Global Patterns of Biosphere-Atmosphere Energy Fluxes in Terrestrial Ecosystems

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Introduction

Energy fluxes of heat and moisture between land surface and atmosphere play an important role in the surface energy budget and in regulating climate. These fluxes and their feedbacks are constrained by biophysical and ecophysiological properties of terrestrial ecosystems, which are largely controlled by environmental conditions and associated changes. However, only few studies synthesized biosphere-atmosphere energy fluxes beyond the regional/continental scale and an early data-driven characterization of general patterns in energy fluxes was based on a limited number of ecosystems. Many **open questions** thus remain **regarding biome and climate specific patterns, general functional relationships and the partitioning of available energy** into sensible and latent heat fluxes. In addition, the effect of land-use on energy fluxes, their partitioning and coupling with air temperature are not well understood.

Objectives

We synthesized data from the **global eddy covariance network FLUXNET** to investigate **general patterns of biosphere-atmosphere energy fluxes** in terrestrial ecosystems across biomes and climates. Our objectives are to:

(1) Characterize seasonal and inter-annual variability of latent (LE) & sensible heat (H) fluxes
(2) Derive general functional relationships for climatic & biophysical controls of energy fluxes
(3) Quantify the effects of land-use change & disturbance on the partitioning of energy fluxes

