

Image: Toolik Lake LTER website



The Arctic on the Fast Track of Change

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Senior Research Scientist
National Snow and Ice Data Center

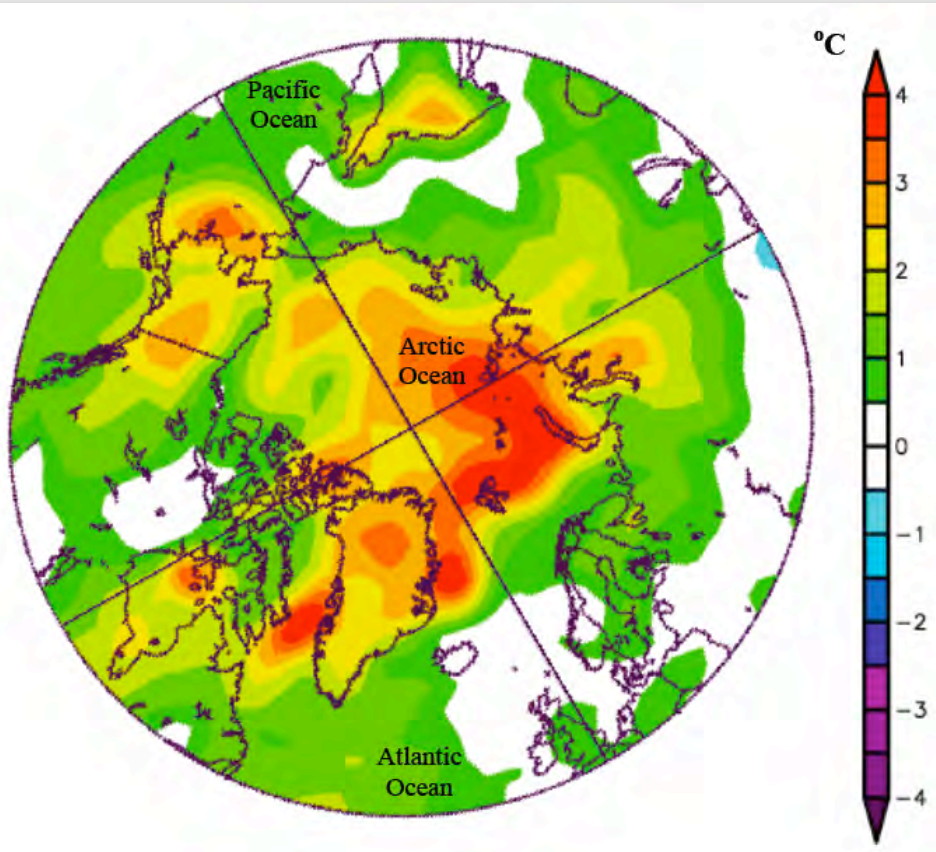
Observed Changes in the Arctic

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The Arctic has Warmed Strongly in Recent Decades

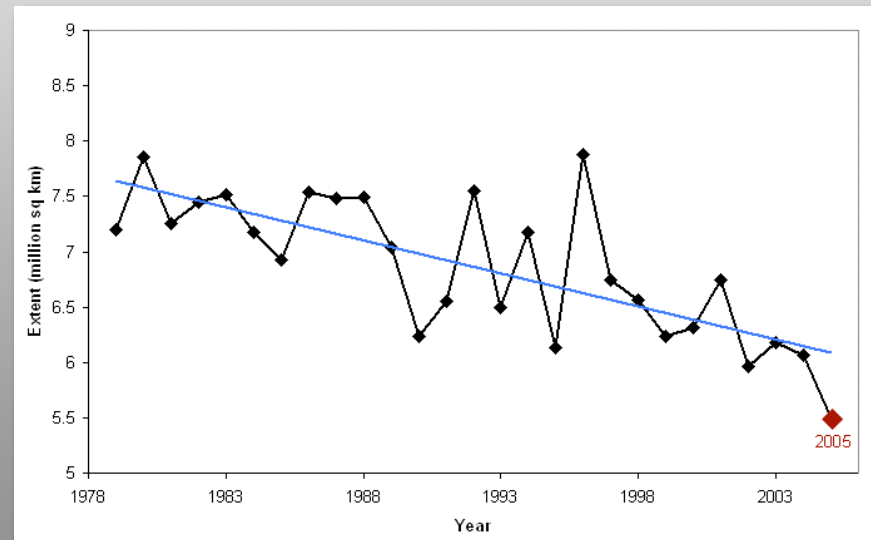
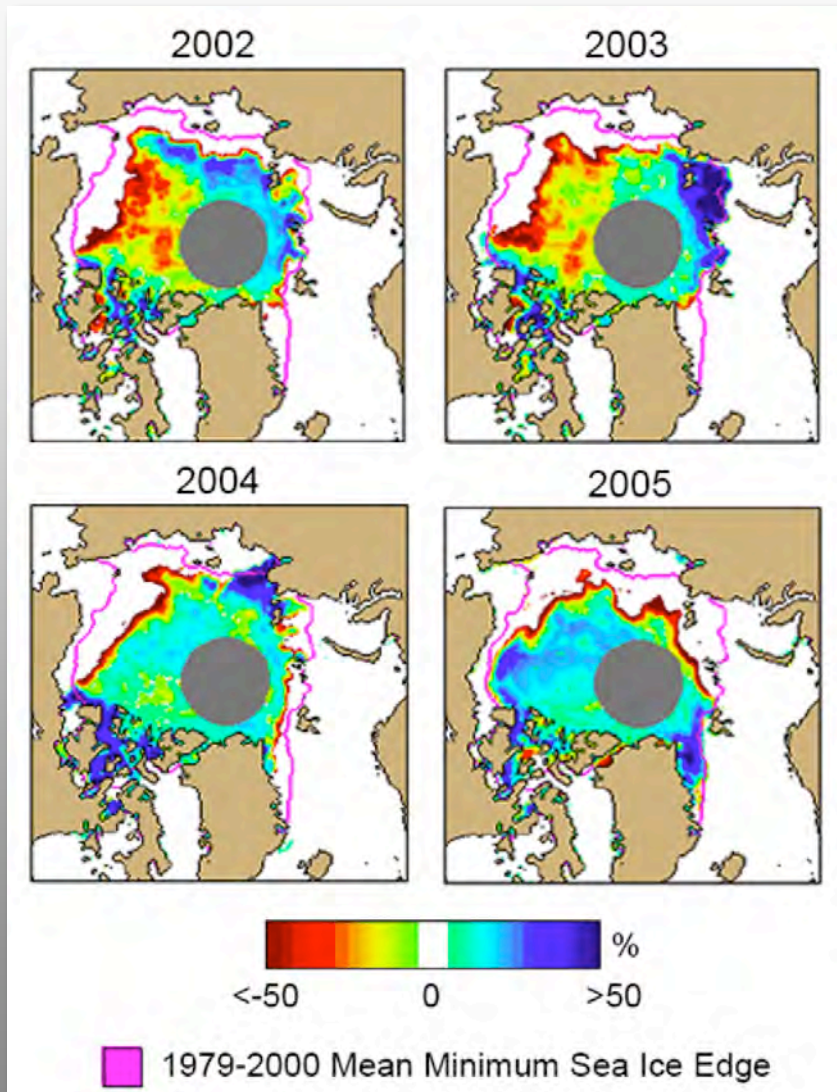
In 2005, temperatures were 2-4 deg. C (4-7 °F) above normal.



