National Snow and Ice Data Center

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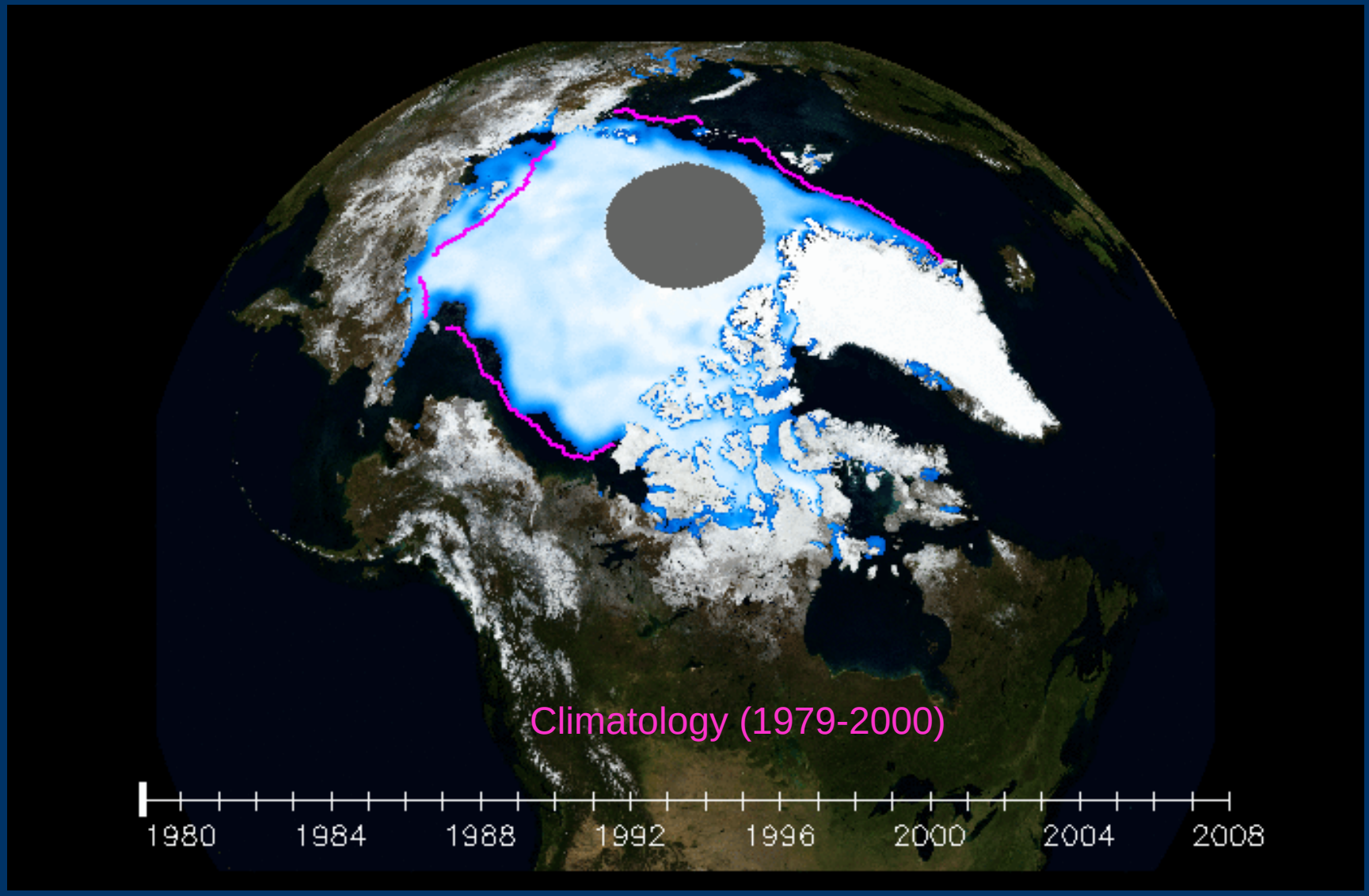
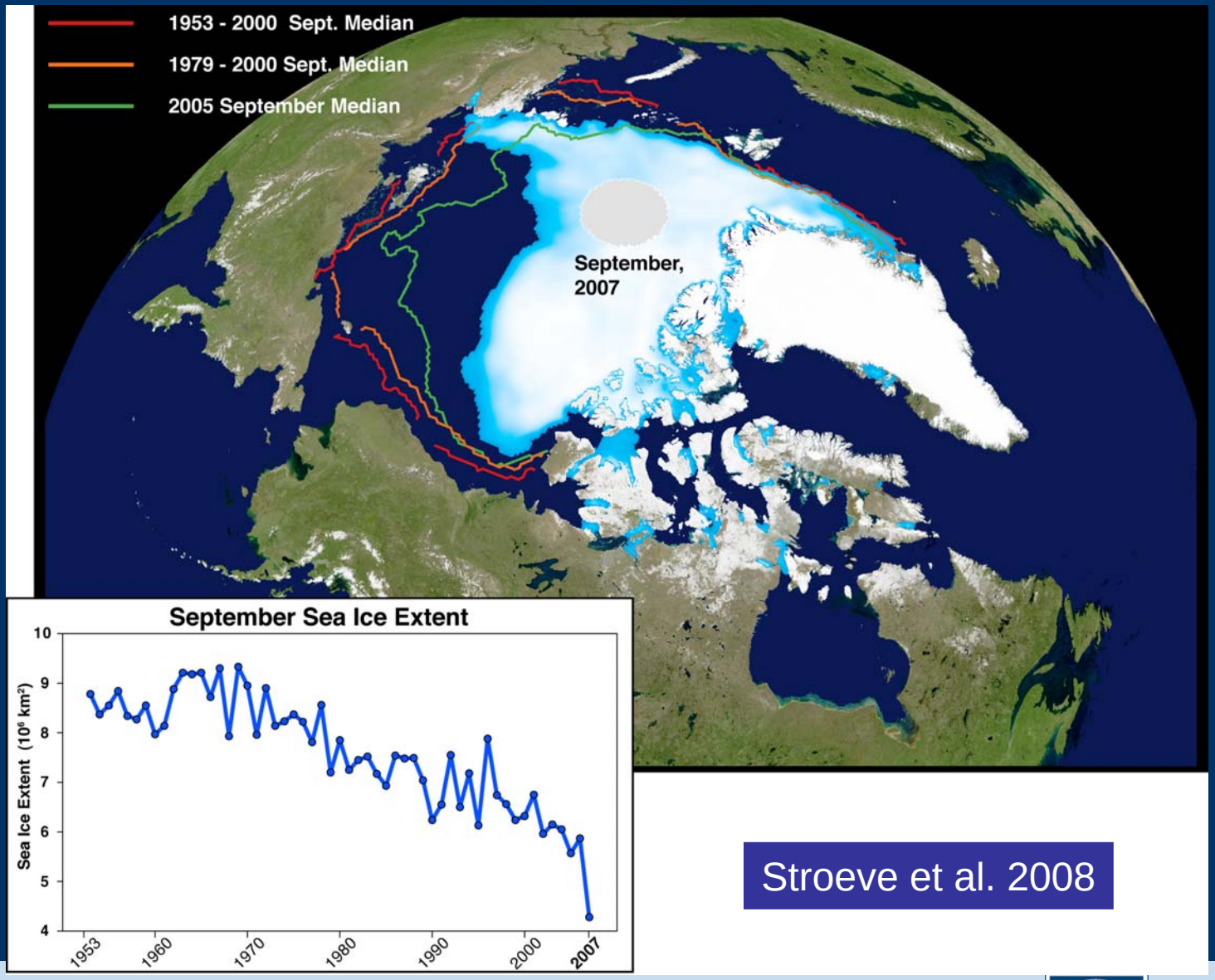
Growing Non-Linearity in Artic Sea Ice Loss

Julienne Stroeve and Don Perovich

We are losing the ice cover fast



Summer 2007: A new record low



Stroeve et al. 2008

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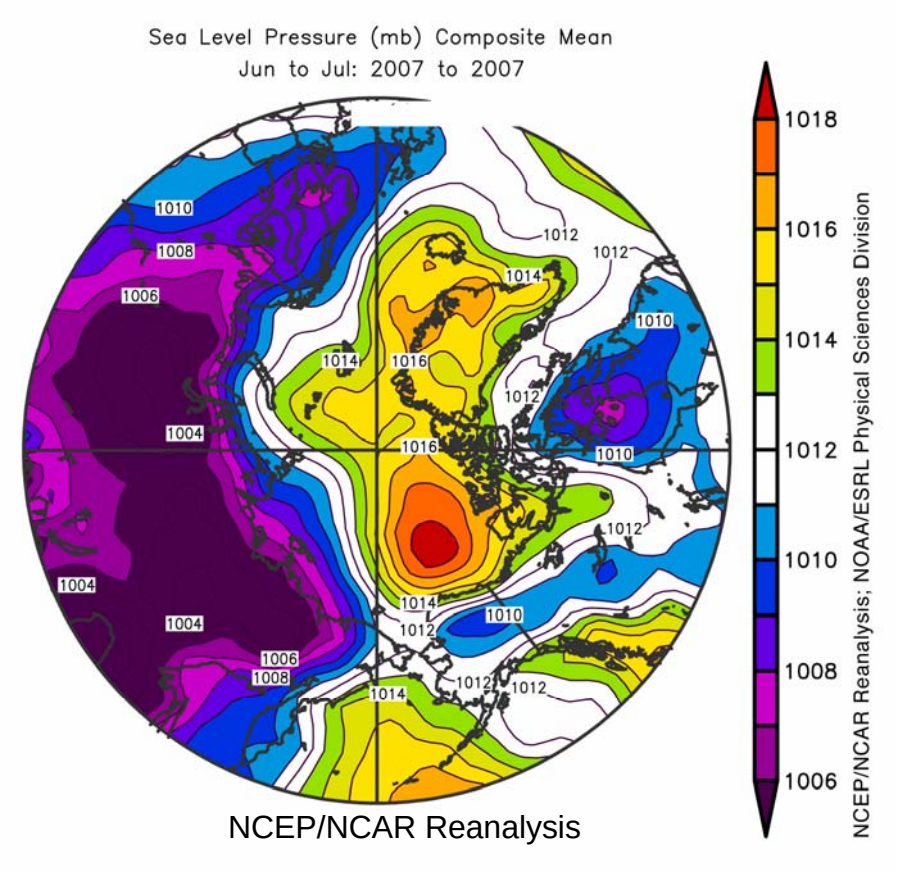
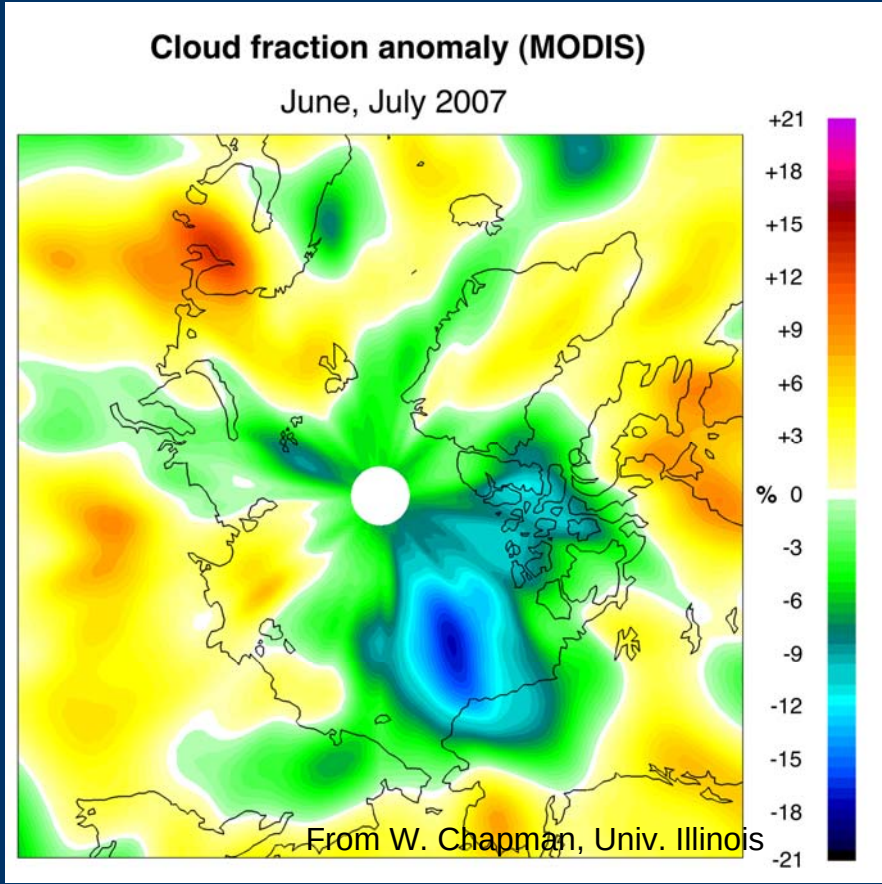
Unusual Atmospheric Circulation Pattern



