Sensitivity of ECMWF seasonal forecasts to stochastic sea-ice

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Grant agreement 101081568

1. Motivation and setup

The next ECMWF seasonal forecasting system (SEAS6) will use SI3 for its sea ice model. However, the ensemble spread for sea ice is too low with strongly underdispersive ensembles.

We try alleviating this by stochastically perturbing sea ice parameters, using an SPP scheme developed by Andrea Storto (Storto and Andriopoulos 2021).

Perturbations are temporally and spatially correlated, with a 10-day decorrelation timescale.
Perturbing many parameters generally gives a larger and more spatially uniform spread increase.

We examine impact in IFS seasonal forecasts.
25 ensemble members, Tco199 (~55km),
0.25° NEMO4/SI3. Cycle 49r2. May and Nov starts.

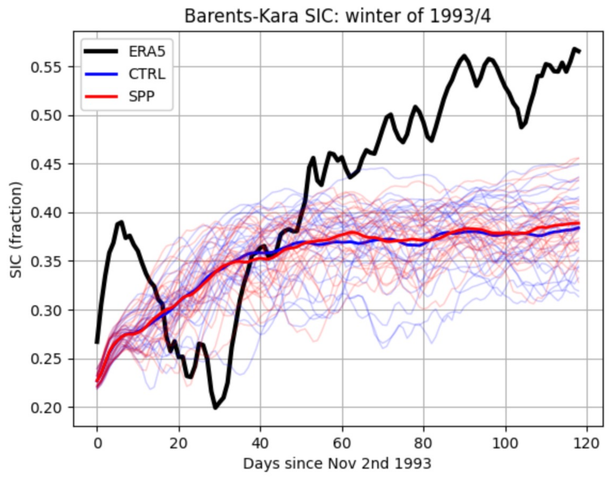

***Fig 1**. An example of an underdispersive sea-ice forecast. Observations are often outside the ensemble distribution.*

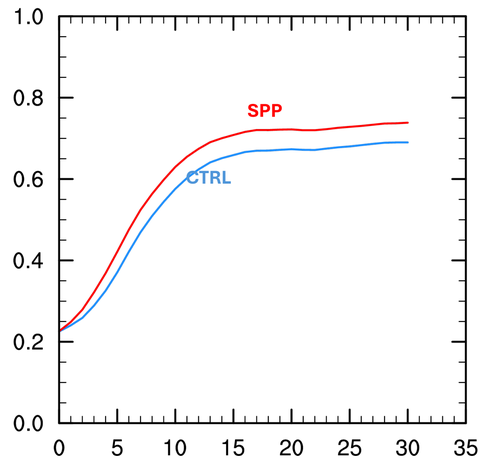

***Fig 2.** Spread-error ratios as a function of lead-time (days since May 1st). SPP improves things but still well below 1 early on in forecast. Verified against ERA5 (1993-2023).*

2. Basic changes to mean and spread of sea-ice concentration

For JJA, SPP more or less uniformly increases spread and decreases the mean. For DJF, effect is more ambiguous, but on average across all gridpoints the spread goes up.

For SIC, changes to spread are closely related to changes in the mean!
(e.g., if the ice vanishes from a gridpoint then the variance is completely lost).

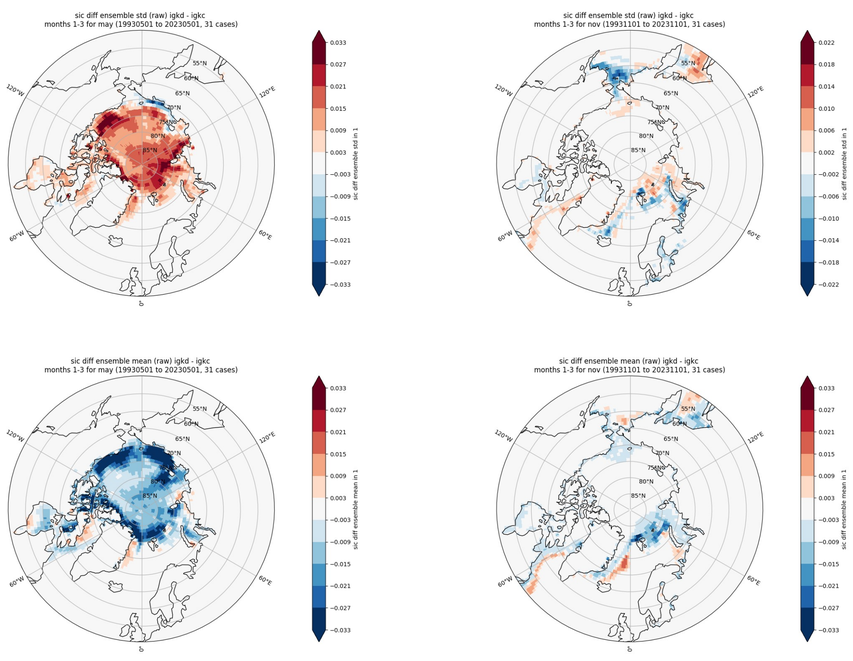

***Fig 3.** Top row: change in SIC spread with SPP in JJA and DJF. Bottom row: same but change in SIC mean. 1993-2023.*

3. Impact on seasonal forecast skill

Past work suggested Arctic-midlatitude teleconnections could be enhanced with stochastic ice (Strommen et al. 2023). Do we see better midlatitude skill with SPP?

