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*Supplement of*

# Uncertainty of the satellite-retrieved sea-ice area record and its trend

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## S1 Regional SIA

Figure S1 shows the respective SIA time-series with the SIA uncertainty range for February and September as representatives for low and high SIA conditions. Also for the regional estimates, the observational uncertainties do not reduce proportionally to the SIA estimates.

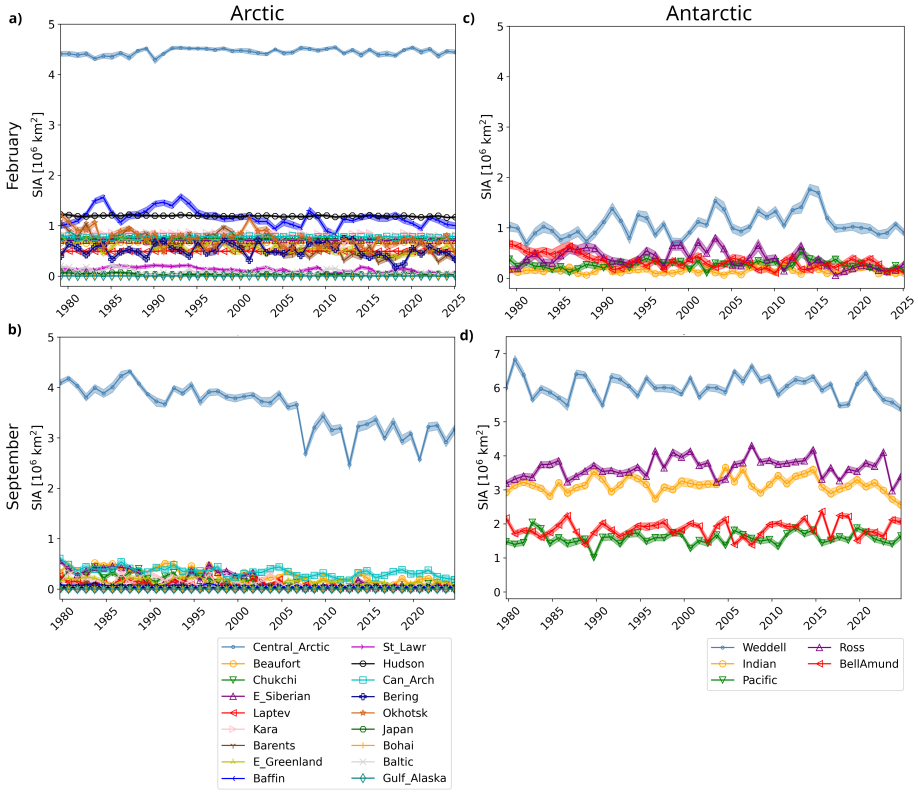


**Figure S1.** Sea Ice Area record for individual regions in the northern (left) and southern (right) hemisphere. Shown are February (top) and September (bottom) monthly mean values (lines) and the respective uncertainties (90% frequency intervals) as shades.

## S2 The yearly evolution of SIC/Ice-Edge/SIA

For a better understanding of the relationship of SIA uncertainty throughout the year, Figure S2 and S3 show example SIC maps, together with the yearly evolution of SIA vs. ice-edge length. It is clear for both hemispheres, that the two quantities are decoupled, and that the ice-edge is much longer when the SIA is retreating, than when it is advancing.

