Supplement to: Uncertainties in 45+ years of Sea-Ice Area and Sea-Ice Area trend observations

Andreas Wernecke[1], Thomas Lavergne[2], Stefan Kern[1], and Dirk Notz[1]

[1]University of Hamburg, Hamburg, Germany

[2]Norwegian Meteorological Institute, Oslo, Norway

Correspondence: Andreas Wernecke (andreas.wernecke@uni-hamburg.de)

1 Regional SIA

Figure 1 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.

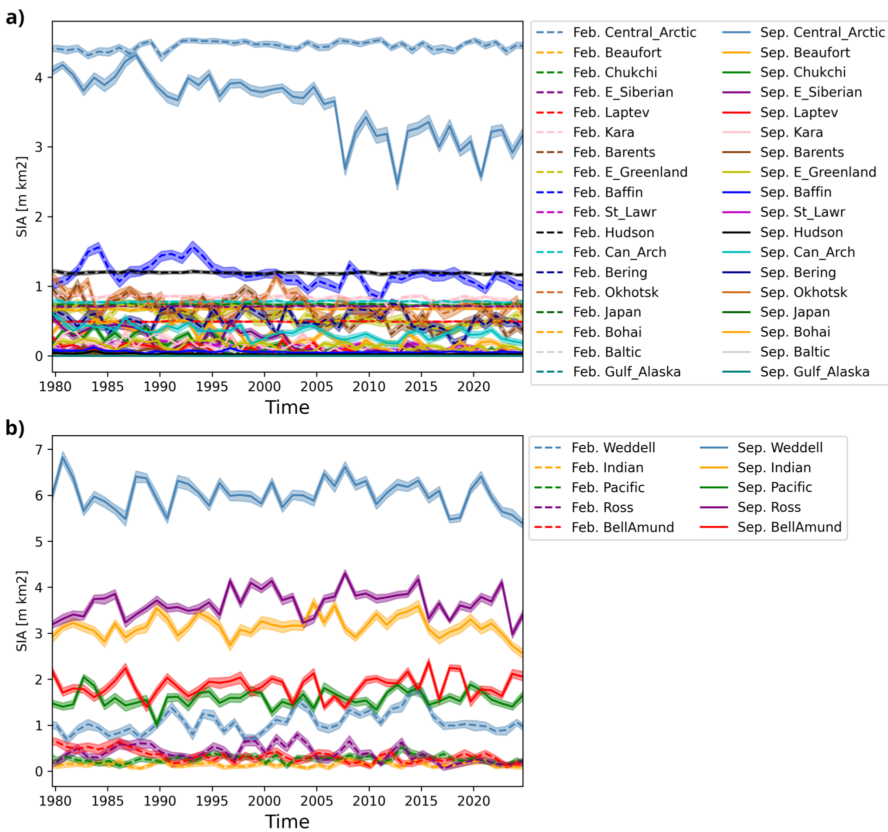

Figure 1. Sea Ice Area record for individual regions in the northern (top) and southern (bottom) hemisphere. Shown are February (left) and September (right) monthly mean values (lines) and the respective uncertainties (90% frequency intervals) as shades.

2 The yearly evolution of SIC/MIZ/SIA

For a better understanding of the relationship of SIA uncertainty throughout the year, Figure 2 and 3 show example SIC maps, together with the yearly evolution of SIA vs. MIZ. It is clear for both hemispheres, that the two quantities are decoupled, and that the MIZ is much longer when the SIA is retreating, than when it is advancing.

