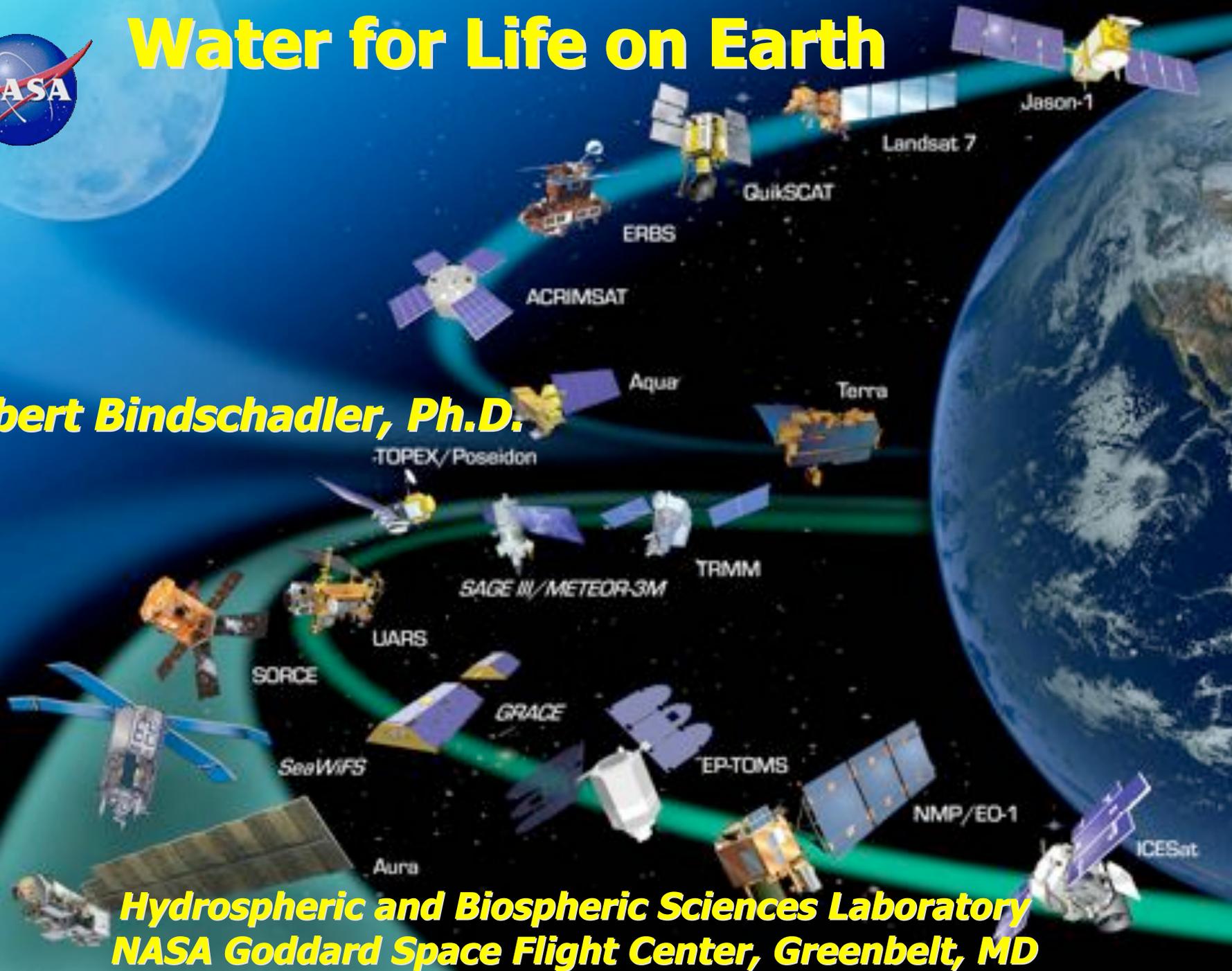


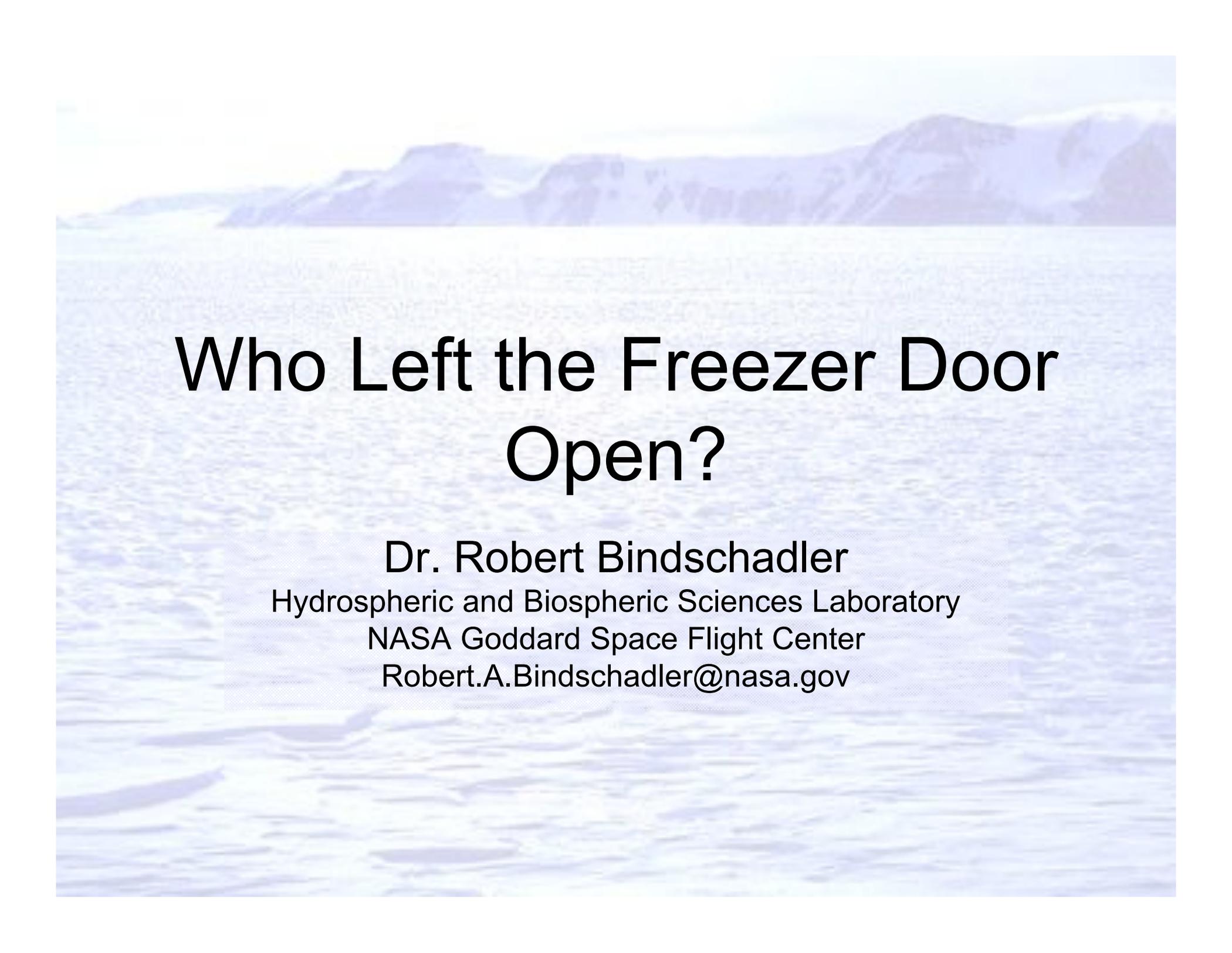


Water for Life on Earth

Robert Bindshadler, Ph.D.



**Hydrospheric and Biospheric Sciences Laboratory
NASA Goddard Space Flight Center, Greenbelt, MD**



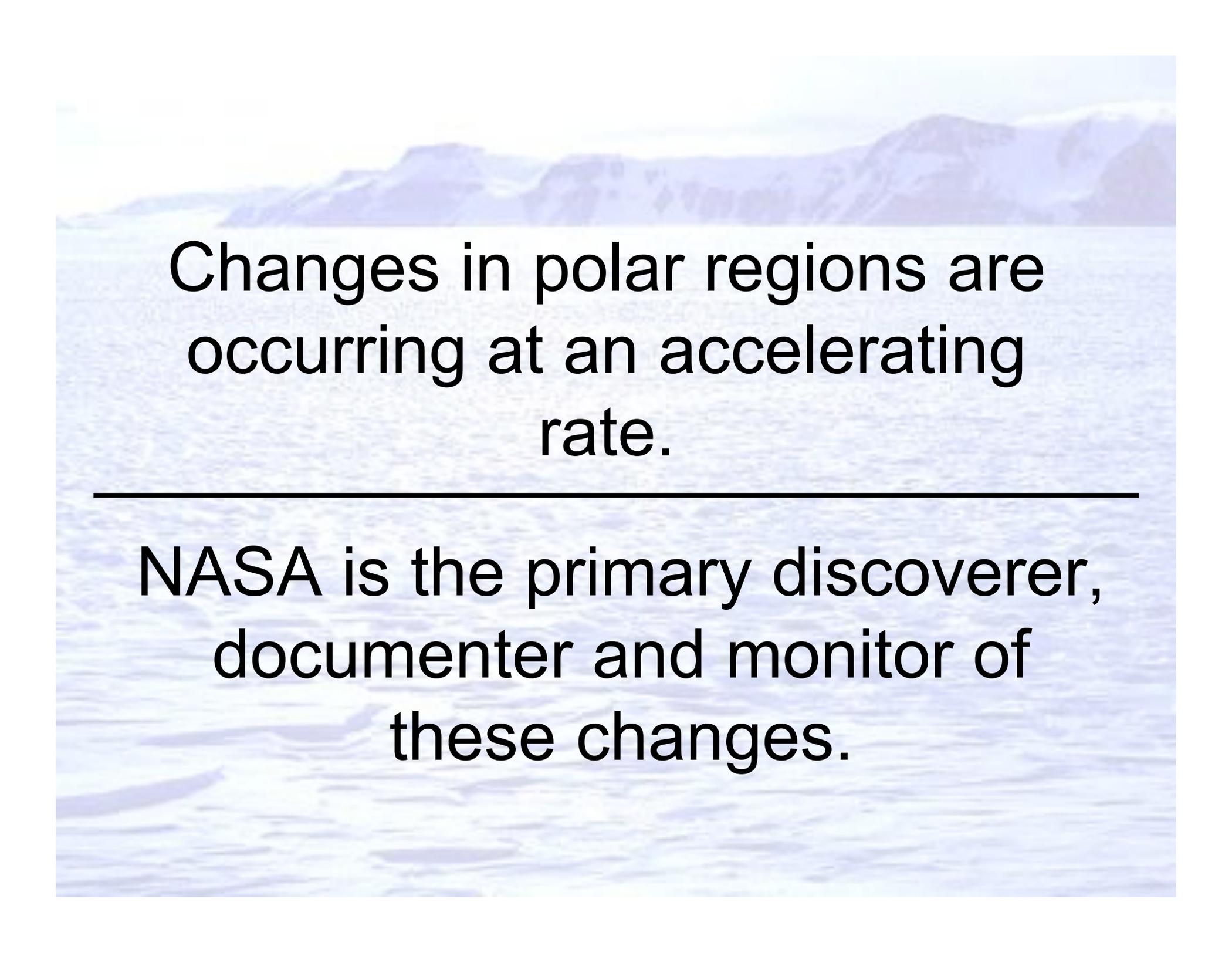
Who Left the Freezer Door Open?

