Getting on target

The EGU's Alberto Montanari, Günter Blöschl, Murugesu Sivapalan and Hubert Savenije advocate a more nuanced approach to hydrology and climate change...

Climate impact studies have recently become topical in hydrology and water resources, since climate change adaptation lists high on the political agenda of many countries. In light of the widespread water-related problems, conflicts and disasters that have appeared in the news in recent years, it is not difficult to conclude that humanity is facing a severe water crisis. Notwithstanding the importance of climate adaptation measures, this crisis needs to be put into a broader perspective. Water-related problems stem from a wide range of factors:

- Rapidly increasing water demands due to the rising human population and changing lifestyles;
- Depletion of freshwater resources due to increasing withdrawals, environmental pollution, and over-exploitation of groundwater;
- The non-concomitant spatial and temporal distribution of freshwater resources and human demand.

The resulting poor distribution of freshwater in relation to demand is already the cause of water scarcity in many parts of the world and the concern is that they may be exacerbated by climate change (Kundzewicz et al, 2007; Blöschl and Montanari, 2010). Also, population pressure in marginal and flood-prone lands has significantly increased flood risk, and urbanisation and road building have enhanced the occurrence of floods and landslides in densely populated areas. While climate change is increasingly important in many of these land and water management issues, it is often not the dominant concern.

Understanding the multiple controls on the water climate system is indeed a major challenge. In the past, hydrologists have chosen a catchment scale perspective, but it is becoming increasingly clear that there are feedback effects between the hydrological cycle and the climate system that operate from local to global scales. Contrary to popular belief, the rainfall that feeds the terrestrial system is largely dependent on evaporation from the land surface: 60% of the moisture above continents is supplied by evaporation from elsewhere in the land surface itself. Fig. 1 shows, for example, how up to about 80% of the precipitation falling over China results from terrestrial evaporation further upwind in Eurasia. Similar conclusions can be drawn for large parts of South America and Africa. Climate models are already attempting to capture some of these feedback effects but there are many hydrological processes yet to be included. For example, macropore flows in the soils control how fast water percolates into the subsurface, which, in turn, will control the wetness of the land surface and hence the partitioning of radiation into sensible and latent heat fluxes. Similarly, groundwater can be a significant control over large scales,

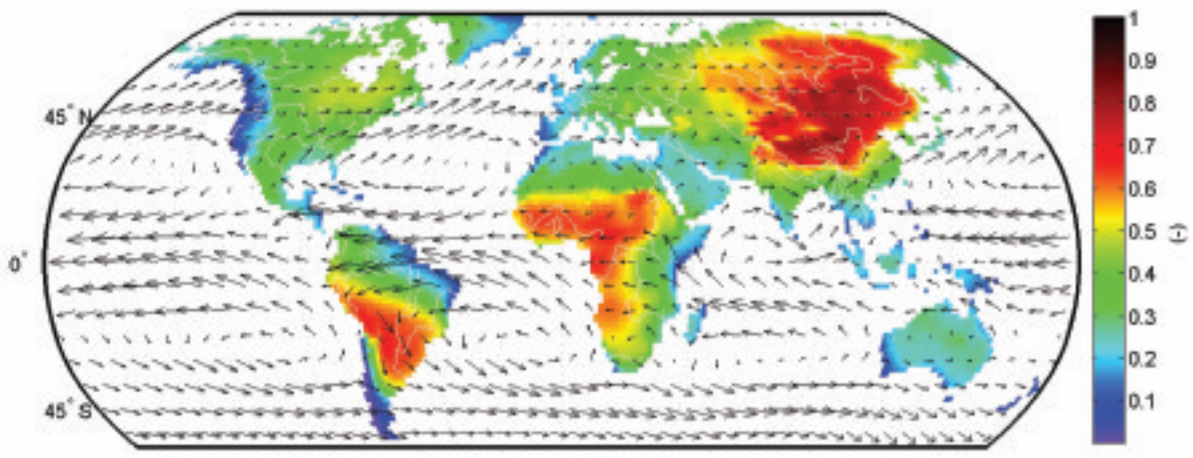

Fig. 1: Global moisture recycling. The colours indicate the amount of atmospheric moisture that is of terrestrial origin. The arrows indicate the dominant moisture fluxes (from Van der Ent et al, 2010)

