Long-range forecasting at Hydrometeorological Center of Russia / Vilfand R.M., Zaripov R.B., Kiktev D.B., Kruglova E.N., Kryjov V.N., Kulikova I.A., Tischenko V.A., Tolstych M.A., Khan V.M. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 12-36.

The basic forecasting methods used in the operational practice of the Hydrometcentre of Russia are discussed. The special role of the development and improvement of hydrodynamic models to increase the predictability and to improve the quality of forecasts is emphasized. The main types of operational and experimental products issued by the Hydrometcentre of Russia and NEACC are presented. A statistical interpretation scheme for hydrodynamic forecasts obtained on the basis of the SL-AV model is implemented in the framework of the MOS concept in order to improve the quality of surface temperature and precipitation forecasts. The important role of ensemble (including multimodel) forecasting systems for predicting the characteristics of extreme meteorological phenomena on seasonal and intra-seasonal time scales is shown. The potential of predicting heat waves on intraseasonal (up to 45 days) time intervals based on the hydrodynamic modeling is demonstrated. The examples of consensus forecasts issued during the sessions of the North Eurasian Climate Forums are presented. The main directions and prospects of further development and improvement of long-term forecasting methods are outlined.

Keywords: technology line, global long-range forecasts, synoptic-statistical interpretation, circulation indices, forecast skill scores, consensus forecasts

Tab. 1. Fig. 8. Ref. 45.

COSMO-Ru high-resolution short-range numerical weather prediction system: its development and applications / Rivin G.S., Rozinkina I.A., Astakhova E.D., Blinov D.V., Bundel' A.Yu., Kirsanov A.A., Shatunova M.V., Chubarova N.Ye., Alferov D.Yu., Varentsov M.I., Zakharchenko D.I., Kopeykin V.V., Nikitin M.A., Poliukhov A.A., Revokatova A.P., Tatarinovich E.V., Churiulin E.V. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 37-53.

The COSMO-Ru operational system for the regional short-range numerical weather prediction for the territory of Russia and adjacent regions with a grid spacing of 13.2 to 1 km has operated at the Hydrometcentre of Russia since 2009. Based on operational tests in 2011, 2016, and 2018, the system was recognized by the Roshydromet Central Methodological Commission as the basic national technology for the numerical short-range weather forecasting. The system is fully consistent with the leading weather services of the world both in terms of forecast accuracy and applied technological solutions. The COSMO-Ru output products (being one of the most demanded) are distributed to the overwhelming majority of Roshydromet forecast centers four times a day.

The COSMO-Ru system and its configurations of the COSMO non-hydrostatic model (developed by the COSMO consortium) are in constant development, in particular, due to close cooperation with specialists of the consortium as well as due to the regular updating of COSMO model versions by the consortium. In turn, the achievements of the Russian specialists either have been implemented or are at the stage of implementation in the software complexes of the consortium. The application of modern technological solutions allows to adapt the COSMO-Ru to a wide range of weather support tasks. For example, the special versions of the COSMO-Ru with a grid spacing of 2.2 and 1.1 km for mountain areas were developed for the Sochi Olympic Games in 2014, for the Universiades in Kazan in 2013 and in Krasnoyarsk in 2019. The development of the version describing urban areas for the Moscow region with a grid spacing of 1 km or less started in 2018 that will allow predicting weather in different parts of the city. The commissioning of the new Roshydromet supercomputer is the key factor of maintaining the achieved level of the national high-resolution technologies for numerical weather prediction and its development.

Keywords: numerical weather prediction, non-hydrostatic atmospheric model, model configuration

Tab. 1. Fig. 8. Ref. 39.

Development of deterministic and ensemble numerical weather prediction systems based on the global spectral atmospheric model of the Hydrometcentre of Russia in 2009-2019 / Rozinkina I.A, Astakhova E.D., Tsvetkov V.I., Alferov Yu.V., Ponomareva T.Ya., Nikitin A.E., Vaskova D.V., Kopeykin V.V., Churiulin E.V. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 54-76.

