Supporting Information for

A modified Vegetation Photosynthesis and Respiration Model (VPRM) for the eastern USA and Canada, evaluated with comparison to atmospheric observations and other biospheric models

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S1. VPRM input data

All flux tower Net Ecosystem Exchange (NEE) and meteorological data (air temperature and radiation) was downloaded from the AmeriFlux (https://ameriflux.lbl.gov/) and National Ecological Observatory Network (NEON; https://www.neonscience.org/) websites. Half-hourly flux tower data was averaged to hourly, discarding hours without both half-hour observations. All flux tower NEE data was u-star filtered using site-specific thresholds determined visually by plotting averaged nighttime NEE along binned u-star intervals (Barr et al., 2013). Small gaps (of two hours or less) in both NEE observations and meteorological data were then gap-filled using linear interpolation. Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) were also extracted at each flux tower location using the R package MODISTools (https://cran.r-project.org/web/packages/MODISTools/index.html) from the MOD13Q1/MYD13Q1 and MOD09A1/MYD09A1 products. EVI and LSWI data was interpolated to daily resolution, assuming that observations occurred in the middle of each composite period (in the absence of satellite overpass information).

Given that the distribution of flux tower site-years in our database is heavily tilted towards the north of the domain, data from northern sites with long records were subsampled to emphasize more recent years, with some sites in locations coincident with other towers also removed (e.g. US-NE1). Yet, even after this procedure, 70% of site-years in the database are still north of 40°N. Also, given that u-star filtering tends to preferentially eliminate night-time relative to day-time data (roughly by a factor of two), a nonparametric bootstrapping procedure (i.e. sampling with replacement, Chernick, 2007) was performed to “create” extra nighttime data. Grouping data by hour and month, bootstrap samples were taken on existing observations in each group to reach the maximum number of hourly data points in that month. This bootstrapped data was then added to existing datapoints. Overall, this procedure ensures an equal distribution of data across the diurnal cycle for each month in the parameter optimization (with a random sampling across sites and years). Before bootstrapping, roughly 15% of the data was also reserved for evaluation of the site-specific VPRM runs. This evaluation data was selected by randomly choosing one full calendar day per month per tower from the original, non-bootstrapped data. This procedure ensures even representation of evaluation data across diurnal and seasonal cycles (but not necessarily across sites, each of which has its own length data record).

For the gridded runs, land cover maps for VPRM are taken from the National Land Cover Database 2016 (NLCD2016; Yang et al., 2018) in the USA, with corn and other crop areas determined from the Cropland Data Layer (Boryan et al., 2011) specifically for 2017. In Canada, the Agriculture and Agri-Food Canada Annual Crop Inventory 2017 (Agriculture and Agri-Food Canada, 2016); which includes non-crop land cover types as well) was used. All high-resolution (i.e 30 m) land-cover products were aggregated up to 0.02° to determine fractional coverage across pixels in our domain.
Gridded maps of Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) are extracted from the MODIS Aqua and Terra products MOD13A2/MYD13A2 and MOD09A1/MYD09A1 at 1 km and 500 m resolution respectively, and then aggregated up to 0.02°. EVI and LSWI maps are interpolated to daily resolution from 8 and 16-day composites respectively, using the actual dates of the satellite overpass within the composite period for each pixel. Using satellite overpass dates in the interpolation has been shown to help improve the simulation of phenology with remotely-sensed vegetation indices, particularly in croplands with short growing seasons (Guindin-Garcia et al., 2012; Lokupitiya et al., 2009). However, the actual gap between successive overpasses can be as short as one or as long as 24 days (with an average interval of 8 days for EVI and 4 days for LSWI).

Gridded air temperature and shortwave radiation data are taken from the High Resolution Rapid Refresh (HRRR; Benjamin et al., 2016) model, which is at 3-km resolution and then downscaled to 0.02°. The high spatial resolution of the HRRR product relative to other meteorological products (like NLDAS, Xia et al., 2012, or the WRF runs for this domain) helps to simulate temperature gradients in urban and mountainous areas better than coarser-resolution products (Figure S1.1). Many radiation products are known to have a clear-sky bias (i.e. they under-represent cloudy conditions; Slater, 2016), including the HRRR radiation product used here, although the HRRR biases are less than those with WRF (as seen in a comparison to flux tower and NEON tower observations and other models in our domain, Figure S1.2). Although biases in the gridded meteorological data can bias flux estimates, we considered the magnitude of these biases to be small relative to other sources of error, and therefore, did not bias-correct the gridded temperature or radiation data. Site-specific weather variables at the flux towers are also used in the parameter optimization rather than modeled met data, given the relatively small model errors seen here.

Figure S1.1: Comparison of gridded temperature data from HRRR, NLDAS and WRF to surface observations at nine NEON and AmeriFlux towers within the domain from Nov. 1, 2016 to Oct. 31, 2017. Daytime and night-time mean biases are shown in the left and center plots, and 24-hour root mean squared errors (RMSE) in the right plot. HRRR data is at 3 km spatial resolution, NLDAS at 1/8th degree (~12 km), and WRF at 9 km (with 1 km and 3 km nests around Washington DC/ Baltimore.)
Figure S1.2: Comparison of gridded shortwave radiation data from HRRR, NLDAS and WRF to surface observations at NEON and AmeriFlux towers. Daytime mean biases and hourly root mean squared errors (RMSE) are shown for each tower, plus the average across towers. Also shown is the distribution of hourly radiation across all towers within four bins (<=150 W/m², 150 to 300 W/m², 300 to 600 W/m² and 600 to 1000 W/m²) for each model and the observations.

S2. Determination of afternoon hours in atmospheric CO₂ observations
In this study, “afternoon” hours are defined as hours when the middle falls five hours after sunrise and just before sunset, thus increasing the number of observations during the height of the growing season relative to studies that use a fixed interval, e.g. 12 pm – 4 pm local time. For example, at DNH (Durham, NH) in the north of the domain, sunrise and sunset on July 1, 2017 are at 5:12 am and 8:35 pm EDT, and thus we would use eleven hourly observations from 10 am - 9 pm EDT on this day. This definition of afternoon hours relative to sunrise and sunset time was determined by examining vertical gradients in measurements across inlet heights (on towers with multiple inlets) to identify when well-mixed conditions are most likely to occur. As seen in Figure 3d in the main text, the gradient across towers during the growing season (July) is lower during afternoon hours compared with other times of day.