Arctic temperatures for 2005, relative to the period 1979 to 2005

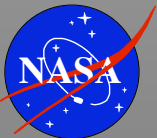
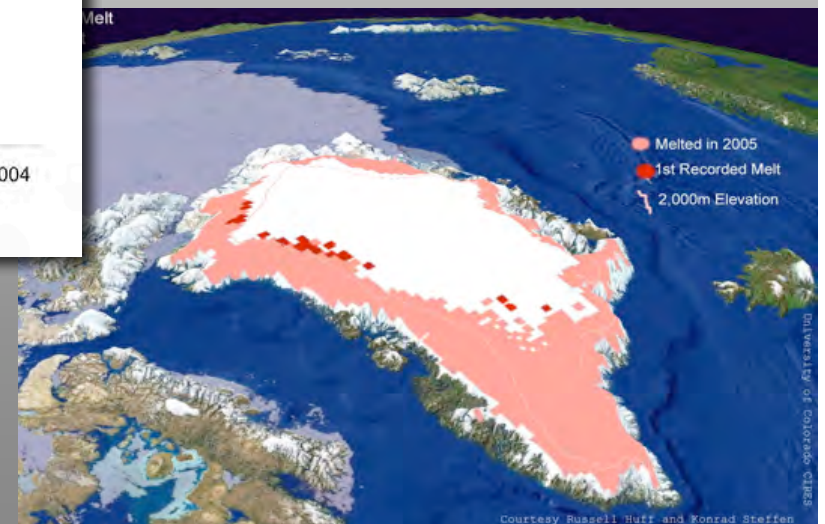
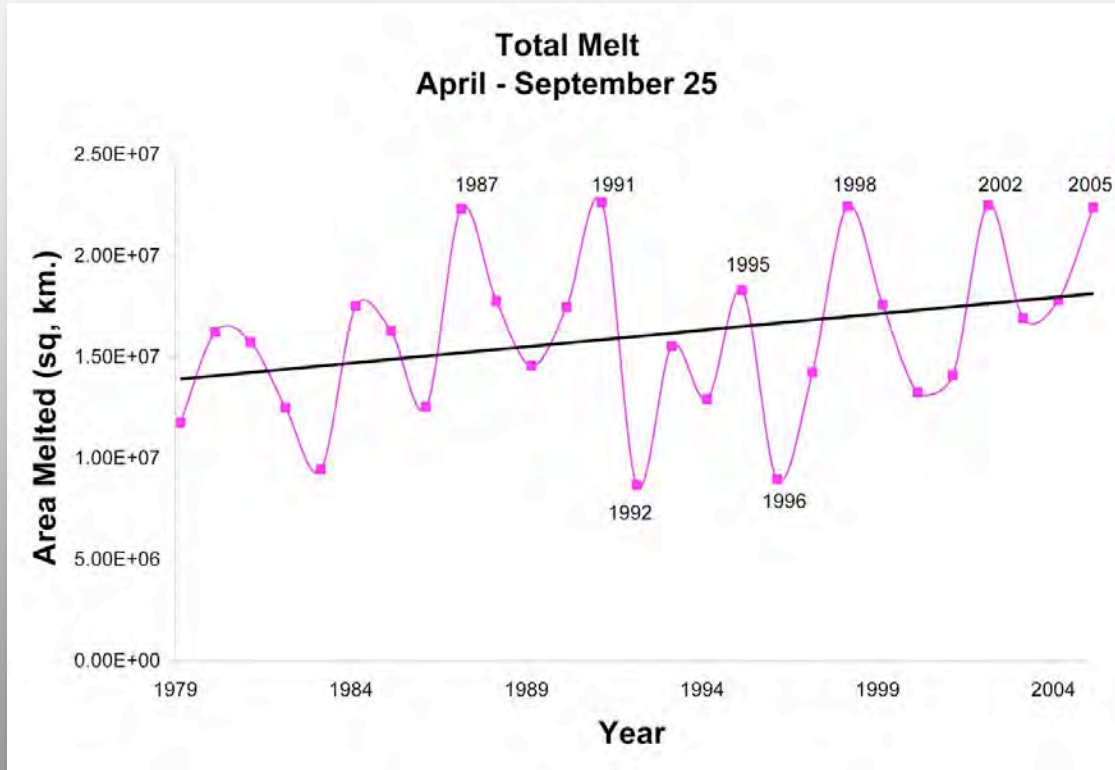
Sea Ice is Disappearing

The Arctic's floating sea ice cover has declined sharply in the past 25 years, with extreme losses in the past four summers.



