

2021 CESM Polar Climate Working Group Meeting

Realism of simulated internal variability in Arctic sea ice



Boulder

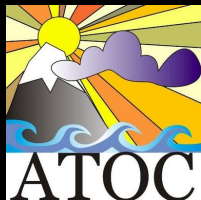
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²*Institute of Arctic and Alpine Research*

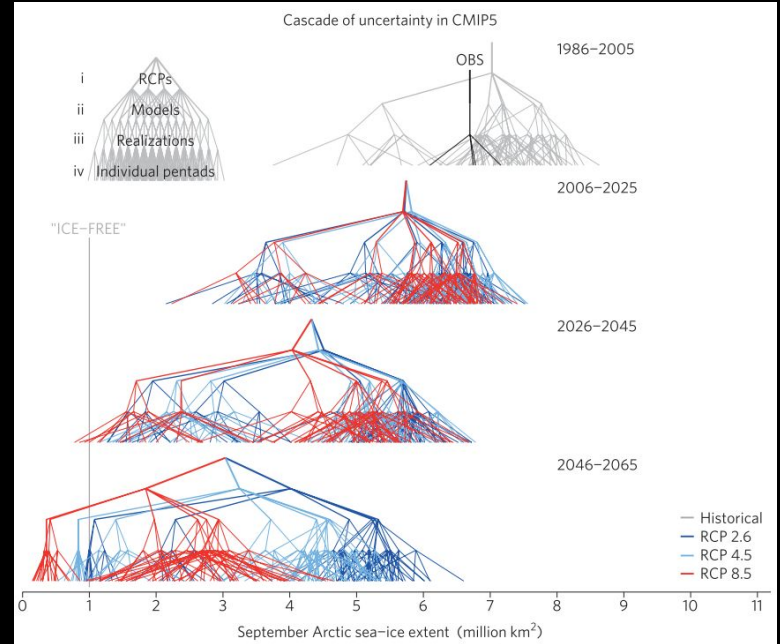
³*Scripps Institution of Oceanography*

⁴*University of North Carolina at Wilmington*



Motivation

- Short and medium-term projection uncertainty for Arctic sea ice is highly dependent on internal variability (Jahn et al., 2016 *GRL*; Olonscheck & Notz, 2017 *JClim*).
- With only one realization of reality, it is difficult to assess the internal variability of observations.
- Resampling applies a directly comparable metric between observations and models.



Swart et al. (2015) *Nature Climate Change*

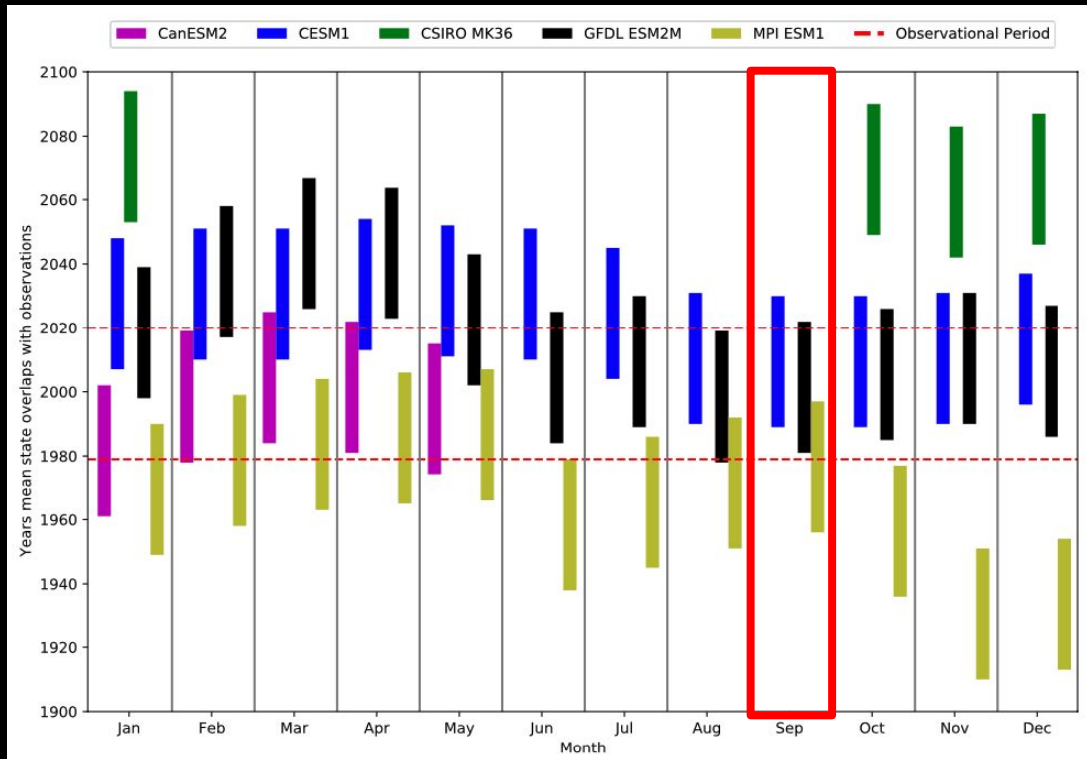
Methods

Data:

- NSIDC Sea Ice Index.
- CLIVAR Multi-Model Large Ensemble Archive (RCP8.5):
 - CanESM2 (50)
 - CESM1 (40)
 - CSIRO MK36 (30)
 - GFDL ESM2M (30)
 - MPI ESM1 (100)

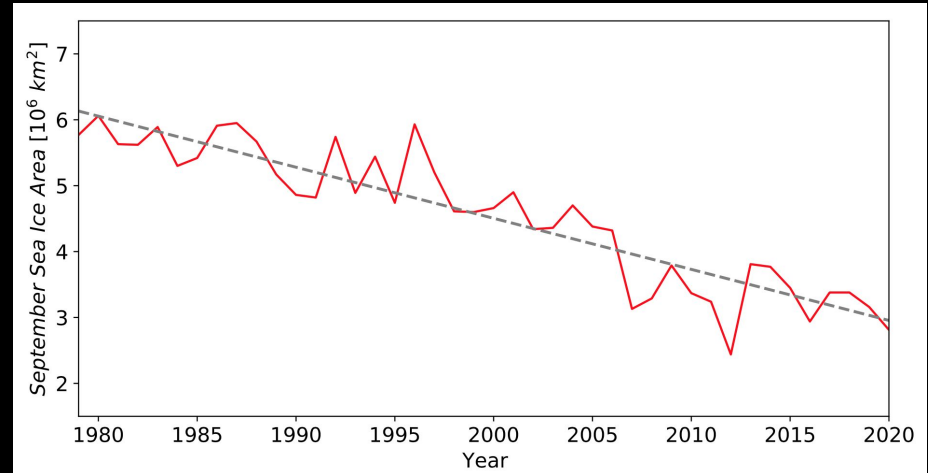
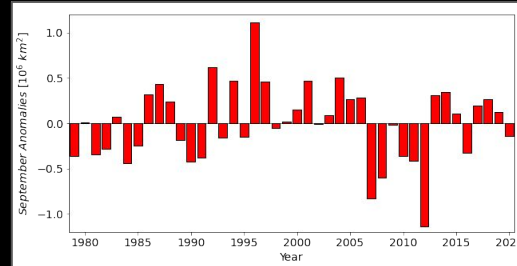
Time periods:

- 1979-2020 for equivalent forcing
- 42-year periods with mean sea ice area equal to observations (denoted XXXX-XXXX).



