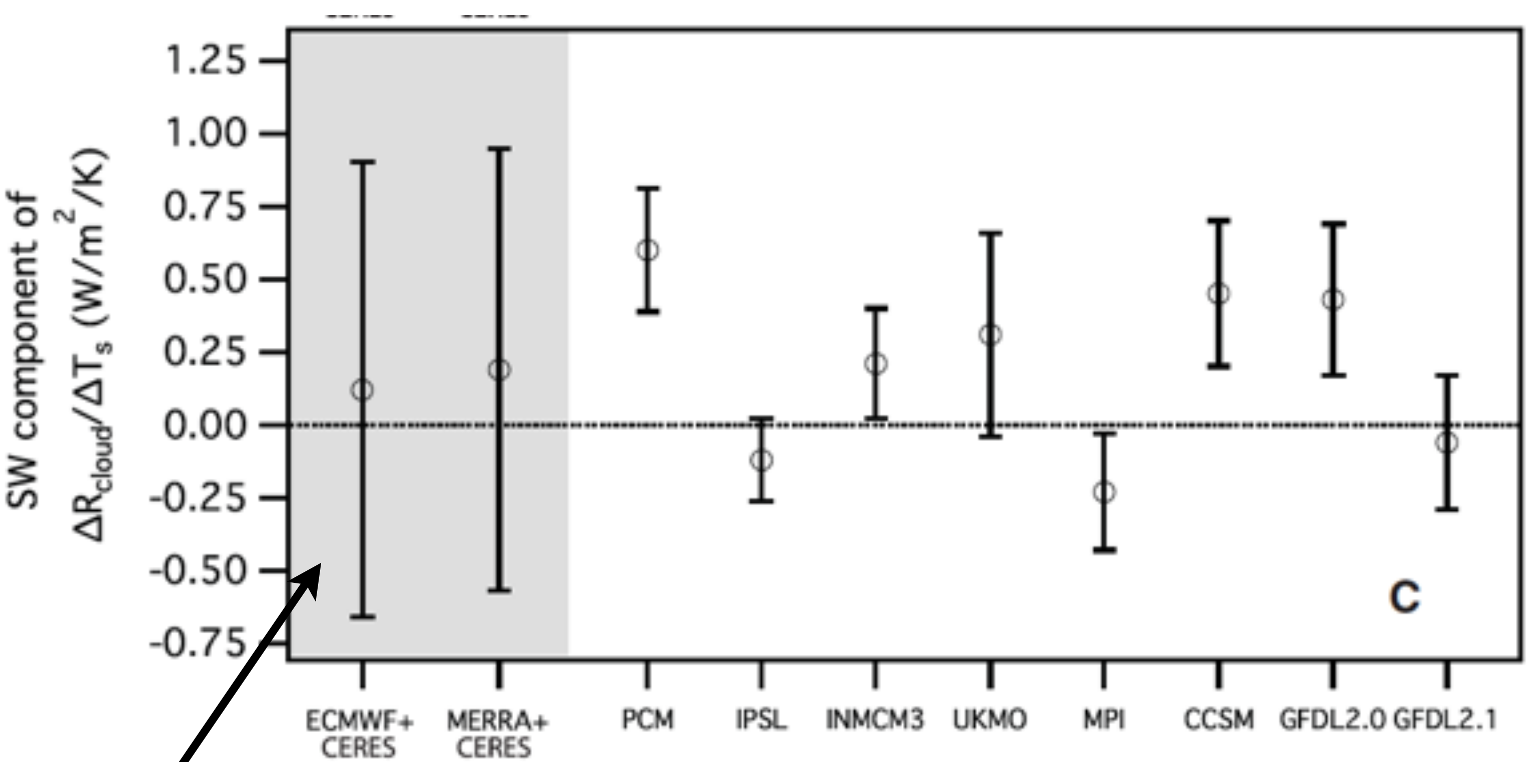
Observational evidence for positive low-cloud feedback and constraints on climate sensitivity

Florent Brient and Tapio Schneider

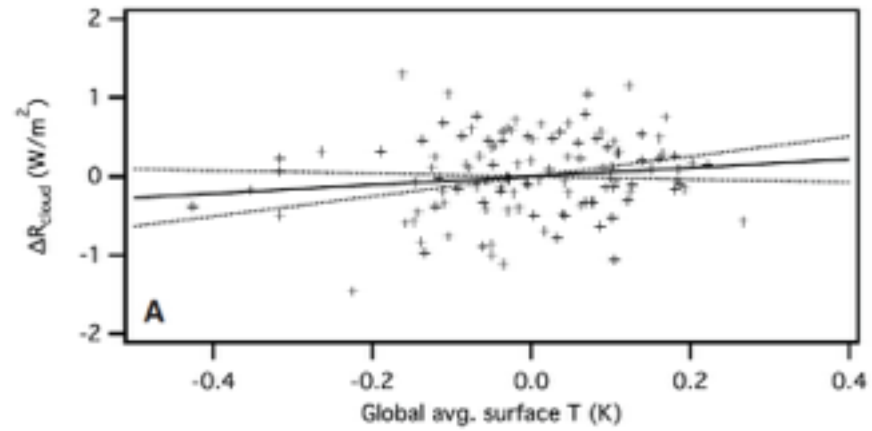
June 8th, 2015

What did we learn from observations ?



Dessler et. al 10, *Science*

Correlation SW cloud feedback versus Ts (global)

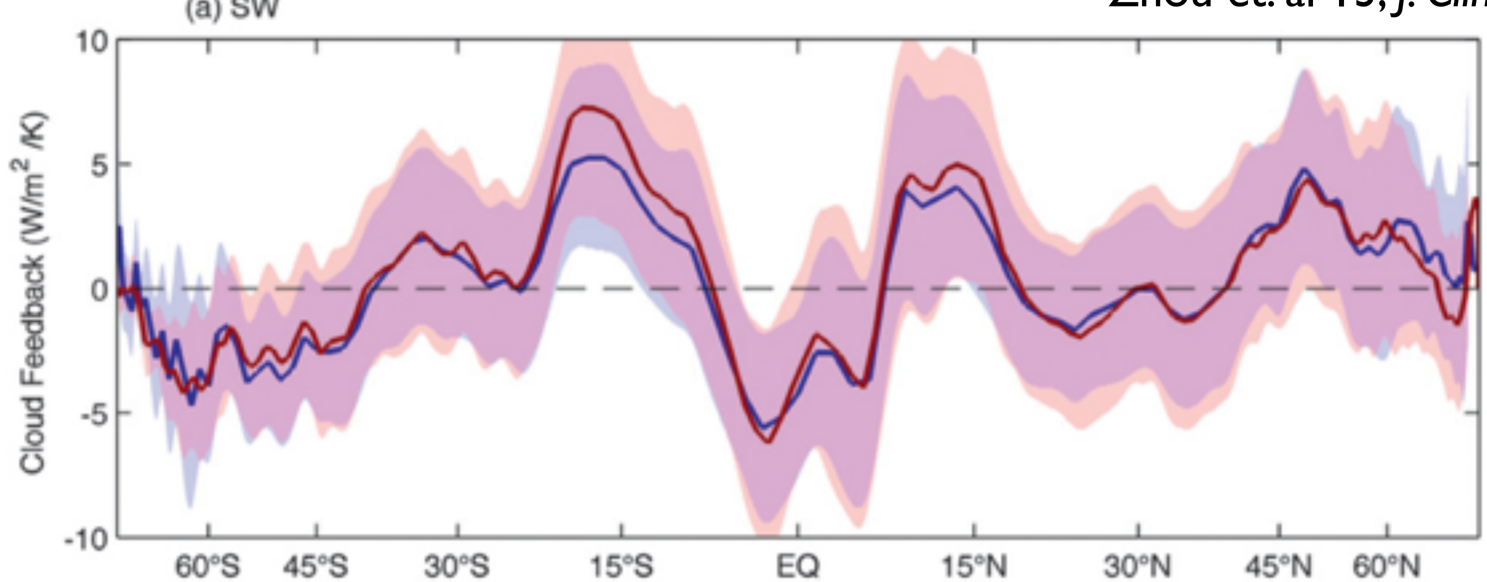


Slight *positive* SW cloud feedback

Strong uncertainty

Strong disagreement across models

Zhou et. al 13, *J. Clim.*



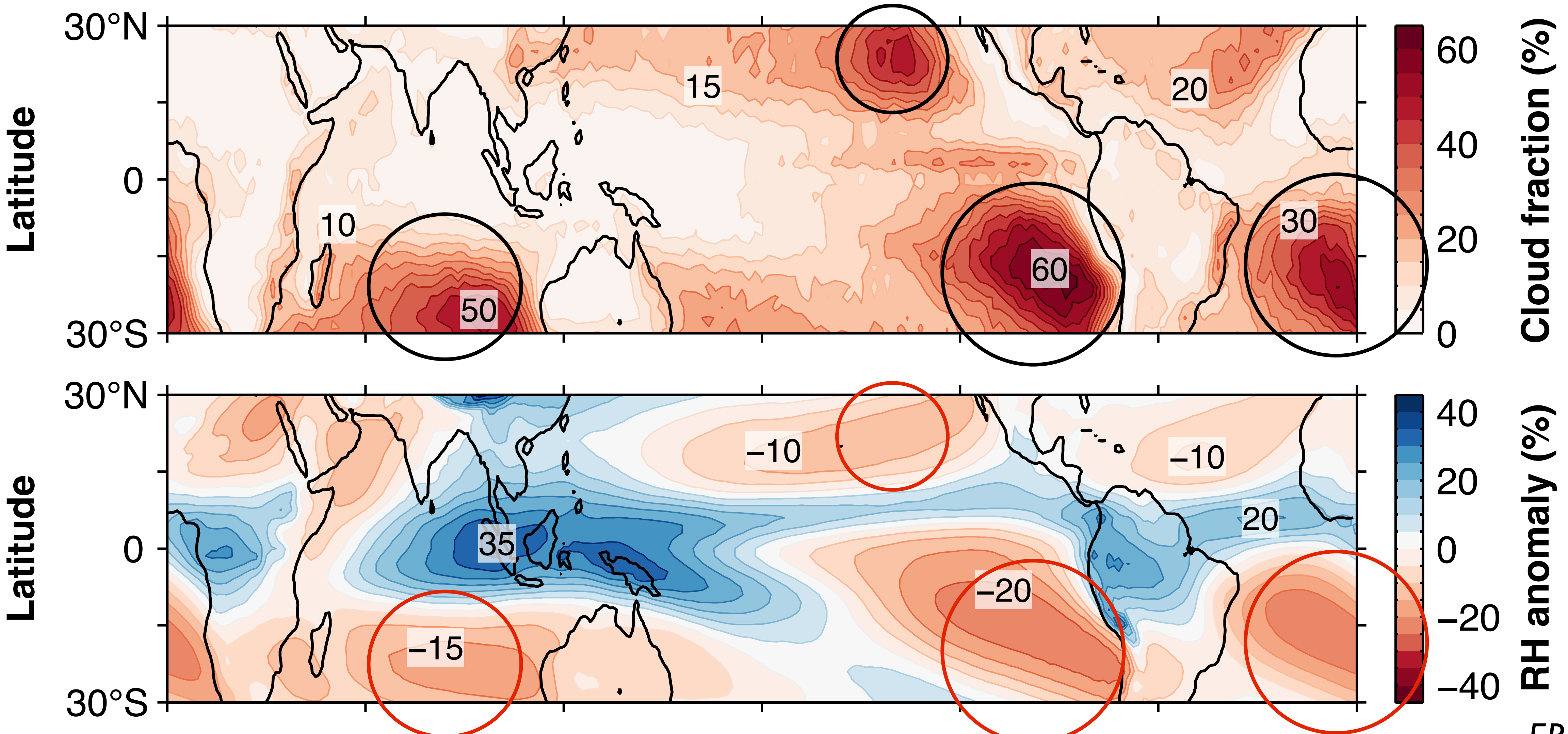
Strong regional discrepancy

Positive feedback over subtropical regions

Is it possible to constrain cloud feedback based on observed variations?

