Validation of the Baltic Sea ice ensemble forecast

Byoung Woong An, Antti Westerlund, Tapani Stipa

FINNISH METEOROLOGICAL INSTITUTE

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Introduction

The Baltic Sea is a brackish and an important waterway for transportation and shipping. Therefore sea ice can be a major hazard for passenger and commercial vessels during the winter and early spring. However, owing to the chaotic nature of the atmosphere and the ocean, it is impossible to predict and quantify the state of the Baltic Sea ice precisely. The main objective of this document is to provide basic information about the operation process for an independent evaluation of the model, therefore this report gives a basic information of the ensemble forecasting procedure and will be helpful for potential users.

Here we describes the procedure of forecasting and validation methods applied for this project and it improves the accuracy of decision-making of the ice conditions. This procedure helps in operation in ice breaker operation.

Methods

Ensemble Forecast

To get more accurate information in the future state of the Baltic Sea ice condition, sea ice-ocean ensemble forecast is operating for time ranges from 30 days to 180 days. The spatial domain covers the Baltic Sea. The ensemble consists of 51 members for monthly and 40 perturbed members for seasonal prediction including one control run in each forecast. The prime objective is to evaluate the capture ice thickness and extension with data.

Ocean-Ice Model: **MITgcm**

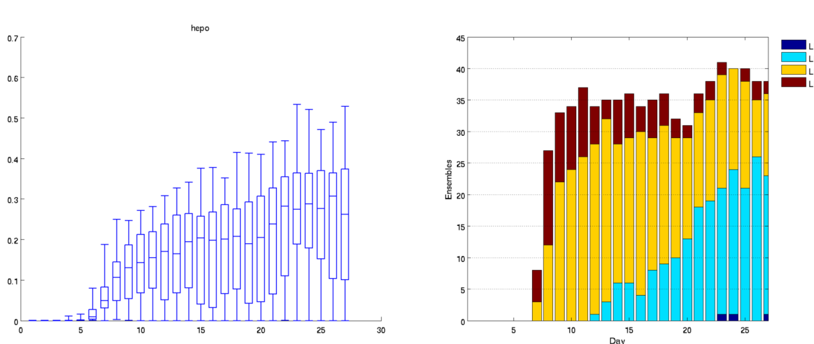
Forecast

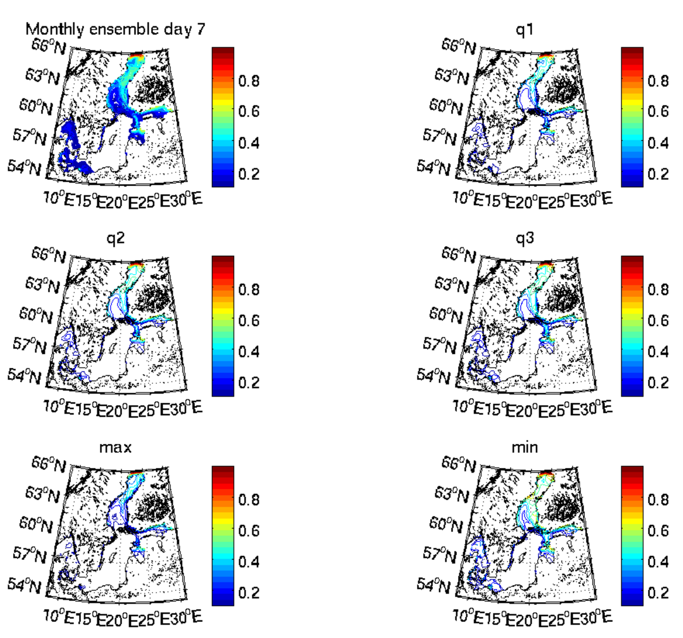
Production:

Possible future probability using multiple forecasts produce different possibilities. Probability forecasts which we are using are in two main ways, and the first is using a range of values in quartiles (min, 25, 50, 75 %, max) and the other is using percentages of probabilistic occurrence.