In 2009-2019, the numerical weather prediction system based on the global spectral atmospheric model of the Hydrometcentre of Russia has been developed in the following directions: a) the increase in the spatial detailing from T85L31 with a 120×145 km horizontal resolution in the mid-latitudes to T169L31 (60×72 km) and T339L31 (30×36 km)ж The T339L31 resolution corresponds to the β-mesoscale and allows the model to reproduce the circulation of pressure formations as small as 200-300 km in size (tropical cyclones at their early stages, Arctic mesocyclones) which was not possible with the previous model versions. The model versions with 63 vertical levels have been prepared; b) the development of the ensemble prediction system: in 2015, the first Russian medium-range global ensemble prediction system was operationally implemented. It includes the full cycle of calculations and data processing meeting the WMO requirements for ensemble technologies used in the World Meteorological Centers. Since 2019, after significant additions to the automated data processing technologies of the Hydrometcentre of Russia, the WMC Moscow ensemble numerical products have been available in the international data exchange network; c) the

development of the technology for the boundary data generation for the COSMO-Ru limited-area short-range numerical forecast system aimed to secure the independence from foreign producers. In 2018-2019, the prototype of such technology based on the T339L31 system was developed and tested.

Keywords: numerical weather prediction, ensemble weather prediction, spectral atmospheric model, verification of weather forecasts, mesoscale processes

Fig. 11. Ref. 19.

Development of SL-AV global semi-Lagrangian atmosphere model in 2009-2019 / Tolstykh M.A., Fadeev R.Yu., Shashkin V.V., Travova (Makhnorylova) S.V., Goyman G.S., Mizyak V.G., Rogutov V.S., Shlyaeva A.V., Yurova A.Yu. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 77-91.

The present paper considers the works on the development of SL-AV atmosphere model during last decade and their results. Different versions of the model applied for operational medium- and long-range forecasting are presented. The results are illustrated with the error evolution plots for the forecasts of different meteorological fields over the period of 2012-2019. The plans for a further model development are presented: in particular, works on the development of the new generation global atmosphere model based on the full nonhydrostatic equations. The approaches selected for the development of the future model dynamical core are described.

Keywords: numerical weather prediction, atmosphere global circulation model, solution of atmosphere dynamics equations, parameterizations for subgrid-scale processes, medium-range weather forecasting

Fig. 3. Ref. 41.

Nowcasting of meteorological parameters and hazards: implementation experience and development prospects / Kiktev D.B., Muravev A.V., Smirnov A.V. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 92-111.

The short time interval of nowcasting (up to 2-6 hours) and the presence of spatiotemporal inertia of weather systems make it possible to forecast weather using its statistical extrapolation, while the forecast for the longer periods - with the growing influence of nonlinearity - is mainly based on hydrodynamic modeling.

The paper considers the main nowcasting approaches and nowcasting technologies used at the Hydrometcentre of Russia as well as the prospects of world and domestic developments in this area of forecasting.

Keywords: nowcasting, very short-range weather forecasting, statistical and hydrodynamic modeling, blended forecasts, radar precipitation estimates, seamless forecasting, meteorological support of the Olympic Games

Fig. 4. Ref. 36.

Development of the data assimilation scheme of the Hydrometcentre of Russia / Tsyrulnikov M.D., Svirenko P.I., Gayfulin D.R., Gorbunov M.E., Uspensky A.B. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 112-126.

The operational 3D-Var based data assimilation scheme of the Hydrometcenter of Russia is described. The scheme employs a 3D background-error covariance model developed by the authors. The covariance model is based on 3D auto-regression and moving-average filters. Here, its multi-scale extension is outlined, which allows a numerically efficient analysis scheme. The main direction of development of the data assimilation scheme is the inclusion of ensemble background-error covariances and implementation of an ensemble-variational scheme. Significant attention has been paid to efficient assimilation of satellite observations, including those produced by sensors deployed on Russian spacecraft. Techniques and results of the experimental assimilation of data from the microwave radiometer MTVZA-GY and the infrared hyper-spectral Fourier spectrometer IKFS-2 are presented. A new approach to processing of radio-occultation data aimingto reduce biases in the lower troposphere is outlined, and experimental results are given.

