Plate 4.1 Mean Annual Actual Evaporation 1973–1992

Introduction

The term «evaporation» (evapotranspiration) is used to describe the conversion of water from a liquid to a gaseous state. This process occurs from both living (vegetation cover) and inanimate surfaces (water, rock, bare soil) and is dependent on prevailing weather conditions and vegetation. The transfer of water vapour into the atmosphere reduces the amount of water which is available on the surface of the Earth and thus represents an «expenditure item» in the hydrological water balance. At the same time, however, considerable amounts of energy are exchanged, which has a decisive influence on the climate of our planet and in fact helps to maintain thermal consistency. In view of this important influence, evaporation is a major factor in studies of agricultural and forestry production, the identification of regional water resources, low water analysis and in research of the climate.

It is difficult to make reliable estimates of evaporation as the process of evaporation includes not only purely physical but also biological phenomena. Furthermore, evaporation may vary considerably with space and time, mainly owing to different local characteristics such as topography, altitude above sea level, land-use, soil conditions, and to climatic variation. Such factors must be taken into consideration when actual evaporation is determined. In contrast, potential evaporation is based on idealised surfaces with unlimited water supplies.

While the results of some point studies on evaporation carried out over limited periods of time in Switzerland are available, so far there has been a considerable lack of information on the spatial distribution of evaporation (areal evaporation), in particular in the Alps. In order to obtain this missing information an increasing number of simulation models have been used recently to determine water balance components, including evaporation.

An evaporation model

The TRAIN evaporation model, which includes information from comprehensive field studies of evaporation and associated sub-processes [1,2], has been designed to simulate the spatial pattern of actual evaporation. The first step in the TRAIN model is to calculate the various evaporation components, which are then combined with actual evaporation in a second step. For the regionalisation of evaporation physiographical characteristics (topography, land-use, soils) and varying meteorological conditions are included in the calculation process, which is independent on scale. The following elements are taken into account:

- available radiant energy fluxes, allowing for varying insolation and shade conditions;
- data concerning different types of land-use, such as height of vegetation, leaf area development, albedo;
- accumulation of the snow cover, snow-melt, and sublimation from snow and ice;
- interception and interception evaporation;
- evaporation through plants (transpiration) depending on the state of growth of the vegetation, soil moisture and weather conditions, calculated according to Penman-Monteith;
- evaporation from open water;
- availability of water in the soil.

The meteorological data needed for the calculations are provided by the climatic and precipitation measuring network run by the Swiss Meteorological Institute (cf. map 2.1). A combination of altitude-dependent regression and the inverse distance method was used for the areal interpolation of the climatic data [3]. Other data series needed to implement the TRAIN model include the landuse statistics, a digital elevation model and information provided by the latter on gradients and aspect, as well as the digital map of soil suitability of Switzerland indicating soil depth and water storage capacity.

In order to simulate the spatial pattern of evaporation, the whole country was divided into 1 km^2 squares. Full meteorological data were available as daily series, interpolated on the grid. It was thus possible to calculate actual evaporation in daily resolution for the period 1973–1992 for each square.

Results

The 1:500 000 isoline map shows mean annual actual evaporation for the 20-year reference period in question. At first glance the altitude dependency of evaporation is very noticeable, with high rates in the central lowlands, the Alpine valleys and in the Ticino, and low values in the Alps, the Pre-Alps and the Jura mountains. The clear reduction in evaporation with increasing altitude is mainly due to the longer period of snow cover and generally lower temperatures, which more than compensate for the increase in short-wave radiation with altitude, which would normally give rise to higher evaporation. In addition, the soil in mountainous areas is often thin and has a low water storage capacity, and the sparse vegetation enjoys only a short period of growth. Vast tracts of land across the Alps support no vegetation and here evaporation is comparatively low (fig. 4). The larger areas of glaciers can easily be recognised on the map, owing to their extremely low evaporation, as can built-up areas, industrial zones and major transport axes. In contrast, it can be seen that some ranges of hills in the central lowlands generate more evaporation; in these cases this phenomenon is due to forest cover. Evaporation from the lakes, however, is by far the highest.

