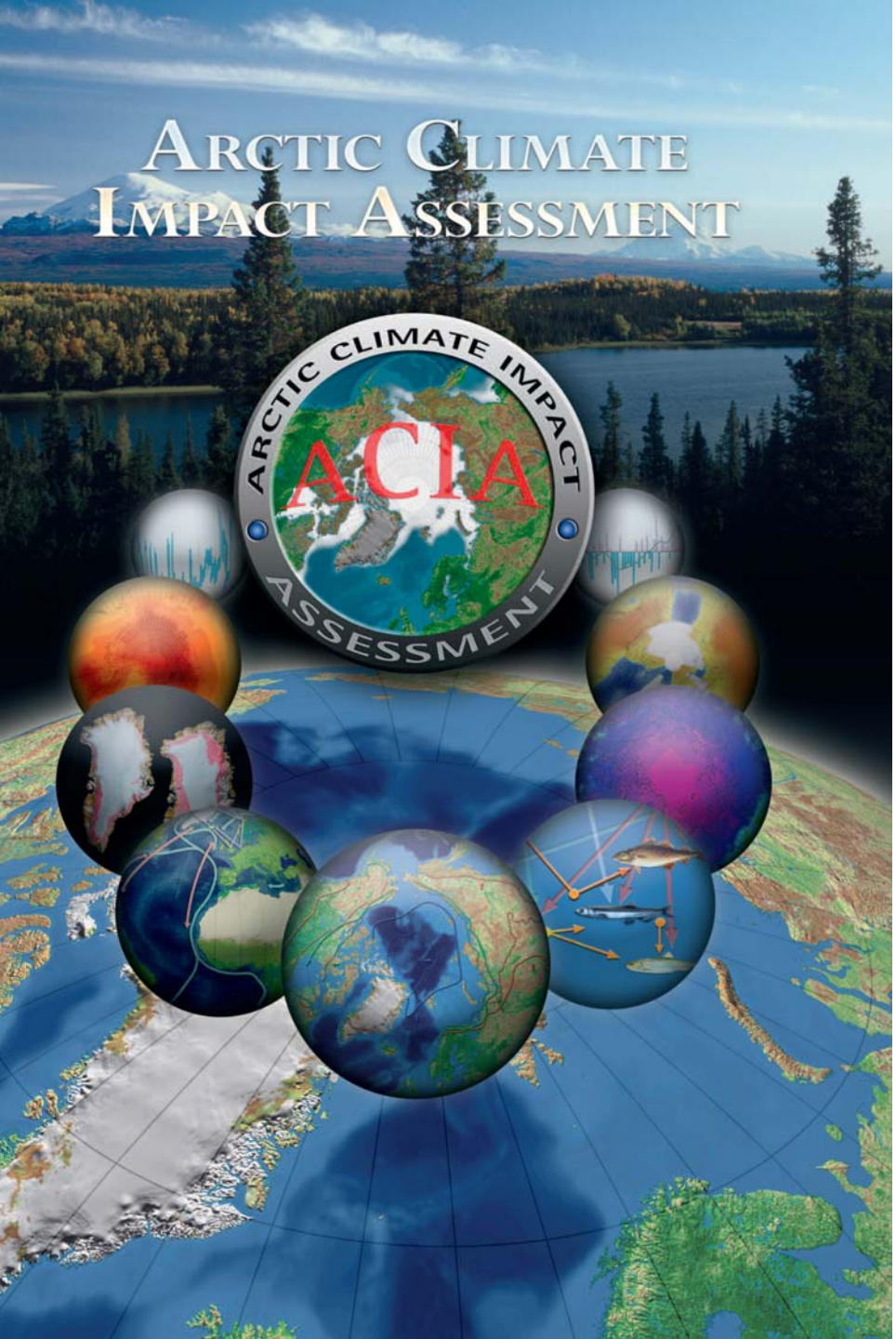
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

*Good Afternoon*




**ACIA** Arctic Climate Impact Assessment

# Climate Change: An Arctic Perspective and Looking Beyond Kyoto

## KSG Student Seminar

Harvard University
Kennedy School of Government
October 25, 2005

www.acia.uaf.edu

## The Presentation will Explore these Four Questions:

1. **What does science tell us, particularly recent findings that have implications across the Arctic Region and Globally?**
2. **What are some examples of strategies and scenarios towards emission reduction?**
3. **What issues of policies related to climate changes have the Ministers of the Arctic Council adopted in their Declaration of November, 2004**
4. **What are the consequences and/or risks of inaction?**

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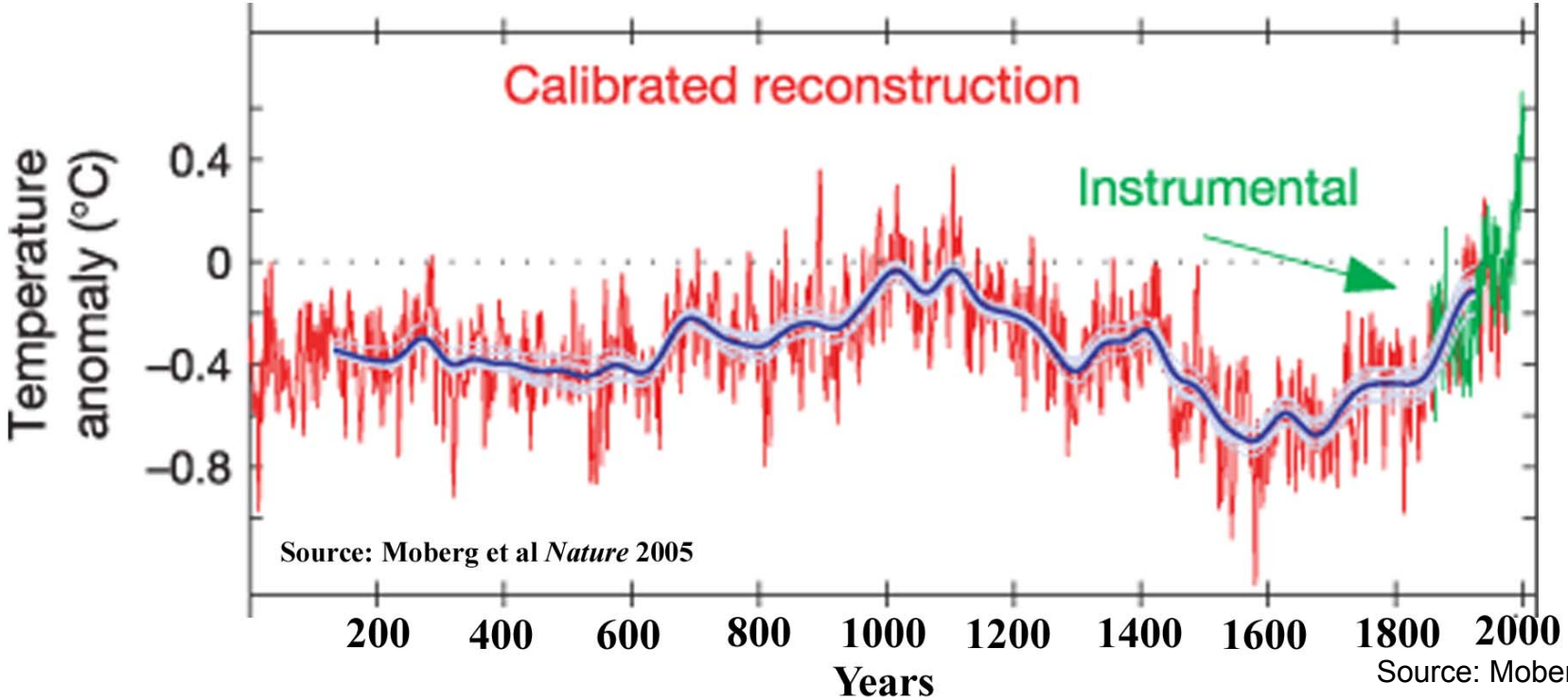
# Temperature Reconstruction for the Past 2000 Years

**2000 Year Northern Hemisphere Reconstruction of Surface Air Temperatures**




Source: Moberg, et al

**Alaska and western Canada, the average winter temperatures have increased by as much as 3 to 4°C over the past 60 years, which is a significant increase given that the global average increase over the past 100 years has been only about 0.6±0.2° C.**

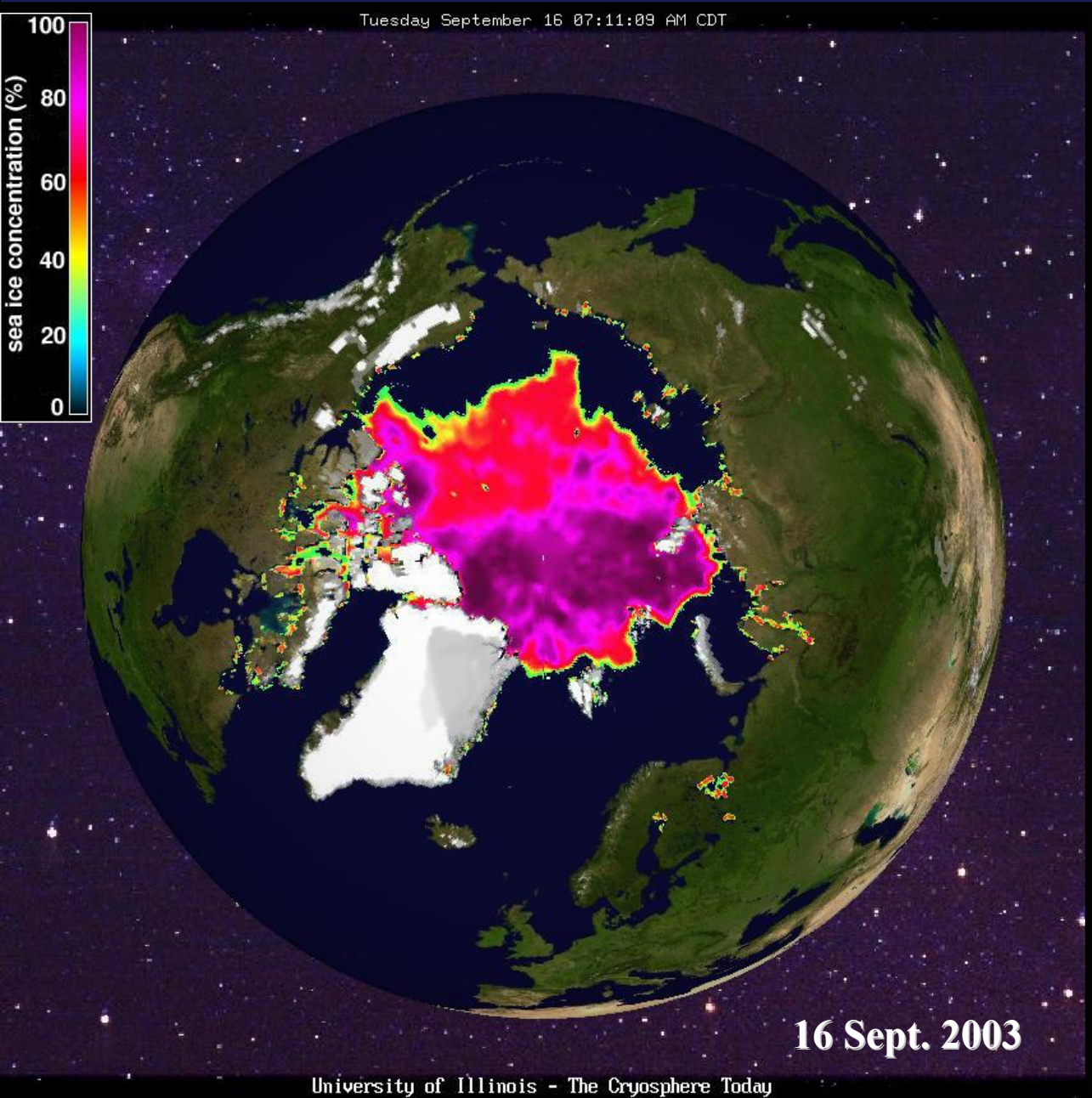
## Three Papers Resolve a Critical Scientific Issue

The problems began in 1990, when an analysis of satellite observations showed the lowest few kilometers of the atmosphere was warming too slowly compared to the surface projections from climate models to be correct. Three companion papers just published (August 11th) in ***Science*** **t**ogether addressed this problem:

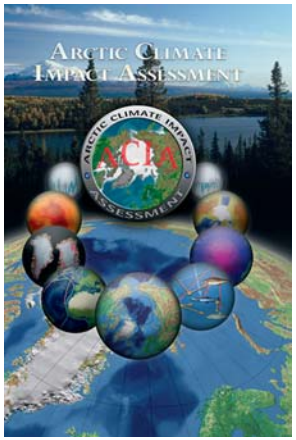
- The first study deals with and corrects satellite measurements,
- The second study with data from weather balloons, and
- The third with the projections of climate models.

Taken together, these three papers correct earlier analyses and conclude that ***both the surface and satellite measurements are fully consistent and conclude that temperature trends in the lower atmosphere are consistent with a warming world.***

