Verification and calibration of sea ice forecasts in a changing climate

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Introduction

Sea ice forecasts days to seasons ahead are being routinely provided by the Copernicus Marine and Climate Change Services. However, user uptake of these forecasts is often hampered by a lack of guidance on forecast uncertainty and calibration. Here, we present methods and tools for verification, calibration and product generation for probabilistic sea ice forecasts in the medium, sub-seasonal and seasonal forecast range. These tools are now available as an open-source software package named ICECAP.

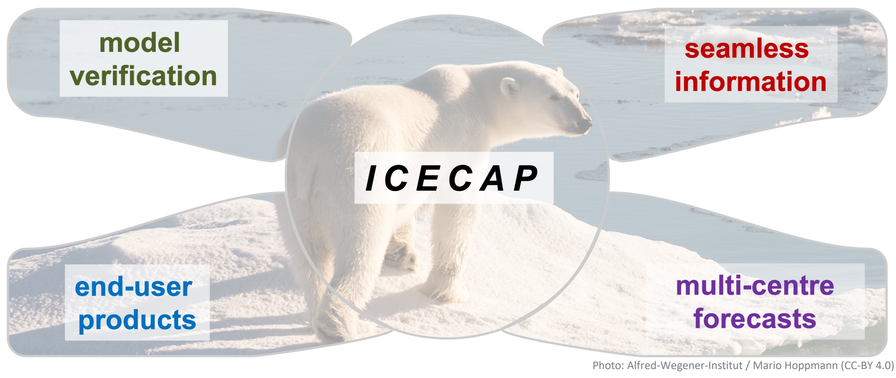

Photo: Alfred-Wegener-Institut / Mario Hoppmann (CC-BY 4.0)

https://github.com/ecmwf/ICECAP

Seasonal outlooks – calibration needs to consider climate trends

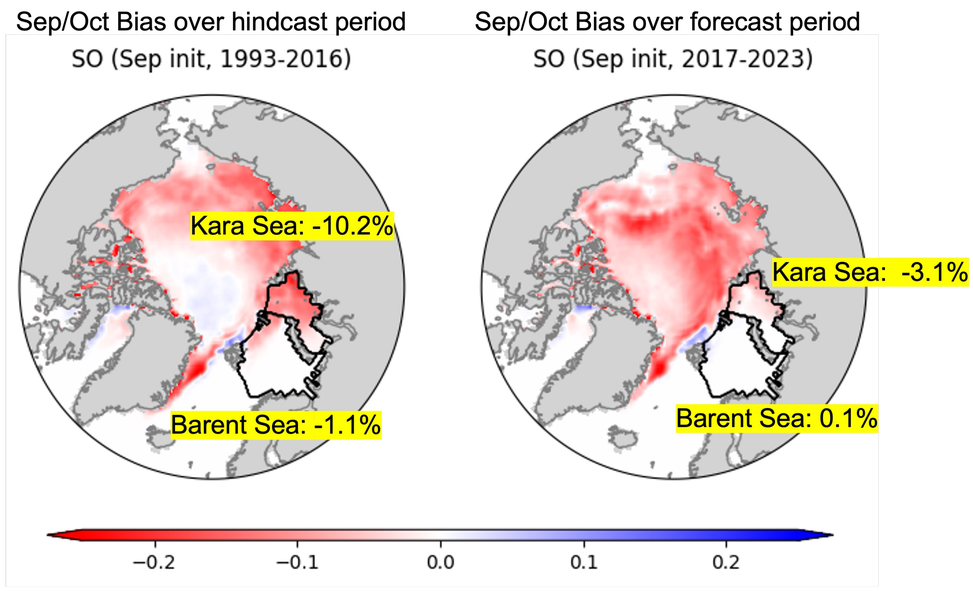

***Fig 1**: SEAS5 sea ice concentration biases for the standard C3S hindcast period (left) and a more recent period over which forecast skill is assessed (right)*

