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Using the palaeorecord to understand the dynamics of the hydrological cycle

Sandy P. Harrison
Geography and Environmental Science, University of Reading, Reading, United Kingdom (s.p.harrison@reading.ac.uk)

The impact of climate changes on the hydrological cycle over the land needs to be understood in terms of changes in stores and in the fluxes between them and with the atmosphere. There are palaeo-records of past changes in many of the stores, including glaciers, lakes, rivers, peatlands, and vegetation. However, there are no palaeo-records of changes in atmospheric and soil water content, the largest and most volatile of the hydrological stores. Vegetation plays a key role in modulating water fluxes, but past changes in vegetation cover are determined by more than climate. Changes in plant water-use efficiency in response to changes in atmospheric CO_2 concentration also have a major impact; one manifestation of this are the differences in the apparent response of vegetation and other water stores to climate change in glacial states. Changes in plant water-use efficiency also affect runoff and thus fluxes to other stores (rivers, lakes, peatlands); interpretation of these records needs to account for both changes in climate and in atmospheric CO_2 concentration. Isotopic records can provide insights into changes in plant water-use efficiency, but the application of such records in this way has been limited. Changes in the hydrological state of the land affect water- and energy-fluxes to the atmosphere, with a positive feedback on climate. The classic example is the exacerbation of climatological drought through the impact of reductions in soil moisture storage on evapotranspiration. However, hydrological changes also have feedbacks to climate via their impact on disturbance, most particularly vegetation susceptibility to fire and windthrow. Disentangling these complex interactions and feedbacks will require (a) exploitation (and reconcilation) of the multiple sources of information about past changes in the components of the hydrological cycle over land, and (b) the combined use of observations and process-based models to interpret these records. The need for this holistic approach is urgent because land-atmosphere interactions are incompletely understood and therefore poorly represented in the earth system models that are used to project future climate changes.