2021 June Sea Ice Outlook
Supplementary Report
ECCC-CanSIPSv2

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Outlook Summary and Methods:

Our outlook includes an estimate of pan-Arctic sea ice extent (SIE) and anomaly extent, as well as spatial forecast fields of sea ice probability (SIP), and ice-free dates (IFDs). The outlook was produced using the Canadian Seasonal to Interannual Prediction System (CanSIPv2; Lin et al., 2020: https://doi.org/10.1175/WAF-D-19-0259.1), which combines ensemble forecasts from two models, CanCM4i and GEM-NEMO, with a total of 20 ensemble members (10 from each model).

- Our pan-Arctic SIE estimate was formulated by calculating (for each ensemble member) the SIE anomaly relative to a piecewise linear trend fitted to the respective model's ensemble-mean SIE time series over 1980-2020. These anomalies were then added to the piecewise linear trend fit to the NSIDC sea ice index SIE time series, and then averaged over all 20 ensemble members. The piecewise linear fit, including the breakpoint year, was found using non-linear least squares.

- Our SIE anomaly forecast was formulated by subtracting a linear-trend fit to hindcast SIE, as per the instructions from SIPN. A 2000-2020 baseline period was used for fitting a linear trend, as this resulted in a better agreement with the SIE anomaly found using a piecewise linear fit to the full 1980-2020 period.

- Sea ice probability maps were produced by first calibrating the ensemble SIC forecasts for each respective model using trend-adjusted quantile mapping (TAQM; Dirkson et al., 2019: https://doi.org/10.1175/JCLI-D-18-0224.1), computing the probability for SIC>15%, and then averaging those probabilities across both models.

- Our IFD forecast has been bias-corrected based on the 2012-2020 mean IFD, where we have defined the IFD as the first date that SIC falls below 15% and 80%, as per the SIPN request (Sigmond et al., 2016: https://doi.org/10.1002/2016GL071396).

- We also produce a probabilistic IFD forecast formulated by applying a calibration method (non-homogeneous censored Gaussian regression; NCGR) to the ensemble of IFDs from each model (Dirkson et al., 2020: https://doi.org/10.1175/WAF-D-20-0066.1).

Pan-Arctic Sea Ice Extent

Pan-Arctic SIE: 4.51 million sq. km (95% CI=3.73,5.28)

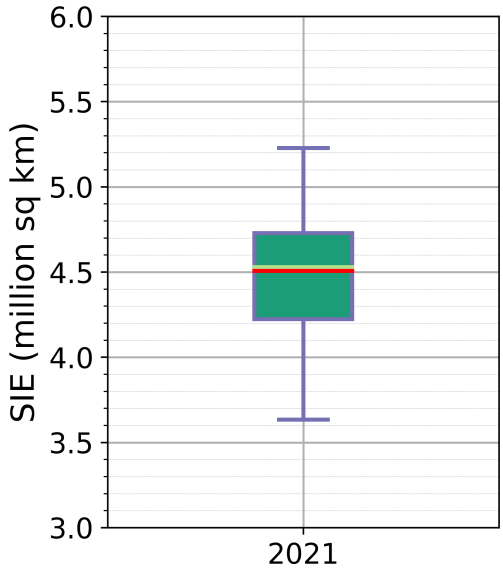

Figure 1 Box-and-whisker diagram of CanSIPSv2 forecast September mean SIE; red line = ensemble mean; lime green line = ensemble median. Note: the 95% confidence interval in red text was obtained by approximating the forecast ensemble as a Gaussian distribution.

