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IMPROVING THE EFFICIENT USAGE OF THE ICEBREAKERS IN THE BALTIC SEA

Finnish Transport and Communications Agency

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FOREWORD

In this report no 109, the Winter Navigation Research Board presents the results of the project on improving the efficient usage of the icebreakers in the Baltic Sea. The project aimed to build a forecast system which will use both extended range forecasts (ERF) and long range forecasts (LRF) to estimate the ice condition development during a winter season in the Baltic Sea.

In the project a forecasting system was established and it is now automatically producing the ERF forecasts and will be finalized to include also the LRF.

The Winter Navigation Research Board warmly thanks Mr. Joni-Pekka Pietikäinen, Mrs. Elisa Lindgren, Mr. Antti Kangas, Mr. Patrick Eriksson and Mr. Jouni Vainio for this report.

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IBASE Final Report

Improving the efficient usage of the icebreakers in the Baltic Sea

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Summary

The IBASE (Improving the efficient usage of the icebreakers in the Baltic Sea) project aimed to build a forecast system to estimate the ice condition development during a winter season in the Baltic Sea.

Weekly and monthly Baltic Sea ice forecasts were produced based on European Centre for Medium- and Long-Range Weather Forecast extended range forecasts (ERF) and long range forecasts (LRF). ERF forecast is up to six weeks long and LRF up to six months. Their usability was tested for three winters in 2016-2019 to see how well they predict the sea ice extent development. Both forecasts show predictive skill and despite their deficiencies the information is valuable in long-range sea ice forecasting.

In the project a forecasting system was established for downloading, processing and plotting ERF and LRF forecasts for winter navigation management and ice service use. The forecasts are used in the Baltic Sea seasonal sea ice forecasts (SEASON). The system is now automatically producing the ERF forecasts and will be finalized to include also the LRF before next winter.

Introduction

The IBASE (Improving the efficient usage of the icebreakers in the Baltic Sea) project was funded in 2018 by the Finnish-Swedish Winter Navigation Research Board. **The project aimed to build a forecast system** on top of the existing ERF pilot system (CLIPS system developed with Academy of Finland key project funding in 2016-2018) **that will use both the ERF information and LRF to estimate the ice condition development during a winter season in the Baltic Sea.** Moreover, the IBASE-project aimed to improve the longer forecasts by employing the local information about the ice conditions for the Baltic Sea as initial state for the ECMWF models. Project duration was December 2018 - May 2019.

The winter navigation operations in the Finnish sea areas are coordinated by the Finnish Transport Infrastructure Agency (FTIA, Väylävirasto in Finnish). The actual icebreaking is operated by a fleet of chartered icebreakers, in recent years chartered from the state-owned company Arctia Icebreaking Ltd and Alfons Håkans Ltd. The fleet's main priority is controlled by FTIA, which in practise means that the icebreaker fleet first has to fulfil the needs coming from FTIA. Only after this the excess in the icebreaking companies' asset capacity can be rented elsewhere. It is not beneficial for FTIA nor the icebreaking companies to keep the Finnish icebreaker fleet (or part of it) in harbours. Naturally, the same applies to the fleet of the Swedish Maritime Administration and thus, there is a real need for reliable ice condition forecasts in seasonal (months ahead) and sub-seasonal (weeks ahead) scales. The earlier we can provide information about the possibility for reaching more easily manageable ice conditions, the sooner the icebreaking companies have the possibility to rent their vessels to other tasks, for example to operations in the Arctic.

FTIA has the responsibility to keep the Baltic Sea routes open for navigation, in particular for merchant vessels, and FTIA would benefit greatly if they had more information of the likely development of ice conditions and also how good the simulation models are at predicting these situations. Combined information about forecasts and weather-type related model skill would potentially add more in the decision making than the current available knowledge about climatic means and predicted anomalies (warmer or colder than normal).

