



## *Supplement of*

# **The biophysics, ecology, and biogeochemistry of functionally diverse, vertically and horizontally heterogeneous ecosystems: the Ecosystem Demography model, version 2.2 – Part 2: Model evaluation for tropical South America**

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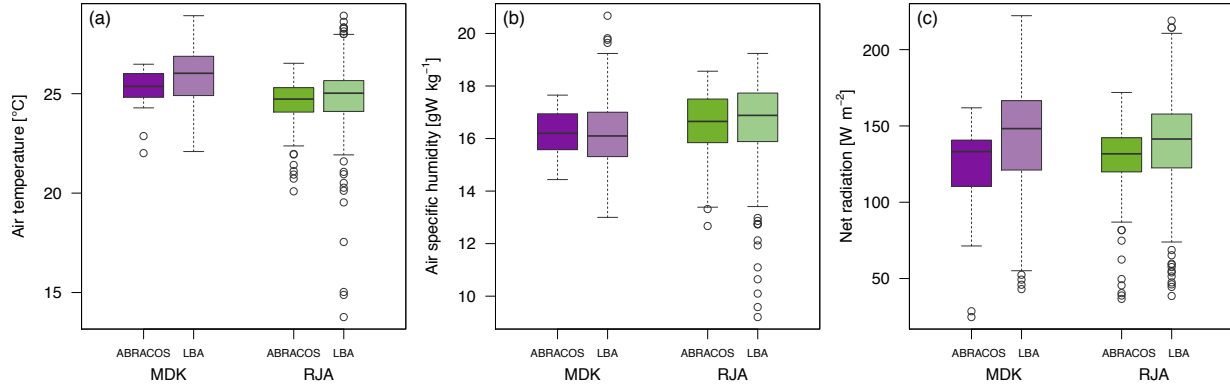


Figure S1: Box-and-whisker plots of the daily averages of (a) temperature, (b) specific humidity, and (c) net radiation of sites Jaru Biological Reserve (RJA) and the nearest sites from Adolpho Ducke Forest Reserve (MDK). The periods of comparison correspond to the Anglo-Brazilian Climate Observation Study (ABRACOS Cabral et al., 1996; Tomasella et al., 2008), and the data from the Large-Scale Biosphere-Atmosphere Experiment in Amazonia Data Model Intercomparison Project (de Gonçalves et al., 2013; de Gonçalves et al., 2013, LBA-MIP). For RJA, we used ABRACOS data from Aug-Sep 1992 and Apr-Jun 1993; for MDK, we used data from Fazenda Dimona (Jul-Aug 1991). For the LBA-MIP, we used the same days of year with ABRACOS measurements, from sites RJA (1999-2002) and K34 (1999-2006). Boxes correspond to the interquartile range, whiskers encompass data within 1.5 times the interquartile range, and the black line in the boxes are the median.

