Understanding biases in decadal predictions

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Mean bias in decadal predictions

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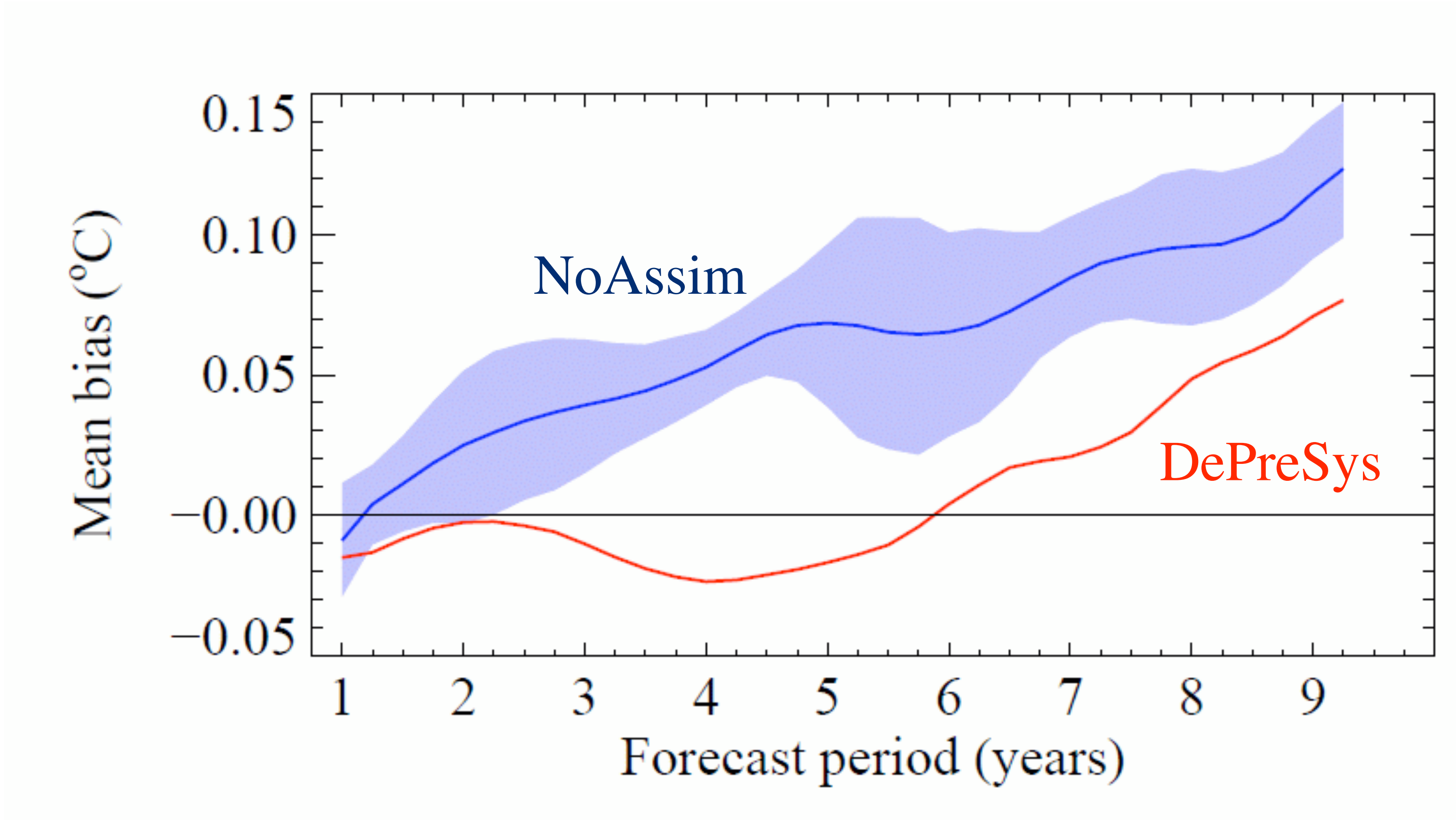

Smith et al. 2007

Biases in DePreSys and NoAssim

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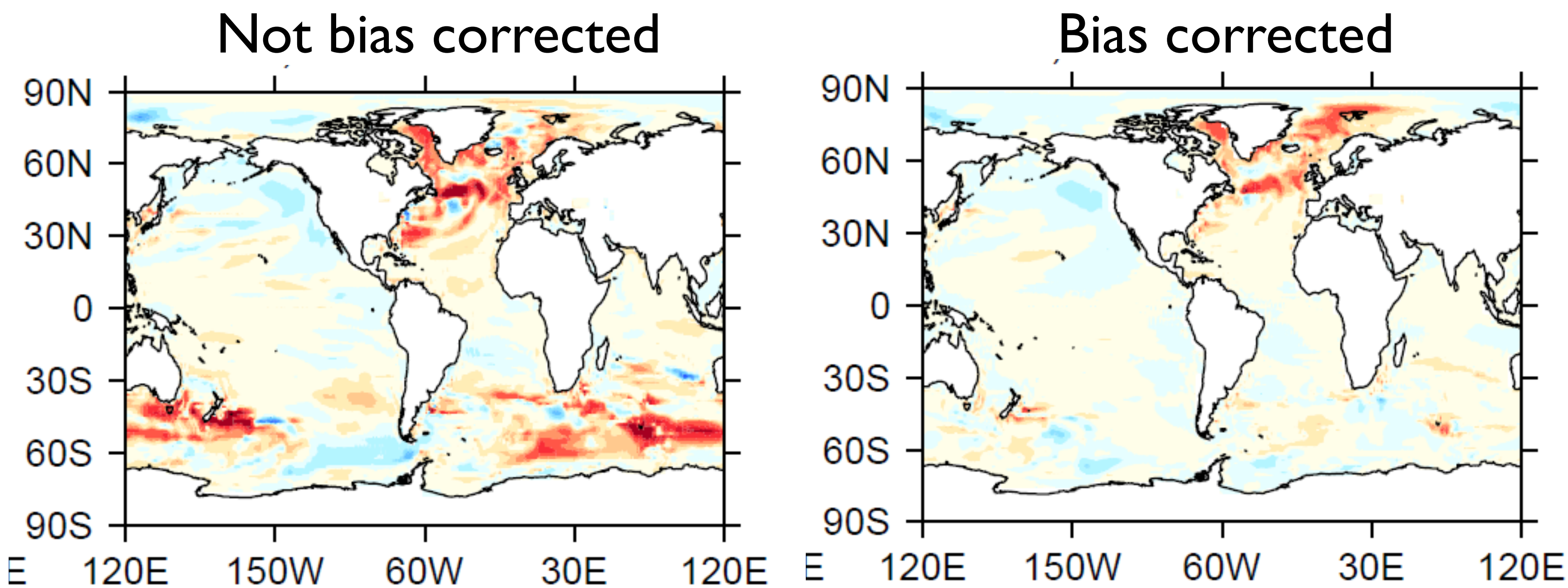
- Possible causes of bias:
  - Sampling uncertainty, due to finite climatology period, hindcast period & ensemble size
  - Drift in transient model runs, especially at depth
  - Rapid adjustment in DePreSys
  - Errors in radiative forcings
    - Lead time dependent (e.g. volcanoes)
    - Lead time independent (e.g. aerosols)
  - Errors in model
- Biases affect RMSE of DePreSys relative to NoAssim

Impact of bias correction on comparison of DePreSys and NoAssim

RMSE difference between DePreSys and NoAssim (version 2007) for 113m ocean heat content



Red = DePreSys better

Robson 2010, PhD thesis

Biases in DePreSys and NoAssim

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  - Errors in model
- Biases affect RMSE of DePreSys relative to NoAssim
- Whether biases should be removed depends on cause

We (mostly) consider using uninitialised forecasts, without 'future' volcanoes, i.e. NoAssim

Lead time dependent forcing bias

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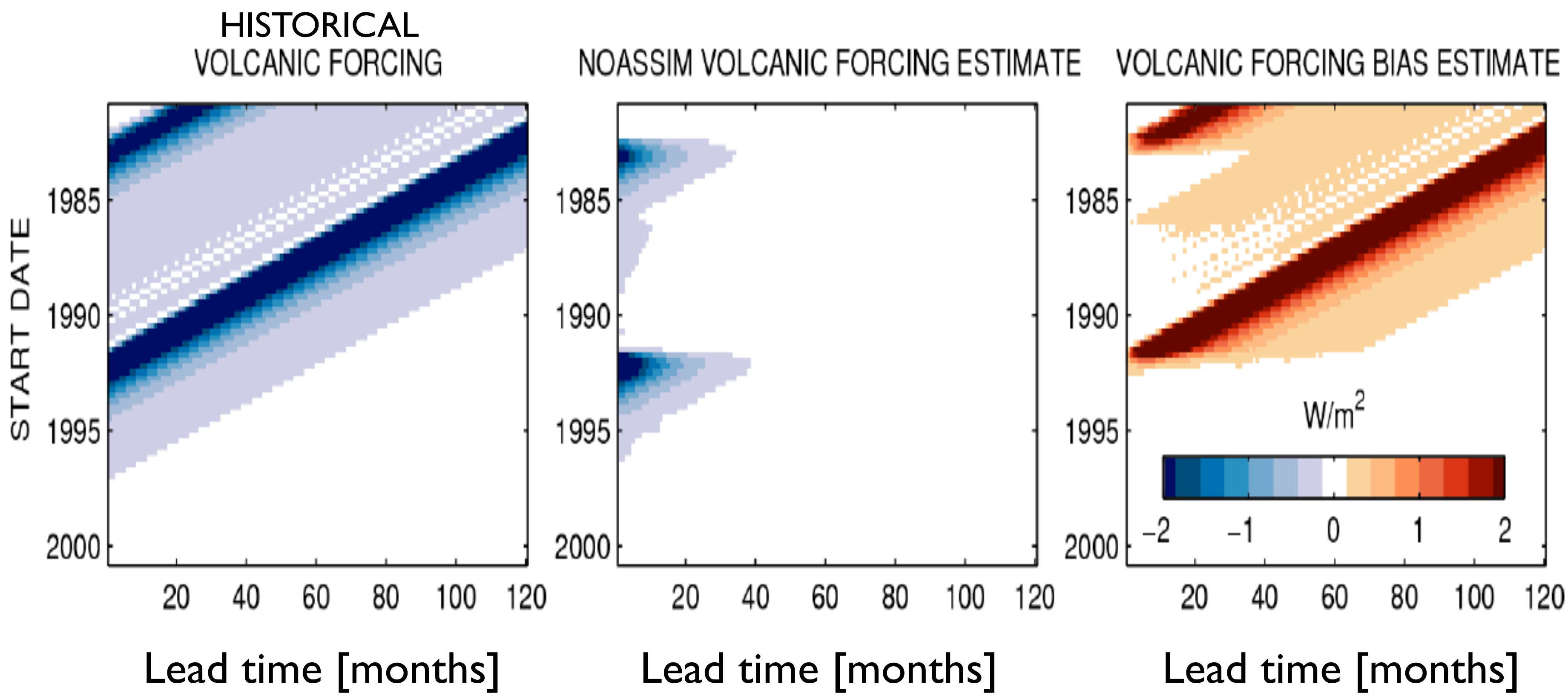

