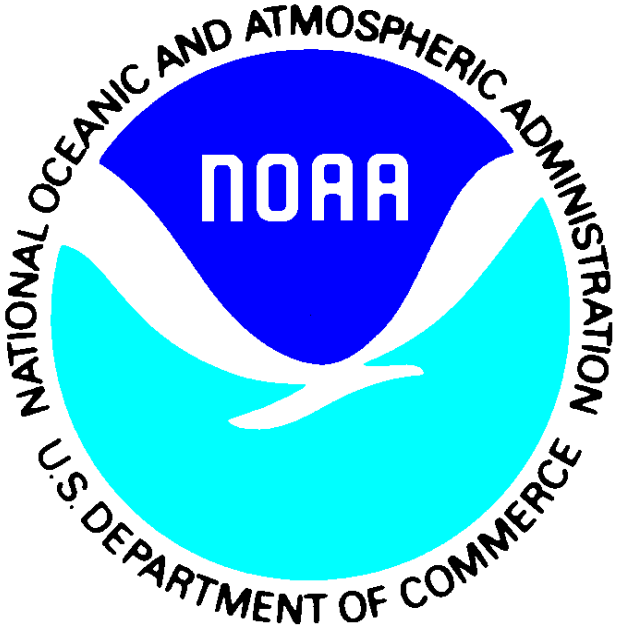

The Blended Global Biomass Burning Emissions Product from MODIS and VIIRS Observations (GBBEPx)

External Users Manual

Version 3.1

October, 2019

TITLE: THE BLENDED GLOBAL BIOMASS BURNING EMISSIONS PRODUCT FROM MODIS AND GEOSTATIONARY SATELLITES (GBBEPx)
EXTERNAL USERS MANUAL VERSION 3.0

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LIST OF CHANGES

Significant alterations made to this document are annotated in the List of Changes table.

DOCUMENT TITLE: GBBEPx External Users Manual					
LIST OF CHANGE-AFFECTED PAGES/SECTIONS/APPENDICES					
Version Number	**Date**	**Changed By**	**Page**	**Section**	**Description of Change(s)**

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Page

1. PRODUCTS

This is an external user's manual document describing the NOAA GBBEPx V3 product and output files. The GBBEPx V3 product system was developed at the Center for Satellite Applications and Research (STAR). It has been delivered to the Office of Satellite and Product Operations (OSPO) to be run operationally.

The intended users of the External Users Manual (EUM) are end users of the output products and files, and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and product testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system.

1.1. Product Overview

1.1.1. Product Requirements

The GBBEPx is derived based on SPSRB requirement (**SPSRB #: 1009-0013**). The NOAA Environmental Modeling System (NEMS) has been serve as the next-generation operational common model infrastructure expected to be running at the NCEP. NEMS is built upon the Earth System Modeling Framework (ESMF) and is designed to enhance the interoperability of the operational model production suite. NEMS has various components in dynamic, physics, and chemistry and communicated with each other through EMSF framework and its development involves institutions across the NOAA. For operational global forecasting, NCEP is testing the NEMS system with GFS meteorology (NEMS/GFS) and also with NASA-GOCART aerosol module (referred to as NEMS/GFS-GOCART). NEMS/GFS-GOCART with dust only forecasting is tested and expected to be implemented. With the anticipation that the NEMS will be implemented in the near future, NCEP is developing the GSI (Gridpoint Statistical Interpolation) capability to ingest the first guess fields from NEMS in the past few years. GSI is now able to perform some NEMS/GFS data assimilations on meteorology fields (referred to as NEMS/GDAS), as well as to ingest the NEMS/GFS-GOCART aerosols fields and MODIS aerosol optical depth observation for aerosol data assimilation developments (referred to as NEMS/GFS-GOCART/DAS). In addition, NOAA Air Resources Laboratory (ARL) is conducting air quality forecasting across the United States using the Community Multiscale Air Quality Modeling System (CMAQ)**.** In support of model development and subsequent operational deployment, NOAA/NESDIS and NASA have developed biomass burning emission datasets that will be transitioned to operations for NCEP's model applications.

