



HOKKAIDO UNIVERSITY

Title	When will Summer Arctic Sea Ice Disappear?
Author(s)	Maslowski, Wieslaw
Relation	地球温暖化による劇変を解明する．平成20年6月24日．札幌市
Issue Date	2008-06-24
Doc URL	https://hdl.handle.net/2115/34395
Type	conference presentation
File Information	Maslowski.pdf



When will Summer Arctic Sea Ice Disappear?



Wieslaw Maslowski
Naval Postgraduate School

Collaborators:

Jaclyn Clement Kinney, Andrew Miller,

Terry McNamara , John Whelan

Jay Zwally

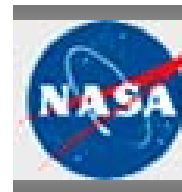
Jaromir Jakacki, Waldemar Walczowski

Agnieszka Beszczynska-Möller

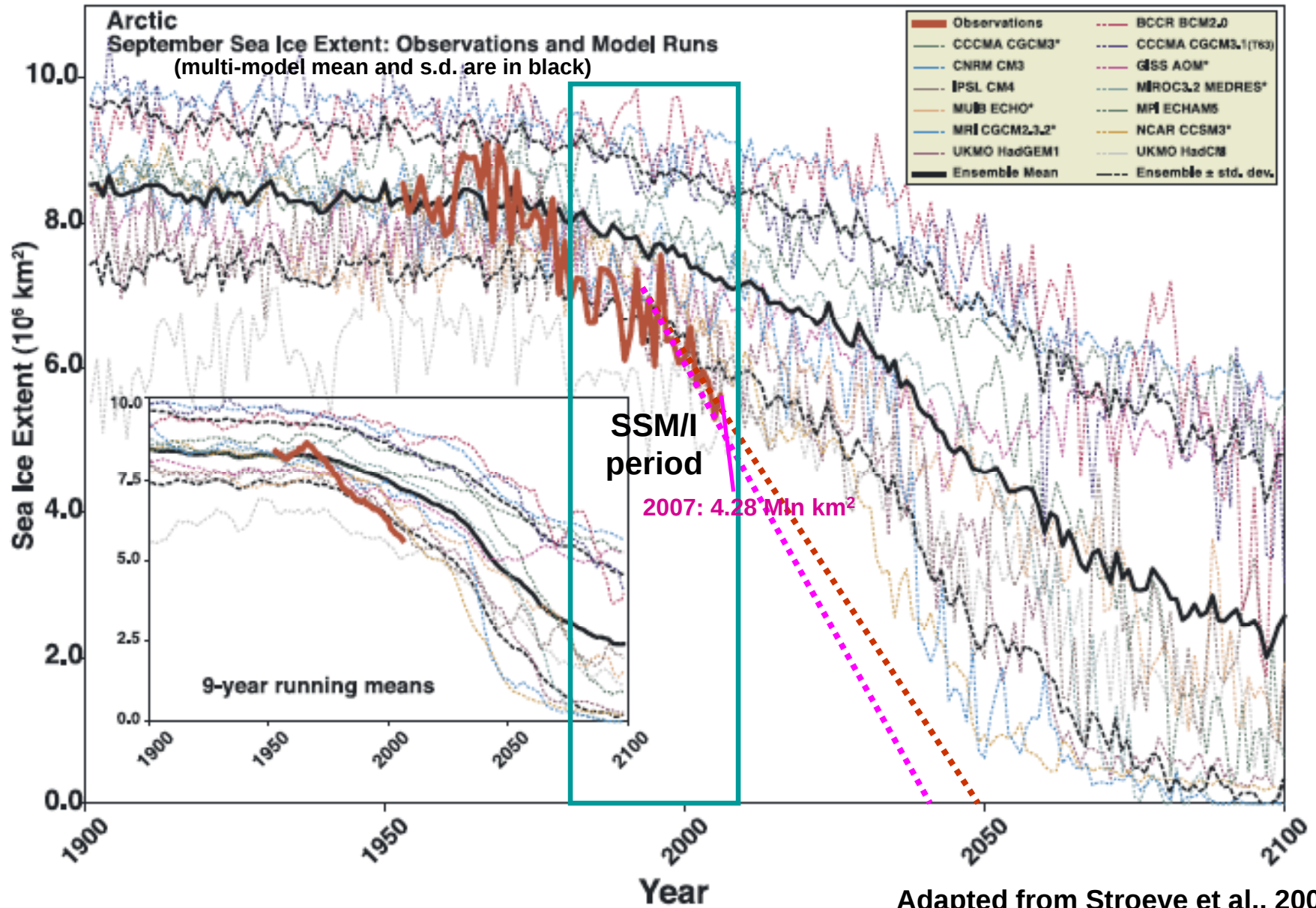
Ron Kwok

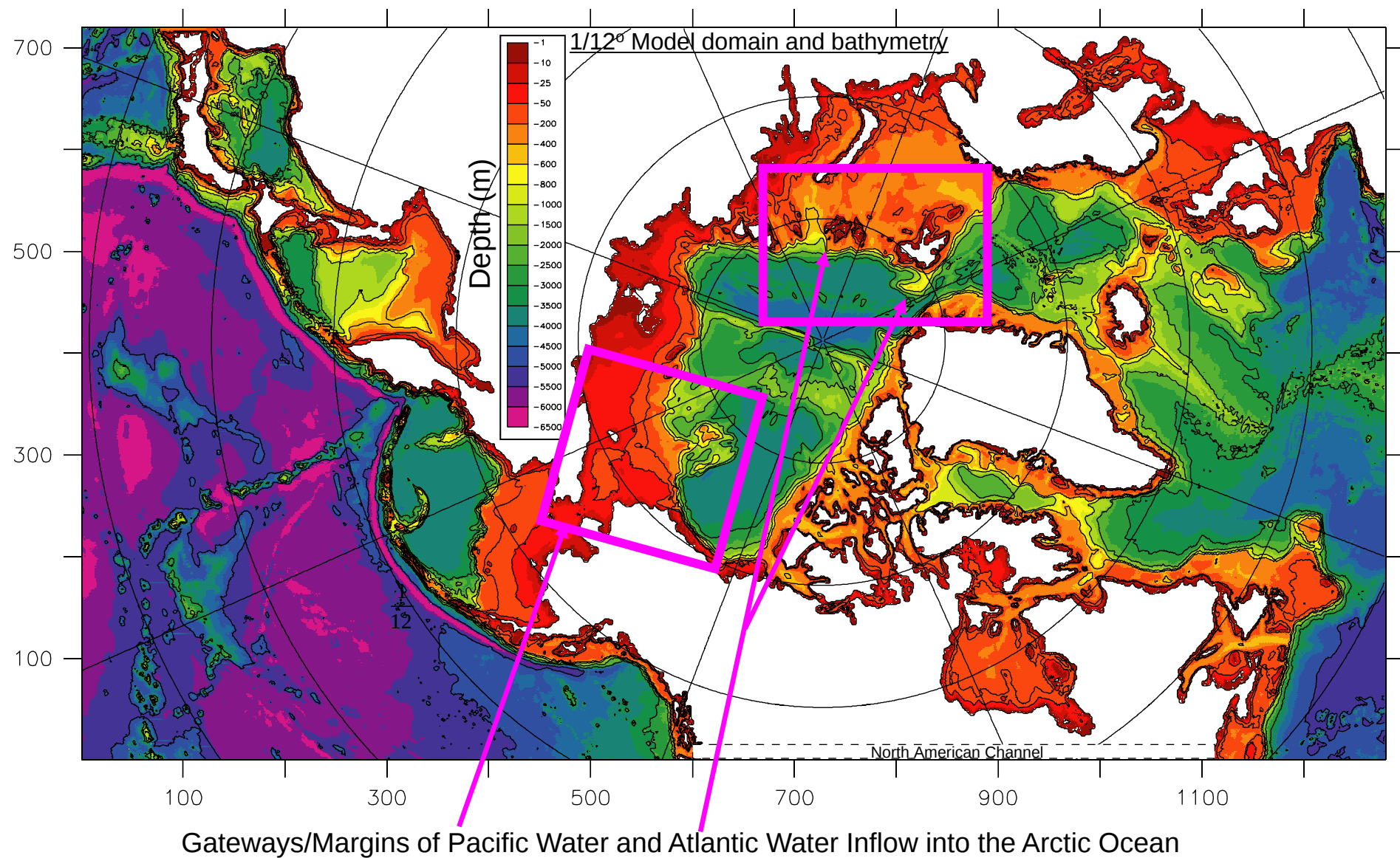
Marika Holland

- **Naval Postgraduate School**
- **NASA / GSFC**
- **Institute of Oceanology, PAS**
- **AWI**
- **NASA / JPL**
- **NCAR**