Dr. Robert Bindshadler

Hydrospheric and Biospheric Sciences Laboratory

NASA Goddard Space Flight Center

Robert.A.Bindshadler@nasa.gov

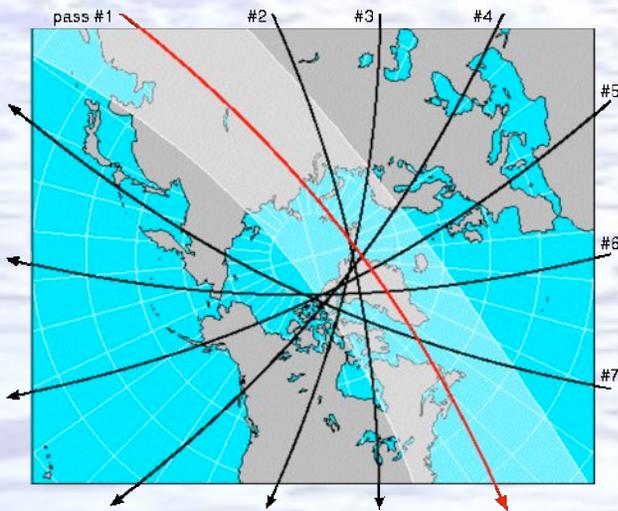


Changes in polar regions are occurring at an accelerating rate.

NASA is the primary discoverer, documenter and monitor of these changes.

Remote sensing has revolutionized polar research

Remote sensing is a natural solution to the remoteness, harshness and dangers of polar regions.



Near-polar orbiting satellites provide denser observations of the polar regions than of mid- or low-latitude regions.

Questions for you

- Who has seen:
 - “March of the Penguins”?
 - Shackleton films or exhibits?
 - Jacques Cousteau’s Antarctic films?
 - Other “polar” films or documentaries?
 - “The Day After Tomorrow”?

Questions for you

- How far north/south have you been?
 - beyond the Arctic or Antarctic Circles?
 - seen the “midnight Sun” or aurora?

Polar Regions

Remote, harsh, unforgiving



...and full of surprises!!

Tonight's Story

The Cast

Dollars and Sense

Get Physical

The Double Whammy

The Triple Whammy

The Day After Tomorrow-corrected

A wide, flat, snow-covered landscape under a pale sky, with a range of snow-capped mountains in the distance. The foreground is a vast, level expanse of white snow, leading to a low horizon line. In the background, a range of rugged mountains is visible, their peaks and ridges covered in snow. The sky is a uniform, light color, suggesting an overcast or hazy day. The overall scene is desolate and cold.

The Cryospheric Cast

Ice sheets and glaciers



Primary impact: sea level

Antarctica is the highest, brightest, coldest, driest, windiest continent on Earth

Ice sheets contain ~75% of all fresh water and can raise sea level 65 meters

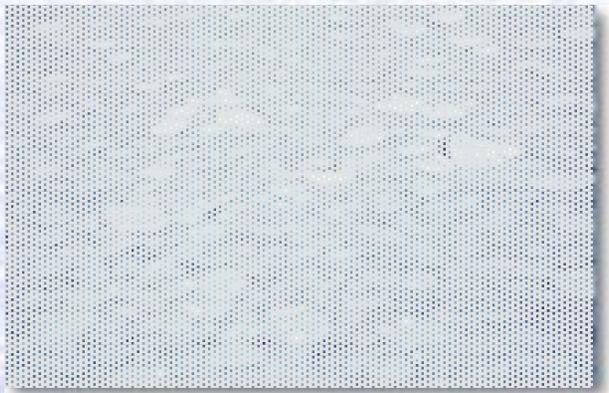
Ice sheets and
glaciers



Sea ice

Primary impact: heat balance
(both local and global)

Ice sheets and
glaciers



Sea ice

Seasonal snow,
lake and river ice

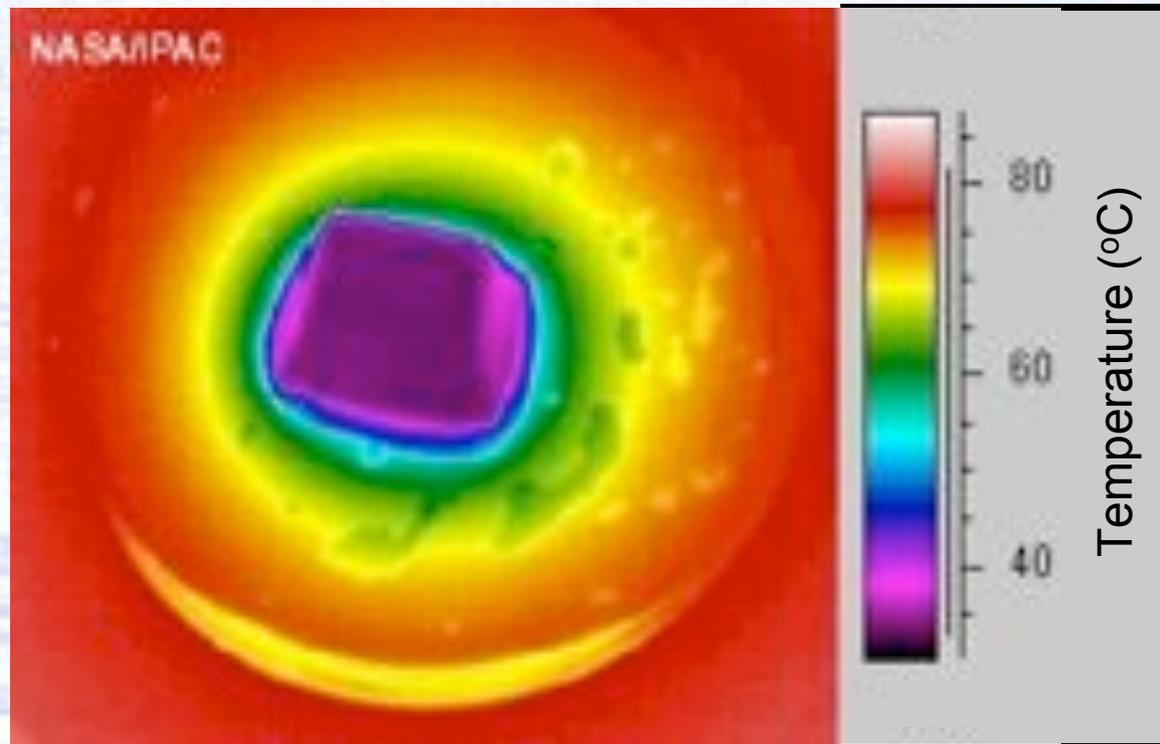


Primary impact: water resource

Dollars and Sense

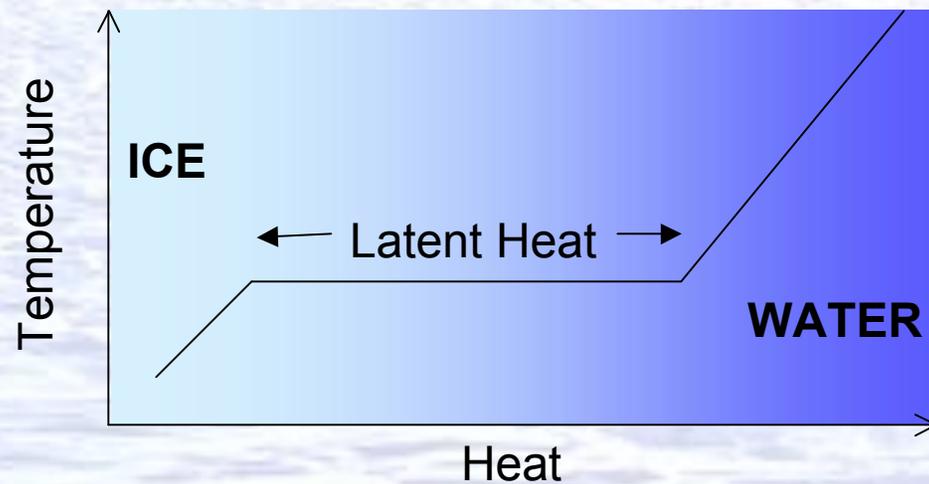
- The daily loss of land in Louisiana?
 - 43 acres per day (33 football fields)
- Cost of 1 meter rise in sea level to US alone?
 - Approximately \$400 billion
- Economic impact of an ice-free Arctic Ocean?
 - Priceless!!

Physics Lesson



Latent Heat of Fusion

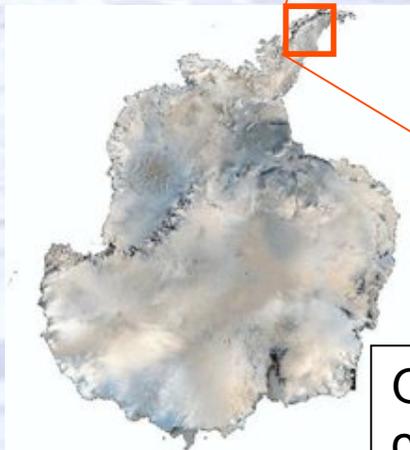
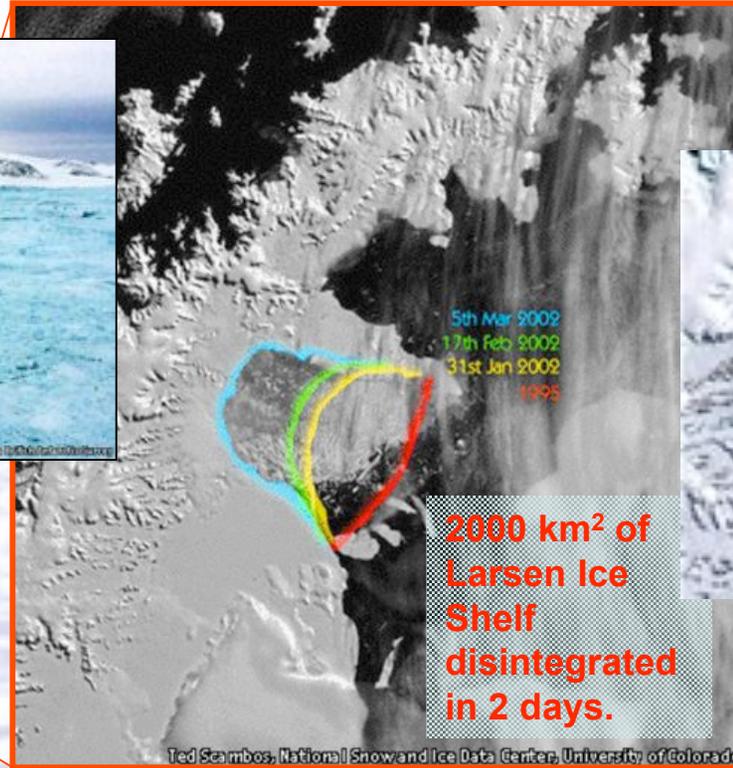
- Start with ice (at 0°C)
 - Add enough heat to melt
 - End with water at 0°C



THE POINT:
Melting
represents a
thermal
threshold that
requires a lot of
heat

- Start with water (at 0°C)
 - Add same amount of heat
 - End with water at 80°C (176°F)!!!

