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 2015

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

09.06.2016

1. Summary of main highlights

Introduced into operation:

- New version of the Global spectral model T339L31 (gaussian grid resolution is approximately 32 km). Forecast lead time – up to 240 hours;

- Global system of ensemble forecast on the bases of two models T169L31 and SLAV-2008 (14 members, lead time 10 days, breeding method);

- New versions of the regional mesoscale model COSMO-Ru with horizontal grid step 2,2 km, which includes continuous data assimilation cycles using “nudging” scheme for the Central Federal district of Russia COSMO-Ru2CFO, Tatarstan (COSMO-Ru2VFO) and the Northern Caucasia with adjacent areas offshore the Black Sea COSMO-Ru2SFO, “inserted” into area of COSMO-Ru7 (grid 7x7 km) for the territories of East Europe and European Russia, Urals and the western part of the West Siberia. Forecasts lead time - 42-48 hours.

- Versions of the regional mesoscale model COSMO-Ru with horizontal grid step 13,2 km for Europe and Northern part of Asia covering the entire territory of Russia, adjoining areas onshore and offshore (COSMO-Ru13-ENA).

Introduced into quasi-operational trial regime:

- Global system of the seasonal forecasting with weekly discreetness and lead time up to 45 days. System is based on the global models of the Hydrometeorological Centre of Russia and Russian Academy of Sciences (model SLAV-2008, 20 ensemble member) and model of the Main Geophysical Observatory (model T42L14, 10 ensemble member);

- New version of the regional mesoscale model COSMO-Ru with horizontal grid resolution 1.1 km for the resort Sochi area, including coastal zone and mountainous areas. Model issuing forecasts with lead time up to 24 hours;

- New version of the Global semi-Lagrangean model SLAV 20 with grid step 20 km (in operational trial);

- Experiments with the model of the deep ocean with inserted mixed layer for use in seasonal forecasts of atmospheric conditions.

2. Equipment in Use

1) Autonomous server ASOOI – server1: 4 processors (4 x 8 cores) Intel Xeon E7-4830 2,13 GHz, memory 256 GB, discs 16 x 1 TB Ethernet 2 x 1 GBE, IPMI

2) Autonomous server ASOOI – server2: 4 processors (4 x 8 cores) Intel Xeon E7-4830 2,13 GHz, memory 256 GB, discs 16 x 1 TB Ethernet 2 x 1 GBE, IPMI

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

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

5) Total disc capacity for clusters: 210 Tb

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	6 000
PILOT	1 650
AMDAR	78 000
AIREP	2 700
SATEM	17 000
SATOB	1 000 000
BUOY	33 000
BUFR-SYNOP	127 000
BUFR-TEMP	800
BUFR-AMDAR(ASDAR)	450 000

Additionally a 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, restricted list: GRIB 2.5°x2.5° and GRIB 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 Offenbach (forecasting maps: digital facsimile), Internet (FTP): GRIB1 0.25°x0.25°, GRIB2 20x20 km – product of the global DWD forecasting system with horizontal resolution 20 km over the COSMO-Ru computational area necessaryID&BCfor the operation of COSMO-Ru07 and COSMO-RuSib models- in framework of COSMO activities;

WMC Washington: Internetanalysis and forecasts of meteorological fields of extended lists GRIB2 1°x1°, 0.5° x 0.5°);

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

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

4. Forecasting System

The global forecasting system of the WMC/RSMC Moscow is formed with the following blocks:

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

B systems of data assimilation and objective analysis;

C global atmospheric models;

D systems of modeling results interpretation;

The bounded 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 range:

The basic initial times for forecasting system (global models SLAV-2008, T339L31 and T169L31), regional model of Hydrometeorological Center of Russia MLp/s, are 00 and 12 UTC., The systems of Data assimilation are functioning for 00, 06, 12 18 UTC - 4 times a day.

SLAV-2008 from initial data for 00 UTCforecasting period: 120 h (readiness time by 03.40 UTC), for initial data 12 UTC – forecasting period: 240 h (produced by 15.50 UTC). Information is delivered to users with 6-hour time step. Technology includes additional procedures for date assimilation of land-surface properties.

T339L31: 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). Information is delivered to users with 6-h time step.

T169L31: same as for T339L31.

Regional forecasting technology COSMO-Ru07: initial data 00 and 12 UTC - forecasting period 78 h, initial data 06 and 18 UTC – forecasting period 48 h with time step for products delivered to users 1 hour for meteograms 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 products presented to users 1 hour for meteograms and GRIB.

Regional model of Hydrometeorological Center of Russia MLp/s for Europe:initial data 00 and 12 UTC - 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.

Short- and medium-range 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.

Long-range forecasting systems – once a month starting one day before a coming month.

Hydrodynamic-statistical forecasts of the mean monthly anomalies of the surface temperatures at the stations throughout the territory of the Former Soviet Union are produced at the end of each month with zero lead time.

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):

- Cyclicity:
  - Cycle of the assimilation system – 4 times a day, observations for: 00, 06, 12, 18 UTC;
  - Objective analysis using the first approximation fields of RSMC Exeter and WMC Washington – 2 times a day for 00, 12 UTC;
- Method of analysis: two versions of technology:

  a) 2-dimentional interpolation for 1-level characteristics and 3-dimentional optimal interpolation for the fields within the bulk of atmosphere,

  b) 3D-Var (under development)

- Products – sea level pressure, surface air temperature, temperature of underlying surface, surface air humidity and wind velocity, total octant cloudiness, snow cover depth, sea surface temperature, geopotential heights at isobaric levels, wind velocity, temperature and air humidity at 38 vertical isobaric levels (from 1075 to 0.5 hPa) at φ/λ grid 0.5°x0.5°;
- The scheme of global cyclic data assimilation based on unified 3D-Var scheme developed in the Hydrometeorological Centre of Russia using the global prognostic atmospheric modal SLAV-2008 is testing in operational trial mode.

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

Traditional contact observations (surface, radiosounding, aircrafts), satellite observations: 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.

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

Horizontal resolution of objective analysis fields is 0.5°x0.5° and 38 vertical levels (from 1075 to 0.5 hPa). Horizontal resolution of analysis increment fields in relation to forecast is 1.5°.