Observed rate of loss of Arctic ice extent is faster than IPCC AR4 predictions

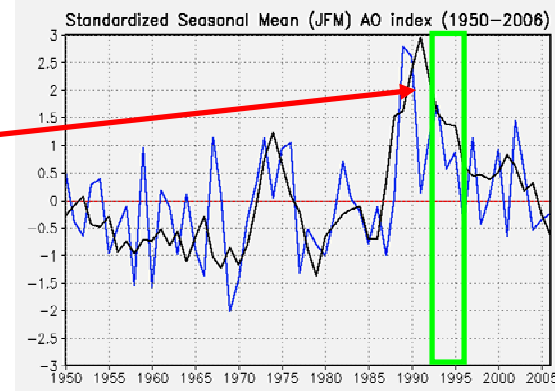
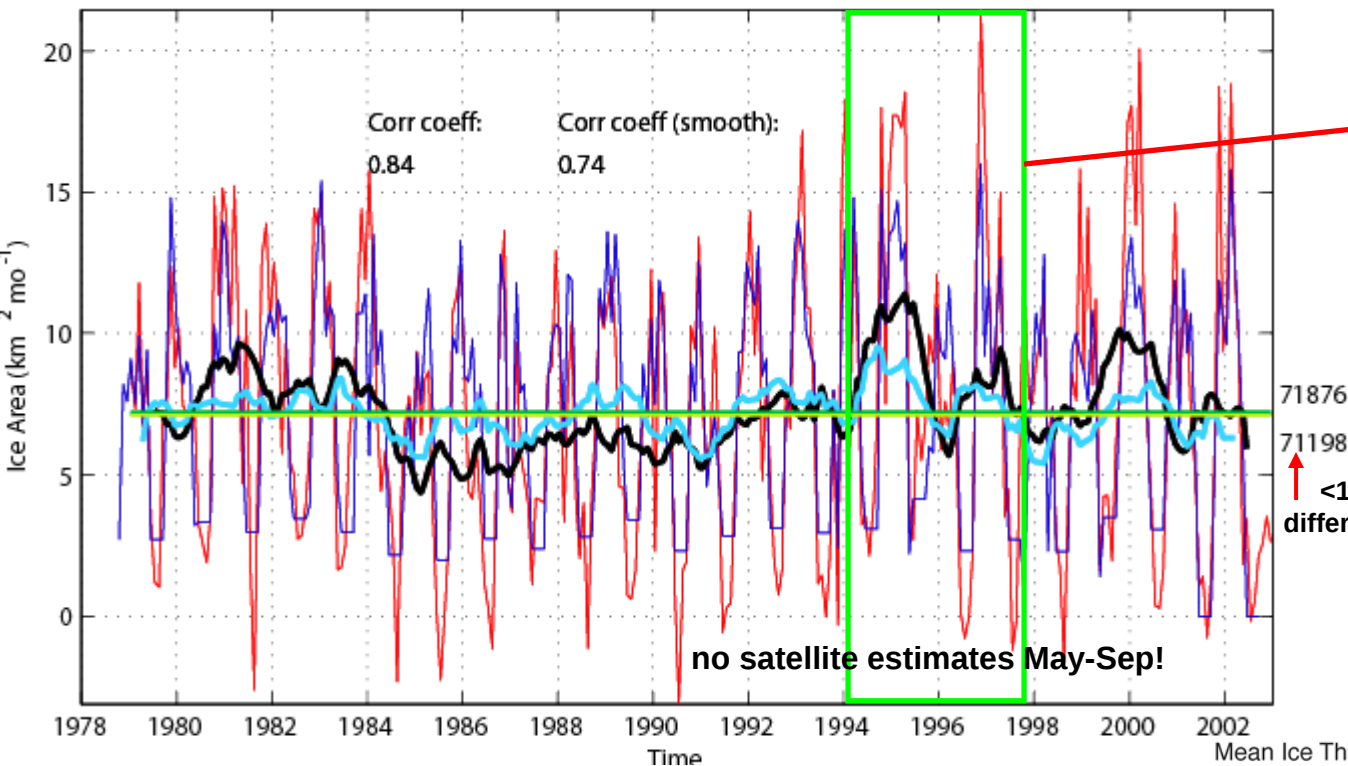




Main uncertainties of importance to global climate

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

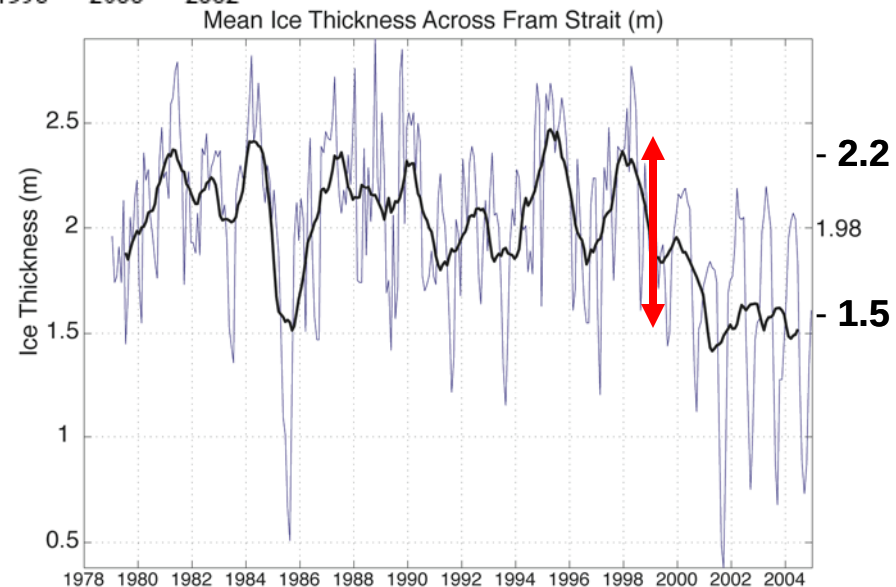
Sea Ice Export through Fram Strait (wind-driven)



