CICE5 physics in RASM with implications for CESM

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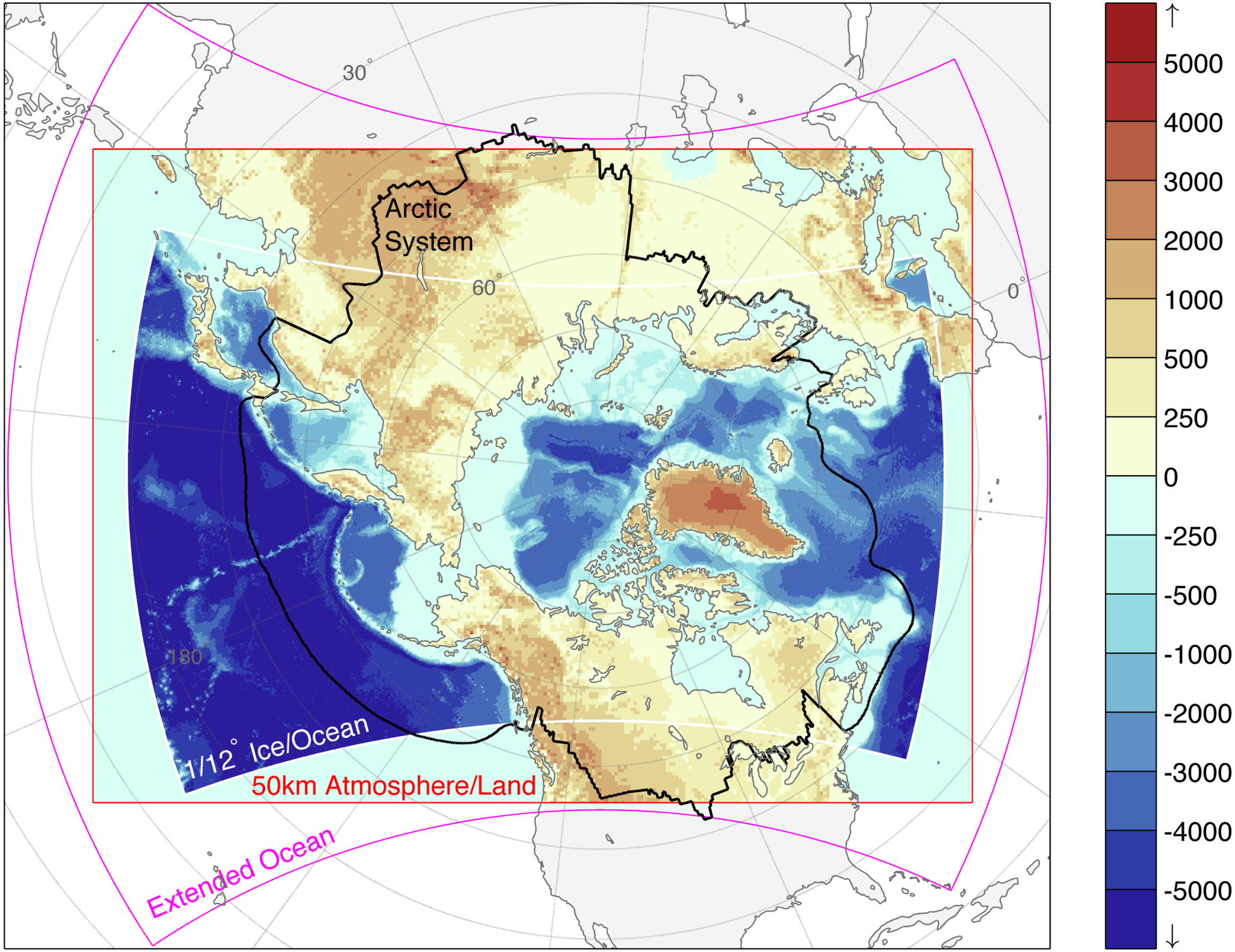
The Regional Arctic System Model Version 1.0



The Regional Arctic System Model Version 1.0

Component	Code	Configuration
Atmosphere	WRF3	50km, 40 levels (10 in the lowest 1000 m), 2.5 minute step RRTMG coupled with Morrison microphysics Spectrally nudging T, U, V above 500 hPa to waves 4/3 (x/y)
Land	VIC4	50km, 3 Soil Layers, 20 minute step RVIC runoff flow convolution scheme
Ocean	POP2	1/12˚, 45 levels (7 in the top 42 m), 10 timesteps / 20 min coupling KPP parameter space based on improved Bering Sea ice extent
Sea Ice	CICE5	1/12˚, 5 thickness categories divided at 0.65, 1.39, 2.47, 4.56, 9.3 m 20 min steps, Delta-Eddington shortwave, level melt ponds, anisotropic mechanics, Bitz-Lipscomb thermodynamics, high-frequency coupling with constant roughness length
Coupler	CPL7	Flux exchange every 20 minutes for all model components ‘RASM1’ Inertially resolving coupling with minimized model lags

No modeling without service

A new strategy for model inter-comparison is needed that will identify specific, key processes of importance to sea ice prediction; incorporate lessons learned from model sensitivity studies; and collaborate closely with model developers to identify approaches to resolve unrealistic model behavior. Regional models and ice-ocean coupled systems will likely be an essential part of the strategy, given the greater control achieved in these approaches by prescribed (e.g., observationally- or reanalysis-derived) lateral and/or surface forcing of the Arctic.

- Seasonal-to-Decadal Predictions of Arctic Sea Ice: Challenges and Strategies, National Research Council, 2012

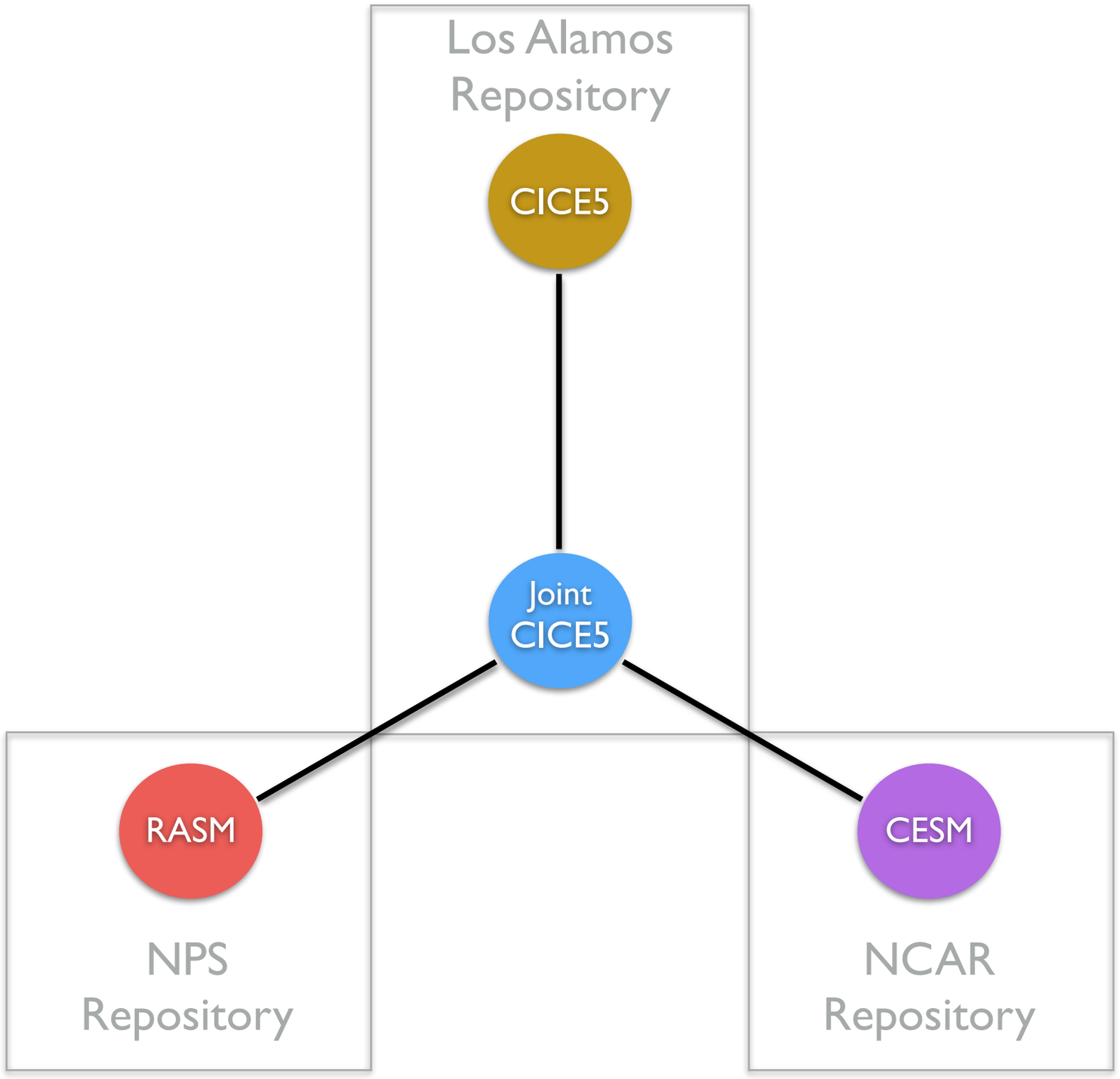
The core focus of the proposed ASM program will be to understand complexity and adaptation in the Arctic System as well as society's role and response in the evolution of that system. The program is designed to complement and work with global Earth System Modeling programs to create reliable probabilistic forecasts of the state of the Arctic on seasonal to decadal timescales.

