Description of GEOS-Carb CASA-GFED3 Land Carbon Flux Products

Document Version: 1.0
Date: 02/20/20

1. Introduction
The GEOS-Carb project seeks to produce a variety of carbon flux and concentration products by heavily leveraging NASA's Global Earth Observing System (GEOS) model, which is developed and maintained at NASA's Goddard Space Flight Center. As part of this effort, the Carnegie-Ames-Stanford-Approach – Global Fire Emissions Database version 3 (CASA-GFED3) model uses remote sensing data to estimate monthly net primary production (NPP) and heterotrophic respiration (Rh) carbon fluxes globally at ~0.5 degree resolution. These data are subsequently used to estimate net ecosystem exchange at a 3-hourly timestep for CO_2 modeling studies using ancillary temperature and radiation information. In addition, biomass burning and fuel wood carbon emissions are estimated by the model on daily and monthly time steps, respectively. All calculations are driven by analyzed meteorological data from NASA's Modern-Era Retrospective analysis for Research and Application (MERRA), Version 2 (MERRA-2) for the period January 2003 through December 2017.

2. Description of the CASA-GFED3 Terrestrial Carbon Cycle Model
The CASA-GFED3 derives from Potter et al. (1993), diverging in development since Randerson et al, (1996). CASA is a light use efficiency type model: NPP is expressed as the product of photosynthetically active solar radiation, a light use efficiency parameter, scalars that capture temperature and moisture limitations, and fractional absorption of solar radiation by the vegetation canopy (FPAR) derived from satellite data. Fire parameterization was incorporated into the model by van der Werf et al. (2004) producing CASA-GFED and the model has undergone several revisions (van der Werf et al, 2006, 2010) leading to its most recent version CASA-GFED3. Wildfire and fuel wood burning are estimated separately.

Input data include air temperature, precipitation, incident solar radiation, a soil classification map, and a number of satellite derived products (Moderate Resolution Imaging Spectroradiometer (MODIS) MOD12Q1 vegetation classification, MOD44B vegetation continuous fields, MOD09GA/MYD09GA based burned area, and Advanced Very High Resolution Radiometer (AVHRR) normalized difference vegetation index (NDVI)). Here, meteorological data (temperature, precipitation, solar radiation) are taken from the MERRA-2 (Gelaro et al., 2017 and https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/). FPAR is derived from the Global Inventory Modeling and Mapping Studies (GIMMS) NDVI, which is produced using data from AVHRR sensors onboard the NOAA satellite series 7, 9, 11, 14, 16, and 17 (Tucker et al., 2005, Los et al., 2000). The original 8-km, bi-weekly NDVI are aggregated to the monthly, 0.5 degree×0.5 degree grid used by CASA-GFED3 by averaging.

The model output includes NPP, heterotrophic respiration (Rh), wildfire emissions (FIRE), and fuel wood burning emissions (FUEL). Wildfire emissions are disaggregated from monthly to daily using the eight-day MODIS MYD14A2 Active Fire Product.

Following the approach of Olsen and Randerson (2004) monthly fluxes are disaggregated into 3-hourly gross biological fluxes using MERRA-2 air temperature and incident solar radiation and added to produce the 3-hourly net carbon flux to the atmosphere. Users should note that

monthly and daily files are on the native 0.5 by 0.5 degree grid used by CASA-GFED while the 3-hourly fluxes are provided on the 0.625 by 0.5 degree grid used for MERRA-2. All fluxes are provided in units of kg Carbon per unit area per time.

These and earlier versions of MERRA-driven CASA-GFED carbon fluxes have been used in a number of atmospheric CO2 transport studies (e.g. Campbell et al., 2008, Kawa et al., 2010, Hammerling et al., 2012, Ott et al., 2015).

Several versions of CASA-GFED3 products are available due to changes in input variables. Version 1, available through the North American Carbon Program (https://nacp-files.nacarbon.org/nacp-kawa-01/) uses the older MERRA meteorological reanalysis (Rienecker et al., 2011) and is available through 2015. Version 2, available through NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC), uses the more modern MERRA-2 meteorological reanalysis which supported its extension through 2016. Version 3, (also available through GES DISC) uses a newer version of GIMMS NDVI (Pinzon and Tucker, 2014) and burned area derived from MODIS Collection 6 (Giglio et al., 2018). In addition, daily fire frequency information estimated following van der werf et al. (2017) is used to disaggregate monthly fire emissions to a daily time step.