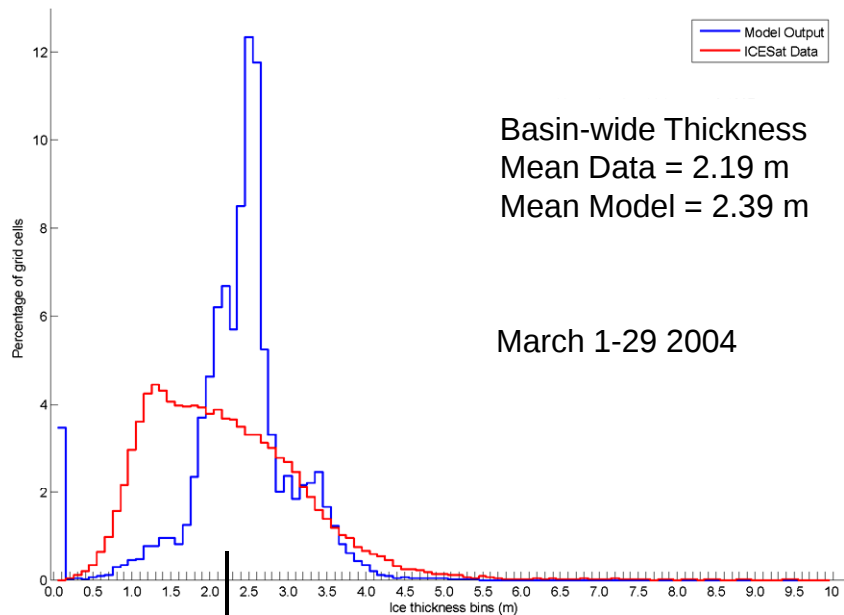
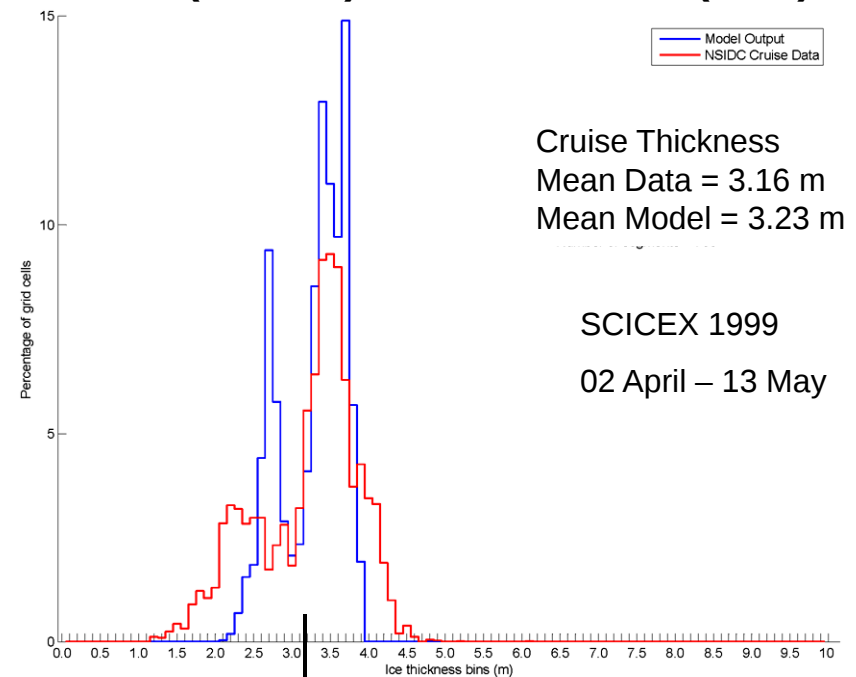
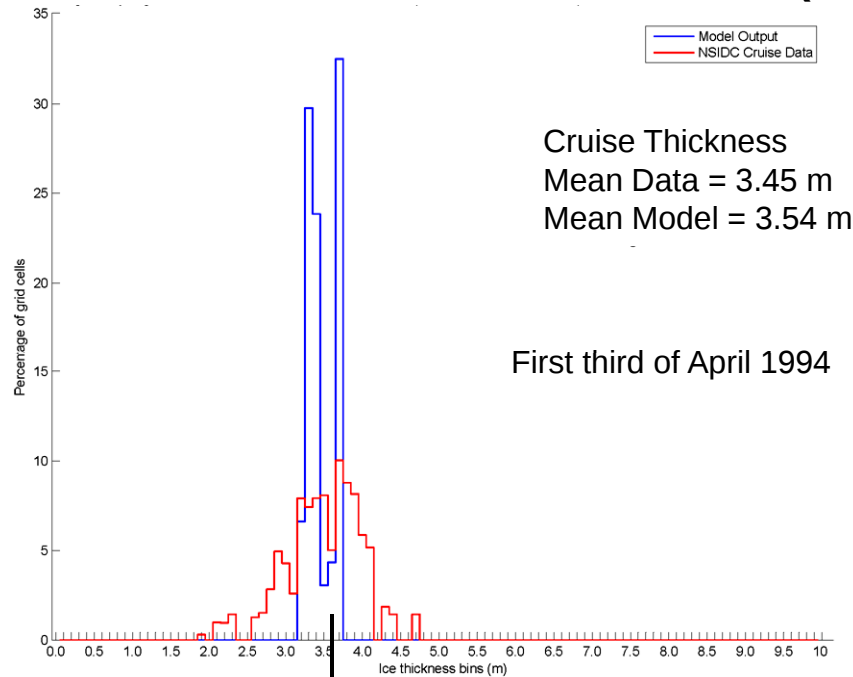
Mean area flux [km^2/mo]
 Estimates from:
 - satellite (Kwok et al., 2004
 blue/cyan/yellow)
 - model (red/black/green)

High export of thick sea ice from the Arctic Ocean in the mid-1990s:

- in response to high positive AO/NAO
- mean thickness of sea ice across Fram Strait decreased by ~70 cm (or ~1/3)
- less multi-year ice in the Arctic Ocean
- warming more pronounced on thinner ice
- thinner ice less stable to perturbations

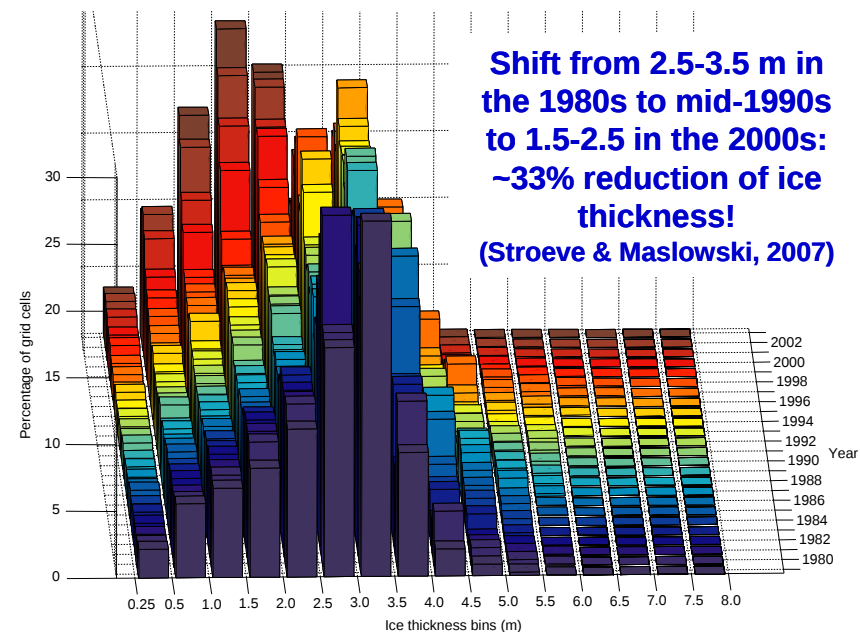


PDFs of ice thickness from submarines (top) / ICESat (bottom) and NPS model (blue)