Disintegrating Ice Shelves: A Climatic Threshold

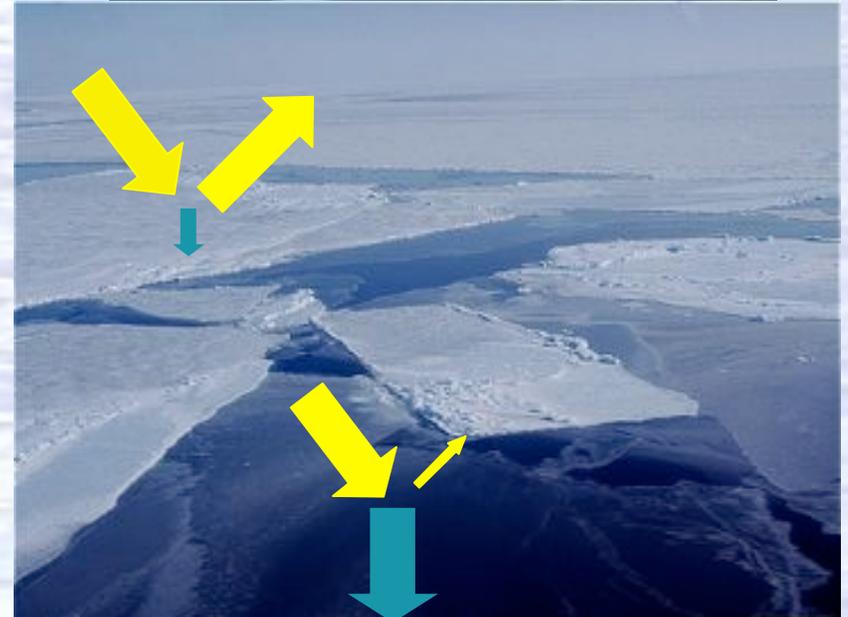


Antarctic Peninsula temperatures have increased 2.5°C in 50 years.

Glaciers feeding ice shelves accelerate after ice-shelf removal confirms "ice-shelf buttressing"

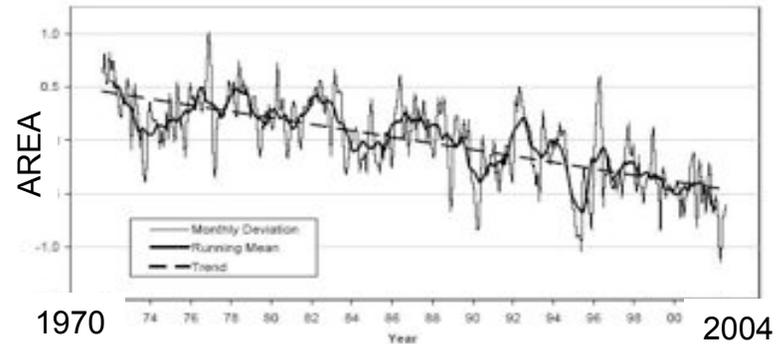
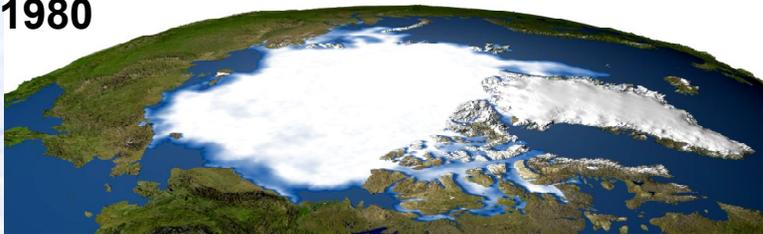
The Double Whammy: Positive Feedbacks of Sea Ice

- What happens when sea ice environment warms?
 - Where sea ice is:
 - Thinner ice allows greater heat exchange between ocean and atmosphere
 - Where sea ice isn't:
 - Exposes dark ocean and absorbs 5 times more solar radiation (ice-albedo feedback)
- Both processes act to amplify thermally-driven change - a “positive feedback”

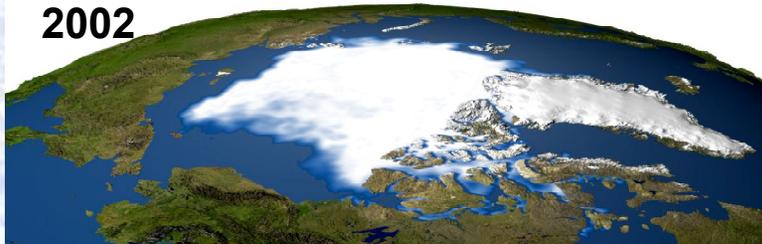


Decline of Perennial Arctic Pack Ice

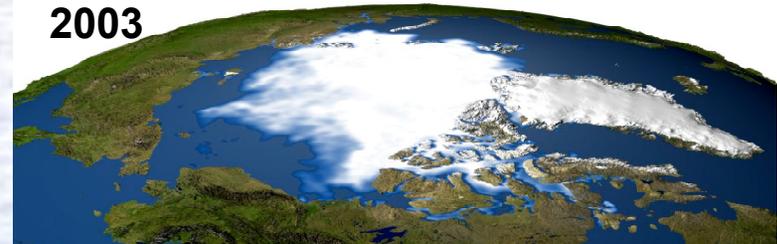
1980



2002



2003

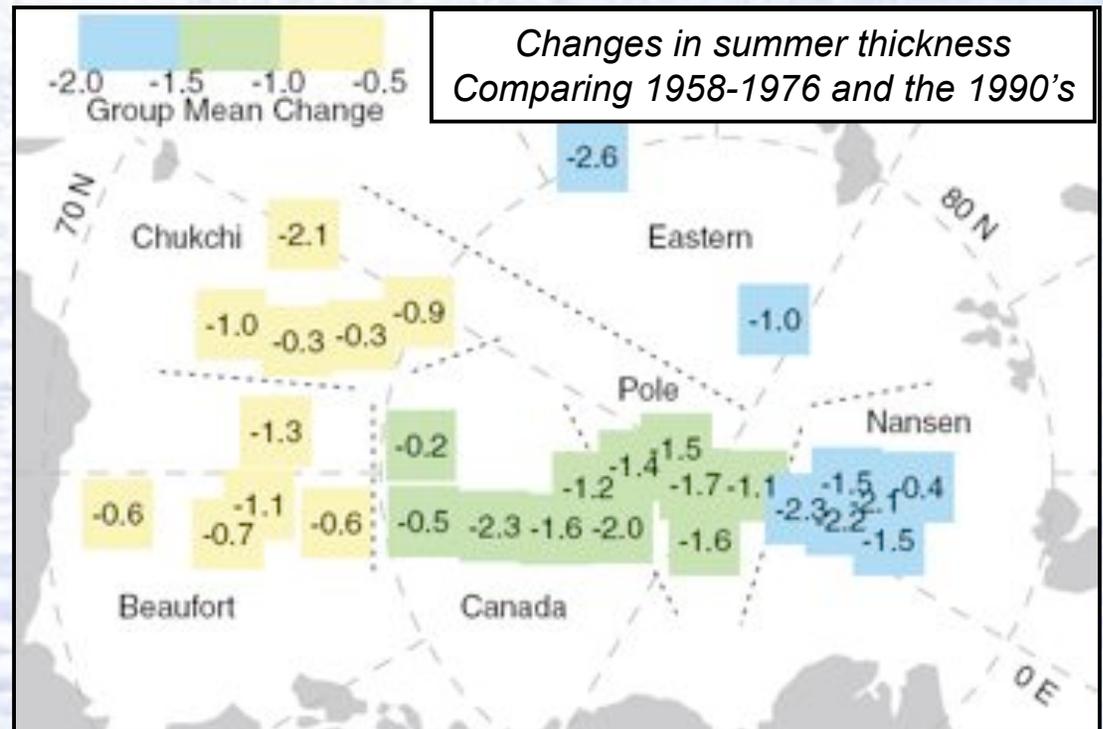
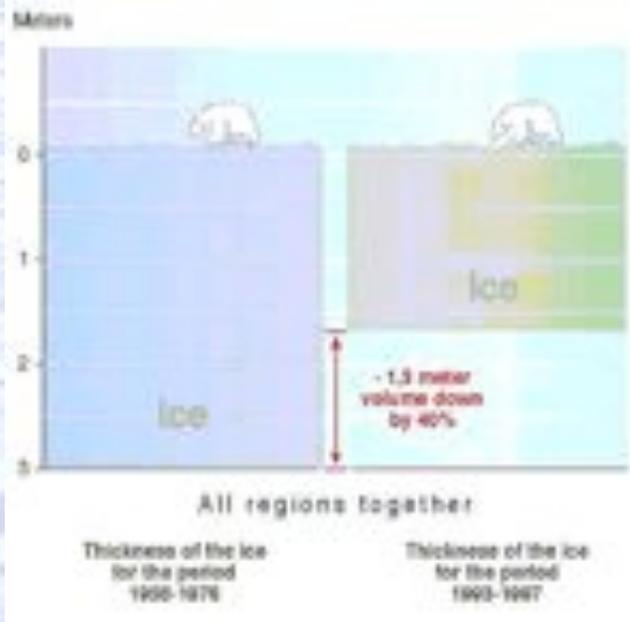
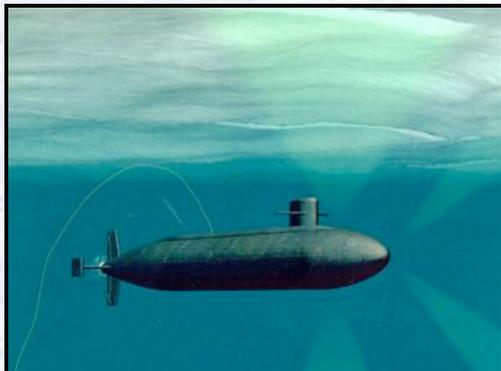


2002, 2003 and 2005 set new records for minimal summer ice extent during the satellite era (i.e., past 30 years)

