

Figure S1. Comparison of measured and modelled water $\delta^2\text{H}$ values across a west-east transect through New Zealand's Southern Alps. Measured values are river samples, taken from small rivers by Kerr et al. (2015); modelled values are those for precipitation at the nearest virtual climate station network (VCSN) point, based on the coefficients of Baisden et al. (2016), and uncorrected and residual-corrected river model values from this study. All model values show an underprediction of $\delta^2\text{H}$ values at the western (windward) end of the transect, and an overprediction at the eastern (leeward) extent of the transect. Root Mean Square Error for the four models across this transect are 13.8‰, 12.5‰, 9.8‰ and 9.6‰ for the precipitation model, uncorrected spatiotemporal river model, ordinary-kriging corrected river model, and regression kriging corrected river model, respectively.

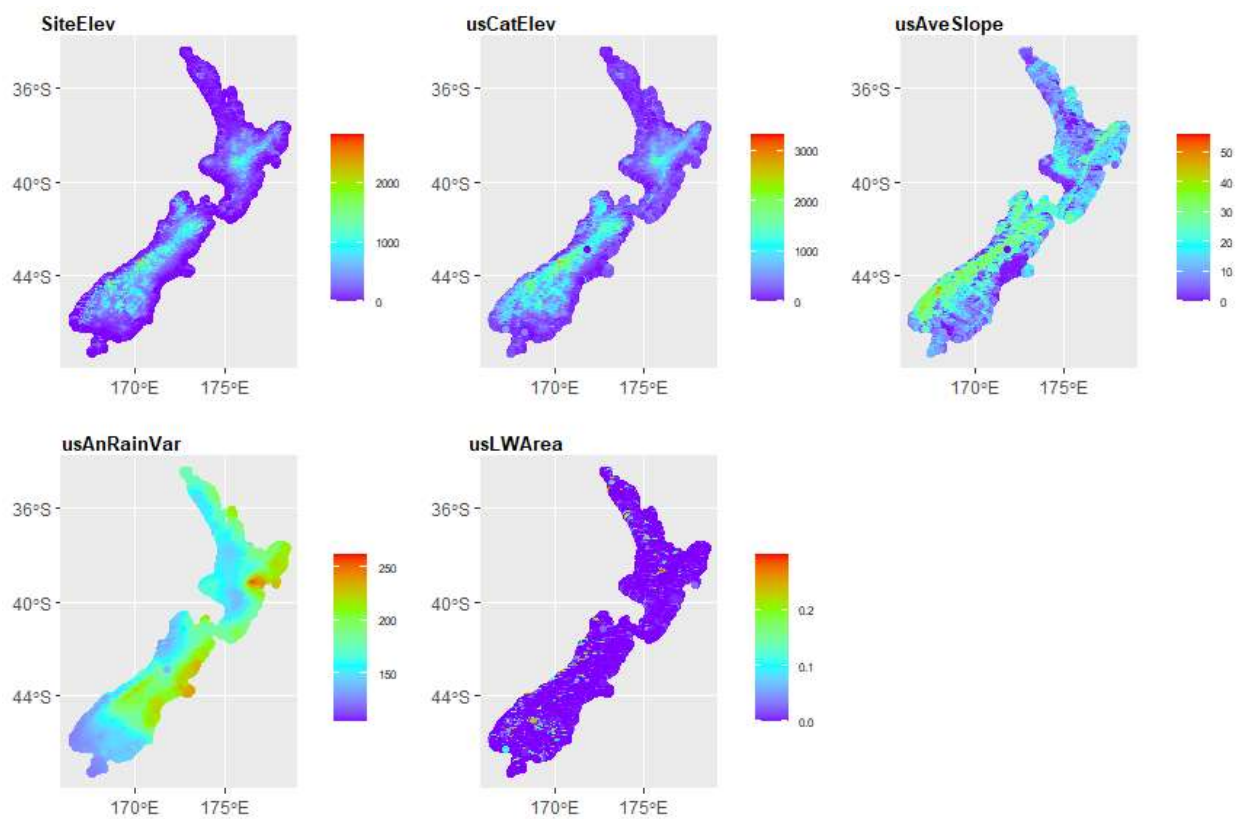


Figure S2. Spatial distribution of the five environmental variables used in regression kriging of residuals (Equation 3). Except “SiteElev”, all other factors are averaged across upstream catchments.

