F: Orographic Rainfall Biases in the ACME/CESM models

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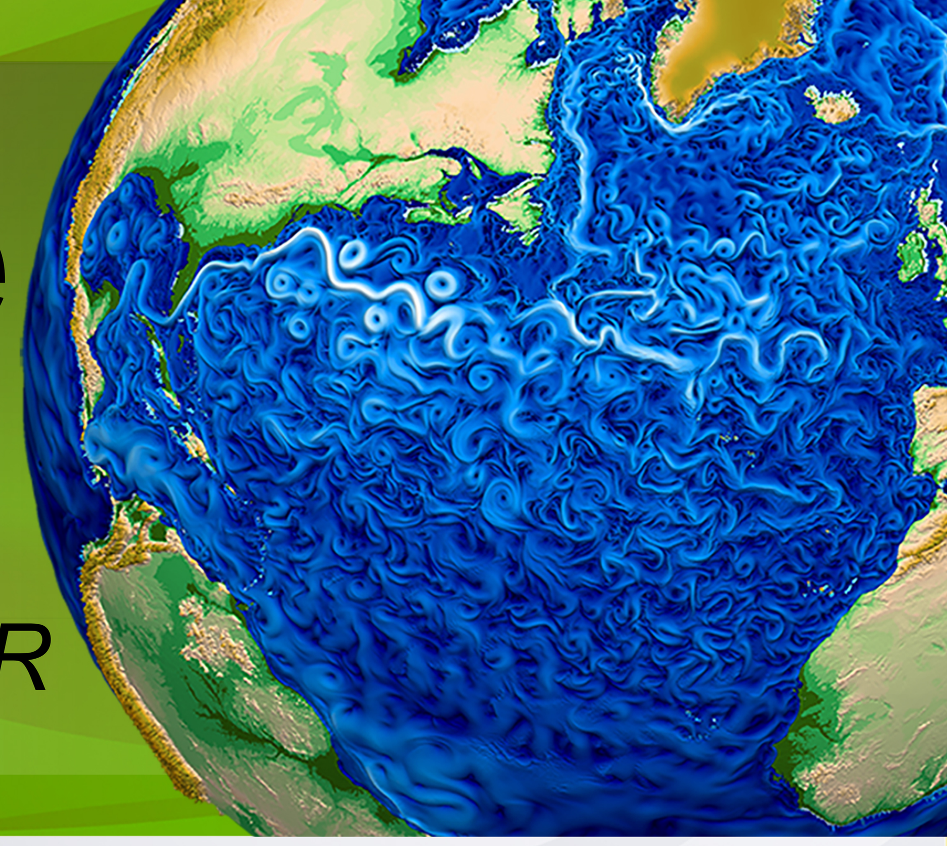

Orographic Precipitation

Biases in CESM

One of the most persistent and impactful errors in CESM and ACME throughout the tropics is the excessive precipitation in close proximity to orography. In particular, positional and magnitude problems near orography are associated with biases in moisture supply, dynamical uplift and the local response of the parameterized moist physics. Chief contributors to these biases are the tropical Andes and Monsoonal Tibetan plateau and in and around the elevated terrain of the Maritime Continent. The observed precipitation distributions tend to be on the upslope of significant terrain (Fig. 1) whereas in model simulation (Fig 2.) there are excessive precipitation peaks atop the highest orography.