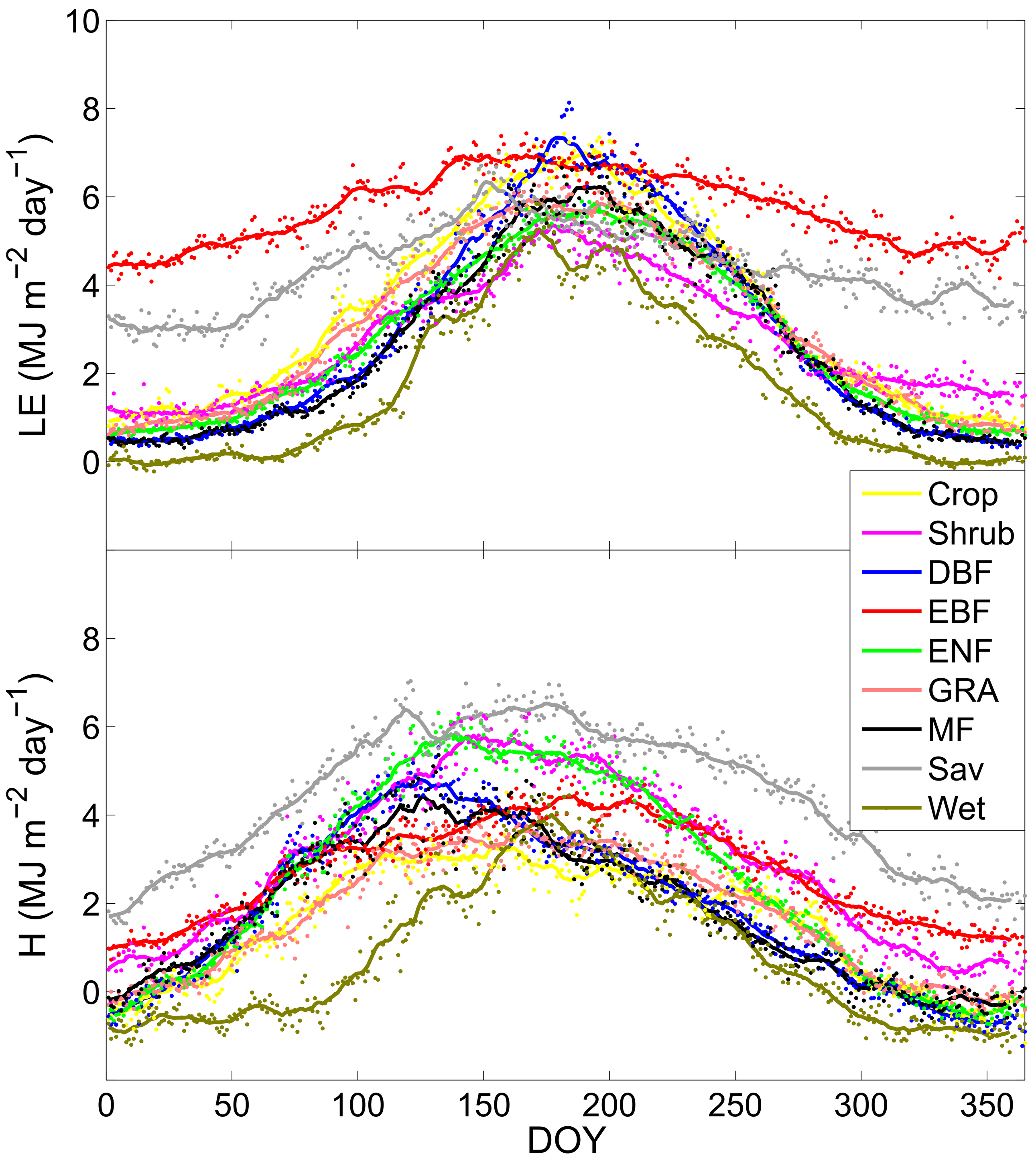

Figure 1. Seasonal variability of daily latent heat (LE) and sensible (H) fluxes by plant functional type (PFT): Cropland (CRO), Shrubland (Shrub), Deciduous Broadleaf Forest (DBF), Evergreen Broadleaf Forest (EBF), Evergreen Needleleaf Forest (ENF), Grassland (GRA), Mixed Forest (MF), Savanna (Sav), Wetland (Wet).

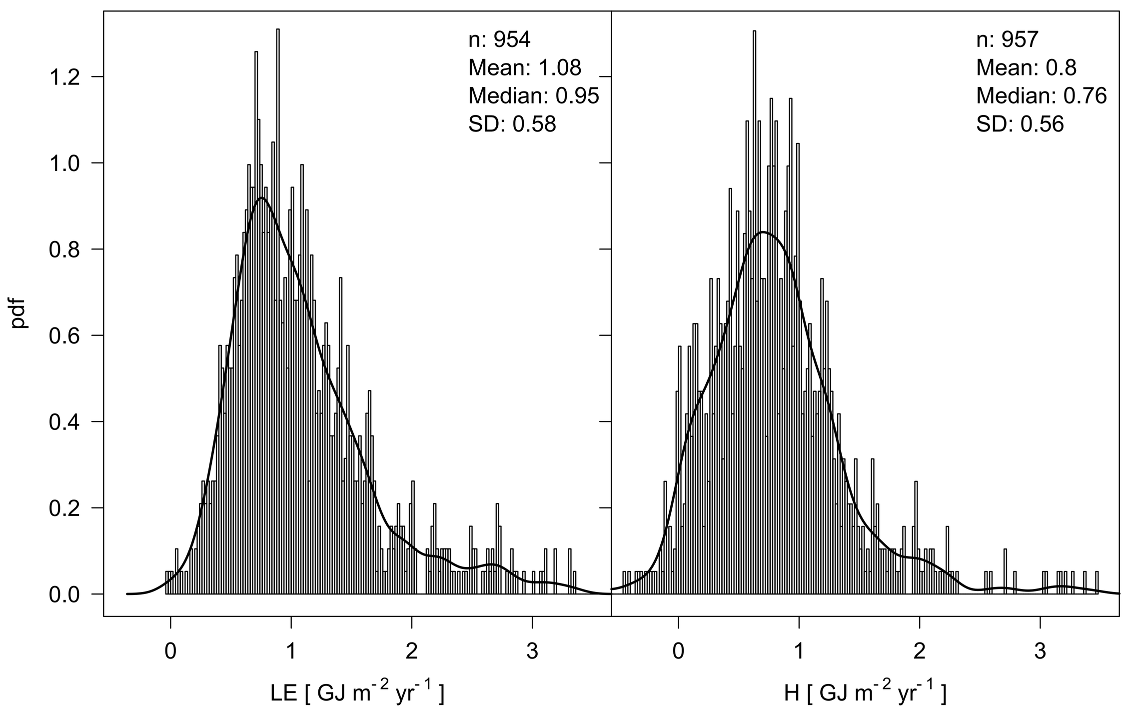

Figure 2. Probability density function (pdf) of annual latent heat (LE) and sensible (H) fluxes across FLUXNET sites. Bars denote histogram and lines the pdf estimated with a non-parametric kernel smoothing method. The annual water equivalent for LE would be 513±278 mm (mean ± SD).

