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Reconstructing hail days in Switzerland with statistical models (1959–2022)

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Table S1. Summary of convective parameters and meteorological variables tested for model building: T and Td are temperature and dew point temperature, θ_e is equivalent potential temperature, z is the geopotential height (gpdam). The subscript indicates a certain constant pressure level; an arrow indicates lifting of an air parcel (e.g., T′x⟶y is the temperature T of a parcel at the y-level, which was initially lifted dry adiabatically from the x-level to its condensation level and moist adiabatically thereafter)

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Variable	Explanation	Unit
BI	Boyden Index $= 0.1\,(z_{700} - z_{1000}) - T_{700} - 200$	Dimensionless
BLH	Boundary layer height	m
BRN	Bulk Richardson Number $= \frac{CAPE}{0.5\left(WS\_06^2\right)}$	Dimensionless
CAPE	Most unstable convective available potential energy	J kg^{-1}
CIN	Convective inhibition	Jkg^{-1}
CT	Cross Total $= Td_{850} - T_{500}$	K
DCI	Deep Convective Index $= T_{850} - Td_{850} - LI$	K
EL_height	Height of equilibrium level	km
EL_press	Pressure of equilibrium level	hPa
EL_temp	Temperature of equilibrium level	°C
WSPD_250	Windspeed at 250 hPa	ms^{-1}
WSPD_500	Windspeed at 500 hPa	ms^{-1}
WSPD_700	Windspeed at 700 hPa	ms^{-1}
WSPD_850	Windspeed at 850 hPa	ms^{-1}
HI	Humidity Index $= (T_{850} - Td_{850}) + (T_{700} - Td_{700}) + (T_{500} - Td_{500})$	K
KO	KO Index $= 0.5\,(\theta_{e500} + \theta_{e700}) - 0.5\,(\theta_{e850} + \theta_{e1000})$	K
KI	K Index $= T_{850} + Td_{850} - T_{500} - (T_{700} - Td_{700})$	K
LCL_height	Height of lifted condensation level	km
LCL_press	Pressure of lifted condensation level	hPa
LCL_temp	Temperature of lifted condensation level	K
LFC_height	Height of level of free convection	km
LFC_press	Pressure of level of free convection	hPa
LFC_temp	Temperature of level of free convection	°C
MSLP	Mean sea level pressure	Pa
omega_vint	Vertically integrated vertical velocity (model levels 1–137)	Pas^{-1}
omega_vint_18	Vertically integrated vertical velocity at 18 UTC (model levels 1–137)	Pas^{-1}
pev	Potential evaporation	m
PII	Potential Instability Index $= \frac{\theta_{e925} - \theta_{e500}}{z_{500} - z_{950}}$	Dimensionless
q_500	Specific humidity at 500 hPa	kgkg^{-1}
q_850	Specific humidity at 850 hPa	kgkg^{-1}
q_vint	Vertically integrated specific humidity (model levels 1–137)	kgkg^{-1}
q_vint_18	Vertically integrated specific humidity at 18 UTC (model levels 1–137)	kgkg^{-1}
rh_850	Relative Humidity at 850 hPa	%
rh_mid	Mean of relative humidity at 500, 700, and 850 hPa	%
SHOW	Showalter Index $= T_{500} - T'_{850 \to 500}$	K
LI	Surface Based Lifted Index $= T_{500} - T'_{Surface \to 500}$	K
SP	Mean surface pressure	hPa
SWISS00	Stability and Wind Shear Index for thunderstorms in Switzerland $= SHOW + 0.4\,(WS\_36) + 0.1\,(T_{600} - Td_{600})$	Dimensionless
SWISS12	Stability and Wind Shear Index for thunderstorms in Switzerland $= LI - 0.1\,(WS\_03) + 0.1\,(T_{650} - Td_{650})$	Dimensionless
SWP	Severe Weather Parameter $= CAPE \cdot WS\_06$	Dimensionless

