Arctic and Antarctic sea ice in CMIP6

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SIMIP Community, Dirk Notz, MPI, Lettie Roach, U. Washington.

SIMIP community

- A number of community papers on the CMIP6 ice model performance.
- An additional set of variables on sea ice budgets, momentum balance, and fluxes that force the sea ice, 10-12 models currently in the archive have a reasonable set of these variables.
- First 2 papers on the Arctic and Antarctic ice have just been published in GRL which include comparisons with CMIP3 and CMIP5 ensembles.
- Last September I gave a talk in ACCESS science day on the first ensemble members of ACCESS-CM2 and ACCESS-ESM1-5 and they fit well within these ensemble results.

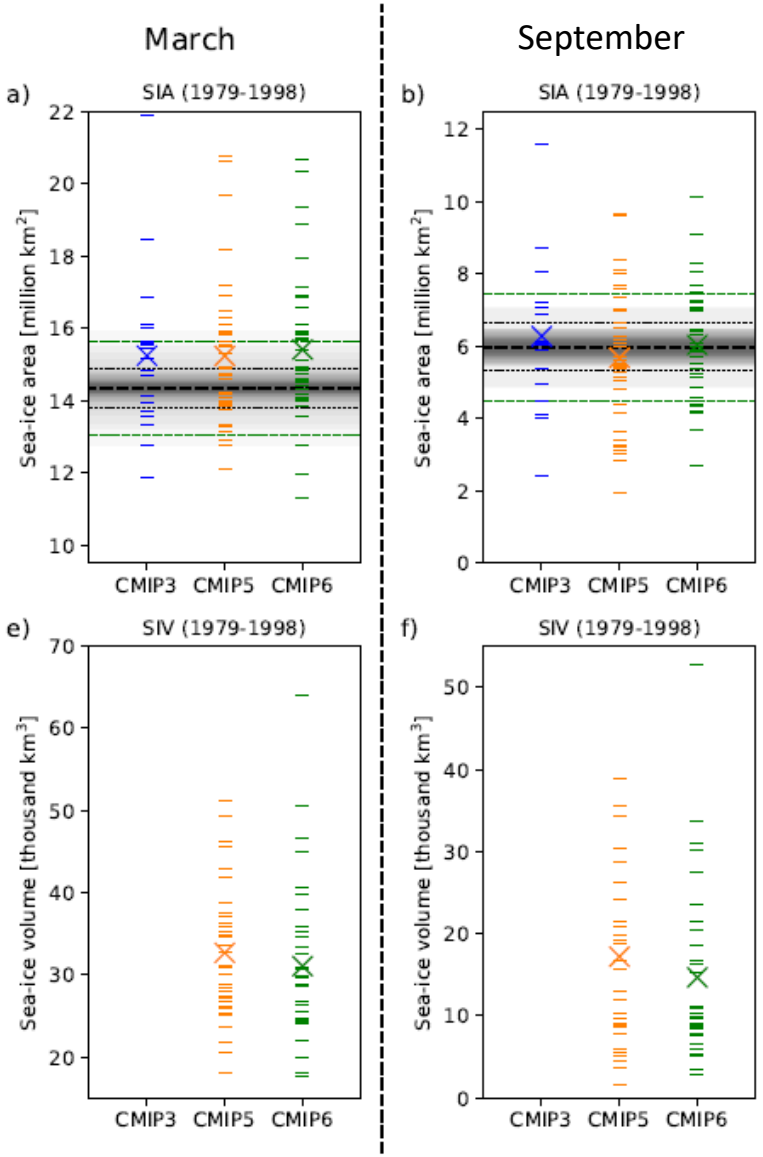
Arctic Sea Ice in CMIP6 –SIMIP Community

Dirk Notz, Jakob Dorr, David Bailey, Ed Blockley, Mitchell Bushuk, Jens Boldingh Debernard, Evelien Dekker, Patricia DeRepentigny, David Docquier, Neven S. Fuckar, John C. Fyfe, Alexandra Jahn, Marika Holland, Elizabeth Hunke, Doroteaciro Iovino, Narges Khosravi, Francois Massonnet, Gurvan Madec, Siobhan O'Farrell, Alek Petty, Arun Rana, Lettie Roach, Erica Rosenblum, Clement Rousset, Tido Semmler, Julienne Stroeve, Bruno Tremblay, Takahiro Toyoda, Hiroyuki Tsujino, Martin Vancoppenolle.