NCEP/NCAR Reanalysis

High pressure over central Arctic Ocean (clearer skies)
Low pressure over Siberia (warm air advection)

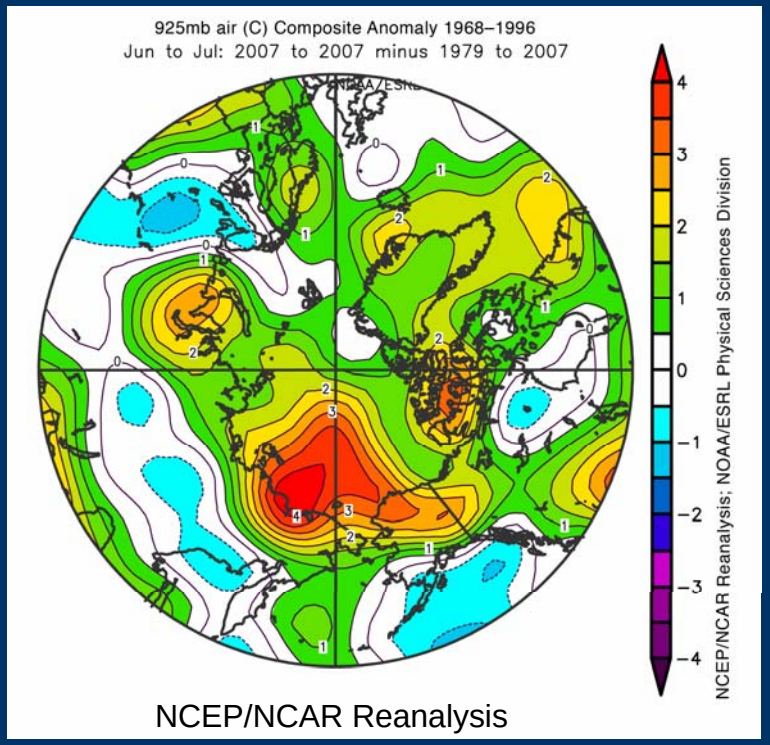


From W. Chapman, Univ. Illinois

Fewer clouds during maximum solar insolation

Unusual Atmospheric Circulation Pattern

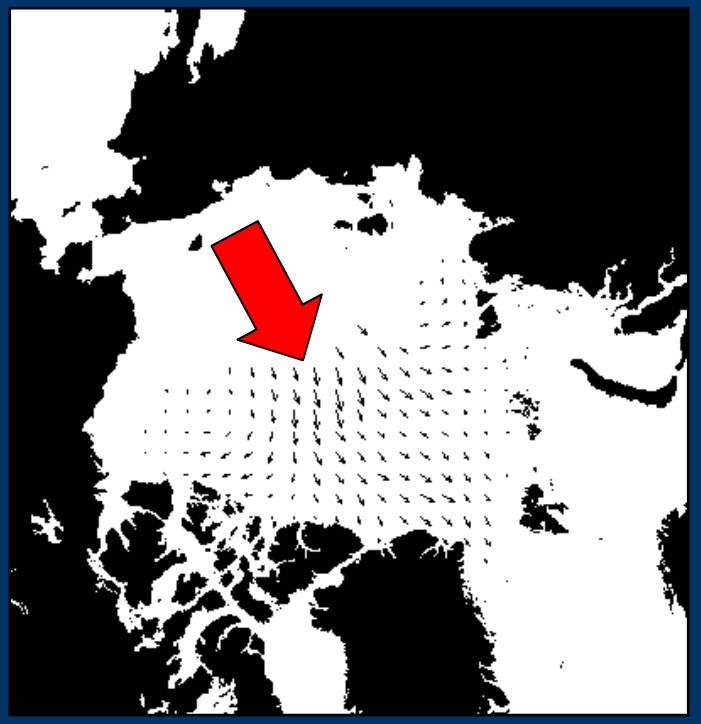
Temperature Anomaly



NCEP/NCAR Reanalysis

A very Warm Arctic

Sea Ice Motion



Atmospheric pressure patterns led to ice drift away from Siberian coast across the Arctic (From AMSE-E passive microwave satellite data)

Another factor: Ice-Albedo Feedback

Anomalously clear skies under the Beaufort high pressure

incident sunlight

Albedo

$$\text{Albedo} = \frac{\text{reflected sunlight}}{\text{incident sunlight}}$$

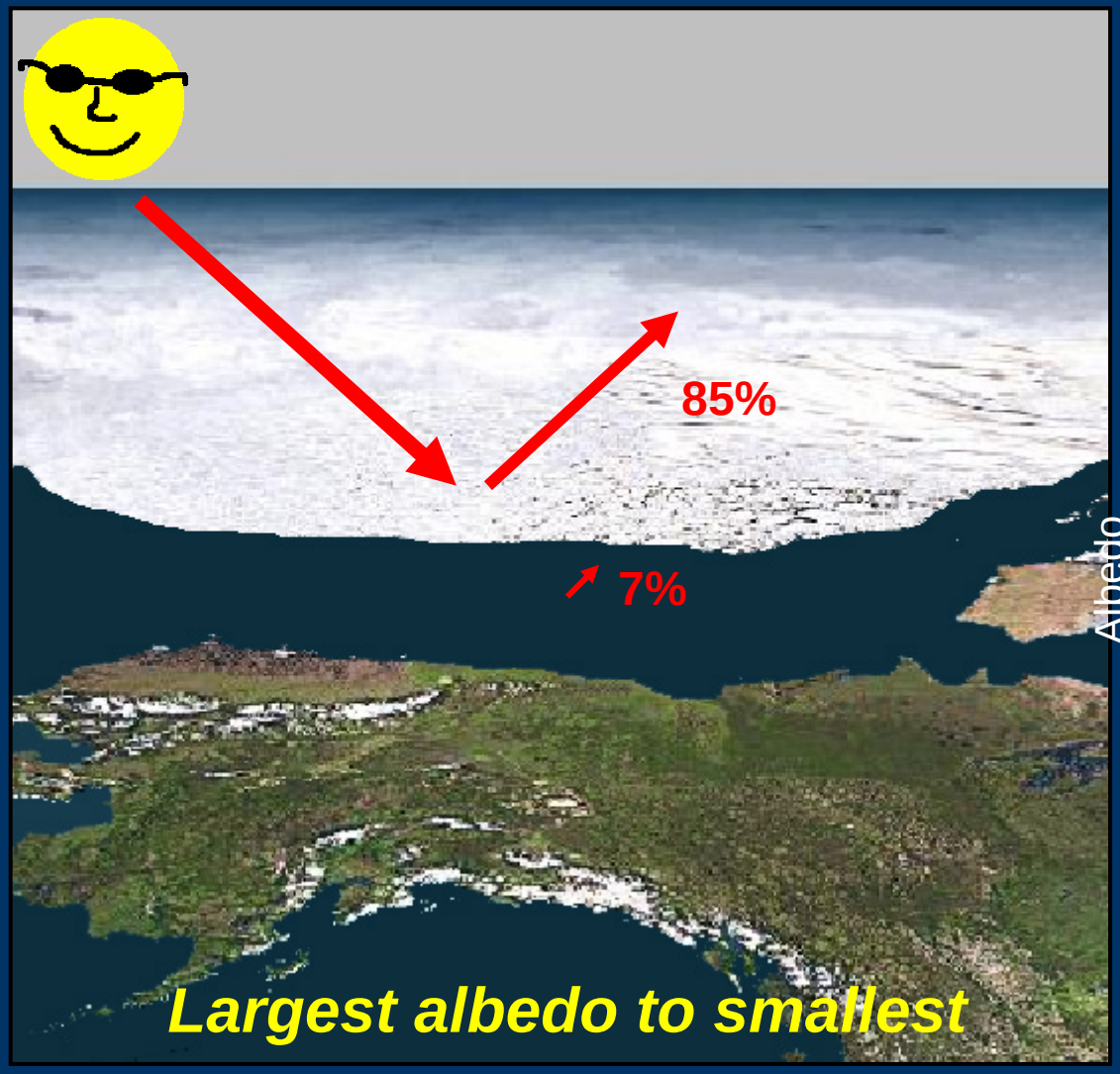
Nothing reflected = 0
All reflected = 1

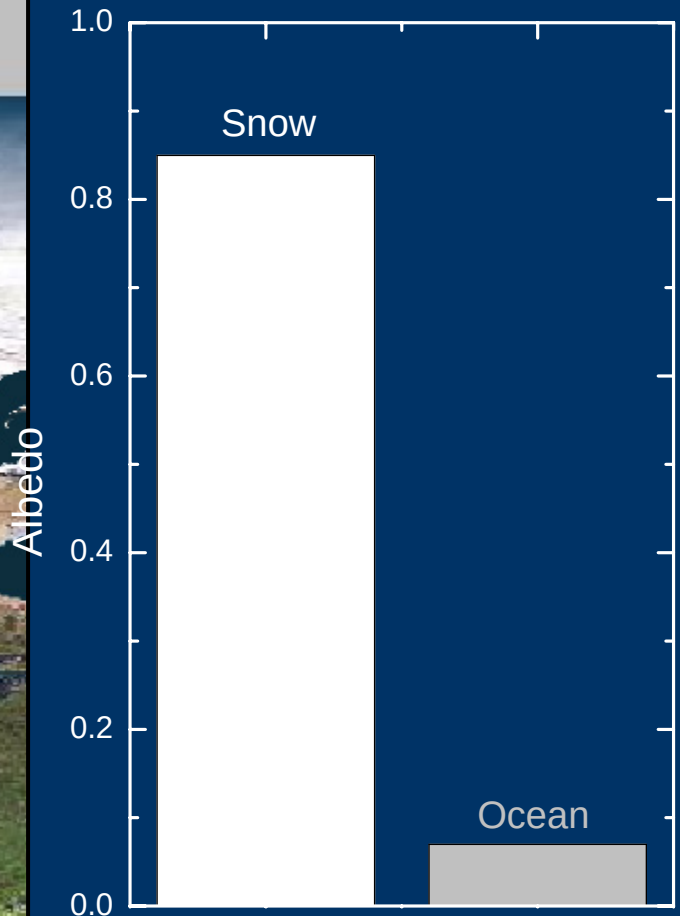
Albedo is fraction of sunlight reflected

