USING THE MODIS RAPID RESPONSE FIRE PRODUCTS TO REFINE WILDLAND FIRE EMISSION ESTIMATES

Biswadev Roy*[1], Alice Gilliland[2], Thomas Pierce[2], Steve Howard[2], and William Benjey[2]

[1] Atmospheric Sciences Modeling Division, National Exposure Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711
[2] Atmospheric Sciences Modeling Division, NOAA Air Resources Laboratory, on assignment to the United States Environmental Protection Agency, Research Triangle Park, NC 27711

e-mail: Roy.Dev@EPA.gov
Voice (919) 541-5338   Fax (919) 541-1379

1. INTRODUCTION

Wildland fires are an important source of airborne fine particulate matter ($PM_{2.5}$) in the form of elemental and organic carbon aerosols. Wildland fire and biomass burning also emit gaseous pollutants and trace gases (Andrae, and Merlet, 2001). Since the gases combine and produce many secondary products in the atmosphere, an accurate determination of wildfire emission rate is important to air-chemistry modelers. At present the operational processing of U.S. Environmental Protection Agency (EPA) Models-3 Community Multi-scale Air Quality (CMAQ) Model takes into account State level emissions from the EPA 2001 National Emission Inventory (NEI) which have temporal resolution of a month. As a first attempt to improve the spatial and temporal resolution, we have used the space-based measurements of the active fire counts using the National Aeronautics & Space Administration (NASA)/ Moderate Resolution Imaging Spectroradiometer (MODIS) data. This sensor was first launched aboard the Terra satellite and began collecting data on February, 2000. An active fire detection algorithm for MODIS was developed by the University of Maryland (UMD) Department of Geography (Justice et al., 2002). We have used their collection 4 data and reprocessed them to get hourly observation maps. These maps contain the 1 km x 1 km fire pixel for each of the CMAQ grid cells. For this study we have selected the months of May, and August, 2001. This is because the NEI baseline emission inventory for year 2001 shows maximum fire emission during these two months. In May, 2001 the State of Florida alone accounts for approximately 60% of the total $PM_{2.5}$ emissions for the contiguous United States (CONUS). In Section 2 we briefly described the MODIS Rapid Response (RR) active fire data and also described the procedure of obtaining the hourly interpolated fire pixel count maps for May, and August 2001. In Section 3 we discuss about the data quality based on the difference of emission rates obtained between satellite-dependent, and satellite independent procedures for few fire events. Section 4 of this paper provides a brief description of the CMAQ model and inputs that are being currently implemented for CMAQ runs, including the redistribution of the NEI emissions using the satellite derived fire pixel count data. Section 5 summarizes what is being done in this study and the planned outcomes.

2.0 DATA DESCRIPTION

The UMD RR collection-4 active fire pixel data is based on an absolute detection criteria using the brightness temperature (apparent observed temperature assuming emissivity equal to 1) information from MODIS sensor at 4 micron (T_{b4}) wavelength and at 11 micron (T_{b11}) wavelength (Justice et al., 2002). This method bases fire detection on either of the two conditions: 1) T_{b4} > 360 K (330 K at night and, 2) T_{b4} > 330 K (315 K at night), and T_{b4} - T_{b11} > 25 K (10 K at night). If neither is satisfied then a relative fire detection algorithm is applied where the fire is distinguished from the background values in the followingmanne

$$T_{b4} > \left(\overline{T_{b4}}\right) + 3\sigma_{T_{b4}}\text{, and}$$

$$T_{b4} - T_{b11} > \left(T_{b4} - T_{b11}\right)_{\text{median}} + 3\sigma\left(T_{b4} - T_{b11}\right)$$

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* *Corresponding author address*: Dev Roy, Mail Code E243-01, U.S. Environmental Protection Agency, RTP, NC 27711.

False detections due to sun-glint are rejected using MODIS 250 m red and near infra-red channel reflectance values (i.e., If they are above 30% and lies within 40^{o} of specular reflection position). The data are continuously available for day- and night-time passes over the Contiguous United States (CONUS).

We used the fire pixel latitude, longitude, acquisition date, time, brightness temperature, pixel count, and the pixel-level confidence (0-100%) data. Terra is a sun-synchronous satellite (i.e., it views the same earth scene during a fixed time of the day). There are 2 possible observations over the entire CONUS per day. Since the satellite retrievals are scattered in time across the CONUS, we have averaged MODIS RR observations for 0600 UTC and 1800 UTC of each day of the months of May and August 2001. The total fire pixel counts are binned over each CMAQ grid cell in Lambert Conformal projection. After this procedure is completed the accumulated maps obtained at 0600 and 1800 UTC are further used to obtain hourly fire pixel count map using linear interpolation. The method used to reallocate the emission inventory using these satellite fire pixel counts and redistribution of the monthly average inventory will be described in Section 3.0.