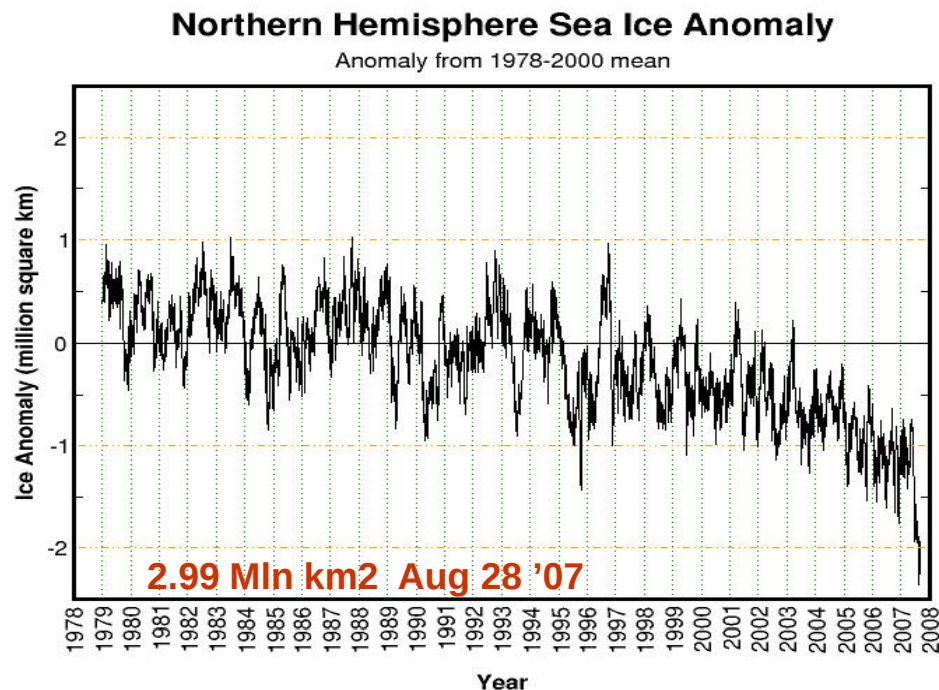
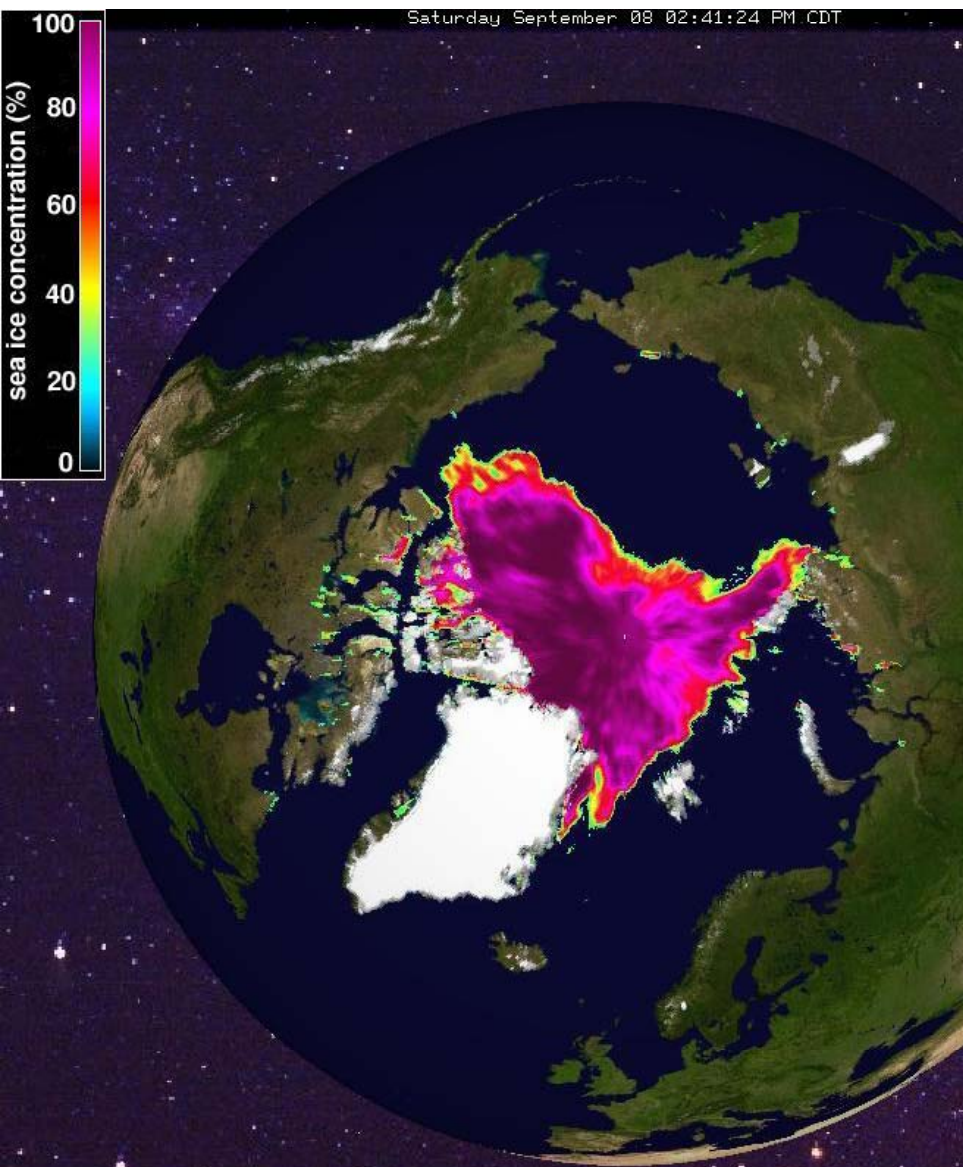


(from McNamara, 2006 and Whelan, 2007)

PDF of Model 1979-2003 Annual Sea Ice Thickness



Atmospheric forcing of the 2007 summer ice minimum?

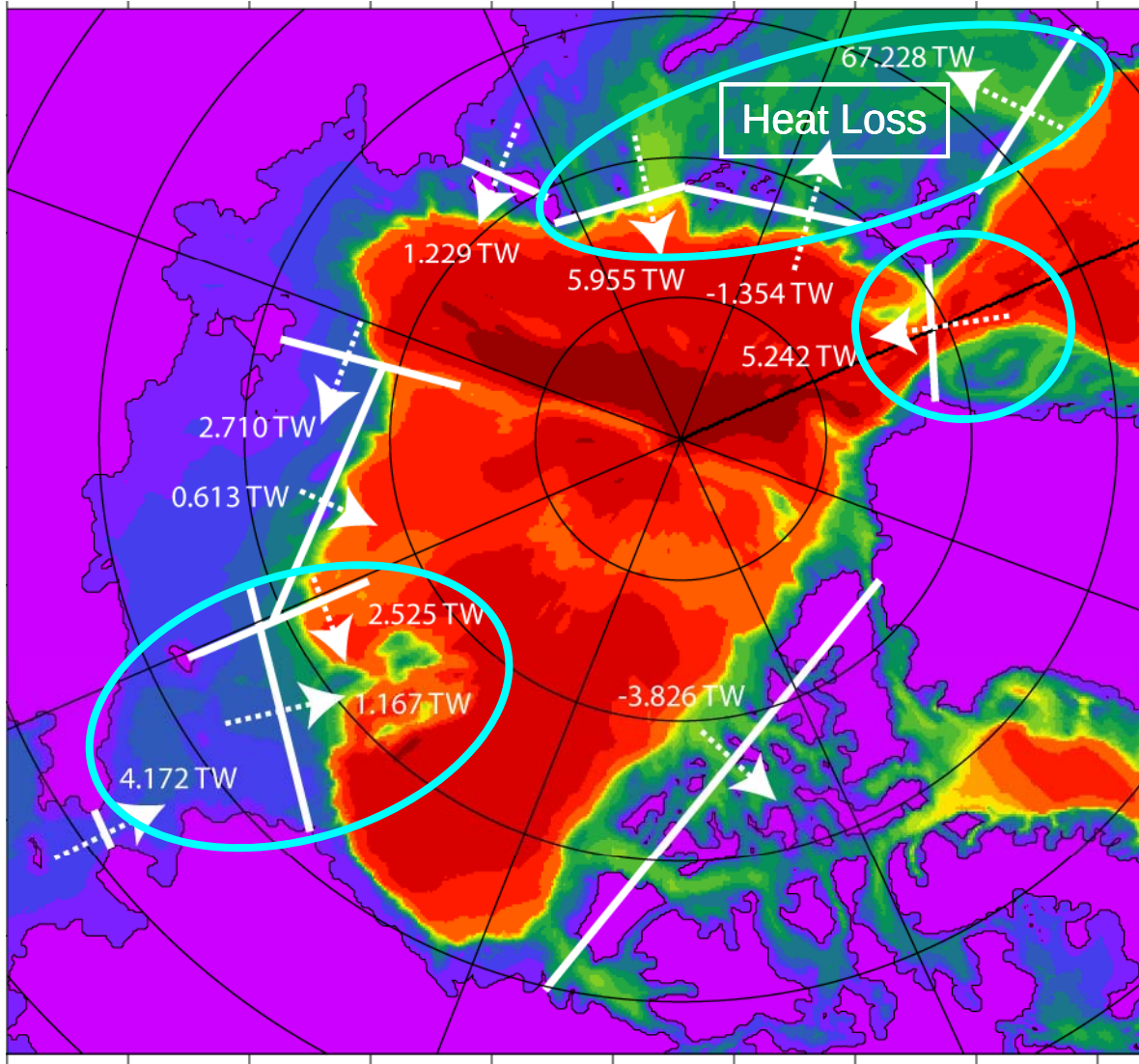


“With the sea-level pressure patterns during the summer of 2006 and 2007 favoring the export of sea ice into the Atlantic Sector, the regional outflow is ~21% and ~15% of the total sea ice retreat in the Pacific sector. “

Kwok GRL 2008

Why no record minimum in 2006?

