Supplement of Nat. Hazards Earth Syst. Sci., 24, 1035–1049, 2024
https://doi.org/10.5194/nhess-24-1035-2024-supplement

Natural Hazards and Earth System Sciences
Open Access

Supplement of

Comparison of debris flow observations, including fine-sediment grain size and composition and runout model results, at Illgraben, Swiss Alps

Daniel Bolliger et al.

Correspondence to: Fritz Schlunegger (fritz.schlunegger@unibe.ch)

Figure S1: Video recordings of debris flows. The video camera is placed at the Survey Station (see Figure 1c in main text)

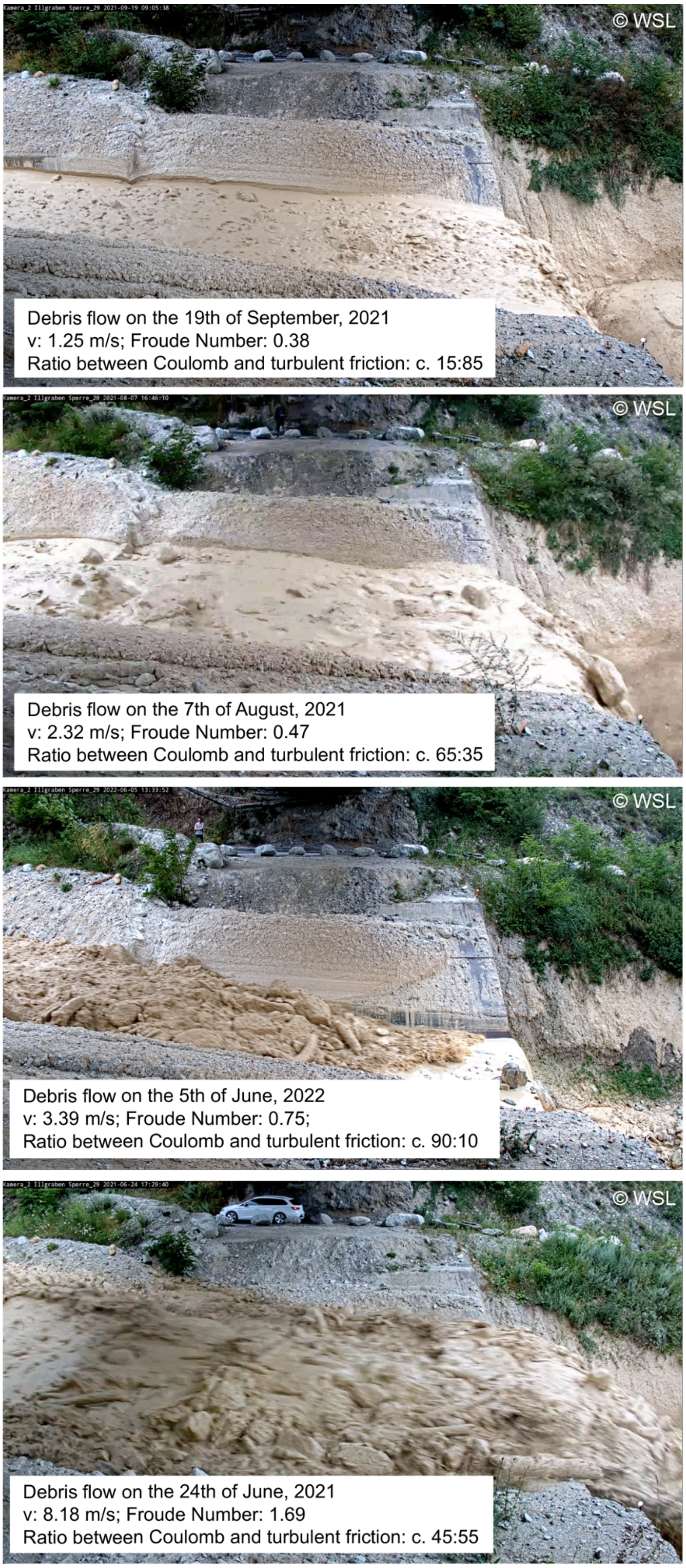

Table S1: Measurements from monitoring station at the Illgraben

Event start	Front velocity CD 28-29 (m/s)	Max flow depth laser (m)	Max flow depth radar (m)	Mean bulk density laser (kg/m^3)	Peak velocity (quantile 0.99) laser CD 28-29 (m/s)	Peak velocity (quantile 0.99) radar CD 28-29 (m/s)	Peak discharge (quantile 0.99) laser CD 28-29 (m/s)	Volume laser CD 28-29 (m^3)	Flow duration (min)
21.06.2019 21:44	6.62	3.13	2.69	1870	6.55	6.57	147.61	97394	43
02.07.2019 01:26	3.86	1.75	1.73	1971	5.78	5.38	65.58	73188	52
26.07.2019 19:46	8.69	1.39	1.41	2223	9.74	9.98	93.26	113310	65
11.08.2019 19:07	6.95	1.81	1.89	2323	6.90	6.91	95.63	88064	88
20.08.2019 19:03	0.89	1.13	1.10	2031	1.36	1.36	8.06	6137	37
24.06.2021 17:11	8.18	2.40	2.49	1750	8.16	8.10	162.20	105032	38
06.07.2021 20:43	8.69	2.50	2.58	1605	8.65	8.67	186.61	76906	28
16.07.2021 05:43	2.78	2.38	2.44	1916	3.22	3.30	60.70	80879	77
07.08.2021 16:22	2.32	2.49	2.17	1884	2.89	2.74	41.19	38737	46
