



Decadal predictions of Southern Ocean sea ice: testing different initialization methods with an Earth-system Model of Intermediate Complexity

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BACKGROUND

1979-2005 sea ice extent trend: positive and statistically significant at the 95% level (Cavalieri and Parkinson, 2008).

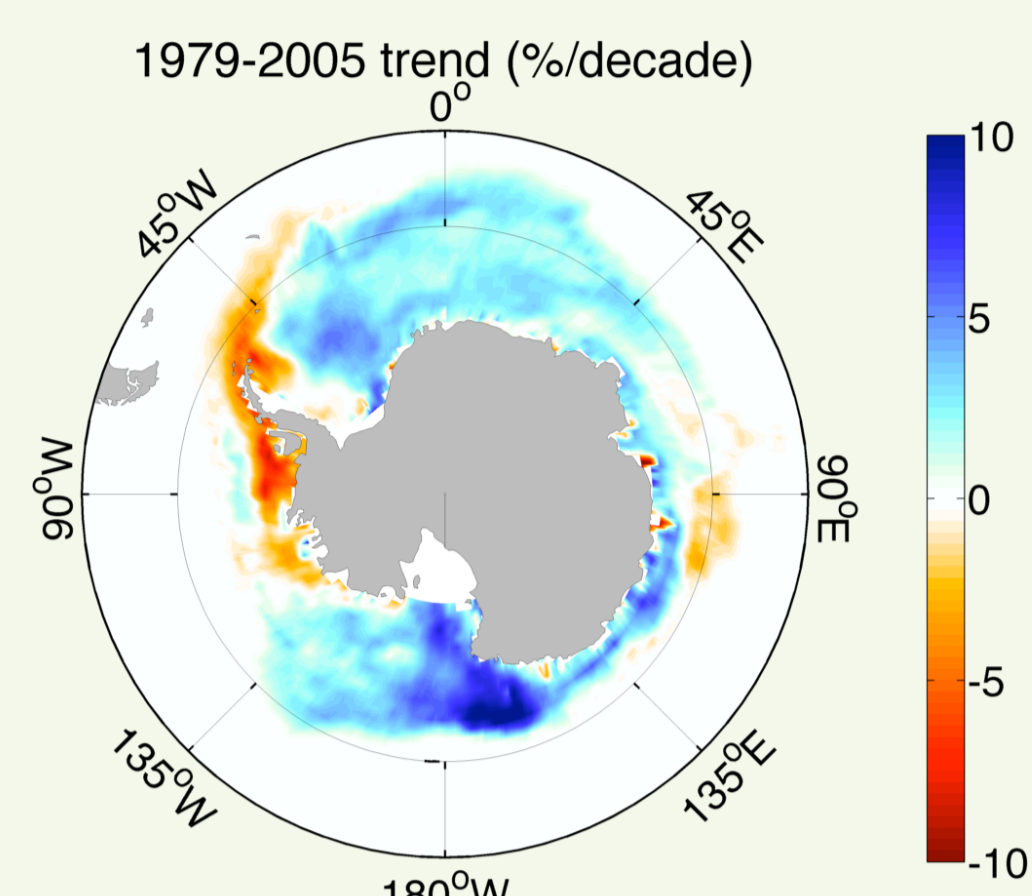


Fig. 1: Trend in observed sea ice concentration from NSIDC (Comiso, 2012)

- Observed expansion of sea ice extent may arise from internal variability, but it is difficult to test this hypothesis because:
 - too short observation time series;
 - General Circulations Models overestimate the internal variability of sea ice extent (Zunz et al., 2013).
- The Southern Ocean displays a high potential predictability at decadal timescales (e.g. Latif et al., 2010).

If the internal variability plays a substantial role in the increase in sea ice extent, a suitable initialization of the model may lead to a better agreement between simulations and observations.

TAKE HOME MESSAGE

In the idealized framework

- First 3 years of hindcast simulations: initialization with pseudo-observations increases the correlation between these latter and the hindcasts (Fig. 4).
- Initialization through a sophisticated method (NPPF): higher correlation than if a simpler method (e.g. a nudging) is used (Fig. 4).
- The lack of observations used to initialize the hindcasts decreases by more than a third the correlation during the first 2 years of simulation (Fig. 4).

