GOESR3 Periodic Reporting

Reporting Period: July 2018 – December 2018 (1st half of FY18 funding cycle)

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Project Title: GOES-R Volcanic Ash Risk Reduction (R3): New operational GOES-R decision support within NOAA’s High Resolution Rapid Refresh.

Project Number: 487

Executive Summary

The GOES-R Advanced Baseline Imager Volcanic Ash Algorithm (ABI-VAA) data are used to initialize the WRF-Chem model. WRF-Chem predicted ash plumes allow to better understand and to verify eruption source parameters (ESP). The goal is to derive realistic ESP and provide a useful volcanic ash hazard mitigation tool. We updated a newer version of the WRF-Chem model (version 3.9) in order to predict volcanic ash plumes. Model runs are executed automatically whenever a volcanic eruption alert is received. Automated routines to ingest volcanic ash alerts within the WRF-Chem and NOAA’s High Resolution Rapid Refresh (HRRR) modelling environments have been developed and are further refined. There were no recent case studies occurring within our modelling domain during the second half of 2018. Further simulations of the Eyjafjallajökull eruption in Iceland (April and May 2010) have been performed to verify modeled particle aggregation processes with observations of ash particle microphysics.

We developed a variation of the volcanic emission driver used within the WRF-Chem model, which allows to run an ensemble of varying ESP within one WRF-Chem run. The objective is to create a near real time hazard mitigation tool, and to have the ability to discuss ABI-VAA (or similar) derived volcanic ESP. The superimposition of plumes originating from a possible range of initial plume altitudes allows to predict areas of ‘negative ash’ with high confidence. Regions of negative ash are of main interest for example for aircraft traffic. The varying plume heights consist of 5 assumed plumes that include as a ‘center plume height’ either the plume height detection from the initial VOLCAT or GOES-R volcanic baseline alert, or the default historic ESP used within WRF-Chem.

Progress toward FY18 Milestones

Main accomplishments for this period were:

1. Automatic WRF-Chem simulations are produced. We updated the volcanic emission driver and implemented the code into WRF-Chem Version 3.9.

2. Our progress has been discussed during a meeting with our collaboration partners from NOAA ESRL in Boulder, Colorado, in September 2018. The volcanic emission application of WRF-Chem is functional, and with the implementation of the volcanic code into the newer version of WRF-Chem, our alerts could be incorporated into the High Resolution Rapid Refresh (HRRR). The implementation will need a reduction of ash bins from currently 10 bins to one or two bins in order to be less computing intensive. Further discussions were focused on the reduction of false volcanic activity alerts. The HRRR runs should potentially show only real cases in near real time.
(3) Typically, volcanic eruption source parameters (ESP) such as erupted mass, particle size distribution or initial plume heights are not well observed in real time. As a consequence, we use default ESP derived from a database based on historic eruptive cases. To account for a range of possible ESP, we would need a number of volcanic ash model runs with varying ESP in order to build a useful real time tool. Good estimates of the initial plume dimensions are important to predict the atmospheric dispersion of the plume realistically. - We have implemented ensembles of plume heights within one WRF-Chem run in order to have model output available at the moment when satellite observations of the ash plume become available. A superimposition of the plume ensemble also allows to create maps of negative ash, which might be of interest especially for aviation stakeholders.

(4) A repository with webpage scripts and a test webpage has been created on Github. Webpage updates with hypothetic ash clouds (from orange coded eruption alerts) and test cases were created at a prototype demonstration webpage was created at http://plume.alaska.edu/index_tmp.html. However we need a more pronounced distinction between hypothetic plumes and real plumes. Webpage graphics have been removed from the webpage for the moment.

(5) Further comparison of modelled ash plumes with particle measurements shows evidence that ash particles mostly tend to aggregate. Work was continued to refine our aggregation parametrization.

We are receiving volcanic activity alerts from the Anchorage Volcanic Ash Advisory Center (VAAC) and from the VOLcanic Cloud Analysis Toolkit (VOLCAT) from M. Pavolonis. Volcanic WRF-Chem runs are automatically executed whenever VAAC or VOLCAT alerts are received, which occurs normally on a daily basis and sometimes multiple times a day. There were no significant events accounting for a case study to evaluate GOES-R volcanic ash alerts during the recent months. However, our work aims to be well prepared for a real-time case. Initial forecast graphics and automatic webpage update scripts have been developed.

