Nonuniform Contribution of Internal Variability to Recent Arctic Sea Ice Loss

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KEY POINTS

- The spatial structure of recent historical (1958-2017) Arctic sea ice changes, as well as its variability, is well represented in the Community Earth System Model Large Ensemble (CESM-LE).
- The observed trends lie approximately 1-2σ from the CESM-LE ensemble mean (forced response), highlighting the role of internal variability.
- Recent sea ice loss in the Barents Sea in April-May is nearly all (80-90%) attributable to internal variability. This is the region of largest variability and corresponds to the first EOF of 50 year changes in the pre-industrial control run.
- Across most of the Arctic in August-September, between one third and one half of the sea ice loss is due to internal variability. In some regions such as the Kara Sea and the Laptev Sea, the contribution of internal variability can reach over 70%.

CESM-LE simulates spatial pattern of Arctic SIC variability and recent trends remarkably well

Figure 1 compares the observed fifty year August-September sea ice change with the CESM-LE ensemble mean change. The spatial structure of the trends is simulated very well but the observed trends are much larger than the estimated forced response, between -2σ and -1σ (with σ estimated from across the 40 member ensemble) away from the ensemble mean, highlighting the importance of internal variability. This in agreement with studies which have focussed on SIE (e.g. Stroeve et al., 2007, Kay et al., 2011, Jahn et al., 2016).