In the realistic framework

- The correlation between the hindcasts and the observations of sea ice extent is low and not statistically significant (Fig. 5).
- Initialization through NPPF increases the 1980-2005 trend in sea ice extent by more than 70 000 km²/decade and this difference is significant at the 95% level (Fig. 6).

In real conditions, the initialization with observations does not improve the ability of the model to follow the year-to-year fluctuations of sea ice extent but it improves the simulated trend in sea ice extent between 1980 and 2005.

1. Strategy

LOVECLIM model (Goosse et al., 2010)

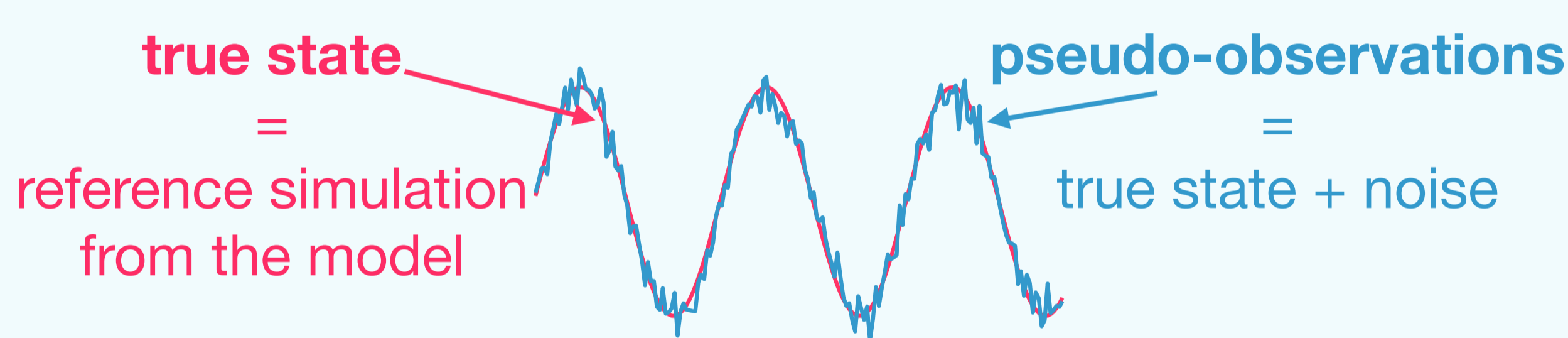
- Earth-system Model of Intermediate Complexity.
- Low computational cost → many simulations.

Hindcasts

- «Forecast» simulations spanning past periods, initialized through data assimilation of (pseudo-) observations.

Idealized framework

- Hindcasts are initialized with **pseudo-observations** of the surface air temperature. Hindcasts results are compared to the true state.



Realistic framework

- Hindcasts initialized with **actual observations** of the surface air temperature, from the HadCRUT3 dataset (Brohan et al., 2006). Hindcasts results are compared to the actual observed state.

2. Initialization methods

Initial conditions extracted from different simulations with **data assimilation**.

Assimilated variable: surface air temperature anomalies.

3 data assimilation methods

Nudging

Adding a term in the model's equations to pull the solution towards the (pseudo-) observations.

Particle filter (PF)

Launching an ensemble of simulations and select the ones that are closer to the (pseudo-) observations (Dubinkina et al., 2011).

Nudging proposal particle filter (NPPF)

Combination of a particle filter and the nudging (Dubinkina et al., 2013).

References

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3. Hindcasts in the idealized framework

Hindcast initialized from a state that has been extracted from a simulation with data assimilation of pseudo-observations.

