WEATHER-TYPE CLIMATOLOGY OF PRECIPITATION IN THE EASTERN ALPS

Hanns Kerschner

Institut für Geographie, Universität Innsbruck, Innrain 52, A-6020 Innsbruck, Austria
E-mail: *Hanns.Kerschner@uibk.ac.at*

Abstract: A simple weather type classification based on 500 hPa airflow and the anomaly of the 500 hPa topography is well suited to describe the spatial structure of the probability for precipitation ≥ 1 mm in the Eastern Alps. The overall improvement over seasonal mean values is 38% in spring, 41% in summer, 50% in autumn and 47% in winter.

Keywords: *Synoptic climatology, precipitation, Eastern Alps*

1. INTRODUCTION

Precipitation in a mountain range like the European Alps is intimately linked to the interaction of airflow patterns and relief. In the past, this interaction was studied in detail by e.g. Fliri (1962), Wakonigg (1970) and Fliri and Schüepp (1984). In the Eastern Alps the weather-type classification system by Lauscher ("Ostalpine Wetterlagen") and Schüepp ("Witterungslagen") were mainly used. Here we use a simple airflow classification to analyse the "Alpine Precipitation" data set by Frei and Schär (1998). The principal aim of the study is to test the applicability of the weather-type classification for a regional synoptic-climatological analysis of precipitation. The area covered (Fig. 1 - 3) reaches from Lake Constance (9°36' E) in the West to Lake Neusiedl (17°6' E) in the East and from the Danube River in Bavaria (49° N) to the northern Istria Peninsula (45°15' N) in the South.

2. WEATHER-TYPE CLASSIFICATION AND DATA SET

The classification is based on a calendar of daily weather types for the Eastern Alps, set up according to the rules of the Swiss Meteorological Office (Schüepp, 1968; Kerschner, 1989). A concise description of the classification system can be found in Stefanicki et al. (1998). The center of the classification area is situated in the Enns valley (Styria) at 14° E, 47°30' N. The calendar includes a series of parameters to describe daily air-flow characteristics and is available for the 1966 - 1983 period (Kerschner, 1989). It has been continued since then and is presently available up to 1994.

Table 1: Weather type classification

500 hPa airflow	500 hPa anomaly		
	≥ upper quartile "anticyclonic"	2^{nd} and 3^{rd} quartile "indifferent"	≤ lower quartile "cyclonic"
NE	+NE	NE	-NE
E	+E	E	-E
etc. etc.			
N	+N	N	-NE
dd and db weak	+H0	F0	-L0
surface low		Ls	
500 hPa low		Lh	

For the classification used in this paper, the 500 hPa airflow (dd) and quartiles of the anomaly of the 500 hPa surface from the daily mean are the principal parameters. If 500 hPa airflow is weak, the surface airflow (db) is used instead. The classification includes 24 directional classes and 5 classes for weak or mixed airflow patterns (Tab. 1), 29 classes in total. A further substantial increase in the number of weather types would lead to a very small sample sizes with some classes and unstable statistical parameters. The anomaly of the 500 hPa surface provides a reasonable distinction between anticyclonic, indifferent and cyclonic weather types (Schüepp, 1979).

The precipitation data come from the gridded daily "Alpine Precipitation Climatology" data set (Version 4.0) by Frei and Schär (1998), which can be downloaded from the Internet. Grid cell spacing is approximately 25 km. The parameter analysed is the probability for precipitation ≥ 1 mm / day (PP), calculated as

$$PP = n(p) / n * 100 \qquad (1)$$

with $n(p)$ as the number of days of a certain weather type with precipitation ≥ 1 mm and n the total number of days of the weather type.

3. RESULTS

PP was analysed with respect to weather types and standard climatological seasons. In a second step, the anomaly of PP (*aPP*) from the seasonal mean (*sm*) was calculated as