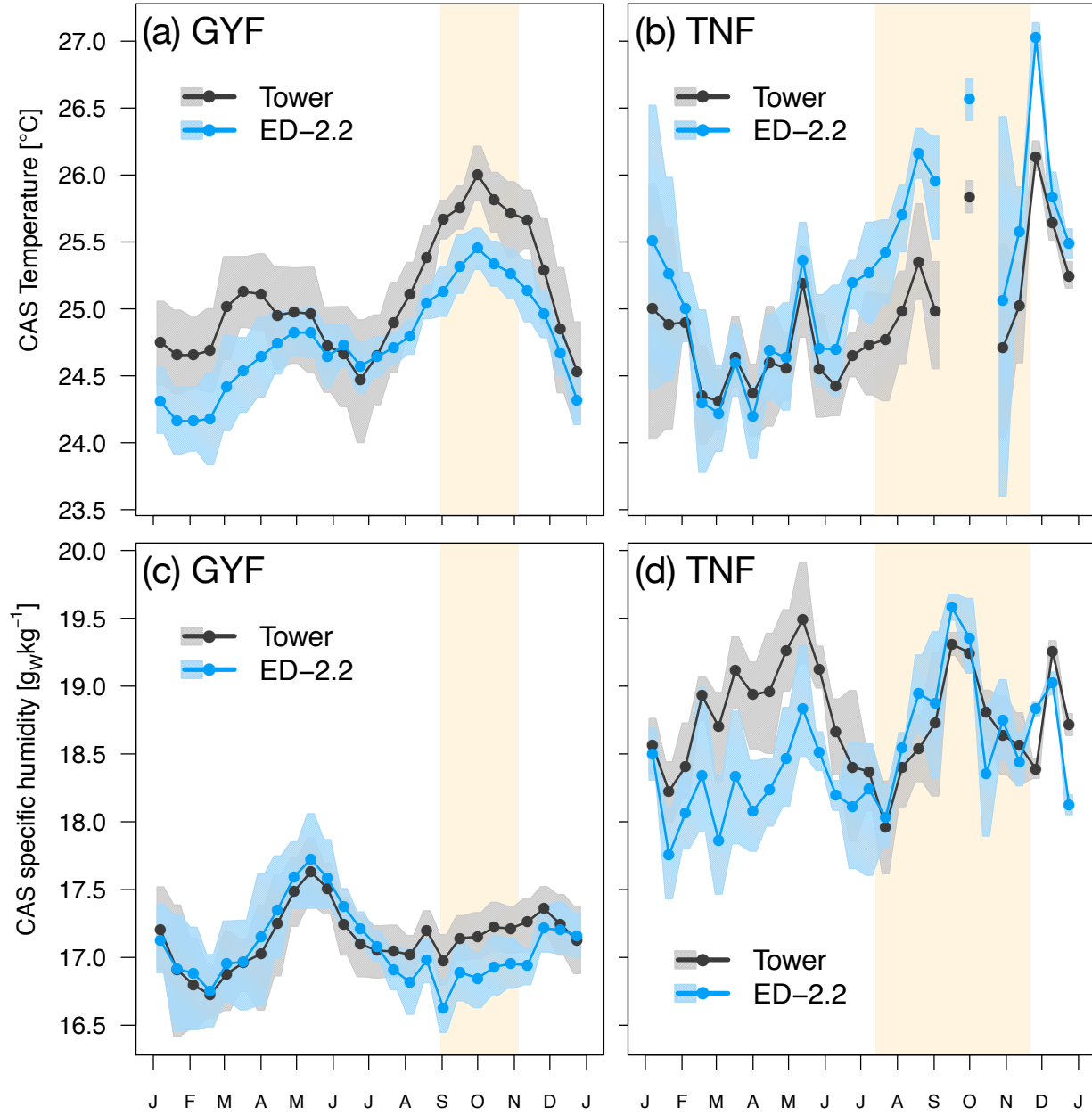


Figure S2: Fortnightly means of the (a,b) mean canopy-air-space temperature and (c,d) mean canopy-air-space specific humidity, obtained from the model and from the vertical average of the (a,c) GYF and (b,d) TNF tower measurements. Data for the TNF tower are available between 2002 and 2005 (Hutyra et al., 2008). Bands are the 95% confidence interval of means obtaining from bootstrapping, and rectangles in the background correspond to the site's climatological dry season. The missing periods are due to insufficient data of all times of the day to generate the fortnightly averages.

