Mitigation and Adaptation Studies

Class 18: Knowing the Hazards: Climate Hazards, Public Health, Food-Water-Energy Nexus

Contents:

- Preliminaries
- Climate Change and Sea Level Hazards
  - Observing the Planet
  - Detecting Changes
  - Assessing Knowledge
  - Understanding the Processes and Causes
  - Having Foresight
- Public Health
- Food-Water-Energy Nexus

Complexity, creeping normalcy and conceit: sexy and unsexy catastrophic risks

Author(s): Karin Kuhlemann , (School of Public Policy, University College London, London, UK)

Purpose

This paper aims to consider few cognitive and conceptual obstacles to engagement with global catastrophic risks (GCRs).

Design/methodology/approach

The paper starts by considering cognitive biases that affect general thinking about GCRs, before questioning whether existential risks really are dramatically more pressing than other GCRs. It then sets out a novel typology of GCRs – sexy vs unsexy risks – before considering a particularly unsexy risk, overpopulation.

Findings

It is proposed that many risks commonly regarded as existential are “sexy” risks, while certain other GCRs are comparatively “unsexy.” In addition, it is suggested that a combination of complexity, cognitive biases and a hubris-laden failure of imagination leads us to neglect the most unsexy and pervasive of all GCRs: human overpopulation. The paper concludes with a tentative conceptualisation of overpopulation as a pattern of risking.

Kuhlemann, K., 2019. Foresight, Vol. 21(1), 35-52.

Complexity, creeping normalcy and conceit: sexy and unsexy catastrophic risks

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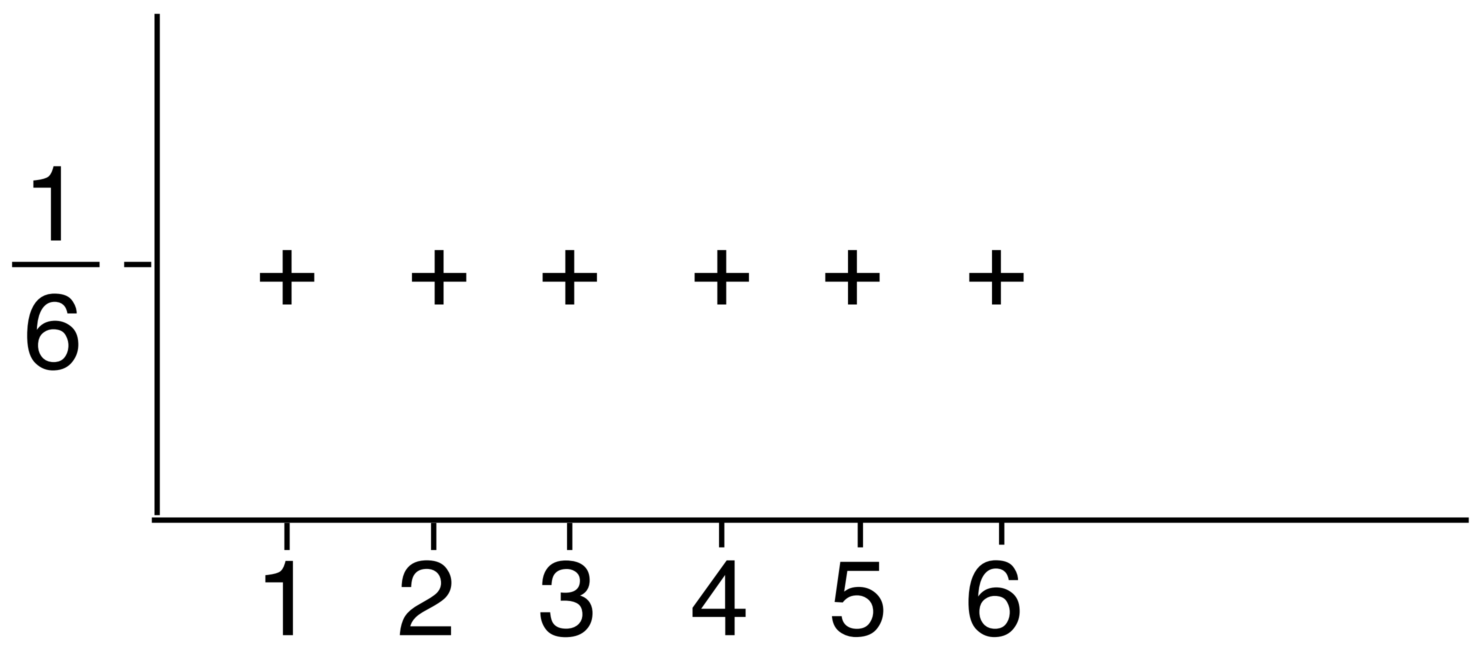
Before delving into the existential vs sub-existential and sexy vs unsexy dichotomies, it is useful to consider three cognitive weaknesses[2] that hinder recognition, engagement and rational responses to GCRs: probabilistic thinking, caring about people we cannot see and valuing the future.

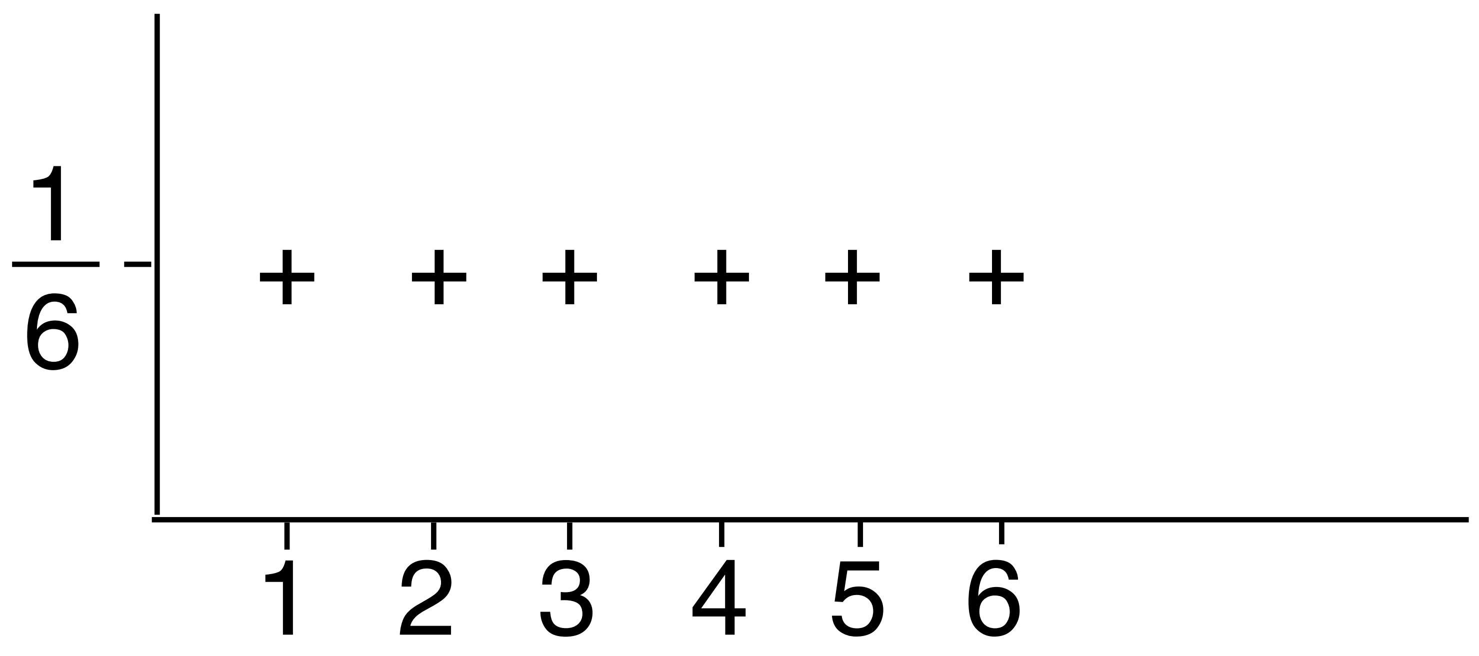
First, and stating the obvious, GCRs are risks. Engaging with risks of any kind requires probabilistic thinking, at which human beings in general are notoriously poor (Dawes, 2001; Tversky & Kahneman, 1974). We tend to inappropriately focus on specific rather than general information, neglecting base rates (Tversky and Kahneman, 1982; Welsh and Navarro, 2012). We are prone to overestimating the probability of positive events and underestimating the likelihood of negative ones (Sharot, 2011), in particular when predicting what will happen to ourselves (Weinstein and Klein, 1995; Weinstein, 1980, 1989) or those we care about (Kappes et al., 2018). We tend to be particularly optimistic in predicting outcomes that will not be known for some time (Armor & Taylor, 2002, pp. 339-340), and our optimistic beliefs tend to persevere even in the face of contrary evidence (Garrett and Sharot, 2017). Faced with information about a risk, we tend to assume that it will not actually materialise, or that its consequences will not really be catastrophic.

Probability Density Function

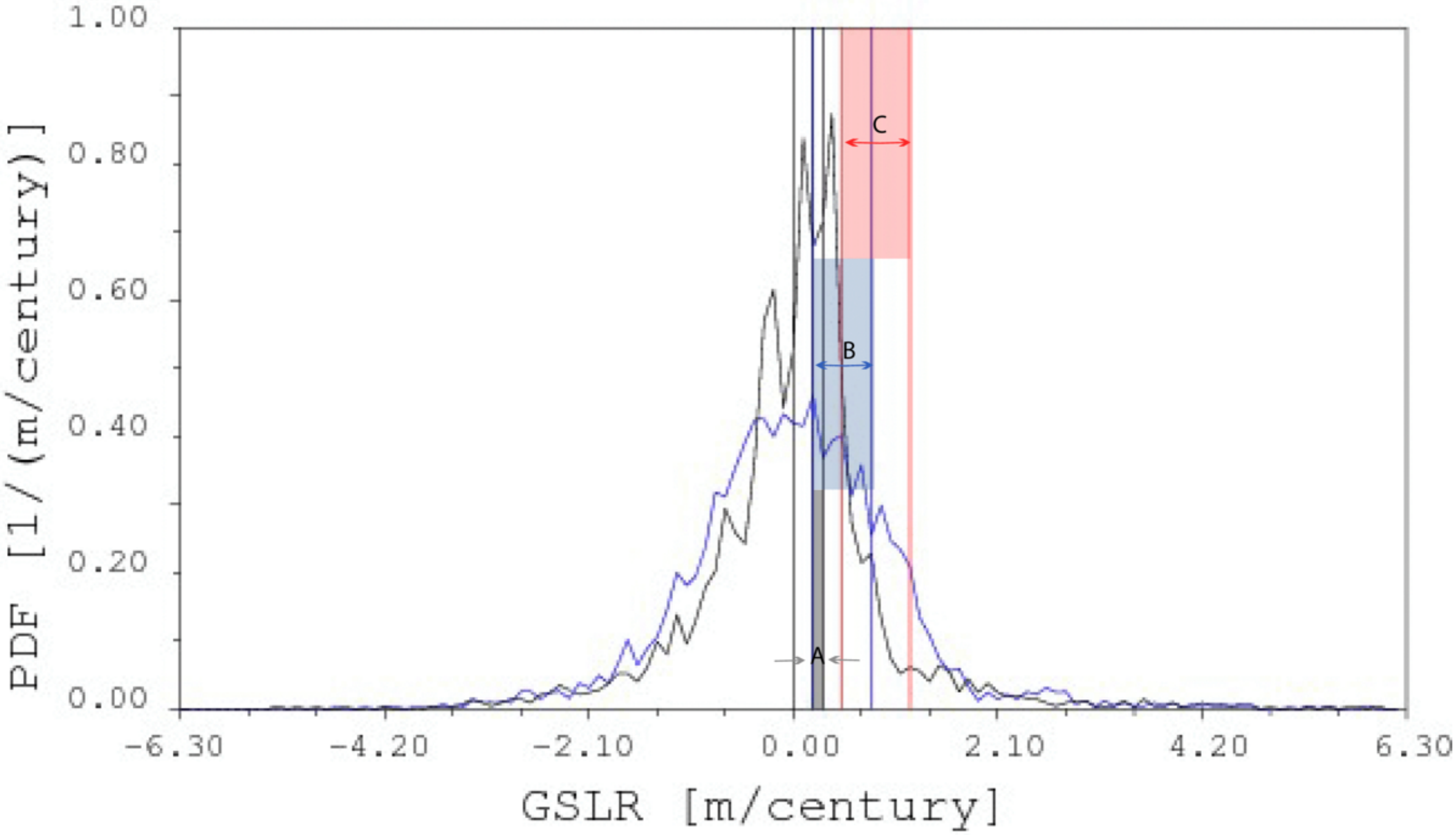
Dice



Probability Density Function
Dice



Probability Density Function
Global sea-level rise per century



Probability Density Function
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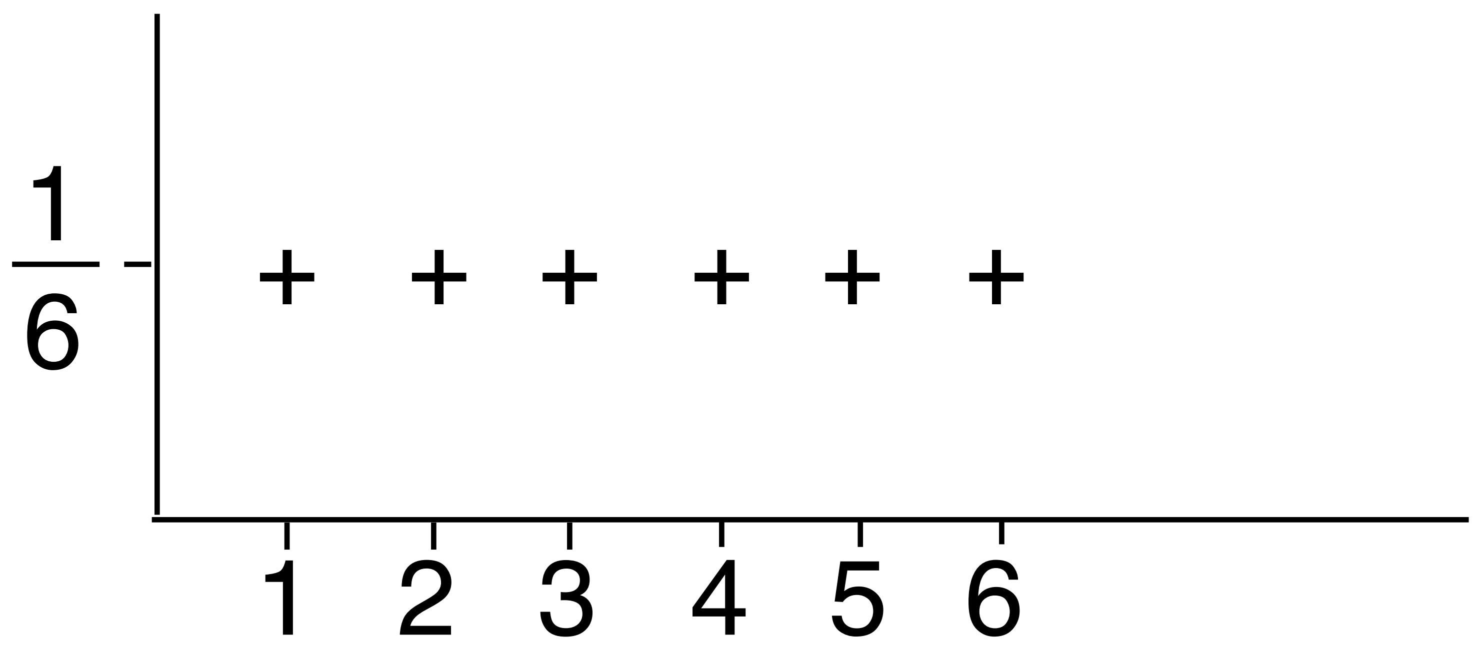

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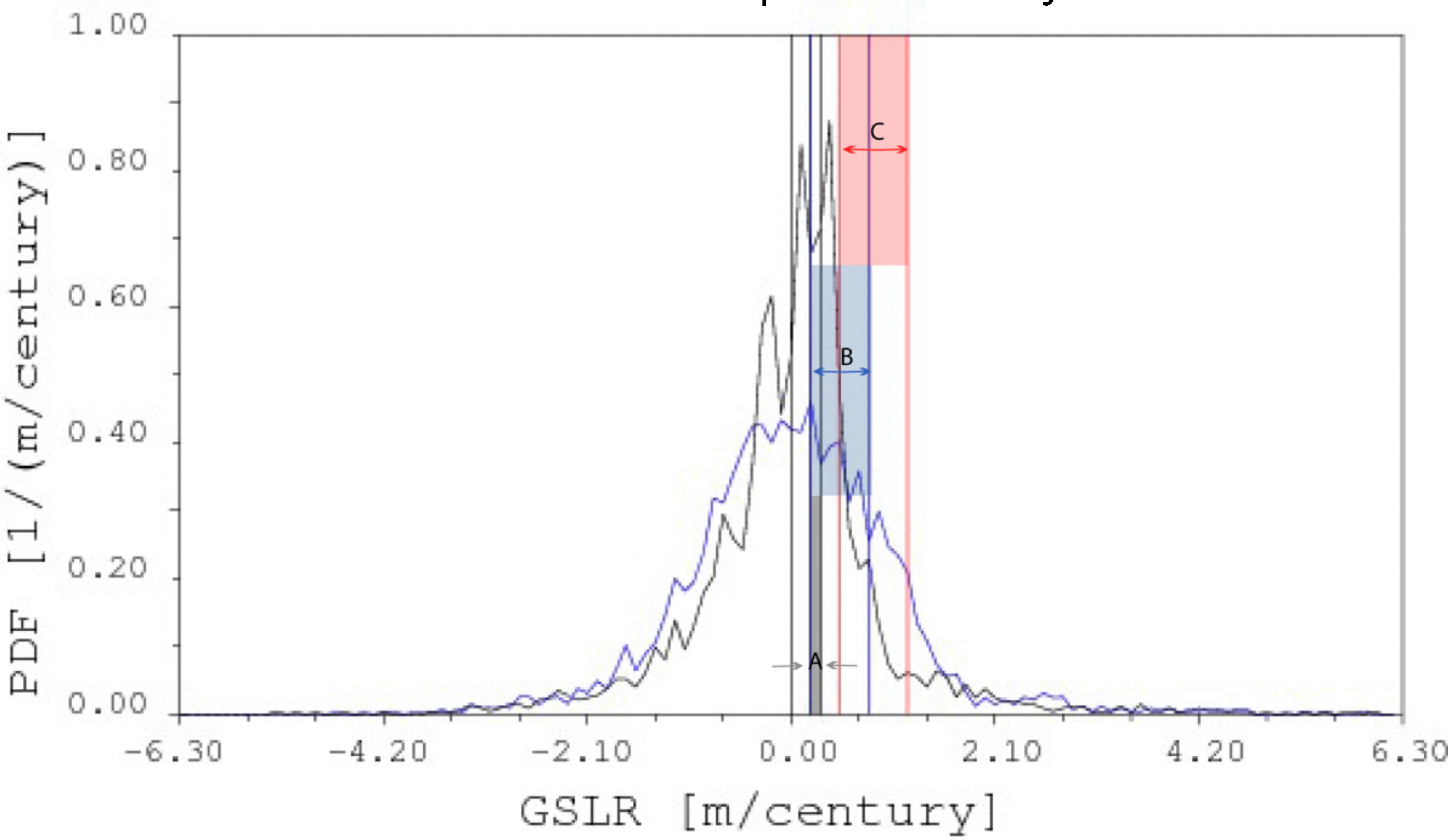
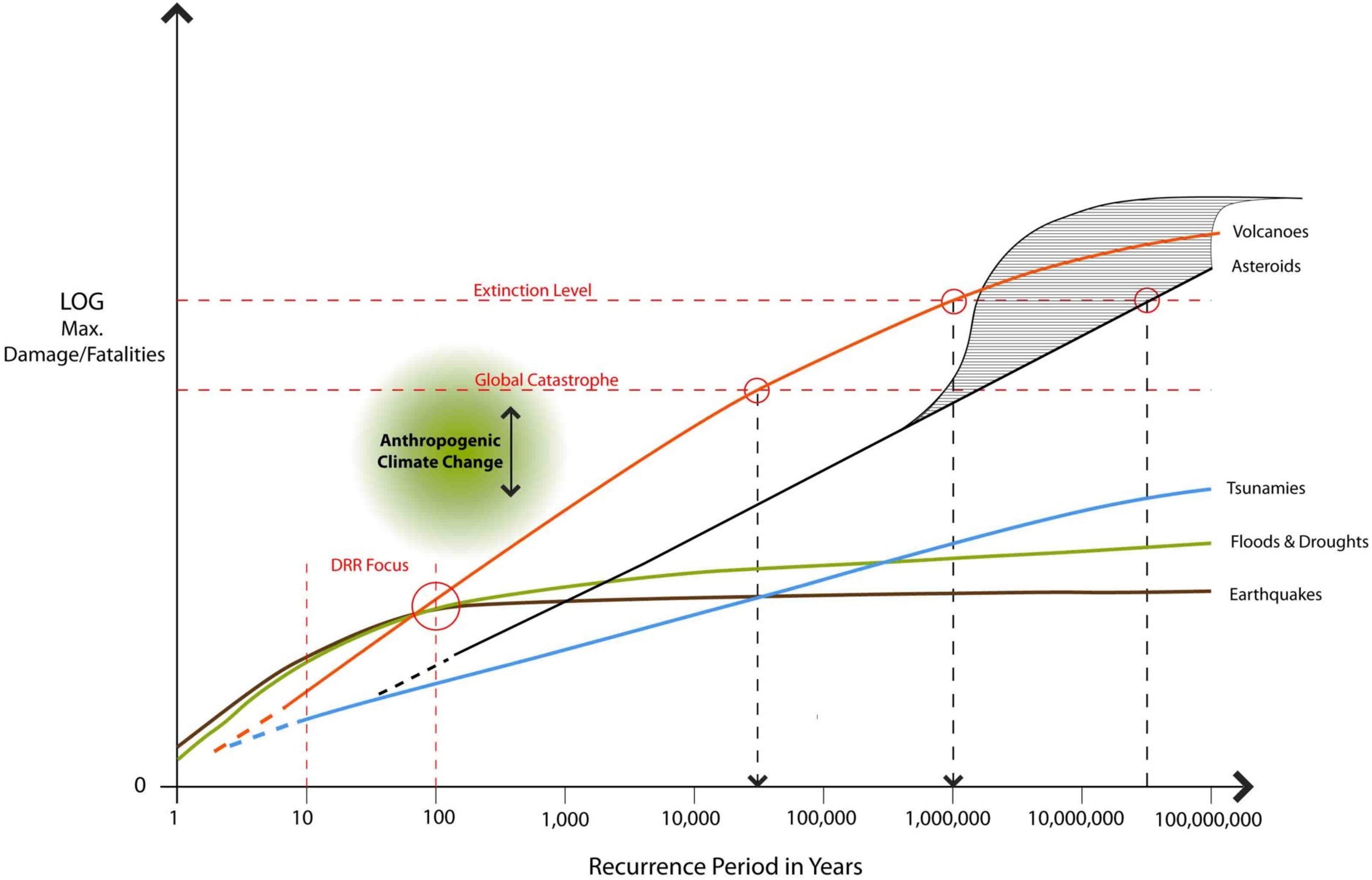
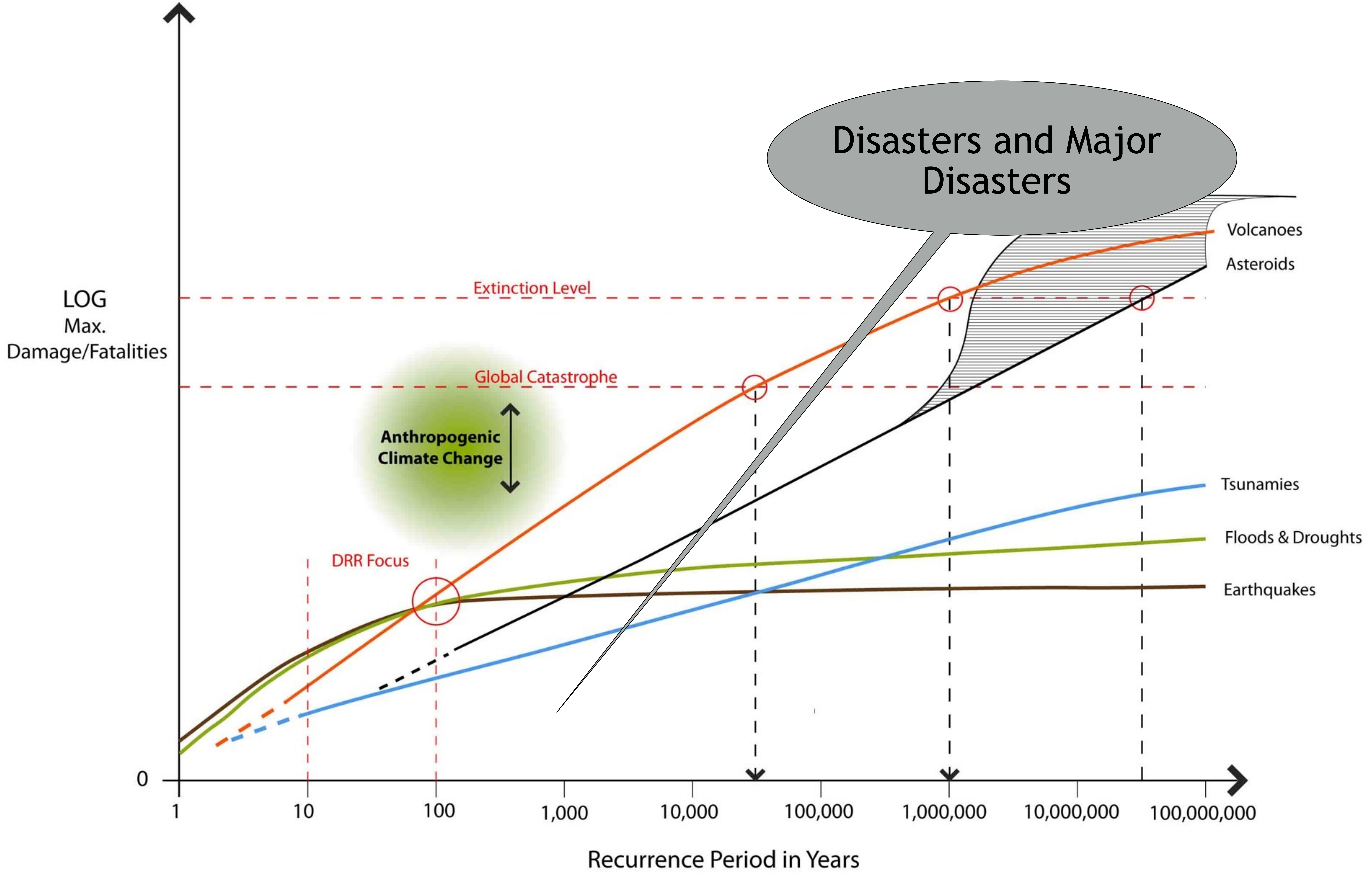


Knowing the probability density function of a hazard

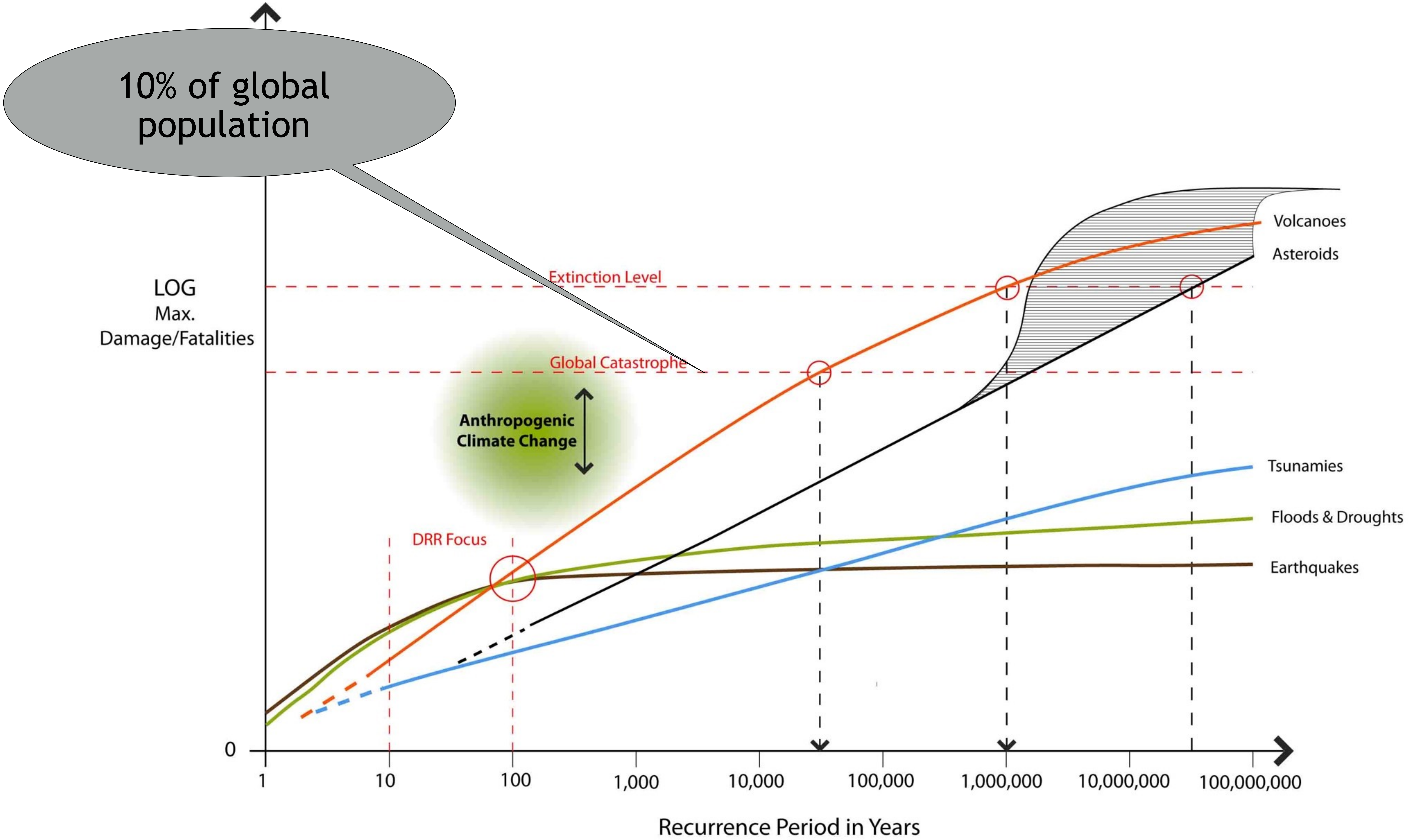
Preliminaries

Preliminaries




Disasters and Major Disasters
LOG
Max.
Damage/Fatalities
Extinction Level
Global Catastrophe
Anthropogenic
Climate Change
DRR Focus
Volcanoes
Asteroids
Tsunamies
Floods & Droughts
Earthquakes
0
1
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
Recurrence Period in Years

Preliminaries



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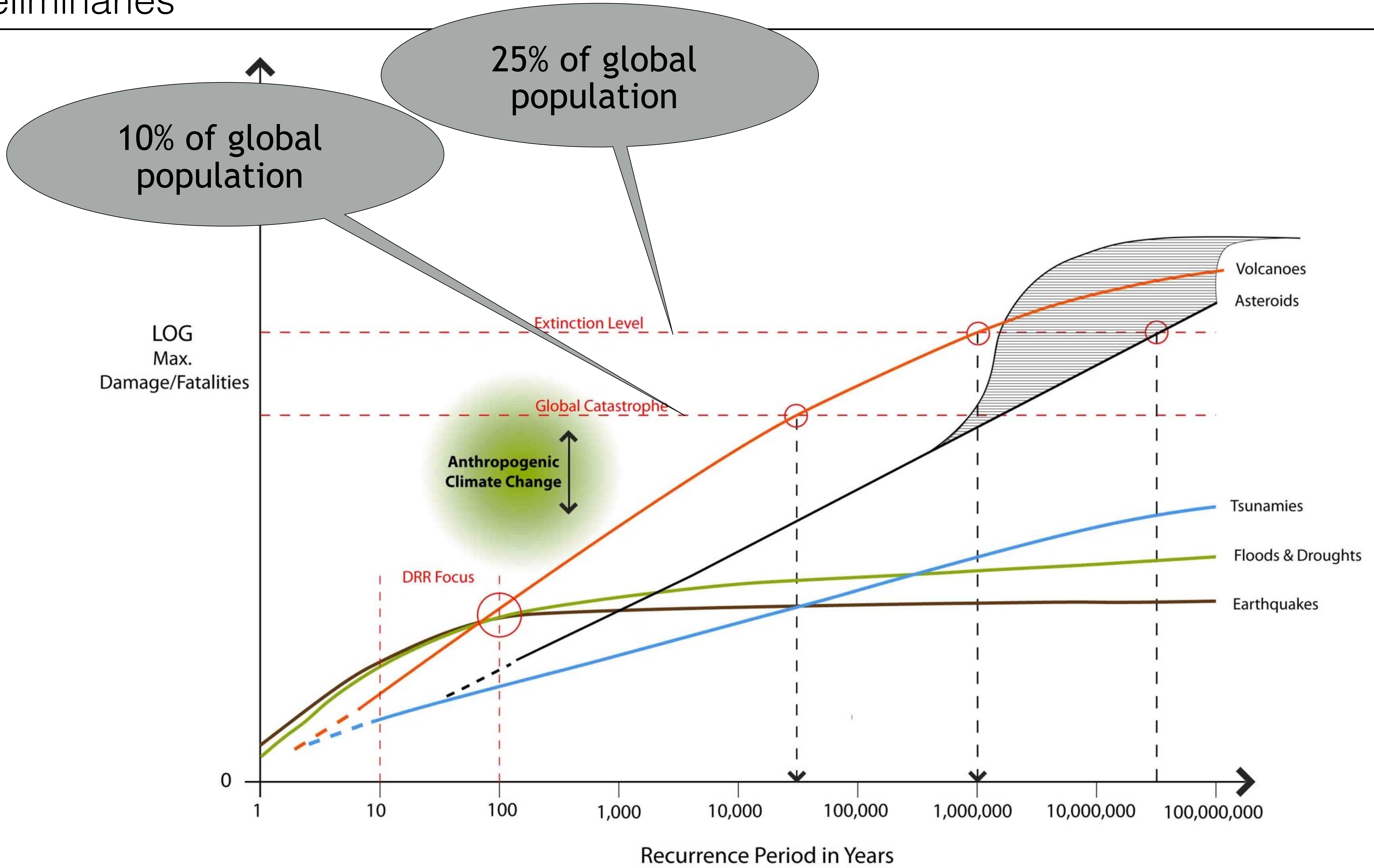

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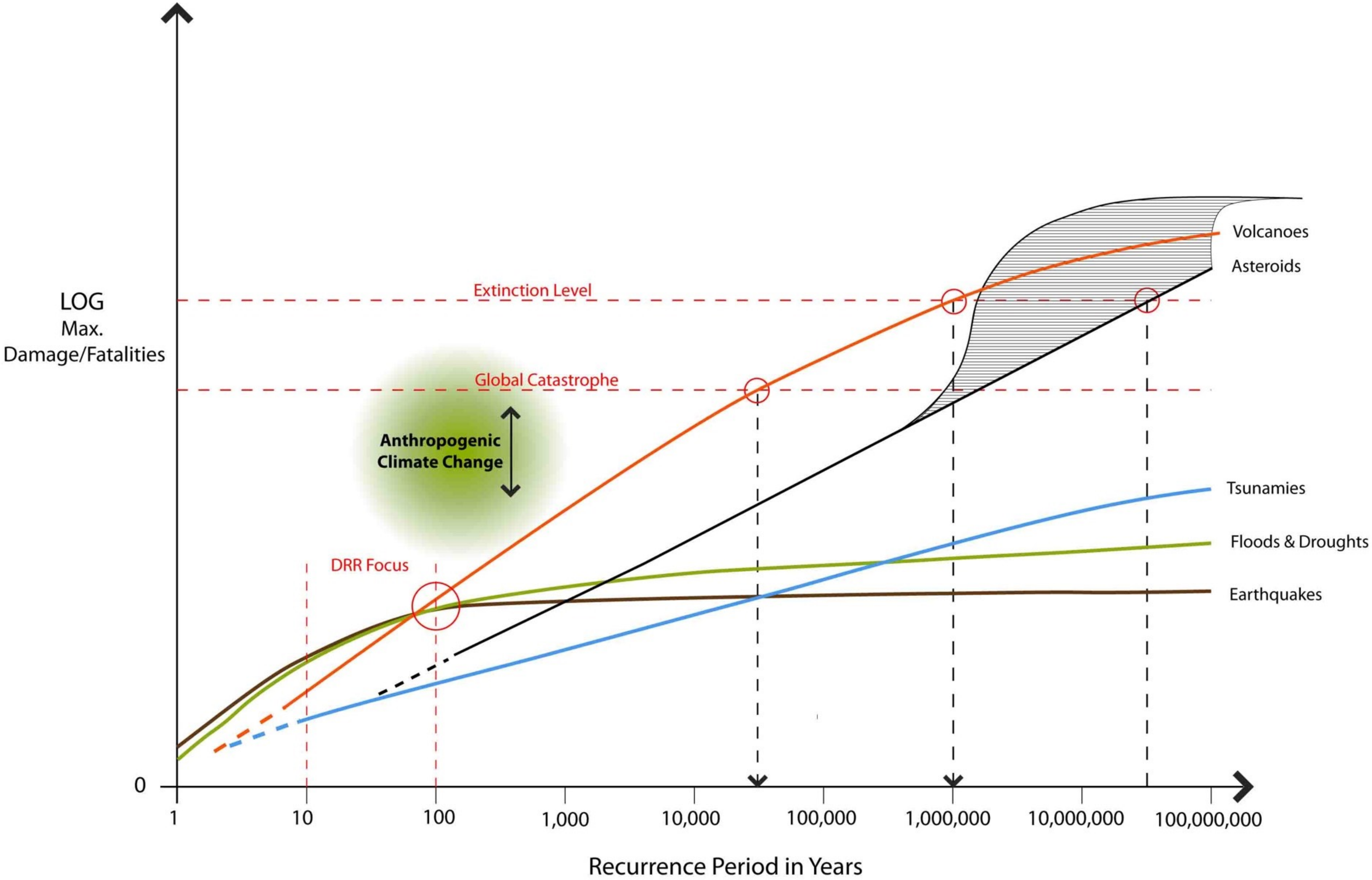
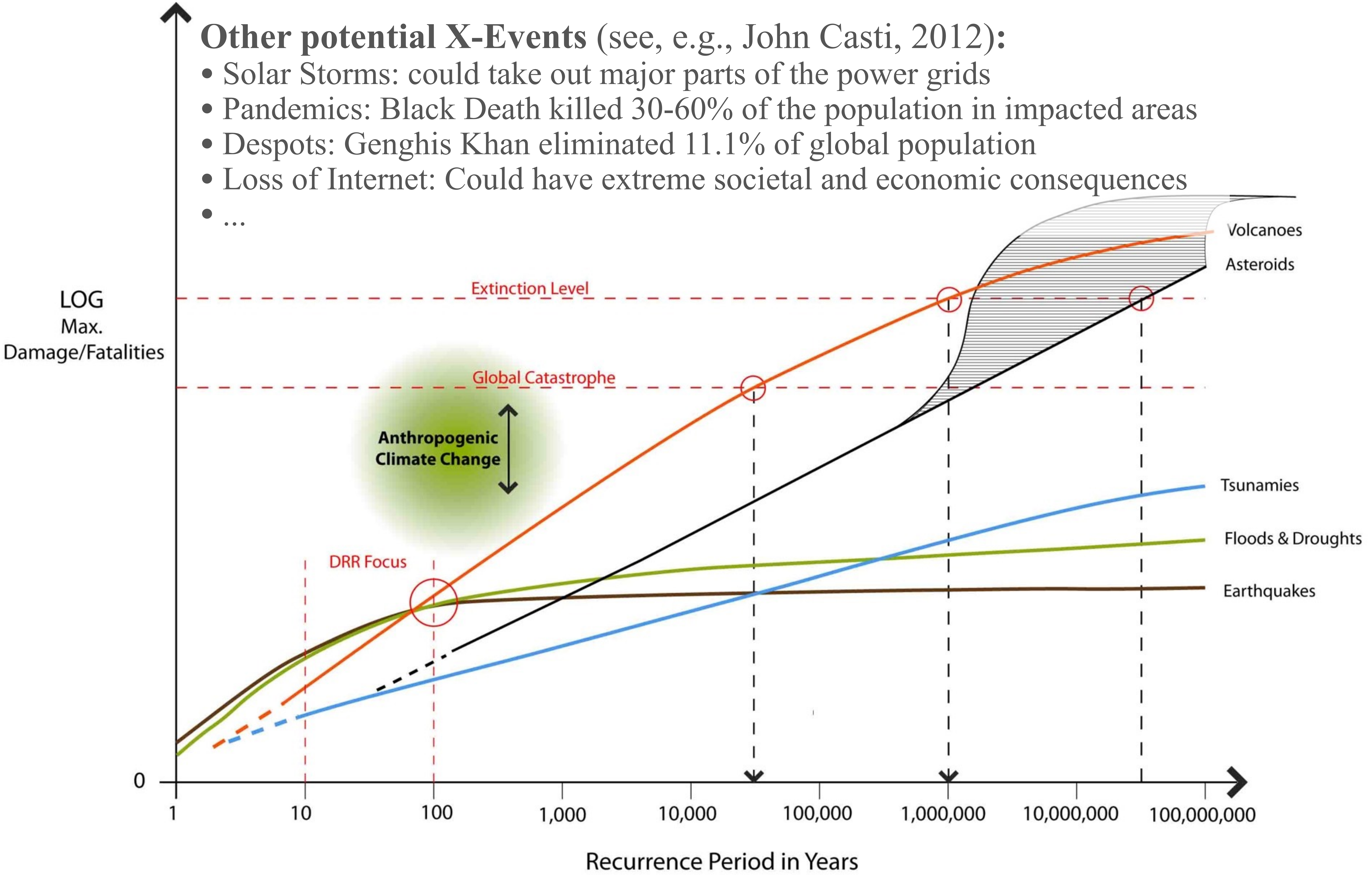


Preliminaries

Other potential X-Events (see, e.g., John Casti, 2012)**:**

- Solar Storms: could take out major parts of the power grids
- Pandemics: Black Death killed 30-60% of the population in impacted areas
- Despots: Genghis Khan eliminated 11.1% of global population
- Loss of Internet: Could have extreme societal and economic consequences
- ...



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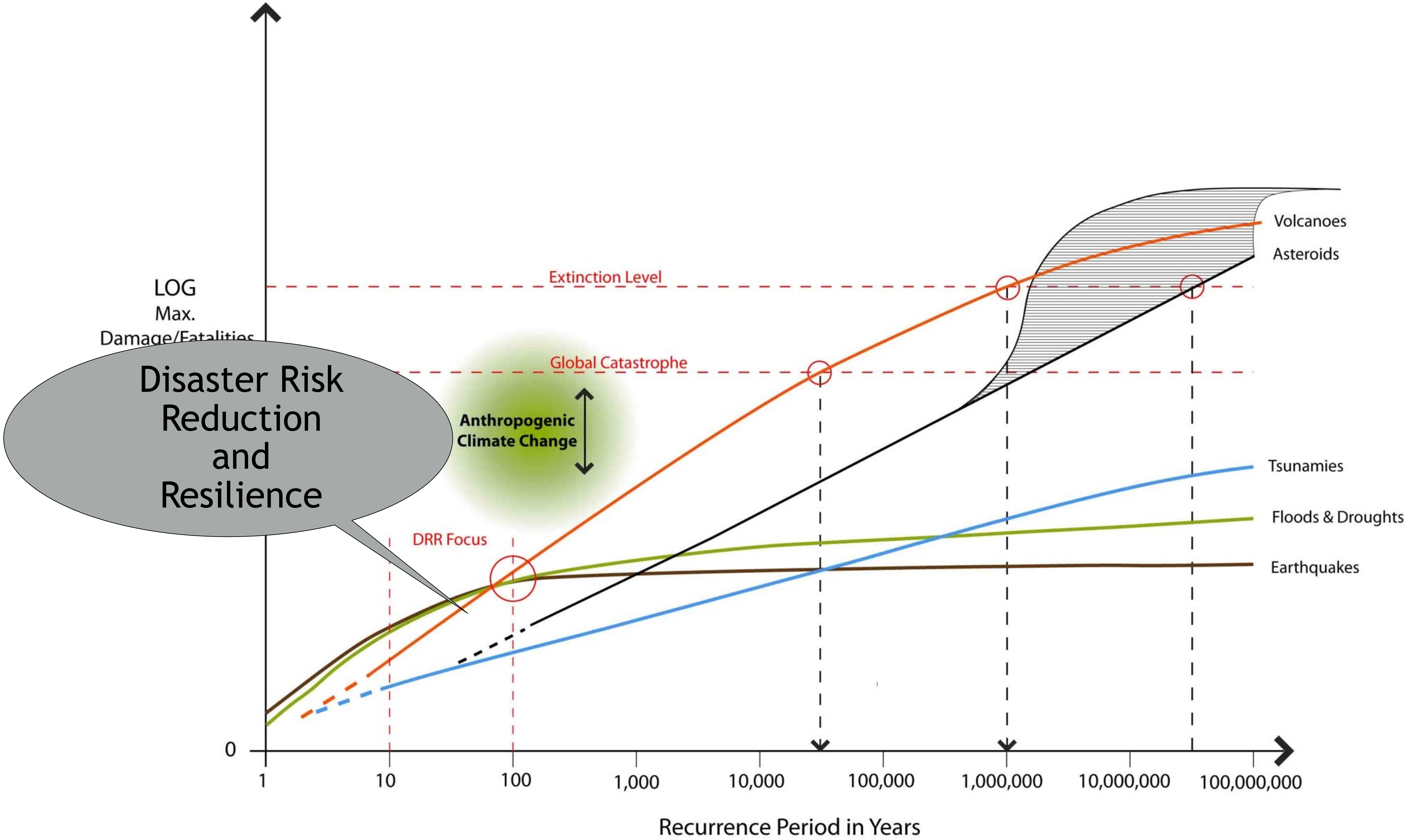

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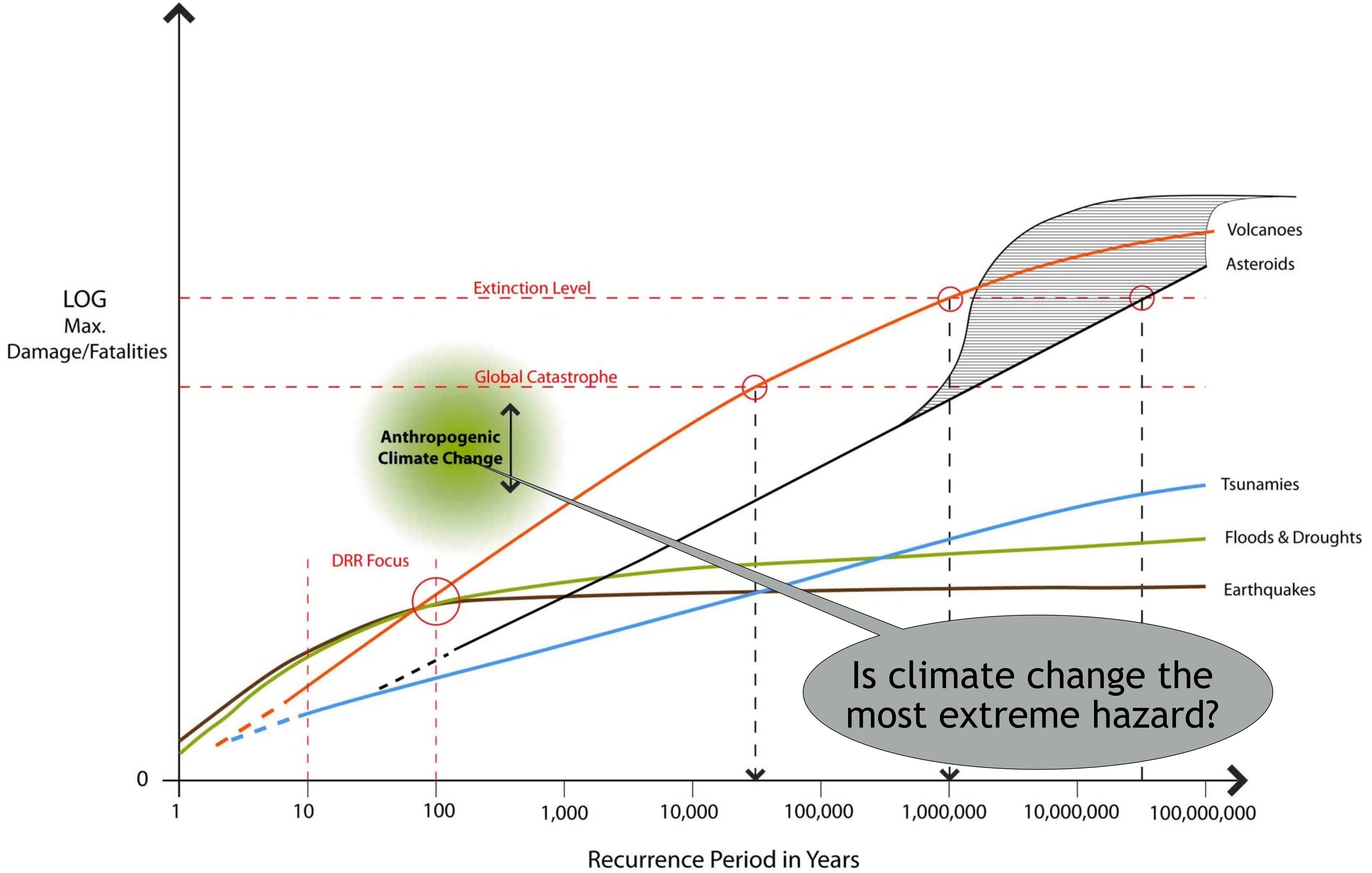

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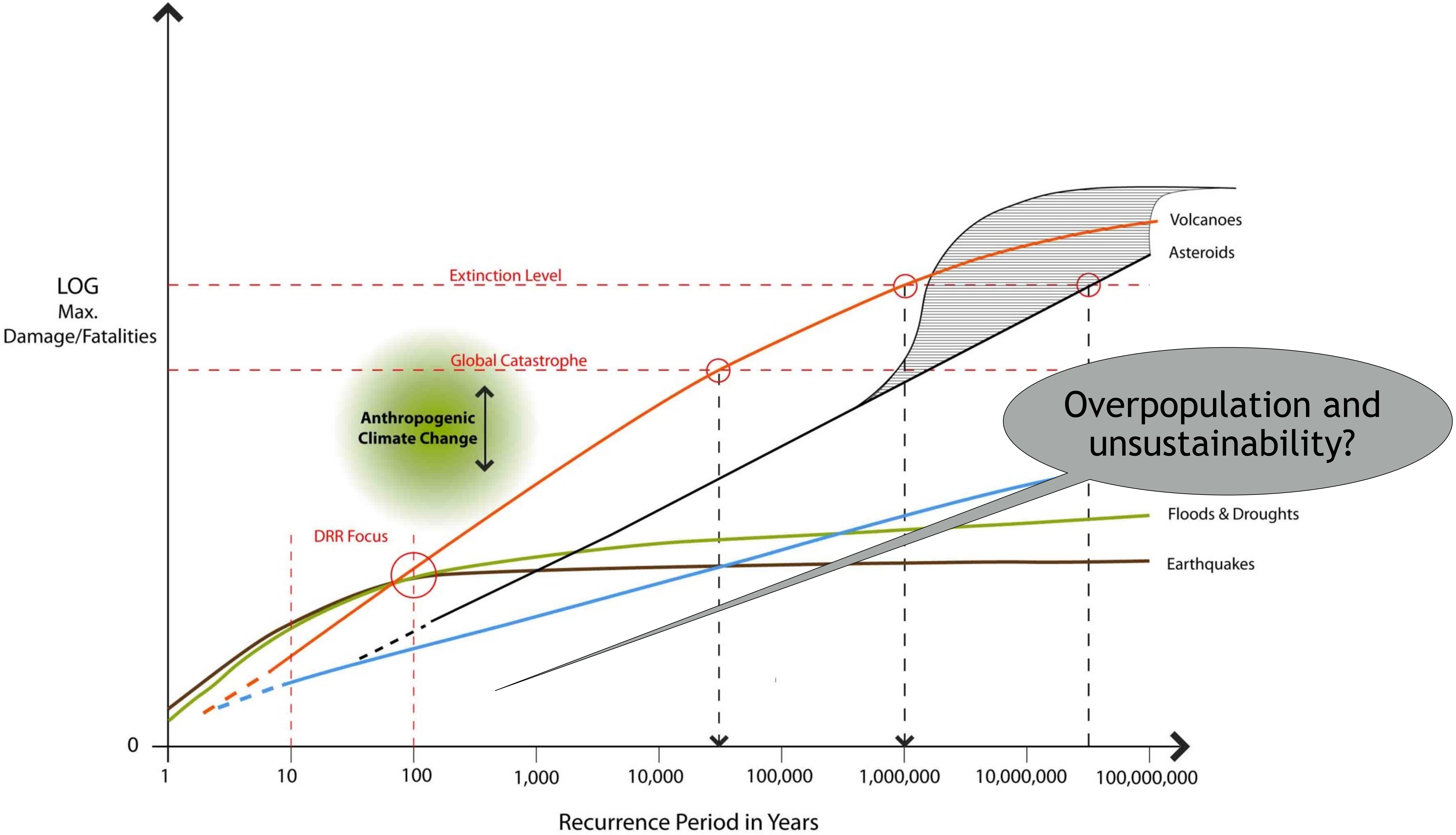

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Climate Change and Sea Level Hazards

Climate change causes changes in the probability density functions of hazards:

Climate Change and Sea Level Hazards

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Changes in means:

- air temperature
- precipitation
- wind field/circulation
- evapotranspiration
- humidity
- soil moisture
- permafrost
- sea and lake levels
- inundation
- river runoff
- desertification
- ice and snow cover

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Questions:
- How well do we know the past and current changes?
- How well do we understand the processes and causes?
- *How are the hazards potentially going to impact human and non-human systems?*
- *To what extent can we predict or anticipate future changes?*
- *Do we have foresight in terms of what might happen?*

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Epistemic Modesty

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Data base
Detecting Change
Assessing Knowledge