Lead-time dependent forcing bias

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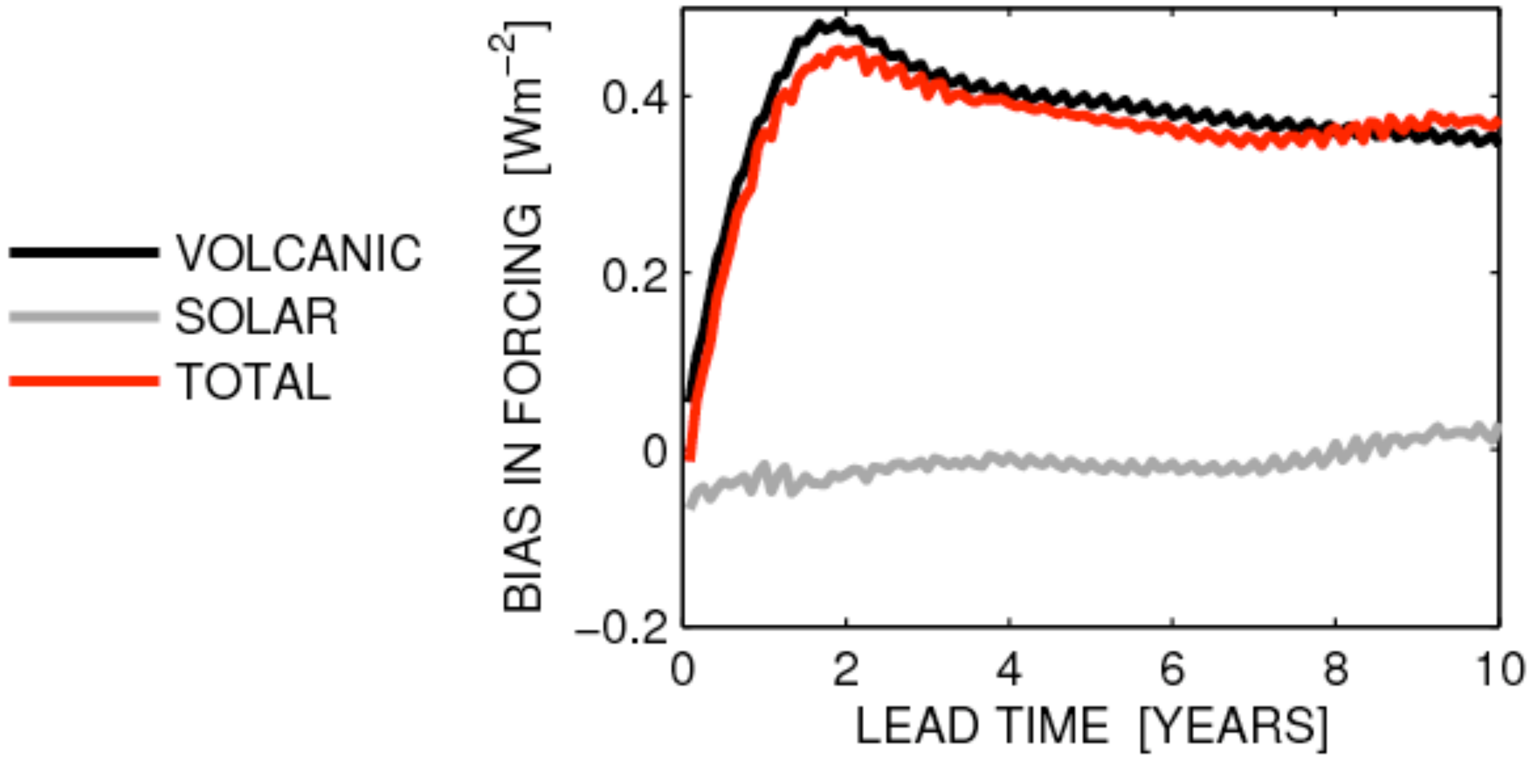

Can we separate the bias due to forcing, and the 'true' model bias?

Toy model

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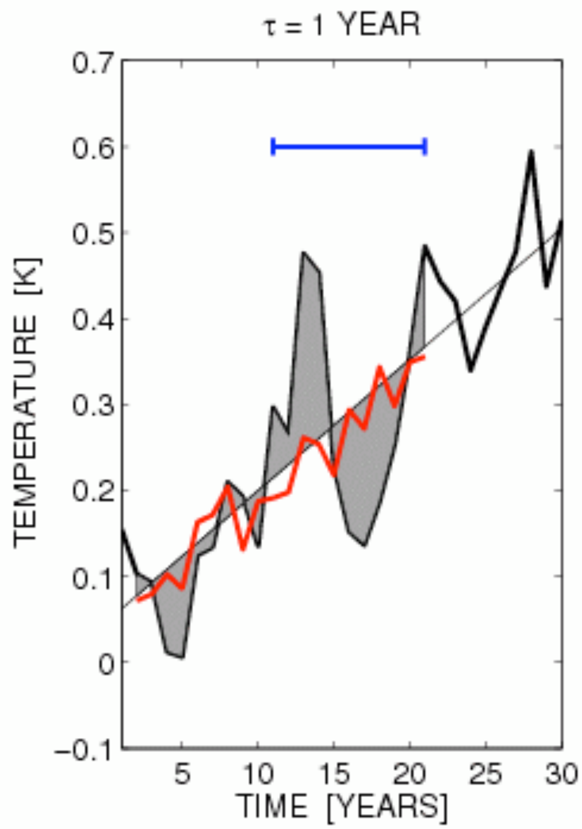
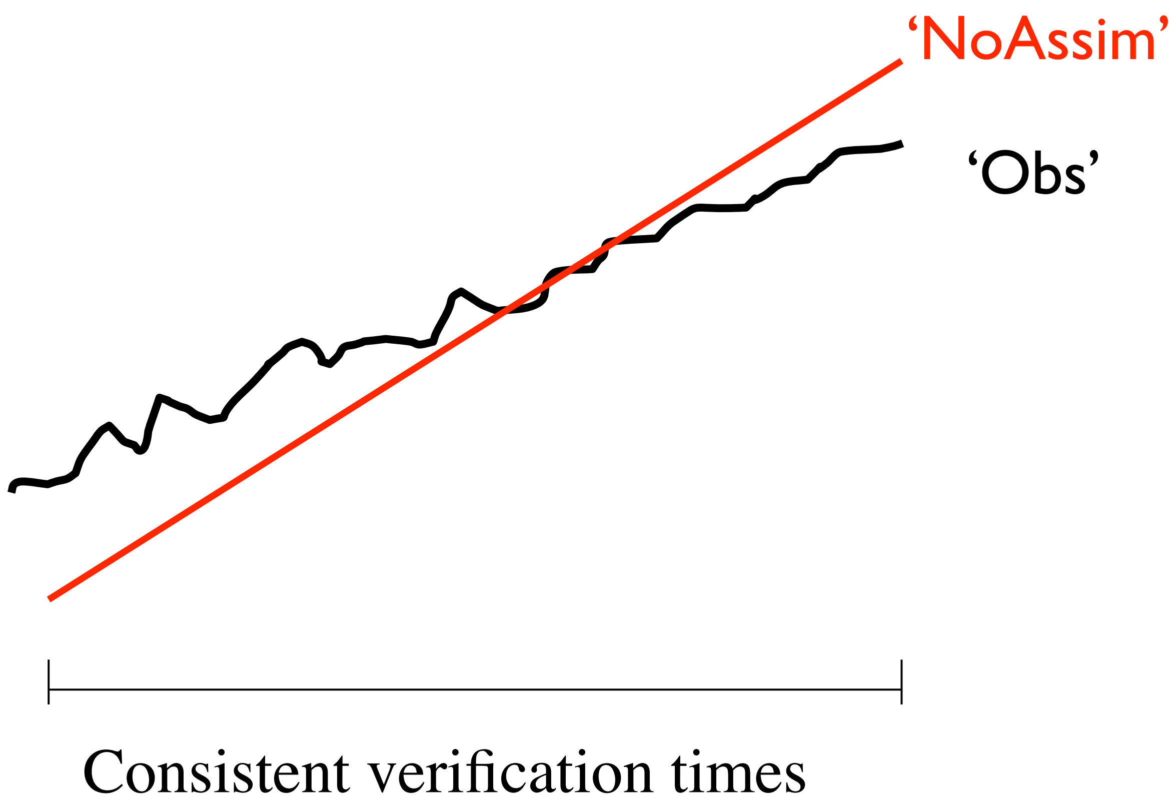
τ = lead time



Black: toy observations

Red: toy uninitialised predictions (ensemble mean)

