RUSSIAN FEDERATION

FEDERAL SERVICE FOR HYDROMETEOROLOGY
AND ENVIRONMENTAL MONITORING OF THE RUSSIAN FEDERATION
(ROSHYDROMET)

ANNUAL JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM (GDPFS) AND RELATED NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2017

Country: **Russian Federation** **Centre:** **WMC/RSMC: Moscow**

31.07.2018

1. Summary of main highlights

Introduced into operation

- COSMO-Ru2 with grid step of 2.2 km for different domains within the European part of Russia;

- System of weekly forecasts release detailed by weeks and months, lead time up to 60 days, based on global Semi-Lagrangian model of Hydrometcenter of Russia and Russian Academy of Siences (model SLAV-2008, 20 ensemble members) and model developed in Main Geophysical Observatory (model T42L14 – 10 ensemble members).

Introduced into quasi-operational trial regime:

- System of statistical radar nowcasting based on ensembles on lag regression iterations for the domain of the Central Federal District (CFD) of Russia on the grid 2x2 km with renewal of output each 10 minutes, forecasting period is 2 hours 30 minutes.

- Model of the deep ocean with inserted mixed layer for use in seasonal atmospheric forecasts;

- System of continuous assimilation of radar meteorological information using the ”nudging” scheme in COSMO-Ru2.

2. Equipment in Use

1) Cluster XSK: “Tornado” 96 nodes, Infiniband, each node: 16 processors (2 x 8 cores) Intel Xeon E5-2690 2.9 GHz;

2) Cluster ICEX: 30 nodes, Infiniband, each node: 2 processors (2 x 10 cores) Intel Xeon E5-2670-v2 2.5 GHz;

3) Intel Xeon E5-4830: 32 processors (4 x 8 cores) 2,13 GHz, memory 256 GB, discs 16 x 1 Tb Ethernet 2 x 1 GbE, IPMI, (Autonomous server-1 of the system of automated processing of information);

4) Intel Xeon E7-4830: 32 processors (4 x 8 cores) 2,13 GHz, memory 256 Gb, discs 16 x 1 Tb Ethernet 2 x 1 GbE, IPMI, (Autonomous server-2 of the system of automated processing of information);

5) Intel Xeon E5-4650 2,70 GHz, 32 processors (4 x 8 cores) memory 1024 Gb, discs 5 x 3 Tb Ethernet 2 x 1 GbE, IPMI, (Autonomous server-3 of the system of automated processing of information)

6) Total disc capacity for clusters: 210 TB

7) Each autonomous server has separate local disk storage system.

3. Used Data and Products Coming from GST and other Communication Systems

Observational data (average number of telegrams per day)

WMC/RSMC Moscow

Code form	Average number of telegrams/day
SYNOP+SHIP	128 000
TEMP	6 500
PILOT	1 650
AMDAR	58 000
AIREP	4 000
SATEM	12 000
SATOB	580 000
BUOY	23 00
BUFR-SYNOP	127 000
BUFR-TEMP	800
BUFR-AMDAR(ASDAR)	700 000

Additionally, heterogeneous satellite information is used - microwave AMSU-A and MHS, radio-eclipsed COSMIC, GRAS and GRACE, scatterometric ASCAT and OSCAT, wind (cloud movement) and humidity fields AMV-Geo, AMV-Polar and AMV-Leogeo. Total amount of information received per day comprises 6,7 GB.

Products received at the WMC/RSMC Moscow:

ECMWF, Reading (analysis and forecasts of the general meteorological fields: GRIB2 0.5°x0.5°);

NMC Exeter (**a**nalysis and forecasts of meteorological fields of extended nomenclature: GRIB1 2.5°x2.5°, GRIB2 1°x1°: forecasting maps for Europe: digital facsimile);

RSMC Tokyo (analysis and forecasts of the basic meteorological fields: GRIB1 1.25°;

RSMC Offenbach (forecasting maps: digital facsimile), Internet (FTP): GRIB 0.25°x0.25°: GRIB 20x20 km – product of the global DWD global forecasting system with horizontal grid step 20 km over the COSMO-Ru computational area necessary for specifying initial and boundary conditions, necessary for the operation of COSMO-Ru7 and COSMO-RuSib models;

WMC Washington: Internet (FTP): analysis and forecasts of meteorological fields of extended nomenclature GRIB 1°x1°, 0.5°x0.5°;

RSMC Novosibirsk: site of the West Siberian Research Institute www.sibnigmi.ru: maps in graphical format of forecasting technologies of RSMC Novosibirsk (primarily, the regional forecasts using COSMO-RuSib;

RSMC Khabarovsk: products from the system of regional mesoscale forecasts for the Far East and seas of the Western Pacific basin.

4. Forecasting System

The global forecasting system of the WMC/RSMC Moscow consists oa the following blocks:

A reception, decoding, primary control and distribution of information from observations in specialized data bases;

B data assimilation systems and objective analysis;

C global atmospheric models and allocation of the results in the data basis;

D systems of modeling results interpretation;

E forming of forecasting models products for transmission via GTS and distribution to ftp-servers.

Limited areas forecasting system of WMC/RSMC Moscow includes the following blocks:

A systems of receiving and control of initial information;

B atmospheric models for bounded areas;

C systems of automated visualization and preparation of data for distribution to users.

4.1 Time schedule and forecast ranges:

The basic initial times for forecasting system (global models SLAV2008, SLAV-20, T339L31 and T169L31), regional model of Hydrometeorological Center of Russia MLp/σ are 00 and 12 UTC. Additionally, systems of objective analysis are functioning for SLAV-20 and COSMO-Ru07/02: for 06 and 18 UTC.

Global forecasting:

SLAV: from initial data 00 UTC – forecasting period: 120 h (readiness time by 03.40 UTC), for initial data 12 UTC – forecasting period: 240 h (produced by 15.50 UTC). Forecasts are delivered to users with 6-hour time step. Technology includes additional procedures for data assimilation of land-surface properties.

T339L31, T169L31: for initial data 00 UTC, forecasting period: 78 h (readiness time – 5.30 UTC); for initial data 12 UTC - forecasting period: 240 hours (readiness time 19 UTC). Forecasts are delivered to users with 6-h time step.

Limited-area forecasting:

COSMO-Ru07: initial data 00 and 12 UTC - forecasting period 78 h, initial data 06 and 18 UTC – forecasting period 48h with time step for products delivered to users of 1 hour for meteogrammes and 3 hours for GRIB generation (readiness time – 4.00, 10.00,16.00, 22.00 UTC).

COSMO-Ru02 for Central (CFD), Southern Federal Districts (SFD), and Tatarstan from initial data 00, 06, 12, 18 UTC – up to 48 hours with time step for meteogrammes presented to users - 1 hour, for GRIB generation – 1 hour.

Regional model of Hydrometeorological Center of Russia MLp/σ with versions for Europe, Siberia, and Far East, using :initial data of 00 and 12 UTC. Lead time - up to 48 h (readiness time – 4.00 UTC and 16.00 UTC). Information is provided in graphical form with 1 hour time step.

Non-hydrostatic mesoscale model of Hydrometeorological Center of Russia with grid spatial step 10x10 km for Moscow and Leningrad Districts and Belorus territory. Lead time is 48 hours. Output is produced with one hour time step. Readiness times are - 5.15 and 17.15 for Moscow and 5.30 and 17.30 for St.-Petersburg and Minsk area.

Short- and medium-range global ensemble forecasting system is integrated once a day with initial start time 12 UTC. Lead time – up to 240 hours with 6-hour time step for output products.

Long-range forecasting systems – once a month starting one day before a coming month with weekly notifications

4.2. Medium-range forecasting systems (4 – 10 days)

4.2.1. Data assimilation, objective analysis and initialization

4.2.1.1. In operational mode:

The global system of data assimilation of the WMC/RSMC Moscow (Hydrometcentre of Russia):

- Recurrence:
  - Cycle of the assimilation system – 4 times a day (00, 06, 12, 18 UTC);
  - Objective analysis using the first guess fields of WMC Washington – 4 times a day for 00, 06, 12, and 18 UTC.
- Method of analysis: 3D-Var
- Products: sea level pressure, surface air temperature, temperature of underlying surface, surface air humidity and wind velocity (10 m), total octant cloudiness, snow depth, geopotential heights and humidity at 38 standard isobaric levels, wind velocity, temperature and air humidity at 38 vertical isobaric levels (from 1075 to 0.5 hPa) at φ/λ grid 0.5º x 0.5º with incremental resolution of 55 km.

3D-Var system is using the following types of meteorological observations:

Traditional contact observations (surface, radiosounding, aircrafts), as well as satellite observations: microwave AMSU-A and MHS, radio-eclipsed COSMIC, GRAS, scatterometric ASCAT and OSCAT, wind (cloud movement) and humidity fields AMV-Geo, AMV-Polar and AMV-Leogeo.

Objective analyses block uses the 6-hour NCEP (USA) forecasts as a first approximation approach.

Initialization – non-linear, normal modes (for spectral T169L31 model) and digital filter (for SLAV-20 model).

Additionally, the system for generation of the initial fields of soil temperature and soil humidity is used in SLAV-20 technology.

4.2.1.2 Research performed in this field:

Works on the local ensemble Kalman filter with ensemble transformation (LETKF) assimilation scheme for the SLAV global semi-Lagrangian model are in progress. Currently, the system assimilates observations from TEMP, SYNOP, SHIP, AIREP, SATOB and demonstrates stable performance for the period of at least two months of cyclic assimilation with 3-dimensional SLAV model. Works on introduction of AMV and ASCAT satellite observation data are carried out. In particular, we have successfully tried to use non-diagonal observation correlation matrix R for AMV data. The FGAT implementation in LETKF is underway.

Research on generation of variation-ensemble scheme of global data assimilation is under way.

4.2.2. Global Models

4.2.2.1. In operation mode:

- Semi-Lagrangian global model SLAV-20 (jointly developed by the Hydrometcentre of Russia and the Russian Academy of Sciences), horizontal longitudinal resolution is 0.225º, variable resolution along latitude – from 0.24º in Southern hemisphere to 0.16º in Northern hemisphere, 51 vertical levels. The maximum forecast range is 240 h for initial data of 12 UTC and 120 h for initial data of 00 UTC.
- The Global spectral atmospheric model T339L31 with 339 spherical harmonics, grid horizontal resolution of approximately 0.56º, 31 vertical levels. The maximum forecast range is 240 h.

