Model equations

Table S1. Water balance equations and constitutive functions (abbreviations see Table 1 and sect. 2.2, 3.1.1, 3.2).

Reservoir	Water balance equation	Constitutive functions
Snow reservoir	$\Delta S_{snow}/\Delta t = P_s - M$	100 m elevation zones: $P = P_l + P_s$ $P_s = \begin{cases} P & T_{mean} \geq T_{temp} \\ 0 & T_{mean} < T_{temp} \end{cases}$ $M = \begin{cases} min \begin{cases} melt_f \cdot (T_{mean} - T_{temp}) \\ S_{snow} \cdot t^{-1} + M_{glacier} \end{cases} & T_{mean} \geq T_{temp} \\ 0 & T_{mean} < T_{temp} \end{cases}$ $M_{glacier} = (melt_f \cdot (T_{mean} - T_{temp}) - S_{snow} \cdot t^{-1}) \cdot glacier\ extent$ *[assumption: $S_{glacier}$ is unlimited]*
Unsaturated reservoir	$\Delta S_u/\Delta t = P_l + M$ $- Q_{uf} - Q_{up} - E_a - Q_{us}$	$Q_{uf} = (1\text{-}D) \cdot C_r \cdot (P_l + M);\ \ C_r = 1/[1 + e^{(-S_u/S_{u,max} + 0.5)/\beta}]$ $Q_{up} = D \cdot C_r \cdot (P_l + M);\ \ C_r = 1/[1 + e^{(-S_u/S_{u,max} + 0.5)/\beta}]$ $E_a = E_p \cdot min \begin{cases} S_u/S_{u,max} \cdot 1/L_p \\ 1 \end{cases}$ $Q_{us} = S_u / S_{u,max} \cdot P_{max}$
Fast reservoir	$\Delta S_f/\Delta t = Q_{uf} - Q_f$	$Q_f = S_f \cdot (1 - e^{-K_f \cdot t}) \cdot t^{-1}$
Slow reservoir	$\Delta S_s/\Delta t = Q_{up} + Q_{us} - Q_s$	$Q_s = S_s \cdot (1 - e^{-K_s \cdot t}) \cdot t^{-1}$

