Does CMIP6 better constrain projections of 21st century Antarctic sea ice loss?

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Navigation and Overview

Navigation

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Overview

Climate models simulate a wide range of historical climatologies of Antarctic sea ice area, and a wide range of future changes. This, and their inability to simulate recent change, mean that projections of Antarctic sea ice are very uncertain.

Here we investigate historical climatology as an emergent constraint on future sea ice change (building on e.g. Bracegirdle et al (2015))

We identify seasonal differences in the variance explained by historical climatology, and identify global mean temperature change as an important driver of differences between models and between model generations.

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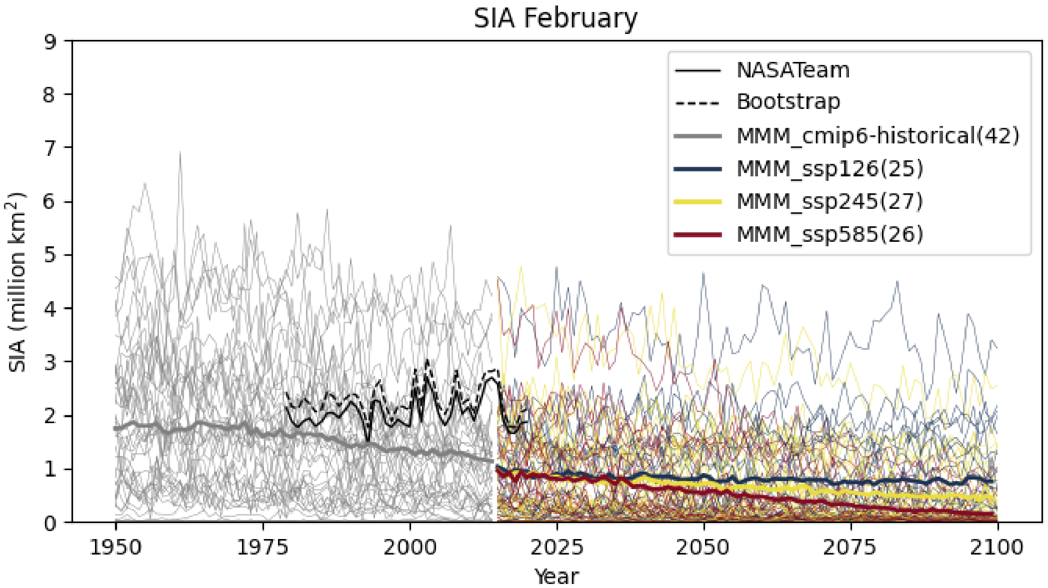
First look: timeseries (CMIP6 only)



The CMIP6 multi-model ensemble displays a wide range of biases in the historical period.

It also simulates a historical decline in sea ice area, while the observations (black and black dashed) do not.

For the future, low-forcing scenarios simulate little ice loss, while high forcing scenarios simulate a reduction to near-zero in the multi model mean.

See also: Roach et al (2020)