4.2.2.2. Research performed in this field:

- In Semi-Lagrangian global model SLAV the planetary boundary layer parameterization was modified, which allowed significantly decrease the error in near-surface temperature.
- Obtained results give the technology basis for realization of new SLAV model version having about 10 km horizontal grid resolution and about 100 vertical levels using the reduced lat-lon grid.
- T339L63 spectral model with the new radiation block is under development.

4.2.3. Operationally available medium-range Numerical Weather Prediction (NWP) Products (Global modeling)

The output of the SLAV-2008, T339L31 and T169L31 models is accommodated at the internal databases of Hydrometcenter of Russia and transmitted to GTS and ftp-servers. A number of maps is transmitted in digital format to prognostic centers of Roshydromet and Hydrometeorological Services of other countries via GTS. Forecasts in graphical format: maps and meteogrammes are available on the website www.meteoinfo.ru.

Forecasts for the Northern and Southern Hemispheres with 6-h time- intervals produce the following characteristics: sea-level pressure, air temperature and humidity at 2 m, wind speed and direction at 10 m, accumulated six-hour precipitation, geopotential heights, wind speed, air temperature and humidity at standard isobaric surfaces, total low and medium level cloud amount.

4.2.4. Applied operational techniques of NWP products (MOS, PPM, KF, Expert Systems etc.), medium range forecast (72 – 240 h)

4.2.4.1. In operational mode:

The system of statistical interpretation of the results of the medium range hydrodynamic modeling (MOS) is used in Hydrometcenter of Russia. The automated system (on the basis of the complex information coming from WMC Moscow, ECMWF Reading, NCEP Washington, RSMC Exeter). System provides the meteorological forecasts of extreme air temperature during the day, accumulated semi-diurnal precipitation, precipitation probability, cloudiness – three times a day, with lead time up to 7 days for 5000 settlements over the globe including the the Russian Federation.

On the basis of MOS system the forecasts of mean air temperature anomalies for the coming 10 days are calculated daily and send to the forecasting centers of Roshydromet three times a month in the form of gif-charts and tables.

4.2.4.2. Research performing in this field:

The system of weather parameters forecasting using the MOS system of the WMC/RSMC Moscow for bounded areas using mesoscale models is under development.

4.2.5. Ensemble Prediction System (EPS) (Number of members, initial state, perturbation method, models used, perturbation of physical parameterizations, post-processing: calculation of indices, clustering)

4.2.5.1. In operational mode:

The ensemble forecasting system for short and medium ranges (12 – 240 h.) based on T169L31 spectral global model and SLAV model.

Ensemble is composed of12 perturbed forecasts with T169L31 model and two control forecasts with models T339L31 and SLAV.

Characteristics of the system:

- Number of ensemble members: 14;
- Number of models: 3;
- Perturbation method: breeding using a total energy norm and regional rescaling;
- Physical parameterizations are not perturbed.

4.2.5.2. Research performed in this field:

- Increasing a set of output products;
- Development of postprocessing and verification methods;
- Studies in the field of combining forecasts based on different models;
- Development of statistical correction methods;
- Development of the ensemble prediction system based on LETKF (40 members) and SLAV model.

4.2.5.3. Operationally available ensemble NWP products

The results of the system operation are placed to the operational database of the Hydrometcentre of Russia; where they are available for Hydrometeorological Centre of Russia forecasters in the form of spaghetti-charts, ensemble means, dispersion maps and maps of probability.

Ensemble meteogrammes for 85 centers of administrative districts of Russia are products placed to the site of Hydrometeorological Centre of Russia (https://meteoinfo.ru/glb-ens-frc) and for Central Asian stations and spaghetti-charts are available at the site http://swfdp-ca.meteoinfo.ru/prognozy/ansamblevye-meteogrammy-moskva (of SWFDP-CA WMO project portal).

4.3 Short-range forecasting system (0-72 hours)

4.3.1. Data assimilation, objective analysis and initialization

4.3.1.1. In operational mode

The same as discussed in Section 4.2.1.1.

A system of continuous assimilation of meteorological information based on “nudging” scheme is implemented on the basis of COSMO-Ru technology.

4.3.1.2. Research performed in this field:

The same as in Section 4.2.1.2.

Additionally, a regional cyclic data assimilation is realized using COSMO-Ru model.

Within the COSMO-Ru technology, the experiments on the assimilation of DMRs data using the “nudging” scheme.

4.3.2. Models for short-range numerical forecasting

4.3.2.1. In operation:

- Non-hydrostatic model COSMO-Ru (developed within the consortium for mesoscale modeling COSMO), version 4.12. Variants:

1) COSMO-RU7 - Horizontal resolution is 7x7 km, 40 vertical levels up to the surface of 100 hPa. The model produces forecasts for the territory of the East Europe, European Russia and Urals.
2) COSMO-Ru2 – grid 2.2x2.2 km for the Central Federal District of Russia (COSMO-Ru2CFO), Tatarstan (COSMO-Ru2VFO) and Northern Caucasia (COSMO-Ru2SFO) inserted into COSMO-Ru7.
3) COSMO-Ru13-ENA. (grid 13.2x13.2 km). Area of integration covers Europe, Northern Asia including the entire territory of Russia, adjacent areas onshore and offshore.

- Non-hydrostatic regional model of the Hydrometcentre of Russia for the domain East Europe – Urals (area of forecast 137x209 grid points, horizontal step 50 km, 30 levels in p and σ system). Two versions of the model were implemented operationally for the Far East and North Caucasus regions with horizontal resolution 25 km. In 2015 horizontal resolution of the model was increased from 50 to 25 km and area of integration was expanded to include the West Europe, entire Russia, Japan, and the seas of West Pacific basin. Model is functioning in operational trial regime.

  The adapted versions of the regional model of the Hydrometcentre of Russia have been put into operation at RSMC Novosibirsk and RSMC Khabarovsk.

- Non-hydrostatic mesoscale model of the Hydrometcentre of Russia for the Moscow and Saint-Petersburg regions, grid 10x10 km.

4.3.2.2. Research performed in this field

- The priority projects studies within the framework of the COSMO Working groups' activities include: development and testing of the enhanced scheme of snow cover, analysis of the specifics of the radiation block operation, development of the scheme describing the turbulent fluxes in the lower boundary layer, development of verification system, and enhanced algorithms of the more accurate initial information preparation based on the observational data SYNOP over the European part of Russia. These include also the development of the forms of presentation of the forecast results to users, and monitoring and studies of success of the near surface weather parameters forecasts using COSMO-RU model (surface air temperature, precipitation, wind speed).
- Development of the COSMO-RuENA (13x13 km) version for the entire territory of Europe, northern Asia and adjusting seas.
- Research of the COSMO-Ru1 version (1x1 km)
- Development of forecasting mesoscale prognostic verification systems.

4.3.3. Available operational products of numerical weather forecasts (modeling for bounded territories)

4.3.3.1 Products of the mesoscale modeling system COSMO-Ru:

Forecasts of the sea level pressure, 3-h accumulated precipitation, surface temperature and wind, cloudiness, 500 hPa height – in the form of GRADS visualized maps. Information in the form of meteorological cables for more than 100 points within the European part of Russia, with time step of 1 h in text and graphical formats: forecasts of sea level pressure, accumulated precipitation considering precipitation forms, temperature and wind profiles from the ground surface up to 500 hPa, cloudiness within the different layers (Information is provided to users in graphical formats via e-mail and distribution at the ftp server.

Wide range of meteorological characteristics at p, z and σ-levels in GRIB formats are provided to users upon request.

4.3.3.2 Products of the versions of regional model of the Hydrometeorological Centre of Russia (50x50 and 25x25 km) for different regions::

The entire territory of Russia and FSU (Former Soviet Union), Europe, eastern part of Atlantic ocean, Northern Caucasia, Black sea, and Far East with adjacent seas.

Types of products:

- Sea level pressure fields, surface temperature and 1-hour precipitation intensity (detailed once an hour);
- Geopotential fields, wind components at 11 standard isobaric surfaces (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100 hPa) detailed each 3 hours;
- Fields of temperature and relative humidity at 9 standard isobaric surfaces (925, 850, 700, 500, 400, 300, 250, 200, 150 hPa) detailed each 3 hours;
- Fields of the semi- and daily accumulated precipitation: continuous, convective and total (lead time 12, 24, 36, 48 hours).

Information is provided to users via data bases and in graphical formats through distribution via e-mail and posting on the site www.meteoinfo.ru (forecasts of the sea level pressure, 1 and 3-hour accumulated precipitation).

4.3.3.3 Production of the mesoscale non-hydrostatic model of the Hydrometeorological Centre of Russia (10x10 km):

Forecasts of surface air temperature and wind are provided with 1 h time step for the Moscow and St.-Petersburg regions. Results are placed to the WMC/RSMC Moscow databases. Data are transmitted via FTP.

4.3.4. Operational techniques for application of NWP products MOS, PPM, KF, Expert Systems, etc.), short range forecasts (0 – 72 h)

4.3.4.1. In operational mode

1) The system of statistical interpretation of the hydrodynamic modeling results (MOS system) is used, (see Section 4.2.4.1).

2) Interpretation system based on statistical correction of the global modeling results: extreme temperatures and values of T2m temperature for the fixed time of measurements, wind speed and direction, accumulated precipitation for meteorological stations of Russia.

3) A system for physical-statistical interpretation based on the regional numerical model results producing short-range forecasts of hazardous weather phenomena (thunderstorms, showers, hail, strong squalls) with the lead time up to 36 h is in operation.

4) Post-processing for aviation:

a) On the basis of output of the COSMO-Ru model with horizontal resolution 7 and 2.2 km: a set of meteorological characteristics and maps (height of the upper and lower boundaries of convective and stratified clouds, levels of icing, turbulence intensity in the lower layer, zero isotherm heigh, cloud amount, etc.) for the airports in the European part of Russia with lead time up to 48 hours.

b) On the basis of the SLAV-2008 model output data: characteristics of convective clouds (height of the upper and lower confines), levels and values of the maximum wind speed, height of dynamic tropopause, heights of the boundaries of icing and turbulence zones, and complex indicators (frontier parameter) with lead time up to 36 hours.