Boxplots

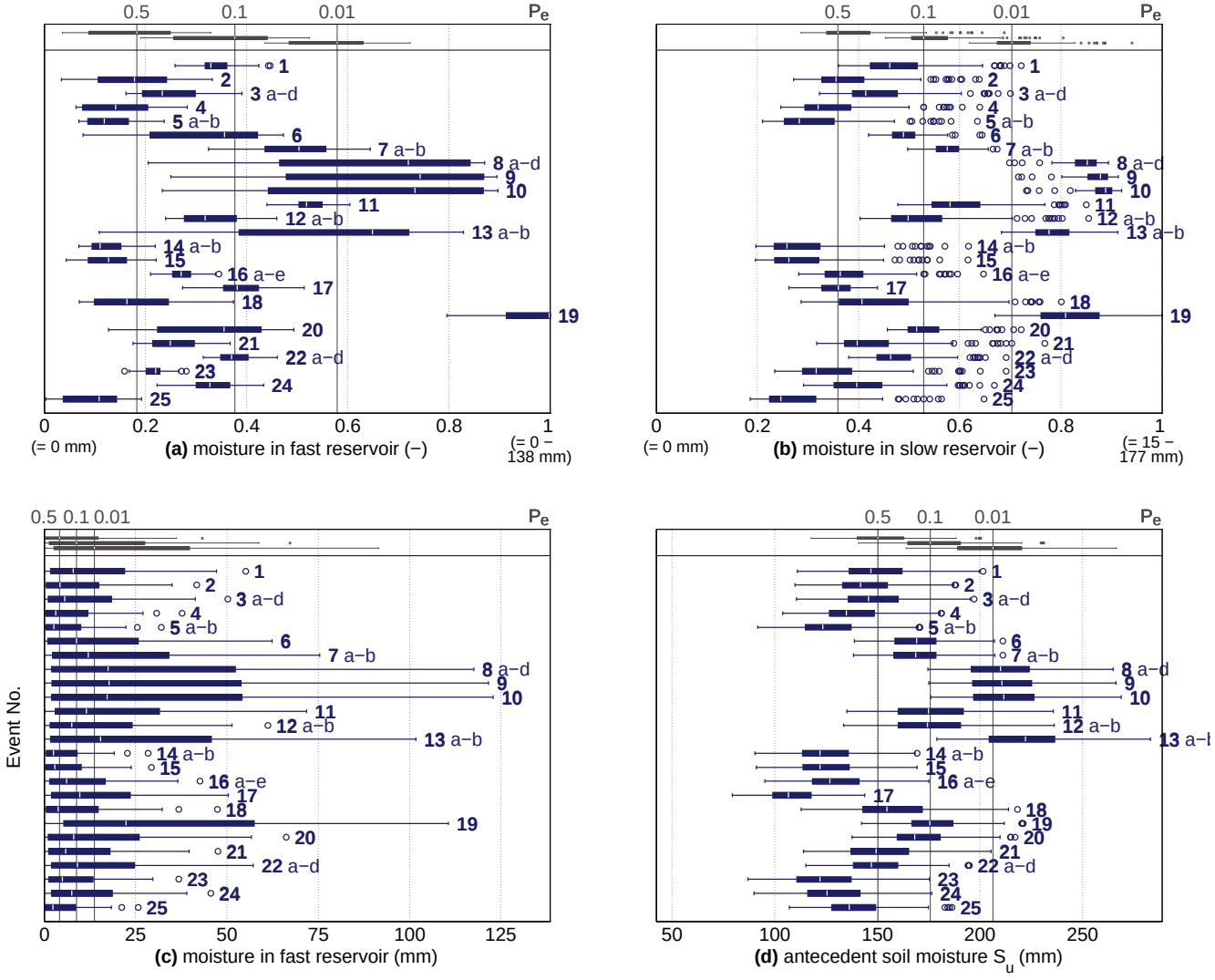
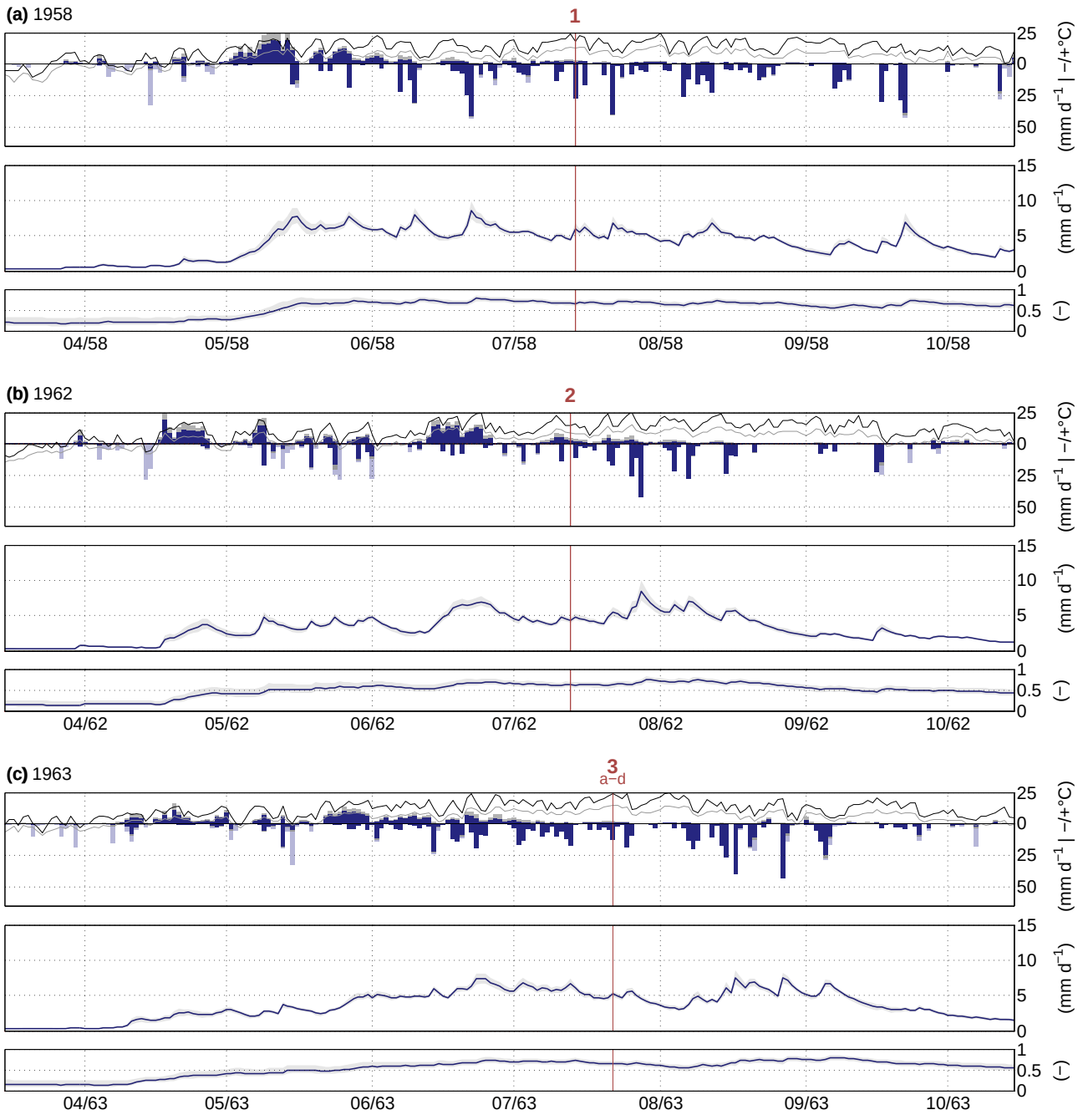
