Regional Arctic Climate System Model - A Review and Selected Results

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William Lipscomb	- LANL
Slawek Tulaczyk	- UCSD
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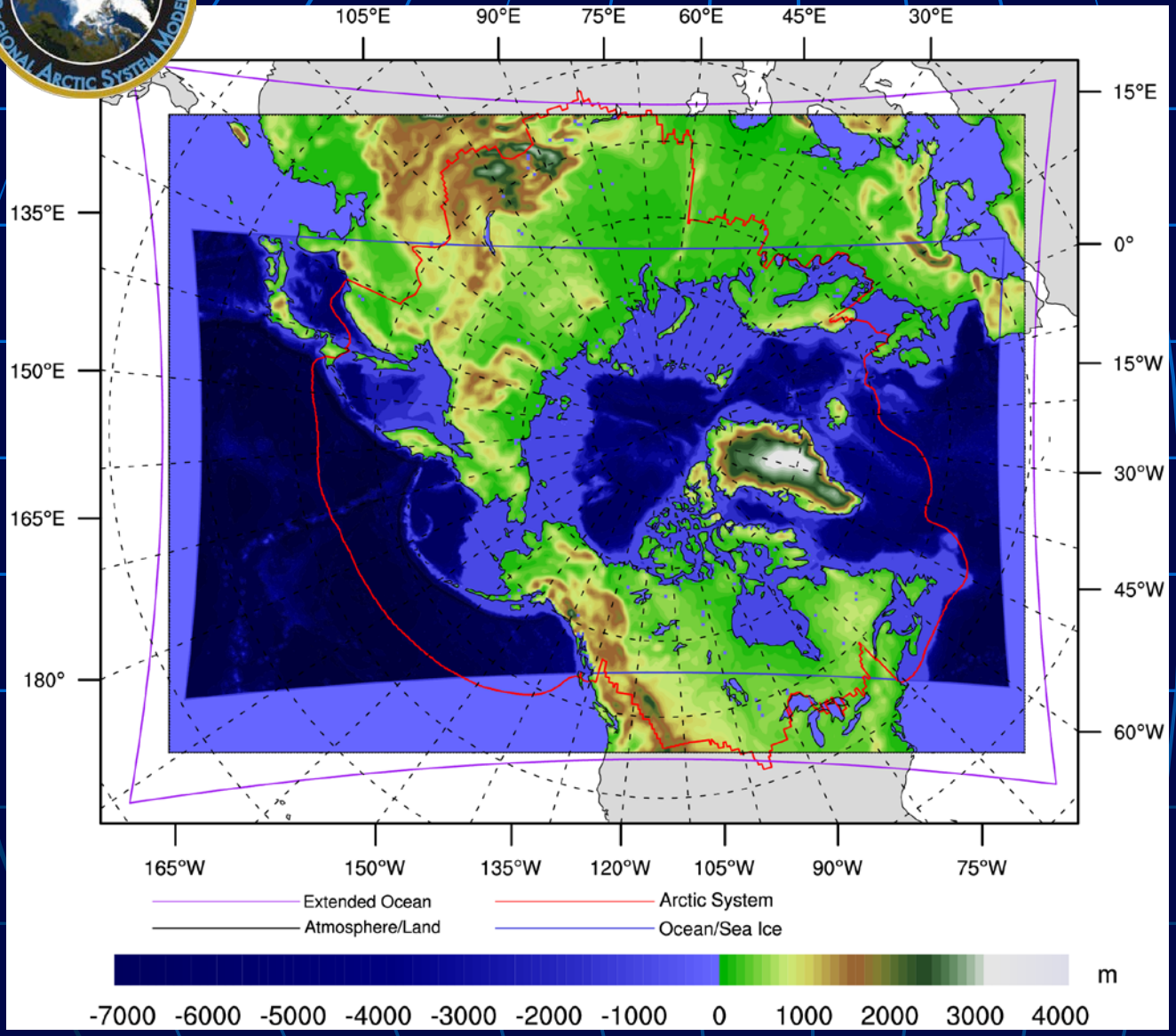
RASM Domains for Coupling and Topography



Pan-Arctic region to include:
- all sea ice covered ocean in the northern hemisphere
- Arctic river drainage
- critical inter-ocean exchange and transport
- large-scale atmospheric weather patterns (AO, NAO, PDO)

The Arctic System domain (red line) after Roberts et al. (2010).

RASM pan-Arctic model domain. WRF and VIC model domains include the entire colored region. POP and CICE domains are bound by the inner blue rectangle. Shading indicates model topobathymetry.

RASM components and resolution

- **Atmosphere - Polar WRF** (gridcell ≤50km) -
- **Land Hydrology – VIC** (same as WRF) |
- **Ocean - LANL/POP** (gridcell ≤10km) |-> RACM
- **Sea Ice - LANL/CICE** (same as POP) |
- **Flux Coupler – NCAR/CESM CPL7** -

+

- **Dynamic Vegetation – VIC(4.1.1) + CLM(4.0)** (same as WRF)
- **Dynamic Ice Sheet – Glimmer-CISM plus** (gridcell ≤5km)
  - Basal sliding due to meltwater penetration to the bed
  - Ocean thermal forcing of ice sheets and tidewater glaciers
- **Glacier and Ice Caps (GIC)**
  - A new parameterization for evolving area and volume of GIC in VIC

RACM/RASM Related Presentations

Talk – Arctic System Session

Higgins et al.: Atmospheric Results from the Regional Arctic Climate Model (RACM)

POSTERS:

Fisel et al.: Multi-regime States of Arctic Atmospheric Circulation

Gutowski et al.: Effects of Spectral Nudging on Simulations of Arctic Temperature and Precipitation Extremes

Lipscomb et al.: Modeling Land Ice in the CESM

Maslowski et al.: Modeling Sea Ice / Ocean Processes and Interaction Using the Regional Arctic Climate Model (RACM)

Tulaczyk et al.: Work on Improvements in Treatment of Oceanic Forcing of Land Ice Flow in the Regional Arctic System Model (RASM)