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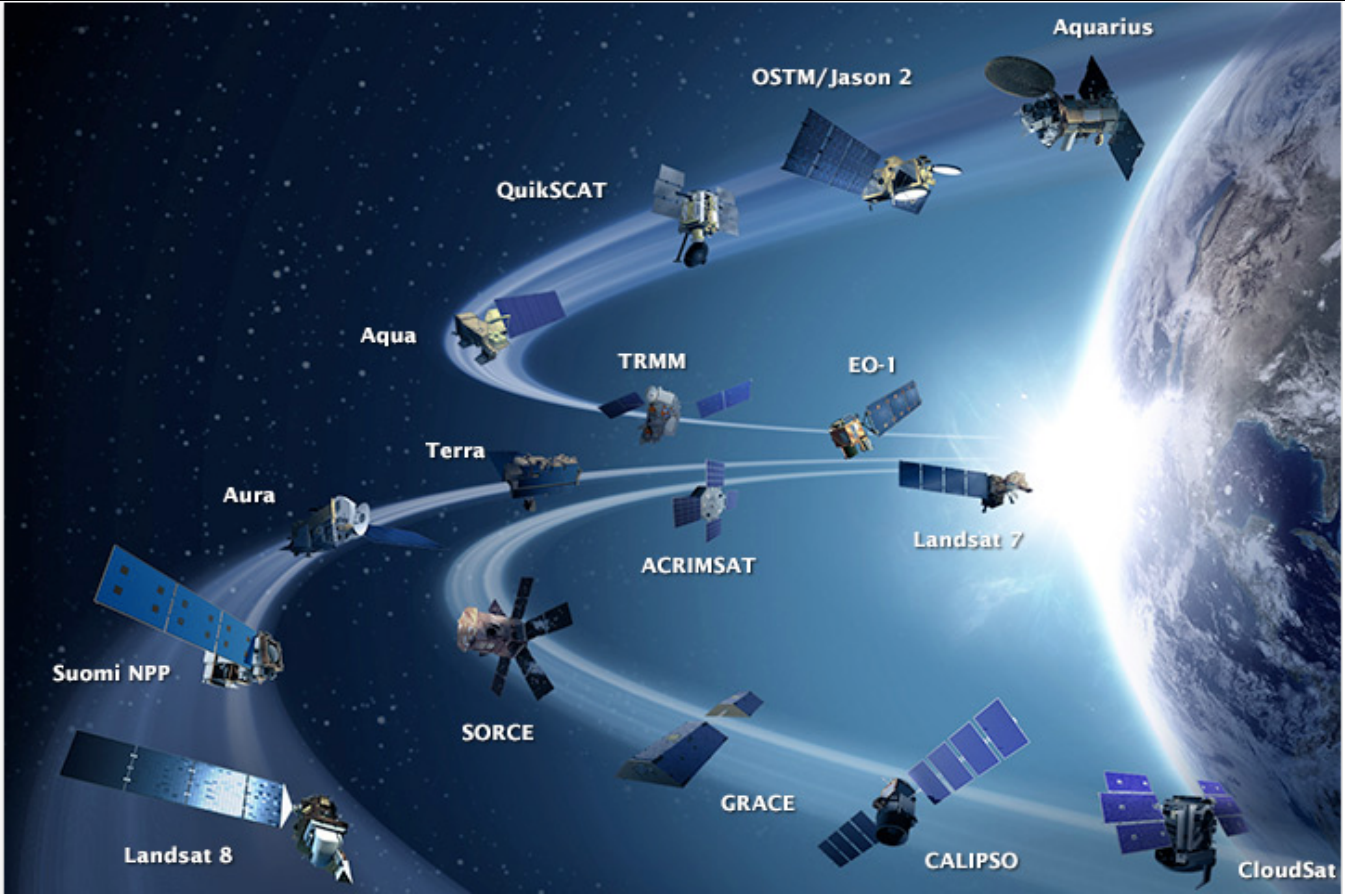
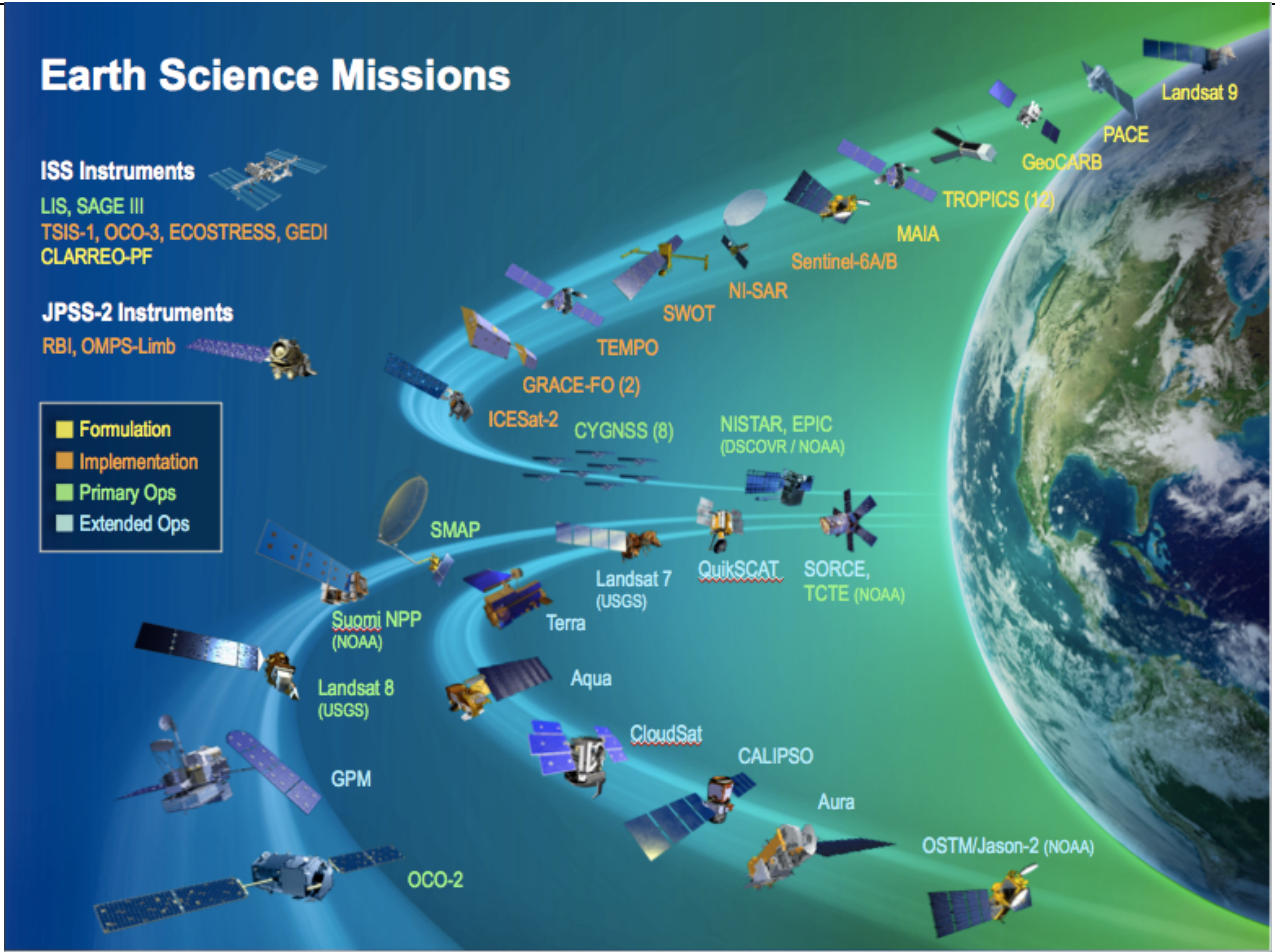
The Data: Space-Based Observations



2013

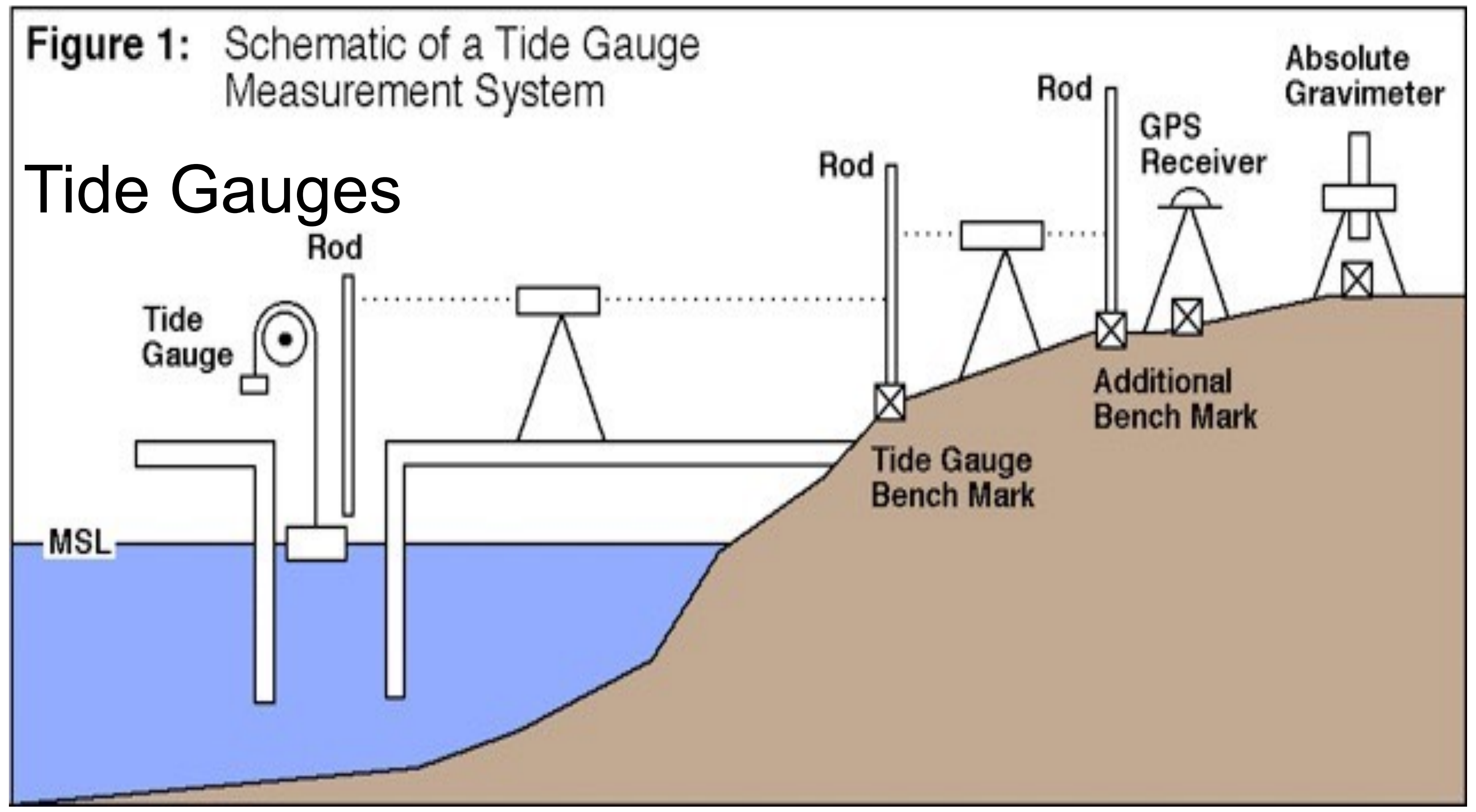
The Data: Space-Based Observations



2018

The Data: Example Sea Level Changes

Geodetic Monitoring of Sea Level

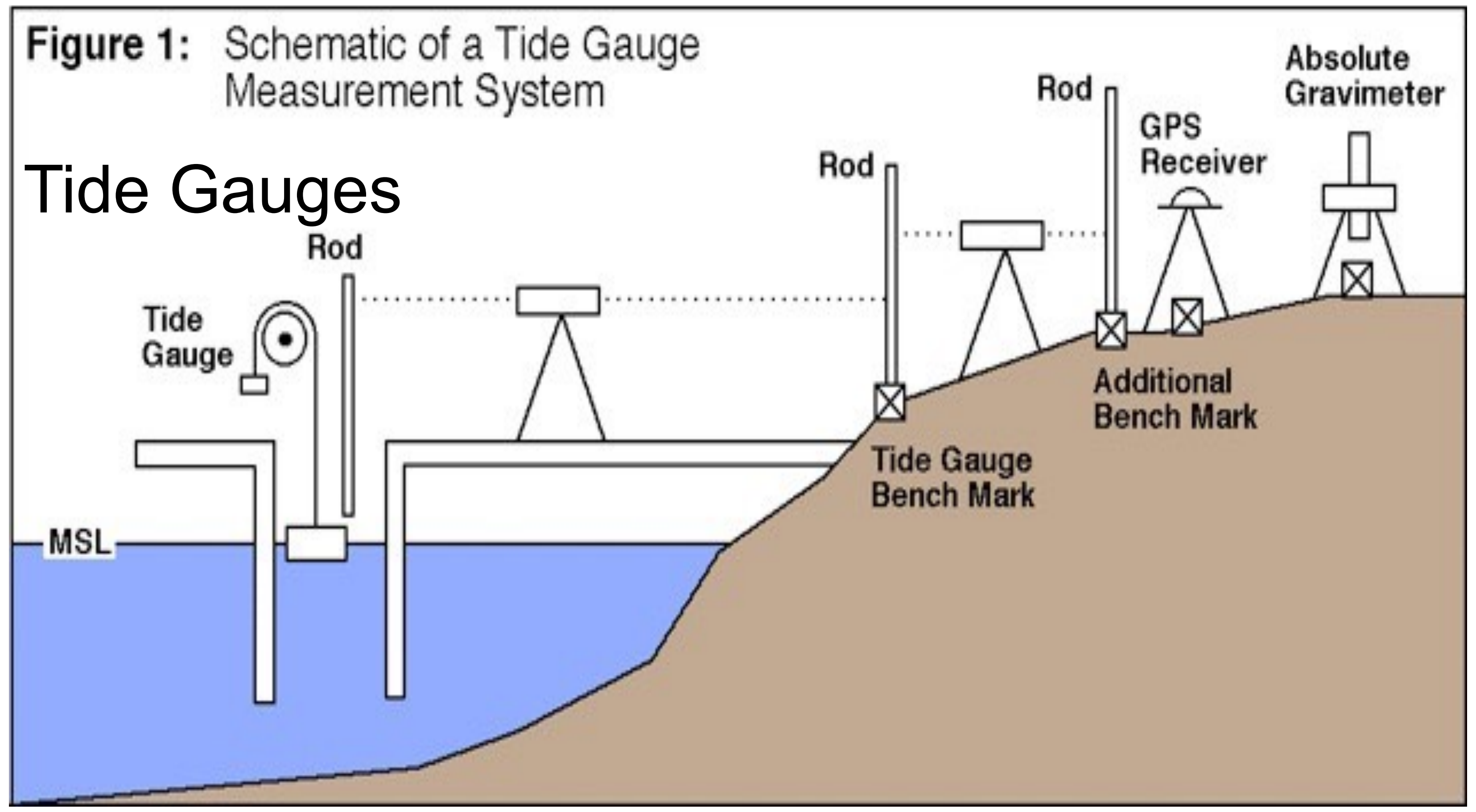


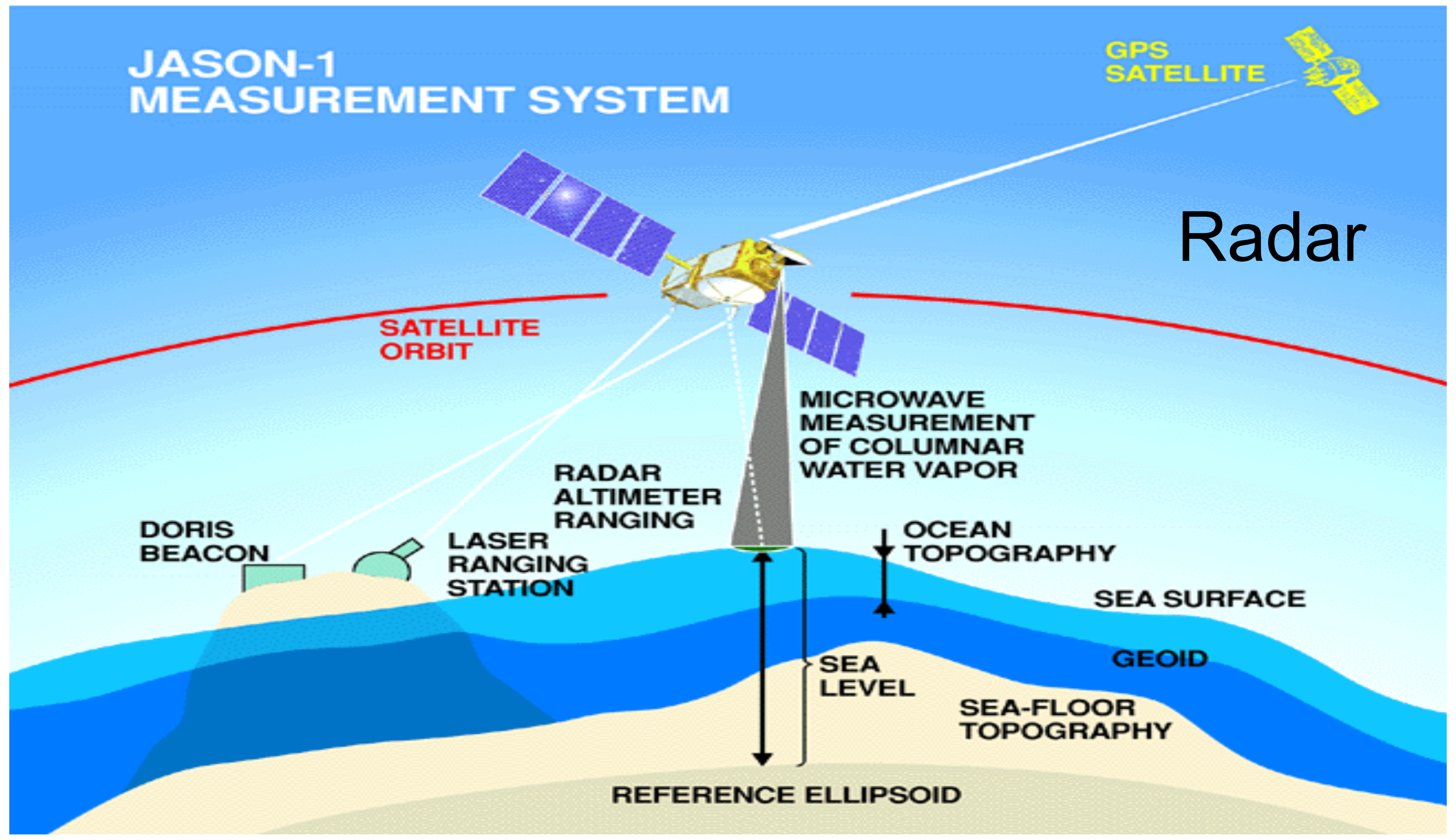
http://sealevel.colorado.edu/tidegauges.html

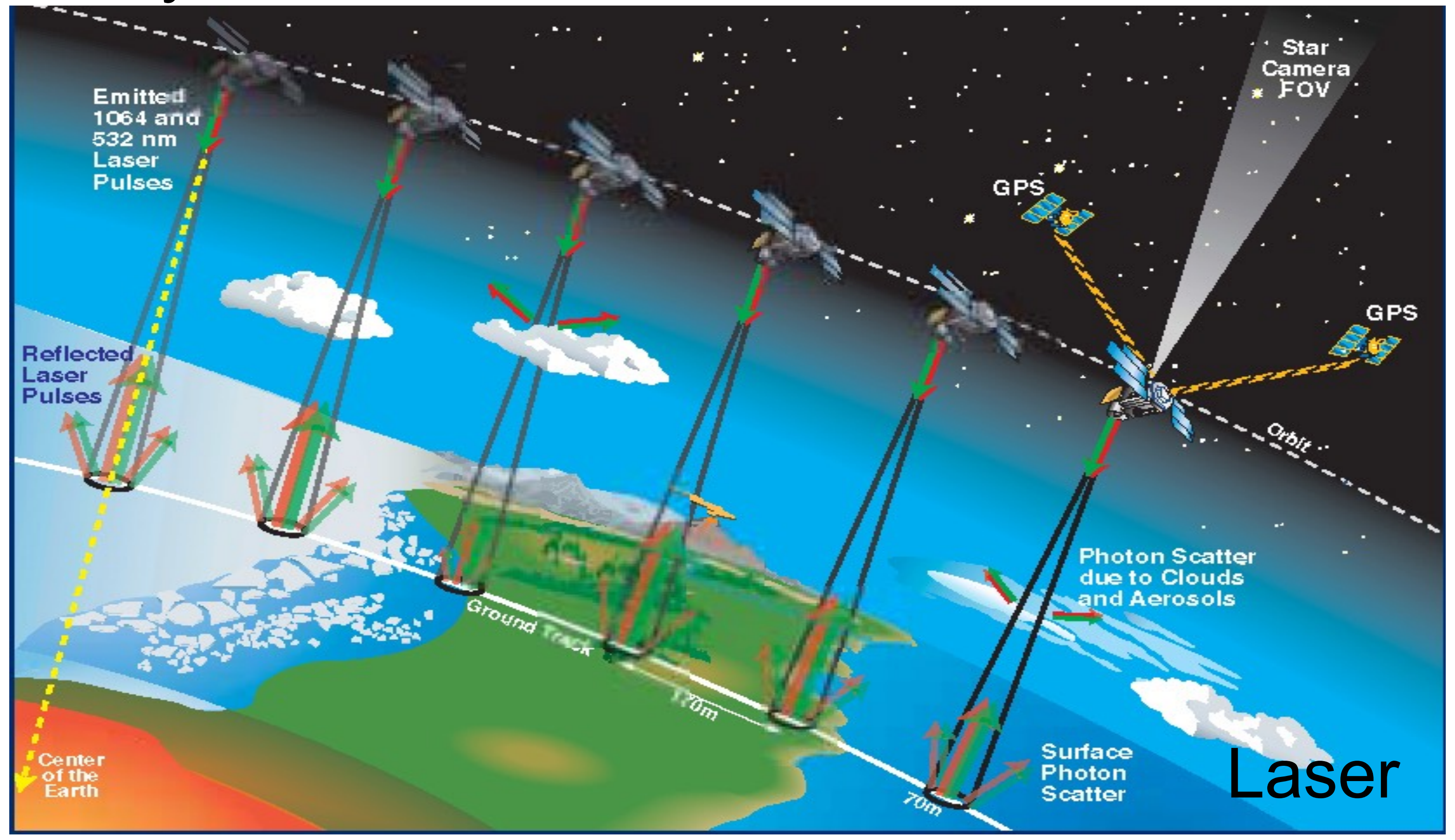
The Data: Example Sea Level Changes

Geodetic Monitoring of Sea Level

Satellite Altimetry







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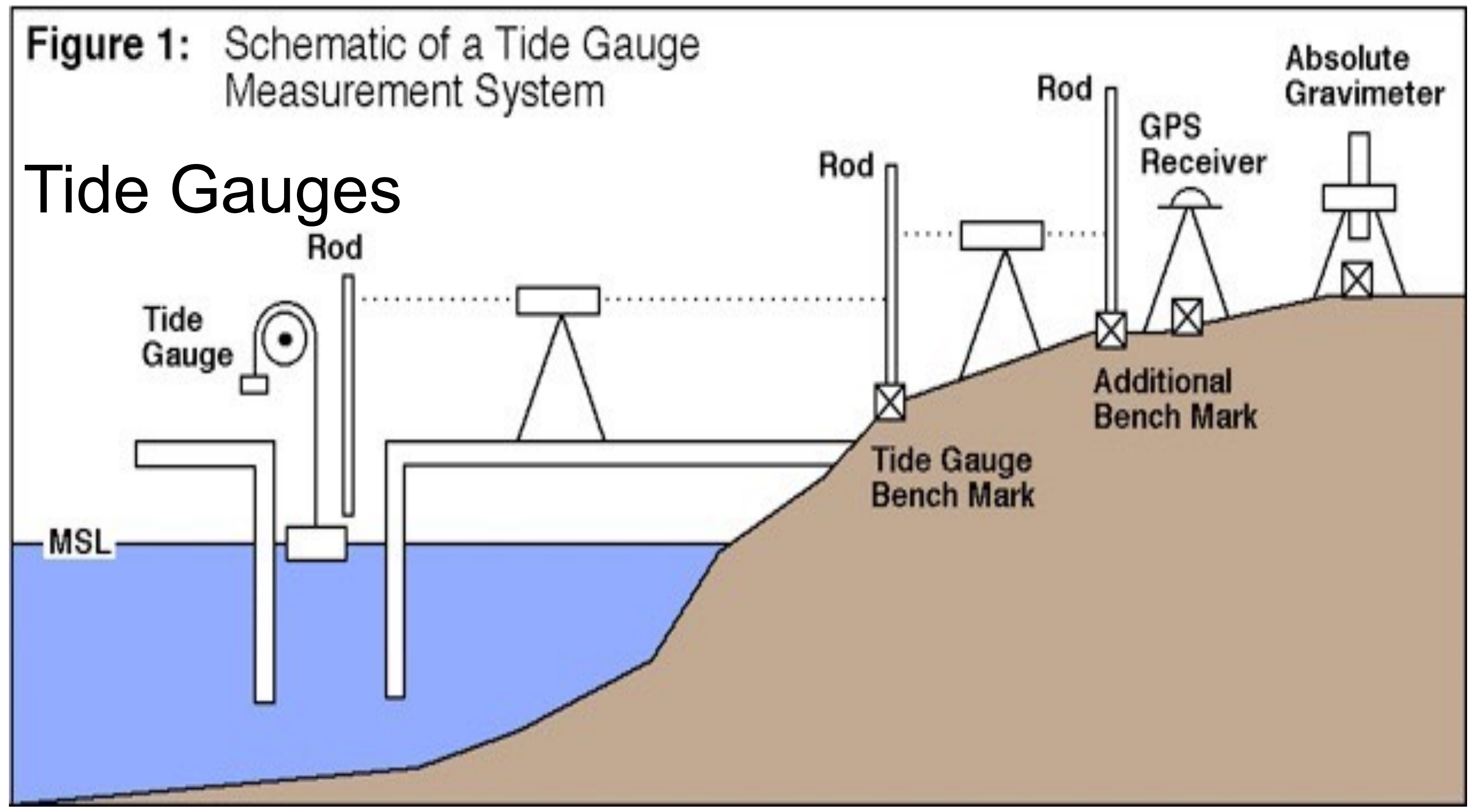

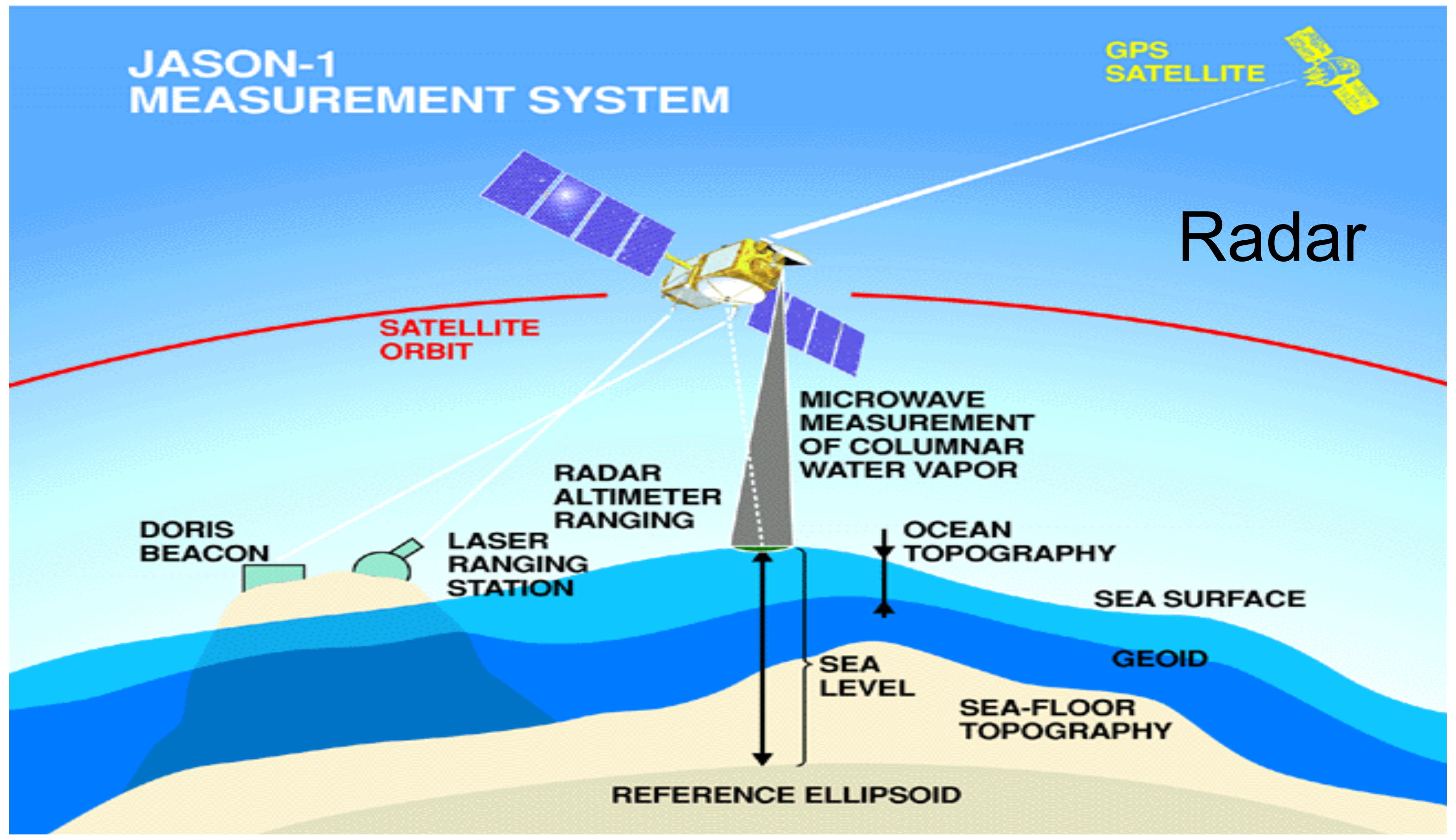

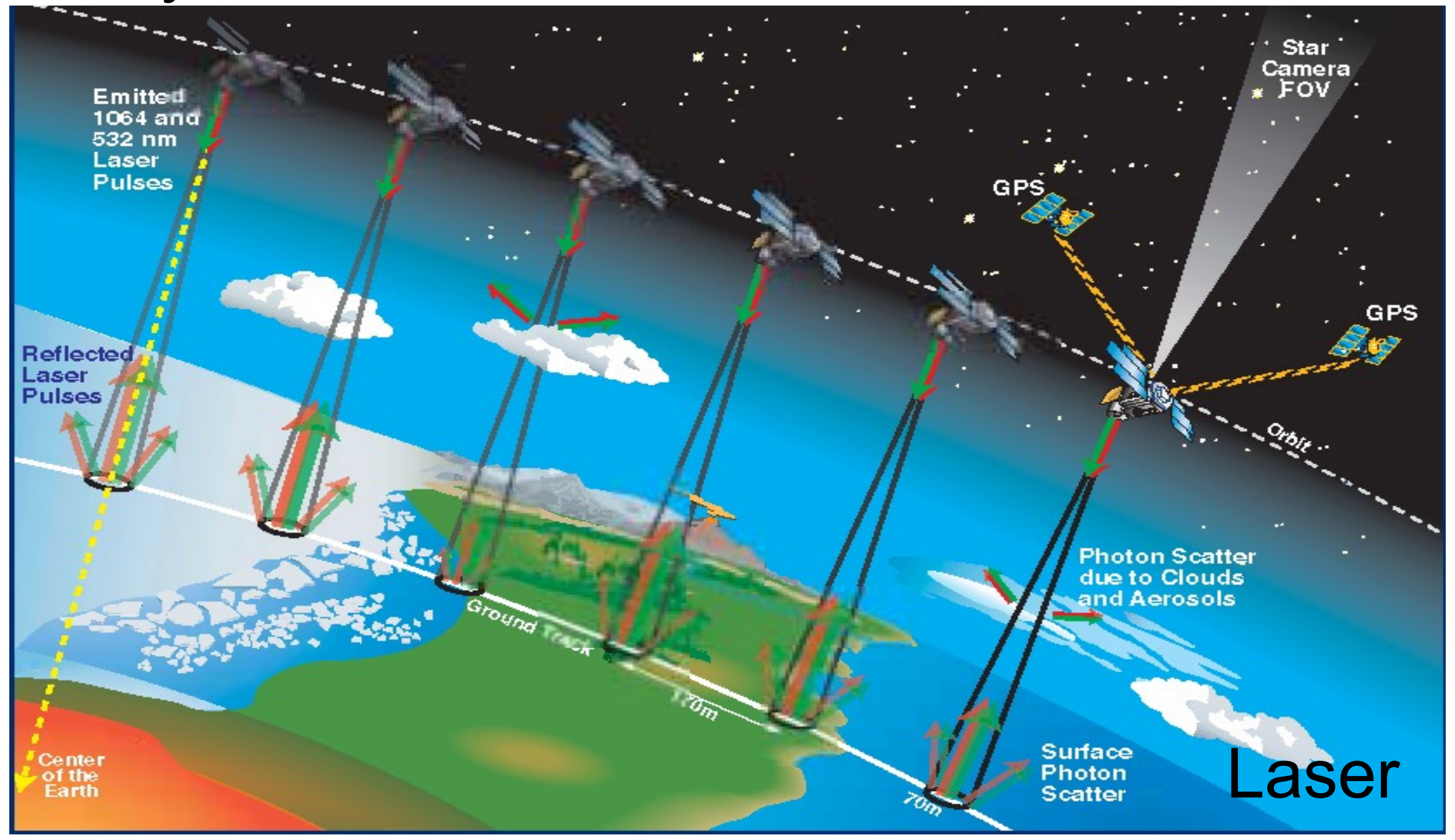

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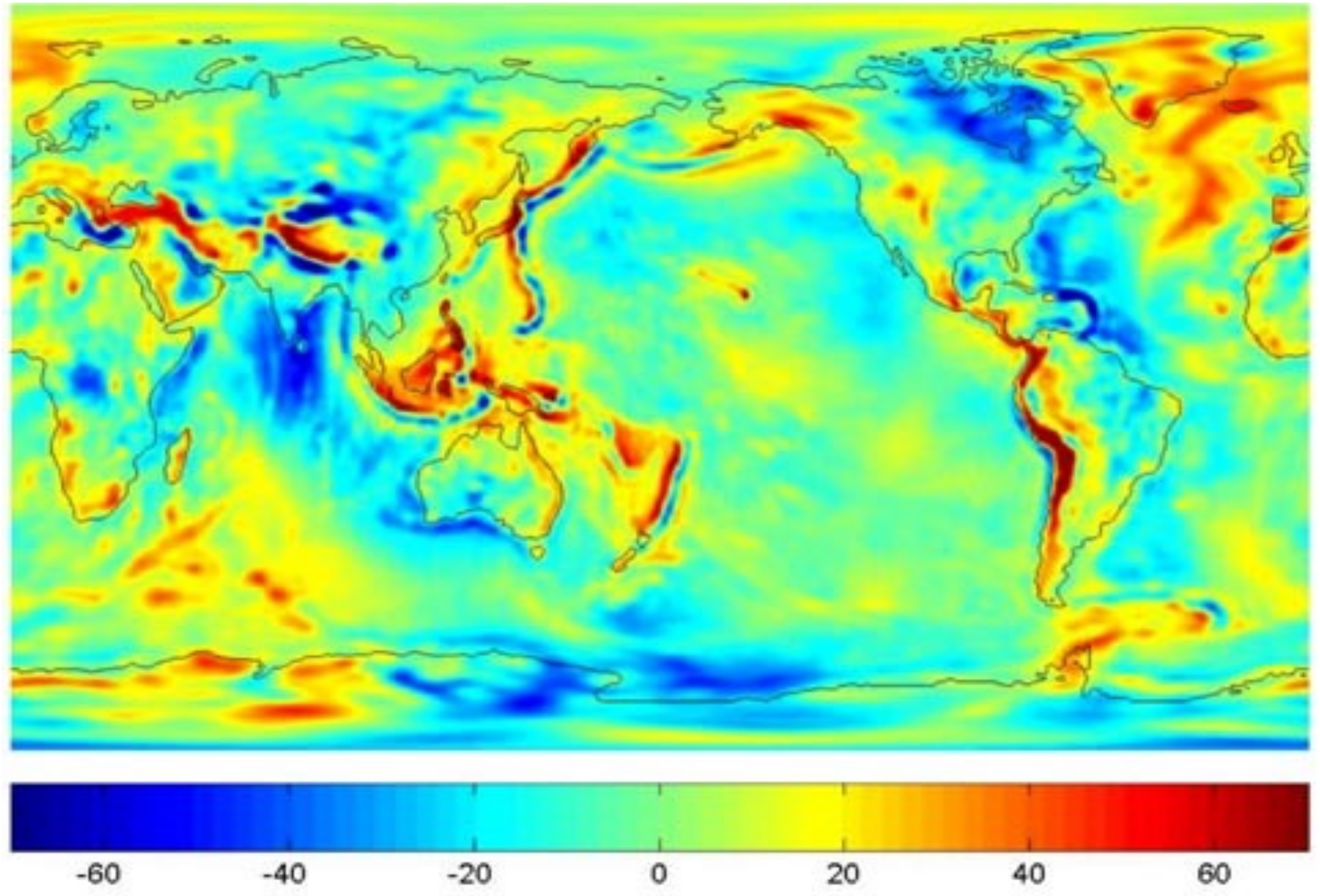

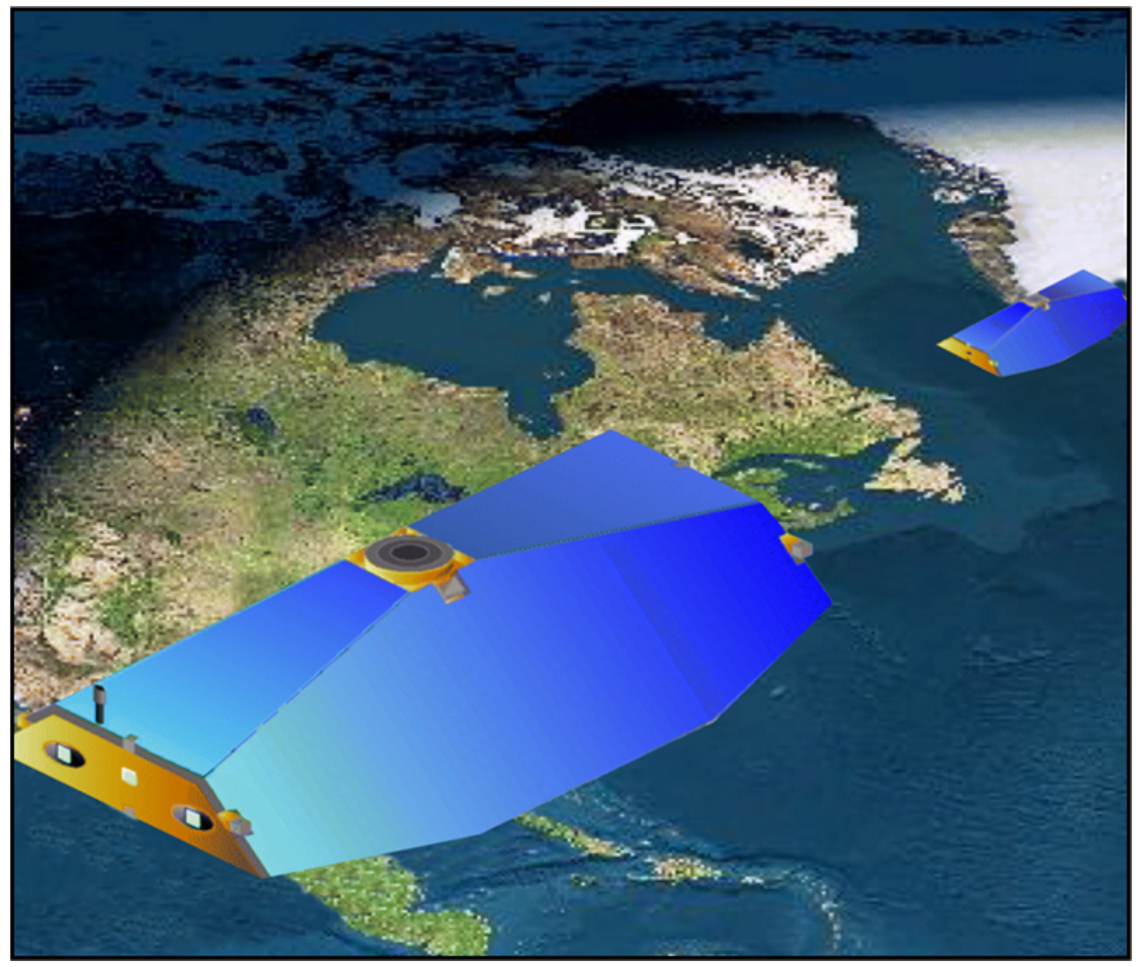

The Data: Example Sea Level Changes

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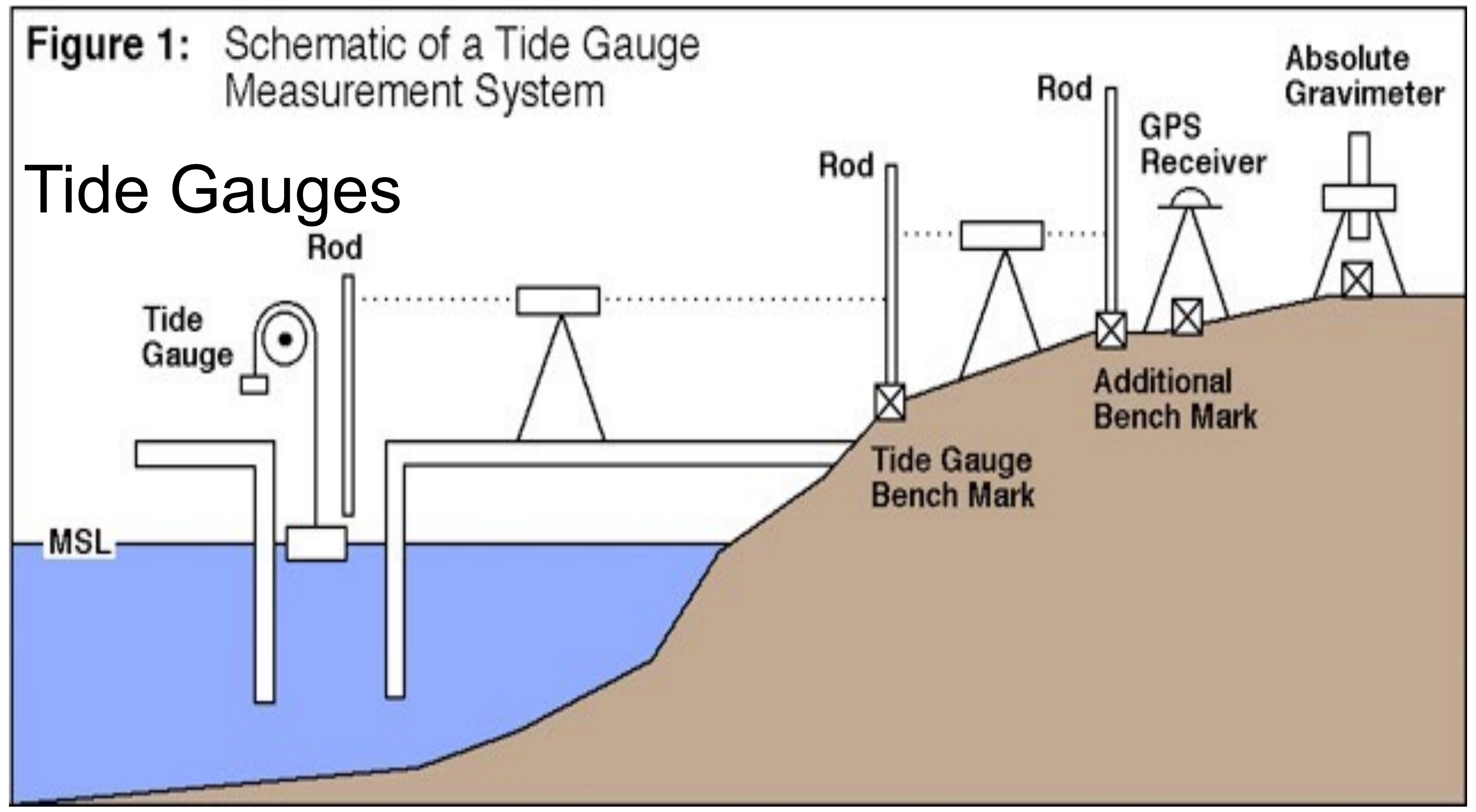

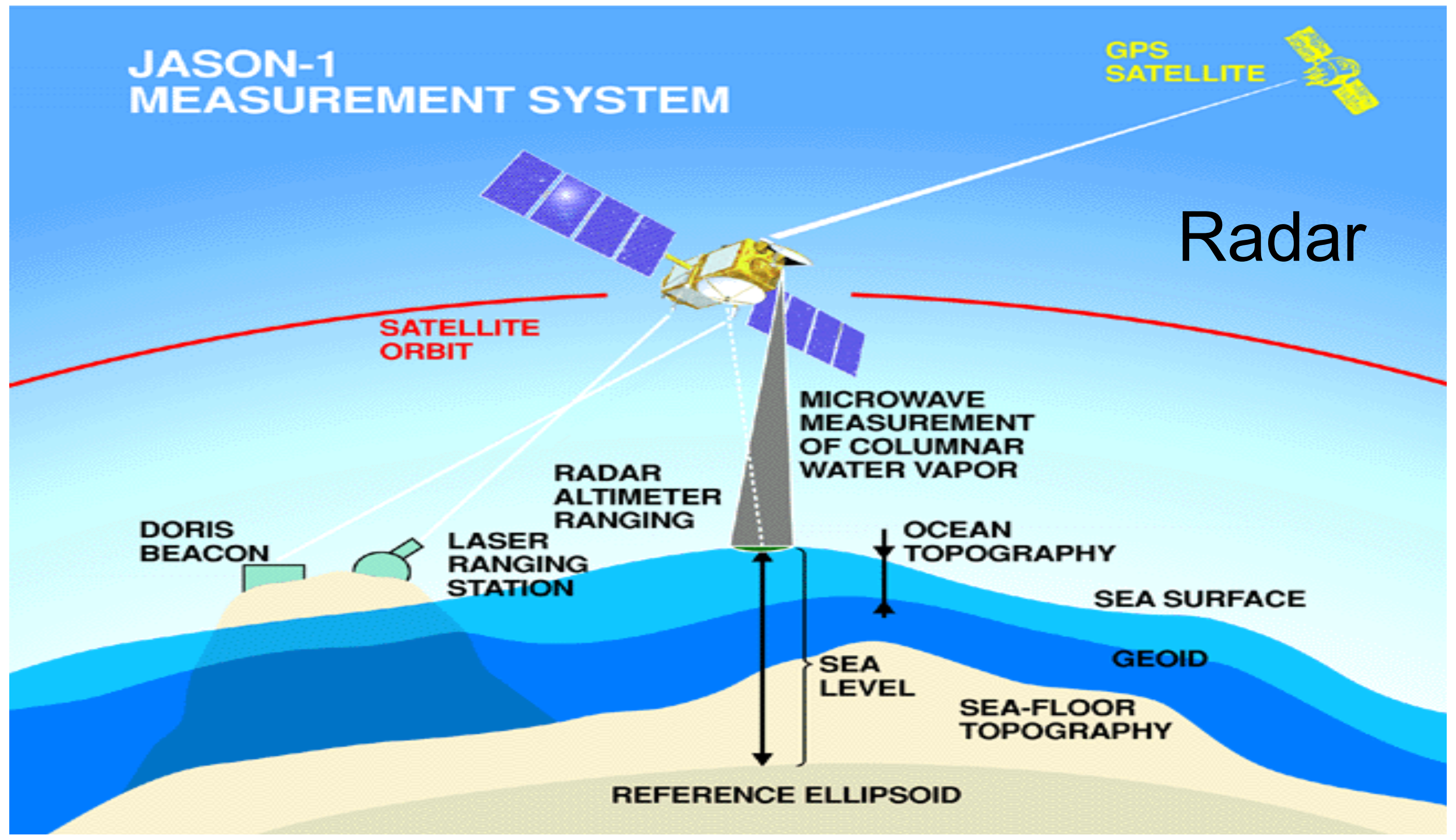

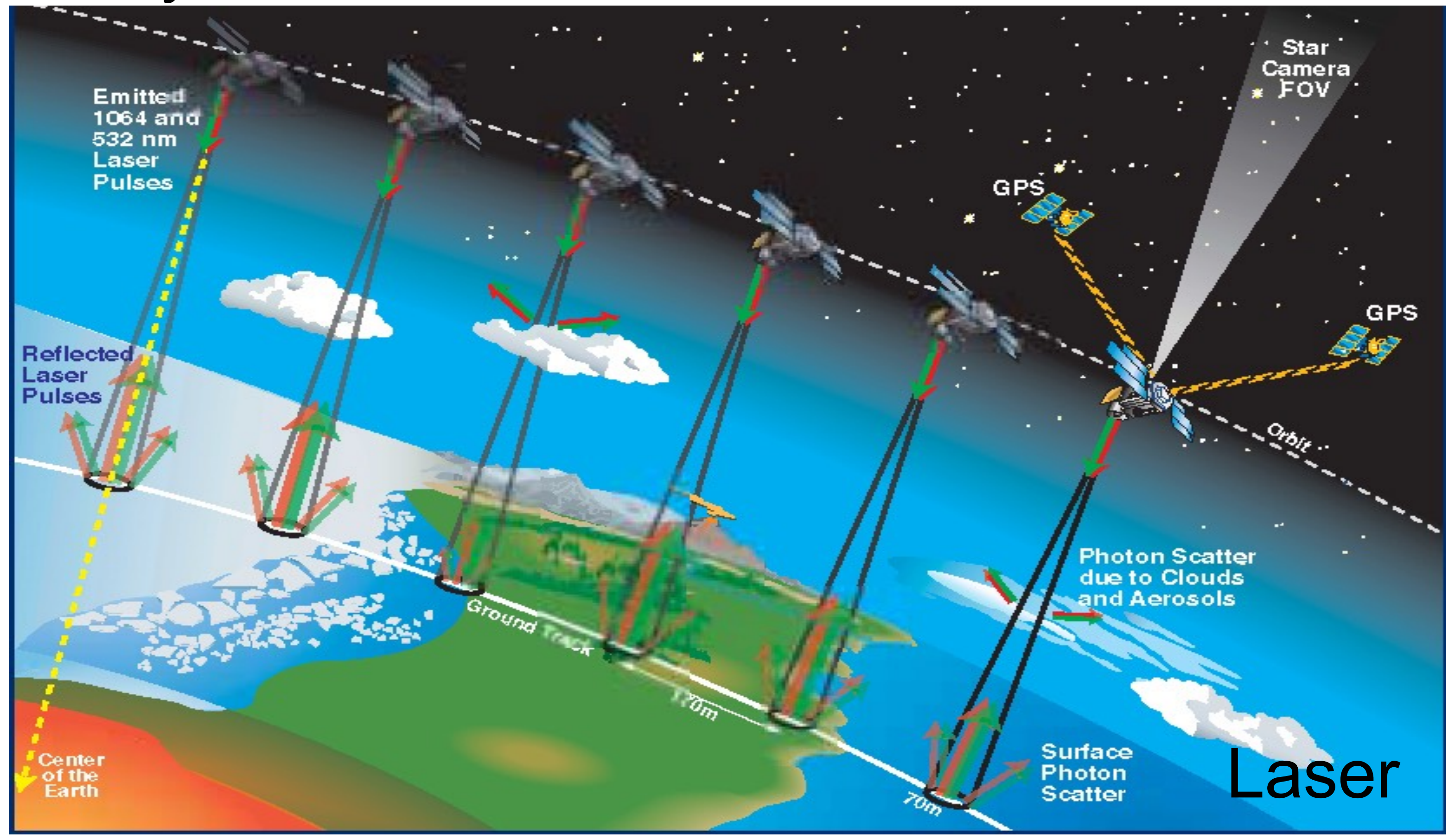

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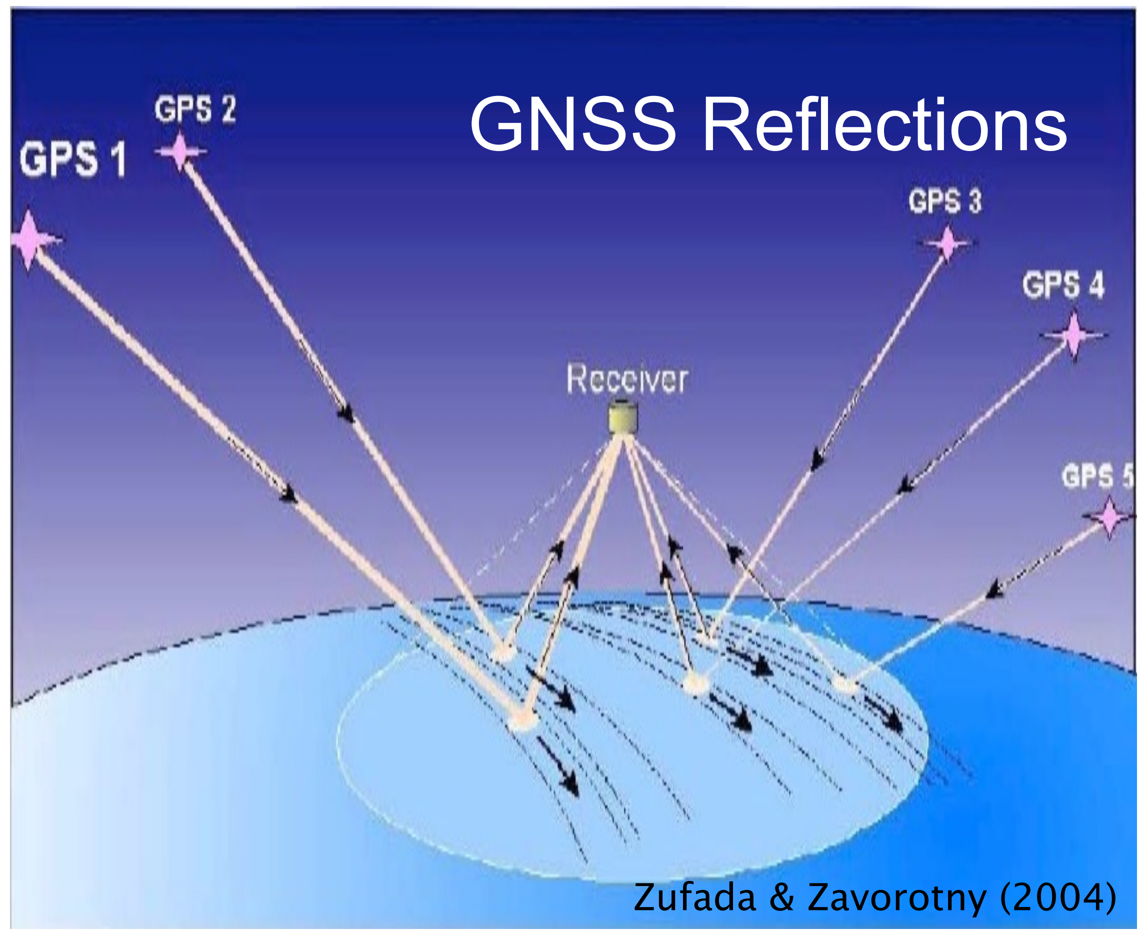
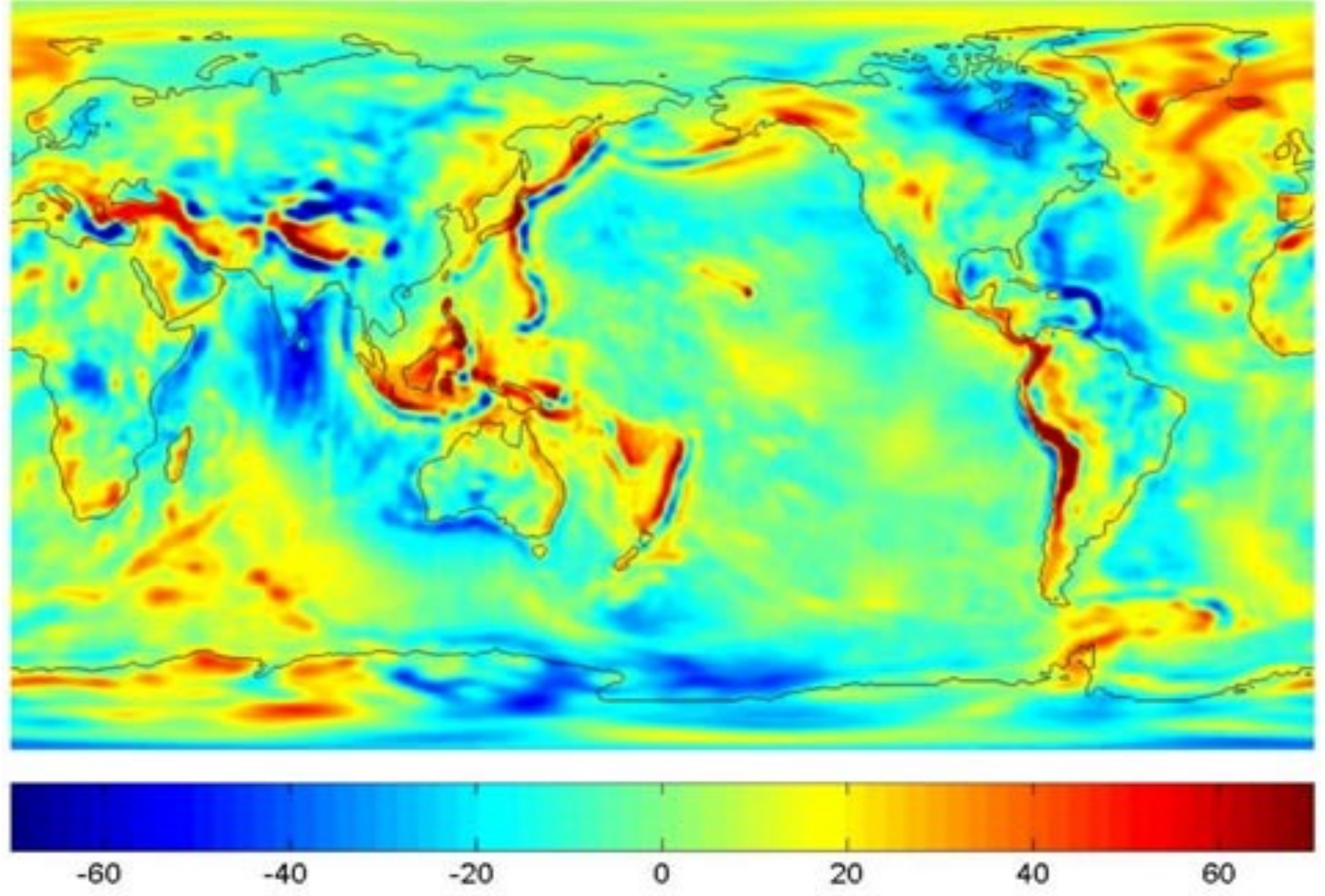
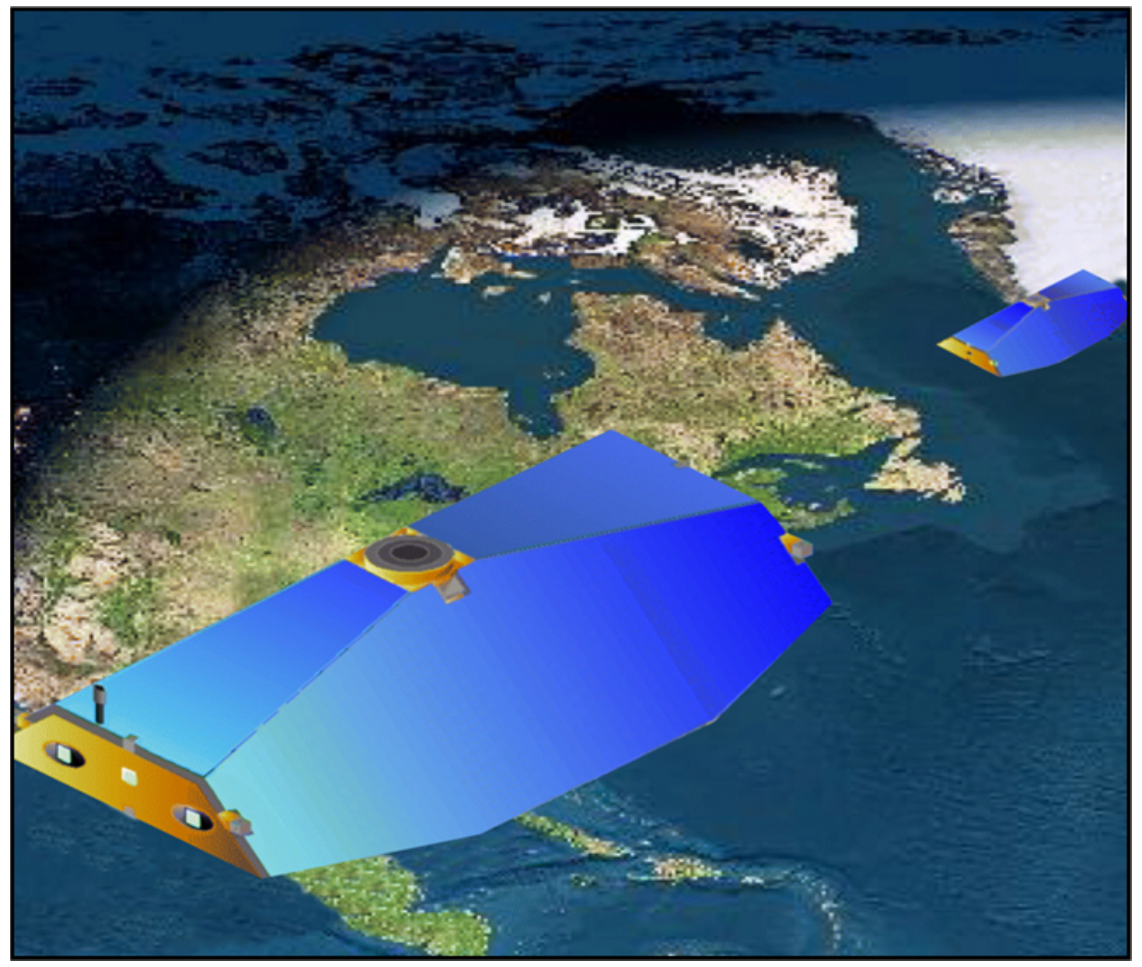
Larson eta l. (2014)



