Changes in the Antarctic marginal ice zone

Doroteaciro Iovino[1], J. Selivanova[1,2], Andrea Cipollone[1], Simona Masina[1]

1 - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
2 - University of Bologna, Italy

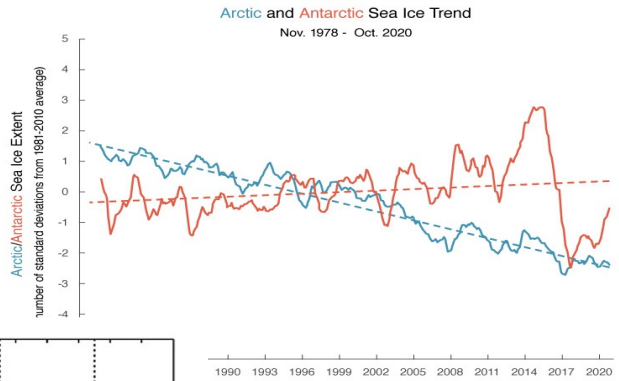
OS.8 The Copernicus Marine Service

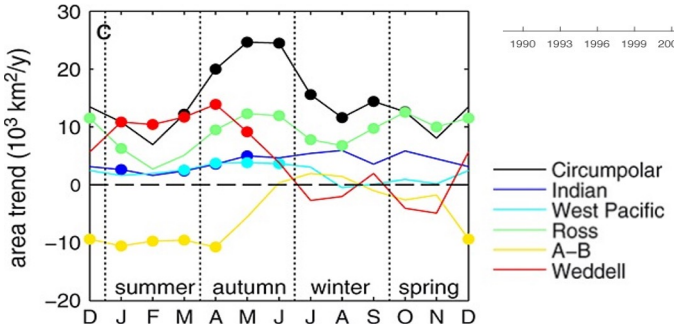
Iovino et al (2022) *The Antarctic Marginal Ice Zone and Pack Ice Area in CMEMS GREP Ensemble Reanalysis Product*. Front. Earth Sci. 10:745274. doi: 10.3389/feart.2022.745274

Iovino et al (2022) *Changes in the Antarctic marginal ice zone.* Ocean State Report 6. JOO (accepted)

BACKGROUND – OBJECTIVES

- the Antarctic has not experienced a stable sea ice loss during recent decades - there is currently no consensus on the origin of the phenomenon
- Changes in circumpolar sea ice area mask high-magnitude spatial and seasonal variability and distribution of different types of ice





Marginal Ice Zone (MIZ) defined as

- *the part of the ice cover which is close enough to the open ocean boundary to be affected by its presence (Wadhams 1986)*
- *the area where open ocean processes, including ocean waves, alter significantly the dynamical properties of sea ice cover*

Sea ice concentration (SIC) thresholds:

marginal ice zone (MIZ; 15-80%)
consolidated pack ice (80-100%)

Validate ORAs accuracy in reproducing Antarctic sea ice

Gain a better knowledge of temporal and spatial variability of <u>different sea ice classes</u> that can provide a deeper insight of possible driving mechanisms behind their changes

Ensemble mean (GREPv2) of four ORA-IP reanalyses produced by CMEMS (GLOBAL_REANALYSIS_PHY_001_031)
global eddy-permitting configuration (0.25° horizontal resolution and 75 vertical levels)
Atmospheric forcing: ECMWF ERA-Interim
Analyzed time period: 1993-2019

Name	**CGLORSv7**	**GLORYS2v4**	**ORAS5**	**GLOSEA5v13 (FOAM)**
Institution	CMCC	Mercator Ocean	ECMWF	UK Met Office
Ocean-ice model	NEMO3.6-LIM2	NEMO3.1-LIM2	NEMO3.4-LIM2	NEMO3.2-CICE4.1
Sea ice data assimilation method	Linear nudging	Reduced order KF	3DVAR-FGAT	3DVAR
DA sea ice data	OSISAF	IFREMER/ Cersat	OSTIA(reprocessed before 2008, analysis from 2008)	OSISAF

