Regional Arctic Climate Model (RACM): Overview and Selected Results

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A 4-year (2007-2011) DOE / ESM project

Why Regional Arctic Climate Model?

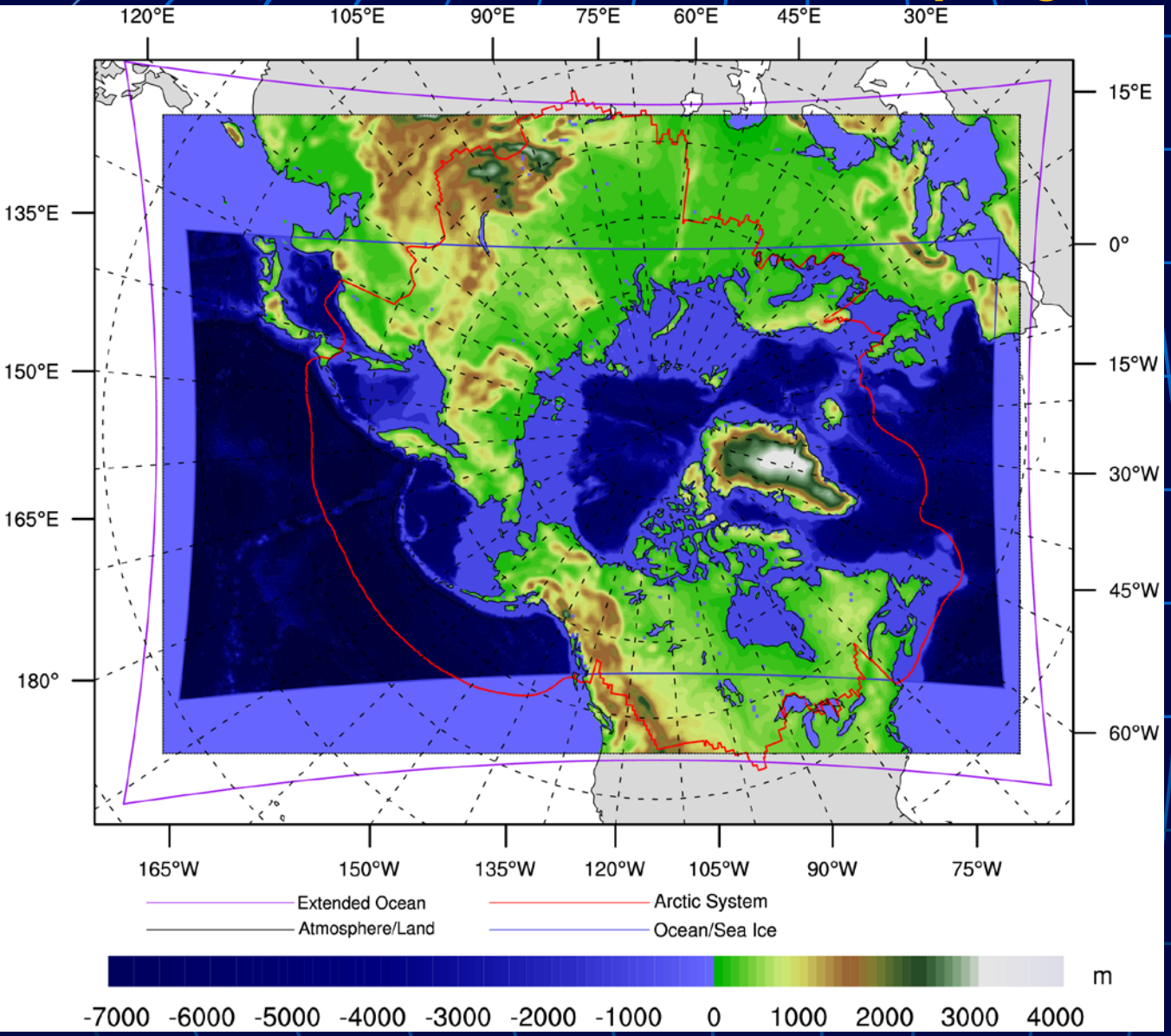
- Large errors in global climate system model simulations of the Arctic climate system
- Missing air-sea-ice feedbacks in regional stand-alone models
- Observed rapid changes in Arctic climate system
  - Sea ice decline
  - Greenland ice sheet
  - Temperature
- Arctic change has global consequences
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

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

Rationale for developing a Regional Arctic Climate system Model (RACM)

1. **Facilitate focused regional studies of the Arctic climate**
2. **Resolve critical details of land elevation, coastline and ocean bottom bathymetry**
3. **Improve representation of local physical processes & feedbacks (e.g. forcing & deformation of sea ice)**
4. **Minimize uncertainties and improve predictions of climate change in the pan-Arctic region**
5. Develop a state-of-the-art Regional Arctic Climate Model (RACM) including high-resolution atmosphere, ocean, sea ice, and land hydrology components

RACM 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)

RACM 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. The Arctic System domain (red line) is defined in Roberts et al. (2010).