1.1.2. Product Team

The GBBEPx V3 development product team consists of members from STAR and OSPO. The roles and contact information for the product team members are identified below:

- IPT Lead: S. Kondragunta (STAR)
- IPT Backup Lead: H. Ding (OSPO)
- NESDIS team:
  - STAR: S. Kondragunta, I. Csiszar
  - OSPO: H. Ding
  - OSGS: Jamese Simms
  - JPSS: Mitch Goldberg, Arron Layns, Nazmi Chowdhury
  - Data Center: Philip Jones (NCEI-NC)
  - Others: Xiaoyang Zhang (SDSU), Fanjun Li (SDSU), Arlindo Da Silva (NASA), Chris Schmidt (UW-Madison), Yufeng Zhu(OSPO)
- User team
  - Lead: Jeff McQueen(NWS/NCEP/MMB)
    - Others:
    - Kate Zhang (ESRL/Global System Division), Daniel Tong (ARL), S. Lu (SUNY-Albany @NCEP/EMC), Jun Wang (NCEP/EMC), Jianping Huang (NCEP/EMC)
- Oversight Panel lead: AC POP
- Other OPs involved: ICAPOP, LSPOP

1.1.3. Product Description

The GBBEPx V3 system produces global biomass burning emissions. The product contains daily global biomass burning emissions blended fire observations from MODIS on Terra and Aqua and VIIRS on SNPP (Suomi National Polar-orbiting Partnership) and JPSS-1 (Joint Polar Satellite System). Note that fire detections from geostationary satellites of AHI and ABI are not available. The details of the algorithm used to generate these products are contained in the peer-reviewed articles listed in the section of reference.

1.2. Product History

GBBEPx V3 is a global product of biomass burning emissions by adding JPSS-1 VIIRS fire detections to previous version and adding a set of different output data formats. Initially, the Geostationary Operational Environmental Satellite Biomass Burning Emission Products (GBBEP) are produced from GOES-E and GOES-W fire products over the North America since 2008 (Zhang et al. 2008). In these products, biomass burning emissions are estimated using burned area and fuel loadings. Late, the GBBEP was generated using diurnal pattern of fire radiative power (FRP) detected from a network of geostationary satellites that consist

of two Geostationary Operational Environmental Satellites (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA), the Meteosat Second Generation satellites (Meteosat-09) operated by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and the Multi-functional Transport Satellite (MTSAT) operated by the Japan Meteorological Agency (JMA). This product is term as GBBEP-Geo, which produces hourly global biomass burning emissions (Zhang et al. 20102). In order to make the biomass burning emissions suitable for NEMS/GFS-GOCART, GBBEP-Geo was blended with MODIS FRP-based biomass burning emissions product, Quick Fire Emissions Dataset (QFED, Darmenov and da Silva, 2013), to produce global daily fluxes of biomass burning emissions for a gird of 0.25°×0.2135°, which is called GBBEPx V1 and was operationally produced at OSPO from 2013-2017. After that, GBBEPx V2 was developed by adding fire emissions estimated from SNPP VIIRS fire observations to GBBEPx V1, which was produced the same product format as GBBEPx V1 for the period of 9/2017—08/2019. With the JPSS-1 available, GBBEPx V3 has been developed by adding the fire emissions estimated from JPSS-1 VIIRS to GBBEPx V2 and operationally produced since 08/2019. GBBEPx V3 extends the output products that include emissions with a grid size of 0.25°×0.2135°, 0.1°×0.1°, FV3 C384. Besides, GBBEPx V3 also provides average FRP and HMS fire data. However, it should be noted that fire detections from geostationary satellites are not included to GBBEPx V3 because fire detections from Himawari AHI and GOES-16/17 ABI are not available.

1.3. Product Access

GBBEPx V3 output data files consist of several different formats including NetCDF, text, plain binary, and jpg files. Only the NetCDF files are made available on data distribution server at NCDC in a near real time manner. For access to this server, information about data files, and associated documentation, the PAL should be contacted. The rest files are available at https://satepsanone.nesdis.noaa.gov/pub/FIRE/GBBEPx-V3/. Moreover, it should be noted that the hourly biomass burning emissions (GBBEP_Geo.Hourly.emissions_v003.yyyymmdd.nc) only covers limited regions because fire detections from AHI and ABI are currently not available.