# The Arctic Sea Ice is Rapidly Melting

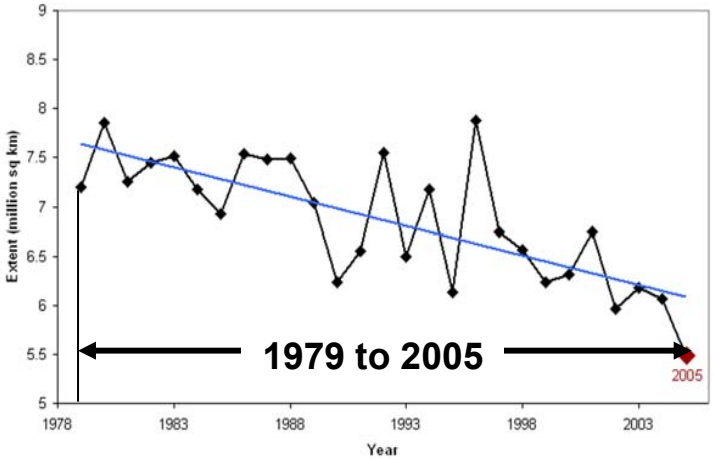


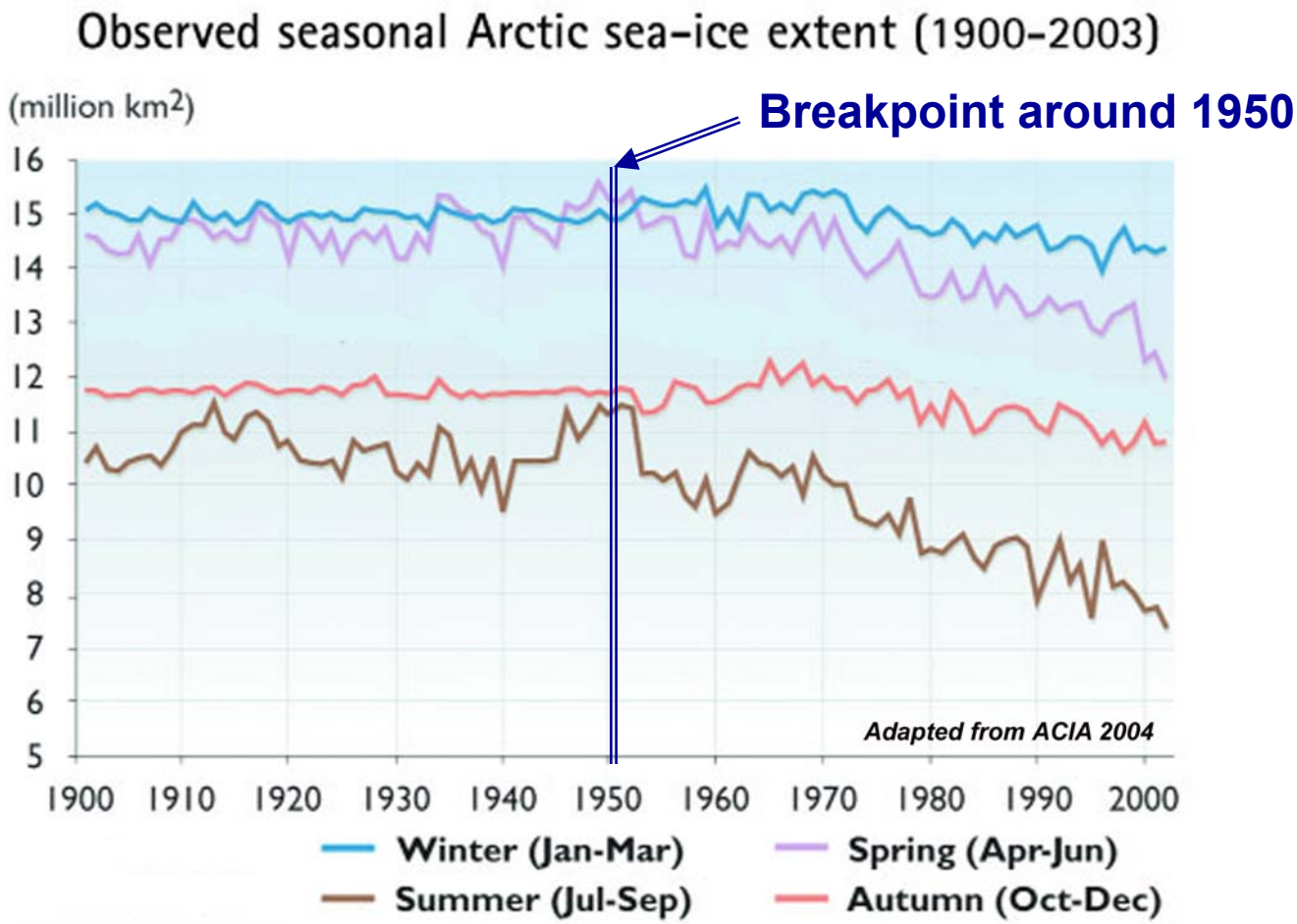

**How Fast is it Melting and, How Important is that Fact for the Rest of the World?**

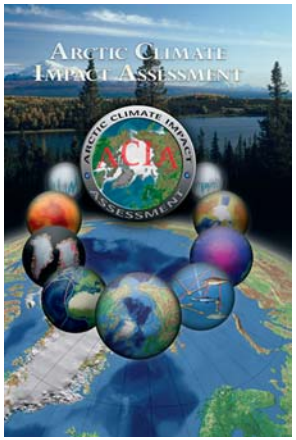



*The Scientific Report*

# Arctic Sea Ice.
# Is it a Short Term Process?

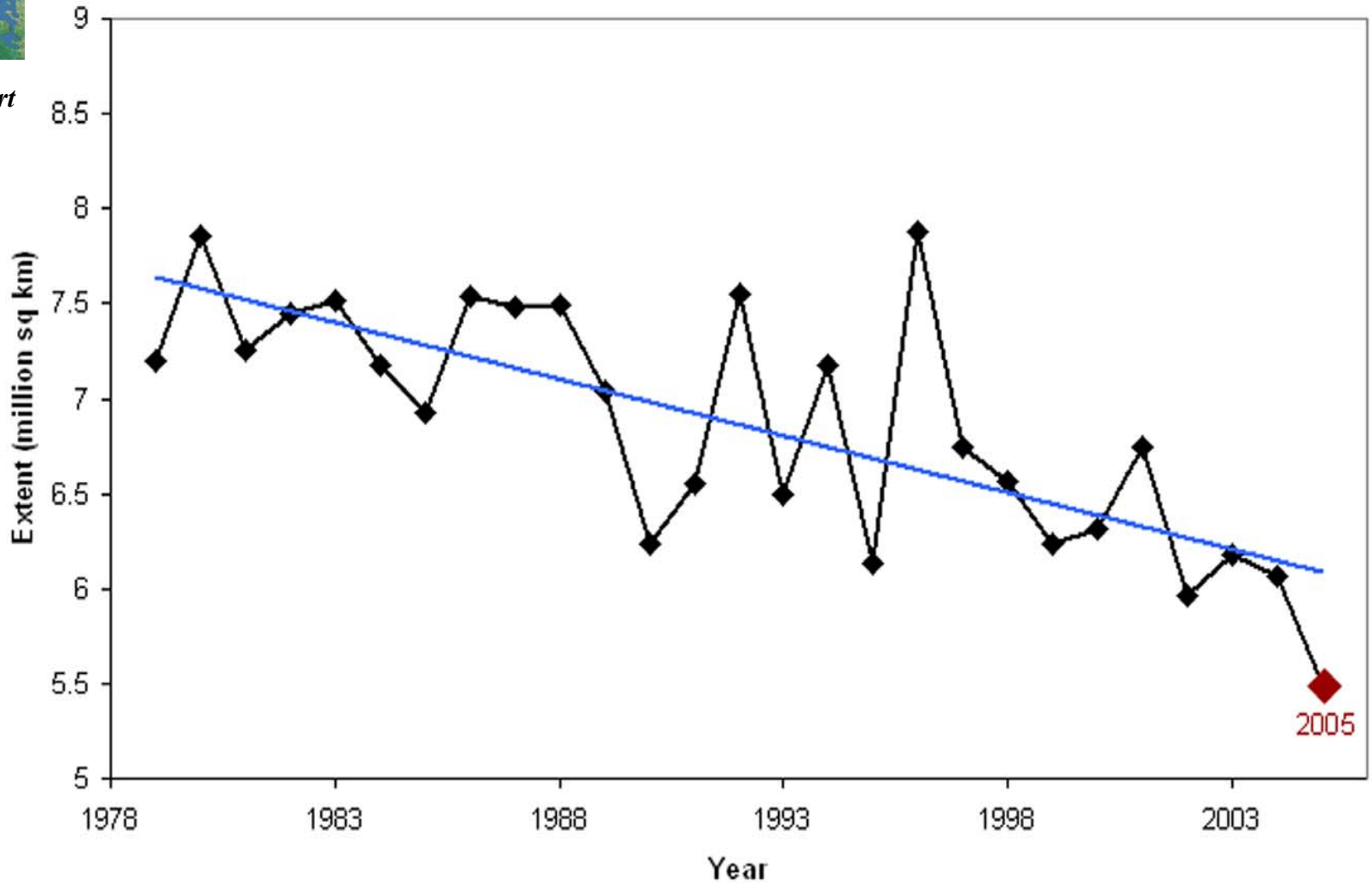


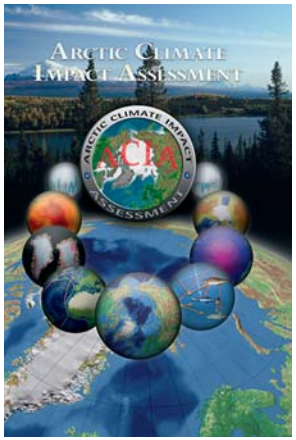






*The Scientific Report*

# Status of the Arctic Sea Ice. What happened in 2005?

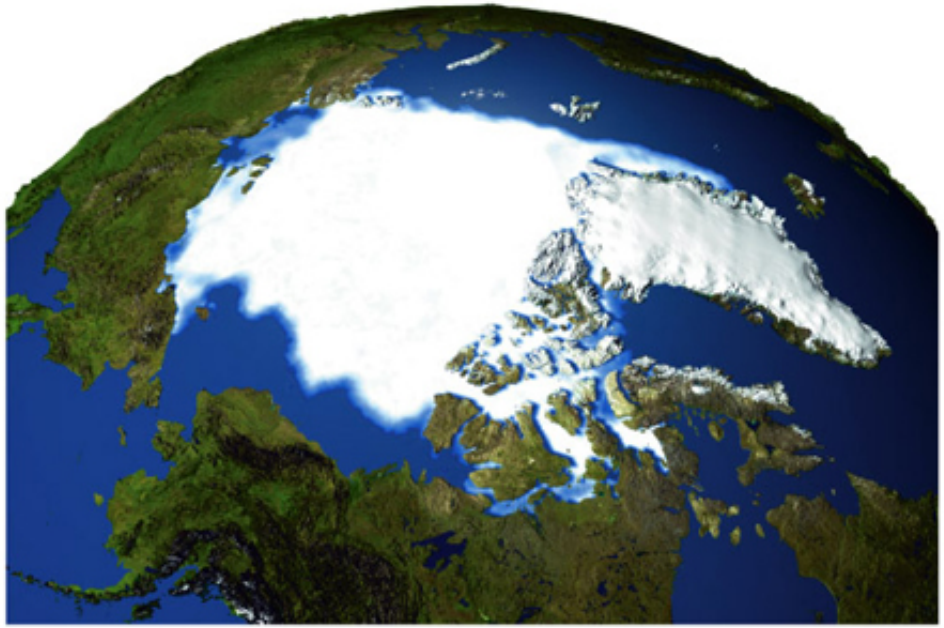




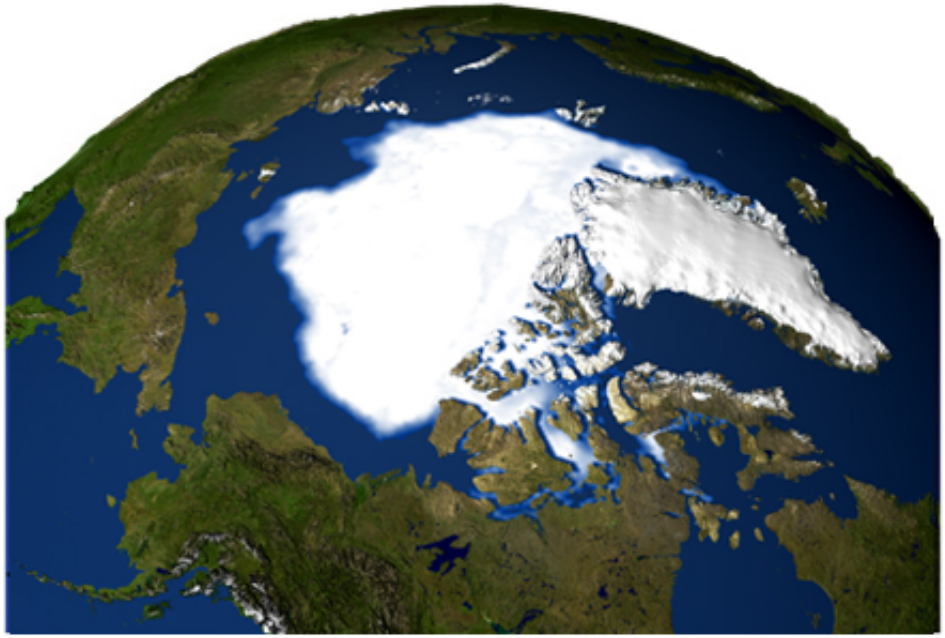

*The Scientific Report*

# Status of the Arctic Sea Ice
# What happened in 2005?

Observed Sea Ice September 1979

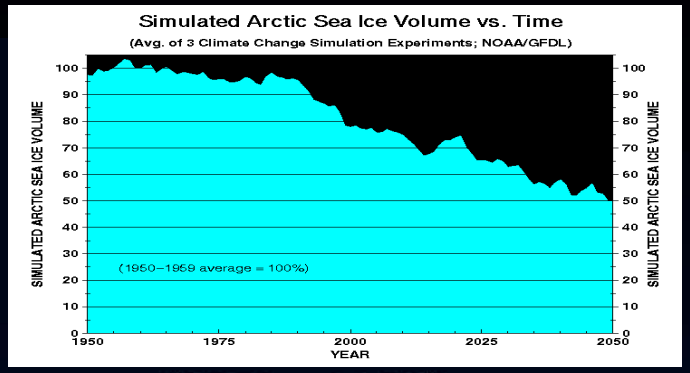


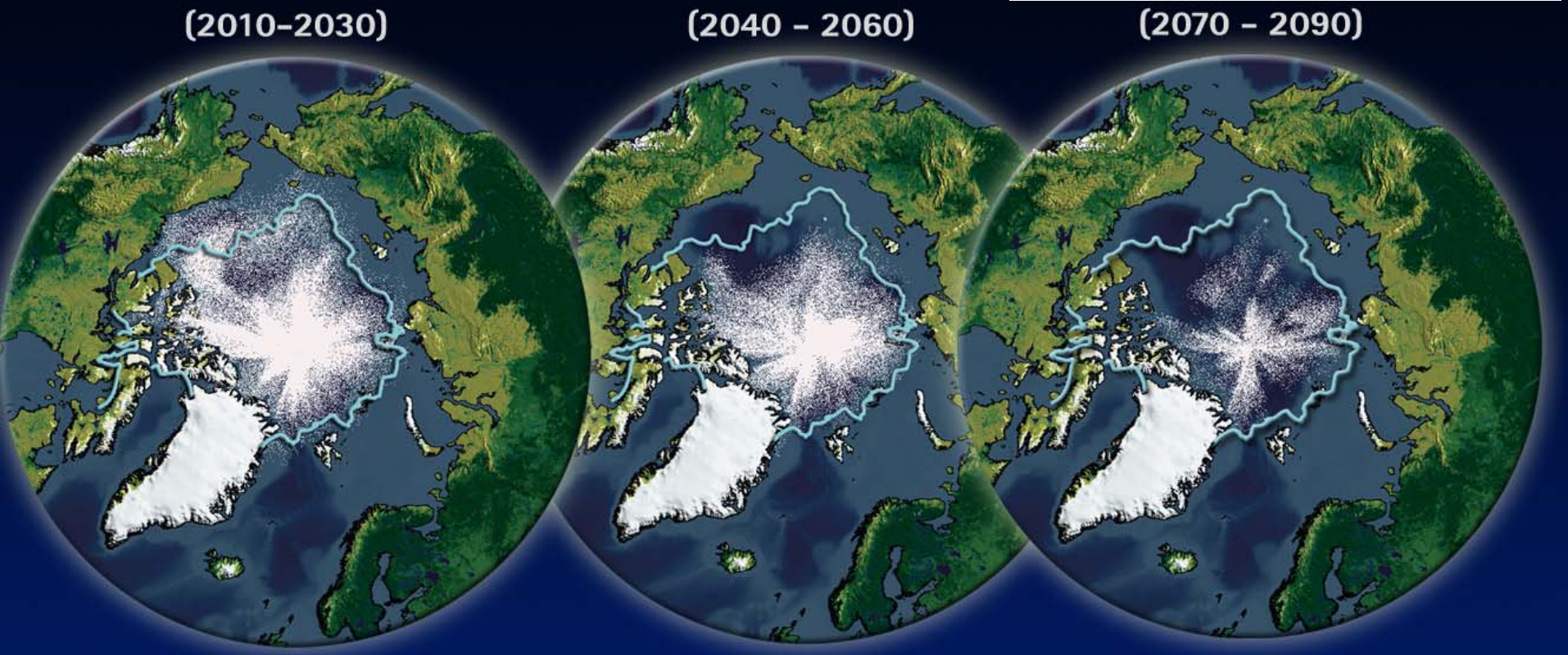
Observed Sea Ice September 2005



©NASA

# GFDL Simulation Projects 50% Reduction by 2050



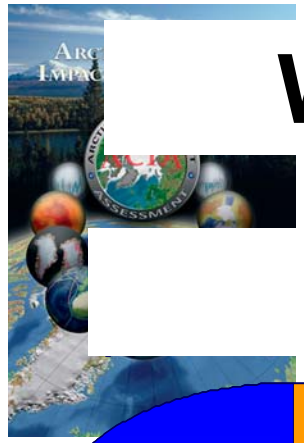



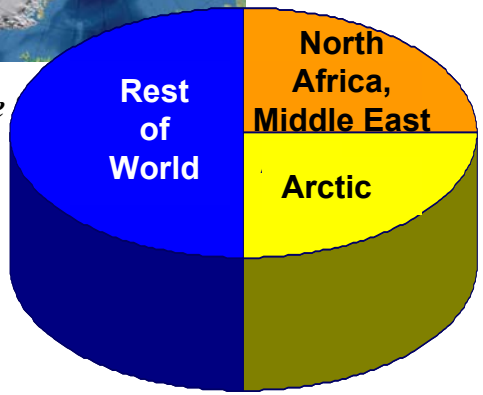

## Five Models Project Sea Ice Extent for Mid-September

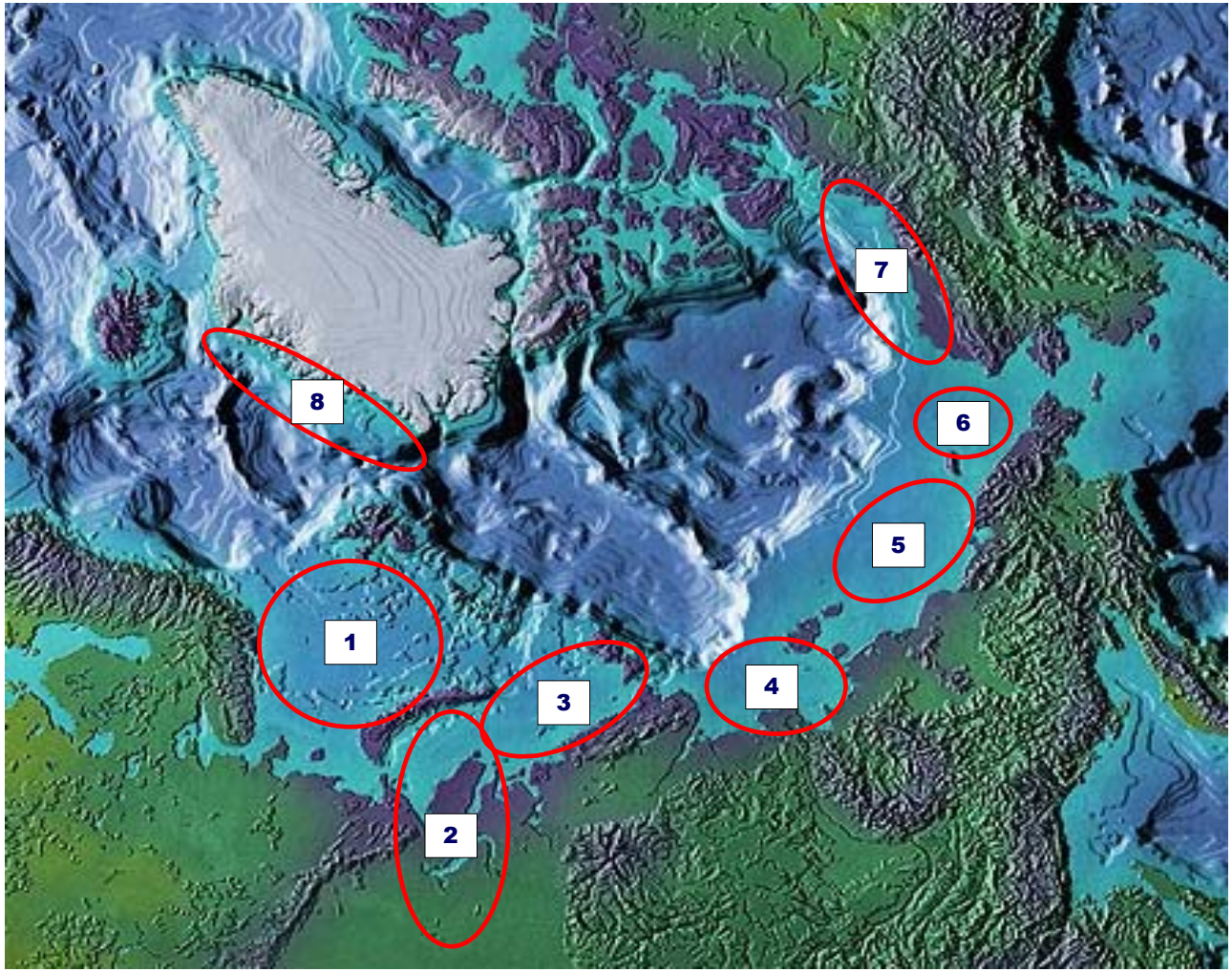
**Northern Sea Route is 45% Shorter than through the Suez Canal**

**The ACIA models projects that the current navigation season of 20-30 days per year will increase to 3-6 months/yr by 2080, with one model indicating an ice-free summer by 2040**

# Worlds Petroleum Potential



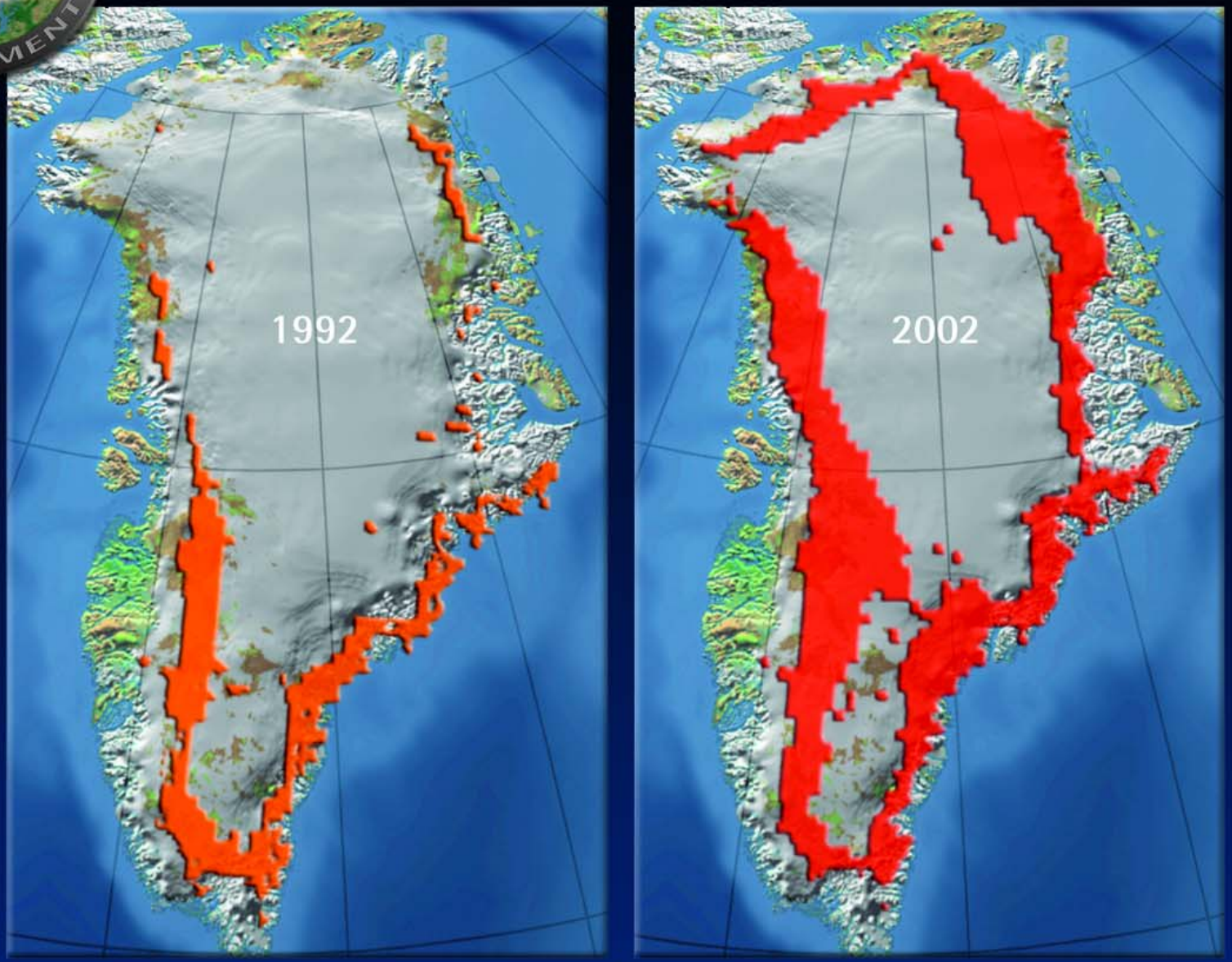



