

On the structural and parametric uncertainties of feedback, adjustment and climate sensitivity

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Outline



- We constructed a PPE for the MIROC5 coupled atmosphere full-ocean GCM (CGCM) without flux corrections.
- To reduce TOA radiation imbalance without flux corrections, we developed a new parameter sampling method.
- * Briefly describe the ensemble design.
- * Compare the MIROC5-CGCM-PPE and the CMIP5-CGCM-MME (& MIROC3-PPE, MIROC3/5 MPE and QUMP PPE).

MIROC5-CGCM-PPE (Shiogama et al. 2012)

- * MIROC5 coupled atmosphere full-ocean GCM
- * Resolutions: T42L40 (atm) & 1° X 1° L49 (ocn)
- * Perturbed 10 atm-land parameters.
- No-flux corrections
- Picontrol and abrupt 4xCO2 runs (Gregory style exp.)
- * 20 years
- * 56 members

Suppressed Imbalance Sampling method



(a) We performed AGCM-CTL runs with the min or max values for each parameter, and estimated the difference of TOA imbalance (max minus min parameter runs).



Suppressed Imbalance Sampling method



- (a) We performed AGCM-CTL runs with the min or max values for each parameter, and estimated the difference of TOA imbalance (max minus min parameter runs).
- (b) We generated 5,000 sets of parameter values using Latin Hypercube (LH) sampling.
- (c) We emulated the TOA imbalance for each LH sample by applying piecewise linear interpolations of (a).
- (d) We selected the sample with the lowest amplitude of TOA imbalance anomalies to be used in the CGCM-PPE.
- (e) From the initial 5000 samples, we removed the selected sample (d), and we also deleted all samples with parameter values that were "very close" to the selected sample.
- (f) We repeated steps (d) and (e) to choose N subsets.

Suppressed Imbalance Sampling method

Shiogama et al. (2012, Clim Dyn, submitted)



Our method works well to prevent large climate drift. When you perturb M parameters, you need perform only 2M+1 (min and max for each para and the standard model) short timeperiod runs of AGCM.

We hope our study encourages the other modeling groups to construct CGCM PPEs.

RF, Feedback and Climate Sensitivity





- MIROC5-PPE has low CS (2-3 degC).
- CS of MIROC3-PPE are larger than 4 degC.
- QUMP-PPE and MIROC3/5 MPE have the wider ranges of CS than the CMIP5 MME.
- No PPE/MPE totally overlap the CMIP5 MME on the RF-Feedback space.

Fraction of variance explained by each component [%]



- Shortwave cloud components mainly induce the ensemble-variances of RF and feedback in both the MIROC5-PPE and the CMIP5-MME.
- The large variance of LWcIr RF in the CMIP5 is caused by the one outlier model.

Ensemble-averages of CALIPSO cloud fraction feedback [%/K]





- High/low level cloud fraction feedbacks are similar in both the ensembles.
- MIROC5 PPE has large increases of mid-level cloud fraction, which lead to low CS.
- CMIP5 MME has little changes in mid-level cloud fraction.



- Stdev of high/low level cloud fraction feedback are large in the tropical Pacific ocean.
- Mid-level cloud fraction in the CMIP5 MME has small stdev.
- By contrast, the MIROC5 PPE has great stdev of mid-level cloud fraction in the tropical Pacific ocean.



- In the MIROC5-PPE, there are clear anti-correlations between the changes in mid-level cloud fractions and the SW cloud adjustment/feedback.
- More decreases (increases) of the cloud fractions lead to more positive (more negative) SW cld adjustment (feedback).
- In the CMIP5-MME, there are no significant correlations between mid-level cloud and SW cloud adjustment/feedback.



- In the MIROC5-PPE, higher fractions of mid-level cloud in the CTL lead to larger decreases (increases) of mid-level cloud in adjustment (feedback).
- The observation length of CALIPSO is not enough to constrain the uncertainty in the MIROC5 PPE.
- Some CMIP5 models have negative biases of mid-level cloud fraction in the CTL. These models may underestimate the responses of mid-level cloud.

Summary



- We developed the new parameter sampling method (suppressed imbalance sampling) to prevent climate drift of CGCM-PPE without flux corrections.
- We constructed the MIROC5-PPE. MIROC5-PPE has low CS.
- No PPE/MPE totally overlap the CMIP5 MME on the RF-Feedback space.
- SW cloud components dominate the variances of RF and feedback in both the CMIP5 MME and MIROC5 PPE.
- In the MIROC5 PPE, changes and the CTL values of mid-level cloud fraction well correlate to the variations of SW cloud adj/fdbk.
- Some CMIP5 models have negative biases of mid-level cloud fraction in the CTL.
- Outputs of COSP from more models are useful.