SIC from set of satellite datasets:
- **NOAA/NSIDC CDR** (https://nsidc.org/data/g02202)
- EUMETSAT OSISAF (OSI-450 & OSI-430-b) (ftp://osisaf.met.no/)
- Ifremer/CERSAT (https://wwz.ifremer.fr/cersat_fr)

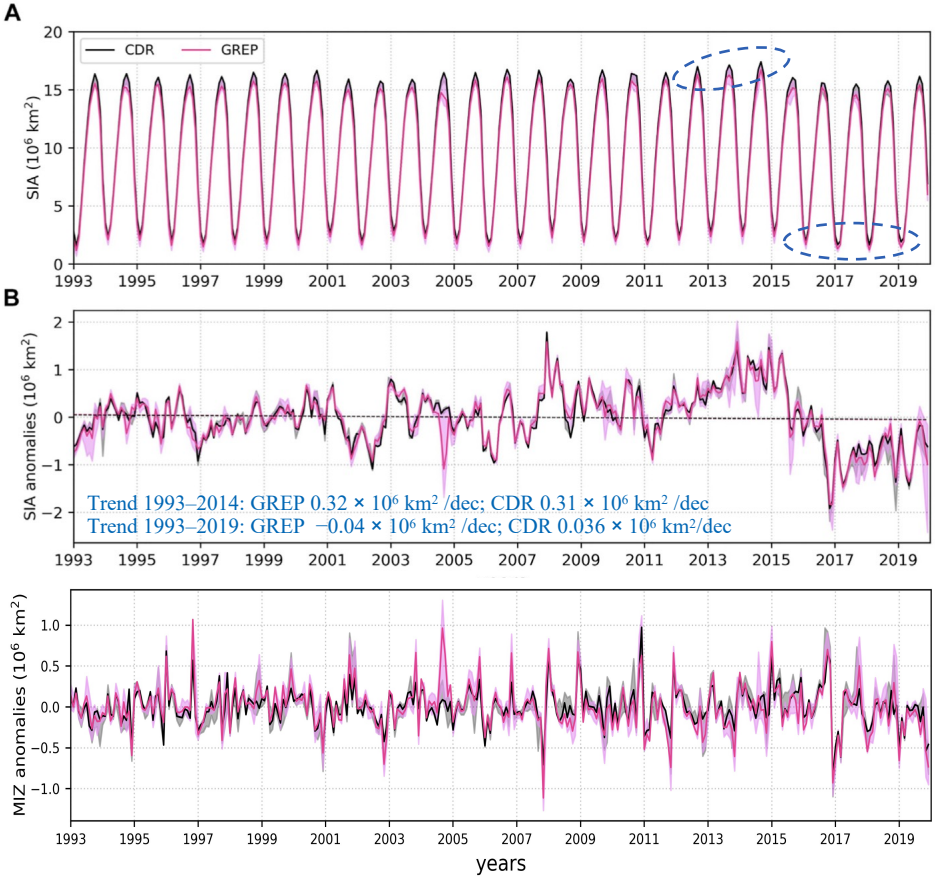
Time Evolution of Antarctic sea ice in GREP

- **GREP SIA** ranges from the February minima to September maxima, with a huge amount of sea ice growing and melting each year **in very good agreement with observations**

- While it slightly underestimates minima and maxima SIA, **GREP correctly reproduces the large interannual variability**, and properly depicts the record high in September 2014 and the marked decreases in the subsequent 3 years, with the record low in February 2017

- **GREP and CDR monthly anomalies of SIA show similar patterns and trends**, with an upward trend in yearly average SIA for 1993–2014, and trend close to zero for the entire period 1993–2019. The close agreement between the three observational products (grey shading) and the four ORAs (pink shading) is notable; differences are greatest at the winter maxima

- There is a general **good agreement between monthly anomalies of MIZ area** in GREP and CRD, but the difference between ensemble and observations envelopes is higher

