NACP Regional Interim Synthesis Project

Description of Observations and Models

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1. Observational Data

1.1. MODIS GPP/NPP

Contact: Maosheng Zhao (zhao@ntsg.umt.edu)
Reference: Zhao et al. (2005)
Description:
The MOD17 MODIS GPP/NPP is the first continuous satellite-driven data set monitoring global vegetation productivity. The algorithm is based on the original logic of Monteith, suggesting that NPP under non-stressed conditions is linearly related to the amount of absorbed Photosynthetically Active Radiation (PAR) during the growing season. In reality, vegetation growth is subject to a variety of stresses that tend to reduce the potential growth rate, especially stresses resulting from climate (temperature, radiation, and water), or the interaction of these primary abiotic controls, which impose complex and varying limitations on vegetation activity in different parts of the world.

1.2. U.S. Forest Biomass

Contact: Gretchen G. Moisen (gmoisen@fs.fed.us)
Reference: Blackard et al. (2008)
Description:
This geospatial data set represents the first attempt by the FIA Remote Sensing Band (RSB) to address the need for geospatial data showing the extent and distribution of forest biomass in greater detail than is possible with the FIA plot data alone. These maps were created by modeling forest biomass collected on FIA sample plots as functions of more than sixty geospatially continuous predictor layers. Among the predictor layers used were digital elevation models (DEM) and DEM derivatives; Moderate Resolution Spectroradiometer (MODIS) multi-date composites, vegetation indices, and vegetation continuous fields; class summaries from the 1992 National Land Cover Data set (NLCD); various ecologic zones; and summarized PRISM climate data. Modeling was performed using a data mining package, Cubist/See5, which was loosely coupled with Leica Geosystems Imagine image processing software. One significant advantage of Cubist/See5 is that it is a non-parametric modeler that assumes nothing about the structure of the input data sets. RSB scientists produced the models and biomass geospatial data sets for their FIA unit's region of responsibility. In addition, each unit produced a forest/non-forest mask. The regional biomass data sets were compiled at the Remote Sensing Applications Center (RSAC), where the final data set was produced.

1.3. NASS Crop NPP

Contact: Tristram O. West (tristram.west@pnnl.gov)
Reference: West et al. (2011)
Description:
Carbon fixed by agricultural crops in the United States creates regional CO_2 sinks where it is harvested and regional CO_2 sources where it is released back to the atmosphere. The quantity and location of these fluxes differ depending on the annual supply and demand of crop commodities. Data on the harvest of crop

biomass, storage, import, and export, and on the use of biomass for food, feed, fiber, and fuel were compiled to estimate an annual crop carbon budget for 1996 to 2008. With respect to U.S. Farm Resource Regions, net sources of CO_2 associated with the consumption of crop commodities occurred in the Eastern Uplands, Southern Seaboard, and Fruitful Rim regions. Net sinks associated with the production of crop commodities occurred in the Heartland, Northern Great Plains, and Mississippi Portal regions.

1.4. MODIS LAI/fPAR (MOD15A2GFS)

Description:
The MODIS LAI/fPAR data products are based on MODIS MOD15A2 8-day, 1km resolution products. The level-4 MODIS global Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation (fPAR) product is composited every 8 days at 1-kilometer resolution on a Sinusoidal grid. Science Data Sets provided in the MOD15A2 include LAI, fPAR, a quality rating, and standard deviation for each variable. The LAI variable defines the number of equivalent layers of leaves relative to a unit of ground area, whereas fPAR measures the proportion of available radiation in the photosynthetically active wavelengths that are absorbed by a canopy. Both variables are used as satellite-derived parameters for calculating surface photosynthesis, evapotranspiration, and net primary production, which in turn are used to calculate terrestrial energy, carbon, water cycle processes, and biogeochemistry of vegetation. The MOD15A2 products were gap-filled and smoothed to derive product MOD15A2GFS for North American Carbon Program (NACP).

