Causes of Changes in Arctic Sea Ice

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Outline

1. Rationale
2. Observational background
3. Modeling insights on Arctic change
   - ❑ Pacific / Atlantic Water inflow
4. Conclusions / Future needs

Arctic Region Supercomputing Center

HPC Modernization Program

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Why worry about the Arctic?

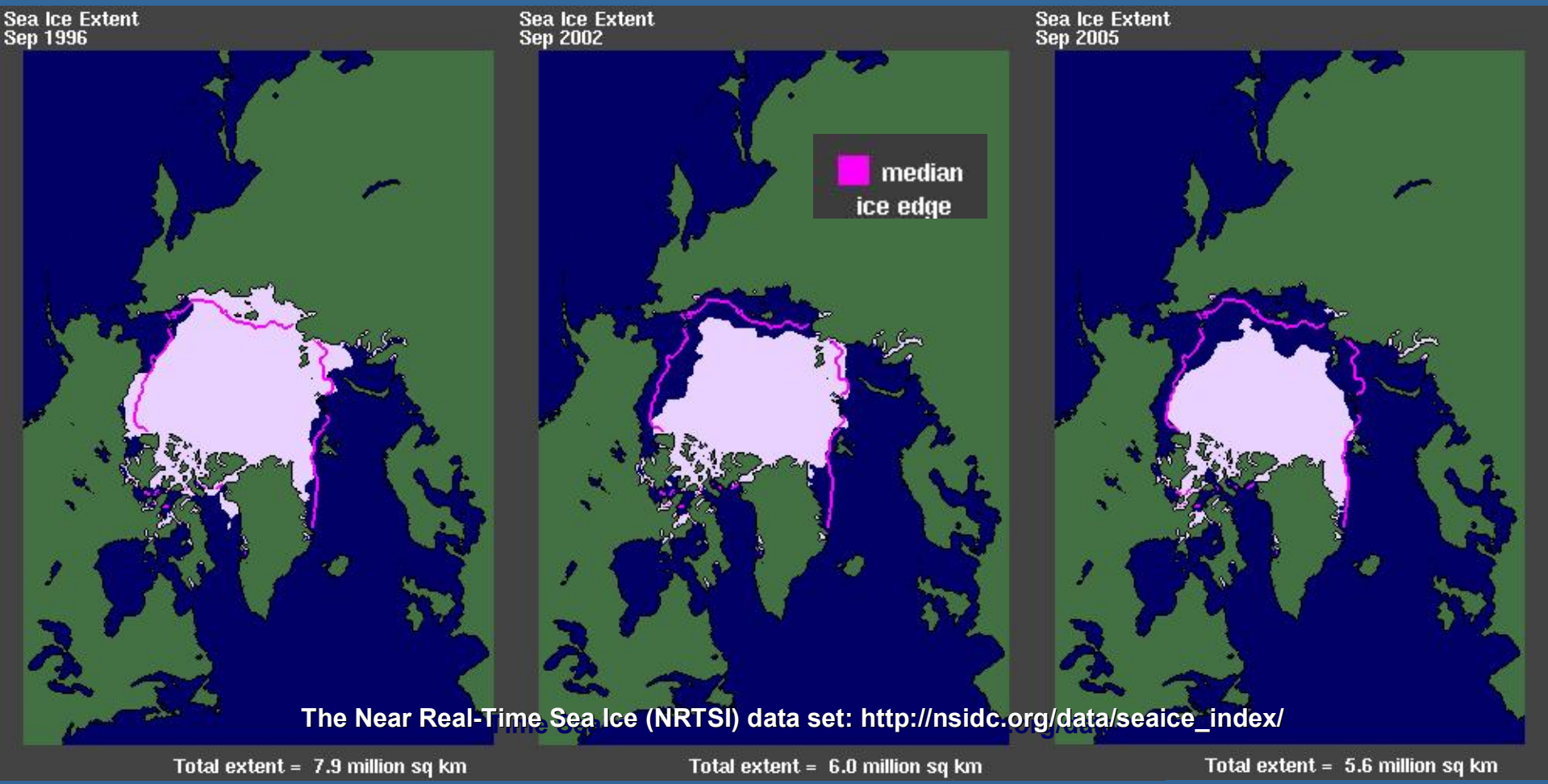
Arctic Sea Ice extent in September 2005 was 1.4 million sq km (i.e. 20%) below its summer average

