Assessment of summer 2023-2024 sea-ice forecasts for the Southern Ocean

Coordinating Seasonal Predictions of
Sea Ice in the Southern Ocean

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1. The Sea Ice Prediction Network South (SIPN South)

Being much thinner than Arctic sea ice and almost entirely seasonal, Antarctic sea ice has long been considered unpredictable beyond weather time scales. However, recent studies have unveiled several mechanisms of sea-ice predictability at seasonal time scales and demonstrated some skill in predictions (Bushuk et al., 2021; Holland et al., 2013, 2017; Marchi et al., 2019; Zampieri et al., 2019). The study of sea-ice predictability does not only represent an academic exercise but has also many potential future applications. For example, knowledge of sea-ice presence from weeks to months in advance would be of great interest to Antarctic shipping operators, since sea ice is one of the many hindrances that vessels face operating in the Antarctic coastal regions. In that context, advance notice of seasonal sea-ice conditions would help reduce costs associated with providing alternative operational logistics.

The Sea Ice Prediction Network South (SIPN South, https://fmassonn.github.io/sipn-south.github.io/) is an international project endorsed by the Year of Polar Prediction (YOPP). One of its main goals is to make an assessment of the ability of current forecasting systems to predict Antarctic sea ice on hemispheric and regional scales, with a focus on the summer season. SIPN South has the ambition to **lay the foundations for a more systematic and coordinated evaluation of seasonal sea-ice forecasts in the Southern Ocean** in the coming years. Findings from six forecasting seasons are summarized in Massonnet et al. (2023).

This technical report summarizes results from the seventh coordinated forecasting exercise organized so far, focusing on summer 2023-2024.

2. Summer 2023-2024 in context

SIPN South analyses focus on austral summer, a season of special interest due to the intense marine traffic at this time of the year. In summer, sea ice retreats to the point that it can expose Antarctic coastlines to the open ocean, thereby offering possible access to the Antarctic continent, ice sheet, or ice shelves.

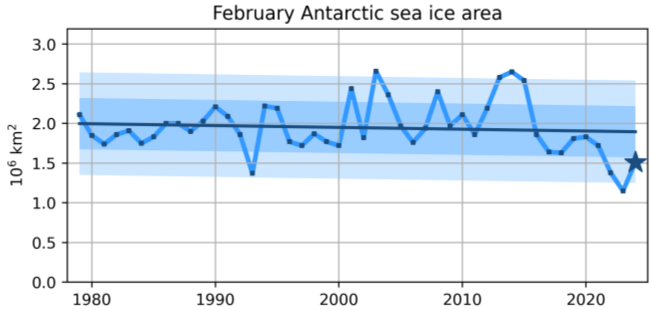

Figure 1. February Antarctic sea-ice area over the satellite observational record (1979-2024) (Fetterer et al., 2017). The star is February 2024. The dashed line is the linear trend and the two shaded intervals show 1 and 2 standard deviations of the residuals around the linear fit, respectively.

February mean was the fourth lowest on record in terms of sea ice area (1.51 million km^2) according to the National Snow and Ice Data Center sea ice index (Fig. 1). The negative sea ice area anomalies have been observed as early as late September and have persisted since then. Spatially, the anomalies were pronounced in the Eastern Ross and Weddell Seas. (Fig. 2) although sea-ice area in other sectors was also anomalously low.

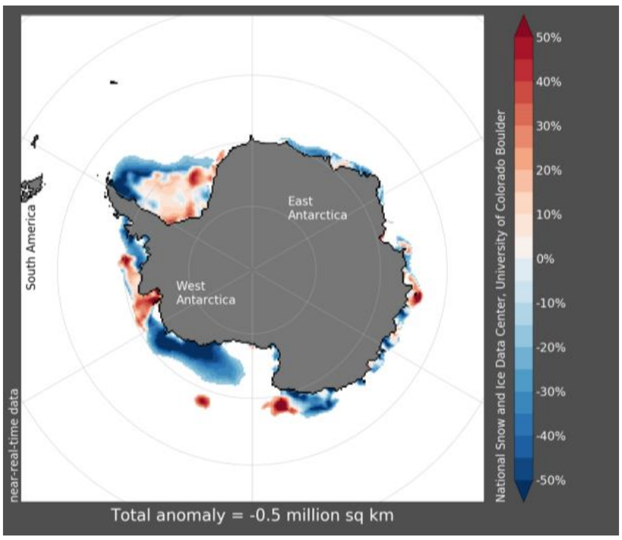

Figure 2. Anomalies of sea-ice concentration in February 2024 relative to the 1981-2010 mean (from www.nsidc.org; Fetterer et al., 2017)