GBBEPx V3 is produced every day with the output files that are listed in the Tables 1-1, 1-2, and 1-3. The outputs consist of the following files. Six NetCDF files contain daily biomass burning emissions in a grid cell of 0.25° x0.3125°, which are the same as those in GBBEPx V2. One NetCDF file contains all emission species at 0.1° x0.1°. One NetCDF file provides hourly emissions and related attributes at individual fire pixels detected from geostationary satellites (this file is kept because it will be used in next version of the product when the fire detections from AHI and ABI are available). One NetCDF file describes the quality confidence

of the emissions from geostationary satellite fires, which is not functional well because fire detections from new generation geostationary satellites are not available. One jpg file shows the spatial pattern of PM2.5 for visualization purpose. One text file is to replace the HMS fire data that contains fire detection information. One text file provides regional PM2.5 to monitor if spurious emissions occur from false fire detections. Forty two plain binary files provide emission species and FRP for FV3 C384 grids, which are generated using Fortran90 binary output.

Tables 1-4 and 1-5 show the detail content of output biomass burning emissions listed in Tables 1-1, 1-2, and 1-3.

Table 1-1 GBBEPx V3 Output Files archived at NCDC

File	Description	Format
GBBEPx_BC.emissions_v003_yyyymmdd.nc	Daily BC emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEPx_CO.emissions_v003_yyyymmdd.nc	Daily CO emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEPx_CO2.emissions_v003_yyyymmdd.nc	Daily CO2 emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEPx_OC.emissions_v003_yyyymmdd.nc	Daily OC emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEPx_PM2.5.emissions_v003_yyyymmdd.nc	Daily PM2.5 emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEPx_SO2.emissions_v003_yyyymmdd.nc	Daily SO2 emissions at 0.25x0.3125 grid and latitude and longitude	netCDF4
GBBEP_Geo.Hourly.emissions_v003.yyyymmdd.nc	Emissions from geostationary satellites. The file contains latitude, longitude, fire radiative energy, ecosystem type, dry mass burned, burned area, and the emissions of PM2.5, BC, CO, CO2. OC, and SO2.	netCDF4
GBBEP_Geo.QA.emissions_v003_yyyymmdd.nc	Emission quality from geostationary satellites	netCDF4
GBBEPx_all01GRID.emissions_v003_yyyymmdd.nc	Daily emissions at 0.1x0.1 degree grid for CO2, CO, SO2, OC, BC, PM2.5, NOx, NH3, and FRP	netCDF4

Table 1-2 GBBEPx V3 Output Files in text and image format

File	Description	Format
GBBEPx_PM2.5.emissions_v003.yyyymmdd.jpg	Spatial pattern in Pm2.5 in jpg map	jpg
GBBEPx_Regional.Total.PM25_v003_yyyymmdd.txt	Statistic data in PM2.5	txt
GBBEPx.HMS_MODIS_VIIRS.003.yyyymmdd.txt	Fire detection information: longitude, latitude, date, time, pixel size, satellite, and land cover type	txt

Table 1-3 GBBEPx V3 Output Files at FV3 C384 grid that are generated using Fortran90 binary output

File	Description	Format
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile1.bin	BC	Binary
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile2.bin	BC	Binary
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile3.bin	BC	Binary
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile4.bin	BC	Binary
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile5.bin	BC	Binary
GBBEPx.emis_bc.003.yyyymmdd.FV3.C384Grid.tile6.bin	BC	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile1.bin	CO	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile2.bin	CO	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile3.bin	CO	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile4.bin	CO	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile5.bin	CO	Binary
GBBEPx.emis_co.003.yyyymmdd.FV3.C384Grid.tile6.bin	CO	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile1.bin	CO2	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile2.bin	CO2	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile3.bin	CO2	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile4.bin	CO2	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile5.bin	CO2	Binary
GBBEPx.emis_co2.003.yyyymmdd.FV3.C384Grid.tile6.bin	CO2	Binary
GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile1.bin	OC	Binary
GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile2.bin	OC	Binary
GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile3.bin	OC	Binary

GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile4.bin	OC	Binary
GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile5.bin	OC	Binary
GBBEPx.emis_oc.003.yyyymmdd.FV3.C384Grid.tile6.bin	OC	Binary
GBBEPx.emis_pm25.003.yyyymmdd.FV3.C384Grid.tile1.bin	PM2.5	Binary
GBBEPx.emis_pm25.003.yyyymmdd.FV3.C384Grid.tile2.bin	PM2.5	Binary
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GBBEPx.emis_pm25.003.yyyymmdd.FV3.C384Grid.tile4.bin	PM2.5	Binary
GBBEPx.emis_pm25.003.yyyymmdd.FV3.C384Grid.tile5.bin	PM2.5	Binary
GBBEPx.emis_pm25.003.yyyymmdd.FV3.C384Grid.tile6.bin	PM2.5	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile1.bin	SO2	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile2.bin	SO2	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile3.bin	SO2	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile4.bin	SO2	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile5.bin	SO2	Binary
GBBEPx.emis_so2.003.yyyymmdd.FV3.C384Grid.tile6.bin	SO2	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile1.bin	Average FRP	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile2.bin	Average FRP	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile3.bin	Average FRP	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile4.bin	Average FRP	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile5.bin	Average FRP	Binary
GBBEPx.FRP.003.yyyymmdd.FV3.C384Grid.tile6.bin	Average FRP	Binary

Table 1-4 GBBEPx V3 Daily Biomass Burning Emission File

Variable	Type	Description	Dim	Units	Range
PM2.5	Float	PM2.5 emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
CO	Float	CO emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
CO2	Float	CO2 emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
OC	Float	OC emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
BC	Float	BC emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
SO2	Float	SO2 emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
NOx	Float	NOx emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
NH3	Float	NH3 emissions	1	$Kg.s^{-1}.m^{-2}$	0 – 100000.0
FRP	Float	Mean fire radiative power (FRP)	1	MW	0 – 100000.0
Longitude	Float	Longitude	1	Degree	-180 – 180
Latitude	Float	Latitude	1	Degree	-90 – 90

Table 1-5 GBBEPx V3 Hourly Biomass Burning Emission File

Variable	Type	Description	Dim	Units	Range
PM2.5_emission	Float	PM2.5 emissions	24	kg	0 – 9000000.0
CO_emission	Float	CO emissions	24	kg	0 – 9000000.0
CO2_emission	Float	CO2 emissions	24	kg	0 – 9000000.0
OC_emission	Float	OC emissions	24	kg	0 – 9000000.0
BC_emission	Flaot	BC emissions	24	kg	0 – 9000000.0
SO2_emission	Float	SO2 emissions	24	kg	0 – 9000000.0
Dry_Mass_Burned	Float	Dry mass burned	24	kg	0 – 9000000.0
Fire_Raditive_Ennergy	Float	Fire radiative energy (FRE)	24	MJ	0 – 9000000.0
Burned area	Float	Burned area	24	Km^2	0 – 9000000.0
Longitude	Float	Longitude	1	Degree	-180 – 180
Latitude	Float	Latitude	1	Degree	-90 – 90
Ecosystem	Float	USGS ecosystem type	1	None	1 – 110

2. ALGORITHM

The detailed description of GBBEPx V3 algorithm can be found in the peer-reviewed articles listed in reference section and ATBD. A brief overview is provided below.

2.1. Algorithm Overview

Daily fire emissions in the GBBEPx V3 product is to calculate biomass burning emissions (PM2.5, BC, CO, CO2, OC, SO2, NOx, and NH3) released from wildfires using fire radiative power (FRP). This emission calculation takes Quick Fire Emission Dataset (QFED) as a basis. Briefly, QFED (version 2) calculates MODIS FRP flux in individual grid cells for four different biome types, respectively. These biomes are tropical forest, extratropical forest, savanna, and grassland. The fire occurrence in cloud covered pixels is assumed to have the same possibility as that in cloud-free pixels within a grid cell. This assumption is used to adjust MODIS FRP in a grid. The FRP is associated to daily biomass burning emissions using biome-based coefficients that are derived by comparing with GFED (Global Fire Emissions Database) and MODIS aerosol optical depth (AOD). The emission calculation is conducted for Terra MODIS and Aqua MODIS separately. The emissions from both Terra and Aqua MODIS fire detections are averaged to produce QFED.

