# 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

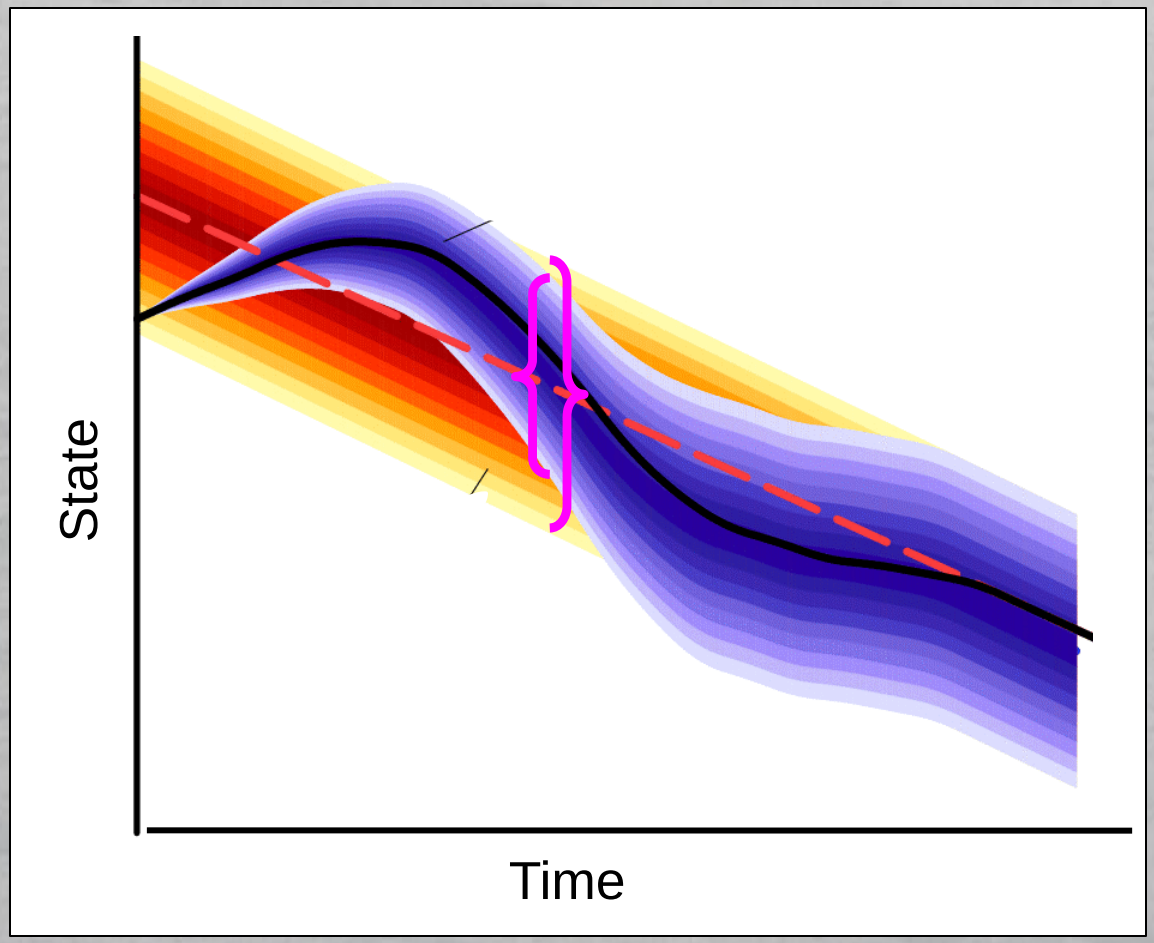
# Kinds of Predictability

Of the First Kind:

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

Of the Second Kind:

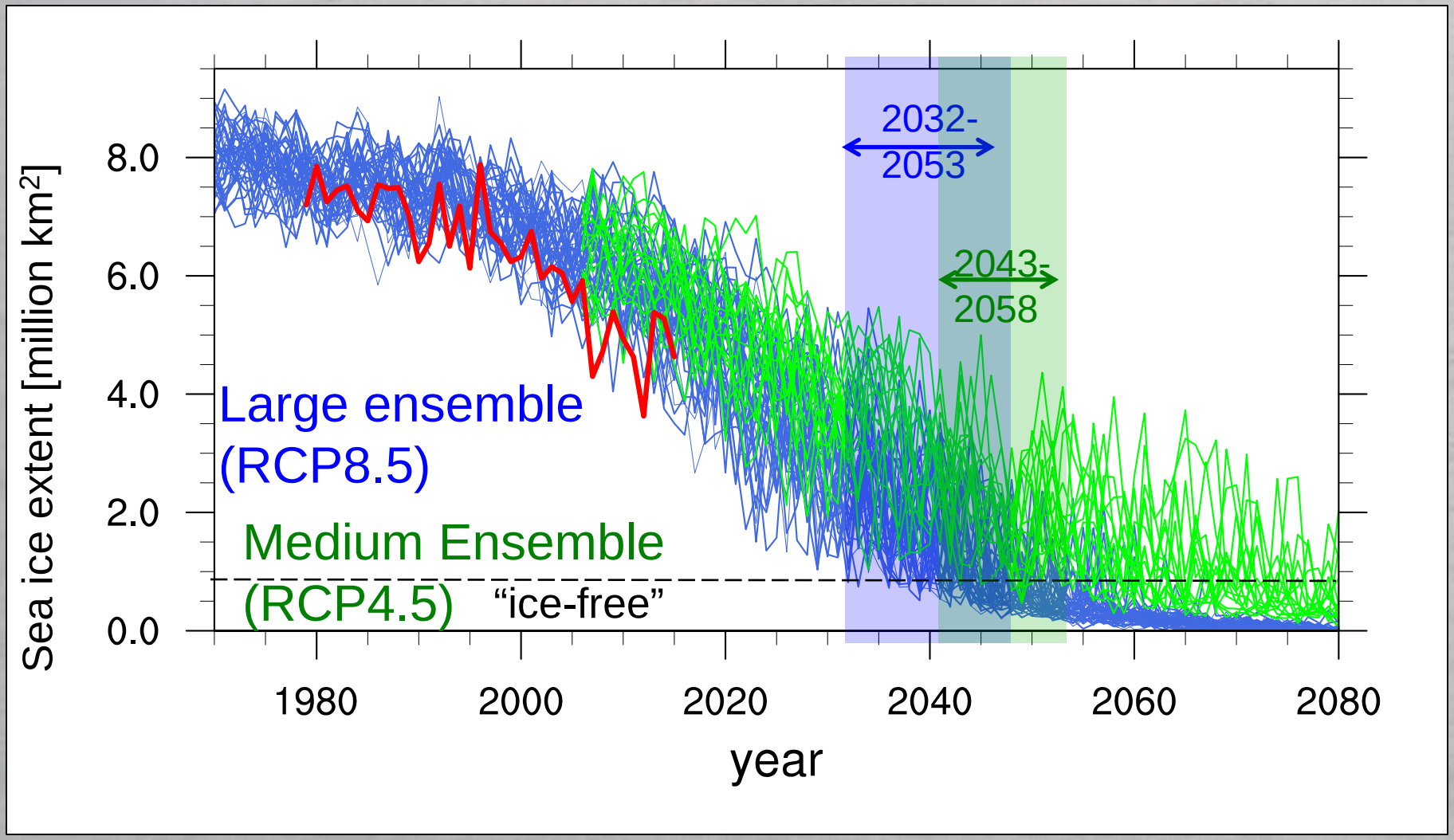
- Boundary value problem
- Prediction of statistical properties of the climate system subject to some external forcing