1979-2004 Mean Oceanic Heat Convergence: 0-120 m; $T_{\text{ref}} = T_{\text{freezing}}$



Modeling Challenges: Inflow of Pacific / Atlantic Water into the Arctic Ocean and impacts on the sea ice

- Pacific Water entering via narrow (~60mi) Bering Strait and across Chukchi shelf

(Clement et al., DSR II 2005)

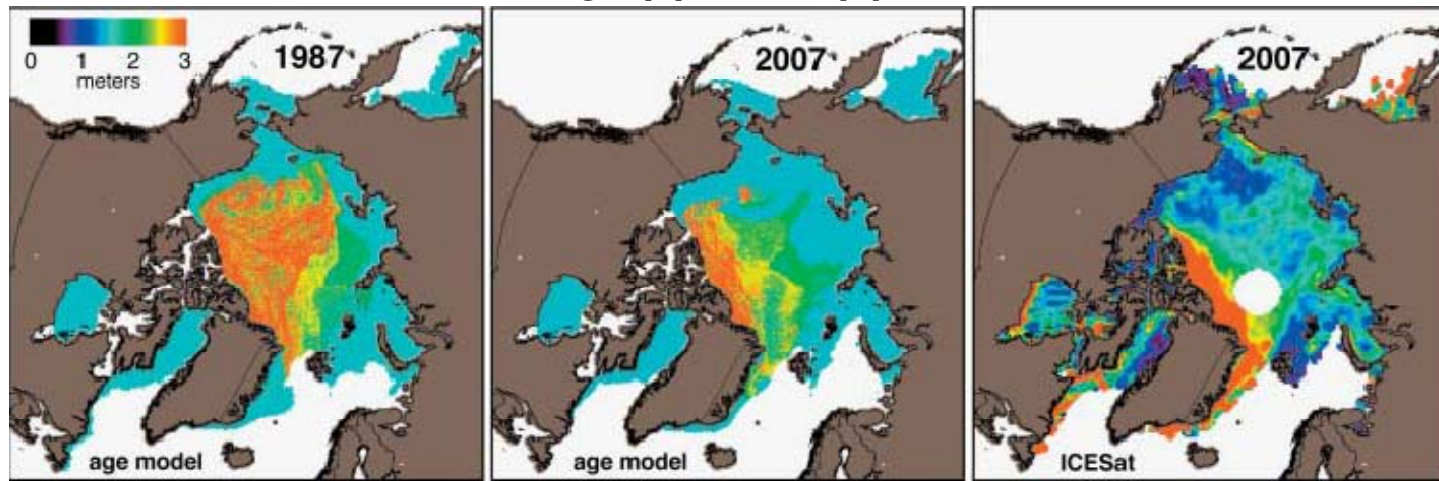
- outflow through Fram Strait vs. Atlantic Water inflow (FSBW/BSBW)
(Maslowski et al., JGR 2004; Stroeve and Maslowski, 2007)

- Atlantic (BSBW) and Pacific Water each losses majority of heat to the atmosphere before entering Arctic Basin

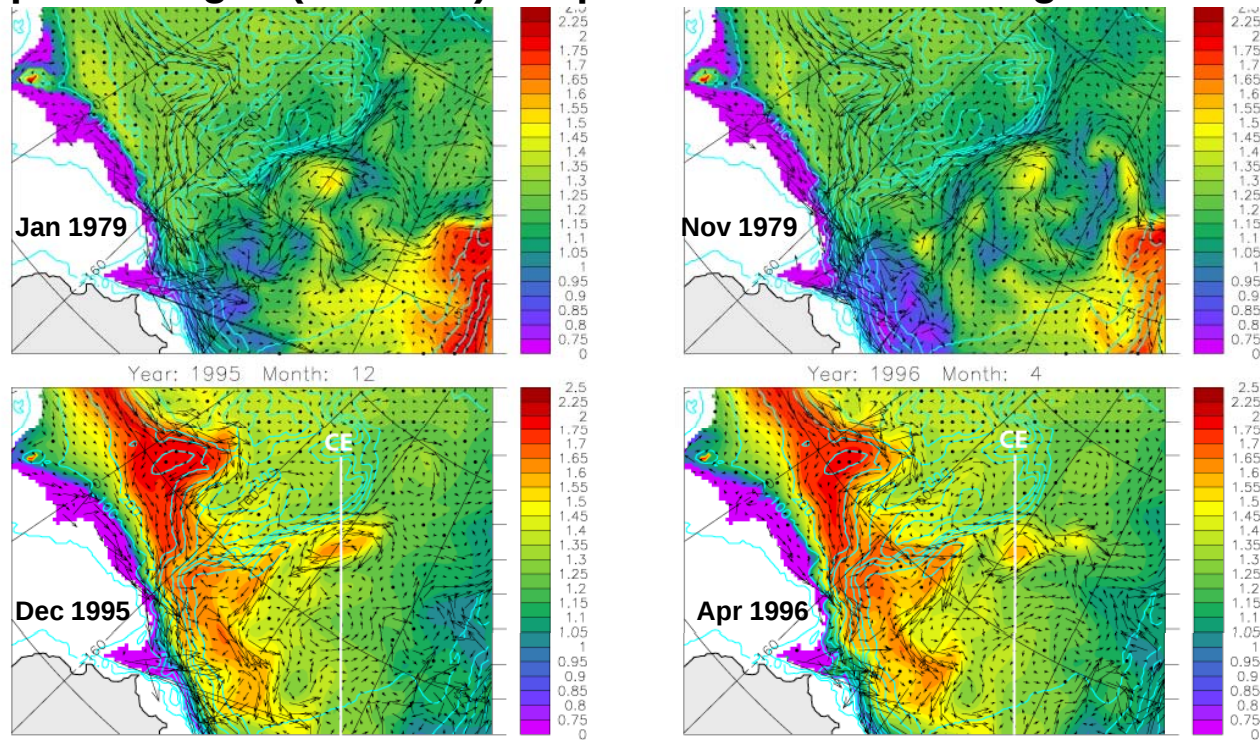
High resolution is one of the top requirements for advanced modeling of Arctic climate

(Maslowski et al., 2008)

Ice Thickness estimates based on age (a) 1987, (b) 2007, and ICESat freeboard (c) 2007