3. Forecasting sea ice for summer 2023-2024

A call for contributions was issued in November 2023 to predict sea-ice conditions during the three-month period from December 1st 2023 to February 28th 2024. **We received contributions from 15 groups or individuals and would like to thank all contributors for their participation.**

Contributors were asked to provide, in order of descending priority, (1) the total Antarctic sea-ice area (denoted "SIA"), (2) the regional sea-ice area per 10° longitude band (denoted "rSIA"), (3) sea-ice concentration (denoted "SIC"), and (4) sea-ice thickness (volume per unit grid cell area, denoted "SIV") for each day of December 2023-February 2024, and (5) "long forecasts" extending beyond February 2024. One submission (Lamont) consisted of monthly means instead of daily means. For this contribution, the forecasts were interpolated to daily resolution using a quadratic function passing at the given monthly values on the 15th of each of the three months. Seven groups used fully coupled dynamical models and seven groups used a statistical model trained on past data (this includes machine learning approaches). One group used an ocean—sea ice model forced by atmospheric reanalysis of previous years. Table 1 summarizes the contributions received for this exercise.

Table 1. Information about contributors to the summer 2023-2024 coordinated sea-ice forecast experiment.

	Contributor name	*Short name (in figures)*	*Forecasting method*	*# of forecasts*	*Initialization date*	*Diagnostics provided*
1	AWI	AWI-CPS	Coupled dynamical	30	Nov. 30th	SIA+rSIA+SIC+SIV
2	BSC	BSC	Coupled dynamical	50	Nov. 1st	SIA+rSIA+SIC
3	CanSIPSv2	CanSIPSv2	Coupled dynamical	20	Nov. 30th	SIA+rSIA
4	CMCC	cmcc	Coupled dynamical	50		SIA+rSIA+SIC
5	EMC	emc	Coupled dynamical	10		SIA+rSIA+SIC
6	GFDL	gfdl	Coupled dynamical	30	Nov. 30th	SIA+rSIA+SIC
7	IOCAS-SIPNet	IOCAS-SIPNet	Statistical	1	Nov. 30th	SIA+rSIA+SIC
8	Lamont	Lamont	Statistical	1	Nov. mean	SIA+rSIA+SIC
9	Walt Meier	Meier-NSIDC	Statistical	1	Dec. 1st	SIA
10	Met Office	MetOffice	Coupled dynamical	42	Nov. 25th	SIA+rSIA+SIC
11	Nico Sun	NicoSun	Statistical	3	Nov. 30th	SIA+SIC
12	Sun Yat-sen University	SYSU-ConvLSTM	Statistical	1	Nov. 30th	SIA
13	Sun Yat-sen University	SYSU-MLM	Statistical	1	Nov. 30th	SIA+rSIA+SIC
14	Sun Yat-sen University	SYSU-KNN	Statistical	1	Nov. 30th	SIA+rSIA+SIC
15	UCLouvain	ucl	Forced dynamical	10	Nov. 1st	SIA+rSIA+SIC+SIV

3.1 Circumpolar sea-ice area

Fig. 3 shows the total sea-ice area (SIA) forecast for each day of December 2023-February 2024 as submitted by the 15 contributors. SIA is not a very sensible geophysical diagnostic as it does not reflect regional variations, but it gives a first indication of how the forecasts behaved. In this figure, two observational references are also included to provide a general idea of the importance of observational uncertainty. As seen in Fig. 3, observational uncertainty is small relative to inter-model spread. In the following analyses, we will, therefore, assume that observational errors are not a major cause for differences between forecasts and observations.