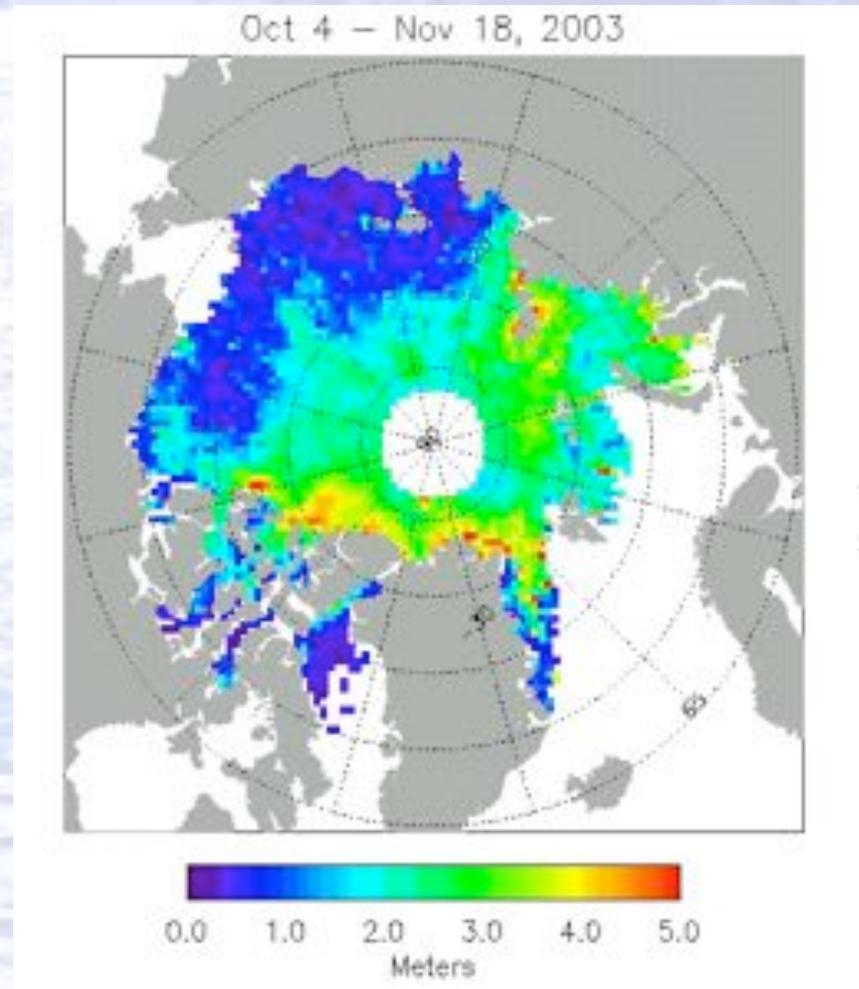
Summer minimum decreasing at 9.2% per decade

37% of 2^*CO_2 warming caused by ice-albedo feedback

Thinning Sea Ice Everywhere



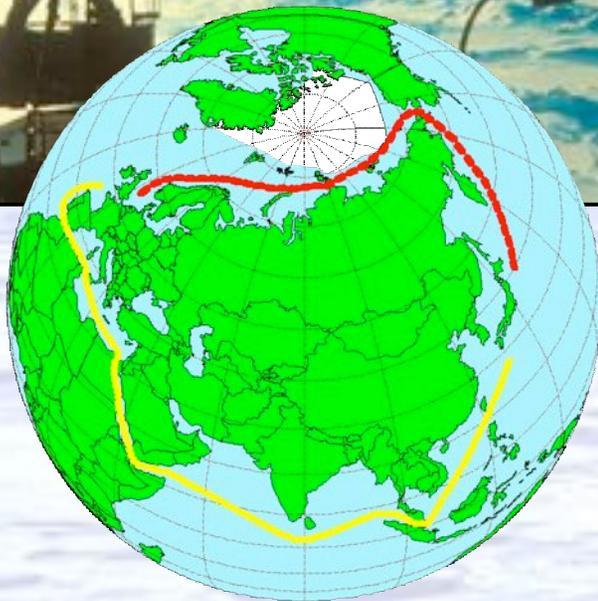
Now possible from space



Winners and Losers of Ice-Free Arctic Ocean

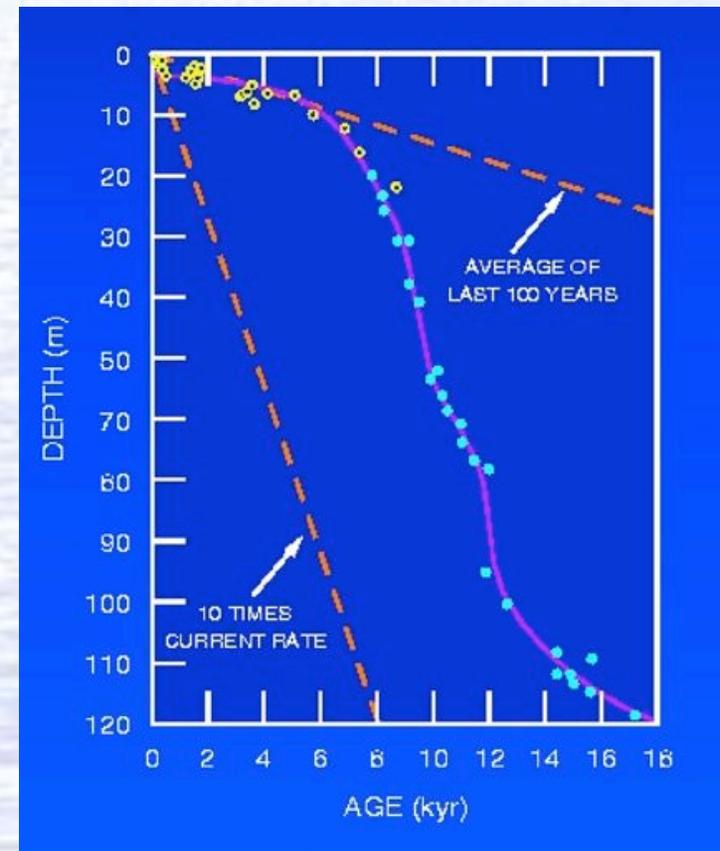


Ice-free Arctic Ocean in summer may occur as early as 2050



Ice Sheets and Sea Level Change

- Steady over past 4000 yrs
 - 1/3 world's population now lives in coastal zone
- Periods of faster rise
 - Up to 50 times present rate
 - Can't be due to melting alone
- Rate of rise as important as magnitude



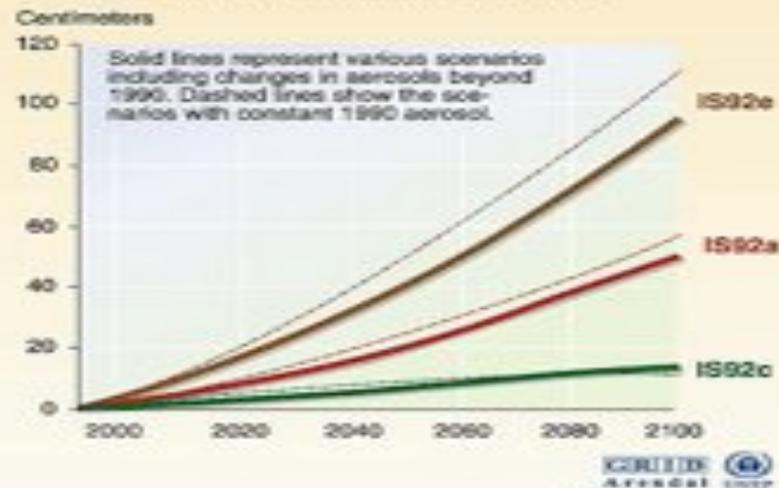
Sea Level Prediction

Sea level rise due to global warming

Sea level rise over the last century

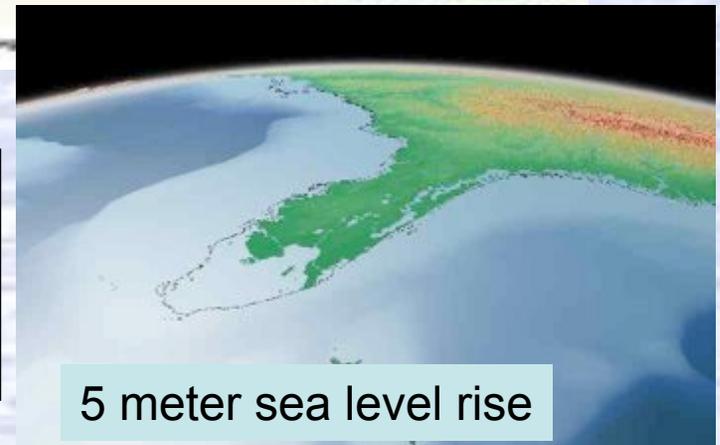


Sea level rise scenarios for 2100



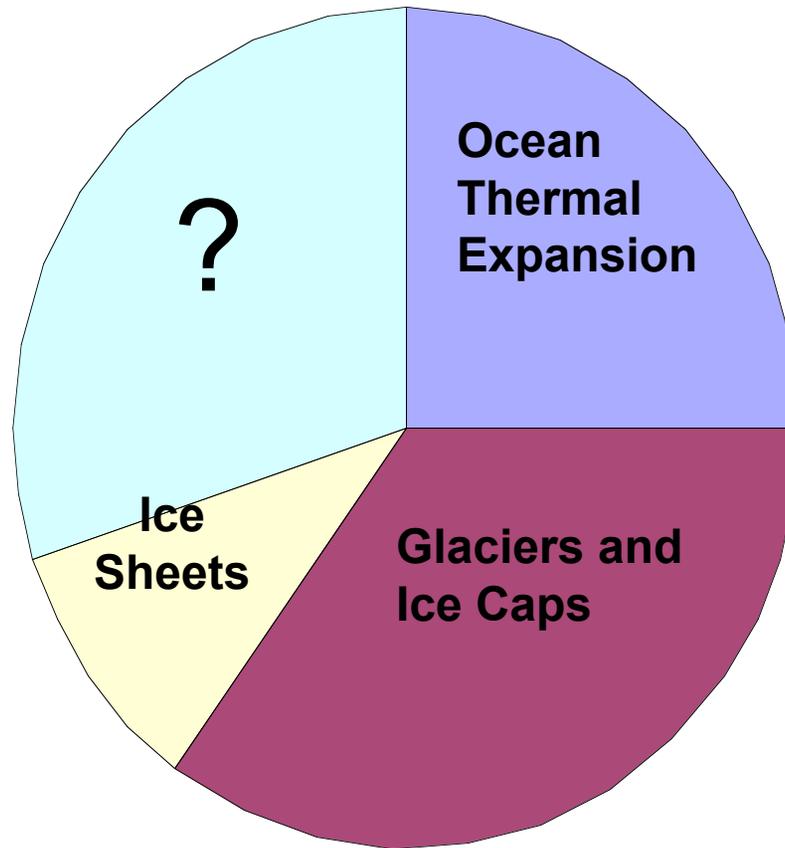
Source: Climate Change 2007, The science of climate change, contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2007. Sea level rise over the last century, adapted from Somerville and Lebedev, 1997.