(Adapted From Branstator and Teng, 2011)

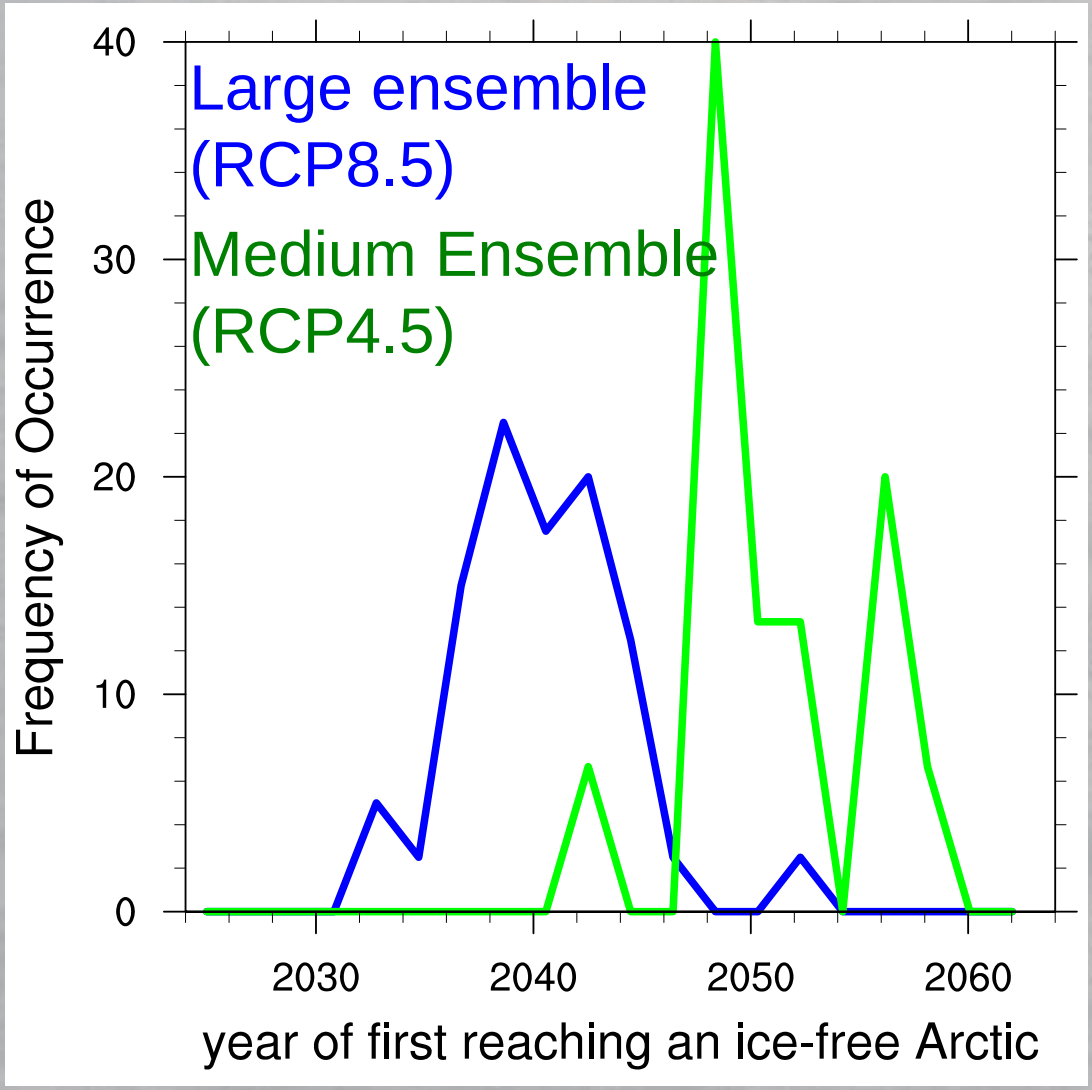
Slide courtesy of Marika Holland

# When will be first see an “ice-free” Arctic Ocean in September?




Jahn et al., in prep

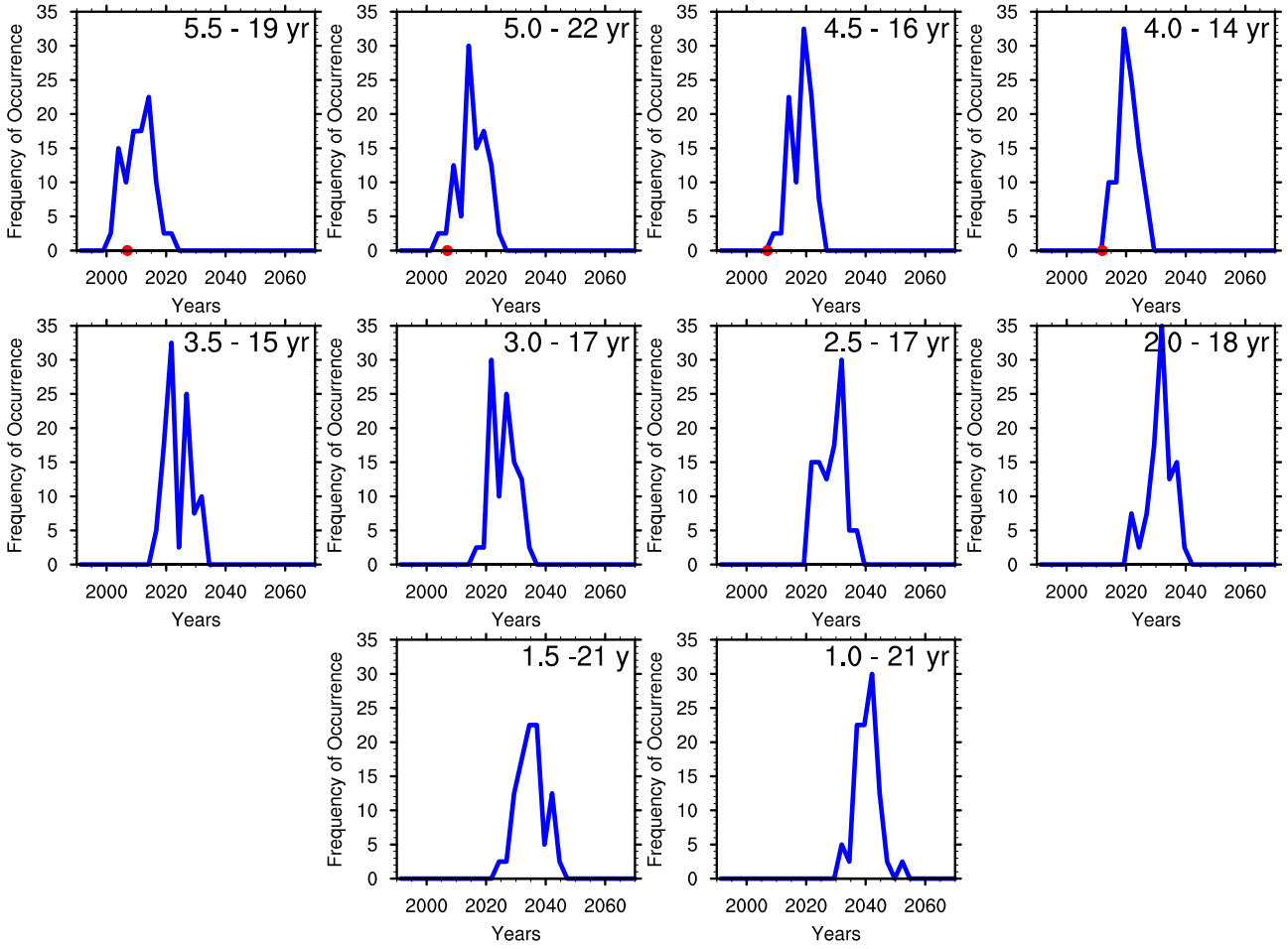
# When will be first see an “ice-free” Arctic Ocean in September?

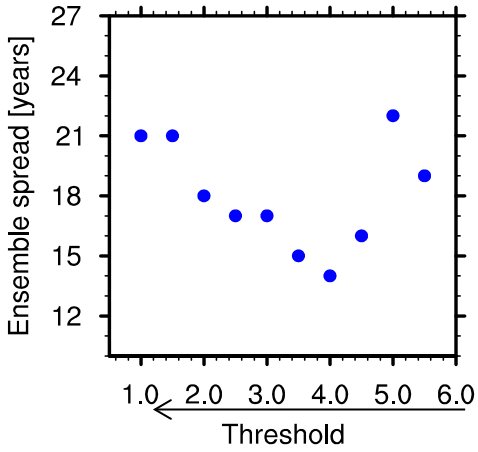



21 year (LE) and 15 year (ME) uncertainty range due to internal variability alone

