# Supplementary Information for "Ensemble design for seasonal climate predictions: Studying extreme Arctic sea ice lows with a rare event algorithm"

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## S1: Observational data

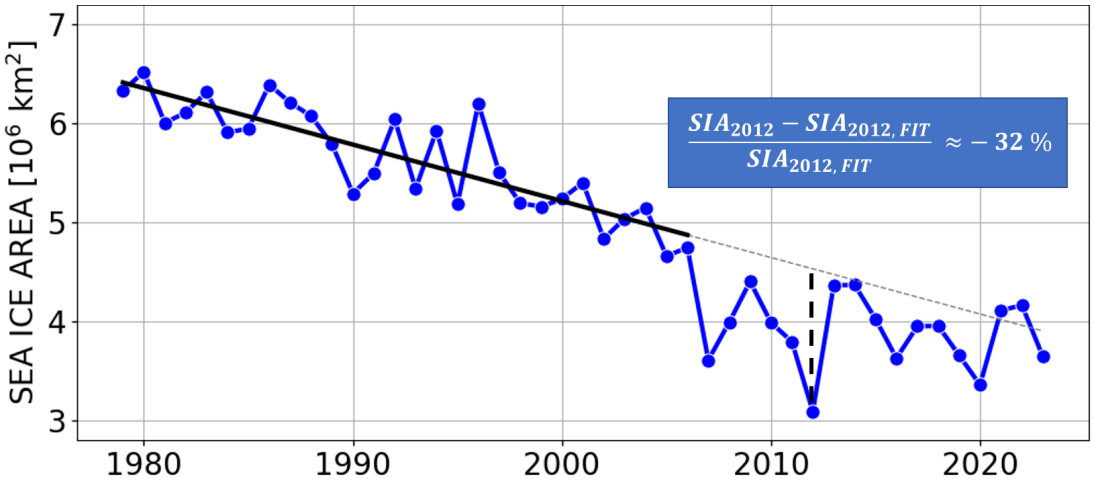


**Figure S1.** August-September mean pan-Arctic sea ice area [$10^6$ km$^2$] from European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Ocean and Sea Ice Satellite Application Facility (OSI SAF) data (EUMETSAT Ocean and Sea Ice Satellite Application Facility, 2024). The black solid and dashed gray lines show a linear trend fitted (FIT) to the data of the period 1979 and 2006. Compared to the entire time series, the period 1979-2006 shows the most linear decline of the sea ice area.

