Geophysical Research Abstracts
Vol. 14, EGU2012-5133, 2012
EGU General Assembly 2012

The role of evapotranspiration and runoff in the development of recent droughts in Central-Western Europe

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Traditionally, droughts are often seen as periods with below-average rainfall. However, when drought is viewed as the below-average availability of subsurface storage instead, it becomes clear that drought evolution is not only controlled by the reduced input of rainfall into the land surface system, but also (as dictated by the subsurface water budget) by the way the drought conditions themselves alter the outgoing hydrological fluxes, in particular evapotranspiration and runoff. The way in which these fluxes respond to drought is not straightforward to predict, and depends on many factors such as soil moisture, land use, and subsurface conditions.

In this study we investigate how the different components of the land surface water budget have contributed to recent droughts in Central Europe. Given the difficulties to predict these fluxes, we focus on observational records instead. The natural unit for such analysis is the (small) catchment scale, at which topography-driven flow convergence facilitates the monitoring of runoff. Here we study the drought development over three catchments in Belgium, Germany and Switzerland, for which concomitant and long-term (decadal) records of precipitation, actual evapotranspiration (by means of eddy covariance or lysimeter) and runoff are available.

Our analysis suggests that runoff and evapotranspiration dynamics have a much larger role in drought evolution than previously thought. In particular, an inverse relation is found between monthly precipitation and evapotranspiration, with evapotranspiration increasing on average with 10% of the precipitation decrease. Whereas evapotranspiration acts to amplify drought with anomalies of up to 1 mm/d, runoff limits the magnitude of drought by reducing at a rate similar to the precipitation anomalies. In addition, we find that GRACE satellite estimates of storage anomaly dynamics can be reproduced based on the catchment water balance, but only when taking into account the positive evapotranspiration anomalies.