Classification and Assessment of Turbulent Fluxes above Ecosystems in North-America with Self-Organizing Feature Map Networks

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AmeriFlux

TERRA PNW

Key environmental and meteorological drivers that influence the magnitude of the fluxes of carbon dioxide, latent heat, and sensible heat were determined using data from different vegetation types at 57 sites of the *AmeriFlux* network in combination with a self-organizing feature map neural network. The SOFM technique was combined with a subsequent k-means clustering procedure to classify the turbulent fluxes. The spatial and temporal comprehensive dataset covering 305 site years, combined with the independence from mechanistic ecological assumptions of the SOFM network approach provides an opportunity to assess the strength of the influence of various environmental parameters on the turbulent fluxes over vegetated areas. The ability to recognize complex patterns along multiple dimensions makes SOFM networks an ideal tool to analyze large datasets of turbulent fluxes and find similarities in flux patterns and cluster the dataset accordingly.

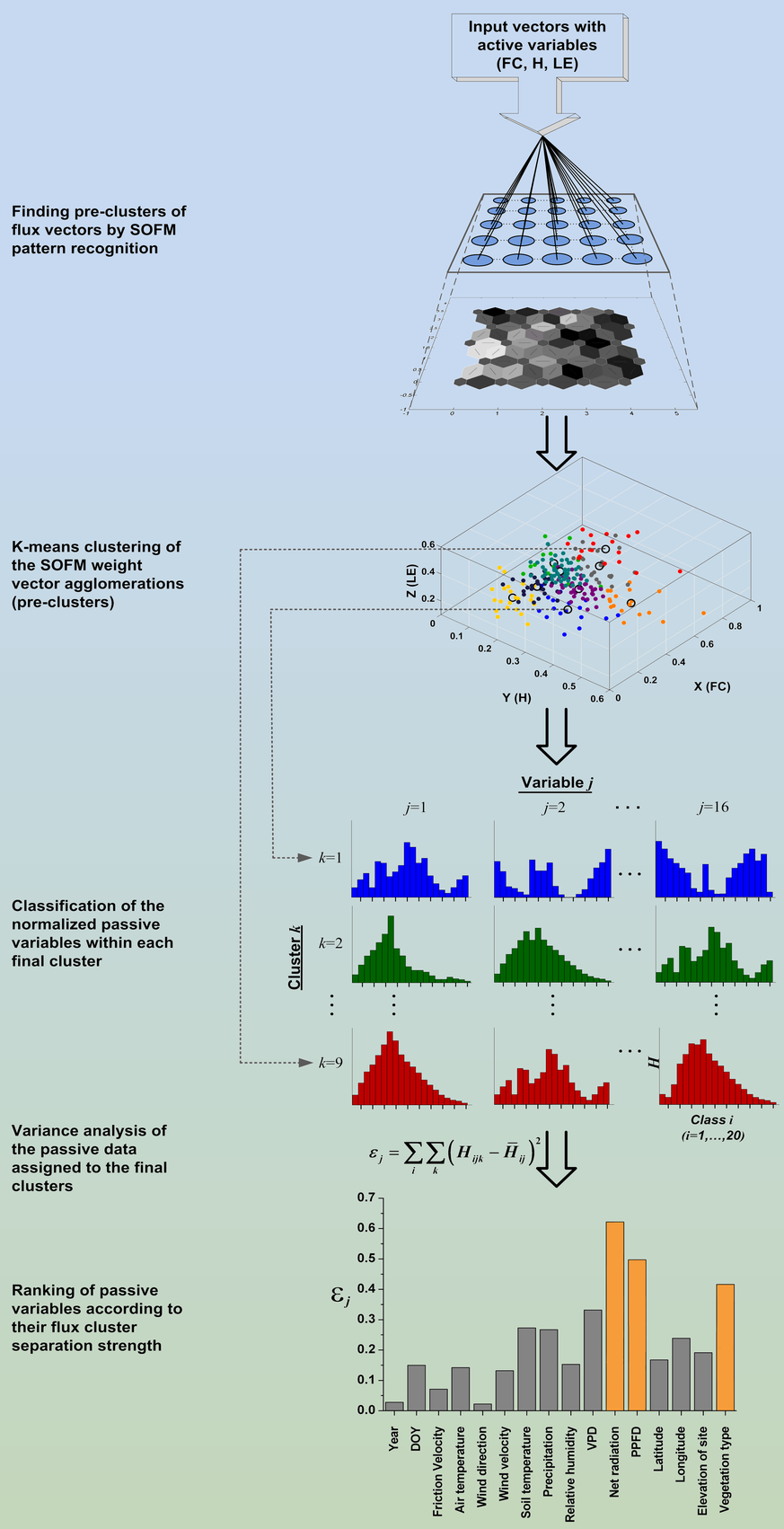

Figure 1: Schematic overview of the applied procedure for the flux data clustering and analysis. The clusters have only been built based on the active variables (*FC, H,* and *LE*) while the environmental conditions that affected the fluxes are quantitatively described by the corresponding passive variables.

