Assessment of February 2018 sea-ice forecasts for the Southern Ocean

Coordinating Seasonal Predictions of Sea Ice in the Southern Ocean for 2017-2019

F. Massonnet, P. Reid, J. L. Lieser, C. M. Bitz, J. Fyfe, W. Hobbs, K. Kusahara

June 7, 2018

Primary contact:

francois.massonnet@uclouvain.be

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

The Sea Ice Prediction Network South (SIPN South) is an international project endorsed by the Year of Polar Prediction (YOPP). Its goal is to make an initial assessment of the ability of current systems to predict Antarctic sea ice on hemispheric and regional scales, with a focus on the summer season. The project has three strategic objectives:

1. Provide a focal point for seasonal outlooks of Antarctic sea ice (winter and summer), where the results are exchanged, compared, discussed and put in perspective with those from the Arctic thanks to interactions with the (regular) SIPN community (https://www.arcus.org/sipn);
2. Provide news and information on the state of Antarctic sea ice, highlight recent published research, report on ongoing observational campaigns and disseminate upcoming events (conferences, workshops, webinars, *et cetera*);
3. Coordinate a realistic prediction exercise targeting austral summer 2019 in conjunction with the Special Observing Period of the YOPP, which will take place in January-February 2019.

As proposed in the SIPN South implementation plan (detailed on the SIPN South web site, http://acecrc.org.au/sipn-south/), an initial assessment of forecast capabilities has been scheduled for February 2018, in order to best prepare the ground for the prediction in 2019. This document reports the results from this first experiment.

2. February 2018 in context

Activities of SIPN South are focused on the month of February that coincides with the annual minimum of Antarctic sea-ice extent. Since the late 1970s, February sea-ice extent has exhibited a slightly positive trend (Fig. 1). According to the National Snow and Ice Data Center (NSIDC), the monthly-mean sea-ice extent in February 2018 was the second lowest on record, just behind 2017, thus going against the long-

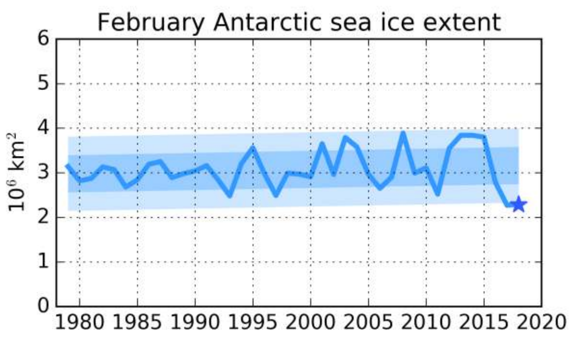

Figure 1. February Antarctic sea-ice extent (Fetterer et al., 2017). The star is February 2018. The dashed line is the linear trend and the two shaded intervals show 1 and 2 standard deviations of the residuals around the linear fit, respectively

term trend. In view of the recent increase in variability (Fig. 1), predicting conditions for this month appears therefore challenging.

The three main spatial regions contributing to this very low ice cover were the Ross (~150°E–130°W), Weddell (~40°W–30°E) and Davis (90°E–100°E) seas (Fig. 2). Positive anomalies were observed across West Pacific Ocean sector (~110°E-140°E). In most sectors, the regional distribution of these anomalies is quite persistent from the retreat period of 2017 (~September 2017), which would suggest that a persistence-based outlook could have produced reasonable results. This persistence is primarily a result of a relatively stable 3-wave atmospheric pattern that developed late in 2017 (Reid et al., 2018). This atmospheric pattern broke down somewhat during February 2018 with the development of a deep Amundsen Sea low-pressure system.

