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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Online coupled meteorology and chemistry models: history, current status, and outlook" *by* Y. Zhang

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Reply to Comments by J. Fast Interactive comment on “Online coupled meteorology and chemistry models: history, current status, and outlook” by Y. Zhang J. Fast, jerome.fast@pnl.gov, Received and published: 26 March 2008

General Comments: I appreciate the author?s effort in assembling a review paper that broadly describes the capabilities of several coupled meteorology and chemical models. A review paper is a useful tool for comparing and contrasting current modeling capabilities and identifying knowledge gaps in our understanding of aerosol-cloud-radiation-chemistry feedback processes. But a review paper also needs to be accurate. Since our group is one of the primary contributors to the WRF-chem model, I would like to point out many of the factual errors in the manuscript that misrepresents the

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capabilities of WRF-chem (listed under the specific comments).

Reply: I appreciate the reviewer’s effort in reading the paper and writing the detailed comments. I agree with the reviewer that the review paper should be accurate. The review of the review paper should also be accurate. Unfortunately, the last statement of the above comment itself is factually incorrect and reflect the reviewer’s misunderstanding of the review paper in several aspects. Please see more detailed point-by-point replies below.

1) Part of the problem is that the author does not indicate which version of the WRFchem model is being referred to. WRF-chem, as with other models mentioned in the paper, undergo periodic revisions. Some of the errors may be associated with describing capabilities in an old version of the code. Version 3 will be released to the public in early April, and it would be most useful for readers to report on capabilities associated with that version.

Reply: The review was written based on the latest publicly-released version of WRF/Chem (v 2.2) and updates to this version by the author’s group. It provides the capabilities of the latest public version of WRF/Chem that is being used for the atmospheric science communities. Version 3 does not exist at the time when the paper was written (June-Oct., 2007) and it has not been released as of March 31, 2008. A review paper should review what has happened, rather than what will happen in the future. It is not clear to the author how errors could happen just because it did not review a future version of WRF/Chem. The version of WRF/Chem has been indicated in the revised version.

2) Another aspect that will confuse readers of this paper is differences between the official ?released? version of the code and versions developed by individual scientists. The author reports on implementation of the CB05 and MADRID modules in the code, that is not yet available in the public community version of WRF-chem (including version 3). These capabilities are only available from the author. This needs to be pointed out in

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the paper. If the author wishes to describe these modules in WRF-chem, then why not describe modules other scientists have implemented in WRF-chem? To be a balanced review article, requires the author to either 1) include all other model developments that have been developed and have yet to be included in the release version (and there are many) or 2) report only on the official release of the code.

Reply: The review paper should provide an unbiased review for major work that have been published in peer-review journals and conference presentations. Community models that are publicly available did not evolve until late 80’s and early 90’s in the atmospheric model development history. Whether the model is officially released or not is irrelevant and cannot be used to justify its inclusion in a review paper. Both public and non-public models have been included in previous review papers on atmospheric models (e.g., Peters et al. (1995), Atmos. Environ., 29, 189–222; Russell, A. G., and R. Dennis (2000), Atmos. Environ., 34, 2283– 2324; Seigneur et al., ES&T, 80A-86A, 1999; Seigneur, J. Air & Waste Manage. Assoc., 51, 1508-1521, 2001). Among the five U.S. models reviewed in-depth in my paper, only two of them (i.e., WRF/Chem and CAM3) are community models in nature that are publicly available. This has been pointed out clearly in the paper and should be sufficient to distinguish them from other models. The reviewer’s suggestion on reviewing only officially-released model is unreasonable. It is against the history of model development and inconsistent with the scope of previous review papers on atmospheric models. As the reviewer also recognized, there are many users for WRF/Chem in the U.S. and beyond, and many of them are adding new modules and/or improving the existing modules. It is impossible for the official code developer and maintainer (i.e., Georg Grell’s group at the U.S. NOAA Earth System Research Laboratory (ESRL)) to keep a complete list of all users and keep tracking all their activities, as not all of them are registered users and report their activities to NOAA-ESRL. The author’s group is a registered user and has no obligations to keep tracking other model developments by other users that have not been published in peer-reviewed journals. Therefore, the reviewer’s suggestion on reviewing

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all other model developments associated with WRF/Chem is not feasible for any review papers of similar kinds.

Specific Comments: Page 1845, line 18: The statement implies that photoloysis rates produced by the Fast- J algorithm are not affected by on-line trace gases and aerosols. This is incorrect.

Reply: This statement is accurate and the reviewer’s understanding of feedbacks of gases to online photolysis calculation is incomplete and the reviewer’s interpretation of the statement is misleading.

As pointed out in page 1847, lines 10-15, the Fast-J algorithm as implemented in WRF/Chem v 2.2 only accounts for feedbacks of predicted O3, aerosols, and clouds. It, however, does not account for feedbacks of other radiatively absorbing gases such as NO2, HCHO, PAN, HO2, and HNO3 to online photolysis calculation from spectral radiative transfer. So, in the paper, the feedbacks of photochemically-active gases and aerosols to photolysis via Fast-J photolysis algorithm in WRF/Chem was given as an example of “some coupling are still partially completed”. This statement does not imply that the Fast- J algorithm is not affected by on-line trace gases and aerosols, it points out, however, the coupling between radiatively absorbing gases and photolysis calculation in FAST-J is rather incomplete.

