SPATIAL VARIATIONS OF DAILY EVAPORATION RATES IN A HIGH ALPINE VALLEY

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The spatial and temporal variations of evaporation in high mountain valleys are not very well known. Due to the many problems associated with direct evaporation measurement and the very heterogeneous topography, soil types, vegetation, and climatological gradients in such catchments, very little regional information is obtainable on the subject. The aims of the study are, therefore, to examine the spatial variations of evaporation for an alpine valley, beginning with the snowmelt season, through the summer season and late autumn, from 1st June to 15th September. Twelve sites ranging in altitude from 1,600 to 2,800m, form the basis of the study. The sites are representative of wet valley floor meadows, high alpine meadows, high alpine pastures, and different categories of alpine shrubs as well as a high periglacial site. Each site was established in a representative region, with aspect and gradient typical for each slope. It is important to emphasise that for such a large regional study it is not sufficient to rely solely on valley floor measurements and to neglect the upper valley slopes. The valley provides an interesting contrast of NE and SW-facing valley slopes which substantially influence insolation and sunshine patterns. The catchment has been subdivided into a valley floor with rich meadows on well-developed soils; slopes covered by forest, over approximately 1/10 of the valley, with intermittent high altitude pastures also on well-developed soils; a predominant zone of alpine shrubs, consisting mainly of *rhododendron ferrugeneum*, etc and growing on poorly-developed soils with a high amount of humus; and a pronounced zone of short alpine grassland on a very stony underground. Above this zone there are mainly scree slopes and fresh moraines, with periglacial activity, including both active and inactive block glaciers and active glaciers. Wet zones, including lakes and moors, are not only predominant on the valley floor but also in remote side valleys and in high-altitude corries.

Evaporation was measured daily at 12 sites (Fig. 1), integrated within a lower and upper valley profile, one within and above the forested area, the other near the glacier in the shrub zone. The other sites were located within the valley floor, and the highest at 2,800m adjacent to the glacier in a pass. Both direct and indirect evaporation was measured. Indirect measurements included meteorological variables while direct measurements included evaporation pans and lysimeters. The sites were divided into three main categories. The main sites included wind direction and velocity, radiation, soil and air temperature, precipitation and humidity measurements, and direct evaporation instruments; secondary sites included lysimeters and evaporation pans as well as wind, temperature and precipitation measurements; and tertiary sites included only evaporation pans, totalisors, and temperature measurements. At each site, additional daily wind, albedo, and air and soil gradients were obtained. In addition, changes in vegetation were incooperated into the measurements. Vegetation growth was monitored at the selected sites in relation to the surrounding vegetation types. During the month of July, a 12-hour evaporation measurement campaign was conducted simultaneously at nine of the sites. These included the upper and lower valley profiles as well as the lake sites.

The results of the summer of 1995 show that the snowmelt season induces the highest evaporation rates whilst the ongoing summer season has fluctuating but generally lower rates. After intensive rainfall, evaporation is particularly high, but rates drop exponentially thereafter. There is a very good correlation between the lysimeter and evaporation pan results (r^2 of 0.96). Some of the preliminary evaporation pan results are illustrated in Fig. 2. It is apparent that the northerly site of the lower profile correlates well with the valley floor site at the same altitude at the end of the valley. The very windy site on the southeast-facing slope of the lower profile also correlates very closely with the windy but northwest-facing site of the upper profile. There is little direct correlation between evaporation and temperature for these sites. Fig. 3 illustrates the pattern of air and soil temperature, as well as percentage humidity from mid June to mid July for the southeast-facing site of the lower profile. The highest evaporation rates were obtained for the snowmelt period, particularly between the 25th of June and 3rd of July. This coincides with a period of low humidity and warm temperatures, as well as rapid vegetation growth.

The NE-facing sites parallel to each other, whilst the SW-facing slopes also show parallel patterns. The highest evaporation rates are found on the valley floor in the windiest regions. Evaporation is not only dependant on exposition and radiation but also on windiness and temperature, and these patterns are not directly correlatable with altitude. Neither does evaporation react directly with the meteorological variables, rather depending on topography and vegetation. Due to these facts, the regionalisation of evapotranspiration needs a succinct geomorphological foundation and cannot be obtained successfully from smart extrapolations of Bowen ratios or similar point measurements alone.

