Generation of a daily snow depth dataset for Austria and some surrounding regions

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1. Introduction

Snow is a significant parameter in our climate system and reacts immediately on temperature and precipitation anomalies. Hence, it is a good indicator for the omnipresent catchword “Climate Change” .Especially the warm winter 2007 demonstrated us the impact of temperature increase to the sensible climate element snow. The small amount of snow during the last winter season 2006/07 had fatal consequences for Austrian tourism and economy. The use of new technologies to produce synthetic snow to extremes, in turn, does affects the natural environment. The Western Austrian actual winter period for 2007/08 with 150 cm of fresh snow in just 2 days shows the exact opposite.
Because of the great variability of this element it is essential to evaluate, interpret, and take further steps to homogenise daily snow data. Nevertheless, there is very little research done in this regard. With a data digitalization initiative within the Project “FORALPS WP5” it was possible to take the first step and close the great gap between data potential and data availability.

2. Digitalisation of daily snow depth data

Out of historical hydrological Yearbooks (1895-1915), data of more than 900 stations in the river basins Danube, Drava, Morava, Mura, Rhine, Adige and Sava were digitalised and corrected (station density is illustrated in Fig.1).
With the software OmniPage Pro 14.0 more than 900000 values were scanned, pre-checked and as xls data files saved. For this work it takes one year time.

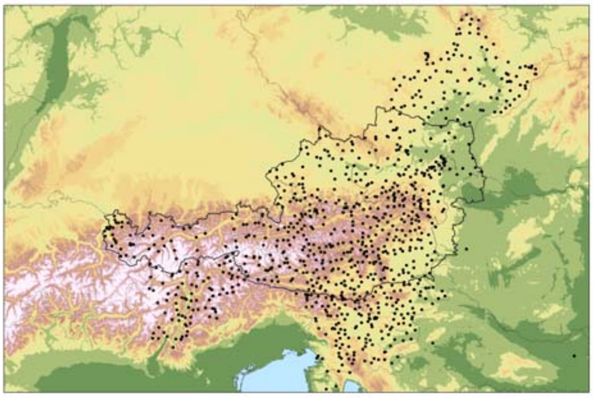

Fig.1: 878 stations (period 1895-1916) that were digitised from historical yearbooks

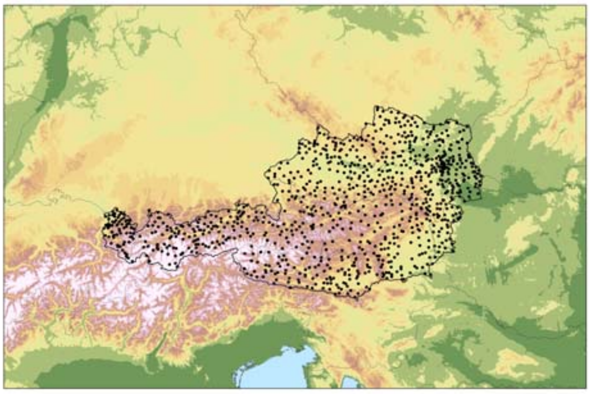

Fig.2: 977 actual stations (period 1980-2000) that are stored in our data base

A detailed overview of the number of stations in single river basins shows Tab.3. With 286 stations, wherefrom 118 stations had a continuous time-slice, the river basin Danube includes the highest number of stations and scanned values respectively.

	number of stations	complete stations	digitalised values
Danube	286	118	300000
Drava	128	46	200000
Morava	128	41	100000
Mura	123	46	100000
Rhine	27	8	25123
Adige	111	17	100000
Sava	119	24	71127
Total	922	300	896250

Table 1: overview of the station number and number of digitalised values

2.1. Metadata

To gather exact information about coordinate and altitude, the generation of a so-called metadata file was another major step in this snow-data digitalisation initiative. Complete Metadata files include the whole existing traceable station history and describe how, where, when and by whom data was collected. Changes of observers, altitudes and coordinates were first signs of station relocations and could produce break points in time series. So the station history is a crucial point for later homogenisation attempts.

