Fire Radiative Power and Fire Radiative Energy Factsheet

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The Fire Radiative Power product (FRP, in megawatts) provides information on the measured radiant heat output of detected fires. It has been demonstrated in small-scale experimental fires that the amount of radiant heat energy liberated per unit time (the Fire Radiative Power) is related to the rate at which fuel is being consumed [1]. This is a direct result of the combustion process, whereby carbon-based fuel is oxidised to CO_2 with the release of a certain "heat yield". Therefore, measuring this FRP and integrating it over the lifetime of the fire provides an estimate of the total Fire Radiative Energy (FRE), which for wildfires should be proportional to the total mass of fuel biomass combusted.

Current methods to obtain fuel combustion estimates are based largely on burned area mapping approaches, with necessary assumptions regarding the fuel density and combustion completeness variables (which may vary with land-cover/climate/timing-of-fire). The FRE approach in theory circumvents the requirement to make these assumptions, providing a geophysical variable potentially more directly related to the amount of combusted biomass. Geostationary observations allow high temporal frequency FRP measurements, and thus a much-improved ability to estimate FRE via temporal integration when compared to the far less-frequent observations made from systems in low-Earth orbit. However, a limitation of geostationary observations results from the fact that the larger pixel sizes used (compared to low-Earth orbit systems) result in a greater fraction of the smaller and/or less intensely burning fires remaining undetected.

The development of the SEVIRI FRP product is being performed in collaboration with the Department of Geography of King's College London and uses the "MIR radiance method" (MIR = middle infrared) of FRP derivation, first proposed by [1] and adapted for use with geostationary systems by [2, 3]

Production algorithm

The FRP product is derived using a so-called Fire Thermal Anomaly (FTA) algorithm, the first stage of which is the detection of all "fire pixels" within the image that are believed to contain actively burning fires. The detection process is based mainly on testing for elevated MIR spectral channel radiances, along with a number of other tests to discriminate fires from other phenomena that may induce similarly elevated MIR channel signals. Specular reflections and cloud edges can present a similar signature to fires under certain daytime conditions [4], so the CLM cloud mask and a supplementary clear sky mask derived from the 0.6 VIS channel is used to identify and remove cloud-contaminated pixels from the analysis.

The fire detection algorithm implemented for use with SEVIRI is an evolution of that described in [3] and is based on the principles used to generate active fire detections within the MODIS fire products [4]. The algorithm works mainly on statistics derived from the 3.9 µm and 11.0 µm brightness temperatures, and their differences. On a first pass a series of absolute thresholds are used with these data to detect "potential" fire pixels, which are then further assessed as "true" or "false" fire detections based on a series of further "contextual" tests whose thresholds are adjusted based on statistics derived from the immediately neighbouring non-fire "background" pixels. Background pixel statistics are obtained from a window surrounding each potential fire pixel, commencing as a 5 × 5 matrix and being expanded until sufficient window pixels are not themselves classed as potential fire pixels (or clouds). Each potential fire pixel must pass all tests to be confirmed as a "true" fire pixel, and a confidence measure is also assigned to the detection.

The second stage of the FTA algorithm is the derivation of FRP at all fire pixels. This is carried out using the MIR radiance method [1], which assumes FRP is proportional to the difference between the observed fire pixel radiance in the SEVIRI middle infrared (MIR, 3.9 µm) channel and the "background" radiance that would have been observed at the same location in the absence of fire. This background radiance is at present derived from the set of fire- and cloud-free pixels surrounding each fire pixel.

Product characteristics

The FRP product will be derived every 15 min at the native SEVIRI pixel resolution. The disseminated product will include for each processed pixel: the FRP (in MW), the corresponding uncertainty in the FRP retrieval based on the variability of the background radiance estimation, and a confidence measure (representing the level of confidence that the observation is indeed a "true" fire). The FRP product will also be available at a reduced spatial resolution, e.g., 1 × 1 degree.

The FRE product will be delivered at a spatial and temporal resolution yet to be determined.

Applications

The FRP product is intended to support emerging operational atmosphere and climate-related applications, such as the following examples:

Air quality forecasting

(Aerosols/relevant trace gases)

Here the interest is in using information on fire timing, location and production rate of key chemical species as sources for input into the atmospheric chemistry and transport models used to provide short-term forecasts of "air quality". Industrial sources of these emissions are relatively well-characterised in space and time, whereas biomass burning sources are highly variable with large variations on short (~ hourly) time scales and thus require careful consideration for accurate modelling.