19.09.2021 08:57	1.25	1.13	1.22	1697	1.41	1.39	10.67	8538	43
05.06.2022 12:33	3.39	2.08	2.15	1690	4.14	4.32	55.42	39498	55
04.07.2022 22:54	8.18	2.49	2.60	1189	8.46	7.36	169.14	175929	39
08.09.2022 02:06	1.91	1.93	1.77	1592	1.85	1.87	20.94	9283	20

Table S2: Exemplary evaluation of the simulations of the debris flow event on 24.06.2021

Table S2a: Input data composed of raster and shape files, simulation settings and measurements from the monitoring station.

Event	**24.06.2021**
DTM	DTM_0.5.tif
DTM resolution [m]	0.5
calculation domain	calcdom.shp
release area	hydrograph.shp
stop parameter [%]	5
sim resolution [m]	0.5
end time [s]	600
dump step [s]	2
erosion layer	erosion.shp
erosion density [kg/m3]	2000
erosion rate [m/s]	0.025
pot. Erosion depth [per kPa]	0.1
critical shear stress [kPa]	1
max erosion depth [m]	1
density [kg/m3]	1750
inflow direction [°]	60
vol [m3]	105032
Qmax [m3/s]	162.2
t1 [s]	10
v [m/s]	8.18
Front velocity CD 28-29 (m/s)	8.18
Max flow depth laser (m)	2.4
Max flow depth radar (m)	2.49
Peak velocity (quantile 0.99) laser CD 28-29 (m/s)	8.16
Peak velocity (quantile 0.99) radar CD 28-29 (m/s)	8.1
Flow duration (min)	38
CD28-CD29	134m
CD27-CD29	460m
Froude number	1.69

Table S2b: Output data with velocity (v) and flow depth (av_maxd_P). These variables were compared with the results of the field survey to determine the best-fit simulation (green) for each *μ.* The z-values are calculated from the laser measurement (Max flow depth laser, see above).

