

# Predictability of an ice-free Arctic using the CESM Large Ensemble

**Alexandra Jahn**

University of Colorado Boulder

Atmospheric and Oceanic Sciences & Institute for Arctic and  
Alpine Research

Collaborators: Marika Holland, Jennifer Kay

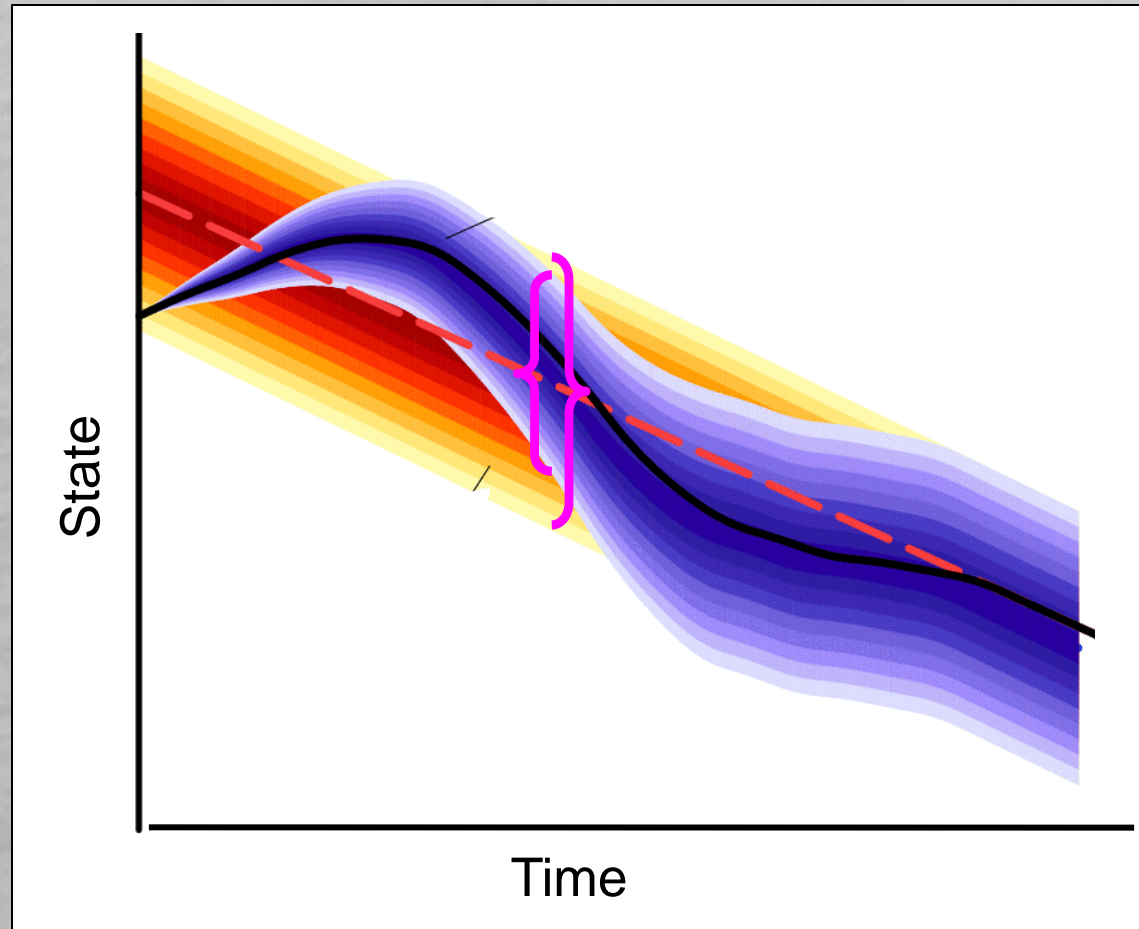
# Kinds of Predictability

## Of the First Kind:

- Initial value problem
- Sensitive dependence on initial conditions limits predictability
- Timescale depends on system

## Of the Second Kind:

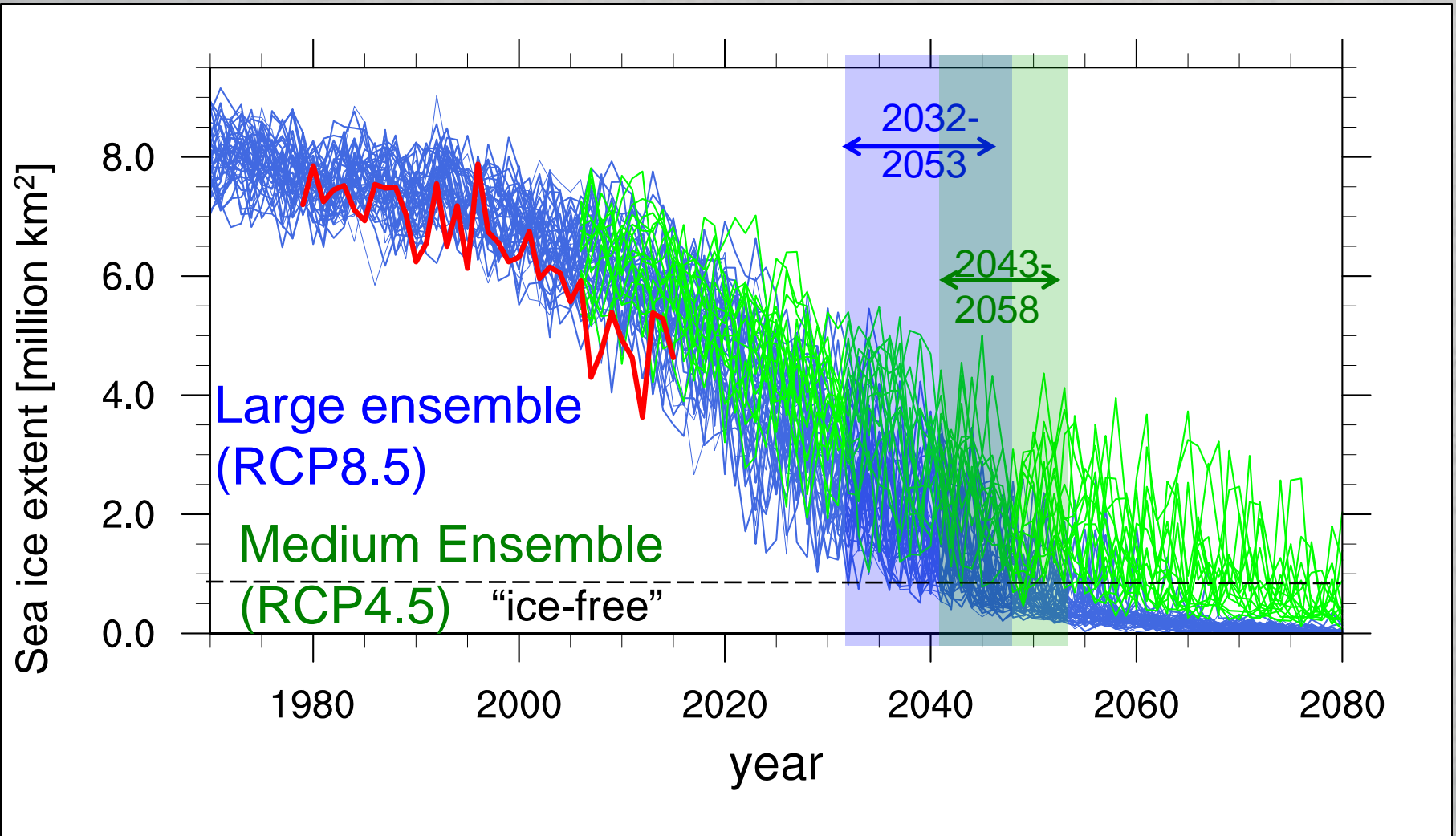
- Boundary value problem
- Prediction of statistical properties of the climate system subject to some external forcing



