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Interactive comment on “**Technical Note:
Evaluation of the WRF-Chem “aerosol chemical to
aerosol optical properties” module using data
from the MILAGRO campaign”** by **J. C. Barnard
et al.**

J. C. Barnard et al.

james.barnard@pnl.gov

Received and published: 8 July 2010

Interactive comment on “Technical Note: Evaluation of the WRF-Chem “aerosol chemical to aerosol optical properties” module using data from the MILAGRO campaign”

by J. C. Barnard et al.

Anonymous Referee #1

Received and published: 29 May 2010

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[REPLY] The comments provided by the reviewer have been very helpful in producing an improved manuscript. We thank the reviewer. In the discussion below, CTOM is an abbreviation for “aerosol chemical properties to aerosol optical properties module”.

General Comments:

This paper provides an important evaluation of a specific WRF-Chem module used to characterize the optical properties of aerosols. The module is isolated from the larger WRF model and evaluated by replacing modeled aerosol levels with measured levels. The results showed the module accurately represented hourly Babs and SSA but failed to accurately represent hourly Bscat. Averaged over a longer period, module outputs of Bscat and SSA matched observed values. A significant difference was found between predicted and measured Babs when averaged over the dry period. The results also demonstrate that the discrepancy between the full modeling predictions of SSA and the observed values of SSA could be largely attributed to the emission inventory. A detailed discussion of uncertainties is included.

Although the implications of these results are a bit limited by the short experimental time period and the single experimental location, the paper is well written, focused, and provides information that will be useful for WRF-Chem users and will help guide model development efforts.

I recommend this paper for publication; however the paper could be improved by providing additional context concerning the optical module and by expanding the discussion of the implications of the findings. See specific comments below.

Specific Comments:

Introduction: If the authors are aware of similar evaluation efforts of other modules used within WRF-Chem or WRF it would helpful to reference these papers.

[REPLY] We have added a listing of publications that describes recent uses of WRF-Chem, where the model as a whole has been evaluated, or the evaluation of specific

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WRF-Chem modules was done. Here's the additional text, placed in the introduction:

Other WRF-Chem modules pertaining to aerosol chemistry have been evaluated by performing idealized box-model studies (e.g. Zaveri et al., 1999, 2008) before their inclusion in WRF-Chem. WRF-Chem has also been evaluated against numerous field campaign measurements, including the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) / New England Air Quality Study (NEAQS) (Gustafson et al., 2007; Chapman et al., 2009; McKeen et al. 2007), the MLAGRO field campaigns (Fast et al., 2009; Tie et al. 2009), and the Texas Air Quality (TexAQS) 2000 and 2006 field studies (Fast et al., 2006; McKeen et al., 2009; Wilzak et al. 2009).

Introduction and Section 2.1: It would be useful for many readers to provide more information about the particular module evaluated here. Is there a reference specifically for the module? There is a choice of optical modules available in WRF-chem, correct? Which optical module is used here? Would the results here be applicable to any of the other optical modules? What about the choice of chemical/aerosol modules, if a different chem/aerosol module were chosen, would the results here be relevant?

[REPLY] In WRF-Chem, there is only one “aerosol chemical properties to aerosol optical properties” (chemical to optical module, or CTOM). For other processes that involve radiative transfer, there can be a choice of modules. For example, photolysis rates can be calculated using either FAST-J or TUV. These modules use the aerosol optical properties calculated by the CTOM as input. To make this distinction clear in the paper we have mentioned these other modules, and noted that the aerosol optical properties used as input to these other modules are calculated by the CTOM. Here's the prose, found in the introduction:

Evaluation of this module is particularly important because the aerosol optical properties calculated by the module serve as input to other WRF-Chem modules that calculate photolysis rates, such as FAST-J (Barnard et al., 2004; Wild et al., 2000), and

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shortwave radiative fluxes (Goddard scheme, Chou et al., 1998). There is no specific reference for the CTOM. Because we evaluating only the CTOM using measured chemical data as input, our results would not change if a different chem/aerosol module were chosen. This change would probably be very relevant to full, prognostic WRF-Chem simulations.

Section 2.1 and 2.2: Both the modeled and measured aerosols were treated as dry. How relevant is this study to module performance in regions with high humidity?

[REPLY] This is a good question! Having dry aerosol makes the evaluation of the CTOM much easier, because measurements of aerosol optical properties and masses are often made for dry (or dried) aerosols, rather than the ambient aerosols. As of now, we cannot say how well the module will work in humid conditions. We have noted this in the text, in the last paragraph of the conclusions:

.. and higher relative humidity. Because the aerosols in the MCMA are dry, we do not know how well the module would perform in areas with large relative humidity and concomitant hygroscopic growth.

P 8936, lines 12-15: Clarify what are the 'major complications' from dust.

[REPLY] This refers to dust absorption, which can be quite strong in the near-UV and visible spectral regions. The original sentence did refer to dust absorption, but to clearly make the point of dust absorption, we have revised the sentence. Here it is:

For this study, focusing on SSA at this wavelength is advantageous because we avoid the possibly major complications of dust absorption (Sokolik and Toon, 1999), and organic carbon absorption, which may become significant at wavelengths less than about 600 nm (Bergstrom et al., 2009; Barnard et al., 2008; and references therein).