4.3.4.2. Research in this field

Improvement of all systems mentioned in Section 4.3.4.1.

4.3.5 Ensemble Prediction System (EPS) (Number of members, initial state, perturbation method, models and number of models used, perturbation of physical parameterizations, post-processing: calculation of indices, clustering)

4.3.5.1. In operational mode

Limited area ensemble forecasts are not issued.

4.3.5.2. Research performed in this field

Research in model-related forecast uncertainty resulted from imperfection of the atmospheric model and its influence on forecast skill. Development of the method of physical parameterizations stochastic disturbance based on the limited area model COSMO.

4.3.5.3. Operationally available ensemble NWP products

Meteogrammes for 85 sites in Russia and 50 sites of the Central Asian countries and “spaghetti” charts for the Central Asian region (using the global ensemble system) – see Section 4.2.5.2

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

4.4.1 Schemes of nowcasting

4.4.1.1 In operation

A statistical ensemble nowcasting system of precipitation following the consequent observations of seven Doppler radars at the territory of Central Fediral District (CFD) on the grid 2x2 km. The system in based on the consequent fields of precipitation intensity obtained from interpretation of reflectivity from Doppler radars deployed over the territory of the CFD and operated by the Central Aerologic Observatory (CAO) of Roshydromet. Ensembles are generated using lag-regression iterations from four starting initial observational fields. Each ensemble consist 45 fields.

The system produces the precipitation forecasts based on the initial fields of radar precipitation separated with 10 minutes time intervals.

Discreetness of forecasts is 10 minutes, lead time is 2 hours and 30 minutes.

4.4.1.2 Research performed in this field

The nowcasting method based on the forecasts of the COSMO-Ru and WRF-ARW models is under development. Method utilizes information from geostationary satellites and radars.

A nowcasting system on the 1x1 grid.

Result of now casting will include (1) three consequent forecasting fields with 10 minutes interval, (2) fields of statistical characteristics of the ensembles (mean values, medians, RMS, inter-quantile deviation, maximum values), and (3) threshold excess (1, 3, 19 mm/hour) based on numerical ensembles.

4.4.1.3 Nowcasting products

The Russian Hydrometcenter statistical nowcasting products: every 10 min, intensity (mm/hour) for Central Fediral District for 2.5 hour for 10-min intervals are presented in numerical and graphical forms in https://meteoinfo.ru/nowcasting

4.4.2 Models used in very Short-range Forecasting Systems.

4.4.2.1 In operation

Information on models in operational use set out 4.4.2.1

4.4.2.2 Research performed in this field

Adaptation of the non-hydrostatic model COSMO-Ru (developed within the consortium for mesoscale modeling COSMO) for nowcasting in configuration COSMO-Ru2. Studies of impact of radar data via LH nudging method on very-short range forecasting of heavy rains, vertical velocities, active convection areas.

4.5. Specialized numerical predictions (sea waves, storm surge, sea ice, marine pollution transport and weathering, tropical cyclones, air pollution transport and dispersion of pollutants, solar ultraviolet (UV) radiation, air quality forecasting, smoke, sand and dust.

4.5.1 *Assimilation of specific data, analysis and initialization*

4.5.1.1 In operation

The system of oceanographic data assimilation was implemented for initialization in the coupled ocean-atmospheric model for seasonal forecasting. The core of the system is the new model of the first approximation errors field based on the tree-dimensional autoregression filters and moving average. For obtaining the first approximation fields, the general circulation oceanic model is used, calculation area is the entire World ocean, excluding the polar area (north to 80°N).

4.5.1.2 Research performed in this field

A transfer of the oceanographic data assimilation system to calculation of the first guess fields using the global model of general circulation of the ocean NEMO (The Nucleus for European Modelling of the Ocean) in ORCA1 configuration are in progress since 2016. Calculations are carried out at 3-pole grid with horizontal resolution in the main part of the area 1°×1° and 50×50 km in the Arctic basin. Data assimilation is based on consequent scheme "analysis-forecast-analysis: using three-dimensional variation analysis. Operational observations of the sea water temperature and salinity incoming from different observational platforms (drifting and anchored buoys, ship observations, data from ARGO buoys, altimetric measurements).

4.5.2 Specialized models

4.5.2.1 In operation

A) Sea wave forecasting:

1) Forecasts based on the spectral-parametric model of wind waves. The solution for the model is based on the division of the spectrum into 2 components: wind waves and swell waves. For wave forecast the objective analysis data and the output of the global spectral T169L31 atmosphere model of the Hydrometcentre of Russia are used for diagnosis and wind velocity forecast on1.25°x1.25° grid.

2) Operational forecasts of the wind wave characteristics (high of significant waves, average direction of propagation, aver4age length, average period, high and direction of propagation of wind waves high and direction of propagation of swell waves) are given using the spectral model WaveWatch III v.3.14. Forecasts are given for a five day period using meteorological numerical forecast information (model SLAV and GFS system) for the World ocean (grid 0.5°x0.5°) and for distinct seas: Baltic sea (grid 1.2'×1.2', ~2 km), Черного (сетка 6.0'×6.0', ~10 км), Азовского (сетка 1.2'×1.2', ~2 км), Caspian sea (grid 3.6'×3.6', ~6 km), Barents sea (grid 0.25°×0.1°, ~10 km), and White sea (grid 3.0'×1.2', ~2 km). Forecasting results are available at website http://hmc.meteorf.ru/sea/.

B) Forecast of sea level variations and current speed:

The system of short-range forecasting (up to 48 hours) of the sea level variations and current velocity for the Barents and White seas based on calculations of the three-dimensional hydrodynamic model with free surface considering tidal flows with 4-km grid step. As input meteorological information, the atmospheric pressure forecasts from the regional atmospheric model of the Hydrometeorological Centre of Russia Mlσ 25-50 are used. Results of forecasts are placed at the website http://hmc.meteorf.ru/sea/index.html.

C) Long-Range forecasting of sea ice in non-Arctic seas of Russia:

Long-range forecasts (with lead time of several months) of sea ice cover are produced regularly. The forecasts include the first date of ice occurrence in the ports, maximum sea icing, maximum thickness of fast ice, dates of ablution of ports from ice, duration of ice period. Forecasts are based on the notion of the cyclist character of the hydrometeorological elements variability and influence of the thermobaric fields during the period, preceding the icing. As the predictors for forecasts a correlation of the ice parameters and atmospheric pressure and temperature during preceding period.

D) In Hydrologic department of WMC Moscow the models Cosmo-Ru 13 (for European Russia – 7 km), and regional model of Hydrometcentre of Russia (resolution 25 km), as well as forecasts of NCEP-NCAR and ECMWF are used to predict the river water yield are used. During the spring freshets the river ice model develop[ped in Hydrometcentre of Russia is used.

4.5.2.2 Research performed in this field

A new version of the storm surges forecasting model using as the initial data the output of the regional hydrodynamic model Mlσ 22-50.

4.6 Extended range forecasts (10 to 30 days), Models, Ensembles, Methodology

The global general circulation model SLAV-2008 currently represents a core of probabilistic numerical long-range forecast of meteorological conditions. Jointly with Main Geophysical Observatory named after Voeikov (MGO) a pilot technology of weekly detailed scheme of multi model forecast with lead time up to 1.5 months is implemented in WMS Moscow.

4.6.1 Models used

1) Model SLAV (Institute of Numerical Mathematics of Russian Academy of Sciences and Hydrometeorologichescal Centre of Russia).

Model includes a set of parameterization of sub-grid scale processes (short- and long-wave radiation transport, deep and shallow convection, planetary bounder laye energy exchange, gravitational waves drag, parameterization of heat and moisture exchange with underlying surface) developed in Meteo France and meteorological services of RC-LACE consortium (Limited Area modeling for Central Europe) (http://www.rclace.eu) for French global operational model ARPEGE and regional model of international consortium ALADIN/ALARO. Model generates 20 ensemble members using breeding technique of escalating growing modes. Hindcasts initial data are taken from ERA Interim reanalysis. The boundary conditions are determined from initial anomalies of SST during the entire period of forecast.

2) The MGO forecasting system is based on calculation of evolution of atmospheric conditions during the period of forecast using the physically complete global spectral model of general circulation T63L15 (horizontal resolution 1.9°×1.9°, 25 vertical layers, time step ~10 minutes). Period of forecast is 127 days. The previously developed block of physical processes parameterizations is used in the new version of the model excluding calculation of gravity wave resistance and horizontal diffusion, which depend on model resolution and require special adjustment. As a result of model validation some coefficients and conditions used in the schemes of physical processes parameterizations were changed. These changes allowed to minimize the systematic errors.

Boundary conditions (SST) are consider the conservative initial temperature anomalies during the whole period of integration. In comparison with the earlier version of the model the distribution of sea ice is changed. Instead of climatic distribution the initial anomalies of sea ice distribution are used, which kept conservative during 14 days period with further relaxation toads climatic distribution. Considering the observational data during resent 20 years (1992-2011) the climatic fields of SST and sea ice characteristics were determined more precisely. To determine probabilistic forecasting distribution the calculation of ensemble forecast (10 ensemble members) are used.

4.6.1.1 In operation

SLAV-2008. Current and retrospective forecasts are produced every week for 63 days period, and two times a month for 135 days on TORNADO server. Model post processing generates 68 fields of atmospheric and surface meteorological characteristics as an output at the global latitude-longitude grid 1.5° x 1.5 °.

T63L25 Forecasts produced in MGO with the T63L25 model are transmitted operationally to Hydrometcentre of Russia in jointly agreed format. According conditions of operational testing, the following time averaging intervals are chose: 1-7 days (1 week); 8-14 days (2 weeks); 15-21 days (3 weeks); 22-28 days (4 weeks); 1-30 days (1 month); 15-45 days (2-nd month). It is possible to scrutinize the results of forecast with daily discreetness, which let producing forecasts of variable time of averaging. Such flexibility allows to change when necessary time windows of forecast and better estimate the quality of forecast (forecasting monitoring).