Before World War I country borders were set different, so parts of Italy, Croatia, Slovenia and Czech Republic belonged to Austro-Hungarian Monarchy and for this reason were published in Austrian Yearbooks. By dint of metadata many station names that were germanised in Austro-Hungarian times could be actualised and renamed.
To illustrate this example we take three uniformly named stations, Schneeberg, with different coordinates and altitudes information. Because of the before mentioned *"germanisation"*, they turned out to be Schneeberg in Lower Austria, Monteneve in Italy and Snježnik in Slovenia.
To demonstrate the great variability of the element snow and the effects of the main global warming of the 20th century, a second recent time slice (see Fig.2, 1980-2000) was selected and compared with the historical digitalised one.
With some validating criterion, such as completeness of the dataset, only 98 (10%) out of 900 stations were chosen for further statistically evaluations, interpolations and significant tests.

2.2. Classification

The dataset containing 98 stations (see Fig.3) were further classified in three categories. If the original data featured no single gap in the two chosen time slices, the station belongs to class one. Otherwise, dependent on the length of the gap, the stations appertain to class two (up to 2 months) or three (up to 2 years).

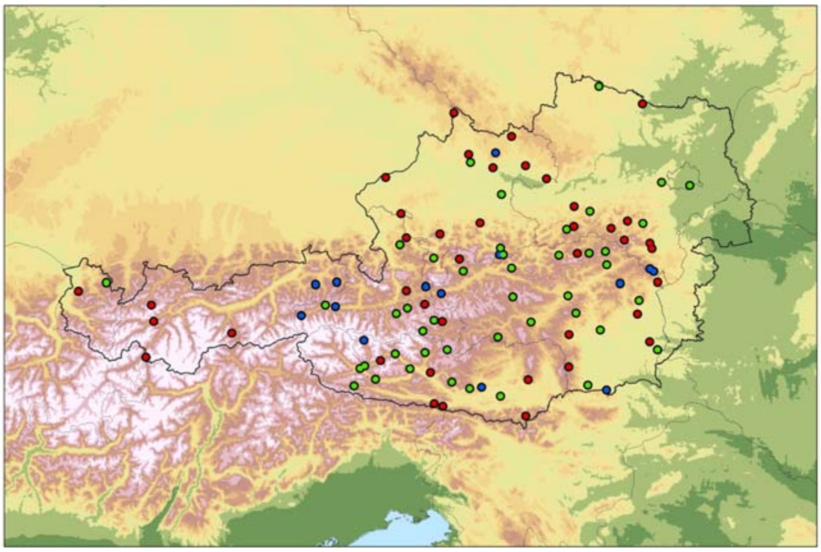
Fig.3.: Classification of the 98 statistically evaluated stations, red- class 1, blue-class 2, green-class 3

3. Quality control

The difference between snow depth of the actual day and snow depth of the previous day was defined as amount of pseudo-fresh snow (*pfs*). Negative values were indicators for snow reduction because of melting or compression. Positive values showed the amount of theoretical fresh snow. Depending on the station altitude, *pfs* limits were set.

- Below 700 m altitude = limit ±30 cm
- Above 700m sea level = limit ±50cm.

With this theoretical parameter many outliers that occurred because of mistakes in digitalisation (input and reading errors) could be detected. Also gaps because of absence or untrustworthiness of observers could be visualised easily and efficiently.
With this theoretical parameter many outliers occurred because of mistakes in digitalisation. Other errors occurred because of absence or untrustworthiness of observers.
Figure 4 shows a typically picture of a short observation break in the year 1905 at the station Gollrad, situated in 1000m above sea level.
At the 26.02.1905 the evaluated *pfs* value is -165cm, a few days later +142cm. The observer simply filled the missing data with zeros values and produces therefore huge outliers.