Simulation	Mu []	Xi [m/s2]	v [m/s]	maxd_P1 [m]	maxd_P2 [m]	maxd_P3 [m]	maxd_P4 [m]	av_maxd_P [m]	Froude number []	Qmax [m3/s]	z value laser	z value radar
1	0.02	1400	8.9	1.99	2.30	2.54	2.93	2.44	1.82	140	0.09	0.09
2	0.02	800	7.9	3.00	2.94	2.84	3.03	2.95	1.47	130	0.23	0.19
3	0.02	1000	7.9	2.63	2.71	2.62	2.89	2.71	1.53	147	0.13	0.10
4	0.02	1200	8.4	2.22	2.38	2.40	2.71	2.43	1.72	140	0.03	0.04
5	0.04	1500	7.9	2.94	2.86	2.65	2.86	2.83	1.50	128	0.18	0.14
6	0.04	2000	8.4	2.60	2.64	2.57	2.69	2.63	1.66	140	0.10	0.06
7	0.04	2500	8.4	2.45	2.55	2.54	2.78	2.58	1.67	137	0.08	0.05
8	0.04	3000	8.4	2.04	2.55	2.69	2.97	2.56	1.68	142	0.07	0.04
9	0.06	12000	7.9	3.21	3.12	3.00	3.12	3.11	1.43	138	0.30	0.25
10	0.06	8000	7.9	3.31	3.22	3.20	3.50	3.31	1.39	124	0.38	0.33
11	0.06	9000	8.4	3.38	3.26	3.16	3.39	3.30	1.48	128	0.37	0.33
12	0.06	10000	7.9	3.19	3.09	2.97	3.22	3.12	1.43	135	0.30	0.25
13	0.06	14000	8.4	2.62	2.59	2.67	2.95	2.71	1.63	135	0.13	0.09
14	0.01	800	8.4	2.62	2.69	2.56	2.87	2.69	1.64	138	0.12	0.08
15	0.01	1000	8.4	2.18	2.33	2.49	2.84	2.46	1.71	138	0.04	0.03
16	0.01	1200	8.9	1.90	2.35	2.68	3.26	2.55	1.78	142	0.11	0.09
17	0.03	1000	7.9	2.94	2.87	2.70	3.04	2.89	1.48	139	0.21	0.16
18	0.03	1500	8.4	2.46	2.59	2.49	2.78	2.58	1.67	144	0.08	0.05
19	0.03	2000	8.9	2.07	2.53	2.71	2.97	2.57	1.77	145	0.11	0.09
20	0.03	2500	9.6	1.95	2.31	2.65	3.05	2.49	1.94	136	0.18	0.17
21	0.04	3500	8.9	1.71	2.12	2.66	3.04	2.38	1.84	136	0.09	0.10
22	0.05	8000	8.9	1.70	2.13	2.51	2.91	2.31	1.87	137	0.10	0.11
23	0.05	10000	8.9	2.04	2.48	2.77	3.10	2.60	1.76	137	0.12	0.10
24	0.05	12000	8.9	1.77	2.45	2.94	3.35	2.63	1.75	136	0.13	0.10
25	0.05	14000	8.9	1.82	2.06	2.55	3.27	2.43	1.82	136	0.09	0.09
26	0.05	6000	8.4	2.16	2.54	2.59	2.80	2.52	1.69	146	0.06	0.03
27	0.06	16000	8.4	2.87	2.73	2.70	2.94	2.81	1.60	133	0.17	0.13
28	0.04	4000	8.9	1.99	2.48	2.70	3.12	2.57	1.77	139	0.11	0.09
29	0.02	1600	7.6	2.09	2.47	2.65	3.13	2.59	1.51	139	0.10	0.08
30	0.02	4000	11.2	1.99	1.93	2.19	2.42	2.13	2.45	152	0.39	0.40
31	0.04	3200	8.9	1.80	2.29	2.65	3.00	2.44	1.82	135	0.09	0.09
32	0.05	7000	8.4	1.77	2.42	2.67	2.93	2.45	1.71	139	0.03	0.03
33	0.06	15000	7.9	2.62	2.58	2.71	3.05	2.74	1.52	137	0.15	0.11

Table S3: Details on the modelling approach

Information on the number of model runs (Table S3a), the intervals between the μ– and ξ–values upon modelling (Table S3b), and event-specific and general input values that were used upon modelling (Tables S3c and S3d, respectively). Finally, Table S3 also lists the results of the model runs per event where the model results and observations had a best fit (Table S3e).

Table S3a: Number of model runs

Event	# of simulations	best z-value
21.06.19	43	0.06
02.07.19	34	0.32
11.08.19	41	0.13
20.08.19	36	0.02
24.06.21	37	0.03
06.07.21	38	0.03
16.07.21	30	0.03
07.08.21	23	0.23
19.09.21	33	0.11
05.06.22	12	0.01
04.07.22	13	0.02
08.09.22	20	0.34
Total	360	

Table S3b: Variations of μ and ξ val

μ	0.01
ξ	1 to > 1000

For μ we only used the values 0.01, 0.02, 0.03, 0.04, 0.05 and 0.06 upon modelling.
Also upon modeling, the intervals between the ξ–values were 1 for those models where we set μ =1. For larger μ–values, we increased the intervals between the subsequent ξ–values to >> 1000. We iteratively changed the values until we found a best-fit between model results and observations.

Table S3c: Input for RAMMS, which were not event-specific

DTM	DTM_0.5.tif
DTM resolution [m]	0.5
calculation domain	calcdom.shp
release area	hydrograph.shp
stop parameter [%]	5
sim resolution [m]	0.5
end time [s]	1000
dump step [s]	2
erosion layer	erosion.shp
erosion density [kg/m3]	2000
erosion rate [m/s]	0.025
pot. Erosion depth [per kPa]	0.1
critical shear stress [kPa]	1
max erosion depth [m]	1
inflow direction [°]	60
t1 Hydrograph [s]	10

Table S3d: Input for RAMMS, which were event-specific

Event	21.06.19	02.07.19	11.08.19	20.08.19	24.06.21	06.07.21	16.07.21	07.08.21	19.09.21	05.06.22	04.07.22	08.09.22
density [kg/m^3]	1870	1971	2323	2031	1750	1605	1916	1884	1697	1690	1189	1592
vol [m^3]	97394	73188	88064	6137	105032	76906	80879	38737	8538	39498	175929	9283
Qmax [m^3/s]	147.61	65.58	95.63	8.06	162.2	186.61	60.7	41.19	10.67	55.42	169.14	20.94
Front velocity CD 28-29 [m/s]	6.62	3.86	6.95	0.89	8.18	8.69	2.78	2.32	1.25	3.39	8.18	1.91
Max flow depth laser [m]	3.13	1.75	1.81	1.13	2.4	2.5	2.38	2.49	1.13	2.08	2.49	1.93
Max flow depth radar [m]	2.69	1.73	1.89	1.1	2.49	2.58	2.44	2.17	1.22	2.15	2.6	1.77
Froude Number	1.19	0.93	1.65	0.27	1.69	1.75	0.58	0.47	0.38	0.75	1.66	0.44