Focus on low-clouds

Unique Low-Cloud fraction (Calipso/CloudSat)



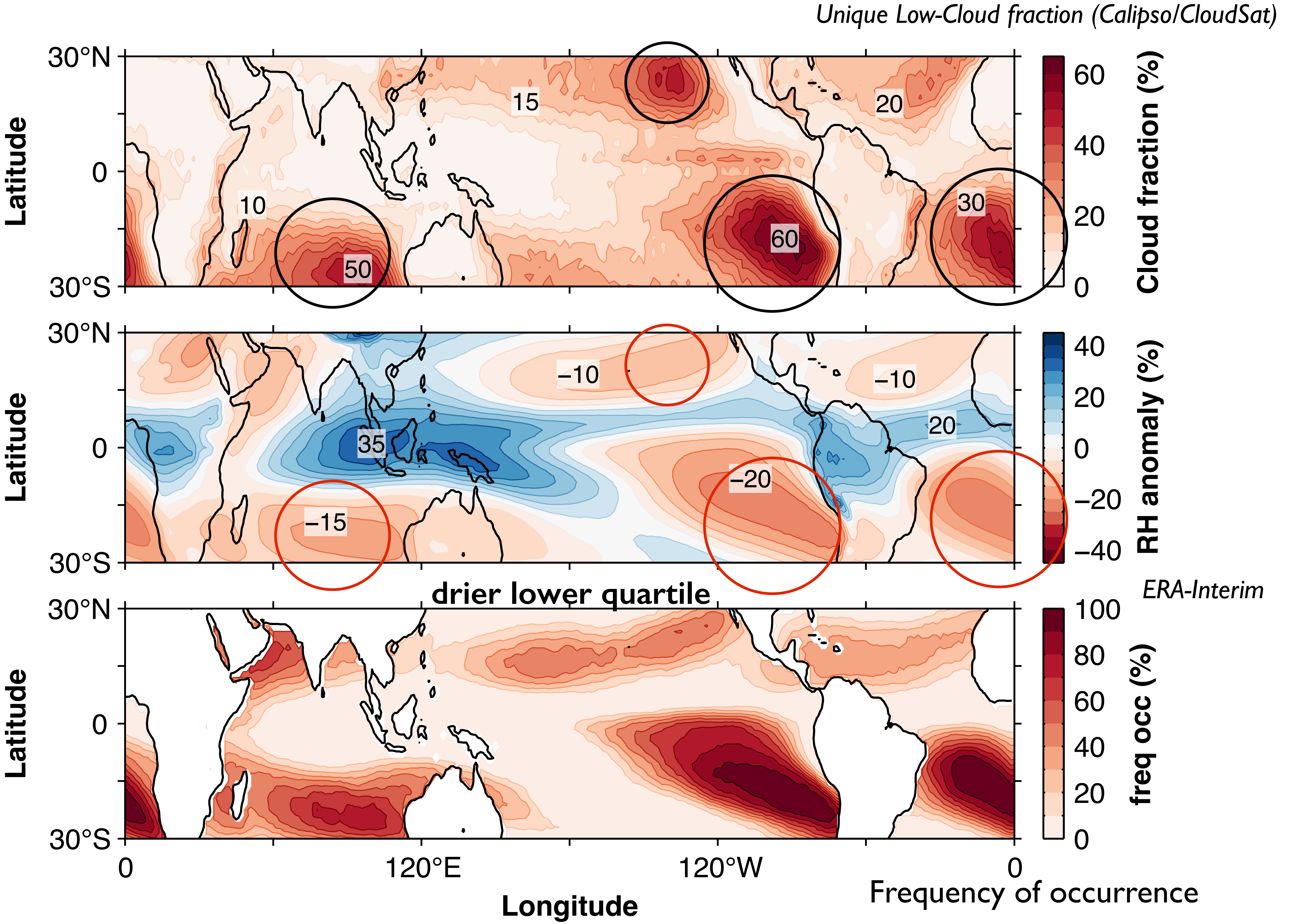
ERA-Interim

Low-clouds are present over subtropical regions (eastern parts of oceans)

Drier than the tropical mean

<u>Lower quartile of RH deviation from tropical-ocean averaged RH</u>

Focus on low-clouds



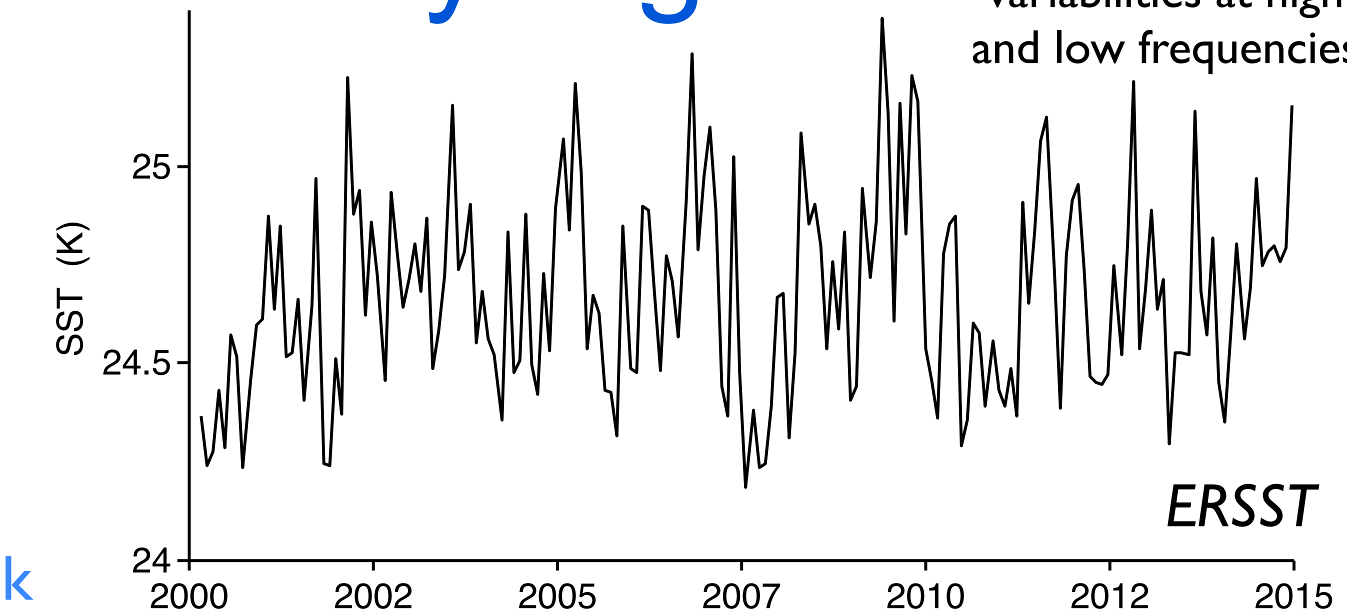
Temporal evolution of dry region

<u>Two observed dataset</u>

CERES-EBAF (2000-2015)

ISCCP-FD (1983-2009) ?