Ice-Albedo Feedback

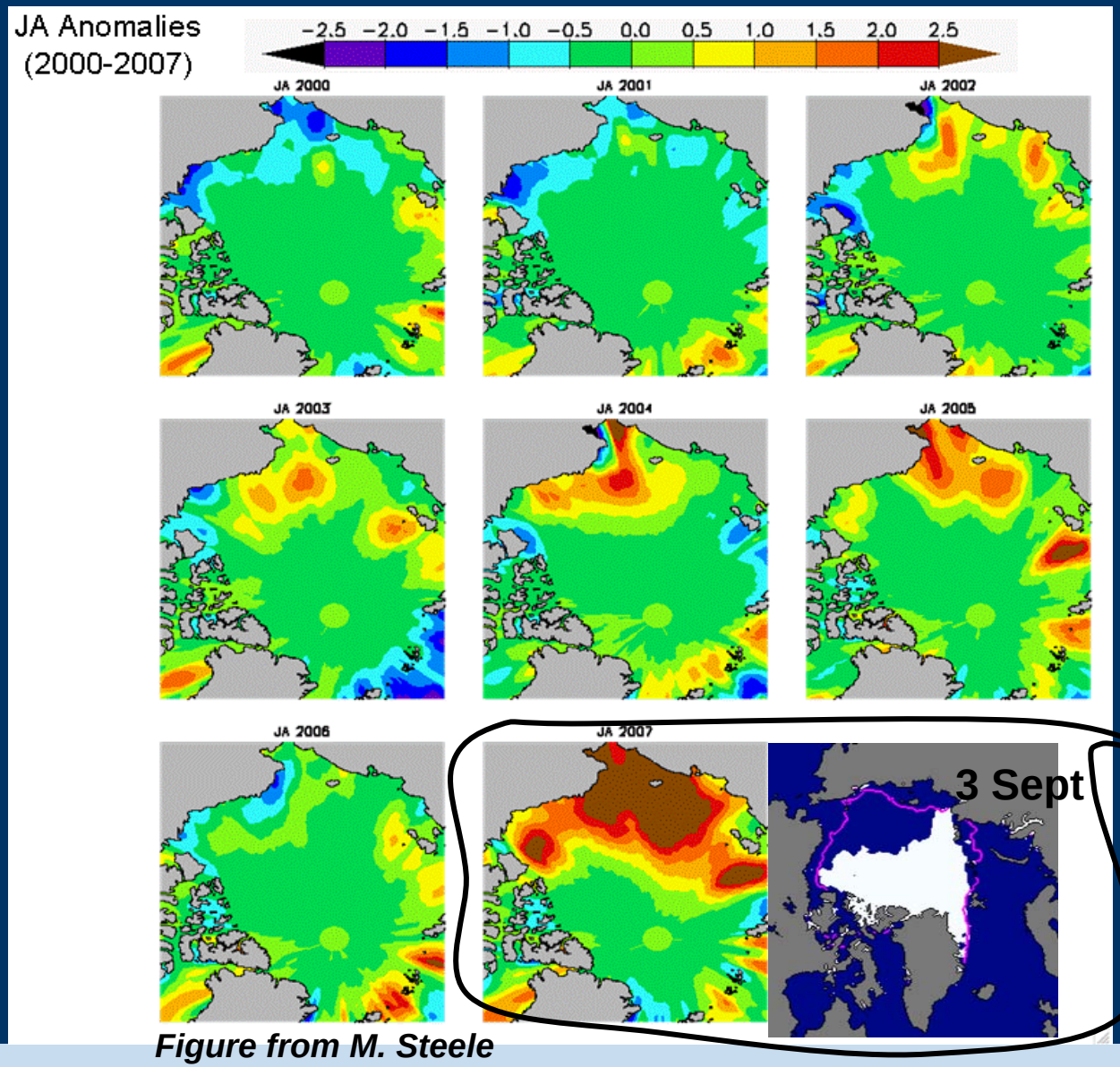
Sea ice in spring

Ice Albedo Feedback: Ice Edge Retreat





High SSTs in 2007



July-Aug SST anomalies (rel. to 1982-2007)

2007: SSTs were 3.5°C above climatology

Figure from M. Steele

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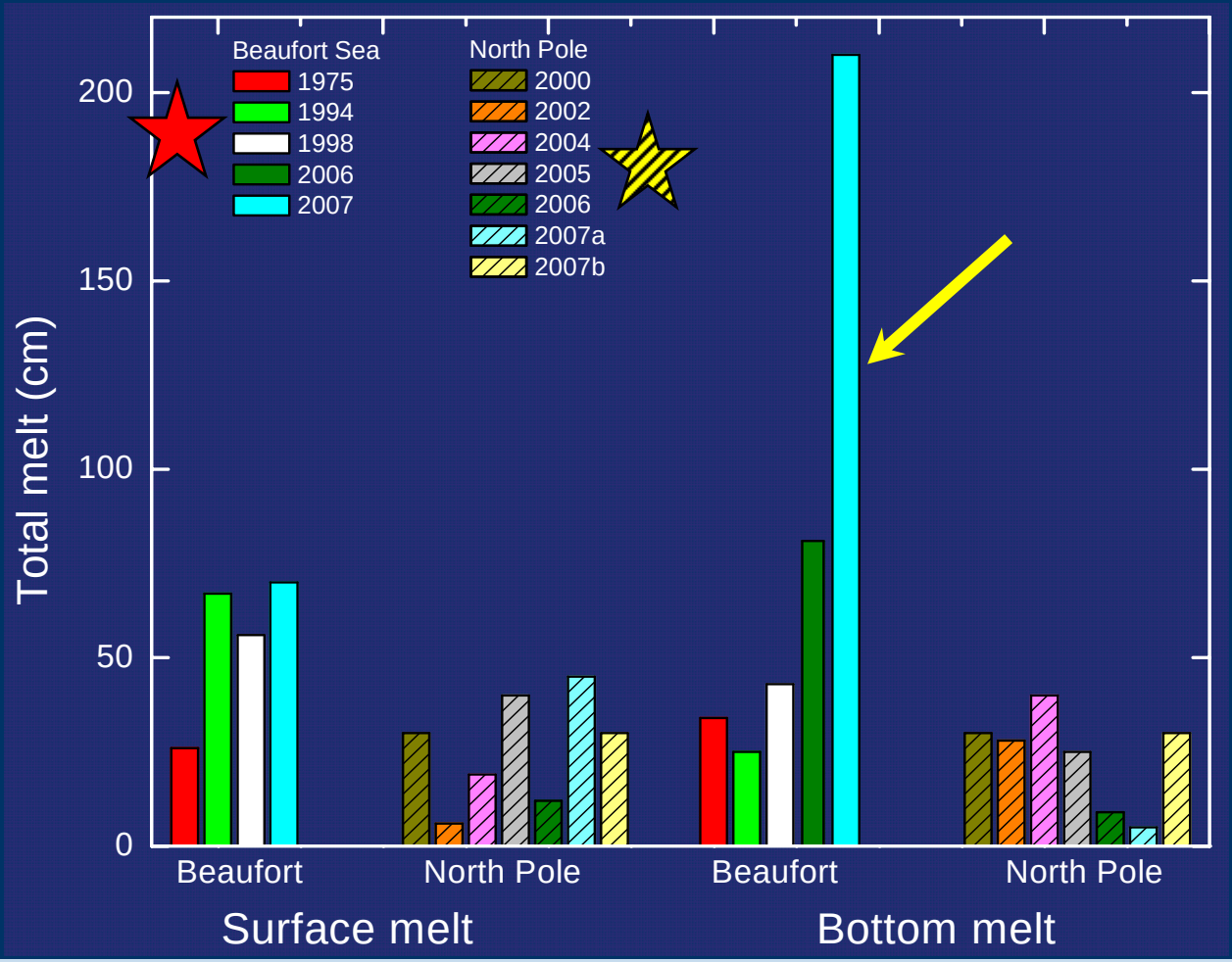
Lots of Basal Melt in Summer 2007

- Extremely large amount of ice bottom melting in Beaufort Sea in summer 2007!



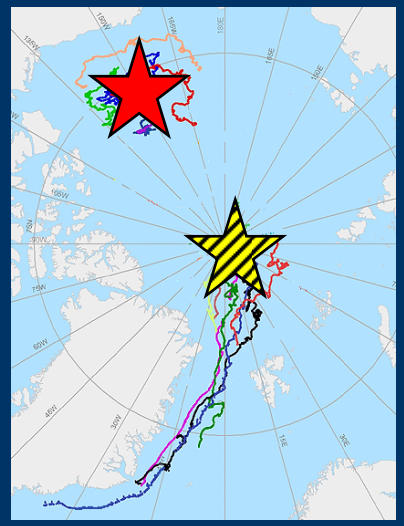


Image from D. Perovich (GRL, 2008)

Ice Albedo Feedback: Interior

Spring
- Uniform appearance
- Snow-covered ice
- Little open water
- Large albedo (~ 0.8)

Summer
- Variegated appearance
- Bare ice, ponds, and leads
- More open water
- Reduced albedo (~ 0.5)

Melting means lower albedo

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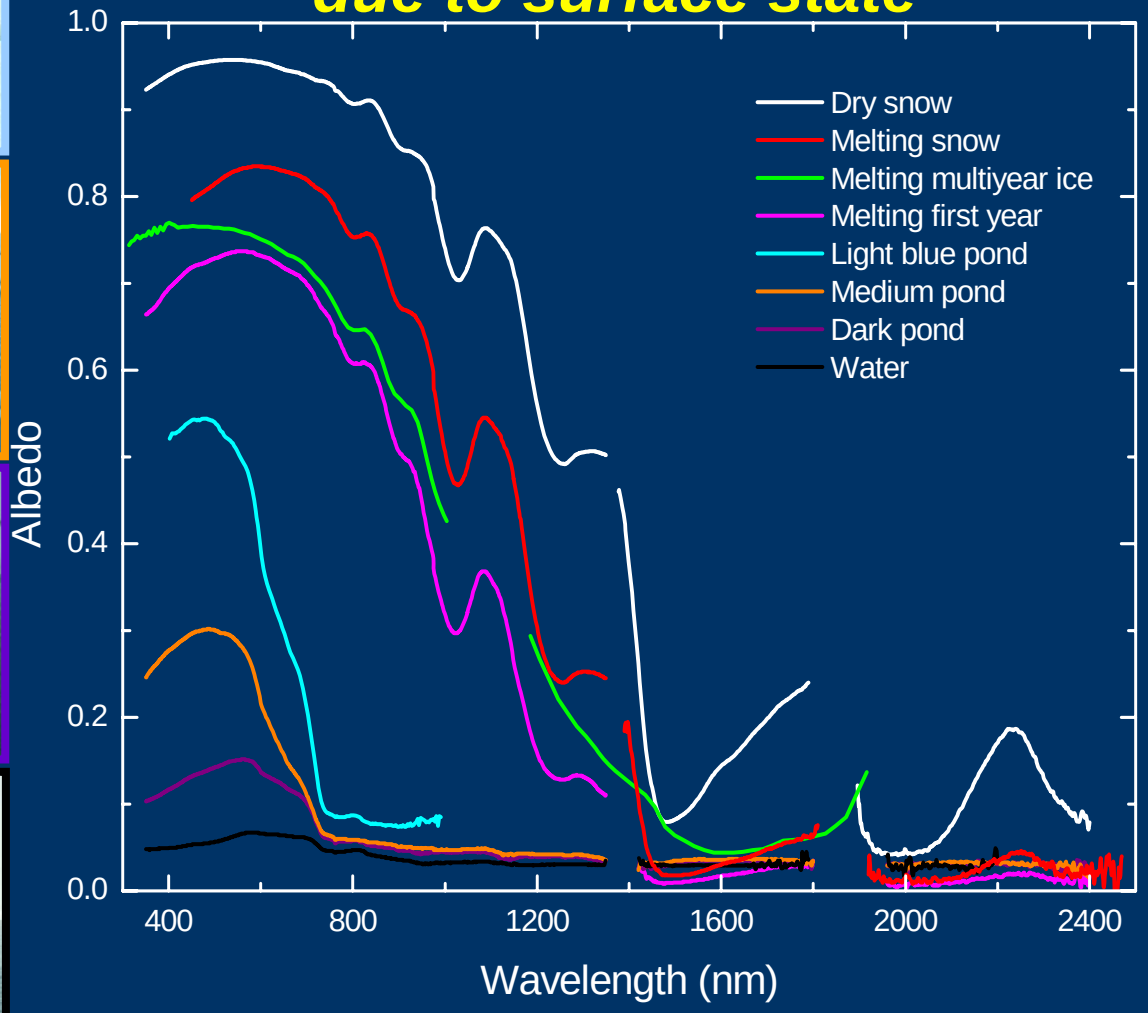
Melt Pond vs. Snow Albedo

