Using MODIS FRP Values to Estimate Forest Fire PM 2.5 Emissions

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1. Introduction

Accurate estimates of PM 2.5 (particulate matter less than 2.5 micrometers in diameter) emissions from wild fires are important for determining regional radiative budgets, investigation of regional atmospheric chemistry, and assessment of health risks. Several different modeling systems are already in use to determine these emissions. The BlueSky system was developed by the U.S. Forest Service to estimate wildfire emissions for dispersion modeling purposes. Recently, this system has been upgraded with a module called SMARTFIRE to incorporate both ground-based fire reports and MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data to provide better fire location, fire size and fire progression information.

MODIS sensor data, collected onboard two satellites, provide data that can be used to estimate FRP (Fire Radiative Power) which is a measure of fire intensity. In this project, MODIS FRP data are used with empirical relationships between FRP and PM2.5 emissions to estimate PM2.5 emissions for selected fires in the Pacific Northwest. These estimates are compared to BLUESKY/SMARTFIRE emissions. Thus the objective is to employ FRP/PM2.5 relationships to provide an independent evaluation of current wildfire emission estimates and to assess the feasibility of the FRP approach for providing emissions for regional air quality modeling.

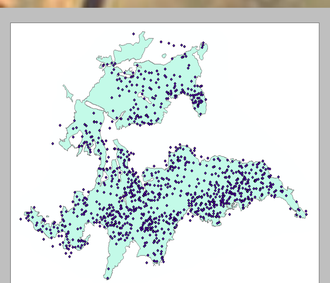
2. Process

For this research, we employ satellite data in terms of time of day, FRP, and area of each FRP detection. Figure 1 shows a fire perimeter with MODIS pixels superimposed on it. Pixels inside or within 1 km of the fire perimeter are considered part of the fire. MODIS data are available several times each day. The total FRP for a MODIS snapshot was calculated as:

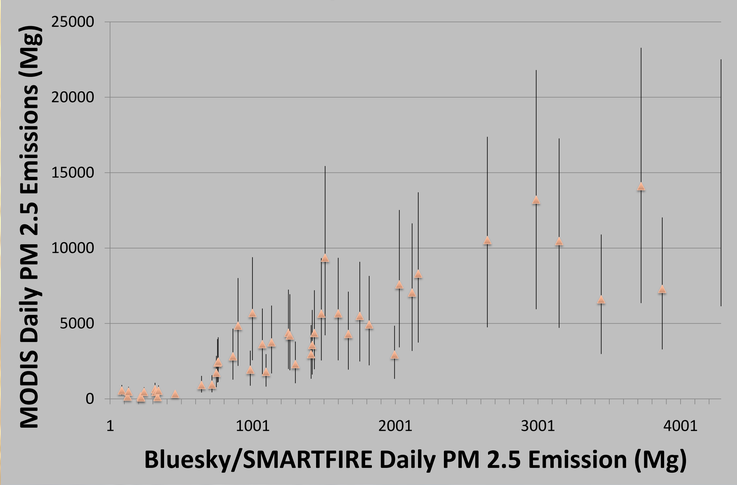
$$FRP = (\sum FRP / \sum \text{pixel area}) \times \text{New Burn Area}$$

The FRP values between each recorded period were assumed to follow a linear path between them. A plot of these values is shown in Figure 2, FRP values are shown as MW per km^2. The area under this curve is called the Fire Radiative Energy (FRE). FRE can be used with empirical regression curves from several recent studies to estimate PM 2.5 emissions for each fire period. Regression relationships have been reported for several different fuel types. For evergreen forests in the Northwest, PM2.5 mass per FRE are in the range of 0.018 and 0.066 kg/MJ; for this project, we take 0.04 kg/MJ as an average and multiply the FRE for each day by this factor to produce daily PM 2.5 emissions in kg/day.