3. File Naming Conventions
The standard full name for CASA-GFED products will follow the format described below:
[**project**]_[**model**]v[**version**]_[**collection**].[**time step**].[**resolution**].[**timestamp**].nc

For all files, **project** = 'GEOSCarb' and **model** = 'CASA_GFED3'. **Version** is either '2' or '3' with the differences described above. **Collection** is either 'Fire' for fire specific daily files or 'Flux', which includes a broader set of variables related to ecosystem exchange of carbon. **Time step** describes the frequency at which variables are written within the file and can be 'Monthly', 'Daily', or '3hour'. **Resolution** indicates the horizontal resolution of the files and is either 'x720_y360' for monthly and daily files, or 'x576_y361' for 3-hourly files. **Timestamp** defines the dates contained in the file and has the form yyyy for monthly and daily files, and the form yyyymm for 3-hourly files. More details on filenames is given in the description of available datasets below.

4. Available Data
Data are provided in netCDF format in the following collections:
GEOSCarb_CASAGFED3v2_Flux.Monthly: GEOS-Carb CASA-GFED Monthly Fluxes, version 2
   Frequency: *yearly, containing 12 monthly values*
   Dimensions: *longitude=720, latitude=360, time=12*
   Granule Size: *~60 MB*
   Short name: *GEOS_CASAGFED_M_FLUX*
   Truncated long name: *GEOS-Carb CASA-GFED Monthly Fire Fuel NPP Rh NEE Fluxes*
   Filename: *GEOSCarb_CASAGFED3v2_Flux.Monthly.x720_y360.**yyyy**.nc where **yyyy** = 2003 through 2016*
   doi: *https://doi.org/10.5067/FZU47Y00Q79U*

Science Variables

Name	Dim	Description	Units
NPP	tyx	Net primary production	kg (Carbon) m-2 mon-1
Rh	tyx	Heterotrophic respiration	kg (Carbon) m-2 mon-1
NEE	tyx	Net ecosystem exchange	kg (Carbon) m-2 mon-1
FIRE	tyx	Fire emissions	kg (Carbon) m-2 mon-1
FUEL	tyx	Wood fuel emissions	kg (Carbon) m-2 mon-1

GEOSCarb_CASAGFED3v2_Fire.Daily: **GEOS-Carb CASA-GFED Daily Fire and Fuel Emissions, version 2**

Frequency: *yearly, containing 365 daily values (366 in leap years)*
Dimensions: *longitude=720, latitude=360, time=365 (366 in leap years)*
Granule Size: *~720 MB*
Short name: *GEOS_CASAGFED_D_FIRE*
Truncated long name: *GEOS-Carb CASA-GFED Daily Fire and Fuel Emissions*
Filename: *GEOSCarb_CASAGFED3v2_Fire.Daily.x720_y360.****yyyy****.nc where ****yyyy**** = 2003 through 2016*
doi: *https://doi.org/10.5067/IYZIZJ8ZFZHU*

Science Variables

Name	Dim	Description	Units
FIRE	tyx	Fire emissions	kg (Carbon) m-2 day-1
FUEL	tyx	Wood fuel emissions	kg (Carbon) m-2 day-1

GEOSCarb_CASAGFED3v2_Flux.3hour: **GEOS-Carb CASA-GFED 3-hourly Ecosystem Exchange Fluxes, version 2**

Frequency: *monthly, containing values every 3 hours*
Dimensions: *longitude=576, latitude=361, time=days per month * 8*
Granule Size: *~390 MB*
Short name: *GEOS_CASAGFED_3H_NEE*
Truncated long name: *GEOS-Carb CASA-GFED 3-hourly Ecosystem Exchange Fluxes*
Filename: *GEOSCarb_CASAGFED3v2_Flux.Monthly.x576_y361.****yyyymm****.nc where ****yyyy**** = 2003 through 2016 and ****mm**** = 1 through 12*
doi: *https://doi.org/10.5067/5MQJ64JTBQ40*

Science Variables

Name	Dim	Description	Units
GEE	tyx	Gross ecosystem exchange	kg (Carbon) m-2 s-1
NEE	tyx	Net ecosystem exchange	kg (Carbon) m-2 s-1

GEOSCarb_CASAGFED3v3_Flux.Monthly**: **GEOS-Carb CASA-GFED Monthly Fluxes, version 3