Pan-Arctic SIE anomaly: +0.57 million sq. km

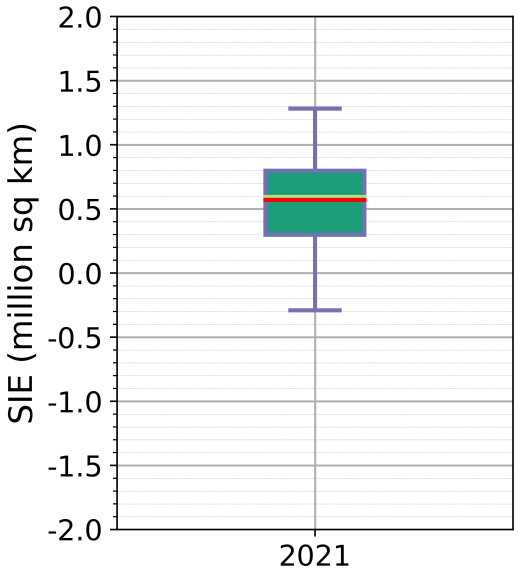

Figure 2 As in Figure 1, but for the SIE **anomaly** relative to the hindcast linear trend.

Note: There is a sizable sensitivity to the number of years we include in our hindcast record to compute the linear trend that is used to calculate the forecast anomaly. Including data back to

1980, 1990, 1995, and 2000 yields anomalies of -0.14, 0.16, 0.41, and 0.57 million sq. km, respectively (a range of 0.71 million sq. km). This highlights the nonlinear nature of the SIE trend, which is why our bias-corrected SIE forecast (Figure 1) was produced using a piecewise linear trend instead of a linear trend. Since the SIE anomaly obtained using the shorter baseline of 2000-2020 to compute a linear trend produces the most consistent result with that obtained using a piecewise linear trend (0.57 vs 0.58), we have opted to submit our SIE anomaly forecast using this shorter baseline period.

Historical SIE and skill:

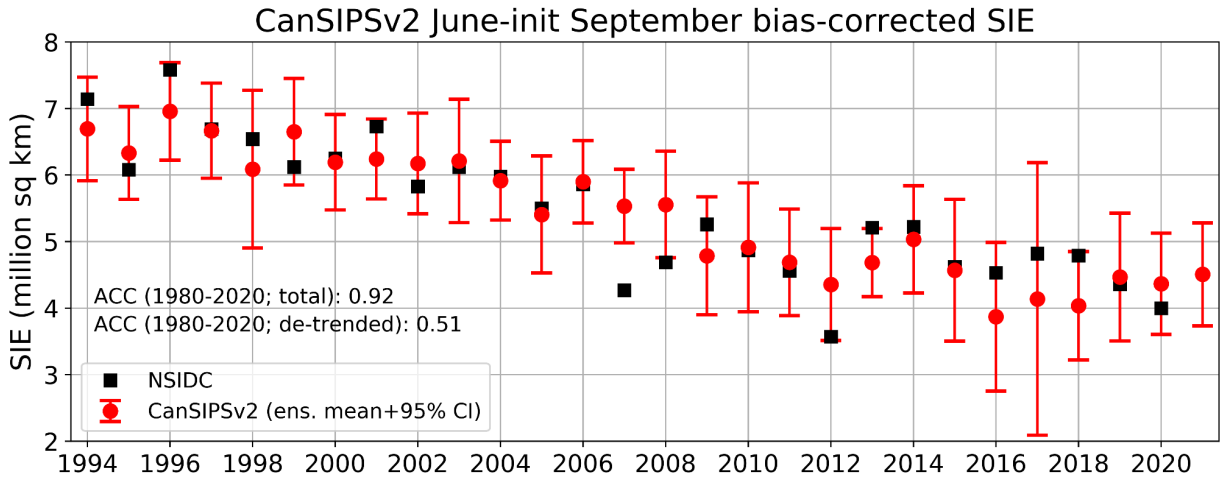

Figure 3 Bias-corrected CanSIPSv2 hindcasts of September mean SIE from 1994-2020. Skill estimates provided (ACC = anomaly correlation coefficient) were computed using the full hindcast record from 1980-2020 and determining anomalies relative to a piecewise linear trend.

