# RUSSIAN FEDERATION

**FEDERAL SERVICE FOR HYDROMETEOROLOGY**

# AND ENVIRONMENTAL MONITORING OF THE RUSSIAN FEDERATION

# (ROSHYDROMET)

# TECHNICAL DOCUMENTATION OF THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM (GDPFS) AND RELATED NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR JANUARY 2020

**Country: Russian Federation Centre: RSMC Khabarovsk**

**1. Summary of main highlights**

**Added to operational schedule:**

* WRF-ARW model with grid spacing of 15 km for territories of Far East and Eastern Siberia put on operation on new cluster CRAY XC.
* Advanced operational numerical forecasting method (lead time is up to 24 h) to predict events of rapid intensification of surface wind (including squalls and squall winds) in Transbaikalia region based on output production of WRF-ARW model with grid spacing of 3 km put on operation on new cluster CRAY XC.
* Numerical forecasting model to predict sea level for the Sea of Okhotsk, north part of Sea of Japan, eastern seashore of Kamchatka Peninsula put on operation on new cluster CRAY XC.

**Added to experimental schedule:**

* Experimental short-term numerical weather prediction system based on WRF-ARW model (v. 3.9.1) with grid spacing of 4.5 km for territories of Far East and Eastern Siberia put on new cluster CRAY XC.
* Post-processing block to predict zones of active convection based on output of WRF-ARW model.

**2. Equipment in Use**

**2.1 Automated system of data transfer ASDT Khabarovsk**

ASDT junction includes four servers Kraftway Express 100 model EI22 with UniMas software, operating under OS Linux. Productivity of ASDT junction at receiving is no less than 130 messages per second; at transmission – no less than 410 messages per second.

**2.2 Data Processing Centre**

* Computational complex based on cluster CRAY XC (75 TFlops, 116 Intel Xeon processors, operational memory is 128 GB, storage volume is 370 TB) includes additionally 2 front-end servers.
* Storage system ‘Synology’ (the memory volume of 15 TB).
* Two computational servers (2 Intel Xeon each).
* Computational complex based on supercomputer ALTIX UV-100 (1 TFlops, 60 Intel Xeon processors) includes additionally six supporting servers and SGI storage system (the memory volume of 10 TB). Complex is placed in FERHRI, Vladivostok.

**3 Used Data and Products Coming from GST**

Total amount of received data comprises 300 MB/day, transmitted data – 600 MB/day (without transit).

**Average number of telegrams per day:**

|  |  |  |
| --- | --- | --- |
| **Code form** | **Number of telegrams** | |
| **Received** | **Used** |
| SATEM | 26300 | 26300 |
| TEMP | 63000 | 63000 |
| SYNOP+SHIP | 78000 | 78000 |
| KN15 | 250 | 250 |
| PILOT | 6600 | 6600 |
| SATOB | 4500 | 4500 |
| AIREP | 1300 | 1300 |
| AMDAR | 55900 | 55900 |
| BUOY | 43600 | 43600 |
| BUFR-SYNOP | 40000 | 40000 |
| BATHY | 5000 | 5000 |
| GRIB (Exeter) | 2500 | 2500 |
| GRIB (Reading) | 74 | 74 |
| GRIB (Moscow) | 386 | 386 |
| GRIB (Tokyo) | 2420 | 2420 |
| Facsimile (Tokyo) | 312 | 312 |

Various production of satellite observations are received and used with total daily amount of 1.5 GB.

*3.1* ***Used Data and Products Available via INTERNET***

Operational products of numerical weather prediction system ‘Global Forecasting System’ (NCEP, USA) in GRIB2 format are downloaded four times a day via FTP (daily volume of downloaded data is 12 GB).

**4. Forecasting System:**

* 1. **Time Schedule and Forecasting Period**

Main initial hours of the forecasting system operation are 00h и 12h UTC (regional and quasigeostrophic synoptic-scale models MLp 11-100/50, MLs 22-50, and regional non-hydrostatic model WRF-ARW).

