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The interpretation of biases in decadal climate predictions

Ed Hawkins, Buwen Dong, Jon Robson, Rowan Sutton

NCAS-Climate, University of Reading

e.hawkins@reading.ac.uk

@ed_hawkins

Two papers to be submitted to Climate Dynamics

University of Reading

Walker INSTITUTE

Mean bias in decadal predictions

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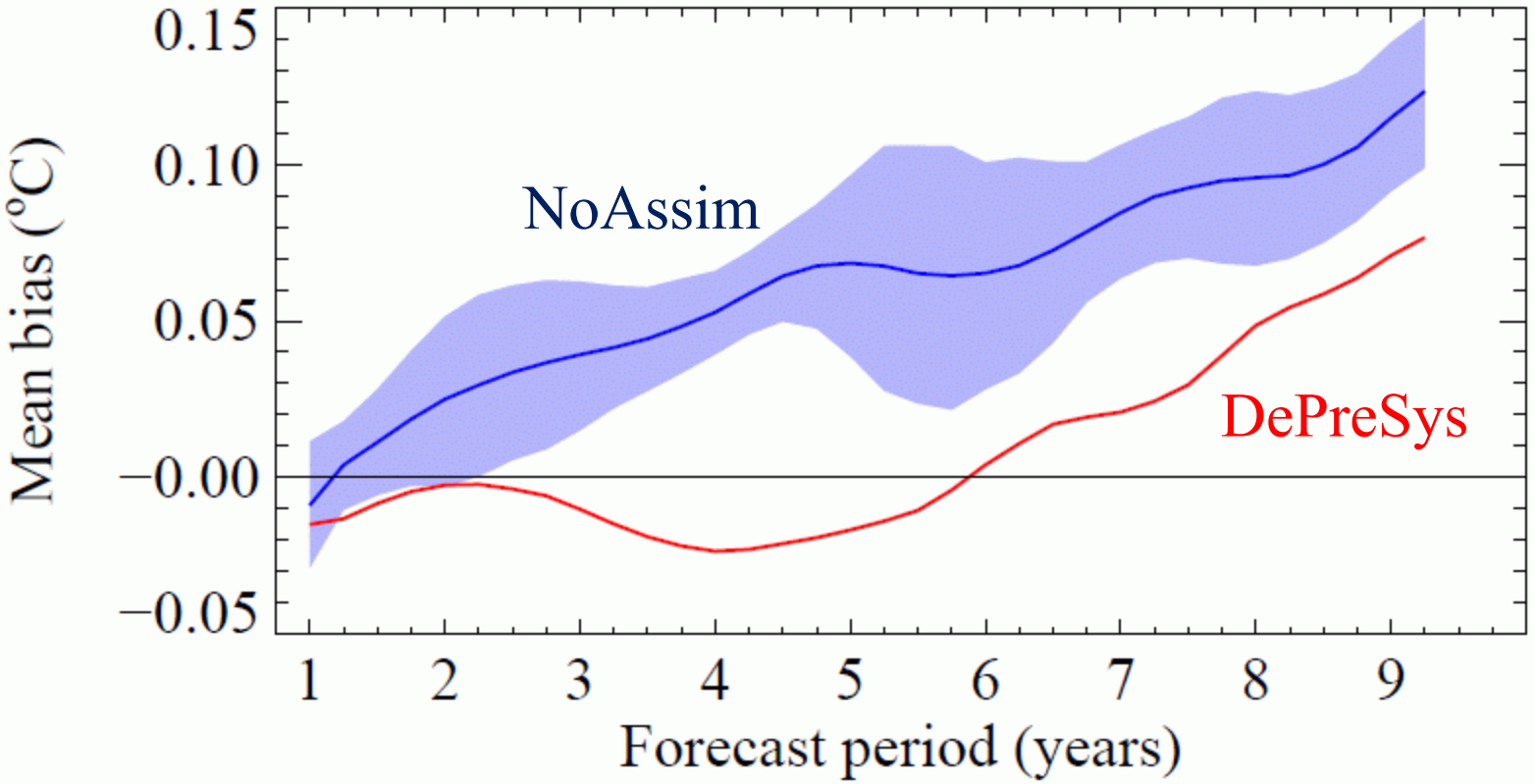

