The new Canadian operational regional ice-ocean prediction system (RIOPS) at 4-5km resolution in the Arctic

F. Dupont, J.-F. Lemieux, G. Smith, F. Roy, C. Beaudoin, Y. Lu, S. Higginson, J. Lei, J. Xu, F. Davidson, G. Garric, R. Bourdalle-Badie and other CONCEPTS collaborators

CONCEPTS
CANADIAN OPERATIONAL NETWORK OF COUPLED ENVIRONMENTAL PREDICTION SYSTEMS

Environment Canada

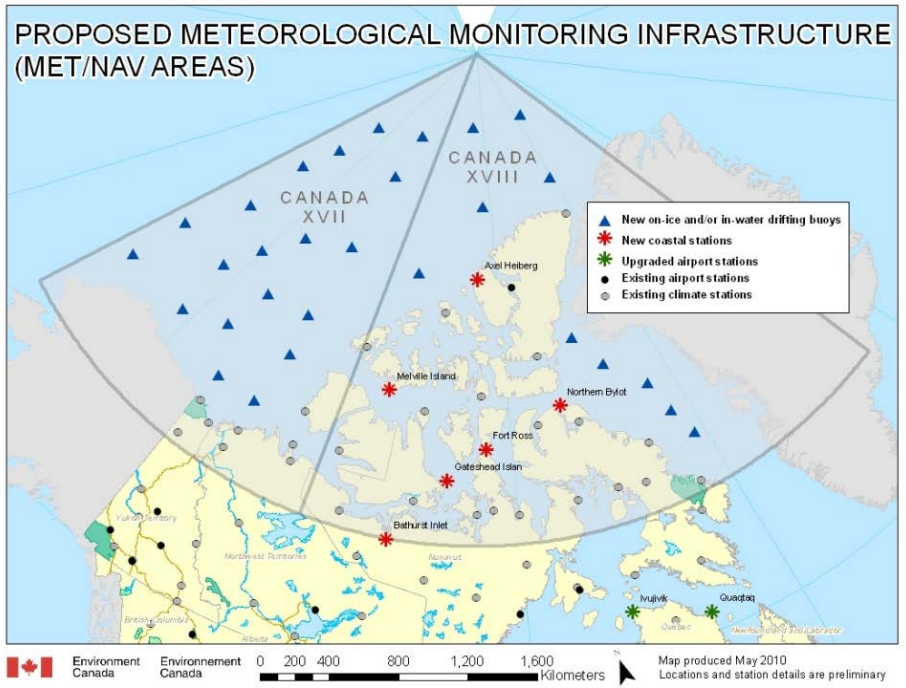
Fisheries and Oceans Canada

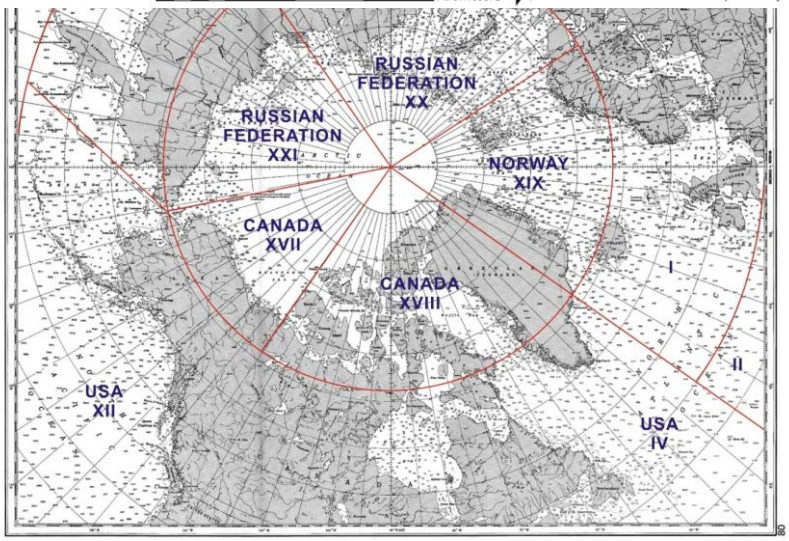
Mercator Ocean
Ocean Forecasters

CONCEPTS

National Defence

EC METAREAs Signature Project





- Development of an integrated marine Arctic prediction system in support of METAREA monitoring and warnings.
- Produce short-term marine forecasts using a regional high-resolution coupled multi-component modelling and data assimilation system
  - Atm, sea ice, ocean, snow, wave
- Improved Arctic monitoring
- Motivated the development of RIPS, and eventually coupled...

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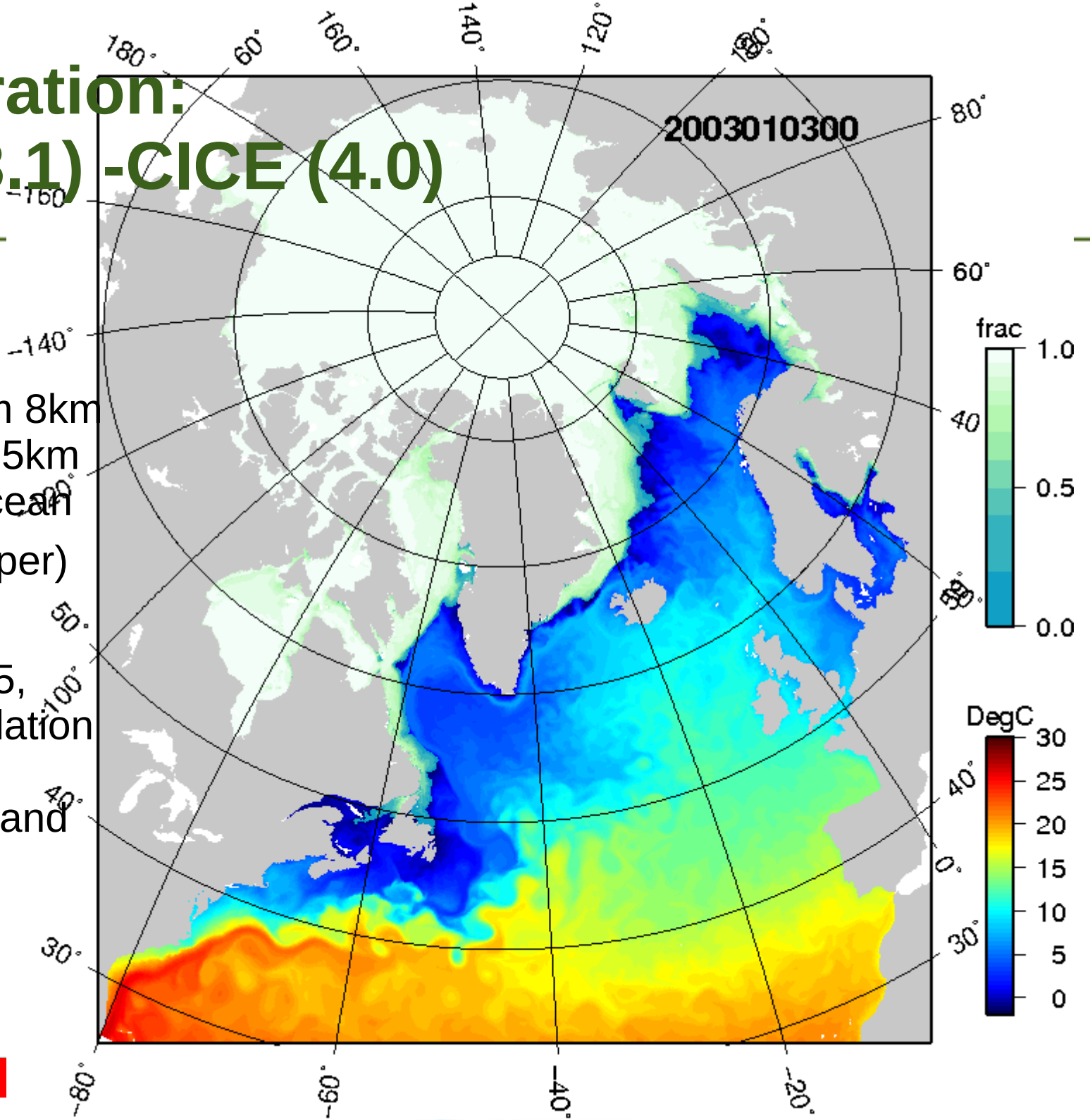
Configuration: NEMO (3.1) -CICE (4.0)

Resolution from 8km to 2km, mostly 5km in the Arctic Ocean (GMD 2015 paper)

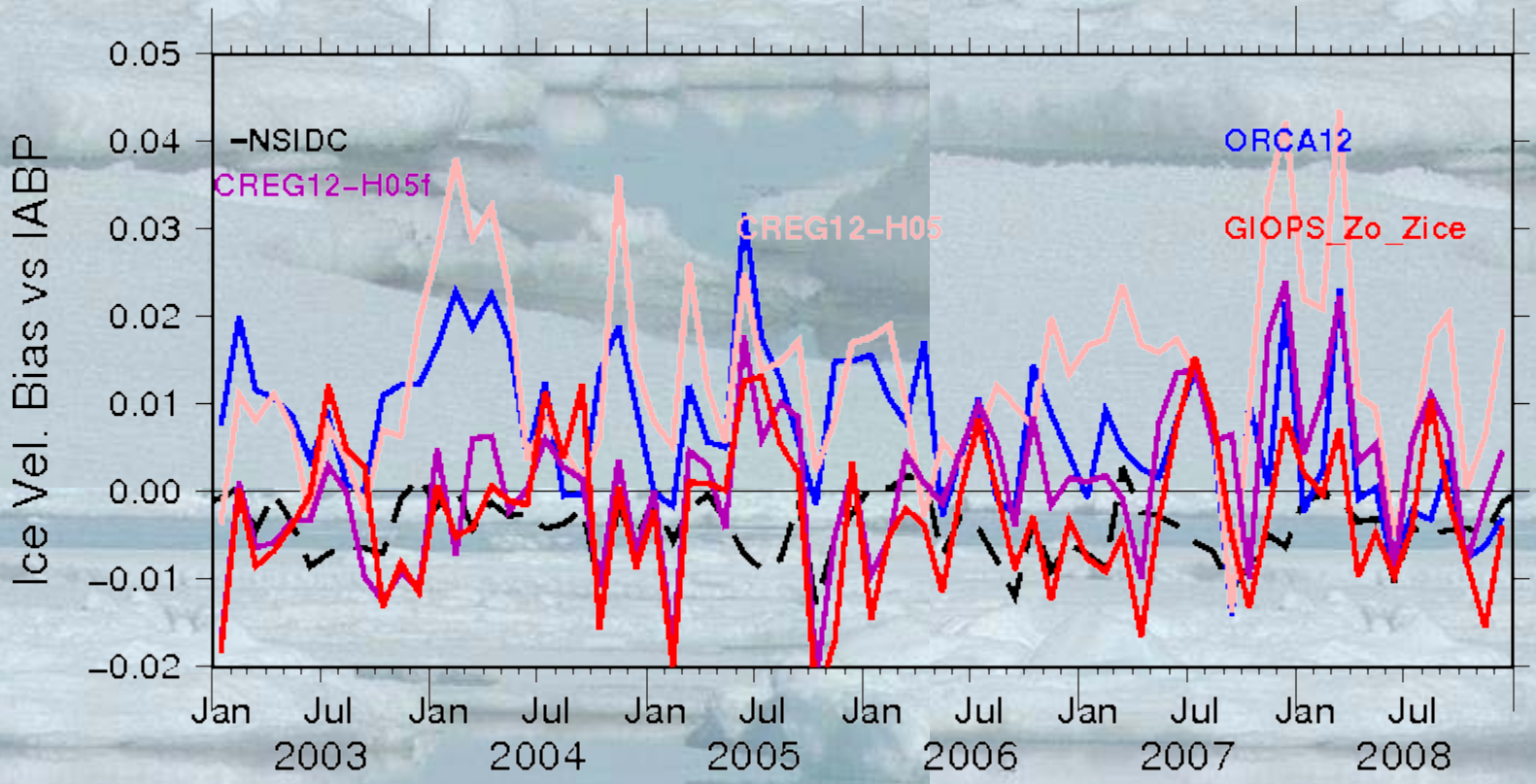
Roy et al. (2015, JGR) on the relation between ice drag,velocities and ice thickness