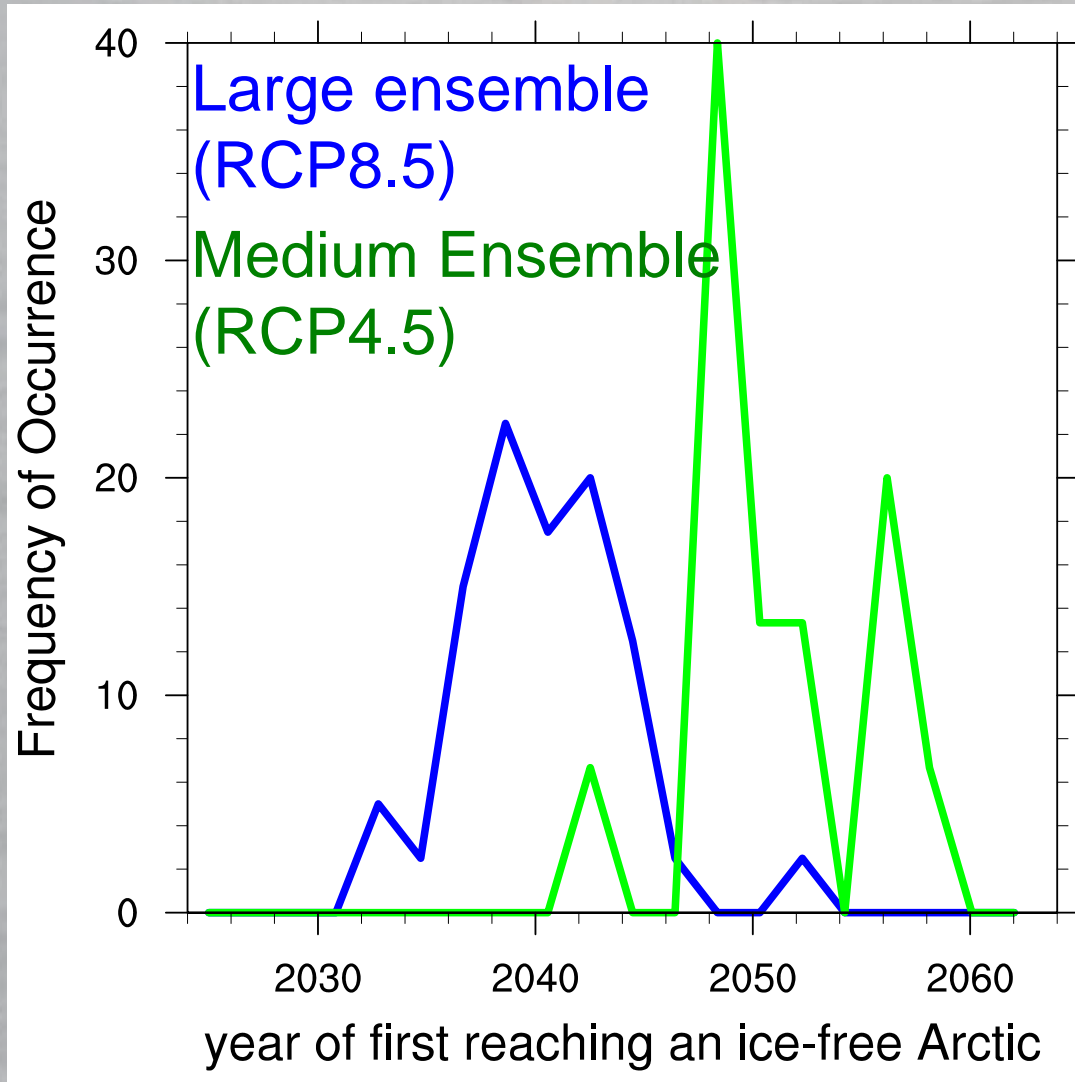
(Adapted From Branstator  
and Teng, 2011)

