



Conference Abstract

Trends and drivers of long-term forest evapotranspiration in Switzerland

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Abstract

Evapotranspiration (ET) from forested ecosystems is a major component of the water cycle, influencing soil moisture, groundwater recharge, and streamflow. ET also modulates local and regional climate through latent heat exchange, affecting temperature and humidity in forest ecosystems. Because ET is tightly linked to photosynthesis, it also indicates forest stress from drought conditions, making it a key metric for assessing forest ecosystem health. However, long-term measurements of ET are rare, thus the effects of a warming climate on forest ET fluxes remain poorly understood. ET fluxes can be limited by a lack of water availability in the subsurface, forcing trees to close stomata and reduce transpiration. In periods of high atmospheric demand, vapor pressure deficit (VPD) can also induce stomatal closure. Furthermore, limited energy availability, i.e., reduced net radiation on cloudy days, constrains ET by limiting latent heat flux. Thus, more detailed analyses of the dominant drivers of ET fluxes based on long-term datasets may help to identify under which environmental conditions ET is limited in forest ecosystems.

Here we present an comprehensive analysis of long-term evapotranspiration data from eddy covariance measurements from two different forest sites in Switzerland: a subalpine evergreen coniferous forest (CH-Dav) and a montane mixed deciduous forest (CH-Lae), both part of Swiss FluxNet (www.swissfluxnet.ethz.ch). H₂O vapor fluxes have been measured using eddy covariance (EC) since 1997 and 2004 at the Davos and Lägeren

sites, respectively. The Davos site is located in the eastern Swiss Alps at an altitude of 1639 masl., has an average annual precipitation of 876 mm and a mean annual temperature of 4.3 °C. The EC system is installed at 35 m, above the canopy of Norway spruce (*Picea abies* (L.) Karst) trees of a mean age of approximately 100 years and an average tree height of 18 m. The Lägeren site is located in the eastern part of the Jura Mountains in Switzerland at an altitude of 682 masl., has an average annual precipitation of 831 mm and a mean annual temperature of 8.8 °C. The EC system is installed at 47 m, above the canopy of a mixed forest, dominated by European beech (*Fagus sylvatica* L.; 40 % cover), ash (*Fraxinus excelsior* L.; 19 % cover) and sycamore maple (*Acer pseudoplatanus* L.; 13 % cover). In addition, at both sites, climate variables (i.e., precipitation, temperature, vapor pressure deficit, solar radiation) and soil water content at different depths (i.e., 5, 10, 25 and 50 cm) have been measured continuously at 30-min resolution. Using this long-term data collection, we

1. analyzed changes in annual and seasonal ET fluxes and
2. assessed the major drivers of ET fluxes across the two forest sites.

To analyze the main drivers of ET fluxes, we used the SHapley Additive exPlanations (SHAP) framework, allowing to estimate the contribution from each potential driver variable to the response variable (i.e., daily ET fluxes). Analyzing long-term ET fluxes at Davos and Lägeren, we found considerable differences between the two forest sites. The subalpine Davos site received slightly higher precipitation and had a lower temperature compared to the Lägeren site, thus soil moisture and vapor pressure deficit were less important drivers of ET at Davos compared to Lägeren. Instead, ET limitations in Davos were mainly related to lower net radiation. At the montane Lägeren site, compound dry events combining soil water deficits and higher VPD triggered decreasing forest ecosystem ET fluxes during the growing season. Analyses of especially dry years (i.e., 2003 – only Davos, 2015, 2018 and 2022) indicated that the spruce dominated Davos site showed higher ET compared to average years, due to favorable growing conditions at this typically energy-limited subalpine site. However, we found that even at the Davos site, extended dry periods (i.e., as observed during the year 2018) lead to higher atmospheric demand and thus lower ET. Overall, the Lägeren site was more vulnerable to dry periods, leading to depletion of soil moisture storage and an increase of VPD, resulting in a significant reduction of ET in the especially dry years. Overall, our results indicate that *i)* forest ecosystems in low-elevation sites are already experiencing frequent periods of ET reduction due to water limitations in the soil and high atmospheric demand while *ii)* high elevation forest ecosystems might become more vulnerable when the durations of high atmospheric demand are extending over longer time periods as projected in a future climate.

Keywords

forest ecosystems, evapotranspiration, long-term data, eddy covariance

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Conflicts of interest

The authors have declared that no competing interests exist.