Sensitivity of SP-CAM3 simulations to GCM resolution and the size of the CSRM domain: Preliminary results

G. Bala, P. B. Duffy
Lawrence Livermore National Laboratory

M. Khairoutdinov and D. Randall
Colorado State University

Background

The Colorado State University (CSU) "Superparameterization" (SP), is a new approach to representing sub-grid scale processes in climate models, in which an embedded 2-d Cloud System Resolving Model (CSRM) takes the place of traditional convection and cloud parameterizations.

The goal of this project is to evaluate the CSU SP within a fine-resolution global climate model (GCM). Although superior simulated climate is expected through a combination of fine spatial resolution and superior representation of subgrid scale processes, the reduction in the size of the CSRM domain at higher GCM resolutions is anticipated to impact the simulation.

Preliminary investigations from the simulations with the SP version of the NCAR CAM3 are presented. We report results of simulations performed at two different GCM resolutions and two different CSRM domain sizes. In this poster, we focus on the simulation of precipitation and precipitable water in the tropics.

Model and Simulations

We use a modified version of the NCAR-DOE Community Atmosphere Model (CAM3). We have adopted the Finite Volume (FV) dynamical core option for our simulations. The model has 26 levels in the vertical. The horizontal resolution of the CSRM is 4 km and the vertical resolution is the same as the GCM.

Besides the conventional-parameterization simulations at the 2x2.5 (b26), and 1x1.25 (c26) resolutions, we performed the following SP-CAM3 simulations:

a) b26-crm - GCM resolution is 2.0x2.5 deg, and the CSRM has 64 grid cells with a domain size of 256 km.
b) c26-crm - GCM resolution is 1.0x1.25 deg, and the CSRM has 32 grid cells with a domain size of 128 km.
c) b26-crm128 - Same as (a), but the number of CSRM grid cells is increased to 128 with a CSRM domain size of 512 km.

The model simulations were initialized on 1 Sept 1978 and run for 16 months using prescribed, observed, monthly-mean sea surface temperatures. The analysis are performed for the year 1979.

Global mean climate

|	B26-crm	B26-crm128	C26-crm	C26-crm	B26	Obs. estimates
Precip (mm/day)	2.923	2.940	2.973	2.968	2.830	2.94 (GPCP)
FLNT (Wm^2)	240.3	239.9	241.3	233.6	233.1	238.9 (CERES)
FSNT (Wm^2)	240.8	241.3	240.1	234.7	234.3	243.5 (CERES)
CLDTOT	40.1	40.0	40.5	57.1	58.4	66.7 (ISCCP)
CLDLOW	29.2	29.6	30.0	39.8	38.7	28.0 (ISCCP D2)
CLDHGH	10.2	10.1	10.5	29.1	32.5	13.0 (ISCCP D2)
FSNS (Wm^2)	165.2	165.8	164.5	159.7	159.8	165.9 (ISCCP)
FLNS (Wm^2)	57.8	57.7	57.6	56.5	58.0	49.2 (ISCCP)
SWCF (Wm^2)	-46.9	-47.0	-47.6	-54.2	-54.4	-49.2 (CERES)
LWCF (Wm^2)	24.0	23.9	24.1	31.6	30.7	27.1 (CERES)
PREH2O (mm)	24.8	24.8	24.6	23.7	23.9	24.6 (NVAP)

Increasing the GCM resolution or changing the domain size of the CSRM in the SP-CAM3 model results in negligible changes in the global mean climate. This is a confirmation of the hypothesis that, unlike in models with conventionl parameterizations, no tuning would be needed when the GCM resolution is changed in SP-CAM3.

