On the sensitivities of marine low cloud cover to the strength of the tropical inversion and sea surface temperature

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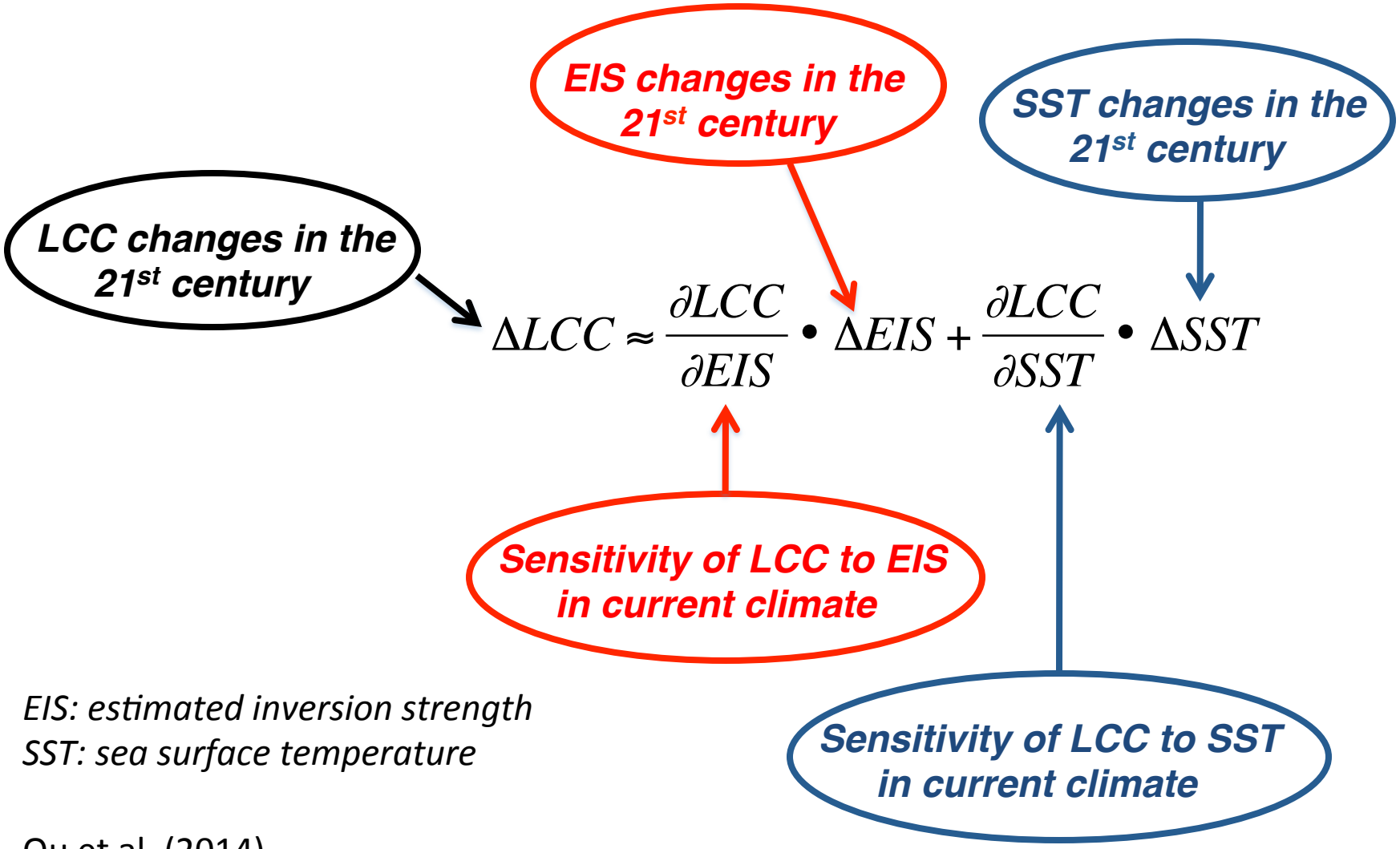
A simple framework to understand and constrain tropical marine low-cloud cover (LCC) feedback