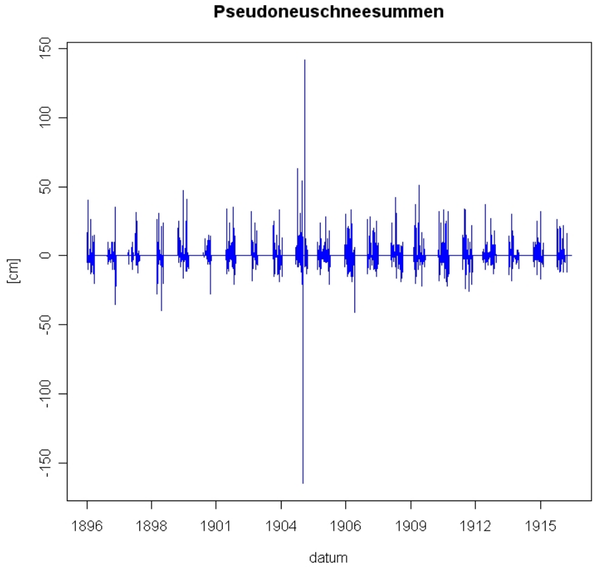

Fig.4: pseudo fresh snow amount at the station Gollrad

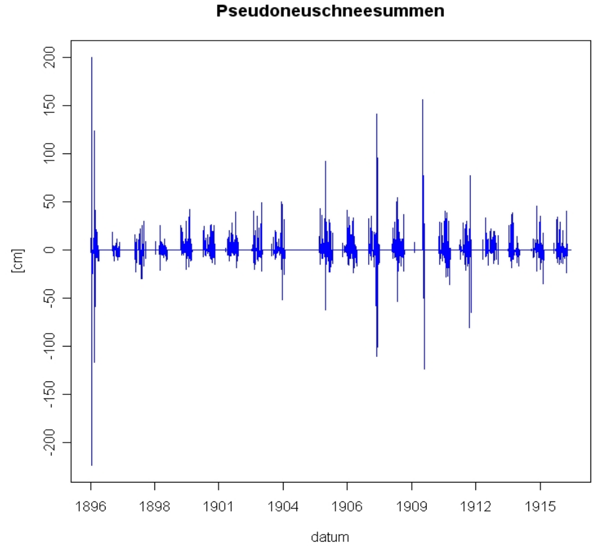

Fig.5: pseudo fresh snow amount at the station Neuhaus am Zellerrain

Figure 5 demonstrates an example of major gaps and sporadic observations. The great variations at the beginning of the measurements are good examples of sporadic observations at the station Neuhaus am Zellerrain. The complete winter season 1904/05 snow depth were not listed nor measured. In 1907 and 1910 the outliers were indicators of premature completion of observations.

4. GAP-closing

To allow time series analysis and comparisons it is necessary to close existing data gaps. Stations with gaps were completed with a well correlated station within the nearest neighbourhood. Snow is a cumulative element so the gaps could be closed with the RATIO Method:

$$sd_{eval} = \frac{sd_{neigh}}{sd_{gap}}$$

with sd_{neigh} being the snow depth data of the neighbourhood station and sd_{gap} the data of the incomplete station. However, we must take into consideration that only short gaps should be closed.

5. Long-term FORALPS time series

For further trend analysis and statistics, an additional second dataset, containing 14 long term (1901-2007) snow depth time series, in daily resolution, was created (see Fig.6: and 7:). Various WP 5 project collaborators and students digitalised out of reports, provided by Austrian hydrographical service (partially sent by post or directly picked up from hydrographical departments) approximately 600000 snow depth data values.

Station	Bundesland	λ	φ	Höhe[m]
Deutschlandsberg	STMK	15.22	46.83	410
Freistadt	OOE	14.50	48.52	548
Kollerschlag	OOE	13.84	48.61	725
Kornat	KNT	12.89	46.69	1047
Landeck	TIR	10.57	47.15	785
Langen	VBG	10.13	47.13	1218
Linz	OOE	14.27	48.32	320
Mallnitz	KNT	13.17	46.99	1196
Nauders	TIR	10.50	46.88	1360
Radstadt	SBG	13.46	47.38	858
Ried im Innkreis	OOE	13.48	48.22	431
Tamsweg	SBG	13.81	47.12	1012
Windischgarsten	OOE	14.34	47.72	601
Bad Bleiberg	KNT	13.69	46.63	907