Slide courtesy of Marika Holland

# When will we first see an "ice-free" Arctic Ocean in September?

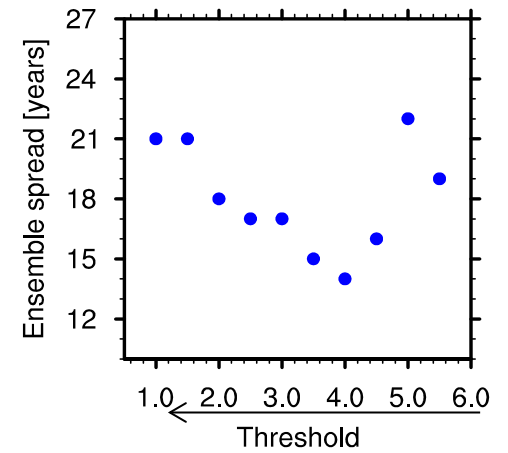
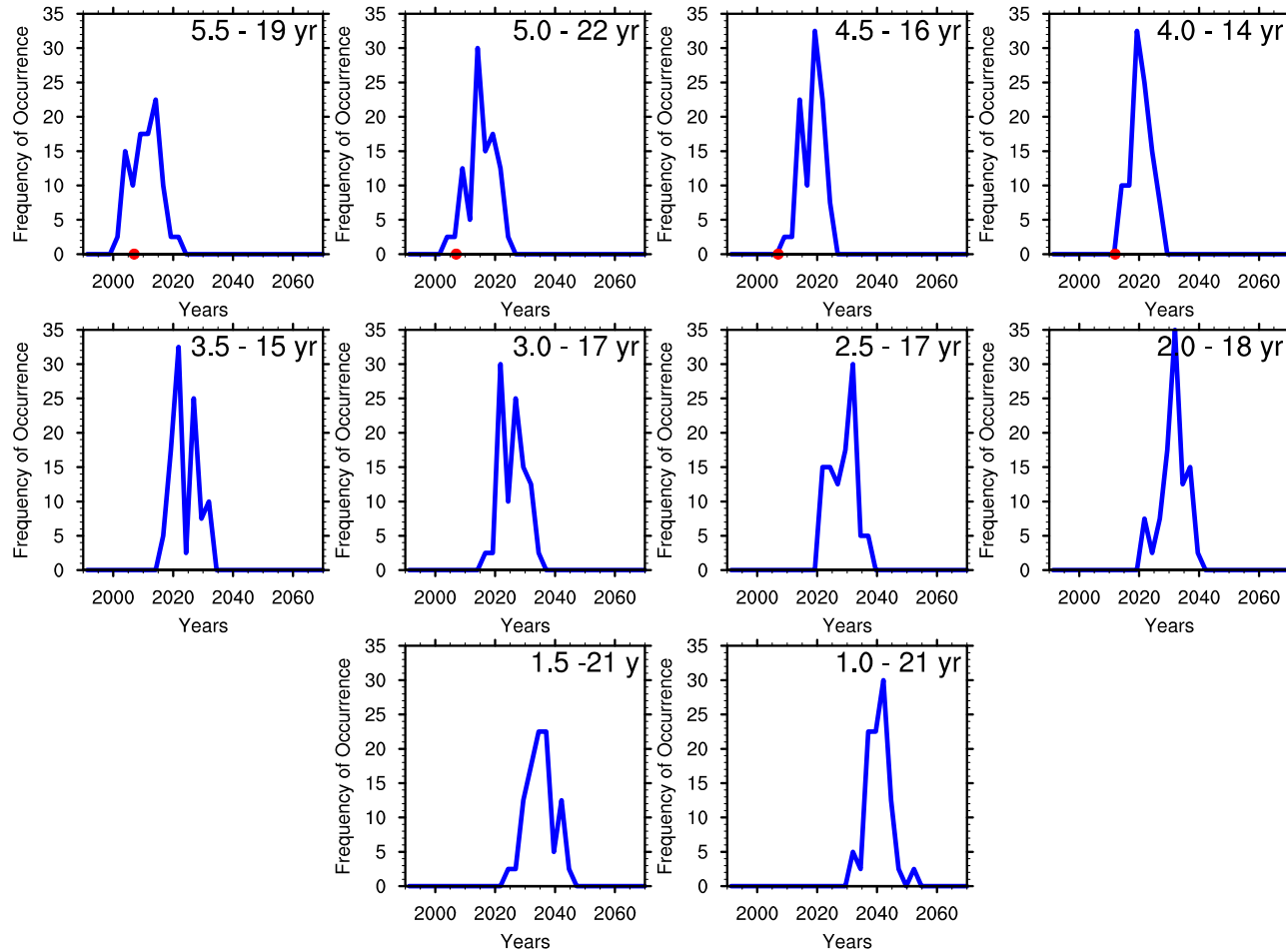