1. Barents Sea
2. Southern Kara Sea and Western Siberia
3. Northern Kara Sea
4. Laptev Sea
5. East Siberian Sea
6. Chukchi Sea
7. Alaska North Slope
8. East Greenland

# IMPACTS OF A WARMING ARCTIC

## Greenland Ice Sheet Melt Extent

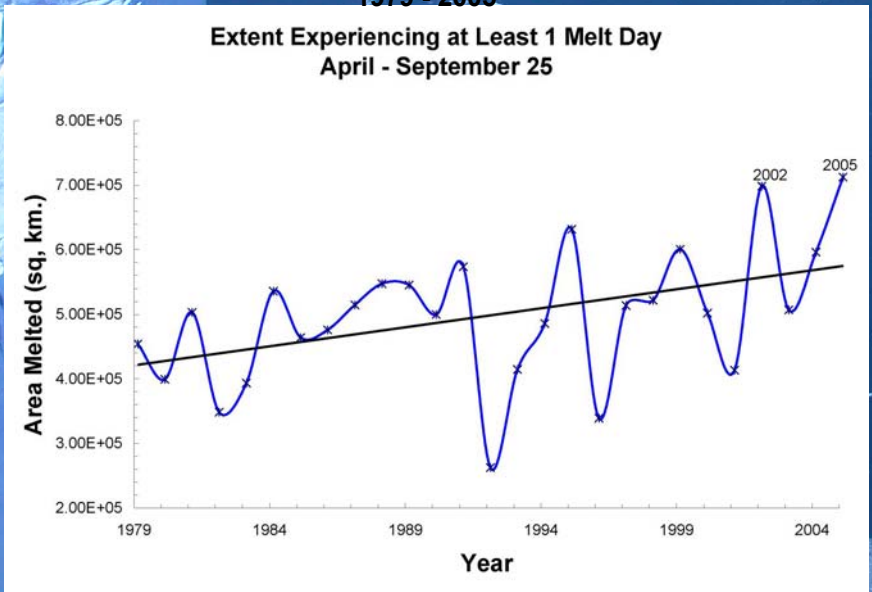


**We expect a record total melt area for 2005 given the fact that the southern and western part of Greenland are still melting in late September, whereas 2002 and 1991 experienced almost no melt in late September and during October.**

**Source: Konrad Steffen and Russell Huff, Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, Colorado**

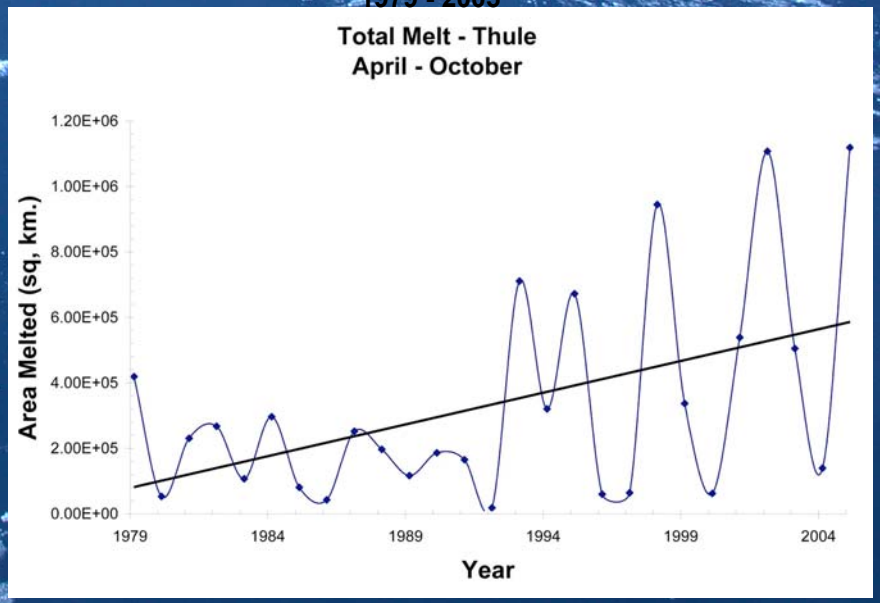
## Melt Area for all of Greenland Melt

1979 - 2005




## Area for NW Thule Area of Greenland

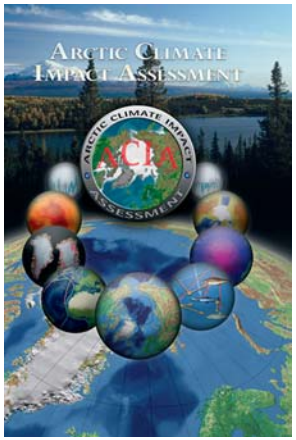
1979 - 2005



# The Greenland Ice Sheet Dominates Land Ice in the Arctic

Over the past two decades, the melt area on the Greenland ice sheet has increased on average by about 0.7%/year (or about16% from 1979 to 2002).

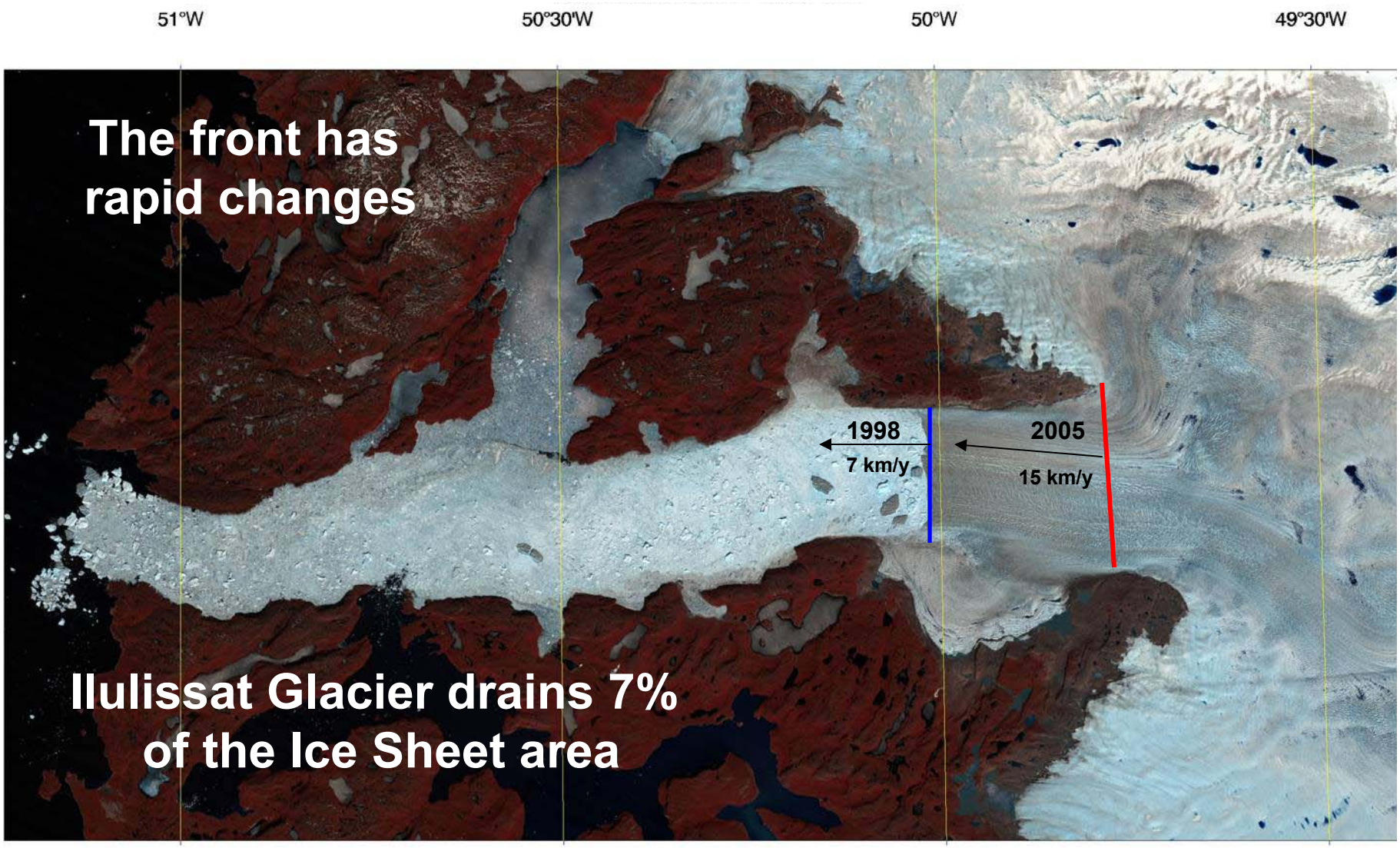
Source: Business Week Aug. 2004




*The Scientific Report*

# Changes in the Greenland Ice Sheet

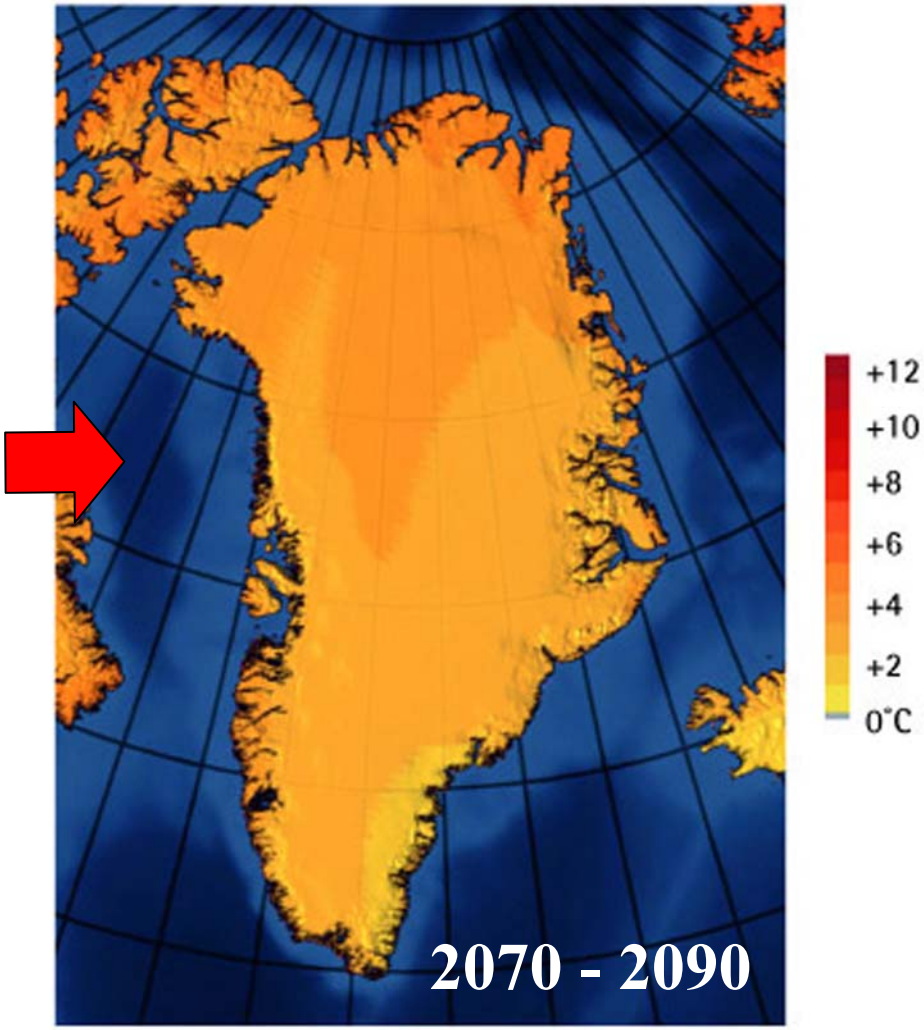
**The glacier front retreated 8 km from 2001 to 2003, the Ice Velocity increased from 10 km/yr to 15 km/yr (1.7m/hr), and the ice is thinning 10 m per year**