1979-1998 before rapid Arctic change

40 CMIP6 Models, 40 CMIP5 Models, 19 CMIP3 Models, plots show first ensemble member.

Sea ice area



For ice area validation, 3 microwave satellite observational products used for the period 1979-1998, Ice area used rather than extent as its not dependant on grids. For ice volume we chose to use no ice thickness product PIOMAS was viewed as a model derived.

Sea ice volume

ACCESS-CM2 Ice area, March 16.1, Sept 6.0 million km^2 Ice volume, March 35.1, Sept 16.6 thousand km^3.

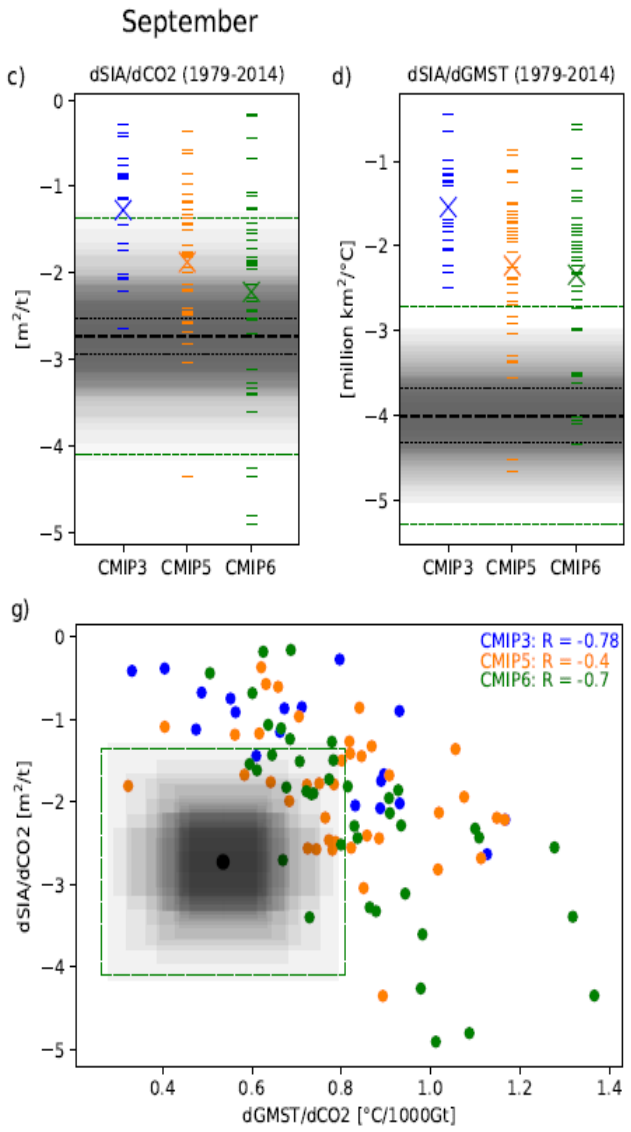
ACCESS-ESM1-5 Ice area, March 14.5, Sept 5.2 million km^2, Ice volume, March 26.4, Sept 10.7.

Rate of change of sea ice are with respect to CO_2 and Global mean surface temperature 1979-2014