Tremendous variability primarily due to surface state



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Ice albedo feedback

Melting

+

+

Absorbed sunlight

Lower albedo

+

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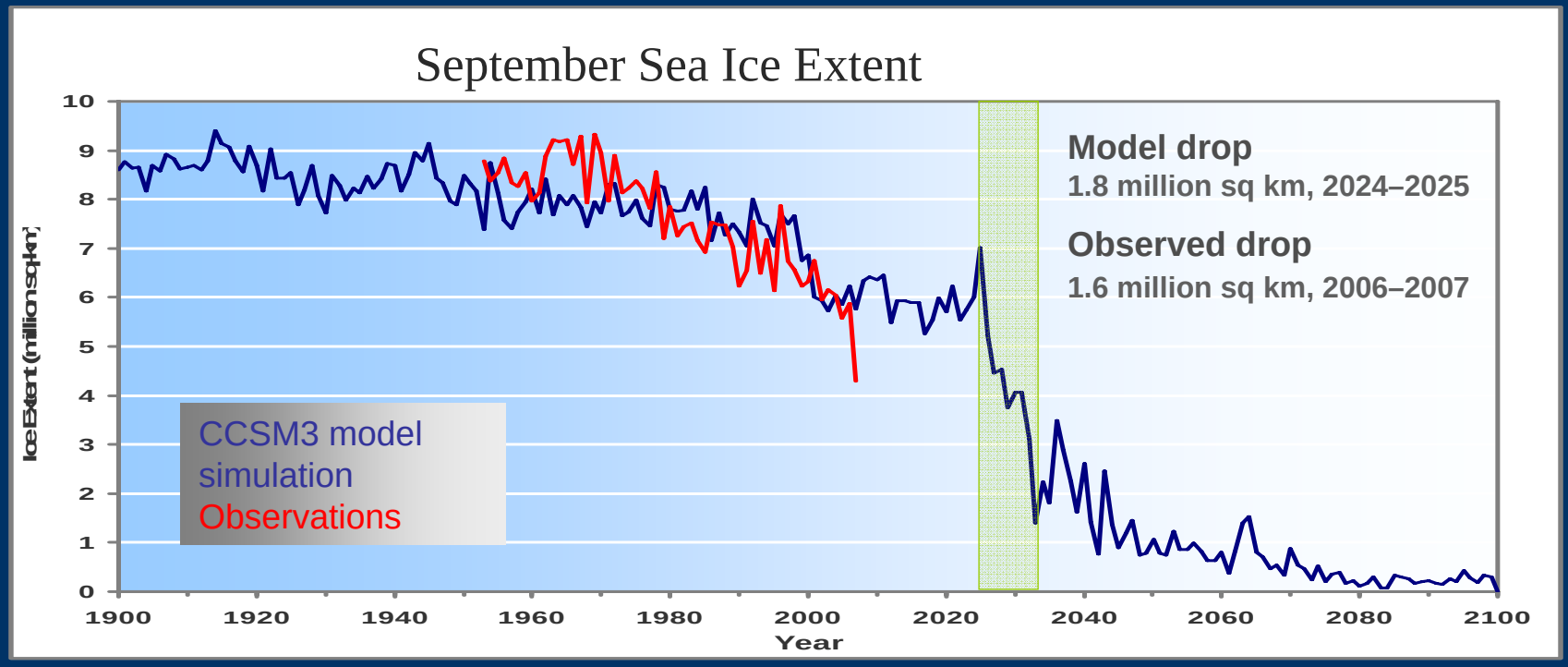
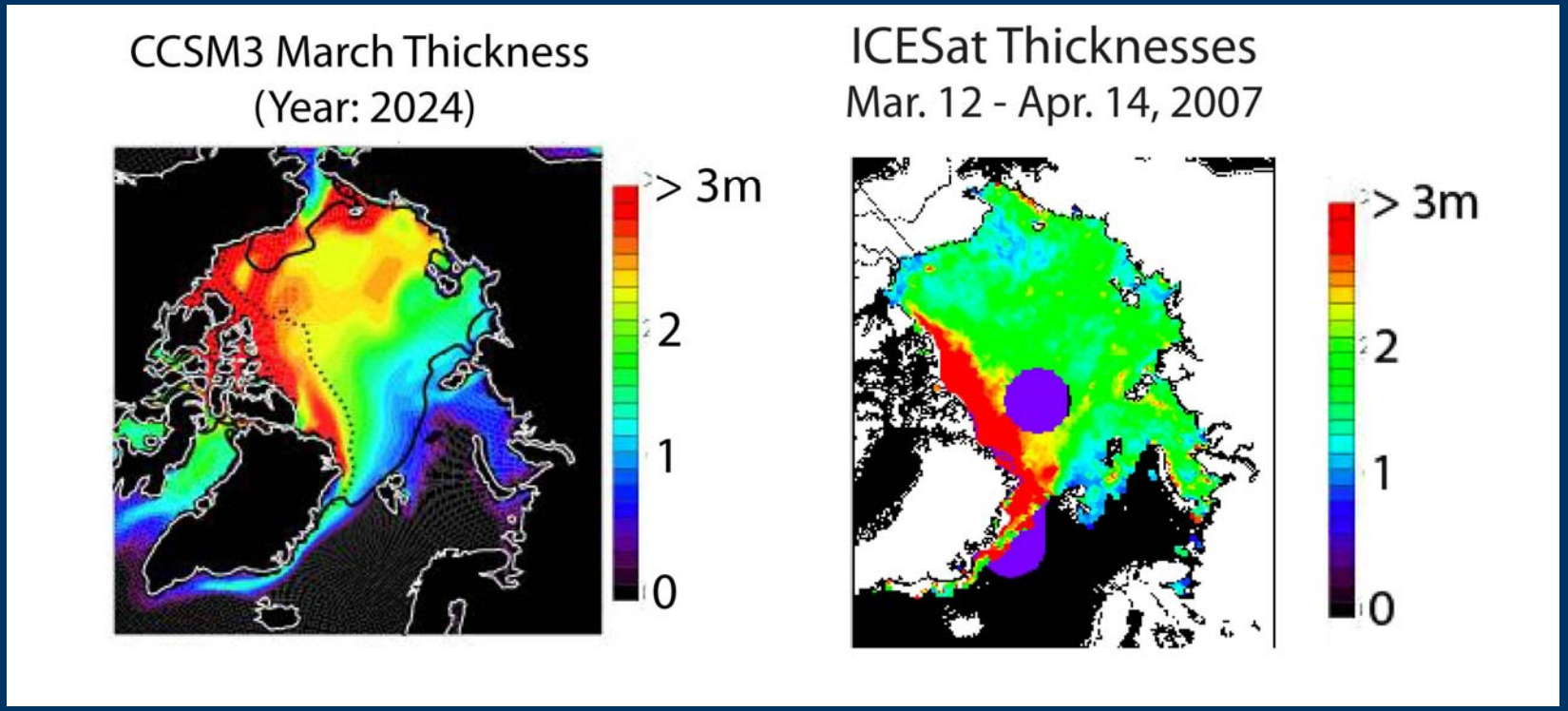
Standing on the Threshold?

- Climate models suggest once the sea ice cover is thinned sufficiently, a strong “kick” from natural variability can initiate a rapid slide towards ice-free conditions in summer (e.g. Holland et al., 2006).



The Set Up Looks Right



- Mean thickness (70-90N) in CCSM3 before abrupt change: 1.71 m
- Mean thickness (70-90N) from ICESat in Spring 2007: 1.75 m (data from D. Yi and J. Zwally)