We adapted and improved our WRF-Chem modeling environment to use a new version of WRF-Chem (version 3.9), and to create an ensemble of possible volcanic eruption source scenarios within one WRF-Chem run. The ensemble is accomplished by changing ash particle concentrations to account for very fine ash (particles less than 3.9 µm in diameter) and coarse ash (particles with 1-2mm in diameter) and associating the 2 particle sizes with various plume heights. Originally, we introduced a number of 10 ash bins in WRF-Chem (Stuefer et al., 2013) to account for ash particles with a range of different sizes. Reducing this range of sizes to only 2 sizes, and associating these 2 sizes to different plume heights (instead of 1 plume height) allows to create a prognostic tool for near real time volcanic plume prediction. Typically, the eruption source parameters (ESP) are not observed well in real time; volcanic ash advisory centers detect seismic activities near a volcano, or there is a thermal anomaly or a combination of thermal anomalies and predicted atmospheric stability to derive a first guess of a volcanic plume. The WRF-Chem ensemble of fine ash and varying plume heights allows to predict the afar dispersion of the plume and areas of ‘negative ash’. Regions of negative ash are of main interest for example for aircraft traffic. The varying plume heights consist of 5 assumed plumes that include as a ‘center plume height’ either the plume height detection from the initial VOLCAT or GOES-R volcanic baseline alert, or the default ESP used within WRF-Chem (Stuefer et al., 2013). Additional plume heights are introduced at 30%, 70%, 150% and 300% of the center height. In analogy to fine ash, we set up WRF-Chem with coarse ash particles and the 5 varying plume heights (as above) in order to predict ash fallout in the vicinity of the erupting volcano. The ash fallout prediction is especially important for hazard mitigation to life on the ground and to protect infrastructure.

Progress was achieved implementing a volcanic ash aggregation scheme into WRF-Chem. Microphysical analysis of ash particles showed strong evidence that ash particles typically aggregate to larger particles during the atmospheric dispersion. We used a simplified version of the Smoluchowski Coagulation Equation, which allowed to parameterize and introduce the aggregation process between particles of fine ash into the base chemistry code of WRF-Chem (Von Smoluchowski, 1917). Aggregation depends on various ash particle collision parameters.
The aggregation model was compared to remote sensing, field measurements of tephra fallout and in situ observations of the April/May 2010 ash particle dispersion during the eruptions of Eyjafjallajökull Volcano in Iceland. We see spatial and temporal agreement between measurements of the plumes and model output, with better agreement in concentrations using the aggregation code. In addition, we note a decrease in the lifetime of volcanic fine ash by a factor of three (Figures 1 and 2). A publication describing the implementation of the aggregation scheme into WRF-Chem is in progress and will be submitted later this spring.

**Plans for Next Reporting Period**

The goal for the next period is to:

- Finalize and submit the ash particle aggregation parameterization publication to a peer reviewed journal.
- Create automated webpage graphics, which will be posted to an updated webpage.
- Make progress with the implementation of the ensemble of plume heights within WRF-Chem, and create graphics showing regions of negative ash.
- Work with our operational partners from NOAA to fine-tune our modelling code for a future HRRR implementation.
- We will be ready to further discuss the GOES-R volcanic ash baseline product and the VOLCAT alerts with modelled ash plumes in case of a real eruption.

**Additional Information**

1. **Interaction with operational partners** –

   We continue to work on the volcanic ash variable integration within HRRR and to discuss our work with our partners from NOAA’s ESRL (R. Ahmadov, T. Alcott, and G. Grell).

   Mike Pavolonis (NOAA/NESDIS/STAR) continues to provide volcanic ash alerting products using his VOLcanic Cloud Analysis Toolkit (VOLCAT). VOLCAT automatically analyses multi-spectral and temporal data derived from spaceborne remote sensing satellites, including GOES-R, to detect volcanic unrest.

2. **Conference/workshop participation** –

3. **Outside project publicity** –

Figure 1: The effects of ash aggregation on the coarse (left) and fine (right) ash particles during the phase 3 eruption of Eyjafjallajökull starting May 12, 2010.

Figure 2: Modeled differences of column integrated volcanic fine ash mass between WRF-Chem simulations of the Eyjafjallajökull eruption on May 18th, 2010 with and without aggregation code enabled.