Sea Ice Dynamics Scaling in the Regional Arctic System Model

Andrew Roberts, Thomas Mills, Wieslaw Maslowski
and the RASM development team

Also see: T. J. MILLS, AN EVALUATION OF SEA ICE DEFORMATION AND ITS SPATIAL CHARACTERISTICS FROM THE REGIONAL ARCTIC SYSTEM MODEL, MASTERS THESIS, NAVAL POSTGRADUATE SCHOOL, DECEMBER 2012.

Department of Defense High Performance Computing Modernization Program

$D \propto L^H$ where $D = \sqrt{Div^2 + Shear^2}$, L = Length Scale, H = Scaling Exponent

Observed Dynamics Scaling

Marsan et al. 2004

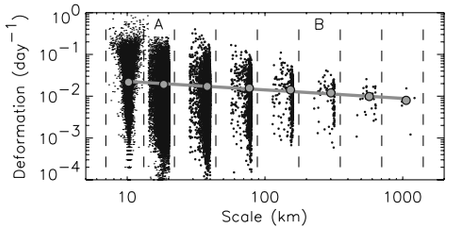


FIG. 2. Total deformation rate $\dot{\epsilon}_L$ as a function of scale L (81586 samples). Vertical dashes define bins. Gray dots are means within each bin. Gray solid line is least squares fit to mean values. *A* is 13–20 km scale; *B* is 160–320 km scale.

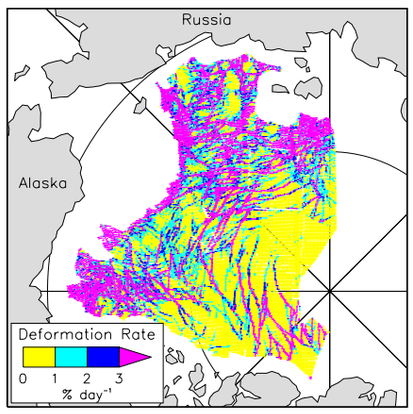


FIG. 1 (color online). Sea-ice deformation rate on 6 November 1997 from 42571 RGPS cells.

H = -0.2

3 day RGPS sampling

Stern and Lindsay 2009

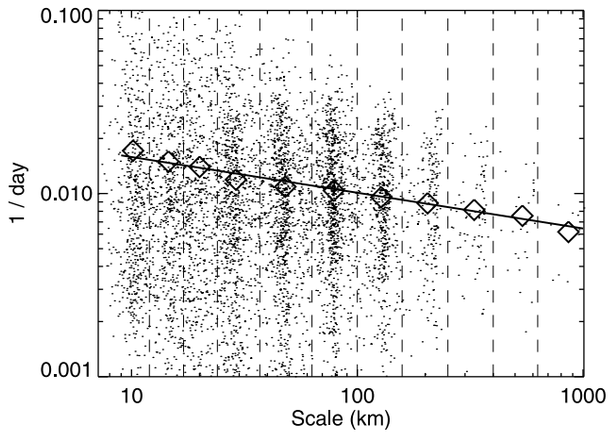
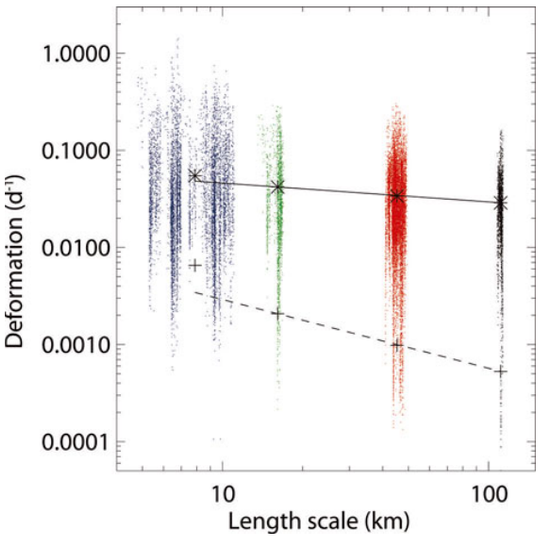


