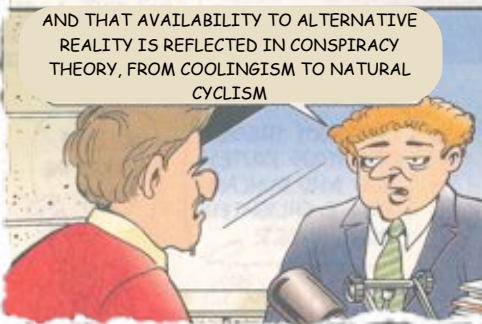


Climate Change & Hampton Roads





Dwoyer OpEd in Daily Press 3/1/2009

A look 'back' at the 21st century and the plight of Hampton Roads

Doug Dwoyer

January 1, 2100
Hampton Roads has endured a period of rapid and challenging change over the last century. The 21st century began with great optimism in the region as the nation's economy and the region's economy were thriving. Many trends of the world's economy and military activity and spending favored Hampton Roads. Our once-thriving port was rapidly expanding, fueled by globalization of trade and growing coal exports. In those heady days, the future of the region indeed looked bright.

At this time, the world began to recognize the emergence of human-induced climate change and its potential to cause major disruptions during the 21st century. In 2007 a report was issued by a body called the Intergovernmental Panel on Climate Change (IPCC), which was sponsored by the United Nations and the World Meteorological Organization. It projected a 5-degree to 9-degree Fahrenheit change in mean global temperature and a 2-foot to 3-foot rise in sea level by 2100. Shortly after this report was issued, scientists began to discover rapid melting and deterioration of the Greenland and West Antarctica ice sheets, leading to hours of even greater sea level rise.

Unfortunately, people around the world, including those in Hampton Roads, did not seriously respond to these warnings and continued to operate as if climate change was something abstract and not important in their daily lives. As we know today, the projections in the 2007 IPCC report on global temperature rise were remarkably accurate, as shown in 2101 it is about 10 degrees warmer around the planet than it was in 2001.

On the other hand, we have experienced a far greater sea level rise than predicted, with today and West Antarctica now losing their rapid melting today. There is no end in sight to rapid sea level rise. The impact of these global changes on our region has been nothing short of devastating. Old-timers in Hampton Roads can recall large areas of our region east of U.S. Route 17 that were above water and populated. Large areas of Gloucester and York counties, as well as major sections of Hampton, Norfolk, Virginia Beach and Chesapeake, were home to thriving communities, businesses, factories and other assets. The city of Portsmouth, which no longer exists, had a population of about 13,000 in 2001 and was a rapidly growing bedroom community. Our major highway links across the harbor, the Hampton Roads Bridge-Tunnel and the Monitor-Merrimac Memorial Bridge-Tunnel are frequently overwashed and require constant repair.

These old-timers can't even remember the devastation of 2010 and 2012 and the loss of the Air Force base at Langley Air Force Base, and by 2075 the

Sunday, March 1, 2009

OPINION

Roads

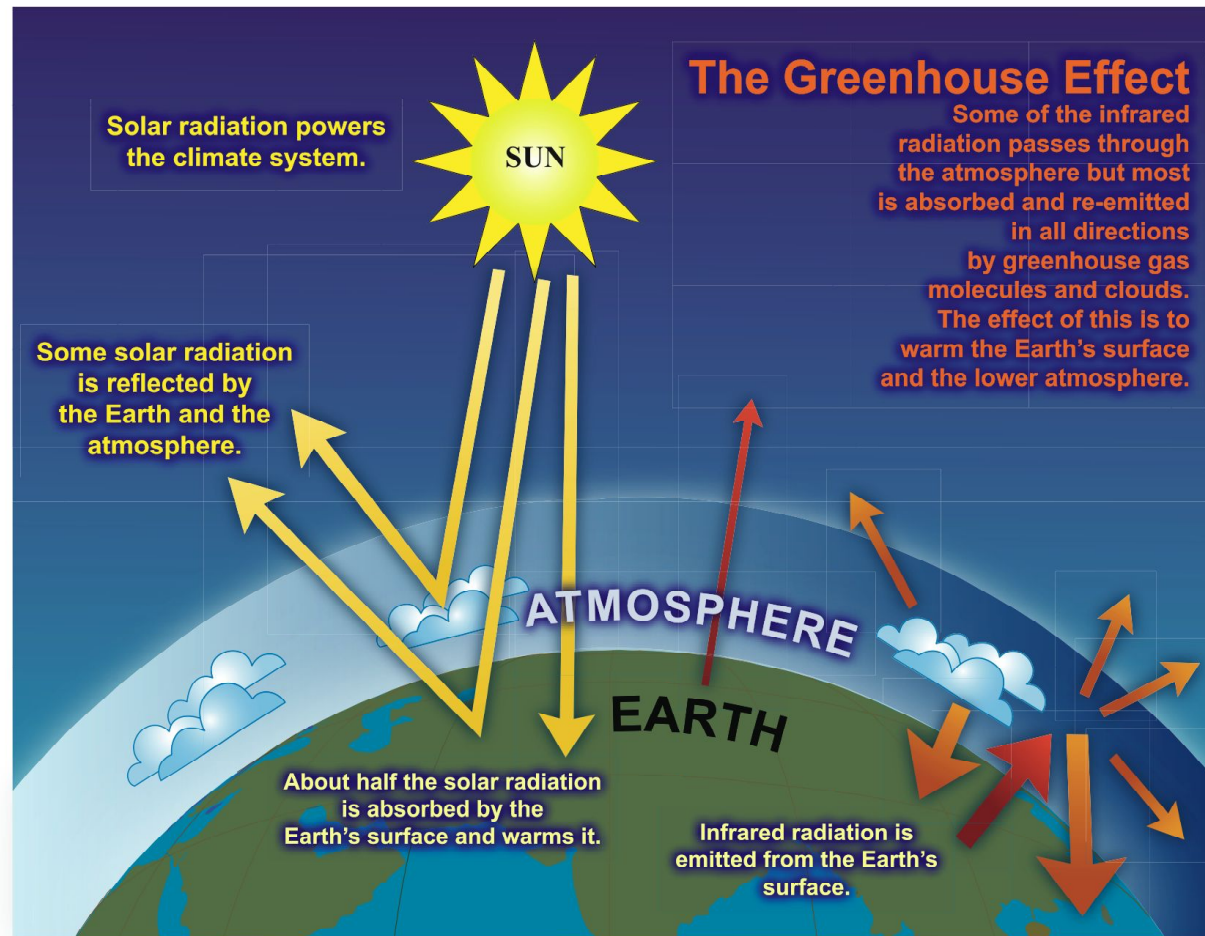
Looking back on this sad state of affairs for Hampton Roads in 2101, we can only pity or mock our ancestors. A few simple warnings more seriously before these irreversible changes began. We could today have a very different, more prosperous and enjoyable Hampton Roads than the sorry state our community has inherited.

Koch OpEd in Daily Press 1/31/2010



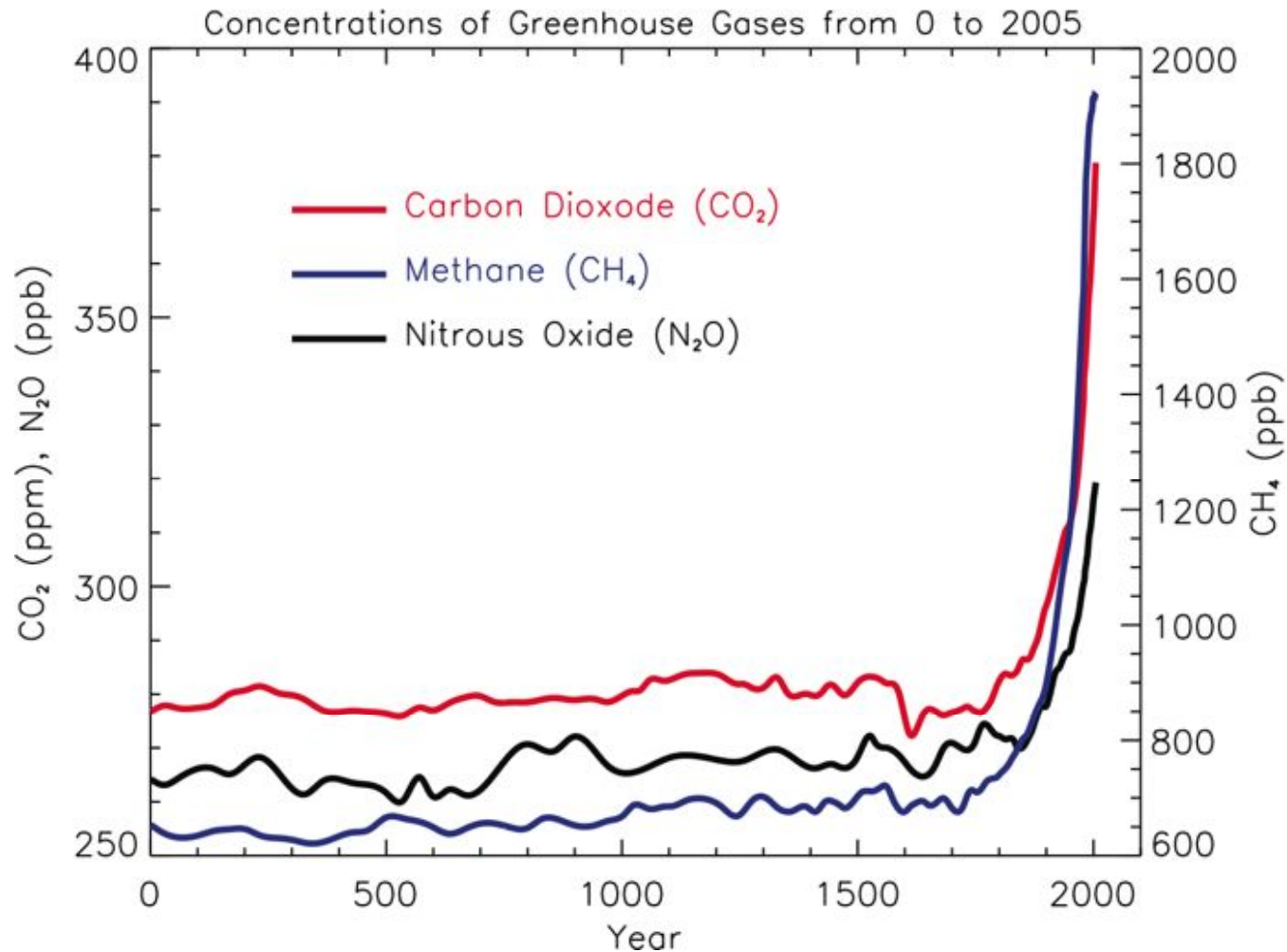
Remember our debates over issues such as the boat tax and the car tax? The financial stakes attached to these laws will seem like small potatoes in the future as we come to grips with the costs of dealing with rising ocean levels. It is time for our elected officials to take notice.