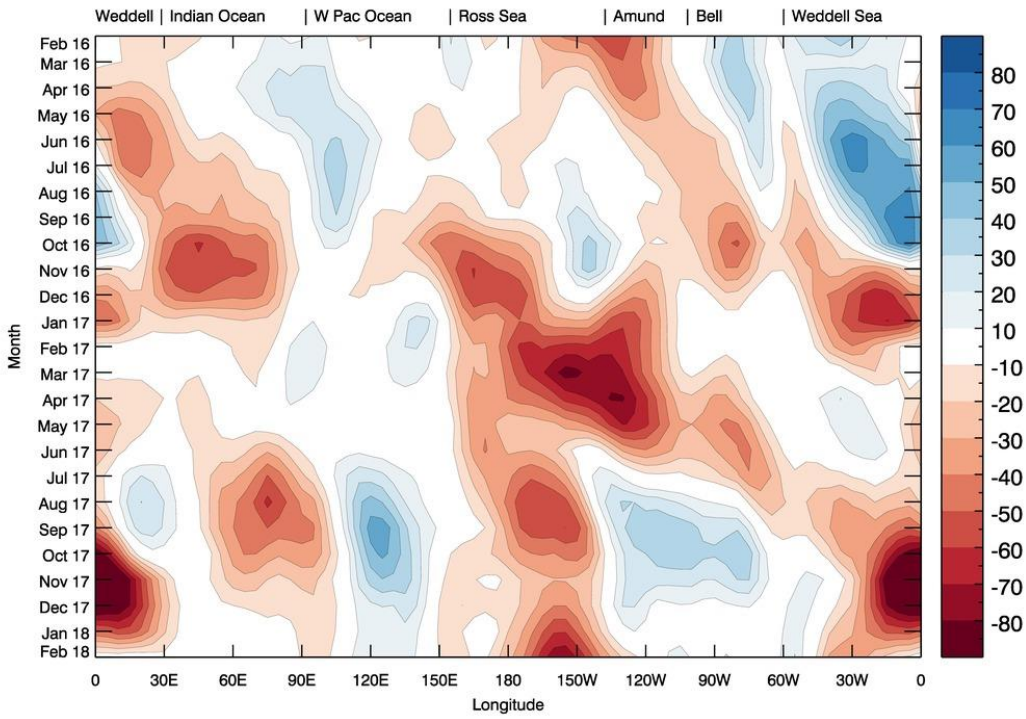

Figure 2. Hovmöller (longitude-time) diagram of Southern Ocean sea-ice extent anomalies relative to the 1981-2010 climatology (km^2 per 5°longitude).

3. Forecasting sea ice for February 2018

A call for contributions was issued in November 2017 to predict sea-ice conditions during the month of February 2018. **We received a total of 13 submissions (160 forecasts) 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") for each day of February 2018, (2) the sea-ice area per 10° longitude band (denoted "rSIA") for each day of February 2018, and (3) sea-ice concentration (denoted "SIC") for each day of February. All 13 contributors were able to submit (1), eight submitted (1) and (2), and five submitted (1), (2) and (3).

Eight groups employed fully coupled dynamical models, one group used an ocean-sea ice model forced by atmospheric forcing from past years and four groups used a statistical model trained on past data (Table 1).

Table 1. Information about contributors to the February 2018 coordinated sea-ice forecast experiment.

	Contributor name	*Short name (in figures)*	*Forecasting method*	*Nb. of forecasts*	*Initialization date*	*Diagnostics provided*
1	Naval Research Lab	nrl	Coupled dynamical model	6	Nov. 6th, 2017	SIA + rSIA + SIC
2	Nico Sun	Nico-Sun	Statistical model	1	Nov. 28th, 2017	SIA
3	NASA-GMAO	nasa-gmao	Coupled dynamical model	10	Nov. 27th, 2017	SIA + rSIA + SIC
4	FIO-ESM	FIO-ESM	Coupled dynamical model	1	Dec. 1st, 2017	SIA
5	ECMWF	ecmwf	Coupled dynamical model	50	Nov. 30th, 2017	SIA + rSIA
6	Antarctic Gateway Partnership	Gateway	Statistical model	1	Dec. 10th, 2017	SIA
7	MPAS-CESM	mpas-cesm	Coupled dynamical model	2	Dec. 1st, 2017	SIA + rSIA
8	Lamont Sea Ice Group	Lamont	Statistical model	1	Oct. 31st, 2017	SIA + rSIA + SIC (monthly mean)
9	NASA-GSFC	NASA-GSFC	Statistical model	1	Nov. 30th, 2017	SIA (monthly mean)
10	Modified CanSIPS	Modified-CanSIPS	Coupled Dynamical Model	20	Nov. 30th, 2017	SIA
11	Met Office	MetOffice	Coupled Dynamical Model	42	Dec. 12th, 2017	SIA + rSIA + SIC
12	UCL	ucl	Ocean-sea ice dynamical model	10	July 1st, 2017	SIA + rSIA + SIC
13	EMC	emc	Coupled dynamical model	15	Dec. 15th, 2017	SIA + rSIA + SIC

3.1 Circumpolar sea-ice area

Fig. 3 shows the total sea-ice area (SIA) forecast for each day of February by the 13 contributors. For two contributions, only the monthly mean was provided, hence horizontal lines are shown. SIA is not a very strong, geophysical diagnostic as it does not reflect regional variations, but it gives a first indication on how the forecasts behaved. In this figure, two observational references are also included to provide a rough idea of the observational uncertainty.