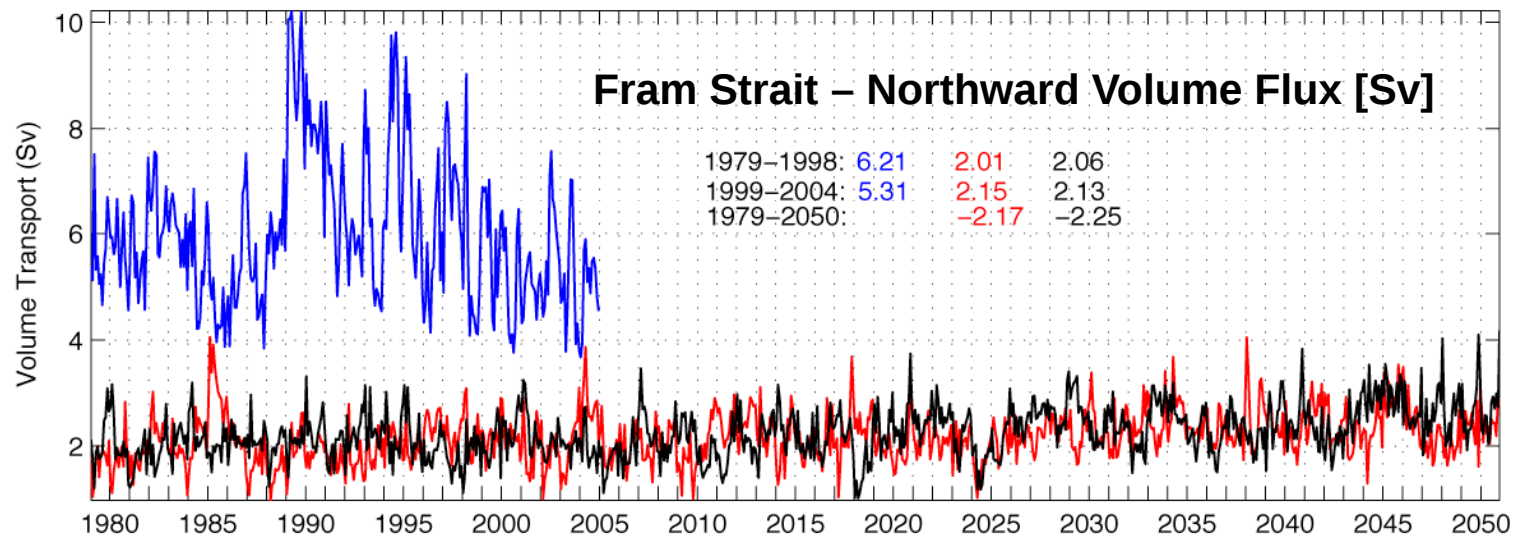
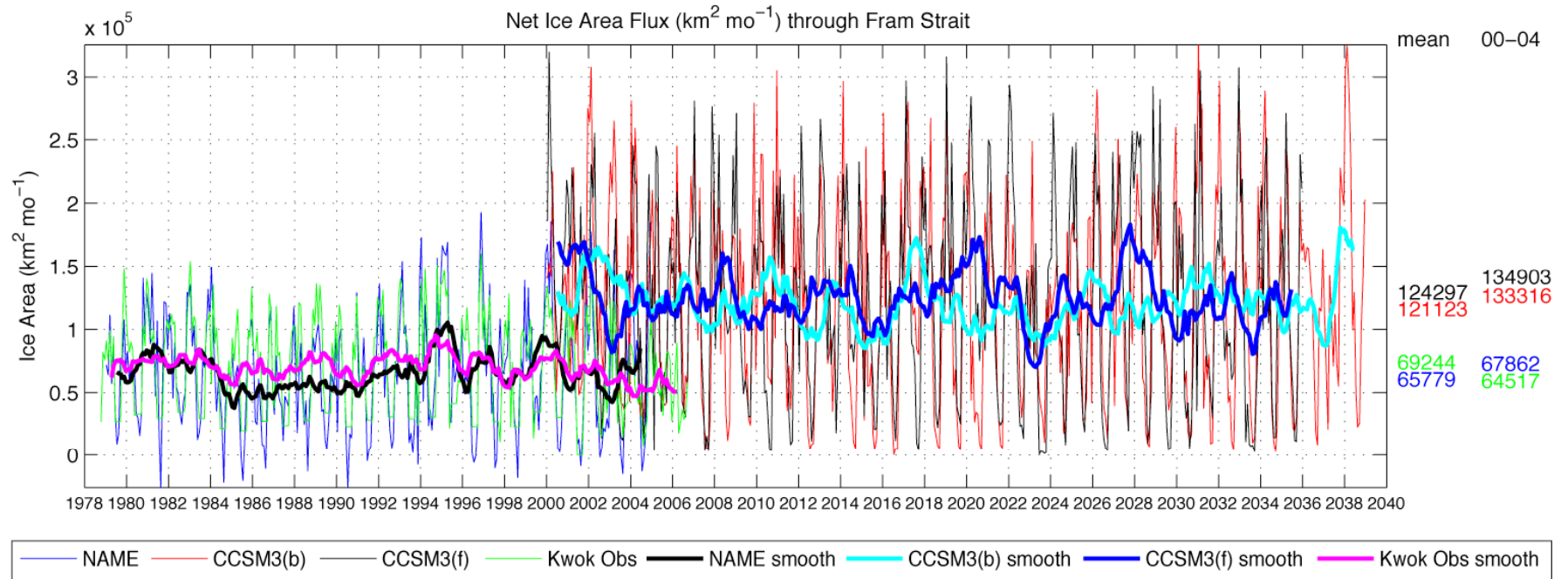


Depth-averaged (65-120m) temperature above freezing and velocity

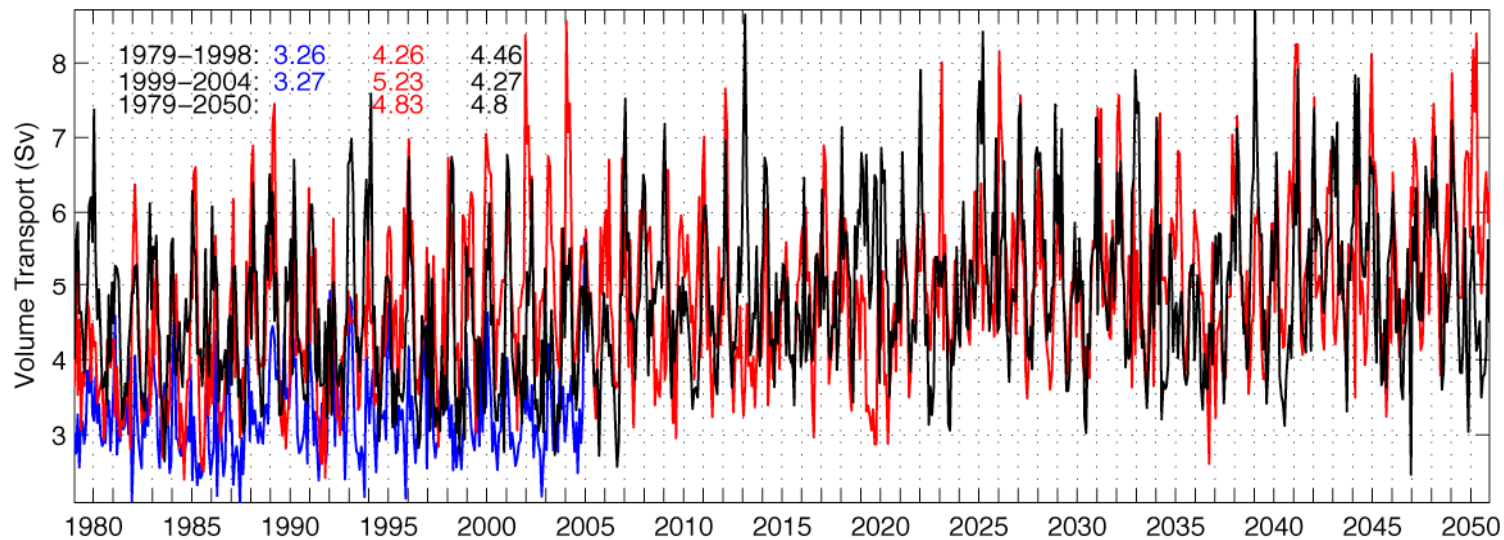


Increasing impact of eddy-driven oceanic heat advection in the western Arctic

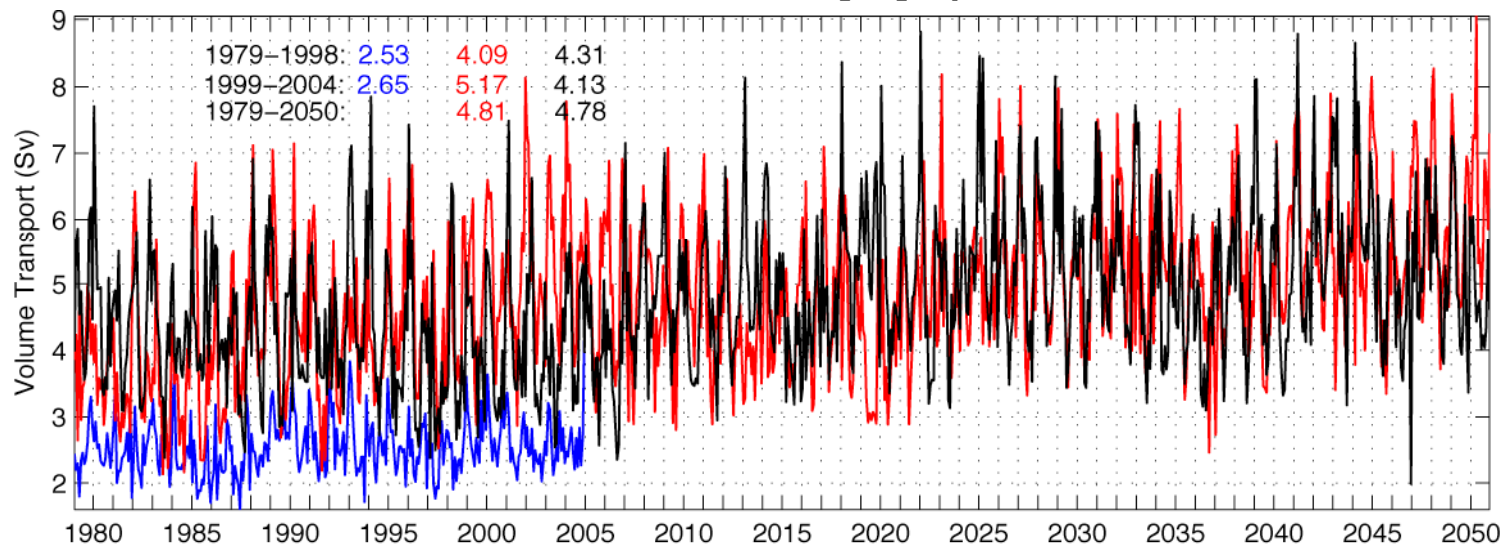
Comparison of areal sea ice export via Fram Strait