Table S3e: Best-fit outputs of RAMMs models

Event	21.06.19	02.07.19	11.08.19	20.08.19	24.06.21	06.07.21	16.07.21	07.08.21	19.09.21	05.06.22	04.07.22	08.09.22
Front velocity CD 28-29 [m/s]	6.7	3.9	7.4	0.9	8.4	8.9	2.8	2.31	1.24	3.35	8.38	1.76
Max flow depth [m]	2.96	2.32	2.02	1.15	2.43	2.47	2.32	1.91	1.01	2.09	2.5	1.29
Froude number	1.24	0.83	1.66	0.27	1.72	1.81	0.59	0.53	0.39	0.74	1.69	0.49
Qmax [m^3/s]	122	54	78	7	140	158	48	35	9	40	143	17
μ	0.06	0.06	0.06	0.01	0.02	0.05	0.05	0.04	0.01	0.06	0.01	0.01
ξ	4500	1000	8500	12	1200	10000	170	105	25	700	1000	50
z-value	0.06	0.32	0.13	0.02	0.03	0.03	0.03	0.23	0.11	0.01	0.02	0.34

Table S4: Measured and calculated properties for each flow (v, flow depth, Froude number, volume, density), best-fit model results (μ, ξ, z) and related total (S) and Coulomb and turbulent frictions

For each debris flow event, distinct μ- ξ pairs can be used to successfully model the flow properties such as flow velocity and flow depth. The best-fit solutions between model results and observations, characterized by the lowest z-values, are highlighted by the yellow bar. The values of these best-fit results are displayed in Table S5.

Event	v [m/s]	Flow Depth [m]	Froude Number	Volume (m^3)	Density (kg/m^3)	μ	ξ	z	Total Friction S [Pa]	Coulomb Friction [Pa]	Turbulent Friction [Pa]	Coulomb Friction [%]	Turbulent Friction [%]
21.06.19	6.6	3.1	1.19	97394	1870	0.01	500	0.07	2166	568	1598	26	74
21.06.19	6.6	3.1	1.19	97394	1870	0.02	550	0.10	2588	1135	1453	44	56
21.06.19	6.6	3.1	1.19	97394	1870	0.03	800	0.10	2702	1703	999	63	37
21.06.19	6.6	3.1	1.19	97394	1870	0.04	1000	0.11	3069	2270	799	74	26
21.06.19	6.6	3.1	1.19	97394	1870	0.05	1300	0.11	3452	2838	615	82	18
21.06.19	6.6	3.1	1.19	97394	1870	0.06	4500	0.06	3583	3405	178	95	5
02.07.19	3.9	1.8	0.93	73188	1971	0.01	200	0.37	1818	347	1470	19	81
02.07.19	3.9	1.8	0.93	73188	1971	0.02	250	0.37	1871	695	1176	37	63
02.07.19	3.9	1.8	0.93	73188	1971	0.03	300	0.37	2022	1042	980	52	48
02.07.19	3.9	1.8	0.93	73188	1971	0.04	350	0.36	2230	1389	840	62	38
02.07.19	3.9	1.8	0.93	73188	1971	0.05	600	0.35	2227	1737	490	78	22
02.07.19	3.9	1.8	0.93	73188	1971	0.06	1000	0.32	2378	2084	294	88	12
11.08.19	7	1.8	1.65	88064	2323	0.01	1000	0.16	1526	409	1117	27	73
11.08.19	7	1.8	1.65	88064	2323	0.02	1000	0.18	1935	819	1117	42	58
11.08.19	7	1.8	1.65	88064	2323	0.03	2500	0.21	1675	1228	447	73	27
11.08.19	7	1.8	1.65	88064	2323	0.04	2000	0.18	2196	1637	558	75	25
11.08.19	7	1.8	1.65	88064	2323	0.05	8000	0.14	2186	2047	140	94	6
11.08.19	7	1.8	1.65	88064	2323	0.06	8500	0.13	2588	2456	131	95	5
20.08.19	0.9	1.1	0.27	6137	2031	0.01	12	0.02	1564	219	1345	14	86
20.08.19	0.9	1.1	0.27	6137	2031	0.02	13	0.03	1679	437	1241	26	74
20.08.19	0.9	1.1	0.27	6137	2031	0.03	12	0.10	2001	656	1345	33	67
20.08.19	0.9	1.1	0.27	6137	2031	0.04	21	0.12	1643	875	769	53	47
20.08.19	0.9	1.1	0.27	6137	2031	0.05	20	0.17	1901	1094	807	58	42
20.08.19	0.9	1.1	0.27	6137	2031	0.06	30	0.25	1850	1312	538	71	29
24.06.21	8.2	2.4	1.69	105032	1750	0.01	1000	0.04	1566	411	1154	26	74
24.06.21	8.2	2.4	1.69	105032	1750	0.02	1200	0.03	1784	822	962	46	54
24.06.21	8.2	2.4	1.69	105032	1750	0.03	1500	0.08	2003	1234	770	62	38
24.06.21	8.2	2.4	1.69	105032	1750	0.04	3000	0.07	2030	1645	385	81	19
24.06.21	8.2	2.4	1.69	105032	1750	0.05	7000	0.03	2221	2056	165	93	7
24.06.21	8.2	2.4	1.69	105032	1750	0.06	14000	0.13	2550	2467	82	97	3
06.07.21	8.7	2.5	1.75	76906	1605	0.01	800	0.06	1883	393	1490	21	79
06.07.21	8.7	2.5	1.75	76906	1605	0.02	1500	0.06	1580	786	794	50	50
06.07.21	8.7	2.5	1.75	76906	1605	0.03	1750	0.08	1860	1179	681	63	37
06.07.21	8.7	2.5	1.75	76906	1605	0.04	3000	0.09	1969	1571	397	80	20
06.07.21	8.7	2.5	1.75	76906	1605	0.05	10000	0.03	2083	1964	119	94	6
06.07.21	8.7	2.5	1.75	76906	1605	0.06	25000	0.12	2405	2357	48	98	2
16.07.21	2.8	2.4	0.58	80879	1916	0.01	65	0.04	2717	450	2267	17	83
16.07.21	2.8	2.4	0.58	80879	1916	0.02	75	0.04	2865	900	1965	31	69
16.07.21	2.8	2.4	0.58	80879	1916	0.03	95	0.05	2902	1351	1551	47	53
16.07.21	2.8	2.4	0.58	80879	1916	0.04	125	0.07	2980	1801	1179	60	40
16.07.21	2.8	2.4	0.58	80879	1916	0.05	170	0.03	3118	2251	867	72	28
16.07.21	2.8	2.4	0.58	80879	1916	0.06	280	0.04	3227	2701	526	84	16