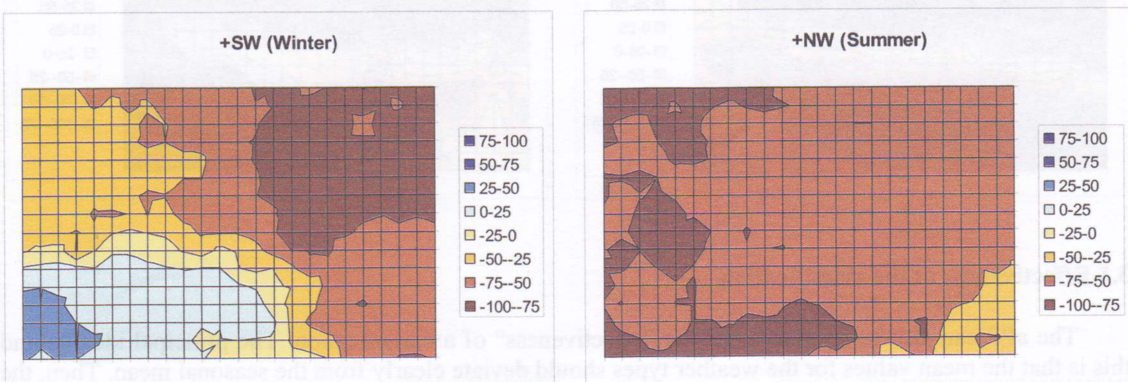
$$\text{PP less than mean:} \quad aPP = (PP - sm) / sm * 100$$

$$\text{PP greater than mean:} \quad aPP = (PP - sm) / (100 - sm) * 100 \qquad (2)$$

Thus, *aPP* ranges from -100 % for no precipitation at all to +100 % for precipitation at every day; it will be used for the following brief discussion of results.

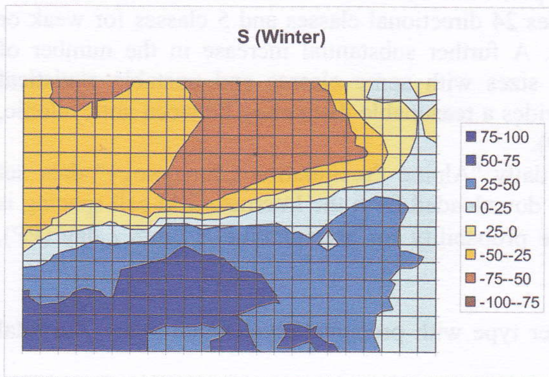
Anticyclonic weather types show usually highly negative values of *aPP* in all seasons. They range usually between -50 and -100 % over the research area with some notable regional patterns, which reflect the interaction between topography and airflow (e.g. +N, +NW, +S, +SW), the presence of distant areas of cyclonic activity, approaching fronts, (e.g. +S, +SW) and the presence or absence of mountain induced convective instability (e.g. +H0 in summer vs. +H0 in winter).

Figure 1: Examples for *aPP*, anticyclonic weather types.



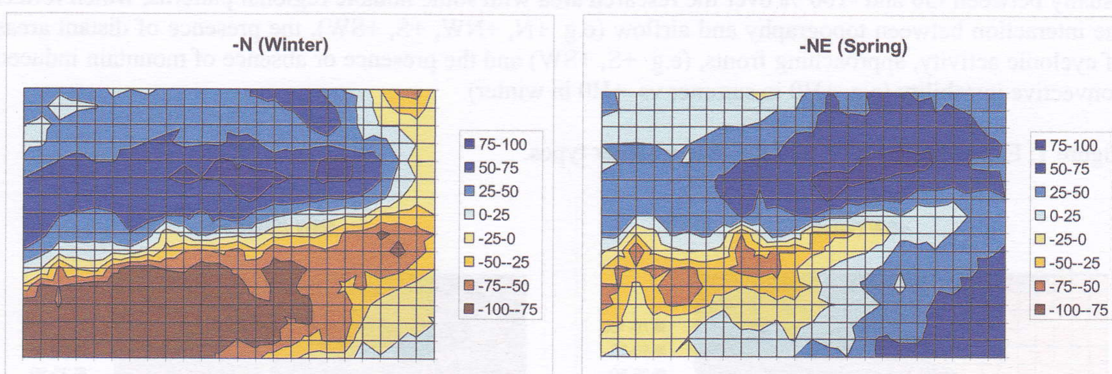
Indifferent weather types are generally characterised by increasingly positive *aPP* values in all seasons. Increased convective instability is most marked in spring and summer. In all seasons, certain weather types also show patterns, which can be attributed to higher frontal activity, increasing contrasts between windward and leeward sides and the closer proximity of regional uplift centres. However, indifferent weather types also encompass weather-types, which seem to be ill-defined, like "W" or "F0". In these cases, *aPP* usually ranges between -25% and +25 % with some discernible regional patterns, like more positive values in the mountains than in the lowlands. This may either reflect a weakness in the classification procedure or weather-types, which are dominated by isolated shower cells ("scattered rainshowers").

Fig. 2: Examples for *aPP*, indifferent weather types.