variabilities at high and low frequencies

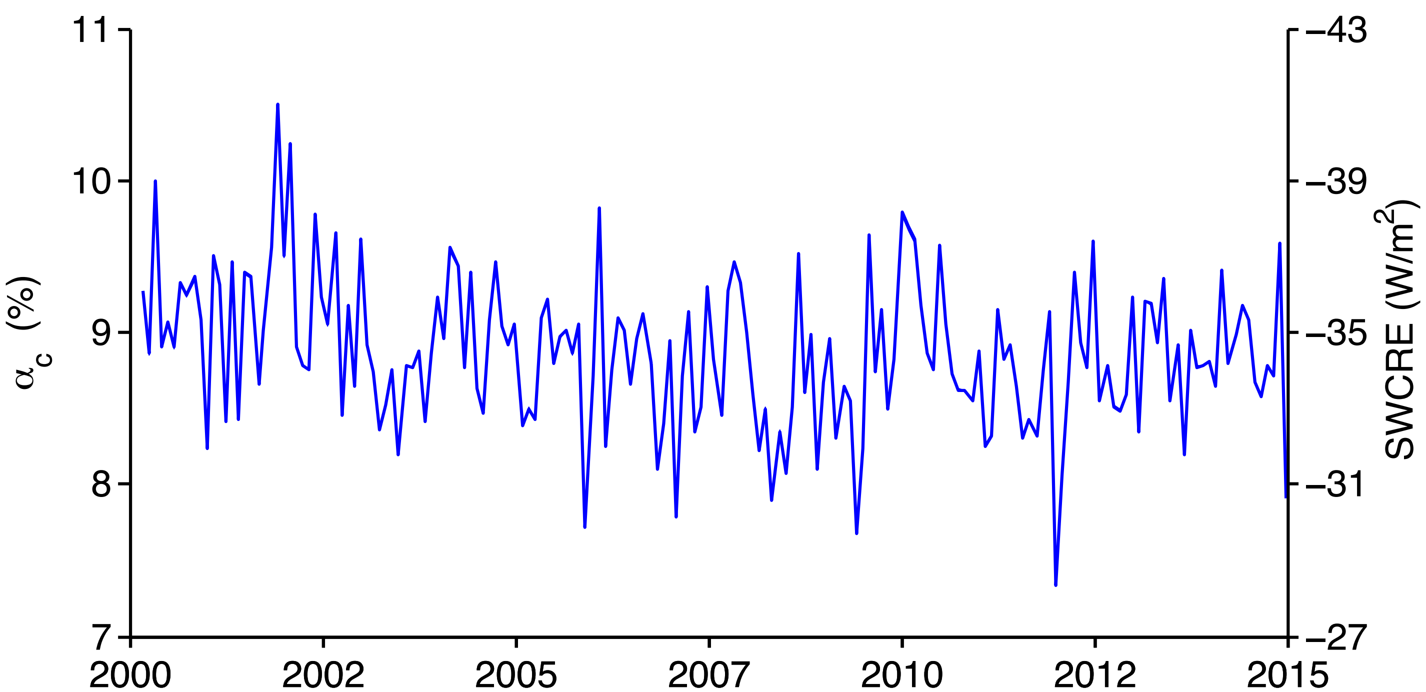


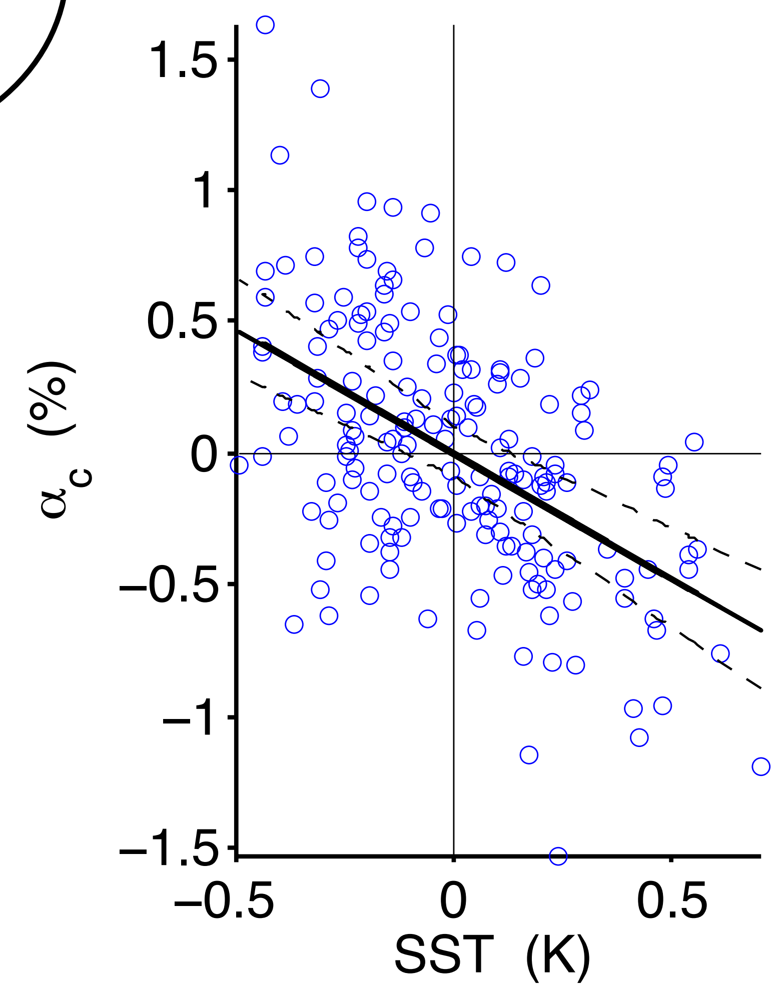
cloud feedback

dominated by volcanoes

$$\alpha_{SW} = \frac{SW_{tot}^{\uparrow}}{SW_{tot}^{\downarrow}} = \overbrace{-\frac{SWCRE}{SW_{tot}^{\downarrow}}}^{\alpha_{cloud}} + \overbrace{\frac{SW_{clear}^{\uparrow}}{SW_{tot}^{\downarrow}}}^{\alpha_{clear}}$$

<u>Earth SW albedo :</u>

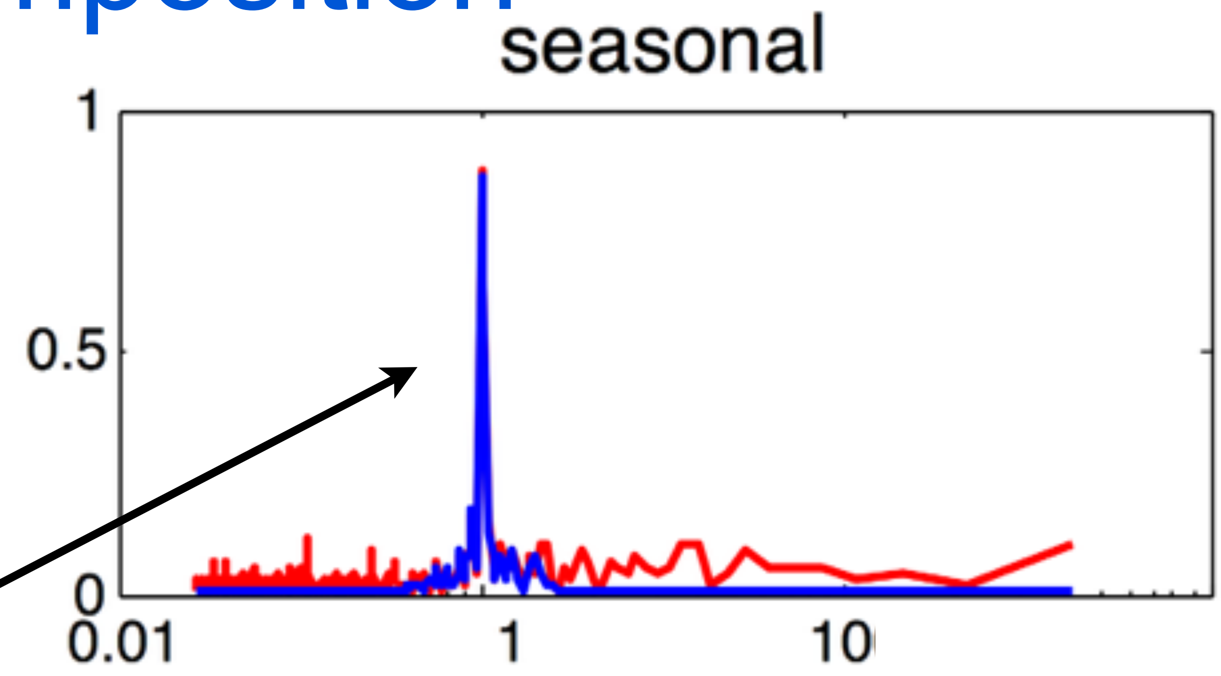




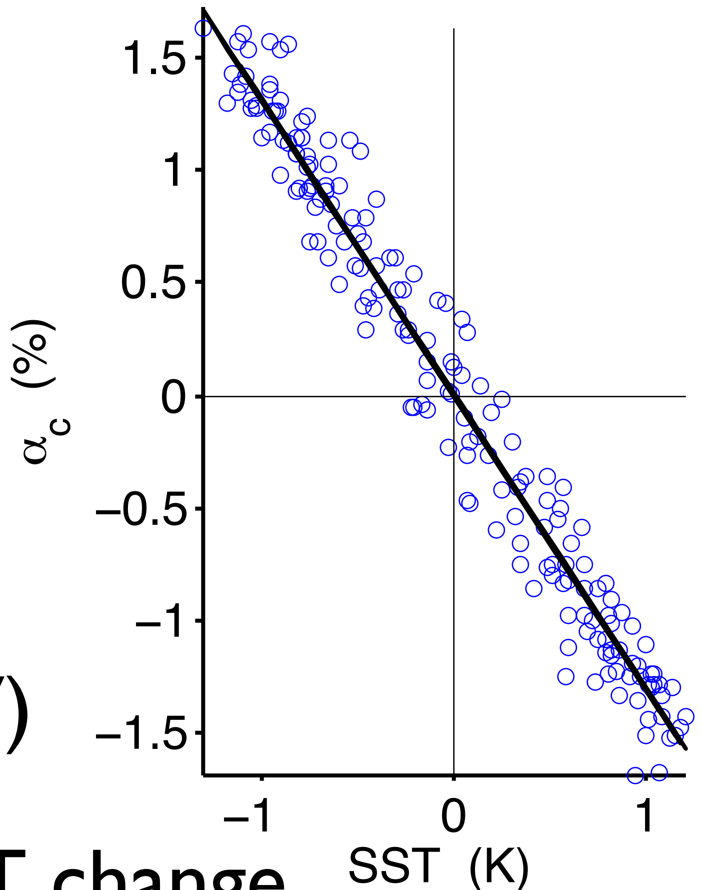
Spectral decomposition

1. Seasonal variability

1-yr bandpass filter with 12-order Chebyshev polynomial



Bandpass filter

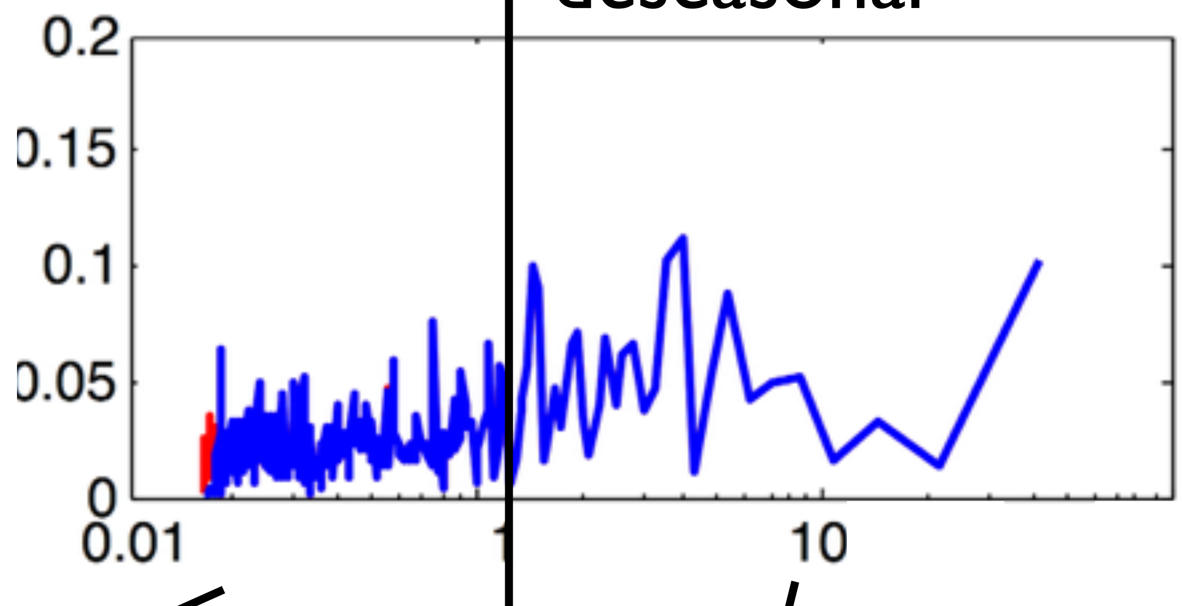


Very strong correlation (R=-0.97)