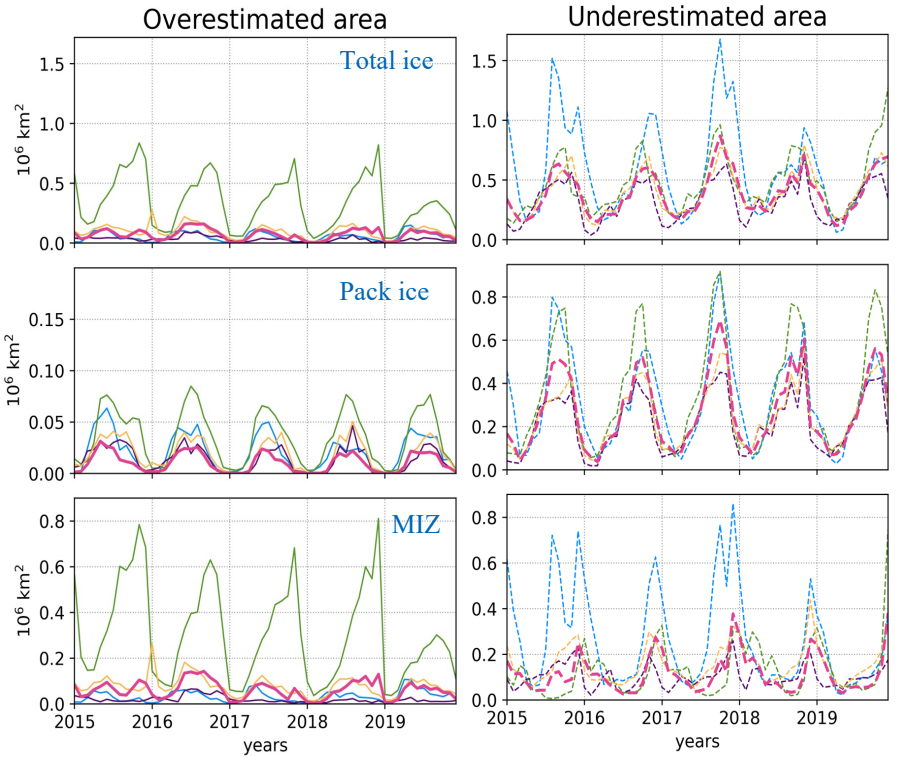


Time series of (A) monthly averages and (B) monthly anomalies of Antarctic sea ice area and (C) MIZ area in GREP (magenta) and CDR (black) from 1993 to 2019.

INCONSISTENCY BETWEEN GREP AND SATELLITE ESTIMATES

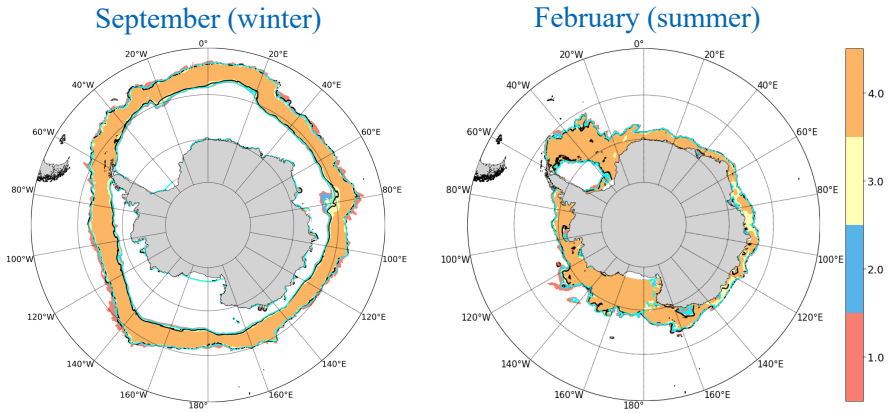
Integrated ice area error IIAE components identify the area of sea ice on which ORAs and observations disagree