Zufada & Zavorotny (2004)





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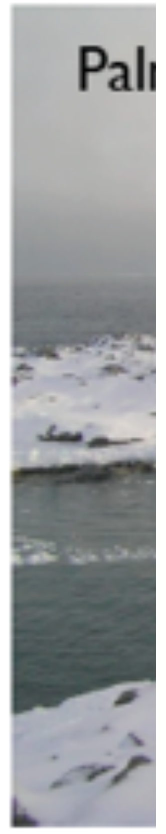
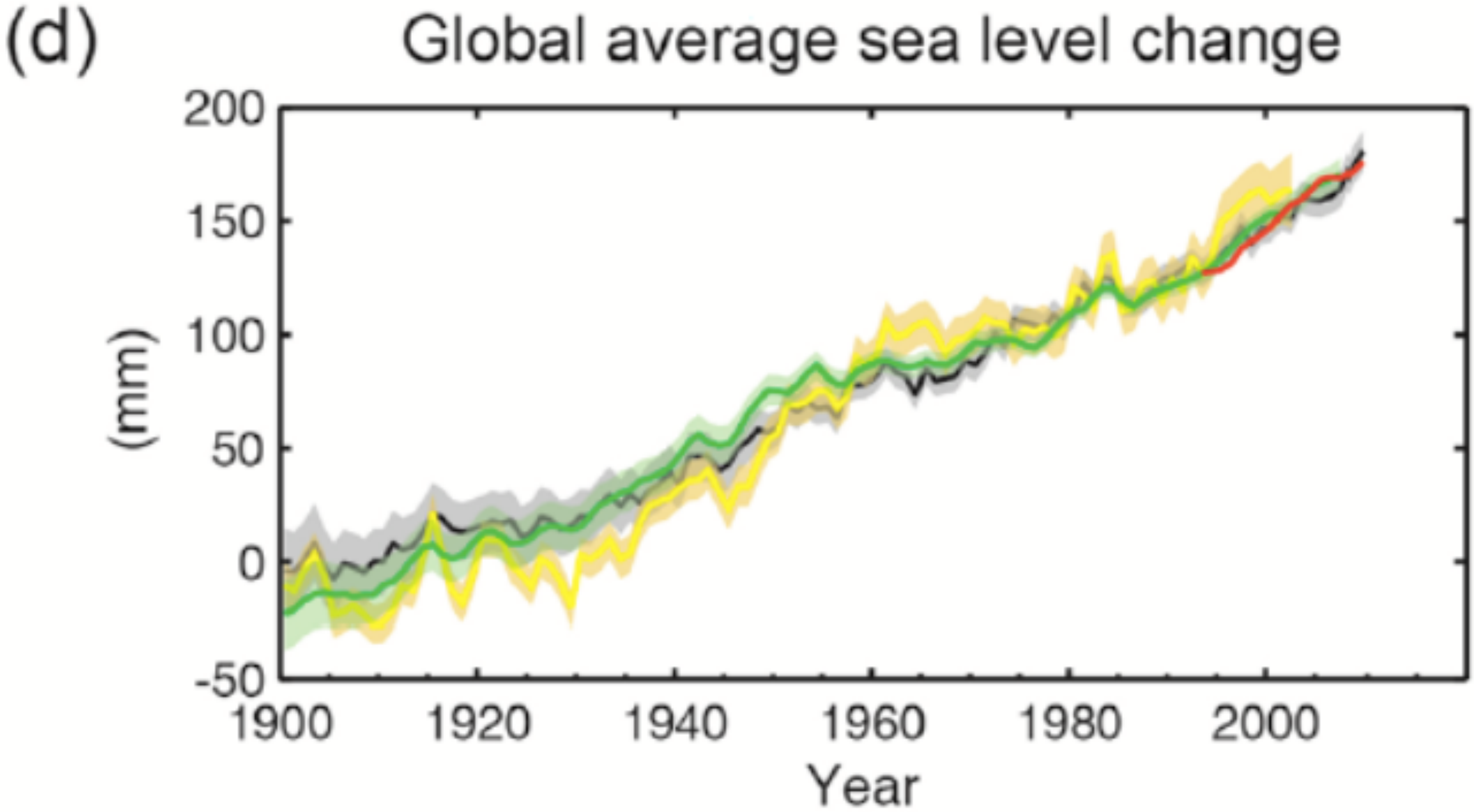
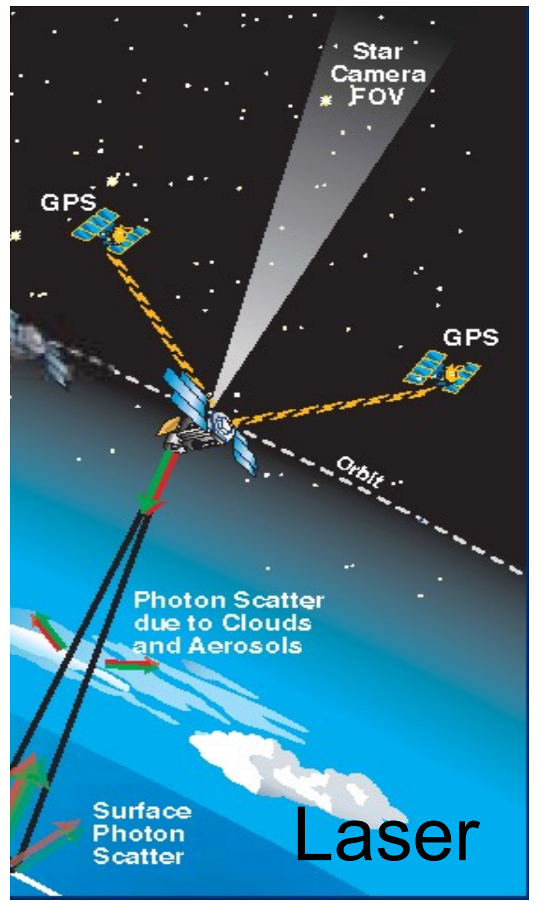
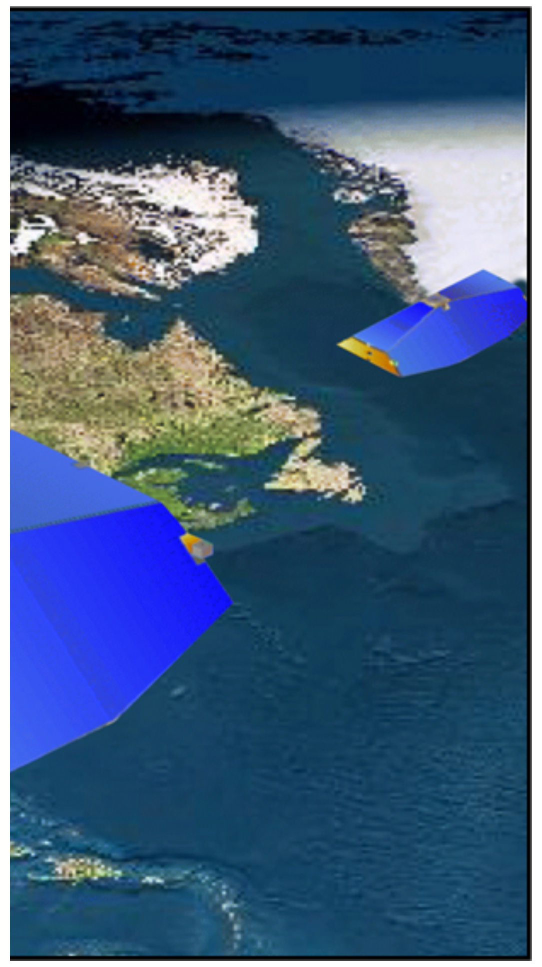


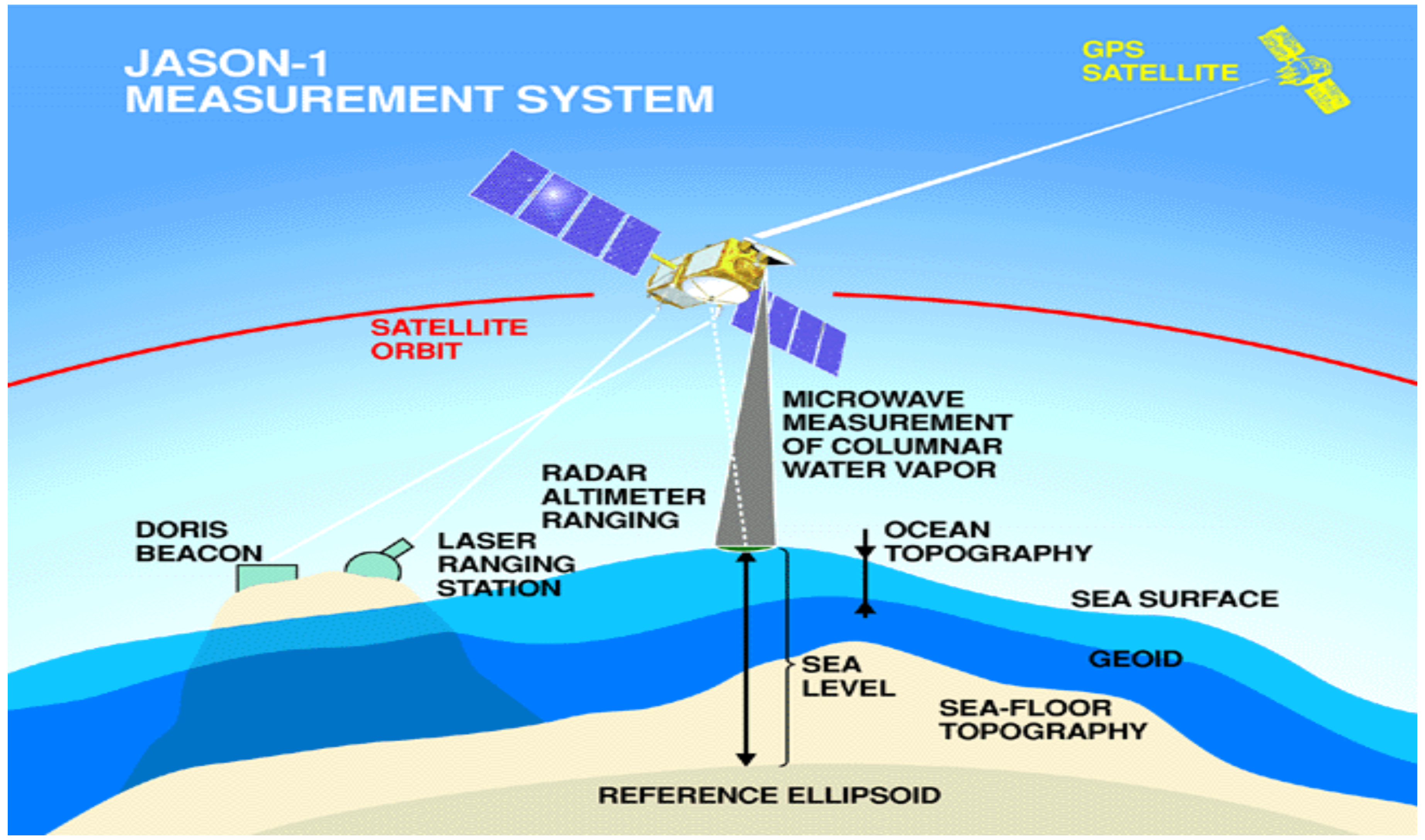






Observing the Planet

Sea surface height (not sea level):



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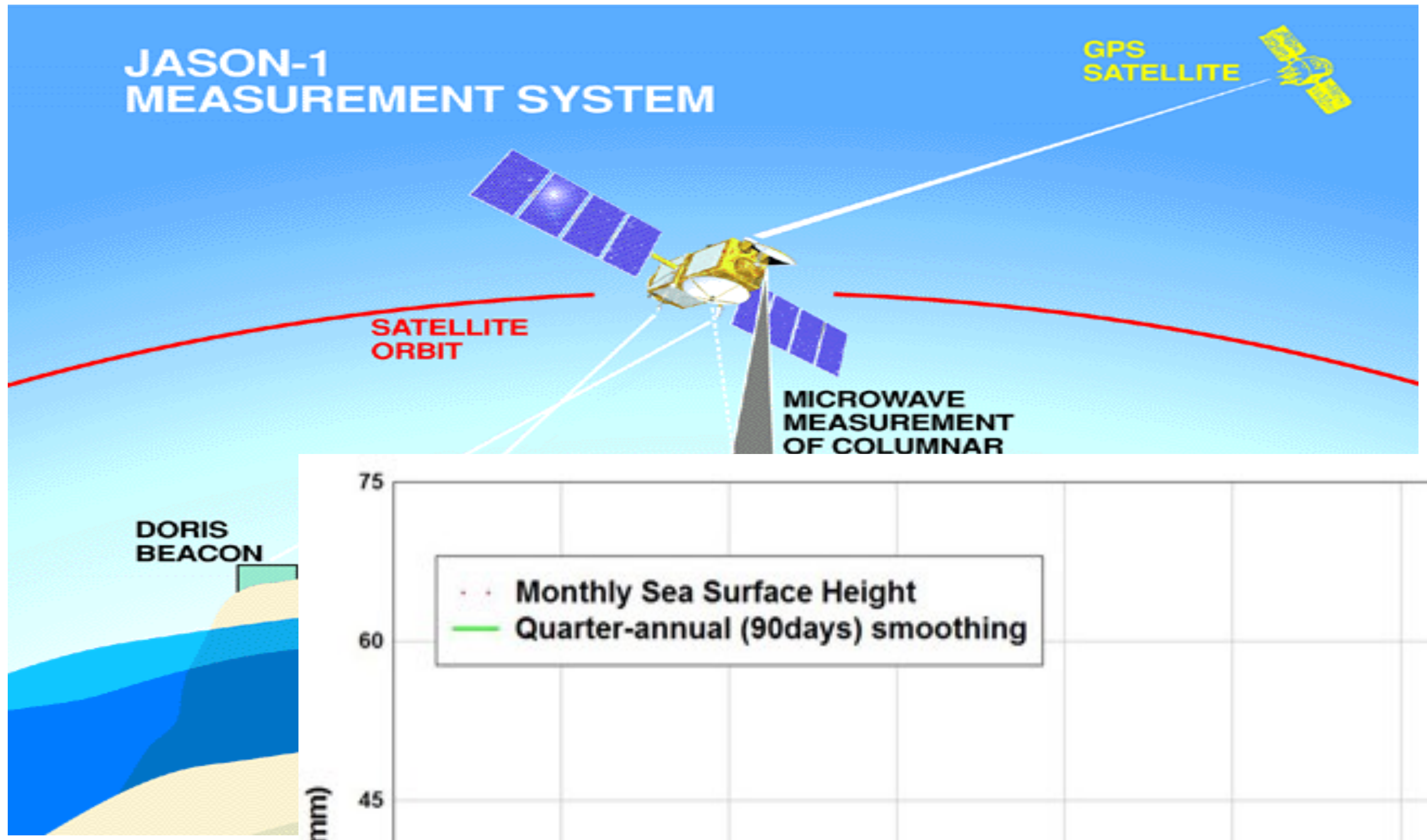

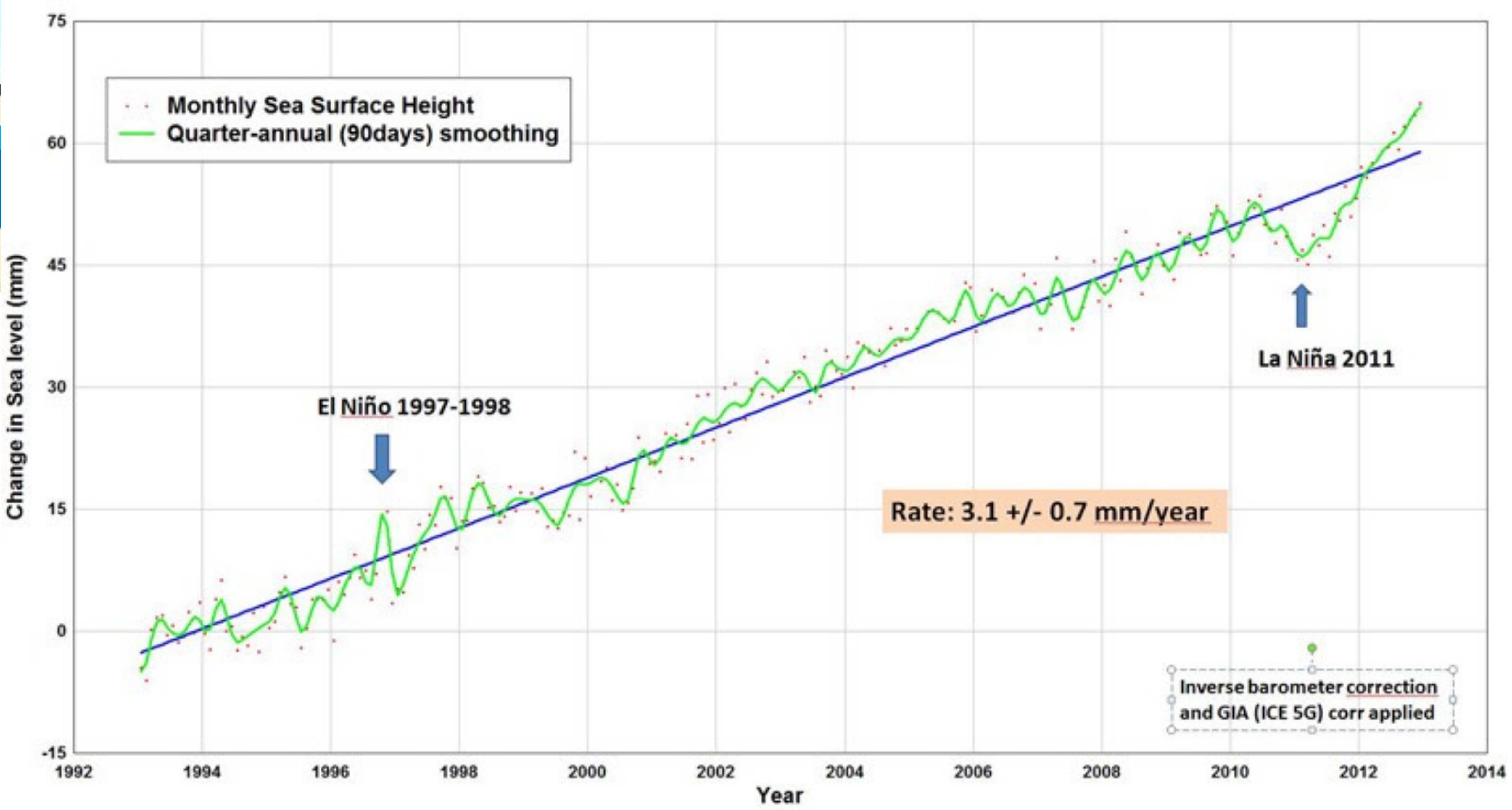

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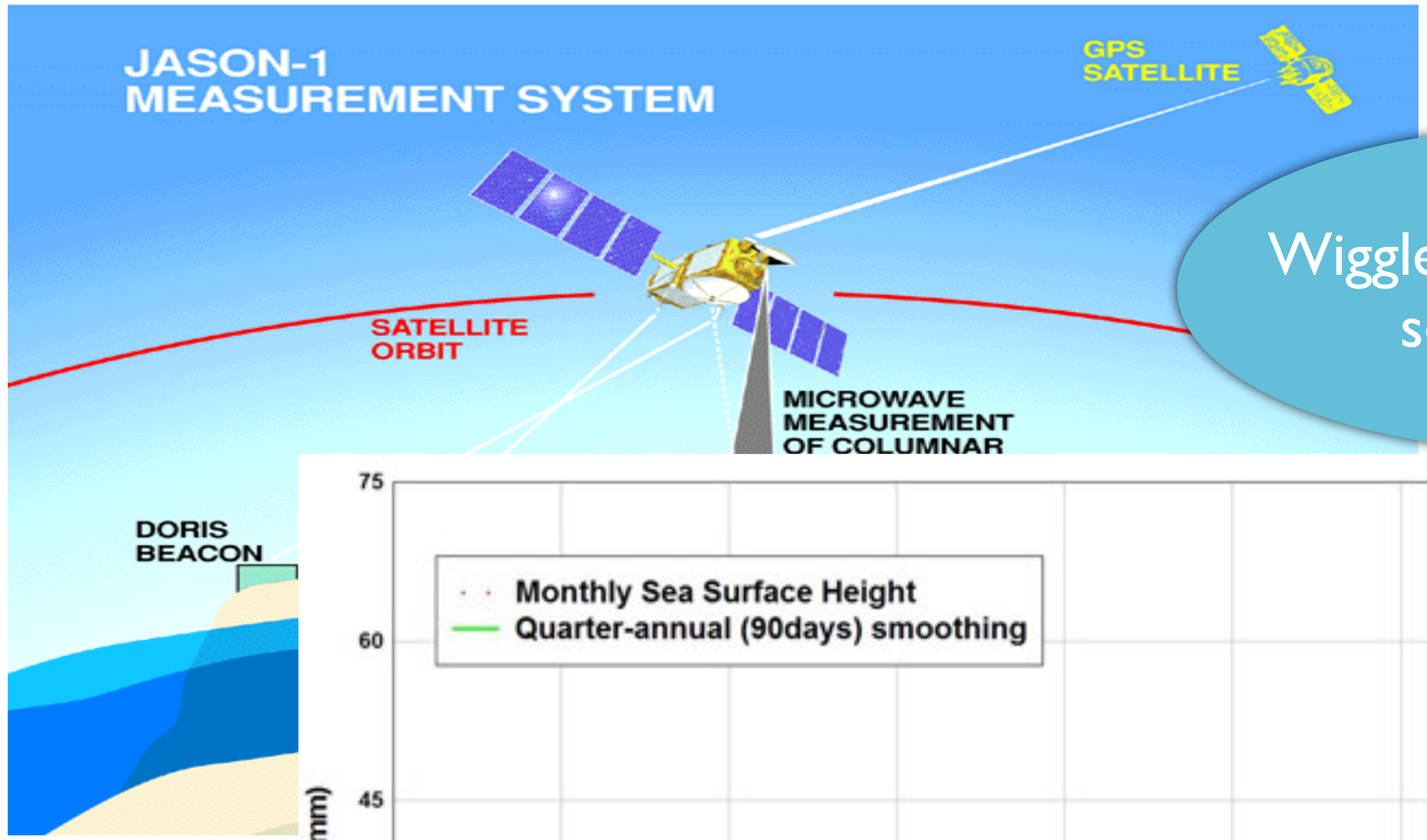

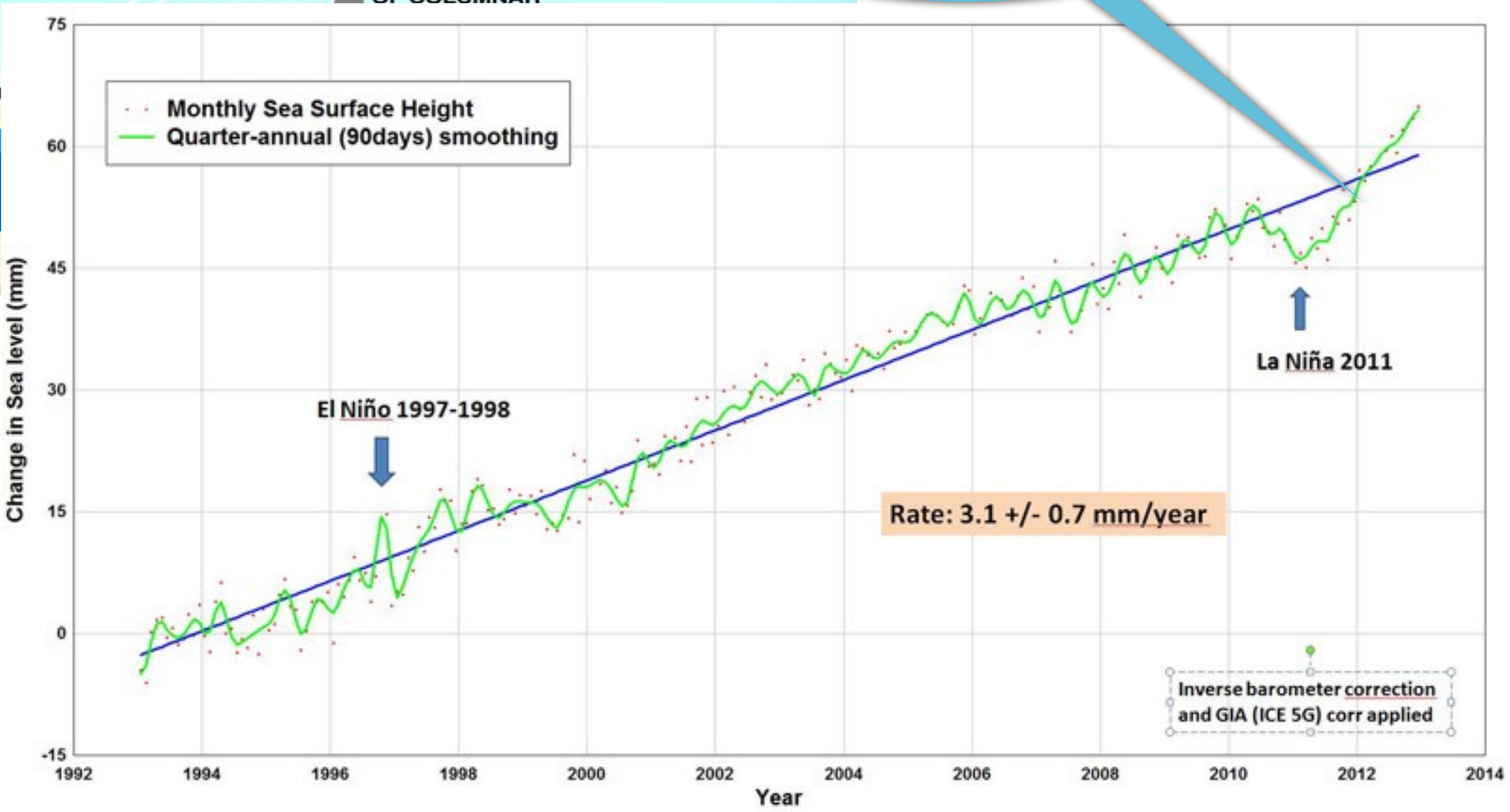

Wiggles of 1-2 cm over several years

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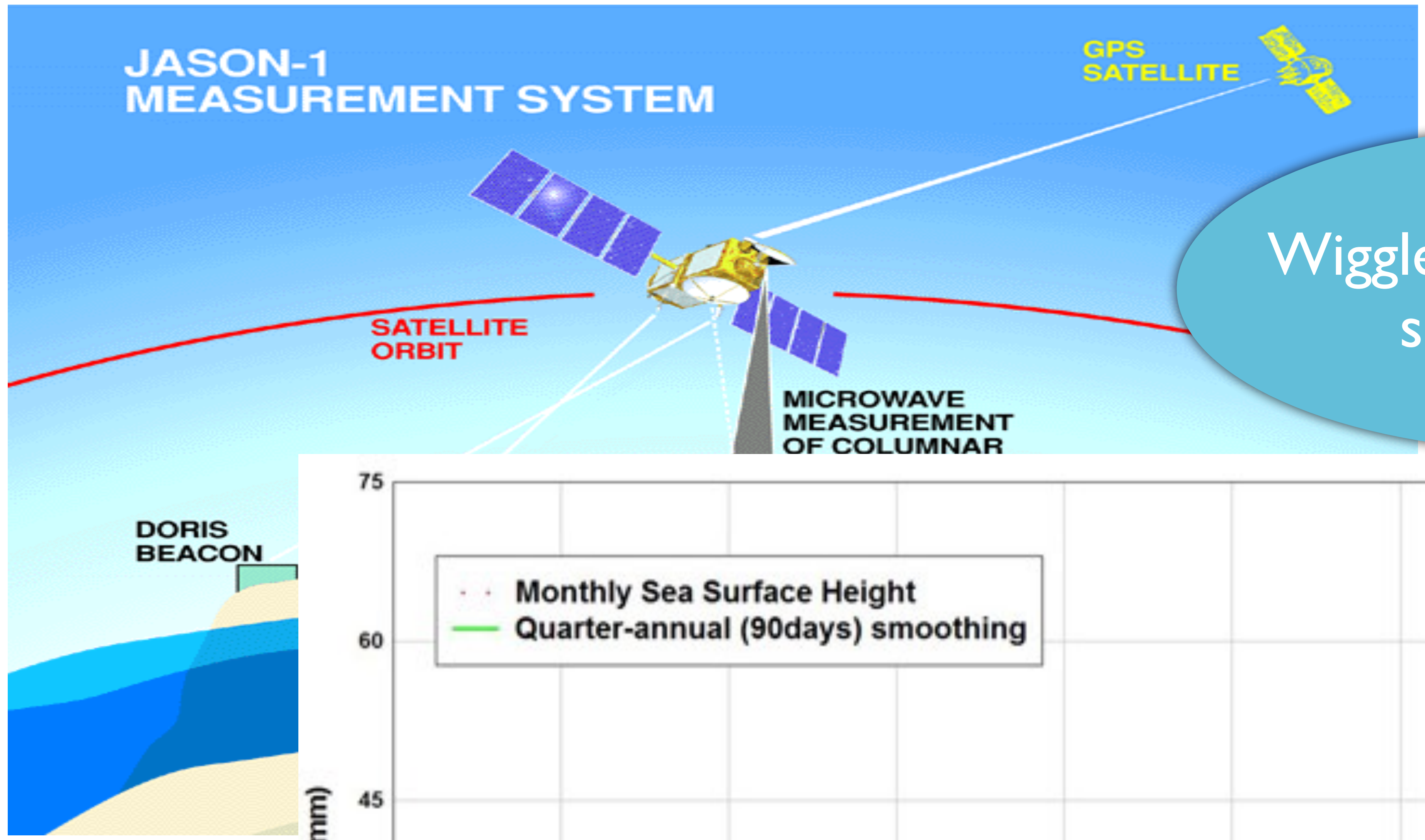
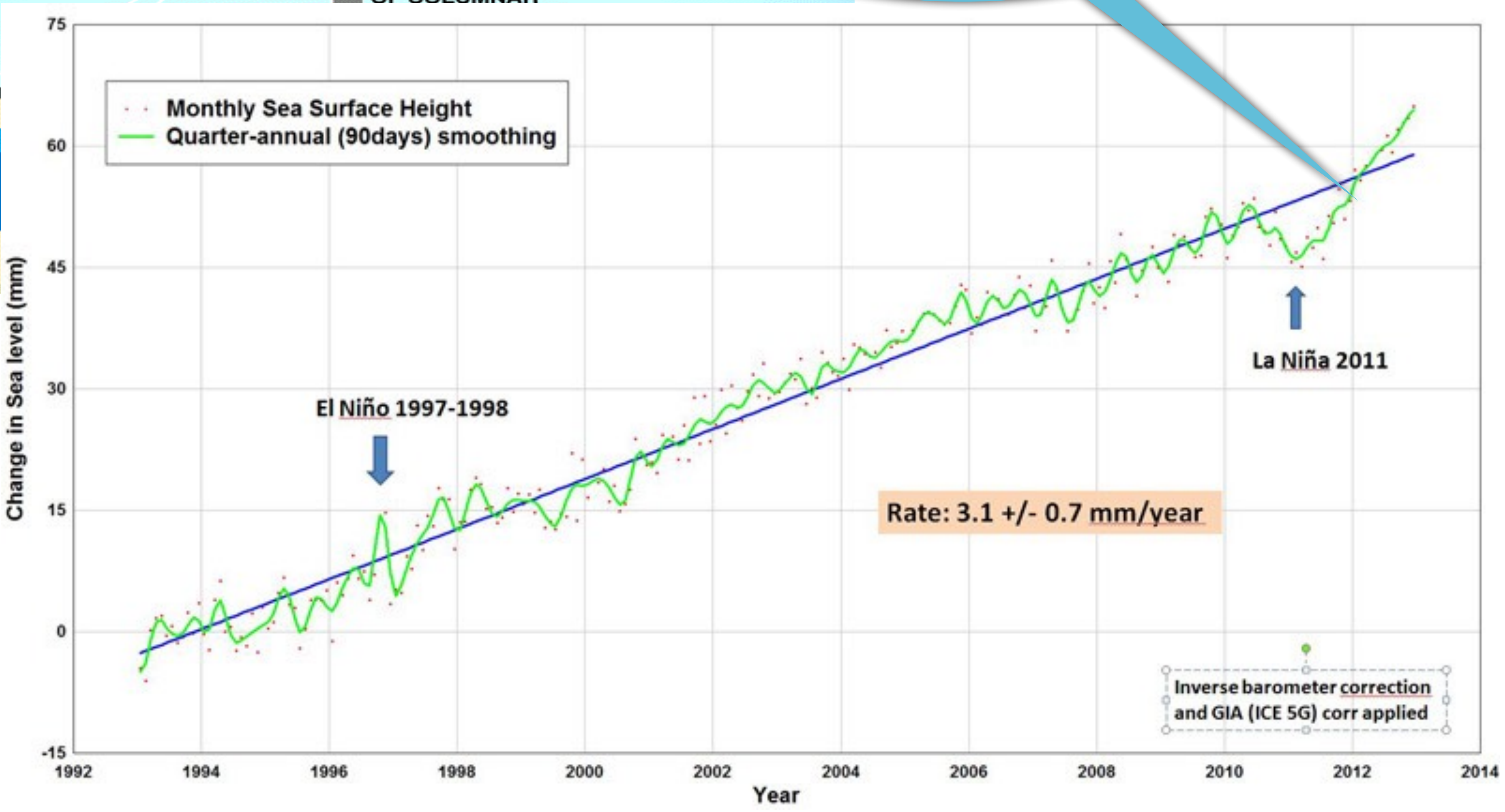




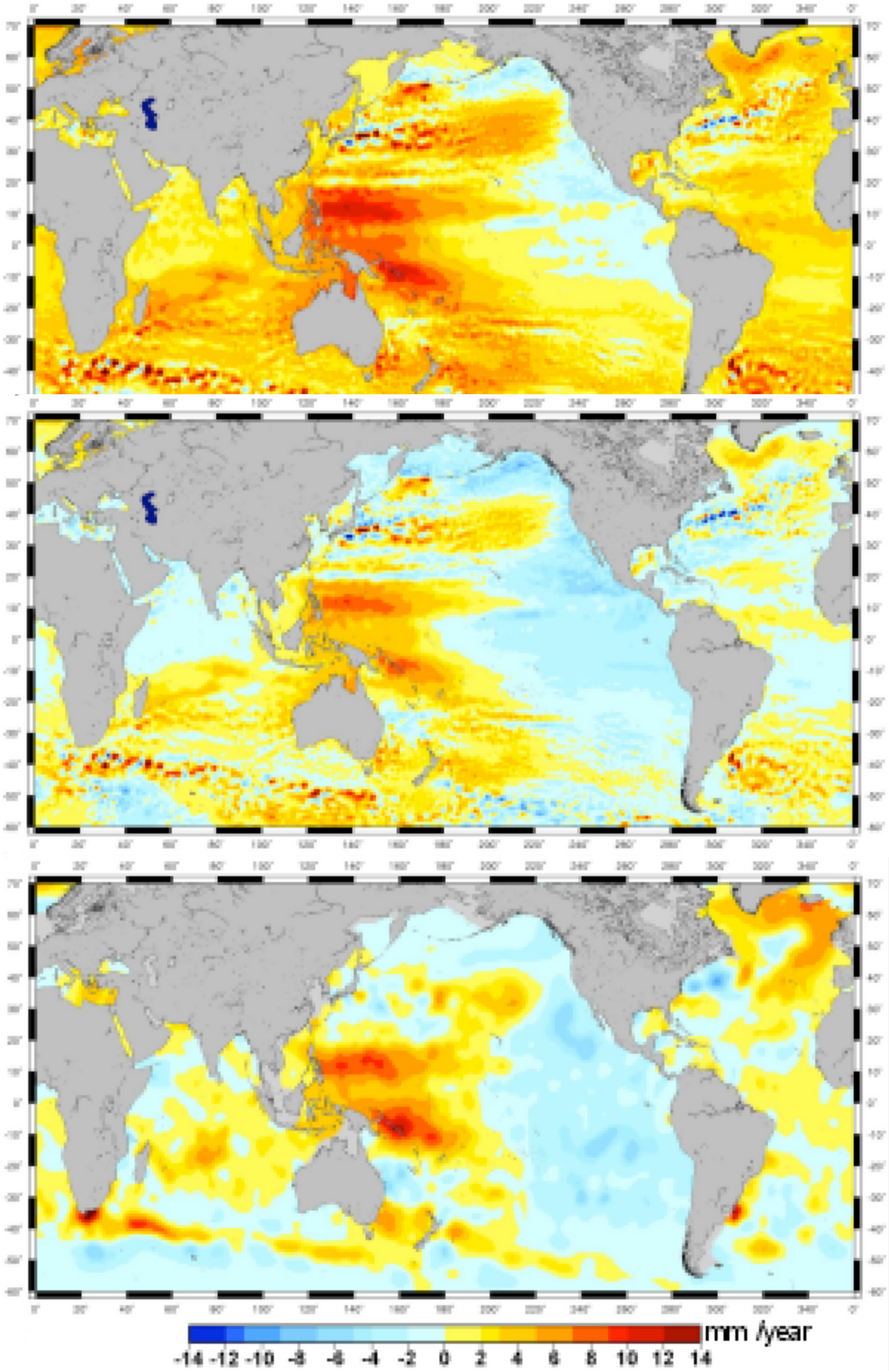
Wiggles of 1-2 cm over several years

Sea surface height

1993-2010

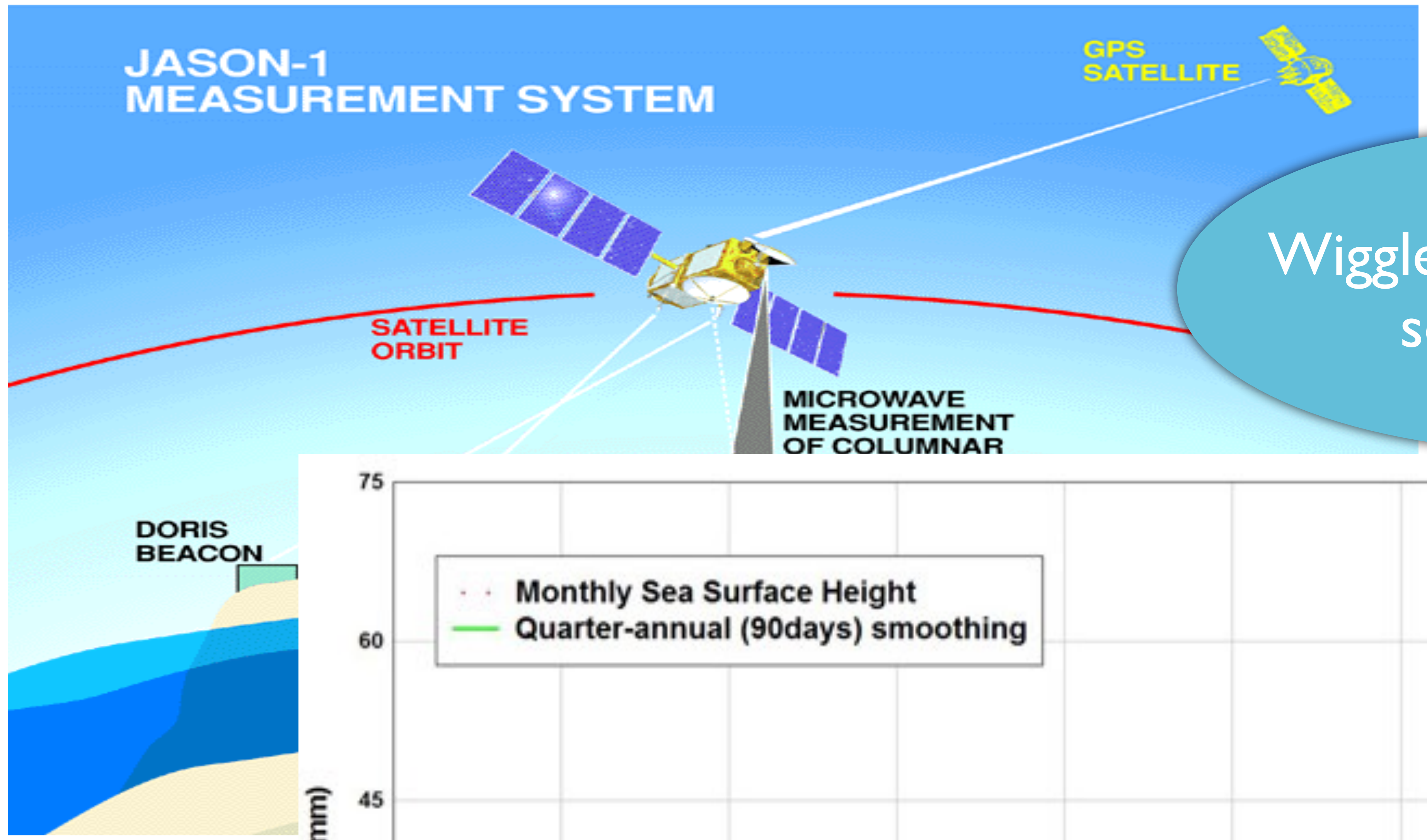
minus
3.2 mm/yr

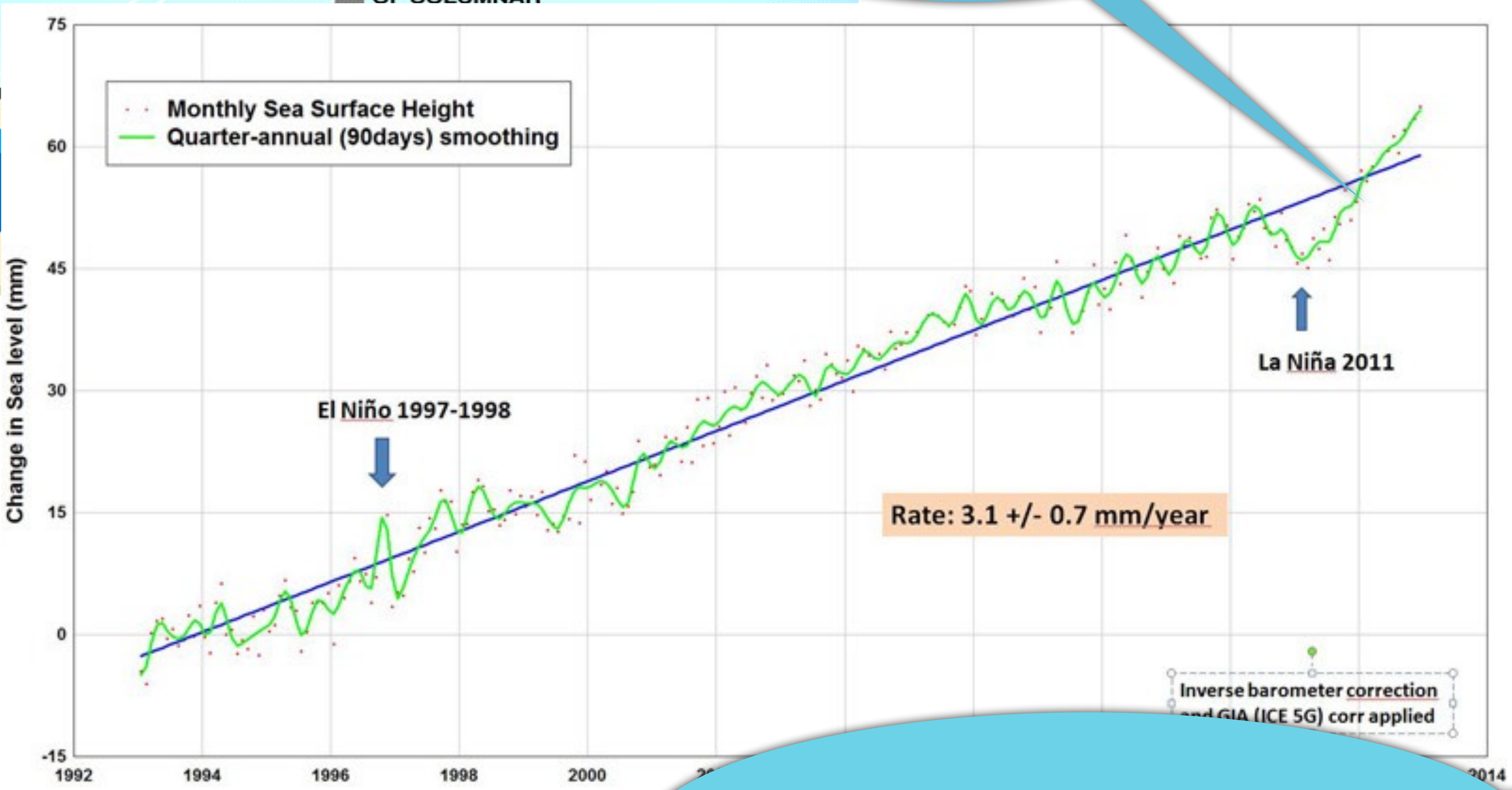
steric height



Meyssignac and Cazenave, 2012

Sea surface height (not sea level):