[%] **5 models**

-2

[%]



- Stdev of high/low level cloud fraction feedback are large in the tropical Pacific ocean.
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MIROC5-AGCM-PPE (Hansen style exp.)

- Picontrol and 4XCO2 runs
- * Perturbations in the 10 atm-land parameters
- * 1-yr spin-up and 10 year runs
- * 56 members



RF estimated by the Gregory and Hansen experiments





Table 1: List of physics parameters that were varied in the AGCM runs. Gray shadingindicates that these parameters were also swept in the CGCM runs.

| Name | Categor y | Description | Standard | Min | Max |
|---------------------|----------------|--|----------------------|----------------------|----------------------|
| wcbmax 1 | Cumulus | Maximum cumulus updraft velocity at cloud base [m/s] | 1.7 | 0.7 | 2.8 |
| precz01 | Cumulus | Base height for cumulus precipitation [m] | 500 | 200 | 1000 |
| preczh ¹ | Cumulus | Reference height for cumulus precipitation [m] | 4500 | 3000 | 6000 |
| clmd ¹ | Cumulus | Entrainment efficiency [ND] | 0.51 | 0.4 | 0.6 |
| meltau ¹ | Cumulus | Timescale of ice melting [s] | 10 | 1 | 15 |
| evataul | Cumulus | Timescale of liquid evaporation [s] | 2 | 0.1 | 4 |
| rcfact ² | Cloud | Random overlapping factor in ice cloud falling [ND] | 0.2 | 0 | 1 |
| vicec ² | Cloud | Factor for ice falling speed [mº.414/s] | 38 | 25 | 40 |
| b13 | Cloud | Berryparameter [m³/kg] | 0.09 | 0.07 | 0.11 |
| b2s | Cloud | Berryparameter [s] | 0.095 | 0.07 | 0.12 |
| faz14 | Turbulen ce | Factor for PBL overshooting [ND] | 1.5 | 1 | 3 |
| alp14 | Turbulen ce | Factor for length scale L_T [ND] | 0.23 | 0.16 | 0.3 |
| alp34 | Turbulen ce | Factor for length scale $L_{\mathbb{F}}$ [ND] | 5 | 2 | 8 |
| octei4 | Turbulen ce | Switch for cloud top entrainment instability | OFF | ON | |
| tnuw ^s | Aerosol | Timescale for nucleation [s] | 18000 | 14400 | 21600 |
| rcmax ³ | Aerosol | Maximum radius of cloud droplet (liquid, ice) [m] | 30×10-6, 185×10-6 | 25×10-6, 150×10-6 | 35×10-6, 200×10-6 |
| ucmin ³ | Aerosol | Minimum cloud droplet number (liquid) [m→] | 2.5×10† | 2.2×10† | 3.0×10† |
| alb ⁵ | Surface | Albedo of ice and snow* | Medium | Low | High |
| talsnw⁵ | Surface | Temperature thresholds for albedo | 268.15, | 253.15, | 258.15, 973.15 |
| wsscl ⁵ | Surface | Lifetime of puddle over land ice [s] | 216000 | 108000 | 432000 |







Histograms of selected parameter values for each parameter in the Latin Hypercube Sampling (blue) and Suppressed Imbalance Sampling (red).









Fig 3 (a) Probability (vertical axis) of the Euclidean distance between two samples (horizontal axis) of LHS (blue) and SIS (red) in the normalized 10-dimensional parameter space. The black vertical line indicates the lowest 4% distance as the threshold of "very close" samples. (b) Probability (vertical axis) of emulated changes in radiation imbalance at the TOA (horizontal axis) [W/m²] in LHS (blue) and SIS (red). (c) Probability (vertical axis) of Spearman's rank correlation between two different parameters (horizontal axis) in LHS (blue) and SIS (red).

Histogram of effective climate sensitivity for a doubling of CO_2 in the MIROC5-CGCM-PPE [°C].









Histogram of SWcld feedbacks [W/m²/K] in the MIROC5-CGCM-PPE



Difference bet. models with Large negative SW cloud feedback and

Small negative SW cloud feedback









Difference bet. models with Large negative SW cloud feedback and

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Fig 14: Red squares represent a scatter plot of radiative forcing $[W/m^2$; horizontal axis] and feedback parameters $[W/m^2/K]$ vertical axis], which are the same as in Fig. 6. Green crosses indicate emulations of LHS members. Blue squares indicate emulations of SIS members that have been performed, and blue crosses indicate the remaining SIS members. Black contours show the effective climate sensitivity for a doubling of CO₂ [°C].

