6 Supplement

6.1 Prior Information

First, plant species with valid, relevant trait data were manually classified into PFTs based on their genus, subject to a combination of expert knowledge, database searches (e.g., BudBurst.org, Kew's Plants of the World Online, WorldFloraOnline.org), photographs, and descriptions. For example, genera where most species were described as "shrubby" or "dwarf trees" where classified as "Shrub," to be utilized as prior information for both Open and Closed Shrublands (OSH and CSH). Similarly, a woody "Broadleaf" class, based on photographs and descriptions of the genus, was used to inform priors for both Evergreen Broadleaf and Deciduous Broadleaf classes, unless the genus was predominantly described as evergreen or deciduous. Graminoids and sedges were both classified into Grasslands (GRS). Genera that were too diverse ("cosmopolitan") were not classified and instead used only as a prior for PFTs that were not already represented by species with valid trait data. This includes Savannas (SAV) and Woody Savannas, which both refer to a potentially broad set of plant types (Bridgewater et al., 2002) that may also be found in other, more specific PFTs. The Mixed Forest (MF) prior for a given trait included trait data from species for any forest type. Species grouped into Cropland (CRO) were based on those that feature in the United Nation's Food and Agriculture Programme (FAO) 2010 agricultural census (FAO, 2010). After classification into PFTs, traits were aggregated by species, taking the median value.

A mapping of TRY database traits to MOD17 parameters is presented in Table 6. While some of the traits are directly represented in MOD17, others were used in combination to derive a given parameter. For example, the `froot_mr_base`, the R_M rate of fine roots per unit C, could be the ratio of two traits: "fine root respiration per fine root dry mass" to "fine root carbon (C) content per fine root dry mass." For `leaf_mr_base`, there is no measurement of R_M available but there are measurements of dark respiration. These were used along with the median value of "leaf respiration in light per leaf respiration rate in the dark" (45% with only 16 species available) in order to derive the leaf respiration rate in light (per unit C).

Table 6: List of traits from the TRY database and the MOD17 parameters they inform.

Trait from TRY Database	MOD17 Parameters Informed
Root respiration temperature dependence	`Q10_froot`
Stem respiration temperature dependence	`Q10_stem`
Fine root carbon (C) content per fine root dry mass	`froot_leaf_ratio`, `froot_mr_base`
Stem carbon (C) content per stem dry mass	`livewood_mr_base`
Leaf carbon (C) content per fine root dry mass	`froot_leaf_ratio`, `leaf_mr_base`
Leaf carbon (C) content per leaf area	SLA
Fine root respiration per fine root dry mass	`froot_mr_base`
Stem respiration rate per stem dry mass	`livewood_mr_base`
Leaf respiration rate in the dark per leaf dry mass	`leaf_mr_base`
Leaf respiration rate in light per [same] in the dark	`leaf_mr_base`

For some traits, there were too few species available to generate priors specific to each PFT. In such cases, all plant species were used to derive a single prior for all PFTs. Maximum likelihood estimation (MLE) was used to fit either Normal or Log-Normal distributions to traits, depending on whether the trait distribution was highly positively skewed, which was often. Table S7 lists the MOD17 free parameters and the priors that were used for model calibration. For $\varepsilon_{\max}$, lacking relevant trait data from TRY, the mean and standard deviation of the "optimum" LUE from a global analysis by Madani et al. (2017) is used, instead.

By definition, livewood mass and respiration are zero in herbaceous plants (GRS and CRO), so these are set to a constant value of zero during calibration of those PFTs. Despite the effort to develop an informative prior for `froot_leaf_ratio`, there is little prior information on the partitioning of C allocation between fine roots and leaves for each PFT. TRY and the Fine-Root Ecology Database (FRED, Iversen et al., 2017) contain few species with this trait recorded and disagree about the relative magnitudes. For example, the mean fine root-leaf C ratio for ENF canopy is about 0.04 based on TRY but 1.33 according to FRED, perhaps due to obscured differences in units or sampling methodology. Using TRY, there are only 14 species in the TRY database for which all the necessary traits were recorded, and after removing the dry-mass normalization of fine-root and leaf C content, all ratios were very close to 1.0. There are also very few species in TRY with prior information on the livewood-leaf ratio. Given this uncertainty, and because we discovered that `livewood_leaf_ratio` is the least-sensitive parameter, we decided to fix both `livewood_leaf_ratio` and `froot_leaf_ratio` at their Collection 6.1 (C61) values, which were informed from a review by M. A. White et al. (2000).

Prior Q10 values for stem respiration in TRY are quite narrow, with a mean of 1.84, which also agrees very well with prior studies (Ryan et al., 1995; Damesin et al., 2002; Bolstad et al., 2004), and is slightly higher for ENF canopy. In TRY, the fine-root temperature dependence (Table S6) was recorded for only one species, so we referred to the literature instead. We adopted the cross-ecosystem Q10 value of 1.6 reported by Burton et al. (2008), which is consistent with the range reported by Atkin et al. (2000), though lower than measurements by Desrochers et al. (2002). With a Normal(1.6, 1.6) prior, the 80th percentile is approximately 3.0, which is consistent with the upper limit for the Q10 of fine root respiration reported by Bahn et al. (2006); it is also wide enough to reflect our uncertainty. Both the livewood (stem) and fine root respiration Q10 priors have means close to the C61 value, which is 2.0 for all PFTs.

The base R_M rates `leaf_mr_base`, `froot_mr_base`, and `livewood_mr_base` in C61 agree well with observations from the TRY database. However, TRY observations indicate that these rates should be higher for all PFTs. The middle 80% of the observed leaf R_M distribution is bounded by [0.005, 0.032] (kg C [kg C]$^{-1}$ day^{-1}), compared to the full range of [0.005, 0.010] in C61. For fine-root R_M, only 23 species are available in TRY, but the middle 80% of [0.006, 0.060] (kg C [kg C]$^{-1}$ day^{-1}) does include the two rates used in C61: 0.00819 for CRO and GRS and 0.00519 for all others. Similarly, though livewood R_M is represented by only 20 species in TRY, the middle 80% of [0.001, 0.042] (kg C [kg C]$^{-1}$ day^{-1}) does include C61's range of [0.0010, 0.0044]; the mean livewood R_M from TRY, 0.005 kg C [kg C]$^{-1}$ day^{-1}, is quite close. These estimates are in the middle of a wide range of reported stem respiration rates for forests (Ryan et al., 1995; Lavigne et al., 1996; Stockfors & Linder, 1998; Damesin et al., 2002; Zha et al., 2004; Bolstad et al., 2004).

SLA in MOD17 is defined as LAI per unit mass of leaf C, which is different from TRY and most field studies, where the numerator would be individual leaf area (m^2) and the denominator would be leaf dry mass. There are multiple TRY traits that could be used to derive SLA, which differ in whether the petiole, rhachis, or midrib are excluded from plant measurements (or whether this is known). When we compare all other "SLA" fields in dry-mass terms (inverse of leaf mass per area, or LMA) or in carbon terms ("Leaf carbon (C) content per leaf area" in TRY, which is the inverse of SLA as defined in MOD17), we find that carbon terms generally agree better with the C61 BPLUT (Table S8), which is based in part on a review by R. White and Engelen (2000). The relative magnitudes of SLA in carbon terms are also consistent with the leaf economics spectrum (Reich et al., 1998; Wright et al., 2004; Poorter et al., 2009); specifically, canopies with short-lived leaves (DBF, CRO) tend to have higher SLA (lower LMA), and woody canopies tend to have lower SLA (higher LMA) than herbaceous canopies (Díaz et al., 2016). SLA for DNF likely should be higher, at least twice that of ENF (Gower & Richards, 1990; Kloeppel et al., 1998), and indeed some samples from TRY support a higher SLA (Figure S8), yet most are from R. White and Engelen (2000), which found a mean SLA of 22 m^{-2} $[kg\ C]^{-1}$.

6.2 Supplemental Figures & Tables

Table 8: Specific leaf area (SLA) can be defined in carbon terms ("Leaf carbon (C) content per leaf area" in TRY) or dry-mass terms (inverse of leaf mass per area, or LMA). Here, Collection 6.1 BPLUT values are compared to the median SLA in carbon terms (m^{-2} $[kg\ C]^{-1}$) and the median SLA across all dry-mass SLA fields (m^{-2} kg^{-1}), grouped by PFT, from the TRY database. Also shown is the overall median in each group as well as the mean value found in the literature review by White et al. (2000).

PFT	Collection 6.1	Carbon terms	Dry mass terms	White et al.
ENF	15.0	12.1	9.3	8.2
EBF	26.9	24.0	12.3	n.a.
DNF	16.9	23.5	10.7	22.0
DBF	24.7	34.5	16.6	32.0
MF	22.6	33.8	19.1	n.a.
CSH	9.4	24.8	13.3	n.a.
OSH	12.0	24.8	13.3	12.0
WSV	28.8	36.9	14.8	n.a.
SAV	28.9	34.9	15.7	n.a.
GRS	38.0	37.4	14.9	49.0
CRO	38.0	43.6	18.4	n.a.
Overall	24.7	29.5	14.8	n.a.