Keywords: data assimilation, weather forecast, satellite observations, ensemble forecast

Tab. 1. Fig. 6. Ref. 23.

Forecast of severe convective weather events in summer / Alekseeva A. A., Losev V. M. / / Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 127-143.

The results of the studies dealing with the forecast of severe convective weather events in summer in the recent decade are presented. The scientific basis of forecasting methods and the ways of their practical implementation are considered. Attention is paid to the automated methods for forecasting heavy rainfalls and squalls (for three gradations of intensity) with a lead time up to 24 hours. In 2011 the methods were recommended for the practical implementation by the Roshydromet Central Methodical Commission on Hydrometeorological and Heliogeophysical Forecasts as

background forecasts. It is noted that the software package for the forecasting of unfavorable and severe convective weather events developed in the Hydrometcentre of Russia provides the forecast of showers, squalls and hailstorms associated with the development of zones of active convection during the warm season and their complexes with the detailing of the type and intensity of phenomena as well as the forecast of cases when such phenomena cause damage. The ways of correcting the automated forecasts (the place and time of occurrence of severe convective events) using the information of Doppler weather radars are demonstrated.

Keywords: forecast, severe convective events, summer, rainfall, squall, hailstorm, diagnosis, radar data

Fig. 7. Ref. 18.

Forecaster's role in a technology for the preparation of short-range weather forecasts / Vasil'ev A.A., Vil'fand R.M. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 144-148.

It is stressed that the main task of a forecaster is to separate noise effects caused by the model imperfection from numerical model forecasts and to eliminate these effects. Forecasters need a constant improvement of knowledge about the formation conditions and physical structure of severe weather events. It also necessary to know the characteristics of numerical models and parameterizations of mesoscale processes. The use of new kinds of observations (satellite and radar data) and the consideration of regional and local effects are also of great importance.

Keywords: forecaster's role, short- and very-short-range weather forecasting, numerical modeling, synoptic correction, empirical determination of biases

Ref. 5.

Marine hydrological forecasts and operational oceanology in the Hydrometeorological Center of Russia / Dumanskaya I.O., Zelenko A.A., Myslenkov S.A., Nesterov E.S., Popov S.K., Resnyansky Yu.D., Strukov B.S. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 149-183.

Information on the development of works in the framework of a relatively new section of physical oceanology associated with obtaining diagnostic and prognostic estimates of the state of the oceans and seas at the Hydrometcentre of Russia in operational mode is presented. The range of the current tasks to be solved for the assessment of the current and expected state of the marine environment and, hence, the composition of the information obtained as a result of their solution is defined by the level of mutual development of the main components of operational oceanology: the observational system, hydrodynamic models and, the computing technologies providing the obtaining of estimates of the main hydrophysical fields interesting to consumers. The history of development of marine forecasts and the achievements of the Hydrometcentre of Russia in the last decade providing a regular production of operational information products are considered: the oceanographic data assimilation system; the technology for forecasting currents and water levels in the seas of Russia; the integrated system for the forecasting of wind wave parameters in the World Ocean and the seas of Russia, with the detailed forecasts in the coastal zone for up to 3-5 days; the method for forecasting dangerous waves in the North Atlantic with an increased lead time up to 10-15 days; ice forecasts for the non-Arctic seas of Russia. The prospects of further development of marine forecasts are outlined.

Keywords: marine forecasts, operational oceanology, observational systems, hydrodynamic models, data assimilation, wind waves, currents, sea level, sea ice

Tab. 2. Fig. 11. Ref. 72.

Current status and prospects for improving the operational hydrological forecasting system in the Hydrometeorological Center of Russia / Belchikov V.A., Borsch S.V., Pavroz Yu.A., Romanov A.V., Silnitskaya M.I., Simonov Yu.A., Khristoforov A.V. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 184-202.

