



Oluwakemi Izomo

Mitigation and Adaptation Studies



Mitigation and Adaptation Studies



Class 5: Diagnosis, Prognosis and Therapy

Conclusions:

- During the Holocene, climate and sea level were exceptionally stable.
- global disasters caused by geohazards, asteroids, solar storms, etc. were very limited and not at the upper end of the scale.
- The Holocene was a “safe operating space for humanity.”
- Civilization could develop despite many anthropogenic conflicts and disasters.
- During the last hundred years, we have introduced rapid and large changes
- The system is already now outside the “normal range” and in the dynamic transition into the Post-Holocene; we have increasing disequilibrium
- There is a significant degradation of the Earth’s life-support system
- Paradigm shifts may be required; for example, instead of “Growth is necessary” assume “Growth is an addiction we need to overcome.”

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Plan for the rest of class:

- Hazards (Extinction, Climate and Coastal, Public Health and Food-Water-Energy Nexus, Ecosystem Services)
- Vulnerabilities (Environment, Built Environment, Economy, Inequality, Injustice)
- Foresight (understanding uncertainty, Decision blocks)
- Decision making (human nature, facing threats)
- Developing options (avoiding adaptation, changing paradigms, mitigating degradation; economy and governance)

Mitigation and Adaptation Studies



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Class 7: Climate and Coastal Hazards



Mitigation and Adaptation Studies



Class 7: Climate and Coastal Hazards

Contents:

- From Class 5: Therapy
- Climate Change and Sea Level Hazards
 - Detecting Changes
 - Assessing Knowledge
 - Understanding the Processes and Causes
 - Predicting Future Changes
 - Having Foresight

The Therapy: Life Style Changes

What are the governments doing?



SUSTAINABLE DEVELOPMENT GOALS



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SDGs and the Agenda 2030 are intended as our "Road to Dignity," and we are on this road together.



SUSTAINABLE DEVELOPMENT GOALS

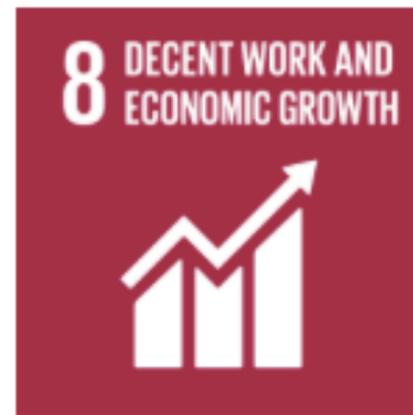
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Instead of being technology and science-driven, the Earth observation and science communities need to be problem-driven and part of the process.

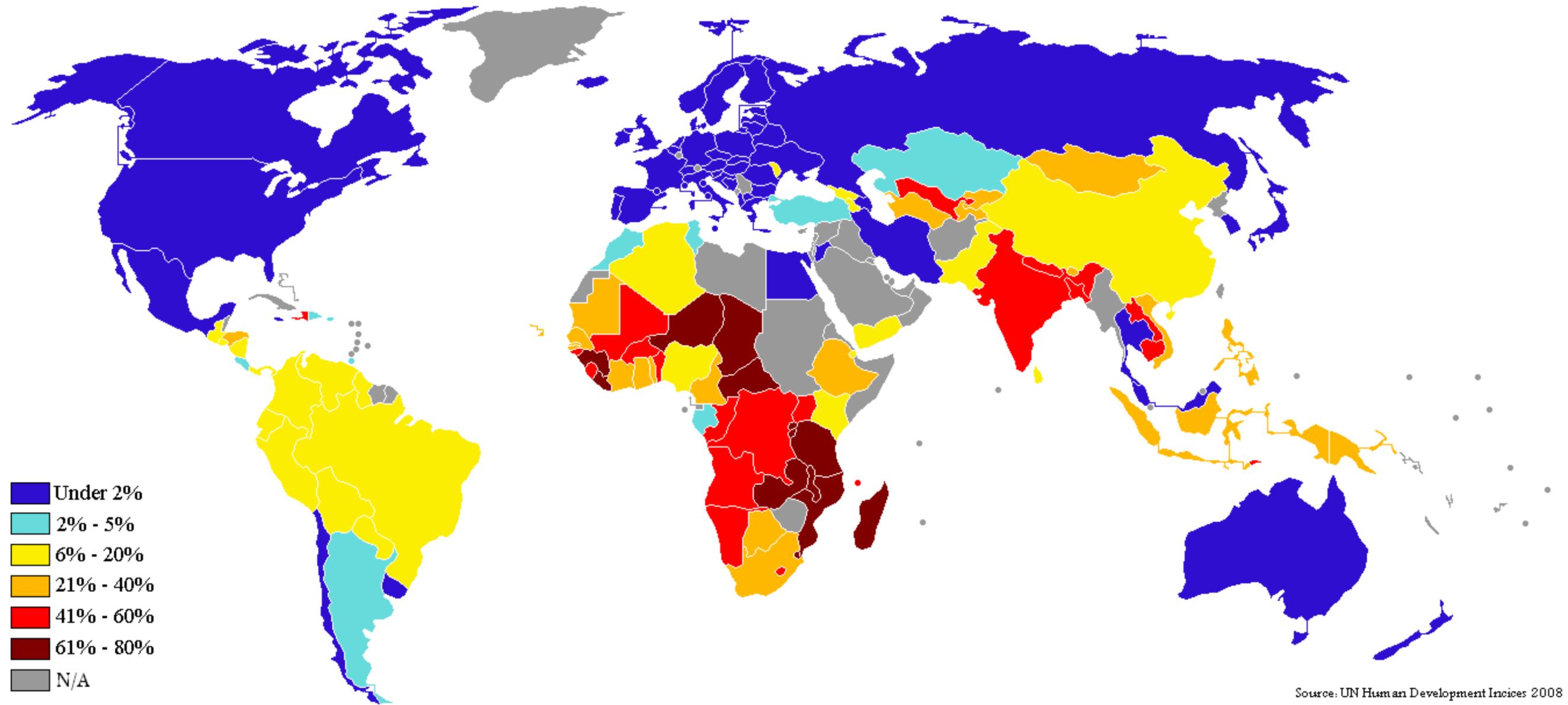


Agenda 2030: "The Road to Dignity"





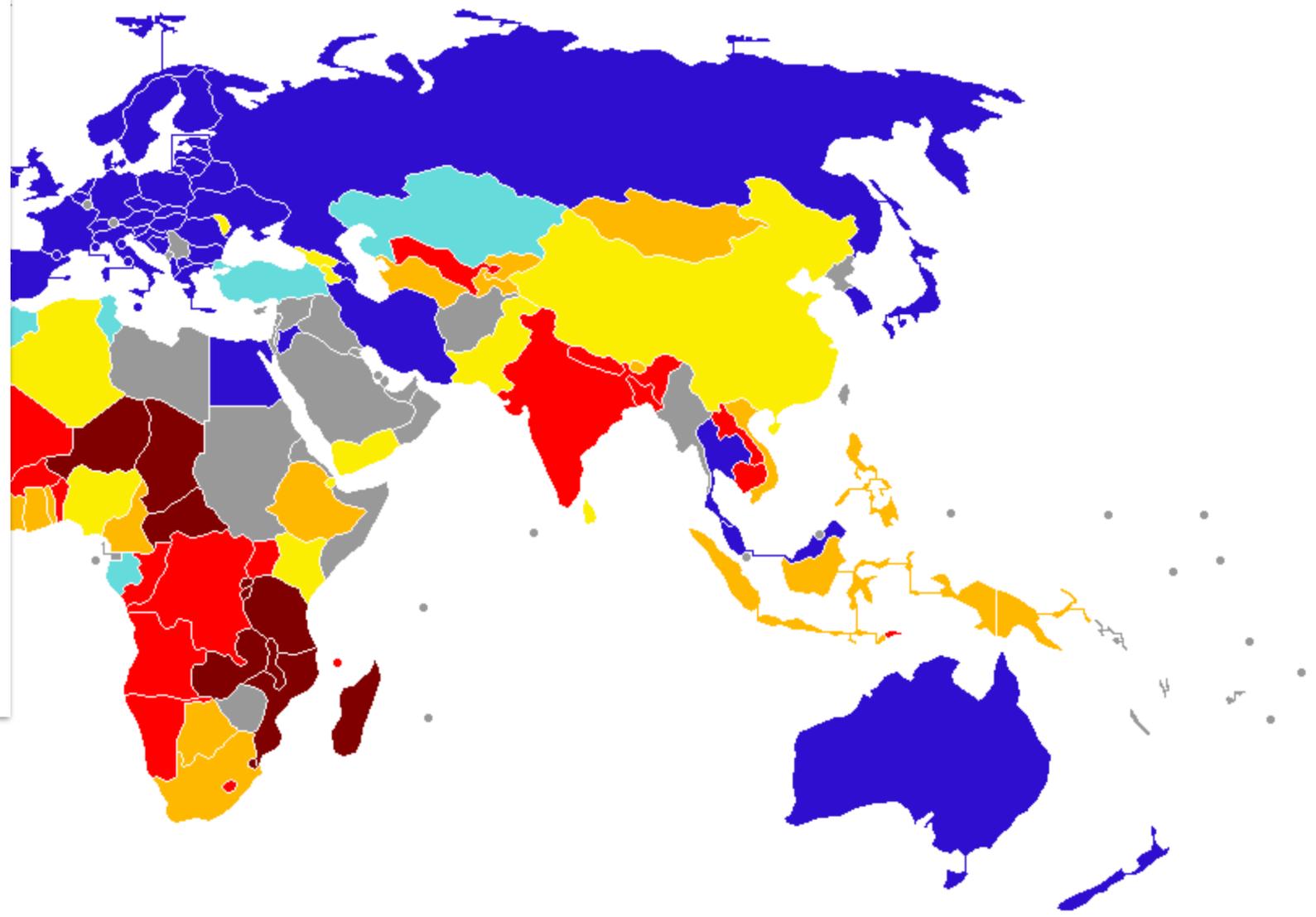
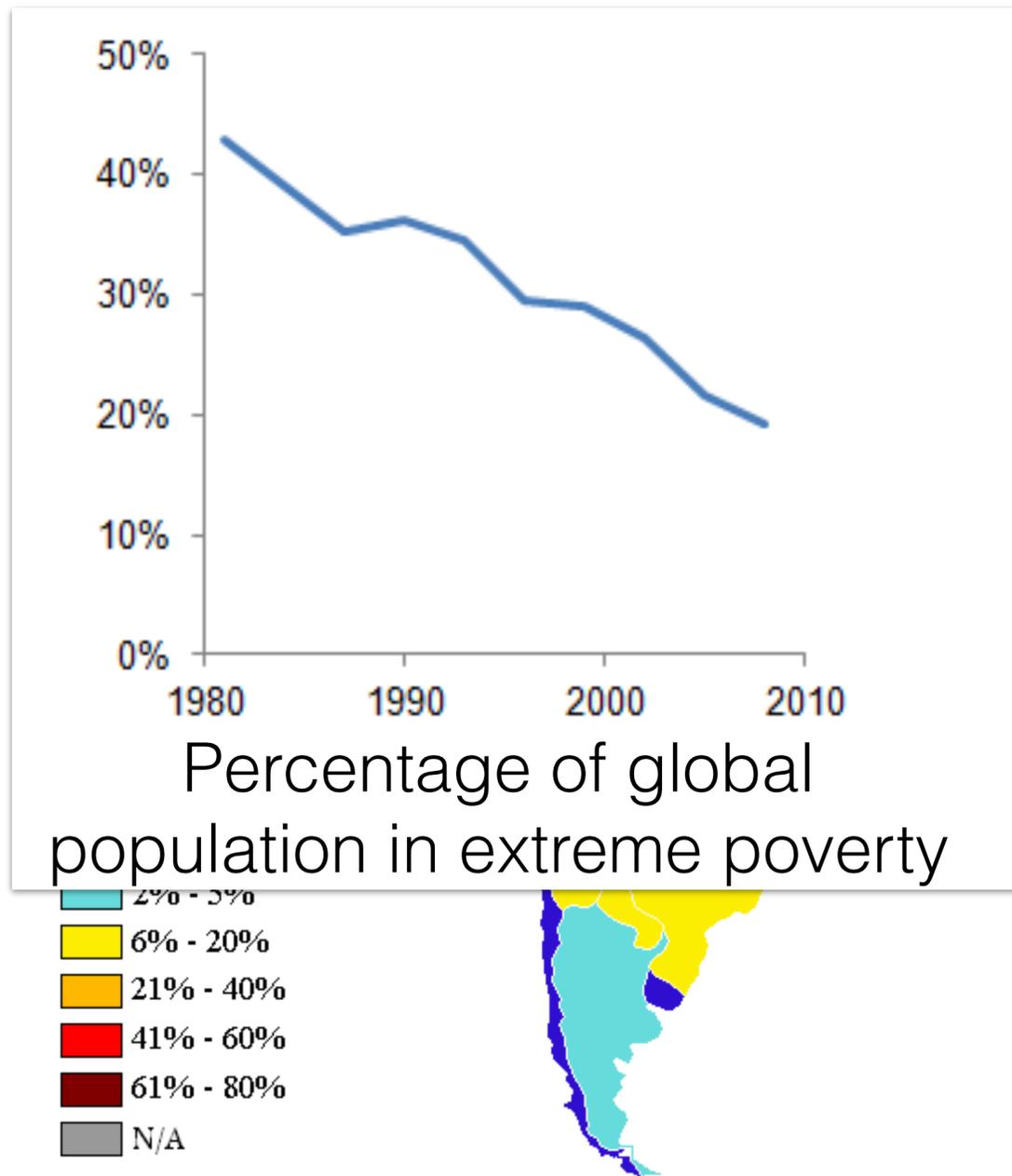
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Percentage of population living on less than \$1 a day (2008-2009), UN Human Development Index, 2008

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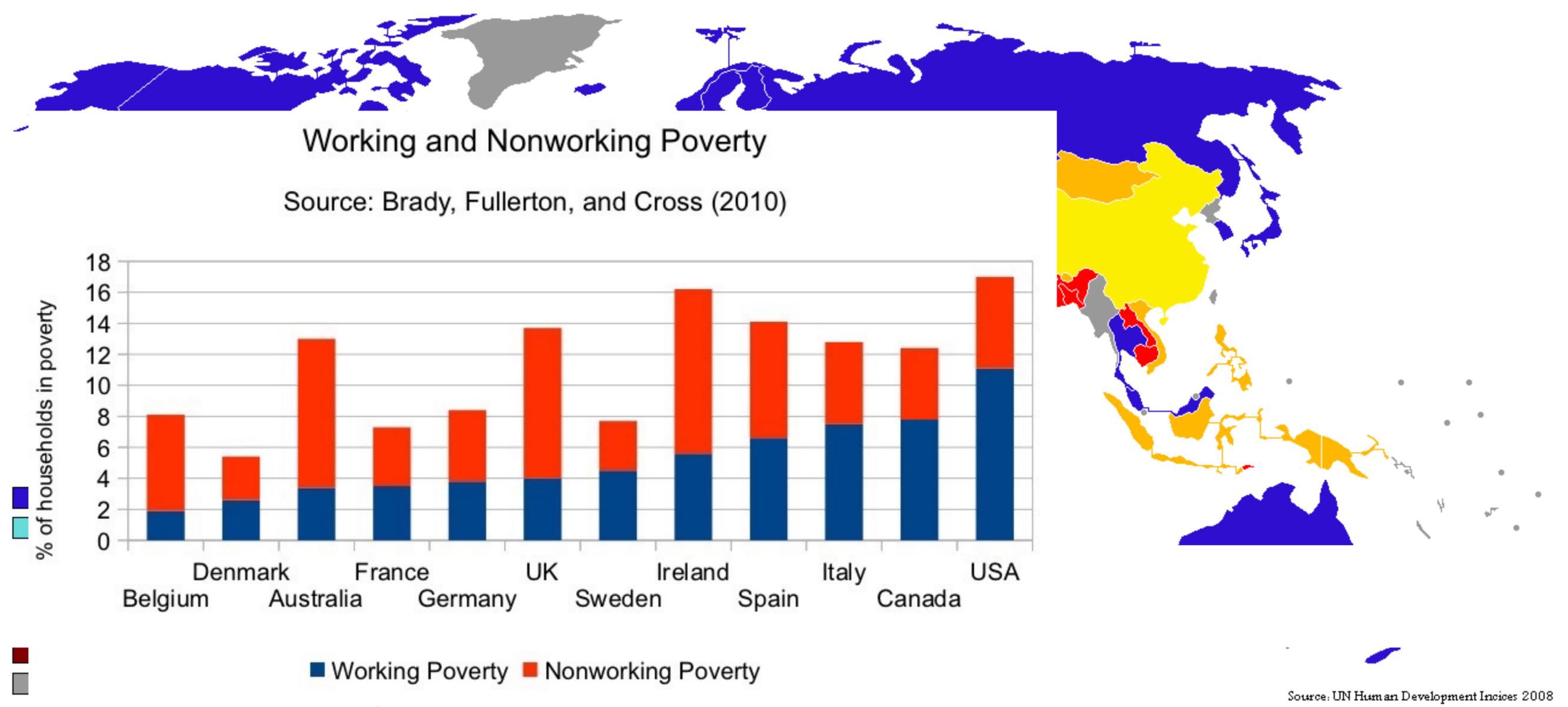


Source: UN Human Development Indices 2008

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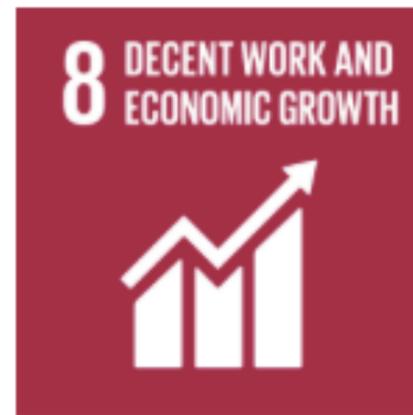
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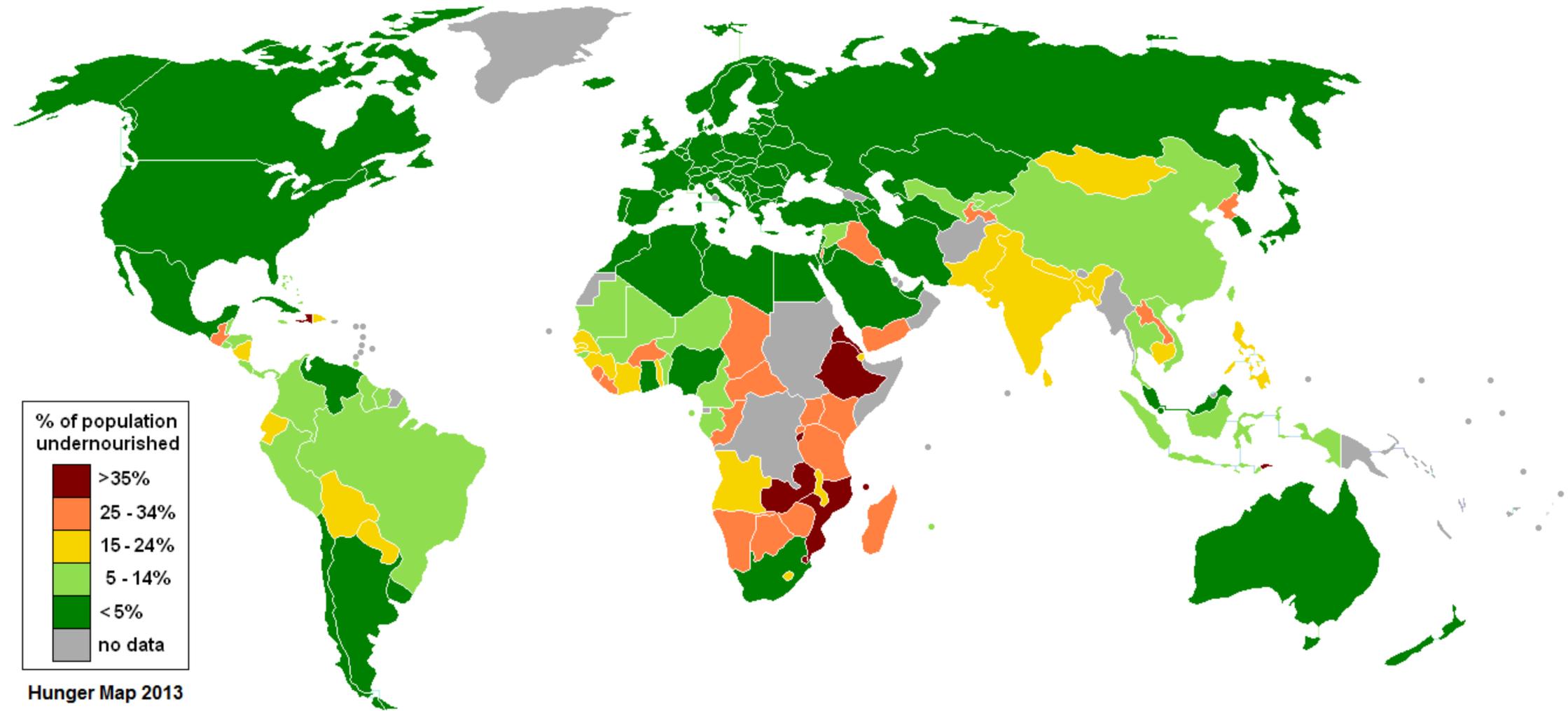
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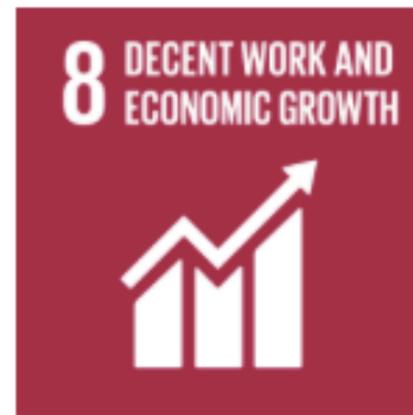




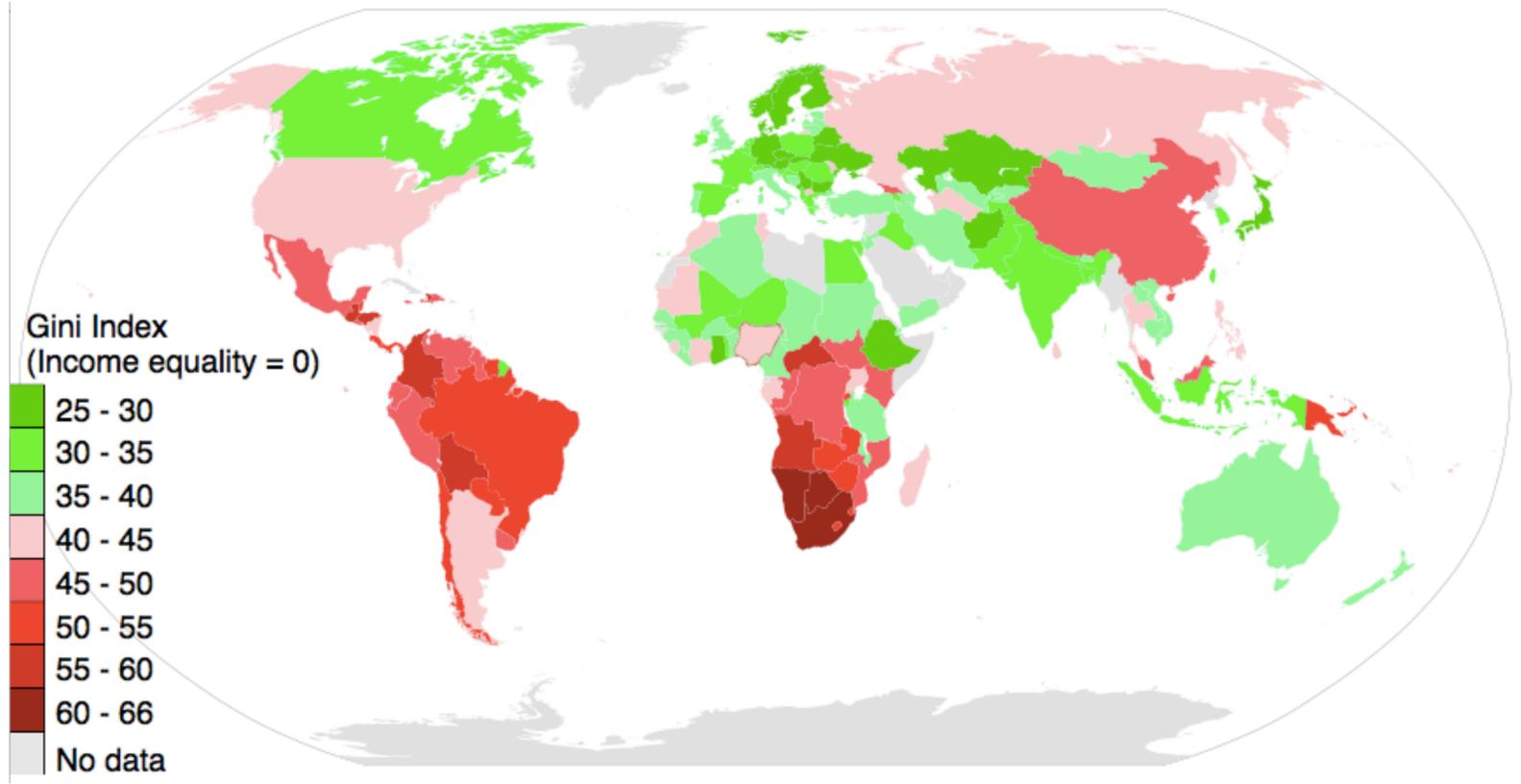
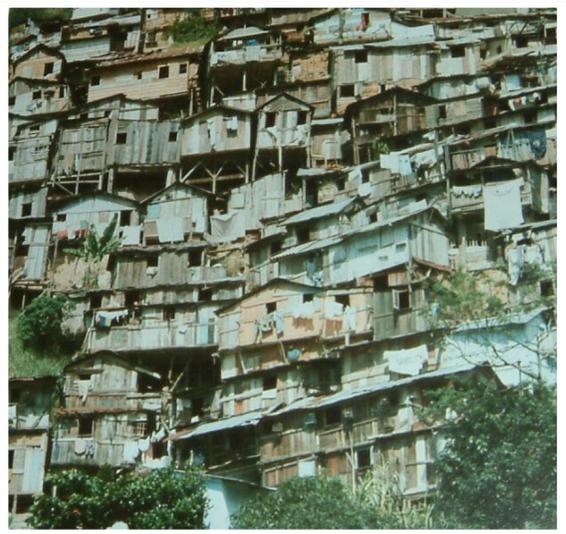
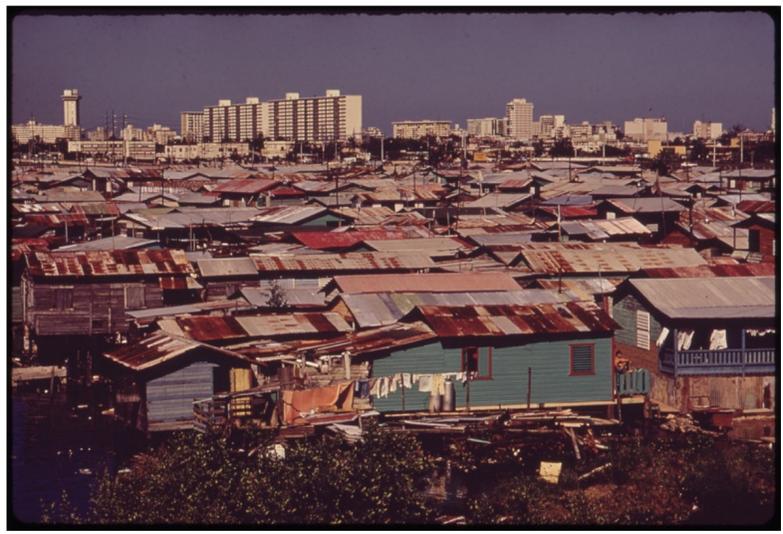
Percentage of population undernourished