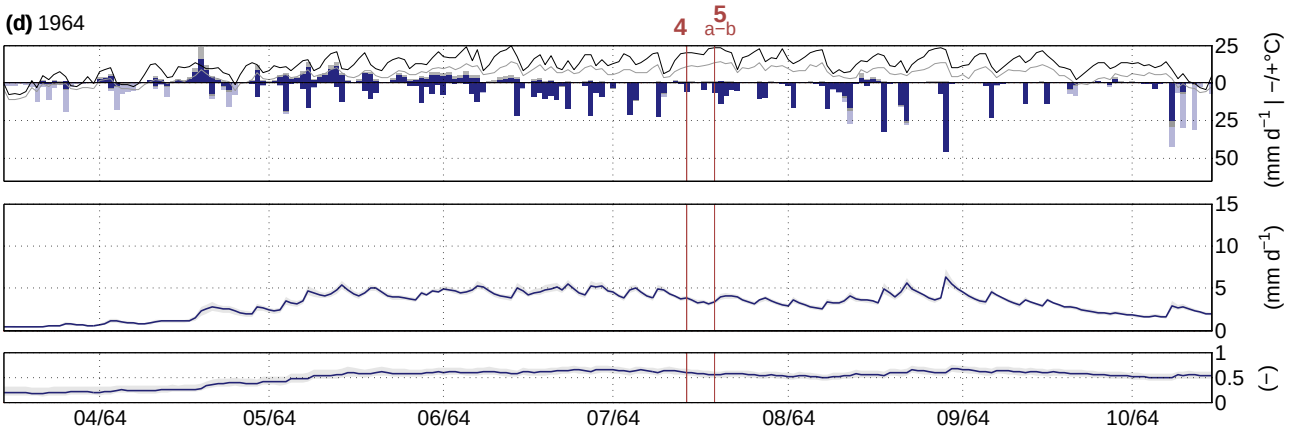
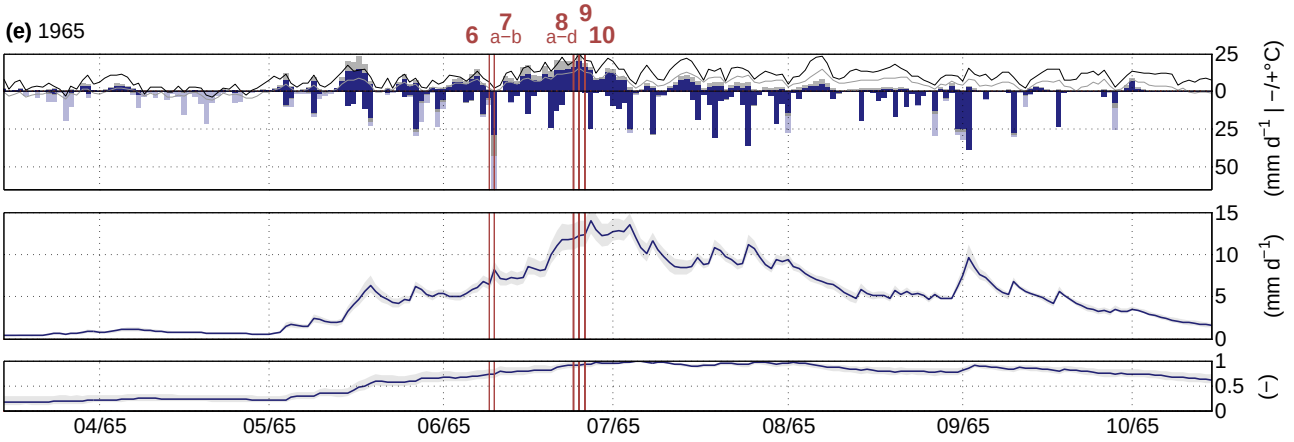