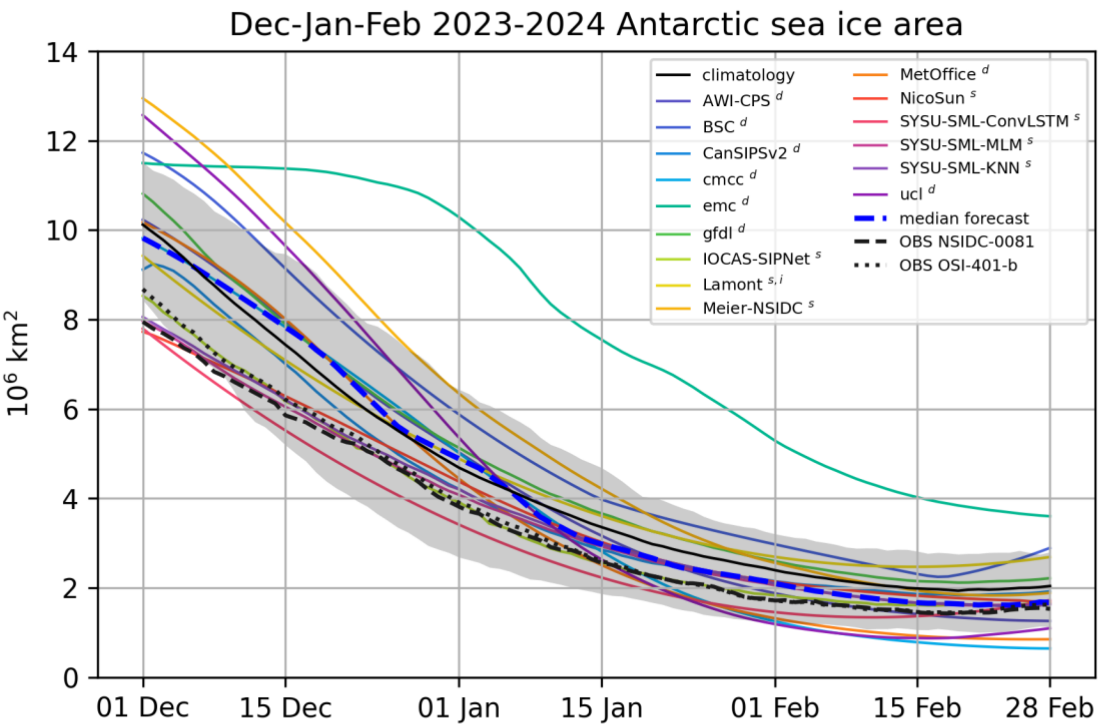

Figure 3. Total (circumpolar) Antarctic sea-ice area of the 15 forecasts for each day of the period December 2023-February 2024. The colored lines are the ensemble medians. The superscripts in the legend indicate whether the submission is based on a statistical or a dynamical approach and, possibly, if monthly data has been interpolated to daily resolution. The black dashed lines are two observational references (Maslanik and Stroeve, 1999 and Tonboe et al., 2017). The grey shading is the observed climatological envelope for the past 30 years, and the dashed blue line is the multimodel median forecast.

Similarly to previous years, an overestimation of sea-ice area is noted already at day 1 of the forecasting period for several dynamical model forecasts. Interestingly, the bias reduces over time and the distribution of forecasts is not incompatible with observations at the minimum, in February.

In order to quantify the relationship between bias and ensemble spread, we use the Continuous Rank Probability Score as in Massonnet et al. (2023). The CRPS is a convenient metric because it penalizes forecasts that are either biased (high or low) or excessively spread out. According to the definition, a CRPS of zero is obtained for a perfect forecast with the mass of the distribution concentrated at the verifying observation value.

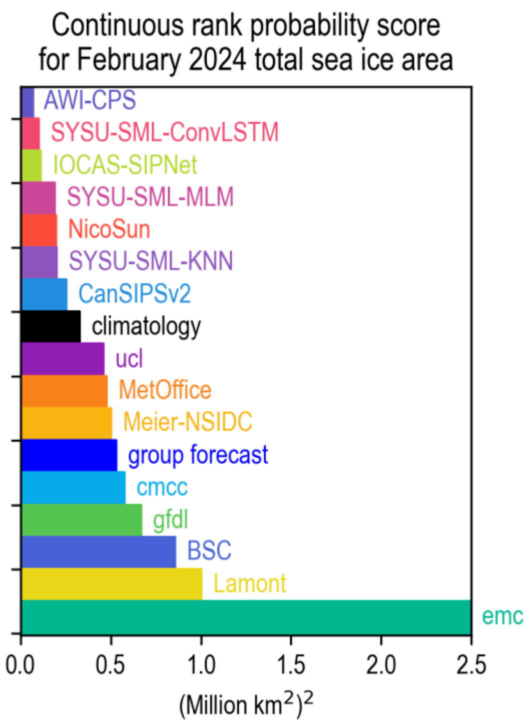

Figure 4. Continuous Rank Probability Score for the ensemble forecasts. The CRPS measures the area between the squared difference between the cumulative density function of the forecast and the cumulative density function of the observations. Lower values indicate higher skill. See Massonnet et al. (2023) for more details.

3.2 Regional sea-ice area

Figure 5 shows the spatial distribution sea ice in February 2024. The spread seen in dynamical contributions suggests that weather variability is a dominant source of uncertainty for summer sea ice prediction but the mean signal is at times well forecasted (e.g., AWI-CPS). Statistical models do show some performance as well (e.g., IOCAS-SIPNet, NicoSun, SYSU-SML-MLM).