- A Science Plan for Regional Arctic System Modeling: A Report by the Arctic Research Community for the National Science Foundation Office of Polar Programs, 2010

Improvements are possible by tapping into model capabilities that already exist in some cases, through strategic cooperation of the sometimes disparate global and regional modeling streams, as well as increased co-operation of global, regional, research-based, and operational modeling efforts.

- A National Strategy for Advancing Climate Modeling, National Research Council, 2012

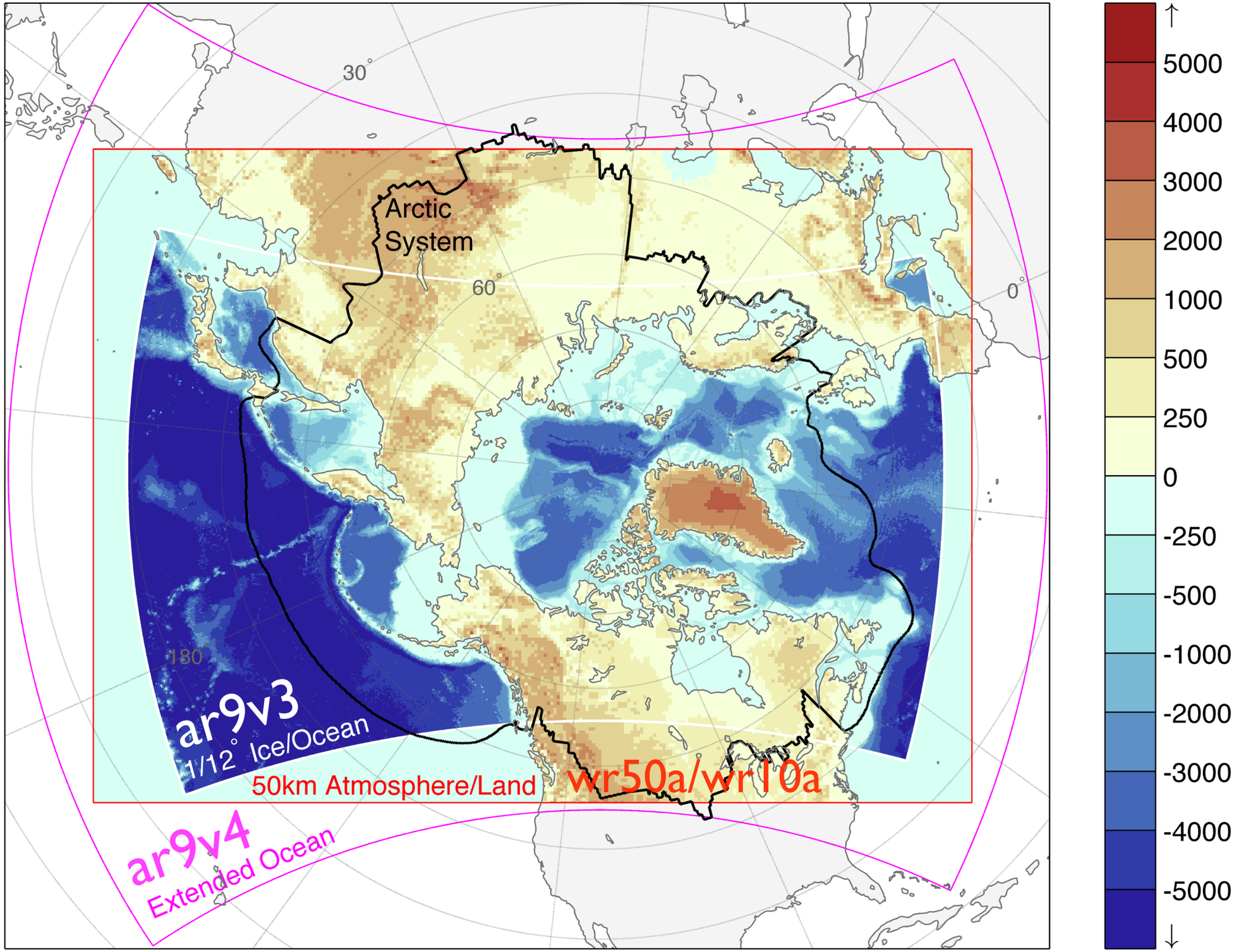
CICE5 implementation in RASM and CESM



CICE5 implementation in RASM and CESM

Model	Components	Architecture
RASM	CICE5+POP+WRF+VIC+RVIC+CPL7x ar9v3, ar9v4, wr50a, wr10a	Spirit (AFRL, SGI Ice X, Intel Compiler) Lightning (AFRL, Cray XC30, Intel Compiler) Garnet (ERDC, Cray XE6, PGI Compiler)
CESM	CICE5+POP+CAM+CLM+RTM+CPL7	Yellowstone (NCAR, IBM, NAG compiler) Spirit (AFRL, SGI Ice X, Intel Compiler) Lightning (AFRL, Cray XC30, Intel Compiler) Garnet (ERDC, Cray XE6, PGI Compiler)

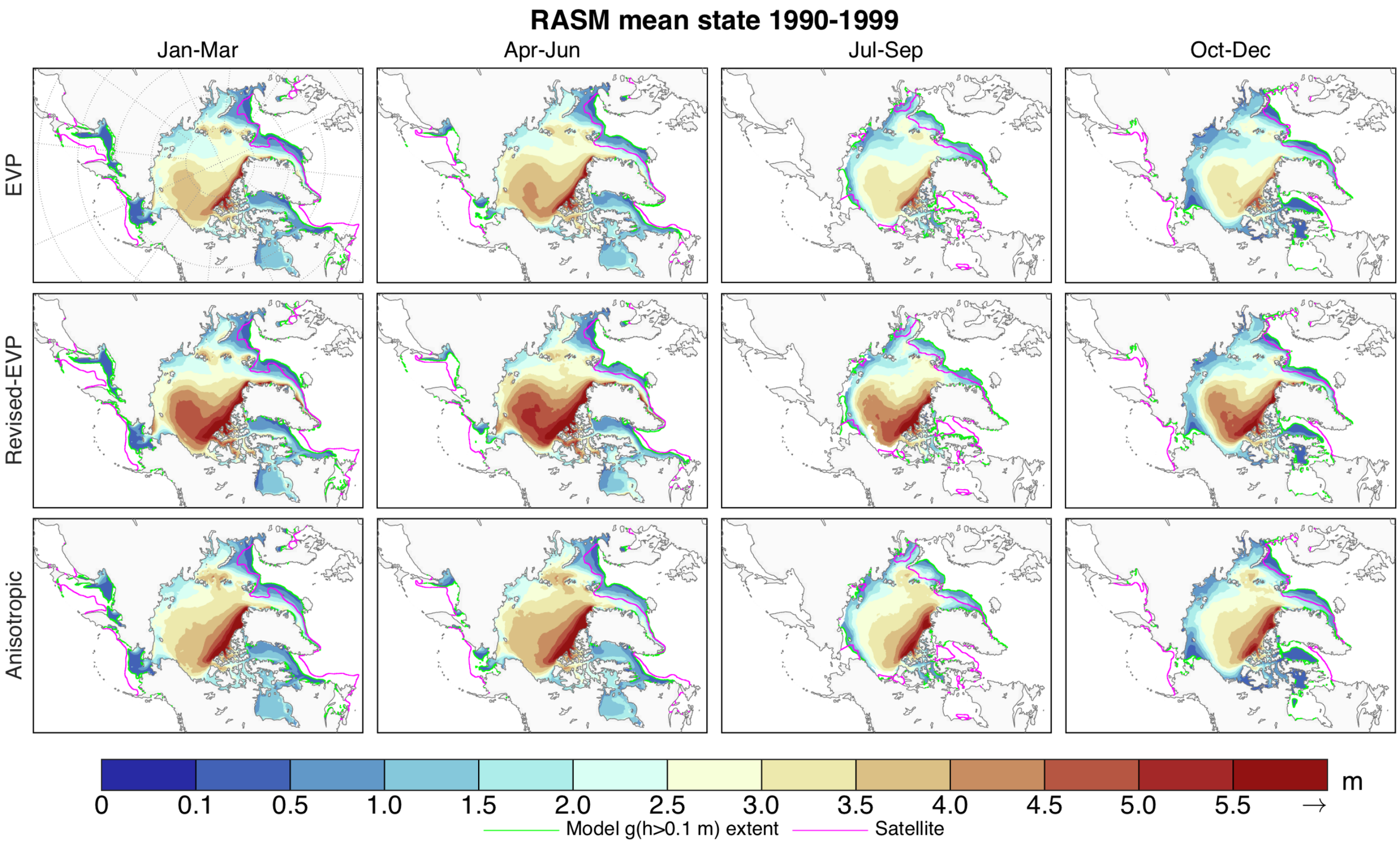
CICE5 implementation in RASM and CESM



RASM CICE5 baseline configuration

CICE5 physics	Decadal testing in RASM	RASM 1.0 Default
Melt Ponds	CESM melt ponds	
	Level-ice formulation	✓
	Topographic formulation	
Vertical Thermodynamics 7 ice layers, 1 snow layer	Bitz-Lipscomb	✓
	Mushy Layer	
Ice Mechanics	Elastic-Viscous-Plastic (EVP)	
	Revised-EVP	
	Elastic Anisotropic Plastic (EAP)	✓
Coupling inertial resolving	RASM High Frequency	✓
	+ Form Drag	-