# When will we first see an "ice-free" Arctic Ocean in September?



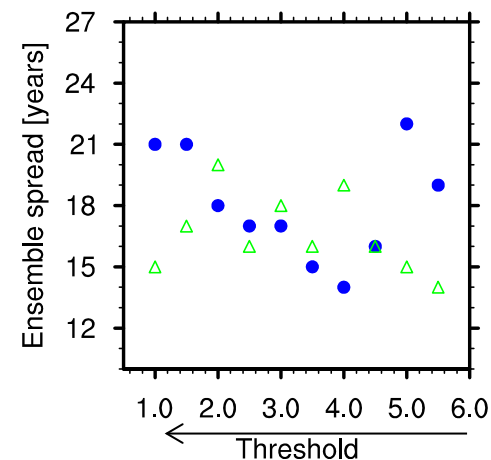
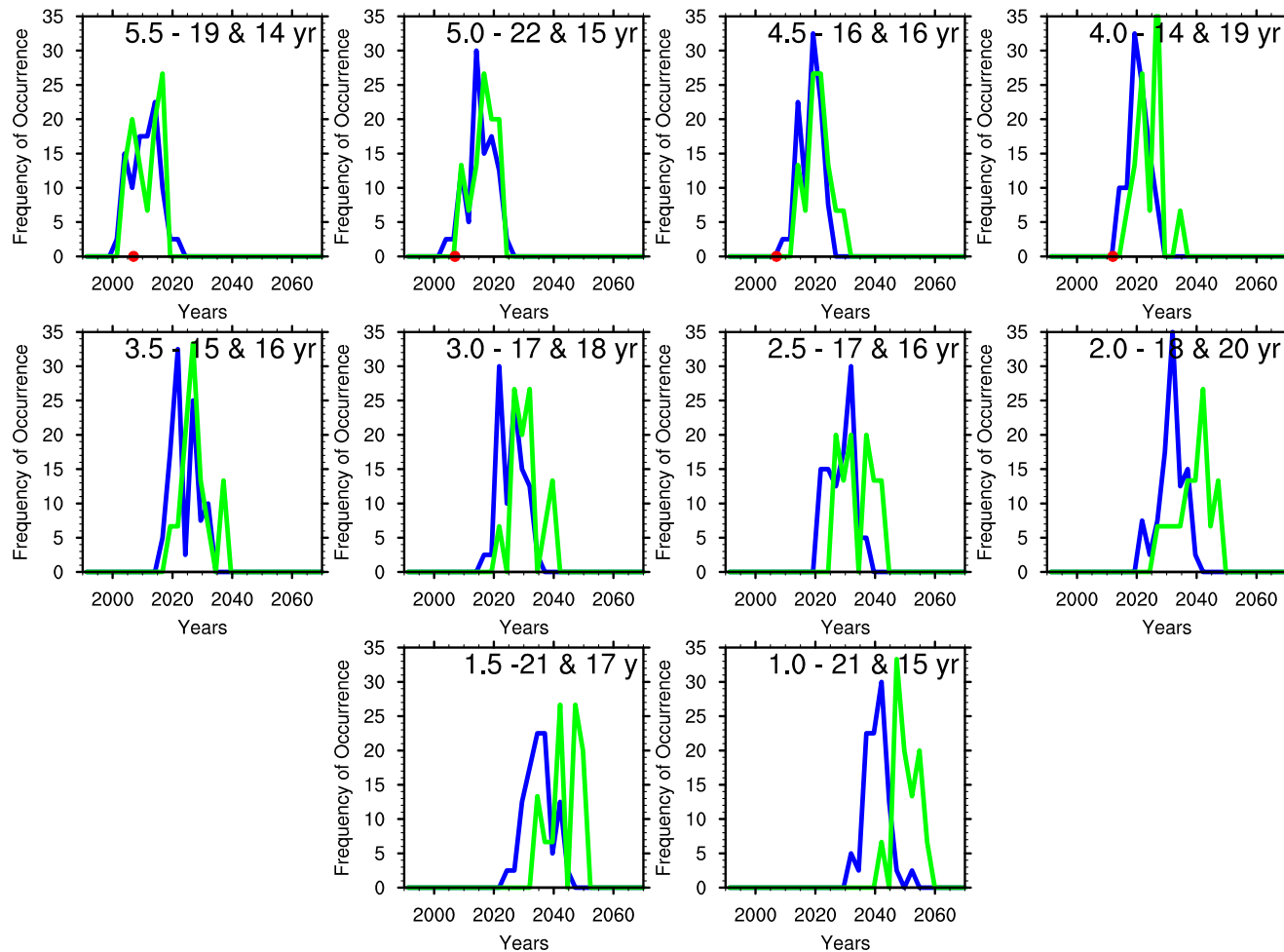
21 year (LE)  
and 15 year  
(ME)  
uncertainty  
range due to  
internal  
variability  
alone