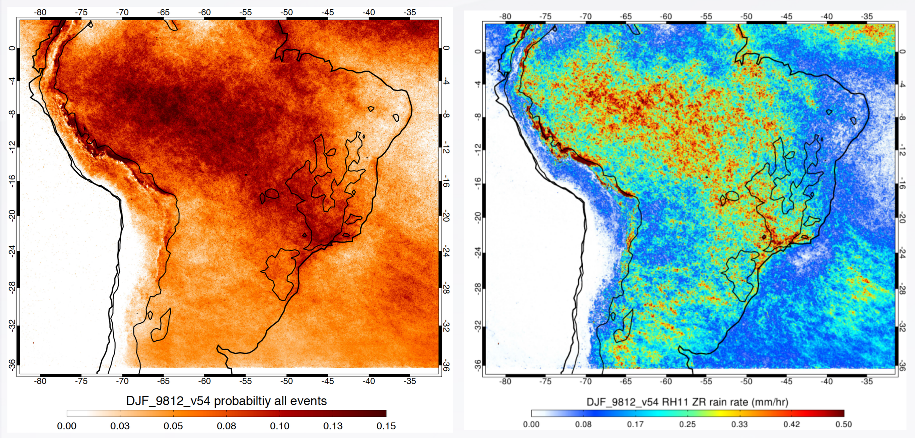

Figure 1: Observed TRMM-PR precipitation over South America in DJF. Probability of events (left) and mean ZR rain rate (right).

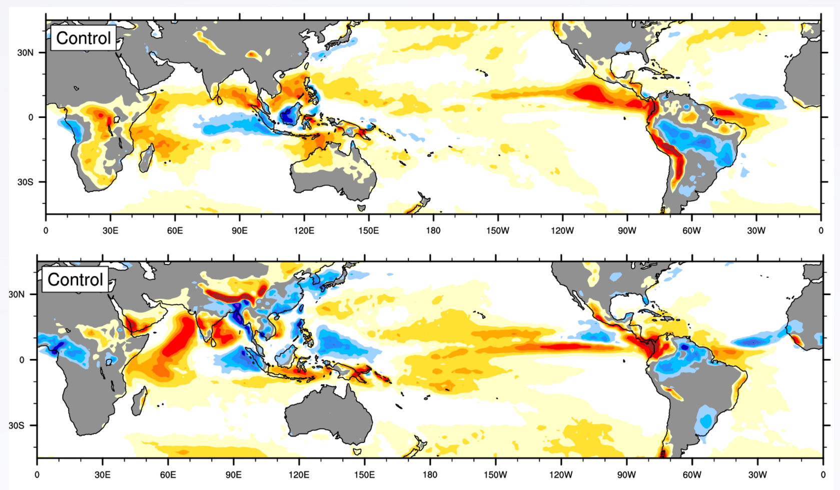

Figure 2: CAM5 tropical precipitation biases in DJF (top) and JJA (bottom).

Diagnosis and causes

Spin-up of precipitation

An analysis of the Andean precipitation biases in CAM5 CAPT hindcasts reveals that the biases begin to be established by day 1 and are near fully established by day 2. There are significant contributions from both resolved scale and parameterized precipitation processes, but the parameterized contributions extend alone a much greater length of the Andean range.

Sensitivity Experiments

We also conducted experiments in which moist heating tendencies were artificially set to zero over regions of high terrain. We used a threshold of 400m in the subgrid orographic standard deviation. The motivation for these experiments is to evaluate the role of feedbacks between heating and moisture convergence. Note that in these runs condensation has not been modified, so that in principle the same precipitation biases can develop as in the control.

Tendency Analysis in SE dycore

We are developing an instrumented version of the SE dycore with detailed tendency output on element-wise data structures (flowchart to right). This will allow us to assess contributions from all of the processes taking place within SE; advection, horizontal diffusion, DSS, time-smoothing and vertical remapping. **Figure 7** shows monthly mean tendencies in mass weighted water vapor across the "rsplit" loop, i.e. horizontal advection, diffusion, DSS.