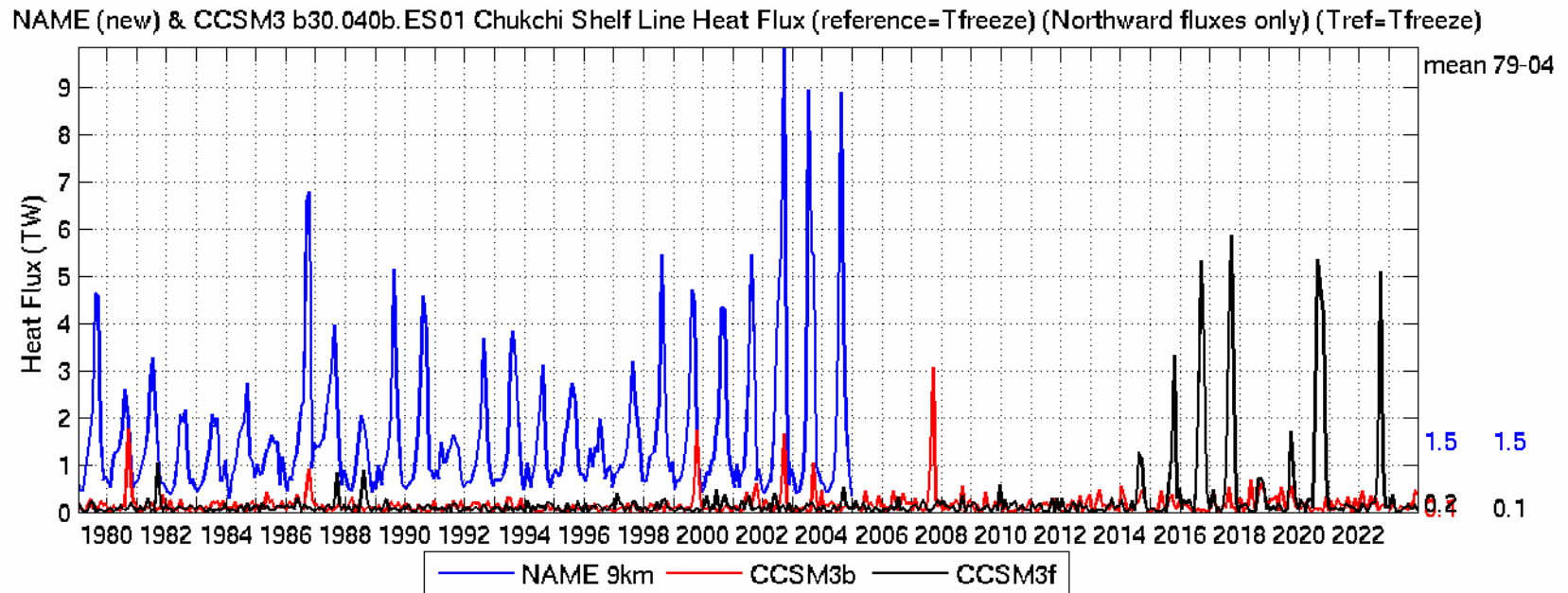
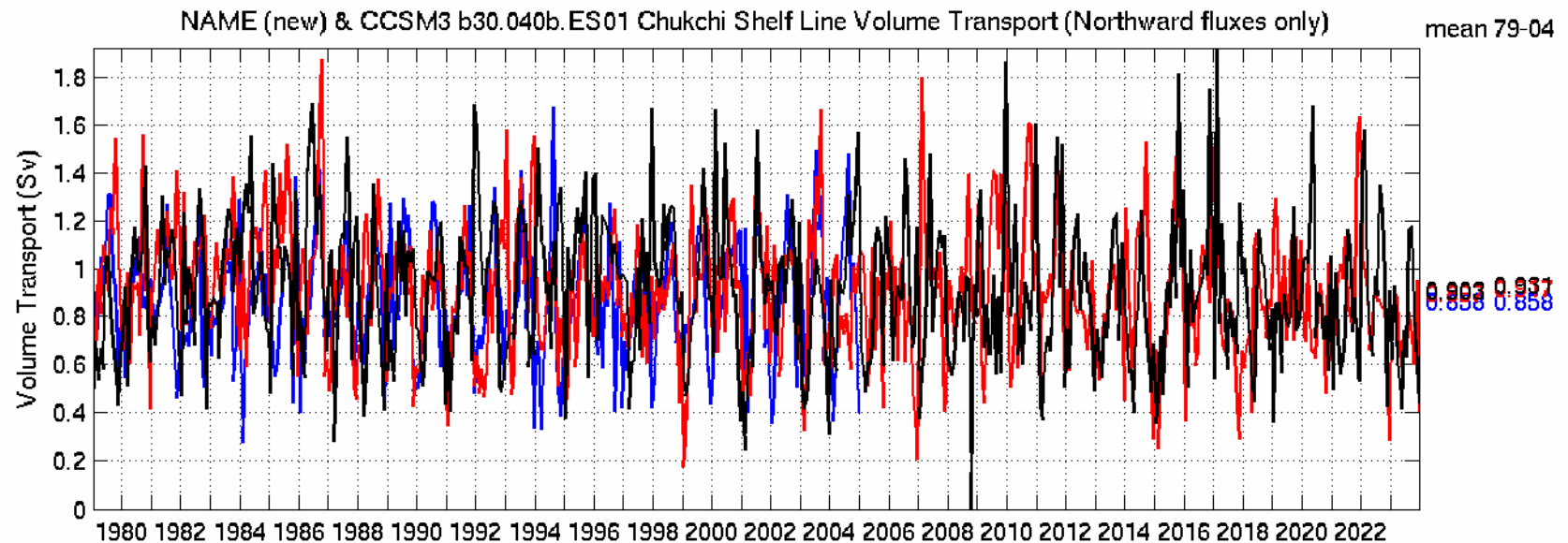
BSO – Net Volume Flux [Sv] – positive east



