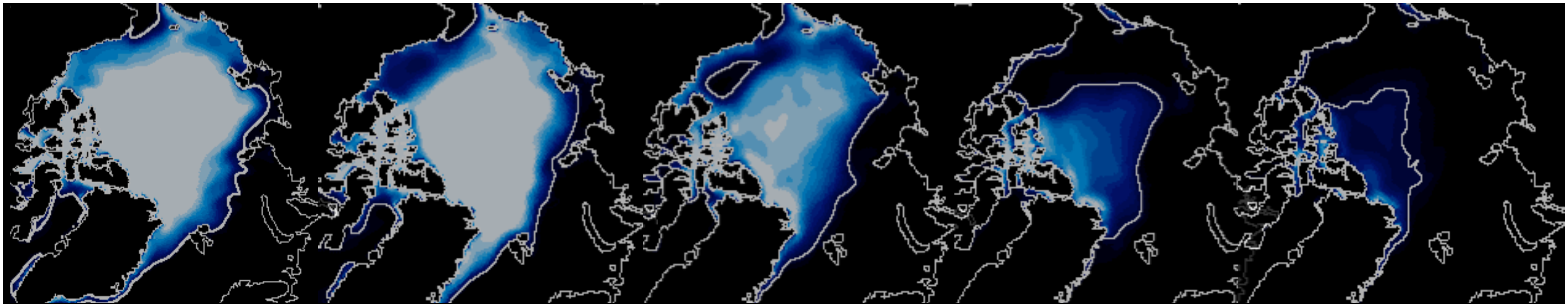
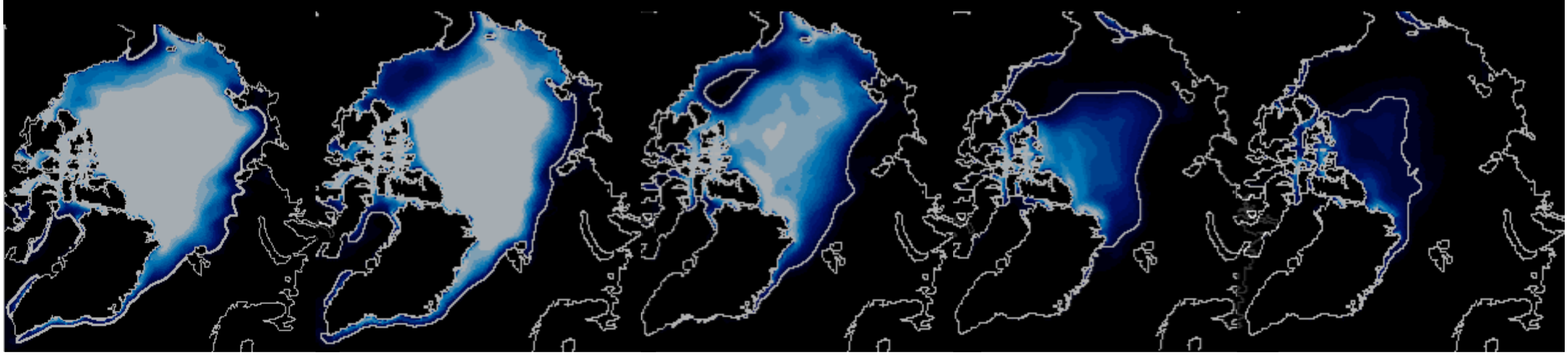


Rapid Arctic Sea Ice Loss

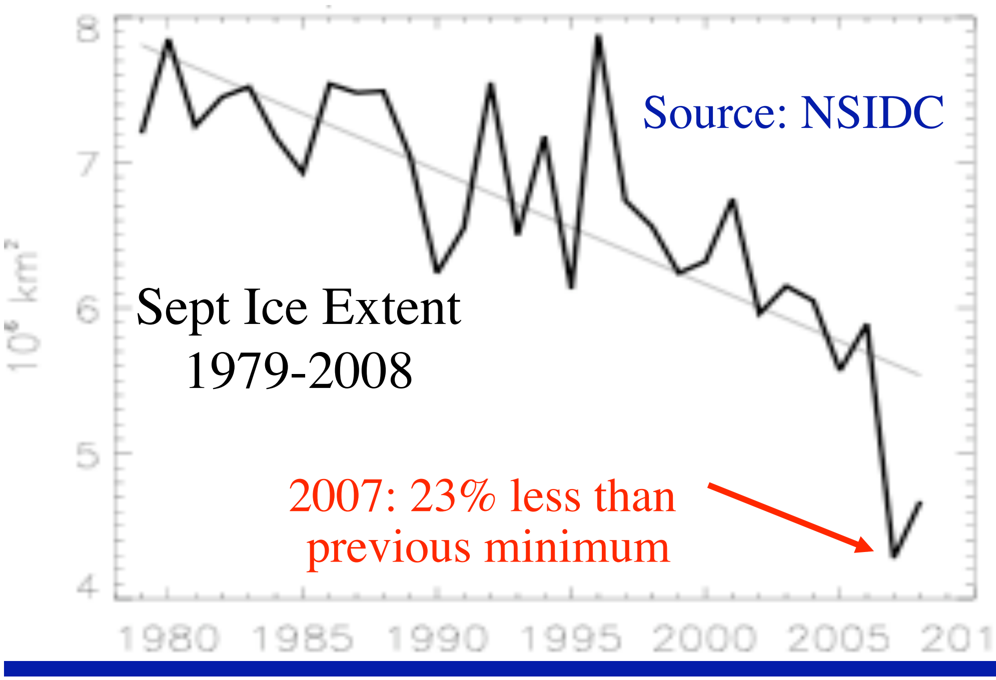
Marika Holland, NCAR

With: C. Bitz (U.WA), B. Tremblay (McGill), D. Bailey (NCAR), J. Stroeve (NSIDC), M. Serreze (NSIDC), D. Lawrence (NCAR), S Vavrus (U. Wisc)

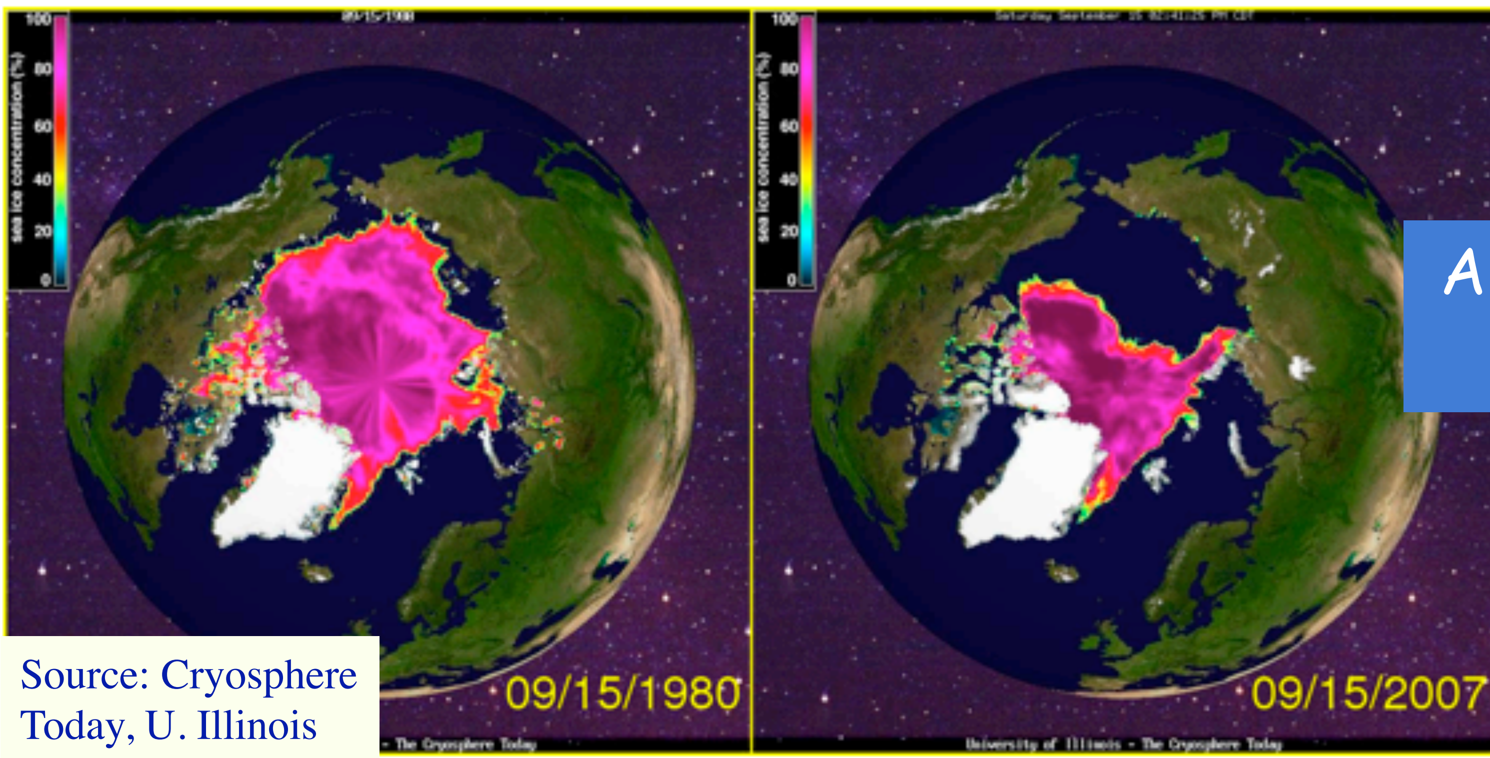


Outline

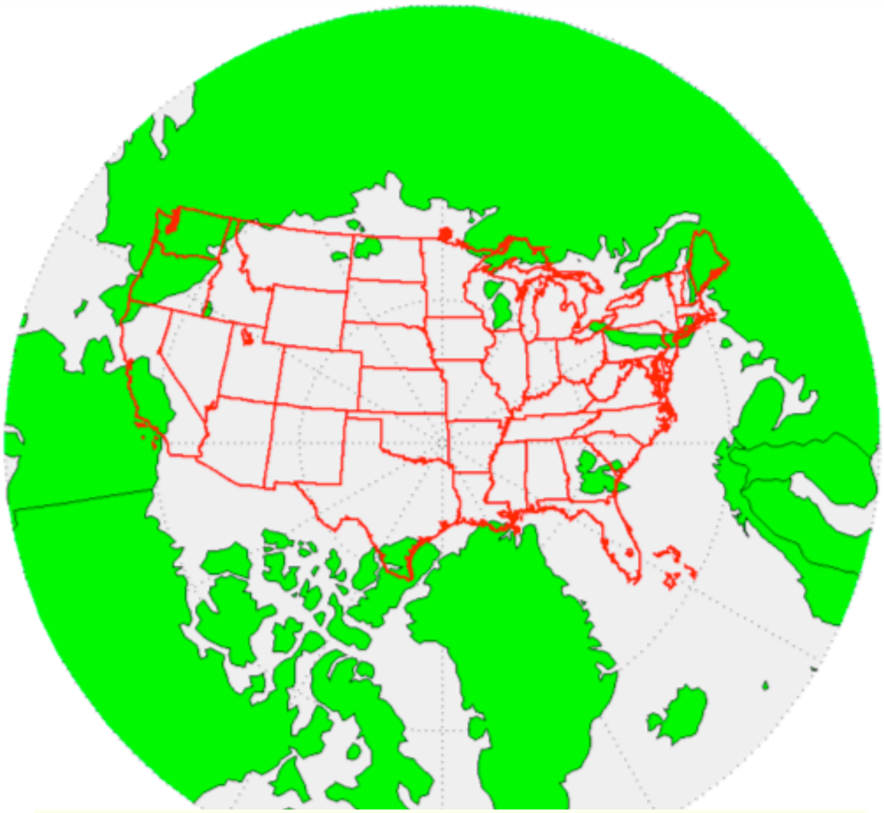
1. Observed Arctic sea ice change
   - Factors influencing change
2. Projected change in future Arctic ice cover
   - Possibility of abrupt transitions
   - Mechanisms driving change
   - Possible "Tipping Point" behavior?
   - How climate models differ
3. Conclusions



Arctic summer sea ice



Source: Cryosphere Today, U. Illinois

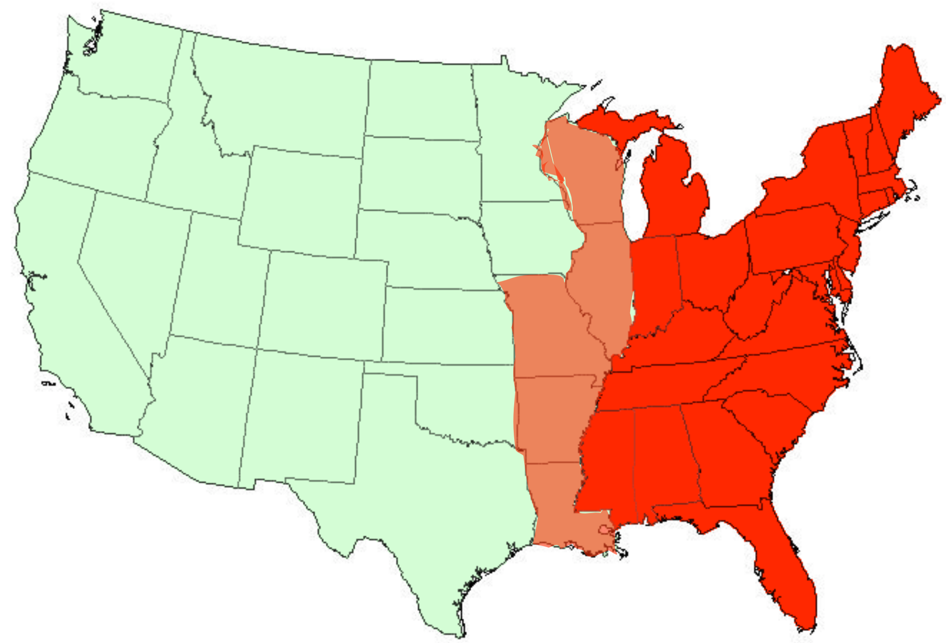


(courtesy of Harry Stern, U. Washington)

Loss of the summer ice cover in context

From 1980 to 2005: ice loss equal to 24 states; most of the US east of the Mississippi

