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Impact of ice thickness assimilation into the CICE model on the short-term ice forecast..

U.S. NAVAL RESEARCH LABORATORY

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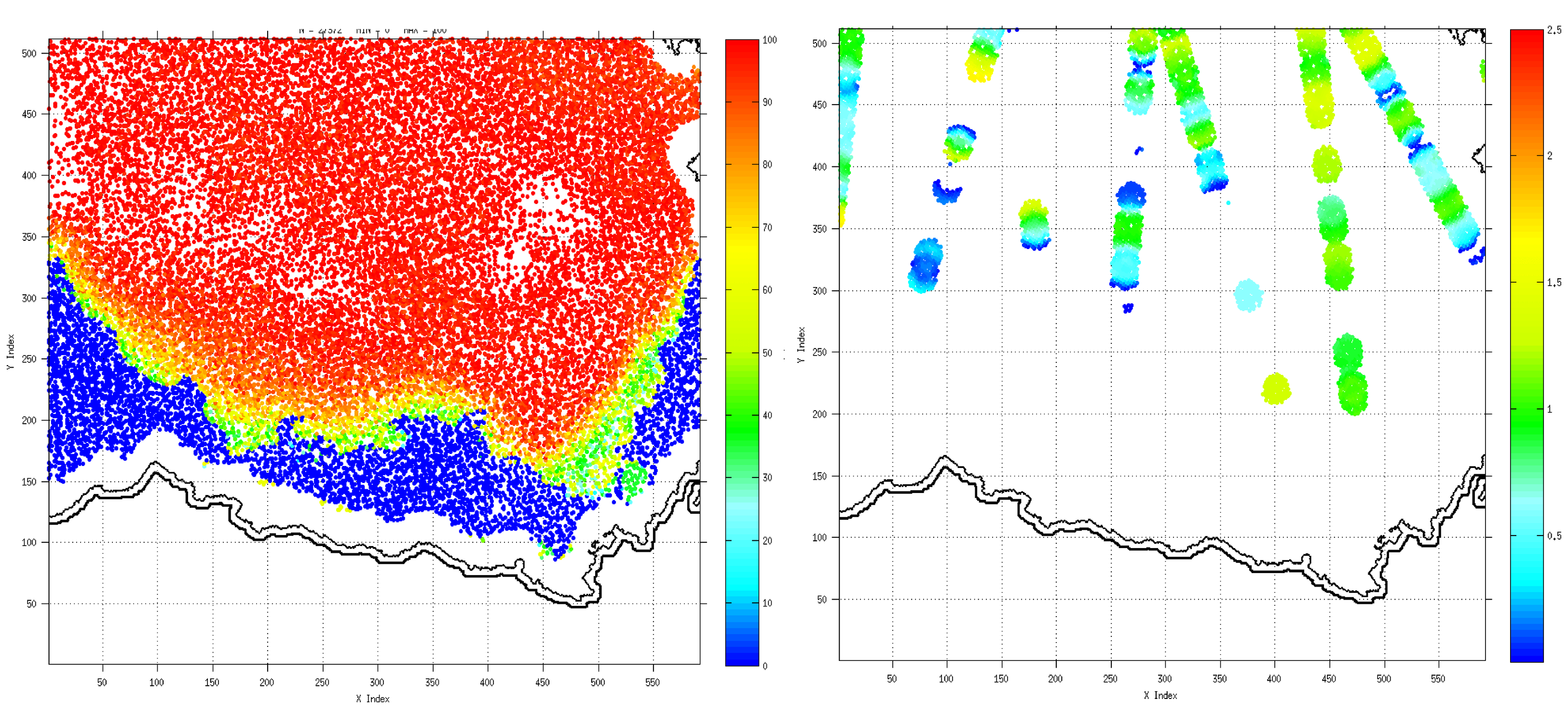
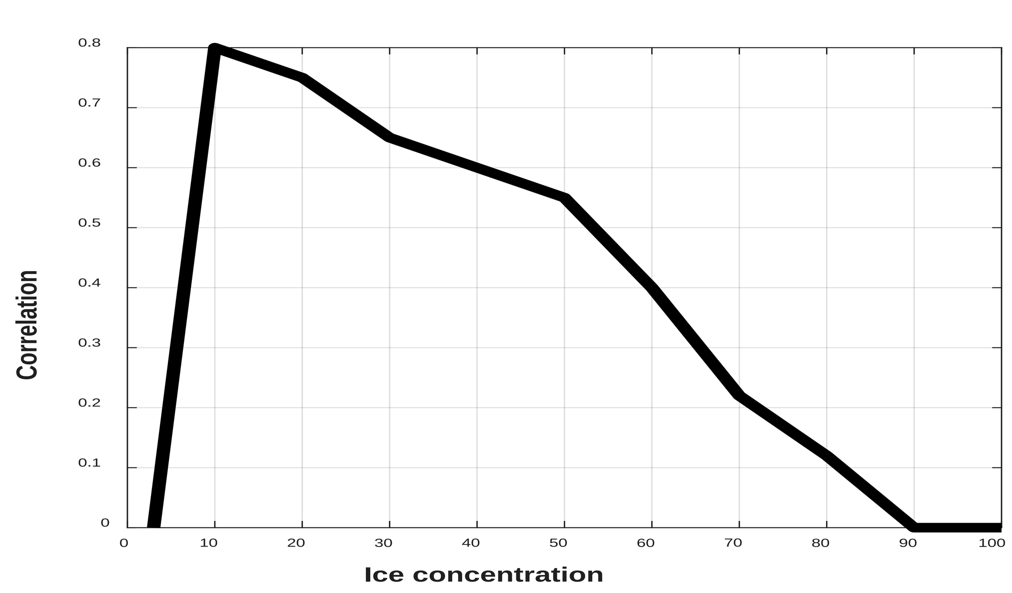
INTRODUCTION

