Evaluating the robustness of snow climate indicators using a unique set of parallel snow measurement series

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Analysis of parallel snow measurements – what could possibly go wrong?

MeteoSwiss

Topics

- What and why – the bigger picture
- Unique parallel data set
- Snow climate indicators
- Results
- Conclusion
- Outlook

Project Hom4Snow

Improve length and quality of snow data series

How does homogenization of snow measurements impact snow climatology in the Alps?

Inhomogeneities are
- omnipresent
- problematic

- What are the effects of inhomogeneities?

- How to deal with inhomogeneities?

Collaboration with University of Graz, Austria -> **Gernot**

Main partner: **MeteoSwiss**

Funded by the Swiss National Science Foundation

Context

Snow: Complex interplay of temperature and precipitation

New snow ~ f(wind, …)

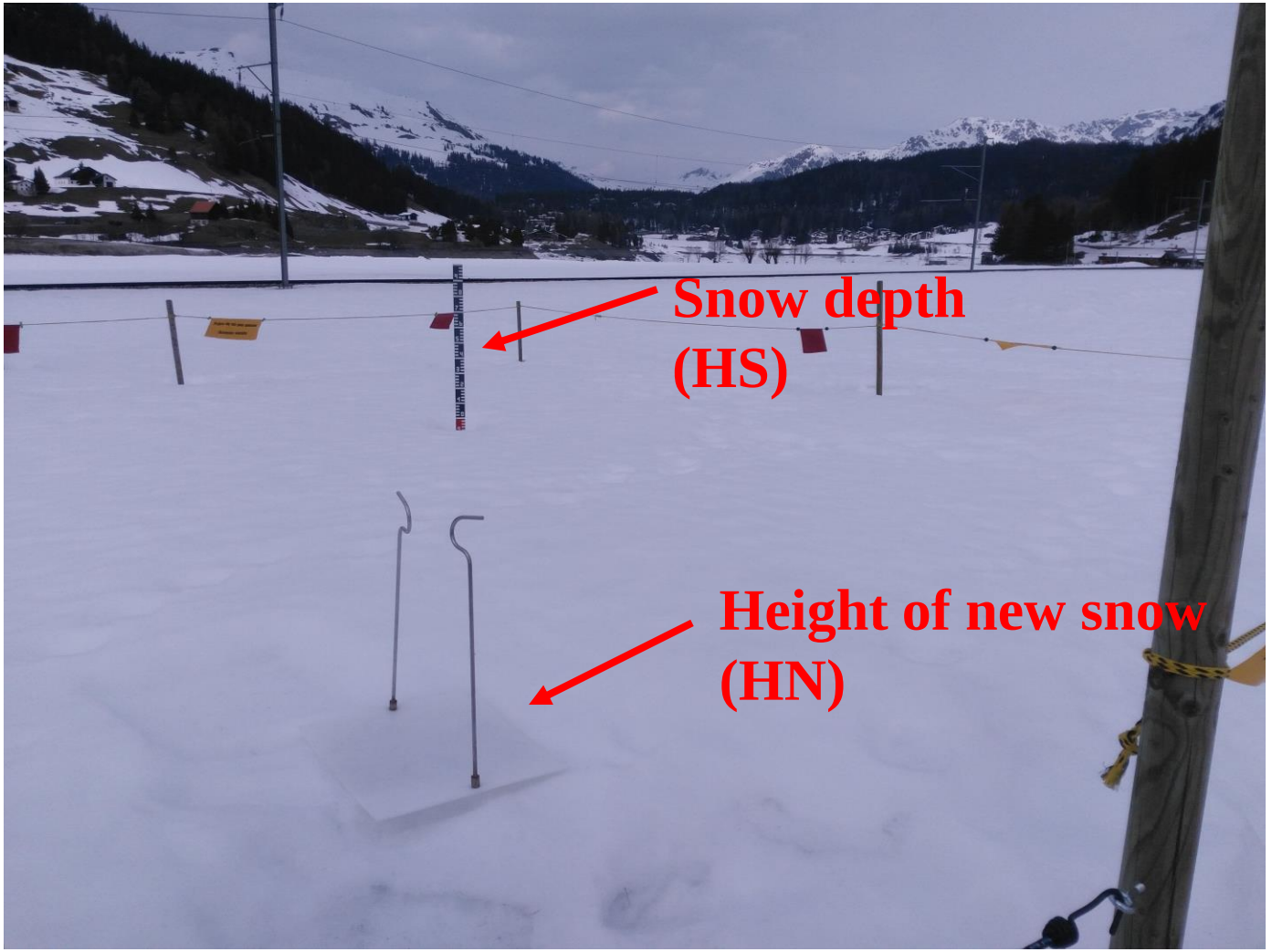
Snow depth ~ f(new snow, aspect, irradiance, ...)

Derived snow climate indicators

Which ones are most robust towards station relocations?

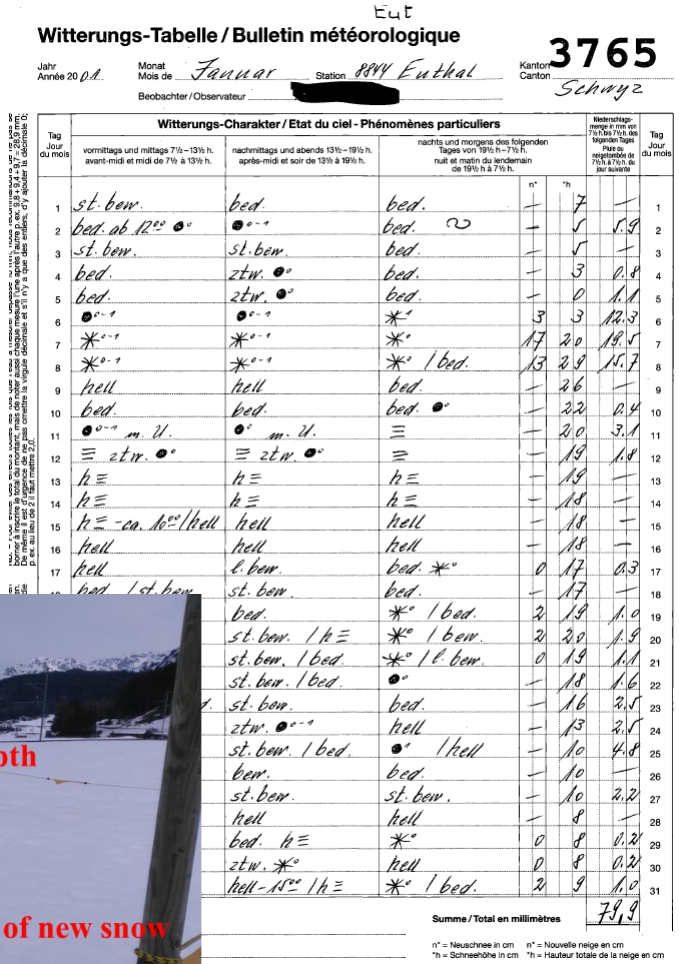
Sensitivity analysis

Single station – manual measurements



Data

- Observer network, manual measurements, daily resolution
- MeteoSwiss and SLF



Witterungs-Tabelle / Bulletin météorologique

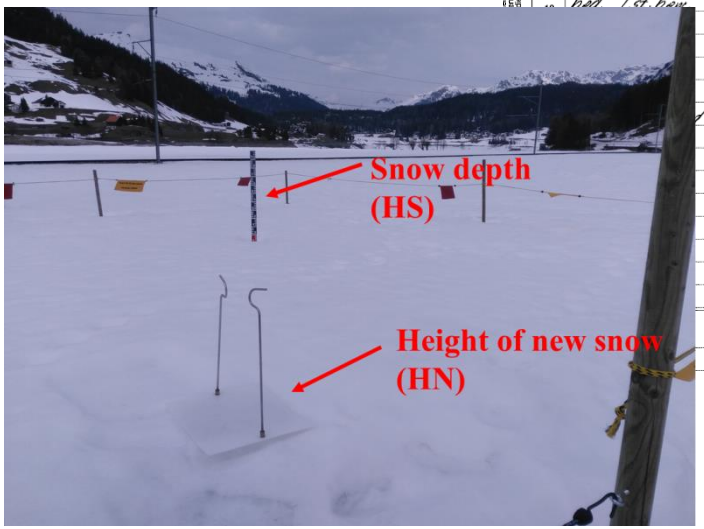
Jahr / Année 2001 — Monat / Mois de Januar — Station 8894 Euthal — Kanton / Canton Schwyz — 3765

