Towards a conceptualization of the hydrological processes behind changes of young water fraction with elevation: a focus on mountainous alpine catchments - supplementary material

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Summary:

This document contains additional information about the stable water isotopes collected in the 27 study catchments with a focus on the DOR and SOU catchments. Some pictures of the Dora del Nivolet catchment are reported in Fig. S1. Fig. S2 shows sinusoidal cycles fitted to the $\delta^{18}O$ data of the 27 study catchments using IRLS with indication of amplitudes and phases of the seasonal cycles. Fig. S3 shows the amount of baseflow obtained applying the Duncan (2019) baseflow filter for all the 27 study sites. Next Fig. S4 illustrates the f_{SCA} timeseries for all the 27 study catchments. Fig. S5 shows the winter baseflow and the total winter flow against the mean elevation. Fig. S6 shows the young water fraction (F^*_{yw}) plotted against the Winter Flow Index (*WFI*). Fig. S7 shows the mean winter discharge against elevation.
In the Supplementary Material have also been made available:

- A Matlab © code with the implementation of the Duncan (2019) baseflow filter.
- A Matlab © code for performing IRLS and for calculating F^*_{yw}, α and τ_{yw}.

Additional information about the stable water isotopes collected in the 27 study catchments.

Regarding the Swiss catchments studied by von Freyberg et al. (2018), stream water samples for isotopic analyses were collected fortnightly until December 2014 and have been collected weekly since January 2015 for the Alp (ALP), Biber (BIB), Erlenbach (ERL), Luempenenbach (LUM) and Vogelbach (VOG) catchments (Staudinger et al., 2020). For the remaining 17 catchments, samples are collected fortnightly (Staudinger et al., 2020). Isotopes in precipitation were not measured at their catchments-set: $\delta^{18}O$ values from monthly cumulative precipitation samples were interpolated from long-term observations at nearby monitoring stations (von Freyberg et al., 2018). In the Noce Bianco at Pian Venezia (NBPV) catchment, stream water samples were collected both manually and automatically (by an ISCO sampler) at the daily or subdaily timescale during summer (Zuecco et al., 2019; Ceperley et al., 2020). In the Bridge Creek Catchment (BCC), stream water samples were collected manually during selected rainfall and snowmelt events, and approximately monthly from May to October 2011–2016 (Penna et al., 2016, 2017; Ceperley et al., 2020). Both for NBPV and BCC bulk samples of rain water were collected monthly at the outlet of the catchment by 5-L bottles equipped with a funnel and a layer of mineral oil to prevent evaporation, whereas snow samples were collected using an aluminum cylinder, inserted vertically from the surface to a depth of 20 cm (Zuecco et al., 2019; Penna et al., 2016). In the Vallon de Nant (VdN) catchment, stream water samples were collected both manually and automatically (by an ISCO sampler). Bulk rain samples were weekly or biweekly collected for isotopic analyses using funnels flowing into insulated bags at three locations (1253, 1500 and 2100 m a.s.l.) between June 2016 and November 2018. Between February 2016 and April 2018, snow samples were collected from the entire snow profile at various locations in the catchment (Ceperley et al., 2020). Finally, for DOR and SOU catchments, stream water samples were manually collected at the outlet points at the monthly timescale, while precipitation samples were collected using a double rain and snowfall isotope sampler installed on a pole 3.7 m high with the same time-resolution.

Additional information on the DOR ans SOU catchments

Dora del Nivolet (DOR) catchment has a catchment area of about 17 km^2 and its elevation ranges from 2390 to 3430 m a.s.l. Average annual precipitation in the period November 2017- January 2022 was about 1800 mm. We monitor precipitation every month with a rain gauge located at roughly 2560 m a.s.l. We measure streamflow continuously (10 min timestep) at the DOR outlet point and in a lateral subcatchment, on the left bank of the mainstream, using piezo-resistive multi-sensors. We call this lateral subcatchment "Source" (SOU), since it is characterized by water emerging from underground. The SOU subcatchment extends for roughly 0.16 km^2 and its elevation ranges from 2390 to 2790 m a.s.l. The DOR catchment experiences a snow-dominated hydro-climatic regime with the snowpack generally persisting from mid-November to mid-May when the snowmelt starts. Since the snowpack melts during the growing season, it uncovers a typical alpine meadow home to plant species including Gentiana Lutea L., Juniperus Communis L., Vaccinium Myrtillus L., Salix Alpina Scop. and Trifolium Alpinum L. The lithology of DOR is dominated by gneiss. Bedrock emerges at high elevations, while at medium elevations talus dominates. At lower elevations we find the alpine meadow, characterized by peat substrate, through which the mainstream flows. Water samples for isotopic analysis are collected of both bulk precipitation and stream water at a monthly time resolution. All precipitation and stream water samples were analyzed with laser spectroscopy at the Forest Hydrology laboratory of University of Padova (Italy).