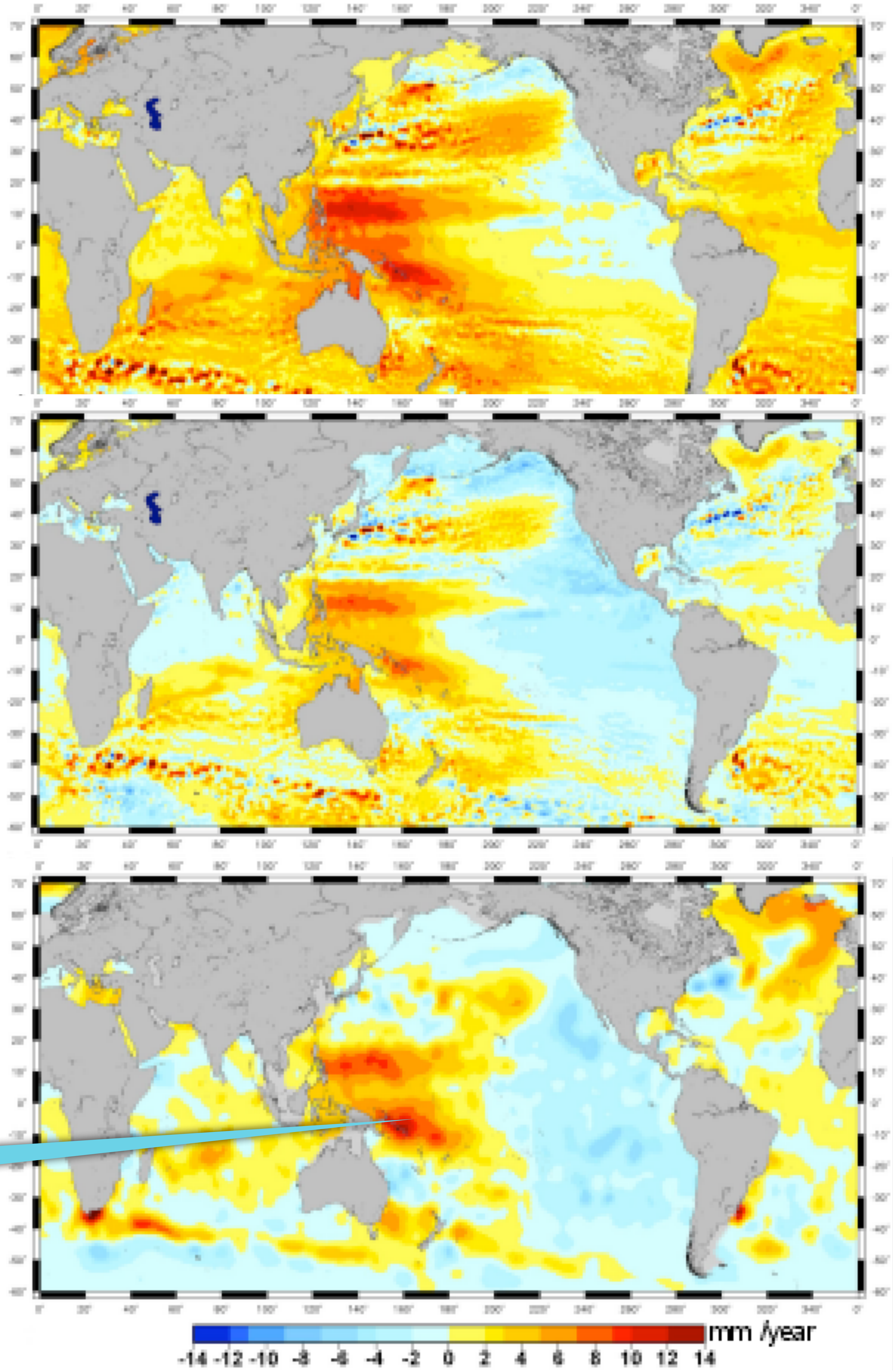
Wiggles of 1-2 cm over several years

Sea surface height

1993-2010

minus
3.2 mm/yr

steric height

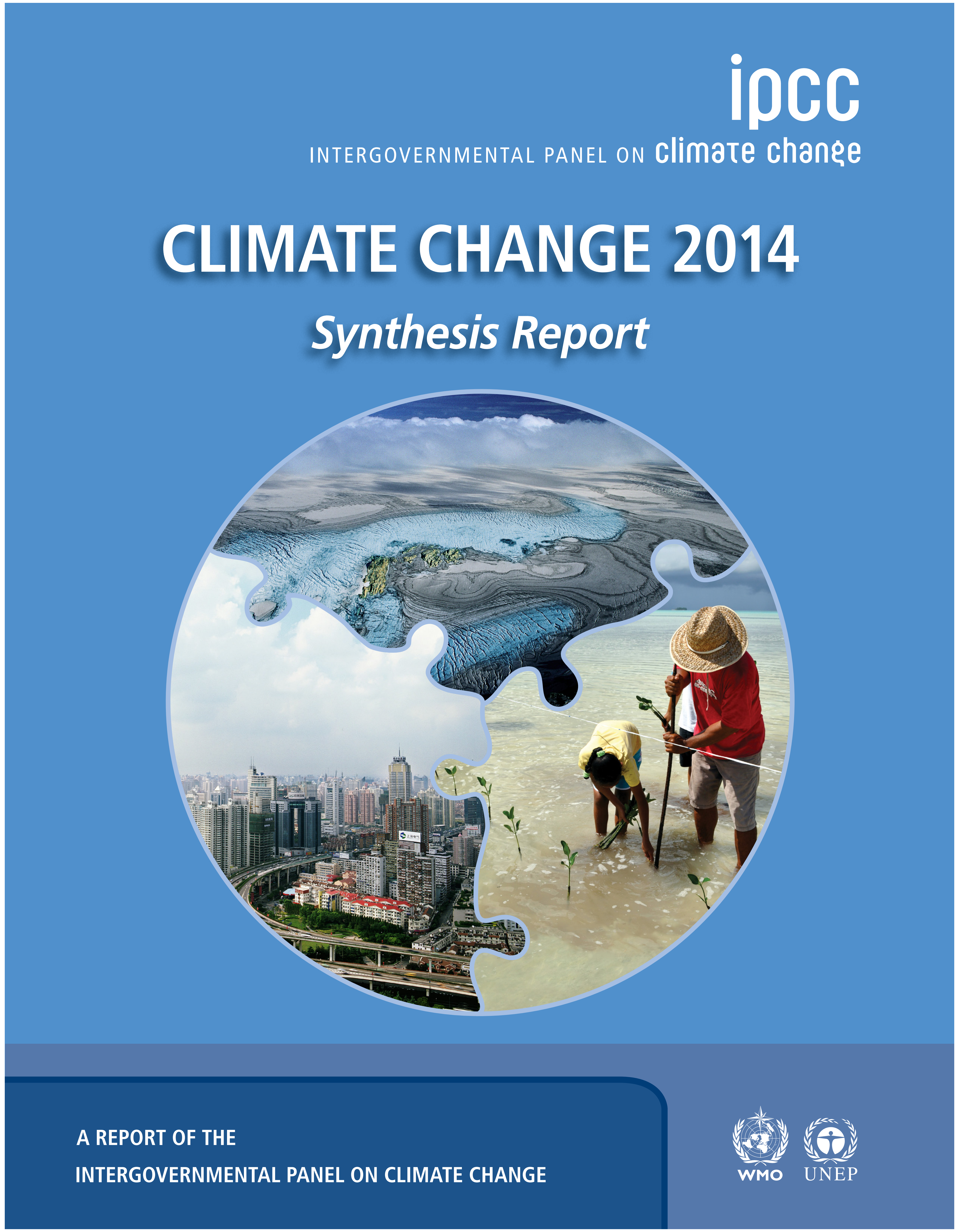


Regional differences of more than 30 cm over 20 years

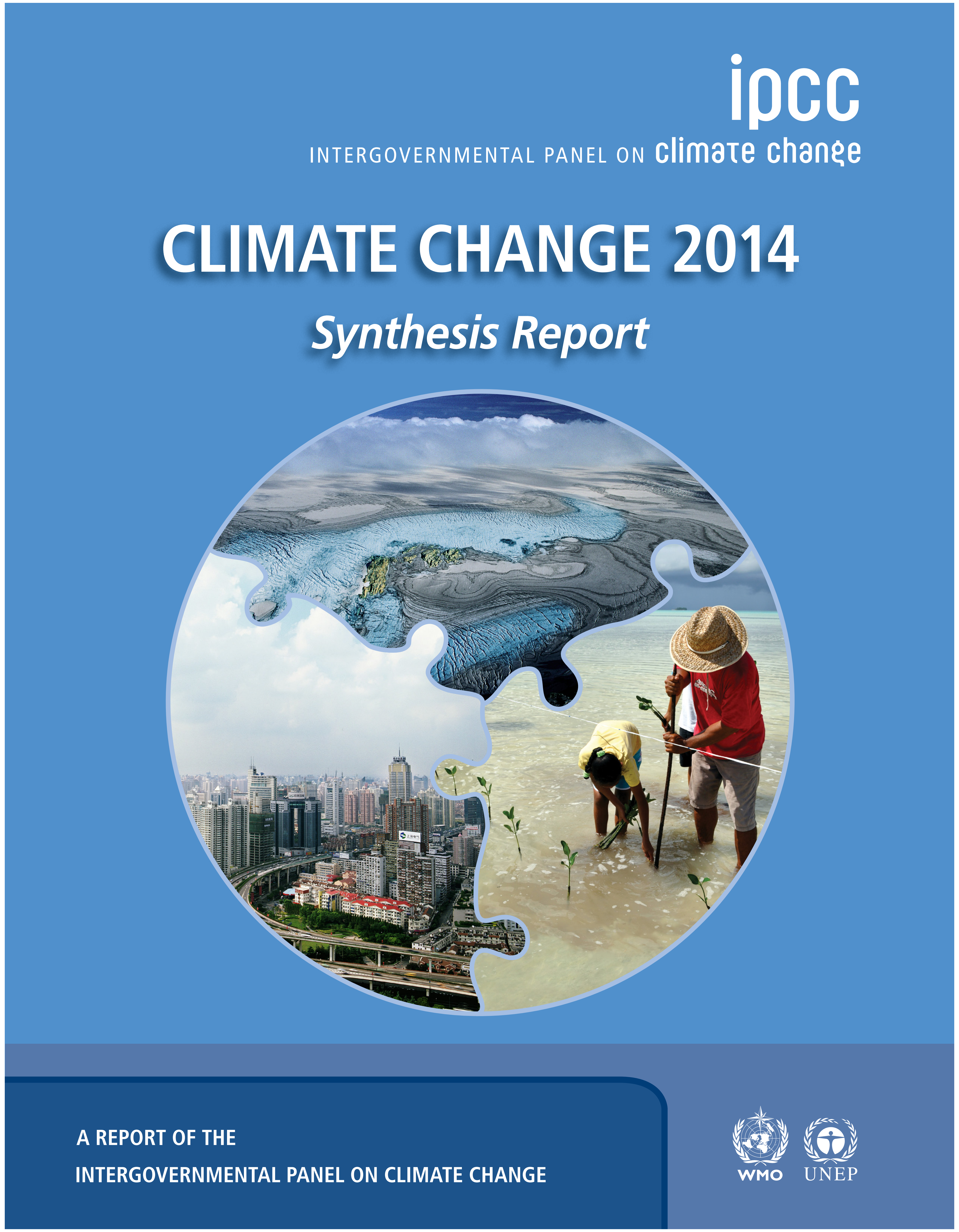
Meyssignac and Cazenave, 2012

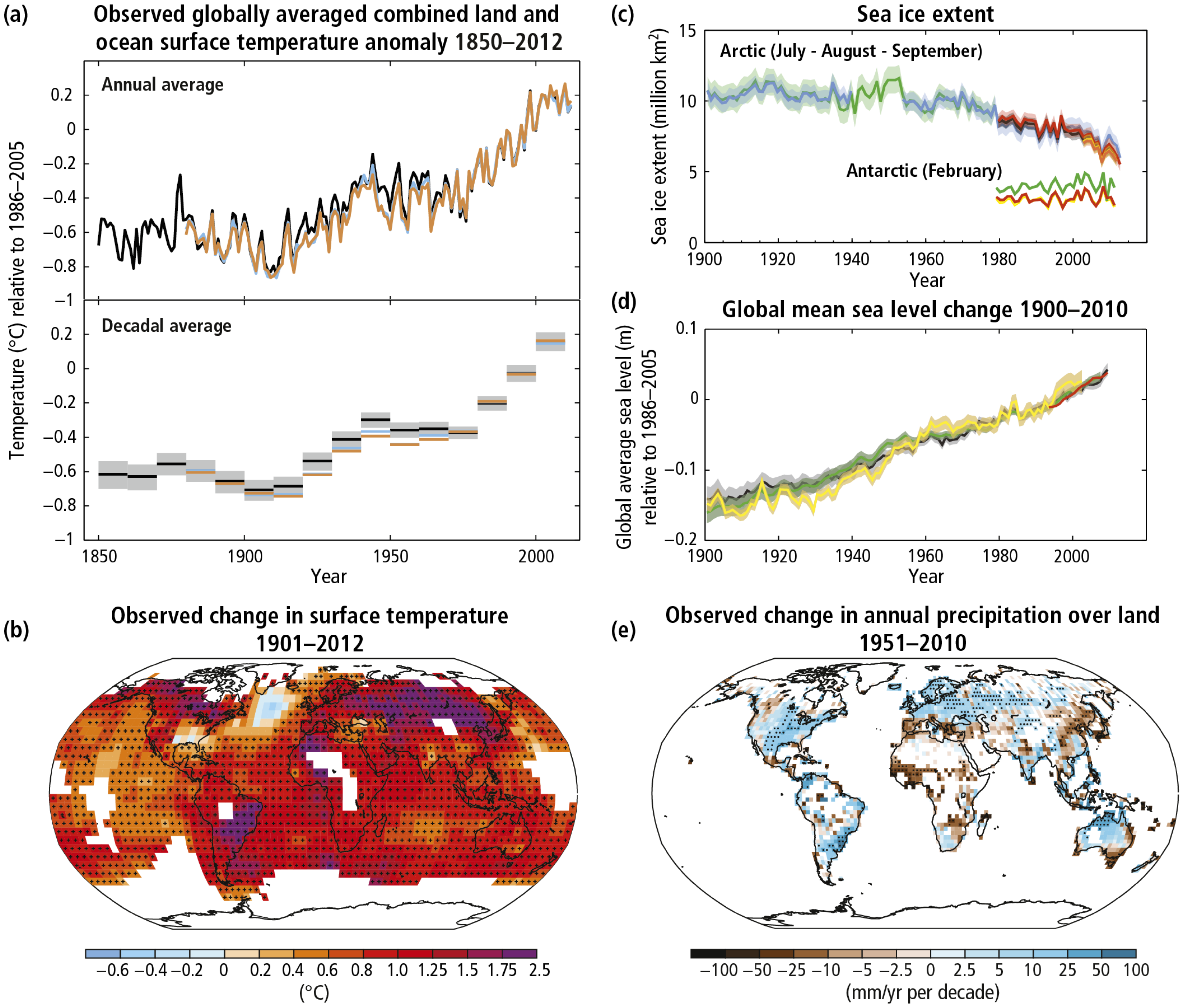
Observing the Planet

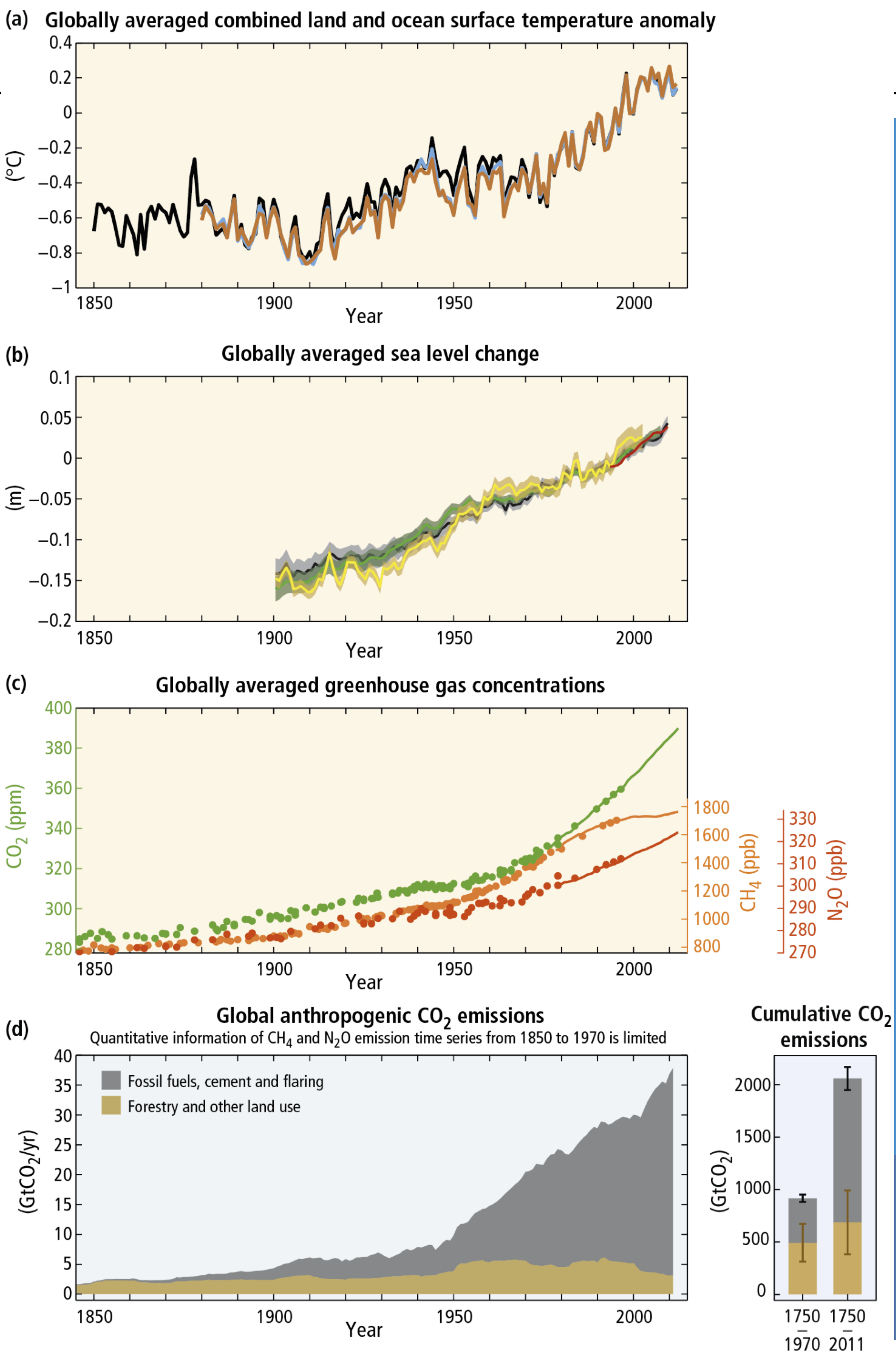
Observing the Planet

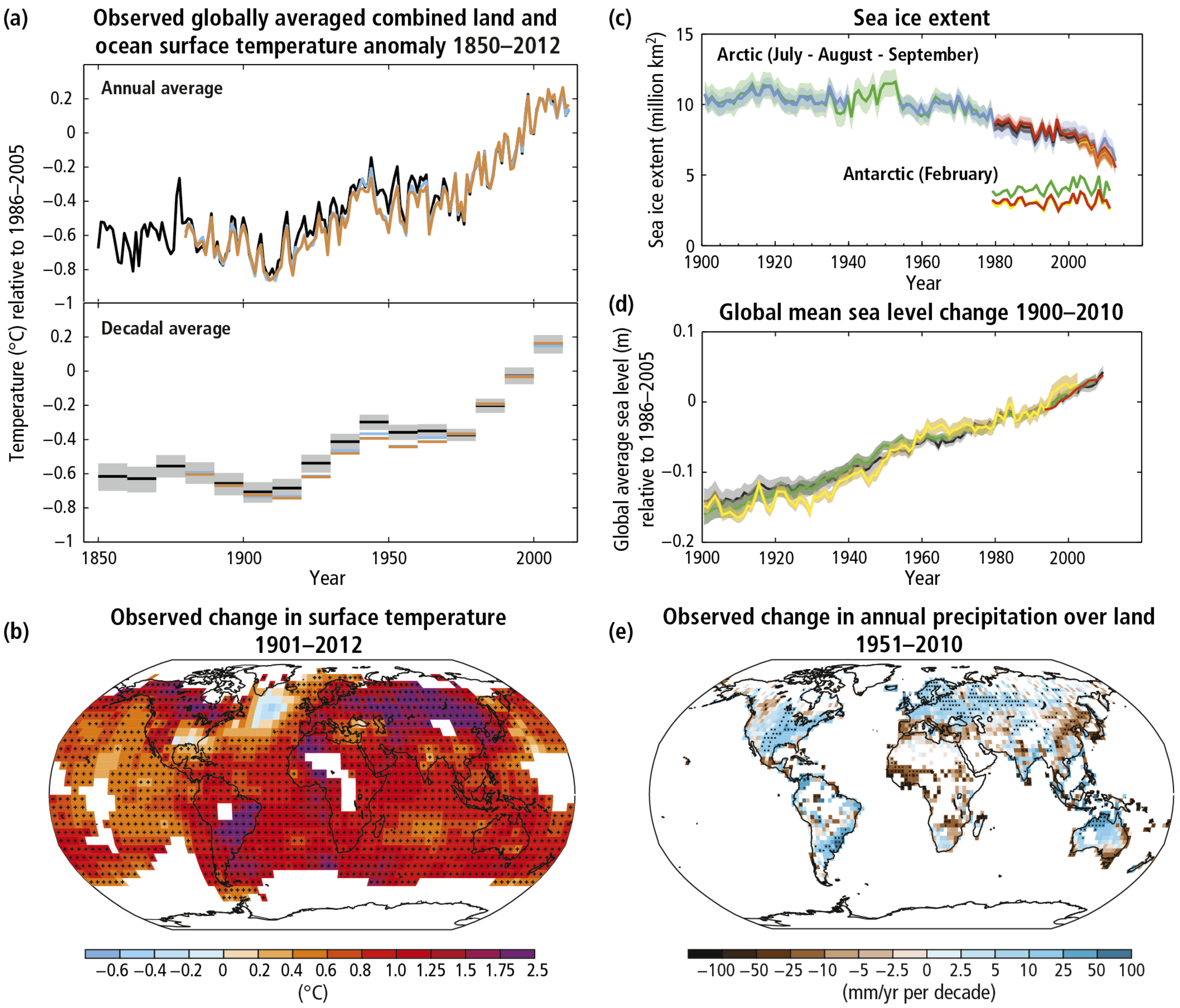


Observing the Planet






(a) Globally averaged combined land and ocean surface temperature anomaly
(°C)
Year
(b) Globally averaged sea level change
(m)
Year
(c) Globally averaged greenhouse gas concentrations
CO_2 (ppm)
CH_4 (ppb)
N_2O (ppb)
Year
(d) Global anthropogenic CO_2 emissions
Quantitative information of CH_4 and N_2O emission time series from 1850 to 1970 is limited
Fossil fuels, cement and flaring
Forestry and other land use
($GtCO_2$/yr)
Year
Cumulative CO_2 emissions
($GtCO_2$)
1750–1970
1750–2011


(a) Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012
Annual average
Decadal average
Temperature (°C) relative to 1986–2005
Year
(b) Observed change in surface temperature 1901–2012
(°C)
(c) Sea ice extent
Arctic (July - August - September)
Antarctic (February)
Sea ice extent (million km^2)
Year
(d) Global mean sea level change 1900–2010
Global average sea level (m) relative to 1986–2005
Year
(e) Observed change in annual precipitation over land 1951–2010
(mm/yr per decade)

Mitigation and Adaptation Studies

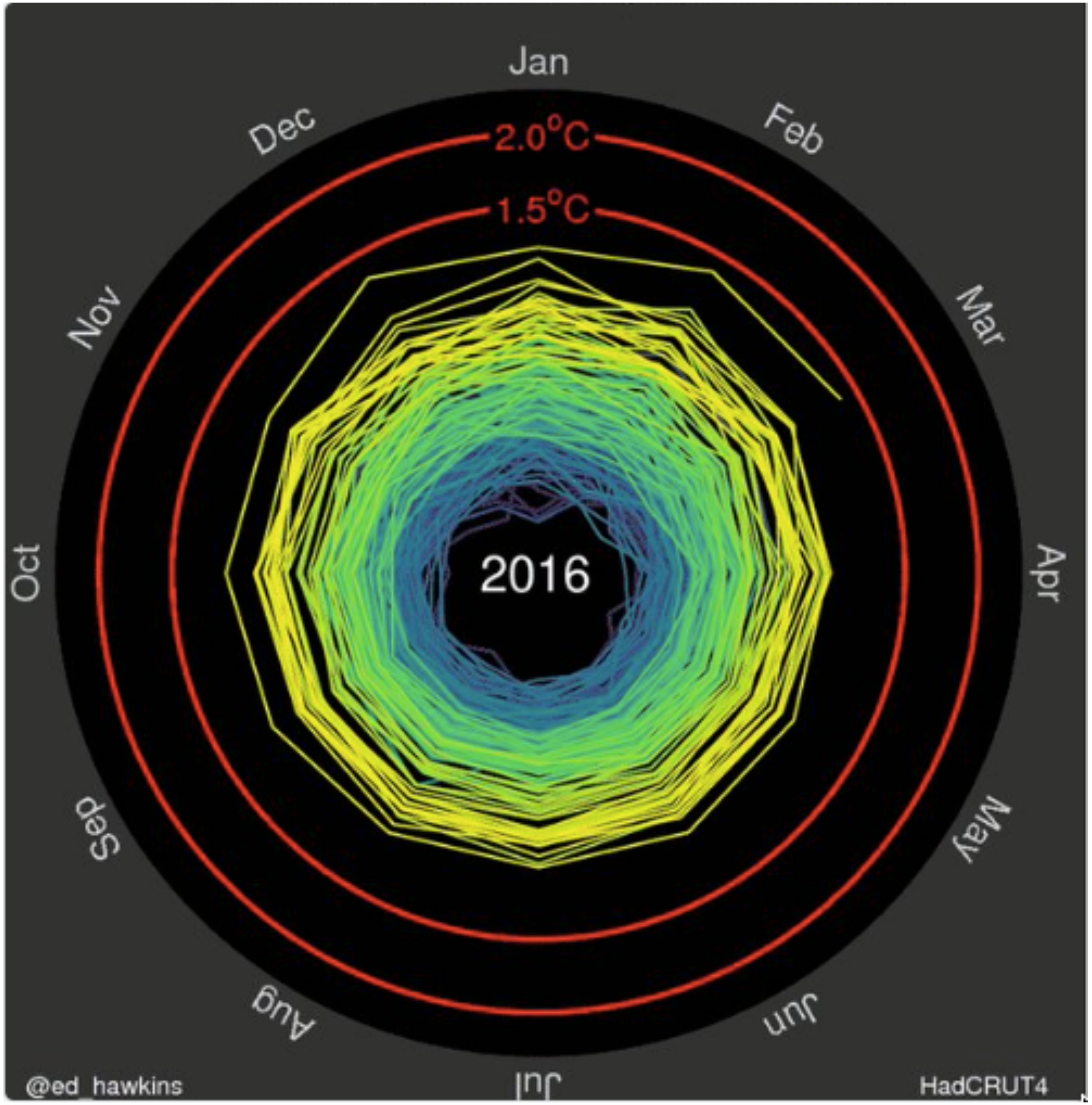
Class 18: Knowing the Hazards: Climate Hazards, Public Health, Food-Water-Energy Nexus

Contents:

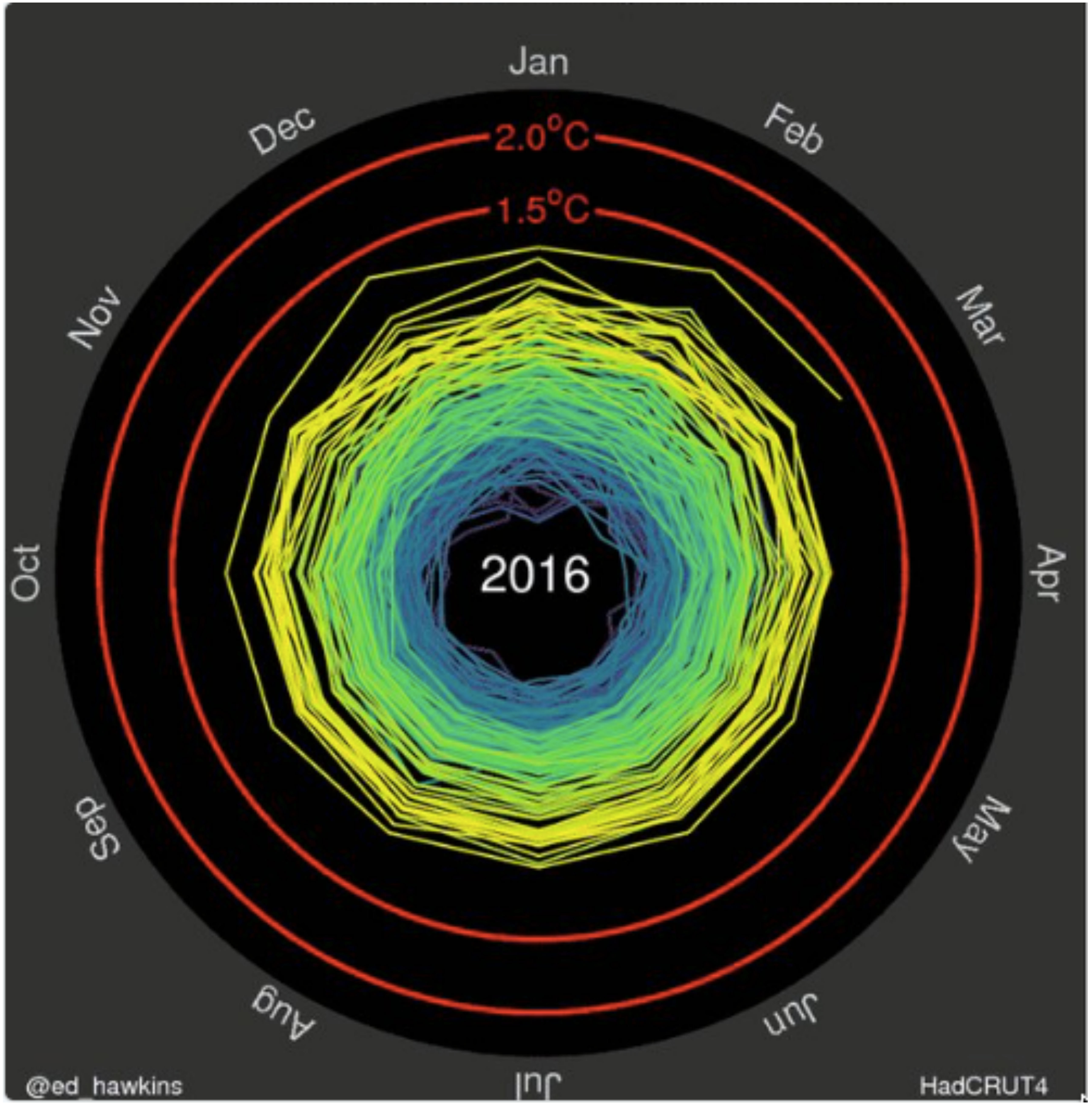
- Preliminaries
- Climate Change and Sea Level Hazards
    - Observing the Planet
    - Detecting Changes
    - Assessing Knowledge
    - Understanding the Processes and Causes
    - Having Foresight
- Public Health
- Food-Water-Energy Nexus

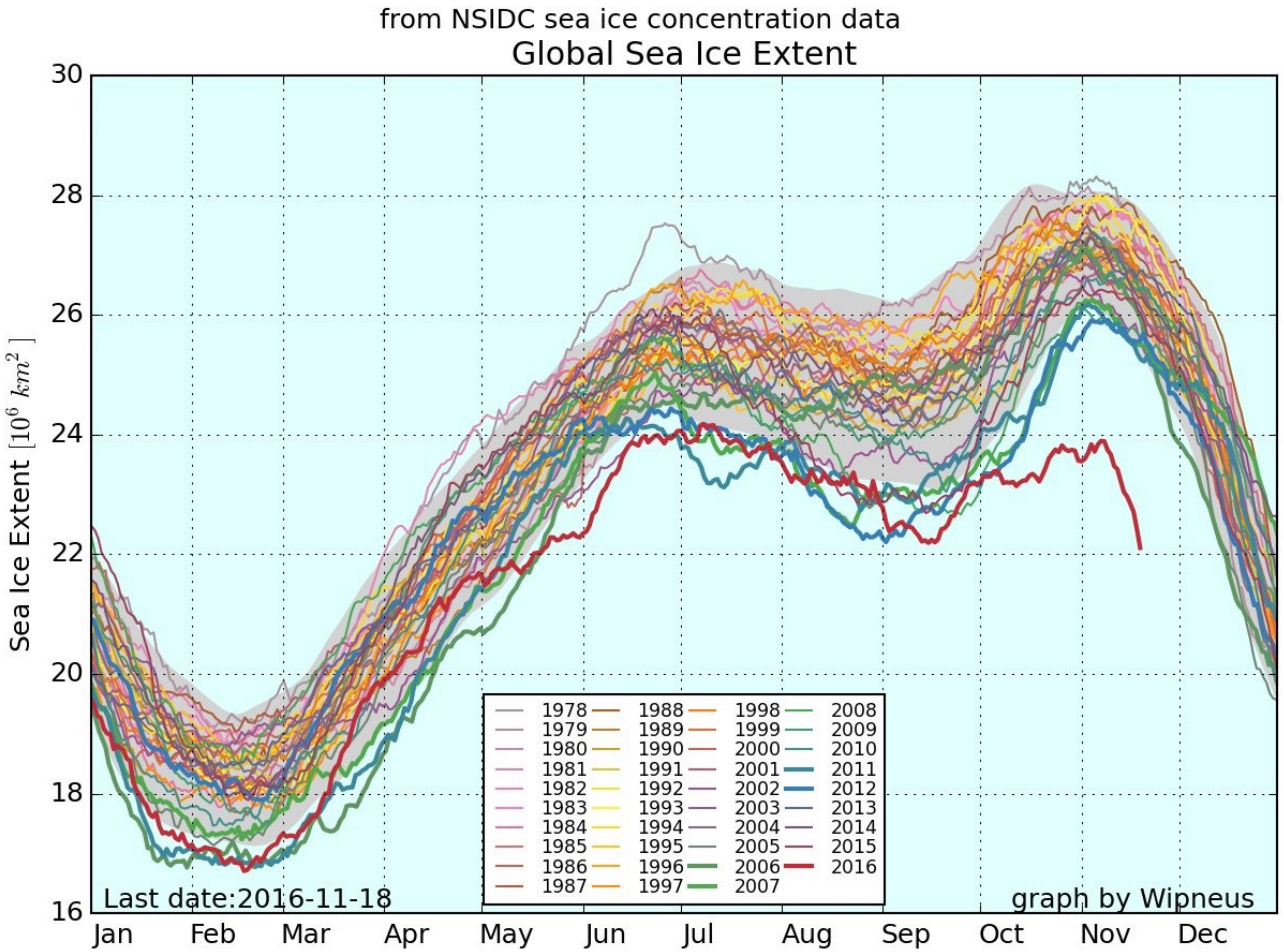
Detecting Changes

Detecting Changes

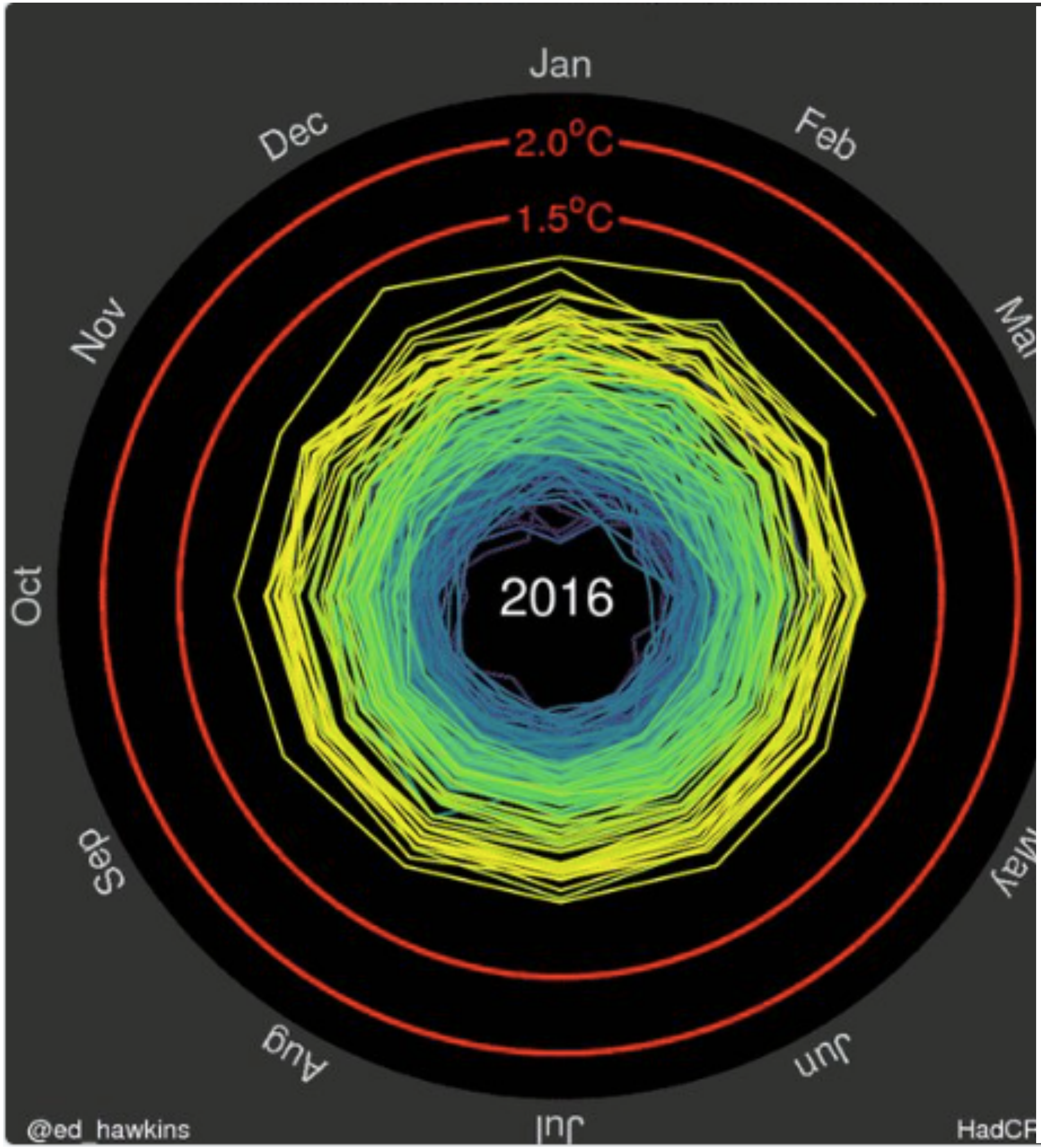


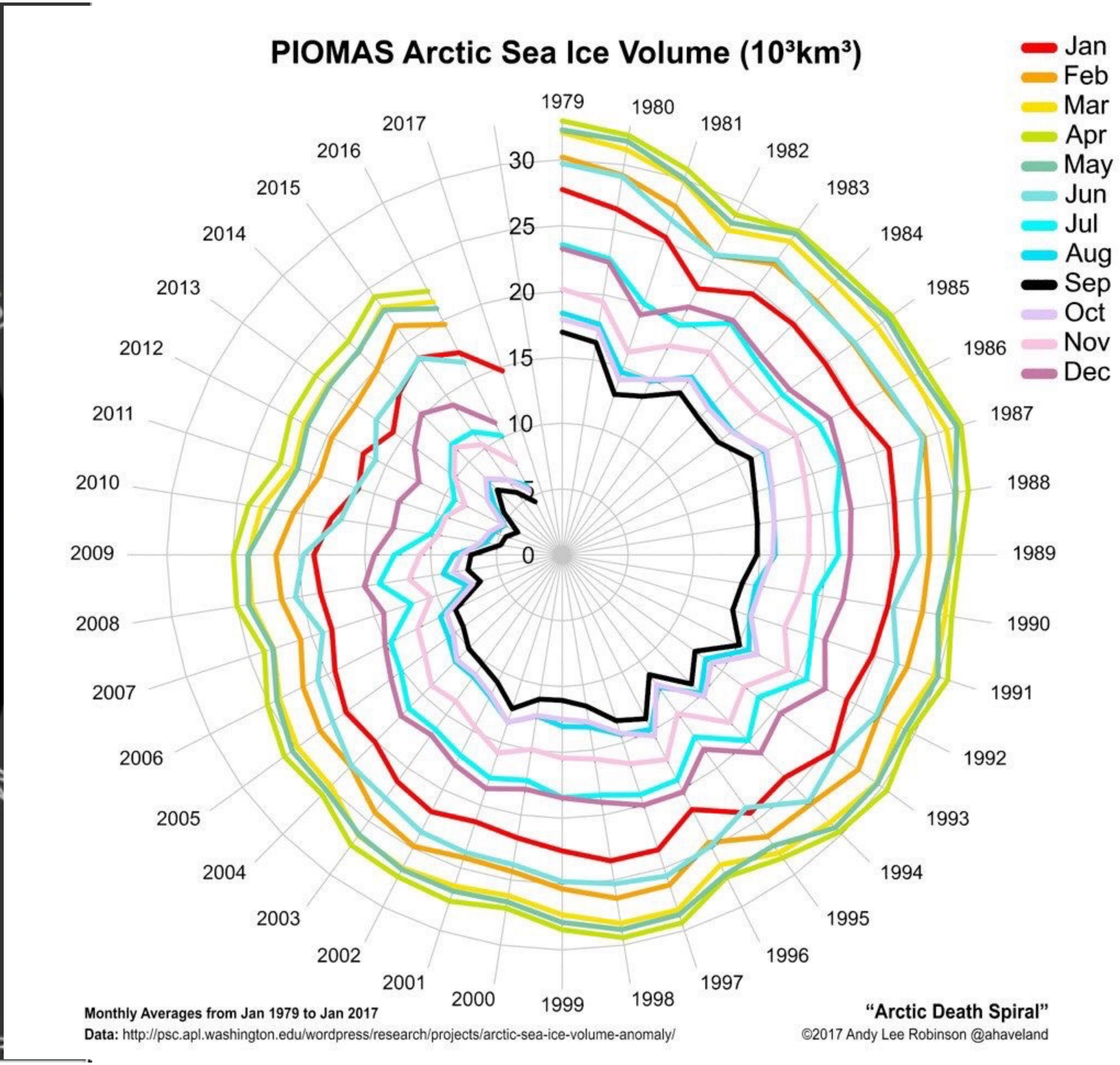
Detecting Changes





Detecting Changes





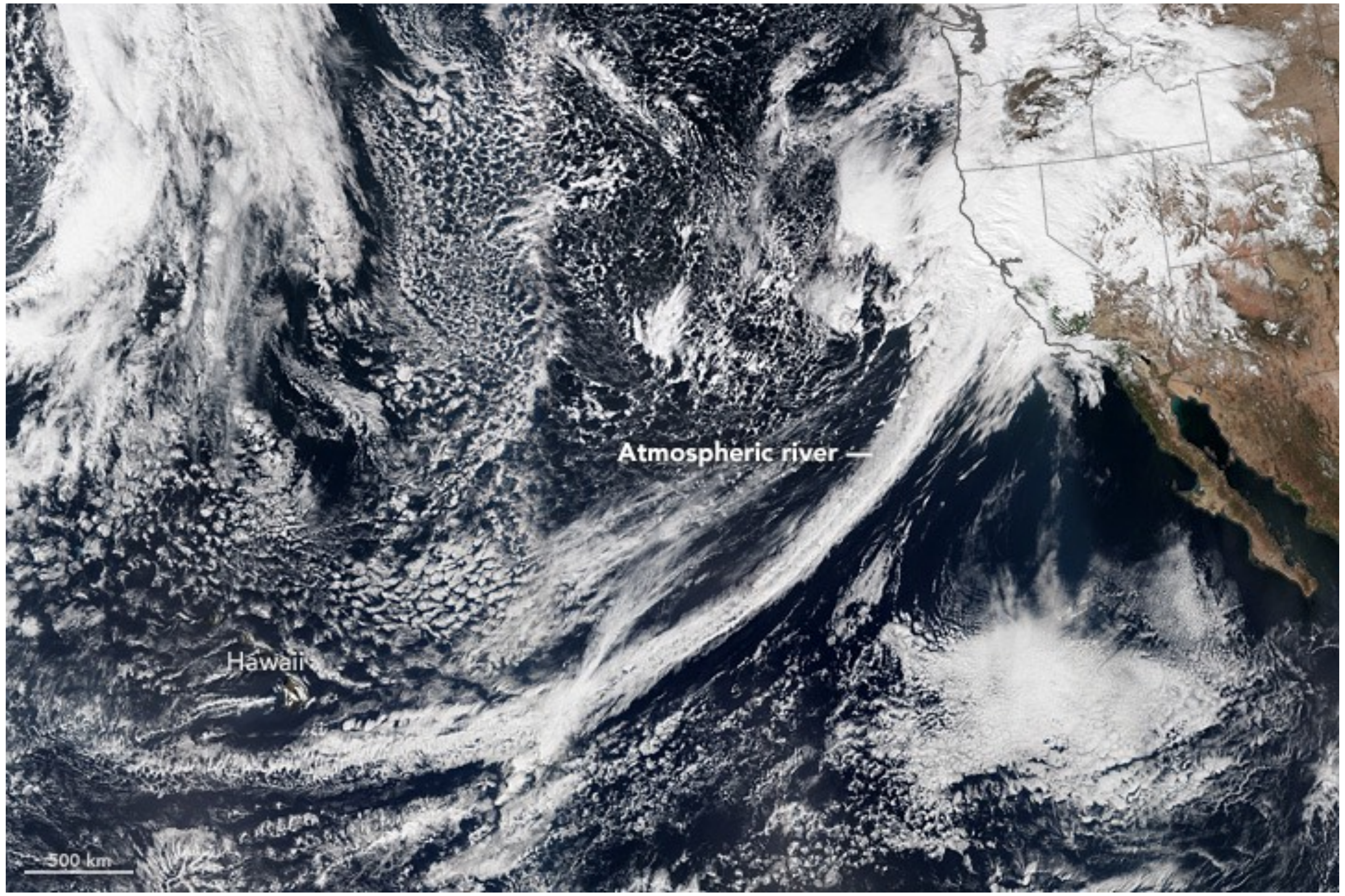
Detecting Changes

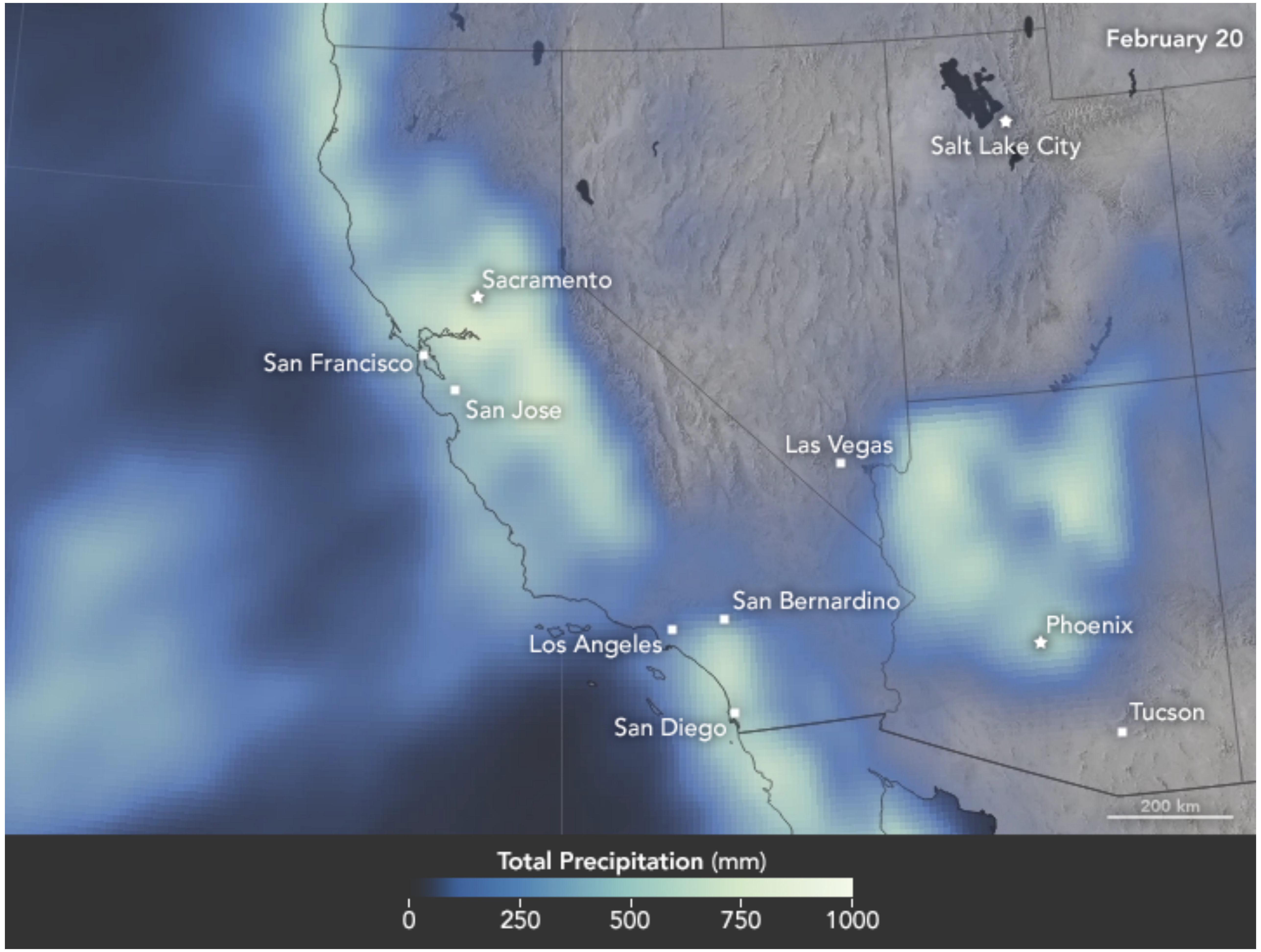
A Crack in an Antarctic Ice Shelf Grew 17 Miles in the Last Two Months

By **JUGAL K. PATEL** FEB. 7, 2017

A rapidly advancing crack in Antarctica's fourth-largest ice shelf has scientists concerned that it is getting close to a full break. The rift has accelerated this year in an area already vulnerable to warming temperatures. Since December, the crack has grown by the length of about five football fields each day.

Detecting Changes





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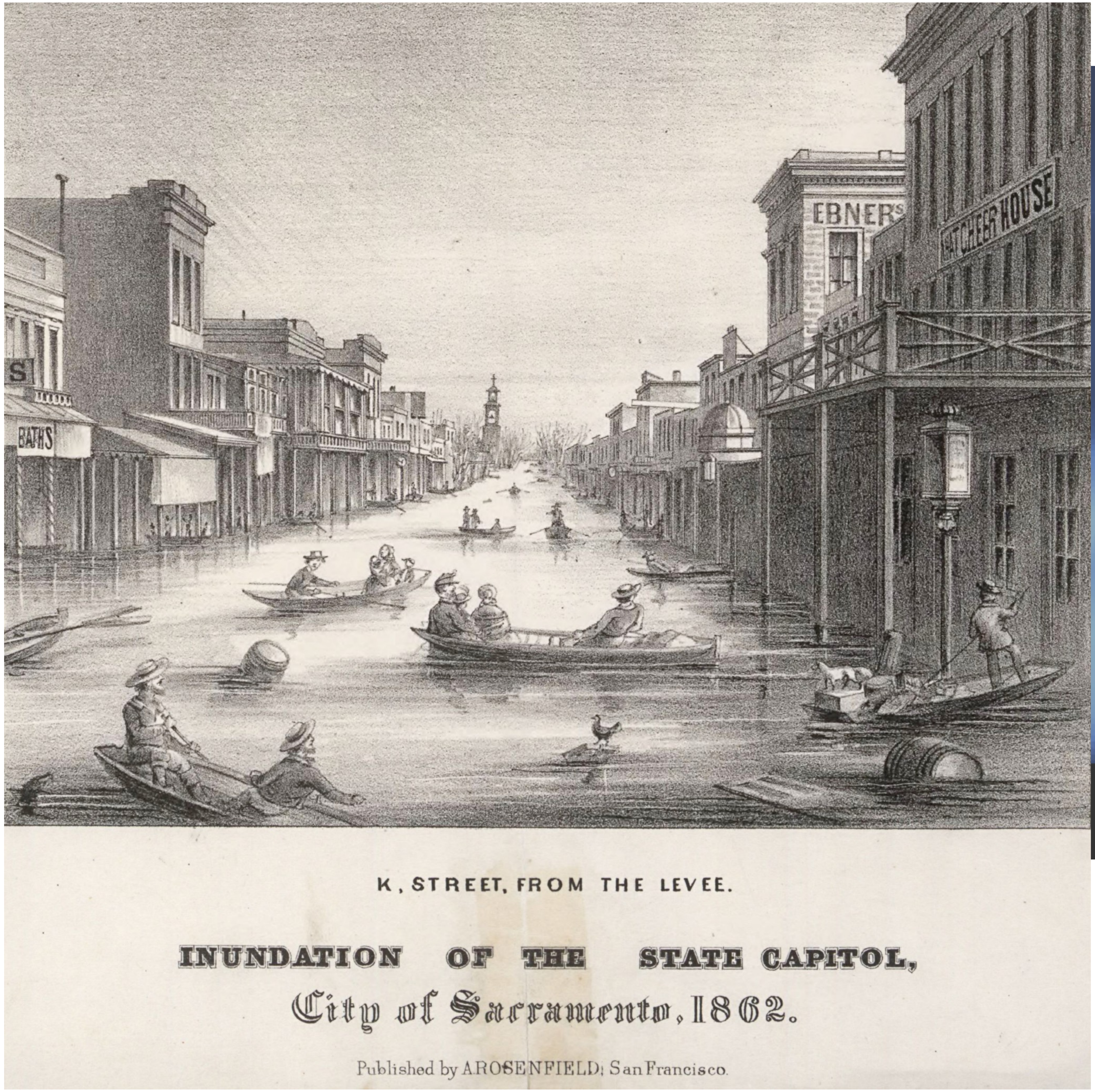
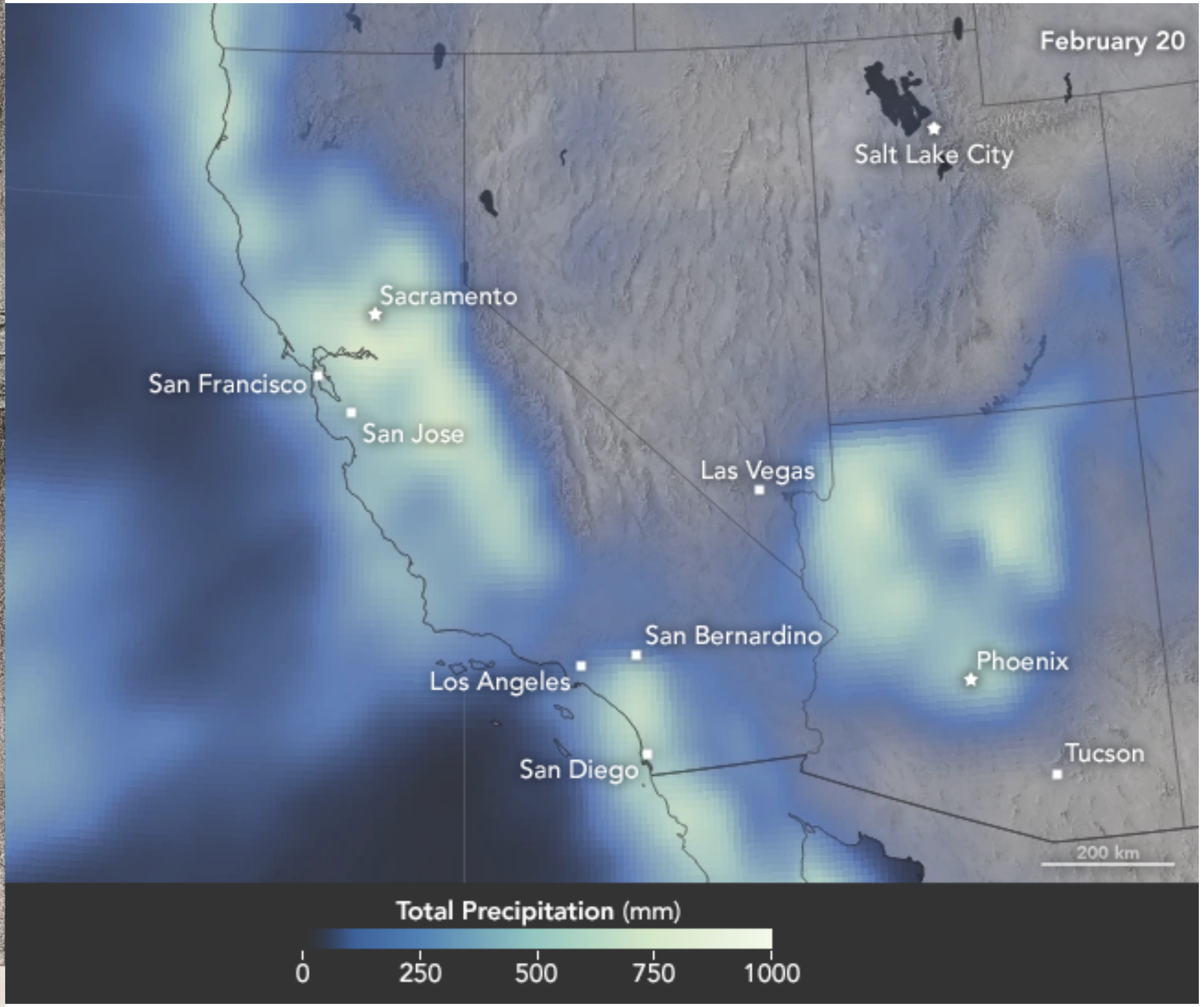
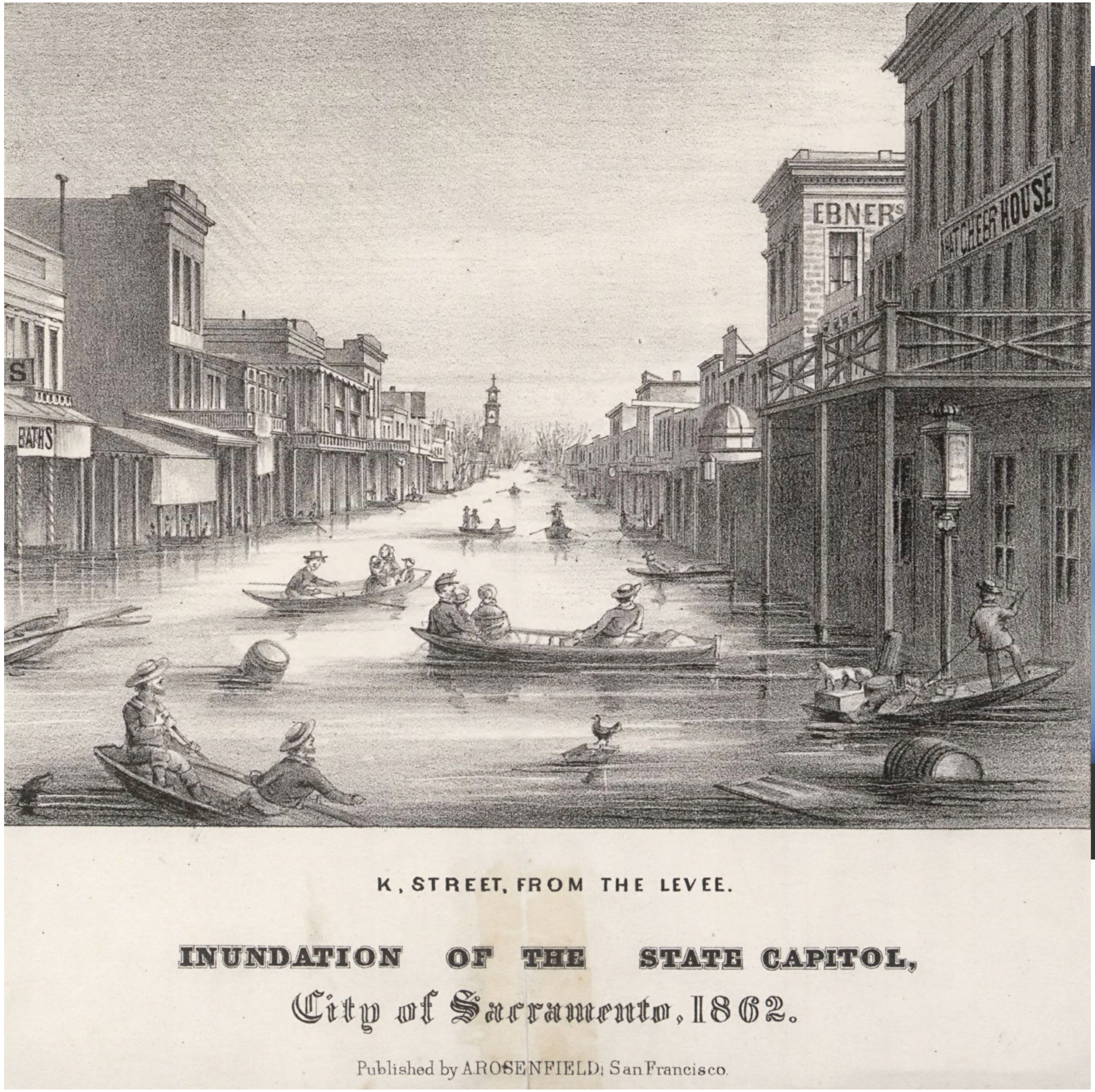




Detecting Changes



Detecting Changes

People paddle and row through the flooded Barlow Market District of Sebastopol, California, after an atmospheric river dumped inches of rain on the region in February, 2019.

PHOTOGRAPH BY ERIC RISBERG, AP

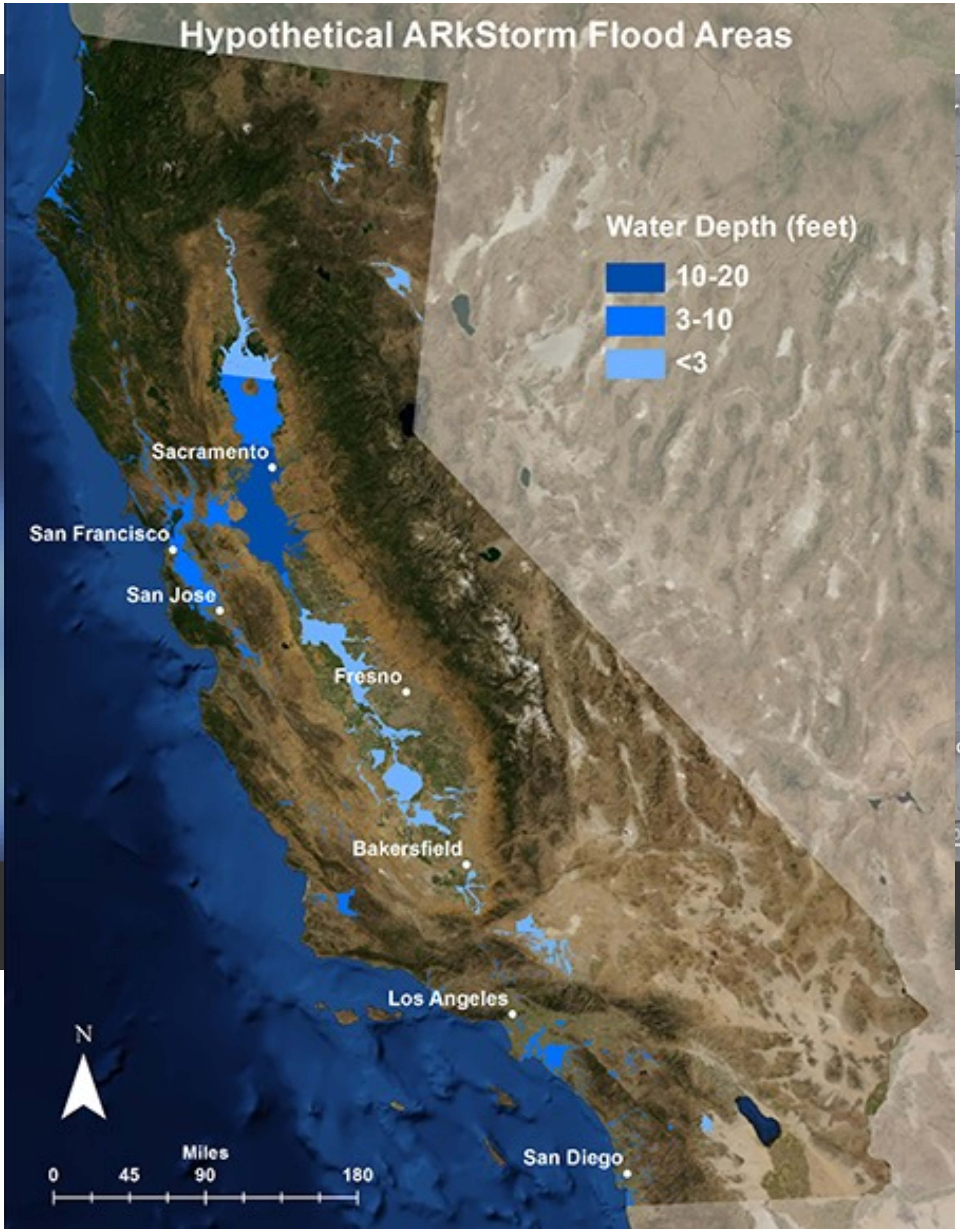
ENVIRONMENT | VIRAL EXPLAINER

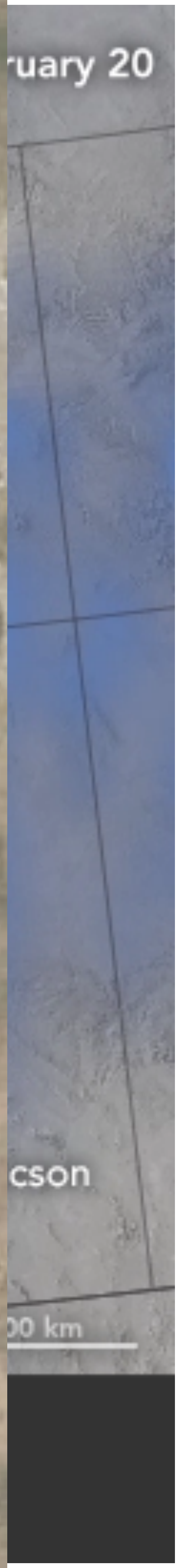
'Rivers in the sky' are why California is flooding

Atmospheric rivers move huge amounts of water through the air above us—and dump rain and snow on land.

