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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1. Background

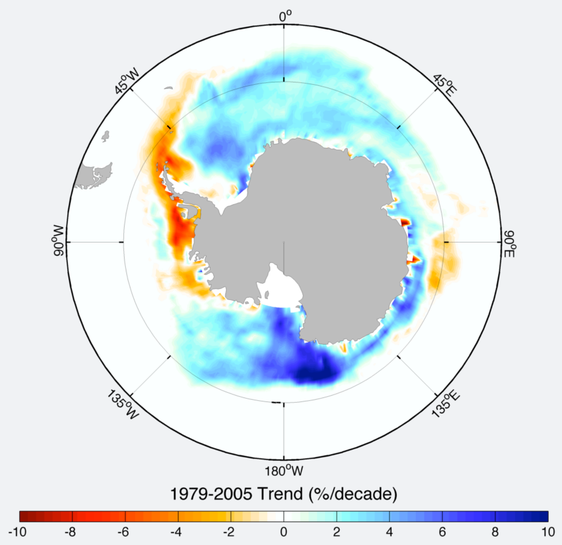

FIG. 1: Trend of observed sea ice concentration from NSIDC (Comiso, 2008)

- 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.

2. Objectives

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.

3. Strategy

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

CMIP5 models outputs

Historical simulations	Hindcast simulations
• ensemble simulations of varying size; • driven by external forcing; • initialised without observational constraints; • used to study models mean state and variability.	• ensemble simulations of varying size; • driven by external forcing; • initialised through data assimilation (mainly nudging) of observations; • used to assess the impact of the initialisation on the predictive skill.
24 models	**10 models**

4. Historical sea ice concentration

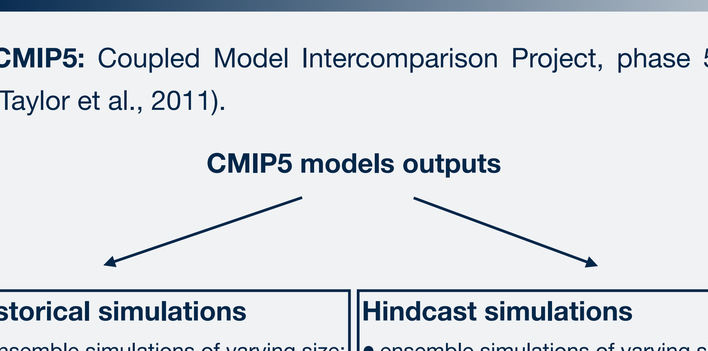

FIG. 2: 1979-2005 Multi-model mean sea ice concentration

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, 2008).