# Other thresholds



# Other thresholds & ME

Jahn et al., in prep

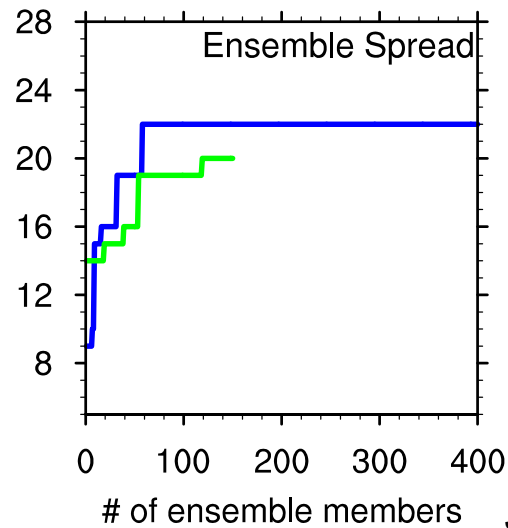
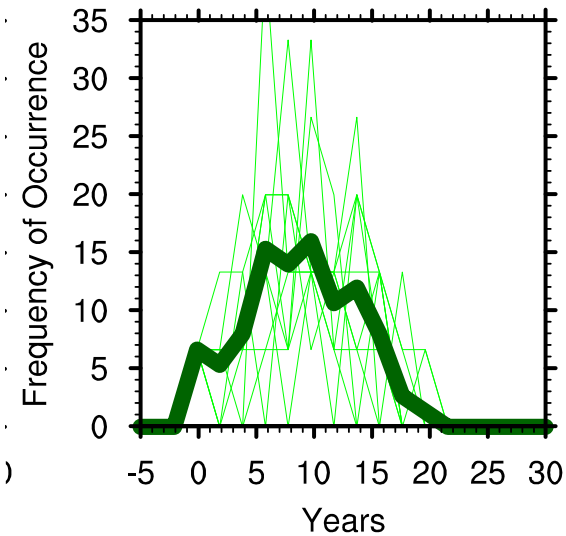
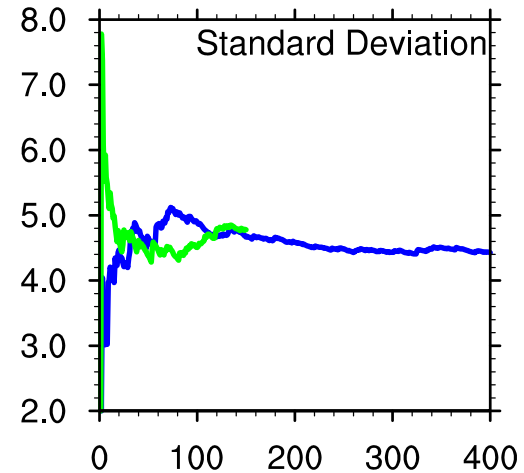
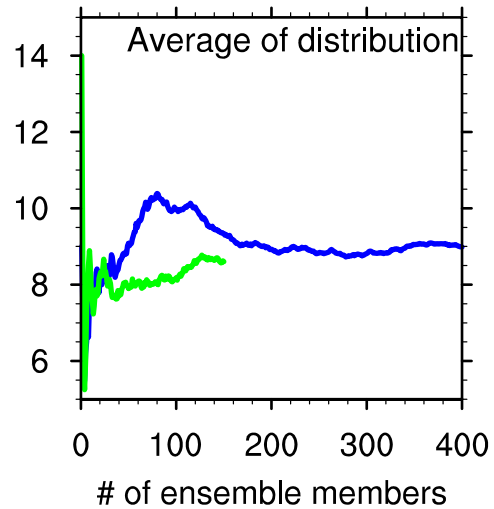
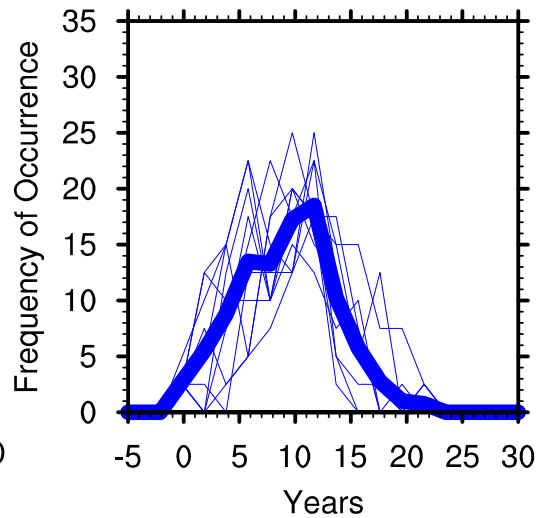