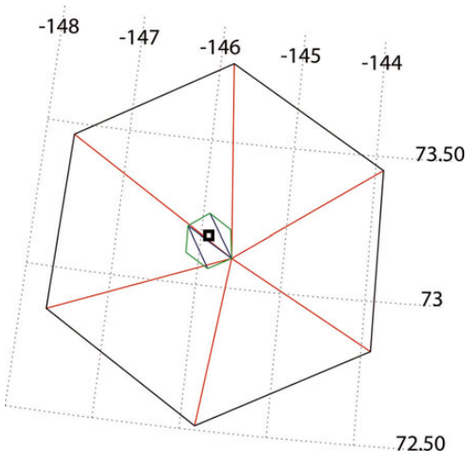
Figure 3. Total deformation $\dot{\varepsilon}$ (day^{-1}) versus spatial scale L (km) for the 6778 samples of deformation computed from the snapshot of 20 April 1999. Each dot represents one estimate of the deformation (vertical axis) at a particular spatial scale (horizontal axis). The vertical dashed lines delineate the scale bins. The diamonds show the mean deformation for each bin, and the straight line is the best linear fit to the means, with a slope of $b = -0.15$ and a squared correlation of 0.96.

H ≈ -0.20

3 day RGPS sampling

Hutchings et al. 2011





H = -0.19

10 minute GPS sampling

Modeled

Girard et al. 2009

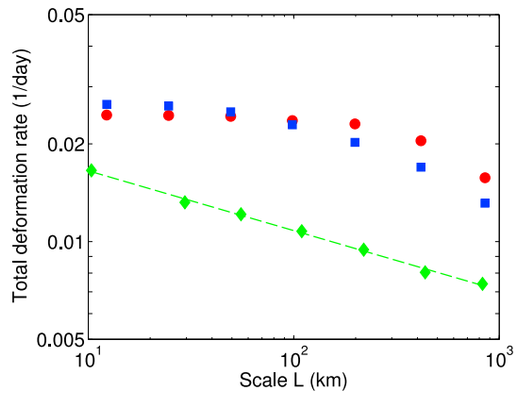


Figure 10. Mean total deformation rate $\langle \dot{\epsilon}_{tot} \rangle$ as a function of spatial scale L, obtained with RGPS observations (green diamonds), LIMVP (red circles), and LIMEVP (blue squares) simulations. The dashed line is the least squares fit for RGPS data $\langle \dot{\epsilon}_{tot} \rangle \sim L^{-0.18}$.

Louvain-la-Neuve Ice Model

Model "almost scale independent"

H = -0.18 (observed)