Despite the several predictions of the *nearly ice-free summer Arctic* within 2013 -2019 (e.g. Maslowski et al., 2012), relatively thick ice is still observed in the central Arctic even in July-August. The *in situ* observations from ships and ocean buys are currently supported by several satellite based observations (Radarsat 2, Sentential 3). Availability of these novel satellite observations is a prerequisite for more accurate predictions of both ice concentration (IC) and ice thickness (IT) that could be done by assimilating these observation into the ice-ocean models. The satellite SSM/IMS IC data are available daily. These observations uniformly cover the entire area of the Arctic Ocean (Figure 1a) , while IT satellite data (e.g. Radarsat 2) are available only along several satellite tracks (Figure 1b). Typically, for the Beaufort Sea area, the volume of the IT data is about one order smaller than IC the amount of observations. At the same time, IC and IT correlate significantly in the marginal ice zones (e.g. Zhang et al., 2006). Our analysis of the output of the Arctic Cap data assimilation system indicates that maximum IC-IT correlation (0.8) occurs in the regions of 10-20% ice concentration (Figure 2). That allows a relatively straightforward generalization of the univariate IC data assimilation scheme currently utilized in the NAVY Arctic Cup by incorporating the observed correlation into the IT-IC covariance matrix. We present preliminary results of assimilating 2-day averaged IT data from the Sentinel-1a satellite into the CICE v5.12 ice model using the diffusion-based cross-correlations which incorporate ice velocities from the background solution.

OBSERVATIONS



Spatial distribution of the ice concentration (left) and ice thickness (right) observations.



Correlation between ice concentration and ice thickness

METHODOLOGY

1. Inhomogeneous/anisotropic correlation model:

$$\mathbf{Cx} = \mathbf{N}\exp\left[-\frac{1}{2}\nabla^{\mathsf{T}}\mathrm{D}(\boldsymbol{x})\nabla\right]\mathbf{x}$$

$$\mathrm{D} = \hat{\mathrm{D}}^{\mathsf{T}}\hat{\mathrm{D}}: \qquad \hat{\mathrm{D}}(\boldsymbol{x}) = r\begin{bmatrix}\sqrt{\lambda(\boldsymbol{x})} & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}\cos\theta(\boldsymbol{x}) & \sin\theta(\boldsymbol{x})\\ -\sin\theta(\boldsymbol{x}) & \cos\theta(\boldsymbol{x})\end{bmatrix}$$

$$\nabla^{\mathsf{T}}\mathrm{D}\nabla = (\tilde{\mathrm{D}}\nabla)^{\mathsf{T}}(\tilde{\mathrm{D}}\nabla)$$