Jahn et al., in prep

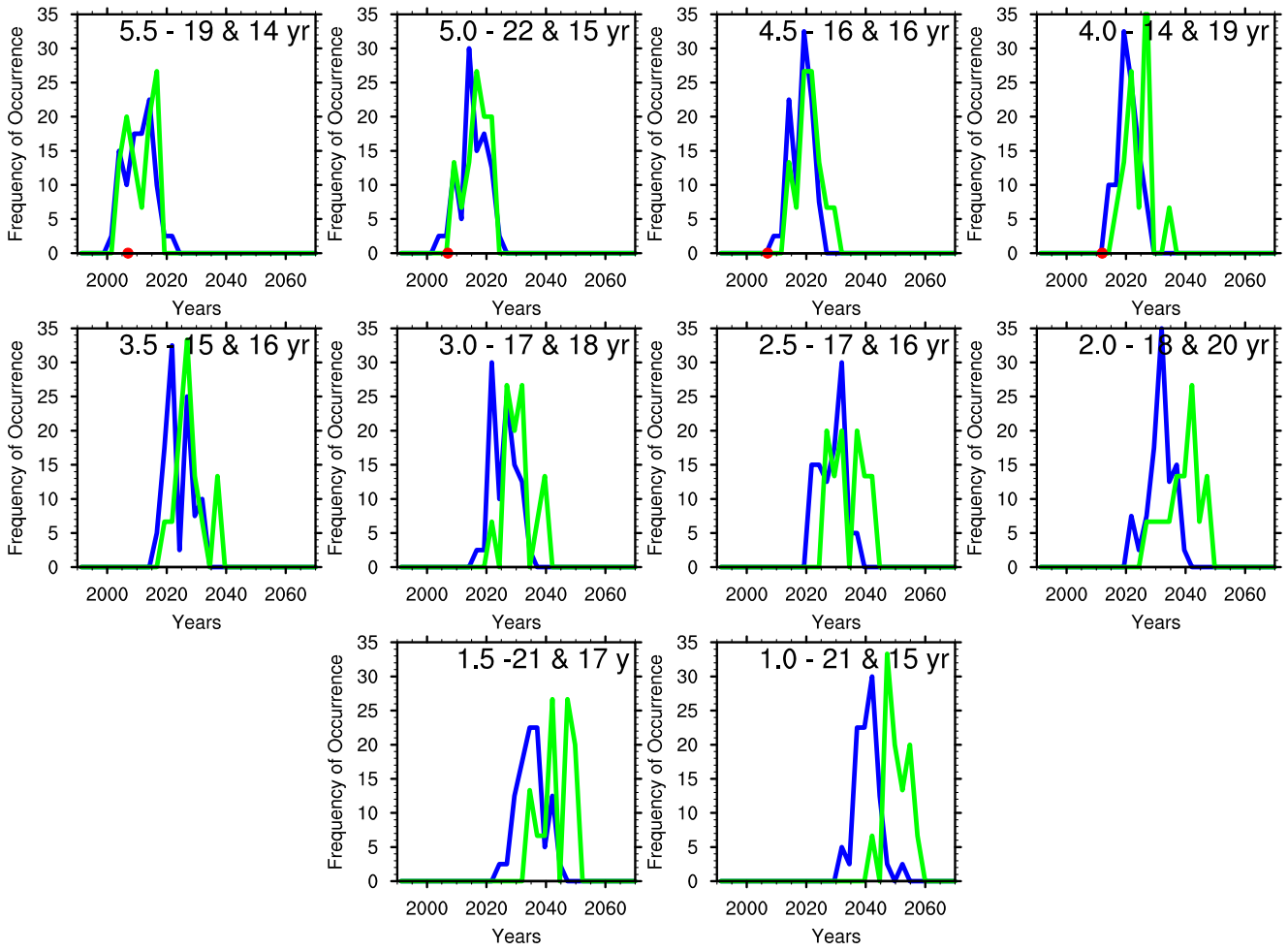
# Other thresholds




Jahn et al., in prep

# Other thresholds & ME

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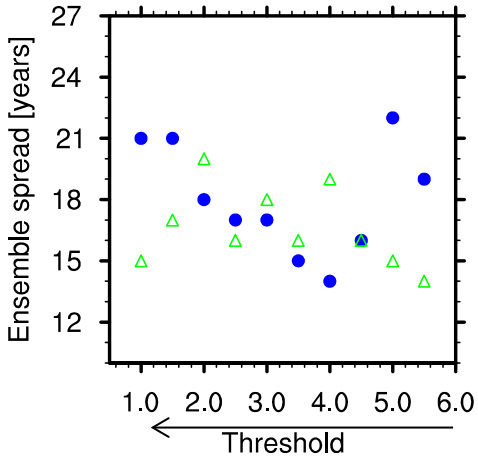
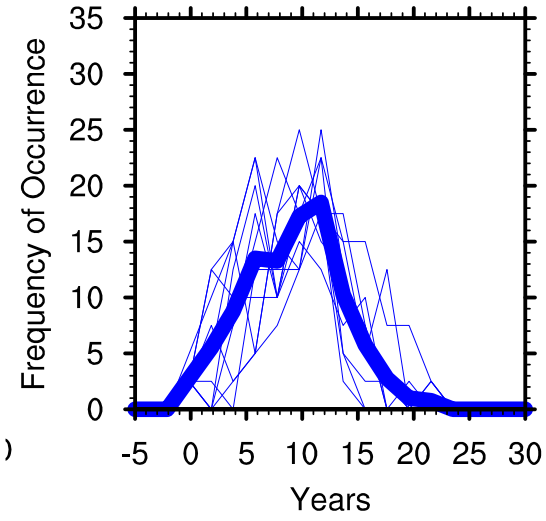