After ranking the environmental and meteorological variables according to their cluster separation strength, the pattern of turbulent fluxes turned out to be three times more sensitive to photosynthetic photon flux density than to air temperature (Fig. 1). Vegetation type and vapor pressure deficit (*VPD*) are also parameters that significantly determine the cluster affiliation of the vectors representing the magnitude of the fluxes, followed by soil temperature and precipitation. Although *VPD* in the *AmeriFlux* database is calculated from relative humidity (*RH*) and air temperature, *VPD* turned out to have an influence on the fluxes that is about twice as high in, terms of the cluster separation strength, as the influence of relative humidity or air temperature, respectively (Fig. 1). Considering the dependency of fluxes on the *VPD* this result affirms the important role of the vegetation cover and physiological response via stomatal activity.

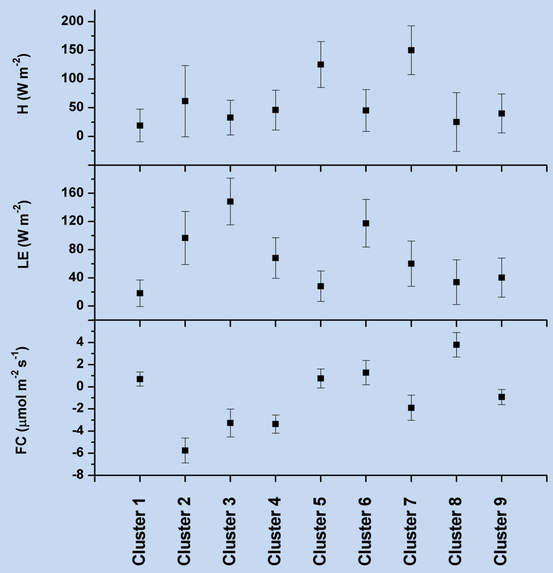

Figure 2: The mean values of the measured fluxes in the final clusters. The error bars show the ±1σ standard deviations to indicate the variability within the clusters.

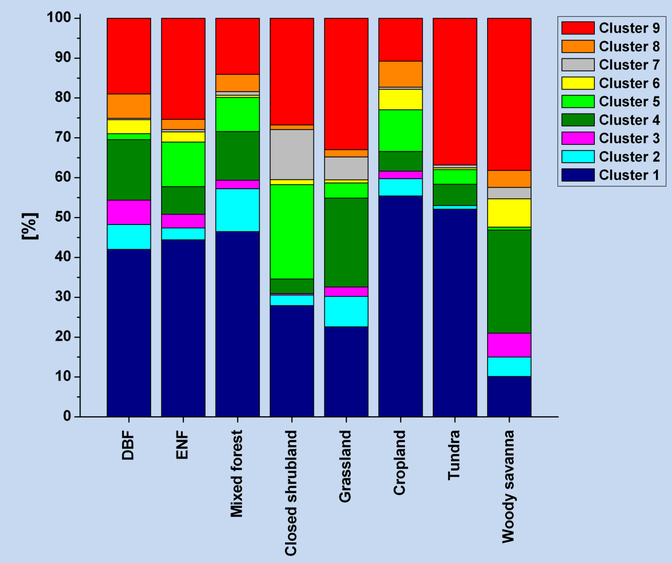

Figure 3: Percentage cluster apportionment of the flux vectors related to the 8 vegetation types.