Smith et al. 2007

Summary

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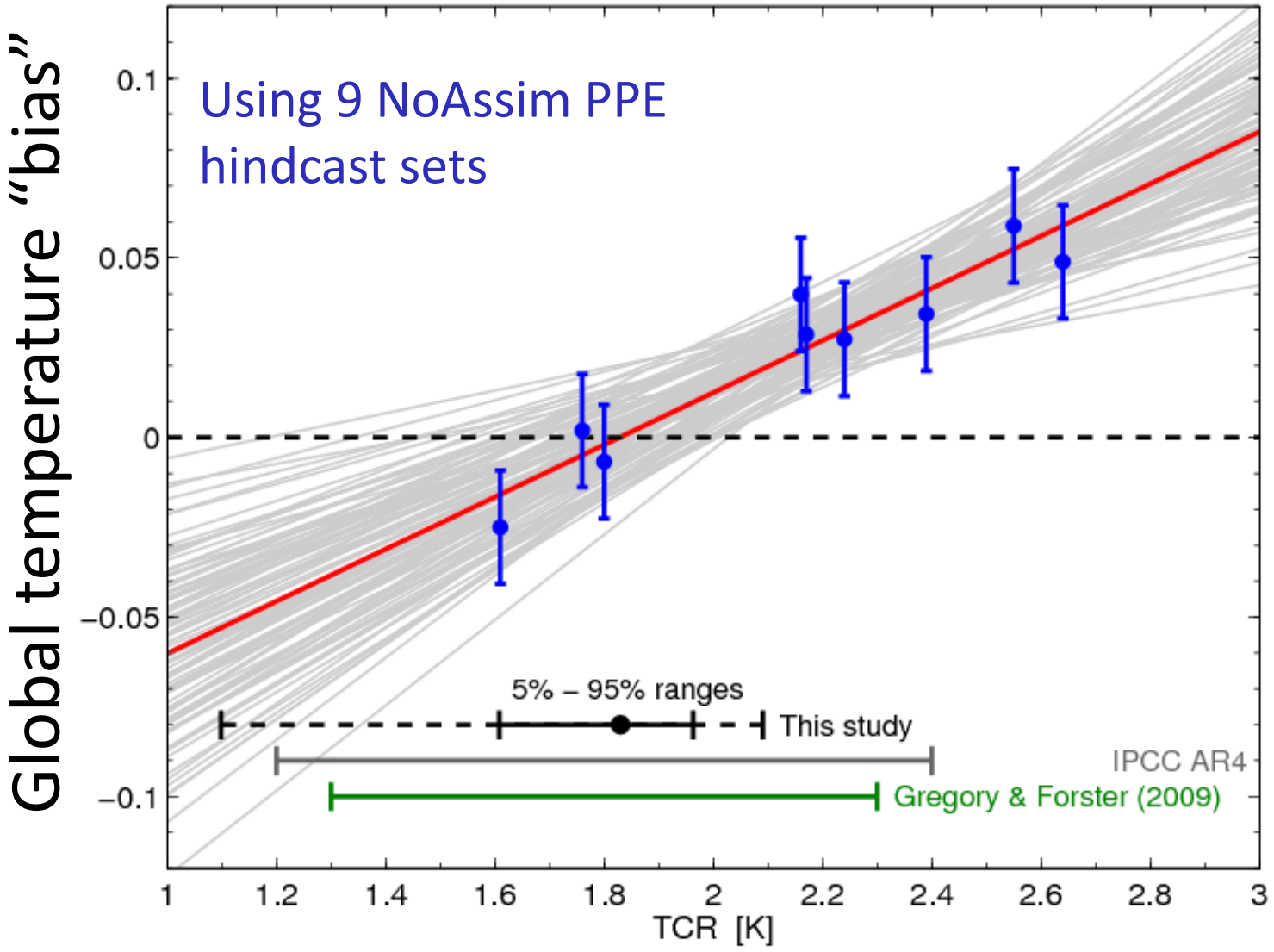
Relating bias to transient climate response (TCR)



Biases in decadal prediction systems

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- Possible causes of bias:
  - Sampling uncertainty, due to finite climatology period, hindcast period & ensemble size
  - Drift in transient model runs, especially in deep ocean
  - Errors in observations
  - Rapid adjustment ('shocks') due to initialisation
  - Errors in radiative forcings
    - Lead time dependent (i.e. volcanoes, solar)
    - Lead time independent (e.g. aerosols)
  - Errors in model ("true model bias")
- Whether biases should be removed from forecasts depends on cause

We use uninitialised forecasts (NoAssim PPE).
These hindcasts do not include 'future' volcanoes.