Regional model (50х50 km), versions MLp 11-100/50 and MLs 22-50: for Sakha Republic, Transbaikalia region, North-eastern part of the Far East of Russia (Kamchatka and Chukchi peninsulas, Kolyma region), South-Eastern part of the Far East of Russia (including Amurskiy, Khabarovsk, Sakhalin and Primorskiy areas) using the initial data for 00h and 12h UTC – up to 48 hours (readiness time 3.00 and 15.00 UTC). Visualization information presents the weather fields with 1-hour time step and information at upper levels with 3-hour time step.

Regional model WRF-ARW:

- Version with spatial resolution of 15x15 km for territories of Eastern Siberia and Far East. Forecasts with lead time lead time of 96 hours are calculated from initial data 00h and 12h UTC, readiness time is 5.45 and 17.45 UTC. Additional forecasts with lead time of 72 hours are calculated from initial data 06h and 18h UTC, readiness time is 11.25 and 23.25 UTC. Output information is produced with 1- and/or 3-hour time step (according to production types).

Version with spatial resolution of 3x3 km for the territory of Transbaikalia region. Forecasts with lead time lead time of 24 hours are calculated from initial data 00h and 12h UTC, readiness time is 8.00 and 20.00 UTC. Output information is produced with 1-hour time step.

**4.2 System for the medium range forecasting (4-10 days)**

***4.2.1 Data assimilation, objective analysis and initialization*** - None

***4.2.2 Global Models*** - None

***4.2.3 Operationally available medium-range Numerical Weather Prediction (NWP) Products***

The output of the models of Hydrometeorological Centre of Russia, ECMWF, NMC Exeter and Tokyo received via GTS is used.

***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 operation:

A statistical interpretation system of the ECMWF forecasts received via GTS is used for 48 points of the Russian Far East to determine extreme and daily averaged surface air temperature, 12-hour accumulated precipitation, surface wind speed and direction is used for 5 days forecasts.

***4.2.5 Ensemble Prediction System*** - None

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

***4.3.1 Data assimilation, objective analysis and initialization***

4.3.1.1 In operation

The objective analysis for the integration area of the regional model uses as the first approximation fields the results of NMC Exeter forecasts with resolution 2.5 x 2.5**º -** twice a day for 00h and 12h UTC. Method of analysis is bilinear interpolation for single surface characteristics and 3-dimensional optimal interpolation for geopotential and wind.

The analyzed parameters include geopotential, air temperature and wind speed components at 12 standard isobaric surfaces (1000, 925, 850, 700,500, 400, 300, 250, 200, 150, 100, 70, and 50 hPa) and fields of dew point temperature at 1000 hPa and dew point deficit at 5 levels (925, 850, 700,500, and 400 hPa).

In the MLs 11-100/50 model initialization of the geopotential fields and the fields of wind speed components using the 4 vertical modes decomposition is conducted.

*4.3.1.2 Research performed in this field* - None

***4.3.2 Models for short-range numerical forecasting***

4.3.2.1. In operation

*A) Regional quasi-geostrophical model of the Hydrometeorological Centre of Russia*

Regional quasi-geostrophical model of the Hydrometeorological Centre of Russia adopted for the Russian Far East in horizontal Cartesian coordinate system is operating in two versions: p- and σ-vertical systems.

MLs 22-50 in σ-coordinate system with horizontal resolution 50 km at 22 vertical levels;

MLp 11-100/50 in p-coordinate system is integrated with horizontal resolutions of 100 and 50 km at 11 standard isobaric surfaces. These versions are used as a back-up operational numerical forecasting system.

*Model configuration*

Three versions of the regional MLs 22-50 and MLp 11-100/50 models are used operatively:

1) 110° – 170° E, 30° – 65° N (south of Russian Far East);

2) 90°– 160° E, 40°– 75° N (Sakha Republic);

3) 120° E – 170° W centered at 160° E, 54° N (Kamchatka Peninsula, Kolyma region and Chukchi Peninsula).