**S2: Importance sampling of extreme Arctic sea ice lows**

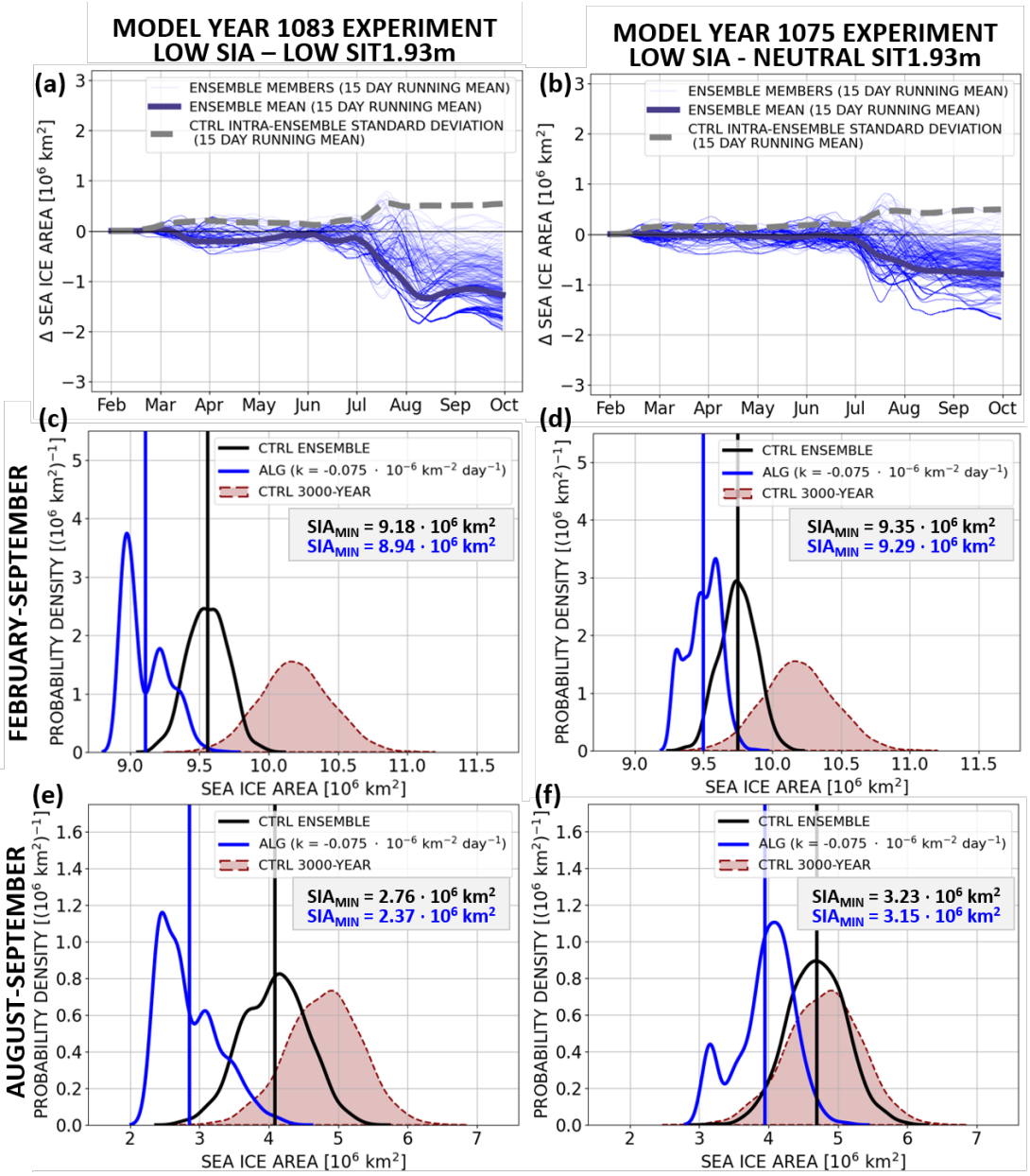


**Figure S2.** Ensemble simulations initialized on (a,c,e) 01 February 1083 and (b,d,f) 01 February 1075 of the control run running for eight months until 30 September. (a,b) Rare event simulations: Trajectories (thin blue lines) and ensemble mean (thick blue line) of daily pan-Arctic sea ice area anomalies relative to the daily climatology of the corresponding control ensembles. The gray dashed lines show the intra-ensemble standard deviations in the control ensembles. All lines are presented as 15-day running means. (c-f) Probability distribution functions of (c,d) February-September and (e,f) August-September mean pan-Arctic sea ice area for (blue) the rare event simulation, (black) the control ensembles and (red) the full 3000-year control run. The vertical lines show the mean of the distributions. The black and blue values indicate the smallest February-September and August-September mean sea ice area value sampled with the control and rare event ensemble simulation respectively.