Table 11: Annual GPP (MOD17A3H) validation metrics, for Collection 6.1 ("C6.1") and the updated BPLUT ("Update"), for years in 2000-2017 with $\geq$ 97% of valid data-days. FLUXNET sites used in calibration are combined with those reserved for validation due to the dearth of data-years available. Bias and RMSE are in units of g C m^{-2} $year^{-1}$. No FLUXNET sites with majority-DNF canopy have years with at least 97% of valid data-days within this span. The statistics are not shown for DBF (2 site-years) because only one site is represented; they are likely not reliable.

PFT	Site-Years	Bias (C6.1)	Bias (Update)	RMSE (C6.1)	RMSE (Update)	nRMSE (C6.1)	nRMSE (Update)
ENF	52	-307	-196	531	543	15.7%	16.1%
DNF	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EBF	44	67	12	491	477	13.1%	12.8%
DBF	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
MF	31	-700	-640	763	694	48.5%	44.1%
CSH	7	77	46	103	108	32.3%	33.9%
OSH	6	-264	-336	718	751	33.0%	34.6%
WSV	29	-47	-155	376	416	28.7%	31.8%
SAV	44	-323	-341	532	506	30.4%	28.9%
GRS	56	-347	-174	589	452	17.2%	13.2%

PFT	Site-Years	Bias (C6.1)	Bias (Update)	RMSE (C6.1)	RMSE (Update)	nRMSE (C6.1)	nRMSE (Update)
CRO	20	-317	-9	433	324	37.0%	27.7%

Table 12: Annual GPP validation metrics at FLUXNET sites for years in 2012-2017 with $\geq$ 97% of valid data-days, based on the candidate VNP17 BPLUT. Bias and RMSE are in units of g C m^{-2} $year^{-1}$. As with MOD17, annual GPP validation includes both calibration and validation FLUXNET sites. No FLUXNET sites with majority-DNF or majority-DBF canopy have years with at least 97% of valid data-days within this span.

PFT	Site-Years	Bias	RMSE	nRMSE
ENF	6	-597	839	27.8%
DNF	0	n.a.	n.a.	n.a.
EBF	11	20	625	29.0%
DBF	0	n.a.	n.a.	n.a.
MF	6	-677	707	99.8%
CSH	7	42	93	29.2%
OSH	4	-1	30	9.0%
WSV	9	-98	491	40.8%
SAV	10	-282	602	39.7%
GRS	21	-181	454	17.9%
CRO	9	-27	327	29.9%

Table 14: 8-day GPP validation metrics based on the candidate VNP17 BPLUT, as compared to FLUXNET sites (2012-2017). Mean Bias, RMSE, and ubRMSE are in units of g C m^{-2} day^{-1}, while the parentheses under RMSE indicate the normalized RMSE. The normalized RMSE (%) is based on the overall observed range of daily GPP or annual NPP; for daily GPP, the observed range is restricted to years 2012-2017 to allow for meaningful comparisons between MODIS and VIIRS. DNF is not represented because no FLUXNET sites in this canopy report data during the period of available VIIRS fPAR and LAI retrievals, 2012-2017.

PFT	N	Bias	RMSE	ubRMSE	Corr
ENF	444	-1.6	2.8 (12%)	1.9	0.87
DNF	0	n.a.	n.a.	n.a.	n.a.
EBF	520	0.6	2.8 (13%)	1.5	0.59
DBF	637	0.2	1.5 (7%)	1.4	0.94
MF	684	-1.0	2.1 (9%)	1.6	0.89
CSH	188	0.1	0.5 (2%)	0.4	0.52
OSH	337	0.4	0.8 (4%)	0.6	0.63
WSV	588	0.0	1.5 (7%)	1.1	0.81
SAV	643	-0.7	2.6 (12%)	2.2	0.75
GRS	878	0.0	1.3 (6%)	0.9	0.77
CRO	614	0.3	3.4 (15%)	3.3	0.61

Table 7: Prior distributions for free parameters in MOD17, excluding temperature and VPD parameters in the GPP model. $\varepsilon_{\max}$, `Q10_froot`, and `Q10_livewood` follow a truncated (only positive) normal distribution with mean and standard deviation (in parentheses) shown. All other parameters follow a log-normal distribution with (log-)mean and (log-)standard deviation (in parentheses) shown.

PFT	$\varepsilon_{\max}$	log(SLA)	`Q10_livewood`	`Q10_froot`	log(`leaf_mr_base`)	log(`froot_mr_base`)	log(`livewood_mr_base`)
ENF	0.98 (0.32)	2.75 (0.78)	1.89 (0.27)	1.60 (1.60)	-4.65 (0.67)	-4.21 (0.84)	-5.27 (1.54)
EBF	1.40 (0.20)	3.21 (0.45)	1.84 (0.22)	1.60 (1.60)	-4.65 (0.67)	-4.21 (0.84)	-5.27 (1.54)
DNF	1.23 (0.20)	3.21 (0.27)	1.89 (0.27)	1.60 (1.60)	-4.35 (0.55)	-4.21 (0.84)	-5.27 (1.54)
DBF	1.68 (0.35)	3.61 (0.63)	1.84 (0.22)	1.60 (1.60)	-4.35 (0.55)	-4.21 (0.84)	-5.27 (1.54)
MF	1.43 (0.37)	3.56 (0.58)	1.84 (0.22)	1.60 (1.60)	-4.56 (0.61)	-4.21 (0.84)	-5.27 (1.54)
CSH	0.80 (0.38)	3.21 (0.31)	1.84 (0.22)	1.60 (1.60)	-4.36 (0.70)	-4.21 (0.84)	-5.27 (1.54)
OSH	0.74 (0.21)	3.21 (0.31)	1.84 (0.22)	1.60 (1.60)	-4.36 (0.70)	-4.21 (0.84)	-5.27 (1.54)
WSV	0.93 (0.37)	3.60 (0.70)	1.84 (0.22)	1.60 (1.60)	-4.36 (0.70)	-4.21 (0.84)	-5.27 (1.54)
SAV	0.93 (0.38)	3.58 (0.53)	1.84 (0.22)	1.60 (1.60)	-4.36 (0.70)	-4.21 (0.84)	-5.27 (1.54)
GRS	1.19 (0.45)	3.60 (0.54)	0.00 (0.00)	1.60 (1.60)	-4.03 (0.54)	-4.21 (0.84)	0.00 (0.00)
CRO	1.94 (0.55)	3.72 (0.60)	0.00 (0.00)	1.60 (1.60)	-3.78 (0.86)	-4.21 (0.84)	0.00 (0.00)

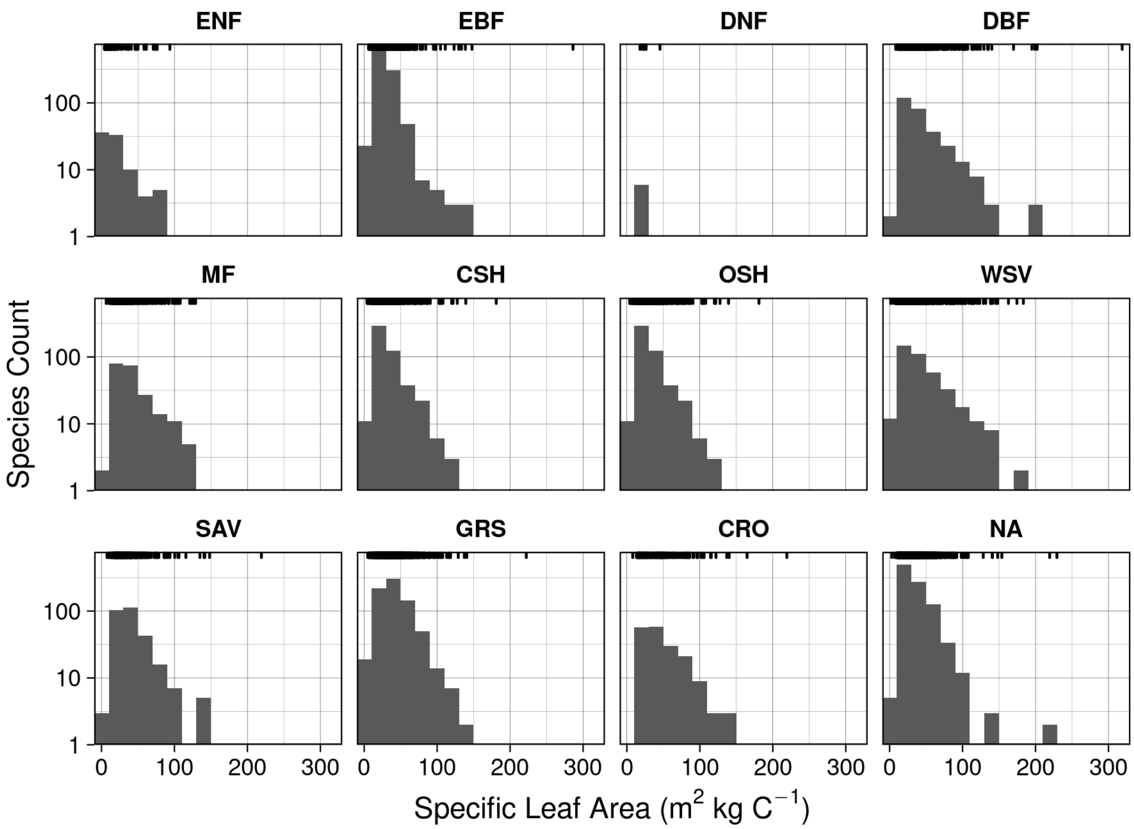

Figure 8: Histograms of specific leaf area (SLA) from the TRY database, in carbon (C) terms (i.e., leaf area per unit C) for each PFT. A rug plot at the top of each subplot shows the distribution of species-level observations.