Inter-comparison of CICE5 Sea Ice Mechanics



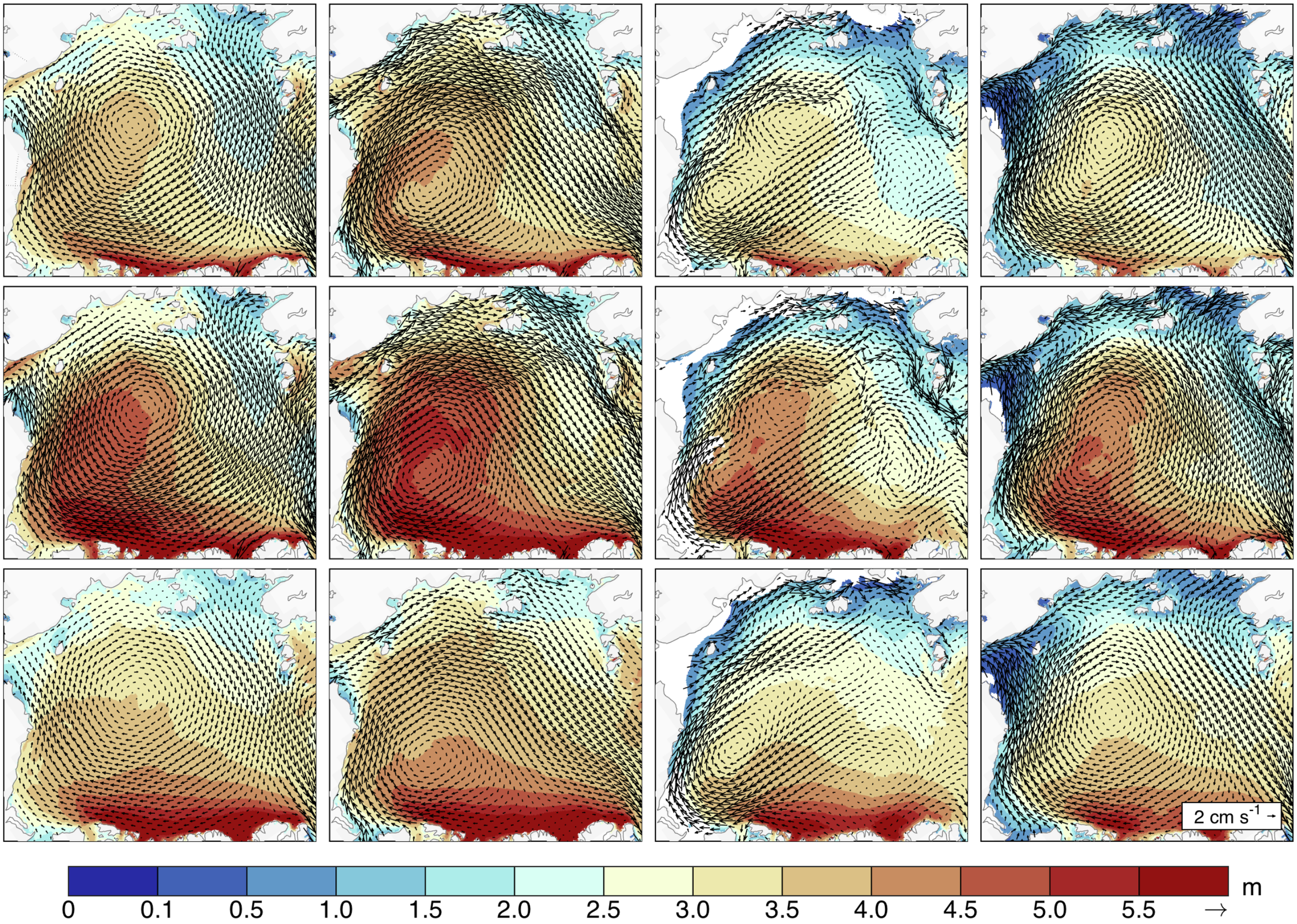
RASM mean state 1990-1999

Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec

EVP

Revised-EVP

Anisotropic



0 0.1 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 → m

Regional Arctic System Model Sea Ice 1979-2008

EVP — Revised-EVP — Anisotropic ····· CESM pre-industrial mean annual cycle

Extent (km^2)

x 10^6

Observed Extent

Area (km^2)

x 10^6

Observed Area South of 87N (84N up to 1988) and model equivalent

Volume (km^3)

x 10^3

ICESat Arctic Ocean volume and model equivalent

Snow Volume (km^3)