Idealized Model of the Greenhouse Effect



FAQ 1.3, Figure 1

Change in Long-Lived Greenhouse Gases



IPCC Predicted Global Surface Warming

Recent predictions based on most optimistic mitigation scenarios

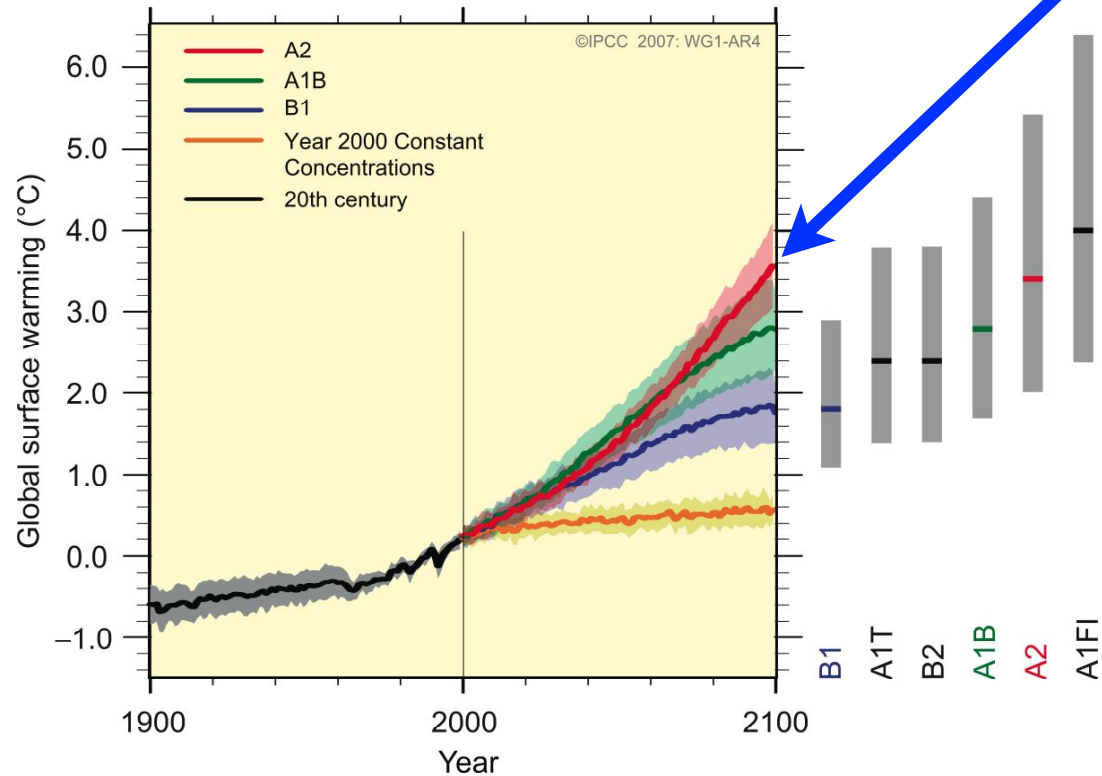
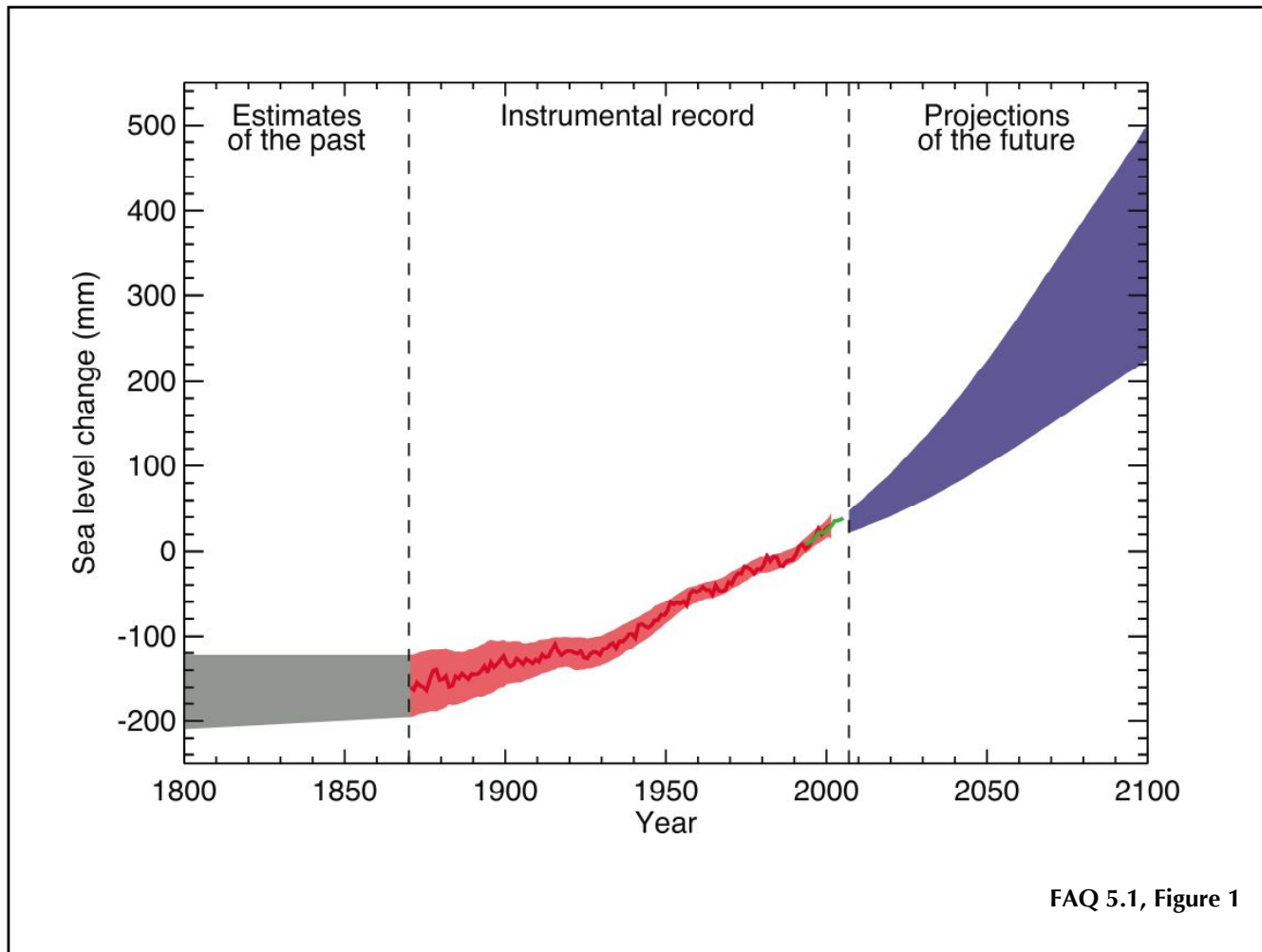


Figure SPM.5

Trend in Global Mean Sea Level (IPCC)



Three Main Points

1. Hampton Roads future is tied directly to the future of the Arctic and the Antarctic
2. Climate change is irreversible
3. A framework for Hampton Roads response to climate change

