Physics Parameter Ensemble of MIROC5 AOGCM

Hideo Shiogama[1], Tomoo Ogura[1], Masahiro Watanabe[2], Masakazu Yoshimori[2], Tokuta Yokohata[1], James D Annan[3], Julia C Hargreaves[3], Manabu Abe1, Seita Emori[1,2], Toru Nozawa[1], Ayako Abe-Ouchi[2] and Masahide Kimoto[2]

1National Institute for Environmental Studies, Japan.
2Atmosphere and Ocean Research Institute, The University of Tokyo, Japan
3Japan Agency for Marine-Earth Science and Technology, Japan

Introduction

- To investigate parameter uncertainty of feedback, RF and CS, we are performing the physics parameter ensemble (PPE) of MIROC5 AOGCM.
- The CS of the standard model is 2.85 K.
- Previous studies of PPE have mainly used AGCM+Slab (ASGCM).
- However, feedbacks are sometimes different between ASGCM and AOGCM.
- Flux adjustments may affect CS.
- We have developed a new method to avoid drifts when we perturb multi parameters of AOGCM without flux adjustment.
- To estimate feedback, RF and CS, we are computing Gregory-style experiments (CTL and 4xCO_2 runs).

Selected parameters to be perturbed.

	Parameter	Scheme	Description
1	wcbmax	cumulus	maximum in cloud base updraft velocity
2	precz0	cumulus	base height for PRECF(z)
3	clmd	cumulus	entrainment efficiency
4	vicec	cloud	ice falling speed
5	b1	cloud	Berry parameter
6	faz1	turbulence	factor for overshooting layer
7	alp1	turbulence	Factors of mixing between free trop. and PBL.
8	tnuw	aerosol	timescale for nucleation
9	ucmin	aerosol	minimum cloud droplet number (liq/ice)
10	albedo	surface	ice and snow albedo

3 cumulus, 2 cloud, 2 turbulence,2 aerosol, and 1 surface parameters

Strategy

How to select sets of parameter values for AOGCM runs?

- We want to perturb multiple parameters simultaneously.

- Sampling parameter space as efficiently as possible given a finite number of runs (<100).
- Parameters should be as uncorrelated with each other as possible.

  → ***Latin Hypercube Sampling***

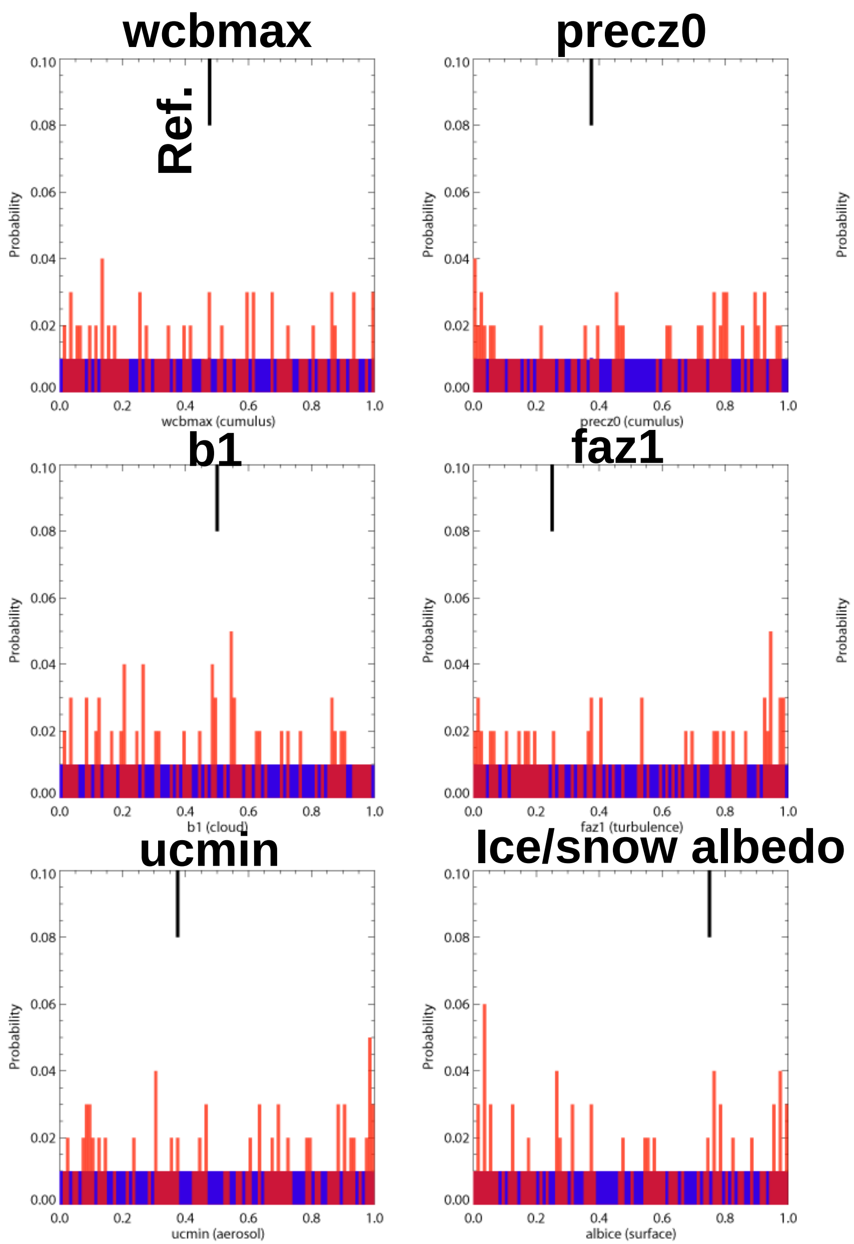
- However, to use AOGCM without flux adjustment, we have to reduce radiation imbalance at TOA to avoid large climate drifts and long spin-up runs.

  → ***New method***

Experimental design of AOGCM runs

1. We performed AGCM-CTL runs with min or max values of each parameter, and estimated changes in the net radiation imbalance at TOA.
2. Generate the potential parameter sets by large Latin hypercube sampling (5000 samples).
3. Emulate imbalance at TOA for each sample by using piecewise linear interpolations of changes in imbalance from the AGCM-CTL runs.
4. Select the sample with lowest change in imbalance, delete it and also delete all samples of "very close" parameter values.
5. Repeat (4) to select 100 subsets.
6. We perform CTL and 4XCO2 runs of AOGCM with the selected 100 *low-imbalance* parameter sets without flux adjustment.