Even more Thin, Young Ice in Spring 2008

ICESat-derived ice thickness

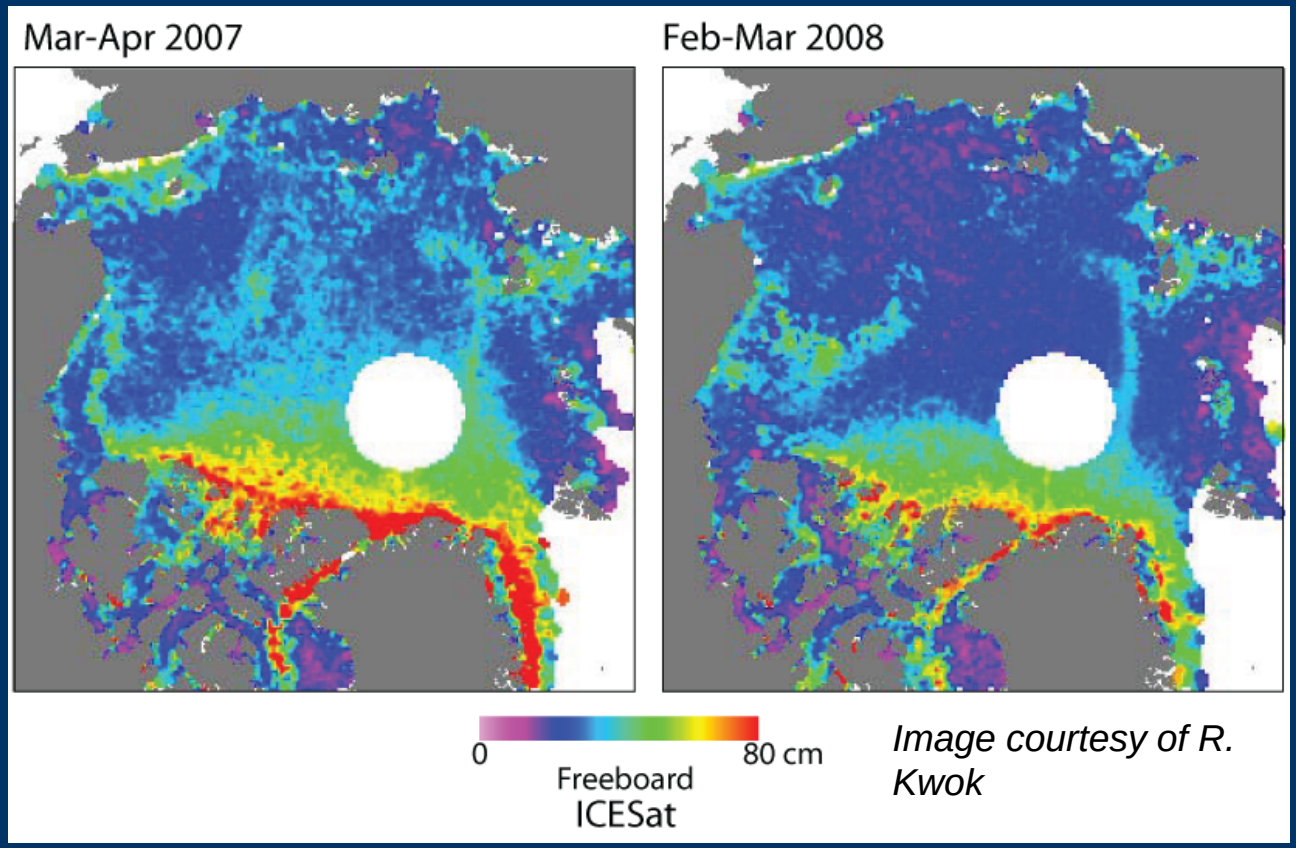
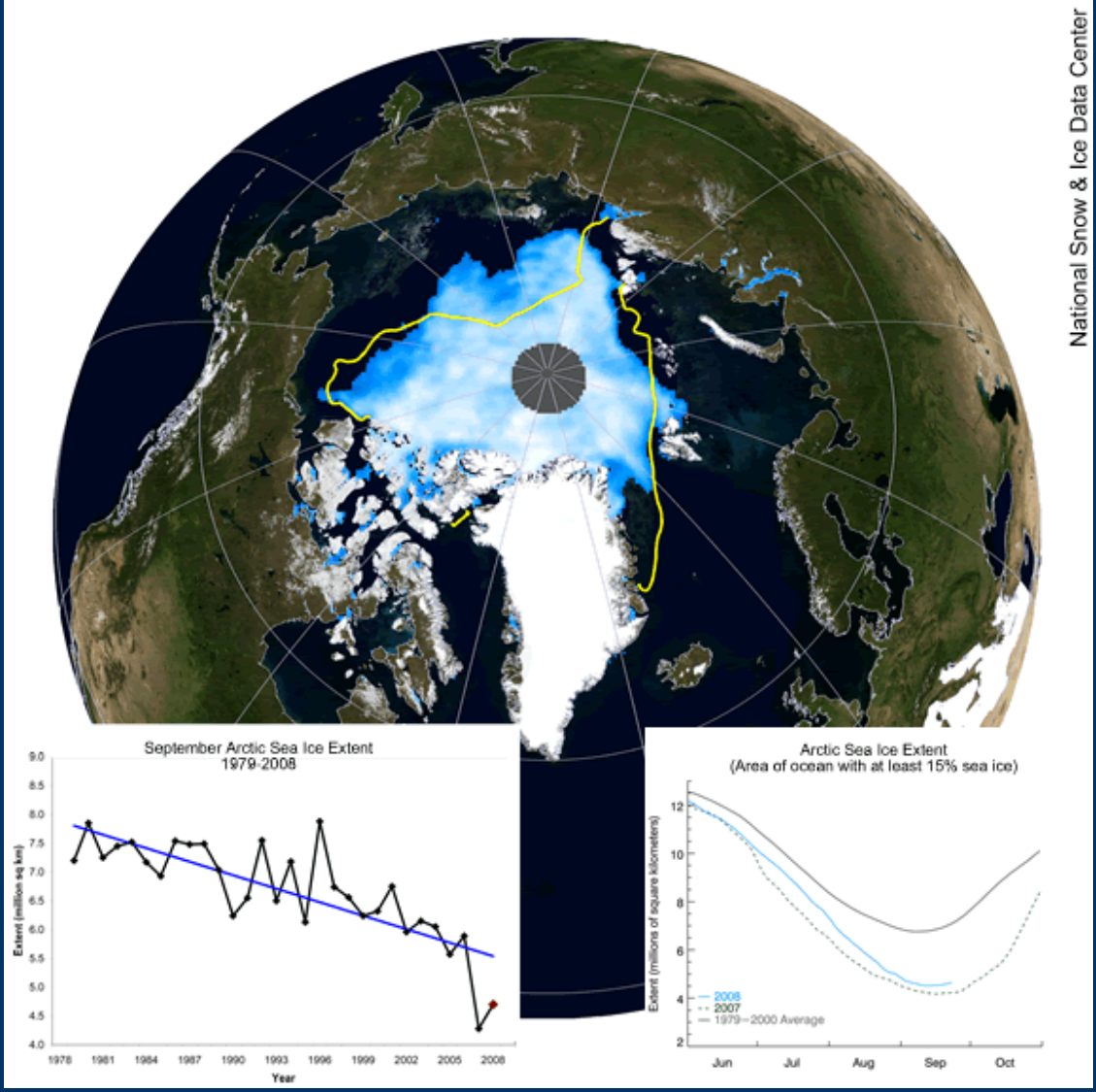


Image courtesy of R. Kwok

Observations from ERS-1 and ERS-2 suggested ice in Chukchi was 50cm thinner (Giles et al., 2008)

Yet, no new record low in 2008

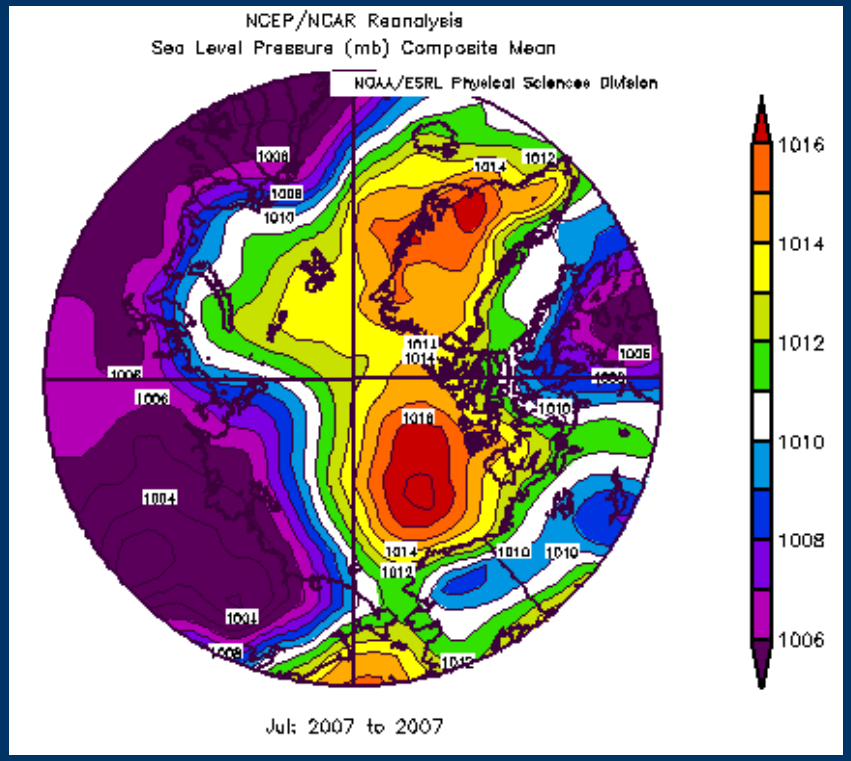


But the trend accelerates further from -10.7 to -11.8%/decade

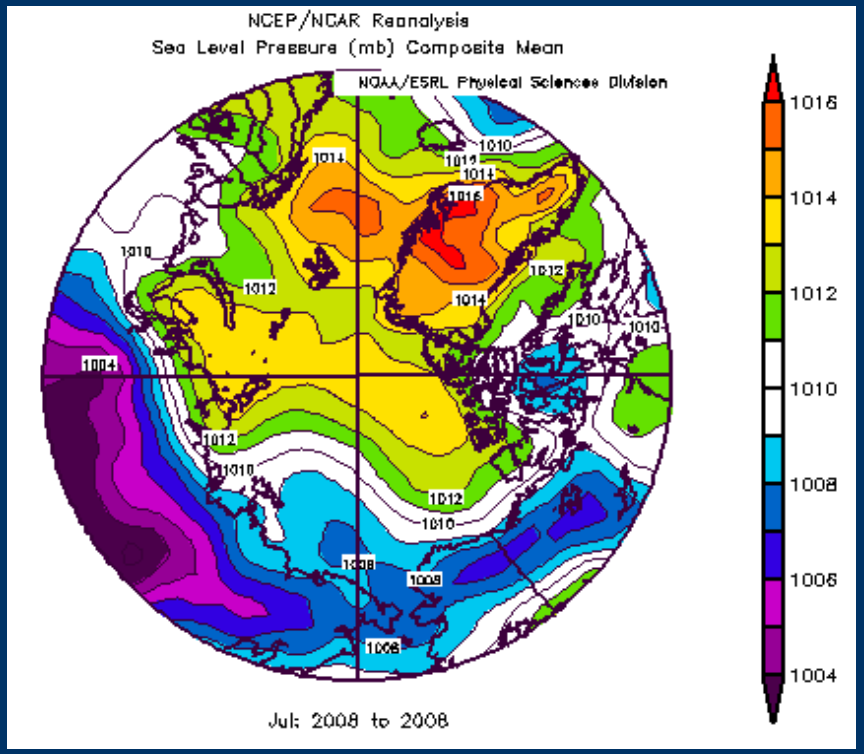
And, total ice loss from March 2008 to September 2008 was greater than in 2007