Sea Ice Probability

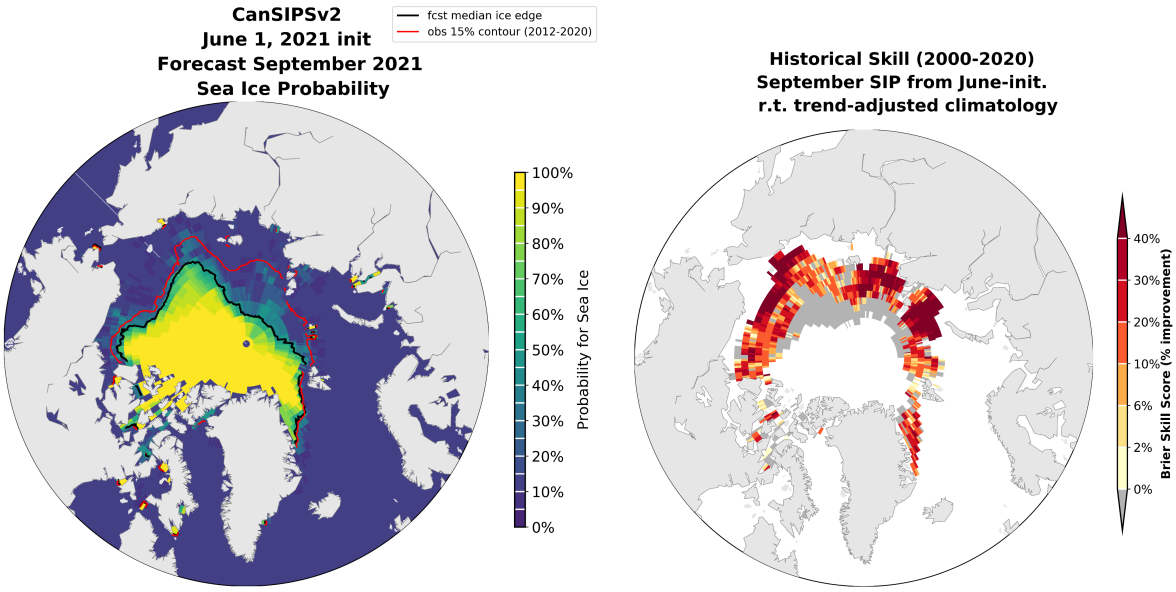

Figure 4. Left: Probability for ice concentration greater than 15%; Right: Historical skill based on the Brier skill score over the period 1990-2020, where skill is quantified relative to a trend-adjusted climatology. Relative to where sea ice is typically present based on the past 9 years of observations, most of the western Arctic is forecast to have high chances of sea ice, whereas most of the eastern Arctic is forecast to have very low chances of sea ice. The Python code for calibrating our SIP forecasts can be found here.

Ice-Free Dates (deterministic)

15% ice concentration threshold:

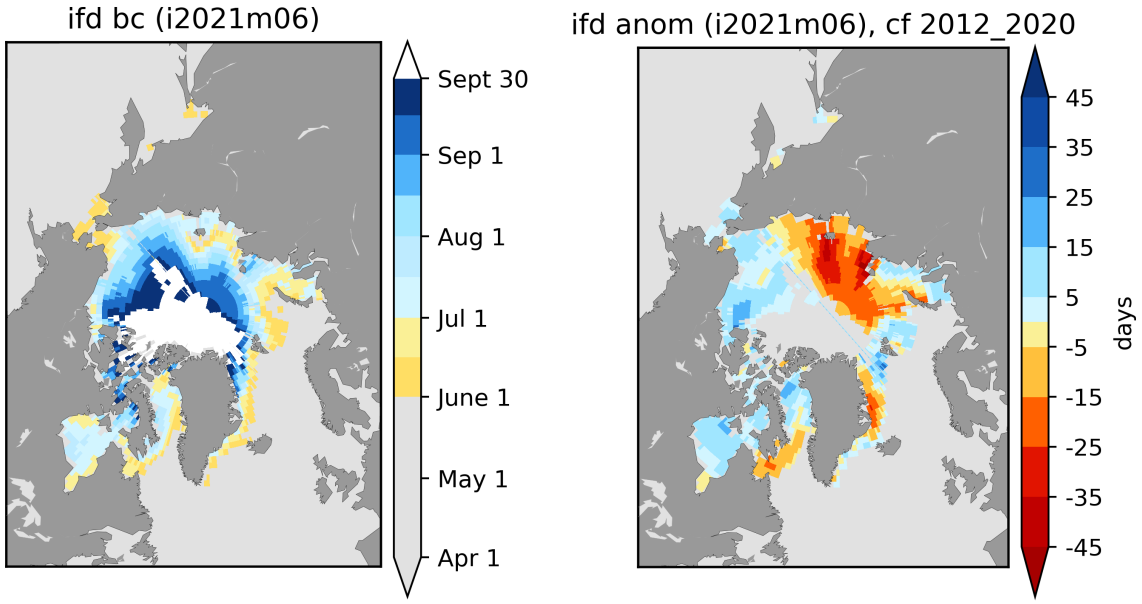

Figure 5. Left: Bias-corrected ice-free date forecast based on the 15% ice concentration threshold. Right: ice-free date anomaly forecast relative to 2012-2020. The early retreat forecasted in the eastern central Arctic is consistent with the low SIP shown in Fig. 4 in the same area.

80% ice concentration threshold:

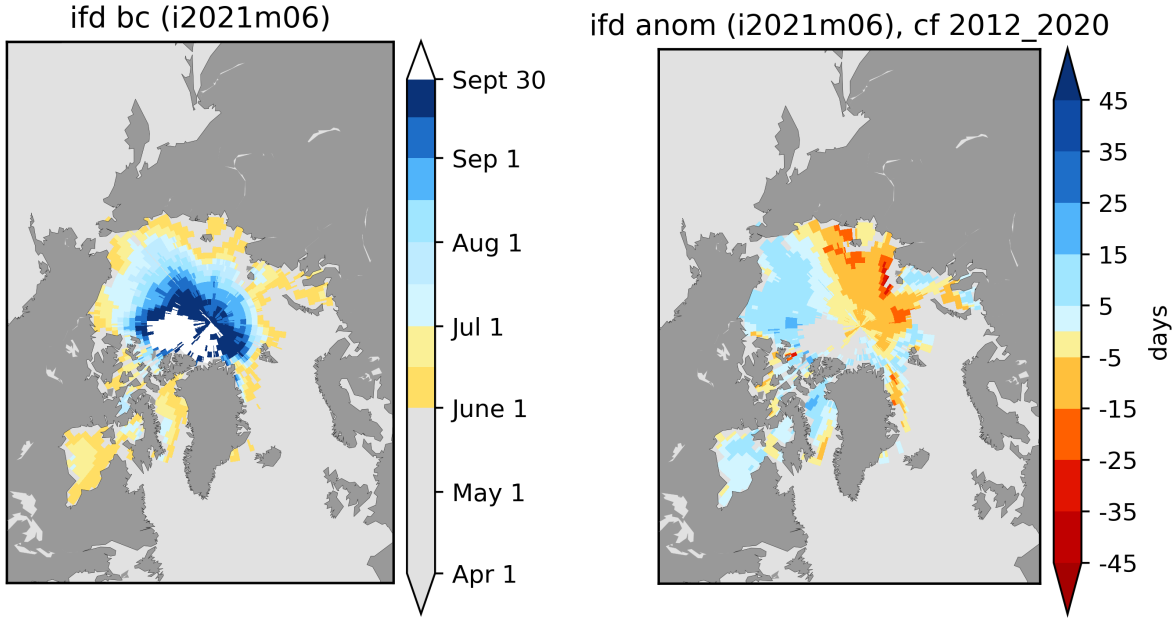

Figure 6. As in Figure 5, but for the 80% ice concentration threshold.

