GOESR3 Periodic Reporting

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Reporting Period: July 2014 - December 2014 (first half of FY14 funding cycle)

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Project Title: GOES-R Volcanic Ash Risk Reduction: Operational decision support within NOAA’s Rapid Refresh (RAP)
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Executive Summary

Our project work aims to build an improved volcanic ash decision support capability within NOAA’s Rapid Refresh (RAP) modelling system. During the previous months, we have provided case studies of volcanic ash dispersion and worked on the pathways for implementation of operational volcanic ash alerts within the RAP modelling environment. The model source code has been updated within WRF-Chem, and close collaboration with NOAA ESRL started to initiate the volcanic ash application within the RAP model.

Work is in progress to compare VAA baseline products to modelled plume dynamics. We collaborate with NOAA NESDIS to implement GOES-R baseline products within the case studies. WRF-Chem case studies have started for the proposed historic eruptions using different source parameters, and we are in the process to compile data for model comparison. A detailed WRF-Chem case study for the event of Kasatochi volcano showed promising results for the first days of the event. Absolute numbers of mass loadings are sensitive to the source parameters used for the model setup. Accurate retrievals of initial plume heights and mass loading are most suitable for RAP/WRF-Chem model initialization, and plume characteristics need to be updated within each model run. A work focus is on better estimates of our assumptions for particle size distributions. Based upon observational data from the Redoubt eruption in spring 2009, we are in the process to test particle aggregation parameterization schemes.

Within the following months we plan to continue with the case studies, and to collaborate with the RAP developers to implement the volcanic source code within the RAP model.

FY14 Milestones

- We have evaluated the ABI VAA baseline product with WRF-Chem model output with the eruptive event of Kasatochi volcano in 2008. The GOES-R type ash retrieval was discussed with modelled ash loadings, and we also used modelled and observed volcanic sulfur dioxide emissions to test our confidence in the WRF-Chem output as well as the satellite retrieval results.
- WRF-Chem model source code changes have been applied to simplify the setup for volcanic emission model runs. This work directly supports volcanic emission model implementation and adaption of the volcanic emissions driver into RAP.
- Different eruption source parameters were used for the case studies in order to test the plume mass loading sensitivities. The results were compared to GOES-R ash retrievals using MODIS data.
- An aggregation parameterization has been implemented within the WRF-Chem volcanic emissions driver, and tests are in progress to derive best assumptions for particle sizes.

**Accomplishments**

Our work focus has been on model source code preparation for operational needs, and on case studies for WRF-Chem model evaluation.

**Model code:** The WRF-Chem Prep-Sources-Chem pre-processing software was extended for volcanic emissions with look-up tables defining specific volcano characteristics as well as default eruption source parameters. In order to change parameters such as plume heights or mass fluxes, the emission driver within WRF-Chem source code needed to be changed, and a model re-compilation was necessary prior to each model run. For model adaptation into the RAP environment, we changed the modelling source code in order to facilitate the flow for operational model runs. A volcanic namelist file including volcanic eruption heights, total mass and changes of eruption source parameters with time was implemented within WRF-Chem; the emission driver reads the file contents removing operational obstacles due to recompilation. The updated code has been tested and will be made available for RAP as a next step.

**Case studies:** (1) We tested WRF-Chem for Kasatochi volcano, which erupted August 7-8, 2008. Mike Pavolonis provided detailed MODIS ash products, which were compared to the WRF-Chem model output. The volcanic emissions were dispersed immediately within a strong cyclogegetic development almost overhead Kasatochi accounting for complex plume dynamics. The total column ash mass loading compared well during the first 3 days of the Kasatochi event with slightly higher modelled concentrations probably due to our source parameter assumptions (Fig. 1a and b). Significant differences in the concentrations were found in the subsequent days (Fig. 1c). On August 11, the model shows more distinct plume branches with higher mass loadings. However there is evidence that the MODIS satellite retrieval is hampered by opaque ash particles; the retrieved ash loading became more and more ‘spotty’ within the distal plume. In order to evaluate our findings, we also looked into the sulfur dioxide (SO$_2$) plume (Egan et al., 2015). Significant amounts of SO$_2$ were emitted during the Kasatochi event, and we investigated the SO$_2$ plume using Ozone Monitoring Instrument (OMI) retrievals and WRF-Chem. WRF-Chem was initialized with volcanic SO$_2$ and we included a SO$_2$ to sulphate conversion parameterization. The satellite retrieved as well as modelled distal SO$_2$ plume extended well over the contiguous U.S. and to the north into Canada’s Arctic (Fig. 2). Changes of SO$_2$ mass were compared with OMI derived mass loadings. A high degree of correlation resulted between model and OMI retrievals.