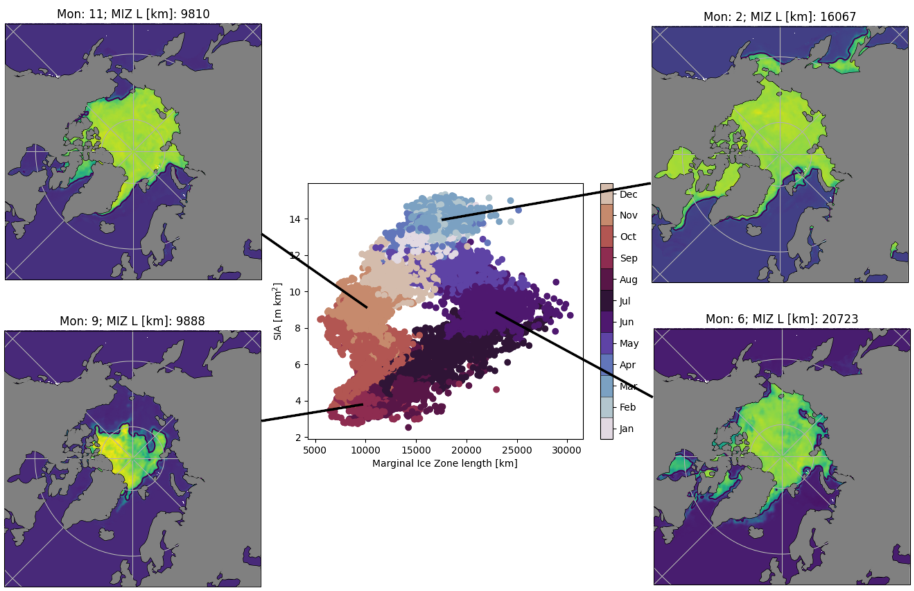

Figure 2. Arctic Sea Ice Area in million km^2 versus length of the Marginal Ice Zone (MIZ), defined here as length of the 50% SIC contour (centre) and example maps of the OSI SAF sea ice concentration (SIC) for individual days in February, June, September, and November with 50% SIC contour line (black) and individual length of the MIZ (above maps). Bright yellow corresponds to SIC near 100% and blue to SIC near 0%.

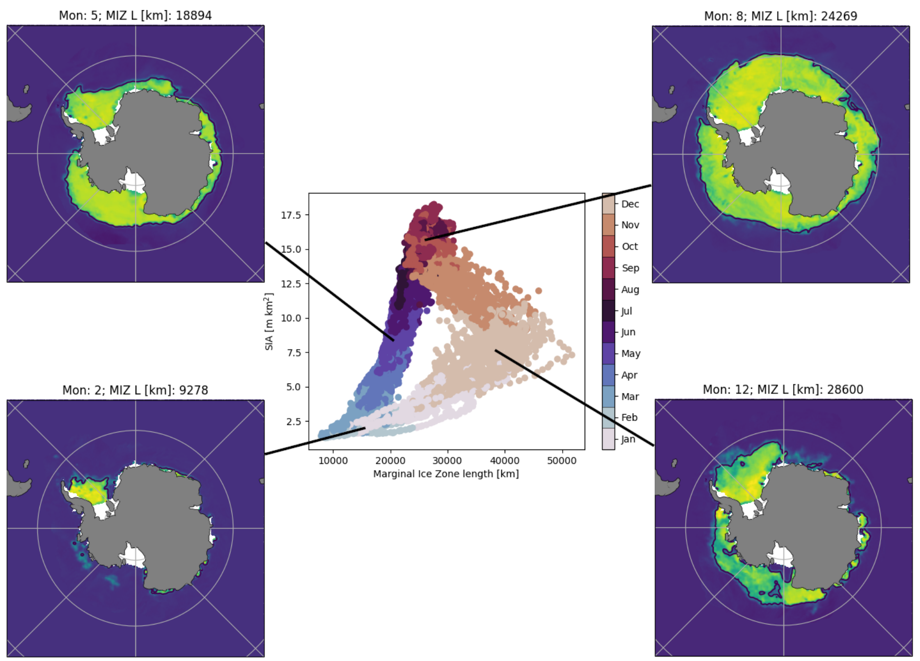

Figure 3. Antarctic Sea Ice Area in million km^2 versus length of the Marginal Ice Zone (MIZ), defined here as length of the 50% SIC contour (centre) and example maps of the OSI SAF sea ice concentration (SIC) for individual days in February, June, September, and November with 50% SIC contour line (black) and individual length of the MIZ (above maps). Bright yellow corresponds to SIC near 100% and blue to SIC near 0%.

3 Trend estimate comparison

Figure 4 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 4).

We find no evidence that trends relative to a climatology (in %/decade) are more consistent than absolute estimates (Figure 5). 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.