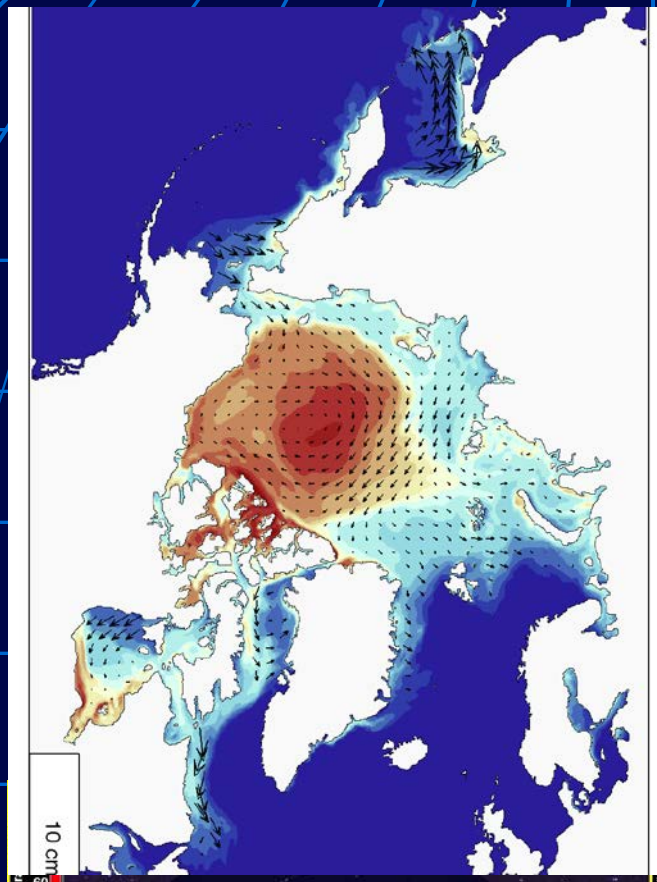
Zeng et al.: Recent Progress in Land Surface Modeling

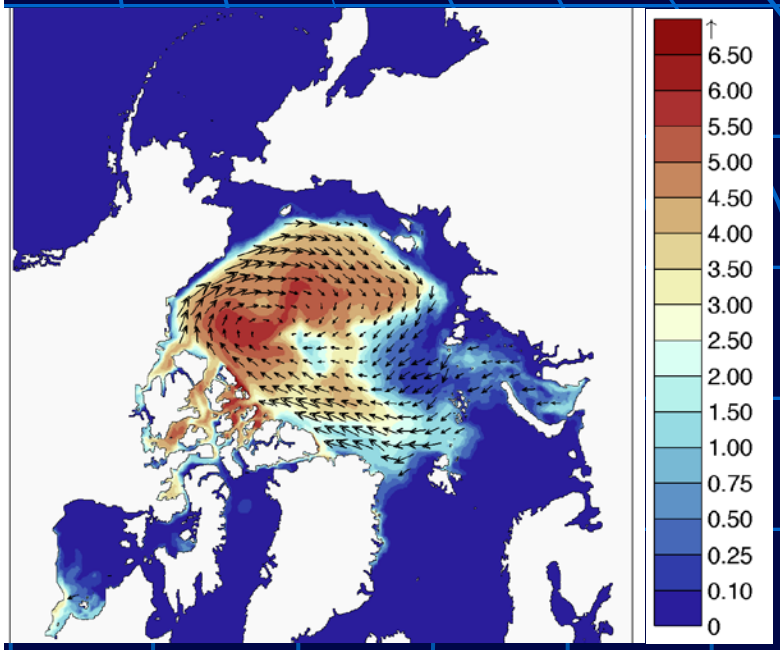
Why Regional Arctic Climate System Model?

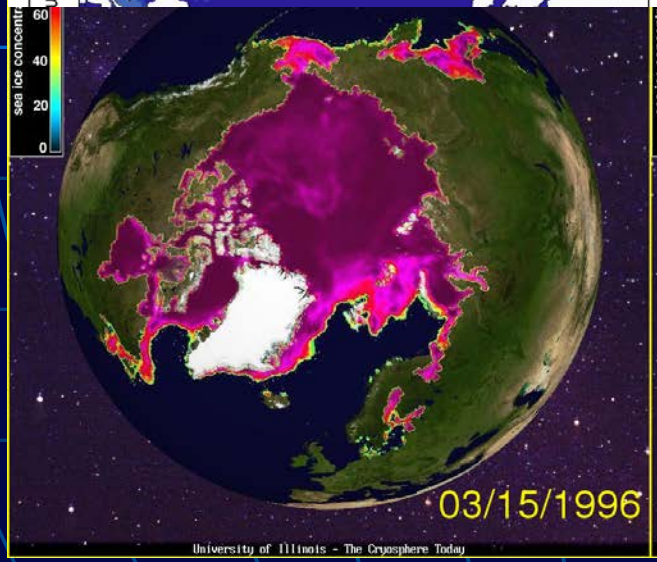
- Observed rapid changes in Arctic climate system
  - Sea ice decline / Greenland ice sheet
  - Permafrost / methane
  - Air & sea temperature / atmospheric circulation
- Arctic climate change has global consequences
  - can alter the global energy / carbon balance and thermohaline circulation
- Large errors in global climate system model simulations of the Arctic climate system
- Missing air-sea-ice feedbacks in regional stand-alone models

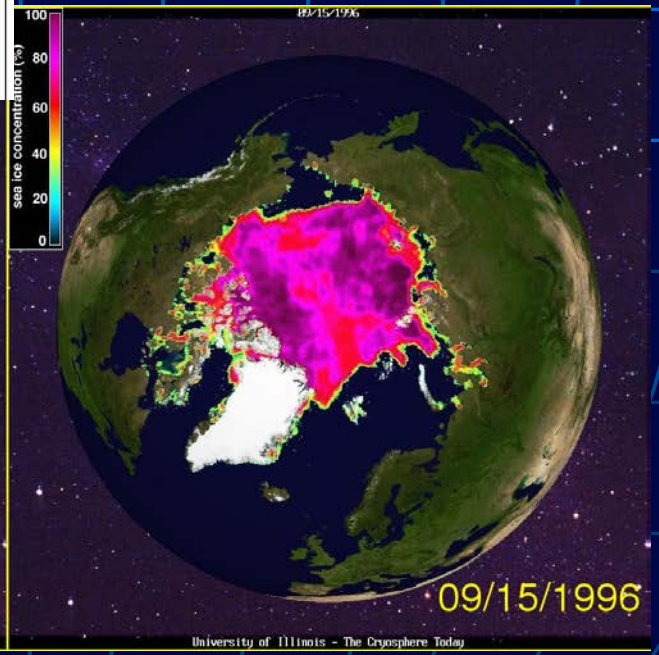
(A Science Plan for Arctic System Modeling – Roberts et al., 2010)