Environment Canada

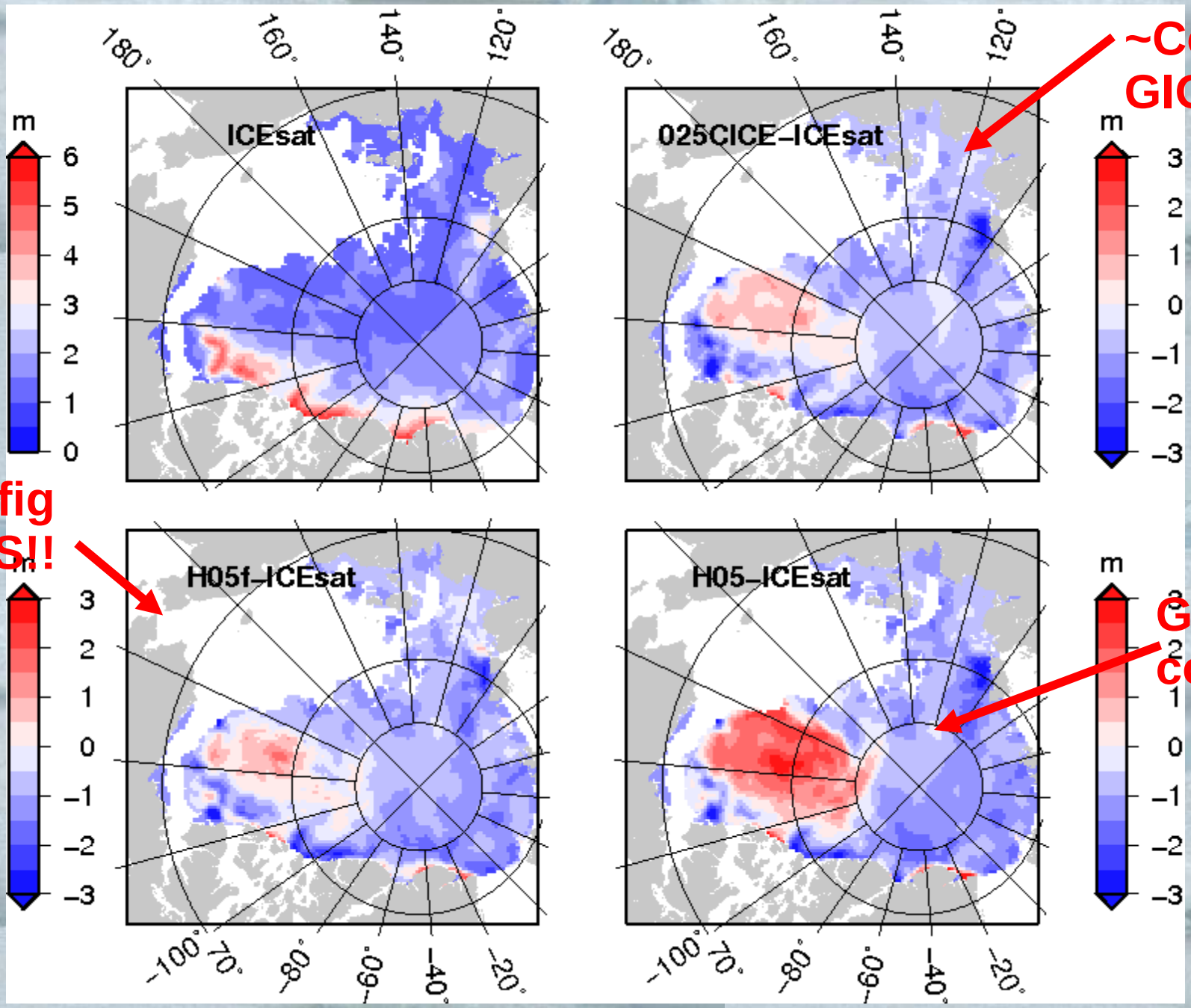
Ice velocity bias relative to IABP

(international Arctic Buoy Program)



Since the GMD paper, we found that the ice velocity can also be improved by changing the physics of the ocean: validation of the idea that the 1.5 Turbulence scheme (H05f) yields better results then those using 2.5 k-eps

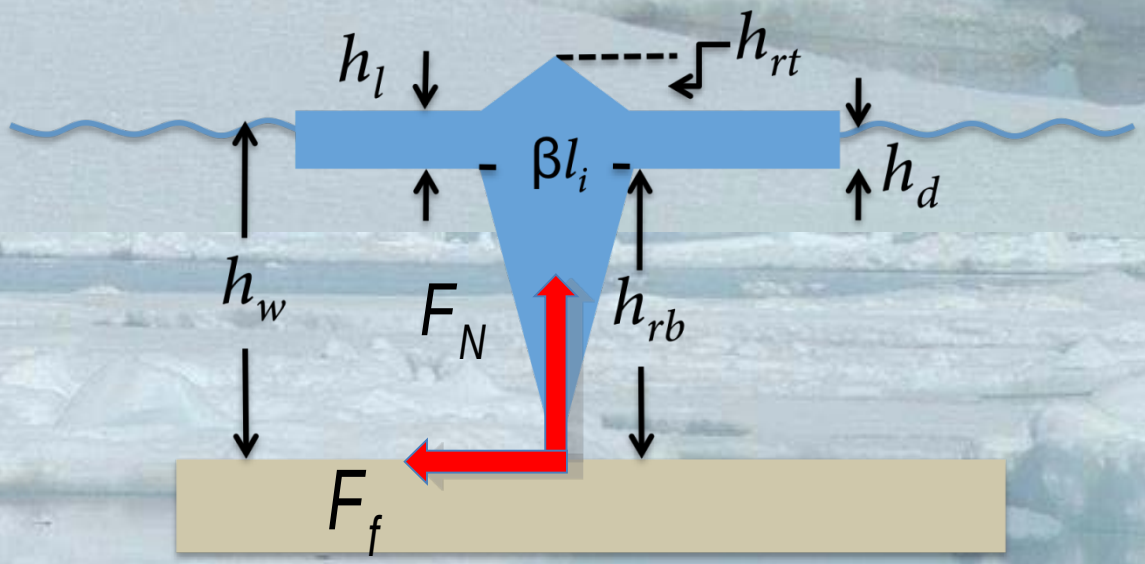
Ice thickness in Fall 2007 relative to ICESat



Other approaches not tested in CREG12 but in CREG025 that are implemented in RIOPS:

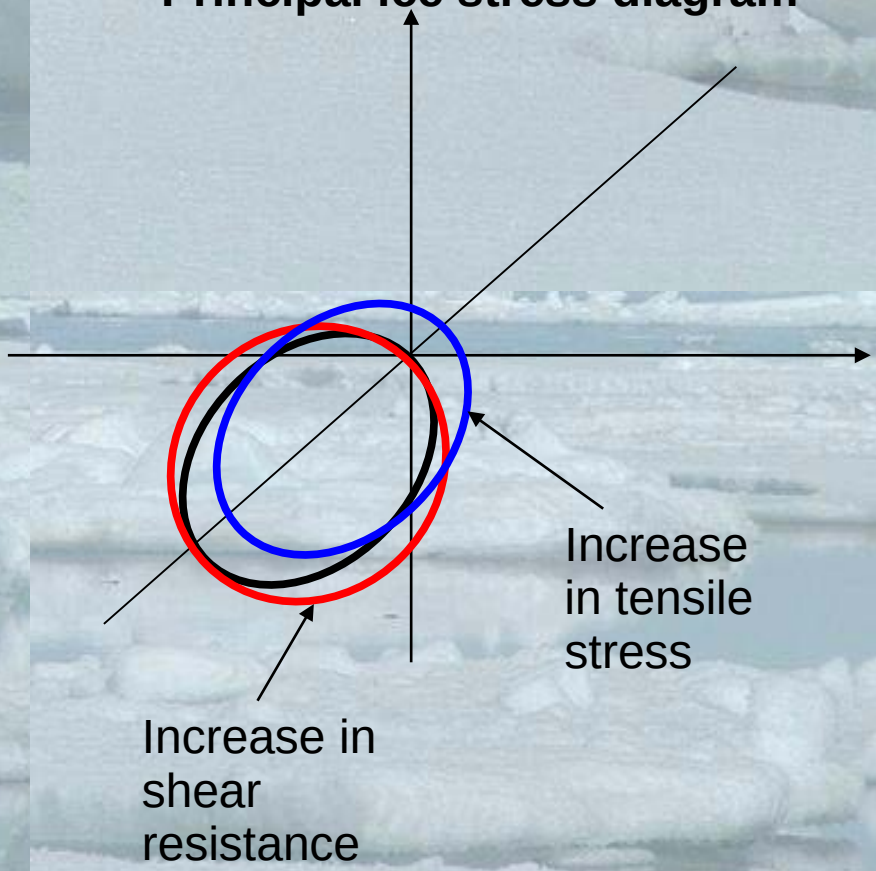
-Grounded landfast ice represented by a basal stress parametrization (Lemieux et al. 2015)

-Increase in shear and tension resistance (Lemieux et al., in preparation) improves the representation of land-locked ice (another form of landfast ice).