Lead time dependent forcing bias



» Bias constant with lead time

Lead time dependent forcing bias

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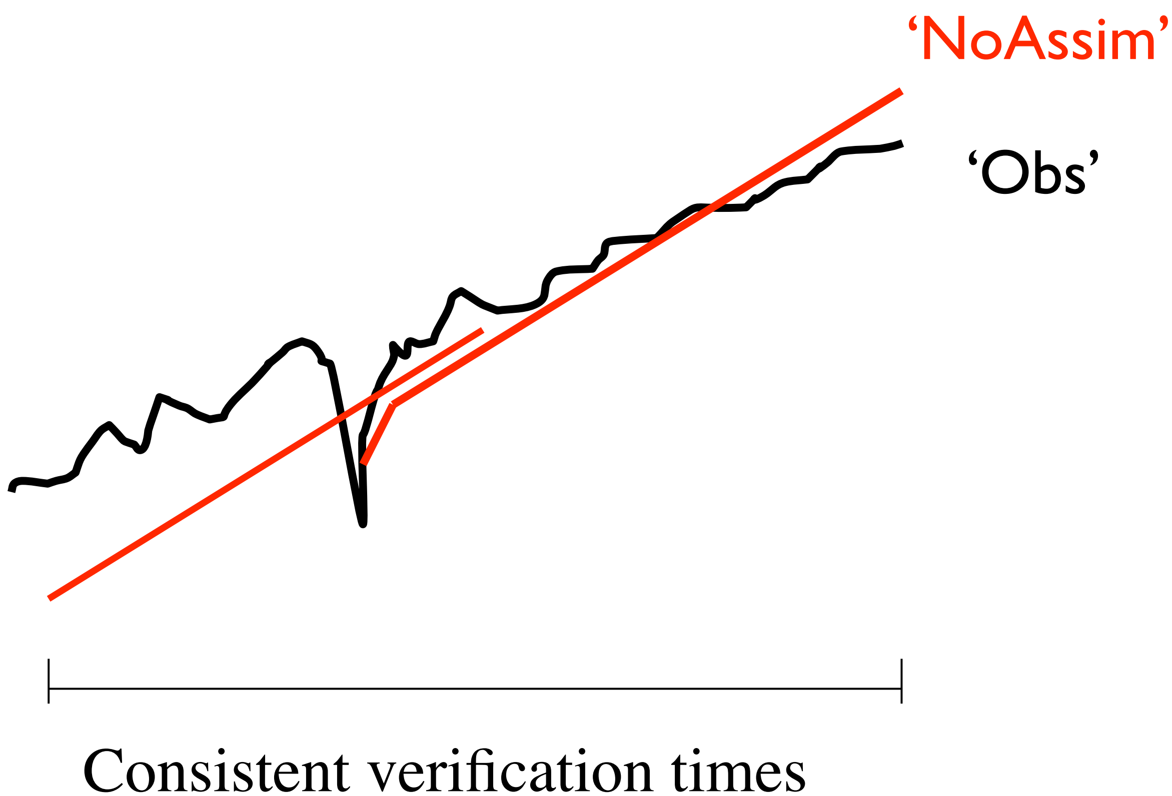
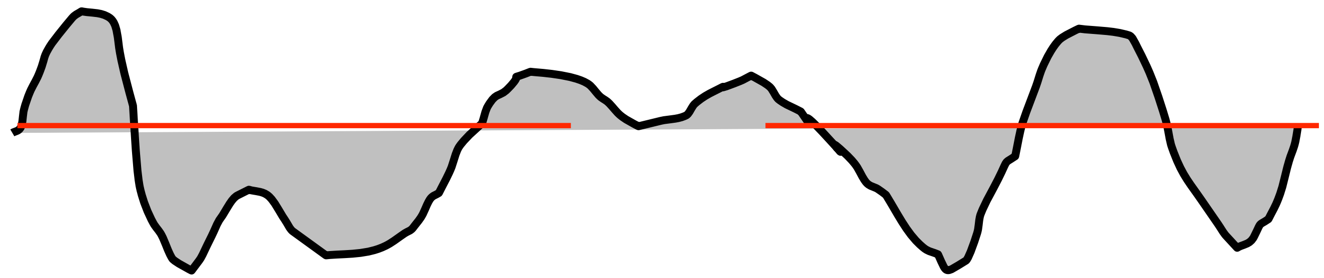


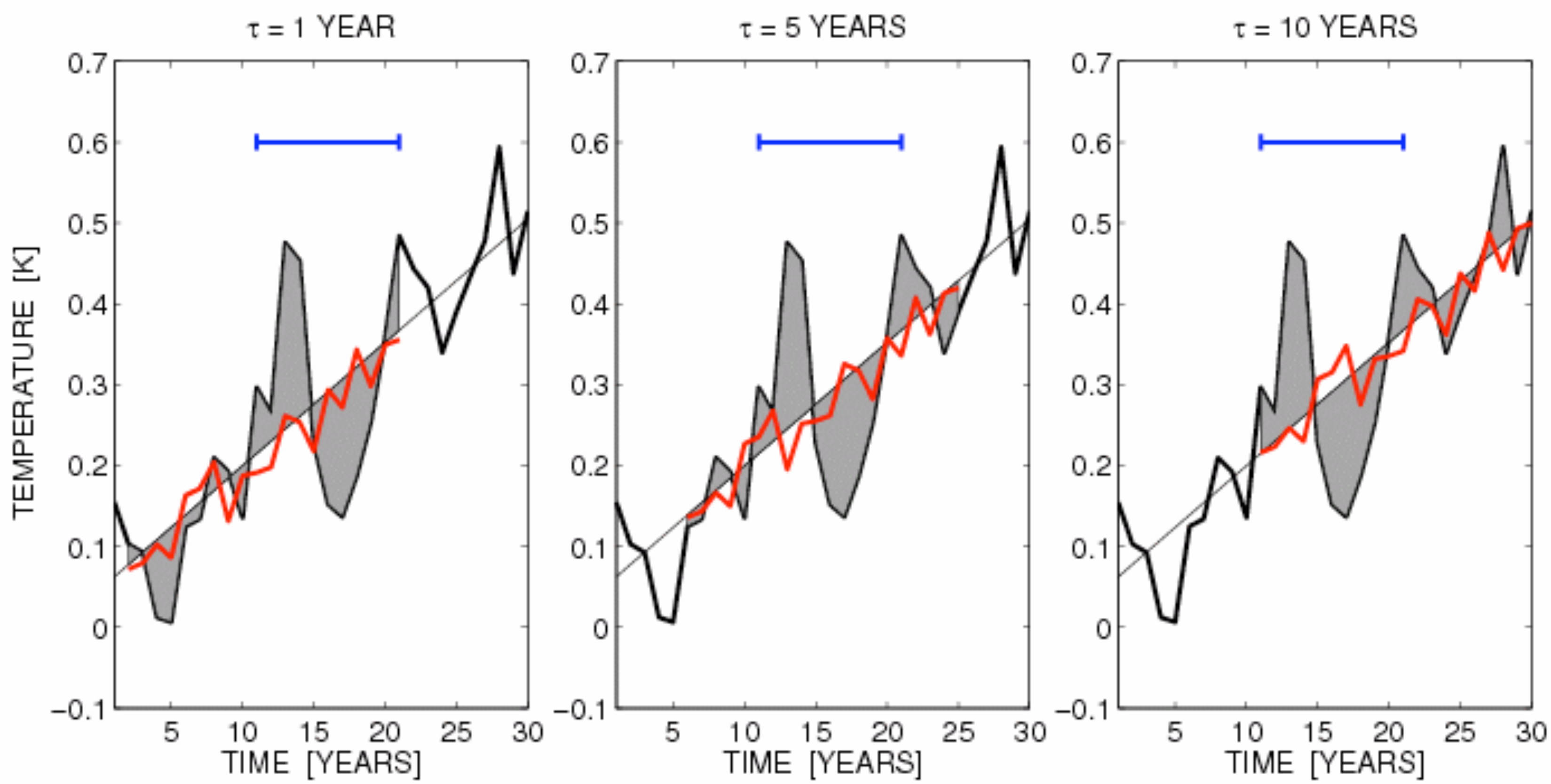
» Bias NOT constant with lead time

"Obsvar" – correcting for sampling



Toy model

τ = lead time



Black: toy observations

Red: toy uninitialised predictions (ensemble mean)

What causes bias in NoAssim (2007)?