1. **Northern Sea Route and/or Northwest Passage from the Pacific to the Atlantic (alternative to the Panama Canal)**
2. **Increased activities (commercial & defense) in the partially / summer ice free Arctic will impose new requirements on the US Navy / DOD / Homeland Security**
3. **Dramatic changes of Arctic Ecosystem (e.g. extinction of polar bears, changes in the carbon cycle)**
4. **Increased freshwater export into the North Atlantic Ocean can affect the global ocean circulation and climate**

The above require understanding and prediction of future environmental change in the Arctic

DETECTING CHANGE:
Northern hemisphere summer sea ice extent

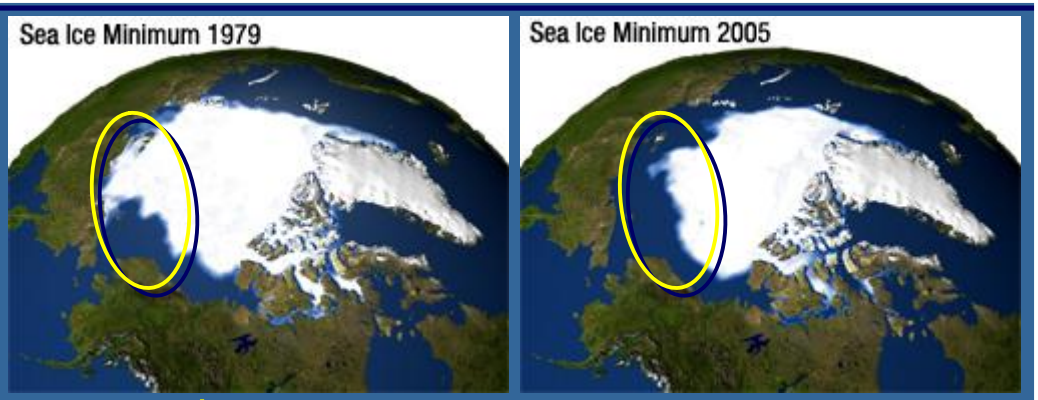
September 1996: 7.9 **September 2002: 6.0** **September 2005: 5.6 x 10^6 km^2**



- Over the last decade September Arctic sea ice extent decreased by 2.3 million km^2
- In September 2005 the sea ice extent decreased by 20% compared to the mean of 1979-2000
- However, we do not have much data on Arctic sea ice thickness or volume change