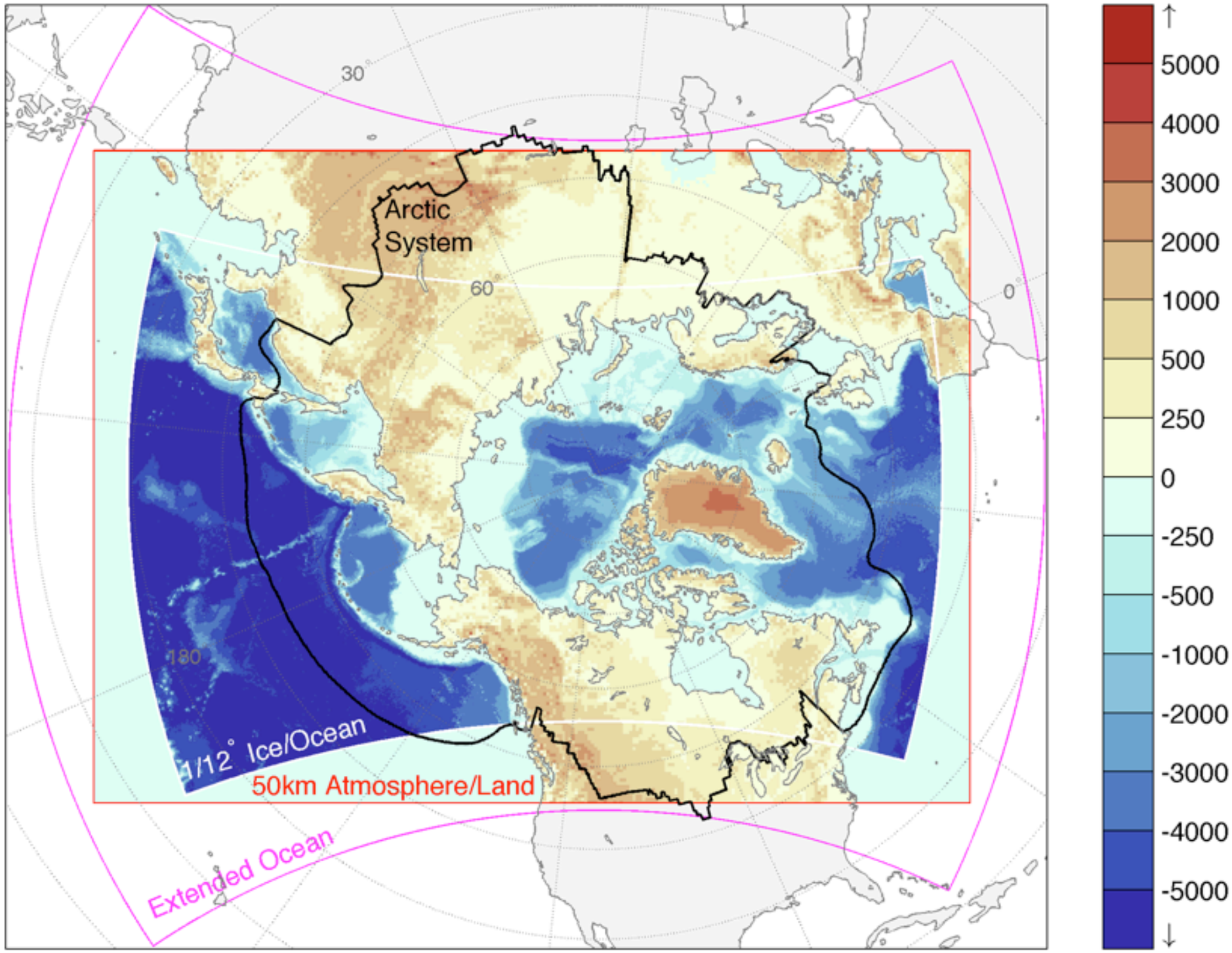
3 day RGPS sampling

H is an example of a metric applicable across multiple model configurations

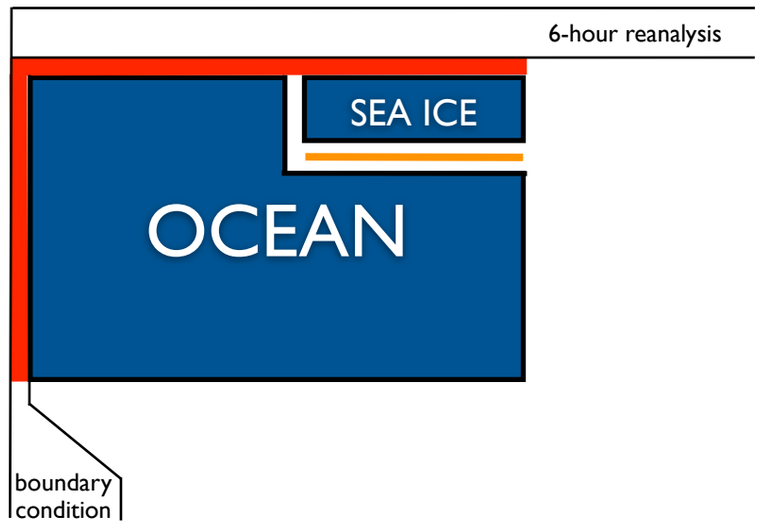
Is *H* a useful metric for high resolution sea ice mechanics simulations?

Broader question:
Have polar biases been introduced into Earth System Models by using development models constrained at coupling boundaries?