Initialization – non-linear, normal modes (for spectral T169L31 model) and digital filter (for SLAV-2008 model).

Additionally, the system for generation of the initial fields of soil temperature and soil humidity is included in the technology of SLAV-2008.

4.2.1.2 Research performed in this field:

Studies on applying of 3D-Var system for the global spectral atmospheric model T169L31 and T339L31 are in progress.

Development of 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.

The system of the oceanographic data assimilation aimed at initializing the coupled ocean-atmosphere model for seasonal forecasting has been developed. Data assimilation is carried out on the basis of consequent scheme "analysis-forecast-analysis" using three-dimensional assimilation at the step of analysis. The core of the scheme is represented by the new model of the first approximation error fields based on the three-dimensional filters of auto-regression and moving average. For obtaining the first approximation fields the oceanic global circulation model is used. As initial information, the operative observations of the sea water temperature and salinity coming from different observational platforms (drifting and anchored buoys, vessel observations, data from ARGO buoys). The preliminary estimates show that the system allows to simulate the structure of the main hydro-physical fields more accurately in comparison with the climatic data.

4.2.2. Global Models

4.2.2.1. In operation mode:

- Semi-Lagrangian global model SLAV-2008 (jointly developed by the Hydrometcentre of Russia and the Russian Academy of Sciences), horizontal resolution 0.72ºx0.9º, 28 vertical levels. The maximum forecast range is 240 h. It produces a standard set of prognostic products including total cloud amount and clouds of low and medium levels.
- 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:

- A parameterization of the long-wave radiation RRTMG-LW v.4.85 was included in the SLAV-20 model program complex.
- The system of soil temperature and soil moisture initialization for multi-level parameterization of the heat and moisture exchange processes in soil developed for the climate model of the Institute of Numerical Mathematics of Russian Academy of Sciences is under development. So far, SEKF soil moisture initialization is implemented with the ISBA soil scheme used in SLAV2008 model.

- Implementation of the hybrid vertical coordinate. Improvement of description of the stratosphere: ozone advection and photochemistry.
- Development of the new SLAV model version having about 10 km horizontal resolution and about 100 vertical levels using the reduced lat-lon grid.
- Development of version T339L63 with advanced block of solar radiation transfer

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

The output of the SLAV-2008, T339L31 and T169L31 models are accommodated at the internal databases of Hydrometcenter of Russia at 2.5x2.5º and 1.25x1.25º grids (GRIB1). 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 meteograms are available on the website www.meteoinfo.ru. Forecasts for the Northern and Southern Hemispheres with 6-h discontinuity 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) provides the meteorological forecasts of extreme temperature, accumulated semi-diurnal precipitation, precipitation probability, cloudiness – three times a day, with lead time up to 7 days for 5000 cites over the globe including the settlements of 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 territorial Hydrometeorologival offices 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 prediction system (EPS) for short and medium ranges (12 – 240 h.) based on T169L31 spectral global model and models T339L31 and SLAV-2008 model.

Ensemble is combined from 12 disturbed forecasts with T169L31 model and two undisturbed forecasts with models T339L31 and SLAV-2008.

Characteristics of the system:

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

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 EPS 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 and dispersion maps (a domestic visualization system "Isograph" of the Hydrometcentre of Russia is recommended). Ensemble meteogrammes for a number of settlements of Russia are produced. Since the beginning of 2015 meteograms are placed to the site of Hydrometeorological Centre of Russia and to the site of SWFDP-CA project.

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.

In COSMO-Ru technology a system of continuous assimilation of meteorological information based on "nudging" scheme is implemented.

4.3.1.2. Research performed in this field:

The same as in Section 4.2.1.2.

Additionally, a regional cyclic data assimilation with unified scheme 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. Versions:

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.

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.

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.

- Regional non-hydrostatic model for the European region (area of forecast 137x209 grid points of the equal Cartesian grid (horizontal step 50 km, 30σ-levels). It produces information on expected weather, in particular precipitation and surface characteristics, the discreteness of output products with 1 hour time step. The adapted versions of the regional model of the Hydrometcentre of Russia have been put into operation at RSMC Novosibirsk and RSMC Khabarovsk. Two versions of the model were implemented operationally for the Far East and North Caucasus regions with horizontal resolution 25 km.
- Mesoscale non-hydrostatic model (15 levels in the atmosphere) for the Moscow and Saint-Petersburg with 10 km resolution.

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. 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 verification systems for mesoscale NWP.

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 maps. Information in the form of meteorological cables for more than 100 points within the European part of Russia, with time resolution 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 Europe, eastern part of Atlantic ocean, Northern Caucasia, Black sea, and Far East with adjacent seas.

Products:

- Sea level pressure fields, surface temperature and 1-hour precipitation intensity (detailed once an hour);
- fields of geopotential heigh, wind components, temperature and relative humiditystandard isobaric surfaces (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

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

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.

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.

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

*Same as shown in Section 4.2.5.1***.**

Currently no mesoscale ensemble forecasts are issued.

4.3.5.2. Research performed in this field

Same as shown in Section 4.2.5.2

Additionally, research in model-related forecast uncertainty resulted from imperfection of the atmospheric model and its influence on forecast skill was conducted.

Comparison of the ensemble forecast results obtained using different schemes within the framework of FROST-2014 project.

4.3.5.3. Operationally available ensemble NWP products

Same as discussed in Section 4.2.5.3

Since June 2014 operative integration of mesoscale ensemble forecasts for Sochi region was completed.

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

4.4.1 Schemes of nowcasting

4.4.1.1 In operation

No nowcasting schemes are in use in WMC/RSMS Moscow in operational mode.

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.

Research within the framework of the international operative-demonstrational WMO project FROST-2014 for meteorological support of Olympic Games Sochi 2014.

Debugging works on adaptation of nowcasting statistical complex for precipitation fields based on the consequent fields of precipitation intensity obtained with interpretation of reflectivity from Doppler radars deployed over the territory 0f the Central Federal District (CFD) and operated by the Central Aerologic Observatory (CAO) of Roshydromet.

First results of ensemble forecasts with several hours lead time based on the initial fields of radar precipitation separated with 10 minutes time intervals are obtained.