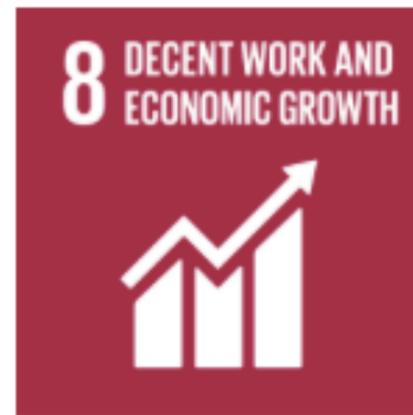
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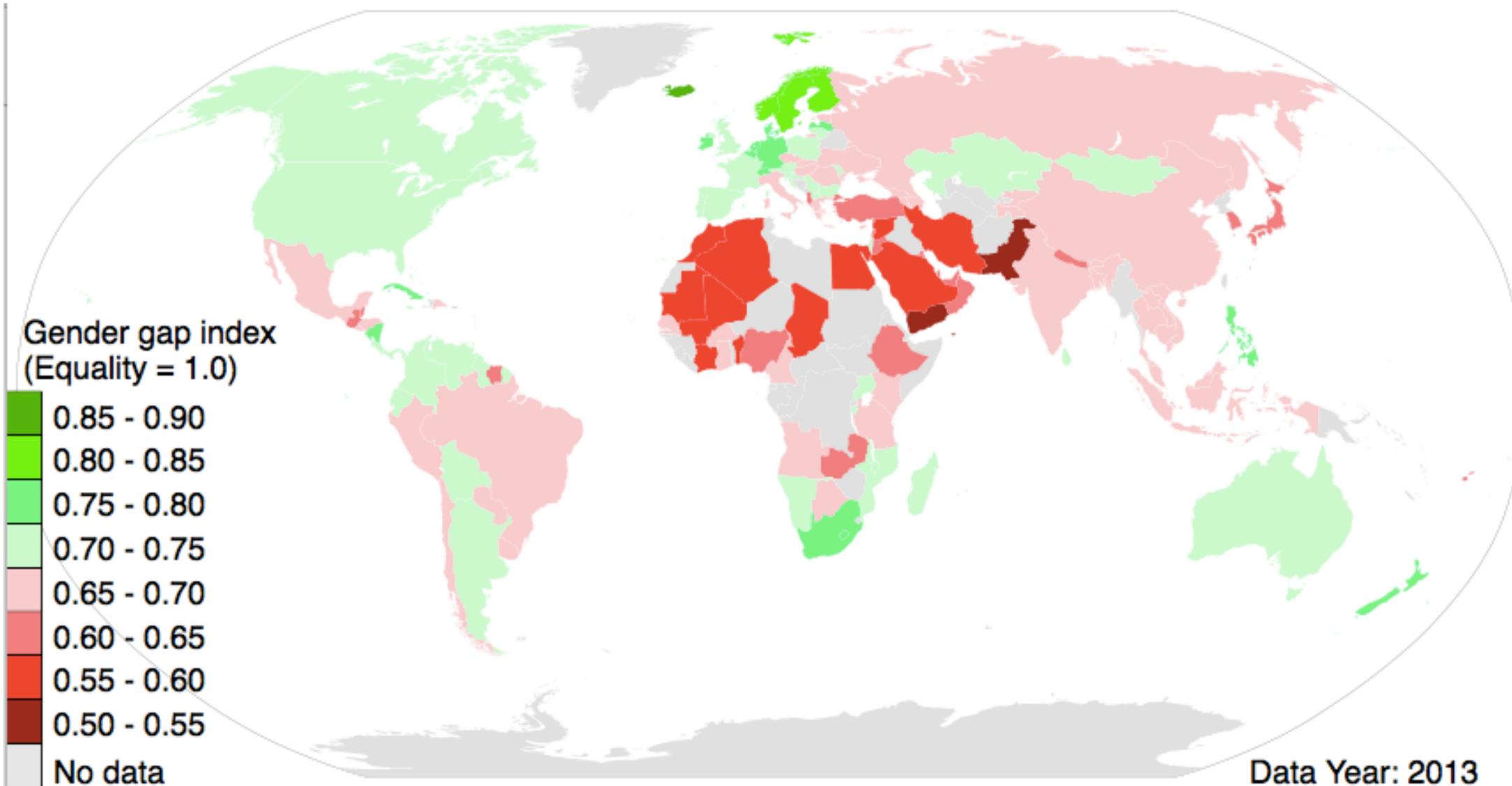


Agenda 2030: "The Road to Dignity"





Women carry out 70% of the global work hours but they only earn 10% of the global salary



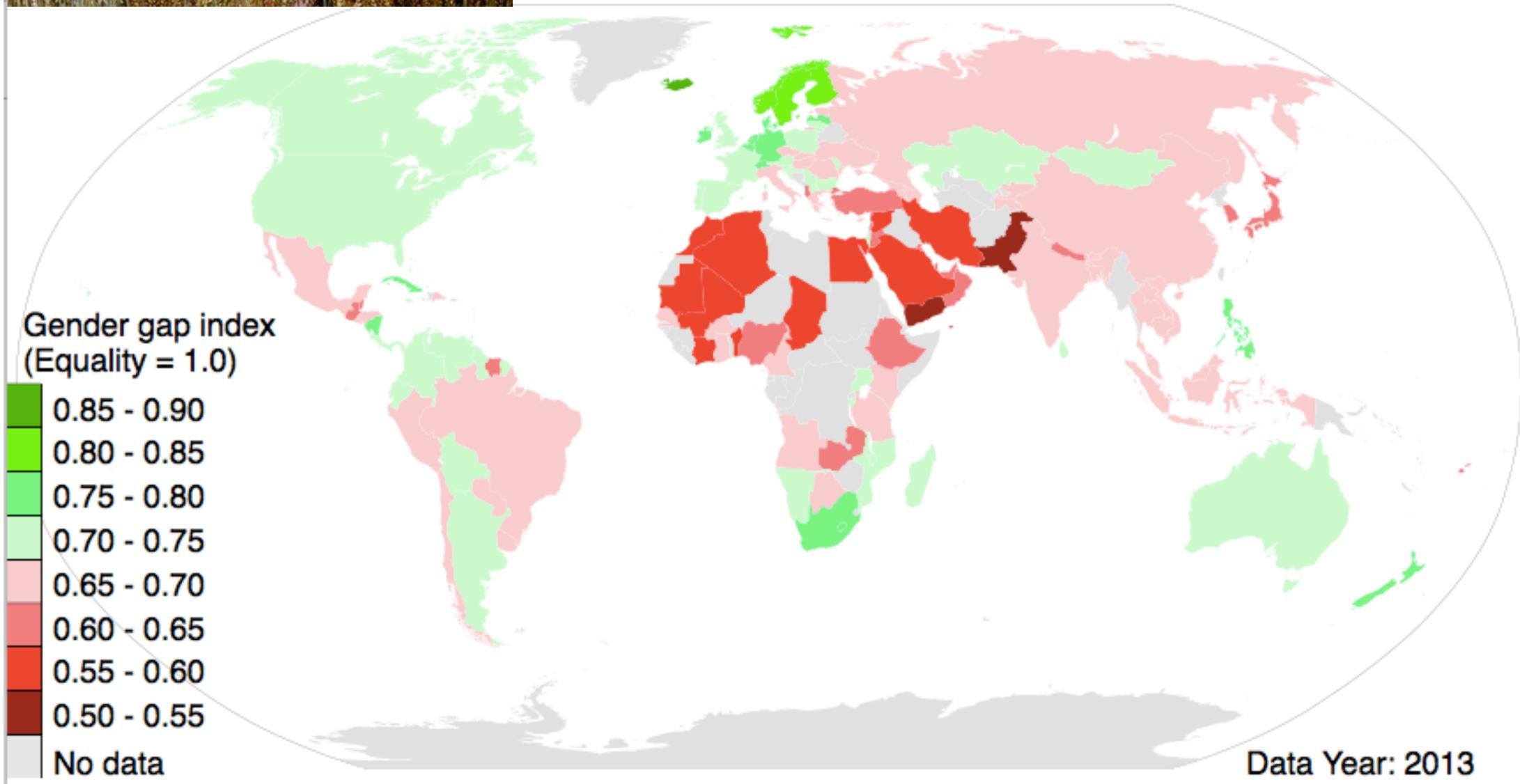
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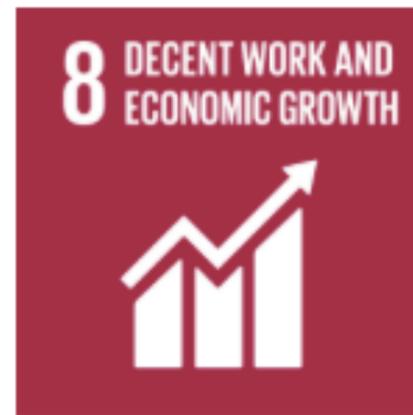
Women make major contributions to crop production. Women have the least access to the means for increasing yields and moving from subsistence crops to market-oriented production



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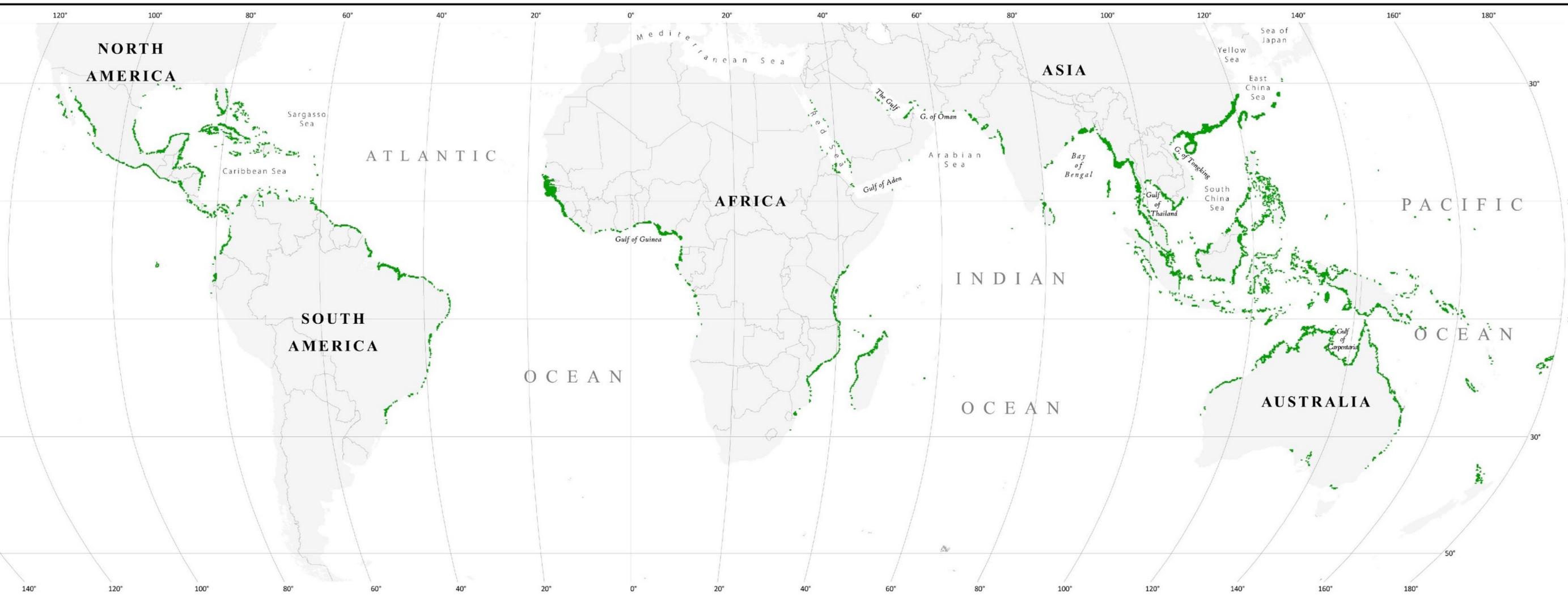
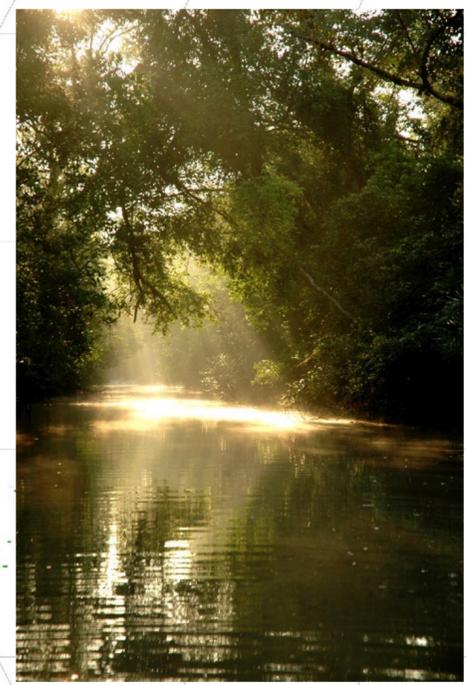


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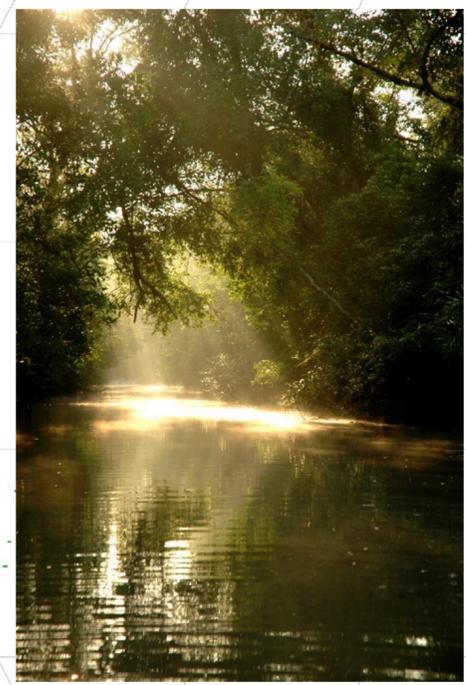
Agenda 2030: "The Road to Dignity"

Mangroves



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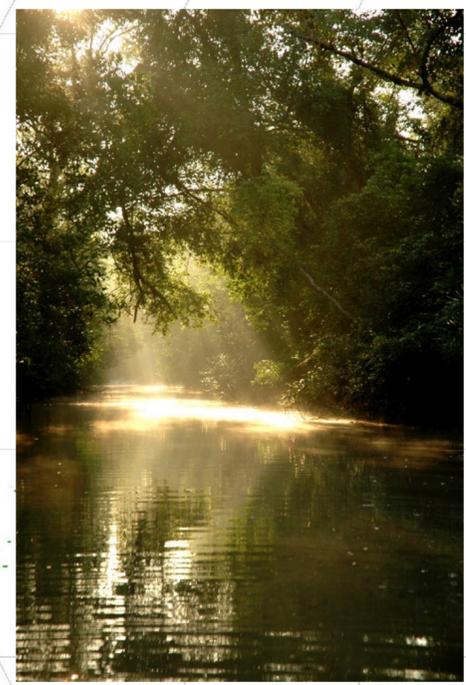
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- shrimp farming
- tourism
- urbanization
- agriculture expansion
- roadways
- marinas, and
- other intrusive developments.



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A Tragedy for our Oceans
Continuing heavy loss of mangrove forests represents a real tragedy for our oceans and the extensive life-support systems mangroves engender.



Agenda 2030: "The Road to Dignity"

Mangroves link many of the SDGs ...



The Therapy: Life Style Changes



Our task: enabling a transition to an economy **for** humanity:
“An economy that meets our needs while safeguarding Earth’s life-support system, on which the welfare of current and future generations depends.”



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Enabling prosperity, security:
- without growth
- with more equality



Hazards:

Climate Change and Sea Level Hazards

Hazards:

Changes in means:

- air temperature
- precipitation
- wind field/circulation
- evapotranspiration
- humidity
- soil moisture
- permafrost
- sea and lake levels
- inundation
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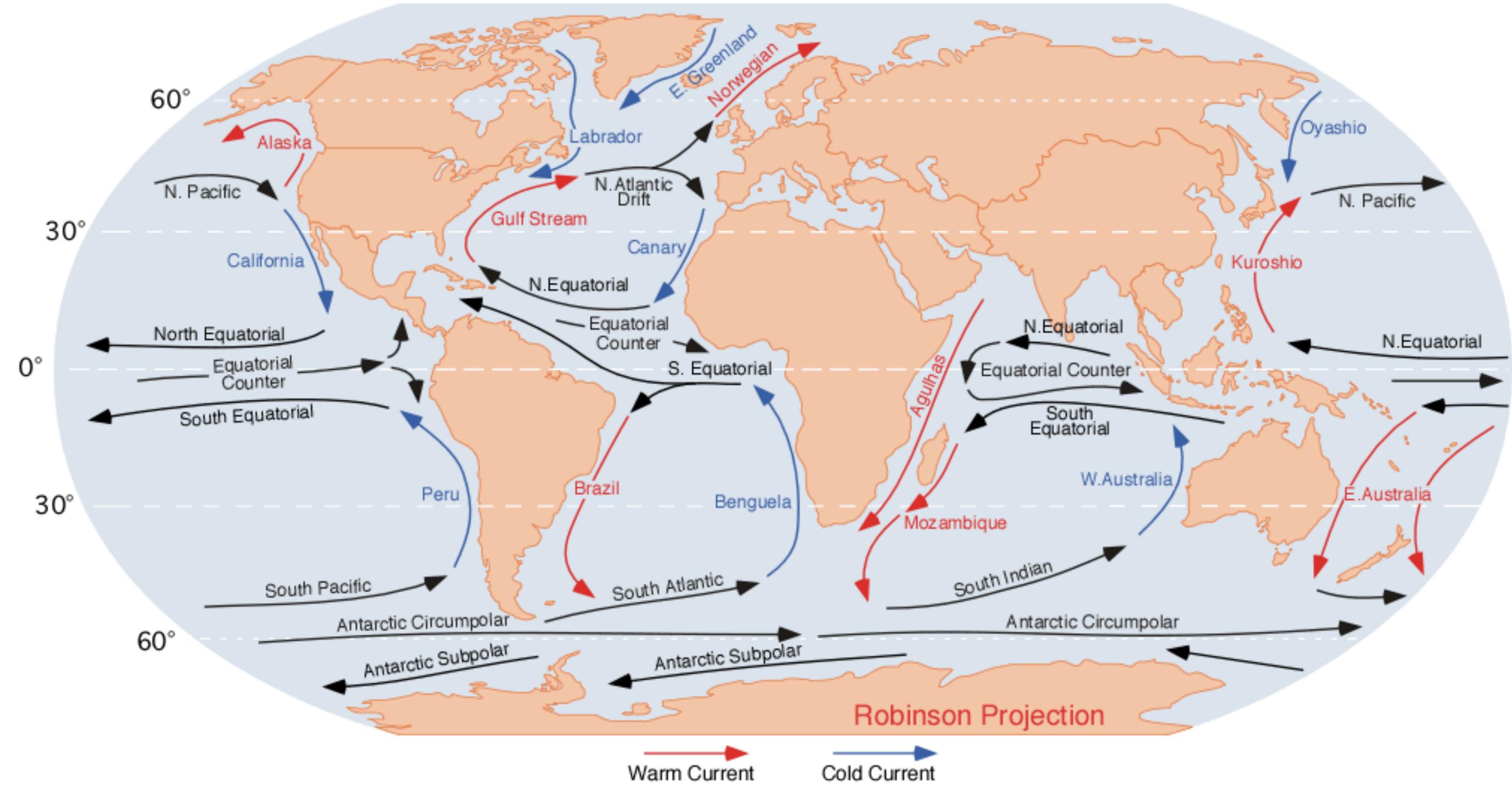
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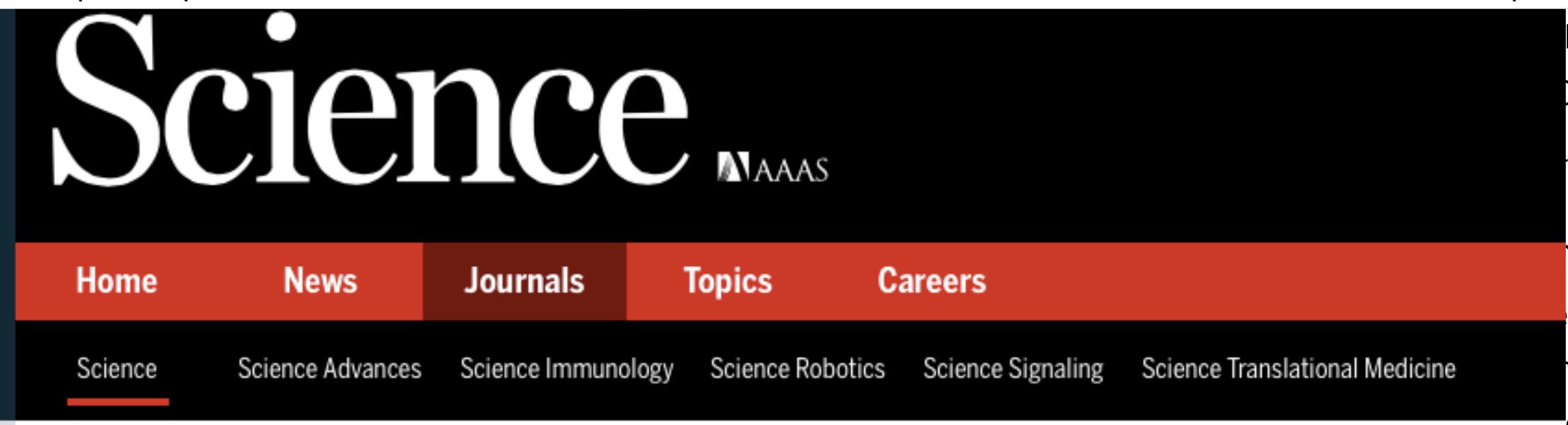
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temperature
acidification
and water chemistry

in biosphere:
from health and services

species

SHARE

REPORT

An unexpected disruption of the atmospheric quasi-biennial oscillation

Scott M. Osprey^{1,*}, Neal Butchart², Jeff R. Knight², Adam A. Scaife^{2,3}, Kevin Hamilton⁴, James A. Anstey⁵, Verena Schenzinger¹, Chunxi Zhang⁴

+ Author Affiliations
*Corresponding author. Email: scott.osprey@physics.ox.ac.uk

Science 08 Sep 2016:

DOI: 10.1126/science.aah4156

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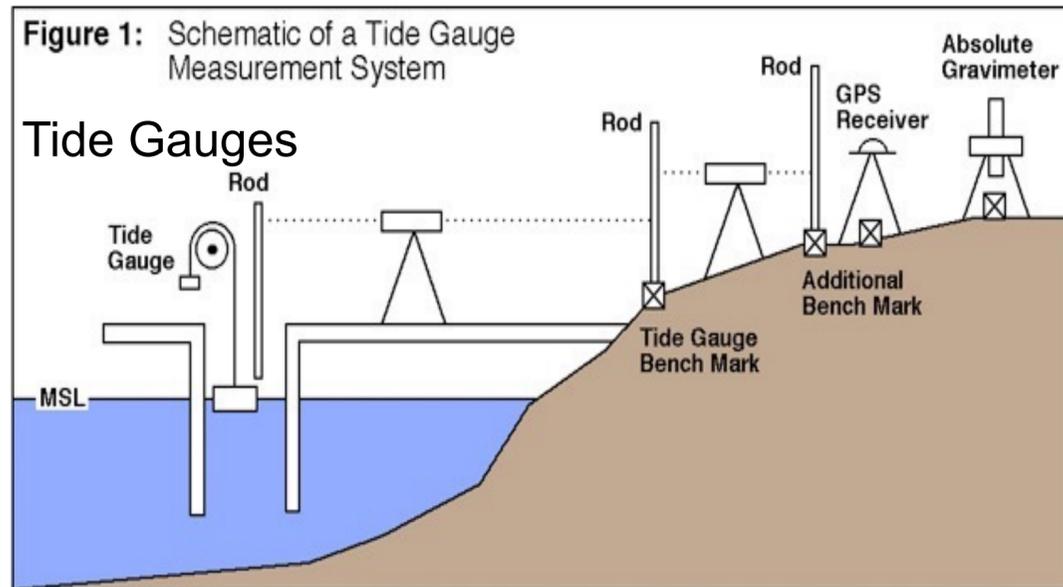
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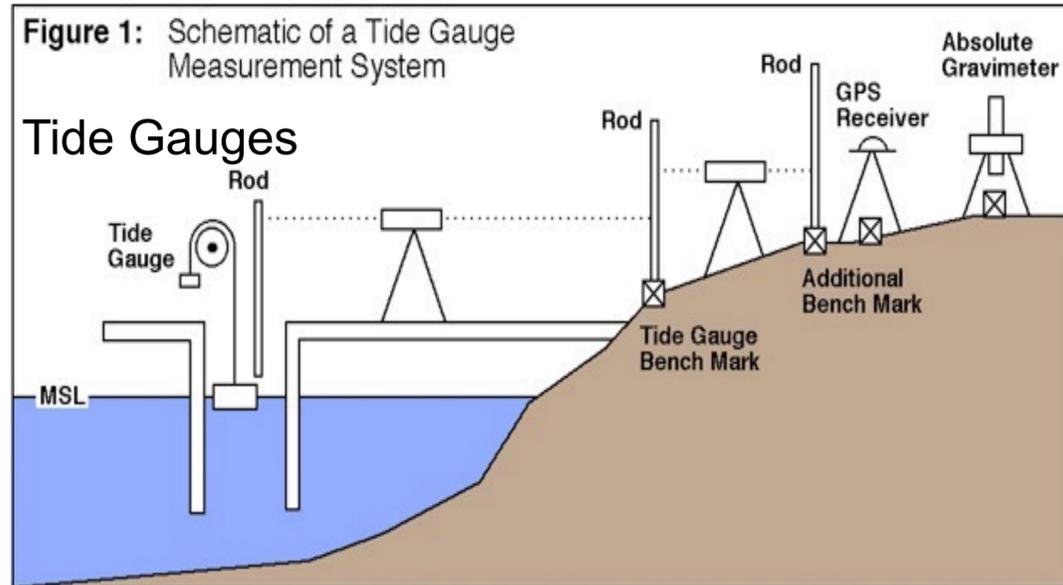
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Geodetic Monitoring of Sea Level



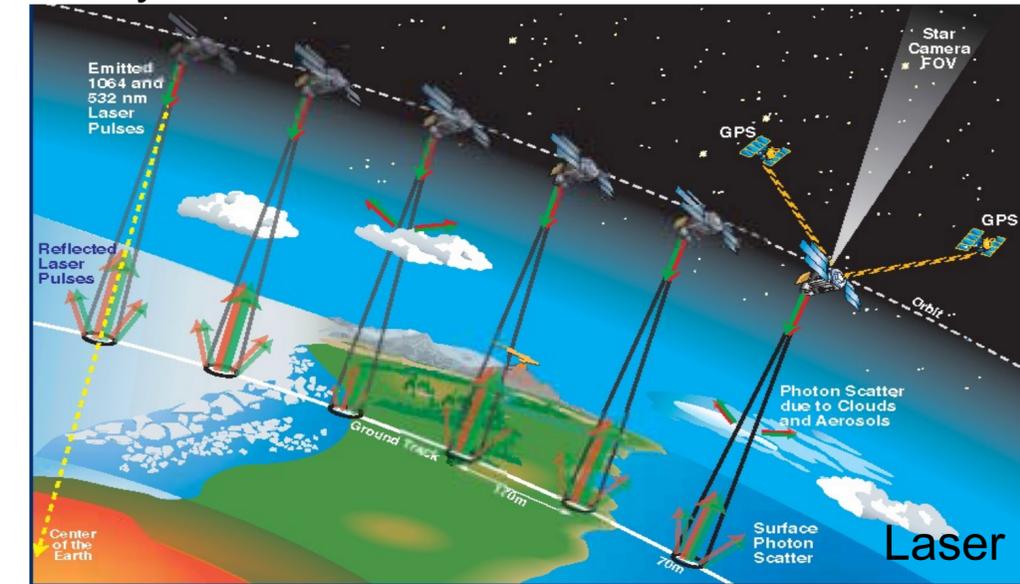
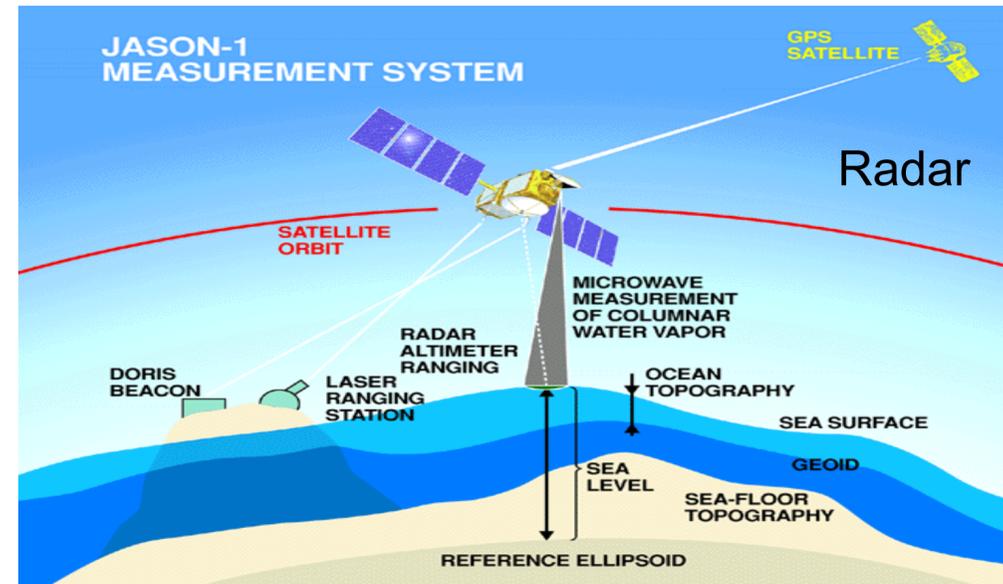
<http://sealevel.colorado.edu/tidegauges.html>

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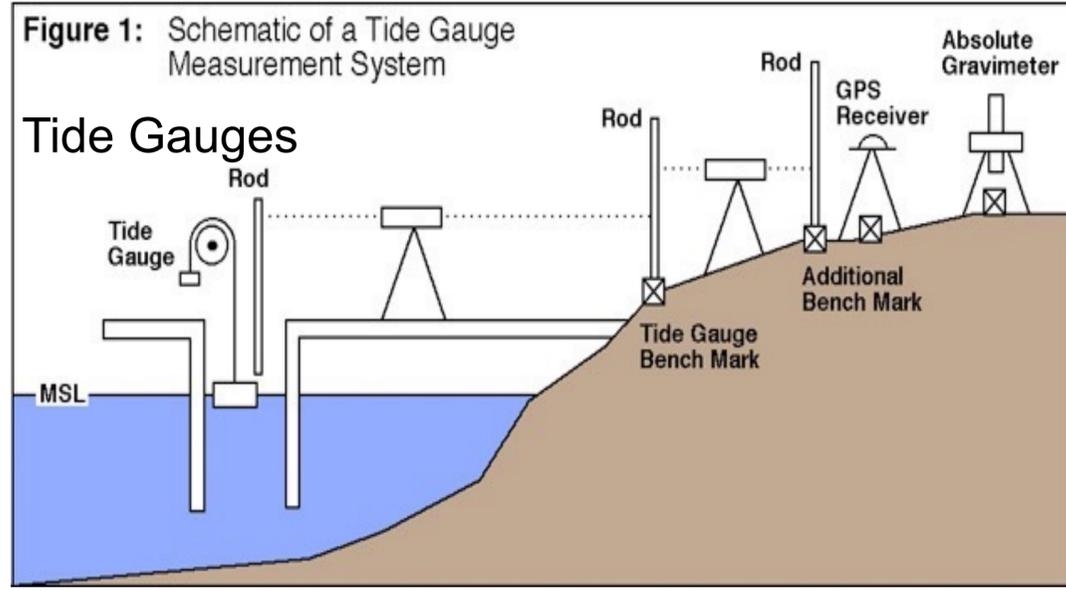


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Satellite Altimetry

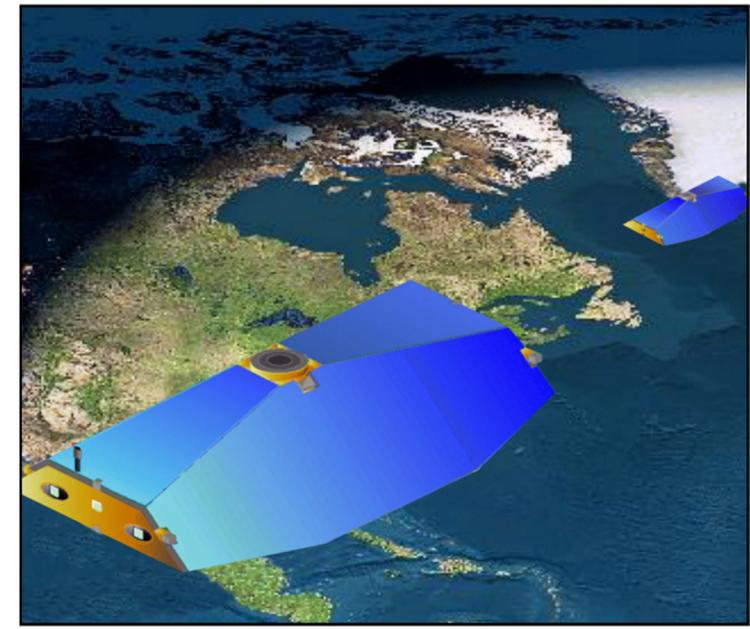
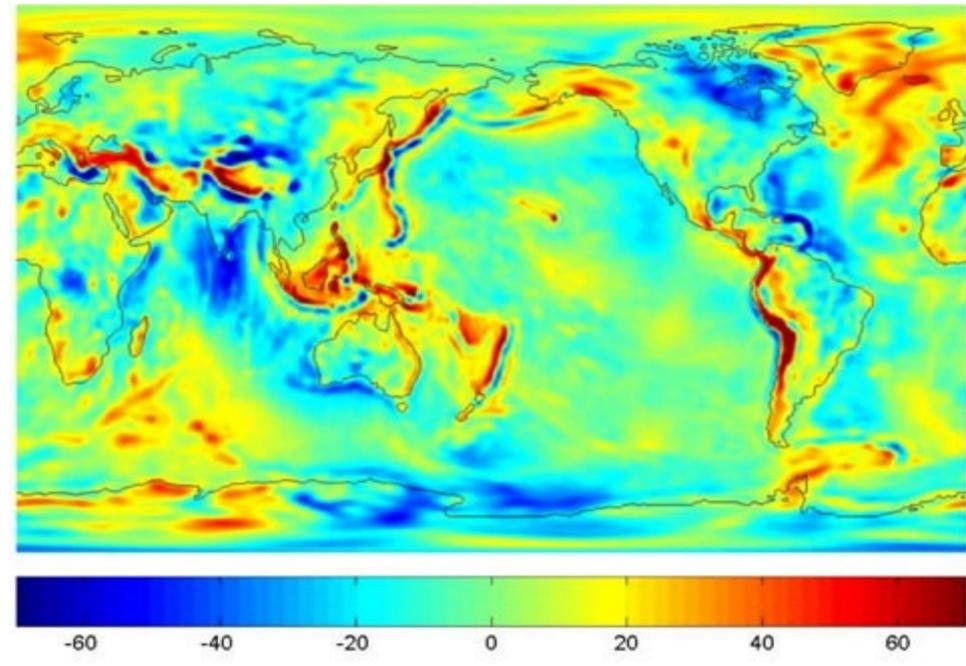
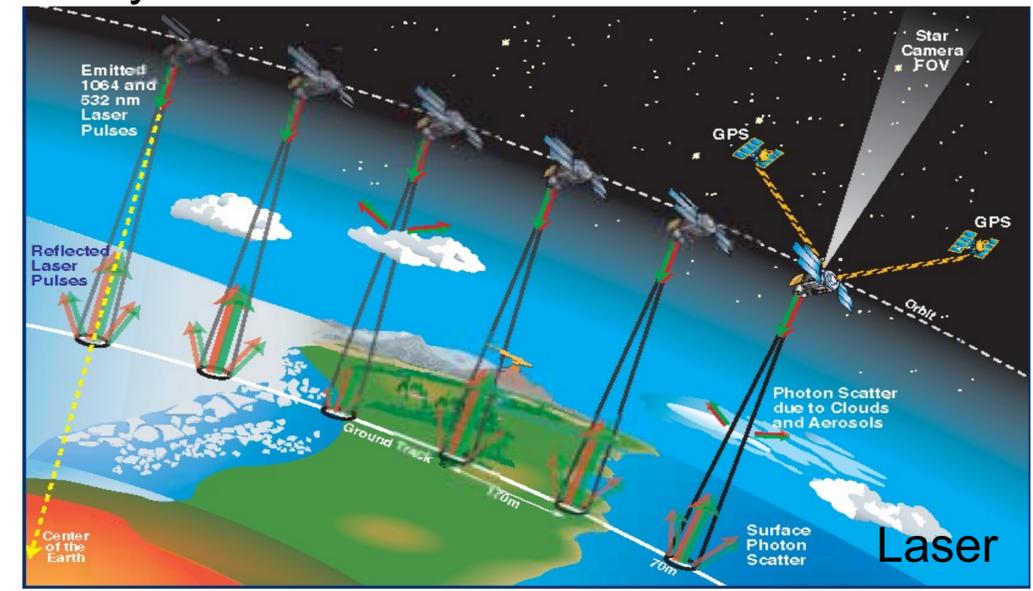
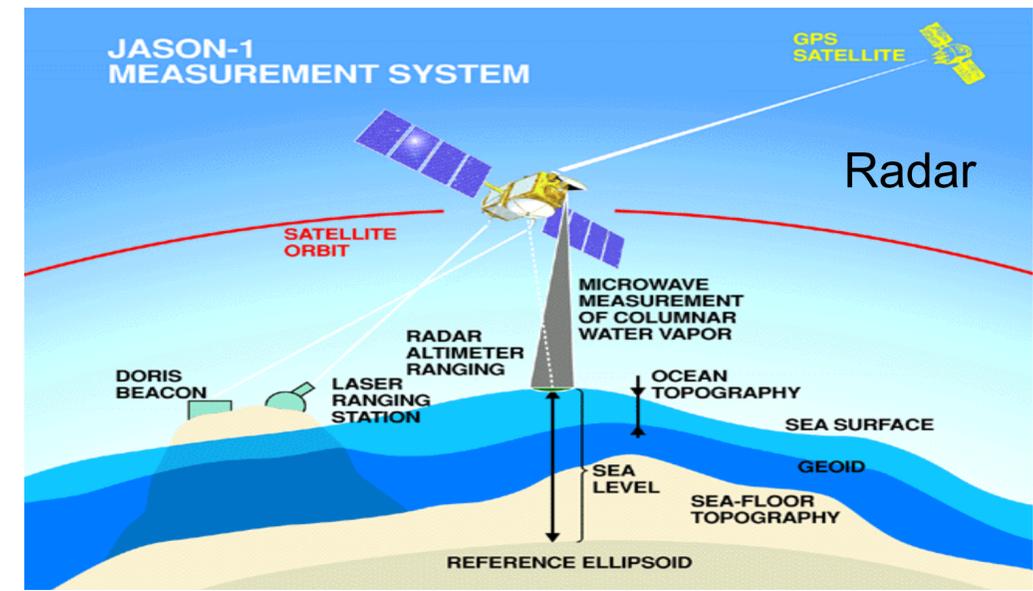


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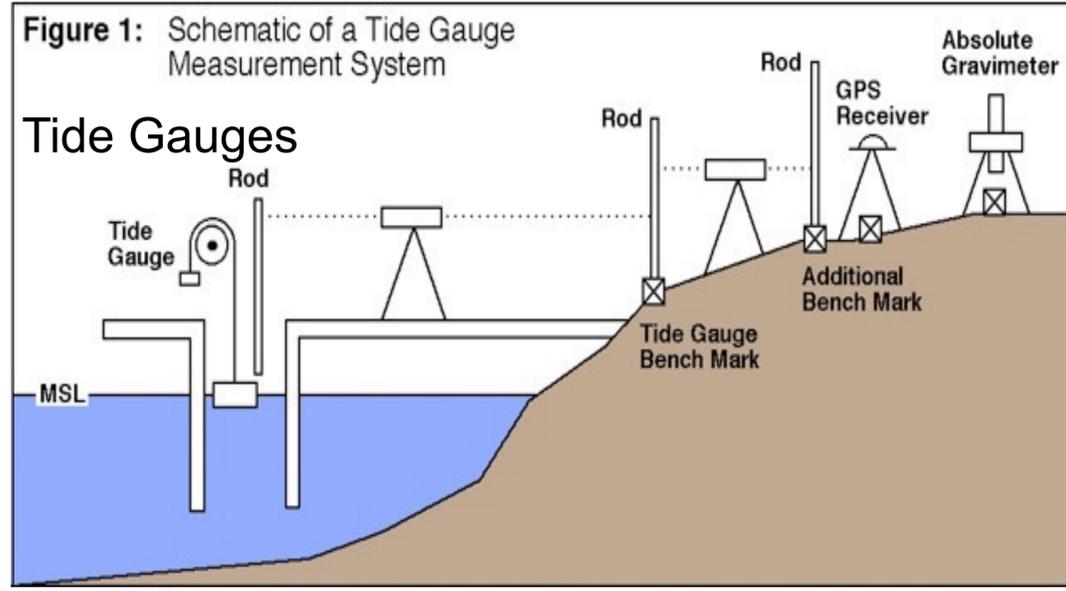


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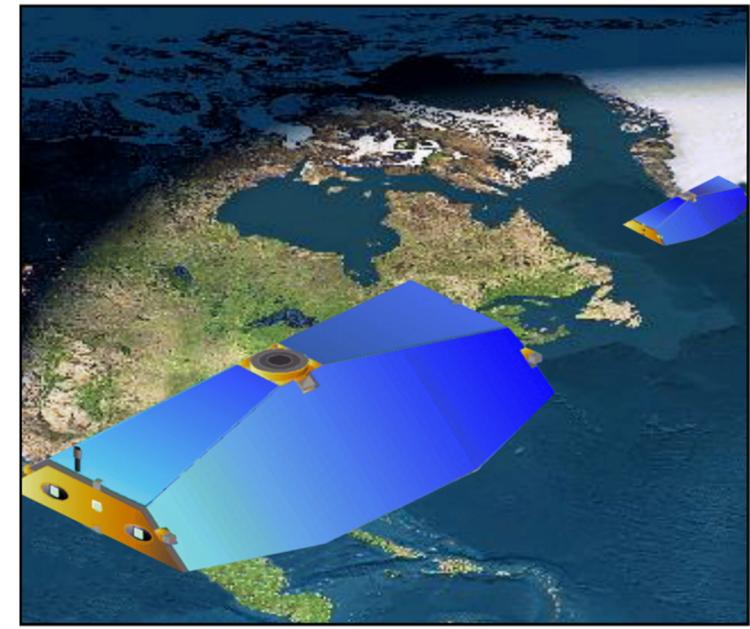
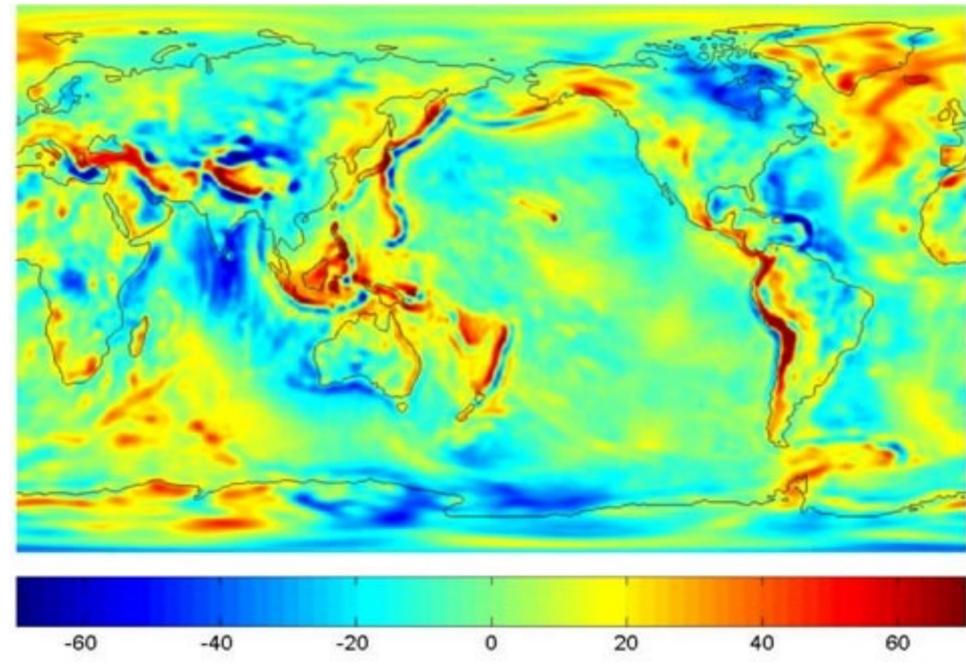
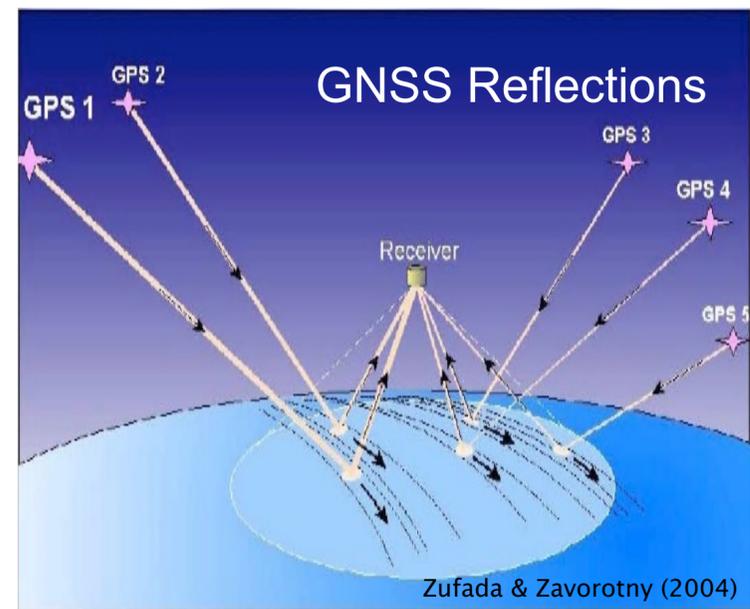
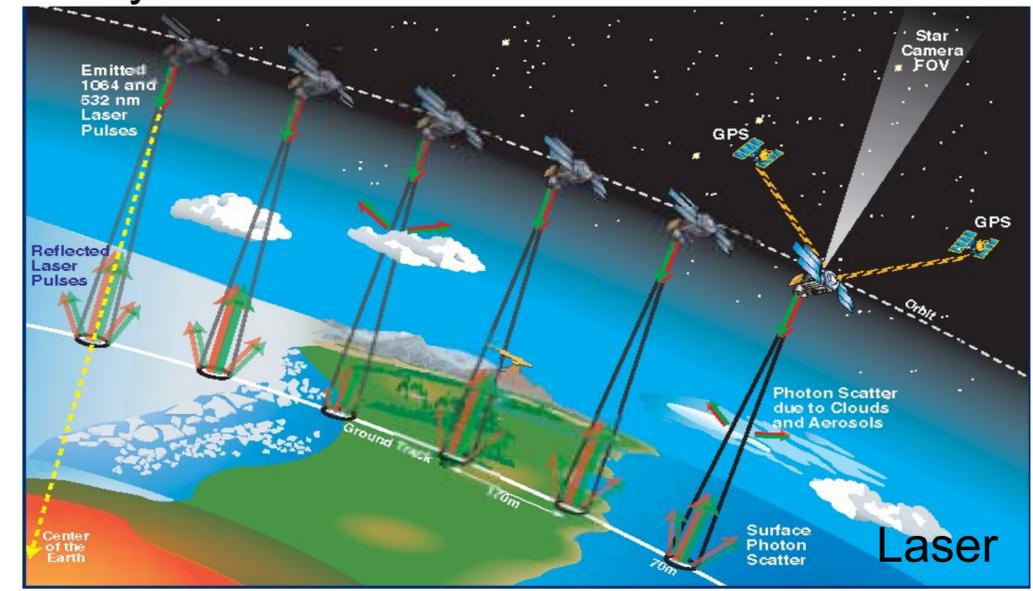
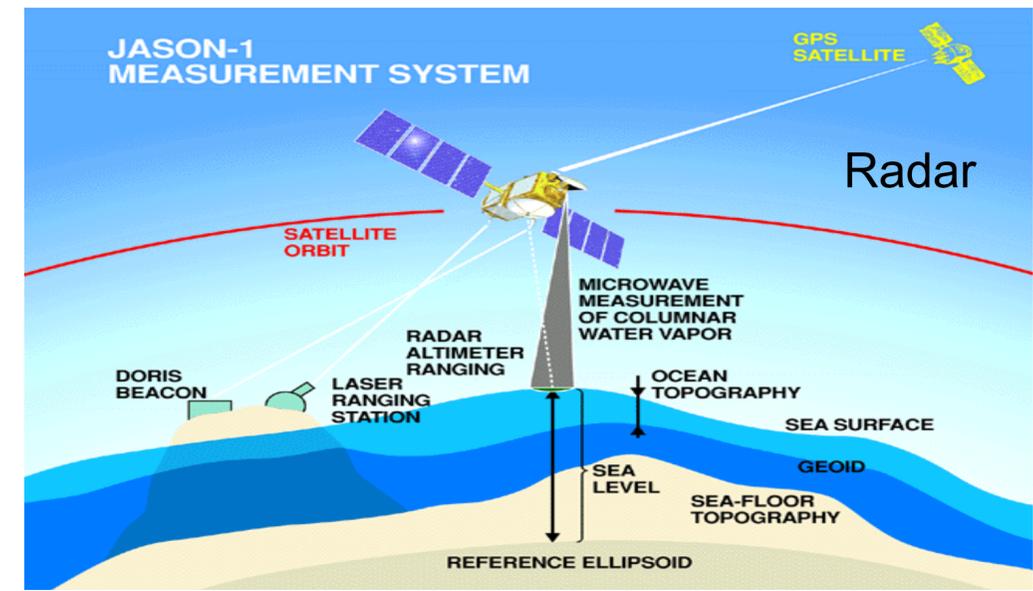