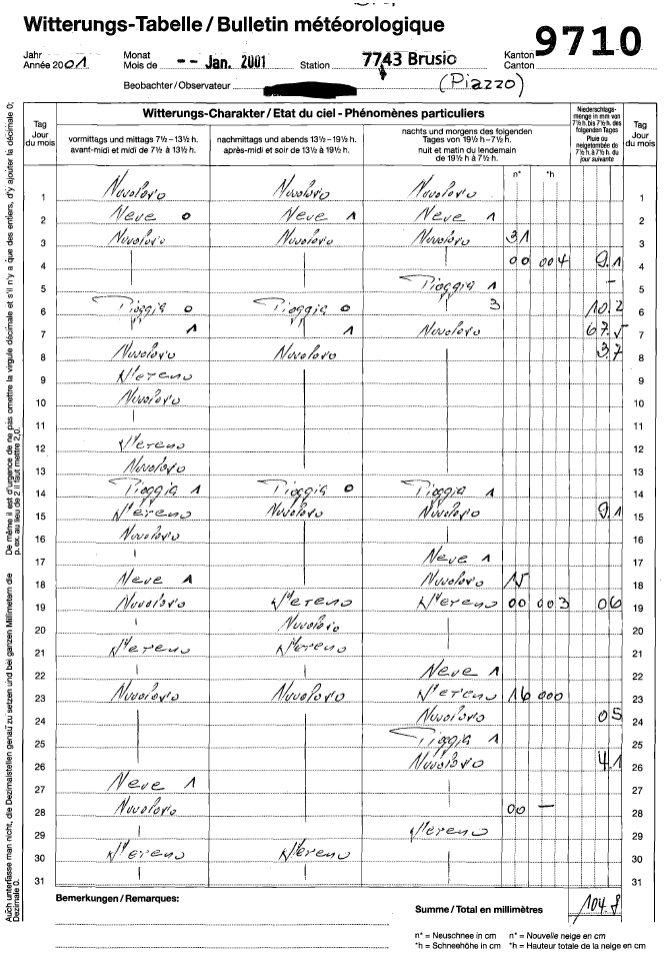
Beobachter / Observateur [redacted]

Tag / Jour du mois	Witterungs-Charakter / Etat du ciel - Phénomènes particuliers: vormittags und mittags 7½ – 13½ h. avant-midi et midi de 7½ à 13½ h.	nachmittags und abends 13½ – 19½ h. après-midi et soir de 13½ à 19½ h.	nachts und morgens des folgenden Tages von 19½ h – 7½ h. nuit et matin du lendemain de 19½ h à 7½ h.	n°	*h	Niederschlagsmenge in mm von 7½ h bis 7½ h. des folgenden Tages. Pluie du précédent de 7½ h à 7½ h. du jour suivant	Tag / Jour du mois
1	st. bew.	bed.	bed.	—	7	—	1
2	bed. ab 12°° ●°	●°⁻¹	bed. ∽	—	5	5.9	2
3	st. bew.	st. bew.	bed.	—	5	—	3
4	bed.	ztw. ●°	bed.	—	3	0.8	4
5	bed.	ztw. ●°	bed.	—	0	1.1	5
6	●°⁻¹	●°⁻¹	✳¹	3	3	12.3	6
7	✳°⁻¹	✳°⁻¹	✳°	17	20	19.5	7
8	✳°⁻¹	✳°⁻¹	✳° / bed.	13	28	11.7	8
9	hell	hell	bed.	—	26	—	9
10	bed.	bed.	bed. ●°	—	22	0.4	10
11	●°⁻¹ m. U.	●° m. U.	≡	—	20	3.1	11
12	≡ ztw. ●°	≡ ztw. ●°	≡	—	19	1.8	12
13	h≡	h≡	h≡	—	19	—	13
14	h≡	h≡	h≡	—	18	—	14
15	h≡ -ca. 16°°/hell	hell	hell	—	18	—	15
16	hell	hell	hell	—	18	—	16
17	hell	l. bew.	bed. ✳°	0	17	0.3	17
18	bed. / st. bew.	st. bew.	bed.	—	17	—	18
19	bed.	bed.	✳° / bed.	2	19	1.0	19
20	st. bew. / h≡	✳° / bew.	✳° / bew.	2	20	1.9	20
21	st. bew. / bed.	✳° / l. bew.	✳° / l. bew.	0	19	1.1	21
22	st. bew. / bed.	●°	—	—	18	1.6	22
23	st. bew.	bed.	—	—	16	2.5	23
24	ztw. ●°⁻¹	hell	—	—	13	2.1	24
25	st. bew. / bed.	●° / hell	—	—	10	4.8	25
26	bew.	bed.	—	—	10	—	26
27	st. bew.	st. bew.	—	—	10	2.2	27
28	hell	hell	—	—	8	—	28
29	bed. h≡	✳°	0	8	0.2	29
30	ztw. ✳°	hell	0	8	0.2	30
31	hell -15°° / h≡	✳° / bed.	2	9	1.0	31

Summe / Total en millimètres: 79.9

n° = Neuschnee in cm n° = Nouvelle neige en cm
*h = Schneehöhe in cm *h = Hauteur totale de la neige en cm





Witterungs-Tabelle / Bulletin météorologique

Jahr / Année 2001 — Monat / Mois de -- Jan. 2001 — Station 7743 Brusio (Piazzo) — Kanton / Canton 9710

Beobachter / Observateur [redacted]

Tag / Jour du mois	Witterungs-Charakter / Etat du ciel - Phénomènes particuliers: vormittags und mittags 7½ – 13½ h. avant-midi et midi de 7½ à 13½ h.	nachmittags und abends 13½ – 19½ h. après-midi et soir de 13½ à 19½ h.	nachts und morgens des folgenden Tages von 19½ h – 7½ h. nuit et matin du lendemain de 19½ h à 7½ h.	n°	*h	Niederschlagsmenge in mm von 7½ h bis 7½ h. des folgenden Tages. Pluie du précédent de 7½ h à 7½ h. du jour suivant	Tag / Jour du mois
1	Nuvolaro	Nuvolaro	Nuvolaro				1
2	Neve ∩	Neve ∧	Neve ∧				2
3	Nuvolaro	Nuvolaro	Nuvolaro	3	1		3
4				00	004	9.1	4
5			Piaggia ∧			—	5
6	Piaggia ∩	Piaggia ∩	3			10.2	6
7	∧	∧	Nuvolaro			6.7	7
8	Nuvolaro	Nuvolaro				3.7	8
9	Vereno						9
10	Nuvolaro						10
11							11
12	Vereno						12
13	Nuvolaro						13
14	Piaggia ∧	Piaggia ∩	Piaggia ∧				14
15	Vereno	Nuvolaro	Nuvolaro			9.1	15
16	Nuvolaro						16
17			Neve ∧				17
18	Neve ∧		Nuvolaro	N			18
19	Nuvolaro	Vereno	Vereno	00	003	0.6	19
20		Nuvolaro					20
21	Vereno	Vereno					21
22			Neve ∧				22
23	Nuvolaro	Nuvolaro	Vereno	16	000		23
24			Nuvolaro			0.5	24
25			Piaggia ∧				25
26			Nuvolaro			4.1	26
27	Neve ∧						27
28	Nuvolaro			00	—		28
29			Vereno				29
30	Vereno	Vereno					30
31							31