The Regional Arctic System Model



Previous modeled *H* results have used calculations with a stand-alone ice-ocean model

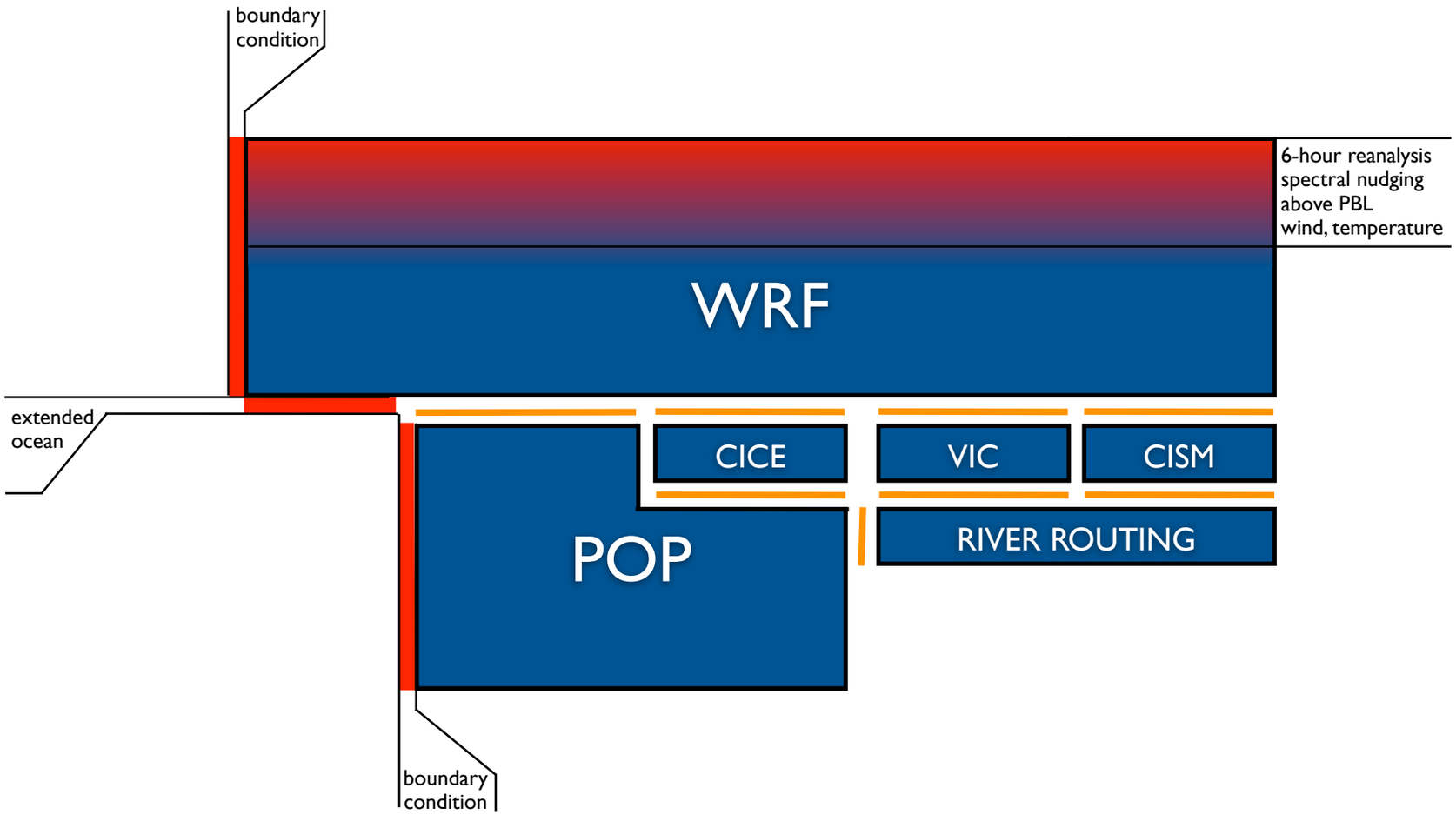


-Oceanic constraint

-Coupling channels between component models

-Component models

Do *H* calculations with constraints removed from coupling boundaries produce the same results?