We apply the methodology described in Section 3.1 of the main text to estimate the young water fraction in DOR and SOU catchments. The flow-weighted young water fractions (F^*_{yw}) are 0.18 ± 0.03 and 0.11 ± 0.03 for DOR and SOU catchments, respectively. The F^*_{yw} results for these two high-elevation catchments agree with F^*_{yw} estimated by Jasechko et al. (2016), Lutz et al. (2018), Ceperley et al.(2020), who found less young streamflow in mountains than in other landscapes.

Figure S1. A) Panoramic view of the Dora del Nivolet (DOR) catchment. © Google Earth B) Outlet point of the Dora del Nivolet catchment where streamwater samples are manually collected. C) Dora del Nivolet catchment during winter D) Rain and snowfall isotope sampler (preventing evaporation) installed on a pole 3.7 m high

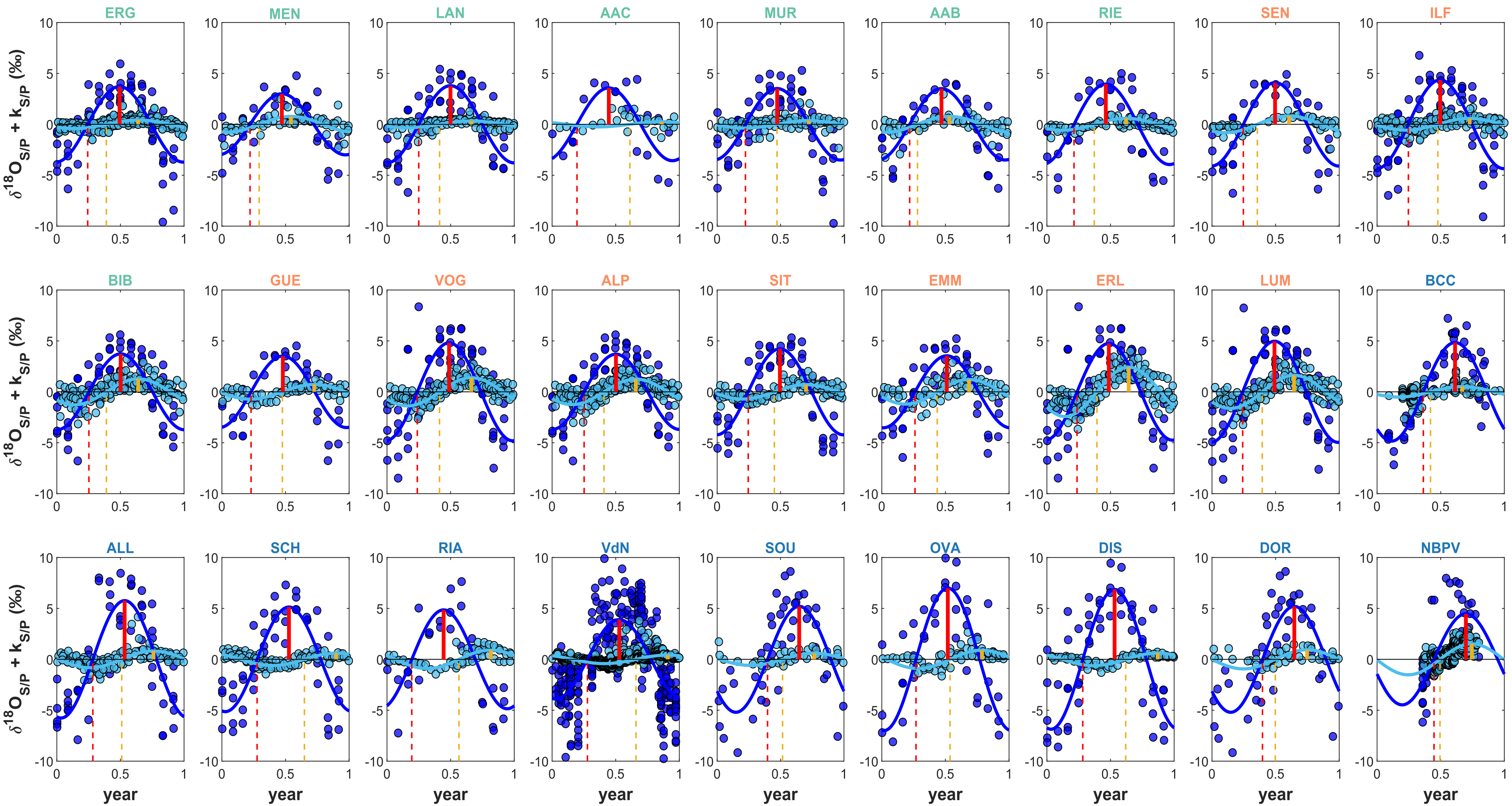

Figure S2. Sinusoidal cycles (lines) fitted to the $\delta^{18}O$ data (points) using IRLS: dark blue color refers to precipitation, light blue color refers to streamwater. Amplitudes (continuous lines) and phases (dotted lines) are indicated in the figure: red color refers to precipitation, yellow color refers to streamwater.