Lead-time dependent forcing bias

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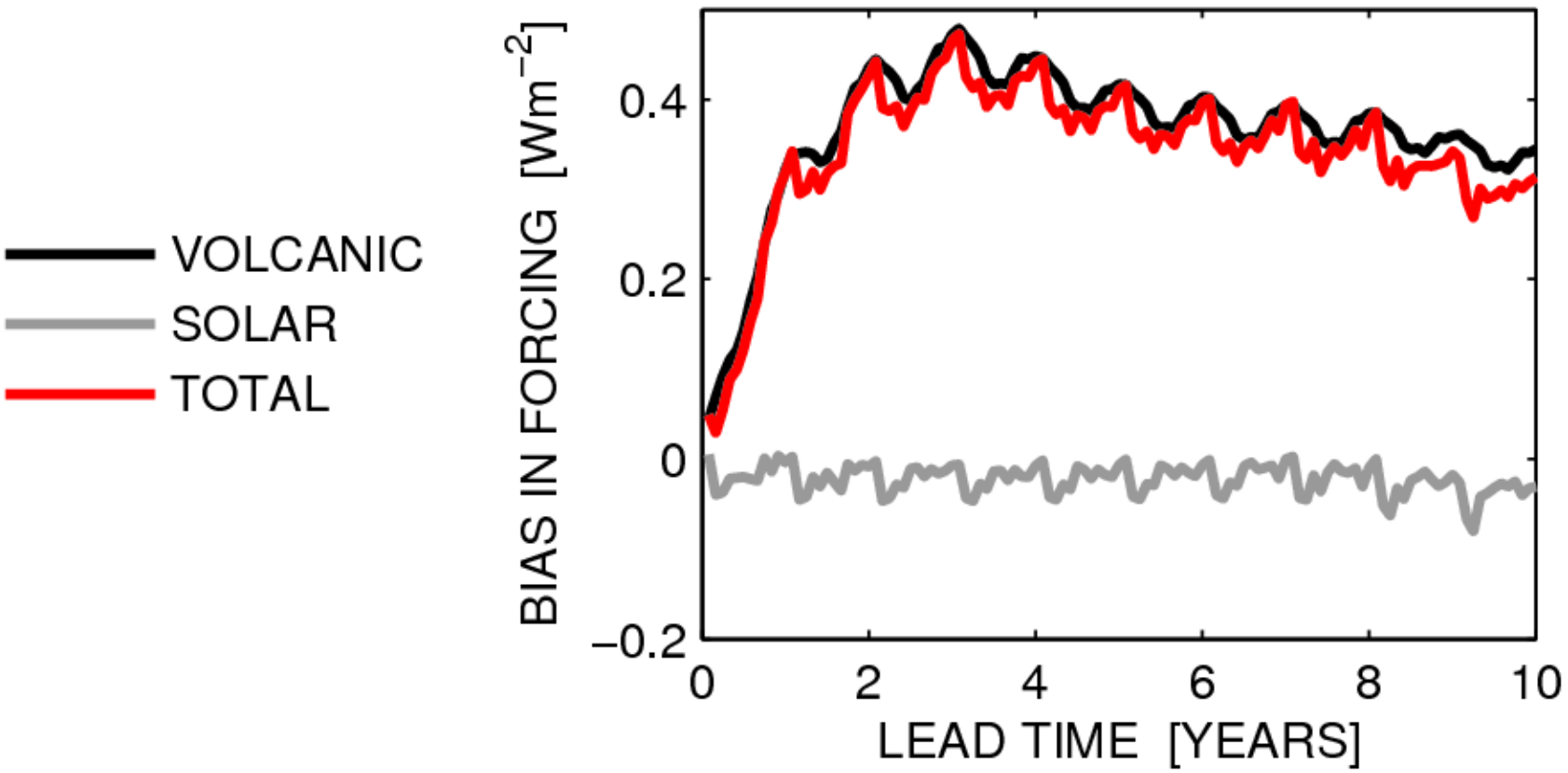

Can we separate the bias due to forcing, and the 'true' model bias?

Toy model – resolving forcing biases

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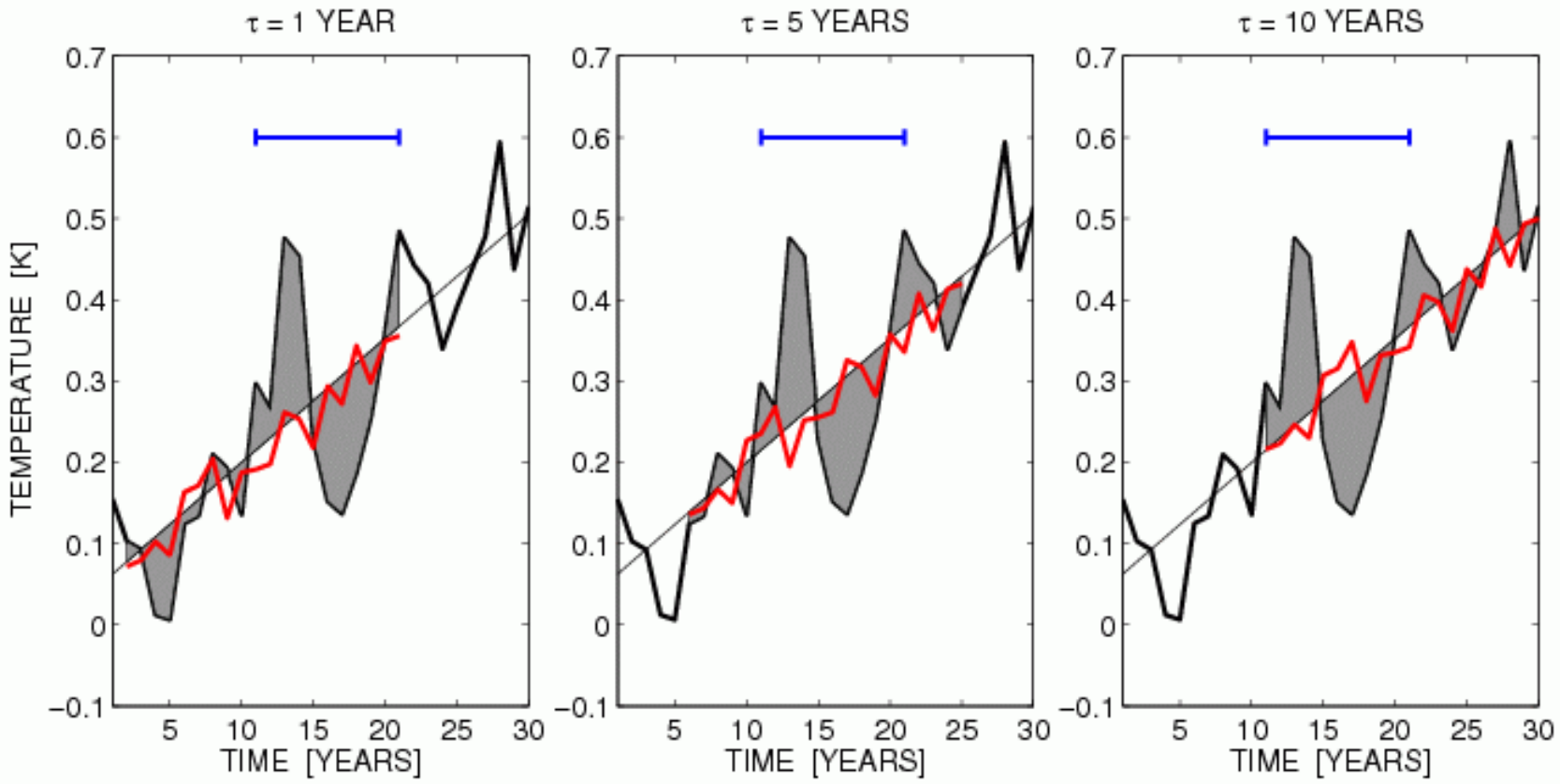
τ = lead time