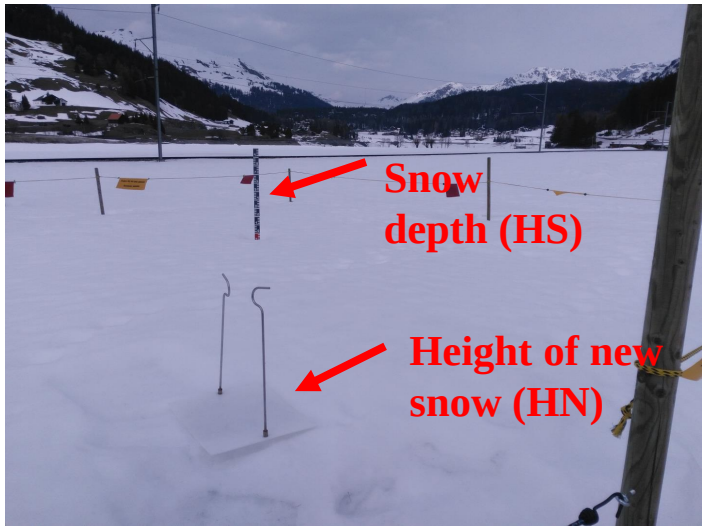
Bemerkungen / Remarques:

Summe / Total en millimètres: 104.8

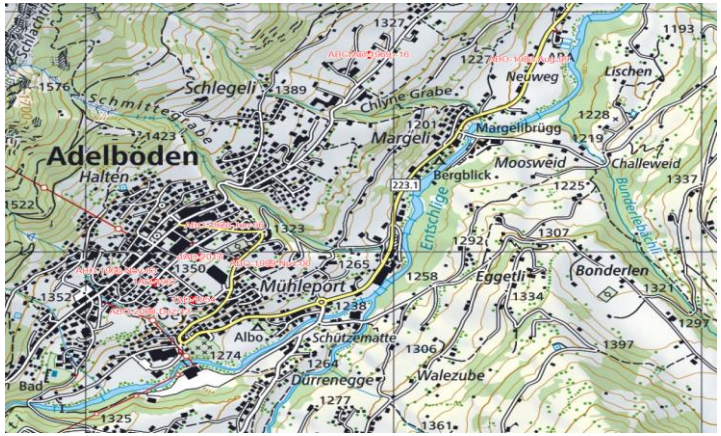
n° = Neuschnee in cm n° = Nouvelle neige en cm
*h = Schneehöhe in cm *h = Hauteur totale de la neige en cm

Introduction and data

Individual station
- available variables (HS, HN)
- available data (hyears)
- manually measured every day (Nov-Apr)
- location
- network (MeteoSwiss or SLF)



Station pair
- close proximity (< 2 km, <100m)
- parallel years > 25 years
- available variables



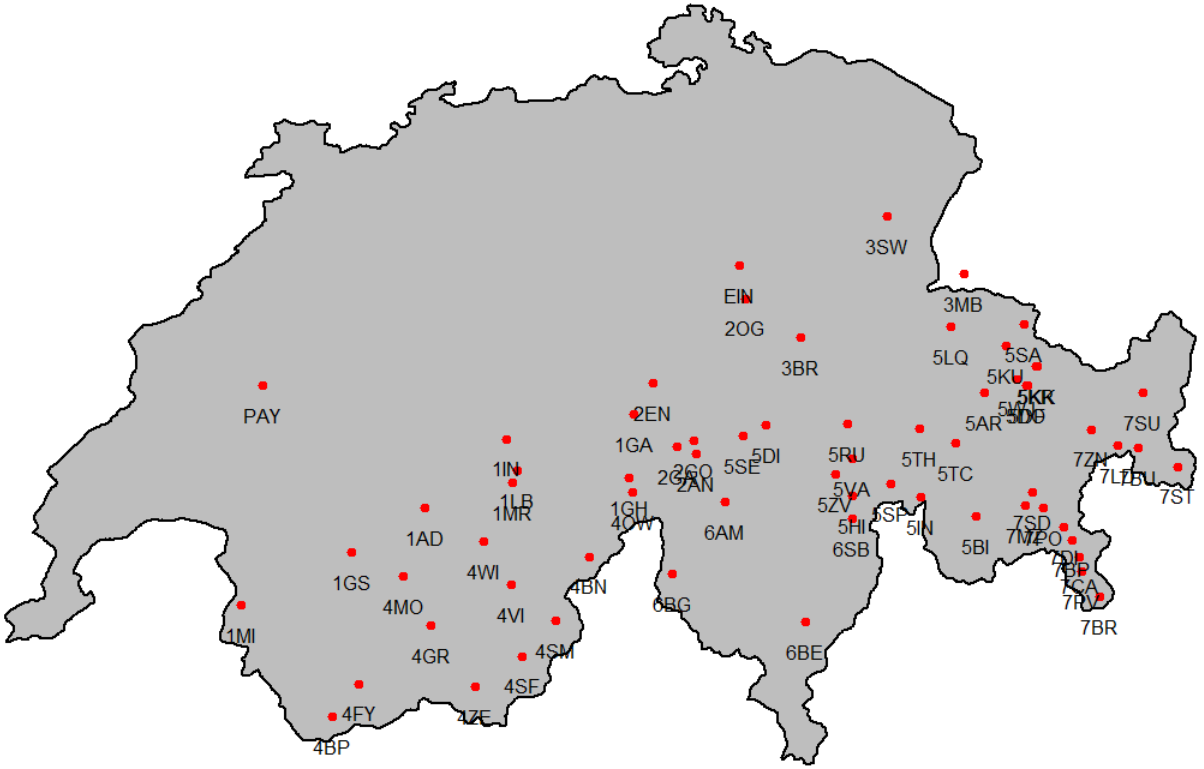
From the many to the few

The evolution of the data set based on QC and other conditions:

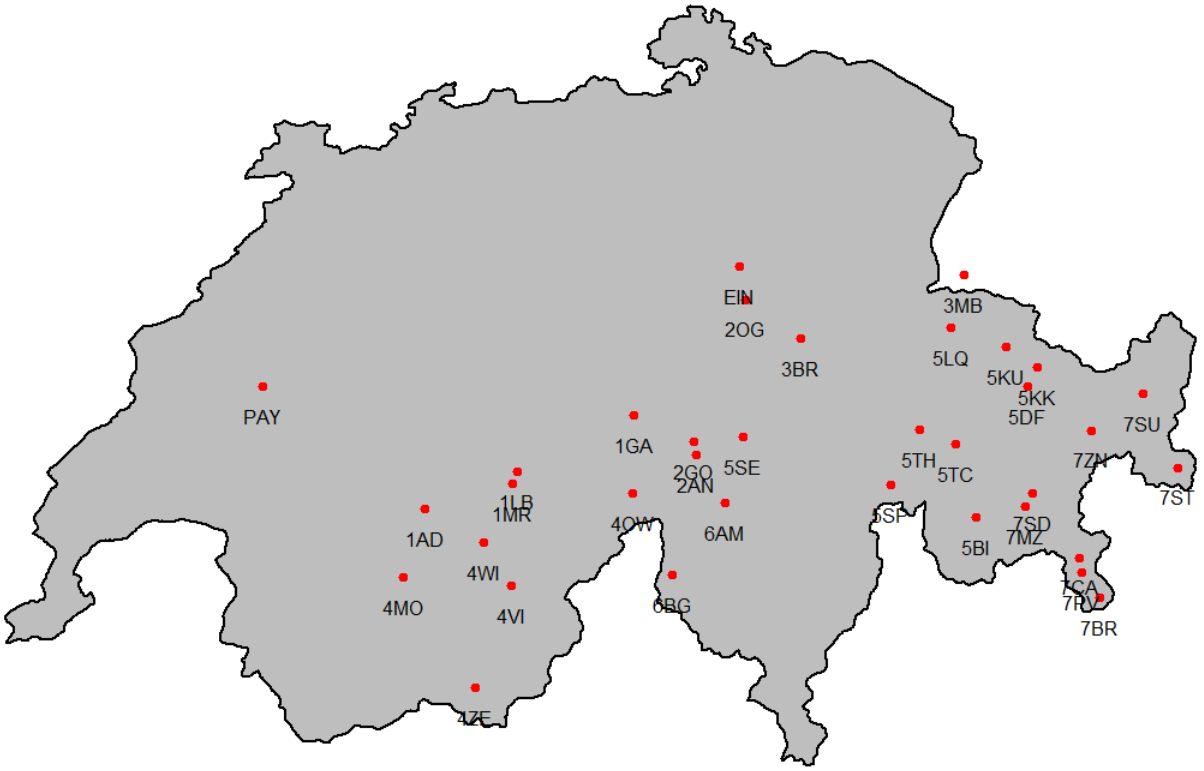
Station pair:
- close proximity (< 2 km, <100m)
- Parallel period (HS and HN)