3.0 DATA QUALITY

The collection-4 MODIS RR data sets provide detection confidence to gauge the quality of individual fire pixels. Figure 1 shows the average values of data confidence (%) as a function of pixel counts. Although the confidence levels vary over a large range, excluding the outliers (<70%) the average confidence remain high for both the months of May and August 2001. Figure 2 shows the values of MODIS RR fire pixel counts over the CONUS for the month of May 2001. Locations having counts up to 7 are only shown here. After reallocation of emissions are performed we have plotted the differences in the PM2.5 emission flux (rate in g/s) for the combined days May 24, 25, 2001 (shown in Figure 3(a)) and for August 18, 19, 2001 (shown in Figure 3(b)). From figures (3) it is evident that satellite derived fire pixel emissions were able to better localized in terms of fire occurrences. The difference in emission rate over the Lafayette County, FL for May 24, 25 combined was about 4752 g/s similarly for the Oregon fire in August the difference found for the August 18, 19 combined was about 5800 g/s. The flux difference values in adjoining regions are found to be negative suggesting that satellite derived pixel-count based apportionment of the monthly emission rates has lowered the emission rates at all other non-fire grid cells. This happened exactly as expected in this case. Earlier, the NEI emission rates were allocated at the state-wide spatial resolution and over the monthly periods of time in contrast with 12 hourly observations and 1 km^2 fire pixel resolutions from the satellite data.

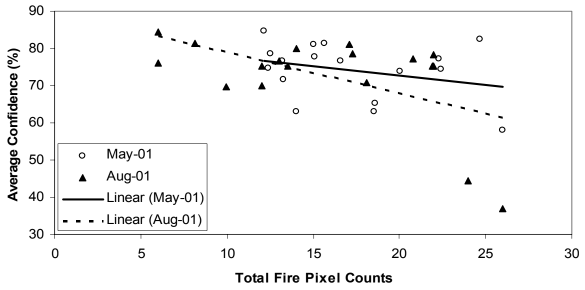

Figure 1 Pixel confidence average value (%) versus pixel counts based on the original RR data for the months of May (5449 samples) and August (8155 samples).

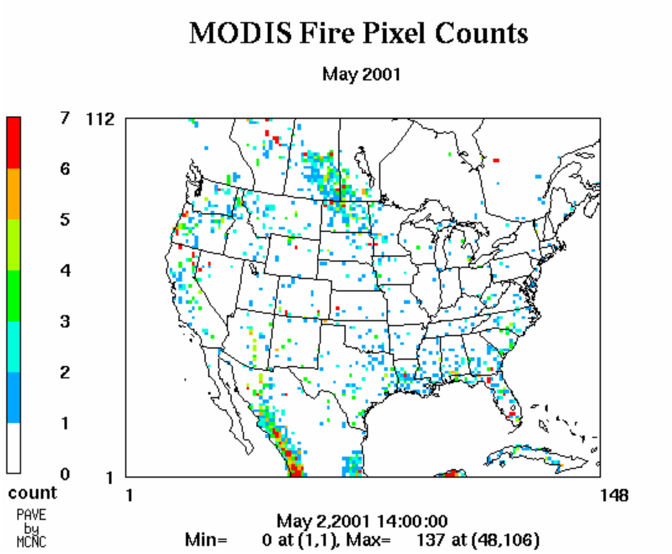

Figure 2 Shows MODIS RR derived fire pixel counts for May 2001. Note maximum number of count is 137 at CMAQ grid cell (48,106).

4.0 AIR QUALITY MODEL DESCRIPTION

The air quality modeling simulations that will be presented in the paper were generated using the USEPA Models-3 Community Multiscale Air Quality (CMAQ) model (Byun and Ching, 1999). The specific model version used was the pre-release version for CMAQ 4.3. The CMAQ model simulations were performed using the Carbon Bond IV (CB4) chemical mechanism (Gery et al., 1989). The CMAQ modeling domains covered the contiguous United States and portions

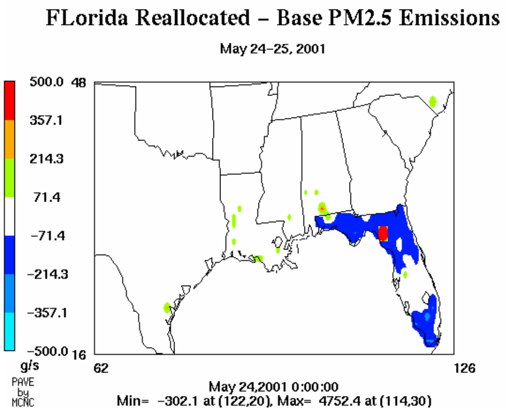

Figure 3 (a): Combined May 24, 25, 2001 difference between the MODIS based re-allocated $PM_{2.5}$ emission rate and the baseline rate in grams/sec. Area shaded in red is due to Lafayette county, FL fire which was most intense on these 2 days.