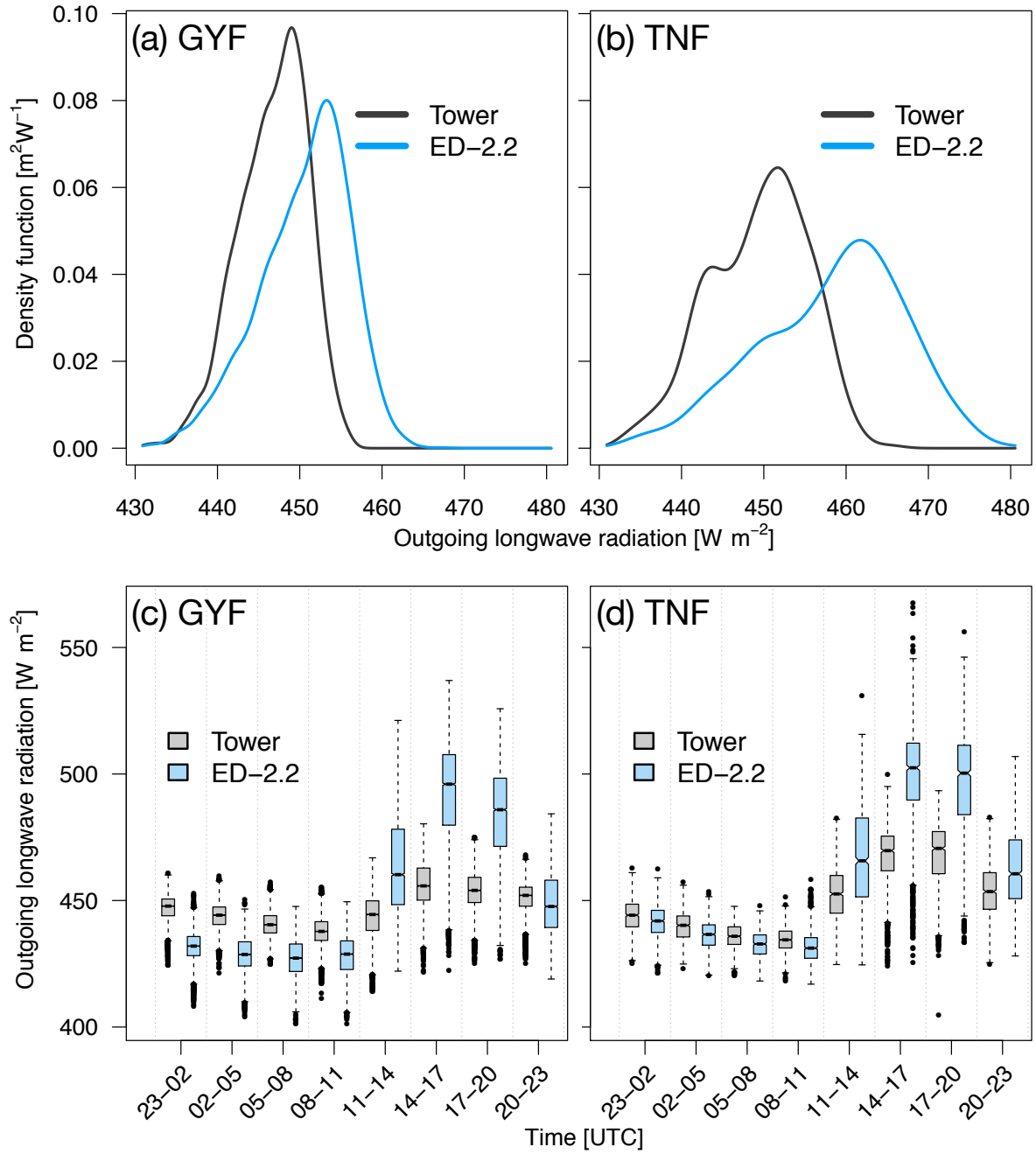


Figure S3: (a-b) Kernel density estimate of daily averages of outgoing thermal infrared (longwave) irradiance predicted by the model and measured at the towers for sites (a) GYF and (b) TNF. Only days with no gaps in observations were used to estimate kernel density for both observations and model. (c-d) Box-and-whisker plot of outgoing thermal infrared irradiance from ED-2.2 and observations, organized by time of day, for sites (c) GYF and (d) TNF. The model distribution includes only the times for which a corresponding observation existed.