1.5. MODIS NDVI/EVI (MOD09A1G)

Description:
The MODIS NDVI/EVI data products are based on MODIS MOD09A1 8-day, 500m resolution products. MOD09A1 provides Bands 1–7 at 500-meter resolution in an 8-day gridded level-3 product in the Sinusoidal projection. Each MOD09A1 pixel contains the best possible L2G (gridded level 2) observation during an 8-day period as selected on the basis of high observation coverage, low view angle, the absence of clouds or cloud shadow, and aerosol loading. Science Data Sets provided for this product include reflectance values for Bands 1–7, quality assessment, and the day of the year for the pixel along with solar, view, and zenith angles. The MOD09A1 data product was gap-filled and smoothed to derive data product MOD09A1G for North American Carbon Program (NACP).

1.6. Flux Anomaly

Contact: Christopher Schwalm (Christopher.Schwalm@nau.edu)
Reference: Schwalm et al. (2009)
Description:
This data contains flux anomalies calculated using upscaled water deficit ~ carbon balance relationships (Schwalm et al., 2009). It contains three variables: nep_anomaly, gep_anomaly, reco_anomaly, which represent net ecosystem productivity, gross ecosystem productivity, and ecosystem respiration, respectively,

at 1-degree spatial and monthly time resolution. Evaporative fraction (water deficit) anomalies used in upscaling were taken from the NCEP 2 Reanalysis data for terrestrial biomes only. Data were regridded from T62 to 1 deg resolution. http://www.cdc.noaa.gov/data/gridded/data.ncep.reanalysis2.html. The biome mask (1 deg resolution), based on the International Geosphere-Biosphere DISCover land cover legend, was taken from ISLSCP II. All co-occurring biomes were used in upscaling (not just the dominant biome).
Caveats:

- Biome mask is invariant over full date record; land-cover change was not modeled.
- The Southern Hemisphere was under sampled (95% of relationships come from Northern Hemisphere).
- Seasonality was defined based on calendar month only, note "stripe" around equator (this is also related to under sampling in the Southern Hemisphere).
- Gap-filled, flux-partitioned eddy covariance data were used, primarily for gross ecosystem productivity and ecosystem respiration. Although only high quality data were accepted, the uncertainty in gap filling and flux partitioning was propagated through this upscaled product.

2. Terrestrial Biosphere Models

2.1. Prognostic Models

2.1.1. Biome-BGC

Contact: David Turner (david.turner@oregonstate.edu)
References: Thornton et al. (2002); Turner et al. (2007)
Description:
Biome-BGC is a process-based model that simulates the storage and fluxes of water, carbon, and nitrogen between the different compartments in the ecosystem and the atmosphere. The model is a development of the Forest-BGC model, and it uses a daily time-step for in- and output variables. There is only one layer in the canopy, but the leaf area is divided into shaded and sunlit parts. Photosynthesis is based on the Farquhar model (Farquhar et al., 1980). Canopy conductance to CO_2 and water vapor is regulated by air temperature, vapor pressure deficit, radiation, and model soil water potential. The litter and soil have one layer each but the layers are divided into four pools, each with different decomposition parameters. The initial stocks of carbon are either given as initial values to the model or are estimated from spin-up simulations. The amounts of nitrogen in the different pools are estimated on basis of amount of carbon and the corresponding C/N-ratio of the respective pool. Turnover rates and allocation parameters decide how the production is distributed between the compartments.

2.1.2. Can-IBIS

Contact: David Price (dprice@nrcan.gc.ca)
References: El Maayar et al. (2002); Foley et al. (1996); Kucharik et al. (2000, 2006)

Description:
Can-IBIS (Canadian Integrated BIosphere Simulator), based on version 2.1 of IBIS (Kucharik et al., 2000), is a DGVM that is hierarchically organized to couple ecological, biophysical, and physiological processes, each of which operates at different timescales (Foley et al., 1996). Carbon exchange and stomatal regulation of both C_3 and C_4 species are simulated with a leaf level enzyme kinetic approach (Ball et al., 1987; Collatz et al., 1991, 1992; Farquhar et al., 1980). Stem and root respiration are dependent on the magnitude of the C pool, and for stems, the sapwood fraction of the total stem biomass (Kucharik et al., 2000). Daily flows of C and nitrogen through decomposition of detritus and soil organic matter are handled similarly to the CENTURY model (Parton et al., 1993). Additional References: El Maayar et al. (2002); Kucharik et al. (2006)

