*Postprocessing of covariates*

Timeseries of environmental covariates were generated from several NEON data products at 30-minute resolution, including DP4.00200.001[1] (bundled eddy covariance for *NEE* and *LH*), DP1.00001.001[2] (2D windspeed, *u*), DP1.00003.001[3] (air temperature, *T*), DP1.00098.001 [4] (relative humidity, *RH*), and DP1.00023.001[5] (global radiation, *Rg*). *NEE* and *LH* were calculated by summing the storage and turbulent carbon and water fluxes provided in the NEON DP4.00200.001[1] product. This differs from the *NEE* and *LH* values provided in the net surface-atmosphere exchange variables in the NEON data files slightly because of the quality flags used by NEON in their eddy4R processing pipeline[6]. Currently, NEON raises a quality flag when any carbon dioxide or water vapor mixing ratio value is missing along the tower. When calculating the net flux, any value where the storage flux has the quality flag raised is treated as missing, and as a result, there are long periods where there are missing *NEE* and *LH* values. In most of cases where storage fluxes were flagged as missing, only one or two mixing ratio measurements were absent. As a result, we decided that the benefit of increasing data coverage and including these storage flux values where the quality flag had been raised outweighed the potential increase in *NEE* and *LH* error introduced by the missing measurements. Since in these cases each tower has at least two measurements still available to calculate the storage flux, we expect the impact of these missing measurements on storage flux calculations to be small [7]. Moreover, NEON forest sites have more than four measurement levels, and thus, have at least three measurements to calculate the storage flux even if two are missing.

We applied -filtering followed by gap-filling of *NEE* and *LH* using the REddyProc package[8]. In brief, *NEE* and *LH* data were filtered for periods of low turbulence that are known to bias eddy covariance fluxes[9] and then gap-filled using the marginal distribution sampling method[10]. We applied a bootstrapping approach to constrain threshold value of the friction velocity , and used the 50th percentile estimate of to filter out data periods with insufficient turbulence. *VPD* was calculated directly from *RH* and *T*, and *VPD*, *Rg*, and *T* were all gap-filled using the marginal distribution sampling of mentioned above [10], with no -filtering necessary. Wind speed was not gap filled. All the 30-minute aggregated variables mentioned above were averaged to a daily scale. The daily values that fall between the range first quantile (Q1) minus of 1.5 times interquartile (IQR) below (Q1 – 1.5 \* IQR) and thirdquantile (Q3) plus 1.5 times IQR (Q3 + 1.5 \*IQR) were preserved.

*Significant test of information quantities*

We performed the significant test for all mutual information and partial information components. We shuffled all the data that was involved in computing mutual information and partial information components 50 times. Then, for each information quantity, we performed a one-sided paired t-test between 50 copies of the information quantity series that were computed from unshuffled data (vertically stacked) and 50 shuffled information quantity series (vertically stacked). The information quantity is concluded as significant if the p-value of the test is smaller than 0.05.

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**Diagram

Description automatically generated**

**Figure S1** The unique information of *δ13C* about net ecosystem exchange (*NEE*) (a) and latent heat flux (*LH*) (d). The unique information of *δ13H* about *NEE* (b) and latent heat flux (*LH*) (e). The unique information of *d* about *NEE* (c) and latent heat flux (*LH*) (f).

Chart, scatter chart

Description automatically generated

**Figure S2** The synergistic information of *δ13C* about net ecosystem exchange (*NEE*) (a) and latent heat flux (*LH*) (d). The unique information of *δ13H* about *NEE* (b) and latent heat flux (*LH*) (e). The synergistic information of *d* about *NEE* (c) and latent heat flux (*LH*) (f).

Chart, diagram

Description automatically generated with medium confidence

**Figure S3** The redundant information of *δ13C* about net ecosystem exchange (*NEE*) (a) and latent heat flux (*LH*) (d). The redundant information of *δ13H* about *NEE* (b) and latent heat flux (*LH*) (e). The unique information of *d* about *NEE* (c) and latent heat flux (*LH*) (f).