RACM / SSM/I sea ice cover

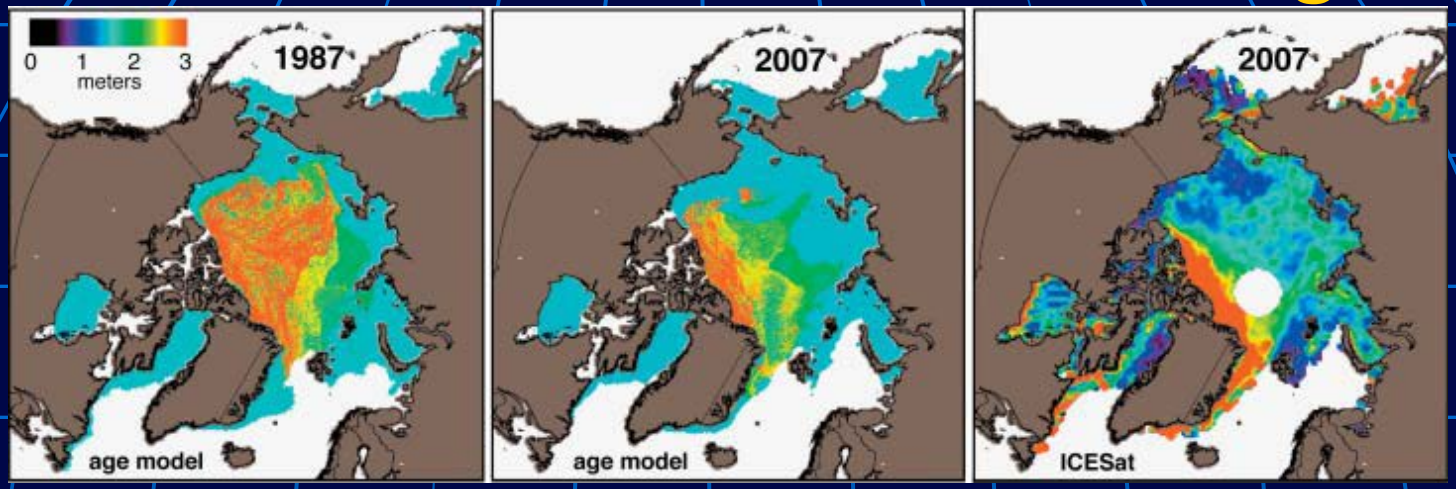




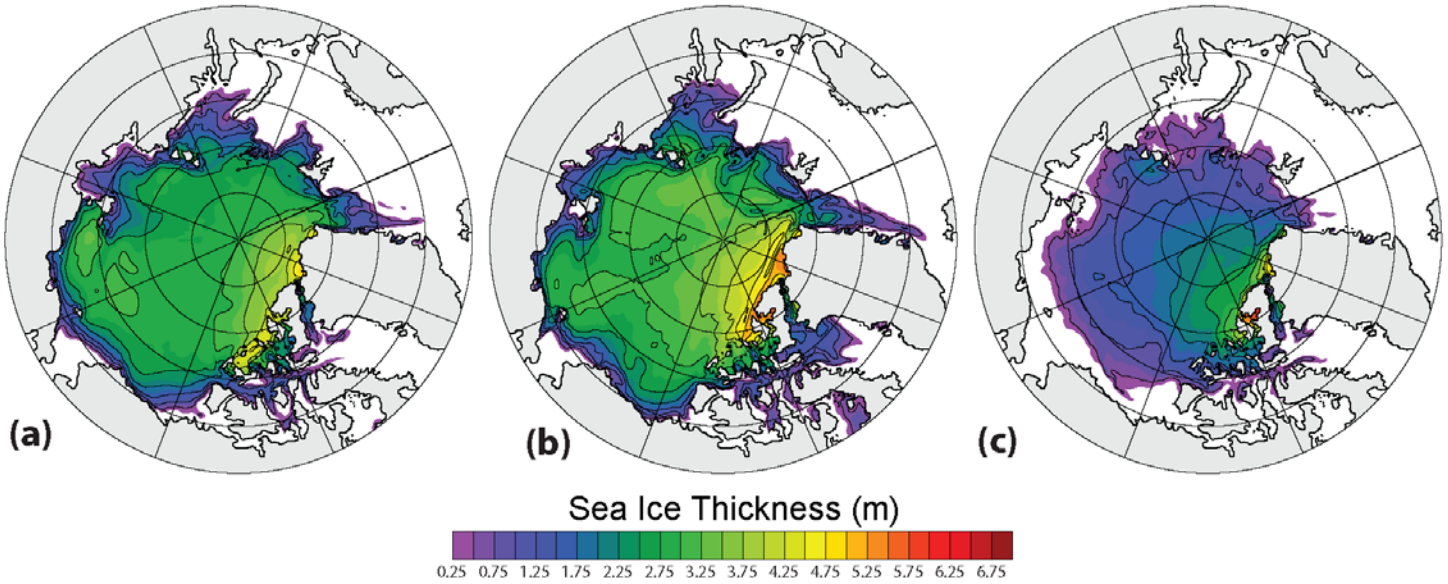




Decadal sea ice thickness change



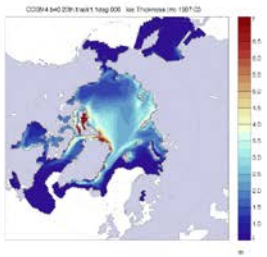
Ice Thickness estimates based on age (a) 1987, (b) 2007, and ICESat freeboard (c) 2007



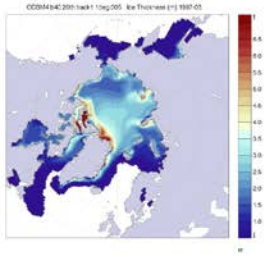
Modeled Arctic sea ice thickness distribution [m] in September a) 1982, b) 1992, c) 2002 - dramatic thinning in the 2000s (Maslowski et al., 2007)