The Finnish Meteorological Institute (FMI) has since 2012 provided seasonal ice condition forecast to the icebreakers concerning the Baltic Sea region. The forecast is based on three elements: 1) the monthly long range forecasts (LRF) from different modelling centres are monitored, 2) the prevailing information about the state of the atmosphere, 3) initial temperature and sea ice conditions, and 4) known sea ice conditions from the past years. After the LRF forecasts have been matched to the current atmospheric and marine states, the meteorologists and ice-experts will make estimates on how the ice season will continue to develop based on earlier winter conditions and how sea ice will affect the icebreaker need and trafficability. This approach, however, has many deficiencies; for example, there are no guarantees that the forecasted winter will continue to develop similarly as the chosen earlier year(s), and any rapid changes in the weather conditions will not affect the forecasts.

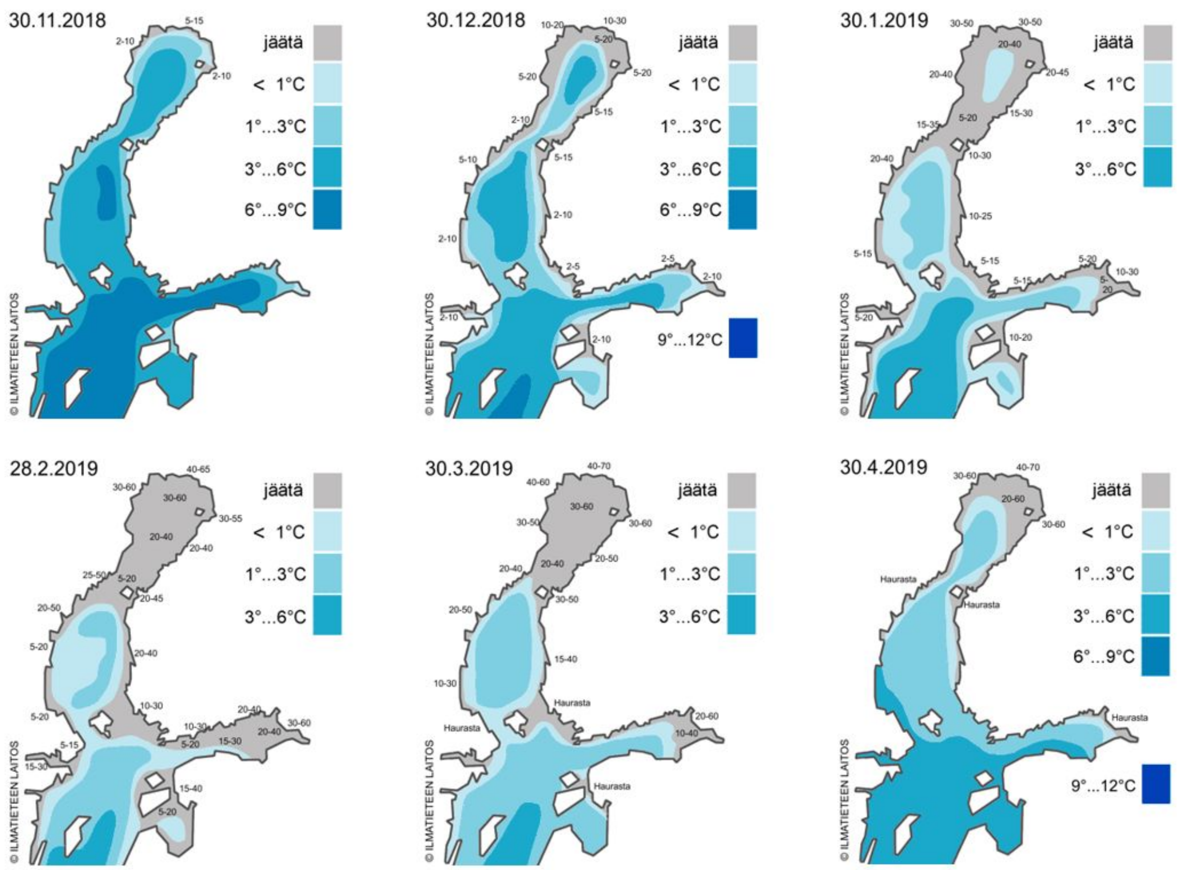


Figure 1. FMI provides seasonal ice condition forecasts (SEASON-forecasts). These ice extent and thickness estimates were made in November 2018 describing the forecasted ice conditions from November 2018 to April 2019.