4.4.2 Models used in very Short-range Forecasting Systems.

4.4.2.1 In operation

Not used.

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.

COSMO-Ru2 – grid 2.2x2.2 km in the versions for the Central Federal District of Russia (COSMO-Ru2CFO), Tatarstan (COSMO-Ru2VFO) and Northern Caucasia (COSMO-Ru2SFO) inserted into COSMO-Ru7

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. Preliminary results demonstrate that the system produces the structure of the hydrophysical fields more accurately than the climatic models.

4.5.1.2 Research performed in this field

Works on transfer of the oceanographic date assimilation system to new model of ocranic general circulation NEMO (The Nucleus for European Modelling of the Ocean) using de-parallel program code and three-pole computational grid allowing capability to conduct global assimilation including Arctic basin..

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 are issued in the operational mode. 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), Caspian sea

(grid 3.6'×3.6', ~6 km), Barewnts 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 sea current velocity :

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 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 developed 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 of Hydrometeocenter of Russia *Mlp/Mlσ* .

To determine the forecasts quality dependence of the sources of meteorological information, verification of wind wave forecasts is conducted along the entire World ocean.

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 of Roshydromet named after Voeykov (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

Model SLAV-2008 is a semi-Lagrange finite-different global model of atmospheric general circulation developed in the Institute of Numerical Mathematics of Russian Academy of Sciences and Hydrometeorologichescal Centre of Russia. Semi-Lagrange method of calculation of advection allows to use in the model time step several times larger than the step envisaged by the CFL number. Specific of block of solution of atmospheric dynamics equations uses fourth-order finite differences at the unstaggered grid to approximate non-advective terms of equations and uses the vertical component of absolute vorticity as prognostic variable. Block of solutions of atmospheric dynamics equations is described in details in [27-29].

Model includes a set of parameterization of sub-grid scale processes (short- and long-wave radiation, deep and shallow convection, planetary bounder layer, 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.

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

- Numerical model SLAV-2008 is used in operational regime. Current and retrospective forecasts are produced every week for 63 days period, and two times a month for 135 days. 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 °.

- 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 time windows of forecast and better estimate the quality of forecast

-Statistical interpretation block implemented at NEACC 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), Voeykov 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, , 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

5.1. The global semi-Lagrangian model of the Hydrometcentre of Russia and the Institute for the Computational Mathematics of the Russian Academy of Sciences (SLAV-2008) for 00 and 12 UTC initial data is in operational use since 2010 on the grid 1.5x1.5° updated in 2012 is available on the site (http://www.wmo.int/pages/prog/www/DPFS/Manual_GDPFS.html).

5.1.1. SLAV-2008, Northern hemisphere (20N-90N)

5.1.1.1 **SLAV-2008, 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	-0,123	-0,061	1,610	1,563	0,976	0,977	0,324	0,325
48	-0,109	-0,113	2,364	2,308	0,948	0,949	0,398	0,399
72	-0,190	-0,199	3,258	3,191	0,901	0,904	0,475	0,476
96	-0,226	-0,210	4,270	4,173	0,832	0,837	0,552	0,554
120	-0,227	-0,219	5,326	5,234	0,742	0,746	0,624	0,627
144		-0,185		6,273		0,640		0,691
168		-0,218		7,177		0,535		0,742
192		-0,245		7,919		0,436		0,782
216		-0,263		8,577		0,347		0,813
240		-0,323		9,101		0,278		0,835

5.1.1.2. **SLAV-2008, Northern hemisphere**, H 850 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	0,220	-0,225	11,253	11,766	0,981	0,979	0,292	0,296
48	0,558	-0,546	16,764	17,210	0,959	0,955	0,368	0,371
72	0,025	-1,183	23,474	23,754	0,919	0,916	0,447	0,449
96	-0,108	-1,150	31,274	31,123	0,857	0,857	0,526	0,527
120	0,054	-1,143	39,538	39,356	0,773	0,772	0,600	0,601
144		-0,728		47,496		0,671		0,667
168		-0,887		54,560		0,570		0,718
192		-1,040		60,499		0,472		0,758
216		-1,059		65,790		0,384		0,791
240		-1,414		70,127		0,311		0,816

5.1.1.3. **SLAV-2008, Northern hemisphere (20N-90N),** H 500

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	-2,047	-2,382	11,818	11,992	0,992	0,991	0,186	0,185
48	-0,446	-1,536	19,575	19,773	0,977	0,976	0,264	0,263
72	-0,203	-1,451	29,619	29,565	0,945	0,945	0,345	0,344
96	0,348	-0,777	41,508	40,929	0,892	0,893	0,425	0,422
120	1,190	-0,192	54,188	53,673	0,814	0,815	0,499	0,497
144		0,741		66,528		0,717		0,564
168		1,126		77,907		0,614		0,618
192		1,499		88,011		0,510		0,662
216		1,970		96,218		0,418		0,696
240		2,150		102,864		0,340		0,721

5.1.1.4. **SLAV-2008, 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	-0,611	-0,253	16,429	16,141	0,992	0,992	0,162	0,162
48	3,854	3,427	27,509	27,391	0,977	0,976	0,232	0,232
72	6,686	6,227	41,155	41,214	0,947	0,946	0,303	0,304
96	9,443	9,077	57,904	57,209	0,894	0,896	0,376	0,374
120	12,375	11,838	75,631	74,875	0,820	0,822	0,445	0,444
144		14,488		92,541		0,728		0,506
168		16,366		108,380		0,628		0,557
192		17,900		122,820		0,526		0,601
216		19,306		134,664		0,433		0,634
240		20,327		144,344		0,351		0,660

5.1.1.5. **SLAV-2008, 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	0,066	-0,045	1,643	1,770	0,911	0,893
48	0,114	-0,019	1,949	2,058	0,877	0,860
72	0,144	-0,001	2,296	2,387	0,833	0,817
96	0,181	0,025	2,712	2,781	0,772	0,759
120	0,218	0,046	3,167	3,224	0,694	0,683
144		0,069		3,688		0,594
168		0,086		4,126		0,501
192		0,100		4,513		0,409
216		0,123		4,806		0,335
240		0,148		5,049		0,271