S3. Customized WRF and STILT runs to generate footprints
Following Lopez-Coto et al. (2020), WRF is configured with three nested domains (9 km, 3 km, and 1 km), with the innermost domain covering the urban area of interest, and 60 vertical levels with monotonically increasing thickness from the surface (34 levels below 3 km) for better boundary layer representation. WRF model runs are configured with the RRTMG radiation scheme (Mlawer et al., 1997), Thompson microphysics scheme (Thompson et al., 2004, 2008), Noah land surface model (Chen & Dudhia, 2001), the Kain-Fritsch cumulus scheme (for the 9 km domain only; Kain, 2004), the 1.5- order closure scheme MYNN (Nakanishi & Niino, 2004, 2006) with the eddy mass-flux option (Olson et al., 2019) and the land-use classification from NLCD 2011 (Yang et al., 2018) which includes four urban categories, from developed open space to developed high intensity. They are also driven by initial and boundary conditions from the North America Regional Reanalysis (NARR) three hourly data (Mesinger et al., 2006).

In STILT, 960 particles were released at each observation location and time period, and then tracked back for 120 hours (at which point the influence of fluxes inside the domain is assumed minimal). Particle influences were summed within each pixel and
hour to determine a spatially and temporally-varying footprint at a 0.1° hourly resolution. A far-field footprint correction (based on work originally done by Fasoli et al., 2018, but modified at NIST) was also implemented to smooth out the discrete nature of the atmospheric influence far away from the towers caused by the limited number of particles released.

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Table S1: flux towers used in the VPRM parameter optimization, along with ancillary information. All data was downloaded from the AmeriFlux (ameriflux.lbl.gov) and NEON (neonscience.org) websites, with NEON towers indicated in the description.

| Description | State/Province | Latitude  | Longitude | Vegetation Description (IGBP) | PFT, this study | Years included in optimization | Included in Hilton et al or Mahadevan et al? | Dataset reference |
|-------------|----------------|-----------|-----------|-------------------------------|----------------|-------------------------------|-----------------------------------------|------------------|
| CA-Gro      | Groundhog River, Boreal Mixedwood Forest | Ontario | 48.217    | -82.156 | Mixed Forests | Evergreen/mixed forests > 40N | 2003-2014 | Hilton | McCAughey (2003-) |
| CA-TP1      | Turkey Point 2002 Plantation White Pine | Ontario | 42.661    | -80.560 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2005-2014 | Arain | (2003-) |
| CA-TP2      | Turkey Point 1974 Plantation White Pine | Ontario | 42.707    | -80.348 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2012-2017 | Arain | (2003-) |
| CA-TPD      | Turkey Point Mature Deciduous | Ontario | 42.635    | -80.558 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2012-2017 | Arain | (2012-) |
| US-ARC      | ARM Southern Great Plains control site | Oklahoma | 35.546    | -98.040 | Grasslands | Grass/pasture | 2005-2006 | Torn et al (2005-2006) |
| US-ARM      | ARM Southern Great Plains | Oklahoma | 36.606    | -97.489 | Croplands | Crops, other | 2003-2004; 2006-2012 | Hilton | Biraud et al (2002-) |
| US-Bar       | Bartlett Experimental Forest (AmeriFlux/NEON) | New Hampshire | 44.065    | -71.288 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2004-2019 | Richardson & Hollinger (2004-) |
| US-Bo1      | Bondville | Illinois | 40.006    | -88.290 | Croplands | Corn/ Crops, other | Corn: 2001, 2005, 2007 Soybean: 2004, 2006 | Mahadevan, Hilton | Meyers (1996-) |
| US-Bo2      | Bondville (companion site) | Illinois | 40.099    | -88.290 | Croplands | Corn | 2006 | Hilton | Bernacchi (2004-2008) |
| US-Br1      | Brooks Field Site 10- Ames | Iowa | 41.975    | -93.691 | Croplands | Corn/ Crops, other | Corn: 2005, 2007, 2011 Soybean: 2006, 2010 | Prueger & Parkin (2001) |
| US-Br3      | Brooks Field Site 11- Ames | Iowa | 41.975    | -93.694 | Croplands | Corn/ Crops, other | Corn: 2006, 2010 Soybean: 2005 | Prueger & Parkin (2001) |
| US-CaV      | Canaan Valley | West Virginia | 39.063    | -79.421 | Grasslands | Grass/pasture | 2004, 2008-2009 | Hilton | Meyers (2004-) |
| US-Ced      | Cedar Bridge | New Jersey | 39.838    | -74.379 | Closed Shrublands | Shrub | 2006-2014 | Clark (2005-) |
| US-ChR      | Chestnut Ridge | Tennessee | 35.931    | -84.332 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2006-2009 | Meyers (2005-) |
| US-CRT      | Curtice Walter-Berger cropland | Ohio | 41.629    | -83.347 | Croplands | Crops, other | 2011, 2012, 2013 | Chen & Chu (2011-2013) |
| US-Dix      | Fort Dix | New Jersey | 39.971    | -74.435 | Mixed Forests | Evergreen/mixed forests < 40N | 2005-2008 | Clark (2005-2008) |
| US-Dk1      | Duke Forest-open field | North Carolina | 35.971    | -79.093 | Grasslands | Grass/pasture | 2001-2005 | Mahadevan, Hilton | Oishi et al (2001-2008) |
| US-Dk2 | Duke Forest-hardwoods | North Carolina | 35.974 | -79.100 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2001 | Mahadevan, Hilton | Oishi et al (2001-2008) |
| US-Dk3 | Duke Forest - loblolly pine | North Carolina | 35.978 | -79.094 | Evergreen Needleleaf Forests | Evergreen/mixed forests < 40N | 2001-2006 | Hilton | Oishi et al (2001-2008) |
| US-GMF | Great Mountain Forest | Connecticut | 41.967 | -73.233 | Mixed Forests | Evergreen/mixed forests > 40N | 2001-2003 | Hilton | Lee (1999-2004) |
| US-Goo | Goodwin Creek | Mississippi | 34.255 | -89.874 | Grasslands | Grass/pasture | 2002, 2004-2006 | Hilton | Meyers (2002-2006) |
| US-Ha1 | Harvard Forest EMS Tower | Massachusetts | 42.538 | -72.172 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2001-2012, 2015, 2017-2019 | Mahadevan, Hilton | Munger (1991-)
| US-Ha2 | Harvard Forest Hemlock Site | Massachusetts | 42.539 | -72.178 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2006-2008, 2012-2013 | Hilton | Hadley & Munger (2004-)
| US-Ho1 | Howland Forest (main tower) | Maine | 45.204 | -68.740 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2010-2017 | Mahadevan, Hilton | Hollinger (1996-)
| US-Ho2 | Howland Forest (west tower) | Maine | 45.209 | -68.747 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2001-2009 | Hilton | Hollinger (1999-)
| US-Ho3 | Howland Forest (harvest site) | Maine | 45.207 | -68.725 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2004-2005 | Hilton | Hollinger (2000-)
| US-IB1 | Fermi National Accelerator Laboratory-Batavia (Agricultural site) | Illinois | 41.859 | -88.223 | Croplands | Corn/ Crops, other | Corn: 2006, 2008, 2010, 2012, 2013, 2016, 2017 Soybean: 2005, 2007, 2009, 2011, 2014, 2015 | Mahadevan, Hilton | Matamala (2005-)
| US-IB2 | Fermi National Accelerator Laboratory-Batavia (Prairie site) | Illinois | 41.841 | -88.241 | Grasslands | Grass/pasture | 2009-2011, 2015-2017 | Mahadevan, Hilton | Matamala (2004-)
| US-KS2 | Kennedy Space Center (scrub oak) | Florida | 28.609 | -80.672 | Closed Shrublands | Shrub | 2003-2006 | Hilton | Drake & Hinkle (2000-2007) |
| US-KUT | KUOM Turfgrass Field | Minnesota | 44.995 | -93.186 | Grasslands | Grass/pasture | 2006-2009 | Mahadevan, Hilton | Desai (2001-)
| US-Los | Lost Creek | Wisconsin | 46.083 | -89.979 | Permanent Wetlands | Wetlands | 2014-2017 | Mahadevan, Hilton | Novick & Phillips (1999-)
| US-MMS | Morgan Monroe State Forest | Indiana | 39.323 | -86.413 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2012-2017 | Mahadevan, Hilton | Novick & Phillips (1999-)
| US-MOz | Missouri Ozark Site | Missouri | 38.744 | -92.200 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2013-2017 | Hilton | Wood & Gu (2004-)
| US-NC1 | NC_Clearcut | North Carolina | 35.811 | -76.712 | Evergreen Needleleaf Forests | Evergreen/mixed forests < 40N | 2005-2009 | Mahadevan, Hilton | Noormets (2005-2013) |
| US-NC2 | NC_Loblolly Plantation | North Carolina | 35.803 | -76.669 | Evergreen Needleleaf Forests | Evergreen/mixed forests < 40N | 2012-2018 | Mahadevan, Hilton | Noormets (2005-)
| US-NC3 | NC_Clearcut#3 | North Carolina | 35.799 | -76.656 | Evergreen Needleleaf Forests | Evergreen/mixed forests < 40N | 2015-2018 | Mahadevan, Hilton | Noormets (2013-)