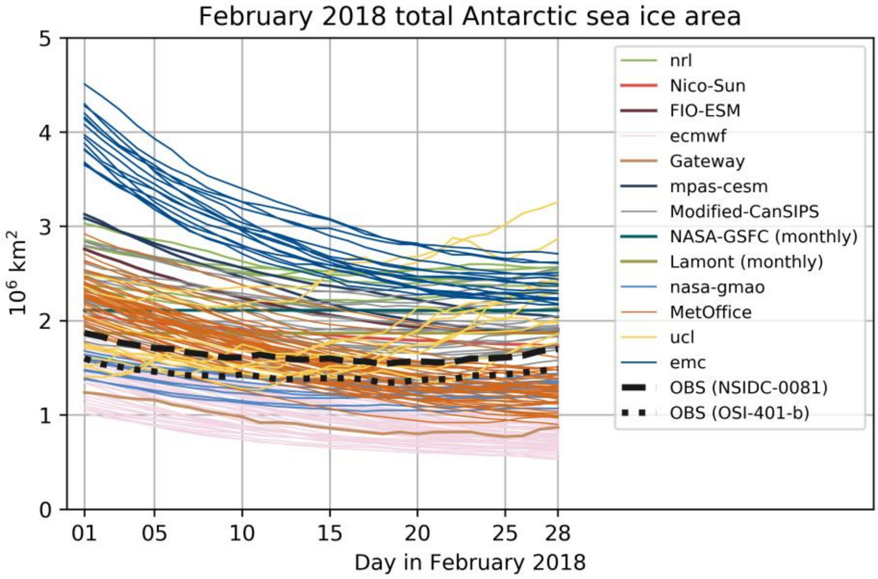

Figure 3. Total (circumpolar) Antarctic sea-ice area of the 13 forecasts for each day of February 2018. The black dashed lines are two observational references (Maslanik and Stroeve, 1999 and Tonboe et al., 2017).

The inter-model spread is generally larger than the spread between forecasts from individual contributions, which is in itself larger than the observational range. It is encouraging that both observational estimates are within the full model ensemble span. However, only five out of 13 contributions have a monthly mean Antarctic sea-ice area that overlaps the observational range (not shown here). This suggests that the majority of forecast systems display systematic prediction errors. It should be noted that the predictions have not been bias-corrected.

We also investigate the ability of the systems to forecast the date of the seasonal minimum of sea-ice area. The timing of the minimum of sea-ice area is a critical parameter from an operational point of view, as it represents the end of the “window of opportunity” before the oceans start to freeze up and sea ice becomes an increasing hindrance to the progression of vessels. All but one predictions fail to date the minimum sea-ice area correctly. Generally, they tend to place it too late (Fig. 4).

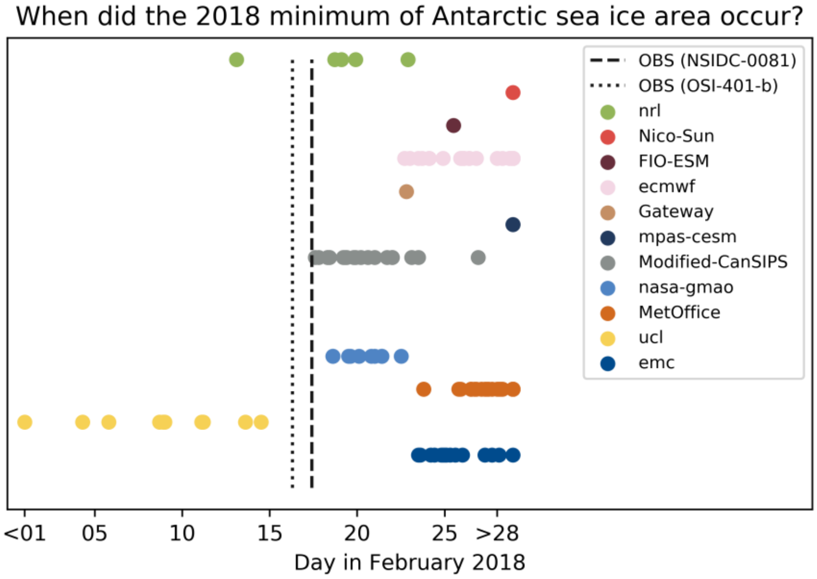

Figure 4. Timing of the seasonal (February) Antarctic minimum sea-ice area of the forecasts (monthly mean forecasts are discarded), along with two observational references (Maslanik and Stroeve, 1999 and Tonboe et al., 2017). To filter the effects of synoptic variability on total sea-ice area, the minimum was determined from a quadratic fit of the daily sea-ice area time series.