FJL-NZ – Net Volume Flux [Sv] – positive east



Volume and Heat Fluxes from the Chukchi Shelf into the Western Arctic



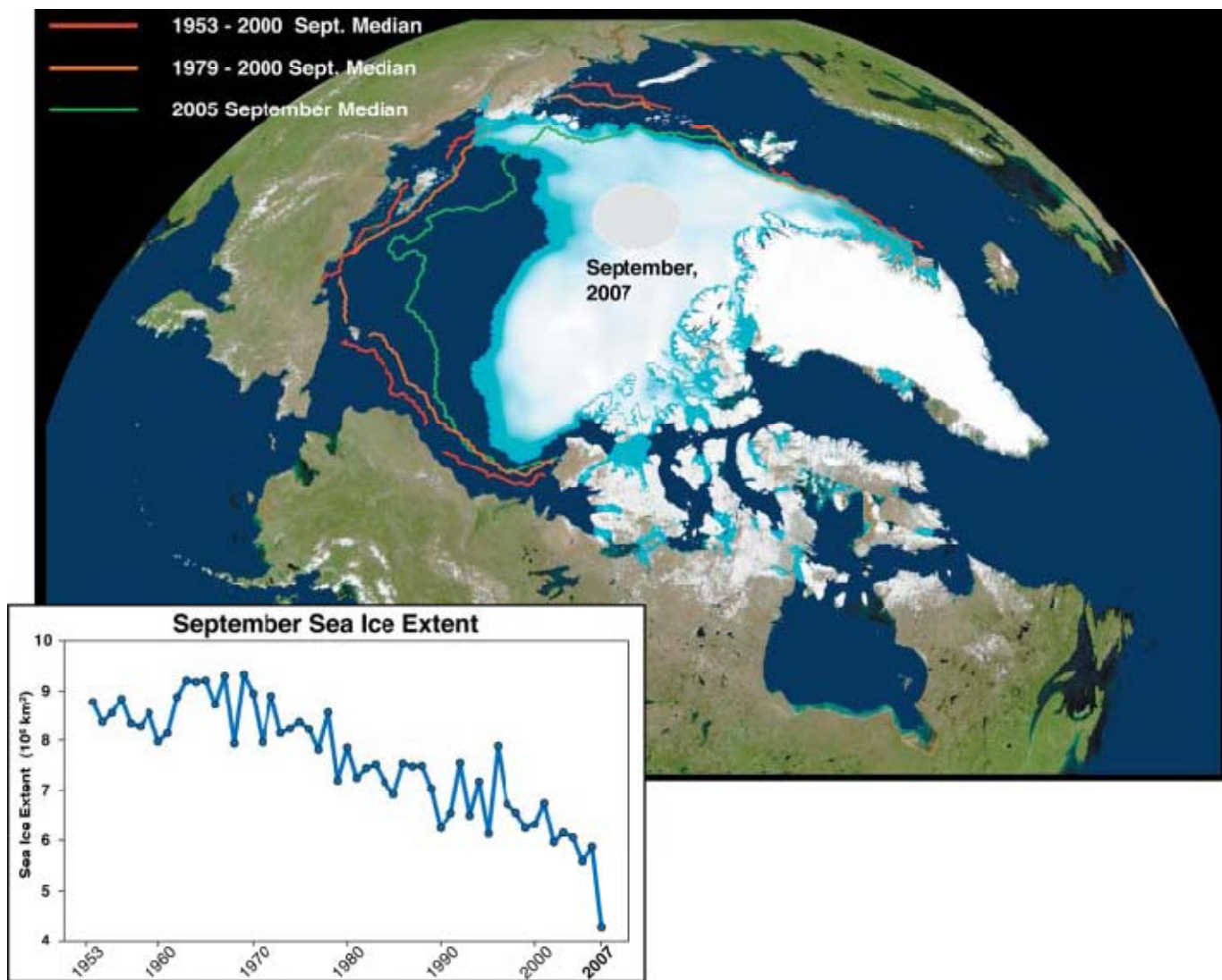
25-year mean volume transport (Sv) / heat transport (TW)

	CCSM(b)			NPS		
	In	Out	Net	In	Out	Net
Fram Strait	<u>2.0/17</u>	-6.9/ -23	-4.9/-6	<u>6.0/45</u>	-8.4/-36	-2.4/+9
Barents Sea Opening	4.8/115.	-0.3/-5	4.5/110	5.0/107	-1.8/-28	3.2/79
FJL-NZ	4.7/32	-0.35/-1	<u>4.35/31</u>	3.4/2.9	-0.8/-0.7	<u>2.6/2.2</u>

‘NPS’ TRANSPORTS (Maslowski et al., JGR, 2004)

Fram Strait ‘in’ obs estimates: 7.0 Sv / 50 TW - Courtesy of A. Beszczynska-Möller, AWI

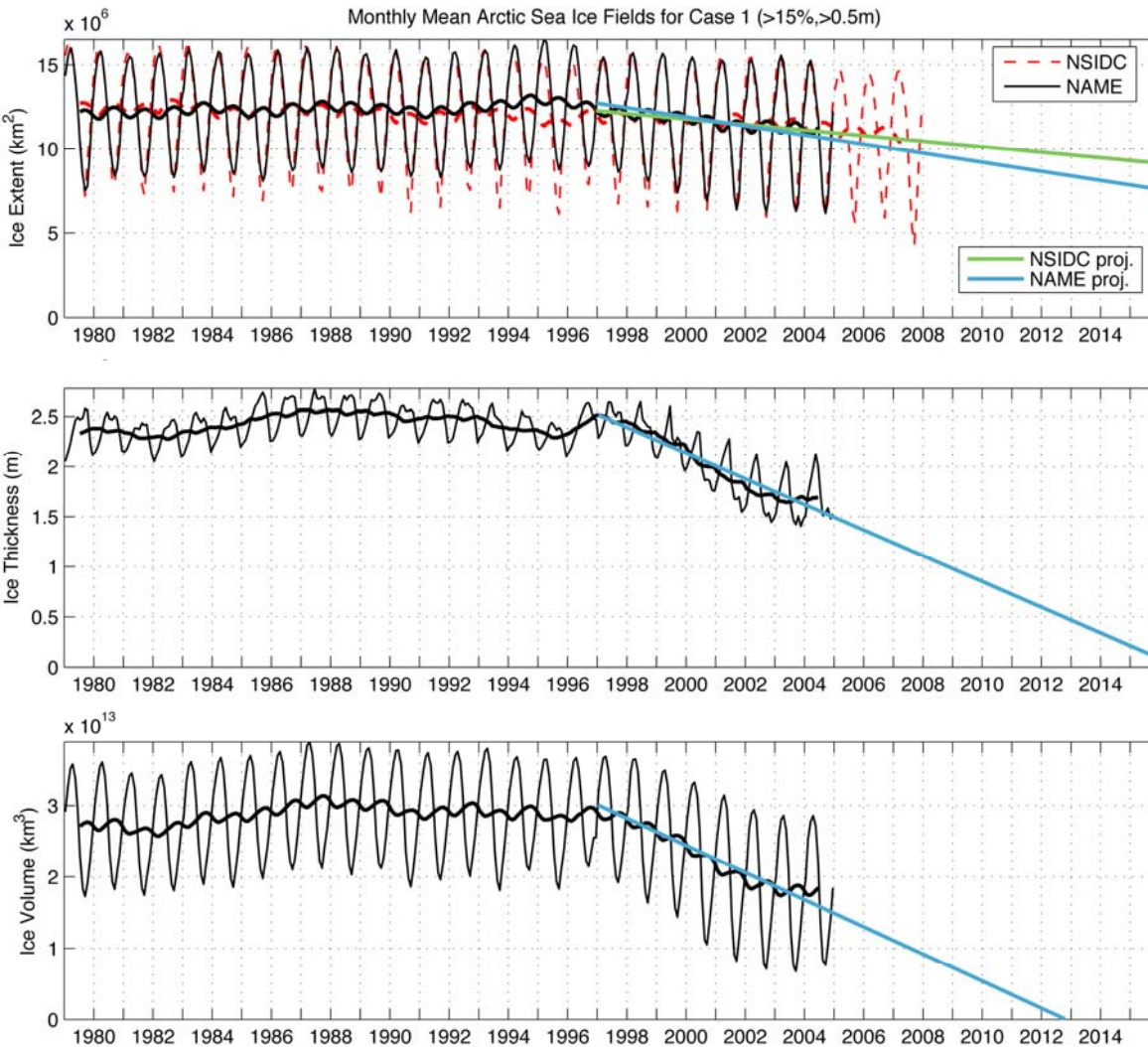
FJL-NZ: near-zero heat transport (Gammelsrod et al., JMS submitted)



“Given these conservative model results, along with the remarkable events of 2007, our view is that a seasonally ice-free Arctic Ocean might be realized as early as 2030.”

Stroeve et al., EOS 01/082008

79-04 time series of Ice Extent, Thickness, and Volume



Between 1997-2004:

- annual mean sea ice concentration has decreased by ~17%
- mean ice thickness has decreased by ~0.9 m or ~36%
- ice volume decreased by 40%, which is >2x the rate of ice area decrease

If this trend persists the Arctic Ocean will become ice-free by ~2013!

Conclusions

1. The rate of decrease of sea ice thickness and volume possibly about 2x greater than that of sea ice extent
2. Anomalous export of sea ice through Fram Strait during the mid-1990s a precursor of sea ice decline
3. Oceanic heat advection has contributed significant forcing (>60%) to sea ice melt during the last decade
4. CCSM3/HadGEM1 (and potentially many other GCMs) simulations compared to NPS and observational estimates:
 - a) have too weak northward heat fluxes through Bering / Chukchi seas, which explains why they have too much ice in the western Arctic
 - b) have too weak northward and recirculating fluxes at Fram Strait, which allow too much ice in the Greenland Sea
 - c) simulate too much volume and heat flux through the Barents Sea and try to melt the sea ice cover from the eastern side

which is why their predictions are too conservative
5. Ice thickness and ocean heat flux data critical for model validation
6. Dedicated computer resources needed to advance Arctic and global climate modeling and prediction

"A linear increase in heat in the Arctic Ocean will result in a non-linear, and accelerating, loss of sea ice."

– Norbert Untersteiner, Professor Emeritus,
University of Washington, July 2006