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| US-NE2 | Mead - irrigated maize/soybean rotation | Nebraska | 41.165 | -96.470 | Croplands | Corn/ Crops, other | Corn: 2009-2012 Soybean: 2002, 2004, 2006, 2008 Mahadevan, Hilton Suyker (2001-) |
| US-NE3 | Mead - rainfed maize/soybean rotation | Nebraska | 41.180 | -96.440 | Croplands | Corn/ Crops, other | Corn: 2009, 2011 Soybean: 2008, 2010, 2012 Hilton Suyker (2001-) |
| US-OH | Oak Openings | Ohio | 41.555 | -83.844 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2005-2007, 2009-2010, 2012 Chen et al (2004-2013) |
| US-ORv | Olentangy River Wetland Research Park | Ohio | 40.020 | -83.018 | Permanent Wetlands | Wetlands | 2011 Bohrer (2011-2016) |
| US-OWC | Old Woman Creek | Ohio | 41.380 | -82.513 | Permanent Wetlands | Wetlands | 2015-2016 Bohrer (2015-2016) |
| US-PFa | Park Falls/WLEF | Wisconsin | 45.946 | -90.272 | Mixed Forests | Evergreen/mixed forests > 40N | 2001-2008 Mahadevan, Hilton Desai (1996-) |
| US-Ro1 | Rosemount- G21 | Minnesota | 44.714 | -93.090 | Croplands | Corn/ Crops, other | Corn: 2005, 2007, 2009, 2011, 2013, 2015 Soybean: 2004, 2006, 2008, 2010, 2012, 2014, 2016 Bohrer & Griffis (2003-2017) |
| US-Ro2 | Rosemount- C7 | Minnesota | 44.729 | -93.089 | Croplands | Crops, other | 2016 Baker & Griffis (2003-2010) |
| US-Ro3 | Rosemount- G19 | Minnesota | 44.722 | -93.089 | Croplands | Corn/ Crops, other | Corn: 2005, 2007 Soybean: 2004, 2006 Bohrer & Griffis (2003-2010) |
| US-Ro4 | Rosemount Prairie | Minnesota | 44.678 | -93.072 | Grasslands | Grass/pasture | 2015-2016 Baker & Griffis (2014-) |
| US-Slt | Silas Little | New Jersey | 39.914 | -74.596 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2010-2014 Clark (2004-) |
| US-StJ | St. Jones Reserve | Delaware | 39.088 | -75.437 | Permanent Wetlands | Wetlands | 2015-2017 Vargas (2015-) |
| US-Syv | Sylvania Wilderness Area | Michigan | 46.242 | -89.348 | Mixed Forests | Evergreen/mixed forests > 40N | 2002-2007, 2012-2017 Hilton Desai (2001-) |
| US-xTA | Talladega National Forest (NEON) | Alabama | 32.951 | -87.393 | Mixed Forests | Evergreen/mixed forests < 40N | 2017-2019 Sturtevant et al (2017-) |
| US-UMB | Univ. of Mich. Biological Station | Michigan | 45.560 | -84.714 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2013-2017 Mahadevan, Hilton Gough et al (1999-) |
| US-UMd | Univ. of Mich. Biological Station, Disturbance | Michigan | 45.563 | -84.698 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2016-2018 Gough et al (2007-) |
| US-WBW | Walker Branch Watershed | Tennessee | 35.959 | -84.287 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2004, 2005, 2007 Meyers (1995-1999) |
| US-WCr | Willow Creek | Wisconsin | 45.806 | -90.080 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2013-2017 Mahadevan, Hilton Desai (1999-) |
| US-WI1 | Intermediate hardwood | Wisconsin | 46.731 | -91.333 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2003 | Chen (2003-2003) |
| US-WI4 | Mature red pine | Wisconsin | 46.739 | -91.166 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2005 | Chen (2002-2005) |
| US-WI5 | Mixed young jack pine | Wisconsin | 46.653 | -91.086 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2004 | Chen (2004-2004) |
| US-WI7 | Red pine clearcut | Wisconsin | 46.649 | -91.069 | Open Shrublands | Shrubbs | 2005 | Chen (2005-2005) |
| US-WI8 | Young hardwood clearcut | Wisconsin | 46.722 | -91.252 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2002 | Chen (2002-2002) |
| US-WI9 | Young Jack pine | Wisconsin | 46.619 | -91.081 | Evergreen Needleleaf Forests | Evergreen/mixed forests > 40N | 2005 | Chen (2004-2005) |
| US-WPT | Winous Point North Marsh | Ohio | 41.465 | -82.996 | Permanent Wetlands | Wetlands | 2011-2013 | Chen & Chu (2011-2013) |
| US-xDL | Dead Lake (NEON) | Alabama | 32.542 | -87.804 | Mixed Forests | Evergreen/mixed forests < 40N | 2017-2018 | Sturtevant et al (2017- ) |
| US-xGR | Great Smoky Mountains National Park (NEON) | Tennessee | 35.689 | -83.502 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2019 | Sturtevant et al (2017-) |
| US-xSC | Smithsonian Conservation Biology Unit (NEON) | Virginia | 38.893 | -78.140 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2017-2019 | Sturtevant et al (2016-) |
| US-xSE | Smithsonian Environmental Research Center (NEON) | Maryland | 39.890 | -76.560 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2017-2019 | Sturtevant et al (2016-) |
| US-xST | Steigerwaldt Land Services (NEON) | Wisconsin | 45.509 | -89.586 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2018-2019 | Sturtevant et al (2017-) |
| US-xTR | Treehaven (NEON) | Wisconsin | 45.494 | -89.586 | Deciduous Broadleaf Forests | Deciduous broadleaf forests | 2017-2019 | Sturtevant et al (2017-) |
| US-xUK | University of Kansas Field Station (NEON) | Kansas | 39.040 | -95.192 | Mixed Forests | Evergreen/mixed forests > 40N | 2017-2019 | Sturtevant et al (2017-) |
| US-xUN | University of Notre Dame Environmental Research Center (NEON) | Michigan | 46.234 | -89.537 | Deciduous Broadleaf Forests | Evergreen/mixed forests > 40N | 2017-2019 | Sturtevant et al (2017-) |
Table S2: optimized VPRM parameters by PFT using the original VPRM respiration model with annual and seasonal parameters (i.e. VPRM<sub>ann</sub> and VPRM<sub>seas</sub>). Deciduous broadleaf forests and urban PFTs share the same parameters. $T_{\text{min}}$, $T_{\text{opt}}$ and $T_{\text{max}}$ parameters are in units of °C, $\lambda$ in ($\mu$mol CO$_2$ m$^{-2}$ s$^{-1}$) / ($\mu$mol PAR m$^{-2}$ s$^{-1}$), PAR$_0$ in $\mu$mol m$^{-2}$ s$^{-1}$, $\beta$ in $\mu$mol CO$_2$ m$^{-2}$ s$^{-1}$ and $\alpha$ in (µmol CO$_2$ m$^{-2}$ s$^{-1}$)/°C.