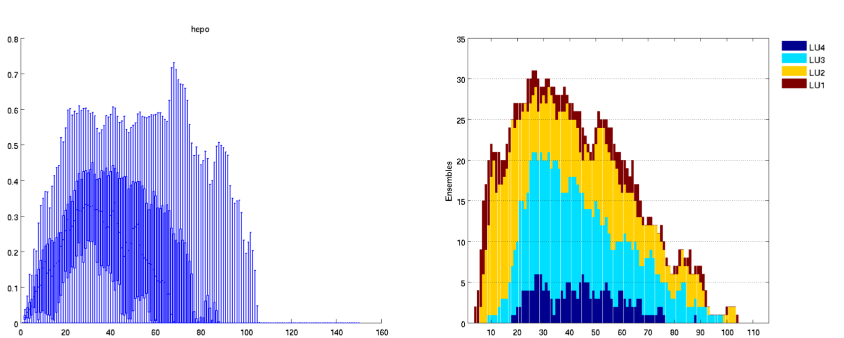
We estimate ice conditions defined as the percentage of forecasts that satisfy a specified event over the total sample space (total number of ensembles). Ice thickness has classified in the range of LU4(=IA, ice thickness > 50 cm), LU3(=IB, ice thickness 30 ~50 cm), LU2(=IC, ice thickness 15~30 cm) and LU1 (ice thickness 10~15 cm).

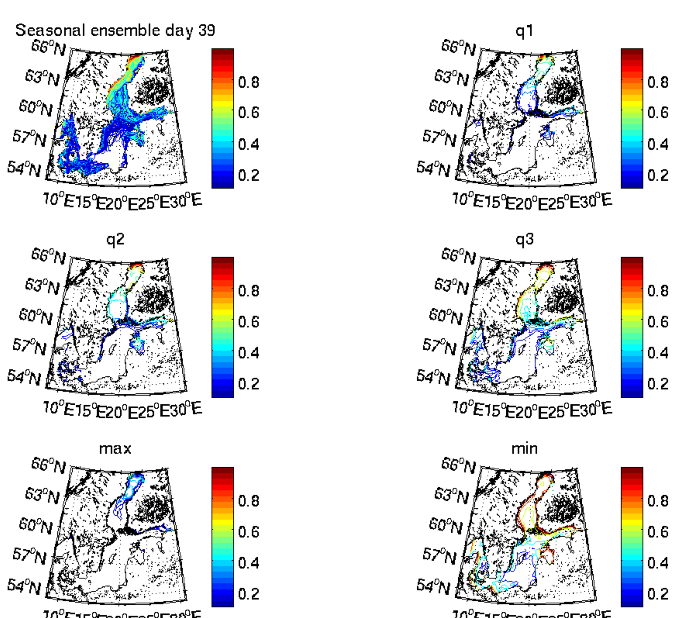
Ensemble ice thickness monthly forecast at Helsinki wave buoy