Cyclonic weather types are usually characterised by highly positive *aPPs* in certain core areas, like the northern fringe of the Alps for -NW and -N, the north-eastern Alps for -NE, the Julian Alps and Alpi Bergamaschi for -S and -SW or the Dolomites for -S. These areas are surrounded by a fringe are with less positive *aPPs* and, further away, slightly negative *aPPs*. Then, after a more or less sharply defined transition, *aPPs* are clearly and sometimes highly negative on the leeward side. This spatial pattern is best developed in spring, autumn and winter, whereas in summer the contrasts are less well developed. On the other hand, the effect of cold air flowing around the eastern side of the Alps (-NW, -N, -NE) can be observed well in summer.

Fig. 3: Examples for *aPP*, cyclonic weather types.



3.1 Effectiveness of the classification

The aPP can also be used to asses the "effectiveness" of a classification. The principal idea behind this is that the mean values for the weather types should deviate clearly from the seasonal mean. Then, the mean value for aPP for all grid points gives an information, how "good" the classification is (Table 2, next page).

4. CONCLUSIONS AND OUTLOOK

Despite being simple, the weather classification represents the spatial patterns of precipitation probability in the Eastern Alps rather well. It seems to work best for anticyclonic types and those weather types, which exhibit clear windward / leeward effects. Weather types, which show little improvement over the climatological means, could be improved by taking frontal processes into account. Some experiments showed that this my be a promising way for further studies, which can be easily done on the basis of the parameters included in the "calendar". However, care should be taken to avoid an overly complicated classification, as the purpose of synoptic climatology is certainly not to emulate synoptic meteorology. Further studies could also put a focus on precipitation sums and extreme events.

Table 2: Average anomaly of precipitation probability (≥ 1 mm/d) in percent (absolute values). Bold letters mark maxima, indented letters minima.

Weather type	Spring	Summer	Autumn	Winter	Weather type	Spring	Summer	Autumn	Winter
+NE	69	44	84	**80**	-NE	37	44	26	36
+E	47	30	80	**79**	-E	20	39	37	29
+SE	**72**	59	**94**	74	-SE	27	**65**	27	38
+S	**71**	56	**86**	62	-S	41	53	46	37
+SW	51	38	70	54	-SW	39	60	50	31
+W	37	31	68	52	-W	19	42	27	26
+NW	48	61	70	49	-NW	36	33	35	46
+N	**77**	**65**	75	55	-N	23	33	36	54
NE	28	*18*	38	62	+H	53	38	**91**	**96**
E	*17*	29	32	51	F	*10*	*18*	32	25
SE	31	21	48	49	-L	21	45	*22*	*21*
S	28	33	37	37	Ls	68	**79**	73	60
SW	22	41	*25*	*20*	Mean	38	41	50	47
W	*12*	*16*	*12*	*21*	Std.Dev.	19	16	23	19
NW	23	22	34	41					
N	40	22	51	42					

REFERENCES

Fliri, F., 1962: Wetterlagenkunde von Tirol. *Tiroler Wirtschaftsstudien* **13**, 436 pp.

Fliri, F. and M. Schüepp, 1984: Synoptische Klimatographie der Alpen zwischen Mont Blanc und Hohen Tauern (Schweiz - Tirol - Oberitalien). *Wissenschaftliche Alpenvereinshefte* **29**, 686 pp.

Frei, Ch. and Ch. Schär, 1998: A precipitation climatology of the Alps from high-resolution rain-gauge observations. *International Journal of Climatology,* **18**, 873-900.

Kerschner, H., 1989: Beiträge zur synoptischen Klimatologie der Alpen zwischen Innsbruck und dem Alpenostrand. *Innsbrucker Geographische Studien*, **17**, 253 pp.

Schüepp, M., 1968: Kalender der Wetter- und Witterungslagen von 1955 bis 1967. *Veröffentlichungen der Schweizerischen Meteorologischen Zentralanstalt*, 11, 43 pp.

Schüepp, M., 1979: Witterungsklimatologie (Klimatologie der Schweiz III). *Beihefte zu den Annalen der Schweizerischen Meteorologischen Anstalt 1978*, 93 pp.

Stefanicki, G., P. Talkner and R.O. Weber, 1998: Frequency changes of weather types in the Alpine region since 1945. *Theoretical and Applied Climatology*, **60**, 47-61.

Wakonigg, H., 1970: Witterungsklimatologie der Steiermark. Verlag Notring, Wien, 255+LXXX pp.