3.2 Regional sea-ice area

Fig. 5 shows the predicted February mean regional sea-ice area (rSIA), with the data expressed as an anomaly with respect to the 1979-2014 daily climatology estimated from the NASA Team sea-ice concentration (Peng et al., 2013). The observations show that rSIA was below average in the Ross Sea and eastern Weddell Sea, and slightly higher than climatology in the eastern Amundsen Sea and eastern Antarctic Sea (~120°E), with near average conditions in the eastern hemisphere. The regional predictions of monthly minimum display the same patterns and are therefore not shown here.

In general, the observed rSIA is within the range of the prediction spread, similar to total sea-ice area (Fig. 2). However, for the Ross Sea, predictions tend towards anomalously high rSIA, whereas a lower-than-usual rSIA was actually observed. This followed a very low January rSIA (Fig. 2; possibly a reemergence of last summer's record low rSIA). The large spread in predictions for the Ross Sea and Weddell Sea reflects the high variance and complex ocean-atmosphere dynamics in these regions.

Fig. 6 shows rSIA anomalies by both day and longitude. Both observations and predictions indicate that regions with negative anomalies tend to have little change

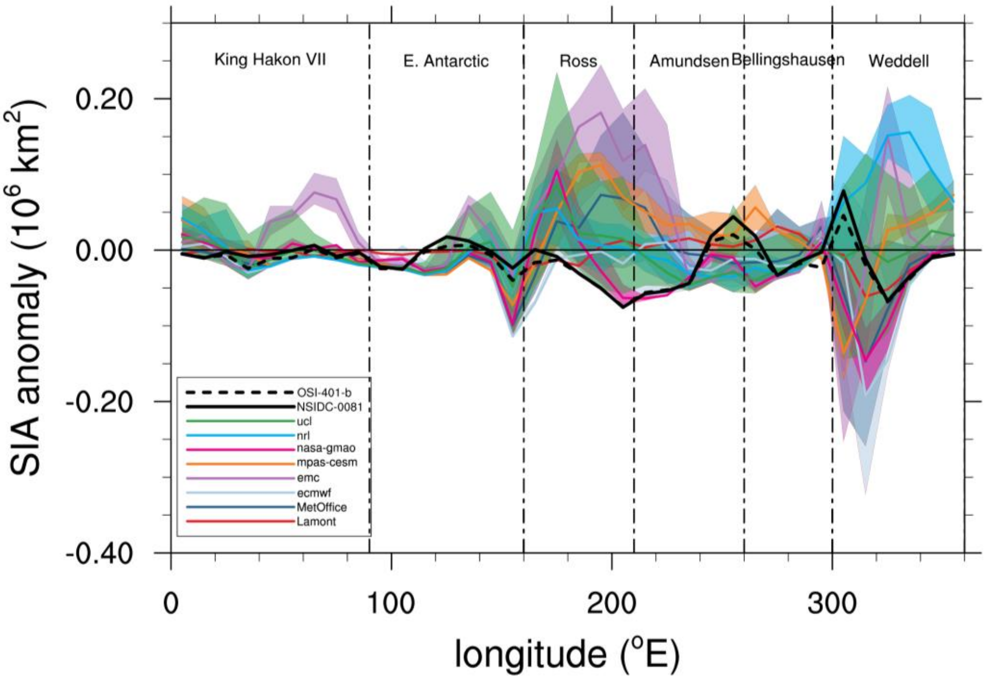

Figure 5. February 2018 mean rSIA anomaly (compared to 1979-2014 NASA Team climatology) by longitude, for each submission, with observed estimates given in black. Solid lines show the ensemble mean for each contribution, with transparent shading indicating the ensemble range (min-max).

over the course of the month. Only the NASA-GMAO predicted the decrease of SIA in the Ross Sea with confidence. Predicted positive anomalies in the Ross-Amundsen region (120-180°W) tend to decrease in intensity over the course of the month (see in particular ensemble means of the UK Met Office, EMC and MPAS-CESM), but this was not observed.