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Variable	Explanation	Unit
T_500	Temperature at 500 hPa	K
T_700	Temperature at 700 hPa	K
T_700_500	Lapse rate between 700 and 500 hPa	K
T_850	Temperature at 850 hPa	K
T_850_700	Lapse rate between 650 and 700 hPa	K
T_2m	Temperature at 2 meters	K
tcw	Total column water from ERA5 single level	kgm^{-2}
Td_500	Dewpoint temperature at 500 hPa	K
Td_850	Dewpoint temperature at 850 hPa	K
Td_2m	Temperature at 2 meters	K
thetae_2m	Equivalent potential temperature at 2 meters	K
thetae_500	Equivalent potential temperature at 500 hPa	K
thetae_500_850	Difference between equivalent potential temperature at 850 hPa and 500 hPa	K
thetae_700	Equivalent potential temperature at 700 hPa	K
thetae_850	Equivalent potential temperature at 850 hPa	K
totalx	Total Totals Index $= VT + CT$	K
u_500	Zonal wind component at 500 hPa	ms^{-1}
u_850	Zonal wind component at 850 hPa	ms^{-1}
u_10	Zonal wind component at 10 hPa	ms^{-1}
u_100	Zonal wind component at 100 hPa	ms^{-1}
v_500	Meridional wind component at 850 hPa	ms^{-1}
v_850	Meridional wind component at 850 hPa	ms^{-1}
v_10	Zonal wind component at 10 hPa	ms^{-1}
v_100	Meridional wind component at 100 hPa	ms^{-1}
vor_500	Vorticity (relative) at 500 hPa	$1\mathrm{s}^{-1}$
VT	Vertical Total $= T_{850} - T_{500}$	K
w_500	Vertical velocity at 500 hPa	Pas^{-1}
w_700	Vertical velocity at 700 hPa	Pas^{-1}
WS_03	Wind shear between 0 km and 3 km	ms^{-1}
WS_06	Wind shear between 0 km and 6 km	ms^{-1}
WS_36	Wind shear between 3 km and 6 km	ms^{-1}
z_500	Geopotential height at 500 hPa	gpdam
z_0°C	Height of zero degree isotherm	m

End of table

Table S2. Mean values, 90^{th} and 10^{th} percentiles of tested model variables of region north and region south separately for the period 1959 to 2022. Mean is the 90^{th} percentile mean.

Variable	Unit	Mean North	90^{th} North	10^{th} North	Mean South	90^{th} South	10^{th} South
BI	Dimensionless	89.61	91.07	87.80	90.00	91.16	88.62
BLH	m	1126.11	1463.56	760.87	1133.79	1535.30	718.09
BRN	Dimensionless	0.42	3.56	0.00	0.69	6.00	0.00
CAPE	Jkg^{-1}	15.91	93.54	0.11	26.87	184.18	0.15
CIN	Jkg^{-1}	117.67	464.81	1.00	135.36	425.25	5.82
CT	K	20.09	23.48	15.28	19.73	23.13	15.33
DCI	K	10.77	24.41	-5.61	11.30	23.86	-4.47
EL_height	km	4.97	8.93	2.18	6.47	9.51	3.38
EL_press	hPa	556.32	777.36	310.24	452.66	667.73	284.47
EL_temp	°C	-15.90	0.08	-40.18	-24.20	-3.98	-43.55
WSPD_250	ms^{-1}	21.11	37.53	8.71	20.33	36.78	7.91
WSPD_500	ms^{-1}	12.56	22.59	5.04	11.42	21.01	4.39
WSPD_700	ms^{-1}	7.61	13.60	3.13	5.26	9.70	2.33
WSPD_850	ms^{-1}	4.98	8.93	2.21	1.92	3.83	0.86
HI	K	26.36	45.83	11.18	47.50	66.37	30.45
KO	K	-0.14	5.99	-6.57	-0.48	4.86	-5.97
KI	K	14.48	25.42	-2.26	16.09	24.10	3.31
LCL_height	km	1.79	2.34	1.33	2.02	2.56	1.54
LCL_press	hPa	816.29	863.71	762.02	793.13	841.12	741.10
LCL_temp	K	278.19	283.30	271.50	277.68	283.16	269.93
LFC_height	km	2.39	4.01	1.49	2.89	4.30	1.93
LFC_press	hPa	758.74	846.97	615.35	712.69	801.57	592.34
LFC_temp	°C	2.09	6.60	-4.99	1.46	6.59	-6.80
Tmin_2m	K	289.53	296.23	282.27	289.26	295.37	281.74
MSLP	Pa	1016.68	1022.49	1009.82	1015.77	1021.37	1009.04
omega_vint	Pas^{-1}	-84.87	609.52	-1128.85	-165.39	735.05	-1358.83
omega_vint_18	Pas^{-1}	-206.32	614.20	-1406.01	-55.74	811.37	-1244.75
pev	m	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
PII	Dimensionless	-0.00	0.02	-0.02	0.00	0.00	-0.00
q_500	$kgkg^{-1}$	0.90	1.65	0.37	0.93	1.68	0.38
q_850	$kgkg^{-1}$	6.40	8.83	4.00	6.72	9.29	3.98
q_vint	$kgkg^{-1}$	17.44	25.08	10.10	17.17	24.12	9.80
q_vint_18	$kgkg^{-1}$	18.16	26.15	10.65	17.87	24.99	10.20
rh_850	%	71.46	87.20	49.0	63.54	80.40	45.5
rh_mid	%	56.20	76.54	35.97	55.17	74.84	38.84
SHOW	K	0.58	4.88	-3.30	0.06	4.33	-3.49
LI	K	0.15	4.85	-3.85	-0.21	4.37	-3.92
SP	Pa	932.52	937.90	925.57	897.94	903.47	890.87
SWISS00	Dimensionless	7.22	12.77	2.59	8.16	13.29	3.71
SWISS12	Dimensionless	2.87	8.11	-1.38	4.54	8.88	0.56
SWP	Dimensionless	173.59	1039.63	0.87	268.29	1923.29	1.34