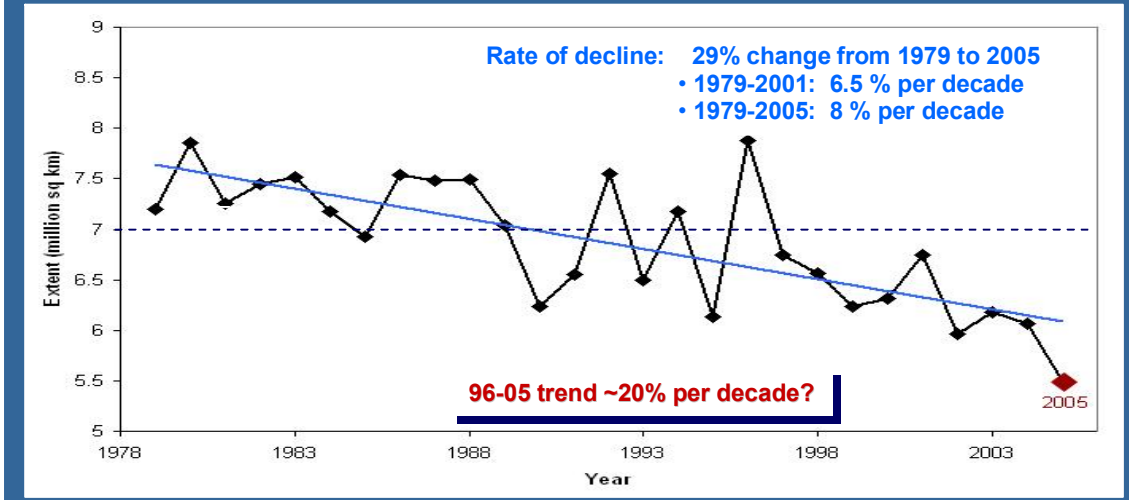
ATTRIBUTION OF CHANGE IN ARCTIC SEA ICE

1. Observed summer sea ice extent change is most extreme in the western Arctic



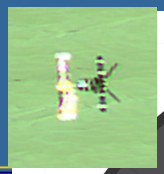
2. Combined atmospheric forcing (winds, advected heat, radiative flux) can explain only ~50% of sea ice extent variability (Francis et al., 2005)
3. Summer sea ice extent variability in the 2000s does not correlate well with atmospheric forcing

Since atmospheric forcing can explain only ~50% of the recent sea ice melt the remaining forcing must originate from the ocean