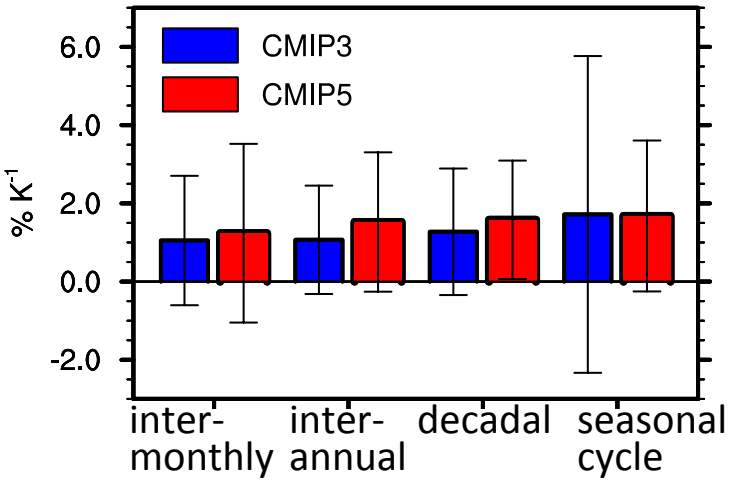
EIS: estimated inversion strength
SST: sea surface temperature

Qu et al. (2014)

What type of climate variability contains the "DNA" of climate change?

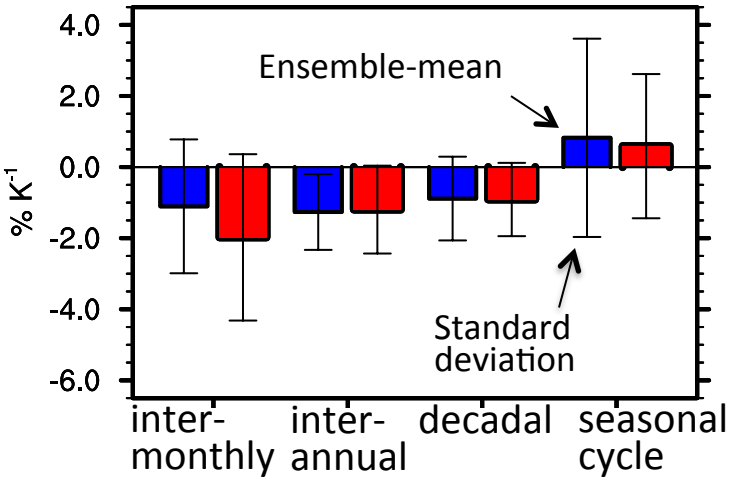
The sensitivity of LCC to EIS, averaged over five subtropical low-cloud regions

based on 20th-century simulations



- *LCC generally increases with increasing EIS.*
- *There is a high degree of time-scale invariance in the EIS sensitivity.*