Black: toy observations

Red: toy uninitialised predictions (ensemble mean)

Lead time dependent forcing bias

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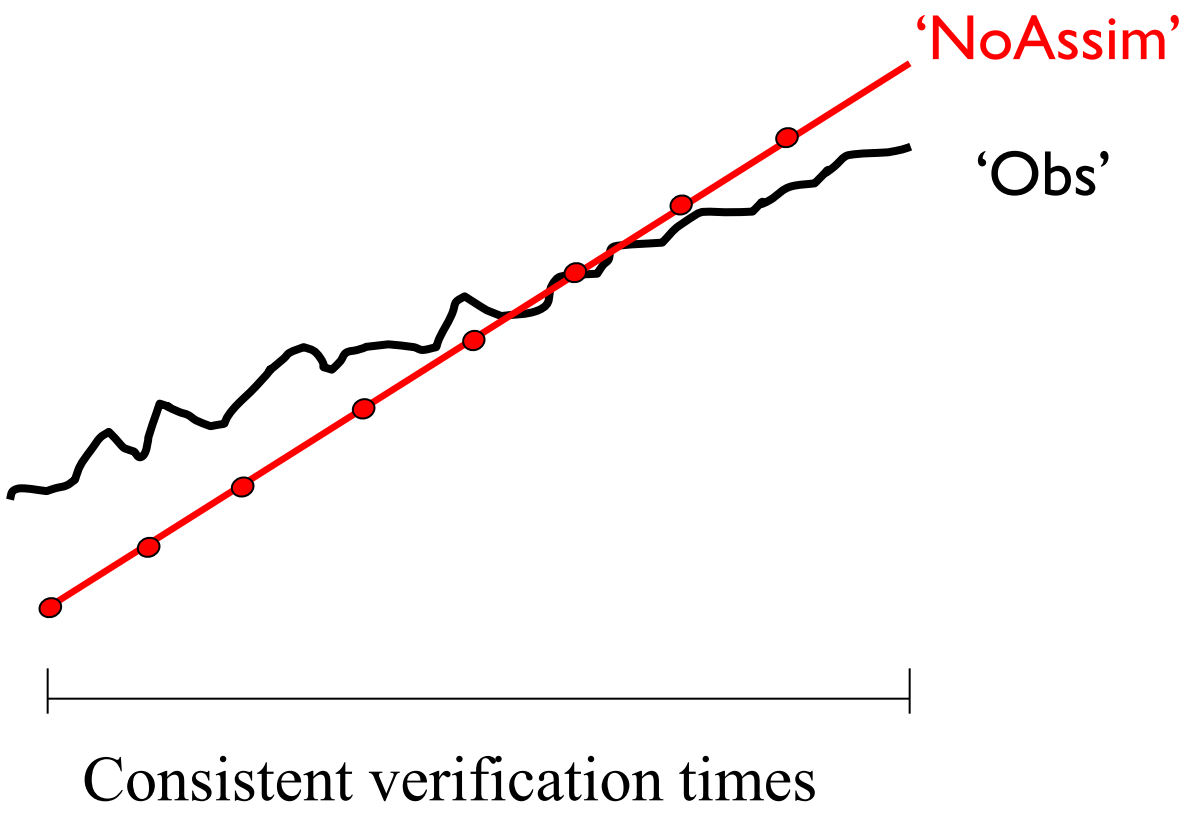

