Regional Arctic System Model (RASM) Progress and Plans

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MODEL LIMITATIONS AND BIASES

There are many arctic physical/climatic **processes** omitted from, or poorly represented in current-generation GC/ESMs, including:

- sea ice thickness distribution, deformation and export, fast ice, snow cover, melt ponds and surface albedo, permafrost,
- oceanic eddies, tides, surface/bottom mixed layer, buoyancy-driven coastal and boundary currents, fronts, cold halocline, upper ocean heat content, dense water plumes and convection,
- atmospheric modes of circulation, clouds and fronts,
- ice-sheets/ocean, fjord-shelf-basin, wave-ice and air–sea-ice interactions and coupling.

another person can possibly come up with a different list

How can an Arctic System Model be used to understand and predict climate change?

1. By resolving unresolved or under represented **processes** in individual system components.

2. By addressing inadequacies along **coupling** channels between different system components

3. By exploring space-dependent **sensitivities** in the parameter space

4. Through a **hierarchical modeling** approach using both regional and global models to help quantify uncertainty.

Maslowski et al. 2012

1/12°Arctic Cap Nowcast/Forecast System (ACNFS)

- ACNFS consists of 3 state-of-the-art components :

  <u>Ice Model</u>: Community Ice CodE (CICE)

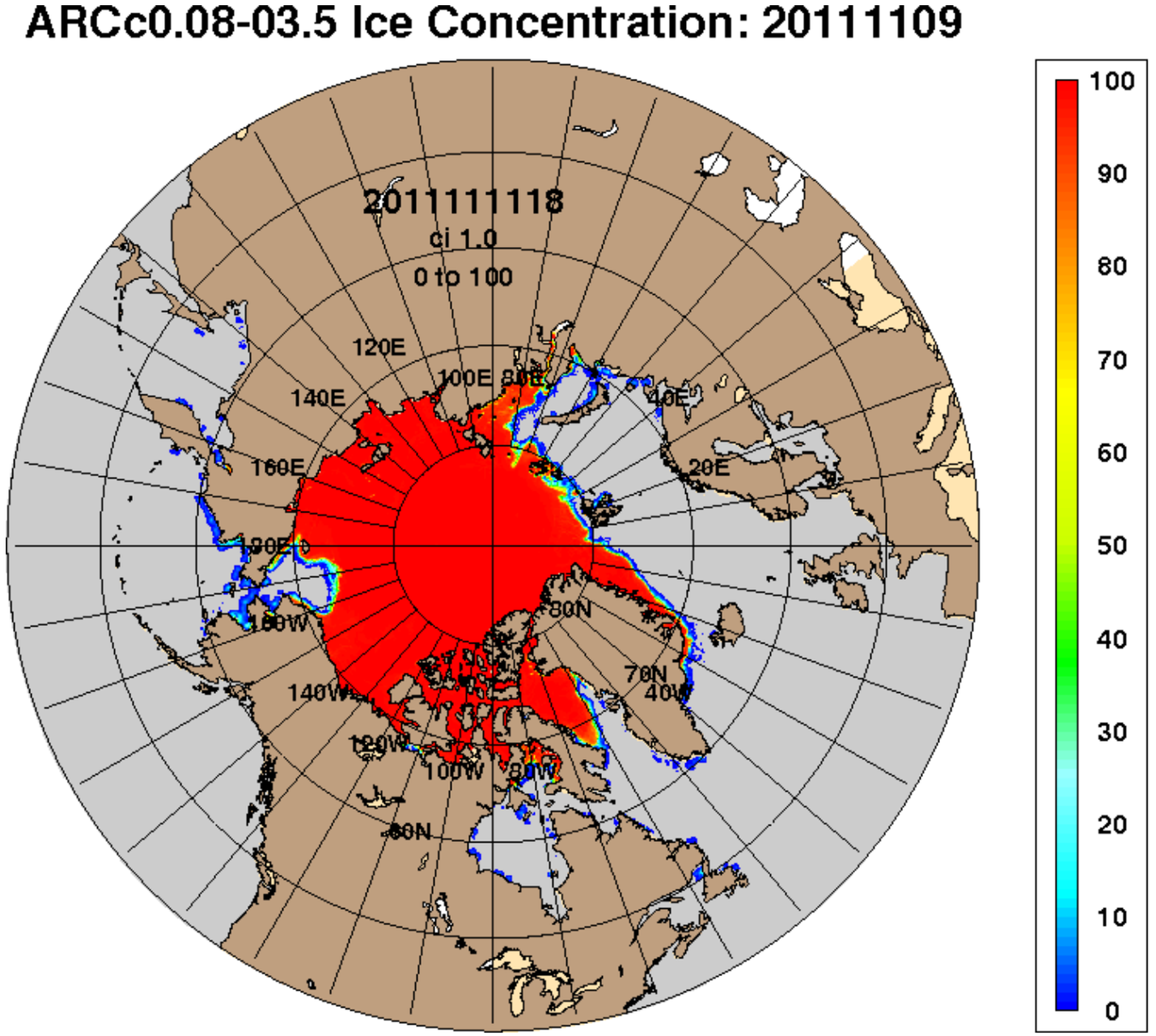
  <u>Ocean Model</u>: HYbrid Coordinate Ocean Model (HYCOM)

  <u>Data Assimilation</u>: Navy Coupled Ocean Data Assimilation (NCODA)

- Assimilates satellite (SSHA, SST, ice concentration) and in-situ ocean data (XBT, CDT, Argo floats, buoys)

- Output consists of a nowcast and out to 7-day forecast

- Currently upgrading from Navy's 0.5°NOGAPS to NAVGEM atmospheric forcing



Model grid resolution ~ 3.5 km near Pole

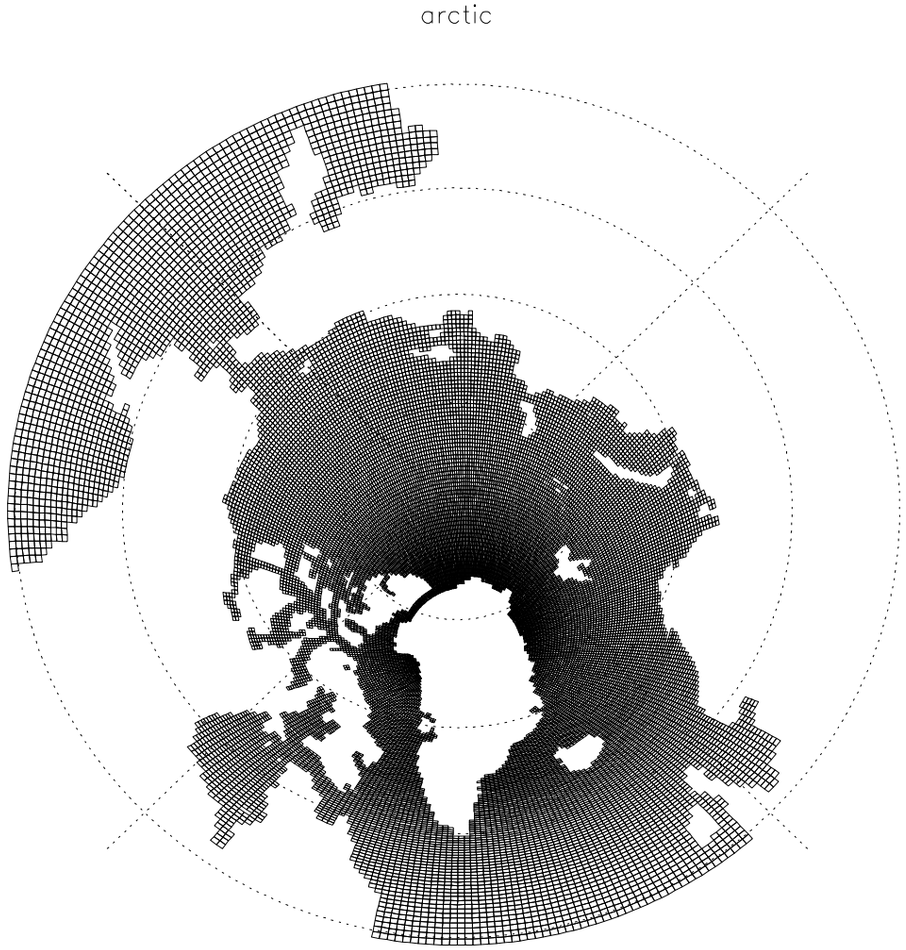
OPTEST final report – completed. NIC supports the promotion of ACNFS into operations.