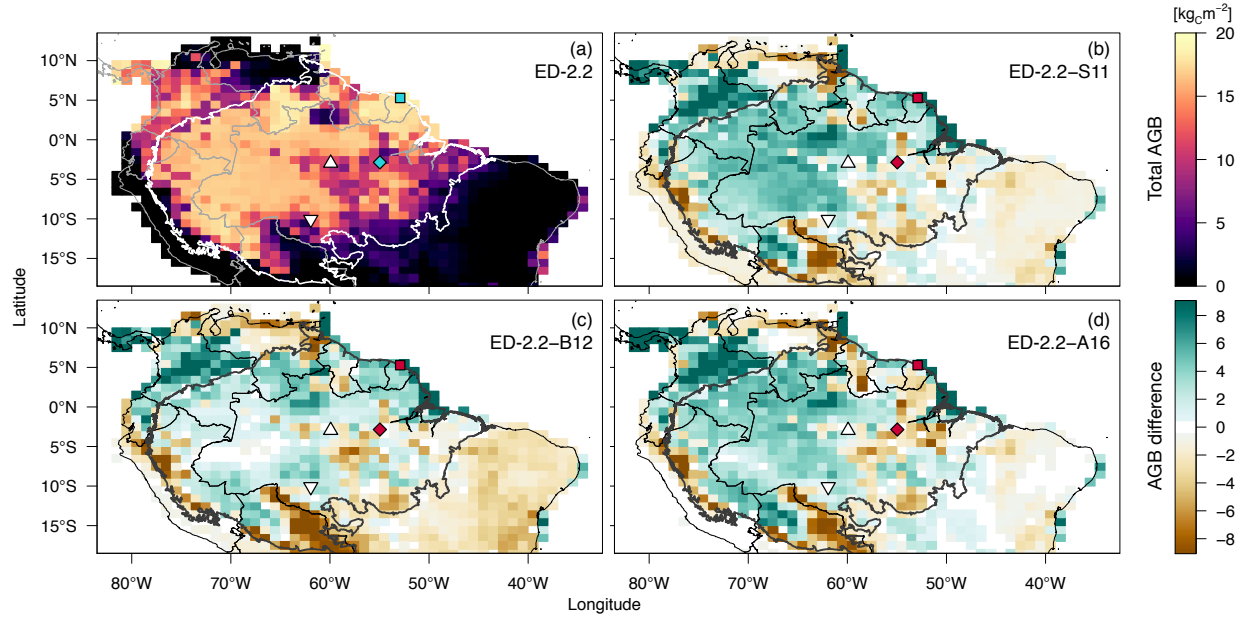


Figure S4: (a) Regional aboveground biomass obtained from ED-2.2, and difference between ED-2.2 and remote-sensing estimates from (b) Saatchi et al. (2011), (c) Baccini et al. (2012), and (d) Avitabile et al. (2016). Remote-sensing maps were aggregated to  $1^\circ$  resolution. Positive (negative) values in (b-d) mean that ED-2.2 predicted higher (lower) aboveground biomass than remote sensing estimates. The location of focus sites of Paracou (GYF,  $\square$ ) and Tapajós (TNF,  $\diamond$ ), and the sites used for radiation profile evaluation: Ducke (MDK,  $\triangle$ ), and Jaru (RJA,  $\nabla$ ) are shown for reference. Thick contour is the domain of the Amazon biome, and thin contours are the political borders.

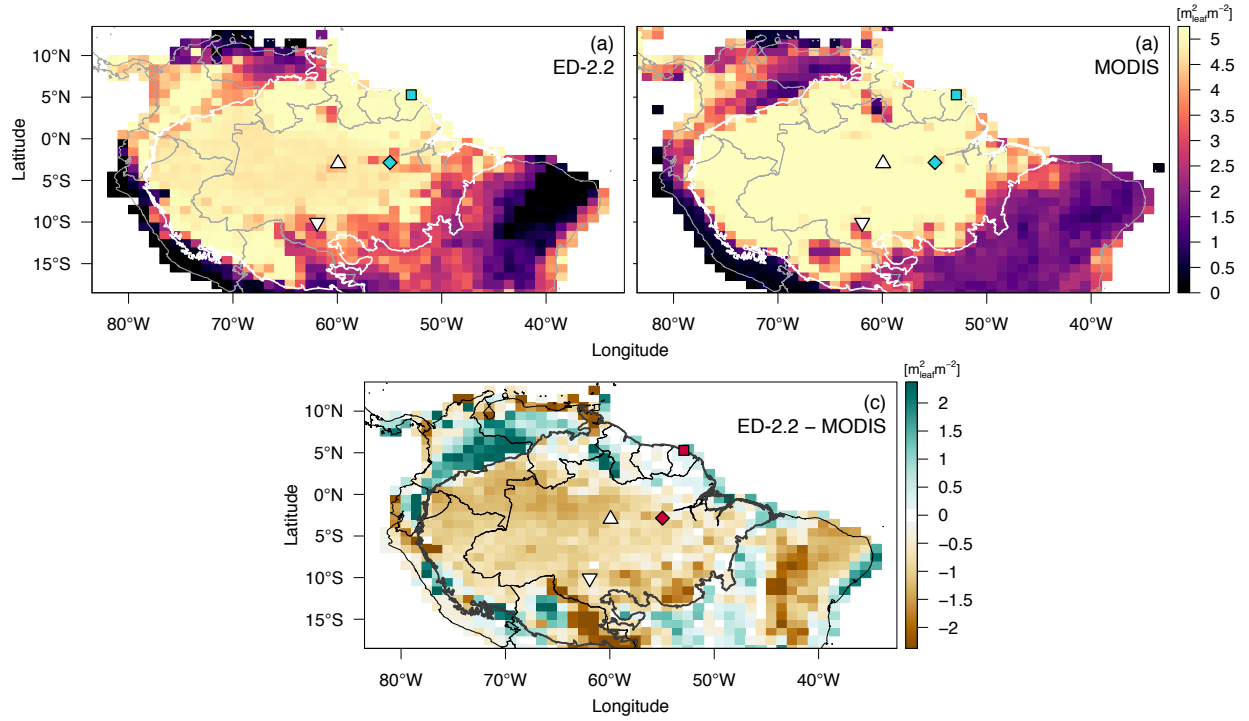


Figure S5: Comparison of leaf area index from (a) ED-2.2, and (b) based on remote-sensing estimates from Moderate Resolution Imaging Spectroradiometer (MODIS), product MCD15A2H, Collection 6 (Yan et al., 2016); (c) Difference between ED-2.2 and the MODIS-MCD15A2H product. Estimates from MODIS-MCD15A2H used all cloud-free, high-quality data available between August 2002 and July 2004. The location of focus sites of Paracou (GYF,  $\square$ ) and Tapajós (TNF,  $\diamond$ ), and the sites used for radiation profile evaluation: Ducke (MDK,  $\triangle$ ), and Jarú (RJA,  $\nabla$ ) are shown for reference. Thick contour is the domain of the Amazon biome, and thin contours are the political borders.