- Complete data between Nov and Apr
- No copy/paste
- At least 25 years of overlap

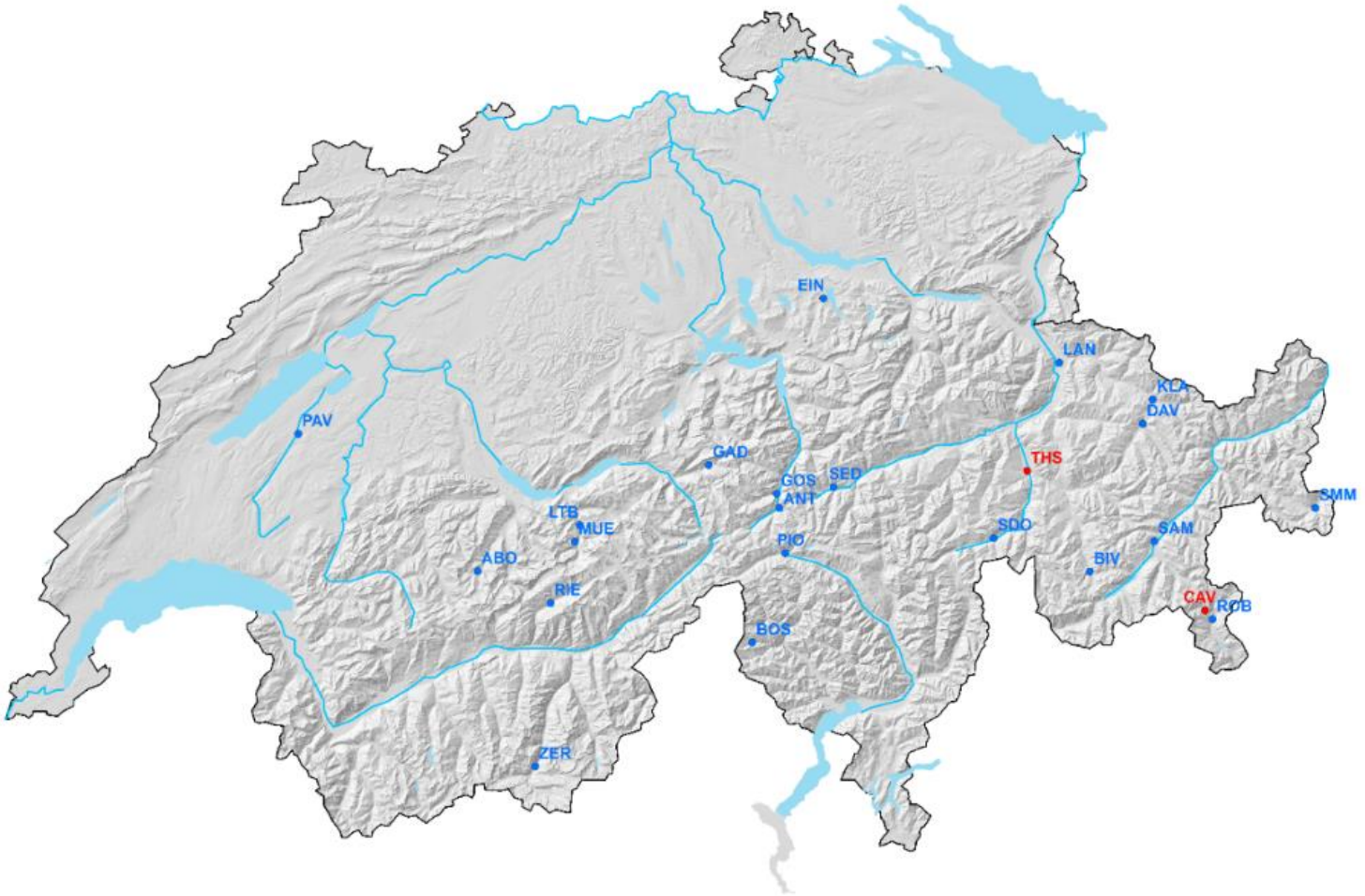
Potential set



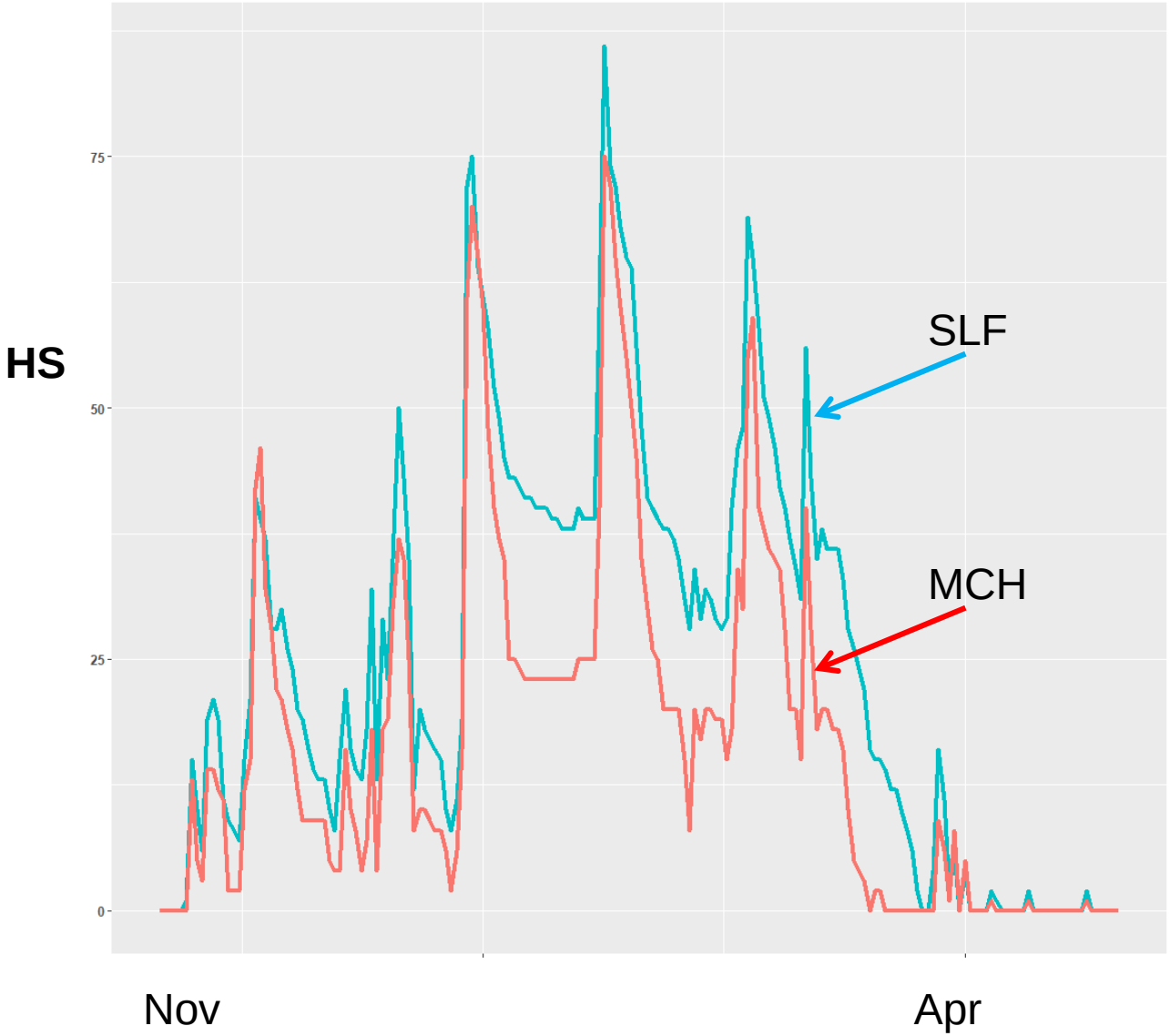
Possible set



Working set – 23 station pairs



Example: HS – Adelboden, 2000

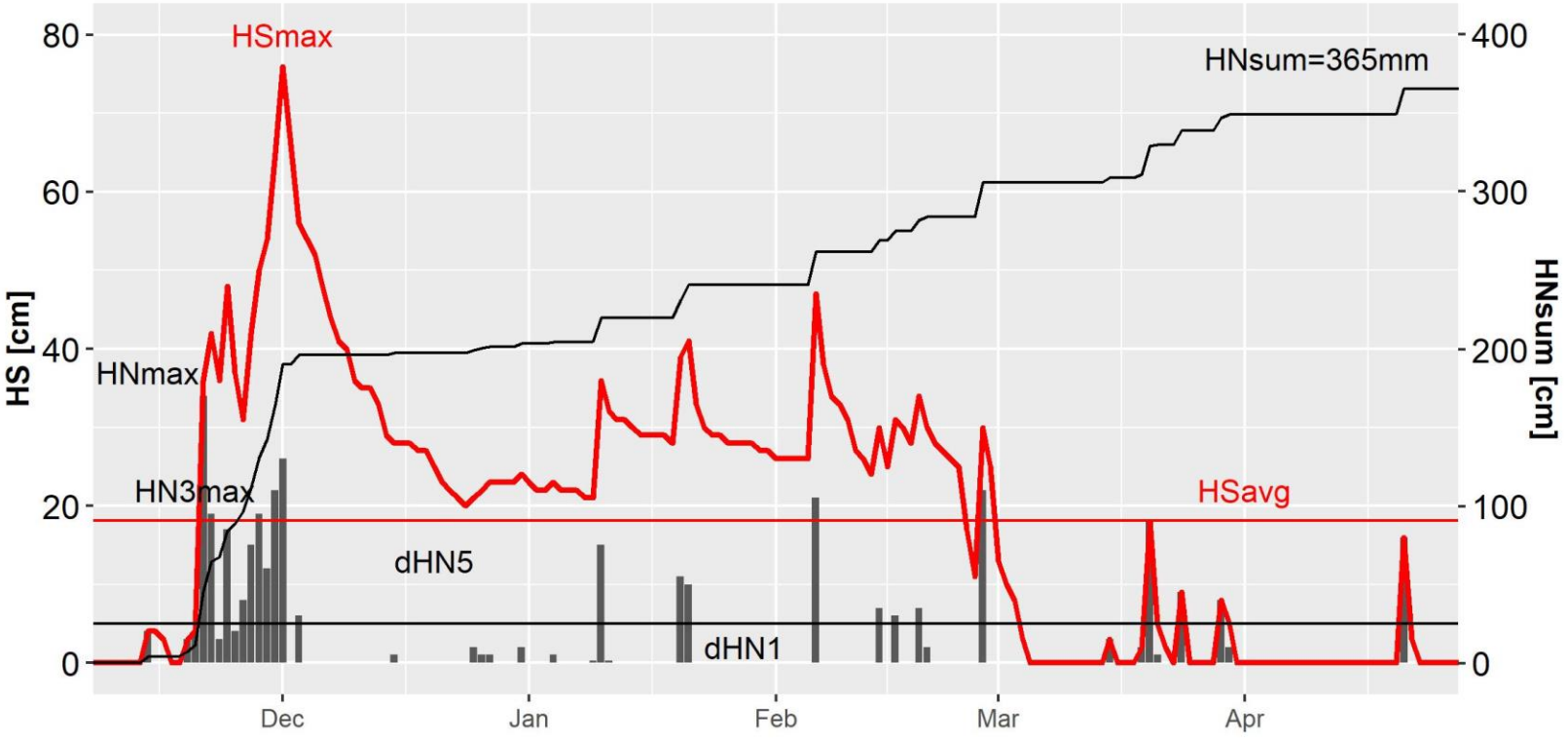


Snow Climate Indicators

Indicator	Description	Unit
HSavg	Mean HS	cm