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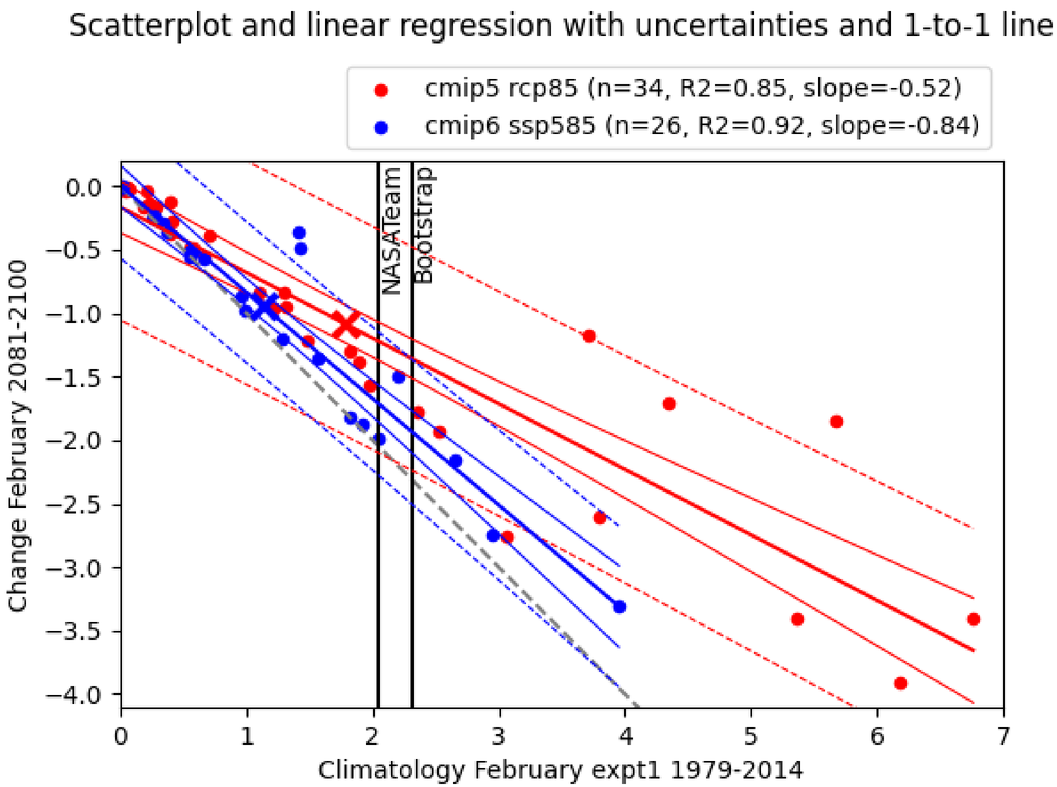
Summer continued

Summer (February)



For both ensembles, the historical climatology of sea ice area (x axis) provides a very strong linear constraint on the projection of sea ice area loss (y axis) under a strong forcing scenario.

For CMIP6, the slope is almost 1-to-1; models lose the majority of their ice.

To use an emergent constraint we need to understand the physical basis: here, this is simply 'a model can only lose as much ice as it has to being with'.

The correlation is weaker in CMIP5, but is skewed by models with large historical biases.

Key: ✖ *multi-model means*
● *individual models (info)*

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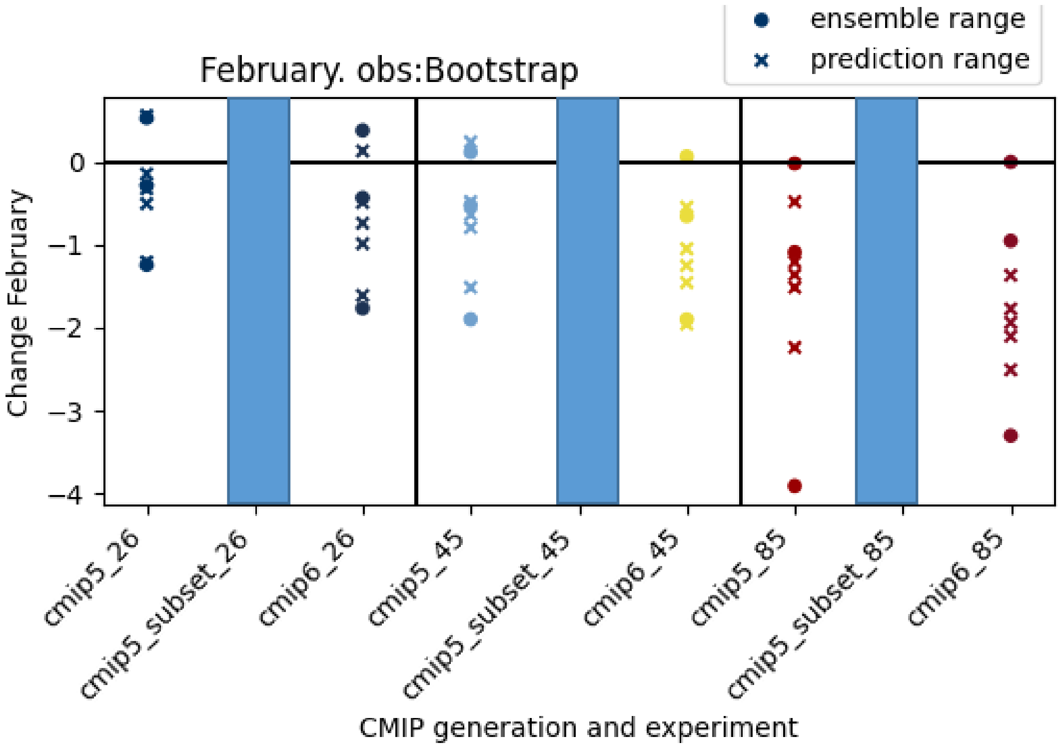
[Summer (continued)](#)

