Advancements and Limitations in Understanding and Predicting Arctic Climate Change

Wieslaw Maslowski
Naval Postgraduate School

Collaborators:

Jaclyn Clement Kinney, Rose Tseng, Timothy McGeehan - NPS
Jaromir Jakacki, Robert Osinski - IOPAS
Ron Kwok, Jay Zwally - NASA JPL/GSFC

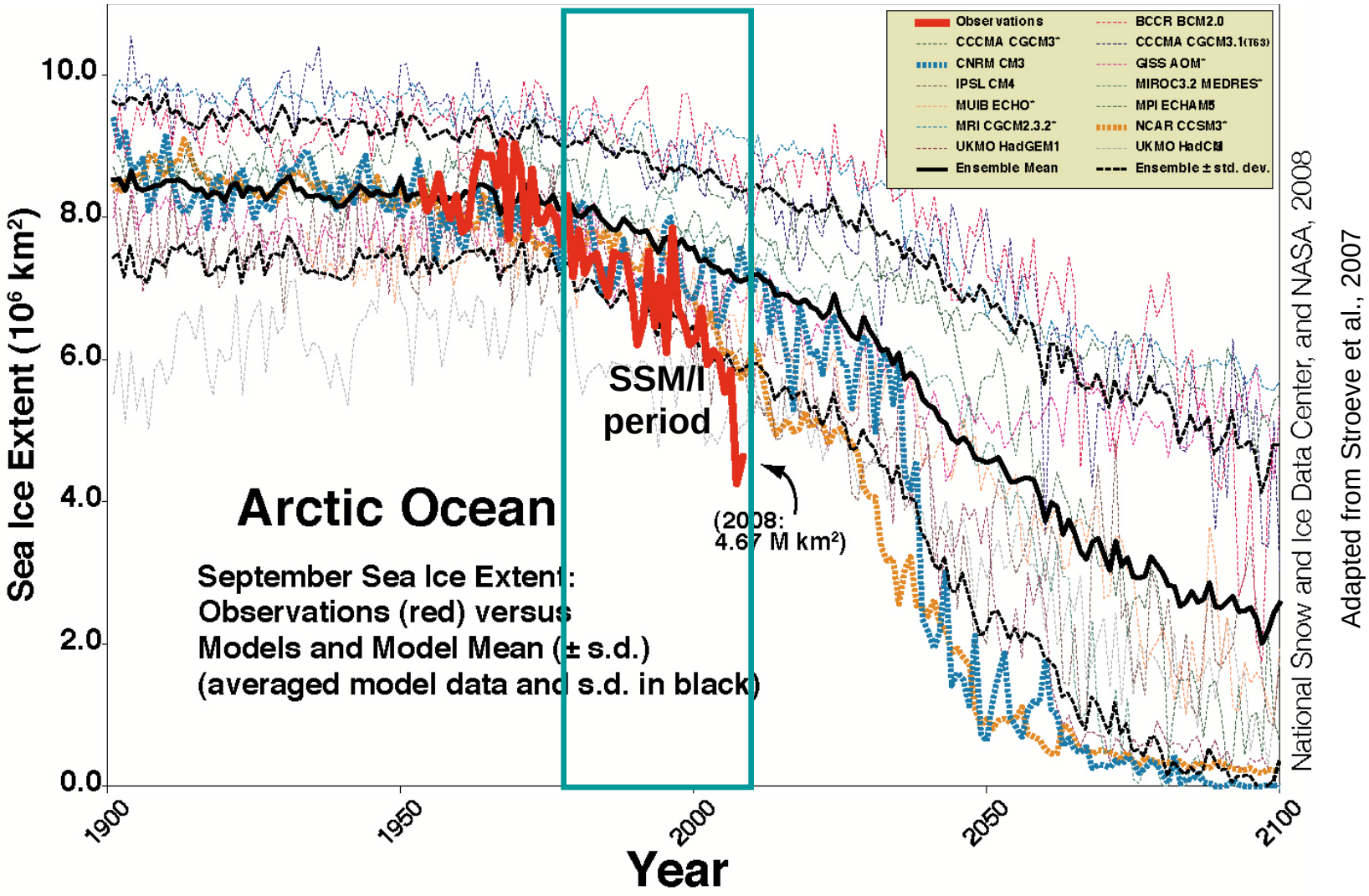
Outline:

- Rate(s) of Arctic climate warming
- Oceanic forcing of sea ice melt
- Conclusions

Sponsors:

State of the Arctic Meeting, Miami, FL, 16-19 March 2010

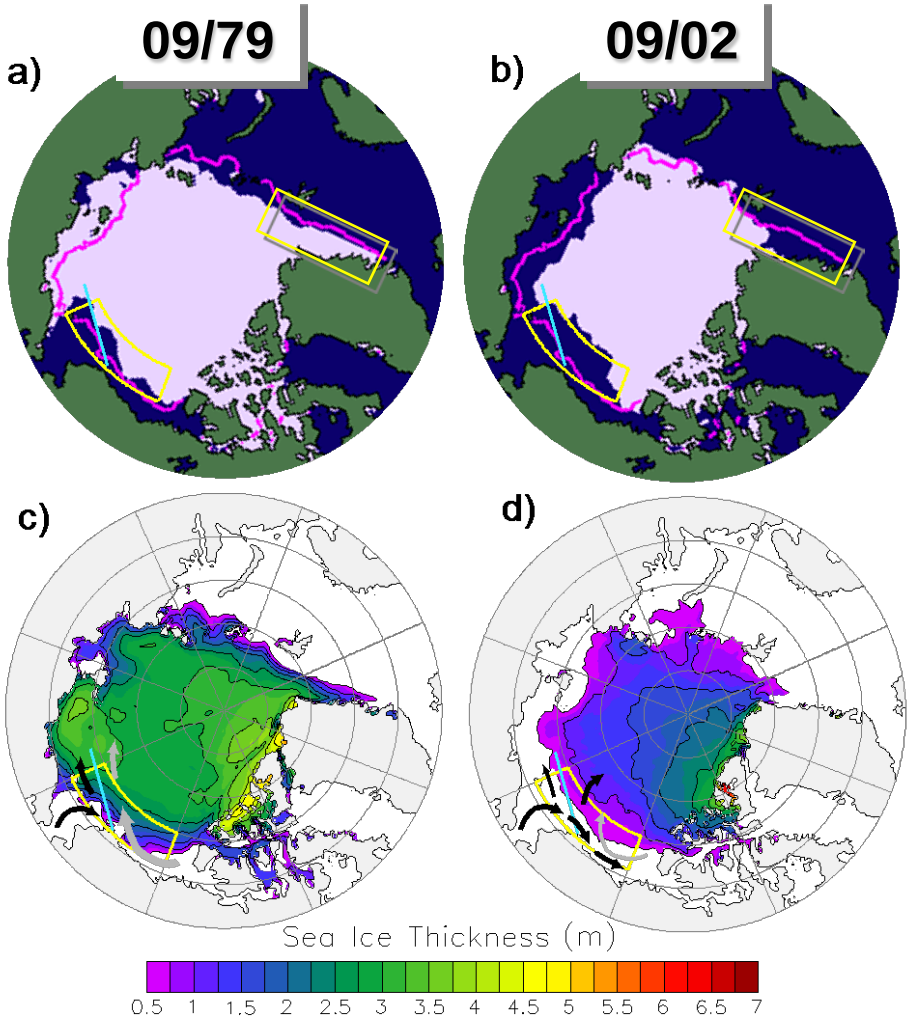
Observed Rate of Ice Extent (2-D) Loss Faster Than in GCMs