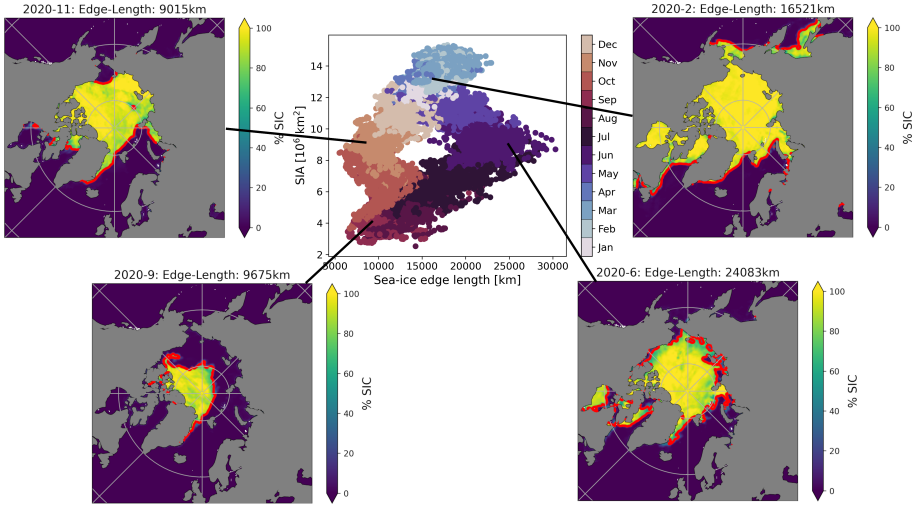


**Figure S2.** Arctic Sea Ice Area in million km$^2$ versus length of the ice-edge, defined here as length of the 50% SIC contour, for the whole record (centre) and example 2020 maps of the OSI SAF sea ice concentration (SIC) for the 15.th of February, June, September, and November with 50% SIC contour line (red).

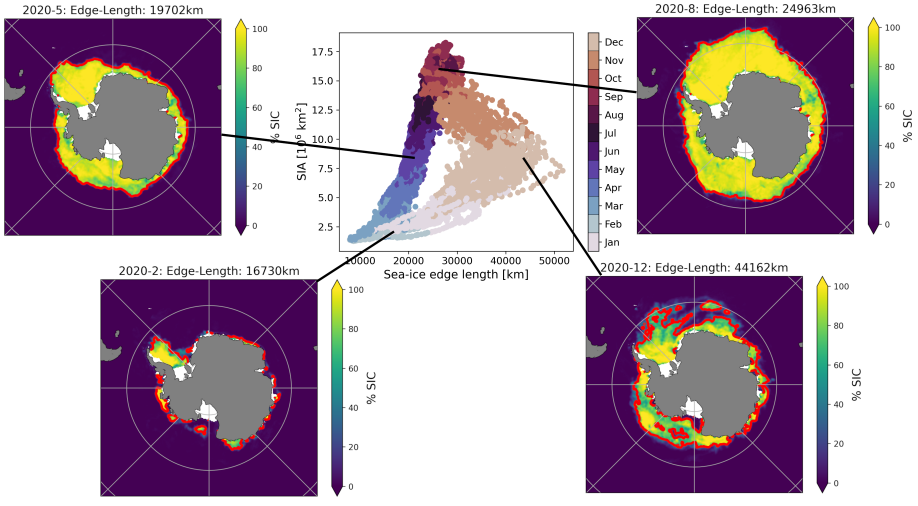


**Figure S3.** Antarctic Sea Ice Area in million km$^2$ versus length of the ice-edge, defined here as length of the 50% SIC contour, for the whole record (centre) and example 2020 maps of the OSI SAF sea ice concentration (SIC) for the 15.th of February, May, August, and December with 50% SIC contour line (red).

## S3 Trend estimate comparison

Figure S4 shows the comparison of the ensemble uncertainty with UHH SIA product estimates (as Figure 4 in the main text) for all months of the year. The inter-product estimates are often clearly outside of the probability distributions (Figure S4).

We find no evidence that trends relative to a climatology (in %/decade) are more consistent than absolute estimates (Figure S5). This indicates that the spread in trends cannot be explained by products which overestimate the SIA (positive bias) to reduce this overestimation proportionally over time on the way to reach an ice free Arctic.