RACM components and resolution

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

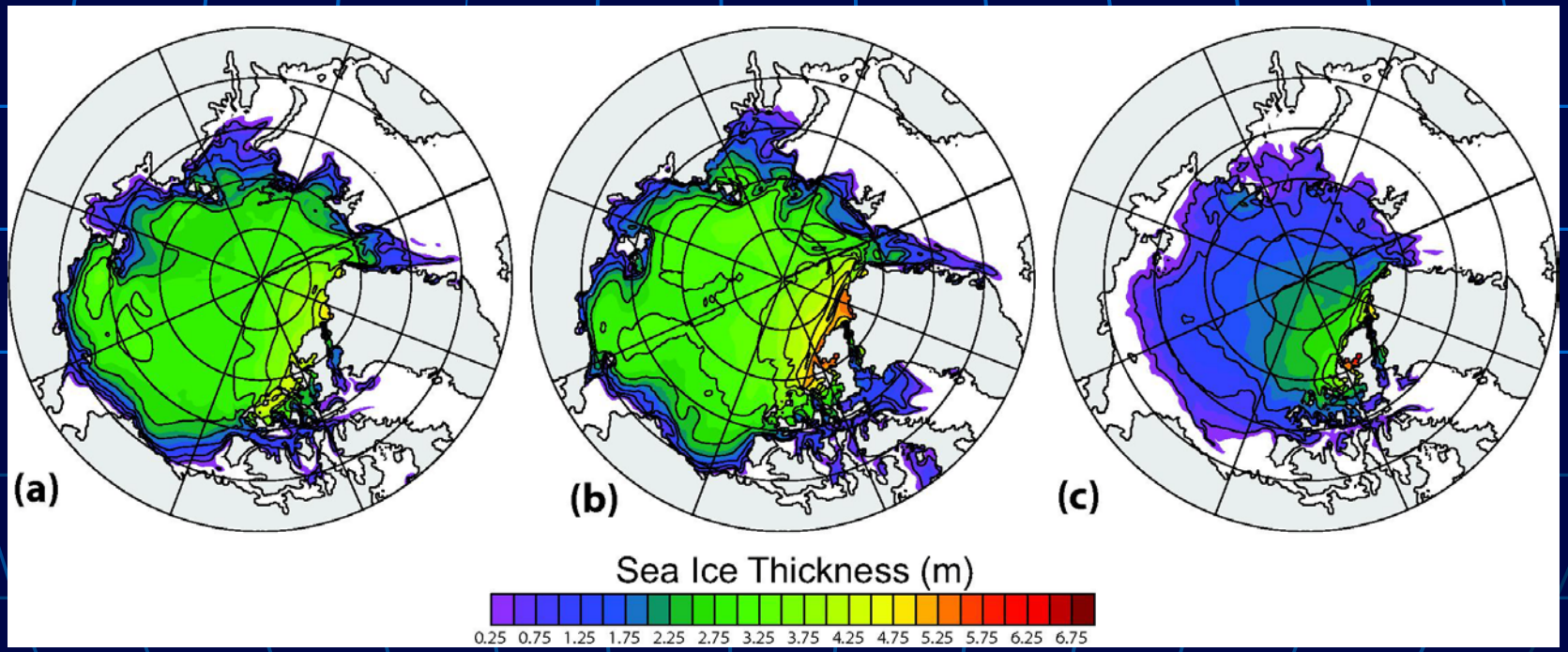
NCAR CCSM4 framework used for developing RACM

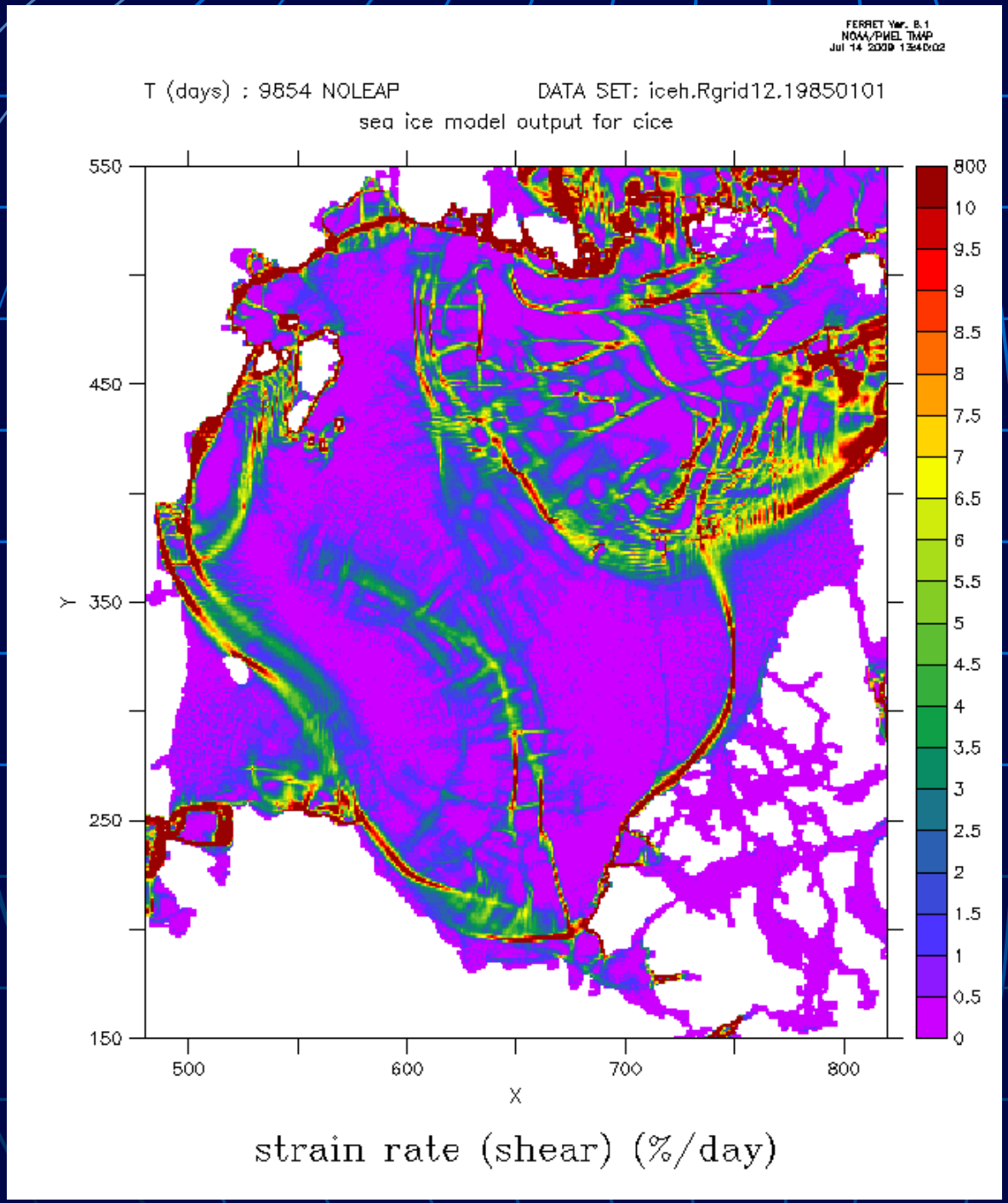
Components with higher resolution are being evaluated