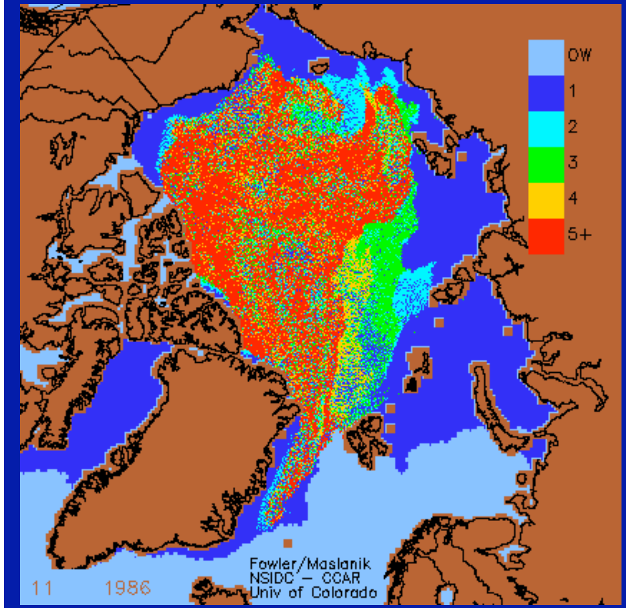
To 2007: 5 additional states



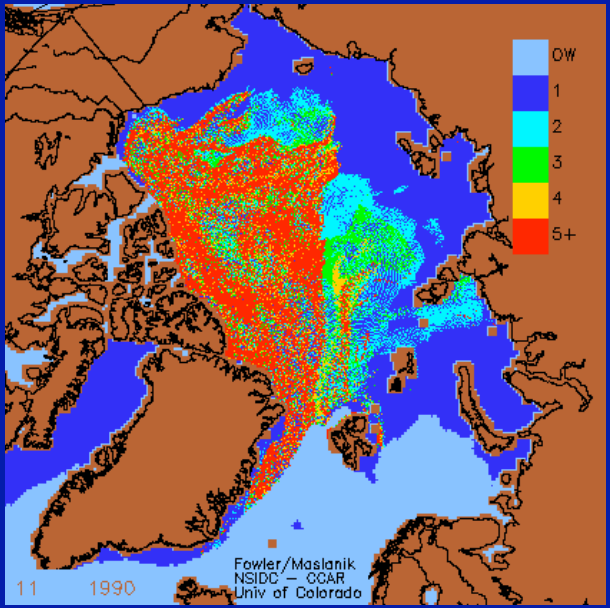
(courtesy of Dr. Don Perovich, CRREL)

Transition Towards Younger, Thinner Ice

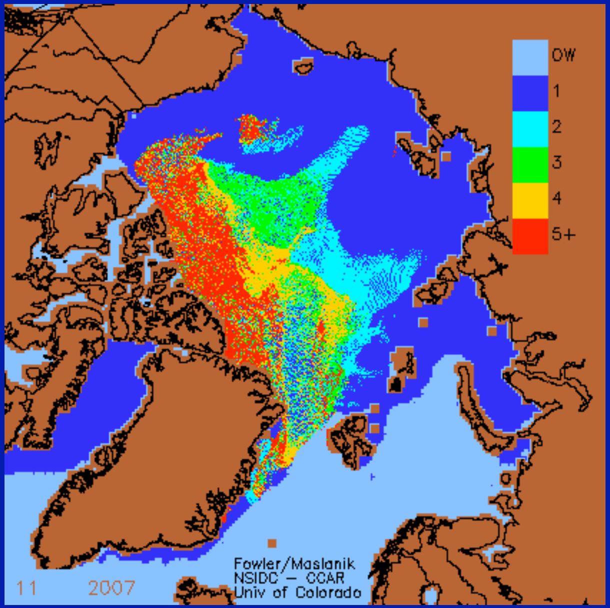
- Ice age tracking algorithm from C. Fowler and J. Maslanik
- By 2007 ice >5 years is only 10% of the perennial ice pack.
- Younger ice is generally thinner ice
- Consistent with ULS data; hindcast model experiments



Spring 1986



Spring 1990

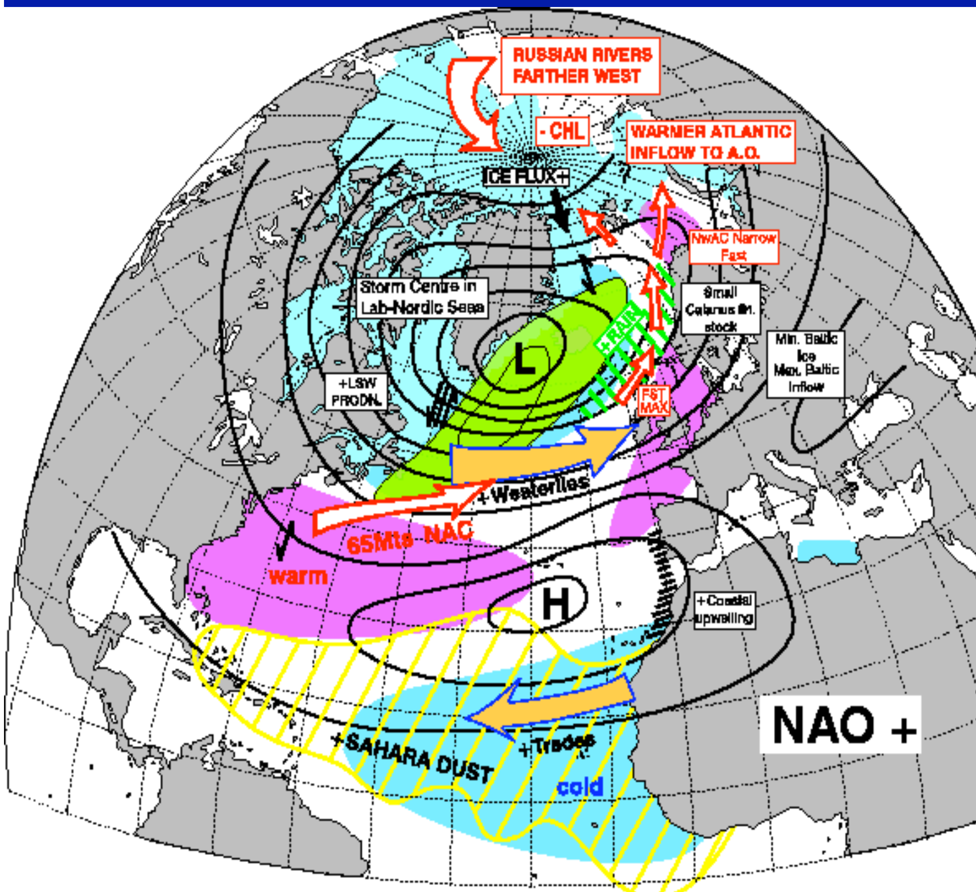


Spring 2007

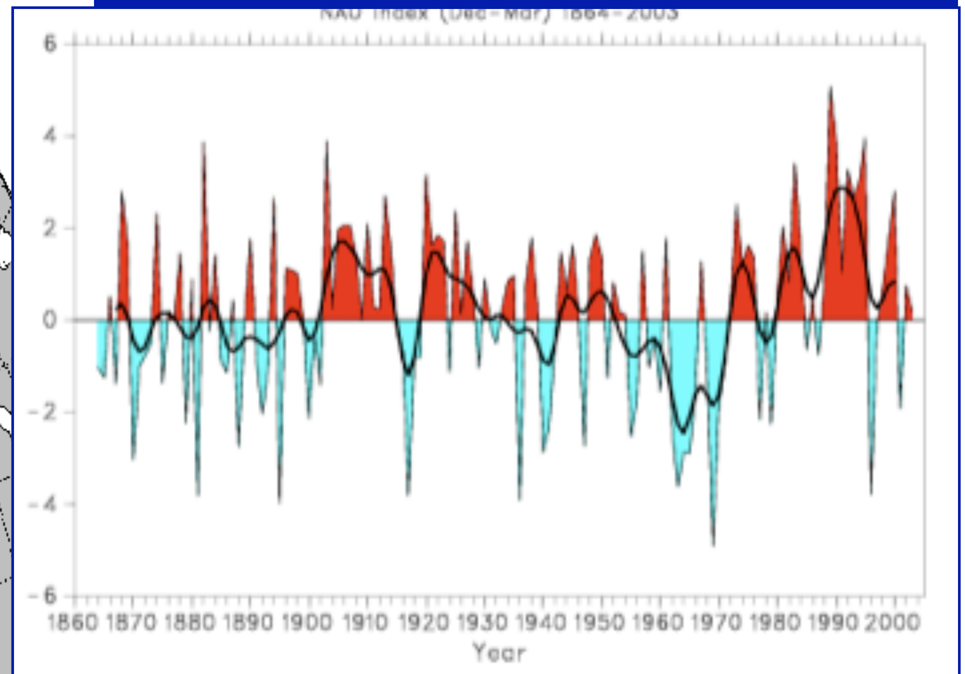
Maslanik et al., 2007

Factors driving observed thinning and retreat

- Dynamic forcing
  - prolonged increase in NAO from 1960s to mid-1990s increased ice transport from the Arctic into the North Atlantic (Rigor et al., 2002; Kwok and Rothrock, 1999)

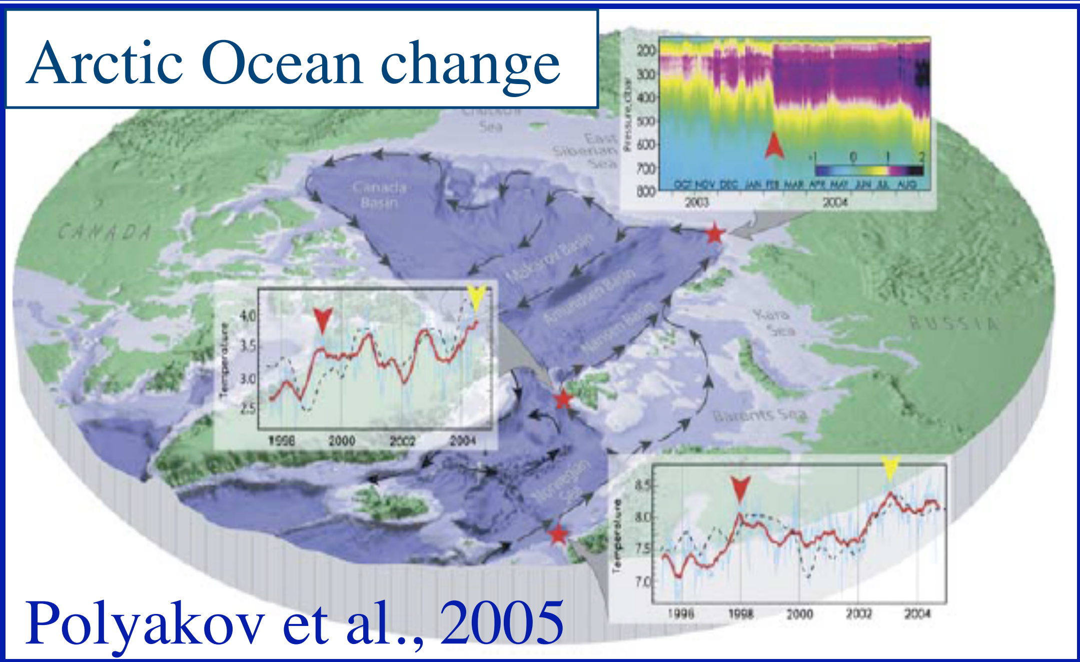


Winter NAO Index; 1864-2003



Factors driving observed thinning and retreat

- Thermodynamic forcing
  - warmer air temperatures and enhanced ice melt (Rothrock and Zhang, 2005); increased down LW (Francis and Hunter, 2006)
  - increased ocean heat transport to the Arctic with possible effects on ice melt/growth



Natural variability or anthropogenic change? Both likely…

Arctic change:
The poster child for global climate change

INTERNATIONAL Herald Tribune | Americas

iht.com Business Culture Sports Opinion

AMERICAS EUROPE ASIA/PACIFIC AFRICA/MIDDLE EAST | TECH/MEDIA STYLE HEALTH

TRAVEL PROPERTIES BLOGS DISCUSSIONS SPECIAL REPORTS AUDIONEWS

'Arctic is screaming,' say scientists seeing new data; worry over 'tipping point'

The Associated Press

Published: December 12, 2007

WASHINGTON: An already relentless melting of the Arctic greatly accelerated during the Northern Hemisphere's hot summer months, a warning sign that some scientists worry could mean global warming has passed an ominous tipping point. One is even speculating that summer sea ice would be gone in five years.

Greenland's ice sheet melted nearly 19 billion tons (17.25 metric tons) more than the previous high mark, and the volume of Arctic sea ice at summer's end was half what it was just four years earlier, according to new NASA satellite data obtained by The Associated Press.

E-Mail Article
Listen to Article
Printer-Friendly
3-Column Format
Translate
Share Article

ENVIRONMENT SUMMIT-Arctic thaw may be at "tipping point"

Fri Sep 28, 2007 8:33am EDT

Email | Print | Share | Reprints | Single Page | Recommend (0) | [-] Text [+]

RELATED NEWS

World sea levels to rise 1.5m by 2100: scientists
15 Apr 2008

By Alister Doyle, Environment Correspondent

OSLO, Sept 28 (Reuters) - A record melt of Arctic summer sea ice this month may be a sign that global warming is reaching a critical trigger point that could accelerate the northern thaw, some scientists say.

USA
GREENLAND
CANADA

Video and Audio
Have Your Say
In Pictures
Country Profiles

Telegraph.co.uk

Home | News | Sport | Business | Travel | Jobs | Motoring | Telegraph TV | SEARCH

Digital Life home
TechNotes blog
Bootcamp
Faqs! Facts! Fax!
Digital Photography
OurLives
On Trial
Games
Science
Digital Cameras
Guide to Digital

Arctic ice hits 'tipping point'

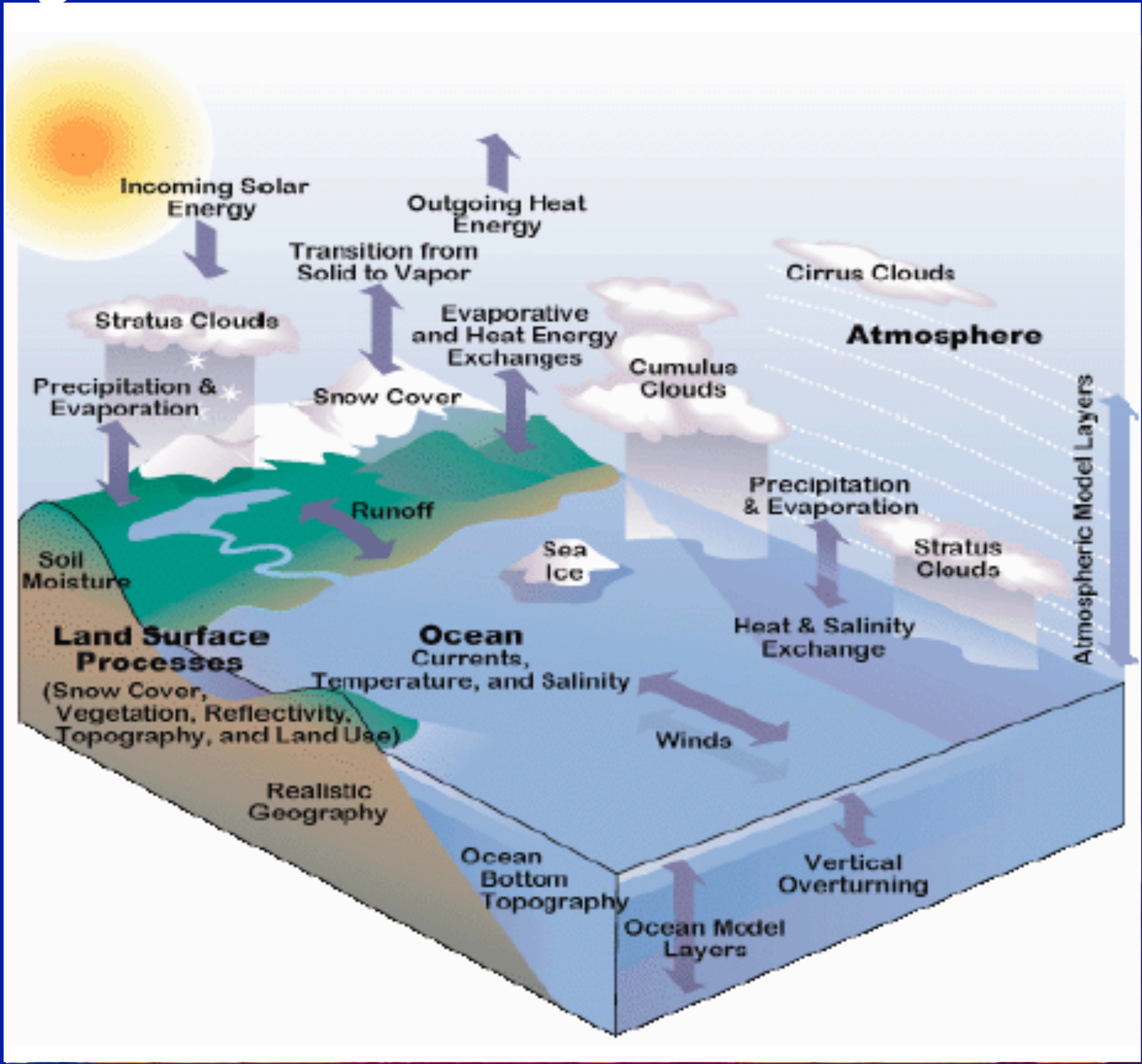
By Roger Highfield, Science Editor
Last Updated: 12:01am GMT 16/03/2007

Dwindling Arctic sea ice may have reached a 'tipping point' that could make British winters even wetter, according to researchers.