Statistical interpretation block implemented at NEACC (The North EurAsia Climate Centre _server includes procedures allowing to realize operatively on the basis on predicted by SLAV-2008 and MGO models global surface air temperature, the temperature at the stations. Method of by linear interpolation is used as the basic method of processing of initial information. Resulting outcome of these procedures is predicted surface air temperature at 70 stations of the FSU.

4.6.1.2 Research performed in this field

A statistical structure of daily climatic archives of air temperature at 2 meters and precipitation necessary for obtaining normalized forecasting anomalies is analyzed.

Possibilities of using teleconnection between surface air temperature and meteorological field characteristic with large-scale patterns of atmospheric circulation and thermal conditions at the underlying surface are considered. It is supposed to estimate additional effects of using teleconnections based on the estimates of the quality of forecasting products.

On the basis of the methods of decision making theory, possibilities of development of methods of selection such products, which could be optimal to some extent or prediction of certain specific meteorological variables in certain geographic conditions are explored.

4.6.2 Operationally available ensemble prediction systems products for 10-30 days:

Forecasts of mean monthly temperature fields are regularly placed on the web-site of the Hydrometcentre of Russia http://www.meteoinfo.ru. Forecasts of air temperature fields near land surface and at the standard isobaric surfaces 500 and 850 hPa, and also those of surface air temperature values for 75 settlements of the former USSR are available to users upon request.

Forecasts of the main meteorological fields, specifically H500, T850, sea level pressure and precipitation with week lead time are placed weekly at the site of NEACC http://seakc.meteoinfo.ru/

4.7 Long-range forecasts (30 days - 2 years), Models, Ensembles, Methodology

4.7.1. In operation:

A technology of global ensemble forecasts with 4 months lead time is realized in Hydrometeorological Centre of Russia. It is based on using models developed in Hydrometeorological Centre of Russia (SLAV-2008) and MGO (T42L14). Maps of the main meteorological fields H500, T850, sea level pressure, surface air temperature, and precipitation are produced with one month and seasonal lead time are produced and placed on NEACC's site http://seakc.meteoinfo.ru/ every month.

Forecasts of the monthly average temperature and precipitation for the FSU territory with lead time up to 6 months for cold and warm periods of the year based on the complex research and development of the scientific institutes of the Russian Hydrometeorological Service (Hydrometeorological Centre of Russia (HMC), Voeikov Main Geophysical Observatory (MGO), Arctic and Antarctic Research Institute, and Far East Hydromet Institute) are available at the site of Hydrometcentre of Russia http://www.meteoinfo.ru.

Within the framework of international cooperation and participation of Hydrometcentre of Russia in APCC project (Pusan, Republic of Korea) global ensemble forecast for 4 months period are produced monthly with one month lead time.

The forecasts for the nearest three months are produced monthly and forwarded to the Asian-Pacific Climate Centre (APCC) (Busan, Republic of Korea) as a contribution to the multi-model ensemble seasonal forecast within the framework of the international project APCN (Asia-Pacific Climate Network) on the long-range forecasting (Seoul, Republic of Korea).

4.7.2. Research performed in this field:

A continuous work on improving the SLAV model is carried out. It is oriented specifically on improvement of blocks of parameterization of short- and long-wave radiation, cloudiness, boundary layer, soil ice, and ozone layer.

Possibilities of adaptation of different statistical methods of regional elaboration are explored (e.g. regression method, by-linear interpolation, probabilistic approach, etc.) aimed to improve global forecast of meteorological fields.

Using the global semi-Lagrangean model SLAV, the studies of regional predictability of low-frequency variability and related regimes of atmospheric circulation at monthly and seasonal time intervals in the Northern Hemisphere are conducted.

Technical efforts on presentation of historical forecasts in compliance with protocols of international projects CHFP и S2S are carried out.

4.7.3. Operationally available products:

Results of the seasonal forecasts of the WMC Moscow using the corresponding hindcast verifications for primary seasons of the year are presented on the site http://wmc.meteoinfo.ru/season, http://wmc.meteoinfo.ru/ПЛАВ.

Every month the results of 3-month seasonal forecasts with one month lead time and the corresponding hindcast seasonal forecasts data of the WMC Moscow are forwarded to the Asian Pacific Climate Centre (APCC) (Busan, Republic of Korea) as an input to the multi-model ensemble seasonal forecast in the framework of the international APCN (Asia-Pacific Climate Network) project on long-range forecasting (LRF). Once a month the seasonal forecasts of the SLAV model with one month lead time are forwarded to the WMO Leading Centre for Multi-model Long-range forecasting in Seoul, Republic of Korea. The list of transmitted forecasting characteristics include monthly averaged and 3-month global fields of geopotential height of the 500 hPa surface, temperature at 850 hPa, sea level pressure, bottom level air temperature and accumulated precipitation for individual ensemble members.

Forecasts of monthly averaged air temperature and precipitation for the FSU territory with 6-month lead time for cold and warm periods of the year based on the complex research and development of the scientific institutes of the Russian Hydrometeorological Service (Hydrometeorological Centre of Russia (HMC), Voeikov Main Geophysical Observatory (MGO), Arctic and Antarctic Research Institute, and Far East Hydromet Institute) are presented on the site http://meteoinfo.ru/veget-period-2014

Forecasts of air temperature and precipitation for one month with zero lead time for the FSU territory based on the NWP (spectral HMC model, spectral MGO model) and synoptic-statistical forecasts are placed on site http://meteoinfo.ru/1month-forc

5. Forecast results verification

5.1. Year average estimates

The global semi-Lagrangian model of the Hydrometcentre of Russia and the Institute for the Computational Mathematics of the Russian Academy of Sciences (SLAV-20)
And Global Spectral model of Hydrometcenter of Russia T339L31
for 00 and 12 UTC initial data in accordance with WMO CBS of 2013

5.1.1. SLAV-20, Northern hemisphere (20N-90N)

5.1.1.1 **SLAV-20, Northern hemisphere**. Sea level pressure

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,026	-0,017	1,361	1,391	0,981	0,981	0,305	0,303
48	0,182	0,104	2,014	2,030	0,959	0,961	0,375	0,373
72	0,203	0,152	2,851	2,867	0,919	0,922	0,448	0,447
96	0,195	0,161	3,866	3,911	0,852	0,855	0,525	0,527
120	0,238	0,196	4,981	5,055	0,758	0,760	0,601	0,605
144		0,249		6,124		0,654		0,669
168		0,289		7,052		0,547		0,723
192		0,294		7,915		0,437		0,768
216		0,279		8,622		0,339		0,798
240		0,264		9,114		0,265		0,820

5.1.1.2. **SLAV-20, Northern hemisphere**, H 500 hPa

Lead time	ME (m)		RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,771	-1,690	10,426	10,858	0,992	0,992	0,168	0,164
48	1,779	0,126	17,129	17,591	0,980	0,979	0,244	0,239
72	1,976	0,313	26,614	27,070	0,950	0,951	0,326	0,320
96	1,180	-0,581	38,312	39,153	0,897	0,896	0,410	0,406
120	0,393	-1,526	51,606	52,348	0,815	0,816	0,491	0,485
144		-2,298		65,225		0,718		0,555
168		-3,255		77,077		0,608		0,614
192		-4,596		87,650		0,501		0,660
216		-6,045		96,681		0,401		0,693
240		-7,475		103,404		0,319		0,718

5.1.1.3. **SLAV-20, Northern hemisphere (20N-90N)** H 250

Lead time	ME (m)		RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-2,248	-3,302	13,843	14,184	0,994	0,994	0,139	0,136
48	1,524	-0,335	23,649	23,818	0,981	0,982	0,211	0,205
72	1,877	-0,023	37,025	37,176	0,954	0,955	0,287	0,280
96	0,517	-1,574	53,357	53,557	0,904	0,905	0,366	0,359
120	-1,053	-3,438	72,012	72,231	0,827	0,828	0,444	0,434
144		-5,460		90,817		0,730		0,503
168		-7,974		107,543		0,624		0,559
192		-11,013		122,485		0,520		0,605
216		-14,344		135,824		0,421		0,638
240		-17,492		146,578		0,337		0,664

5.1.1.4. **SLAV-20, Northern hemisphere (20N-90N)**
Air temperature at 850 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,052	0,006	1,531	1,734	0,916	0,895
48	0,157	0,061	1,846	2,056	0,882	0,857
72	0,192	0,065	2,163	2,373	0,841	0,814
96	0,171	0,025	2,538	2,756	0,783	0,755
120	0,125	-0,036	2,992	3,202	0,703	0,675
144		-0,083		3,641		0,585
168		-0,127		4,048		0,491
192		-0,185		4,427		0,398
216		-0,229		4,743		0,315
240		-0,278		4,987		0,248

1.1.1.4. **SLAV-20, Northern hemisphere (20N-90N)**
Air temperature at 500 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,056	0,071	0,790	0,795	0,973	0,973
48	0,158	0,166	1,196	1,197	0,941	0,943
72	0,175	0,184	1,643	1,648	0,890	0,892
96	0,164	0,161	2,142	2,142	0,815	0,819
120	0,124	0,120	2,641	2,648	0,719	0,724
144		0,064		3,124		0,616
168		-0,011		3,528		0,512
192		-0,092		3,867		0,417
216		-0,181		4,167		0,332
240		-0,271		4,405		0,266

5.1.1.7. **SLAV-20, Northern hemisphere (20N-90N)**
Air temperature at 250 hPa

Lead time	ME (K)	RMSE (K)	KA

(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,056	0,071	0,790	0,795	0,973	0,973
48	0,158	0,166	1,196	1,197	0,941	0,943
72	0,175	0,184	1,643	1,648	0,890	0,892
96	0,164	0,161	2,142	2,142	0,815	0,819
120	0,124	0,120	2,641	2,648	0,719	0,724
144		0,064		3,124		0,616
168		-0,011		3,528		0,512
192		-0,092		3,867		0,417
216		-0,181		4,167		0,332
240		-0,271		4,405		0,266