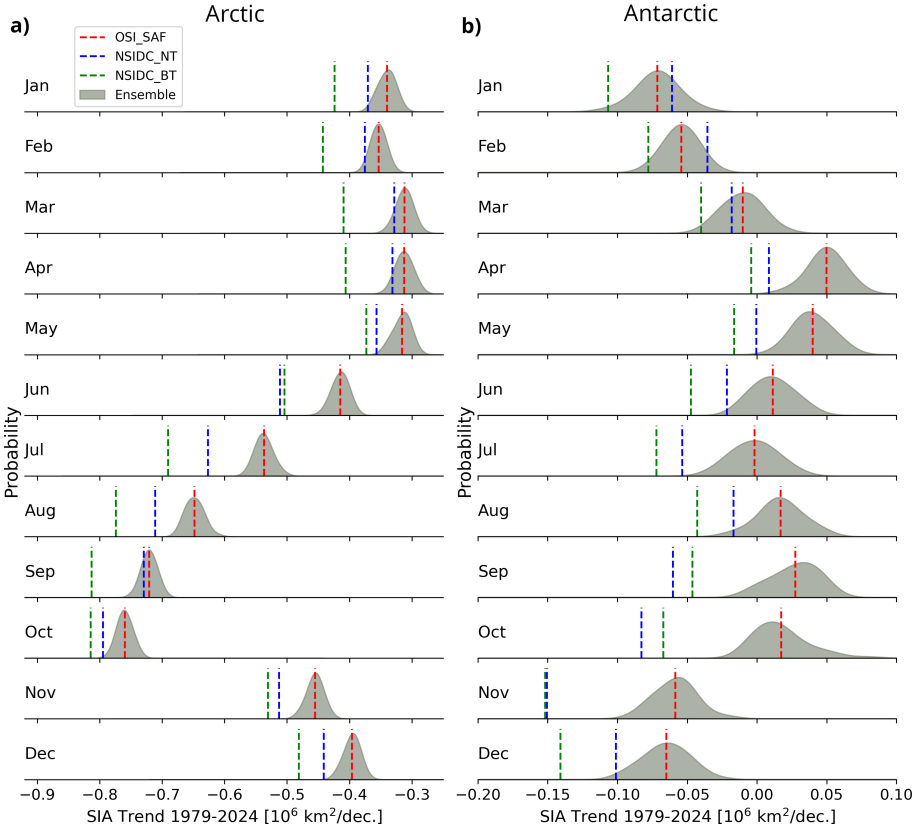


**Figure S4.** SIA trend estimates for 1979 to 2024 (inclusive) (coloured lines) (Rauschenbach et al., 2024; Thomae et al., 2025) and probability distributions of our ensemble estimate (gray), centred on the OSI SAF estimate. Shown are trend estimates for each month in the Arctic (left) and Antarctic (right).

Adding to the visual comparison between UHH SIA trends and ensemble SIA trends in Figure S4 and Figure S5, we want to provide some quantitative estimates. The very small sample size of three UHH SIA products for 1979-2024 and lack of knowledge about the distribution lead us to use the Max-Min as measure of the sample spread. This intuitive measure avoids any assumption about the frequency distribution, but it is an symptotically biased estimator; The Max-Min value is on average increasing with increasing sample size. For the comparison in Figure S6 we randomly select three ensemble members before calculating the Max-Min for each month of the year separately. This random selection is repeated 51 times and the median of this is highlighted as black dot (one per month of the year) in Figure S6.

The Max-Min within sets of three ensemble members is about 0.02 $\cdot 10^6$ km$^2$/dec. throughout the year for both hemispheres, while the same measure is between 0.05 $\cdot 10^6$ km$^2$/dec. and 0.15 $\cdot 10^6$ km$^2$/dec. in the Arctic and 0.03 $\cdot 10^6$ km$^2$/dec. and 0.10 $\cdot 10^6$ km$^2$/dec. in the Antarctic.