# Ilulissat Glacier Retreat 1998-2005

# Greenland's Annual Temperatures are Projected to Increase

**Projected to be in the range of + $3^0$ to $6^0$ C**




©2004, ACIA / Map ©Clifford Grabhorn

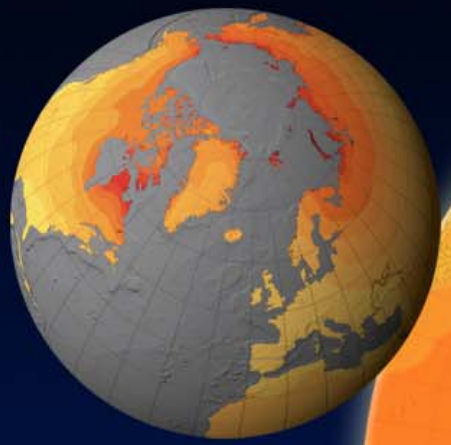
**Climate models indicate that the local warming over Greenland is likely to be up to three times the global average.**

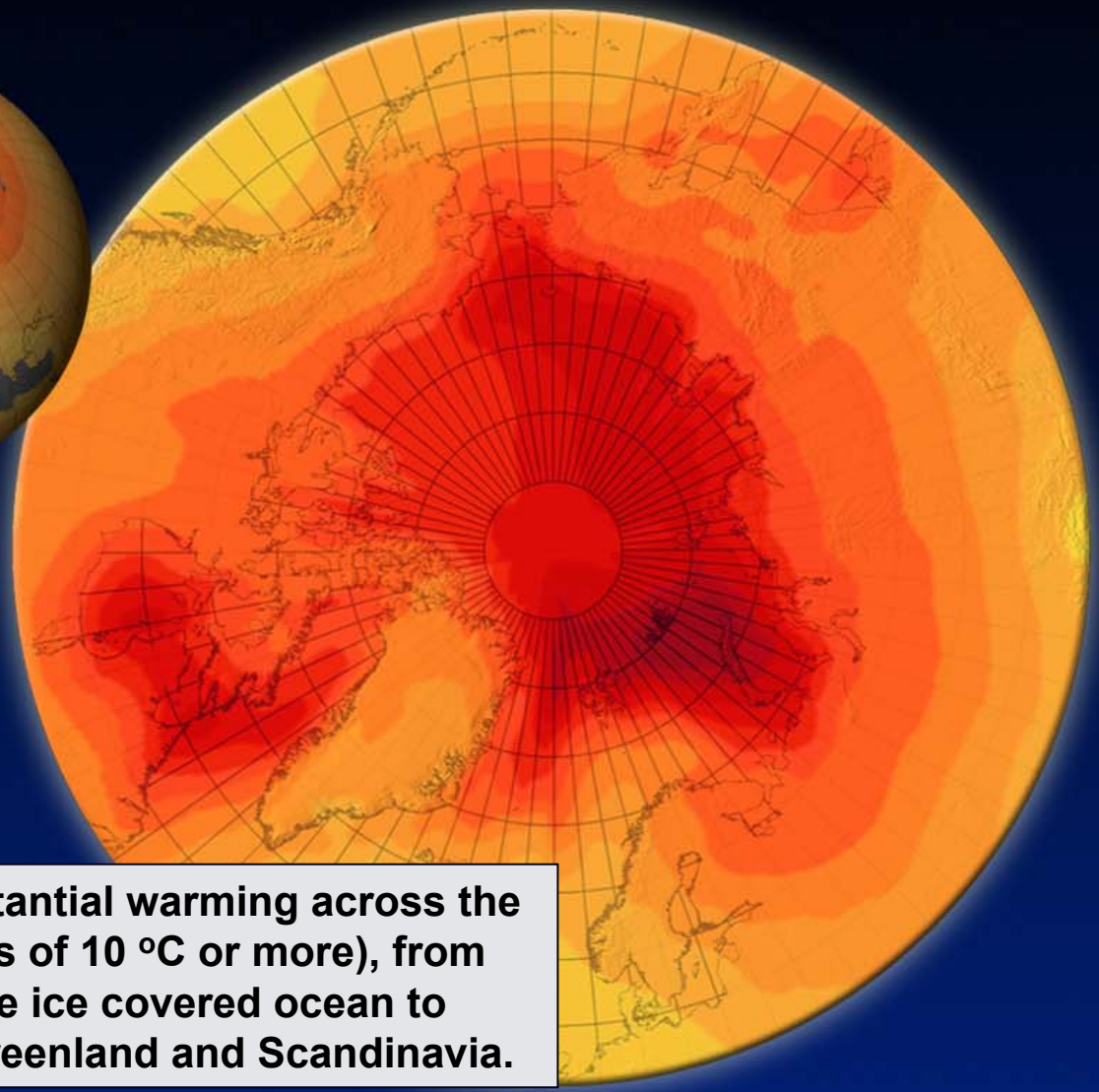
# IMPACTS OF A WARMING ARCTIC

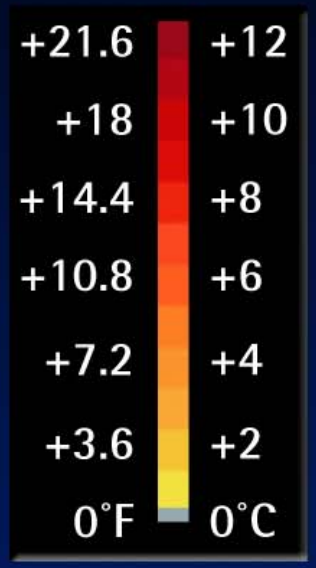
## Areas in Florida Subject to Inundation with 100 Centimeter Sea Level Rise

# IMPACTS OF A WARMING ARCTIC

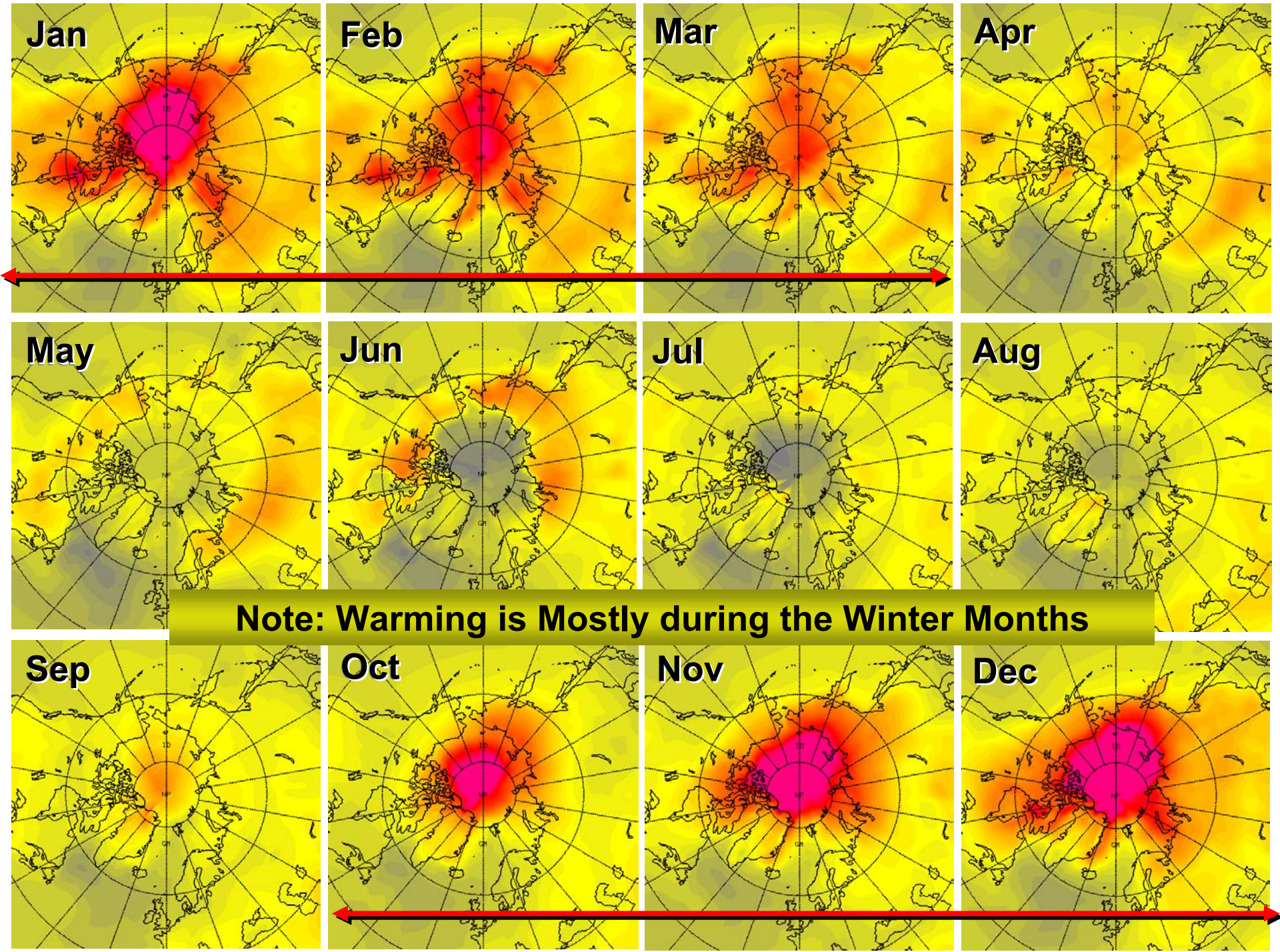
## Projected Surface Air Temperature Change: 1990s–2090s (winter Dec–Feb)







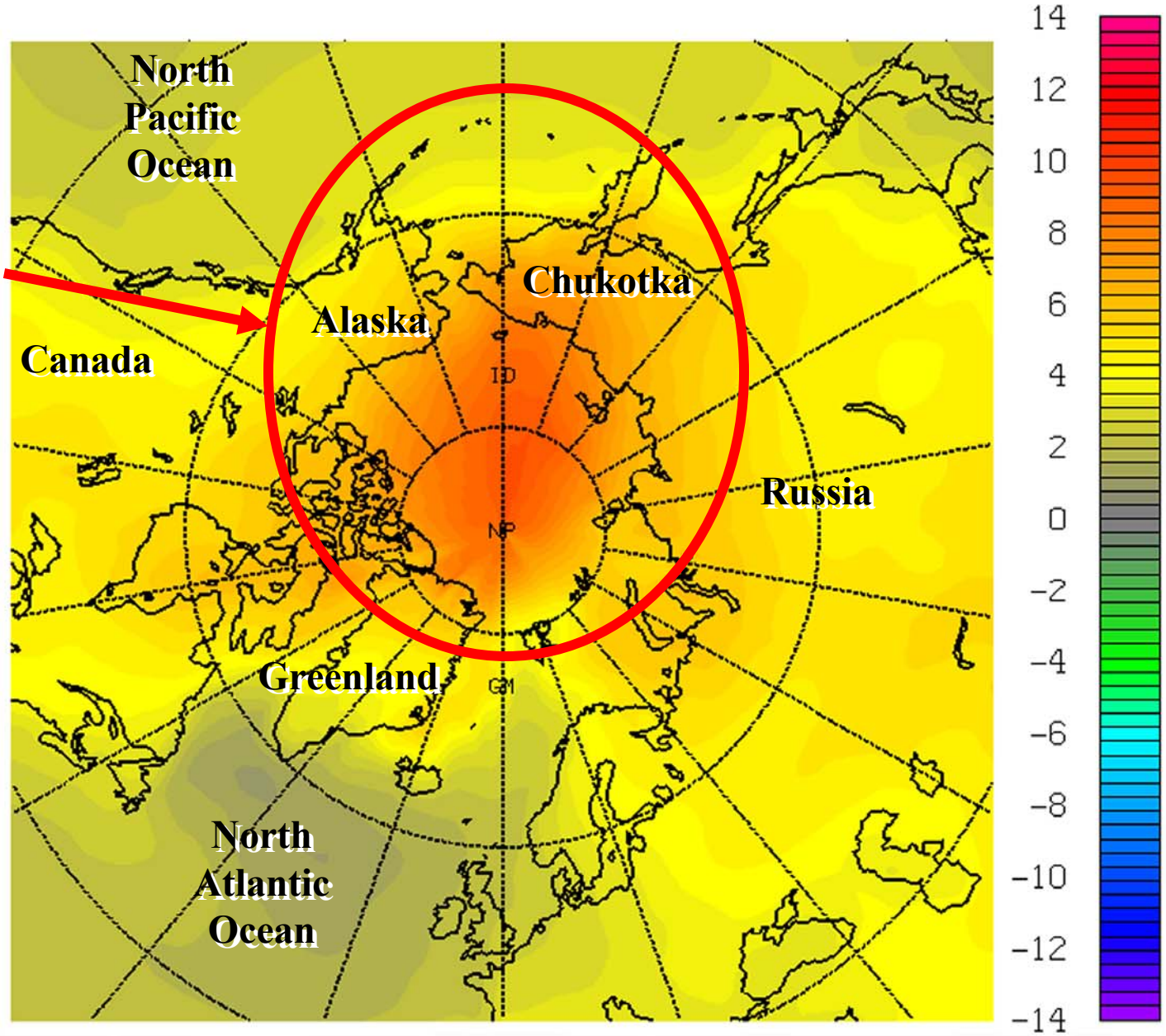

**Note: The substantial warming across the Arctic, (upwards of 10 °C or more), from very warm in the ice covered ocean to less warm in Greenland and Scandinavia.**




**Note: Warming is Mostly during the Winter Months**

**Note:**

The warming is in the range of about plus $8^0$ to $10^0$ C, for Alaska and about plus $4^0$ to $6^0$ for Greenland.

