FORECASTING THE TYPE OF PRECIPITATION FROM CUMULONIMBUS CLOUDS

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Abstract

Original techniques for determining the type of precipitation, including the dangerous phenomena on the basis of experimental observations of the cumulonimbus clouds are described. The experimental basis for the developed method was the data of radar observations of the evolution of cumulonimbus clouds over the territory of the Republic of Moldova in 2006–2011 using the ASU-MRL software-hardware radar complex. It is shown that the error of separation of the precipitation type does not exceed 2% of cases and is largely determined by the accuracy of determination of W_{max}.

1. Introduction

Forecasting the type of precipitation from cumulonimbus clouds (*Cb*) with great vertical development is one of the most pressing problems in improving and enhancing the quality of weather forecasts as well as in solving many applied problems which use information about Cb clouds. It is cumulonimbus clouds that are associated with hazard phenomena, such as hailstorms, heavy rainfalls, etc., which often have disastrous effects. The nature shows examples of their negative consequences every year throughout the world, including the Republic of Moldova.

Synoptic forecasting based on weather maps, satellite information, and the thermodynamic state of the atmosphere is generalized probabilistic data on the area of formation of these clouds and their characteristics, without reference to localized areas of the Earth's surface that can be subjected to adverse effects of heavy rainfall or hail from particular *Cb* clouds. In this regard, more detailed information on the distribution of cumulonimbus clouds in space and time is provided by the use of radar aids (weather radars) for researching the radio-echo fields of *Cb* clouds. To date, on the basis of radar and thermodynamic characteristics of clouds, such as radar reflectivity (Z dBZ), maximum reflectivity (Z_{max}), cloud isosurface top temperature with Z = 45 dBZ (Z_{45}), zero degree isotherm height (H_0), and their combinations, some methods (techniques) for forecasting the type of precipitation events have been developed. However, these methods have considerable zones of ambiguity in indicating the precipitation falling on the Earth (22 to 46%) [1–4]; this leads to significant errors in their use in actual practice and to respective consequences.

It is extremely important to improve the methods (techniques) of precipitation type forecasting for the active influences on Cb clouds in implementing the actions (programs) to prevent hail damage, trigger more precipitation, etc. At present, programs of active influence, in varying degrees, are being implemented in many countries, including the Republic of Moldova.

The establishment of a network of "storm warning" of people about hazard weather phenomena on the basis of radar observations of the cloudy atmosphere is currently widespread in many countries.

In all cases, for the implementation of the above actions, forecasting the type of precipitation from high-intensity cumulonimbus clouds is of great importance.

2. Description of the Proposed Model

The proposed method of forecasting the type of precipitation falling on the Earth's surface is based on the modern concepts of the physics of formation and growth of precipitation particles (liquid and ice phases) and conditions of their accumulation and falling out depending on specific thermodynamic and radar characteristics of convective clouds.

The experimental basis for the developed method was the data of radar observations of the evolution of cumulonimbus clouds over the territory of the Republic of Moldova in 2006–2011 using the ASU-MRL software-hardware radar complex in cooperation of the Special Service for Active Influences on Hydrometeorological Processes of the Republic of Moldova and the Institute of Electronic Engineering and Nanotechnology "D.Gitsu," Academy of Sciences.

The study covered 107 days with synoptic and thermodynamic conditions favorable for the development of deep convection clouds; during these days, hailstorms (with varying diameters) and rainfalls (with varying intensity) from Cb clouds were observed. During these days, using the currently available techniques, prognostic stratifications of air temperature and humidity in the troposphere have been plotted and the following parameters have been determined:

- upper convection level (km);
- convection top air temperature (degrees C);
- zero degree isotherm height (km);
- maximum updraft speed, W_{max} (m/s);
- temperature at maximum updraft speed (degrees C);
- altitude of maximum updraft speed (km), etc.

The most important factor that determines the size of hail particles in clouds is updraft speed. To determine it, we use the formula of N. Glushkova, which is widely applied for this purpose [5]:

$$W_{\max} = \sqrt{2\Delta T_{\max} \cdot \eta}\,, \quad \eta = \frac{T_{h1} - T_{h2}}{T_{h1}} \lg \frac{P_{cond}}{P_m}\,, \quad \Delta T_m = (T' - T)_{\max} \tag{1}$$

$T_{h1} - P_{cond}$ are the condensation-level temperature and pressure;

T_{h2} and P_m are the temperature and pressure at the upper stratum boundary $(T' - T)_{max}$;

$W=W_{max}$, $(T' - T)_{max}$ is the maximum deviation of the condition curve (T′) from the stratification curve(T); it characterizes the instability of the atmosphere.

During the above days, we analyzed 216 convective cells, in which, based on the value of radar parameter Z_{max}, we determined the presence of large precipitation particles in the cloud and recorded the precipitation of hail or rain (ice particles melted in the warm sub cloud layer) on the Earth's surface.