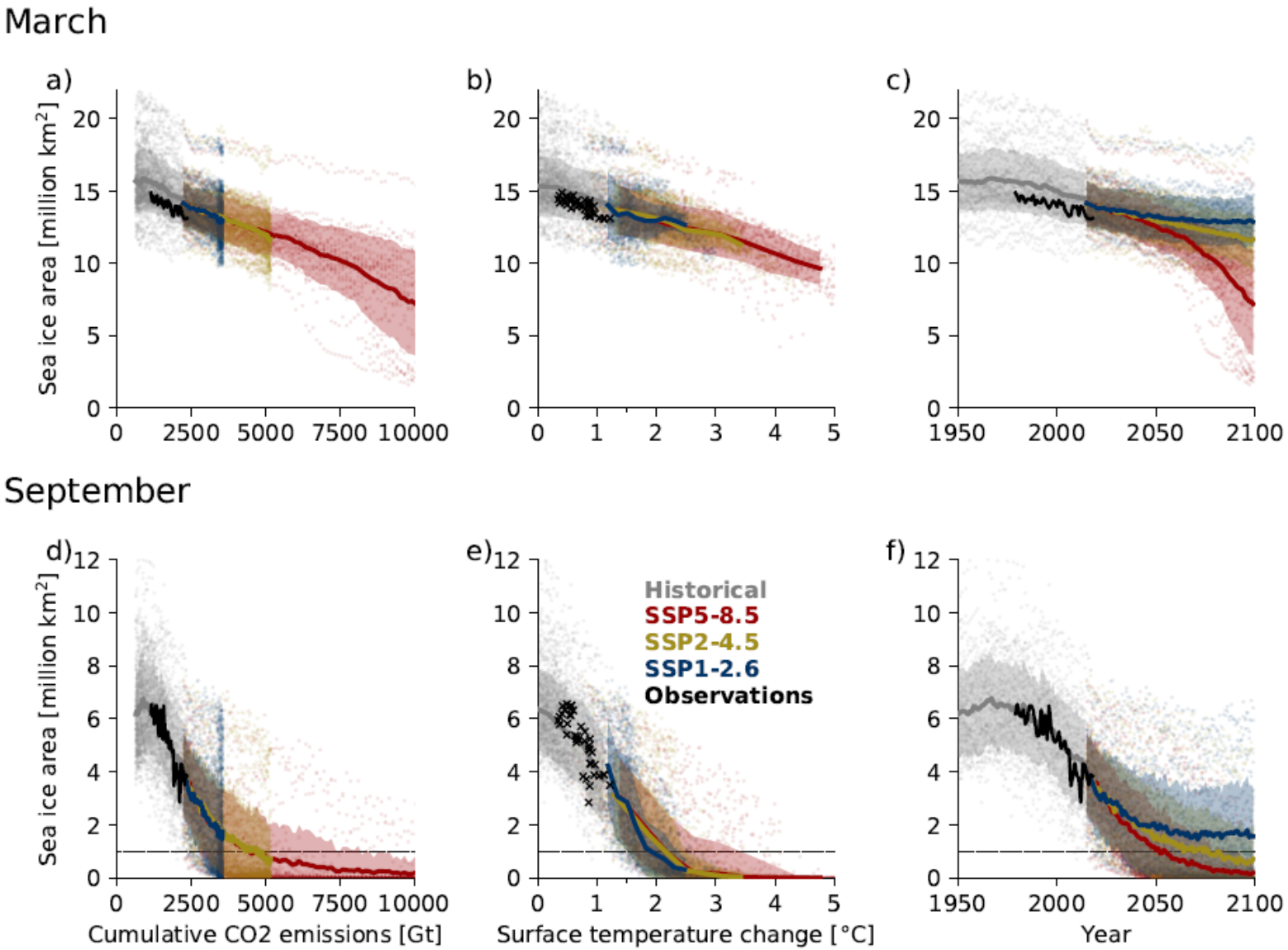
$dSIA/dCO_2$ ACCESS-CM2 2.31 m^2/t, ACCESS -ESM1-5 -1.76 m^2/t.

dSIA/dGMST ACCESS-CM2 -2.72 million $km^2/^oC$, ACCESS-ESM1-5 -1.87 million $km^2/^oC$.

dGMST/dCO2 ACCESS-CM2 0.79 $^oC/1000Gt$ ACCESS-ESM1-5 0.88 $^oC/1000Gt$, historical period climate sensitivity