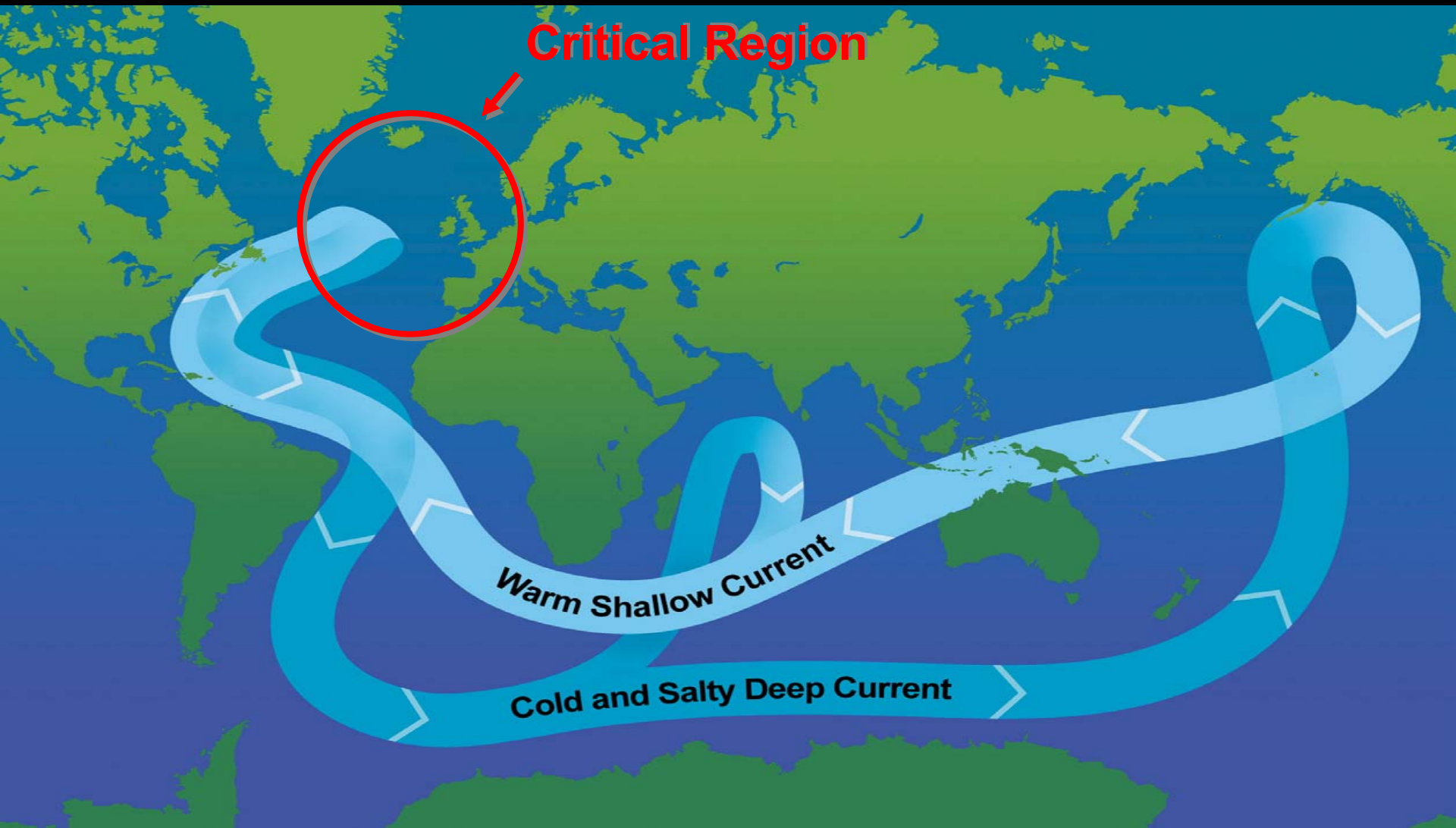



**Projections 2060 to 2089**

**Surface Temperatures Projected by Five ACIA Models**
**Annual Differences for the 2060 to 2089**

Base: Average of 1961 - 1990

# Does this Melting of Sea Ice have other Effects, such as an Impacts on Oceanic Circulation?

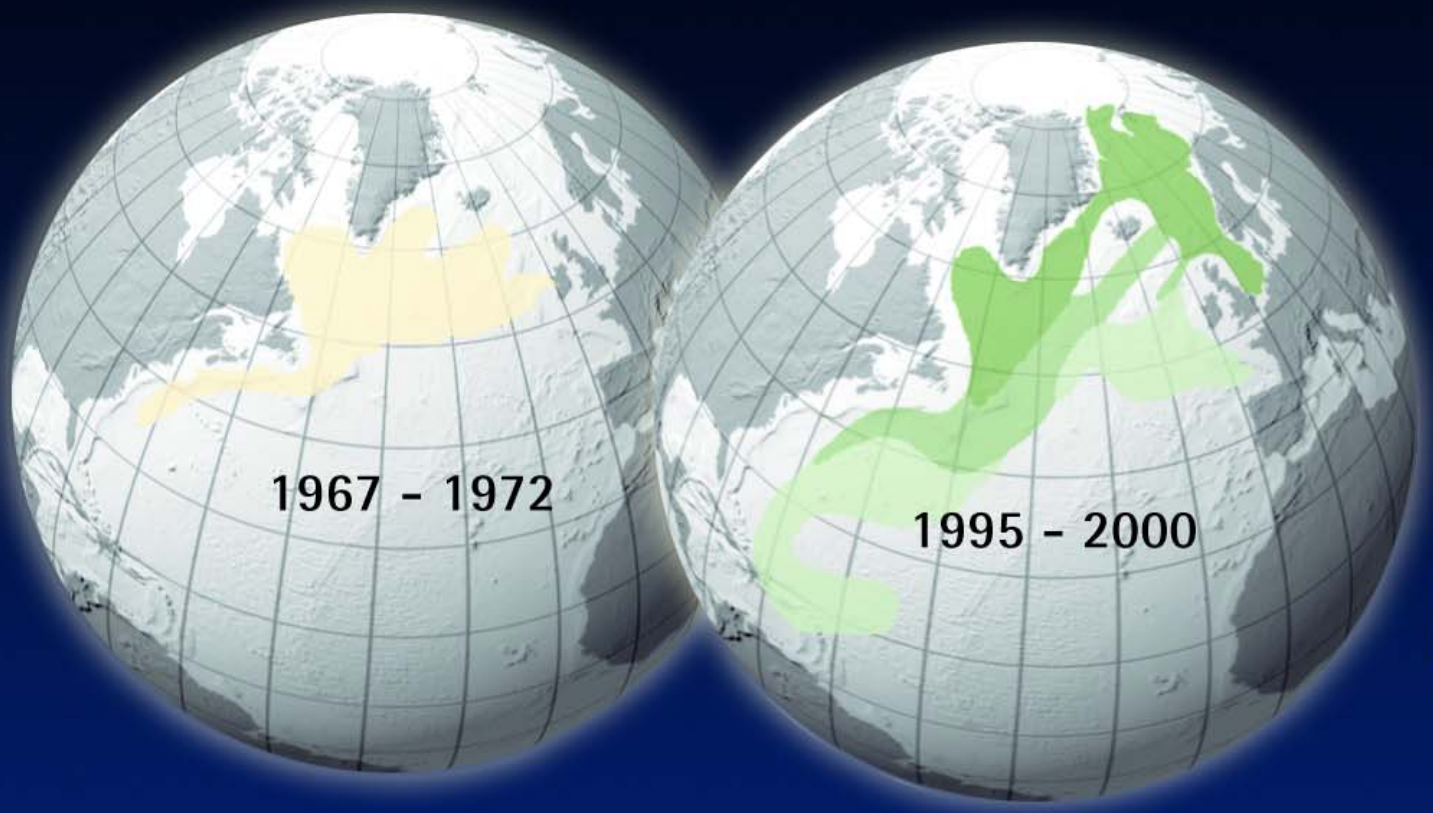


# What about Salinity?

- Oceans contain  97% of Earth's water
- Oceans experience 86% of evaporation
- Oceans receive 78% of planetary precipitation
- A 1% increase in Atlantic precipitation equals the annual Mississippi runoff
- A key element of the global water cycle

# IMPACTS OF A WARMING ARCTIC

## Reduced Salinity of North Atlantic Waters

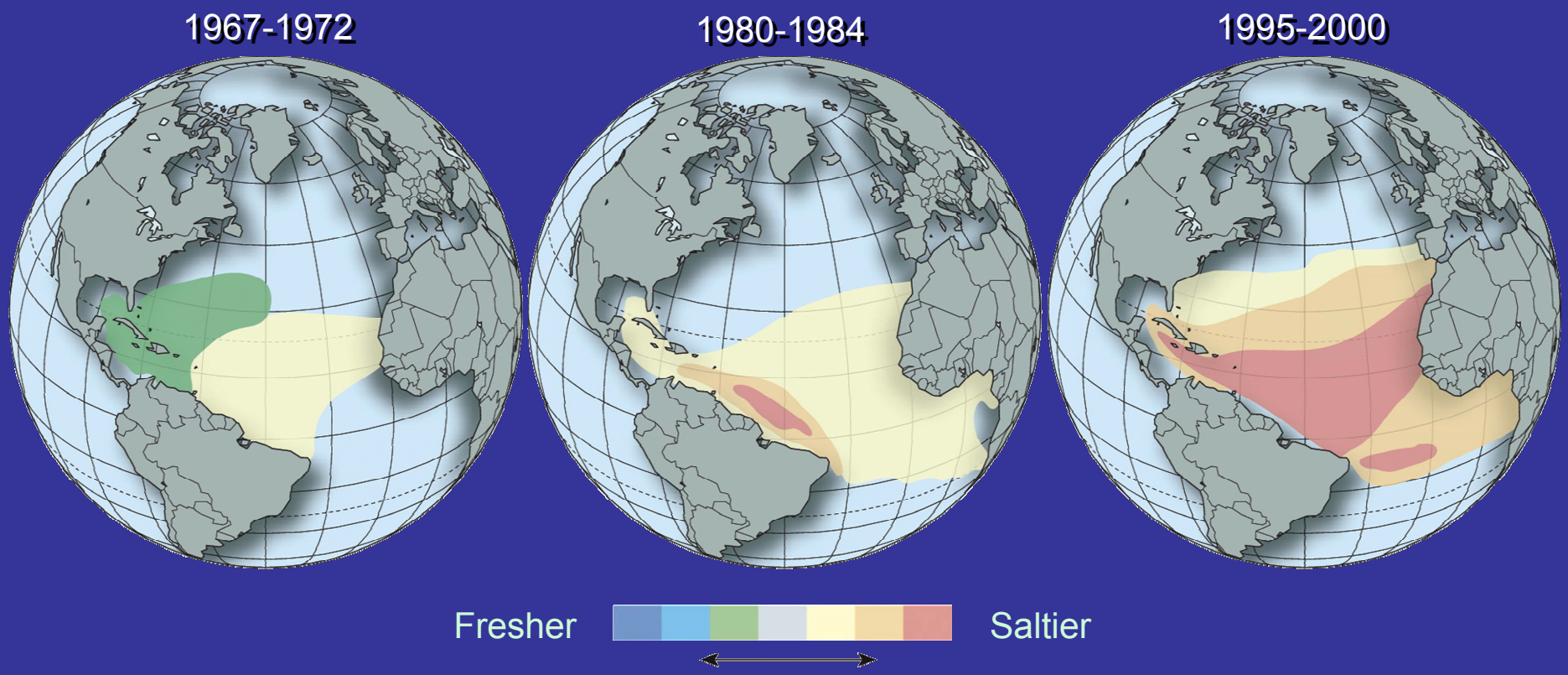



Saltier

Less salty

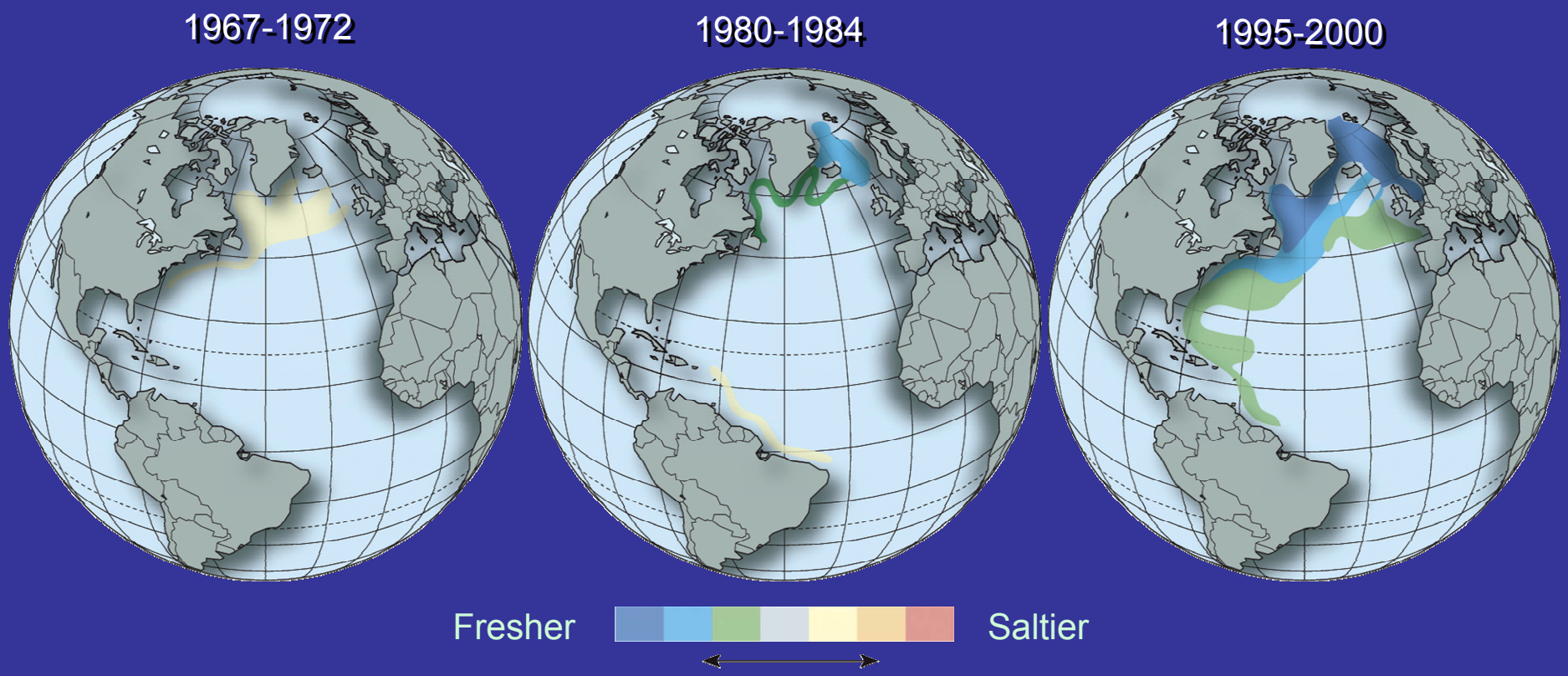
(than 1950–1959 baseline)