On the map of the USA shown in Figure 4 the cluster affiliations of the different sites that were *analyzed* in this study are shown. The map generally shows that sites in the Northeast and the Midwest areas have a higher percentage of fluxes affected by the cold temperatures and low ecosystem exchange rates of CO_2 and energy during wintertime (cluster 1, Fig.2). In contrast, the sites in the Pacific Northwest show more fluxes from the clusters 4, 5, and 7. As shown in Figure 4 the northwest sites are dominated by evergreen needle-leaf forests (ENF) that are still able to take up CO_2 during some periods of the relatively mild winters. This explains the ongoing moderate uptake of CO_2 that is represented in cluster 4. With respect to the vegetation types, the cluster affiliations also show that the flux values of the different forest types exhibit a similar distribution of cluster percentages (Fig. 3 and Fig. 4). With exception of the group of deciduous broadleaf forests (DBF) which has less of the flux vectors assigned to cluster 5 which is also characterized by a noticeable average amount of CO_2 uptake. The high percentage of the fluxes above the shrubland biomes assigned to cluster 5 (Fig. 3) is, with respect to the cluster-specific averages (Fig. 2), obviously related to the frequently high values of *H* above the arid and semi-arid areas where the shrubland sites are located (Fig. 4).

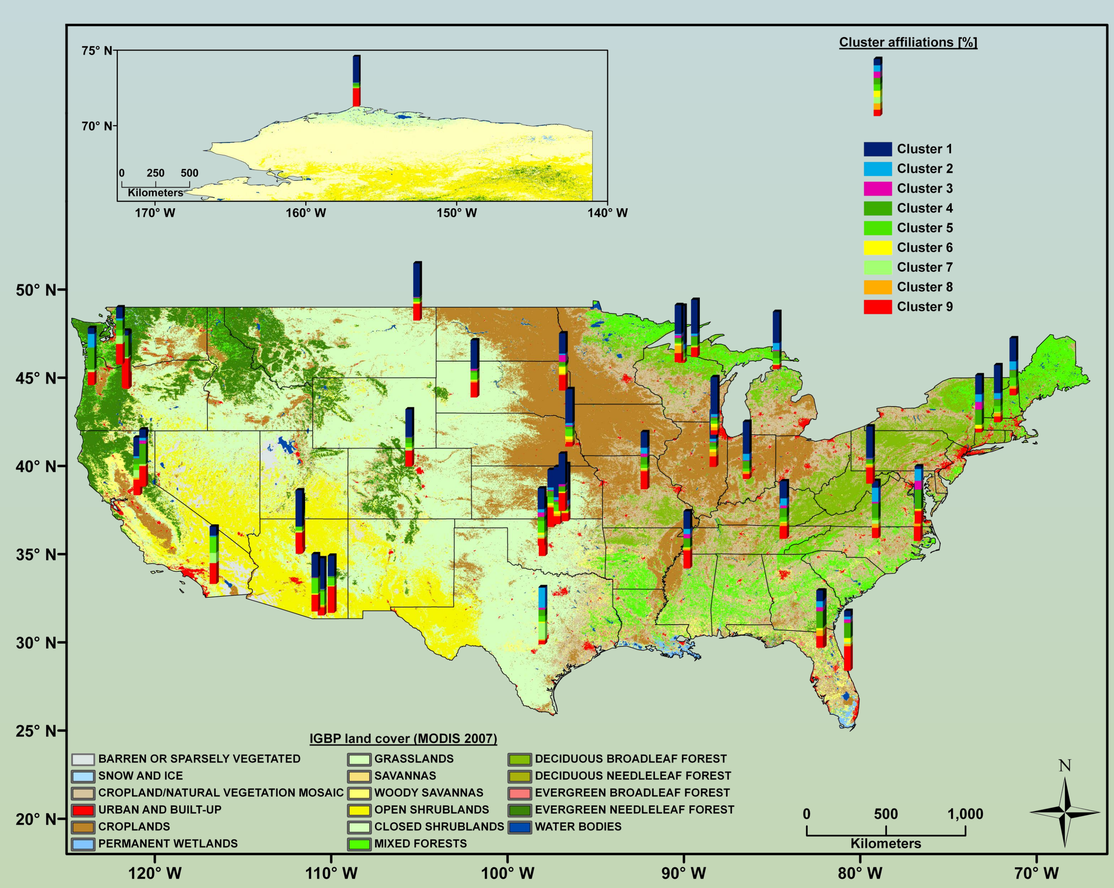

Figure 4: Map of mainland USA showing the land cover, the position of the *AmeriFlux* sites, and the percentage cluster affiliations of the corresponding flux data.

With respect to the findings in this study, for the continental USA the effect of the increased temperature on the fluxes will probably be overcompensated at many sites by the counteractive effect of reduced incoming radiation caused by the generally increased cloud cover.
Furthermore, the large response of fluxes to vegetation type in connection with the average FC values and vegetation types in the clusters indicate that deforestation and transformation into agriculturally used areas will probably lead to a decreased carbon sequestration in most cases.

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