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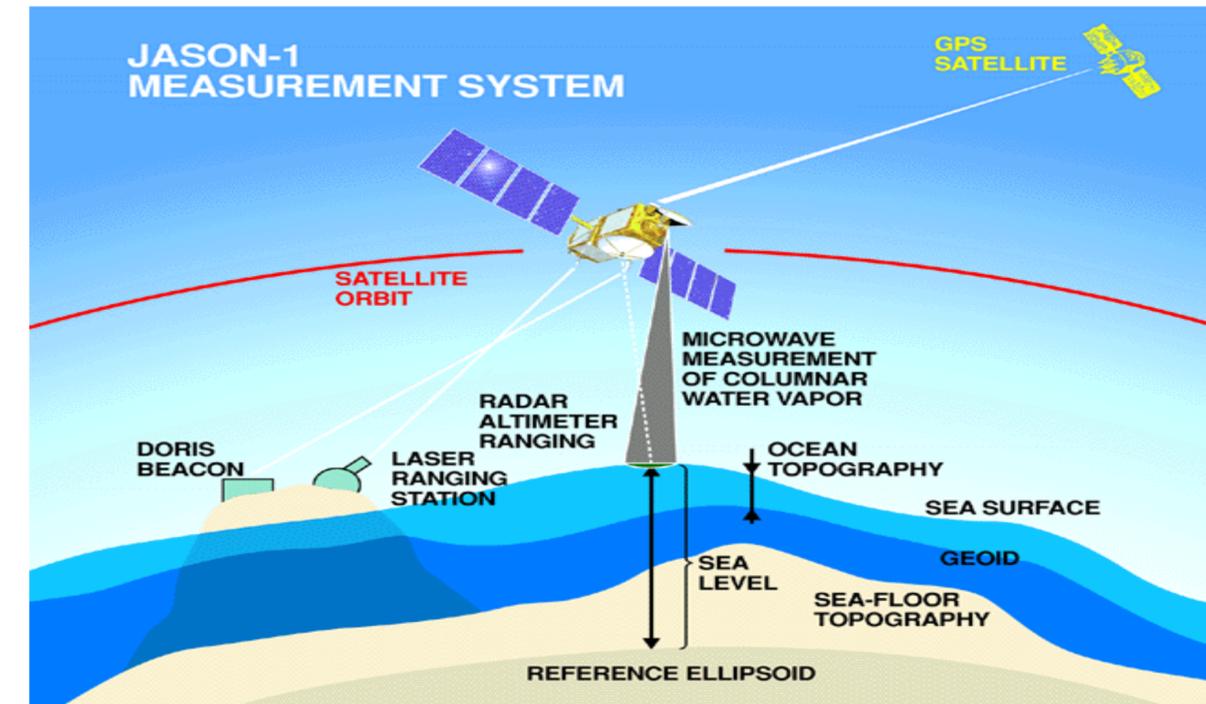


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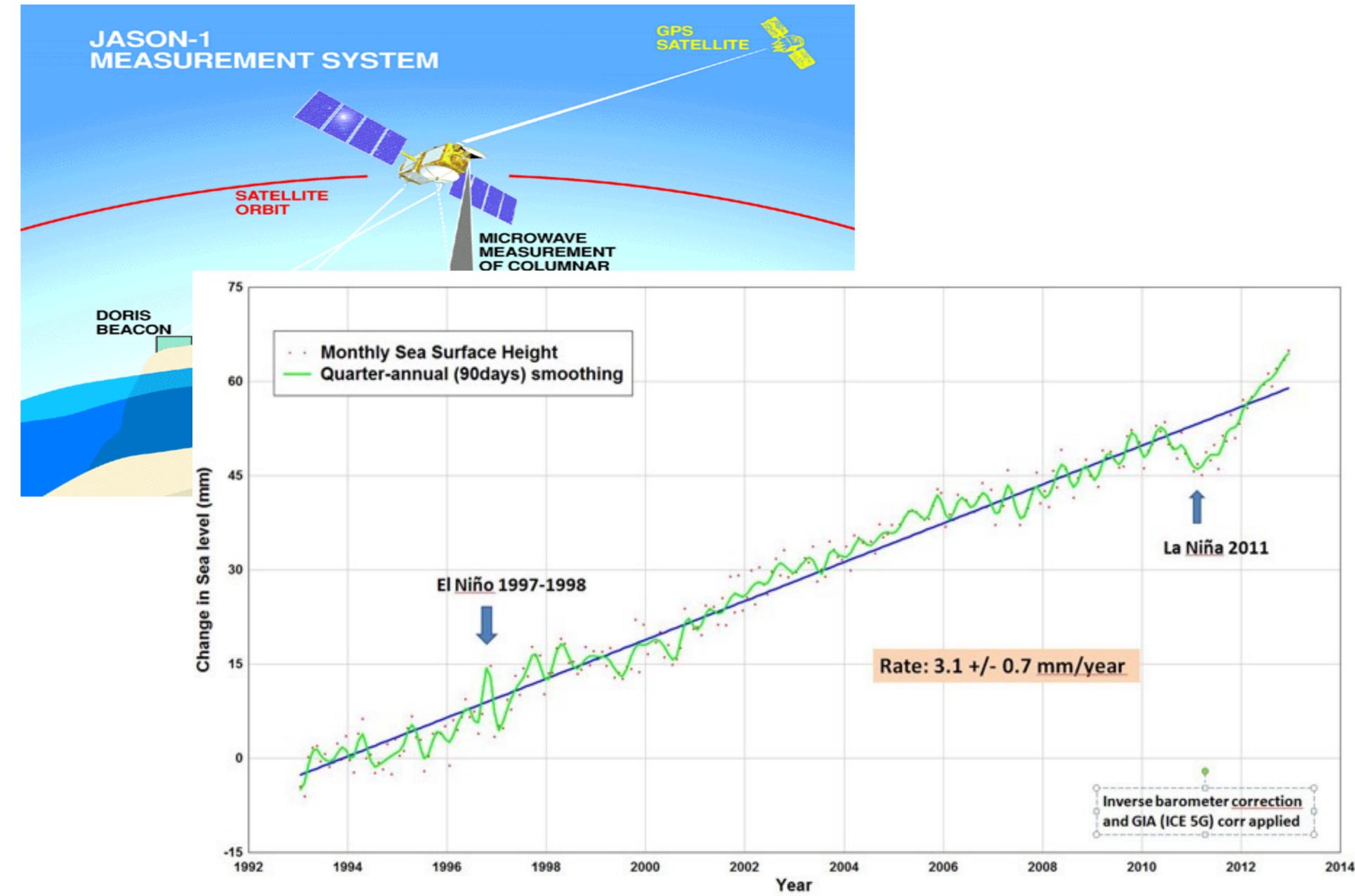
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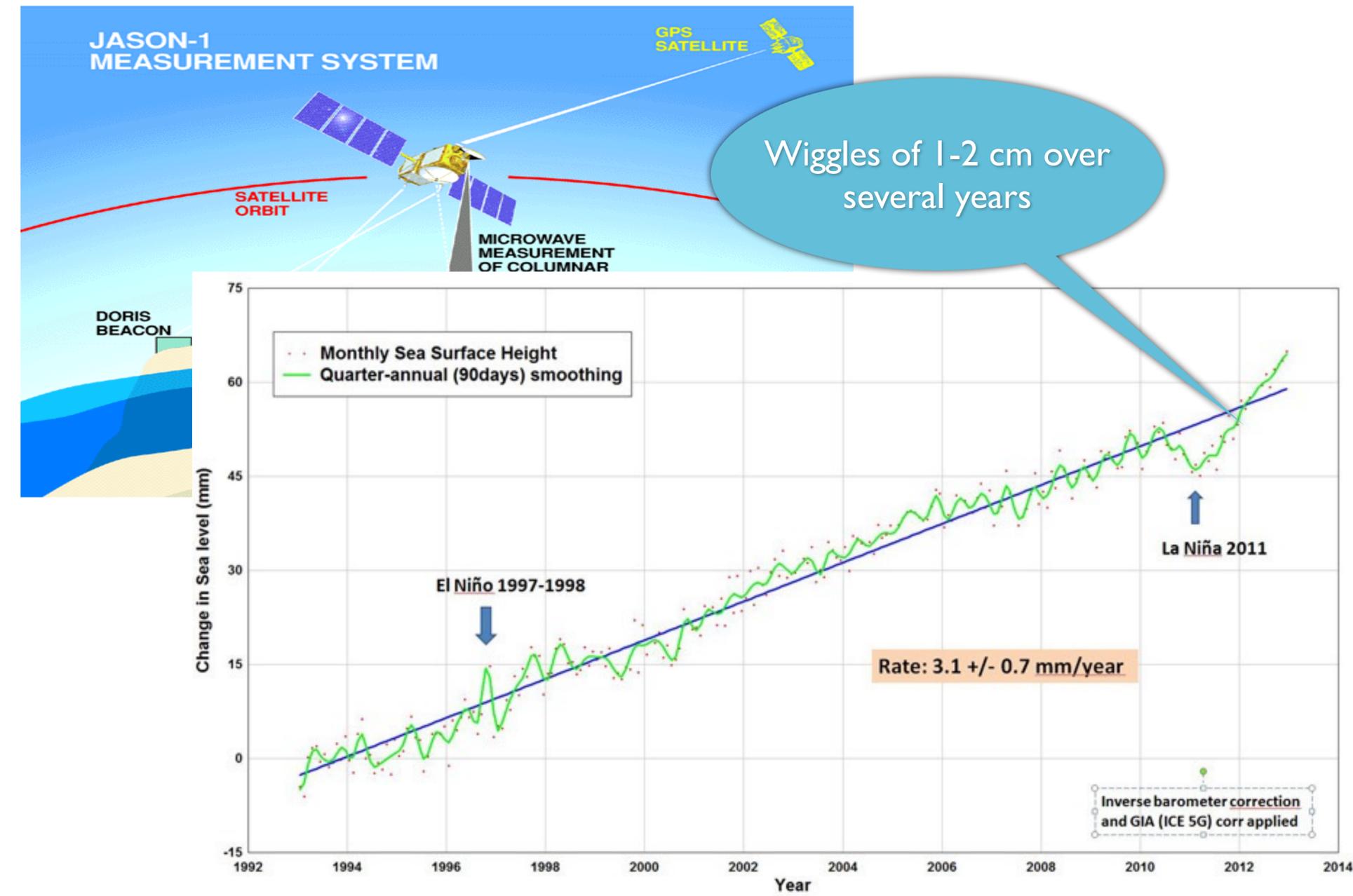
Sea surface height (not sea level):



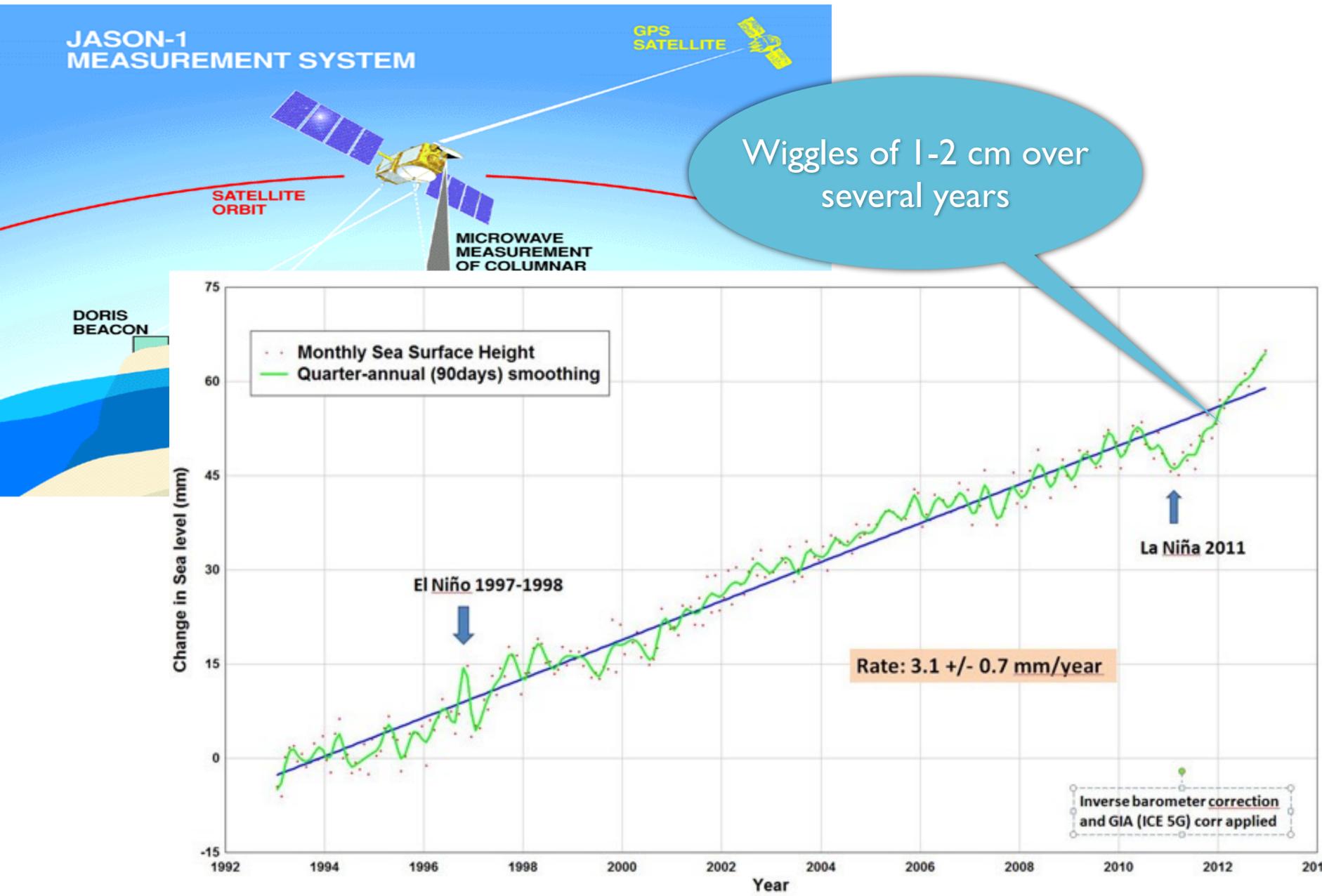
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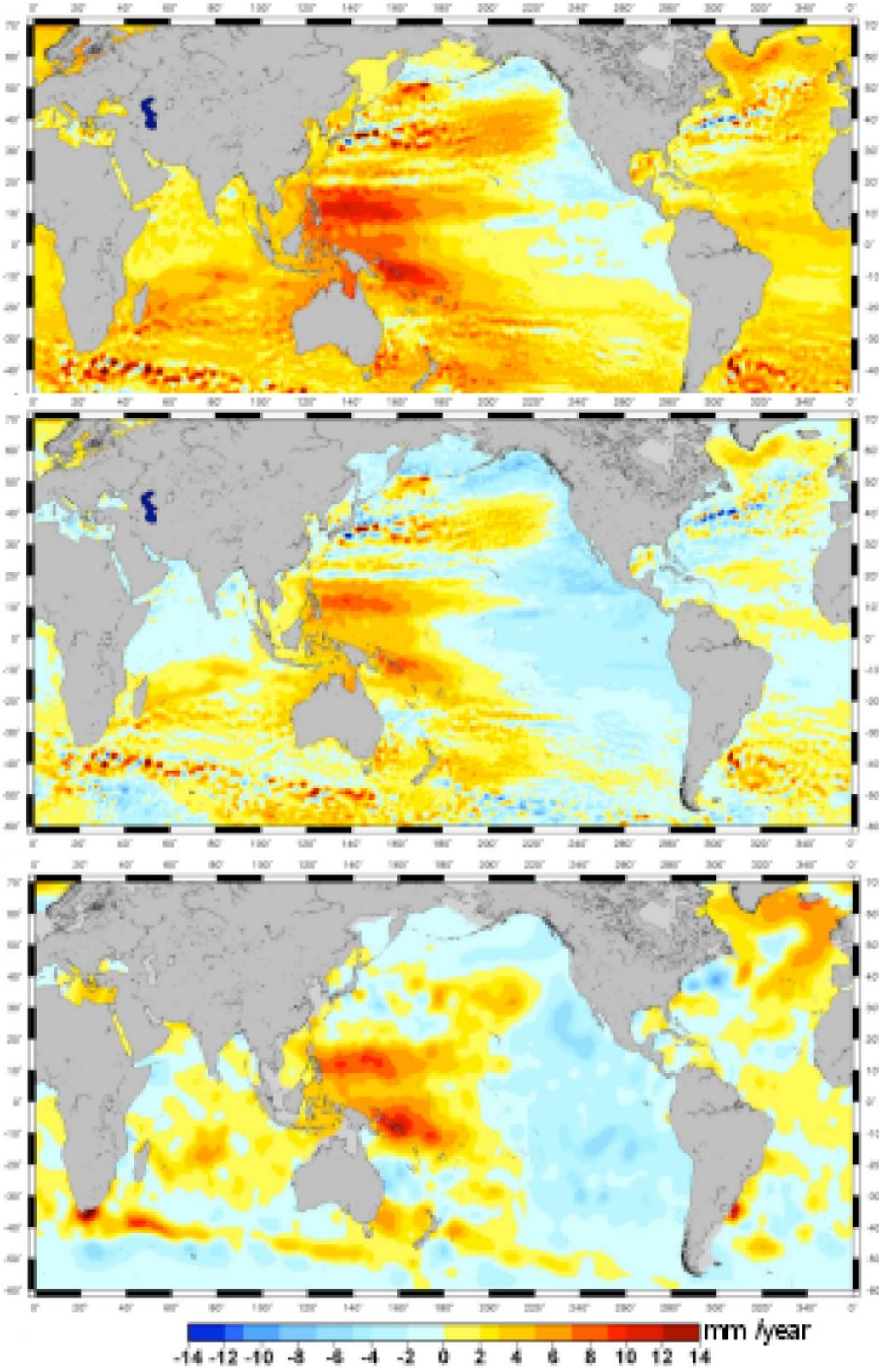


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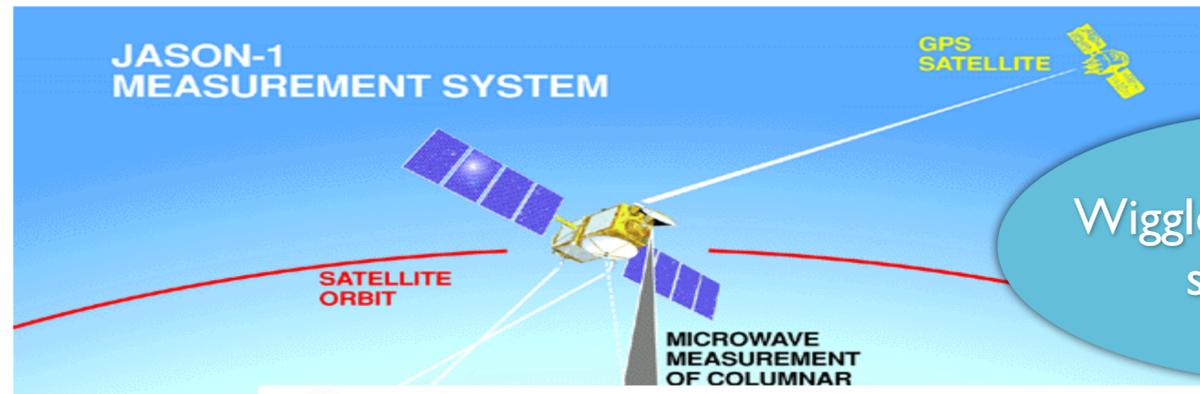
1993-2010

minus 3.2 mm/yr

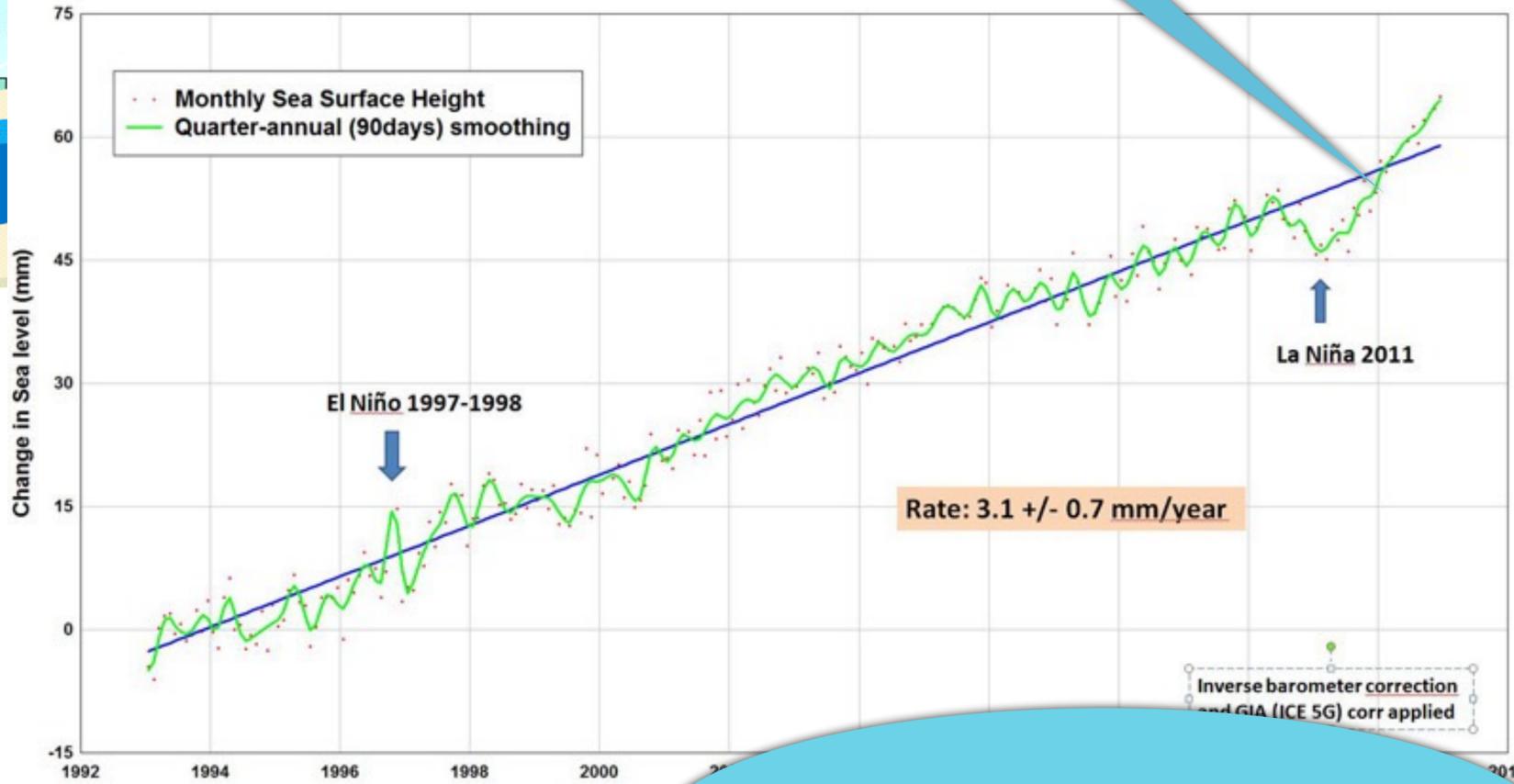
steric height



Sea surface height (not sea level):



Wiggles of 1-2 cm over several years



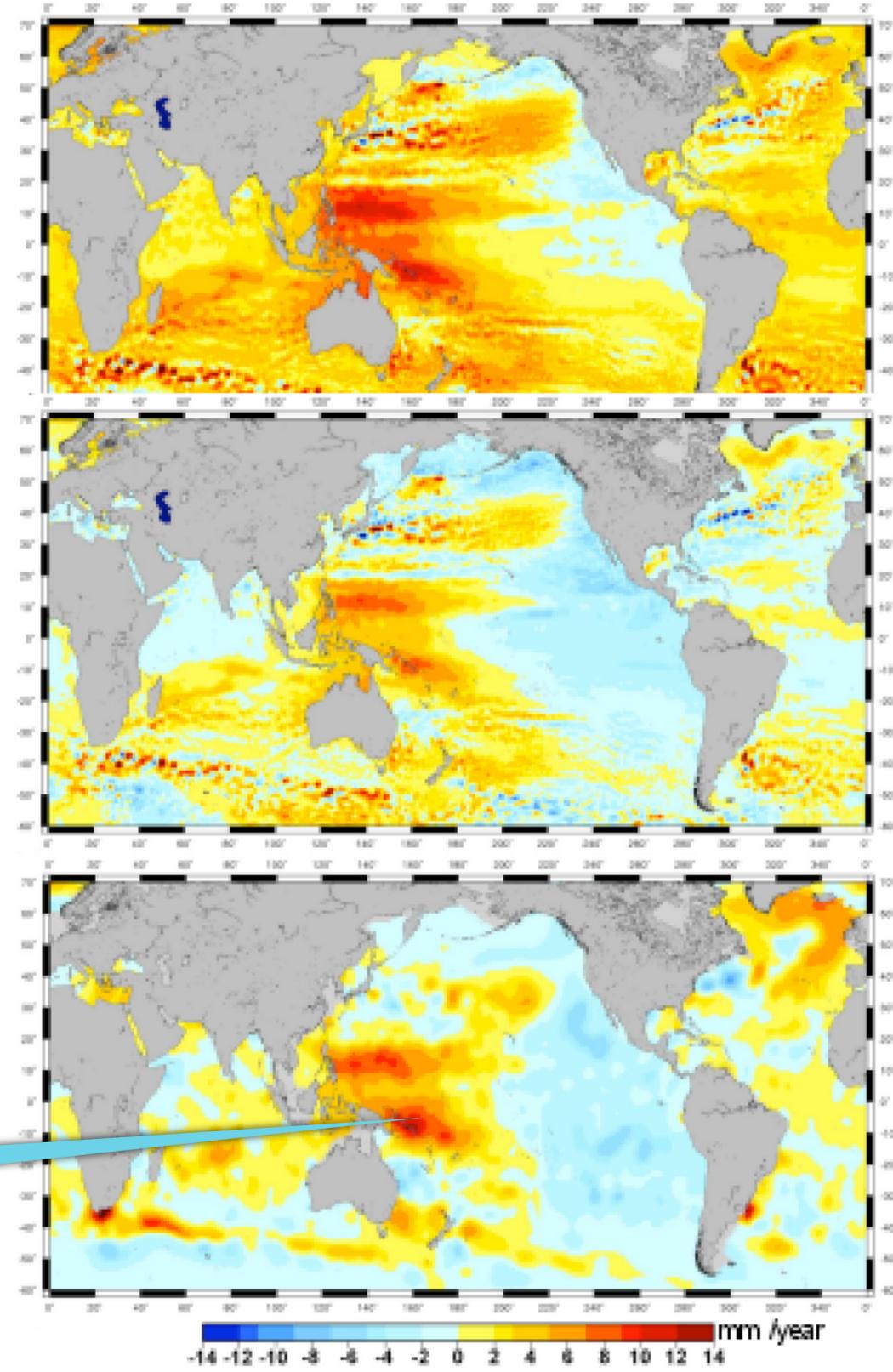
Regional differences of more than 30 cm over 20 years