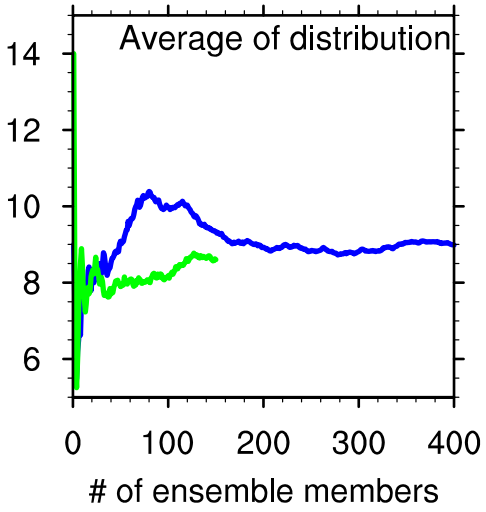

LE (RCP8.5)

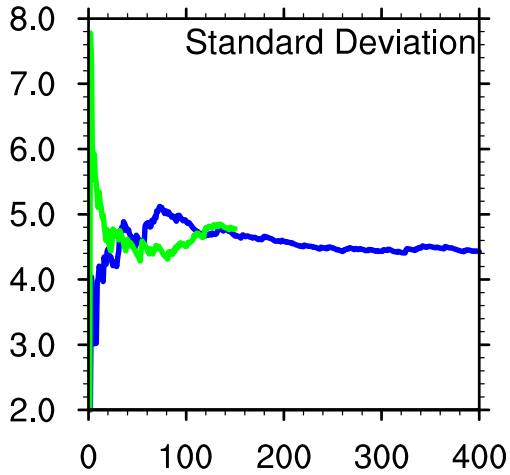
ME (RCP4.5)

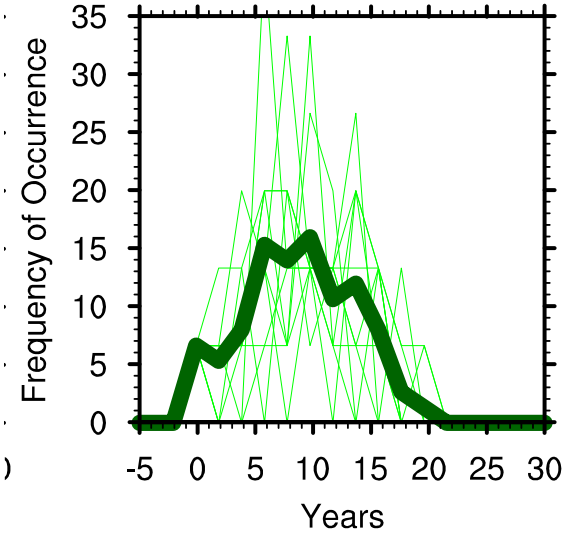
Large uncertainty in prediction of threshold crossing due to internal variability

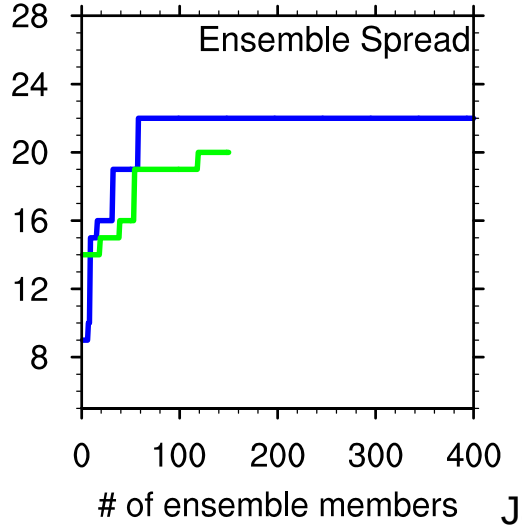
# Are 40 members enough?