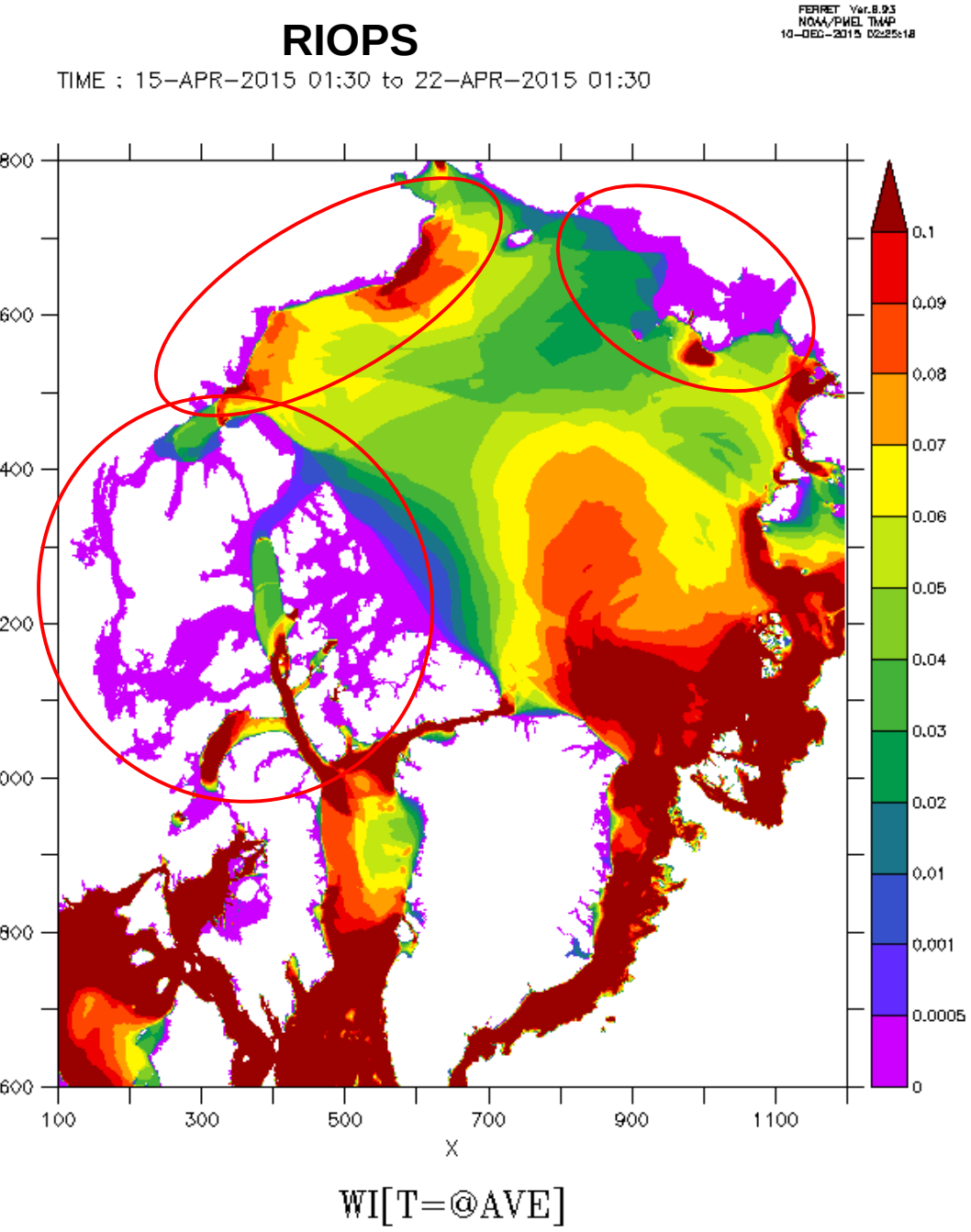
Ice ridge touching the ground

Principal ice stress diagram

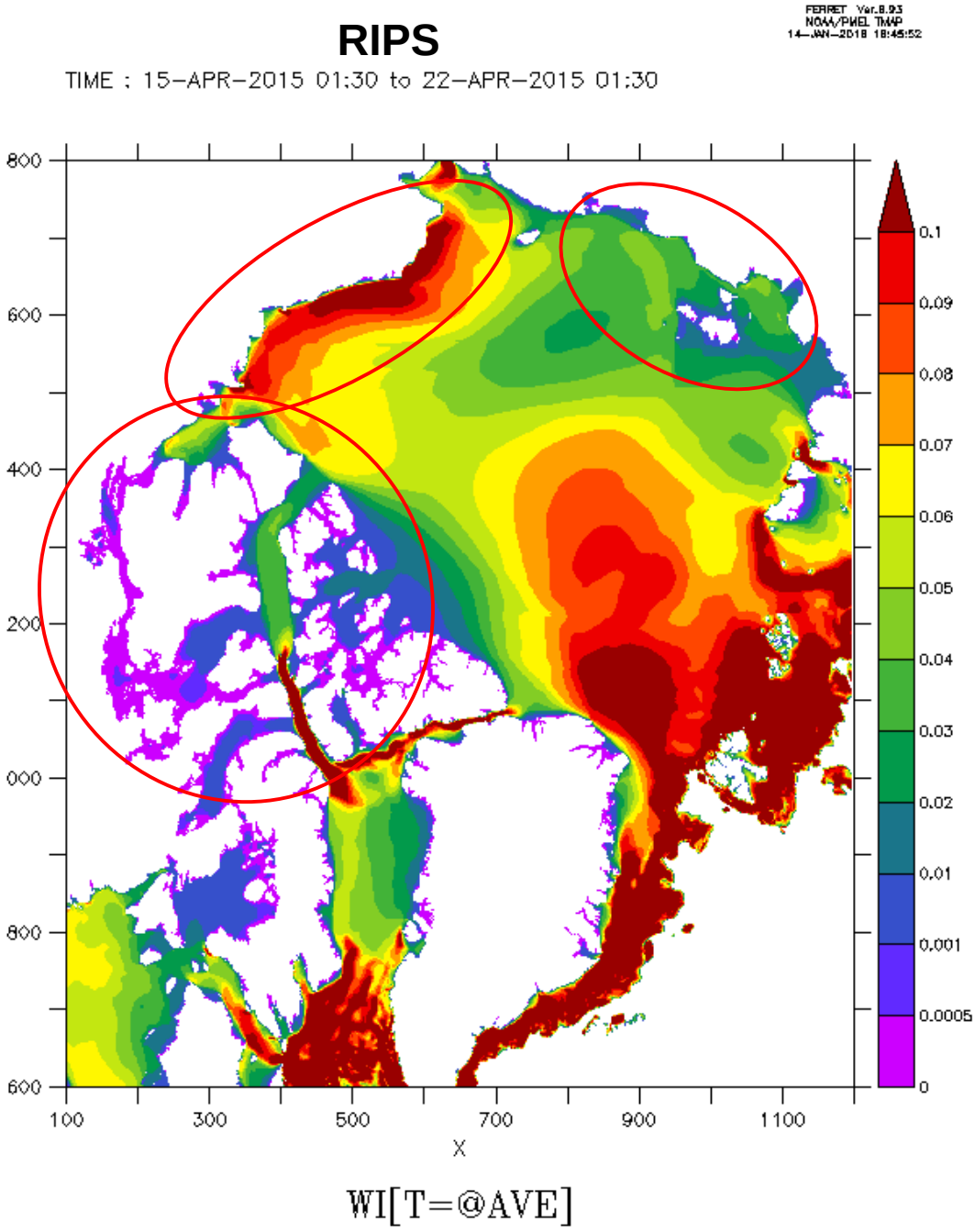


Landfast ice detection from mean ice speed over 7 days from 3-hourly averaged output. RIOPS is the more realistic of the two.

RIOPS



RIPS



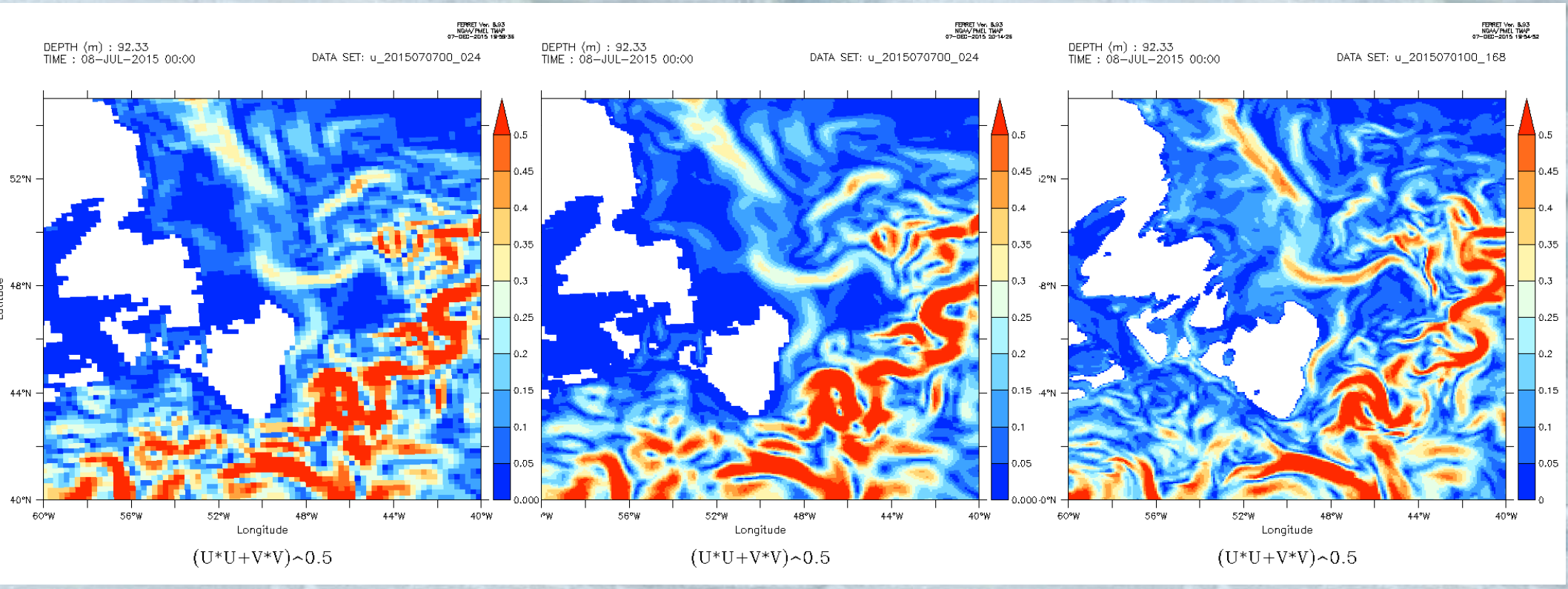
RIOPS initialization

-continuous cycle with tides

-ice: insertion from the 3D-Var CMC ice regional analysis (ice concentration increment is spread among 10 categories)

-ocean: spectral nudging toward global ocean analysis at coarser ¼ degree resolution (GIOPS)

Comparison of velocity on 2015-07-08



GIOPS

GIOPS interpolated on CREG12

RIOPS

Use of spectral nudging (in space) towards GIOPS with timescale of 1 day

RIOPS evaluations

-DGLA (error against CMC ice regional analysis)

-IMS scores. Issue with the threshold value to convert ice concentration to mask

-scores against RadarSat (manually-) analyzed ice concentration. tricky because of lack of coverage in time and space