The sensitivity of LCC to SST, averaged over five subtropical low-cloud regions

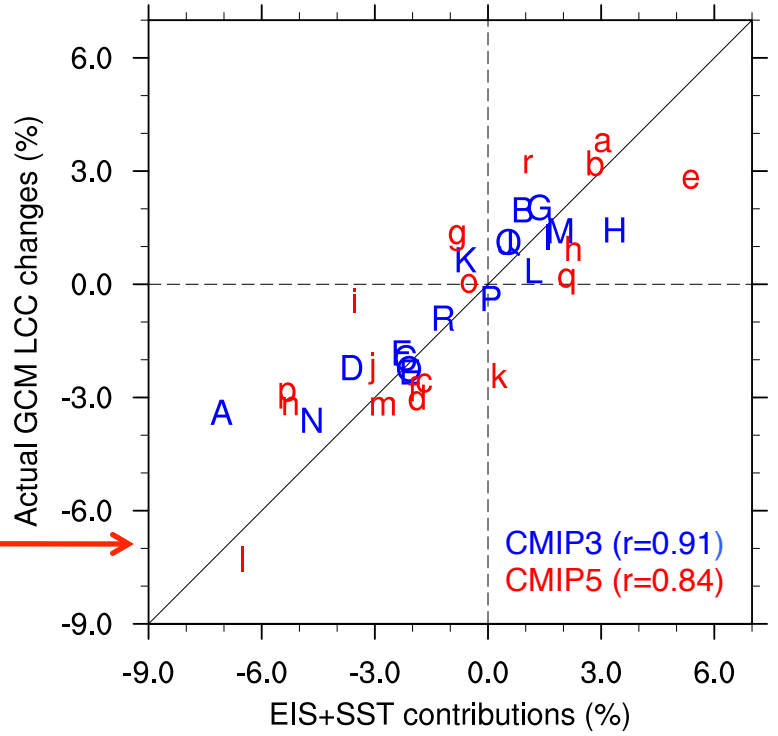


- *LCC generally decreases with increasing SST, except for the seasonal cycle.*
- *The SST sensitivity is similar on interannual and decadal time scales.*

What type of climate variability contains the "DNA" of climate change?

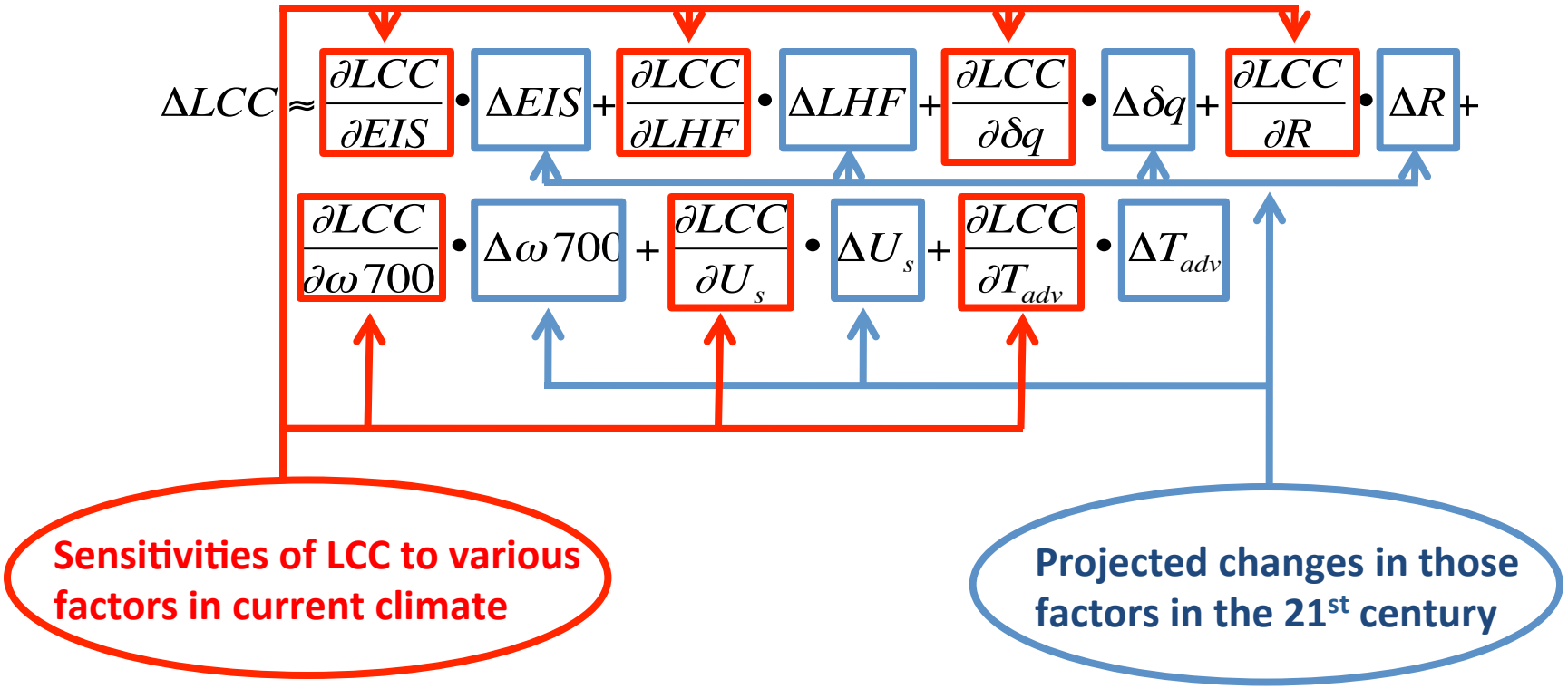
Cross-model correlation between the simple model-predicted and actual GCM LCC changes in Scenario A1B and RCP8.5 simulations

