Extending the Applicability of the Community Multiscale Air Quality Model to Hemispheric Scales: Motivation, Challenges, and Progress

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Abstract The adaptation of the Community Multiscale Air Quality (CMAQ) modeling system to simulate O_3, particulate matter, and related precursor distributions over the northern hemisphere is presented. Hemispheric simulations with CMAQ and the Weather Research and Forecasting (WRF) model are performed for the year 2006 using identical projections and grid configurations. The ability of the model to represent long-range transport of air pollutants is analyzed for selected cases through comparison with available surface, aloft and remotely sensed observations. These demonstrate the feasibility of extending the applicability of the CMAQ modeling system to hemispheric scales to provide a conceptual framework to examine interactions between atmospheric processes occurring at various spatial and temporal scales in a consistent manner.

1. Introduction

Atmospheric chemistry-transport models must address the increasing complexity arising from emerging applications that treat multi-pollutant interactions at urban to hemispheric spatial scales and hourly to annual temporal scales. To assist with the design of emission control strategies that yield compliance with more stringent air quality standards, models must possess the fidelity to accurately simulate ambient pollutant levels across the entire spectrum ranging from background to extreme concentrations. Regional model calculations over annual cycles have pointed to the need for accurately representing impacts of long-range transport. Efforts linking regional and global scale models have met with mixed success as biases in the global model can propagate and influence regional calculations and often confound interpretation of model results. Since transport is efficient in the free-troposphere and since simulations over Continental scales and annual cycles provide sufficient opportunity for "atmospheric turn-over", i.e., exwith the measured profile during Spring (Fig. 1a); however, by summer, overestimations still persisted. In the CB05 mechanism, the species NTR is used to represent organic nitrates and serves as a reservoir for oxides of nitrogen (NO_x; through photolysis and reaction with OH). On the hemispheric scale, organic nitrates formed from isoprene are the largest contributor to the simulated tropospheric NTR burden and can consequently modulate the simulated tropospheric O_3 burden. An additional simulation (Case 3) was performed wherein the physical sinks of NTR were enhanced by mimicking its dry deposition and wet scavenging to HNO_3. The comparisons shown in Figure 1 illustrate the relatively large effects of the modulation of the resultant NTR burden on the simulated O_3 burden through much of the lower to mid-troposhere. In limited area calculations with the CB05 mechanism it is likely that the NTR produced is advected out of the regional domains before it can significantly alter O_3 production. However, over the space and time-scales of northern hemispheric calculations, NO_x recycled from NTR can modulate the simulated background O_3; consequently accurate characterization of its sources and sinks becomes critical. The hemispheric calculations, thus provides a framework for examining the role of various physical and chemical processes on atmospheric chemical budgets in a consistent manner.

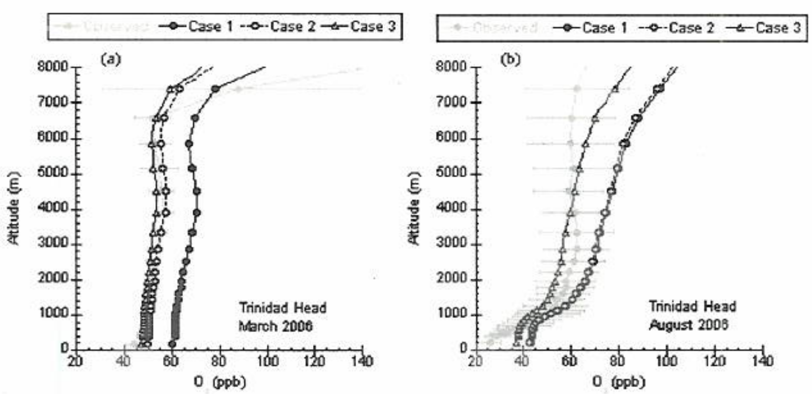

Fig. 1 Comparisons of simulated average vertical profiles of O_3 with ozonesonde measurements at Trinidad Head, CA: (a) for March, 2006 and (b) for August, 2006. Also shown is the ±1 standard deviation of the observed mixing ratios.

Figure 2 presents similar comparisons of simulated composite vertical profiles of O_3 (from Case 3) with measurements from the DC-8 aircraft during the INTEX-B field campaign (Singh et al., 2009) and indicate that the model exhibits good skill in replicating the 3-D tropospheric O_3 structure over the Pacific.

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Singh, H.B., W.H. Brune, J. H. Crawford, F. Flocke, and D.J. Jacob, 2009, Chemistry and transport of pollution over the Gulf of Mexico and the Pacific: spring 2006 INTEX-B campaign overview and first results, *Atmos. Chem. Phys.*, 9, 2301-2318.

Questions and Answers

A. Venkatram: Conservation of mixing ratio in regional models has been a long standing problem, which is important for results on transport of tracers. How have you addressed this problem?

Answer: CMAQ is formulated with a 3-D mass consistent tracer advection algorithm. Through rediagnosis of the vertical wind velocity, the scheme ensures that the Continuity equation is strictly satisfied, thereby ensuring tracer mass conservation as well as conservation of a well mixed tracer.

A. Venkatram: How do you compare aircraft measurements with model results which have an implied averaging time?

Answer: The raw aircraft measurements are typically at different time resolutions for different species and also at temporal scales finer than the model output time step. In the comparisons presented here, we "flew" the aircraft through the model domain and sampled the simulated 3-D field based on time and location of the aircraft. All observed values for each hour within a model grid cell were averaged to ensure that the model and measured values were averaged over similar space and time scales; these are the values were then used to construct the vertical profile comparisons plots.