Summer: Implications of Constraint



Multi-model ensemble raw output (dot markers):

near-zero or positive change happens for at least one model for all forcing scenarios

CMIP6 and CMIP5 mean change are similar

Constrained output (cross markers show mean, 5-95% ci and 5-95% pi):
CMIP6 projected change is significantly stronger

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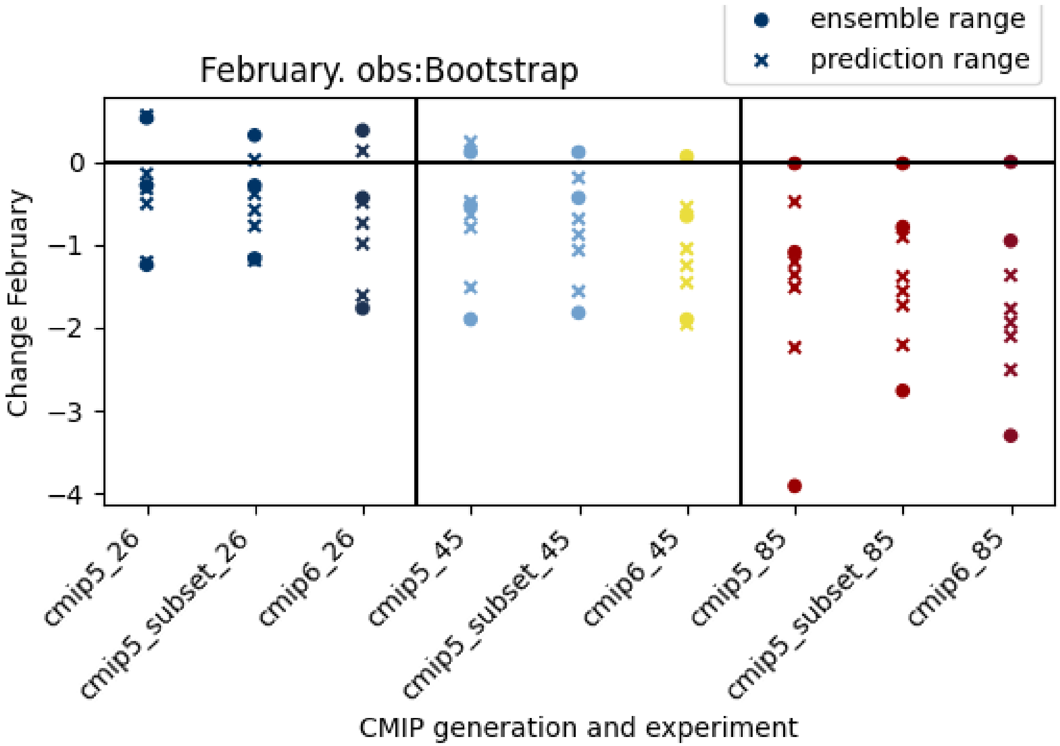
Summer: subsetting CMIP5



Central column of each scenario displays results for CMIP5 using models in the historical range of CMIP6 only