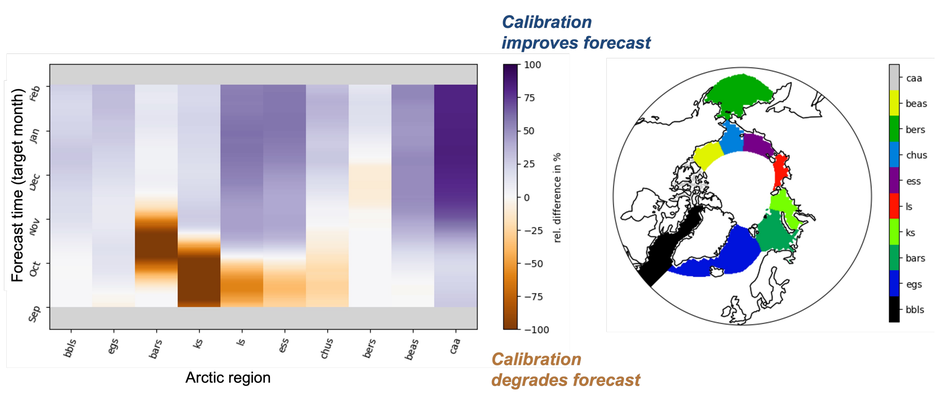

***Fig 2**: Impact on diagnosed ice edge forecast skill (IIEE) when calibrating the forecasts 2017-2023 by removing the the biases from the 1993-2016 period.*

The IIEE (integrated ice edge error, Goessling et al, GRL 2016) is the area where the categorical forecast of ice concentration being above or below 15% does not match the observed outcome.

Calibration over standard C3S hindcast period can be detrimental.
Using more recent hindcast periods or applying a trend correction is required.

Short-to-medium range forecasts – reducing uncertainty of initial conditions is key

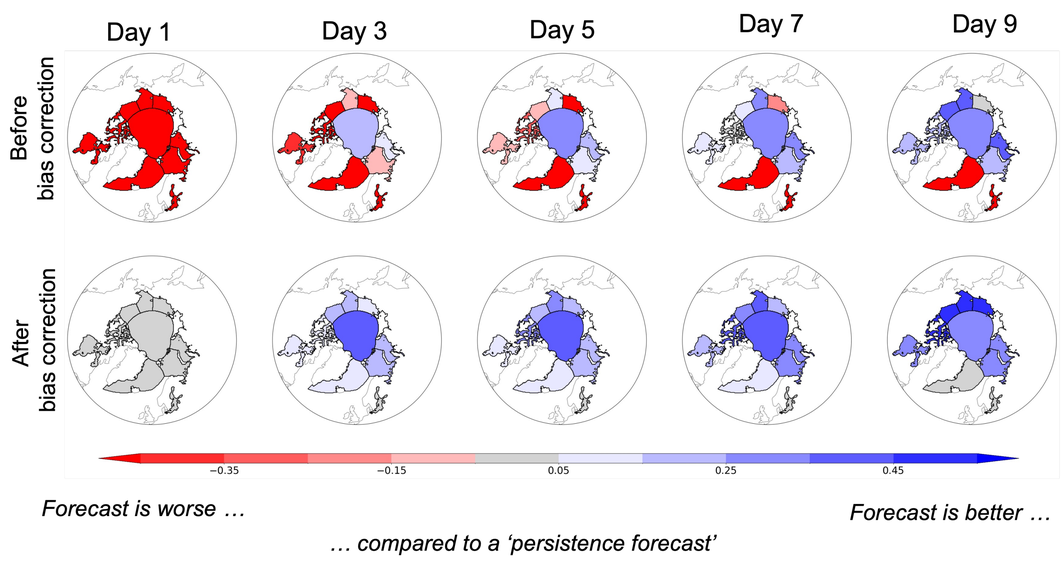

***Fig 4**: Regional IIEE skill score for ECMWF forecasts for Nov 2023 to Jan 2024 compared to a persistence forecast. Top row: uncalibrated forecast. Bottom row: after removing the initial-condition bias defined as the difference between day 1 of the forecast and observations on the previous day (cf. Palerme et al., The Cryosphere 2024)*

Skill of short-range forecasts is hampered by uncertainty of sea ice initial conditions, but after accounting for initial condition bias, dynamical forecasts provide added value over a persistence forecast in most regions.