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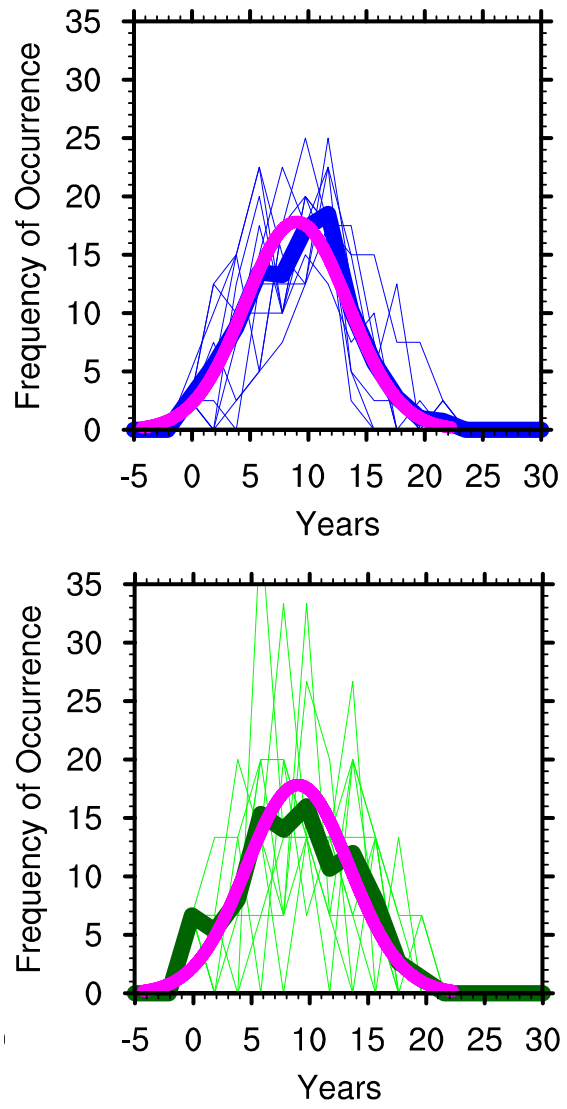
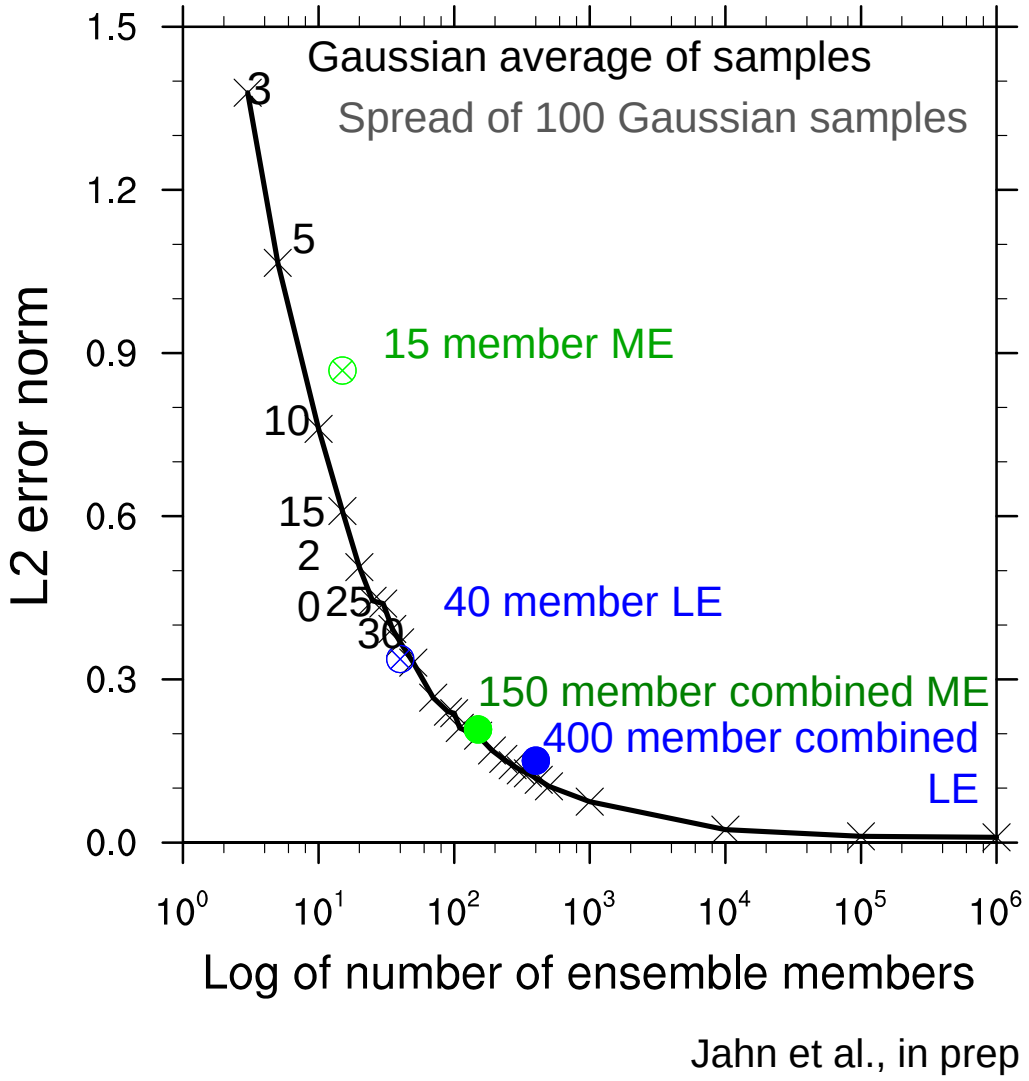
# How many members do we need?