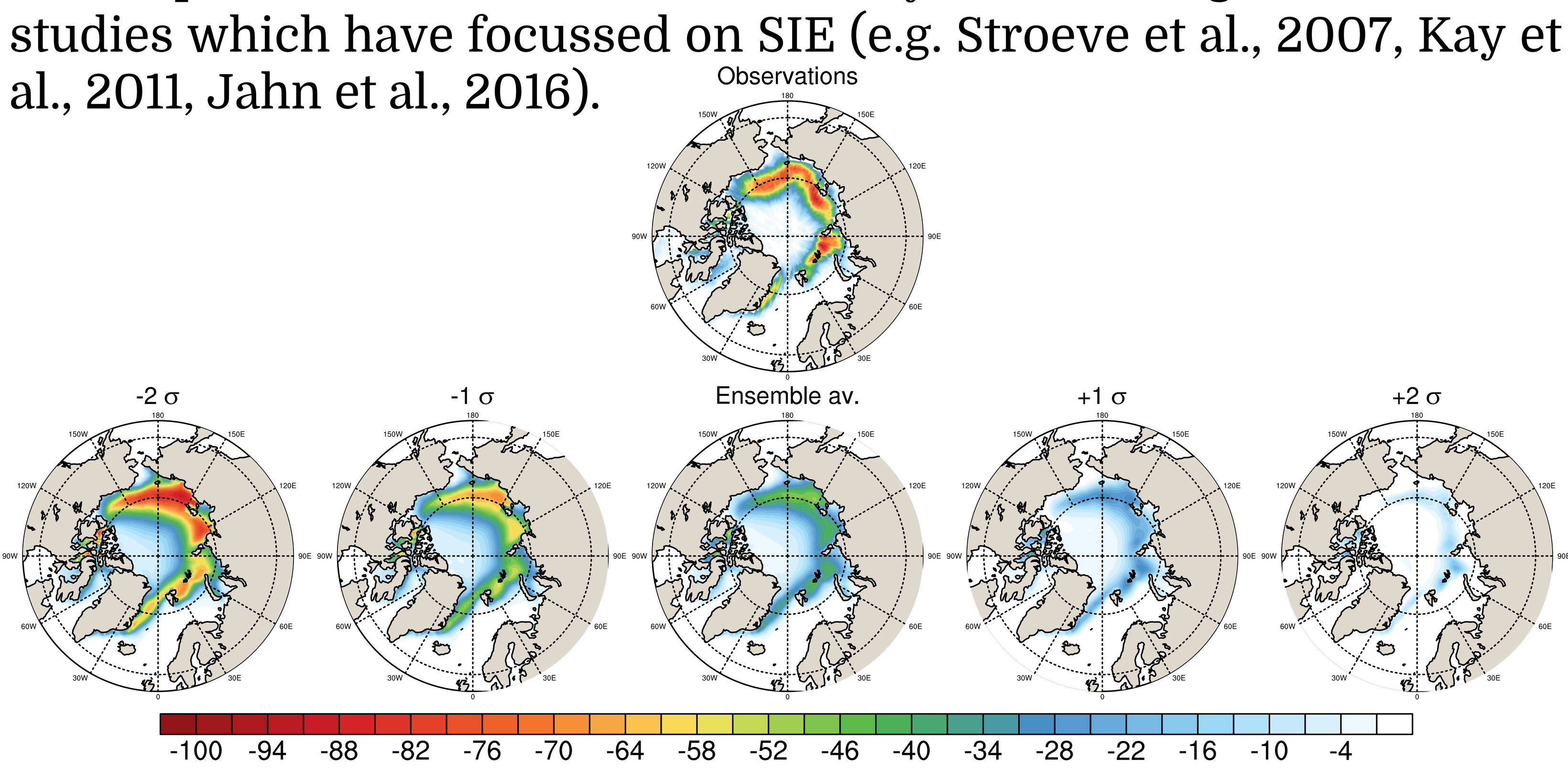


Figure 1: Decadal averaged 50-year August-September Arctic sic change [%] from the HadISST dataset (top) and the ensemble mean (bottom centre) of the forty member CESM-LE for the recent past (the decades 1958-1967 to 2008-2017). Multiples of σ are estimated from the the forty members and then added to the ensemble mean.

The CESM-LE also simulates the spatial structure of the interannual sea ice variability in a realistic manner, as shown in **Figure 2**. The regional structure is remarkably consistent with observations. The CESM-LE performs the best out of CMIP5 models with at least four ensemble members.

