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# A COMPUTATION OF THE EVAPORATION OVER FINLAND DURING A RAINLESS PERIOD BASED ON THE DIVERGENCE OF THE WATER-VAPOR FLUX

by

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Abstract

A calculation has been made of the evapotranspiration over Finland during a rainless period based on the divergence of the water-vapor flux. Comparisons have been made with simultaneous hydrological observations of the evaporation.

## *Introduction*

During the last few years investigations on the circulation of atmospheric water vapor have demonstrated that the amounts of precipitation and evaporation can be satisfactorily estimated by computing the net influx or outflux of water vapor in the regions in question. A notable example is the hemispherical study of STARR, PEIXOTO and LIVADAS [4], in which an attempt was made to measure the horizontal divergence of the vertically integrated moisture flux over the northern hemisphere for the calendar year 1950. The feasibility of this method was also suggested by the studies on moisture flux over North America made by BENTON and ESTOQUE [1]. These large-scale investigations are of great interest, but it nevertheless seems probable that many characteristic features of the water-balance of a smaller area are lost when very large areas, such as major continents or latitudinal zones, are considered. It therefore seems very desirable to make further investigations on the water-balance of a relatively small area for which adequate aerological observations are available. A good and detailed example of studies of the latter type is that made by Hutchings [2], who computed the transfer of water vapor for the three-month summer period June—August 1954 at four aerological stations in southern England at the following levels: surface, 950, 900, 850, 800, 750, 650, 550, 450 and 350 mb. From the divergence of the flux and the observed precipitation he then computed the evaporation. The results agree very well with the results obtained by other methods. Nyberg [3] has made an investigation, which shows that reliable values of evapotranspiration over Finland based on the computation of water vapor flux at various levels can be obtained even for as short a period as one month, if synoptic charts are utilized for the levels: surface, 950, 850, 700 and 500 mb. Nyberg used the geostrophic approximation, which evidently reduces the accuracy of the computations of the flux divergence.

In the following study basically the same methods have been used as in the afore-mentioned investigations, and it has been shown that in even as short a period as eight days reasonable results for evaporation can be computed from the water vapor flux and even for an area as small as Finland. The case selected for computations was the synoptic period August 9—16, 1959. During this eight-day period an unusually warm and rainless air current prevailed over eastern Scandinavia and Finland. In consequence of the absence of rain, the precipitation term $P$ can be neglected in Eq. (1) and the evaporation intensity $E$ can be computed directly from the equation.

## *Computation of horizontal water vapor flux*

In considering the total amount of moisture in an air column we can distinguish the main factors affecting the total water budgets as follows:

a) The flux of water vapor through the vertical walls and the upper boundary of the column,

b) the flux of liquid water through the same boundaries,

c) the precipitation,

d) the evaporation from the ground.

From the continuity equation of moist air, the following expression for the residual, precipitation minus evaporation $(P—E)$ per unit time and area, can be derived:

$$P - E = -\frac{1}{g}\frac{\partial}{\partial t}\int_0^{p_0} q\,dp - \frac{1}{g}\int_0^{p_0} \nabla_p \cdot (q\mathbf{v})\,dp\,. \tag{1}$$

Here $q$ denotes the specific humidity and $q\mathbf{v}$ the transport vector of the moisture. In deriving Eq. (1) the variations in the total mass of air and the effect (b) have been neglected as small quantities.

The rate of precipitation is negligible in the situation studied here and the local change of water vapor content being a small quantity can also be neglected. This fact is verified in Fig. 2, which shows the

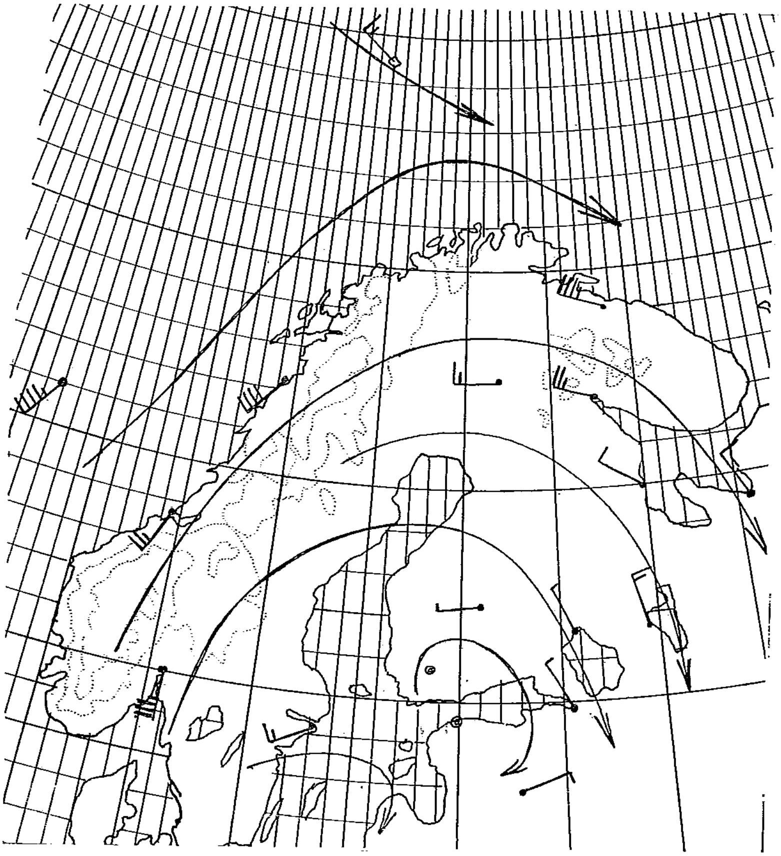

Fig. 1. Time-averaged transport vectors and streamlines of the moisture flux at 700 mb level for the period August 9—16, 1959.