2. Univariate (concentration) 2dVar NCODA:

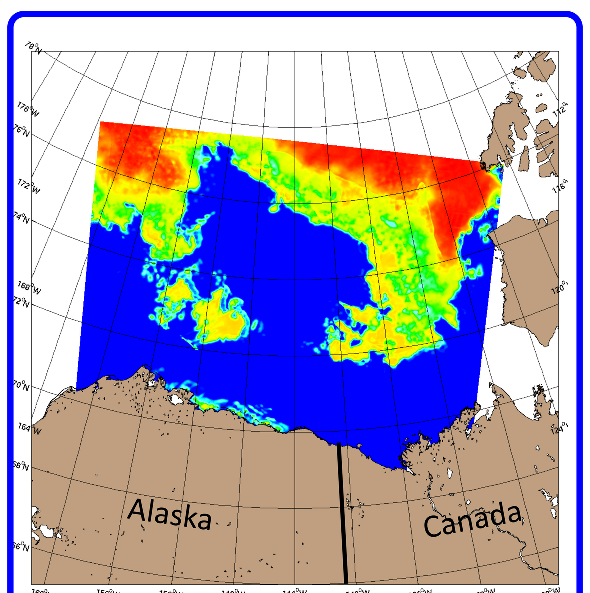
$$\delta\mathbf{x} = \mathbf{VC}\hat{\mathbf{H}}^{\mathsf{T}}(\hat{\mathbf{H}}\mathbf{C}\hat{\mathbf{H}}^{\mathsf{T}} + \mathbf{I})^{-1}\mathbf{R}^{-1}\delta\mathbf{d} \qquad \hat{\mathbf{H}} = \mathbf{VHR}^{-1}$$

3. Multivariate (ice concentration and thickness) 2dVar NCODA:

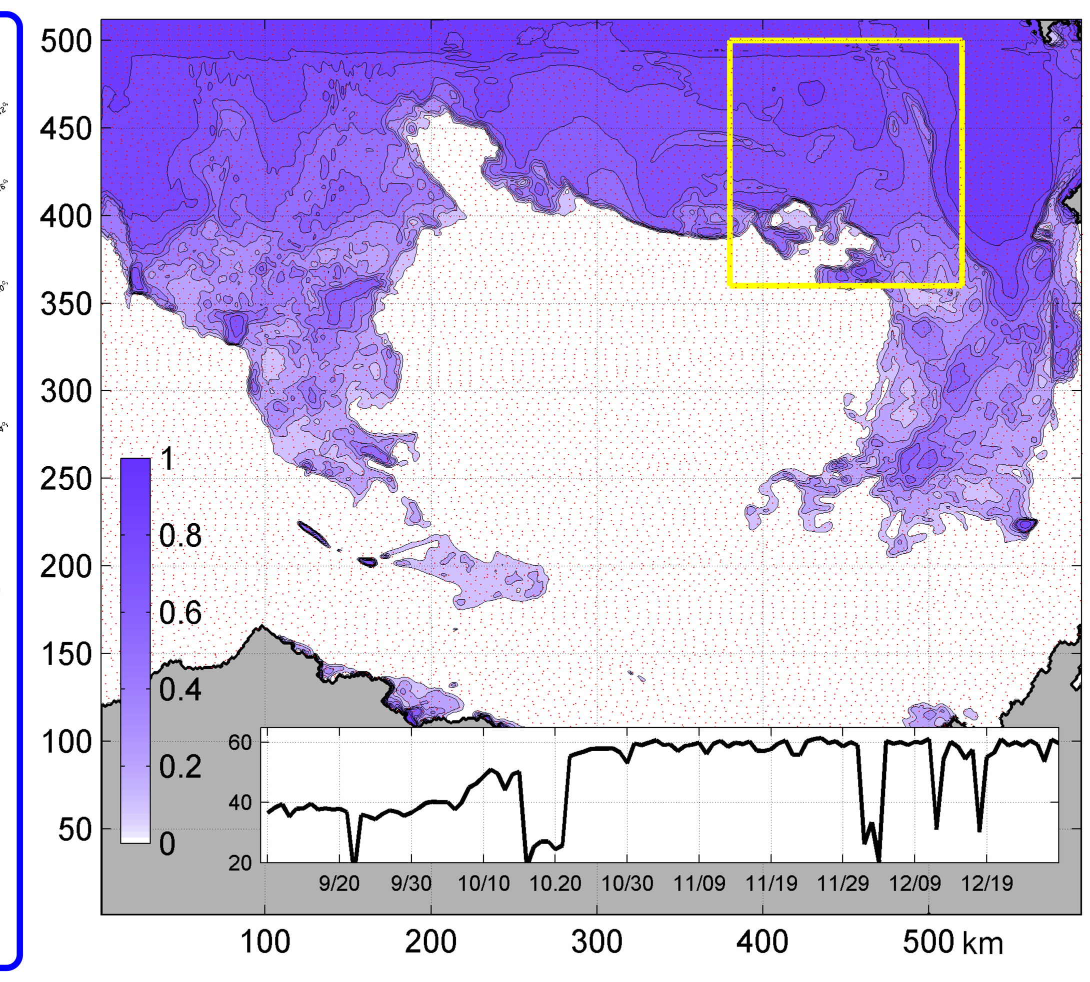
$$\mathbf{C}^{\mathsf{IC}}_{\mathsf{IT}} = \begin{bmatrix}\sqrt{\mathbf{C}} & 0\\ 0 & \sqrt{\mathbf{C}}\end{bmatrix}\begin{bmatrix}\mathbf{I} & \mathbf{D}\\ \mathbf{D} & \mathbf{I}\end{bmatrix}\begin{bmatrix}\sqrt{\mathbf{C}} & 0\\ 0 & \sqrt{\mathbf{C}}\end{bmatrix}$$