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Variable	Unit	Mean North	90^{th} North	10^{th} North	Mean South	90^{th} South	10^{th} South
T_500	K	257.29	262.21	250.21	257.72	262.61	250.70
T_700	K	273.15	278.60	266.42	273.86	279.04	267.35
T_700_500	K	16.02	18.00	13.82	16.31	18.17	14.30
T_850	K	282.58	289.03	275.48	284.61	289.93	277.80
T_850_700	K	9.65	11.60	7.32	10.85	12.33	9.08
T_2m	K	290.58	297.51	282.98	290.21	296.27	282.46
tcw	kgm^{-12}	17.58	25.29	10.22	17.28	24.24	9.90
Td_500	K	245.07	253.18	235.95	245.52	253.33	236.48
Td_850	K	277.00	282.07	270.35	277.27	282.59	270.04
Td_2m	K	282.67	287.62	276.06	281.93	286.99	274.79
thetae_2m	K	320.92	336.23	304.66	324.27	339.02	307.27
thetae_500	K	316.85	324.03	306.88	317.42	324.50	307.48
thetae_500_850	K	2.30	9.78	-5.24	0.24	7.16	-6.76
thetae_700	K	312.03	321.56	300.80	314.74	324.10	302.90
thetae_850	K	314.32	327.28	300.38	316.99	329.58	302.67
totalx	K	42.41	47.96	34.03	43.37	47.78	37.07
u_500	ms^{-1}	7.33	18.81	-3.58	6.82	17.50	-3.55
u_850	ms^{-1}	1.53	6.40	-2.80	0.14	1.42	-1.46
u_10	ms^{-1}	0.73	2.71	-1.25	-0.03	0.74	-0.82
u_100	ms^{-1}	1.01	3.89	-1.76	0.00	1.05	-1.11
v_500	ms^{-1}	0.30	11.44	-10.98	-0.31	10.22	-10.56
v_850	ms^{-1}	0.14	4.30	-3.73	0.76	2.71	-1.45
v_10	ms^{-1}	-0.36	1.60	-2.34	0.61	1.39	-0.52
v_100	ms^{-1}	-0.46	2.31	-3.23	0.80	1.94	-0.83
vor_500	$1s^{-1}$	-0.00	0.00	-0.00	0.00	0.00	-0.00
VT	K	25.59	29.06	21.85	27.09	29.73	24.26
w_500	Pas^{-1}	-0.02	0.12	-0.22	-0.01	0.15	-0.24
w_700	Pas^{-1}	-0.01	0.13	-0.21	-0.04	0.16	-0.31
WS_03	ms^{-1}	5.92	11.39	2.02	4.76	8.64	1.95
WS_06	ms^{-1}	11.09	20.73	3.85	11.21	20.72	3.99
WS_36	ms^{-1}	6.11	11.66	2.14	7.09	13.63	2.41
z_500	gpdam	559.54	571.90	543.02	560.48	572.61	544.09
z_0°C	m	2433.65	3426.54	1137.65	2256.94	3161.47	1133.94

End of table

Table S3. Correlation of all variables to the hail-day time series of both regions. The correlation was only calculated for the period where we have information on hail days, so for years 2002–2022. *r* is the Pearson correlation and *p*-value is the respective *p*-value, whereby zero means an extremely small number (smaller than can be calculated by R´s package Hmisc::rcorr).