07.08.21	2.3	2.5	0.47	38737	1884	0.01	50	0.25	2417	461	1955	19	81
07.08.21	2.3	2.5	0.47	38737	1884	0.02	65	0.26	2426	922	1504	38	62
07.08.21	2.3	2.5	0.47	38737	1884	0.03	65	0.25	2888	1383	1504	48	52
07.08.21	2.3	2.5	0.47	38737	1884	0.04	105	0.23	2776	1845	931	66	34
07.08.21	2.3	2.5	0.47	38737	1884	0.05	150	0.25	2957	2306	652	78	22
07.08.21	2.3	2.5	0.47	38737	1884	0.06	230	0.27	3192	2767	425	87	13
19.09.21	1.3	1.1	0.38	8538	1697	0.01	25	0.11	1308	183	1125	14	86
19.09.21	1.3	1.1	0.38	8538	1697	0.02	30	0.12	1303	366	938	28	72
19.09.21	1.3	1.1	0.38	8538	1697	0.03	43	0.17	1203	548	654	46	54
19.09.21	1.3	1.1	0.38	8538	1697	0.04	50	0.18	1294	731	563	57	43
19.09.21	1.3	1.1	0.38	8538	1697	0.05	80	0.23	1265	914	352	72	28
19.09.21	1.3	1.1	0.38	8538	1697	0.06	160	0.20	1272	1097	176	86	14
05.06.22	3.4	2.1	0.75	39498	1690	0.01	130	0.06	1822	347	1474	19	81
05.06.22	3.4	2.1	0.75	39498	1690	0.02	160	0.05	1893	695	1198	37	63
05.06.22	3.4	2.1	0.75	39498	1690	0.03	210	0.05	1955	1042	913	53	47
05.06.22	3.4	2.1	0.75	39498	1690	0.04	260	0.04	2127	1390	737	65	35
05.06.22	3.4	2.1	0.75	39498	1690	0.05	400	0.03	2216	1737	479	78	22
05.06.22	3.4	2.1	0.75	39498	1690	0.06	700	0.01	2359	2085	274	88	12
04.07.22	8.2	2.5	1.66	175929	1189	0.01	1000	0.02	1075	291	784	27	73
04.07.22	8.2	2.5	1.66	175929	1189	0.02	1200	0.04	1236	582	654	47	53
04.07.22	8.2	2.5	1.66	175929	1189	0.03	1500	0.07	1396	873	523	63	37
04.07.22	8.2	2.5	1.66	175929	1189	0.04	2000	0.09	1556	1164	392	75	25
04.07.22	8.2	2.5	1.66	175929	1189	0.05	6000	0.04	1586	1455	131	92	8
04.07.22	8.2	2.5	1.66	175929	1189	0.06	20000	0.08	1785	1746	39	98	2
08.09.22	1.9	1.9	0.44	9283	1592	0.01	50	0.34	1424	296	1128	21	79
08.09.22	1.9	1.9	0.44	9283	1592	0.02	60	0.36	1532	592	940	39	61
08.09.22	1.9	1.9	0.44	9283	1592	0.03	80	0.37	1593	888	705	56	44
08.09.22	1.9	1.9	0.44	9283	1592	0.04	125	0.39	1636	1185	451	72	28
08.09.22	1.9	1.9	0.44	9283	1592	0.05	150	0.35	1857	1481	376	80	20
08.09.22	1.9	1.9	0.44	9283	1592	0.06	350	0.41	1938	1777	161	92	8