5.1.1.6. **SLAV-2008, 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	-0,189	-0,136	0,949	0,928	0,965	0,965
48	-0,081	-0,031	1,330	1,313	0,929	0,929
72	-0,019	0,031	1,777	1,769	0,875	0,874
96	0,039	0,090	2,272	2,247	0,799	0,801
120	0,100	0,151	2,764	2,737	0,705	0,708
144		0,203		3,202		0,605
168		0,256		3,605		0,505
192		0,307		3,962		0,408
216		0,351		4,224		0,330
240		0,394		4,442		0,264

5.1.1.7. **SLAV-2008, 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	0,480	0,482	1,400	1,368	0,930	0,932
48	0,606	0,609	1,862	1,827	0,868	0,870
72	0,726	0,746	2,280	2,254	0,794	0,795
96	0,811	0,837	2,682	2,651	0,704	0,705
120	0,890	0,922	3,048	3,018	0,609	0,608
144		0,975		3,320		0,517
168		1,020		3,563		0,438
192		1,038		3,773		0,364
216		1,054		3,935		0,305
240		1,070		4,061		0,256

5.1.1.8. **SLAV-2008, Northern hemisphere (20N-90N)**

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	-0,367	-0,368	3,329	3,283
48	-0,442	-0,451	4,270	4,210
72	-0,517	-0,526	5,305	5,233
96	-0,576	-0,579	6,387	6,302
120	-0,608	-0,613	7,434	7,350
144		-0,626		8,280
168		-0,627		9,009
192		-0,622		9,566
216		-0,627		10,038
240		-0,614		10,405

5.1.1.9. **SLAV-2008, 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	-0,274	-0,281	3,903	3,892
48	-0,397	-0,421	5,431	5,392
72	-0,464	-0,501	7,087	7,017
96	-0,512	-0,555	8,798	8,688
120	-0,546	-0,582	10,458	10,359
144		-0,591		11,904
168		-0,603		13,166
192		-0,621		14,216
216		-0,628		15,043
240		-0,649		15,663

5.1.1.10. **SLAV-2008, Northern hemisphere (20N-90N)**

Wend sped 250 hPa

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,708	-0,659	5,591	5,515
48	-0,866	-0,865	7,868	7,805
72	-1,025	-1,024	10,248	10,221
96	-1,178	-1,188	12,818	12,701
120	-1,254	-1,267	15,372	15,225
144		-1,347		17,513
168		-1,402		19,433
192		-1,492		21,079
216		-1,577		22,436
240		-1,666		23,439

5.1.2. SLAV-2008, Tropics (20N-20S)

5.1.2.1. SLAV-2008, Tropics (20N-20S). Sea level pressure

Lead time	RMSE (hPa)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	1,028	1,028	0,780	0,773	0,452	0,466
48	1,396	1,354	0,652	0,661	0,484	0,501
72	1,689	1,627	0,564	0,585	0,513	0,529
96	1,820	1,717	0,517	0,560	0,533	0,547
120	1,951	1,864	0,471	0,512	0,550	0,564
144		1,972		0,457		0,580
168		2,093		0,397		0,595
192		2,184		0,348		0,607
216		2,266		0,297		0,617
240		2,335		0,250		0,625

5.1.2.2. **SLAV-2008, Tropics (20N-20S),** H 850 hPa

Lead time	RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	8,428	8,685	0,774	0,755	0,534	0,538
48	11,250	11,410	0,656	0,627	0,574	0,581
72	13,534	13,564	0,566	0,540	0,617	0,620
96	14,335	14,076	0,526	0,513	0,643	0,646
120	15,259	15,166	0,479	0,459	0,667	0,670
144		15,830		0,407		0,692
168		16,662		0,347		0,712
192		17,080		0,312		0,729
216		17,612		0,264		0,740
240		18,071		0,221		0,752

5.1.2.3. **SLAV-2008, Tropics (20N-20S),** H 500 hPa

Lead time	RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	8,077	8,116	0,863	0,871	0,486	0,484
48	9,497	9,728	0,798	0,796	0,536	0,534
72	10,894	11,212	0,735	0,726	0,584	0,579
96	11,514	11,730	0,702	0,692	0,619	0,616
120	12,555	12,837	0,644	0,632	0,655	0,652
144		13,972		0,561		0,685
168		15,217		0,480		0,714
192		15,964		0,422		0,739
216		16,906		0,352		0,761
240		17,662		0,291		0,777

5.1.2.4. **SLAV-2008, Tropics (20N-20S),** H 250 hPa

Lead time	RMSE (m)		KA		S1	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	11,206	10,945	0,895	0,898	0,399	0,402
48	13,673	13,285	0,836	0,844	0,451	0,454
72	16,171	15,456	0,772	0,788	0,492	0,497
96	18,715	17,725	0,702	0,723	0,527	0,533
120	21,370	20,139	0,619	0,644	0,562	0,567
144		22,627		0,556		0,600
168		24,804		0,471		0,629
192		26,732		0,395		0,653
216		28,458		0,325		0,674
240		30,225		0,255		0,694

5.1.2.5. **SLAV-2008, Tropics (20N-20S),** temperature at 850 hPa

Lead time	RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	1,308	1,325	0,576	0,583
48	1,419	1,435	0,516	0,525
72	1,519	1,539	0,466	0,475
96	1,611	1,647	0,419	0,421
120	1,700	1,747	0,374	0,372
144		1,842		0,322
168		1,942		0,267
192		2,036		0,214
216		2,109		0,171
240		2,166		0,135

5.1.2.6. **SLAV-2008, Tropics (20N-20S),** temperature at 500 hPa

Lead time	RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	0,739	0,731	0,795	0,789
48	0,889	0,891	0,698	0,687
72	0,994	0,988	0,622	0,619
96	1,092	1,073	0,548	0,551
120	1,177	1,154	0,482	0,484
144		1,229		0,419
168		1,304		0,354
192		1,367		0,293
216		1,415		0,246
240		1,466		0,204