HSmax	Max HS	cm
HNmax	Max HN	cm
HNsum	Sum HN	cm
HN3max	Max sum over three days	cm
dHS1	Number of days with HS > 0 cm	days
dHS5	Number of days with HS > =5 cm	days
dHN1	Number of days with HN > 0 cm	days
dHN5	Number of days with HN > =5 cm	days

(Buchmann *et al.*, 2020)

Snow Climate Indicators



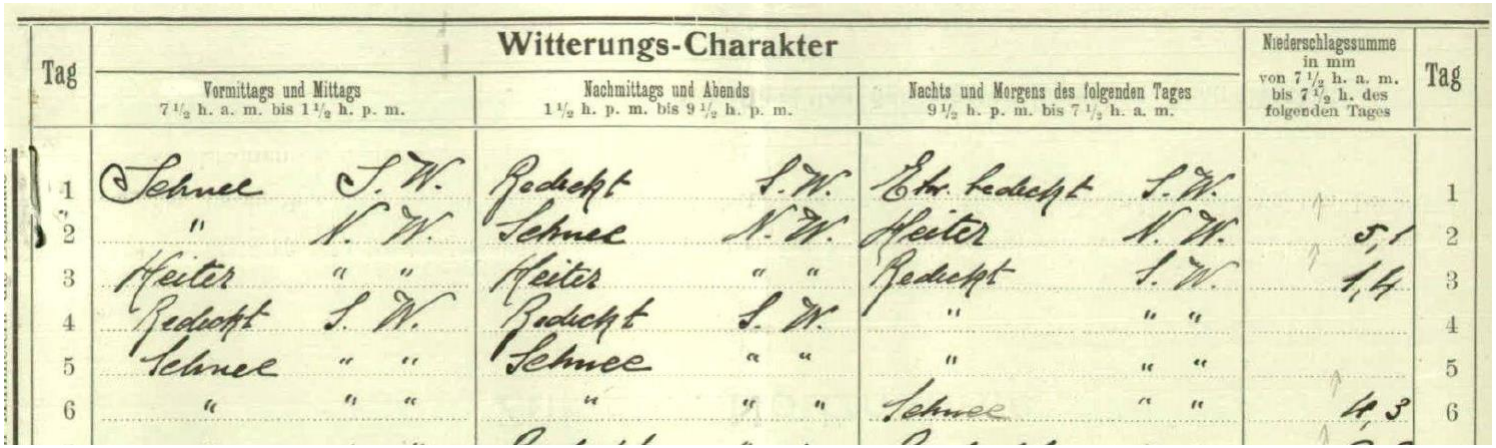
(Buchmann *et al.*, 2020)

