How does internal variability influence the ability of CMIP5 models to reproduce the recent trend in Southern Ocean sea ice extent?

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Background

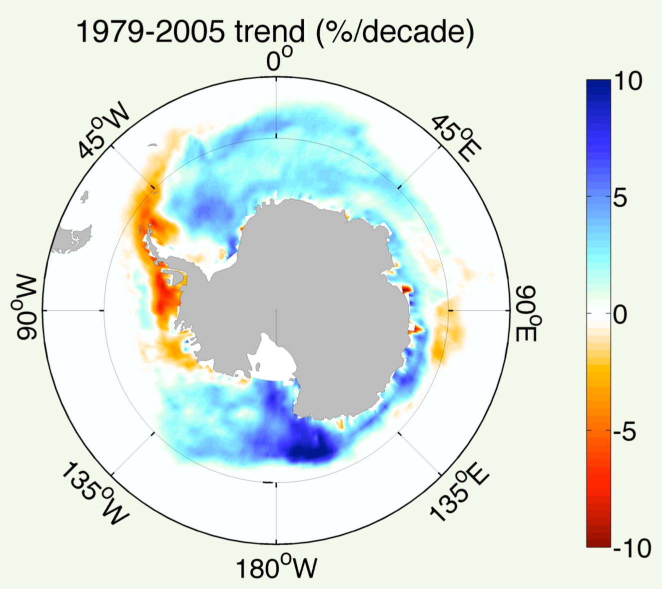


Fig. 1: Trend in observed sea ice concentration from NSIDC (Comiso, 2012)

1979-2005 sea ice extent trend: positive and statistically significant at the 95% level.

- Possible causes of the recent expansion of Southern Ocean sea ice have not been fully identified yet.
- Current GCMs are generally unable to reproduce the observed trend.

Objectives of this study

To test 2 possible explanations for the misrepresentation of the positive trend in sea ice extent by climate models:

- an unrealistic internal variability
- an inadequate initialization of the system

through the analysis of CMIP5 simulations.

Take home message

According to model results, is the trend of observed sea ice extent compatible with a combination of the forced response and the internal variability?

- Most of the CMIP5 historical simulations respond to the forcing, including the one due to stratospheric ozone depletion, by decreasing their sea ice in the Southern Ocean (Fig. 4).
- Some models can provide a large range of trends that encompasses the observed positive trend (Fig. 4), suggesting that this latter can arise from internal variability.

Does the models' internal variability agree with the one of the observations?

- Most of the models overestimate the interannual variability of sea ice extent (Fig. 3b and 4b). This bias prevents us from firmly assessing the link between the internal variability and the increase in sea ice extent.

How does the initialization method impact the simulated trend in sea ice extent?

- No clear improvement arising from the initialization through current data assimilation methods (Fig. 5).

1. Strategy

CMIP5: Coupled Model Intercomparison Project, phase 5 (Taylor et al., 2011).

CMIP5 models outputs

Historical simulations

- ensemble simulations of varying size;
- driven by external forcing;
- initialised without observational constraints;
- used to study models mean state and variability.

24 models

Hindcast simulations

- ensemble simulations of varying size;
- driven by external forcing;
- initialized through data assimilation (mainly nudging) of observations;
- used to assess the impact of the initialization on the predictive skill.