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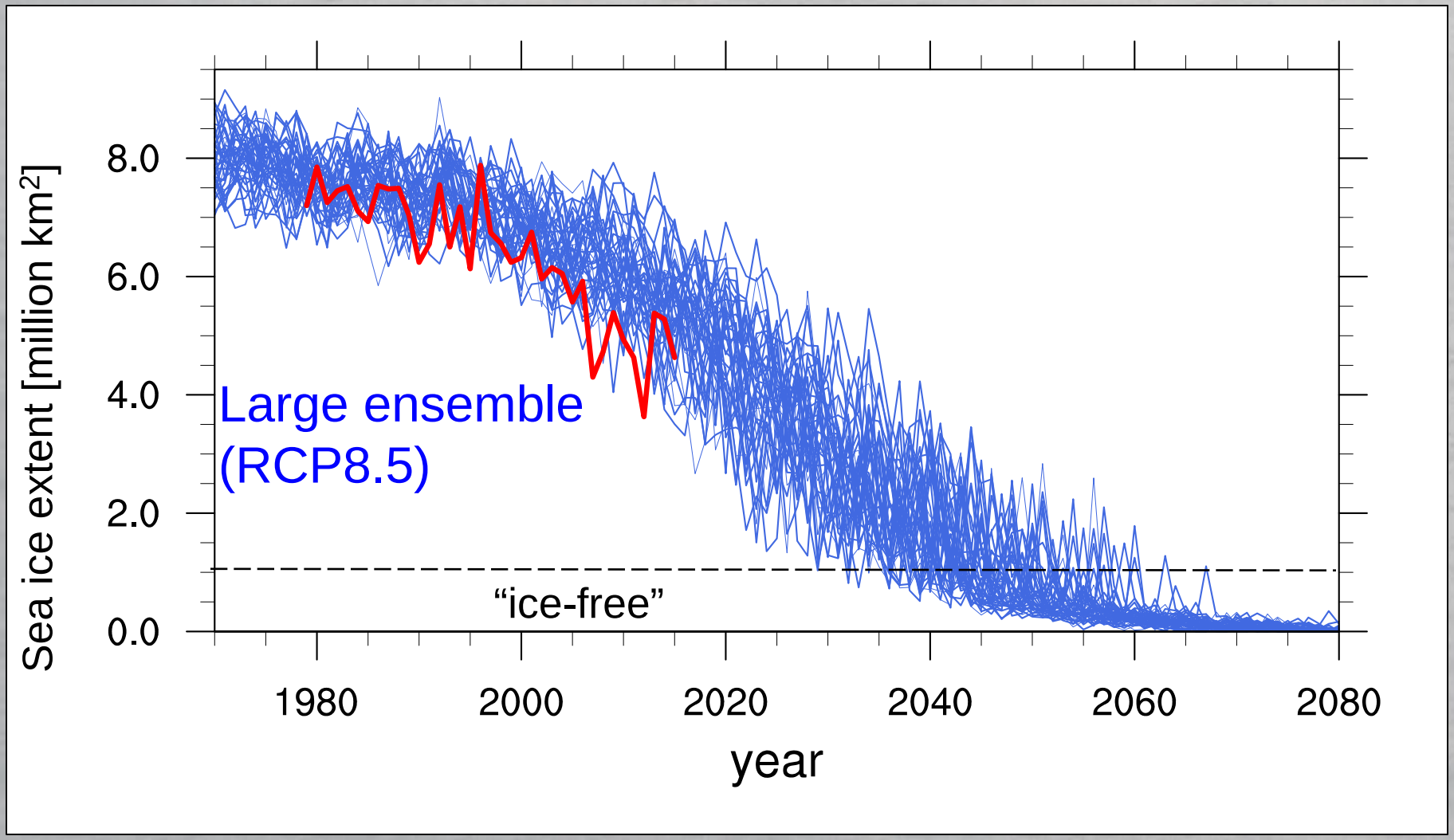
# Can we tell which CESM trajectory is most likely, given present sea ice state?

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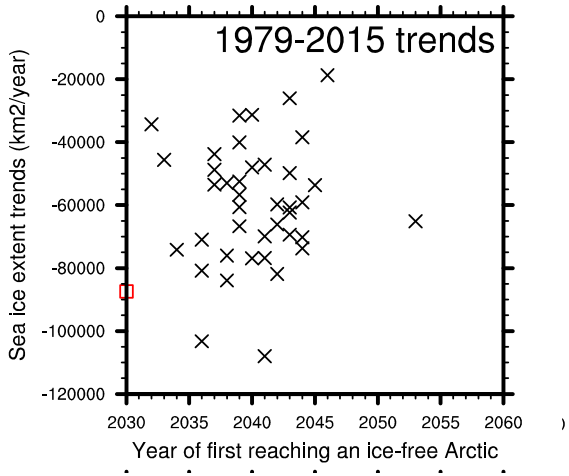
# Any indication of which trajectory we are on, based on current sea ice state?

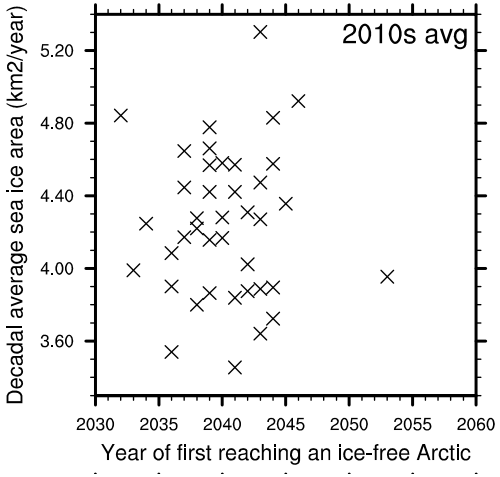
Sea ice extent trend versus ice-free year

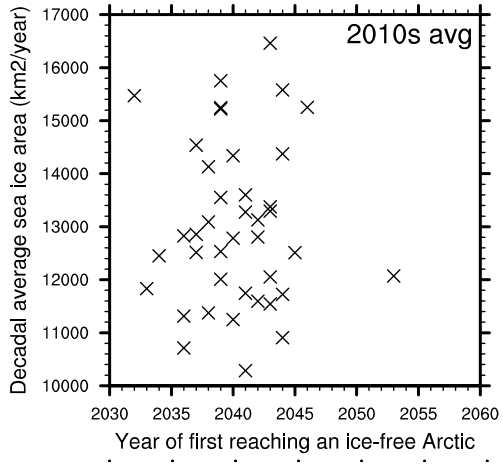
Decadal average sea ice area versus ice-free year