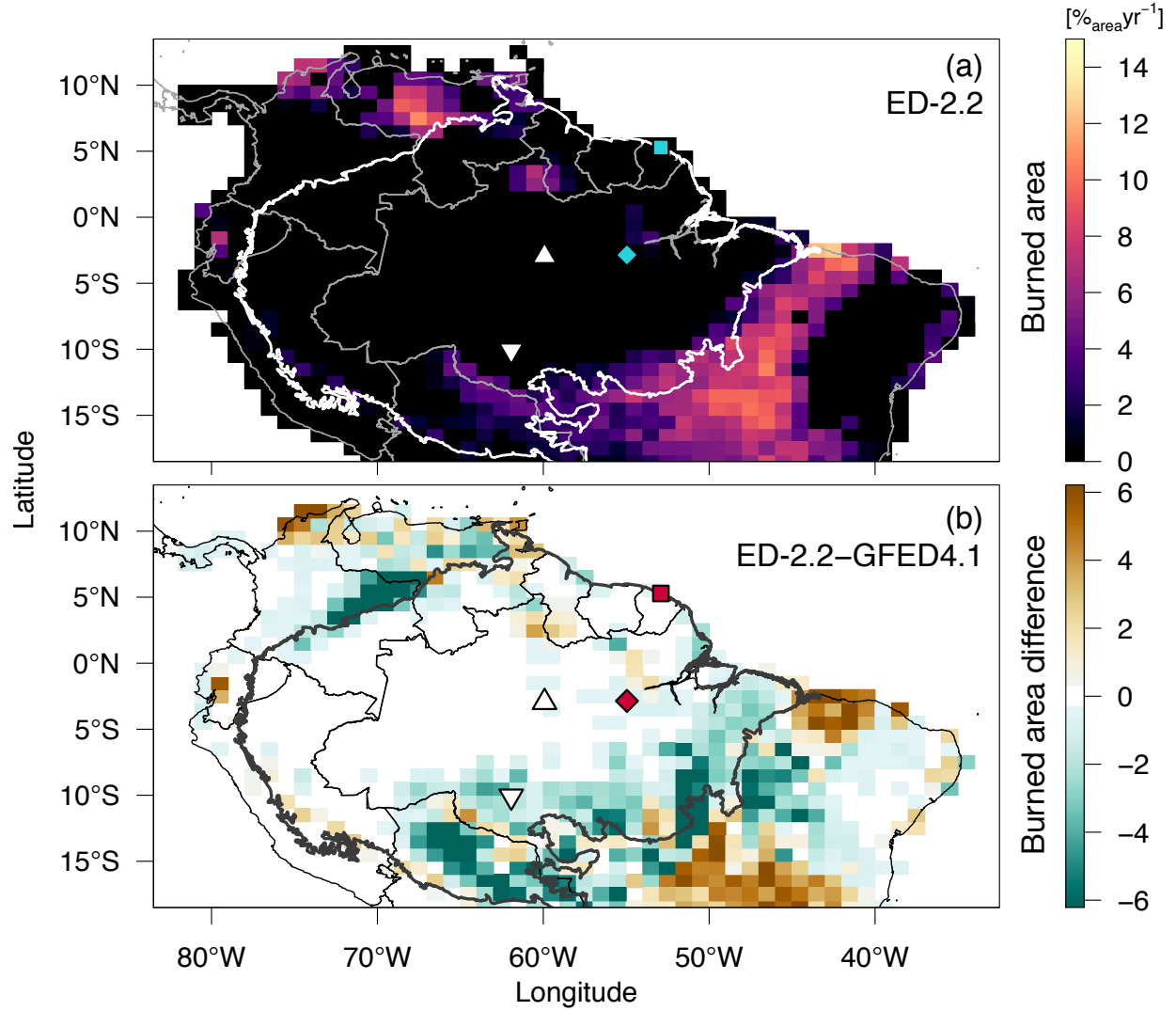


Figure S6: (a) Regional burned area obtained from ED-2.2, and (b) difference between ED-2.2 and the Global Fire Emission database (GFED4.1 Giglio et al., 2013; Randerson et al., 2018) burned area product (1997–2015 average). The GFED4.1 map was aggregated to 1° resolution. Positive (negative) values in (b-d) mean that ED-2.2 predicted higher (lower) aboveground biomass than GFED4.,1 estimates. The location of focus sites of Paracou (GYF,  $\square$ ) and Tapajós (TNF,  $\diamond$ ), and the sites used for radiation profile evaluation: Ducke (MDK,  $\triangle$ ), and Jaru (RJA,  $\nabla$ ) are shown for reference. Thick contour is the domain of the Amazon biome, and thin contours are the political borders.