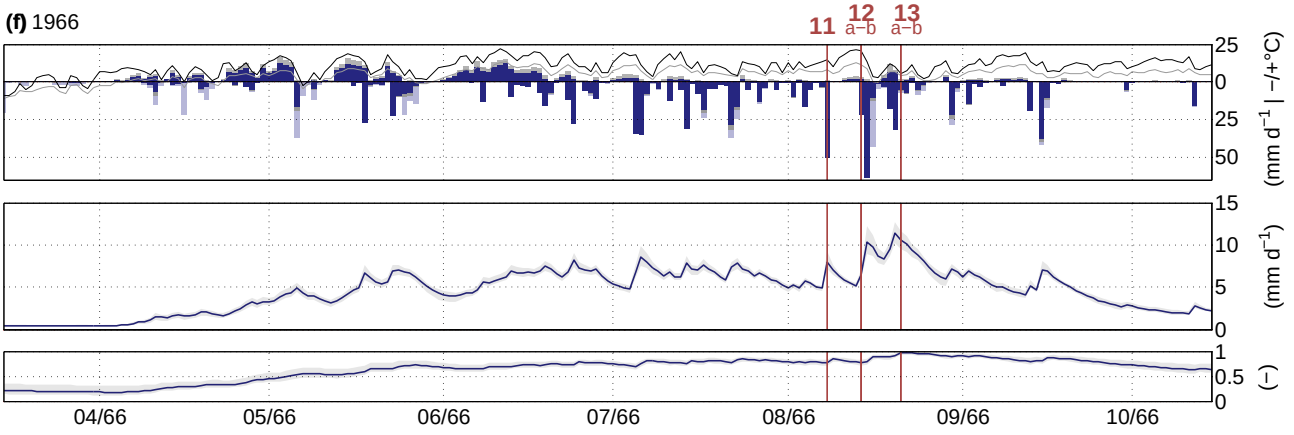
Figure S1. Examples of ill-performing system variables (a-b) and ill-performing absolute x-axis definitions for storage elements (c-d): both the debris flow event days' boxplots (blue) and the threshold values' boxplots (grey) show wide variations within the behavioral models i.e. the classification of the debris flows' system variables (high moisture, low moisture, etc.) would – to a greater extent – depend on which model parameter set one considers as "correct" (which cannot be determined due to model equifinality).