Decadal average sea ice volume versus ice-free year

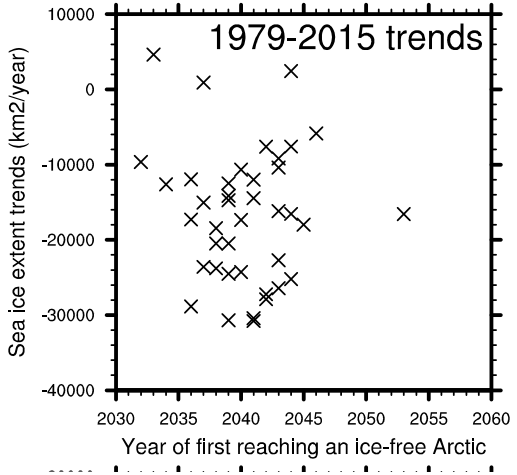
September

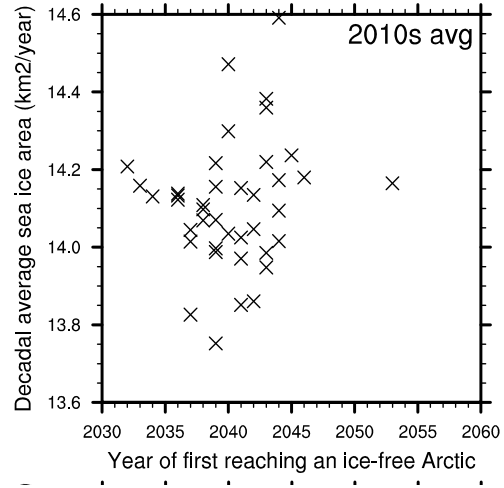


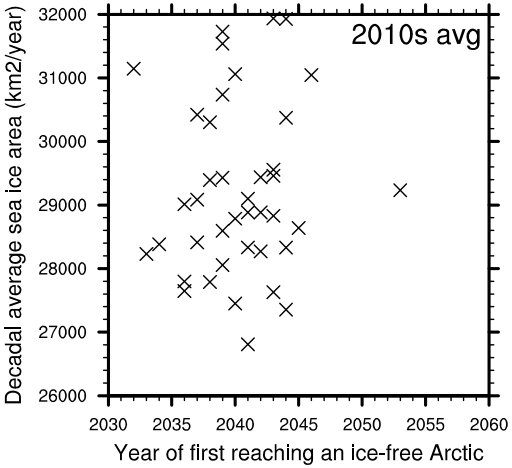




March

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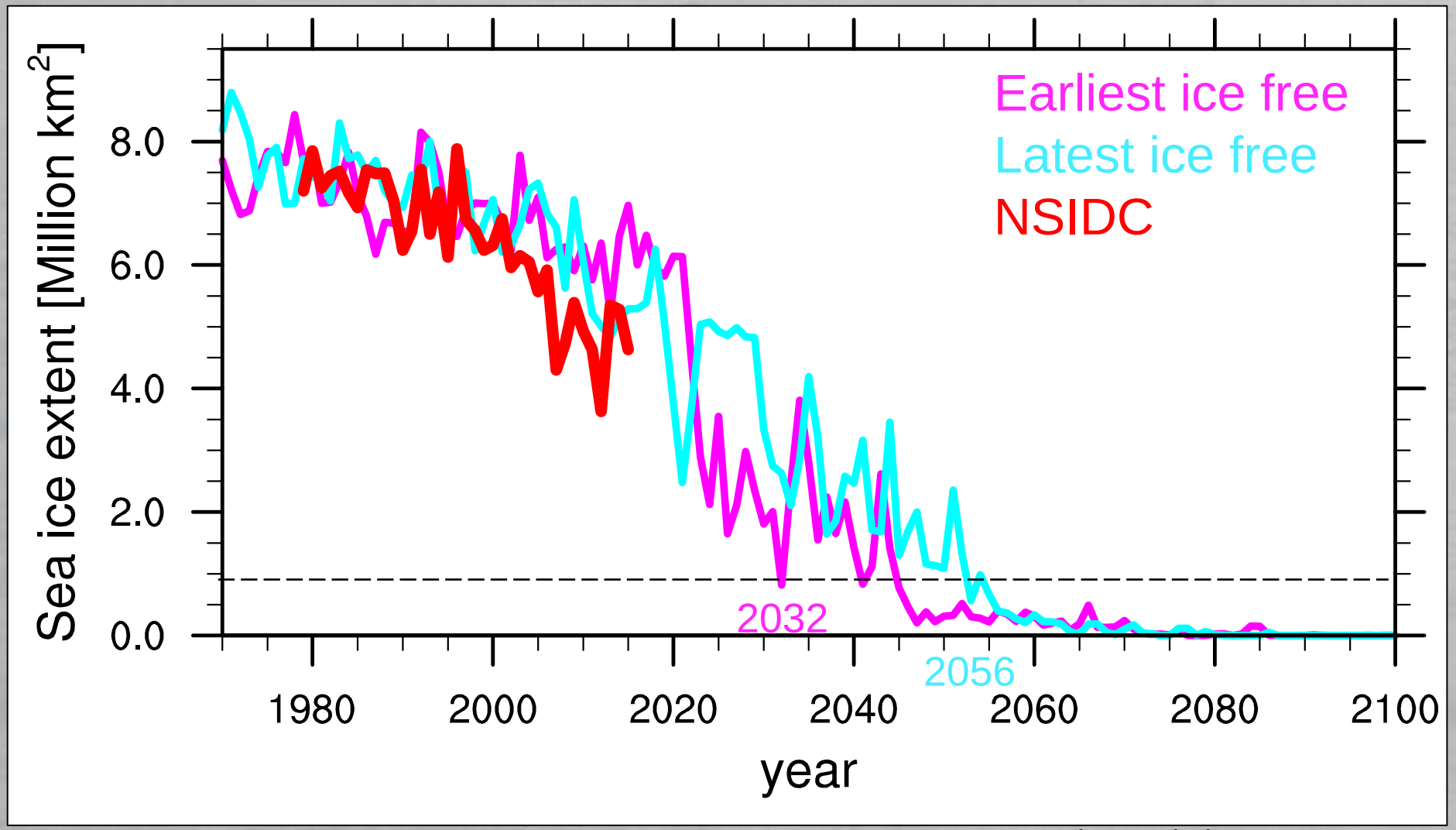
# Trajectory of early versus late ice-free simulations