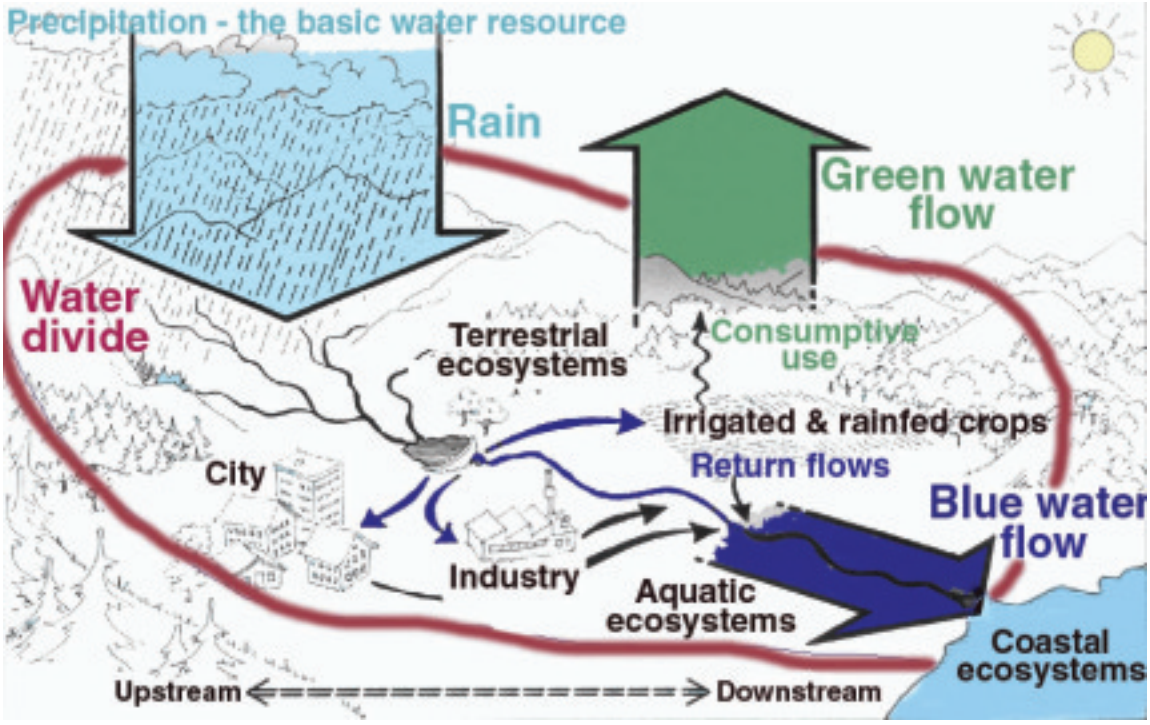

Fig. 2: Green and blue water in the hydrological cycle. From Falkenmark and Lannerstadt (2005)

both in terms of the flows and the buffering of climate processes, and yet neither of them is represented well in climate models (Schaller and Fan, 2009; Fan et al, 2007; Miguez-Macho et al, 2007).