Greenland Ice Sheet is Melting

There are indications of accelerated melt of the Greenland Ice Sheet

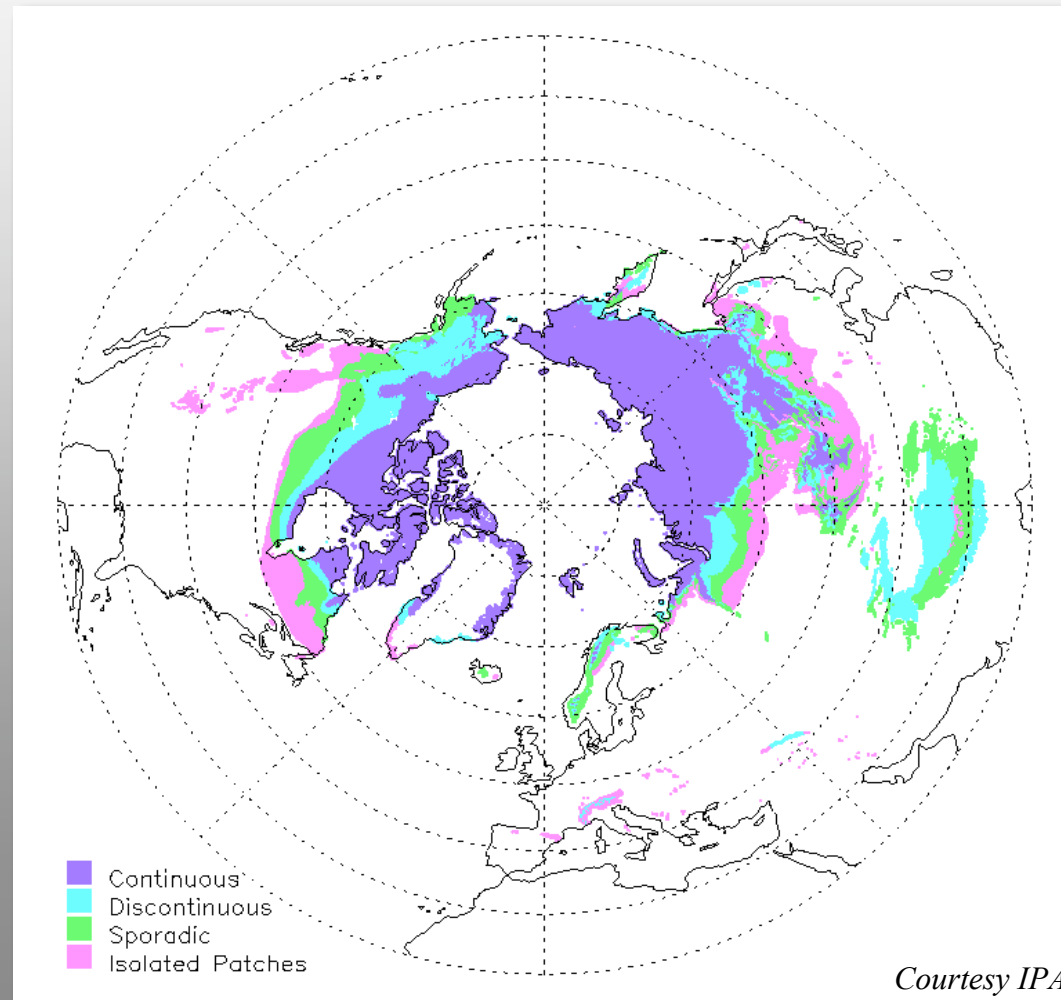


Melting Fosters Further Melting



Permafrost

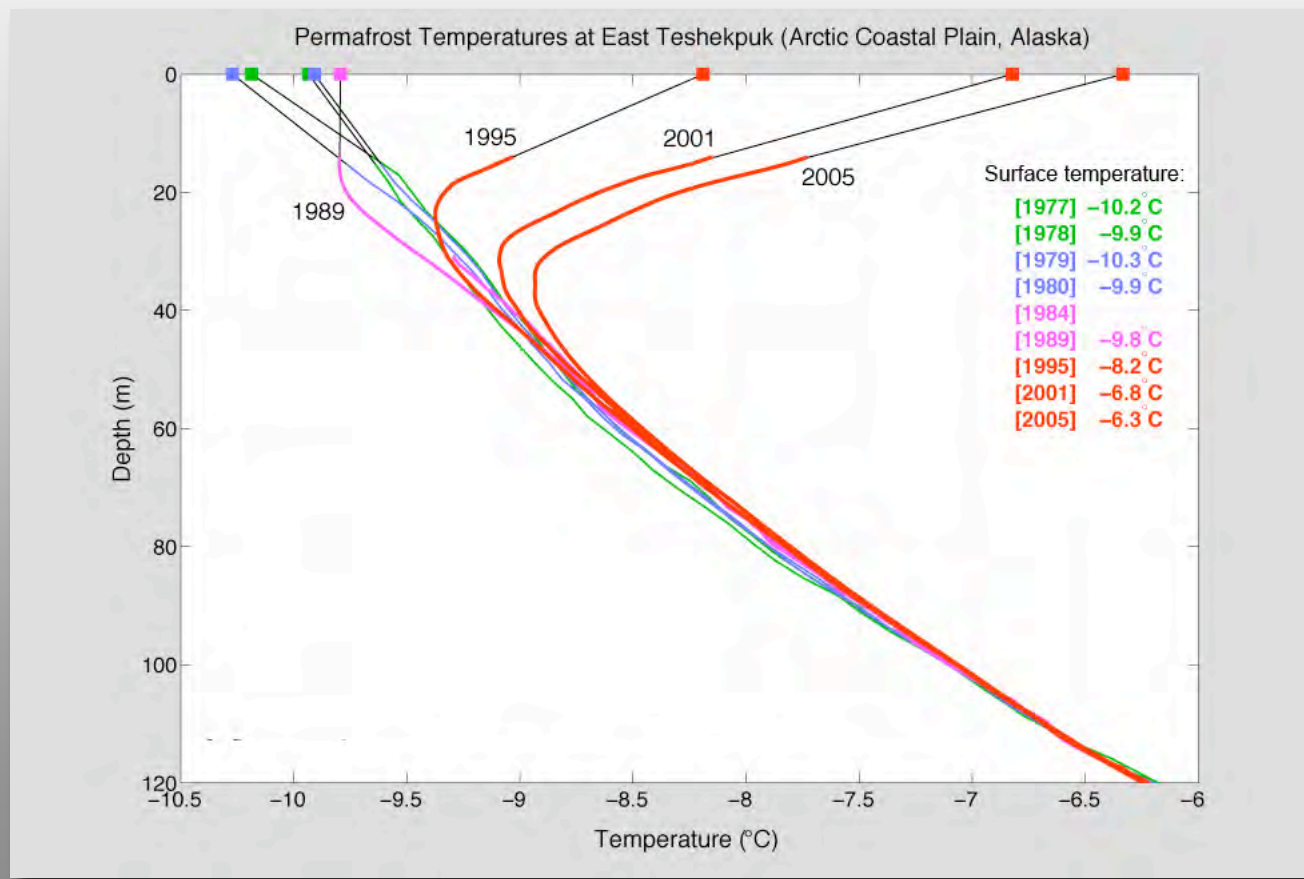
Permafrost - perennially frozen ground -
underlies most of the Arctic



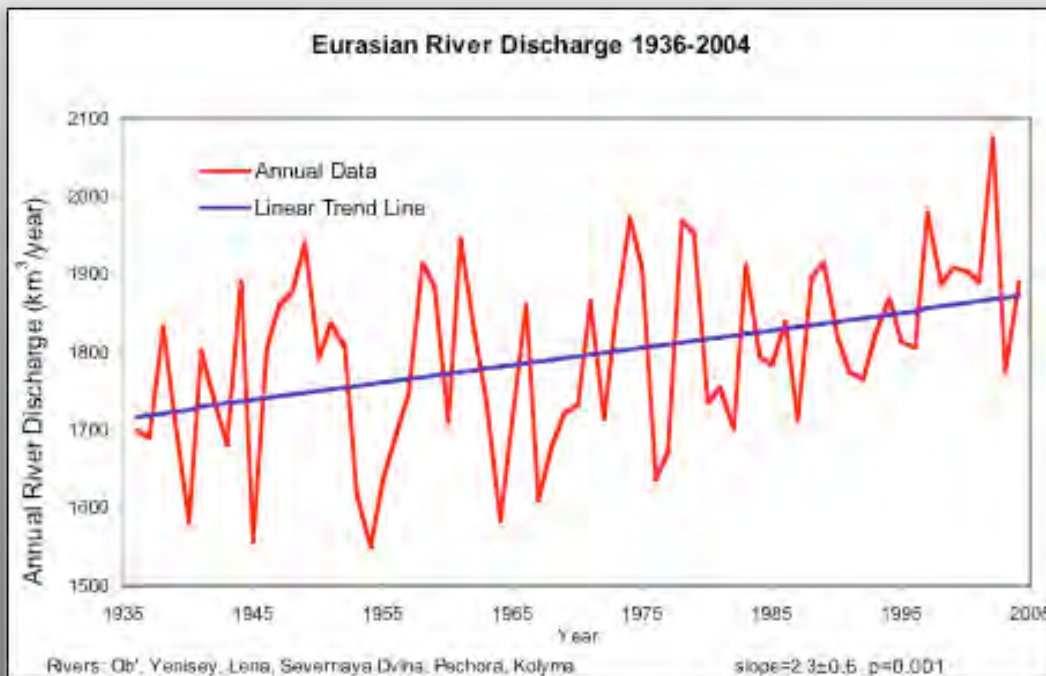
Courtesy IPA

Permafrost is Warming

Permafrost is warming, and in some areas is thawing, altering ecosystems, hydrology and infrastructure



