Antarctic Sea Ice in CMIP6

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IPCC AR5: There is ‘low confidence’ in climate model projections for Antarctic sea ice due to “the wide inter-model spread and the inability of almost all of the available models to reproduce the mean annual cycle, interannual variability and overall increase of the Antarctic sea ice areal coverage observed during the satellite era” (Collins et al., 2013)

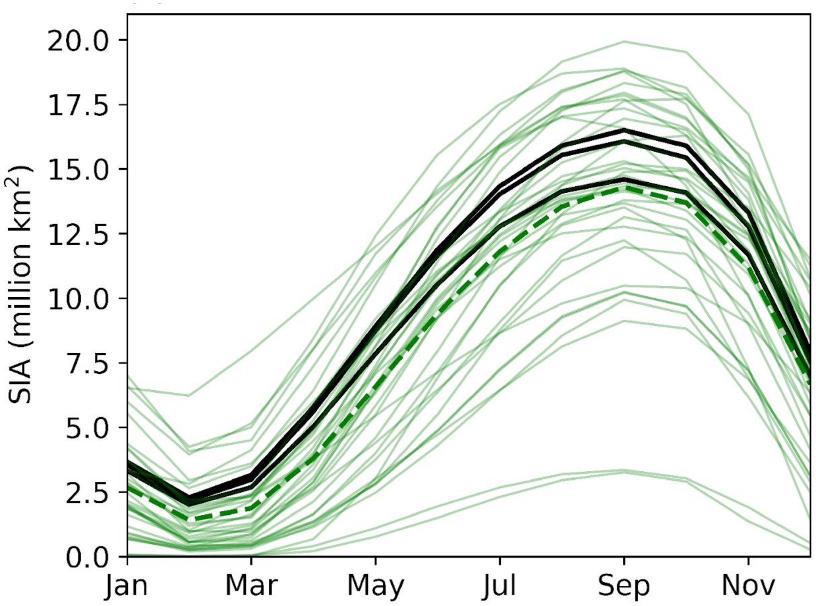
What’s new in CMIP6?

Methods

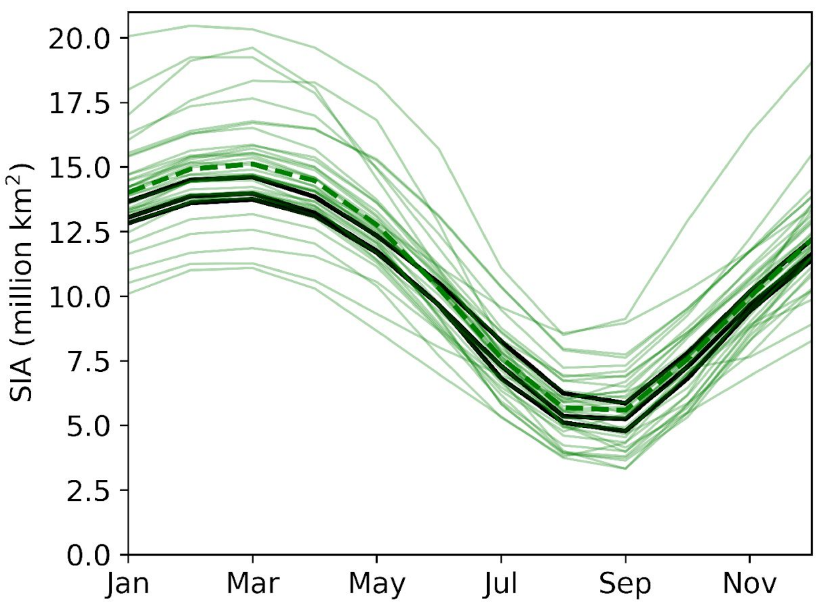
- Similar approach to SIMIP community paper on Arctic sea ice
  - Using SIA rather than SIE
- Focusing on areal quantities rather than thickness
- Also looking at spatial distribution of sea ice
- Three observational products for SIC
- 37 CMIP6 models available at the time of writing
  - Did not account for model interdependence