Observed cloud albedo is related SST change

Spectral decomposition

deseasonal



1. Seasonal variability

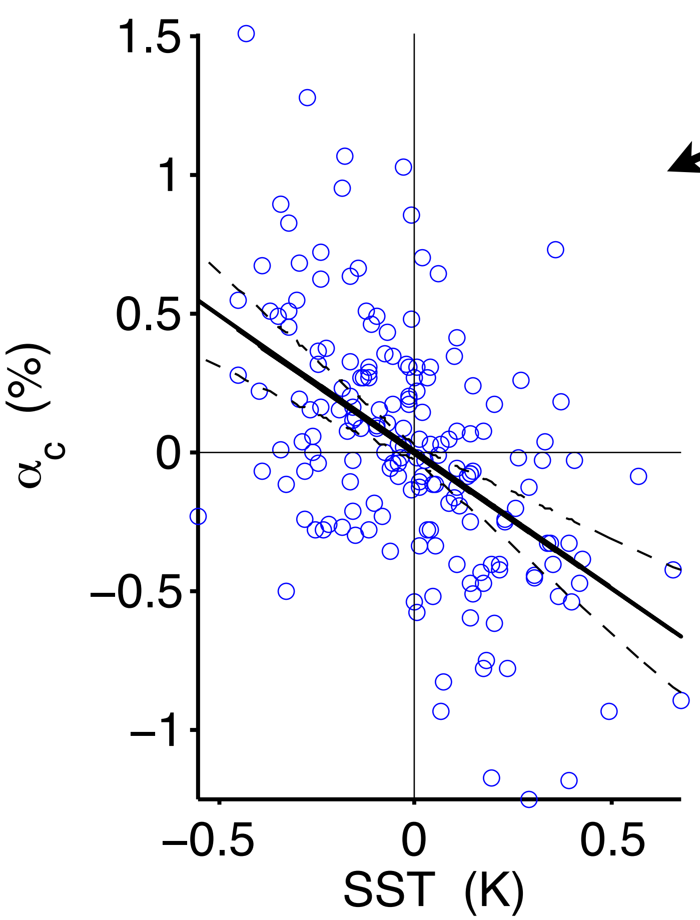
1-yr bandpass filter with 12-order Chebyshev polynomial

2. Deseasonal variability

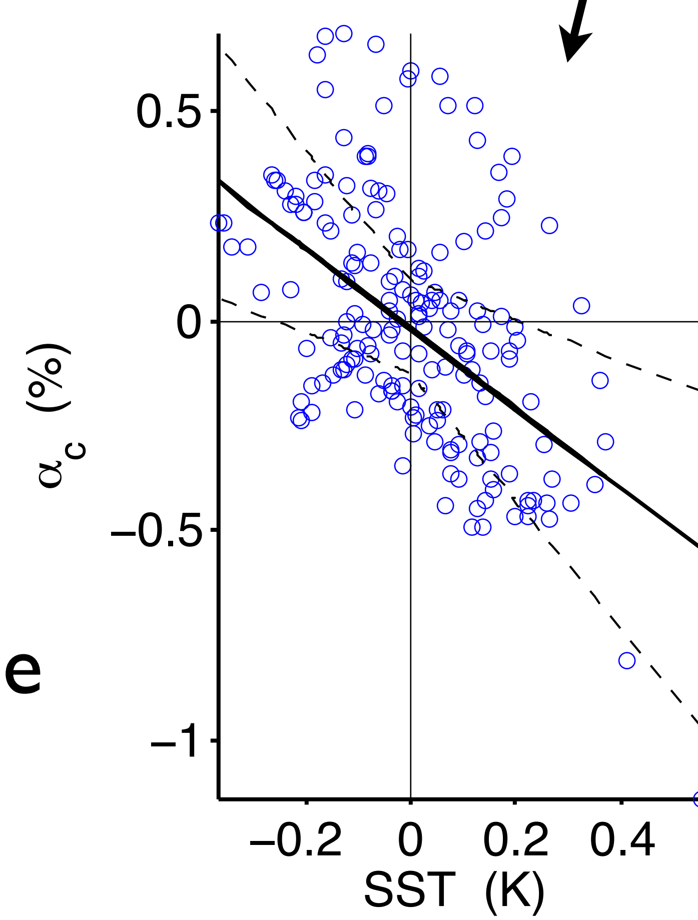
1-yr high/low pass filter
with 12-order Chebyshev polynomial

intra-annual
variability

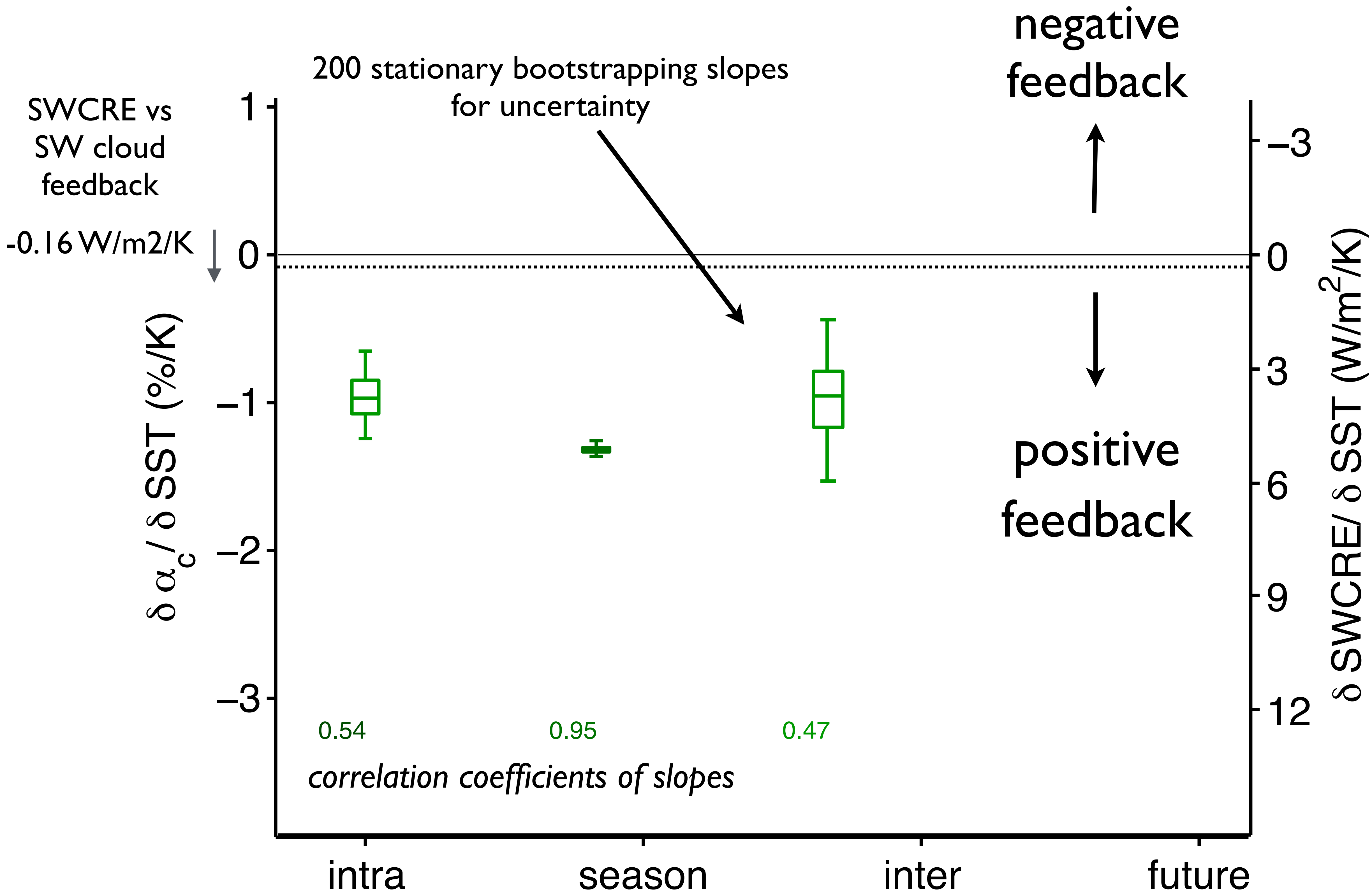
inter-annual
variability



Robust negative slope
(positive feedback)