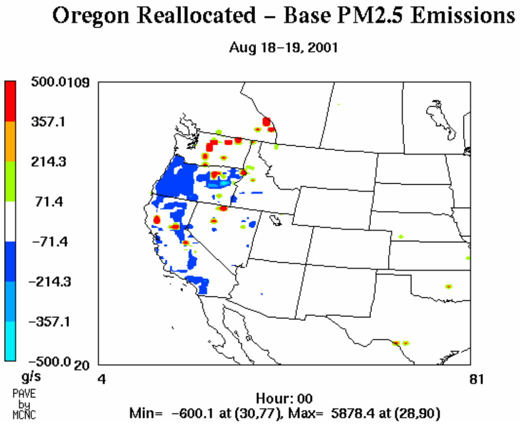

Figure 3 (b): Same as in Figure 2(a) but shows the northwestern states for days August 18 and 19, 2001.

of Canada and Northern Mexico (Figure 3). TheCMAQ aerosol predictions are based on a modal aerosol model (Binkowski and Roselle, 2003) and the ISORROPIA thermodynamic equilibrium model (Nenes et al., 1998). Chemical boundary conditions for CMAQ were prepared from a global simulation with the GEOS-CHEM model (Bey et al., 2001). Evaluation results for this annual simulation will be presented in other papers from this conference including Eder et al. (2005), Phillips et al. (2005), and Gilliland et al. (2005). The CMAQ aerosol predictions are based on a modal aerosol model (Binkowski and Roselle, 2003) and the ISORROPIA thermodynamic equilibrium model (Nenes et al., 1998). Chemical boundary conditions for CMAQ were prepared from a global simulation with the GEOS-CHEM model (Bey et al., 2001). Evaluation results for this annual simulation will be presented in other papers from this conference including Eder et al. (2005), Phillips et al. (2005), and Gilliland et al. (2005). The meteorological inputs to CMAQ are based on the Penn State/NCAR Mesoscale Model or MM5 (Grell et al., 1994) version 3.6.1. Both the MM5 and CMAQ simulations were conducted at 36 km x 36 km horizontal resolution for entire year of 2001. The model-ready meteorology fields developed using the Meteorology-Chemistry Interface Program (MCIP) version 2.2, and the MM5 vertical layer structure was collapsed to 14 sigma layers from the surface to 100mb, with the first layer being 36 m thick.

Mobile emissions were generated using the MOBILE6 module (U.S. EPA, 2003) for mobile source emissions, and the BEIS3.12 model for biogenic emissions (http://www.epa.gov /asmdnerl/biogen.html). The emission inventory for other sources were based on the USEPA NEI for 2001 which relies on state reported values. The seasonality of the ammonia emissions, an important consideration for prediction of $PM_{2.5}$, was estimated based on seasonal information from Gilliland et al. (2003) and Pinder et al. (2004). MODIS-derived fire pixels have been introduced in this study to improve the fire-related NEI emissions by redistributing the monthly-averaged, state-level NEI inventory flux estimates. For prior simulations, wildland fire emissions had been distributed evenly over the state and the month because that was the highest resolution of information available from state-reported values.

For this reallocation of wildland fire emissions, the county monthly averages of fire-related emissions from the NEI were apportioned to each CMAQ model grid cell on an hourly basis. We reallocated 90% of the emissions using the spatial and temporal distribution of the MODIS-derived fire pixel count. The remaining 10% of the emissions were left intact, to account for fires missed by the MODIS platform since satellite-determined fires are detected at an efficiency of less than 100%. We feel that this is a reasonable approximation because, according to Hao et al., (http://www.wrapair.org/forums/fejf/documents/wildland_fire/agenda/040505/T1-B2_Hao.pdf) MODIS-derived data account for at least 90% of the burned area due to wildland fire of size at least 6 km^2.

5.0 SUMMARY

State-reported wildland fire emissions in the NEI only provide information at the state and month level. In this study, MODIS derived fire pixel data are being used to reallocate these emissions at a higher spatial and temporal resolution.

Wildland fire emissions contribute to elemental and organic carbon aerosols, and the accuracy of wildland fire emissions during major episodic fires could substantially affect CMAQ aerosol predictions. Two months, and 2 regions over the CONUS with major fire episodes have been selected for this sensitivity study, May and August 2001. We have seen that using the MODIS fire pixel count and locations data the $PM_{2.5}$ emission flux is able to be distributed more accurately. CMAQ simulations using the satellite based re-distributed emissions will be compared against the base CMAQ simulations .

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