4 MINUTE READ

BY **ALEJANDRA BORUNDA**



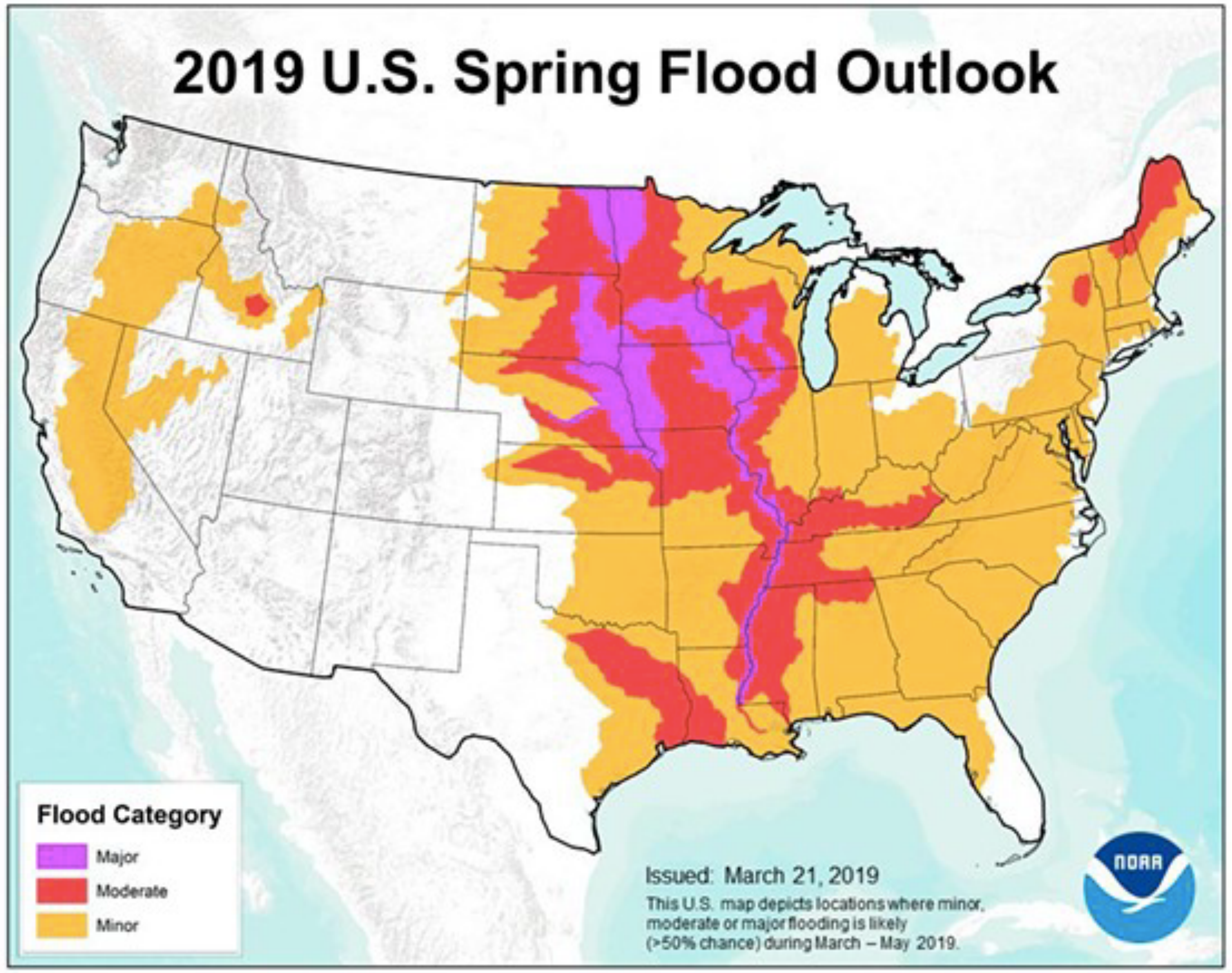


Detecting Changes

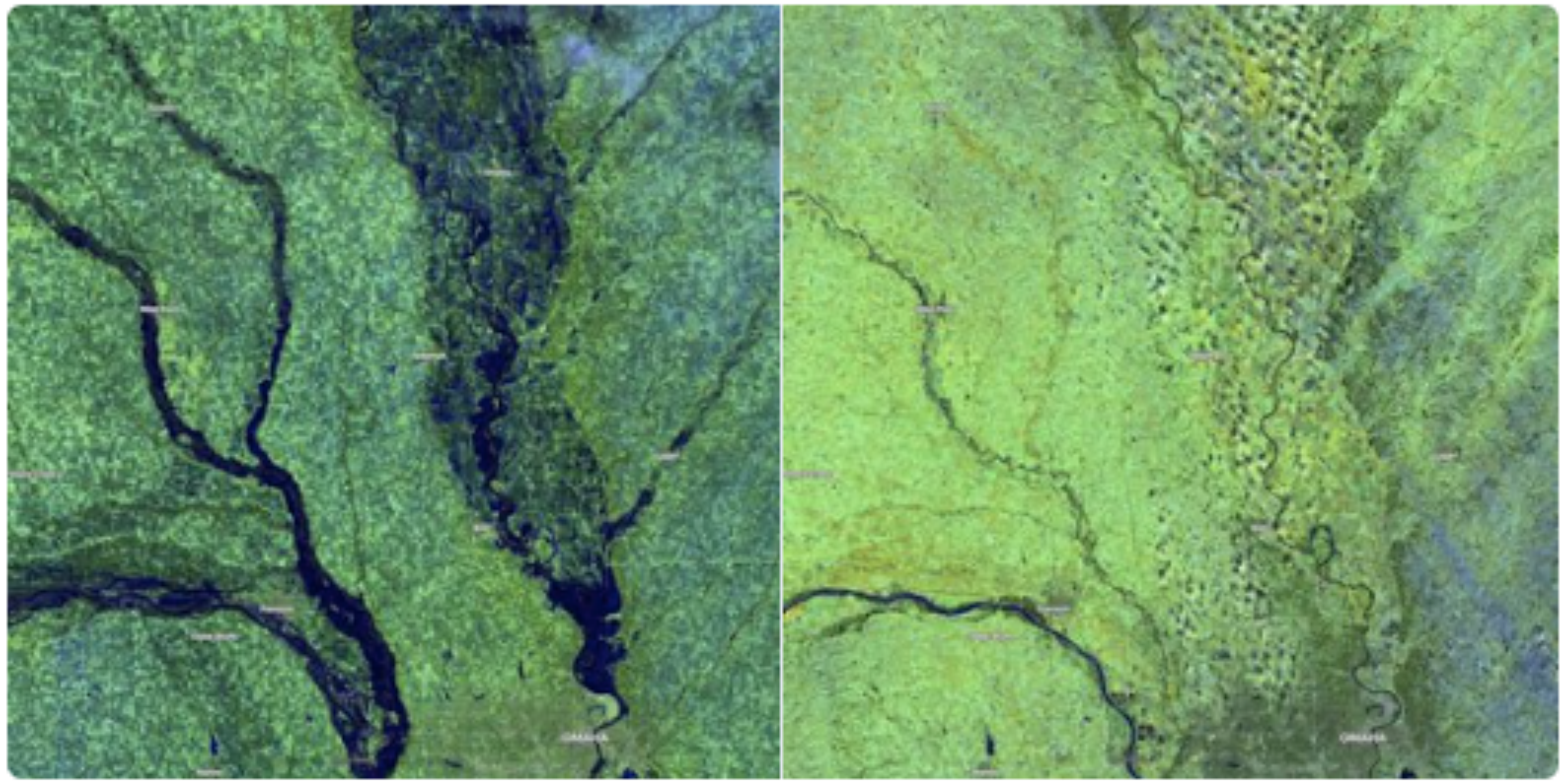
Unprecedented spring flooding expected in 25 states, including Arkansas

Posted By Max Brantley on Fri, Mar 22, 2019 at 7:08 AM

click to enlarge



Flooding isn't just a problem in Nebraska and some other states that have dominated recent news coverage. The New York Times notes Weather Service findings that indicate 25 states, including Arkansas, could experience "major or moderate" flooding this spring.



Detecting Changes

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

Save for later

Bullit Marquez/AP | View Caption

Detecting Changes

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Bullit Marquez/AP | View Caption

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REPORT

An unexpected disruption of the atmospheric quasi-biennial oscillation

Scott M. Osprey[1,*], Neal Butchart[2], Jeff R. Knight[2], Adam A. Scaife[2,3], Kevin Hamilton[4], James A. Anstey[5], Verena Schenzinger[1], Chunxi Zhang[4]

+ Author Affiliations

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

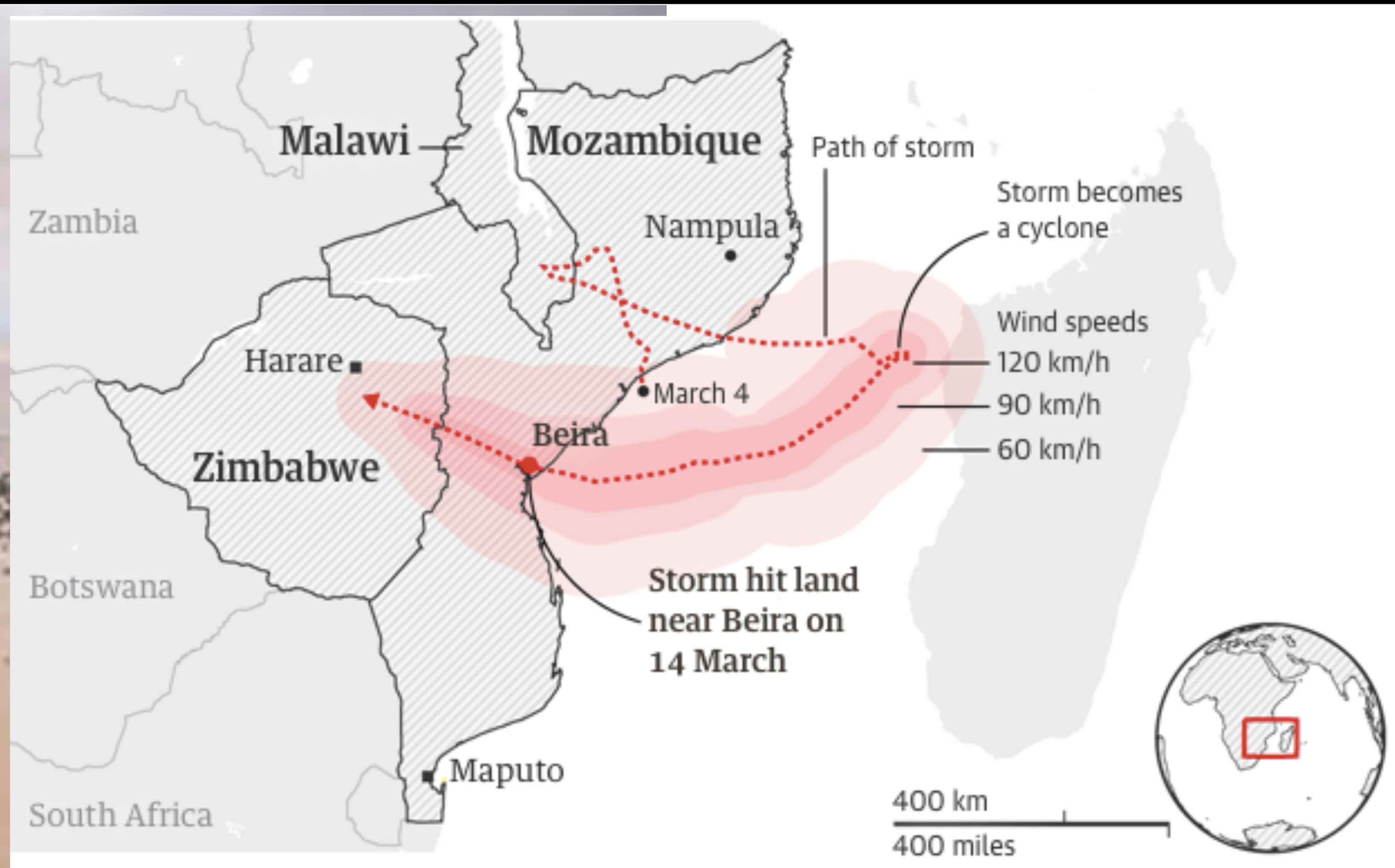
Science 08 Sep 2016:

DOI: 10.1126/science.aah4156

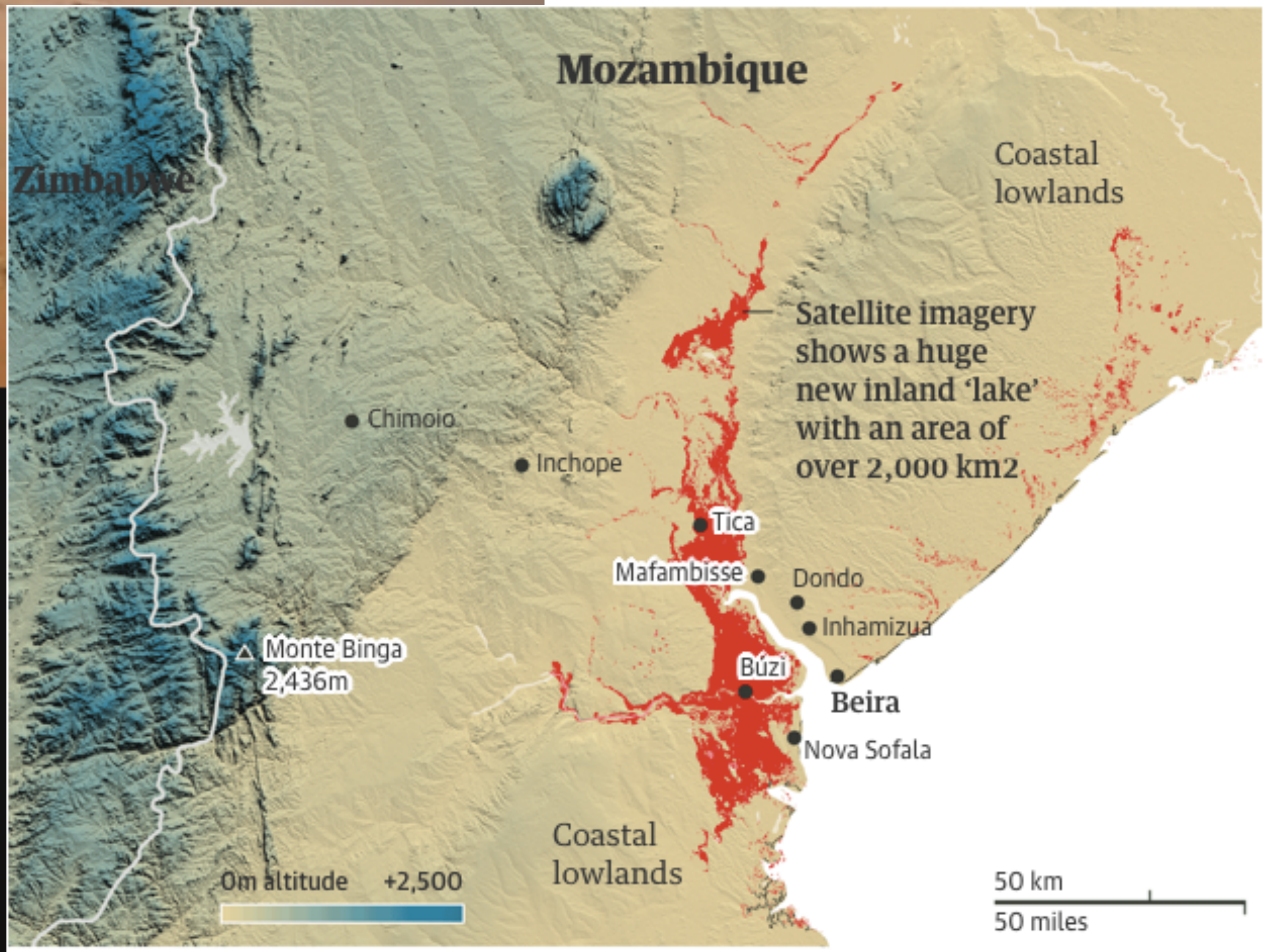
Detecting Changes

▲ Floodwaters have created an inland lake in some of Mozambique's most densely population areas. Photograph: Adrien Barbier/AFP/Getty Images

Cyclone Idai brings devastation to Mozambique - visual guide



Source: Global Disaster Alert and Coordination System



Source: Unitar, Unosat

Detecting Changes

Cyclone Idai

Cyclone Idai death toll passes 750 with more than 110,000 now in camps

Devastated areas of Mozambique, Zimbabwe and Malawi brace for the spread of waterborne diseases such as cholera and malaria

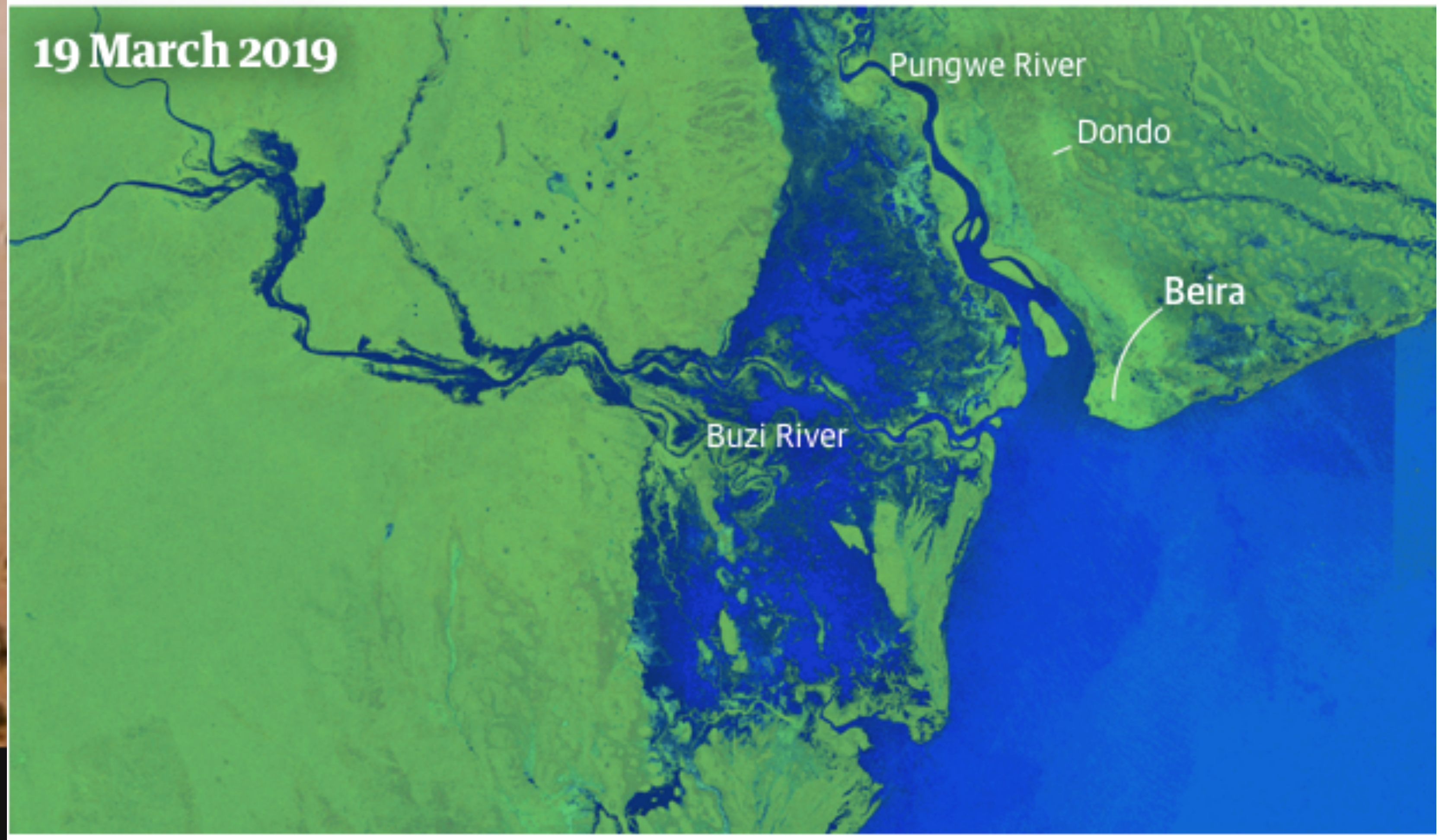
Agencies in Beira
Sun 24 Mar 2019
19.53 EDT

539

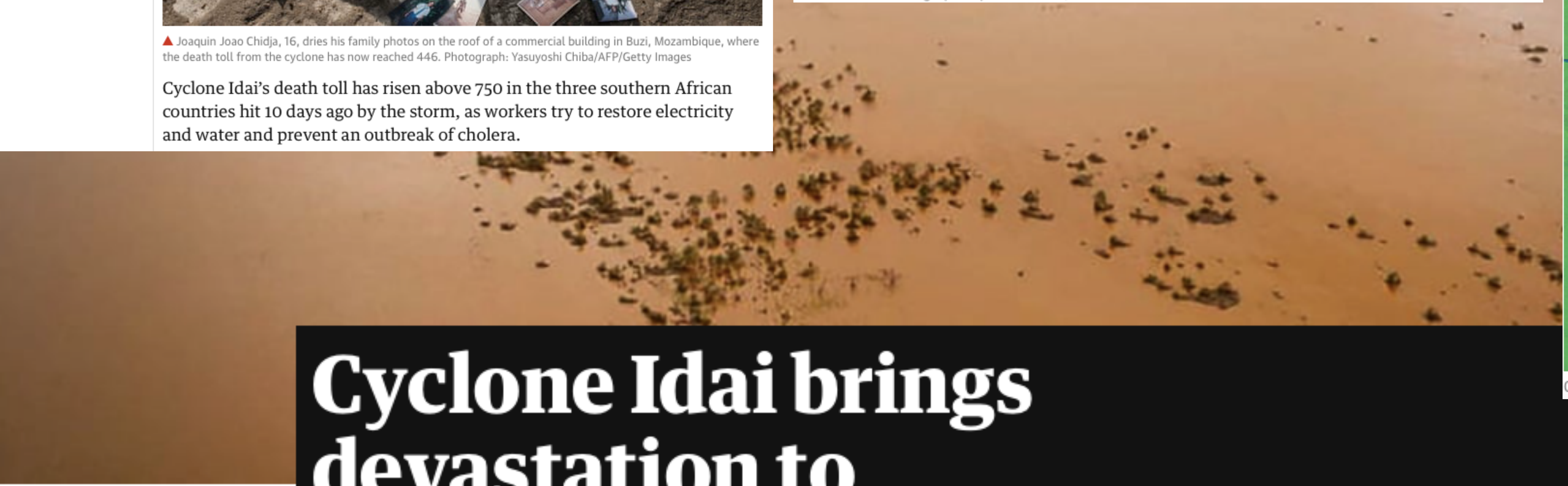
▲ Joaquin Joao Chidja, 16, dries his family photos on the roof of a commercial building in Buzi, Mozambique, where the death toll from the cyclone has now reached 446. Photograph: Yasuyoshi Chiba/AFP/Getty Images

Cyclone Idai's death toll has risen above 750 in the three southern African countries hit 10 days ago by the storm, as workers try to restore electricity and water and prevent an outbreak of cholera.

▲ A local paddles past a woman at her home during floods after Cyclone Idai, in Buzi district, outside Beira. Photograph: Siphiwe Sibeko/Reuters



Guardian graphic. Source: Google Earth (before); Sam Bowers / University of Edinburgh (after)



▲ Floodwaters have created an inland lake in some of Mozambique's most densely population areas. Photograph: Adrien Barbier/AFP/Getty Images

Cyclone Idai brings devastation to Mozambique – visual guide

Detecting Changes

Flooding in Papua in March 2019 Photo: Jubi

Photo: Jubi

PACIFIC / WEST PAPUA

Mass funeral for Papua flood victims as death toll passes 100

4:43 pm on 21 March 2019

Share this

Mass burials are being planned as the death toll rises from the Sentani flash floods in Indonesia's Papua Province.

Australia's north prepares for the worst as two cyclones approach

By Emma Young and Chris McLennan
March 23, 2019 — 2.01pm

A A A

1 View all comments

TODAY'S TOP STORIES

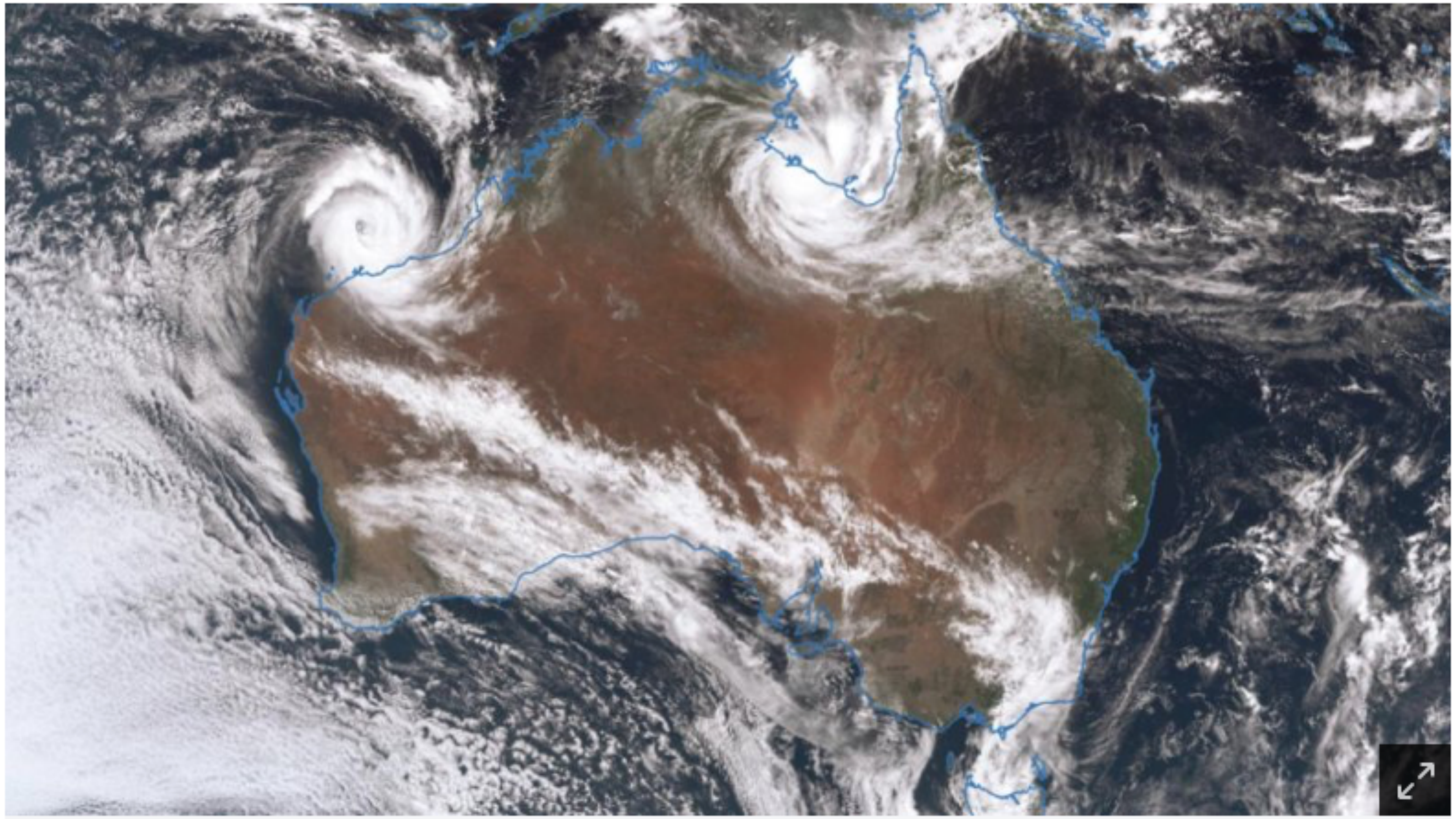
ASYLUM SEEKERS

Morrison's $9 billion proposal that made Hockey 'hit the roof'

57 minutes ago

AUSTRALIA VOTES

Star candidate, controversial doctor in battle to replace Laundy in crucial seat



A satellite image shows twin Cyclone systems in the Australian top end, as at 1pm Saturday. Cyclone Veronica (left) and Cyclone Trevor (right). BUREAU OF METEOROLOGY

Detecting Changes

LIVESCIENCE

NEWS TECH HEALTH PLANET EARTH SPA

Live Science › Planet Earth

Terrifying Tornado Clusters on the Rise

By Becky Oskin, Senior Writer | October 16, 2014 02:00pm ET

57 28 1 4 57 MORE

Credit: NOAA

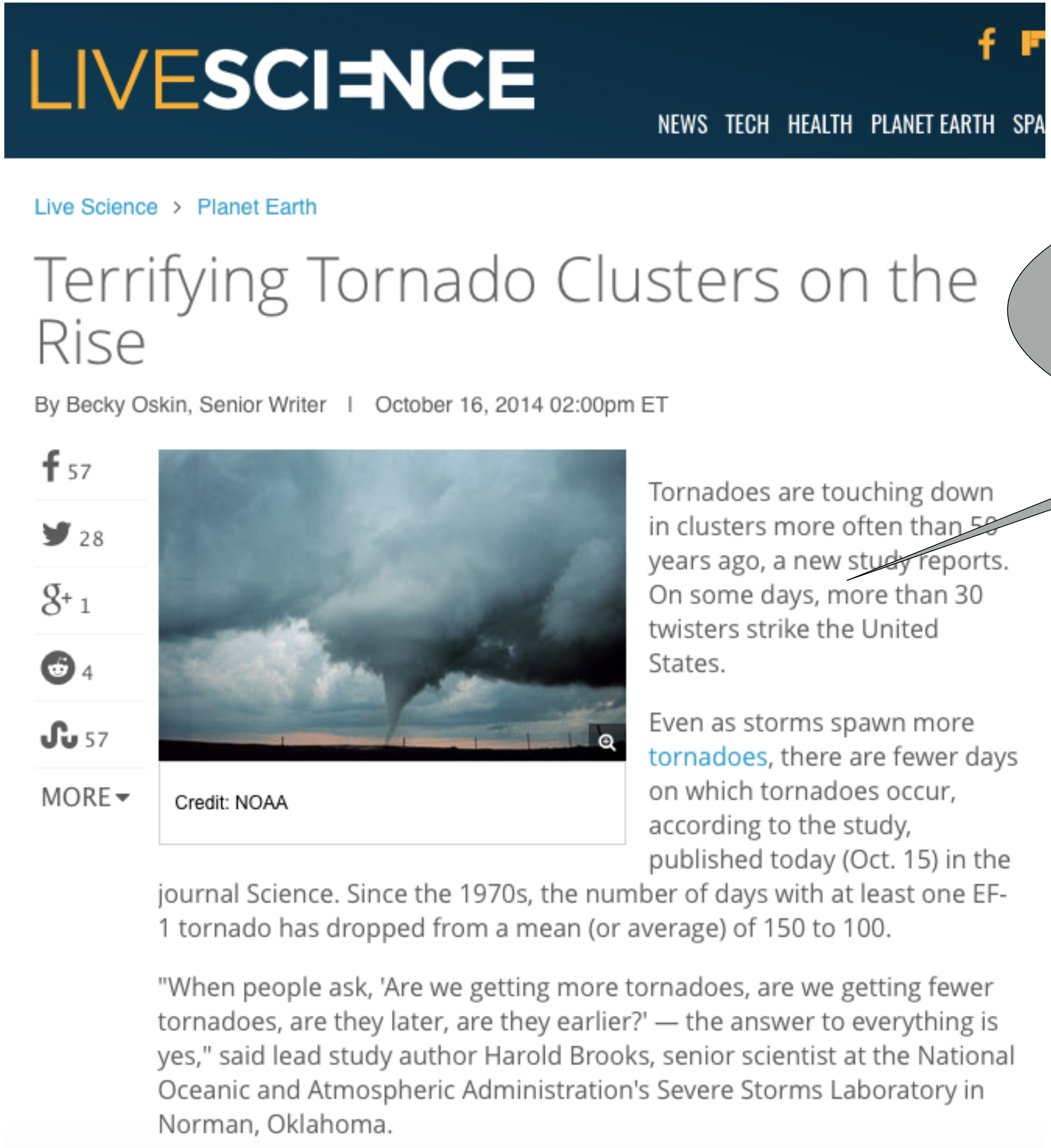
Tornadoes are touching down in clusters more often than 50 years ago, a new study reports. On some days, more than 30 twisters strike the United States.

Even as storms spawn more tornadoes, there are fewer days on which tornadoes occur, according to the study, published today (Oct. 15) in the journal Science. Since the 1970s, the number of days with at least one EF-1 tornado has dropped from a mean (or average) of 150 to 100.

"When people ask, 'Are we getting more tornadoes, are we getting fewer tornadoes, are they later, are they earlier?' — the answer to everything is yes," said lead study author Harold Brooks, senior scientist at the National Oceanic and Atmospheric Administration's Severe Storms Laboratory in Norman, Oklahoma.

http://www.livescience.com/48316-tornados-cluster-more-often.html

Detecting Changes



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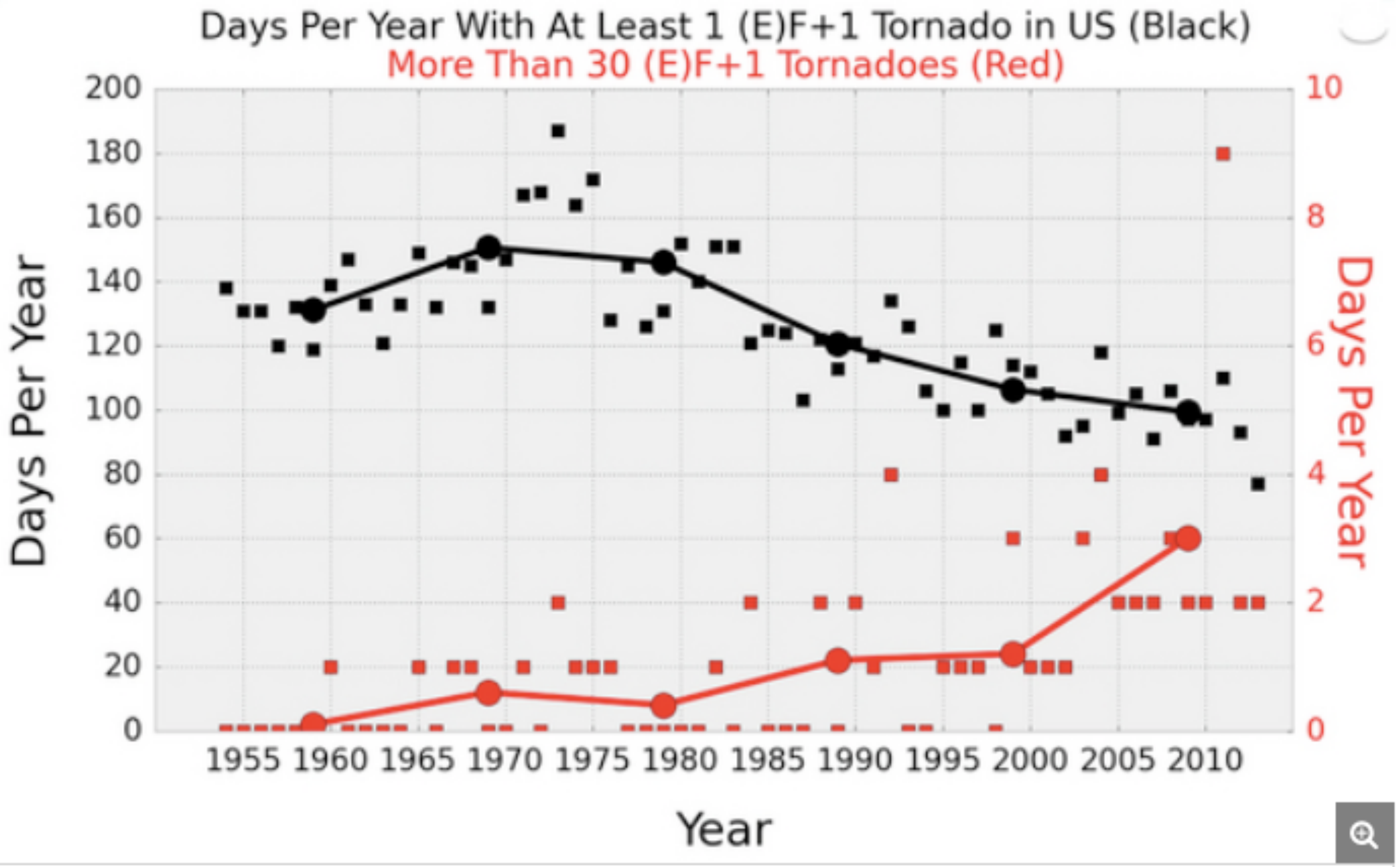
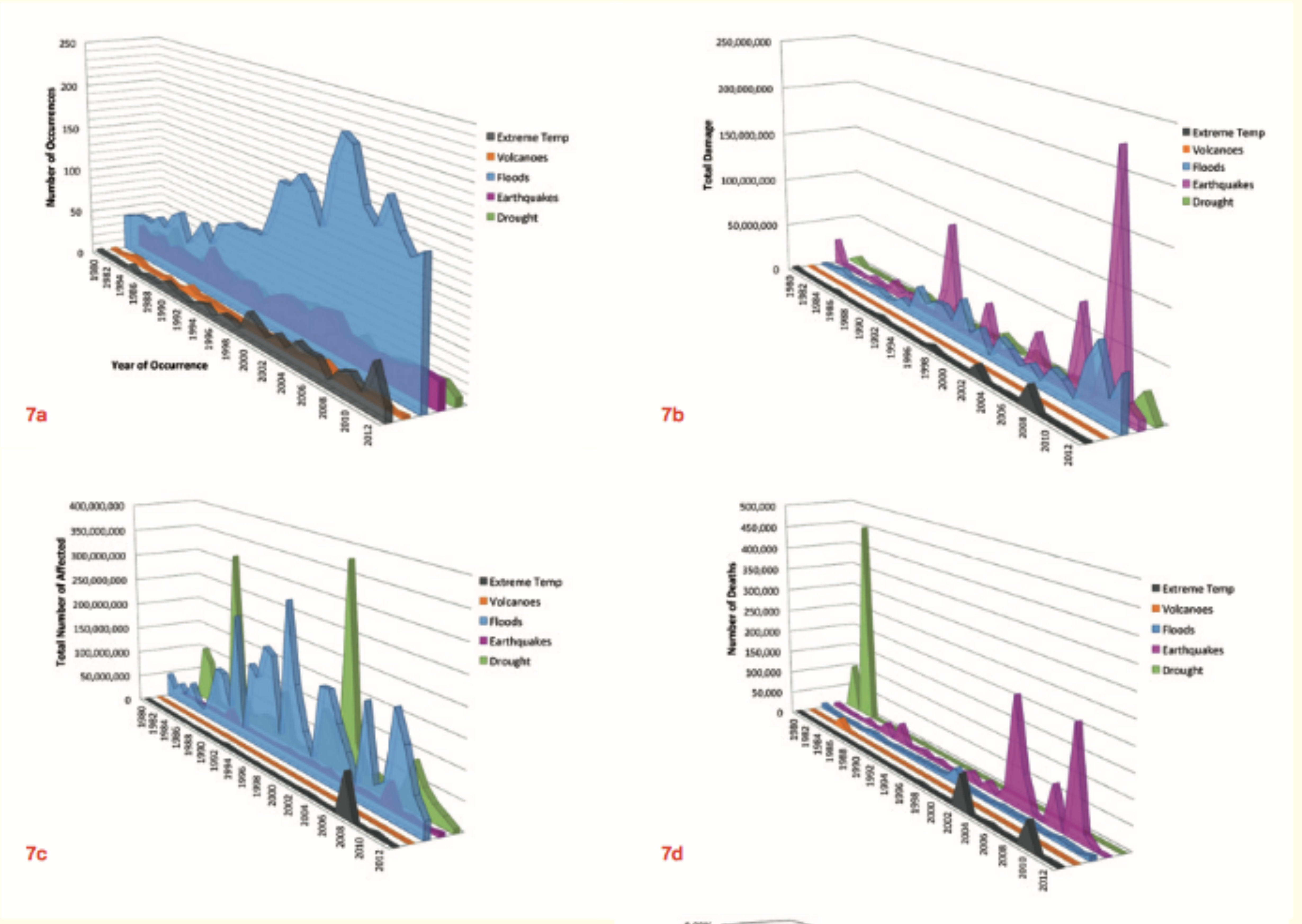


Black squares show one tornado that is rated EF-1 or greater on the Enhanced Fujita Scale, and red squares show there were more than 30 tornadoes rated EF-1 or higher.

Credit: NOAA

http://www.livescience.com/48316-tornados-cluster-more-often.html

Detecting Changes



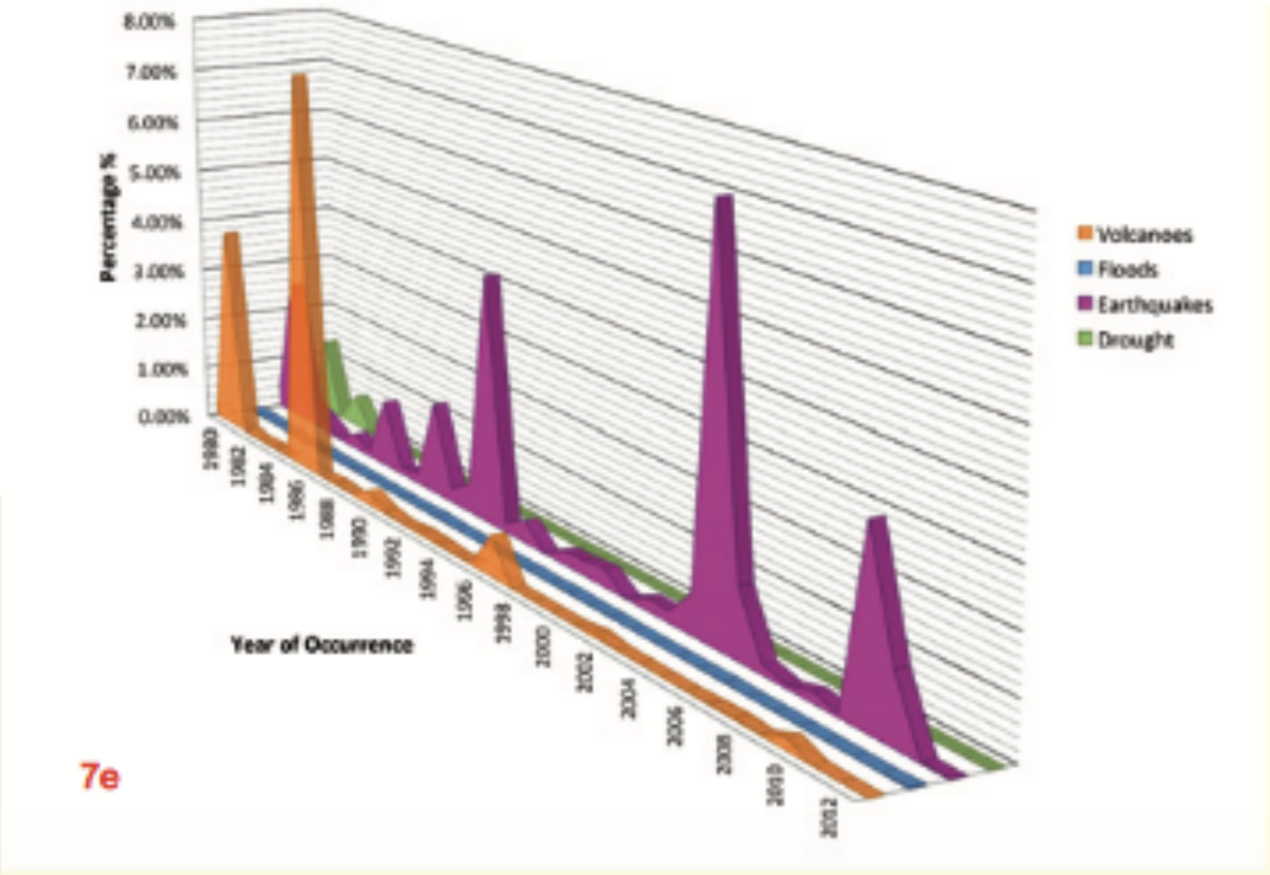
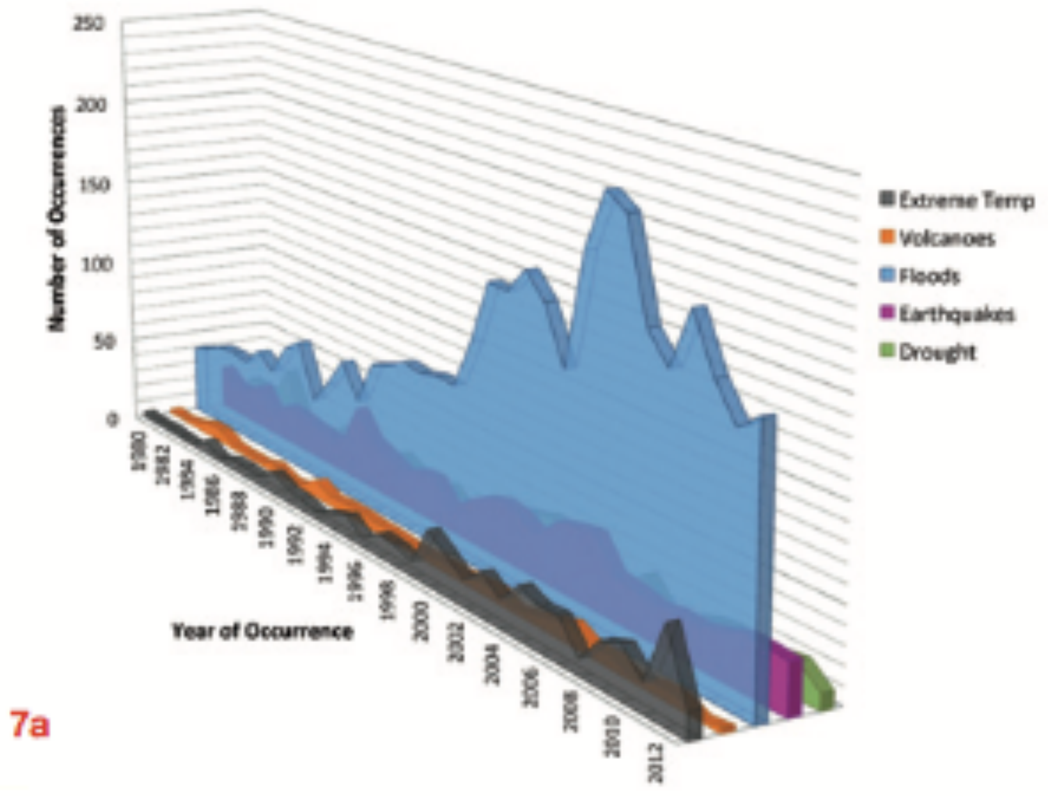


Figure 7. Natural Hazards for the time period between 1980 and 2013. Source is the International Disaster Database accessible through http://www.emdat.be/advanced-search/
7a: Number of occurrences
7b: Total damage in $1,000
7c: Number of affected population
7d: number of deaths
7e: ratio of number of deaths to affected population

Plag et al., 2015

Detecting Changes



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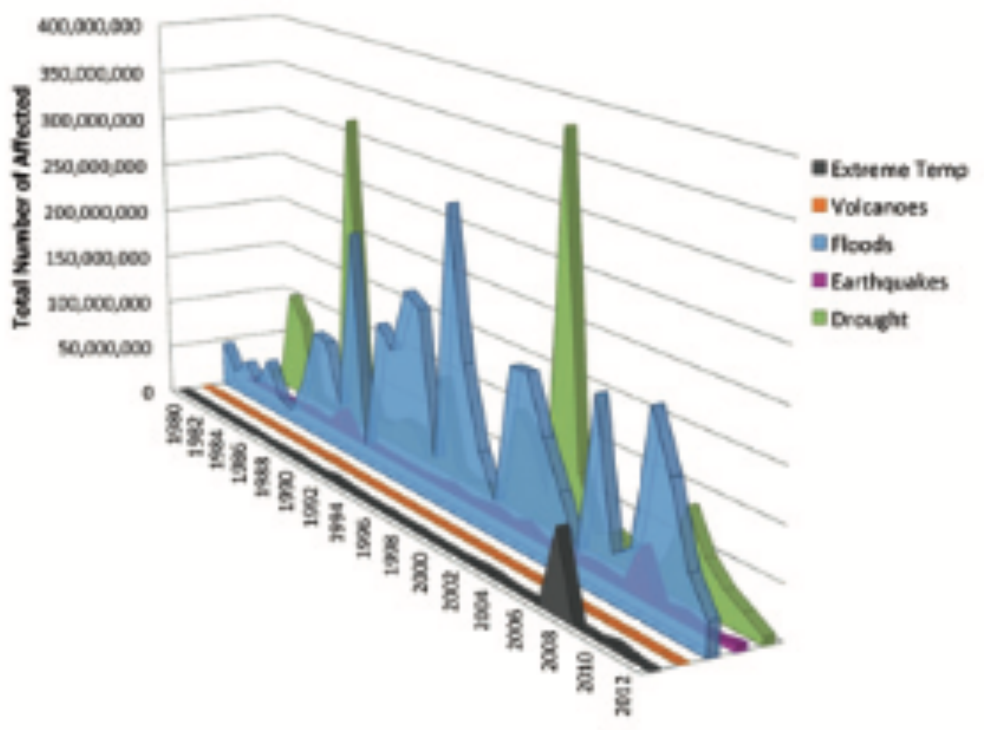

7c

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Table 4. Detailed disaster statistics for the period 1980 to 2008. Data from http://www.preventionweb.net/english/professional/statistics/. The database is the OFDA/CRED International Disaster Database, maintained by University Catholique de Louvain, Brussels, Belgium. Data version: v11.08. Damage is in million US $. Hazards are ordered according to fatalities. *R* is the ratio of fatalities to the affected population in percent. See Table 3 for a caveat on the accuracy of the numbers.

Hazard	Events	Fatalities	Per year	Affected	Per year	Damage	Per year	*R*
Drought	410	558,565	19,261	1,551,455,122	53,498,452	76,949	2,653	0.036
Cyclone	1,211	402,911	13,893	496,560,639	17,122,781	533,371	18,392	0.081
Earthquake	706	385,630	13,298	136,333,515	4,701,156	351,079	12,106	0.283
Tsunami	18	229,551	7,916	2,481,879	85,582	10,046	0.346	9.249
Flood	2,887	195,843	6,753	2,809,481,489	96,878,672	397,334	13,701	0.007
Heatwave	126	89,889	3,100	4,614,411	159,118	21,990	758	1.948
Volcano	140	25,197	869	4,080,791	140,717	2,871	99	0.617
Landslide	366	20,008	690	7,031,523	242,466	6,060	209	0.285
Cold wave	156	11,595	400	6,875,103	237,073	5,902	204	0.169
Tornado	182	4,780	165	12,710,204	438,283	31,511	1,087	0.038
Avalanche	73	3,532	122	69,637	2,401	807	28	5.072
Wild fire	294	1,666	57	5,766,092	198,831	42,807	1,476	0.029

Plag et al., 2015

Mitigation and Adaptation Studies

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Assessing Knowledge

Assessing Knowledge

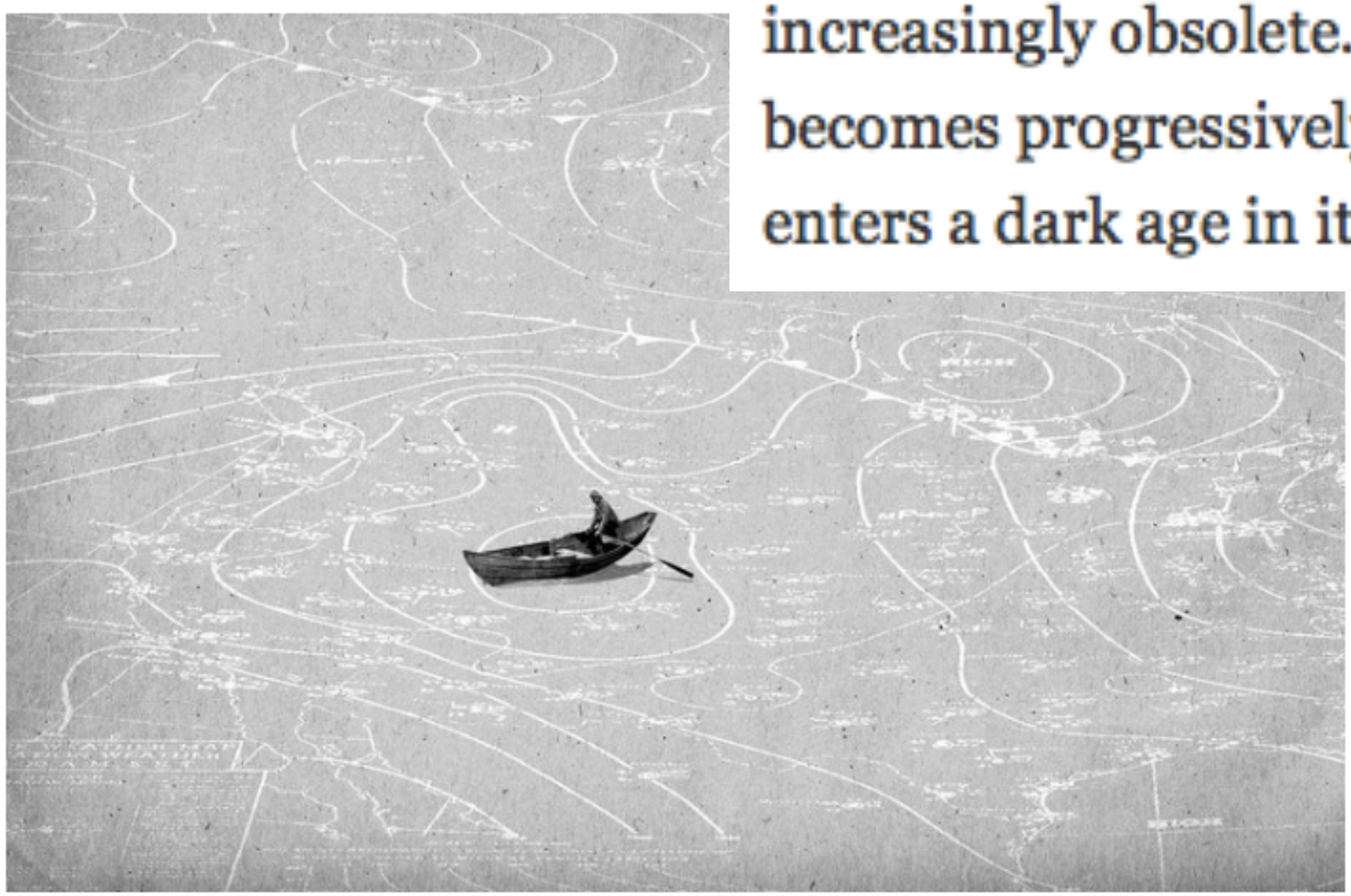
HOME SEARCH

The New York Times

The Opinion Pages | OP-ED CONTRIBUTOR

A New Dark Age Looms

By WILLIAM B. GAIL APRIL 19, 2016



Boulder, Colo. — IMAGINE a future in which humanity's accumulated wisdom about Earth — our vast experience with weather trends, fish spawning and migration patterns, plant pollination and much more — turns increasingly obsolete. As each decade passes, knowledge of Earth's past becomes progressively less effective as a guide to the future. Civilization enters a dark age in its practical understanding of our planet.

Assessing Knowledge

Assessing Knowledge

How solid is our knowledge?

Assessing Knowledge

How solid is our knowledge?

Example sea level rise

How solid is our knowledge?