3.1. Impact of the initialization

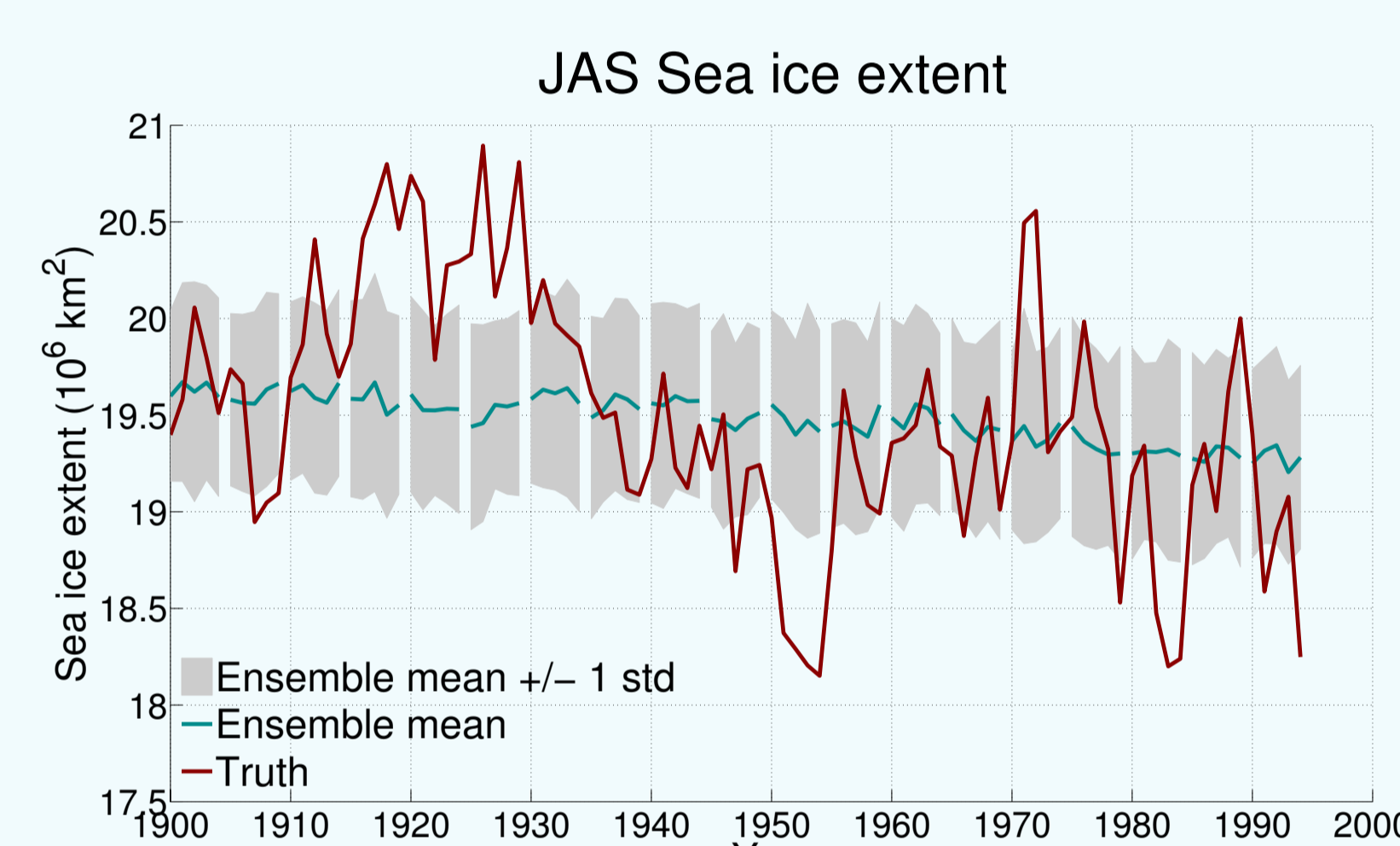


Fig. 2: 96-member hindcast simulations, initialized every 5 years without pseudo-observations constraint.