Sea ice area seasonal cycle

Antarctic



Arctic

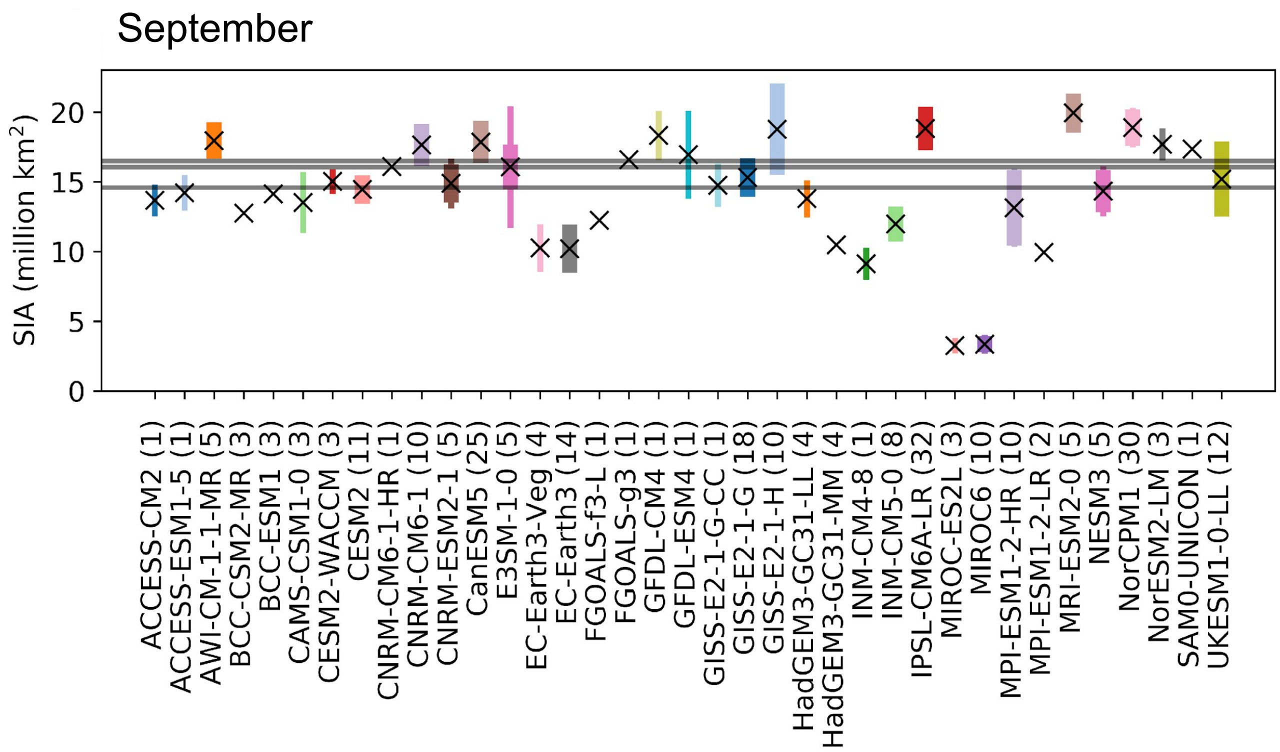


1979-2014

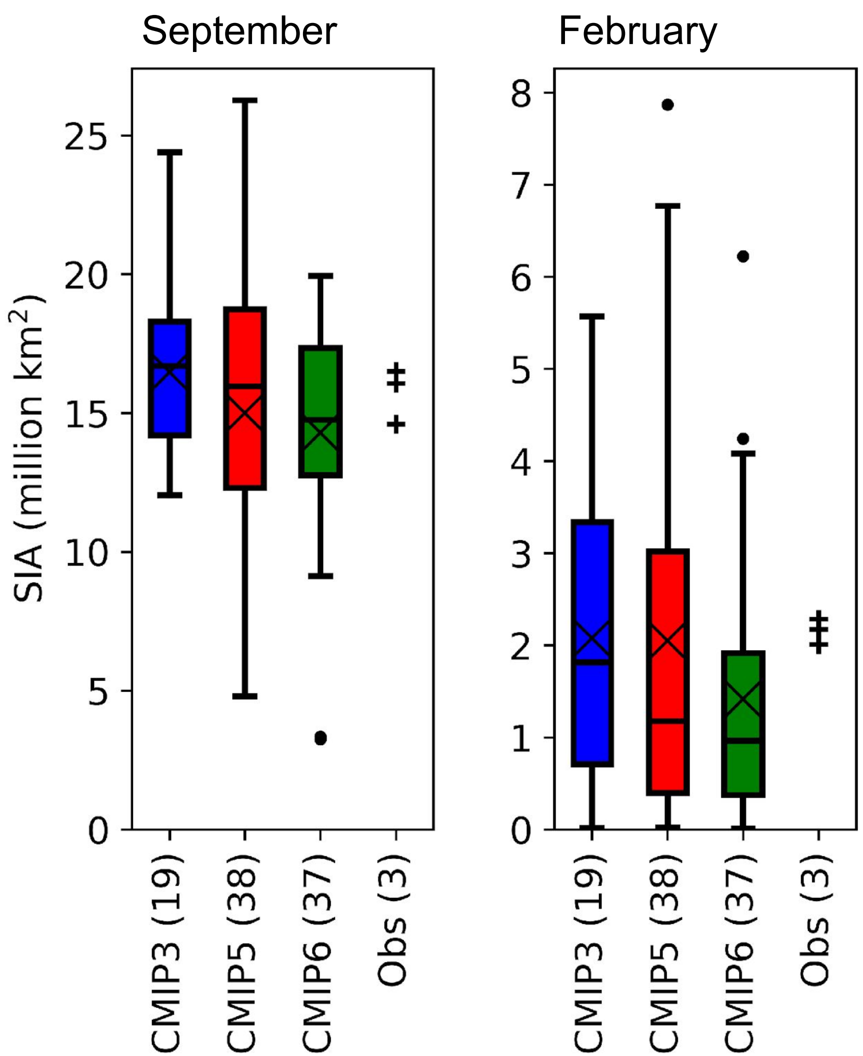
Sea ice area

Internal variability: two standard deviations across

- Ensemble members, if more than four available
- Pre-industrial control otherwise



1979-2014

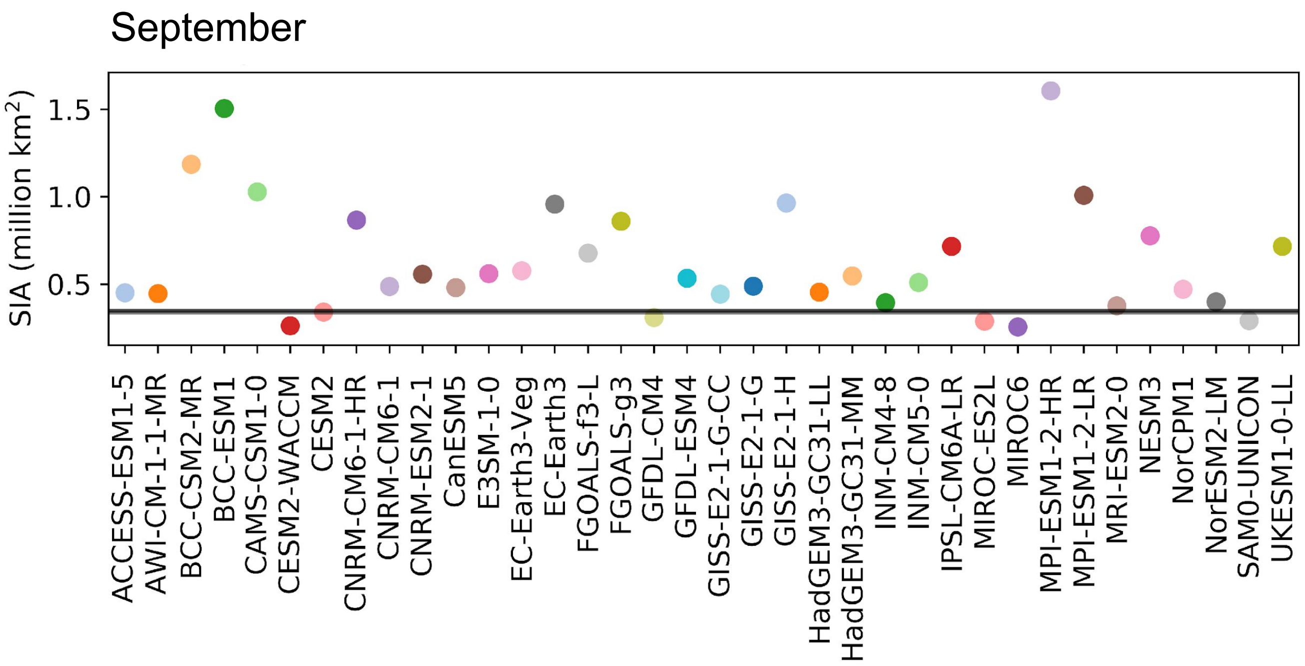


- Reduced inter-model spread
- Broad consistency in September
- Consistent underestimation in February