	CMIP3	CMIP5
Seasonal cycle	0.12	-0.09
Intermonthly	0.51	0.15
Interannual	0.81	0.46
Decadal	0.91	0.84



- *Decadal variations contain the information most relevant for climate change.*

What drives the SST sensitivity?: Lesson from a seven-variable framework



Six other factors:

LHF: surface latent heat flux

δq=q(surface)-q(700hPa): vertical moisture gradient in the lower-troposphere

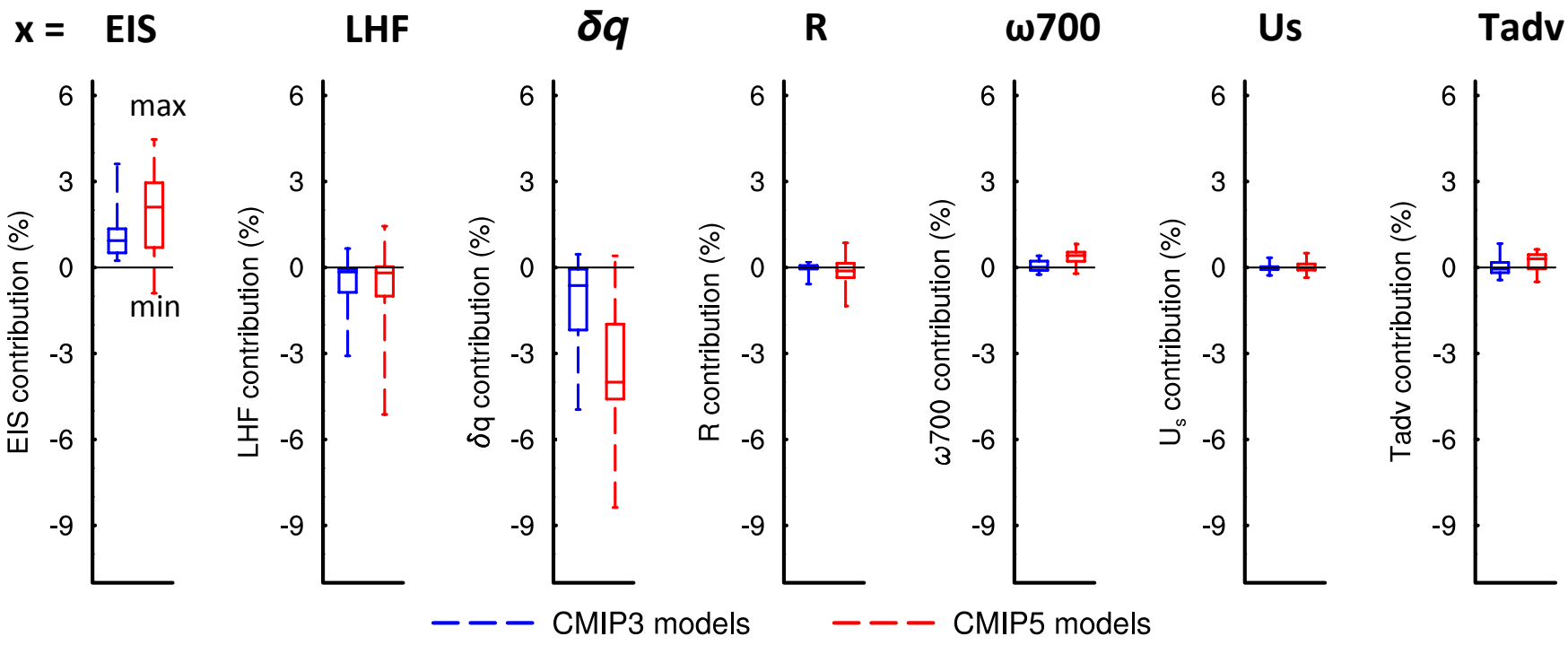
R: mean relative humidity in the free-troposphere