During the second half of the winter 2017/2018 FMI tested if the extended-range forecast (ERF) from the European Centre for Medium-Range Forecast (ECMWF) can improve ice condition forecasting. The ERF provides an overview of the forecast for the coming 46 days, mainly focusing on the week-to-week changes. At FMI, as a first test, the ice cover ERF was post-processed to 6-weeks long climate forecasts. This is nowadays possible, because the ECMWF's ERF and LRF systems were improved in November 2016 to include a coupled ocean model component (NEMO model), which calculates the ice dynamics using the LIM2 ice model (Louvain-la-Neuve Sea Ice Model). This coupling allows, for example, for the melting of sea ice during atmospheric warming in spring, and in general it enables a more accurate interaction between sea ice, ocean and atmosphere.

Results

The work during this project focused on developing the ERF/LRF-forecast based system, research on how these forecasts perform, and on developing the forecasts through collaboration with the ECMWF. Eventually the focus on these topics will improve the seasonal sea ice forecasts for the Baltic Sea.

Table 1 summarizes the project deliverables and the results.

The project results are described in the following sub-chapters in detail.

Table 1: List of deliverables and current statuses

Deliverable	Task	Status	Comments
1st deliverable	Operational ERF and LRF system for ice conditions	ERF forecasts are operational. LRF will be operational for next winter.	LRF image plotting requires currently manual work, but is nevertheless working.
2nd deliverable	Improved ECMWF sea ice initial condition in the Baltic Sea	PENDING for ECMWF decision and implementation	Currently FMI has done it's best to help ECMWF to use better initial conditions. ECMWF is updating their model system and data assimilation methods.
3rd deliverable	Improved skill to predict the sea ice condition in the Baltic Sea	ERF and LRF are integrated to FMI's forecast routines.	-

Extended range forecasts (ERF) validation

The Extended Range Forecasts were tested and validated in winters 2016-2017, 2017-2018 and 2018-2019 (Figure 2). The first ice season in 2016-2017 was mild in the Baltic Sea. An exceptionally warm December was followed by two weeks of cold weather in January and a colder period in early February, but then the weather turned milder and the maximum ice extent reached only 88 000 km2 on 12th of February. The ERF forecasts had difficulties in predicting the warm December and gave signals of quickly growing ice extent. When the weather actually turned colder and the ice extent grew in early February (weeks 5-7), the forecasts started with an initial amount of ice that was less than half of the real ice extent. When the ice extent started to decrease in March due to mild weather, the forecast had catched up the real situation and predicted very well the shrinking of the ice covered area.

The following winter 2017-2018 was an average ice season. December started again as warm and the ice extent grew slowly but in January and early February the area of ice increased in a regular manner. The forecasts were following this rather well although the initial condition for the ice extent was again this year too low compared to the real ice extent. In mid-February the weather changed clearly and cold weather hit the Baltic Sea region. In the end of January there had been no signal of this cold weather in the weather forecasts and this probably explains why the ERFs did not predict the fast growth of ice covered area for February and March. The peak of the ice winter was reached on 5th of March. The forecasts did not, however, show any sign of improvement in the initial ice extent and were for the rest of the winter predicting a much lower ice extent than what was observed. In April the weather was warmer than usual which accelerated the ice melting and although the ERF ice extent was a bit too low, it predicted the timing of the ice free Baltic Sea rather well.

