Tests of Monte Carlo Independent Column Approximation With a Mixed-Layer Ocean Model

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1. Introduction

The Monte Carlo Independent Column Approximation (McICA) separates the description of unresolved cloud structure from the radiative transfer solver

very flexible :) !

unbiased with respect to ICA :) !

However, the radiative fluxes and heating rates contain conditional random errors ("McICA noise"). :(?

The topic of this poster: **how does McICA noise influence climate simulations?**

All previous tests of McICA have used prescribed sea-surface temperatures (SSTs). Here, **we test the impact of McICA noise in the ECHAM5 atmospheric GCM coupled with a mixed-layer ocean model.**

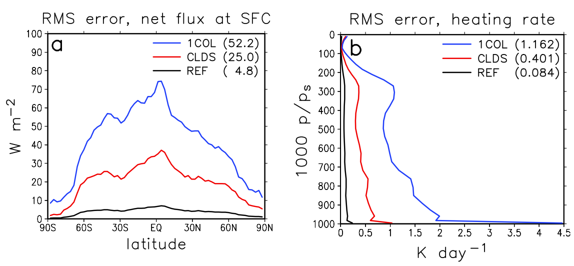

Figure 1. Root-mean-square sampling errors in local instantaneous total (LW+SW) net flux at the surface and total radiative heating rate for the 1COL, CLDS, and REF approaches. Global rms values are given at the upper right hand corner of the plots.

2. Simulations

- **ECHAM5** (resolution T42L31) + **mixed-layer ocean model** interactive SST and sea ice)
- Extensive simulations: at least 70 years per experiment

(a) McICA experiments

Three implementations: the basic assumptions about cloud structure are the same, but the magnitude of McICA random errors differs much (**Fig. 1**).

(1) **1COL**: a "stupid" implementation of McICA that deliberately maximizes random errors

(2) **CLDS**: a typical GCM implementation of McICA

(3) **REF**: a computationally expensive reference simulation with small random errors

For comparison, some results are shown for experiments that used **prescribed SST.**

(b) Non-McICA experiments

Motivation: compare the impact of McICA noise to minor systematic perturbations of the model

(4) **CTRL**: control run, standard version of ECHAM5

(5) **RE**: water cloud effective radius increased by 0.1 m

(6) **SOLC**: solar constant multiplied by 1.002

3. Results

In ECHAM5, McICA noise leads to slightly reduced low cloud fraction and cloud shortwave radiative effects. Little else happens when the SST is prescribed (**Figs. 2a-b, 3a-b; Table 1**).

When a mixed-layer ocean model is used, a "global warming" response results (**Fig. 3c-d**) and low cloud fraction is reduced further (a positive feedback). For a reasonable implementation of McICA (i.e., CLDS), the warming due to McICA noise is comparable to the effect of increasing water cloud effective radius by 0.1 μm, or the solar constant by 0.2% (**Fig. 3e-f**). Note that this model version has a high climate sensitivity (4.5-5 C for doubling of CO_2).

Curiously, in the eastern equatorial Pacific (near the Galapagos Islands), McICA noise has a significantly larger effect than the perturbation of effective radius or solar constant (**Fig. 4**).

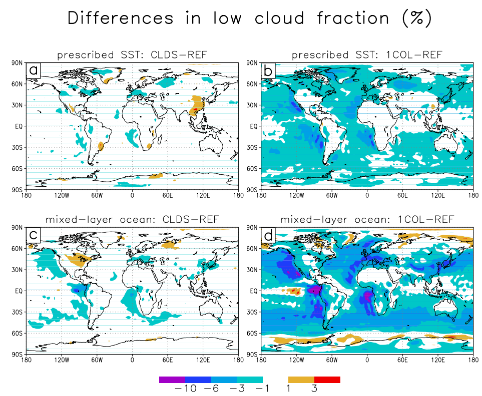

Figure 2 (above): Impact of McICA noise on low cloud fraction (%) when (a-b) the SST is prescribed, and (c-d) when the mixed-layer ocean model is used.

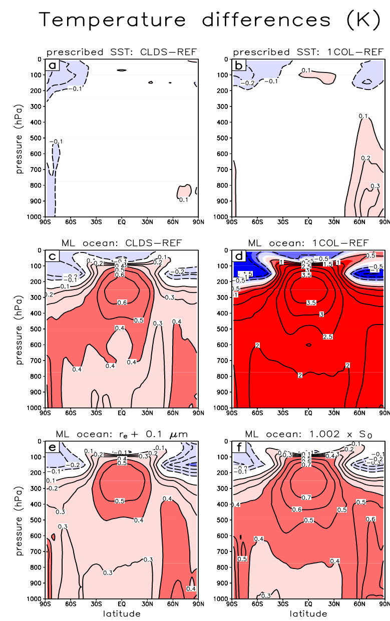

Figure 3 (right): Zonal-mean temperature differences due to McICA noise (a-b) when the SST is prescribed and (c-d) when the mixed-layer ocean model is used, and due to (e) increasing water cloud effective radius by 0.1 μm, and (f) multiplying the solar constant by 1.002.

	SWCRE	LWCRE	C_{tot}	C_{low}	T_{2m}	precip.
McICA noise: CLDS-REF	0.36	0.02	-0.002	-0.003	0.33	0.025
- for prescribed SST	0.20	-0.03	-0.001	-0.001	0.00	-0.001
McICA noise: 1COL-REF	2.31	0.03	-0.017	-0.024	1.92	0.148
- for prescribed SST	1.56	-0.17	-0.009	-0.013	0.05	-0.010
Effective radius + 0.1 μm	0.33	0.05	-0.001	-0.002	0.31	0.024
Solar constant x 1.002	-0.09	0.02	-0.001	-0.001	0.38	0.030

Table 1. Impact of McICA noise and other model perturbations on global-mean values of selected variables. SWCRE (LWCRE) = shortwave (longwave) cloud radiative effect at the TOA (W m^{-2}); C_{tot} (C_{low}) = total (low) cloud fraction; T_{2m} = 2-meter temperature (K), precip. = precipitation (mm/d).

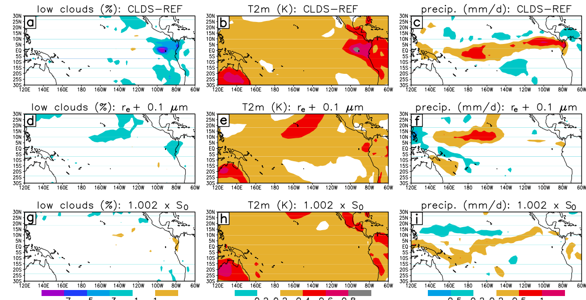

Figure 4. Differences in low cloud fraction, 2-m temperature, and precipitation in the tropical Pacific (a-c) due to McICA noise (CLDS-REF); (d-f) due to increasing water cloud effective radius by 0.1 μm; and (g-i) due to multiplying the solar constant by 1.002.