- IPCC report predicts accelerating sea level rise
- Probably an underestimate



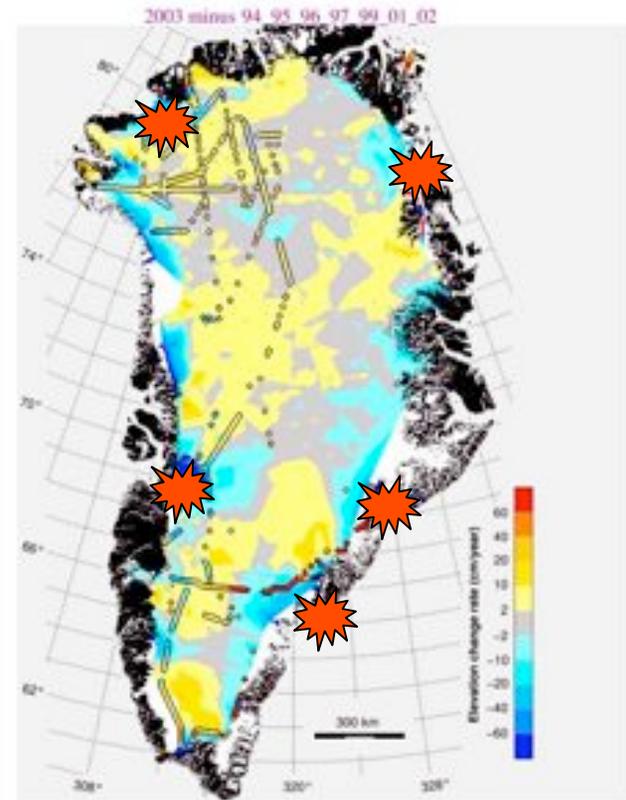
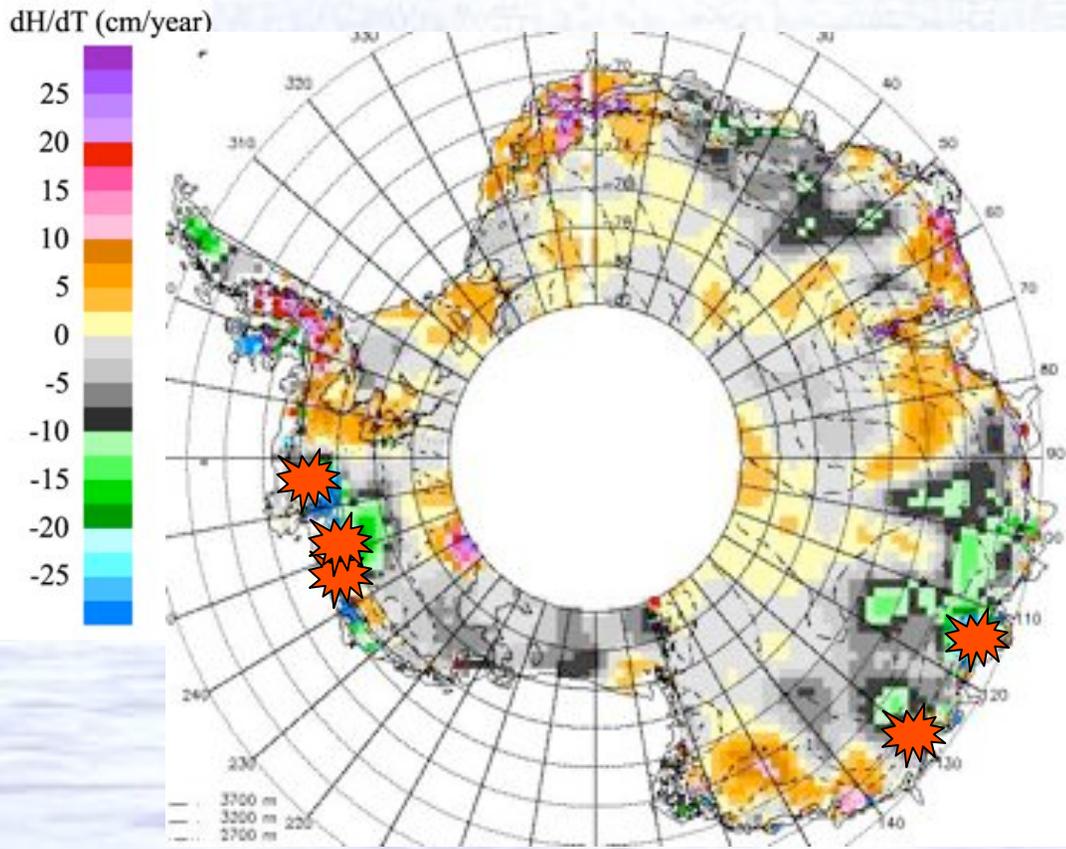
5 meter sea level rise

Where is the water coming from?



Present rate = 2 mm/year

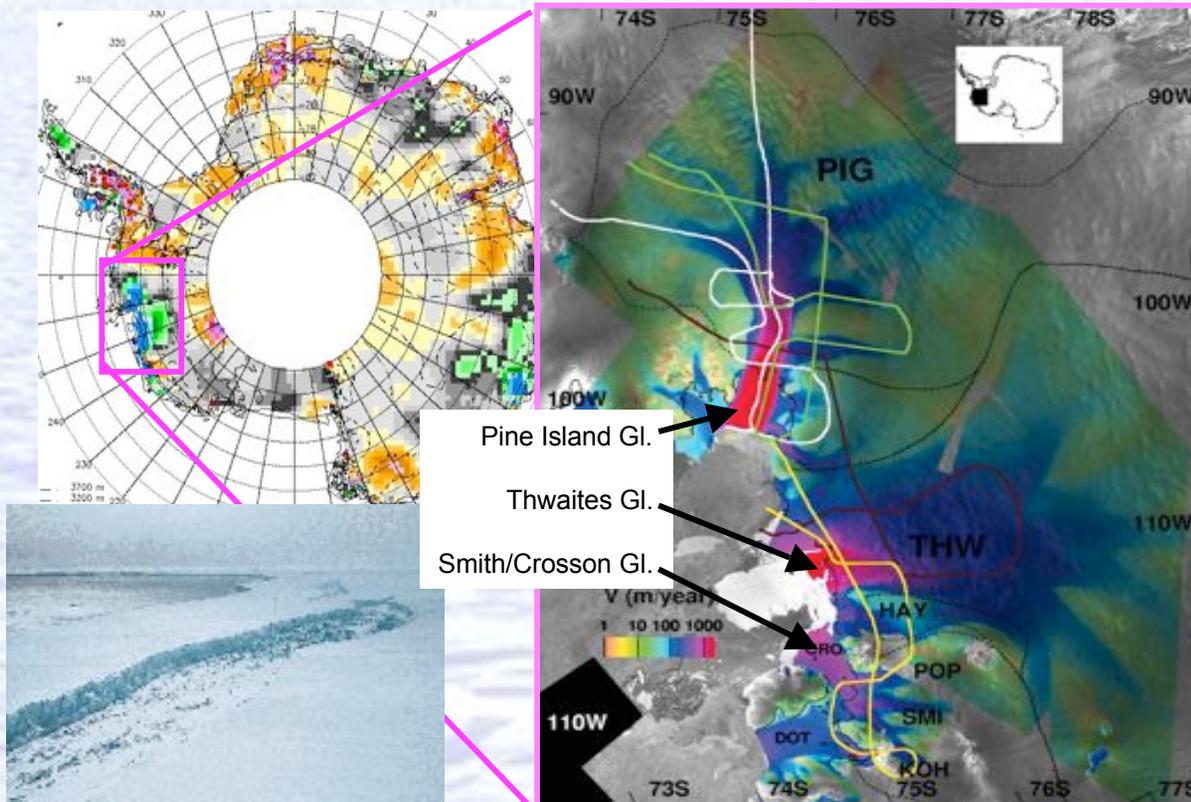
Satellite Data show Ice Sheets are Changing



Rapid thinning is concentrated at outlet glaciers exiting deep subglacial valleys

Fingerprint of Collapse

What would be the signs of a collapsing ice sheet?



- Thinning increasing towards coast (satellite altimetry)
- Flow acceleration (InSAR)
- Retreat of grounding line (Landsat)
- Calving of large icebergs (MODIS)

All glaciers in this area exhibit these signs.
All observations made by satellite sensors.

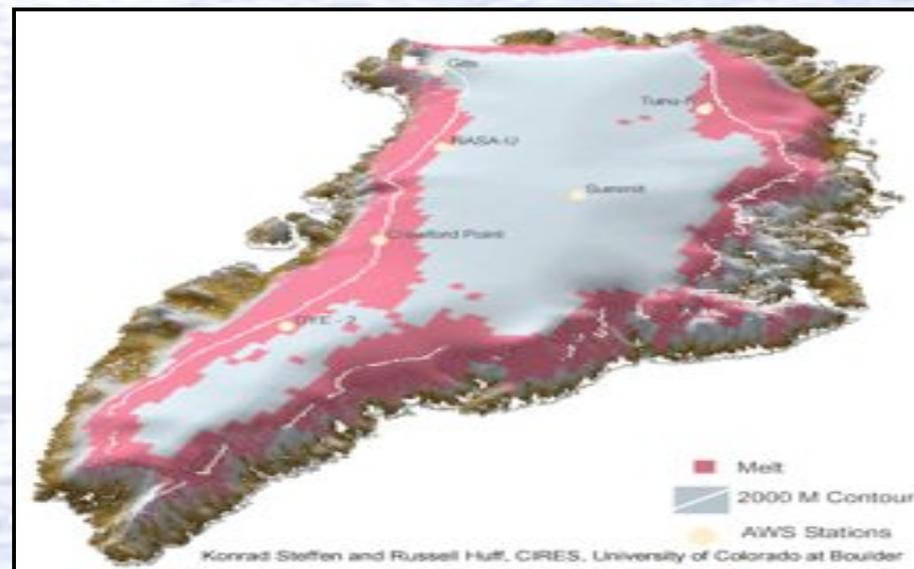
The Triple Whammy

Once again, it's the heat

- Heat produces meltwater that runs off into the oceans
 - Greenland is a very, very big glacier
 - 10 times larger than all glaciers and ice caps combined