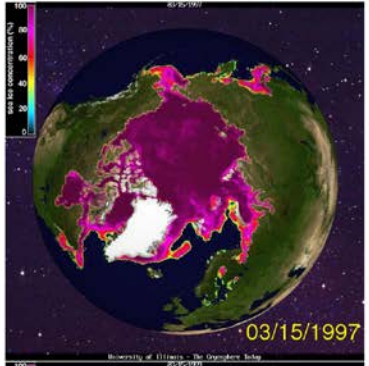
Sea Ice Thickness: CCSM4 & NPS models

CCSM4 b40.20th.track1.1deg.006
Ice Thickness Mar 1997

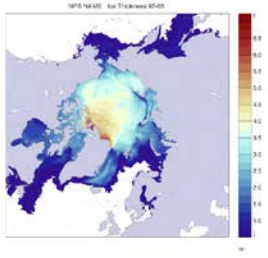


CCSM4 b40.20th.track1.1deg.005
Ice Thickness Mar 1997

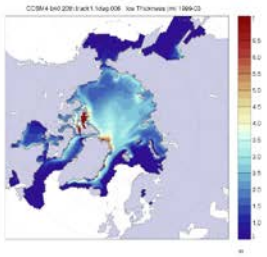




PIPS Ice Thickness Mar 1997



CCSM4 b40.20th.track1.1deg.006
Ice Thickness Mar 1999



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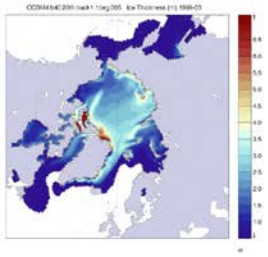
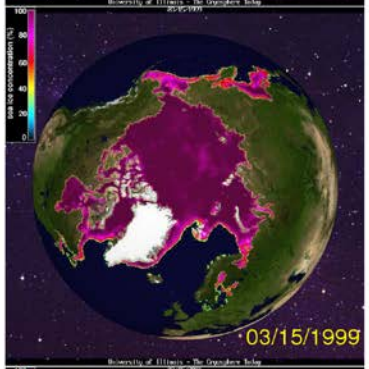
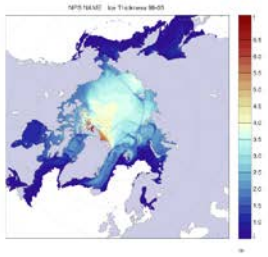




PIPS Ice Thickness Mar 1999



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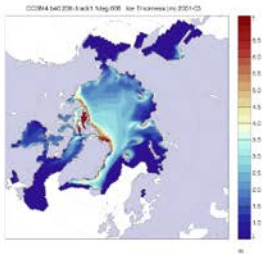
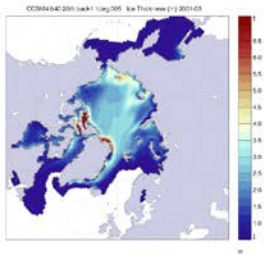
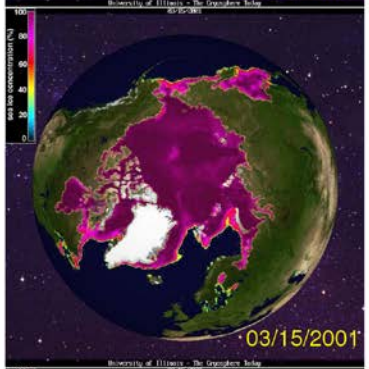
Ice Thickness Mar 2001

