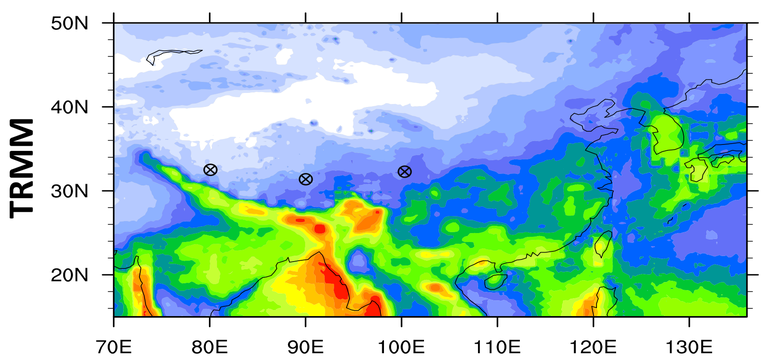
Improvement of rainfall simulation on the steep edge of the Tibetan Plateau

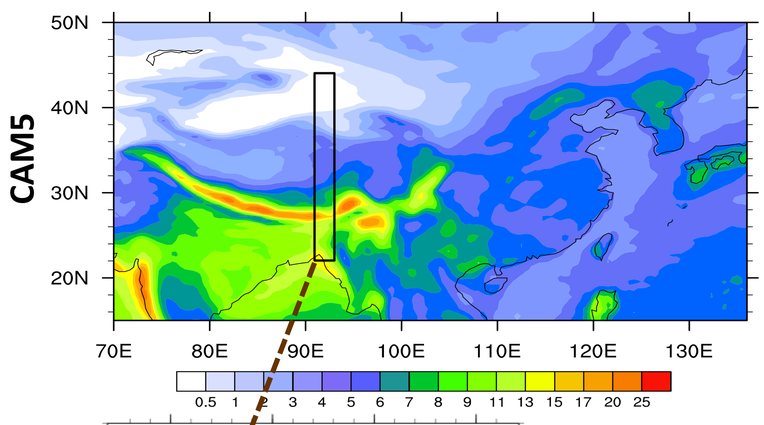
—— using a finite-difference transport scheme in CAM5

Abstract. Overestimation of precipitation over steep mountains is a long-lasting bias in many climate models. The excessive (insufficient) amount of precipitation over the higher (lower) part of the steep slope is partially caused by the multi-grid water vapor transport of the semi-Lagrangian method. After replacing the semi-Lagrangian method with a finite-difference approach for trace transport algorithm in NCAR CAM5, the modified model (M-CAM5) results in a significant improvement of simulation in precipitation over the steep edge of the Tibetan Plateau. The M-CAM5 restrains the "overshoot" of water vapor to the high-altitude region of the windward slopes and significantly reduces the overestimation of precipitation in areas above 2000 m.

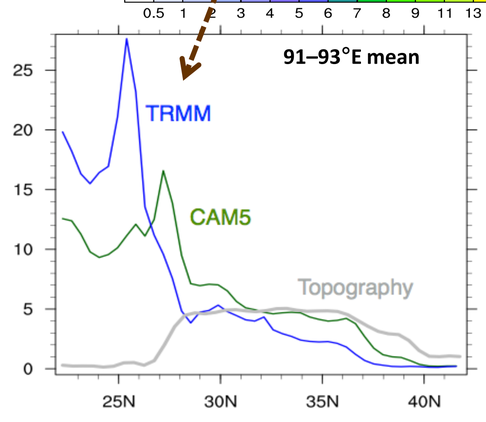
I. The excessive precipitation over the steep edges of Tibetan Plateau is a long-standing problem in new numerical models. And this bias impairs climate simulation, numerical weather prediction, and data assimilation products.



The summer (JJA) mean precipitation amount (unit: mm day^{-1}) from TRMM.



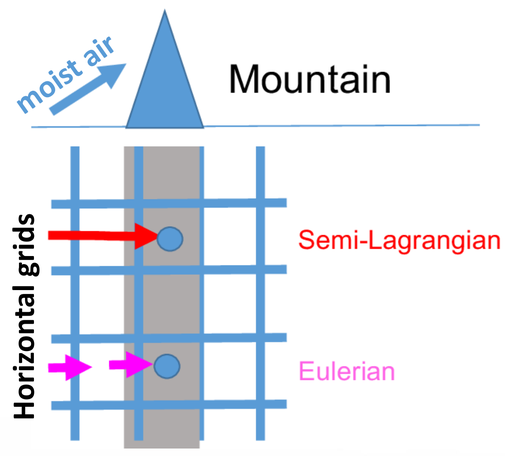
The summer (JJA) mean precipitation amount (unit: mm day^{-1}) simulated by CAM5.



Summer mean precipitation averaged between 91-93°E.

The nature of the bias over steep edges is the northward dislocation of the rainfall belt.

