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Geoscientific Model Development Discussions

Interactive comment on "WRF-CMAQ two-way coupled system with aerosol feedback: software development and preliminary results" *by* D. C. Wong et al.

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Dear Mr. Savage,

Thank you so much for the positive and constructive comments and here are our responses: (notation: C – Referee's comment, R – Authors' response)

C: In the introduction, while mention is made of the direct radiative effects of aerosols, no mention is made of the indirect effects. While it is reasonable to begin the coupling with only the direct radiative effect, the indirect effects should not be ignored in the introduction and this should be noted as a limitation of the initial current coupled set up. (I note that a plan to add indirect effects is mentioned in the Summary and Further

Work section).

R: We added the following sentences after the first sentence in the last paragraph of the Introduction:

Feedback can be categorized as direct or indirect effects: the former refers to how aerosols directly affect the radiation by scattering and absorption and the latter considers how aerosols affect cloud formation and duration by acting as cloud condensation nuclei (CCN) which can alter cloud optical properties and cloud lifetime. In this article, we focus on the direct effects.

C: The description of the coupler is very limited. In particular there is insufficient detail on how the aerosol optical properties are calculated and this section needs to be expanded with details of the methods used. It would be particularly helpful to compare and contrast these with the methods used to calculate these properties in WRF-Chem.

R: We have replaced the last paragraph in Section 2.3 Coupler with the following paragraphs and additional references:

In WRF-Chem (Fast et al. 2006) the optical processes are done by calculating extinction, scattering and asymmetry factor by summing a parametric method originally developed for a modal approach by Ghan et al. (2001). This approach first calls a full Mie code to calculate optical properties over exponentially spaced intervals of x (2* pi * radius / wavelength) for a set of seven refractive indices. A polynomial fit is made for extinction, scattering, and asymmetry factor for each of the refractive indices. All subsequent calls use the polynomial approximations for extinction, scattering and asymmetry factor. The integral properties are calculated by summing over all size bins.

In our approach, feedback effects from chemical species calculated by CMAQ are transferred to WRF for calculating the influence of these species on the radiation fluxes computed by WRF. The new aerosol codes to be used with CAM and RRTMG calculate the aerosol extinction, single scattering albedo, and asymmetry factor for short-

wave (SW) radiation and aerosol extinction for long-wave (LW) radiation. The aerosol chemical species calculated by CMAQ are combined into five groups: water-soluble, insoluble, sea-salt, black carbon, and water. The refractive indices for these species are taken from the OPAC database using linear interpolation to the central wavelength of the CAM and RRTMG wavelength intervals.

The efficient Gauss-Hermite numerical-quadrature method calculates the extinction and scattering coefficients along with the asymmetry factor by integrating the Bohren & Huffman Mie codes over the log-normal size distributions representing the Aitken, accumulation, and coarse modes produced by CMAQ.

Fast, J.D, Gustafson, W. I. Jr., Easter, R. C., Zaveri, R. A., Barnard, J. C., Chapman, E. G., and Grell, G. A.: Evolution of ozone, particulates, and aerosol direct forcing in an urban area using a new fully-coupled meteorology, chemistry, and aerosol model, J. Geophys. Res., 111:D21305, 2006.

Ghan S.J., Laulainen, N. S., Easter, R. C., Wagener, R., Nemesure, S., Chapman, E. G., Zhang, Y., and Leung, L. R.: Evaluation of aerosol direct radiative forcing in MIRAGE, J. Geophys. Res., 106:5295-5316, 2001.

C: The results are in two sections on the performance of the coupler and the scientific performance. I feel that the section on the scientific performance is not as well developed as it needs to be. The comparison with the observations of radiation should be made more quantitative by adding some calculations of root mean square errors and average biases. These should also be calculated for the comparison with the AOD. It would also be useful to include some comparisons with other meteorological variables such as relative humidity and wind speed/direction.

R: Unfortunately there is only one Integrated Surface Irradiance Study (ISIS) site in the study domain. We chose to examine how the areosol impact the radiation by showing the measure versus the model output in three different days.

C: Finally, the only run carried out was in conditions where the aerosol loading was relatively high. It would strengthen the case for the importance of coupling if the benefits (or detriment?) outside of a strong fire episode were to be included.

Figures 9a and 10a show similar performance of the twoway coupled model with respect to O3 and PM25 for the entire domain (fire primary on the northern part of the domain) and duration. Figure 9b and 10b show better performance for the twoway model in the high aerosol loading situation. Hence, this demonstrates the benefit of the twoway coupled model without any detriment.

In future studies, and publications, we will investigate the effects of aerosol feedbacks for long simulations (entire years) over the continental US.

R: It would also be helpful to examine the impact of the calling frequency on the model skill as well as the computational performance.

This supposes to be an initial paper that describes the development of this model and show preliminary result. We intend to study the impact of various call frequencies and possible to help user to determine the optimal one in the near future.

C: If any user guide for this coupled configuration has been produced it would be useful to include it in the supplementary material for the paper.

R: We have produced a release notes which includes brief description of the twoway model in particular aerosol information that will contribute to the direct effect, accompanying with the release of the twoway coupled model.

C: Also is it planned to add this code to the main CMAQ and WRF code bases or maintain them as separate modifications indefinitely?

R: We've planed to provide all the necessary WRF modifications to NCAR in the near future. All the necessary CMAQ modifications are already in the latest CMAQ 5.0 public release version. As a result, there will be no separate code maintenance.

C: Technical corrections

R: They have been corrected.

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