PRECIPITATION AT THE SOUTH SIDE OF THE ALPS AND WEATHER TYPES

Jože Rakovec[1], Gregor Vertačnik[1]

[1] Chair of Meteorology, Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
E-mail: *joze.rakovec@fmf.uni-lj.si*

Abstract: Statistical investigation is performed to find connections between the two "vectors": one describing weather type (like shape of the geopotential field, wind direction and velocity, stability, moisture, etc.) and the other describing precipitation (for example location of precipitation spot, its area and shape, the accumulated precipitation amount, etc.). The most precipitation-relevant descriptor variables in regions south of the Alps are found to be geopotential height, relative humidity, wind direction and vorticity.

Keywords *– precipitation south of the Alps, relief, weather types*

1. INTRODUCTION

Climatologically there are two precipitation maxima at the southern side of the Alps: in Julian and Karnic Alps and in Ticino, separated by a relatively drier gap in-between (Frei and Schär, 1998). Such a "bipole" distribution can be partly explained by different types of weather processes, and by certain relief characteristics (Rakovec et al. 2004), e.g. concavity, steepness etc. Here we search for the most relevant fileds of meteorological variables that influence and »explain« the most of precipitation variability in our regions of interest. For our regions of interest if was found that fields of temperature, specific humidity and geopotential height at 500, 700 in 850 hPa discriminate most of the prevaling weather types relevant for precipitation at different locations south of the Alps.

2. METHOD OF OBJECTIVE CLASSIFICATION

The main criterion of importance for a particular variable v to be precipitation-relevant is chosen to be the distribution of precipitation amount p as a function of that variable $p(v)$. A well expressed maximum in $p(v)$ means that there is empirically a lot of precipitation at that value of variable v. An algorithm to find which variables are relevant for precipitation events, these variables v are classified by their increasing values into 10 percentile classes (n = 10), separately for seasons (DJF, MAM, JJA, SON). For each variable the dispersion is computed, to serve as the main objective criterion for these variables to become precipitation amount predictors. For each decile class j and for each of the selected regions (Figure 2) the class-average precipitation amount $\overline{p}_j$ is calculated. The dispersions s^2 of the class-averages of precipitation according to the average $\overline{p}$ for that variable, region and season are computed:

$$s^2 = \frac{1}{n-1}\sum_{j=1}^{n}\frac{h_j}{\overline{h}}\left(\frac{\overline{p}_j - \overline{p}}{\overline{p}}\right)^2 ;$$

here $h_j/\overline{h}$ compensates the fact that all classes do not have exactly the same number of days. As dispersion is normalized with the average of daily precipitation of that season, its maximum is thus limited with the number of classes ($s^2 \leq 10$). A similar approach to this objective classification was described by Bardossy et al. (1995).

3. DATA

The data cover six year period 1990-1995 (2191 days). Daily values of the measured precipitation for the Alpine region are available at http://www.map.ethz.ch/map-doc/rr_clim.htm (Frei and Schär, 1998). The latest version 4.0 is used, covering also the regions of our interest. As input for objective precipitation predictors the ECMWF re-analyses (ERA 40) for 00 UTC and 12 UTC over Europe are used: utilized fields are temperature, specific humidity and geopotential height at 500, 700 and 850 hPa. From these some other fields are computed, like geostrophic wind, relative geopotential, potential temperature, cyclonality etc.

4. RESULTS

The method aims upon finding appropriate precipitation predictors. Empirical distributions of predictor variables over the selected domains and the precipitation amounts in the eleven regions of interest (see Figure 1) were computed. There are two domain sizes: the large one from 5° to 18° E and from 42° to 50° N (as ERA 40 data are interpolated into 0.5 ° grid, that means 27x21 points), and the small ones: 7 degrees of longitude per 4 degrees of latitude (15x9 points). There are five smaller domains: the central one, and four additional, shifted for 2 degrees south or north, or for 3 degrees west or east.
Averages of daily precipitation amounts in each of the regions 1 to 11 (see Figure 2) are computed as weighted averages: the points inside the region have weights 1, while the ones close to the border or at the edge of the region have weights ½ or ¼.

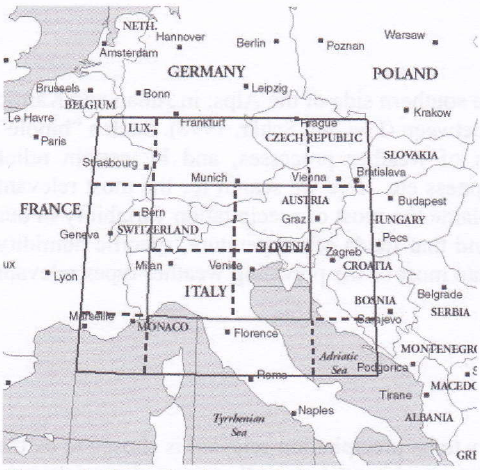

Figure 1. Domains in which the weather variables from ECMWF reanalyses are considered as precipitation relevant "predictors".