It is found that the separation of the type of precipitation from convective cells of cumulonimbus clouds is most clearly described by the value of dimensionless parameter *K*, which is the ratio between the values of the layer of growth of hail particles in the cloud $\Delta N = N_{45} - H_0$ and the layer of their melting, i.e., the layer below the zero degree isotherm (H_0), as well as by the value of updraft speed in the cloud layer W_{max}. The value of K is calculated through the formula:

$$K = (H_{45} - H_0) / H_0 . \tag{2}$$

The relation of K and W_{max} for various types of precipitation (liquid, ice) is diagrammatically shown in the figure; the table lists the values of these quantities from the curve of their separation.

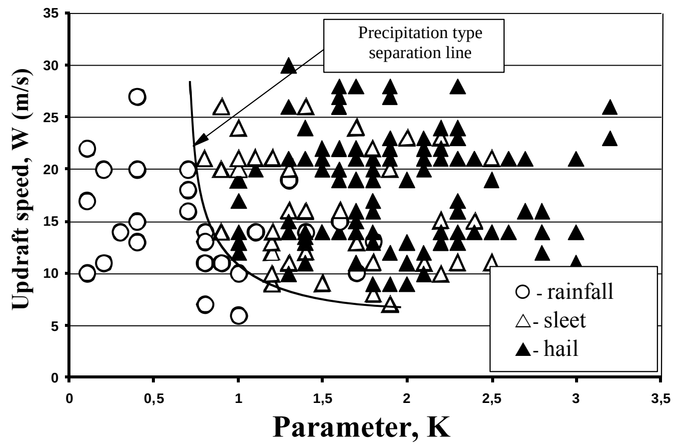

Fig. 1. Type of precipitation from cumulonimbus Cb clouds depending on the values of updraft speed (W_{max}, m/s) and parameter K.

Table 1. Separation of the type of precipitation from cumulonimbus clouds into rain, mixed (rain and solid), and solid precipitation (o—rainfall; Δ—sleet; ▲—hail) according to values of $\mathbf{W_{max}}$ and $\boldsymbol{K}$

W, m/s	k <1	k =1	k =1.25	k =1.5	k =1.75	k =2.0	k =2.25	k =2.5	k =2.75	k ≥3.0
5 <W<7.5	○	○	○							
7.5 ≤W<10	○	○	○	○/Δ, ▲	○/Δ, ▲	Δ, ▲	Δ, ▲			
10 ≤W<12.5	○	○/Δ, ▲	○/Δ, ▲	○/Δ, ▲	○/Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
12.5 ≤W<15	○	○/Δ, ▲	○/Δ, ▲	○/Δ, ▲	○/Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
15 ≤W<17.5	○	○/Δ, ▲	○/Δ, ▲	○/Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
17.5 ≤W<20	○	○/Δ, ▲	○/Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
20 ≤W<22.5	○	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
22.5≤W<25	○	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
25≤W<27.5	○/Δ		Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲
27.5≤W<30			▲	▲	Δ, ▲	Δ, ▲	Δ, ▲	Δ, ▲	▲	▲

The error of separation of the precipitation type does not exceed 2% of cases and is argely determined by the accuracy of forecasting of W_{max}.

To calculate W_{max}, it is necessary to do the following.

1. Based on constant-pressure maps, calculate the prognostic values of temperature (T) and humidity (T_d) at the time of maximum development of convection.
2. On a blank form for an aerological diagram in skew coordinates for the warm period (ADSW), taking into account the obtained values of temperature and humidity, plot a "stratification curve" and a "condition curve" of the atmospheric air. In the absence of advection, it is necessary to use stratification curves (actual) plotted from radiosonde data for 03 h and the ground-level values of T and T_d at the time of maximum heating of the near-ground air.
3. According to the stratification and condition curves on a convective instability (CI-4) aerological diagram, calculate the value of $\Delta \boldsymbol{T_m}$, which is the maximum deviation of the condition curve from the stratification curve, or the degree of contact of the nearest moist adiabatic line and the stratification curve.
4. Based on the stratification and condition curves plotted on a blank form for ADSW, determine the values of other terms appearing in formula (1) and the value of W_{max}.

The zero degree isotherm height (H_0) is also determined according to the stratification curve plotted on a blank form for ADSW.

The maximum level of isosurface with Z = 45 dBZ for each convective cell (its radar image) is determined from a series of vertical cross sections of the cloud that are displayed on a PC monitor after the automatic collection of information on the cloudy atmosphere using an ASU-MRL system.

After substituting the values of N_{45} and H_0 into formula (2), the value of K is calculated.

3. Conclusions

Based on experimental data of radar observations of the evolution of cumulonimbus clouds over the territory of the Republic of Moldova in 2006 ÷ 2011 using the ASU-MRL software-hardware radar complex was developed an original method for determining the type of precipitation, including the dangerous phenomena. In this case error of separation of the precipitation type does not exceed 2% of cases and is largely determined by the accuracy of determination of W_{max}.

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