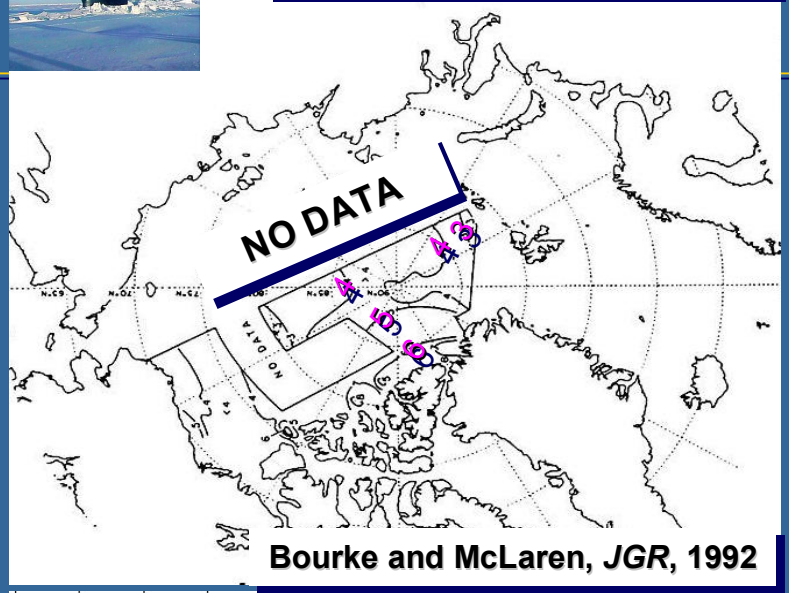


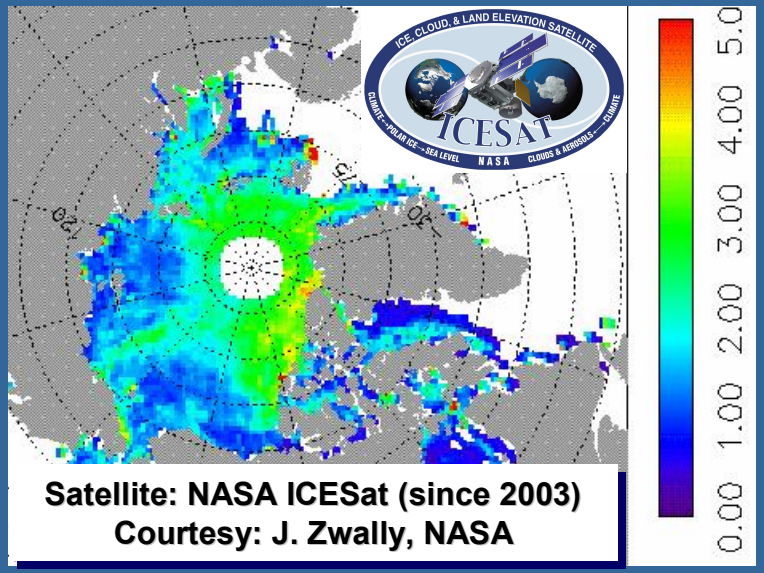
SSM/I Arctic sea ice extent - September

Arctic Sea Ice Thickness Data is Limited in Time and Space

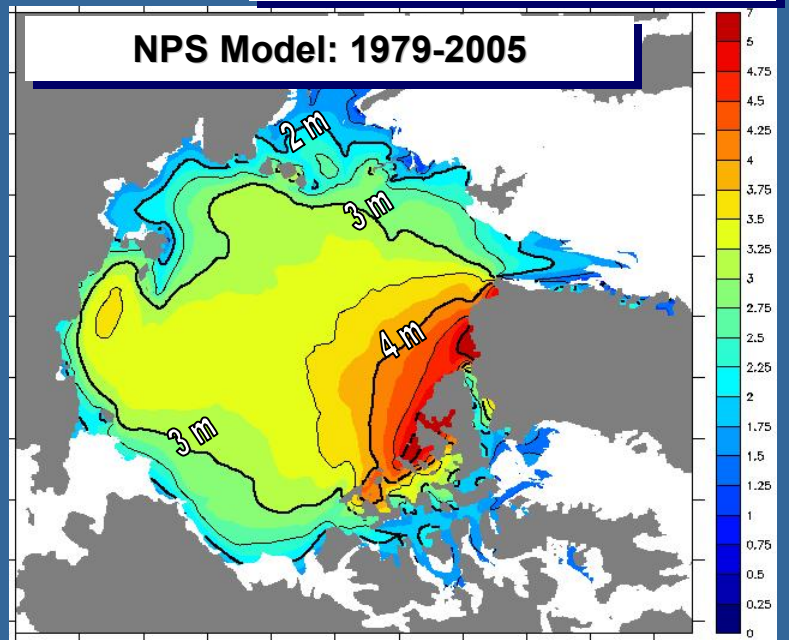


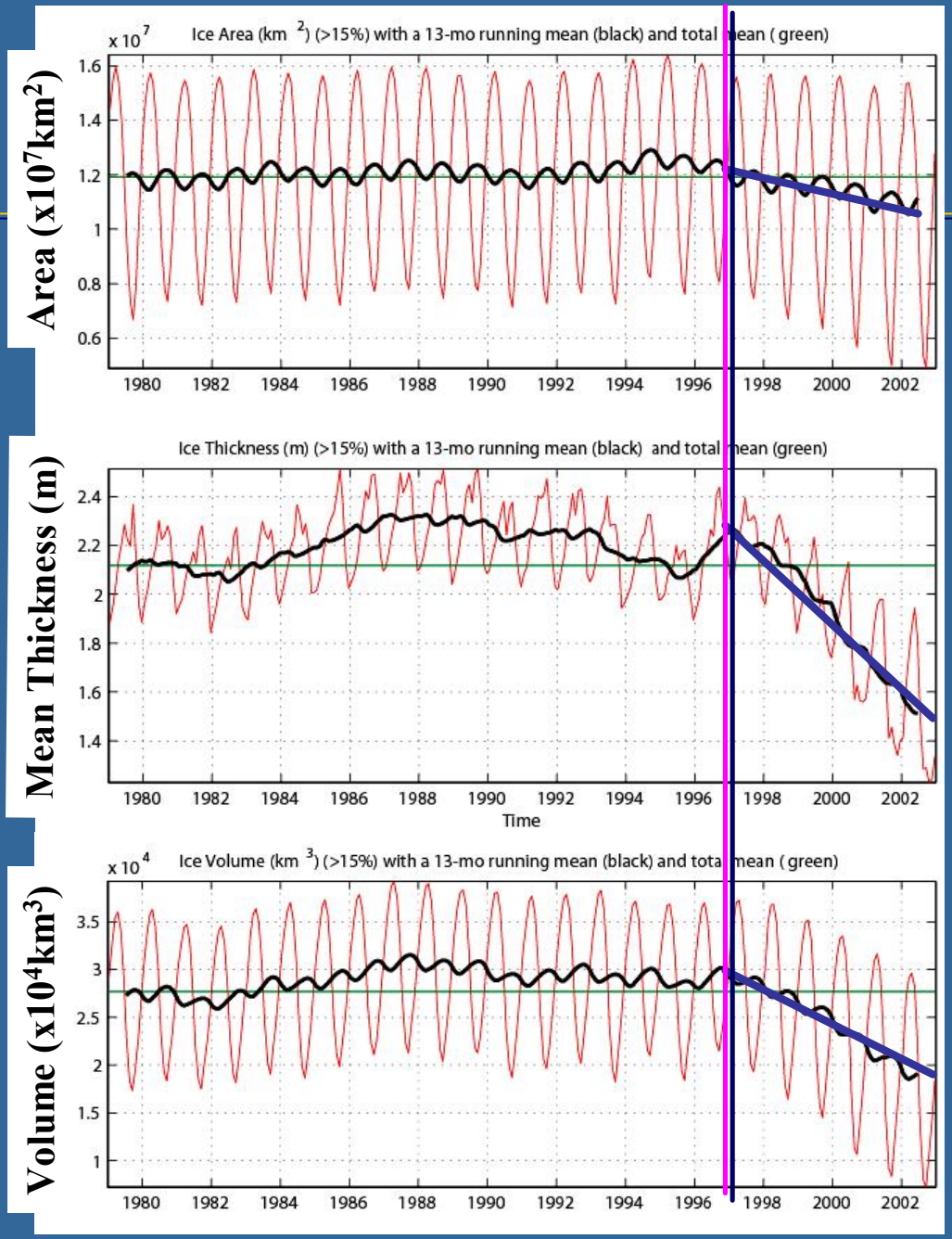
Laxon et al., 2003