> *'Offering insightful explanations for predicted changes may be more helpful than perfecting the estimates of what are inherently uncertain changes. Such a nuanced assessment will gain wider acceptance in society and will bring more credibility to the research community.'*

The controls on the water climate system exerted by human-induced land and water management can also be significant. Land use change, deforestation and land degradation, through regional teleconnections, may result in considerable reduction of precipitation amounts in downwind regions, as illustrated in Fig. 1. Land use activity in Eurasia could affect China's water resources. Deforestation in northeast Brazil could produce locally increased floods and at the same time cut off atmospheric moisture supply, which may result in droughts in inland regions through moisture teleconnections (Makarieva et al, 2009). We know that increased water abstractions from freshwater resources for irrigation have resulted in diversions of large water masses from streams (ie. blue water flow) to the atmosphere (ie. green water flow) (Fig. 2), thus massively enhancing transpiration and reducing the inflow to the oceans. Examples include the Colorado River in the United States, where a series of dams with a total reservoir storage of five times the average annual flow have reduced river discharges to the Californian Gulf to a mere trickle. The mighty Yellow River in China completely dried up in 1972 for the first time in its history. In 1997 its no-flow period lasted 226 days and moved 700km upstream (Falkenmark and Lannerstadt, 2005). While the effect these water management activities will have on climate still needs to be clarified, their impact may yet be considerable. Evidently, the link between climate and hydrology is not a one-way street (Koutsoyiannis et al, 2009).

In view of these problems, it is vital that research efforts on water and climate are better adjusted so they are effective. It is no longer feasible to research climate, water and humans in isolation. Considerable effort must be made, and soon, to understand the interactions and feedbacks between soils, vegetation, climate and humans across a range of scales. This may require a better targeted interdisciplinary approach. From the point of view of hydrology, we need a new modelling philosophy based on thermodynamic system theory (Zehe et al, 2010; Schymanski et al, 2009; Wagener et al, 2010) and novel spatial measurement methods to monitor water fluxes and storages from local to global scales (Western et al, 2004; Westhoff et al, 2007; Winsemius et al, 2006). The current paradigm of scenario analyses in climate impact studies will need to be expanded to put a stronger emphasis on uncertainty, as uncertainty is indeed an inherent property of complex systems that contain feedbacks. There are significant differences in the level of uncertainty of climate impacts on water resources, covering a range from hard to soft facts, as Böhm (2008) put it. Changes in hydrological processes directly related to air temperature (such as stream temperatures and snowmelt) tend to be hard facts, those related to rainfall tend to be soft facts, and the further one moves towards extremes (such as floods and droughts) the higher the uncertainty and softer the facts become.

Given this complex system perspective, scientists need to be more transparent about how hard and soft facts are defined, and about what can and cannot be predicted. Offering insightful explanations for predicted changes may be more helpful than perfecting the estimates of what are inherently uncertain changes. Such a nuanced assessment will gain wider acceptance in society and will bring more credibility to the research community. It will also convey a message to politicians that there are no simple answers to the complex system issues involved.

In the context of fast increasing water demand, and steadily declining and poorly distributed freshwater resources, climate change mainly enters as a source of great uncertainty in water management. In many regions of the world, factors other than climate change are far more important for water resource management, and hence a more nuanced approach to climate impact assessment will likely prove more useful. Hydrology does matter, however, in terms of managing the water crisis as well as climate change predictions. Key to future research efforts in respect of both is close collaboration across disciplinary boundaries. International scientific organisations can therefore serve as catalysts for concerted action in climate change adaptation efforts, including those related to water. The European Geosciences Union (EGU), comprising well over 10,000 members with expertise in meteorology, hydrology, soil science, ecology and other earth sciences, is ready and willing to mobilise its membership towards meeting the target of interdisciplinary research efforts on water and climate.