The third winter season 2018-2019 was again mild and started with a warm November and December. The beginning of January was also mild but then in mid-January cold air flowed from north to Fennoscandia. The cold weather continued until the end of January and the ice area grew rapidly reaching the maximum of 88 000 km2 on 27th of January. This quick change from mild to cold weather went unnoticed by the ERFs and the forecasts had difficulties in adjusting to this rapid change and thus missed the peak of the ice season. February was on average 2-5 degrees warmer than the climatological mean and the ice extent started to shrink, but the beginning of March was cold and the ice covered area expanded. The ERFs showed some early signals of the cold March and then started to predict the shrinking of ice covered area and ice melting. April and May were both warmer than usual and the Baltic Sea was ice free on 14th of May.

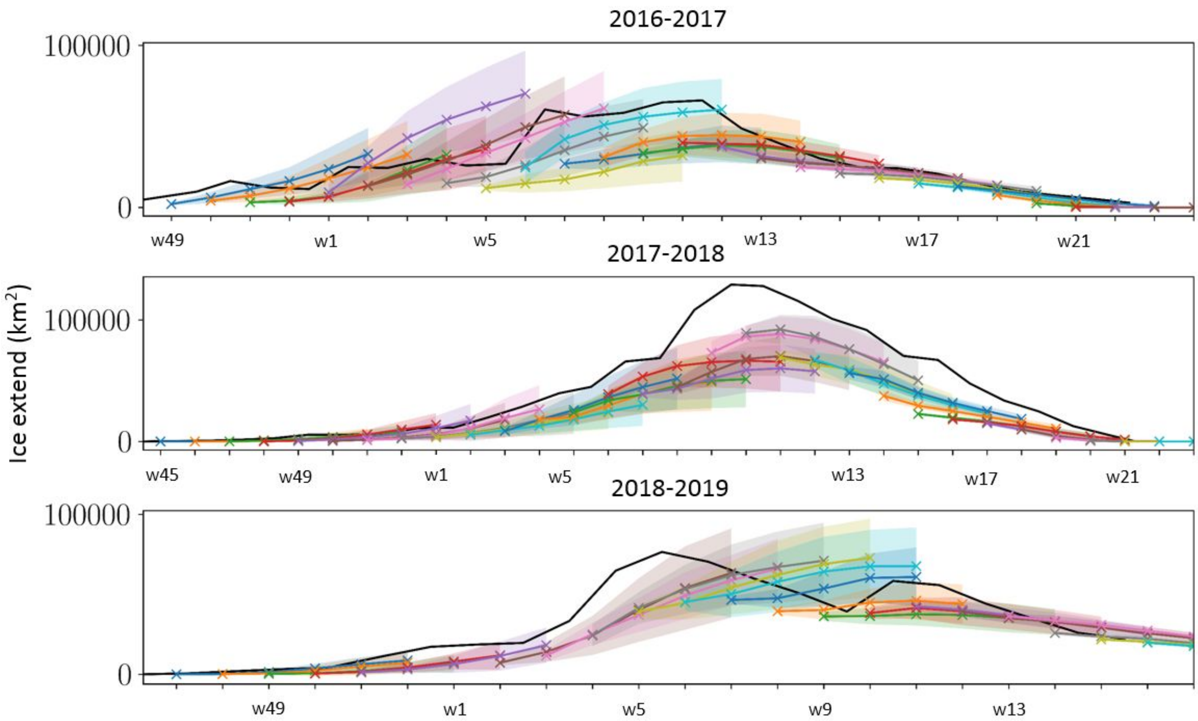


Figure 2. Extended range forecasts comparison against the observed ice area for years 2016-2017, 2017-2018 and 2018-2019. The weekly averages of the ERF forecasts are plotted with coloured lines and the shadowed area shows the variation in the ensemble. The black line is the weekly average of the ice extent that was obtained from FMI ice charts.

Even though the ERFs are most accurate for the first couple of weeks and at the moment mainly add value to 1-3 weeks forward, the potential to increase the skill for longer periods is there. Based on our analysis, the biggest error source in the system is in the initialization of the model, i.e. the model starts from a state that is too far from the reality and can not capture the real path anymore. If the 6-weeks forecasts would start from a more accurate initial state, the forecast skill would increase significantly.