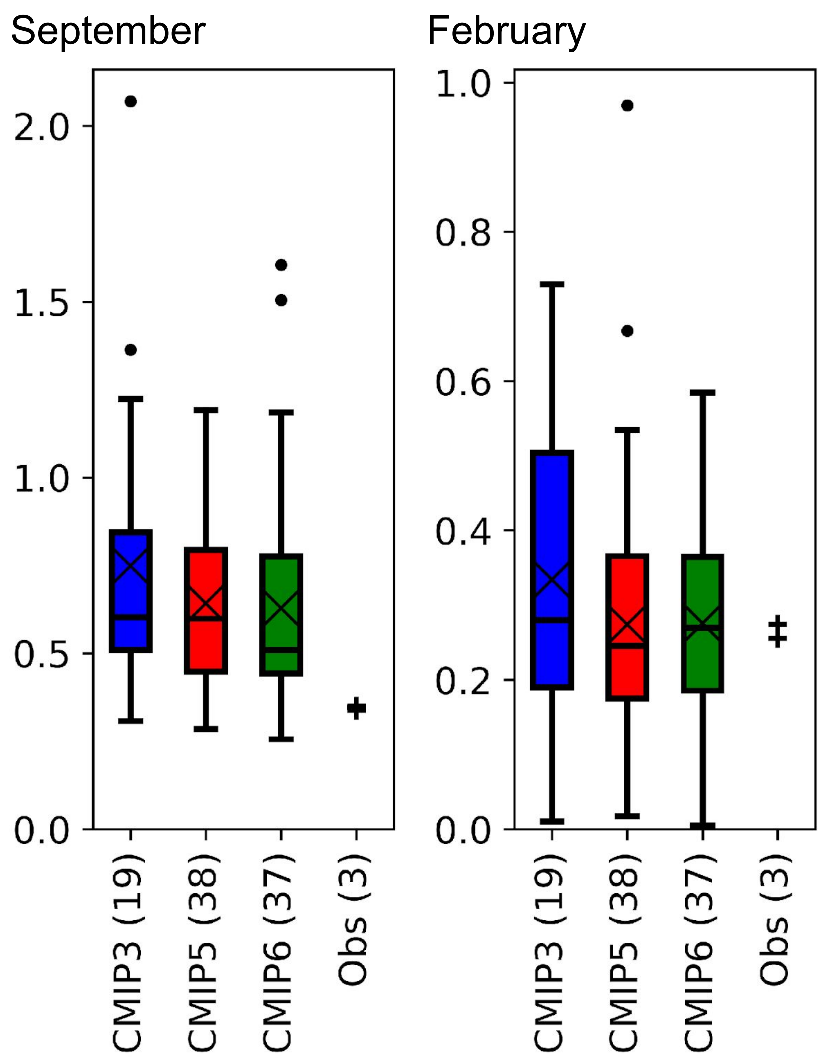
Sea ice area interannual variability

1979-2014

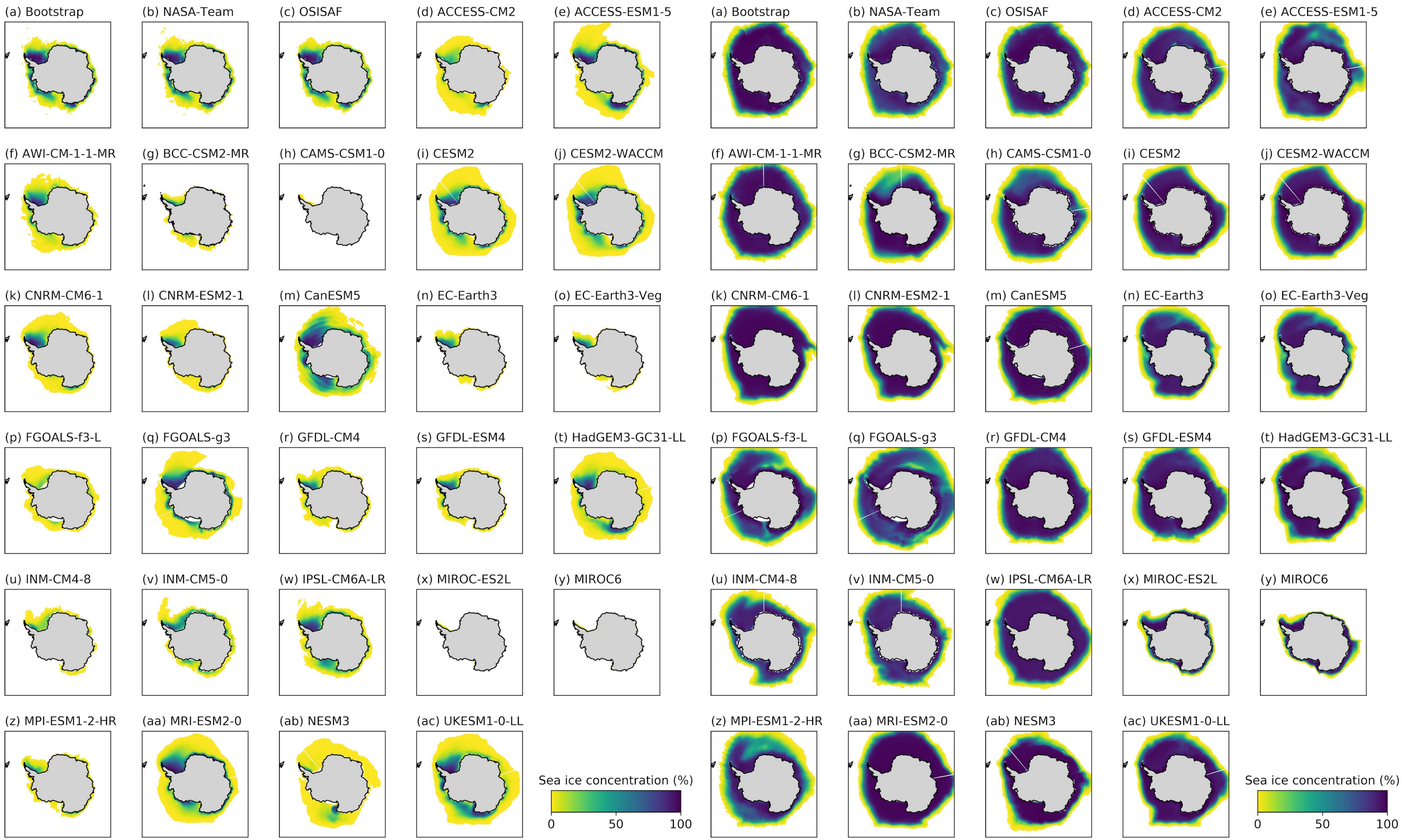
Inter-annual variability: standard deviation of detrended time series