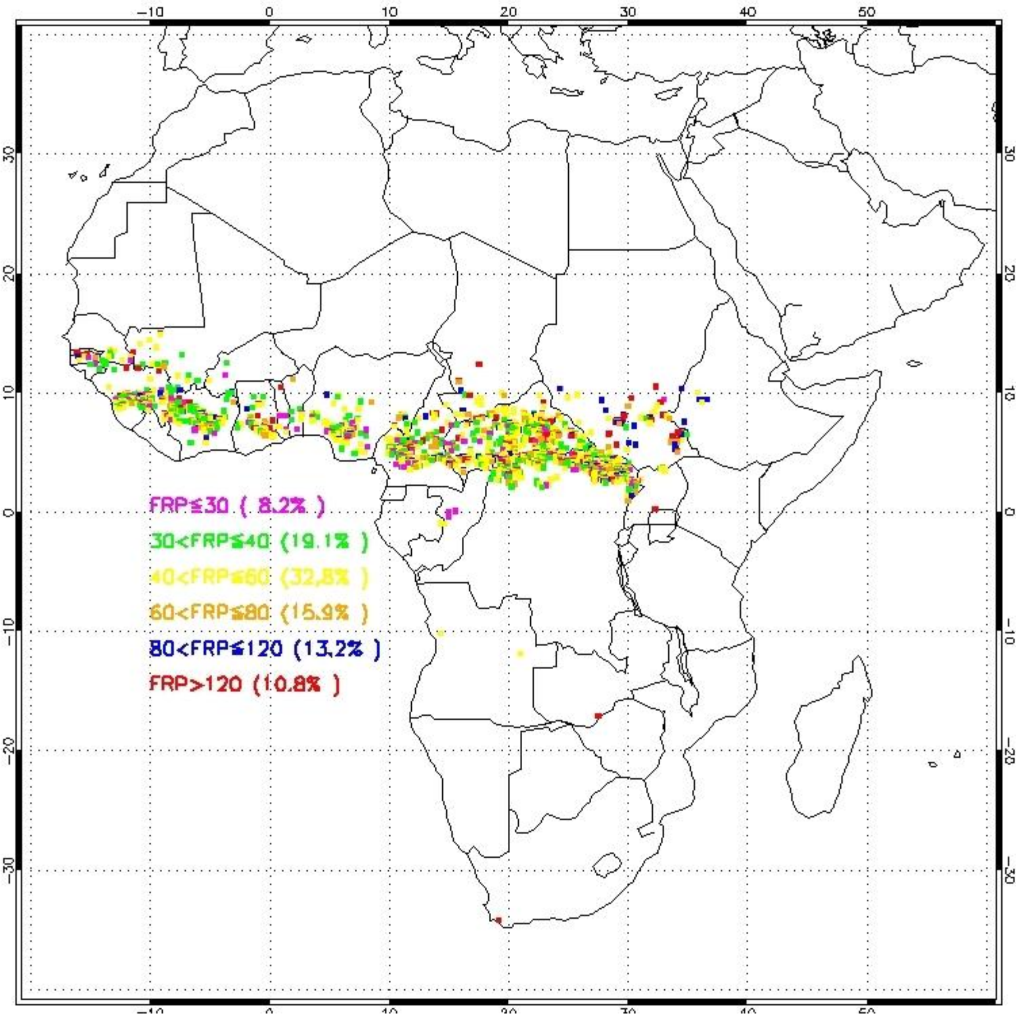
Carbon cycle assessment and modelling

Biomass burning is a key process by which terrestrially stored carbon is released into the atmosphere (primarily as carbon dioxide, CO_2). Since biomass burning activity shows large (i.e. order of magnitude) variations, so does the carbon released from these fires. As one consequence of this, the annual increase in CO_2 concentration in the atmosphere shows significant inter-annual variability. However, it is uncertain exactly how much of this variability is due to fire, and how much to other mechanisms (e.g. climate-related variations in vegetation growth, soil microbial processes etc.). Coupled models of the land-atmosphere system are attempting to better understand these processes, with one aim to be able to represent the inter-annual variability of atmospheric CO_2 increase (and ultimately to forecast this into the future). Therefore information on the amount of carbon released by fire is key to this modelling and understanding.