*B) WRF-ARW model*

*Model configuration*

Currently two versions of the model are used operationally:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Title | Version | Horizontal resolution (km) | Number of points, centered at | Area of integration | Time step | Lead time (hours) |
| Khab-15 | 3.4.1 | 15 | 501 x 401;  Khabarovsk | 20°–70° N; 100°–170° W | 60 | 72–96 |
| Zab-9 | 3.4.1 | 3 | 651 x 401;  54°N, 110°E | 35°–60° N; 90°–120° E | 10 | 24 |

‘Khab-15’ model is executed four times a day starting from 00, 06, 12 and 18 UTC.

‘Zab-9’ model is executed twice a day starting from 00 and 12 UTC. ‘Zab-9’ is used for prediction of extreme convective weather phenomena (strong showers, squalls and squall winds) in Transbaikal region.

The following parameterizations are used:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Title | Convec-tion | Boundary and surface layers | Microphysics | Soil processes | Radiation (long-, and short wave) |
| Khab-15 | Kain-Fritsch | MM5 similarity and Yonsei University scheme | WRF Single-Moment 6-class | Noah Land Surface Model | Rapid Radiative Transfer Model |
| Zab-9 | none | Eta similarity and Mellor-Yamada-Janjic scheme | Thompson | Noah Land Surface Model | Rapid Radiative Transfer Model, Dudhia scheme |

4.3.2.2 Research performed in this field

* Development of forecasting and diagnostic methods for the aviation meteorological service based on operational production of WRF-ARW models.
* Study to define possibilities to forecast active convection zones and associated with them extreme weather phenomena by various indices of atmospheric state which are calculated on operational production of WRF-ARW models.
* Development of methods for air turbulence prediction based on operational production of WRF-ARW models.
* Estimations of the stability of the forecasts in the transition to a grid step of 1–3 km.
* Study to improve the quality of surface air temperature forecasts.

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

4.3.3.1 Output of the different versions of regional models MLs 22-50 and MLp 11-100/50 (100х100 and 50х50 km)

Transbaikalia region, Sakha Republic, Kolyma region, Kamchatka Peninsula, Chukchi Peninsula, Sakhalin Island, Kuril Islands, Priamurye, Primorye and adjacent areas of Eastern Siberia, Mongolia, North-West China, Korea, Japan, Sea of Japan and Sea of Okhotsk.

Types of products (forecasts)

* PMSL 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 air temperature and relative humidity at 9 standard isobaric surfaces (925, 850, 700, 500, 400, 300, 250, 200, 150 hPa) detailed each 3 hours;

Information is provided to users via e-mail, ftp protocol, and is presented at khabmeteo.ru (PMSL, T2, and 1 hour accumulated precipitation).

4.3.3.2 Output of the regional mesoscale non-hydrostatic model WRF-ARW (15х15 km)

Forecasts are provided for the territory of the Eastern Siberia, Russian Far East and adjacent territories of Mongolia, North-West of China, Korea, Japan, Sea of Japan and Sea of Okhotsk.

Types of products (forecasts)

1) For Far Eastern HydroMet service (UGMS)

* PMSL, T2, 10 m wind speed and direction (with emphasized zones of strong winds), 3-hour accumulated precipitation detailed each 3 hours;
* PMSL and total amount of precipitation detailed each 3 hours;
* Cloud distribution and amount of precipitation detailed each 3 hours;
* Geopotential fields, air temperature, wind speed and direction at standard isobaric surfaces (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100 hPa) detailed each 3 hours.
* QNH, icing zones, active convection index, low level turbulence detailed each 3 hours.
* Total precipitation forecasts for partial basins of the Amur River.
* Meteograms for 115 points of Eastern Siberia and Far East includes hourly forecasts of PSFC, T2, Td2, RH2, 3-hour forecasts of meteorological distance of visibility, vertical shift of horizontal wind vector, top and bottom cloud heights, cloud cover, 3-h precipitation amount and distribution of air temperature, wind, and relative humidity in layer of surface – 10 hPa with lead time of 72 hours.

Information is presented on the exchange server as images (maps) and text (tables) reflecting the forecasts of weather characteristics at 333 points of the Eastern Siberia and Far East.