Effect on SIC forecasts

Forecasts of JJA SIC do improve wrt to CRPS: **Figure 4.** DJF more ambiguous (as in Figure 3), with worse forecasts in some crucial regions (e.g. Barents-Kara seas).

The improvements in CRPS are related to reduced biases against ERA5 and enhanced spread (see also **Figure 2**).

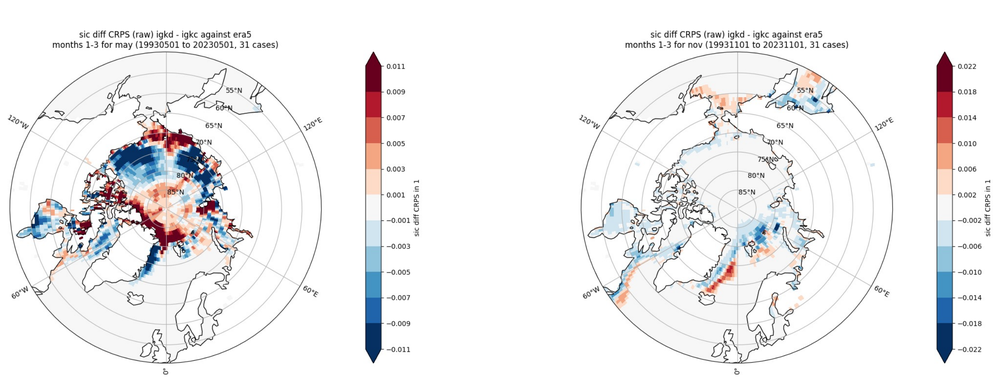

***Fig 4.** Change in CRPS scores for forecasts of JJA (left) and DJF (right) SIC means. Blue means better, red means worse. Verified against ERA5 (1993-2023).*

Effect on Z500 forecasts

Improvements to Z500 anomaly correlations are less clear due to sampling uncertainty. But consistent with changes to SIC CRPS, there is a suggestion that JJA gets better better and DJF worse: **Figure 5.**

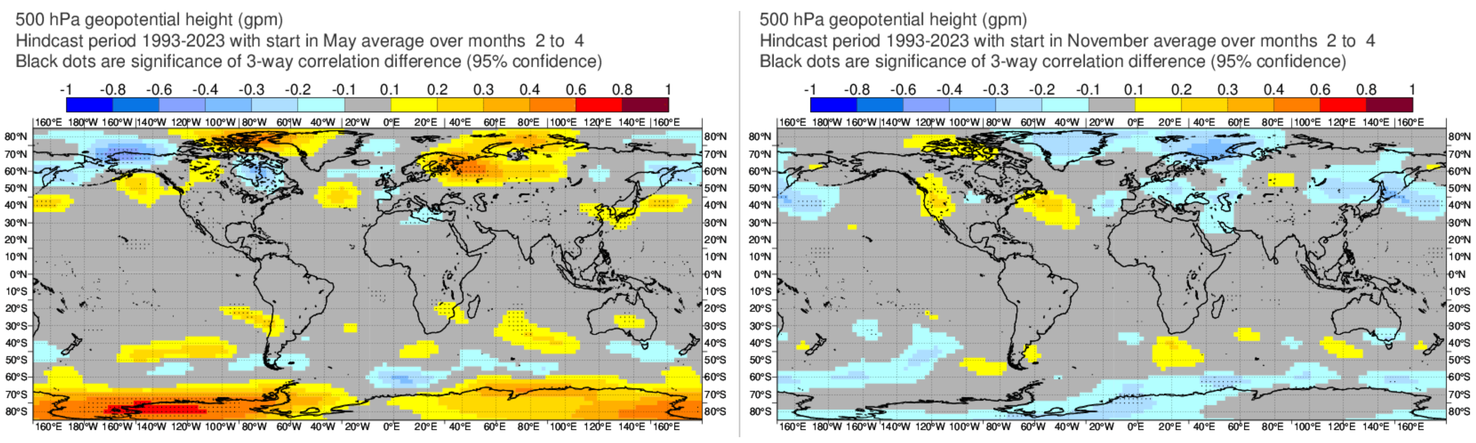

***Fig 5.** Change in ensemble mean Z500 correlations for forecasts of JJA (left) and DJF (right). Blue means worse, red means better. Verified against ERA5 (1993-2023). Thanks to Stephanie Johnson.*

4. Summary and Next Steps

Ice-SPP enhances spread, but underdispersion remains.

Ice-SPP has positive effect on skill in JJA.
Ambiguous/negative effect on skill in DJF.
Both are likely related to SPP-induced mean state changes.

Going forward

- Look more at improvements in summer, e.g. over Eurasia. Are they real or random?
- Look at impact on sub-seasonal forecasts with multiple startdates.
- Can we gain extra boost in spread by also perturbing the ocean? (SSTs strongly modulate ice in some regions).

References

Strommen, K., Juricke, S., and Cooper, F.: Improved teleconnection between Arctic sea ice and the North Atlantic Oscillation through stochastic process representation, Weather Clim. Dynam., 3, 2022.
Storto A, Andriopoulos P. A new stochastic ocean physics package and its application to hybrid-covariance data assimilation. *Q J R Meteorol Soc*. 2021