LE (RCP8.5)

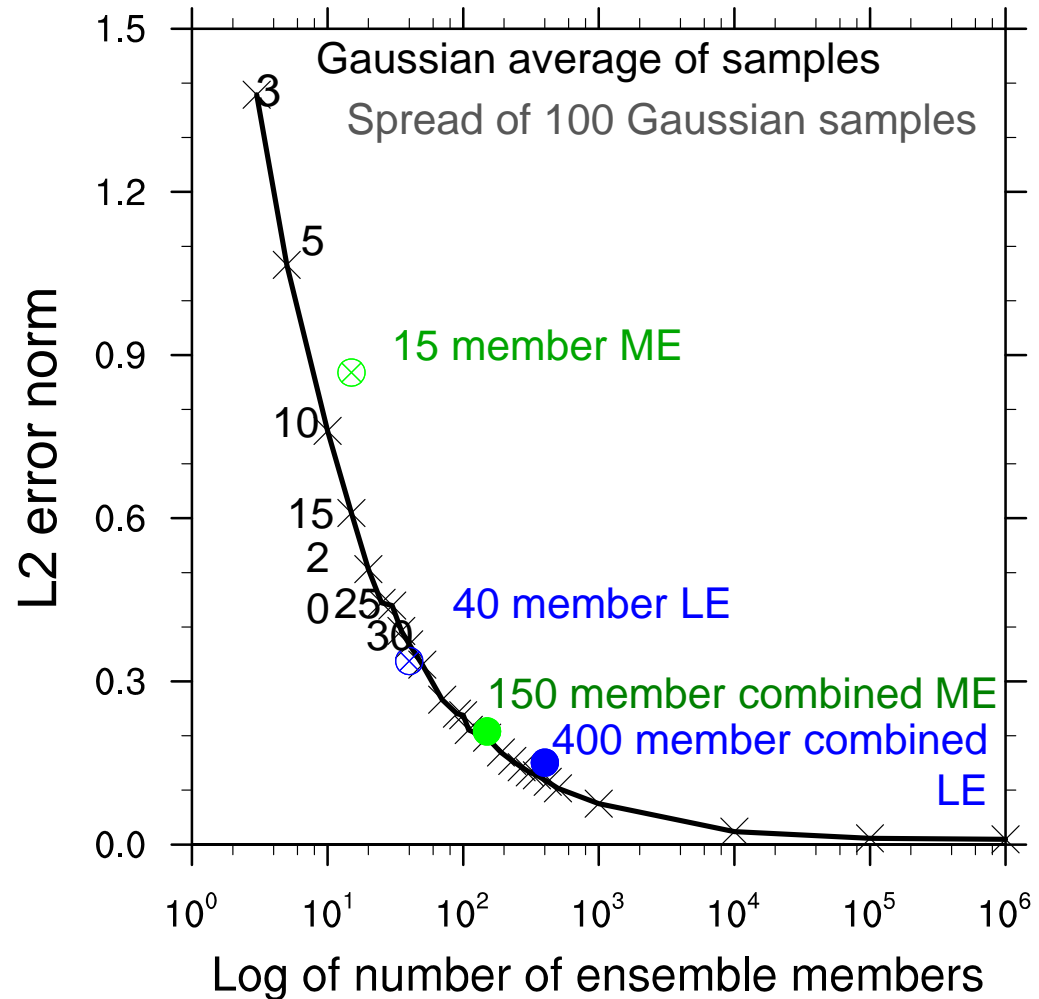
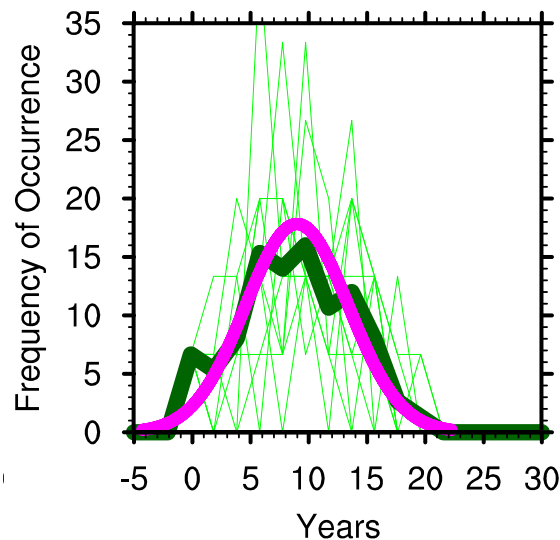
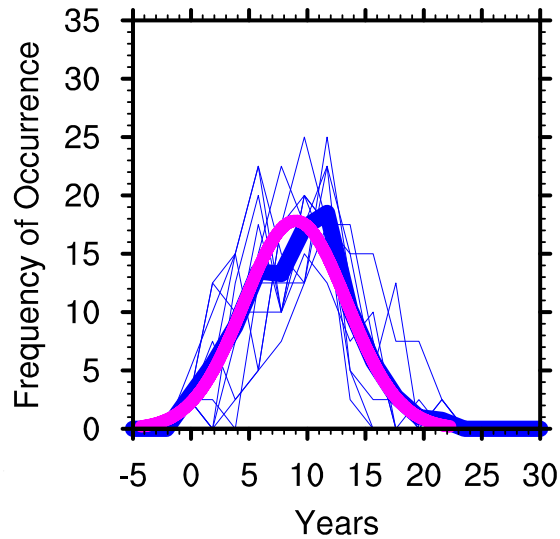
ME (RCP4.5)