Satellite: NASA ICESat (since 2003)
Courtesy: J. Zwally, NASA





Modeled Sea Ice Area, Thickness, and Volume

Decrease from 1997 to 2002:

- Ice area by 15-18%, in agreement with observations

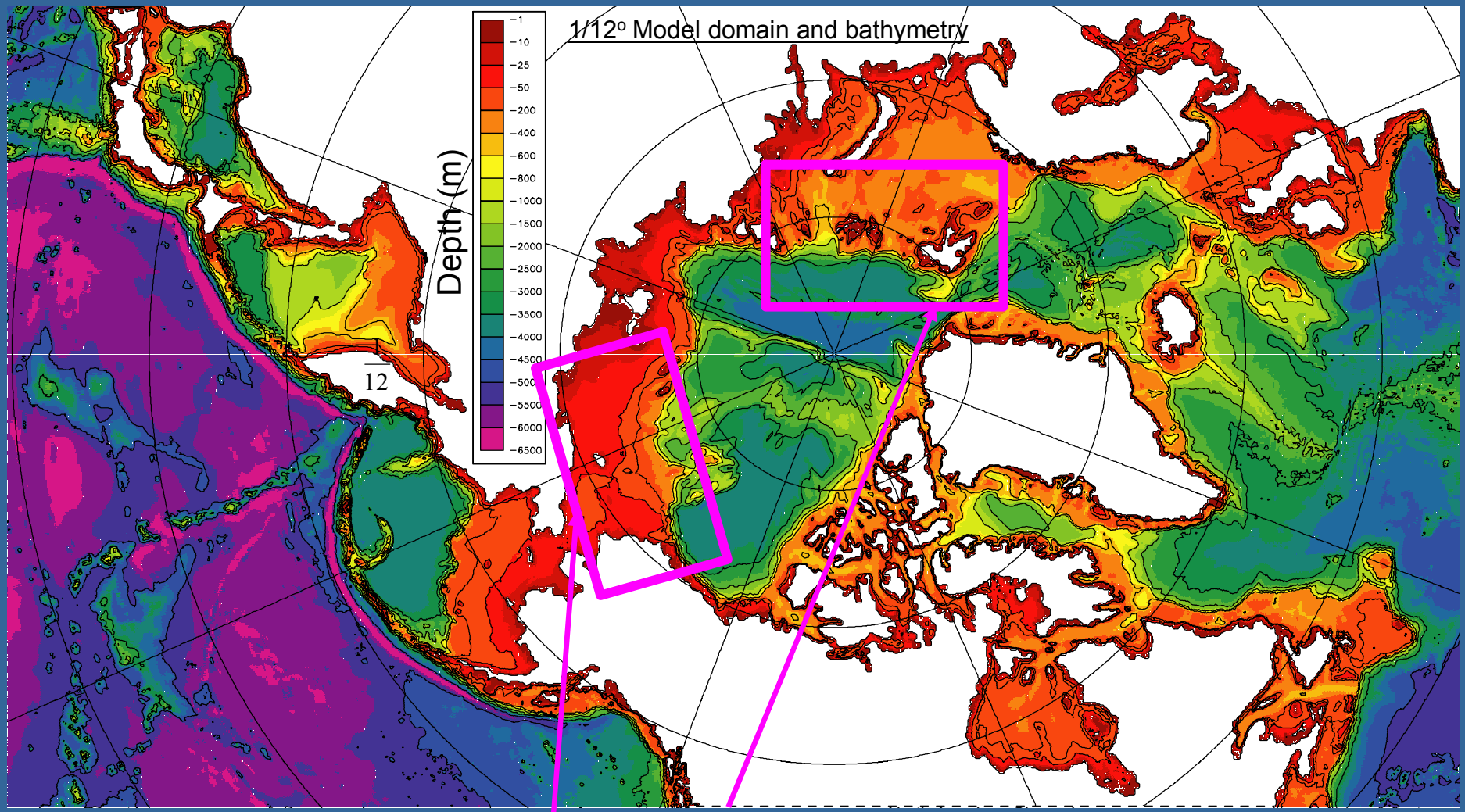
- Ice thickness by ~35% (or 80 cm from 2.3 m to 1.5 m)