Extended range forecasts (ERF) development

At the moment the ECMWF model system assimilates sea ice concentration data from OSTIA (The Operational Sea Surface Temperature and Ice Analysis), that is a daily observational product produced by the UK Met Office. Results showed major issues in sea ice assimilation for the model. OSTIA product typically underestimated the sea ice extent, leading to underestimation in the model forecasts. This issue was reported to ECMWF with improvement proposal: FMI and the Swedish Meteorological and Hydrological Institute (SMHI) jointly produces high-resolution daily charts of the Baltic Sea ice conditions and these could be used as the initial state for the forecast models. The product is available free of charge from FMI or CMEMS (Marine environment monitoring service) servers.

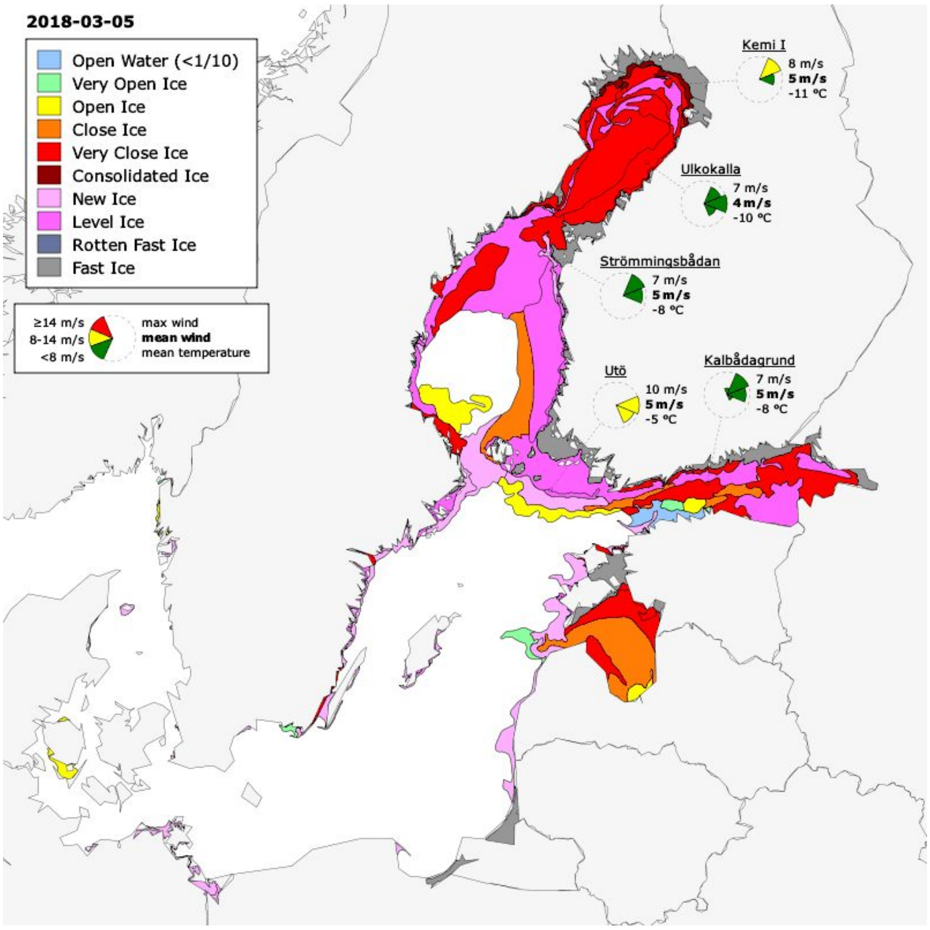


Figure 3. Ice chart produced operationally by FMI and SMHI on a daily basis. The ice type classification is made in vector format from high-resolution satellite imagery and can be exported to grid format with desired resolution.