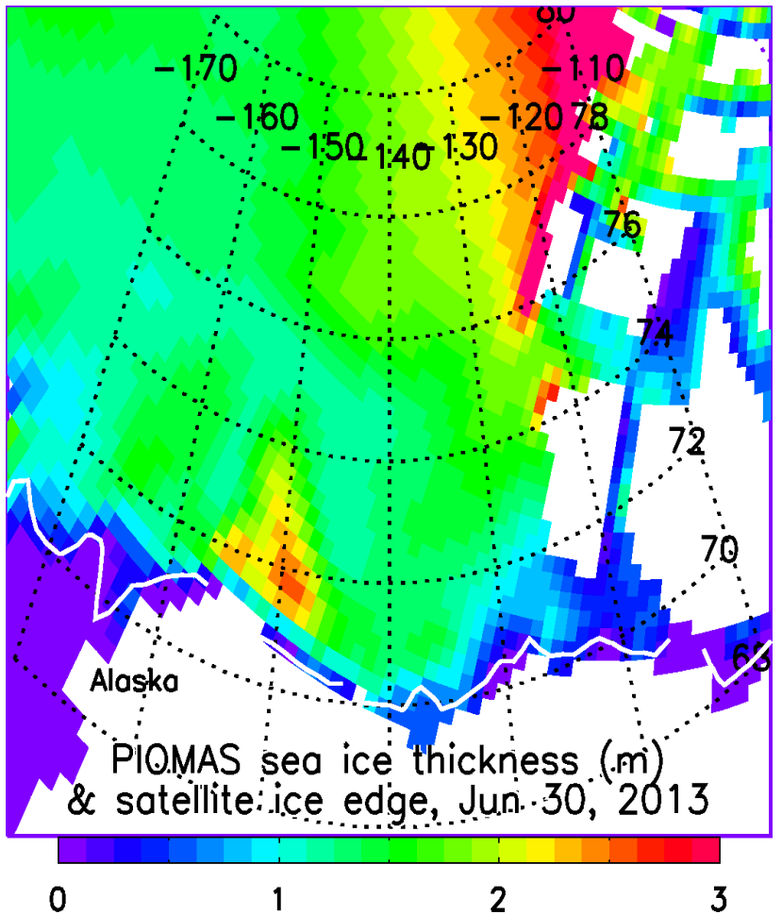
(1) Pan-Arctic Ice–Ocean Modeling and Assimilation System (PIOMAS)

Average resolution ~22 km; open boundary along 49N

(2) Marginal Ice Zone Modeling and Assimilation System (MIZMAS)

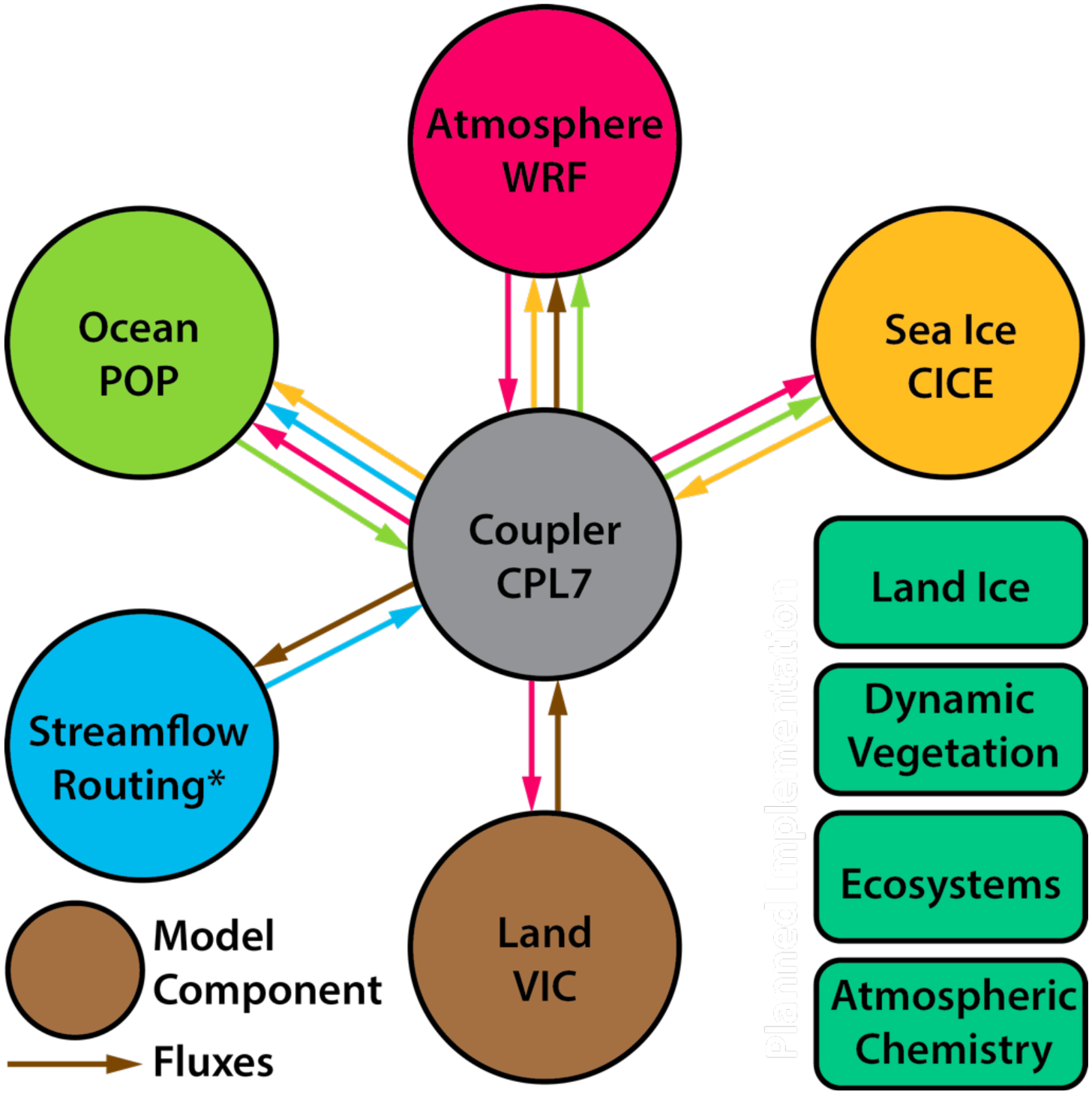
High resolution (~10 km) in the Pacific Arctic; open boundary along 39N



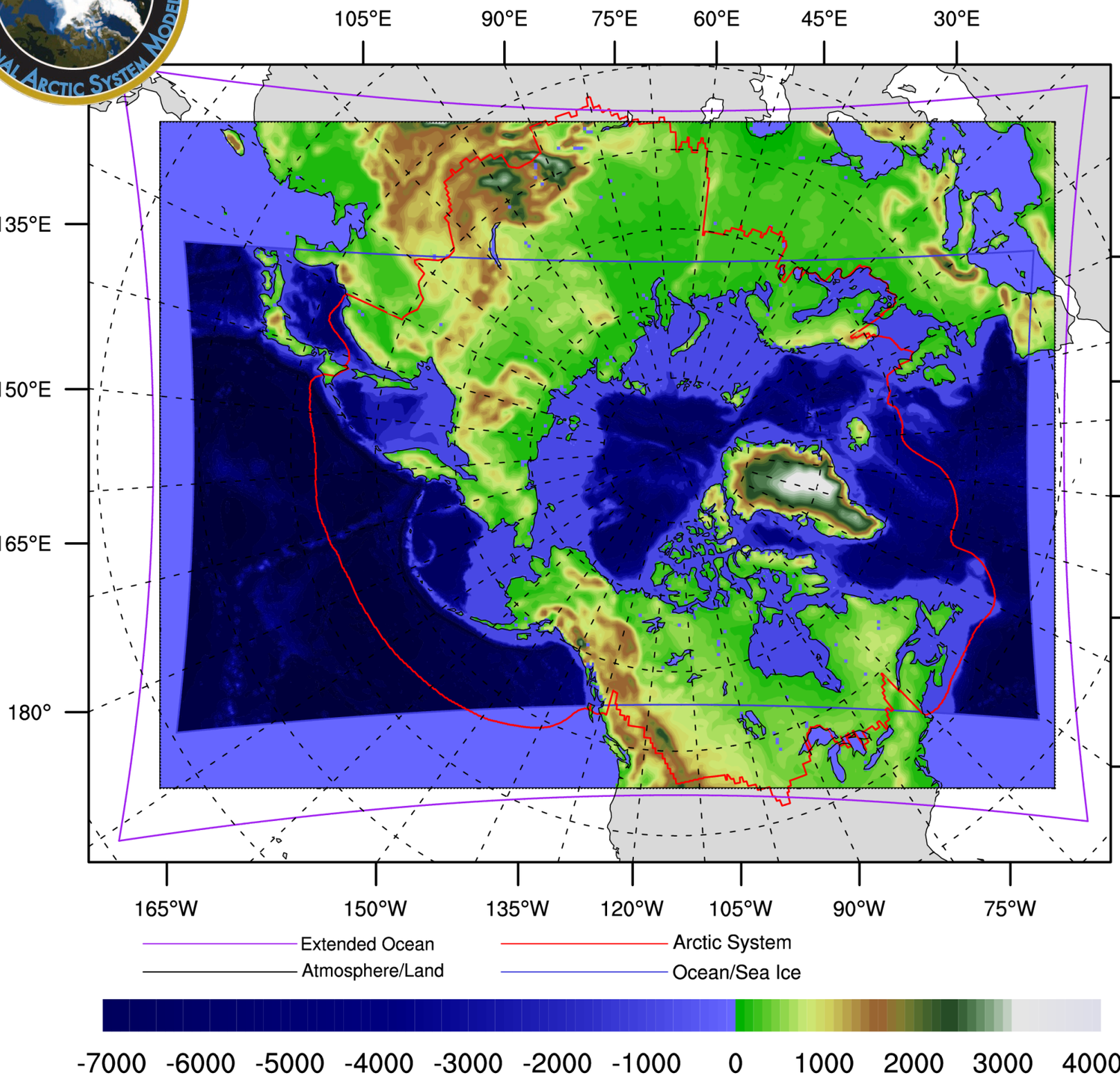


- **TED (Thickness & Enthalpy Distribution) sea ice model**
- **POP (Parallel Ocean Program) ocean model**
- **Nested to a global model via open boundary conditions**
- **Assimilation of daily satellite sea ice concentration and SST**
- **Hindcast (48-present) driven by near real-time daily NCEP/NCAR forcing**
- **Ensemble seasonal forecast of sea ice by NCEP/NCAR forcing in recent past**
- **Limits: forecast is based on past experience; no atmospheric model component**