Natural Variability Remains Important

SLP, July 2007



SLP, July 2008

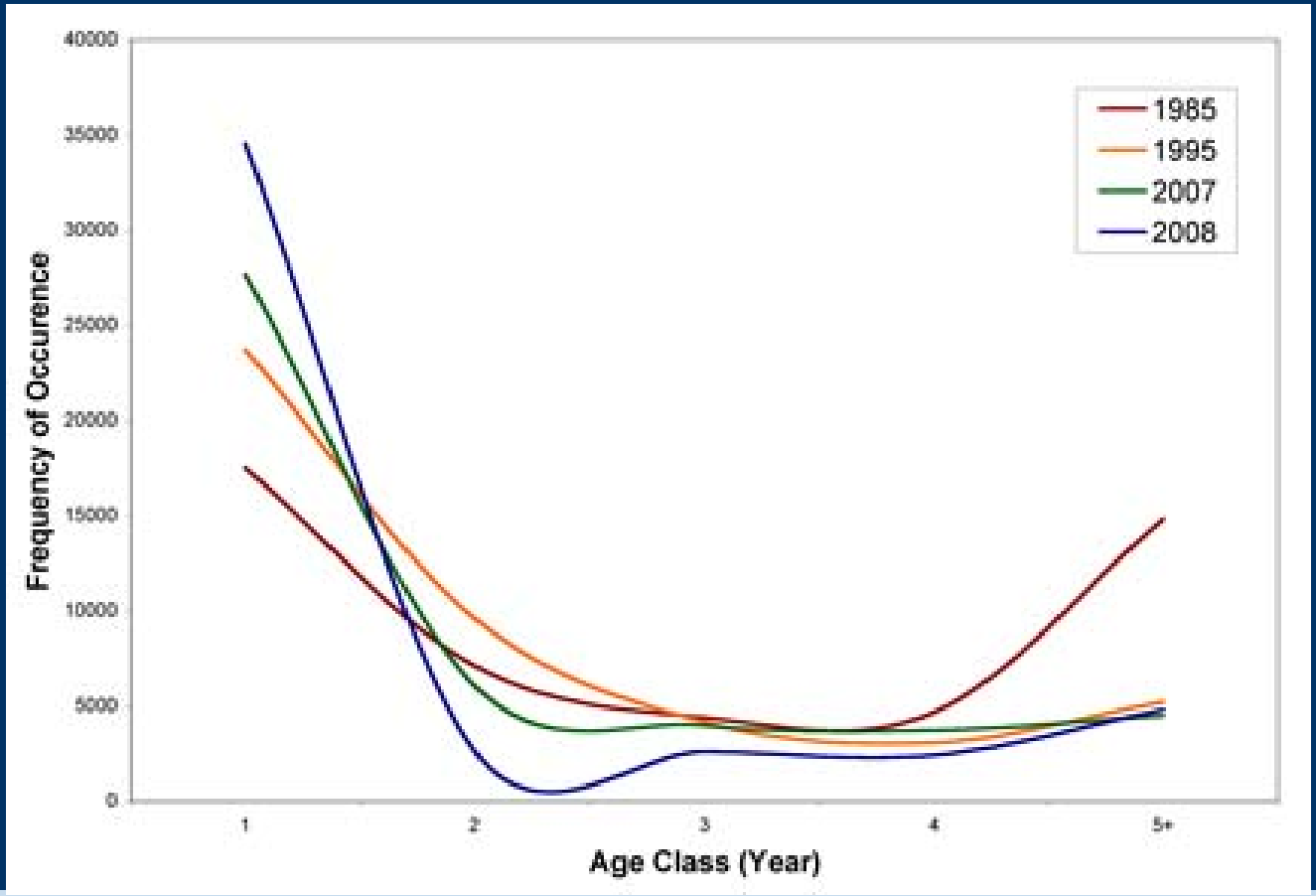


Mutually Supporting Processes Further Ice Loss

- Transition towards thinner ice
- Stronger ice-albedo feedback
- Warmer temperatures

Arctic no Longer Contains much Thick, Old Ice

- During thick-ice regime, anomalously warm summer may result in a lot of ice melt (large ice volume loss), but little change in areal extent of ice.



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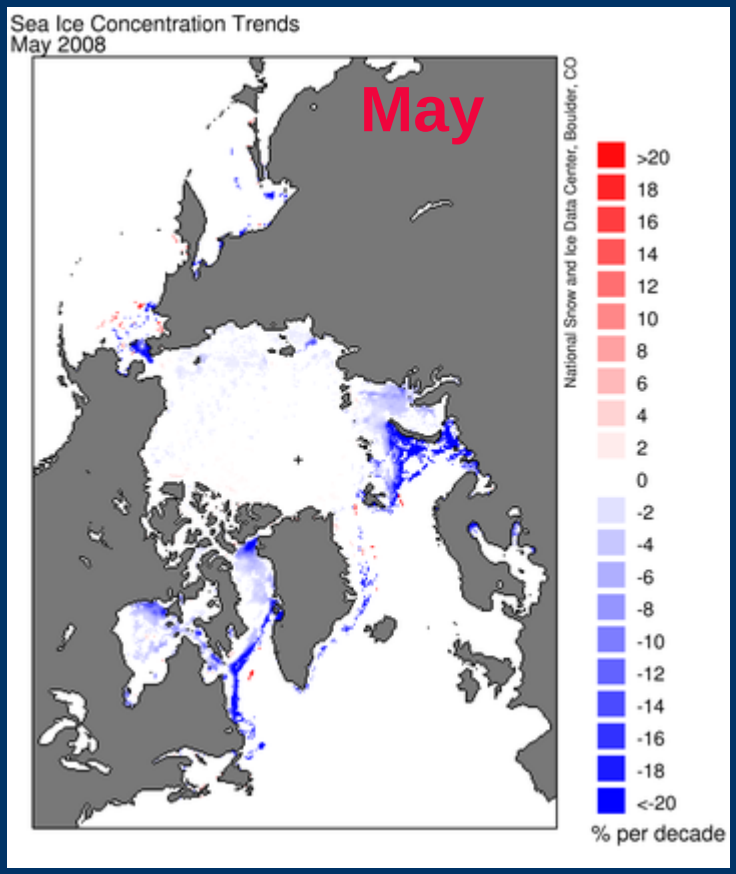
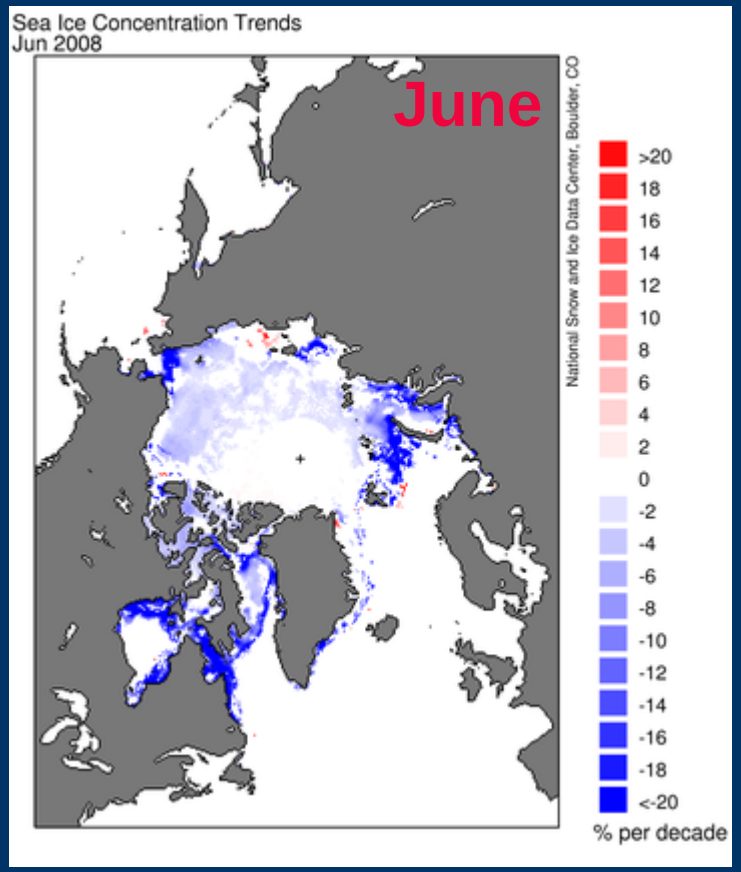
Stronger Ice-Albedo Feedback

- Thin ice leads to open water areas developing earlier and persisting longer throughout the melt season
- More open water leads to a growing importance of the ice-albedo feedback that further accentuates ice melt
  - Overall reduction in albedo of the Arctic basin

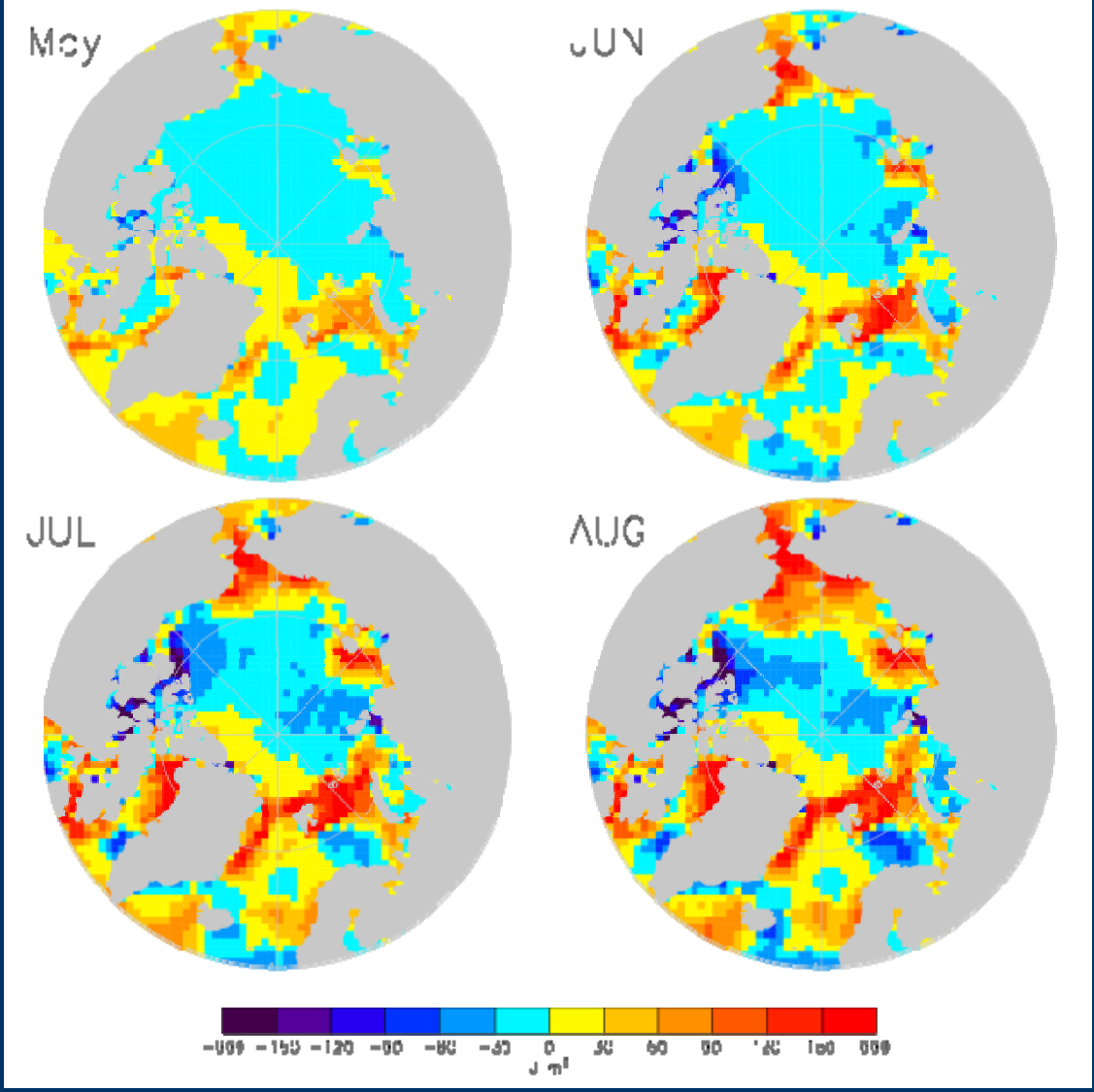
Earlier Development of Open Water

Ice Concentration Trends (1979-2008)