River Flow to the Arctic Ocean is Increasing



This increase from the major arctic rivers is freshening the Arctic Ocean

Tundra is Transitioning to Shrub



Changes in Shrub
Abundance:
Chandler River, AK

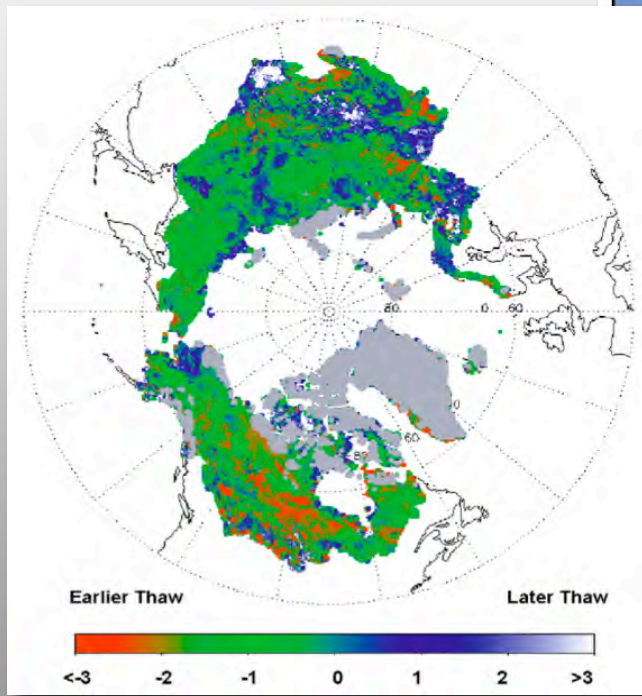
Sturm, Racine and Tape: Fifty Years of Change in Arctic Alaskan Shrub Abundance



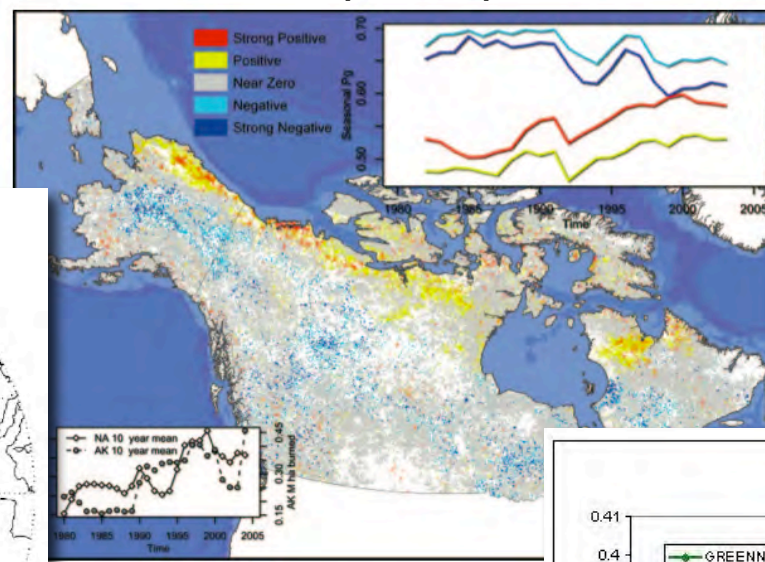
Satellite-Observed “Greening”

Increased plant production

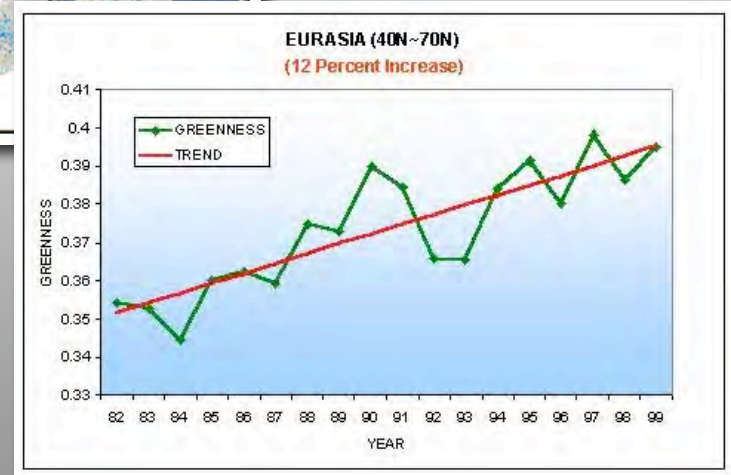
Longer growing period



Start of Growing Season
Change per year over 1988-2001



Vegetation index



From: McDonald t al. 2002, Goetz et al. 2005, Myneni et al. 2001



Impacts on Humans and Wildlife



Shrubs ➡ less lichen forage, harder walking

Dr. Charles Vörösmarty

Director, Complex Systems Research Center
University of New Hampshire

Feedbacks and Global Linkages

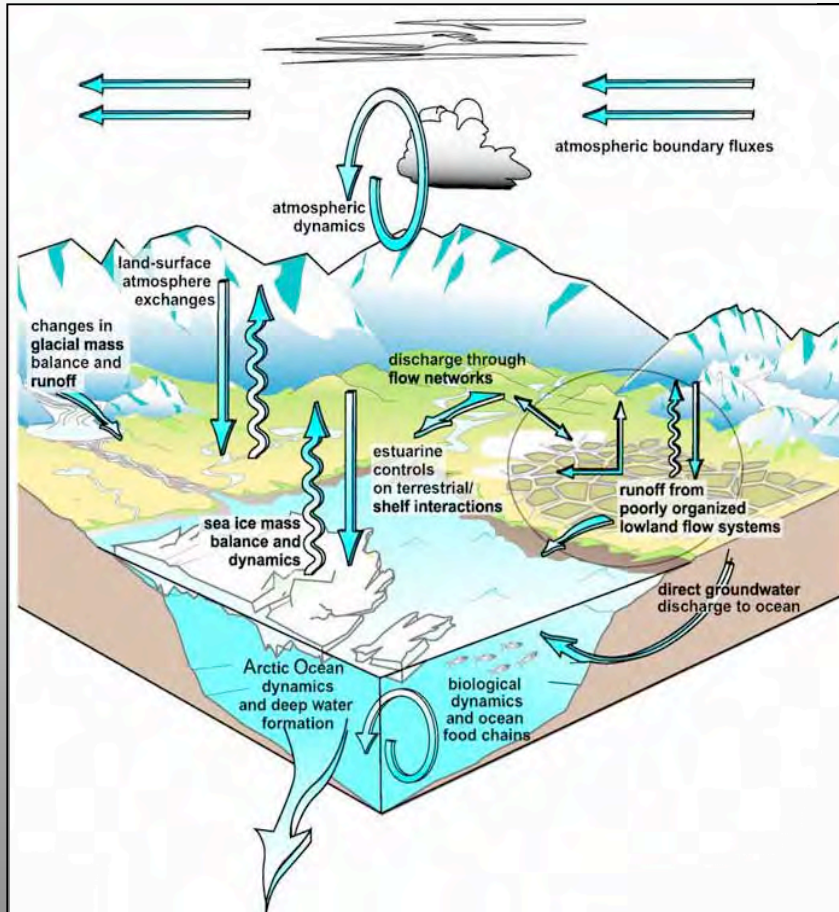
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Arctic Changes Have Global Implications

- Are these changes a collection of independent events or are they linked?
- Are these changes a purely arctic phenomenon?
- Are there tipping points and surprises?