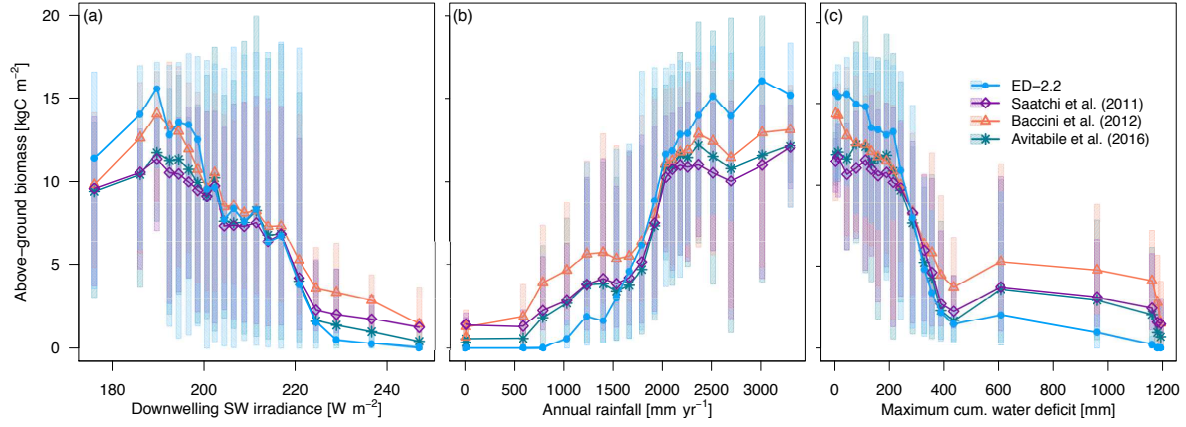


Figure S7: Average biomass predicted by ED-2.2 and based on remote-sensing maps, aggregated by annual averages of (a) downwelling shortwave irradiance; (b) mean annual precipitation; (c) maximum cumulative water deficit. For each annual average of environmental properties, grid points were grouped into 20 quantile bins: points represent the average within each bin, and shaded area corresponds to the 90% quantile range within each bin. Data source for the annual means: downwelling shortwave irradiance and precipitation Princeton Global Meteorological Forcing (PGMF; Sheffield et al., 2006) (1969-2008), which were also used as drivers for the ED-2.2 simulation; maximum cumulative water deficit was based on the same approach as Malhi et al. (2009a), using the PGMF precipitation.