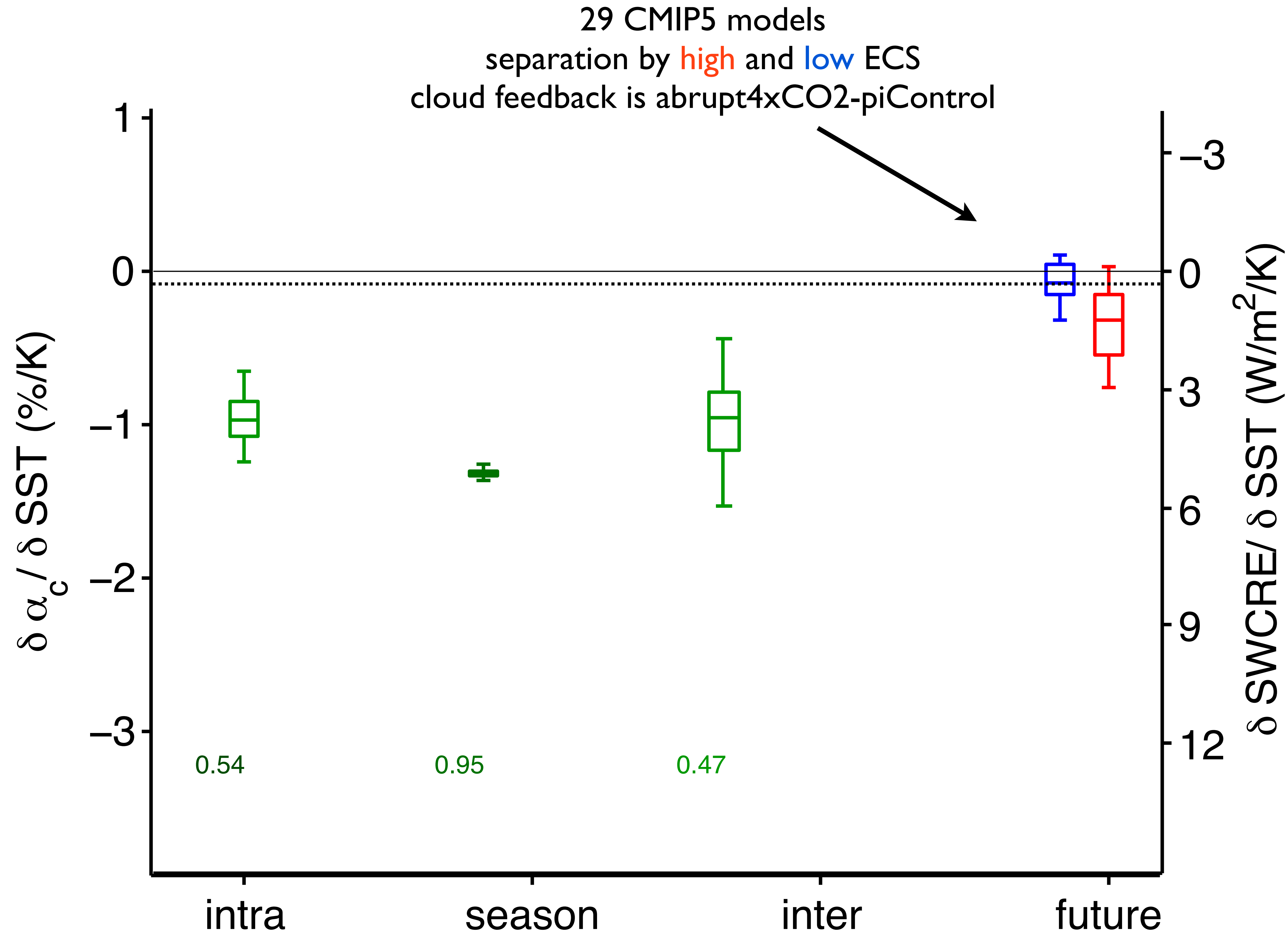


Slope albedo vs SST

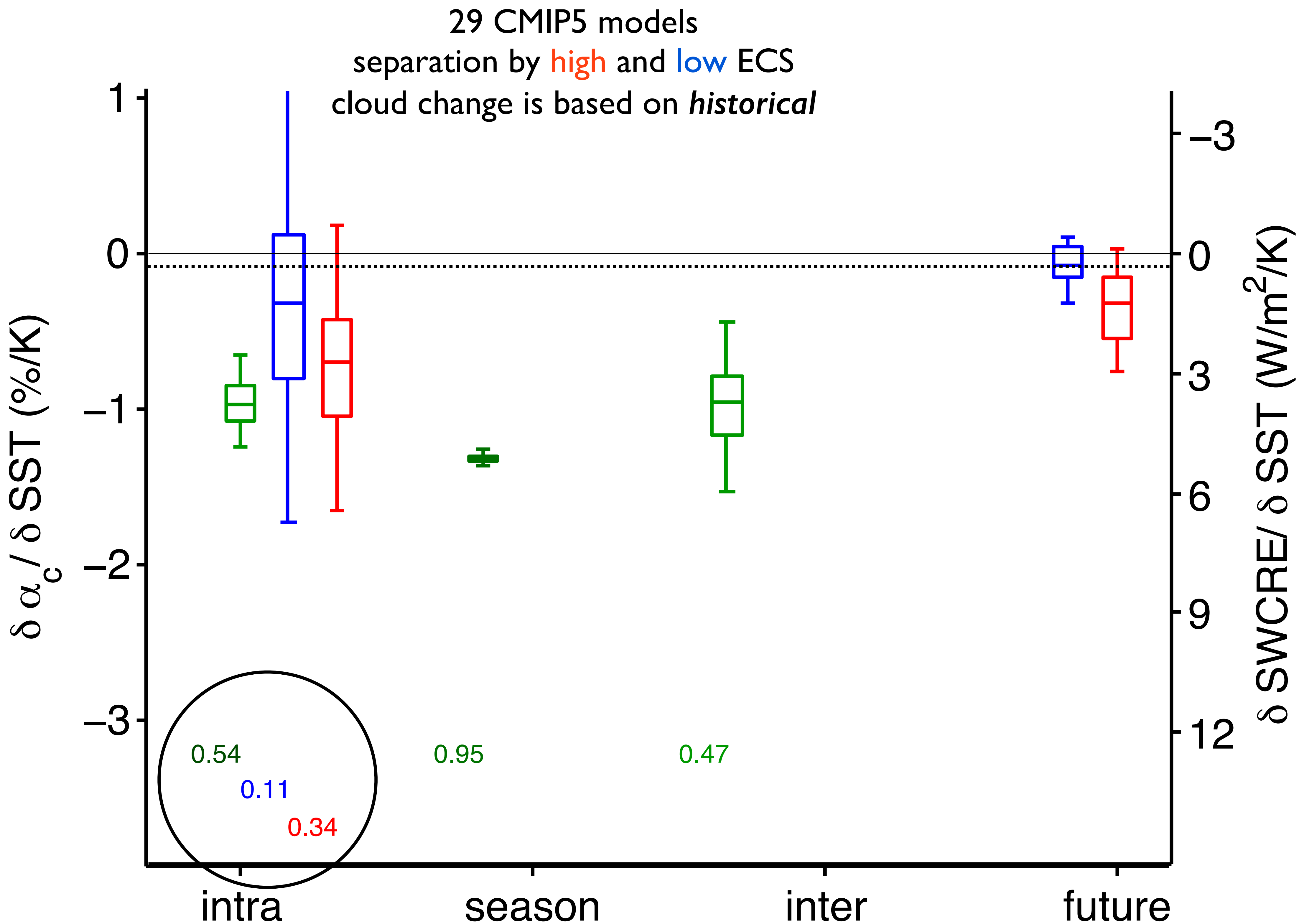


where are CMIP5 models ?

