AGU 2010 Fall Meeting
ID# A21B-0029

# Detailed Analysis of the EOS-MODIS Instrument's Fire Radiative Power Product

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## Abstract

Fire emissions account for a significant amount of the earth's radiation budget, yet this process is still not well understood. The most practical way to gain a global perspective on biomass burning and its effects on the environment and climate is through spaceborne measurements, such as with the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board the Earth Observing System (EOS) satellites, Terra and Aqua. Analysis of airborne measurements over active fires allowed the MODIS fire science team to develop a semi-empirical algorithm for deriving the fire radiative power (FRP) product. Though this product has made its way into the scientific community, it has only been used tentatively due in part to the fact that it has not yet been validated. The algorithm itself has undergone dramatic changes in its latest update, but this has only resulted in more uncertainty especially due to the effects that MODIS' scanning characteristics have on FRP measurements. This poster will present the work done insofar to characterize the uncertainty and gain an accepted, standard FRP product that can be used confidently within the scientific community. For instance, one of the error sources quantified and corrected for was the duplication of pixels for certain fires measured at a scan angle greater than about 15° due to MODIS' 'bow-tie' effect. Comparisons between near-coincident FRP measurements from Terra and Aqua at high latitudes where the two satellite overpass times are close, with one observing a specific fire near nadir and the other off nadir, has shown that, in addition to its scan angle dependency, differences also exist based on the fire strength. A brief illustration of fire visualization tools, specializing in the use of the FRP product, developed for both the scientific and public community will also be shown.

## Ingredients

- Fire Radiative Power (FRP) from the MOD14 Level 2 MODIS product (Collections 4 and 5)
- Comparisons between MODIS onboard Terra and MODIS onboard Aqua
- Comparisons between MODIS and the airborne Autonomous Modular Scanner (AMS)

## Duplicate MODIS Fire Detections

Multiple fire detections are often made of the same fire in subsequent MODIS scans due to the "bow-tie" effect, or rather, that a given detector covers greater ground area off-nadir.

A general algorithm to remove duplicate fires was developed that is dependent only on location within a MODIS scene instead of location on the Earth's surface (see Table 1 and Figure 1).

In order to check the validity of applying this general algorithm to MODIS fire data, single-pixel fires' FRP values were compared against their duplicate values and these ratios were binned into 0.1 intervals as shown in Figure 2. The resulting bell shaped curve implies that, generally speaking, it is acceptable to simply remove a "random" duplicate fire pixel using this algorithm.

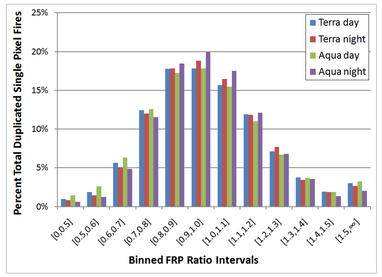
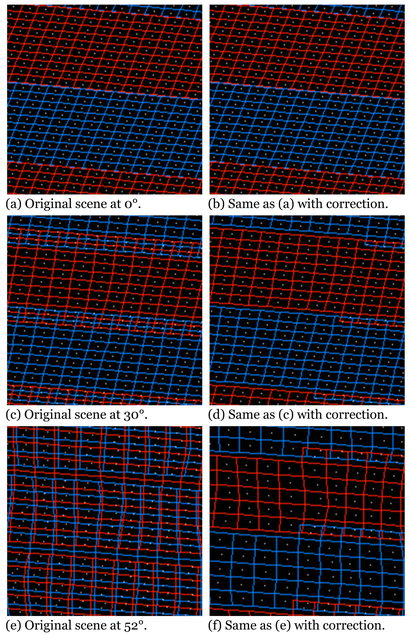



*Figure 2: FRP ratios of identical fires measured on subsequent scans are binned as shown to intervals of 0.1 for all single-pixel fires in the years 2003-2009.*



(a) Original scene at 0°. (b) Same as (a) with correction.
(c) Original scene at 30°. (d) Same as (c) with correction.
(e) Original scene at 52°. (f) Same as (e) with correction.