For emergent constraint results, closer to CMIP6

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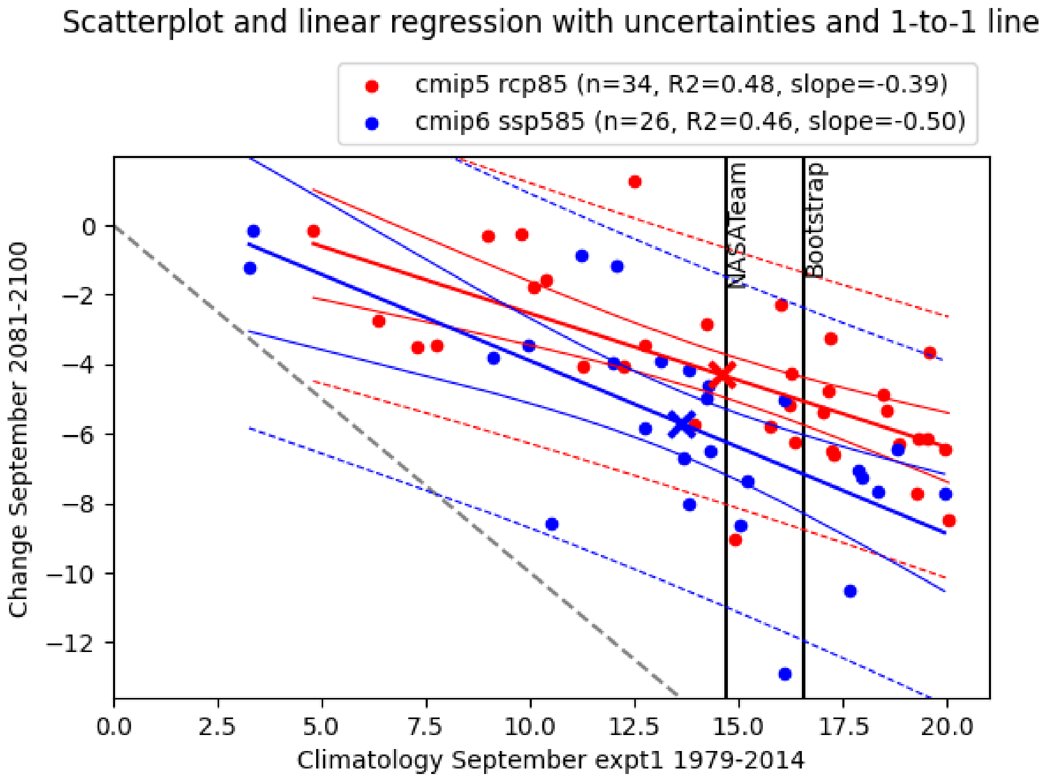
Winter continued

Winter (September)



(Red and blue dashed lines in the left hand plot show 5-95% prediction interval;
Red and blue solid lines show 5-95% confidence interval)

There is a statistically significant, but weaker, relationship.