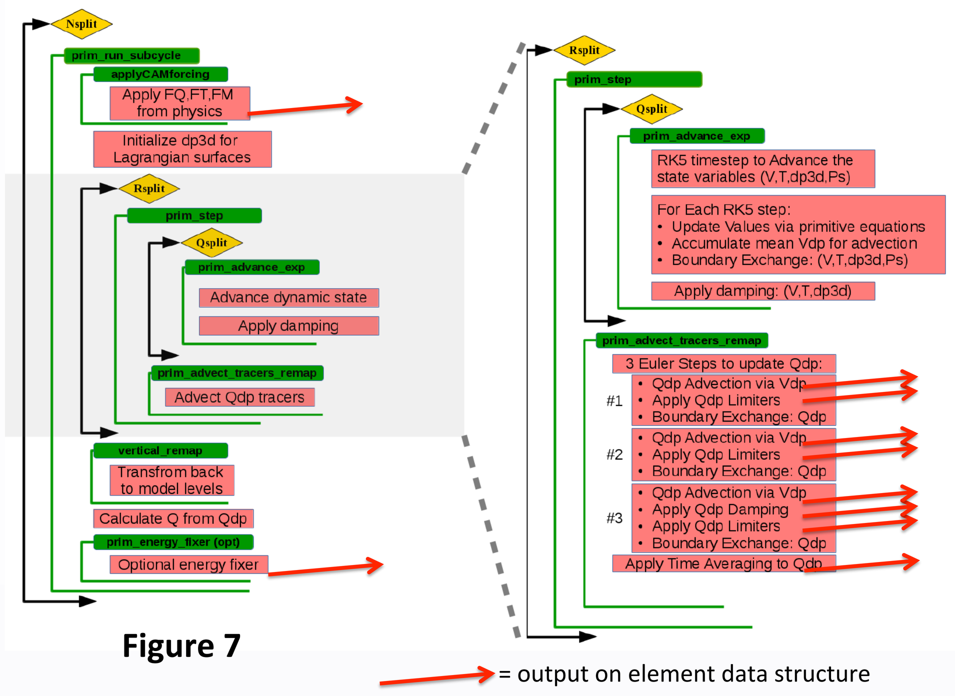

Figure 7

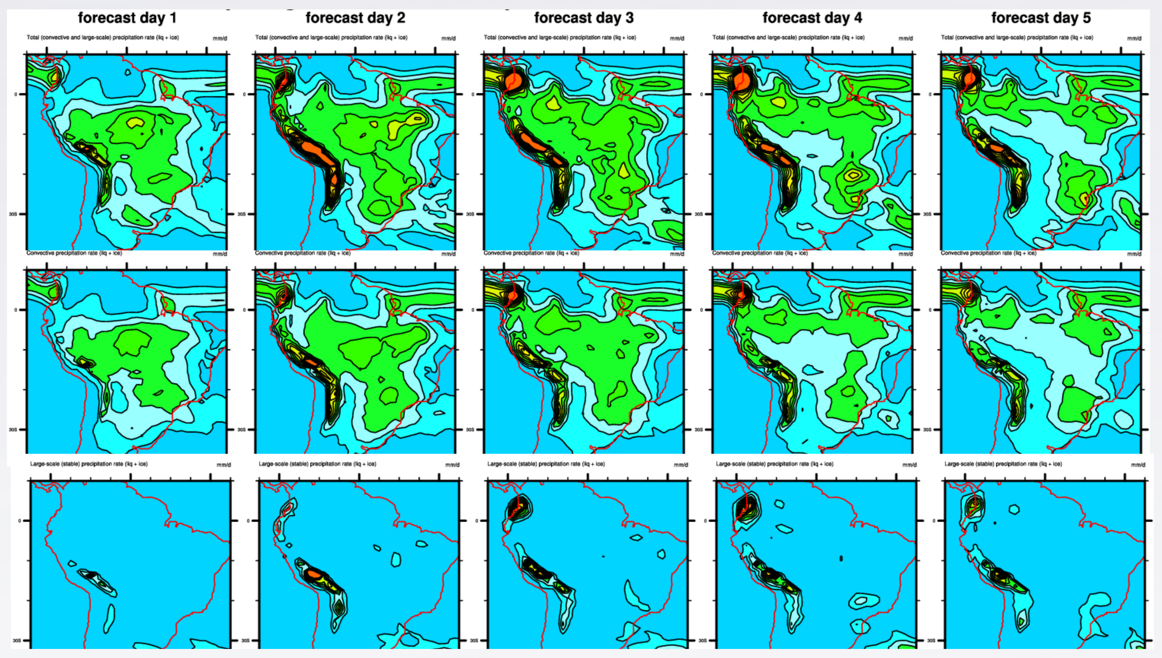

Figure 3: Spin-up characteristics of total (top) convective (middle) and resolved large-scale (bottom) precipitation over South America including the Andes, from a set of CAPT hindcast simulations initialized daily during Dec/Jan/Feb 2008/09.

