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Geoscientific Model Development Discussions

Interactive comment on "Inclusion of Ash and SO_2 emissions from volcanic eruptions in WRF-CHEM: development and some applications" *by* M. Stuefer et al.

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We added requested statements describing the various options to model volcanic emissions with WRF-Chem. The reviewer notes a lack of detail in the description of the ash deposition. We included sentences describing the assumptions, and discuss the case studies in more detail. The response to the specific comments is described below. The revised manuscript was copied in the supplement for reference.

Technical Comments: - Page 2578, l. 9-10: The statement 'Computational cost is minimal.' refers to the inclusion of ash in trace mode without any chemistry parameterization nor radiative feedback. We clarified the different approaches to include ash

in WRF-Chem within the paragraph, and added on to the sentence: 'Computational cost is minimal, since no chemistry is involved and additional computations are derived mostly from advective transport of the 4 additional variables.' Would it be reasonable to use WRF-Chem in an emergency situation: => Yes. WRF-Chem is used in operations by weather services and agencies all over the world. - We answer the question about the potential use of WRF-Chem for volcanic emission advisories within the summary and conclusions: 'Within the NOAA-NASA GOES-R initiative (http://www.goes-r.gov/), we are currently developing an automated scheme to produce operational experimental WRF-Chem volcanic ash emission forecasts for modeling domains within the Anchorage Volcanic Ash Advisory Center (http://vaac.arh.noaa.gov/). Once the meteorological source and boundary fields are created, a WRF-Chem run for volcanic ash within 10 particle size bins and SO2 takes about 25 minutes using 64 2.6 GHz AMD Opteron processors, and a modeling domain with a 12 kilometer horizontal resolution, 300 by 300 horizontal grid cells (3600x3600 kilometers), and 50 vertical levels; the experimental runs calculate dry and wet deposition of ash.' The WRF-Chem option using 4 fine ash bins (instead of the 10 ash bins) takes about 10% less calculation time with the same processors and domain definition. As for the wet deposition: Wet deposition uses a simple scavenging rate of 0.5, applied both for parameterized and large-scale precipitation. - Section 3: The reviewer asks for a description of the wet and dry deposition processes in WRF-Chem: Whenever we choose to use WRF-Chem with 4 or 10 ash bins in tracer mode, we neglect dry deposition, only gravitational settling is applied. We explain this in more detail within the text. Dry deposition is included if the user chooses to include the ash in the WRF-Chem P2.5 and P10 variables (option 3 in the text). We also added explanation concerning the wet deposition. - A statement concerning the ash hygroscopy and the suggested reference was added: 'Few data on the microphysical properties of volcanic ash exist to date; Lathem et. al (2011) analyzed the hygroscopic properties of ash originating from 6 different eruptions for ash with diameters less than 125 μm. They concluded a lower hygroscopicity for ash when compared to atmospheric mineral dust aerosol and clays due to the molecular struc-

ture of the ash particles. Within this version of the WRF-Chem model, the optical and hygroscopic properties of the volcanic aerosol are assumed to be the same as generic crustal derived dust with a hygroscopicity κ=0.1.' - Is model able to predict pyrocumuli? Statement was added within the 'emission preprocessor chapter' below the description of the volcanic plume model: 'Note that this method does not account for the individual dynamics of the erupted plume above the volcano vent; we further do not include any data on the thermodynamics of the eruption itself. Phenomena such as pyrocumuli are not resolved within the model. Data on atmospheric heat release during an eruption, or detailed plume dynamics are very sparse.'

- Page 2579: The parameter d has been defined as the duration of an eruption, the units are seconds. We erroneously used the wrong parameter designation in line 23 of this page. The sentence needs to read: 'A 500 m error in h at an assumed injection height of 5 km amounts to a mass eruption rate error of about 40 tons per second;'. Section 4: WRF-Chem was used in tracer mode with 10 ash variables for both case studies. We added information on the initial and boundary conditions, and the eruption source parameters. - Page 2580, l.15-18, the difference between dry deposition and settling: We added statements in the 'inclusion of volcanic emissions in WRF-Chem' paragraph, and made the 'initial applications' paragraph consistent and more clear: The options with inclusion of 4 or 10 bins of volcanic ash within WRF-Chem considers gravitational settling and wet deposition of the ash particles. More sophisticated depositional processes are included in the 3rd option of inclusion of volcanic ash within the PM (PM2.5 and PM10) variables in WRF-Chem. The dry deposition follows the deposition parameterization as described by Grell et al, 2005. However in terms of dry deposition of ash, we believe that the settling due to gravity is a good approximation of the deposition velocity. - Section 4.2. Case studies: The Eyjafjallajökull eruption seems a perfect case to demonstrate the capabilities of the model to estimate atmospheric ash dispersion. We added to the discussion of the case studies, and changed the figures. The LIDAR measurements over Leipzig offer a great opportunity to compare the vertical dispersion of the modeled ash. There have been other modeling stud-