Sampled parameter values

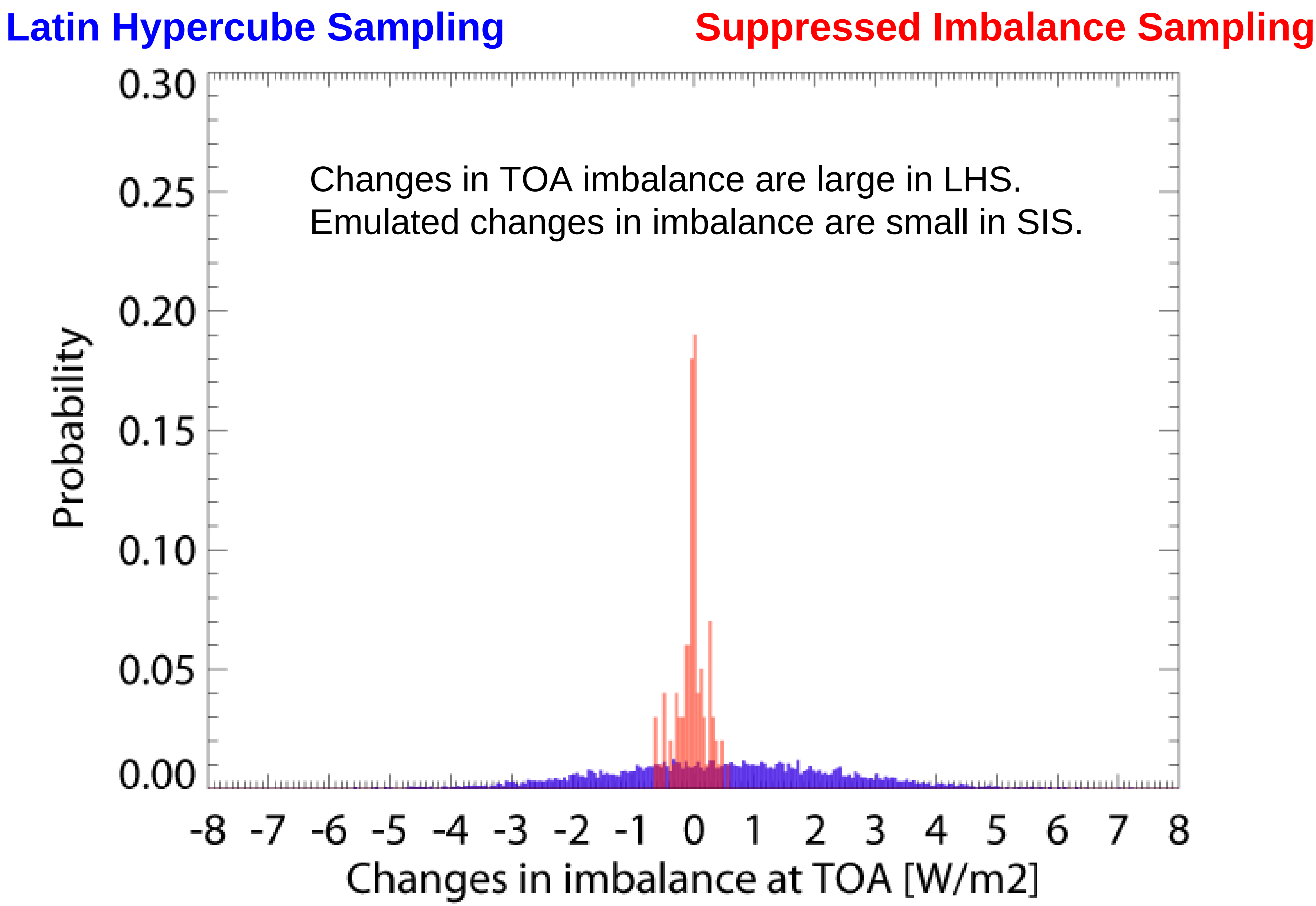


Latin Hypercube Sampling

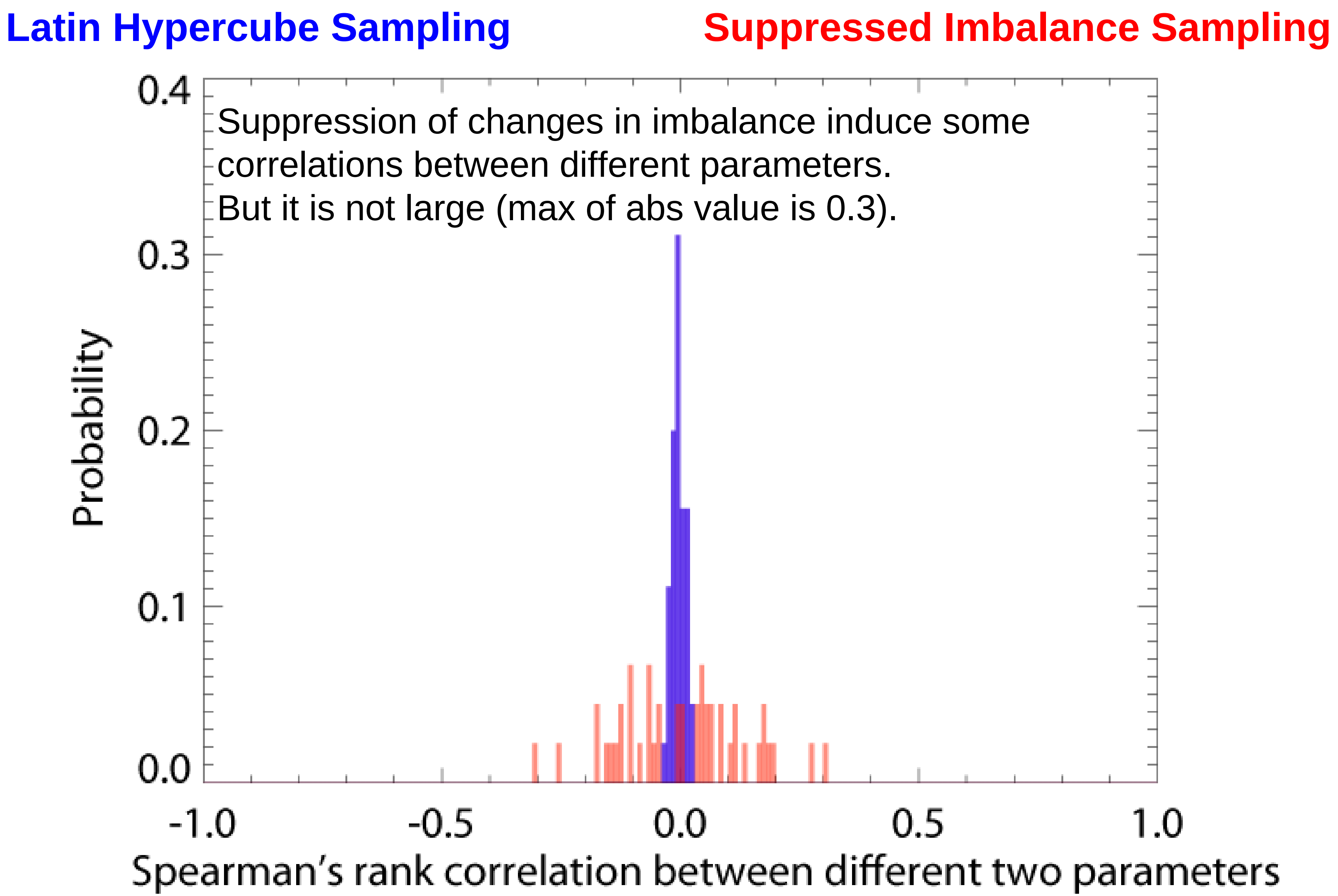
Suppressed Imbalance Sampling