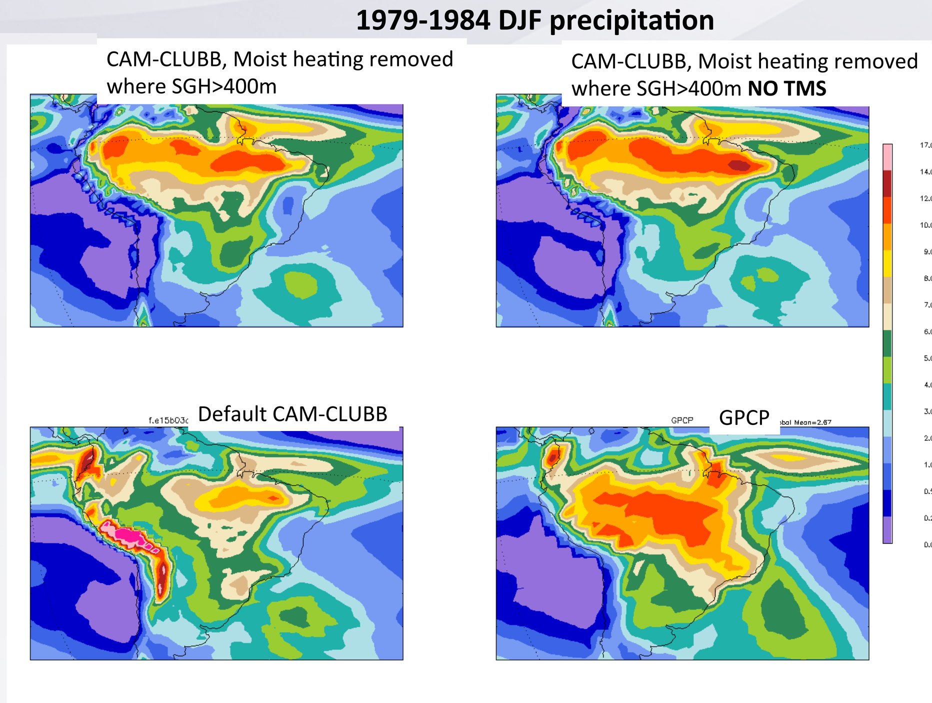

Figure 5: Sensitivity experiments using CAM6-beta AMIP simulations in which moist heating is removed wherever the subgrid orographic standard deviation SGH>400. Condensation is not modified. Disappearance of bias over Andes suggests feedback between moist heating and moisture convergence. Note improved precipitation over Amazon basin in sensitivity runs.