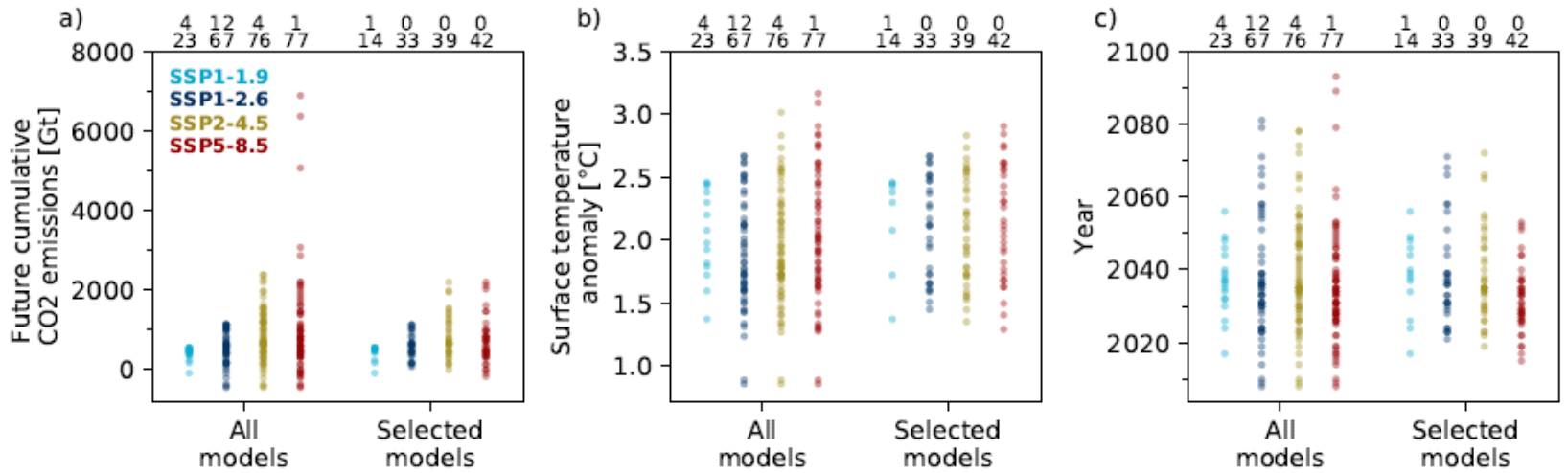


Models that have realistic ice loss in historical period and realistic response in GMST in historical period, ACCESS-CM2, BCC-CSM2-MR, CNRM-CM6-1-HR, FGOALS-f3-L, FIO-ESM-2-0, GFDL-ESM4, GISS-E2-1-G, GISS-E2-1-G-CC, MPI-ESM-1-2-HAM, MPI-ESM1-2-HR, MPI-ESM1-2-LR, MRI-ESM2-0, NorESM2-MM



Historical March multi-model mean is slightly greater than observed, September tracks closely when plotted against time, Cumulative CO_2 emissions and Global Surface temperature change. Some models simulations are responding faster and are below the main envelope of all CMIP6 ensemble members.

Projections of Cumulative emissions, global surface temperature anomaly and the Year when Arctic sea ice drops below 1 million km^2 for the first time.



Selected models are those that have the sea ice are observations within their model ensemble for September sea ice from 2005-2014, and the observed sensitivity of sea ice area to cumulative CO_2 over 1979-2014.

Conclusions of Arctic SIMIP Paper

- CMIP6 model simulations of Arctic sea-ice area capture the observational record in the multi-model ensemble spread
- The sensitivity of Arctic sea ice to changes in the forcing is better captured by CMIP6 models than by CMIP5 and CMIP3 models
- The majority of available CMIP6 simulations lose most summer sea ice before 2050 in all scenarios; the future of the ice cover is not that sensitive to which scenario path we are on.
- The CMIP6 multi-model ensemble mean provides a more realistic estimate of the sensitivity of September Arctic sea-ice area to a given amount of anthropogenic CO2 emissions and to a given amount of global warming, compared with earlier CMIP experiments.
- However, most CMIP6 models fail to simulate at the same time a plausible evolution of sea-ice area and of global mean surface temperature.