5.1.2.7. **SLAV-2008, Tropics (20N-20S),** temperature at 250 hPa

Lead time	RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	0,918	0,875	0,670	0,693
48	1,170	1,120	0,505	0,526
72	1,335	1,274	0,375	0,401
96	1,448	1,380	0,284	0,313
120	1,524	1,454	0,217	0,247
144		1,503		0,196
168		1,528		0,156
192		1,544		0,125
216		1,557		0,101
240		1,566		0,081

5.1.2.8 **SLAV-2008, Tropics (20N-20S),** 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	-0,466	-0,477	2,942	2,860
48	-0,723	-0,722	3,587	3,502
72	-0,895	-0,912	4,092	4,031
96	-1,064	-1,056	4,547	4,486
120	-1,134	-1,123	4,906	4,833
144		-1,151		5,118
168		-1,232		5,411
192		-1,266		5,628
216		-1,337		5,819
240		-1,355		5,953

5.1.2.9 **SLAV-2008, Tropics (20N-20S),** 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	-0,316	-0,313	2,994	3,005
48	-0,383	-0,390	3,912	3,935
72	-0,372	-0,374	4,653	4,669
96	-0,385	-0,388	5,286	5,281
120	-0,419	-0,431	5,823	5,800
144		-0,476		6,262
168		-0,505		6,677
192		-0,548		7,038
216		-0,559		7,352
240		-0,584		7,578

5.1.2.10. **SLAV-2008, Tropics (20N-20S),** 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	-0,485	-0,489	5,608	5,634
48	-0,698	-0,753	7,195	7,220
72	-0,937	-0,950	8,318	8,355
96	-1,106	-1,148	9,208	9,233
120	-1,220	-1,278	9,989	10,004
144		-1,377		10,745
168		-1,402		11,404
192		-1,434		11,998
216		-1,479		12,532
240		-1,500		12,965

5.1.3. SLAV-2008, Southern hemisphere

5.1.3.1. **SLAV-2008, Southern hemisphere (20S-90S)**.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	-0,385	-0,303	2,863	2,741	0,954	0,958	0,289	0,286
48	-0,749	-0,635	3,771	3,591	0,919	0,927	0,366	0,363
72	-0,987	-0,879	4,789	4,618	0,869	0,879	0,443	0,440
96	-1,093	-1,016	5,965	5,827	0,794	0,804	0,517	0,516
120	-1,246	-1,166	7,202	7,071	0,698	0,709	0,585	0,584
144		-1,268		8,211		0,603		0,642
168		-1,298		9,180		0,499		0,687
192		-1,319		10,008		0,405		0,722
216		-1,321		10,661		0,325		0,747
240		-1,311		11,260		0,249		0,766

5.1.3.2. **SLAV-2008, Southern hemisphere (20S-90S)**. 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	-2,780	-2,173	21,476	20,769	0,958	0,961	0,256	0,253
48	-5,357	-4,503	27,782	26,923	0,931	0,935	0,329	0,326
72	-7,126	-6,362	35,309	34,570	0,889	0,893	0,402	0,399
96	-7,818	-7,358	44,408	43,989	0,821	0,825	0,473	0,472
120	-8,973	-8,489	54,231	53,860	0,731	0,735	0,538	0,538
144		-9,294		63,014		0,634		0,595
168		-9,595		71,109		0,529		0,640
192		-9,794		78,061		0,432		0,676
216		-9,863		83,667		0,348		0,702
240		-9,839		88,721		0,268		0,723

5.1.3.3. **SLAV-2008, Southern hemisphere (20S-90S)**, H500

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	-2,495	-2,933	13,197	13,041	0,992	0,992	0,165	0,164
48	-4,031	-4,079	22,792	22,867	0,977	0,976	0,238	0,238
72	-5,052	-4,522	35,063	35,134	0,943	0,943	0,314	0,313
96	-5,162	-5,480	49,396	49,753	0,885	0,884	0,388	0,388
120	-6,064	-6,036	64,635	65,066	0,802	0,801	0,456	0,457
144		-6,388		79,394		0,703		0,516
168		-6,552		92,131		0,597		0,565
192		-6,658		103,193		0,495		0,603
216		-6,658		112,160		0,404		0,632
240		-2,933		119,808		0,321		0,656

5.1.3.4. **SLAV-2008, Southern hemisphere (20S-90S)**, H250

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	-0,818	0,231	17,434	16,993	0,993	0,993	0,138	0,136
48	0,224	1,802	29,656	29,628	0,978	0,978	0,203	0,201
72	1,858	3,344	45,747	45,641	0,947	0,948	0,269	0,268
96	3,867	5,035	64,621	64,993	0,893	0,893	0,337	0,336
120	4,715	5,807	84,974	85,478	0,814	0,813	0,402	0,401
144		6,773		105,158		0,716		0,458
168		7,626		122,466		0,613		0,507
192		8,476		137,529		0,512		0,545
216		9,095		150,005		0,421		0,575
240		9,735		160,552		0,338		0,599

5.1.3.5. **SLAV-2008, Southern hemisphere (20S-90S), T850**

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,006	-0,04	1,794	1,759	0,895	0,899
48	0,038	0,008	2,101	2,050	0,854	0,862
72	0,062	0,028	2,470	2,419	0,799	0,807
96	0,080	0,040	2,916	2,865	0,722	0,732
120	0,082	0,040	3,372	3,324	0,630	0,640
144		0,037		3,753		0,543
168		0,011		4,084		0,454
192		-0,002		4,390		0,369
216		-0,016		4,631		0,301
240		-0,033		4,825		0,242

5.1.3.6. **SLAV-2008, Southern hemisphere (20S-90S), T500**

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,189	-0,147	1,015	0,991	0,966	0,966
48	-0,087	-0,041	1,411	1,403	0,929	0,930
72	-0,011	0,035	1,897	1,887	0,872	0,874
96	0,048	0,092	2,419	2,414	0,793	0,795
120	0,092	0,130	2,941	2,939	0,694	0,697
144		0,172		3,426		0,587
168		0,202		3,830		0,484
192		0,226		4,146		0,394
216		0,246		4,411		0,318
240		0,261		4,637		0,248

.