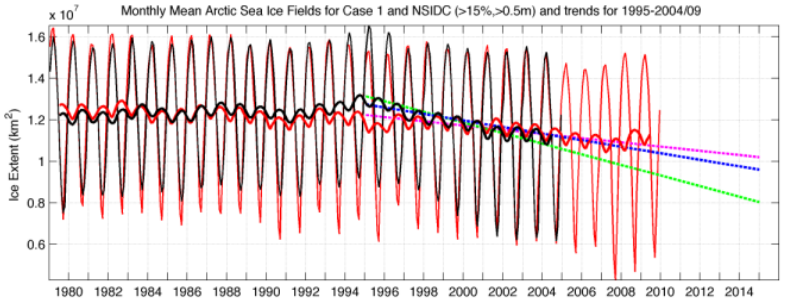
Observed Arctic sea ice extent (a,b) and modeled sea ice thickness (c,d) during September 1979 (a,c) and 2002 (b,c)

SSM/I – 2D

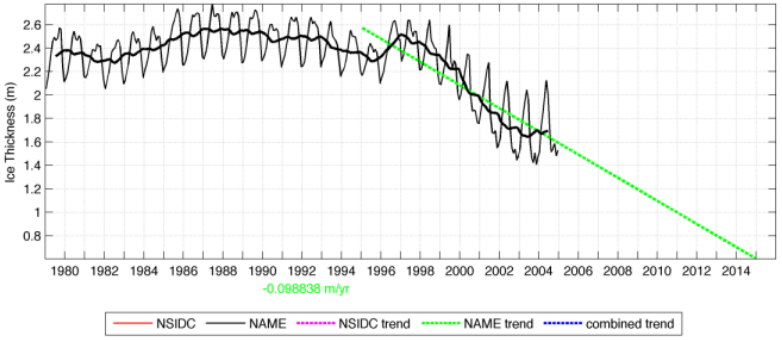
MODEL - 3D (Maslowski et al., 2007)



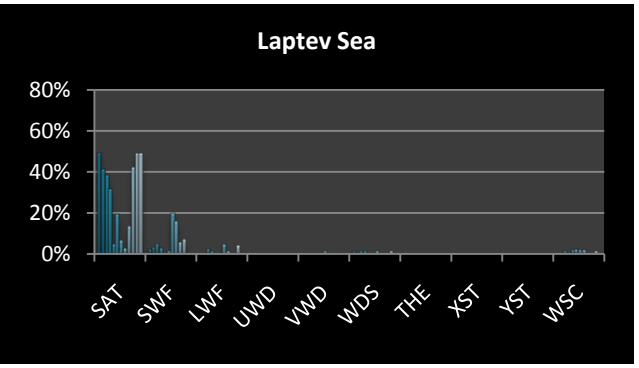
Observed/modeled reduction sea ice extent: 17-20%

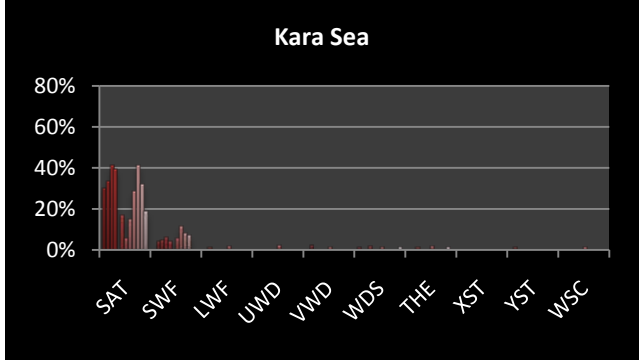


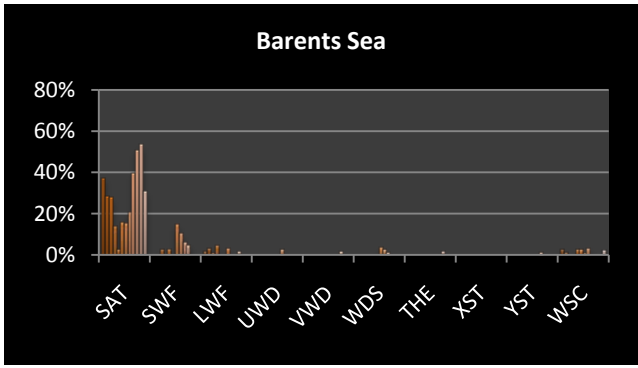
Modeled ice thickness: 1.5-2.0 m or ~35%



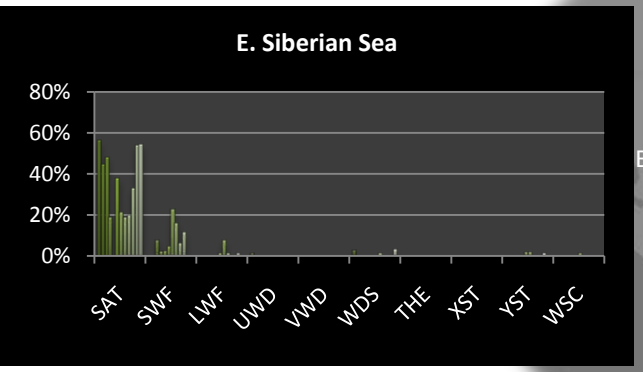
Modeled rate of Arctic sea ice thinning faster than that of observed/modeled ice extent!

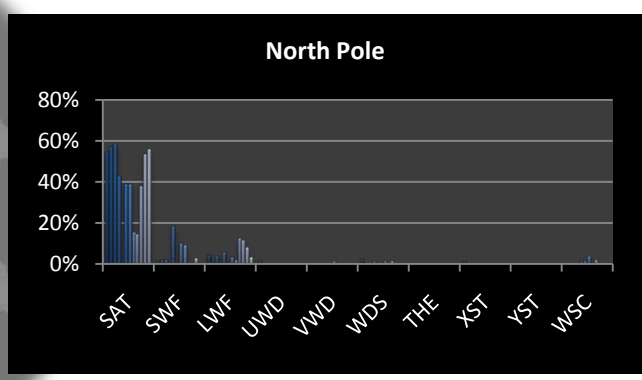




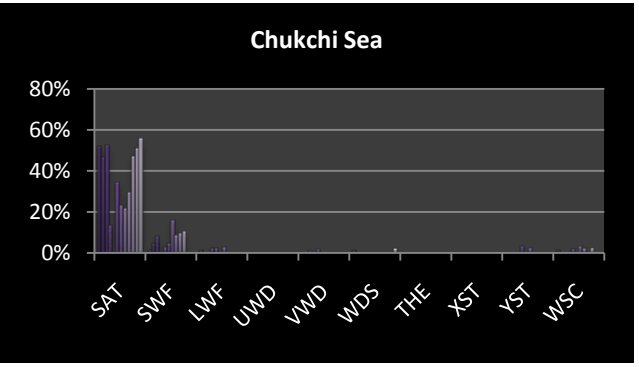


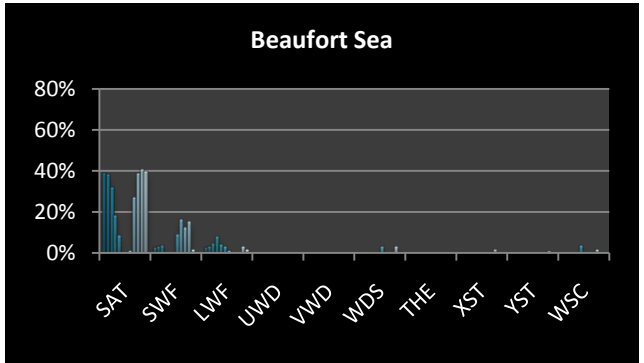
Atmospheric Forcing Account of Anomalous Sea Ice Volume Variability Central Arctic (1979-2004)