ω700: vertical velocity at 700 hPa.

Us: surface wind speed

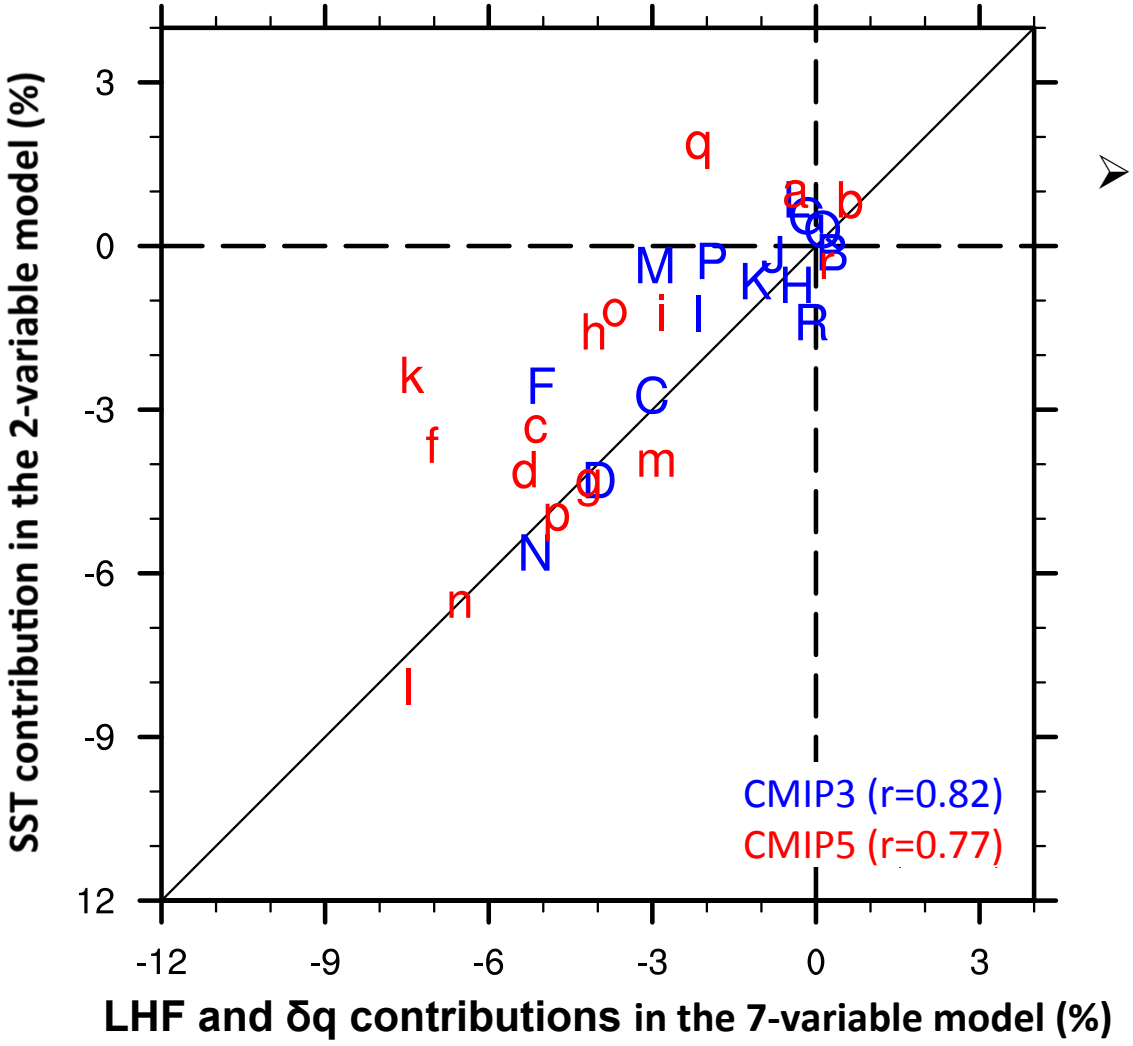
Tadv: temperature advection

Comparison of 7 terms: $\frac{\partial LCC}{\partial x} \bullet \Delta x$