Slope albedo vs SST

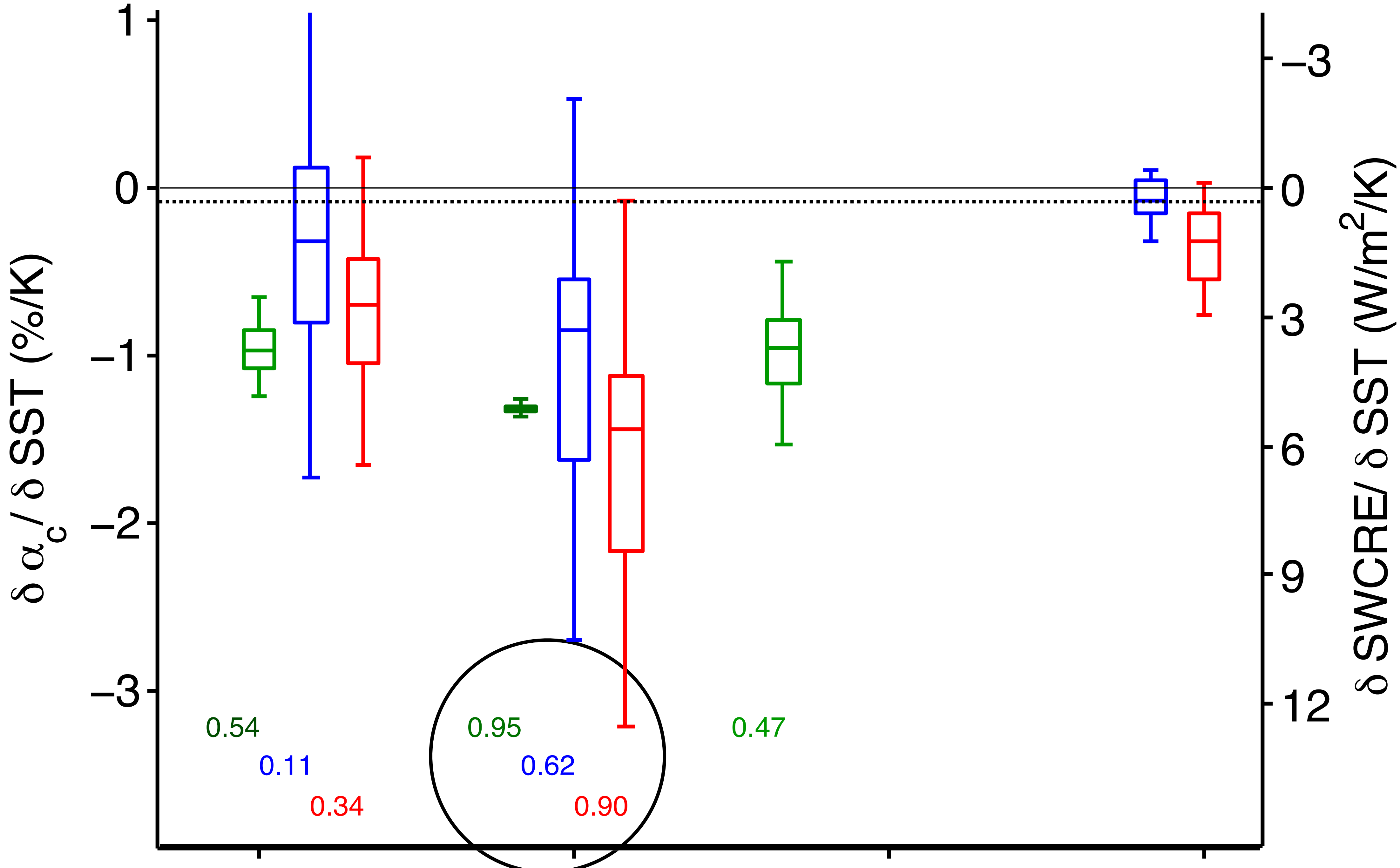


Slope albedo vs SST



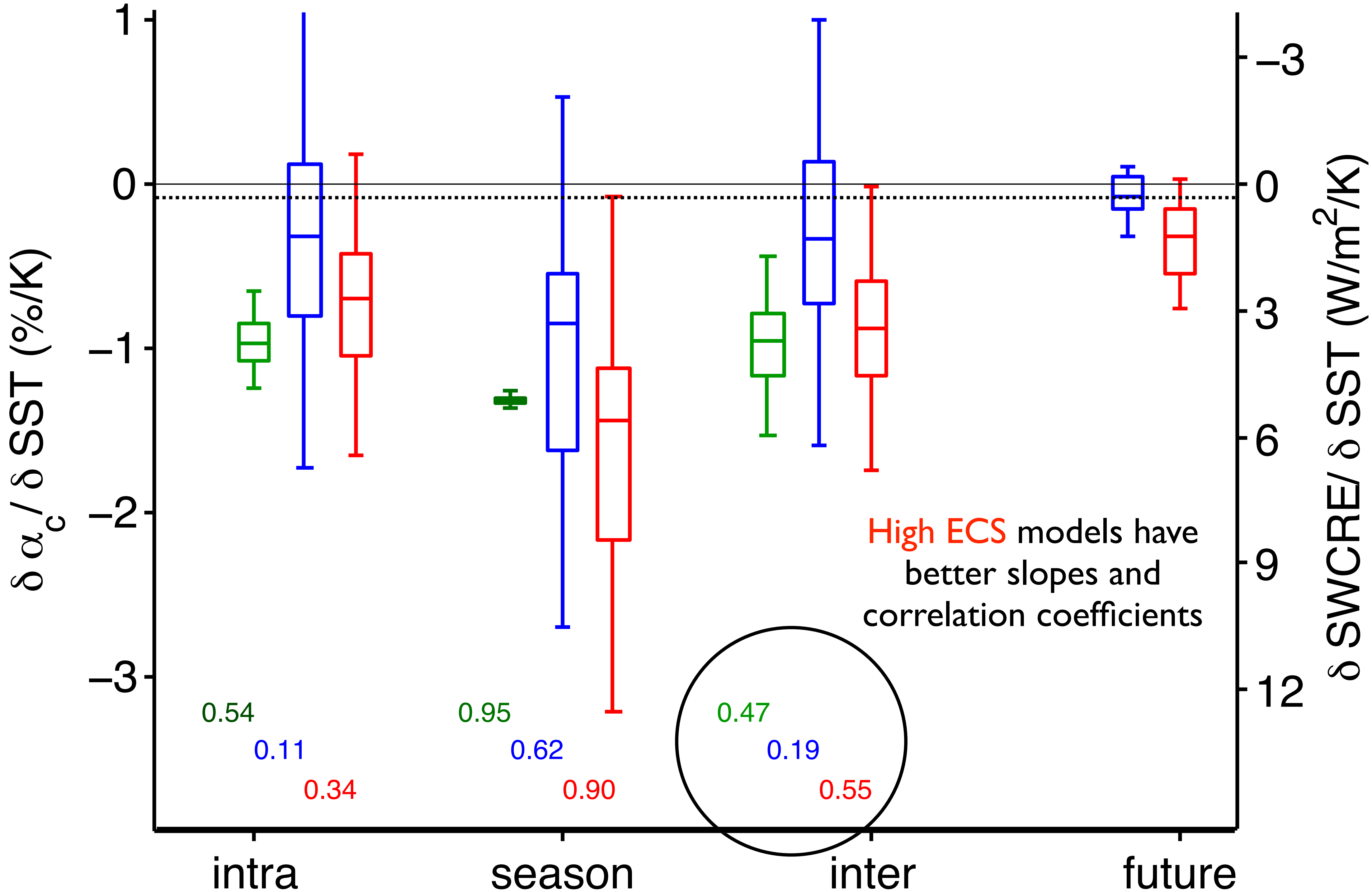
Models have difficulties to represent
high-frequency variabilities (MJO?)

Slope albedo vs SST



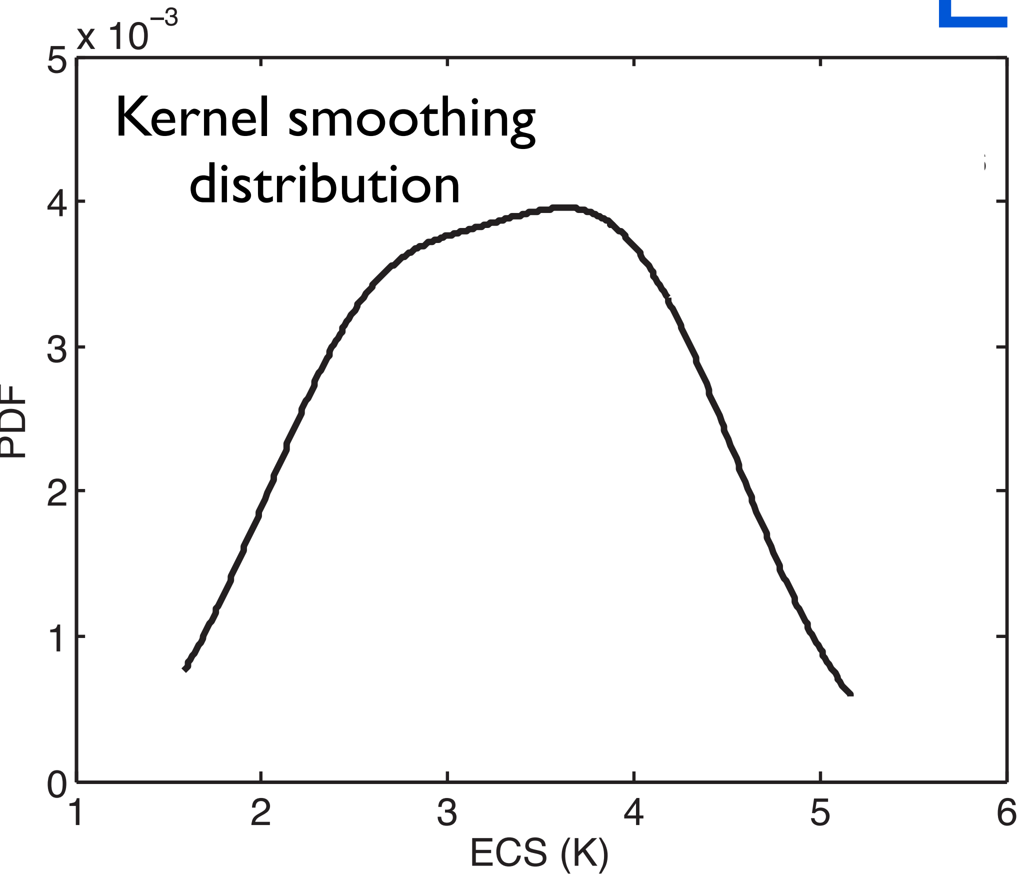
High ECS models have better slope and correlation coefficients

Slope albedo vs SST

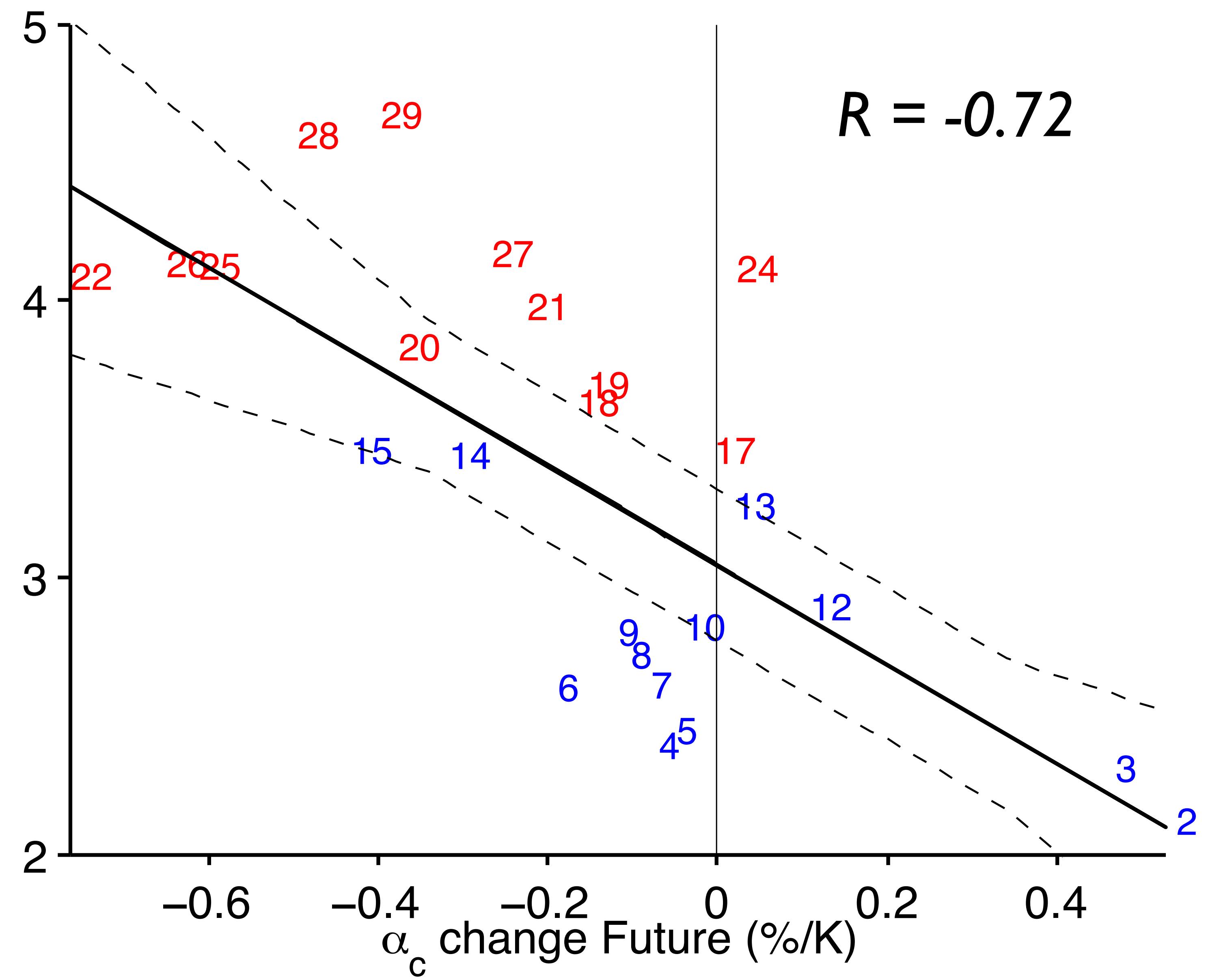


Can we constrain model ECS by observed variabilites ?