The paper describes the results of the work of the Division of River Hydrological Forecasts of the Hydrometeorological Center of Russia over the past decade. These works were aimed at improving and introducing new methods for forecasting the hydrological regime of rivers and reservoirs, designing the Roshydromet observational network, developing and implementing end-to-end early warning and flood forecasting systems, and developing methods for the verification of hydrological forecasts and their presentation in a probabilistic form. The current state of the operational hydrological forecasting system is assessed, and the prospects for its improvement on the basis of the Russian and world experience are considered taking into account modern technologies and a need to increase the efficiency of water use and protection from hydrological hazards.

Keywords: operational hydrological forecasting system, water and ice regimes of rivers and reservoirs, end-to-end early warning flood forecasting systems, forecast verification, probabilistic form of forecasts

Fig. 2. Ref. 14.

Air quality forecasting system based on chemical transport models / Kusnetsova I.N., Shalygina I.U., Nahaev M.I., Tkacheva U.V., Rivin G.S., Kirsanov A.A., Borisov D.V., Lezina E.A. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 203-218.

A system for the numerical operational prediction of air pollution developed in the Hydrometeorological Center of Russia in the recent years is described. The simulations of pollutant concentrations are performed by the CHIMERE and COSMO-ART chemical transport models (CTM) using the COSMO-Ru7 system weather forecast data and the EMEP and TNO emission databases. The problems of the quality of global emission inventory data and the methods for their correction with account of specific features of regional air pollution are discussed. The developed technique for preparing real data of urban motor vehicle emissions for their assimilation in chemical transport models is briefly described. The examples of the effective application of postprocessing of simulated concentrations are given. The future plans on the CTM-based air quality forecasting system development are presented.

Keywords: air quality forecast, chemical transport model, regional adaptation of emissions, vehicle emissions

Tab. 2. Fig. 4. Ref. 28.

Current state and problems of agrometeorological support of agriculture in Russia / Strashnaya A.I., Bereza O.V., Tarasova L.L., Maksimenkova T.A., Shulgin I.A., Purina I.E., Chekulaeva T.S. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 219-240.

The current state and problems of operational agrometeorological support of the agricultural sector of the Russian economy at the federal level under the observed changes in agroclimatic resources are considered. A brief analysis of agrometeorological observations at Roshydromet hydrometeorological stations is given. The agrometeorologist's workplaces developed in the PROMETEI software and hardware complex for the automated processing of hydrometeorological information are described, the examples of agrometeorological monitoring visualization based on ten-day data are given. The results of new studies in the area of agrometeorological forecasting based on ground observations as well as on the integration of surface and satellite data are presented. The new methods for forecasting the productivity of winter wheat, grain and pulse crops, including those taking into account the wintering conditions of winter crops and sunflower are proposed. The new methods for calculating the sowing time of winter grain crops and for quantifying their state by the time of vegetation termination in autumn based on ground and satellite data are presented. The results of studying the adequacy of identification of dry and wet episodes using the Standardized Precipitation Index (SPI) as compared to the hydrothermal coefficient are given. The results of the joint operational analysis of observations at hydrometeorological stations and satellite data on soil moisture are presented.

Keywords: agriculture, agrometeorological support, agroclimatic resources, productive moisture reserves, atmospheric drought, state of crops, yield forecast, Earth remote sensing, NDVI, satellite monitoring, automated monitoring technologies

Fig. 10. Ref. 35.

Aviation weather forecasting based on numerical weather prediction products / Shakina N.P. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 241-256.

Aviation being the main and the most demanding consumer of meteorological information constantly needs short- and very short-range forecasts as well as nowcasts of weather phenomena and meteorological parameters many of which are currently not predicted directly in the numerical weather prediction models. These parameters include the jet stream wind speed and axis height, tropopause height, clear-air turbulence and possible icing zones, atmospheric convection parameters, zero isotherm height, cloud base and top heights, etc. During the last 40 years, the methods to forecast them have been developed in the Aviation Meteorology Department (AMD) by means of postprocessing output data of global and regional numerical models which are in operational use in the Hydrometeorological Centre of Russia. Such studies require, on the one hand, the deep understanding of physical and dynamical nature of processes and the ability to apply the achievements of dynamic meteorology to the practical tasks; on the other hand, the databases of special observations (in particular, the METAR aerodrome observations) and model output data are needed. So, the important tasks of AMD are the data collection and the database development.