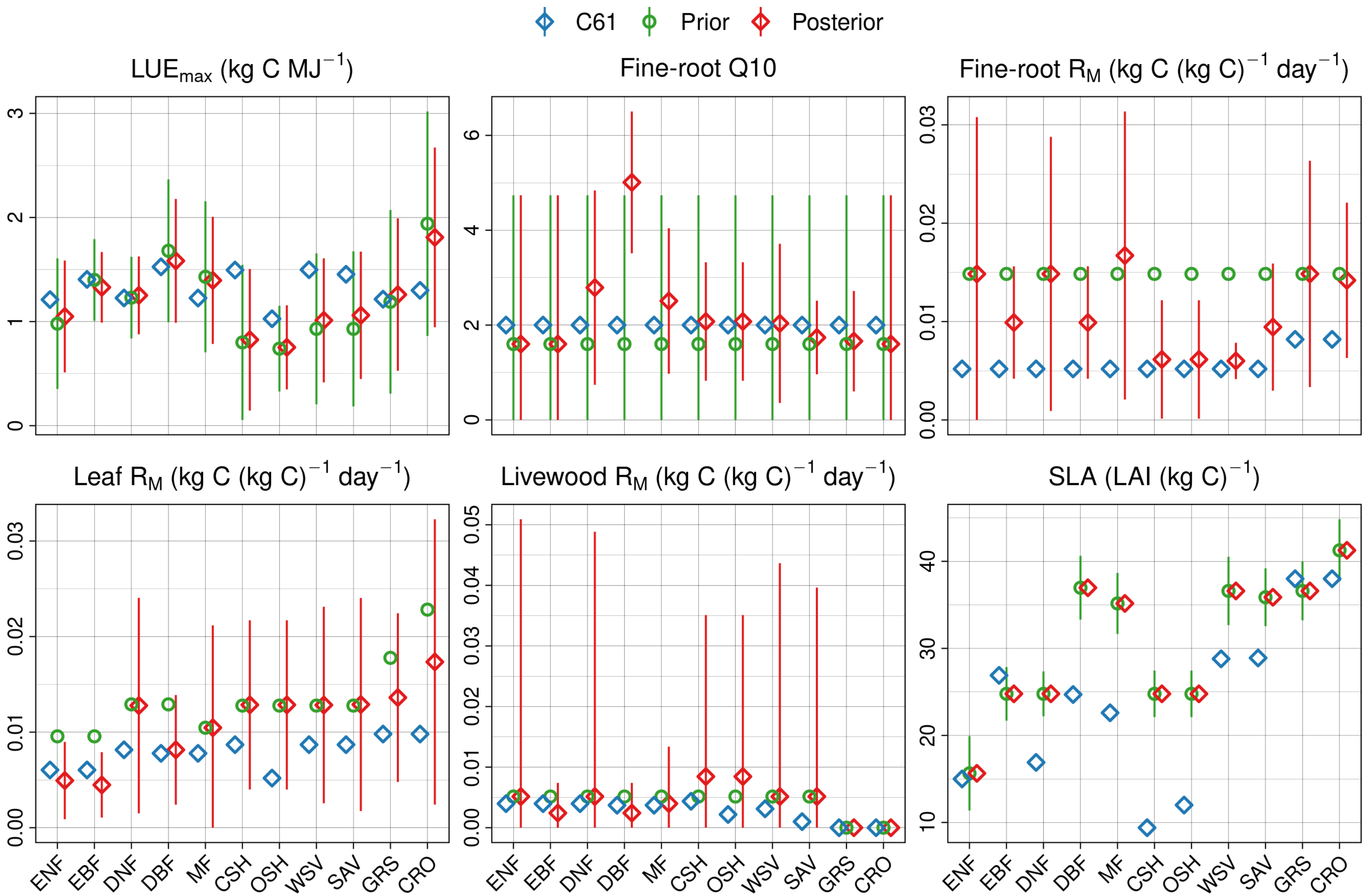

Figure 9: Distribution of BPLUT parameters for MOD17, comparing original Collection 6.1 (C61) values, the prior distribution and prior mean from TRY ("Prior"), and posterior distribution and mean ("Posterior"). For `froot_mr_base`, `leaf_mr_base`, and `livewood_mr_base`, the prior is derived from the literature or from a small number of species in TRY, so no distribution is shown. SLA was fixed at its prior mean, so only the prior distribution is shown and the "posterior" mean is the same as the prior mean.

Table 9: Updated BPLUT for the MOD17 and VNP17 GPP models, based on the optimal posterior estimates. Both MOD17 and VNP17 use the same parameters for the VPD and T_{min} environmental scalars. The lower bounds on T_{min} and VPD, respectively $T_{\mathrm{min},\leftarrow}$ and $\mathrm{VPD}_{\leftarrow}$, are fixed at their MOD17 Collection 6.1 values. To facilitate comparison, the upper bounds are rounded to the nearest 1 deg C or 50 Pascals, which is consistent with the model's low sensitivity to these parameters.

GPP Parameter	ENF	EBF	DNF	DBF	MF	CSH	OSH	WSV	SAV	GRS	CRO
MOD17 $\varepsilon_{\mathrm{max}}$ (g C MJ^{-1})	1.05	1.33	1.25	1.58	1.40	0.83	0.75	0.96	1.06	1.26	1.81
VNP17 $\varepsilon_{\mathrm{max}}$ (g C MJ^{-1})	1.01	1.29	1.24	1.56	1.36	0.81	0.76	1.00	1.05	1.24	1.80
$T_{\mathrm{min},\leftarrow}$ (deg C)	-8	-8	-8	-6	-7	-8	-8	-8	-8	-8	-8
$T_{\mathrm{min},\rightarrow}$ (deg C)	4	20	4	21	18	19	11	14	8	5	21
$\mathrm{VPD}_{\leftarrow}$ (Pa)	650	1000	650	650	650	650	650	650	650	650	650
$\mathrm{VPD}_{\rightarrow}$ (Pa)	4650	4300	2450	3450	3900	4650	5350	3650	5100	4150	4950

Table 10: Updated BPLUT for the MOD17 annual NPP model, based on the optimal posterior estimates. `froot_leaf_ratio` and `livewood_leaf_ratio` are fixed at their Collection 6.1 values.

Parameter	ENF	EBF	DNF	DBF	MF	CSH	OSH	WSV	SAV	GRS	CRO
MOD17 SLA (LAI [kg C]$^{-1}$)	15.6	24.8	24.8	37.0	35.2	24.8	24.8	36.6	35.9	36.6	41.3
VNP17 SLA (LAI [kg C]$^{-1}$)	16.2	26.7	25.3	38.2	36.2	25.4	25.0	37.2	36.8	37.8	41.9
`froot_leaf_ratio`	1.2	1.1	1.7	1.1	1.1	1.0	1.3	1.8	1.8	2.6	2.0
`livewood_leaf_ratio`	0.18	0.16	0.17	0.20	0.20	0.08	0.04	0.09	0.05	0.00	0.00
`froot_mr_base`	0.0148	0.0099	0.0148	0.0099	0.0167	0.0061	0.0061	0.0026	0.0094	0.0148	0.0142
`leaf_mr_base`	0.0049	0.0045	0.0128	0.0081	0.0105	0.0129	0.0129	0.0128	0.0129	0.0136	0.0173
`livewood_mr_base`	0.0051	0.0024	0.0051	0.0024	0.0040	0.0084	0.0084	0.0051	0.0051	0.0000	0.0000
`Q10_froot`	1.60	1.60	2.79	5.01	2.51	2.08	2.08	2.33	1.74	1.66	1.60
`Q10_livewood`	1.92	1.75	1.89	1.86	1.86	1.85	1.85	1.85	1.83	0.00	0.00

Table 13: 8-day GPP (MOD17A2H) validation metrics, for Collection 6.1 ("C6.1") and the updated BPLUT ("Update"), as compared to FLUXNET sites (2000-2017). Mean Bias, RMSE, and ubRMSE are in units of g C m^{-2} day^{-1}, while the parentheses under RMSE indicate the normalized RMSE. The normalized RMSE (%) is based on the overall observed range of daily GPP or annual NPP; for daily GPP, the observed range is restricted to years 2012-2017 to allow for meaningful comparisons between MODIS and VIIRS.