Three Main Points

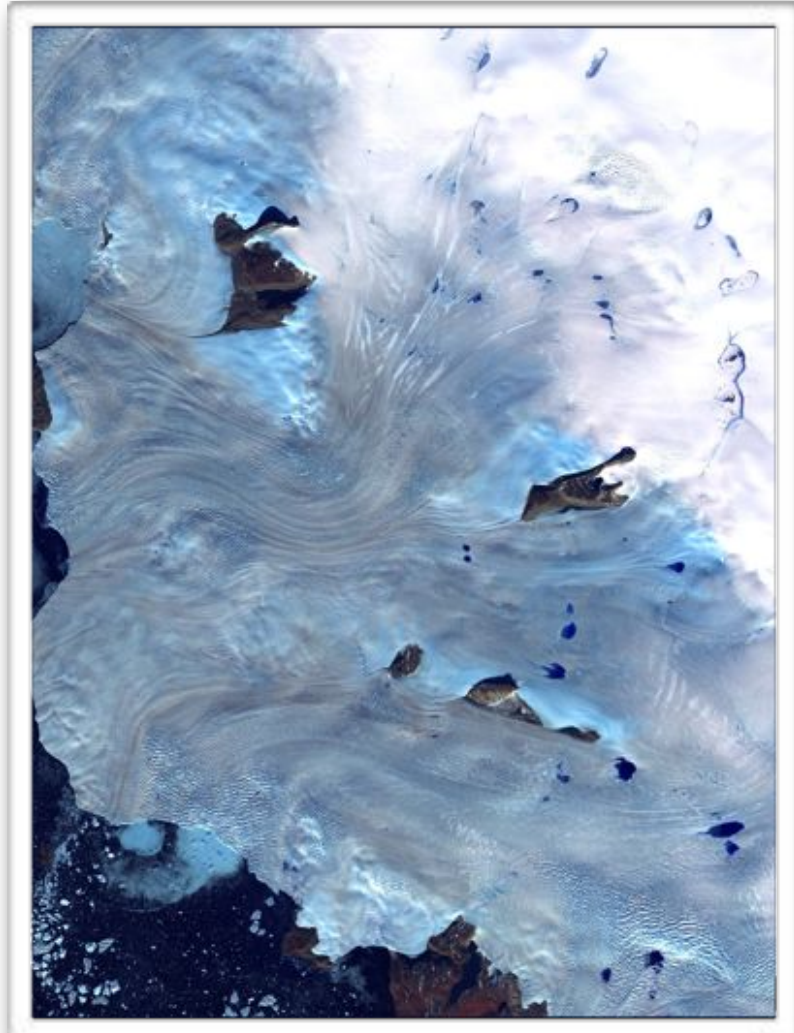
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Do we know what's going on?

- Changes in predictions in last few years
 - Arctic ice free by 2100 now down to 2013 by some estimates
 - Sea-level rise from .2 m to .5 m up to .8 m to 2 m (factor of 4)
 - Global average ocean temperature at record high of 62.8°F
- ✓ Poor understanding of, and limited ability to model ice-sheet dynamics
- ✓ CO₂ rising faster than IPCC's most aggressive scenario
- ✓ Feedbacks missing in climate models coming into play?

The Fate of Hampton Roads is tied to the Future of the World's Great Ice Sheets

- There are three major ice sheets which contain 99% of the ice capable of raising sea level if melted
 - Greenland
 - East and West Antarctic
- IPCC projections of sea level rise do not account for potential melting of these ice sheets
- The Greenland and West Antarctic sheets contain enough water to raise sea level approximately 40 feet if fully melted

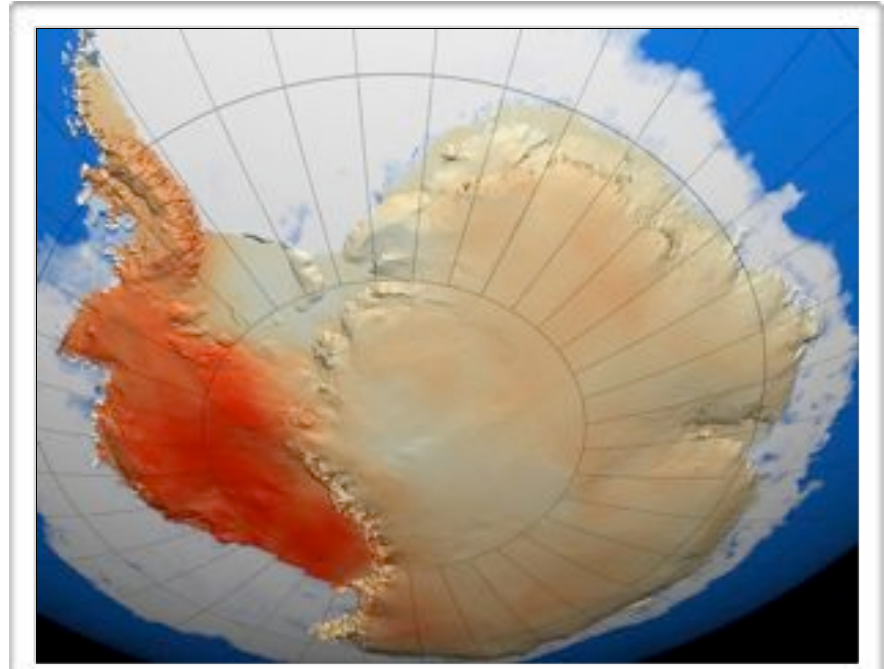


Antarctica is Warming...

Warming of Antarctic Ice Sheet Surface
1957 - 2006

West Antarctica $0.16 \pm 0.06^{\circ}\text{C}/\text{decade}$
East Antarctica $0.10 \pm 0.07^{\circ}\text{C}/\text{decade}$

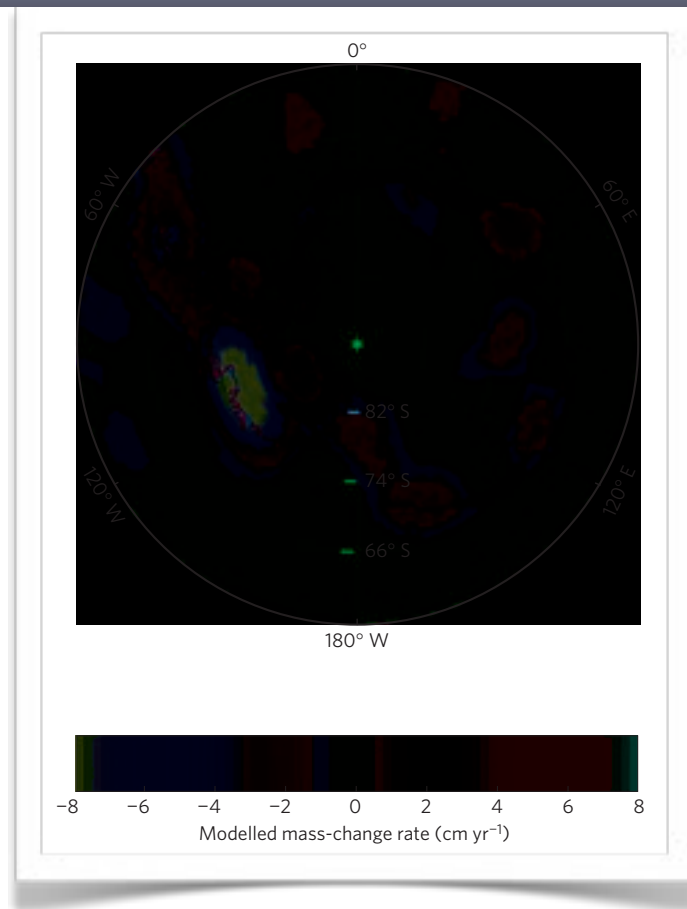
Many climate models have been predicting
Antarctic cooling!



...and the Ice is Responding

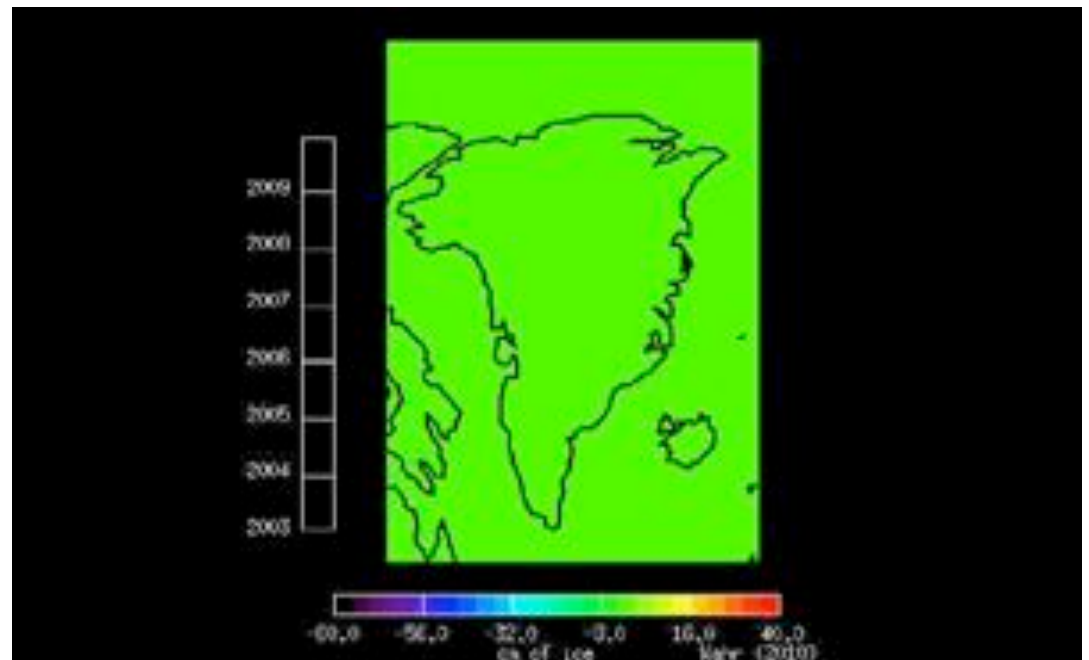
- Satellite gravity measurements from 4/2002 through 1/2009 show accelerated ice mass loss from both Antarctic ice sheets
 - 190 ± 77 Gt/yr
 - Western outlet glaciers thinning at up to 9 m per year
- Greenland ice sheet losing between 40 mi^3 and 60 mi^3 of ice per year
- Recent projection of sea-level rise based on paleo and projected temperatures (using IPCC temperature predictions) is 0.8 m to 2.0 m by 2100
- Recent Copenhagen Climate Science conference statement projects up to 1.0 m sea-level rise by 2100 (using IPCC temperature predictions)

