Plate 2.8 Weather Types and Distribution of Precipitation throughout the European Alps

Introduction

Recurring weather events are frequently observed in the Alpine region. A typical example is a foehn situation, whereby air masses are driven against the Alps from the north or south, resulting in rainfall on the windward side of the mountain chain and a warm, dry wind on the leeward side. Such observations are used in the process of classifying weather types where similar meteorological situations are allotted to the same category. This enables weather events to be described more simply using typical patterns. On the other hand, experience shows that each day's weather is unique and is never repeated in an identical way. Even on days which are allotted to the same category, there may be considerable variations in the temporal aspect, local characteristics or the intensity of meteorological phenomena. Not all cases of large-scale southerly air-flow advected against the Alps result in foehn storms in the valleys on the northern slopes. A description of weather events using a limited series of different weather types is therefore bound to be incomplete.

These two aspects, i.e. the simplified but incomplete description, are at the same time the strength and the weakness of weather type classifications. The present plate therefore not only emphasises the characteristic features of weather types but also illustrates the differences within weather types. As far as hydrology is concerned, weather type categories offer an insight into the links between large-scale atmospheric circulation and precipitation. As a tool for weather forecasting, however, they are not so reliable as modern, numerical procedures.

The present plate describes typical weather types in the European Alps and the distribution of precipitation that results from them. In addition, it illustrates variations in the frequency of weather types between one season and another and between one year and another, as well as of the relationship between prevailing weather types and spatial distribution of air pressure and temperature over continental Europe.

Automatic weather type classification

In many automatic weather type classification systems both the types and categorisation of individual days are ascertained in one calculation step. Figure 1 illustrates this principle: using a statistical procedure (e.g. cluster analysis) all the days included in a given period are divided into groups so that there is less variation in the distribution of pressure or another parameter within the group than between the different groups. The mean values of meteorological parameters (air pressure, precipitation, etc.) of all the days within a group then describe the common characteristics of the days within that weather type.

The classification system chosen for the present plate is known by the abbreviation PCACA [6]. For our purposes, a variant of this system has been used that differentiates between nine weather types and is intended for use in relation to the Alpine region. It has been shown as part of a systematic comparison of classification systems [1] that PCACA is especially suitable for describing the distribution of precipitation in the Alps [8]. This automatic classification system is an alternative to the non-automatic systems after Schüepp and Perret commonly used in Switzerland [5,9] and is suitable for use in climatology owing to the fact of its completely automatic and objective calculation (see also [7]).

Weather types and precipitation

The maps show different weather types. Means for precipitation, temperature deviation from the seasonal mean and air pressure across Europe are indicated for a selection of weather types for each season. In addition, the frequency of wet days and days with moderate rainfall is shown for these weather types, as well as the variation of this frequency in the Alpine region. The frequency within individual weather types is shown in relation to the mean frequency for the entire period studied. The following descriptions show two examples of how the maps can be interpreted: in the case of the westerly weather type, the Alps are affected by a broad western current over central Europe, often on the southern edge of a low pressure system over the North Sea. In winter such weather brings moderate rainfall or snow over the whole of central Europe, the highest rates of precipitation being seen on the western side of the Alps. During such situations, the number of wet days is as much as double the mean, especially on the western edge of the Alps. Heavy rainfall is three or more times likely to occur on the western edge and to the north-west of the Alps. On the southern side, there are still more wet days during such a weather situation, but moderate rainfall is less frequent than the norm.

There are systematic differences in the characteristics of weather types between the various seasons. This can be seen in the example of westerly-type weather, which is shown for all four seasons. In autumn and winter, westerly currents are stronger and the associated precipitation patterns are more pronounced than during spring and summer. Moreover, the arrival of maritime air masses results in comparatively milder temperatures, while during the rest of the year the resulting temperatures tend to be average.

In a high-pressure situation in winter, the centre of the anticyclone is often to the east of the Alps. Its influence will stretch across a large swathe of continental Europe, however, where precipitation will be low. The blocking effect of anticyclones steers low-pressure systems coming in from the Atlantic northwards, which can result in heavy rainfall over the British Isles and Scandinavia. Across the whole Alpine area, the anticyclonic weather type is associated with dry conditions. As a result, for example, in this weather type there are between two and four times fewer wet days in the Alpine countries in winter than the norm. Moderate precipitation is very rare, in fact about 10 times less frequent than the norm.

Despite a pattern of similarity, individual days within the same weather type and the same season may vary considerably. Figure 1 (right-hand side) shows four winter days of the north-westerly weather type. There are considerable differences in the distribution of air pressure, temperature and precipitation, as well as marked deviations from the typical characteristics of the weather type. In conclusion, the significance of a weather type as far as regards meteorological characteristics for individual days is rather limited.

Variations in frequency of weather types

Different types of weather occur with varying frequency in the different seasons (fig. 2, top right). It is particularly noticeable that in summer more or less every other day can be allotted to the flat pressure weather-type category. Situations where there are no marked large-scale weather currents are especially frequent in summer and local weather conditions are then strongly influenced by other factors. Other weather types are almost never seen in summer, although they occur with equal regularity at other times of the year (high pressure, troughs of low pressure, westerly flow over northern Europe, south-easterly flow or south-south-westerly flow). The frequency of westerly, north-westerly and north-easterly weather types does not vary greatly throughout the year.

The frequency of different types of weather also varies from one year to the next. These fluctuations are partly linked to fluctuations in local climatic factors. Figure 2 (bottom) shows an example of such a link to precipitation (see the top left of the four diagrams: “Winter, Alpennordseite”). The lower part shows annual precipitation anomalies calculated for an area on the northern side of the Alps (see map entitled “Untersuchungsgebiete”) for the winter months (December to February). The columns in the upper part of the diagram indicate the relative frequency of weather types for each year given. The nine weather types are arranged in such a way that those on the northern side of the Alps which are on average drier are shown in the column below. The colour of the weather type indicates whether it corresponds on average to dry, quite dry, quite wet or wet conditions.

The diagrams clearly show that part of the annual fluctuations in total precipitation can be explained by fluctuations in the frequency of weather types. In dry years, weather types that bring dry conditions are more common, while in wetter years, weather types that bring more rain are predominant. On the other hand it is also clear that the frequency of weather types does not fully explain precipitation anomalies. If for example 1988 is compared with 1996, it can be seen that in 1988, when westerly and north-westerly weather types, which are normally associated with high precipitation, were more frequent, the actual total volume of precipitation measured was similar to that in 1996. This can only be explained by marked variations within a weather type.

Data sources

The weather-type data used for this plate were obtained from COST 733 [1]. The sea-level air pressure re-analysis data for the Alps and surrounding areas (classification area in figure 2) used for weather type classification were obtained from the ERA-40 [10]. These air pressure data and the precipitation and temperature grids used to draw up the overview maps were part of the ENSEMBLES project [4]. High-resolution precipitation grids for the Alps were used to calculate the frequency of wet days and days with moderate rainfall [2,3].

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Basis for maps