In Table 2, the correlation of predicted rSIA by longitude with the NSIDC-0081 passive microwave estimate is summarised as a coarse metric of forecast skill. The correlations are taken along all longitude bins. The NASA-GMAO ensemble has the best agreement with observations (i.e. correlations closest to +1), while EMC, MPAS-CESM and UK MetOffice show the lowest agreement. Unsurprisingly, this indicates that overall forecast agreement was largely set by the very challenging Ross Sea region.

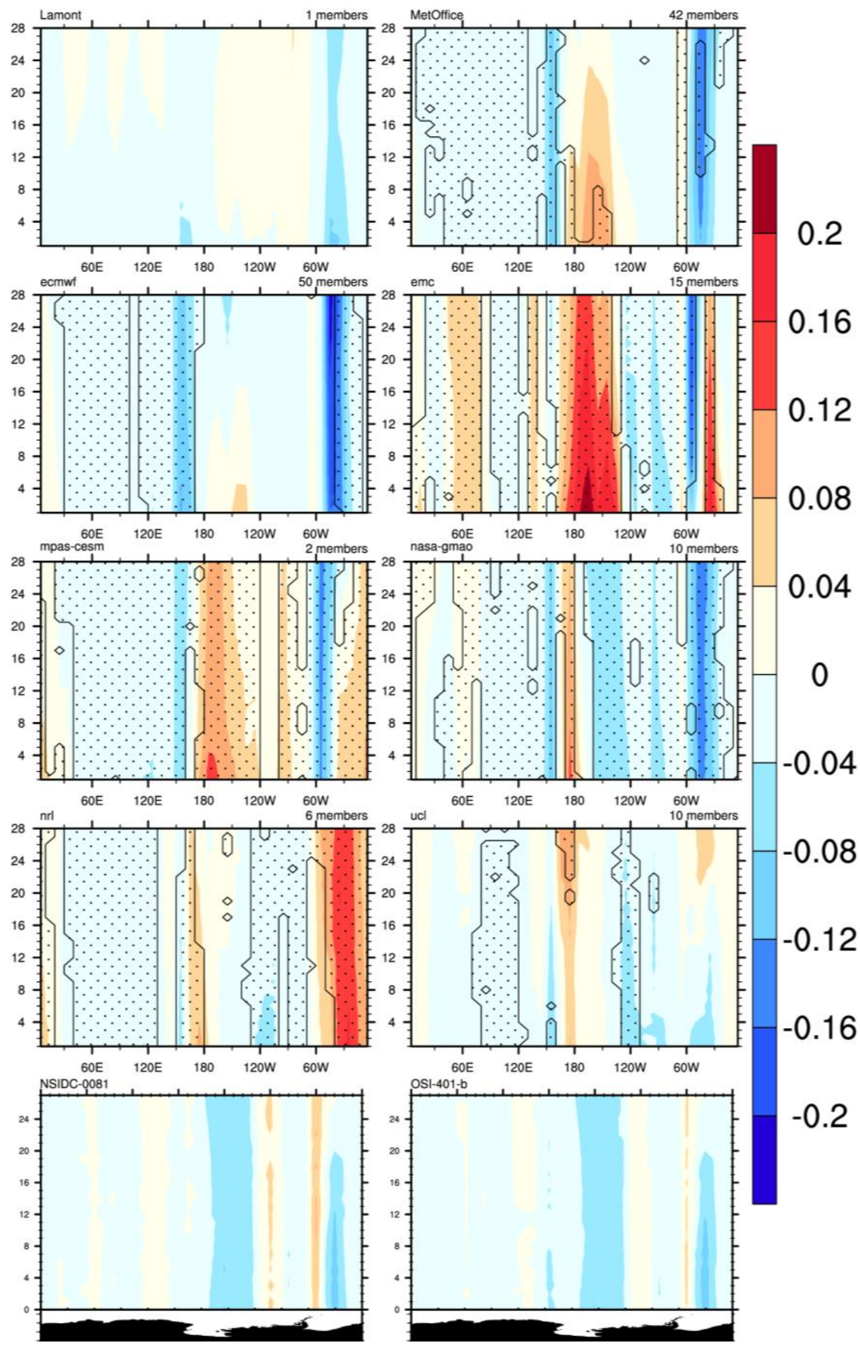

Figure 6. Ensemble-mean predicted daily rSIA anomaly (compared to 1979-2014 NASA Team SIC climatology) for February 2018 [10^6 km^2] as a function of longitude (horizontal dimension) and time in February (vertical dimension). For submissions with an ensemble of members, hatching indicates where the sign of the predicted anomaly agrees across all the submission members.