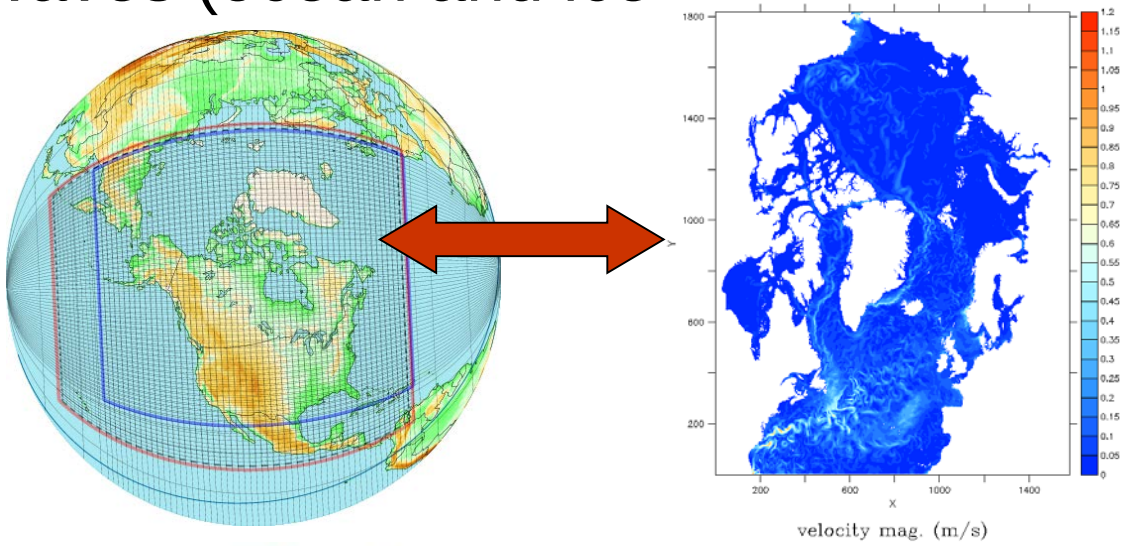
-IMS distance to ice edge. in progress

-Ice velocity against buoys (IABP)

-Class-4 metrics for oceanic characteristics

Future perspectives

- Data assimilation to be tested this summer (tides are tricky!)
- CICE5 over the summer
- Inverse barometer can be activated => storm surge
- Extension to Pacific
- Interaction with surface waves (ocean and ice)
- Coupling to GEM
- YOPP coming

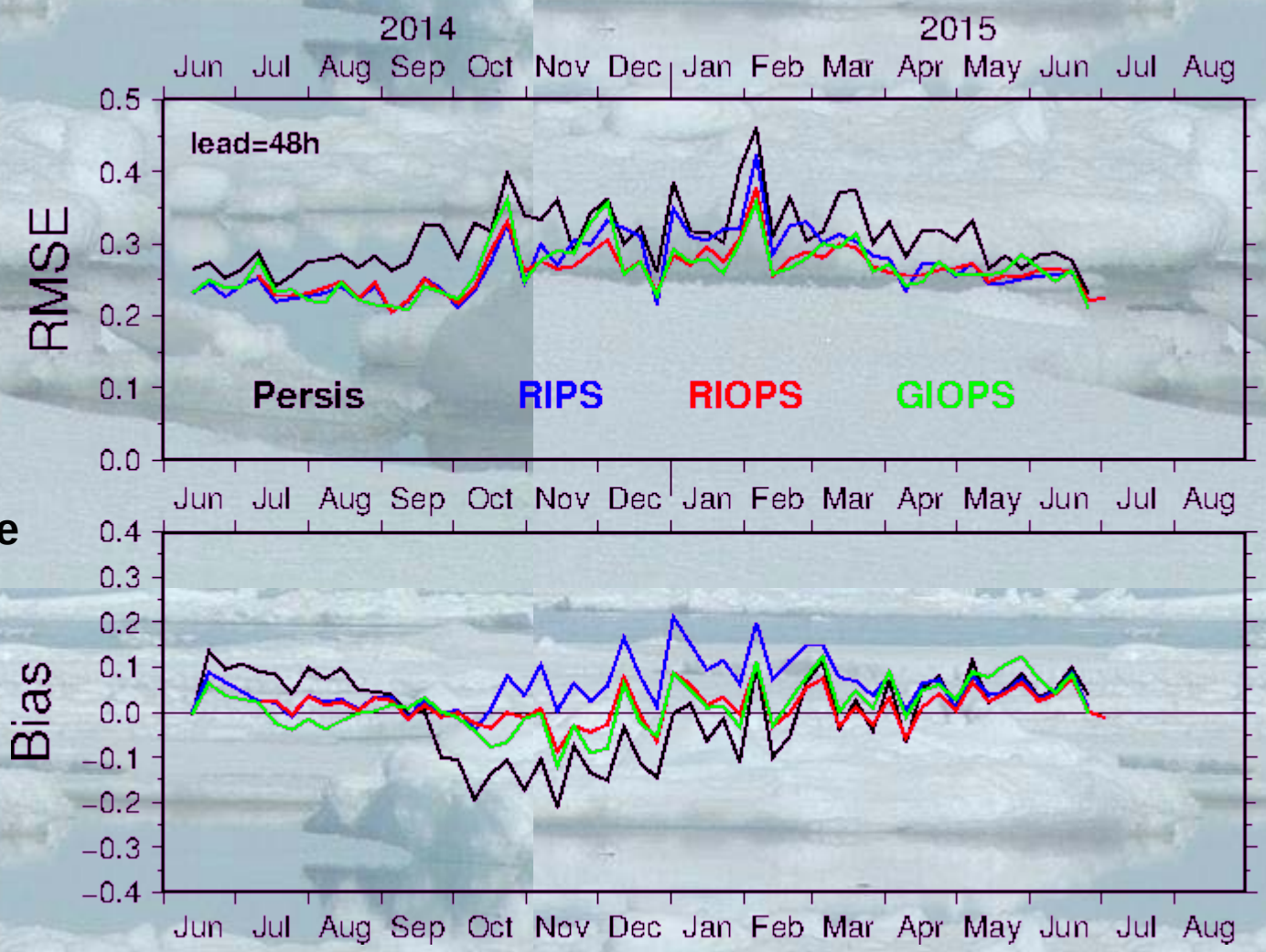


Ice concentration error metric 1: DGLA error

(against own analysis)

DGLA definition: where the analysis changes by more than 10% over the lead time, the difference between model-analysis is computed. Bias and RMS are then derived for the whole region (here whole domain).

DGLA scores against RIPS-A (2.2) valid at 00Z for 48h persistence of RIPS-A (2.2), RIPS-2.2-F (48h), RIOPS-F (38h), GIOPS-F (48h).



RIPS shows a positive bias during winter (too much ice growth) relative to GIOPS and RIOPS (and our analysis)

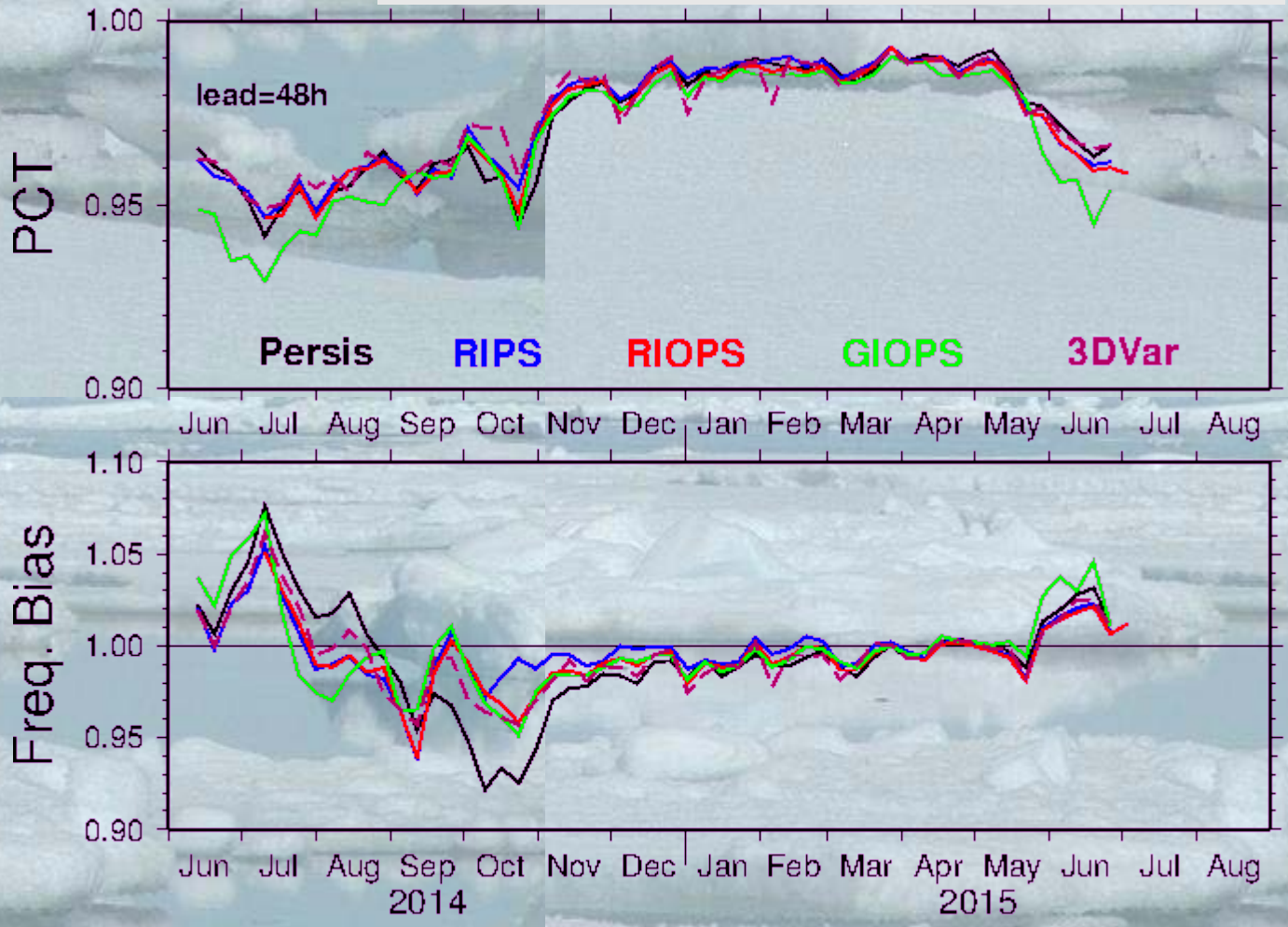
Metric 2: IMS scores valid at 00Z for 48h persistence of RIPS-A (2.2), RIPS-A (3DVar), RIPS-2.2-F (48h), RIOPS-F (48h), GIOPS-F (48h).

	IMS ice	IMS no ice
Forecast ice	Hit ice	False alarm
Forecast no ice	Miss	Hit water

IMS (Ice Mapping Service) from NIC (U.S.) provides a ice/no ice field at 4km. A contingency table is derived using an ice concentration threshold from which one can derive:

-PCT=(Hit ice+Hit water)/all

-Frequency bias=(Hit ice+False alarm)/(Hit ice+miss)



RIOPS forecast skills roughly equivalent to that of RIPS, slightly larger bias in Oct-Dec (but closer to your analysis), Better PCT than GIOPS in melt period.