The evaporation pattern which emerges shows highly fragmented spatial differentiation due to a combination of the influences of climate, altitude and aspect, land-use and soil characteristics. This is especially marked in the 1:1 100 000 pixel map. Owing to generalisation, these extremely localised variations in evaporation are not reflected in the 1:500 000 isogram map, which is based on the former.

Mean evaporation according to surface type throughout Switzerland can be determined by regrouping the squares with similar land-use types. The result shows a specific evaporation of 901 mm for open water, 616 mm for forest, 436 mm for agricultural land and mountain pastures, 434 mm for built-up areas and industrial zones, 234 mm for rocky areas, 199 mm for communication routes and 156 mm for ice and firn; this gives a mean of 484 mm for the whole country.

Figure 2 shows the correlation between altitude and total evaporation; it can be seen that maximum mean annual evaporation is around 560 mm at altitudes of up to approximately 700 m above sea level. If the lakes, with their high evaporation, are included, the mean annual evaporation rises to over 700 mm in the lowest areas. In view of the smaller proportion of surface area occupied by lakes at higher altitudes, the influence of this factor on overall evaporation above 700 m becomes negligeable. Up to an altitude of around 3000 m evaporation decreases steadily to a mean annual value of approximately 230 mm. Above 3000 m there is no significant correlation between altitude and evaporation, which can be partly explained by the lack of data for such altitudes. The correlation pattern between altitude and evaporation shown in Figure 2 for the two main types of land-use (forest and agricultural land/mountain pastures) corresponds to that of mean total evaporation, although absolute values may vary considerably. A marked phenomenon is the high evaporation from forest, which illustrates the importance of interception evaporation in such areas.

Figure 1 shows spatial variation in the annual mean along the Ajoie–Valais profile. Apart from the clear influence of altitude, variations in evaporation are also due to differences in land-cover, aspect and varying soil characteristics. For example, the lower evaporation in the Jura mountains is due not only to altitude, particularly since this area includes large tracts of forest which normally generate high evaporation. In the Jura the comparatively unfavourable soil conditions (shallow soil, poor water retention) which limit transpiration have a clear effect. Evaporation is high in the tree-covered areas of the Ajoie, however, thanks to soil and climatic conditions which are ideal for transpiration. The spatial pattern of evaporation is most marked on the north-west flank of the Alps, where high values for Lake Thun contrast strongly with values of under 200 mm for the largely glaciated areas of the Bernese Alps to the south.

The temporal variation in evaporation given in figure 4 is based on three areas of different land-cover along the Ajoie–Valais profile and daily means are shown for each area. It can be seen that evaporation is virtually zero during the winter months in the agricultural area in the central lowlands. Daily values rise rapidly in April and May, however, when crops and grass are growing at their fastest. The forested area in the Ajoie at times produces considerably more evaporation than the agricultural area in the central lowlands. High values of interception evaporation during winter are a contributory factor here. As will be seen from the rocky area in the Valais Alps, evaporation from bare surfaces can also give rise to a fair amount of evaporation: on the one hand, there is evaporation from snow in the winter and during the spring melt, and on the other, interception evaporation from the bare surfaces is significant. In the latter case, high values during the short summer period imply frequent alternation between wet and dry surface conditions.

The examples given in figure 4 refer to specific areas of 1 km^2 each, and should therefore not be understood as characteristic for the whole region. Large forested areas, which can be found in all parts of the country, were used to obtain a regional picture of evaporation in zones of similar land-use. In order to facilitate comparisons between different regions, only areas at altitudes of between 800 m and 1000 m were studied. Figure 3 shows the results in the form of mean seasonal variability of daily evaporation. Clear differences in evaporation from forested areas can be seen between one region and another. Values are high in the summer for the eastern part of the central lowlands, the Bernese Oberland and the canton of Vaud, while evaporation from forested areas in the Jura and the Ticino is limited during the summer, which once again indicates the comparatively unfavourable soil conditions of these areas. During the winter months evaporation is relatively high for forested areas in the Ticino, more favourable climatic conditions evidently being the main contributory factor in this case.

References

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