Sub-seasonal forecasts – large untapped potential for end-users

Illustration Photo: Rosatomflot

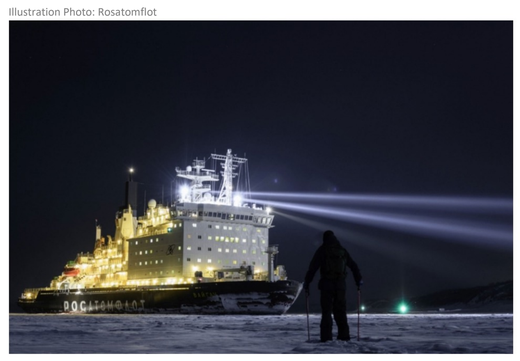

Illustration photo: Rosatomflot

A critical situation might be in the making on the Northern Sea Route

An early freeze has taken shippers by surprise and a big number of vessels are in danger of getting stuck in thick sea-ice.

Article in *The Barents Observer*, 8 November 2021: more than 20 ships stuck in sea ice on the Northern Sea Route.

Could forecasts have been used to provide early warning?

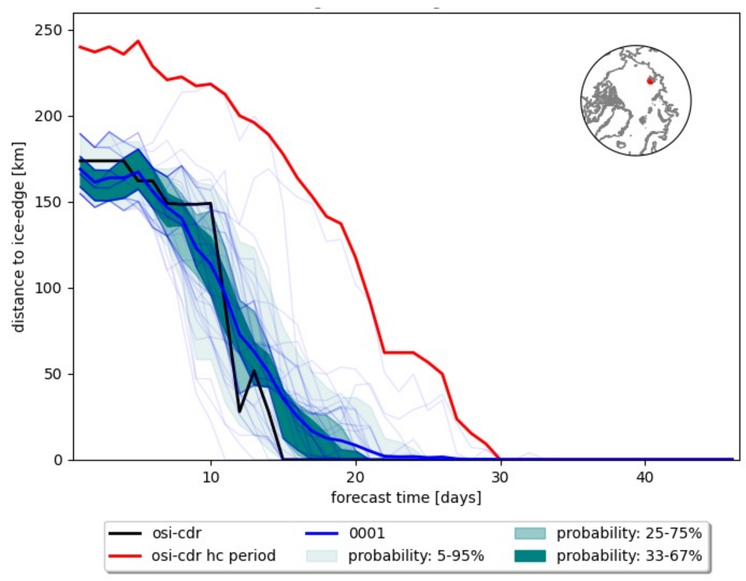

***Fig 3**: Prediction of the distance of the ice edge from the location of the beset ships derived from ECMWF forecasts initialized on 7 Oct 2021. The thick blue line is the forecast mean, the red line is a climatological forecast based on the previous 5 years, and the black line is the observed outcome. Forecast uncertainty is indicated by ensemble quantiles (shading) and individual ensemble members (thin blue lines). The forecast was calibrated by removing reforecast bias over the previous 5 years.*

ECMWF sub-seasonal forecasts indicated an earlier than usual freeze-up at the location and therefore could have been used to provide an early warning for difficult conditions.

Summary

We demonstrate that sea ice forecast biases can be problematic even in the medium range and should be accounted for when interpreting the forecast. In the sub-seasonal to seasonal forecast range, we demonstrate that the forecasts can add value over simple forecasts based on past observations. We stress that care needs to be taken when calibrating for systematic errors diagnosed from retrospective forecasts, because climate change signals in the Arctic and sub-Arctic regions are large. In summary, we propose that a careful uncertainty quantification and calibration of sea ice forecasts offered by the Copernicus Services can unlock their large potential to benefit stakeholders in the rapidly changing Arctic regions.