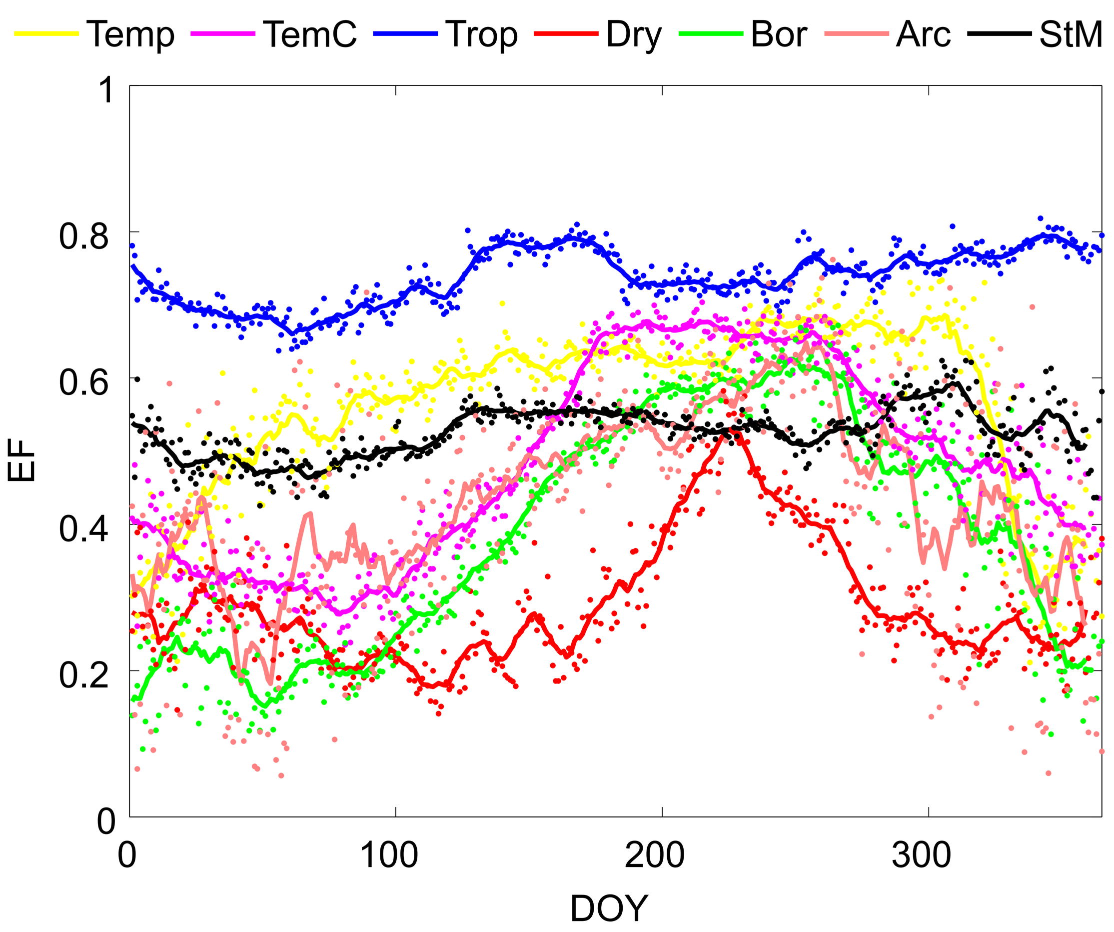

Figure 4. Seasonal variability of evaporative fraction (EF) by climate: Temperate (Temp), Temperate-continental with hot or warm summers (TempC), Tropical (Trop), Arid and semi arid (Dry), Boreal (Bor), Arctic (Arc), Subtropical-Mediterranean (StM).