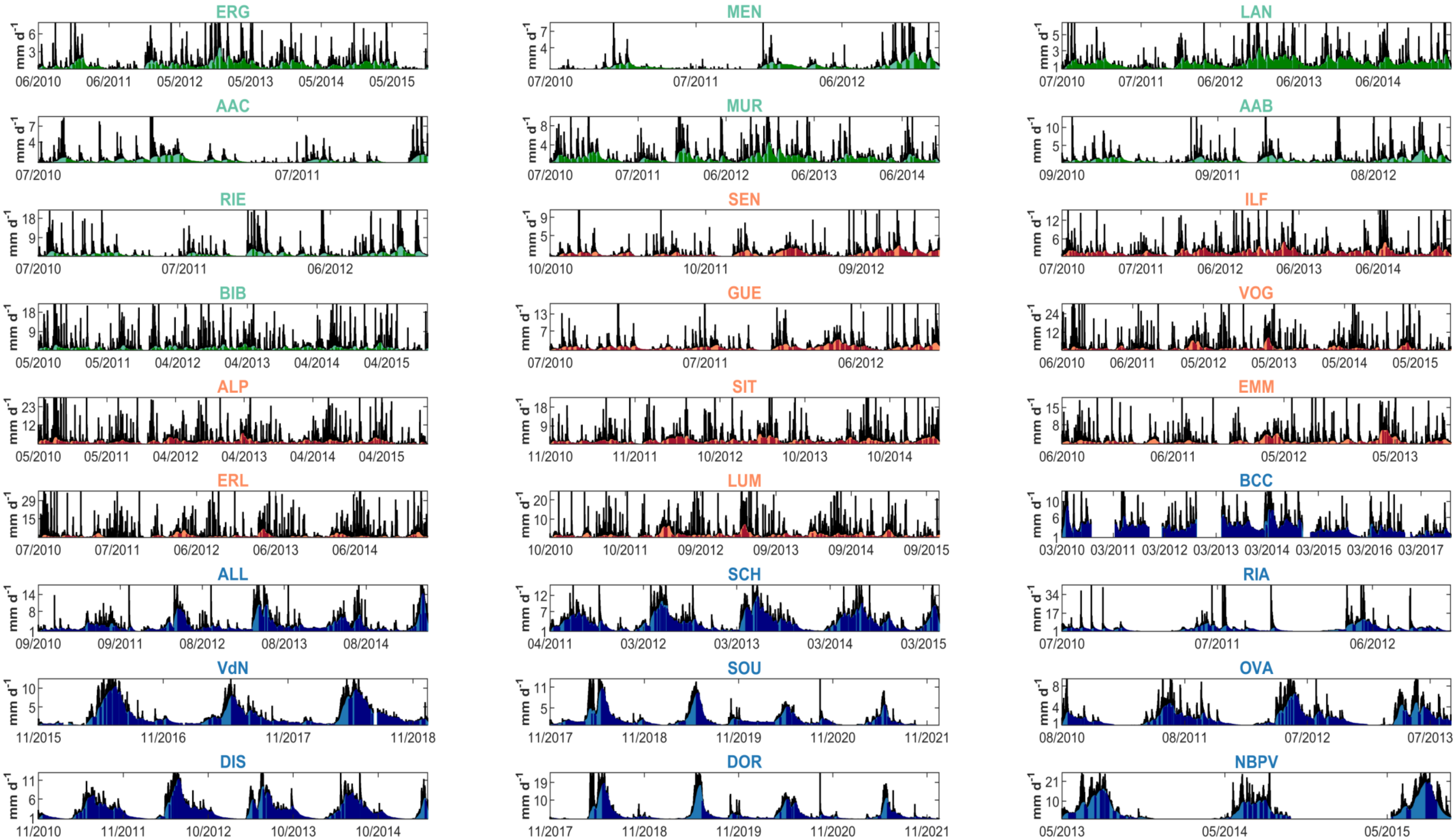

Figure S3. Baseflow separation using the Duncan (2019) filter for all the study sites. The darker color indicates low-flow periods.

