PRECIPITATION RATE AS A FUNCTION OF HORIZONTAL DIVERGENCE

KENDALL R. PETERSON

Hydrometeorological Section, U. S. Weather Bureau, Washington, D. C.

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There is much current interest in the relationship between horizontal velocity divergence and precipitation rates, as well as the relationship with such phenomena as tornadoes. This widespread interest suggests that forecasters and synoptic meteorologists need to acquire a quantitative idea of the magnitude of convergence associated with precipitation rates. The purpose of this paper is to present such relationships based on a fairly realistic model.

The rate of precipitation from a layer of saturated air ascending pseudo-adiabatically was derived by Fulks [1] who used vertical velocity as his basic parameter. Conversely, Bannon [2] used precipitation rates to estimate vertical velocities of the air. Because measurements of

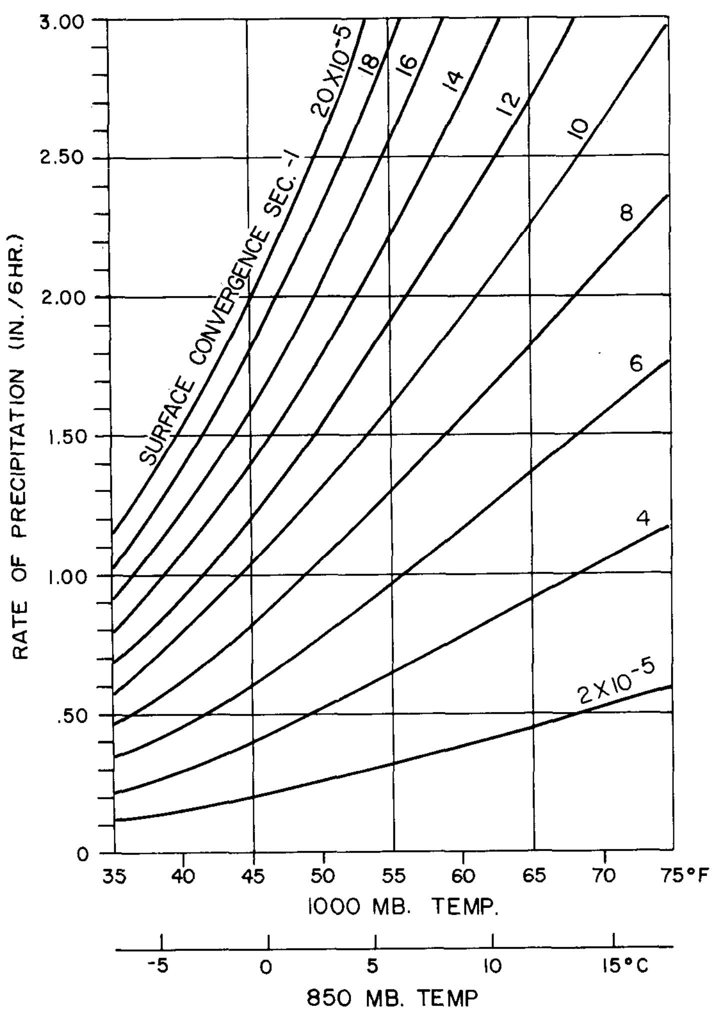

FIGURE 1.—Rates of precipitation from pseudoadiabatically ascending air, assuming constant convergence with height. Convergence values expressed in sec^{-1} may be multiplied by the conversion factor 0.036×10^5 to obtain convergence expressed in hr^{-1}.