1979-2014



- Overestimation of winter sea ice area variability
- But, addition of 2015-2018 increases observed variability


(a) Bootstrap
(b) NASA-Team
(c) OSISAF
(d) ACCESS-CM2
(e) ACCESS-ESM1-5
(f) AWI-CM-1-1-MR
(g) BCC-CSM2-MR
(h) CAMS-CSM1-0
(i) CESM2
(j) CESM2-WACCM
(k) CNRM-CM6-1
(l) CNRM-ESM2-1
(m) CanESM5
(n) EC-Earth3
(o) EC-Earth3-Veg
(p) FGOALS-f3-L
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(w) IPSL-CM6A-LR
(x) MIROC-ES2L
(y) MIROC6
(z) MPI-ESM1-2-HR
(aa) MRI-ESM2-0
(ab) NESM3
(ac) UKESM1-0-LL
Sea ice concentration (%)
0
50
100

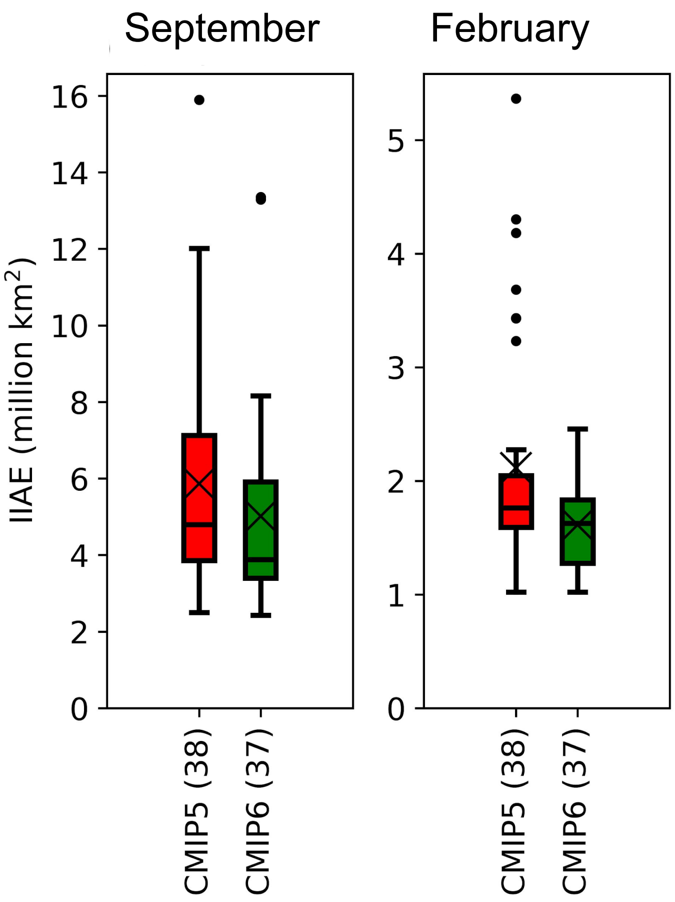
1979-2014

Integrated ice area error

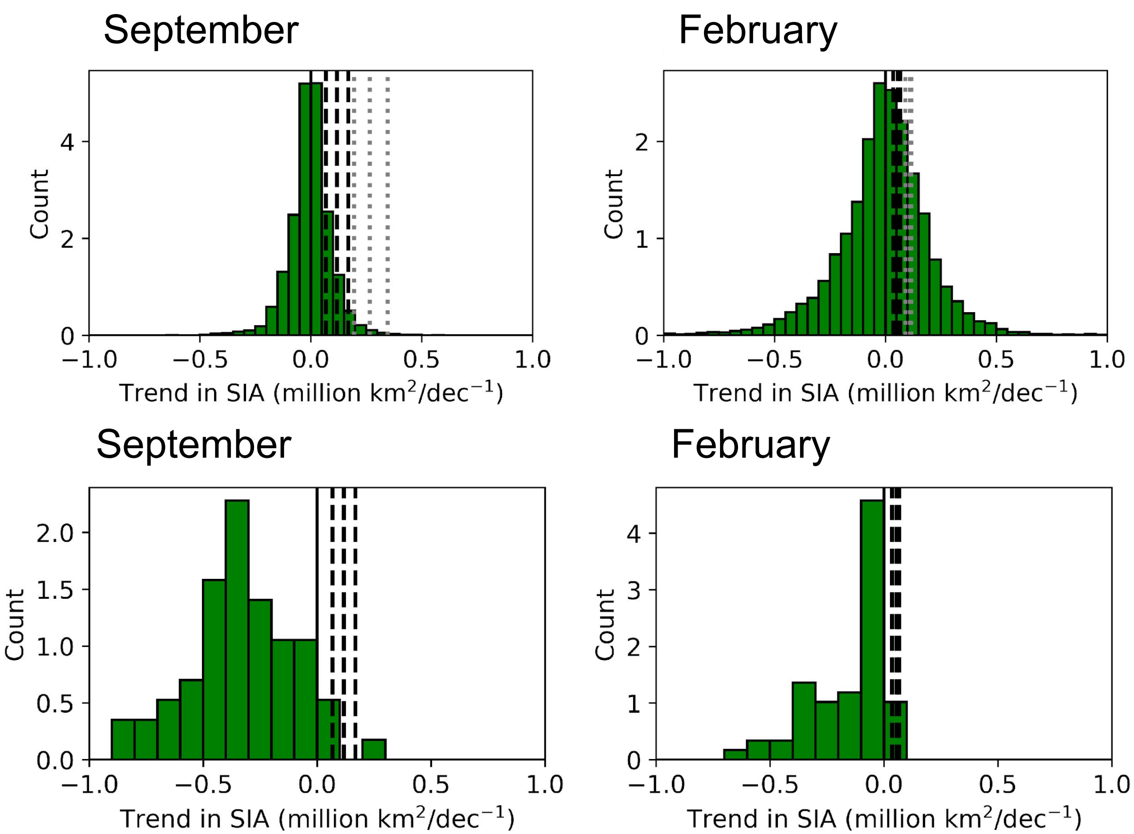
$$\mathrm{IIAE} = O + U,$$

$$O = \int_A \max(c_m - c_o, 0)\mathrm{d}A$$