10 models

2. Historical sea ice concentration

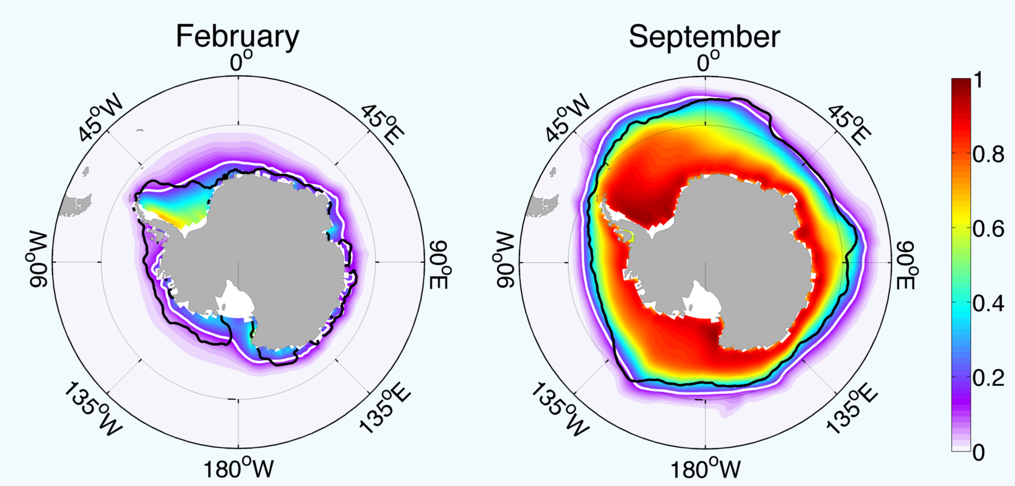


Fig. 2: 1979-2005 Multi-model mean sea ice concentration. Figure from Zunz et al. (2013).

Concentration is an average computed over 24 models historical simulations. White (black) line refers to the sea ice edge, i.e. the 15% concentration limit of the models ensemble mean (observations, Comiso, 2012).

- Good agreement between the muli-model mean and the observed sea ice edge.

3. Historical sea ice extent mean state and variability

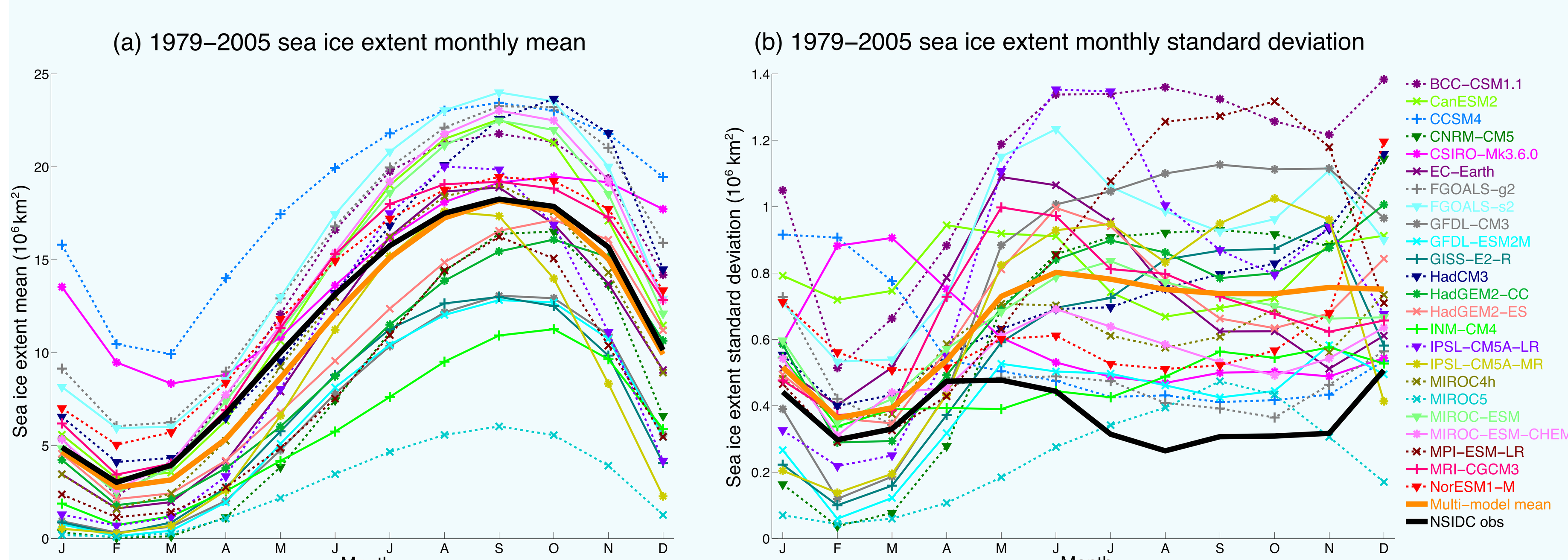


Fig. 3: Colors correspond to the ensemble mean of historical simulations from the 24 models. Dotted lines refer to models that provide both historical and hindcast simulations but here, results are only from historical simulations. Figure from Zunz et al. (2013).