Large uncertainty in prediction of threshold crossing due to internal variability

# Are 40 members enough?

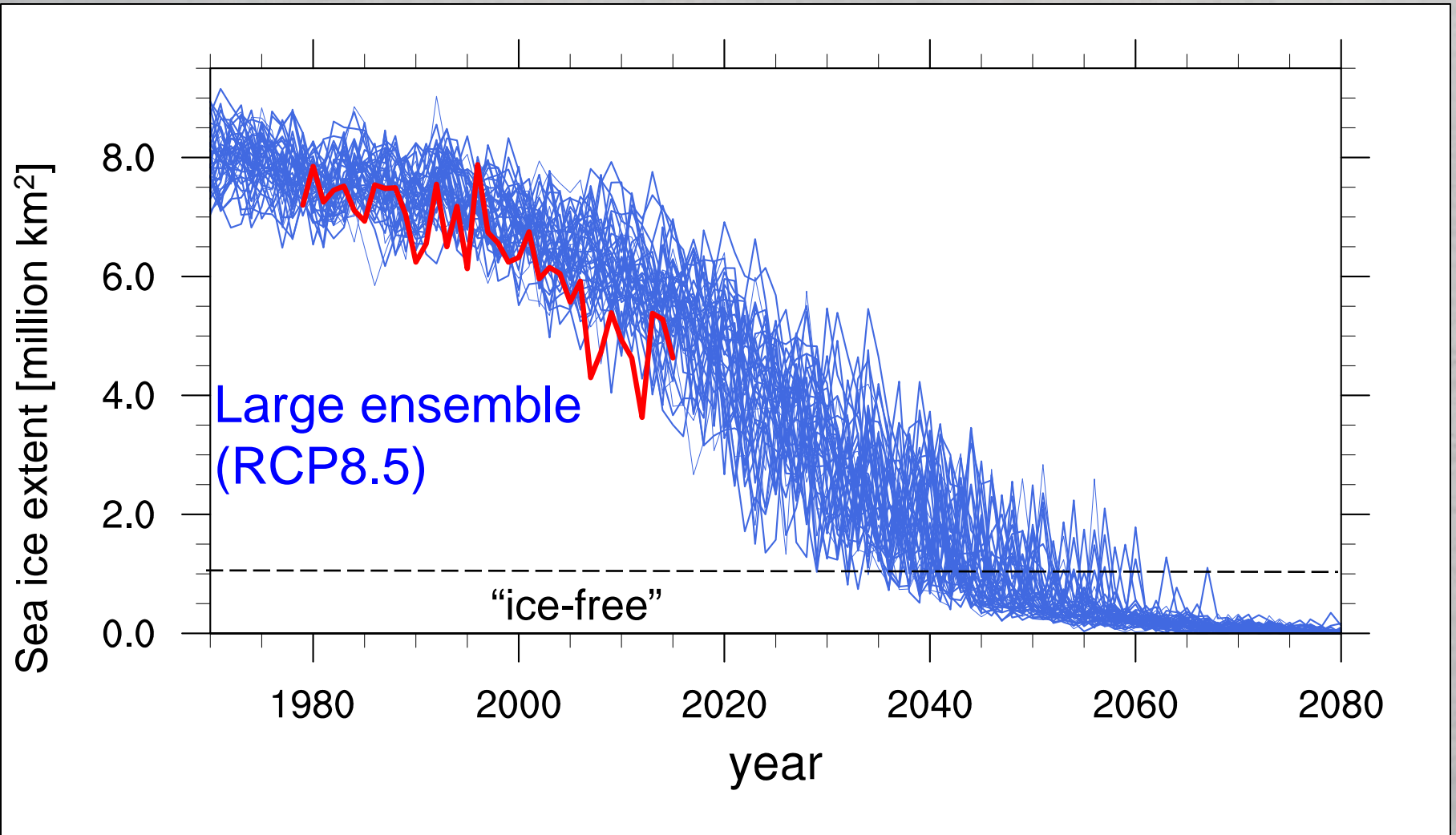


# How many members do we need?





# Can we tell which CESM trajectory is most likely, given present sea ice state?



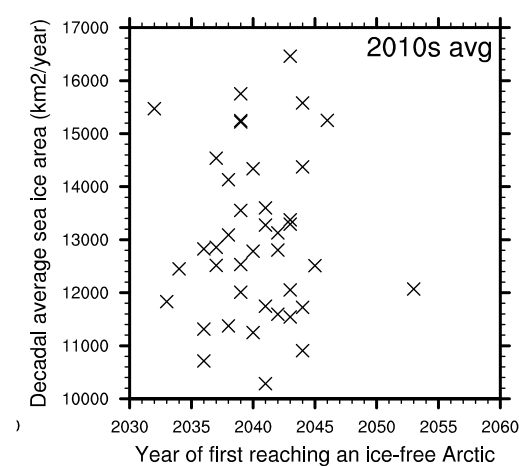
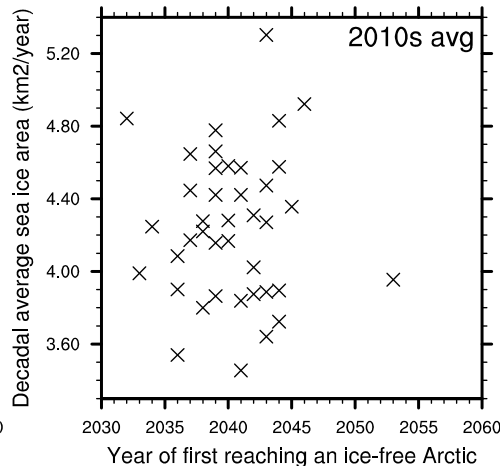
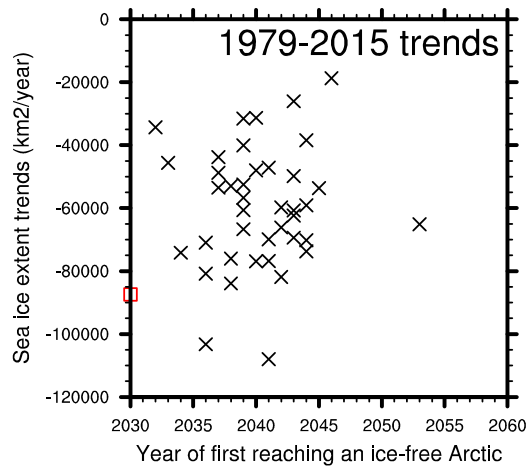
# Any indication of which trajectory we are on, based on current sea ice state?

Sea ice extent trend versus ice-free year

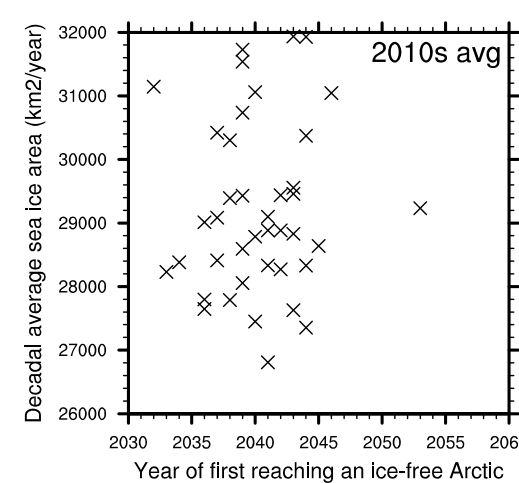
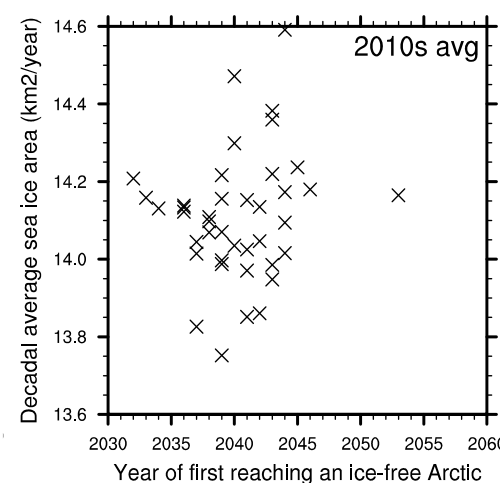
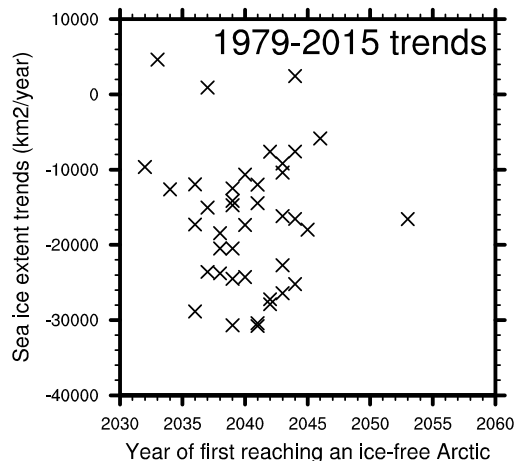
Decadal average sea ice area versus ice-free year