*Figure 1: MODIS scans (shown in alternating colors) overlap each other due to the "bow-tie" effect. A general algorithm can remove these overlapping pixels.*

*Table 1: Considering a MODIS scan having a width of 10 pixels along track, the range of sample indices (along scan) that do not overlap by at least half a pixel with the previous scan are recorded here for a given track number.*

| Track # of Scan | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Valid Range (sample) | 465 ~ 888 | 199 ~ 1154 | 111 ~ 1242 | 35 ~ 1318 | 0 ~ 1353 | 0 ~ 1353 | 0 ~ 1353 | 0 ~ 1353 | 0 ~ 1353 | 308 ~ 1045 |
| Equivalent Scan Angles | ±17.2° | ±38.8° | ±46.0° | ±52.1° | ±55.0° | ±55.0° | ±55.0° | ±55.0° | ±55.0° | ±29.9° |

## FRP Measurement Variability

Collection 5 FRP incorporates a pixel area term that Collection 4 does not (see Figure 3). Since this area term is incorporated after the fire determination stage, there exists a tendency for Collection 5 FRP to be greater off-nadir than at nadir (<15°).

A comparison between Terra and Aqua helps determine the extent of FRP measurement variability in Collection 5 and to find an adjusted FRP algorithm in order to obtain a 1-to-1 FRP ratio between different scan angles (see Figure 4).

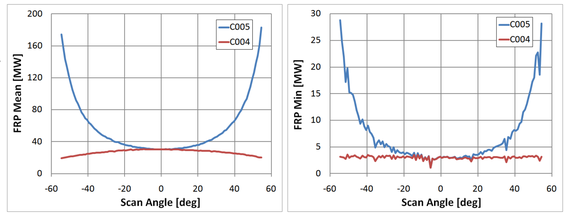
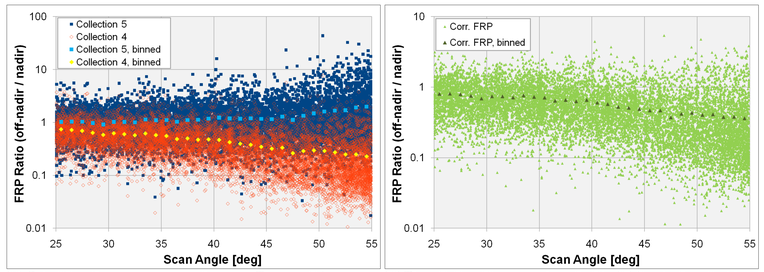
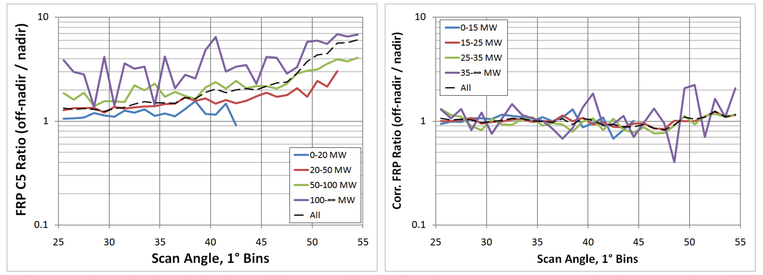



*Figure 3: Mean FRP and minimum FRP values are shown here verses scan angle for Collection 4 (without an area term) and Collection 5 (with an area term).*



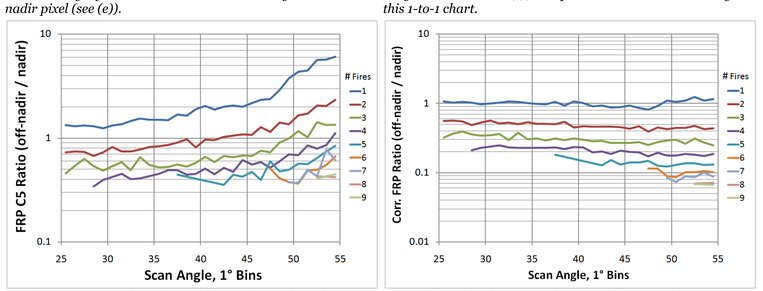

*(a) Coincident fire measurements between Terra and Aqua at different scan angles show a downward trend of FRP with scan angle for Collection 4 and an upward trend for Collection 5.*