- Ice volume by ~33% (from 30×10^3 km^3 to 20×10^3 km^3), which is twice the ice area

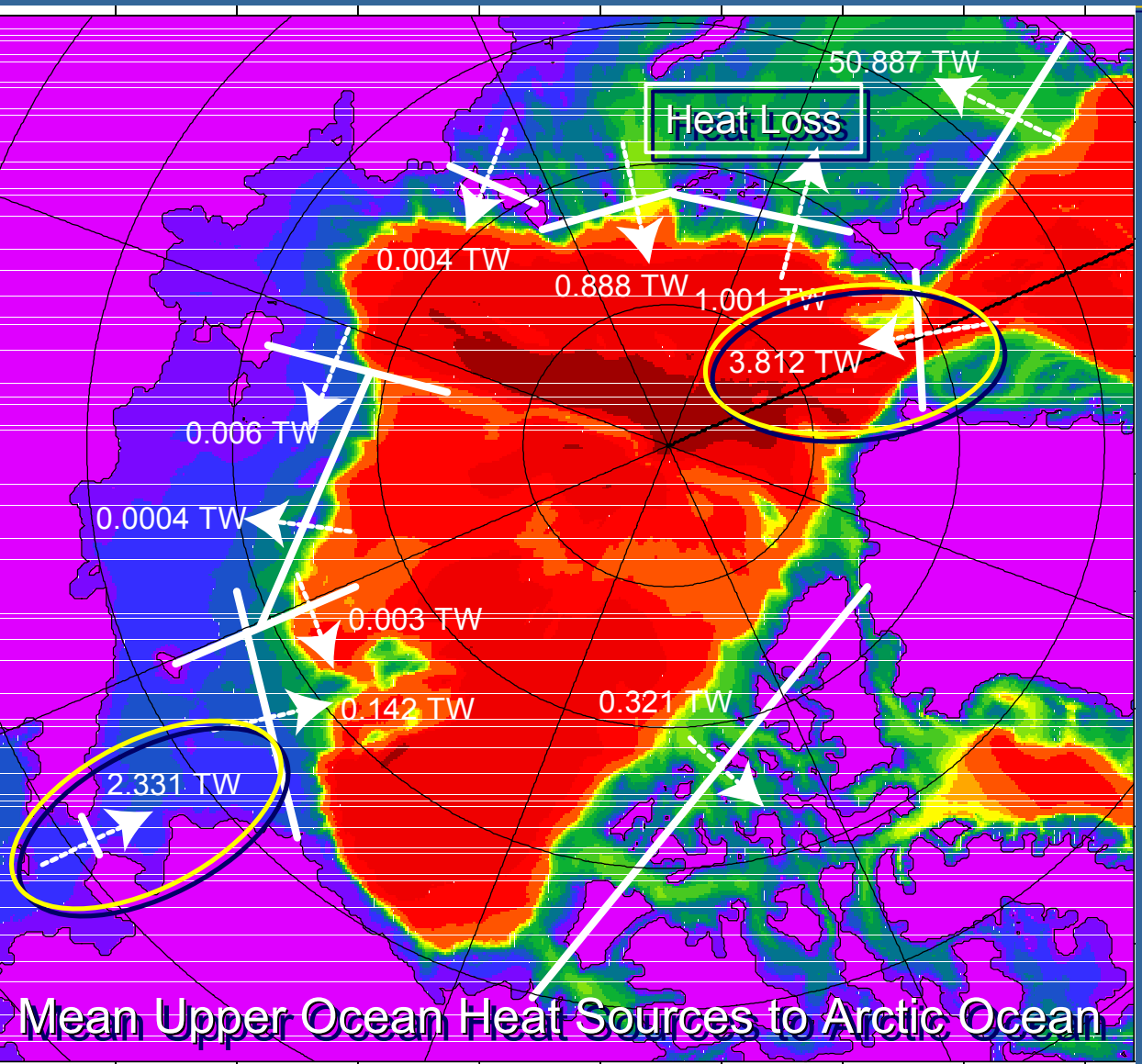
If this trend persists for another 10 years (and it has through 2005) the Arctic Ocean could be ice-free in summer!