Ice melt map of Antarctic Ice Sheets



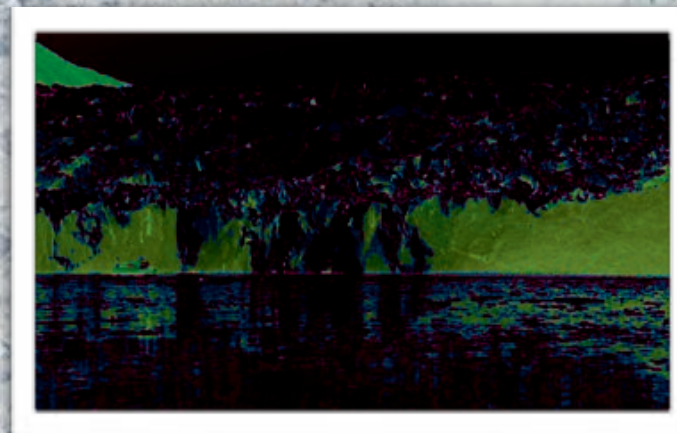
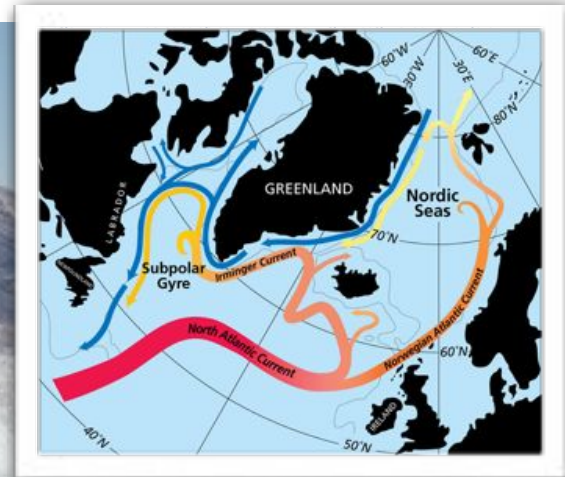
Greenland is Responding Rapidly

- The Arctic is warming faster than anyplace on the planet
- The loss of the Arctic ice cap is an example of response
- More disturbingly, Greenland is significant losing ice mass over most of the ice sheet
 - Over 60 mi³ per year

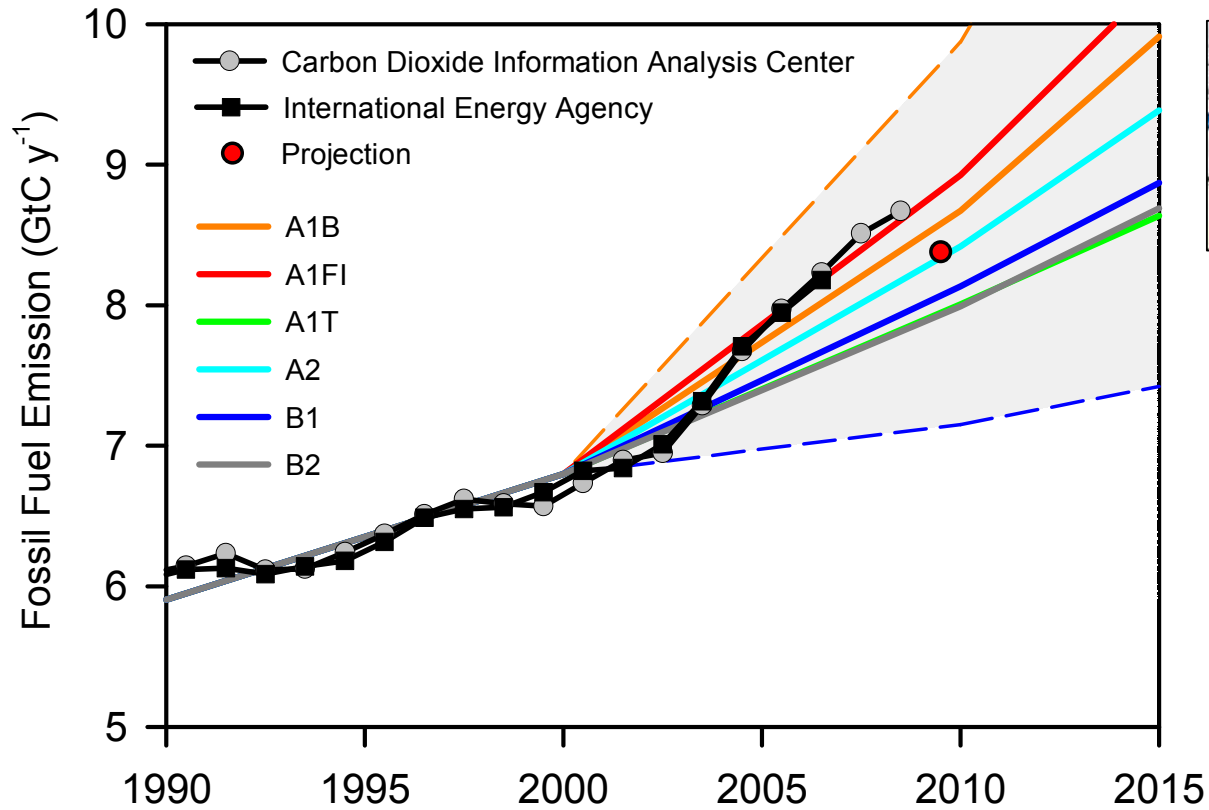


Subtropical Waters Flushing Greenland Fjords

- Recent changes in ocean currents bring subtropical water to coast of Greenland
- Along-shore wind events drive warm water into Fjords and accelerate submarine melting of glacier termini
- A factor in the significant acceleration of glacial retreat in many Greenland Fjords which governs the loss side of ice-sheet mass balance



Global Fossil Fuel Emissions: Actual vs. IPCC Scenarios



Projection **2009**
 Emissions: -2.8%
 GDP: -1.1%
 C intensity: -1.7%



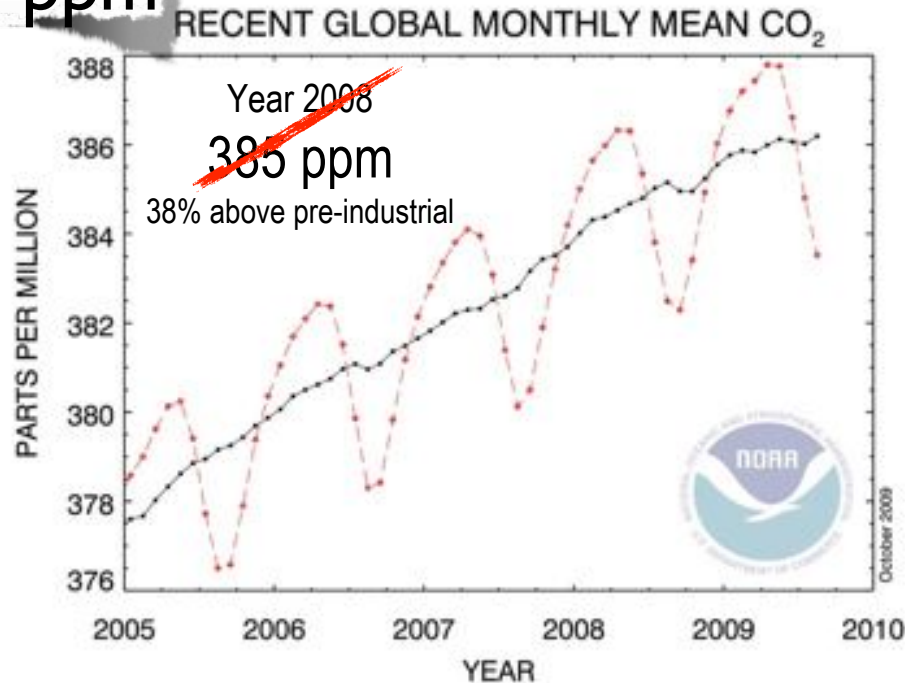
Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature-geoscience; International Monetary Fund 2009



Atmospheric CO₂ Concentration

May 2010

392.7 ppm



Annual Mean Growth Rate

2008	1.79
2007	2.12
2006	1.77
2005	2.41
2004	1.62
2003	2.22
2002	2.40
2001	1.85
2000	1.24

1970 – 1979: 1.3 ppm y⁻¹
 1980 – 1989: 1.6 ppm y⁻¹
 1990 – 1999: 1.5 ppm y⁻¹
2000 - 2008: 1.9 ppm y⁻¹



Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

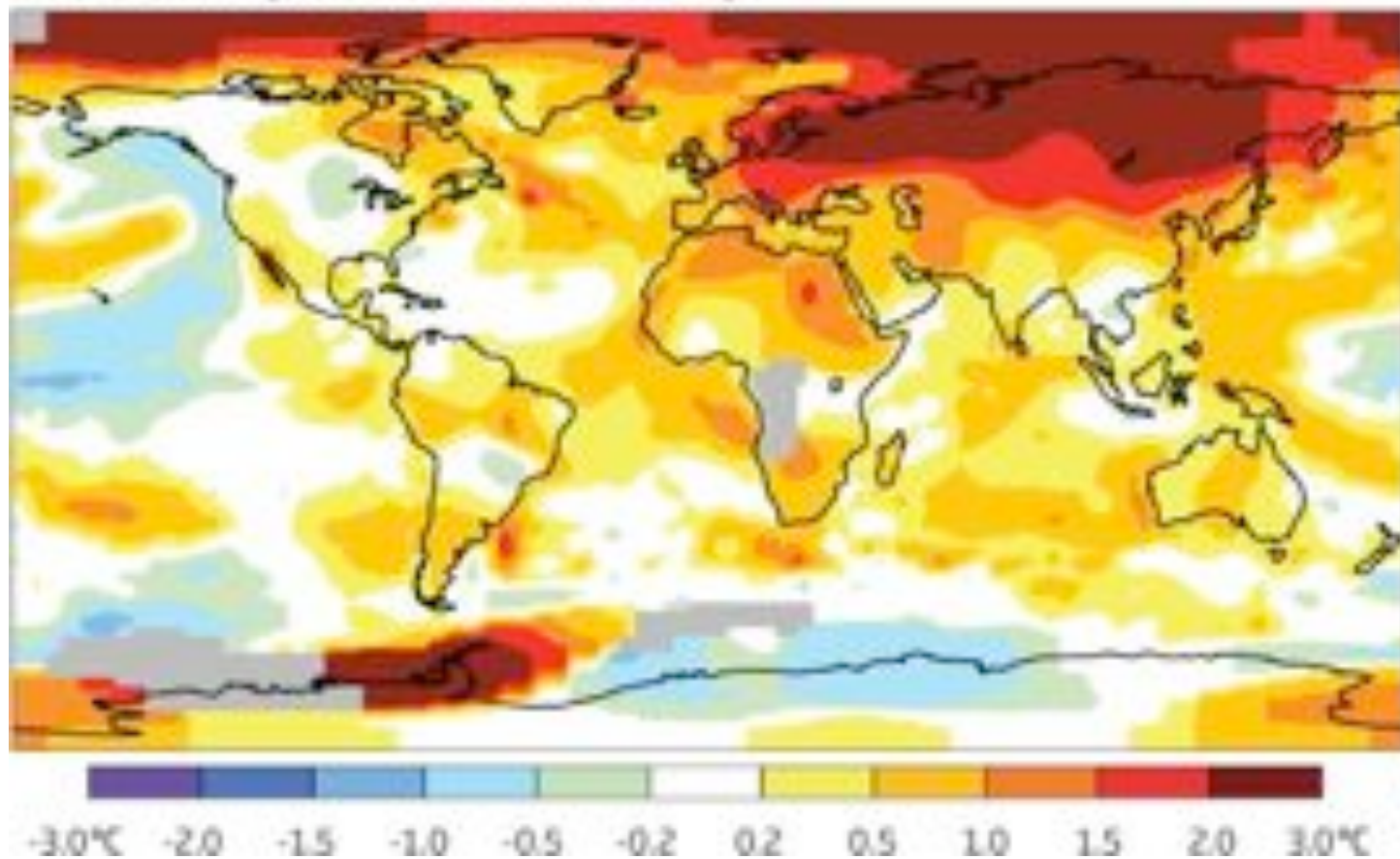


Missing Feedbacks

- ✓ Fossil C from tundra released as CH₄ and CO₂
- Oceanic releases of CH₄ and CO₂
- Decline in Efficiency of Natural CO₂ Sinks with warming
- Albedo reduction due to melting sea ice and ice sheets
- Ocean circulation changes, reduced DO, H₂S production
- Aerosols and clouds

Fossil C Release from Tundra

2008 Temperature Anomaly from 1951 - 1980 Average



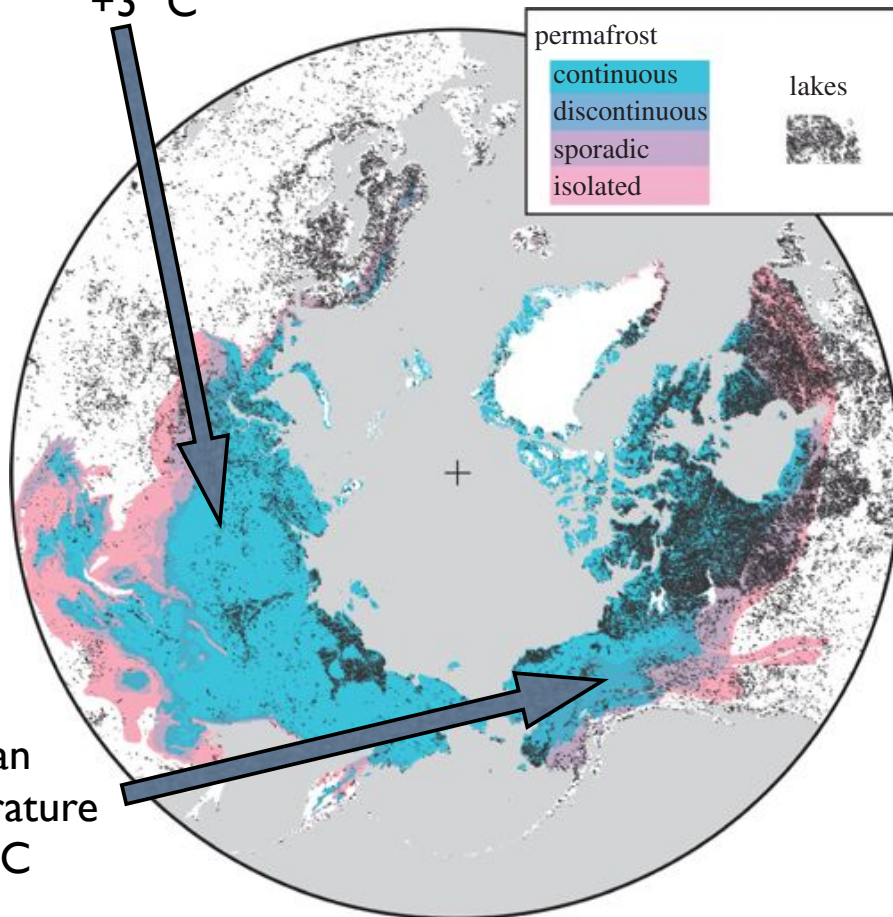
Fossil C Release from Tundra

Arctic Permafrost and Lakes

500 & 1000 Year Siberian Lake Thaw Scenarios

Mean Temperature Increase

+3° C



Mean
Temperature
-1° C

- Thermokarst lake CH₄ Emissions between 50 and 100 Tg/yr
- Current IPCC Anthropogenic CH₄ Emission Scenario Range 236 to 597 Tg/yr
- Similar amounts of C remaining in northern hemisphere lakes but not included in analysis