During the winter 2018/2019 we contacted ECMWF several times regarding the usage of FMI's high-resolution ice cover product as an initial state for ECMWF models. Our suggestion has been received and the topic has been discussed with the ECMWF researchers and modellers via e-mail and face-to-face. ECMWF has showed cautious interest in the ice chart data and their modelling experts have planned to at least run technical tests with the high-resolution data. The problem in this case is that the ECMWF models are global models and thus the regional data is not easy to incorporate to them, or to be more specific, model developers at ECMWF are not keen on applying special condition to local areas. Thus we are not expecting ECMWF to start operationally assimilating FMI's ice chart data, unless closer technical studies both in FMI and in ECMWF are first carried out.

Even though we were not able to find a way for assimilation of the ice chart data, the closer discussions with ECMWF personnel and feedback of the error sources has provided ECMWF ideas on what to focus on in the development work in the future. ECMWF is at the moment developing a new ocean and sea-ice analysis system OCEAN6 that has a special focus on improving the sea ice performance both in terms of sea ice model and data assimilation. They are currently testing a new multicategory SI3 model (Sea Ice modelling Integrated Initiative, the sea ice component of NEMO-ocean model) and testing direct assimilation of L3 OSI-SAF (The Ocean & Sea Ice Satellite Application Facility) sea ice concentration data instead of OSTIA data and these updates are expected to improve the ERF forecasts for the winter season 2019-2020.

Long range forecasts (LRF) development

Through the IBASE funding we brought the equivalent LRF product for testing (see example of the forecast in attachment 2). The forecast length is up to six months and the forecast is updated once per month, which is the update frequency of the latest generation of ECMWF's seasonal forecasting system SEAS5. FMI forecast system downloads the LRF data from ECMWF and plots the monthly forecast images.

Based on the feedback from the ice forecasters, the forecast shows the ice cover extent at the end of each forecasted month, which is the same as the FMI's SEASON forecast.

ERF and LRF product availability

In the project an FMI-internal web page was created for viewing the ERF and LRF forecasts. The ERF forecasts are automatically processed, and the images for next year will be available as the Baltic Sea starts to freeze. Due to large data volumes in LRF, the FMI automatic processing for forecast images is incomplete. Examples of the LRF forecasts were made manually and FMI continues work to finalize the processing of the forecast images for the next winter. The delivery method of the ERF and LRF forecasts (examples in attachment 1 and 2) for FTIA and SMA has to be agreed on. One option is to use FMI's existing 'Ilmanet' portal.