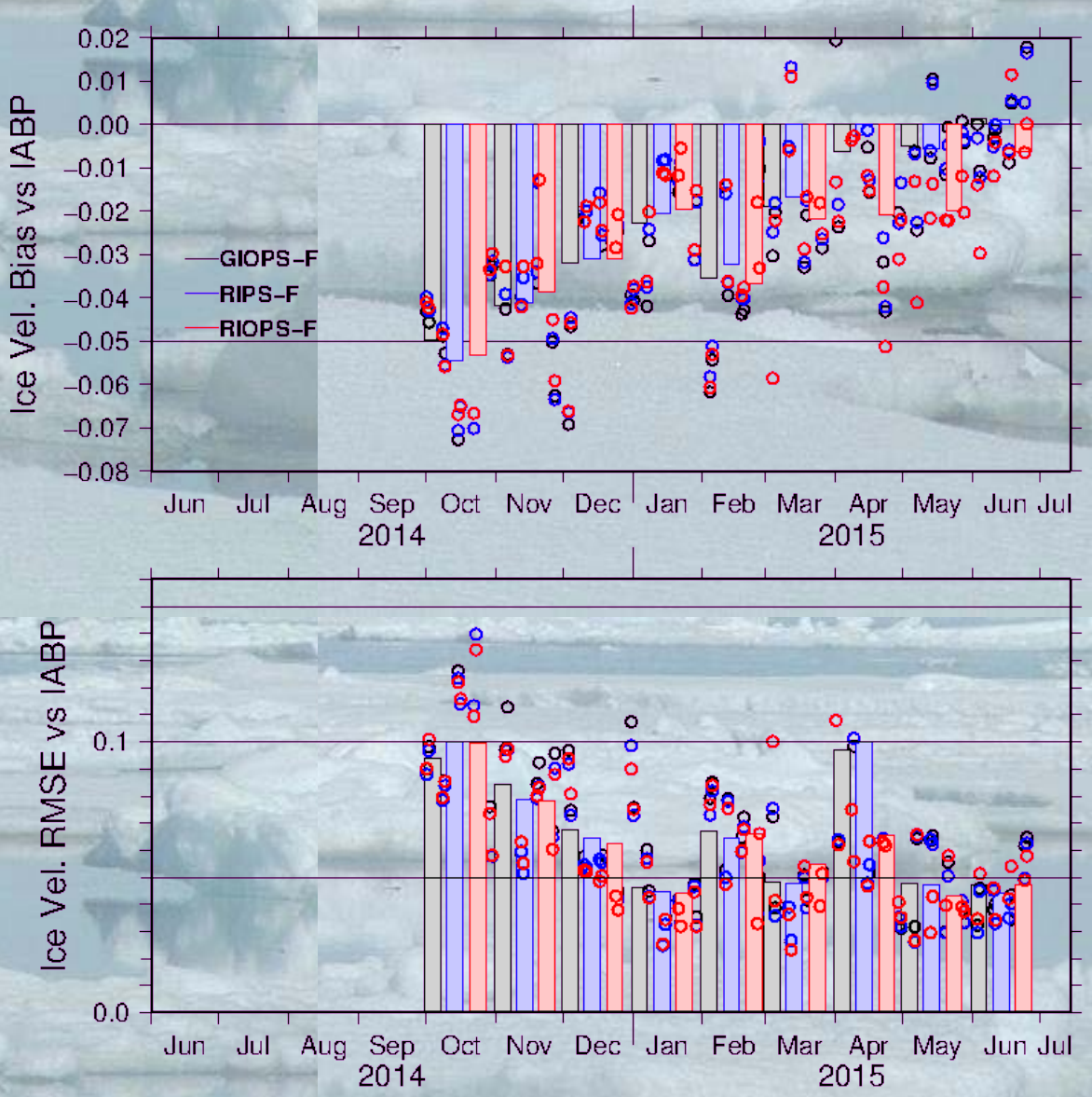
Ice velocity comparison against IABP data

$bias=\Sigma(\|\mathbf{V}_m\|-\|\mathbf{V}_o\|)/n$

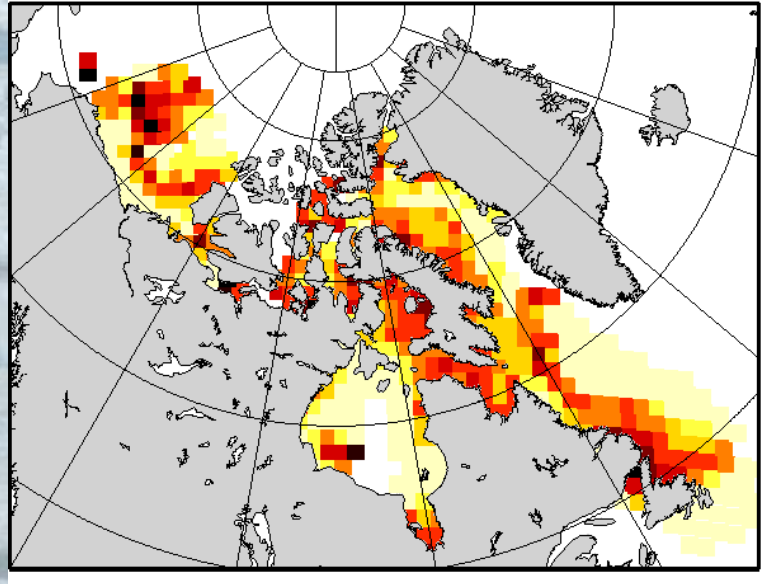
$RMSE=sqrt(\Sigma(\|\mathbf{V}_m-\mathbf{V}_o\|^2)/n)$

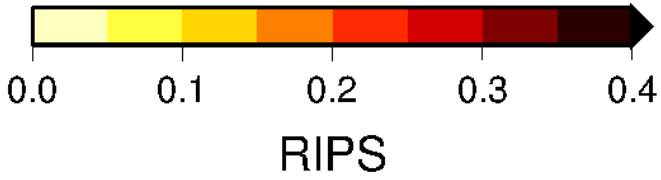
	GIOPS	RIPS	RIOPS
bias	-0.024	**-0.023**	-0.028
RMSE	0.067	0.066	**0.062**

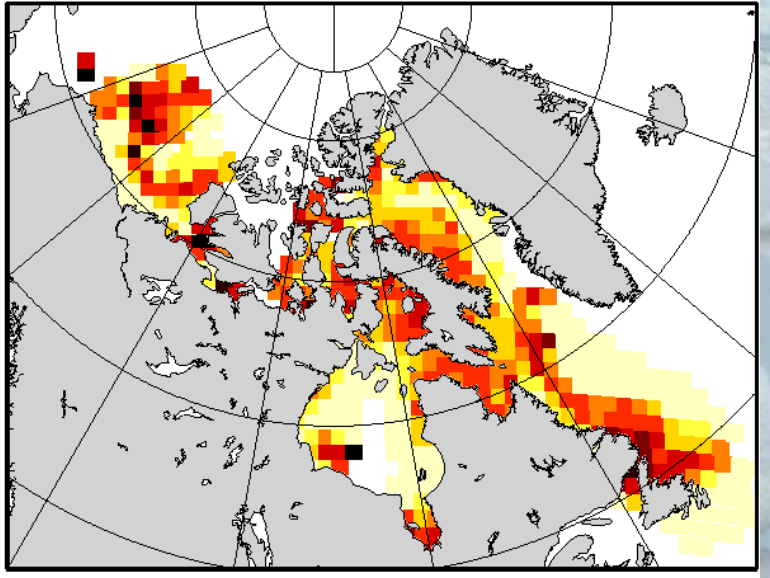
RIOPS is slightly more negatively biased than GIOPS or RIPS but the standard deviation is much improved. We speculate that this is due to the increased in resistance to shear and tension.