1) For Yakut UGMS

* Fields of geopotencial, air temperature, wind speed and direction on 500, 700, 850, 925 hPa detailed each 3 hours;
* PMSL, 10 m wind speed and direction, 3-h amount of precipitation and T850 detailed each 3 hours;
* Text files (tables) include forecasts of T2, 10 m wind speed and direction, 6-h amount of precipitation for 33 points of Sakha Republic;
* Meteograms includes hourly forecasts of PSFC, T2, Td2, RH2, 3-h forecasts of, cloud cover, 3-h precipitation amount and distribution of air temperature, wind, and relative humidity in layer of surface – 800 hPa with lead time of 72 hours.

Production (maps, meteograms and text files) is transferred to Yakut UGMS by e-mail and GTS.

3) For Sakhalin UGMS – set of products (text files, meteograms and maps) is transferred to ftp server. For Kolyma and Kamchatka UGMS – set of products (text files, meteograms and maps) is transferred by e-mail and available on khabmeteo.ru/kam.

Operational production of ‘Khab-15’ model in lat-lon grid with spacing of 0.5° (GRIB1) is available in GTS of Roshydromet.

4.3.3.3 Output of the regional mesoscale non-hydrostatic model WRF-ARW (3х3 km) for the Transbaikal region

Types of products (forecasts)

* PMSL, T2, 10m wind speed and direction (with emphasized zones of strong winds), index of squall wind, amount of precipitation detailed each hour;
* Fields of geopotencial, air temperature, wind speed and direction on 500 hPa detailed each 3 hours.

Production (maps, meteograms and text files) is transferred to Transbaikal UGMS by e-mail.

Some operational forecasts of regional WRF-ARW models are presented at the sites of khabmeteo.ru, ferhri.org, meteo-dv.ru. Operational numerical products are available for remote users on <ftp://meteo-dv.ru> under a request.

***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 operation

Forecasts of 6-hour accumulated precipitation at 333 points of the Far East and Eastern Siberia using the model data in the closest forecasting grid point with addition of the maximum value from the four nearest grid points are produced.

Forecasts of sea-level pressure and surface air temperature at 333 points of the Far East and Eastern Siberia are produced using bilinear interpolation of the model data from 4 grid points nearest to the forecasting point.

Forecasts of the surface wind is produced using the special interpolation method of the wind components from 4 nearest forecast grid points to the point of forecast.

Additionally forecasts in points are calculated to meteogram producing:

* Forecasts of vertical shift of horizontal wind vector in surface – 500 m AGL layer.
* Total cloud cover, top and bottom cloud heights, active convection index and meteorological distance of visibility.
* Vertical distribution of temperature, wind and relative humidity.
* Zones of possible icing.
* Index of active convection.

4.3.4.2 Research performed in this field

* The research aimed to develop and improve the incorporated physical-statistical forecasting methods for prediction of extreme weather phenomena, including phenomena of convective nature for Far East and Eastern Siberia (abrupt wind speed intensification, squalls, intensive showers, very intensive precipitation, thunderstorms).
* Studies aimed to produce specialized forecasts (especially for meteorological aviation service).
* Study to improve statistical post-processing to correct extreme surface air temperature in a point of interest.

***4.3.5 Ensemble Prediction System (EPS)*** - None

**4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)** – None

**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, etc.)**

* Sea level forecasting model for the coastal line and offshore of the Sea of Okhotsk and the North part of the Sea of Japan.
* Forecasting of position and evolution of tropical cyclones by regional HWRF model for the Northwest part of the Pacific Ocean (helded in FERHRI, Vladivostok);
* Forecasting of wind sea waves (helded in FERHRI, Vladivostok).
  + 1. ***Assimilation of specific data, analysis and initialization (where applicable)***

The forecasting products of the hydrodynamic model MLs 22-50 and operative information from the observational network (flow rate, intensity of ice phenomena in the mouth of the Amur River) from the code forms Hydro and Sea are operatively assimilated.

