Using VIIRS Fire Radiative Power data to simulate biomass burning emissions, plume rise and smoke transport in a real-time air quality modeling system

R. Ahmadov[1], G. Grell[1], E. James[1], I. Csiszar[2], M. Tsidulko[2], B. Pierce[2], S. McKeen[1], S. Benjamin[1], C. Alexander[1] G. Pereira[3], S. Freitas[3], M. Goldberg[2]

[1] Earth System Research Laboratory, NOAA, Boulder, CO, USA

[2] NOAA/NESDIS, College Park, MD, USA

[3] NASA/GSFC, Greenbelt, MD, USA

In this presentation, we present a new smoke modeling system High Resolution Rapid Refresh (HRRR-Smoke) to simulate biomass burning (BB) emissions, plume rise and smoke transport in real time. The HRRR model (without smoke) is run as an operational numerical weather prediction system at the National Weather Service. HRRR is NOAA Earth System Research Laboratory's version of the Weather Research and Forecasting (WRF) model. Here we make use of WRF-Chem (the WRF model coupled with chemistry) and simulate fine particulate matter (smoke) emissions emitted by BB as well as anthropogenic sources. The model includes an aerosol aware double moment Thompson microphysics scheme [1], which allows to simulate smoke feedback on microphysics in a computationally efficient manner.

The HRRR-Smoke modeling system ingests fire radiative power (FRP) data from the Visible infrared Imaging Radiometer Suite (VIIRS) sensor on the Suomi National Polar-orbiting Partnership (S-NPP) satellite to calculate BB emissions. The current NOAA operational VIIRS Active Fire product is generated by the Suomi NPP Data Exploitation (NDE) system. The product is based on processing 750m resolution "M" bands to generate 1) a fire mask for each VIIRS granule with thematic classification of each pixel into fire detections at three confidence levels, cloud, water, non-fire clear land and other quality indicators, and 2) a sparse array, including fire radiative power (FRP) for each fire pixel, and other quality indicators and supplementary information [2]. The algorithms for fire detection and FRP retrieval are consistent with those used to generate the MODIS collection 6 product [3].

The NOAA NDE product is available globally at approximately 2-hour latency. For the purpose of ingesting VIIRS fire data into various end applications, text files have also been generated to provide the location and detection confidence of fire pixels, as well as FRP. For this study, the text files were generated at NOAA/NESDIS/STAR immediately after the baseline operational product was available and transferred to NOAA ESRL for ingest into HRRR-Smoke. The VIIRS FRP data from the text files are processed and remapped over the HRRR-Smoke domains. We process the FRP data to calculate BB emissions (smoldering part)

and fire size for the model input. In addition, HRRR-Smoke uses the FRP data to simulate the injection height for the flaming emissions using concurrently simulated meteorological fields by the model.

Currently, there are two 3km resolution domains covering the contiguous US and Alaska are used to simulate HRRR-Smoke in real time. In our presentation, we focus on the CONUS domain. HRRR-Smoke is initialized 4 days per day to forecast smoke concentrations for next 36 hours over the CONUS domain. The VIIRS FRP data mapped on the CONUS grid, near-surface and vertically integrated smoke mass concentrations are visualized for every forecast hour. These plots are provided to public via the HRRR-Smoke web-page: https://rapidrefresh.noaa.gov/HRRRsmoke/. In Figure 1 we present two plots from the web-page displaying the VIIRS FRP and predicted smoke concentrations on September 15, 2016.

In this talk we also discuss the HRRR-Smoke performance for two case studies - August 2015 and 2016 time periods over CONUS. The model evaluations for the case studies are presented, where simulated smoke concentrations are compared with hourly PM2.5 measurements from EPA's Air Quality System network. These comparisons demonstrate the model's ability in simulating high aerosol loadings during major wildfire events in the western US.

References:

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[2] Giglio, L., Schroeder, W., Csiszar, I., and Tsidulko, M, Algorithm Theoretical Basis Document For NOAA NDE VIIRS Active Fire, version 2.6 (June 2016). Available at https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_NDE_AF_v2.6.pdf. Accessed on January 13, 2017.

[3] Giglio, L., Schroeder, W., and Justice, C.O., The collection 6 MODIS active fire detection algorithm and fire products. Remote Sensing of Environment 178, pp. 31-41, http://dx.doi.org/10.1016/j.rse.2016.02.054

Figure 1. Spatial distributions of the Fire Radiative Power and near-surface smoke concentrations from the experimental HRRR-Smoke forecast on September 14th 0600 UTC for 09/15 0000 UTC, 2016.