# Opinion note: Climate and Water

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For the past several decades, much of popular and scientific attention has been focused on the 'global warming' aspect of climate change, because the observed change is that increasing temperatures are likely being induced by a change in net surface radiative heating by increasing atmospheric carbon dioxide abundance. Consequently, research has focused on the atmospheric and surface processes affecting the global and surface energy balances and much of the concern has focused on the consequences of rising surface temperatures. Yet even a focus on energy balance involves a water cycle at its core: the essential energy balance of the planet can be described as solar heating of the surface, evaporative cooling of the surface, heating of the atmosphere by precipitation and cooling of the atmosphere by thermal radiation. Thus, the planetary balance of solar heating and thermal radiation cooling involves an exchange of water between the surface and atmosphere. Moreover, it can be argued that, of all the consequences of climate change on the biosphere and human society, changes in water supply may be more profound and more difficult to mitigate than small changes in temperature or even the consequent rise of sea level.

The issue of water supply actually encompasses a number of different aspects: drought and floods are the most dramatic ones, but even smaller shifts of the amount of water available at the surface can produce important problems for agriculture–the whole biosphere in general–and for managing the urban environments where a majority of people now live. Surface water supply on land is usually considered to be a balance between precipitation and evaporation, but it actually depends as well on what happens to the water on the surface, how it moves into and out of the various near-surface reservoirs.

Significant progress in observing and understanding the energy balance processes has resulted from all of this research, although much work still remains to elucidate the precise role of cloud-radiative processes. We now have collected and/or analysed many observations of these atmospheric processes: winds (general circulation), atmospheric temperature-humidity-ozone profiles, clouds, radiative fluxes. We also can quantify the many properties of the ocean and land surface, including its temperature, solar reflectivity and some vegetation properties. Despite the difficult problems that remain for understanding the energy budget and atmospheric feedback processes, it is not too early to turn more attention to the water processes, including cloud-precipitation processes and land surface hydrological processes, which are not as advanced. The particular aspect of land hydrological questions in a climate context necessitates observations that are both global coverage and sustained over long time periods to be able to diagnose the atmosphere-surface exchanges of water from weather to climate scales. This necessity arises because the atmosphere rapidly couples different land areas to each other as well as the land to the ocean. Thus, although crucial details may come from in situ measurements, the climate-scale observations must be developed from satellite remote sensing.

Satellite observations of the atmosphere, land and ocean properties that affect the radiative energy exchange or are concerned with weather processes are quite well advanced, as suggested above, but more attention now should be paid to developing ways to use satellite observations to diagnose not only atmosphere-surface water exchanges (precipitation, evaporation, water vapour transport) but also the hydrological processes that affect water exchanges among land surface reservoirs. Work has already begun to exploit satellite microwave measurements to infer soil moisture and snow water amounts, but combined multi-satellite approaches are needed to determine land surface runoff and river discharge, as well as the amounts of water held in lakes and underground aquifers. In particular, the main satellite microwave measurements can be combined with specialty instruments now being launched to better determine soil moisture and with altimetry and gravity measurements that allow for determinations of changes of water levels in lakes and rivers and of the changes in total water. Combining the gravity-based total water changes with determinations of precipitation and evaporation, together with water vapour transports and determinations of surface water amounts in the soil, in snow packs, rivers and lakes, has the potential to diagnose the hydrological exchanges that are key to water supply. To realise this potential, comprehensive multi-satellite analysis approaches are needed, but these results must also be used to identify key future satellite instrumentation needed to complete the task of understanding these processes.