## Switching from Conventional to SP
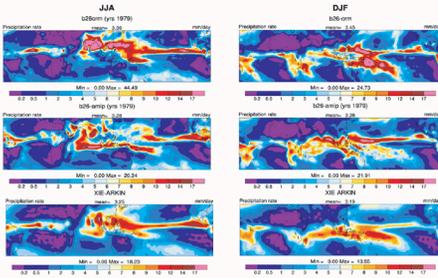
Switching from conventional parameterization to SP reduces the ITCZ split in the western Pacific in JJA and improves the pattern of precipitation in the SPCZ in DJF. However, it results in a "red spot" in the SPCZ in DJF and wet bias in the Monsoon region in JJA.

Effect of increasing GCM resolution (Precipitation)
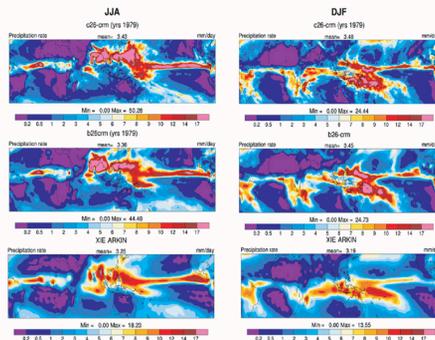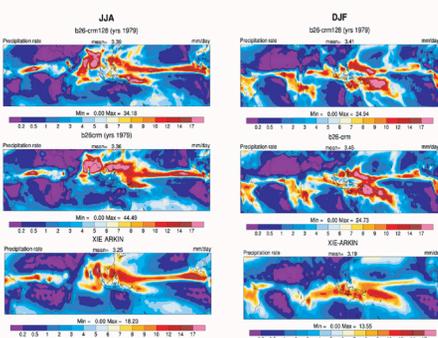

## Effect of increasing GCM resolution (Precipitable water)
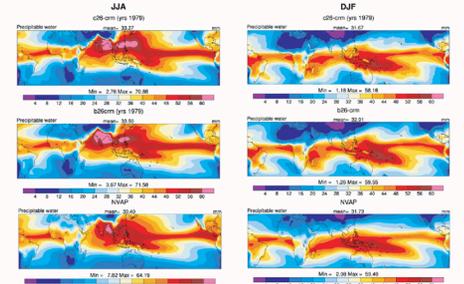
Increasing the GCM resolution (while reducing the CRM domain size) does not lead to any improvement in the pattern of precipitation (box to the left) or precipitable water (above). Rather, it leads to an increase in the biases in JJA.

Effect of the CSRM domain size (Precipitation)

Effect of the CSRM domain size (Precipitable water)
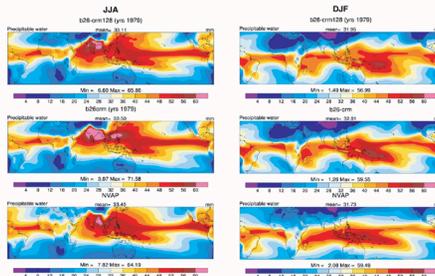
The wet bias in precipitation (box to the left) and the moist bias in precipitable water in JJA in the Indian sub-continent (above) are reduced when the CSRM domain size is doubled. These biases are also reduced in DJF in the western Pacific.

What have we learned so far?

An increase in the GCM resolution (and reduction in the size of the CSRM domain) does not lead to improvement in the pattern of precipitation or precipitable water. Rather, biases increase. Possible causes are the periodic boundary conditions of the CSRM and near-breakdown of the quasi-equilibrium assumption as the CSRM domain size is decreased.

We test this hypothesis by performing another simulation using an increased CSRM domain size. Here, the wet biases in precipitation and precipitable water in the tropics are reduced. This suports the hypothesis, and suggests that having one CSRM domains that completely encircle the earth might reduce the biases further.

The CSU SP increases the computational run time of the CAM3 model by ~200x compared to using traditional parameterizations; b26-crm is ~200x more expensive than b26.

Since the GCM uses a negligible fraction of the total run time in the SP-CAM3 model, the compute time increases by only ~2x in c26-crm and b26-crm128 compared to b26-crm since the number of CRM columns are just doubled; c26-crm and b26-crm128 are ~ 400x more expensive than b26.