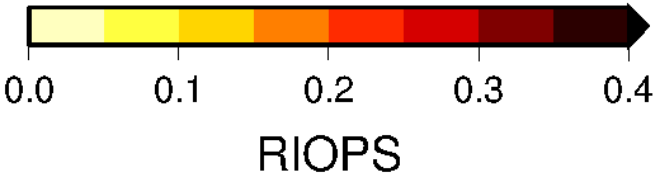


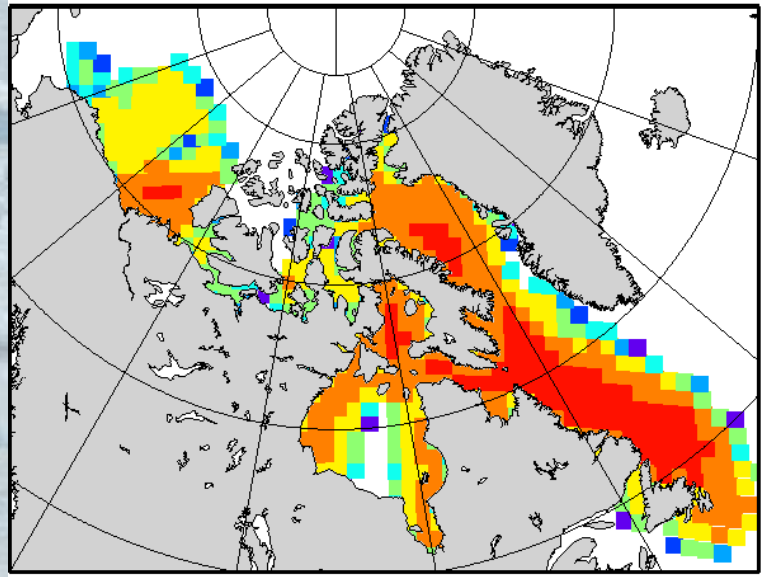
RadarSat scores comparisons

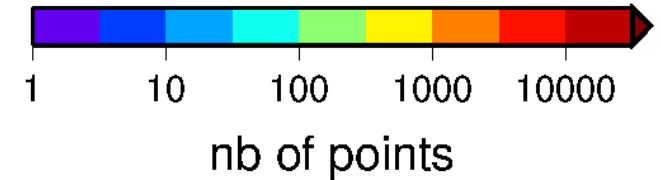


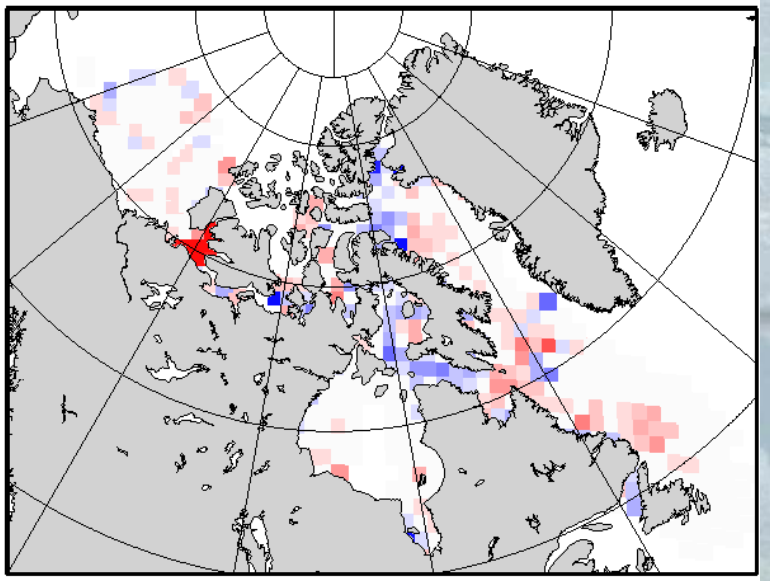


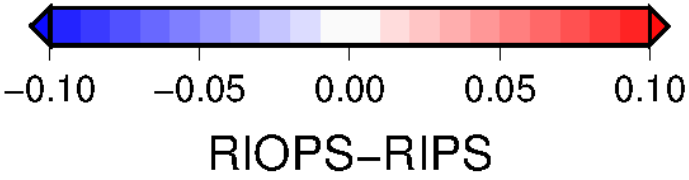




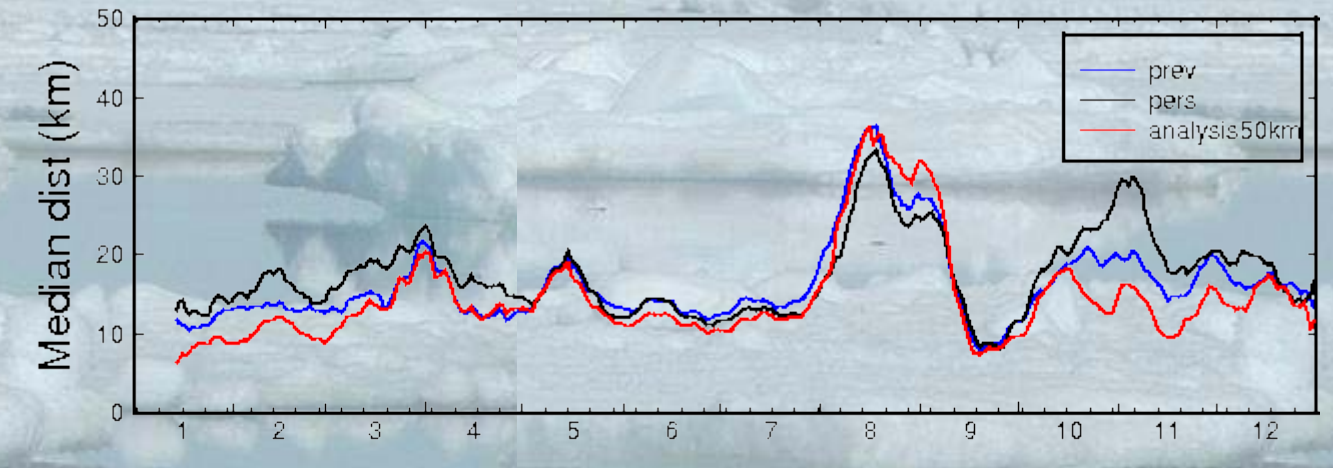


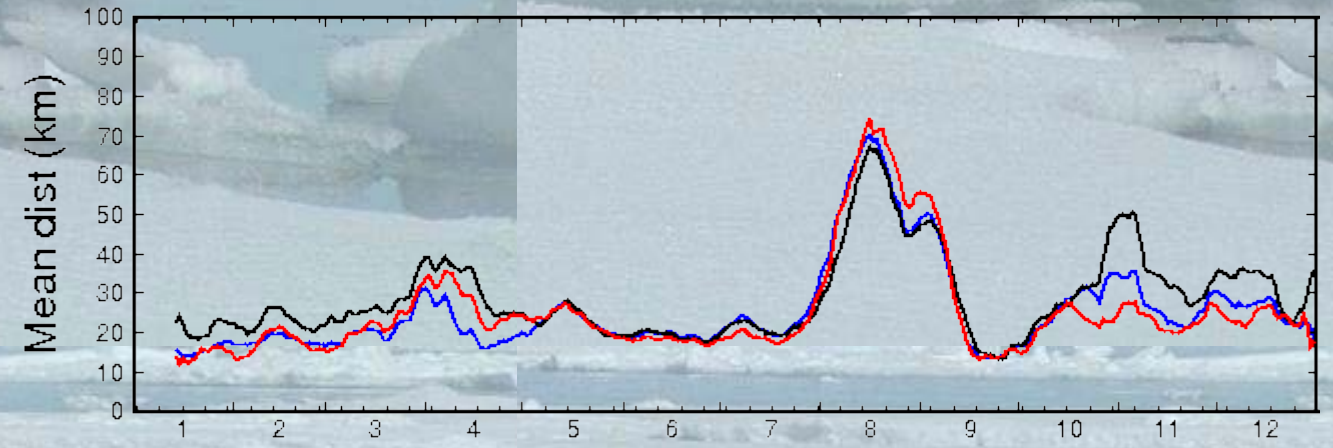


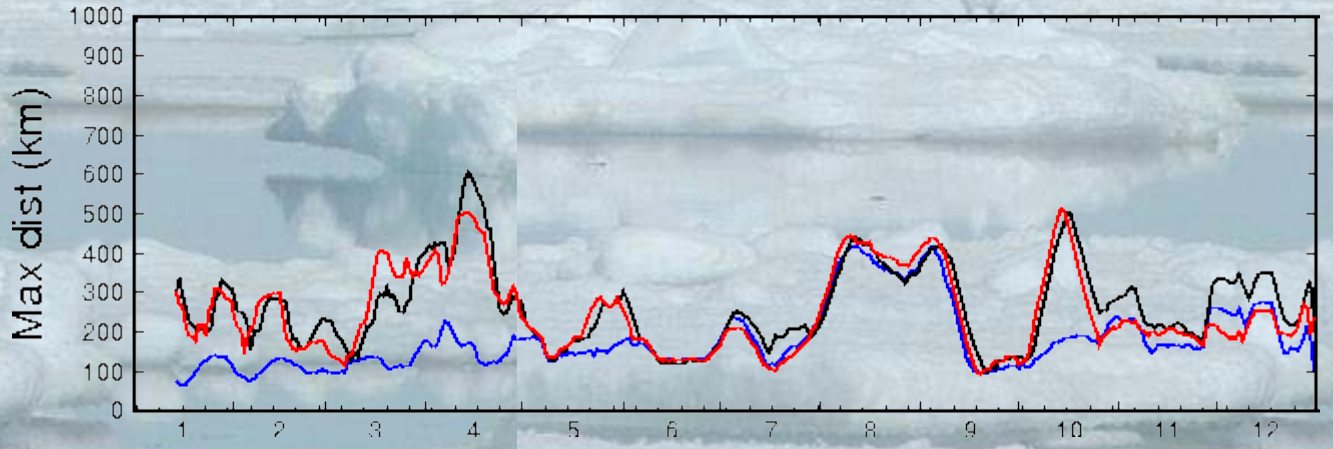




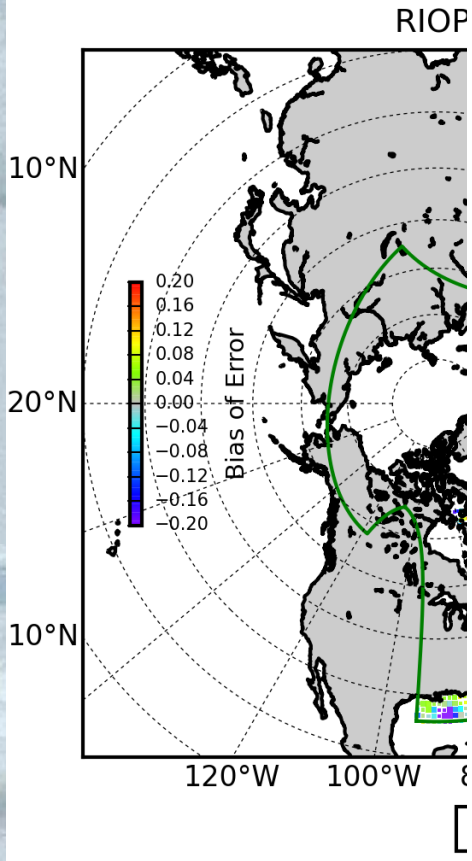
Distance to ice edge

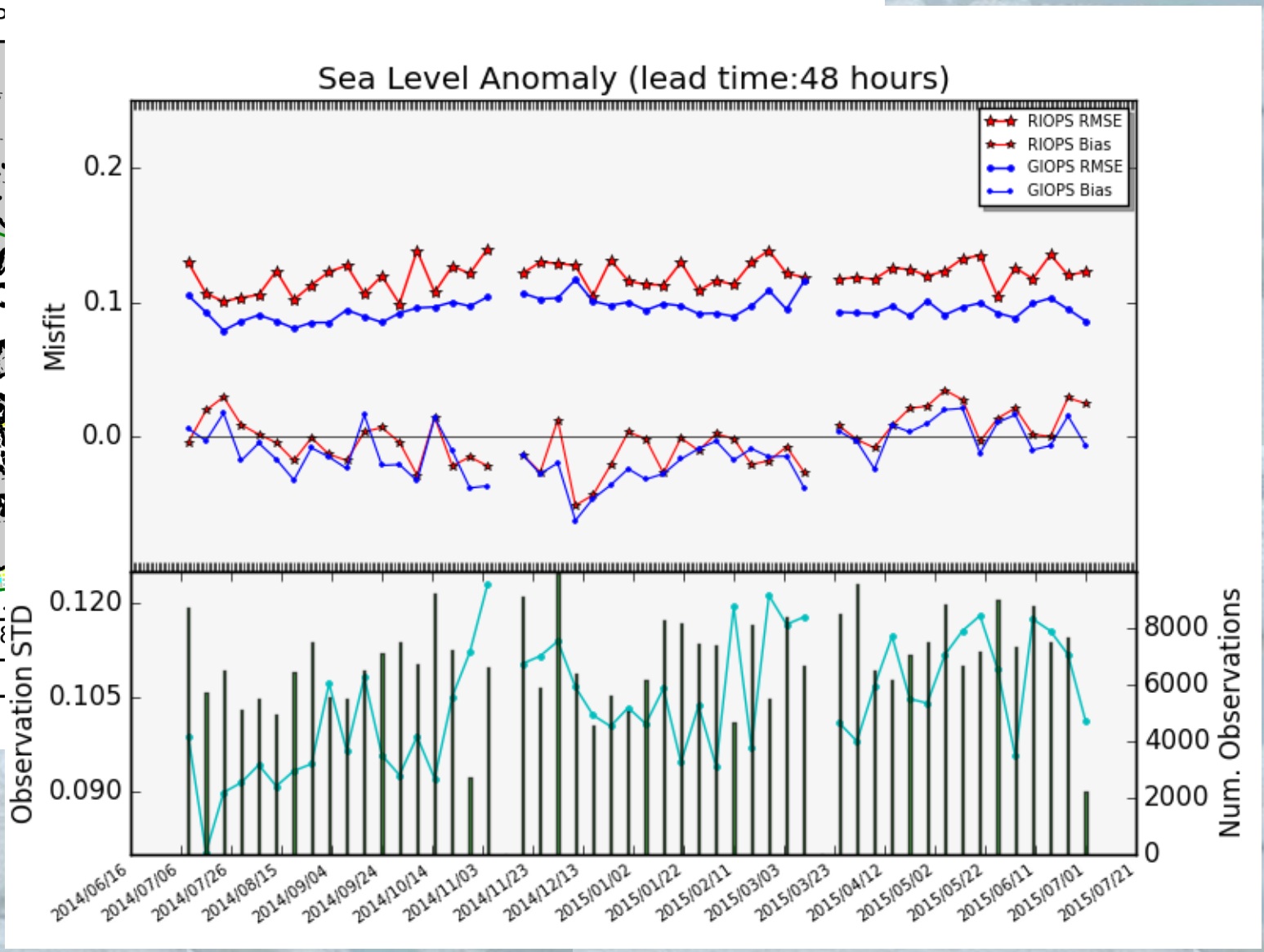




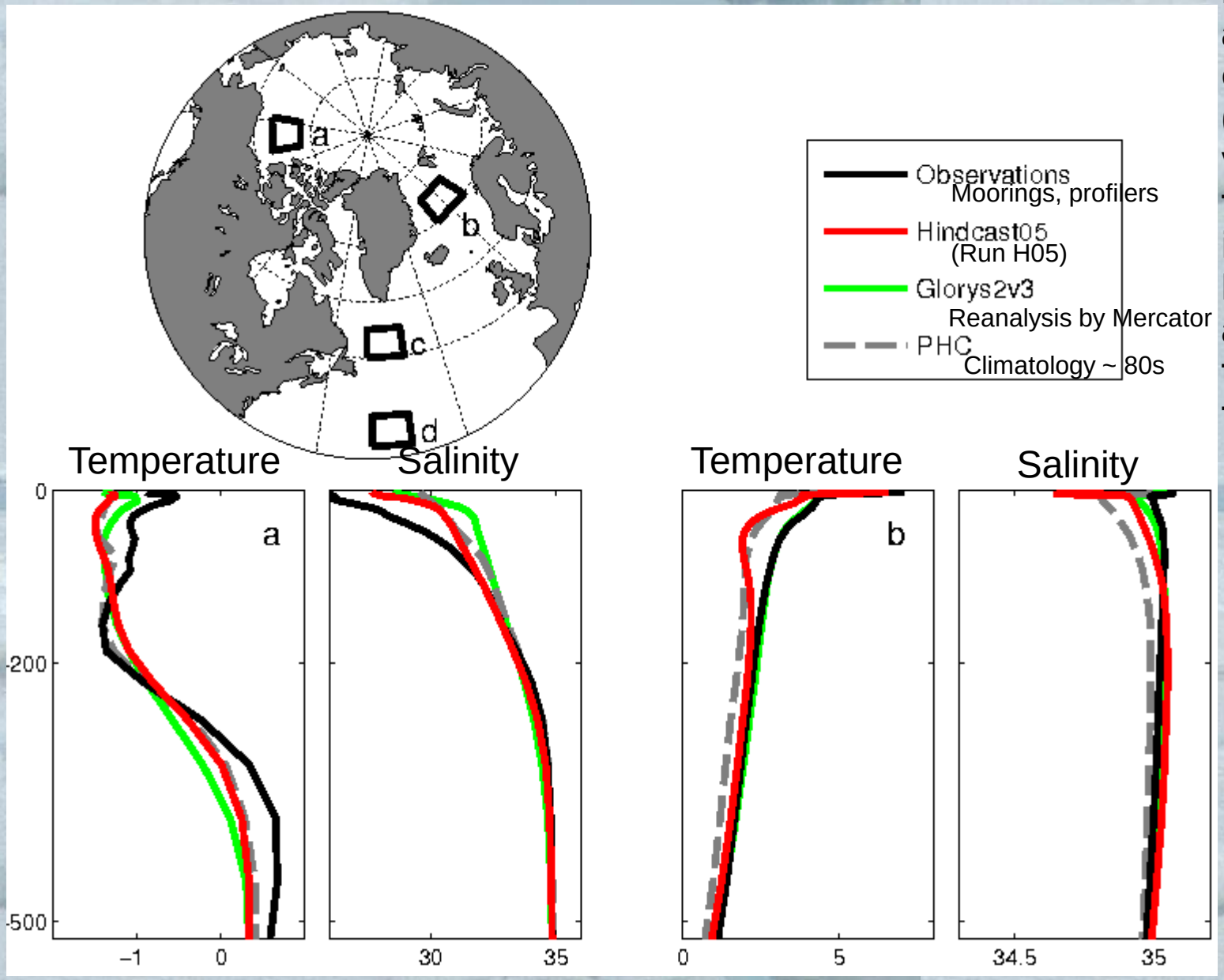


Class-4 metric for RIOPS against GIOPS