Conclusion, p 8947, lines 23-25: Here you state the module may be useful for climate simulations. Does this mean the module will be useful as part of the prediction of radiative aerosol forcing? Is the discrepancy between observed and modeled Babs

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during the clear sky period of concern to larger climate models? If available, some context as to the relative sensitivity of radiative aerosol forcing to the optical properties investigated here would be helpful.

[REPLY] The differences between calculated and observed aerosol optical properties will lead to errors in the calculation of aerosol radiative forcing. Using the method of McComiskey et al. (2008), we estimated the uncertainty in radiative forcing caused by inaccuracies in the module's calculation of the aerosol optical properties, SSA, and Bext. (These calculations are very straightforward.) This necessitated the addition of text and a new table, Table 4. Table 4 shows the model parameters used to calculate the aerosol radiative forcing, as well as the results of the forcing calculations. The discrepancy between observed and modeled Babs carries over to the discrepancy between observed and modeled SSA; which in turn has a large effect on TOA radiative forcing.

The new text is inserted at the end of the section 3.2. Here it is:

The differences between calculated and observed aerosol optical properties as listed in Table 2 will lead to errors in aerosol direct radiative forcing. These errors can be estimated using the method described in McComiskey et al. (2008). We define the top of atmosphere (TOA) aerosol broadband forcing, F , in the conventional manner, $F = (f_{\text{aerosol, up}} - f_{\text{aerosol, down}}) - (f_{\text{no_aerosol, up}} - f_{\text{no_aerosol, down}})$, where $(f_{\text{aerosol, up}} - f_{\text{aerosol, down}})$ denotes the net instantaneous downwelling shortwave broadband flux at the TOA in the presence of aerosols, and $(f_{\text{no_aerosol, up}} - f_{\text{no_aerosol, down}})$ is the net instantaneous downwelling TOA flux without aerosols. Following McComiskey et al., we find the average solar forcing, F_{ave} , where the average is taken over 24 hours at the equinox. The flux calculations are made using the SBDART model (Ricchiazzi et al., 1998), with atmospheric conditions typical for the T1 site. The base case aerosol optical properties represent plausible values for the T1 site, and are specified at 870 nm: optical depth, $\tau = 0.12$; asymmetry parameter, $g = 0.58$; extinction angstrom exponent (EAE) = 1.3, absorption angstrom exponent

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(AAE) = 1.0, and SSA = 0.78. The value specified for SSA is the observed surface value, and we assume that it is constant throughout the depth of the atmosphere. The surface spectral albedo for the T1 site is from the analysis of Coddington et al. (2008). SBDART input variables, and the TOA forcings are listed in Table 4, for: (1) case one, the base case, (2) case two, same as the base case, except SSA is set equal to the WRF-Chem module calculated value of 0.74 instead of the observed value of 0.78, and (3) case three, same as the base case, except the observed tau ($= 0.12$) is scaled by the factor $B_{\text{ext,calculated}}/B_{\text{ext,observed}}$ ($= 42.1 \text{ Mm}^{-1}/43.8 \text{ Mm}^{-1} = 0.96$), where $B_{\text{ext,calculated}}$ and $B_{\text{ext,observed}}$ are the average extinction coefficients calculated from the module and the observations, respectively. Here we assume that the surface scaling of extinction can be uniformly extrapolated throughout the atmosphere. For the base case, the TOA forcing is -2.3 W/m^2 . For case two, the forcing is -0.86 W/m^2 , a difference of about 1.4 W/m^2 from the base case. The difference between the base case and case three is negligible. McComiskey et al. (2008) state that the largest contributor to forcing uncertainty is SSA and this is consistent with our results. The 1.4 W/m^2 difference is somewhat greater than the maximum uncertainty in TOA forcing, 1.1 W/m^2 , as estimated by McComiskey et al. (2008) (e.g., see Table 4 in McComiskey et al.). However, when making this comparison, we must be mindful that they considered other sources of uncertainty, in addition to just SSA and tau. We also added some additional text in the “conclusions” section:

Our estimate of the uncertainty in averaged, TOA aerosol forcing, attributable to module inaccuracies in calculating SSA and B_{ext} , is 1.4 W/m^2 . The bulk of this uncertainty is induced by the difference between calculated and observed SSA.

Figure 1 and 6: By starting the vertical axis at 0.4 you have maximized the visual impact of the difference between the model output and the observed values. Starting the vertical axis at 0.0 would provide the reader a more intuitive visual indication of the magnitude of differences between modeled and observed values.

[REPLY] We changed the vertical axis on Figures 1 and 6 to extend from 0.0 to 1.0

Technical Comments:

Figure 5: The figure caption should read instead: “The top panel shows the absorption coefficient, B_{abs} , . . . bottom panel . . . scattering coefficient, B_{scat} . . .”

[REPLY] Done.

Page 8946, line 11. “The reasons for this behavior are not understood. . .” Please specify what “this behavior” refers to.

[REPLY] After re-reading the paragraph that contains this sentence, we decided that the sentence did not make much sense in this context and we deleted it.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 8927, 2010.

ACPD

10, C5021–C5027, 2010

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