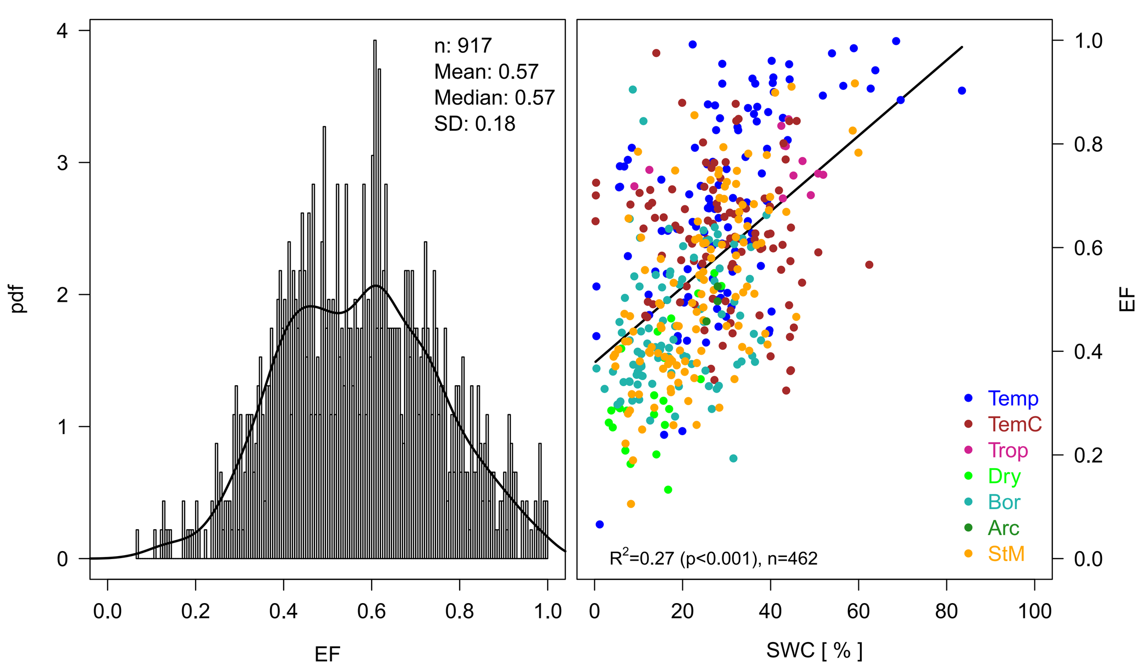

Figure 5. Probability density function (pdf) of evaporative fraction (EF; left panel) and dependency of EF on soil water content (SWC; right panel) by climate across FLUXNET sites.

Results

Seasonal variability of daily latent heat fluxes (Fig. 1) was lowest in the tropics, particularly in evergreen broadleaf forest and savanna, and these plant functional types (PFTs) had the highest absolute fluxes of LE. Mean annual LE exceeded mean H across all FLUXNET sites (Fig. 2). Vapour pressure deficit (D) was one of the main controls on hourly LE, with most observations below 1 kPa and pronounced reductions in LE beyond 2 kPa (Fig. 3). The partitioning of available energy (AE) into latent and sensible heat revealed climate specific patterns (Fig. 4): the evaporative fraction (EF) had the lowest seasonal variability in tropical and subtropical regions. The highest EF was found in the tropics (>0.7). In contrast, a larger proportion of AE was converted to sensible heat in arid & semi-arid regions, with EF <0.3 during most of the year. Soil moisture was the main climatic control of annual energy flux partitioning across FLUXNET sites, without pronounced climate specific patterns (Fig. 5).