3.7. **SLAV-2008, Southern hemisphere (20S-90S),** T250

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,382	0,373	1,378	1,350	0,938	0,941
48	0,507	0,510	1,865	1,851	0,882	0,884
72	0,645	0,651	2,317	2,305	0,811	0,813
96	0,744	0,753	2,746	2,737	0,724	0,726
120	0,822	0,836	3,152	3,143	0,625	0,627
144		0,895		3,499		0,526
168		0,938		3,787		0,437
192		0,968		4,012		0,362
216		0,985		4,198		0,296
240		0,997		4,338		0,246

5.1.3.8. **SLAV-2008, Southern hemisphere (20S-90S)**, V850

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,262	-0,244	3,462	3,452
48	-0,405	-0,383	4,669	4,649
72	-0,506	-0,477	5,982	5,950
96	-0,569	-0,539	7,276	7,287
120	-0,623	-0,599	8,508	8,522
144		-0,623		9,627
168		-0,657		10,526
192		-0,686		11,218
216		-0,713		11,756
240		-0,731		12,159

5.1.3.9. **SLAV-2008, Southern hemisphere (20S-90S)**, **V500**

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,297	-0,267	4,125	4,141
48	-0,431	-0,386	5,835	5,836
72	-0,486	-0,454	7,669	7,676
96	-0,509	-0,488	9,568	9,621
120	-0,571	-0,543	11,414	11,476
144		-0,591		13,131
168		-0,610		14,563
192		-0,635		15,674
216		-0,669		16,559
240		-0,697		17,265

5.1.3.10. **SLAV-2008, Southern hemisphere (20S-90S)**, V250

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(m/s)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,472	-0,461	5,624	5,588
48	-0,758	-0,691	8,136	8,082
72	-0,934	-0,868	10,744	10,677
96	-1,042	-1,009	13,425	13,414
120	-1,184	-1,156	16,134	16,141
144		-1,253		18,670
168		-1,341		20,804
192		-1,415		22,572
216		-1,494		23,956
240		-1,567		25,074

5.2. Global Spectral Model of the Hydrometeorological Centre of Russia, version T339L31

5.3.1. T339L31, 2015, 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	-0,1	-0,1	1,9	2,0	0,97	0,97	0,34	0,35
48	0,0	0,0	2,9	2,9	0,94	0,93	0,43	0,44
72	0,1	0,0	3,9	4,0	0,89	0,88	0,52	0,53
96		0,0		5,2		0,80		0,62
120		0,0		6,4		0,70		0,69
144		0,0		7,4		0,60		0,76
168		0,0		8,2		0,50		0,80
192		-0,1		8,9		0,42		0,84
216		-0,1		9,6		0,35		0,86
240		0,1		10,1		0,28		0,88

5.3.1.2. T339L31, Northern hemisphere, H500

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	0,1	0,0	13,3	13,5	0,99	0,99	0,20	0,20
48	0,3	-0,6	23,0	23,6	0,97	0,97	0,28	0,28
72	0,9	-1,0	35,6	36,2	0,92	0,92	0,37	0,37
96		-1,7		50,7		0,85		0,46
120		-2,8		65,2		0,76		0,54
144		-3,7		78,5		0,65		0,60
168		-5,5		89,5		0,55		0,65
192		-6,5		99,0		0,45		0,69
216		-7,5		107,3		0,36		0,72
240		-8,4		114,4		0,28		0,74

5.3.1.3. T339L31, Northern hemisphere, H250

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	-0,2	-0,5	18,0	18,1	0,99	0,99	0,17	0,17
48	0,0	-0,9	31,7	32,1	0,97	0,97	0,25	0,25
72	-0,9	-1,3	48,7	49,2	0,93	0,93	0,33	0,33
96		-2,2		68,7		0,86		0,41
120		-3,9		88,9		0,77		0,48
144		-4,7		107,7		0,65		0,54
168		-6,7		123,8		0,57		0,58
192		-8,1		137,5		0,47		0,62
216		-8,9		149,0		0,38		0,65
240		-9,4		159,0		0,31		0,67

5.3.1.4 T339L31, Northern hemisphere, T500

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,0	0,1	1,1	1,1	0,95	0,95
48	-0,1	-0,1	1,5	1,5	0,91	0,91
72	-0,3	-0,3	2,0	2,0	0,84	0,84
96		-0,6		2,6		0,75
120		-0,8		3,1		0,65
144		-1,1		3,6		0,55
168		-1,3		4,1		0,46
192		-1,6		4,4		0,37
216		-1,8		4,8		0,30
240		-2,0		5,0		0,25

5.3.1.5. T339L31, Northern hemisphere, T250

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	1,4	0,92	0,92
48	0,8	0,7	1,9	1,9	0,84	0,84
72	0,8	0,8	2,4	2,4	0,76	0,76
96		0,7		2,8		0,66
120		0,5		3,1		0,57
144		0,3		3,3		0,49
168		0,1		3,5		0,42
192		-0,2		3,7		0,36
216		-0,4		3,9		0,32
240		-0,6		4,0		0,28

5.3.1.6. T339L31, Northern hemisphere, V500

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,3	-0,3	4,4	4,3
48	-0,3	-0,2	6,1	6,0
72	-0,2	-0,2	7,9	7,9
96		-0,2		9,7
120		-0,2		11,4
144		-0,2		12,8
168		-0,3		14,1
192		-0,3		15,0
216		-0,3		15,7
240		-0,3		16,2

5.3.1.7. T339L31, Northern hemisphere, V 250

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-1.0	-0,9	6,2	6,1
48	-1,0	-1,0	8,7	8,6
72	-0,8	-0,9	11,4	11,3
96		-1,1		14,0
120		-1,1		16,5
144		-1,3		18,6
168		-1,4		20,6
192		-1,5		21,9
216		-1,6		23,0
240		-1,6		23,9

5.3.2 - T339L31., 2015 Tropics (20 N – 20 S)

5.3.2.1 - T339L31, Tropics, 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	0,5	0,4	7,2	7,6	0,86	0,86	0,49	0,52
48	0,6	0,4	8,9	9,0	0,84	0,82	0,52	0,55
72	0,6	-1,5	10,2	12,0	0,80	0,75	0,55	0,59
96		-1,6		13,6		0,71		0,61
120		-1,7		14,8		0,66		0,62
144		0,2		14,0		0,64		0,63
168		-1,9		16,6		0,58		0,66
192		-0,1		15,6		0,56		0,67
216		-2,2		18,0		0,51		0,69
240		-2,2		18,1		0,49		0,73