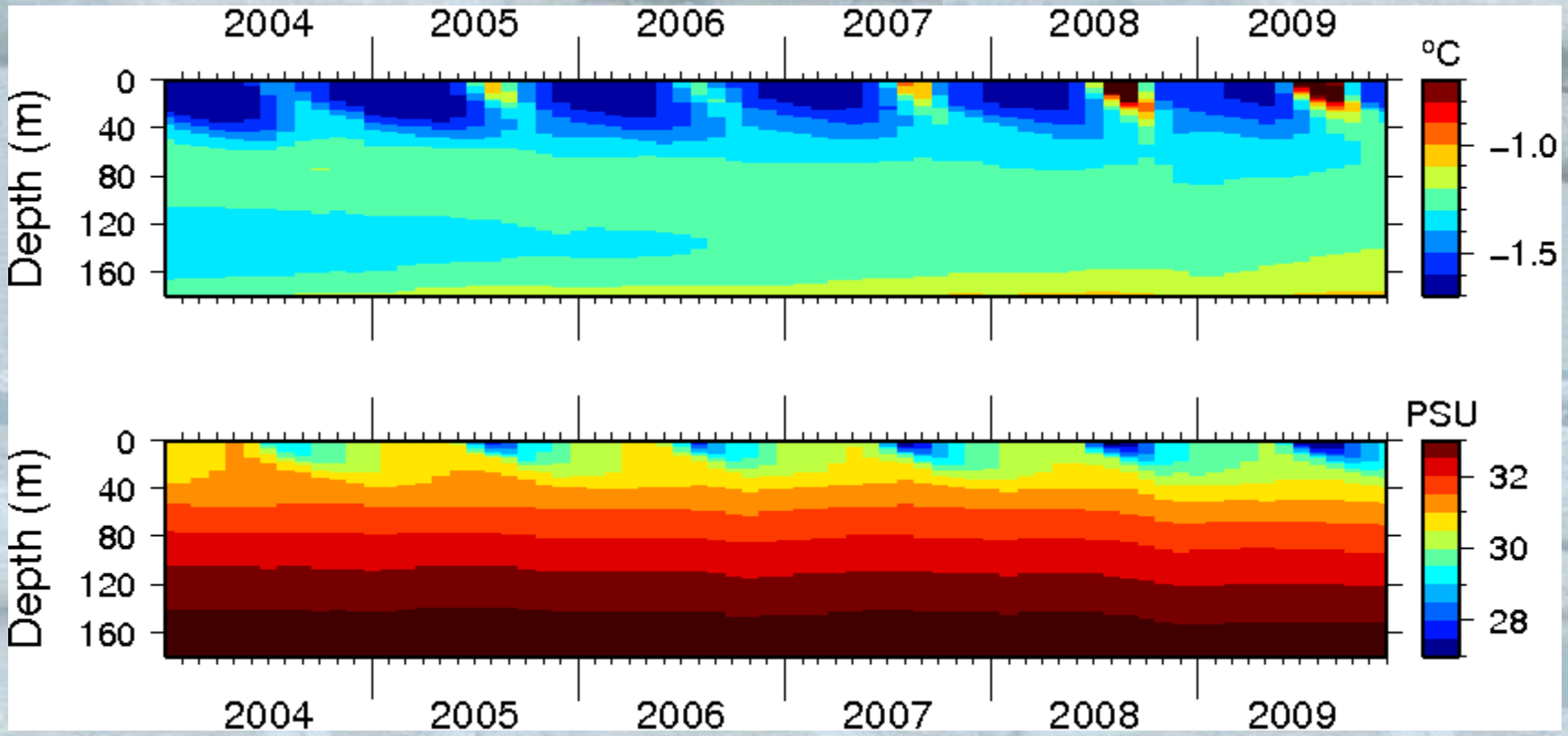


Shows that getting the right stratification in Beaufort Sea is not that easy, memory from initial conditions



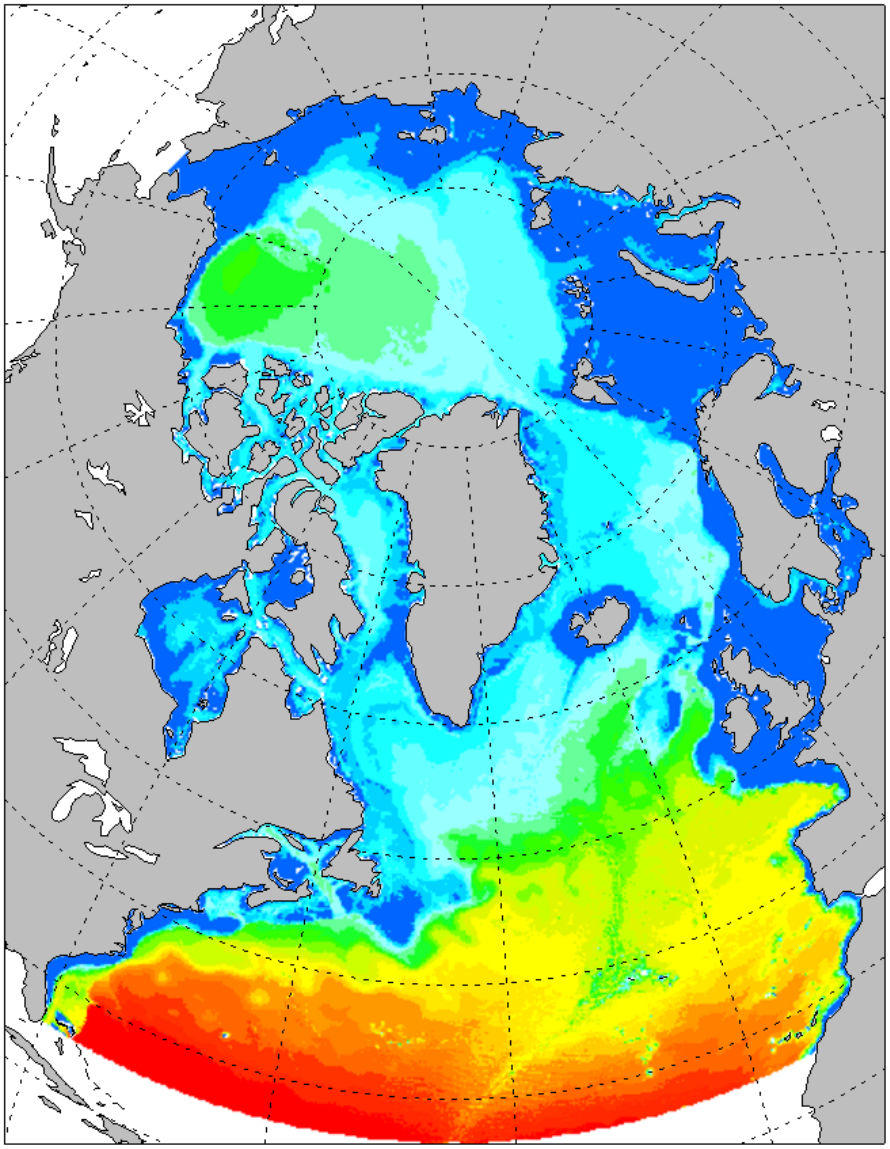
Important for accurate ice-ocean heat flux (therefore ice volume), thermal structure is important for DND too, surface and bottom temperature for fisheries

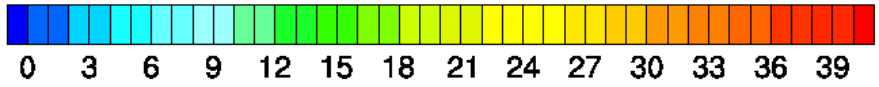
What you get from the 3D model (CREG12-H05f) averaged laterally over the southern BG. The heat in the Pacific Summer Water quickly dies off, the heat of the Atlantic layer diffuses up.