Methods

Focus on
- Period 1980 – 2004
- Complete data
  - 23 pairs

Ignore!
- Relocations
- Observer changes

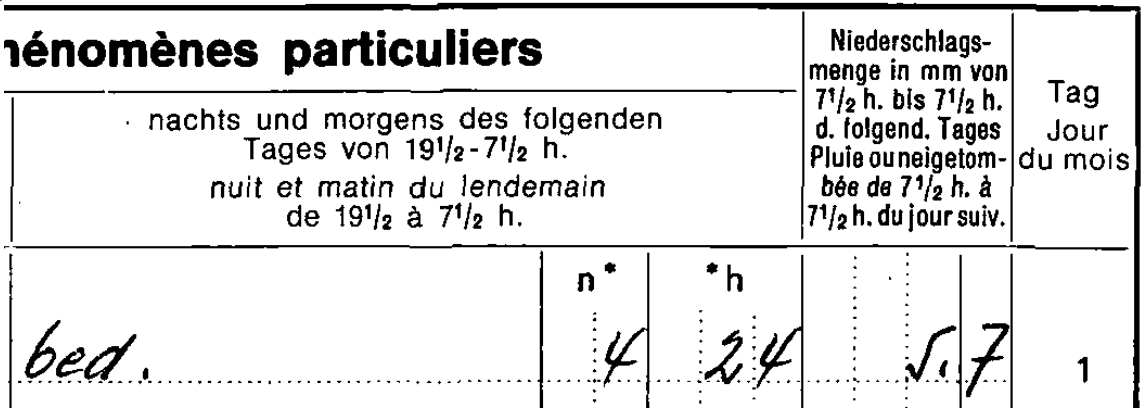
Sensitivity analysis:
- Correlations (spearman’s rank correlation)
- Relative percentage deviations (RPD)



Tag	Witterungs-Charakter: Vormittags und Mittags 7½ h. a. m. bis 1½ h. p. m.	Witterungs-Charakter: Nachmittags und Abends 1½ h. p. m. bis 9½ h. p. m.	Witterungs-Charakter: Nachts und Morgens des folgenden Tages 9½ h. p. m. bis 7½ h. a. m.	Niederschlagssumme in mm von 7½ h. a. m. bis 7½ h. des folgenden Tages	Tag
1	Schnee S. W.	Bedeckt S. W.	Ebr. bedeckt S. W.		1
2	" N. W.	Schnee N. W.	Heiter N. W.	5,1	2
3	Heiter " "	Heiter " "	Bedeckt S. W.	1,4	3
4	Bedeckt S. W.	Bedeckt S. W.	" " "		4
5	Schnee " "	Schnee " "	" " "		5
6	" " "	" " "	Schnee " "	4,3	6

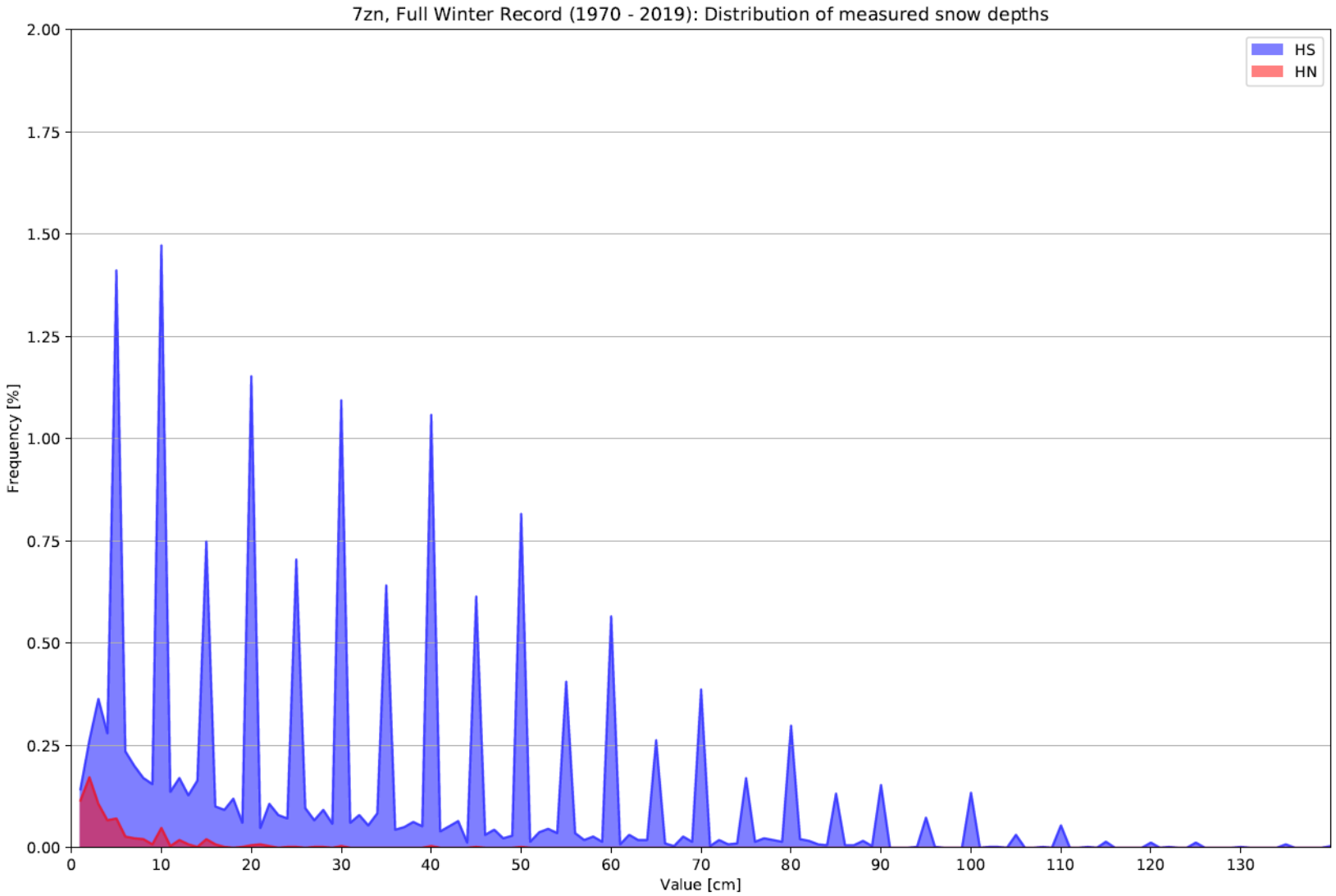
Tag Jour du mois	Witterungs-Charakter / Etat du ciel - Phénomènes particuliers: vormittags und mittags 7½-13½ h. avant-midi et midi de 7½ à 13½ h.	nachmittags und abends 13½-21½ h. après-midi et soir de 13½ à 21½ h.	nachts und morgens des folgenden Tages von 21½-7½ h. nuit et matin du lendemain de 21½ à 7½ h.	n°	°h	Niederschlagsmenge in mm von 7½ h. bis 7½ h. d. folgend. Tages Pluie ou neige tombée de 7½ h. à 7½ h. du jour suiv.	Tag Jour du mois
1							

Tag Jour du mois	Witterungs-Charakter / Phénomènes particuliers – État du ciel: Vormittags und mittags 7½–13½ h. Matinée et midi de 7 h ½ à 13 h ½	Nachmittags und abends 13½–19½ h. Après-midi et soir de 13 h ½ à 19 h ½	Nachts und morgens des folgenden Tages von 19½ h–7½ h. Nuit et matin du lendemain de 19 h ½ h à 7 h ½	Schnee in cm von 7½ bis 7½ h d. folgen. Tages Neige en cm de 7 h ½ à 7 h ½ du jour suivant	Niederschlagsmenge in mm Précipitations tombées en mm	Tag Jour du mois



Tag Jour du mois	nachts und morgens des folgenden Tages von 19½-7½ h. nuit et matin du lendemain de 19½ à 7½ h.	n°	°h	Niederschlagsmenge in mm von 7½ h. bis 7½ h. d. folgend. Tages Pluie ou neige tombée de 7½ h. à 7½ h. du jour suiv.	Tag Jour du mois
1	bed.	4	24	5,7	1