- For every month, errors are very low relative to the mean SIA values. GREP tends to underestimate total SIA area with the error ranging (0.1 × 10^6 km^2 in March-April to 0.7 × 10^6 km^2 in October-December)
- Reanalyses generally tend to reproduce lower SIC than CDR, within the pack ice region: while IIAE O component in pack ice is relatively small and similar among the individual ORAs, IIAE U component grows in August-November and doubles for two reanalysis products
- The MIZ also contributes to the total overestimated and underestimated area, but the error does not generally exceed 0.2 × 106 km2. There is one ORA outlier that generally contributes to overestimating SIA, and one to underestimating it in the MIZ
- Overall, GREP performs well owing to minimization of systematic errors in individual products. Additionally, the error in the ensemble mean is consistent throughout the years, which is not the case for single ensemble members



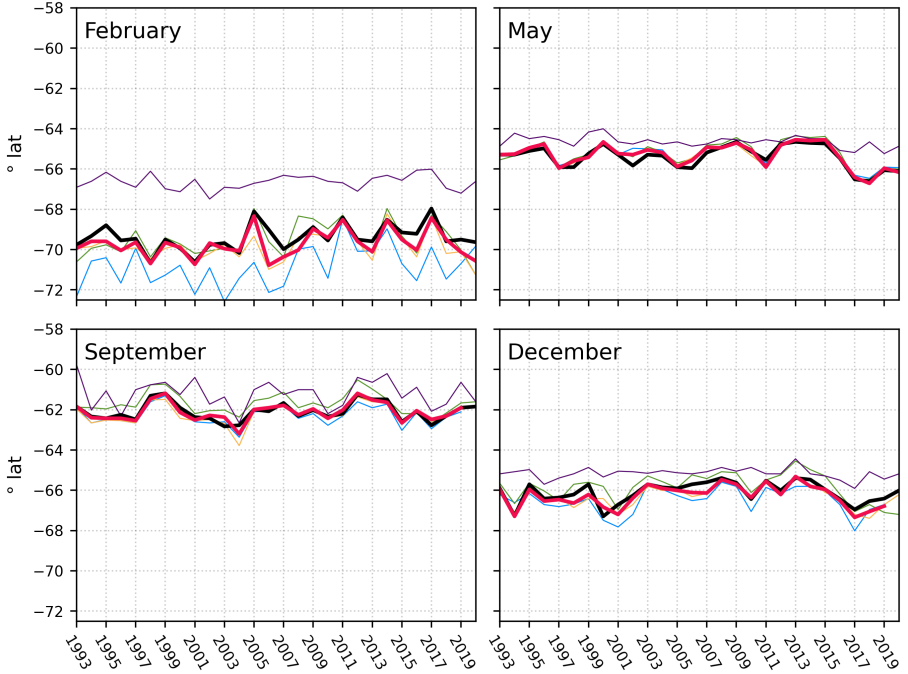
Time series of the GREP integrated ice area error components (in magenta) calculated against CDR for total ice, pack ice and the MIZ area. Area of sea ice where GREP simulates higher (lower) SIC is on the left (right) column. *The y-axis scales for pack ice are different.* Thin lines represent the individual ORAs.

Average Location of the MIZ



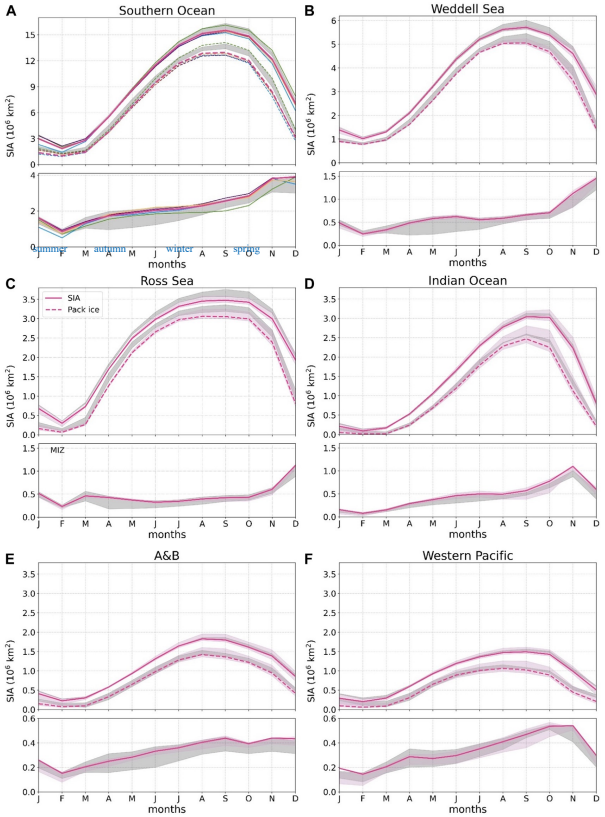
Number of ORAs per grid cell where 15% ≤ SIC < 80%. CDR (black) and GREP (cyan).