50% of Greenland ice loss is
by melting

Melting is increasing



The Triple Whammy

Once again, it's the heat

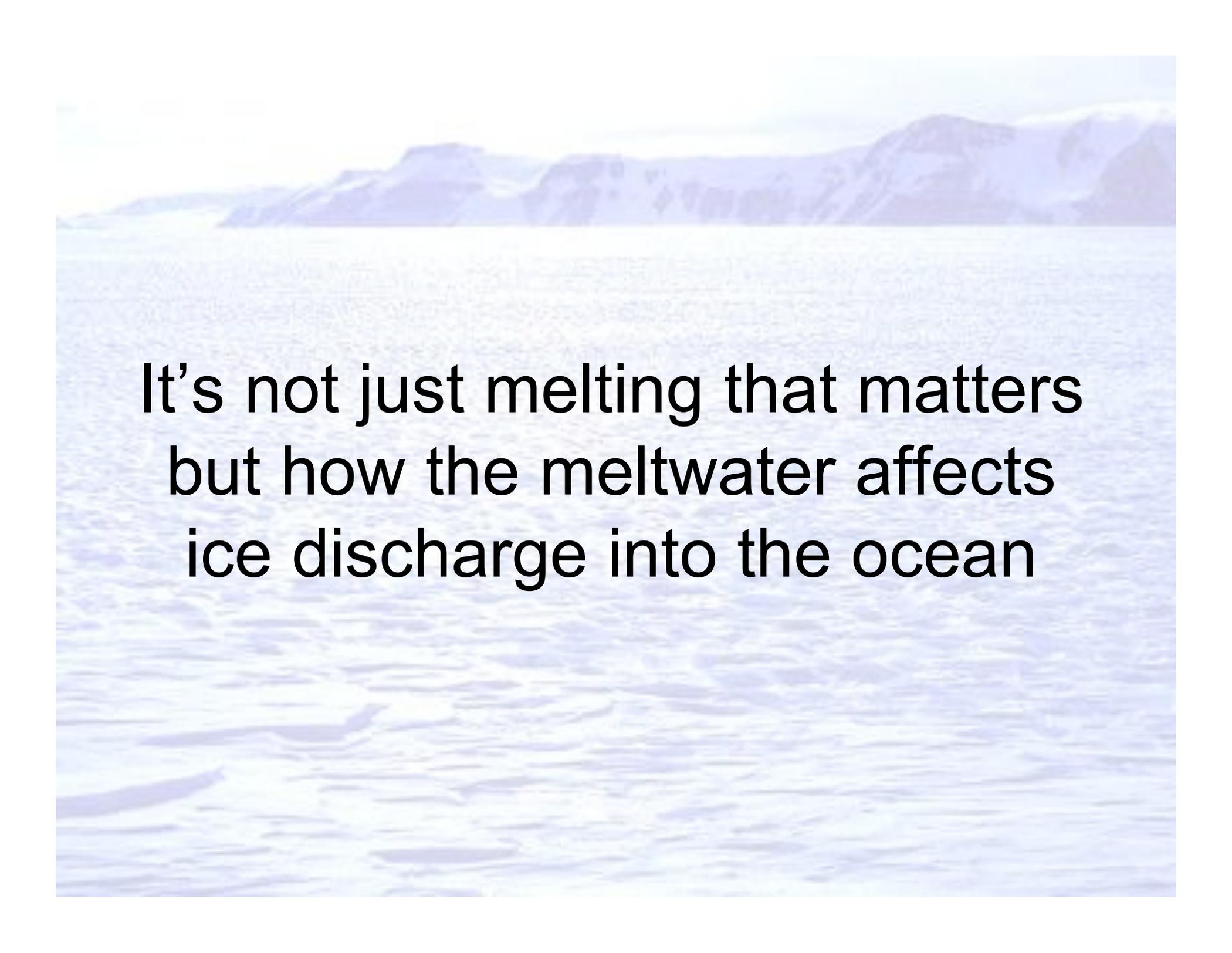
- Heat produces meltwater that runs off into the oceans
 - Greenland is a very, very big glacier
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- **As this water flows along the glacier bed, it accelerates ice flow**
 - More rapid ice discharge thins ice sheet



The Triple Whammy

Once again, it's the heat

- Heat produces meltwater that runs off into the oceans
 - Greenland is a very, very big glacier
 - 10 times larger than all glaciers and ice caps combined
- As this water flows along the glacier bed, it accelerates ice flow
 - More rapid ice discharge thins ice sheet
- Warmer ocean water melts the underside of ice shelves reducing their buttressing of outlet glaciers
 - the “cork in the bottle”

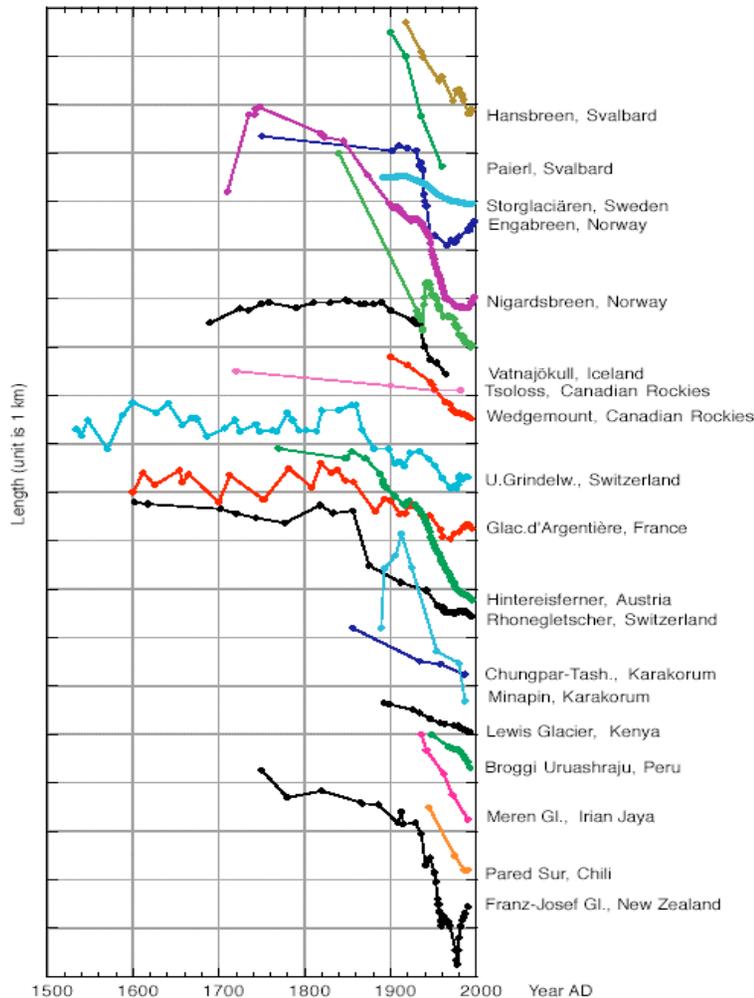


It's not just melting that matters
but how the meltwater affects
ice discharge into the ocean

A wide, flat, snow-covered landscape under a pale sky, with snow-capped mountains in the distance. The foreground is a vast, level expanse of snow, possibly a tundra or a frozen body of water. The mountains in the background are rugged and covered in snow, with some darker patches visible. The overall scene is desolate and cold.

Polar Miscellany

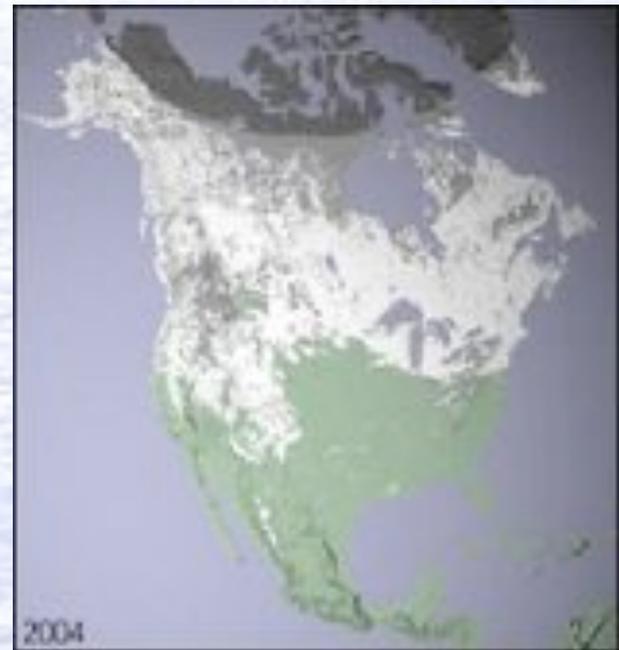
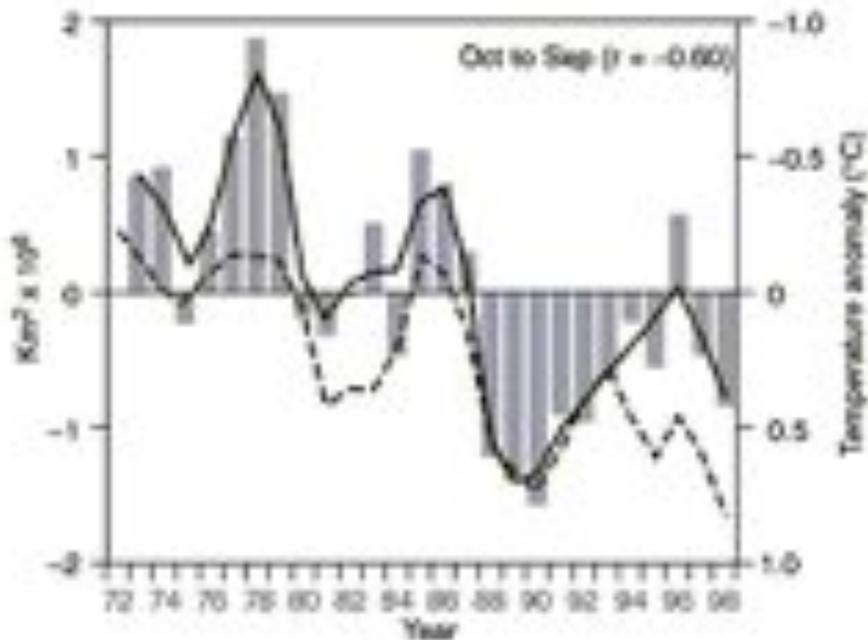
Worldwide Glacier Retreat



- Glaciers in all regions now retreating
- Satellite data increase the quality and quantity of retreat records