Arctic sea ice levels naturally ebb and flow throughout the year and are always lowest in September. But September 2005 marked their lowest level in 50 years and satellite data show average September sea ice extent down by 8.6 per cent per decade and accelerating.

Some computer models even predict an ice-free Arctic Ocean in September by 2050.

Peering into the future…



Community Climate System Model 3 (CCSM3), IPCC Model Simulations

20th century runs

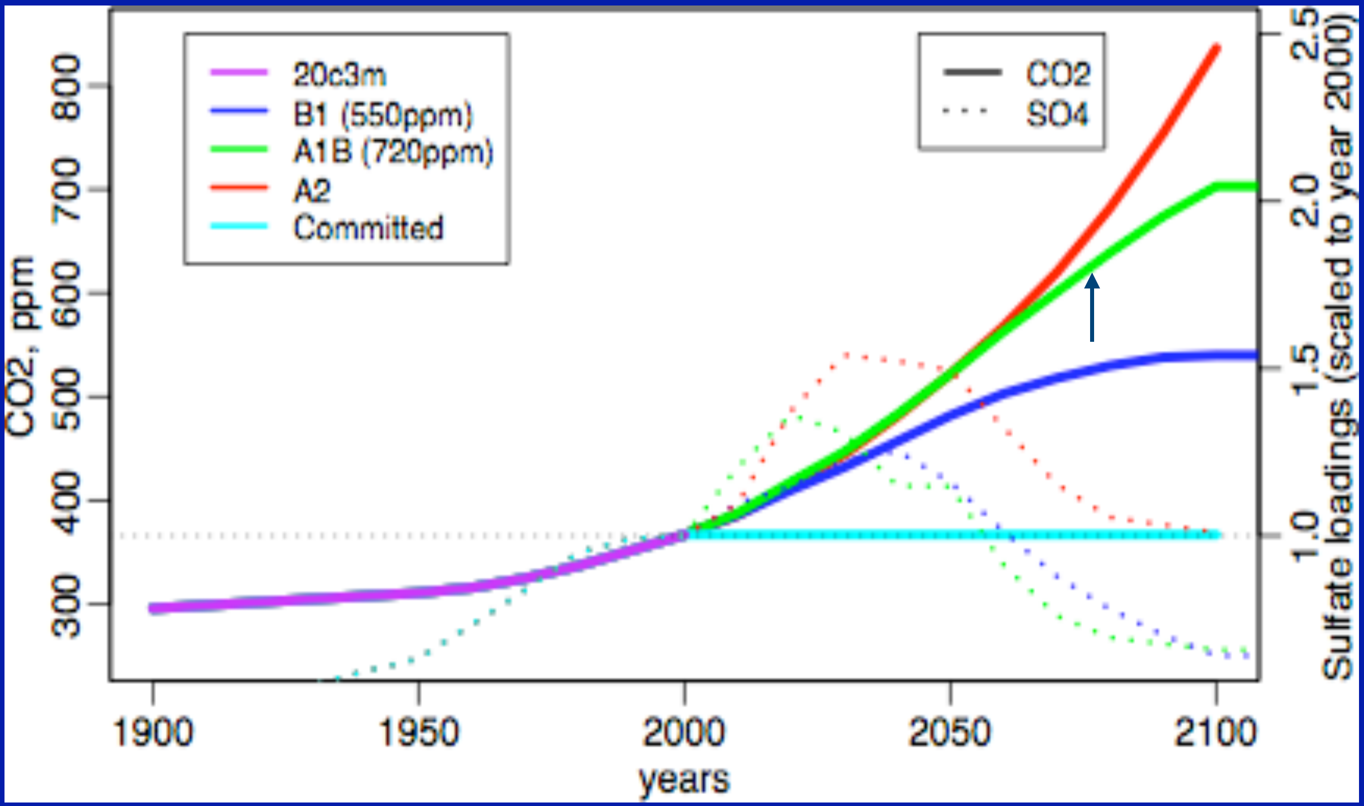
- branched from 1870 control run
- include variations in sulfates, solar input, volcanoes, ozone, GHGs (CO_2, CH_4, N_2O), Halocarbons (CFCs), black carbon

21st century runs

- *A1B scenario: rapid economic growth; global* population that peaks mid-century; rapid introduction of new and more efficient technologies; balance across fossil/non-fossil energy sources.

Future climate scenarios

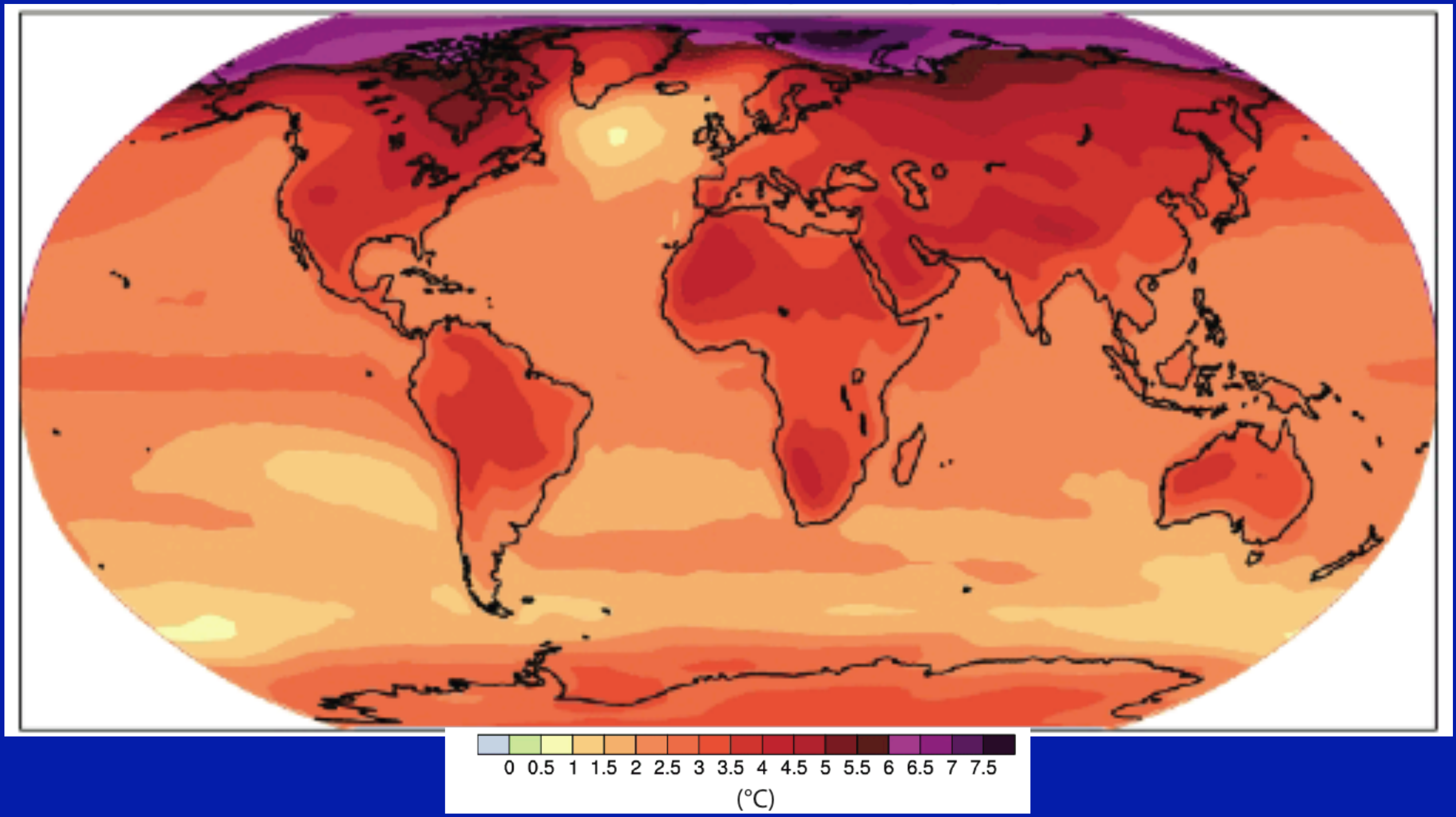
- Relatively gradual forcing.
- Relatively gradual response in global air temperature



IPCC-AR4

Air Temperature: Typical "business as usual" scenario by 2100

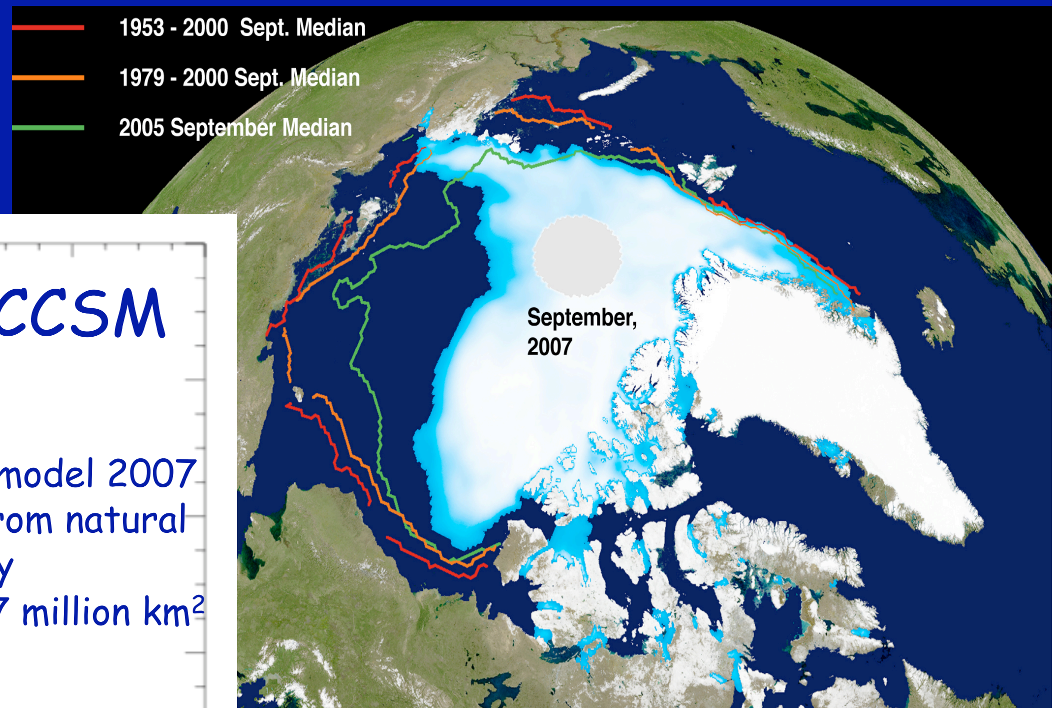
Global mean warming of ~2.8°C (or ~5F);
Much of land area warms by ~3.5°C (or ~6.3F)
Arctic warms by ~7°C (or ~12.6F)