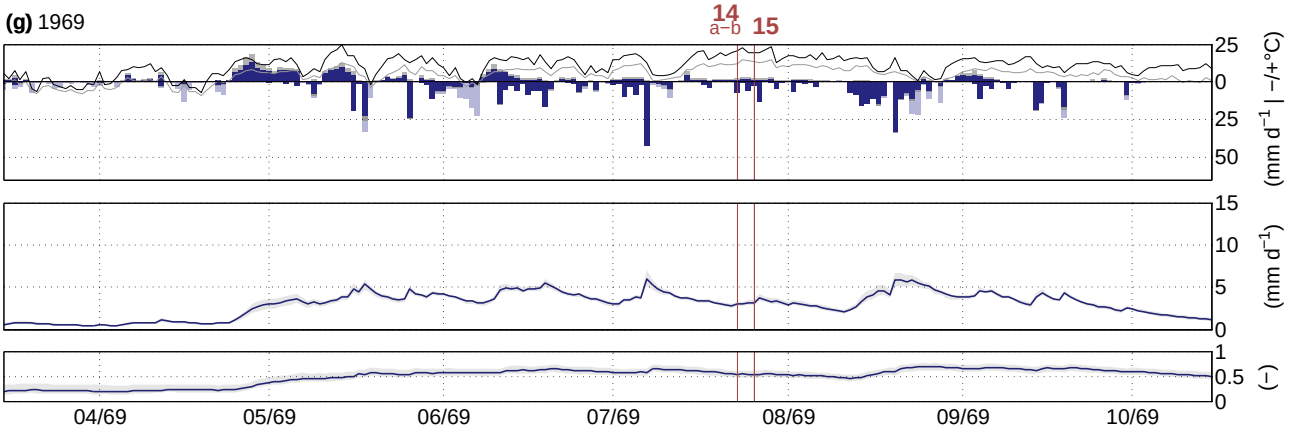
Timeseries plots

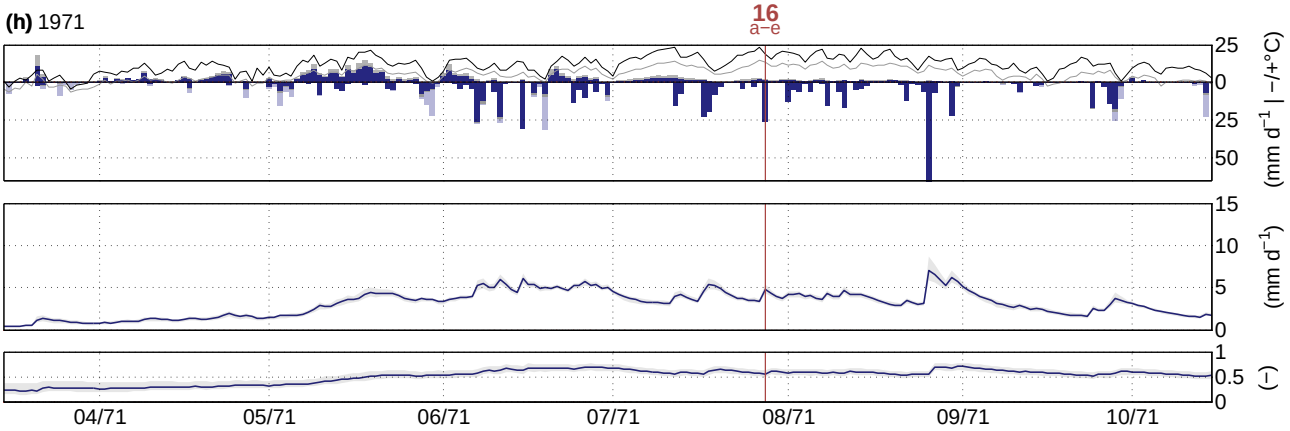


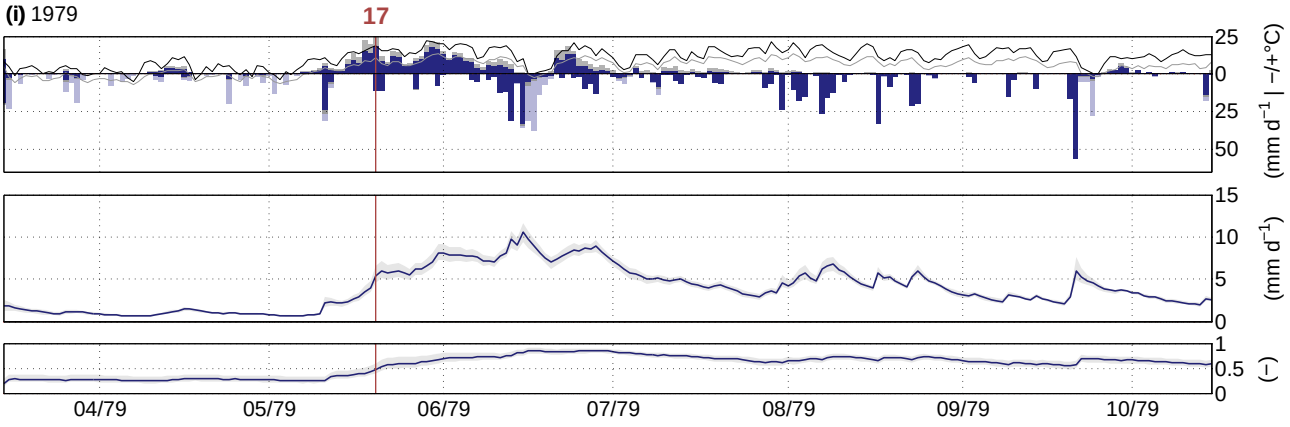

(d) 1964
4
5
a–b
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(–)
04/64
05/64
06/64
07/64
08/64
09/64
10/64

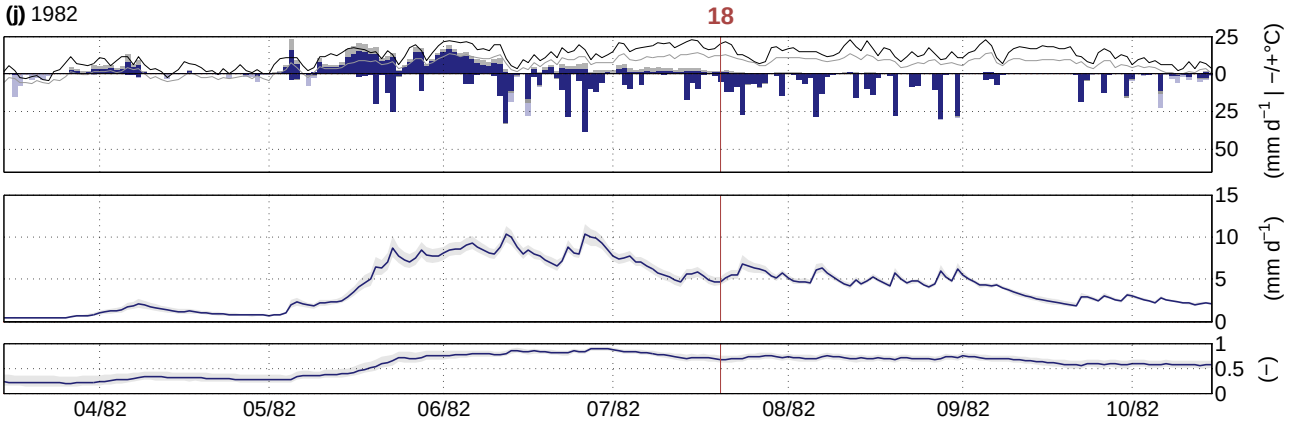

(e) 1965
6
7
a–b
8
a–d
9
10
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(–)
04/65
05/65
06/65
07/65
08/65
09/65
10/65