RASM wiring diagram



RASM Domains for Coupling and Topography

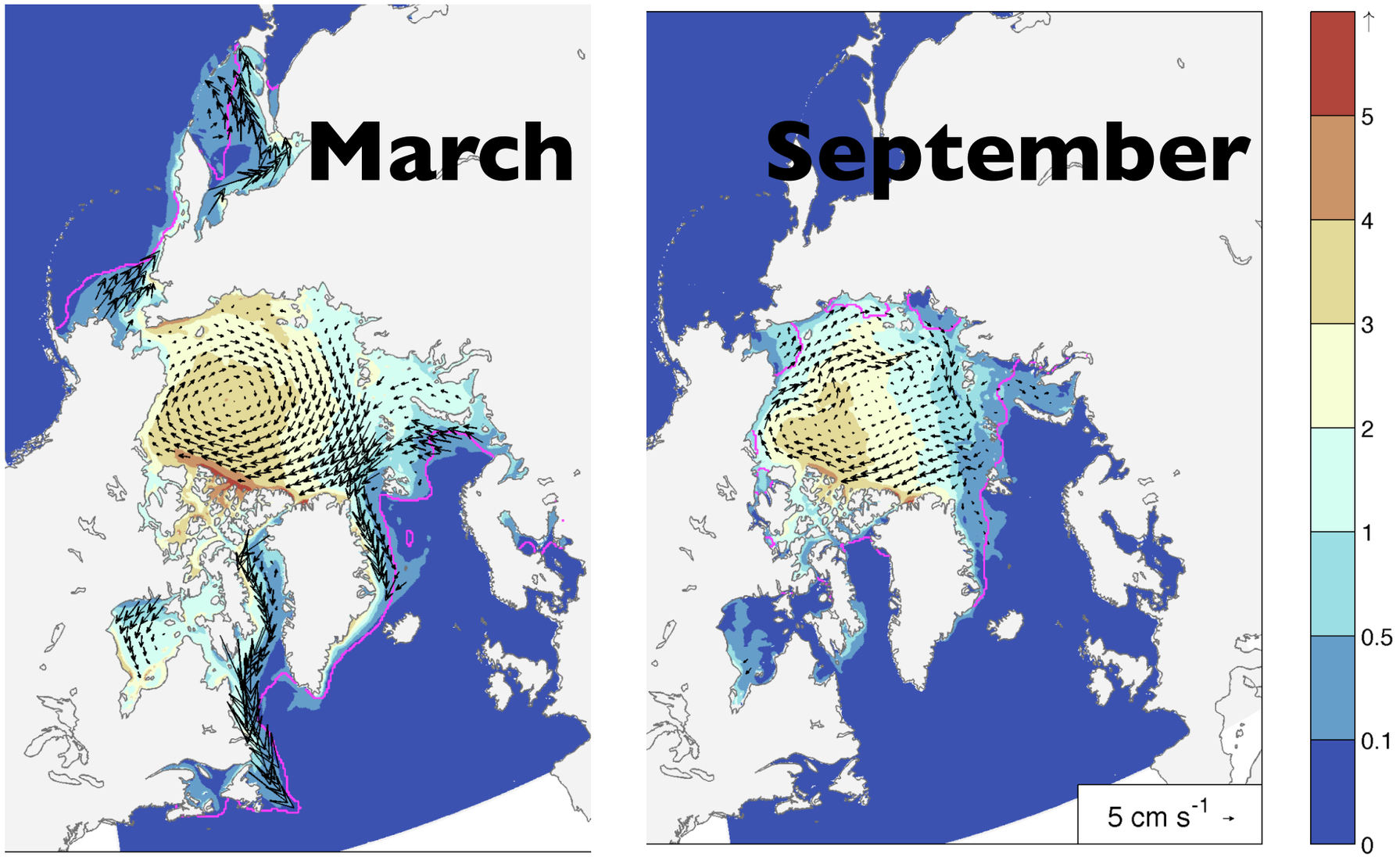


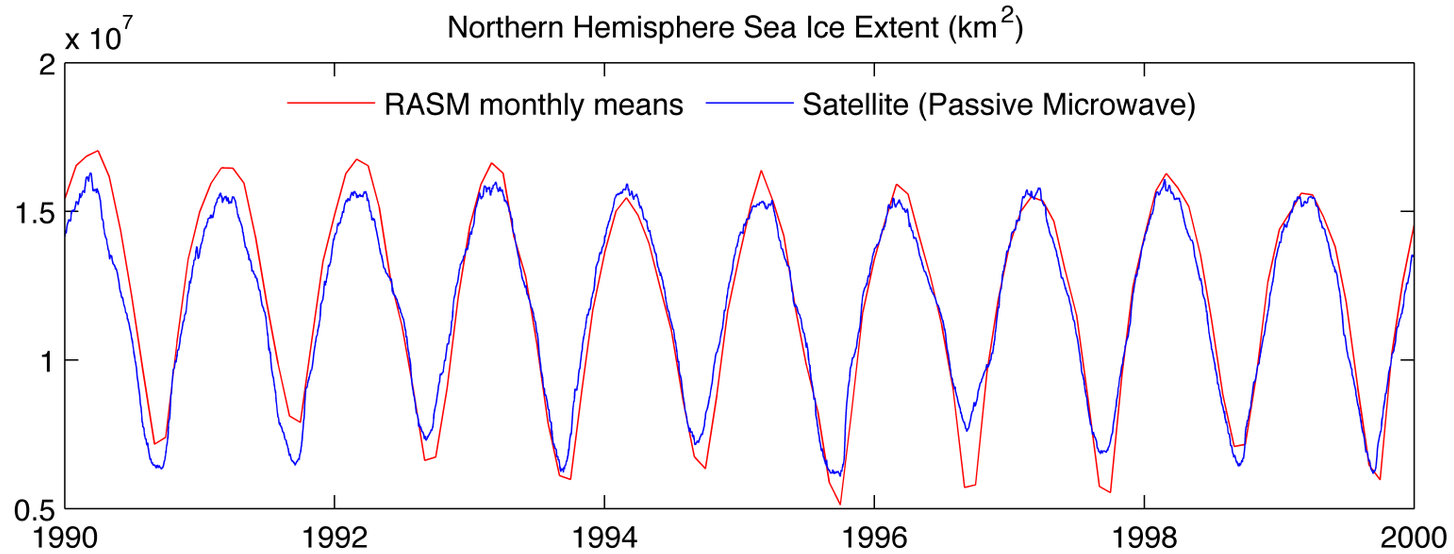
Pan-Arctic region include:

- all sea ice covered ocean in the NH
- Arctic river drainage
- inter-ocean exchange and transport
- large-scale weather patterns (AO, PDO)
- WRF and VIC model domains (50-km) cover the entire colored region
- POP and CICE domains (9-km) cover the inner colored region

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

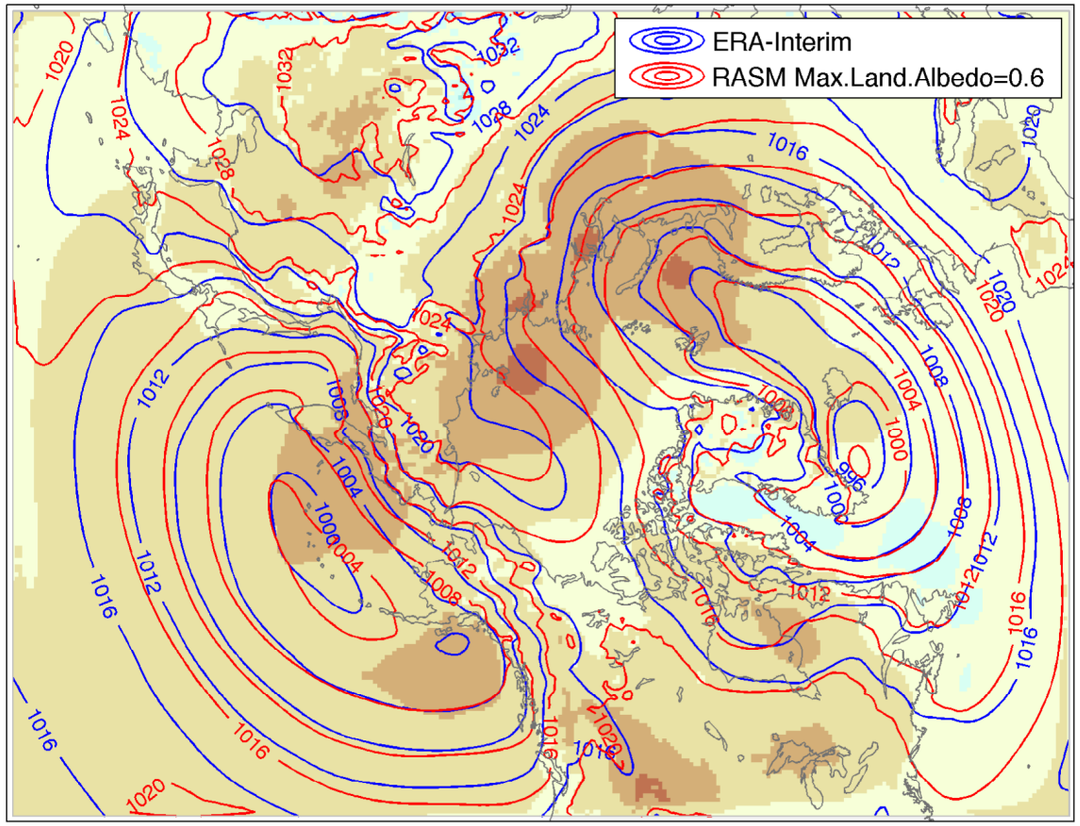
RASM sea ice - mean (1990-1997)