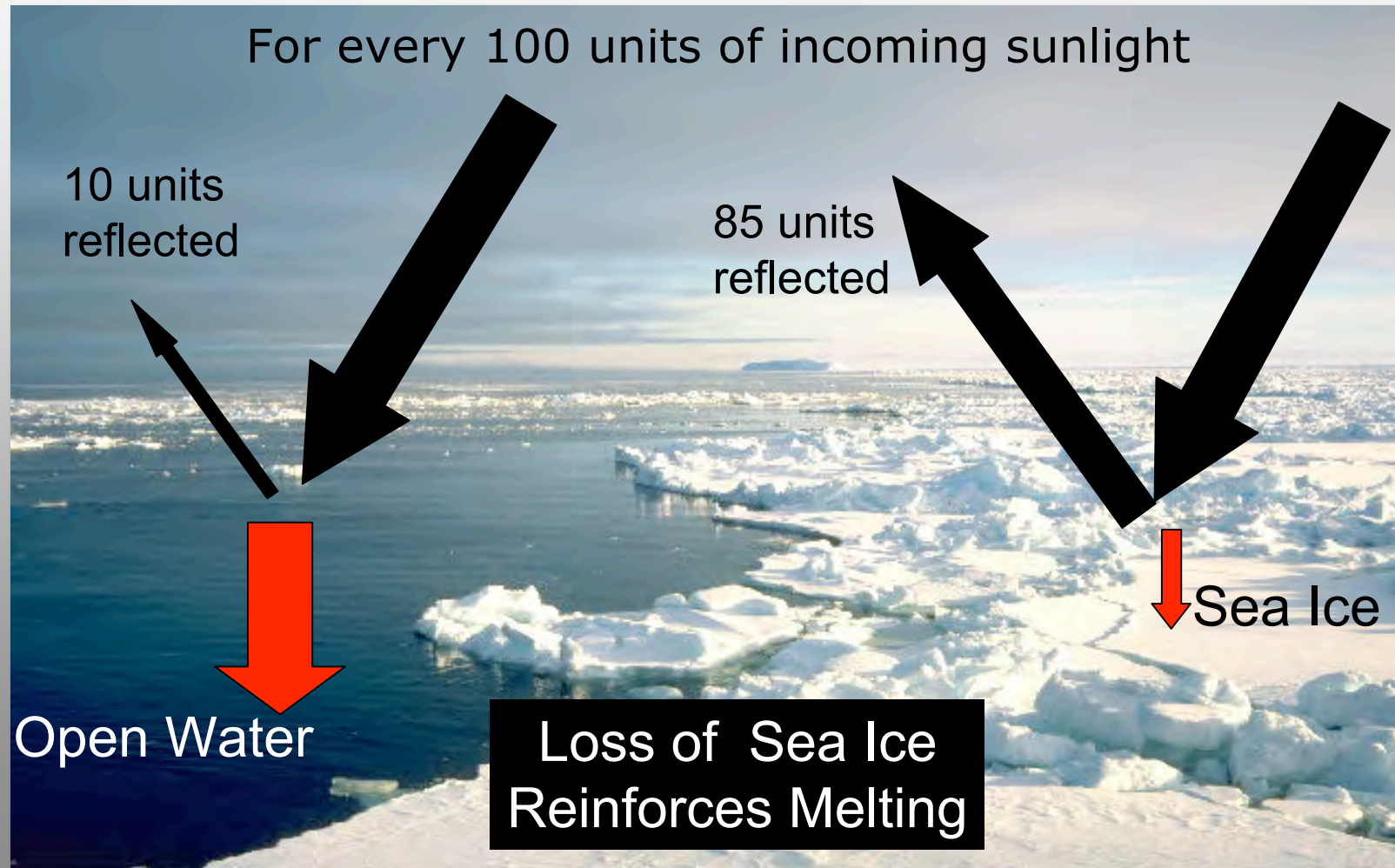
The Arctic has Important Roles in the Larger Earth System