Modeled Sea Ice Thickness Loss

Sea ice thickness (m) in (a) 1982, (b) 1992, (c) 2002

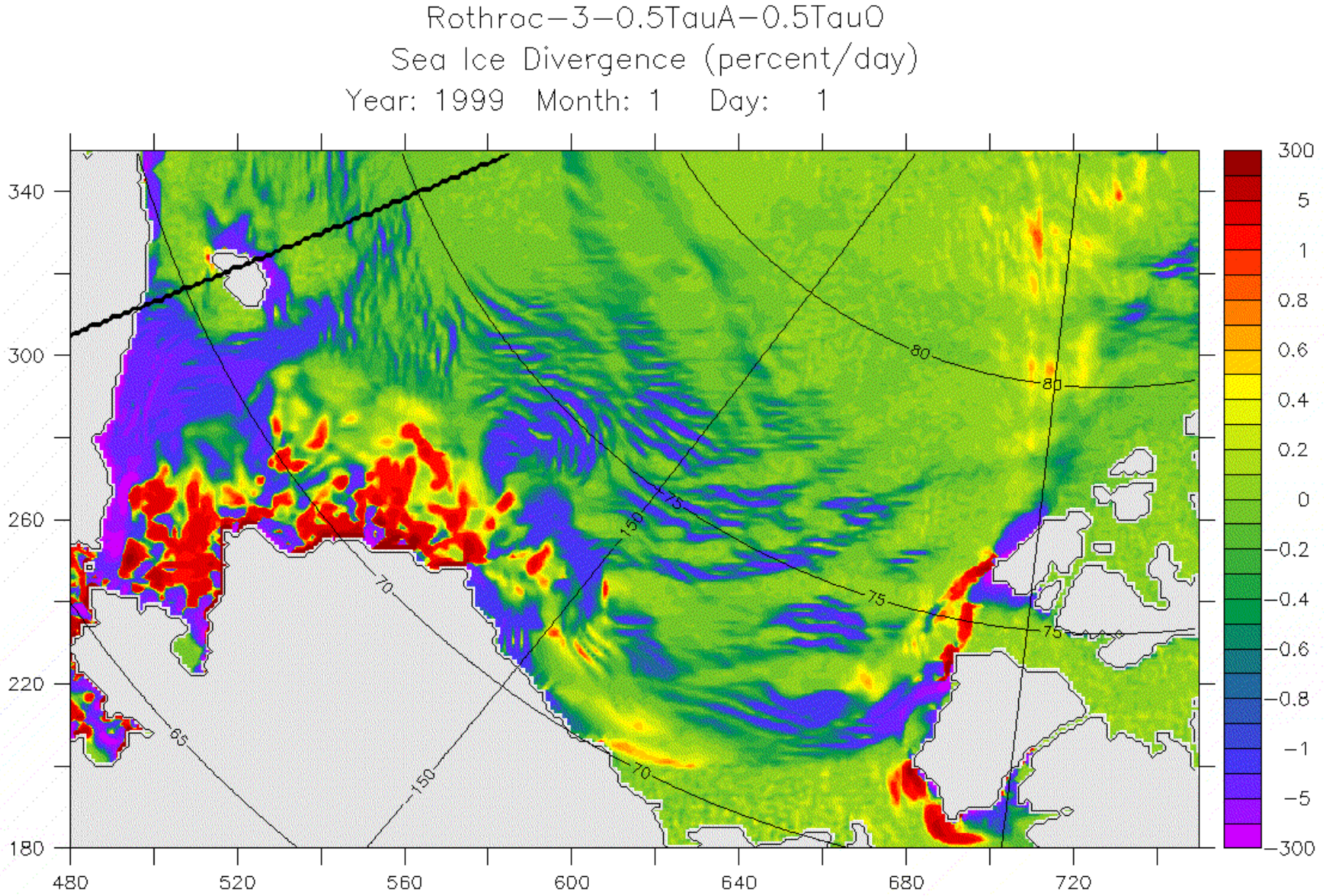
(Maslowski et al., 2007)





Sea Ice Shear in CICE-9km

Ice thickness distribution and small-scale deformations are critical to air-sea interactions and challenging to represent in GCMs


Rothroc−3−0.5TauA−0.5TauO
Sea Ice Divergence (percent/day)
Year: 1999 Month: 1 Day: 1
340
300
260
220
180
480
520
560
600
640
680
720
80
75
70
65
150
300
5
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−5
−300

Ocean: Heat Transport

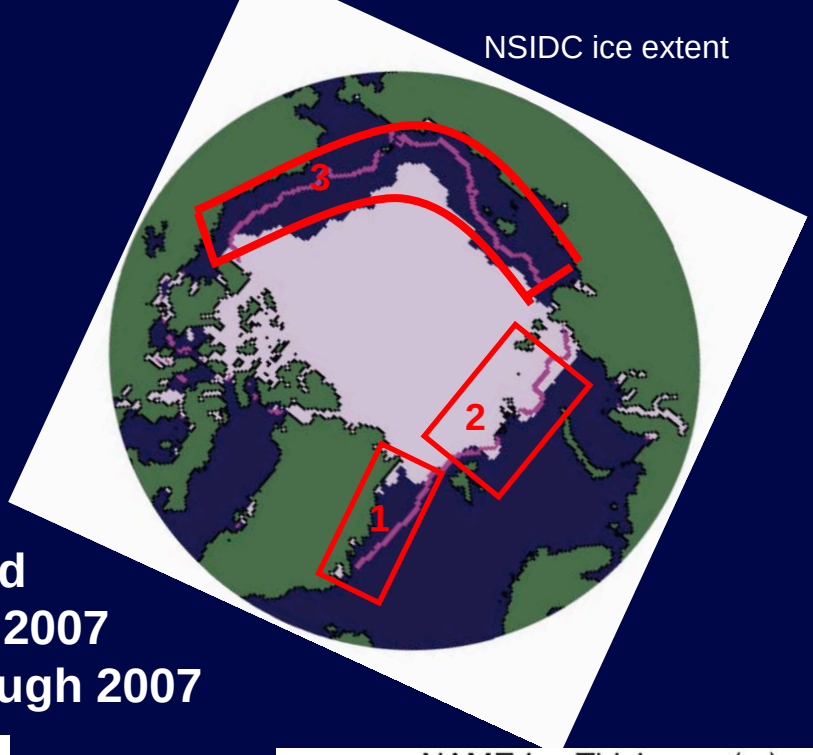
25 yr mean volume transport (Sv) / Heat Transport