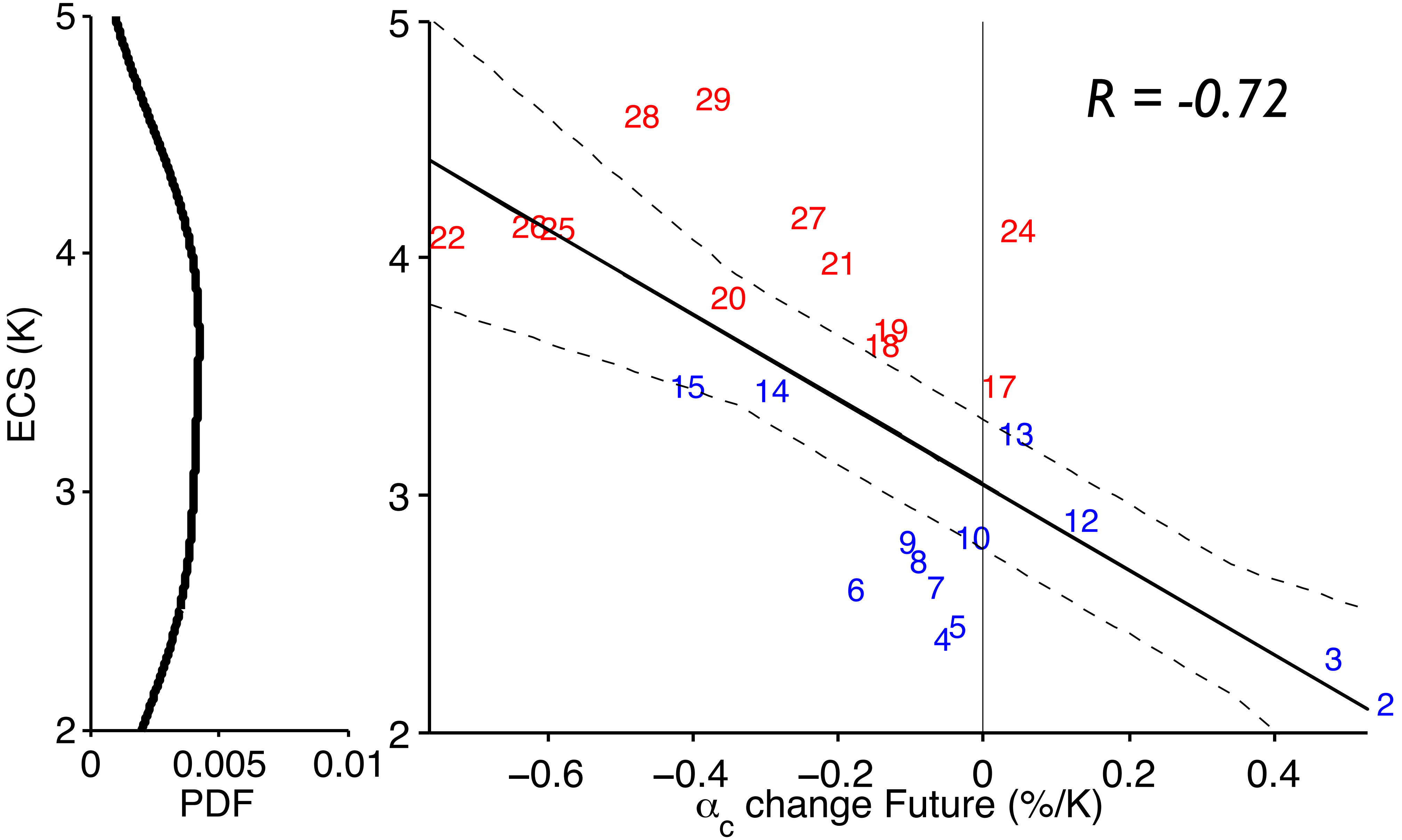
ECS estimate



CMIP5 ECS range is [2.1 , 4.6] K, with a max probability of 3.6 K

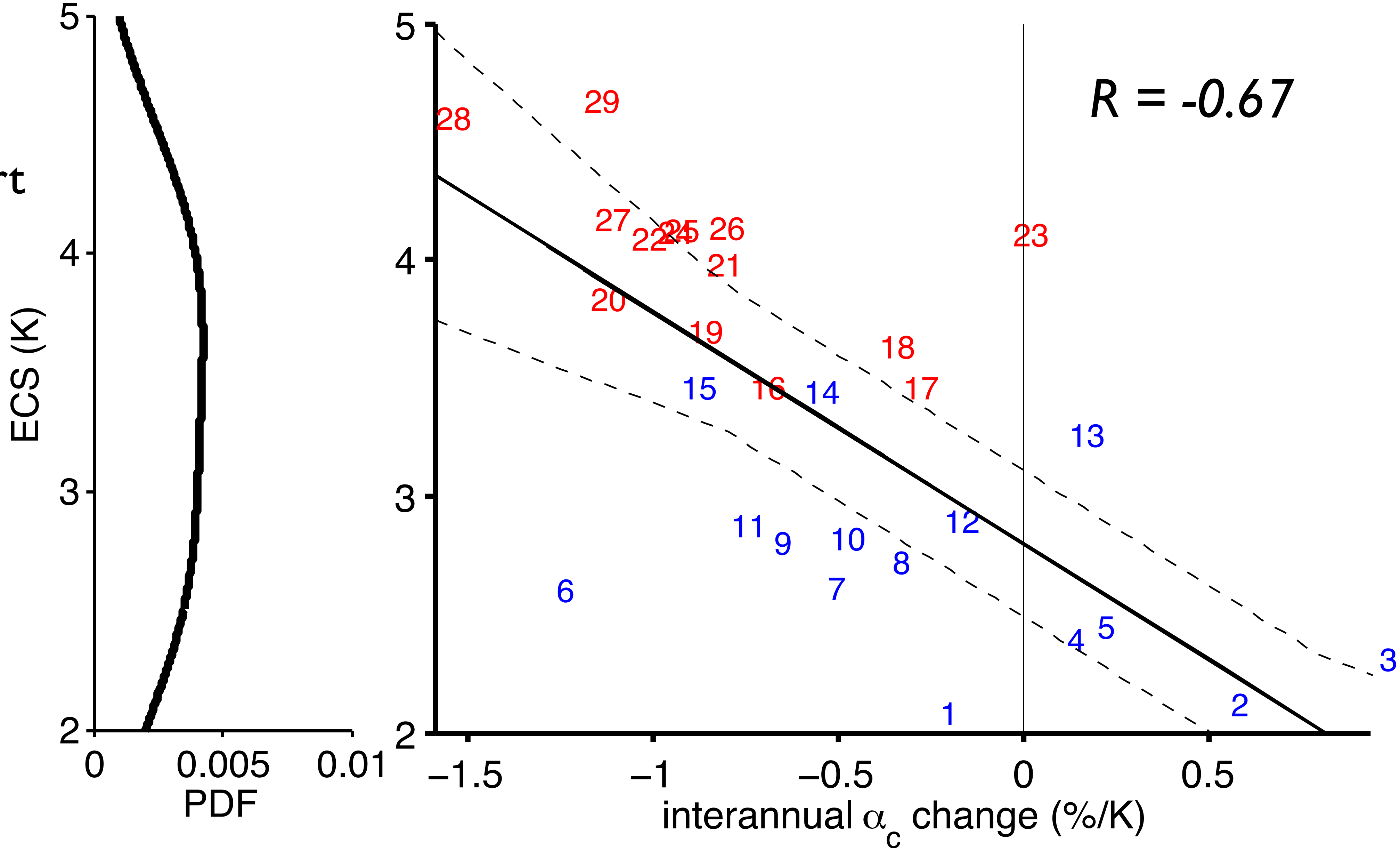


ECS estimate

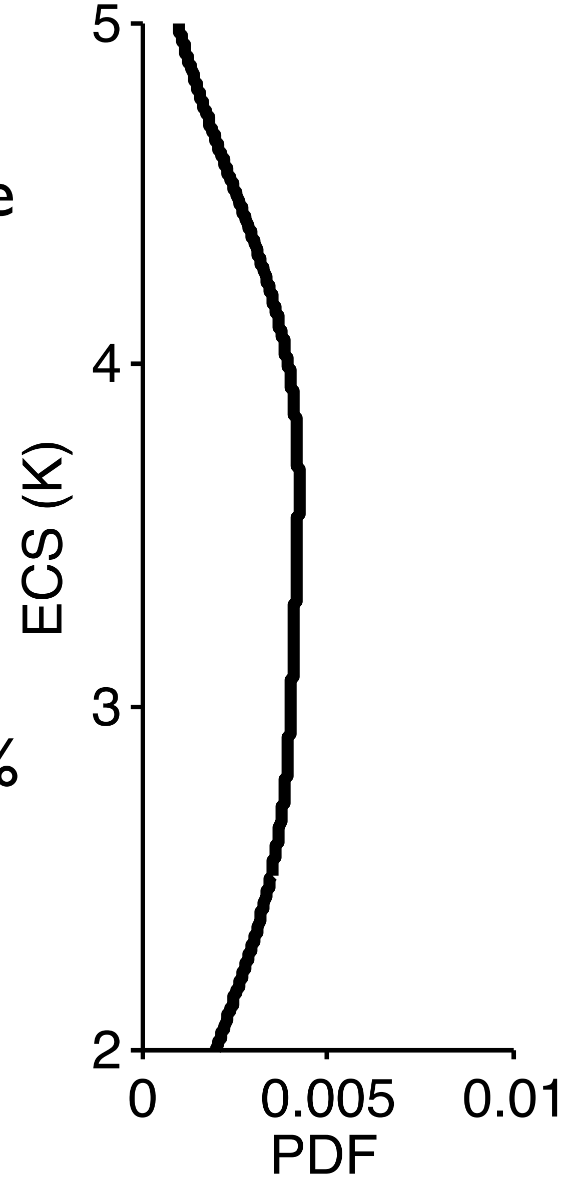


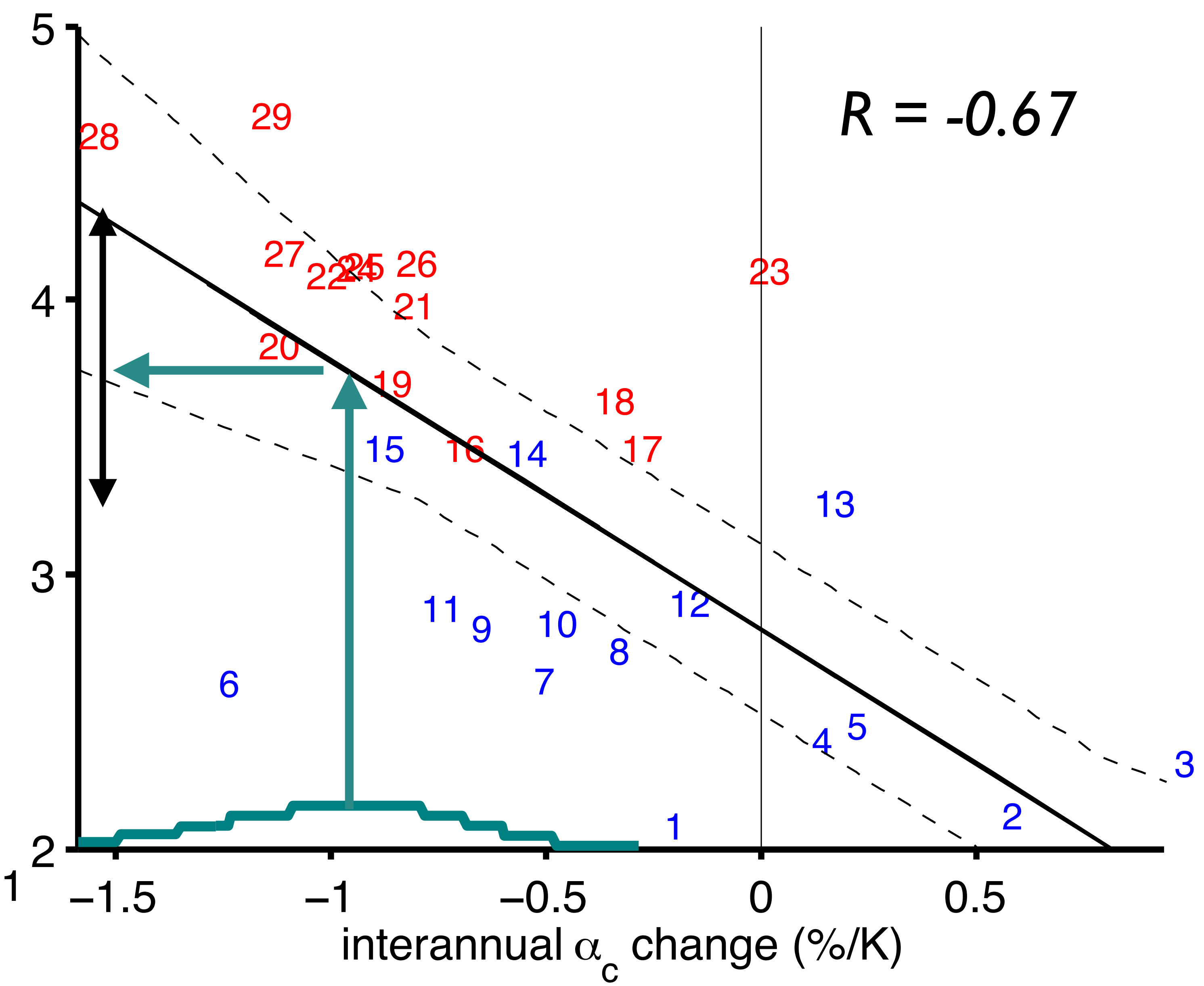
ECS estimate

Interannual variability explains a significant part of the spread of ECS



ECS estimate





CERES observations give a slope of -0.9 %/K

Inferred ECS gives a 90% confidence interval of [3.3 , 4.3] K (based 200*200 samples)