5.1.1.9. **SLAV-20, Northern hemisphere (20N-90N)**
Wind speed at 500 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,266	-0,232	3,591	3,620
48	-0,288	-0,244	5,011	5,036
72	-0,310	-0,258	6,584	6,609
96	-0,336	-0,280	8,286	8,378
120	-0,356	-0,308	10,035	10,110
144		-0,332		11,674
168		-0,381		13,014
192		-0,416		14,120
216		-0,462		14,963
240		-0,475		15,603

5.1.1.10. **SLAV-20, Northern hemisphere (20N-90N)**
Wind speed at 250 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,388	-0,327	4,671	4,668
48	-0,388	-0,315	7,008	6,958
72	-0,461	-0,392	9,488	9,426
96	-0,567	-0,499	12,171	12,111
120	-0,644	-0,621	14,882	14,801
144		-0,765		17,323
168		-0,891		19,470
192		-1,030		21,297
216		-1,136		22,731
240		-1,172		23,819

5.1.2. SLAV-20, Tropics (20N-20S)

5.1.2.1. SLAV-20, Tropics (20N-20S). H850

Lead time	ME (m)		RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,845	-2,355	7,204	8,186	0,797	0,763	0,508	0,521
48	-2,257	-3,419	8,775	9,728	0,734	0,700	0,562	0,570
72	-2,743	-3,751	9,564	10,167	0,690	0,682	0,580	0,587
96	-3,526	-4,422	10,462	11,058	0,648	0,634	0,598	0,607
120	-4,241	-5,171	11,419	12,267	0,604	0,571	0,617	0,627
144		-5,922		13,645		0,499		0,645
168		-6,686		15,015		0,421		0,665
192		-7,491		16,192		0,353		0,682
216		-8,170		17,343		0,284		0,696
240		-8,760		18,451		0,229		0,709

5.1.2.2. SLAV20, Tropics **(20N-20S)**
H 250 hPa

Lead time	ME (m)		RMSE(m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-8,379	-7,692	12,235	11,734	0,922	0,925	0,365	0,369
48	-7,626	-6,872	13,777	13,447	0,880	0,881	0,428	0,429
72	-8,766	-8,724	16,252	16,242	0,832	0,837	0,464	0,465
96	-13,157	-13,675	20,343	20,629	0,782	0,790	0,502	0,504
120	-18,245	-19,006	25,373	25,833	0,717	0,727	0,540	0,543
144		-24,559		31,505		0,652		0,578
168		-30,070		37,197		0,574		0,610
192		-35,482		42,880		0,493		0,640
216		-40,864		48,562		0,410		0,667
240		-45,905		53,749		0,339		0,689

5.1.2.3.SLAV20, Tropics **(20N-20S)**
Air temperature at 850 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,004	-0,013	1,244	1,335	0,653	0,629
48	0,157	0,097	1,464	1,609	0,549	0,485
72	0,167	0,089	1,576	1,763	0,491	0,398
96	0,118	0,032	1,640	1,840	0,449	0,353
120	0,066	-0,030	1,698	1,912	0,413	0,314
144		-0,099		1,986		0,272
168		-0,170		2,058		0,231
192		-0,233		2,131		0,187
216		-0,296		2,191		0,148
240		-0,352		2,236		0,115

5.1.2.4.SLAV20, Tropics **(20N-20S)**
Air temperature at 250 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,529	-0,509	0,824	0,821	0,782	0,775
48	-0,673	-0,666	1,021	1,027	0,682	0,669
72	-0,768	-0,794	1,156	1,185	0,596	0,584
96	-0,901	-0,956	1,306	1,357	0,522	0,511
120	-1,043	-1,106	1,459	1,521	0,453	0,438
144		-1,257		1,684		0,374
168		-1,395		1,832		0,316
192		-1,524		1,971		0,263
216		-1,657		2,109		0,216
240		-1,782		2,244		0,174

5.1.2.5 SLAV20, Tropics **(20N-20S)**
Wind speed at 850 hPa

Lead time	Mean speed error (м/с)		RMSEV (м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,347	-0,228	3,117	3,074
48	-0,084	0,010	3,775	3,707
72	-0,107	-0,070	4,177	4,056
96	-0,167	-0,115	4,481	4,354
120	-0,195	-0,156	4,800	4,660
144		-0,207		4,951
168		-0,266		5,248
192		-0,309		5,518
216		-0,331		5,744
240		-0,348		5,916

5.1.2.6 SLAV20, Tropics **(20N-20S)**
Wind speed at 250 hPa

Lead time	Mean speed error (м/с)		RMSEV (м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,447	-0,397	4,782	4,813
48	-0,360	-0,341	6,236	6,264
72	-0,429	-0,465	7,373	7,339
96	-0,576	-0,593	8,251	8,271
120	-0,691	-0,719	9,051	9,093
144		-0,862		9,885
168		-0,983		10,644
192		-1,073		11,348
216		-1,176		11,996
240		-1,239		12,529

5.1.3. Verification. SLAV20. Southern hemisphere

5.1.3.1. SLAV20, Southern hemisphere **(20S-90S)**.SLP

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,062	-0,034	2,013	1,909	0,976	0,978	0,250	0,249
48	-0,081	-0,074	2,771	2,649	0,954	0,958	0,325	0,325
72	-0,096	-0,127	3,701	3,597	0,918	0,921	0,400	0,400
96	-0,041	-0,099	4,817	4,741	0,860	0,861	0,472	0,476
120	-0,035	-0,077	6,046	6,021	0,779	0,774	0,541	0,547
144		-0,074		7,299		0,668		0,610
168		-0,052		8,369		0,564		0,659
192		0,013		9,250		0,466		0,699
216		0,078		10,001		0,375		0,728
240		0,140		10,580		0,300		0,749

5.1.3.2. SLAV20, Southern hemisphere **(20S-90S)**. H 500 hPa

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	2,028	2,056	12,065	11,934	0,994	0,994	0,136	0,137
48	2,722	2,715	20,121	20,189	0,982	0,981	0,207	0,208
72	2,434	2,014	30,975	31,214	0,955	0,954	0,279	0,282
96	1,665	1,077	43,993	44,357	0,909	0,906	0,353	0,356
120	0,441	-0,023	58,312	59,228	0,840	0,832	0,422	0,428
144		-1,475		74,324		0,734		0,493
168		-2,763		88,380		0,625		0,549
192		-3,643		99,580		0,522		0,592
216		-4,568		109,023		0,427		0,625
240		-5,515		116,583		0,344		0,649

5.1.3.3. SLAV20, Southern hemisphere **(20S-90S)**. H 250 hPa

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-1,182	-0,983	14,238	14,219	0,995	0,995	0,107	0,108
48	0,121	0,526	25,181	25,500	0,984	0,984	0,168	0,171
72	-0,365	-0,487	39,389	40,309	0,961	0,959	0,233	0,238
96	-2,541	-2,775	56,714	57,920	0,918	0,914	0,301	0,307
120	-5,983	-5,880	76,432	78,046	0,852	0,843	0,368	0,377
144		-9,598		98,850		0,749		0,441
168		-13,325		118,610		0,640		0,496
192		-16,953		134,670		0,537		0,540
216		-20,515		148,427		0,441		0,574
240		-23,792		159,535		0,356		0,600

5.1.3.4. SLAV20, Southern hemisphere **(20S-90S)**
Temperature at 500 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,020	0,040	0,796	0,796	0,978	0,971
48	0,073	0,112	1,220	1,230	0,949	0,936
72	0,069	0,104	1,666	1,683	0,903	0,882
96	0,015	0,054	2,152	2,177	0,835	0,806
120	-0,073	-0,026	2,661	2,694	0,747	0,710
144		-0,126		3,188		0,609
168		-0,230		3,646		0,519
192		-0,344		4,006		0,427
216		-0,460		4,303		0,350
240		-0,574		4,547		0,280

5.1.3.5. SLAV20, Southern hemisphere **(20S-90S)**
Temperature at 250 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,314	-0,295	0,927	0,926	0,972	0,971
48	-0,354	-0,338	1,347	1,358	0,934	0,932
72	-0,407	-0,398	1,788	1,804	0,878	0,874
96	-0,504	-0,505	2,237	2,268	0,803	0,794
120	-0,634	-0,623	2,671	2,715	0,714	0,699
144		-0,747		3,114		0,599
168		-0,867		3,466		0,501
192		-0,991		3,758		0,414
216		-1,104		3,983		0,345
240		-1,199		4,185		0,283

5.1.3.6. SLAV20, Southern hemisphere **(20S-90S)**.
Wind speed at 500 hPa

Lead time	Mean speed error (м/с)		RMSEV (м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,289	-0,251	3,661	3,682
48	-0,285	-0,243	5,320	5,334
72	-0,267	-0,225	7,039	7,062
96	-0,276	-0,243	8,851	8,887
120	-0,340	-0,287	10,653	10,758
144		-0,325		12,523
168		-0,344		14,129
192		-0,403		15,358
216		-0,461		16,301
240		-0,516		17,054

5.1.3.7. SLAV20, Southern hemisphere **(20S-90S)**.
Wind speed at 250 hPa

Lead time	Mean speed error (м/с)		RMSEV (м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,296	-0,311	4,637	4,663
48	-0,300	-0,256	6,982	7,077
72	-0,355	-0,333	9,480	9,639
96	-0,514	-0,478	12,164	12,398
120	-0,698	-0,656	14,949	15,270
144		-0,811		18,047
168		-0,936		20,543
192		-1,067		22,570
216		-1,196		24,159
240		-1,288		25,379

5.3. Global spectal model of Hydrometeorologival Centre of Russia, version T339L31

5.3.1. Estimates T339L31 for 2016 г., Northern hemisphere (20ºN – 90ºN)

5.3.1.1. T339L31, **Northern hemisphere, Sea level pressure**,

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,0	-0,1	1,9	1,9	0,97	0,97	0,34	0,34
48	0,1	0,0	2,8	2,8	0,94	0,94	0,42	0,43
72	0,1	0,0	3,8	3,9	0,89	0,89	0,51	0,51
96		0,0		5,0		0,82		0,59
120		0,0		6,0		0,73		0,67
144		0,0		7,1		0,63		0,73
168		0,1		8,0		0,53		0,78
192		0,1		8,8		0,44		0,82
216		0,1		9,4		0,37		0,84
240		0,1		9,9		0,32		0,86