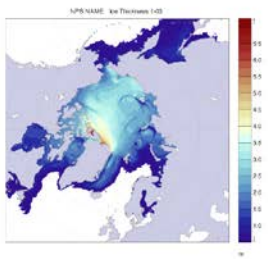


CCSM4 b40.20th.track1.1deg.005
Ice Thickness Mar 2001

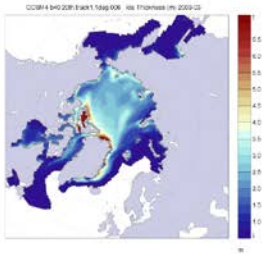




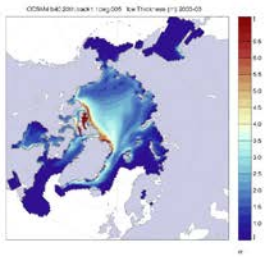
PIPS Ice Thickness Mar 2001

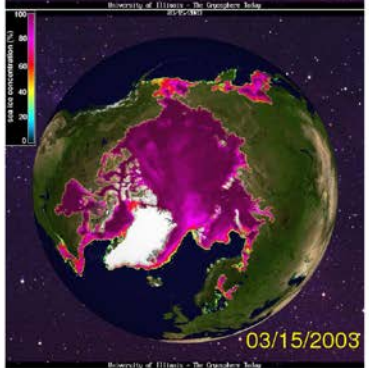


CCSM4 b40.20th.track1.1deg.006
Ice Thickness Mar 2003

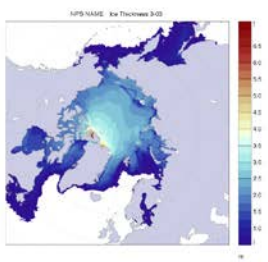


CCSM4 b40.20th.track1.1deg.005
Ice Thickness Mar 2003

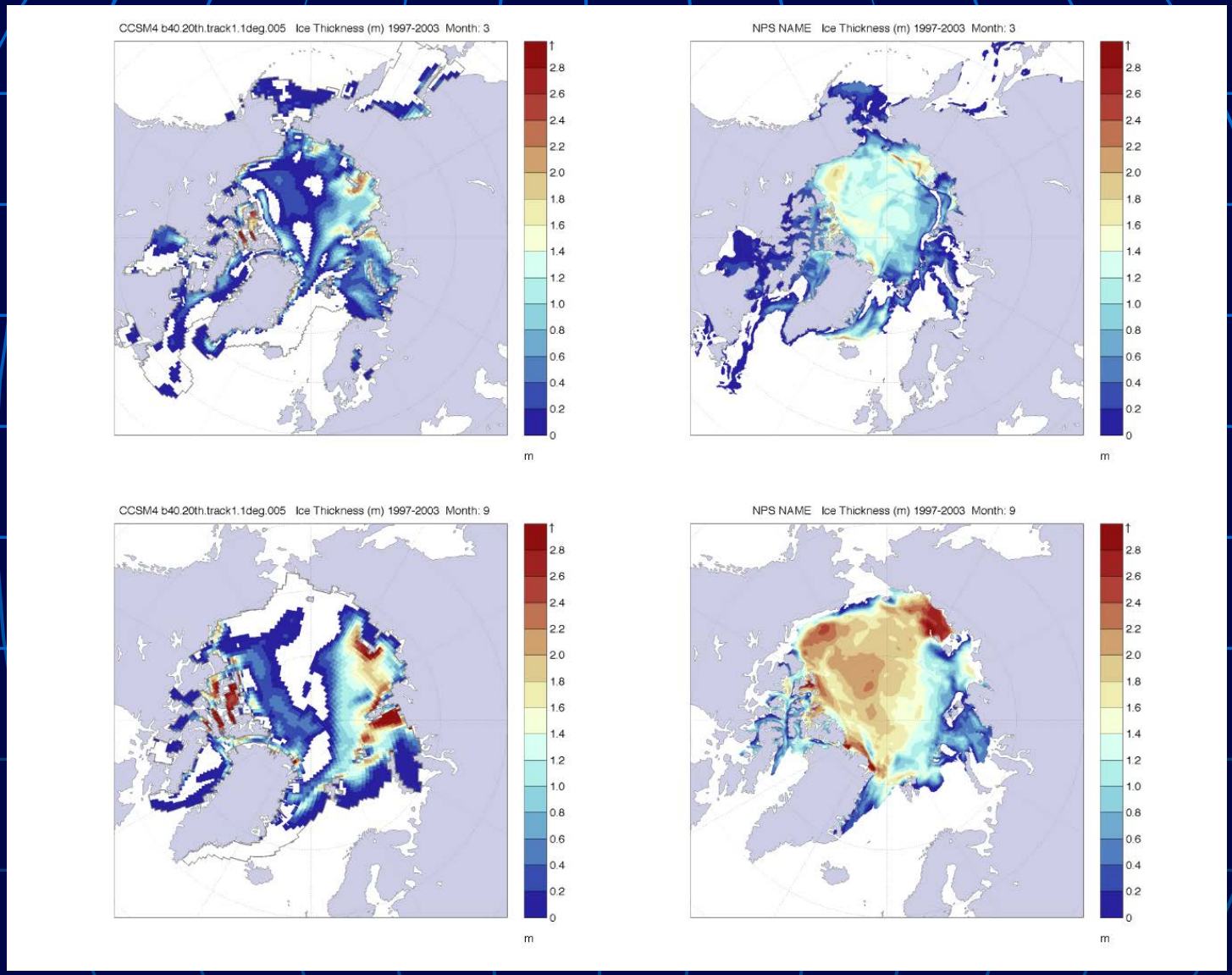




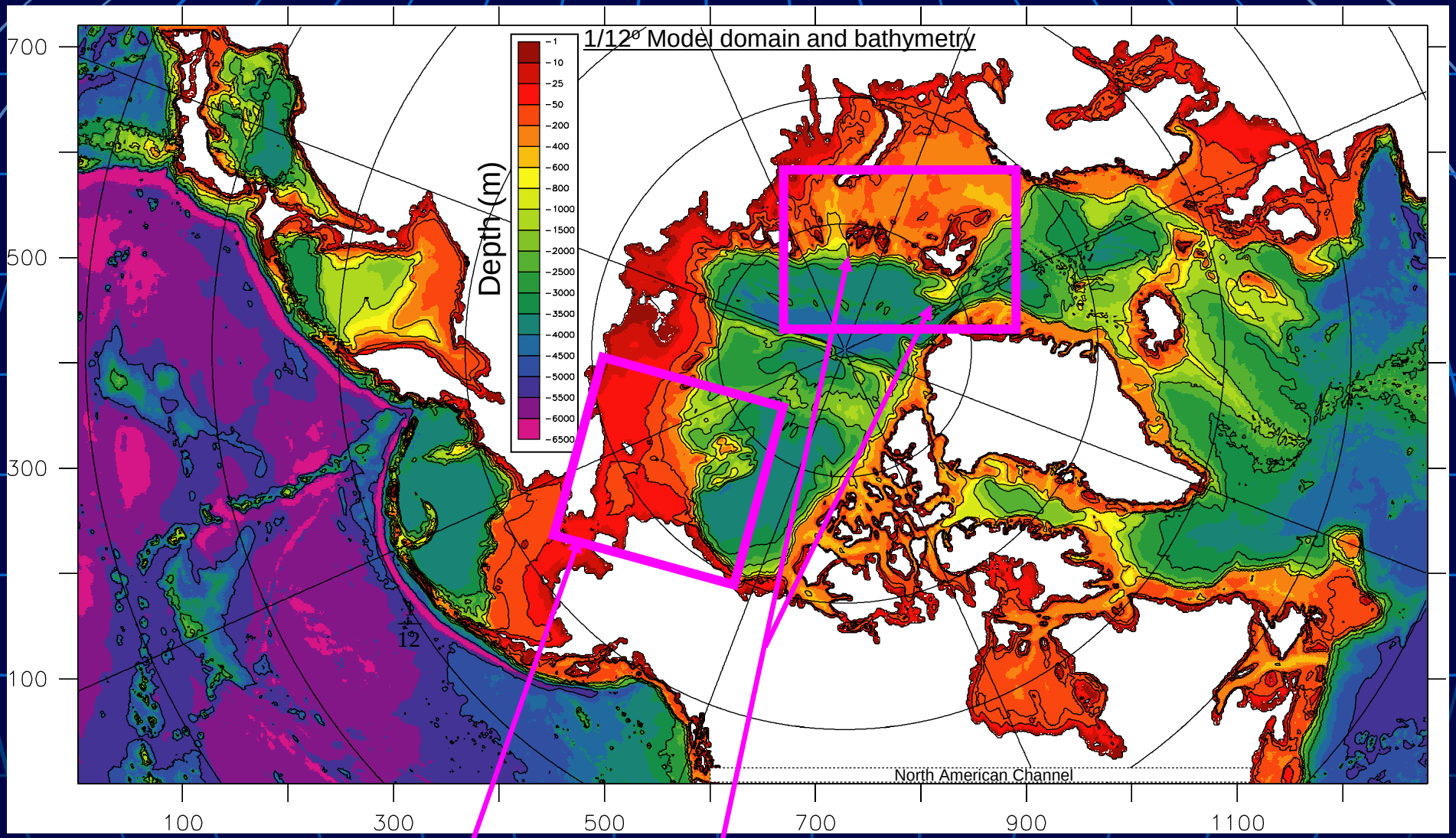
PIPS Ice Thickness Mar 2003



Sea Ice Thickness Change (1997-2003): CCSM4 & NPS



Excessive ice melt in the Eastern Arctic; not enough melt in the Western Arctic in CCSM4