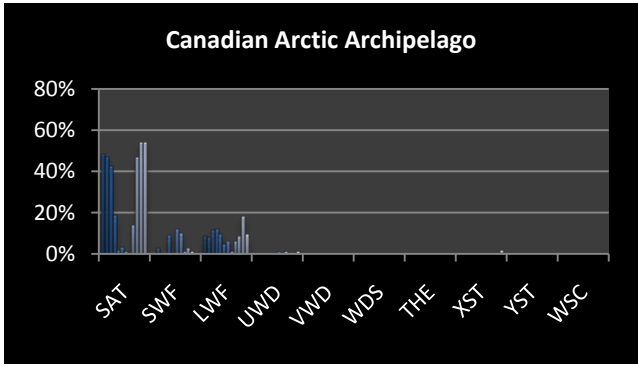




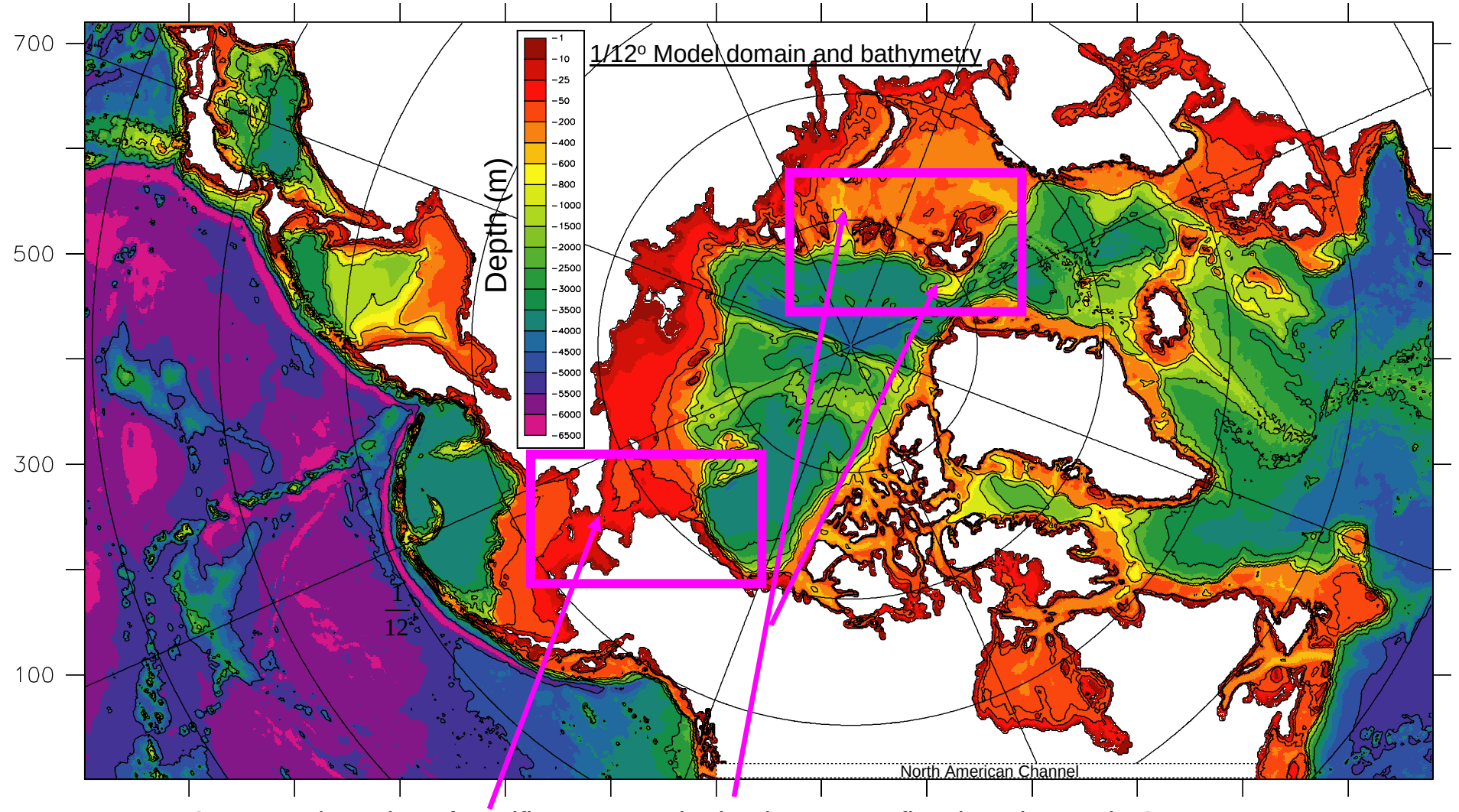
"… the long-term retreat of Arctic sea ice since 1979 in all seasons is due to factors other than wind-driven atmospheric thermal advection."
- Deser and Teng, 2008







(R. Tseng, NPS MS Thesis, 2010)



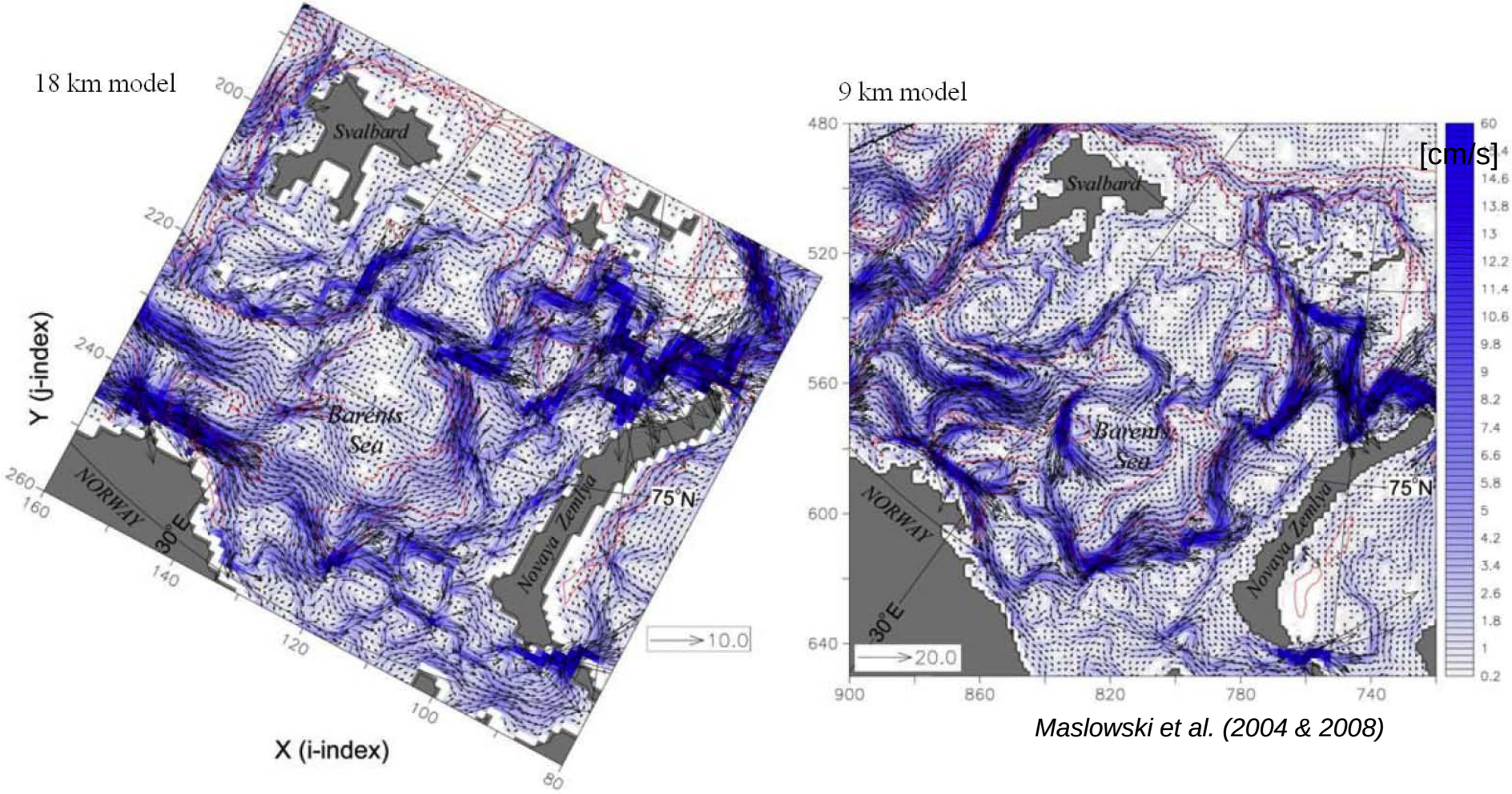
Gateways/Margins of Pacific Water and Atlantic Water Inflow into the Arctic Ocean