| PFT | $T_{\text{min}}$ | $T_{\text{max}}$ | $T_{\text{opt}}$ | $\lambda$ | PAR$_0$ | $\beta$ | $\alpha$ |
|-----|-----------------|-----------------|-----------------|----------|--------|--------|--------|
| Deciduous Broadleaf Forest & Urban | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Evergreen/ Mixed Forest, >40°N | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Evergreen/ Mixed Forest, <40°N | 15 | 20 | 15 | 19 | 26 | 24 | 31 |
| Shrub/ Savannah | 0.135 | 0.155 | 0.246 | 0.071 | 0.129 | 0.111 | 0.099 |
| Grass/ Pasture/ Dev-open | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wetlands | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Crops, other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Crops, corn | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Season | $T_{\text{opt}}$ | $\lambda$ | PAR$_0$ | $\beta$ | $\alpha$ |
|--------|-----------------|----------|--------|--------|--------|
| Winter (DJF) | 12 | -0.0260 | 968 | 0.92 | 0.031 |
| | 10 | -0.0725 | 96 | 0.57 | 0.019 |
| | 14 | -0.0892 | 732 | 0.55 | 0.106 |
| | 17 | -0.1446 | 814 | 1.66 | 0.029 |
| | 9 | -0.4617 | 215 | 0.62 | 0.031 |
| | 17 | -0.4617 | 21 | 0.54 | 0.031 |
| | 6 | -0.0857 | 310 | 0.47 | 0.010 |
| | 0 | -0.4822 | 19 | 0.45 | 0.021 |
| Spring (MAM) | 21 | -0.0671 | 696 | 0.98 | 0.129 |
| | 18 | -0.0741 | 536 | 0.91 | 0.122 |
| | 18 | -0.0890 | 1125 | 0.23 | 0.211 |
| | 9 | -0.1034 | 1231 | 1.44 | 0.069 |
| | 15 | -0.0930 | 1004 | 0.74 | 0.116 |
| | 24 | -0.0733 | 730 | 0.77 | 0.105 |
| | 16 | -0.4115 | 1021 | 0.54 | 0.105 |
| | 40 | -0.4115 | 80 | 0.49 | 0.093 |
| Summer (JJA) | 22 | -0.0883 | 695 | 2.94 | 0.129 |
| | 18 | -0.0923 | 603 | 1.40 | 0.184 |
| | 25 | -0.0959 | 1276 | 0.193 | 0.251 |
| | 22 | -0.0845 | 862 | 0.173 | 0.103 |
| | 24 | -0.0885 | 971 | 0.068 | 0.158 |
| | 29 | -0.0852 | 684 | 0.029 | 0.123 |
| | 23 | -0.0481 | 1849 | 0.120 | 0.104 |
| | 31 | -0.0628 | 3740 | -0.072 | 0.139 |
| Fall (SON) | 20 | -0.0872 | 626 | 1.40 | 0.111 |
| | 15 | -0.1005 | 535 | 0.184 | 0.251 |
| | 19 | -0.0914 | 829 | 0.213 | 0.103 |
| | 16 | -0.0877 | 990 | 0.173 | 0.158 |
| | 24 | -0.1231 | 590 | 0.068 | 0.123 |
| | 28 | -0.0904 | 584 | 0.029 | 0.104 |
| | 22 | -0.0391 | 1311 | 0.120 | 0.139 |
| | 30 | -0.0456 | 3510 | -0.072 | 0.139 |
Table S3: optimized VPRM parameters by PFT using the new respiration model (i.e. VPRM$_{\text{new}}$) developed in this study. $T_{\text{min}}$, $T_{\text{opt}}$, $T_{\text{max}}$, $T_{\text{crit}}$ and $T_{\text{mult}}$ parameters are in units of °C, $\lambda$ in (µmol CO$_2$ m$^{-2}$s$^{-1}$)/(µmol PAR m$^{-2}$s$^{-1}$), PAR$_0$ in µmol m$^{-2}$s$^{-1}$, $\beta$ in µmol CO$_2$ m$^{-2}$s$^{-1}$, $\alpha_1$ and $\alpha_2$ in (µmol CO$_2$ m$^{-2}$s$^{-1}$)/°C, $\theta_1$ in (µmol CO$_2$ m$^{-2}$s$^{-1}$)/(unitless W$_{\text{scale}}$), $\theta_2$ in (µmol CO$_2$ m$^{-2}$s$^{-1}$)/°C * unitless W$_{\text{scale}}$, and $\theta_3$ in (µmol CO$_2$ m$^{-2}$s$^{-1}$)/°C$^2$ * unitless W$_{\text{scale}}$.