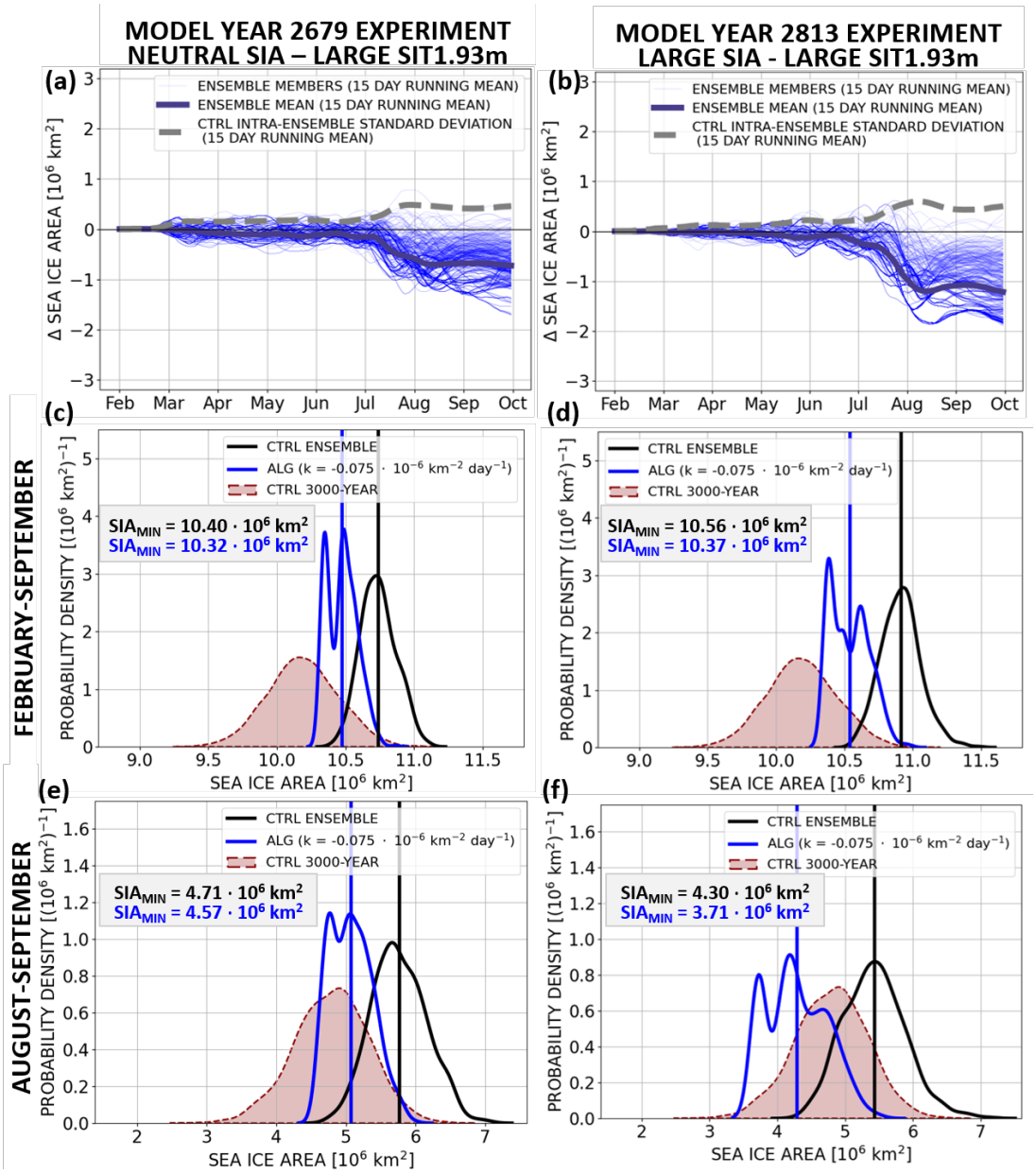


**Figure S3.** Ensemble simulations initialized on (a,c,e) 01 February 2679 and (b,d,f) 01 February 2813 of the control run running for eight months until 30 September. (a,b) Rare event simulations: Trajectories (thin blue lines) and ensemble mean (thick blue line) of daily pan-Arctic sea ice area anomalies relative to the daily climatology of the corresponding control ensembles. The gray dashed lines show the intra-ensemble standard deviations in the control ensembles. All lines are presented as 15-day running means. (c-f) Probability distribution functions of (c,d) February-September and (e,f) August-September mean pan-Arctic sea ice area for (blue) the rare event simulation, (black) the control ensembles and (red) the full 3000-year control run. The vertical lines show the mean of the distributions. The black and blue values indicate the smallest February-September and August-September mean sea ice area value sampled with the control and rare event ensemble simulation respectively.

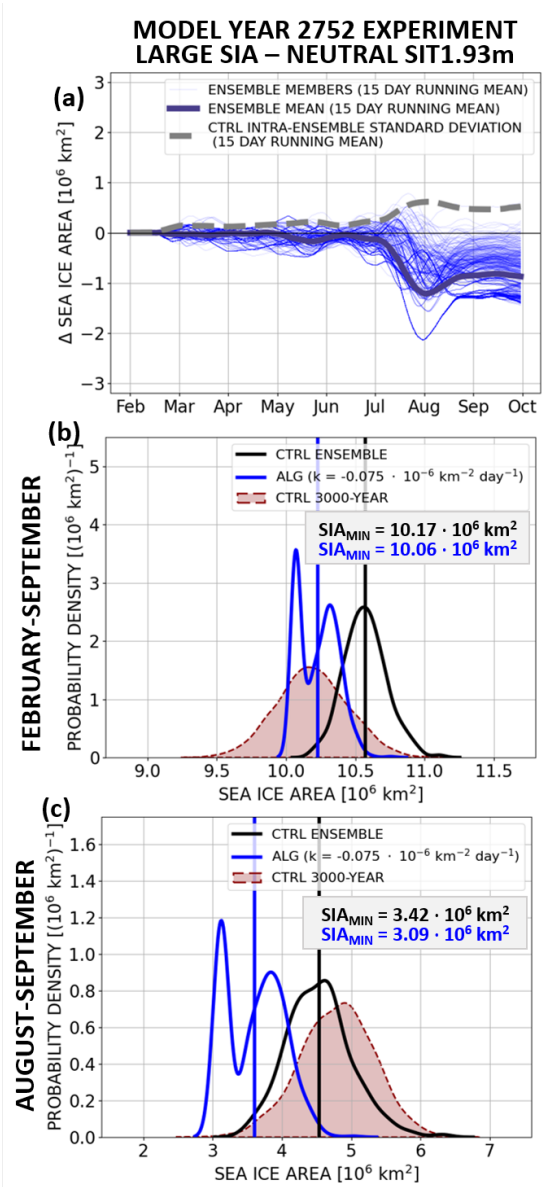


**Figure S4.** Ensemble simulations initialized on 01 February 2752 of the control run running for eight months until 30 September. (a) Rare event simulation: Trajectories (thin blue lines) and ensemble mean (thick blue line) of daily pan-Arctic sea ice area anomalies relative to the daily climatology of the corresponding control ensemble. The gray dashed lines show the intra-ensemble standard deviation in the control ensemble. All lines are presented as 15-day running means. (b-c) Probability distribution functions of (b) February-September and (c) August-September mean pan-Arctic sea ice area for (blue) the rare event simulation, (black) the control ensembles and (red) the full 3000-year control run. The vertical lines show the mean of the distributions. The black and blue values indicate the smallest February-September and August-September mean sea ice area value sampled with the control and rare event ensemble simulation respectively.

## References

EUMETSAT Ocean and Sea Ice Satellite Application Facility: Monthly Mean Northern Hemisphere Sea Ice Area from EUMETSAT OSI SAF, v2p2, OSI-420, Norwegian Meteorological Institute, accessed 13 February 2024: ftp://osisaf.met.no/prod_test/ice/index/v2p2/nh/osisaf_nh_sia_monthly.nc, 2024.