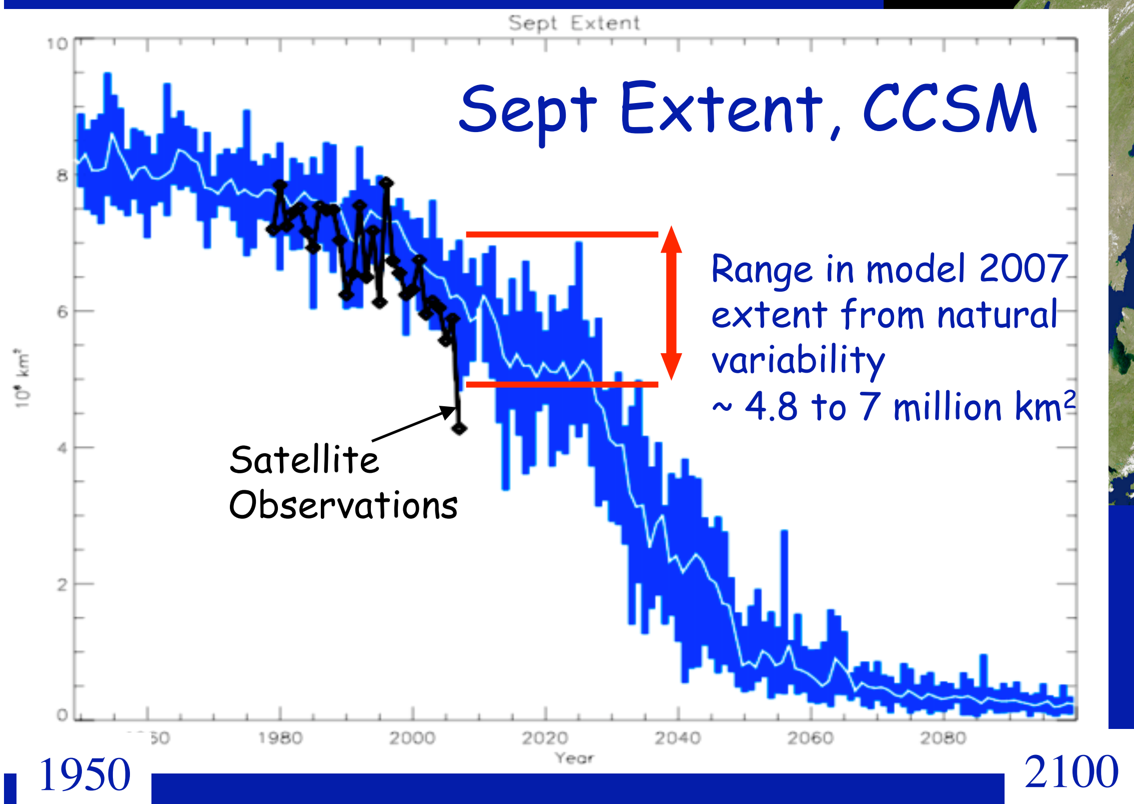


NCAR

IPCC-AR4

Simulated change over historical record



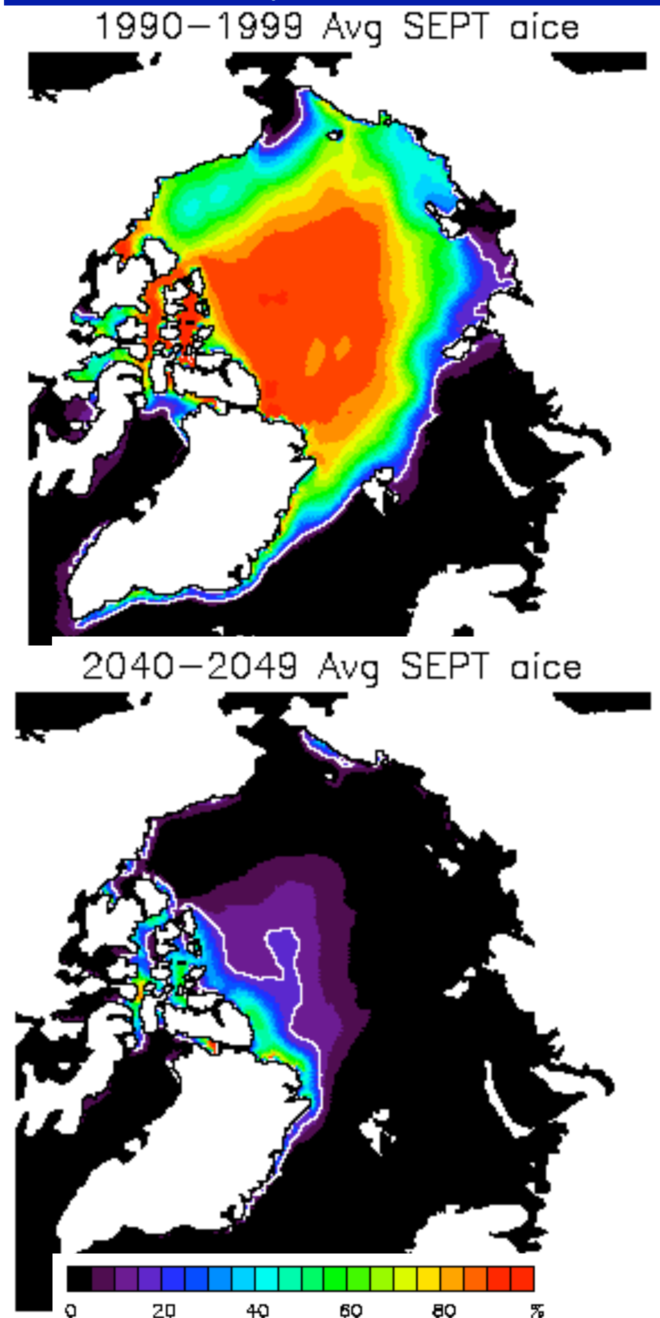


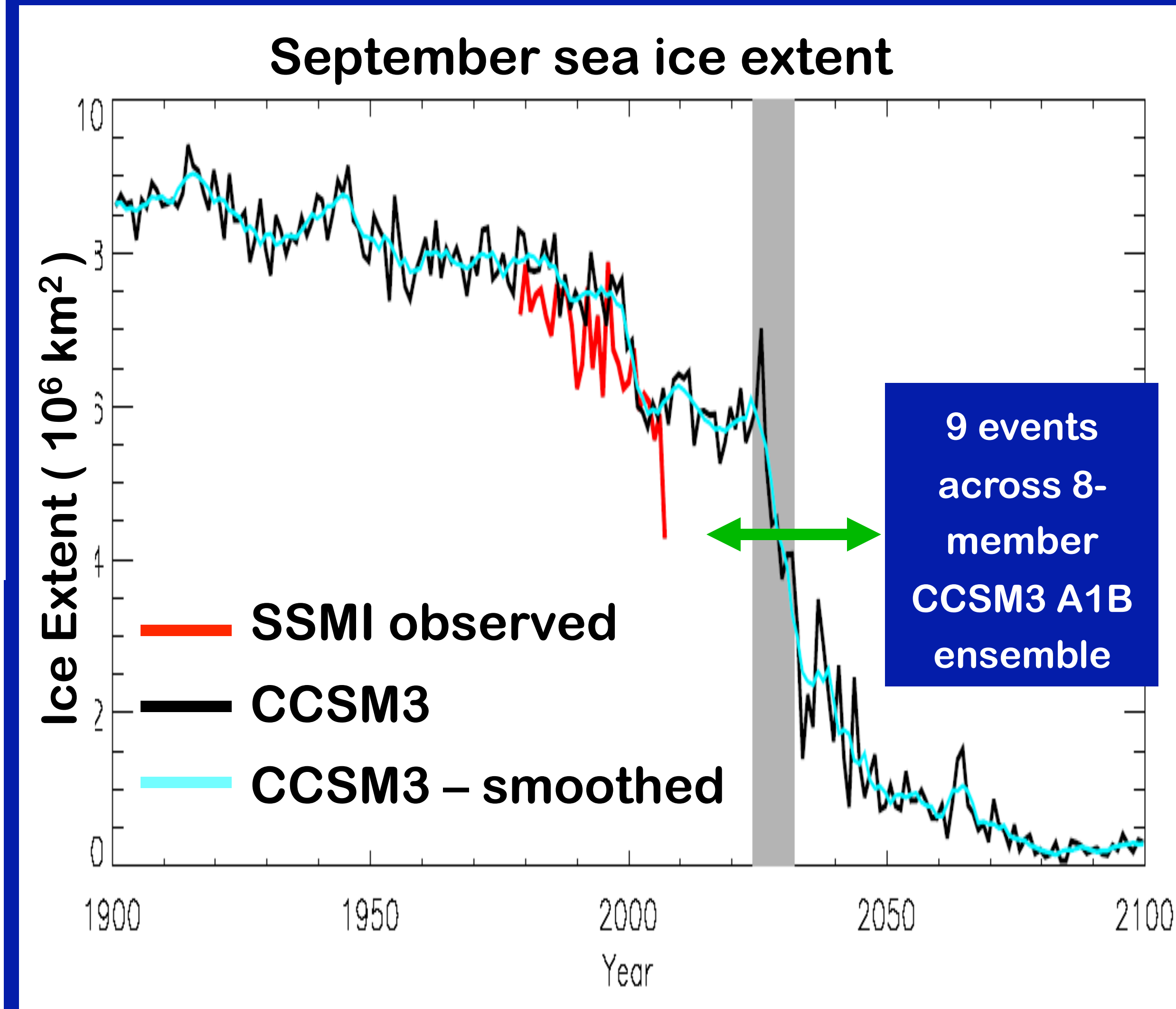
Simulated trend generally consistent with observed loss

CCSM3 does not obtain 2007-like conditions until 2013

Simulated natural variability is considerable and comparable to obs

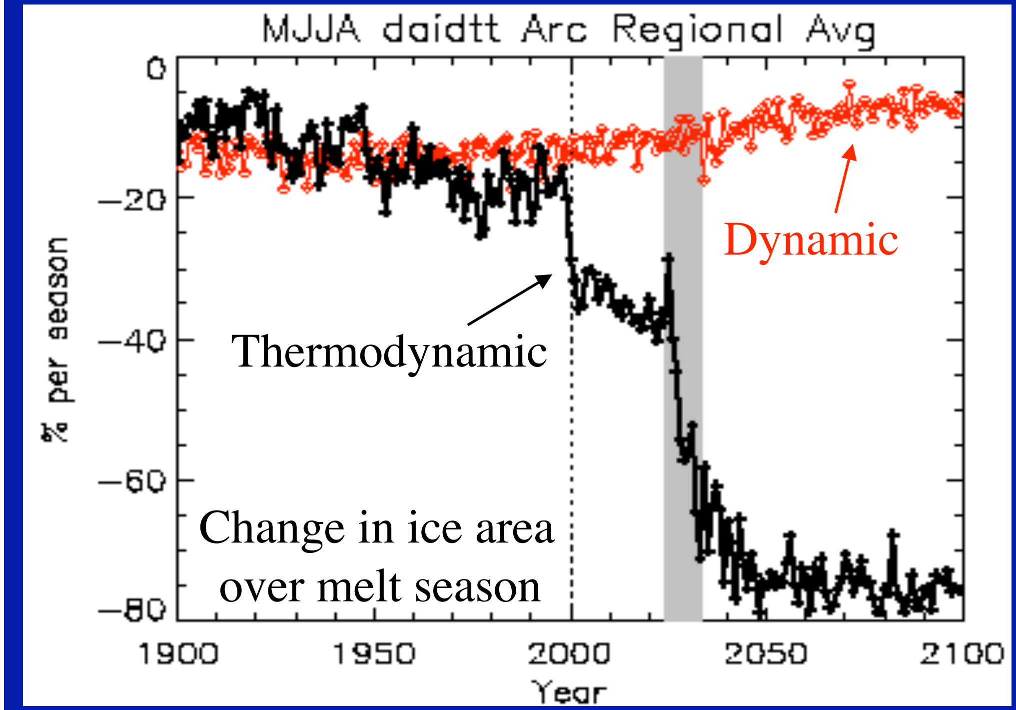
Abrupt reductions in the September sea ice cover



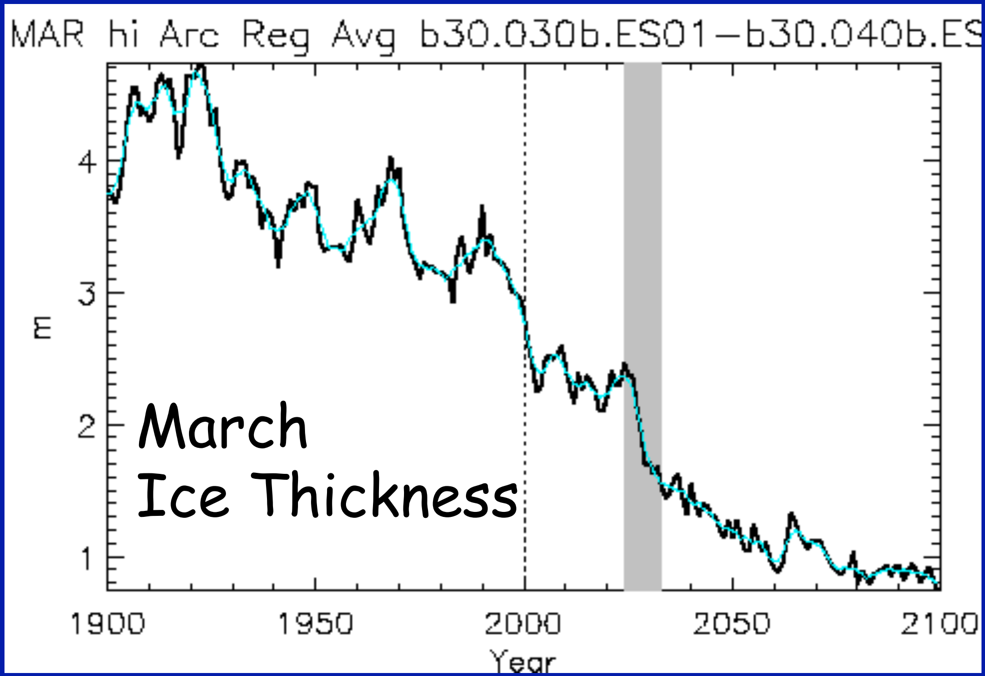


Holland et al., 2006

Forcing of the Abrupt Change

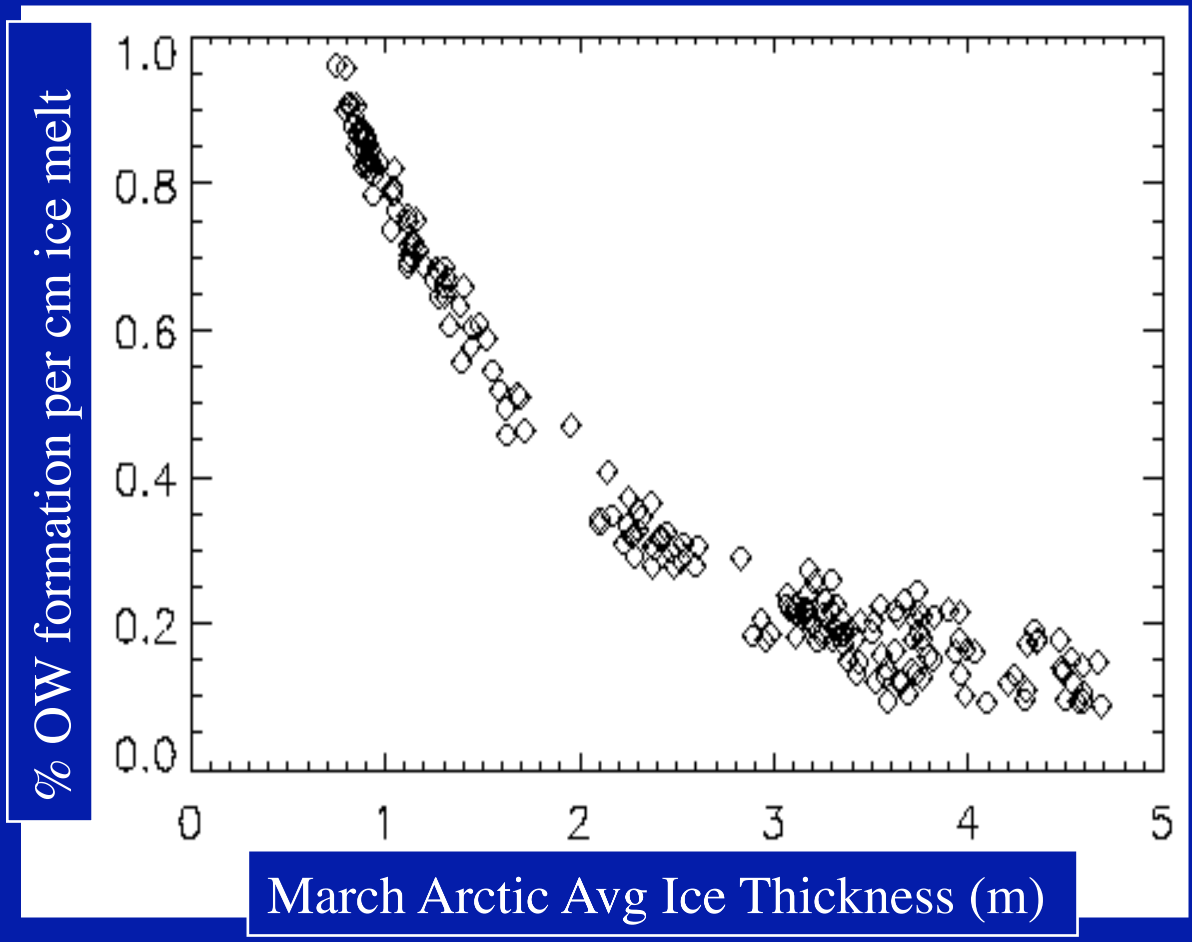


- Change is driven thermodynamically
- Dynamics plays a small stabilizing role



- Ice melt rates directly modify ice thickness
- Ice thickness shows large drop associated w/ event
- This change is similar to earlier reductions in 20th century that had little ice extent change.

