Impact of Horizontal Resolution on Climate Model Simulations of Tropical Moist Processes

Research Highlight

Global climate systems models place great demands upon computational resources. Despite the substantial increases in computer power, the increasing sophistication of the models requires decisions on the best use of the resources available. One of the possible avenues for using this expansion in computing power is to increase the horizontal resolution of the climate models. Thus, there is a need to assess the value of doing so. In order to study the impact of horizontal resolution on climate model simulations of tropical moist processes, short-term forecasts using the Community Atmospheric Model (version 4) at several resolutions are performed for a period encompassing the Tropical Warm Pool-International Cloud Experiment (TWP-ICE). TWP-ICE occurred in the environment of Darwin, Australia, in January and February 2006. The experimental period encompasses a number of atmospheric phenomena, such as an MJO passage, mesoscale convective systems, monsoon trough, and active and dry conditions. The CAM is run with four horizontal resolutions: 2°, 1°, 0.5°, and 0.25° latitude-longitude.

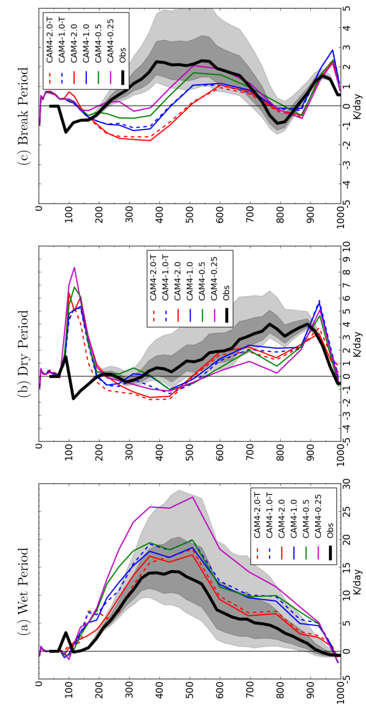
This work brings three new elements to the large body of research on the effects of horizontal grid resolution in a global climate model. First, the climate model is used as a forecast model during a specific observational experiment. This permits verification on the weather regimes for a specific time period and less reliance on statistical properties. The availability of special observations and analysis during the forecast period allows for the evaluation of the fast physical processes at certain locations with a level of detail often not used in GCM studies. Second, the spectrum of grid model resolutions is wide, 2°to 0.25°. This spread of resolutions encompasses the range of what is practical for global coupled model research for the immediate future. Finally, a set of integrations were performed with all the resolutions having the exact same settings of some of the poorly constrained aspects of the parameterizations. Models are usually 'tuned' with arbitrary parameter settings varied to achieve in some sense (usually top-of-atmosphere energy balance) an optimal simulation. Here both tuned and untuned versions of the model are used, permitting a comparison whereby the only difference is horizontal grid resolution. This is not to say that tuning the model is in any way suspect: rather, running identical versions of the model across resolutions provides a useful perspective when comparing the results.

Simulated profiles of diabatic heating and moistening at the TWP-ICE site show that the model parameterizations respond reasonably well for all resolutions to the sequence of varying conditions imposed by the analyses used to initialize the model.

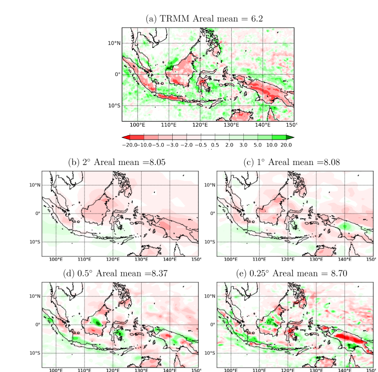
Figure 1 displays vertical profiles of apparent heating estimates from the ARM variational analyses and the models averaged over three periods for the TWP-ICE region. Christian Jakob (Monash University) and collaborators have estimated the possible errors in the radar-derived rainfall from a comparison with rain gauge data and used these estimates to calculate an ensemble of rainfall scenarios.

The spatial patterns of global model biases in time mean precipitation are largely unchanged over resolutions, and in some regions, the 0.25° model significantly overestimates the observed precipitation.

There are substantive positive aspects of finer resolution. The diurnally forced circulations over the Maritime continent are more realistically captured by the 0.25° simulation, which is able to better resolve the land-sea breeze. This improvement in the diurnal rainfall is shown in Figure 2. The figure shows the January and February mean 00 GMT rainfall from TRMM and the models with the daily mean having been subtracted. 00 GMT is 8AM local time at 120°E and is about the time of the peak of the observed rain over the ocean. This time was chosen to illustrate a pattern of relative extrema in the land-sea contrasts of the diurnal cycle.



Variational analysis observed and modeled apparent heating for the TWP-ICE wet (a), dry (b), and break (c) periods. Note the change in scale between panels (a) and (b-c). The dark shading encompasses the 25th and 75th percentiles of the variational analysis ensemble. The lighter shading encompasses the 10th and 90th percentile of the analysis ensemble. Units are °K per day.



TRMM and modeled precipitation at 00 GMT averaged over January and February 2006 with the daily mean removed. The TRMM data display the morning peak in offshore precipitation. Captions include the mean rainfall over the depicted region. Units are mm/day.

The intensity distribution of rainfall events is also improved at higher resolution through an increased frequency of very intense events and an increased frequency of little or no precipitation. Finally, the ratio of stratiform to convective precipitation systematically increases towards better agreement with observational estimates with increases in resolution.

Reference(s)

Boyle JS and SA Klein. 2010. "Impact of horizontal resolution on climate model forecasts of tropical precipitation and diabatic heating for the TWP-ICE period." Journal of Geophysical Research – Atmospheres, 115, D23113, doi:10.1029/2010JD014262.

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Working Group(s)

Cloud Life Cycle