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In a Warming World, Is Snowmelt Slower or Faster?

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Changes to the snowmelt regime are of critical importance to the hydrological cycle in many regions of the world. Recently Musselman et al (2017, Nature Climate Change) presented evidence to show that snowmelt rates are slower when temperatures are warmer in the western USA, while Wu et al's (2018, Geophysical Research Letters) study of the northern hemisphere suggested slower snowmelt rates for warmer temperatures in many places, but also faster snowmelt rates in regions with deeper snowpack.

Musselman et al (2017) suggested that the reason for slower snowmelt might be that warming led to smaller snowpacks, which could be completely melted earlier in the warm season, on days when available energy was relatively low, and, crucially, not leaving any water to melt in late spring or summer, when incoming energy is higher. Wu et al (2018) suggested that the reason for faster snowmelt in deeper snowpacks (cf shallow snowpacks) might be the extra energy available for melt in late spring or early summer. At this stage the explanations for impact of warming on snowmelt rates remain ad hoc, without a unified explanation of the phenomena.

Using a generalisation of Woods (2009, Advances in Water Resources), we present a simple theoretical explanation for the varying responses of melt rate to warming. The theory predicts that warming will lead to (i) faster snowmelt in very cold climates (ii) slower snowmelt in intermediate climates (iii) faster snowmelt in warm climates. The mechanisms are consistent with the explanations proposed by Musselman et al (2017) and Wu et al (2018). According to this theory, the dimensionless temperatures which define transitions from faster to slower and back to faster snowmelt are dependent on the precipitation regime: if the precipitation rate is higher, then the transition is predicted to occur at a higher (dimensionless) temperature.

With this theory, it is possible to provide coherent first order explanations for the variety of snowmelt responses to warming, which may provide a useful organising principle for further data-based investigations into this issue, especially across large climate ranges.