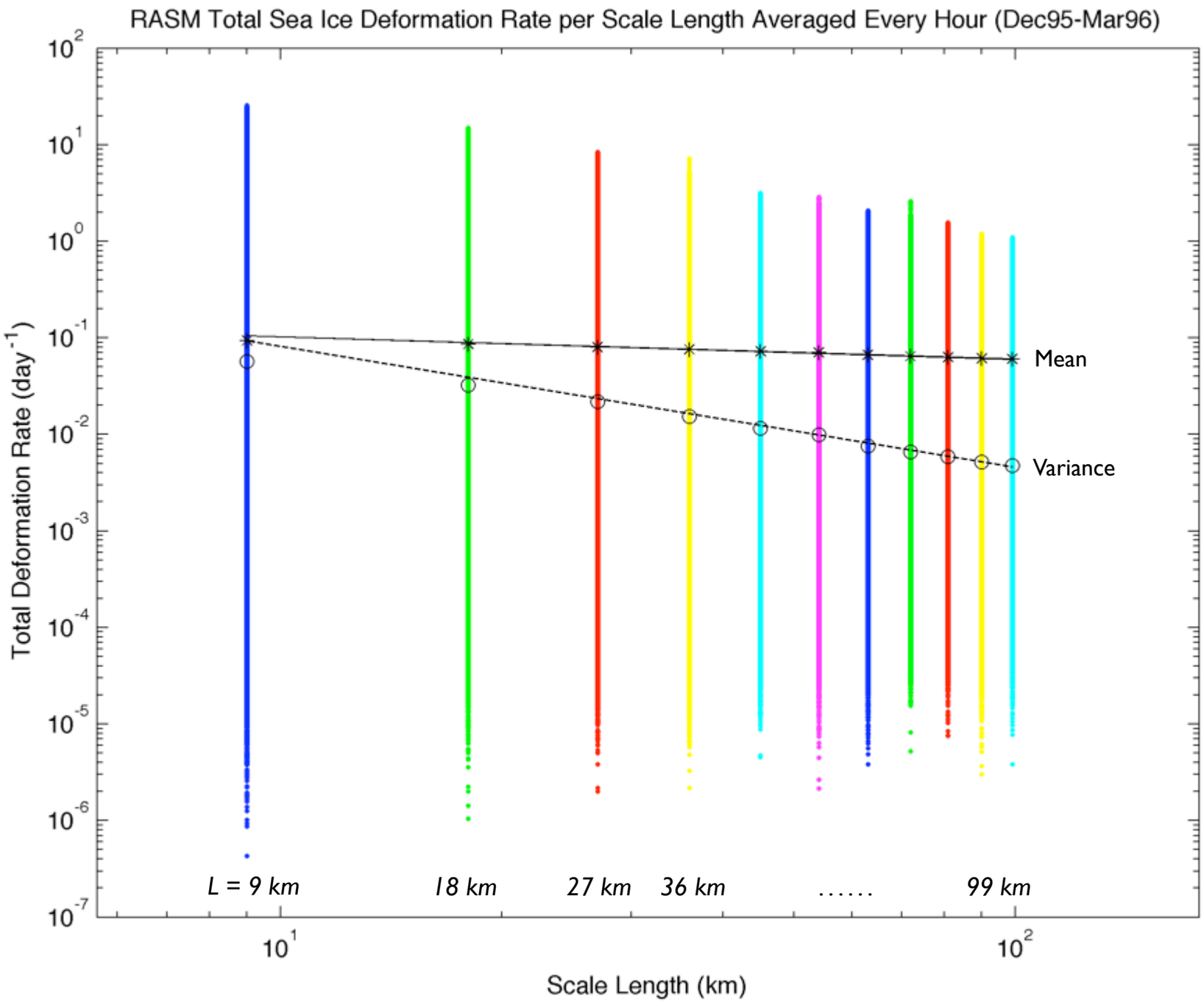


-Atmospheric and oceanic constraint