Fig.6: Table of stations

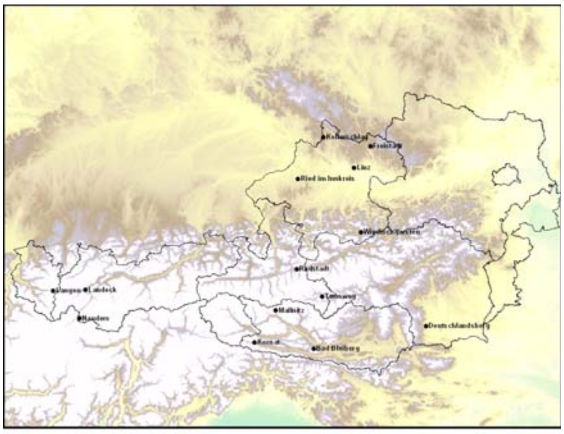

Fig.7: 14 long term time series

In comparison to the first dataset, this dataset still contains greater gaps within the World War years, which could not be easily completed because of the non-existence of reference stations in the next neighbourhood.

Using the above mentioned pseudo fresh snow parameter we could detect lacks and sporadic observations of data in time series (see Fig. 8, example station: Radstadt situated in 850msl) effortless.

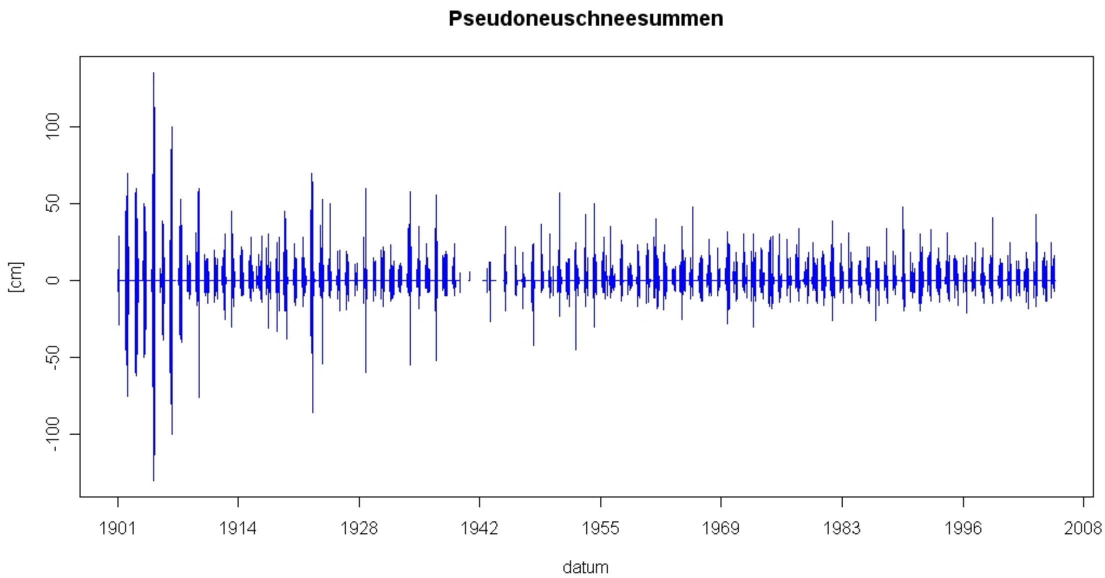

Fig.8: sporadic observations between 1901 and 1908, gaps in World Wars I and II at the station Radstadt

6. References

Aguilar E, Auer I, Brunet M, Peterson TC, Wieringa J. 2003. Guidelines on Climate Metadata and Homogenization. WCDMP-No.53. WMO-TD No. 1186, 51pp.

Böhm R. 1992. Description of the Procedure of Homogenizing Temperature Time Series in Austria. Central European Research Initiative, PG Meteorology, WP 2. Central Institute for Meteorology and Geodynamics.