(2) A main goal of further case studies is to improve our ash particle size distribution assumptions. We started a detailed analysis of the 2009 March 22 until April 9 eruption of Mount Redoubt with WRF-Chem. The Redoubt event has been well documented (Bull and Buurman, 2013), and observational data on plume dynamics as well as on particle deposits exist (Wallace et al., 2013). The Redoubt ash plume dynamics were strongly influenced by ash particle aggregation accounting for a shift of the ash size
distribution to larger particles. This shift accounts for increased ash depositional effects near the volcano, and reduced mass loadings within the distal plumes. Based upon the Redoubt findings, we started to test various options to include a particle aggregation parameterization scheme within WRF-Chem. Experimental evidence suggests that the majority of coarse and fine ash settle out of volcanic plumes where liquid water is present. Coarse ash settles quickly due to its density and settling velocity, while fine ash aggregates due to hydrometeor-enhanced aggregation. Experimental testing suggests that this aggregation process is highly dependent on the amount of water present. For example, the size selectivity of the aggregation process decreases with increasing water content, with plume water concentrations greater than 15 wt% leading to less size selective processes.

In the case of Redoubt, Doppler radar measurements indicated that the plume height of the 23 March eruption decreased from 15km to 10km within the first 30 minutes of the eruption. We hypothesize that this decrease in plume height results from a majority of fine ash < 250um (95% total fine ash mass) aggregating into heavier lapilli. Field measurements also suggest rapid aggregation with fallout decreasing substantially within 20km of the vent (A. Eaton, pers. communication).

To test this, we implemented a rapid aggregation scheme into WRF-Chem that is activated upon the presence of liquid water. The presence of liquid water is determined from the Clausius-Clapeyron equation, using pressure and temperature at each grid cell as a selection criteria. If liquid water is present, 95% of the mass of that grid cell is removed and added to the coarse ash bin over a 30 minute period of time. If ice is present, currently no additional aggregation takes place.

Additional Information

1. Interaction with operational partners – We work with Georg Grell from NOAA ESRL to implement the volcanic ash parameterization within RAP, and to prepare for the RAP case studies. Mike Pavolonis provided the ash retrievals for the Kasatochi case study. Further collaborators are A. Eaton, L. Mastin, and H. Schwaiger from the United States Geological Survey (USGS).

2. Conference/workshop participation –

3. Funding concerns – Georg Grell from NOAA agreed to work with us in person at the University of Alaska Fairbanks. We tried to use travel funds to invite Georg, but unfortunately project money can not returned to NOAA for travel arrangements. We plan to visit NOAA ESRL for RAP work. No funding concerns otherwise.

4. Outside project publicity –

5. Journal articles –


6. References:


**Plans for the next Reporting Period:**

Immediate future work will be aimed on further case studies with WRF-Chem, compare Mike Pavolonis’ ash retrieval for the Redoubt test case and refine our ash particle size assumptions. We will collaborate closely with Georg Grell to initiate RAP model runs with volcanic ash. Dependent on time availability of our collaborator, student travel (S. Egan) to NOAA ESRL will be arranged. We plan to participate at the 13th JCSDA Workshop in May 2015.

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**Key Graphics**

**Figure 1a:** August 8, 2008

**Figure 1b:** August 10, 2008
Figure 1c: August 11, 2008

Figure 2: Dispersion of the Kasatochi SO2 plume as modeled by WRF-Chem (left) and calculated by the NASA’s Level 2 SO2 product (ColumnAmountSO2_STL, right).