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Key Points:

- CMIP6-mean Antarctic sea ice area is close to observations, but intermodel spread remains substantial
- We find modest improvements in the simulation of sea ice area and concentration compared to CMIP5
- Most CMIP6 models simulate sea ice losses and stronger-than-observed GMST trends over 1979–2018

Supporting Information:

- Supporting Information S1

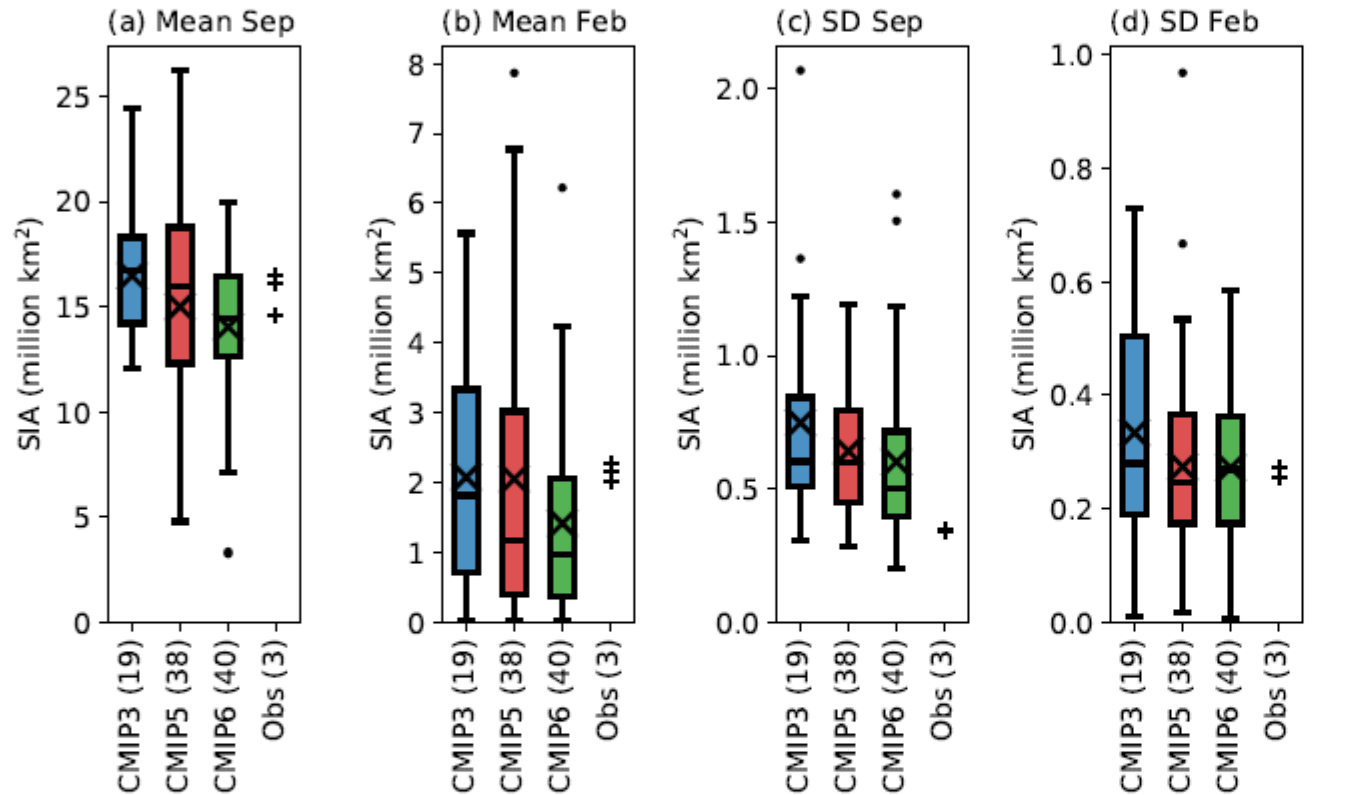
Antarctic Sea Ice Area in CMIP6

Lettie A. Roach[1], Jakob Dörr[2], Caroline R. Holmes[3], François Massonnet[4], Edward W. Blockley[5], Dirk Notz[2,6], Thomas Rackow[7], Marilyn N. Raphael[8], Siobhan P. O'Farrell[9], David A. Bailey[10], and Cecilia M. Bitz[1]

[1]Atmospheric Sciences, University of Washington, Seattle, WA, USA, [2]Max Planck Institute for Meteorology, Hamburg, Germany, [3]British Antarctic Survey, Cambridge, UK, [4]Georges Lemaître Center for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, Belgium, [5]Met Office Hadley Centre, Exeter, UK, [6]Earth System Research and Sustainability (CEN), University of Hamburg, Hamburg, Germany, [7]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Climate Dynamics, Bremerhaven, Germany, [8]Department of Geography, University of California, Los Angeles, CA, USA, [9]CSIRO Oceans and Atmosphere, Aspendale, Victoria, Australia, [10]Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, USA