|                  | Deciduous Broadleaf Forest & Urban >40°N | Evergreen/Mixed Forest, <40°N | Evergreen/Mixed Forest, >40°N | Shrub/Savannah | Grass/Pasture/Dev-open | Wetlands | Crops, other | Crops, corn |
|------------------|-----------------------------------------|-----------------------------|-----------------------------|----------------|------------------------|---------|-------------|-------------|
| $T_{\text{min}}$ | 0                                       | 0                           | 0                           | 0              | 0                      | 0       | 0           | 0           |
| $T_{\text{max}}$| 45                                      | 45                          | 45                          | 45             | 45                     | 45      | 45          | 45          |
| $T_{\text{opt}}$| 23                                      | 18                          | 20                          | 17             | 20                     | 29      | 26          | 35          |
| $T_{\text{crit}}$| -15                                     | 1                           | 0                           | 5              | 11                     | 6       | 7           | -1          |
| $T_{\text{mult}}$| 0.55                                    | 0.05                        | 0                           | 0.1            | 0.1                    | 0.05    | 0           | 0           |
| $\lambda$        | -0.1023                                 | -0.1097                     | -0.0920                     | -0.0996        | -0.1273                | -0.1227 | -0.0732     | -0.0997     |
| PAR$_0$          | 539                                     | 506                         | 896                         | 811            | 673                    | 456     | 1019        | 1829        |
| $\beta$          | 0.12                                    | 0.47                        | 0.28                        | 1.53           | -6.18                  | -0.82   | -1.20       | -0.02       |
| $\alpha_1$       | 0.065                                   | 0.088                       | 0.025                       | 0.004          | 0.853                  | 0.261   | 0.234       | 0.083       |
| $\alpha_2$       | 0.0024                                  | 0.0047                      | 0.0058                      | 0.0049         | -0.0250                | -0.0051 | -0.0060     | -0.0018     |
| $\gamma$         | 4.61                                    | 1.39                        | 4.18                        | 0.09           | 5.19                   | 3.46    | 3.85        | 4.89        |
| $\theta_1$       | 0.116                                   | -0.530                      | -0.729                      | -1.787         | 1.749                  | -0.777  | 0.032       | 0.150       |
| $\theta_2$       | -0.0005                                 | 0.2063                      | 0.1961                      | 0.4537         | -0.2829                | 0.0990  | -0.0429     | -0.1324     |
| $\theta_3$       | 0.0009                                  | -0.0054                     | -0.0055                     | -0.0138        | 0.0166                 | 0.0018  | 0.0090      | 0.0156      |
Table S4: Comparison of model components for the VPRM, CASA and SiB4 implementations included in this study.