Fire activity models

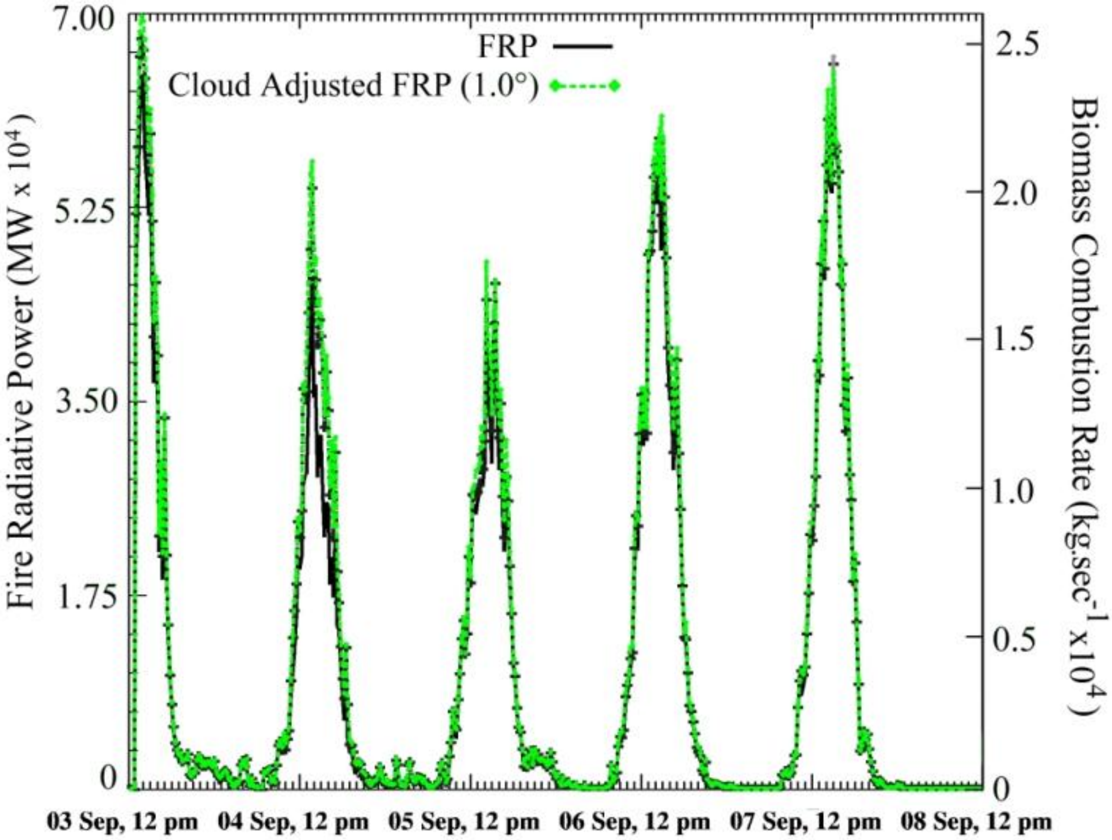
Linked to the previous item is the fact that forecasts of future land-atmosphere interactions will require careful representation of biomass burning, for example to represent emissions of pyrogenic carbon and to identify regions where significant and semi-permanent fire-related changes in land cover may be expected (e.g. conversion from forest to grasslands). A number of vegetation fire models (including the stages of ignition, progression and combustion) are available to represent regional to global patterns of fire. These models require validation, and long-term fire-related observations from satellites are seen as a key validation data source.

Examples of products



FRP map

The FTA algorithm will provide the Fire Radiative Power product in megawatts at pixel resolution for every processed SEVIRI imaging slot. This image shows an example of the FRP product in MW derived from a slot acquired by Meteosat-8 on 7 February 2004 at 12:12 UTC.



Fire Radiative Energy

The temporal integration of the FRP provides the Fire Radiative Energy (in megajoules). This figure shows an example of time series of FRP for Angola for 3-8 September 2003, taken from [3]. The raw FRP time series is shown, together with that normalised for cloud cover fraction and 1° grid cell resolution. Due to the small amount of cloud cover present at this time, the "raw" and "cloud-normalised" measures are very similar, providing a measured FRE of 4.5×10^9 MJ for the period.

Validations

The FRP and FRE products will be initially assessed via comparisons with near-simultaneous results derived from MODIS. MODIS currently represents the standard for operational global fire detection and characterisation [4], including the derivation of FRP via two 3.9µm channels having different gain settings and saturation temperatures (331 and 500 K respectively).

References

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[3] Roberts, G., M. J. Wooster, G. L. W. Perry, N. Drake, L.-M. Rebelo, and F. Dipotso (2005), Retrieval of biomass combustion rates and totals from fire radiative power observations: Application to southern Africa using geostationary SEVIRI imagery, J. Geophys. Res., 110, D21111, doi:10.1029/2005JD006018.

[4] Giglio, L., Descloitres, J., Justice, C. O., and Kaufman, Y. J., (2003) An enhanced contextural fire detection algorithm for MODIS, *Remote Sens. Environ.* 87. 2-3. 273-282.