5.3.1.2. T339L31, **Northern hemisphere,** H 500 hPa

Lead time	ME (м)		RMSE (м)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,4	-0,3	12,8	12,8	0,99	0,99	0,19	0,19
48	-0,5	-0,2	22,4	22,5	0,97	0,97	0,28	0,28
72	0,2	0,4	35,0	34,9	0,93	0,93	0,37	0,37
96		0,4		48,6		0,87		0,45
120		0,1		62,2		0,78		0,52
144		0,4		75,8		0,68		0,59
168		-0,2		87,0		0,58		0,63
192		-0,1		96,9		0,49		0,67
216		-0,1		104,1		0,41		0,70
240		0,0		109,6		0,35		0,72

5.3.1.3. T339L31, **Northern hemisphere,** H 250 hPa

Lead time	ME (м)		RMSE (м)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,2	-0,1	18,0	18,2	0,99	0,99	0,16	0,17
48	-0,3	-0,3	31,3	31,4	0,97	0,97	0,24	0,24
72	0,6	0,4	48,3	48,2	0,93	0,93	0,32	0,32
96		0,9		66,9		0,87		0,40
120		0,7		86,1		0,78		0,47
144		1,4		105,1		0,69		0,53
168		0,3		120,3		0,59		0,58
192		0,3		134,0		0,50		0,61
216		0,3		144,1		0,43		0,64
240		0,4		151,2		0,38		0,66

5.3.1.4 T339L31 **Northern hemisphere,** ,

Air temperature at 500 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,1	0,2	1,1	1,1	0,95	0,96
48	0,0	0,0	1,5	1,5	0,91	0,92
72	-0,2	-0,2	2,0	2,0	0,85	0,85
96		-0,4		2,5		0,77
120		-0,7		3,0		0,68
144		-0,9		3,5		0,57
168		-1,1		3,9		0,48
192		-1,4		4,3		0,40
216		-1,6		4,6		0,34
240		-1,8		4,8		0,29

5.3.1.5. T339L31, **Northern hemisphere,** ,

Air temperature at 500 hP250 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,7	0,7	1,4	1,5	0,92	0,92
48	0,8	0,8	2,0	2,0	0,83	0,84
72	0,9	0,9	2,4	2,4	0,74	0,74
96		0,8		2,7		0,64
120		0,6		3,0		0,55
144		0,4		3,3		0,46
168		0,1		3,5		0,39
192		-0,1		3,6		0,33
216		-0,3		3,8		0,28
240		-0,6		3,9		0,24

5.3.1.6. T339L31, **Northern hemisphere**,

Wind speed at 500 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,3	-0,3	4,3	4,2
48	-0,2	-0,2	5,9	6,0
72	-0,1	-0,1	7,8	7,7
96		-0,1		9,5
120		-0,1		11,1
144		-0,2		12,5
168		-0,2		13,6
192		-0,3		14,6
216		-0,4		15,3
240		-0,4		15,8

5.3.1.7. T339L31, **Northern hemisphere**,
Wind speed at 250 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,9	-0,8	6,0	5,9
48	-0,9	-0,9	8,4	8,4
72	-0,8	-0,9	11,1	11,1
96		-1,0		13,7
120		-1,1		16,1
144		-1,3		18,2
168		-1,5		19,9
192		-1,6		21,4
216		-1,7		22,5
240		-1,8		23,4

5.3.2 T339L31 Estimates 2016 , Tropics (20 N – 20 S)

5.3.2.1 - T339L31, Tropics H 850 hPa

Lead time	ME (м)		RMSE (м)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,1	0,0	7,1	7,2	0,86	0,86	0,48	0,49
48	-0,1	0,0	8,2	8,3	0,83	0,82	0,50	0,52
72	-0,2	0,1	9,5	9,5	0,79	0,78	0,52	0,54
96		0,4		10,7		0,74		0,56
120		0,4		11,9		0,69		0,59
144		0,2		13,1		0,62		0,61
168		-0,2		14,5		0,57		0,64
192		-0,5		15,2		0,55		0,65
216		-0,5		15,9		0,51		0,66
240		-0,5		16,3		0,49		0,68

5.3.2.2 - T339L31, Tropics H 250 hPa

Lead time	ME (м)		RMSE (м)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	2,0	2,1	12,3	12,3	0,91	0,90	0,52	0,52
48	1,6	1,1	14,2	14,1	0,87	0,86	0,55	0,55
72	0,1	0,2	15,8	15,6	0,83	0,83	0,57	0,57
96		0,6		18,0		0,77		0,60
120		-0,4		20,7		0,71		0,63
144		-1,7		23,6		0,64		0,64
168		-3,4		27,1		0,57		0,67
192		-4,7		30,2		0,50		0,69
216		-5,6		32,6		0,44		0,71
240		-6,3		34,7		0,37		0,72

5.3.2.3 - T339L31, Tropics
Air temperature at 850 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	1,4	1,4	1,9	1,9	0,65	0,60
48	1,3	1,2	1,9	1,9	0,58	0,52
72	1,1	0,9	1,9	1,9	0,53	0,45
96		0,7		1,8		0,41
120		0,4		1,8		0,37
144		0,2		1,9		0,35
168		0,0		1,9		0,32
192		-0,2		2,0		0,30
216		-0,3		2,1		0,28
240		-0,5		2,1		0,25

5.3.2.4 - T339L31, Tropics
Air temperature at250 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	1,1	1,0	1,4	1,3	0,70	0,69
48	1,6	1,5	1,9	1,7	0,61	0,61
72	1,7	1,5	2,0	1,8	0,55	0,54
96		1,3		1,7		0,47
120		0,9		1,5		0,42
144		0,6		1,4		0,37
168		0,2		1,3		0,33
192		-0,2		1,4		0,29
216		-0,6		1,5		0,26
240		-0,9		1,7		0,24

5.3.2.5 - T339L31, Tropics
Wind speed at 850 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	0,5	0,6	3,9	3,7
48	0,2	0,2	4,4	4,2
72	-0,1	0,0	4,8	4,7
96		-0,2		5,1
120		-0,5		5,5
144		-0,6		5,8
168		-0,6		6,1
192		-0,7		6,3
216		-0,7		6,5
240		-0,7		6,6

5.3.2.1 - T339L31, Tropics
Wind speed at 250 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV (m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,2	-0,2	5,9	5,8
48	-0,3	-0,3	7,3	7,3
72	-0,2	-0,3	8,5	8,5
96		-0,4		9,5
120		-0,6		10,3
144		-0,8		10,9
168		-1,0		11,6
192		-1,1		12,3
216		-1,3		12,9
240		-1,3		13,3

5.3.3. - T339L31 estimates for 2016 г., Southern hemisphere

5.3.3.1 - T339L31, Southern hemisphere Sea level pressure

Lead time	ME (hPa)		RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,0	0,0	2,2	2,3	0,98	0,98	0,27	0,28
48	0,0	0,0	3,2	3,2	0,96	0,95	0,36	0,36
72	0,0	-0,1	4,5	4,5	0,91	0,91	0,45	0,45
96		-0,1		5,9		0,85		0,53
120		0,0		7,4		0,77		0,60
144		0,0		8,7		0,68		0,65
168		0,0		9,8		0,60		0,70
192		0,0		10,5		0,54		0,73
216		0,0		11,1		0,49		0,75
240		-0,1		11,5		0,45		0,77

5.3.3.2 - T339L31, Southern hemisphere, H 500 hPa

Lead time	ME (m)		RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,9	0,7	16,3	16,4	0,99	0,99	0,18	0,18
48	0,4	0,4	26,8	26,9	0,97	0,97	0,26	0,26
72	0,1	0,4	40,8	41,0	0,93	0,93	0,34	0,34
96		0,7		56,8		0,87		0,41
120		1,1		73,7		0,78		0,48
144		1,4		90,4		0,67		0,54
168		0,9		103,9		0,55		0,59
192		0,8		113,6		0,47		0,62
216		0,8		121,1		0,40		0,65
240		0,8		127,2		0,33		0,66

5.3.3.3 - T339L31, Southern hemisphere , H 250 hPa

Lead time	ME (m)		RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	1,4	1,4	22,7	22,7	0,99	0,99	0,16	0,16
48	0,5	0,8	37,2	37,1	0,97	0,97	0,23	0,23
72	-0,1	0,9	54,3	54,3	0,93	0,94	0,29	0,29
96		1,4		74,4		0,88		0,36
120		2,0		96,6		0,79		0,43
144		2,3		119,3		0,69		0,49
168		1,6		138,4		0,57		0,53
192		1,5		151,8		0,49		0,57
216		1,4		162,2		0,42		0,59
240		1,5		170,6		0,35		0,61

5.3.3.4 - T339L31, Southern hemisphere
Температура воздуха на поверхности 500 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,1	0,1	1,1	1,1	0,95	0,95
48	0,1	0,1	1,6	1,6	0,91	0,91
72	0,0	0,0	2,1	2,1	0,85	0,85
96		-0,2		2,6		0,77
120		-0,3		3,1		0,66
144		-0,5		3,6		0,55
168		-0,7		4,0		0,43
192		-0,9		4,3		0,34
216		-1,1		4,6		0,27
240		-1,3		4,8		0,21

5.3.3.5 - T339L31, Southern hemisphere
Температура воздуха на поверхности 250 hPa

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,6	0,6	1,5	1,5	0,92	0,92
48	0,6	0,6	2,0	1,9	0,85	0,85
72	0,6	0,6	2,3	2,3	0,78	0,78
96		0,4		2,6		0,71
120		0,2		2,9		0,63
144		0,0		3,2		0,55
168		-0,3		3,5		0,47
192		-0,6		3,7		0,42
216		-0,9		3,9		0,38
240		-1,1		4,0		0,35

5.3.3.6 - T339L31, Southern hemisphere, Wind speed at 500 hPa

Lead time	MEAN SPEED ERROR (м/с)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,4	-0,4	4,4	4,5
48	-0,3	-0,2	6,4	6,4
72	-0,1	-0,1	8,4	8,4
96		0,0		10,4
120		-0,1		12,4
144		-0,1		14,2
168		-0,2		15,6
192		-0,3		16,6
216		-0,3		17,4
240		-0,4		18,0

5.2.3.1 - T339L31, Southern hemisphere
Wind speed at 250 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,9	-0,9	6,2	6,2
48	-0,7	-0,8	9,0	8,9
72	-0,6	-0,7	11,7	11,6
96		-0,8		14,5
120		-0,9		17,3
144		-1,1		20,0
168		-1,3		22,3
192		-1,5		24,0
216		-1,6		25,1
240		-1,8		25,9

Legend:
ME – mean error (BIAS)
RMSE – root mean square error;
RMSEV – wind speed RMSE;
KA - anomaly correlation coefficient;
S1 – skill score

5.4 Verification of ensemble forecasts output

For assessment of the ensemble forecasts success, the probability estimates corresponding to the requirements of the leading centre on verification of ensemble forecasts (Japan, http://epsv.kishou.go.jp/EPSv/, Guideline on the Exchange and Use of EPS Verification Results, http://epsv.kishou.go.jp/EPSv/guideline.pdf). Monthly averaged values are transmitted to the site of the Centre of ensemble verification where they are presented in graphical format.