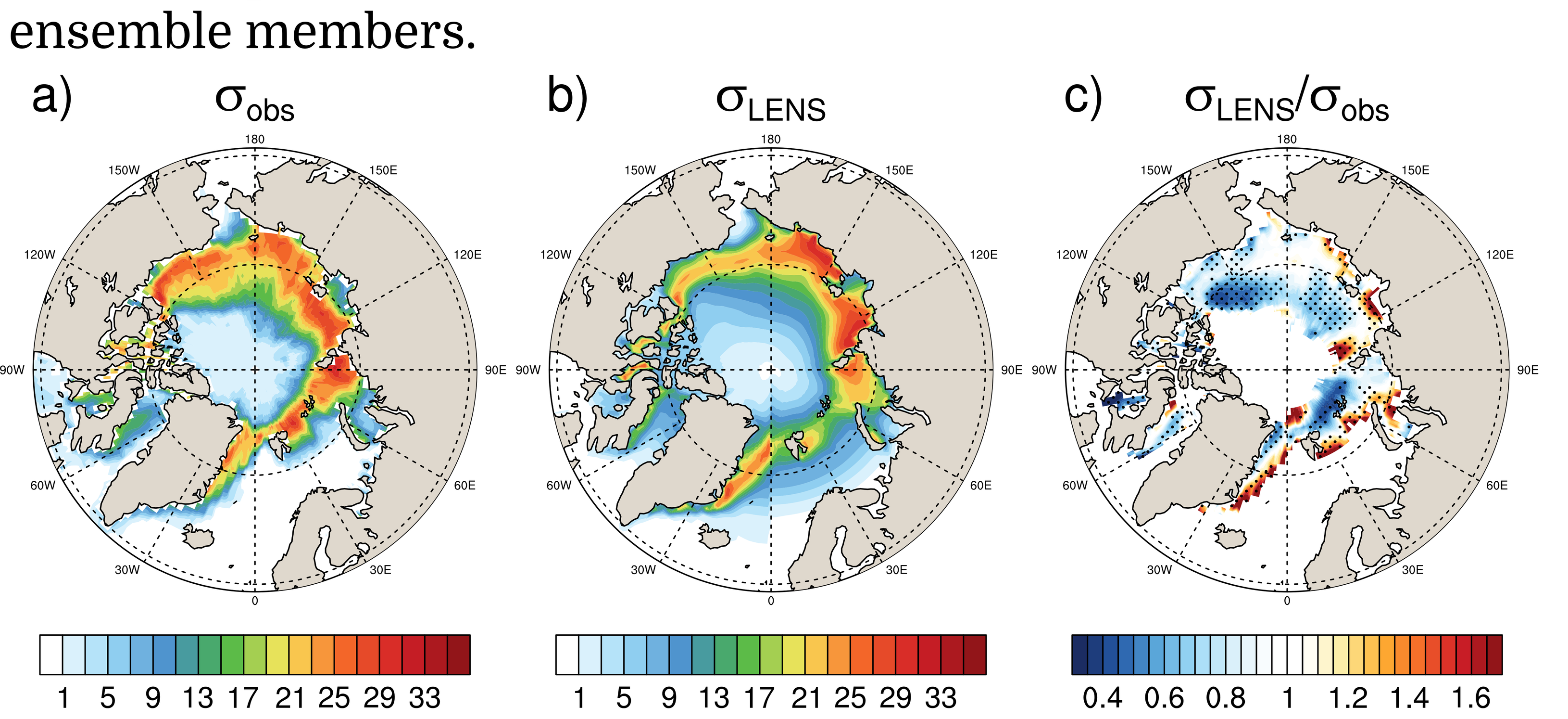


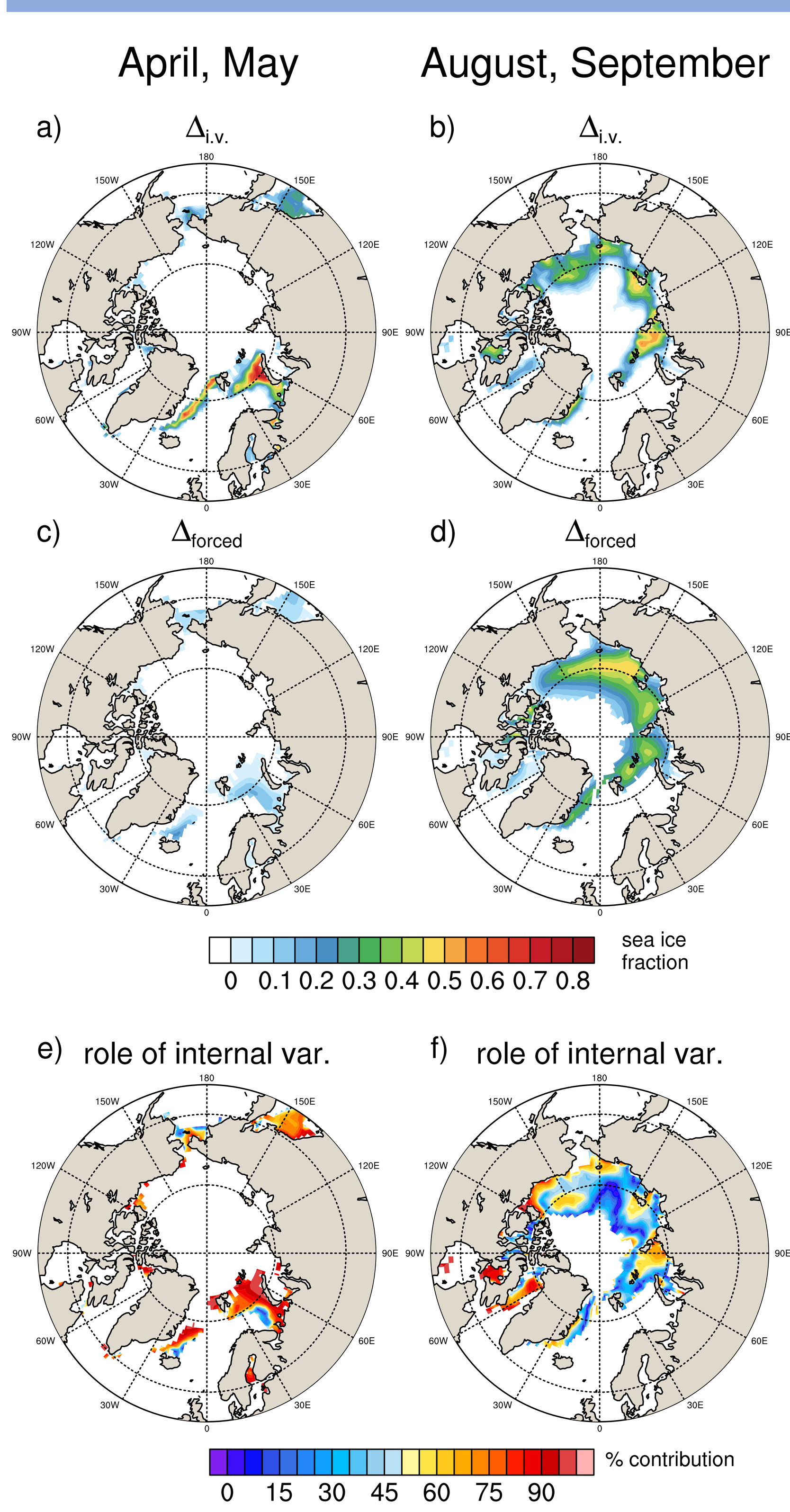
Figure 2: σ of detrended August-September sic 1950-2017 from HadISST observational dataset (a), a pooled timeseries from the forty members of the CESM-LE (b) and their ratio (c). Significant differences between the two σs are stippled using a false detection rate of 10% (accounting for differing length of timeseries).