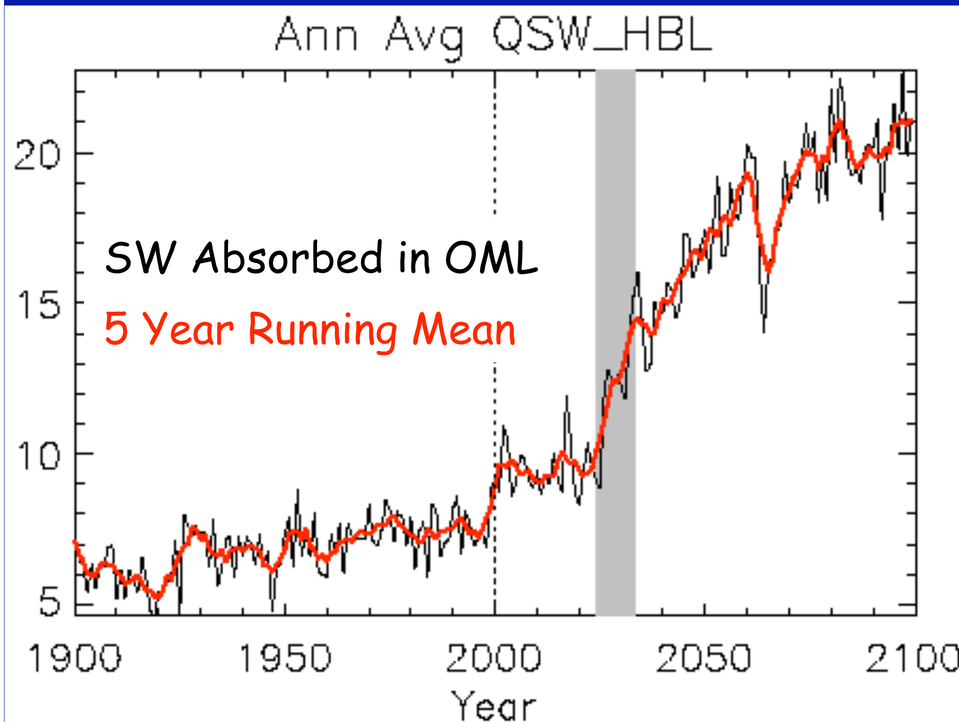
Processes contributing to abrupt change

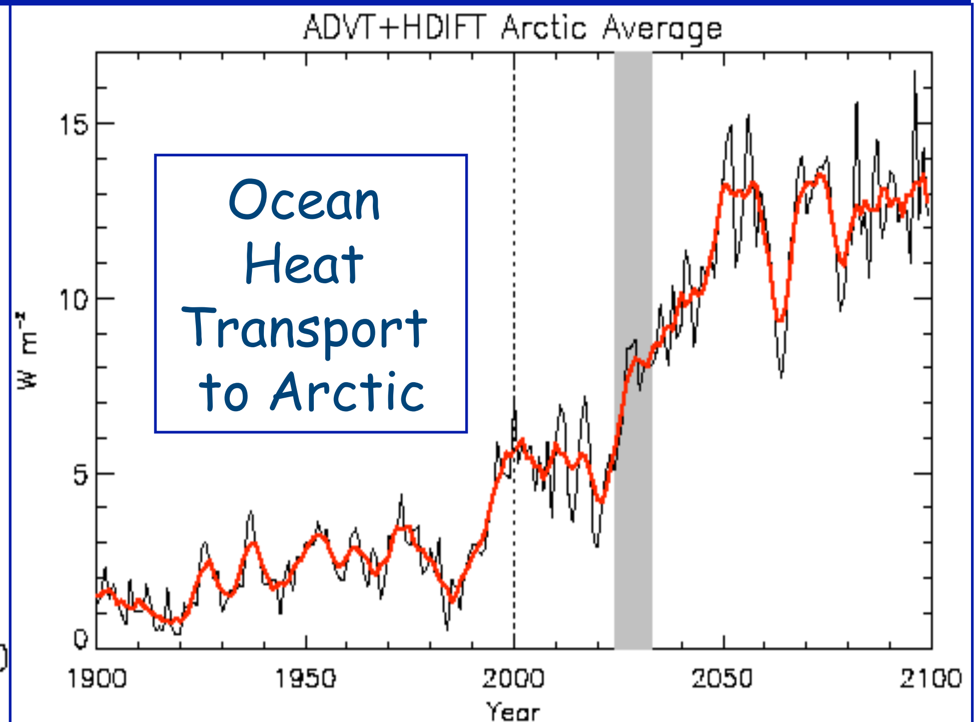


Increased efficiency of OW production for a given ice melt rate

- As ice thins, vertical melting more efficiently produces open water
- Relationship with ice thickness is non-linear

Processes contributing to abrupt change





Albedo Feedback

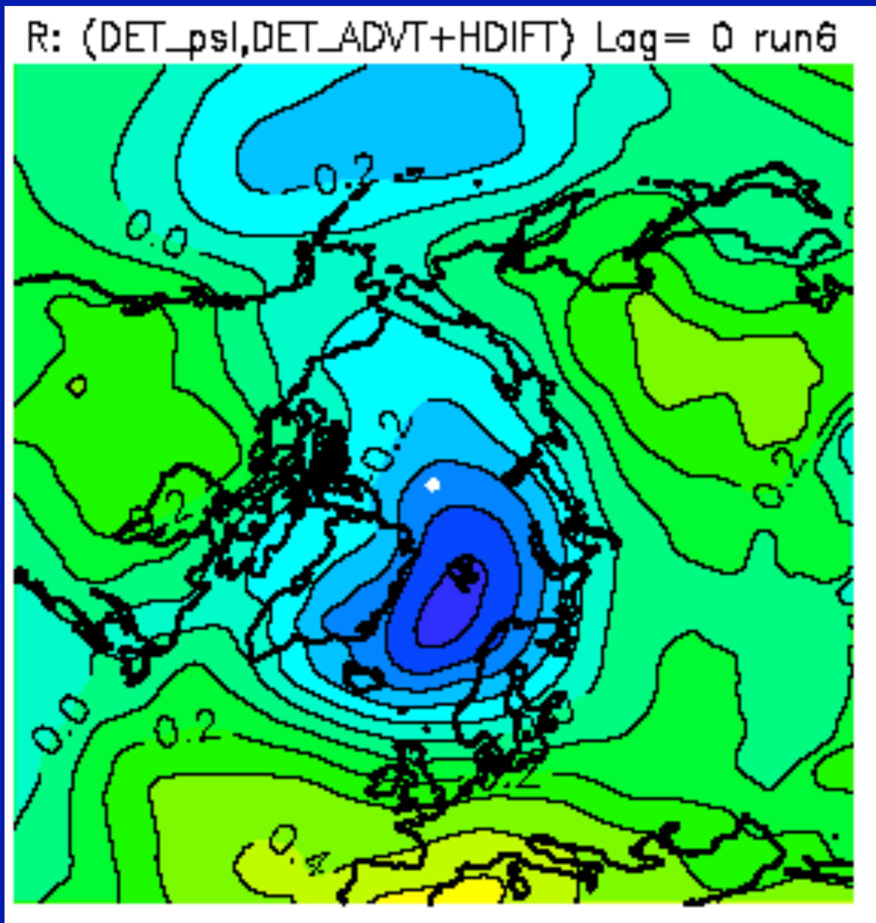
Increases in absorbed solar radiation as the ice recedes.

Contributes to increased basal melting

Increases in ocean heat transport over abrupt transition.

Contributes to increased basal melting and provides a possible "trigger" for the event.

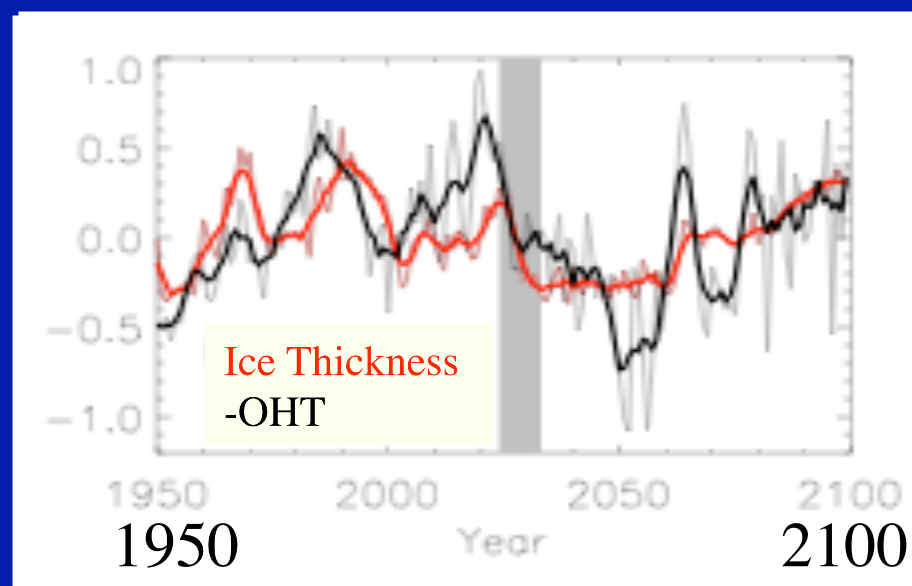
Both trend and shorter-timescale variations in OHT appear important



(Holland et al, in press)

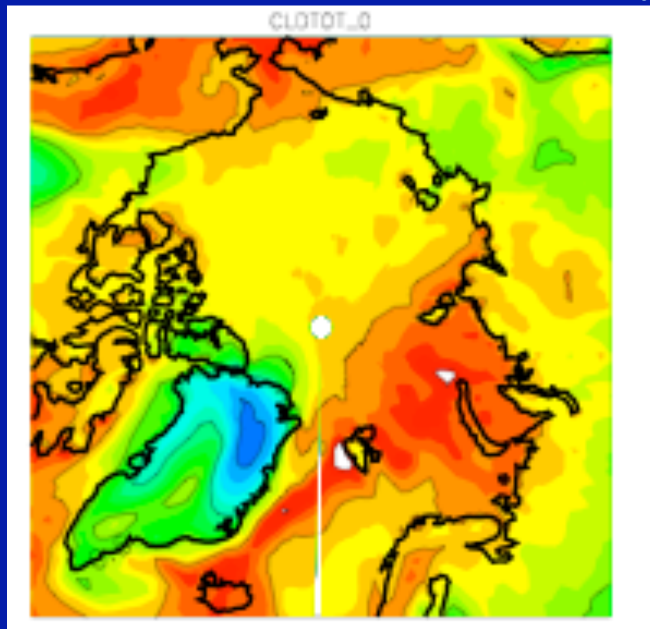
OHT "natural" variations lead changes in ice cover

Correlated to an NAO-type pattern in SLP

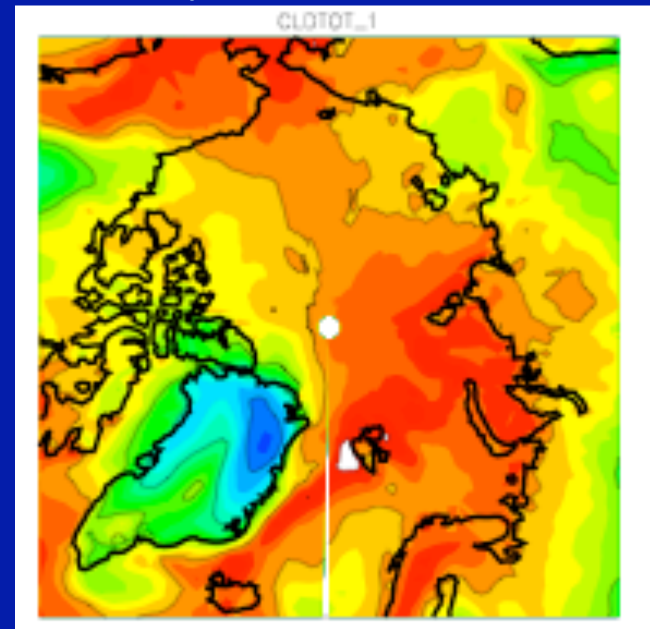


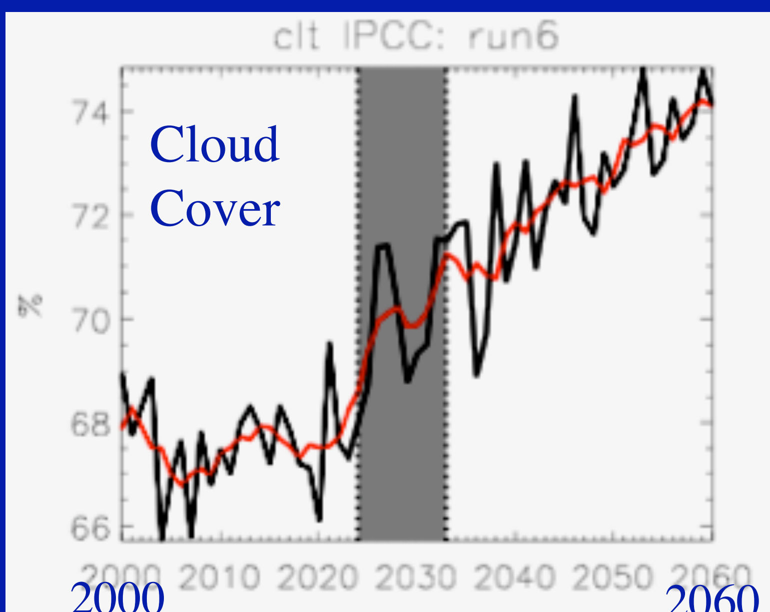
A possible role for cloud feedbacks?