Variable	r North	p-value North	r South	p-value South
BI	0.03	0.05	-0.00	0.87
BLH	0.06	0.00	-0.04	0.01
BRN	0.08	2.24×10^{-6}	0.11	3.16×10^{-12}
CAPE	0.49	0.00	0.45	0.00
CIN	0.40	0.00	0.06	0.01
CT	0.22	0.00	0.29	0.00
DCI	0.44	0.00	0.36	0.00
EL_height	0.56	0.00	0.39	0.00
EL_press	-0.53	0.00	-0.38	0.00
EL_temp	-0.56	0.00	-0.39	0.00
WSPD_250	-0.13	2.22×10^{-16}	-0.06	0.00
WSPD_500	-0.09	6.98×10^{-8}	-0.00	0.86
WSPD_700	0.01	0.60	0.03	0.04
WSPD_850	-0.07	1.08×10^{-5}	-0.07	5.97×10^{-6}
HI	-0.07	4.65×10^{-5}	-0.06	9.42×10^{-5}
KO	-0.49	0.00	-0.42	0.00
KI	0.39	0.00	0.33	0.00
LCL_height	0.12	1.31×10^{-13}	-0.11	1.35×10^{-11}
LCL_press	-0.12	4.48×10^{-13}	0.10	3.35×10^{-10}
LCL_temp	0.34	0.00	0.33	0.00
LFC_height	0.18	0.00	-0.02	0.35
LFC_press	-0.20	0.00	0.00	0.86
LFC_temp	0.15	0.00	0.23	0.00
Tmin_2m	0.40	0.00	0.26	0.00
MSLP	-0.13	4.44×10^{-16}	-0.09	2.06×10^{-8}
omega_vint	-0.19	0.00	-0.26	0.00
omega_vint_18	-0.31	0.00	-0.26	0.00
pev	-0.29	0.00	-0.10	1.36×10^{-9}
PII	0.52	0.00	-0.42	0.00
q_500	0.26	0.00	0.20	0.00
q_850	0.42	0.00	0.33	0.00
q_vint_12	0.40	0.00	0.33	0.00
q_vint_18	0.44	0.00	0.32	0.00
rh_850	-0.06	0.00	0.03	0.07
rh_mid	0.01	0.70	0.03	0.06
SHOW	-0.46	0.00	-0.40	0.00
LI	-0.47	0.00	-0.41	0.00
SP	-0.06	0.00	-0.02	0.14
SWISS00	-0.38	0.00	-0.27	0.00
SWISS12	-0.37	0.00	-0.30	0.00
SWP	0.43	0.00	0.41	0.00

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Variable	r North	p-value North	r South	p-value South
T_500	0.20	0.00	0.17	0.00
T_700	0.31	0.00	0.26	0.00
T_700_500	0.30	0.00	0.25	0.00
T_850	0.41	0.00	0.28	0.00
T_850_700	0.39	0.00	0.11	7.93×10^{-12}
T_2m	0.38	0.00	0.25	0.00
tcw	0.39	0.00	0.33	0.00
Td_500	0.22	0.00	0.19	0.00
Td_850	0.36	0.00	0.33	0.00
Td_2m	0.39	0.00	0.34	0.00
thetae_2m	0.45	0.00	0.35	0.00
thetae_500	0.23	0.00	0.19	0.00
thetae_500_850	-0.51	0.00	-0.42	0.00
thetae_700	0.39	0.00	0.30	0.00
thetae_850	0.44	0.00	0.35	0.00
totalx	0.35	0.00	0.30	0.00
u_500	0.04	0.01	0.12	1.78×10^{-14}
u_850	0.01	0.47	0.08	1.33×10^{-7}
u_10	-0.02	0.34	0.05	0.00
u_100	-0.02	0.28	0.05	0.00
v_500	0.29	0.00	0.22	0.00
v_850	0.23	0.00	0.16	0.00
v_10	0.17	0.00	0.10	3.40×10^{-10}
v_100	0.17	0.00	0.10	2.10×10^{-10}
vor_500	-0.13	2.00×10^{-15}	0.04	0.01
VT	0.42	0.00	0.24	0.00
w_500	-0.16	0.00	-0.20	0.00
w_700	-0.13	1.33×10^{-15}	-0.21	0.00
WS_03	0.14	0.00	0.07	3.41×10^{-5}
WS_06	0.00	0.76	0.01	0.55
WS_36	-0.15	0.00	-0.04	0.02
z_500	0.19	0.00	0.14	0.00
z_0°C	0.28	0.00	0.23	0.00

