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Generation of Global Biomass Burning Emissions Product (GBBEPx) by Blending Fire Observations from MODIS and Geostationary Satellites

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Abstract- The Blended Global Biomass Burning Emissions Product (GBBEPx) produces daily biomass burning emissions (PM2.5, CO, OC, BC, CO2, and SO2) released from wildfires. Specifically, the GBBEPx is derived by blending biomass emissions estimated from a network of geostationary satellites (GBBEP-Geo) and quick fire emissions data (QFED) from polar-orbiting satellites of Terra and Aqua MODIS. It is timely updated on a daily basis globally. Because it is calibrated with MODIS AOD, GBBEPx is expected to meet the requirements for NOAA NWS NCEP to provide global aerosol forecasts. The product also provides hourly biomass burning emissions from GBBEP-Geo without model-based adjustments, which could be applied in other air quality models.

1. Biomass burning emission model

The smoke particle emissions and other trace gases can be estimated using the following model:

$$E = DM \times F = FRE \times \beta \times F = \int FRP dt \times \beta \times F$$

where E represents emissions from biomass burning (kg); DM is the dry fuel mass combusted (kg); FRP is fire radiative power (MW); FRE is fire radiative energy (MJ); and β is biomass combustion rate (kg/MJ); F is the emission factor, and t is time (second). Based on this model, GBBEPx is produced using FRP from MODIS and Geostationary satellite data (Figure 1).

2. Biomass burning emissions from geostationary satellites (GBBEP-Geo)

GBBEP-Geo estimates fire emissions from FRP derived from a network of geostationary satellites (**Table 1**). Diurnal variation in FRP data for each individual fire pixel is simulated using a climatological diurnal FRP pattern. The algorithm assumes that the shape of the FRP diurnal pattern is similar for a given land cover type and that the diurnal pattern of FRP for a given fire pixel can be reconstructed by fitting the climatological diurnal curve corresponding to that land cover type to the timely detected fire FRP values. The reconstructed diurnal pattern provides estimates of FRP for instantaneous fires that are undetected or poorly detected from WF_ABBA V65 (**Figure 2**).

3.Quick Fire Emissions Dataset (QFED)

QFED calculates the flux of biomass burning emissions in each grid cell (0.25°x 0.315°) from MODIS fire products. The FRP density is calculated from MODIS fire observations. FRP and cloud mask are obtained from MODIS active fire product (MOD14 and MYD14) and geolocation is extracted from MODIS geolocation product (MOD03 and MYD03). The FRP density in a grid cell is calculated by assuming that the FRP density in cloud obscured pixels is equivalent to that in cloud-free pixels. FRP flux is calculated for four biome classes (tropical forest, extratropical forest, savanna, and grassland), separately. The biomass burning emissions are initially calculated using an emission coefficient (α) of 1.37×10^{-6} kgJ^{-1}. It is then calibrated using MODIS AOD.

4. Blending QFED and GBBEP-Geo

A complete global biomass burning emissions product is generated by blending QFED and scaled GBBEP-Geo. The GBBEP-Geo is calibrated by comparing the daily GBBEP-Geo emissions in 2011 with QFED for GOES, Meteosat, and MTSAT observations, respectively, using the following equations:

$$\begin{cases} CE_{GOES} = E_{QFED} = \gamma_1 E_{GOES} \\ CE_{Meteosat} = E_{QFED} = \gamma_2 E_{Meteosat} \\ CE_{MTSAT} = E_{QFED} = \gamma_3 E_{MTSAT} \end{cases}$$

where CE_{GOES}, $CE_{Meteosat}$, and CE_{MTSAT} are the scaled emissions flux for GOES, Meteosat, and MTSAT. E_{GOES}, $E_{Meteosat}$, and E_{MTSAT} are the emission fluxes which are the values calculated from diurnal FRP divided by grid area and 24 hours (60×60×24 seconds). r_1, r_2, and r_3 are the scaling factors.

Table 1. Inputs of FRP and cloud cover datasets from polar orbit satellites.

Satellite/Sensor	Algorithm Version	Spatial Resolution	Parameters in fire pixels	Temporal Resolution
GOES-E: WF_ABBA fire Product	V65	4 km	FRP Latitude Longitude Quality flag Land cover type	30 min
GOES-W: WF_ABBA fire Product	V65	4 km	FRP Latitude Longitude Quality flag Land cover type	30 min
Meteosat SEVIRI: WF_ABBA fire Product	V65	3km	FRP Latitude Longitude Quality flag Land cover type	15 min
MTSAT Imager: WF_ABBA fire Product	V65	4 km	FRP Latitude Longitude Quality flag Land cover type	30 min

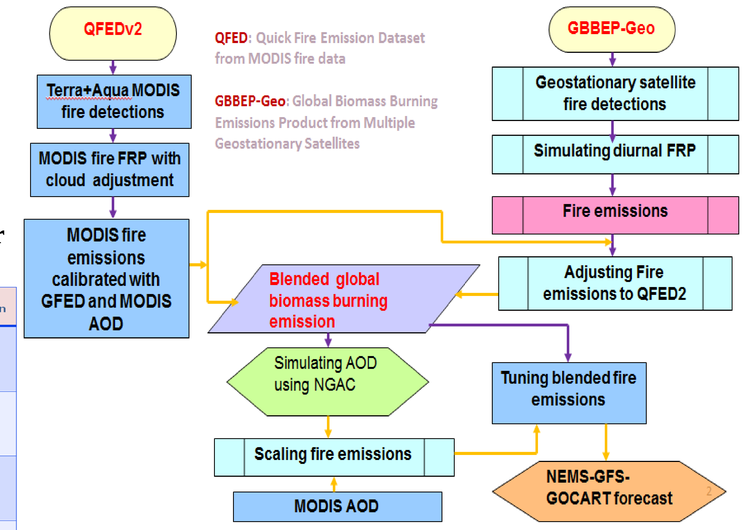

Figure 1. Processing of the product of biomass burning emissions.