VIIRS fire emissions are estimated from VIIRS FRP that is detected using a very similar approach to MODIS FRP detections. Because FRP is a proxy of biomass burning emissions, VIIRS FRP is used to directly calculate fire emissions using emission coefficients that are

derived by comparing daily VIIRS FRP with daily QFED at a continental scale (North America, South America, Africa, Europe, Asia, and Australia). The coefficients are derived based on data of SNPP VIIRS observations from April 2016-March 2017. The correlation coefficients are then used to estimate daily biomass burning emissions from SNPP VIIRS and JPSS-1 VIIRS.

GBBEP-Geo is produced from FRP retrieved from a network of multiple geostationary satellites. However, fire detections from ABI and AHI are not available for this version of product although Meteorsat-11 fire data are currently produced. Thus the GBBEP-Geo is basically not used in current version.

The final GBBEPx V3 product is the average of SNPP VIIRS fire emissions, JPSS-1 VIIRS fire emissions, and QFED. If the emissions are only valid from one dataset (or sensor), the values are taken as the final results.

The GBBEPx V3 also produces daily average FRP for each grid. The FRP in a grid is first adjusted using cloud proportion from two MODIS and two VIIRS sensors at 8 different times during a day. Then the average from the 8 observations is provided for a given grid.

2.2. Input Satellite Data

2.2.1. Fire radiative power from satellite Instruments

GBBEPx V3 produces biomass burning emissions using FRP data that are retrieved from geostationary satellites (not available in this version of emissions product), and polar-orbiting satellites (SNPP and JPSS-1 VIIRS, and Terra and Aqua MODIS). FRP is theoretically a function of fire size and fire temperature. It is empirically related to the difference of brightness temperature between a fire pixel and ambient background pixels at the middle infrared (MIR) wave band of satellites. Further, FRP is approximated as the difference of MIR spectral radiances between a fire pixel and ambient background pixels in a linear form.

Fire observations from polar orbiting satellites provide a nominal spatial resolution of 1 km for MODIS and 750m for VIIRS observations. Each MODIS and VIIRS instrument scans a surface location twice a day in low-middle latitudes. The local time crossing the equator is ~10:30 AM/PM for Terra, ~12:40 AM/PM for JPSS-1, and ~1:30 AM/PM for Aqua and SNPP.

The input products from MODIS and VIIRS are active fire detections, cloud mask data, and geolocation product.

2.2.2. Pre-Processing Steps

The processing of GBBEPx V3 is to input MODIS fire products and VIIRS fire products to estimate biomass burning emissions, separately. The flowchart of data process is described in the Figures 2-1 and 2-2. Figure 2-1 presents the emissions estimation from VIIRS fires. It is calculated from VIIRS FRP and emission coefficients that are derived by comparing VIIRS FRP and QFED emissions during a year period. This calculated is performed for SNPP VIIRS and JPSS-1 VIIRS separately. Figure 2-2 shows the emission calculation for GBBEPx V3, which is simply averaged from QFED, SNPP VIIRS emissions, and JPSS-1 VIIRS emissions.

