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Interactive Comment

Interactive comment on "Application of WRF/Chem version 3.4.1 over North America under the AQMEII Phase 2: evaluation of 2010 application and responses of air quality and meteorology–chemistry interactions to changes in emissions and meteorology from 2006 to 2010" *by* K. Yahya et al.

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Reply to Comments from Reviewer 3

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Interactive comment on “Application of WRF/Chem version 3.4.1 over North America under the AQMEII Phase 2: evaluation of 2010 application and responses of air quality and meteorology–chemistry interactions to changes in emissions and meteorology from 2006 to 2010” by K. Yahya et al. Anonymous Referee #3 Received and published: 19 March 2015

This paper evaluates the WRF/Chem model performance on reproducing the air quality and meteorology-chemical interactions in years 2006 and 2010 by comparing the model predictions of WRF/Chem and WRF, model results with each other and with observations. A series of sensitivity simulations have been conducted to evaluate the model response to changes in emission, meteorology and chemical BC/IC. The authors put a lot of effort to evaluate the model performance for various variables. The manuscript is well written and very informative in terms of statistical evaluation of the model against observations.

Reply:

We thank the reviewer for careful review of this manuscript and recognition of the values of this work. We have carefully addressed all the comments raised by the reviewer to improve the technical and presentation quality of our manuscript. Please see below our point-by-point replies.

However i have a number of major comments : 1) I would expect a lot more information on the model development part considering the journal it is submitted to. However, there are just references to other papers regarding the developments. The study as is more than the application of the model version developed in previous studies by these authors.

Reply:

Most of the model developments have already been described in great detail in Wang et al. (2014). Note that Wang et al. (2014) only conducted simulations over a specific short episode (i.e., July 2006). This paper extended the simulation periods to two full years, which has rarely been done by the air quality communities for online-coupled air quality models in the past. The model evaluation, in particular, the evaluation over a long-term period, is considered to be part of the model development and improvement efforts as most papers on model development and improvement limit their simulations to be a short time period. This work aims to examine the capability of WRF/Chem with a new chemistry and aerosol option (i.e., CB05-VBS) for long-term simulations and also the capability in reproducing the trend of air quality and meteorology-chemistry interactions under different emission, meteorological and chemical initial and boundary conditions. A number of model limitations have been identified via a comprehensive evaluation and analyses, which would be particularly useful for model improvement. We therefore believe that our work is a valuable contribution to model development and improvement and it is within the scientific scope of the Journal of GMD, which is supported by the fact that our paper passed the initial assessment by the journal Editor before its acceptance for GMDD. Further, to our understanding, GMD has accepted papers that focus purely on model evaluation in the past, e.g., see a paper by Appel et al. (2013) at http://www.geosci-model-dev.net/6/883/2013/gmd-6-883-2013.pdf and a paper by Tessum et al. (2015) at http://www.geosci-model-dev.net/8/957/2015/gmd-8-957-2015.html.

To address the reviewer's concern, we added a brief summary of the model development in this version of WRF/Chem in the Introduction Section. We also added a few statements regarding how the major findings from this work help shape the model further development and improvement in the future in the conclusion. For example, improvements in predictions of precipitation as well as cloud-aerosol interaction treatments are necessary. Large uncertainties exist in one of the important cloud-aerosol processes, i.e., aerosol activation to form CCN, the ability of the existing aerosol activation scheme in WRF/Chem to reproduce the state of the atmosphere and also inter-

GMDD
8, C776–C782, 2015

annual trends should be improved.

2) i find it difficult draw robust conclusions on feedback mechanisms using two different years with different emissions and meteorology. This is particularly challenging over temporally and regionally averaged variables. Regarding the feedbacks, i would expect to see some episodic evaluations where these feedbacks really make a difference and see if the model is capable of simulating these effects.