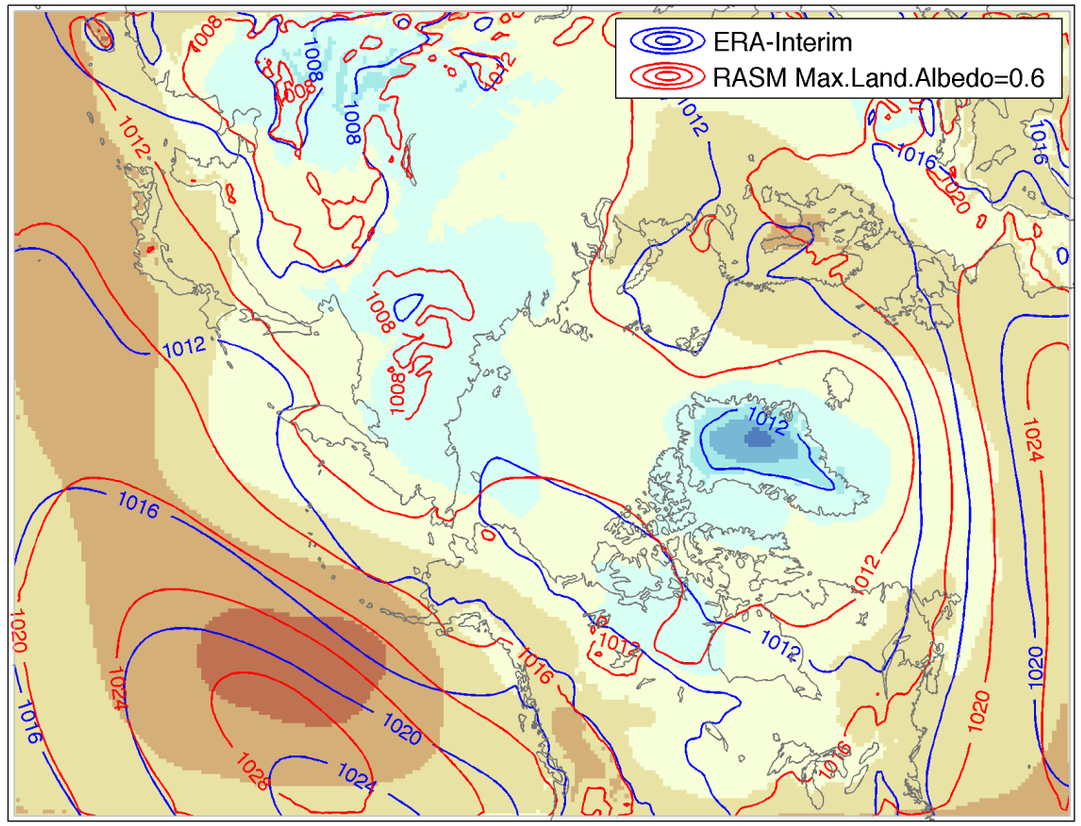


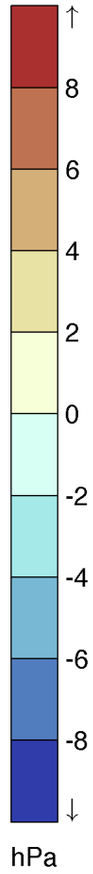
MSLP RASM/WRF and ERA-I

DJF PMSL and difference from ERA-Interim 1990-2000



JJA PMSL and difference from ERA-Interim 1990-2000

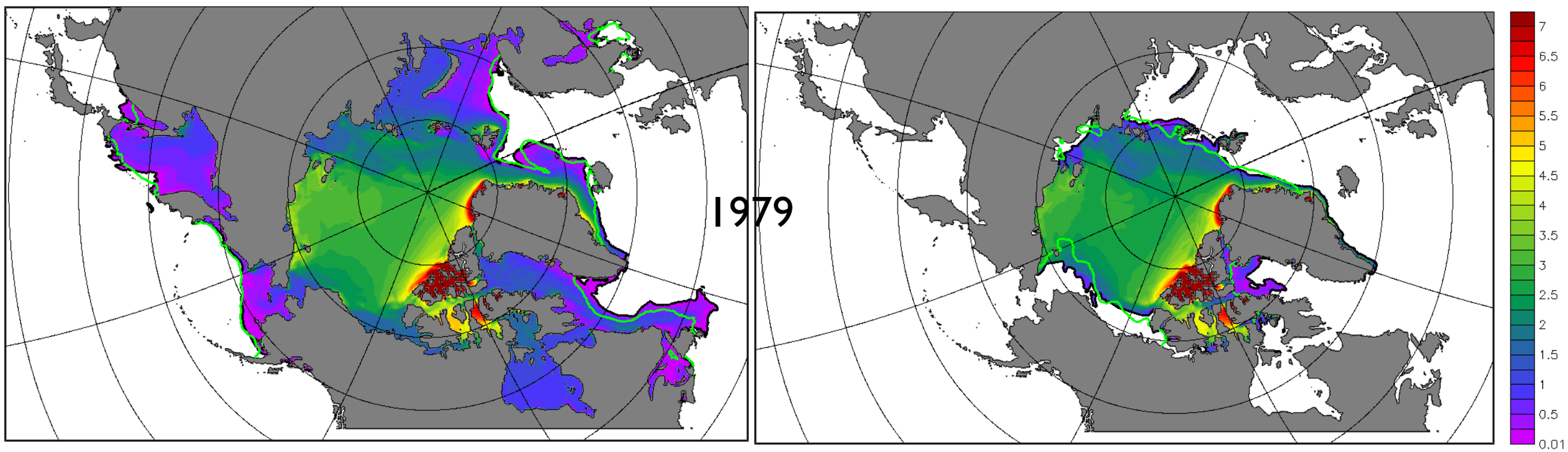


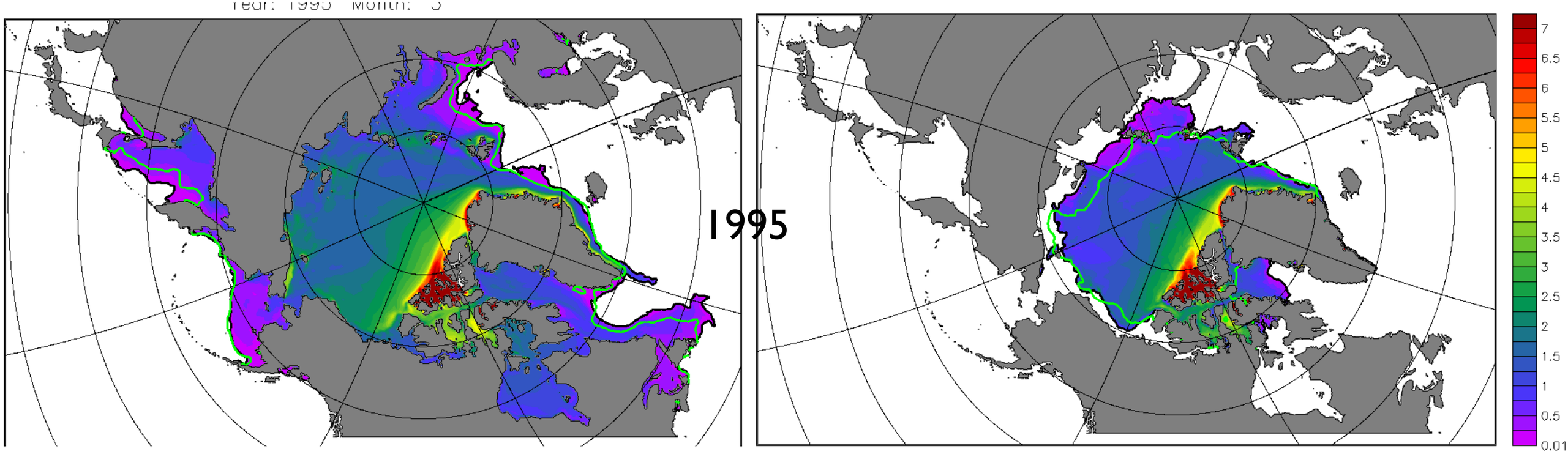


RASM H-compset forced with CORE2 vs SSM/I

March

September





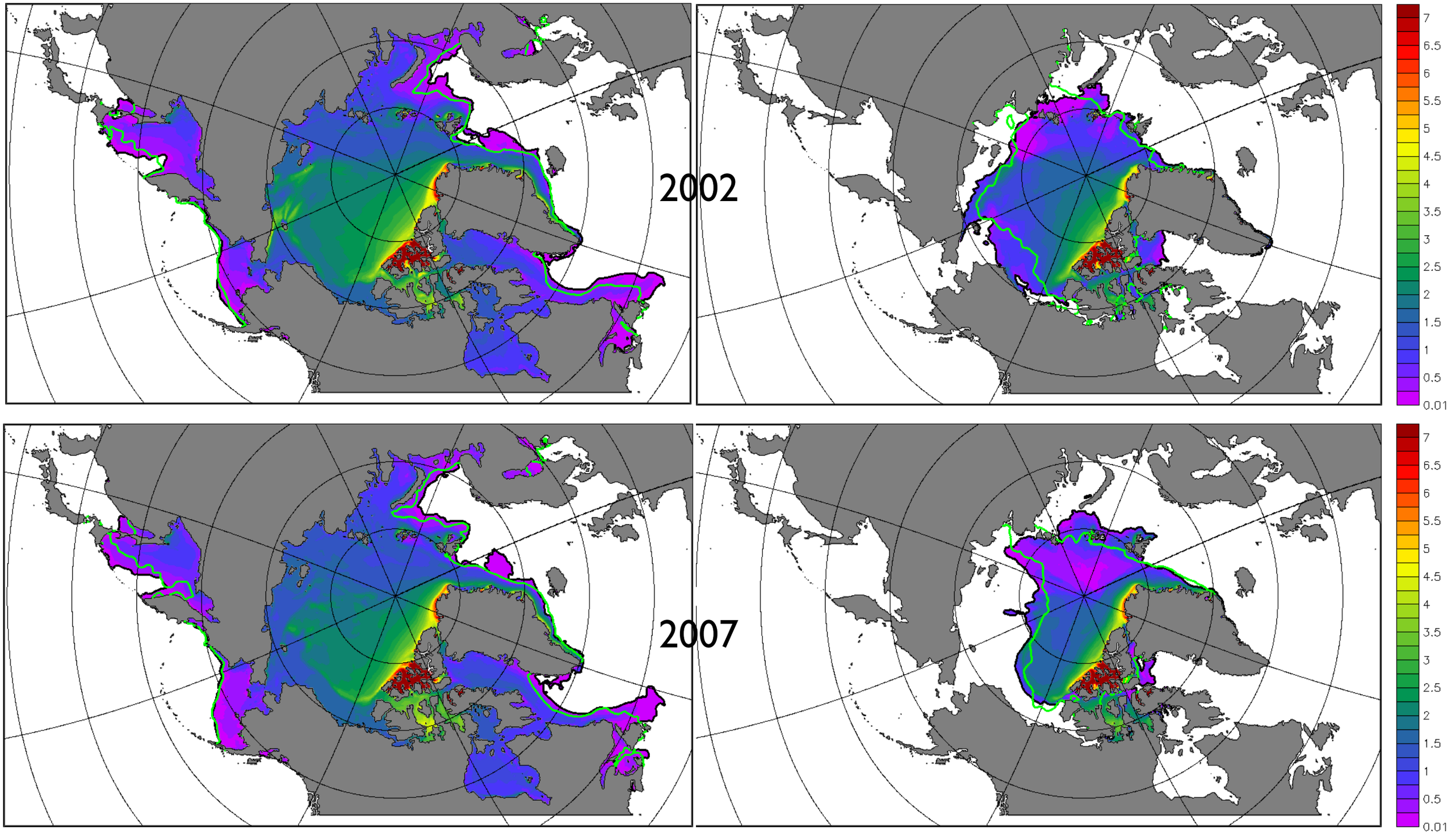
RASM H-compset forced with CORE2 vs SSM/I