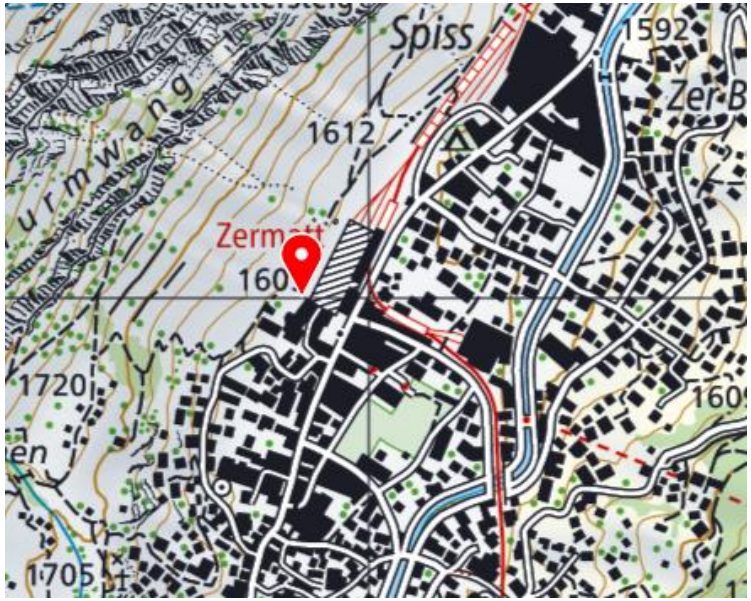
Observer behaviour

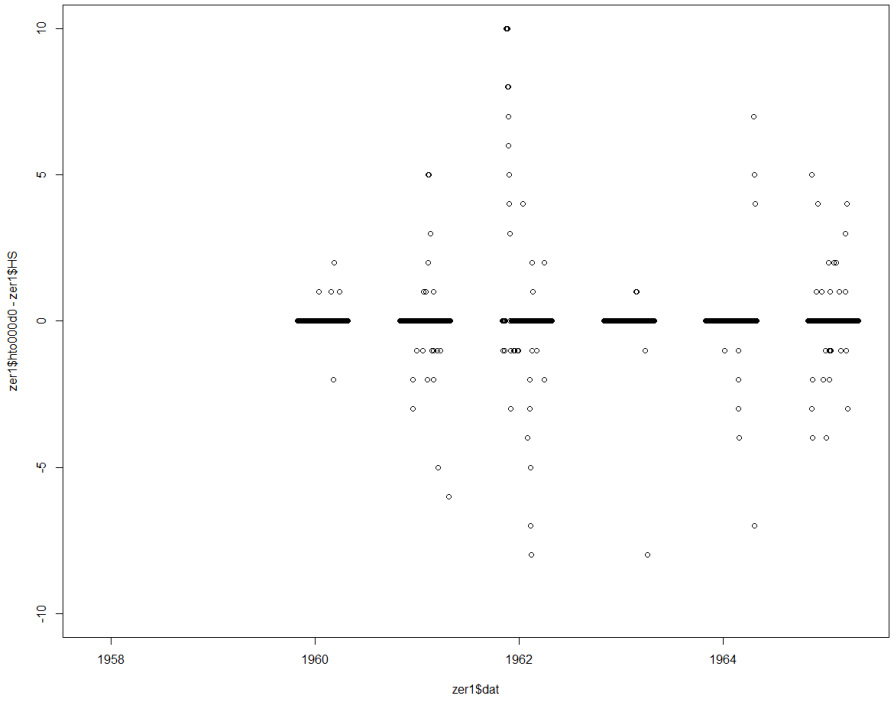


Aschauer

Metadata example

			yt1gres0, yt1htos0		
ZER	17.02.1959	17.02.1959	are000z0, dkl010z0, fkl010z0, fve010z0, gor000z0	Zustandsmeldung (z.B. Defekte, vorübergehende Inbetriebnahme resp. Ausserbetriebsetzung oder Störung): ganze Station	DIE MESSUNGEN DER SCHNEEHOEHE SOWIE DER NEU-SCHNEEMENGE WIRD NICHT IN DER KLINIK ST.THEODUL VORGENOMMEN SONDERN AUF DEM MESSFELD DES SLF OESTLICH DES BAHNHOFES ERMITTELT.