# Tropical Salinities Increasing for last 40 years



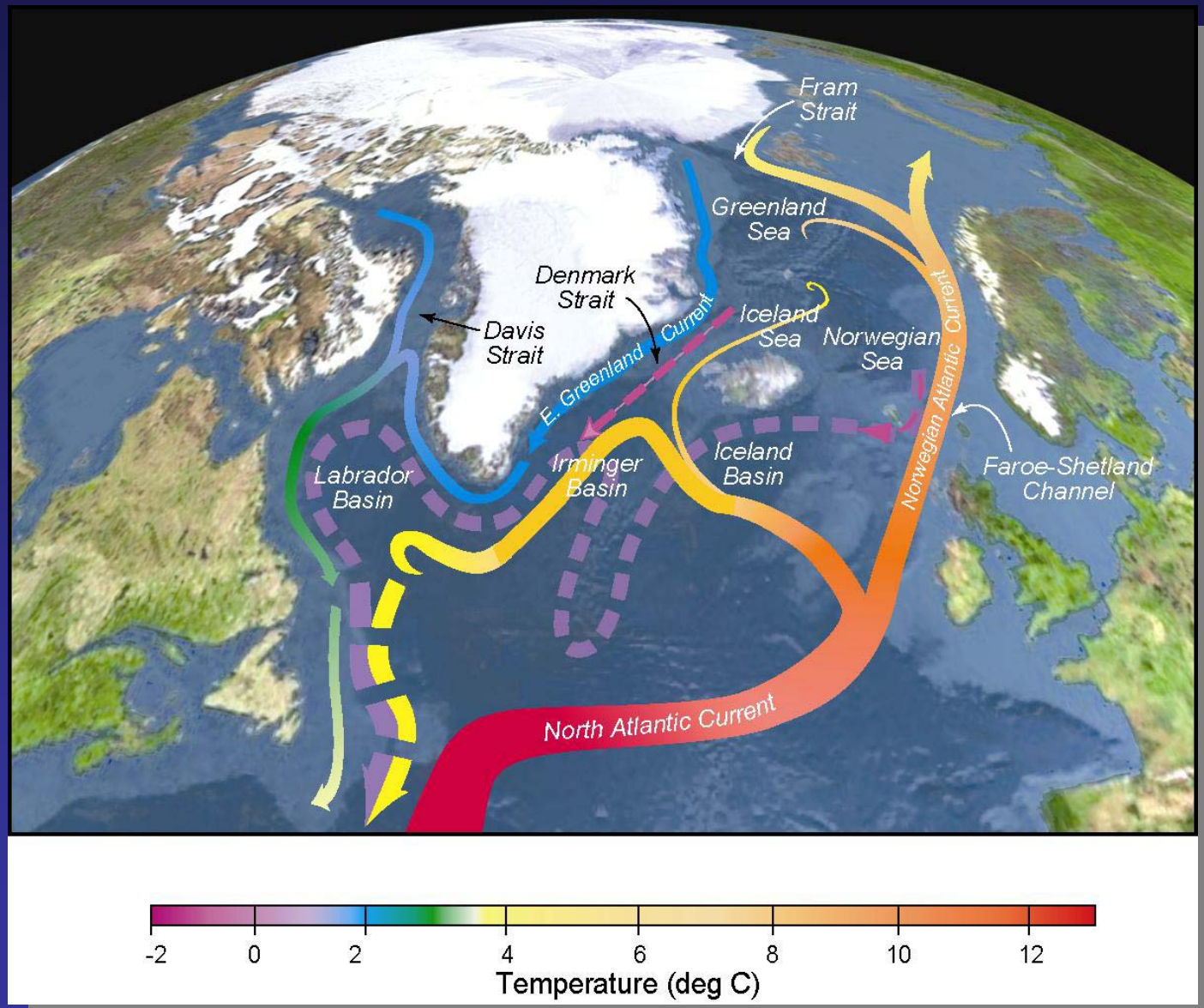

*Ruth Curry (pers. comm.)*

# Fresher Deep Water Flowing South at 3000 m

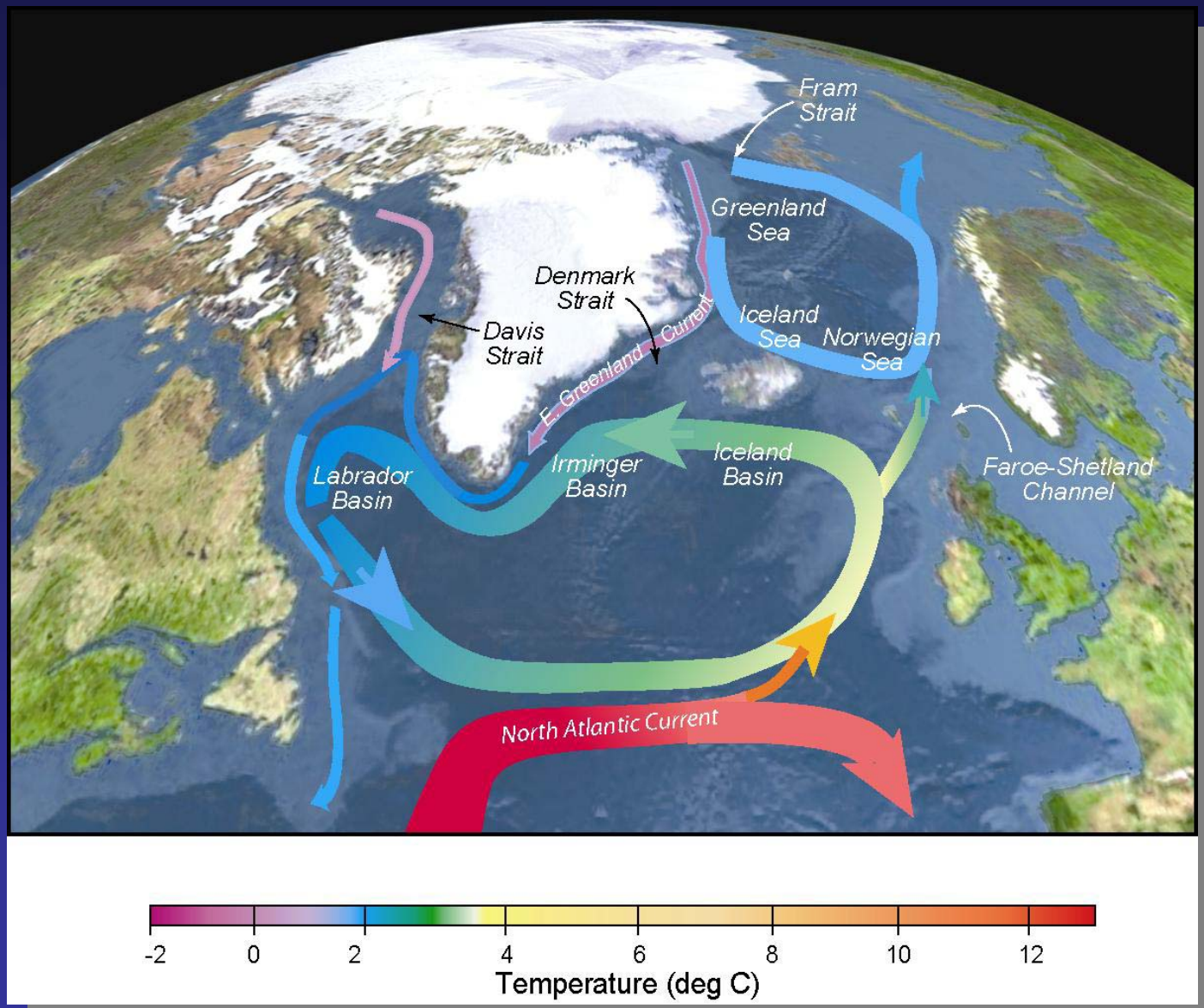



*Ruth Curry (pers. comm.)*

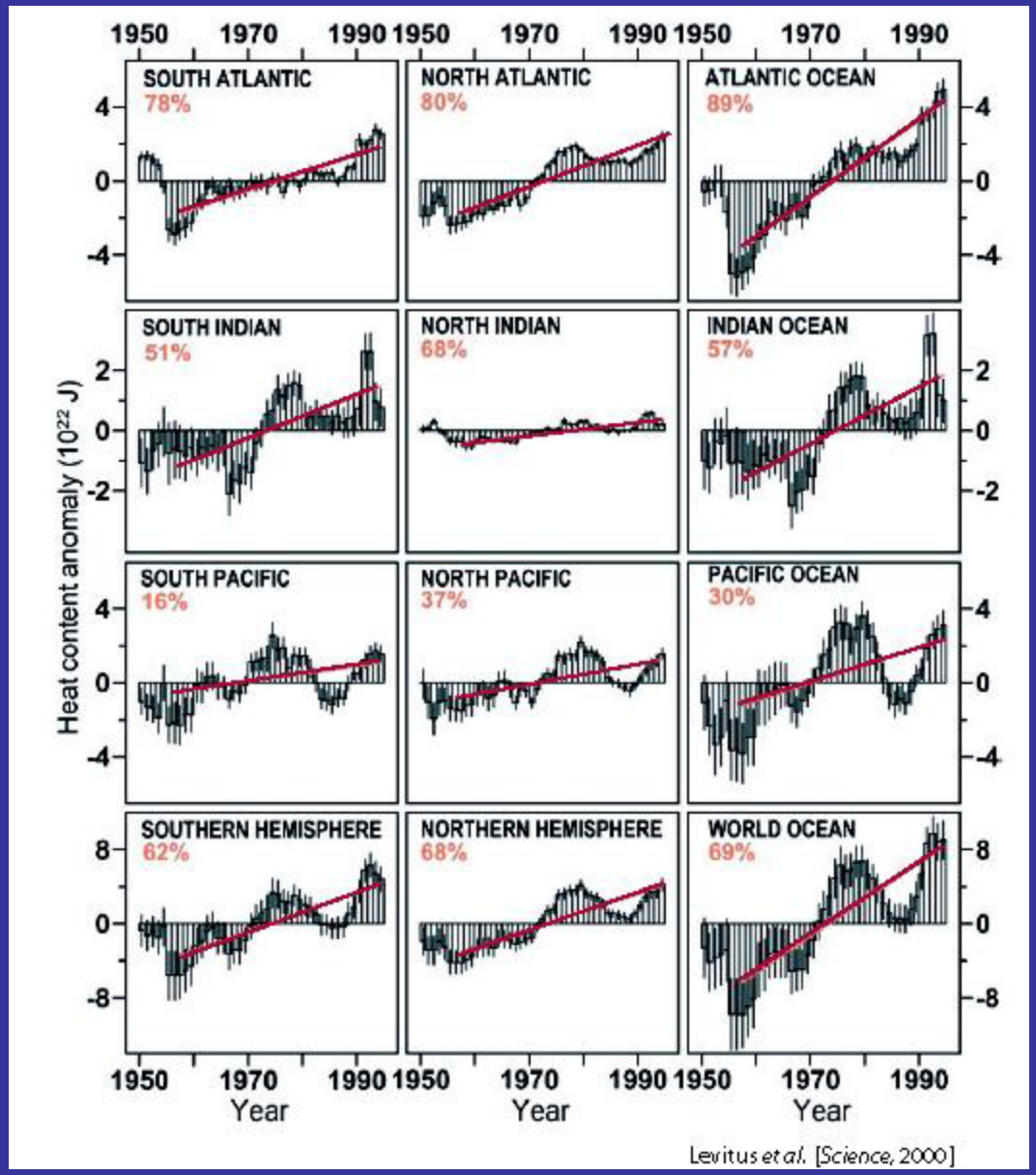
# Changes in Oceanic Temperatures of Importance.



# Conveyor OFF




- Strong cooling in North Atlantic
- Warming everywhere else
- No net global change




In the last half of the 20th century, it is clear that the world oceans are heating up.

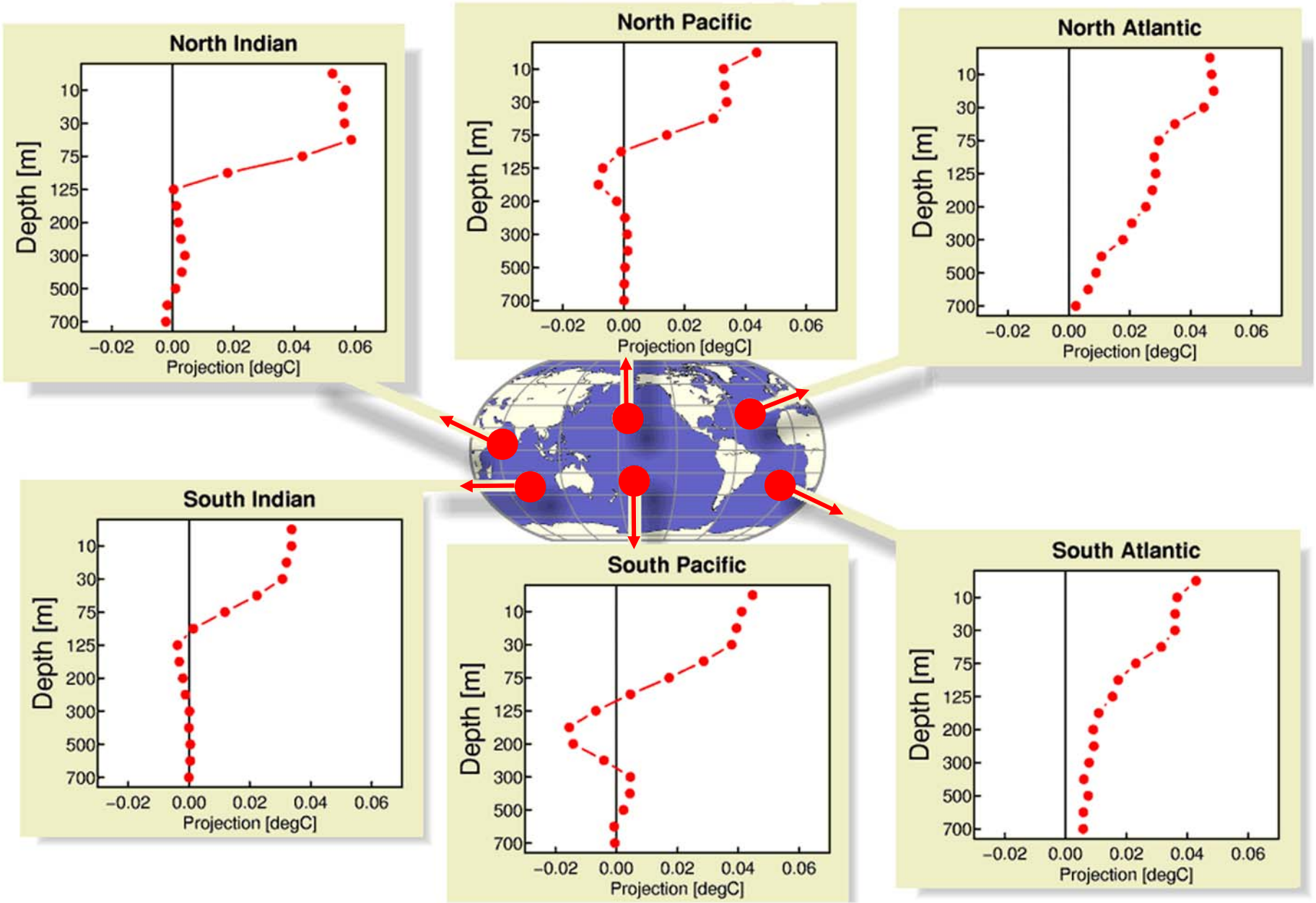
The oceans have absorbed about 30 times more heat than the atmosphere since 1955

| | |
|---|---|
| Oceans | $18.2 \times 10^{22}$ J |
| Atmosphere | $6.6 \times 10^{21}$ J |

*Levitus et al. Science, 2000*

# Penetration of Ocean Warming Signal (1955–1999)

**Red = Millions of observations from the World's Oceans over 40 years and down to 700 meters.**



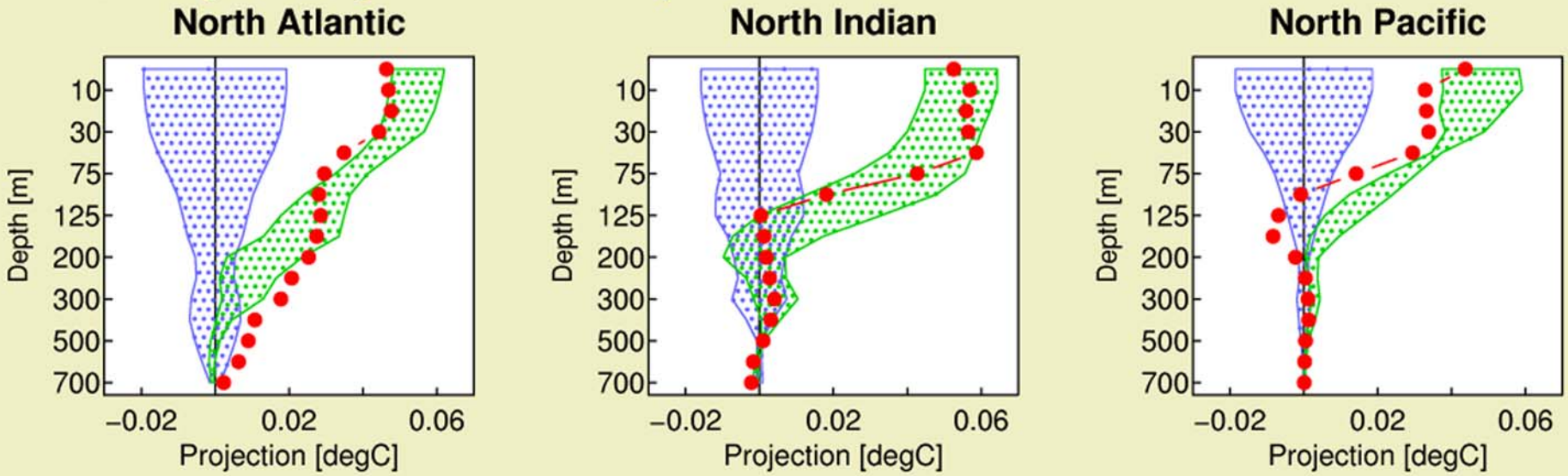
# Global Warming of the World's Oceans (T.P. Barnett, et al 2005)

**No Anthropogenic Forcing (Blue)**

**With Anthropogenic Forcing (Green)**

**Observational Data (Red)**

## HadCM3 (Hadley CM3 Model)




**Key:**

**Blue:** Temperature distribution with no anthropogenic forcing (the blue swath). Signal strength values falling within this region can be forced simply by 'natural variability'.

**Green:** Temperature distribution produced by five different climate-change model runs with anthropogenic forcing (greenhouse gasses and aerosols produced by human activity).

**Red:** The red dots show the signal strength estimated from the observations. The agreement between what is observed, and what is expected to arise from anthropogenic forcing, is excellent in all ocean basins.