Further development

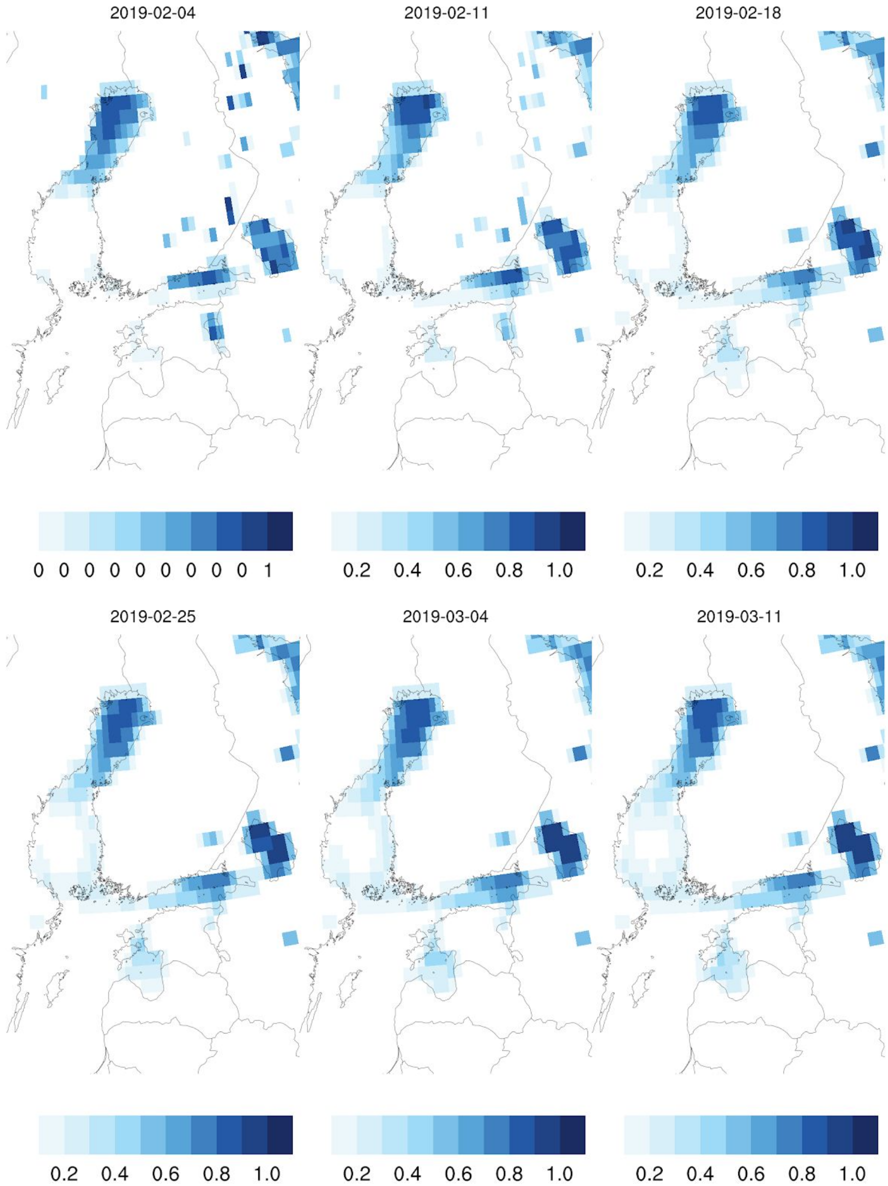
In this work, the ECMWF's ERF and LRF ice cover product was used to introduce new and valuable information for the Winter navigation management and ice forecasters. For these forecasts, ECMWF uses an ensemble method, which means running the forecast multiple times with slightly modified initial conditions. In IBASE, we made the final products by averaging the ice cover forecasts over the ensemble. This is a valid approach, but can be further developed to include information about the probabilities (or we could move directly to probabilistic forecasting product). This means, in practice, that we would do a more comprehensive analysis how the ensemble behaves in different areas of the Baltic Sea and provide probabilities for the ice cover extent. To add an indication on the severity of the ice season, we could start testing the six week wind forecasts that have been piloted in FMI within the CLIPS-project in 2016-2018. The information on wind conditions could be useful for the ice experts to predict the drifting and ridging of ice.

Another way to improve both ERF and LRF product(s) is to add more information from other seasonal services. This means moving towards a multi-model ensemble, which has been shown to improve the skill of seasonal products. In the near future, this can be done using the Copernicus Climate Change Service's (C3S) climate data store (CDS), where reanalysis and forecast products are freely available for download. This service has just opened and is still under development. However, it would bring us the direct possibility to utilize seasonal ice cover forecasts from other modelling centres. Also, by using other modelling systems we would see how well their initial conditions represent the actual initial measured state. An assessment of the skill of operational forecast systems by Zampieri et al. (2018) suggests, as well as we do, that by improving the data assimilation method, the sub-seasonal forecast results could be taken to the next level. Future cooperation with the ECMWF and closer technical studies in FMI would be beneficial so that if needed, we could provide our sea and sea ice products as an initial state for different coupled modelling systems.