Example sea level rise

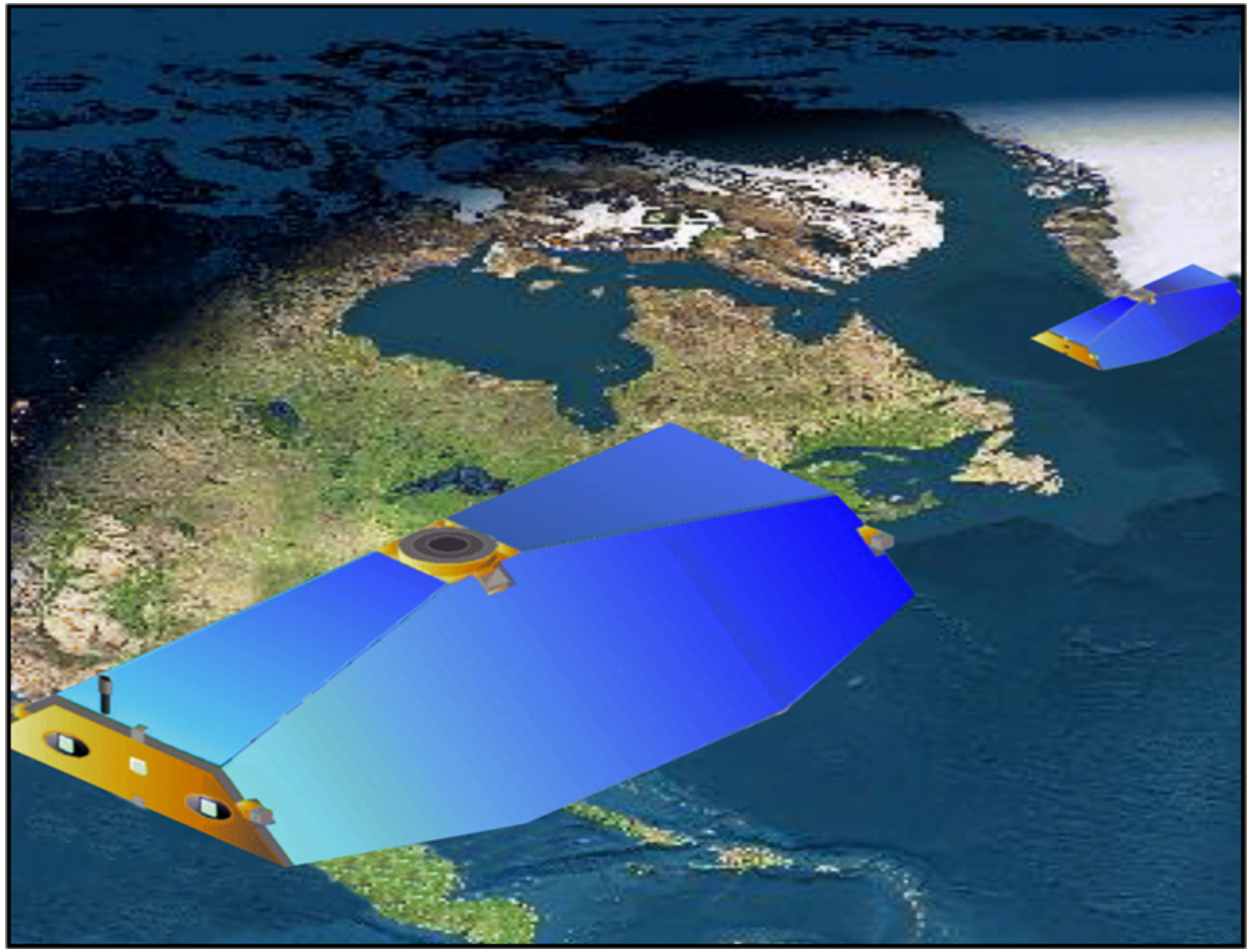
Accepted knowledge in 2000:

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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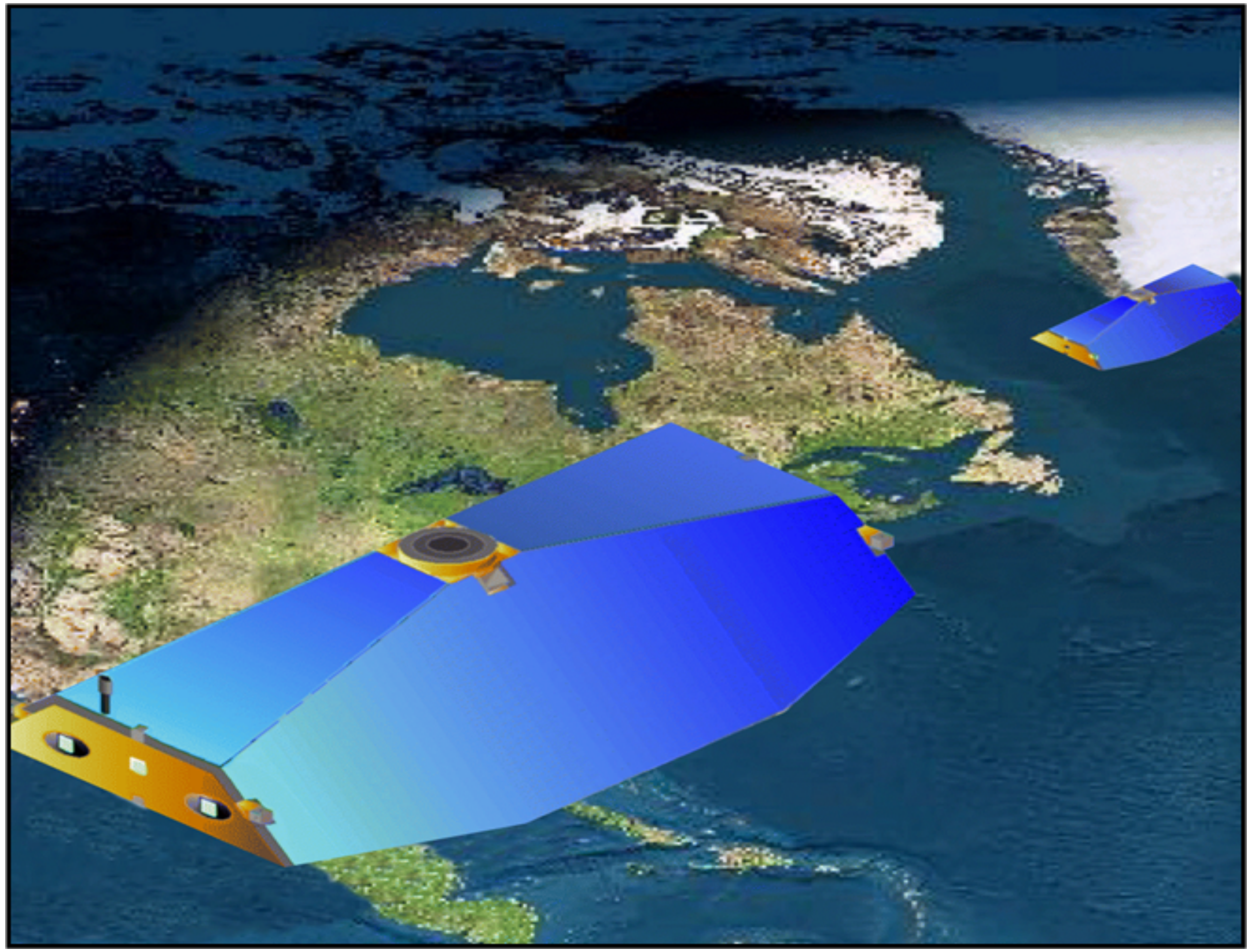

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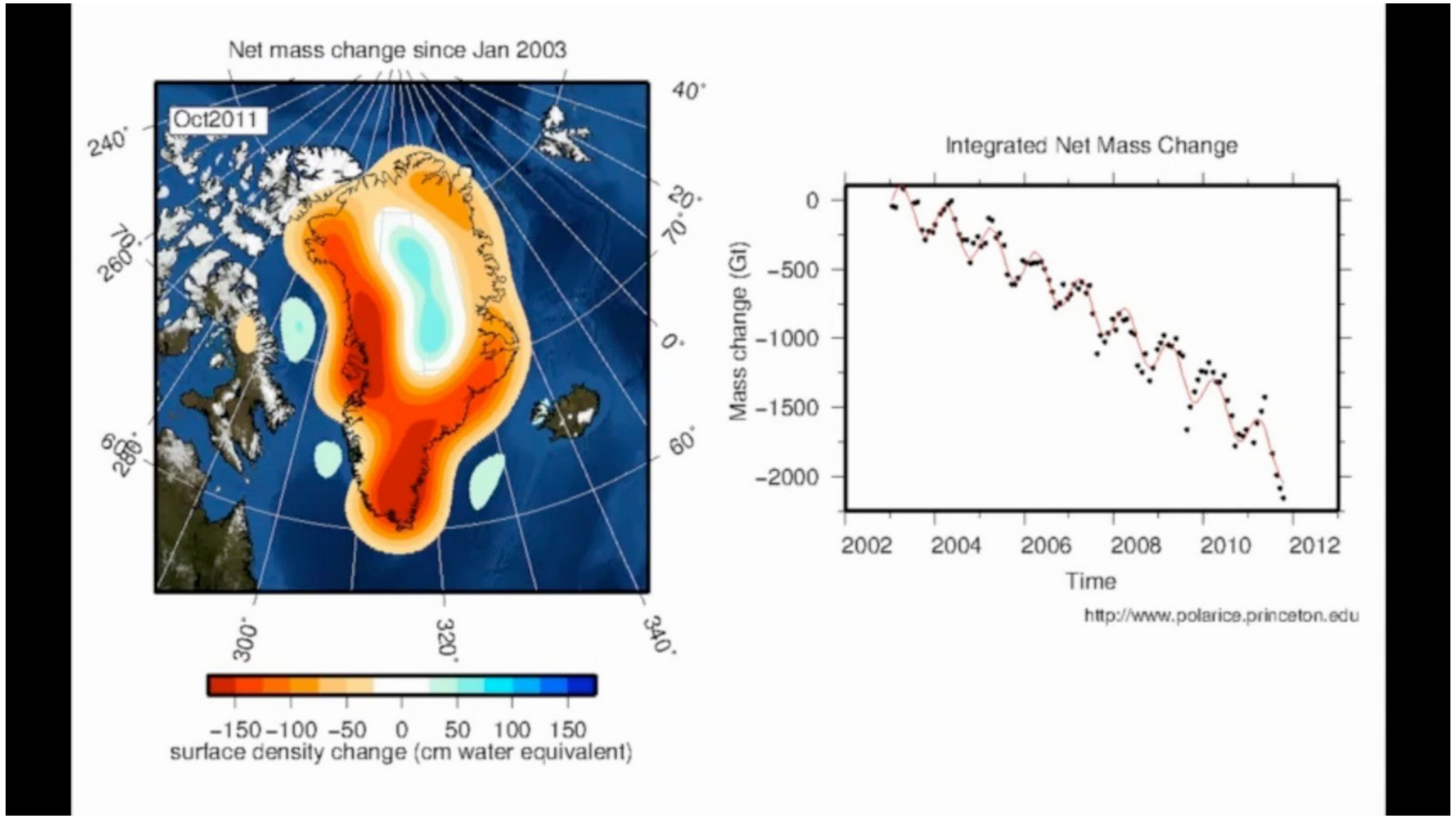
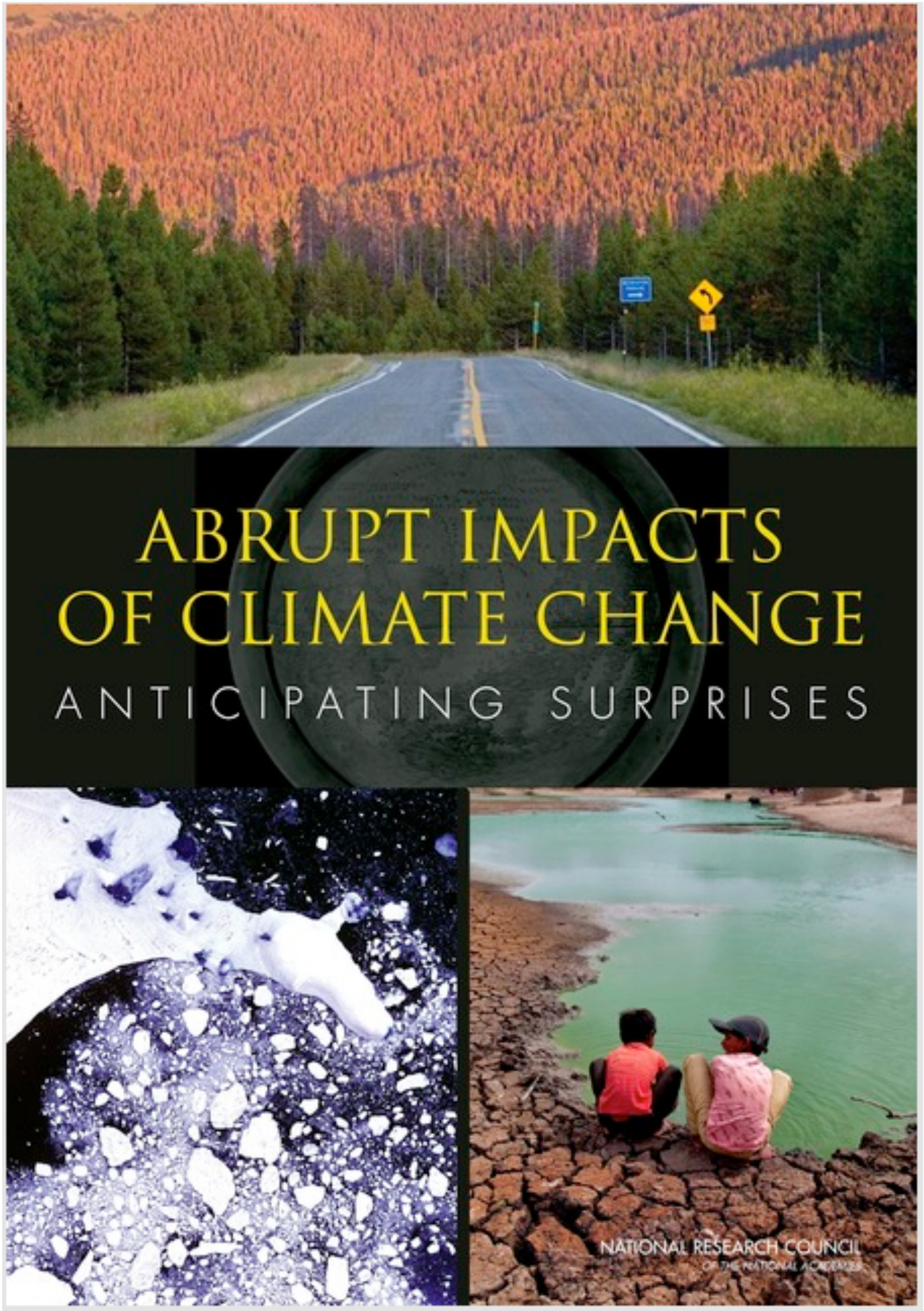


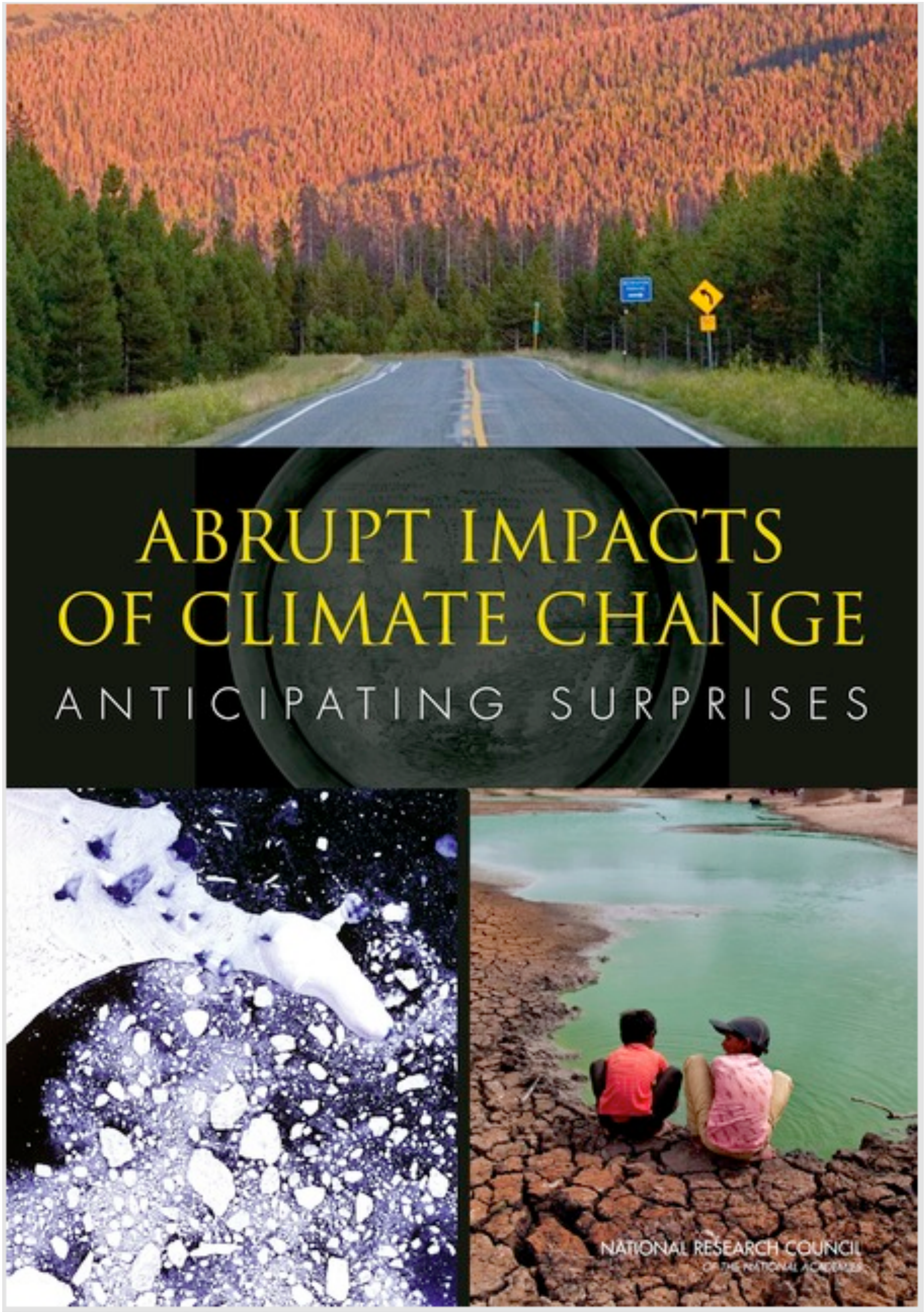
Assessing Knowledge



National Research Council in 2013:

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

Assessing Knowledge



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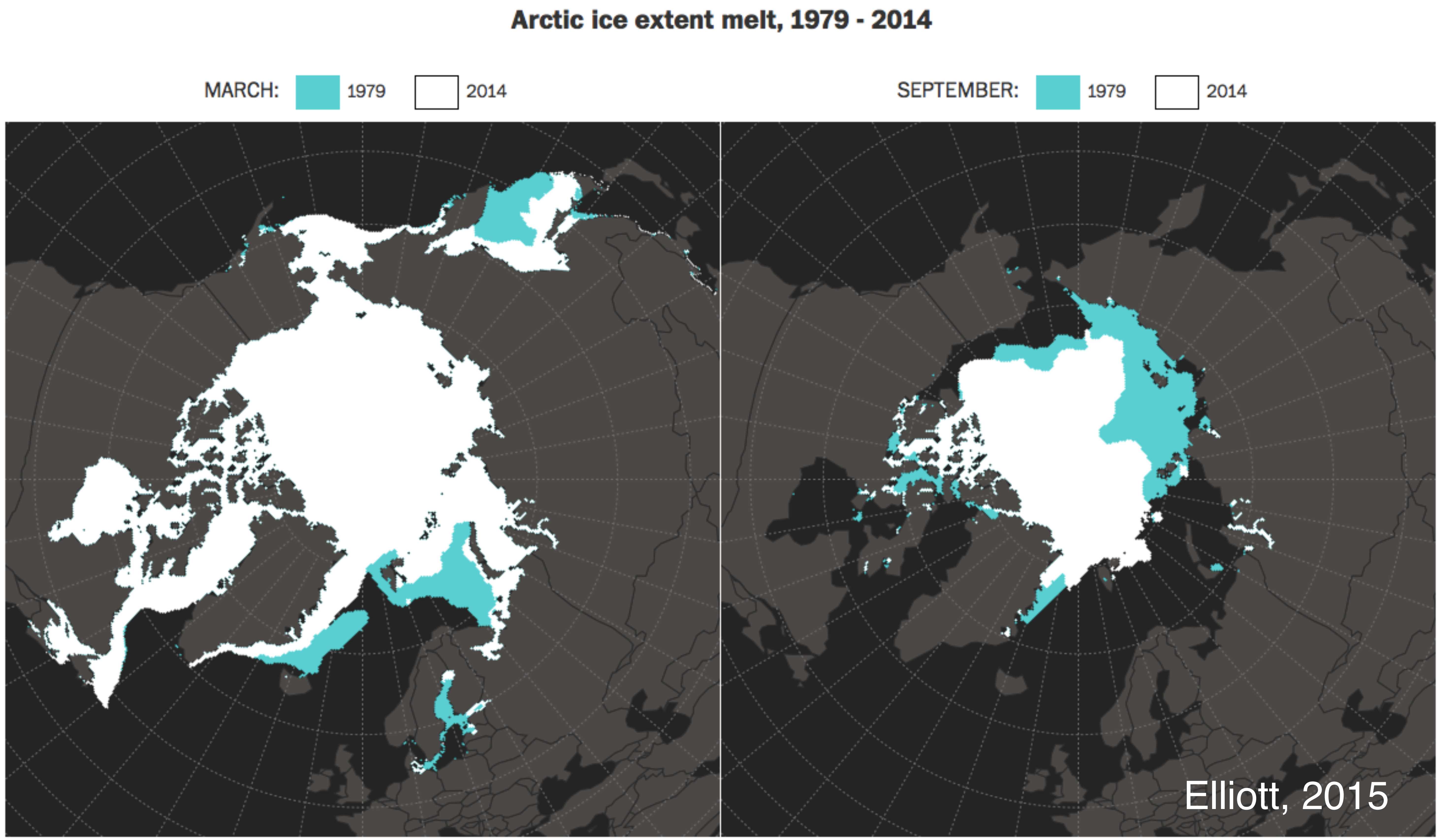
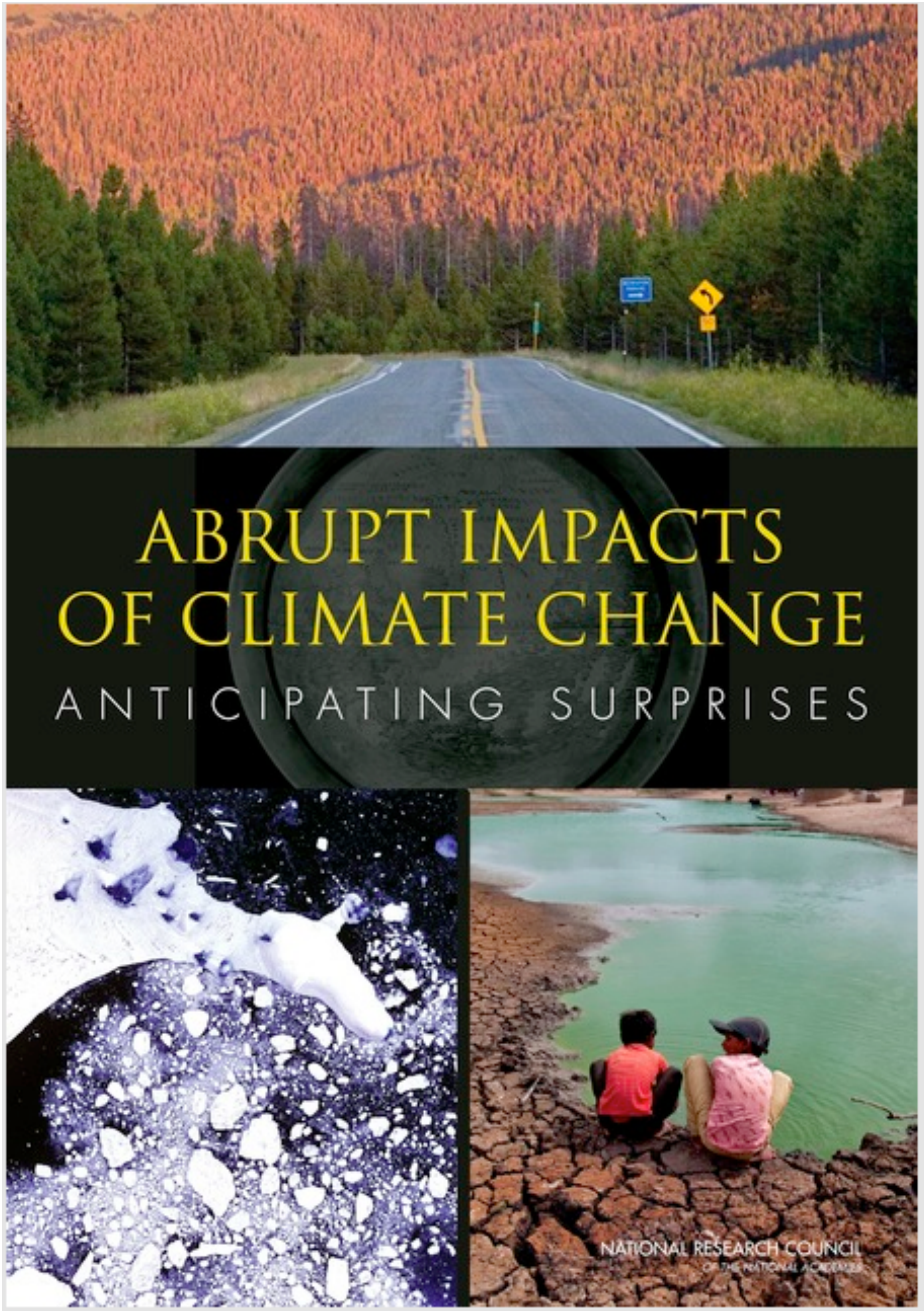
Already happening: Disappearance of late-summer Arctic sea ice



Assessing Knowledge



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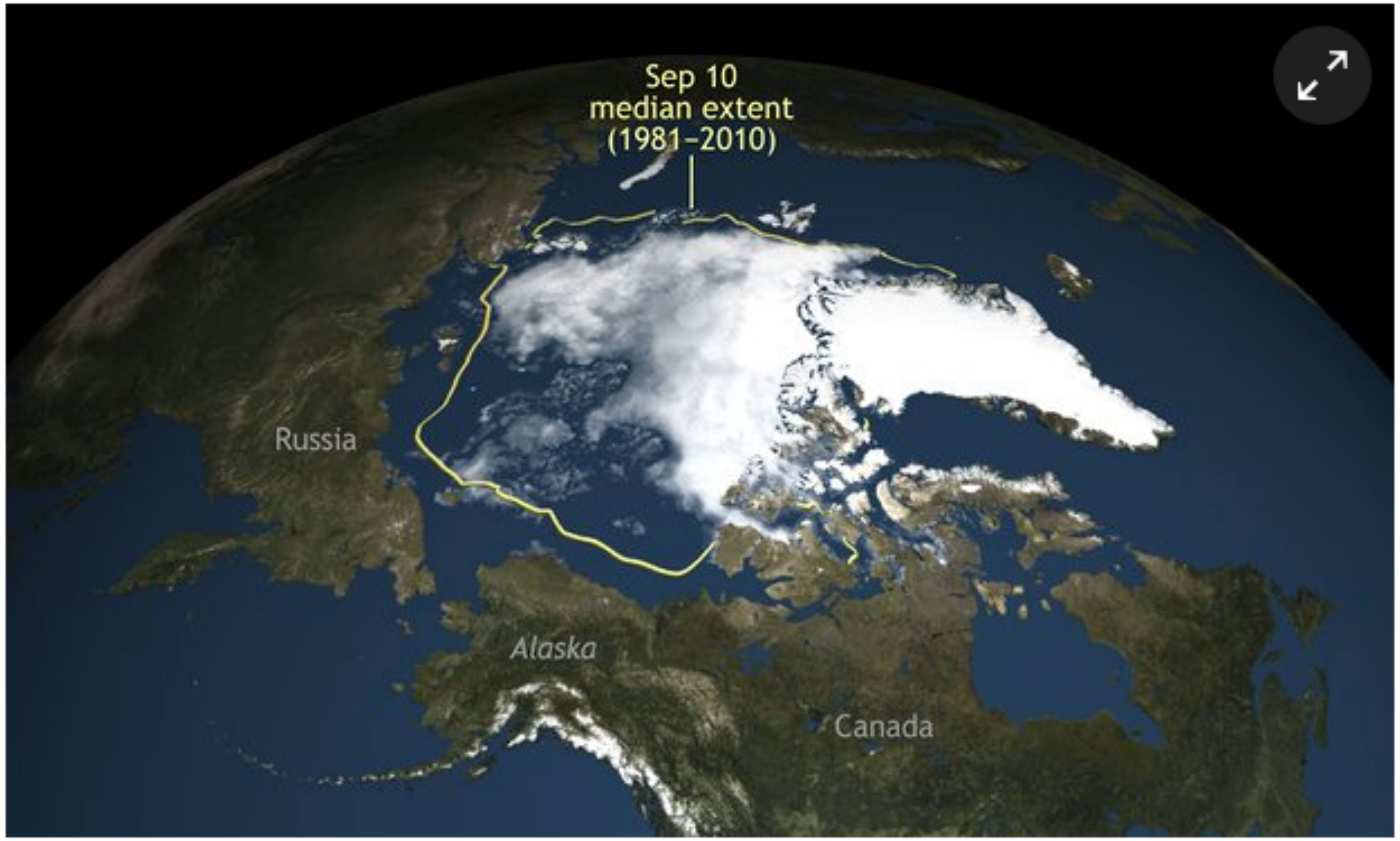
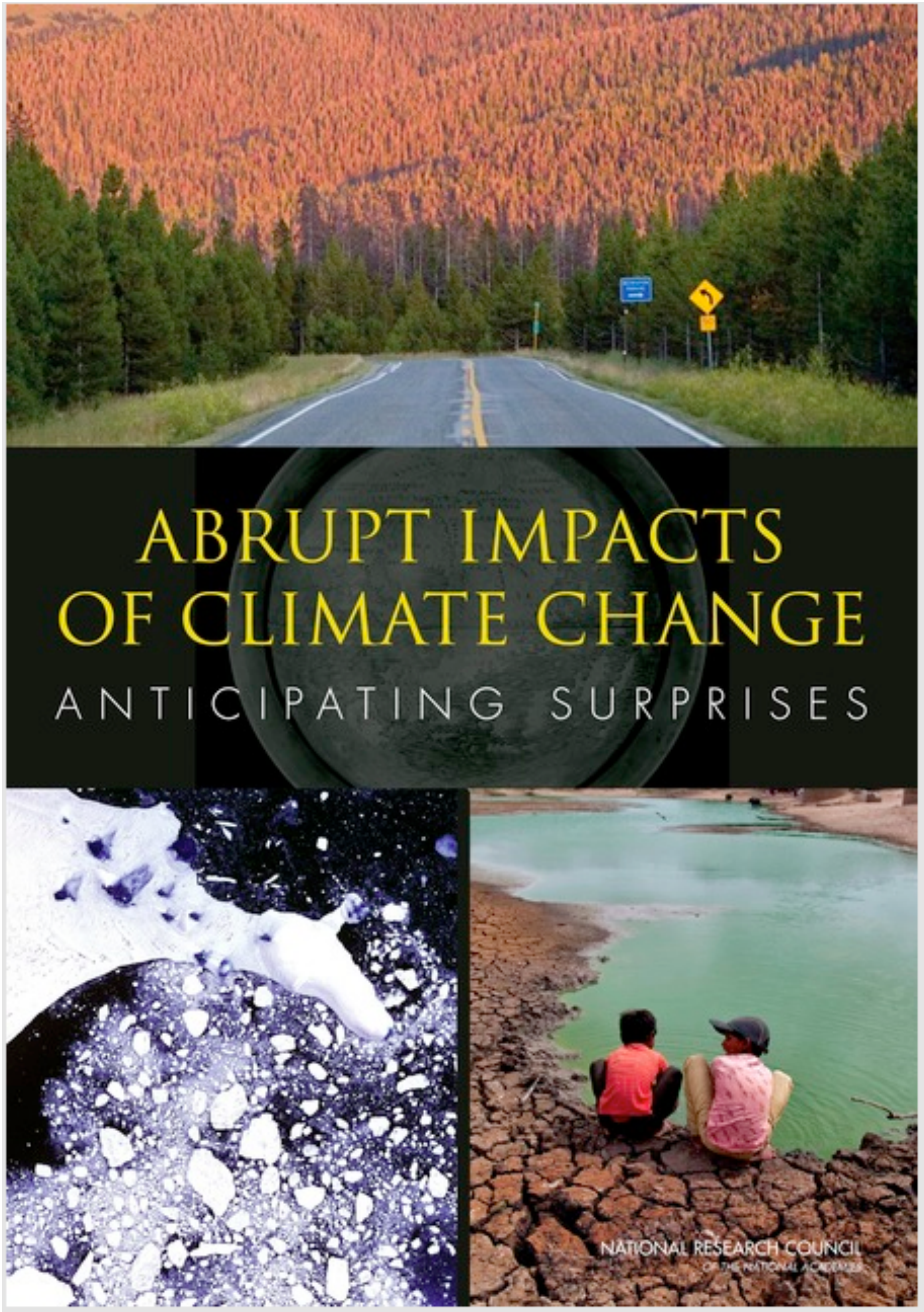
Arctic sea ice shrinks to second lowest level ever recorded

'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

Assessing Knowledge



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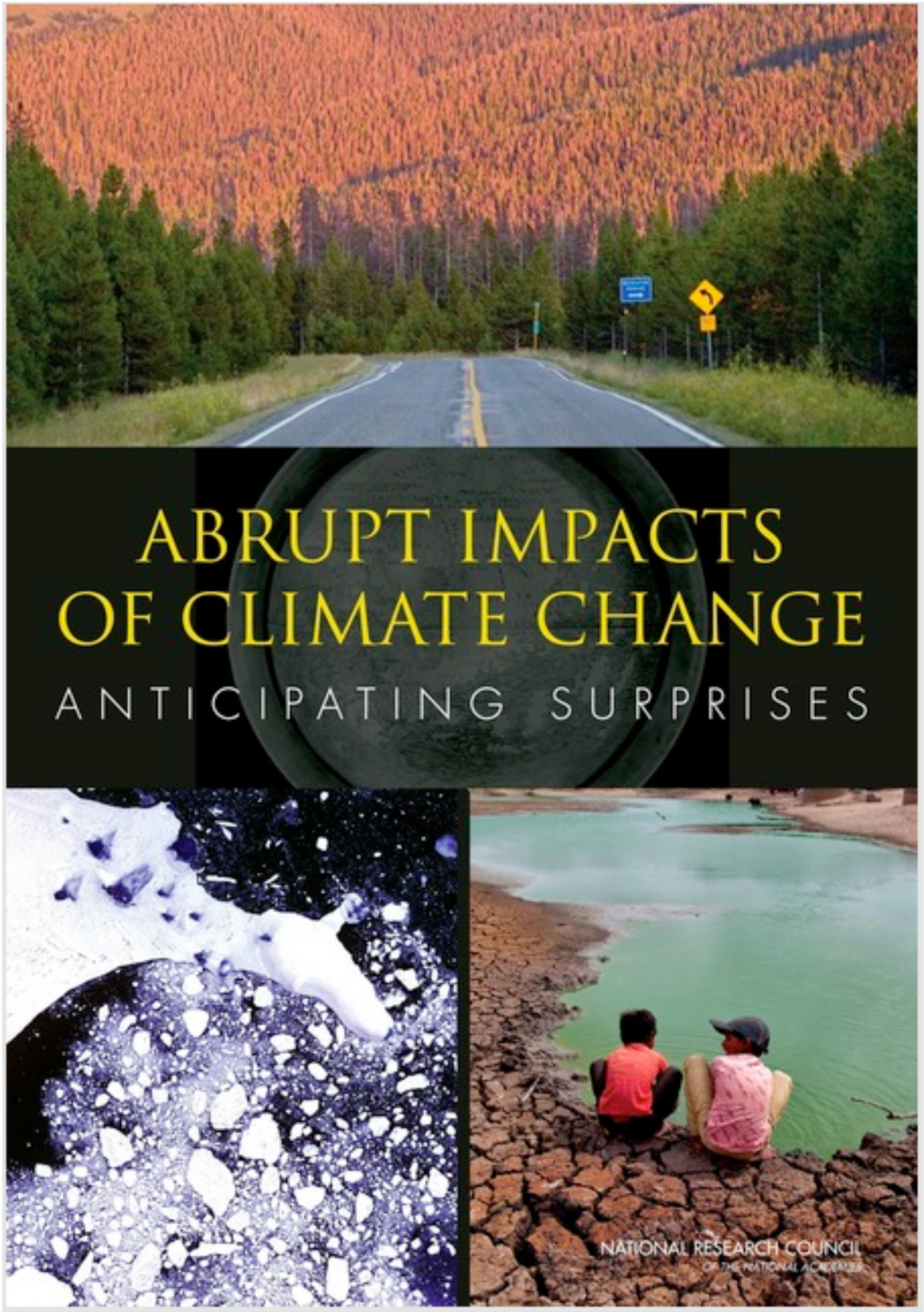

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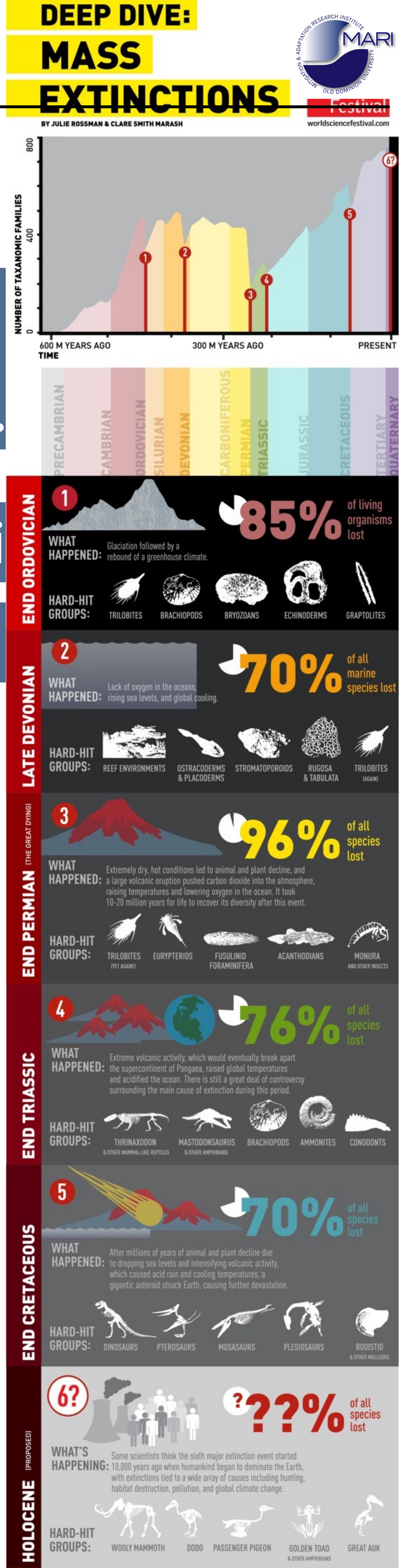

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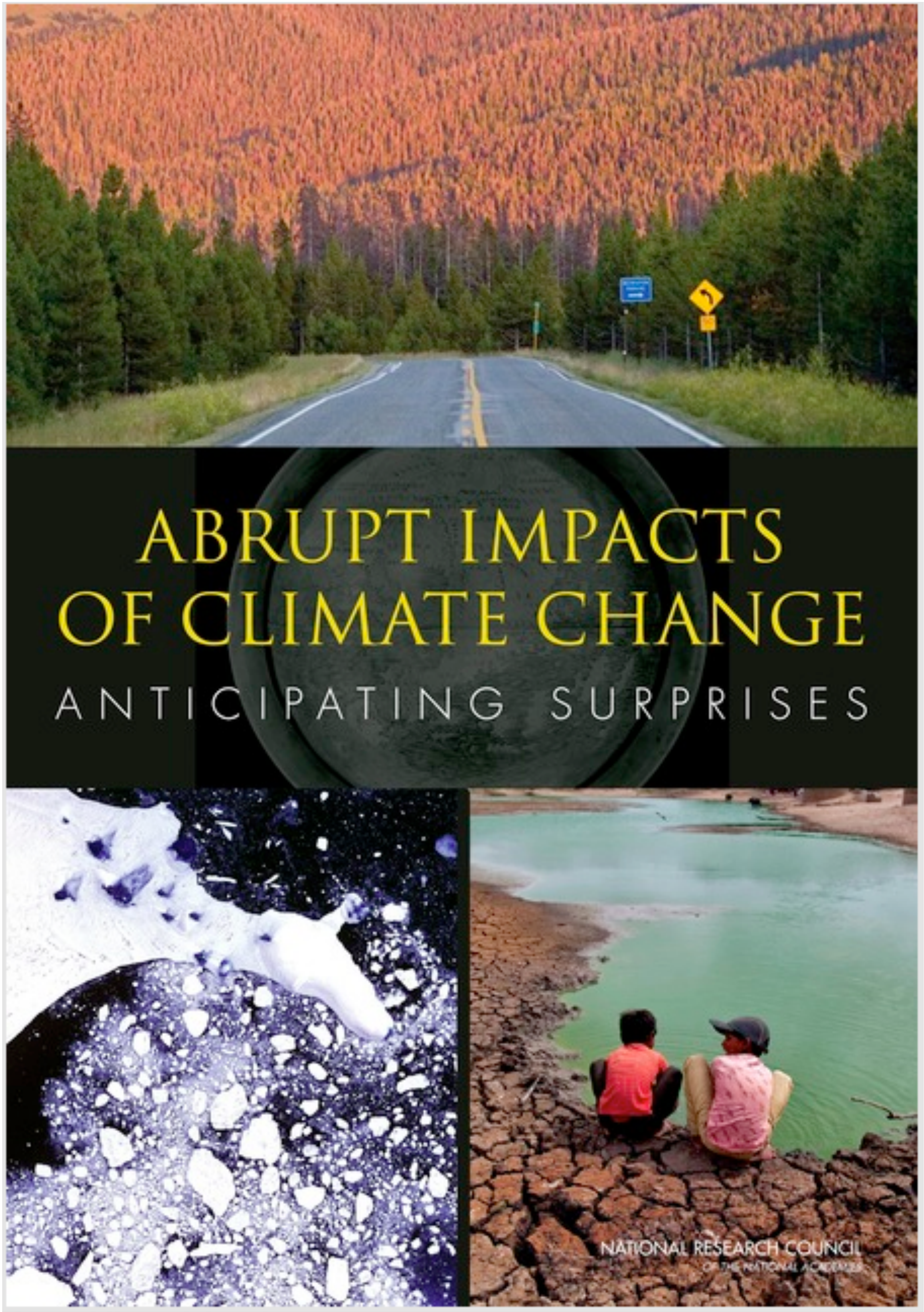

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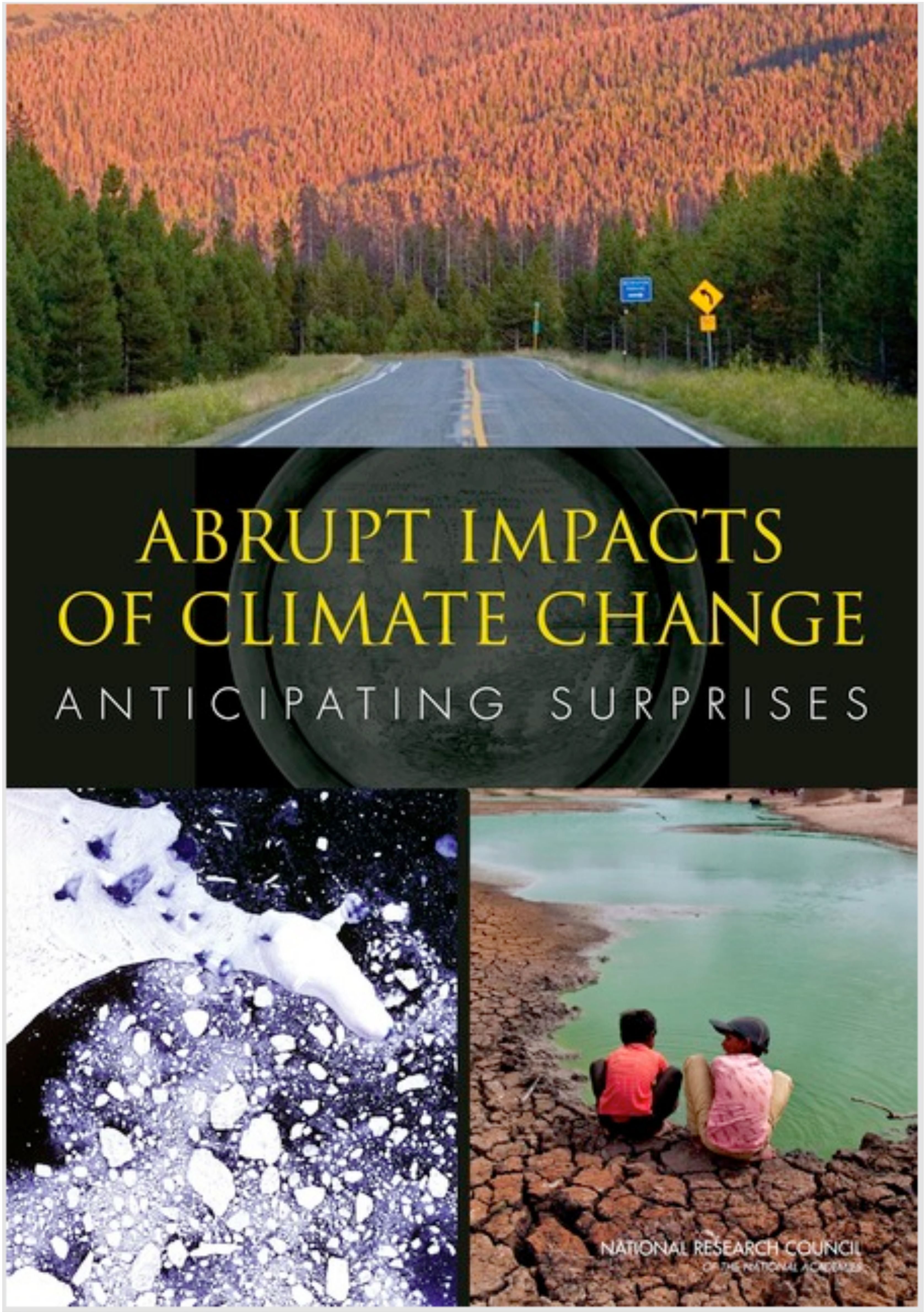

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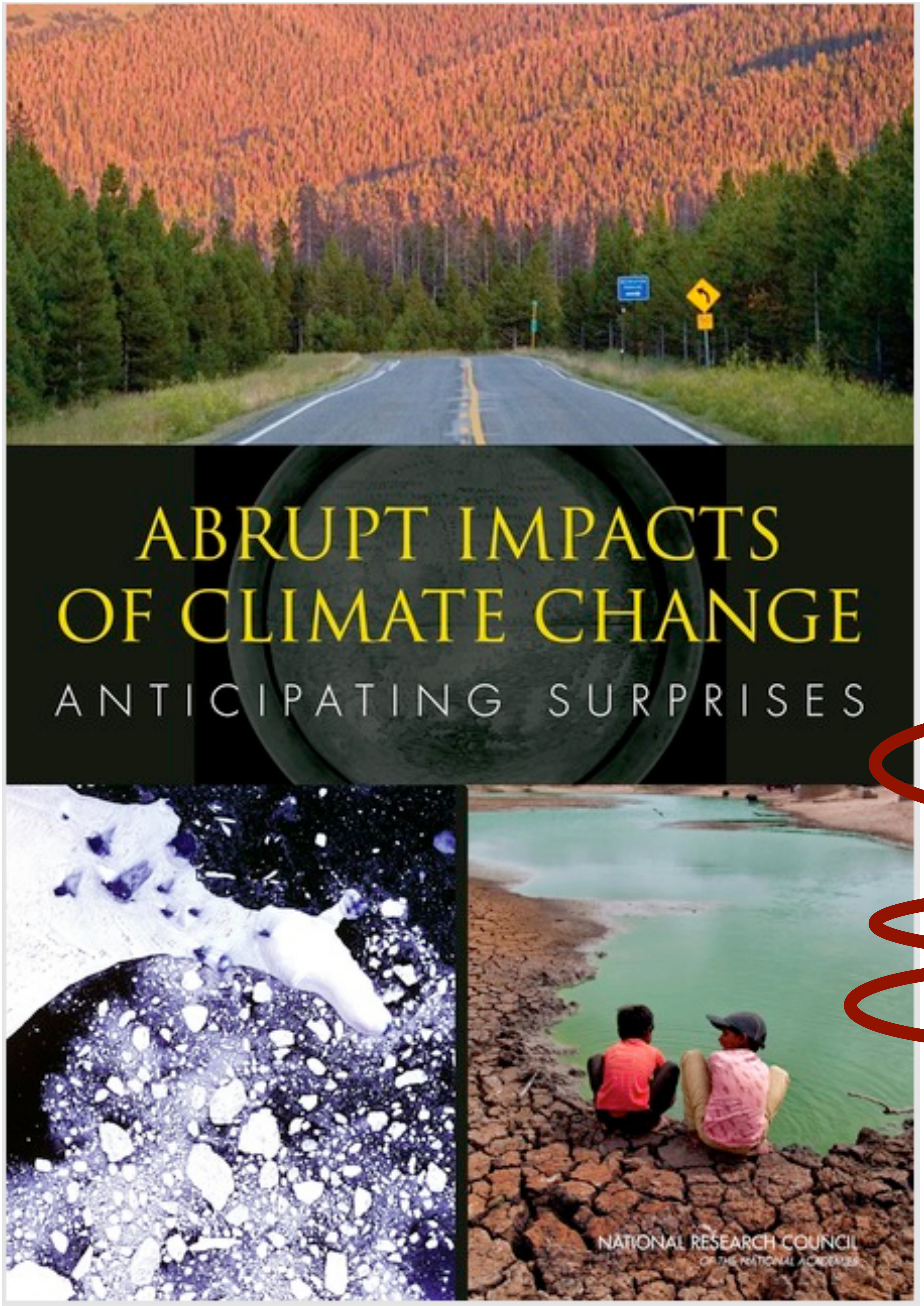

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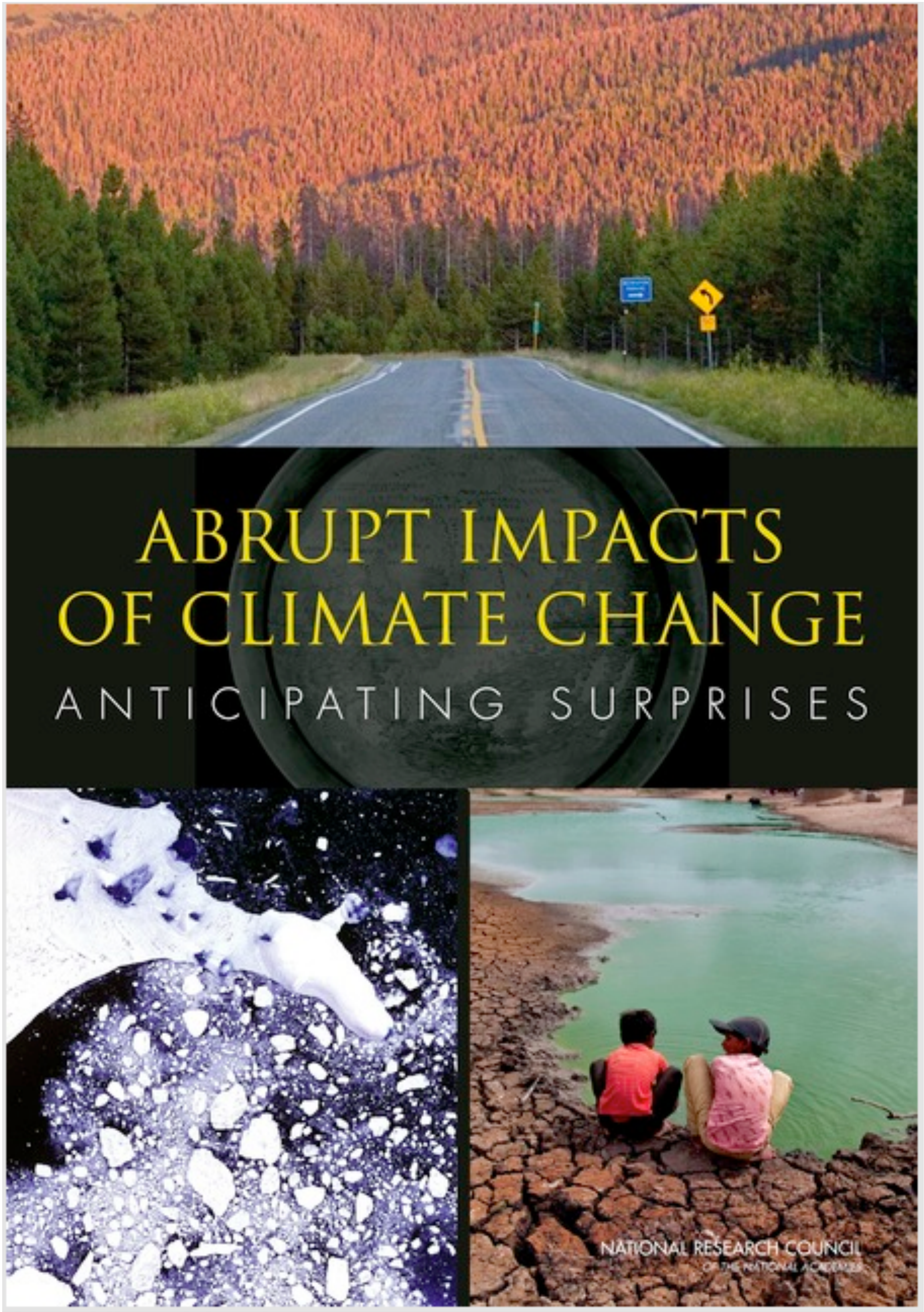

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Assessing Knowledge

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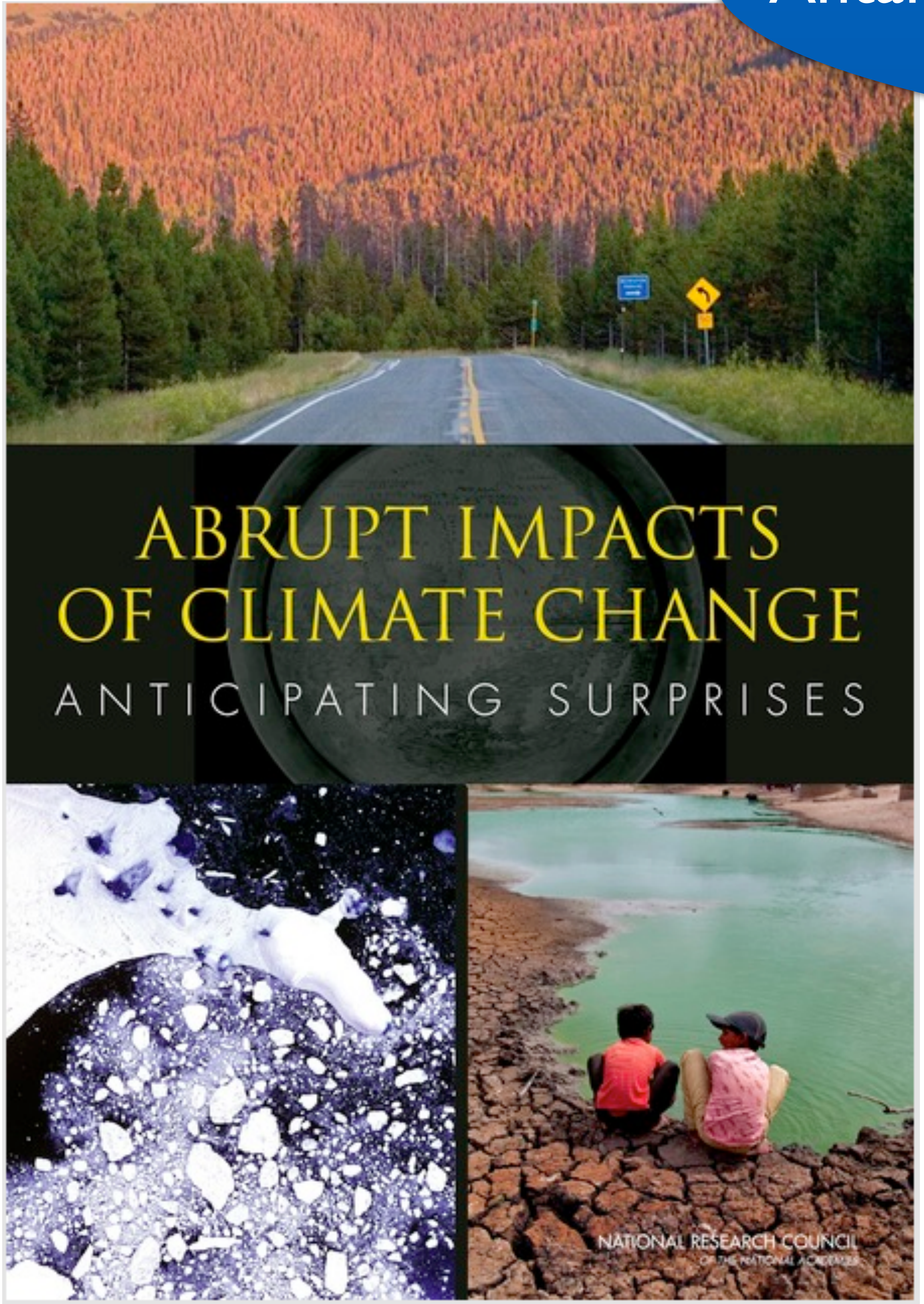

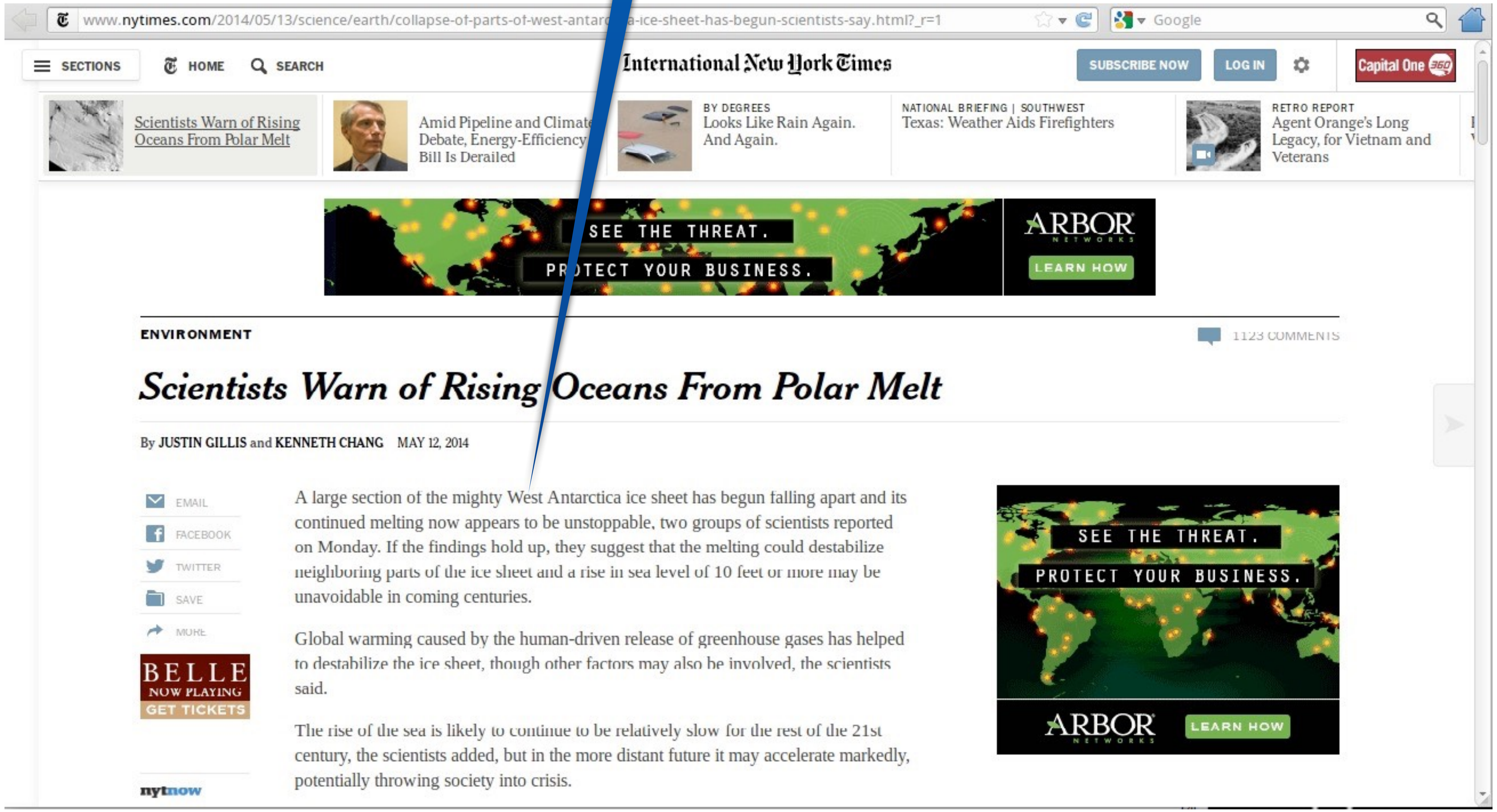
www.nytimes.com/2014/05/13/science/earth/collapse-of-parts-of-west-antarctica-ice-sheet-has-begun-scientists-say.html?_r=1

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ENVIRONMENT

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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.