Sampled values are not concentrated in small subspaces.

Emulations of change in imbalance at TOA



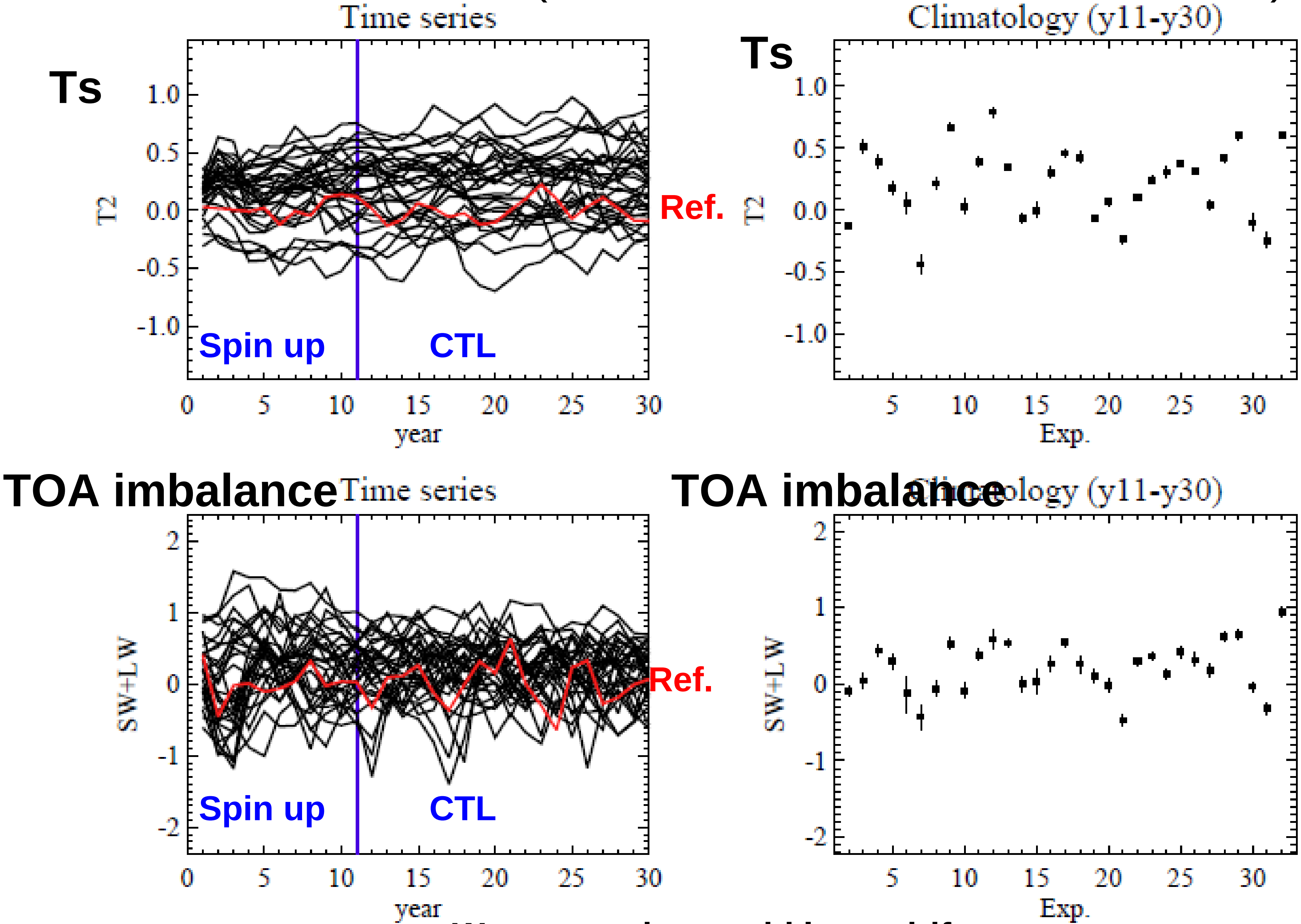
Rank correlations between different parameters