The forecasting products of the ‘Khab-15’, operative information from the observational network (flow rate, intensity of ice phenomena in the mouth of Amur River) from the code forms Hydro and Sea and operational satellite information of sea cover by JMA (Japan) are operatively assimilated.

4.5.1.2 Research performed in this field – None

***4.5.2 Specialized models***

A) A non-linear non-stationary numerical forecasting hydrodynamic model of sea level with grid spacing of 7.5 km (nested domains of 2.5 km grid spacing) for the coastal line and offshore of the Sea of Okhotsk and North part of the Sea of Japan with assessment probabilities of exceeding critical sea levels in the coastal points.

B) Forecasting of position and evolution of tropical cyclones by regional HWRF model for the Northwest part of the Pacific Ocean by HWRF R27r9L43 model with grid spacing of 27 km (typhoon grid spacing of 9 km).

C) Forecasting of wind sea waves (heights of significant waves; average propagation direction, average length, mean period, height and direction of propagation of wind waves, height and direction of propagation of swell waves of three systems) by discrete spectral WaveWatch III (v. 4.06) model.

4.5.2.1 In operation

A) Sea level forecasts (up to 72 h) are produced to predict the extreme marine phenomena for the coastal line and offshore of the Sea of Okhotsk and North part of the Sea of Japan with grid spacing of 7.5 km (nested domains of 2.5km grid spacing). Forecasts of extreme phenomena (storm surge, sea swell, ice breaking, water entering solid mass of ice) for mouth of the Amur River are additionally produced. Calculations perform twice a day (00 and 12 UTC). Readiness time is 7 and 19 UTC.

B) Forecasting of position and evolution of tropical cyclones on the territories of North-west part of the Pacific Ocean and South-east part of Far East by HWRF-R27r9L43 model with grid spacing of 27 km (typhoon grid spacing of 9 km). Calculations perform twice a day (00 and 12 UTC). Readiness time is 7 and 19 UTC.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Title | Version | Horizontal resolution (km) | Number of points, centered at | Area of integration | Time step | Lead time (hours) |
| HWRF- FERHRI- R27r9L43 | WRF-NMM 3.3.1 | 27/9 | 216 x 216;  grid center is placed in Philippine Sea | 10° S-60° N; 100°-180° E | 54 | 72 |

The following parameterizations are used:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Title | Convection | Boundary and surface layers | Microphysics | Soil processes | Radiation (long-, and short wave) |
| HWRF- FERHRI- R27r9L43 | Arakawa- Schubert scheme | Modified GFDL surface layer and a GFS PBL schemes | Ferrier-Aligo scheme | GFDL SLAB | GFDL longwave and shortwave scheme |

Model ‘HWRF- FERHRI- R27r9L43’ uses information of GFS with grid spacing of 0.5° (NCEP, USA) and specialized text messages ‘TCVITAL’ (JTWC, Japan).

C) Forecasting of wind sea waves by WaveWatch III v. 4.06 model performs twice a day (00 and 12 UTC) with leading time of 5 days for the Pacific Ocean (grid spacing of 0.5°), Bering Sea (0.17°), Sea of Okhotsk and Sea of Japan (0.07°). Model used information about sea surface wind on 10 m from GFS with grid spacing of 0.5° (NCEP, USA).

4.5.2.2 Research performed in this field

A) Study to expand forecasting area of sea level model.

B) Study to improve quality of forecasting TC position and evolution.

C) Study to use spherical multiple-cell grid in a wind wave model.

***4.5.3 Operational products of specialized prediction***

A) Text messages with hourly information about sea level and its tidal and run-up components for seashore points of the Russian Far East and warning text messages with information about possible hazardous weather phenomena are available by e-mail (Primorsky, Kolyma, Kamchatka and Sakhalin UGMS) and via data exchange server (Far Eastern UGMS).