Decadal average sea ice volume versus ice-free year

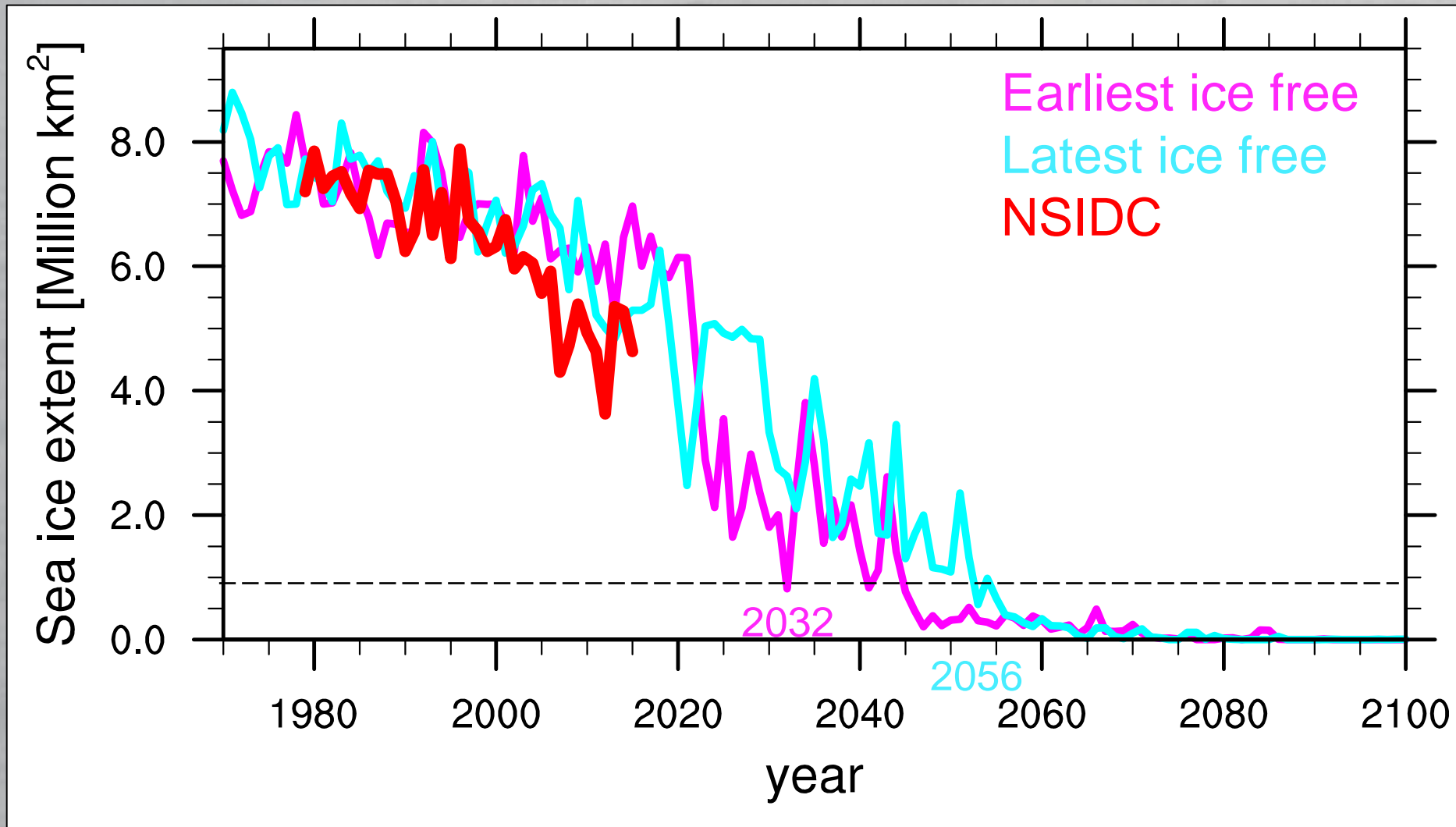
September



March



# Trajectory of early versus late ice-free simulations

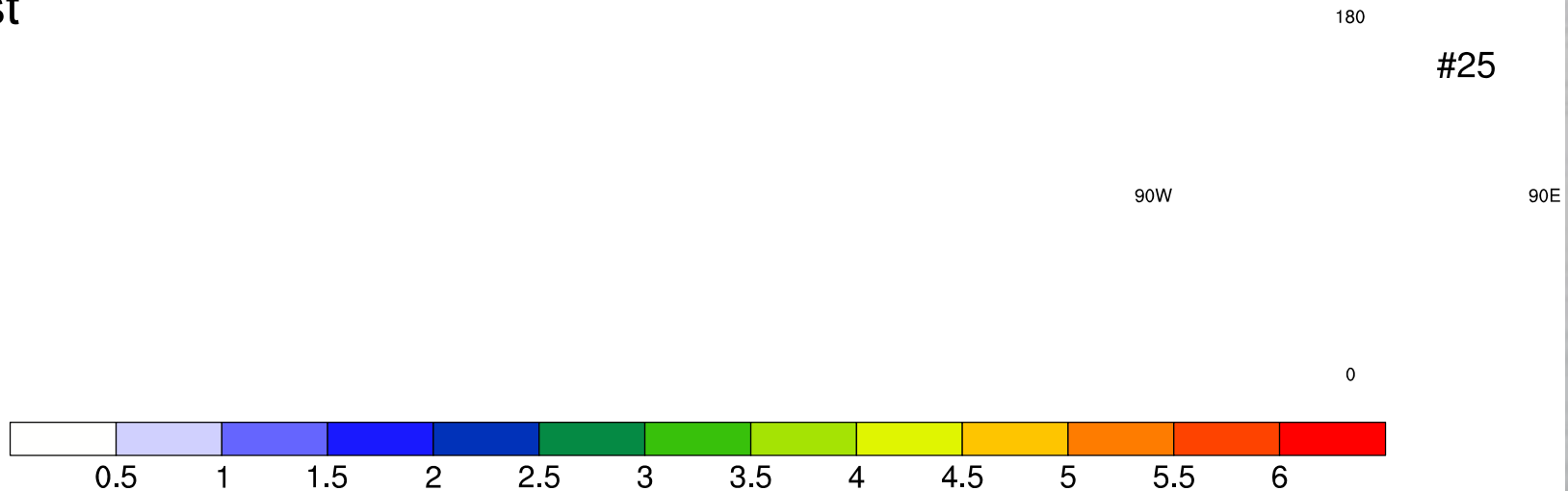


# Sea ice thickness in early versus late ensemble members (Sept)

Latest



Earliest



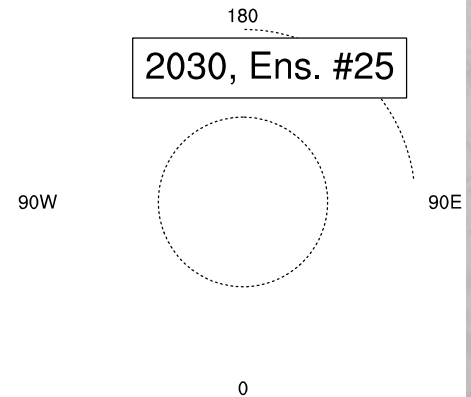
Ice thickness in 2015 or 2020 is no indicator for ice-free conditions in 2032 or later

# Sea ice thickness in early versus late ensemble members (March)

Latest



Earliest



Ice thickness in 2015 or 2020 is no indicator for ice-free conditions in 2032 or later

Jahn et al., in prep

# Summary

- Internal variability introduces uncertainty ~20 years to predictions of threshold crossing in the Arctic sea ice cover
- In CESM, uncertainty based on internal variability is larger than scenario uncertainty between RCP8.5 and RCP4.5
- A large number of ensemble members is needed to fully represent the distribution, but each addition member improves statistics of simulated climate
- The current sea ice state in CESM can **not** be used as an indicator of which ensemble member will be ice-free first