$$\mathbf{D} = \mathrm{diag}\{c^{\mathsf{it}}_{\mathsf{ic}}(\boldsymbol{x})\}$$

EXPERIMENT SETTING



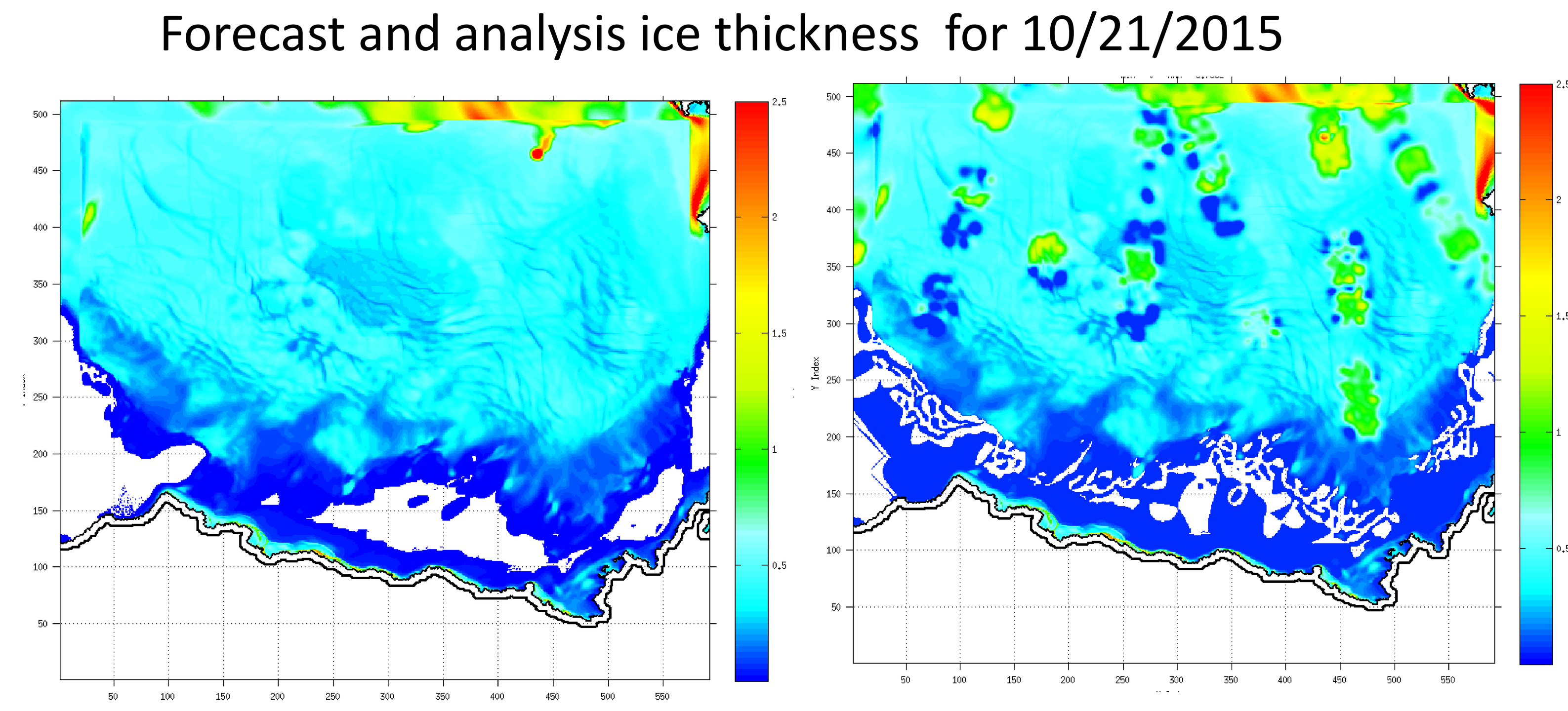
CICE at 2 km driven by:
NAVGEM 1.2 forcing
and GOFS 3.1
(1/12º HYCOM/NCODA)
Assimilation period:
9/2/2015-12/31/2015