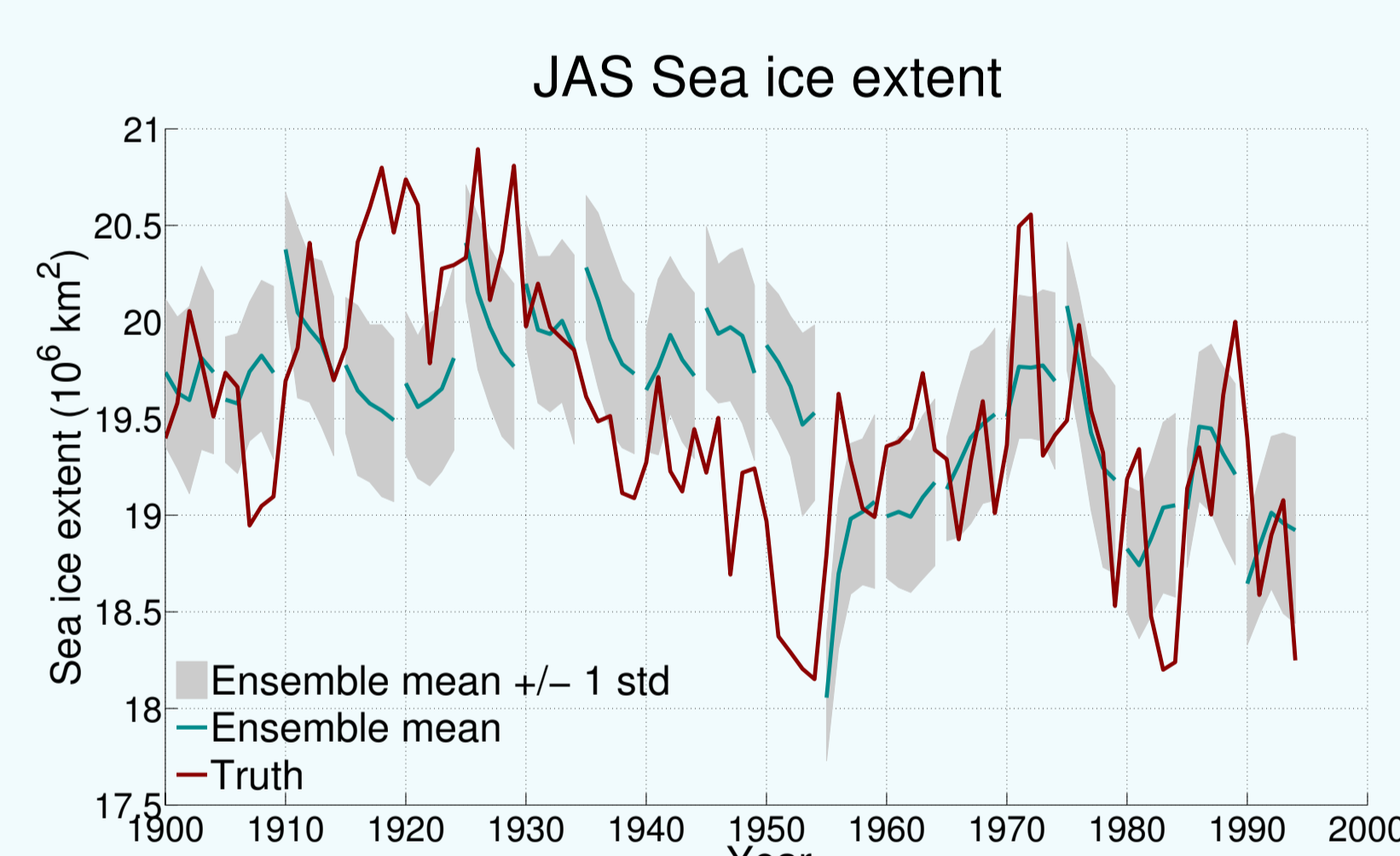


Fig. 3: 96-member hindcast simulations, initialized every 5 years from a simulation assimilating pseudo-observations with the NPPF.

- Hindcasts initialized through the data assimilation of pseudo-observations seem to agree better with the truth but we need to quantify the accuracy.

3.2. Quantifying the accuracy

→ anomaly correlation coefficient, COR (Pohlmann et al., 2009).