5.5 Research performed in this field

The forecast adaptation in localized areas close to the forecasting grid cells (fuzzy) and object-oriented methods of mesoscale forecast verification adjustment to streams of operational radar observation information formed with AKSOPRI complex developed in the Central Aerological Observatory is under development. Main attention is paid to verification problems in complicated mountainous relief considering meteorological support of the Sochi 2014 Olympic Games. Studies on variety of functions of precipitation patterns junction and coupling (selected on the bases of the hourly accumulated precipitation threshold) are carried out using statistical package R SpatialVx. Experiments are conducted for the period of forecast quality assessment during Sochi 2014 Olympic Games (January 15 – March 15, 2014). It was demonstrated that option of cutting off small objects (area is lesser than specified grid points) is useful.

Operative implementation of unified verification system of short-range numerical forecasting VERSUS-2 (jointly developed by the members of COSMO consortium), is supplemented with blocks of probabilistic forecast quality calculation as well as calculation of confidence intervals.

Development of the long-range forecasting verification systems:

Realization of the operational use of verification characteristics for long-range forecasting recommended by WMO (2002) - the root mean quality (MSSS), relative operational characteristic (ROC), reliability diagrams, and Derrity indicator in addition to standard statistical characteristics (correlation coefficient, sign correlation, etc.). Inclusion of procedures of cross-checking for stabilizing of quality assessment and broadening of forecasting fields nomenclature for SLAV model version is planned for seasonal forecasts according to the protocol of the project S2S.

Methods of parametric and non-parametric forecast significance assessment for long-range forecasting schemes with different successfulness are developed and partly implemented using the different statistical packages (IMSL, STATISTICA, R).

6. Plans for future (2016-2018)

6.1. Development of GDPFS

6.1.1. Main changes in operational GDPFS expected in 2016:

Operational implementation:

- Completion of operational trial and implementation of new version of SLAV model with horizontal grid step 20 km.
- Improved version of the global spectral model T339L31.
- New version of COSMO-Ru technology with horizontal resolution 1 km for Sochi recreation area.

6.1.2. Main changes in operational GDPFS expected in 2017-2020

Implementation of cyclic assimilation for global models_of the Hydrometeorologic Centre of Russia.

Improvement and implementation of the new version of the semi-Lagrangian SLAV model with spatial resolution 20-25 km and 50 vertical levels.

Implementation of new version of the global spectral model T339L63.

Implementation of a new version of ensemble medium-range forecasting system with increased dimension of ensemble and model resolution, expanded set of output products with improved post-processing, which will include statistical correction.

Implementation of a mesoscale ensemble prediction system based on COSMO model.

Development of technological infrastructure (based on improved web-technologies) for producing seasonal – inter-yearly forecasts for the territory of Russia. Implementation of unified common technology of monthly and seasonal forecasting.

Development of the existing 3D-Var analysis scheme for the limited area forecasting model (within the activities of COSMO consortium).

Assimilation of oceanographic data:

- Inclusion into assimilation system the data of satellite altimetery.
- Operative technology assimilation system implementation.
- Re-analysis of the hydrophysical oceanographic fields on the interval 2005-current.
- Increase the resolution of the global ocean circulation model.

6.2. Planned research in NWP, very short and long-range forecasting in 2016-2018

6.2.1. Planned research in NWP

- Data assimilation: Development of ensemble approach. Improvement of the local ensemble Kalman filter with ensemble transformation (LETKF) for the SLAV model – gradual introduction of satellite observations OSCAT/ASCAT and other. Development of mesoscale assimilation system. Inclusion of the real statistics of the satellite observation errors. Data assimilation from observational satellite system Meteor-M.

- Global modeling: Improvement and renewing of the physical parameterizations in the global models (spectral and finite-difference semi-Lagrangian models) for the new model configurations. Development of the non-hydrostatic dynamic core for semi-Lagrangian atmospheric model. Increasing of the SLAV model vertical resolution from 51 to 60 levels and upper level of computational area from 5 to 1 hPa. Numerical experiments with the SLAV model version 0,11x0,09 degrees, 60 levels. Implementation of the reduced lat-lon grid in the full version of the SLAV model. Transfer to hybrid vertical coordinate. Improve stratospheric block: ozone transport and photochemistry.

In the global spectral model – increase the number of vertical levels from 31 to 63.

- Ensemble forecasts: Two possible approaches to organization of future EPS are investigated, in which initial data perturbations are prepared using a hybrid ensemble variational data assimilation or a global LETKF. Tuning of statistical correction scheme.

- Development of the COSMO-RU system: improvement of the initial data preparation blocks for underlying surface and lower layers of the atmosphere using the detailed synoptic observations. Trial implementation of the mesoscale forecasting system based on COSMO-Ru2 and version with the grid step 1 km for the Moscow region.

6.2.2. Planned research in long-range forecasting:

- Improvement of SLAV model in long-range forecasting version (new parameterizations, increased horizontal resolution - 0.9x0.72 degrees). Experiments with coupled atmospheric model (SLAV) and ocean model (INMOM) using the historic seasonal forecasts. Development of technology of operational implementation of joint model;
- Forecast of the meteorological extreme phenomena statistical characteristics;
- Research of predictability dependence from the phases of large scale variability modes;
- Investigation on predictability while using different schemes of physical parameterizations;
- Investigation of predictability while using different schemes of hydrodynamic models complexation.

Additional researches are planned within the framework of the North-Eurasian climate centre (NEACC) projects.

1) Development of the average on-station forecasts using the super-ensemble NEACC model with modified adaptation technique based on weekly discreetness of output model product.

2) Inclusion of on-station forecast procedure for the territory of the former USSR into the operational scheme of NEACC integrated for 90 days with weekly discreetness..

7. Participation in Consortiums

Russia (Roshydromet) is a member of the **Co**nsortium for **S**mall-scale Modeling (COSMO).

7.1. Modeling system

7.1.1. In operation (see maps):

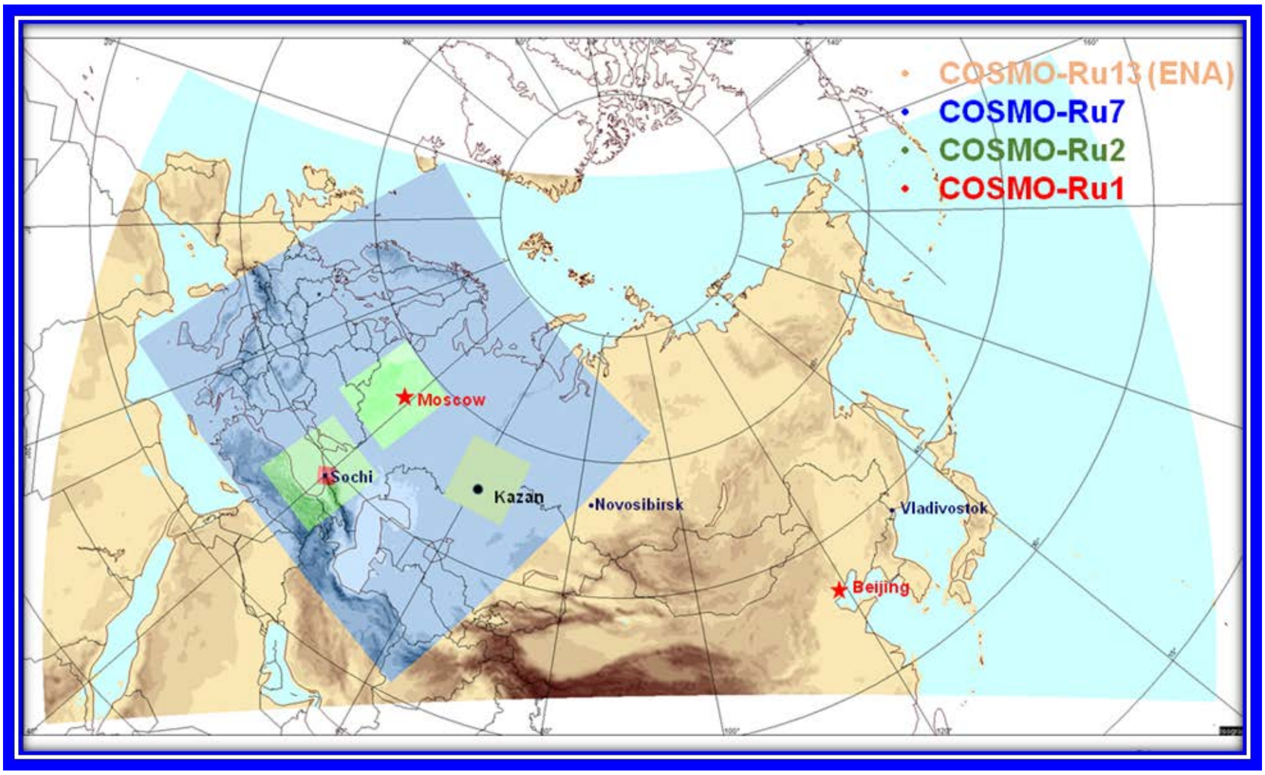
COSMO-Ru is a COSMO model version adapted for the WMC Moscow technological process.