The AOGCM ensemble

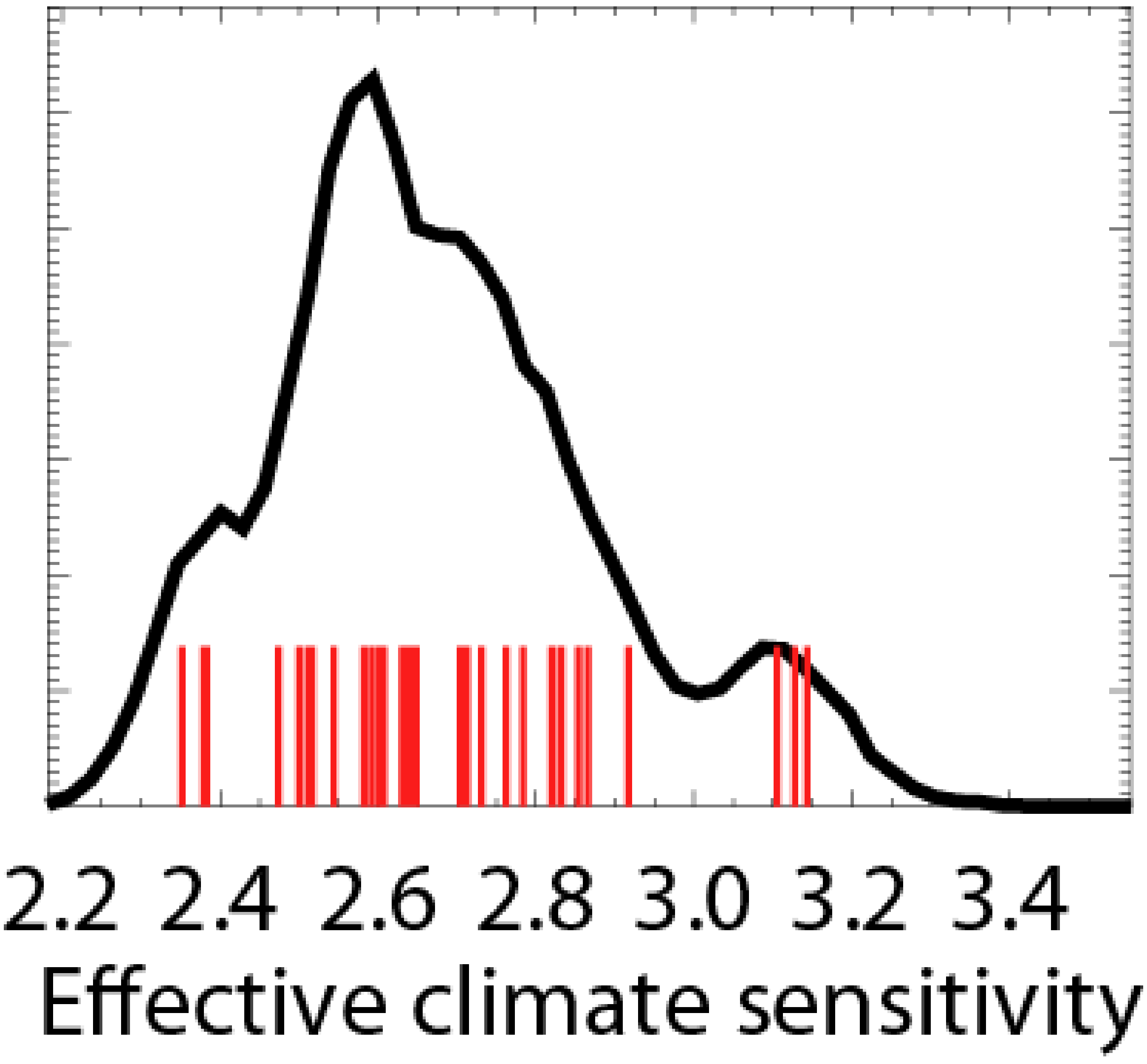
-32 ensemble members-

AOGCM-CTL runs (anomalies from the standard model)

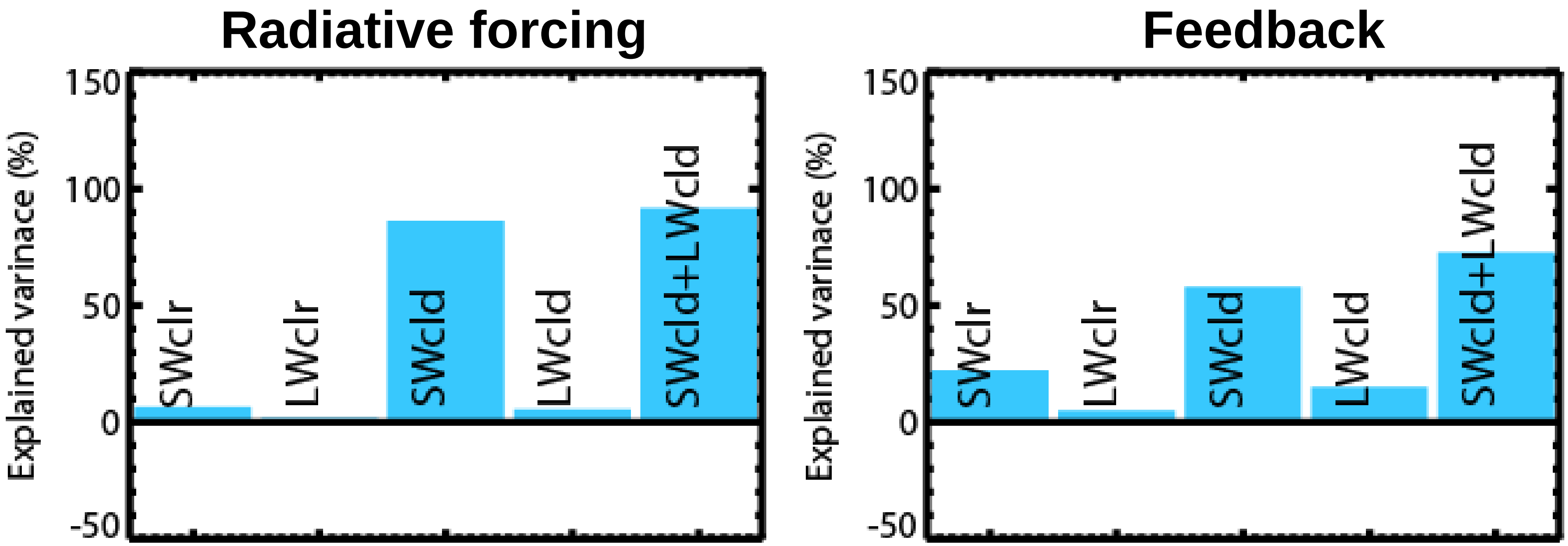


We succeed to avoid large drifts.