Table 2. Correlations between predicted and observed (NSIDC-0081) rSIA. For ensemble submissions, the weakest, strongest and median correlations are indicated.

	Minimum	Median	Maximum
Lamont	-	0.05	-
MetOffice	-0.63	-0.23	0.06
ECMWF	-0.20	0.11	0.41
EMC	-0.67	-0.61	-0.53
MPAS-CESM	-0.64	-0.50	-0.35
NASA-GMAO	0.15	0.20	0.40
NRL	-0.29	-0.14	0.02
UCL	-0.42	0.00	0.47

3.3 Spatial information

Five groups submitted the spatial information of sea-ice concentration for each day of February 2018. Each of these groups used a dynamical model and contributed several ensemble members. Members are usually meant to sample uncertainty associated to the (unpredictable) evolution of the climate system, so that each member of a given model could be seen as a possible realisation of that model. If the model is free of errors and it is given correct initial and boundary conditions, then the observed realisation would be statistically indistinguishable from the model's members.

Fig. 7 displays the ensemble mean of monthly mean sea-ice concentration for February 2018, together with the sea-ice edge lines (15% sea-ice concentration contours) for each of the members. Sea ice was forecast to be present in the Weddell Sea along the Antarctic Peninsula by all contributions and did indeed occur in the two observational references. This is a region where sea ice is climatologically present. Consistent with the analyses conducted in the previous section, significant spread developed in the Ross Sea as reflected by the uncertain sea-ice edge position in the forecasts. There, it turned out to be nearly no sea ice in that sector in February according to the two observational records. Ross Sea sea ice appears to be very challenging to predict judging from the large spread of some models in that region (e.g., Met Office, UCL).