x 10^2

Year

RASM mean state 1990-2004

Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec

EVP

Anisotropic

0 0.1 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 → m

Model g(h>0.1 m) extent — Satellite

RASM comparison with Pathfinder motion 1990-2004

Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec

EVP

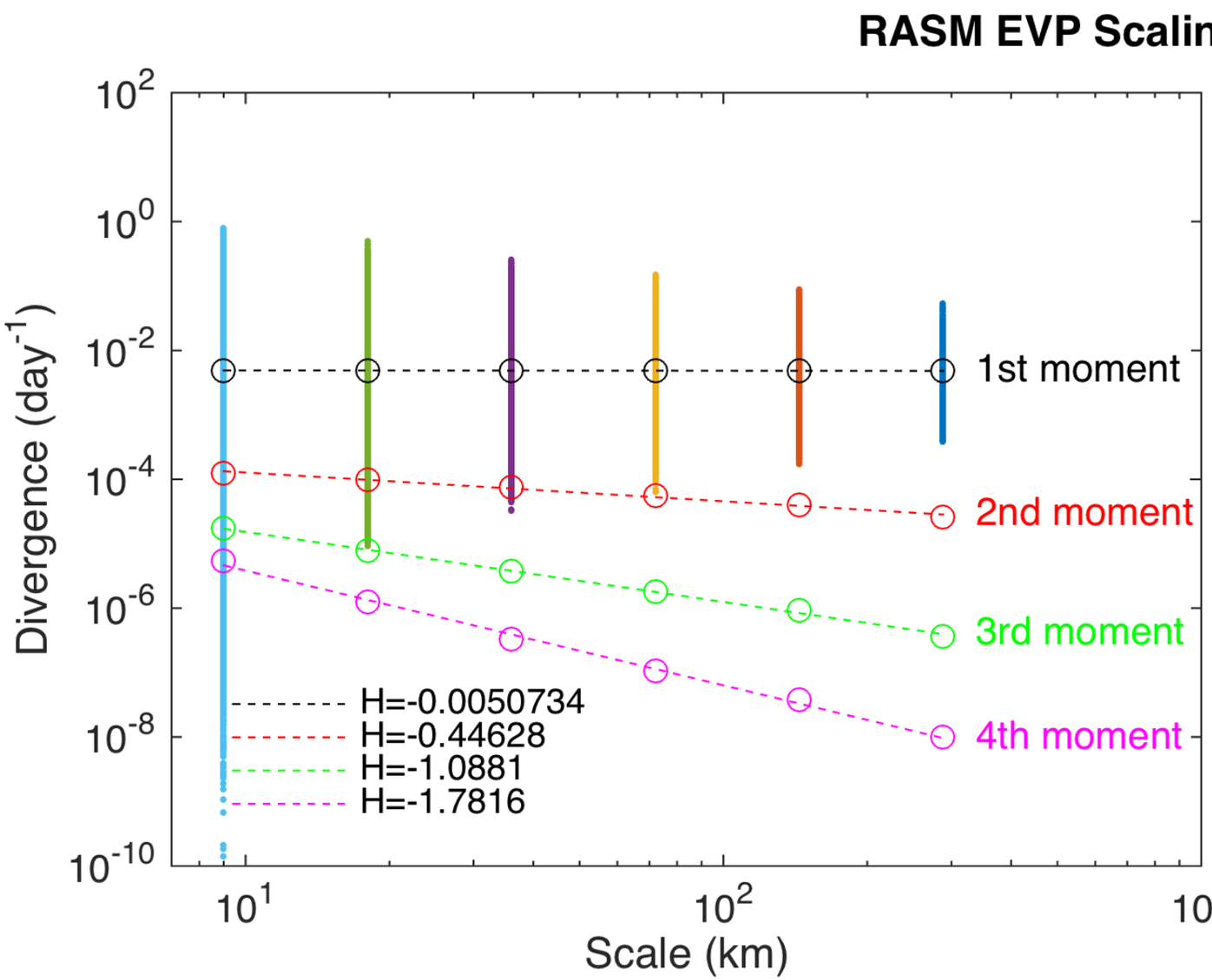
Anisotropic

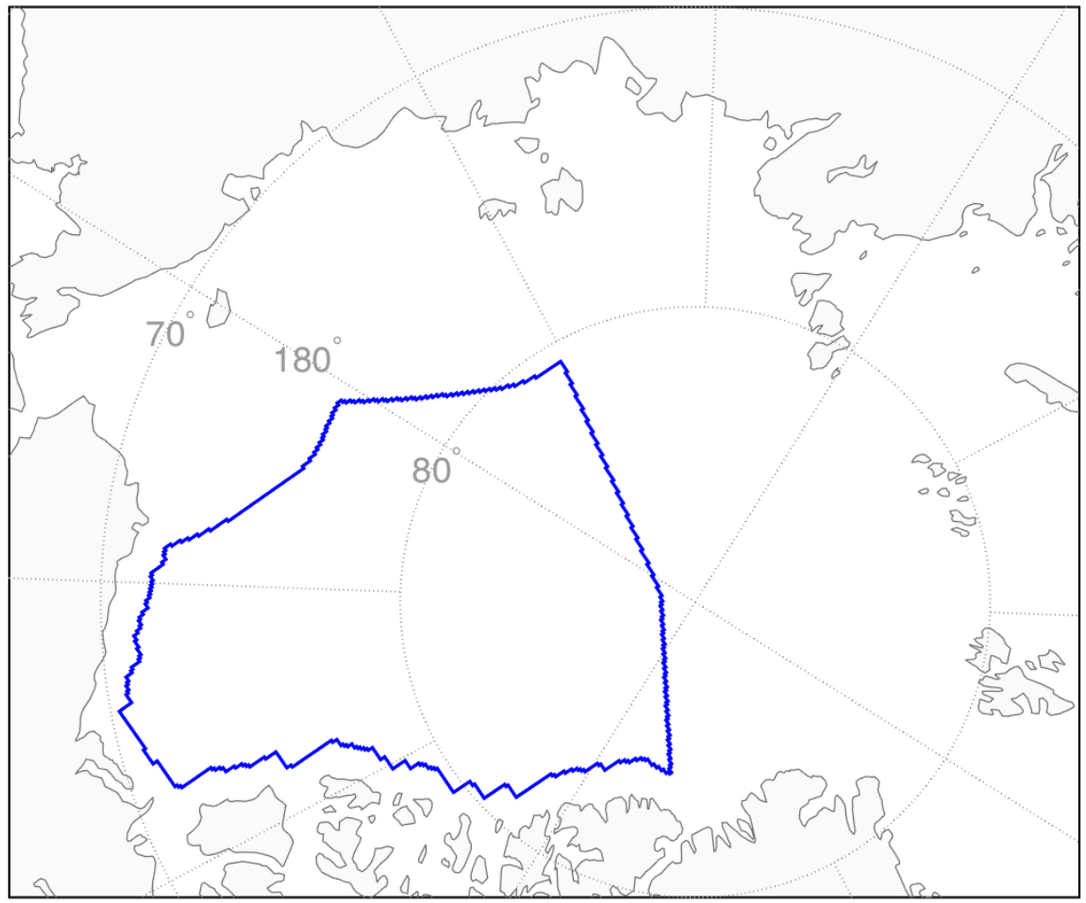
Pathfinder

↑ 10 9 8 7 6 5 4 3 2 1 0

cm s^{-1}

Scaling in sea ice divergence from 2 hourly snapshots



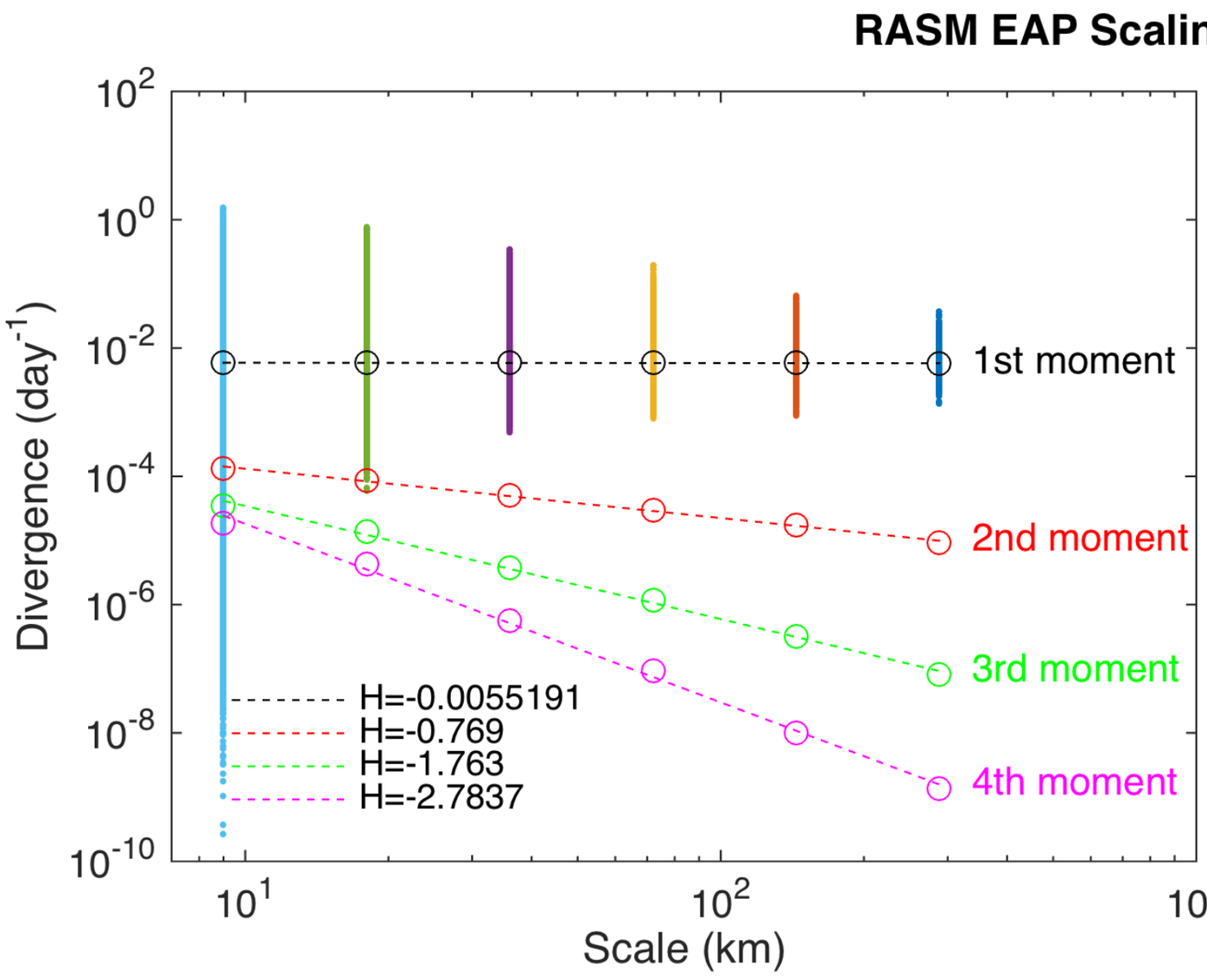


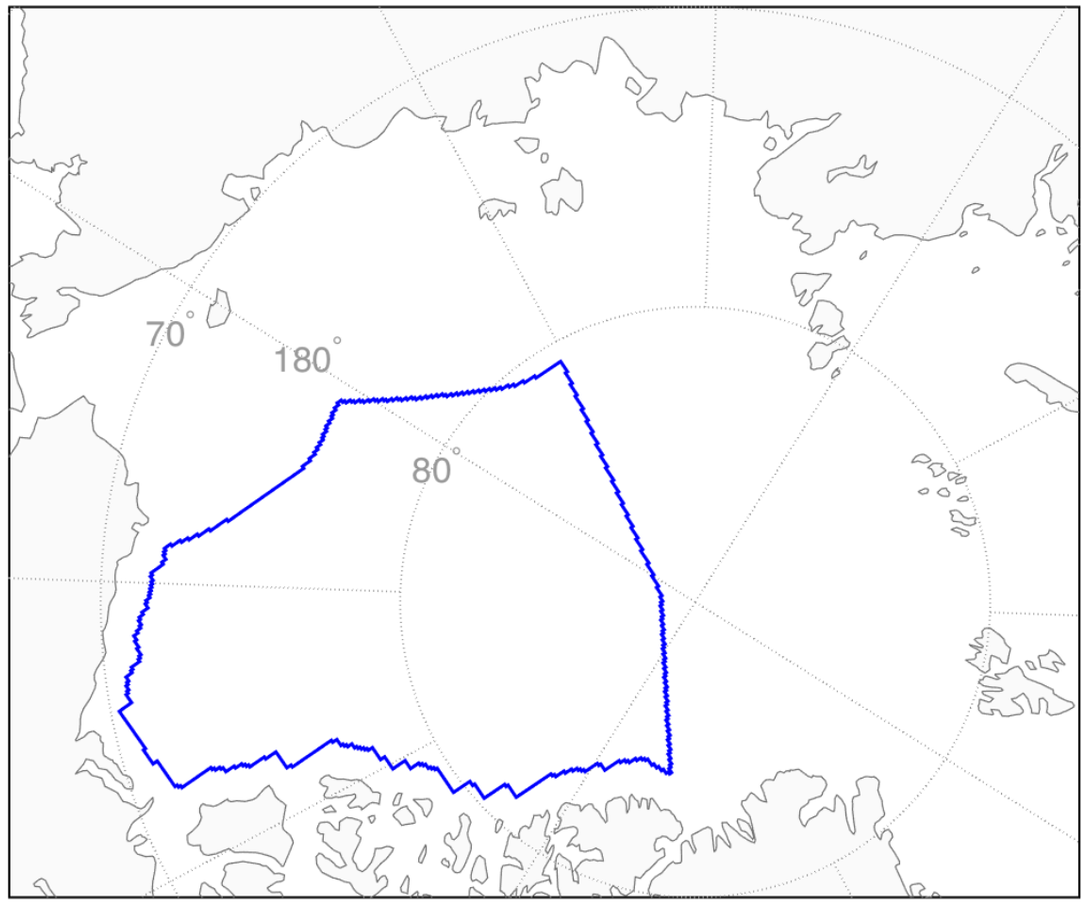
$$\left|\nabla \cdot \tilde{u}\right| \propto L^{H}$$

$\tilde{u}$ = sea ice velocity, L = length scale

H = 1st moment scaling exponent (observations $\cong -0.20$)

Scaling in sea ice divergence from 2 hourly snapshots





$$\left|\nabla \cdot \tilde{u}\right| \propto L^{H}$$

$\tilde{u}$ = sea ice velocity, L = length scale

H = 1st moment scaling exponent (observations $\cong -0.20$)