Page 1846, line 23: Fast (2005) is an inappropriate reference here. It is a conference proceeding that describe and evaluation of the boundary layer characteristics produced by two PBL schemes in WRF, and does not document chemistry modules.

Reply: Fast (2005) is a typo, it has been replaced with the correct reference for PNNL’s version of WRF/Chem of Fast et al. (2004) in the revised version.

Page 1846, line 26: CB05 is not yet part of the publicly available version of the WRFchem code, and this needs to be stated here. Version 3 also includes a version of the Kinetic PreProcessor (KPP) that builds code compatible with WRF-chem so that users

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can build any chemical mechanism they want.

Reply: CB05 is being tested by the author’s group and will be released in the future, this has been indicated in the revised paper. The KPP was indeed included in WRF/Chem v2.2, rather than version 3. This feature has been indicated in the revised paper.

Page 1847, line 2: MADRID is not yet part of the publicly available version of the WRFchem code, and this needs to be stated here. The aerosol model from the GOCART global climate model is now part of the version 3 release of WRF-chem.

Reply:

MADRID is being tested by the author’s group and will be released in the future, this has been indicated in the revised paper. The GPCART-aerosol module is not included in this review paper as it does not exist in the latest released version of WRF/Chem.

Page 1847, line 17: Fast (2005) is an inappropriate reference here.

Reply: See previous reply on this.

Page 1850, line 17: As stated previously, CB05 is not part of WRF-chem version 3.

Reply: As stated previously, the review paper reviewed the latest version (v2.2) of WRF/Chem and updates from the author’s group from v2.2. It is appropriate to include the development work that is not yet included in the public release version, it is, however, inappropriate to include a future version 3 of WRF/Chem in the current review paper.

Page 1850, line 23: MOSAIC does not employ bulk Carnegie Mellon aqueous chemistry.

Reply: WRF/Chem-MOSAIC indeed uses the bulk Carnegie Mellon aqueous chemistry (see module_cmu_bulkaqchem in WRF/Chem v2.2). Below is the note on the history

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of this module copied from this module, note that S. Pandis was a tenured professor at CMU and now a research professor at CMU. ! This code was obtained from S. Pandis in July 2003. ! It was converted to Fortran-90 and adapted for use in WRF-chem with ! the MOSAIC aerosol modules by R. Easter (PNNL) in July 2005. The aqueous-phase chemistry is not directly treated inside the aerosol modules MOSAIC or MADRID, but it is part of package associated with the use of MOSAIC and MADRID. The statement has been reworded to avoid confusion.

Page 1852, line 1: Fast (2005) is an inappropriate reference here.

Reply: See previous reply on this.

Page 1852, line 4: Gustafson et al. (GRL, 2007) describes cloud-aerosol interaction processes and aerosol indirect effects we coupled with MOSAIC in WRF-chem.

Reply: “Jerome Fast, personal communication” has been replaced by Gustafson et al.

Page 1852, line 21: Table 3 implies that MADE/SORGAM and MOSAIC aerosol treatments are identical except that one is modal and one is sectional. For MOSAIC, seasalt is treated as separate species: Na and Cl. MOSAIC also includes aerosol water, calcium, calcium carbonate, and menthansulfonate. The number of sections for MOSAIC in version 3 of WRF-chem is either 4 or 8 (not 8 reported in the table); however, the code can be easily modified for any number of sections. Aerosol properties are similar to, but not the same as in MIRAGE.

Reply: Sea-salt is treated as separate species in all other models. This is a common approach used in air quality models; there is no need to state that they are separate species. Aerosol water is always treated in all aerosol modules. It has been added for all five models for completeness. Calcium is also treated in GATOR-GCMOM, Caltech unified GCM, and WRF/Chem-MADRID. Carbonate is also treated in GATOR/GCMOM and WRF/Chem-MADRID. Table 3 and relevant text have been modified to include

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additional species treated in MOSIAC and other models, and to distinguish aerosol species treated in the three aerosol modules in WRF/Chem. The number of aerosol size section included in the parenthesis in Table 3 after “Sectional” is the one for typical application, rather than a full list of all sections used. A footnote has been added in the Table to help the reviewers to interpret this. 8 sections are typically used for MOSAIC and MADRID applications (e.g., see Fast et al., 2004, 2006; Zhang et al., 2005a, 2007 in the reference list of this APCD paper). “Sectional (8): variable” in Table 3 means that the number of section can be varied, depending on the specific applications. This has been explicitly indicated in the relevant text section in the revised version. Table 3 intends to summarize the major treatments in each model at a level of methodology rather than the actual specific treatments, namely, whether they use the same approach and what the main differences among major approaches are. “the same as in MIRAGE2” means the treatments for aerosol radiative properties in WRF/Chem are the same, namely, it uses the parameterized RI and optical properties based on wet radius and RI of each mode. When the same approach is implemented into different models, some differences may of course appear in its actual implementation, but the basic approach remains the same. The text explanation for aerosol radiative properties indeed made this point clearly, e.g., it states the following:

MIRAGE2, WRF/Chem, and Caltech unified GCM predict RIs and optical properties using Mie parameterizations that are function of wet surface mode radius and wet RI of each mode.