2.1.3. CLM-CASA, CLM-CN

Contact: Forrest Hoffman (forrest@climatemodeling.org), Peter Thornton (thorntonpe@ornl.gov)
References: Dickinson et al. (2006); Thornton and Rosenbloom (2005)
Description:
Both CLM-CASA and CLM-CN merge the biophysical framework of the Community Land Model (CLM 3.0) (Bonan and Levis, 2006; Dickinson et al., 2006; Oleson et al., 2004) with a terrestrial biogeochemistry model. Photosynthesis is computed by CLM for both models. For C_3 plants, photosynthesis is based on the models of Farquhar et al. (1980) and Collatz et al. (1991), while for C_4 plants, uptake is based on the models of Collatz et al. (1992) and Dougherty et al. (1994). For CLM-CASA, the leaf litterfall is specified by CLM's phenology based on satellite observations (Huntzinger et al., 2012). Autotrophic respiration is a fixed fraction (50%) of net canopy photosynthesis, and decomposition follows the CENTURY model as described for the versions of CASA with only C considered. CLM-CN follows the fully prognostic carbon and nitrogen dynamics of the terrestrial biogeochemistry model Biome-BGC (version 4.1.2) (Thornton and Rosenbloom, 2005; Thornton et al., 2002). Canopy-level photosynthesis is calculated in a similar fashion as CLM-CASA, but with a different canopy integration scheme. The sunlit and shaded leaf-level rates are scaled by the sunlit and shaded leaf area indices, with potential reductions due to limited availability of mineral nitrogen. The model treats maintenance and growth respiration processes separately (Thornton and Rosenbloom, 2005). Output of models CLM-CASA and CLM-CN originated from project Carbon Land Model Intercomparison Project (C-LAMP, http://www.climatemodeling.org/c-lamp). There are 4 CLM-CASA simulations and 2 CLM-CN simulations involved in the NACP regional interim synthesis:

CLM-CASA Simulations	i01.54casa	CLM3.6-CASA with new down-regulated PFT physiology, new surface dataset, and Q_{10} = 2.0
	i01.54casa_q15	CLM3.6-CASA with new down-regulated PFT physiology, new surface dataset, and Q_{10} = 1.5

	i01.55casa	CLM3.6-CASA with new down-regulated and grass optical properties PFT physiology, new surface dataset, and Q_{10} = 2.0
	i01.55casa_q15	CLM3.6-CASA with new down-regulated and grass optical properties PFT physiology, new surface dataset, and Q_{10} = 1.5
CLM-CN Simulations	i01.56cn	CLM3.6-CN with new CN PFT physiology, N deposition time series, new surface dataset, and Lloyd & Taylor decomposition respiration
	i01.57cn_q15	CLM3.6-CN with new CN PFT physiology, N deposition time series, new surface dataset, strong day length control on photosynthesis, Q_{10} = 1.5 for decomposition respiration, and Q_{10} = 1.5 for maintenance respiration

2.1.4. DLEM

Contact: Hanqin Tian (tianhan@auburn.edu)

References: Tian et al. (2008); Ren et al. (2007); Liu et al. (2008)

Description:

The Dynamic Land Ecosystem Model (DLEM) simulates daily carbon, water and nitrogen cycles as influenced by atmospheric chemistry (CO_2, ozone concentration and nitrogen deposition), climate, land-cover and land-use change, and other disturbances (fire, insect/disease, hurricane, and harvest) (Tian et al., 2010a, 2011a; Liu et al., 2008; Xu et al, 2010; Ren et al., 2011). Photosynthesis is calculated using a modified Farquhar model (Bonan and Levis, 2006; Collatz et al., 1991, 1992; Dougherty et al., 1994; Farquhar et al., 1980) that is constrained by nitrogen and phosphorus availability (Lu et al., 2012) and tropospheric ozone influences (Ollinger et al., 1997; Ren et al, 2007; Zhang et al., 2007). DLEM simulates vegetation carbon loss through autotrophic respiration (maintenance and growth) (Tian et al., 2010a), decomposition, and disturbances (e.g., land conversion and harvest) (Tian et al., 2003; Houghton et al., 1983). The decomposition of litter and soil organic carbon is controlled by soil temperature, moisture, and nitrogen content (Tian et al., 2010a). DLEM also simulates soil carbon loss through CH4 emissions from ecosystem to the atmosphere (Tian et al., 2010b, 2011b; Xu et al., 2010).