» Bias constant with lead time

Lead time dependent forcing bias

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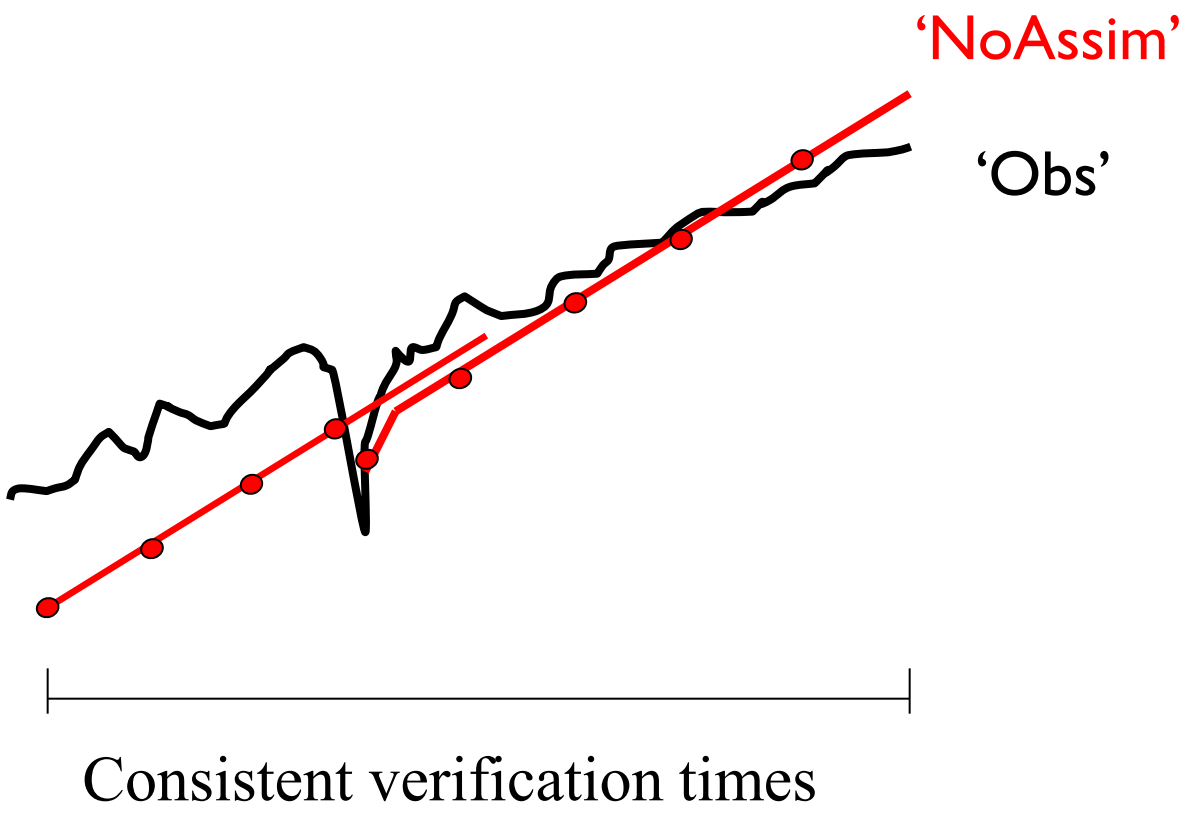

» Bias NOT constant with lead time

Toy model – correcting for sampling

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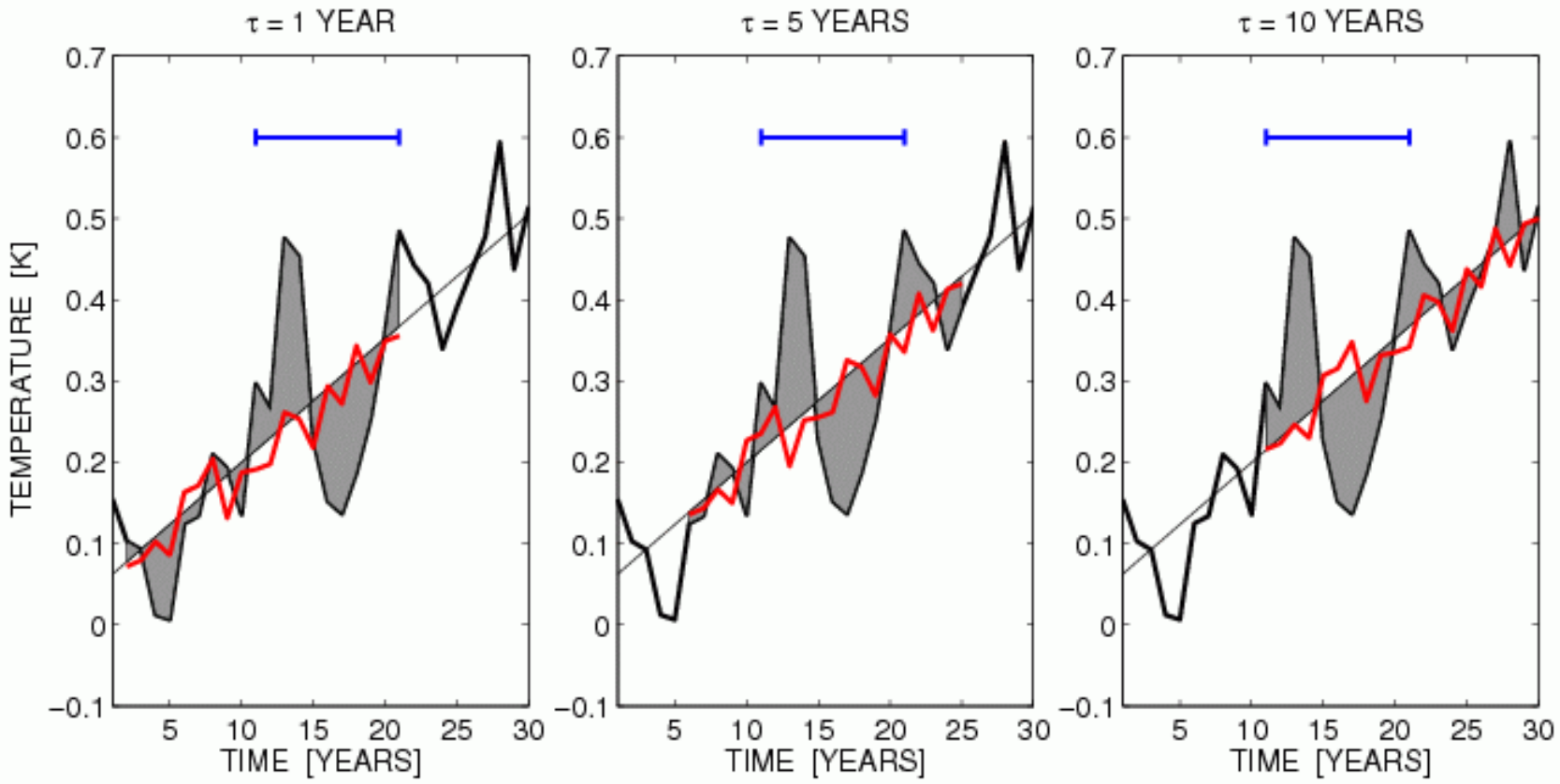
τ = lead time