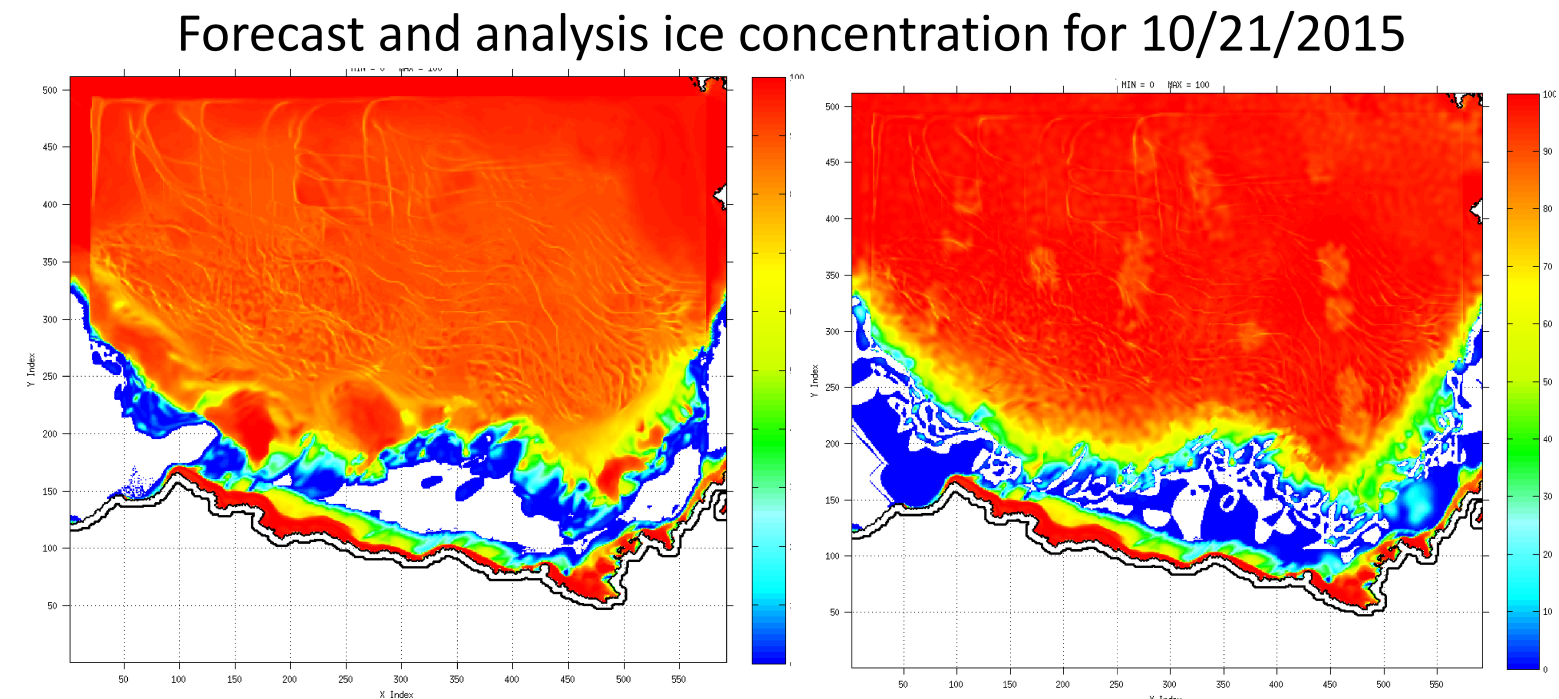
Forecast skill assessment: $s^n(a|r) = 1 - \dfrac{(\mathbf{Hx}^n_a - \mathbf{d}^n)^{\mathsf{T}}(\mathbf{Hx}^n_a - \mathbf{d}^n)}{(\mathbf{Hx}^n_r - \mathbf{d}^n)^{\mathsf{T}}(\mathbf{Hx}^n_r - \mathbf{d}^n)}$