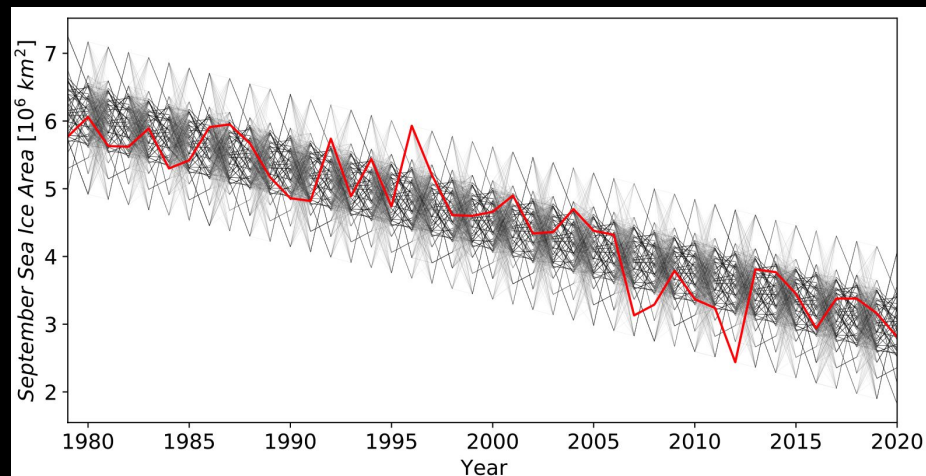
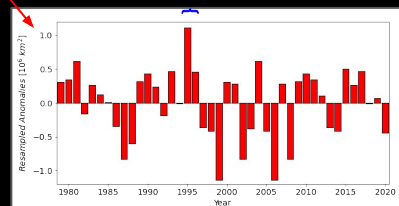
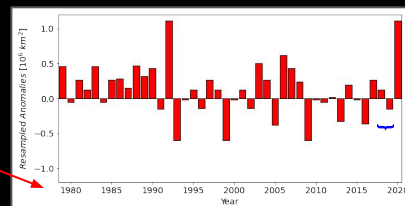
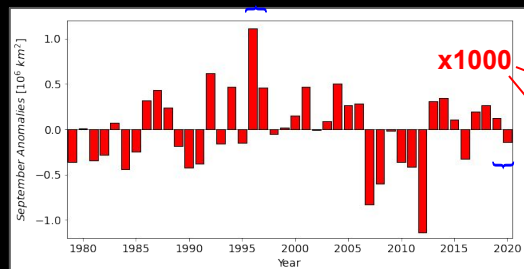
Methods

- Forced response \cong linear trend
- Internal variability \cong detrended anomalies



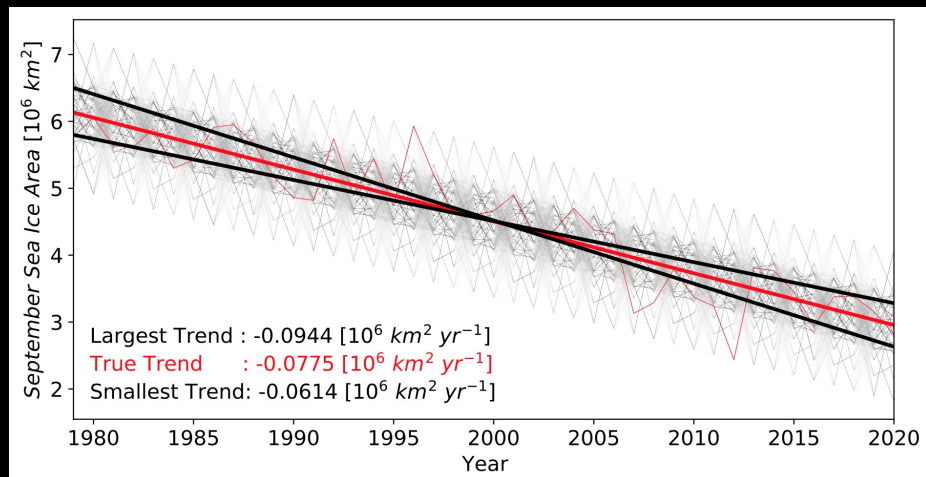
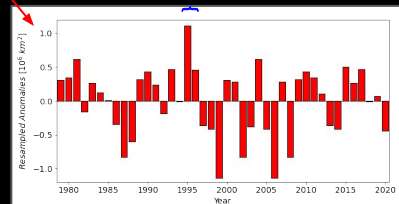
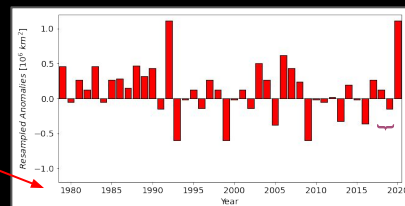
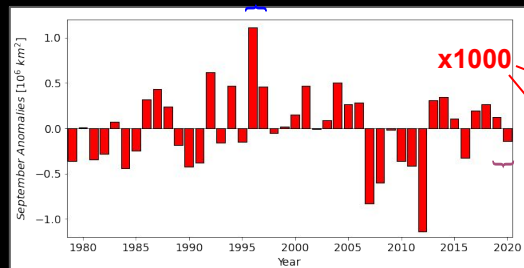
Methods

- Forced response \cong linear trend
- Internal variability \cong detrended anomalies
- 1000 equally possible scenarios are created by resampling anomalies (in a 2 year block size) from observations and ensemble members, following McKinnon et al. (2017; 2018) - *J. Clim.*