$$U = \int_A \max(c_o - c_m, 0)\mathrm{d}A,$$



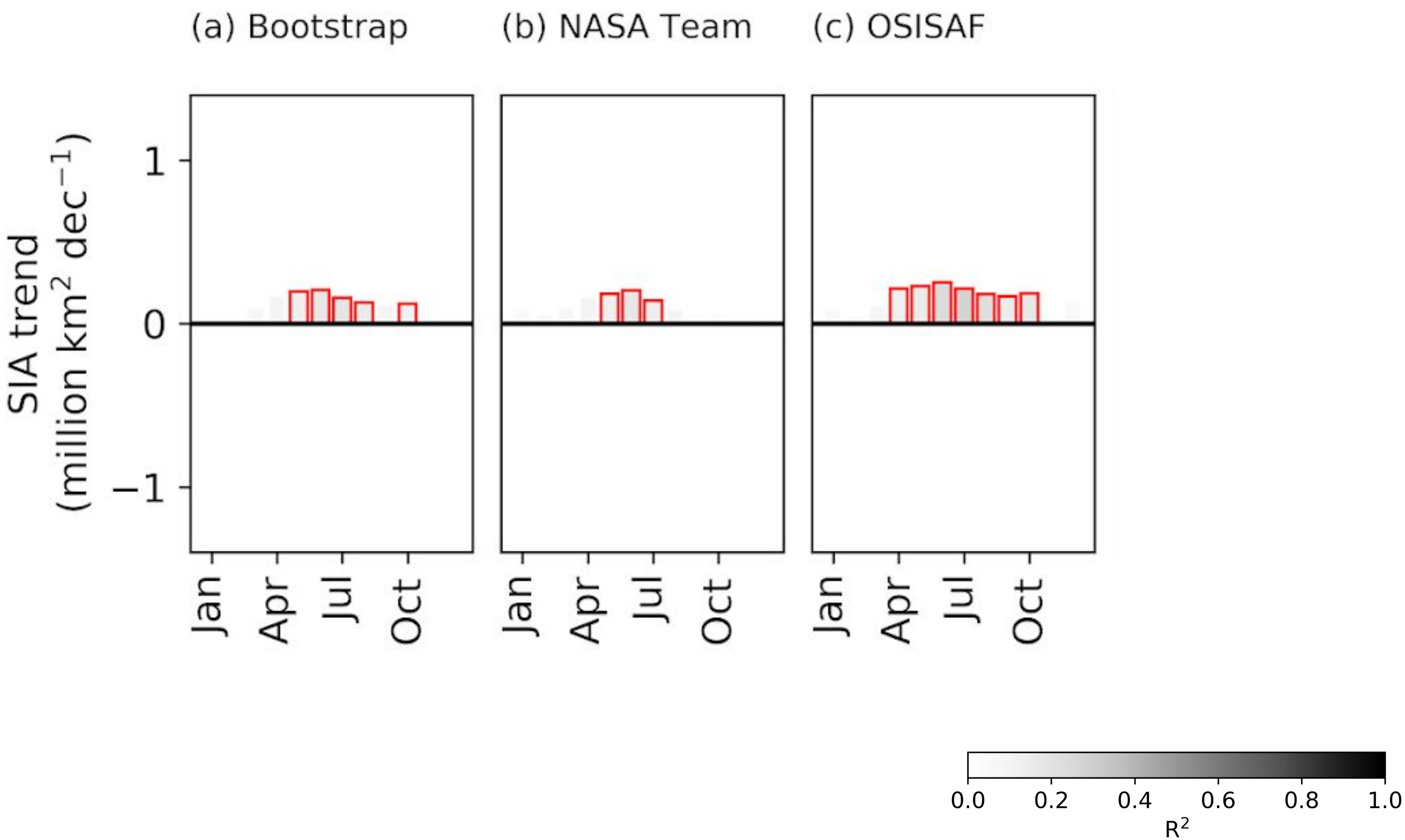
Sea ice area trends



Pre-industrial control

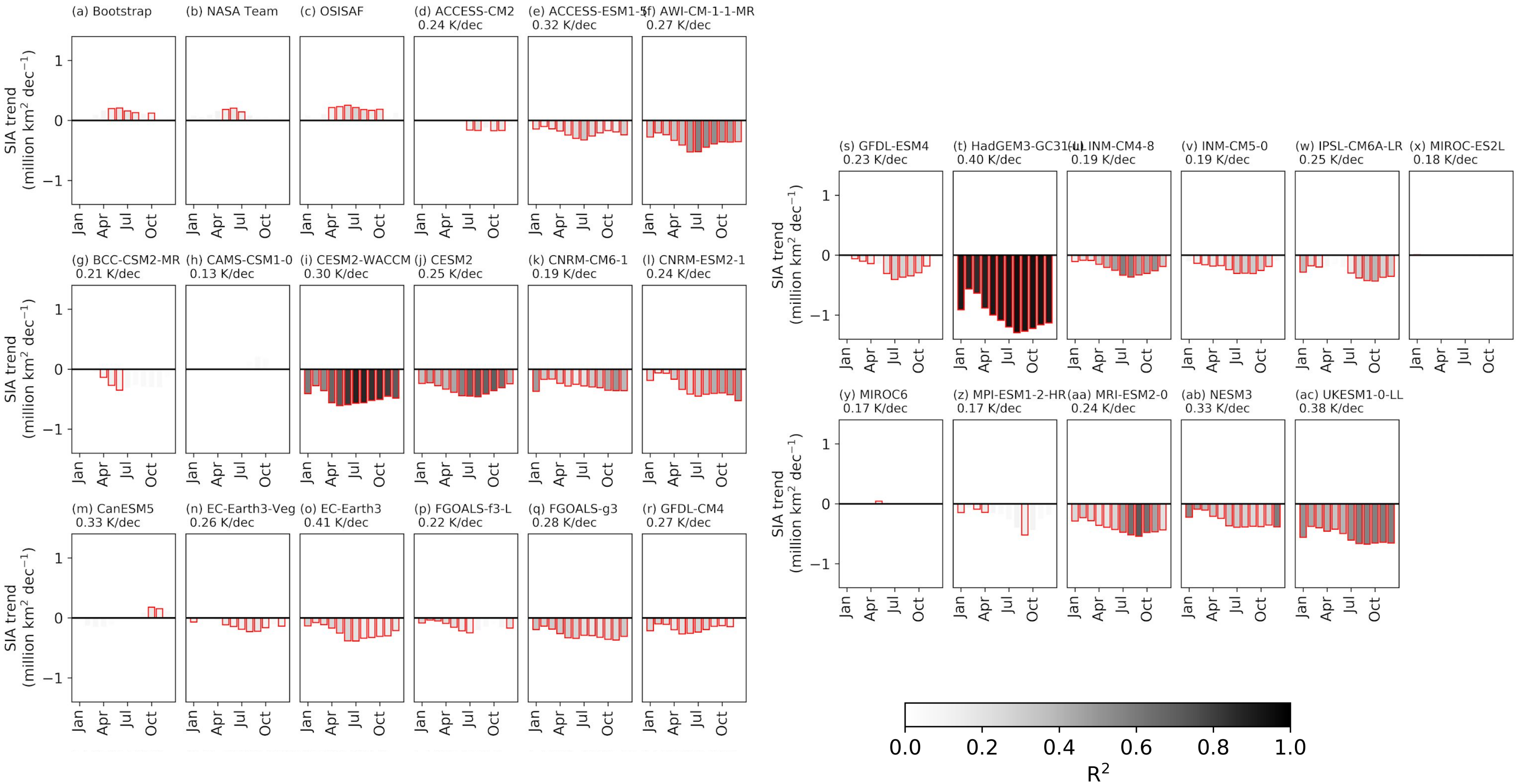
Historical + SSP2-4.5

1979-2018



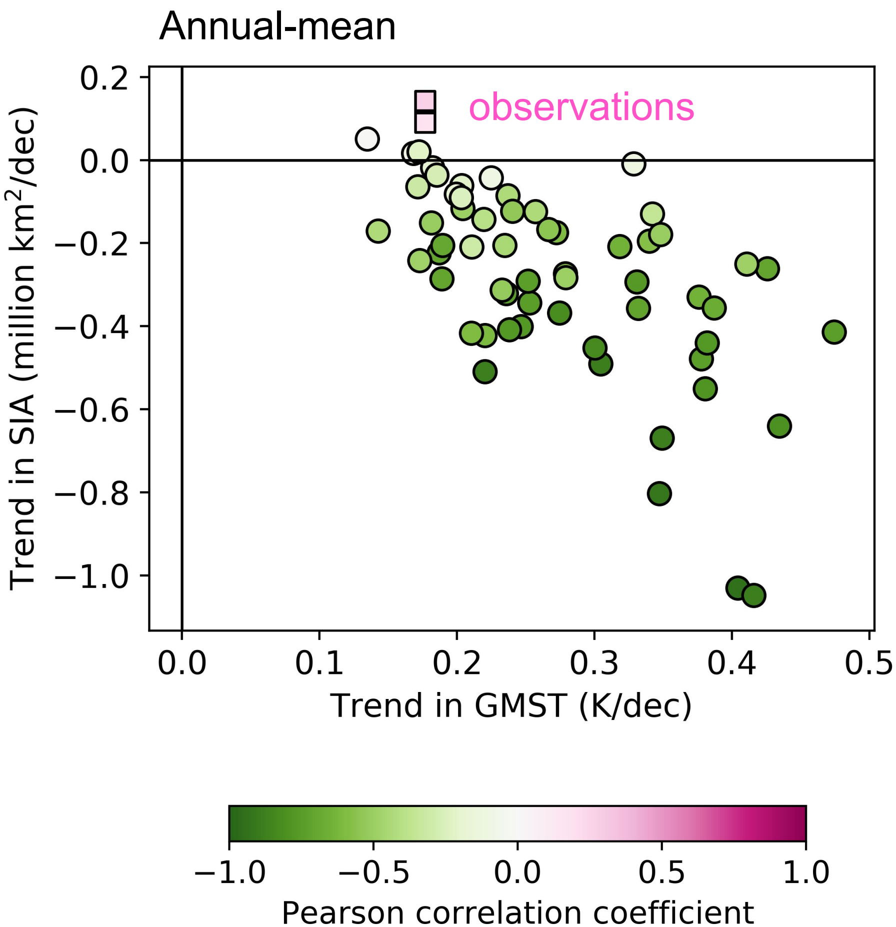
(a) Bootstrap
(b) NASA Team
(c) OSISAF
SIA trend
(million km^2 dec^{-1})
1
0
−1
Jan
Apr
Jul
Oct
0.0
0.2
0.4
0.6
0.8
1.0
R^2