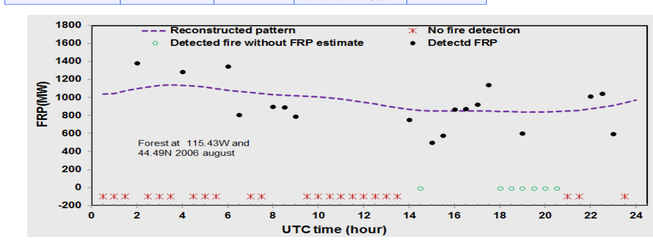

Figure 2. Simulating FRP diurnal pattern using available FRP observation for a given fire pixel and climatologic diurnal pattern. It is assumed that the shape of FRP diurnal pattern is similar in a given ecosystem.

5. Results of Biomass Burning Emissions

The global GBBEPx produces two products. The first is the GBBEP-Geo without any scaling factor adjustment. This product in a netCDF4 format contains hourly emission vaariables of fire radiative energy, dry mass burned, PM2.5, BC, CO, CO2, OC, SO2, and burned area for individual fire pixels detected from geostationary satellites (**Figures 3 and 4**).

The second is the blended biomass burning emissions product. It contains a set of daily emissions flux in a grid cell of 0.25°x0.315°. Each emission species (PM2.5, BC, CO, CO2, OC, and SO2) is outputted in a separated netCDF4 file (**Figure 5**).

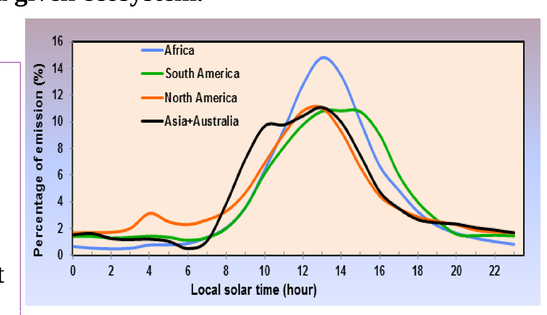

Figure 3. Diurnal variability in the PM2.5 emissions derived from GBBEP-Geo in 2010.

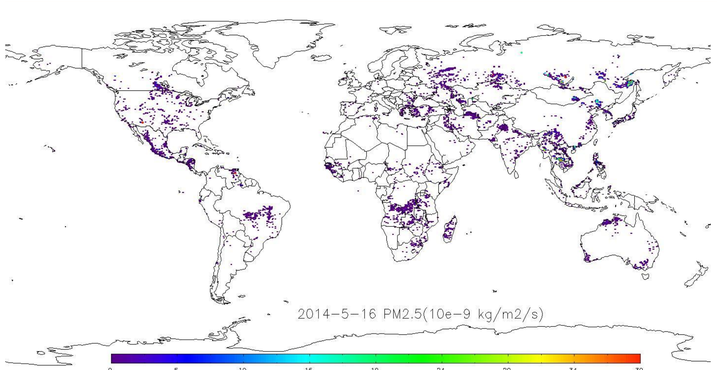

Figure 5. Spatial pattern of GBBEPx - derived PM2.5 flux in May 16, 2014.

6. Conclusions

- GGBBEP-Geo is developed using diurnal patterns of FRP which reduces impacts of missing fire observations caused by cloud cover, sensor saturation, etc.
- QFEDv2 from MODS FRP is calibrated by taking MODIS AOD as a reference and GBBEP-Geo is then calibrated using QFEDv2. GBBEPx blends these two datasets to generate a global biomass burning emissions product, which is expected to meet well the requirement of global aerosol forecasting (NEMS-GFS-GOCART).
- The operational product also keeps GBBEP-Geo data which provide hourly emissions for individual fire pixels without any model-based calibration.

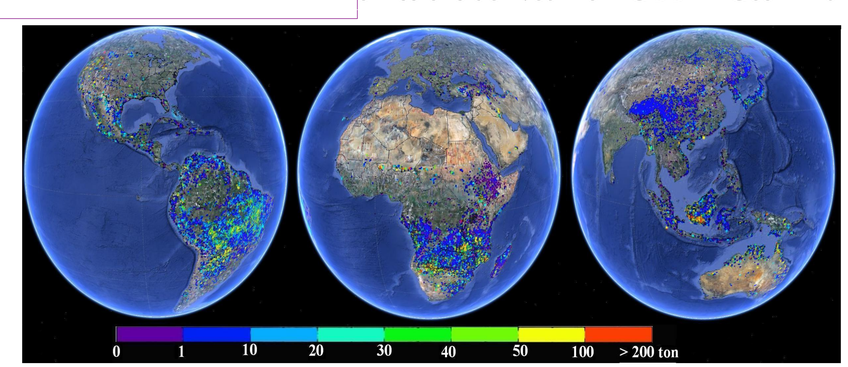

Figure 4. GBEP-Geo PM2.5 in Sept. 15-30, 2009.