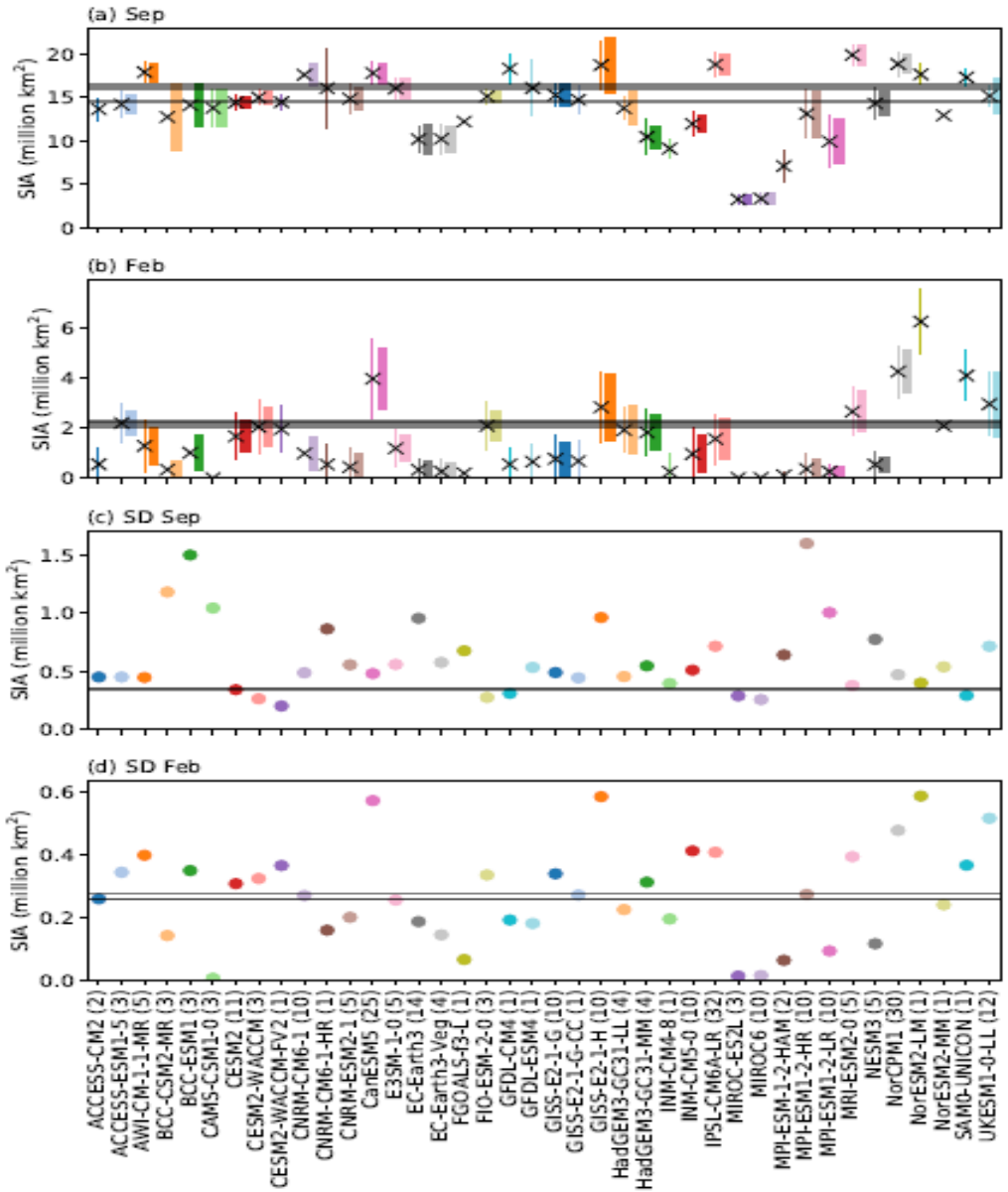
Abstract Fully coupled climate models have long shown a wide range of Antarctic sea ice states and evolution over the satellite era. Here, we present a high-level evaluation of Antarctic sea ice in 40 models from the most recent phase of the Coupled Model Intercomparison Project (CMIP6). Many models capture

Antarctic ice area in CMIP3 (19 models), CMIP5 (38 models), CMIP6 (40 models), Observations are from 3 satellite products. First ensemble member included.