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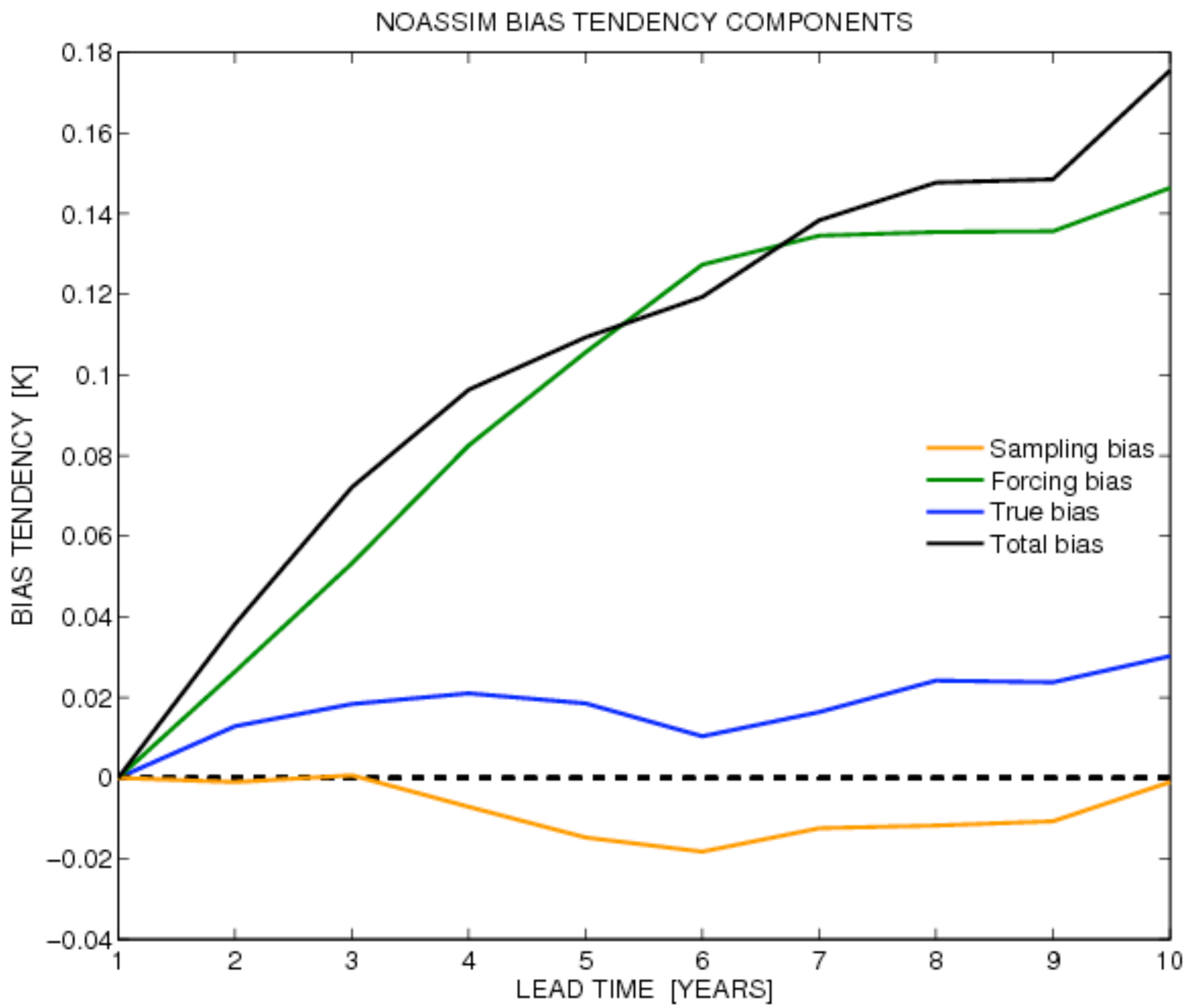

Decomposing bias

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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

- NoAssim (2007) has a small positive bias in global temperature, suggesting HadCM3 is slightly too sensitive

- Questions:
  - What can be learnt from the spatial pattern of the different bias components?
  - 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

Global mean SAT bias

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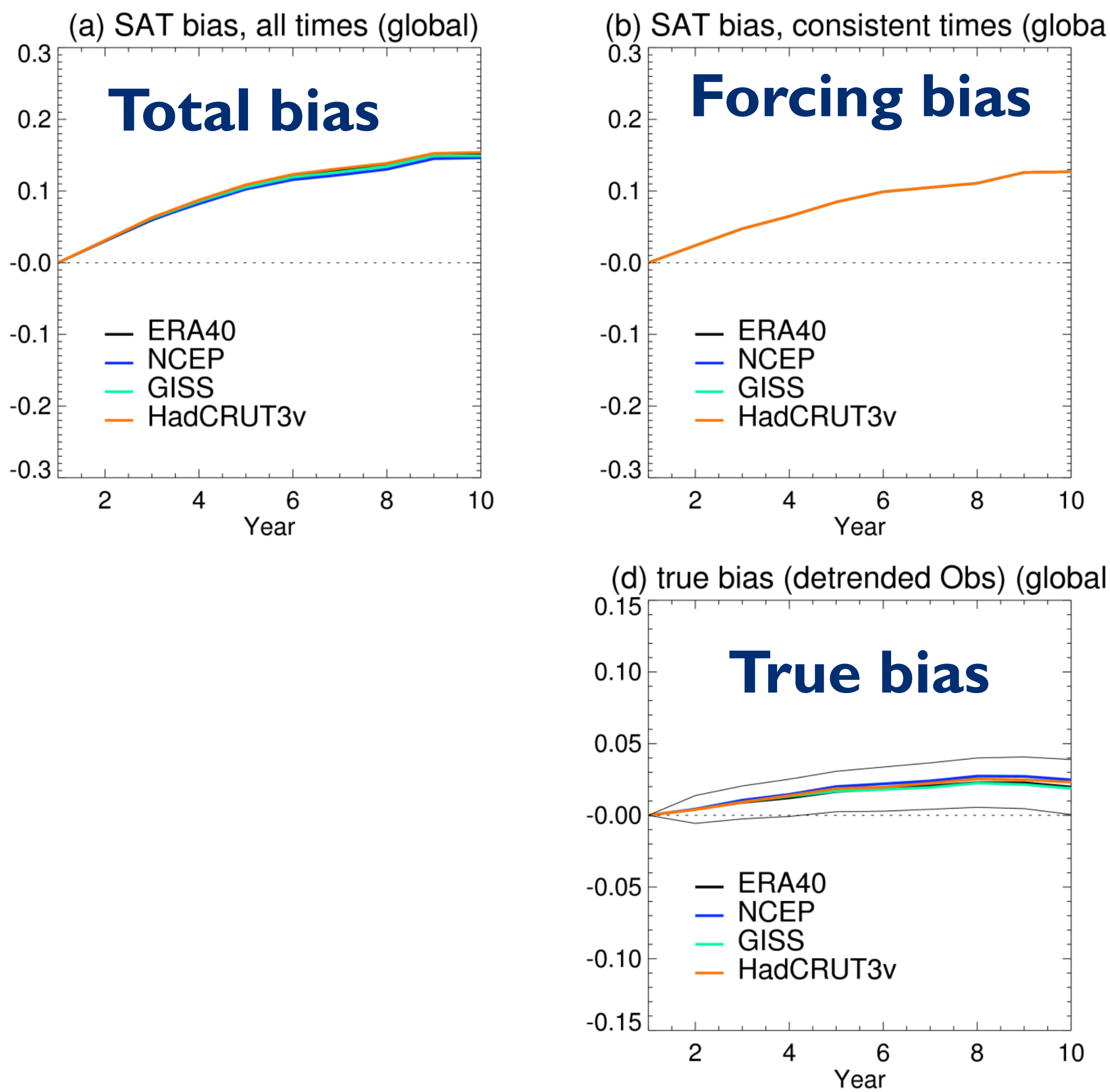
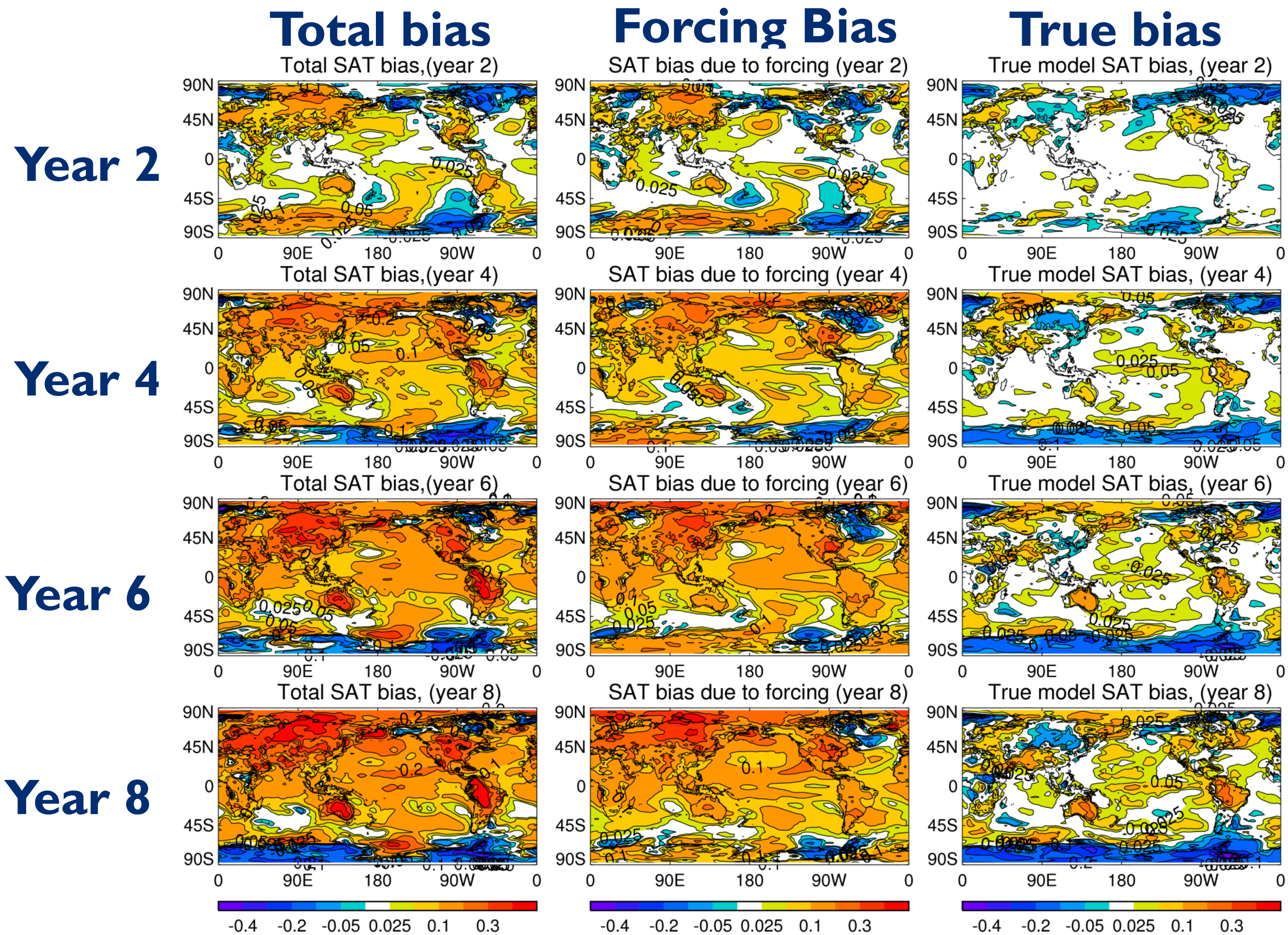
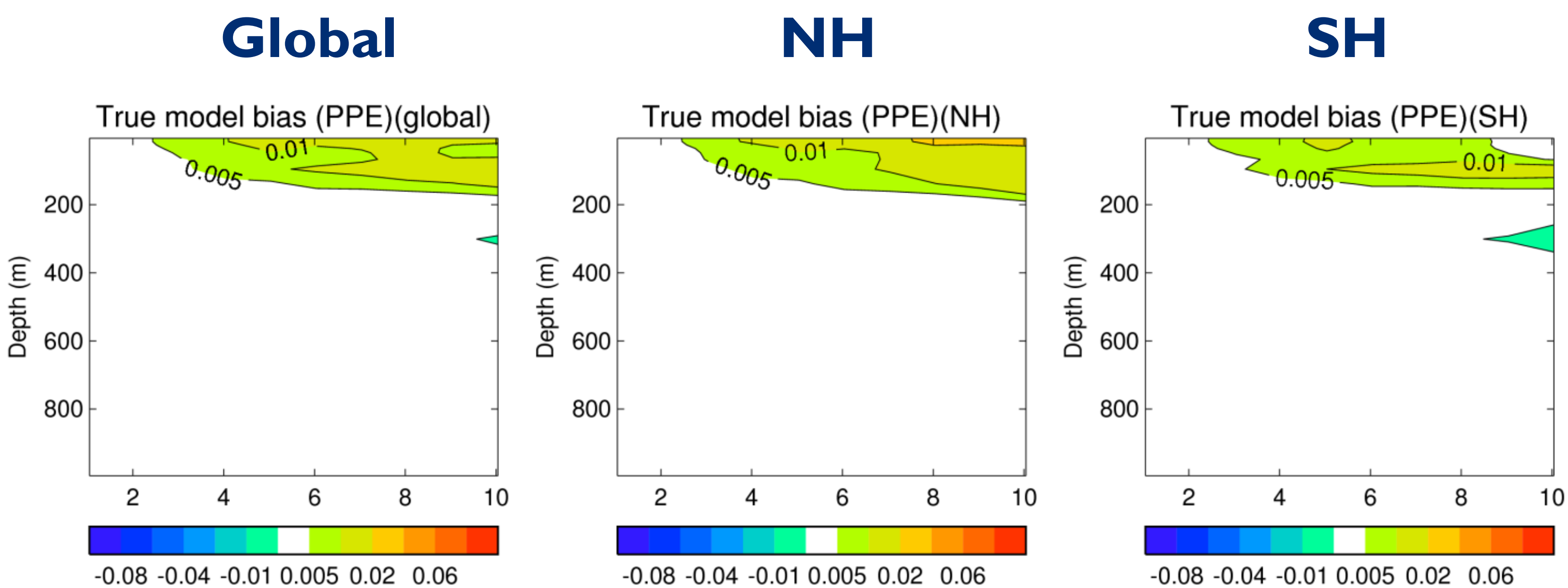