The major area of the AMD work is the operational forecasting of significant weather at the high and medium atmospheric levels which is carried out by the Laboratory for Zonal Forecasting. It daily issues 24 forecast charts transmitted to the aviation consumers. The forecasts of significant weather at low levels (low and convective clouds and its boundaries, turbulence, icing zones, and zero isotherm height as a result of the COSMO-Ru7 model product postprocessing) are published on the special Roshydromet portal.

Keywords: post-processing, numerical weather prediction, jet streams, tropopause, turbulence, icing, convection, low clouds, databases, aerodrome observations, significant weather (SW), SW forecasting at high, medium and low levels

Fig. 3. Ref. 42.

Automated technology of the Hydrometeorological Center of Russia for operational information processing in a high-performance cluster infrastructure / Stepanov Yu.A., Zhabina I.I., Purina I.E., Nedachina A.Yu., Eliseev G.V. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 257-285.

In accordance to the established rules for the preparation and issue of information (forecast) products, Hydrometeorological Center of Russia being the World Meteorological Center of WMO (WMC Moscow) carries out a complex processing of the large flow of heterogeneous information using the automated information processing technology (ASOOI-GMTs) developed by its specialists. The main purpose of ASOOI-GMTs is to organize a centralized, time-controlled start, mutually coordinated (in terms of data and management) computation of many different prognostic and specialized applied tasks belonging to different hydrometeorological areas and to ensure their interaction via shared databases. An integral part of the technology is software systems for receiving, decoding and placing input hydrometeorological data to appropriate databases as well as for generating output products in various formats based on the ASOOI database for local use, in particular, at the Prometei software and hardware complex workplaces, and for the distribution of operational forecast products of the Hydrometeorological Center of Russia to external consumers via the ASPD and GST networks.

The results of the ASOOI-GMTs operation on various autonomous operational servers of the Hydrometeorological Center of Russia exhibited its operability, high reliability and demand by consumers.

As WMC Moscow has been equipped with high-performance cluster platforms, including Tornado, the ASOOI-GMTs technology functionality has been developed and adapted. Currently, these works are carried out on the new CRAY-XC40 supercomputer.

Keywords: cluster, integrated development environment, IDE, three-tier management architecture, programming language, object-oriented approach, scalability, portability, event logging, transaction

Tab. 5. Fig. 6. Ref. 10.

Experience of Providing Weather Services for Major Sports Events in the Russian Federation in 2010–2019 / Luk'yanov V.I., Dmitrieva T.G., Vasil'ev E.V., Zaimskikh G.A. // Hydrometeorological Research and Forecasting, 2019, no. 4 (374), pp. 286-309.

Based on the experience of holding the major sports events in Russia in the recent decade (2014 Winter Olympic and Paralympig Games in Sochi, 2018 FIFA World Cup, 2019 Winter Universiade in Krasnoyarsk, etc.), the concept and features of providing weather services for them are discussed. In particular, the organization of weather services for the major winter outdoor sports events under conditions of complex terrain is considered by example of the XXII Olympic Winter Games and XXIX Winter Universiade. It is shown that the system of weather services for such activities should include the organization of subsystems for observations, weather forecasts, data collection and transmission, staff recruitment and training, etc. The types of the issued forecast products and the requirements for them are presented, the forecasting difficulties are analyzed. It is concluded that the successful provision of weather services for the major sports events and the meeting of the modern consumer's requirements need to carry out the set of activities. The activities include the organization of the three-dimensional observation network with a high spatial and temporal resolution, the development of numerical weather prediction models with a high spatiotemporal resolution, the thorough investigation of local climate, and the high-quality analysis and interpretation of the whole volume of observation and forecast data by forecasters. The experience of establishing the interaction between the Roshydromet team providing weather services for such activities and the organizing committees of competitions, international and national sports federations, and media being an important factor of the successful holding of competitions is discussed.

Keywords: weather services, outdoor sports competitions, detailed forecasts, high-resolution weather prediction model, 2014 Winter Olympics, 2019 Winter Universiade

Tab. 1. Fig. 3. Ref. 6.