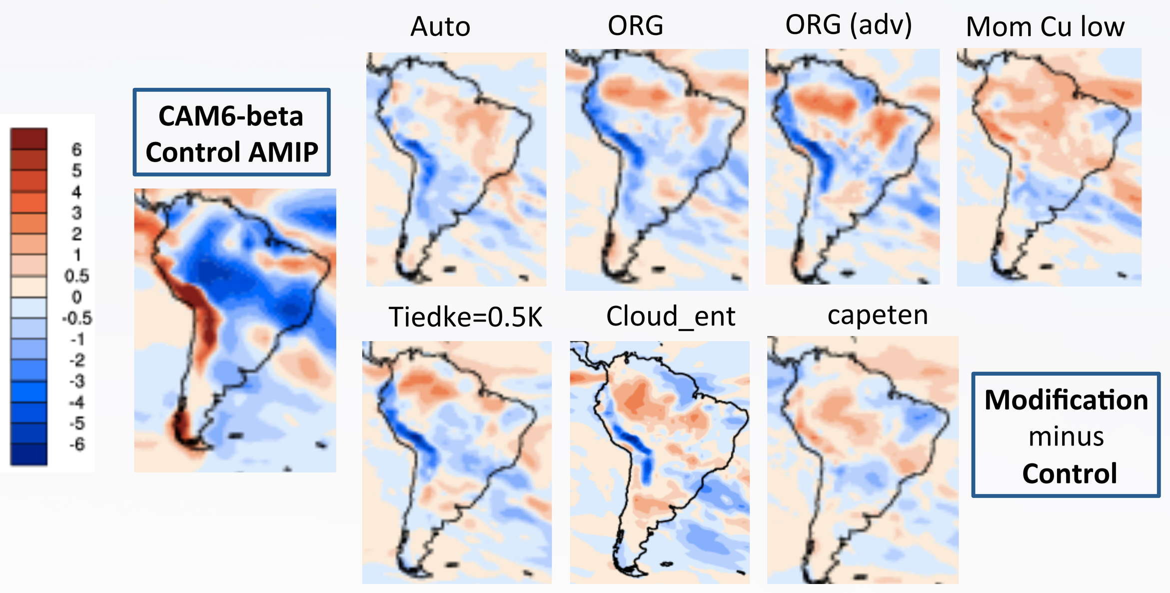

Figure 4: Scoping experiments in CAM6-beta AMIP simulations showing the sensitivity of South American DJF precipitation to deep convection settings.

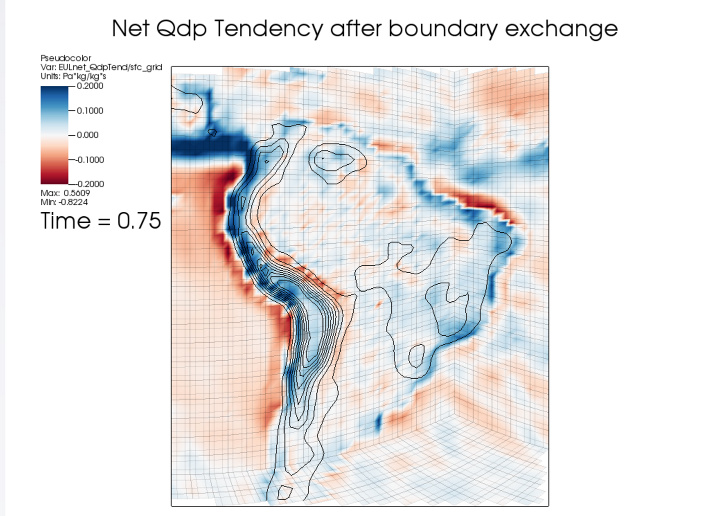

Figure 6: Monthly mean tendency of mass-weighted Q across "rsplit" loop in SE dycore (see flowchart). This includes horizontal advection and diffusion. Note large positive tendencies over Andes.

Potential improvements

Future Diagnosis – Parameterized physics

We intend to perform further analyses of the precipitation in and around orography, not just in the tropics, but in important extra-tropical regions, including the US Rockies and over Greenland. There is a potential pathway for improving some of these errors via modification of the role of the deep convection scheme in ACME. Figure 4 shows significant sensitivity to parameter value selection, with many configurations resulting in a reduction in precipitation in CAM6. With this knowledge we will perform a similar analysis in the ACME model with these and more advanced modifications to the deep convection parameterizations.

Future Diagnosis - Idealized tracer/adjusted water vapor experiments

We will introduce idealized tracers that are reinitialized upon each entry to the SE dycore. These will include tracers initialized as $\chi=\exp(-z/H)$. The evolution of these tracers through the SE dycore will be tracked using the framework described earlier. To reduce the influence of erroneous circulations induced by excessive orographic precipitation we will initialize from observed fields. In these experiments we will focus on separating the effects of diffusion and advection.

ACME Accelerated Climate Modeling for Energy

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