Sea surface height

1993-2010

minus 3.2 mm/yr

steric height



ipcc

INTERGOVERNMENTAL PANEL ON climate change

CLIMATE CHANGE 2014

Synthesis Report



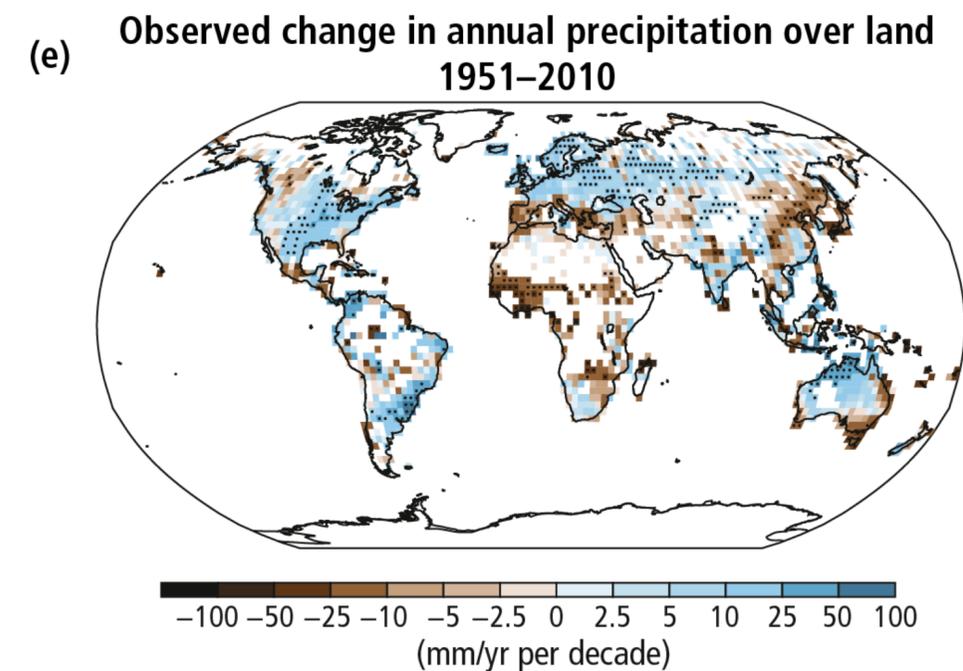
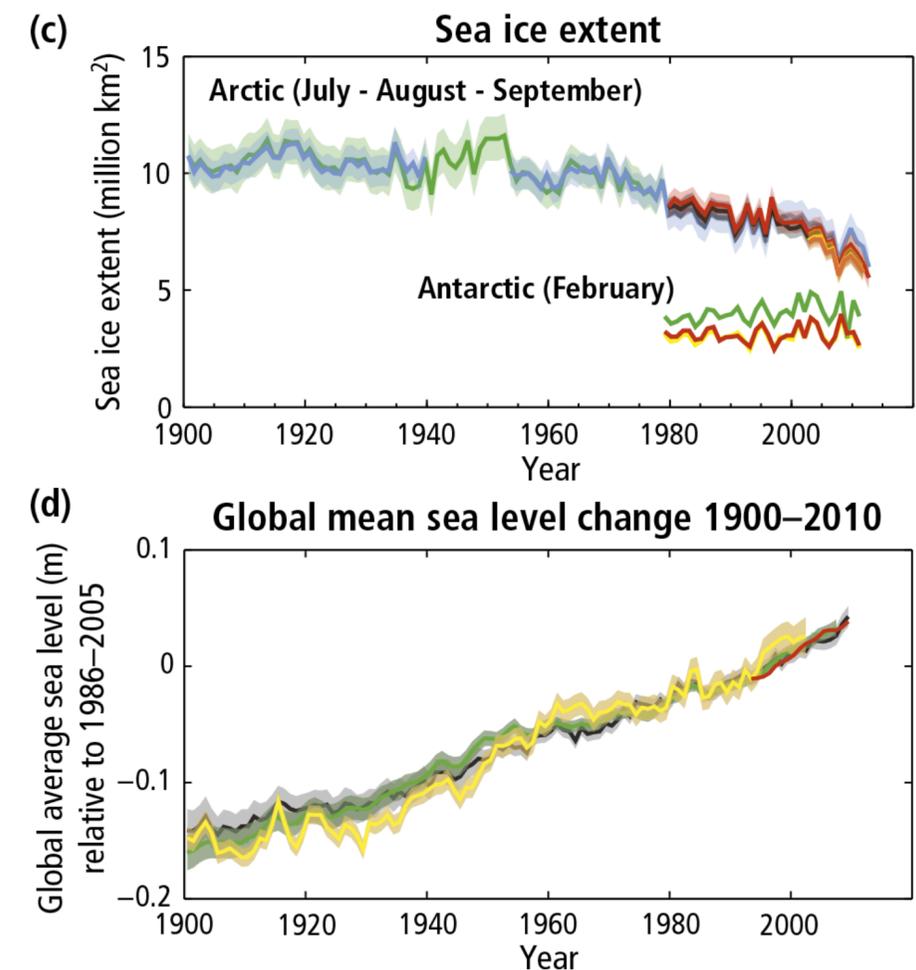
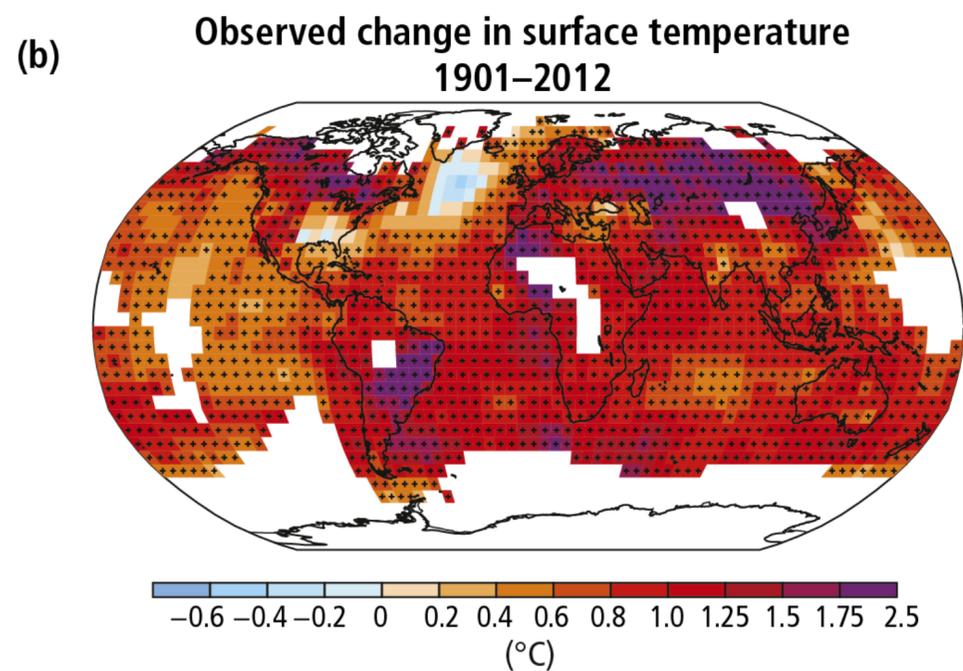
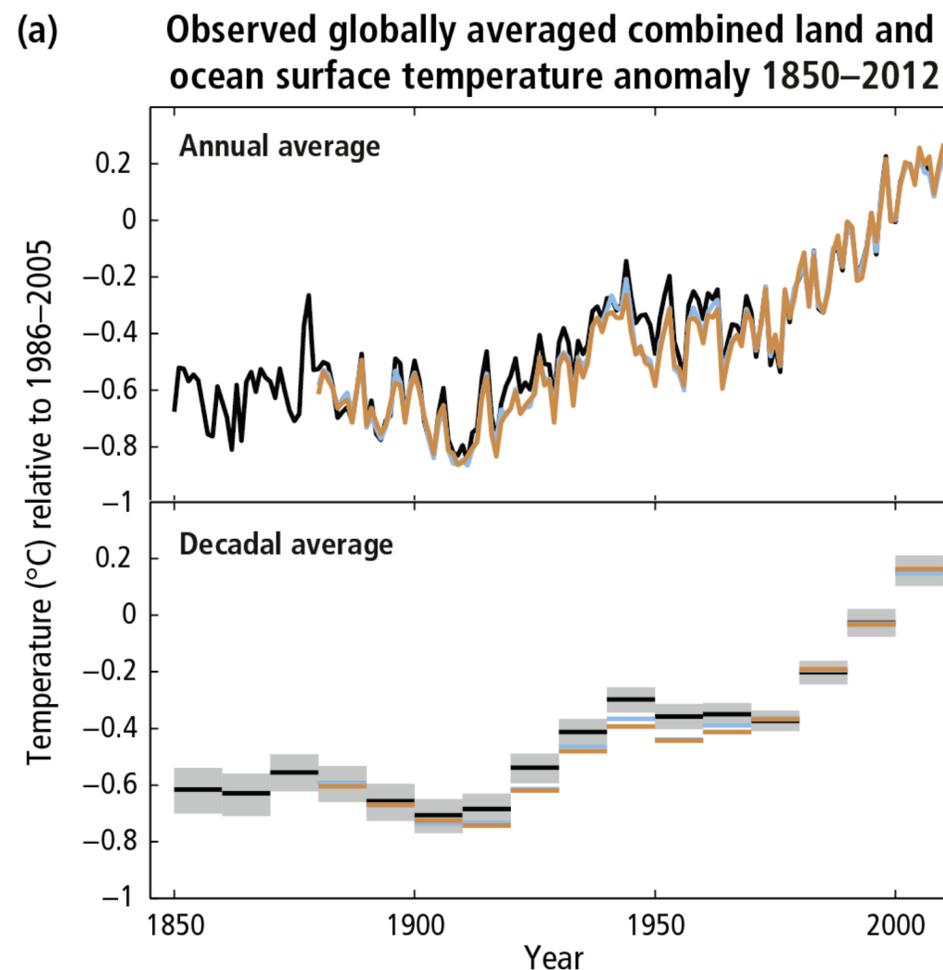
A REPORT OF THE
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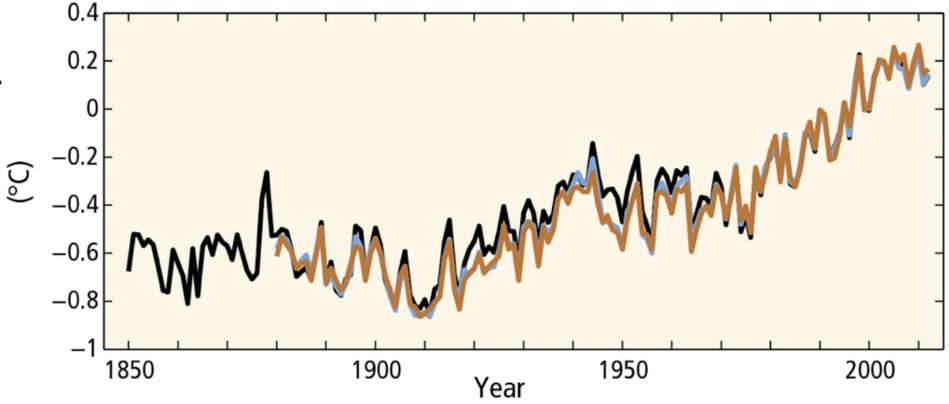
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INTERGOVERNMENTAL PANEL ON climate change

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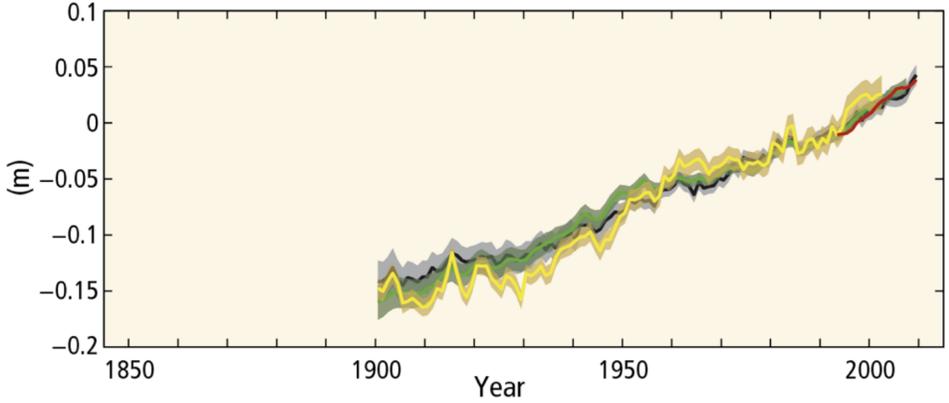
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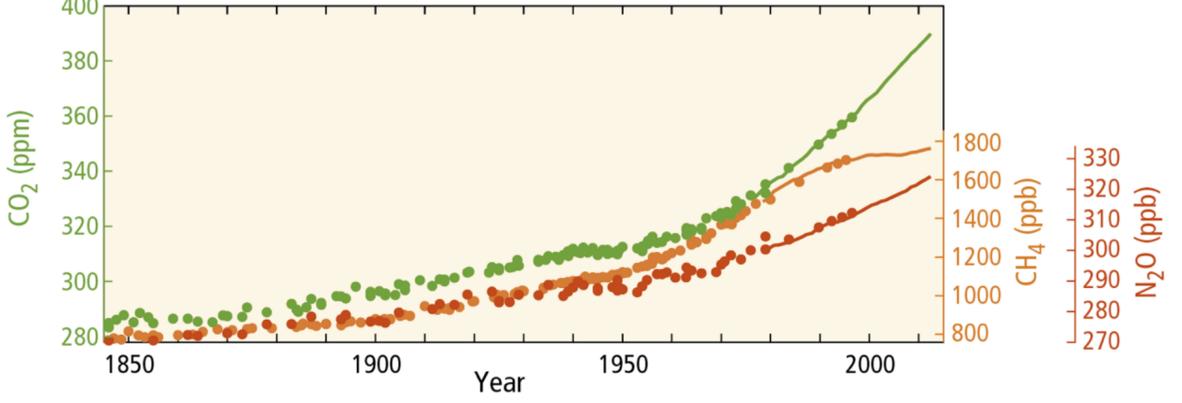
(a) Globally averaged combined land and ocean surface temperature anomaly



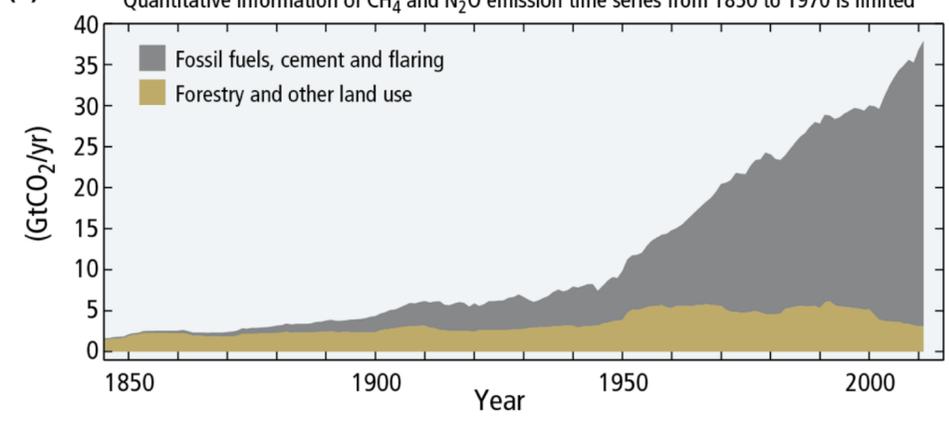
(b) Globally averaged sea level change



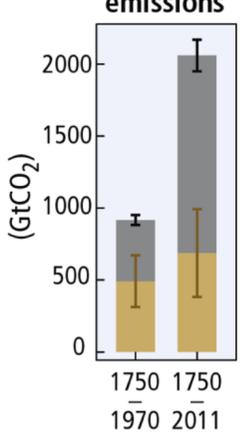
(c) Globally averaged greenhouse gas concentrations



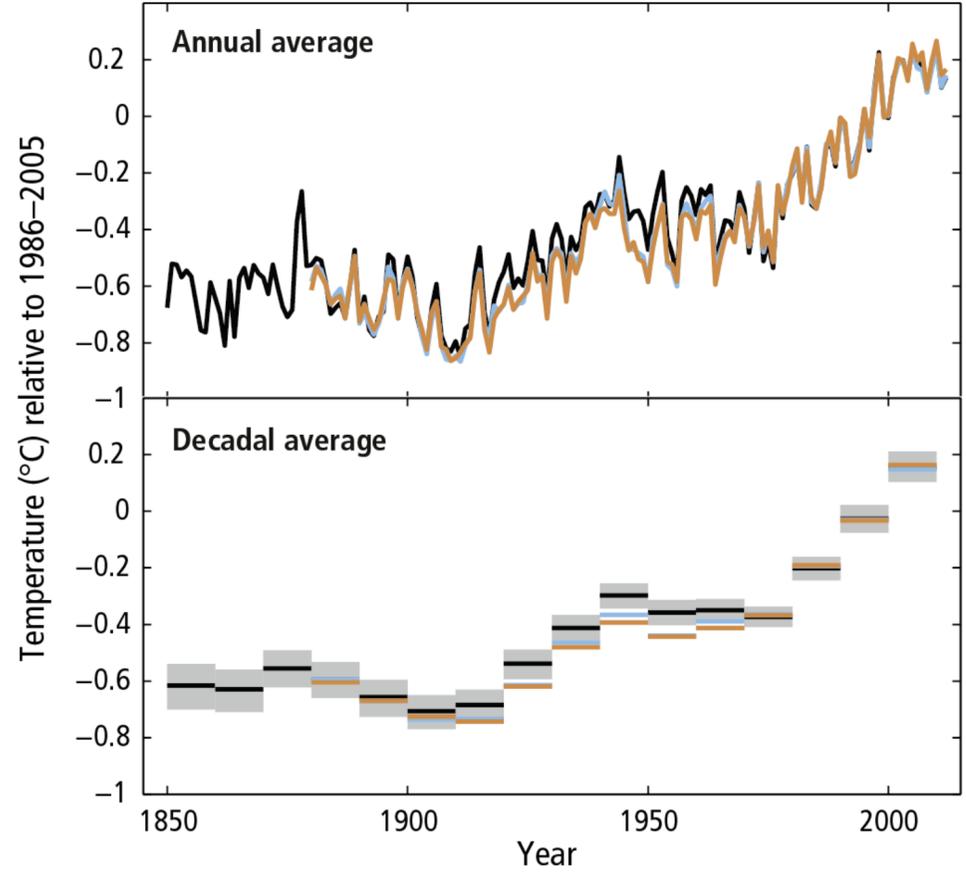
(d) Global anthropogenic CO₂ emissions



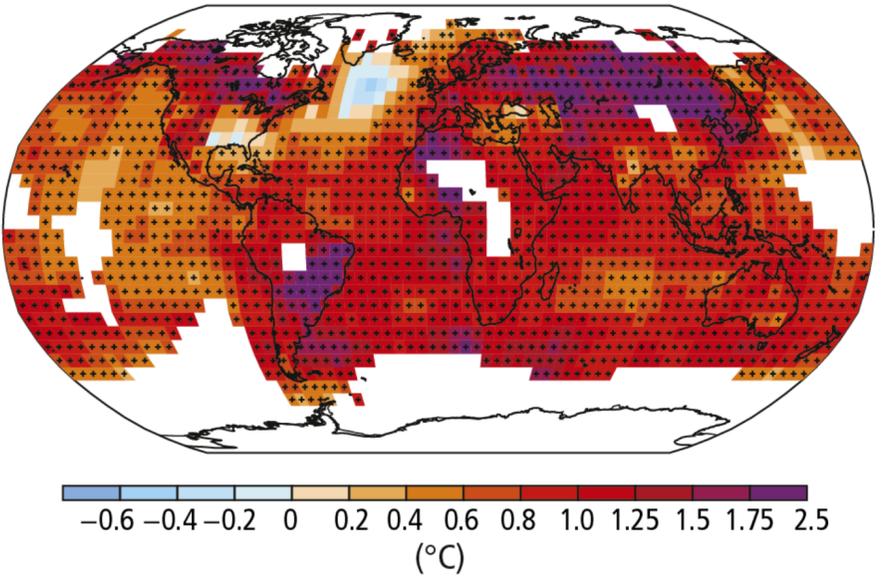
Cumulative CO₂ emissions



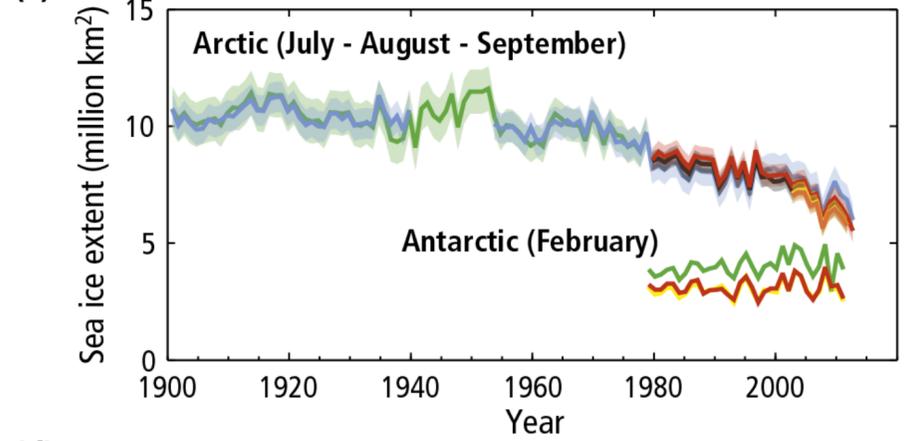
(a) Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012



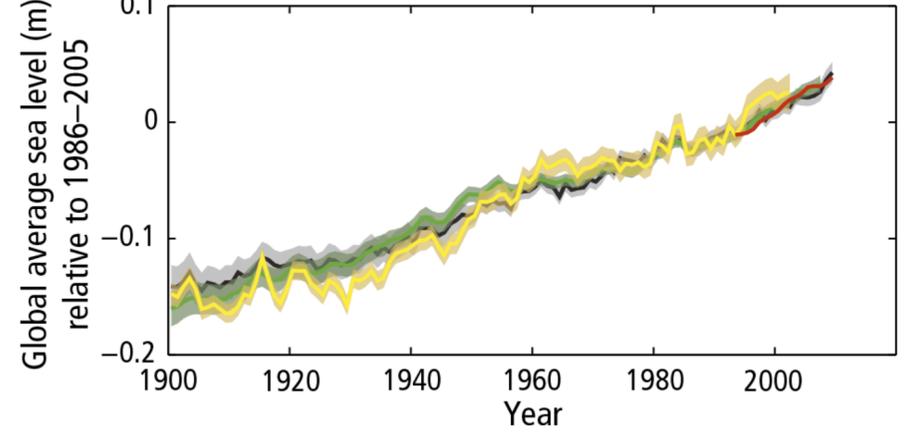
(b) Observed change in surface temperature 1901–2012



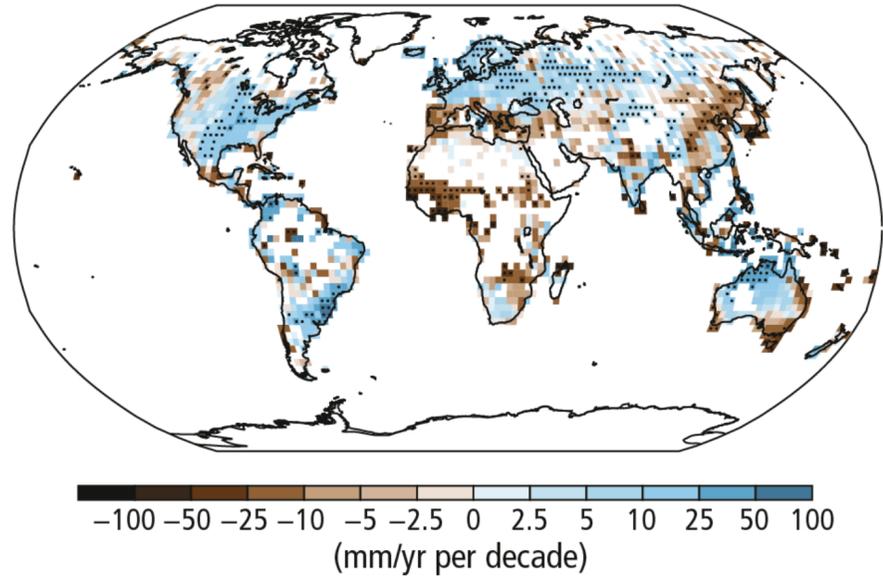
(c) Sea ice extent



(d) Global mean sea level change 1900–2010



(e) Observed change in annual precipitation over land 1951–2010



Is climate change intensifying typhoons in Asia?