5. Historical sea ice extent mean state and variability

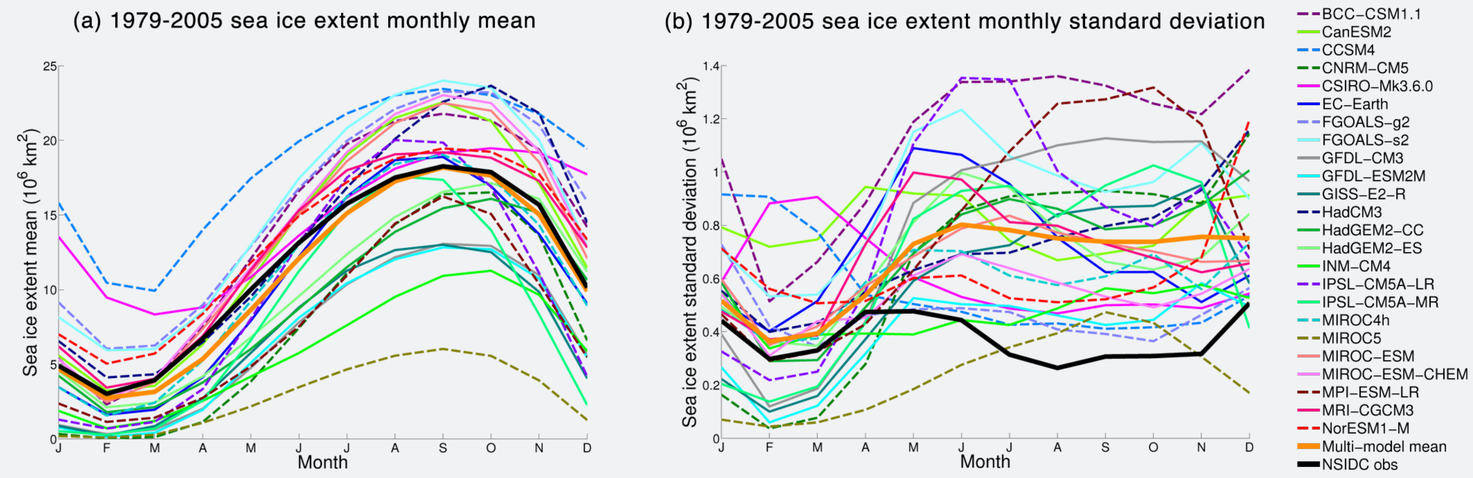

FIG. 3: Colors correspond to the ensemble mean of historical simulations from the 24 models. Dashed lines refer to models that provide both historical and hindcast simulations but here, results are only from historical simulations.

- 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).

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

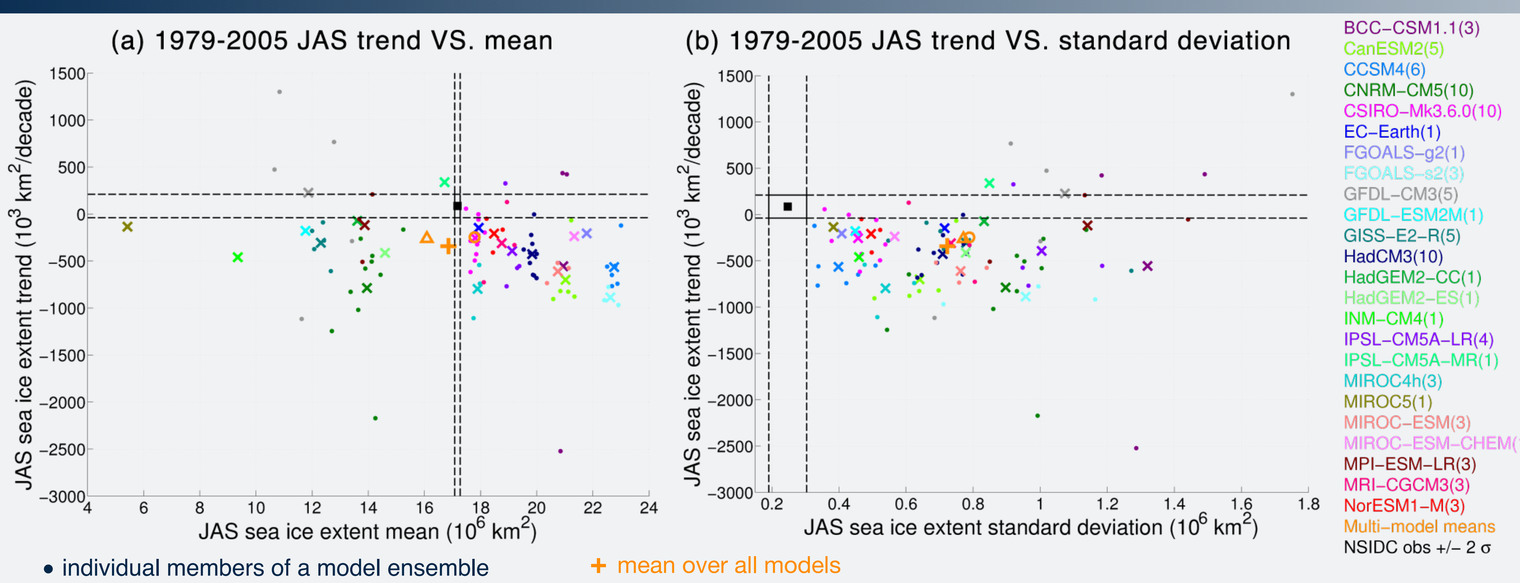

FIG. 4: Colors refer to the 24 models. The number of members in each model is indicated in brackets.

- 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.

7. 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*.

- 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 initialisation with data assimilation sometimes trigger model drift, resulting in a strong artificial positive or negative trend.

8. Summary and perspectives

- The multi-model mean fits well the observation of summer/winter ice edge (Fig. 2) and of the annual cycle of sea ice extent (Fig. 3a).
- Large spread of the seasonal cycle of individual models (Fig. 3a).
- Overestimate of the internal variability by the models (Fig. 3b), implying difficulties to highlight a link between the internal variability and the trend in sea ice extent.
- Decrease in sea ice extent simulated by the models in response to the forcing, including the one due to stratospheric ozone depletion (Fig. 4).
- No clear improvement of the simulated trend in sea ice extent arising from the initialisation through current data assimilation methods (Fig. 5).

Perspectives: systematic tests of more sophisticated data assimilation methods.

References

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