5.3.2.2 - T339L31, Tropics, H250

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	1,6	1,5	11,4	11,3	0,91	0,90	0,54	0,53
48	1,4	0,4	13,5	13,9	0,87	0,85	0,56	0,56
72	0,8	-0,9	15,8	16,7	0,82	0,81	0,59	0,59
96		-2,0		20,4		0,74		0,61
120		-4,0		24,2		0,68		0,64
144		-6,2		28,1		0,61		0,66
168		-8,5		31,8		0,53		0,68
192		-10,4		35,2		0,46		0,71
216		-12,2		38,1		0,40		0,72
240		-14,0		40,8		0,35		0,74

5.3.2.3 - T339L31, Tropics, T850

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	1,3	1,3	1,8	1,8	0,64	0,59
48	1,2	1,1	1,9	1,8	0,58	0,52
72	1,0	0,9	1,8	1,8	0,54	0,48
96		0,6		1,8		0,44
120		0,4		1,8		0,42
144		0,2		1,8		0,39
168		0,0		1,8		0,37
192		-0,2		1,9		0,34
216		-0,4		2,0		0,31
240		-0,6		2,1		0,29

5.3.*2.4 - T339L31, Tropics, T250*

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,9	0,8	1,2	1,2	0,74	0,71
48	1,4	1,3	1,7	1,6	0,65	0,62
72	1,5	1,3	1,9	1,7	0,60	0,57
96		1,2		1,7		0,50
120		0,9		1,6		0,44
144		0,6		1,4		0,40
168		0,2		1,4		0,36
192		-0,2		1,4		0,32
216		-0,6		1,5		0,30
240		-1,0		1,8		0,28

5.3.2.5 - T339L31, Tropics, V850

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

5.3.2.1 - T339L31, Tropics, V250

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

5.3.3. - T339L31, 2015, 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	-0,1	-0,2	2,8	2,9	0,96	0,96	0,29	0,30
48	-0,2	-0,2	3,8	3,8	0,94	0,93	0,37	0,38
72	-0,2	-0,3	5,0	5,0	0,90	0,89	0,46	0,46
96		-0,3		6,4		0,83		0,54
120		-0,3		7,7		0,75		0,61
144		-0,3		8,9		0,66		0,66
168		-0,3		9,9		0,58		0,70
192		-0,3		10,7		0,51		0,74
216		-0,2		11,4		0,44		0,76
240		-0,2		11,9		0,40		0,77

5.3.3.2 - T339L31, Southern Hemisphere, H500

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	1,1	16,7	17,7	0,98	0,99	0,18	0,18
48	0,6	0,8	28,1	28,6	0,97	0,97	0,26	0,26
72	0,6	0,7	42,1	41,1	0,92	0,92	0,34	0,34
96		0,7		58,7		0,86		0,42
120		0,7		74,2		0,77		0,48
144		0,7		89,7		0,67		0,54
168		1		101,9		0,57		0,58
192		-0,2		112,9		0,47		0,62
216		-0,5		122,7		0,38		0,65
240		-0,8		129,7		0,32		0,66

5.3.3.3 - T339L31, Southern Hemisphere, H250

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	0,6	0,8	22,2	22,5	0,99	0,99	0,16	0,16
48	-0,1	0,2	37,7	38,4	0,97	0,97	0,23	0,23
72	-0,3	0,1	55,7	56,8	0,93	0,93	0,30	0,30
96		0,3		77,2		0,86		0,37
120		0,3		97,6		0,78		0,43
144		0,2		118,1		0,68		0,48
168		-1,2		135,0		0,59		0,53
192		-1,9		150,3		0,49		0,56
216		-2,7		163,8		0,40		0,59
240		-3,5		173,7		0,33		0,61

5.3.3.4 - T339L31, Southern Hemisphere, T500

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,0	0,0	1,1	1,1	0,96	0,96
48	0,0	0,0	1,6	1,6	0,91	0,91
72	0,0	-0,1	2,1	2,1	0,85	0,85
96		-0,2		2,6		0,76
120		-0,4		3,1		0,66
144		-0,6		3,6		0,55
168		-0,9		3,9		0,45
192		-1,1		4,3		0,36
216		-1,3		4,6		0,29
240		-1,6		4,8		0,24

5.3.3.5 - T339L31, Southern Hemisphere, T250

Lead time	ME (K)		RMSE (K)		KA	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC	00 UTC	12 UTC
24	0,5	0,5	1,4	1,4	0,92	0,92
48	0,5	0,5	1,9	1,9	0,84	0,85
72	0,5	0,4	2,2	2,2	0,77	0,77
96		0,3		2,6		0,69
120		0,0		2,9		0,61
144		-0,2		3,1		0,52
168		-0,5		3,4		0,45
192		-0,7		3,6		0,39
216		-1,0		3,8		0,34
240		-1,02		4,0		0,30

5.3.3.6 - T339L31, Southern Hemisphere, V500

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-0,4	0,5	4,6	4,6
48	-0,3	0,5	6,6	6,6
72	-0,2	0,4	8,5	8,6
96		0,3		10,6
120		0,0		12,4
144		-0,2		14,1
168		-0,5		15,4
192		-0,7		16,4
216		-1,0		17,2
240		-1,2		17,8

5.3.3.1 - T339L31, Southern Hemisphere, V250

Lead time	MEAN SPEED ERROR (m/s)		RMSEV(м/с)	
(hours)	00 UTC	12 UTC	00 UTC	12 UTC
24	-1,0	-1,0	6,4	6,4
48	-0,9	-1,0	9,1	9,0
72	-0,9	-0,9	11,8	11,8
96		-1,0		14,7
120		-1,3		17,3
144		-1,4		19,8
168		-1,6		21,8
192		-1,8		23,4
216		-1,9		24,7
240		-2,0		25,6

Legend:
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:

- new version of SLAV model with horizontal grid step 20 km.
- Improved version of the global spectral model T339L31.
- Systems of ensemble short and medium-range forecasts based on three global atmospheric models with approximately 70-km horizontal resolution using the “breeding” method. 14 ensemble realizations.