First Rossby radius of deformation

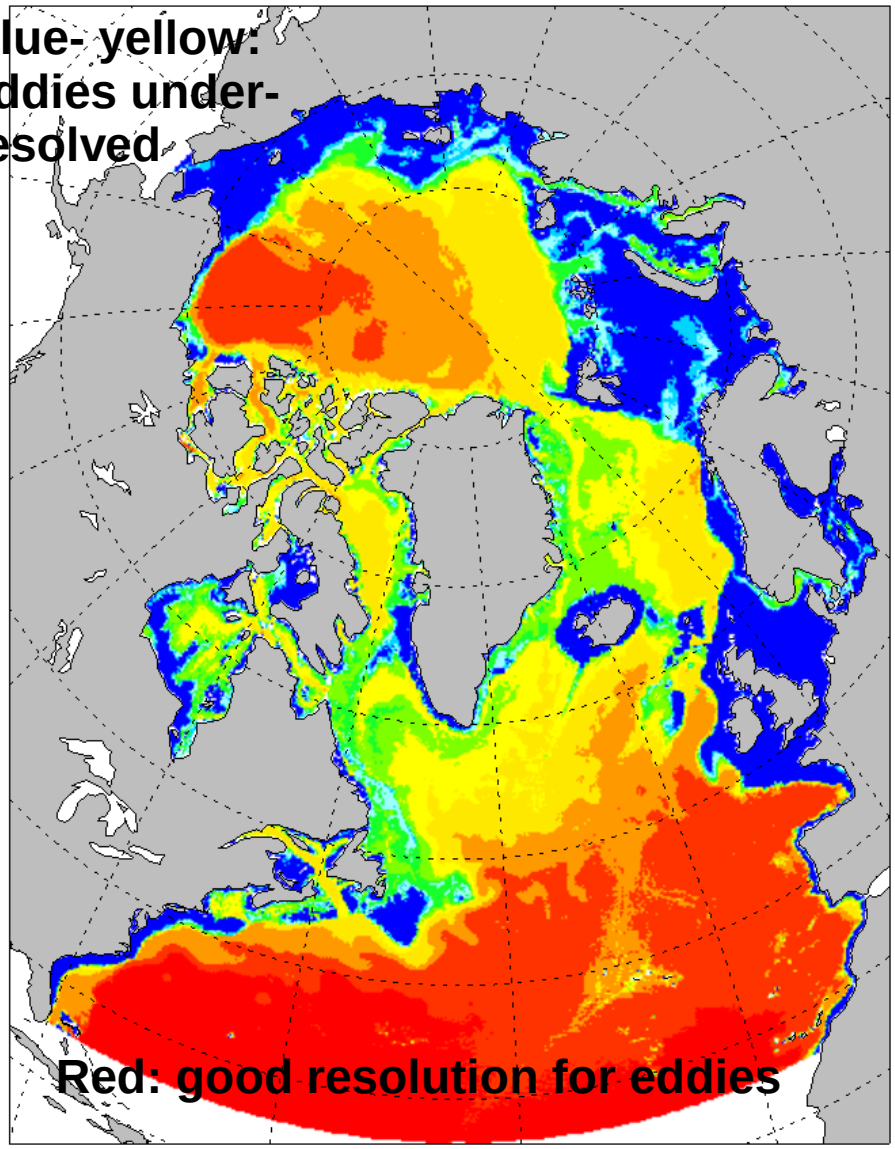
Radius (km)





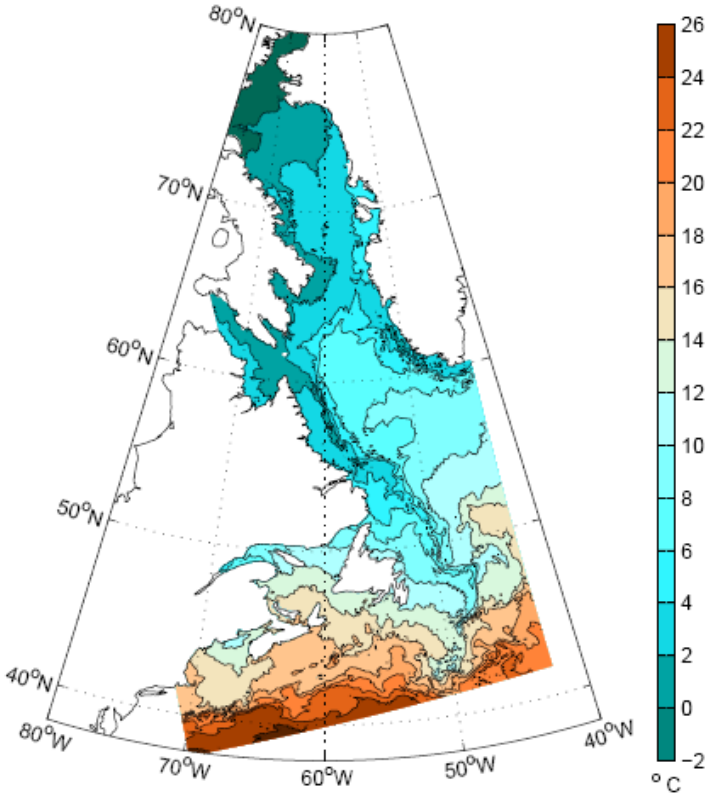
Radius/DX (log2)

Blue- yellow: eddies under-resolved



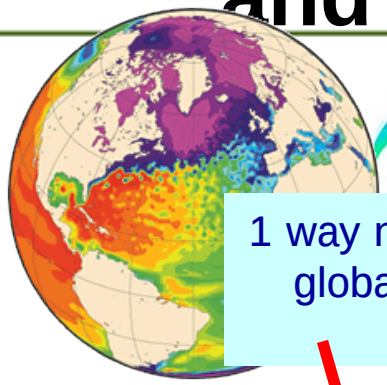
Red: good resolution for eddies

CECOM (based on 10km POM + multicat sea ice)



- Forced with RDPS
- Runs daily 48h
- monoproc

CNOOFS (based on NEMO-LIM2, ¼ and 1/12th degree)



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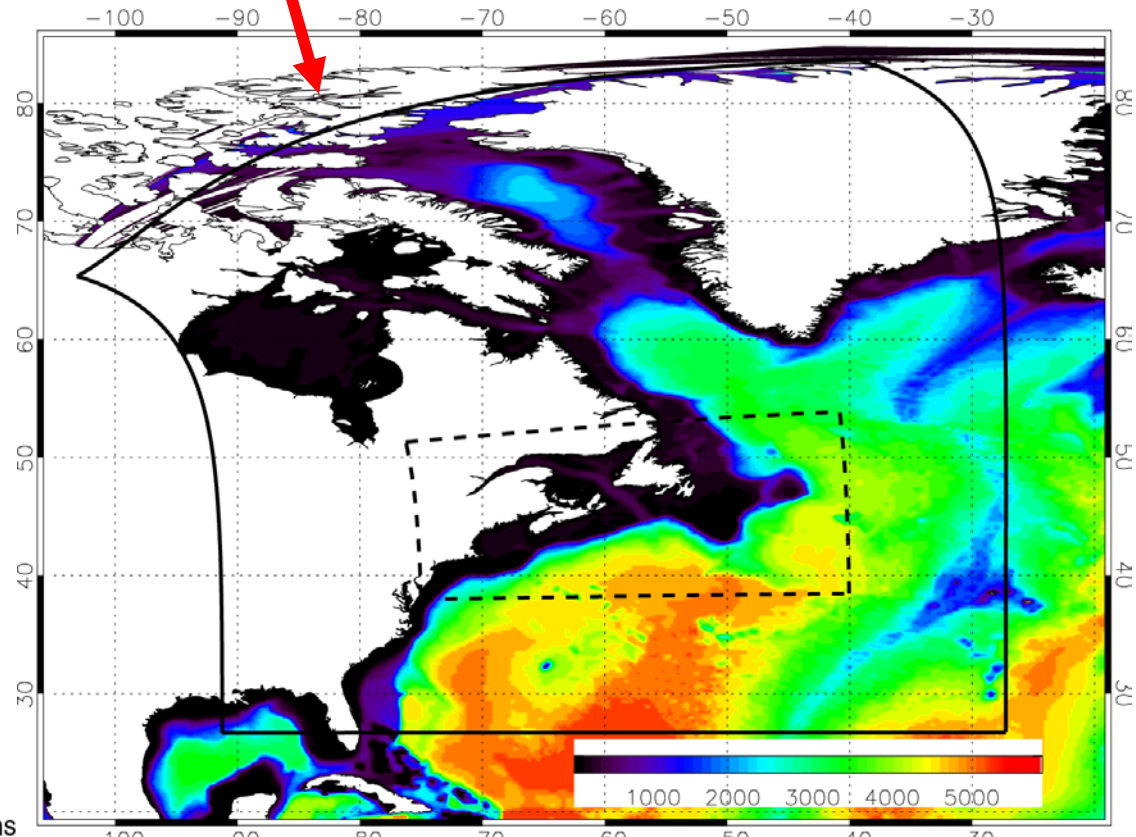
1 way nesting from global analysis

- Forced with 33km forecast wind from CMC
- Runs once daily 6 day forecast



Environment Canada

Fisheries and Oceans Canada

Ocean Forecasters

CONCEPTS

Defence

Fisheries and Oceans applications:

-CECOM and CNOOFS have been used for:

-iceberg drift forecasting

-SAR, oil spills and other Lagrangian applications (dead whales, ballast waters ...etc)

-State of the Ocean Report (annual): temperature evolution.

-Ecological and biologic significant areas (EPSA): marine protected areas (pollution)

-fisheries management (bottom temperature)