COSMO-Ru7 is a COSMO-Ru model version with grid step 7 km covering the area from France to the west of Western Siberia in the zonal direction and from the Barents and Kara Seas on the north to the Mediterranean Sea on the south. The number of grid points is 700×620×40.

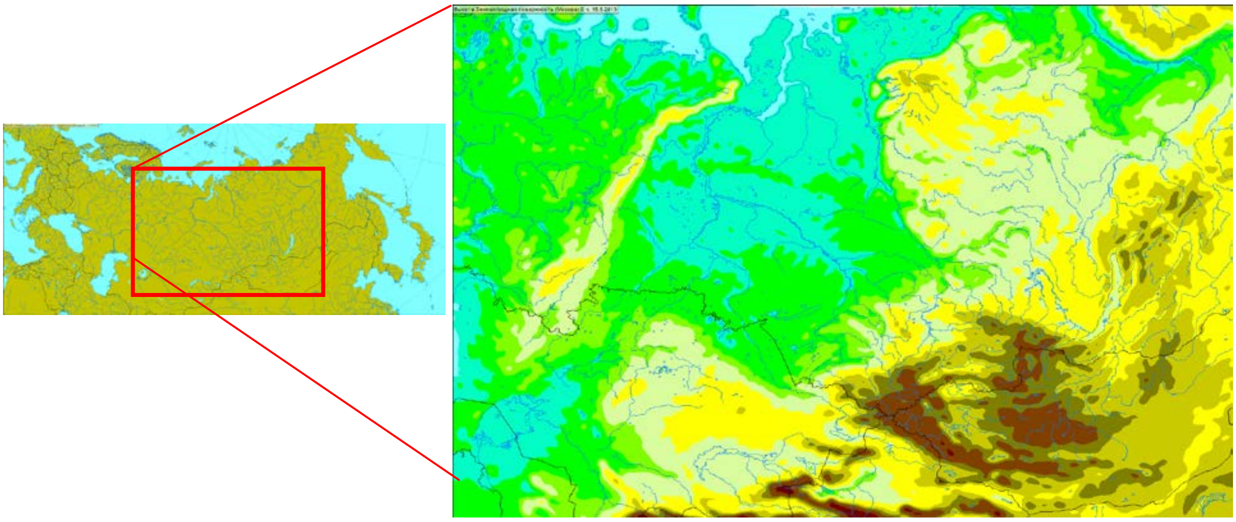
COSMO-RuSib is a COSMO-Ru version with a 14x14 km grid covering the area from European Russia to the Far East and from the Arctic Ocean coast to the southern border of Russia and Mongolia.

COSMO-Ru2cfo, COSMO-Ru2sfo and COSMO-Ru2vfo are COSMO-Ru versions (2.2x2.2 km) nested in the COSMO-Ru7 domain for the Central Federal District of Russia (COSMO-Ru2cfo), the Northern Caucasia region (COSMO-Ru2sfo) and Volga region (COSMO-Ru2vfo) respectively.

COSMO-Ru1SFO – version of the COSMO-Ru model, nested in COSMO-Ru2SFO – horizontal grid step 1,1 km, Sochi region.



Domains of integration of the short-range forecasting system COSMO-Ru with resolution 13.2 km (COSMO-Ru13(ENA)), 7 km (COSMO-Ru7, blue rectangle), 2.2 km (COSMO-Ru2, green rectangles), 1.1 km (COSMO-Ru1, red rectangle).



Integration domain of COSMO RuSib14

7.1.2. Research performed in this field

- Developing a new configuration of COSMO-Ru with an integration domain covering the whole territory of Russia with a 6.6-km step.
- Activities within the COSMO working groups: WG1: development of data assimilation technologies; WG3a: participating in the development of a new turbulence scheme (shallow convection) for modeling with a resolution less than 2 km; WG3b: development of a bog surface parameterization, development of a system for improved calculation of snow water equivalent within the snow depth data assimilation system; WG5: development of probabilistic score algorithms for ensemble forecast verification, participation in INSPECT project aimed to compare different spatial methods of verification; WG6: testing of new COSMO model versions; and WG7: development of mesoscale ensemble prediction methods .

7.2. Systems run schedule and forecast ranges

COSMO-Ru13-ENA from 00 and 12 UTC: start +02-50, end +04-20, maximum lead time is 120 hours, products are issued with a 3h lead time step;

COSMO-Ru13-ENA: from 06 and 18 UTC, start +02-50, end +04-00, maximum lead time is 78 часов, products are issued with a 3h lead time step;

COSMO-Ru7: from 00 and 12 UTC: start +02-50, end +03-30, maximum lead time is 78 hours, products are issued with a 3h lead time step;

COSMO-Ru7: from 06 and 18 UTC: start +02-50, end +03-15, maximum lead time is 48 h, products are issued with a 3h lead time step;

COSMO-Ru2cfo: from 00 and 12 UTC: start +03-40, end +04-15, maximum lead time is 24 h, products are issued with a 1h lead time step;

COSMO-Ru2cfo: from 06 and 18 UTC: start +03-15, end +03-50, maximum lead time is 24 h, products are issued with a 1h lead time step;

COSMO-Ru2sfo: from 00 and 12 UTC: start +04-20, end +05-25, maximum lead time is 48 h, products are issued with a 1h lead time step;

COSMO- Ru2sfo: from 06 and 18 UTC: start +03-50, end +05-10, maximum lead time is 48 h, products are issued with a 1h lead time step;

COSMO- Ru1sfo: from 00, 06, 12, and 18 UTC: start +01-05, end +01-25, maximum lead time is 36 h, products are issued with a 1h lead time step;

COSMO- Ru2vfo: from 00, 06, 12, and 18 UTC: start +03-50, end +05-10, maximum lead time is 48 h, products are issued with a 1h lead time step.

7.3. List of countries participating in the Consortium:

Germany, Switzerland, Italy, Greece, Poland, Rumania, Russia.

Each country supports its own technology based on the model codes provided by the Consortium, the initial and boundary conditions from the Deutscher Wetterdienst or from the European Centre for Medium-Range Weather Forecasts global models, and infrastructure elements (verification, post-processing). The model software allows using the initial and boundary conditions from a system of embedded grids.

7.4. Data assimilation, objective analysis and initialization

7.4.1. In operation

The results of the Deutscher Wetterdienst global data assimilation system are used; they are provided for each initial time from the GME global modeling system (the grid step was 20 km in 2014).

System of continuous observational data assimilation embedded into COSMO software is bsed on “nudging” method.

7.4.2. Research performed in this field

- Improvement of the nudging-based continuous data assimilation system supported by the COSMO software for COSMO-Ru07 and COSMO-Ru02 by additional assimilation of synoptic surface temperature measurements and temperature correction in the lower atmospheric layers and upper soil layers. Analysis of efficiency of this system.
- Adaptation of algorithms and technology of the 3D-Var global system of the WMC Moscow for data assimilation within the COSMO-Ru systems.

7.5. Operationally available Numerical Weather Prediction products

7.5.1. In GRIB code:

A wide range of forecast products is provided in the model grid in different vertical coordinates:

- basic elements: temperature, wind speed, air humidity, geopotential heights at standard isobaric surfaces, radiation fluxes;
- one-level characteristics: of cloudiness at different levels, near-surface air characteristics: air temperature at 2 meters, dew point at 2 meters, accumulated precipitation, wind speed components and gusts at 10 meters, surface pressure and sea-

level pressure, heat and radiation balance components, snow depth and its water equivalent;

GRIB messages are provided to users according to choice lists via FTP to users' addresses.

7.5.2. In graphical format

A) Maps

About 2000 maps for 00:00 UTC are automatically generated in GRADS and are distributed to users via the Internet (FTP) and local networks:

- -sea-level pressure + mid-level clouds+ 3h accumulated precipitation;
- -500 hPa geopotential + near-surface air temperature+ sea-level pressure;
- -near-surface background wind and its gusts;
- stream function, 10m wind and gusts over the Baltic, Black, and Caspian seas;
- -heights of convection boundaries and 500 hPa wind.

Selected graphical products are published in open access at:

- http://meteoinfo.ru/cosmo-maps,
- http://metavia2.ru/main.php,
- http://sibnigmi.ru/cgi-bin/inst/index.pl?5&2.

B) Meteograms:

Meteograms based on the GRADS visualization package are generated daily at the WMC Moscow for 300 grid points in Russia and are distributed via FTP, Internet, and local networks to users. Part of meteograms is in open access at http://www.meteoinfo.ru/cosmo-ru.

7.6. Verification of prognostic products

Temperature and pressure, precipitation, cloudiness, wind speed and due point forecast quality scores are regularly calculated based on the VERSUS-2 COSMO verification system for the European part of Russia and the entire area covered by COSMO consortium countries. Conditional verification is also carried out, i.e. calculation of the main weather elements under prescribed meteorological conditions (limited or total cloud cover, etc.). Verification results are presented on the site of COSMO consortium.

The forecast verification is made operationally using the WMC Moscow (Hydrometcentre of Russia) verification system for 12-h accumulated precipitation, temperature, dew point, background wind speed and wind gusts, and pressure.

7.7 Plans for the future (2018 – 2019):

7.7.1 Major changes in operational technology

- To organize operational runs of COSMO-Ru model in new configuration for the integration area including entire territory of Russia with a 6.6-km step (after installing new hardware, previously the grid step was 13.2 km for technical reasons).

- To implement into operation a system of data assimilation for snow water equivalent using SYNOP data and snow depth and meteorological observations at the stations.

***7.7.2. Planned research activities*:**

- Development of a COSMO-Ru modeling system with a 1-km step with modification of the numeric method and physical parameterizations (primarily, the planetary boundary layer and continuous data assimilation).
- Development of parameterizations in the TERRA underlying surface model.
- Development of turbulence parameterizations in the atmospheric planetary boundary layer (PBL).
- Further development of spatial methods of mesoscale model output verification.
- Activities within the COSMO working groups according to the Consortium scientific plan.

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