Data availability

The analyses presented in this report can be reproduced bit-wise by cloning the SIPN South Github project at https://github.com/fmassonn/sipn-south-public (branch develop_2023-2024). Instructions to retrieve the data and process the analyses are given in the README.md file of this repository.

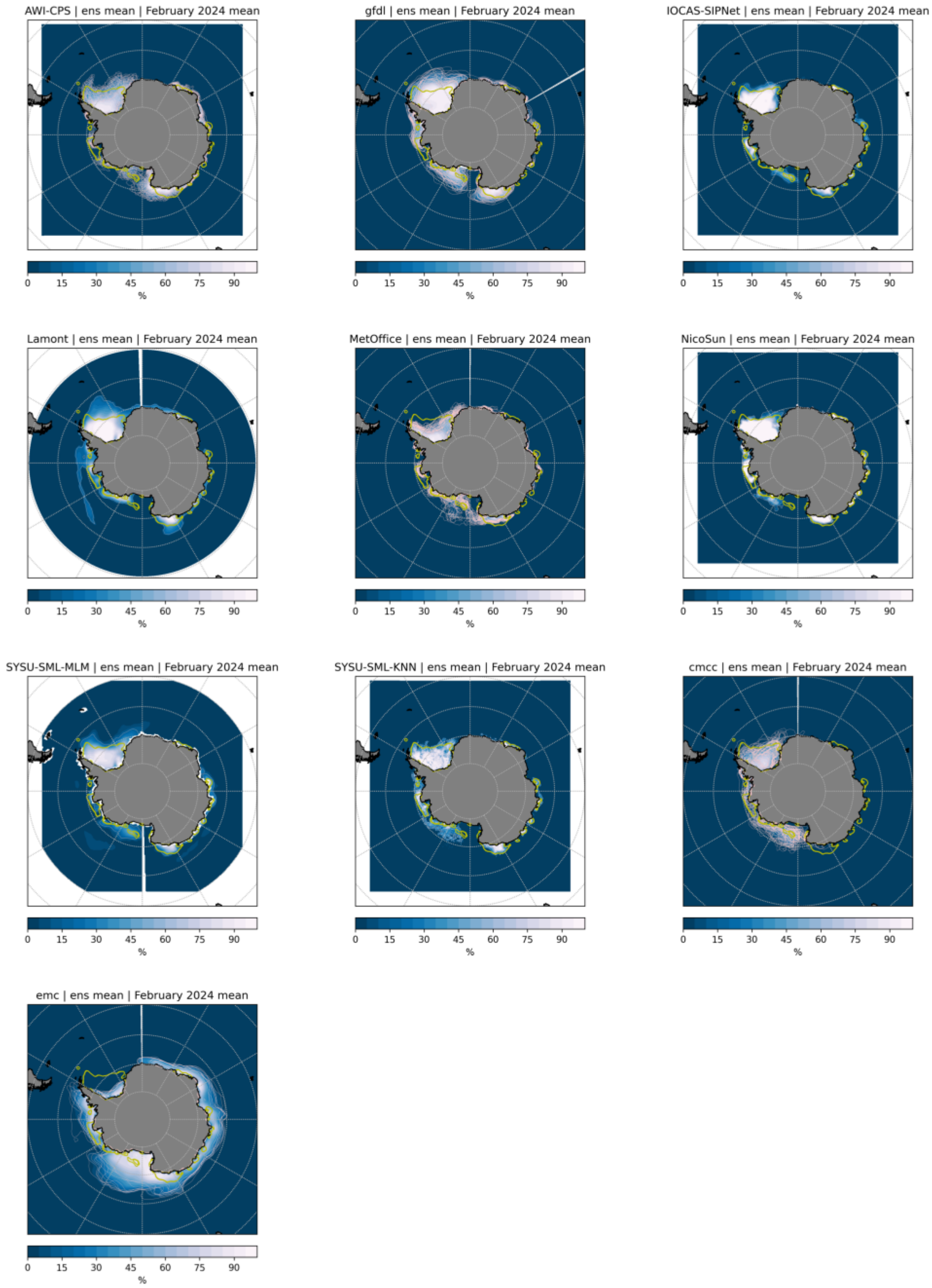

Figure 5. Spatial distribution of February 2024 monthly mean sea ice concentration (color background), the sea ice edges (15% concentration contours) from all ensemble members, and the verifying observation (yellow line). The BSC and ucl contributions are not shown due to plotting issues in the Southern Hemisphere (to be fixed).

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