*(b) Though the adjustment described in (d) for single-coincident -pixel situations is 1-to-1, the overall trend is still somewhat downward and the scatter remains high.*




*(c) The upward trend as described in (a) is split here into different FRP ranges for situations where there is only one coincident nadir pixel (see (e)).*

*(d) In order to attempt to accommodate for scan angle and FRP range as described in (c), an equation was derived resulting in this 1-to-1 chart.*




*(e) There is a strong dependency also on the number of corresponding nadir fire pixels contained within the fire pixel measured at a larger scan angle.*

*(f) Applying the adjustment shown in (d) causes the curves in (e) to level out with scan angle, though the FRP ratio still drops with an increase in nadir fire pixels.*

*Figure 4: Comparisons between Terra and Aqua FRP measurements are shown above. Single-pixel fires at larger scan angles are compared with the sum of corresponding nadir FRP values of the same fire measured by the other satellite. Collection 5 values are shown in the leftmost column, and adjusted values based on an equation dependent on scan angle and FRP are shown on the right.*

## Airborne Integration

Several attempts have been made to use airborne measurements to compare with MODIS measurements to help validate the FRP product. The following lists the researched airborne instruments:

- AMS (old configuration): saturation prevents any useful conclusions,
- MAS: geo-location variability and saturation cause too much uncertainty,
- MASTER: too few instances of coincident fire data with MODIS,
- new instrument: the cost of designing, building and implementing a new instrument is too high.

The current course of action is to pursue using the AMS instrument with its new configuration that includes four additional replica IR channels that are low-gain to help solve the saturation issues. This new configuration is currently being tested.

## Conclusions & Future Research

Detailed analyses between MODIS Terra and MODIS Aqua have been conducted, identifying how different variables affect FRP measurements as well as how Collection 5 FRP data might be adjusted. Collection 6 data will be collected and analyzed as soon as it becomes available. The AMS instrument will also be utilized as much as possible in the coming fire season.

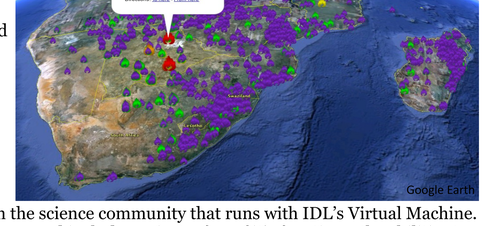
## Visualization Tools

### Google Earth

Available on the FEER website are Google Earth .kml files which can be loaded into Google Earth that display MODIS fires for any given day, such that:

- the fires are colored by fire category based on FRP thresholds, and
- a popup displays relevant information about each fire.

*http://feer.gsfc.nasa.gov/tools/globalmodisfires/*

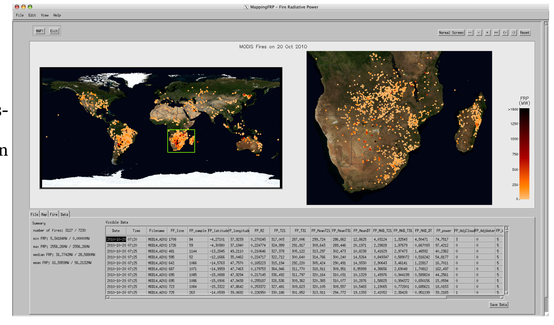



### MappingFRP

A visualization program called MappingFRP has been developed for use within the science community that runs with IDL's Virtual Machine. MappingFRP visualizes MODIS fires on a map and includes as just a few of it's functions, the abilities to:

- color fires by their FRP values,
- filter the fire data according to different variables,
- change the display icons for different filters,
- fine-tune the display characteristics,
- zoom into different areas with an easy-to-use interface
- save and open images and data of selected fires, and
- batch processing.

*Coming soon!*



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