- The seasonal cycle of the multi-model mean fits the one of the observations (Figure 3a).
- The modeled sea ice extent is strongly scattered around the observations (Fig. 3a).
- Some models are nearly sea-ice free during summer (Fig. 3a).
- The interannual variability differs from one model to the other (Fig. 3b).
- All the models overestimate winter sea ice variability (Fig. 3b).
- Most models have a stronger variability in winter than in summer, resulting in a biased seasonal cycle of the standard deviation (Fig. 3b).

4. Historical sea ice extent trend VS. mean and standard deviation

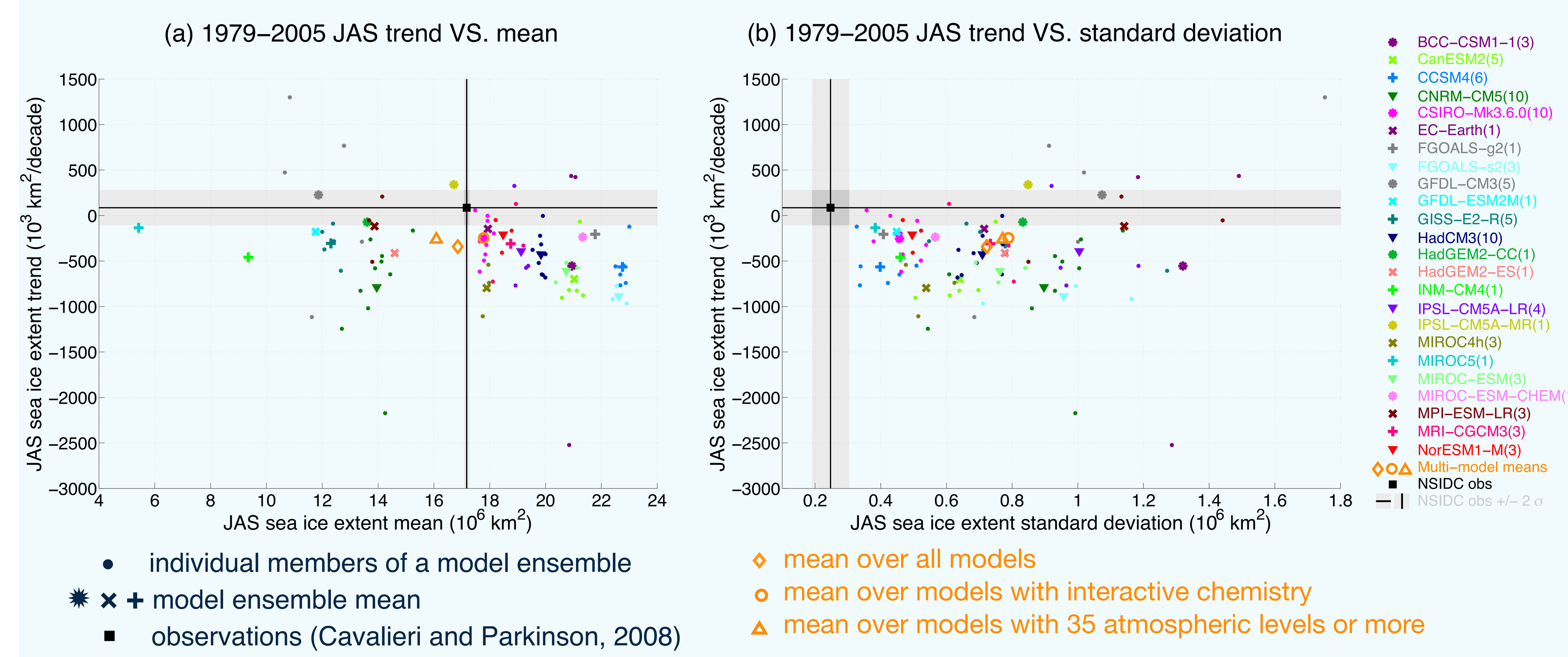
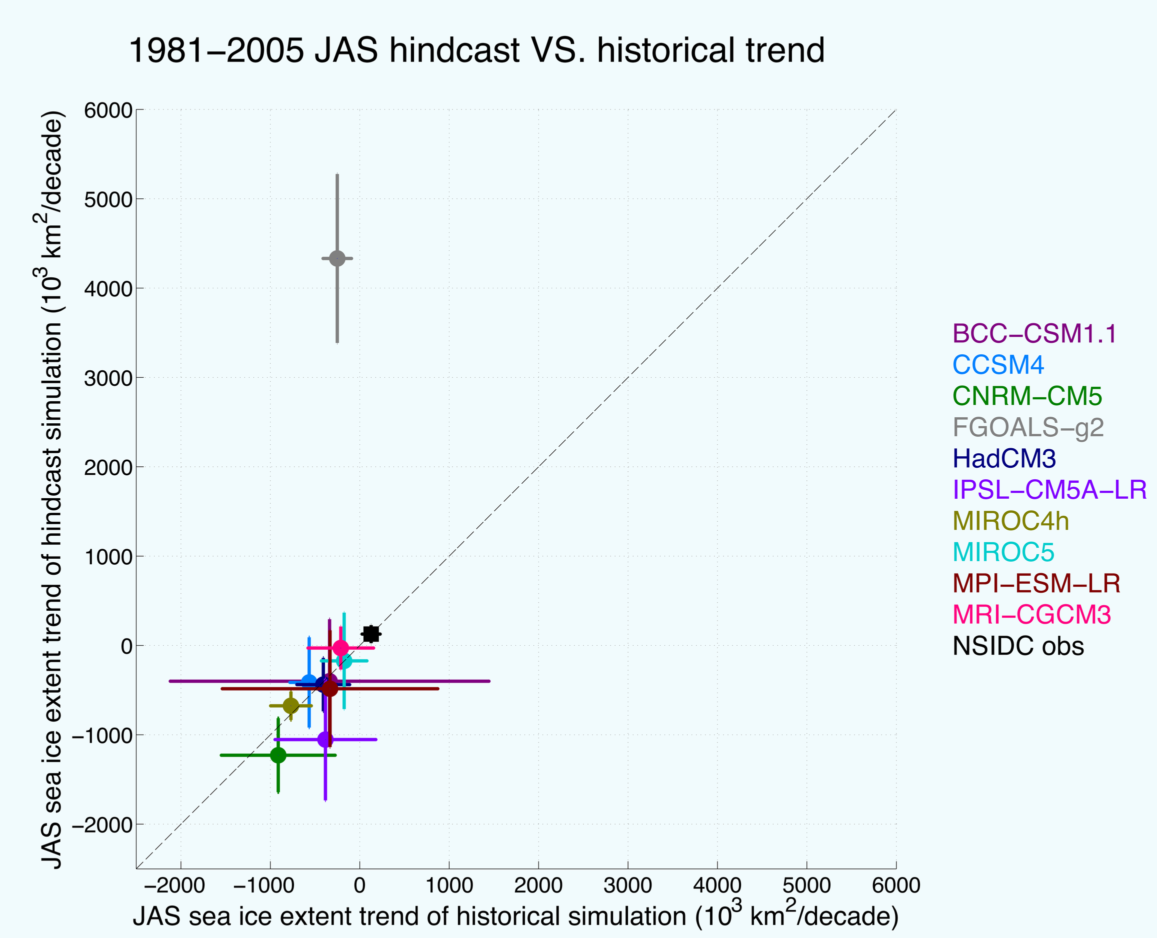


Fig. 4: Colors refer to the 24 models. The number of members in each model is indicated in brackets. Figure from Zunz et al. (2013).

- Almost all of the simulations display a negative trend.
- The trend may strongly differ between members of the same model ensemble.
- Simulations displaying a trend close to the observed one have generally a much larger standard deviation than the one of the observations (Fig. 4b).
- Higher atmospheric resolution and interactive chemistry do not have major impact on the simulated trends.

5. Hindcast VS. historical sea ice extent trend



←**Fig. 5:** Horizontal (vertical) bars show the standard deviation of the trend of the historical (hindcast) simulations. Dashed line represents the line *y(x)=x*. Figure from Zunz et al. (2013)

- MIROC4h, MIROC5 and MRI-CGCM3 have a hindcast trend slightly closer to the observation than are their historical trend.
- The 7 other models have a hindcast trend not better or even worse than their historical trend.
- The initialization with data assimilation sometimes triggers model's drift, resulting in a strong artificial positive or negative trend.

6. Ongoing work

Systematic tests of more sophisticated initialization methods with an Earth-system model of intermediate complexity (see poster Z286 in session CL3.2/NH1.12/NP5.3 on Wednesday).

References

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