Scaling in sea ice divergence from 2 hourly snapshots

H	EVP		EAP	
	March	**September**	**March**	**September**
Canada Basin	-0.005	-0.021	-0.006	-0.011
Central Arctic	-0.036	-0.022	-0.034	-0.059

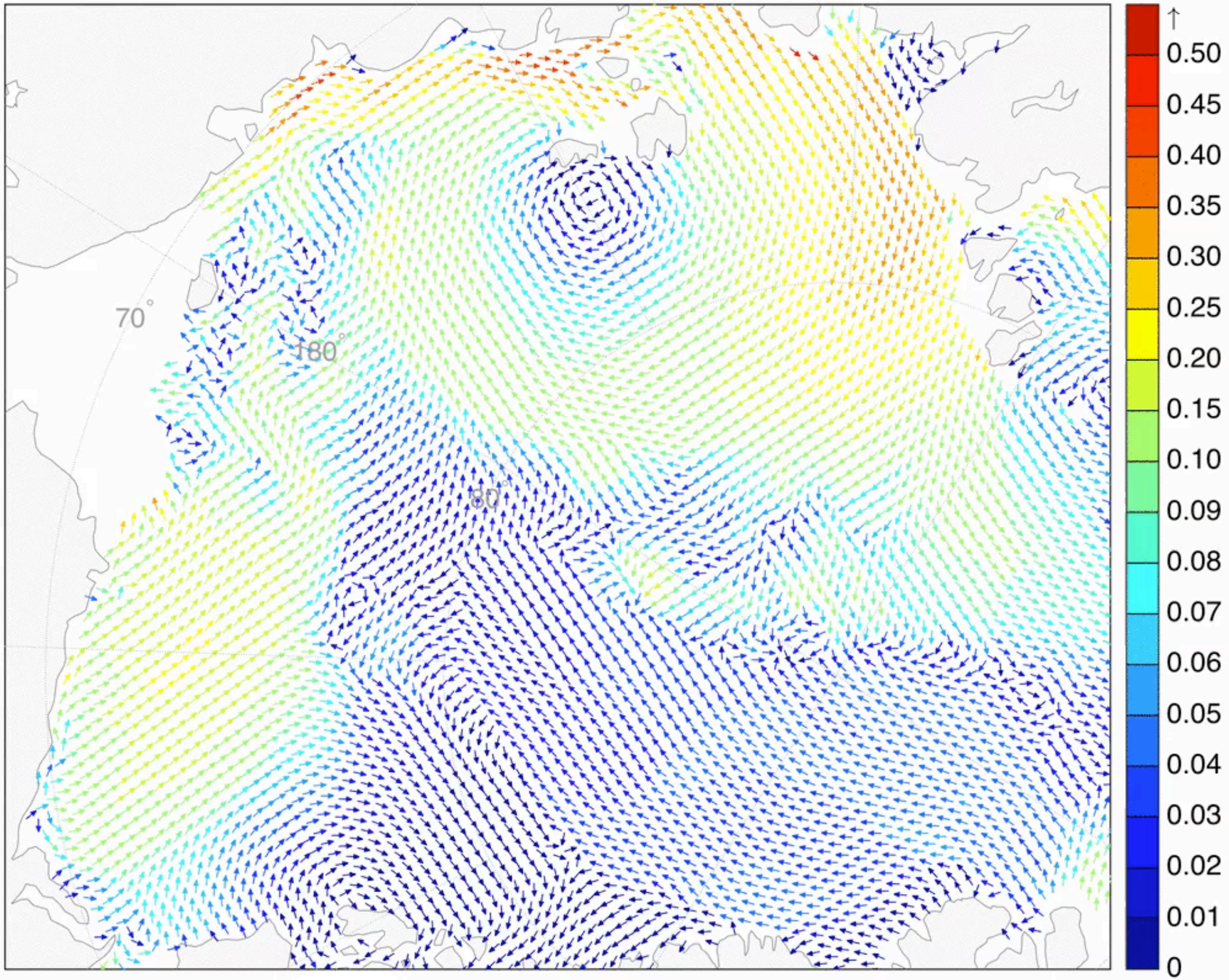
$$|\nabla \cdot \tilde{u}| \propto L^{H}$$

$$\tilde{u} = \text{sea ice velocity}, L = \text{length scale}$$

$$H = \text{1st moment scaling exponent (observations} \cong -0.20)$$

Previous results in RASM with thinner sea ice have produced values of *H*=-0.23, suggesting a role of sea ice thickness in the precise value of *H*.

RASM Anisotropic Sea Ice Velocity 1996-07-31



EVP spring thickness evaluation against Kwok and Cunningham (2008) on SSM/I mesh

February-March 2004 | February-March 2005 | February-March 2006 | March-April 2007 | Februry-March 2008

RASM

ICESat

Difference

7.0
6.0
5.0
4.0
3
2.5
2.0
1.5
1.0
0.5
0.1
m

2.5
2.0
1.5
1.0
0.5
-0.5
-1.0
-1.5
-2.0
-2.5
m

Anisotropic spring thickness evaluation against Kwok and Cunningham (2008) on SSM/I mesh