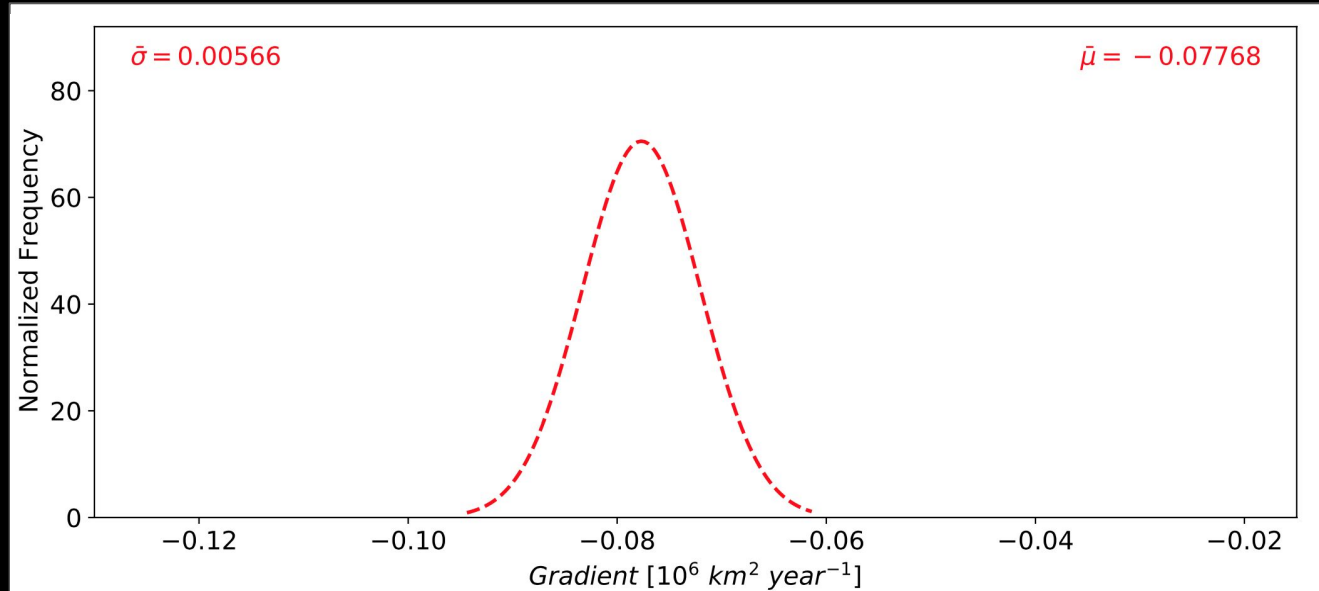
Methods

- Forced response \cong linear trend
- Internal variability \cong detrended anomalies
- 1000 equally possible scenarios are created by resampling anomalies (in a 2 year block size) from observations and ensemble members, following McKinnon et al. (2017; 2018) - *J. Clim.*
- The standard deviation of the 1000 simulations is one possible metric of internal variability, as is the standard deviation of non-resampled large ensemble members.



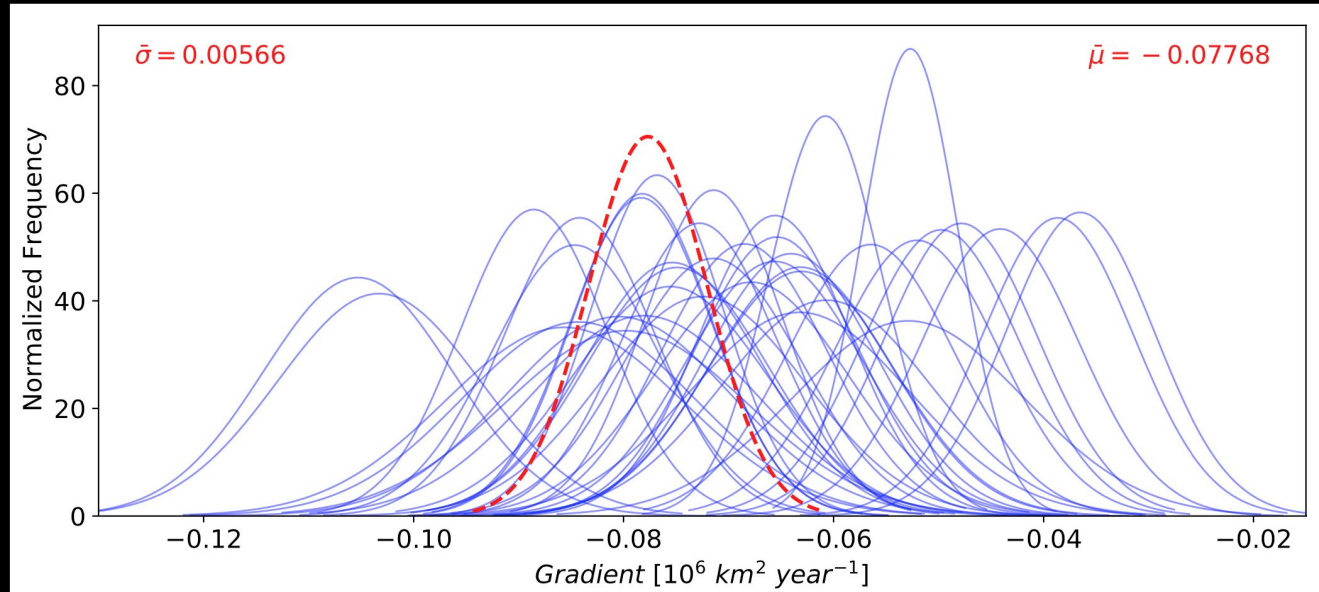
Comparing observations and members

- Assuming a normal distribution, we show the spread of possible observed trends.



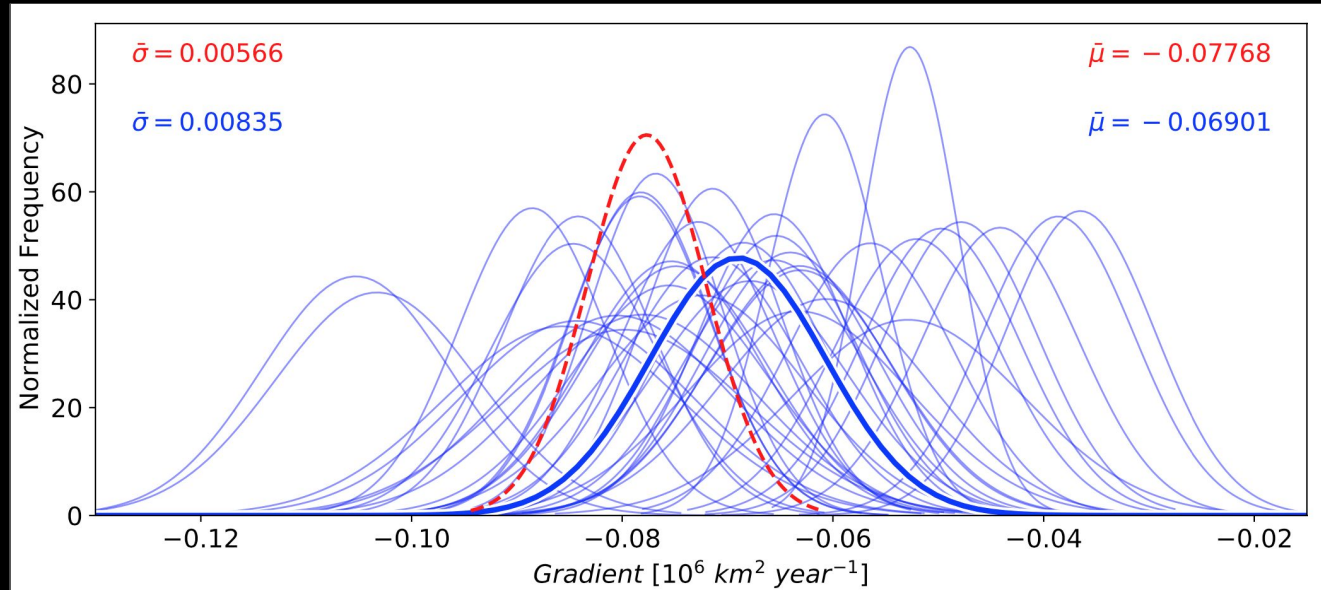
Comparing observations and members

- Each ensemble member can be resampled in the same way, the 40 CESM1 members are shown



