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Examination of the sensitivity to resolution and to the interaction between dynamics and parameterizations in high resolution CAM5

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We consider the sensitivity of persistent CAM5 biases to horizontal, vertical and temporal (time step) resolution. We also consider the sensitivity of the interaction between the dynamical core and the parameterization suite, and between the components of the suite to changes in resolution and to changes in the components themselves. We illustrate these sensitivities by considering the biases in the Tropical Eastern Pacific where the model precipitation is too strong and the precipitable water is too large. The same behaviors occur elsewhere. These biases increase with increasing horizontal resolution but are not affected by increased vertical resolution. In addition to these mean biases, at high resolution (0.25 degree) standard CAM5.2 produces erroneous slowly propagating, strong, small scale precipitation events lasting several days. Such events do not occur at lower resolution (1 degree). The sensitivity of these events has been commonly attributed to increased horizontal resolution. We show that they are primarily due to temporal resolution, with horizontal resolution playing only a secondary role. They can be avoided by making assumed time scales in the parameterizations consistent with the time step. These events, however, are not responsible for the mean precipitation bias.

We demonstrate via short forecasts and examination of conditionally averaged heat and water budgets that the mean biases are due to a strong local interaction between the dynamics and the parameterizations which occurs on a very fast time scale. We identify the cause of this interaction by introducing idealized modifications to parameterized heating which shift a fraction of the parameterized heating to higher elevation more consistent with observed Q1 profiles. Unfortunately we have not yet successfully modified the parameterizations themselves to create such heating profiles, and perhaps we cannot with the CAM5.2 parameterization suite. Eliminating the bias is difficult because of strong, potentially compensating, responses from other parameterization components. We will summarize a variety of experiments which attempt to elevate the heating. Some examples are: 1) decrease shallow convection by decreasing the maximum updraft fractional area. The decreased low level convective heating is compensated by increased heating from the macrophysics which converts more vapor to cloud liquid. 2) decrease the time scale of deep convection to make it more active. The increase in convective heating is compensated by less heating from conversion of vapor to cloud water in the microphysics which is accompanied by less conversion of cloud water to rain. 3) convergence with decreasing parameterization time step while keeping ratio of the deep convection time scale to time step constant. The resulting behavior is very similar to 2). 4) increase deep convection evaporation efficiency to provide more low level cooling. There is very little increase in cooling because the model is already very humid there.

It seems to be very difficult to prevent such compensation when the individual parameterizations are capable of performing similar or opposing operations on a given atmospheric state. Perhaps these compensating behaviors arise because the parameterizaton components are developed somewhat independently and each component is unaware of how the preceding components acted other than through the state itself.