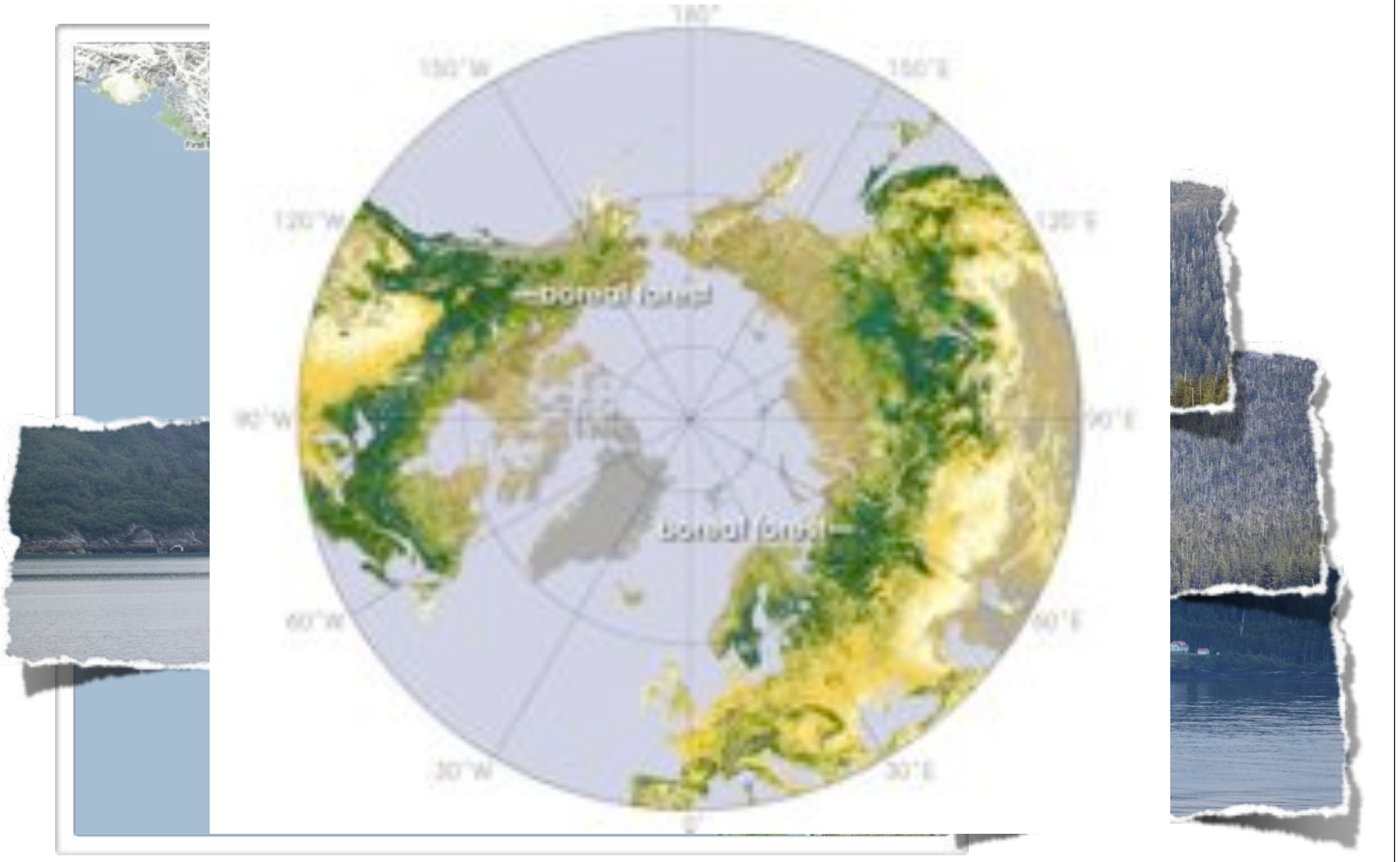
Fossil C Release from Tundra

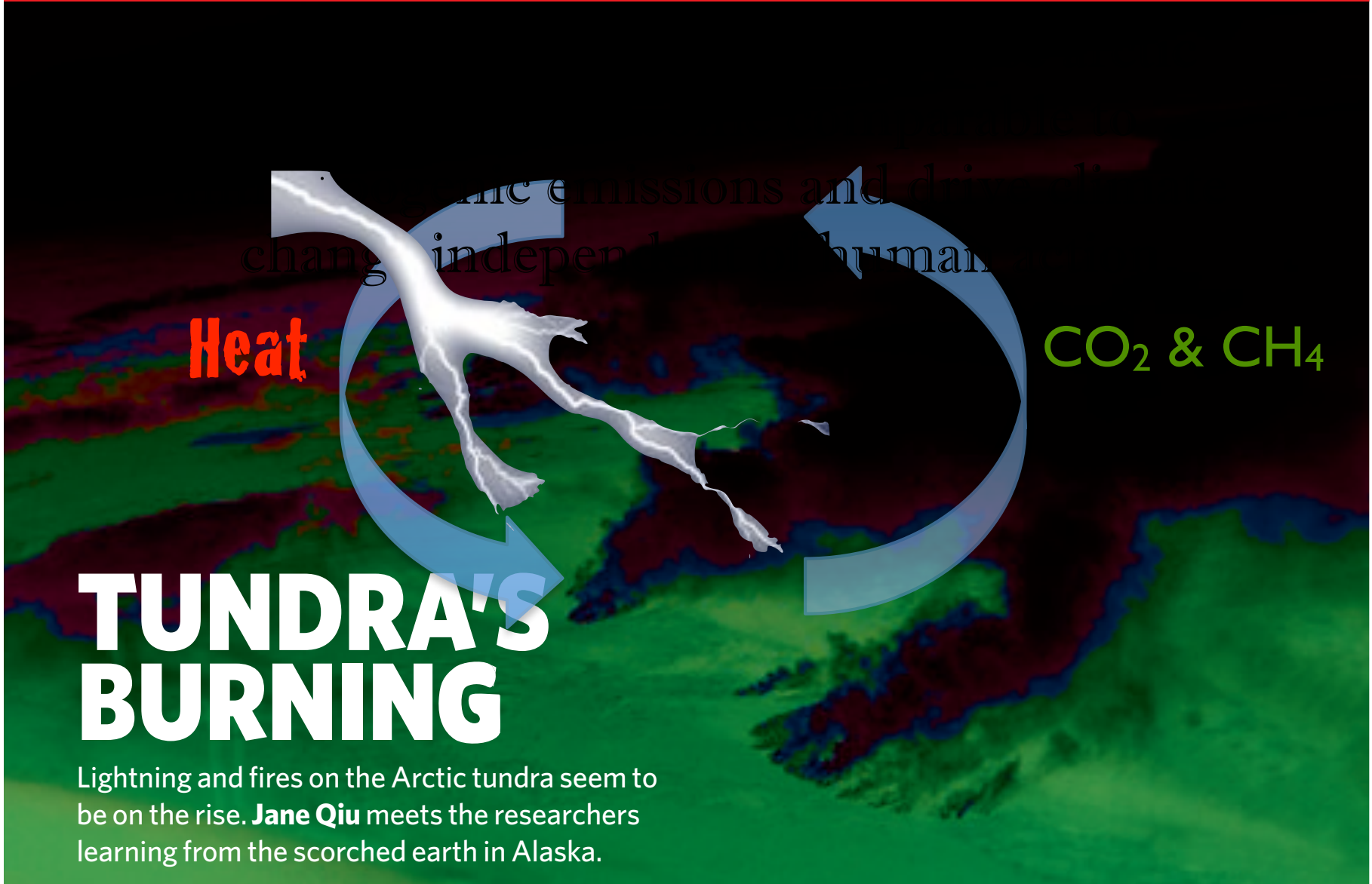
Potential CH₄ from Thermokarst Lakes
= 10 X CH₄ in Atmosphere Today