- New version of COSMO-Ru technology with horizontal resolution 1 km for Moscow and Sochi areas.

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

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.

- 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

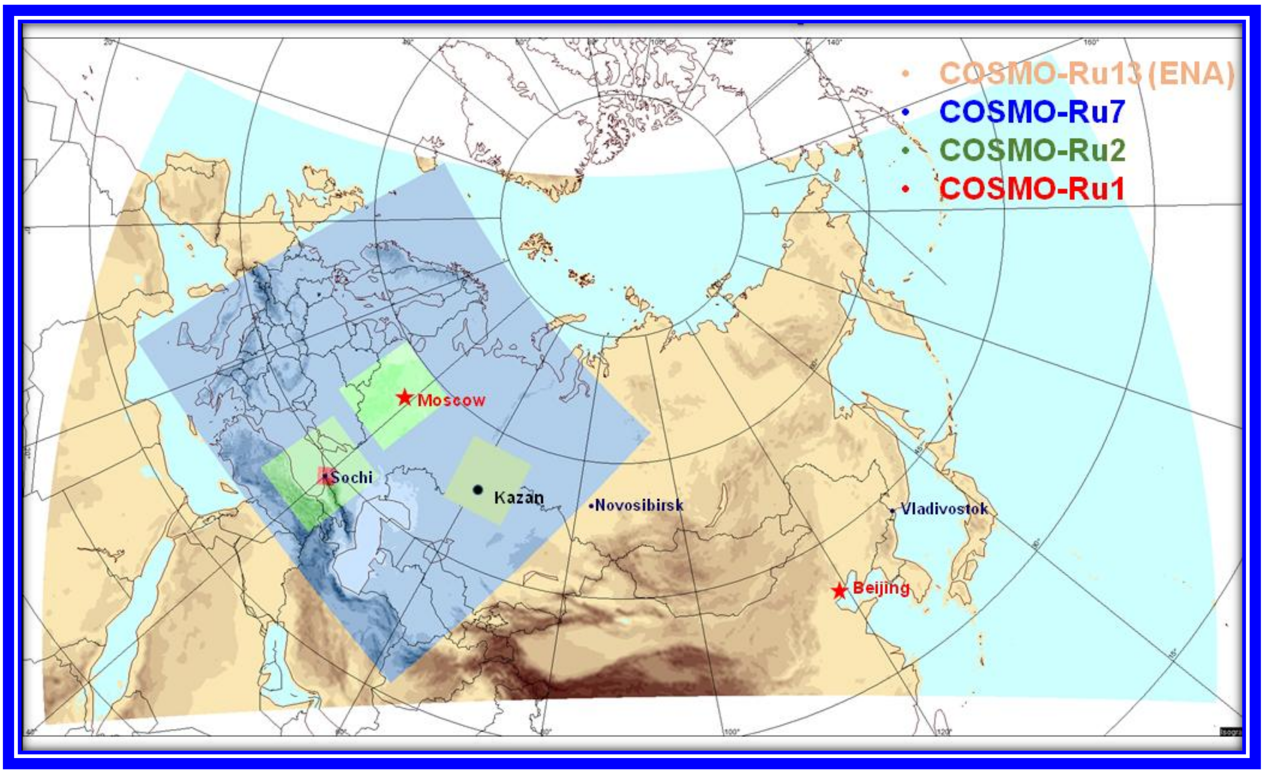
7.1.1. In operation (see maps):

COSMO-Ru7 is a COSMO model version (grid step 7 km) adapted for the WMC Moscow infrastructure 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.

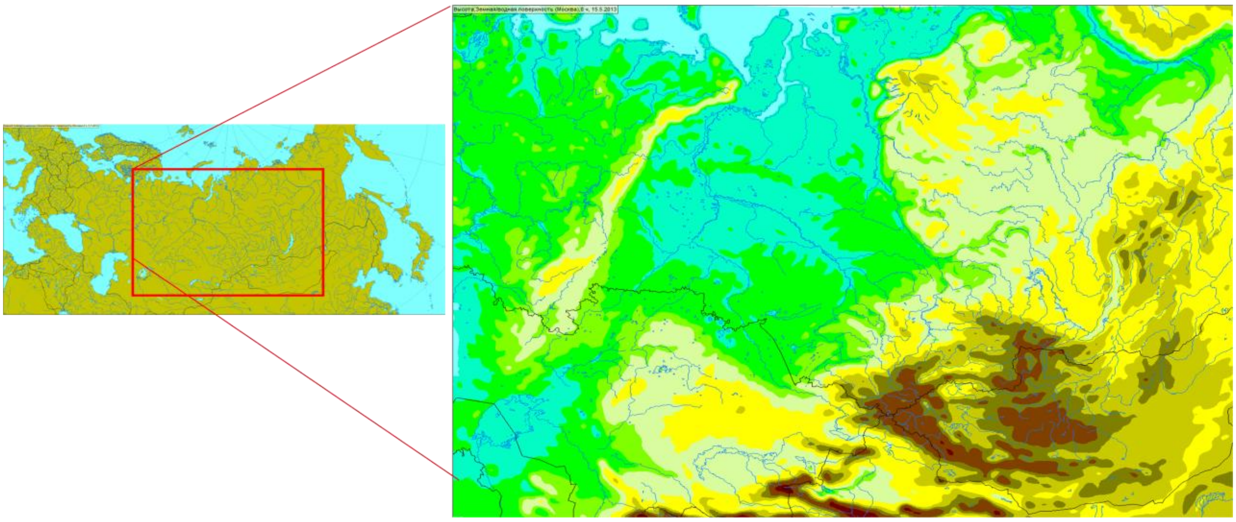
COSMO-RuSib is a COSMO-Ru version with a 14x14 km grid covering the area from European Russia to the Far East and from the Arctic Ocean coast to the southern border of Russia and Mongolia.

COSMO-Ru2cfo, COSMO-Ru2sfo and COSMO-Ru2vfo are COSMO model 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 modeling.

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 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 and 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 (meteoinfo.ru).

7.7 Plans for the future (2016 – 2017):

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 parameterizati***on***s (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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