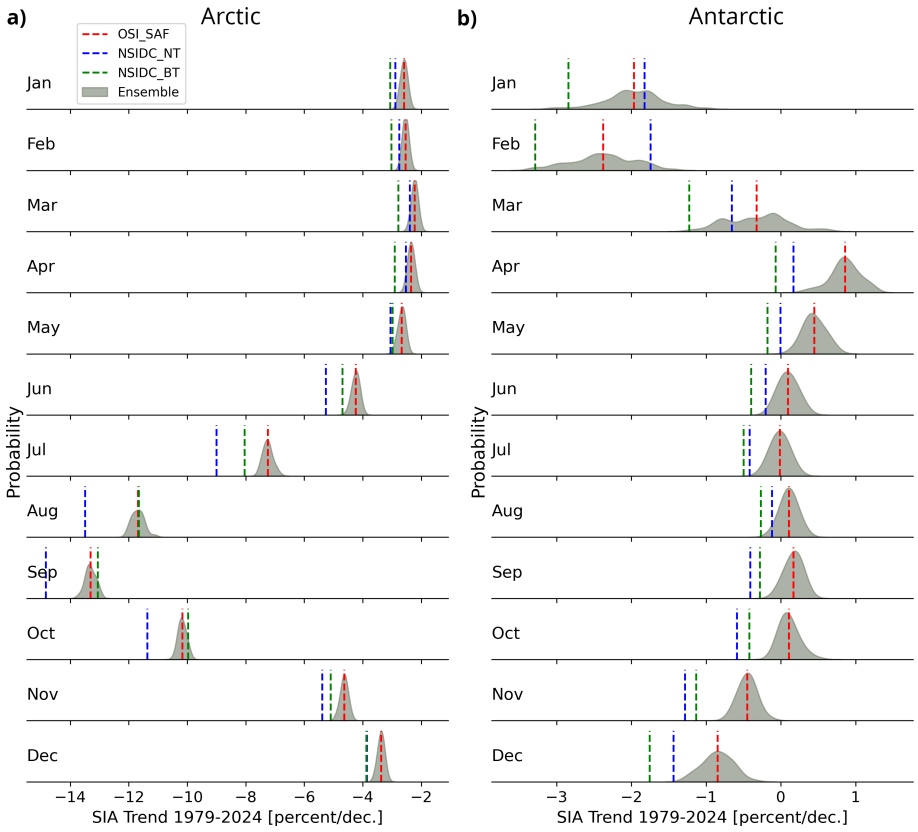


**Figure S5.** SIA trend estimates for 1979 to 2024 (inclusive) (coloured lines) (Rauschenbach et al., 2024; Thomae et al., 2025) and probability distributions of our ensemble estimate (gray), centred on the OSI SAF estimate. Shown are trend estimates for each month in the Arctic (a) and Antarctic (b). Trends are calculated relative to the commonly used 1981-2010 climatology.

## S4 Sensitivity of SIA Uncertainty to SIC Uncertainty

The SIA uncertainties analysed in this study rely on the OSI SAF SIC uncertainties. Even though it is not the purpose of this study to validate the OSI SAF product, we can show how sensitive our results are on the provided SIC uncertainties. This consists of two steps: (1) define a reasonable range of SIC uncertainty mismatches and (2) analyse the relationship between SIC uncertainty and SIA uncertainty in this range.

For step (1) we turn to the literature. The number of published reports on the quality of the OSI SAF SIC uncertainty estimate is unfortunately small and they focus on near 100% SIC and near 0% SIC conditions (CDR SVR, CCI+ PVIR, Lavergne et al. 2019). For those conditions the *total_uncertainty* variable is typically small (<= 5% SIC). According to the CDR SVR, for near 100% SIC conditions the OSI-450a total uncertainty is typically within 0.5% SIC of the RMSE of the OSI-450a SIC with high quality validation data (winter time converging ice motion from SAR). For near 0% SIC conditions the OSI-450a *total_uncertainty* typically overestimate the RMSE by about 1% SIC. However, since this represents only cases with relatively small SIC uncertainty values it is likely an underestimation of the uncertainty of the *total_uncertainty* variable for locations with higher values. Therefore we run sensitivity experiments for an increase and decrease of the total_uncertainty by 25 percent (relative). For context, the hemispheric mean *total_uncertainty* for ice covered regions is about 9% (absolute), meaning that the sensitivity runs equate to an average increase/decrease of more than twice the values in the Scientific Validation Report.