Main uncertainties of importance to global climate

1. Northward heat transport from the N. Atlantic/Pacific to Arctic Ocean *
2. Heat accumulating in the upper ocean due to the shrinking sea ice cover *
3. Arctic sea ice thickness and volume *
4. Sea Ice / Freshwater export from the Arctic to North Atlantic

Flow Atlantic Water through the Barents Sea

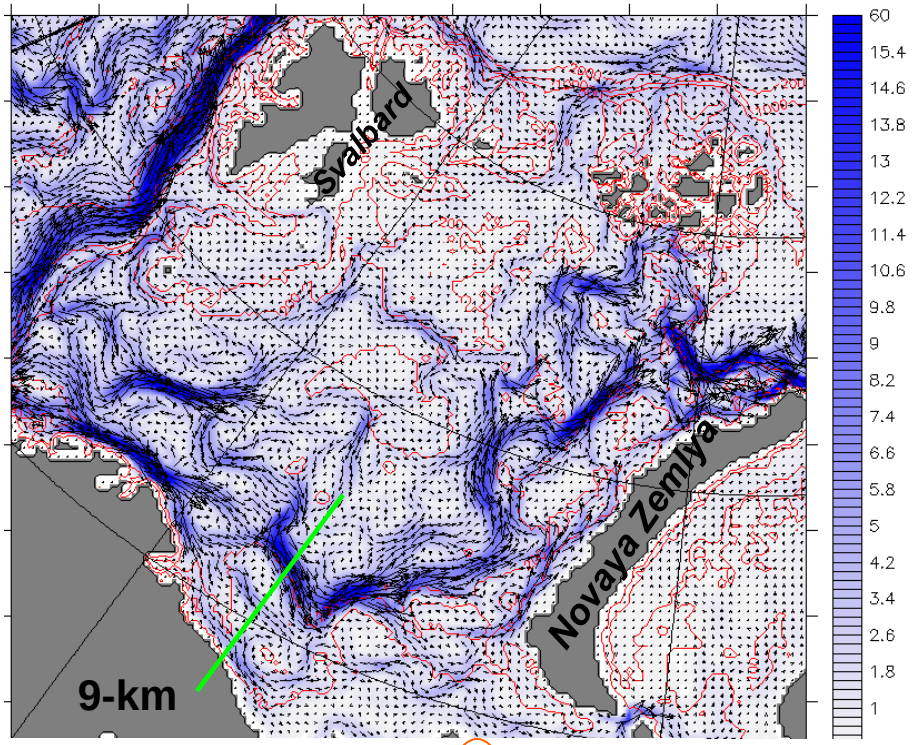
1980 annual mean velocity [cm/s] at 0-223m

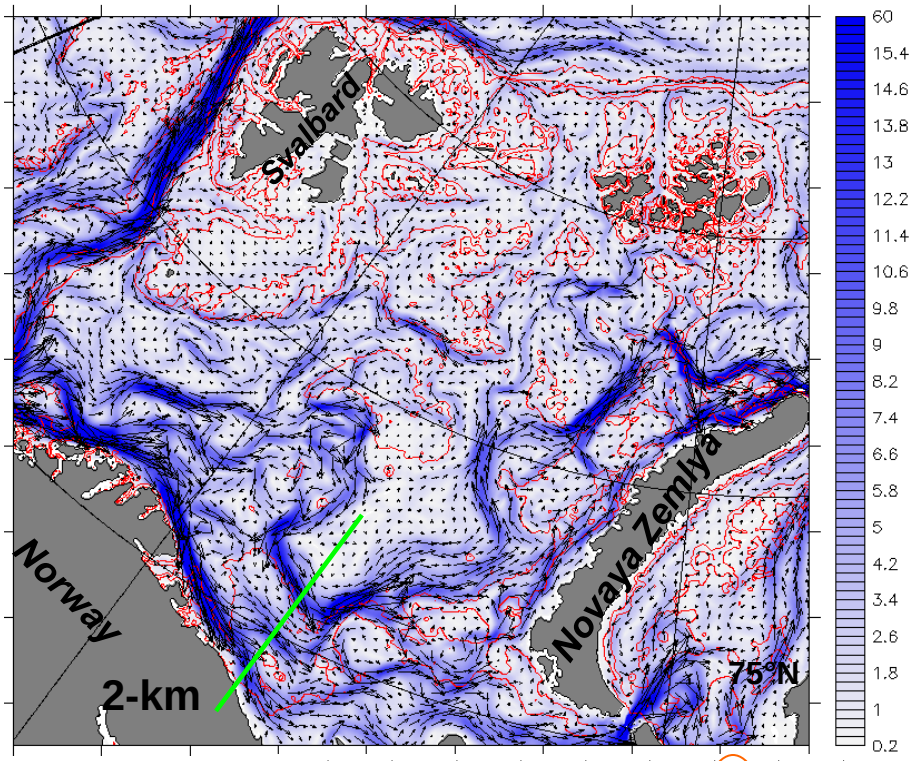


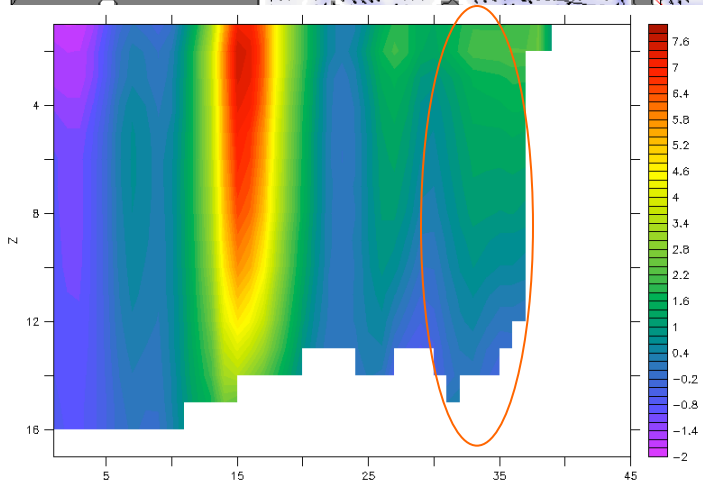
Maslowski et al. (2004 & 2008)

- **More realistic representation of WSC and NCC in 9-km model**
- **Circulation around Central Bank, west of Novaya Zemlya**
- **Limited interaction between AW and NCC in the 18km model**

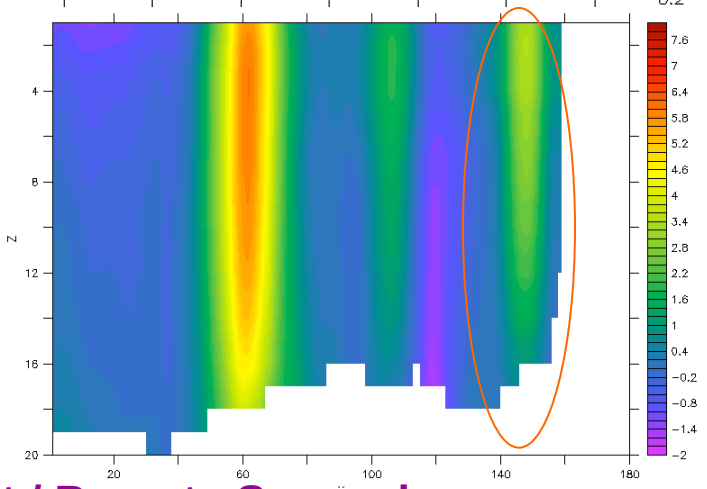
Annual mean (1983) velocity [cm/s] at 0-223 m in the Barents Sea