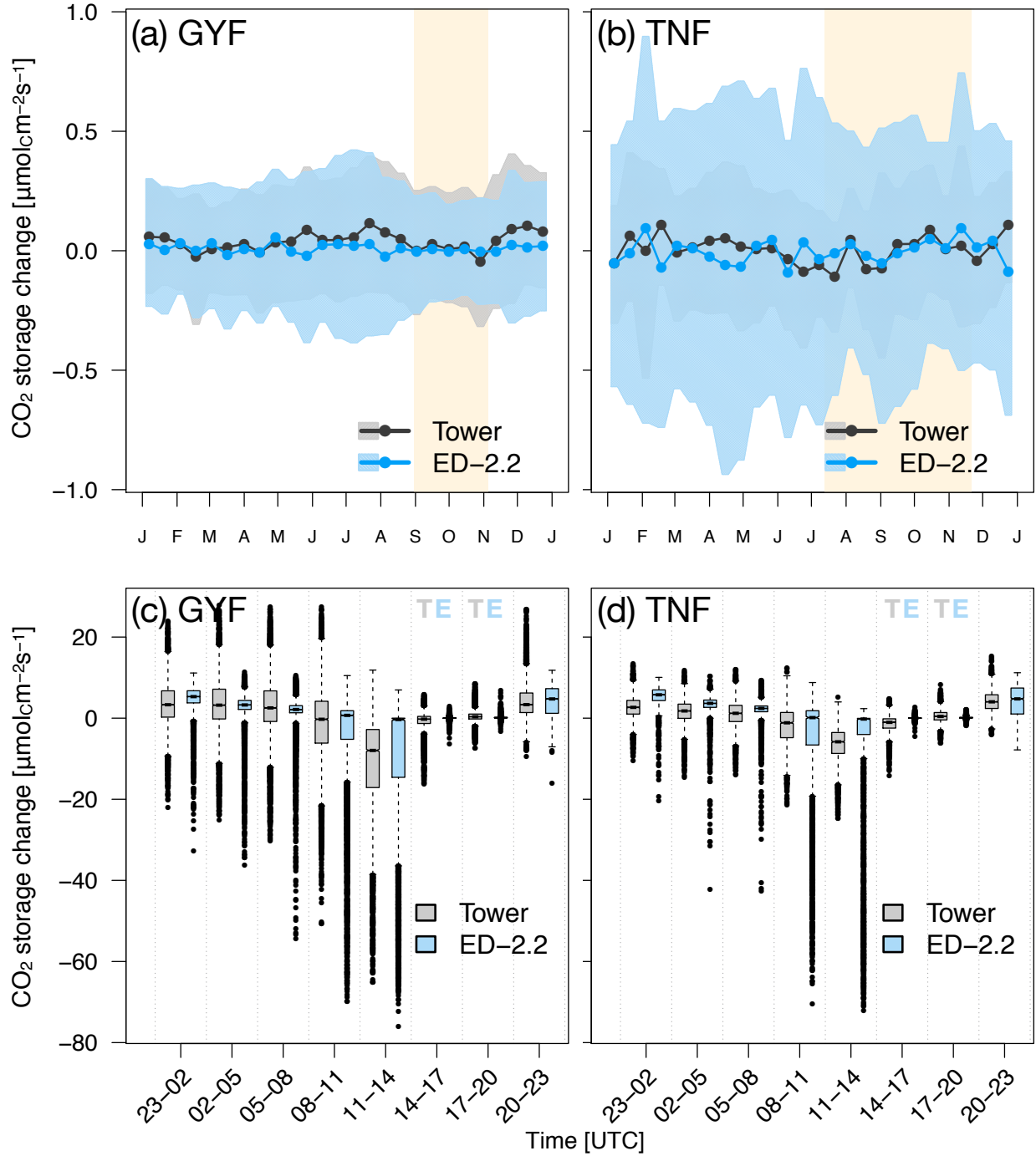


Figure S8: Mean annual cycle from fortnightly means of change in CO<sub>2</sub> storage in the canopy air space for (a) GYF and (b) TNF. Bands are the 95% confidence interval of means, and rectangles in the background correspond to the site's climatological dry season. Box plot of change in CO<sub>2</sub> storage in the canopy air space aggregated by time of day for all hours with available data for (c) GYF and (d) TNF.