PFT	N	Bias (C61)	Bias (Update)	RMSE (C61)	RMSE (Update)	ubRMSE (C61)	ubRMSE (Update)	r (C61)	r (Update)
ENF	808	-1.0	-1.1	2.2 (11%)	2.2 (11%)	1.7	1.6	0.88	0.89
EBF	427	0.2	0.3	2.6 (13%)	2.4 (13%)	2.2	2.2	0.70	0.75
DNF	71	-0.7	-0.2	2.5 (13%)	2.5 (13%)	1.9	2.0	0.75	0.73
DBF	994	-0.2	-0.2	2.5 (13%)	2.0 (10%)	2.3	1.7	0.84	0.90
MF	667	-0.9	-0.7	2.0 (10%)	1.8 (9%)	1.6	1.5	0.90	0.90
CSH	94	0.2	0.1	0.6 (3%)	0.7 (3%)	0.4	0.5	0.25	0.04
OSH	406	0.4	0.3	0.9 (5%)	0.8 (4%)	0.7	0.6	0.69	0.72
WSV	562	-0.1	-0.4	1.3 (7%)	1.5 (8%)	1.1	1.0	0.86	0.84
SAV	788	-1.0	-0.8	2.5 (13%)	2.3 (12%)	2.1	2.0	0.74	0.77
GRS	604	0.2	0.5	1.4 (7%)	1.5 (7%)	1.2	1.1	0.77	0.76
CRO	853	-1.2	-0.3	5.1 (26%)	4.0 (21%)	4.8	4.0	0.74	0.83

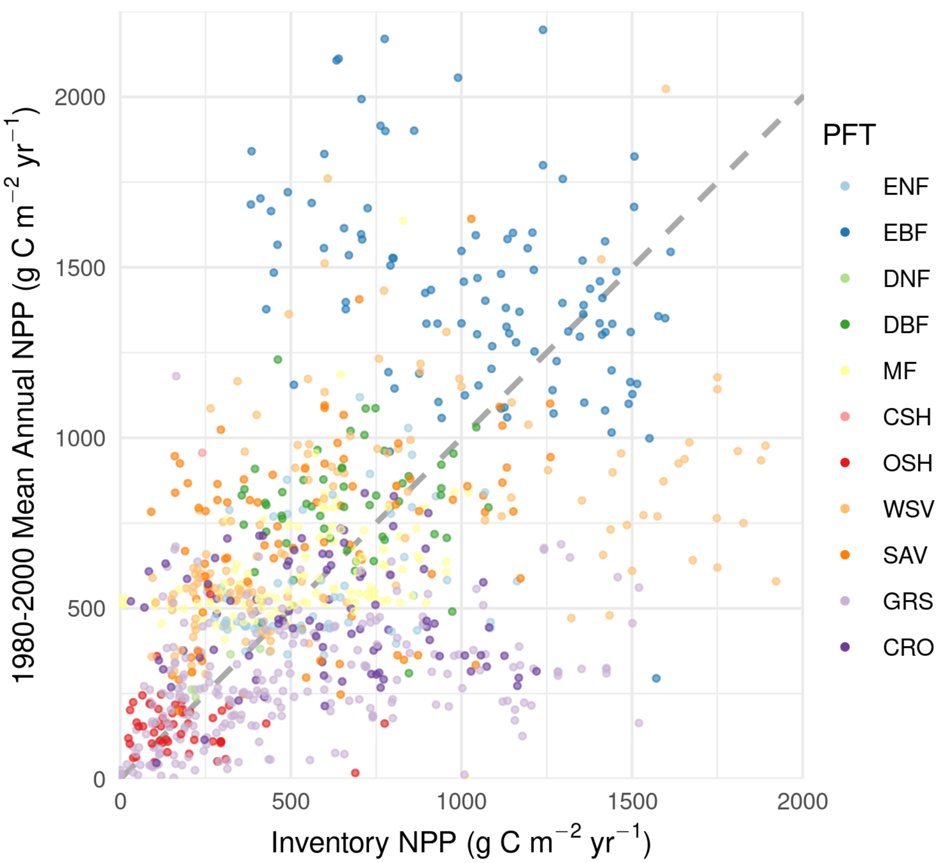

Figure 10: MOD17 predicted mean annual NPP, using the Collection 6.1 BPLUT, against observed mean annual NPP from the field. The dashed line indicates the 1:1 line.

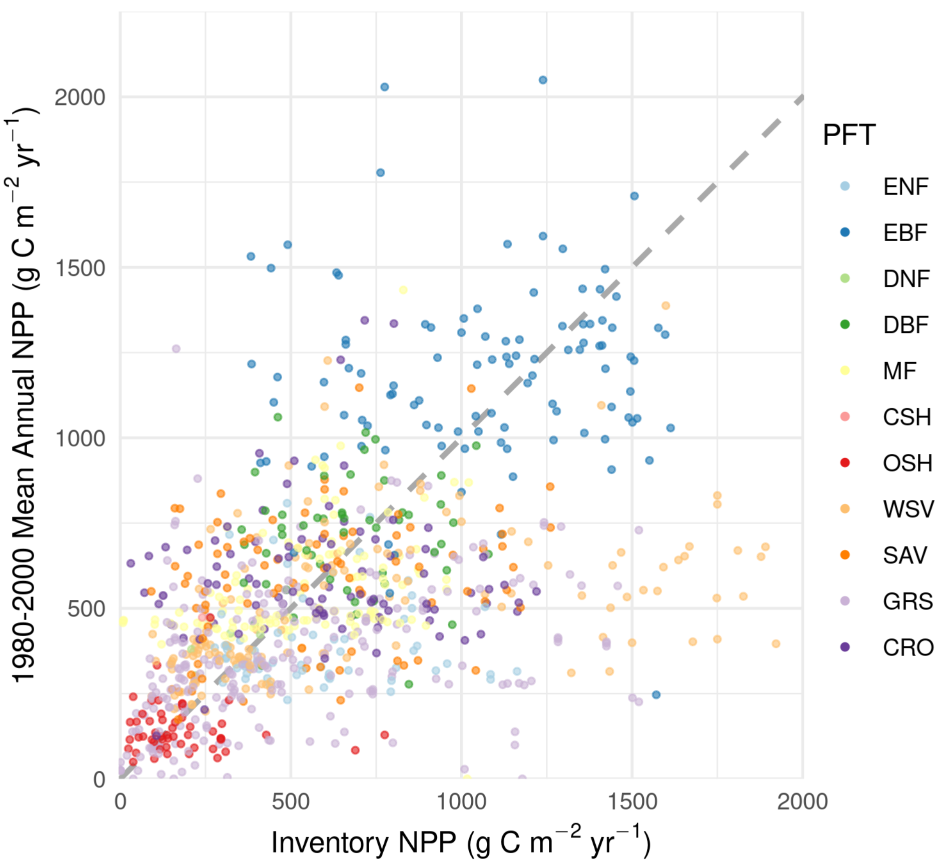

Figure 11: MOD17 predicted mean annual NPP, using the updated BPLUT, against observed mean annual NPP from the field. The dashed line indicates the 1:1 line.

Table 15: Annual MOD17 NPP validation metrics at Cal-Val inventory sites, based on k-folds cross-validation. RMSE is in units of g C m^{-2} $year^{-1}$. Statistics are not available for CSH because of too few sites.