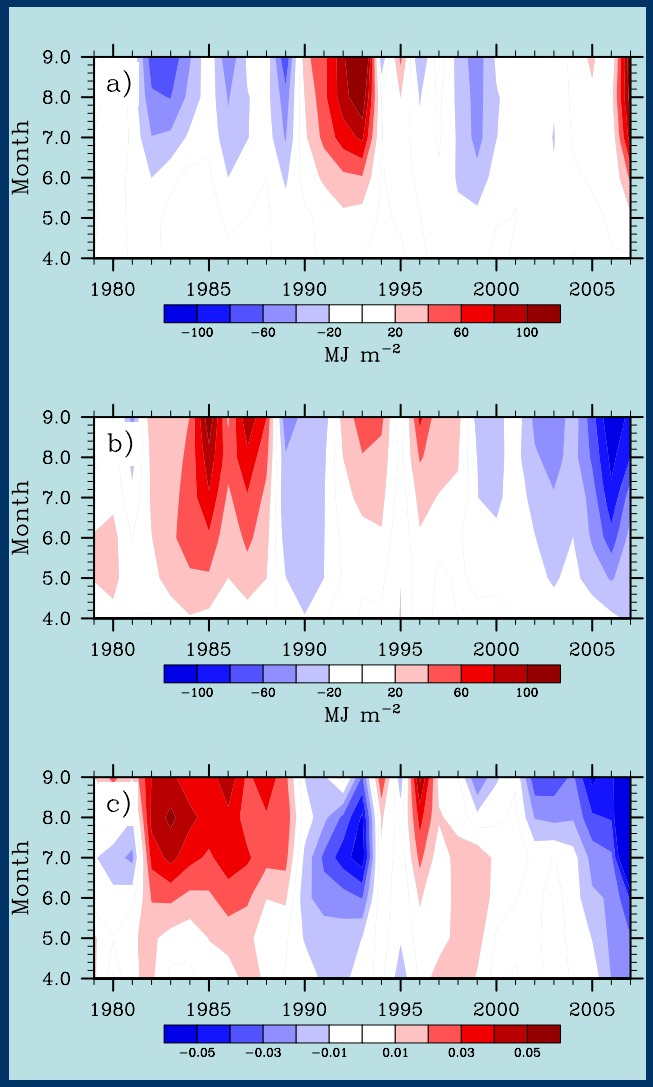
A Growing Ice-Albedo Feedback



Cumulative anomalies in absorbed solar radiation from JRA-25, 2002-2007, relative to 1979-2007

Perovich et al. 2008 found anomalies of 500% in absorbed solar radiation in the Beaufort and Chukchi Seas in 2007.

JRA-25 Shortwave Flux Anomalies



Net absorbed solar radiation anomalies

Incoming solar radiation anomalies

Surface albedo anomalies

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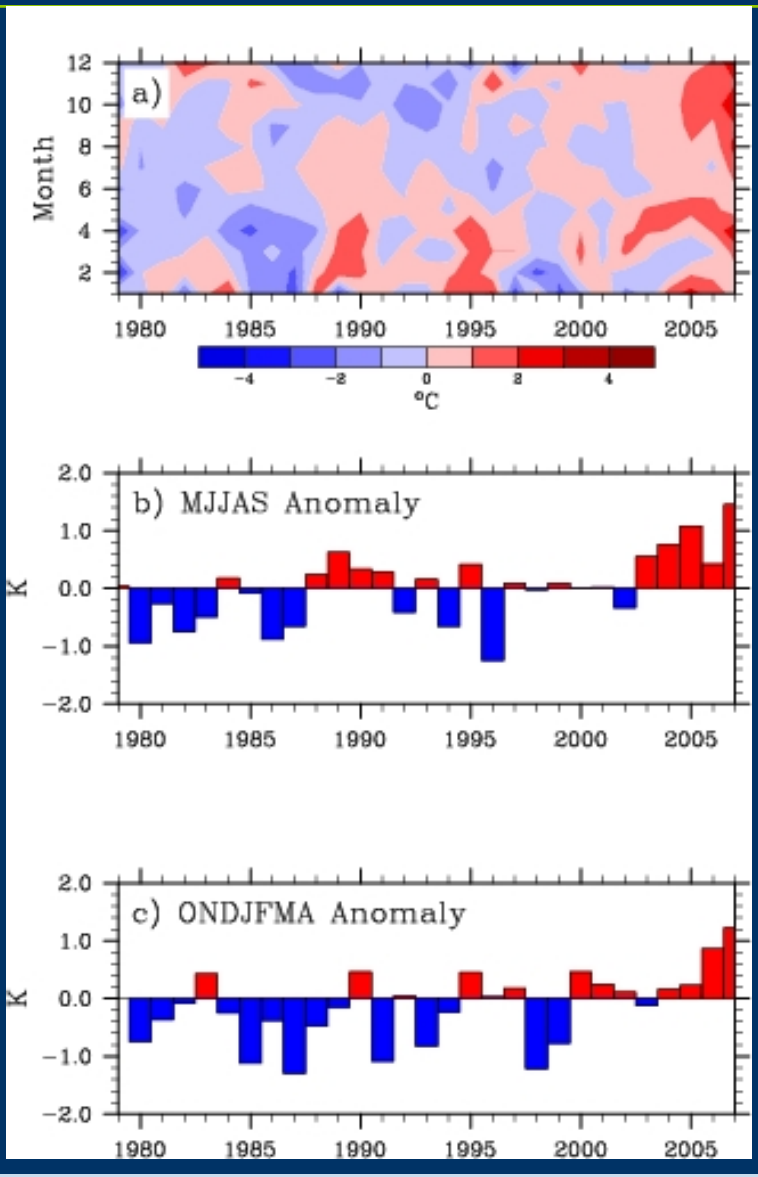
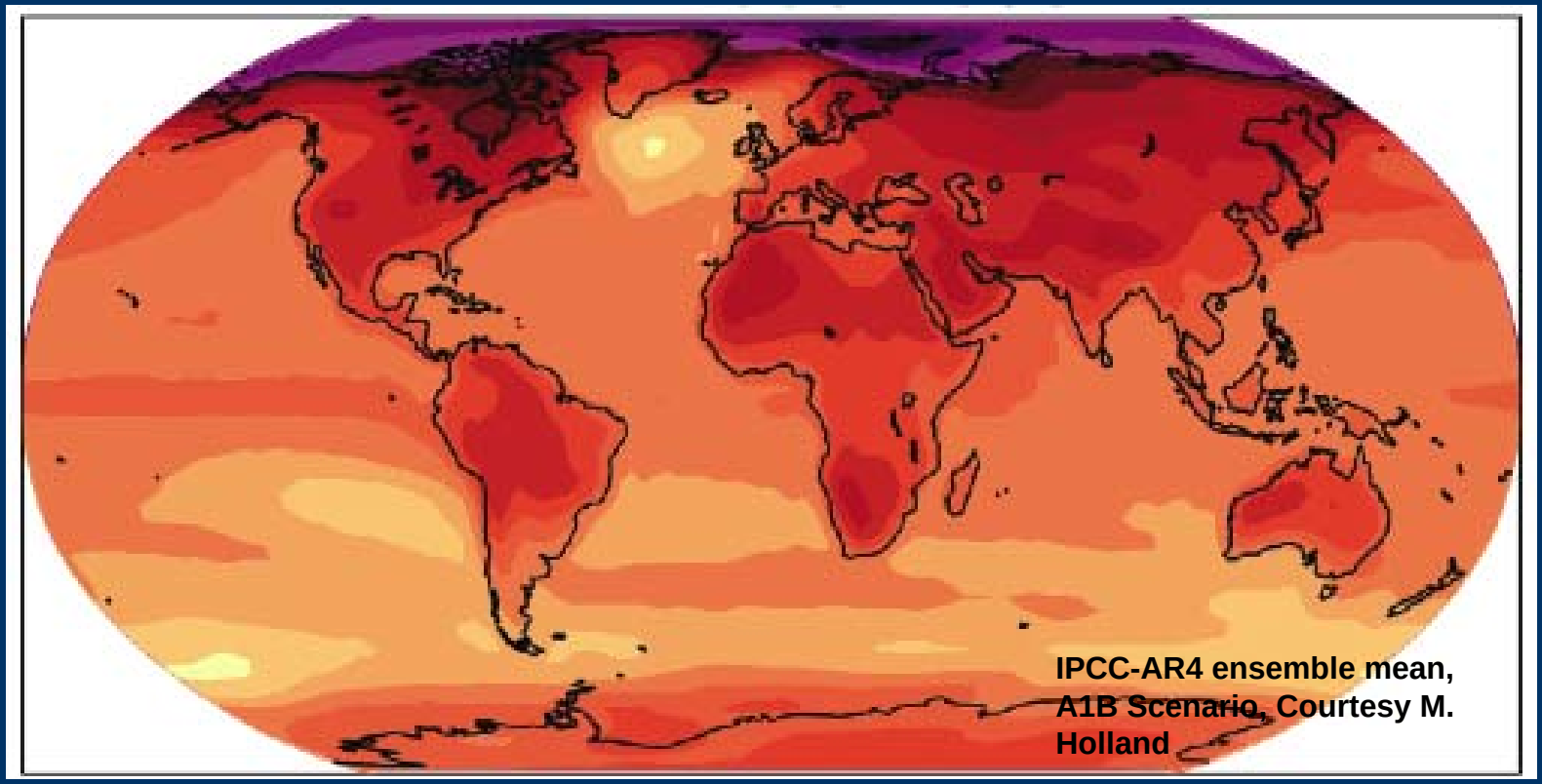
The Arctic is warming in all seasons



JRA-25 surface temperature anomalies by year and month (top) and by extended summer (middle) and extended winter (bottom)

Since about 2000, warming is happening in all months.