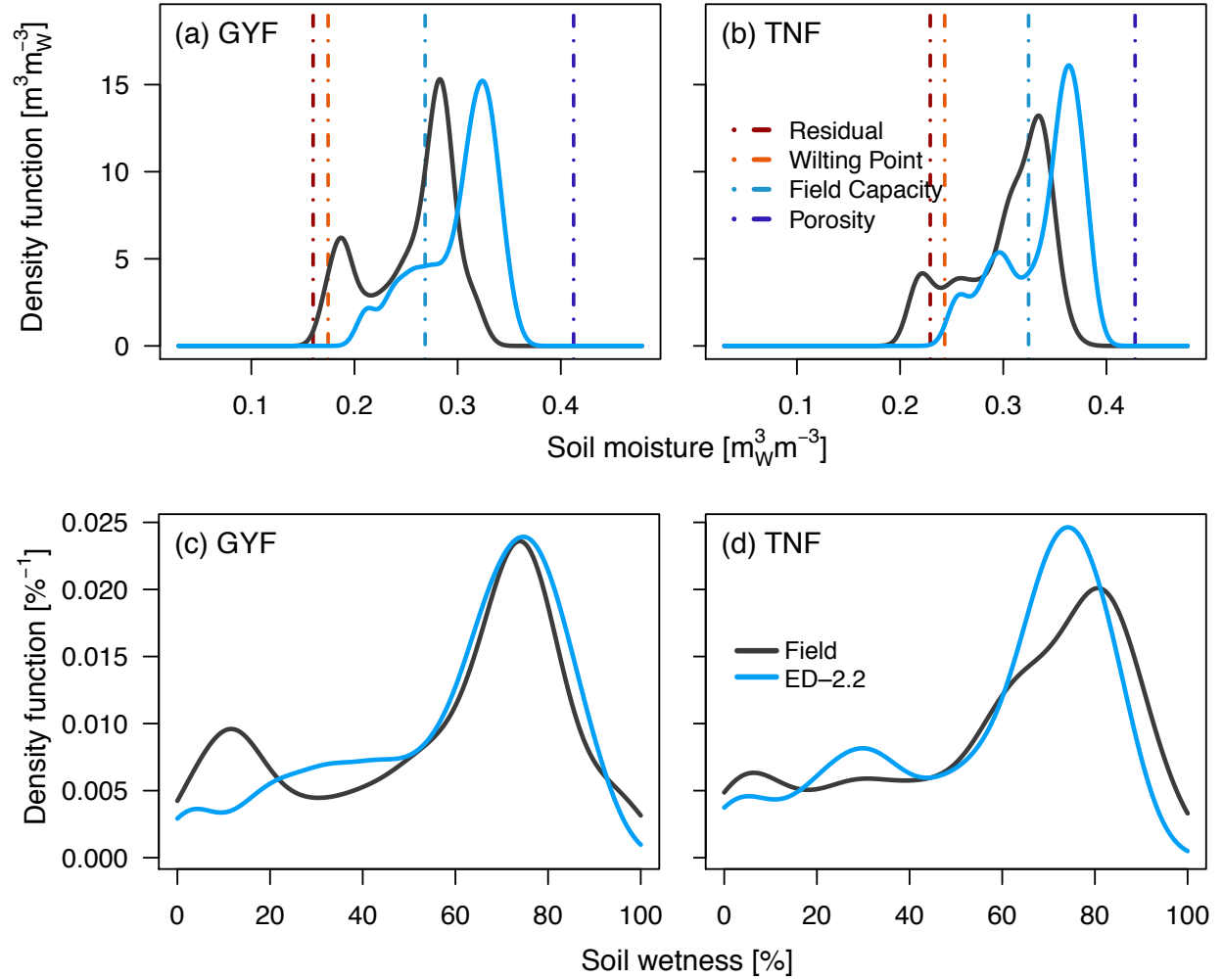


Figure S9: Kernel density estimate of daily averages of (a-b) volumetric soil moisture and (c-d) relative soil moisture at (a,c) GYF (depth 53 cm) and (b,d) TNF (depth 20 cm). Data for GYF were collected at the tower site (2007-2012), and data for TNF were collected at a site located 15 km south of the tower between 2001 and 2003 and available from Miller et al. (2009) and de Gonçalves et al. (2013). Vertical dashed lines in panels (a) and (b) correspond to the residual, permanent wilting point, field capacity and porosity calculated by ED-2.2 using the reference soil texture at each site: (56% sand; 9% silt; 35% clay) for GYF (Bonal et al., 2008), and (39% sand; 2% silt; 59% clay) for TNF (Nepstad et al., 2002). Soil wetness was defined as the relative water content between residual (0%) and porosity (100%).

## S1 Derivation of the respiration estimates at Guyaflux (GYF)

To obtain respiration estimates at Guyaflux (GYF), we followed the same methodology described by Malhi et al. (2009b), and used the same approach to obtain the standard error estimates. Whenever possible, we used published estimates of the different terms of the respiration terms.

- *Leaf respiration.* Individual-level leaf respiration was measured and reported by Stahl (2010). Leaf-level measurements were scaled to ecosystem scale using LAI-2000 measurements also by Stahl (2010). Following Malhi et al. (2009b) and Lloyd et al. (2010), the value was scaled down by 34% to account for diurnal down-regulation of dark respiration.
- *Stem respiration.* Individual-level stem respiration was measured and reported by Stahl (2010); Stahl et al. (2011). Values from both *terra firme* and seasonably flooded forest were included. Wet season and dry season values were weighted by the season length in 2008, also reported by Stahl et al. (2011). Although Stahl et al. (2011) had scaled to stand level, we recalculated their estimate to be consistent with Malhi et al. (2009b), by finding the mean stem area index from the forest inventory, following Chambers et al. (2000, 2004). The stem area index was  $1.07 \pm 0.03 \text{ m}^2 \text{ m}^{-2}$ .
- *Total soil respiration.* Total soil respiration was reported by Epron et al. (2006) and Bréchet et al. (2011). Following Malhi et al. (2009b), their estimates were averaged using an weighting factor equivalent to the sampling area times the square root of the duration of the measurements.
- *Coarse woody debris respiration.* Coarse woody debris (CWD) respiration was reported by Rowland et al. (2013). Their estimates of coarse woody debris respiration were scaled by soil water content, and thus these estimates are not entirely observed.
- *Soil Heterotrophic respiration.* This term was estimated by Bréchet (2009), using trenching method.
- *Root respiration.* This term was assumed to be the difference between total soil respiration and soil heterotrophic respiration, following Malhi et al. (2009b).
- *Aggregated respiration terms.* Heterotrophic respiration (soil + CWD), autotrophic respiration (leaf + root + stem), and ecosystem respiration (heterotrophic + autotrophic) were defined as the sum of the terms, as defined above. Uncertainties were assumed independent, and propagated similarly to Malhi et al. (2009b).

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