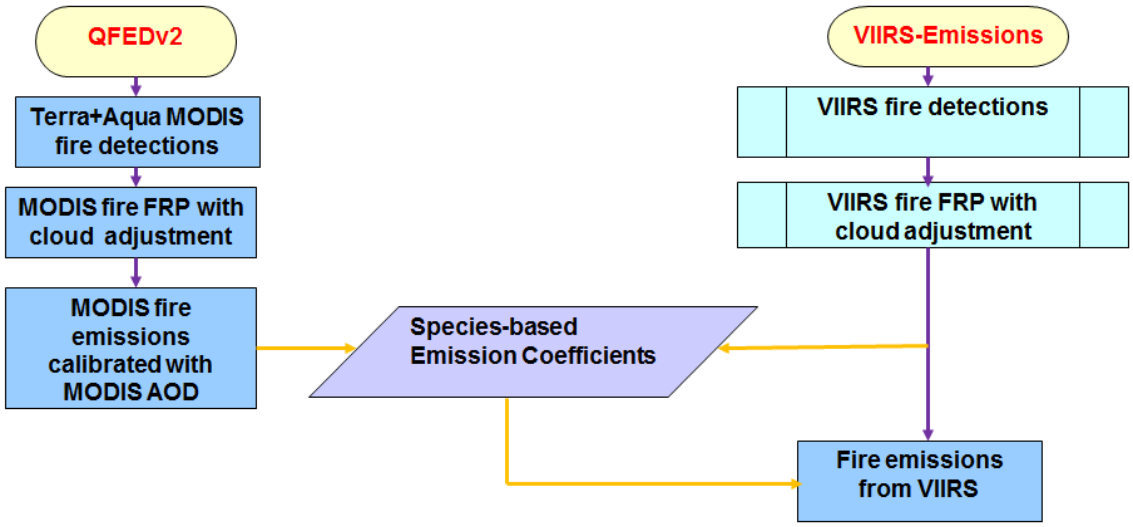

Figure 2-1. Adjusting VIIRS fire emissions using QFED2.

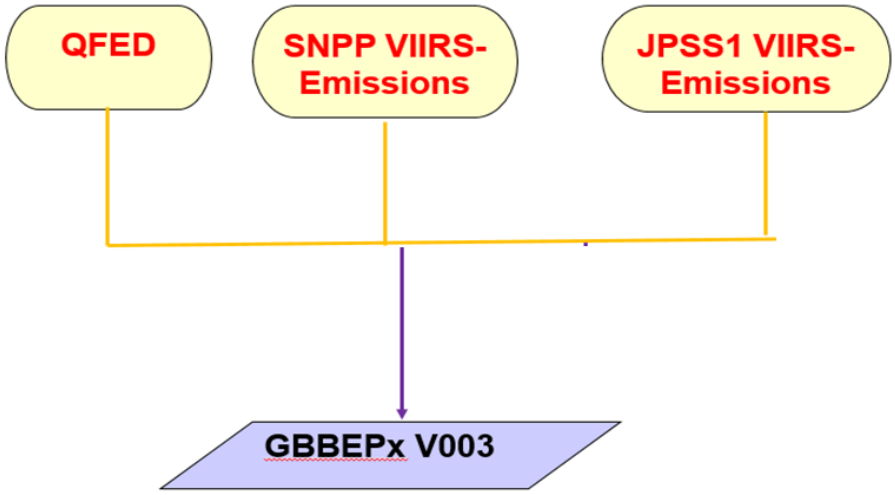

Figure 2-2. Generation of GBBEPx V3 by blending QFED and VIIRS fire emissions.

2.3. Input Ancillary Data

2.3.1. Emission factors

Emission factor varies with emission species. Thus, a set of emission factors are collected from literature and coded in the codes.

2.3.2. Emissions coefficients for VIIRS FRP

VIIRS fire emissions are directly calculated from VIIRS FRP using a set of coefficients. These species-specific coefficients are derived by comparing SNPP VIIRS FRP and QFED data at continental scales from April 2016 - March 2017. Thus the coefficients are provided for CO2, CO, PM2.5, OC, BC, SO2 at North America, South America, Africa, Europe, Asia, and Australia, respectively.

2.3.3. IGBP land cover

A global 1km IGBP land cover type is used to stratify land surface into tropical forests, extra-tropical forest, cerrado/woody savanna, and grassland/cropland. From these land cover type, emissions factors are assigned in QFED.

2.3.4. Template Files

The system uses a number of template files. These are all static files that will only change with a new delivery of the system. They are never modified by the scripts and programs that use them. Scripts will only copy these files to a local directory or create soft links to them.

3. REFERENCES

Darmenov, A., and da Silva, A. 2013, The Quick Fire Emissions Dataset (QFED) - Documentation of versions 2.1, 2.2 and 2.4, In M. J. Suarez (Editor), *Technical Report Series on Global Modeling and Data Assimilation*, Volume 32.

Zhang, X., Kondragunta, S., Schmidt, C., Kogan, F., 2008. Near real-time monitoring of biomass burning particulate emissions (PM2.5) using multiple satellite instruments. *Atmospheric Environment,* 42 (29), 6959-6972,

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