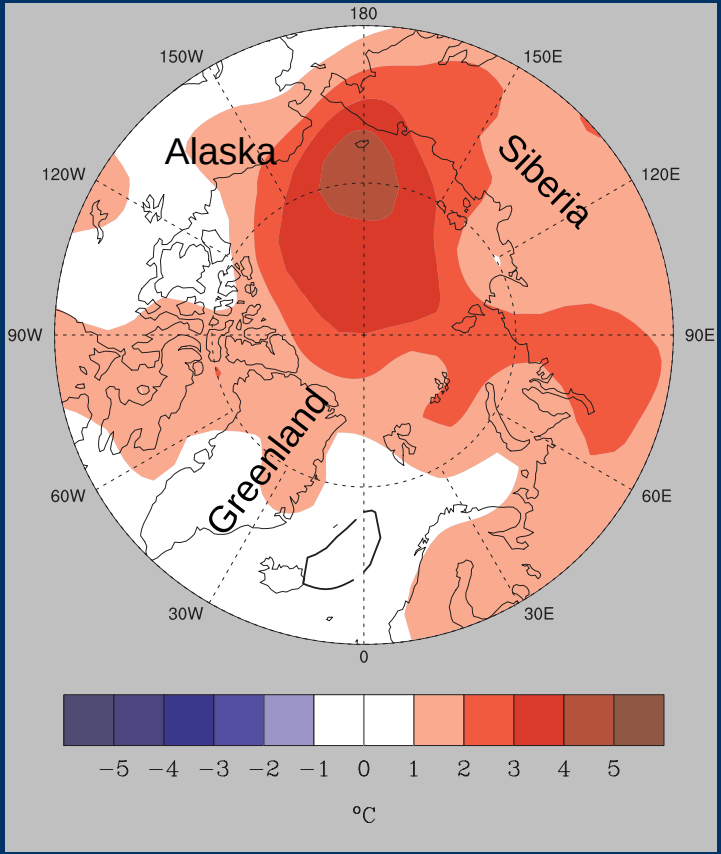
Arctic Amplification

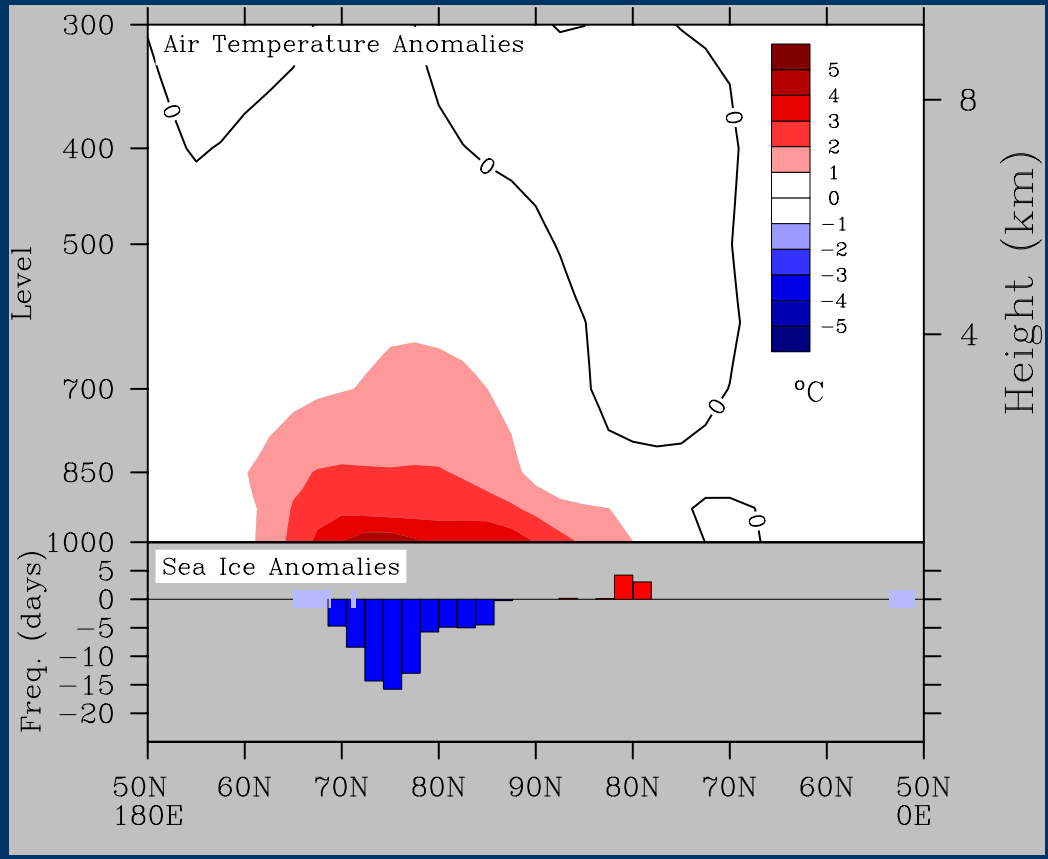


IPCC-AR4 ensemble mean, A1B Scenario, Courtesy M. Holland

Air Temperature: "Business as Usual" Scenario by 2100
Global mean warming of ~2.8°C (or ~5F);
Much of land area warms by ~3.5°C (or ~6.3F)
Arctic warms by ~7°C (or ~12.6F)

Arctic Amplification has Emerged

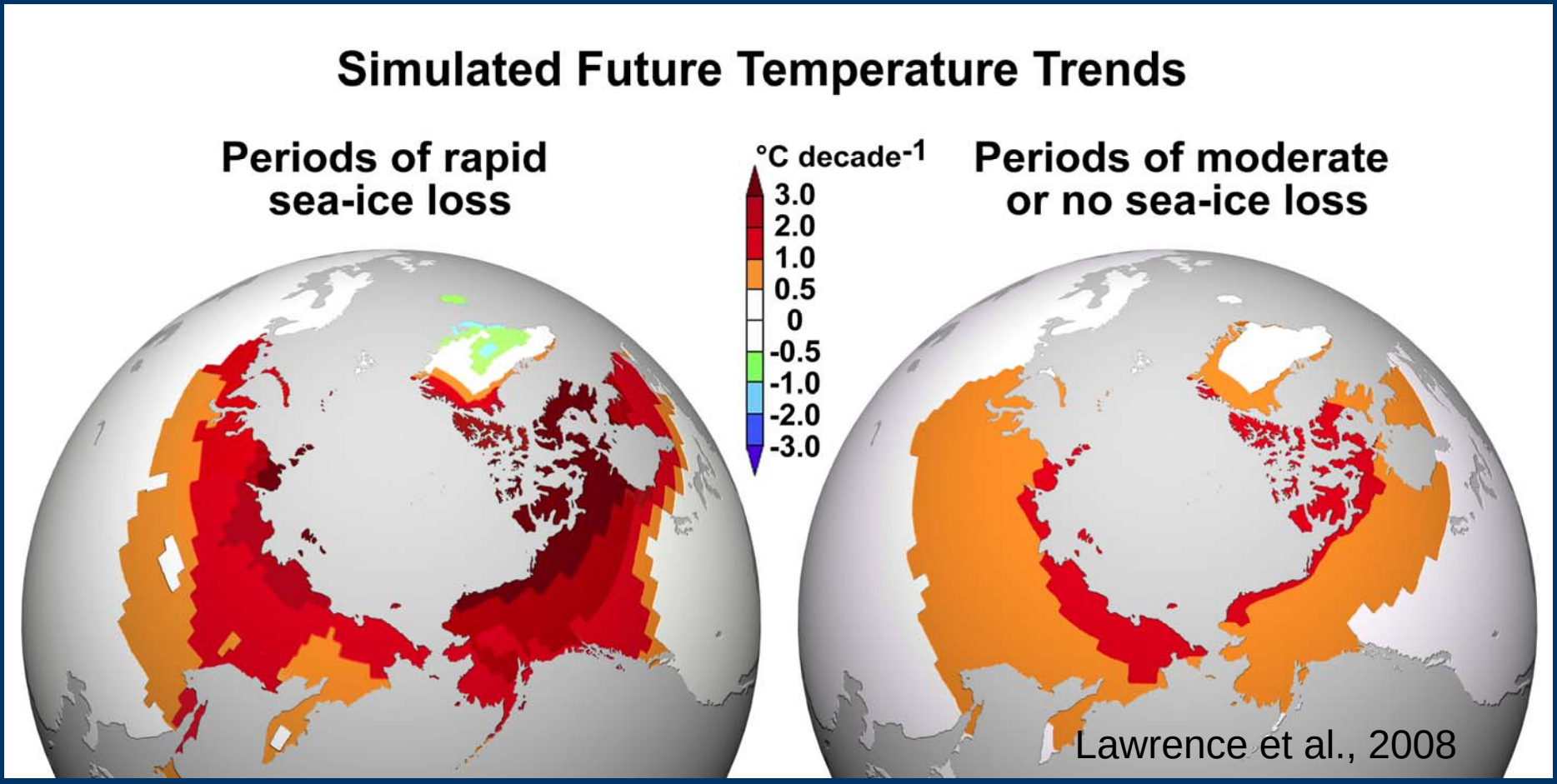




Air Temperature and Sea Ice Anomalies: 2004-2008 minus 1979-2008

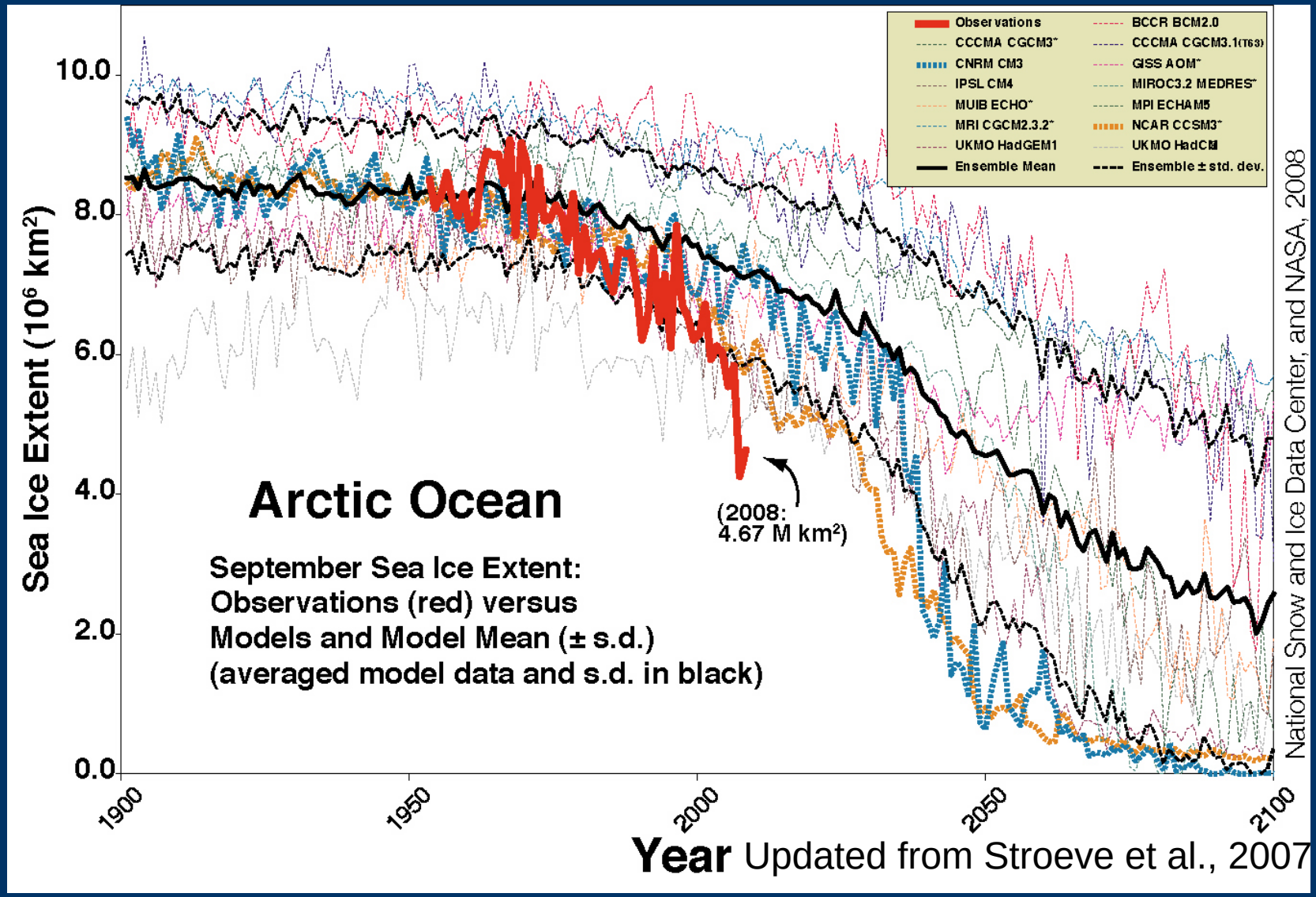
Updated from Serreze et al., 2008

Impact of Sea Ice Loss on Land Temperatures



Permafrost contains about 950 Gt of carbon (Zimov et al., 2006: *Science*). For comparison, carbon content of Earth's atmosphere: ~730 Gt today.

On the Fast Track of Change



Closing Thoughts

- We are quickly losing the Arctic sea ice cover
  - Ice-free summers by 2030? Earlier?
- Several mutually supporting processes are hastening the transition towards a seasonally ice free Arctic state
  - Ice-albedo feedback a key component
  - Urgent need for accurate sea ice albedo observations
- Arctic amplification will be a big issue
  - Impacts on terrestrial warming and carbon cycle
  - Impacts on atmospheric circulation