Table S5: Best-fit model results per event

Each debris flow event can be characterized by a distinct μ- ξ pair with a lowest z-value. See Table S2b for best-fit μ- ξ pairs per event.

Event	v [m/s]	Flow Depth [m]	Froude Number	Volume (m^3)	Density (kg/m^3)	μ	ξ	z	Total Friction [Pa]	Coulomb Friction [Pa]	Turbulent Friction [Pa]	Coulomb Friction [%]	Turbulent Friction [%]
21.06.19	6.6	3.1	1.19	97394	1870	0.06	4500	0.06	3583	3405	178	95	5
02.07.19	3.9	1.8	0.93	73188	1971	0.06	1000	0.32	2378	2084	294	88	12
11.08.19	7	1.8	1.65	88064	2323	0.06	8500	0.13	2588	2456	131	95	5
20.08.19	0.9	1.1	0.27	6137	2031	0.01	12	0.02	1564	219	1345	14	86
24.06.21	8.2	2.4	1.69	105032	1750	0.02	1200	0.03	1784	822	962	46	54
06.07.21	8.7	2.5	1.75	76906	1605	0.05	10000	0.03	2083	1964	119	94	6
16.07.21	2.8	2.4	0.58	80879	1916	0.05	170	0.03	3118	2251	867	72	28
07.08.21	2.3	2.5	0.47	38737	1884	0.04	105	0.23	2776	1845	931	66	34
19.09.21	1.3	1.1	0.38	8538	1697	0.01	25	0.11	1308	183	1125	14	86
05.06.22	3.4	2.1	0.75	39498	1690	0.06	700	0.01	2359	2085	274	88	12
04.07.22	8.2	2.5	1.66	175929	1189	0.01	1000	0.02	1075	291	784	27	73
08.09.22	1.9	1.9	0.44	9283	1592	0.01	50	0.34	1424	296	1128	21	79

Table S6: Grain size data

Table S6a: Weight percent passing per mesh size for each sample, and Table S6b complete overview of results from sieving (next pages).