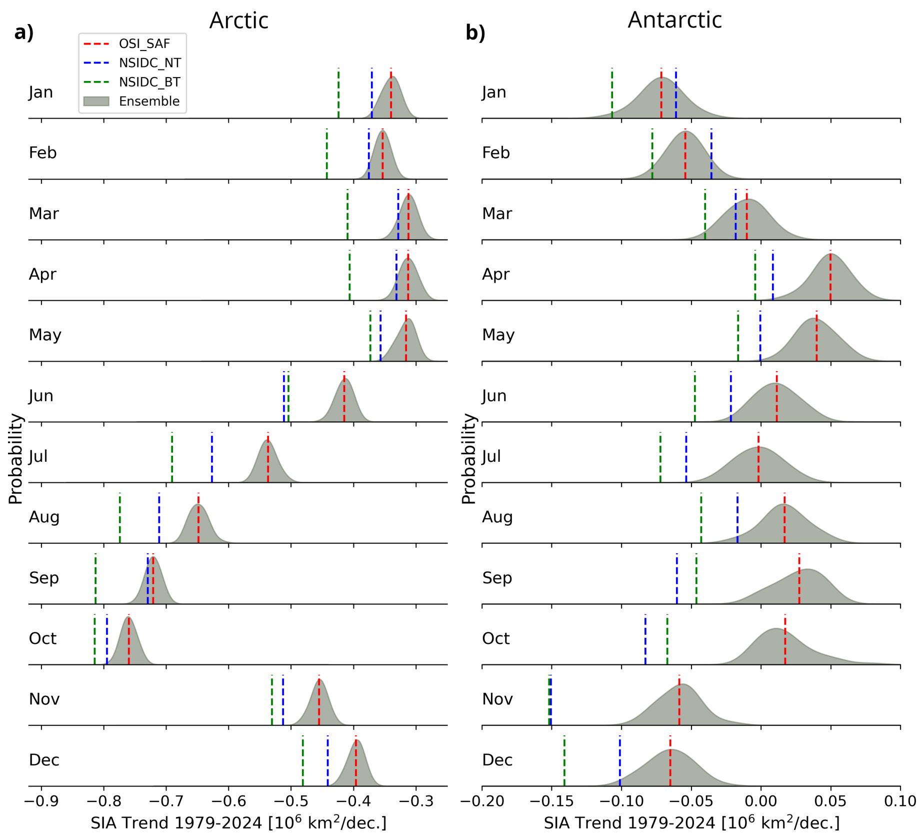

Figure 4. SIA trend estimates for 1979 to 2024 (inclusive) (coloured lines) (Rauschenbach et al., 2024; Thomae et al., 2025) and probability distributions of our ensemble estimate (gray), centred on the OSI SAF estimate. Shown are trend estimates for each month in the Arctic (left) and Antarctic (right).

Adding to the visual comparison between UHH SIA trends and ensemble SIA trends in Figure 4 and Figure 5, 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 6 we randomly select three ensemble members before