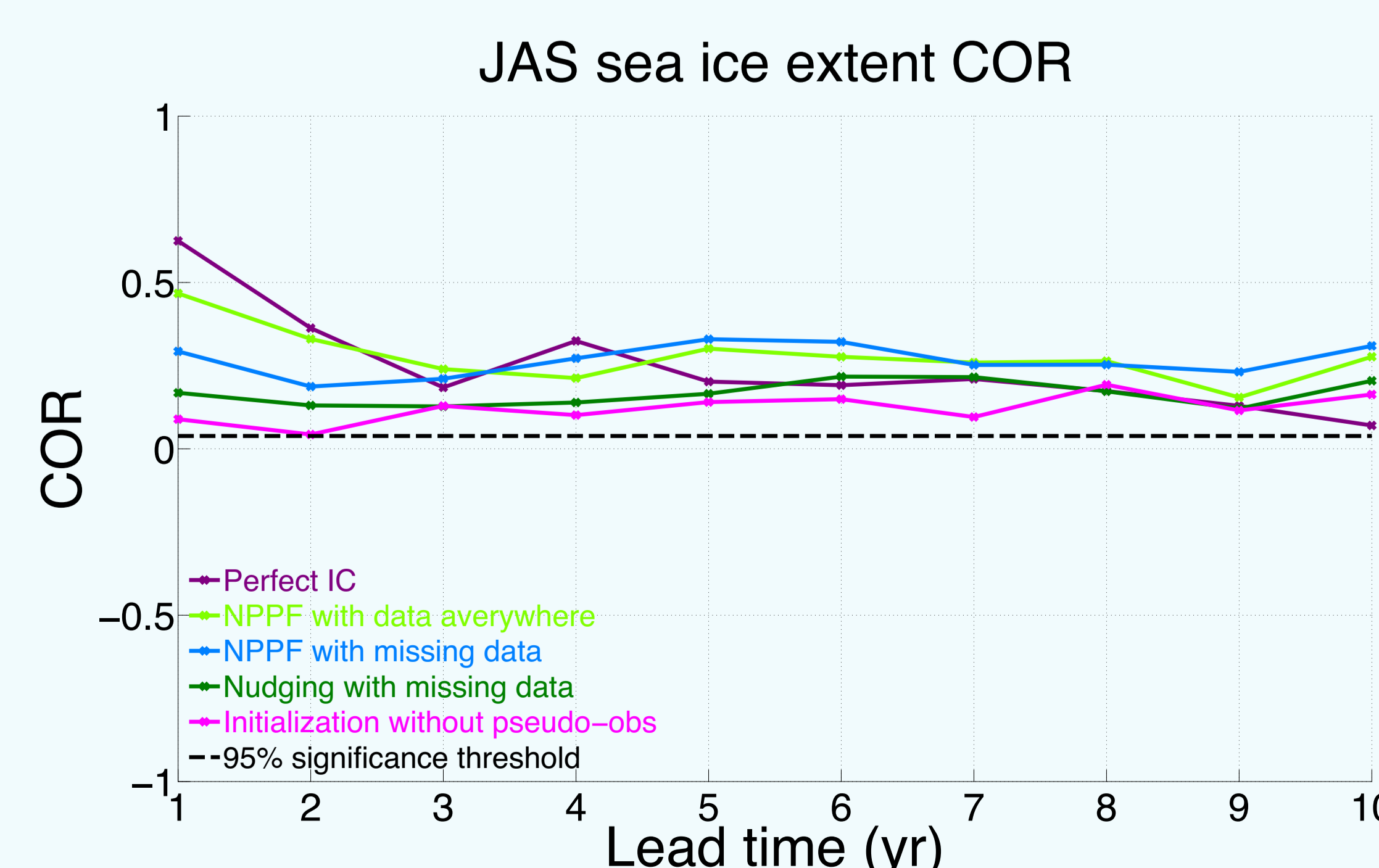


Fig. 4: Anomaly correlation coefficient computed for 10-year hindcasts, initialized every 5 years between 1900 and 1990. The different colors correspond to different initialization methods. Dashed line is the 95% significant threshold.

4. Hindcasts in the realistic framework

Hindcast initialized from a state that has been extracted from a simulation with data assimilation (the NPPF) of actual observations.