| Parameter type | VPRM (Mahadevan et al, 2008; this study) | CASA (Zhou et al, 2020) | SiB4v2 (Haynes et al, 2019) |
|----------------|------------------------------------------|--------------------------|-----------------------------|
| Spatial resolution | 0.02 degree | 5km in Canada, 500m in USA | 0.5 degree |
| Temporal resolution | hourly | monthly, downscaled to 3-hourly with temperature & radiation | hourly |
|  | diagnostic (based on 8-day MODIS EVI/LSWI from overlapping 16-day composites) | diagnostic (based on monthly MODIS PAR) | prognostic, climate-driven, daily temporal resolution |
| Photonics | light-use efficiency with downscaling for temperature & water stress | light-use efficiency with downscaling for temperature & water stress | enzyme-kinetic (operates at sub-hourly timescale) |
| Respiration model | original model: linear function of temperature for each PFT, new respiration model: function of quadratic temperature, water stress and interactions with temperature, and EVI | From literature and maximum light-use efficiency calibrated with flux tower GPP observations from towers across North America; ensemble approach where individual members vary light-use efficiency, T<sub>opt</sub> and Q<sub>10</sub>; ensemble mean across 27 members of L2 product used here | From literature, previous versions of SiB |
| Parameter selection | optimized using NEE observations from flux towers in eastern US & Canada operating since 2001. original model: optimized with 24 hours of hourly flux tower NEE observations, new respiration model: respiration parameters optimized with night-time average flux tower NEE observations, GPP parameters optimized with hourly day-time GPP "observations" (i.e. NEE - predicted respiration) | MOD12Q1 Global Land Cover, modified with National Forest Type and North American Forest Dynamics products; tree and grass cover from MOD44B Vegetative Continuous Fields and non-woody) savannahs, grasslands, deciduous broadleaf forests, mixed forests, closed and open shrublands, woody ecosystems (and non-woody) savannahs, grasslands, croplands, urban and built-up, cropland/natural vegetation mosaic | MOD12Q1 Global Land Cover, modified for CLM 3.0 as in Lawrence and Chase (2007) |
| Land cover map | USA: NLCD2016 for all categories, except crops (https://www.mrlc.gov/data/nlcd-2016-land-cover-conus); crops from Cropland Data Layer (https://www.nass.usda.gov/Research_and_Science/Cropland/Release/); Canada: Canadian Annual Crop Inventory 2017 for all categories (https://open.canada.ca/data/en/dataset/ba2645d5-445b-414d-b196-6303ac06c19f). | MOD12Q1 Global Land Cover, modified for CLM 3.0 as in Lawrence and Chase (2007) | weighted fractional coverage |
| Land-cover within pixel | weighted fractional coverage | weighted fractional coverage | weighted fractional coverage |
| Plant functional types | Deciduous broadleaf forests, Evergreen needleleaf/mixed forests (>40N), Evergreen needleleaf/ mixed forests (<40N), Grass/pasture/dev-open, Shrub/savannah, wetlands, corn, other crops | From MODIS IGBP: evergreen needleleaf forest, deciduous broadleaf forest, mixed forests, closed and open shrublands, woody ecosystems (and non-woody) savannahs, grasslands, croplands, urban and built-up, cropland/natural vegetation mosaic | In this domain: evergreen needleleaf forest, deciduous broadleaf forest, shrubs, C3 grasslands, C4 grasslands, maize, soybean, wheat, generic C3 crops |
| Crops | corn vs. other crops (separate parameters & land-cover) | single crop type | separate parameters for corn, wheat, soybean and generic C3 and C4 crops; crop-specific prognostic phenology determined by growing-degree-days |
| Urban | Low, medium and high intensity developed land classified as urban; heterotrophic respiration (i.e. half of total respiration) reduced by fraction of impervious surface coverage (Hardiman et al, 2017); developed-open included with grasslands | zero flux when dominant land-cover | not separately simulated (no urban PFT) |
| Meteorological variables | air temperature and shortwave radiation | air temperature, total precipitation, shortwave and longwave radiation | air temperature, precipitation, shortwave and longwave radiation, surface pressure, wind speed, specific humidity |
| Meteorological model | HRRR (3km resolution) | 5km runs: NARR (32 km resolution; 3-hourly) 500m runs: PRISM (30 arc-seconds) for precipitation and air temperature; NLDAS-2 (0.125°) for radiation | MERRA, regridded to 0.5° resolution; precipitation scaled to GPCP (as in Baker et al, 2010) |
Table S5: Towers with observed CO$_2$ mole fraction data calibrated to the WMO-CO2-X2007 scale, sorted from north to south. Also shown are other tower characteristics, including months with observations from November 2016 to October 2017, and the percentage of each land cover within annual average footprints, calculated using the average of WRF-STILT and NAMS-STILT transport. Data providers are the National Oceanic and Atmospheric Administration (NOAA), Environment Canada (EC), Harvard University (HU) and Penn State University (PSU), with the data provider ‘EN-NIST’ referring to towers operated by Earth Networks (EN) and funded by the National Institute of Standards & Technology (NIST; Karion et al, 2020). Tower locations are also shown in Figure 2 of the main text.

| Name       | Description                  | Data Provider | Latitude | Longitude | Elevation (masl) | Inlet height (m) | Months with data | DBF | ENF/MF, > 40N | ENF/MF, < 40N | Wetlands | Shrubs | Crops | Grass/pasture/dev-open | Developed (low/med/high) |
|------------|------------------------------|---------------|----------|-----------|------------------|------------------|------------------|-----|----------------|----------------|-----------|--------|--------|-----------------------|-------------------------|
| LEF        | Park Falls, WI               | NOAA          | 45.945   | -90.273   | 474              | 396              | all              | 30  | 18             | 0              | 30        | 1      | 11     | 8                     | 1                       |
| AMT        | Argyle, ME                   | NOAA          | 45.035   | -68.682   | 53               | 107              | all              | 17  | 45             | 1              | 15        | 3      | 6      | 9                     | 4                       |
| DNH        | Durham, NH                   | EN-NIST       | 43.709   | -72.154   | 560              | 100              | all              | 28  | 34             | 1              | 7         | 2      | 9      | 13                    | 5                       |
| UNY        | Utica, NY                    | EN-NIST       | 42.879   | -74.785   | 489              | 45               | all              | 31  | 17             | 2              | 8         | 2      | 4      | 14                    | 21                      |
| TPD        | Turkey Point, Ontario        | EC            | 42.617   | -80.550   | 198              | 35               | all              | 23  | 9              | 2              | 7         | 1      | 37     | 14                    | 6                       |
| HAF        | Harvard_Forest               | HU            | 42.538   | -72.172   | 344              | 29               | all              | 28  | 31             | 2              | 10        | 2      | 8      | 14                    | 7                       |
| MSH        | Mashpee, MA                  | EN-NIST       | 41.657   | -70.498   | 32               | 46               | all              | 20  | 28             | 3              | 10        | 2      | 8      | 16                    | 14                      |
| MLD        | Mildred, PA                  | PSU           | 41.466   | -76.419   | 591              | 61               | all              | 36  | 16             | 3              | 6         | 2      | 14     | 18                    | 18                      |
| BRI        | Bremen, IN                   | EN-NIST       | 41.458   | -86.194   | 252              | 100              | Dec-Oct           | 16  | 4              | 2              | 8         | 1      | 50     | 13                    | 7                       |
| HCT        | Hamden, CT                   | EN-NIST       | 41.434   | -72.945   | 197              | 100              | Nov-Mar, Jul     | 34  | 17             | 3              | 8         | 2      | 10     | 17                    | 11                      |
| SNJ        | Stockholm, NJ                | EN-NIST       | 41.144   | -74.539   | 407              | 53               | May-Nov          | 36  | 13             | 3              | 8         | 1      | 12     | 19                    | 7                       |
| SOL        | Mooresville, IN              | PSU           | 39.581   | -86.421   | 256              | 121              | all              | 25  | 2              | 5              | 4         | 1      | 44     | 16                    | 5                       |
| TMD        | Thurmont, MD                 | EN-NIST       | 39.577   | -77.488   | 564              | 113              | May-Oct          | 34  | 6              | 9              | 5         | 1      | 17     | 22                    | 6                       |
| BUC        | Bucktown, MD                 | EN-NIST       | 38.460   | -76.043   | 3                | 75               | all              | 22  | 5              | 12             | 18        | 2      | 21     | 16                    | 6                       |
| SFD        | Stafford, VA                 | EN-NIST       | 38.446   | -77.530   | 76               | 152              | Jul-Oct          | 31  | 5              | 15             | 7         | 2      | 14     | 21                    | 6                       |
| RIC        | Richmond, VA                 | EN-NIST       | 37.509   | -77.576   | 89               | 95               | all              | 27  | 3              | 19             | 7         | 2      | 14     | 21                    | 7                       |
| SKY        | Somerset, KY                 | EN-NIST       | 36.961   | -84.568   | 375              | 100              | Apr-Jul          | 37  | 1              | 14             | 3         | 1      | 15     | 25                    | 4                       |
| DVA        | Danville, PA                 | PSU           | 36.706   | -79.437   | 278              | 215              | Dec-Oct          | 33  | 2              | 18             | 4         | 3      | 12     | 24                    | 5                       |
| MNC        | Middlesex, NC                | EN-NIST       | 35.831   | -78.145   | 73               | 213              | Oct              | 20  | 2              | 22             | 13        | 2      | 19     | 18                    | 5                       |
| SMT        | Signal Mountain, TN EN-NIST  | EN-NIST       | 35.207   | -85.286   | 610              | 100              | Nov-Apr          | 36  | 1              | 16             | 3         | 2      | 11     | 26                    | 6                       |
| SCT        | South Carolina Tower, NOAA   | NOAA          | 33.406   | -81.833   | 114              | 305              | all              | 16  | 1              | 23             | 20        | 5      | 12     | 18                    | 5                       |
Table S6: mean absolute error (MAE) across towers of monthly mean biases between simulated and observed biospheric atmospheric CO$_2$ enhancements (in µmol/mol), shown by TBM and month. Statistics calculated using the “optimal” monthly background conditions with WRF-STILT convolutions are shown on the upper left and NAMS-STILT convolutions on the upper right. The lower left box shows statistics calculated with mean WRF-STILT and NAMS-STILT convolutions, but with each set of background conditions (CTE, left and CT19B, right). For all boxes, MAE values <= 1.00 µmol/mol are highlighted in light yellow, with the TBM having an MAE <= 1.00 µmol/mol and the minimal value across models highlighted in orange.