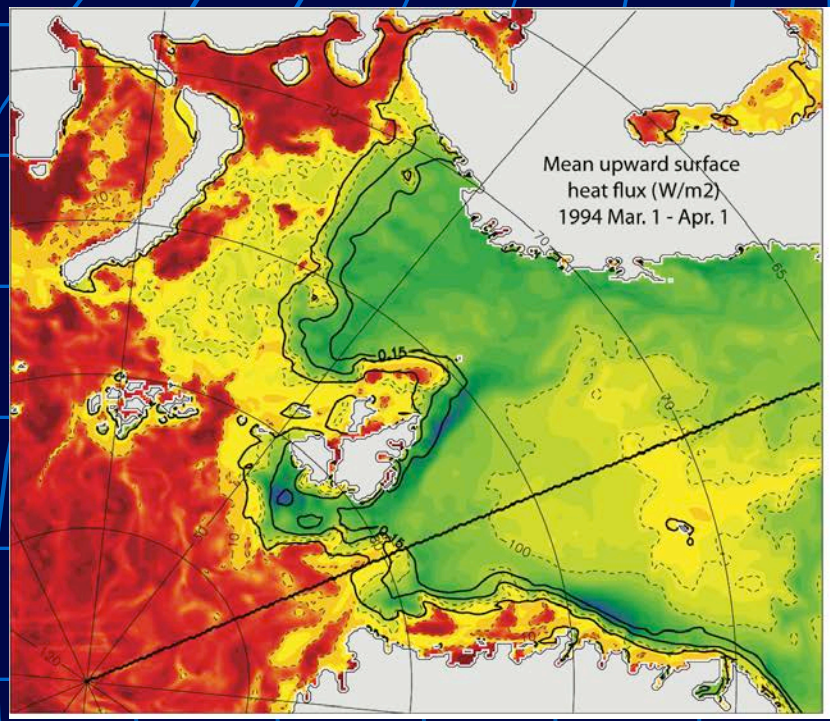


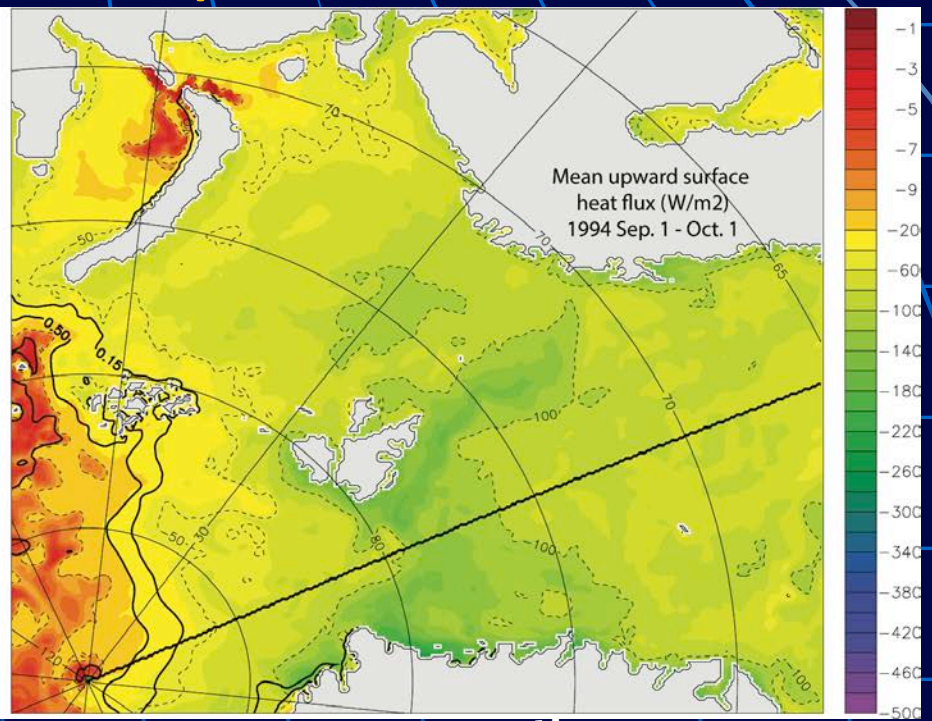
Gateways/Margins of Pacific Water and Atlantic Water Inflow into the Arctic Ocean

Main uncertainties of importance to global climate

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

RACM Oceanic Heat Transport / Surface Flux

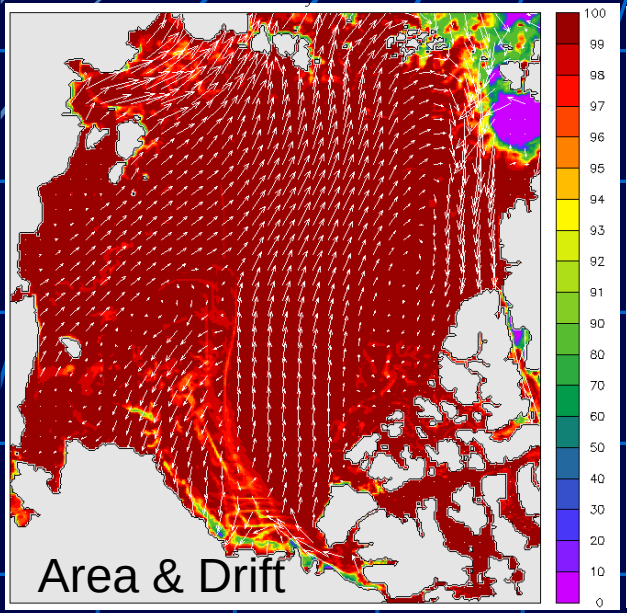


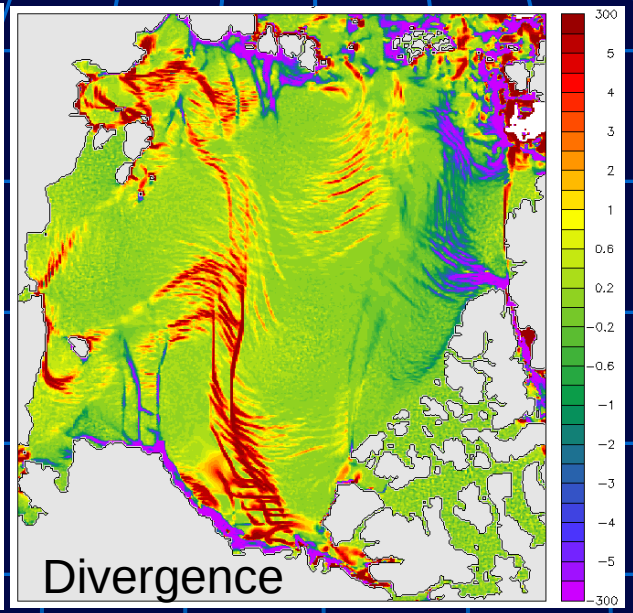


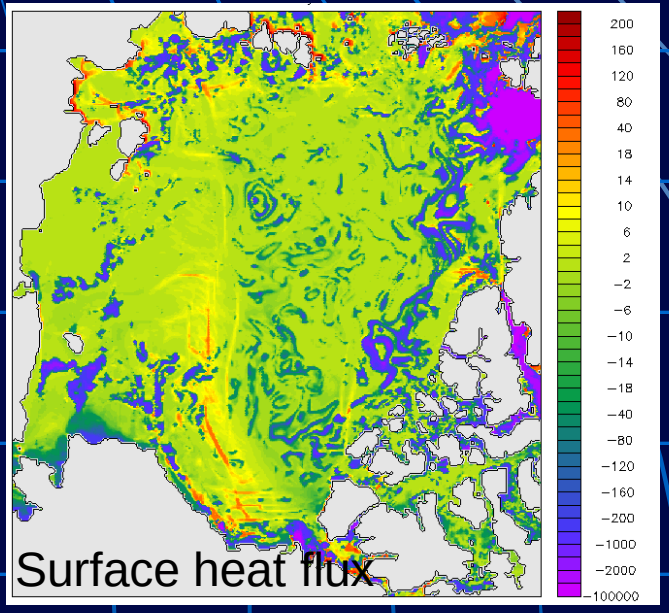
	Observations	NAME: POP/CICE	CCSM
Fram Strait (Inflow)	6.6 Sv / 50 TW	6.9 Sv / 45 TW	2.0 Sv / 17 TW
FJL – NZ (Net)	NA / Near zero	2.6 Sv / 2.2 TW	4.35 Sv / 31 TW