Page 1853, line 28: For MOSAIC, aerosol number is always treated prognostically. The text somehow implies that the user can choose either diagnostic or prognostic.

Reply: The statement refers to WRF/Chem MADE-SORGAM, rather than MOSAIC and MADRID. The version of MADE-SORGAM aerosol module in WRF/Chem v2.2 is a very older version of the aerosol module used in CMAQ that was developed by Frank Binkowski (as of March, 1999). In this version, the standard deviation (sigma_g) was

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fixed for both Aitken and accumulation modes, and the modal mean diameters are diagnosed from 3rd moment and number. This old version of MADE-SORGAM was previously reviewed in Zhang et al. (AS&T, 31, 487-514, 1999), and it has been concluded that the modal approach with a fixed sigma_g is incorrect and cannot reproduce the aerosol growth via condensation and coagulation. Using fixed sigma_g and diagnosed modal mean diameter in MADE-SORGAM introduces errors in the aerosol mass and number concentration simulation in WRF/Chem. The above point will be clarified in the revised version.

Page 1854: line 19: For WRF-chem version 3, the user can choose either volume averaging, Maxwell-Garnett, or shell-core mixing rules when using either MADE/SORGAM or MOSAIC. This is description is out-of-date.

Reply: This review paper reviews the latest released version (v2.2) of WRF/Chem that has been and is being used by the atmospheric science community and is not out of date in any way. As indicated previously, the review paper should not review a future version of WRF/Chem.

Page 1857, line 5: MARS is no longer used for MADE/SORGAM in WRF-chem version 3. It now uses ISORROPIA.

Reply: As indicated previously, the review paper should not review a future version of WRF/Chem.

Page 1858, line 23: MOSAIC does not treat SOA in the WRF-chem version 3 release as implied in the text. We are currently developing several approaches for treating SOA in MOSAIC, but they will not be included in the released version of the code until they are thoroughly tested and reported in a peer-reviewed publication. It should be noted that the understanding of SOA is far from complete and SOA predicted by most models is much lower than observed (e.g. Volkhammer, GRL 2006).

Reply: According to Rahul Zaveri, the developer of MOSAIC at PNNL, SOA treatment

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has been incorporated into an offline MOSAIC based on MADE-SORGAM, but it is however not implemented in the MOSAIC version in WRF/Chem v2.2. This has been clarified in the revised version.

Line 1863, line 15: Cloud-aerosol interactions affect precipitation rates when using MOSAIC.

Reply: The statement in Page 1863, line 15 is as follows: "The effects of aerosols on precipitation rates are taken into account in GATOR/GCMOM, but are neglected in other models." The reviewer has misunderstood the above statement. This statement refers Table 6, under "In-cloud Scavenging", it states that "precip. rate independent of aerosols" for all models except for GATOR-GCMOM in which precip. rate is dependent of aerosol size and composition. In GATOR-GCMOM, aerosols are discretely size resolved, and clouds form directly on each size of aerosol. The discretely-size-resolved cloud drops then coagulate to form rain. Each size of cloud+rain drops also coagulates with each size of interstitial aerosol. Cloud/raindrops fall from their current layer of the model to the next layer based on their size and mass. Aerosols incorporated within clouds (since all aerosols are tracked within cloud drops) are removed with the cloud/rain drops from each layer. As such, aerosols can be removed by clouds/rain in two ways, and both are discretely size resolved: (1) nucleation scavenging where the cloud drop grows on the aerosol particle, then becomes larger and falls out; (2) impact scavenging, where size-resolved cloud/rain drops coagulate with interstitial aerosols then grow until they fall out, removing the aerosols. The above treatments are not included in a similar way in other models. The treatments in other models differ from those in GATOR-GCMOM in three aspects. First, cloud / rain size distributions are not discretely size resolved. Second, they all treat removal of aerosols as an empirical function of the rainfall rate, so there is no physical interaction of size-resolved aerosols with size-resolved rainfall. Third, none of them track all the aerosol components that the clouds formed on within size resolved cloud drops. As such, they do not know the correct amount of aerosol particle to remove. The above points will be indicated in the

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revised version for clarification.

It would also be useful to comment on the treatments employed in the meteorological parts of the code (i.e. nonhydrostatic, data assimilation, etc) in addition to chemistry, since the paper is on ?coupled meteorology and chemistry models? as stated in the title.

Reply: As stated in the abstract and introduction section, the review focuses on aerosol microphysics treatments, aerosol feedbacks to planetary boundary layer meteorology, and aerosol-cloud interactions, which is far beyond just the “chemistry”. Given its broad scope and length constraint of a journal paper, it is not feasible to include all aspects of the coupled meteorology and chemistry models.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 1833, 2008.

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Interactive Comment