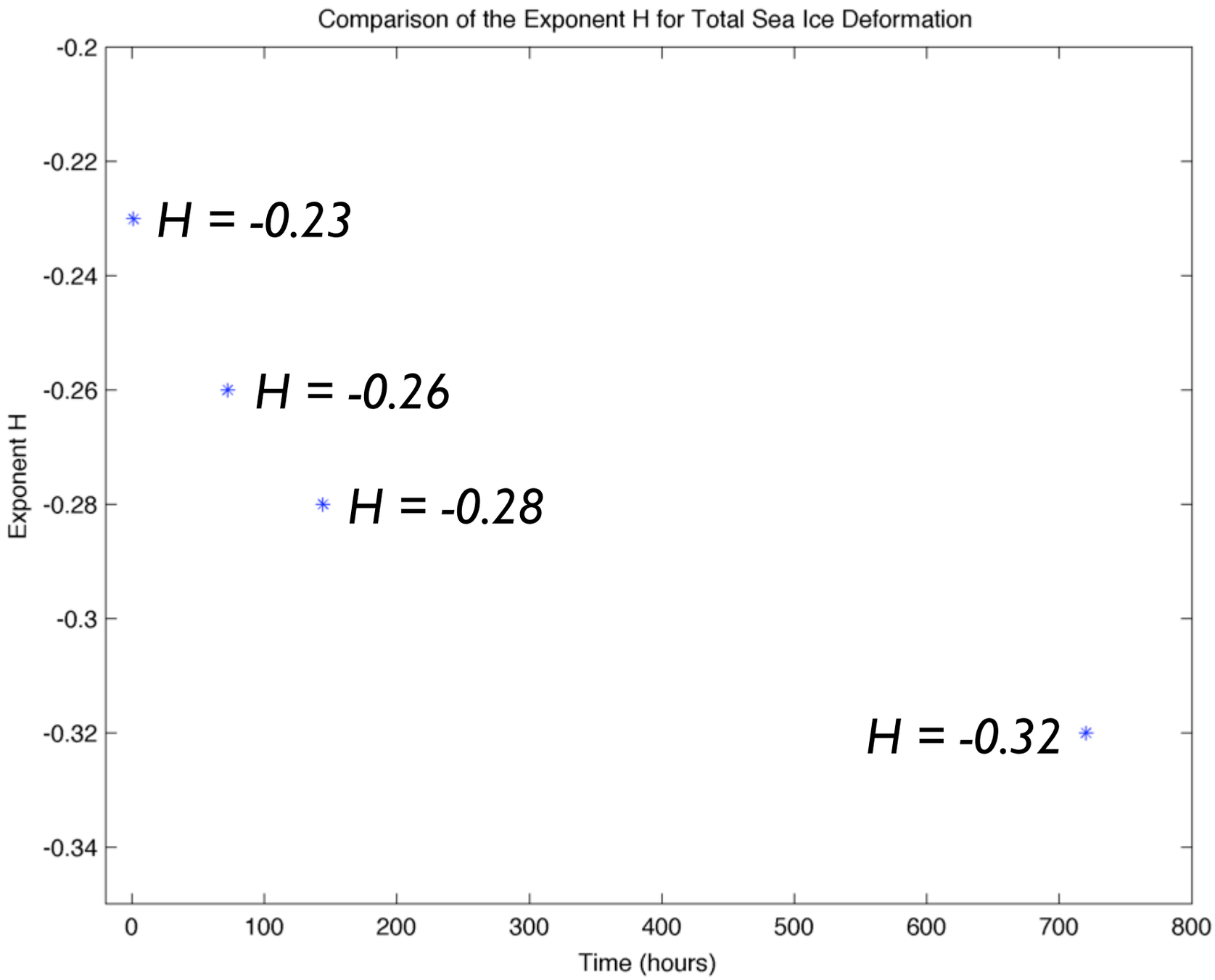
-Coupling channels between component models