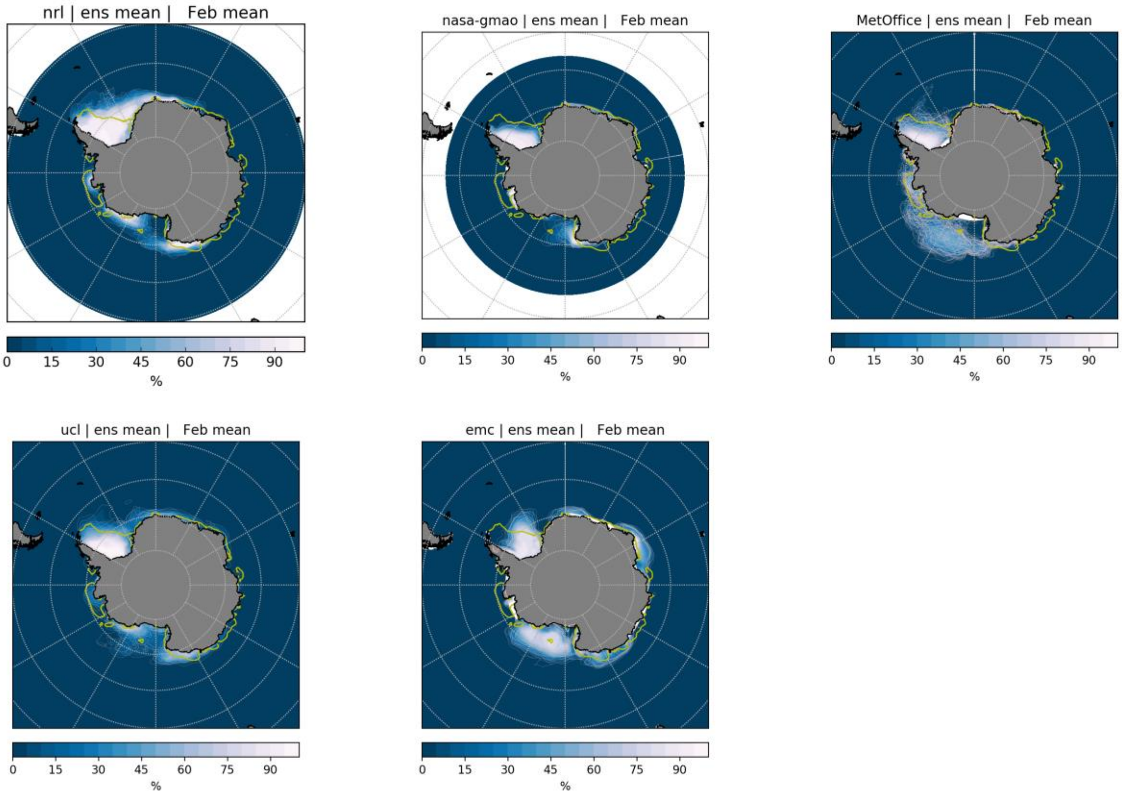

Figure 7. Ensemble mean of February 2018 monthly mean sea-ice concentration, as forecast by the five groups that contributed daily sea-ice concentration information. The thin lines are the ice edge position for each forecast member, determined as the 15% contour line of the monthly mean sea ice concentration for the member. Yellow lines are the 15% contours of monthly mean sea-ice concentration from the two observational references OSI-401-b and NSIDC-0081.

Maps of ensemble mean February sea-ice concentration (Fig. 7) are useful to appreciate the average conditions that could have prevailed in February, but the maps are difficult to interpret for potential final users of the forecasts. Therefore, we finally compute the daily probability of sea-ice presence (Fig. 8). Green pixels are those where sea ice was forecast to be unlikely present, while red ones are those where sea ice was forecast to be likely present. Unlike the four other submissions, the NASA-GMAO system had forecast a very low to null probability of sea-ice presence in the Ross Sea, opening possible pathways to Antarctic coasts. According to the two observational products used, the region has indeed been free of sea ice during the whole month. More forecasting experiments will be necessary to determine whether that successful forecast can be reproduced for other conditions.

4. Conclusions

We warmly thank all 13 contributors to this first coordinated forecast of sea ice in the Southern Ocean. The great enthusiasm for SIPN is much appreciated and we are

