Methods of studying and forecasting of storm winds in the territory of Russia

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Abstract. This review paper provides information about methods of storm wind research and forecasting. A storm wind is a dangerous hydrometeorological phenomenon that occurs on land or causes strong waves at sea. The mechanism of development of this phenomenon is associated with a powerful action of some conventional processes in the atmosphere. The importance of studying and forecasting storm-force winds is related to the damage that such winds can cause. Currently, the observation network in Russia is still insufficient for a full-scale assessment of convective phenomena. An exception is the Central Federal District, where there is a continuous coverage of the territory by observation data. Therefore, an important step in this direction is to equip the country's territories with a network of sensors for continuous recording of the meteorological situation. The most optimal device that allows determining the structure and physical characteristics of the origins of storm winds is the weather radar. Another comprehensive approach to assessing the origins and passage of storm winds is the use of remote sensing data. Methods based on the non-hydrostatic general use models WRF-NMM (Weather Research and Forecasting-Nonhydrostatic Mesoscale Model) and WRF-ARW (Weather Research and Forecasting) have made significant progress in predicting storm winds. These models have been developed in the USA. The world practice of forecasts shows that these models can reproduce the mesoscale convective processes quite well and be used in a system of early warning of the danger of strong winds.

1. Introduction

Every year, the number of weather anomalies is growing everywhere. This summer was also marked by squally winds that swept through many regions of the Russian Federation at the beginning of the calendar summer: the hurricane that swept through Moscow turned into not only serious multimillion-dollar material damage, but also injured and killed people.

It should be recalled that storm winds include squalls, tornadoes, which are dangerous hydrometeorological phenomena. According to the classification proposed by the International Committee of such winds are measured in points, where 8 points wind — storm, strong wind with speed of 20 m/s, which hampered any movement against the wind; 12 points — hurricane speeds over 29-33 m/s [1, 2].

Squally winds are accompanied by powerful cumulonimbus clouds. Such cloud formations in meteorology and climatology are called Mesoscale convective systems (MCSs), which are formed due to physical, dynamic processes of the atmosphere, where there is a powerful dynamics of vertical formation of a cold air mass, which according to various estimates can be 200-300 km [3, 4].

It is important to emphasize that the strength of Gale-force winds is very destructive, despite the short-term impact. Statistics of hurricanes in the world show that over the past 200 years, this element...
has caused the death of almost 2 million people. Material losses reached hundreds of billions of dollars. The table shows the most destructive elements that took place in the United States (table 1) [5].

Table 1. Hurricane statistics in the world.

| Hurricane Name | Year | Hurricane Damage (billion $) |
|----------------|------|------------------------------|
| Matthew        | 2016 | 6                            |
| Katrina        | 2005 | 125                          |
| Wilma          | 2005 | 20.6                         |
| Ivan           | 2004 | 18.8                         |
| Andrew         | 1992 | 26.5                         |

In 2016 and 2017, hurricanes occurred in the Orenburg region. The statistics do not contain data on the dead. Nine residential buildings were damaged. Their roofs were torn off. There was also a wire break.

In 2014, a hurricane in Bashkiria led to the destruction of more than a hundred homes. Two elderly men were killed. In June 2017, there was a hurricane in Tatarstan. He caused great damage to the Republic. Houses were damaged; trees and power poles were uprooted. In 2015, there was a devastating hurricane in Chuvashia. Several localities were de-energized. 18 houses and 1 school were damaged. In June 2017, there was a hurricane in the Crimea. More than 2 thousand people were left without electricity [5]. Also, the territory of the Central Chernozem zone is marked by fairly frequent hurricane-force winds [6].

The study of conventional processes in the physics of the earth's atmosphere is of high theoretical and practical significance for specialists who study climate phenomena, which is confirmed by many published works [1-17]. Most of these works are devoted to tropical areas where tornadoes and tornadoes are often observed [8-10]. Such studies were also conducted in moderate [11,12] and high [13,14] latitudes, which have their own development features. So, according to Pomortseva A. A., Kalinin N. A. (2016) the formation and development of the MCSs at these latitudes occurs in the vertical and horizontal layers of the atmosphere, but these dimensions are much smaller than in the tropics. Accordingly, storm winds in moderate latitudes have a local link with the convective segments of the MCSs and they are no larger than 30 km in size. The time of their existence, as a rule, is no more than an hour [4,15].