4.1. Sea ice extent correlation

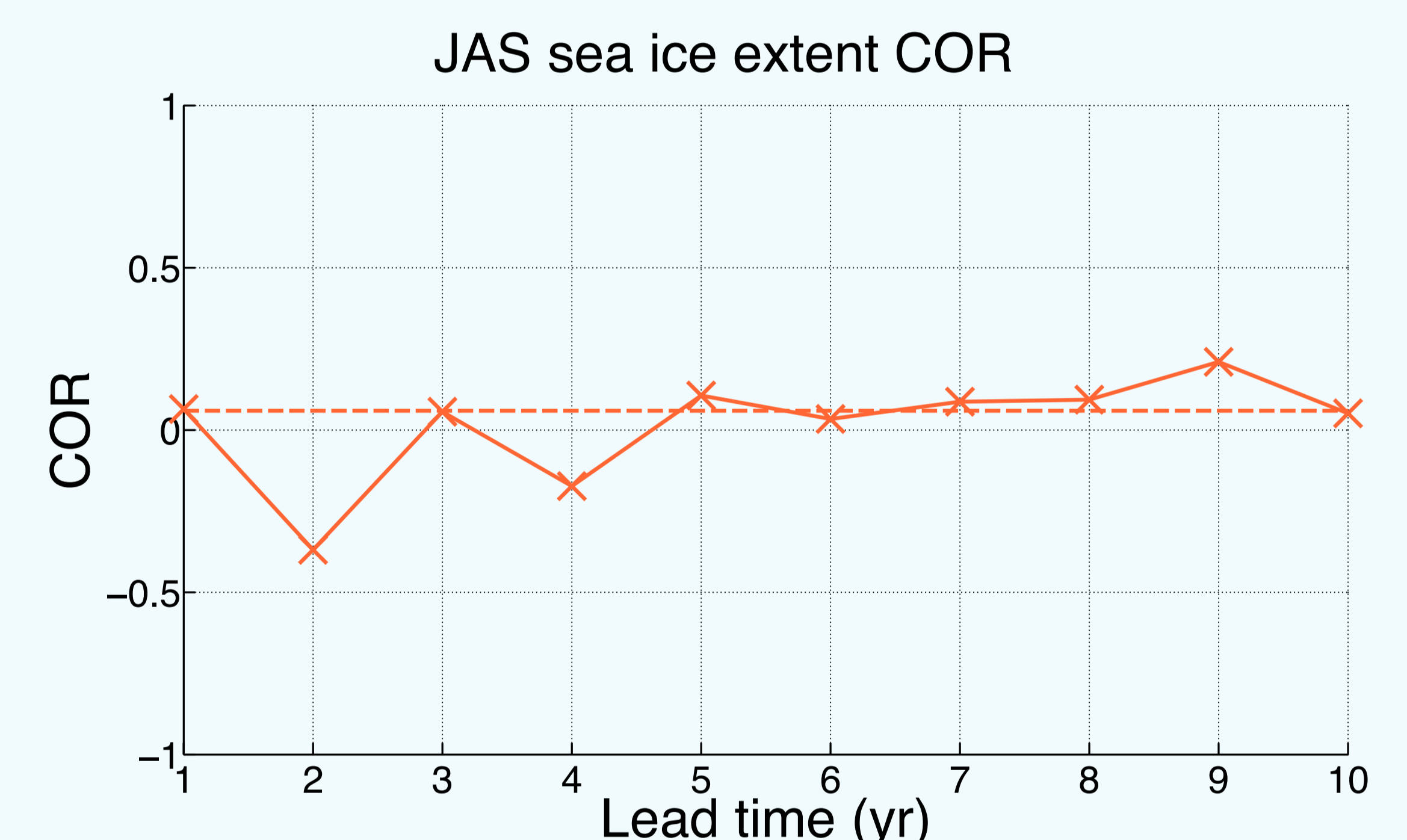


Fig. 5: Anomaly correlation coefficient computed for 10-year hindcasts, initialized every 2 years between 1980 and 1994. Each hindcast is a 96-member ensemble. Dashed line is the 95% significant threshold.

- Correlation is barely significant, for any leading year.