Mesh size [mm]	21.06.2019	02.07.2019	26.07.2019	11.08.2019	20.08.2019	24.06.2021	06.07.2021	16.07.2021	07.08.2021	19.09.2021	04.10.2021	05.06.2022	04.07.2022	08.09.2022
16.0000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
8.0000	85.0	99.8	88.3	86.5	87.2	91.8	86.2	80.6	85.3	89.0	88.1	86.4	81.7	84.4
4.0000	73.7	97.5	78.6	76.3	76.5	83.6	75.1	69.5	74.8	79.9	79.7	78.2	70.5	74.5
2.0000	66.0	92.5	71.0	68.5	69.0	76.7	68.0	63.1	68.6	73.5	73.7	71.5	63.2	68.1
1.0000	59.0	85.6	63.8	61.1	62.1	69.9	61.1	58.6	63.2	67.7	68.5	64.5	56.8	61.8
0.5000	52.0	77.6	56.7	53.8	55.3	62.5	53.7	54.4	57.6	60.9	62.6	56.6	50.2	54.9
0.2500	44.8	68.6	48.6	50.1	47.8	53.7	46.7	49.0	50.7	52.4	56.1	48.8	43.2	47.5
0.1250	37.6	59.0	41.3	44.0	40.6	44.9	39.1	42.1	43.4	43.6	47.8	41.5	35.8	40.4
0.0630	31.7	49.1	34.4	36.3	34.1	37.0	32.0	35.4	35.9	35.7	39.8	34.0	29.4	33.0
0.0462	28.3	44.4	30.5	32.6	30.7	33.2	28.7	32.2	32.3	32.1	36.0	29.8	26.3	29.3
0.0339	24.8	39.6	26.1	28.3	27.0	28.9	24.5	28.0	27.7	27.0	30.5	25.7	22.8	25.8
0.0224	19.4	30.8	20.1	21.5	20.6	22.9	18.9	22.1	21.7	20.4	23.6	19.9	17.3	20.4
0.0135	13.0	21.3	13.3	14.0	14.4	15.2	13.0	15.1	14.4	13.4	15.8	13.2	12.0	13.0
0.0081	7.9	12.5	8.0	8.4	8.9	8.9	7.1	9.5	8.6	8.0	9.5	8.3	7.1	7.9
0.0050	5.1	7.8	5.3	5.4	5.7	5.7	4.5	5.8	5.0	5.0	5.9	5.4	4.8	5.3
0.0032	3.2	4.8	3.5	3.6	3.7	3.8	3.1	4.1	3.4	3.2	4.0	3.8	3.5	3.9
0.0015	1.3	2.5	1.8	1.6	2.1	2.4	1.9	2.2	1.5	1.8	2.8	2.3	1.9	2.3
0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Event	21.06.19			02.07.19			26.07.19			11.08.19			20.08.19		
	Sample mass [g]	1958.7			1772.4			2856.1			3299.7			3001.5		
Method	Mesh size [mm]	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm
dry sieving	125.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	63.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	31.5000	0.0	100.0	100.0	0.0	100.0	100.0	55.7	98.1	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	16.0000	365.0	81.4	100.0	0.0	100.0	100.0	158.9	92.5	100.0	472.6	85.7	100.0	327.9	89.1	100.0
	8.0000	239.7	69.1	85.0	3.4	99.8	99.8	308.3	81.7	88.3	380.6	74.1	86.5	341.7	77.7	87.2
	4.0000	180.2	59.9	73.7	40.5	97.5	97.5	258.1	72.7	78.6	288.3	65.4	76.3	287.4	68.1	76.5
	2.0000	122.5	53.7	66.0	88.3	92.5	92.5	199.3	65.7	71.0	220.4	58.7	68.5	198.8	61.5	69.0
	1.0000	110.5	48.0	59.0	123.6	85.6	85.6	189.9	59.0	63.8	211.7	52.3	61.1	184.7	55.3	62.1
	0.5000	111.4	42.3	52.0	142.0	77.6	77.6	187.3	52.5	56.7	206.6	46.1	53.8	182.5	49.3	55.3
wet sieving	0.2500		36.4	44.8		68.6	68.6		45.0	48.6		42.9	50.1		42.6	47.8
	0.1250		30.6	37.6		59.0	59.0		38.2	41.3		37.7	44.0		36.2	40.6
	0.0630		25.8	31.7		49.1	49.1		31.8	34.4		31.1	36.3		30.4	34.1
slurry test	0.0462		23.0	28.3		44.4	44.4		28.2	30.5		27.9	32.6		27.4	30.7
	0.0339		20.2	24.8		39.6	39.6		24.2	26.1		24.2	28.3		24.0	27.0
	0.0224		15.8	19.4		30.8	30.8		18.6	20.1		18.4	21.5		18.3	20.6
	0.0135		10.6	13.0		21.3	21.3		12.3	13.3		12.0	14.0		12.8	14.4
	0.0081		6.4	7.9		12.5	12.5		7.4	8.0		7.2	8.4		7.9	8.9
	0.0050		4.1	5.1		7.8	7.8		4.9	5.3		4.6	5.4		5.1	5.7
	0.0032		2.6	3.2		4.8	4.8		3.2	3.5		3.1	3.6		3.3	3.7
	0.0015		1.1	1.3		2.5	2.5		1.7	1.8		1.4	1.6		1.9	2.1
	0.0000		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0

