

Energy partitioning and water use efficiency anomalies 2018 at Eddy-Covariance sites across ecosystems

Alexander Graf (1), Anne Klosterhalfen (1), Christian Bernhofer (2), Christian Brümmer (3), Clemens Drüe (4), Pia Gottschalk (5), Thomas Grünwald (2), Günther Heinemann (4), Bernard Heinesch (6), Janina Klatt (7), Jan Konopka (8), Anne De Ligne (6), Bernard Longdoz (6), Matthias Mauder (7), Patrizia Ney (1), Inken Rabbel (9), Corinna Rebmann (10), Torsten Sachs (5), Marius Schmidt (1), Frederik Schrader (3), Caroline Vincke (11), Ingo Völksch (7), Stephan Weber (8), Christian Wille (5), and Harry Vereecken (1)

(1) Institute for Bio- and Geosciences: Agrosphere (IBG 3), Forschungszentrum Jülich, Germany, (2) Institute for Hydrology and Meteorology, Technische Universität Dresden, Tharandt, Germany, (3) Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany, (4) Institute for Environmental Meteorology, Universität Trier, Germany, (5) German Research Centre for Geosciences (GFZ), Potsdam, Germany, (6) TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium, (7) Institute for Meteorology and Climate Research (IMK-IFU), Karlsruher Institut für Technologie (KIT), Garmisch-Partenkirchen, Germany, (8) Technische Universität Braunschweig, Climatology and Environmental Meteorology, Institute of Geocology, Germany, (9) Department of Geography, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany, (10) Department of Computational Hydrosystems, Helmholtz-Zentrum für Umweltforschung GmbH (UFZ), Leipzig, Germany, (11) Université catholique de Louvain, Belgium

Droughts and heat waves deeply interact with the exchange of energy and matter between land surface and atmosphere. The conditions associated with a combined heat wave and drought can have positive or negative effects on the sensible heat flux (H), latent heat flux (LE), and net flux of CO₂ (NEE). In return, while each of these fluxes can exert different local feedbacks on temperature, atmospheric humidity and soil moisture, all of them result in bulk heating of the troposphere (H and LE through direct local and indirect non-local heat transfer, and NEE through radiative forcing). H is positively affected by increased solar irradiation, but can be suppressed by advection of warm air diminishing the gradient between surface and air temperature. Potential LE is positively affected by irradiation, temperature and water vapour pressure deficit, but actual LE can be suppressed by stomatal closure of plants and by reduced soil moisture from low rainfall and high past LE. NEE is the result of plant photosynthesis (GPP) and plant and soil respiration (R), both of which can be enhanced by high temperatures or irradiation, and suppressed by drought.

Focusing on direct measurements mostly by a network of Eddy-Covariance (EC) stations of the ICOS (www.icos-ri.eu), TERENO (www.tereno.net) and other networks, we hypothesize that the net effect of the 2018 event at a site, and thus its feedback on global warming, depends on the balance between co-existing positive and negative effects of the combined heat wave and drought on the respective fluxes. Variables such as albedo, growing degree days (GDD), soil moisture and ecosystem-level water use efficiency help to separate these co-existing positive and negative effects from each other. Preliminary results indicate different degrees of heterogeneity between sites for different variables. As expected, reduced precipitation and soil moisture, as well as increased GDD, could be found at almost all sites in the affected region. NEE was mostly less negative, indicating a weaker sink or even a source for CO₂, as expected from past studies on earlier events. The network density and number of site-years available now confirms that this was true for all major ecosystem types - forest, grassland and (rainfed) cropland, and resulted in increased atmospheric CO₂ concentrations. However, notable exceptions occurred at elevated low mountain range sites and during early stages of the event, supporting the hypothesis of a balance between positive and negative effects, where the former may prevail at strongly energy-limited sites with a usually large water surplus. H was mostly above-average, indicating that local heat production contributed to the event and was typically not suppressed by warm air advection. LE as well as inferred GPP and R reacted most heterogeneously across sites, demonstrating the large discrepancy between potentially high fluxes due to high irradiation and temperature on the one hand, and suppression by water shortage on the other hand. Despite the variability in LE, its relation to NEE was such that ecosystem-level water use was less efficient than usual at the majority of sites through reduced CO₂ uptake.