March

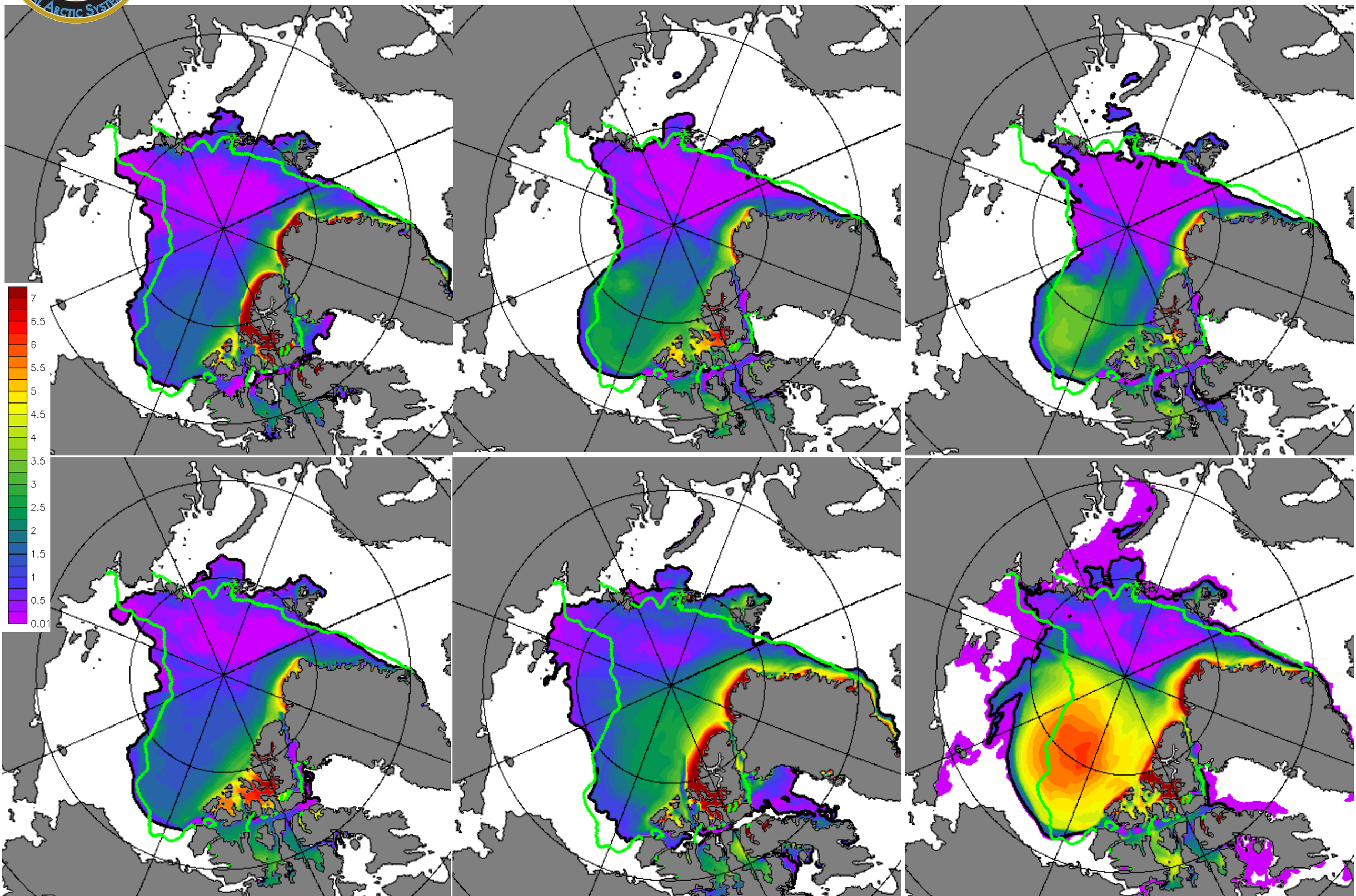
September

2002

2007

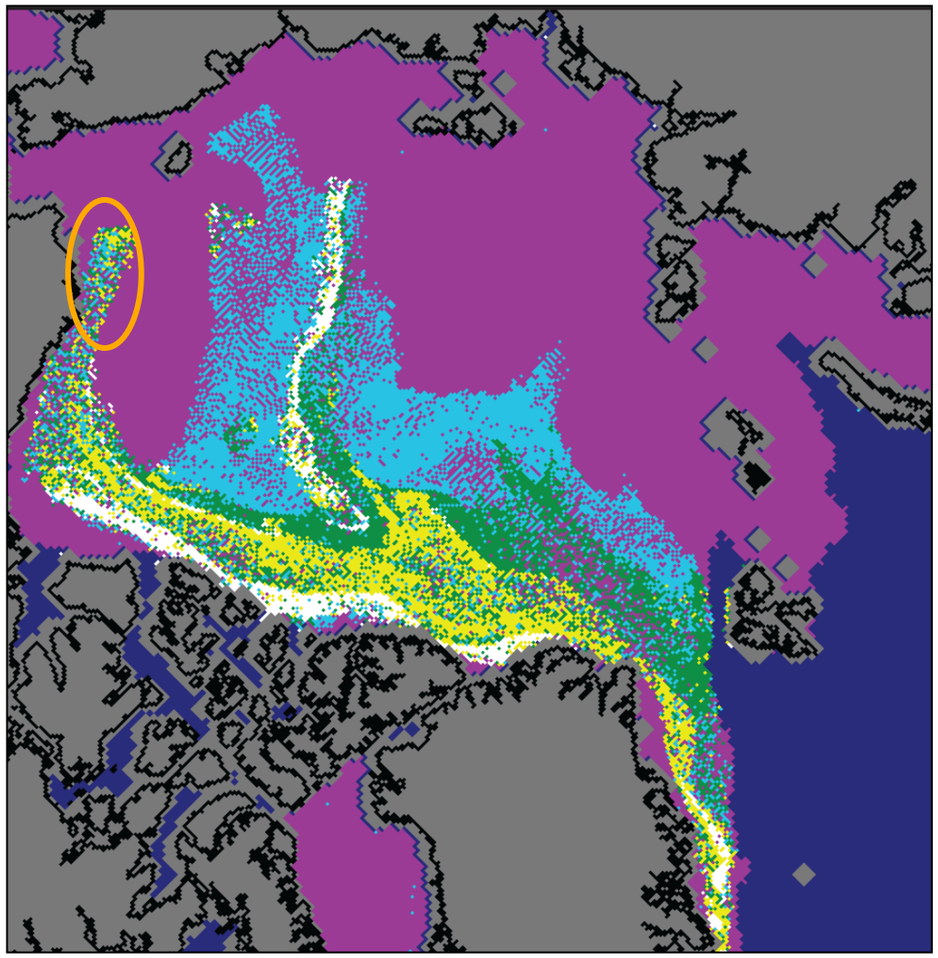


RASM H-compset sensitivity results: Sep 2007

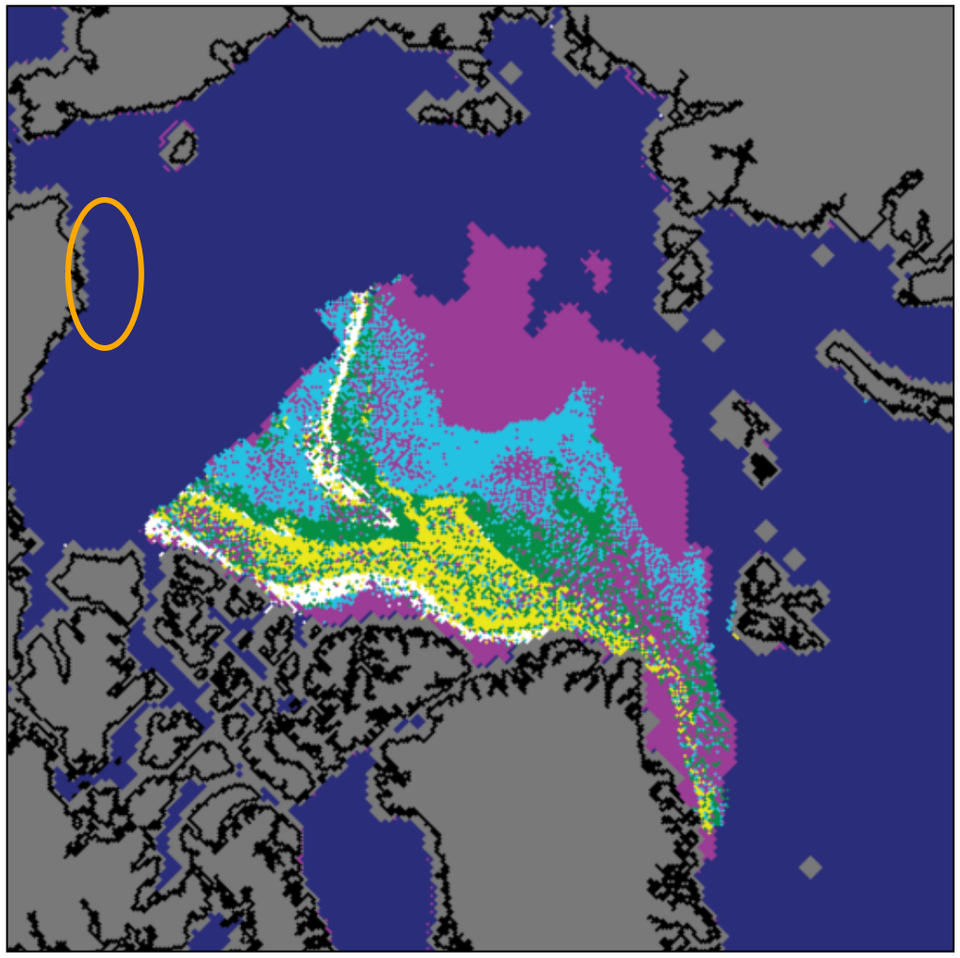


Melt of old ice during summer 2012

March 2012



September 2012



First-year ice (<1 year old)

Second-year ice (1-2 years old)

Third-year ice (2-3 years old)

Fourth-year ice (3-4 years old)

5+-year ice (5+ years old)