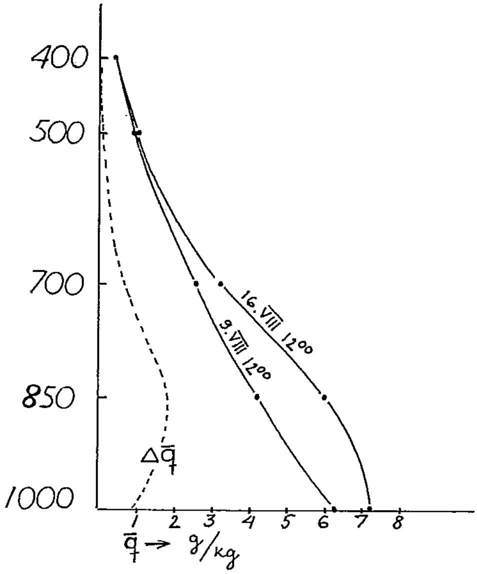

Fig. 2. Vertical distribution of the mean $q$-values and their difference at the beginning and end of the period.

vertical distribution of the mean $q$-values at the beginning and end of the period. The difference $\Delta q$ represented in Fig. 2 corresponds to an evaporation of less than one-tenth of a millimeter per day. Thus for the evaporation intensity the following approximate equation can be used:

$$E \sim \frac{1}{g} \int_0^{p_0} \nabla_p \cdot (q\mathbf{v})\, dp\,, \tag{2}$$

or in the component form:

$$E \sim \frac{1}{g} \int_0^{p_0} \left[ \frac{\partial(qu)}{\partial x} + \frac{\partial(qv)}{\partial y} - \frac{qv}{a} \tan\varphi \right] dp\,, \tag{3}$$

where $a$ is the radius of the earth and the last term is the correction due to the convergence of the meridians.

The aerological stations used in this study are indicated in Fig. 1, which shows the time-averaged transport vectors and the streamlines of the humidity at 700 mb level. The wind and humidity data for every observation time during the period were divided into the zonal and meridional components $qu$ and $qv$, and these were plotted at the levels of 1000, 850, 700 and 500 mb. On each surface the transport-isotaches were analyzed and the values of the divergences were determined from the tangents of the curves $qu(\lambda)$ and $qv(\varphi)$ at the gridpoints shown in Fig. 3.

The results of these calculations are shown in Fig. 3, where the vertically integrated values of the mean vapor-flux divergences are marked at every gridpoint. The unit of the divergence values corresponds to the amount of evapotranspiration as millimeters per 24 hours. Evidently the divergence computations are to some extent uncertain at the gridpoints on the boundary of the area. For instance, some negative values in Fig. 3 are not possible and obviously arise from the boundary errors. The most reliable values are surely at the three points in the middle of the area. For this reason the vertical distribution of the mean

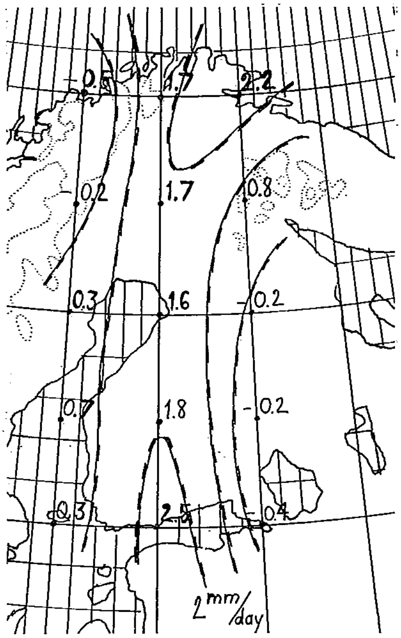

Fig. 3. The field of the mean vapor-flux divergence. Unit: millimeters per 24 hours.

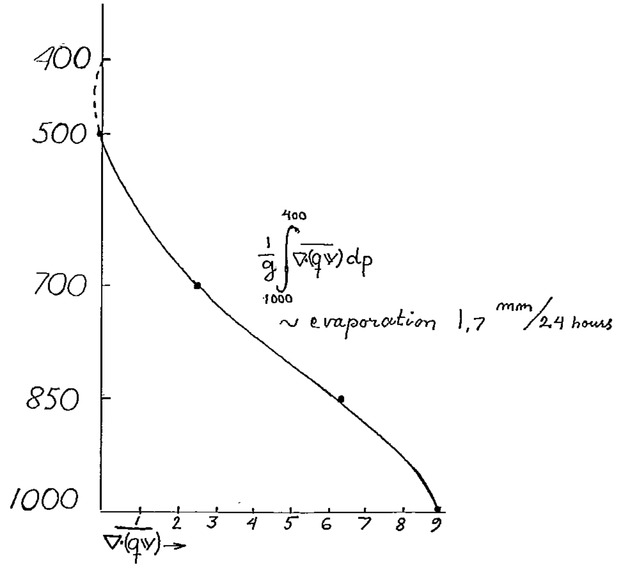

Fig. 4. The vertical distribution of the mean flux-divergence for the three points in the middle of the area.

flux-divergence for the whole period is presented only for these three points in Fig. 4. The mean evaporation intensity for the central part of our area is 1.7 millimeters per 24 hours. This result corresponds very well to the simultaneous evaporation observations made by Mr. J. VIRTA from the Finnish Hydrological Office. The mean value of his observations made at several points in central and northern Finland for the same period is 2.1 millimeters per 24 hours. Obviously, in view of our present knowledge regarding the evaporation observations as well as the evaporation calculations performed in this investigation, we must deal with our results as the mean values of larger areas. At any rate, our results seem to be very reliable and afford a valuable check of the adequacy of hydrological data obtained in other ways.

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