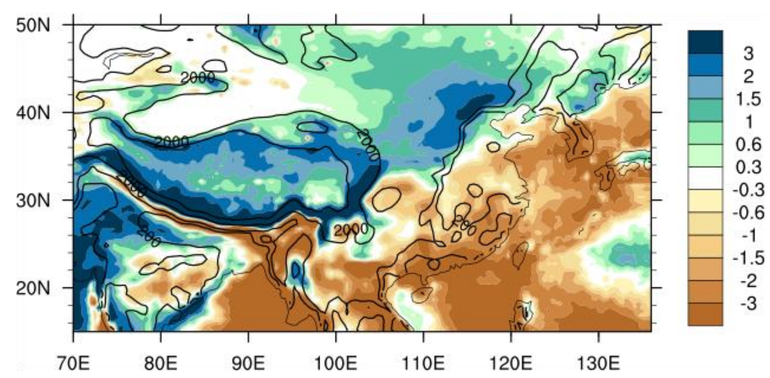
II. Possible reason for the bias: Too much water vapor is transported to the high and cold regions on the upper parts of the steep slopes. Then the water vapor is transformed to precipitation via the grid-scale condensation and precipitation process in the model, which leads to large amount of unrealistic weak precipitation events.



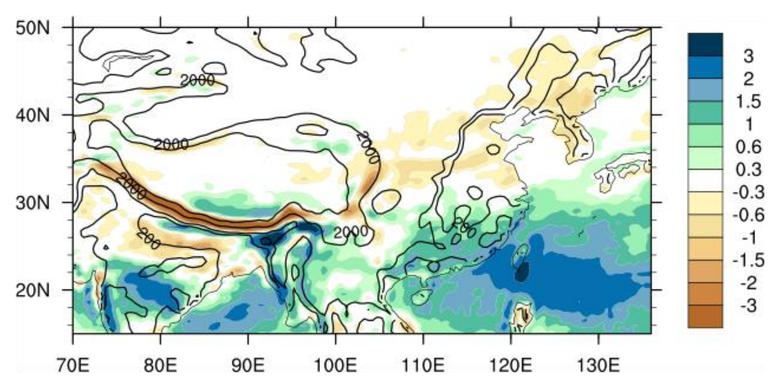
Schematic diagram for water transport over a mountain, Gray shading indicates the area of Mountain.

Immediate cause of the spurious transport of water vaper is the multi-grid long distance transport in the semi-Lagrangian scheme.

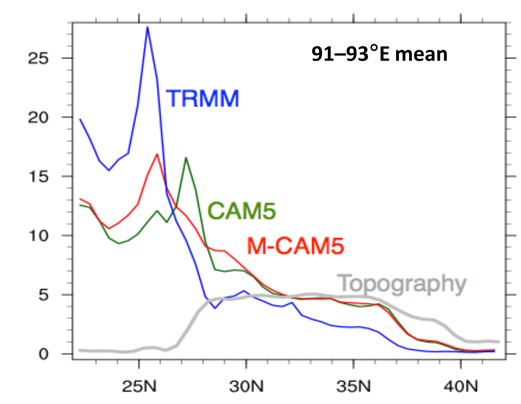
III. The semi-Lagrangian method was replaced with a finite-difference approach (TSPAS) for trace transport algorithm in NCAR CAM5. The shift of transport scheme leads to significant improvement in the simulation of precipitation over the steep edges.



Precipitation biases in CAM5 (unit: mm day^{-1}).

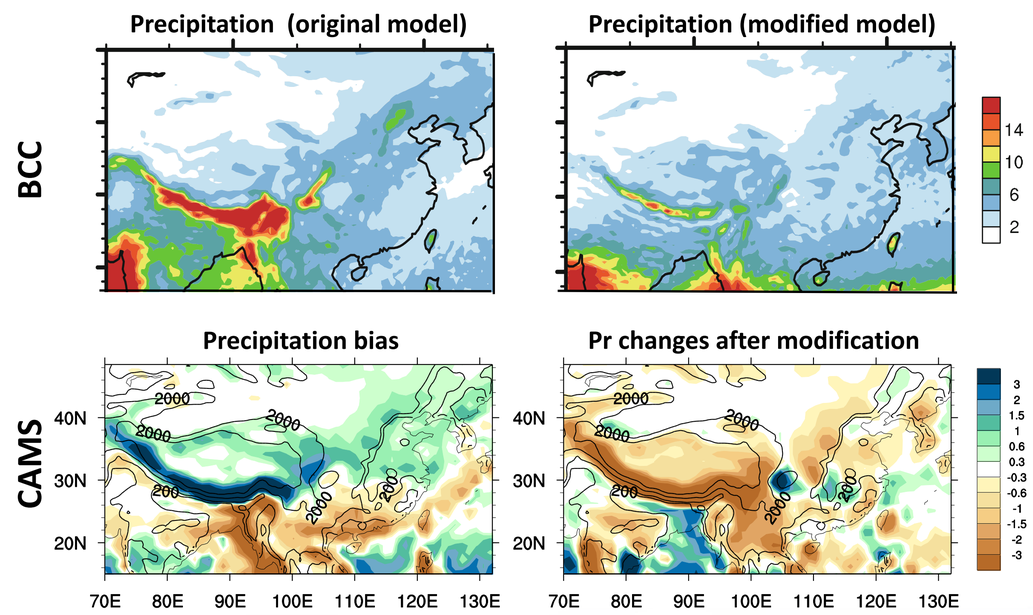


Precipitation differences between modified CAM5 and CAM5 (unit: mm day^{-1}).



The peak of precipitation has moved southward and downward in the modified model (red) and located at a similar position with the TRMM data (blue).

IV. Similar modification has been implemented in BCC model and CAMS model and both of them have shown significant improvement in precipitation around the Tibetan Plateau.



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