The Arctic Generates Important Planetary Feedbacks

The Ice-Albedo (Reflectivity) Feedback

For every 100 units of incoming sunlight

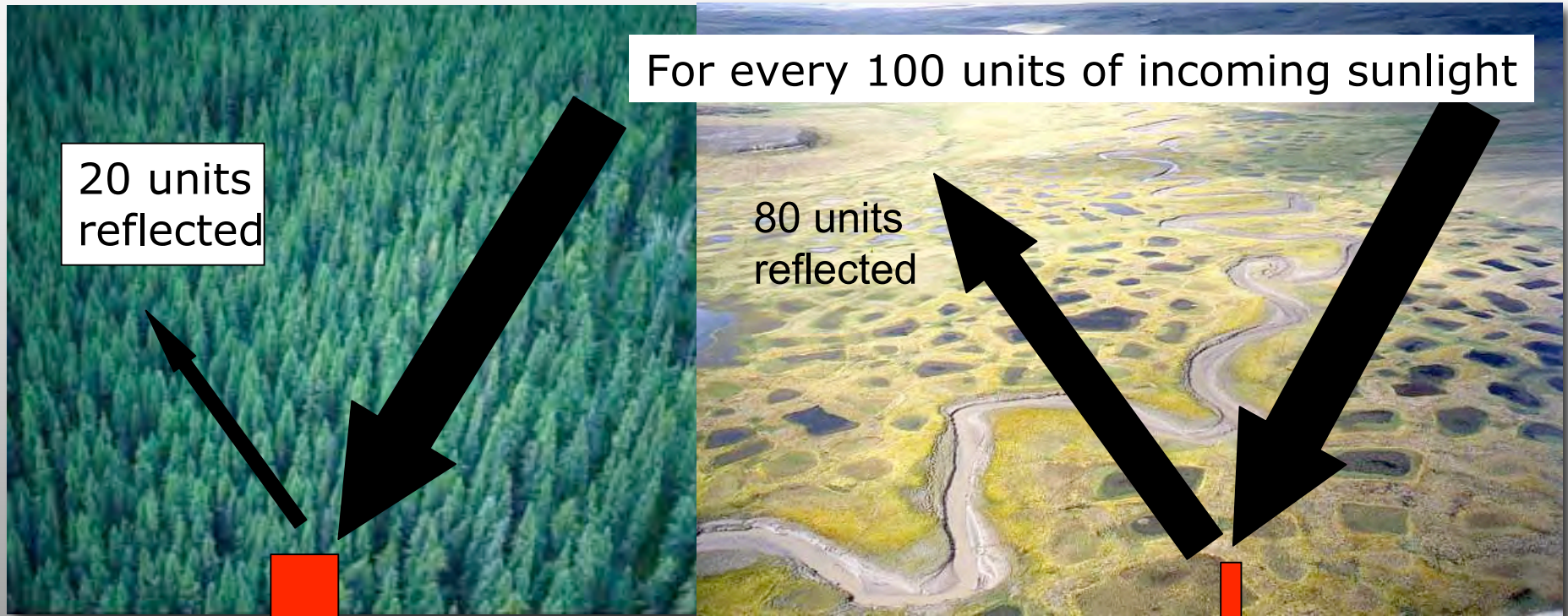


**Loss of Sea Ice
Reinforces Melting**



The Arctic Generates Important Planetary Feedbacks

The Taiga-Tundra Feedback



Forest

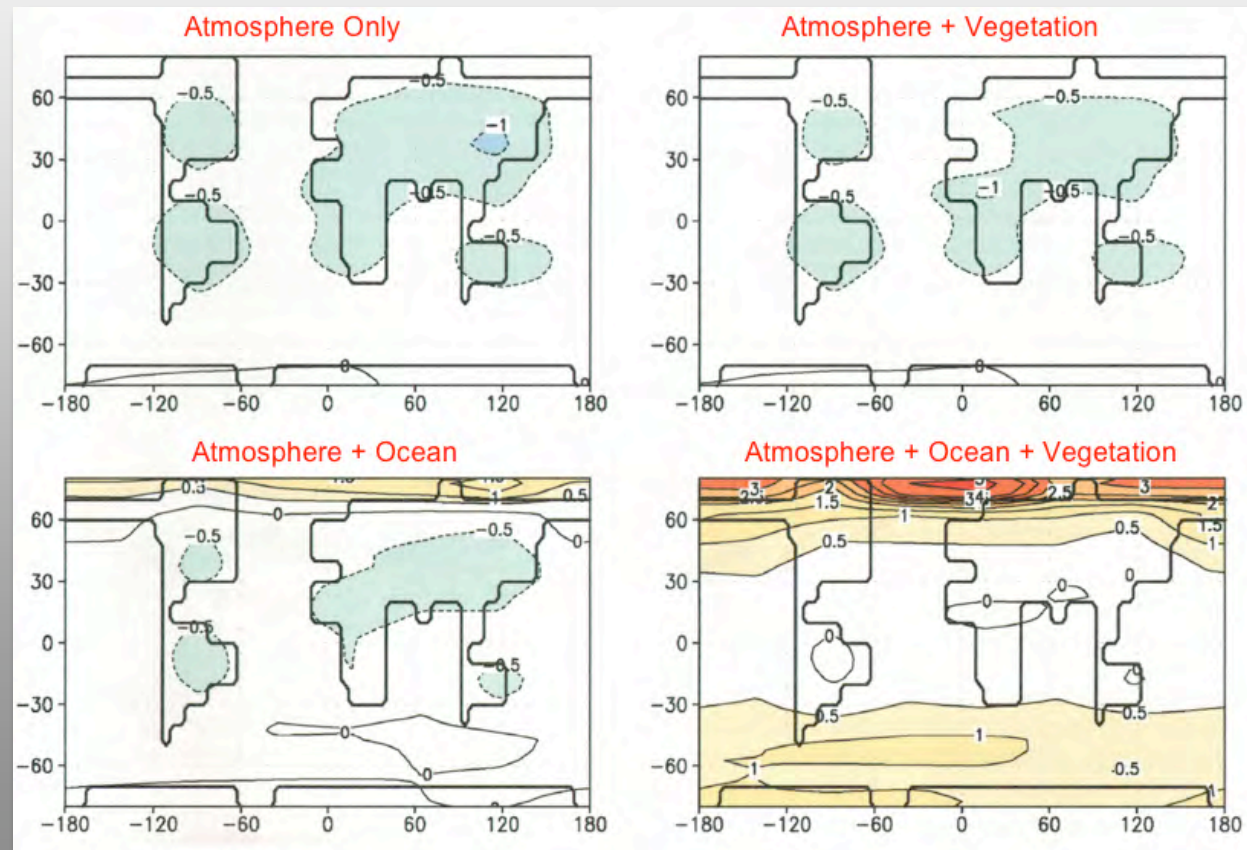
Tundra

Expansion of Boreal Forest
Melts Snow Earlier
Lengthens Ice-Free Period
Reinforces Warming

These Feedbacks Amplify and Reinforce Each Other

Physics and Biology Define the System State

Earth system model sensitivity tests...stepwise inclusion of processes

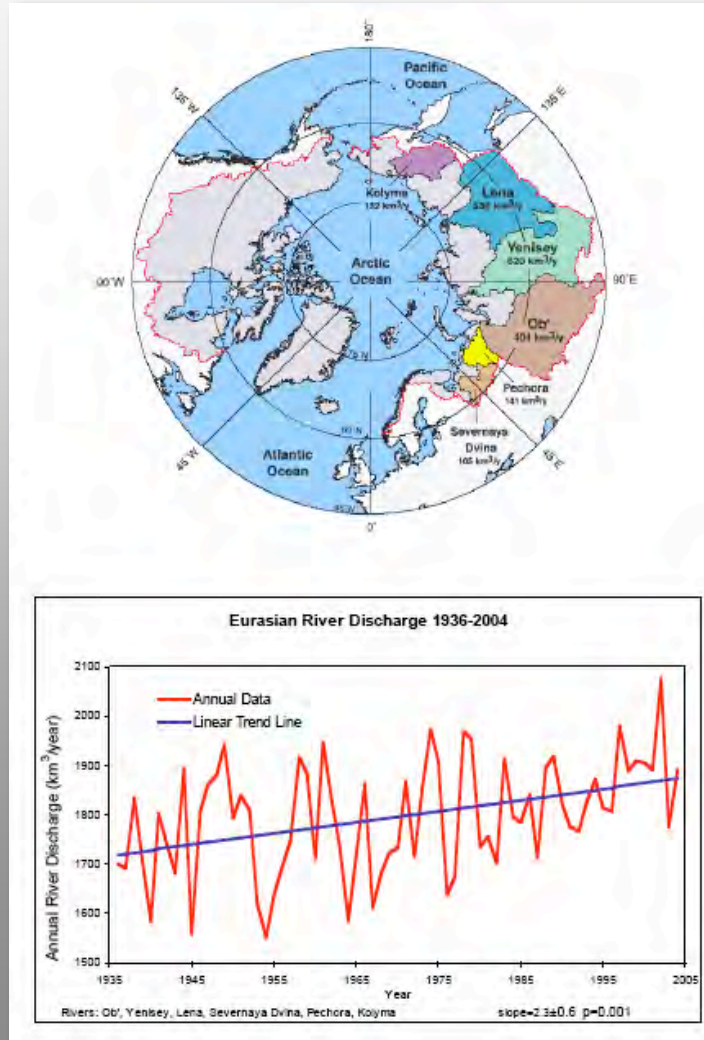


(temperature change relative to common benchmark)

From: Wasson and Claussen 2002

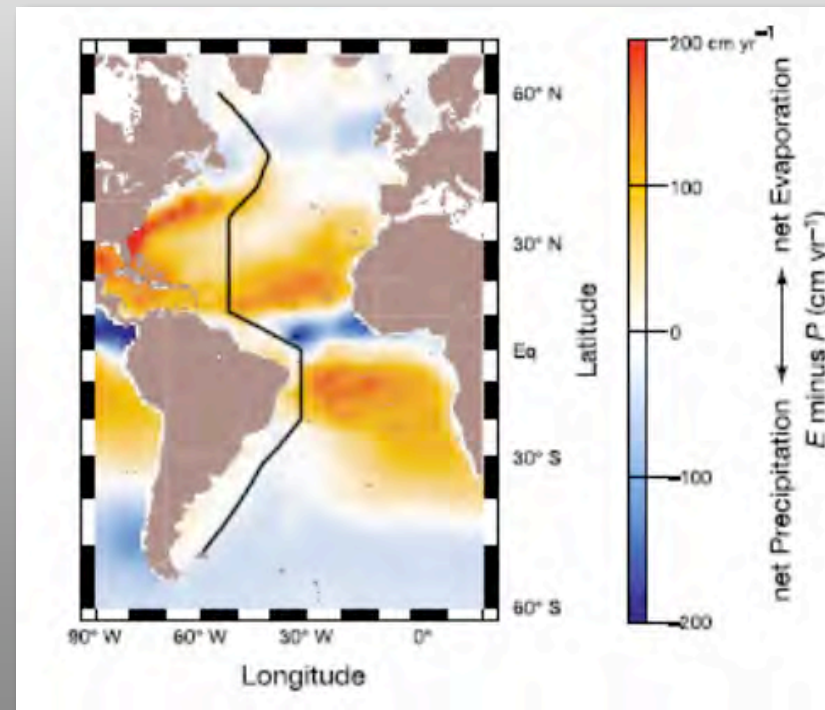
Arctic Freshwater Moves into the Atlantic