Model and observational uncertainties of importance to global climate

1. Northward heat transport from the N. Atlantic/Pacific to Arctic Ocean
2. Arctic sea ice thickness and volume
3. Freshwater export from the Arctic to North Atlantic



ATTRIBUTION OF CHANGE: Oceanic forcing of Arctic Sea Ice



Challenges for models:

Inflow of Pacific / Atlantic Water into the Arctic Ocean

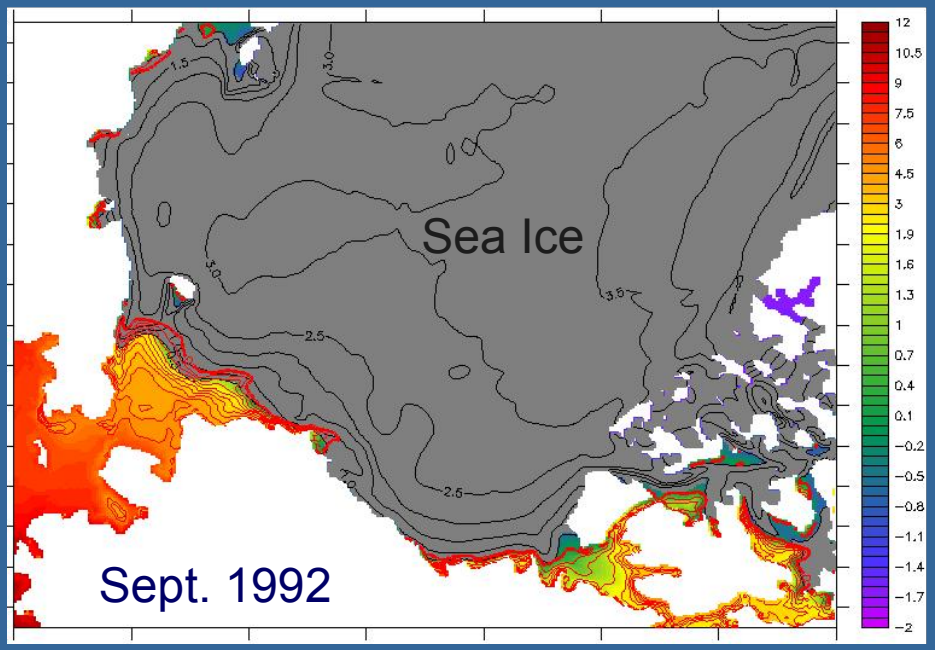
- Pacific Water enters via narrow (~60mi) Bering Strait
- outflow through Fram Strait prevents Atlantic Water inflow
- Atlantic Water entering through Barents Sea losses ~98% of heat to atmosphere
- sea-ice-air feedbacks