1979-2018



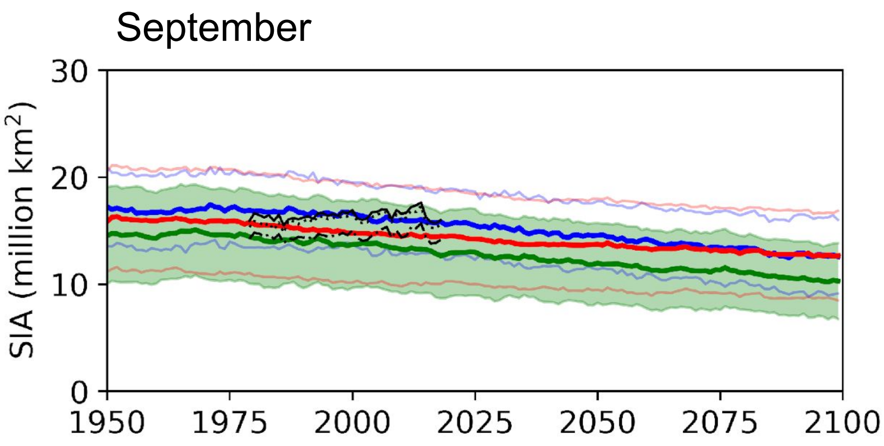
(a) Bootstrap
(b) NASA Team
(c) OSISAF
(d) ACCESS-CM2 0.24 K/dec
(e) ACCESS-ESM1-5 0.32 K/dec
(f) AWI-CM-1-1-MR 0.27 K/dec
(g) BCC-CSM2-MR 0.21 K/dec
(h) CAMS-CSM1-0 0.13 K/dec
(i) CESM2-WACCM 0.30 K/dec
(j) CESM2 0.25 K/dec
(k) CNRM-CM6-1 0.19 K/dec
(l) CNRM-ESM2-1 0.24 K/dec
(m) CanESM5 0.33 K/dec
(n) EC-Earth3-Veg 0.26 K/dec
(o) EC-Earth3 0.41 K/dec
(p) FGOALS-f3-L 0.22 K/dec
(q) FGOALS-g3 0.28 K/dec
(r) GFDL-CM4 0.27 K/dec
(s) GFDL-ESM4 0.23 K/dec
(t) HadGEM3-GC31-LL 0.40 K/dec
(u) INM-CM4-8 0.19 K/dec
(v) INM-CM5-0 0.19 K/dec
(w) IPSL-CM6A-LR 0.25 K/dec
(x) MIROC-ES2L 0.18 K/dec
(y) MIROC6 0.17 K/dec
(z) MPI-ESM1-2-HR 0.17 K/dec
(aa) MRI-ESM2-0 0.24 K/dec
(ab) NESM3 0.33 K/dec
(ac) UKESM1-0-LL 0.38 K/dec
SIA trend (million km^2 dec^{-1})
Jan Apr Jul Oct
R^2
0.0 0.2 0.4 0.6 0.8 1.0

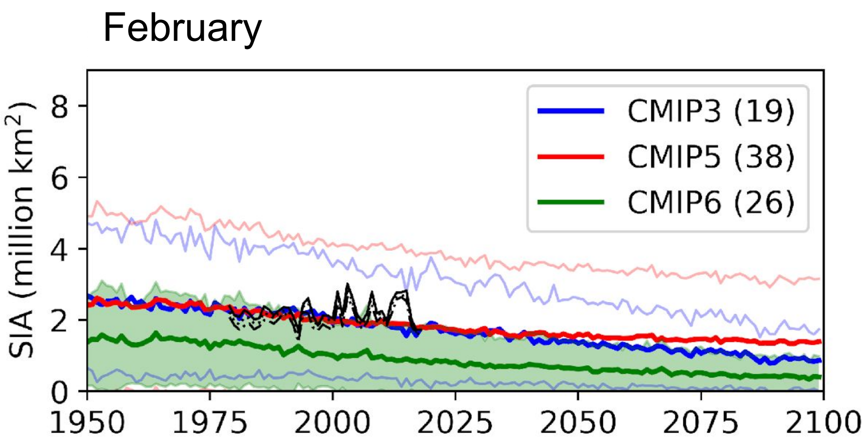
1979-2018



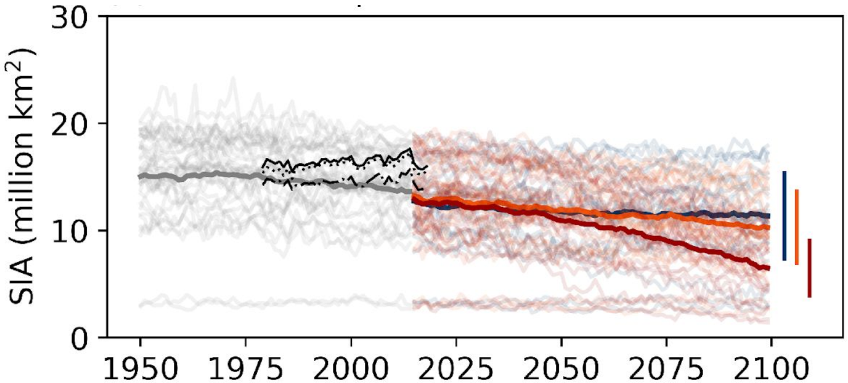
- Sea ice area trend mis-match relates in large part to model climate sensitivity, rather than processes specific to the polar regions