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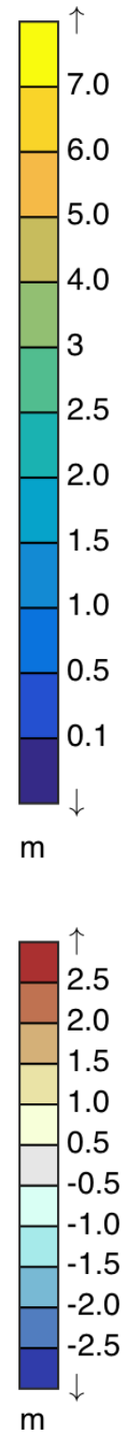
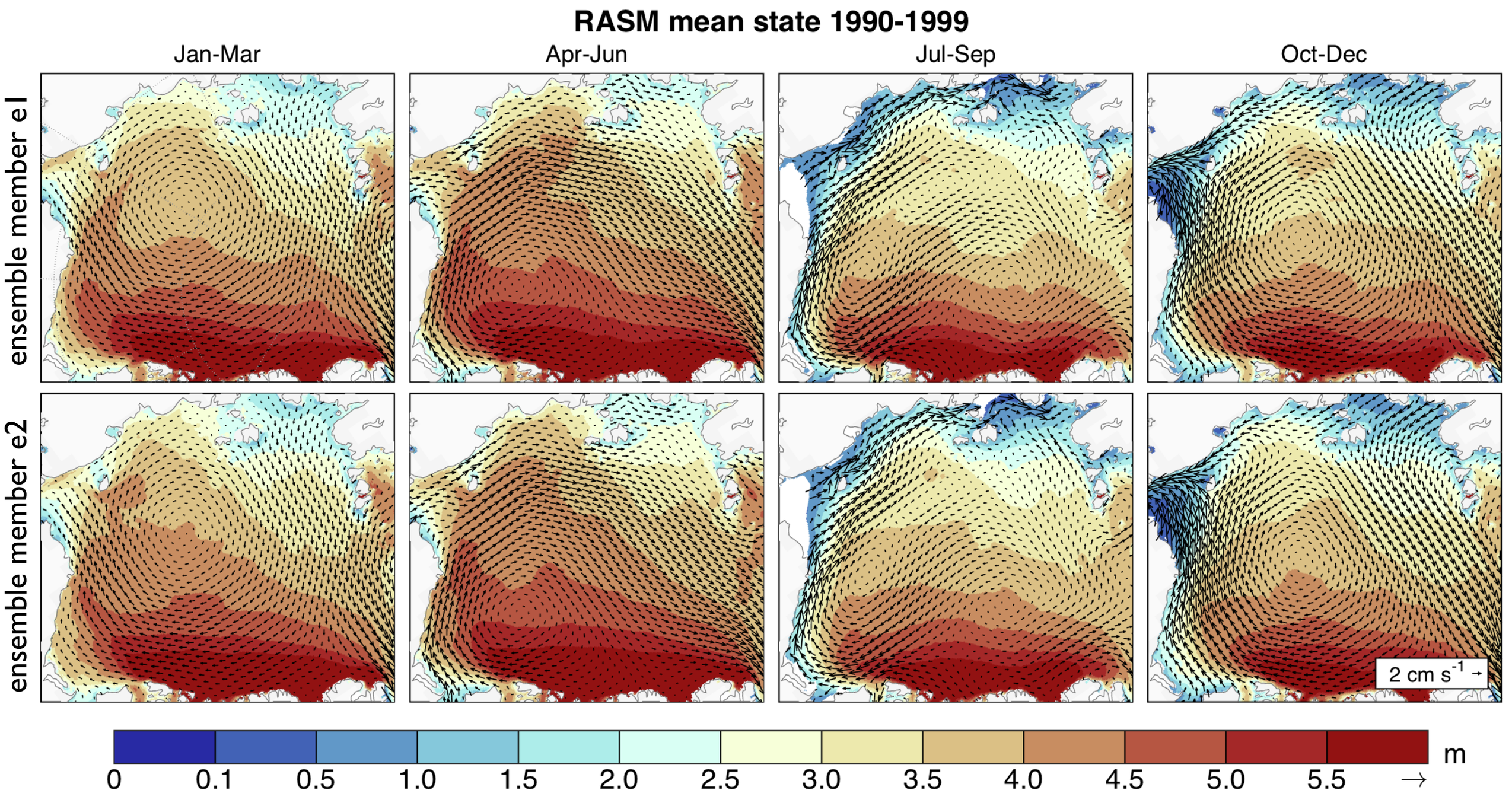
RASM