Assessing Knowledge

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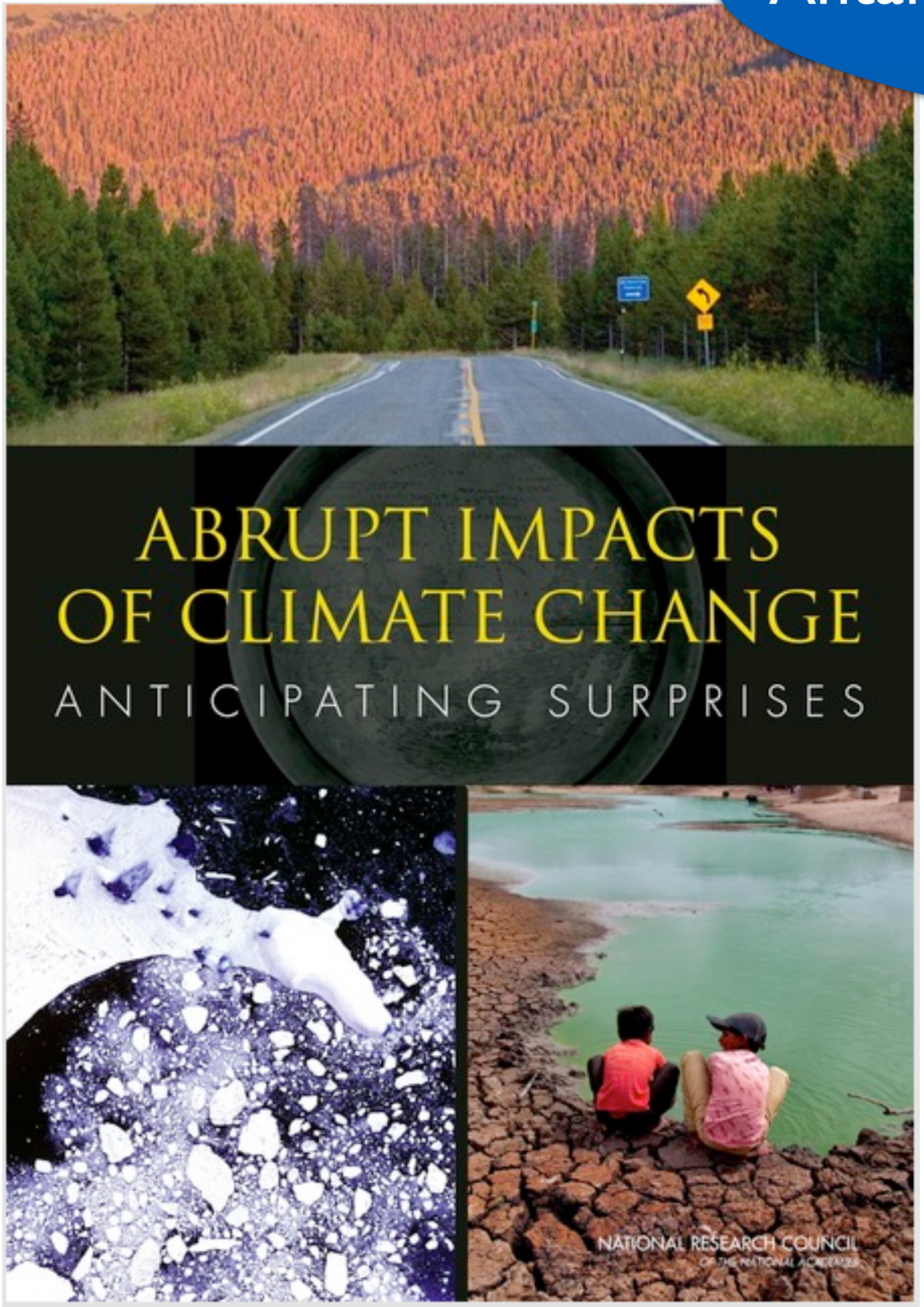

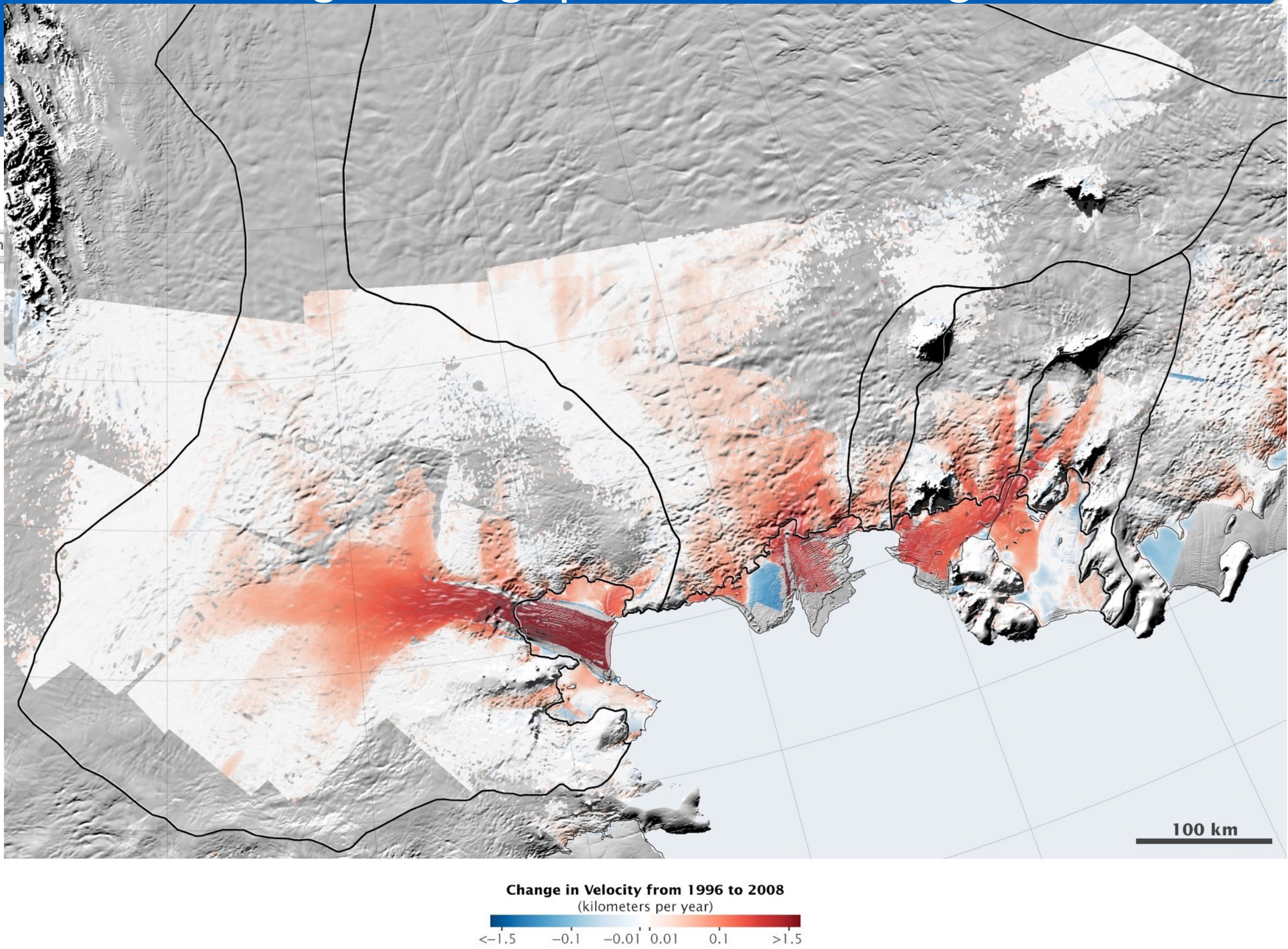

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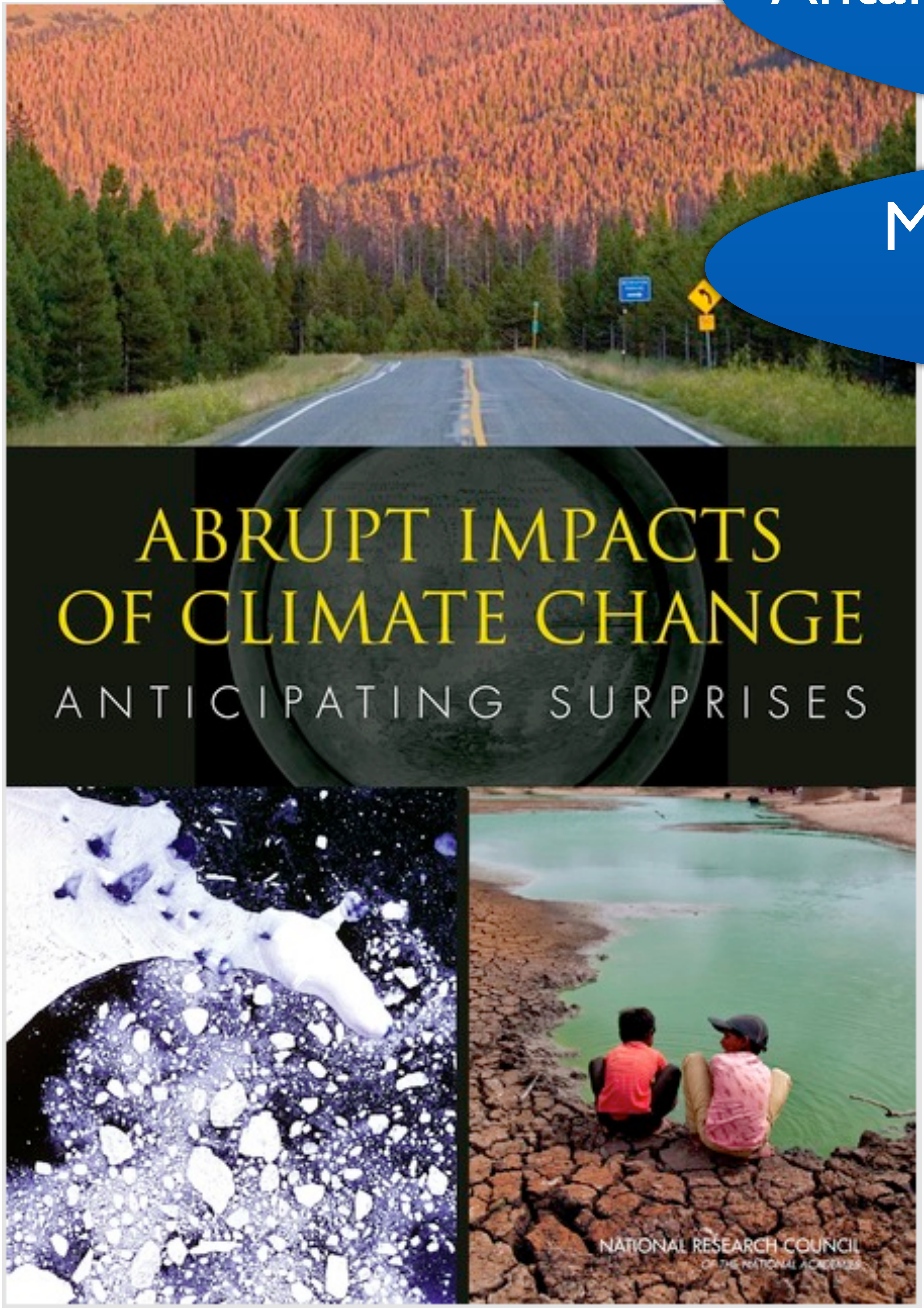


Greenland will be far greater contributor to sea rise than expected

http://www.eurekalert.org/...

Greenland will be far greater ...

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

Irvine, Calif. – Greenland's icy reaches are far more vulnerable to wa... 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 uncharte... deep valleys stretching for dozens of miles under the Greenland Ice Sheet.

The bedrock canyons sit well below sea level, meaning that a... 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 accelerate... 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 ...top 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

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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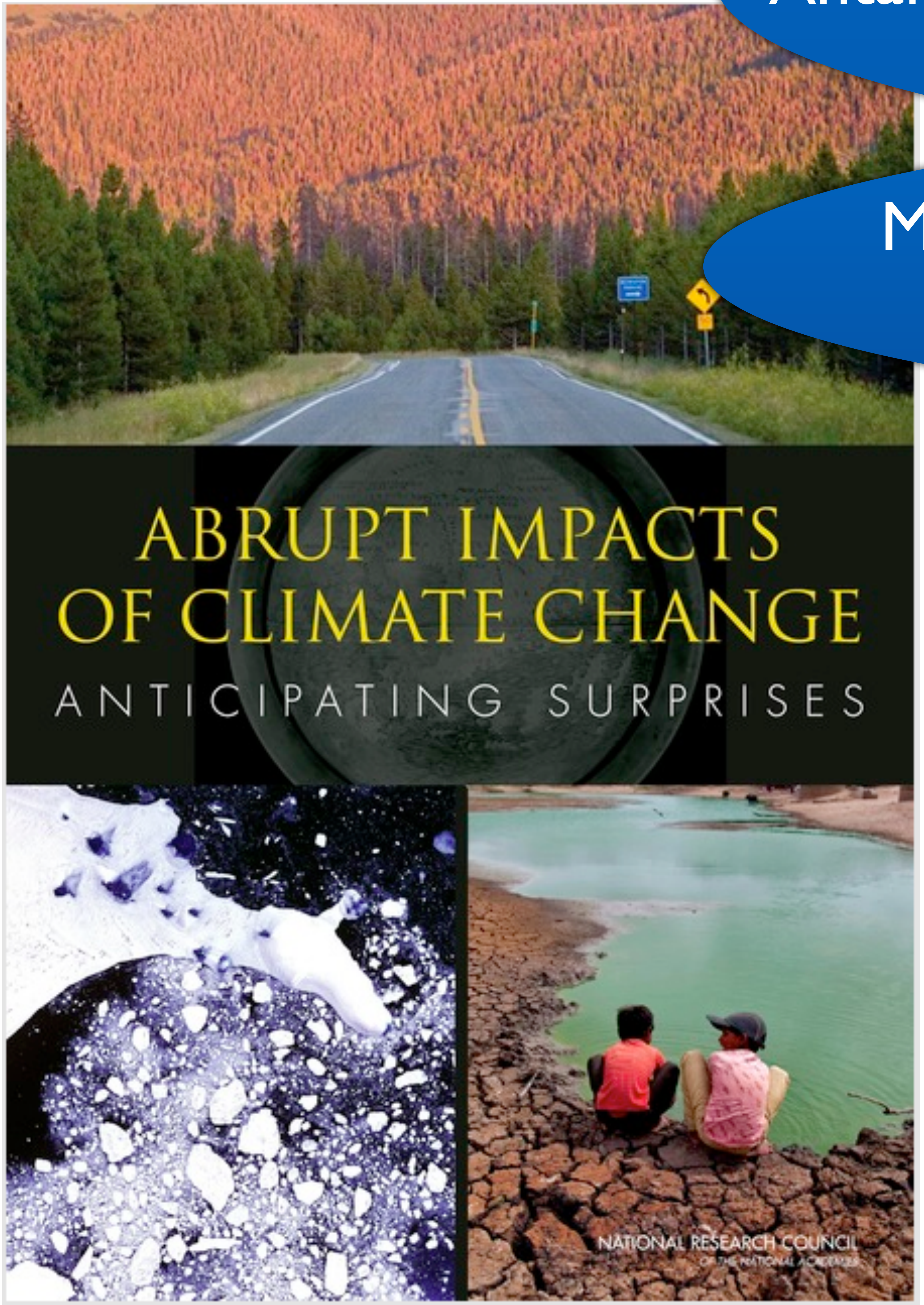

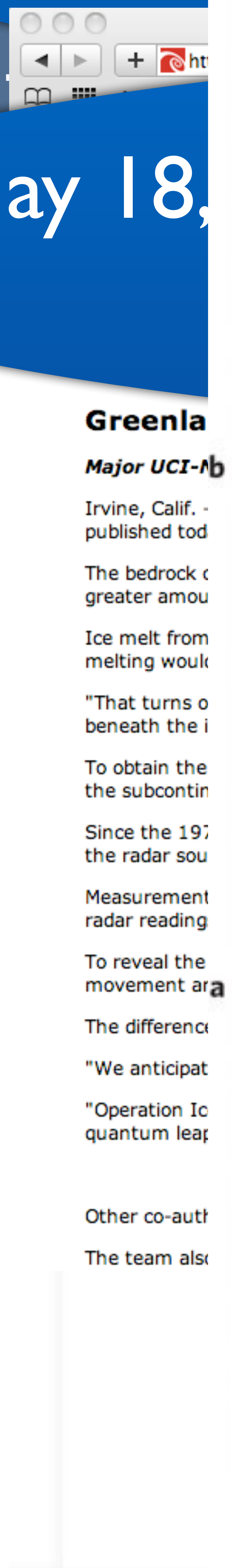

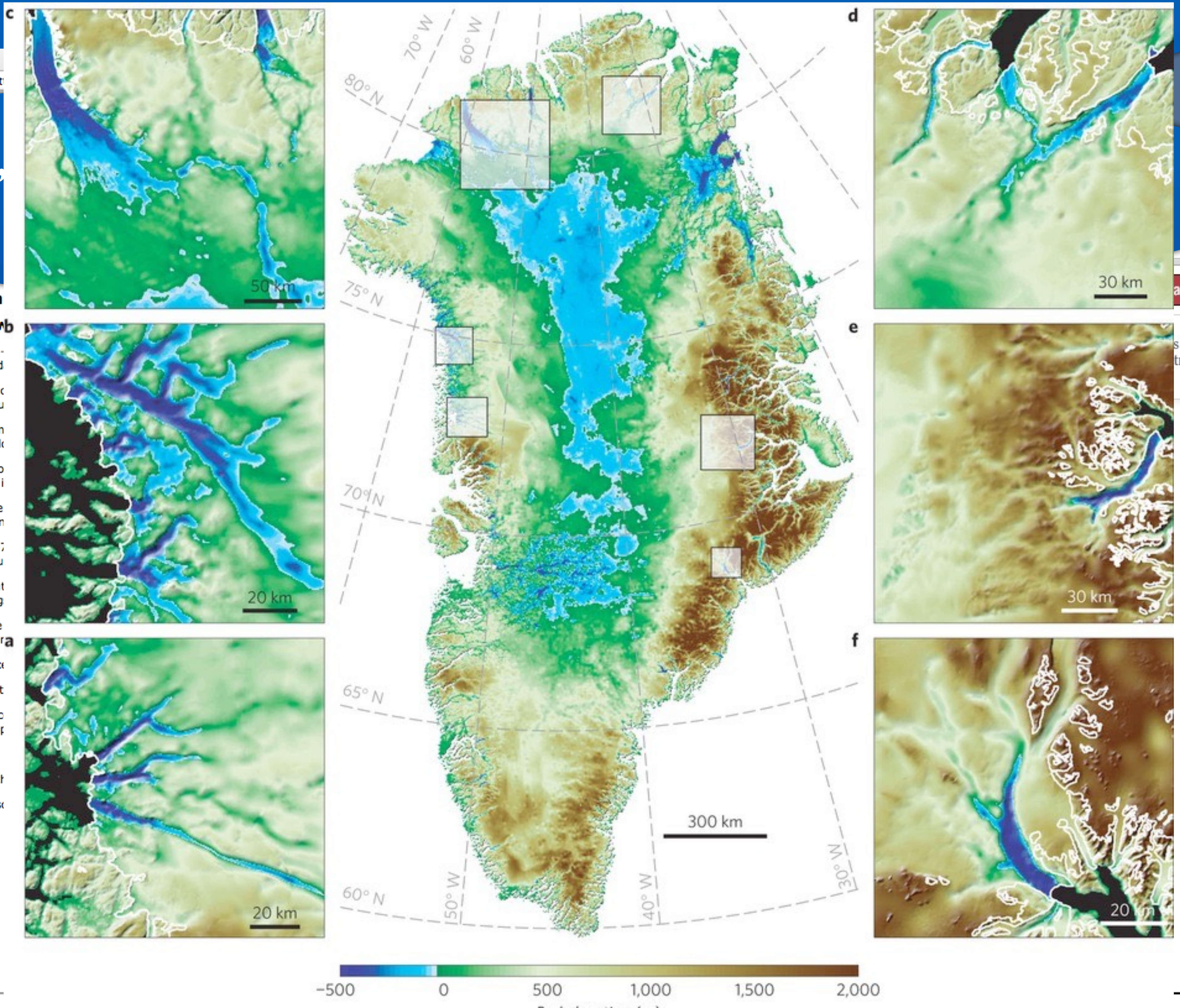

Assessing Knowledge

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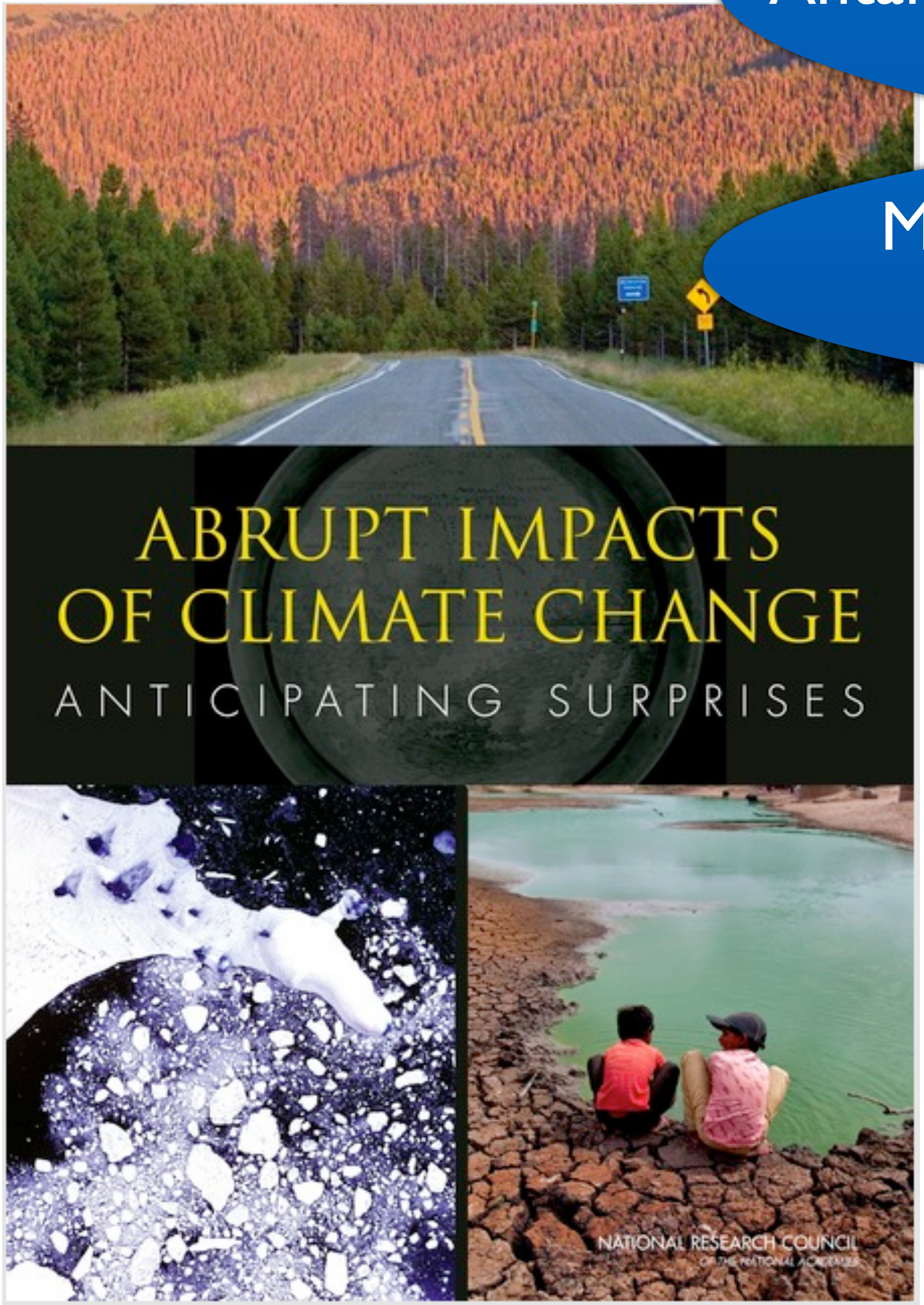
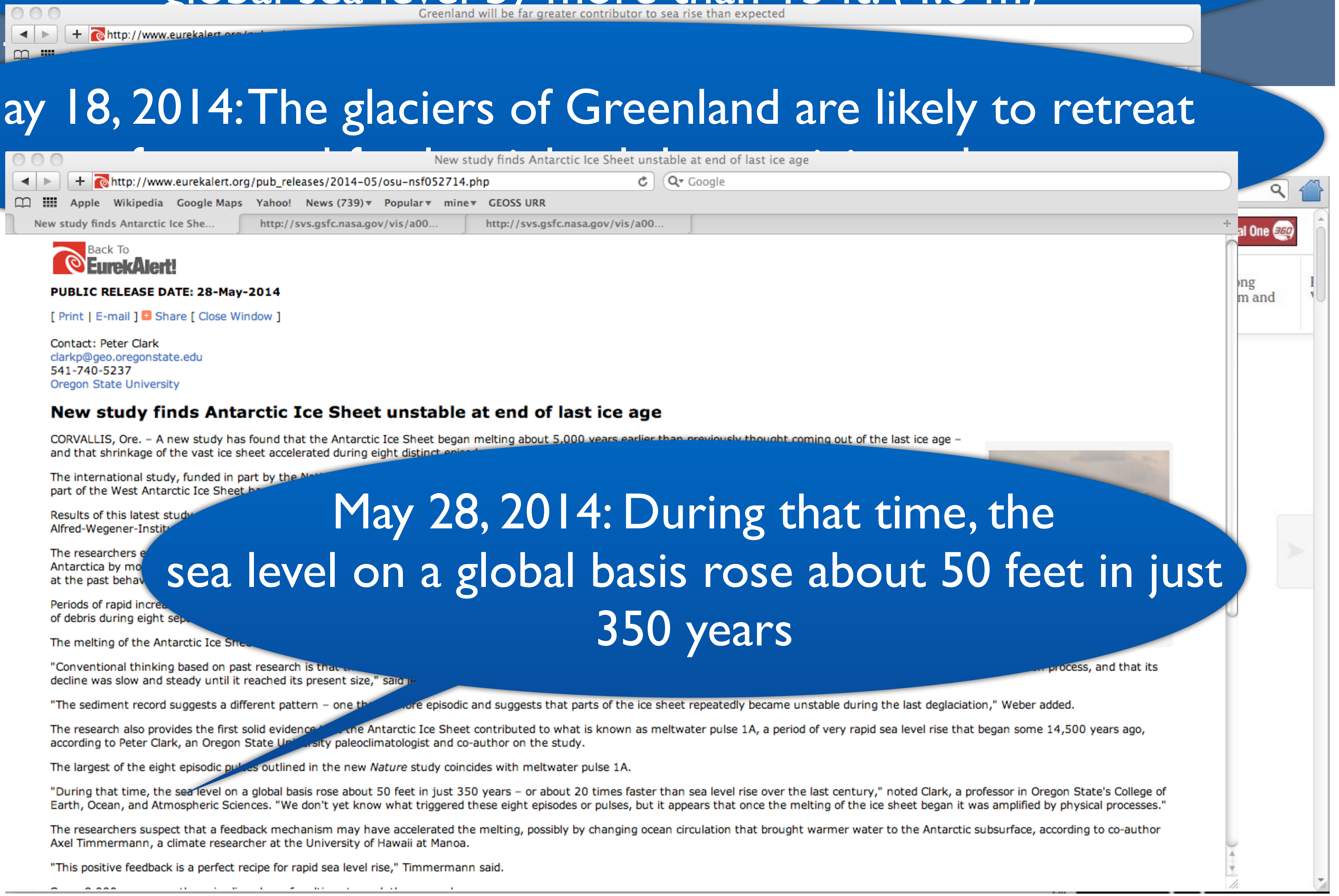
May 28, 2014: During that time, the sea level on a global basis rose about 50 feet in just 350 years





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 epi...

The international study, funded in part by the Nat... part of the West Antarctic Ice Sheet h...

Results of this latest study... Alfred-Wegener-Instit...

The researchers e... Antarctica by mo... at the past behav...

Periods of rapid incre... of debris during eight sep...

The melting of the Antarctic Ice She...

"Conventional thinking based on past research is that ... process, and that its decline was slow and steady until it reached its present size," said ...

"The sediment record suggests a different pattern – one th... ore 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 ... 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 Un...sity paleoclimatologist and co-author on the study.

The largest of the eight episodic pu...es 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."

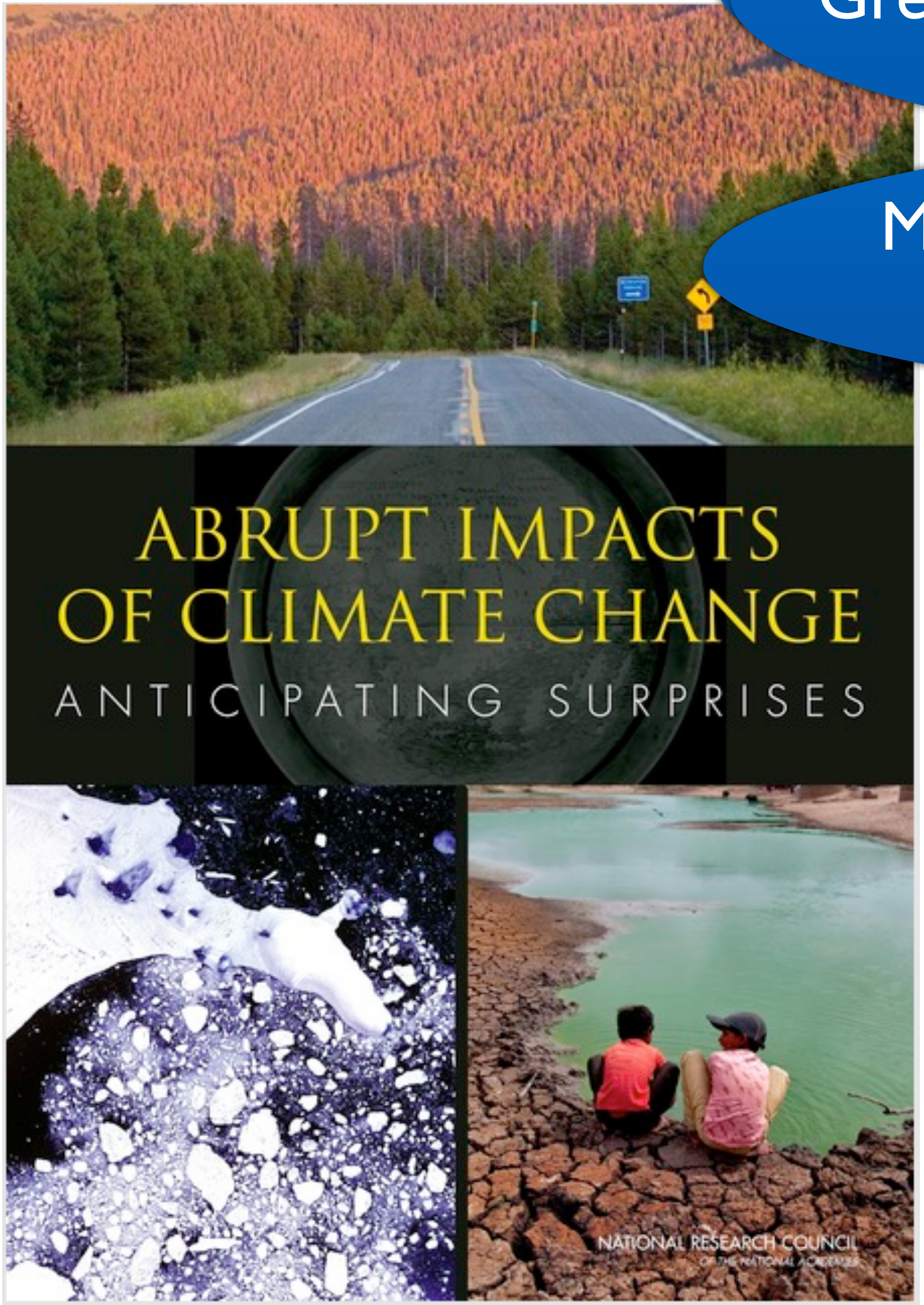
The researchers suspect that a feedback mechanism may have accelerated the melting, possibly by changing ocean circulation that brought warmer water to the Antarctic subsurface, according to co-author Axel Timmermann, a climate researcher at the University of Hawaii at Manoa.

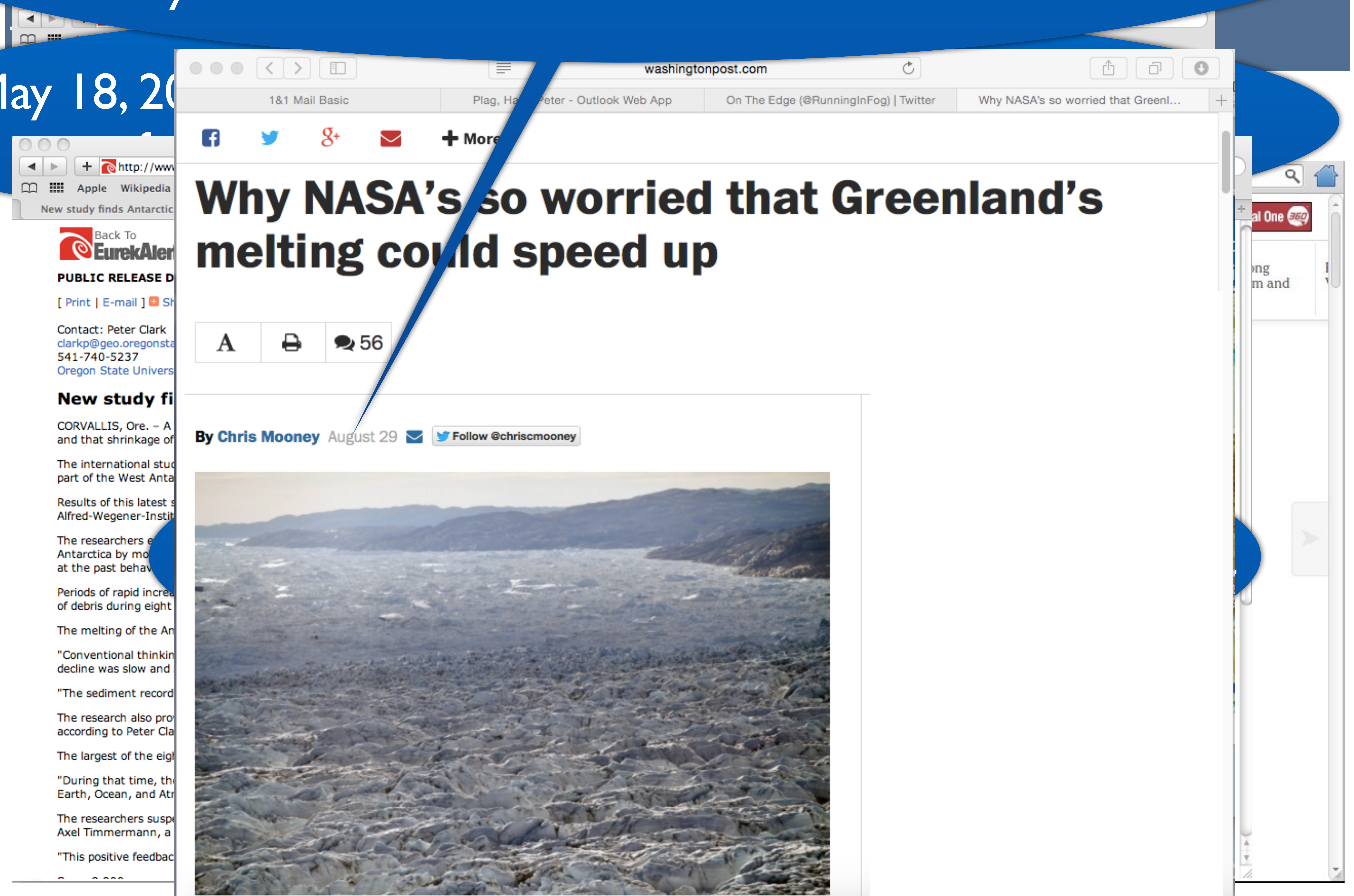
"This positive feedback is a perfect recipe for rapid sea level rise," Timmermann said.

Assessing Knowledge

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?"

May 18, 20





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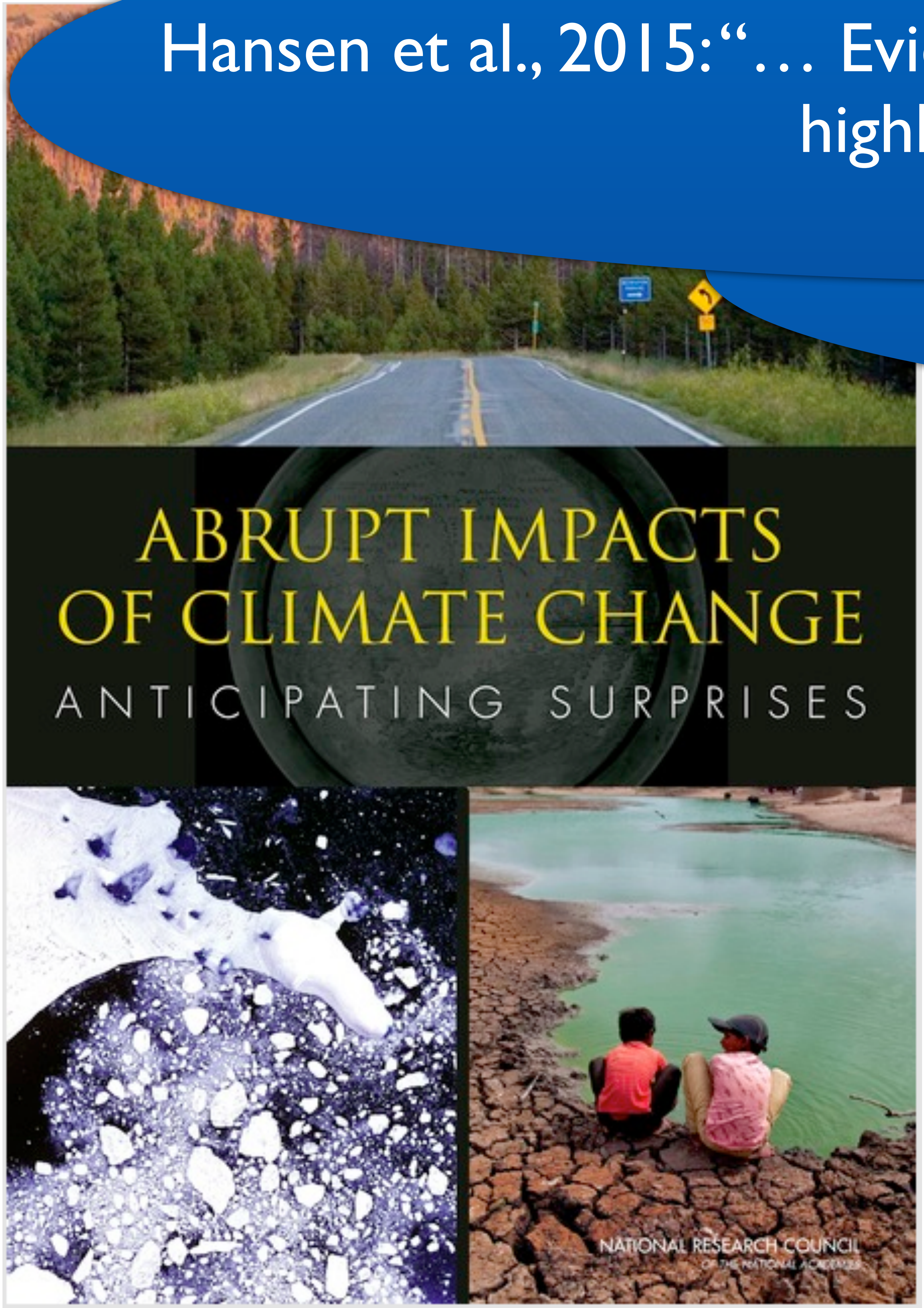
… 2015: "The critical question thus becomes: Is

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

Review Status: This discussion paper is under review for the journal Atmospheric Chemistry and Physics (ACP).

J. Hansen[1], M. Sato[1], P. Hearty[2], R. Ruedy[3,4], M. Kelley[3,4], V. Masson-Delmotte[5], G. Russell[4], G. Tselioudis[4], J. Cao[6], E. Rignot[7,8], I. Velicogna[7,8], E. Kandiano[9], K. von Schuckmann[10], P. Kharecha[1,4], A. N. Legrande[4], M. Bauer[11], and K.-W. Lo[3,4]
[1]Climate Science, Awareness and Solutions, Columbia University Earth Institute, New York, NY 10115, USA
[2]Department of Environmental Studies, University of North Carolina at Wilmington, North Carolina 28403, USA
[3]Trinnovium LLC, New York, NY 10025, USA
[4]NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
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[6]Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China
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[8]Department of Earth System Science, University of California, Irvine, California, 92697, USA
[9]GEOMAR, Helmholtz Centre for Ocean Research, Wischhofstrasse 1–3, Kiel 24148, Germany
[10]Mediterranean Institute of Oceanography, University of Toulon, La Garde, France
[11]Department 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

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The Washington Post

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

The Washington Post

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)

Assessing Knowledge

attribution: NASA Goddard

Cracks in the Greenland Ice Sheet let one of its aquifers drain to the ocean, new NASA research finds. The aquifers, discovered only recently, are unusual in that they trap large amounts of liquid water within the ice sheet. Until now, scientists did not know what happened to the water stored away in this reservoir -- the discovery will help fine tune computer models of Greenland's contribution to sea level rise.

http://www.dailykos.com/story/2017/2/20/1635162/-NASA-defies-Trump-s-doubts-on-climate-science-Identifies-new-path-for-Greenland-meltwater-to-Ocean

Assessing Knowledge

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?

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Greenland: no significant contribution to sea level rise
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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

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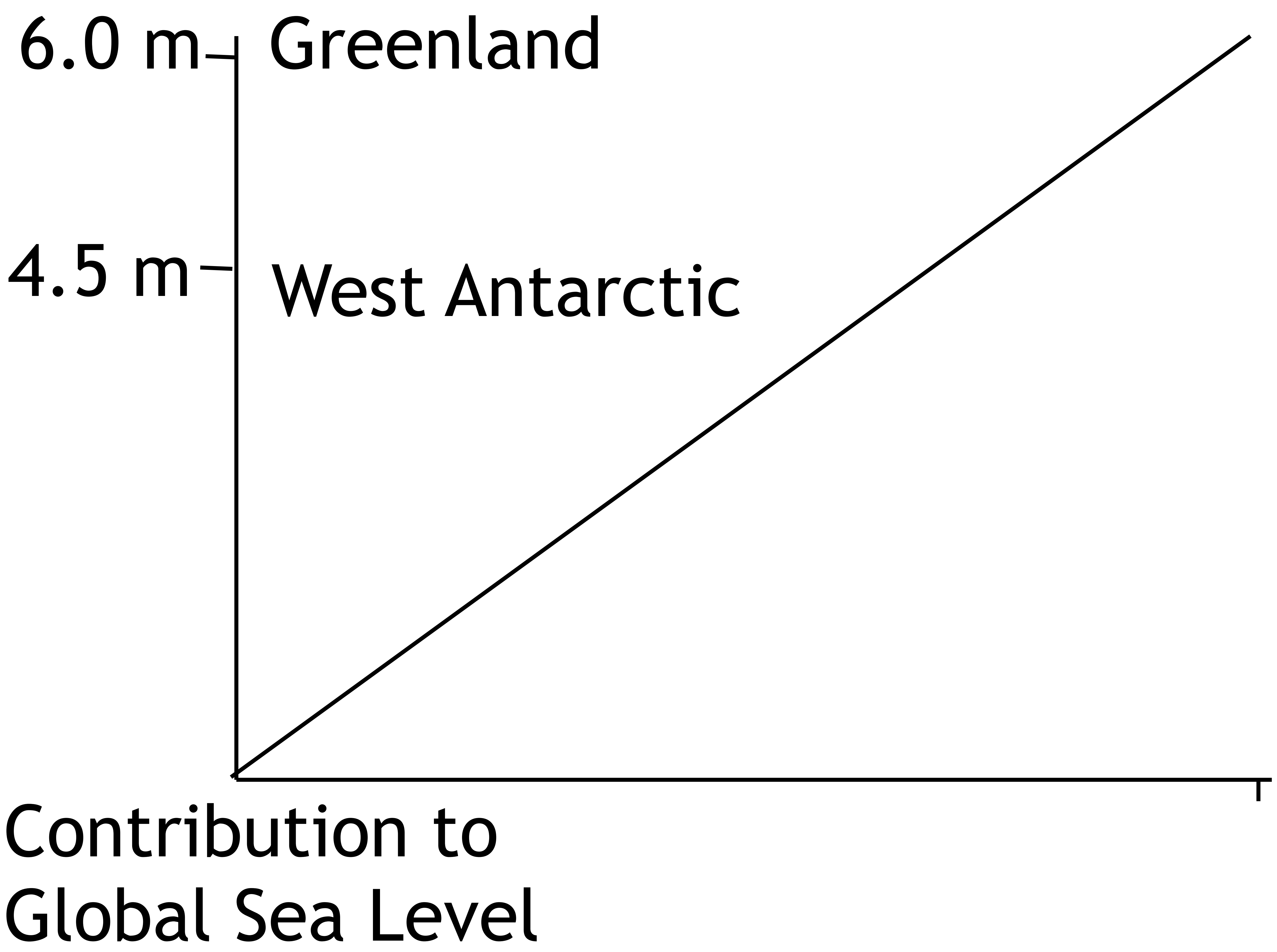

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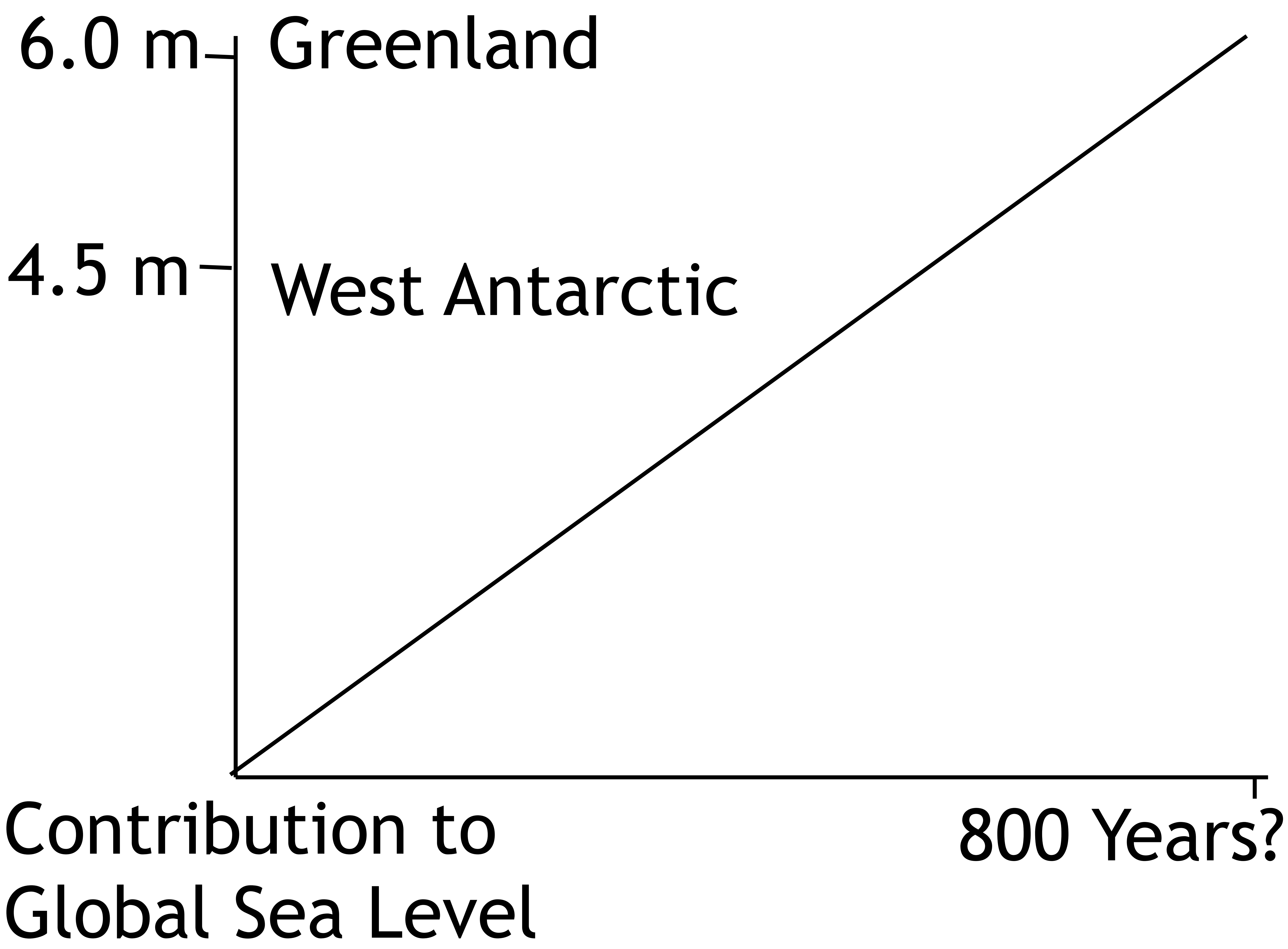

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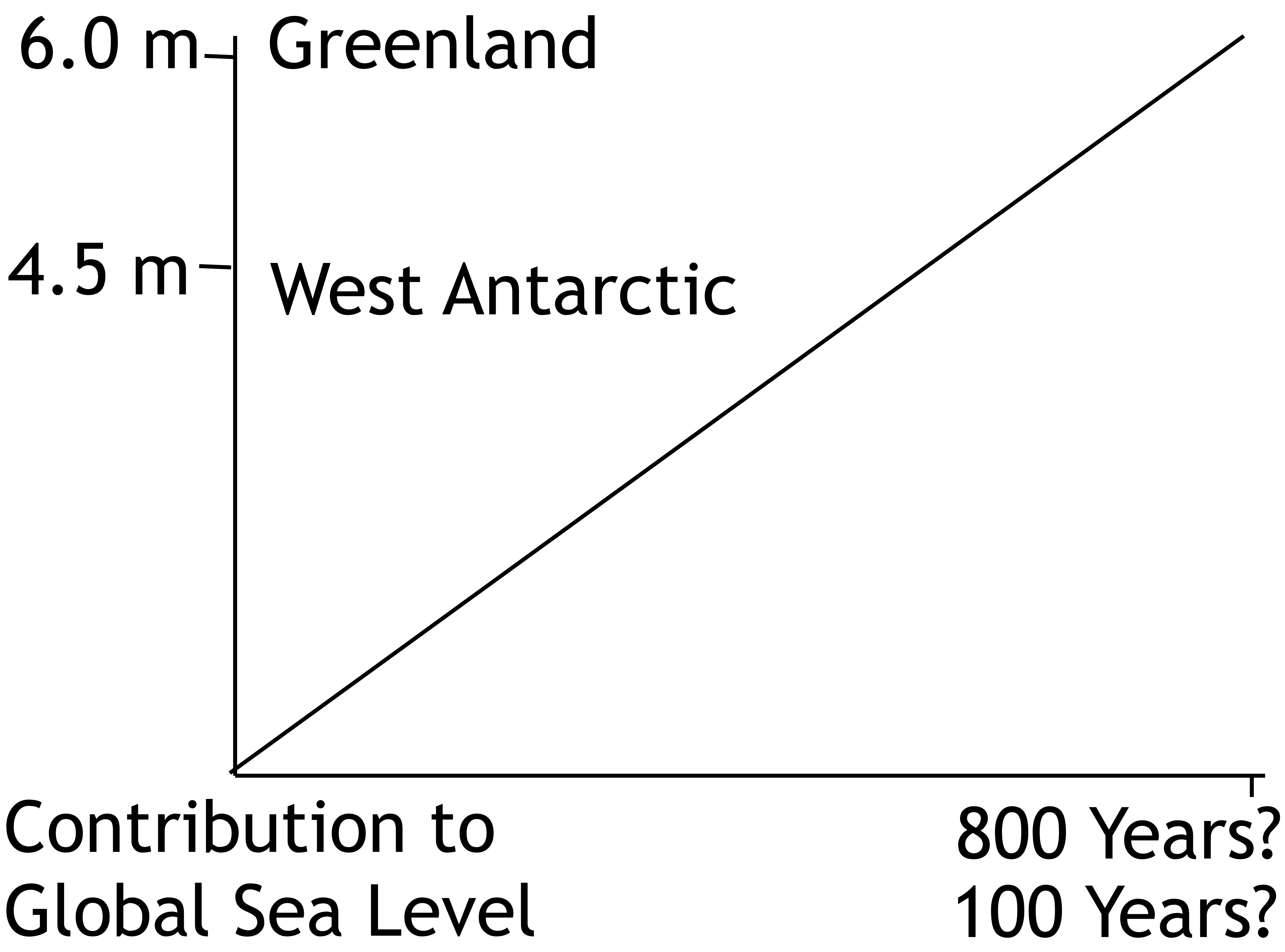

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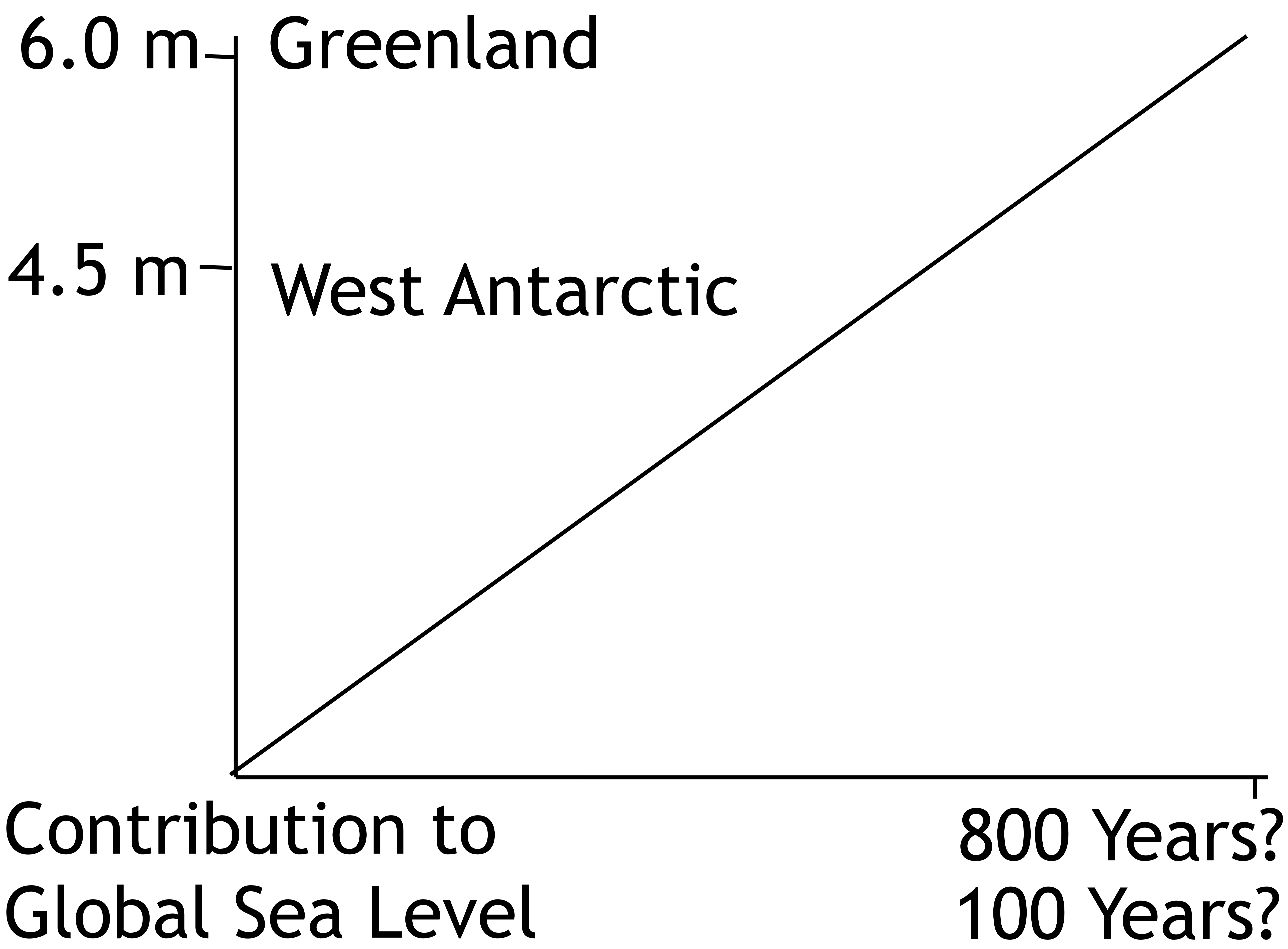

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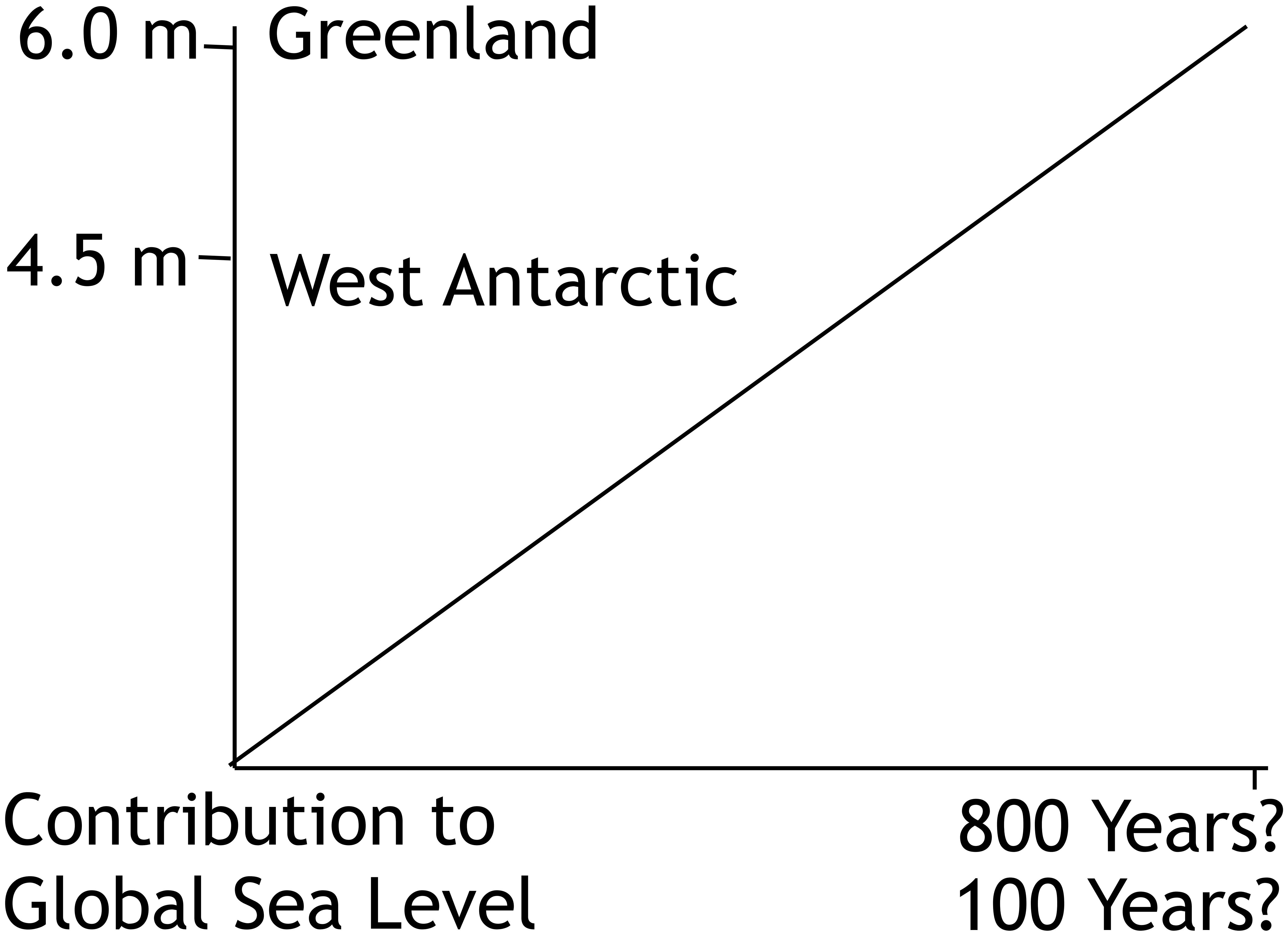
How worried should we be?