S. Beck '01

Devastation of the Boreal Forest





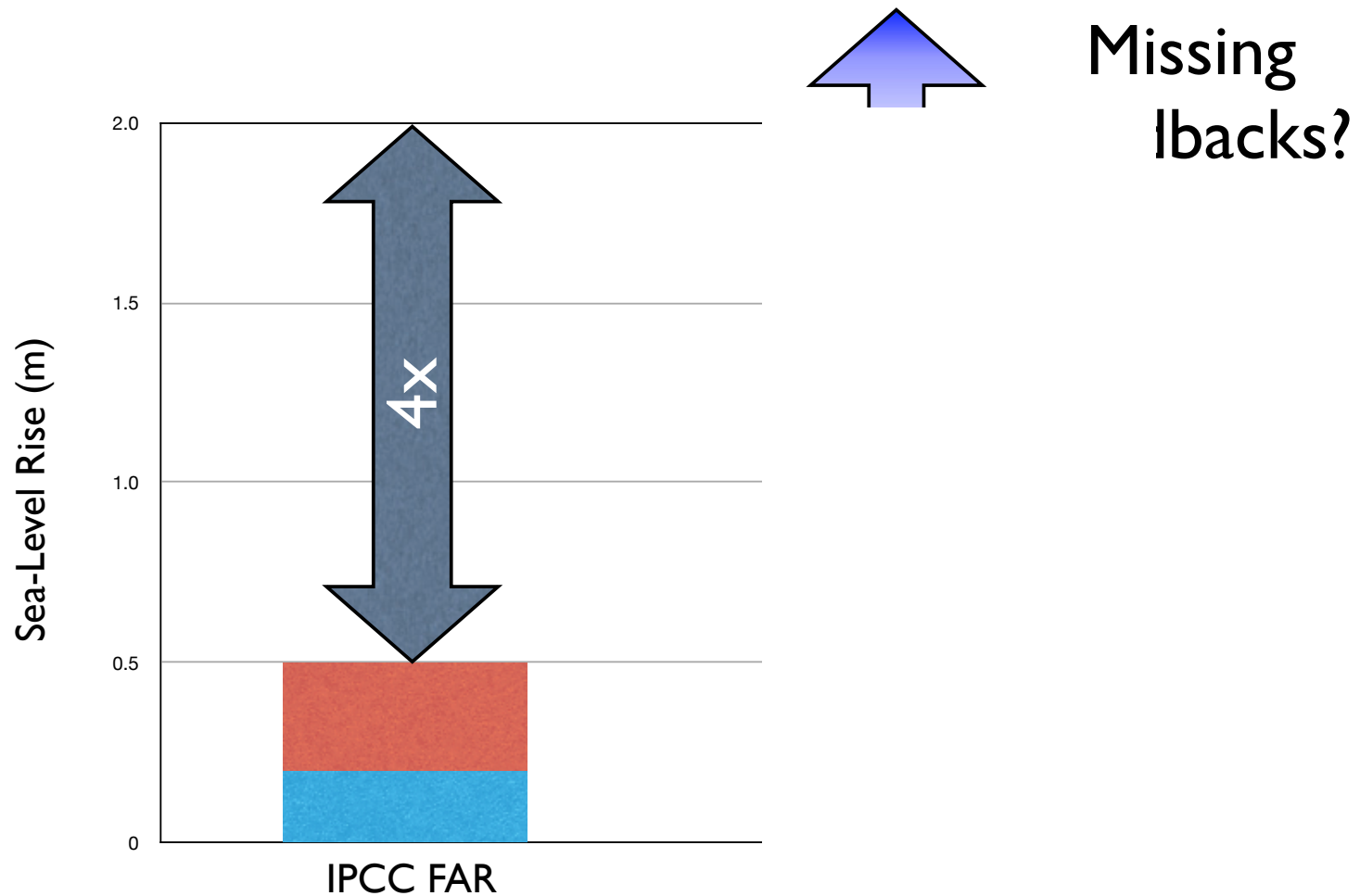
Heat

CO₂ & CH₄

TUNDRA'S BURNING

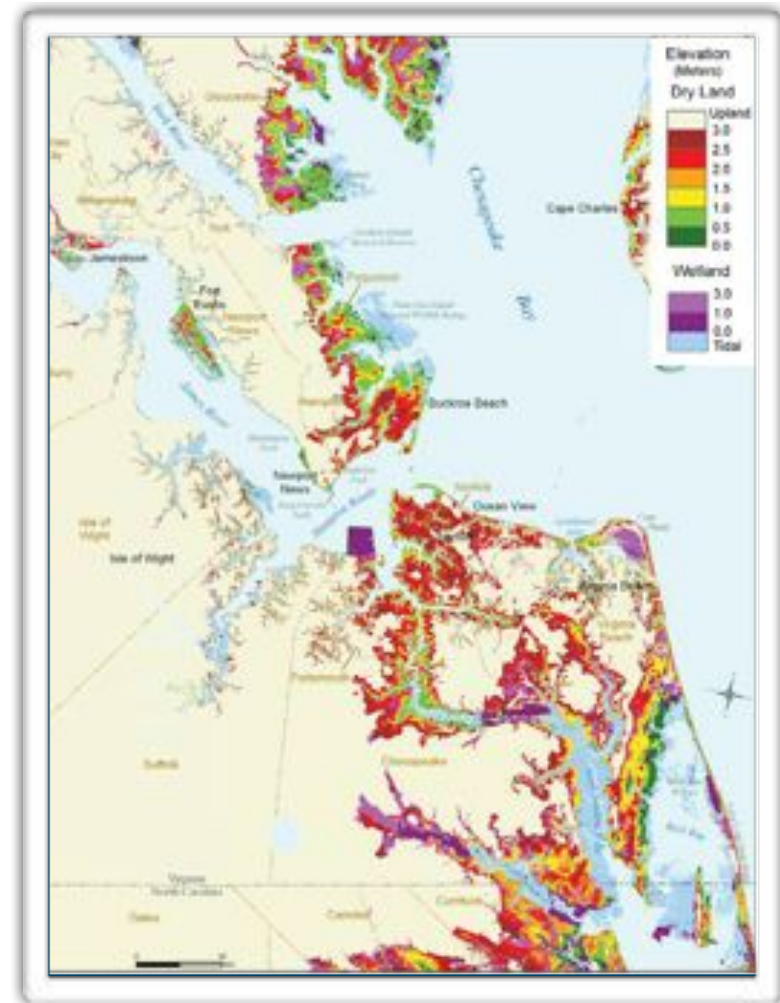
Lightning and fires on the Arctic tundra seem to be on the rise. **Jane Qiu** meets the researchers learning from the scorched earth in Alaska.

Potential 21st Century Sea-Level Rise



Hampton Roads 21st Century Sea-Level Rise

- To estimate tidal change by 2100 sea-level rise projections are additive to the 0.15 to 0.23 m (0.5 to 0.75 ft) of land subsidence by 2100 in HR
- A 0.8 to 2.0 m rise in sea level
 - Yields a net tidal change of 0.95 to 2.23 m (3.12 to 7.32 ft)
 - Could be greater due to feedbacks currently unaccounted for in predictions



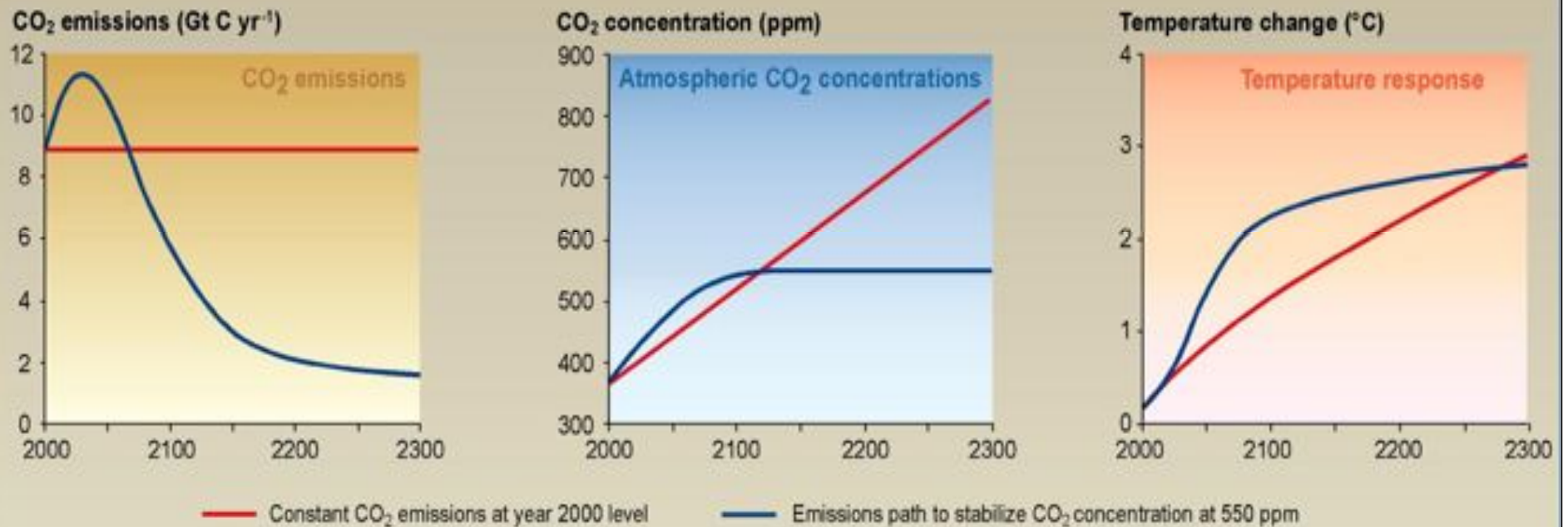
Hampton Roads Sea-Level Rise Map

Three Main Points

1. Hampton Roads future is tied directly to the future of the Arctic and the Antarctic
- 2. Climate change is irreversible**
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Potential Future Scenarios*

Impact of stabilizing emissions versus stabilizing concentrations of CO₂

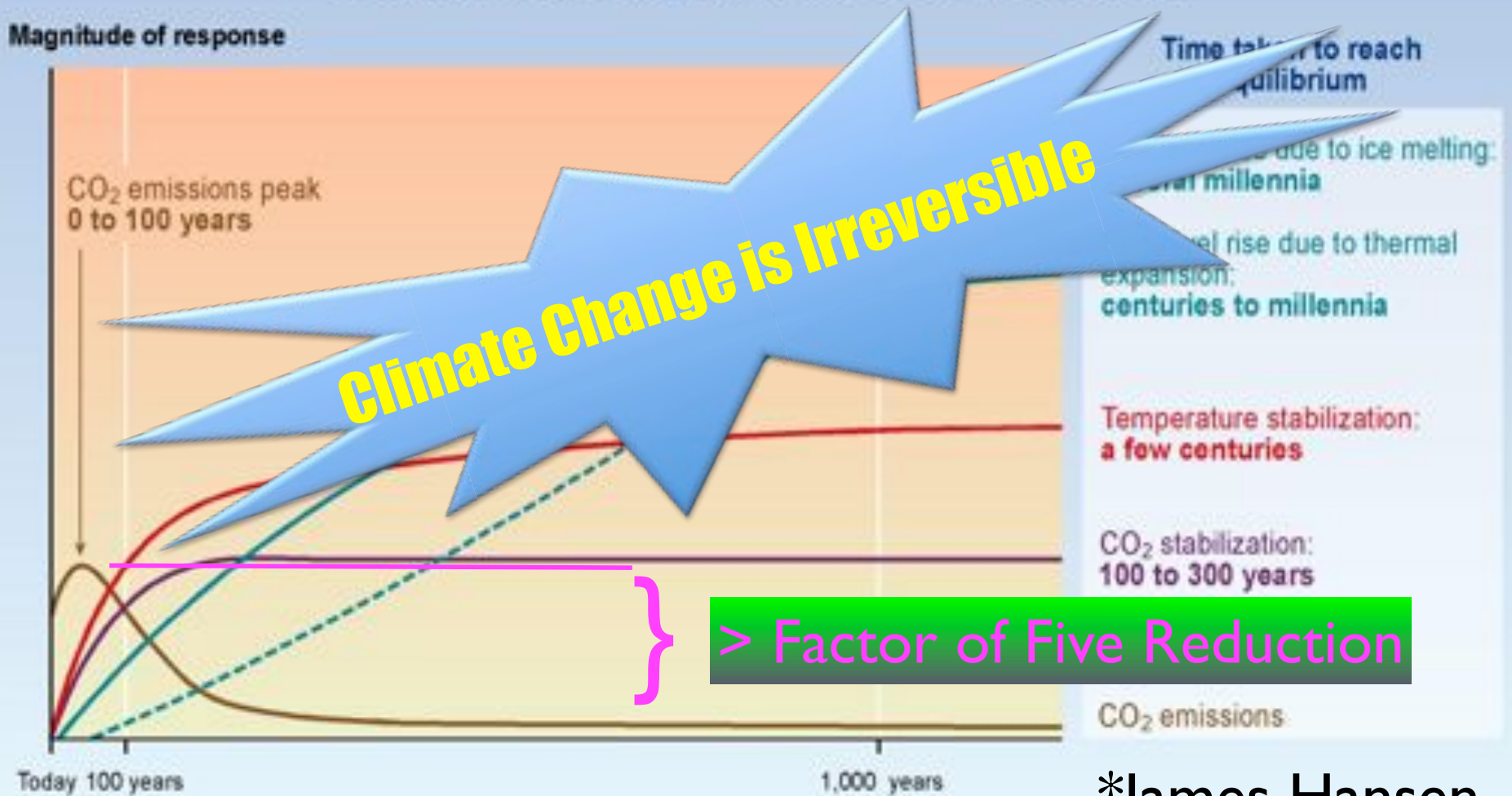


*James Hansen

System Response Delay*

CO₂ concentration, temperature, and sea level continue to rise long after emissions are reduced