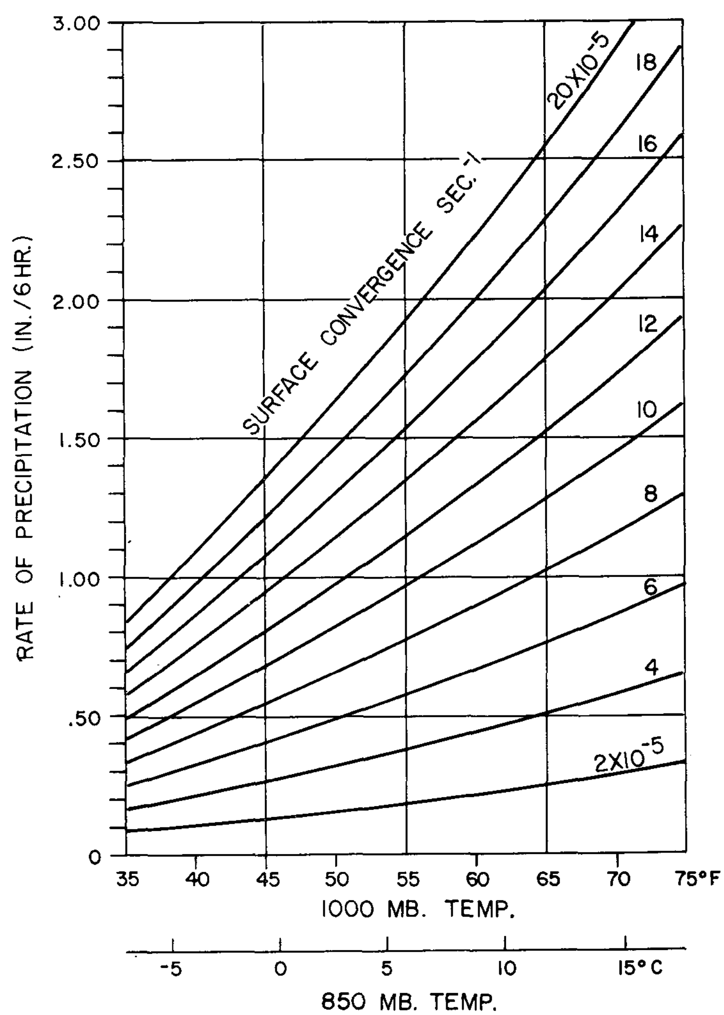

FIGURE 2.—Rates of precipitation from pseudoadiabatically ascending air, assuming a linear decrease of convergence with height to Div $\mathbf{V}=0$ at 4.5 km.

vertical velocity are not available synoptically, Thompson and Collins [3] in computing precipitation rates, used horizontal velocity divergence which can be readily obtained by Bellamy's technique [4] or by other procedures. While Thompson and Collins' method requires divergence computations at several levels for each synoptic case, an approximation of the precipitation resulting from a given value of surface divergence (or vice versa) can be obtained by assuming the vertical variation of horizontal divergence.

Figures 1 and 2 show the precipitation-convergence relationships for two assumed divergence distributions. These relationships were computed under assumptions similar to those used by Fulks, except that instead of his constant (unit) vertical velocity the horizontal convergence was assumed first to be constant with height (fig. 1) and then to have a linear decrease with height to the level of non-divergence (assumed to be at 4.5 km. or approximately 600 mb.) (fig. 2). The latter assumption is believed to be more realistic of atmospheric conditions during periods of cyclonic activity since it closely approximates the model used by Petterssen et al. [5].

Figures 1 and 2 give the rate of precipitation (in./6 hr.) provided that the surface convergence and surface temperature are known. A comparison of the two graphs shows that for the range of surface temperatures used and for a given value of surface convergence, the precipitation rates with a linear decrease of convergence are as much as 55 to 75 percent of the rates with a constant decrease with height. This suggests that the precipitation rate depends largely upon the surface convergence and is not extremely sensitive to the vertical distribution of divergence; thus a linear decrease with height seems to be a reasonable assumption for assessing the magnitude of the relationships. Figure 2 shows that the precipitation rate increases with both increasing surface temperature and increasing convergence.

Given a surface temperature of 60° F. and a surface convergence of 5×10^{-5} sec^{-1}, a 6-hour precipitation of only 0.55 inches is shown by figure 2. Therefore, under the assumptions mentioned, extreme values of surface convergence of about 10^{-3} sec^{-1} must exist in order to obtain heavy rainfall amounts of 2 inches per hour.

For the temperatures used, the greatest 1-km. contribution to the total rainfall rate generally occurred between 3 and 5 km. for a constant convergence, and between 2 and 3 km. for a linear decrease of convergence with height. As a typical example, figure 3 presents histograms of the precipitation rate for 1-km. layers for a surface convergence of 10^{-4} sec^{-1} and a surface temperature of 60° F.

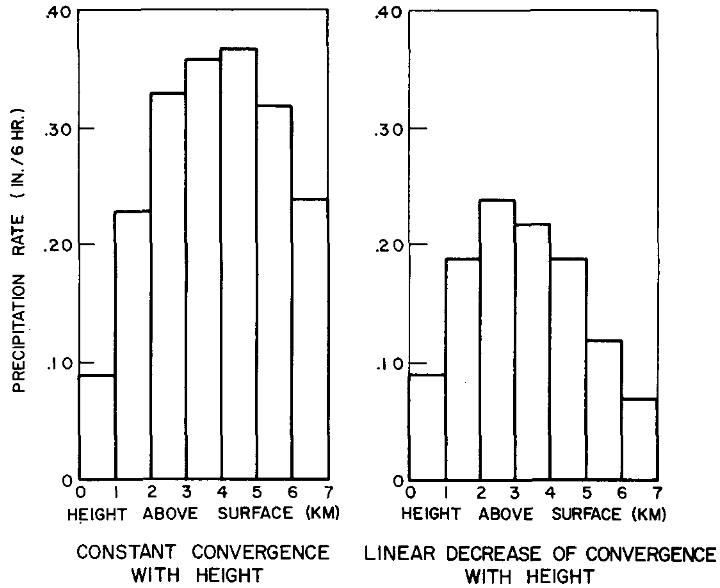

FIGURE 3.—Histograms of precipitation rate for 1-km. layers for a surface convergence of 10^{-4} sec^{-1} and a surface temperature of 60° F.

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