Cloud cover before event

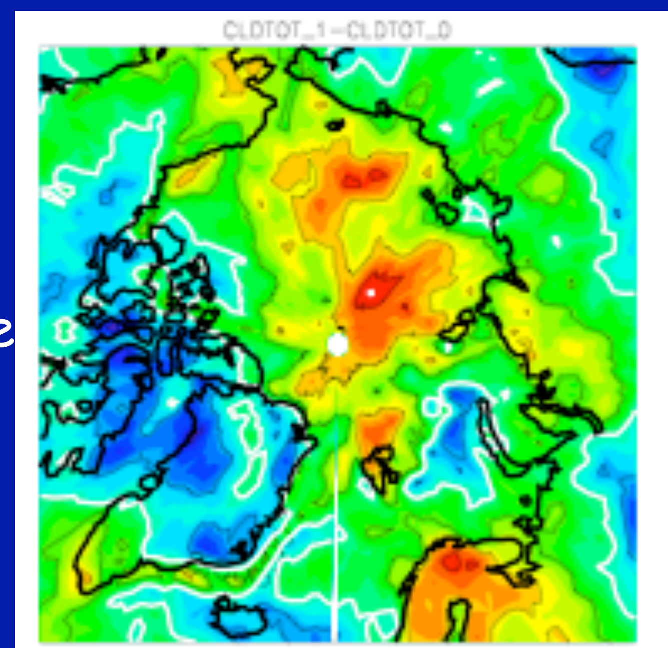


Cloud cover after event

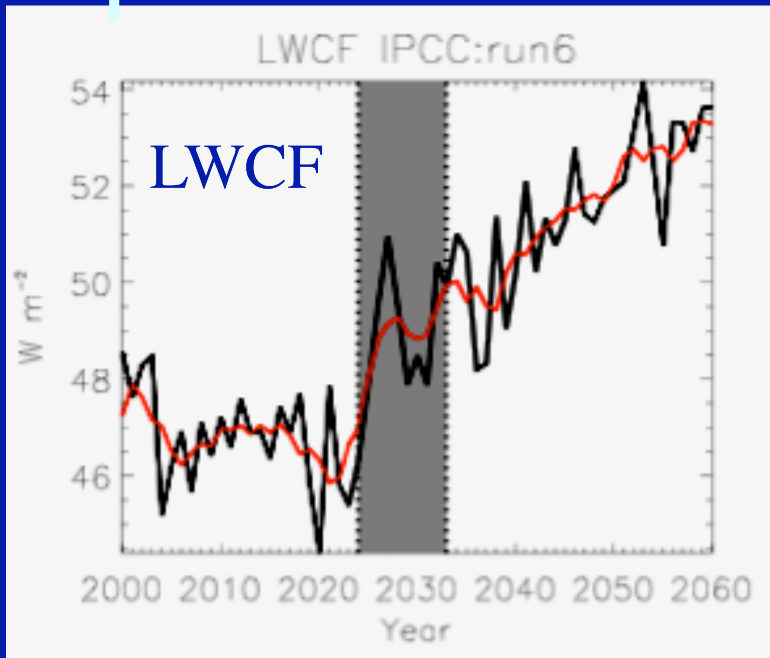


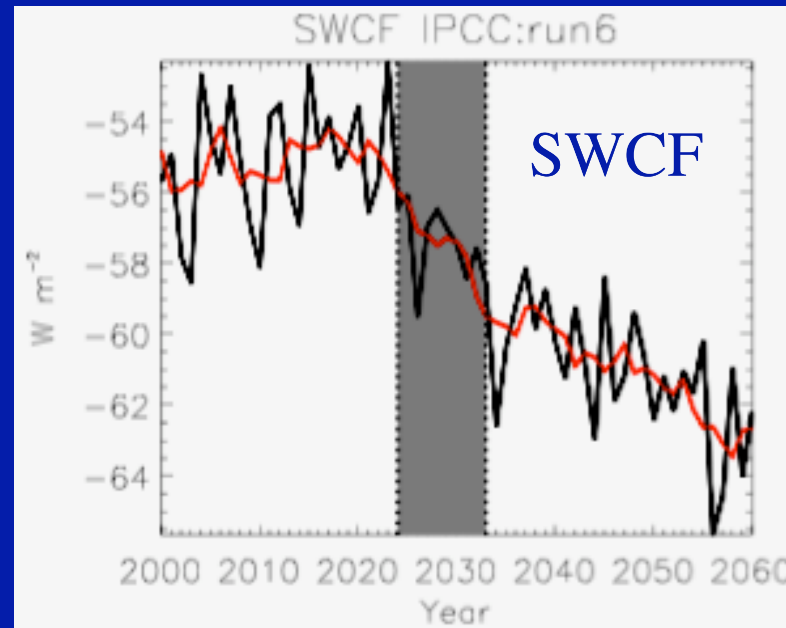


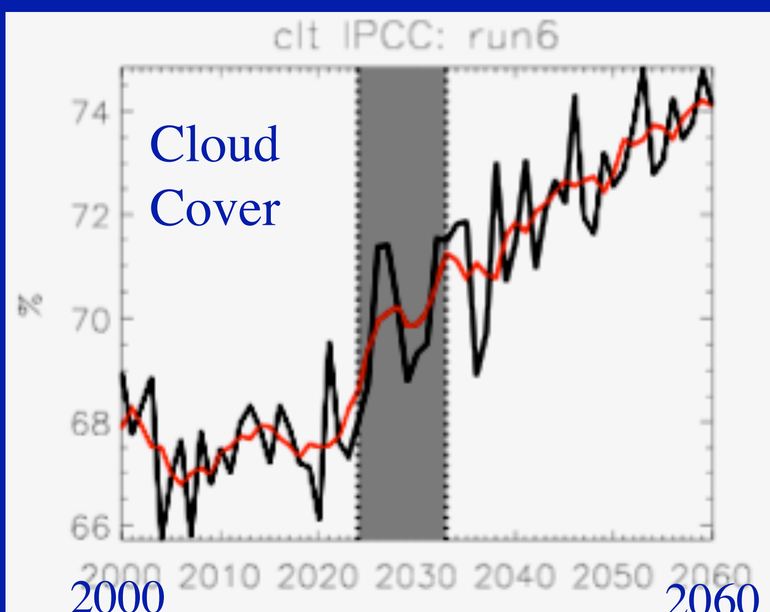
Cloud cover difference



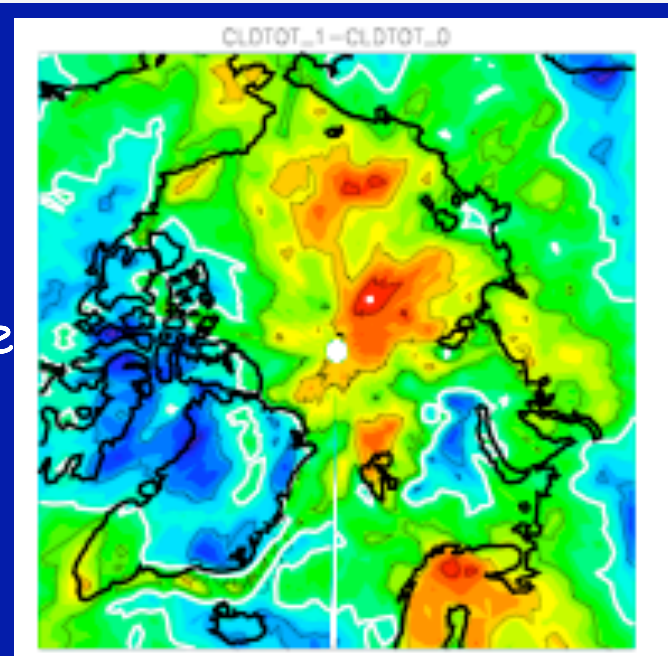
A possible role for cloud feedbacks?







Cloud cover difference



Mechanisms Driving Abrupt Transition

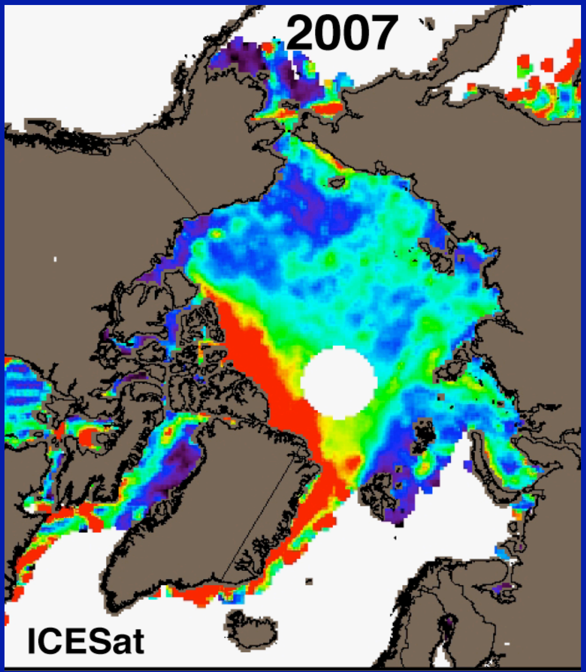
1. Transition of ice to a more vulnerable state
   - thinning of the ice
2. A Trigger - (Natural?) rapid increases in OHT.
   - Other natural variations could potentially play the same "triggering" role
3. Positive feedbacks that accelerate the retreat
   - Surface albedo feedback
   - OHT feedbacks? Mechanisms not fully understood.
   - Possible cloud feedbacks under investigation

Similar mechanisms at work for abrupt events in other ensemble members
Relative importance of various factors differs among events

Conditions implicated in 2007 ice loss

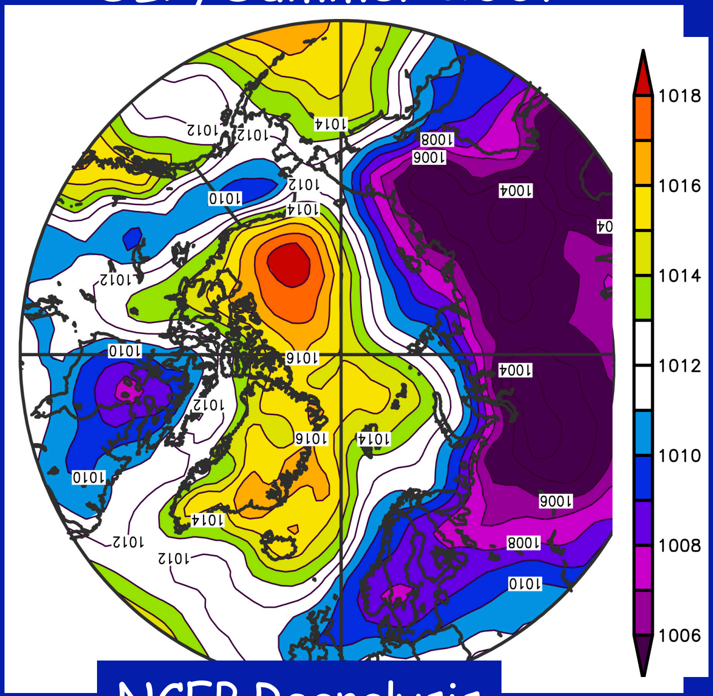
1. Thinning of ice to a more vulnerable state
2. A Trigger - anomalous high pressure over Beaufort Sea
   - Other associated variations possibly played a role
3. Positive feedbacks that could accelerate future retreat
   - Surface albedo feedback

Ice Thickness



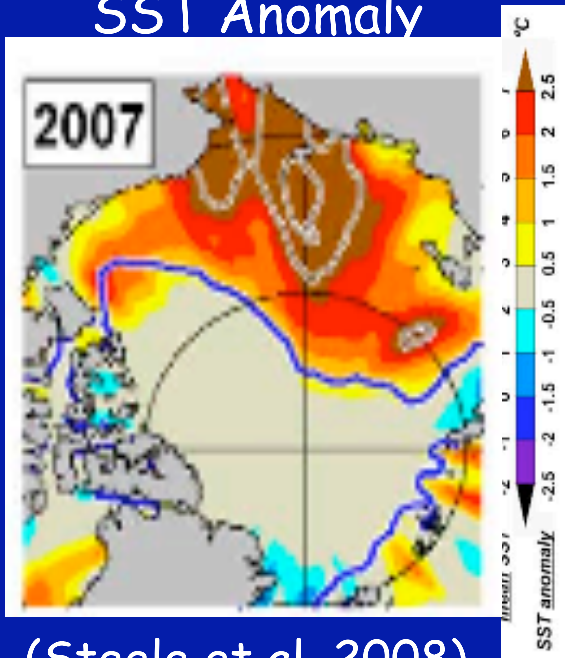
(Stroeve et al., 2008)

SLP, Summer 2007



NCEP Reanalysis

SST Anomaly

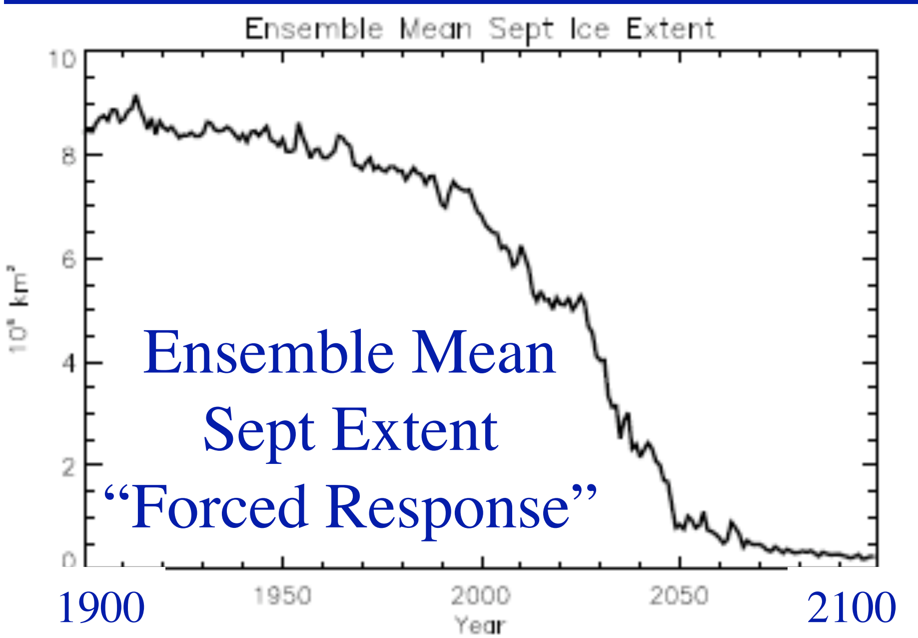


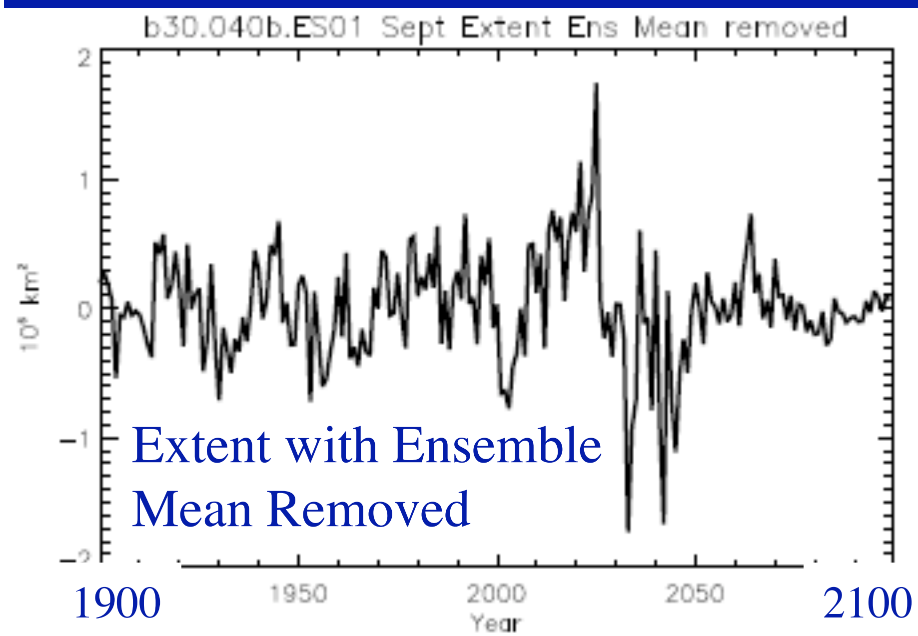
(Steele et al, 2008)

Is simulated Rapid Ice Loss a consequence of "Tipping Point" behavior?