2.1.5. ISAM

Contact: Atul Jain (jain@atmos.uiuc.edu)

References: Jain and Yang (2005); Yang et al. (2009)

Description:

The Integrated Science Assessment Model (ISAM) was originally developed as a tool to project the likely impacts of future changes in CO_2 on terrestrial ecosystems as a result of fossil fuel burning, land-use and land-cover change, and forest fires (Jain et al., 1996; Jain and Yang, 2005; Yang et al., 2009). NPP is represented as a semi empirical function of temperature, precipitation (Huntzinger et al., 2012), and biomass and is formulated to increase with rising CO_2 (Polglase and Wang, 1992). Through the development of a process-based representation of the complete N cycle, ISAM now accounts for the effect of mineral N availability on NPP. Respiration from vegetation pools follows the Q10 formulation described by Kheshgi et al. (1996). ISAM links C and N in vegetation and soil through litter fall, decomposition, N mineralization, and N uptake by plants (Yang et al., 2009). The C decomposition dynamics in aboveground litter and soil are based on the CENTURY model (Parton et al., 1987), while C dynamics in belowground litter follow that of the RothC model (Jenkinson et al., 1991).

2.1.6. LPJmL

Contact: Ben Poulter (ben.poulter@pik-potsdam.de)
References: Gerten et al. (2004); Sitch et al. (2003)
Description:
The Lund-Potsdam-Jena managed Land (LPJmL) model is a dynamic global vegetation model (DGVM) that simulates the carbon and water cycles of natural, semi-natural, and anthropogenic ecosystems (Bondeau et al., 2007; Sitch et al., 2003; Zaehle et al., 2007). GPP is calculated for each plant functional type (PFT) as a linear function of absorbed photosynthetically active radiation (APAR) with limiting rates in the equation derived from the Farquhar photosynthesis equation (Haxeltine and Prentice, 1996a,b; Sitch et al., 2003). Autotrophic respiration is the sum of growth respiration, which is a fixed (25%) fraction of the amount of carbon produced, and maintenance respiration that includes fixed C:N ratios (Ryan, 1991; Sprugel et al., 1995). Soil carbon decomposition is based on an empirical Arrhenius equation, dependent on temperature (Lloyd and Taylor, 1994), tissue type, and moisture (Foley, 1995).

2.1.7. MC1

Contact: Ronald P. Neilson (rneilson@fs.fed.us)
Reference: Bachelet et al. (2001)
Description:
MC1 (Bachelet et al., 2000, 2001, 2004; Daly et al., 2000; Lenihan et al., 2008) is a DGVM that consists of three linked models simulating biogeography [MAPSS model (Neilson, 1995)], biogeochemistry [modified version of CENTURY (Parton et al., 1987, 1993)], and fire disturbance (Lenihan et al., 1998). The biogeography module predicts the composition of deciduous/evergreen trees and C_3/C_4 grass life form mixtures, and then classifies the predicted biomass into different vegetation classes. The biogeochemistry module (CENTURY) simulates above- and belowground processes, including plant production, soil organic matter decomposition, and water and nutrient cycling. NPP is calculated as an empirical function of soil (Huntzinger et al., 2012), temperature, soil moisture, and nutrient availability, which decrease or augment set values of maximum potential productivity. Decomposition follows that of CENTURY and is a function of temperature, soil moisture, soil texture, and N dynamics. MC1 also simulates the occurrence, behavior, and effects of severe fires. NPP, Rh and NEE are strongly sensitive to water supply from direct inputs and demand based on temperature, plant phenology, rooting depth, and canopy conductance.

2.1.8. ORCHIDEE

Contact: Nicolas Viovy (viovy@lsce.ipsl.fr)
Reference: Krinner et al. (2005)
Description:

The Organizing Carbon and Hydrology in Dynamic Ecosystems (ORCHIDEE) model is a DGVM that describes carbon, energy, and water fluxes (Krinner et al., 2005; Viovy et al., 2000). Photosynthesis follows Farquhar et al. (1980) for C_3 plants and Collatz et al. (1992) for C_4 plants. Autotrophic respiration is treated as the sum of maintenance and growth respiration. In the model, maintenance respiration is a function of temperature, biomass, and fixed C:N ratios, and growth respiration is calculated as a fixed (28%) fraction of production for each PFT. The treatment of heterotrophic respiration follows that of the CENTURY model (Parton et al., 1993), and depends on soil moisture and temperature using a modified Arrhenius function (Lloyd and Taylor, 1994).