- ORAs compare well with CDR on the average MIZ location
- Less consistency in the Western Antarctic where some products lack sea ice
- Time evolution of monthly-averaged latitudes of the MIZ in good agreement between GREP and CDR
- Contraction of the MIZ in the most recent years during growing and melting seasons



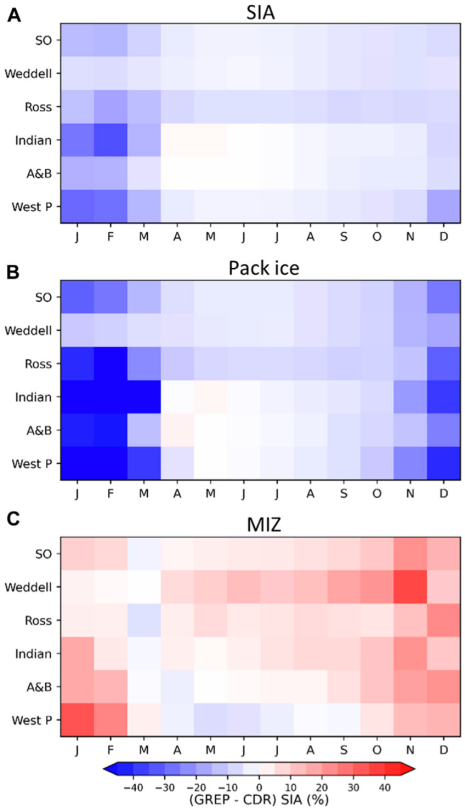
Time series of monthly-averaged latitudes of MIZ for GREP (red) and CDR (black) in February, May, September, and December.

SEASONAL AND REGIONAL VARIABILITY



Mean seasonal cycle (1993–2019) in total SIA (solid), pack ice (dashed), and the area covered by MIZ (lower subplots) computed for GREP (in magenta) and the individual ORA (thin colored lines) in the Antarctic-wide region (A) and in five sub-sectors (B-F). Pink (grey) shading denotes the envelope of GREP members (observational estimates). *Please note the different y-axis scales.*

Seasonal cycle of (GREP minus CDR, in %) monthly climatology of (A) total ice, (B) pack ice and (C) MIZ area in the Southern Ocean and its five sectors. Differences are shown as a percentage of CDR values computed for the years 1993–2019. Red (blue) indicates that GREP reproduces higher (lower) SIA compared to CDR.



CONCLUSIONS

- GREP (and ORAs) properly reproduce the hemispheric and regional variability of total and marginal ice area and generally agree with satellite estimates (more evident discrepancies between GREP and CDR are seen during summer in the eastern Antarctica)
- GREP smooths the strengths and weaknesses of single systems and provides the most consistent and reliable estimates of the mean state and variability of sea ice area
- This spatial distinction in GREP performance is attributed to the proportion of pack ice and the MIZ in the regions (most accurate representation of SIC in the Weddell Sea, less accurate in the Indian Ocean and the Western Pacific)
- The different seasonality of sea ice classes is a notable result that confirms a different interplay of ice classes with the ocean and the atmosphere
- The MIZ area did not experience a significant average trend over the analyzed period
- Substantial regional trends, particularly for regions covered by marginal ice.