Effective climate sensitivities

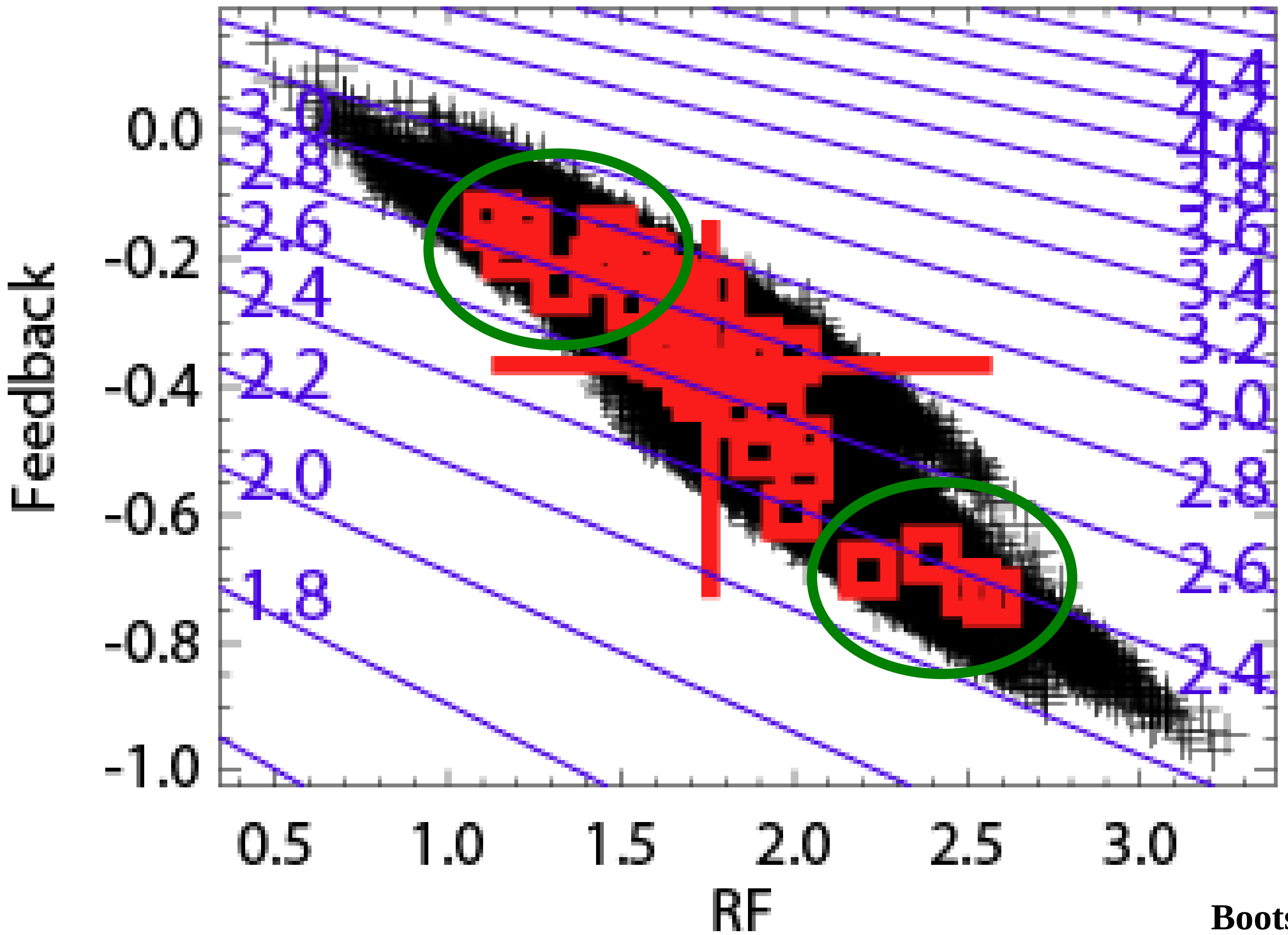


Inter-model variances of total forcing and feedback explained by each component



SWcld is the most important component for both the variances of forcing and feedback.

Forcing and feedback (SWcld)