Spatial pattern of SAT bias



Vertical structure of ocean temperature bias



True model bias

Relationship between SAT and OHC bias

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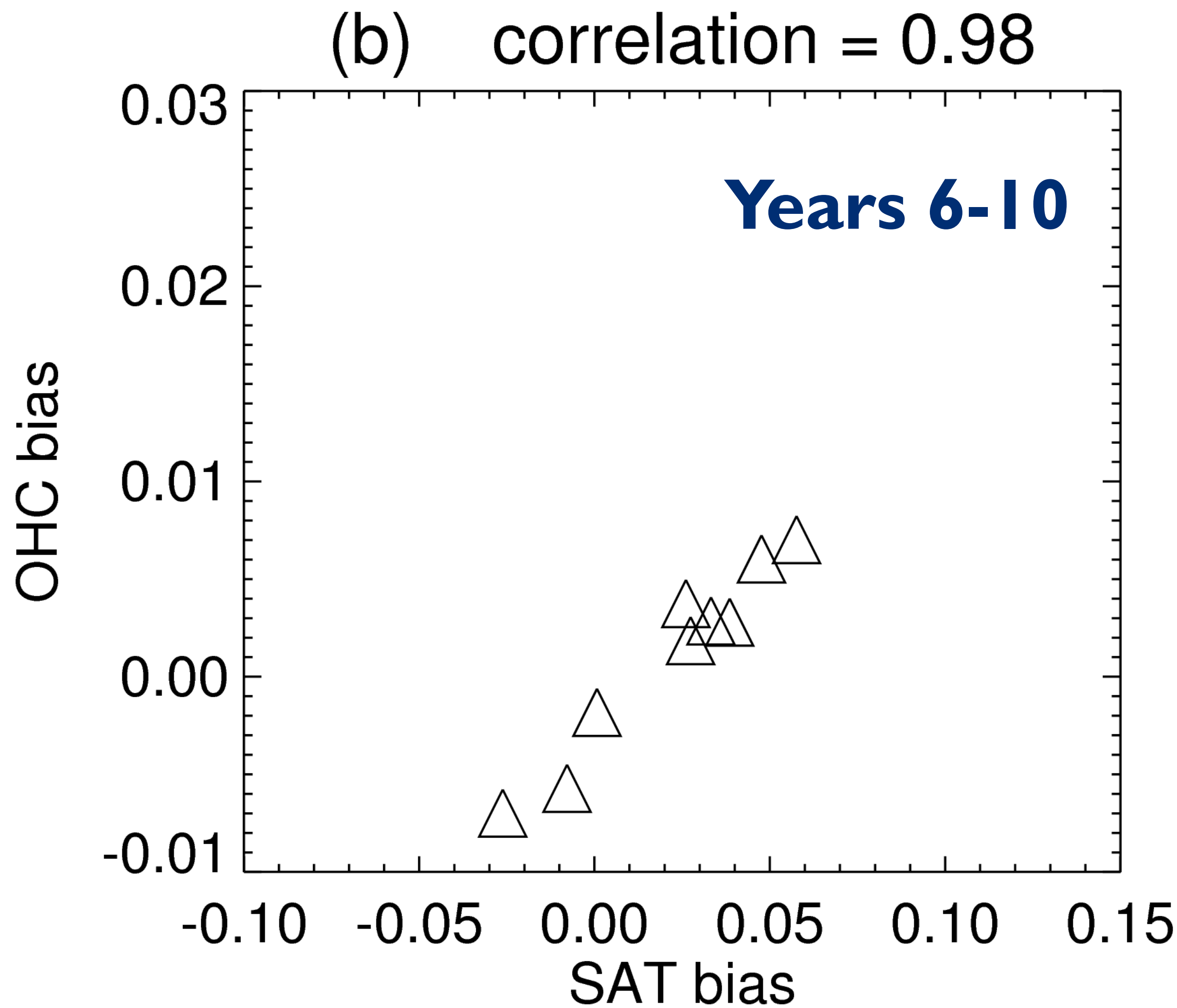