ies published, which all show a less confined vertical structure of the distal ash cloud. We refer this discrepancy mainly to uncertainties introduced by offline models, which have been discussed in detail by Grell and Baklanov (2011). The WRF-Chem results are promising for future volcanic emission modeling. We published WRF-Chem Eyjafjallajökull results in the JGR, however those results seem very suitable to be added herein as a case study within the WRF-Chem model description paper. We did additional runs of WRF-Chem for the Eyjafjallajökull eruption using the S1 particle size distribution in order to show the effects of less fine particles in the model initialization. The figure 5 was changed to support this discussion about the different particle size distributions. - Fig.4: Numbers have been added to denote the contour intervals (2, 10, 100, 1000 g/m2) and the latitudes/longitudes of the original graphic from Scott and McGimsey .(1994). The solid lines of the 1994 graphic show the isopachs of the ash deposited during the successive eruption on December 16, 1989. Scott and McGimsey indicate their measurement sites by the small dots within the graphic (larger dots are geographic references). They further state concerning the calculation of deposits: 'We plotted MPUA measurements for each event on a base map and drew contours of equal MPUA, or isomasses (Fig. 1), from which we could calculate total mass of the reconstructed distribution. The accuracy of the reconstructions varies widely among events and is related to the numbers of samples.' - Fig.6: The LIDAR figure shows the evolution of the major ash plume over Leipzig on 16 April 2010 (in red, 3–5 km height, 1347–1532 UTC) in terms of 1064–nm range–corrected (RC) lidar signal (arbitrary units). The figure annotation was changed.

Minor Comments: 1.extra spaces: Search was performed and extra spaces deleted. 2.inconsistent use of name WRF-Chem: WRF-Chem has been changed to WRF-Chem in the title. 3.The sentence 'The volcanic ash model includes as source' was changed to: 'The modeled volcanic ash is subdivided into 10 different bins representing the size spectrum of the particles typically ranging from a few micrometers up to one or two millimeters.' 4.The sentence on p. 2574, l. 10-11 was changed accordingly to 'We have developed a volcanic emissions package for initializing the ash fields

within the model based on a look-up table containing the ESP data.' 5.The 'a' has been added: '..(Freitas et al., 2009), has been used as a template and adapted to suit WRF-Chem.' 6.The word 'correspondent' on p2575 has been changed to 'the corresponding erupted volume' and 'the corresponding percentage'. 7.Page 2576, line 27 was changed to '..it is important to use accurate assumptions not only of SO2 emission rates, but also of injection heights.' 8.Page 2577, l. 9: a colon was inserted. 9.Page 2578, l. 11 reads now 'The next step up is to use the full 10 particle size bins.' 10.Page 2578, l. 15: 'the' added. 11.Page 2580, l. 7: We started with the WRF-Chem volcanic emission application a few years back, and conducted experiments for a number of different volcanoes. Two significant eruptions were selected for this paper. The results presented herein were produced with a developmental version of WRF-Chem 3.3.1. The described implementation was released to the WRF-Chemn community with version 3.4 in April of 2012. We changed the senetence accordingly. 12.Page 2582, l13: Changed to 'The WRF-Chem modeled magnitude proved to be close to the LIDAR data.' 13.Page 2582, l25: 'and' added. 14.Page 2583, l.27: 'SO2 was implemented in WRF-Chem by distributing SO2 in an umbrella shaped plume in similar fashion to the ash.' 15.Fig.2 caption was corrected to 'The global dataset of volcanoes described in Mastin et al. (2009) and included in WRF-Chem model to simulate ash-cloud movement.' 16.Fig.4: The labels have been increased in size to be readable. 17.The authors of the papers are partly identical, or from the same collaborating groups. The permission has been obtained.

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/5/C1013/2012/gmdd-5-C1013-2012-supplement.pdf

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