2.1.9. SiB3.1

Contact: Ian Baker (baker@atmos.colostate.edu)
Reference: Baker et al. (2008)
Description:
The Simple Biosphere model (SiB) is a land-surface parameterization scheme originally used to simulate biophysical processes in climate models (Baker et al., 2008; Sellers et al., 1986), but later adapted to include ecosystem metabolism (Denning et al., 1996; Sellers et al., 1996). The parameterization of photosynthetic carbon assimilation is based on enzyme kinetics (Farquhar et al., 1980) and linked to stomatal conductance, and therefore to the surface energy budget and atmospheric climate (Collatz et al., 1991, 1992; Sellers et al., 1996). Soil respiration is calculated from the temperature and moisture of each soil layer. Historically, SiB has scaled heterotrophic respiration to achieve carbon balance over an annual cycle (Denning et al., 1996). In SiB3.1, respiration is still scaled, however the scaling factors are dependent on the previous year's respiration. Thus SiB3.1 reaches carbon balance over longer simulation periods rather than annually.

2.1.10. TEM6

Contact: A. David McGuire (ffadm@uaf.edu)
References: McGuire et al. (2001); Felzer et al. (2004); Euskirchen et al. (2006); Balshi et al. (2007)
Description:
The Terrestrial Ecosystem Model (TEM) is a process-based, global-scale biogeochemistry model that uses spatially explicit climate, vegetation, and soil data to estimate monthly pools and fluxes of C and N in the terrestrial biosphere (Melillo et al., 1993; Zhuang et al., 2006). Photosynthesis is a function of PAR, leaf area, canopy leaf biomass, temperature, atmospheric CO_2, canopy conductance, and nitrogen availability (Zhuang et al., 2002). TEM considers the limiting effects of plant nitrogen status on GPP (McGuire et al., 1992; Pan et al., 1998). The results presented here are from simulations using a version of the model (TEM6) that considers the influence of transient global atmospheric CO_2 concentration, tropospheric ozone pollution effects, permafrost and active layer dynamics, atmospheric nitrogen deposition, biological nitrogen fixation, dissolved organic C leaching and N losses, wildfire, agricultural conversion and abandonment, and timber harvest on terrestrial C dynamics (McGuire et al., 2010).

2.1.11. VEGAS

Contact: Ning Zeng (zeng@atmos.umd.edu)
References: Zeng et al. (2005a,b)
Description:
The Vegetation Global Atmosphere and Soil (VEGAS) model is a DGVM that simulates the dynamics of vegetation growth and competition among 4 PFTs (Zeng, 2003; Zeng et al., 2004, 2005a,b). Photosynthesis is calculated by light-use efficiency, and is a function of temperature, soil moisture, and atmospheric CO_2. Different photosynthetic pathways are distinguished for C_3 and C_4 plants, and carbon assimilation is allocated into three vegetation carbon pools: leaf, root, and wood. After accounting for autotrophic respiration, the biomass turnover from these carbon pools is transported into fast, intermediate, and slow soil carbon pools. Temperature and moisture dependent decomposition returns carbon back into the atmosphere.

2.2. Diagnostic Models

2.2.1. BEPS

Contact: Jing Chen (chenj@geog.utoronto.ca)
References: Chen et al. (1999); Liu et al. (1999); Ju et al. (2006)
Description:
The Boreal Ecosystems Productivity Simulator (BEPS) (Chen et al., 1999; Ju et al., 2006) is based on the site-level process model, FOREST-BGC (Running and Coughlan, 1988), and uses satellite data to map the net carbon absorption rate by plants across North America. Daily C fixation is calculated using a Farquhar's leaf biochemical model (Farquhar et al., 1980), while stomatal conductance is computed using a modified version of the Ball–Woodrow–Berry model (Ball et al., 1987; Huntzinger et al., 2012). The canopy is stratified into overstory and understory layers, and each layer is separated into sunlit and shaded leaf groups. For each layer, C, water, and energy fluxes are simulated separately, and then are scaled spatially and temporally up to canopy level (Chen et al., 1999). Plant respiration is a function of GPP and air temperature, while BEPS's module for soil C, N, and heterotrophic respiration follows that of the CENTURY model (Parton et al., 1993). Soil water balance within the model is calculated using a one-layer bucket model.