Frequency: *yearly, containing 12 monthly values*
Dimensions: *longitude=720, latitude=360, time=12*
Granule Size: *~60 MB*
Short name: *GEOS_CASAGFED_M_FLUX*
Truncated long name: *GEOS-Carb CASA-GFED Monthly Fire Fuel NPP Rh NEE Fluxes*
Filename: *GEOSCarb_CASAGFED3v3_Flux.Monthly.x720_y360.**yyyy**.nc where **yyyy** = 2003 through 2017*
doi: *https://doi.org/10.5067/03147VMJE8J9*

Science Variables

Name	Dim	Description	Units
NPP	tyx	Net primary production	kg (Carbon) m-2 mon-1
Rh	tyx	Heterotrophic respiration	kg (Carbon) m-2 mon-1
NEE	tyx	Net ecosystem exchange	kg (Carbon) m-2 mon-1
FIRE	tyx	Fire emissions	kg (Carbon) m-2 mon-1
FUEL	tyx	Wood fuel emissions	kg (Carbon) m-2 mon-1

GEOSCarb_CASAGFED3v3_Fire.Daily**: **GEOS-Carb CASA-GFED Daily Fire and Fuel Emissions, version 3

Frequency: *yearly, containing 365 daily values (366 in leap years)*
Dimensions: *longitude=720, latitude=360, time=365 (366 in leap years)*
Granule Size: *~720 MB*
Short name: *GEOS_CASAGFED_D_FIRE*
Truncated long name: *GEOS-Carb CASA-GFED Daily Fire and Fuel Emissions*
Filename: *GEOSCarb_CASAGFED3v3_Fire.Daily.x720_y360.**yyyy**.nc where **yyyy** = 2003 through 2017*
doi: *https://doi.org/10.5067/7TQL49XLIMBD*

Science Variables

Name	Dim	Description	Units
FIRE	tyx	Fire emissions	kg (Carbon) m-2 day-1
FUEL	tyx	Wood fuel emissions	kg (Carbon) m-2 day-1

GEOSCarb_CASAGFED3v3_Flux.3hour**: **GEOS-Carb CASA-GFED 3-hourly Ecosystem Exchange Fluxes, version 3

Frequency: *monthly, containing values every 3 hours*
Dimensions: *longitude=576, latitude=361, time=days per month * 8*
Granule Size: *~390 MB*
Short name: *GEOS_CASAGFED_3H_NEE*
Truncated long name: *GEOS-Carb CASA-GFED 3-hourly Ecosystem Exchange Fluxes*

Filename: *GEOSCarb_CASAGFED3v3_Flux.Monthly.x576_y361.**yyyymm**.nc where **yyyy** = 2003 through 2017 and **mm** = 1 through 12*
doi: *https://doi.org/10.5067/VQPRALE26L20*

Science Variables

Name	Dim	Description	Units
GEE	tyx	Gross ecosystem exchange	kg (Carbon) m-2 s-1
NEE	tyx	Net ecosystem exchange	kg (Carbon) m-2 s-1

5. Glossary

FIRE: wildfire emission flux to the atmosphere
FUEL: fuel wood emission flux to the atmosphere
GEE: gross ecosystem exchange, carbon uptake from the atmosphere
NEE: net ecosystem exchange, net carbon flux to the atmosphere
NPP: net primary productivity, carbon flux to the vegetation
NEP: net carbon flux to the vegetation
Rh: heterotrophic respiration from ecosystem

Derivable flux variables:
NEP: monthly net ecosystem productivity, NEP=NPP-Rh
NBP: monthly net biome productivity, net flux to the ecosystem, NBP=NPP-Rh-FIRE-FUEL
3-hourly net flux to the atmosphere = NEE+FIRE+FUEL
Re: 3-hourly total ecosystem respiration: Re=NEE-GEE

6. Contacts

Lesley Ott (Lesley.Ott@nasa.gov)
Jim Collatz (George.J.Collatz@nasa.gov)
Randy Kawa (Stephan.R.Kawa@nasa.gov)

7. Acknowledgement of Funding

8. References

Campbell, J.E., Carmichael, G. R., Chai, T., Mena-Carrasco, M., Tang, Y., Blake, D.R., Blake, N.J., Vay, S.A., Collatz, G.J., Baker, I., Berry, J.A., Montzka, S.A., Sweeney, C., Schnoor, J.L., and Stanier, C.O., 2008, Photosynthetic control of atmospheric carbonyl sulfide during the growing season. Science, 322, 1085-1088.