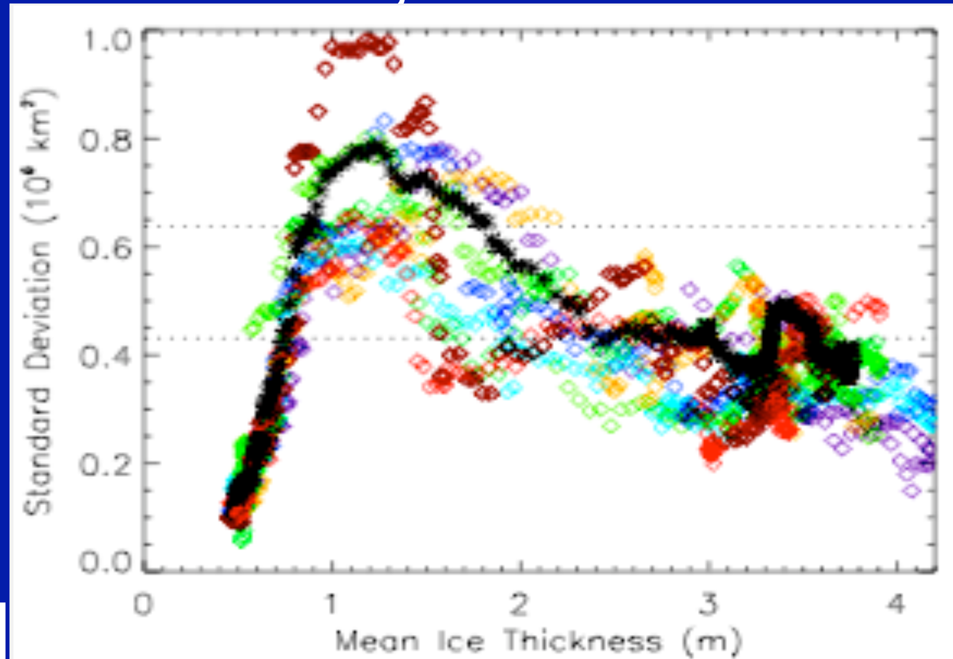
Where, Tipping Point = an intrinsic threshold such that sea ice decline will become rapid and irreversible once the threshold is crossed

Role of forced versus natural change





30 Yr Running Standard Deviation

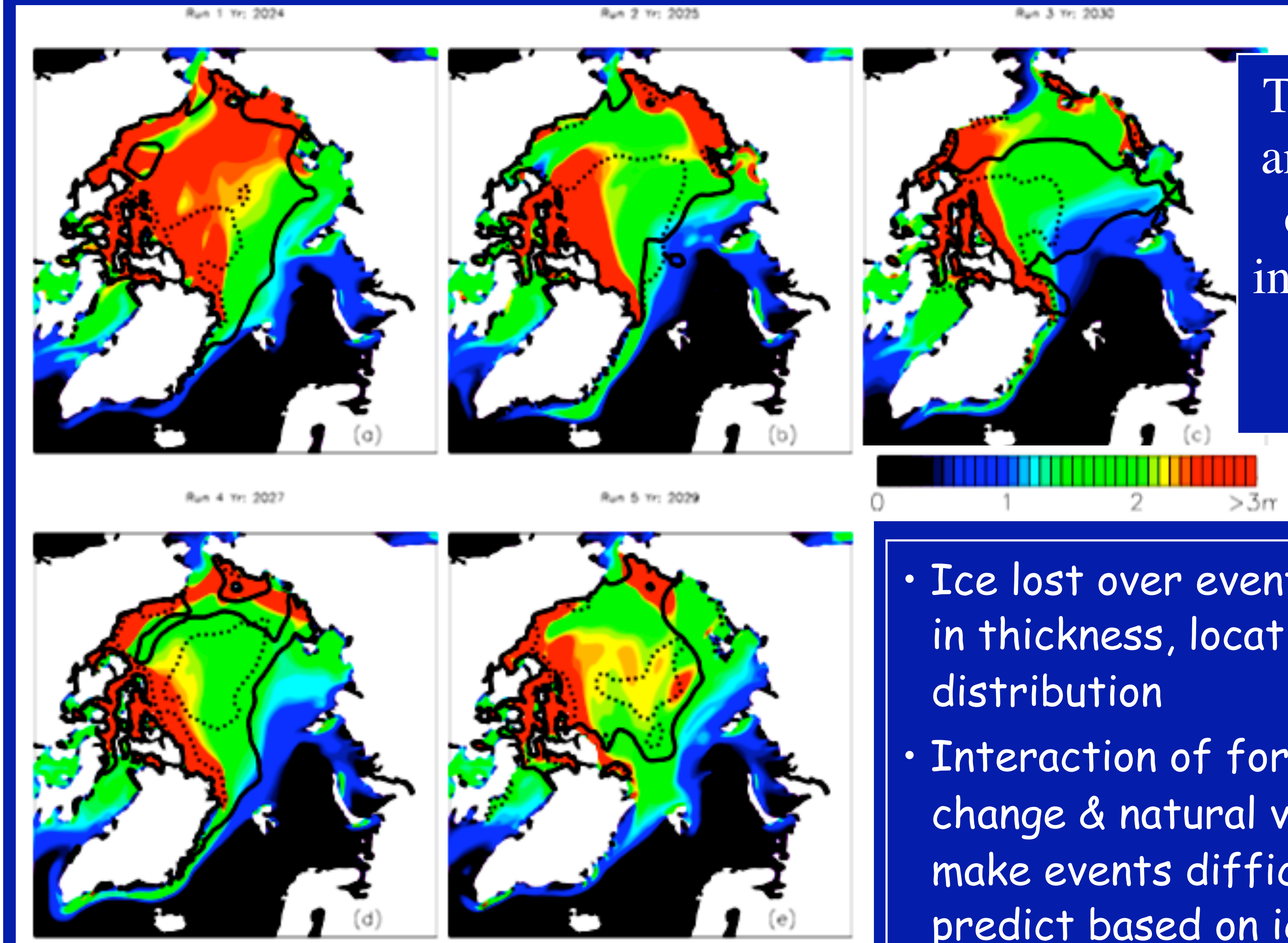


As ice thins, the “natural” variability in extent increases

A combination of large “forced” change and large intrinsic variability necessary

(Holland et al., in press)

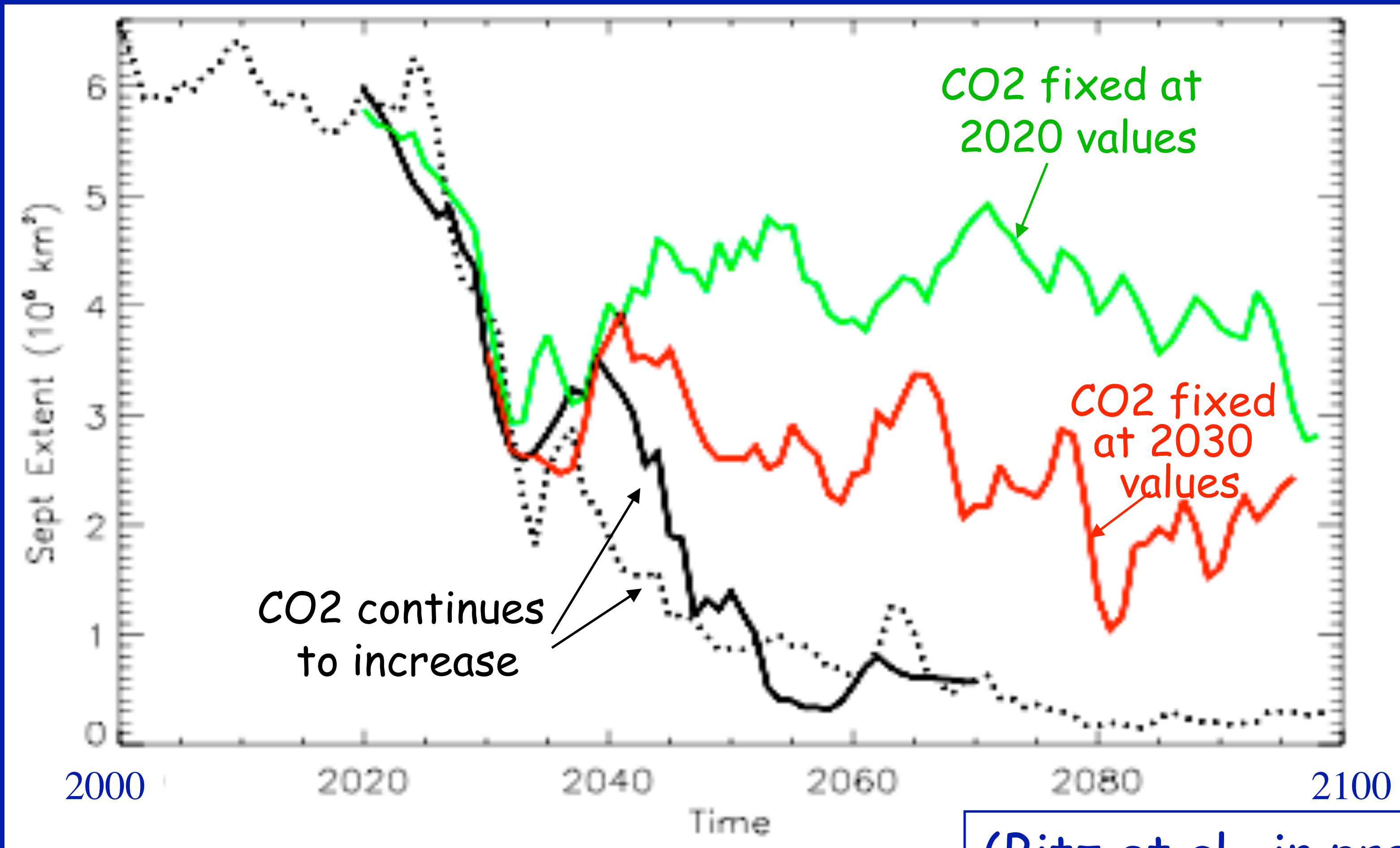
Searching for a “critical” ice threshold



Thickness and extent of ice at initiation of abrupt retreat

- Ice lost over events varies in thickness, location, distribution
- Interaction of forced change & natural variations make events difficult to predict based on ice state

If fix CO2, does ice continue to retreat?



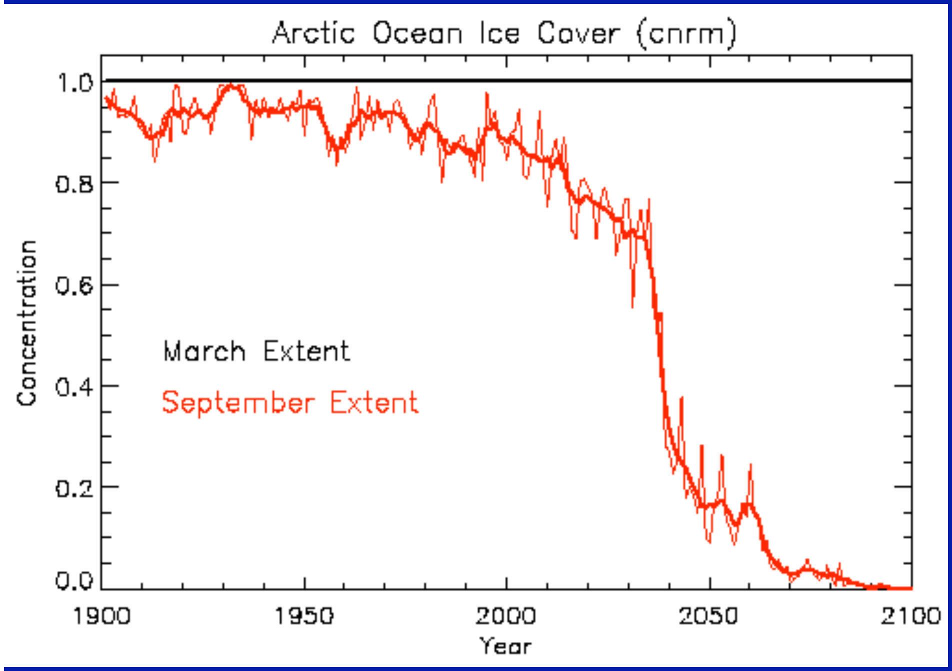
(Bitz et al., in prep)

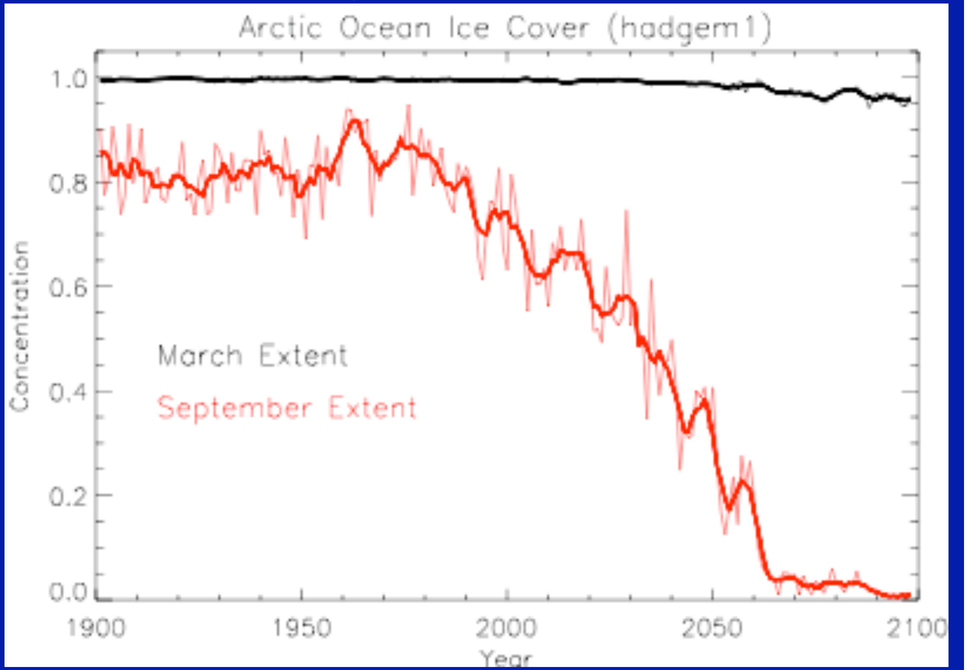
Model results suggest

- that sea ice may not go seasonally ice-free if no continued increases in CO2
- Strongly suggests this is not Tipping Point behavior

Do other models have abrupt transitions?

Some do... Some don't...