The idea of regionalisation, an approach moving away from conventional point measurements, seeks for new techniques of interpretation carried out by means of two digital terrain models on different scales, the geographic information system ARC/INFO, coupled with an interpretation of LANDSAT TM taken the year before during the same season as the actual evaporation measurements. The digital terrain models serve for various functions, amongst others to calculate the daily potential radiation, whereby the first DTM is based on a grid mesh of 25 by 25m, and the second, on a grid mesh of 10 by 10m for resolution comparison reasons. In addition, the DTM serves to calculate the topographical roughness, which is calculated 3-dimensionally between adjacent grid cells. Of utmost importance is the notion that a detailed geomorphological map forms the basis of the parameterisation of hydrological response units each with their own layers of topographical, soil, vegetation, and meteorological characteristics. The hydrological units form the basis of the regional extrapolation of results, together with the remote sensing techniques used. The results are modelled by means of the Modular Modelling System.

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Figure 1

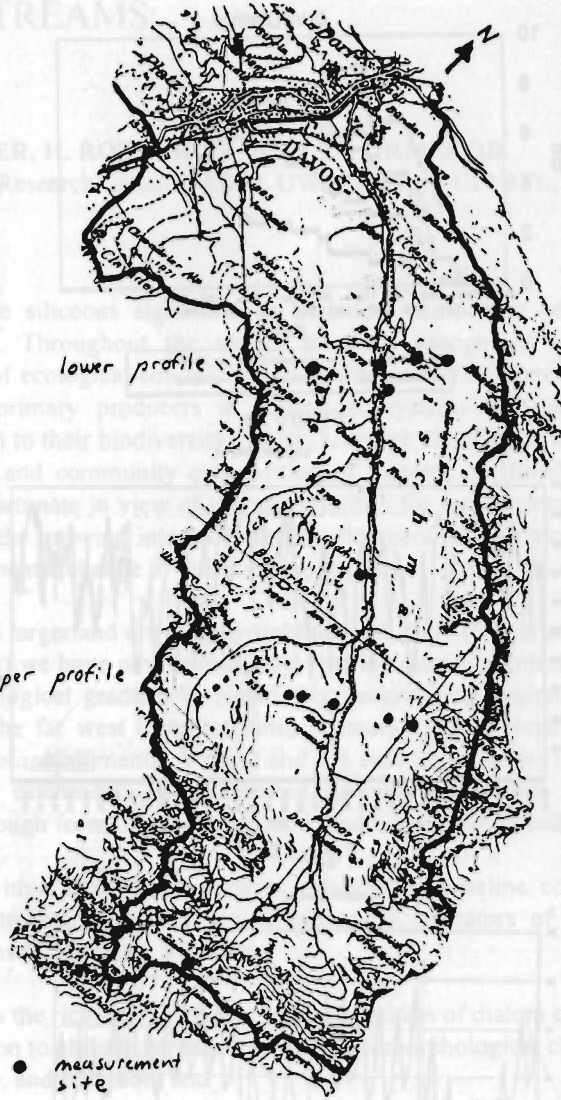

Figure 2

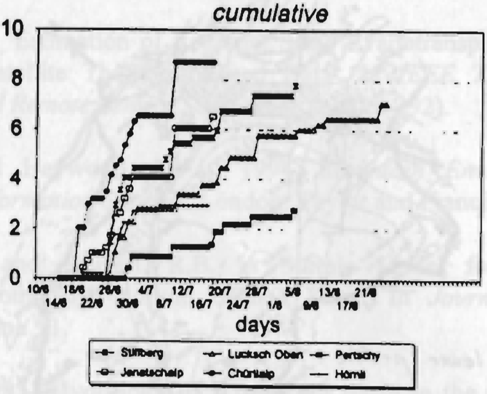

Figure 3a

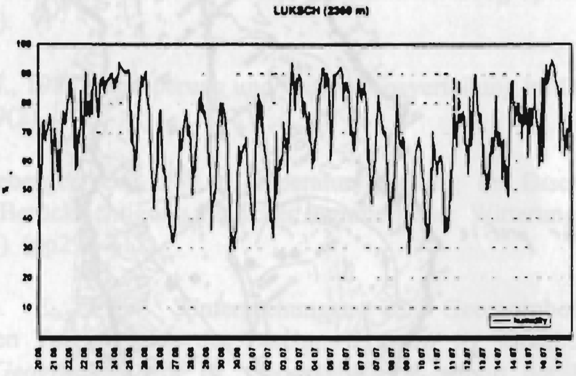

Figure 3b