Reply:

We agree with the reviewer that it is difficult to draw robust conclusions on feedback mechanisms using different emissions and meteorology for two different years. The aerosol-cloud-radiation feedbacks from a single year (2006) comparing WRF and WRF/Chem meteorological and chemical surface and column variables have been discussed in great detail in Yahya et al. (2014). In this study, our focus is on long-term simulations, however, our analyses are carried out on a seasonal basis as we think that each season has similar characteristics in terms of emissions and meteorology and seasonal analyses are sufficient to quantify the feedbacks and their seasonal variations. In addition, we had conducted several sensitivity simulations for January and July 2010 in our original paper to estimate the relative impacts of changes in emissions, meteorology and chemical ICONs/BCONs on model predictions in 2010.

Regarding "some episodic evaluations where these feedbacks really make a difference and see if the model is capable of simulating these effects", such evaluations require comparison of model predictions from two sets of simulations: one with and one without feedbacks, and evaluate both sets of model predictions against observations. To our understanding, the feedback mechanisms in WRF/Chem are hard-coded and there is no public version of WRF/Chem that does not treat feedbacks. So, it is not possible for us to perform WRF/Chem simulations without the feedbacks. Such episodic evaluations have been indeed performed using another model, i.e., GEM-MACH, and presented in Makar et al. (2014 a, b) as part of the 2014 AQMEII-Phase II special is-

GMDD
8, C776–C782, 2015

sues in Atmospheric Environment. In their work, GEM-MACH was specially designed to include and exclude feedback treatments to enable such episodic evaluations.

To address the reviewer's comments, we have added further analyses in Section 4.4 and also acknowledged a need to perform such episodic evaluations using WRF/Chem that excludes such feedback mechanisms. In addition, we added a new Table (Table 4) to evaluate how changes in emissions and meteorology in Jan. and Jul 2010 on the model's capability in reproducing the observed variation trends of meteorological and chemical variables, including variables that can indicate the magnitudes of chemical feedbacks such as CCN, AOD, COT, CWP, CF, Precip, and SWDOWN. Those results are representative episodic evaluation (i.e., in Jan. and Jul.) and they can provide information regarding if the changes in emissions and meteorology can affect the observed trends in CCN, AOD, COT, CWP, CF, Precip, and SWDOWN, which can show whether these feedbacks through changes in emissions and meteorology really make a difference in the model's capability in reproducing observed variation trends in those variables. We feel that such additional evaluations, though not exactly what the reviewer expected, can complementarily provide further insights into the impact of feedbacks on model predictions during the two representative periods of simulations.

3) I would expect more in depth discussion on the sensitivity section rather than just showing increase or decrease in the species.

Reply:

We have added more in-depth discussion in Section 4.4. For example, we discussed the effect of different emissions and meteorology on O3 mixing ratios as follows:

"As shown in Figures 13 and 14 (column 2), changes in O3 are influenced by all factors and the overall change of O3 mixing ratio is a combination of changes in emissions, meteorological and chemical ICONs/BCONs. The O3 mixing ratios are greatly increased due to the use of 2010 emissions as compared to 2006 emissions (column 2 in Figure 13), indicating that using a different set of emissions can produce an increase of

GMDD
8, C776–C782, 2015

up to a domain mean of 6 ppb domainwide. Conversely, O3 mixing ratios are greatly decreased (with a reduction of a domain mean of 6ppb) due to the use of the 2010 chemical ICONs/BCONs compared to 2006 ICONs/BCONs (column 3 in Figure 13). The use of different meteorological ICONs/BCONs also results in varying degrees of changes of O3 mixing ratios domainwide as O3 mixing ratios are influenced by photolysis and other meteorological parameters including wind and PBLH (column 4 in Figure 13)."

In addition, we added a new Table (Table 4) along relevant discussions in Section 4.4 to evaluate if the sensitivity simulations with different meteorology, emissions, and chemical ICs/BCs for Jan. and July 2010 can improve the model's capability in reproducing the trends in both meteorological and chemical variables, as comparing to baseline results in 2006 and 2010.

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GMDD

8, C776–C782, 2015

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