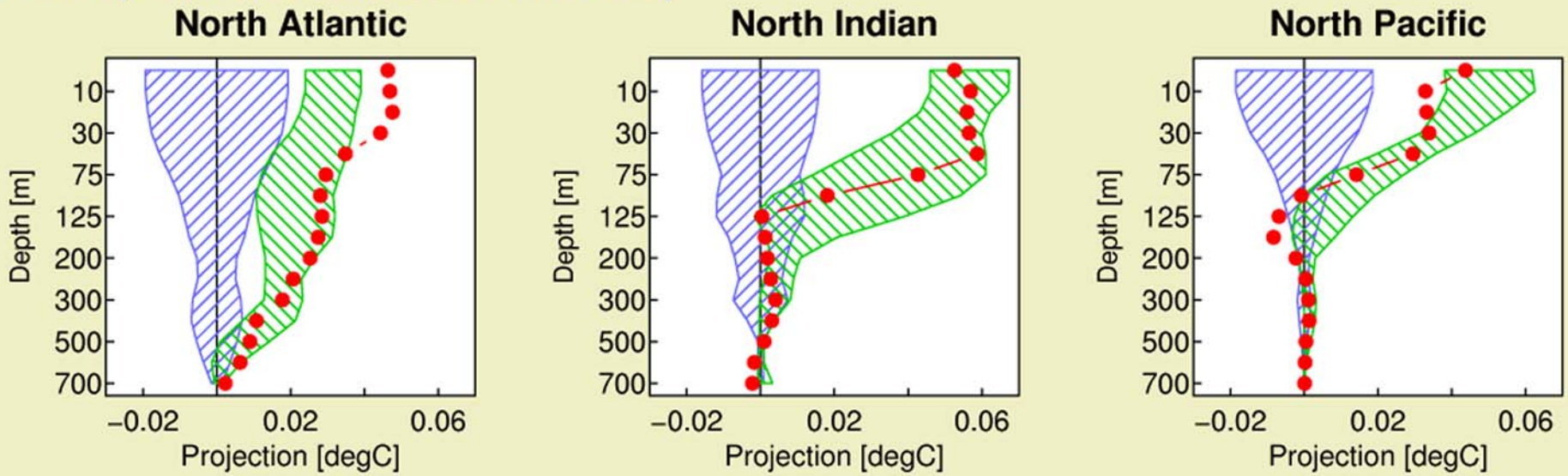
# Global Warming of the World's Oceans (T.P. Barnett, et al 2005)

**No Anthropogenic Forcing (Blue)**

**With Anthropogenic Forcing (Green)**

**Observational Data (Red)**

## PCM(Parallel Climate Model)

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# Earth's Energy Imbalance: Confirmation and Implications

James Hansen, et al (*Science* 2005)

**Significance of Hansen's *Science* Paper:**

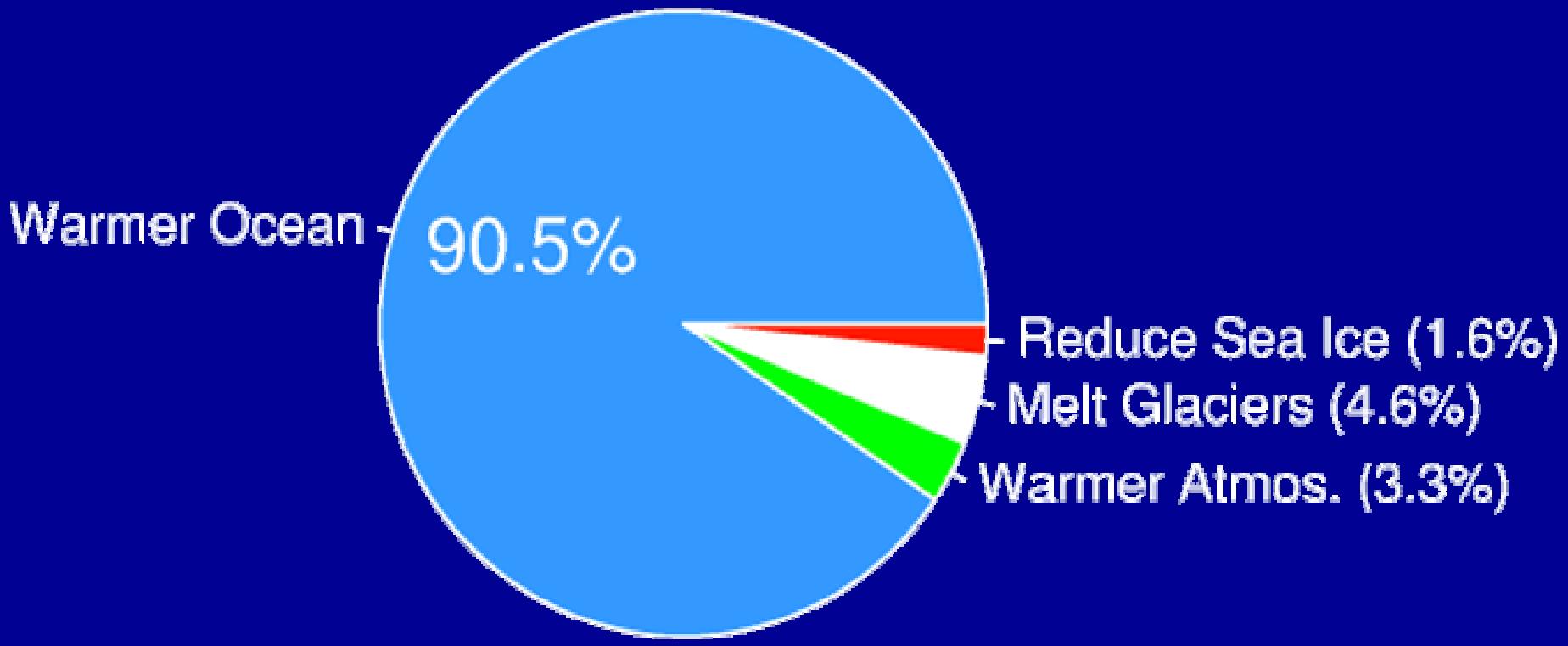
**The Earth is now absorbing 0.85 +/- 0.15 W/m$^2$ more energy from the Sun than it is re-emitting back into space. This imbalance is confirmed by precise measurements of increasing ocean heat content over the past 10 years.**

**Major implications:**

> ***"An expectation of additional global warming of about 0.6$^o$C without further change of atmospheric composition."***

# Why are the oceans Important?

***Because, that is where the heat goes !***




Data from Levitus et al, *Science*, 2001

# What is the Ocean's Role in Climate?

- The ocean covers 70% of the earth's surface
- The ocean stores a thousand times more heat than the atmosphere
- Seawater stores four times more heat per unit mass than air
- It transports 25 to 50% of the energy received from the sun

# What is the Ocean's Role in Climate?

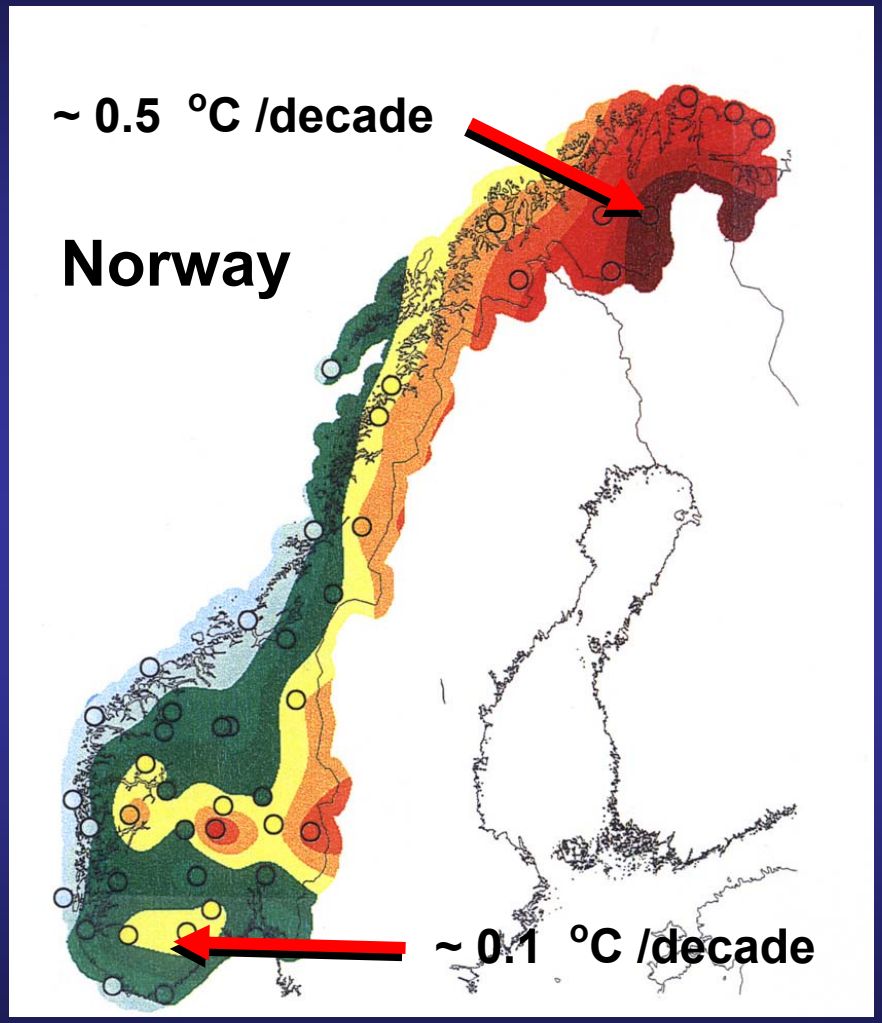
- It circulates slowly, on time scales of decades to centuries
- It is the major source of heat to some regions like the North Atlantic
- It sets long-term patterns of atmospheric circulation affecting climate systems like ENSO, NAO

# How will the Oceans Change as the Earth Warms?

- As the oceans warm: sea level will rise, oceanic salinity balance will be altered, oceanic pH will change, and the ocean's ability to absorb $CO_2$ will change.
- It will impact atmospheric circulation, storm tracks, severe storms, and the frequency and distribution of droughts

# Impacts are Local:

While IPCC and climate and global change research, during the past 10-20 years, have substantially enhanced and deepened our knowledge of the global means and large-scale trends of climate change and is consequences, the reality is that now **we must extend that knowledge to the regional or more local scales** where the "patchiness", extremes, and "surprises" are most likely to be expressed. This is where residents, stakeholders, and governments "see" the consequences of climate variability and change.



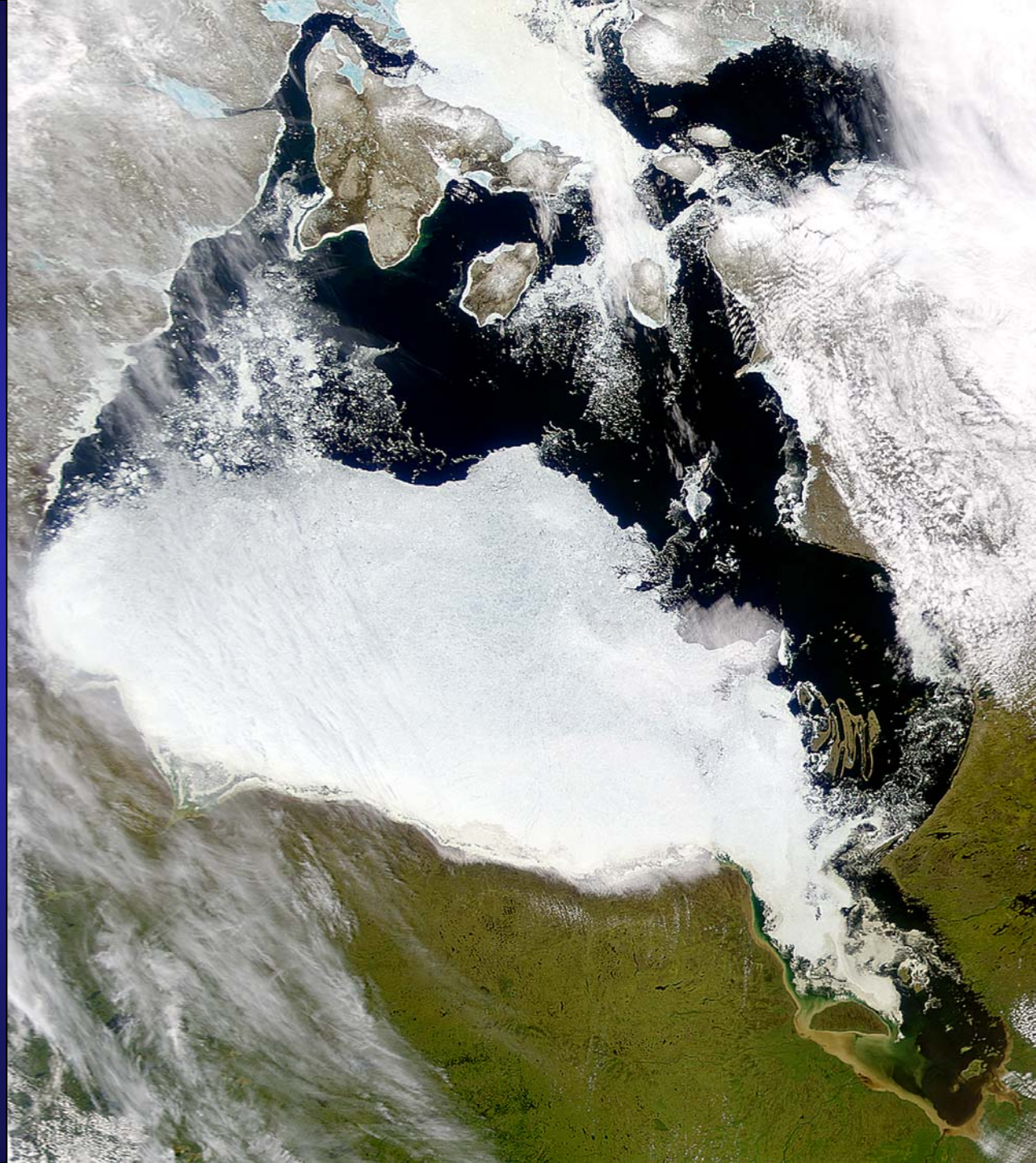

**Regional variations are significant.**

**“Right now the weather is unpredictable. In the older days, the edlers used to predict the weather and they were always right, but now, when they try to predict the weather, it’s always something different…..”**

**Z. Aqqiaruq, Igloolik 2000**

# Hudson Bay

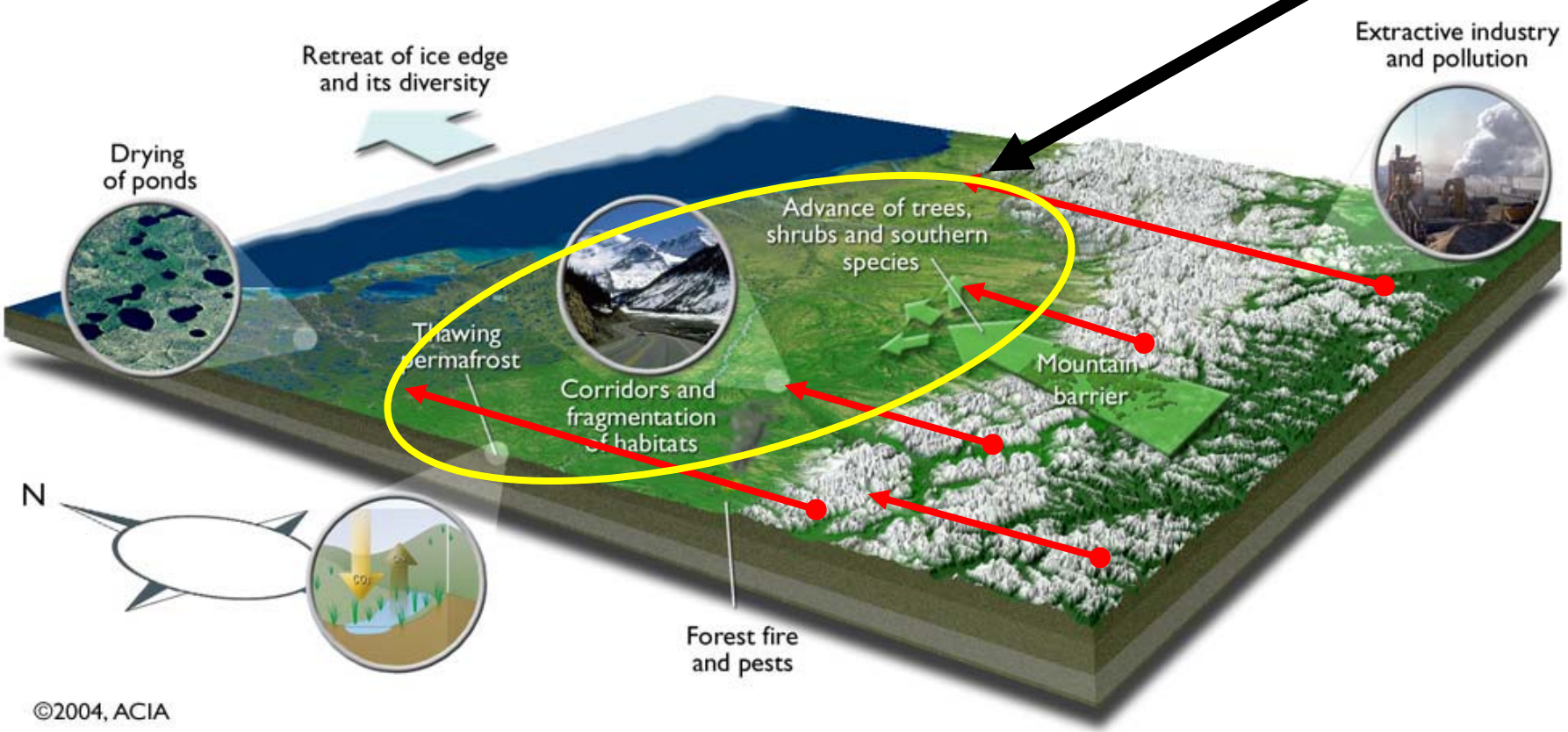
An early indicator of the changing climate



# The Adaptive Capacity of Ecosystems is "Rate Limited" and is "Asynchronous"

This is a "new" ecosystem with "new" and unknown arrangements between the species, with major impacts on herding pastures !