	Observations	NAME: POP/CICE	CCSM 3
Fram Strait (Inflow)	7.0 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

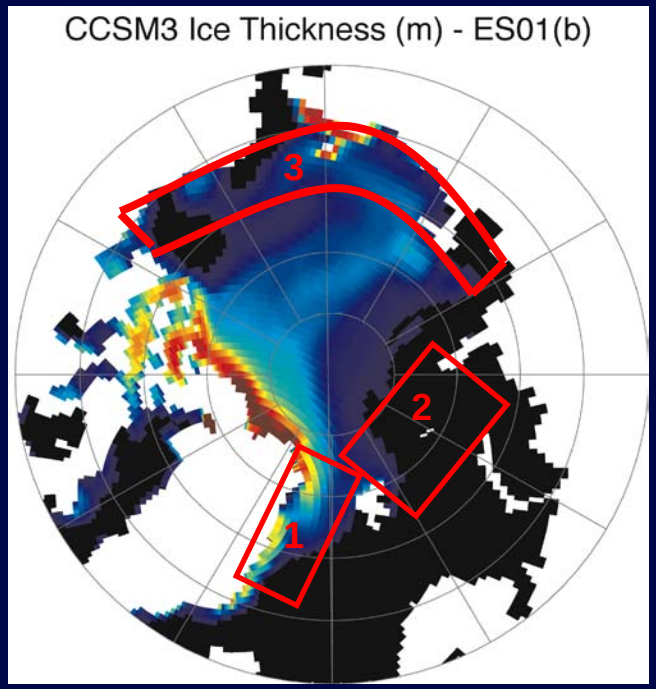
'NPS' transports (Maslowski et al., JGR, 2004)
CCSM3 (IPCC-AR4 b&f) transports
Fram Strait 'in' obs estimates - Courtesy of A. Beszczynska-Möller, AWI
FJL-NZ - (Gammelsrod et al., JMS 2008)

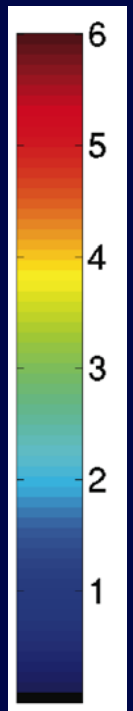
GCM Comparison:
September 2002

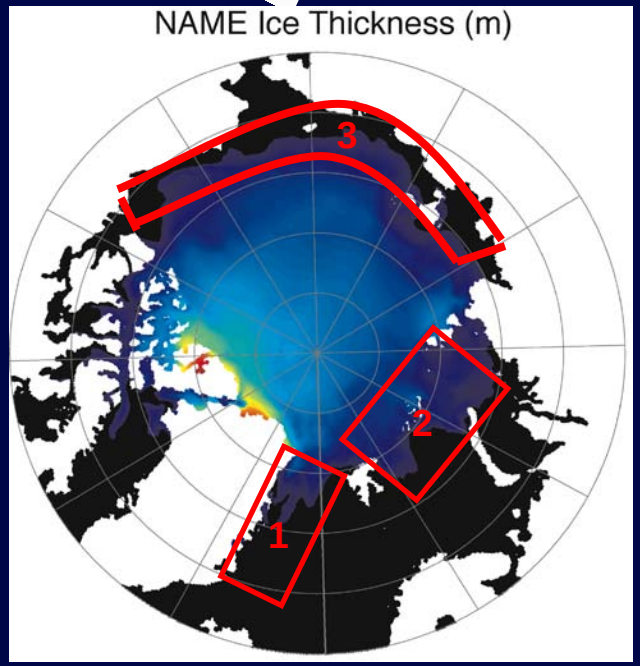
Regions:
1 – Greenland Shelf
2 – Eastern Arctic
3 – Western Arctic



- **Too much ice in the western Arctic and over Siberian shelves through 2007**
- **Too little ice in the eastern Arctic through 2007**







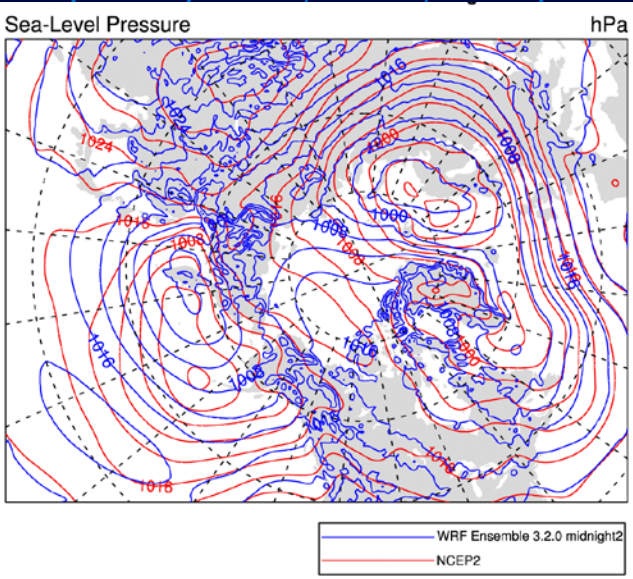
WRF in the Regional Arctic Climate Model