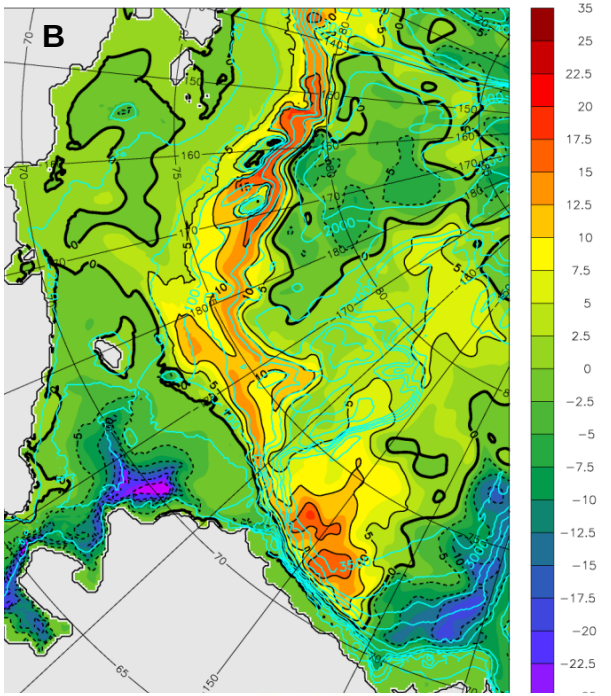


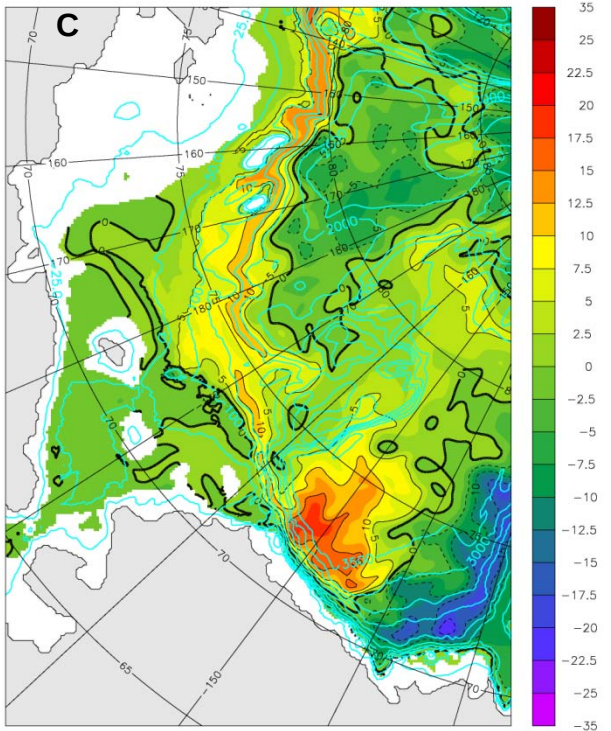
NCC stronger and extended into the Kara Sea in 2km model

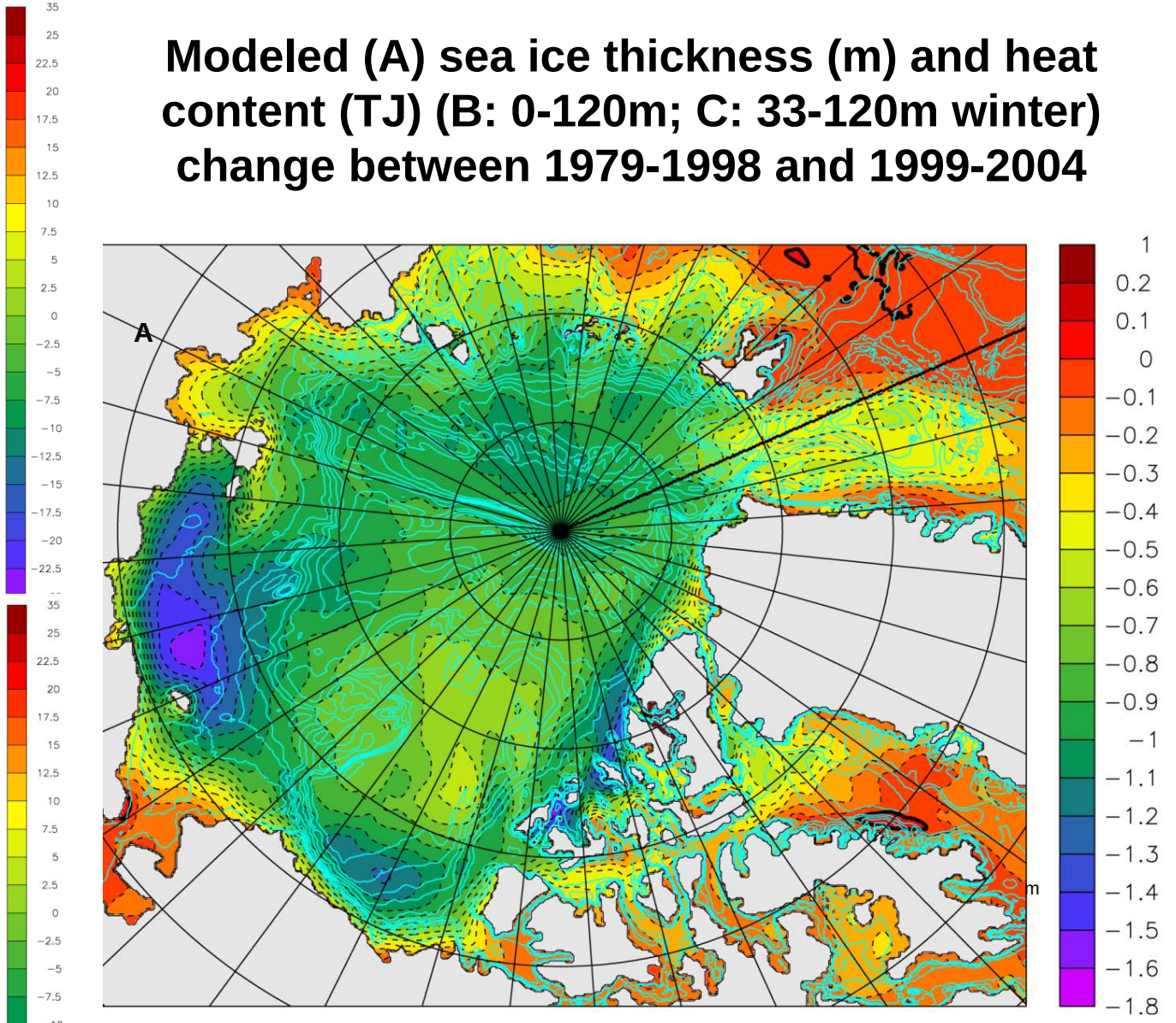


Flow of Atlantic Water through Fram Strait / Barents Sea and heat release to the atmosphere depends on model resolution!

Modeled (A) sea ice thickness (m) and heat content (TJ) (B: 0-120m; C: 33-120m winter) change between 1979-1998 and 1999-2004