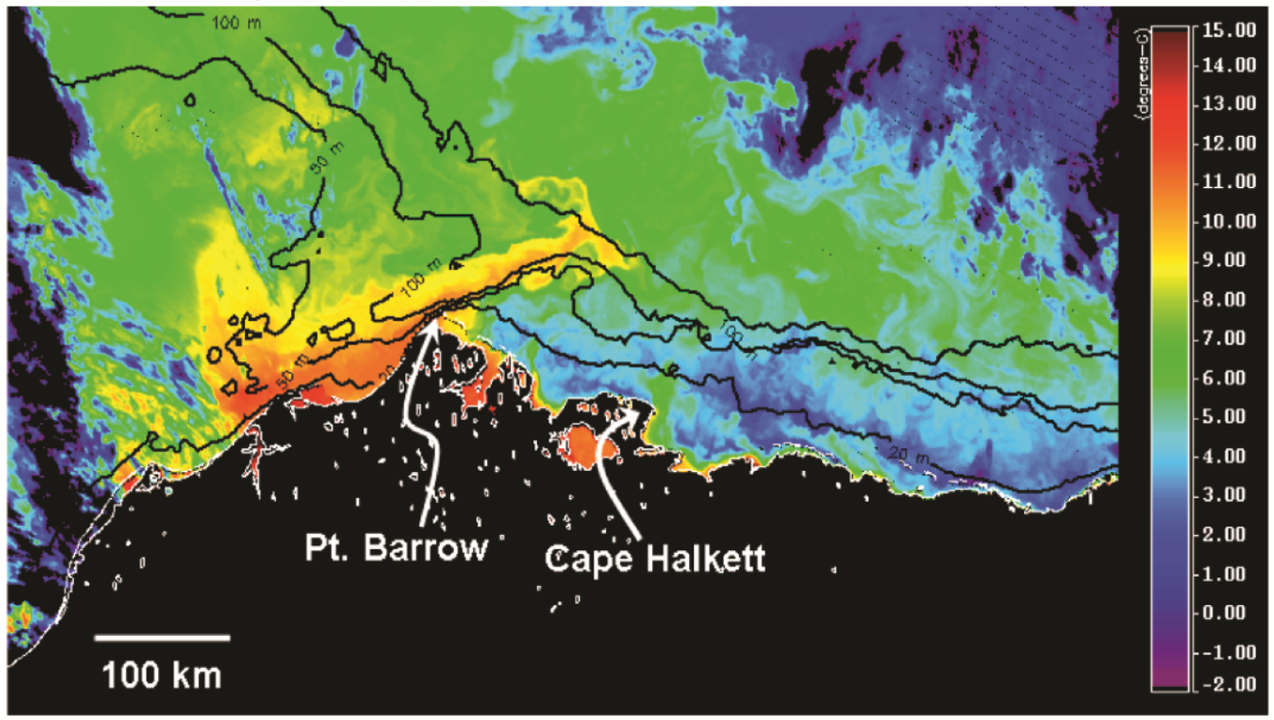
CIRES

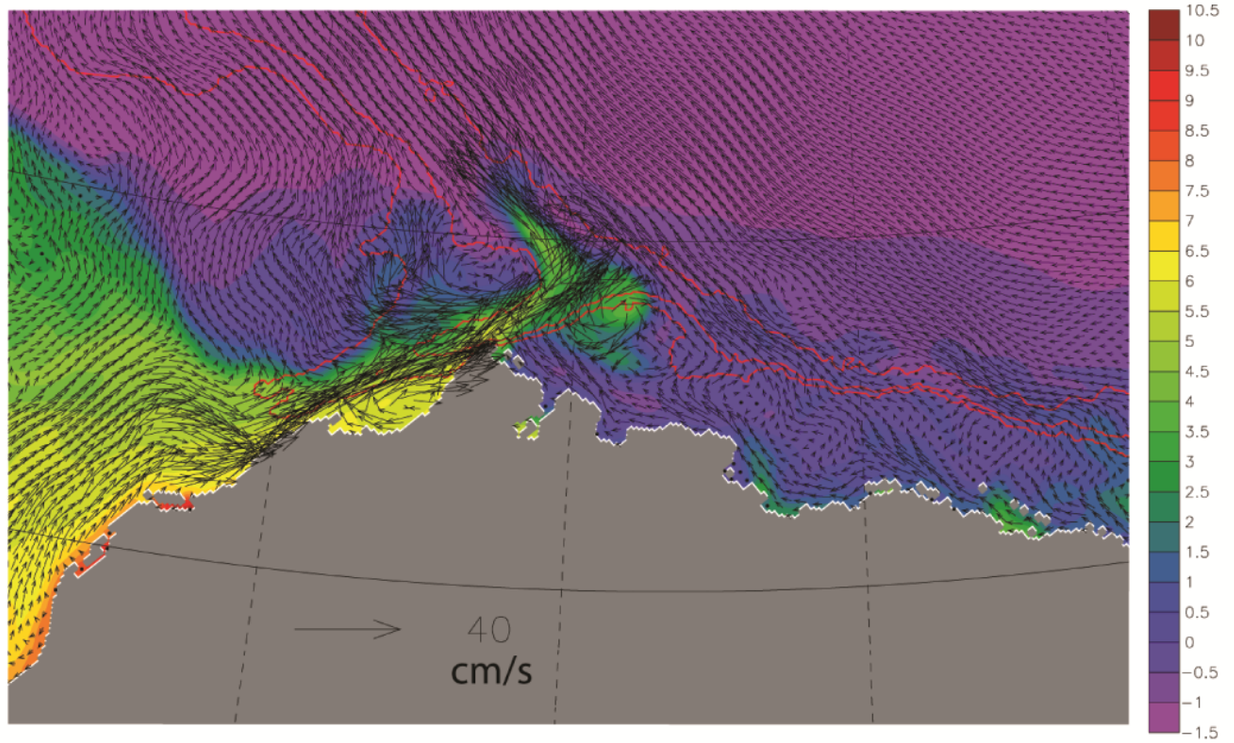
Courtesy of Walt Meier: Based on satellite observations from J. Maslanik, M. Tschudi, Univ. Colorado

NSIDC

Ice-albedo & ocean circulation

MODIS sea surface temperatures for 10 August 2007, 2335 UT. Vector-averaged winds for the 24-hour period preceding the image acquisition were from the east-southeast at 4.1 m s^{-1}. Okkonen et al., 2009.