Magnitude of response



*James Hansen

Three Main Points

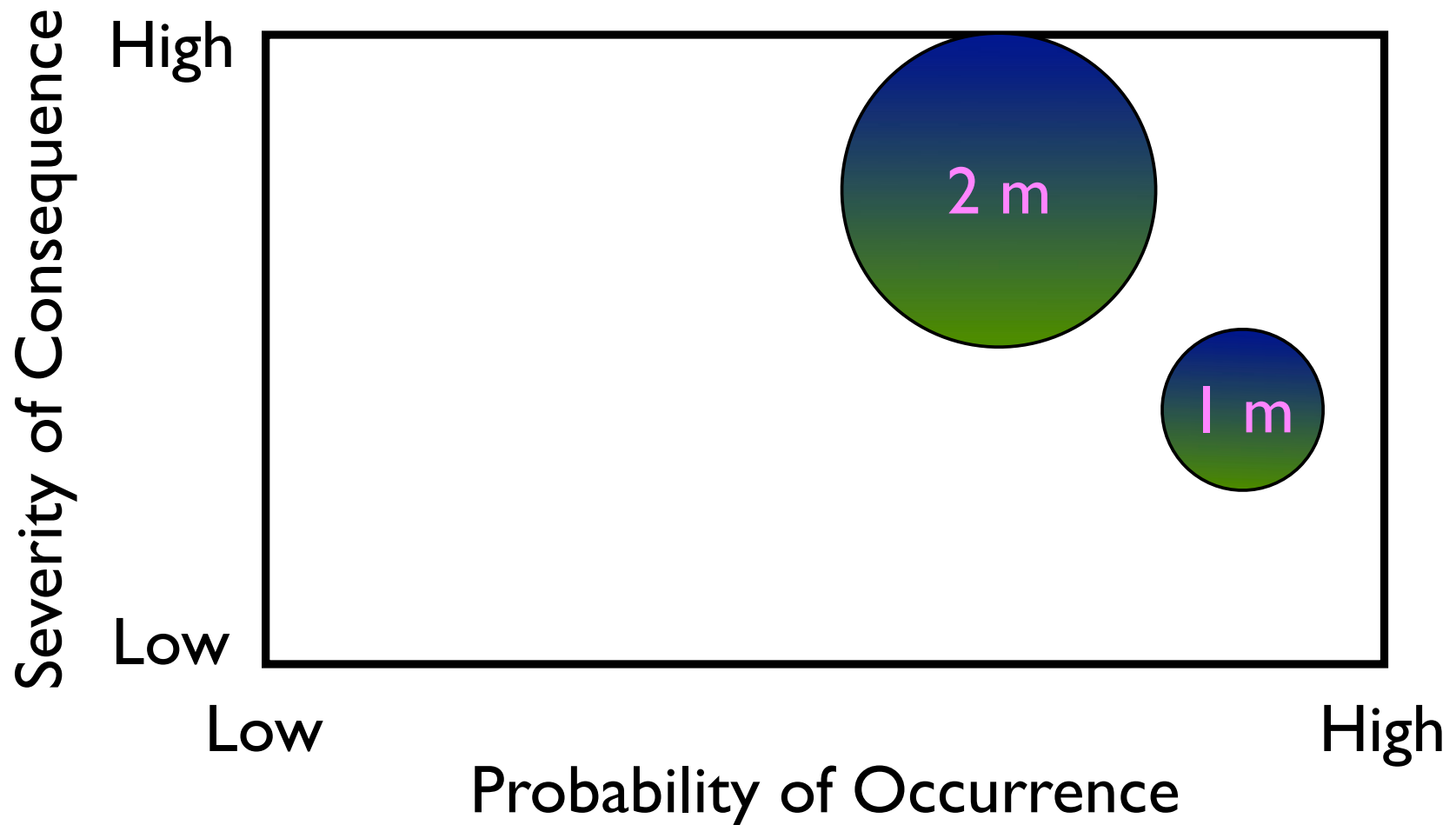
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US Impact



Qualitative Risk vs. Consequence for Sea-Level Rise in Hampton Roads

$$\text{Risk} = \text{Probability} \times \text{Severity}$$



Clarifying the Options for Hampton Roads

- Mitigation

- Reduce/regulate GHG emissions (e.g. House Energy Bill)
- Emission regulation vs. GHG concentration targets
- Optional, society chooses (on a global scale to be effective)

- Adaptation

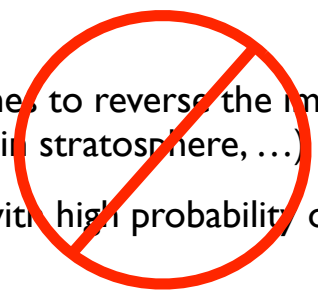
- Strategies to deal with the impacts we know are coming (coastal inundation, water shortages, ...)
- Major public works projects and social engineering programs requiring decades and \$100's B to execute
- Situation will demand adaptation but strategic adaptation (e.g. **pl**anNYC) optional

- Reversal

- “Geoengineering” schemes to reverse the impacts of elevated GHG concentration (e.g. orbiting mirrors, sulfate aerosols in stratosphere, ...)
- Desperation measures with high probability of unintended consequences

Hampton Roads Sets Example

Hampton Roads Must



A Real Carbon Footprint Reduction Opportunity



<http://www.dom.com/dominion-virginia-power/customer-service/energy-conservation/green-power.jsp>

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HOW CLIMATE CHANGE WILL AFFECT
MAN-ON-A-DESERT-ISLAND CARTOONS

Whither Hampton Roads?

- Climate change will lead to major challenges for our region
 - Rising sea level will lead to local inundation and more severe flooding associated with storms
 - Public health will be impacted by issues of water quality, new diseases, and more days of temperatures above 90°
 - Major disruption or loss of ecosystem services
- Irreversibility of climate change indicates it must be accounted for in land-use, evacuation, transportation, etc. planning
- Regional public officials could engage the regional scientific community in helping assess future impacts and developing an adaptation strategy

Hampton Roads Dilemma

- “Official” predictions (IPCC FAR) on sea-level rise and other impacts on Hampton Roads for 21st Century not that dire
- Recent scientific results appearing largely in the peer-reviewed literature begin to paint a more dire scenario
- Emerging trends and feedbacks unaccounted for in FAR could make situation even more dire

Hampton Roads Dilemma

- Is the future risk defined well enough to justify action?
 - How do public officials evaluate unfolding peer-reviewed science?
 - Is there sufficient credibility of the climate-change skeptics in the public domain?
- If the region waits until the risk is well defined is it too late to respond?

Individual Action

- The “CFT - Prius” approach while commendable won’t get the job done, even if we all did it!
- We must demand action at the global, national, and regional scale (mitigation & adaptation)
- We must recognize that effective response and/or no response to climate change will be very painful with major economic and sociological dislocations
 - We’ll all just have to bite this bullet sooner rather than later!

Obama looking at cooling air to fight warming

AP Associated Press

[b Buzz Up](#) | [Send](#) | [Share](#) | [Print](#)

By SETH BORENSTEIN, AP Science Writer – 1 hr 36 mins ago



AP — John Holdren talks about his role as President Obama's science adviser during an interview with The Associated ...

WASHINGTON — Tinkering with Earth's climate to chill runaway global warming — a radical idea once dismissed out of hand — is being discussed by the White House as a potential emergency option, the president's new science adviser said Wednesday.

That's because global warming is happening so rapidly, John Holdren told The Associated Press in his first interview since being confirmed last month.

That's because global warming is happening so rapidly, John Holdren told The Associated Press in his first interview since being confirmed last month.

"It's got to be looked at," he said. "We don't have the luxury ... of ruling any approach off the table."

His concern is that the United States and other nations won't slow global warming fast enough and that several "tipping points" could be fast approaching. Once such milestones are reached, such as complete loss of summer sea ice in the Arctic, it increases chances of "really intolerable consequences," he said.

Twice in a half-hour interview, Holdren compared global warming to being "in a car with bad brakes driving toward a cliff in the fog."

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The 65-year-old physicist is far from alone in taking geoengineering seriously. The National Academy of Sciences is making it the subject of the first workshop in its new climate challenges program for policymakers, scientists and the public. The British Parliament has also discussed the idea. At an international meeting of climate scientists last month in Copenhagen, 15 talks dealt with different aspects of geoengineering.

The American Meteorological Society is crafting a policy statement that says "it is prudent to consider geoengineering's potential, to understand its limits and to avoid rash deployment."

[http://news.illinois.edu/slideshows/
bylot_glacier/index.html](http://news.illinois.edu/slideshows/bylot_glacier/index.html)

Why 350 (ppm that is)?

- CO₂ for all of human history up to industrial revolution at 275 ppm
- Today we are at 390 ppm
- Leading climate scientists lead by James Hansen warn that anything beyond 350 ppm leads to environment outside the range we are adapted to



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Hampton Roads 2 m Sea-Level Rise
Map