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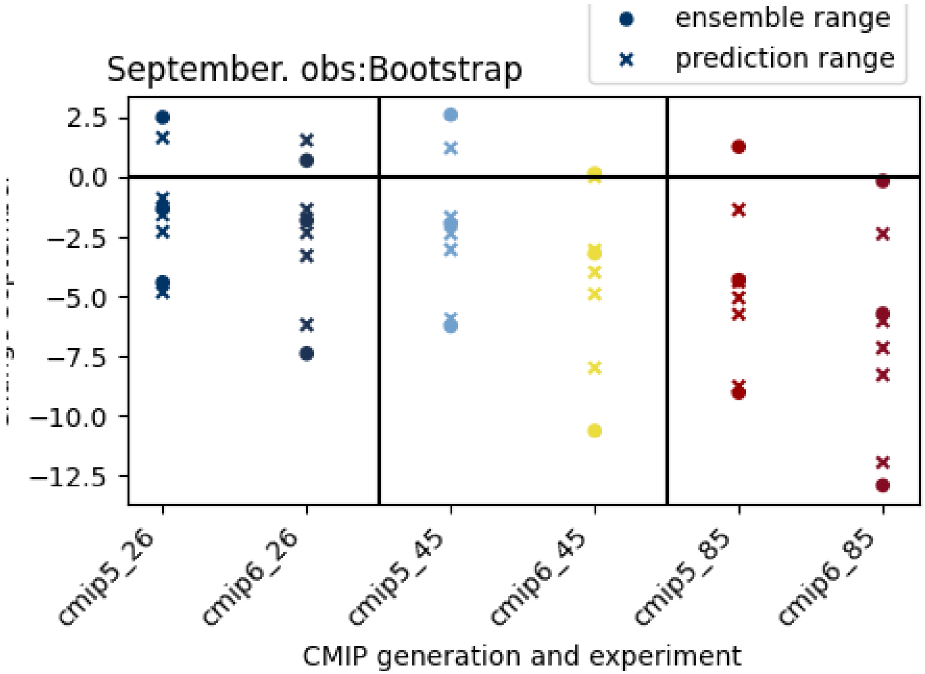
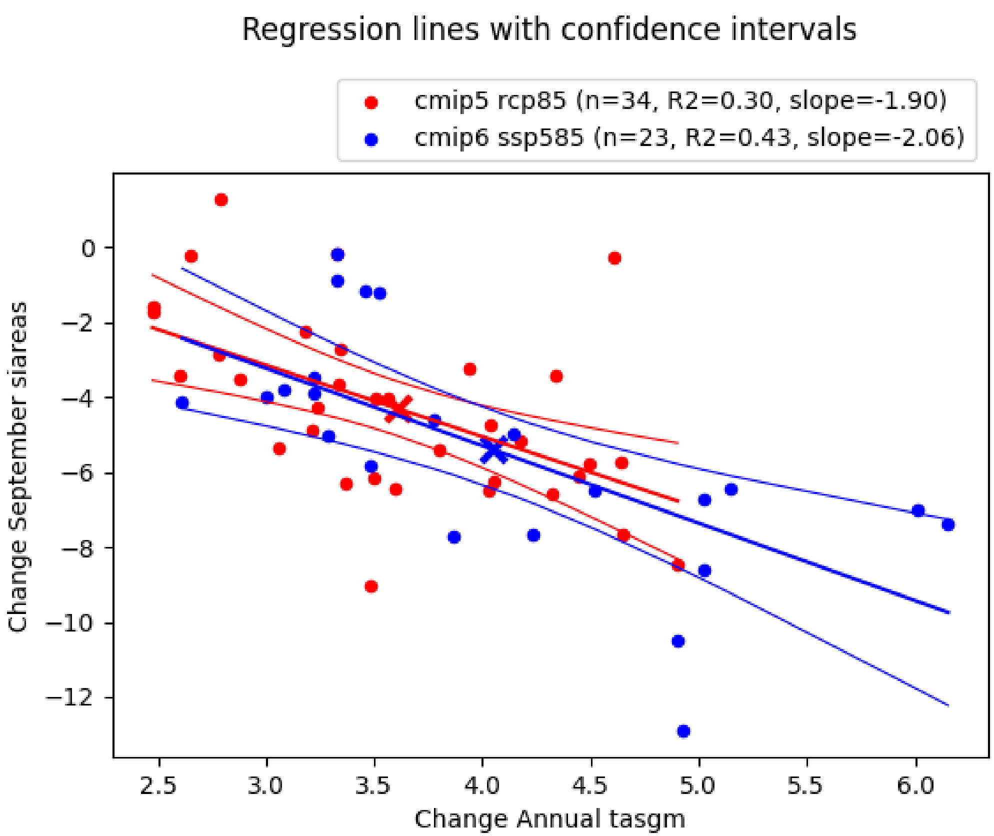
Winter (continued)

Winter: implications of constraint



For strong forcing scenario, sea ice area loss is projected to be greater than projected by the ensemble.

Winter: Link to Temperature Change



In both ensembles there is a relationship between global mean temperature change (x-axis) and sea ice area loss (y-axis)

This relationship is indistinguishable between the ensembles.

So the greater sea ice area loss in CMIP6, which we saw as offset in the regression against climatology, is related to greater warming

Links to ECS

Global mean surface temperature change C21 is correlated ($r>0.9$) with ECS in CMIP5 and CMIP6 strong forcing scenarios, so these results relate the fate of Antarctic sea ice to the realism of high ECS in CMIP6.

e.g. Zelinka et al (2020) ‘Causes of Higher Climate Sensitivity in CMIP6 Models’ and Zhu et al (2020): ECS in CESM2

Antarctic sea ice in climate models may also be too sensitive to global mean temperature: e.g. Roach et al (2020) “Antarctic Sea Ice Area in CMIP6" Figure 3; and Schneider, D.P. and Deser, C., (2018) “Tropically driven and externally forced patterns of Antarctic sea ice change: Reconciling observed and modeled trends"

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So: does CMIP6 better constrain projections of 21st century Antarctic sea ice area?

1- The absence of summer high-biased models in CMIP6 leads to a narrower band of projections for 21^{st} century summer sea ice area which is further constrained by regression against climatology

2- When models of similar historical climatology are compared, CMIP6 models lose more ice than those in CMIP5 in both summer and winter.