End of table

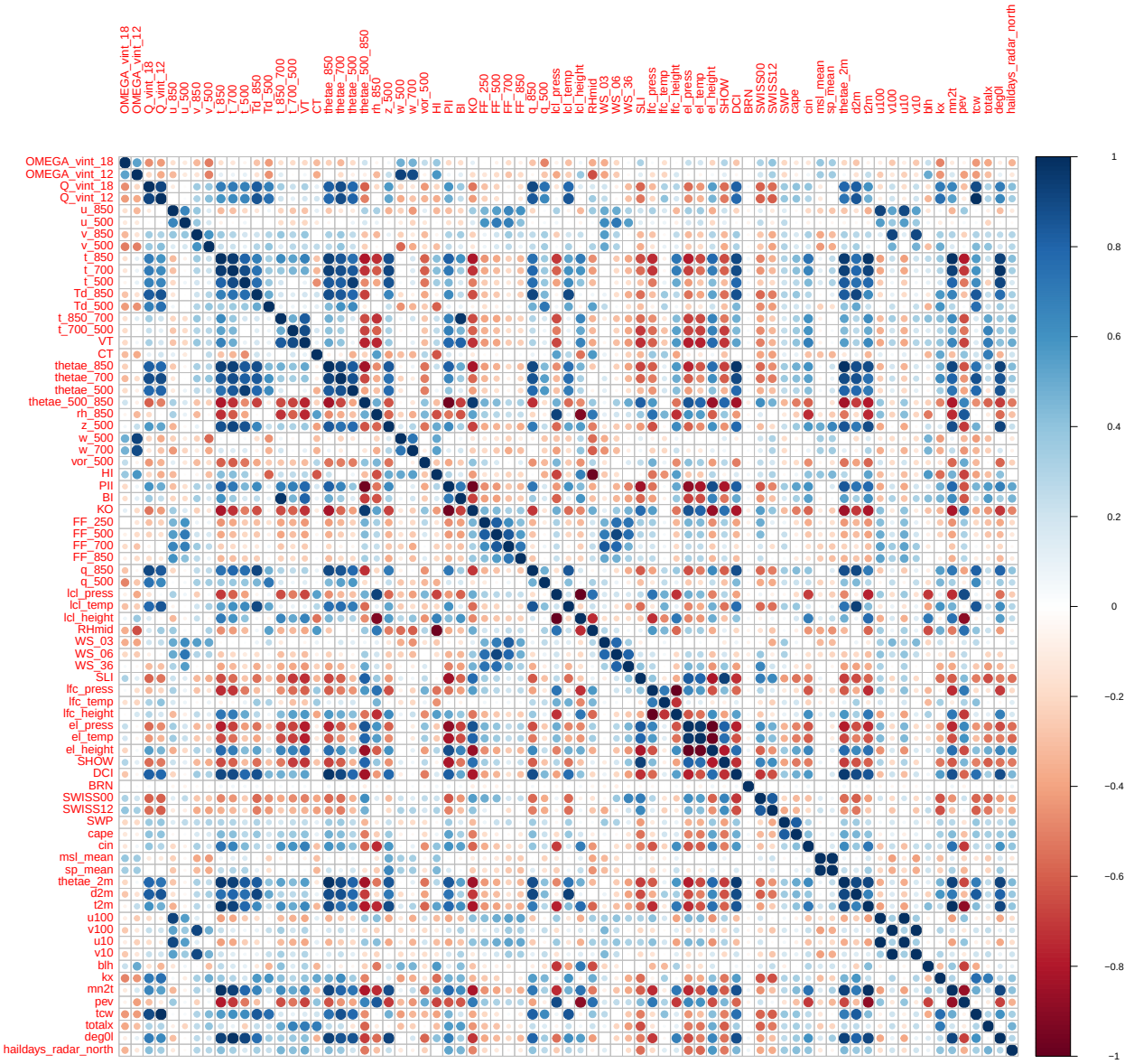

Figure S1. Correlation matrix of all tested model variables and the hail-day time series for region north (period 2002–2022).