Assessing Knowledge

How solid is our knowledge?



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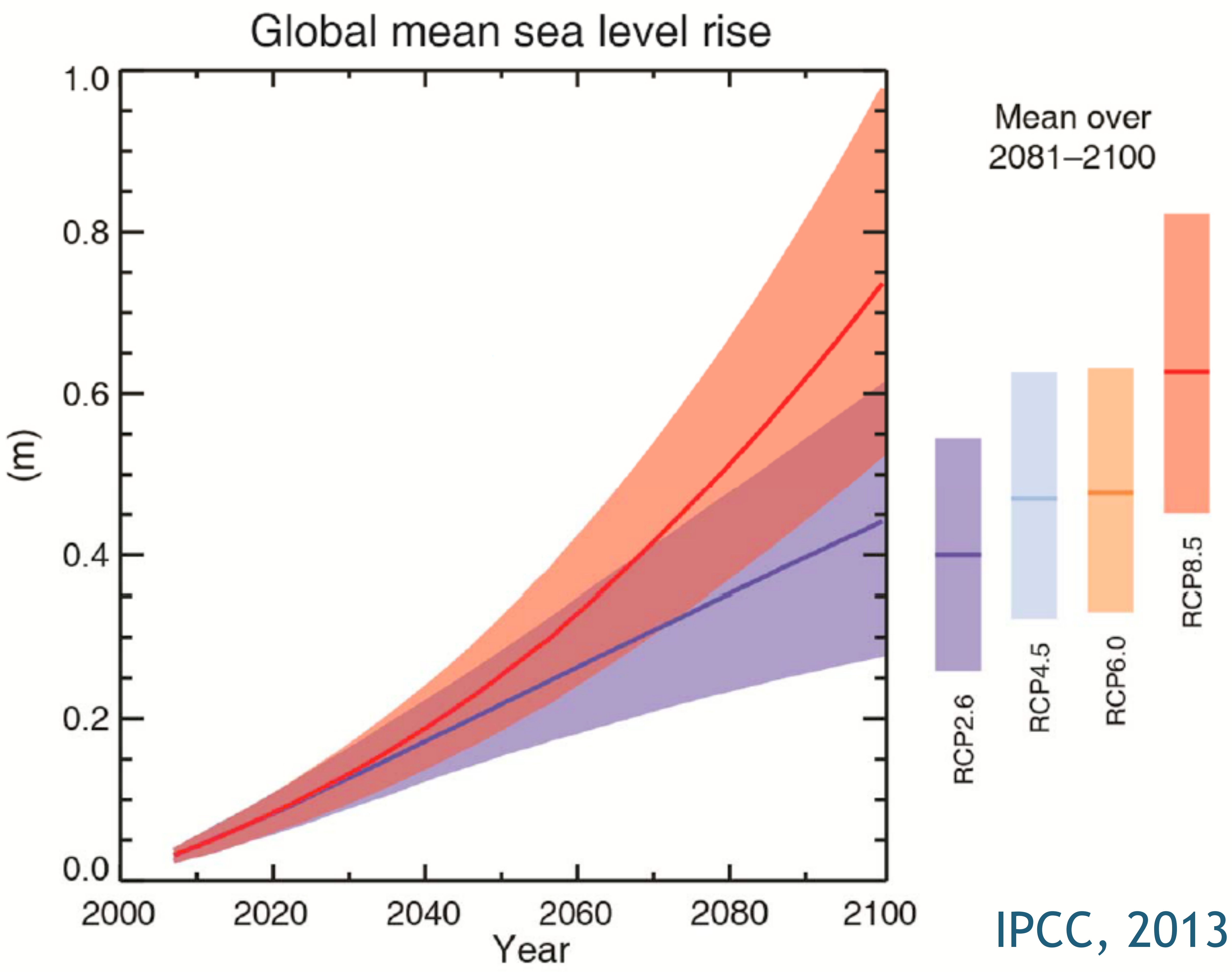
How worried should we be?

What should we be worried about?

Assessing Knowledge

Assessing Knowledge



IPCC, 2013

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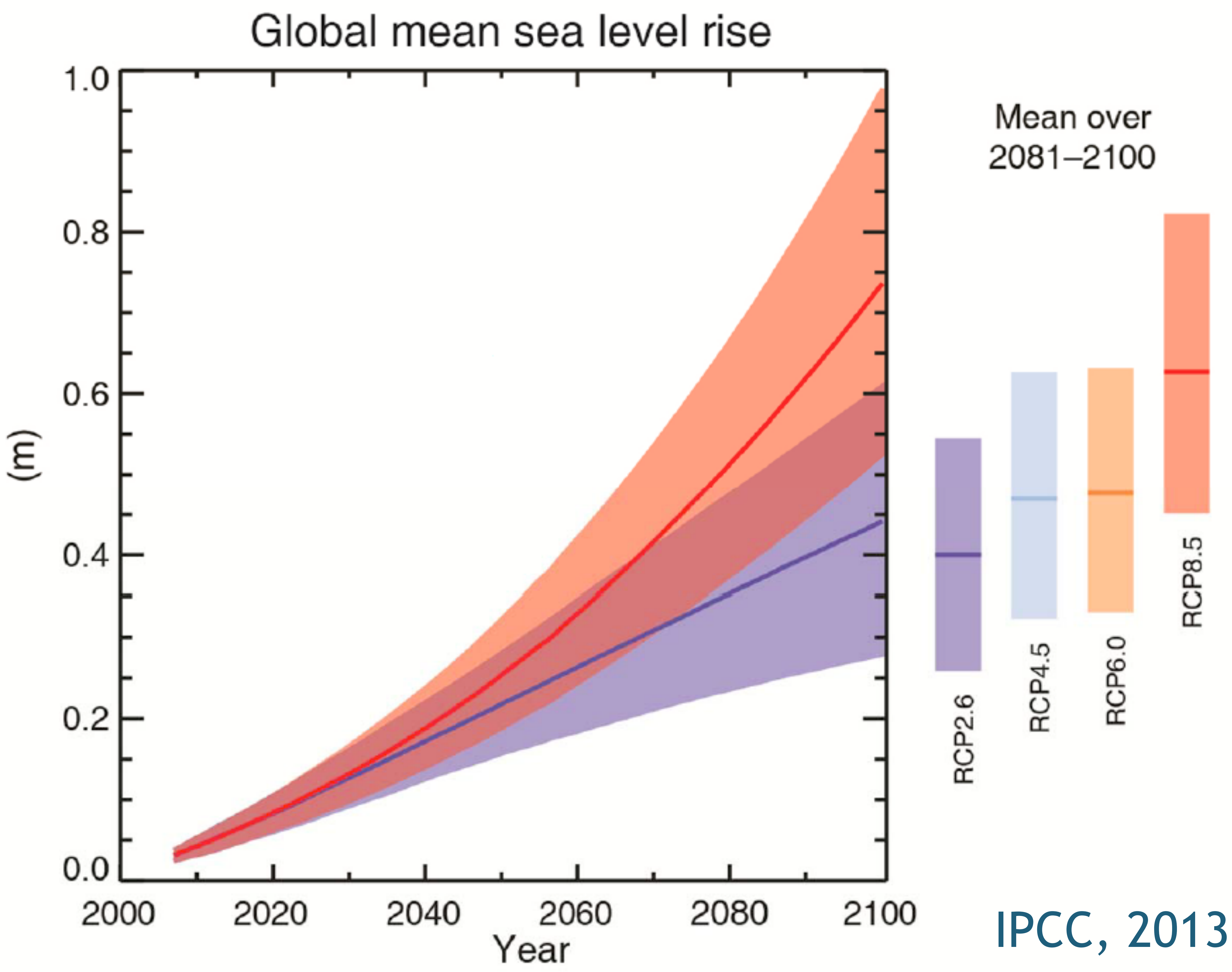

IPCC, 2013

Note: No accelerated contribution from Greenland and Antarctic ice sheets considered

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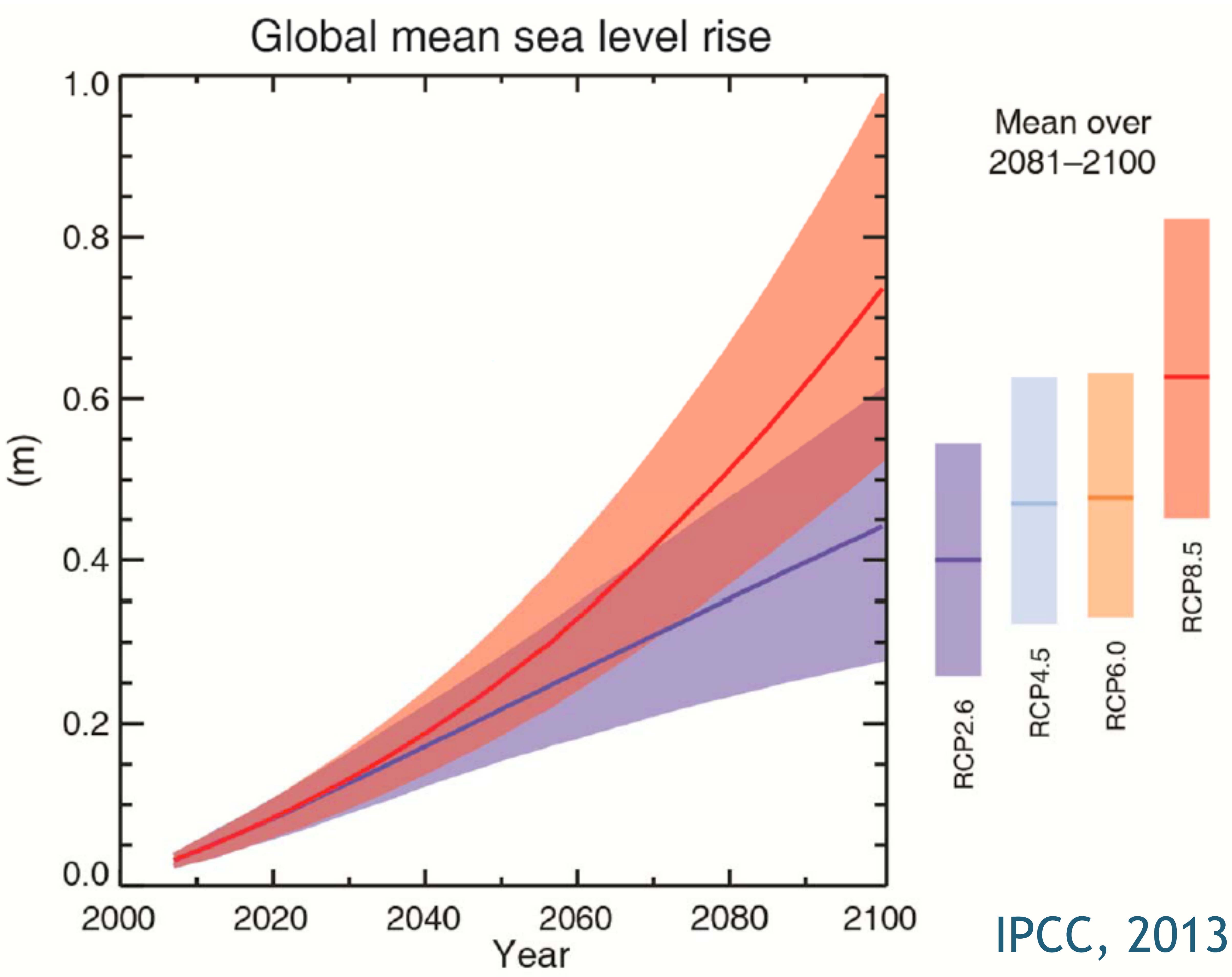

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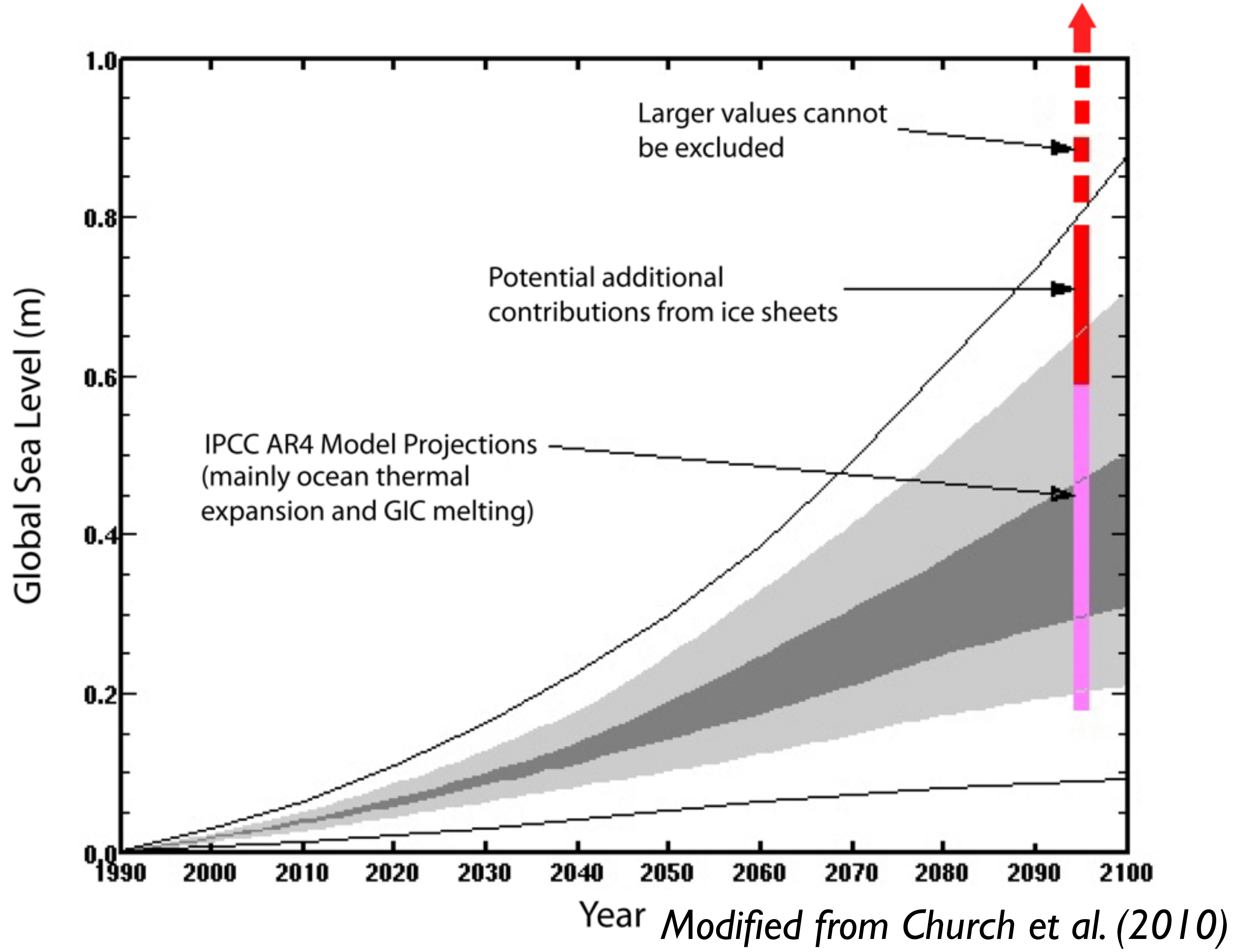

Modified from Church et al. (2010)

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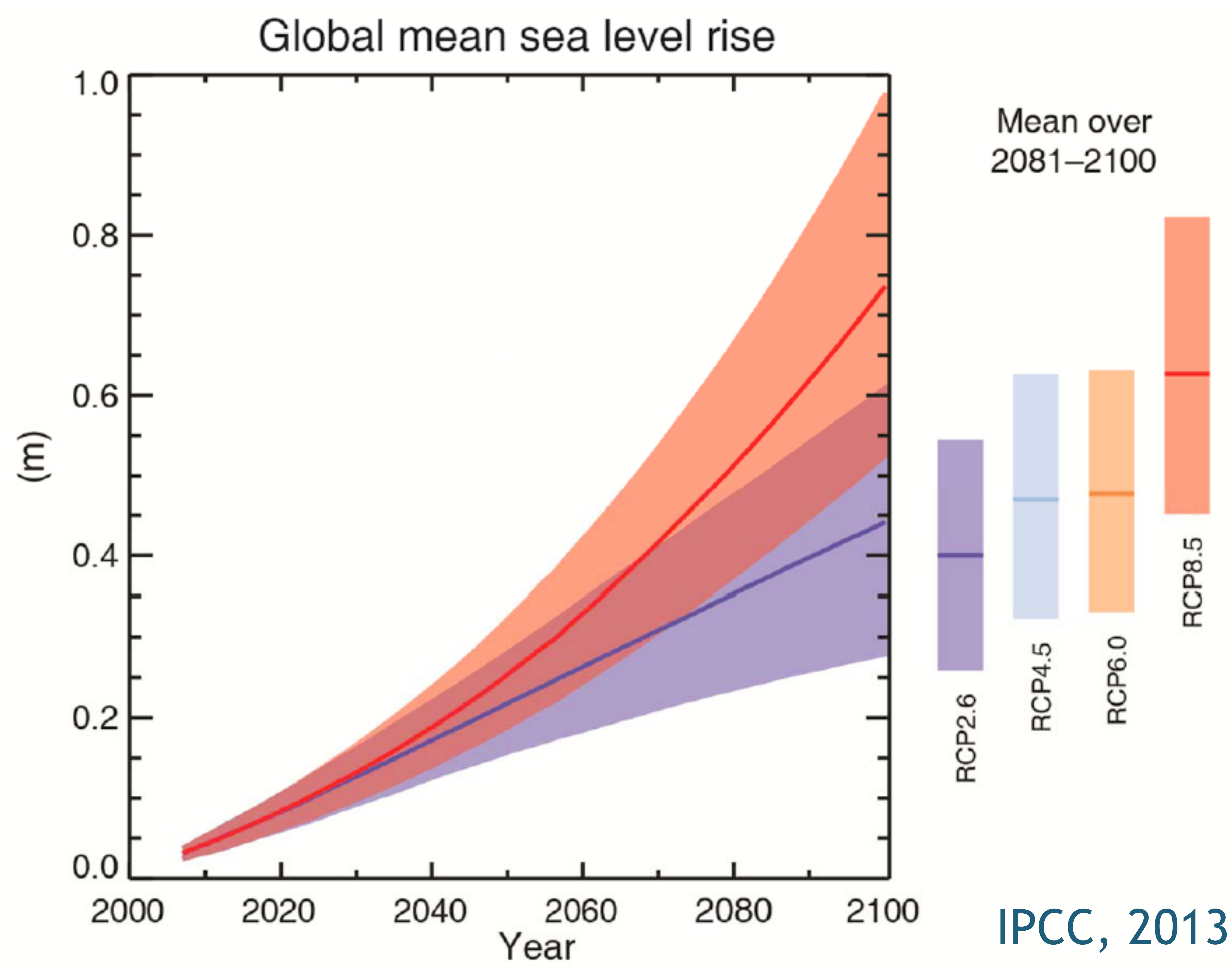
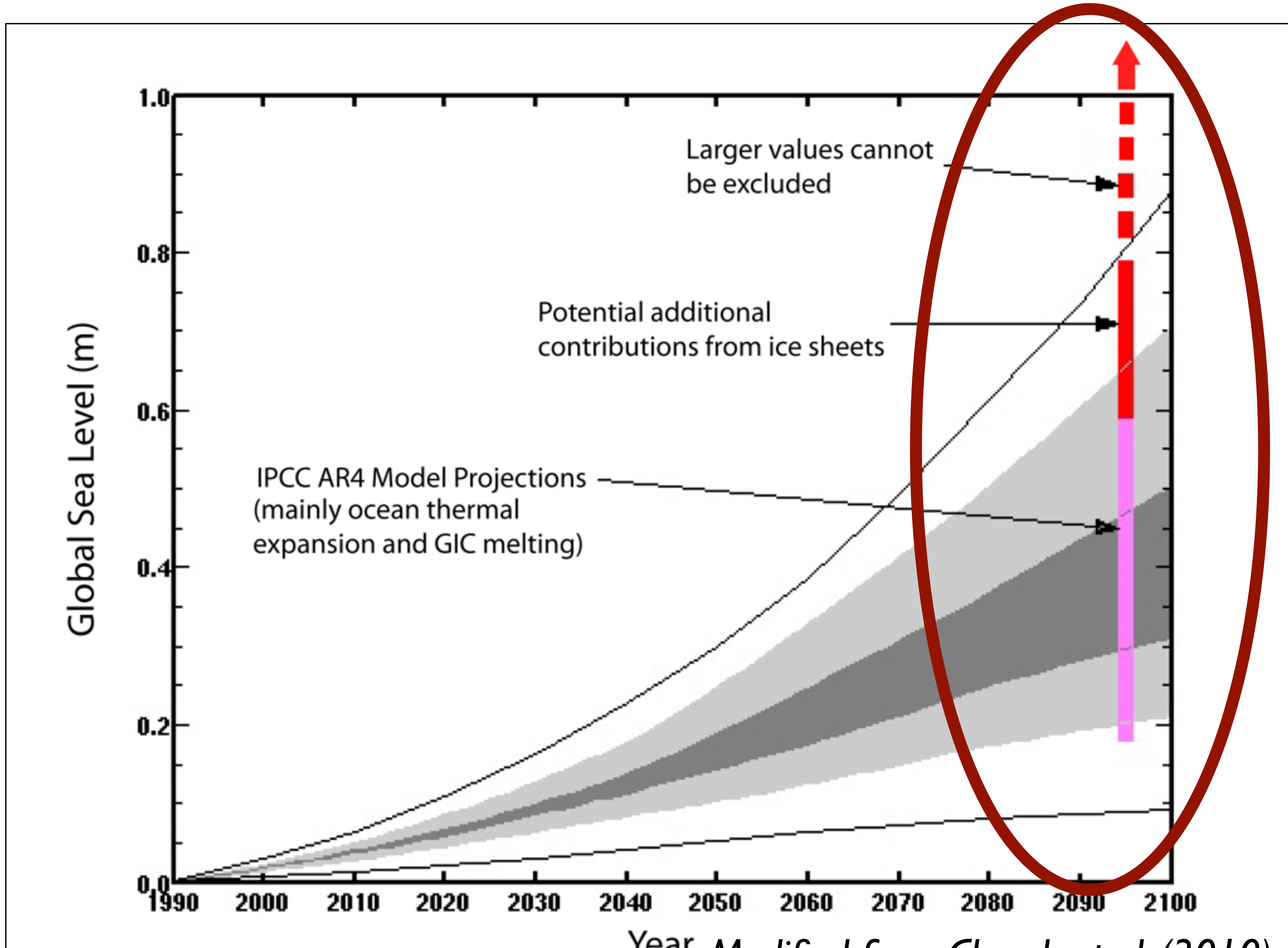


IPCC, 2013



Modified from Church et al. (2010)

Mitigation and Adaptation Studies

Class 18: Knowing the Hazards: Climate Hazards, Public Health, Food-Water-Energy Nexus

Contents:

- Preliminaries
- Climate Change and Sea Level Hazards
  - Observing the Planet
  - Detecting Changes
  - Assessing Knowledge
  - Understanding the Processes and Causes
  - Having Foresight
- Public Health
- Food-Water-Energy Nexus

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
- river runoff
- desertification
- ice and snow cover

Changes in extremes:
- Storms (hurricanes, typhoons, tornados, thunderstorms)
- Floods
- Droughts
- Heat Waves
- Ice storms and snow fall

Changes in dynamics and chemistry:
- ocean circulation
- atmospheric circulation
- ocean temperature
- ocean acidification
- soil, air and water chemistry

Changes in biosphere:
- ecosystem health and services
- migration
- invasive species
- extinction

Questions:
- How well do we know the past and current changes?
- How well do we understand the processes and causes?
- *How are the hazards potentially going to impact human and non-human systems?*
- *To what extent can we predict or anticipate future changes?*
- *Do we have foresight in terms of what might happen?*

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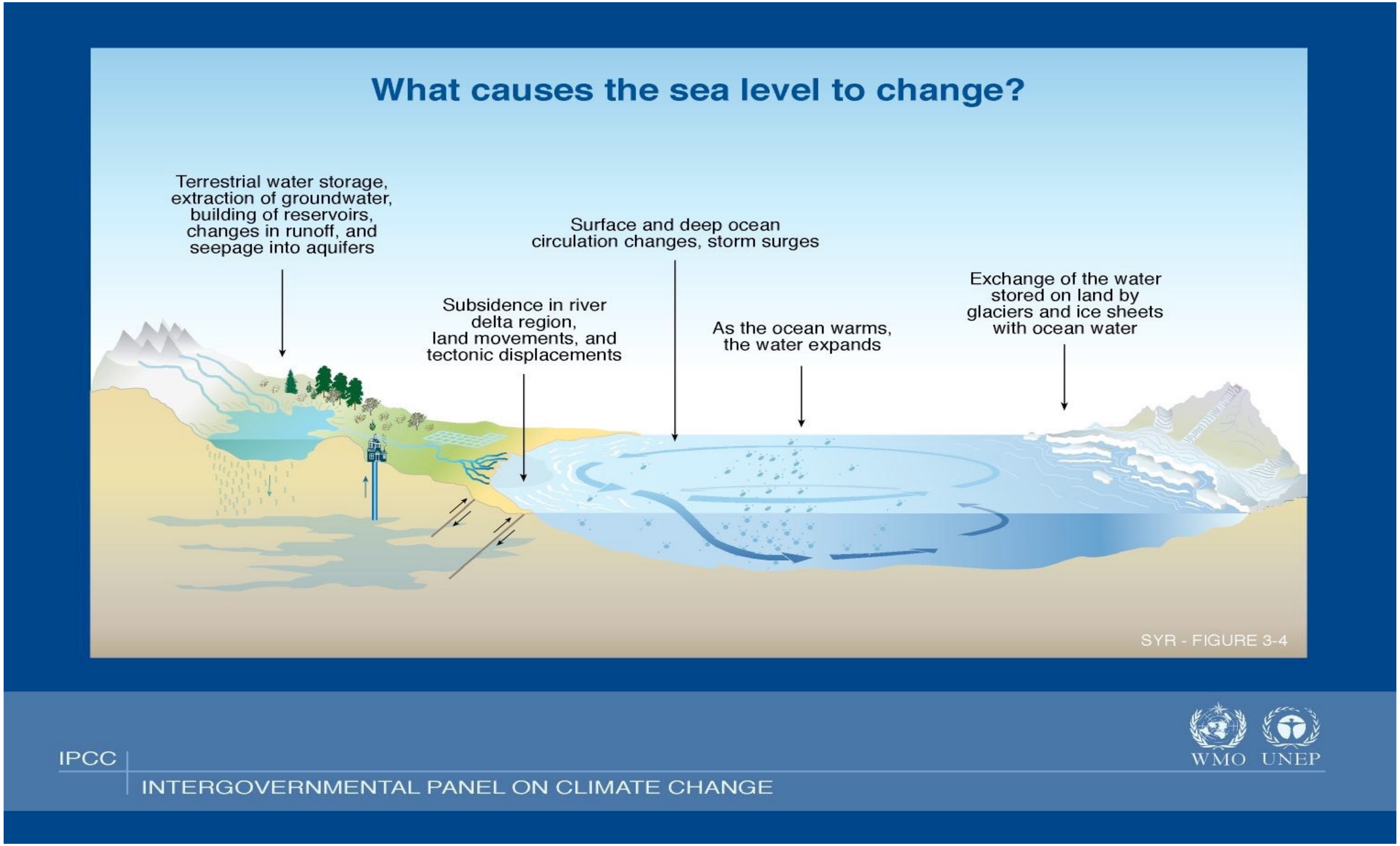
Understanding the Processes

Understanding the Processes



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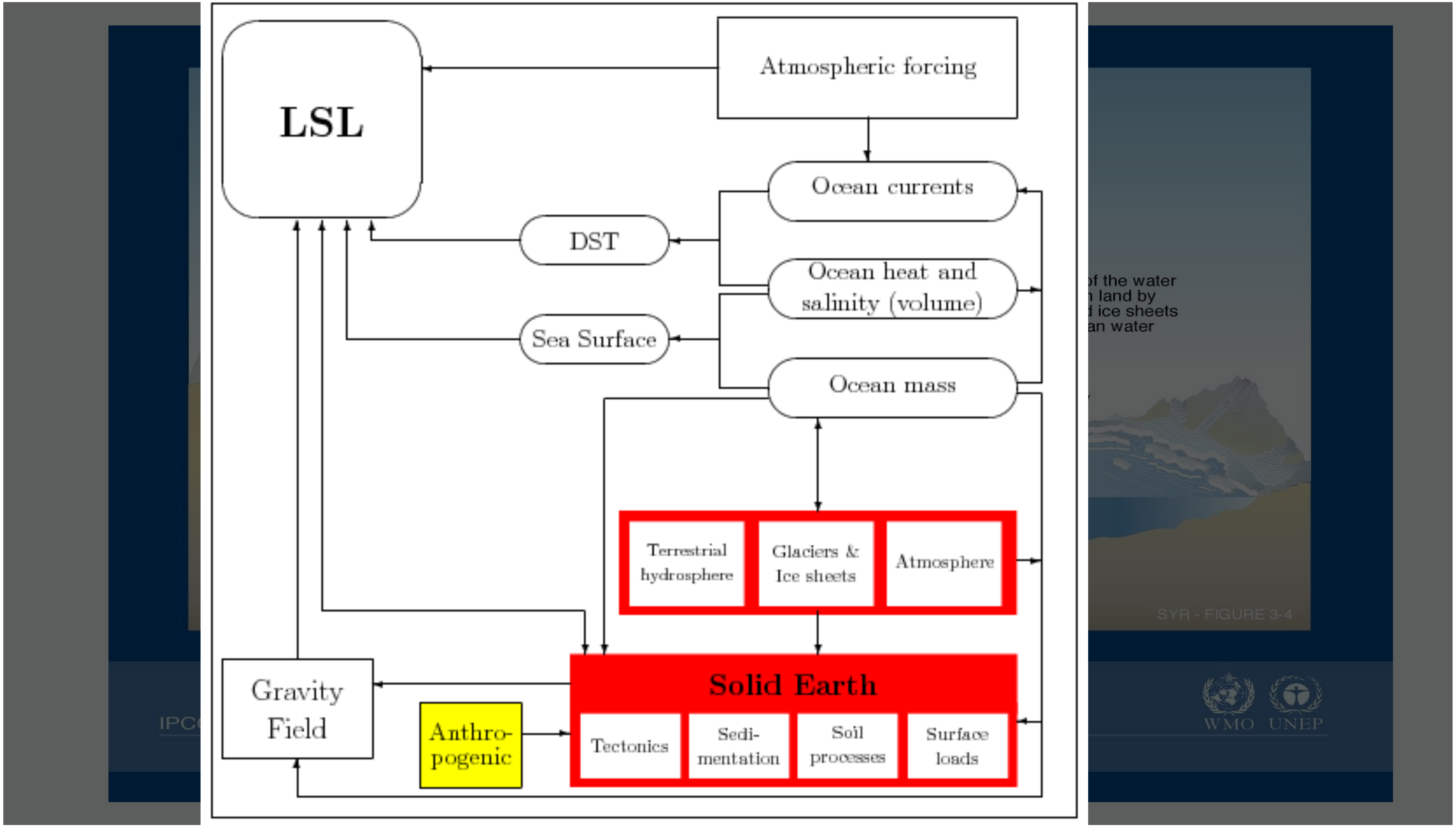
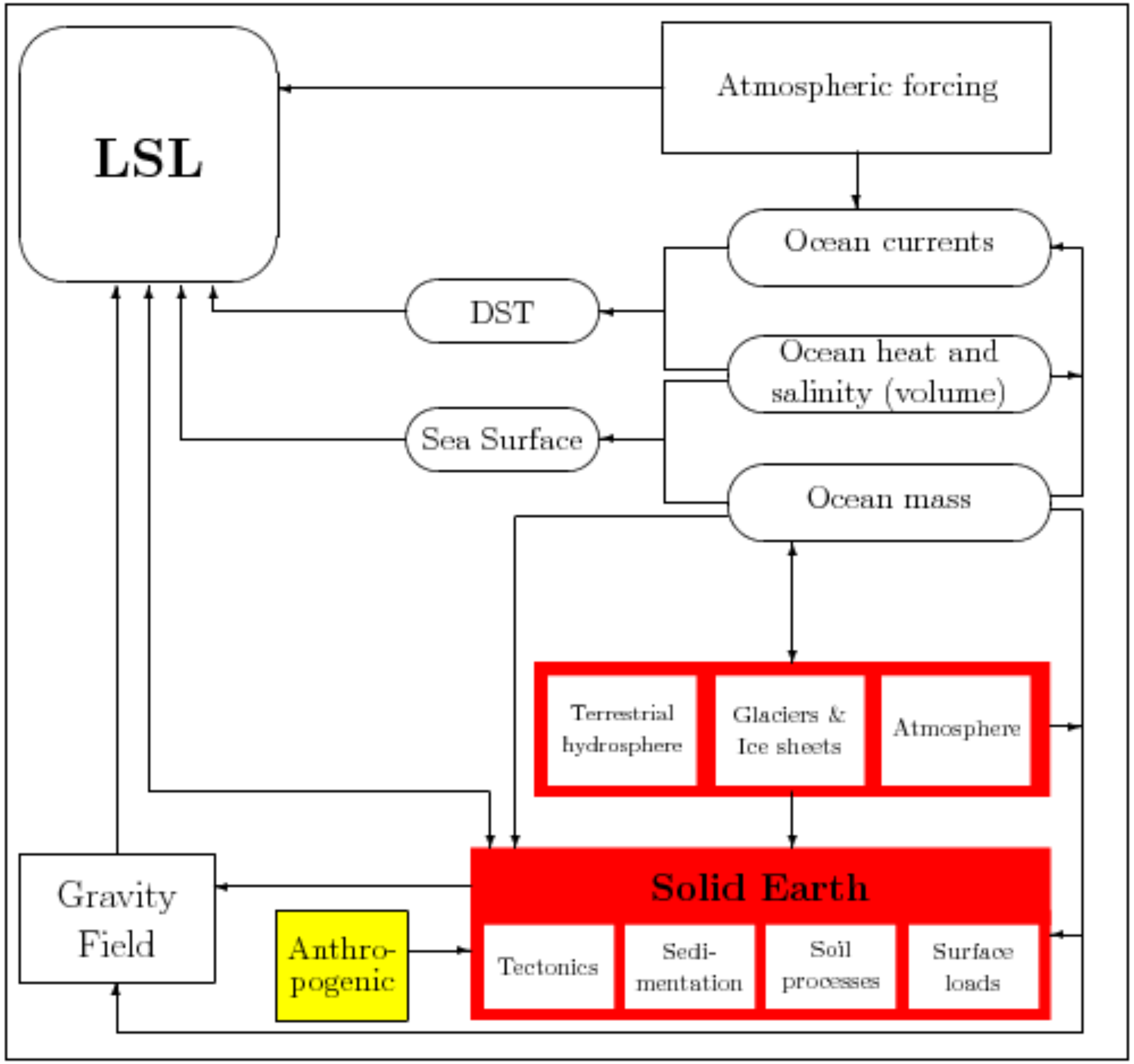


Understanding the Processes

Local sea level is the result of many local, regional and global processes and can only be fully understood in a complex-system approach



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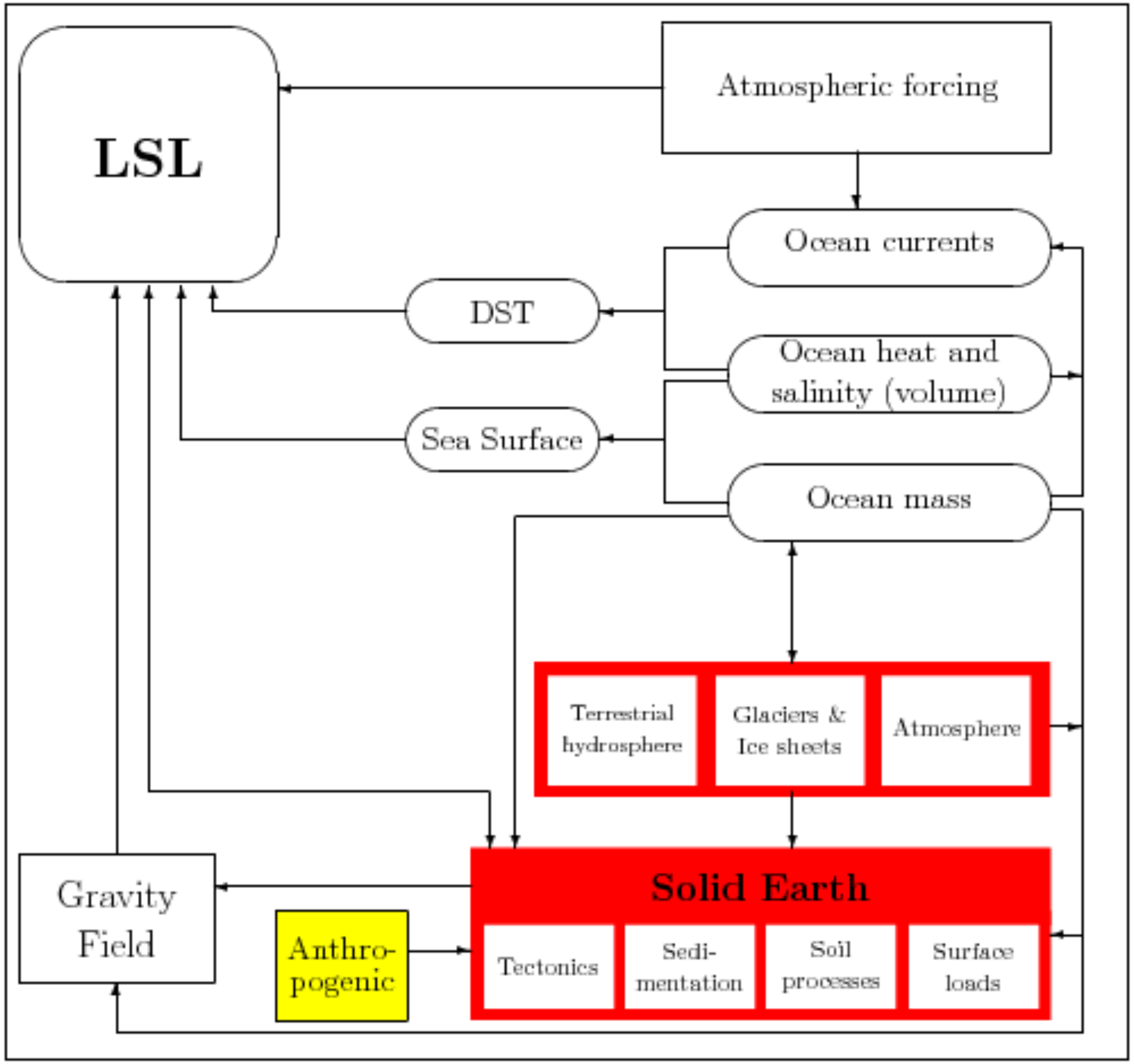
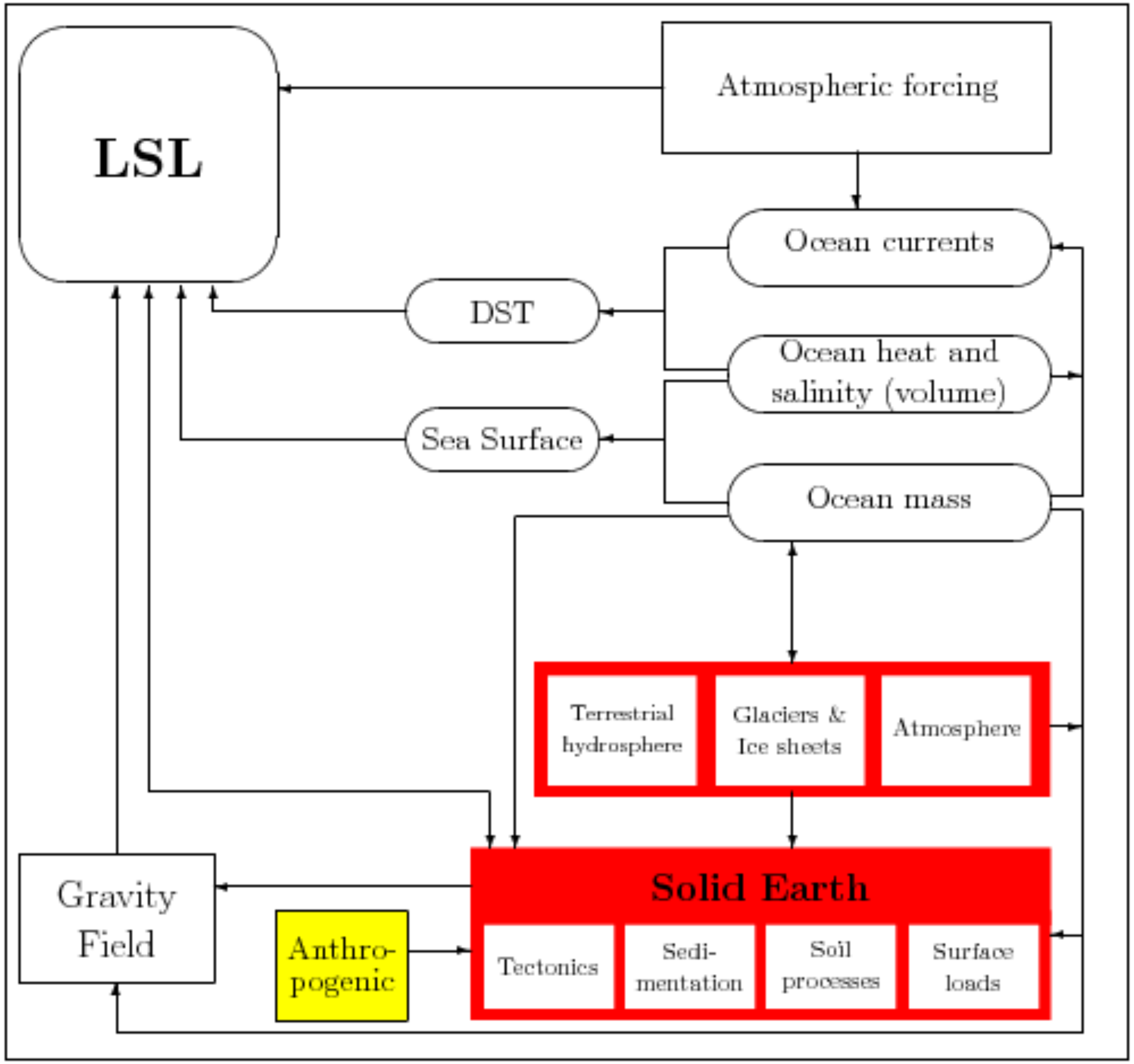
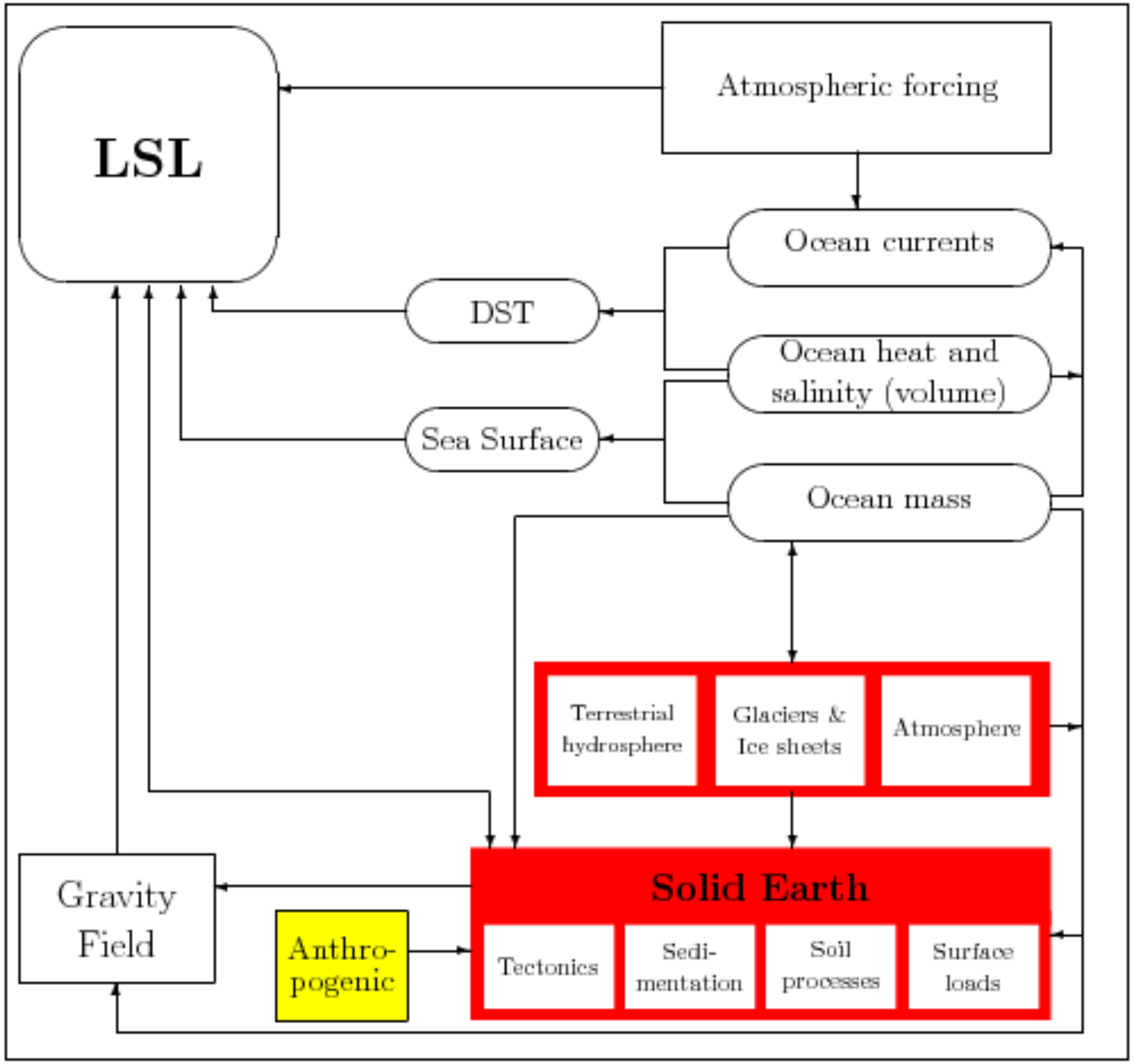


Local Sea Level:
vertical distance between sea surface and land surface



Local Sea Level:
vertical distance between sea surface and land surface

Local Sea Level (LSL) changes =
Sea Surface Height (SSH) changes -
Land surface height (LSH) changes.



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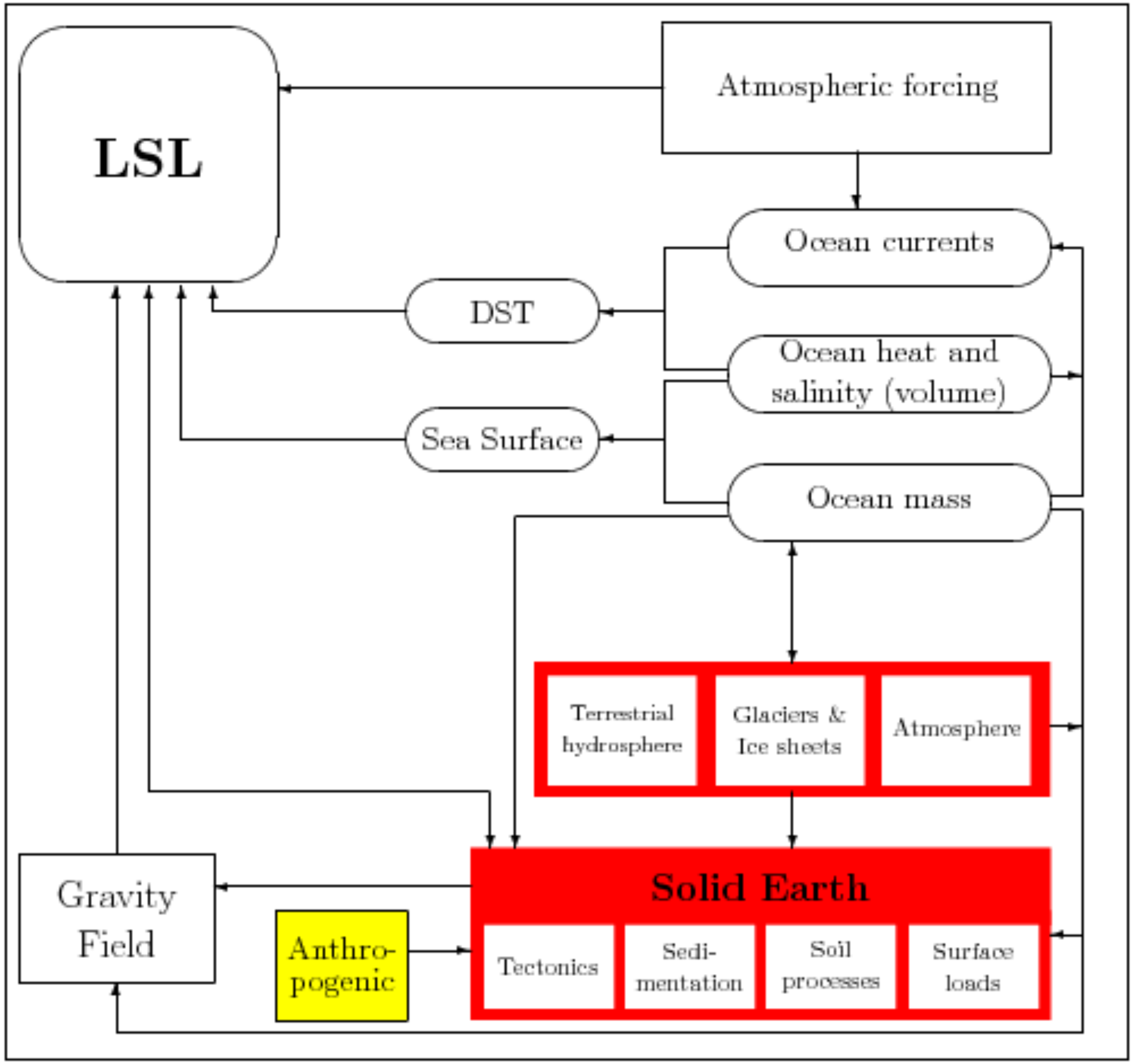
$$LSL(x,t) = SSH(x,t) - LSH(x,t)$$



Understanding the Processes

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Important for projection of maximum flood levels

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Important for projection of maximum flood levels

Short-period variations are the result of local to regional processes

LSL = short-period part + long-period part

$$\delta h_{\mathrm{M}}(\vec{x},t) = N(\vec{x},t) + S(\vec{x},t) + C(\vec{x},t) + F(\vec{X},t) + A(\vec{x},t) + I(\vec{x},t) + G(\vec{x},t) + T(\vec{x},t) + P(\vec{x})(t-t_0) + V_0(\vec{x})(t-t_0) + \delta V(\vec{x},t) + B(\vec{x},t)$$

N: nodal tide
S: steric changes
C: changes in ocean currents
A: changes in atmospheric circulation
F: freshening
I: changes in the mass of the large ice sheets
G: changes in continental glaciers
T: changes in terrestrial hydrosphere
P: postglacial rebound
V_0: secular vertical land motion
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Low-Frequency part of the LSL equation:

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Important for projections of LSL

Long-period variations are the result of local to global processes

LSL = short-period part + long-period part

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$$\delta h_M(\vec{x},t) = N(\vec{x},t) + S(\vec{x},t) + C(\vec{x},t) + F(\vec{X},t) + A(\vec{x},t) + I(\vec{x},t) + G(\vec{x},t) + T(\vec{x},t) + P(\vec{x})(t-t_0) + V_0(\vec{x})(t-t_0) + \delta V(\vec{x},t) + B(\vec{x},t)$$

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Comments on the relation between mass changes (exchange and redistribution) and LSL

Important for projections of LSL

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