Eurasian Arctic Rivers show increasing flow



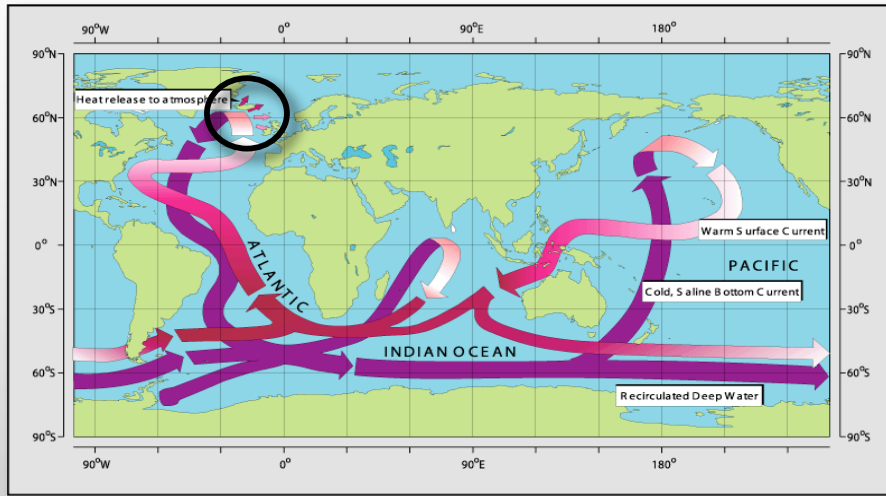
Peterson et al. 2002

Hemispheric-Scale freshening of the North Atlantic Measured Changes over 1950s-1990s



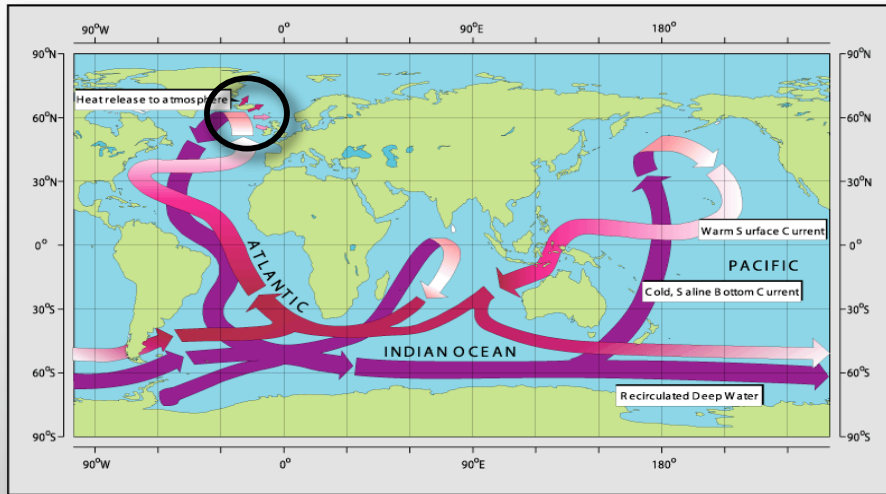
Curry et al. 2003

Arctic Water Drives Ocean Circulation



← Circulation is dependent on freshwater in the Arctic and mixing in high latitude seas

Arctic Water Drives Ocean Circulation

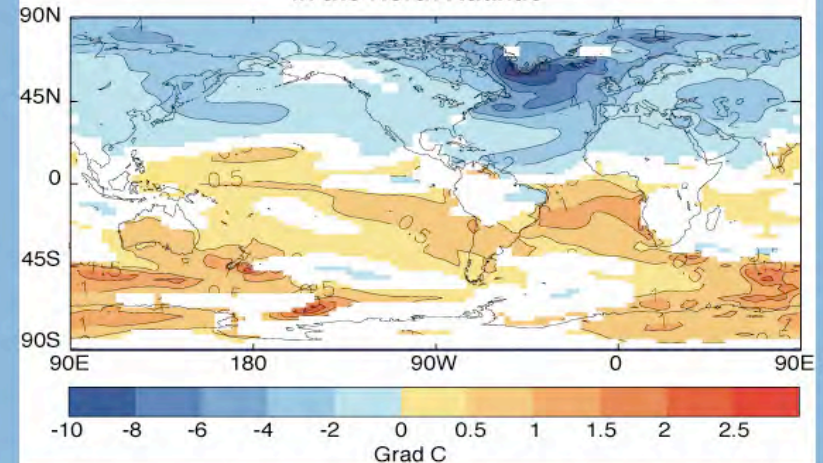


← With increasing freshening... a potential and potentially rapid slowdown could occur with important implications on planetary heat balance

Consequences of Arctic hydrological change thus could:

- have thresholds
- invoke global footprints →
- occur when we have many more billions of people to feed and support

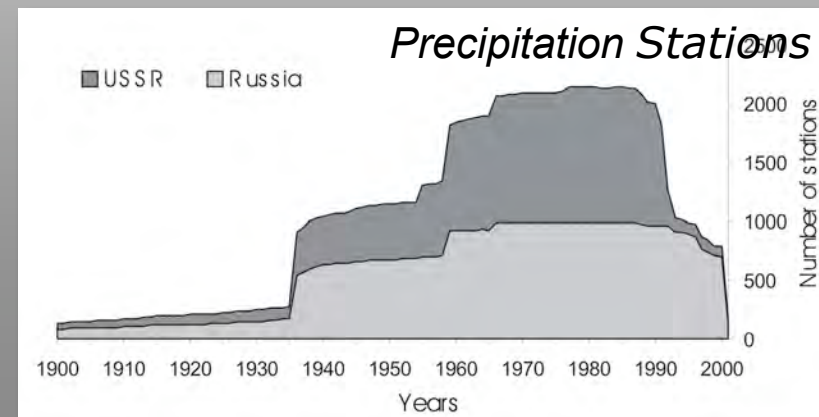
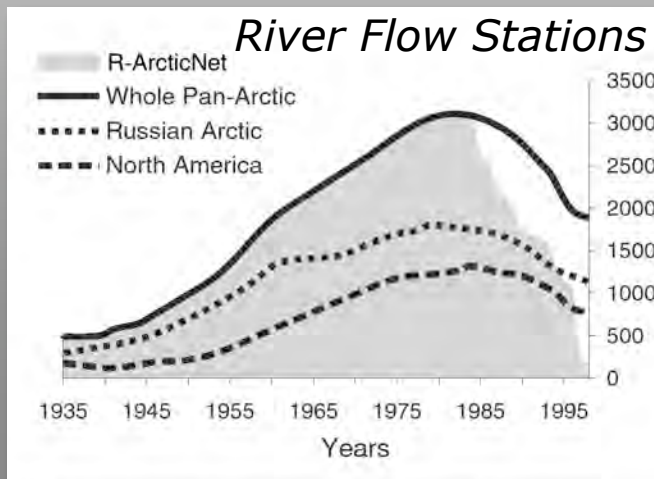
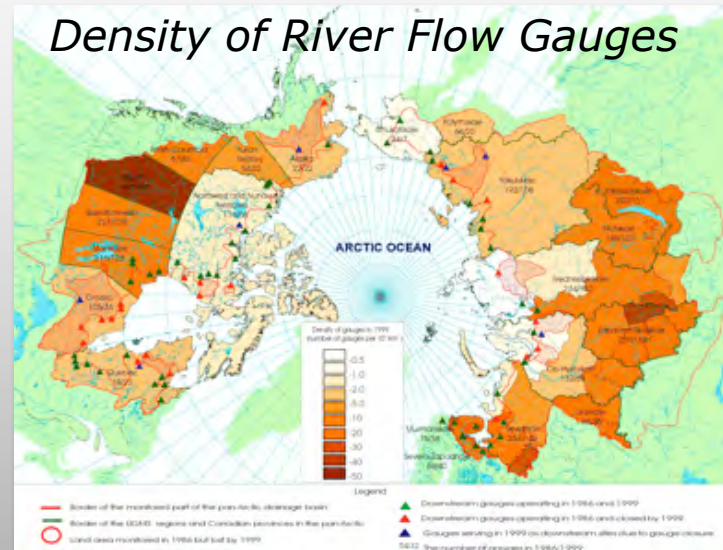
Change in surface air temperature after a collapse of the thermohaline circulation in the North Atlantic