Introduction

Over the last fifty years, Arctic sea ice extent (SIE) has decreased by nearly 60% in September (Serreze and Stroeve, 2015) and it is likely that we will experience an ice free Arctic by the middle of the century. Most studies estimate that only half of recent observed sea ice loss is due to anthropogenic forcing. The remaining half has been attributed to internal variability inherent to the climate system (Stroeve et al., 2007; Kay et al.; 2011, Stroeve et al., 2012).

Current estimates for the role played by internal variability in historic Arctic sea ice trends have been limited to looking at aggregate measures e.g. SIE. In this study we ask the question: **are there regions in which internal variability plays a more important role than the forced response?** Given that recent trends have substantial seasonal and regional variations (Onarheim et al., 2018) it is important to understand the contribution of internal variability in different regions.

In which seasons and regions does internal variability dominate over the forced response?



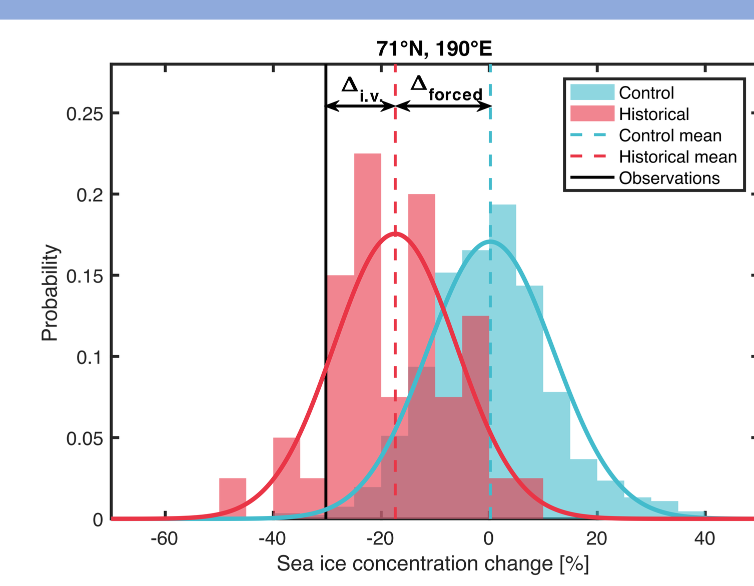


Figure 3: For (left) April-May and (right) August September: 50-year sic change attributed to (a & b) internal variability and (c & d) the forced response. (e & f) Percentage contribution of internal variability to the observed Arctic sic trend from HadISST. The histograms are an example of this calculation for one grid point (71°N, 190°E).