PFT	Count	Bias (C6.1)	Bias (Update)	RMSE (C6.1)	RMSE (Update)	nRMSE (C6.1)	nRMSE (Update)	r (C6.1)	r (Update)
ENF	63	-11	-175	187	236	23.0%	29.0%	0.33	0.00
EBF	104	230	11	380	292	29.4%	22.7%	0.43	0.55
DNF	5	226	13	372	288	27.7%	21.4%	0.46	0.57
DBF	54	205	19	338	267	25.1%	19.9%	0.47	0.56
MF	110	158	18	292	243	18.9%	15.8%	0.54	0.58
CSH	1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
OSH	53	134	11	268	225	17.2%	14.5%	0.64	0.68
WSV	141	113	-12	298	254	16.3%	13.9%	0.56	0.60
SAV	83	117	-22	301	257	16.5%	14.1%	0.54	0.57
GRS	248	22	-5	298	260	16.1%	14.1%	0.51	0.56
CRO	89	8	8	296	265	16.0%	14.3%	0.49	0.53

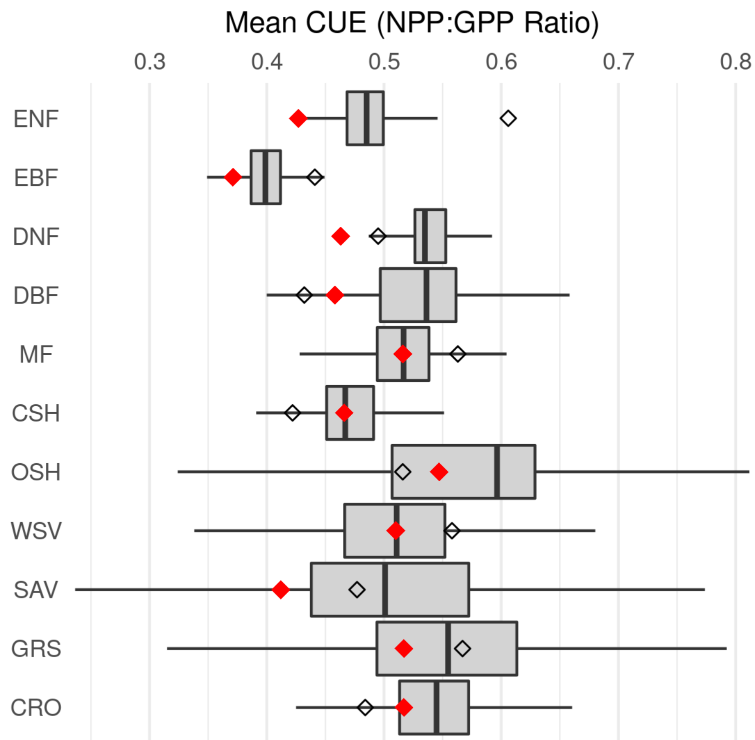

Figure 12: Plant carbon-use efficiency (CUE) values from the MsTMIP global, gridded ensemble mean (2000-2010), shown as boxplots, along with the overall mean CUE in the updated MOD17 product, shown as red diamonds. The new VNP17 BPLUT results in overall, global mean CUE values that are nearly identical to those shown here for MOD17.

Table 16: Annual VNP17 NPP validation metrics at Cal-Val inventory sites, based on k-folds cross-validation. RMSE is in units of g C m^{-2} $year^{-1}$. Statistics are not available for CSH because of too few sites.

PFT	Count	Bias	RMSE	nRMSE	r
ENF	63	-148	201	24.7%	0.37
EBF	104	90	335	26.0%	0.52
DNF	5	91	330	24.6%	0.54
DBF	54	78	300	22.3%	0.54
MF	110	61	265	17.2%	0.57
CSH	1	n.a.	n.a.	n.a.	n.a.
OSH	53	48	244	15.7%	0.67
WSV	141	-12	271	14.8%	0.54
SAV	83	-8	272	14.9%	0.53
GRS	247	-50	271	14.6%	0.51
CRO	89	-46	274	14.8%	0.49

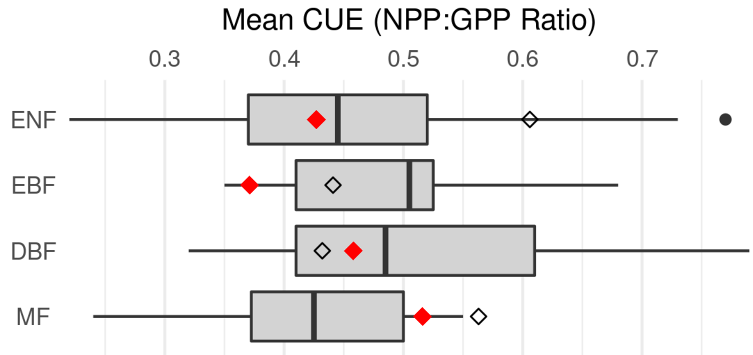

Figure 13: Plant carbon-use efficiency (CUE) values from the synthesis by Collalti & Prentice (2019), which included data only for forests, shown as boxplots, along with the overall mean CUE in the updated MOD17 product, shown as red diamonds. The new VNP17 BPLUT results in overall, global mean CUE values that are nearly identical to those shown here for MOD17.

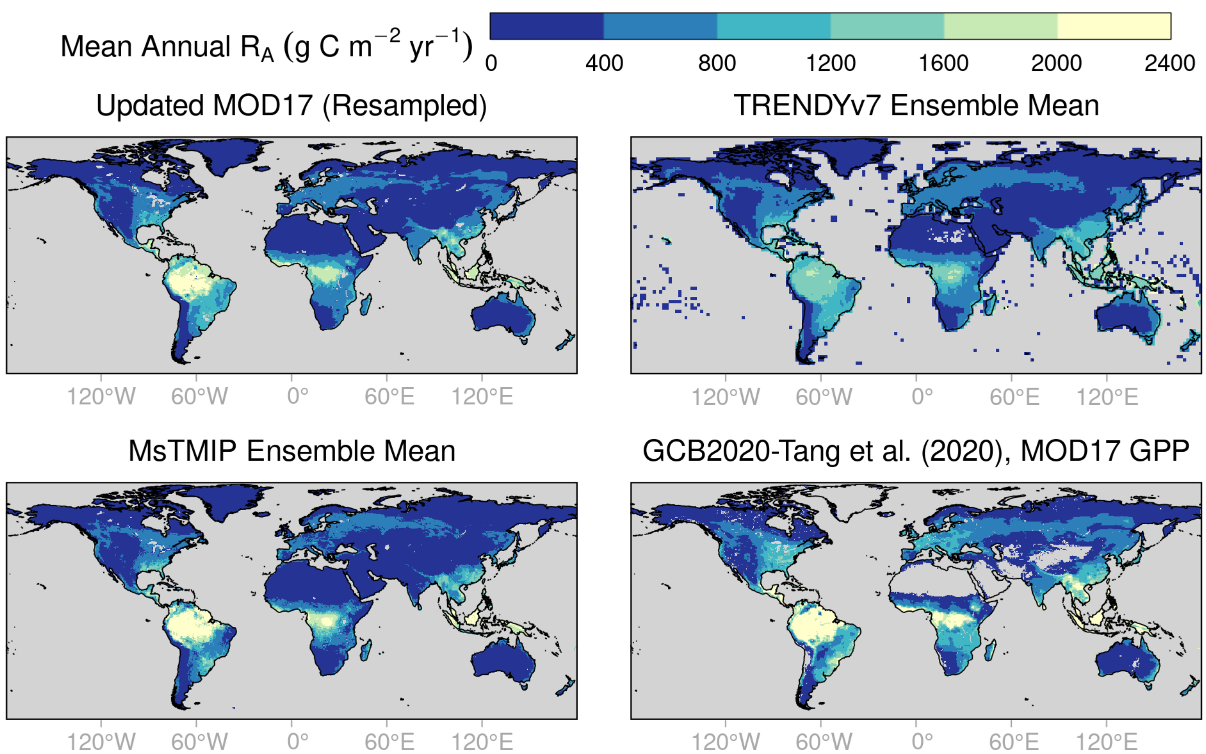

Figure 14: Plots of mean annual autotrophic respiration (R_A) for 2000-2010, which is a period of record common to all datasets. The TRENDYv7 Ensemble Mean is shown on a 1-degree equirectangular grid, all others are shown on a 0.5-degree grid. The Updated MOD17 map is based on a bilinear resampling from the original 5-km, MODIS Sinusoidal projection. The Global Carbon Budget-Tange et al. (2020) synthesis, "GCB2020-Tang et al. (2020)" is computed by subtracting that annual NPP product from the Updated MOD17 annual GPP product.)

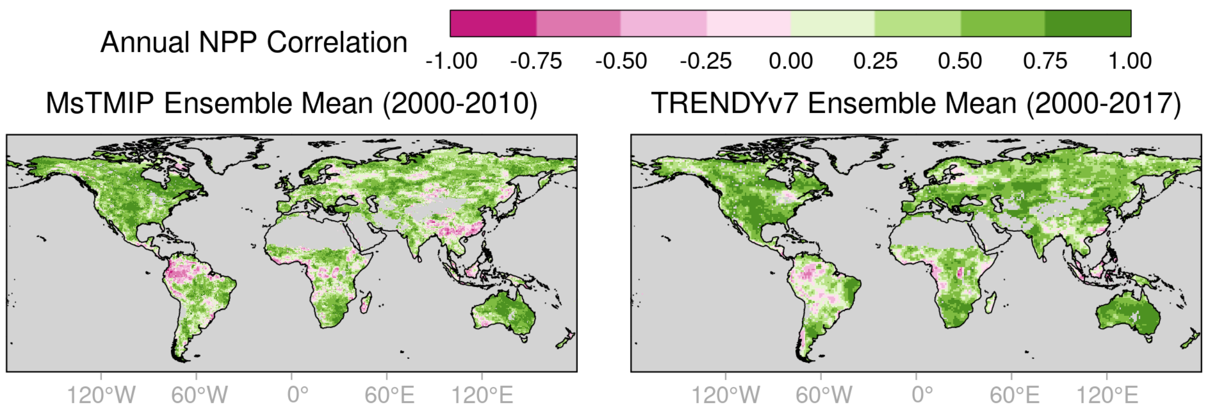

Figure 15: Plots of temporal correlations in annual NPP between the updated MOD17 product and two bottom-up modeling ensembles. The TRENDYv7 Ensemble Mean is shown on a 1-degree equirectangular grid, all others are shown on a 0.5-degree grid.