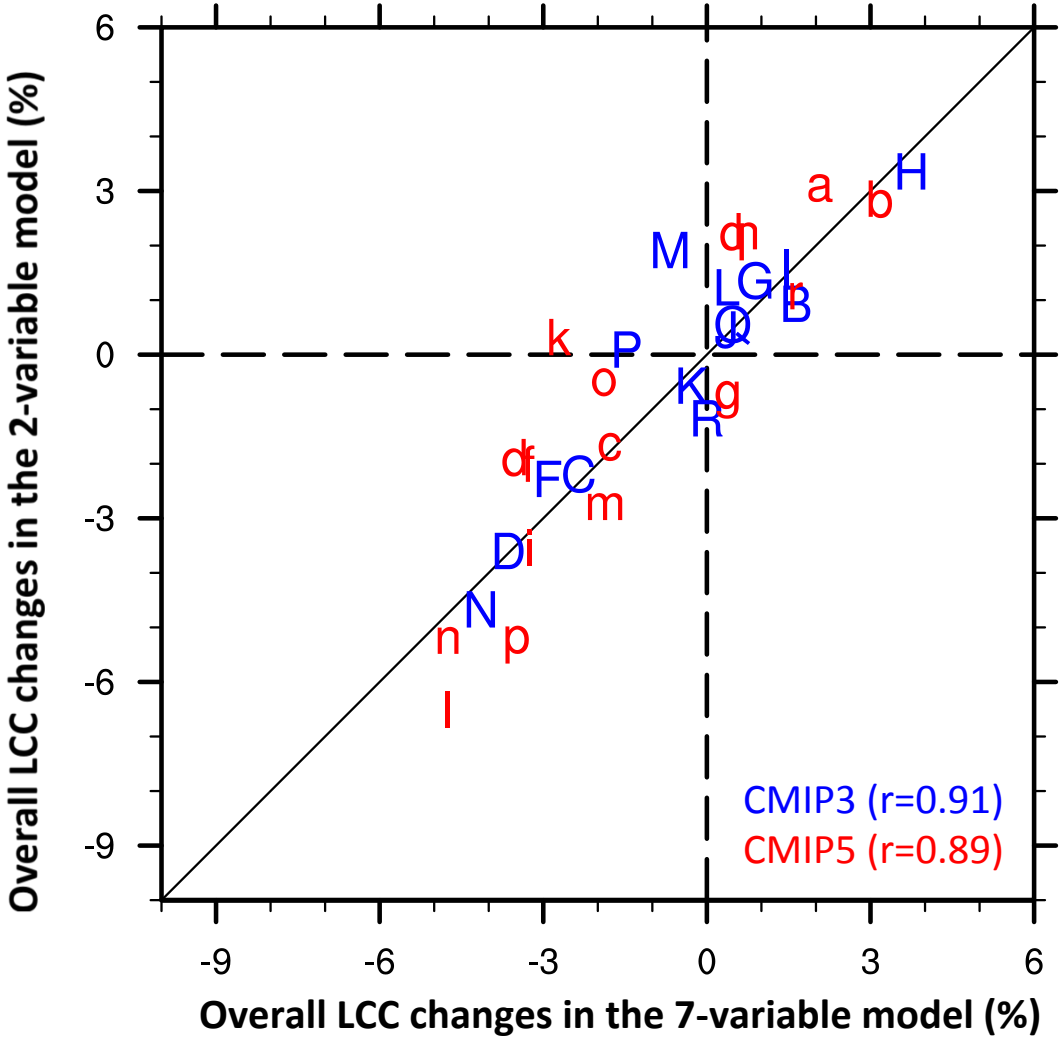
- *The dominant terms are the EIS, LHF and δq terms.*
- *The EIS term is generally positive, while the LHF and δq terms are generally negative.*