In the past four decades, the frequency of category 4 and 5 typhoons increased four-fold from a once-a-year occurrence to four times a year.

By Seth Borenstein, Associated Press | SEPTEMBER 5, 2016

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Bullit Marquez/AP | [View Caption](#)

How solid is our knowledge?

How solid is our knowledge?

Example sea level rise

How solid is our knowledge?

Example sea level rise

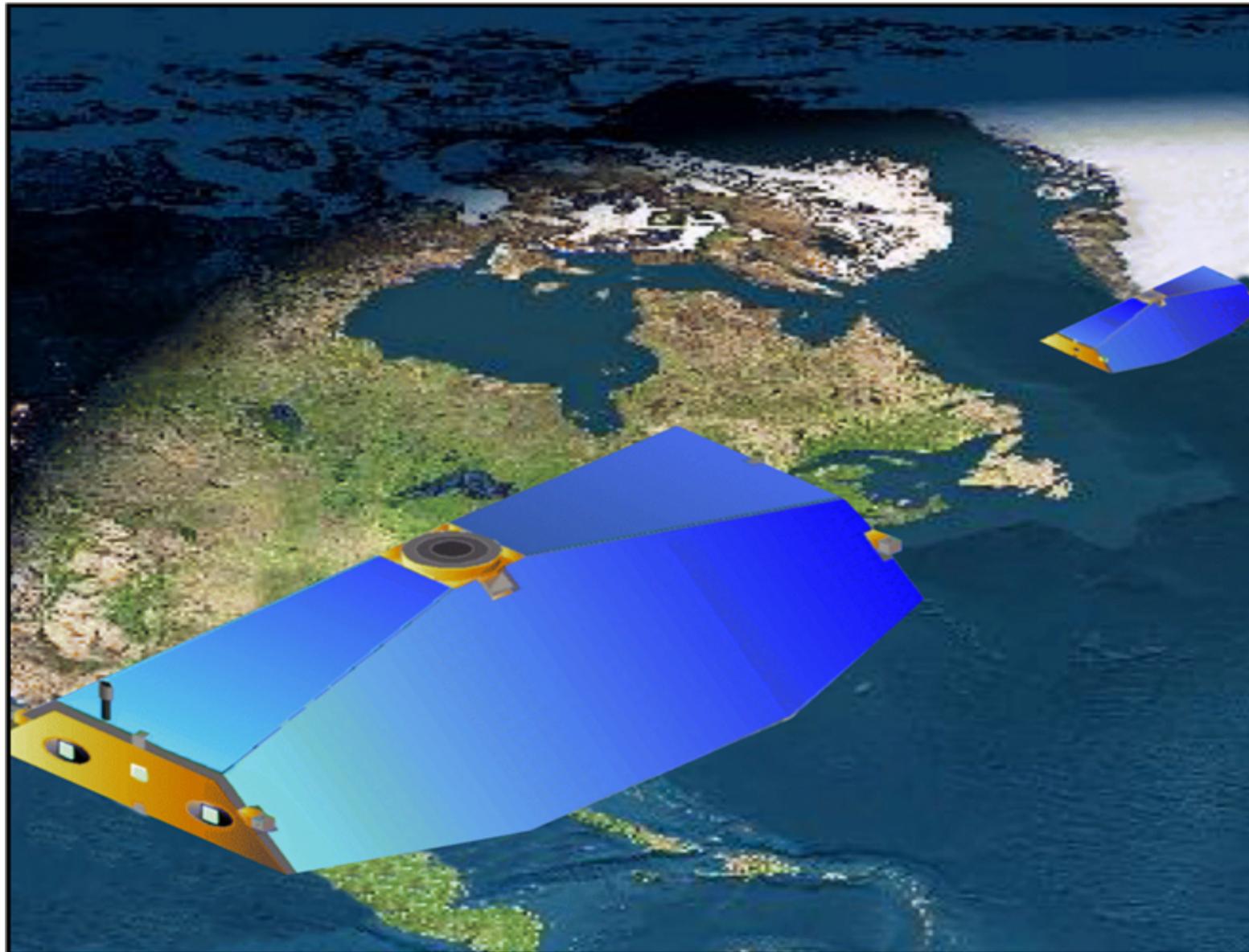
Accepted knowledge in 2000:

Greenland: no significant contribution to sea level rise

Antarctica: minor contribution

Main contribution: steric changes

How solid is our knowledge?



Gravity Recovery and Climate Experiment (GRACE)

Example sea level rise

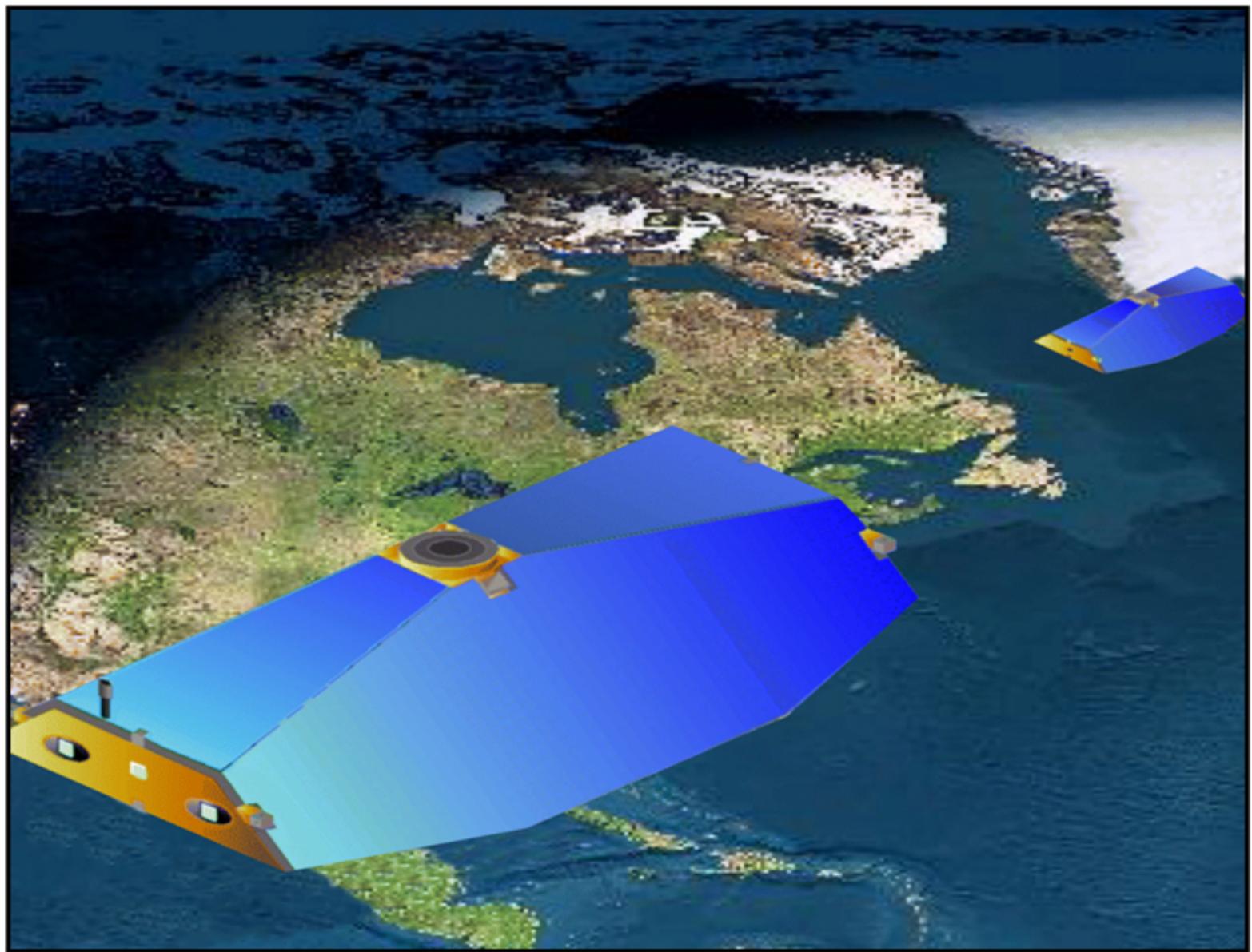
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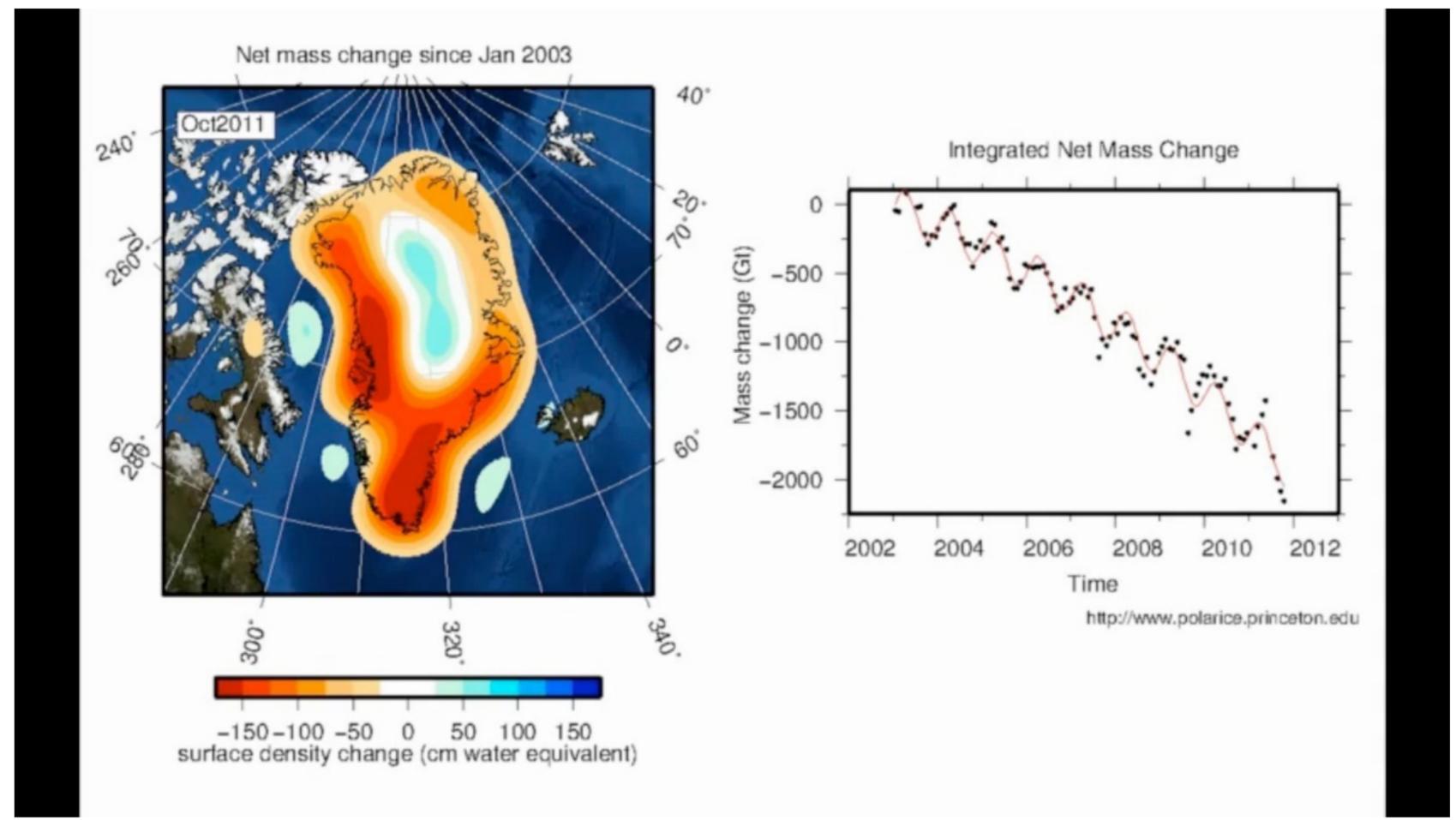
How solid is our knowledge?



Gravity Recovery and Climate Experiment (GRACE)

Example sea level rise

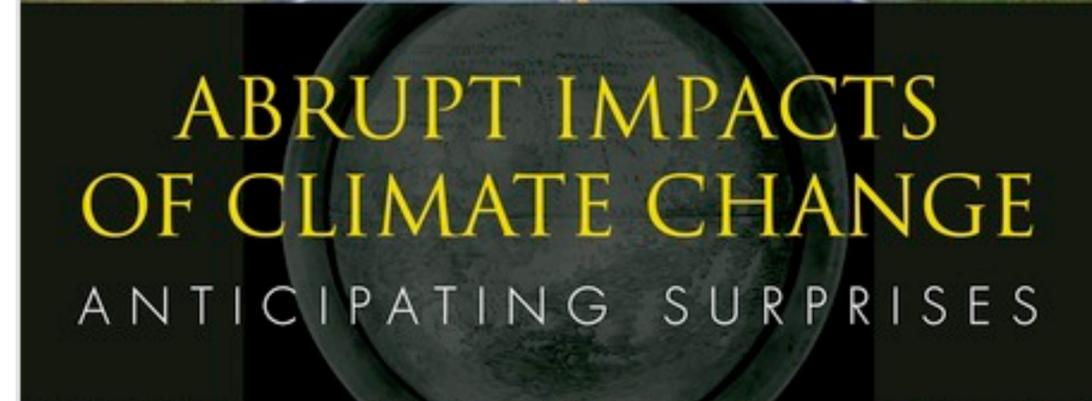
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National Research Council in 2013:
There is the potential for surprises and new extremes ...

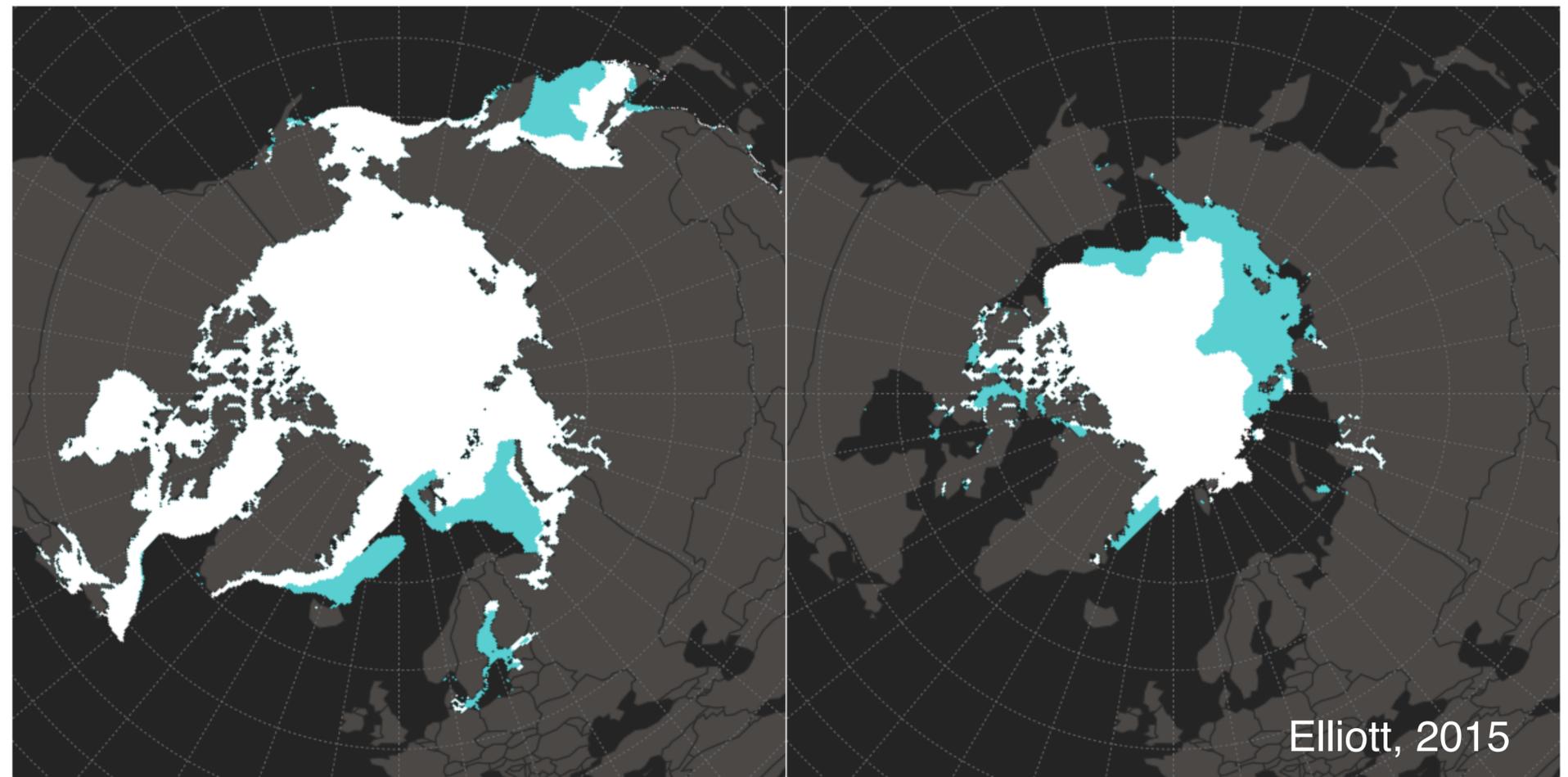
Already happening: Disappearance of late-summer Arctic sea ice



Arctic ice extent melt, 1979 - 2014

MARCH:  1979  2014

SEPTEMBER:  1979  2014



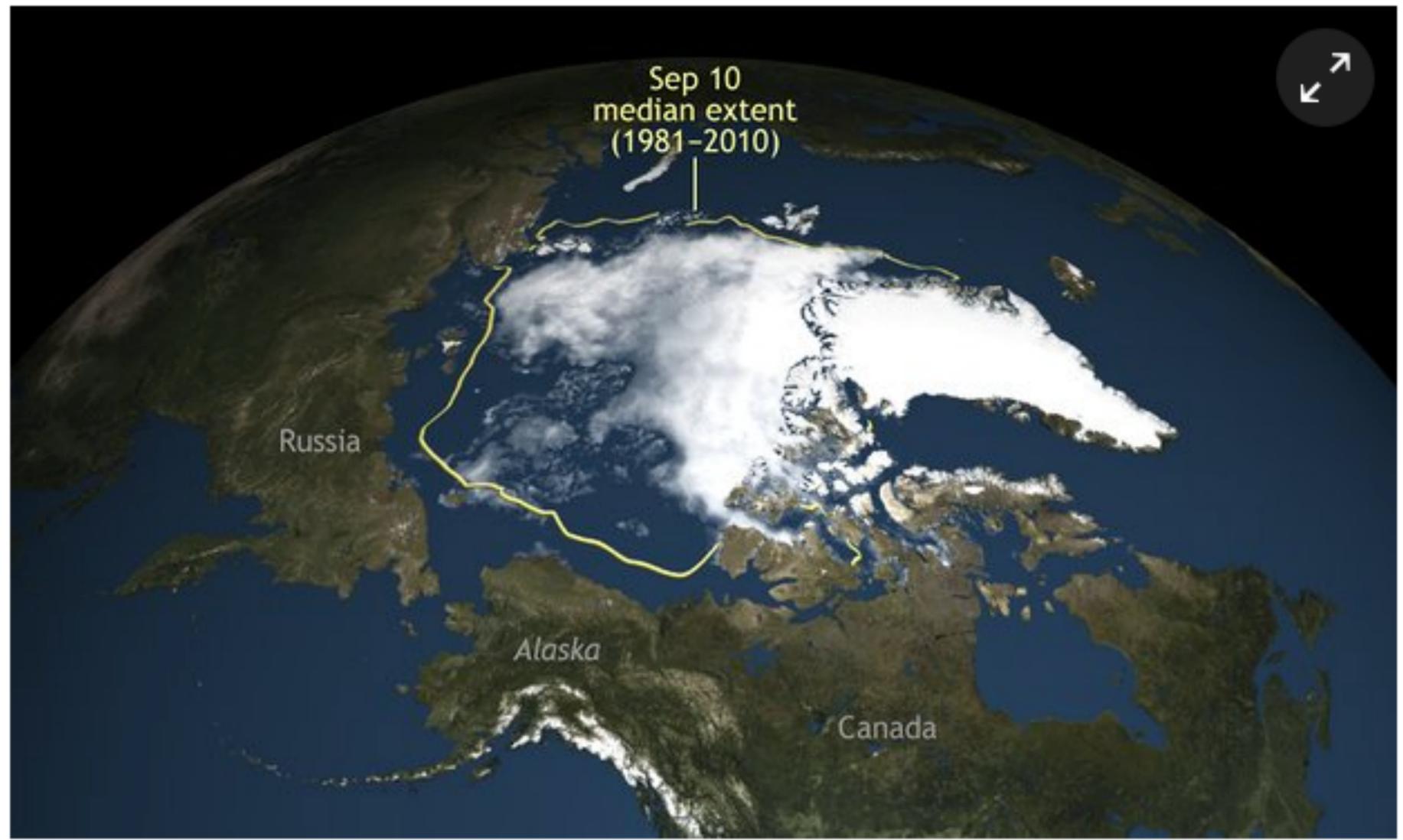
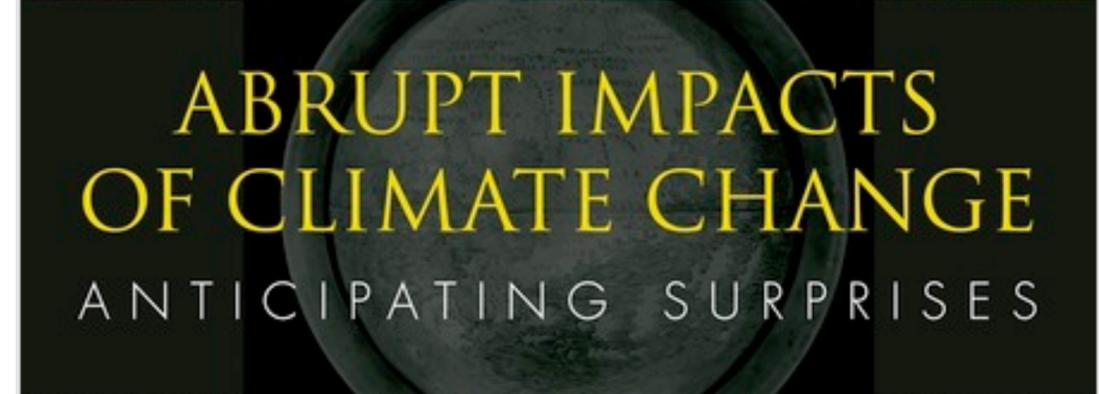
Arctic sea ice shrinks to second lowest level ever recorded

Nati

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Alrea

"Tremendous loss" of ice reinforces clear downward trend towards ice-free summers due to effects of climate change



Arctic sea ice this summer shrank to its second lowest level since scientists started to monitor it by satellite. Photograph: AP

National Research Council in 2013:
There is the potential for surprises and new extremes ...

Already happening: Disappearance of late-summer Arctic sea ice



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OF CLIMATE CHANGE**
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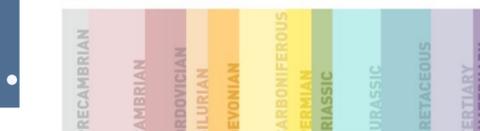
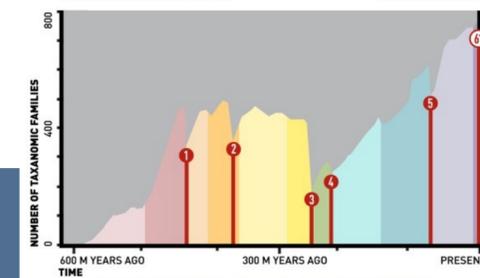
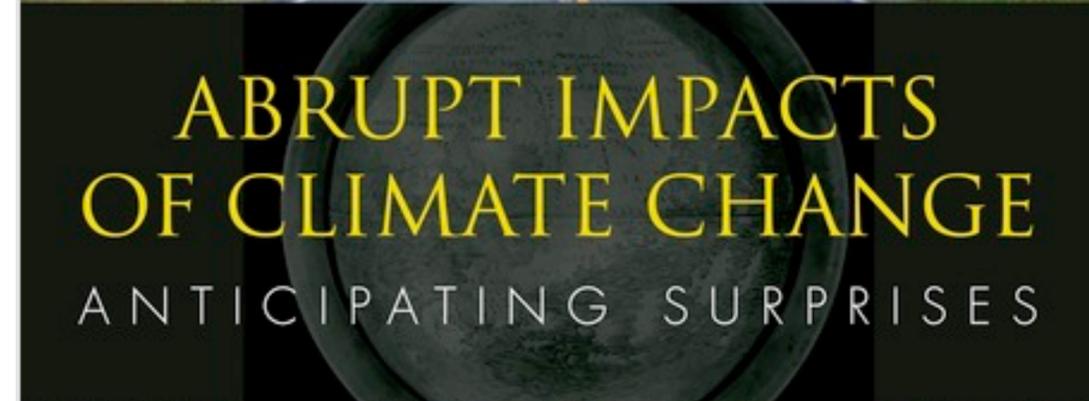
Assessing Knowledge



National Research Council in 2013:
There is the potential for surprises and new extremes ..