	Event	24.06.21			06.07.21			16.07.21			07.08.21			19.09.21		
	Sample mass [g]	2652.5			3341.9			2511.2			2965.8			2553.6		
Method	Mesh size [mm]	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm
dry sieving	125.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	63.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	31.5000	0.0	100.0	100.0	296.0	83.3	100.0	434.0	84.8	100.0	602.3	81.7	100.0	212.2	92.9	100.0
	16.0000	102.7	94.8	100.0	290.2	66.9	100.0	615.7	63.2	100.0	795.1	57.7	100.0	405.6	79.4	100.0
	8.0000	152.8	87.0	91.8	163.4	57.7	86.2	349.9	51.0	80.6	279.6	49.2	85.3	261.1	70.7	89.0
	4.0000	151.6	79.2	83.6	131.8	50.3	75.1	200.7	44.0	69.5	199.4	43.1	74.8	217.9	63.5	79.9
	2.0000	127.9	72.7	76.7	84.7	45.5	68.0	116.3	39.9	63.1	119.0	39.5	68.6	151.8	58.4	73.5
	1.0000	125.9	66.3	69.9	81.8	40.9	61.1	80.2	37.1	58.6	102.7	36.4	63.2	139.3	53.8	67.7
	0.5000	138.8	59.2	62.5	87.4	35.9	53.7	76.7	34.4	54.4	106.6	33.2	57.6	162.5	48.3	60.9
wet sieving	0.2500		50.9	53.7		31.2	46.7		31.0	49.0		29.3	50.7		41.6	52.4
	0.1250		42.5	44.9		26.2	39.1		26.6	42.1		25.0	43.4		34.6	43.6
	0.0630		35.1	37.0		21.4	32.0		22.4	35.4		20.7	35.9		28.3	35.7
slurry test	0.0462		31.5	33.2		19.2	28.7		20.3	32.2		18.6	32.3		25.5	32.1
	0.0339		27.4	28.9		16.4	24.5		17.7	28.0		15.9	27.7		21.5	27.0
	0.0224		21.7	22.9		12.7	18.9		14.0	22.1		12.5	21.7		16.2	20.4
	0.0135		14.4	15.2		8.7	13.0		9.5	15.1		8.3	14.4		10.7	13.4
	0.0081		8.4	8.9		4.8	7.1		6.0	9.5		5.0	8.6		6.4	8.0
	0.0050		5.4	5.7		3.0	4.5		3.6	5.8		2.9	5.0		4.0	5.0
	0.0032		3.6	3.8		2.1	3.1		2.6	4.1		1.9	3.4		2.5	3.2
	0.0015		2.3	2.4		1.3	1.9		1.4	2.2		0.9	1.5		1.4	1.8
	0.0000		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0

	Event	04.10.21			05.06.22			04.07.22			08.09.22		
	Sample mass [g]	2788.3			2866.9			2677.2			3400.6		
Method	Mesh size [mm]	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm	Weight [g]	Weight % passing	Weight % passing max. 16 mm
dry sieving	125.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	63.0000	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0
	31.5000	147.8	92.5	100.0	116.2	93.4	100.0	315.5	89.0	100.0	167.8	94.9	100.0
	16.0000	284.9	77.9	100.0	312.6	75.8	100.0	553.6	69.6	100.0	527.1	78.9	100.0
	8.0000	180.9	68.7	88.1	182.8	65.5	86.4	364.6	56.8	81.7	406.8	66.6	84.4
	4.0000	128.7	62.1	79.7	109.5	59.3	78.2	221.3	49.1	70.5	256.4	58.8	74.5
	2.0000	92.4	57.4	73.7	90.7	54.2	71.5	145.4	44.0	63.2	168.7	53.7	68.1
	1.0000	78.2	53.4	68.5	93.5	48.9	64.5	126.4	39.5	56.8	162.7	48.8	61.8
	0.5000	89.8	48.8	62.6	106.9	42.9	56.6	132.2	34.9	50.2	181.1	43.3	54.9
wet sieving	0.2500		43.7	56.1		37.0	48.8		30.1	43.2		37.5	47.5
	0.1250		37.2	47.8		31.5	41.5		24.9	35.8		31.9	40.4
	0.0630		31.0	39.8		25.8	34.0		20.4	29.4		26.1	33.0
slurry test	0.0462		28.0	36.0		22.6	29.8		18.3	26.3		23.1	29.3
	0.0339		23.8	30.5		19.5	25.7		15.9	22.8		20.4	25.8
	0.0224		18.4	23.6		15.1	19.9		12.1	17.3		16.1	20.4
	0.0135		12.3	15.8		10.0	13.2		8.4	12.0		10.3	13.0
	0.0081		7.4	9.5		6.3	8.3		4.9	7.1		6.2	7.9
	0.0050		4.6	5.9		4.1	5.4		3.4	4.8		4.2	5.3
	0.0032		3.1	4.0		2.9	3.8		2.5	3.5		3.0	3.9
	0.0015		2.2	2.8		1.8	2.3		1.3	1.9		1.8	2.3
	0.0000		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0

Table S7: Results of powder x-ray diffraction analysis
Measured weight percent per mineral for all four analyzed samples.

	02.07.2019	26.07.2019	20.08.2019	16.07.2021
Albite	2.0	2.0	1.8	2.0
Calcite	10.6	7.4	10.2	17.9
Dolomite	24.4	16.7	23.7	19.4
Muscovite	17.7	22.2	19.6	18.2
Orthoclase	3.4	2.9	2.8	3.0
Quartz	29.9	36.0	29.2	30.9
Chlorite	0.3	0.1	0.2	0.0
Illite	11.3	12.1	11.7	8.4
Kaolinite	0.0	0.1	0.1	0.0
Smektite	0.2	0.6	0.7	0.3