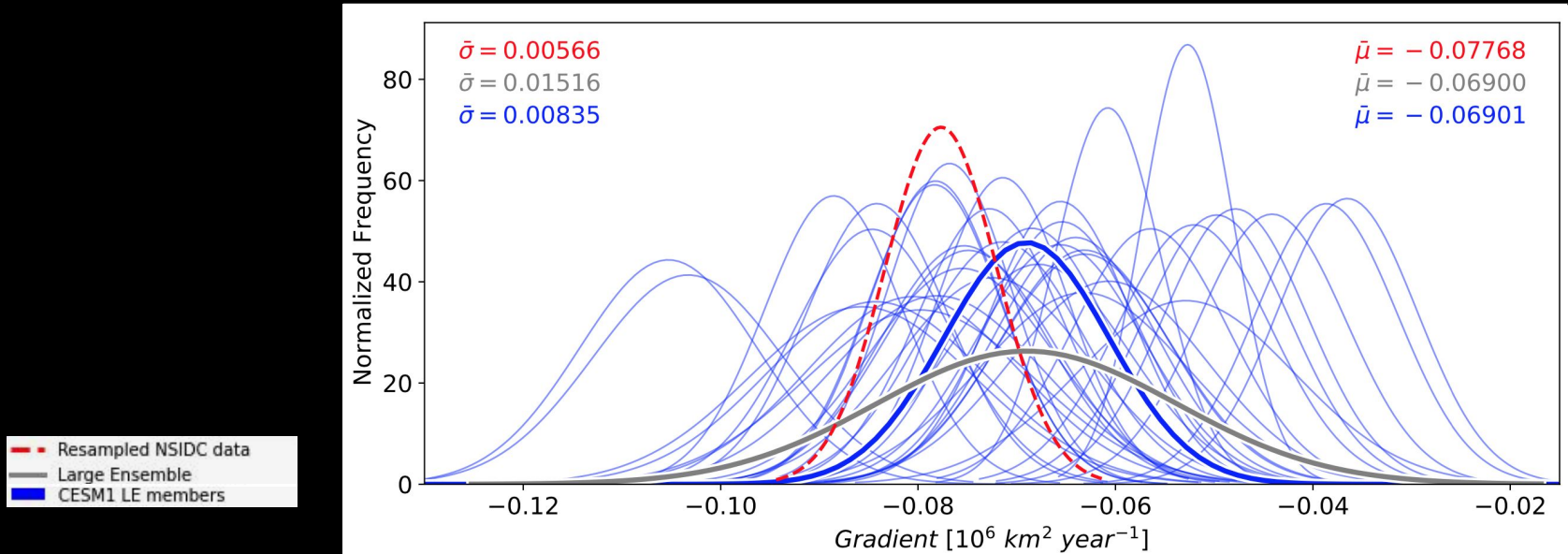
Comparing observations and members

- The bold blue line shown the 'typical' CESM1 member.



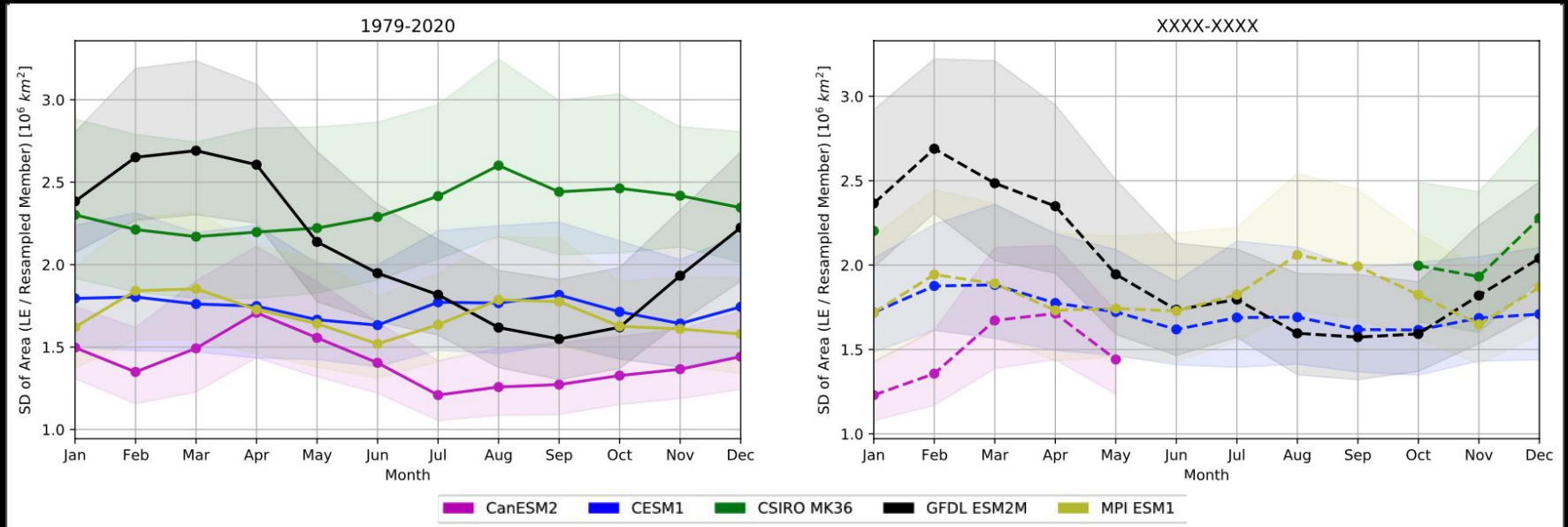
Comparing observations and members

- We can include the standard deviation between the (non-resampled) large ensemble members
- LE / Member = 1.8



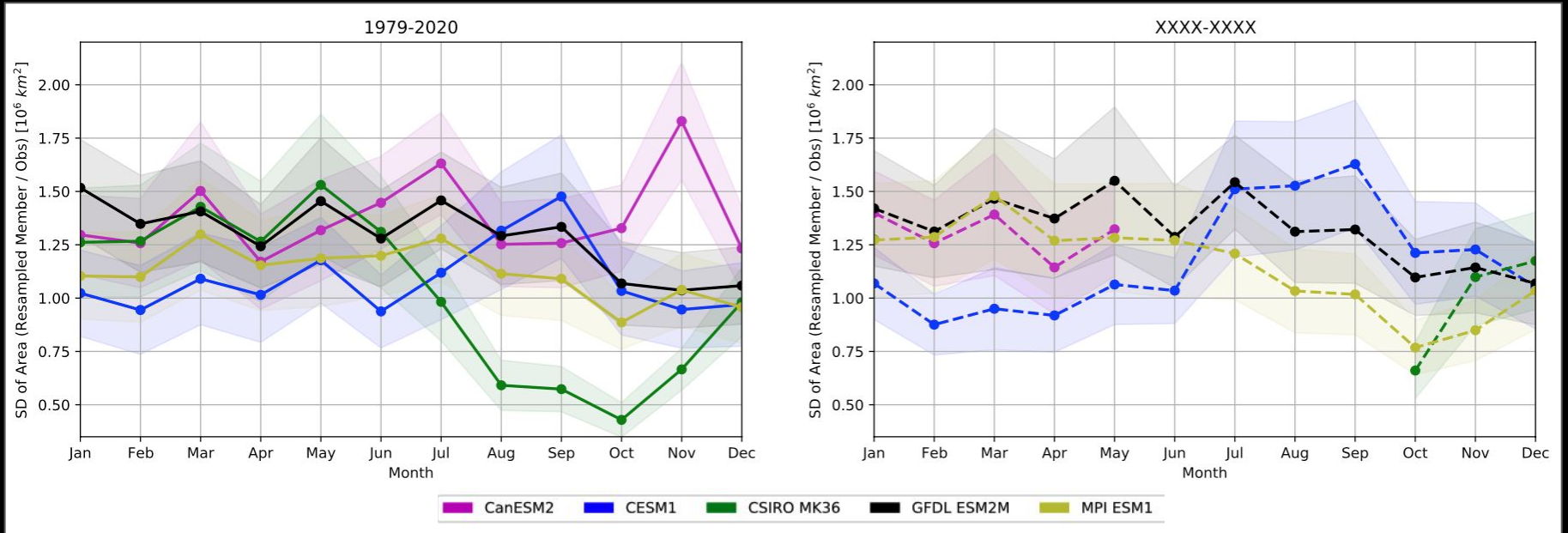
Large Ensemble / Resampled Member

- LE standard deviation \sim 1-3 times larger than resampled members: resampling does not capture all internal variability.
- 1979-2020 and equivalent time periods are very similar