Constraining Transient Climate Response

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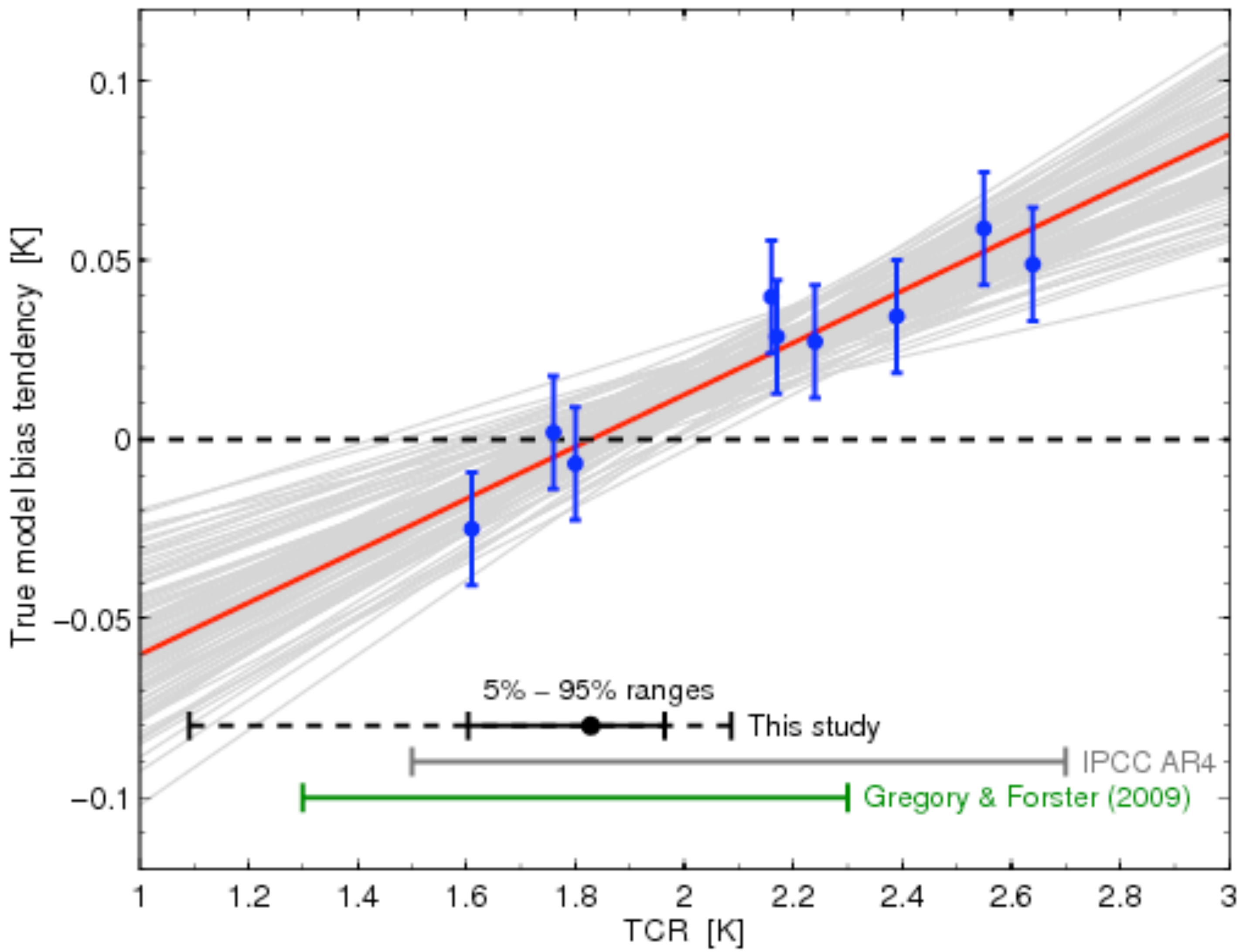
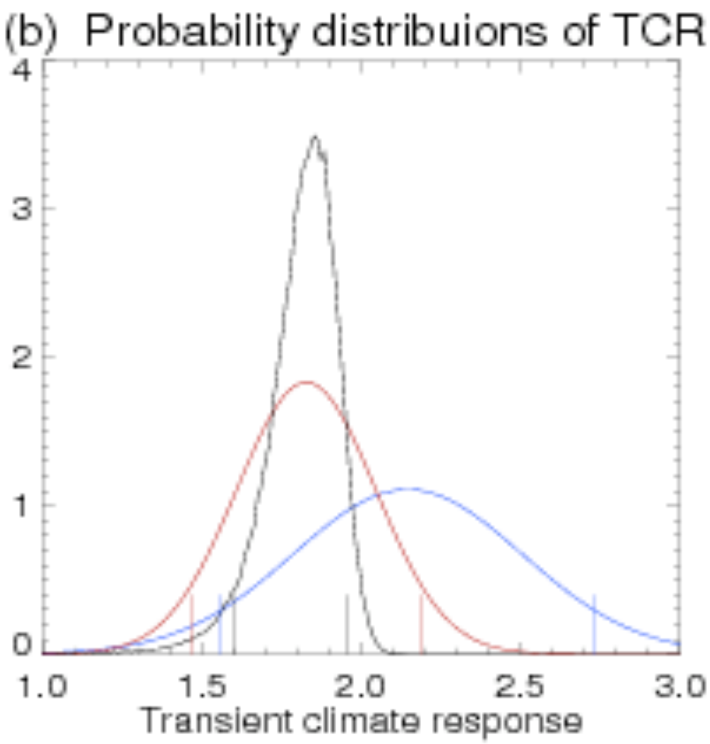
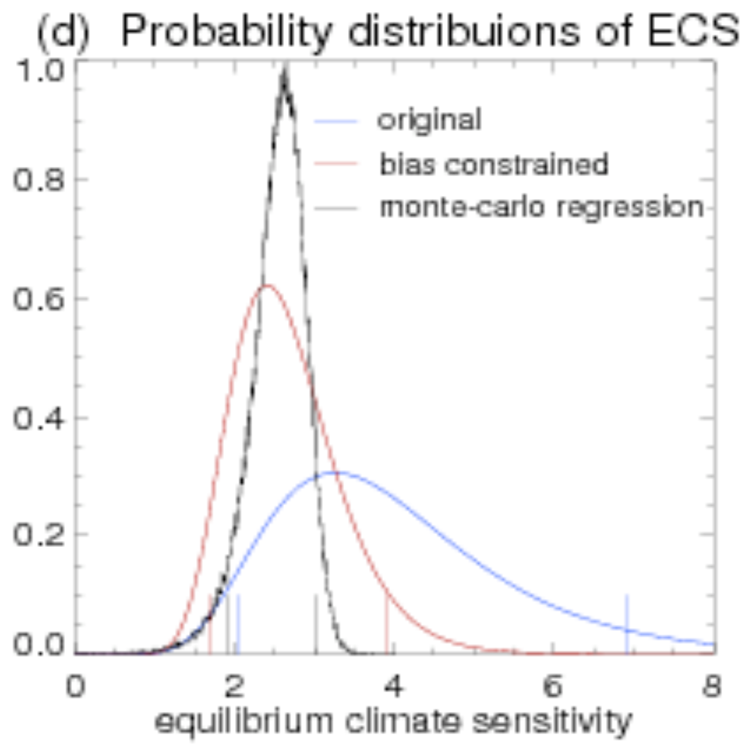


Constrained PDFs for TCR and ECS





Summary

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

Open questions

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

Consequences for ensemble design:

1. CMIP5 protocol doesn't have 'consistent' times, unless 5 year means are used
2. In toy model, more start dates more useful than more ensemble members (for global mean SAT)

1. Forecast 'reliability' is more important than skill

2. Initialised (decadal) climate predictions are not just about improving forecast skill

Decadal predictions have the potential to:

- help build trust in climate model projections
- learn about model bias and climate variability
- learn about physical processes leading to forecast error
- inform model development and improvements
- inform design of effective climate monitoring systems

Spatial pattern of true model bias (ERA40 and Met Office ocean analysis)

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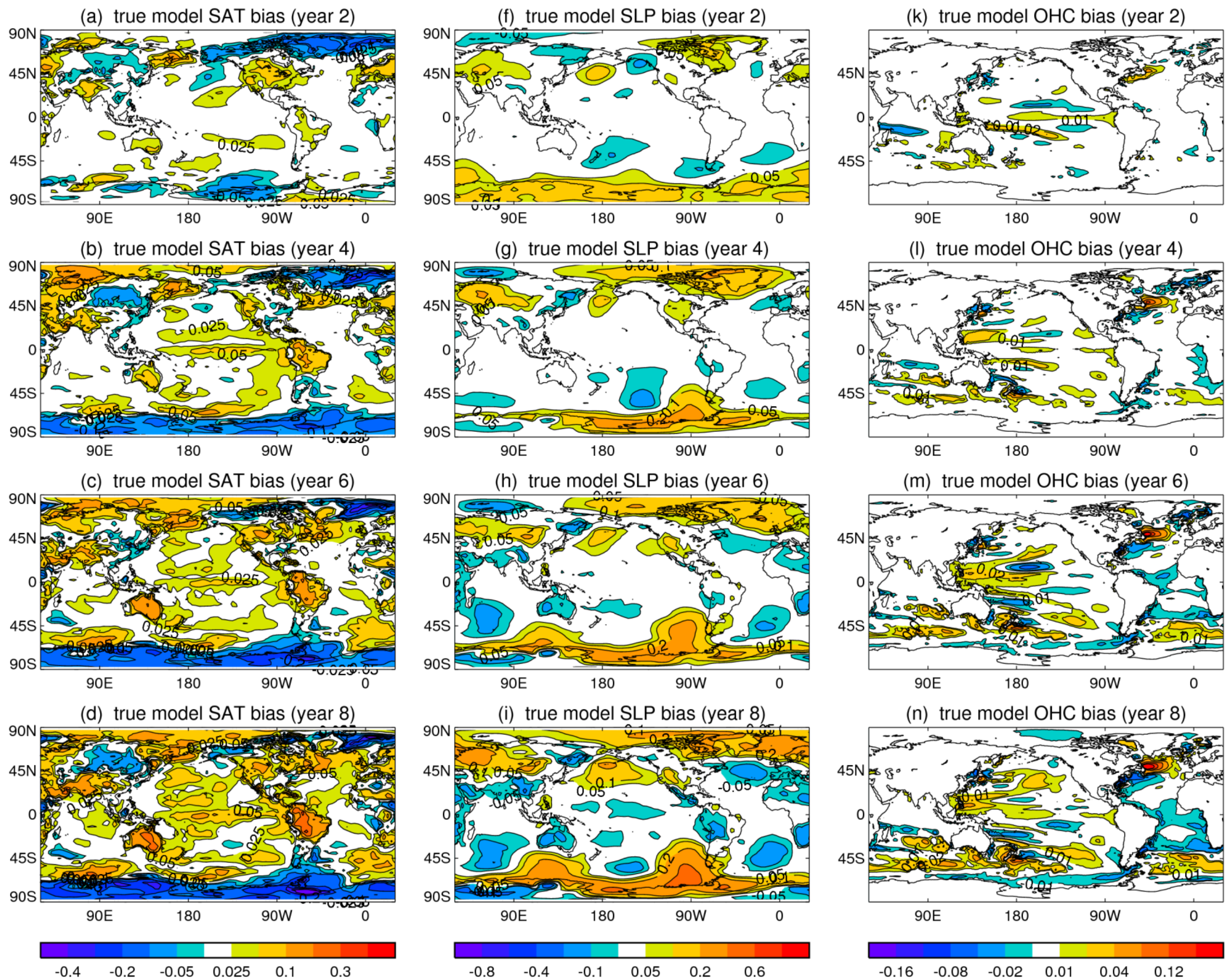
SAT | SLP | OHC (top