2. Methods for studying and forecasting storm winds

Storm winds occur, as a rule, in the central part of a powerful thundercloud, with very high humidity in the process of precipitation [8, 9, 15].

Analysis of climate data shows that detecting such weather events is still difficult and often, if such a phenomenon occurs outside a locality, it is impossible to detect it, since the effect of such a storm wind has a short time period (no more than 30 minutes), and the territory of passage is about 10-15 km. Gale force winds are usually recorded in a densely populated area, when their intensity can be judged by the results of damage [4, 16-17].

It should be noted that at present the observation network on the territory of the Russian Federation is still insufficient for a full-scale assessment of convective atmospheric dynamic processes. Therefore, a necessary step in this direction is the technical equipment of the observed territories with a network of continuous sensors [17, 18].

Registration of weather and climate and especially dangerous phenomena is an urgent task [19]. The most optimal weather and climate device that allows you to determine the structure and physical characteristics of the origin of storm winds is a weather radar [15, 19] (Figure 1).
The mechanism of operation of meteorological radars is based on the analysis of data on the dynamics of convective processes in the atmosphere, which are performed in automatic mode [19,20]. The radar system monitors information about the horizontal and vertical structures of the atmosphere based on the radar reflectance of cloud masses, their horizontal and vertical velocity of particles and droplets inside the cloud with a resolution of up to 1 km in 5-10 minutes [4, 17-21].

Another method for monitoring convective atmospheric dynamic processes is the use and processing of remote sensing data obtained (RSDO) from near-earth spacecraft [18, 19] (Figure 2).

Based on the obtained data, it is possible to create composite maps of the spatial and temporal
distribution of storm winds in the studied territories in the mode of constant observation [4].

Knowledge of the nature of thermodynamics’ physics of the earth's atmosphere can be used in methods for predicting the occurrence of storm winds. This direction of meteorological forecasting was widely used in the Soviet period (60s of the XX century) by employees of the Hydro Meteorological Center of the USSR B. E. Peskov, A. I. Snitkovsky, G. D. Reshetov [20-21].

Currently, the Hydro Meteorological Center of Russia is implementing a physical and statistical approach to determining and forecasting storm winds. This approach is based on output meteorological data obtained from a regional hydrodynamic model (a 30-level model for forecasting fields of meteorological elements with a spatial resolution of 75 km) [4, 14, 20].

Another group of methods takes into account the kinetic energy of turbulent pulsations. The calculation of wind gusts is based on the assumption of a normal distribution of wind speed, and the turbulent kinetic energy is considered as the dispersion of wind speed [4, 15-18].

For assessment and prediction of zones of active convection and the formation of storm winds in several scientific reports [12, 13, 23, 24] are available calculation of the potential vortex in the troposphere (vortex II), which considered the presence of positive anomalies of potential vortex in the upper and middle layers of the troposphere, according to the laws of thermodynamics and physics of the Earth's atmosphere leads to a decrease in the convective stability in the lower atmosphere. The use of this method gives grounds for its widespread use in the practice of storm wind forecasts, as it provides a better and more reliable forecast compared to traditional diagnostic methods and can significantly reduce the number of so-called "false alarms"[4, 22].

Methods based on no hydrostatic NMM models (Nonhydrostatic Mesoscale Model) have gained great opportunities in predicting storm-force winds) and the models are known as WRF-ARW (Advanced Research WRF). The proposed models (WRF-ARW and WRF-NMM) were developed in the United States and are widely used in the practice of forecasting the ISS and related atmospheric phenomena (heavy rains and gale-force winds). [23]. The predictive assessment and validity of model forecasts, as well as verification of the results of the presented models, is based on the analysis of data obtained from meteorological radars and RSDO [24]. Based on the models (WRF-ARW and WRF-NMM), developments are underway in the field of early warning of weather, climate and natural threats, such as storm winds, thunderstorms, heavy precipitation, etc. [24].

3. Conclusions
Thus, the combination and integrated use of radar systems and the use of remote sensing Data obtained from near-earth spacecraft makes it possible to give accurate forecasts of the formation and development of mesoscale convective systems in the Earth's atmosphere.

Extensive use of physical and statistical approaches and software models WRF-ARW and WRF-NMM make it possible to build early warning systems for meteorological threats6 and is an important and urgent task in mesometeorology.

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