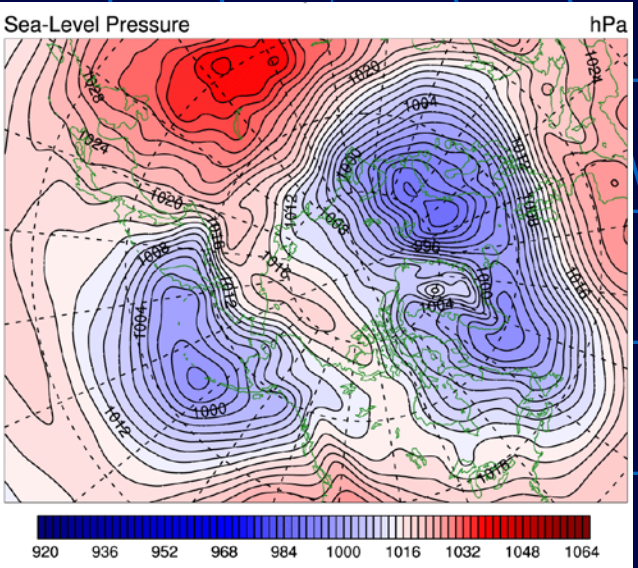
- WRF successfully coupled as atmospheric component in RACM
- Significant circulation bias in WRF stand-alone and coupled runs over the Arctic
- Biases can be minimized by extending WRF top to 10 mb or by spectral nudging
- Future versions of RACM will incorporate the 10 mb model top.

January, 2007 SLP

Stand-alone WRF 3.2.0, “best case” with default 50 mb top

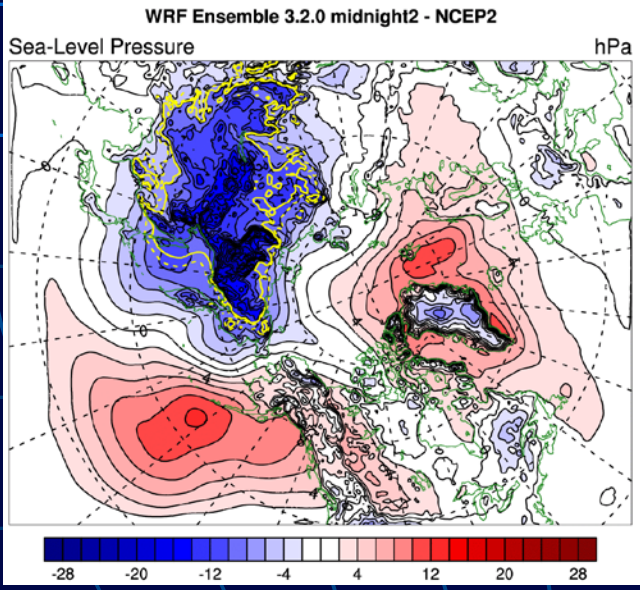
Overlay: WRF (blue), NCEP2 (red)