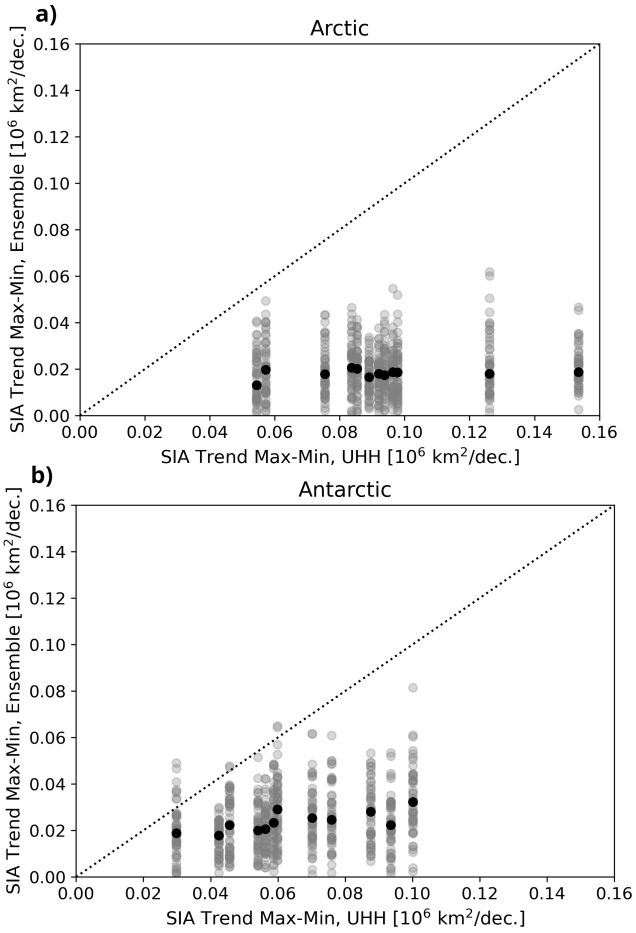


**Figure S6.** Arctic (a) and Antarctic (b) Sea Ice Area trend ranges (Max - Min) of the UHH SIA product (OSI SAF, NASA-Team and Bootstrap) versus the trend range of 51 repeated random selections of three ensemble members (transparent dots) and its median (black dot). All trends are for the period 1979 to 2024 (inclusive) and for each month of the year separately.

For step (2), Figure S7 shows that the SIC and SIA uncertainties are linearly related: A 25% increase (decrease) in SIC uncertainty leads to a 25% increase (decrease) in SIA uncertainty.

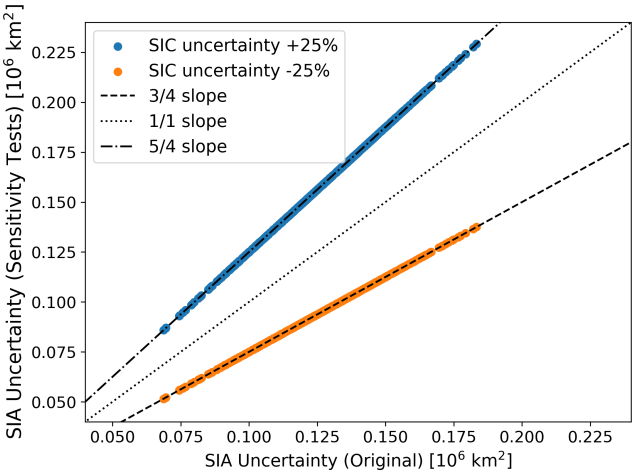


**Figure S7.** Uncertainties of the monthly SIA record for increased (blue) and decreased (orange) SIC uncertainties compared to the original (unchanged) SIC uncertainty fields. The same stochastic realizations (seeds) are used for the altered uncertainties as for the original.

## References

Rauschenbach, Q., Dörr, J., Notz, D., and Kern, S.: UHH Sea-Ice Area product (Version 2024_fv0.01) [Data set], https://doi.org/10.25592/uhhfdm.11346, 2024.

Thomae, S., Rauschenbach, Q., Dörr, J., Notz, D., and Kern, S.: UHH Sea-Ice Area product (Version 2025_fv0.01) [Data set], https://doi.org/10.25592/uhhfdm.18163, 2025.