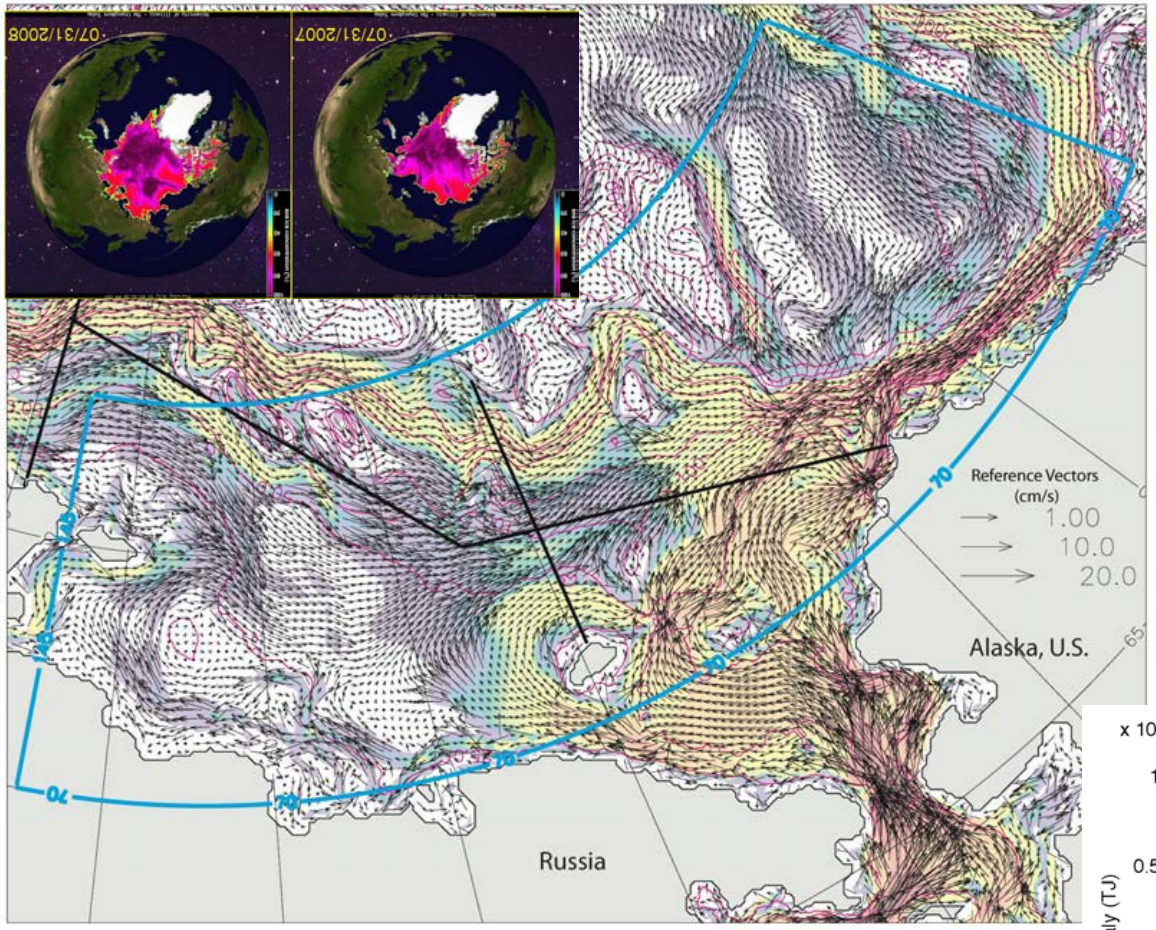




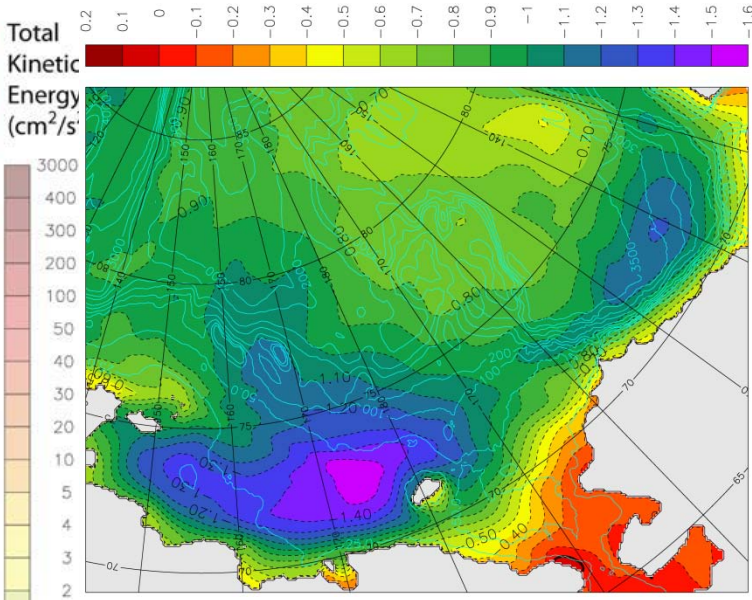


Origins of increased heat content possibly due to advection of warm water from shelves, anticyclonic eddies, slope upwelling / advection, local insulation

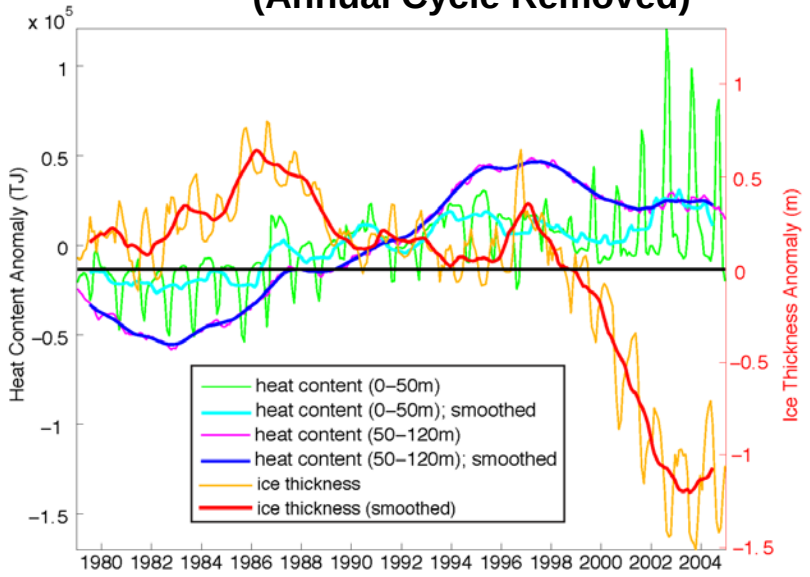
Modeled 26-yr Mean Depth Averaged (0-120 m) Circulation and Total Kinetic Energy in the Western Arctic Ocean