3- For winter, this appears to be related to greater global mean temperature change in CMIP6. The sensitivity of sea ice to that warming does not appear to change between generations. So:

- Is the increased global mean warming in CMIP6 realistic?
- Is the sensitivity of modelled to sea ice to global temperature realistic?
    - Answer to both may be ‘no’ (previous slide)

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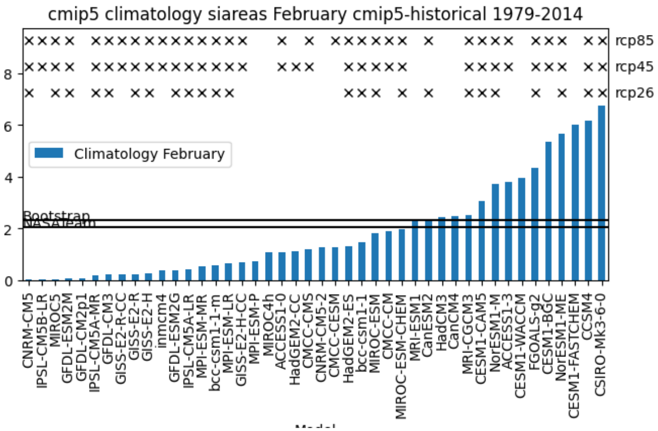
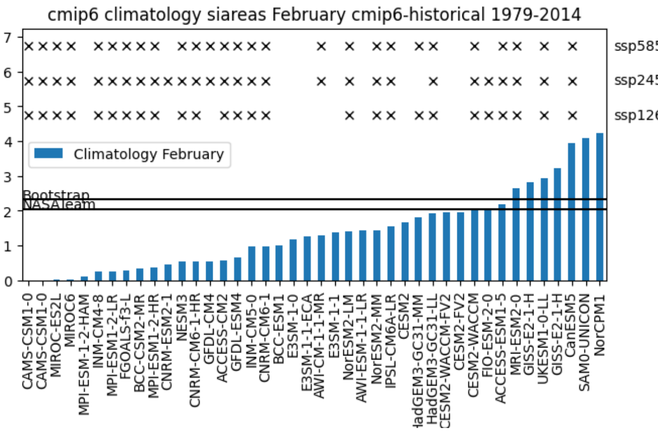
Model Identification

1979-2014 climatology

CMIP5 February

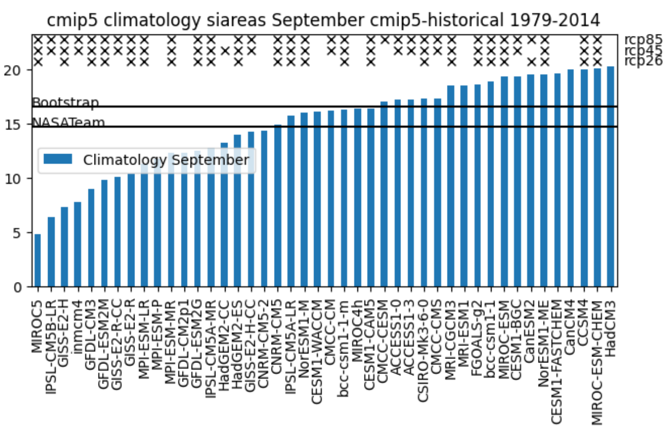


CMIP6 February

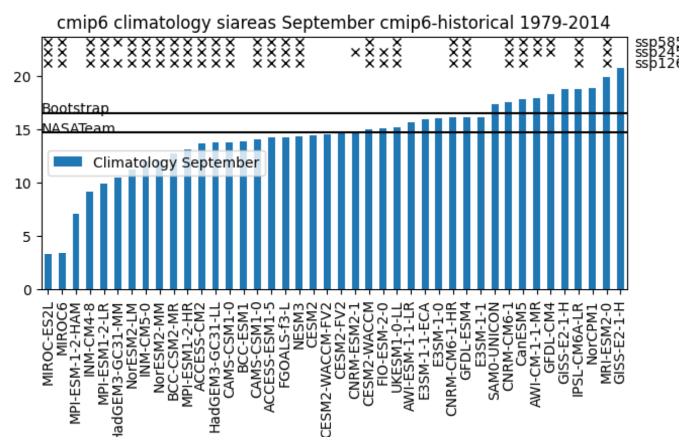


Crosses indicate availability of C21 scenario simulations

CMIP5 September



CMIP6 September



Note: a comprehensive evaluation of CMIP6 sea ice appears in Roach et al (2020); these figures use a different subset