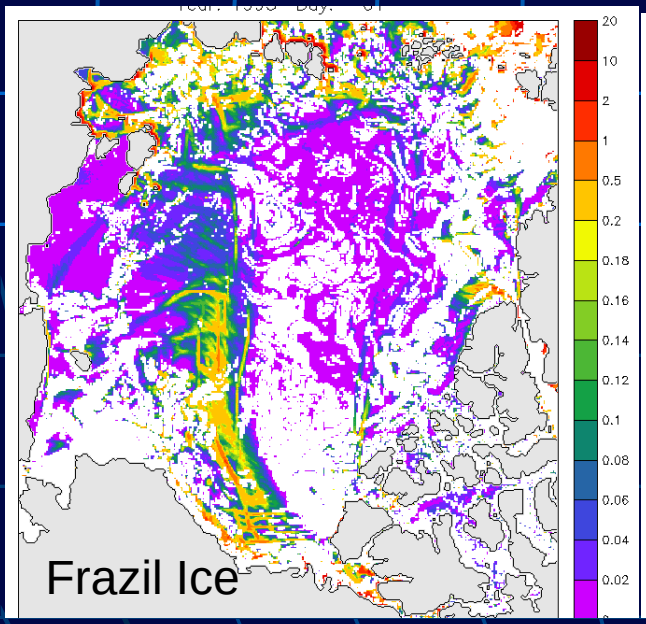
CCSM3 (IPCC-AR4 b&f) transports; NAME transports (Maslowski et al., JGR, 2004)
Obs: Fram Strait - Courtesy of A. Beszczynska-Möller, AWI; FJL-NZ - Gammelsrod et al.,2008

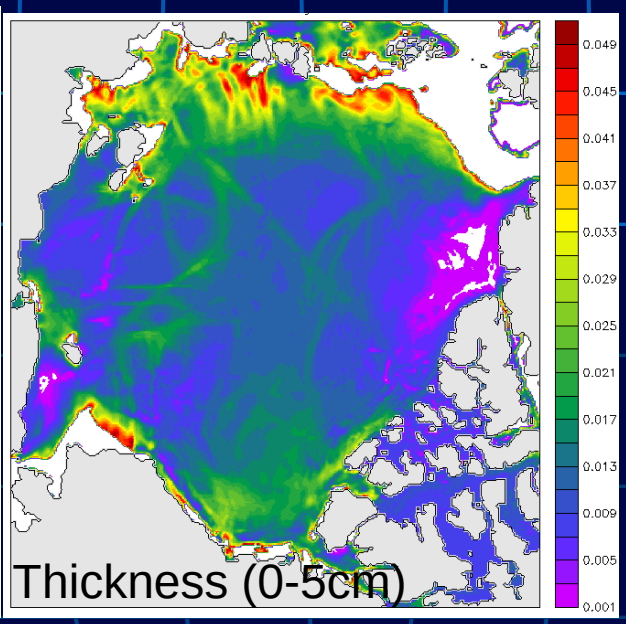
RACM sea ice drift, deformations, effect on thickness distribution