Black: toy observations

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Decomposing bias

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- A 'toy model' analysis has shown that the total bias can be decomposed into:
  A. 'True' model bias (incorrect sensitivity or forcings)
  B. Lead time dependent forcing bias (volcanoes & solar)
  C. Sampling bias
- Questions:
  - What can be learnt from the spatial pattern of the different bias components? (not shown here)
  - How do these biases change with different model versions, i.e. perturbed physics predictions?

Using NoAssim PPE

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- Period of hindcasts: each year between 1960-2005
- 9 member uninitialised hindcasts with HadCM3
  - each member uses model with different parameters
  - each model has a different (known) climate sensitivity
- No 'future' volcanoes
- Estimate bias tendencies

  (i.e. bias relative to bias at 1 year lead time – to remove mean bias)

Global SAT bias using ensemble mean

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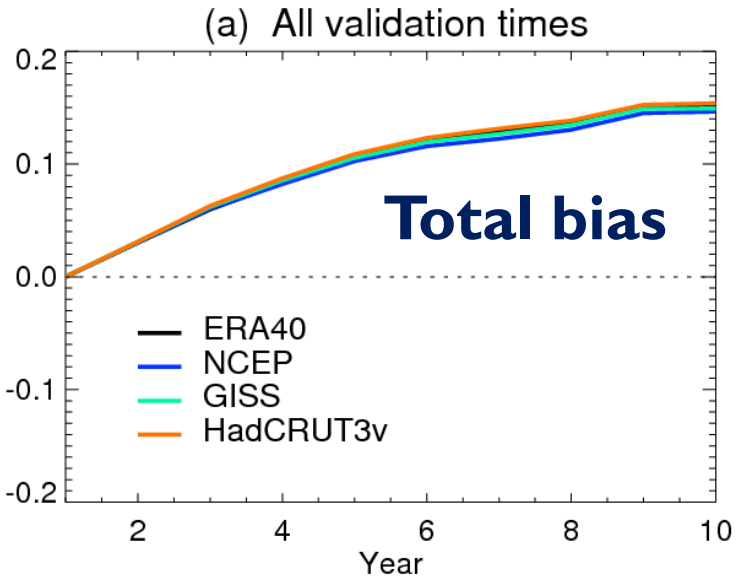