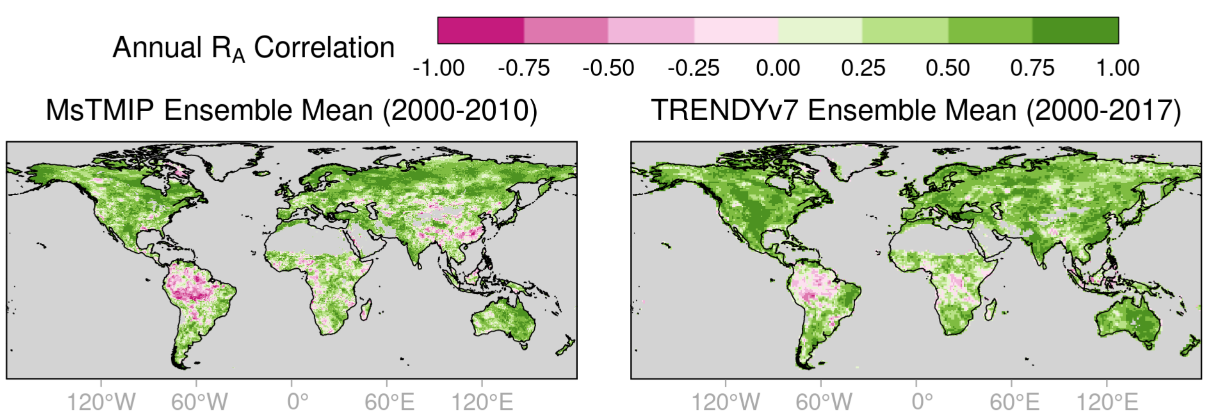

Figure 16: Plots of temporal correlations in annual autotrophic respiration (R_A) between the updated MOD17 product and two bottom-up modeling ensembles. The TRENDYv7 Ensemble Mean is shown on a 1-degree equirectangular grid, all others are shown on a 0.5-degree grid.

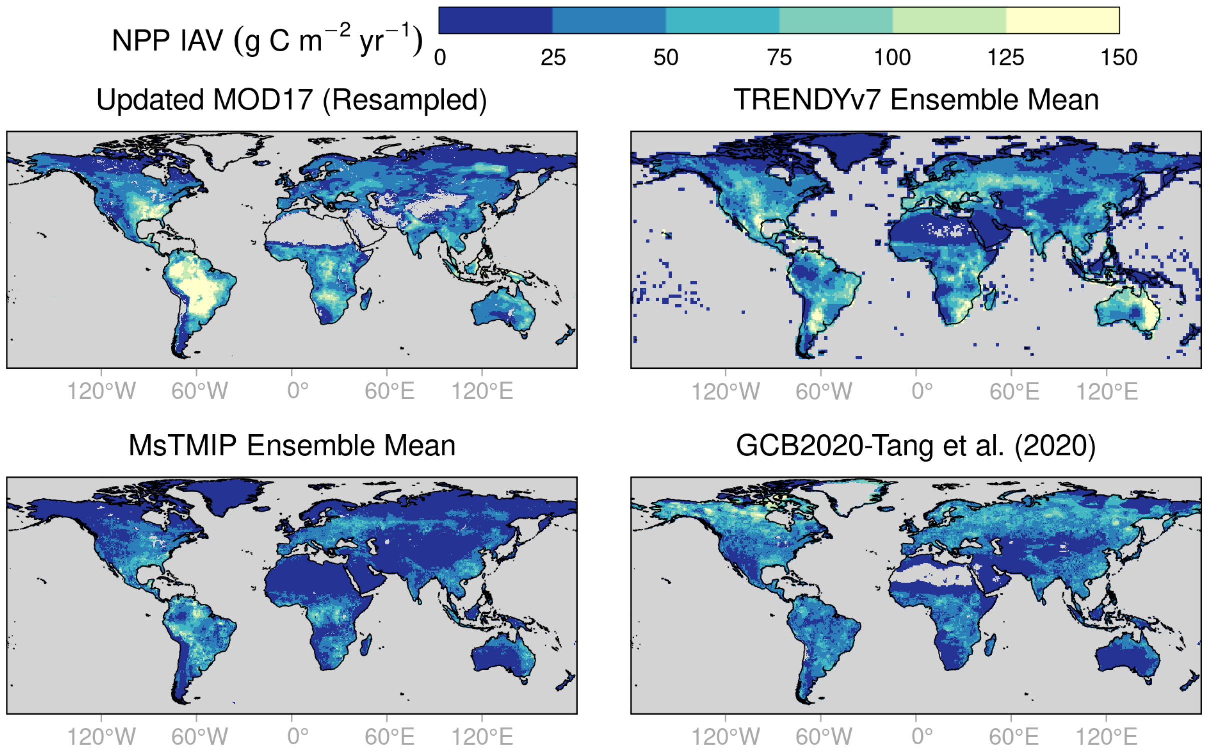

Figure 17: Interannual variability (standard deviation across the years 2000-2010) in annual NPP. The TRENDYv7 Ensemble Mean is shown on a 1-degree equirectangular grid, all others are shown on a 0.5-degree grid. The Updated MOD17 map is based on a bilinear resampling from the original 5-km, MODIS Sinusoidal projection.

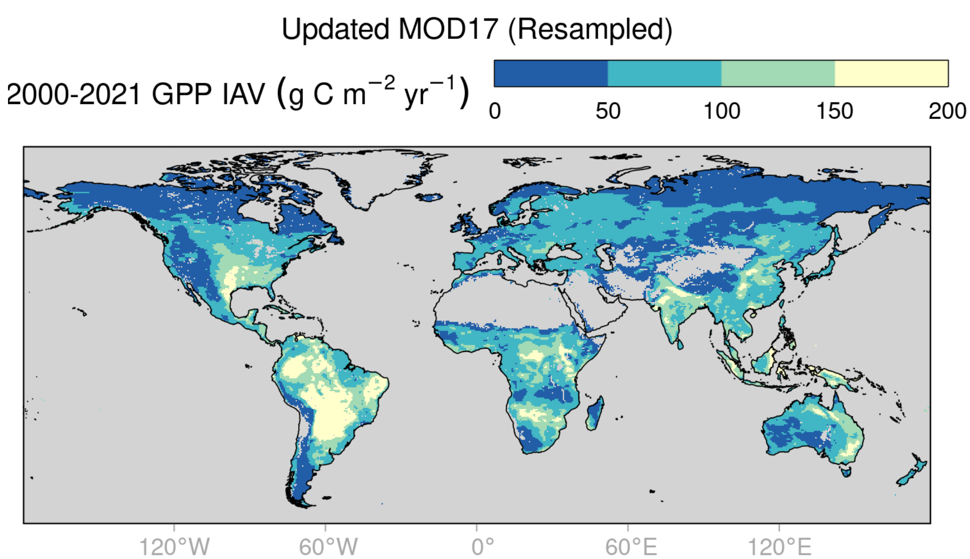

Figure 18: Interannual variability (standard deviation across the years 2000-2021) in annual GPP, based on the updated MOD17 BPLUT and resampling onto a 0.5-degree grid.

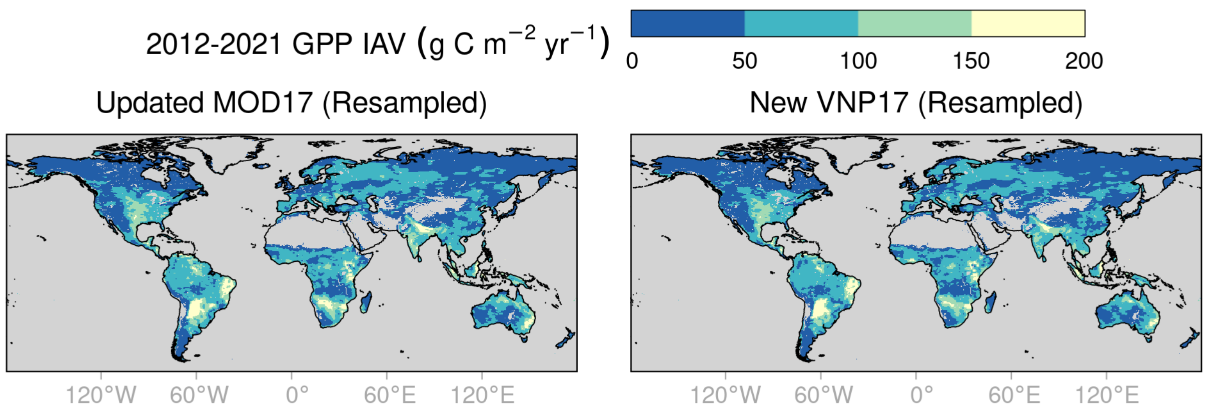

Figure 19: Interannual variability (standard deviation across the years 2012-2021) in annual GPP, based on resampling onto a 0.5-degree grid.