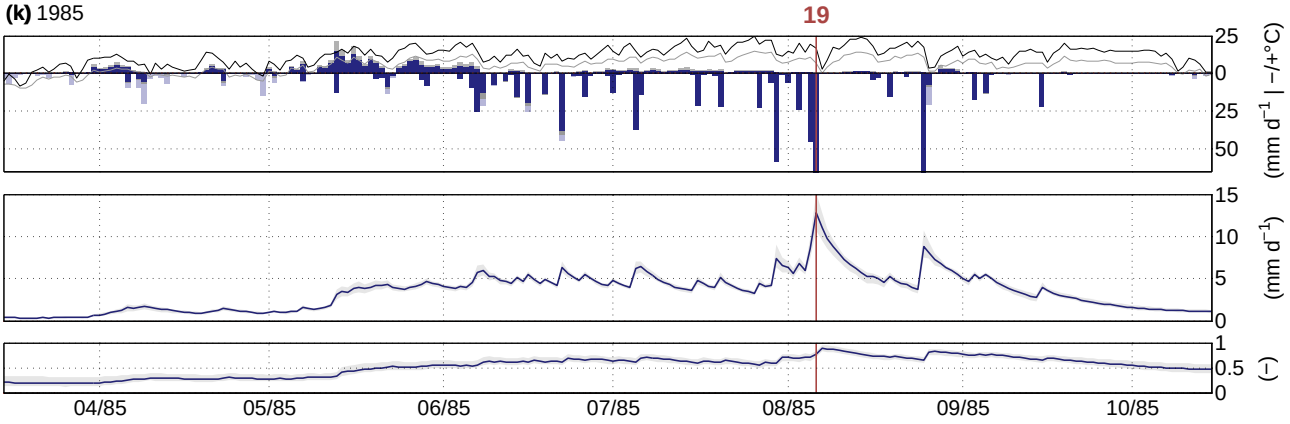

(f) 1966
11
12
a–b
13
a–b
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(–)
04/66
05/66
06/66
07/66
08/66
09/66
10/66

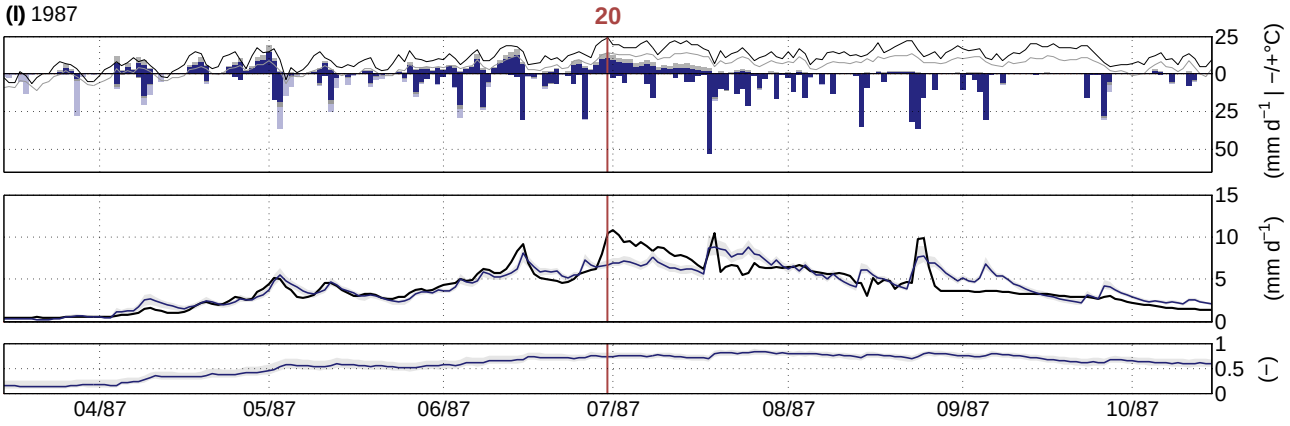

(g) 1969
14
a–b
15
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/69
05/69
06/69
07/69
08/69
09/69
10/69

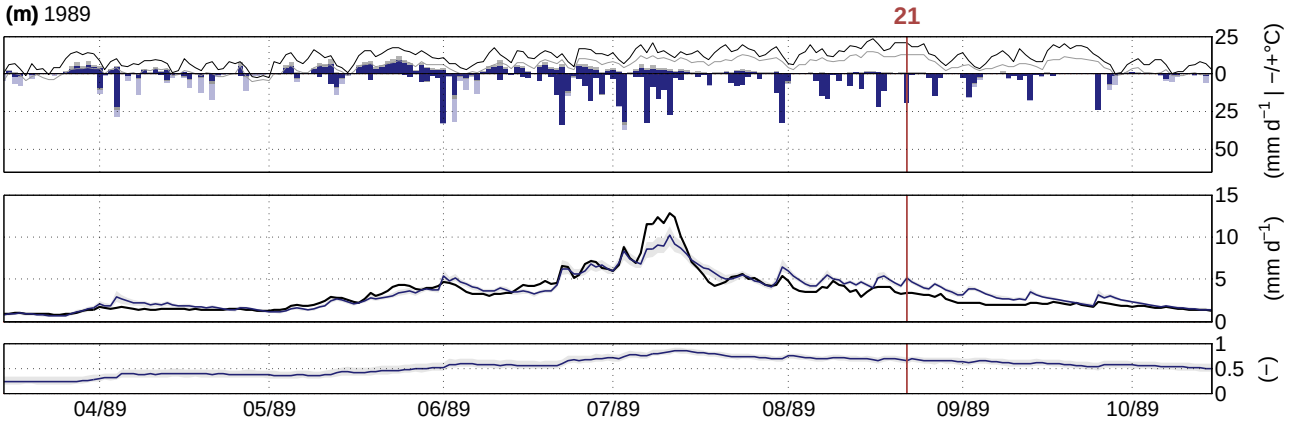

(h) 1971
16
a–e
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/71
05/71
06/71
07/71
08/71
09/71
10/71