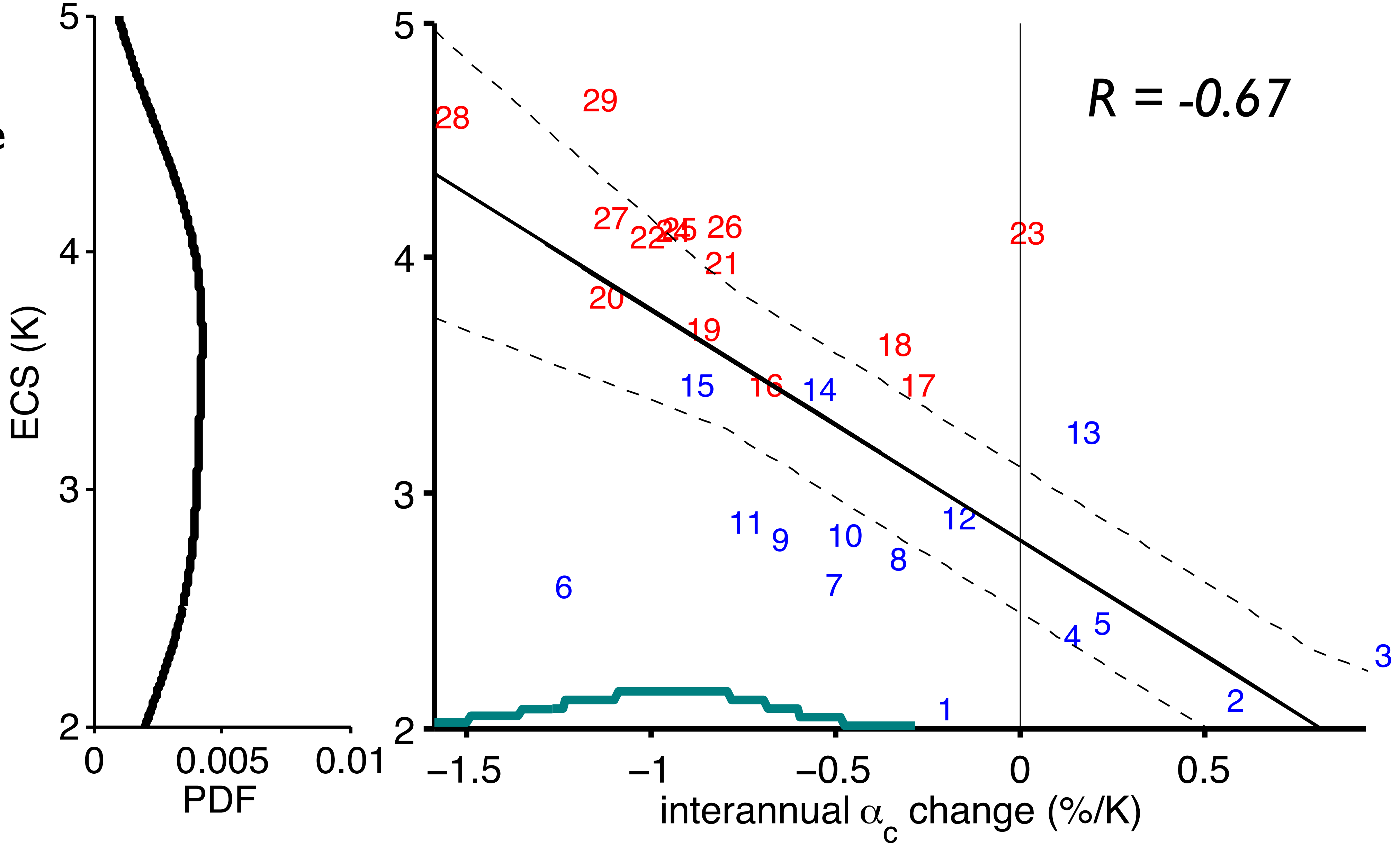
Too strong influence of lowest sensitivity models (by their impact on the slope)

Too weak influence of some realistic models

→ Using Bayesian Model Averaging

ECS estimate

<u>CERES observations</u> give
a slope of -0.9 %/K



likelihood function

$$w_i = \frac{P(\alpha_{obs}|M_i)}{\Sigma_k P(\alpha_{obs}|M_k)}$$

Proba of the model given the obs

$$P(ECS|\alpha_{obs}) = \Sigma_k \; w_k \; P(ECS|M_k)$$

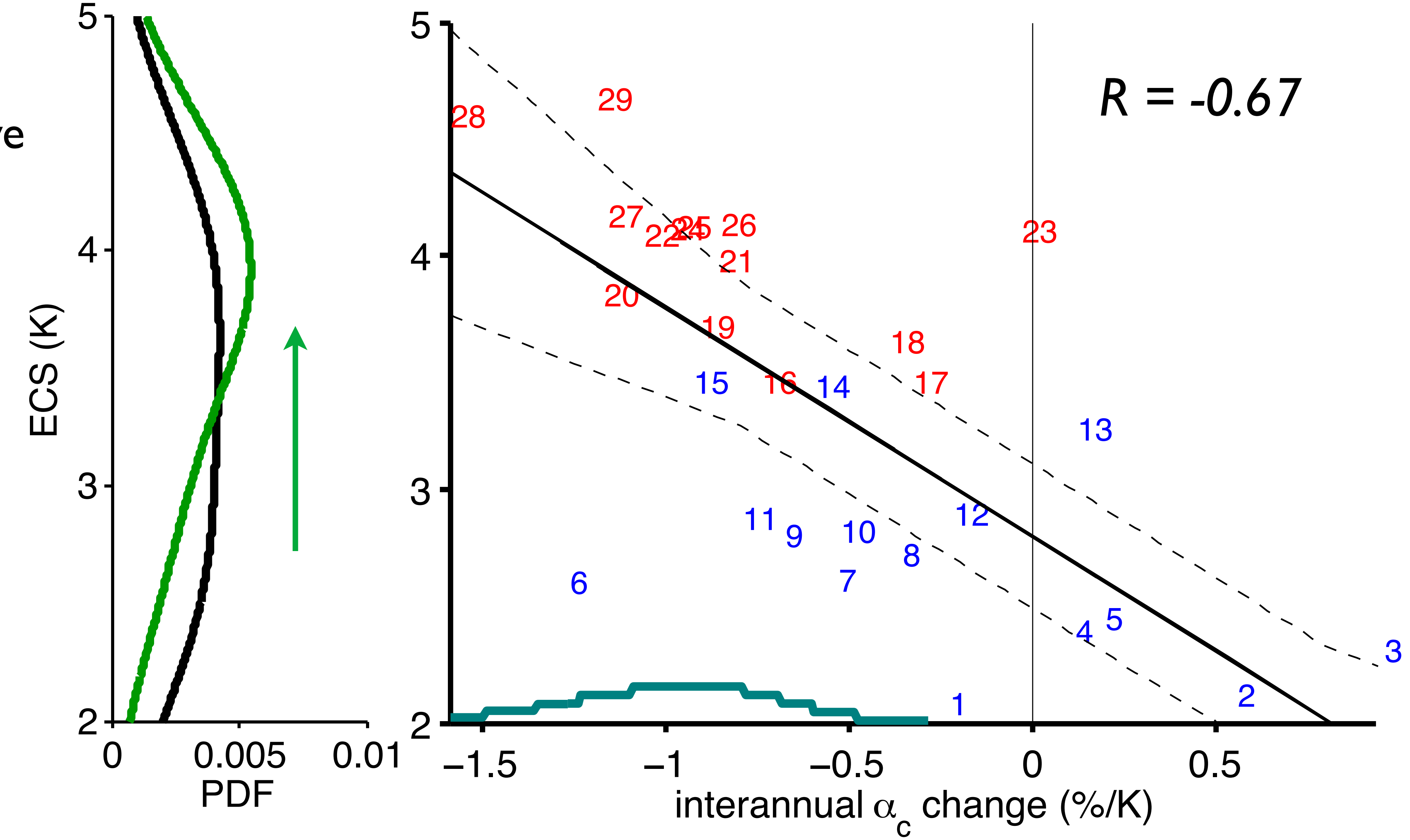
Proba of ECS given the obs

Strengthen the weight of realistic models

ECS estimate

CERES observations give a slope of -0.9 %/K

BMA methodology gives a 90% confidence interval of [2.4 , 4.9], with a max probability of 3.9K



likelihood function

$$w_i = \frac{P(\alpha_{obs}|M_i)}{\Sigma_k P(\alpha_{obs}|M_k)}$$

Proba of the model given the obs

$$P(ECS|\alpha_{obs}) = \Sigma_k \; w_k \; P(ECS|M_k)$$

Proba of ECS given the obs

Strengthen the weight of realistic models

Conclusions

Robust positive low-cloud feedback <u>across temporal variability</u>

<u>Seasonal variability</u> of cloud albedo change is related to surface warming
→ misrepresentation by CMIP5 models and possible constrain to improve models

Spread of ECS by CMIP5 models is 2.1-4.5K with a most probable value of 3.3K

<u>ECS lower bounds</u> increases from 2.1K to 2.4 K

<u>Most probable ECS</u> value is higher (3.9K)

Need process-oriented analysis of observed low-cloud change (especially by their vertical development)