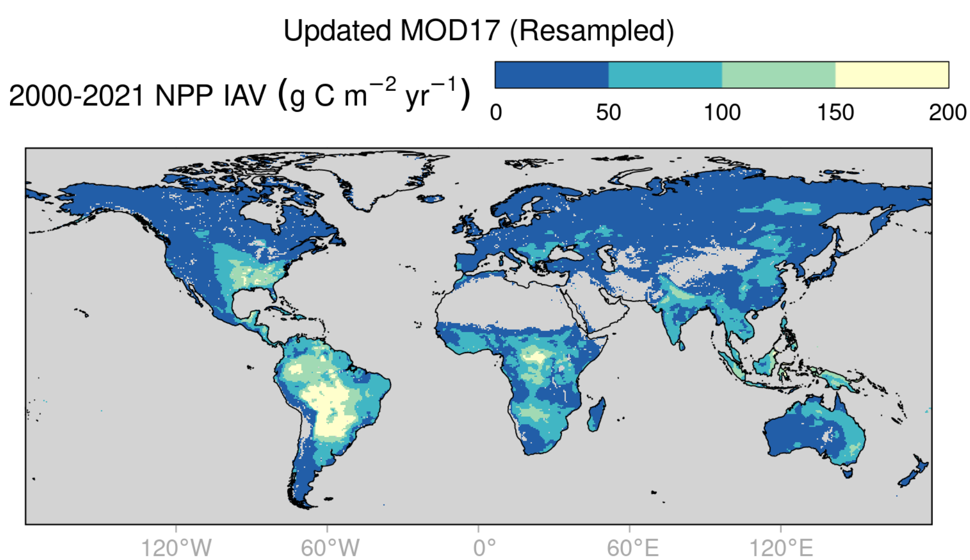

Figure 20: Interannual variability (standard deviation across the years 2000-2021) in annual NPP, based on the updated MOD17 BPLUT and resampling onto a 0.5-degree grid.

Table 17: Average root-mean squared error (RMSE) in annual GPP or NPP (g C m^{-2} $year^{-1}$) for each product, compared to independent datasets. The MOD17 and VNP17 (5-km resolution) data were projected onto a 0.5-degree or 1-degree equirectangular grid with bilinear resampling, prior to computing RMSE. Standard deviation across the years is also given.

NPP Dataset	Flux	MOD17 Update	New VNP17
TRENDYv7 Ensemble	Annual GPP	310 $\pm$11	307 $\pm$9
MsTMIP Ensemble	Annual GPP	383 $\pm$8	n.a.
Global Carbon Budget-Tang et al.	Annual NPP	260 $\pm$5	260 $\pm$8
TRENDYv7 Ensemble	Annual NPP	192 $\pm$12	179 $\pm$4
MsTMIP Ensemble	Annual NPP	230 $\pm$8	n.a.

Table 18: Pearson's correlation coefficients and RMSE, within each PFT group, between annual net primary production (NPP) estimated by MOD17/VNP17 and annual NPP based on the Global Carbon Budget (2020). 2010-2016 annual NPP is calculated from the Global Carbon Budget's estimate of net ecosystem exchange (NEE) based on atmospheric inversion and combined with an up-scaled, global, 1-degree map of heterotrophic respiration from Tang et al. (2020). Coefficients for the New VNP17 BPLUT are based on only the years 2012-2016.

PFT	RMSE (C61)	RMSE (MOD17 Update)	RMSE (VNP17 Update)	r (C61)	r (MOD17 Update)	r (VNP17 Update)
ENF	201	397	391	0.306	0.162	0.170
EBF	622	395	421	-0.513	-0.385	-0.464
DNF	138	148	62	-0.509	-0.407	-0.274
DBF	285	229	252	-0.178	-0.049	-0.153
MF	179	148	141	-0.133	-0.083	-0.122
CSH	171	265	270	-0.444	-0.421	-0.577
OSH	146	190	180	0.322	0.430	0.523
WSV	409	158	166	0.432	0.233	0.332
SAV	566	268	281	0.198	-0.047	-0.076
GRS	223	266	272	0.393	0.110	0.066
CRO	397	364	365	0.109	0.214	0.251

Table 19: Pearson's correlation coefficients and RMSE, within each PFT group, between annual net primary production (NPP) estimated by MOD17/VNP17 and mean annual NPP from the TRENDYv7 ensemble (2000-2017). Coefficients for the New VNP17 BPLUT are based on only the years 2012-2017.

PFT	RMSE (C61)	RMSE (MOD17 Update)	RMSE (VNP17 Update)	r (C61)	r (MOD17 Update)	r (VNP17 Update)
ENF	333	543	255	-0.169	-0.458	0.134
EBF	707	597	708	-0.631	-0.446	-0.474
DNF	348	354	81	0.651	0.766	-0.286
DBF	245	192	165	-0.028	0.260	0.383
MF	250	289	202	0.043	-0.219	-0.302
CSH	236	114	76	0.264	0.254	0.281
OSH	105	150	114	0.465	0.443	0.494
WSV	234	221	151	0.548	0.244	0.608
SAV	382	296	332	0.493	0.046	0.541
GRS	191	256	300	0.668	0.445	0.317
CRO	235	206	215	-0.005	0.043	-0.079

Table 20: Pearson's correlation coefficients and RMSE, within each PFT group, between annual net primary production (NPP) estimated by MOD17 and mean annual NPP from the MsTMIP ensemble (2000-2010).

PFT	RMSE (C61)	RMSE (MOD17 Update)	r (C61)	r (MOD17 Update)
ENF	265	455	-0.050	-0.349
EBF	823	651	-0.843	-0.563
DNF	199	206	0.412	0.596
DBF	212	163	0.286	0.547
MF	302	325	-0.258	-0.316
CSH	170	163	0.770	0.726
OSH	229	257	0.261	0.287
WSV	288	178	0.636	0.347
SAV	437	360	0.446	-0.116
GRS	203	235	0.685	0.514
CRO	279	245	0.141	0.263

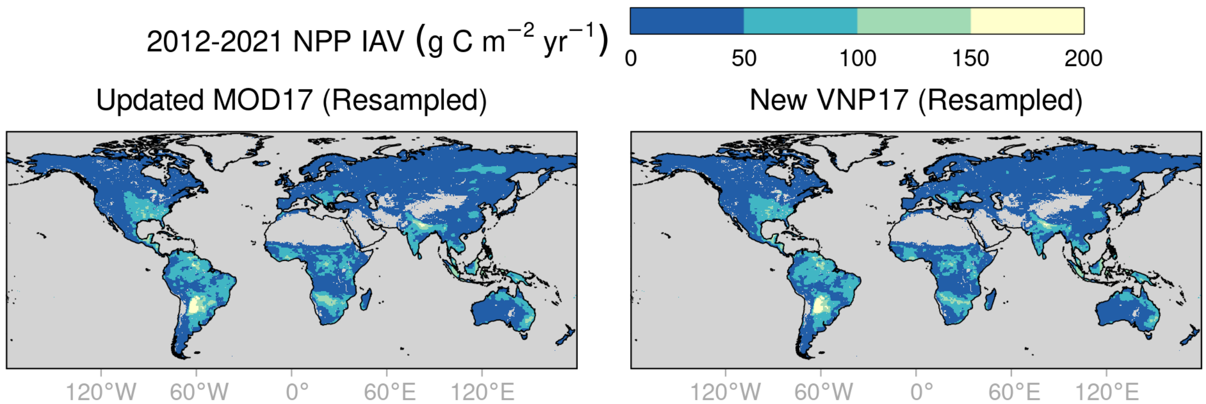

Figure 21: Interannual variability (standard deviation across the years 2012-2021) in annual NPP, based on resampling onto a 0.5-degree grid.

Table 21: Annual GPP and NPP fluxes (Pg C year^{-1}) for different products in different time periods.

