Technology Nowcasting of Dangerous Weather Phenomena

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Abstract. The paper presents the developed elements of the system nowcasting hazardous weather events in the North Caucasus. The approach is based on complex analysis and extrapolation of instrumental observations data (weather radar, lightning detection network, weather stations, satellite information) and numerical modeling data based on the mesoscale model of the atmosphere. For the detection and warning of dangerous fast-growing convective processes developed automated working place of acceptance, a comprehensive analysis and display of radar, lightning detection, satellite and ground weather information. The system allows you to monitor individual convective cells, determine the speed and direction of their movement, the trend of their development. The evolution of convective cells is also predicted on the basis of calculations based on a three-dimensional numerical model with detailed microphysics. Keywords: nowcasting, thunderstorms, hail, radar data, numerical model.

1. Introduction

The problem of reducing the risk of emergencies caused by particularly dangerous natural phenomena (downpours, thunderstorms and hail) is quite urgent, both for our country and abroad. The safety of human life and protection of various objects from the effects of natural phenomena is largely determined by the timely detection of the location of the dangerous phenomenon and the control of its state. Of great importance for the detection and identification of natural hazards and measures of protection against them have early warning systems based on remote sensing of the cloudy atmosphere. In particular, widespread all over the world gets mesoscale technology - nowcasting [1-4]. It is a technology for collecting, processing, transmitting and ultra-short-term forecasting with 0-3 hours of real-time current weather information in advance.

Currently, the implementation of forecasts for a very short time is based on a wide range of information: ground, radar, satellite, numerical modeling. These are automatic weather stations, which transmit data on pressure, temperature, humidity, wind speed and direction (with averaging from several seconds to several minutes), radar measurements. In addition, the system includes the organization of continuous data streams, assimilation of these data by numerical models with high spatial resolution.

As one of them quickly used of these systems can be noted a system of quick updates (Rapid Refresh, RAP). It is an operational hourly assimilation / modelling system adopted by the US National centers for environmental prediction (NCEP). It consists mainly of a 13 km numerical weather prediction model (installed over North America) and an analysis/assimilation system to initialize the model. RAP is complemented by a model with higher resolution (3 km) and fast update (High-Resolution Rapid Refresh, HRRR). It also updates the data hourly, but covers a smaller area [5]. The
RAP system is developed to provide users who need ultra-short-term weather forecasts with the ability to quickly adjust, for example, for aviation [6].

In our country begin work on the creation of systems of nowcasting, they are in a stage of development. For example, the Hydrometeorological center (Moscow) in 2017 began to create highly accurate short-term forecasts - nowcasting. They give an idea of the weather in a particular area for a few hours, but are able to track the movement of each cloud. Accurate weather forecast is needed not only for people, but also for the economy.

The aim of this work was to develop a software system nowcasting hazardous weather events in the North Caucasus. The approach is based on complex analysis and extrapolation of instrumental observations data (meteorological radar, ground-moving network, weather stations, satellite information) and numerical modeling data based on the mesoscale model of the atmosphere.

2. Comprehensive analysis and display of meteorological information

Currently, information systems are widely implemented in radiometeorology, whose tasks include combining the results of observations of several meteorological radars (WR) with intersecting areas of space survey [7]. Such consolidation of information of several WR allows to receive the uniform complex radar map of the region (or the whole country) which informativeness is much higher, than from separate radars. The total for the time interval maps of hazards allow us to estimate the total area exposed to hydro-meteorological processes.

In order to detect and warn about dangerous fast-developing convective processes in the territory of the North Caucasus, an automated workplace (AWP) of reception, complex analysis and display of radar, lightning, satellite and ground (automatic weather stations) meteorological information was developed at the High-Mountain geophysical Institute [8-10]. This paper presents a description of the software, methods and algorithms for processing data of remote sensing of the atmosphere.

Meteorological information on the AWP comes through communication channels from weather radar MRL-5 [11], new Doppler radars DMRL-C [12], lightning detection system LS8000 [13], automatic weather stations and other sources. Recognition thunderclouds carried radar methods based on the data of lightning detection [10,11,14]. The algorithms of the current forecast of meteorological phenomena dynamics are based on approximation and extrapolation of data, and on formalization of regularities obtained in the study of convective processes [9].