MODIS SST – 08/10/2007, 2335UT

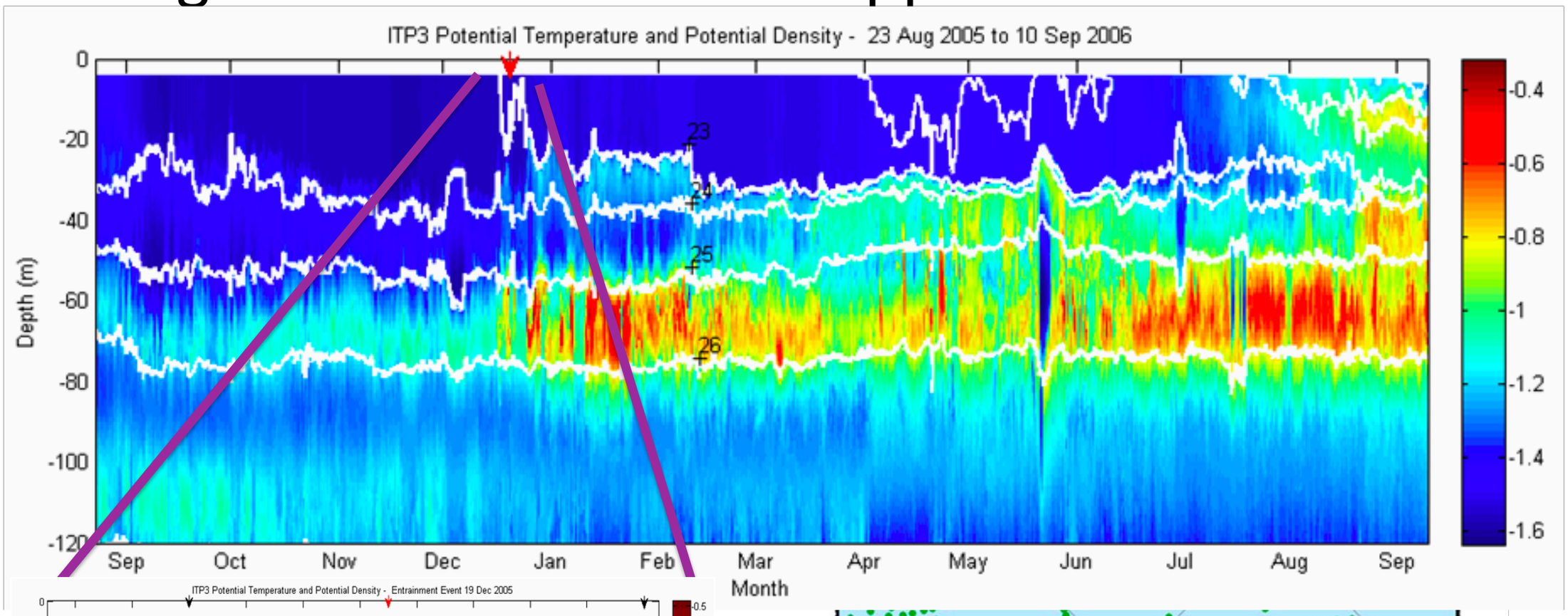
Modeled SST and Velocity – 08/15/1988

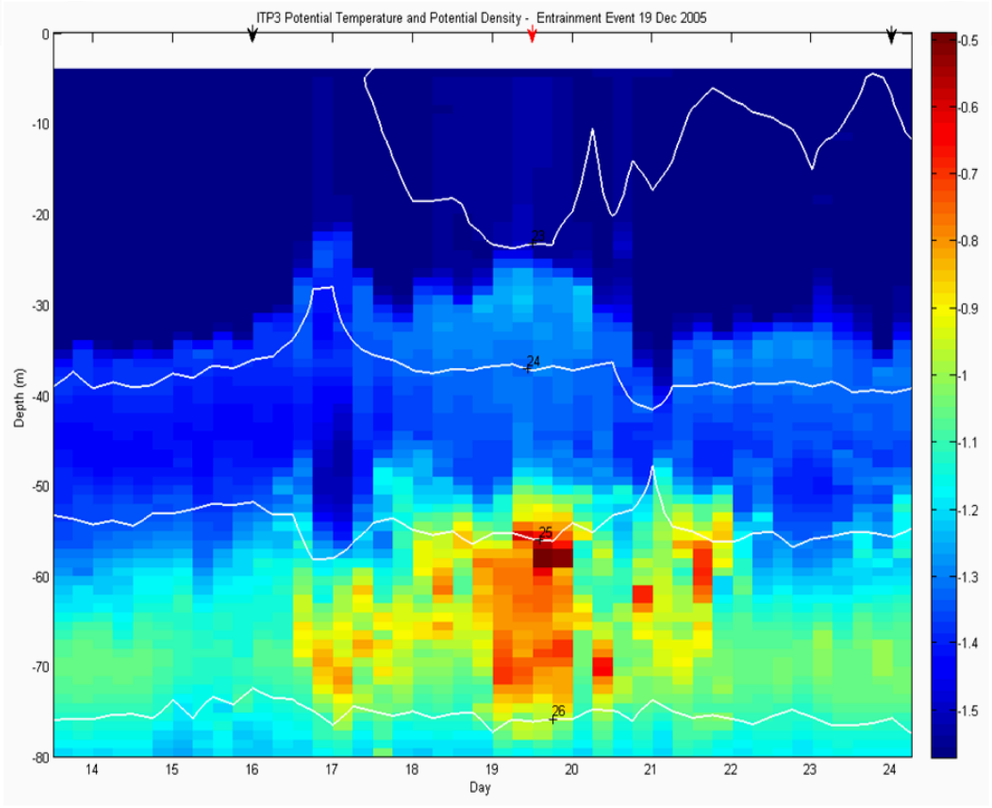
- Surface warming due to ice-albedo effect up to 7°C (local warming / limited flow)

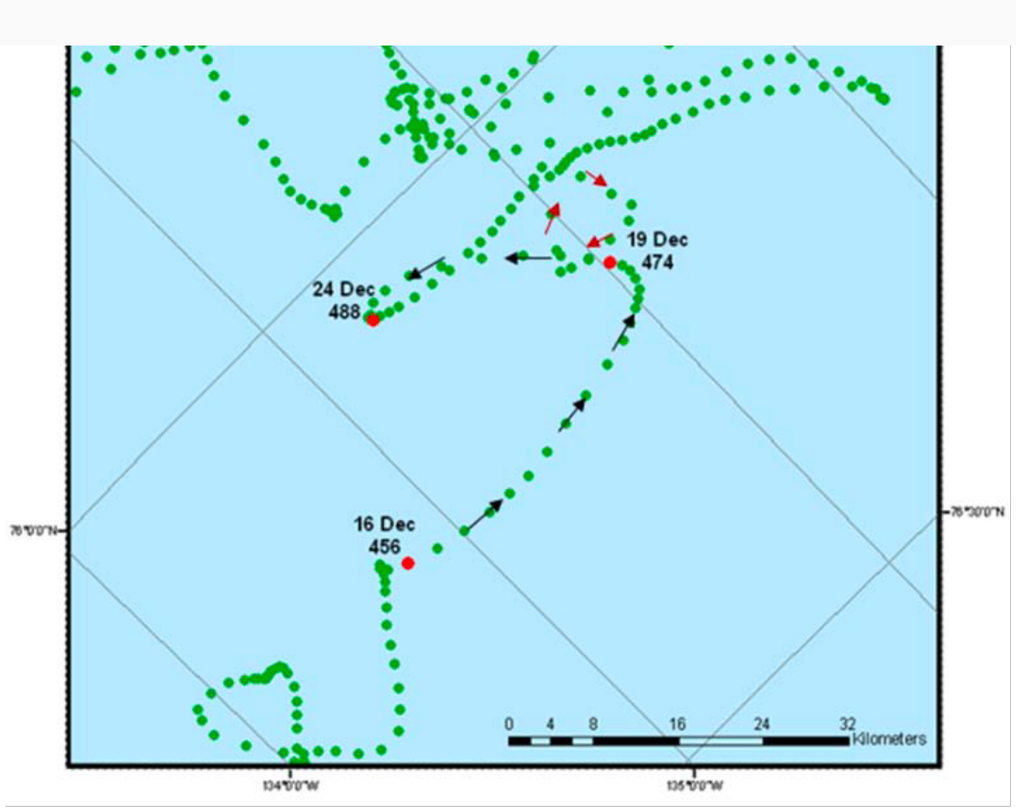
- ACC carries water up to 13°C and it extends below the surface (strong advection)

- At resolution of ~2 km models can capture details of ocean circulation, eddy generation and heat distribution