F1. Columbia Complex Fire shown in ArcGIS



F3. SMARTFIRE vs. MODIS Emission Comparison



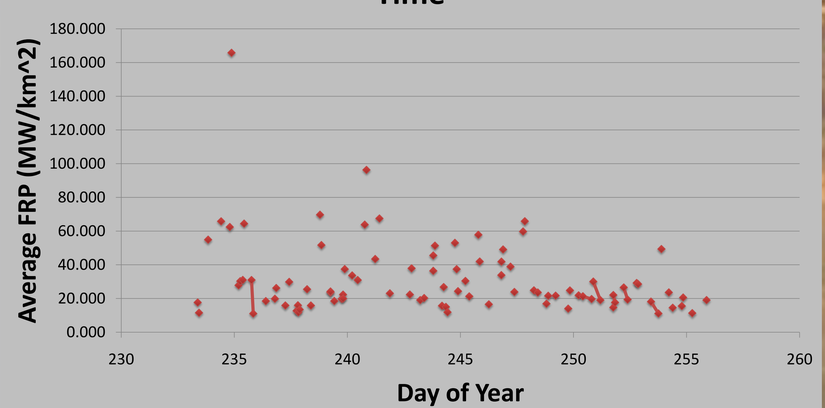
3. Results

To date, six fires have been analyzed using this approach. Figure 3 and 4 are from the Tripod Complex fire which burned in the summer of 2006. Figure 3 shows the data found using MODIS compared to the data found with BlueSky/SMARTFIRE, each orange triangle represents a data point found using an emission factor of .04 kg/MJ. Each corresponding line shows the relative uncertainty in this emission factor and how it could affect the end result. This plot shows a good correlation between the two systems; for this fire, however, MODIS FRP emissions were about 3 times those from BlueSky/SMARTFIRE.

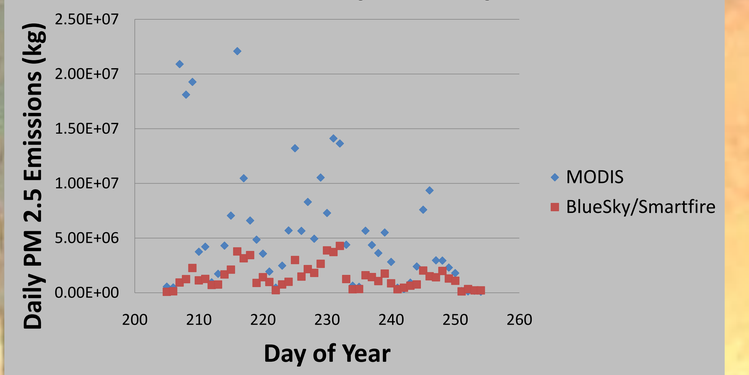
Figure 4 shows MODIS and BlueSky/SMARTFIRE results vs. time. This makes it easy to see the relationship between the two methods. For the most part, when SMARTFIRE results showed an increase in PM 2.5 emissions, MODIS did as well.

Figure 5 is a plot of the best-fit lines for each fire we analyzed. The two steep lines represent the Tripod and Columbia Complex fires in Washington. The other four fires occurred in central Idaho during the same summer of 2006. These latest best-fit lines show a close relationship, perhaps because of the close proximity and timing of the fire events.

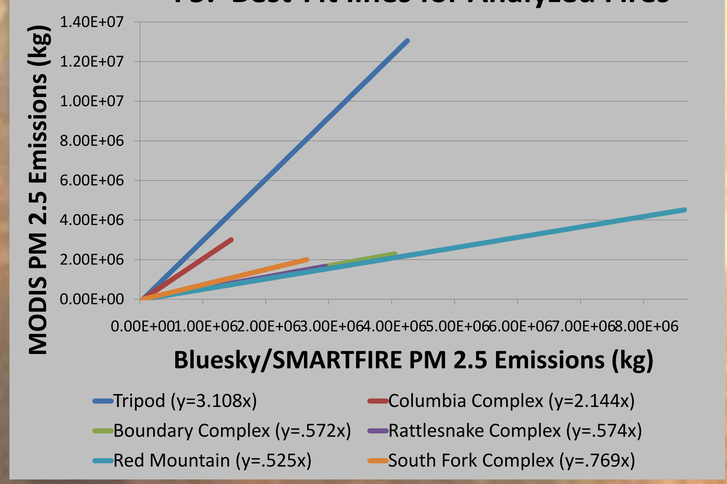
F2. Columbia Complex FRP Recordings over Time



F4. 2006 Tripod Complex



F5. Best-Fit lines for Analyzed Fires



4. Uncertainties

Analysis of the MODIS FRP data relies on averages and integrating over time. This becomes a problem considering that the satellites cannot record data at all times, sometimes going over a day without new FRP recordings. In these cases, what in reality is a short burst of power from the fire shows up as lasting a whole day in our results, greatly increasing its value. A possible solution to this would be using sine curves instead of straight lines to extrapolate values. This would more accurately estimate the behavior of wild fires.

5. Future Work

Emission factors to be found at the University of Idaho may later be used in this research.

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