Interpreting the SST contribution in the 2-variable model



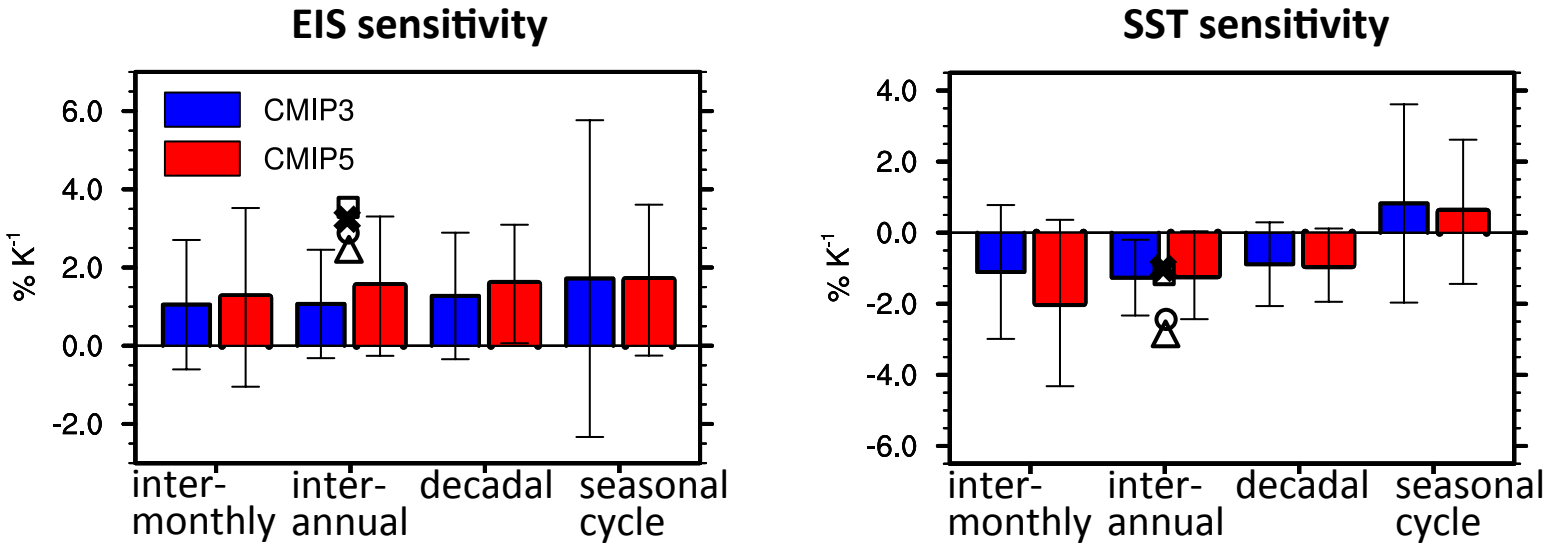
- *The SST contribution in the 2-variable model can be interpreted by the contributions of two-warming induced changes:*
  - an increase in vertical moisture gradient in the lower-troposphere
  - an increase in surface latent heat flux