Retreat is accelerating

Decreasing Snow Cover

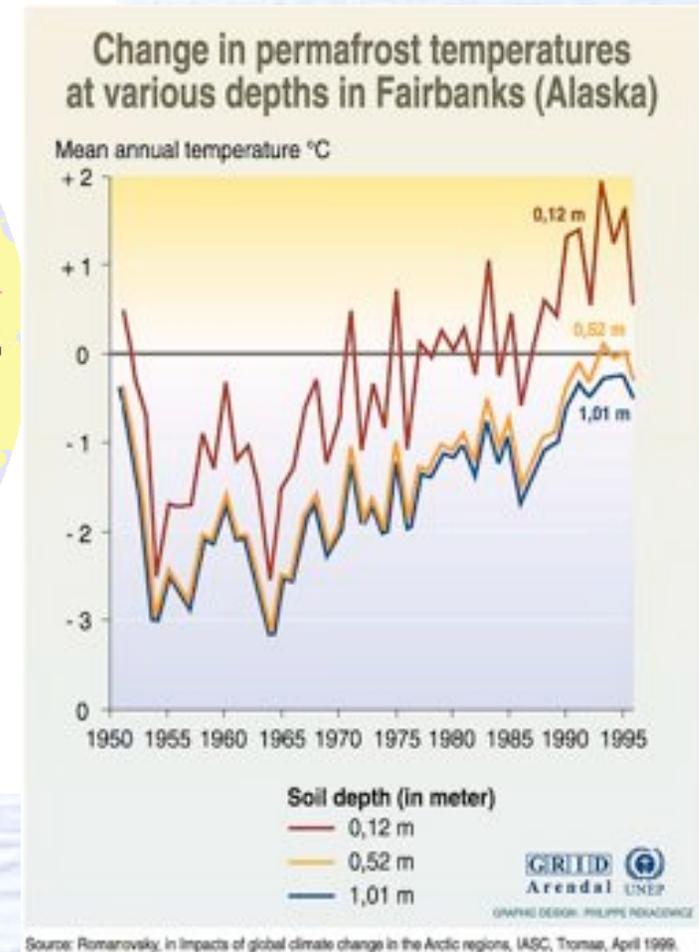
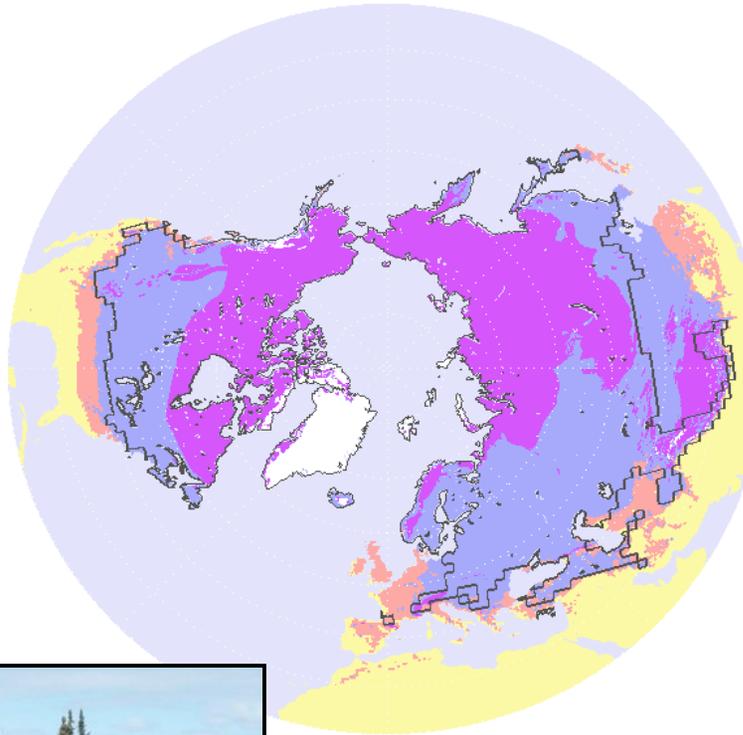


**10% decrease in NH
winter snow extent since
1966—primarily in
springtime**

**Global snow
amount remains
unknown (+50%)**

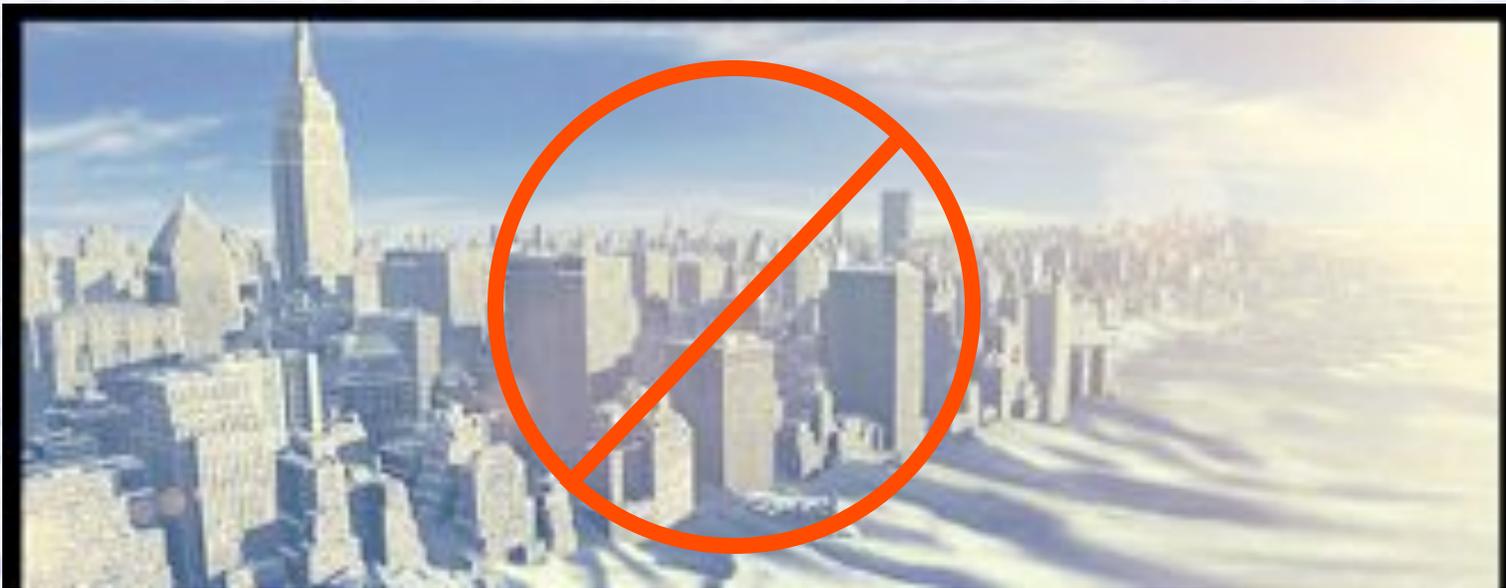
Permafrost is Melting

Permafrost regions: about 23.9% of the land mass; Seasonally frozen ground regions: up to 68%, the single largest component of the cryospheric elements.