|       | WRF       | NAMS       |
|-------|-----------|------------|
|       | VPRM$_{ann}$ | VPRM$_{seas}$ | VPRM$_{new}$ | CASA | SiB4 | VPRM$_{ann}$ | VPRM$_{seas}$ | VPRM$_{new}$ | CASA | SiB4 |
|       |           |            |             |      |      |           |            |             |      |      |
| 201611| 1.01      | 0.84       | 0.85        | 1.17 | 1.35 | 0.90      | 1.01        | 1.00        | 0.95 | 1.09 |
| 201612| 1.71      | 2.43       | 1.78        | 1.11 | 1.19 | 1.98      | 2.74        | 2.08        | 1.35 | 1.24 |
| 201701| 0.93      | 1.78       | 1.13        | 0.79 | 1.56 | 1.43      | 2.43        | 1.71        | 1.13 | 1.54 |
| 201702| 0.75      | 0.75       | 0.67        | 1.65 | 1.49 | 0.71      | 0.86        | 0.66        | 1.53 | 1.19 |
| 201703| 0.34      | 0.58       | 0.43        | 0.74 | 0.98 | 0.42      | 0.66        | 0.53        | 0.61 | 0.78 |
| 201704| 0.81      | 0.73       | 0.55        | 0.78 | 1.38 | 0.74      | 0.76        | 0.50        | 0.66 | 1.54 |
| 201705| 0.54      | 0.58       | 0.76        | 1.55 | 1.27 | 0.55      | 0.95        | 0.50        | 1.38 | 0.95 |
| 201706| 0.97      | 1.43       | 1.10        | 1.49 | 1.31 | 2.28      | 1.32        | 1.46        | 0.78 | 1.38 |
| 201707| 1.59      | 1.21       | 1.33        | 1.49 | 1.54 | 3.39      | 1.90        | 1.51        | 1.23 | 3.90 |
| 201708| 1.09      | 1.23       | 1.28        | 1.28 | 1.16 | 1.95      | 1.28        | 1.43        | 0.90 | 1.32 |
| 201709| 1.50      | 1.44       | 2.40        | 1.05 | 2.19 | 1.50      | 1.45        | 2.45        | 0.93 | 2.55 |
| 201710| 0.80      | 0.82       | 0.83        | 1.72 | 1.47 | 0.85      | 0.85        | 0.87        | 1.74 | 1.82 |

|       | CASA SiB4 | CASA SiB4 | CASA SiB4 |
|-------|-----------|-----------|-----------|
| 201611| 1.07      | 1.07      | 1.07      |
| 201612| 1.07      | 1.07      | 1.07      |
| 201701| 1.07      | 1.07      | 1.07      |
| 201702| 1.07      | 1.07      | 1.07      |
| 201703| 1.07      | 1.07      | 1.07      |
| 201704| 1.07      | 1.07      | 1.07      |
| 201705| 1.07      | 1.07      | 1.07      |
| 201706| 1.07      | 1.07      | 1.07      |
| 201707| 1.07      | 1.07      | 1.07      |
| 201708| 1.07      | 1.07      | 1.07      |
| 201709| 1.07      | 1.07      | 1.07      |
| 201710| 1.07      | 1.07      | 1.07      |