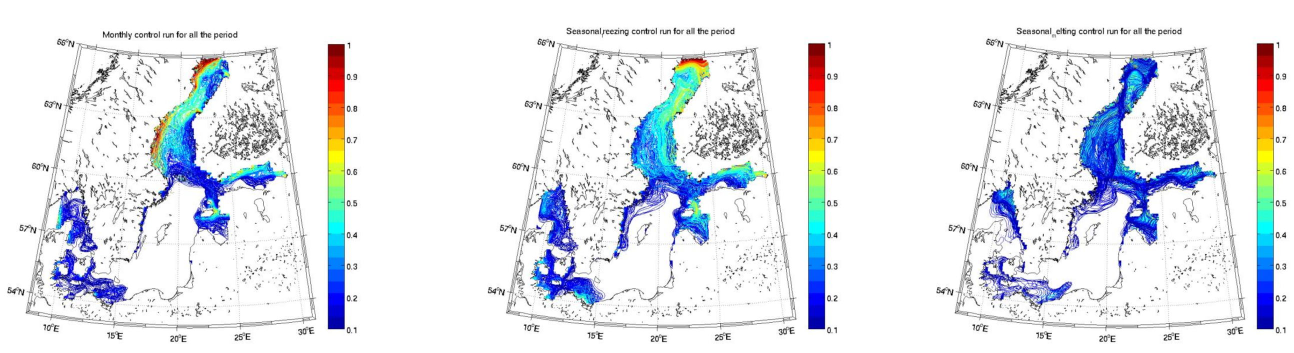


Ensemble ice thickness seasonal forecast at Helsinki wave buoy





Ice thickness monthly and seasonal forecast



Validation

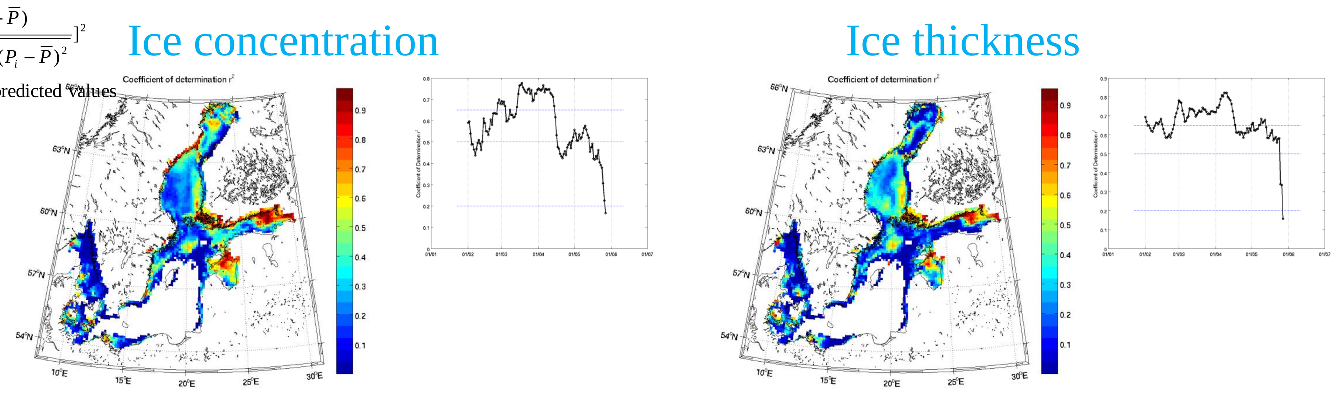
Control run Seasonal Forecast Skills:

Coefficient of determination index

$$r^2 = \left[\frac{\sum_{i=1}^{n}(O_i-\overline{O})(P_i-\overline{P})}{\sqrt{\sum_{i=1}^{n}(O_i-\overline{O})^2}\sqrt{\sum_{i=1}^{n}(P_i-\overline{P})^2}}\right]^2$$

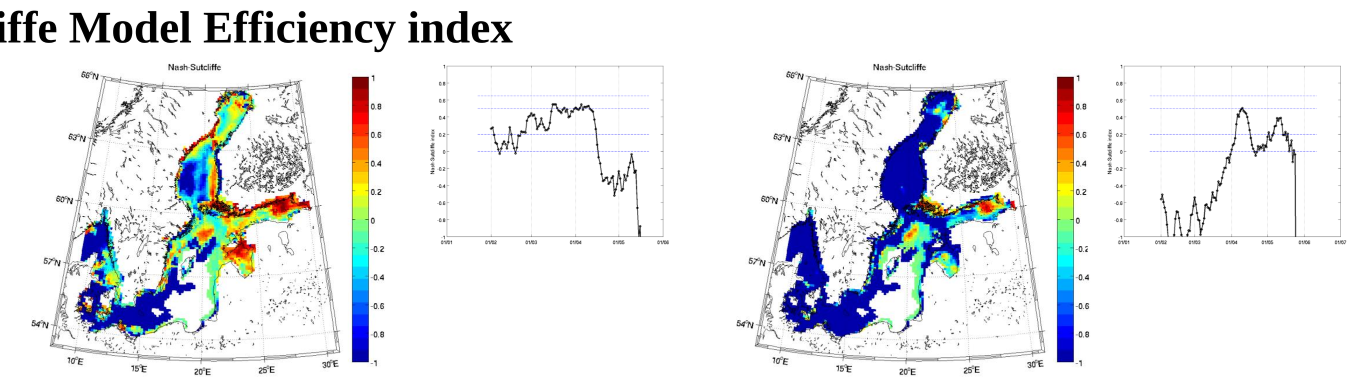
where O is observed and P is predicted values