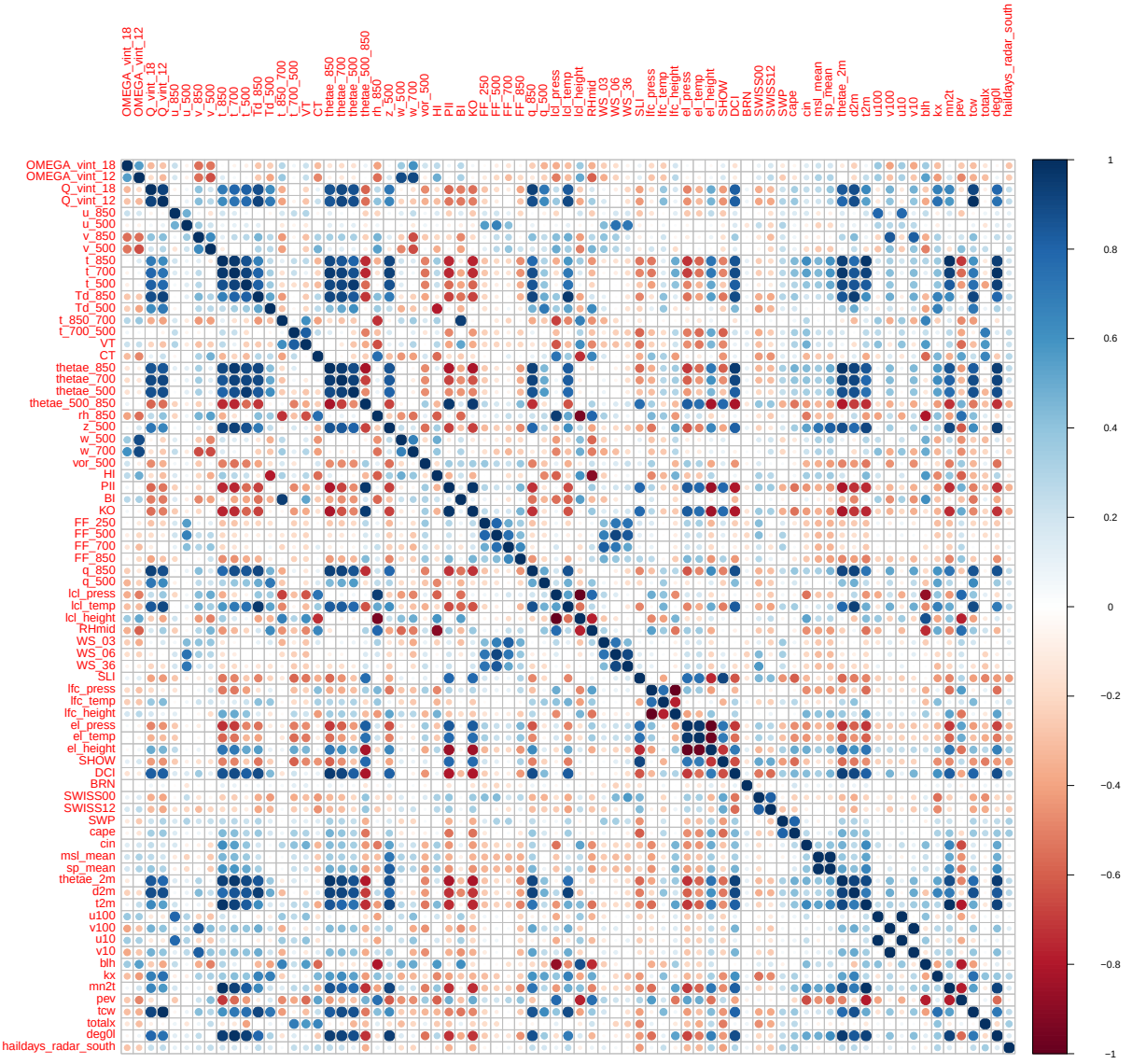

Figure S2. Correlation matrix of all tested model variables and the hail-day time series for region south (period 2002–2022).