Already happening: Disappearance of late-summer Arctic

Already happening: Increases in extinction threats



1	END ORDOVICIAN	<p>85% of living organisms lost</p> <p>WHAT HAPPENED: Glaciation followed by a rebound of a greenhouse climate.</p> <p>HARD-HIT GROUPS: TRILOBITES, BRACHIOPODS, BRYOZOANS, ECHINODERMS, GRAPTOLITES</p>
2	LATE DEVONIAN	<p>70% of all marine species lost</p> <p>WHAT HAPPENED: Lack of oxygen in the oceans, rising sea levels, and global cooling.</p> <p>HARD-HIT GROUPS: REEF ENVIRONMENTS, OSTRACODERMS & PLACODERMS, STROMATOPOROIDS, RUGOSA & TABULATA, TRILOBITES, JAGANI</p>
3	END PERMIAN (THE GREAT DYING)	<p>96% of all species lost</p> <p>WHAT HAPPENED: Extremely dry, hot conditions led to animal and plant decline, and a large volcanic eruption pushed carbon dioxide into the atmosphere, raising temperatures and lowering oxygen in the ocean. It took 10-20 million years for life to recover its diversity after this event.</p> <p>HARD-HIT GROUPS: TRILOBITES (EX AGANI), EURYPTERIDS, FUSULINID FORAMINIFERA, ACANTHODIANS, MONIRA AND OTHER INSECTS</p>
4	END TRIASSIC	<p>76% of all species lost</p> <p>WHAT HAPPENED: Extreme volcanic activity, which would eventually break apart the supercontinent of Pangaea, raised global temperatures and acidified the ocean. There is still a great deal of controversy surrounding the main cause of extinction during this period.</p> <p>HARD-HIT GROUPS: TIRINAXODON & OTHER NORMAL LAKE REPTILES, MASTODONSAURUS & OTHER AMPHIBIANS, BRACHIOPODS, AMMONITES, CONODONTS</p>
5	END CRETACEOUS	<p>70% of all species lost</p> <p>WHAT HAPPENED: After millions of years of animal and plant decline due to dropping sea levels and intensifying volcanic activity, which caused acid rain and cooling temperatures, a gigantic asteroid struck Earth, causing further devastation.</p> <p>HARD-HIT GROUPS: DINOSAURS, PTEROSAURS, MUSAURS, PLESIOSAURS, RUOSTID & OTHER MOLLUSCS</p>
6?	HOLOCENE (PROPOSED)	<p>??% of all species lost</p> <p>WHAT'S HAPPENING: Some scientists think the sixth major extinction event started 10,000 years ago when humankind began to dominate the Earth, with extinctions tied to a wide array of causes including hunting, habitat destruction, pollution, and global climate change.</p> <p>HARD-HIT GROUPS: WOOLY MAMMOTH, DOODO, PASSENGER PIGEON, GOLDEN TOAD & OTHER AMPHIBIANS, GREAT AUK</p>

Rossman&Marash (2014)

National Research Council in 2013:
There is the potential for surprises and new extremes ...

Already happening: Disappearance of late-summer Arctic sea ice

Already happening: Increases in extinction threats



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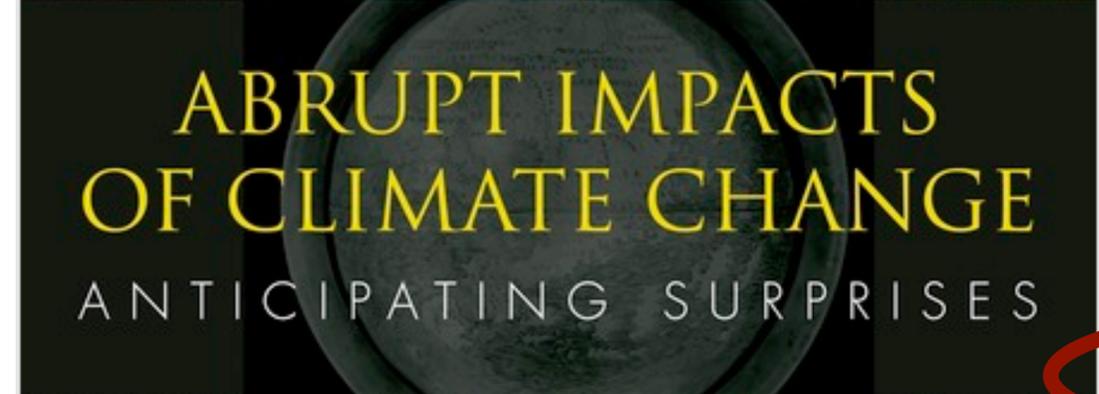
Already happening: Increases in extinction threats

Disruption of Atlantic Meridional Overturning Circulation: unlikely in the 21st century; but gradual change could have severe consequences

Greenland ice sheet: abrupt changes very unlikely in the 21st century

West Antarctic Ice Sheet: up to 4.8 m sea level rise; abrupt changes unlikely in the 21st century

Most likely (low-probability) rapid impact: ocean acidification



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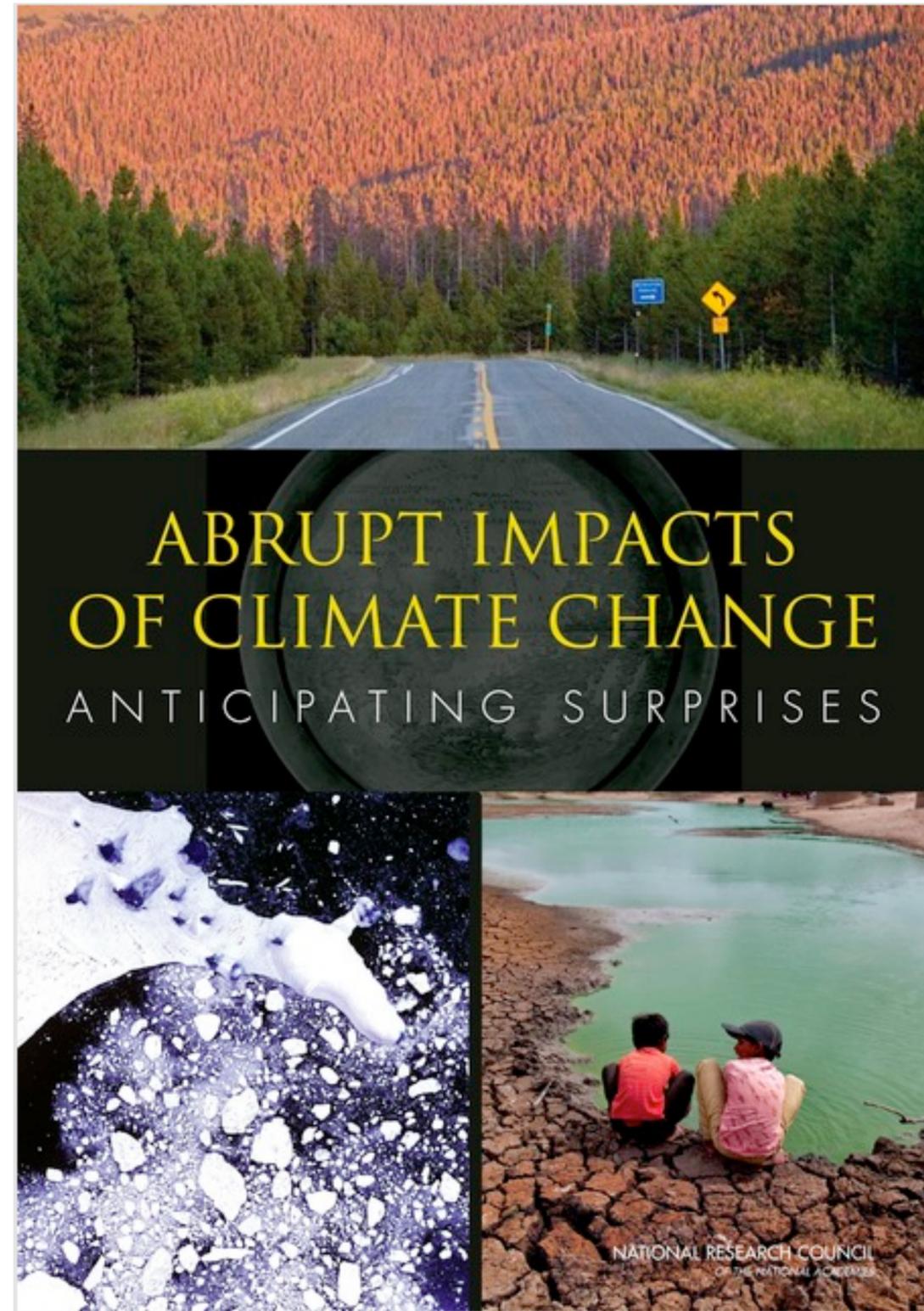
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There is the potential for surprises and new extremes ...



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www.nytimes.com/2014/05/13/science/earth/collapse-of-parts-of-west-antarctica-ice-sheet-has-begun-scientists-say.html?_r=1

International New York Times

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Scientists Warn of Rising Oceans From Polar Melt

By JUSTIN GILLIS and KENNETH CHANG MAY 12, 2014

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A large section of the mighty West Antarctica ice sheet has begun falling apart and its continued melting now appears to be unstoppable, two groups of scientists reported on Monday. If the findings hold up, they suggest that the melting could destabilize neighboring parts of the ice sheet and a rise in sea level of 10 feet or more may be unavoidable in coming centuries.

Global warming caused by the human-driven release of greenhouse gases has helped to destabilize the ice sheet, though other factors may also be involved, the scientists said.

The rise of the sea is likely to continue to be relatively slow for the rest of the 21st century, the scientists added, but in the more distant future it may accelerate markedly, potentially throwing society into crisis.

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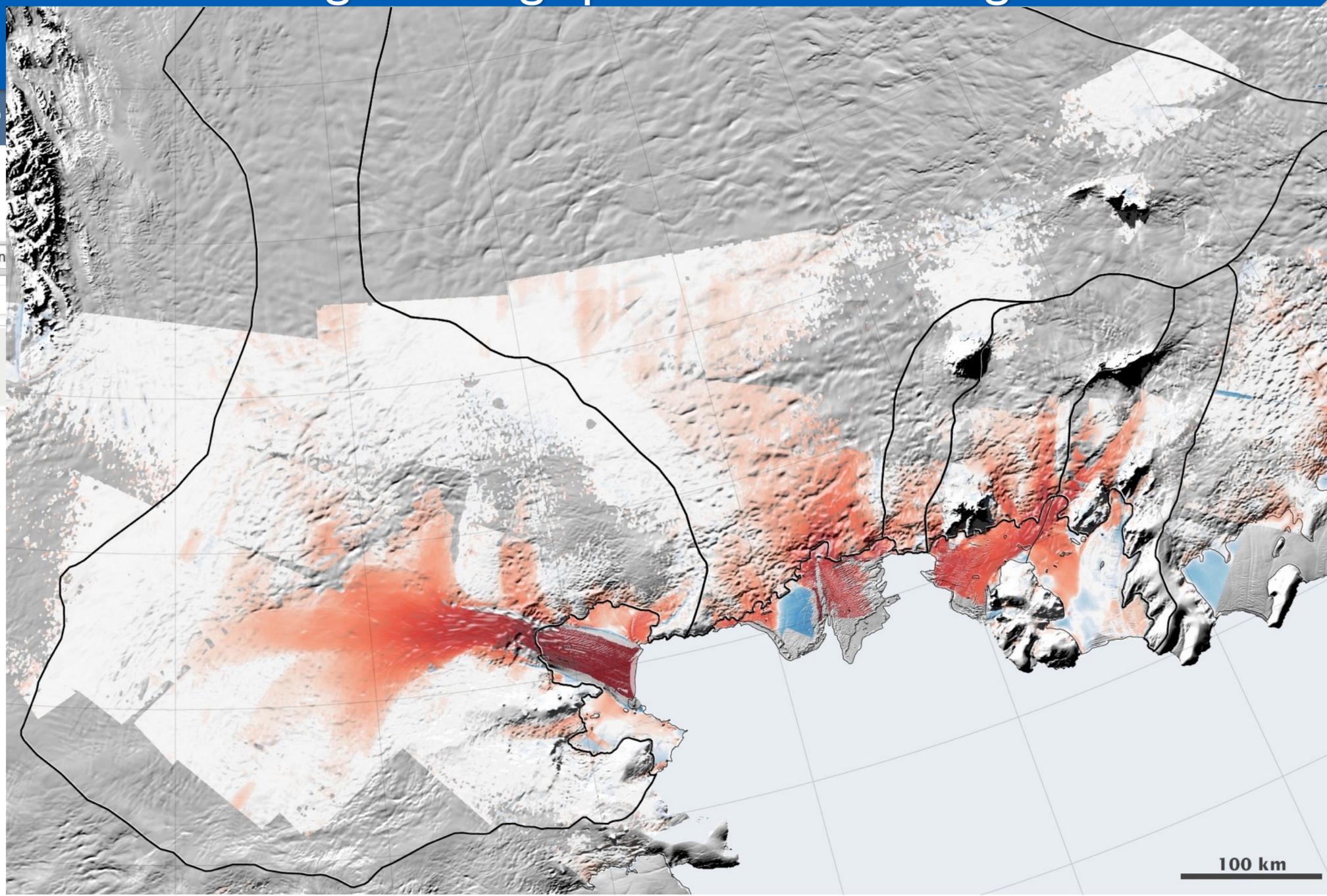
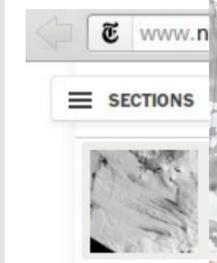
May 12, 2014: A large section of the mighty West Antarctic ice sheet has begun falling apart ... That's enough ice to raise



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OF CLIMATE CHANGE**
ANTICIPATING SURPRISES



There



Change in Velocity from 1996 to 2008
(kilometers per year)

<-1.5	-0.1	-0.01	0.01	0.1	>1.5
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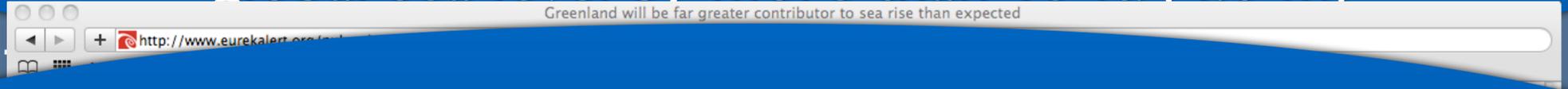
May 12, 2014: A large section of the mighty West Antarctic ice sheet has begun falling apart ... That's enough ice to raise global sea level by more than 15 ft. (4.6 m)

May 18, 2014: The glaciers of Greenland are likely to retreat faster and further inland than anticipated



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Greenland will be far greater contributor to sea rise than expected

Greenland will be far greater contributor to sea rise than expected

Major UCI-NASA work reveals long, deep valleys connecting ice sheet to the ocean

Irvine, Calif. – Greenland's icy reaches are far more vulnerable to warm ocean waters from climate change than had been thought, according to new research by UC Irvine and NASA glaciologists. The work, published today in *Nature Geoscience*, shows previously uncharted deep valleys stretching for dozens of miles under the Greenland Ice Sheet.

The bedrock canyons sit well below sea level, meaning that as subtropical Atlantic waters hit the fronts of hundreds of glaciers, those edges will erode much further than had been assumed and release far greater amounts of water.

Ice melt from the subcontinent has already accelerated as warmer marine currents have migrated north, but older models predicted that once higher ground was reached in a few years, the ocean-induced melting would halt. Greenland's frozen mass would stop shrinking, and its effect on higher sea waters would be curtailed.

"That turns out to be incorrect. The glaciers of Greenland are likely to retreat faster and farther inland than anticipated – and for much longer – according to this very different topography we've discovered beneath the ice," said lead author Mathieu Morlighem, a UCI associate project scientist. "This has major implications, because the glacier melt will contribute much more to rising seas around the globe."

To obtain the results, Morlighem developed a breakthrough method that for the first time offers a comprehensive view of Greenland's entire periphery. It's nearly impossible to accurately survey at ground level the subcontinent's rugged, rocky subsurface, which descends as much as 3 miles beneath the thick ice cap.

Since the 1970s, limited ice thickness data has been collected via radar pinging of the boundary between the ice and the bedrock. Along the coastline, though, rough surface ice and pockets of water cluttered the radar sounding, so large swaths of the bed remained invisible.

Measurements of Greenland's topography have tripled since 2009, thanks to NASA Operation IceBridge flights. But Morlighem quickly realized that while that data provided a fuller picture than had the earlier radar readings, there were still major gaps between the flight lines.

To reveal the full subterranean landscape, he designed a novel "mass conservation algorithm" that combined the previous ice thickness measurements with information on the velocity and direction of its movement and estimates of snowfall and surface melt.

The difference was spectacular. What appeared to be shallow glaciers at the very edges of Greenland are actually long, deep fingers stretching more than 100 kilometers (almost 65 miles) inland.

"We anticipate that these results will have a profound and transforming impact on computer models of ice sheet evolution in Greenland in a warming climate," the researchers conclude.

"Operation IceBridge vastly improved our knowledge of bed topography beneath the Greenland Ice Sheet," said co-author Eric Rignot of UC Irvine and NASA's Jet Propulsion Laboratory. "This new study takes a quantum leap at filling the remaining, critical data gaps on the map."

###

Other co-authors are Jeremie Mouginot of UC Irvine and Helene Seroussi and Eric Larour of JPL. Funding was provided by NASA.

The team also reported stark new findings last week on accelerated glacial melt in West Antarctica. Together, the papers "suggest that the globe's ice sheets will contribute far more to sea level rise than

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Global warming caused by the human-driven release of greenhouse gases has helped to destabilize the ice sheet, though other factors may also be involved, the scientists said.

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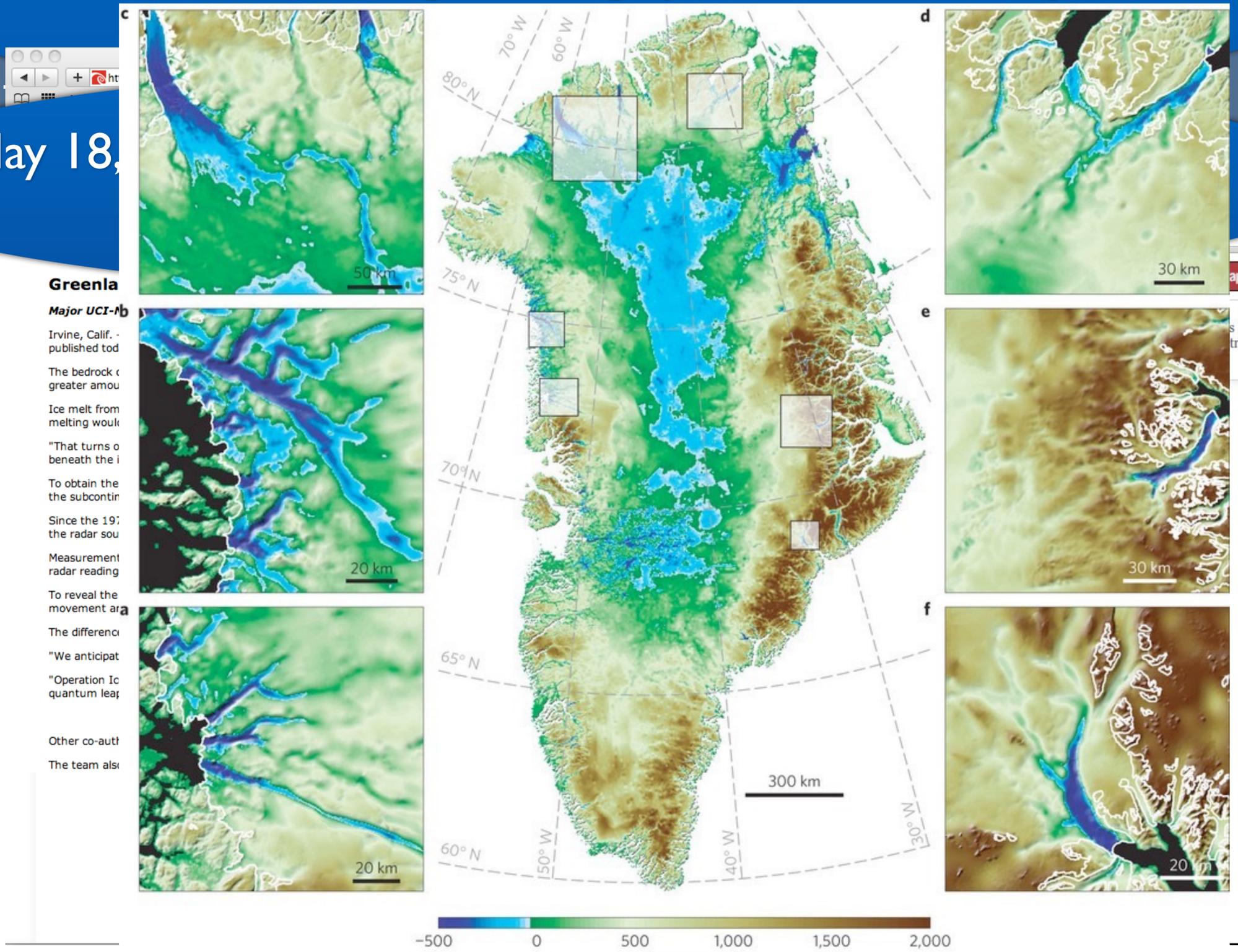
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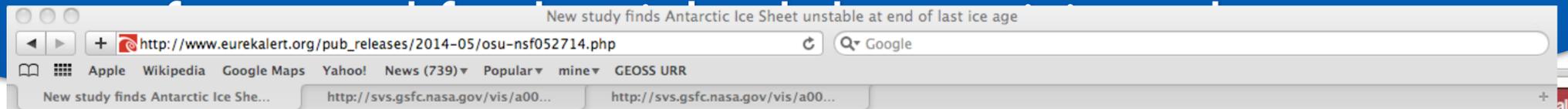
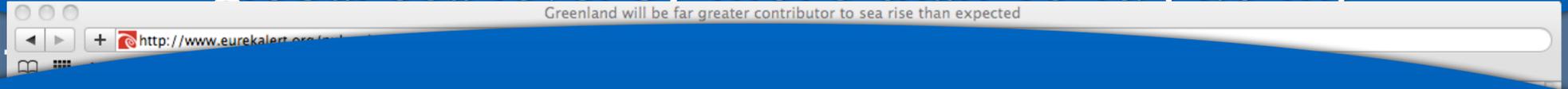
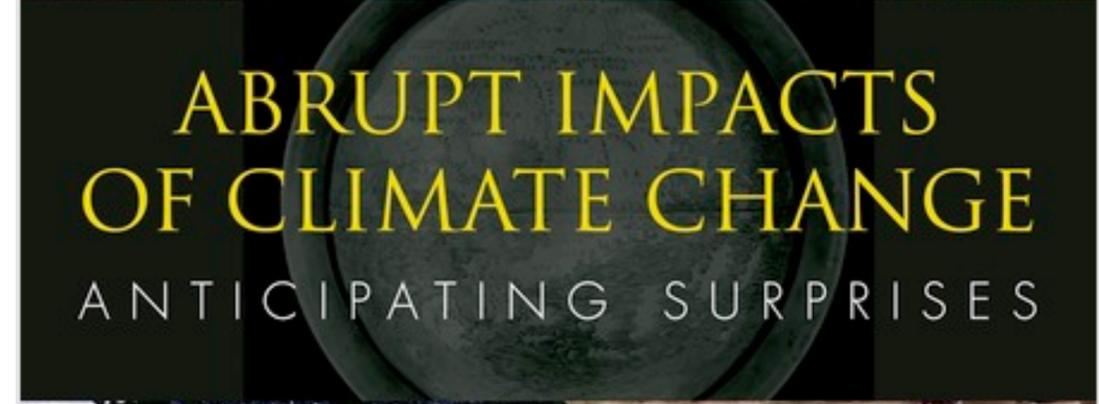
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May 18, 2014: The glaciers of Greenland are likely to retreat



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PUBLIC RELEASE DATE: 28-May-2014

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Contact: Peter Clark
clarkp@geo.oregonstate.edu
541-740-5237
Oregon State University

New study finds Antarctic Ice Sheet unstable at end of last ice age

CORVALLIS, Ore. – A new study has found that the Antarctic Ice Sheet began melting about 5,000 years earlier than previously thought coming out of the last ice age – and that shrinkage of the vast ice sheet accelerated during eight distinct episodes.

The international study, funded in part by the National Science Foundation, found that the melting of the West Antarctic Ice Sheet began about 5,000 years earlier than previously thought, and that shrinkage of the vast ice sheet accelerated during eight distinct episodes.

Results of this latest study were published in the journal *Nature* on May 28, 2014. The study was led by Peter Clark, a professor in Oregon State University's College of Earth, Ocean, and Atmospheric Sciences, and co-authored by Axel Timmermann, a climate researcher at the University of Hawaii at Manoa.

The researchers used sediment cores from the Alfred-Wegener Institute in Antarctica to study the ice sheet's behavior at the past behavior.

Periods of rapid increase in sea level rise and of debris during eight separate episodes.

The melting of the Antarctic Ice Sheet was not a steady process, and that its decline was slow and steady until it reached its present size," said Clark.

"The sediment record suggests a different pattern – one that is more episodic and suggests that parts of the ice sheet repeatedly became unstable during the last deglaciation," Weber added.

The research also provides the first solid evidence that the Antarctic Ice Sheet contributed to what is known as meltwater pulse 1A, a period of very rapid sea level rise that began some 14,500 years ago, according to Peter Clark, an Oregon State University paleoclimatologist and co-author on the study.

The largest of the eight episodic pulses outlined in the new *Nature* study coincides with meltwater pulse 1A.

"During that time, the sea level on a global basis rose about 50 feet in just 350 years – or about 20 times faster than sea level rise over the last century," noted Clark, a professor in Oregon State's College of Earth, Ocean, and Atmospheric Sciences. "We don't yet know what triggered these eight episodes or pulses, but it appears that once the melting of the ice sheet began it was amplified by physical processes."

The researchers suspect that a feedback mechanism may have accelerated the melting, possibly by changing ocean circulation that brought warmer water to the Antarctic subsurface, according to co-author Axel Timmermann, a climate researcher at the University of Hawaii at Manoa.

"This positive feedback is a perfect recipe for rapid sea level rise," Timmermann said.

May 28, 2014: During that time, the sea level on a global basis rose about 50 feet in just 350 years

August 29, 2015: "The critical question thus becomes: Is Greenland likely to lose even more ice than it's currently losing per year — and could Antarctica do the same?"



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May 18, 2015

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clarkp@geo.oregonsta
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New study fi
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1&1 Mail Basic Plag, Ha Peter - Outlook Web App On The Edge (@RunningInFog) | Twitter Why NASA's so worried that Greenl...