Modeled sea ice thickness change (m) between 79-98 and 99-04

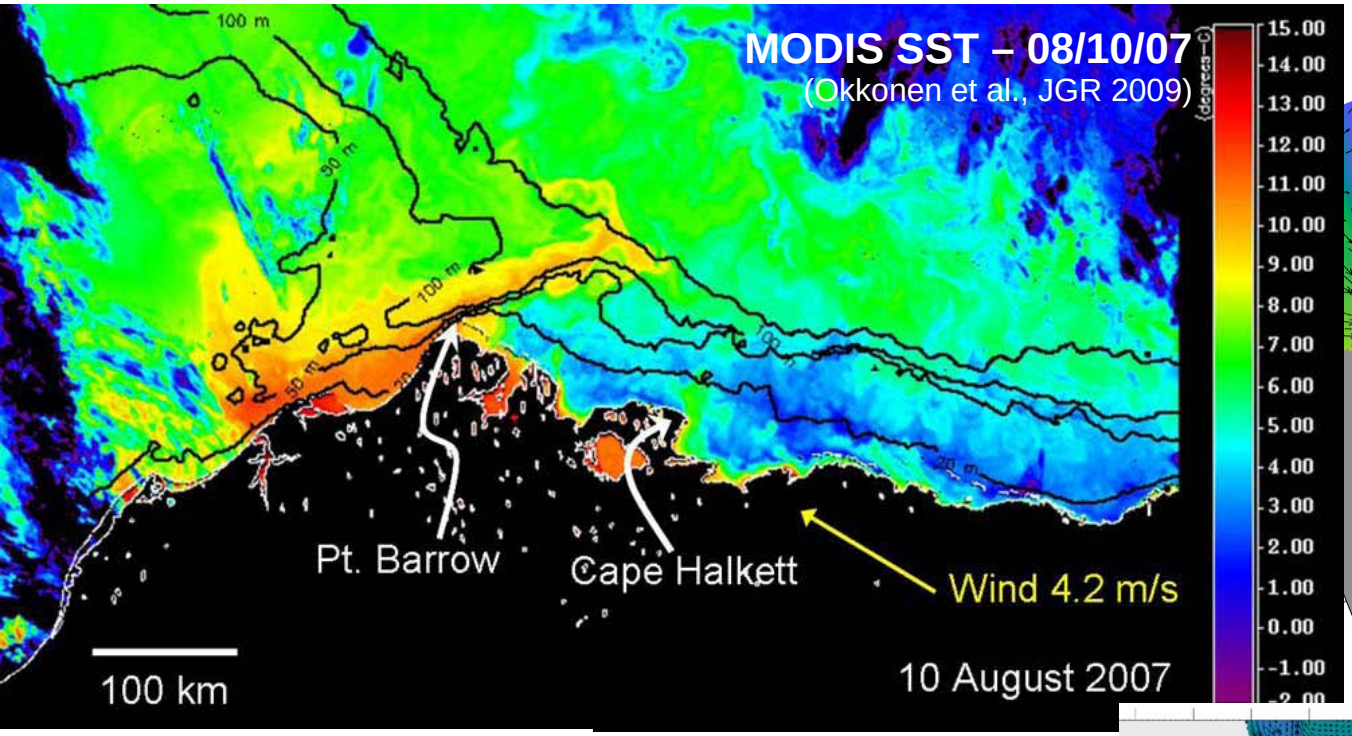


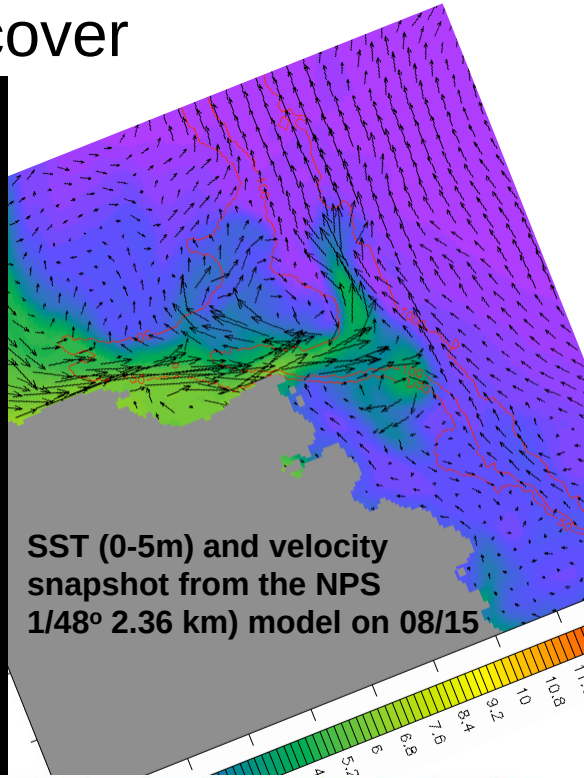
Modeled Upper Ocean Heat Content and Ice Thickness Anomalies (Annual Cycle Removed)

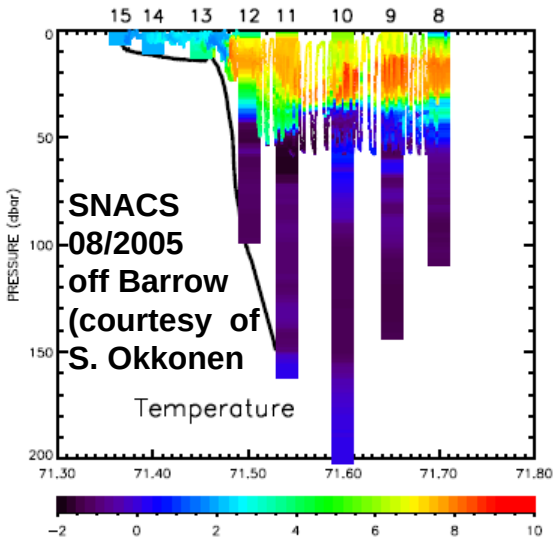


Heat content accumulating in the sub-surface ocean since mid-1990s may explain over 60% of total ice thickness change

Oceanic advection and eddies transports heat from the Chukchi Shelf towards and under the ice cover

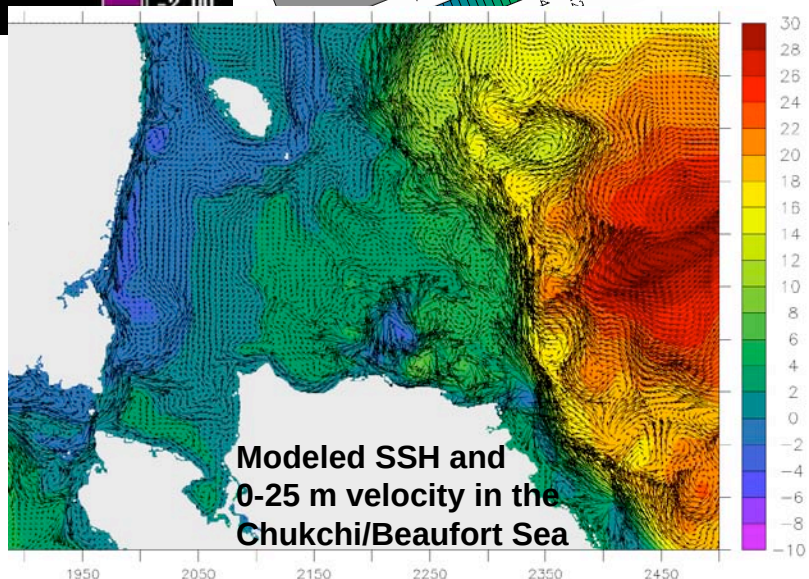




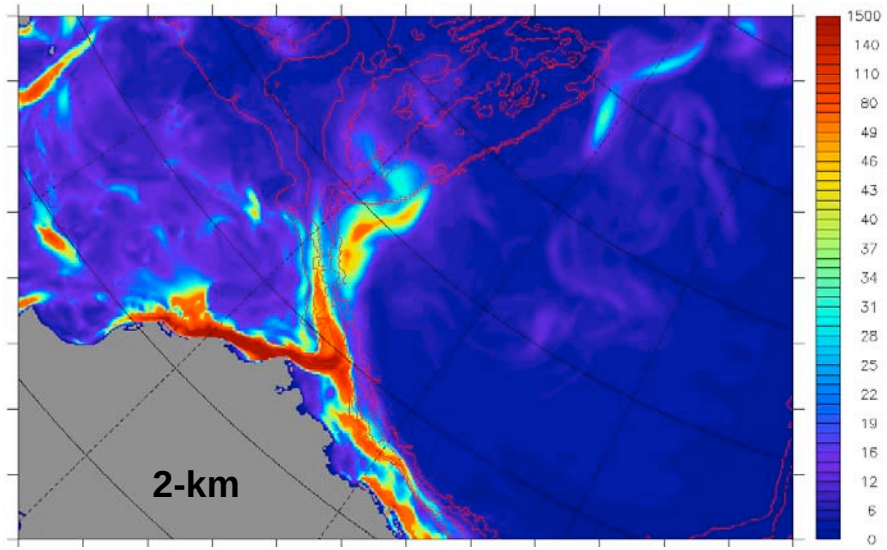


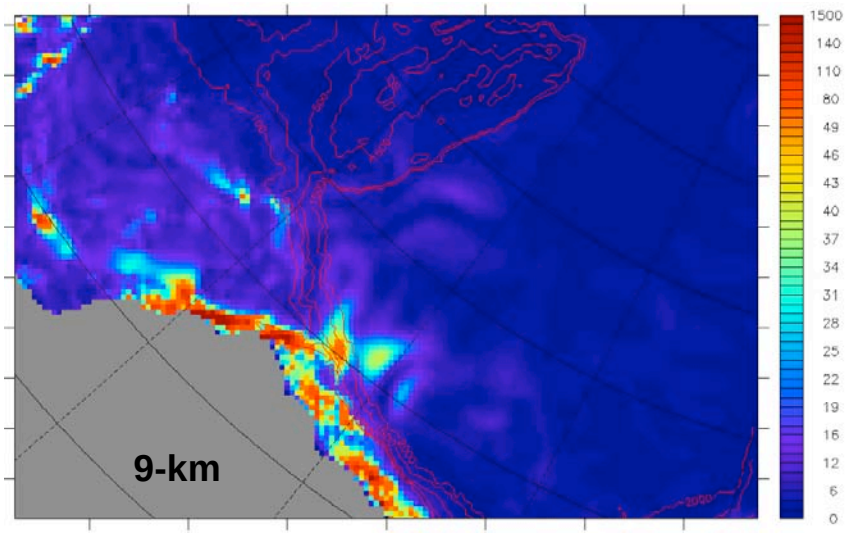
Alaska Coastal Current accounts for ~67% of the Total Heat Export from the Chukchi Shelf