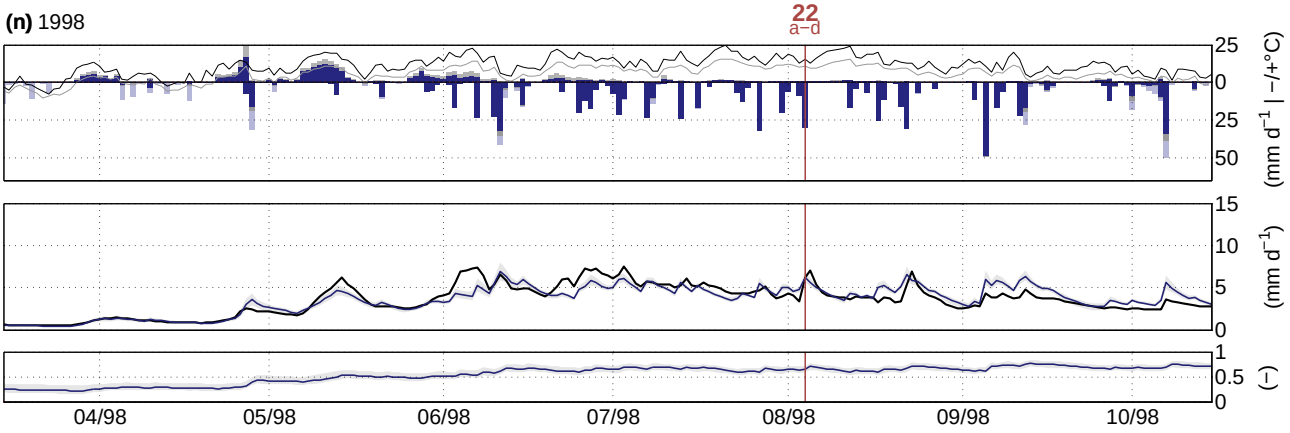

(i) 1979
17
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/79
05/79
06/79
07/79
08/79
09/79
10/79

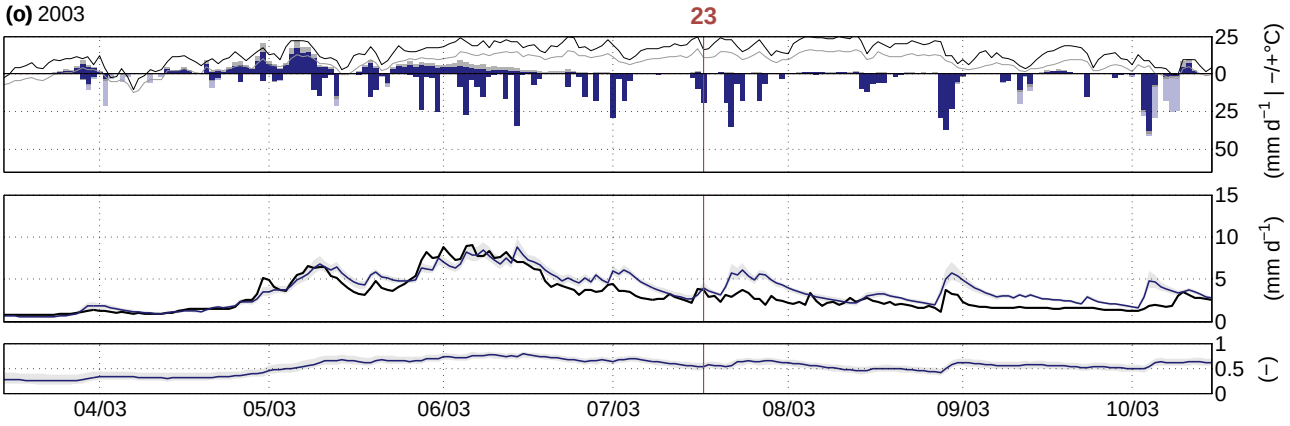

(j) 1982
18
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/82
05/82
06/82
07/82
08/82
09/82
10/82


(k) 1985
19
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/85
05/85
06/85
07/85
08/85
09/85
10/85


(l) 1987
20
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/87
05/87
06/87
07/87
08/87
09/87
10/87


(m) 1989
21
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/89
05/89
06/89
07/89
08/89
09/89
10/89