-Component models

Sea Ice Deformation Scaling in RASM
Hourly Velocity : *H = -0.23*



Sea Ice Deformation Scaling in RASM
Relationship of scaling to period



RASM results in context

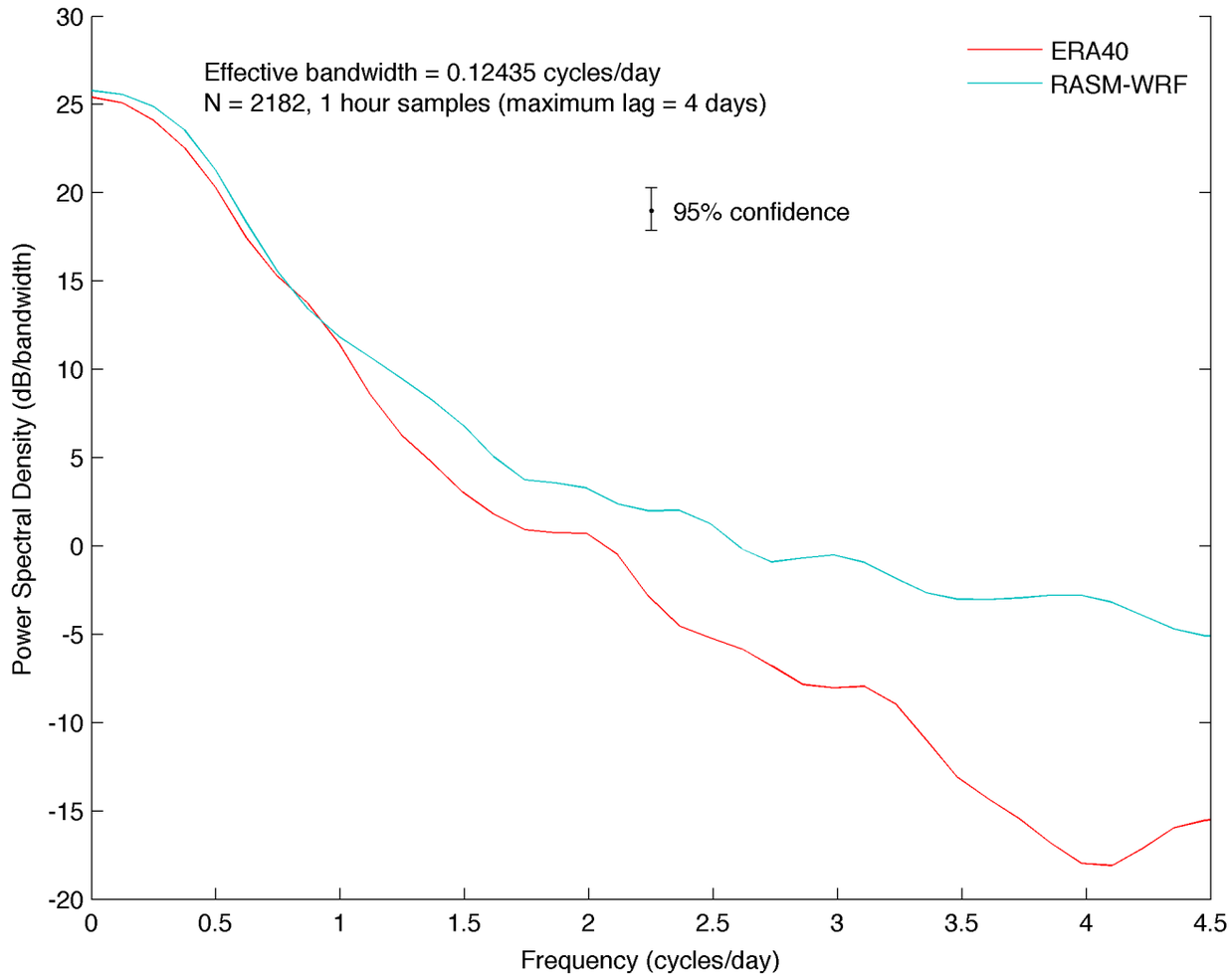
Source	Method of Observation	Temporal Sampling	*H*
Marsan et al. (2004)	RGPS	3 Days	-0.2
Stern and Lindsay (2009)	RGPS	3 Days	~-0.2
Girard et al. (2009)	RGPS	3 Days	-0.18
Hutchings et al. (2010)	GPS Buoys	10 minutes	-0.19

Source	Model	Temporal Sampling	*H*
Girard et al. (2009)	LIM in DRAKKAR 12km	3 Days	"almost scale independent"
Mills (2012)	CICE in RASM ~9km	1 hour; 3, 6 & 30 days	-0.23, -0.26, -0.28, -0.32

Coupled atmospheric models supply red noise to the ice and ocean at higher frequencies than do reanalyses

$$m\frac{\partial \widetilde{u}}{\partial t} = \widetilde{\tau}_w + \widetilde{\tau}_a - mf\mathbf{k}\times\widetilde{u} - mg\nabla\eta - m\left(\widetilde{u}\cdot\nabla\right)\widetilde{u} + \frac{\partial \sigma_{mn}}{\partial x_n}$$

Beaufort Sea Wind Speed



Toward a FAMOS coordinated sea ice experiment

How can we account for constraints on the Arctic System in a FAMOS coordinated experiment?

Have biases been introduced into Earth System Models by using developments from ice-ocean models constrained at coupling boundaries?