2.2.2. CASA-GFEDv2, CASA, NASA-CASA

Contact: Jim Randerson (jranders@uci.edu), Chris Potter (chris.potter@nasa.gov), Guido van der Werf (guido.van.der.werf@falw.vu.nl)
References: Randerson et al. (1997); Potter et al. (1993, 2007); van der Werf et al. (2006)
Description:
The Carnegie-Ames-Stanford-Approach (CASA) is a satellite-data driven, biogeochemical model that uses a system of first-order linear differential equations to represent the flow of carbon between various pools and track the long-term change in terrestrial carbon stocks on a monthly time-step (Potter et al., 1993;

Randerson et al., 1997; Schaefer et al., 2008). There are three versions of CASA included in this study (CASA, CASA-GFEDv2, and NASA-CASA), each of which computes monthly productivity as a product between fPAR and a light use efficiency constant that is modulated by temperature and moisture effects (Potter et al., 1993). In addition, CASA's below ground soil organic matter model largely follows the structure of CENTURY (Parton et al., 1987). Here, the model termed "CASA" is based on the steady-state simulations from Randerson et al. (1997), where fPAR is estimated from NOAA/NASA Pathfinder NDVI. These fluxes served as a priori information in, among other studies, the TransCom3 inversion intercomparison study (Gurney et al., 2004). CASA GFEDv2 (van der Werf et al., 2004, 2006) is based on CASA (Randerson et al., 1997), although fPAR is estimated from Advanced Very High Resolution Radiometer (AVHRR) NDVI and the model accounts for the indirect effects of forest fires (e.g. mortality and subsequent decay and re-growth) on carbon stocks in CASA's above-ground carbon pools (leaf, wood, and litter). In both CASA and CASA GFEDv2, the light utilization efficiency term is set uniformly to a value derived from calibration of predicted annual net primary production (NPP) to previous field estimates (Potter et al., 1993). NASA-CASA (Potter et al., 2007) is an updated, more recent version of CASA that estimates fluxes on a finer, 8-km resolution using an aggregated version of the Moderate Resolution Imaging Spectroradiometer (MODIS) 1-km land-cover (Friedl et al., 2002; Huntzinger et al., 2012). Instead of using NDVI to estimate fPAR, NASA-CASA is set up to use MODIS enhanced vegetation index (EVI) data sets. In addition, the light utilization efficiency constant has been adjusted for different cropland types to account for the impact of nutrient addition to crop yield and biomass production, and the water stress term has been set to be unity (no water stress) in irrigated lands (Potter et al., 2007).

2.2.3. EC-LUE

Contact: Shuguang Liu (sliu@usgs.gov)
Reference: Yuan et al. (2007)
Description:
The Eddy-Covariance Light Use Efficiency (EC-LUE) model is, as its name implies, a light use efficiency model for predicting gross primary production (GPP) across biomes based on eddy covariance flux data (Yuan et al., 2007). There are two main assumptions within the model: (1) fPAR is a linear function of NDVI; and (2) the realized light use efficiency is controlled by air temperature or soil moisture, or whichever is most limiting. The calculated GPP is independent of vegetation type and no other component fluxes or carbon pools are estimated. EC-LUE was calibrated and validated using daily GPP estimates derived from 28 eddy covariance flux towers from the AmeriFlux and EuroFlux networks, covering a variety of forests, grasslands, and savannas.

2.2.4. EC-MOD

Contact: Jingfeng Xiao (j.xiao@unh.edu)
References: Xiao et al. (2008, 2010, 2011)
Description:
EC-MOD is based on a regression tree analysis that predicts relationships between

various MODIS variables and NEE and GPP at 1km resolution across North America (Xiao et al., 2008, 2010, 2011). The predictive relationships are based on observed NEE and estimated GPP from eddy covariance measurements along with the MODIS satellite indices: enhanced vegetation index (EVI), land surface temperature (LST), normalized difference water index NDWI (an index of canopy water stress), fPAR, and LAI. The site level data set of AmeriFlux and MODIS data was split into a training set (2000–2004) and a test set (2005–2006).

