Theoretical Problems

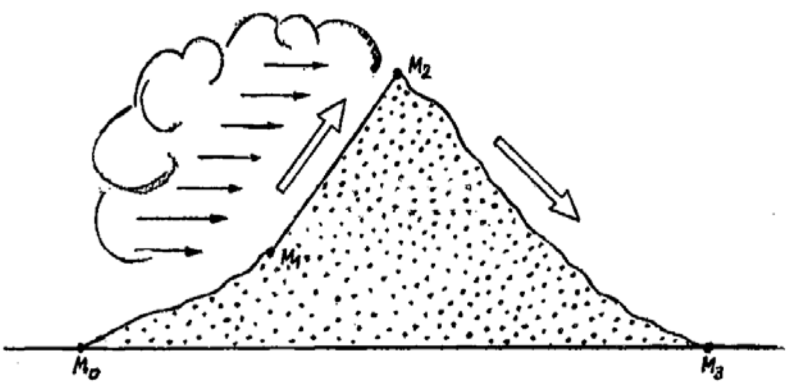
Problem 1: Ascending moist air

Moist air is streaming adiabatically across a mountain range as indicated in the figure.

Equal atmospheric pressures of 100 kPa are measured at meteorological stations M_0 and M_3 and a pressure of 70 kPa at station M_2. The temperature of the air at M_0 is 20° C.

As the air is ascending, cloud formation sets in at 84.5 kPa.

Consider a quantity of moist air ascending the mountain with a mass of 2000 kg over each square meter. This moist air reaches the mountain ridge (station M_2) after 1500 seconds. During that rise an amount of 2.45 g of water per kilogram of air is precipitated as rain.



1. Determine temperature T_1 at M_1 where the cloud ceiling forms.
2. What is the height h_1 (at M_1) above station M_0 of the cloud ceiling assuming a linear decrease of atmospheric density?
3. What temperature T_2 is measured at the ridge of the mountain range?
4. Determine the height of the water column (precipitation level) precipitated by the air stream in 3 hours, assuming a homogeneous rainfall between points M_1 and M_2.

5. What temperature T_3 is measured in the back of the mountain range at station M_3? Discuss the state of the atmosphere at station M_3 in comparison with that at station M_0.

Hints and Data

The atmosphere is to be dealt with as an ideal gas. Influences of the water vapour on the specific heat capacity and the atmospheric density are to be neglected; the same applies to the temperature dependence of the specific latent heat of vaporisation. The temperatures are to be determined to an accuracy of 1 K, the height of the cloud ceiling to an accuracy of 10 m and the precipitation level to an accuracy of 1 mm.

Specific heat capacity of the atmosphere in the pertaining temperature range:

$c_p = 1005\ \mathrm{J \cdot kg^{-1} \cdot K^{-1}}$

Atmospheric density for p_0 and T_0 at station M_0: $\rho_0 = 1.189\ \mathrm{kg \cdot m^{-3}}$

Specific latent heat of vaporisation of the water within the volume of the cloud:

$L_v = 2500\ \mathrm{kJ \cdot kg^{-1}}$

$\frac{c_p}{c_v} = \chi = 1.4$ and $g = 9.81\ \mathrm{m \cdot s^{-2}}$