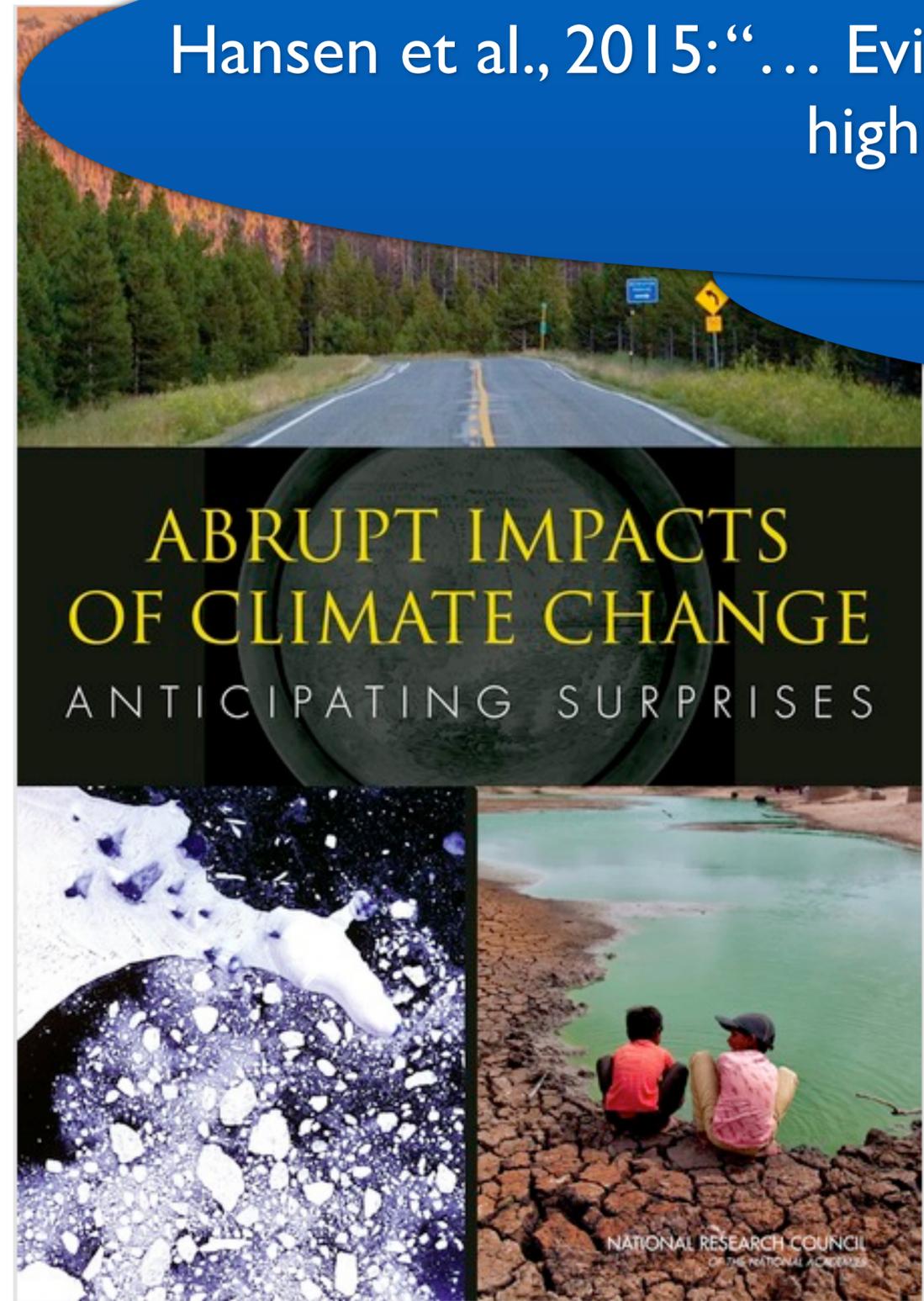
Why NASA's so worried that Greenland's melting could speed up

By Chris Mooney August 29



Hansen et al., 2015: "The critical question thus becomes:

Hansen et al., 2015: "... Evidence ... that 2°C global warming is highly dangerous."



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Atmos. Chem. Phys. Discuss., 15, 20059-20179, 2015
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doi:10.5194/acpd-15-20059-2015
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Research Article 23 Jul 2015

Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous

J. Hansen¹, M. Sato¹, P. Hearty², R. Ruedy^{3,4}, M. Kelley^{3,4}, V. Masson-Delmotte⁵, G. Russell⁴, G. Tselioudis⁴, J. Cao⁶, E. Rignot^{7,8}, I. Velicogna^{7,8}, E. Kandiano⁹, K. von Schuckmann¹⁰, P. Kharecha^{1,4}, A. N. Legrande⁴, M. Bauer¹¹, and K.-W. Lo^{3,4}

¹Climate Science, Awareness and Solutions, Columbia University Earth Institute, New York, NY 10115, USA
²Department of Environmental Studies, University of North Carolina at Wilmington, North Carolina 28403, USA
³Trinnovium LLC, New York, NY 10025, USA
⁴NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
⁵Institut Pierre Simon Laplace, Laboratoire des Sciences du Climat et de l'Environnement (CEA-CNRS-UVSQ), Gif-sur-Yvette, France
⁶Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China
⁷Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 91109, USA
⁸Department of Earth System Science, University of California, Irvine, California, 92697, USA
⁹GEOMAR, Helmholtz Centre for Ocean Research, Wischhofstrasse 1-3, Kiel 24148, Germany
¹⁰Mediterranean Institute of Oceanography, University of Toulon, La Garde, France
¹¹Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY, 10027, USA

Received: 11 Jun 2015 – Accepted: 09 Jul 2015 – Published: 23 Jul 2015

Abstract. There is evidence of ice melt, sea level rise to +5–9 m, and extreme storms in the prior interglacial period that was less than 1 °C warmer than today. Human-made climate forcing is stronger and more rapid than paleo forcings, but much can be learned by combining insights from

Journal metrics
IF 5.053

Energy and Environment

Scientists find more reasons that Greenland will melt faster

By Chris Mooney April 30 ✉️



Photograph of Torsukatat Avannarleq, a tidewater glacier in West Greenland, with 2 visible sediment plumes at its terminus. These plumes are made up of

Energy and Environment

Dominoes fall: Vanishing Arctic ice shifts jet stream, which melts Greenland glaciers

By Chelsea Harvey May 2 ✉️



Iceberg, with Mount Dundas in the background, Qaasuitsup, west Greenland, Denmark. (Photo by DeAgostini/Getty Images)

How solid is our knowledge?

Example sea level rise

Accepted knowledge in 2000:

Greenland: no significant contribution to sea level rise

Antarctica: minor contribution

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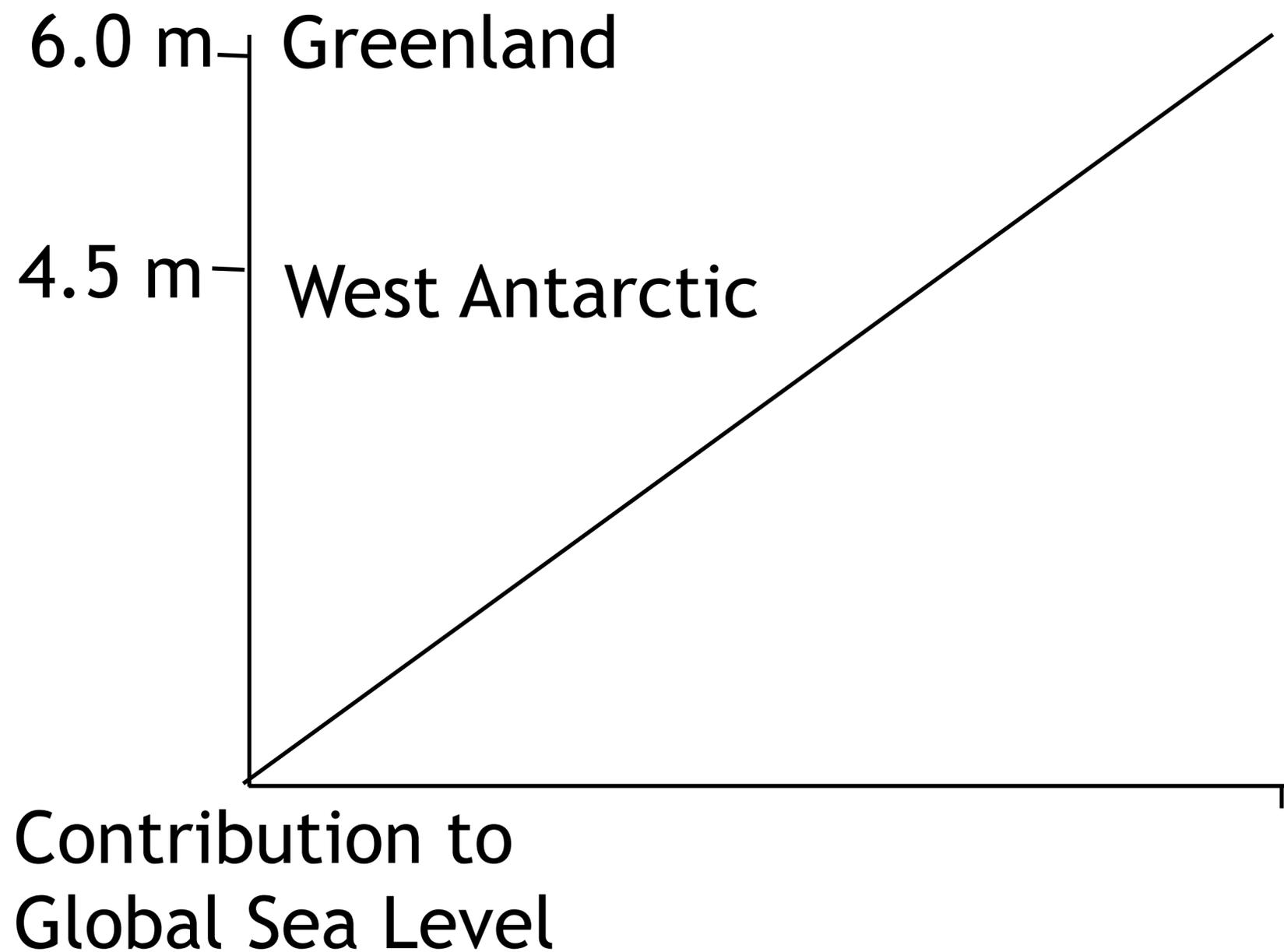
Main contribution: steric changes

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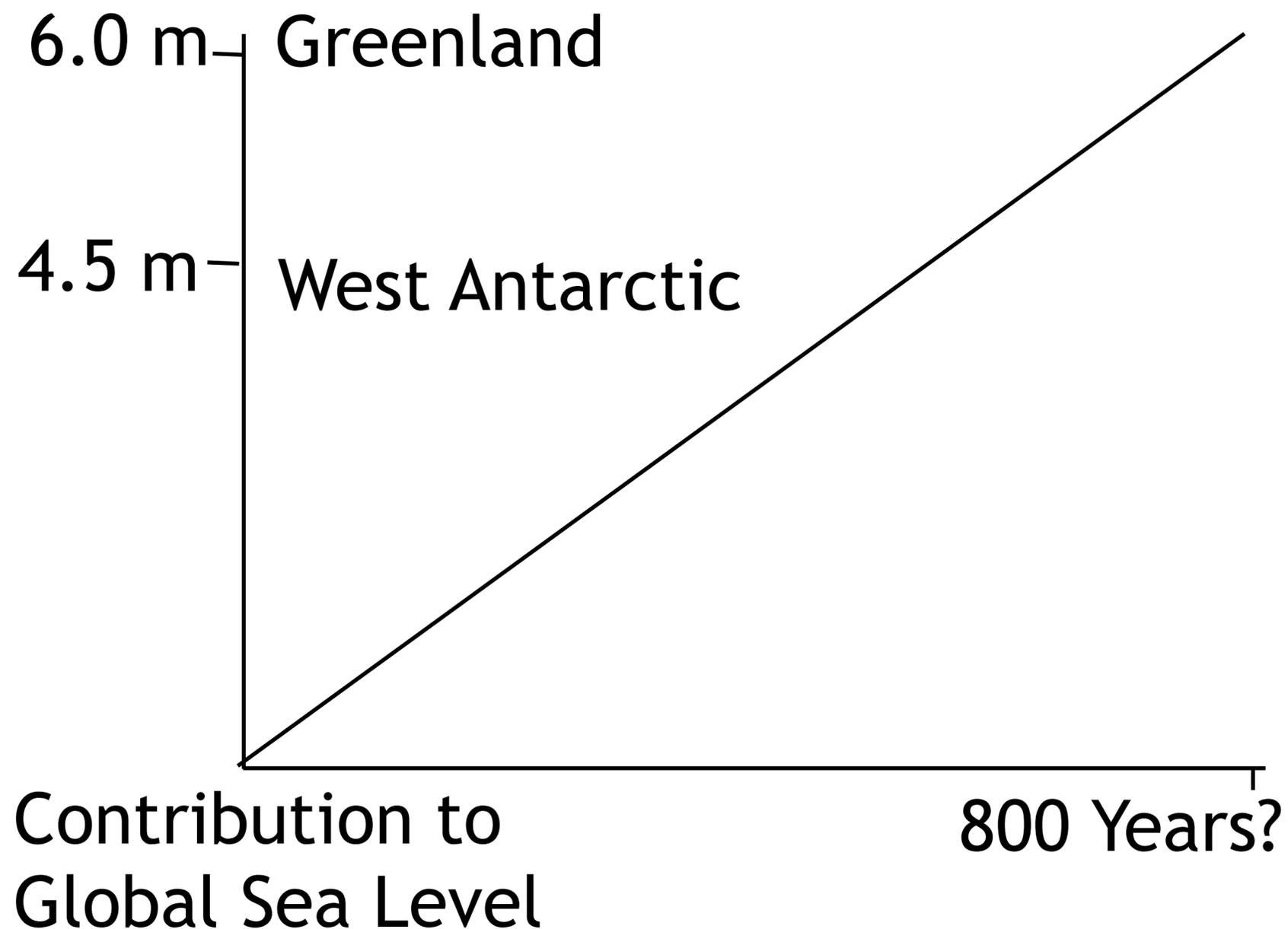
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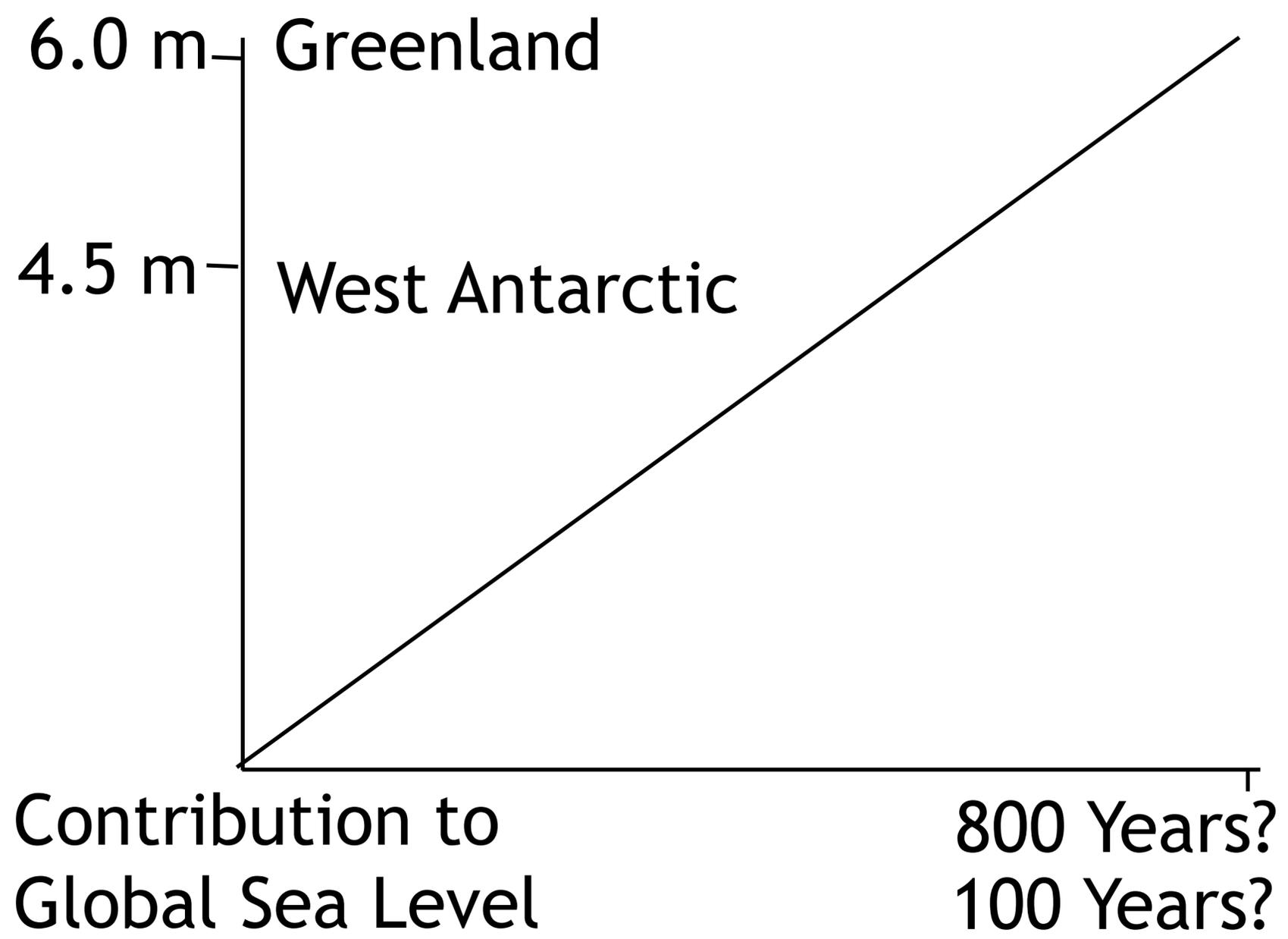
Main contribution: steric changes

Knowledge in 2016:

Greenland: is contributing, is accelerating; increasing potential for a large contribution to sea level rise due to deep warm water around Greenland and impact of changes in atmospheric circulation.

Antarctica: West Antarctic ice sheet (WAIS) will contribute 4.5 m

How solid is our knowledge?



Example sea level rise

Accepted knowledge in 2000:

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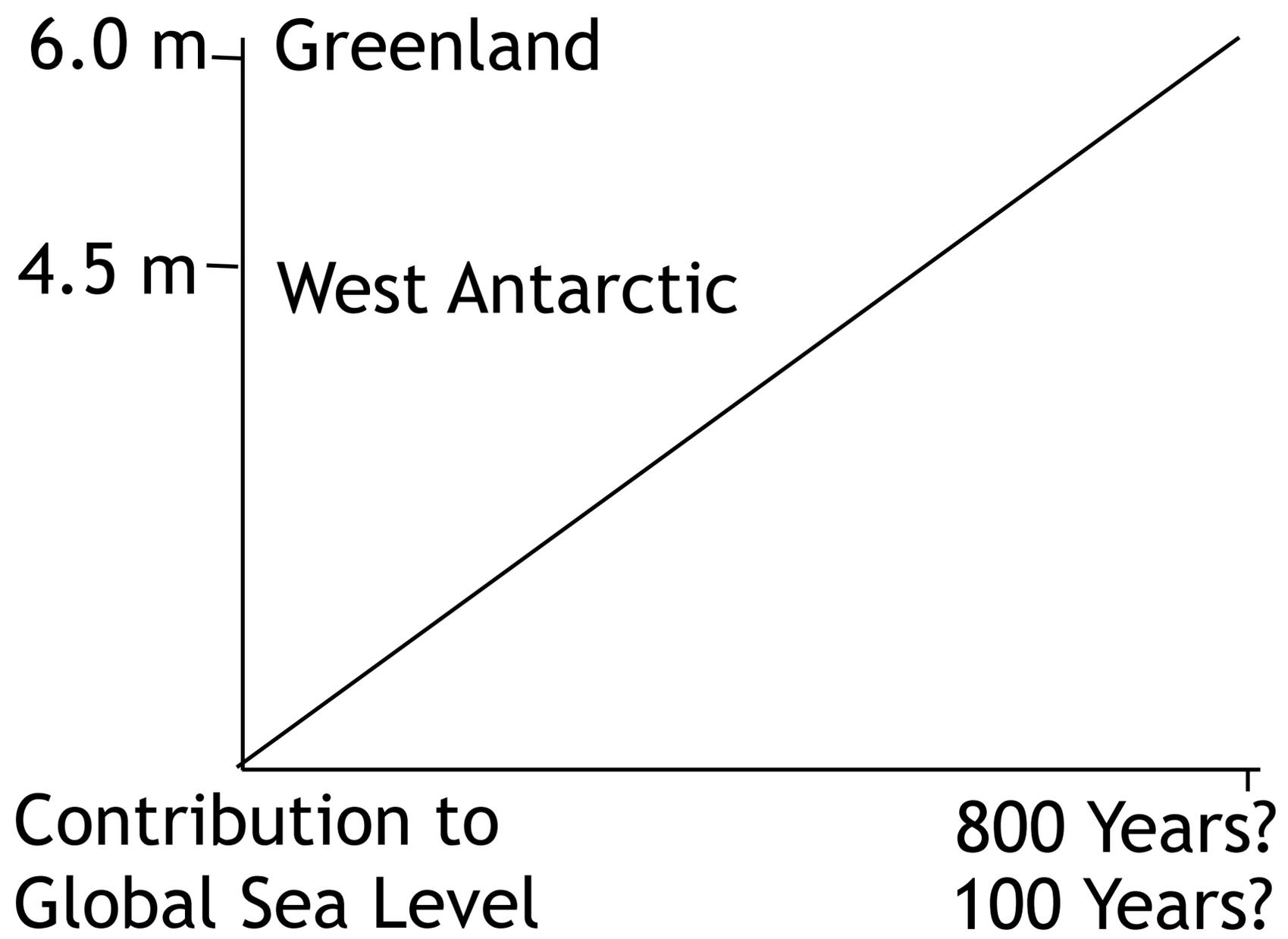
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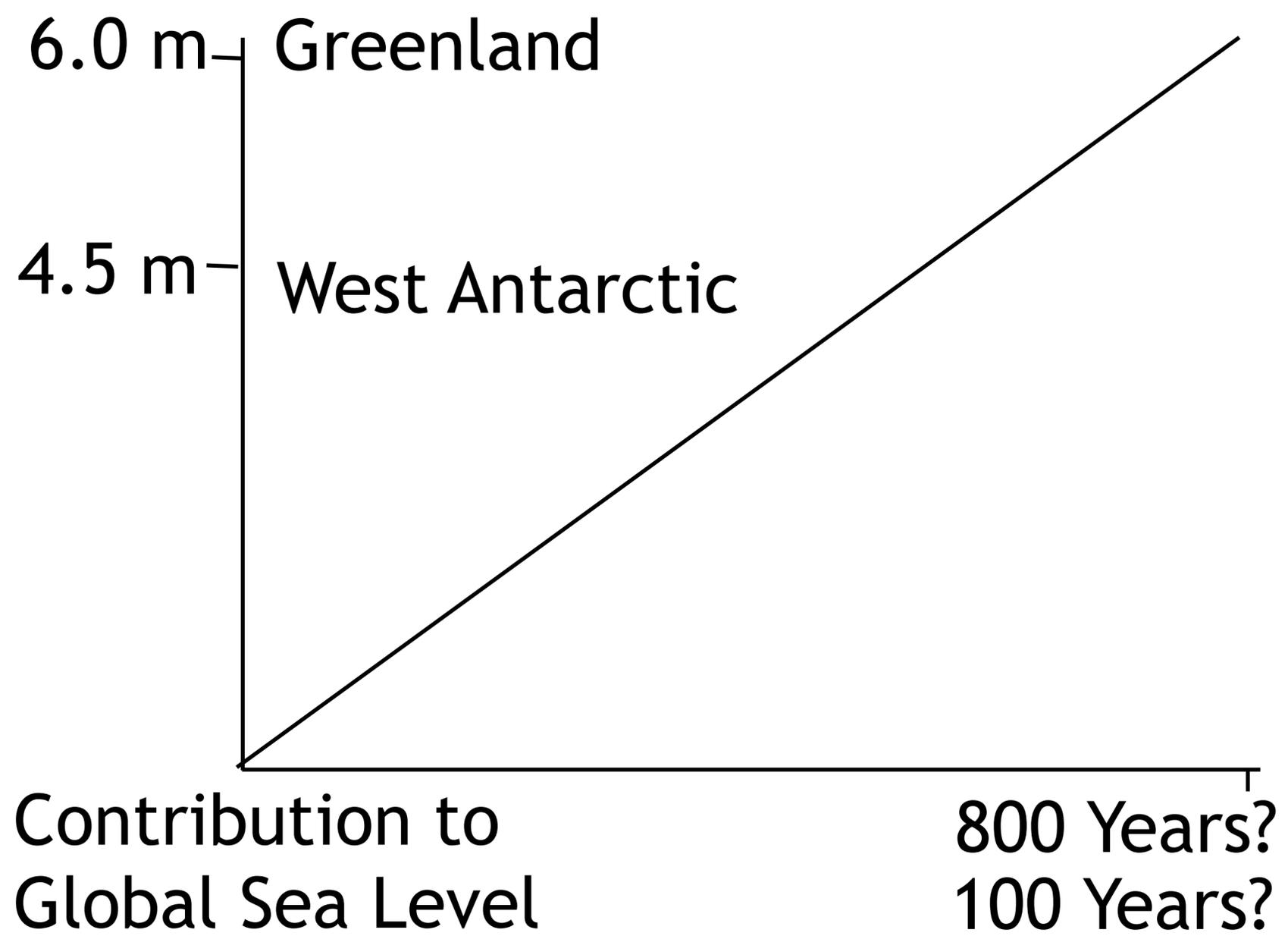
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How worried should we be?

How solid is our knowledge?



Example sea level rise

Accepted knowledge in 2000:

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How worried should we be?

What should we be worried about?