Missing Heat Source - Arctic Upper Ocean Heat Content

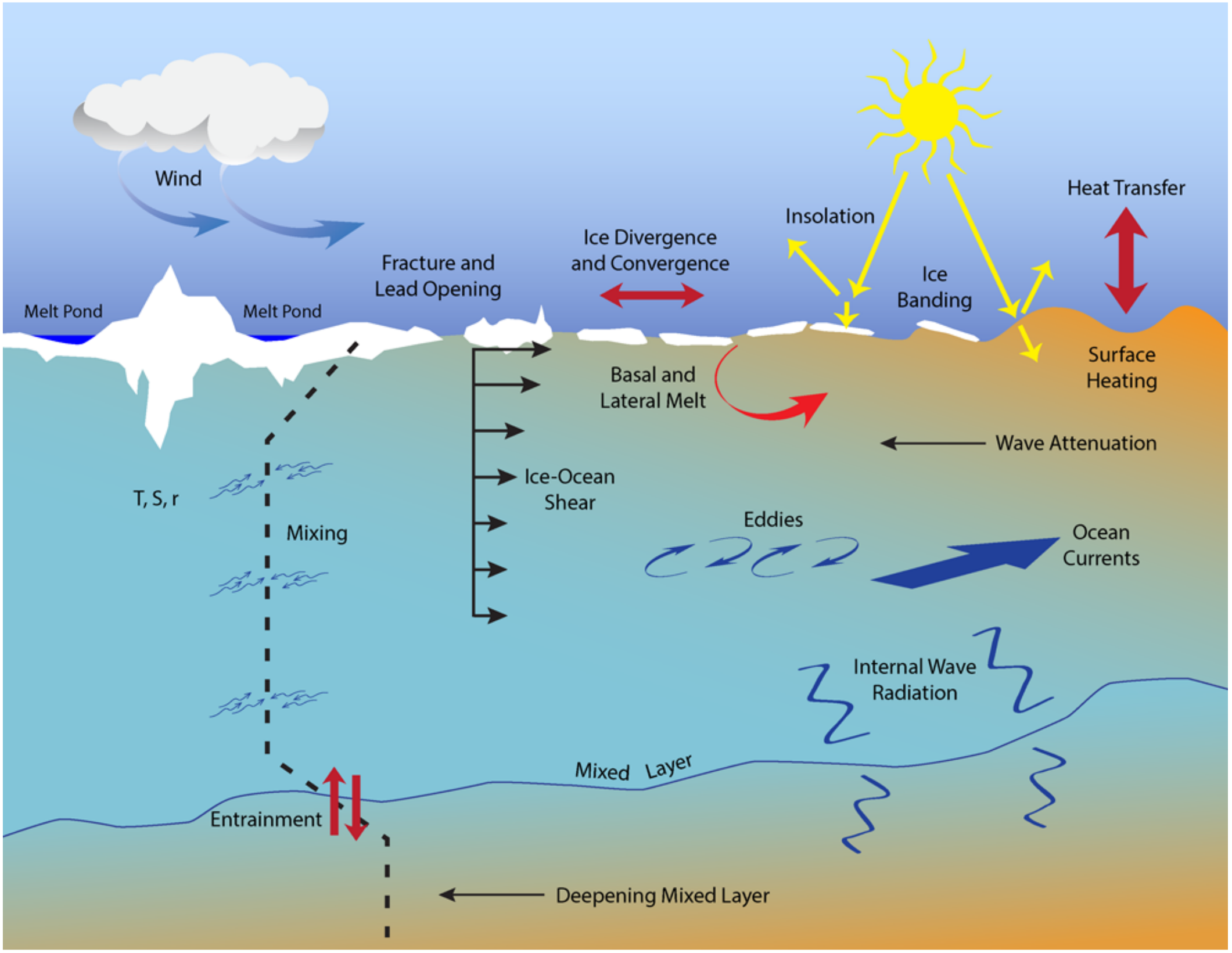






Oceanic heat in reality is removed only from the ocean mixed layer (10-40m) but not from the subsurface ocean (>40m)

Atmosphere, sea ice, and upper ocean processes in the MIZ



ONR/DRI MIZ Science Plan

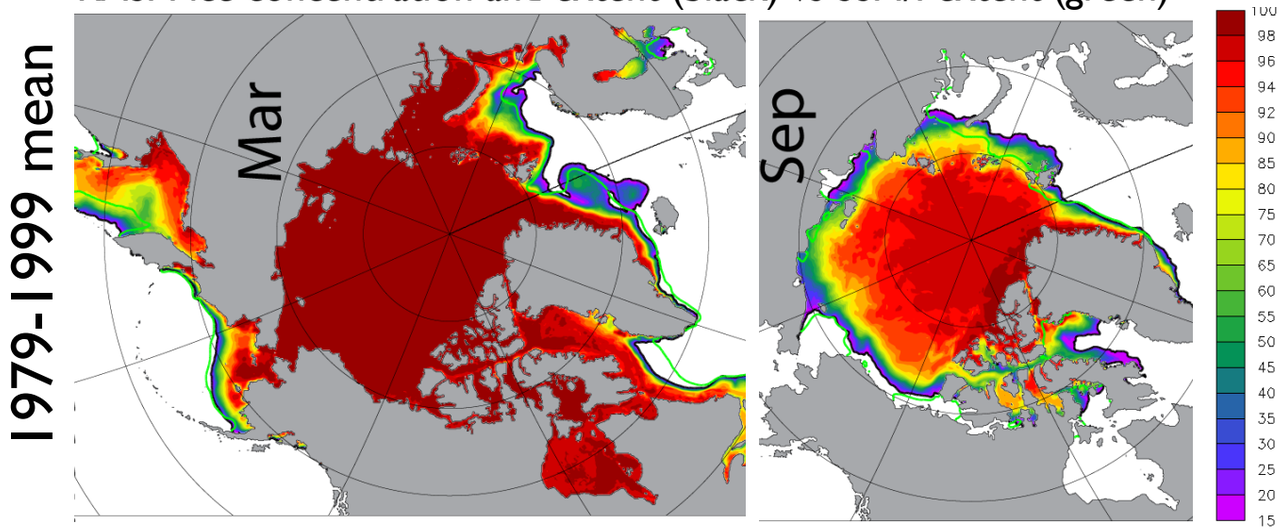
Future Plans

1. Parameter space sensitivity studies in fully coupled RASM
2. Alternative BCs for WRF
   - NCEP/CFSR - underway
   - 21st century global climate model scenarios (e.g. CESM)
3. Ensemble generation in RASM
4. Higher resolution RASM component model configurations
   - 25 & 10-km WRF / VIC
   - 1/48° (~2.3 km) POP / CICE
5. Addition of new components:
   - ecosystem / marine BGC
   - tidewater fjords with ice-sheet/ocean interactions

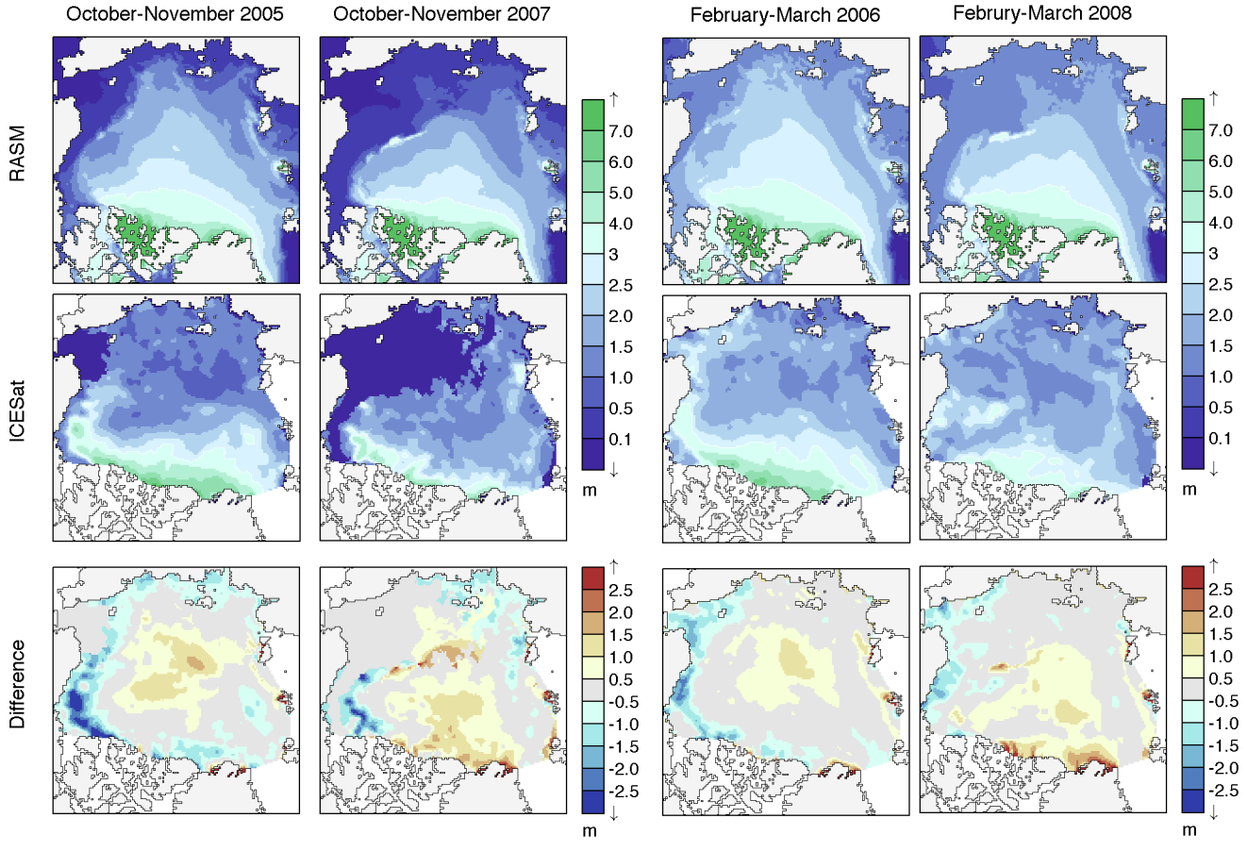
Thank You!

RASM-H sea ice analyses with observations

RASM ice concentration and extent (black) vs SSM/I extent (green)



RASM sea ice thickness vs IceSat (Kwok & Cunningham,2008)



RASM / Pathfinder sea ice streamlines and speed