ***Society will need to be flexible to take account of the uncertainties surrounding the consequences of climate change.***
- ***Currently, poor land use policy and increasing urbanisation are key drivers of rising flood risk***
  - ***Climate change adaptation measures must take account of planning policies that affect flood risk in coastal areas.***

In conclusion

- ***Satellite, in concert with in-situ, systems are essential to collect the observations needed to understand climate change.***
- ***This understanding is required to be able to model and predict its future evolution.***
- ***Society needs this capability to assess mitigation and plan effective adaptation measures.***