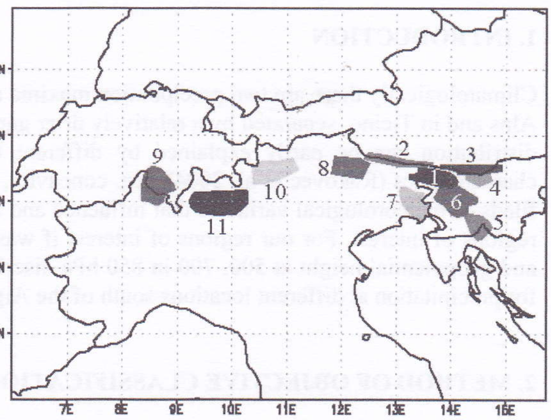

Figure 2. Eleven regions in which precipitation accumulations are studied. For explanation see the heading of Table 1.

For start it is worth to inspect correlations between precipitation accumulations in different regions (Table 1); the borders of our selected regions cover the common geographical areas, except for Friuli and Dolomiti, where our regions are smaller. In Table 1 Julian Alps are taken as a reference and precipitation in all other regions are correlated with it. Correlations are computed also with time lags »dt« – for example; the value dt = -1 means that today's precipitation in Julian Alps are compared with one day earlier precipitation in other regions.

It is evident that the correlation decreases with the geographical distance from the reference (Julian Alps in this case). In time are the highest correlations shifted by only a couple of hours – the greatest time lag is between Ticino and Snežnik (region 5), where the highest correlation is obtained for a time lag of one and a half days. As Snežnik at Alpine-Dinaric barrier is not highly correlated also with neighbouring regions, that could suggest that precipitation processes there in average are governed by separate weather processes.

Table 1. Correlation of precipitation daily amounts in different regions with daily amounts in Julian Alps. (The regionas are: Juli (Julian Alps), Karn (Karnic Alps), Kara (Karavanke), Kamn (Kamniško-Savinjske Alpe), Sub (Western subalipne Slovenia), Snež (Snežnik), Friu (Friuli), Dolo (Dolomiti), Tici (Ticino), Ortl (Ortler), Berg (Alpi Bergamasce).

dt [day]	1 Juli	2 Karn	3 Kara	4 Kamn	5 Sub	6 Snež	7 Friu	8 Dolo	9 Tici	10 Ortl	11 Berg
-3	0.07	0.04	0.03	0.03	0.06	0.06	0.06	0.03	0.09	0.05	0.08
-2	0.14	0.10	0.09	0.09	0.11	0.09	0.13	0.06	0.15	0.07	0.14
-1	0.34	0.27	0.22	0.22	0.27	0.16	0.29	0.24	0.32	0.27	0.40
0	1.00	0.85	0.89	0.87	0.83	0.46	0.79	0.64	0.36	0.62	0.50
1	0.34	0.33	0.33	0.33	0.33	0.66	0.25	0.24	0.09	0.39	0.18
2	0.14	0.12	0.13	0.13	0.17	0.30	0.14	0.07	0.04	0.11	0.07
3	0.07	0.06	0.07	0.07	0.08	0.17	0.07	0.03	0.02	0.06	0.05

Next we consider the dispersions of precipitation between classes (deciles of predictor variables): as an example we present the dispersions of geopotential height Z, temperature T, wind direction WD and relative humidity RH at 850 and 500 hPa in the large domain (Table 2).

Table 2. Normalized dispersions in classes in large domain.

season\variable	Z850	Z500	T850	T500	WD850	WD500	RH850	RH500
spring (MAM)	0.55	0.25	0.32	0.24	1.75	1.82	0.25	0.68
summer (JJA)	0.99	0.4	0.17	0.33	1.41	2.34	0.22	0.81
autumn (SON)	0.43	0.15	0.7	0.33	1.66	2.36	0.25	0.58
winter (DJF)	2.01	0.84	0.37	0.25	1.37	2.68	1.12	2.22

First, an inspection of several dispersions between classes of variables (not only the ones from Table 2), shows that geopotential height Z, relative humidity RH, wind direction WD and average cyclonality ($\sim\nabla^2 Z$) over the whole domain could be used as the most appropriate precipitation predictors for precipitation-relevant events. Better understanding can be achieved by looking upon Figures 3 and 4 with box plots; in this example for the wind direction.