The (Correct) Day After Tomorrow

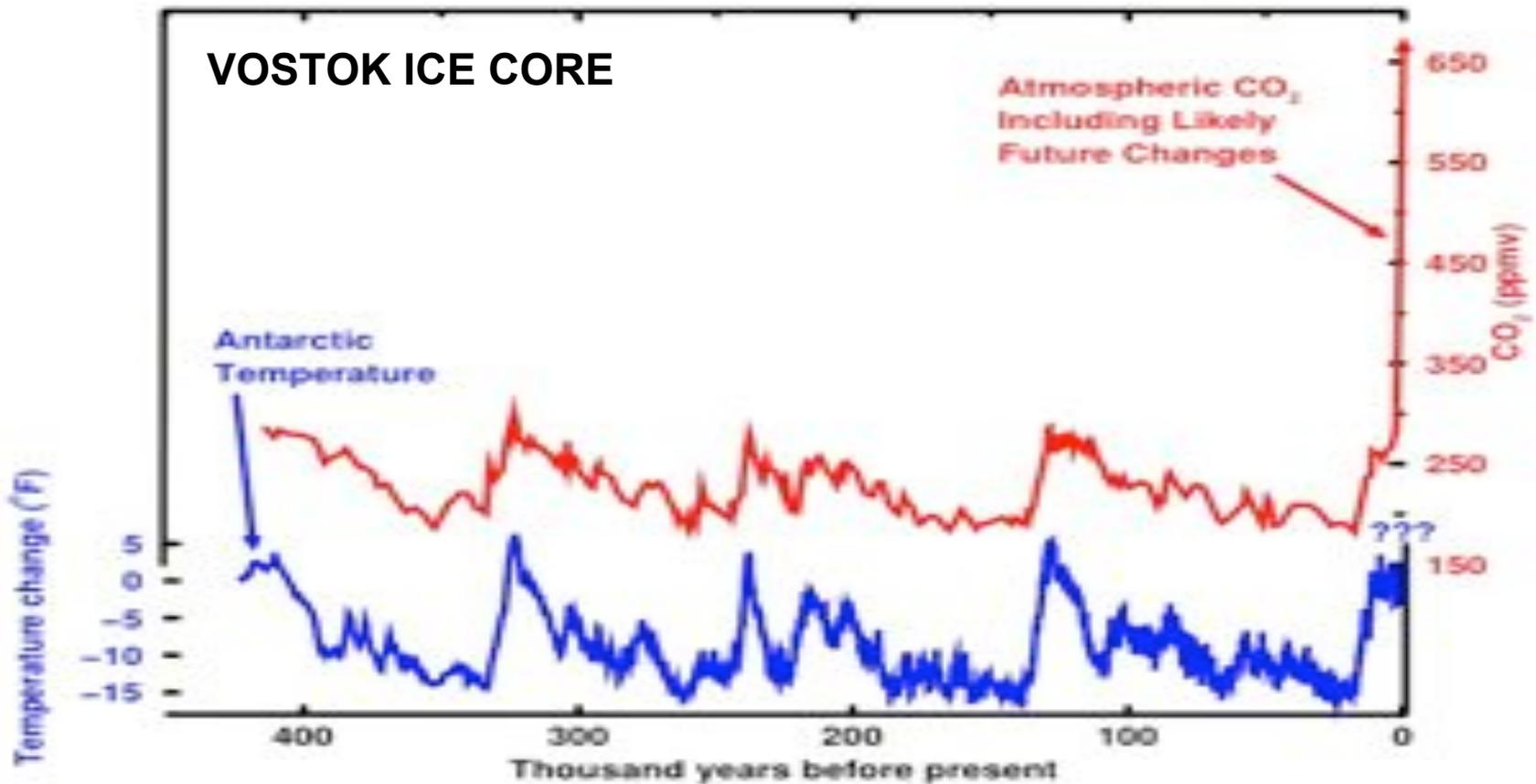
More heat = less ice



Hollywood's view of the future

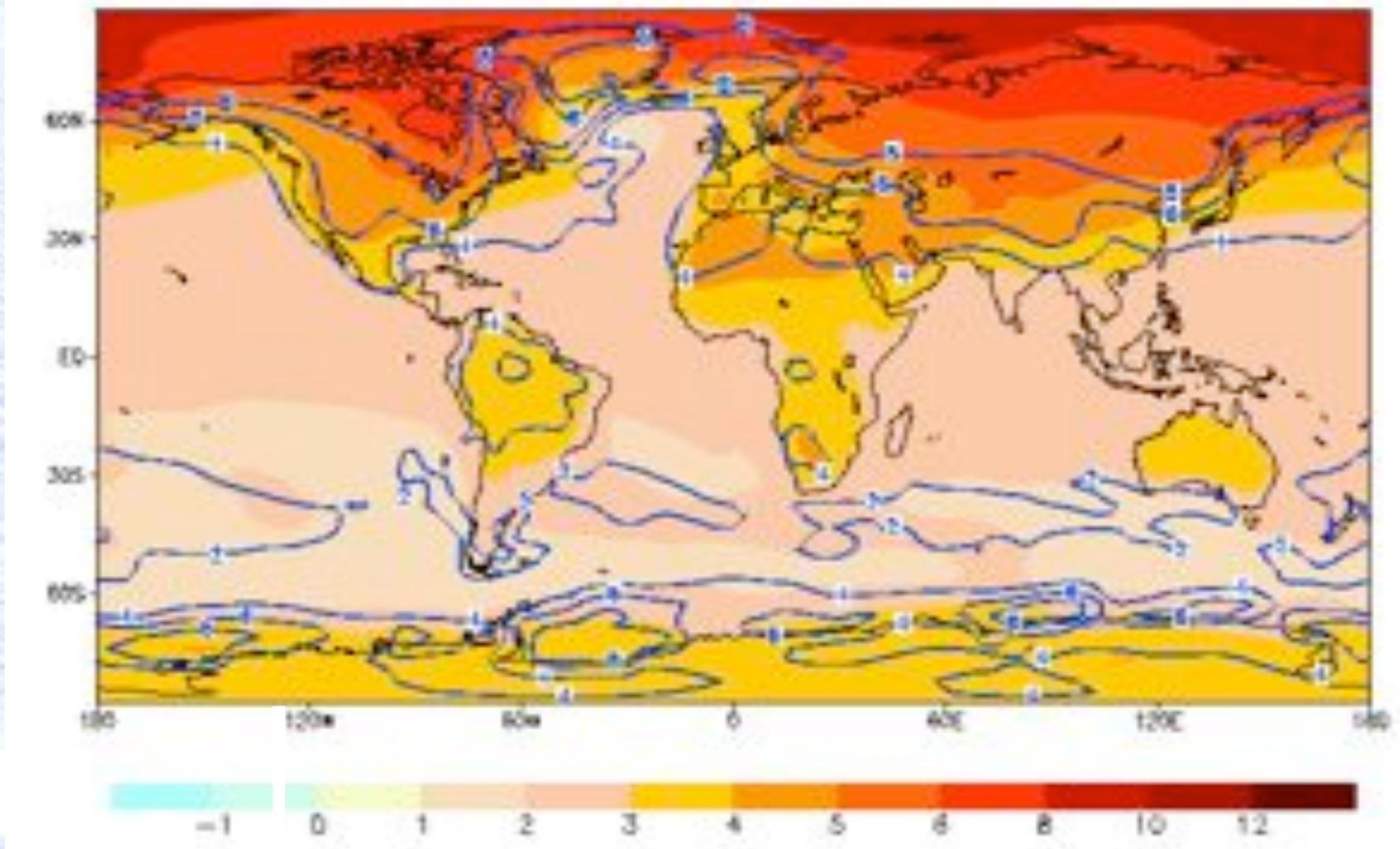
The (Correct) Day After Tomorrow

More heat = less ice

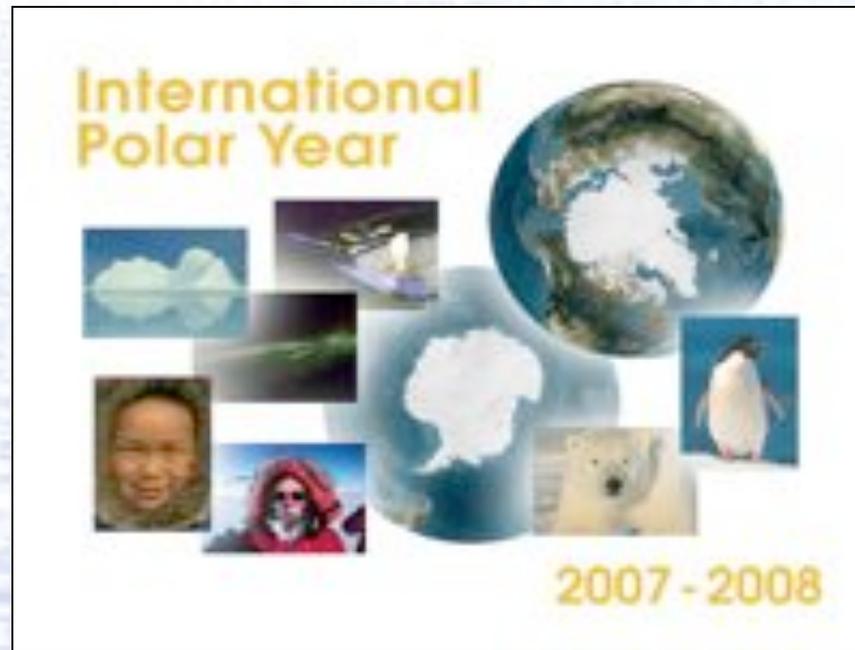


Climate Projections

Predicted 100-year surface temperature change (IPCC)



International Polar Year



An international program of coordinated research to explore the polar regions, deepen understanding of polar interactions including their role in global climate, expand our ability to detect changes, and extend this knowledge to the public and decision makers.

Take Home with You:

- Polar regions are warming faster than the rest of the planet
 - positive feedbacks
- This warming is causing major loss of ice, raising sea level and melting permafrost
- Recovery is difficult
 - remember latent heat
- Global consequences will continue and probably accelerate
- NASA will continue to monitor these changes and predict their consequences

A scenic view of a large body of water, likely a lake or a wide river, with snow-capped mountains in the background. The water is a deep blue, and the mountains are a mix of brown and white. The sky is a pale, hazy blue. The overall mood is serene and peaceful.

Thank you!

References:

- International Polar Year: <http://www.ipy.org> and <http://us-ipy.org>
- Intergovernmental Panel on Climate Change: <http://www.ipcc.ch/>
- US Global Change Research Program: <http://www.usgcrp.gov/>
 - Section 2.2.5: Changes in the Cryosphere
 - Chapter 11: Sea Level
- Arctic Climate Impact Assessment: <http://www.acia.uaf.edu/>
- West Antarctic Ice Sheet Initiative:
<http://igloo.gsfc.nasa.gov/wais>
- Hydrospheric and Biospheric Sciences Laboratory:
<http://neptune.gsfc.nasa.gov>
- Climate change figures:
<http://www.grida.no/climate/vital/index.htm>

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CANARY IN A COAL MINE.

IN YEARS, coal and oil miners took canaries with them into a mine. If the canary died, this was a signal that dangerous gases were present and that immediate action was needed. In a similar way, today's scientists see Adelle penguins as the sign of a growing problem... climate change. The average winter temperature along the Antarctic Peninsula has increased nearly 3°F over the past 50 years. Sea ice has retreated by a fifth since the mid-1970s, depriving the penguins of an important feeding ground. Scientists are using Earth-Observatory satellites, such as AURA, to help track climate change around the globe. You can too. Turn over this poster and read more about climate change and simple things you can do in your home, school and community to help. Or visit our website at www.aura.nasa.gov



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Water for Life on Earth

NASA Earth Sciences Research Questions

How does the Earth work?

- *The Earth environment sustains life.*
- *Understand the forces that sustain the Earth's environment.*

Why is the Earth Changing?

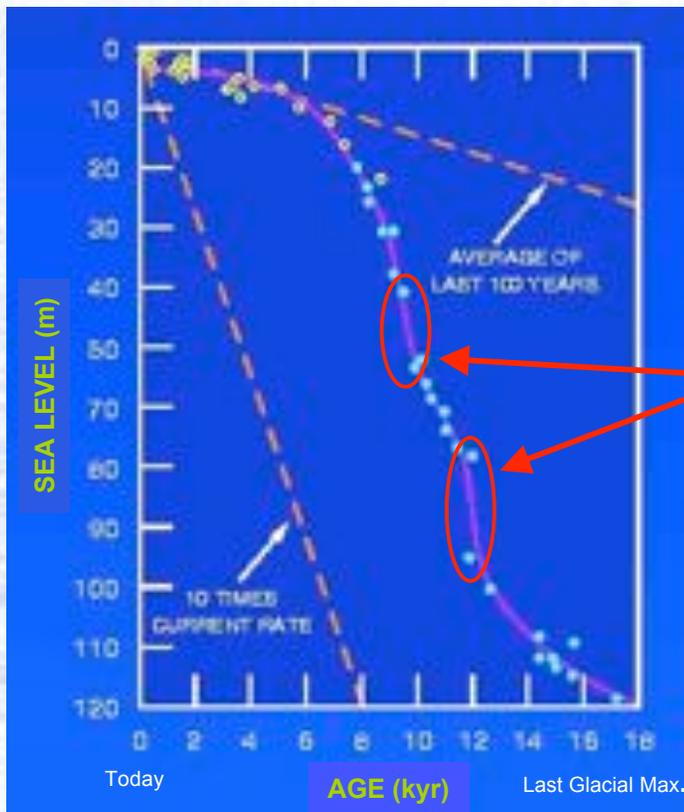
- *Earth history includes major changes.*
- *Understand the forces behind these changes.*

What do these changes mean for life on Earth?

- *Changing Earth conditions change ecosystems and habitability.*
- *Understand the forces that change Earth habitability.*



Past Evidence of Rapid Sea-level Rise



(from R. Fairbanks)

Ice sheets reactions to past climate changes are recorded in sea level variations.

Periods of sea level rise 30X faster than today

Modest rates of sea-level rise have fostered human proximity to coasts

Nearly HALF of world's population lives near the coast

Vegetation Stresses

1949



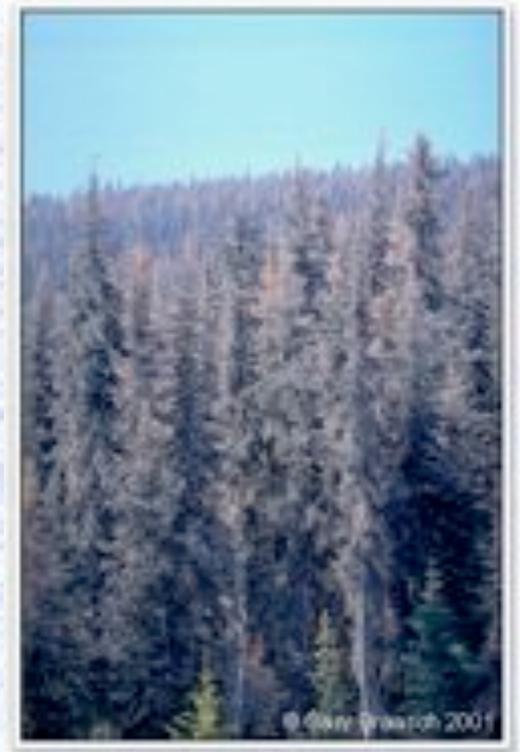
2001



Chandler River, 50 miles S. of Umiat

Shrubs and trees are moving north

Spruce forest dying
(Kenai Penin.)
due to infestation of
beetles



© Gary Shaver, 2001

Large Iceberg Calving



Pine Island Glacier (Nov. 2001)

Large calving events continue at the fronts of fast moving outlet glaciers

More frequent calving of very large Antarctic icebergs causing gradual retreat of ice shelf fronts



Connecticut-size iceberg calved from Ross Ice Shelf in 2002

Optical (Landsat, MODIS, ASTER) and radar imagers monitor iceberg calving

Sea Ice