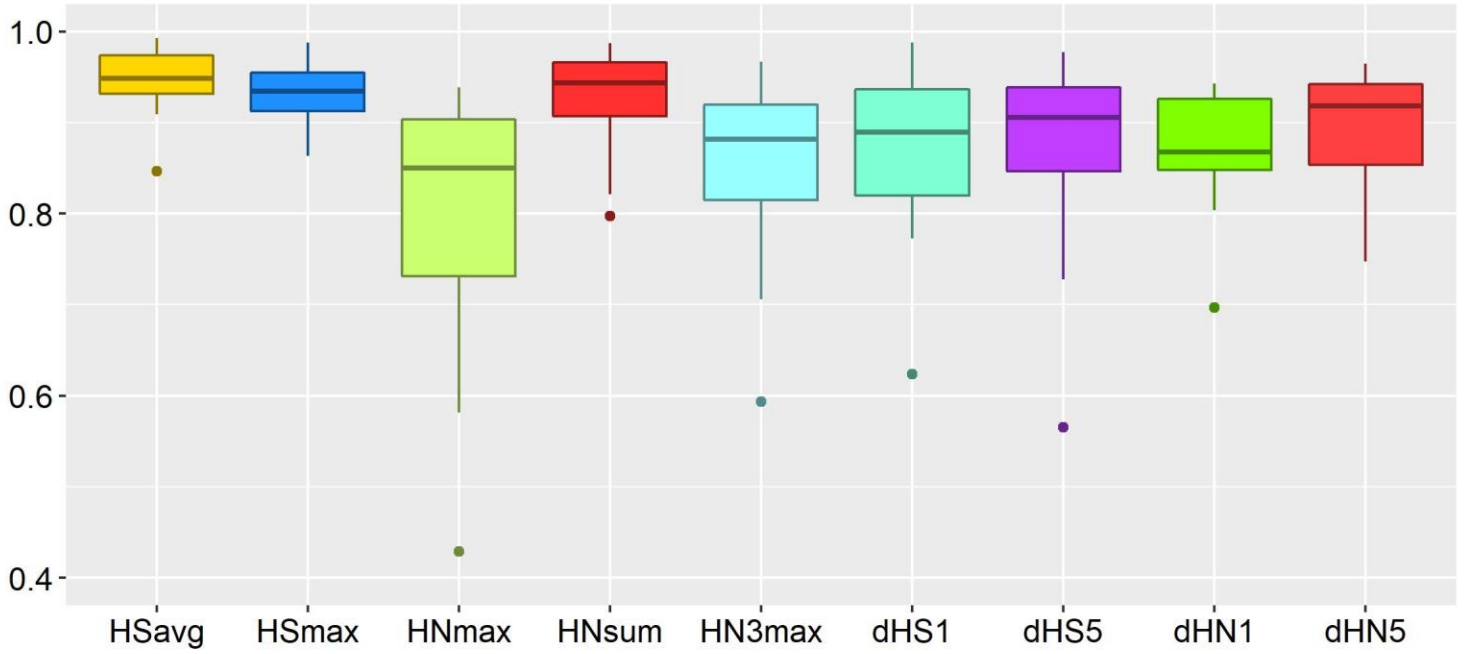




HSmean – Station pair Adelboden

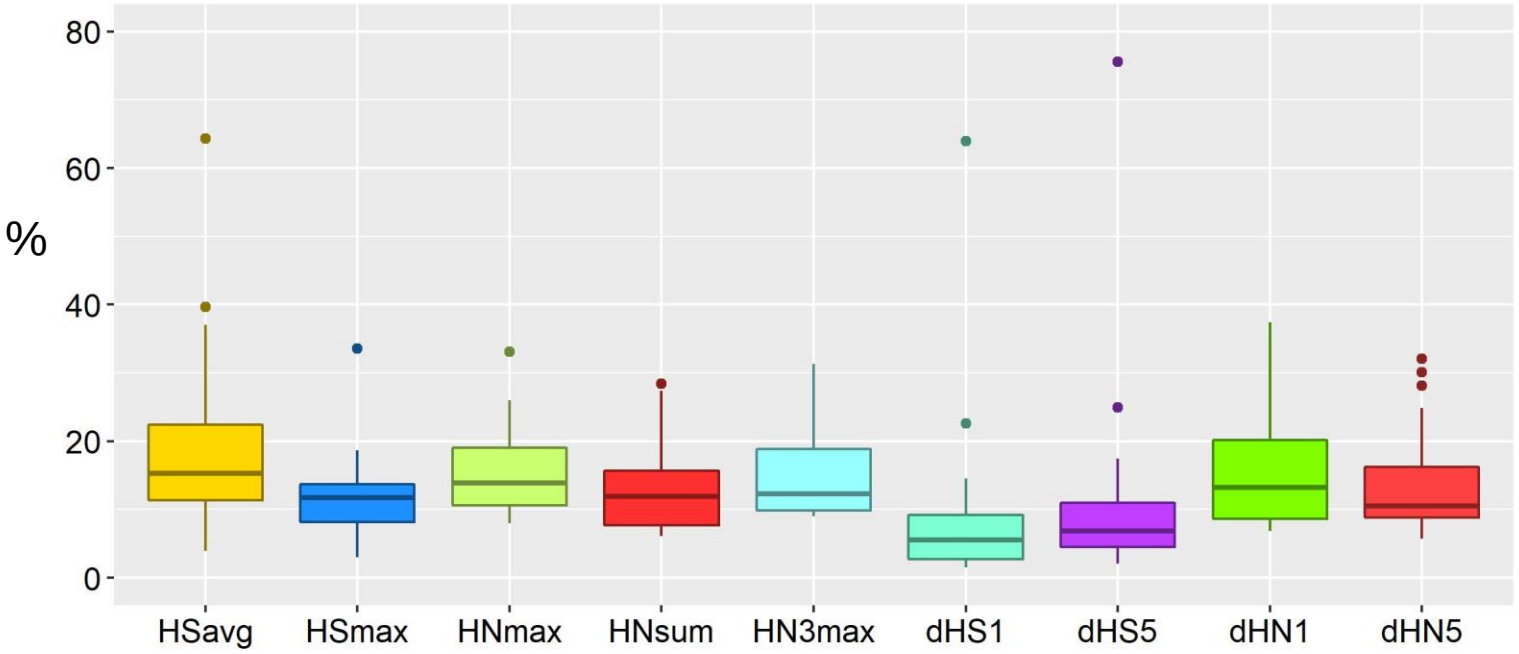
Corr=0.9615

Results - correlation



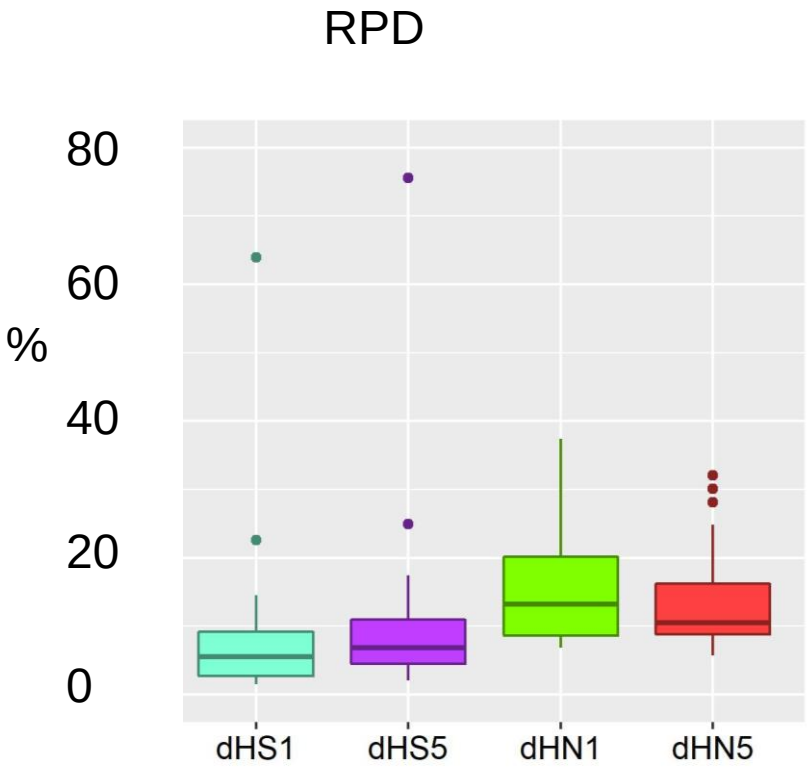
(Buchmann *et al.*, 2020)

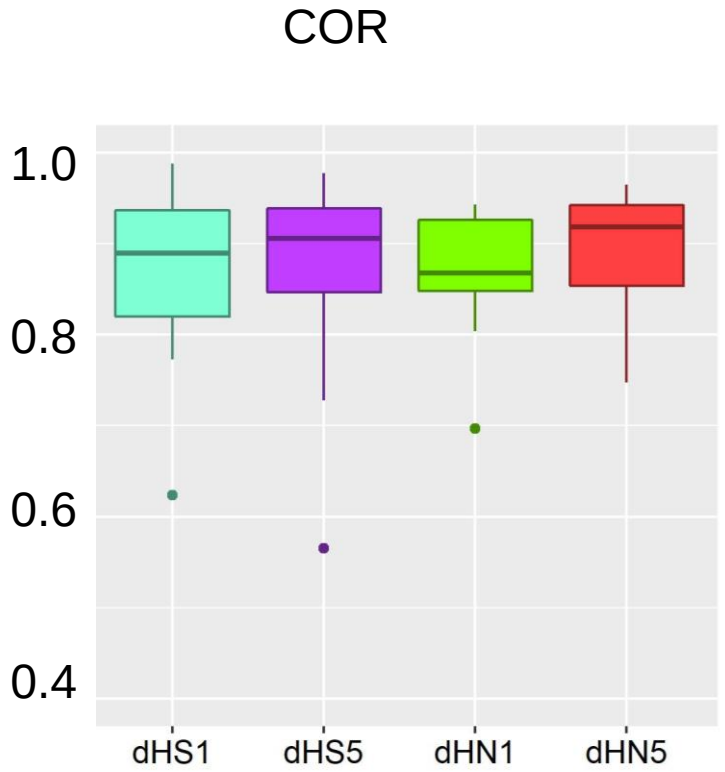
Results – relative percentage differences



(Buchmann *et al.*, 2020)

Results – days with snow (-fall)





(Buchmann *et al.*, 2020)

Conclusions

Despite all the stumbling blocks associated with snow measurements, snow appears to be quite a good-natured parameter after all

- Overall quite high correlation values > 0.8
- Median RPD between 10 and 15%

- No striking difference between **dHS1 and dHS5** as well as **dHN1 and dHN5**

Most robust indicators:
HSmax, dHS1/dHS5, and HNsum

Literature

Aschauer, J., Bavay, M., Begert, M., and Marty, C.: Comparing methods for gap filling in historical snow depth time series, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-17211, https://doi.org/10.5194/egusphere-egu2020-17211, 2020

Buchmann M, Begert M, Brönnimann S, Marty C. 2020. Evaluating the robustness of snow climate indicators using a unique set of parallel snow measurement series. *International Journal of Climatology*, joc.6863. https://doi.org/10.1002/joc.6863.

Resch, G., Chimani, B., Koch, R., Schöner, W., and Marty, C.: Homogenization of long-term snow observations, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-8807, https://doi.org/10.5194/egusphere-egu2020-8807, 2020