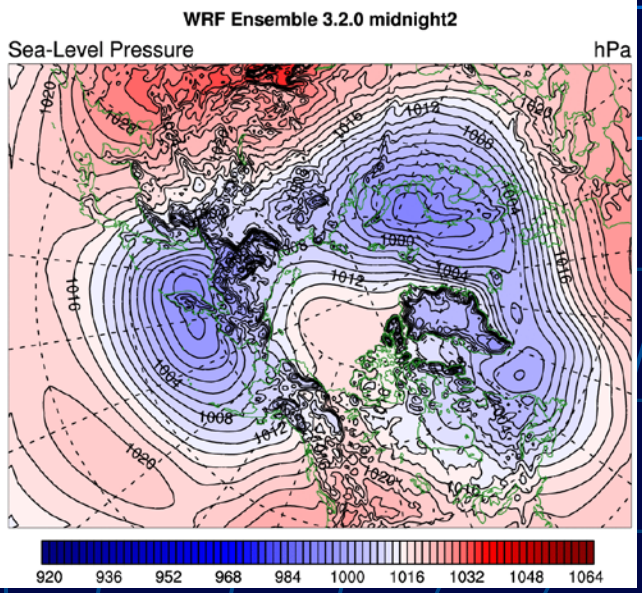




NCEP2

Difference



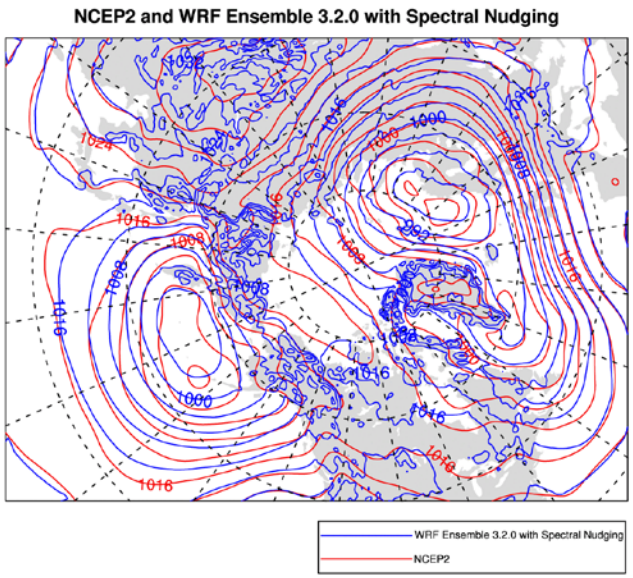


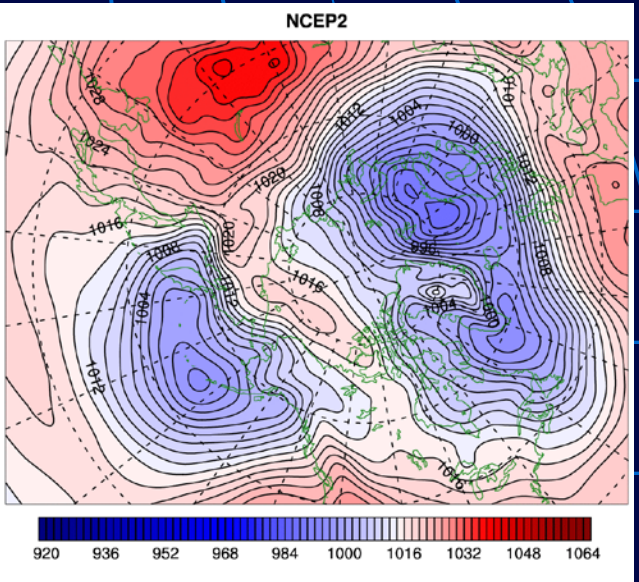
WRF

January, 2007 SLP

Stand-alone WRF 3.2.0, “best case”, default 50 mb top, spectral nudging

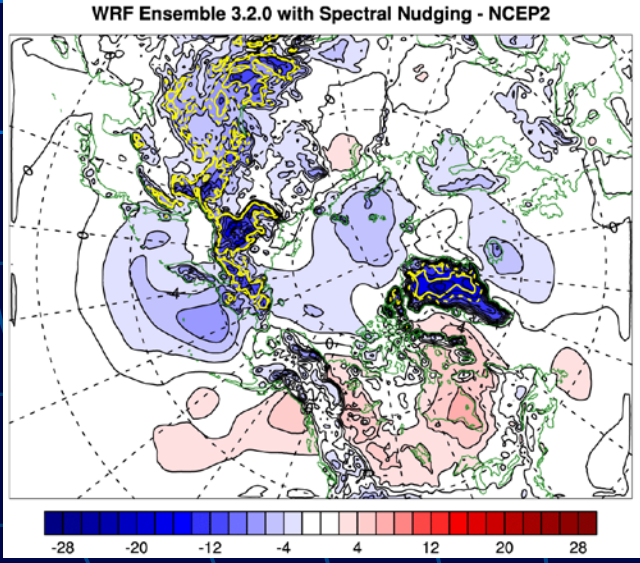
Overlay: WRF (blue), NCEP2 (red)

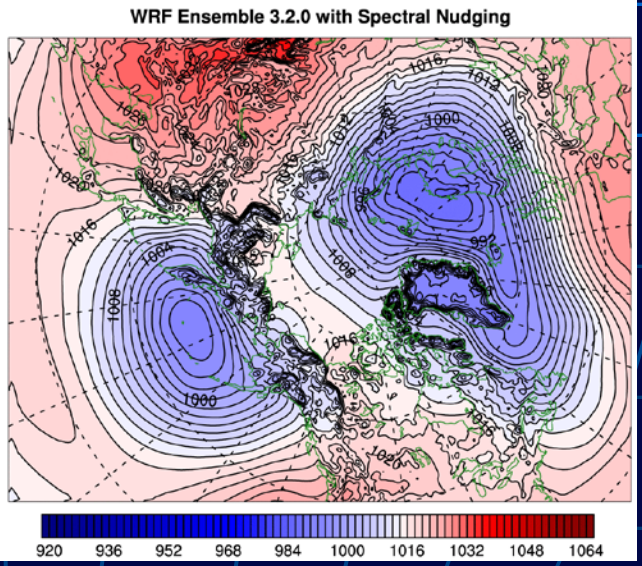




NCEP2

Difference



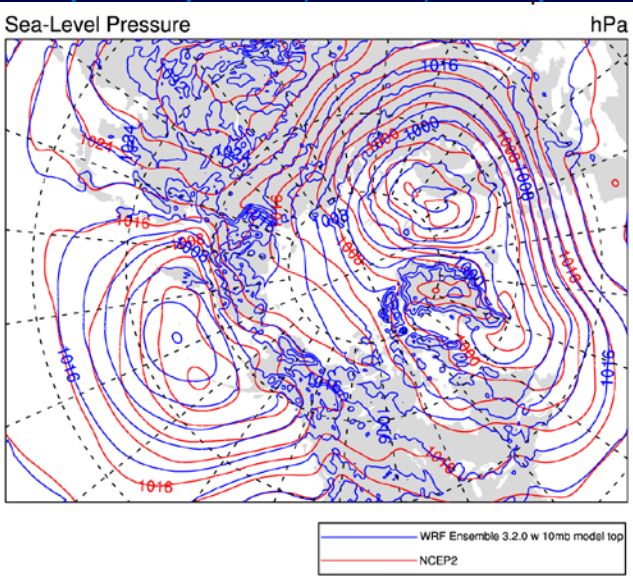


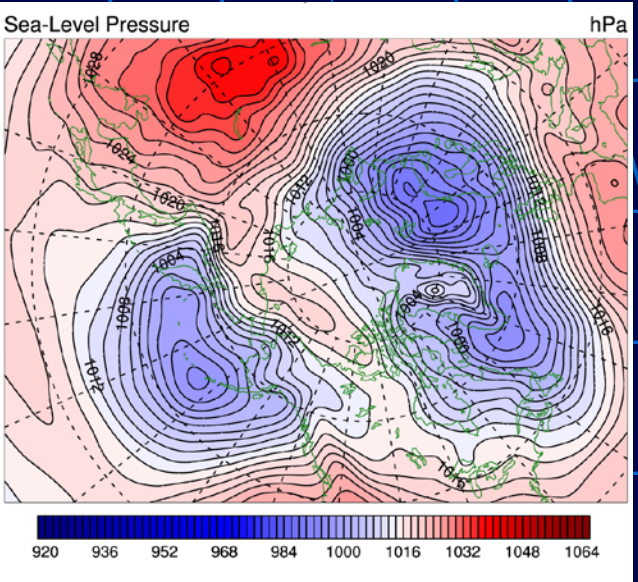
WRF

January, 2007 SLP

Stand-alone WRF 3.2.0, “best case”, 10 mb top, **no** spectral nudging

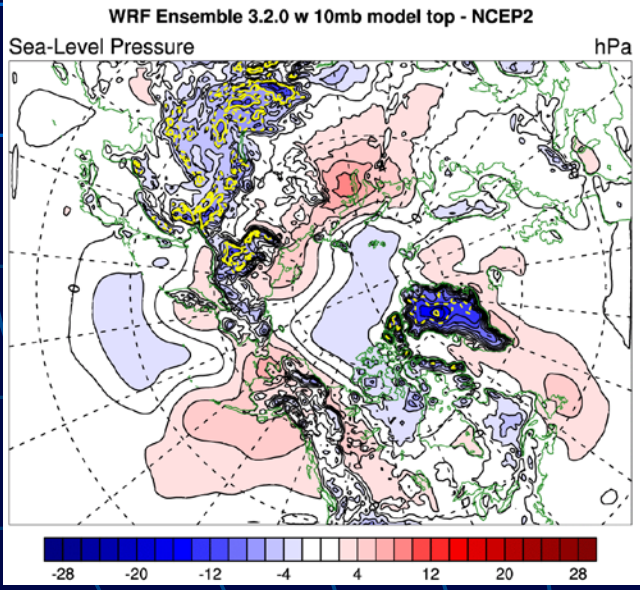
Overlay: WRF (blue), NCEP2 (red)