Boxes extend from the lower to upper quartile values of the data with a line at the median and a cross (`X') at the mean. Whiskers show 1.5 times the interquartile range, and data outside this range are considered outliers and shown as dots.

Sea ice area mean and standard deviation from 40 CMIP6 models 1979-2014, historical runs, variability measured from preindustrial control and other from ensemble members.

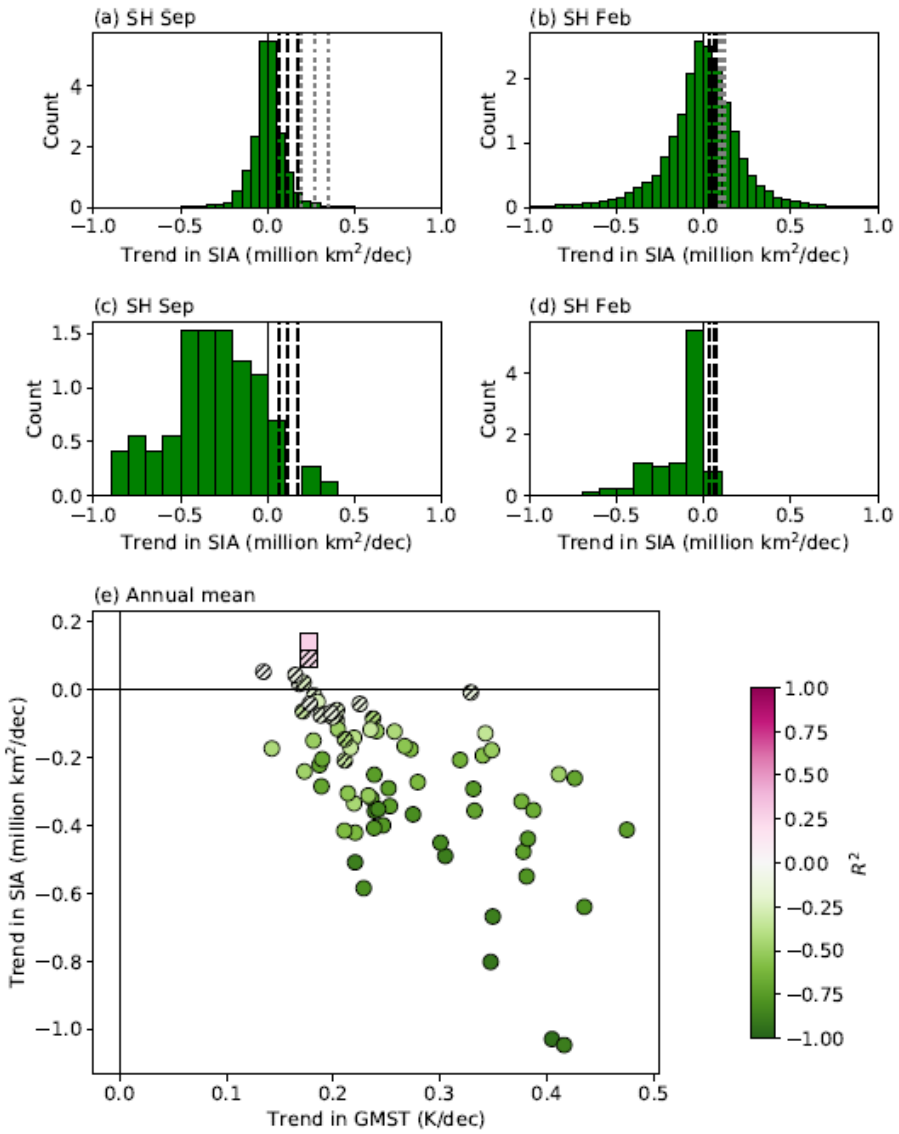


CMIP6 SH ice area model trends

All Pre-industrial 40 year trends

Trend from 1979-2018 (Historical+ssp245), all ensemble members

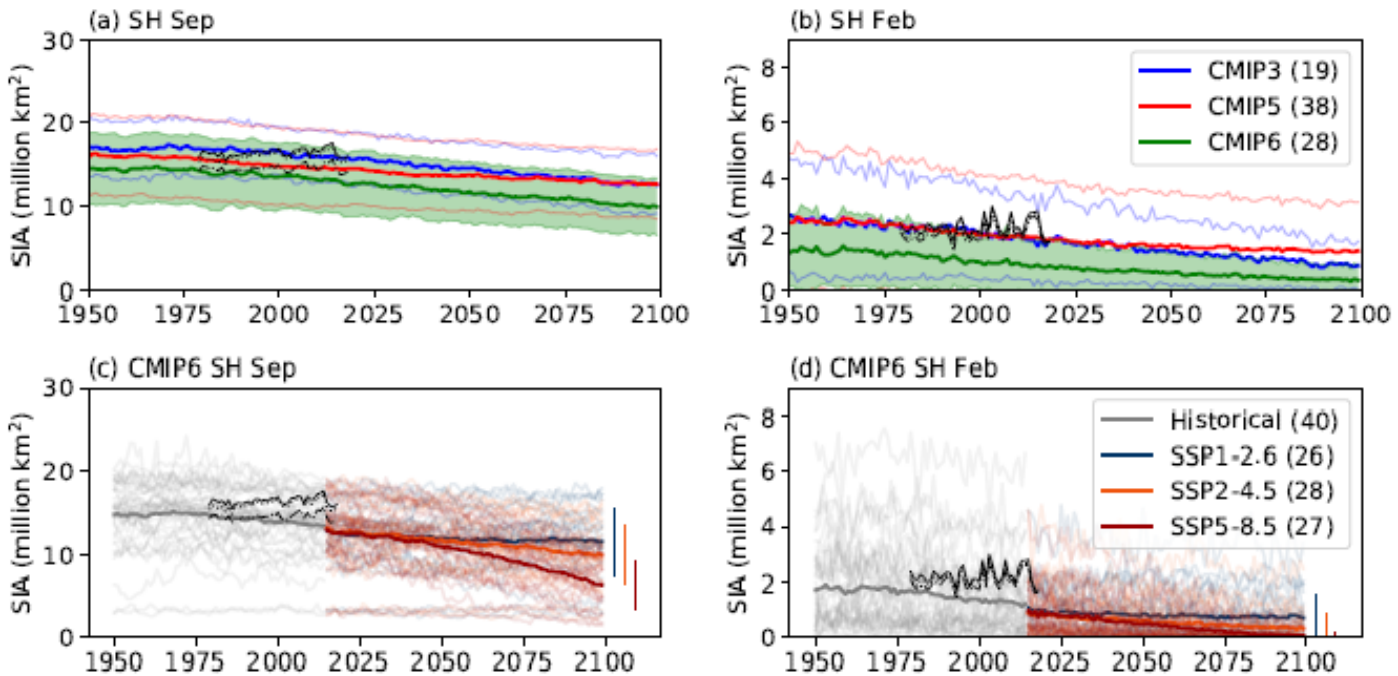
Trend in ice area v trend in global mean surface temperature 1979-2018, all ensemble members.



Observations 1979-2018 -----, 1979-2014 …….

Colour scale, Pearson correlation coefficient, hatching statistical not-significant, 1 model ensemble hidden under observation boxes.

Future Projections of sea ice area, compared CMIP6 SSP245, with CMIP5 RCP45, and CMIP3 SRESA1B, envelope of models is lower for both Sep and Feb, mean model area lower, wider initial model range, and *Climate sensitivity differences.*



Within the CMIP6 scenarios, SSP1-2.6, in the mean there is stabilization at a new lower winter climatology at the end of the century, continual decline for higher scenarios.

Conclusions of SIMIP Antarctic Paper

- CMIP6-mean Antarctic sea ice area is close to observations but inter-model spread remains substantial.
- We find modest improvements in the simulation of sea ice area and concentration compared to CMIP5.
- Most CMIP6 models simulate sea ice losses and stronger-than-observed GMST trends over 1979-2018.
- Models project sea ice loss over the 21st century in all scenarios, but confidence in the rate of loss is limited as most models show stronger global warming trends than observed over the recent historical period.