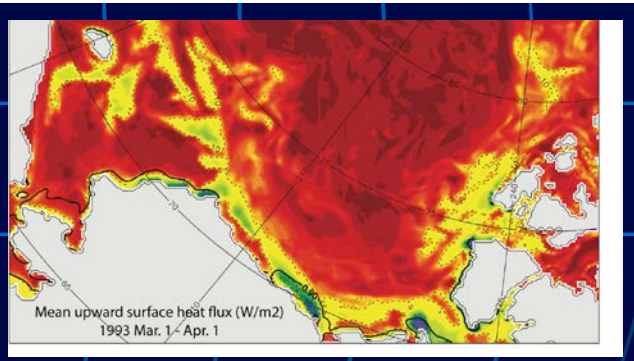


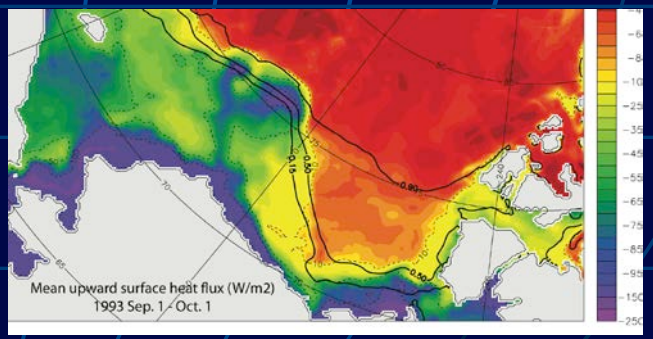








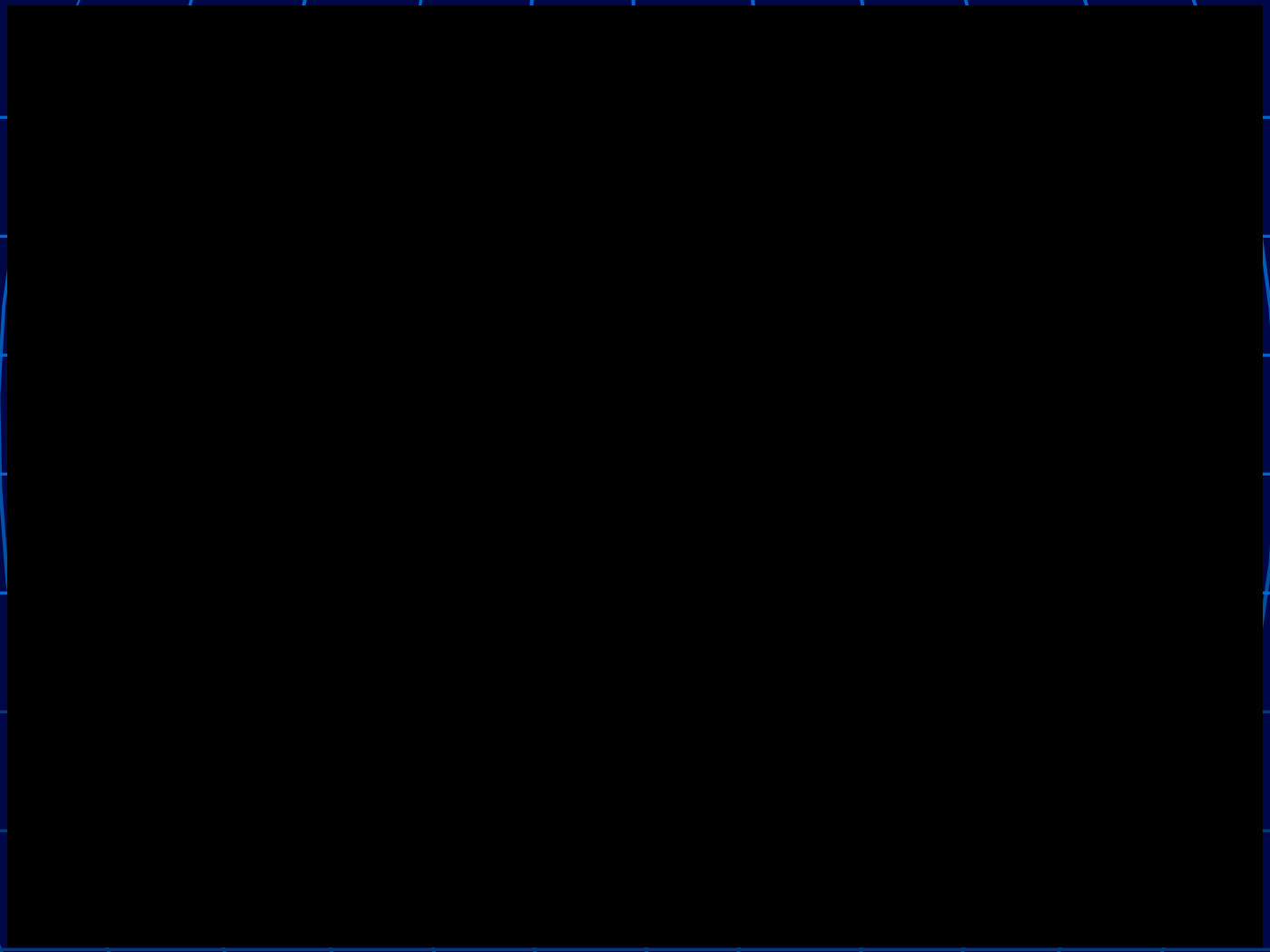




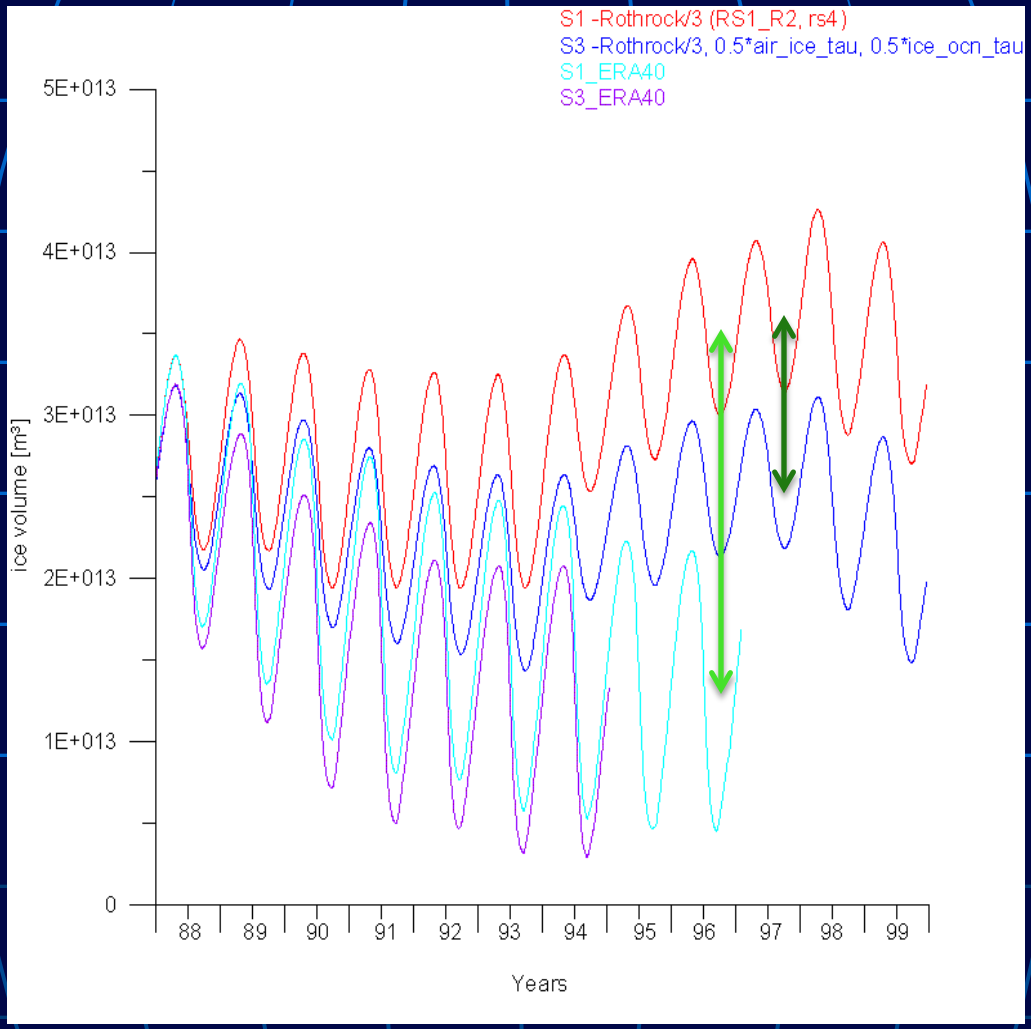
March 2, 1993, 0000Z

Hourly Sea Ice Divergence – March 1995

Animation



Sea ice thickness / volume sensitivity



Different atmospheric forcing / sea ice parameterizations yield large changes in sea ice volume within a decade

Summary - RASM Goals

- RACM has been developed, integrated for multi-decades, and results are being evaluated, papers in prep
- RASM aims to advance understanding of past and present states of arctic climate and to improve seasonal to decadal/centennial predictions.
- Focus on variability and long-term change of energy and freshwater flows through the Arctic climate system.
- Address modes of natural climate variability and extreme / rapid climate change
- A testbed of CESM for regional applications
- Arctic-focused model to contribute to future IPCC ARs
- Facilitate studies of climate impacts (e.g., droughts and fires) and of ecosystem adaptations to these impacts.

Thank You!