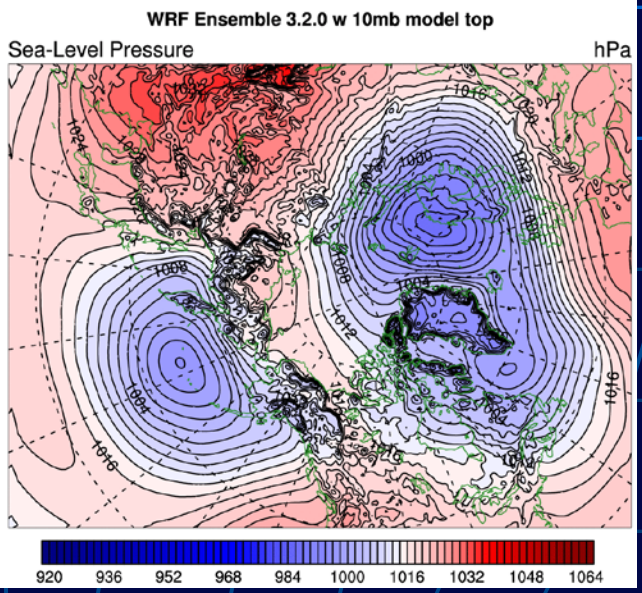




NCEP2

Difference





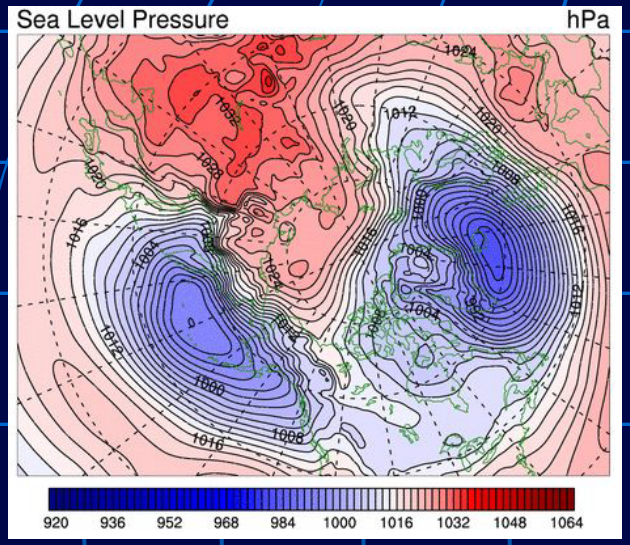
WRF

RACM Simulations

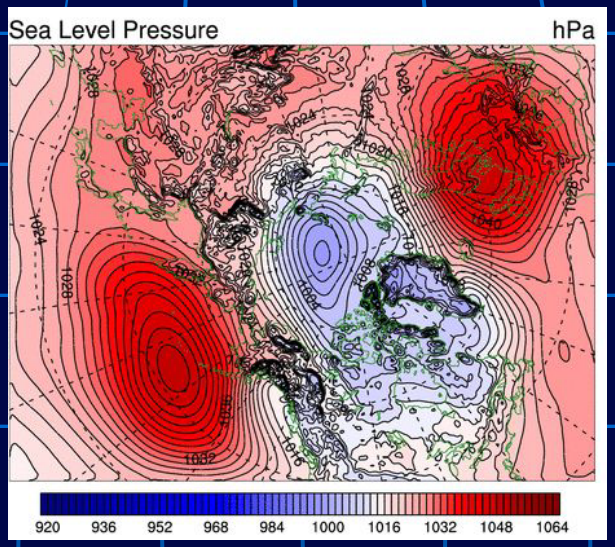
- Several years of fully coupled RACM simulation (September 1989 – December 1992)
- ERA-Interim LBCs and ICs for atmosphere
- Land / ocean / ice ICs from stand-alone simulations