References

Blöschl G, Montanari A (2010). Climate change impacts – Throwing the dice? Hydrol. Proc., 24, 374-381

Böhm R (2008). Heiße Luft: Reizwort Klimawandel – Fakten, Ängste, Geschäfte (Hot air: the climate change controversy – facts – fears – funding). Edition Va Bene, Wien, Klosterneuburg, p. 261

Falkenmark M, Lannerstad M (2005). Consumptive water use to feed humanity – curing a blind spot, Hydrol. and Earth Sys. Sci., 9, 15–28

Fan Y, Miguez-Macho G, Weaver C P, Walko R, Robock A (2007). Incorporating water table dynamics in climate modeling: 1. Water table observations and equilibrium water table simulations, J Geophys Res, 112, D10125, doi:10.1029/2006JD008111

Kundzewicz Z W, Mata L J, Arnell N W, Döll P, Kabat P, Jiménez B, Miller K A, Oki T, Sen Z, Shiklomanov I A (2007). Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M L Parry, O F Canziani, J P Palutikof, P J van der Linden and C E Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210

Koutsoyiannis D, Montanari A, Lins H F, Cohn T A (2009). Discussion of 'The implications of projected climate change for freshwater resources and their management'. Climate, hydrology and freshwater: towards an interactive incorporation of hydrological experience into climate research, Hydrol. Sci. J., 54, 394-405

Makarieva A M, Gorshkov V G, Li B-L (2009). Precipitation on land versus distance from the ocean: Evidence for a forest pump of atmospheric moisture, Ecol. Complex., 6, 302-307, doi:10.1016/j.ecocom.2008.11.004

Miguez-Macho G, Fan Y, Weaver C.P, Walko R, Robock A (2007). Incorporating water table dynamics in climate modeling: 2. Formulation, validation, and soil moisture simulation, J Geophys Res, 112, D13108, doi:10.1029/ 2006JD008112

Schaller M F, Fan Y (2009). River basins as groundwater exporters and importers: Implications for water cycle and climate modelling. J Geophys Res, 114, D04103

Schymanski S J, Sivapalan M, Roderick M L, Hutley L B, Beringer J. (2009). An optimality-based model of the dynamic feedbacks between natural vegetation and the water balance, Water Resour. Res., 45, W01412, doi:10.1029/2008WR006841

Van der Ent R J, Savenije H H G, Schaefli B, Steele-Dunne S C. (2010). The origin and fate of atmospheric moisture over continents, Water Resour. Res. (in press)

Wagener T, Sivapalan M, Troch P A, McGlynn B L, Harman C J, Gupta H V, Kumar P, Rao P S C, Basu N B, Wilson J S. (2010). The future of hydrology: An evolving science for a changing world, Water Resour. Res., 46, W05301, doi:10.1029/2009WR008906

Western A W, Zhou S-L, Grayson R B, McMahon T A, Blöschl G, Wilson D J. (2004). Spatial correlation of soil moisture in small catchments and its relationship to dominant spatial hydrological processes, J. of Hydrol., 286, 113-134

Westhoff M C, Savenije H H G, Luxemburg W M J, Stelling G S, van de Giesen N C, Selker J S, Pfister L, Uhlenbrook S. (2007). A distributed stream temperature model using high resolution temperature observations, Hydrol. and Earth Sys. Sci., 11, 1469-1480

Winsemius H C, Savenije H H G, Gerrits A M J, Zapreeva E A, Klees R. (2006). Comparison of two model approaches in the Zambezi river basin with regard to model reliability and identifiability, Hydrol. and Earth Sys. Sci., 10, 339-352

Zehe E, Blume T, Blöschl G. (2010). The principle of 'maximum energy dissipation': a novel thermodynamic perspective on rapid water flow in connected soil structures, Philosophical Transactions of the Royal Society. B-Biological Sciences, 365, 1377-1386

Alberto Montanari
President
Hydrological Sciences Division
European Geosciences Union
alberto.montanari@unibo.it

Günter Blöschl
Institute of Hydraulic Engineering and Water Resources Management
Vienna University of Technology
bloeschl@hydro.tuwien.ac.at

Murugesu Sivapalan
Departments of Civil and Environmental Engineering and Geography
University of Illinois at Urbana-Champaign
sivapala@uiuc.edu

Hubert Savenije
Department of Water Management
Delft University of Technology
H.H.G.Savenije@tudelft.nl