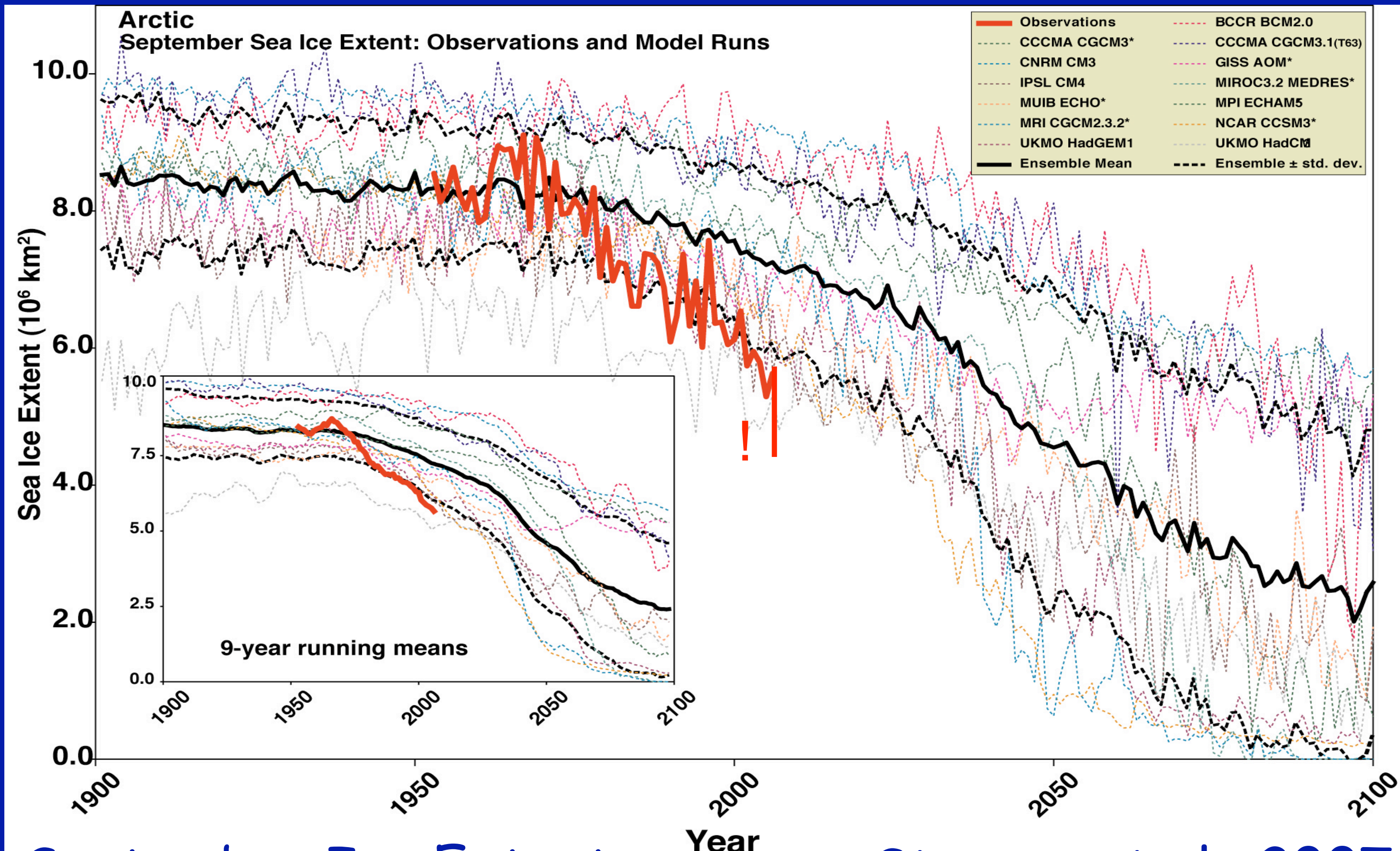




From an analysis of 15 additional IPCC-AR4 models, we find that 50% of them simulate abrupt reductions for some future forcing scenario. Rapid ice loss is more likely in simulations with higher anthropogenic forcing.

Data from IPCC AR4 Archive at PCMDI

IPCC-AR4 climate model projections



September Ice Extent

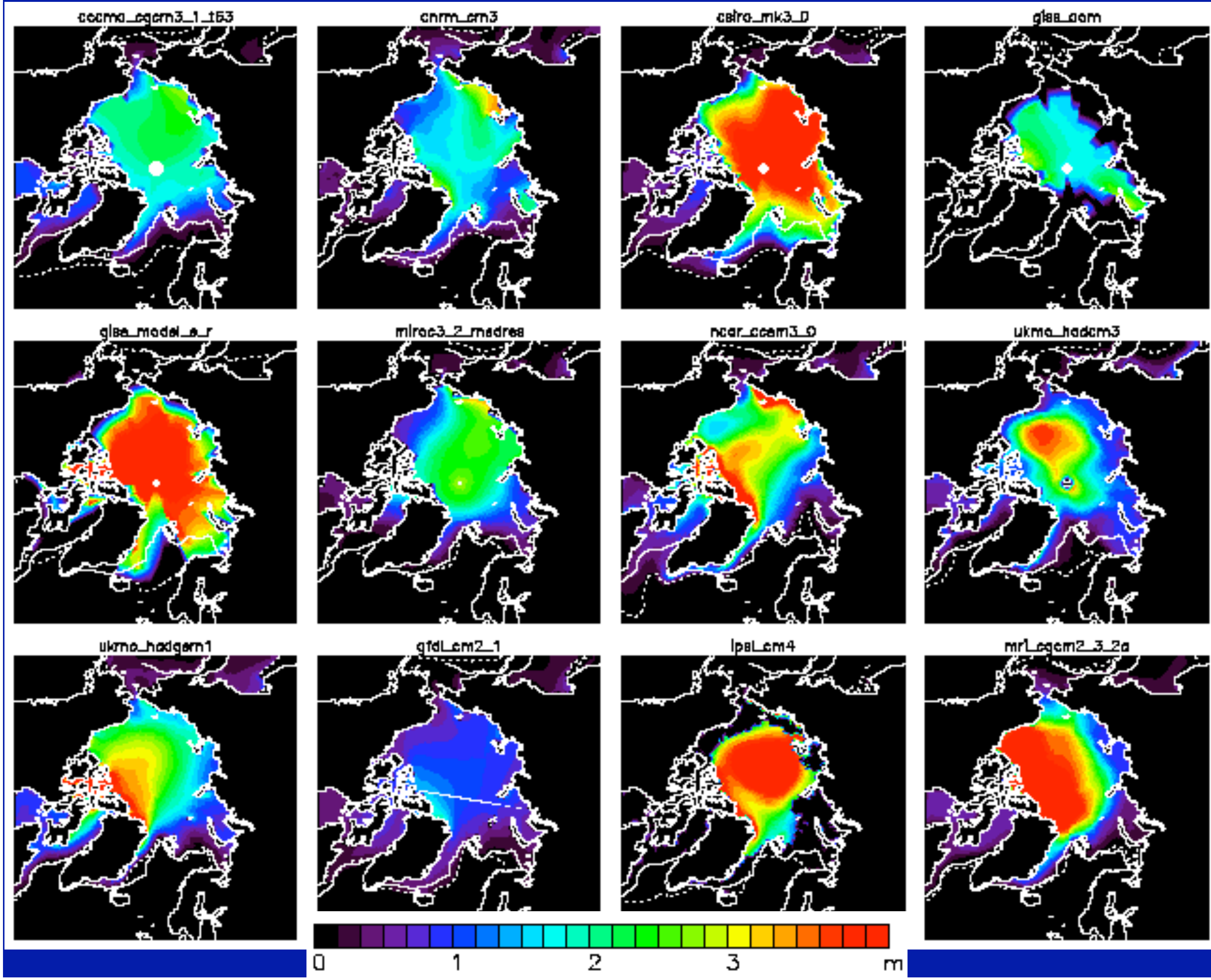
Stroeve et al., 2007

Large range in simulated ice extent and extent loss

Models generally conservative compared to observations

Is it possible to identify why various models exhibit differences in their possible future abrupt ice retreat?

Simulated late 20th century ice conditions



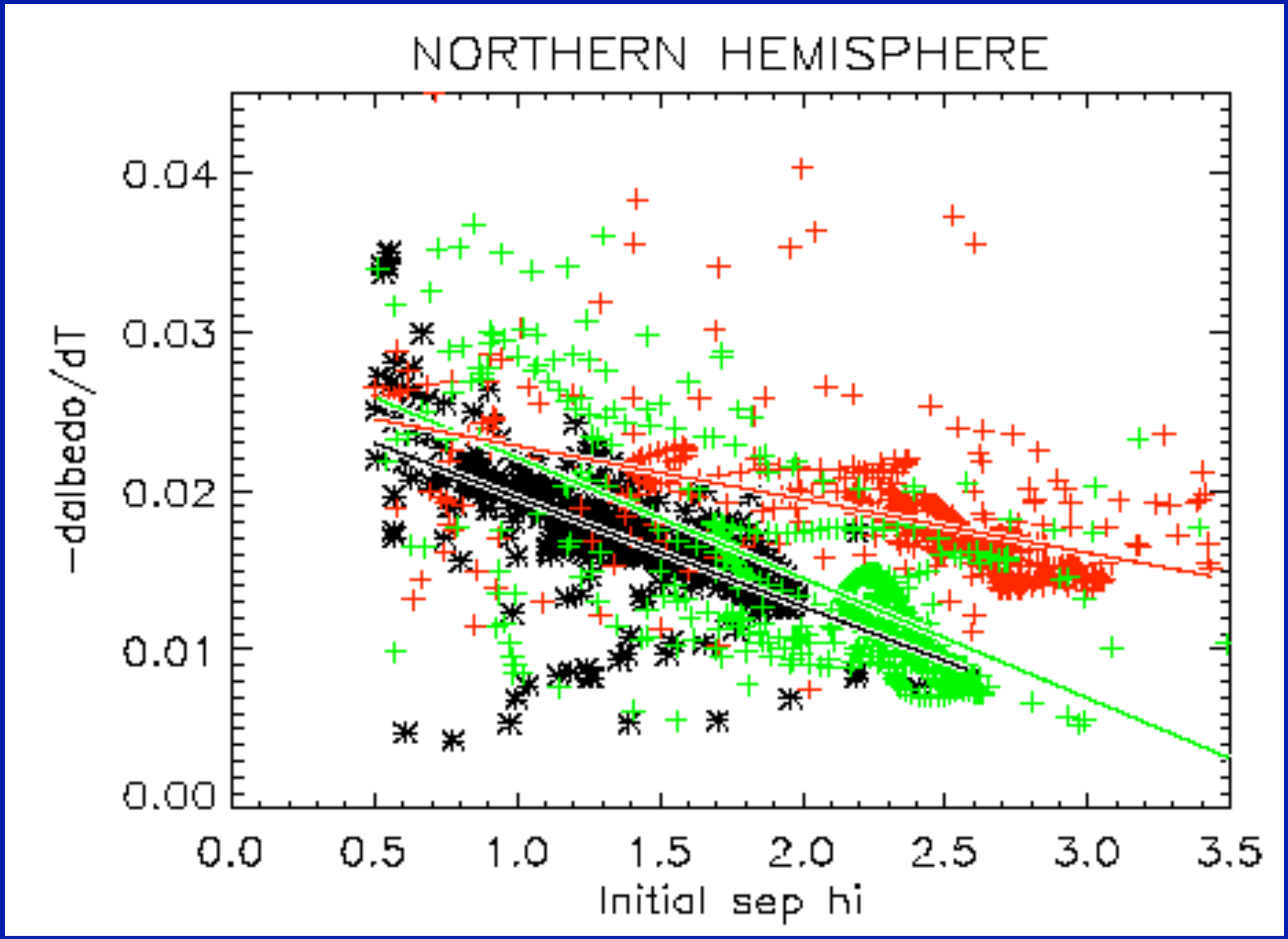
Ann avg
1980-1999 ice
thickness

IPCC AR4

Dash=March extent

White=Obs Extent

Feedback Strength and Model Parameterizations

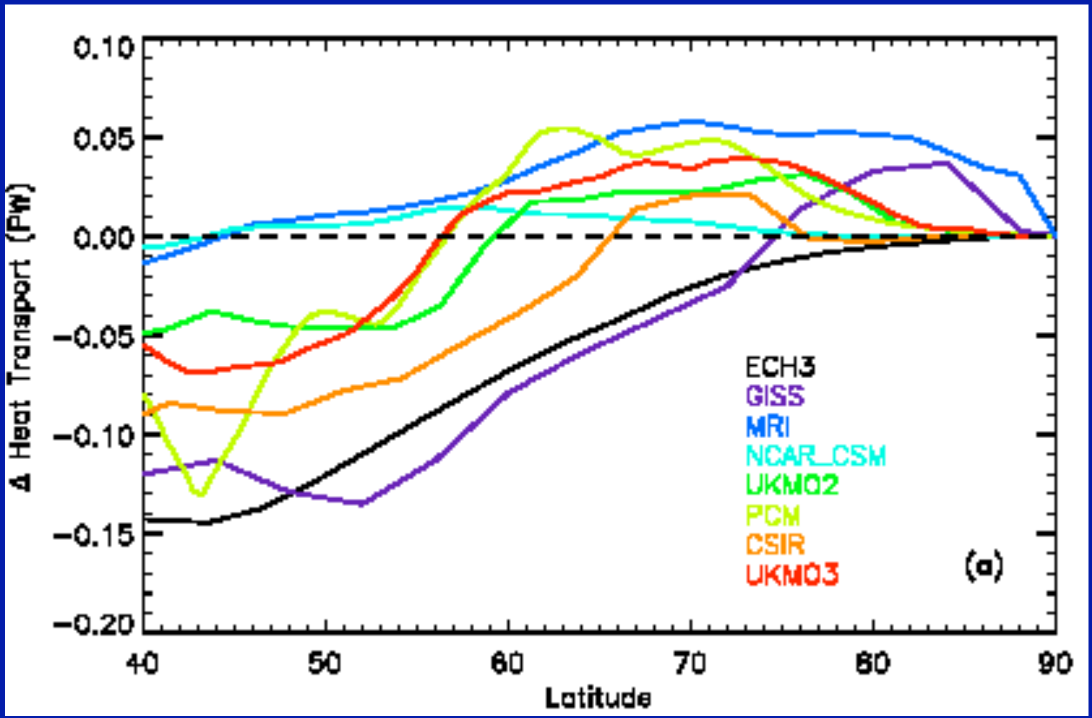


ITD (5 cat)
1 cat.
1cat tuned

(Holland et al., 2006)

For example, studies suggest that including a subgridscale ice thickness distribution enhances the albedo feedback

Increases in Ocean Heat Transport to the Arctic



Change in OHT
2XCO2-present day

Change in poleward ocean heat transport at 2XCO2 conditions in CMIP2 models

OHT increases to the Arctic are common in climate models but vary considerably in their magnitude

(From Holland and Bitz, 2003)

Conclusions

- Rapid summer ice loss has occurred since 1979 and climate models project that this could accelerate in the future
- In most extreme case, conditions go from near-present day to near-ice free Septembers in ~10 yrs
- The transitions result from:
  - A vulnerable, thin ice state: Increased OW per melt rate
  - A trigger: Increased OHT (natural variability?)
  - Accelerating feedbacks: Albedo change/OHT?/Clouds?
- Rapid ice loss results from interaction of natural variability and anthropogenic change
- Little indication that these are a "tipping point" response
- Models differ on simulation of abrupt summer ice loss


Questions?