Each run

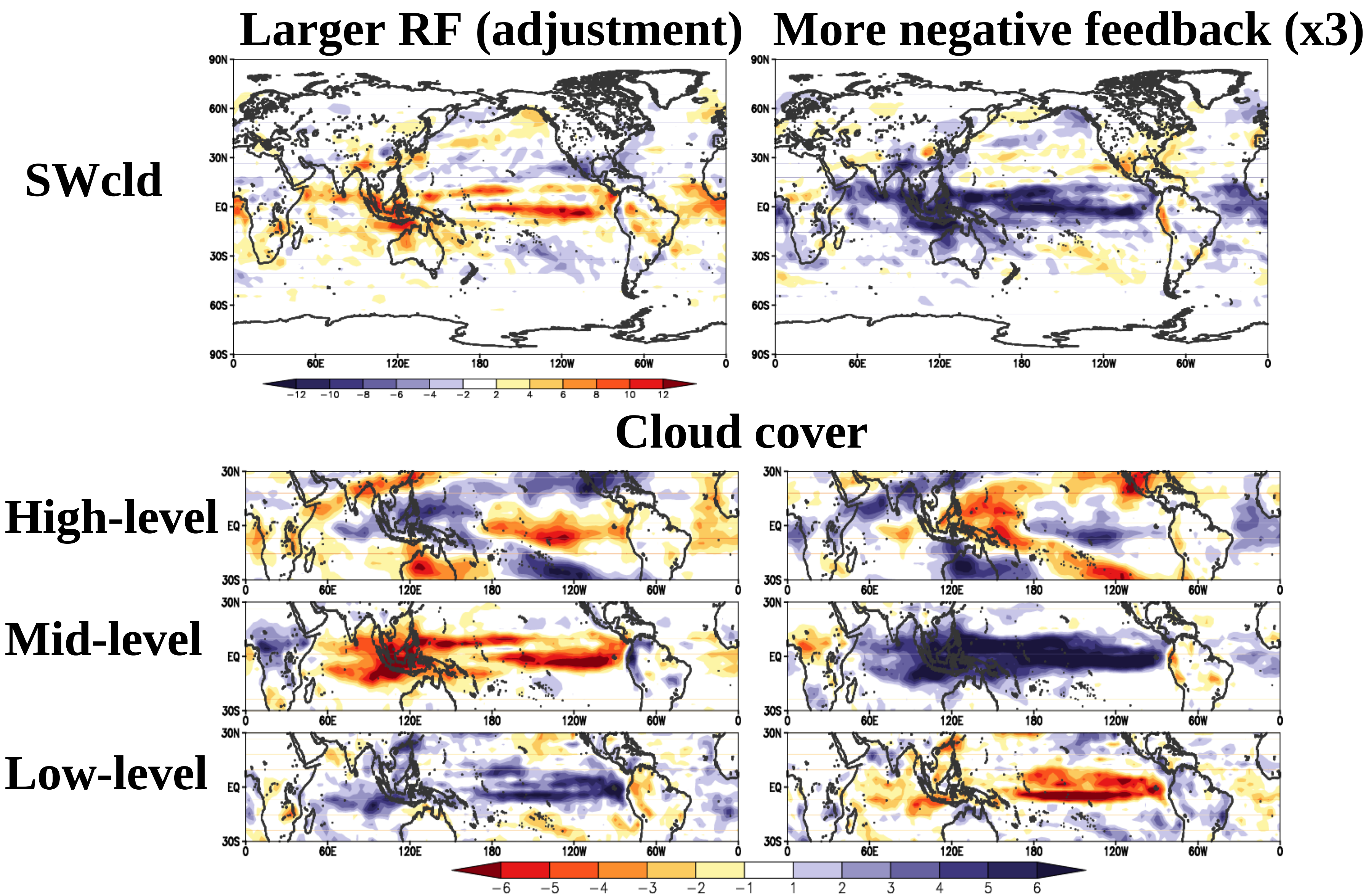
Bootstrap samples

Since all the models have negative FDB, the CS of them are low.
There is an anti-correlation bet. RF and FDB, which also reduce the range of CS.

Differences of composite:

(large positive SWcld RF, more negative SWcld FDB) minus

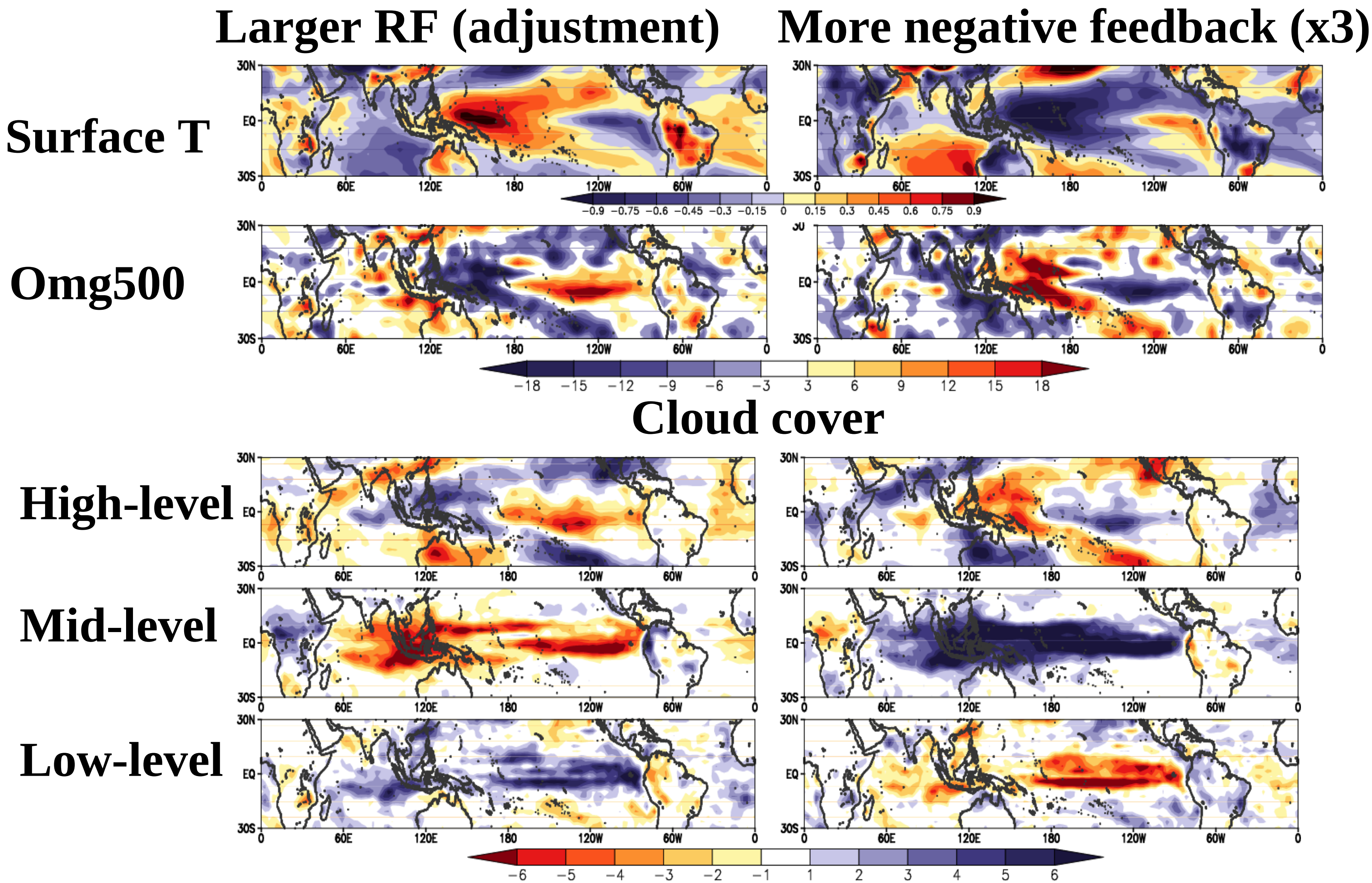
(small positive SWcld RF, less negative SWcld FDB)



Differences of composite:

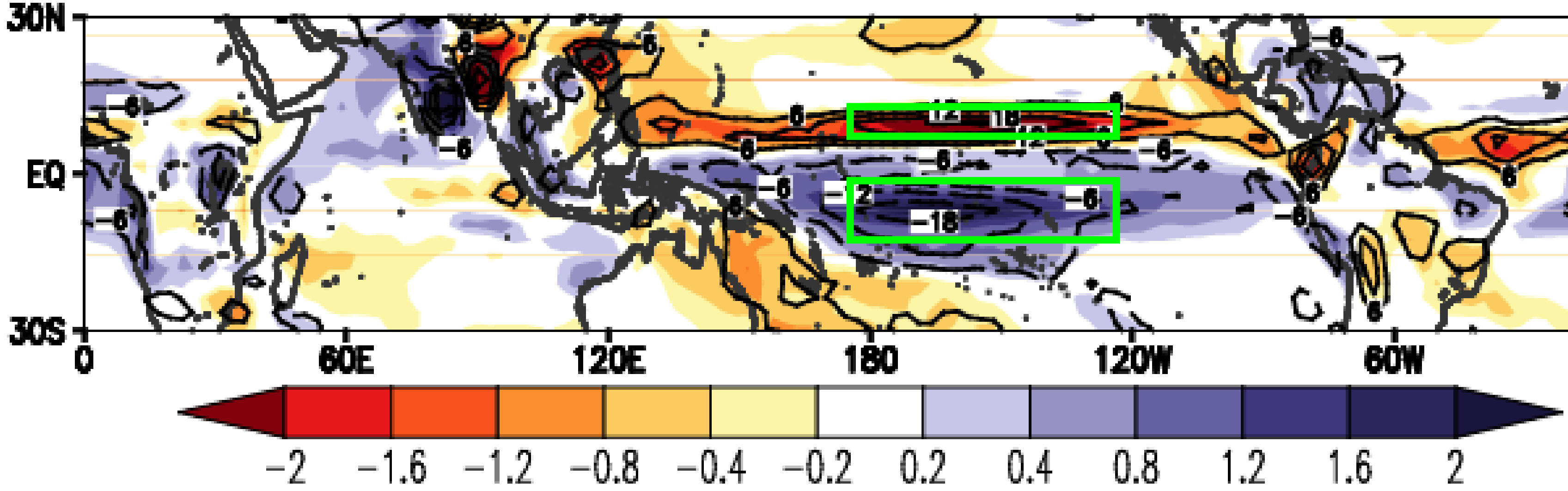
(large positive SWcld RF, more negative SWcld FDB) minus

(small positive SWcld RF, less negative SWcld FDB)

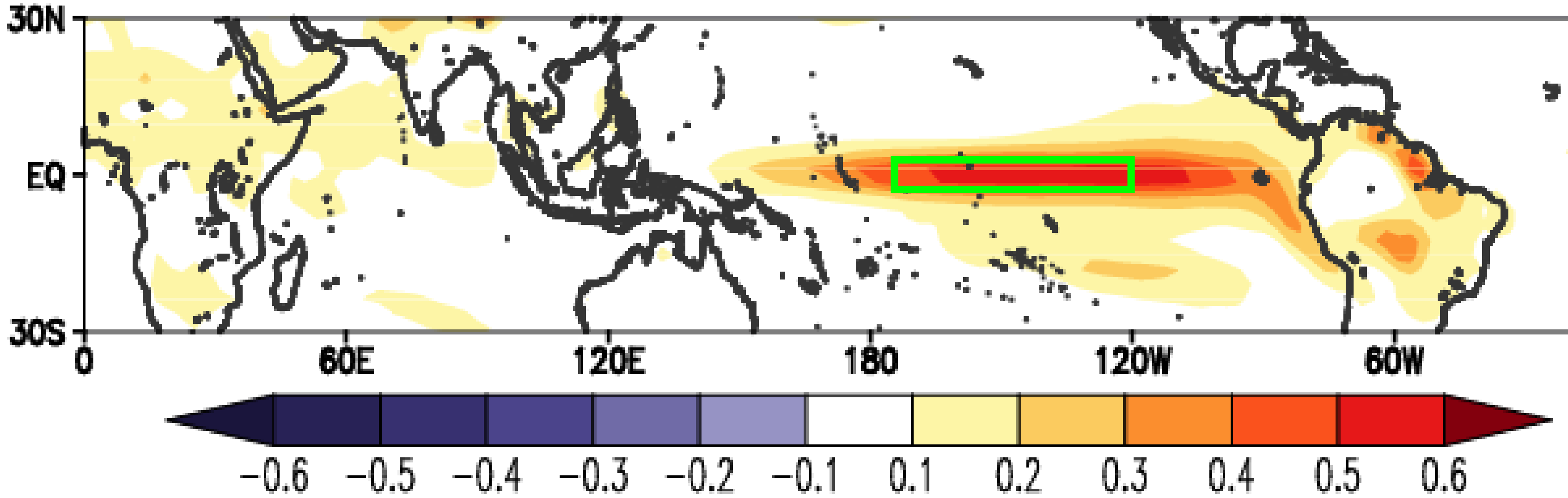


Differences in climate state of the control runs

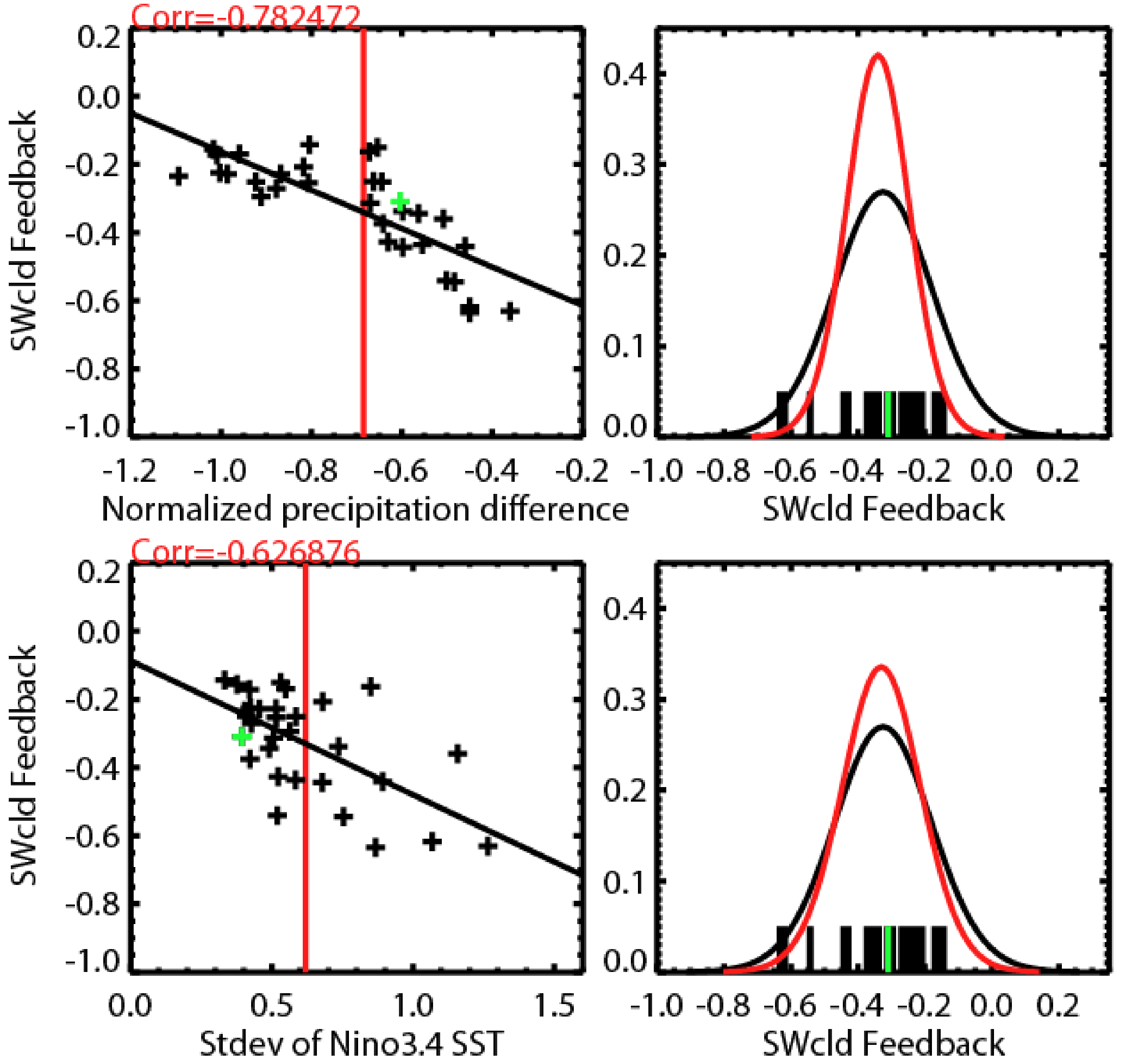
Precipitation (shaded) & omg500 (contours)