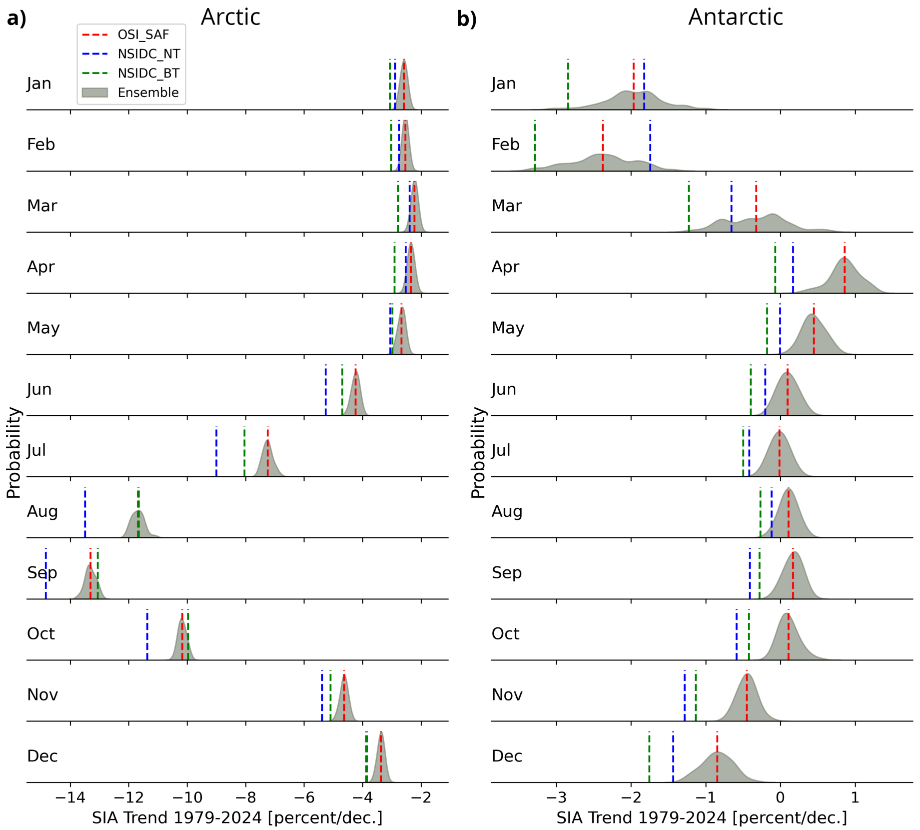

Figure 5. SIA trend estimates for 1979 to 2024 (inclusive) (coloured lines) (Rauschenbach et al., 2024; Thomae et al., 2025) and probability distributions of our ensemble estimate (gray), centred on the OSI SAF estimate. Shown are trend estimates for each month in the Arctic (a) and Antarctic (b). Trends are calculated relative to the commonly used 1981-2010 climatology.

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 6.

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.

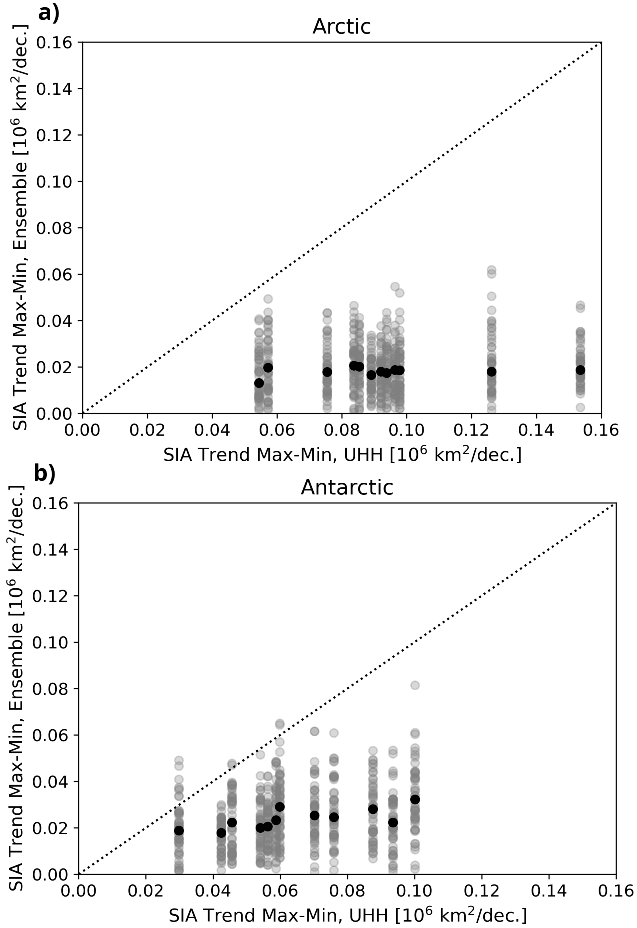

Figure 6. Arctic (a) and Antarctic (b) Sea Ice Area trend ranges (Max - Min) of the UHH SIA product (OSI SAF, NASA-Team and Bootstrap) versus the trend range of 51 repeated random selections of three ensemble members (transparent dots) and its median (black dot). All trends are for the period 1979 to 2024 (inclusive) and for each month of the year separately.

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.