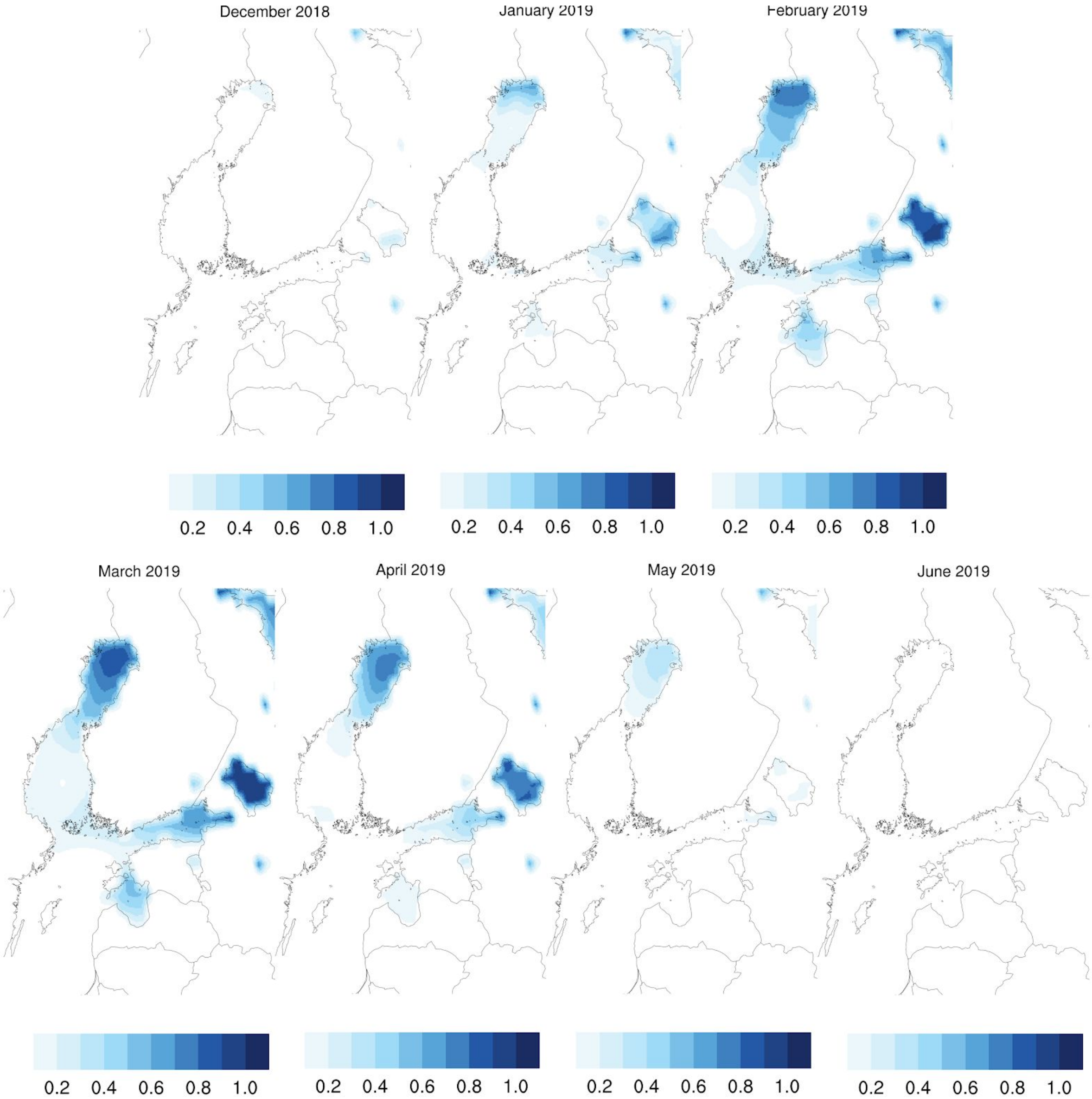
References

Zampieri, L., Goessling, H., and Jung, T. (2018). Bright prospects for Arctic sea ice prediction on subseasonal time scales. Geophysical Research Letters, 45, 9731-9738.

Attachments



Attachment 1. The six week sea ice forecast produced from the ERF forecasts. This example shows a forecast produced on 31st January 2019, predicting sea ice covered area to increase until mid March.



Attachment 2. The six months forecasts produced from the LRF forecasts. The product shows the sea ice extent forecasted for the end of each month.