Year 2

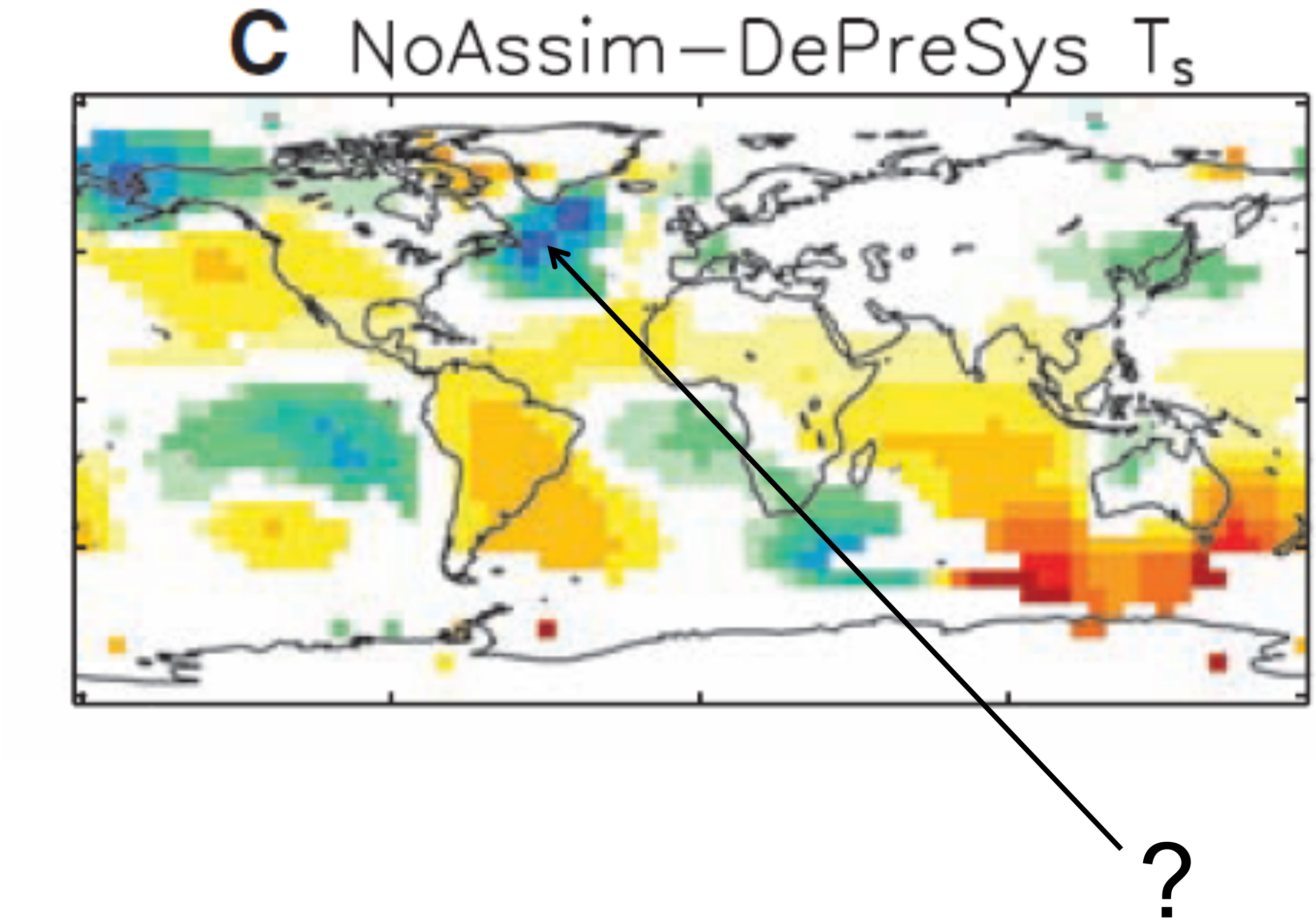
Year 4

Year 6

Year 8



RMSE difference



Global mean surface air temperature SAT bias (land vs ocean)

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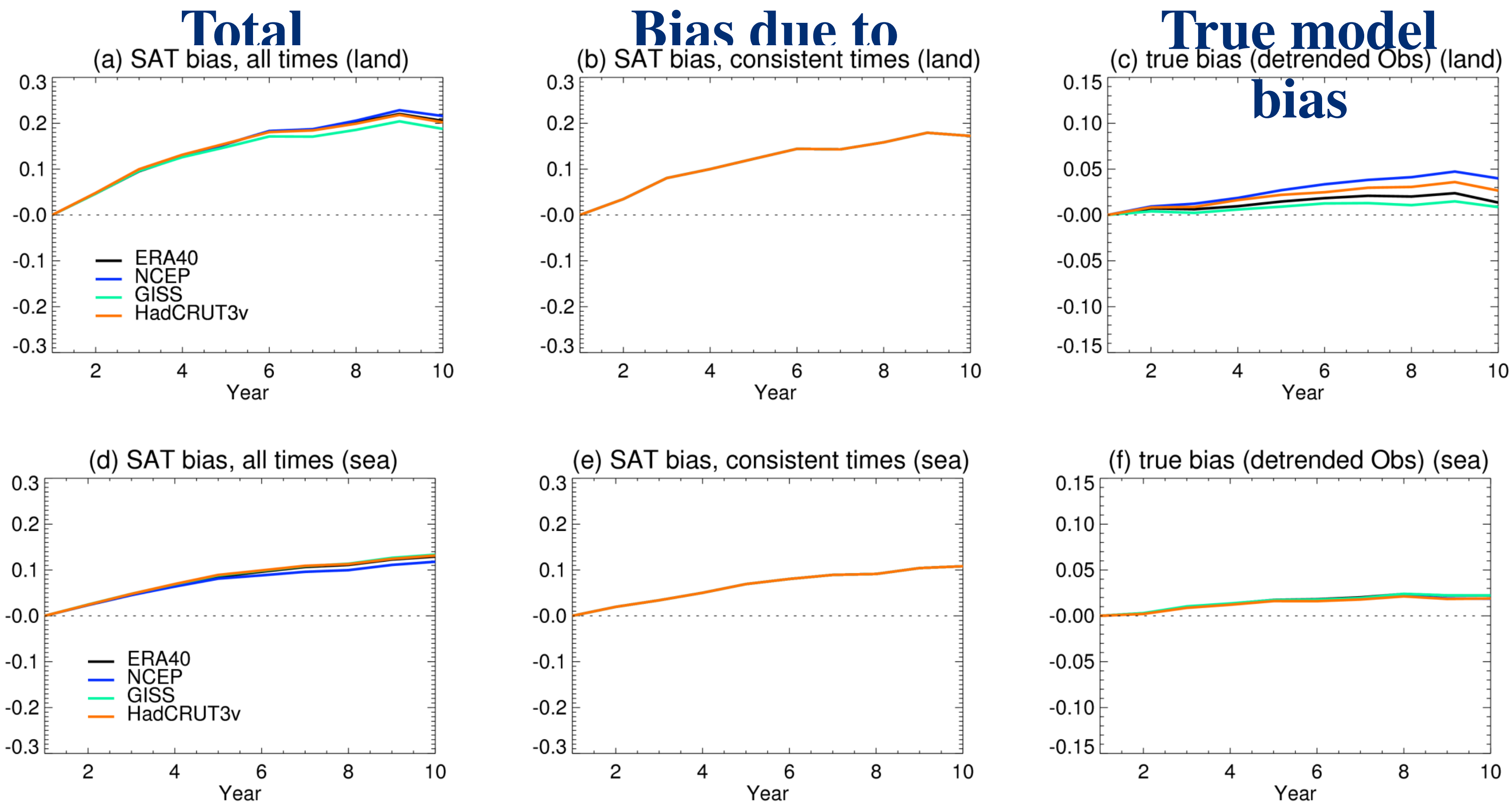
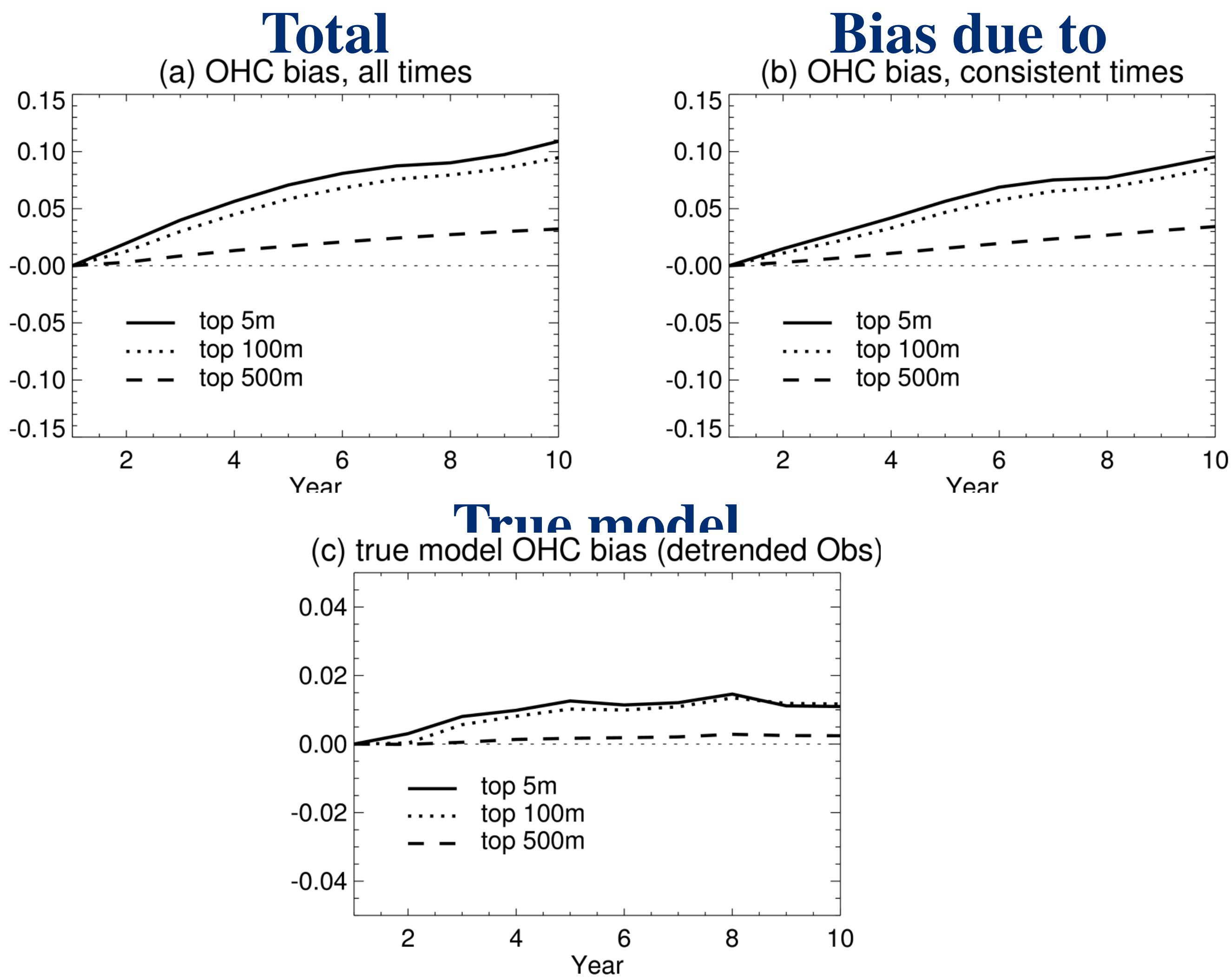
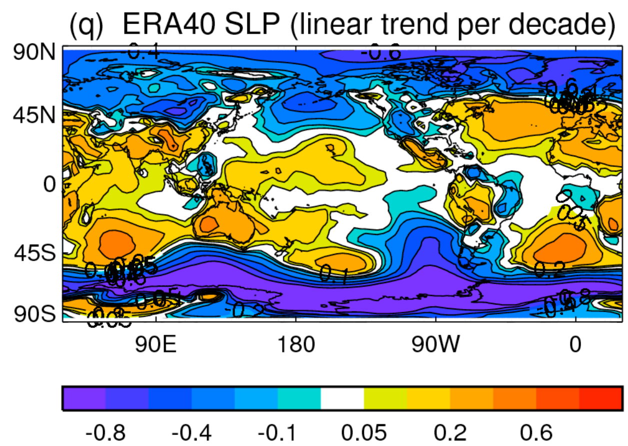
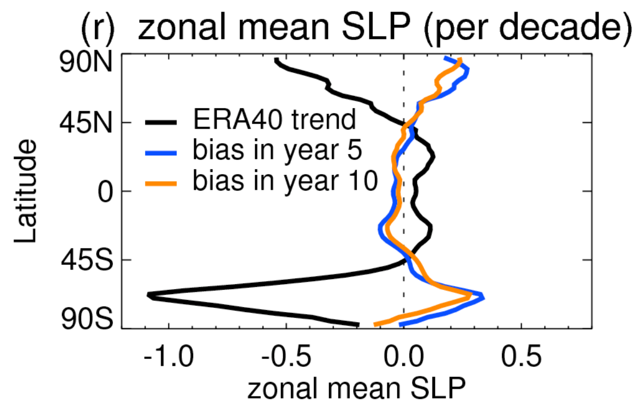