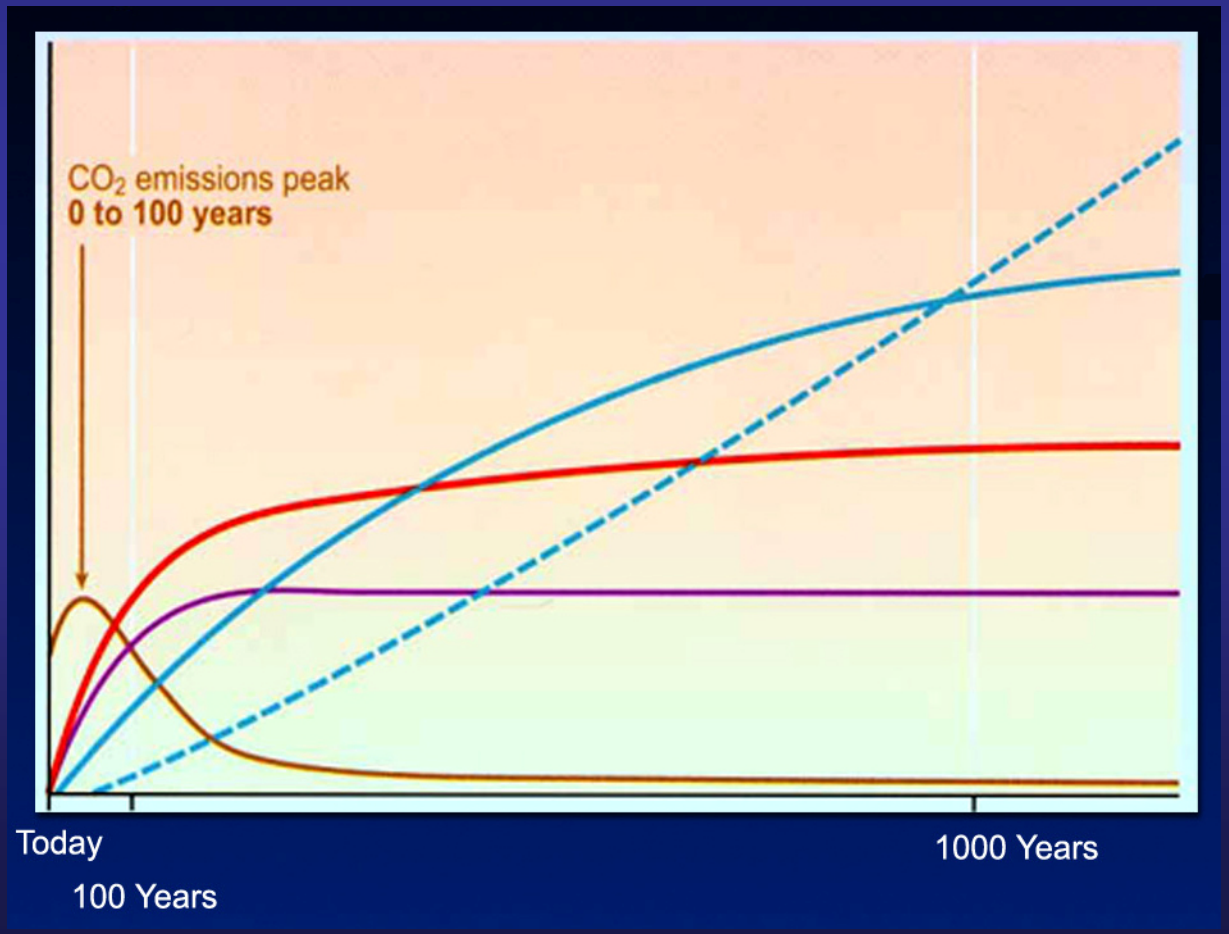




# A Fundamental Asymmetry Exists

There is a fundamental asymmetry between the time scales that the climate system reacts to increases in greenhouse gases and the time scales to recover from such increases.

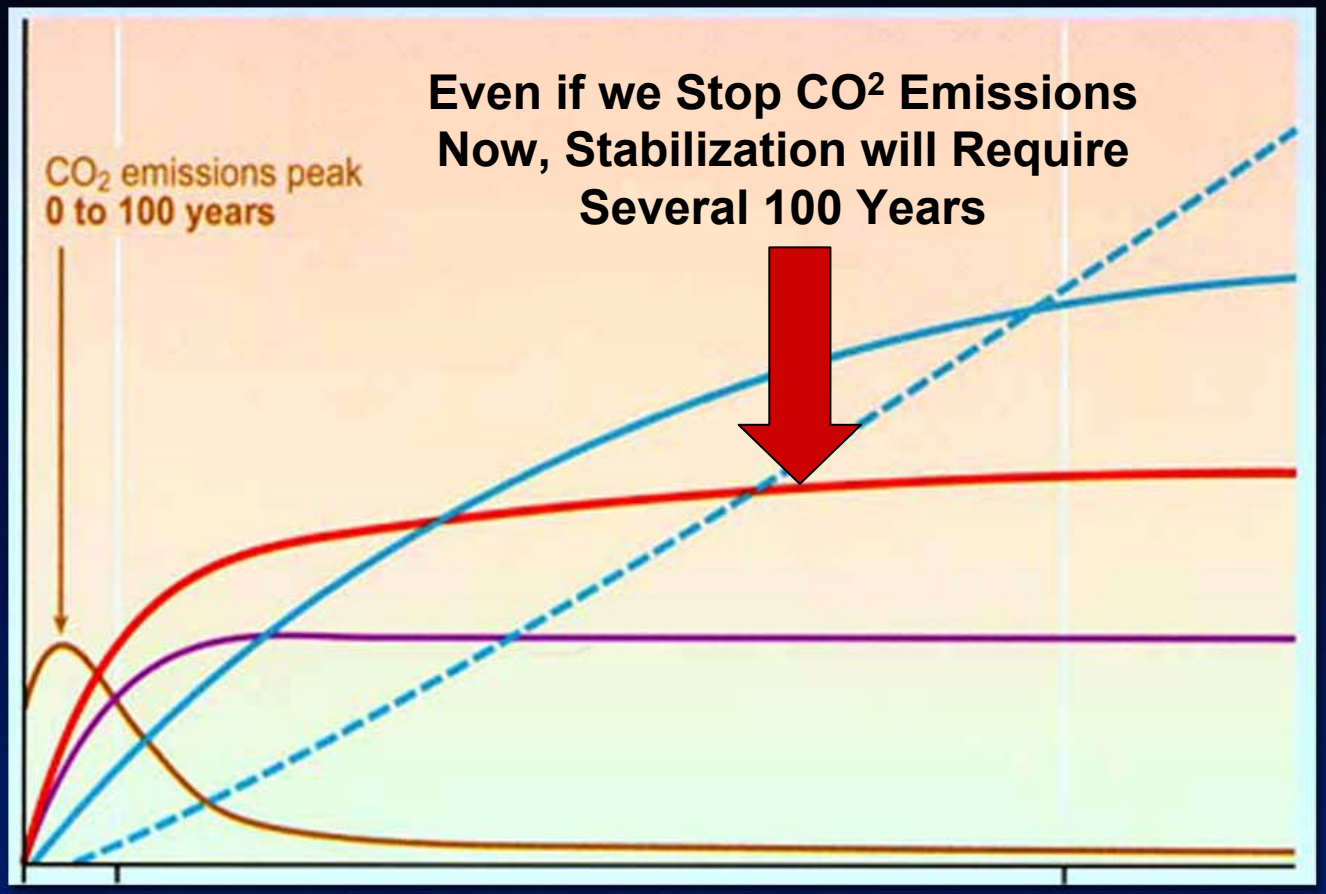
It takes roughly ten times as long as for the planet to recover from increases in greenhouse gases than it takes to increase these gases in the first place from anthropogenic sources.



# $CO_2$ concentration, temperature, and sea level continue to rise long after emissions are reduced

Magnitude

Time to Equilibrium




Sea-level rise due to ice melting:
SEVERAL MILLENNIA

Sea-level rise due to thermal expansion:
CENTURIES TO MILLENNIA

Temperature Stabilization:
A FEW CENTURIES

$CO_2$ Stabilization:
100 to 300 YEARS

$CO_2$ Emissions

Today

100 Years

1000 Years

## The Presentation will Explore these Four Questions:

1. What does science tell us, particularly recent findings that have implications across the Arctic Region and Globally?
2. What are some examples of strategies and scenarios towards emission reduction?
3. What issues of policies related to climate changes have the Ministers of the Arctic Council adopted in their Declaration of November, 2004
4. What are the consequences and/or risks of inaction?

ARCTIC CLIMATE IMPACT
ACIA
ASSESSMENT
Thank You
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## The Presentation will Explore these Four Questions:

1. What does science tell us, particularly recent findings that have implications across the Arctic Region and Globally?
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**Strategies can be thought of as measures or actions that can address the potential consequences of climate change. Here are a few examples for our discussions:**

- **EU:** The European Union, for example, declared in the late 1990's and continues to consider measures so that global average temperatures would not exceed 2 degrees Celsius above pre-industrial level.
- **UK:** Prime Ministry Tony Blair indicated that the UK should reduce greenhouse gas emission by 60% by 2050.
- **In the US and Canada:** The six New England states in the U.S. and the four maritime provinces of Canada have a climate action plan to address these goals:

  **A Short-term Goal:** Reduce regional GHG emissions to 1990 emissions by 2010,

  **A Mid-term Goal:** Reduce regional GHG emissions by at least 10% below 1990 emissions by 2020, and establish an iterative five-year process, commencing in 2005, to adjust the goals if necessary and set future emissions reduction goals, and

  **A Long-term Goal:** Reduce regional GHG emissions sufficiently to eliminate any dangerous threat to the climate; current science suggests this will require reductions of 75–85% below current levels.

## Strategies (another example for our discussions):

**Portland, Oregon** in the U.S. adopted a climate action plan in 1993, the first to do so, with a set targets and a timetable to:

- Reduce the City's emissions by 10% by 2010 (not just from Government).
- **To purchase 100% of local government energy from renewable sources by 2010.**
- Taking forward plans for a utility-scale wind power project to supply city facilities.
- Achieving 60% recycling rate by 2005.

**Portland has made major progress and has achieve:**

- Almost doubling of public transit use since 1990.
- **13% reduction in per capita greenhouse gas emissions since 1990.**
- 10% of local government's energy currently sourced from renewables.
- Construction of over 40 high-performance green buildings.
- With energy savings of over $300 million for businesses and residences, and over $11 million in energy costs to the city.

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## Reykjavik Declaration:

- "**Recognize** that the Arctic climate is a critical component of the global climate system with worldwide implications,
- **Acknowledges** the need to consider the findings of the ACIA and other relevant studies in implementing their commitments under the UNFCCC and other agreements, including through adoption of climate change mitigation strategies across relevant sectors, and
- **Endorses** the ACIA policy recommendations for mitigation, adaptation, research, monitoring and outreach."

# Reykjavik Declaration further Notes:

## Mitigation:

“To address the risks associated with climate change in the Arctic of the magnitude projected by the ACIA and other relevant studies, timely, measured and concerted action is needed to address global emissions.“

# More on ”Mitigation” from the Reykjavik Declaration

- ”Adopt climate change mitigation strategies across relevant sectors. These strategies should address net greenhouse gas emissions and limit them in the long term to levels consistent with the ultimate objective of the UNFCCC....”
- ”Promote the development and adoption of appropriate energy sources, uses, technologies and efficiencies. The International Partnership for Hydrogen Economy (IPHE) and The Carbon Sequestration Leadership Forum (CSLF) , together with initiatives to promote renewable energy production and more efficient energy use, are examples of relevant initiatives.”

# Reykjavik Declaration further Notes:

## Adaptation:

"While mitigation is necessary to address the risks associated with climate change, the scenarios used by the ACIA and elsewhere project that some climate change is inevitable, indicating that continued adaptation is needed."

## The Presentation will Explore these Four Questions:

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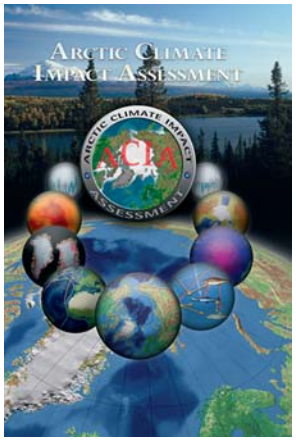
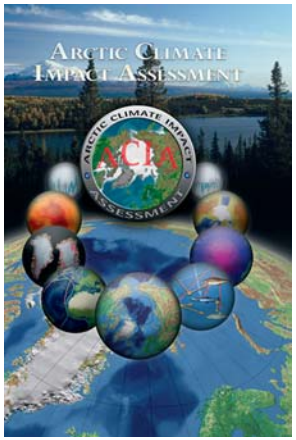



*The Scientific Report*

# Recent Developments

- **Legislative Bodies:**
- **An Intergovernmental Dialogue on Climate Change:**
- **A Royal Colloquium on Climate Change in the Arctic:**
- **United Nations Commission on Sustainable Development:**
- **UK Scientific Symposium on Stabilization of Greenhouse Gases:**
- **Climate Change: Looking Beyond Kyoto:**




*The Scientific Report*

# Major Geopolitical Issues are Unresolved across the Arctic Basin

- **ACCESS:** Issues of Access and Rights of Passage through the Northern Sea Route (Russia) and the Northwest Passage (Canada)
- **SEAWARD CLAIMS:** Claims of seaward ownership within the Arctic oceanic basin. Median Line Method (i.e., Divide into areas proportional to the amount of coastline of a country), and the Sector Method (Divide into areas by essentially longitudinal line from the countries to the pole).
- **BOUNDARY DISPUTES:** Many boundary disputes still exist.
- **VENUE:** Is the Law of the Sea the venue to resolve these geopolitical issues, or other international frameworks required?

# Two Summary Thoughts

***First*, addressing the issues of moving knowledge to action in the interests of society, its people, its economic welfare, and its environmental stewardship, is complex, demanding, and challenging. Is it possible that series of "Climate Round Tables" or "Dialogues", conducted under "Chatham House Rules" among world leaders might aid in bridging these difficult challenges for societies?**

# Two Summary Thoughts

***Second*, it is increasingly clear that even with the best of mitigation measures, the climate will continue change: temperatures will rise, sea level will increase, and other consequences of a warming planet will present challenges and opportunities of societies. The issue of adapting to these changes primarily occurs a local levels and among common sectors, e.g., water managers, farmers, health services, natural resources managers, city leaders, etc.. Is it time to work on adaptation strategies and practices at these local and sectoral levels such groupings as Farmer, Business and Industry, Workers and Trade Unions, Local Authorities, Non-Governmental Organizations, Children and Youth, Women, and Indigenous People, and the Science and Technology Communities?**