Average change of annual mean surface air temperature over the years 50-100 after a collapse of the THC in HadCM3. Areas with temperature differences that fall within the natural variability of the control run (at the 95% confidence level) appear as white. (courtesy of Michael Vellinga).

Need for Monitoring

Monitoring of the changing state of the pan-Arctic is far from complete and remains in jeopardy



Dr. Joshua Schimel

Chair and Professor of Environmental Studies
University of California, Santa Barbara

Challenges and Opportunities



Policy Issues

Change creates both challenges and potential opportunities

How to minimize damage to the U.S., while maximizing our benefits?

Three types of responses:

- Minimize change (mitigation)
- Manage change (adaptation)
- Take advantage of opportunities that arise

National to Global

Biggest challenges of warming will be through water:

A more “energetic” water cycle:

- More evaporation- worse droughts & bigger storms
- Loss of the mountain snowpack:
Increased forest and wildland fire

Higher sea level:

- Coastal storm erosion and storm surge:
Florida, the Gulf coast, and northern Alaska

Major Changes in the Arctic

Warming means melting:

Loss of sea ice:

- Coastal erosion- loss of coastal communities
- Altered marine conditions & resources

Melting permafrost:

- Infrastructure- buildings, roads, pipelines, etc.
- Exploration- "hard frozen" days are decreasing

Major Changes in the Arctic

- Changing vegetation
- Altered subsistence and game hunting: changing lifestyles



Approaches to Change

Minimizing change: *Must be national to international*

- The economy is global
- Energy costs will remain high

Thus: the future economy will be driven increasingly by alternative energy, energy efficiency, and “climate friendly” technology.

Investing in developing that future economy is likely to benefit the U.S. regardless of what other nations do and how much the climate changes.

Specific Arctic Policy (managing and taking advantage)

We must respond to changing:

Ocean conditions:

- Coastal settlements

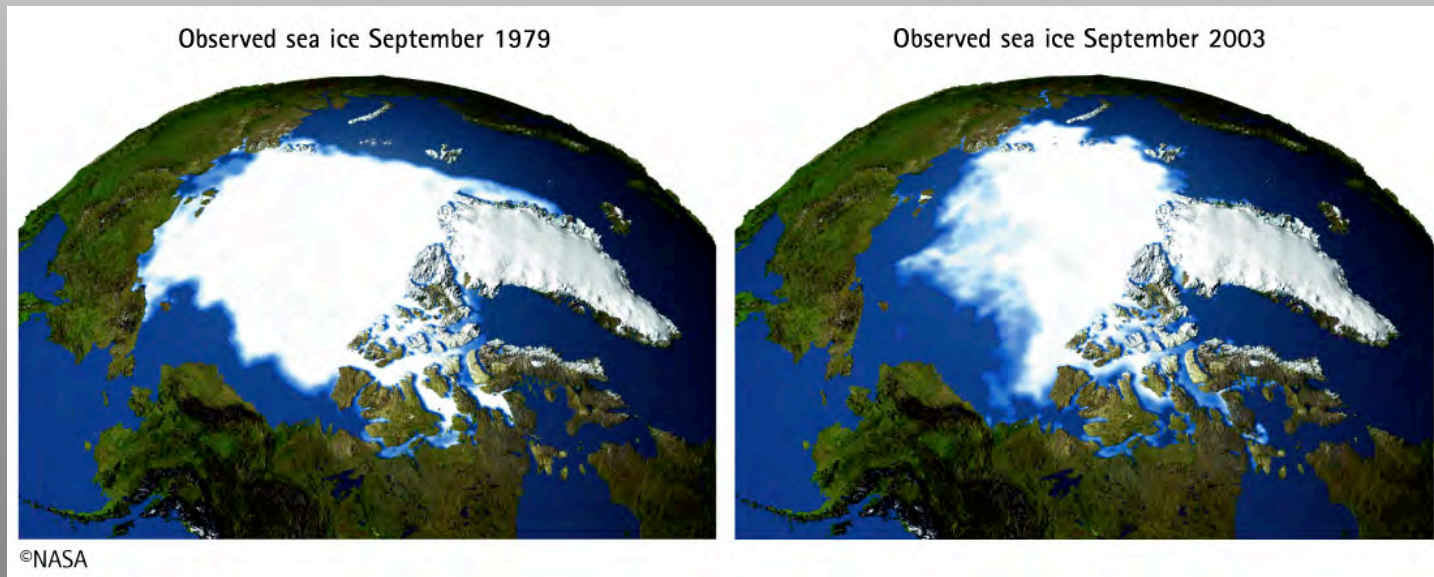


Specific Arctic Policy (managing and taking advantage)

We must respond to changing:

Ocean conditions:

- Coastal settlements
- Marine resources changing
- Sea lanes opening up



Specific Arctic Policy (managing and taking advantage)

We must respond to changing:

Land conditions:

- Infrastructure (residential, transportation, industry) is at risk



Specific Arctic Policy (managing and taking advantage)

We must respond to changing:

Land conditions:

- Infrastructure (residential, transportation, industry) is at risk
- Natural resource industries changing
- Subsistence resources changing

A photograph showing a long pipeline stretching across a valley between snow-capped mountains. The pipeline is supported by wooden posts and runs from the foreground into the distance. The mountains are rugged and covered in snow, with some rocky outcrops visible. The sky is a pale blue with light clouds. The overall scene is a vast, open landscape.

Example of:

- Good science
- Good planning
- Good engineering
- Good policy

\$60 Million per day

The Challenge

What We Know Now

- Changes are here, real, pronounced, and affecting the entire Arctic system
- The changes are rapid and global
- We must deal with the Arctic as a system, and not piecemeal
- Arctic change is already affecting commerce and people

**This set of changes are going to require policy,
and good policy requires good information**

The Challenge

What We Can Offer

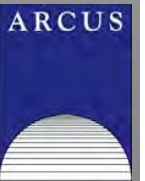
- Information about what, when, and how changes are occurring
- The implications of change

**It's urgent that scientists and
policy makers talk now**

Thank You

Questions?

Thank you to Senator Murkowski's office



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