Reduced fraction of young water in Alpine catchments with increased seasonal snow cover

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Background
- Water age is important for water management
- Improve drought management
- Relevant in cold climates with snow melt
- Especially as snowpacks more intermittent (global climate change)
- Alps are an important water source for downstream areas

How (and how fast) does snow move through catchment?

Study Sites
- Vallon de Nant, Vaud, CH: 13.5 km², 1189-3051 m. asl., stream 5 km, LC mix grassland, forest, rocks (3% glacier)
- Noce Bianco at Pian Venezia, Italy: 8.5 km², 2298-3769 m. asl., stream3 km, LC dominated by bare rock, and glacier (42%)
- Bridge Creek Catchment, Italy: 0.14 km², 1932-2121 m. asl., stream <300 m, LC dominated by alpine grassland (no glacier)

Approach
- Stable Isotopes of water, becoming easier and more cost-effective to analyze, allow for an estimation of the fraction of young water (with an age < 3 months).

\[ F_{yw} = \frac{40}{6.22} = 6.5\% \]

Ratio Method (Kirchner, 2016)
- Shortcomings:
  - Does not account for snowpack storage
  - Does not account for irregularities in sampling (widespread in seasonally inaccessible locations)
  - Assume Gamma distributed transit times

We propose a new framework to assess young water fraction
1. Sine fit incoming precipitation
   - Effect date assignment, weight, handling multiple samples for rain and snow
   - Isotope phase shift, \( \Phi_{w/s} = \Phi_{r} - \Phi_{w} \)
2. Simple Snow Model \(\Rightarrow P_{eq}\) (equivalent precipitation)
   - Degree-day
   - \( P_{eq} = \text{Melt} + \text{Rain} \)
   - Full mixing
   - 100 m elevation band
   - Temperature Lapse Rate
3. Convolution
   - Allows estimation of \( F_{yw} \) without fitting sine curve
   - Uses all information from input and output
   - Fourier transform of gamma distribution
   - Identifies distributional parameters matching observations

Conclusions
- High elevation Alpine catchments might have relatively "old" water or low fractions of young water.
- New framework finds a greater fraction of young water.
- Sampling design and construction of time series can have important changes on final Fyw.

References
- Kirchner, 2016. HESS, 20(1), 279-297.

Photos show changing snowpack in Vallon de Nant, by authors.