|       | VPRM$_{ann}$ | VPRM$_{seas}$ | VPRM$_{new}$ | CASA | SiB4 | VPRM$_{ann}$ | VPRM$_{seas}$ | VPRM$_{new}$ | CASA | SiB4 |
|-------|-------------|---------------|---------------|------|------|-------------|---------------|---------------|------|------|
| 201611| 0.81        | 0.82          | 0.80          | 0.97 | 1.15 | 0.83        | 0.86          | 0.86          | 1.01 | 1.12 |
| 201612| 1.84        | 2.59          | 1.93          | 1.22 | 1.15 | 2.00        | 2.75          | 2.09          | 1.37 | 1.18 |
| 201701| 1.10        | 2.08          | 1.36          | 0.90 | 1.49 | 1.66        | 2.67          | 1.94          | 1.21 | 1.46 |
| 201702| 0.87        | 0.64          | 0.63          | 1.92 | 1.62 | 0.63        | 1.05          | 0.73          | 1.24 | 1.08 |
| 201703| 0.51        | 0.47          | 0.51          | 0.95 | 1.01 | 0.47        | 0.92          | 0.68          | 0.44 | 0.71 |
| 201704| 0.90        | 0.62          | 0.55          | 0.72 | 1.40 | 0.70        | 0.98          | 0.62          | 0.79 | 1.56 |
| 201705| 0.50        | 0.74          | 0.61          | 1.44 | 1.10 | 0.60        | 0.77          | 0.77          | 1.61 | 1.25 |
| 201706| 1.48        | 1.17          | 1.11          | 0.92 | 0.96 | 1.21        | 1.44          | 1.21          | 1.35 | 1.23 |
| 201707| 2.31        | 1.32          | 1.23          | 0.85 | 2.58 | 2.44        | 1.34          | 1.22          | 0.97 | 2.62 |
| 201708| 1.22        | 1.14          | 1.28          | 1.00 | 1.15 | 1.53        | 0.97          | 1.19          | 0.96 | 1.01 |
| 201709| 2.10        | 1.95          | 3.11          | 1.22 | 2.80 | 1.08        | 1.11          | 1.76          | 1.15 | 2.13 |
| 201710| 0.81        | 0.79          | 0.80          | 1.68 | 1.60 | 0.87        | 1.19          | 0.85          | 2.59 | 2.23 |
Figure S1: Boxplots of site-specific optimized parameters from the original VPRM model with annual parameters (i.e. VPRM$_{ann}$), clustered by the Plant Functional Type (PFT) classification used in the paper.
Figure S2: Interannual variability in monthly air temperatures (top row) and precipitation (bottom row) from 2001-2020. (These data were obtained from the NASA Langley Research Center POWER Project funded through the NASA Earth Science Directorate Applied Science Program, available at https://power.larc.nasa.gov/).
Figure S3: comparison of daily interpolated EVI used in VPRM (from overlapping 16-day MODIS composites) vs. monthly fPAR used in CASA from November 2016 to October 2017. EVI and fPAR data are spatially aggregated across the cropland and deciduous broadleaf forest pixels indicated in Figure 1 of the main text.

Figure S4: Mean spatially integrated footprints in July 2017 as a function of hours back from receptor time for two towers: UNY (45 m inlet height) and MNC (213 m inlet height). Time series are shown for each afternoon receptor hour, averaged across all days in the month, with receptor hours starting at 12 – 4 pm EST shown with a thicker line width. Note that the expanded definition of “afternoon” in this study allows for more hours with well-mixed conditions during summer months (shown with green shading). Other hours back in time are shaded to indicate day (yellow) or night (blue).
Figure S5: Scatter plots of observed air temperature vs. night-time hourly average NEE for out-of-sample flux tower observations reserved from parameter optimization. Also shown are model fits for \( VPRM_{\text{ann.orig}} \), \( VPRM_{\text{ann}} \), \( VPRM_{\text{ann.ND}} \), \( VPRM_{\text{seas}} \), and \( VPRM_{\text{new}} \), with four lines for \( VPRM_{\text{seas}} \) corresponding to each season. Results are shown for the six PFT’s not shown in Figure 6 in the main text (representing ~60% of total land cover in domain): evergreen needleleaf/mixed forests >40°N (12%), evergreen needleleaf/mixed forests <40°N (8%), grasslands (including pasture and developed-open, 17%), soybean/other crops (13%), wetlands (8%), and shrublands and savannah (2%). NSC values are shown comparing each model to observations by PFT.
Figure S6: monthly mean seasonal cycles of night-time NEE comparing model predictions from different VPRM model formulations to reserved flux tower observations not included in the parameter optimization. Results are shown for the six PFT’s not shown in Figure 6 in the main text.
Figure S7: Mean 24-hour gridded seasonal NEE at 0.1° for VPRM_{ann}, VPRM_{seas} and VPRM_{new}. Corresponds to Figure 8 in the main text.
Figure S8: Percent of deciduous broadleaf forests (top row) and croplands (bottom row) at the aggregated 0.5° spatial scale, as seen in the underlying land cover maps for SiB4, VPRM and CASA (with data sources for each model shown in Table S1). The CASA map is based on the 500 m dominant land cover across the domain.
Figure S9: Seasonal cycle of weekly mean GPP (top row), and ecosystem respiration (bottom row), spatially aggregated across pixels with predominantly deciduous broadleaf forests (left column) and croplands (right column), as indicated in Figure 1.
Figure S10: Mean diurnal cycle in July of GPP (top row), and ecosystem respiration (bottom row), spatially aggregated across pixels with predominantly deciduous broadleaf forests (left column) and croplands (right column), as indicated in Figure 1.
Figure S11: Monthly mean simulated vs. observed biological CO$_2$ enhancements at 4 towers with convolutions using WRF-STILT transport. Other details are shown in the Figure 10 caption in main text.
Figure S12: Monthly mean simulated vs. observed biological CO$_2$ enhancements at 4 towers with convolutions using NAMS-STILT transport. Other details are shown in the Figure 10 caption in the main text.
Figure S13: Monthly mean biases (simulated - observed) in biospheric CO$_2$ enhancements from November 2016 to October 2017 across biospheric models using WRF-STILT convolutions (top) and NAMS-STILT convolutions (bottom). Other details are the same as in Figure 11 in the main text.
Figure S14: Monthly mean biospheric CO₂ enhancement biases (model – observations) for all towers for each biospheric model (3 versions of VPRM, CASA and SiB4). Mean of WRF-STILT and NAMS-STILT convolutions, Vulcan3.0 fossil fuel emissions and “optimal” background conditions are used for all months. Towers are color-coded to show approximate geographic position and/or land cover influence (gray: towers near edge of domain, orange: cropland influence, dark green: northeastern US, green: PA/NY/CT, turquoise: mid-Atlantic, blue: southern).
Figure S15: NSC and adjusted $R^2$'s (bottom row) comparing simulated to observed biologic CO$_2$ enhancements across towers for each TBM. This is the same as Figure 12 in the main text but using WRF-STILT (top row) and NAMS-STILT (bottom row) convolutions separately.