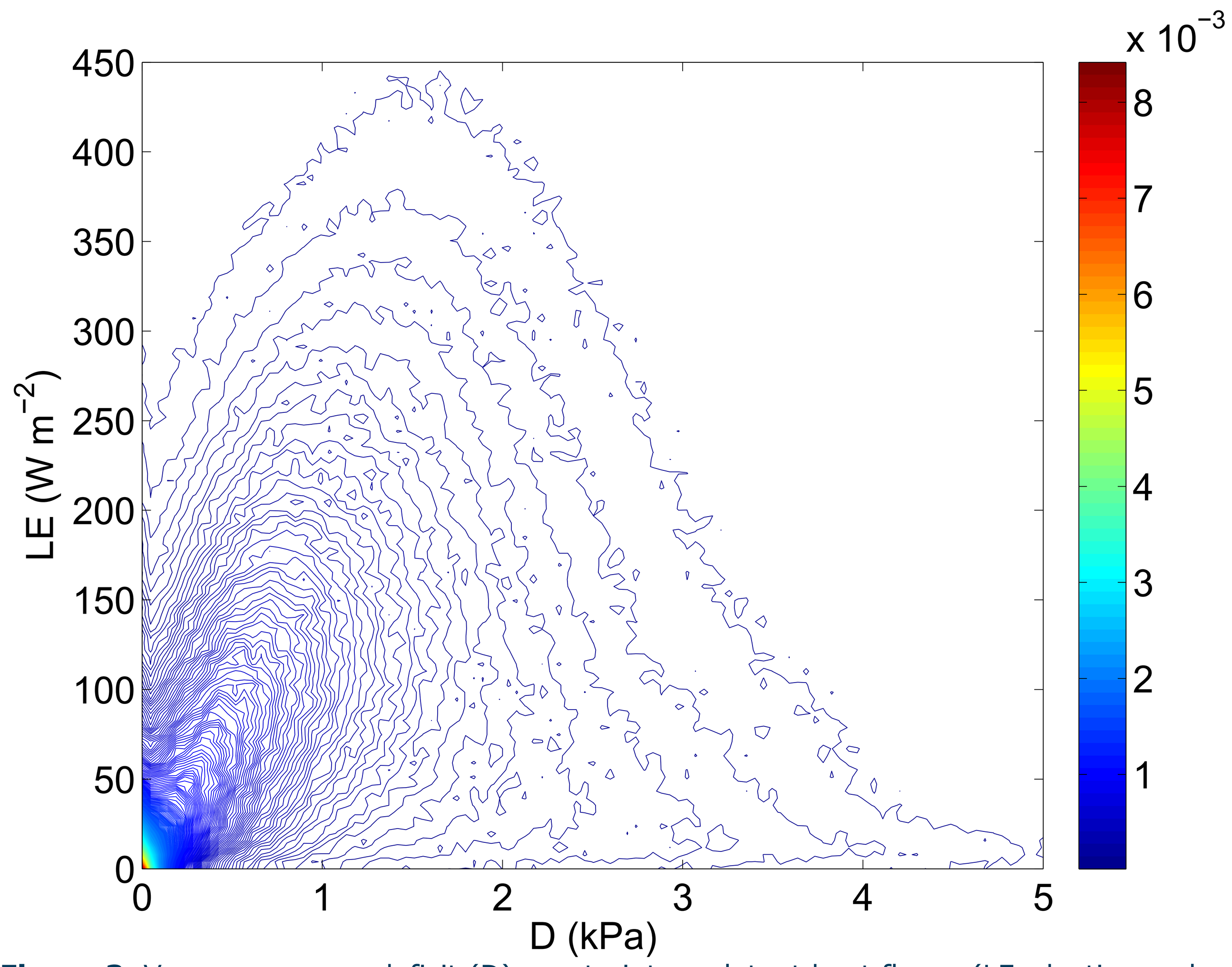

Figure 3. Vapour pressure deficit (D) constraints on latent heat fluxes (LE; daytime only, hourly data). Colours denote 2D kernel density estimate (nonparametric probability density function).

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Conclusions

The importance of the tropics for the global hydrological cycle is highlighted by (1) the highest absolute rates of latent heat, and (2) the largest proportion of available energy converted to latent heat. In addition to tropical forests, savanna ecosystems contribute among the highest latent heat fluxes across all sites. Vapour pressure deficit limits latent heat fluxes above ~1.5 kPa through plant physiological control by stomatal closure. Evaporative fractions shows a bimodal distribution across all sites and differentiates terrestrial ecosystems by the availability of moisture, i.e. dry *vs.* wet systems.

The general patterns and functional relationships derived from this synthesis will improve the understanding of variations in energy fluxes globally and will provide valuable insights for land-surface models based on direct measurements.