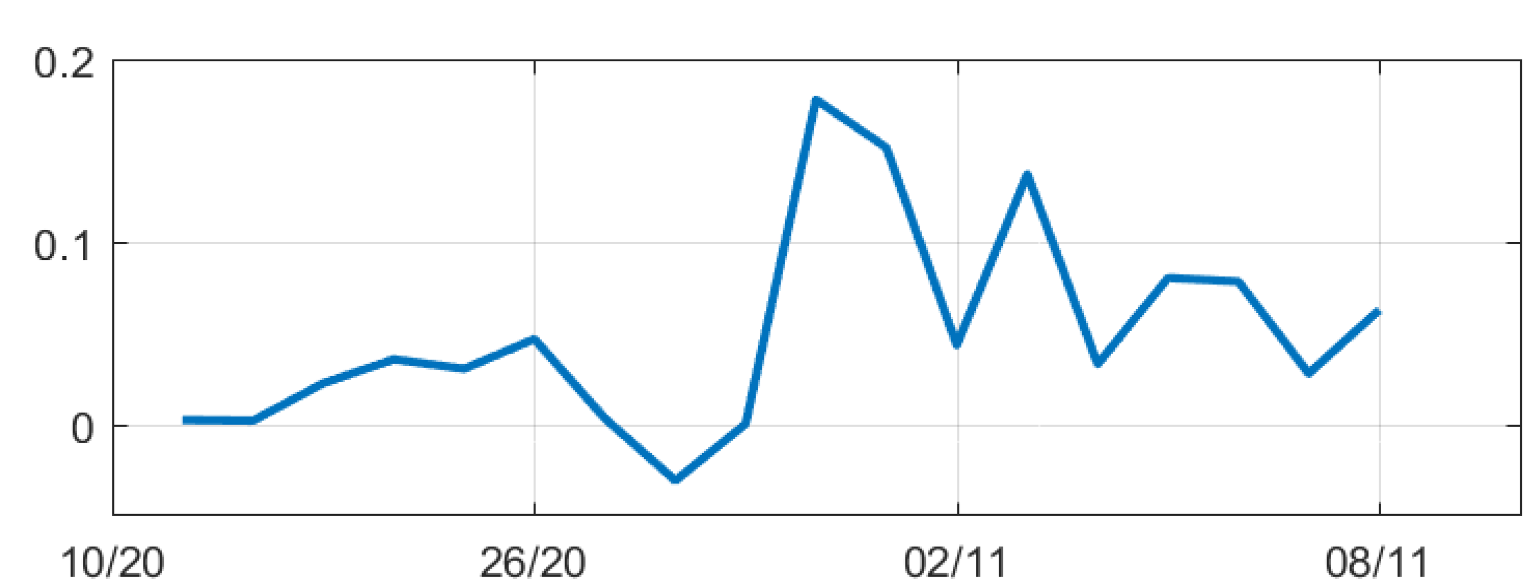
IMPACT OF THE MULTIVARIATE ASSIMILATION

Forecast and analysis ice thickness for 10/21/2015



Forecast and analysis ice concentration for 10/21/2015





The IT forecast skills *s* in Beaufort Sea test domain for the preliminary (18 day) data assimilation NCODA-CICE model run .

SUMMARY

Preliminary data assimilation experiments with the combined NCODA-CICEsystem indicate stability of the developed data assimilation (DA) algorithms. Efficiency of the developed DA procedure depends on the error variance of the ice thickness observations which is rather high (0.5-1.5 m). Despite relatively low accuracy of satellite IT data, a moderate impact of the IT assimilation is clearly observed after 1-2 weeks. Preliminary results indicate an increase of the IT forecast skill and gradual increase of the mean IT in the southern part of the Beaufort Sea that agrees well with Cryosat 2 data. Multivariate assimilation allows using the observed IT-IC correlations and improves the IT forecast. Inhomogeneous (ocean velocity driven) correlation model contributes by a minor (1-2%) improvement in the IT forecast skill.