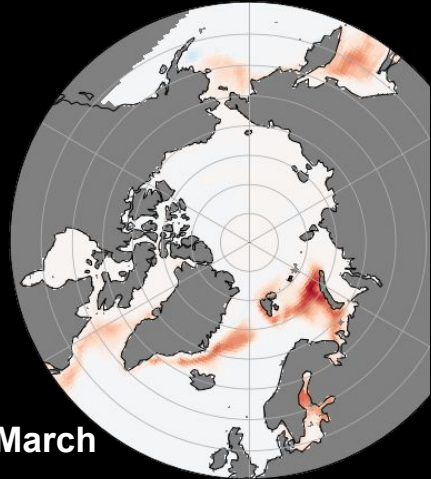


Resampled Member / Resampled Observations

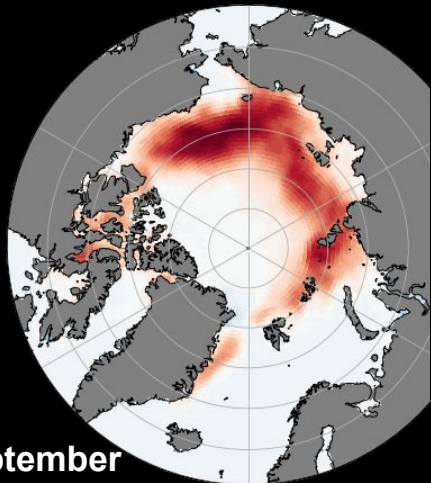
- Selected models' members are ~1.0-1.6 times larger than observations in terms of standard deviation of resampled area.



Trend 1979-2020 (NSIDC)



March



September

% SIC trend per decade

Trend 1979-2020 (NSIDC)

SD of resampled trends

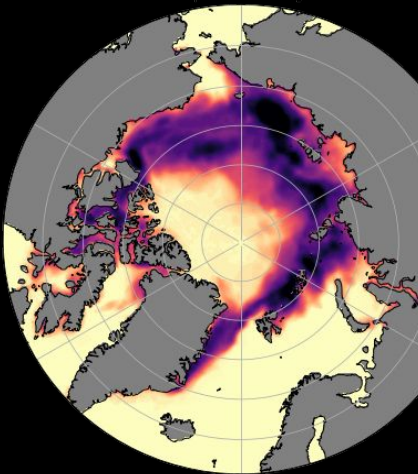
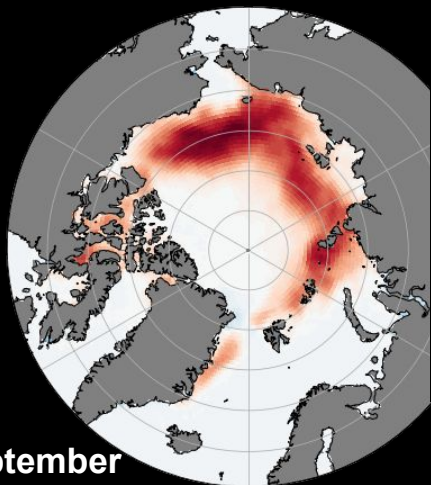
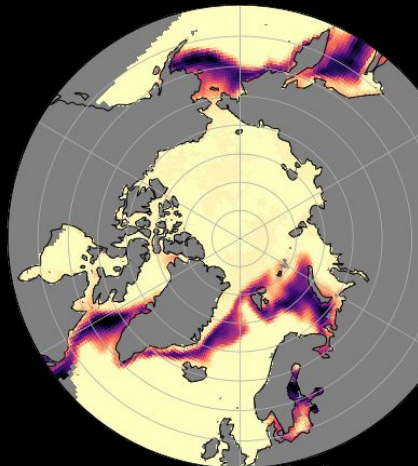
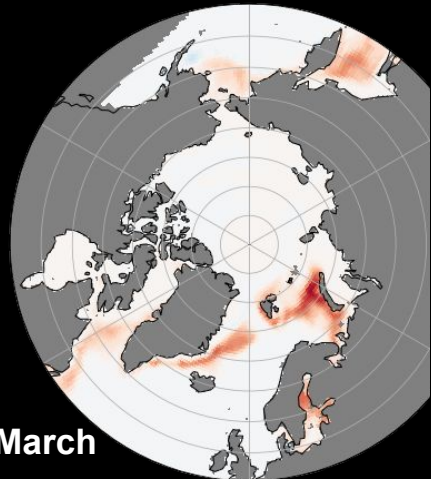
NSIDC March 1979-2020 (mean standard deviation)

NSIDC September 1979-2020

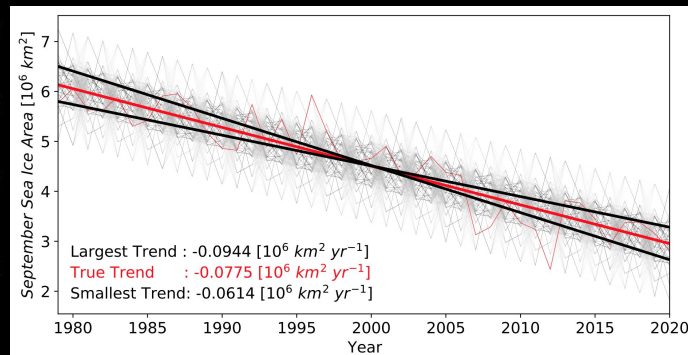
March

% SIC trend per decade

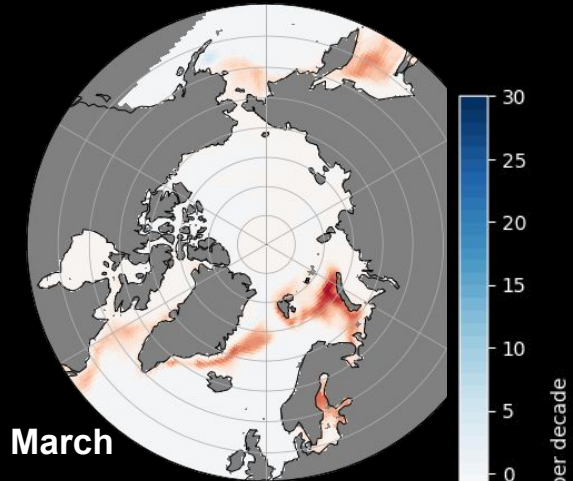
Standard Deviation [%]