Giglio, L., Boschetti, L., Roy, D.P., Humber, M.L., and Justice, C. O., 2018, The Collection 6 MODIS burned area mapping algorithm and product. Remote Sensing of Environment, 217, 72-85. doi:10.1016/j.rse.2018.08.005.

Hammerling, D.M., Michalak, A.M., O'Dell, C., and Kawa, S.R., 2012, Global CO2 distributions over land from greenhouse gases observing satellite (GOSAT). Geophysical Research Letters, 39, L08804, doi:10.1029/2012GL051203

Kawa, S.R., Mao, J., Abshire, J.B., Collatz, G.J., Xun, X., and Weaver, C.J., 2010, Simulation studies for a space-based CO2 lidar mission. Tellus 62B, 759-769.

Los, S.O., Collatz, G.J., Sellers, P.J., Malmstrom, C.M., Pllack, N.H., DeFries, R.S., Bounoua, L., Parris, M.T., Tucker, C.J., and Dazlich, D.A., 2000, A global 9-yr biophysical land surface dataset from NOAA AVHRR data. Journal of Hydrometeorology 1, 183-199.

Olsen, S.C, and Randerson, J.T., 2004, Differences between surface and column atmospheric CO2 and implications for carbon cycle research. Journal of Geophysical Research, 109, D02301, doi:10.1029/2003JD003968

Ott, L.E., Pawson, S., Collatz, G.J., Gregg, W.W., Menemenlis, D., Brix, H., Rousseaux, C.S., Bowman, K.W., Liu, J., Eldering, A., Gunson, M.R., and Kawa, S.R., 2015, Assessing the magnitude of CO2 flux uncertainty in atmospheric CO2 records using products from NASA's Carbon Monitoring Flux Pilot Project. J. Geophys. Res. Atmos., 120, 734-765, doi:10.1002/2014JD022411.

Pinzon, J.E., and Tucker, C.J., 2014, A Non-Stationary 1981–2012 AVHRR $NDVI_{3g}$ Time Series. Remote Sens., 6, 6929-6960.

Potter, C.S., Randerson, J.T., Field, C.B., Matson, P.A., Vitousek, P.M., Mooney, H.A., and Klooster, S.A. (1993), Terrestrial ecosystem production – A process model based on global satellite and surface data, Global Biogeochem. Cycles, 7, 811–841.

Randerson, J.T, Thompson, M.V., and Malmstrom, C.M., 1996, Substrate limitations for heterotrophs: Implications for models that estimate the seasonal cycle of atmospheric CO2. Global Biogeochemical Cycles 10, 585-602.

Rienecker, M. M., et al., 2011, MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications, J. Climate, 24, 3624–3648.

Tucker, C.J., Pinzon, J.E., Brown, M.E., Slayback, D.A., Pak, E.W., Mahoney, R., Vermote, E.F., and El Saleous, N., 2005, International Journal of Remote Sensing 26, 4485-4498.

van der Werf, G.R., Randerson, J.T., Collatz, G.J., Giglio, L., Kasibhatla, P.S., Arellano, A.F., Olsen, S.C., and Kasischke, E.S., 2004, Continental-scale partitioning of fire emissions during the 1997 to 2001 El Nino/La Nina period. Science 303, 73-76.

van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Kasibhatla, P.S., and Arellano Jr, A.F., 2006, Interannual variability of global biomass burning emissions from 1997 to 2004. Atmospheric Chemistry and Physics 6, 3423-3441

van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Mu, M., Kasibhatla, P.S., Morton, D.C., DeFries, R.S., Jin, Y., and van Leeuwen, T.T., 2010, Global fire emissions and the contribution of deforestation, agriculture, and peat fires (1997-2009). Atmospheric Chemistry and Physics 10, 11707-11735

van der Werf, G.R., Randerson, J.T., Giglio, L., van Leeuwen, T.T., Chen, Y., Rogers, B.M., Mu, M., van Marle, M.J.E., Morton, D.C., Collatz, G.J., Yokelson, R.J., and Kasibhatla, P.S., 2017, Global fire emissions estimates during 1997–2016, Earth Syst. Sci. Data, 9, 697–720, doi:10.5194/essd-9-697-2017.