4.2. 1980-2005 trend of winter sea ice extent

Density distribution of JAS sea ice extent trend between 1980 and 2005

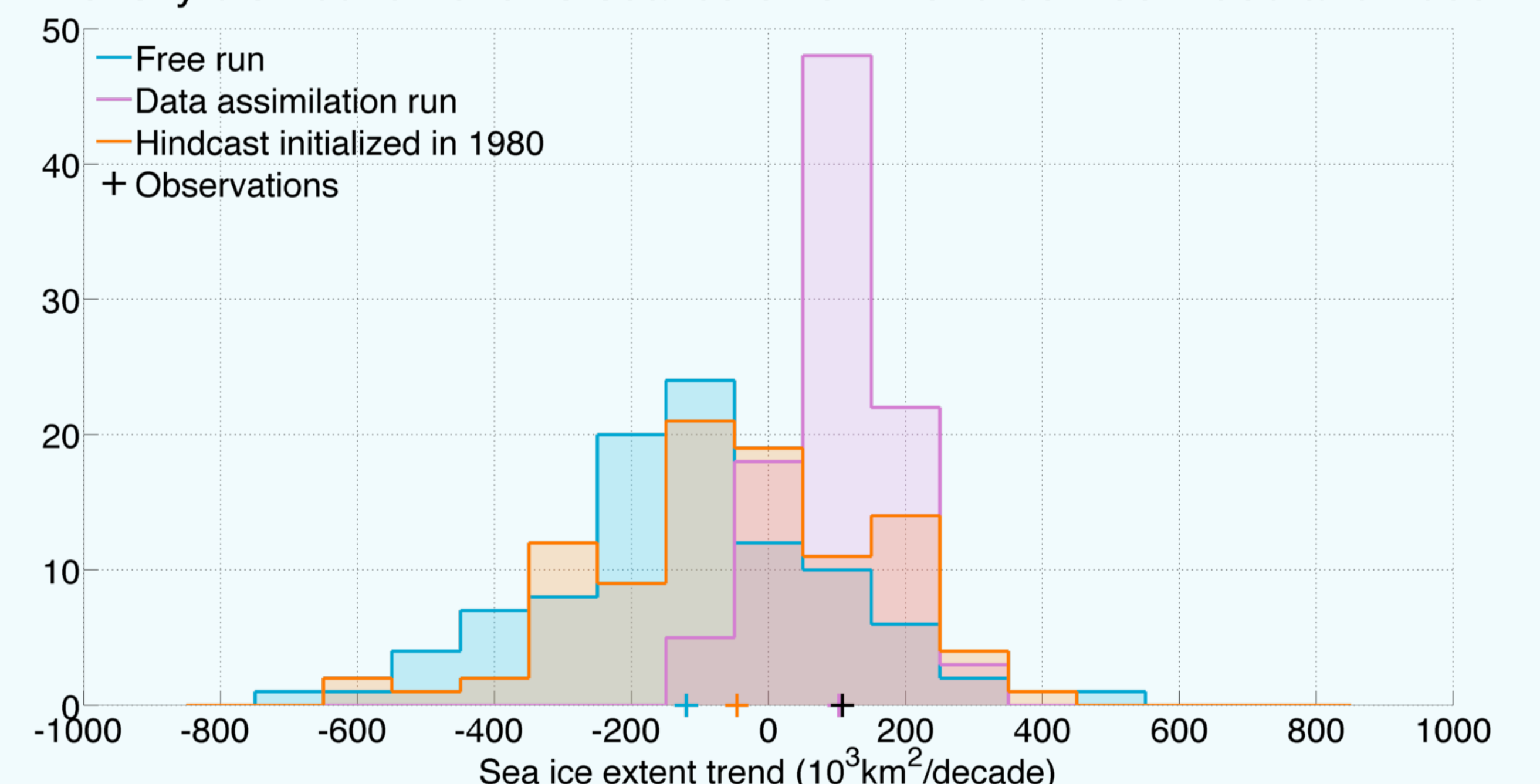


Fig. 6: Distribution of sea ice extent trends from 3 ensembles of 96 members each. Different colors correspond to different ensembles. Colored plus signs are for the ensemble means. Black plus sign corresponds to the observations.

- The assimilation of surface temperature shifts the distribution towards positive values of the trend in sea ice extent (ensemble mean = 102 x 10³ km²/decade).
- The ensemble mean of the hindcasts is still negative (-47 x 10³ km²/decade) but it is closer to the observations (108 x 10³ km²/decade) than the free run which is only driven by external forcing (-120 x 10³ km²/decade). This increase in the trend is statistically significant at the 95% level.

5. Ongoing work

- Initialization through data assimilation with the simple particle filter in the realistic framework, to avoid model drift that could arise from the nudging.
- Adding a random freshwater flux from the West Antarctic ice shelf.
- Assessing the performance of the initialization methods in the individual sectors of the Southern Ocean.