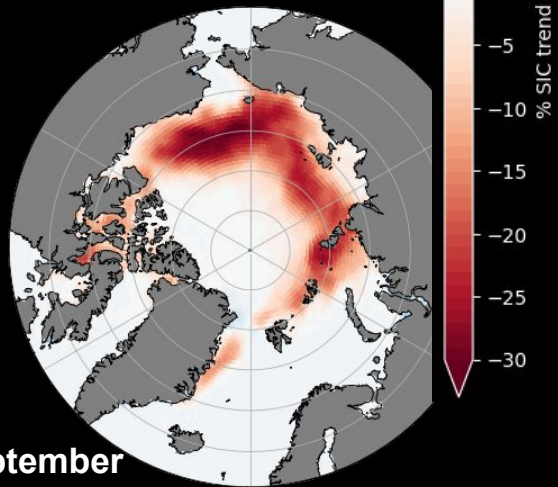
September



Trend 1979-2020 (NSIDC)



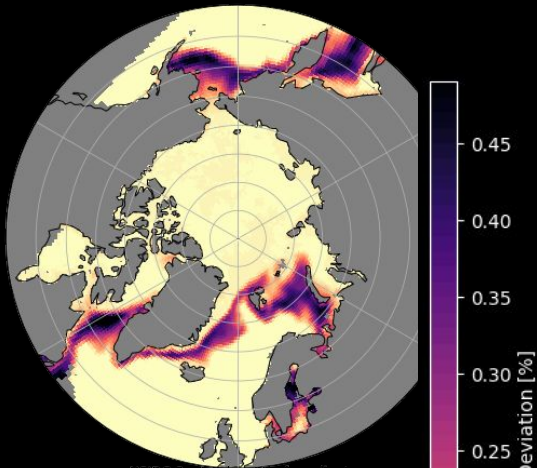
March



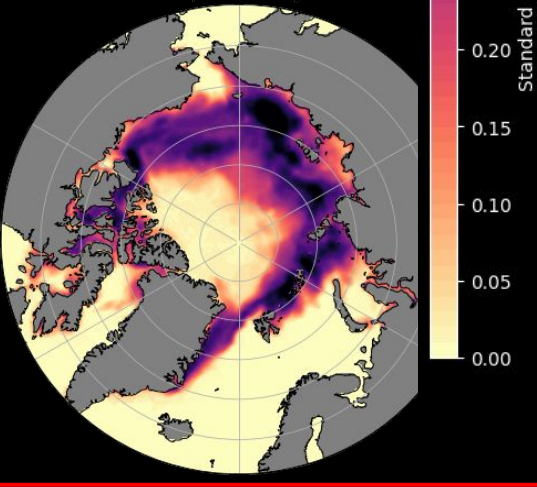
September

SD of resampled trends

NSIDC March 1979-2020 mean standard deviation

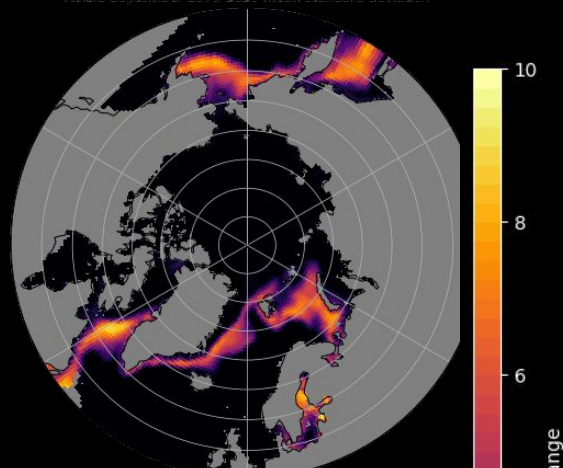


NSIDC September 1979-2020 mean standard deviation

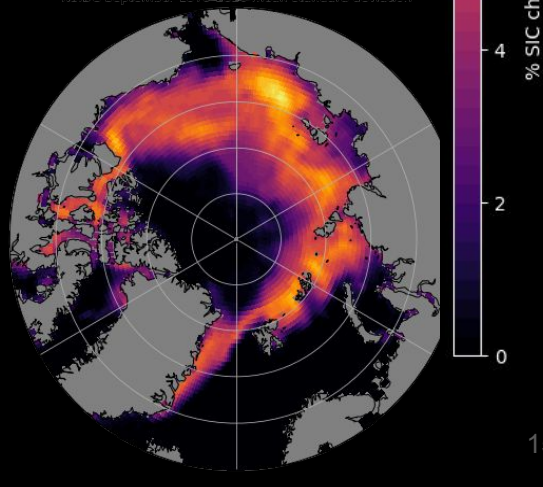


After 41 years

NSIDC September 1979-2020 mean standard deviation



NSIDC September 1979-2020 mean standard deviation



NSIDC (1979-2020)

CanESM2 (1979-2020)

CESM1 (1979-2020)

CSIRO MK36 (1979-2020)

GFDL ESM2M (1979-2020)

MPI [Still running!]

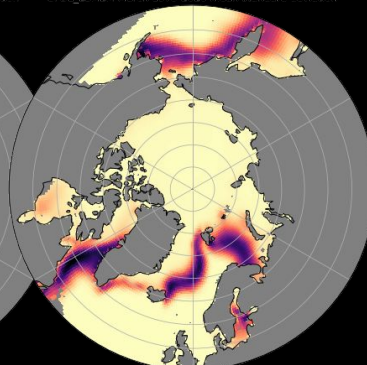
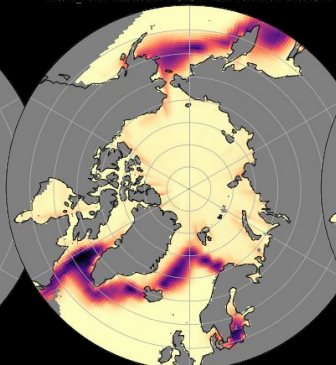
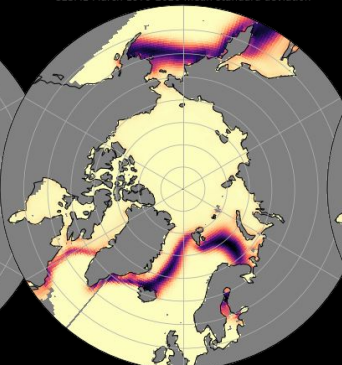
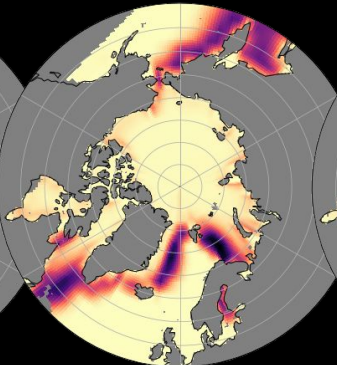
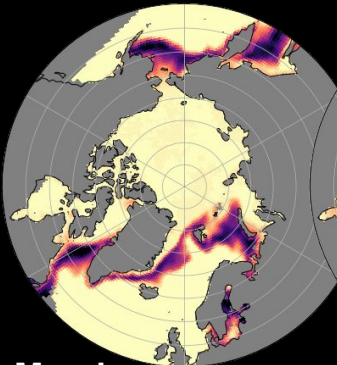
NSIDC March 1979-2020 mean standard deviation

CanESM2 March 1979-2020 mean standard deviation

CESM1 March 1979-2020 mean standard deviation

CSIRO_MK36 March 1979-2020 mean standard deviation

GFDL_ESM2M March 1979-2020 mean standard deviation



March

NSIDC (1979-2020)

CanESM2 (1979-2020)

CESM1 (1979-2020)

CSIRO MK36 (1979-2020)

GFDL ESM2M (1979-2020)

MPI [Still running!]