(n) 1998
22
a–d
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/98
05/98
06/98
07/98
08/98
09/98
10/98


(o) 2003
23
25
0
25
50
(mm d−1 | −/+°C)
15
10
5
0
(mm d−1)
1
0.5
0
(−)
04/03
05/03
06/03
07/03
08/03
09/03
10/03

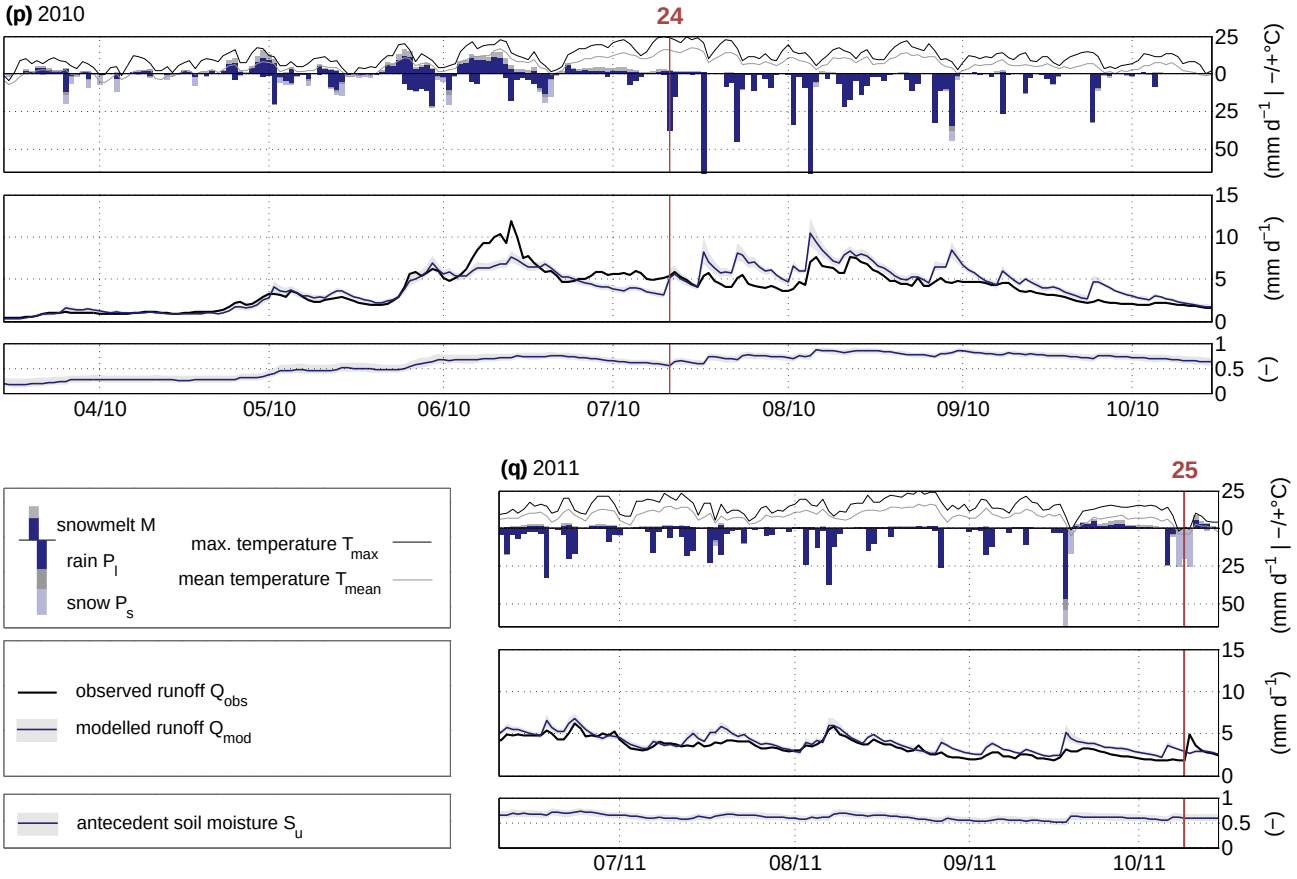


Figure S2. Observed daily stream flow Q_{obs} (black solid line), daily mean temperature T_{mean} at mean elevation (grey solid line) and maximum temperature T_{max} at mean elevation (black solid line) as well as, based on observed precipitation data, modelled daily rainfall P_l (dark blue downward columns for 5th percentile, incl. grey downward columns for 95th percentile), daily snowfall P_s (light blue downward columns for 5th percentile, incl. grey downward columns for 95th percentile) and daily snowmelt M (dark blue upward columns for 5th percentile, incl. grey upward columns for 95th percentile), modelled stream flow (dark blue line for the median and the grey shaded area for the 5/95th percentiles of all behavioral model solutions) and modelled relative soil moisture (solid blue line for the median and the grey shaded area for the 5/95th percentiles) for all years with debris flow occurrence.