The author has developed an applied software and mathematical software that performs the following functions: receiving data; mapping the spatial structure of the fields of clouds, precipitation and thunderstorms on the background of the terrain map; mapping the dangerous weather phenomena (storm precipitation, thunderstorms) on the background of the map of the administrative boundaries of the region; analysis of the evolution of cloud structures, the direction and speed of moving clouds, cloud systems and weather hazards.

Examples of maps of storm broadcasting in the North Caucasus are presented in figures 1 – 3. Figure 1 shows the cross-linking of radar information from several MPL in 10 minutes time interval with high resolution (250m), which is provided by modern radars.

Figure 2 shows the distribution of lightning discharges in the North Caucasus over a 10-minute time interval according to the LS8000 lightning detection system. On the left, figure 2 shows a color palette - the interval of the number of bits in the storm clouds during observation.

The developed software allows to perform combination of radar, lightning and satellite data.
The developed program is designed to form a single composite maps of weather phenomena on a regional scale (figure 3). The figure shows the identified weather phenomena according to several SCLC and lightning detection system. The circles represent the radius of the individual weather radar. The program uses algorithms and criteria for recognition of dangerous convective processes from [11,14].

System nowcasting severe weather allows you to keep track of individual convective cells in the Northern Caucasus, to determine the speed and direction of their movement, the trend of their development (strengthening or weakening).

However, in the processing of information of different remote sensing of the atmosphere there is a problem associated with different spatial and temporal scales of measurement data. It can be overcome by using numerical modeling [15], which is able to process these data (select approximating functions) and move to uniform grids in time and space. The use of numerical models will contribute not only to improving the reliability of the dangerous weather phenomena forecasting, but also to assessing the degree of their danger (alleged damage). The effectiveness of the models for these purposes can be enhanced through the implementation of parallel calculations of parameters of atmosphere and clouds.
Based on the results of numerical modeling [16,17], three-dimensional radar images of clouds are already in good agreement with observations at this stage of model development. Three-dimensional visualization of convective cloud parameters [18] makes it possible to interpret numerical data in a natural form, coinciding with the actual volume data of the DMRL-C and the lightning detection system, it significantly improves the capabilities of data analysis and decision-making.

Figure 3. A comprehensive map of weather phenomena on the territory of the southern Federal district and the North Caucasus.

In the algorithm of tracking convective cells laid processing of the following options [19]: the emergence of a new object; matching traceable object; separation of the object; merging objects; disappearance of the object.

Figure 4 shows two cells observed by the radar at successive moments of time with an interval of 3.5 min. horizontally, three images are combined, in which two convective cells are depicted. Between fragments (t2) and (t) the time interval is 7 min. Observed in the United drawings, the upper cell develops, the bottom cell collapses. The arrows indicate the direction of displacement of the convective cells.

Figure 4. Mapping of objects in a deterministic tracking.
Technology nowcasting dangerous weather phenomena allows to increase the reliability of warnings on hazardous hydrometeorological processes at the expense of complex processing of continuously incoming information and the results of numerical simulation.

Thus, the paper presents a tried and tested elements of the system nowcasting hazardous weather events in the North Caucasus.

3. Conclusion
In the context of increasing the frequency of natural phenomena and disasters, humanity must improve methods and means to ensure safe living conditions.

Has been developed and is pilot testing three-dimensional non-stationary numerical model of a convective cloud with detailed description of thermo-hydro-dynamic, microphysical and electrical processes.

Developed software combining radar and lightning detection information, which is highly efficient for the identification of hazardous weather events through the use of in addition to radar, more information on lightning discharges with lightning detection system and satellite data. The software is used in storm warning centers and paramilitary services to generate composite maps of weather hazards across the North Caucasus region.

Developed elements of a modern system of nowcasting hazardous weather events in the North Caucasus.

The developed software tools make it possible to alert and prepare in advance the special services, the population and economic facilities to prevent damage from approaching powerful thunderstorms clouds.

4. References
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