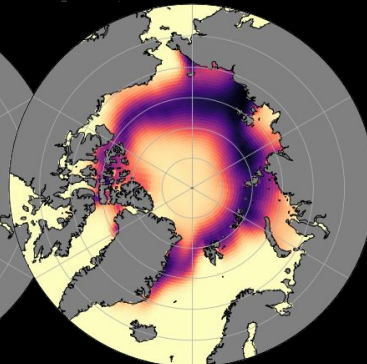
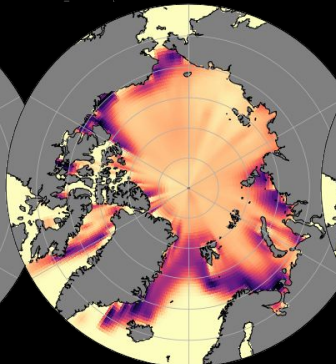
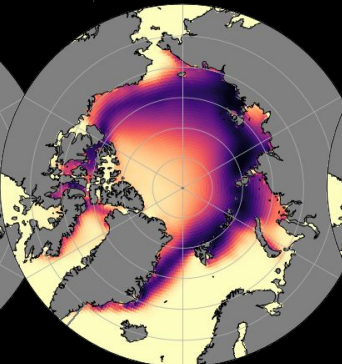
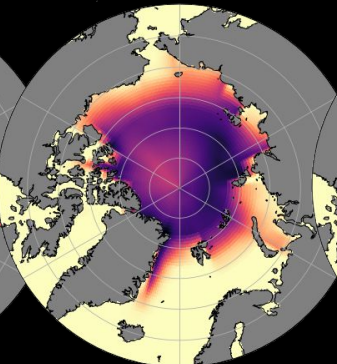
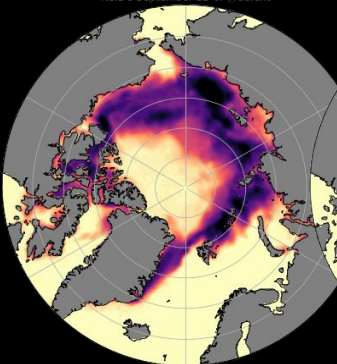
NSIDC September 1979-2020 mean standard deviation

CanESM2 September 1979-2020 mean standard deviation

CESM1 September 1979-2020 mean standard deviation

CSIRO_MK36 September 1979-2020 mean standard deviation

GFDL_ESM2M September 1979-2020 mean standard deviation



September

NSIDC (1979-2020)

NSIDC March 1979-2020 mean standard deviation

CanESM2 (1984-2025)

CanESM2 March 1984-2025 mean standard deviation

CESM1 (2010-2051)

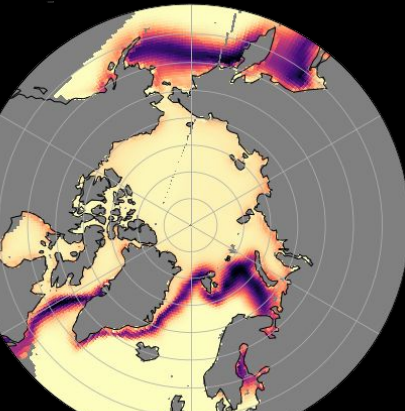
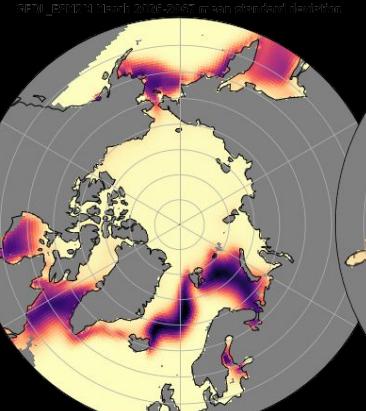
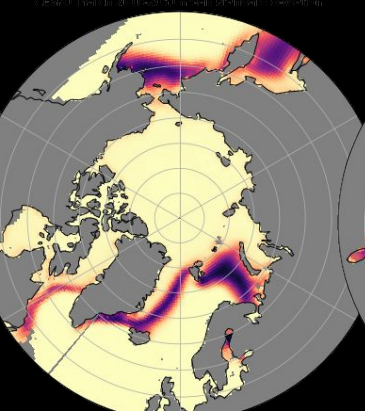
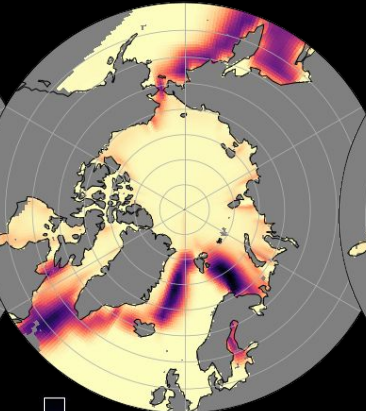
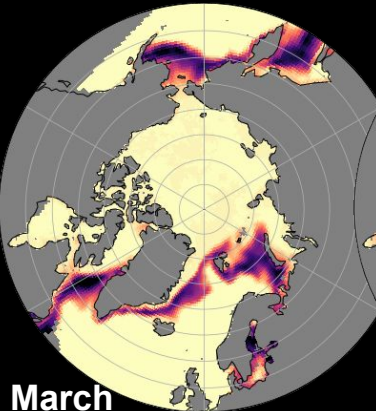
CESM1 March 2010-2051 mean standard deviation

GFDL ESM2M (2026-2067)

GFDL ESM2M March 2026-2067 mean standard deviation

MPI ESM1 (1963-2004)

MPI ESM1 March 1963-2004 mean standard deviation



March

NSIDC (1979-2020)

NSIDC September 1979-2020 mean standard deviation

CESM1 (1989-2030)