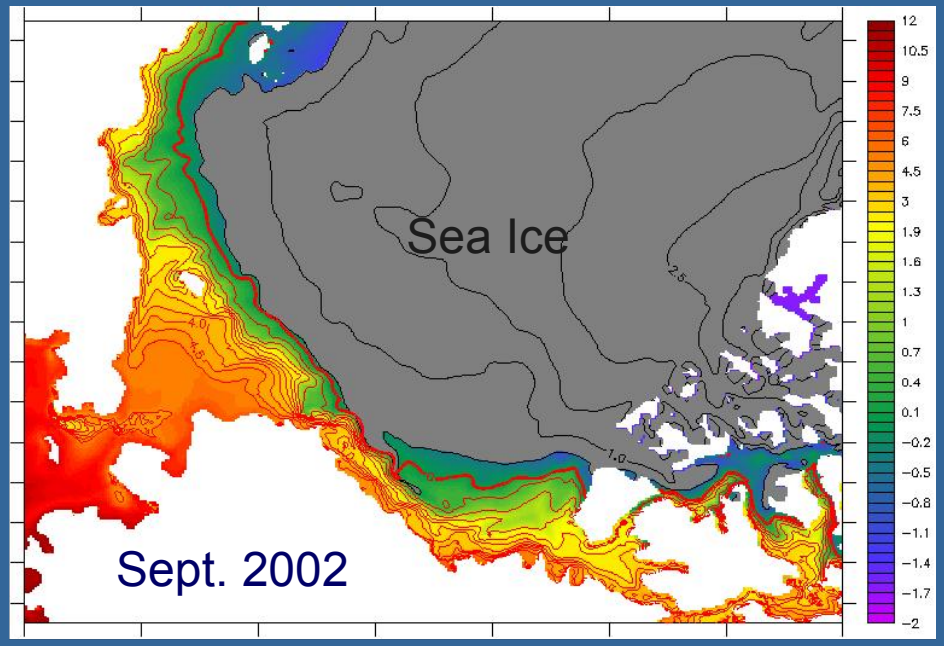
The above challenges require substantial increase of dedicated computer power for climate change studies

ATTRIBUTION OF CHANGE:

Pacific Water forcing of sea ice in the western Arctic Ocean

Sea surface temperature (color) and sea ice thickness (grey)





-Increased northward heat flux off the Chukchi Shelf coincides with the sea ice retreat in the 2000s

- Oceanic forcing can explain ~60% of sea ice melt (both extent and thickness) in the western Arctic Ocean

Conclusions

- NPS model shows significant skill in simulating Arctic sea ice change
- Model estimates about 33% loss of Arctic Sea Ice during 1997-2002
- Earlier model predictions of Arctic Sea Ice melt are possibly highly underestimated
- Up to 60% of recent decrease of sea ice in the Western Arctic can be due to oceanic forcing:
  - northward inflow of Pacific Water - increased inflow of warmer water
  - Less ice allows more solar absorption, which leads to warmer ocean, which in turn will melt more sea ice (the so-called ice-albedo feedback)
- The increased heat fluxes via Pacific/Atlantic Water explain the lack of correlation between sea ice and atmospheric forcing in the 2000s

Future needs:

- Continuous sea ice thickness observations needed to understand Arctic climate change and validate models
- Long-term observations at key locations needed to determine oceanic forcing of sea ice
- Regional studies of ice-ocean-atmosphere interactions are needed to explain warming amplification in the Arctic Ocean
- Improved models with sufficiently high grid-cell resolution will allow more realistic representation of Arctic and global climate change
- Need significant increase in computer power dedicated for climate change studies