Agreement between the 2- and 7-variable models



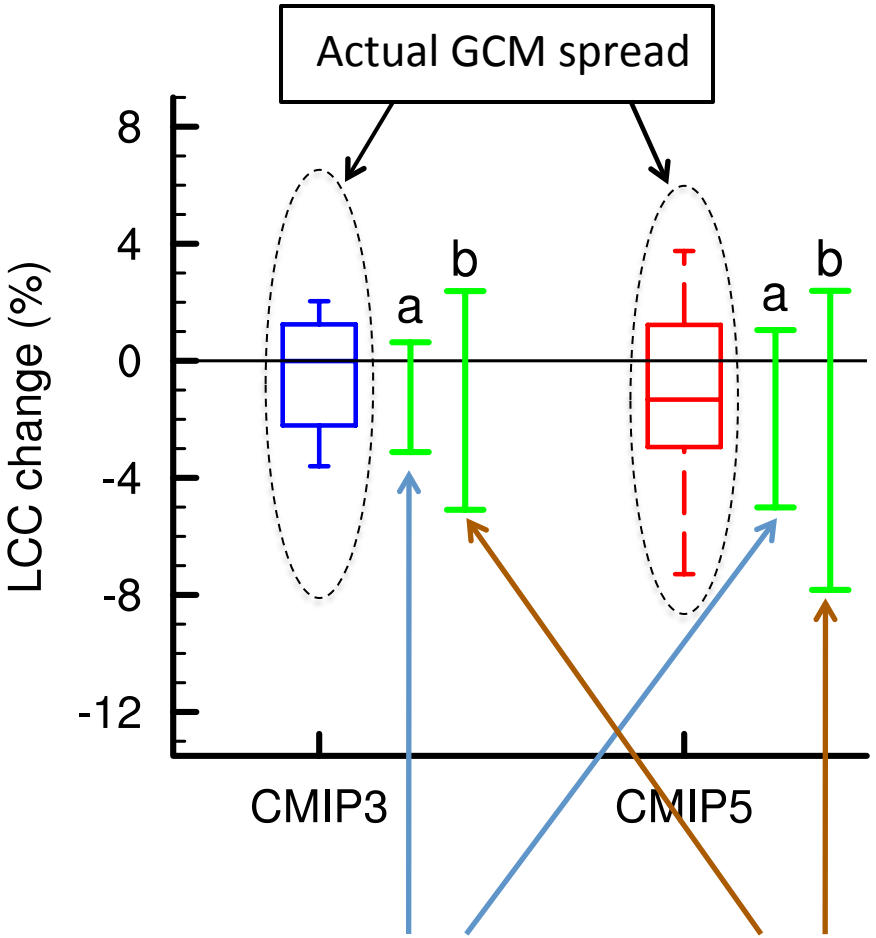
- *Two simple models capture almost exactly the same portion of the intermodel variance in LCC changes.*

Observed constraints of EIS and SST sensitivities in the 2-variable model



- *Observed EIS sensitivity ranges from 2.5 to 3.5 %/K, while observed SST sensitivity ranges from -3 to -1 %/K.*
- *Many GCMs underestimate the magnitudes of both EIS and SST sensitivities.*

Observed constraints of LCC changes



- *In almost all predictions constrained by observations, the large LCC increases in some GCMs are excluded.*
- Applying a similar methodology to abrupt4xCO2 simulations, we find that a strong negative LCC feedback is unlikely.

Using observed sensitivities and ensemble-mean EIS and SST changes

Using observed sensitivities and EIS and SST changes in each model

Take home message

1. *LCC changes in GCMs can be interpreted as a linear combination of contributions by EIS and SST.*

2. *The negative SST contribution (due to a negative LCC sensitivity to SST) originates primarily from two warming-induced changes: increases in surface latent heat flux and increases in vertical moisture gradient.*

3. *The sensitivities of LCC to EIS and SST can be constrained by observations.*

4. *If realistic EIS and SST sensitivities are simulated in GCMs, a strong negative LCC feedback is unlikely.*

Outstanding questions

1. *Why are EIS and SST sensitivities diagnosed from longer term climate variations better predictive of climate change than those from shorter term climate variations?*

2. *What are the causes of model bias in EIS and SST sensitivities?*

3. *Is there any way to reduce the uncertainties in observed EIS and SST sensitivities?*