SNAPSHOT

Snow-related water woes

Snow is a natural reservoir, directly providing freshwater to two billion people. Indeed, huge populations are now plumbed on snow (and ice)-fed rivers from distant mountains: California, supported by snowmelt from the Sierra Nevada; China, India and Bangladesh, by the Hindu-Kush Himalaya; and Chile and Argentina, by melt in the Andes. It is for this reason that mountains are often described as water towers, storing water in its frozen form during the cold winter months, to be slowly released during spring and summer as temperatures rise. Water managers have long-exploited this natural cycle of availability, using dams and reservoirs to maximize freshwater accessibility during periods of peak summertime demand, when water would otherwise be less available.

However, changes are afoot in snow-dominant hydrological systems. As Justin Mankin, Assistant Professor at Dartmouth College, USA, notes “On the one hand, snow is simple — you heat it up, it melts”. As a result, rising temperatures have shifted snowmelt from summer to spring[1], systematically offsetting the timings of peak river discharge and peak demand. “Because temperature also governs how precipitation is portioned into snow and rain, it of course plays a critical role in our understanding of snow cover changes”, comments Daniel Viviroli, Senior Scientist at the University of Zurich, Switzerland; with less precipitation falling as snow, the diminished snowpack is more vulnerable to earlier melt.

It is these shifts in snowpack size and snowmelt characteristics that are of key concern, disrupting the seasonal rhythms that societies have developed around. Water infrastructure, for example, is designed for summertime melt, such that earlier — and reduced — melt poses challenges for supply management. Limited reservoir capacity means that the ‘early water’ is lost to the ocean rather than being stored for subsequent periods of heightened demand.

In the Northern Hemisphere it is likely that snow resources will be affected by anthropogenic forcing, impacting water supply for nearly two billion people[2]. For example, in the western United States, approximately 75% of freshwater currently originates as snow in the

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Sierra Nevada, Rocky and Cascade mountains. Here, dramatic changes have been observed in snow hydrology: 90% of sites now show declines in snowpack[3], with a corresponding one month shift in snowmelt-driven runoff[4], and reductions in river flow. Detection and attribution studies have linked these trends to anthropogenic forcing[5], with broad consensus that they will continue in the future.

“High Mountain Asia is another hot spot of vulnerability” notes Walter Immerzeel, Associate Professor at Utrecht University, The Netherlands. Several of the world’s major river basins — the Indus, Amu Darya, Ganges, Brahmaputra, Yangtze, and Yellow rivers — are fed, at least partially, by snow and glacial melt in the broader Himalaya region. All support large populations and extensive agriculture, and many of these basins have observed a shift towards earlier springtime melt. Unlike in the western United States, however, Immerzeel comments that due to temperature-related increases in glacial melt, the threat to water supplies in these regions may not be imminent: “glaciers do not disappear overnight and will continue to provide meltwater for decades to come”. Nevertheless, it is anticipated that increased glacial melt may not be able to fully compensate for decreasing snow cover, particularly in the Indus and Brahmaputra basins, which are largely snow-fed[6].

As Mankin explains, these problems are widespread: “the Chilean Andes also suffered massive snow declines during 2010–2015, causing water management emergencies in both Chile and Argentina; Iran has been gripped by a massive drought as the Zagros and Alborz ranges held lower-than-average March 2018 snowpacks; and Turkey and the wider Caucasus are also places to watch for reduced reservoir and river flow from snow declines”.

Such threats emphasize the need for increased adaptation efforts. Hard construction — that is, extending or building new dams and reservoirs — is of course an option, but is controversial. Viviroli also notes barriers to feasibility in the form of “major impacts on ecosystems, an absence of financial resources, particularly in developing countries, or the fact that suitable locations may already be fully exploited”. Thus, he proposes that it may be more important to develop more effective water management strategies to reduce water use.

However, our ability to effectively manage water resources is hampered by inadequate observations. Snow water equivalent, for example, remains an unresolved issue in mountain hydrology, and although efforts have been made to quantify regional snow characteristics (such as under NASA’s Airborne Snow Observatory), these are in their infancy. Increased global observations — both in situ and remotely sensed — will not only be useful in their own right, but also offer opportunities to evaluate and improve climate models, with subsequent benefits for quantifying natural variability and uncertainty.

With shifting snowmelt characteristics and associated offsets between supply and demand, water resource managers face an ever-more-difficult task to maintain water security under anthropogenic warming. When also considering other stakeholders — ecosystems, agriculture and hydropower — the loss of mountain snow cover represents an ongoing global issue. ❐

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