ICESat

Difference



Internal variability in RASM 1.0: Initial conditions



RASM Geostrophic Surface Wind Streamlines 1989-1999

e1 e2 ERA-Interim

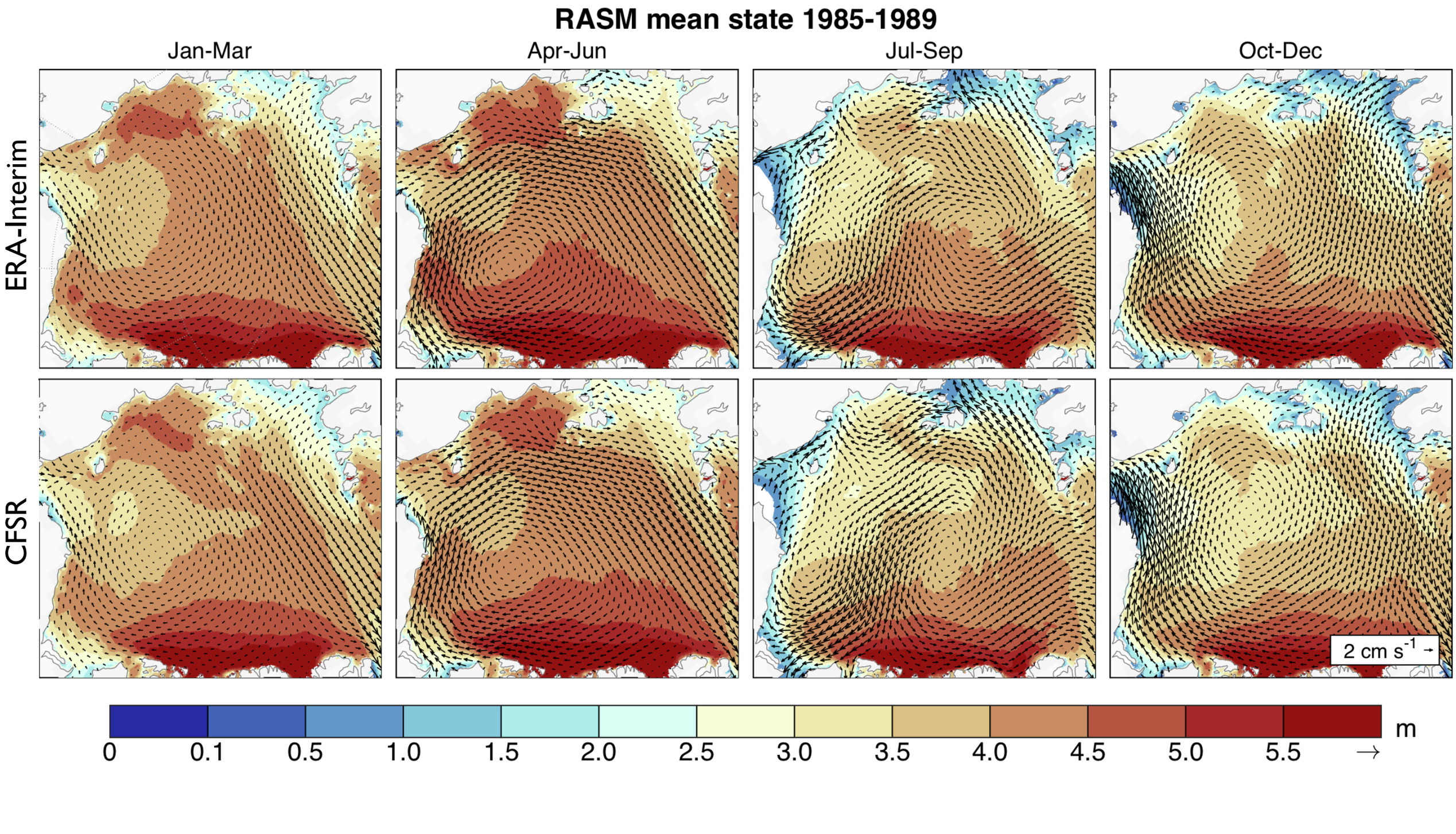
December-February

March-May

June-August

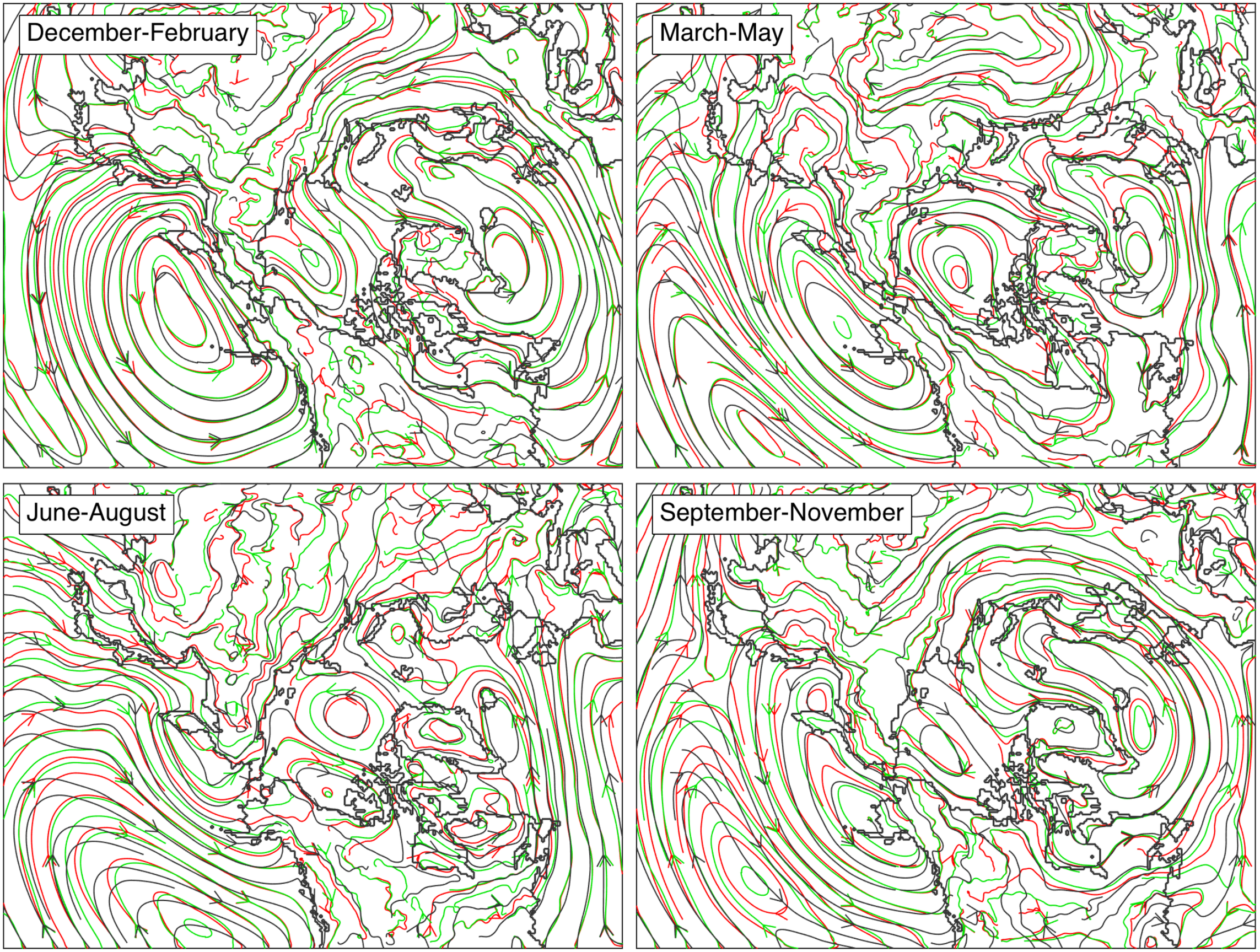
September-November

Internal variability in RASM 1.0: Boundary conditions

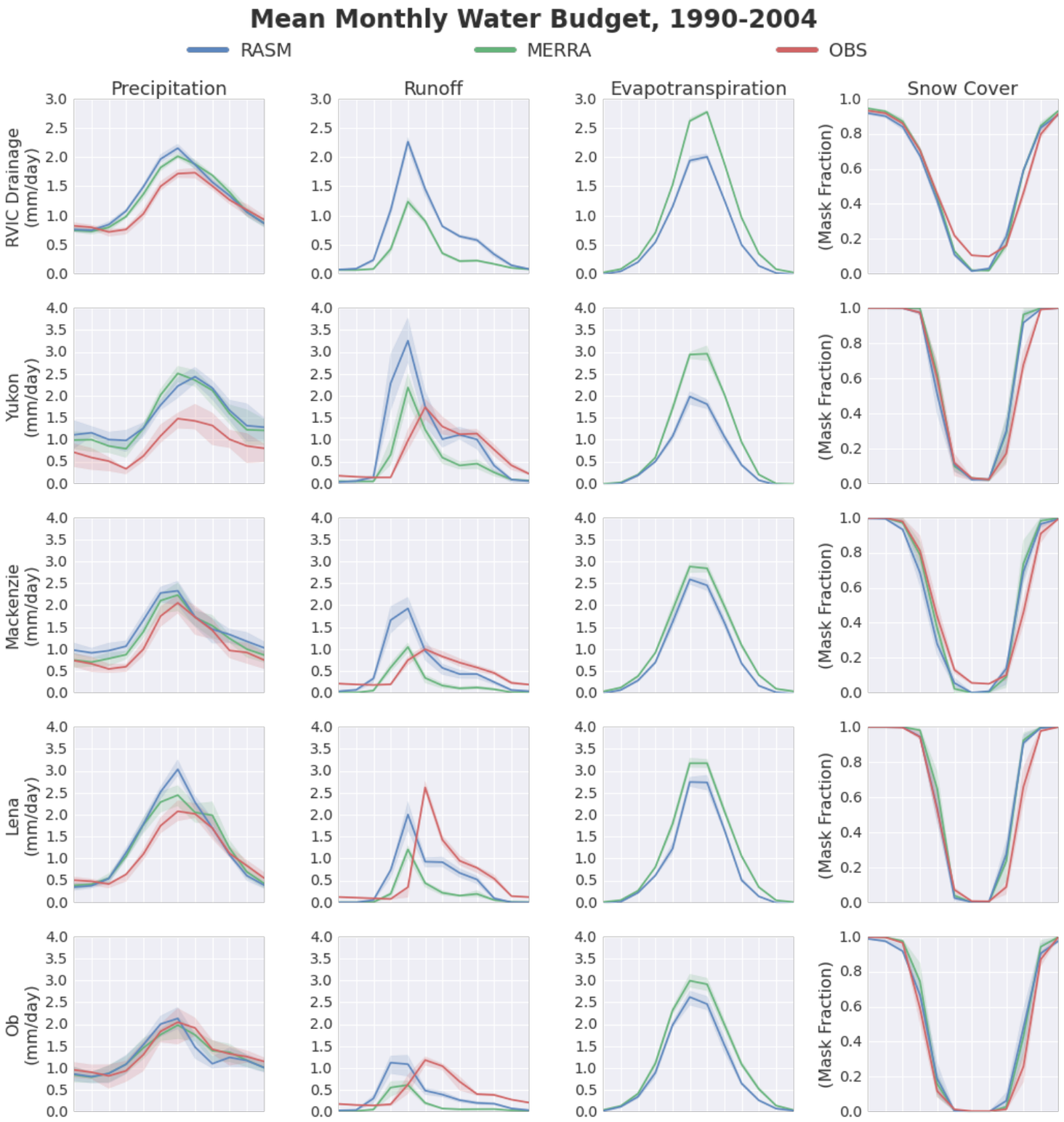


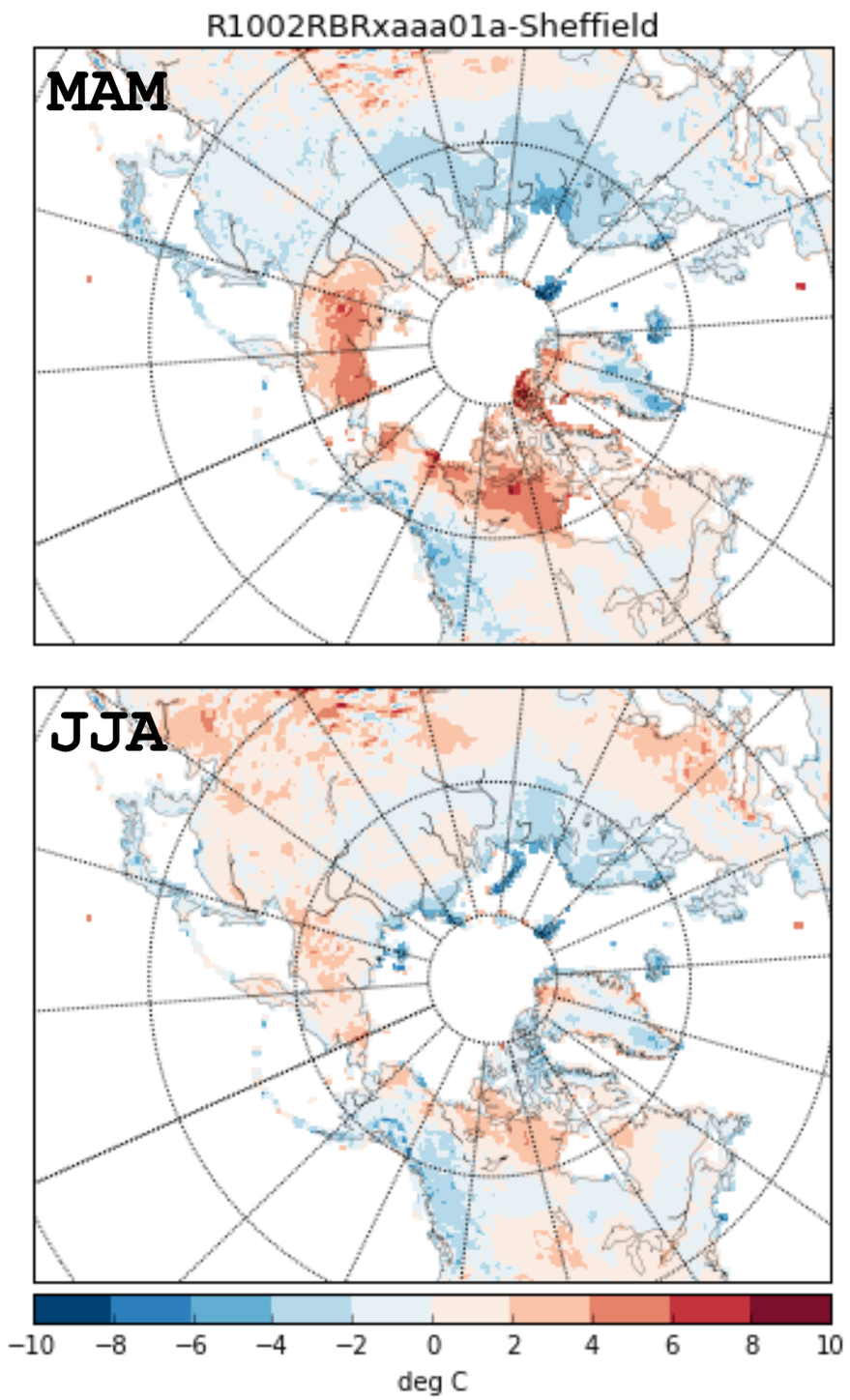
RASM Geostrophic Surface Wind Streamlines 1979-1989