Table S1. Full list of catchment environmental characteristic variables

	Variable	Meaning	Source
1	SiteLat	The latitude of the reach (degree)	REC (Snelder and Biggs 2002)
2	SiteElev	The elevation of the site (m)	Derived from 30m DEM (Snelder and Biggs 2002)
3	CatMaxElev	Upstream maximum elevation (m)	FENZ (Leathwick et al. 2010)
4	CatArea	Upstream drainage area (km ²)	FENZ (Leathwick et al. 2010)
5	PET	Annual average potential evapotranspiration (mm)	VCSN (Tait et al. 2006)
6	AET	Annual average actual evapotranspiration (mm)	VCSN (Tait et al. 2006)
7	Precip	Annual average precipitation (mm)	VCSN (Tait et al. 2006)
8	Dist2Sea	The distance to sea (m) : from the stream to the outlet stream	FENZ (Leathwick et al. 2010)
9	dsAveSlope	Downstream average slope (degree)	FENZ (Leathwick et al. 2010)
10	Order	A number describing the Strahler order of a stream in the stream network (-)	REC (Snelder and Biggs 2002)
11	usAnRainVar	Coefficient of variation of annual upstream catchment rainfall (-)	FENZ (Leathwick et al. 2010)
12	usAveSlope	Average upstream catchment slope (degree)	FENZ (Leathwick et al. 2010)
13	usAvTCold	Average upstream temperature in cold seasons (degree)	FENZ (Leathwick et al. 2010)
14	usAvTWarm	Average upstream temperature in warm seasons (degree)	FENZ (Leathwick et al. 2010)
15	usFlow	Upstream annual flow (m ³ /s)	FENZ (Leathwick et al. 2010)
16	usLowFlow	Upstream mean low flow (m ³ /s)	FENZ (Leathwick et al. 2010)
17	usSolarRadSum	Upstream solar radiation in summer (W/m ²)	FENZ (Leathwick et al. 2010)
18	usSolarRadWin	Upstream solar radiation in winter (W/m ²)	FENZ (Leathwick et al. 2010)
19	usCatElev	Upstream catchment average elevation (m)	FENZ (Leathwick et al. 2010)
20	usLowGrad	Proportion of catchment with slope >30° (steep)	FENZ (Leathwick et al. 2010)
21	usLWArea	percentage of catchment in LCDB category (lakes, and inland and coastal wetlands) (%)	FENZ (Leathwick et al. 2010)
22	E_P	Ratio of evaporation over precipitation of the upstream catchment (-)	Calculated based on AET and precipitation from VCSN (Tait et al. 2006)

	Variable	Meaning	Source
23	PET_P	Ratio of potential evaporation over precipitation of the upstream catchment (-)	Calculated based on AET and precipitation from VCSN (Tait et al. 2006)
24	DrainDsO1	Drainage density for Strahler order 1 catchment	Derived from 30m DEM (Snelder and Biggs 2002)
25	DrainDsO2	Drainage density for Strahler order 2 catchment	Derived from 30m DEM (Snelder and Biggs 2002)
26	DrainDsO3	Drainage density for Strahler order 3 catchment	Derived from 30m DEM (Snelder and Biggs 2002)
27	Dist2HeadO1	Distance to Strahler order 1 headwater catchment (m)	Derived from 30m DEM (Snelder and Biggs 2002)
28	Dist2HeadO2	Distance to Strahler order 2 headwater catchment (m)	Derived from 30m DEM (Snelder and Biggs 2002)
29	Dist2HeadO3	Distance to Strahler order 3 headwater catchment (m)	Derived from 30m DEM (Snelder and Biggs 2002)
30	Aspect	Average of upstream geographic aspects	Derived from 30m DEM (Snelder and Biggs 2002)
31	Aspect_sd	Standard deviation of upstream geographic aspects	Derived from 30m DEM (Snelder and Biggs 2002)