Ice-Free Dates (probabilistic)

15% ice concentration threshold: (probabilities relative to 2012-2020)

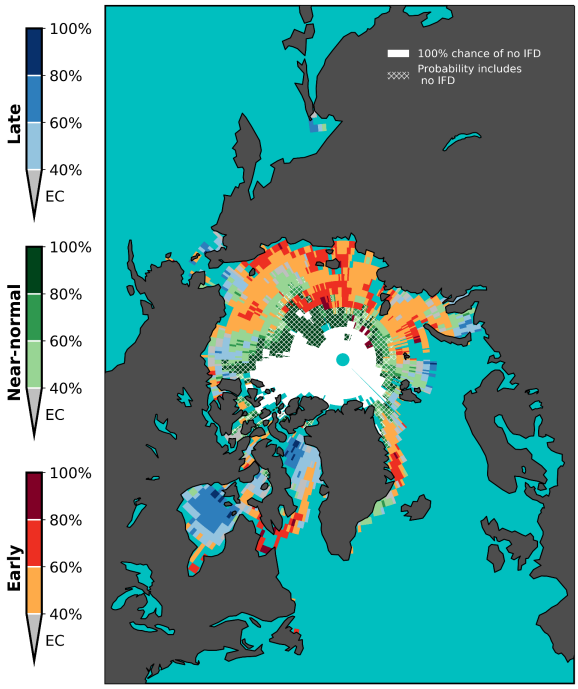

Figure 7. Probabilistic forecast for early, near-normal, or late ice-free date (IFD); the most likely category is plotted at each grid point. The forecast probabilities for each category are computed relative to the last 9 years of observed dates (2012-2020); EC=equal chances. The Python package for calibrating probabilistic IFD/FUD forecasts can be found here.

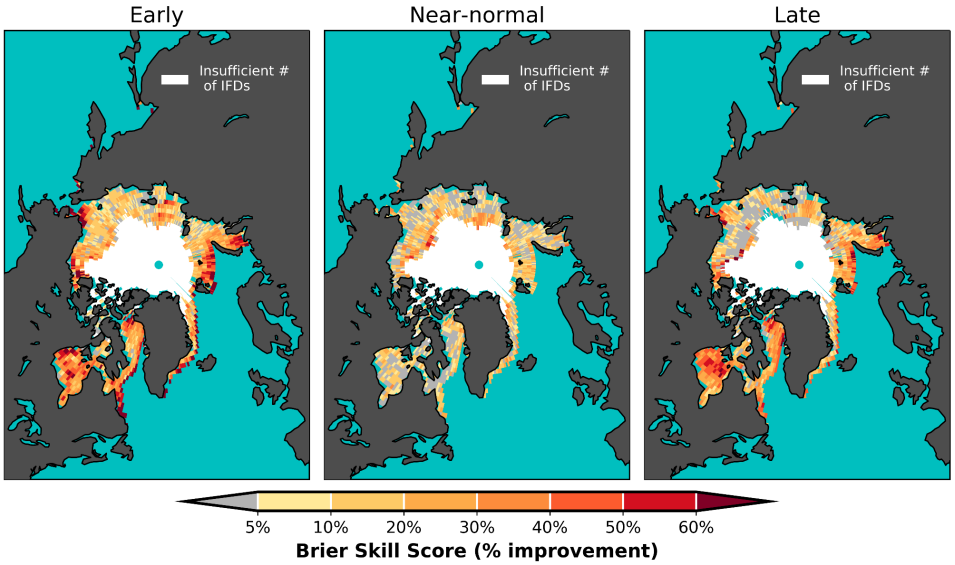

Figure 8. Historical skill for calibrated probabilistic IFD forecasts over 2000-2020, relative to a trend-adjusted climatology benchmark. Skill scores are calculated per forecast category.