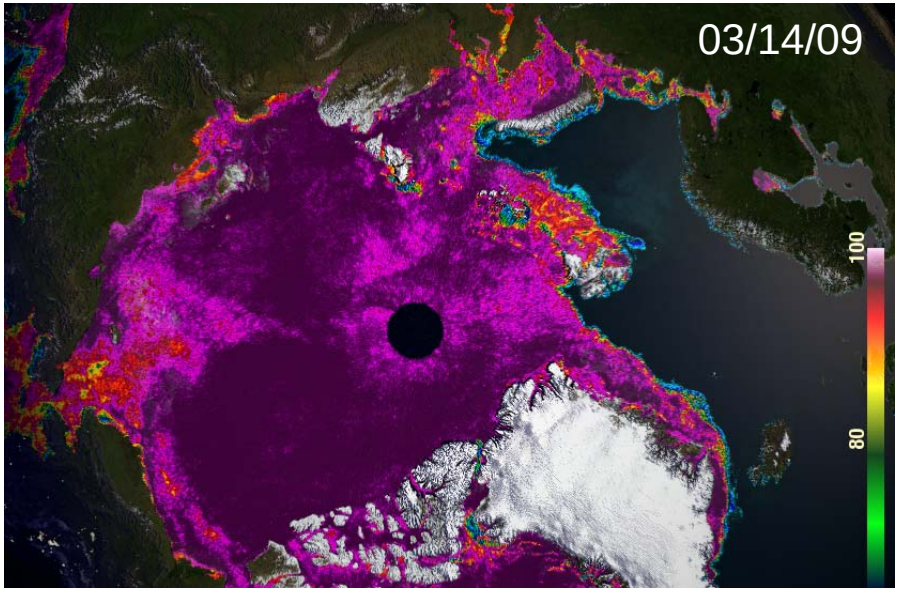
(see 2 posters by J. Clement Kinney and R. Osinski)

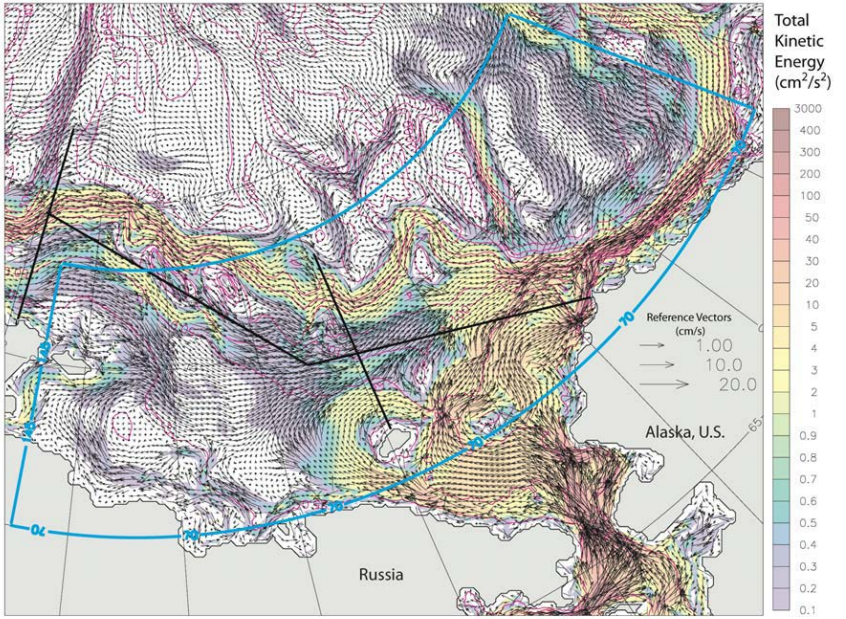


Eddy activities over the Northwind Ridge : Summer (JAS) mean EKE in the upper 110m from 1/48^{o} (left) and 1/12^{o} (right) model



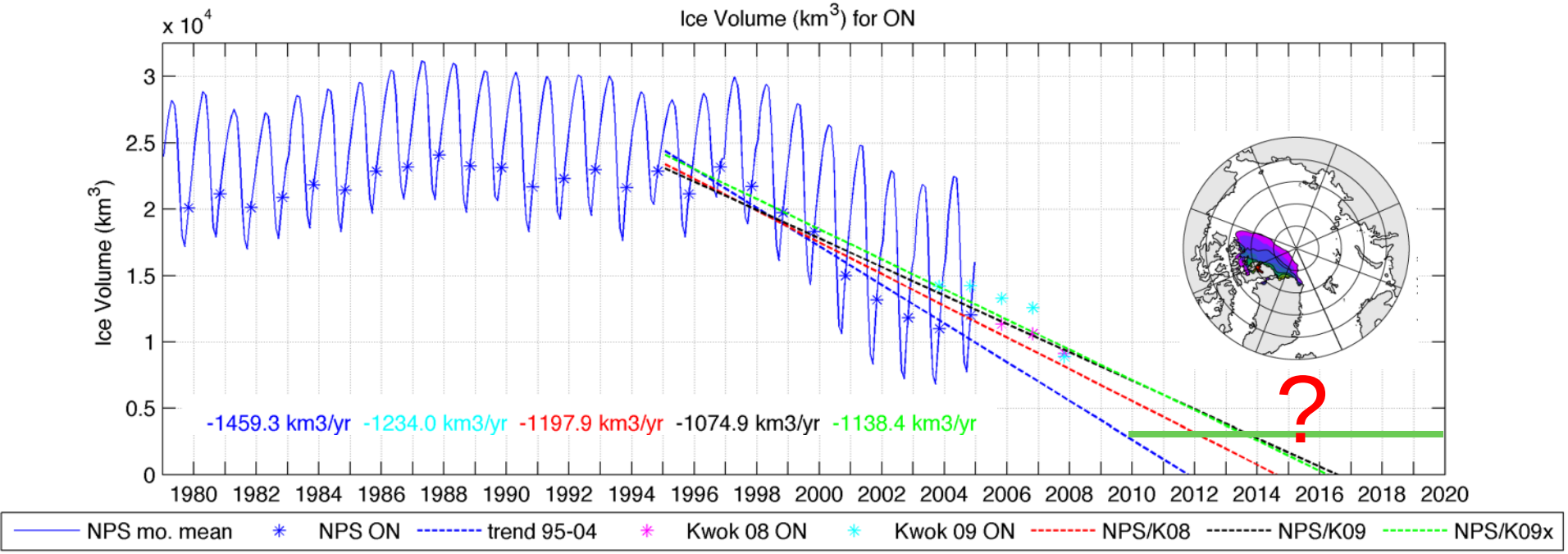






Oceanic impact on sea ice in the western Arctic …… continues!

Arctic Sea Ice Volume Trends



Observational estimates (cyan / purple stars):

- Obs Fall (ON) '07 volume <9000 km^3 (~20% uncertainty)
- Negative volume trends: 1197 - 1234 km^3/yr
- Combined (95-07) model / data linear volume trend of -1075 km^3/yr
  projects ice-free fall by 2016 (±3yrs uncertainty - 95-07)
- Some (?) sea ice may remain beyond due to increased ridging of thinner ice

(Kwok et al., JGR 2009, Kwok & Cunnigham, JGR 2008)

Lowest Winter (Feb-Mar) Arctic sea ice volume in 2009: 11900 km^3 !!!

(R. Kwok, NASA/JPL, Personal communication)

Conclusions

1. **The rate of decrease of sea ice thickness and volume appears to be much greater than that of sea ice extent**
2. **Oceanic heat has contributed critical preconditioning to sea ice melt in the western Arctic since the mid-1990s**
3. **Near ice-free summer Arctic might become a reality much sooner than GCMs predict**
4. **A regional high-resolution Arctic Climate System Model can address GCM deficiencies and improve predictive skill of climate models at seasonal to decadal scales**

(presented by J. Cassano et al., Theme 1.3 at 2:30pm today)