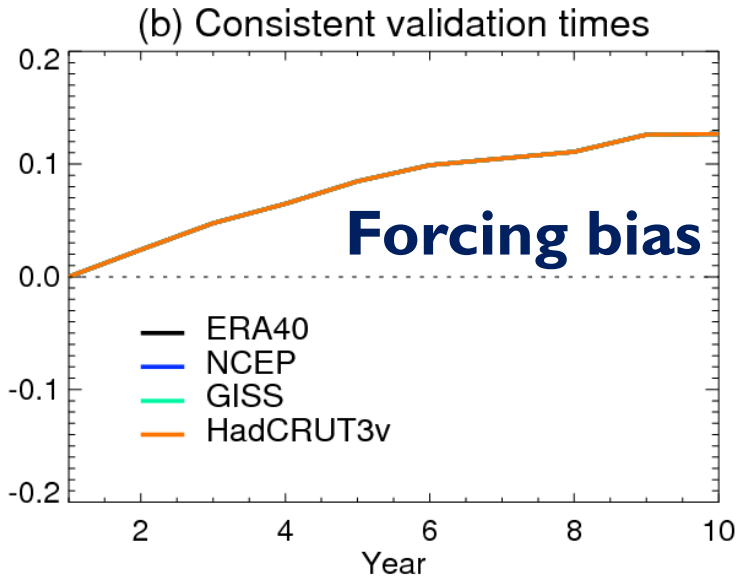

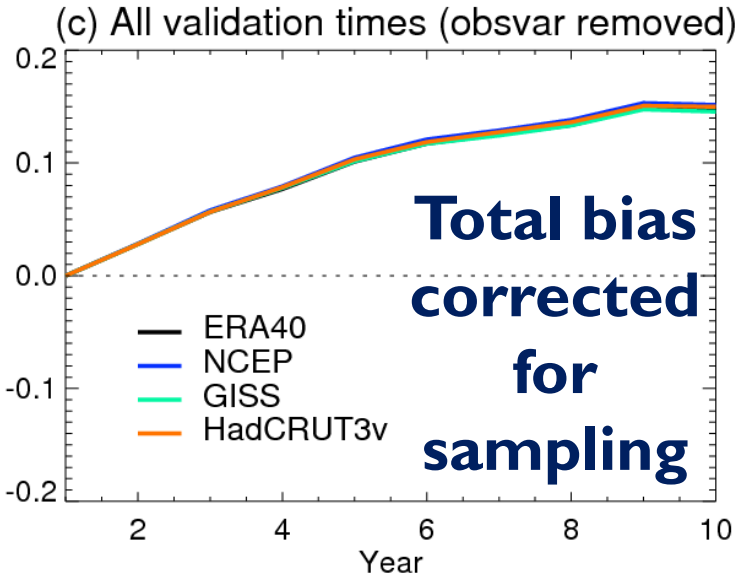

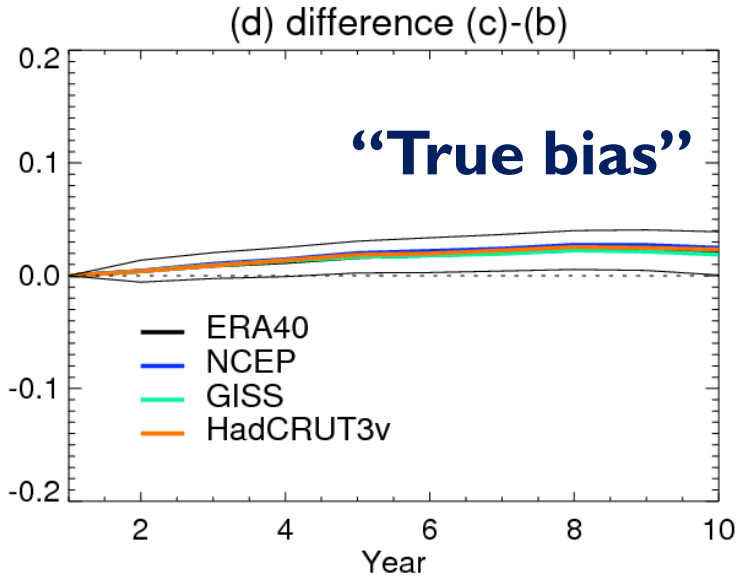

Relationship between SAT and OHC bias

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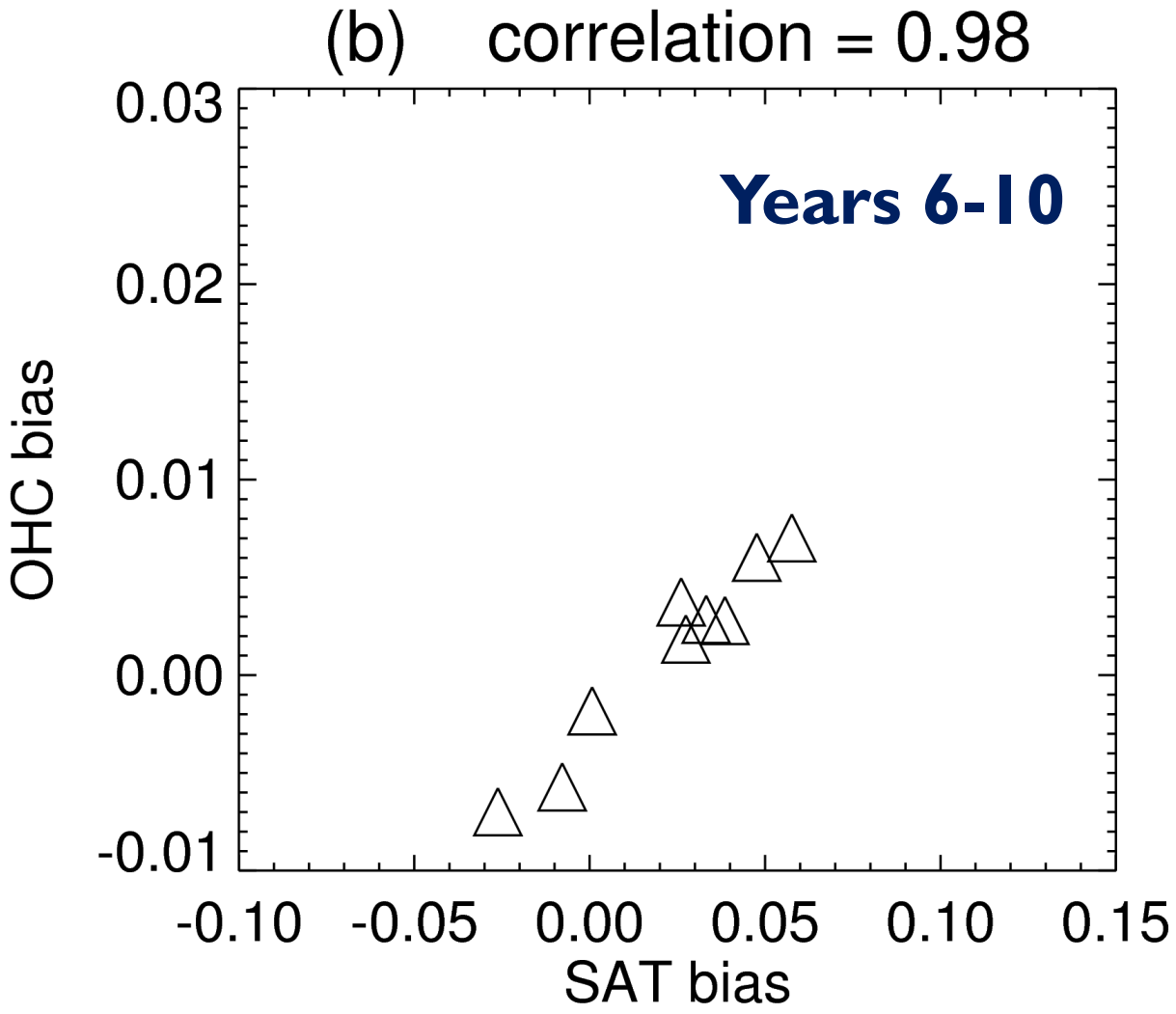