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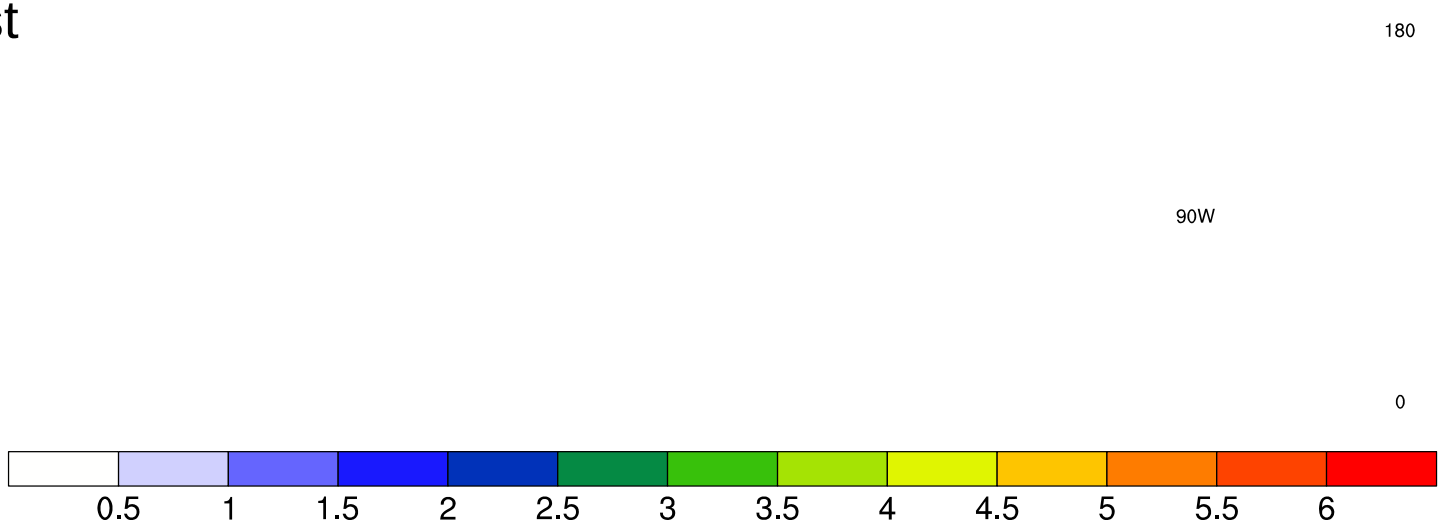
# Sea ice thickness in early versus late ensemble members (Sept)

Latest

Earliest




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

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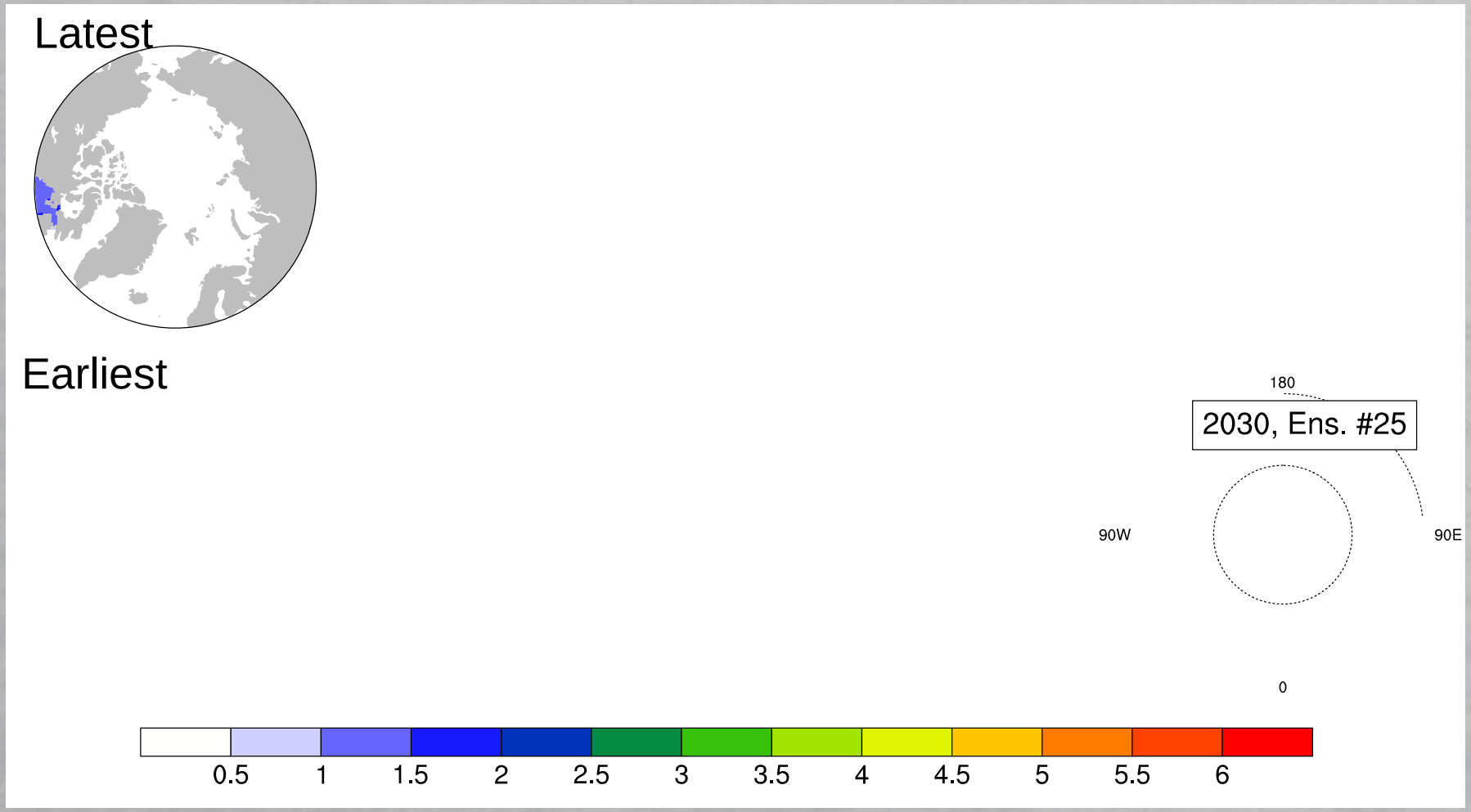
# Sea ice thickness in early versus late ensemble members (March)

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# 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