Ice concentration | Ice thickness



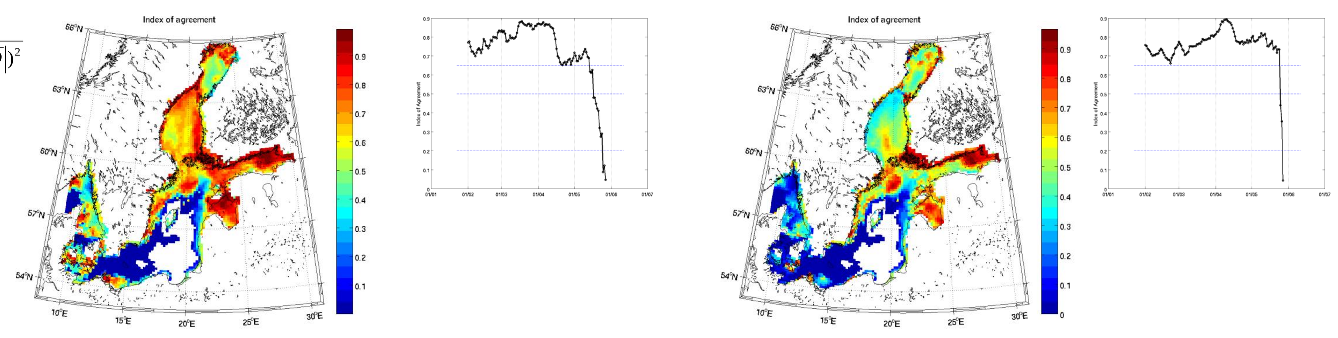
Nash-Sutcliffe Model Efficiency index

$$E = \frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\overline{O})^2}$$



Index of agreement

$$d = 1-\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(|P_i-\overline{O}|+|O_i-\overline{O}|)^2}$$

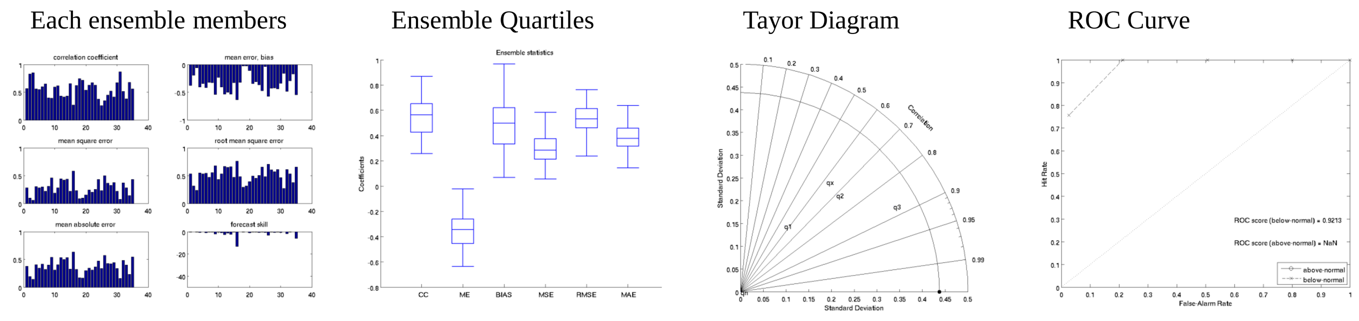


Ensemble Seasonal Forecast Skills:

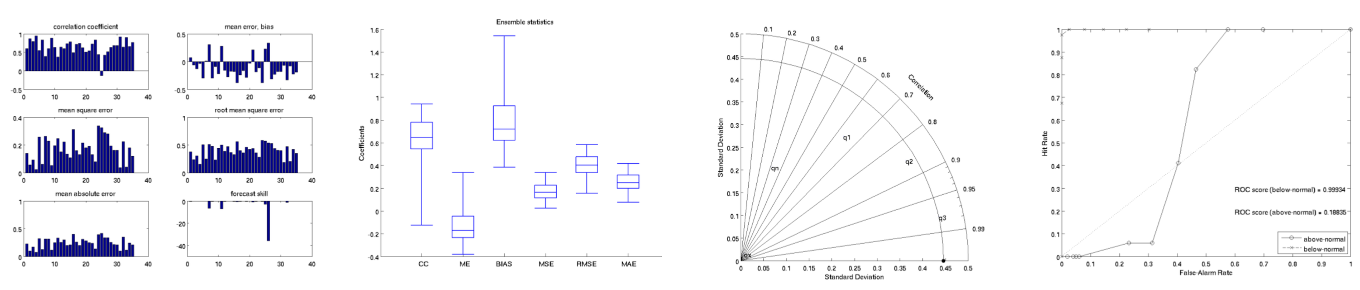
Ice concentration

Helsinki wave buoy

Each ensemble members | Ensemble Quartiles | Tayor Diagram | ROC Curve

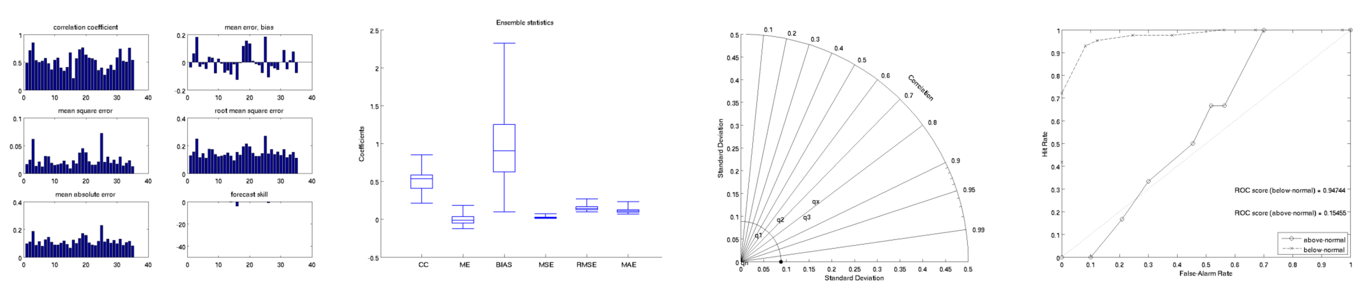


Gavle



Ice thickness

Helsinki wave buoy



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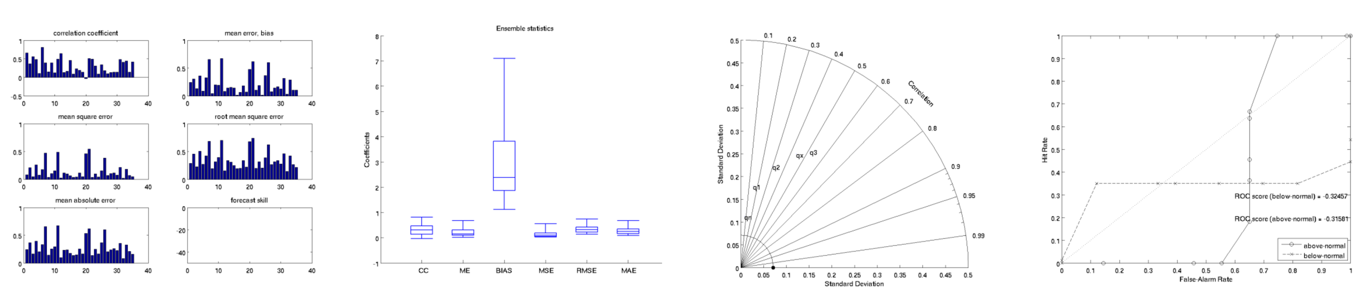

$$\text{CC(Correlation Coefficient)} = \frac{\text{Cov}(O,P)}{\text{std}(O)\cdot\text{std}(P)}$$

$$\text{MSE(Mean Square Error)} = \frac{1}{n}\sum_{i=1}^{n}(O_i-P_i)^2$$

$$\text{MAE(Mean Absolute Error)} = \frac{1}{n}\sum_{i=1}^{n}|O_i-P_i|$$

$$\text{ME(Mean Error)} = \frac{1}{n}\sum_{i=1}^{n}(O_i-P_i)$$

$$\text{RMSE(Root Mean Square Error)} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i-P_i)^2}$$

$$\text{BIAS} = \frac{\overline{P}}{\overline{O}}$$

$$\text{Forecast Skills} = 1-\frac{\frac{1}{n}\sum_{i=1}^{n}(O_i-\overline{O})^2}{\frac{1}{n}\sum_{i=1}^{n}(P_i-\overline{P})^2}$$

ROC(Relative Operating Characteristic) Curve : by using multiple thresholds, a deterministic forecast system can be evaluated across a range of possible decision theshold using ROC and relative value.

Hit and False Alarm Rate

$$\text{HR(Hit Rate)}_n = \frac{O_n}{O_n+NO_n}$$

where O is number of Observed instances and NO is number of non - observed instances.

$$\text{FAR(False Alarm Rate)}_n = \frac{NO_n}{O_n+NO_n}$$

AUC(Area Underneath the roc Curve)

ROC Score = (2 · AUC) -1

Summary and Future work

We have been providing the Baltic Sea sea-ice prediction with ECMWF ensemble forcings. We explored here the ability of our ensemble forecasts and its validations. The method on the validation provides information on the spatial and temporal forecasting skills. From these validation analyses we see that while there are still in need of improvement our prediction, the operational model is reasonably reliable for monthly and seasonal forecasts and falls within the range of prediction. For more accurate, we will continue to develop a new method of probabilistic forecast products and check the reliability between forecast probability and observed data.

Acknowledgements

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