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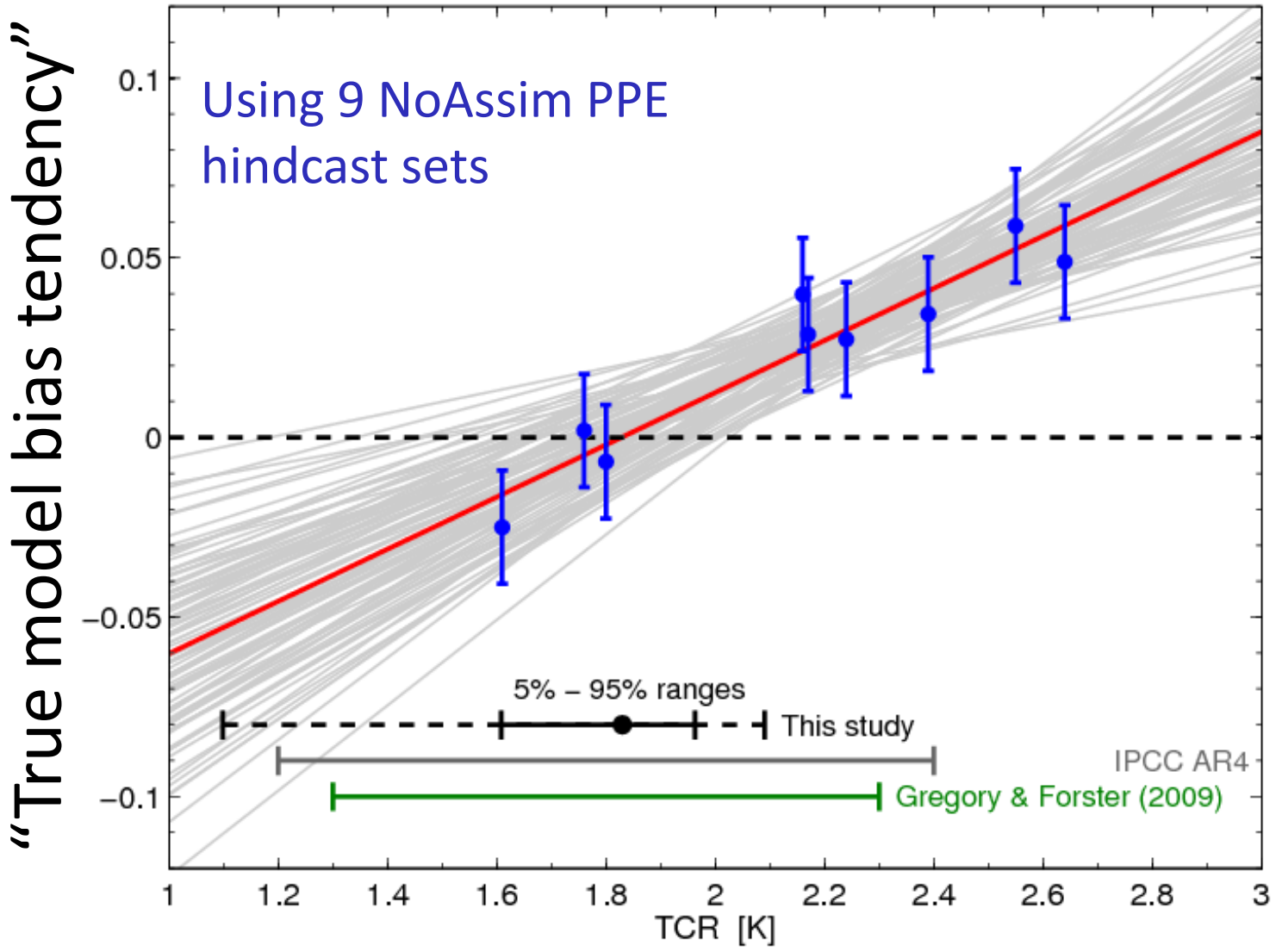

Summary

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- Bias of uninitialised decadal hindcasts has 3 contributions:
  - bias from forcing errors
  - bias from insufficient sampling of the natural variability
  - the true model bias

which can be separated

- Space–time development of true model bias provides information about model and/or forcing errors, e.g. ocean heat uptake
- The analysis of biases in decadal hindcasts offers a new approach to identify, quantify and understand climate model errors, and to constrain climate projections
- TCR can be constrained effectively (1.6 to 2.0 K) using estimates of bias from decadal hindcasts
- Major caveat: assumed correct radiative forcings!

Open questions

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I. Which bias estimate should we use for correcting out-of-sample forecasts?
II. How can this methodology be applied to initialised forecasts, i.e. dealing with the shock

Consequences for ensemble design:

1. Standard CMIP5 protocol doesn't have 'consistent verification' times, unless start dates every year are performed
2. In toy model, more start dates more useful than more ensemble members for estimating correct bias in global mean SAT