Period	Product	GPP	NPP
2000-2010	Collection 6.1	117.4 ±2.2	58.2 ±1.7
2000-2010	FLUXCOM RS+METEO (ERA5)	115.7 ±0.4	n.a.
2000-2010	GCB2020-Tang et al.	n.a.	49.8 ±0.4
2000-2010	MOD17 Update	125.4 ±2.0	56.1 ±1.5
2000-2010	MsTMIP Ensemble Mean	109.9 ±1.7	51.6 ±0.9
2000-2010	TRENDYv7 Ensemble Mean	124.9 ±1.6	60.5 ±1.0
2000-2018	Collection 6.1	119.2 ±2.9	59.3 ±1.9
2000-2018	FLUXCOM RS+METEO (ERA5)	115.5 ±0.4	n.a.
2000-2018	GCB2020-Tang et al.	n.a.	49.6 ±0.6
2000-2018	MOD17 Update	127.2 ±2.8	57.1 ±1.8
2000-2018	MsTMIP Ensemble Mean	109.9 ±1.7	51.6 ±0.9
2000-2018	TRENDYv7 Ensemble Mean	126.3 ±2.4	61.2 ±1.3
2012-2018	Collection 6.1	121.6 ±1.6	60.7 ±1.1
2012-2018	FLUXCOM RS+METEO (ERA5)	115.2 ±0.2	n.a.
2012-2018	GCB2020-Tang et al.	n.a.	49.6 ±0.8
2012-2018	MOD17 Update	129.7 ±1.7	58.5 ±1.1
2012-2018	New VNP17	129.6 ±1.7	58.4 ±1.1
2012-2018	TRENDYv7 Ensemble Mean	128.6 ±1.4	62.3 ±0.9
2012-2021	Collection 6.1	121.9 ±1.4	60.7 ±0.9
2012-2021	FLUXCOM RS+METEO (ERA5)	115.2 ±0.2	n.a.
2012-2021	GCB2020-Tang et al.	n.a.	49.6 ±0.8
2012-2021	MOD17 Update	130.1 ±1.6	58.6 ±0.9
2012-2021	New VNP17	129.8 ±1.5	58.4 ±0.9
2012-2021	TRENDYv7 Ensemble Mean	128.6 ±1.4	62.3 ±0.9

Table 22: Error budget for the MOD17 daily GPP model. All units are g C m^{-2} day^{-1}. σ(fPAR) is the error in daily GPP due to error in MODIS MOD15A2HGF fPAR; $\sigma(\varepsilon_{max})$ is the error in daily GPP due to uncertainty in the maximum light-use efficiency parameter, ε_{max}. The "Overall" row corresponds to the pooled, stratified result, where every PFT is approximately equally represented.

PFT	Test RMSE	σ(fPAR)	$\sigma(\varepsilon_{max})$
ENF	2.23	1.84	0.08
EBF	2.44	2.88	0.12
DNF	2.47	2.57	0.07
DBF	2.02	1.57	0.05
MF	1.84	1.53	0.05
CSH	0.66	1.17	0.02
OSH	0.84	1.05	0.02
WSV	1.49	1.13	0.05
SAV	2.32	1.86	0.07
GRS	1.45	2.05	0.04
CRO	4.04	2.18	0.04
Overall	2.48	1.81	0.05

Table 23: Error budget for the VNP17 daily GPP model. All units are g C m^{-2} day^{-1}. σ(fPAR) is the error in daily GPP due to error in MODIS VNP15A2HGF fPAR; $\sigma(\varepsilon_{max})$ is the error in daily GPP due to uncertainty in the maximum light-use efficiency parameter, ε_{max}. The "Overall" row corresponds to the pooled, stratified result, where every PFT is approximately equally represented.

PFT	Test RMSE	σ(fPAR)	$\sigma(\varepsilon_{max})$
ENF	2.79	1.77	0.08
EBF	2.84	2.78	0.11
DNF	n.a.	2.55	0.07
DBF	1.53	1.55	0.05
MF	2.06	1.49	0.05
CSH	0.48	1.15	0.02
OSH	0.62	1.06	0.02
WSV	1.48	1.31	0.05
SAV	2.58	1.84	0.07
GRS	1.29	2.01	0.04
CRO	3.33	2.16	0.04
Overall	2.17	1.73	0.05

Table 24: Error budget for the MOD17 annual NPP model, where the error is expressed as the coefficient of variation in the RMSE due to uncertainty in a given parameter, relative to Test RMSE (units: g C m^{-2} $year^{-1}$). This budget assumes that the allometric parameters, `froot_leaf_ratio` and `livewood_leaf_ratio` are fixed at their true values.

PFT	SLA (LAI [kg C]$^{-1}$)	`Q10_froot`	`Q10_livewood`	`froot_mr_base`	`leaf_mr_base`	`livewood_mr_base`
ENF	60%	44%	1%	59%	9%	33%
EBF	65%	82%	<1%	23%	10%	2%
DNF	11%	5%	<1%	20%	8%	9%
DBF	31%	1%	<1%	7%	5%	1%
MF	28%	11%	<1%	6%	10%	<1%
CSH	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
OSH	2%	<1%	<1%	<1%	<1%	<1%
WSV	43%	7%	<1%	3%	32%	10%
SAV	23%	1%	<1%	3%	3%	7%
GRS	21%	2%	<1%	29%	3%	<1%
CRO	25%	27%	<1%	2%	1%	<1%
Overall	29%	16%	<1%	14%	7%	3%

Table 25: Error budget for the VNP17 annual NPP model, where the error is expressed as the coefficient of variation in the RMSE due to uncertainty in a given parameter, relative to Test RMSE (units: g C m^{-2} $year^{-1}$). This budget assumes that the allometric parameters, `froot_leaf_ratio` and `livewood_leaf_ratio` are fixed at their true values.

PFT	SLA (LAI [kg C]$^{-1}$)	`Q10_froot`	`Q10_livewood`	`froot_mr_base`	`leaf_mr_base`	`livewood_mr_base`
ENF	73%	53%	1%	70%	11%	37%
EBF	54%	72%	<1%	18%	8%	2%
DNF	10%	4%	<1%	17%	7%	8%
DBF	29%	1%	<1%	6%	4%	<1%
MF	28%	7%	<1%	5%	8%	<1%
CSH	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
OSH	1%	<1%	<1%	<1%	<1%	<1%
WSV	43%	6%	<1%	3%	31%	9%
SAV	23%	1%	<1%	3%	3%	7%
GRS	21%	2%	<1%	27%	3%	<1%
CRO	24%	26%	<1%	2%	1%	<1%
Overall	28%	16%	<1%	13%	7%	3%

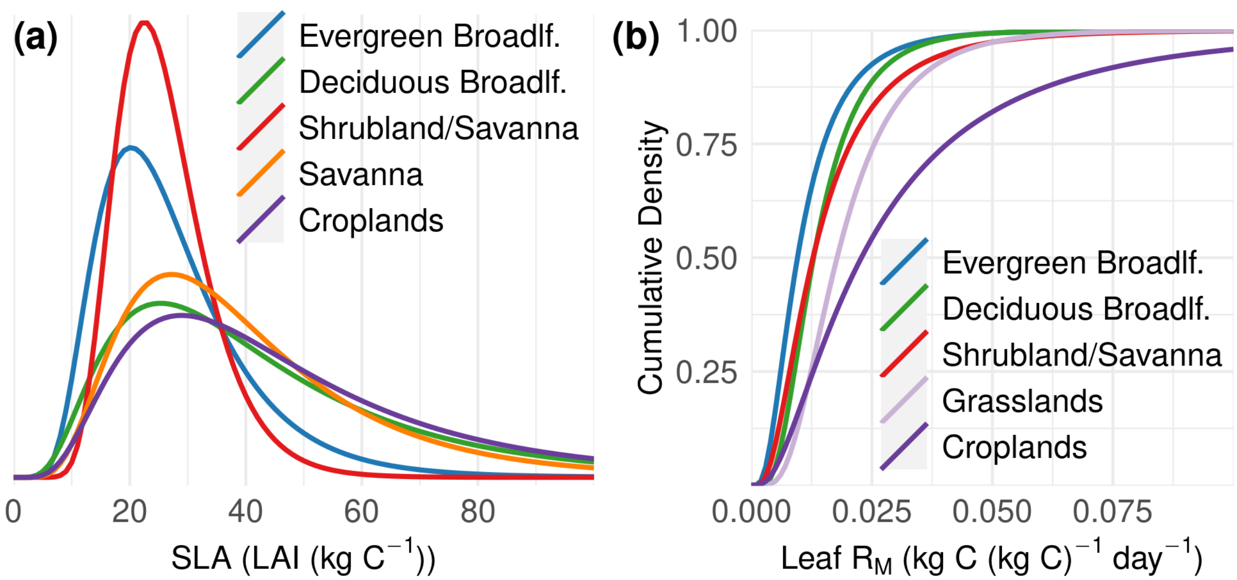

Figure 22: Uncertainty in TRY prior values, for select PFTs, as indicated by the prior probability density function for specific leaf area (a) and the prior cumulative density function for leaf R_M (b).