Standard deviations of annual mean Ts



Observational constraints on SWcld feedbacks



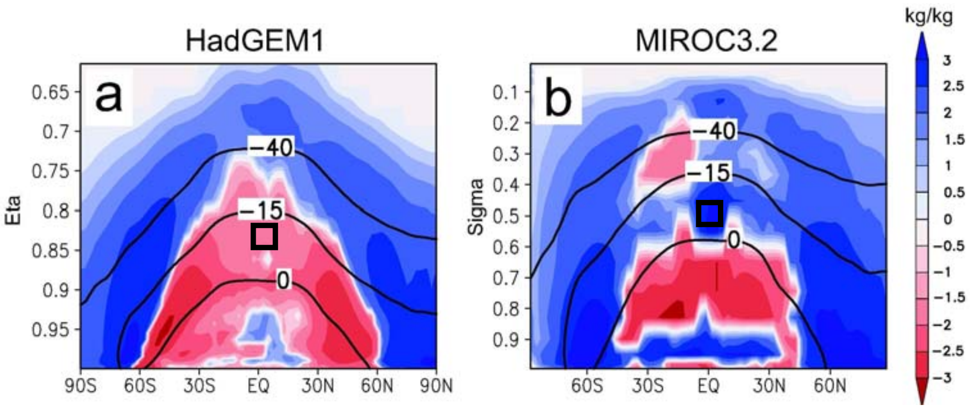
Understanding cloud responses with tendency terms

Cloud water in a GCM is calculated using a tendency equation. Terms on the RHS can be monitored to help understand how the cloud water responds to CO2 increase.

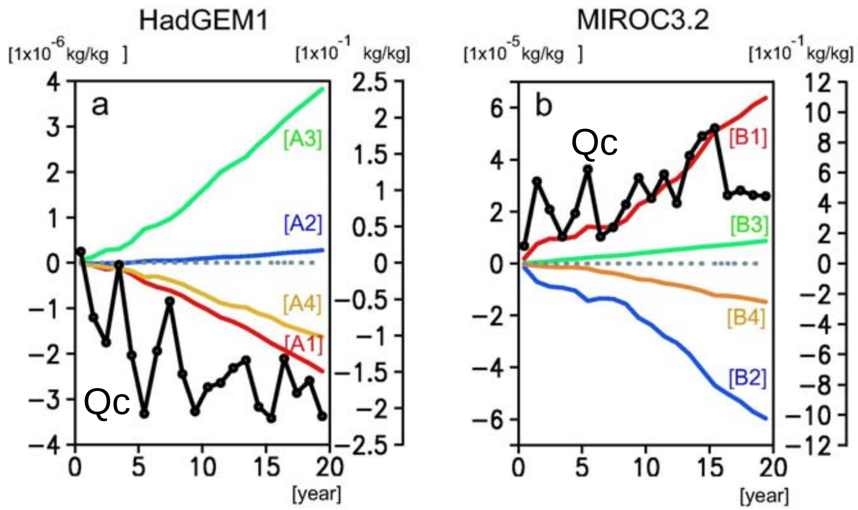
$$\frac{\partial Qc}{\partial t} = \begin{bmatrix} \text{Condensation} \\ \text{Evaporation} \end{bmatrix} - [\text{Precipitation}] + \begin{bmatrix} \text{Advection} \\ \text{Diffusion, etc.} \end{bmatrix} + [\text{Residual}]$$

They provide additional information on which terms (processes) are consistent with the Qc variation.

Response to CO2 doubling
cloud water Qc



Response to CO2 doubling
Qc and time-integrated tendency terms [Ai], [Bi]



Summary

- We have developed a method to perform PPE of AOGCM without flux adjustment.
- The range of CS is not large (2.2K-3.3K).
- SWcld is the most important component for the variances of forcing and feedback.
- SWcld feedback is negative in all the members.
- We found an anti-correlation between forcing and feedback, which reduces the range of CS.
- The anti-correlation is caused by La-Nina like adjustment and El Nino-like feedback patterns.

Summary

- SW cloud feedback is associated with the biases of precipitation in the tropical Pacific and the amplitude of ENSO. It is possible to constrain the physics parameter uncertainties of SW cloud feedback and adjustment.
- Cloud tendency diagnostics will be used to better understand the difference in MIROC-PPE and CFMIP2-MME cloud responses
- For information on setting the diagnostics up for the CFMIP2 experiments, please refer to the guidance notes;
  → http://cfmip.metoffice.com/cctd.pdf