2.2.5. MOD17-plus

Contact: Enrico Tomelleri (etomell@bgc-jena.mpg.de)
Reference: Reichstein et al. (2005)
Description:
MOD17+ is a semi-empirical diagnostic model that estimates NEE, NPP, and ecosystem respiration (Re) using satellite data (Reichstein et al., 2005). The model is based on the same radiation-use efficiency model used in the global MODIS-GPP product (Running et al., 2004). The MOD17+ algorithm is optimized, however, against GPP time series from the FLUXNET measurement network through Bayesian data model synthesis, where the efficiency terms in the MODIS-MOD17 biome specific look-up table (Heinsch et al., 2003) are used as priors. Respiration is dependent on both GPP and temperature (Reichstein et al., 2003), and like the MODIS MOD17 product, no carbon pools are used.

3. Inverse Models

3.1. CarbonTracker

Contact: Andy Jacobson (andy.jacobson@noaa.gov), CarbonTracker team (carbontracker.team@noaa.gov)
Reference: Peters et al. (2007)
Description:

Institution	NOAA Earth System Research Laboratory, Boulder, CO 80305 U.S.A.
URL	http://carbontracker.noaa.gov
Inversion spatial resolution	Around 200 global regions, supersets of the 22 Transcom regions. Each terrestrial Transcom region is divided by Olson ecosystem types, of which there are 19. Nonexistent combinations are discarded (e.g., boreal forests in north Africa). Thirty (30) ocean regions from ocean inversions are used. These are subdivisions of the 11 Transcom ocean regions. There are 29 such regions in North America; 12 in region 1, and 17 in region 2.
Inversion temporal resolution	Fluxes are solved for on a weekly basis from 2000-2006.

Inversion methodology	Ensemble Kalman filter is used to estimate scaling factors. These factors multiply first-guess fluxes from process models. Fossil fuel emissions are prescribed. The land process model is a CASA variant used in computing GFEDv2 fire emissions (van der Werf et al., 2006). The fire emissions themselves are not optimized, but the CASA NPP and Rh fluxes are combined into a non-fire NEE, which is scaled by the optimization. The ocean process model builds on the ocean inversions of Jacobson et al. (2007 a,b). Net air-sea exchange is modeled as a pCO_2 disequilibrium multiplied by a gas transfer velocity parameterized from TM5 wind speeds.
Atmospheric transport	TM5 with 6x4 degree global resolution, refined to 1x1 degree over North America.
Can do 1x1 degree fluxes?	Yes. There is a prescribed 1x1 distribution underlying the fluxes in each of the inversion regions. Grid boxes are centered on 0.5-degree values.
Can provide formal 22-region errors?	Yes.
Other references	van der Werf et al. (2006); Jacobson et al. (2007a,b)

3.2. University of Toronto Nested Global

Contact: Jing Chen (chenj@geog.utoronto.ca)
Reference: Deng et al. (2007)
Description:

Institution	University of Toronto/Environment Canada
URL	http://www.geog.utoronto.ca/info/facweb/Chen/Chen's homepage/res_inverse.htm
Inversion spatial resolution	Thirty (30) regions in North America, delineated with ecosystem and province/state boundaries; Transcom outside of North America (20 remaining regions).
Inversion temporal resolution	Monthly, 1994-2003
Inversion methodology	Bayesian Synthesis
Atmospheric	NIES

transport	
Can do 1x1 degree fluxes?	yes, on 0.5-degree centers
Can provide formal 22-region errors?	yes
Other references	For bottom-up used for constraint: Chen et al. (2003)

3.3. Michigan Geostatistical

Contact: Anna Michalak (amichala@umich.edu)
Reference: Michalak et al. (2004)
Description:

Institution	University of Michigan & NOAA
URL	none
Inversion spatial resolution	1x1 from 10-70N, 50-170W
Inversion temporal resolution	2004 and 2006 only, 8-day and monthly resolution
Inversion methodology	Geostatistical inversion estimating both biospheric & fossil fuel fluxes using: (1) hourly concentration data from 13 continuous measurement sites and weekly flask measurements from 6 more sites within United States, Canada, and Caribbean; (2) boundary conditions from Carbon Tracker; (3) STILT particle-tracking model with high-resolution nested WRF winds; and (4) auxiliary environmental data from remote-sensing, biospheric / climatological model output, and socioeconomic data sets. Method selects statistically significant set of auxiliary variables for model of trend flux and optimizes spatial covariance parameters of flux residuals using atmospheric data. Final estimates are combination of trend flux and spatio-temporally correlated flux residuals.
Atmospheric transport	STILT with nested WRF winds
Can do 1x1 degree fluxes?	yes, on 0.5-degree centers
Can provide formal 22-region errors?	no

Other references	Mueller et al. (2008); Gourdji et al. (2008)

3.4. LSCE No.1 (Peylin-LSCE)

Contact: Philippe Peylin (Philippe.Peylin@lsce.ipsl.fr), Philippe Ciais
Description:

Institution	LSCE
URL	N/A
Inversion spatial resolution	Transcom regions
Inversion temporal resolution	monthly, 2000-2004
Inversion methodology	Bayesian synthesis, pixel based
Atmospheric transport	LMDz
Can do 1x1 degree fluxes?	N/A
Can provide formal 22-region errors?	N/A
Other references	N/A

3.5. LSCE no.2 (Chevallier-LSCE)

Contact: Frederic Chevallier (Frederic.Chevallier@lsce.ipsl.fr), Philippe Peylin (Philippe.Peylin@lsce.ipsl.fr)
References: Chevallier et al. (2005, 2007)
Description:

Institution	LSCE
URL	
Inversion spatial resolution	global 3.75x2.5
Inversion temporal resolution	8-day increments on top of 3-hourly fluxes
Inversion	variational

methodology	
Atmospheric transport	LMDZ
Can do 1x1 degree fluxes?	yes, using prior subgrid distributions
Can provide formal 22-region errors?	yes, via Monte Carlo
Other references	Chevallier (2007)

3.6. Jena

Contact: Christian Rödenbeck (christian.roedenbeck@bgc-jena.mpg.de)
References: Rödenbeck (2005); Rödenbeck et al. (2003)
Description:

Institution	Max-Planck-Institut für Biogeochemie Jena (MPI BCG)
URL	http://www.bgc-jena.mpg.de/~christian.roedenbeck/download_CO2/
Inversion spatial resolution	approximately 4x5 degrees over land
Inversion temporal resolution	daily, but sub-weekly variations are smoothed
Inversion methodology	- Individual flask or hourly data, - prior constraints via 'statistical flux model' setting spatial/temporal correlations and weighting, - iterative solution by re-orthogonalized Conjugate Gradients
Atmospheric transport	TM3
Can do 1x1 degree fluxes?	yes, by subsampling
Can provide formal 22-region errors?	yes
Other references	

3.7. CSU no. 1 (MLEF-PCTM)

Contact: Ravi Lokupitiya (ravi@atmos.colostate.edu), Scott Denning (denning@atmos.colostate.edu)
Reference: Lokupitiya et al. (2008)
Description:

Inversion	CSU no. 1 (MLEF-PCTM)
Institution	Colorado State University
URL	
Inversion spatial resolution	2.5x2 degrees
Inversion temporal resolution	hourly
Inversion methodology	Ensemble based with Maximum Likelihood Estimation. Estimate separates multiplicative biases in photosynthesis, respiration, and air-sea gas exchange.
Atmospheric transport	PCTM
Can do 1x1 degree fluxes?	yes, by interpolation
Can provide formal 22-region errors?	yes
Other references	Zupanski et al. (2007)

3.8. CSU no. 2

Contact: Andrew Schuh (aschuh@atmos.colostate.edu), Scott Denning (scott.denning@colostate.edu)

Description:

Institution	Colorado State University
URL	
Inversion spatial resolution	100 km (60x36 grid)
Inversion temporal resolution	Prior at hourly, inversion at semi-weekly to monthly, 2004 only
Inversion methodology	SiB-generated prior flux estimates at hourly resolution. Sequential independent bayes inversions at semi-weekly to monthly time scale, of hourly tower observations.
Atmospheric transport	RAMS
Can do 1x1 degree fluxes?	Yes
Can provide formal	Possibly, limited domain, possibly truncating extreme northern

22-region errors?	portions of North America
Other references	

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