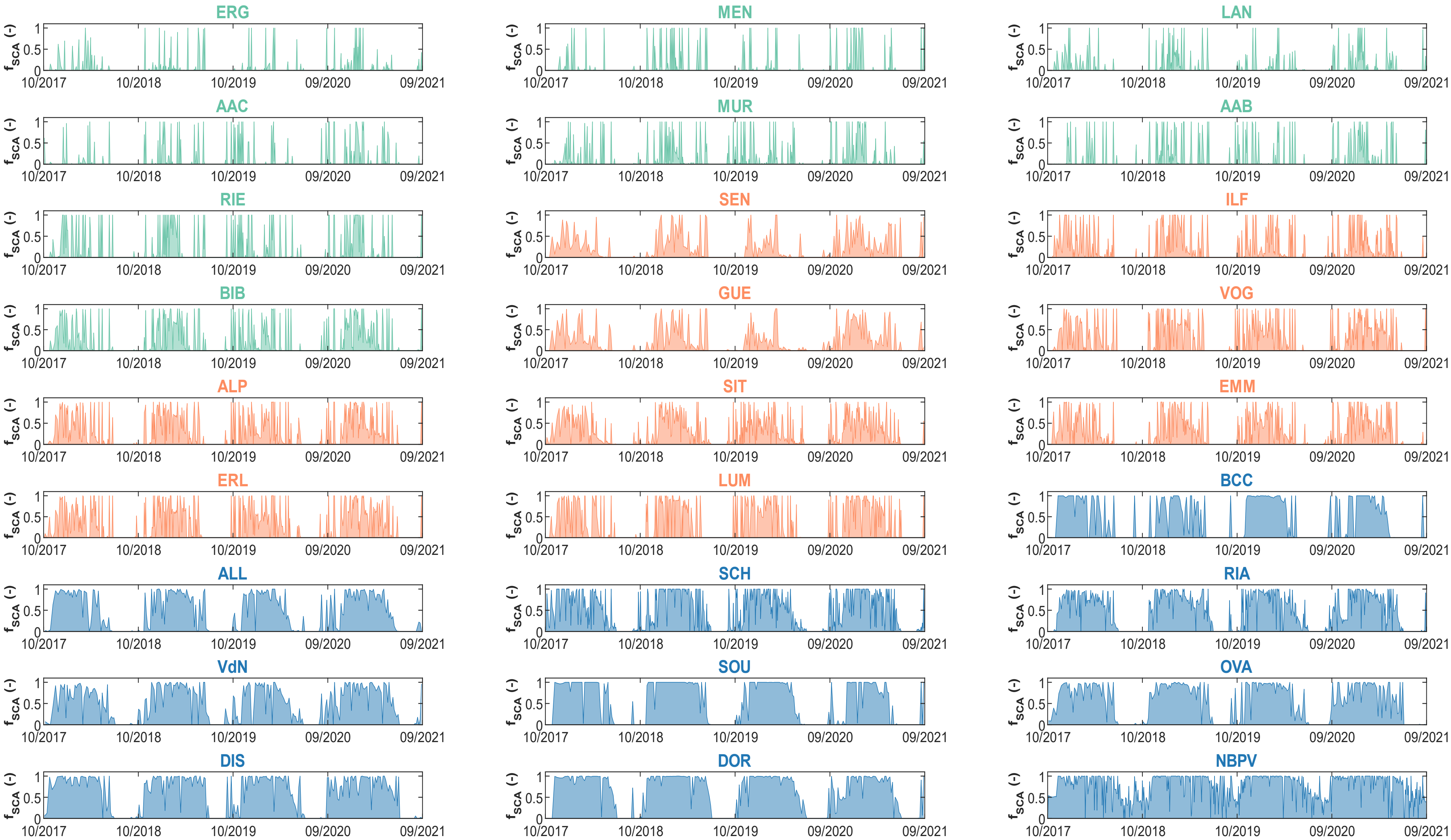

Figure S4. f_{SCA} timeseries for all the study sites.

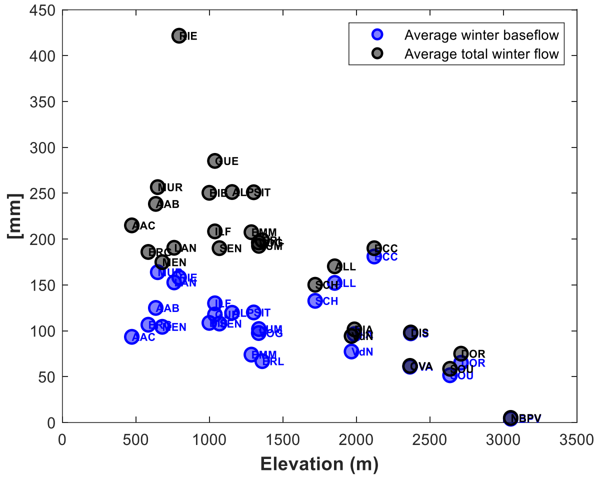

Figure S5. Winter baseflow and total winter flow against elevation.

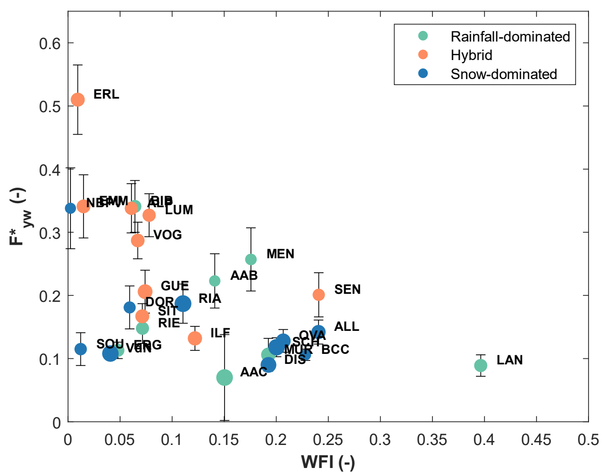

Figure S6. Young water fraction against Winter Flow Index. Points dimension is proportional to τ_{yw}.

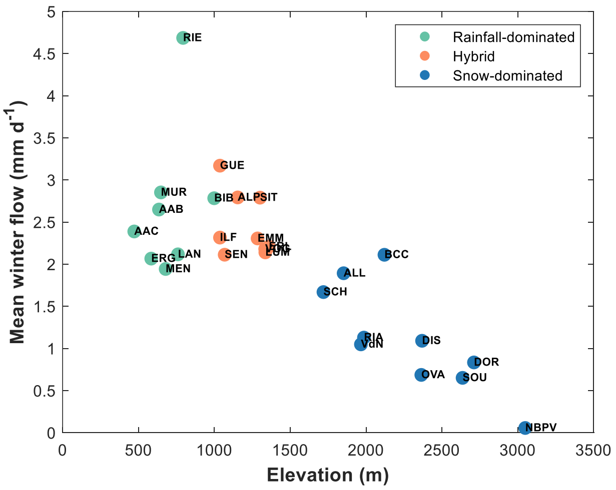

Figure S7. Mean winter discharge against elevation.

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