Using the CESM-LE historical runs and the long pre-industrial control, we are able to estimate the contribution of internal variability to the observed 50-year change. **Figure 3.** Our results indicate that sea ice loss in the Barents Sea in April-May is largely driven by internal variability (~80-90%). This can be seen as the first EOF of 50-year trends found in the control run, **Figure 4.** In late summer, internal variability accounts for 30-50% of the change in most regions apart from some hotspots such as the Kara Sea (related to 1st EOF) and the Laptev Sea (appears in 2nd EOF), where internal variability plays a dominant role.

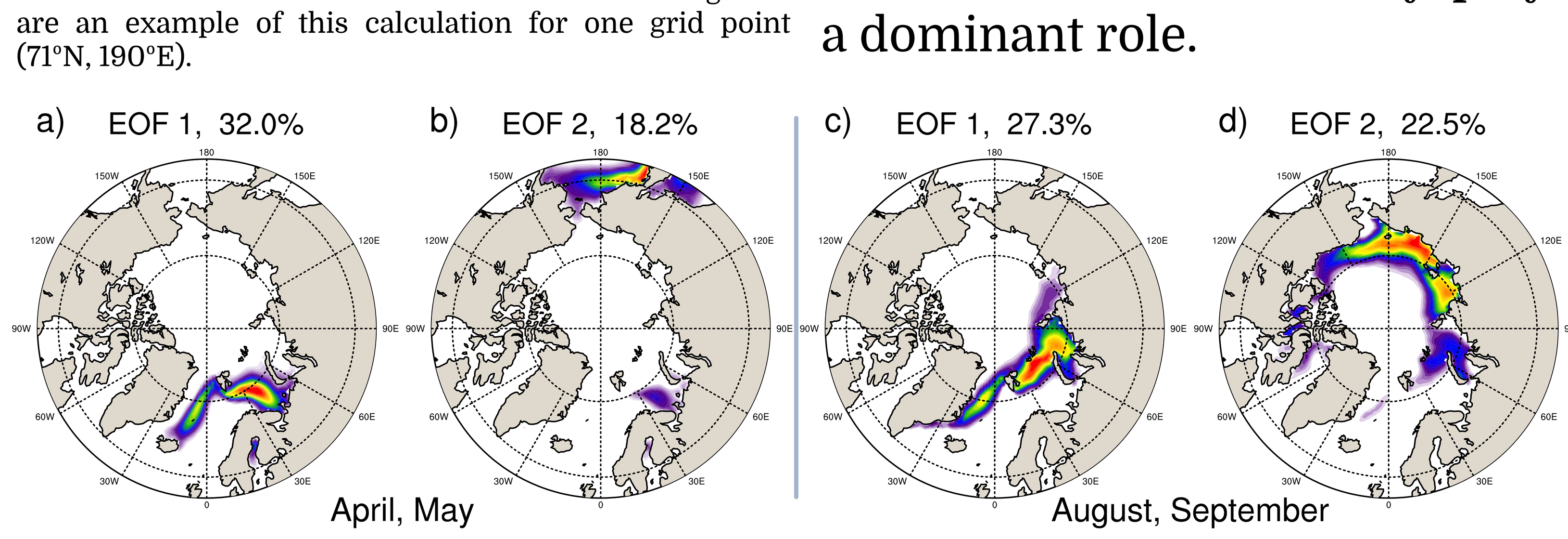


Figure 4: The first two leading EOFs of decadal-averaged 50-year Arctic sic changes from the CESM pre-industrial control run, providing 1,741 overlapping fifty-year trends. We analyse the months April-May (left) and August-September (right). The percentage of the total variance explained by the EOF is displayed.

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