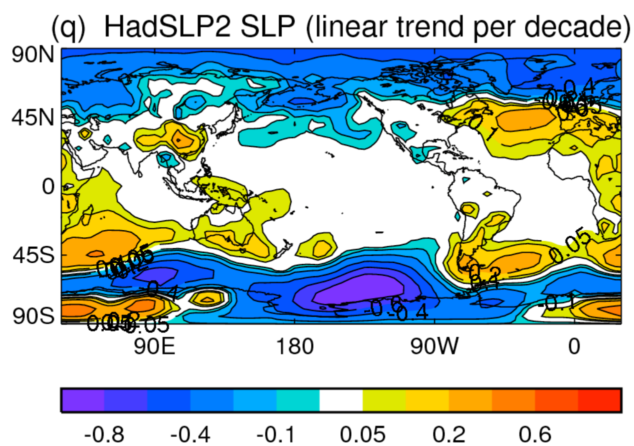
Global mean ocean surface temperature and OHC bias

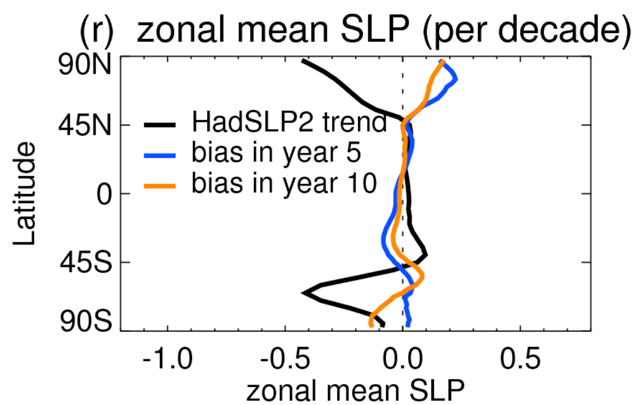


Spatial pattern of linear trends during 1958-2001









Seasonal cycle of true model SAT bias

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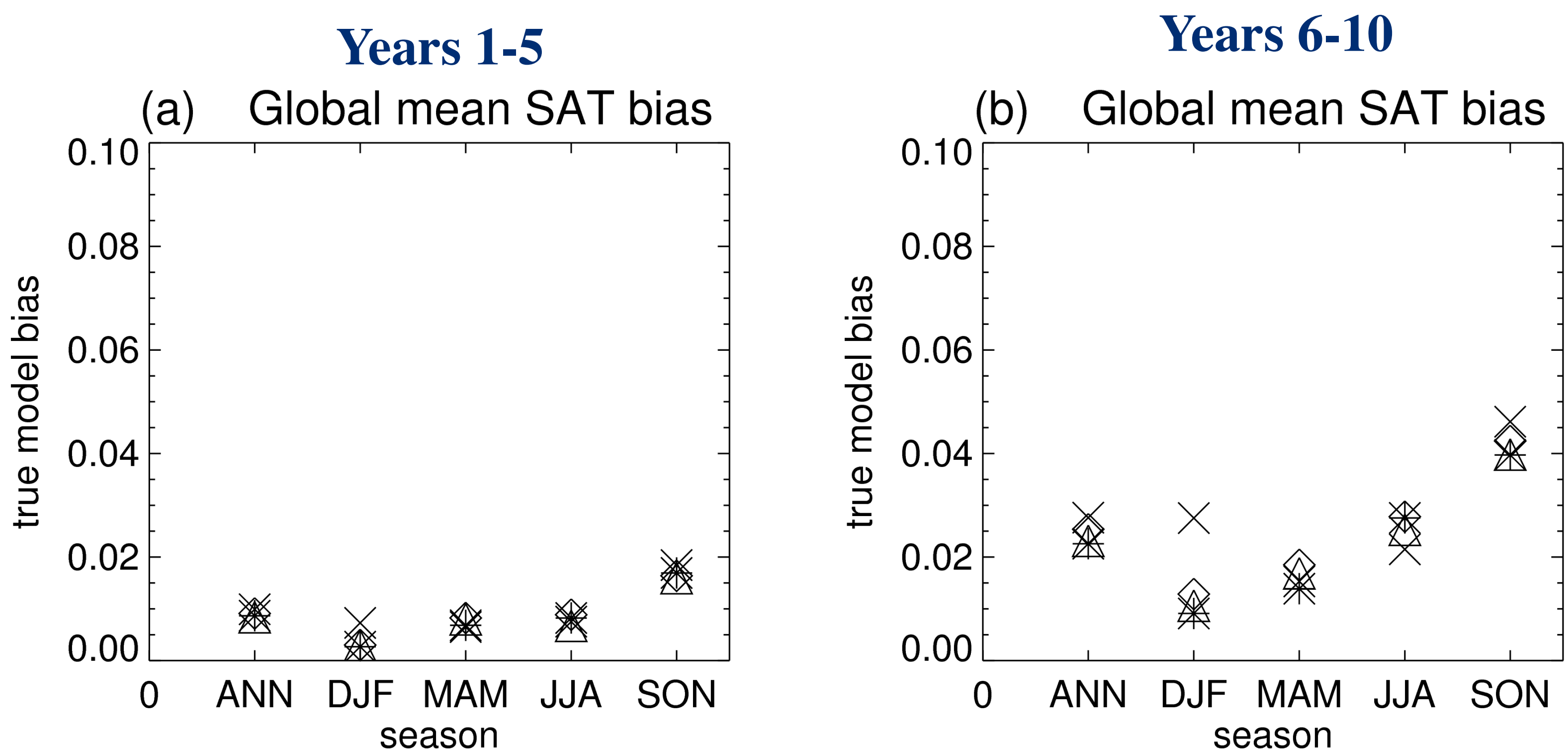

Time mean SAT bias for leading time of 1-5 years and 6-10 years against four observational (reanalysis) data sets.

Constrained 5-95% ranges and medians (in bracket) of TCR and ECS (^oC)

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	TCR	ECS
Original	1.6-2.7 (2.1)	2.0-6.9 (3.7)
Constrained ranges using method 1		
ERA40	1.5-2.2 (1.9)	1.7-4.0 (2.7)
NCEP	1.4-2.2 (1.8)	1.6-3.8 (2.5)
GISS	1.5-2.2 (1.9)	1.8-4.1 (2.7)
HadCRUT3v	1.5-2.2 (1.8)	1.7-3.9 (2.6)
Constrained ranges using method 2		
ERA40	1.6-2.0 (1.9)	2.0-3.1 (2.7)
NCEP	1.6-1.9 (1.8)	1.8-3.0 (2.5)
GISS	1.7-2.0 (1.9)	2.0-3.2 (2.7)
HadCRUT3v	1.6-2.0 (1.8)	1.9-3.0 (2.6)
Constrained ranges using method 1 (HadCRUT3v data mask)		
ERA40	1.4-2.2 (1.8)	1.6-3.9 (2.5)
NCEP	1.3-2.1 (1.7)	1.5-3.5 (2.3)
GISS	1.5-2.2 (1.8)	1.7-4.1 (2.6)
HadCRUT3v	1.5-2.3 (1.9)	1.8-4.4 (2.9)
Constrained ranges using method 2 (HadCRUT3v data mask)		
ERA40	1.5-1.9 (1.8)	1.8-3.0 (2.5)
NCEP	1.4-1.9 (1.7)	1.5-2.8 (2.3)
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