Midrange scenarios

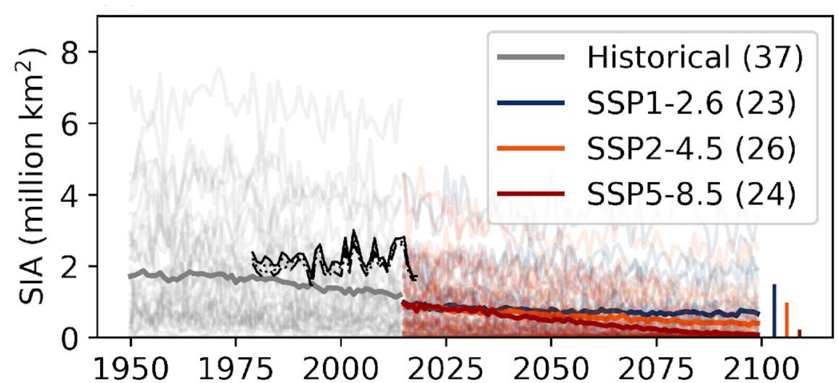




September



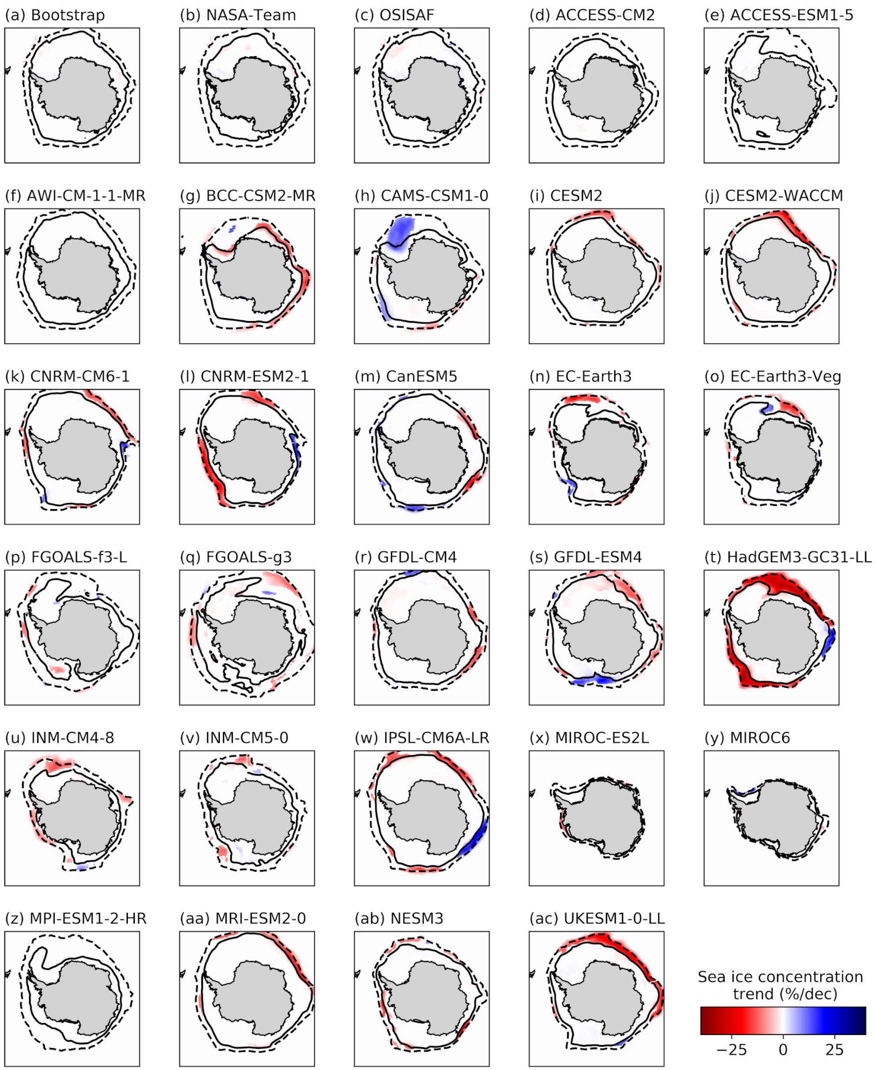
February



- September: sea ice area loss of 17% in SSP1-2.6 and 50% in SSP5-8.5
- February: sea ice area loss of 37% in SSP1-2.6 and 90% in SSP5-8.5

Summary

- Modest improvements compared to CMIP5: regional distribution of sea ice improved, inter-model spread in mean sea ice quantities has decreased
- Less of a discrepancy between models and observations than previously identified due to the extended observational record
- Underestimation of summer sea ice and overestimation of winter sea ice inter-annual variability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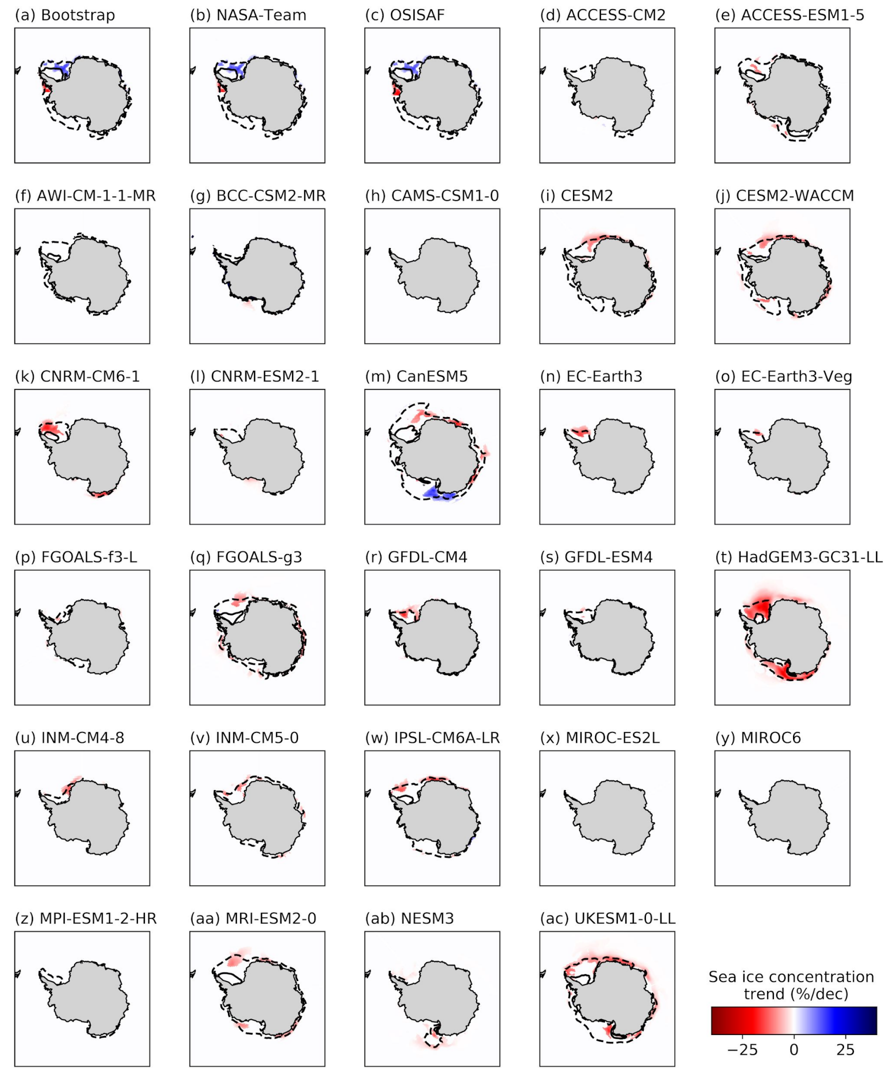
(y) MIROC6
(z) MPI-ESM1-2-HR
(aa) MRI-ESM2-0
(ab) NESM3
(ac) UKESM1-0-LL
Sea ice concentration trend (%/dec)
−25
0
25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Sea ice concentration trend (%/dec)
−25
0
25