SLP January 1990

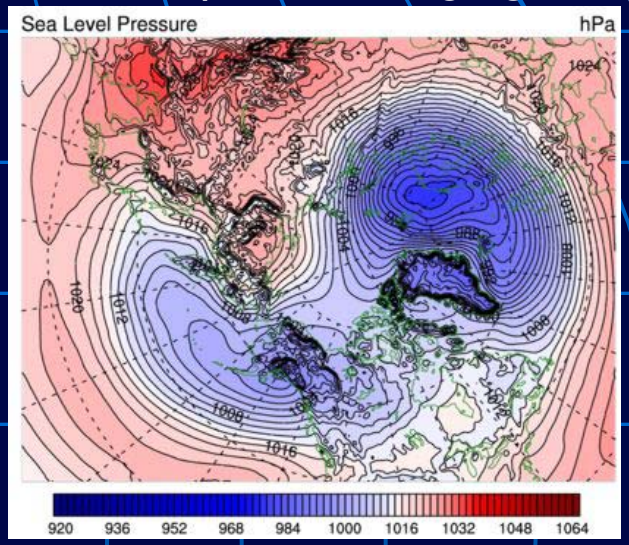
ERA-Interim



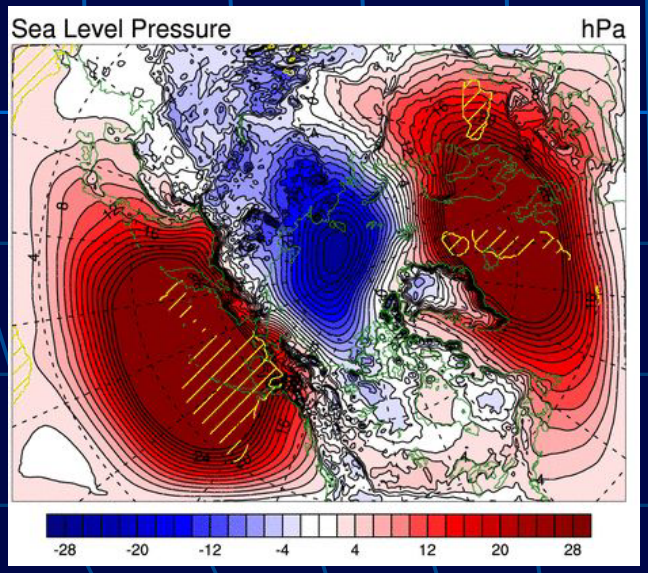
WRF 3.1; 50 mb top, no spectral nudging

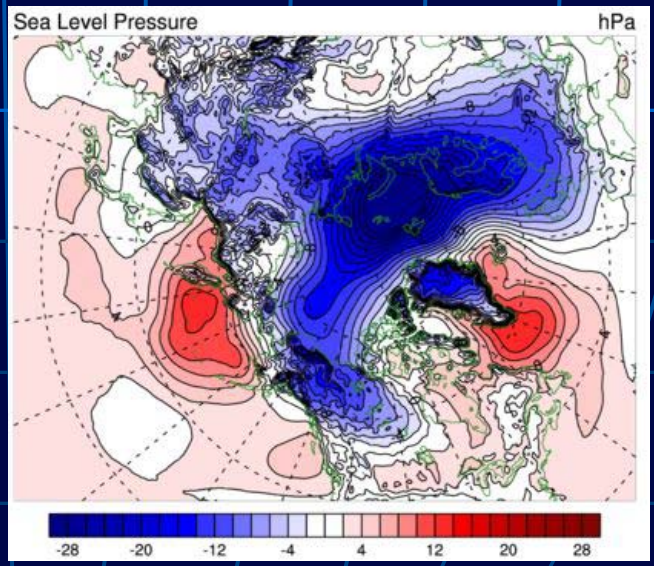


Coupled RACM; 50 mb top, no spectral nudging



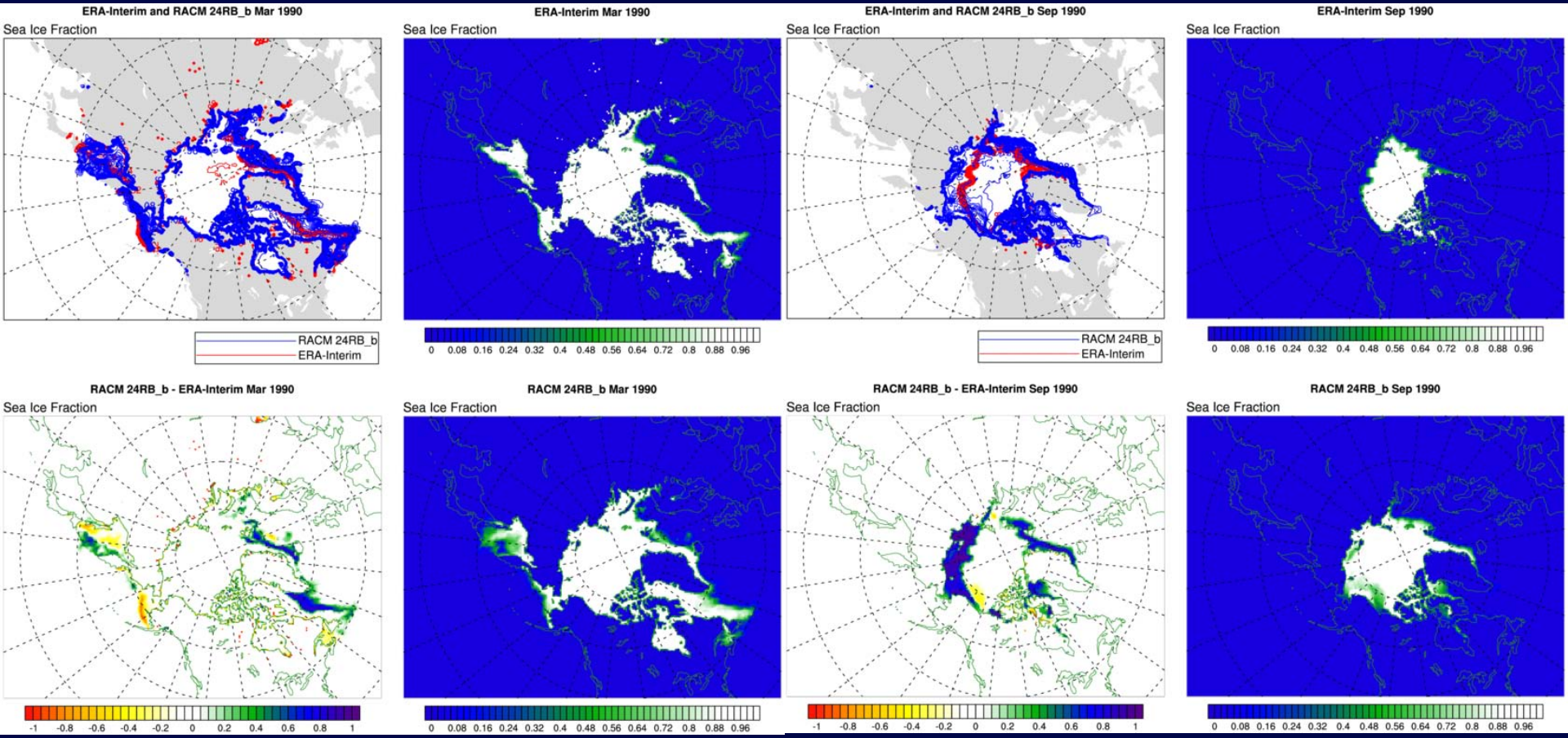
WRF – ERA-Interim





RACM – ERA-Interim

RACM: Sea Ice Concentration



March 1990

September 1990

RACM Outlook

- RACM Spinup 1979-1989 with:
  - POP/CICE/VIC ICs from stand alone runs
  - WRF LBCs and ICs from ERA Interim
- Baseline integration: 1989-2010
  - RACM feedbacks/gains vs GCM focused on sea ice
  - Atm : WRF+VIC, RACM
  - Lnd: VIC-offline, WRF-VIC, RACM