ERA-Interim BCs — CFSR BCs — ERA-Interim



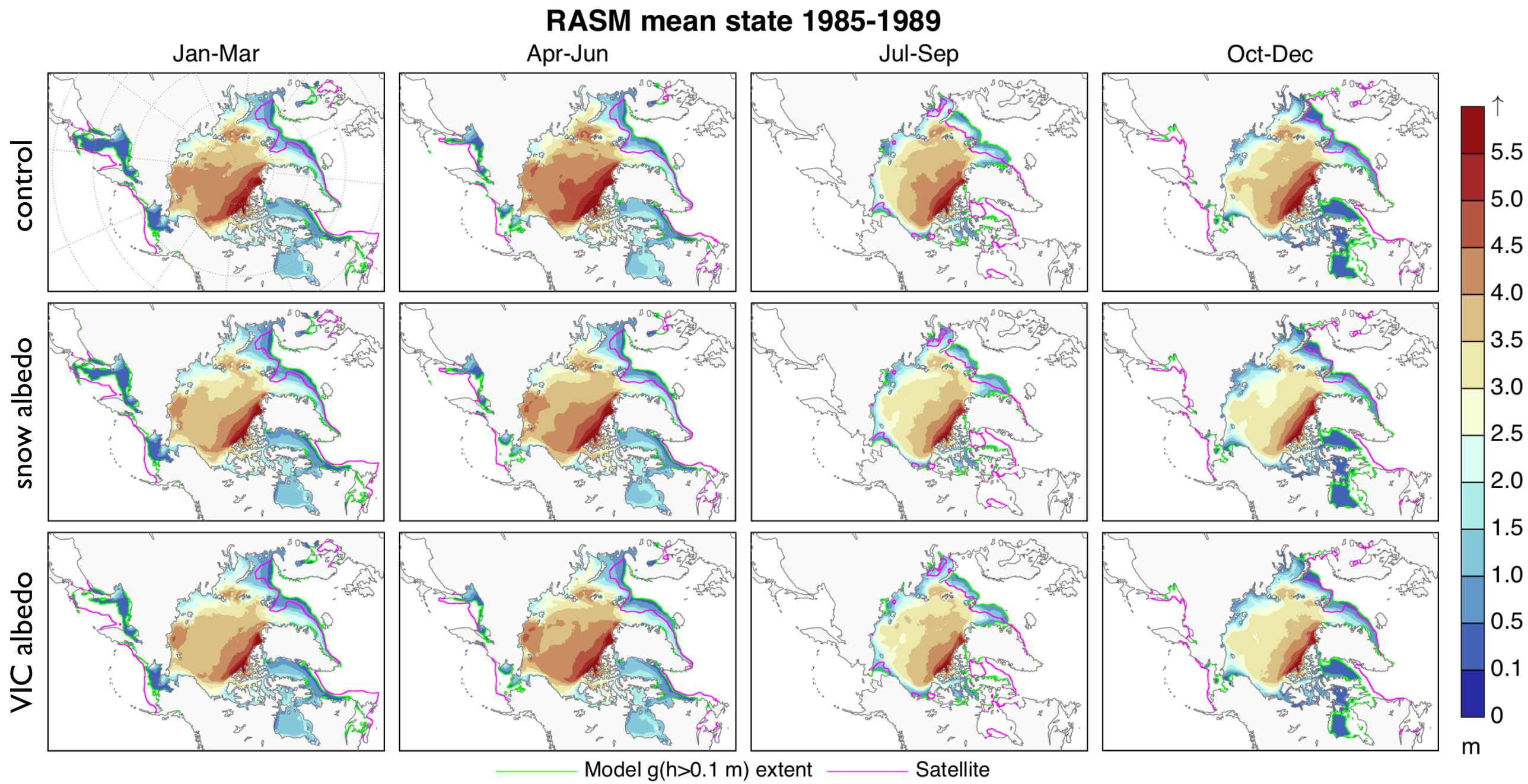
A broader look: Behavior in the Land Model





Courtesy of Joe Hamman and Bart Nijssen, University of Washington

Conclusion: RASM 1.0 is frozen except for CICE5 parameter space estimation and physics tests



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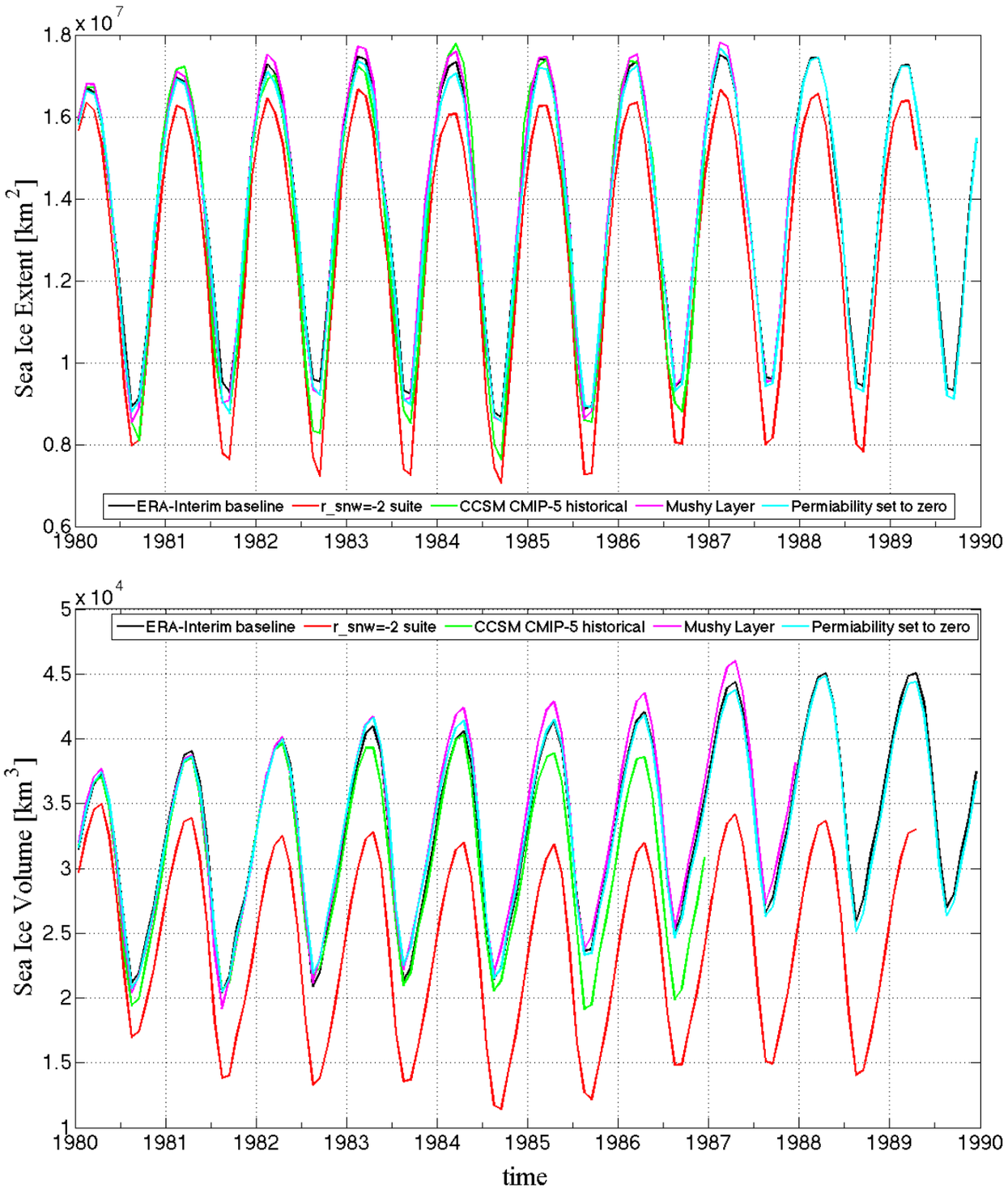

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