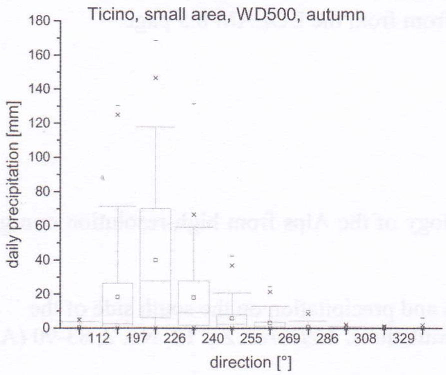

Figure 3. Box plots for daily precipitation according to wind direction at 500 hPa - WD500 in autumn.

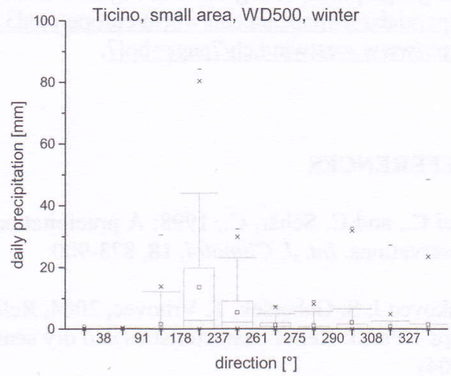

Figure 4. Box plots for daily precipitation according to wind direction at 500 hPa - WD500 in winter.

(Explanation of box plots – short lines represent extremes, crosses the 1st and the 99th percentile, the error bars extend from 5th to 95th percentile, boxes from 25th to 75th percentile, boxes separated by median into two parts; average is represented by squares).

The autumn wind directions distributions is an example showing that the highest precipitation amounts in the small domain are systematically connected with the air flow direction: the maximum is in class 3 or close to it – southerly winds. The winter precipitation is connected with a somewhat different flow regime.

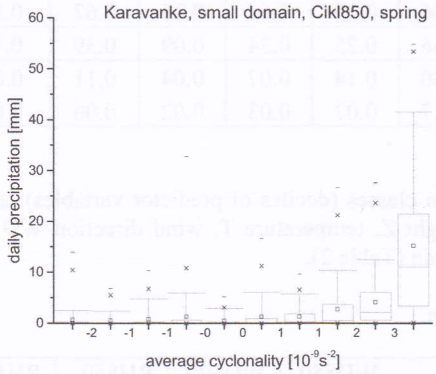

Figure 5. Box plots for daily precipitation according to cyclonality at 850 hPa - WD500 in spring.

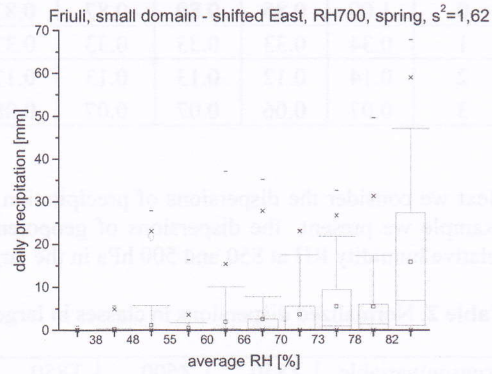

Figure 4. Box plots for daily precipitation according to relative humidity at 700 hPa - WD500 in spring.

Another two examples depict the precipitation distribution according to the average cyclonality for Karavanke and acording to average relative humidity for Friuli (Figures 5 and 6). Other variables (not shown here) contribute to a better classification of precipitation-relevant weather types.

Acknowledgement

Dr. Gregor Gregorič from Meteorological Office of ARSO provided us with the ECMWF reanalyses data. The geographical background of Figure 1 and 2 are taken from : http://alabamamaps.ua.edu/world/europe/med3.jpg, and from from the BOLAM 6.5 page: http://www.westwind.ch/?page=bol7.

REFERENCES

Frei C., and C. Schär, C., 1998: A precipitation climatology of the Alps from high-resolution rain-gauge observations. *Int. J. Climatol.* **18**, 873-900.

Rakovec J. S. Gaberšek, T. Vrhovec, 2004, Relief shapes and precipitation on the south side of the Alps – Part I: Relief characteristics and dry sensitivity simulations. *Meteorol. Z.*, **13**, No. 2, 83-90 (April 2004)

Bardossy A., L. Duckstein, and I. Bogardi, 1995: Fuzzy rule-based classification of atmospheric circulation patterns. *Int. J. Climatol.* **15**, 1087-1097.

Bronštejn I. N., K. A. Semendjajev, G. Musiol, and H. Mühlig, 1997: *Matematični priročnik* (*Handbook of Mathematics*), Ljubljana, 967 pp, Tehniška založba Slovenije.