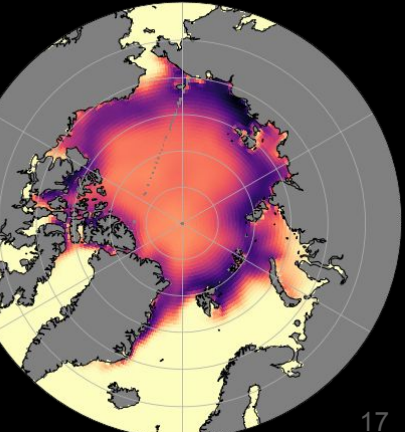
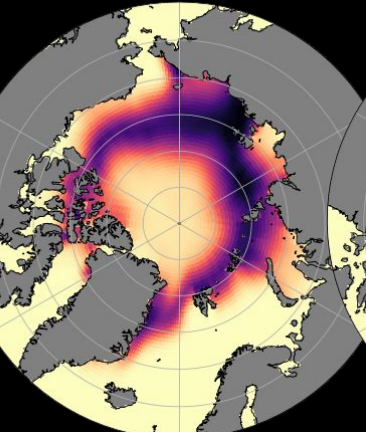
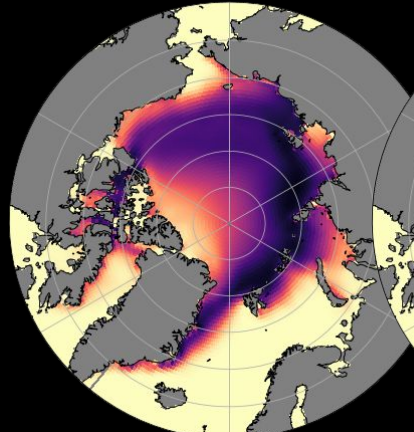
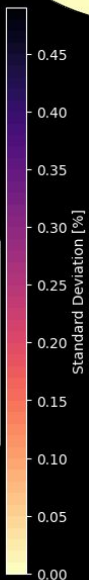
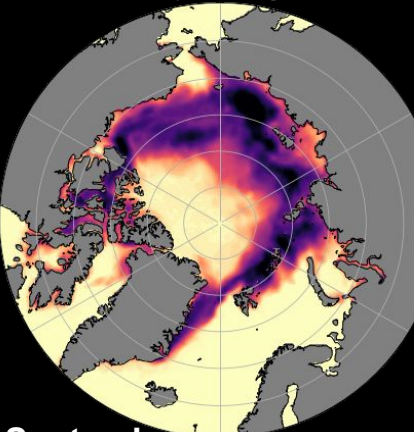
CESM1 September 1989-2030 mean standard deviation

GFDL ESM2M (1981-2022)

GFDL ESM2M September 1981-2022 mean standard deviation

MPI ESM1 (1956-1997)

MPI ESM1 September 1956-1997 mean standard deviation



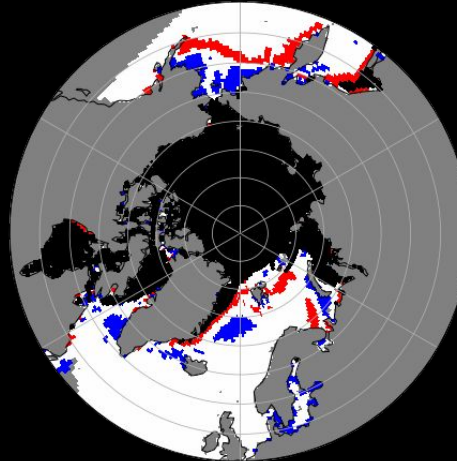
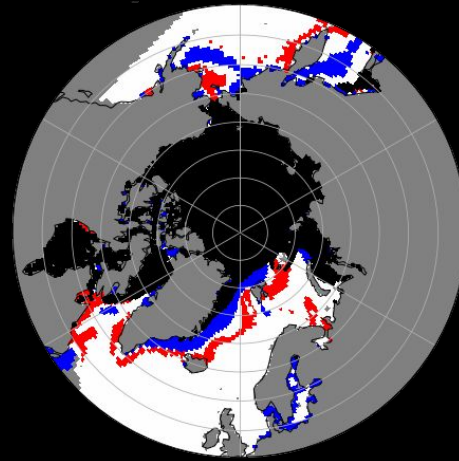
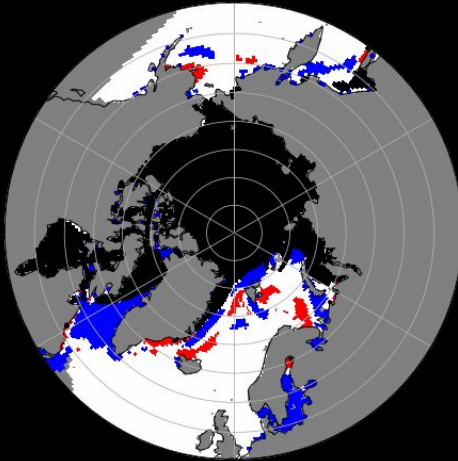
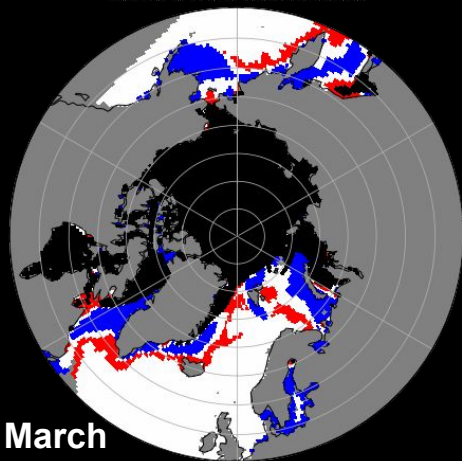
September

CanESM2 (1984-2025)

CESM1 (2010-2051)

GFDL ESM2M (2026-2067)

MPI ESM1 (1963-2004)



March

CESM1 (1989-2030)

GFDL ESM2M (1981-2022)


MPI ESM1 (1956-1997)

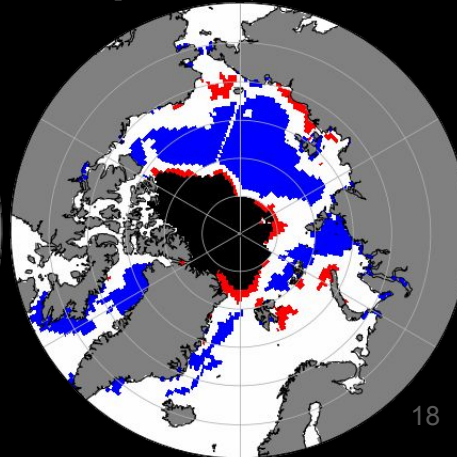
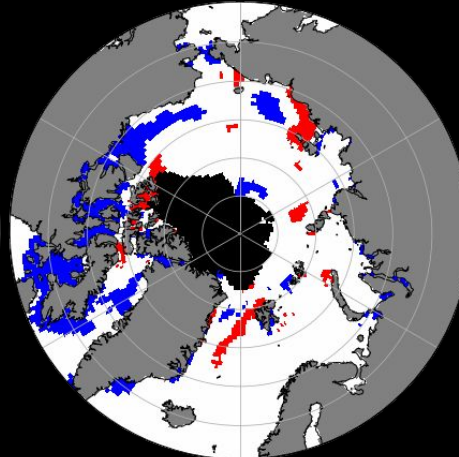
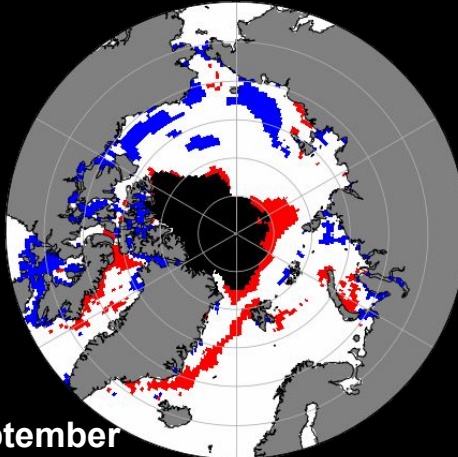


Variability too low
in all members



Variability too high
in all members

 >97% SIC



September

Conclusions

- Resampling does not capture all internal variability - typically a half to a third to that of a large ensemble
- There is large variation in internal variability realism between models in September, with more agreement in March.
- When using a resampling technique, the internal variability for most regions and models is not inconsistent with observations.