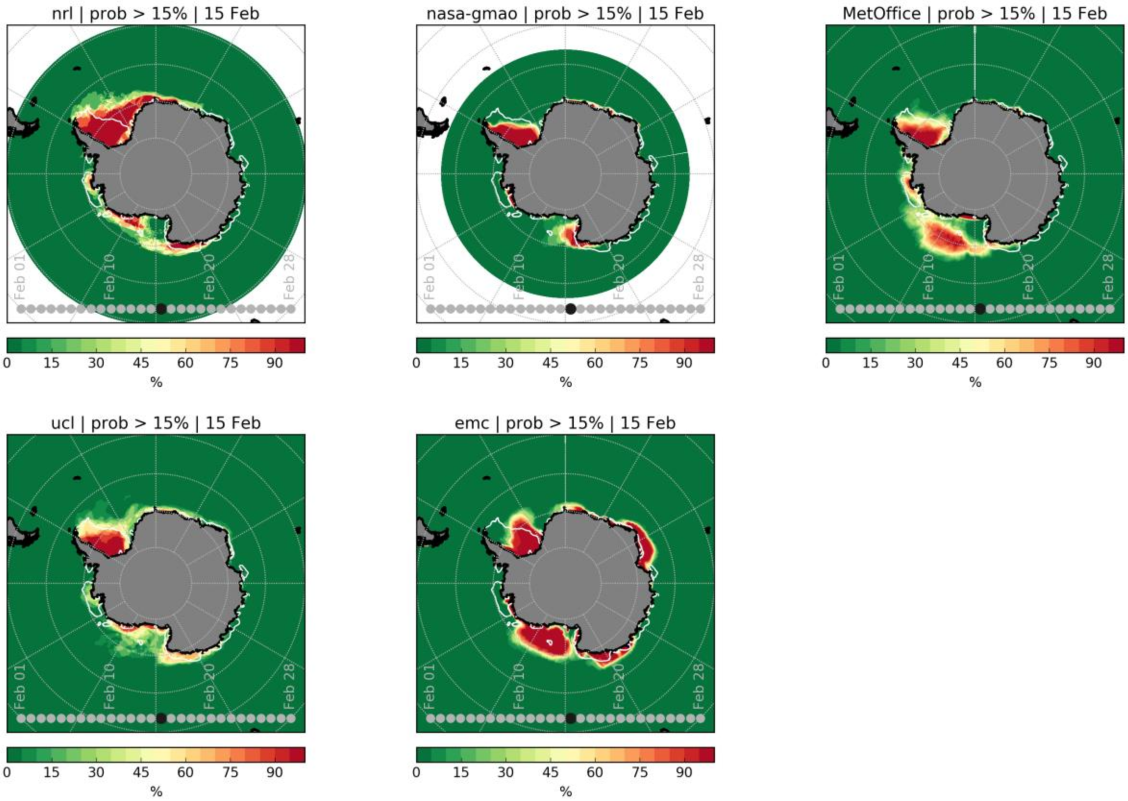

Figure 8. Probability of sea-ice presence for 15th February 2018, as forecast by the five groups that submitted daily sea-ice concentration information. The sea-ice edge as observed by two products (OSI-401-b and NSIDC-0081) is shown in white. The probability of presence for a given day corresponds to the fraction of ensemble members that simulate sea-ice concentration larger than 15% in a given grid cell, for that day. A dynamic animation of the figure showing all 28 days of February is available at http://acecrc.org.au/sipn-south/.

looking forward to continuing our activities with even more participants for the exercise targeting the Special Observing Period of January-February 2019.

This first analysis has revealed several elements:

- When viewed as a group, the multi-model forecast of total February Antarctic sea-ice area encompasses the observational range. However, errors can be large for individual submissions (up to 100% of the observed values). In most cases, observational uncertainty cannot explain the model-data mismatch.
- According to submissions for which ensemble members were available, the irreducible forecast uncertainty – i.e., uncertainty due to the unpredictable nature of the climate system – is relatively large: the range of the three submissions with more than 20 members exceeds 1 million square kilometers (that is, about 60% of the observed area) for the circumpolar Antarctic sea-ice area.
- All but one forecasts miss the date of Antarctic sea-ice minimum (putting it later than observed). The timing of the minimum is in part driven by the

change in insolation (which is predictable) and can be modulated by a few days by the passage of synoptic weather systems. It remains to be seen whether the tendency of models to delay the minimum is a systematic deficiency, or the observed timing of 2018 was simply unpredictable.

- Most forecasts could not predict the anomalously low conditions in the Ross Sea, where sea-ice area reached levels close to zero. On the other hand, in the Weddell Sea the observed conditions remained close to the climatological average and within the forecast range.

It is difficult to give firm and absolute statements on forecast quality, firstly because there is no reference for comparison to other exercises, but also because many more forecast exercises will be necessary to detect systematic forecast errors. A critical question will be to ascertain whether (fully coupled) model forecasts are superior to trivial ones like climatology or persistence forecast.

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. Instructions to retrieve the data and process the analyses are given in the README.md file of this repository.

Citing this report

F. Massonnet, P. Reid, J. L. Lieser, C. M. Bitz, J. Fyfe, W. Hobbs (2018). Assessment of February 2018 sea-ice forecasts for the Southern Ocean. Technical Note, Université catholique de Louvain (2018), available at http://acecrc.org.au/sipn-south/

References

Fetterer, F., K. Knowles, W. Meier, M. Savoie, and A. K. Windnagel, 2017, updated daily. Sea Ice Index, Version 3 (G02135). Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5K072F8. [Accessed May 2018].

Maslanik, J. and J. Stroeve, 1999, updated daily. Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations, Version 1. [NSIDC-0081]. Boulder, Colorado USA. NASA National Snow

Peng, G., W. Meier, D. Scott, and M. Savoie, 2013. A long-term and reproducible passive microwave sea ice concentration data record for climate studies and monitoring, *Earth Syst. Sci. Data*. 5. 311-318. http://dx.doi.org/10.5194/essd-5-311-2013 and Ice Data Center Distributed Active Archive Center. doi: http://dx.doi.org/10.5067/U8C09DWVX9LM. [Accessed January 30th, 2018].

Reid, P., S. Stammerjohn, R. A. Massom, J. L. Lieser, S. Barreira, and T. Scambos, 2018. [Antarctica] Sea ice extent, concentration and seasonality [accepted for "State of the Climate in 2017"]. Bulletin of the American Meteorological Society.

Tonboe, R., J. Lavelle, R. H. Pfeiffer and E. Howe, 2017. Product User Manual for OSI SAF Global Sea Ice Concentration (Product OSI-401-b). http://osisaf.met.no/docs/osisaf_cdop3_ss2_pum_ice-conc_v1p6.pdf [Accessed May 30th, 2018]