B) Forecasting production of ‘HWRF- FERHRI- R27r9L43’ includes maps, meteograms and text messages:

* PMSL and total amount of precipitation detailed each 3 hours;
* Cloud distribution and precipitation detailed each 3 hours;
* Geopotential fields, air temperature, wind speed and direction at standard isobaric surfaces (1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100 hPa) detailed each 3 hours.
* Total precipitation forecasts for partial basins of Amur River (tables).
* Meteograms includes hourly forecasts of PSFC, wind maximum, average and maximum precipitation amount, wind speed and its direction in the location of TC with leading time of 72 hours.
* Text messages about position and intensity of TC in Northwest part of the Pacific Ocean each 3 hours.

Production is available on ferhri.org and via data exchange server (Primorsky UGMS).

C) Forecasting of wind sea waves model (heights and propagation direction of significant waves) with time step of 6 hours are available on ferhri.org.

**4.6. Extended range forecasts (10 to 30 days)**

***4.6.1 In operation***

The forecasting of the weather parameters (surface air temperature, wind speed, precipitation occurrence and amount) with one month lead time are produced for the points of Khabarovsk kray with one-day detailed elaboration. The forecasts are produced on the basis of the analogous year.

***4.6.2 Research performed in this field*** – None

***4.6.3 Operationally available ensemble prediction systems products (10-30 days)***

Forecasts in the points of the Russian Far East.

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

The 6-month lead time forecasts are produced based on the analogous year conditions and forecasts received from the Far East Research Hydrometeorological Institute. Monthly average surface air temperature, temperature anomalies and monthly average accumulated precipitation are predicted.

**5. Verification of prognostic products**

**5.1 Review of mean annual results**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Assessment of forecasts of air temperature at 2 m and wind at 10 m  produced in 2019 against observations | | | | | | | | | | | | |
| ***MLs 22-50 model*** | | | | | | | | | | | | |
| Lead time (hours) | Temperature at 2 m | | | | | Wind at 10 m | | | | | | |
| **PH** | | | **ME** | **ABS** | **ME\_V** | **MSE\_V** | | **ABS** | | **ME** | |
| **12** | 51 | | | 0.9 | 3.6 | 12.2 | 15.5 | | 6.5 | | 3.5 | |
| **24** | 52 | | | 1.2 | 3.7 | 11.4 | 12.4 | | 6.6 | | 4.4 | |
| **36** | 52 | | | 1.1 | 3.6 | 12.0 | 15.4 | | 6.6 | | 5.8 | |
| **48** | 51 | | | 1.3 | 3.8 | 11.8 | 12.4 | | 6.6 | | 5.8 | |
| ***WRF-ARW model, version ‘Khab-15’*** | | | | | | | | | | | |
| Lead time (hours) | | Temperature at 2 m | | | | Wind at 10 m | | | | | |
| **PH** | **ME** | | **ABS** | **ME\_V** | **MSE\_V** | **ABS** | | **ME** | |
| **12** | | 61 | -1.3 | | 3.4 | 3.0 | 4.2 | 2.0 | | 1.2 | |
| **24** | | 59 | 0.0 | | 3.6 | 3.4 | 4.7 | 2.2 | | 1.3 | |
| **36** | | 58 | -1.4 | | 3.6 | 3.2 | 4.4 | 2.2 | | 1.4 | |
| **48** | | 56 | -0.1 | | 3.8 | 3.6 | 4.8 | 2.3 | | 1.4 | |
| **60** | | 56 | -1.4 | | 3.9 | 3.4 | 4.6 | 2.3 | | 1.4 | |
| **72** | | 53 | -0.2 | | 4.0 | 3.7 | 5.1 | 2.4 | | 1.5 | |

Abbreviations:

PH – forecast accuracy (as per RosHydromet guidelines) (%),

ME – mean error (degrees for temperature, m/s for wind),

ABS – absolute error (degrees for temperature, m/s for wind).

ME\_V – absolute error of wind vector forecast (m/s),

MSE\_V – wind vector root-mean-square error (m/s).

**5.2 Research performed in this field** *-* None

**6. Plans for the future (2020 – 2022)**

**6.1. Development of the GDPFS**

***6.1.1. Major changes in the operational DPFS expected in 2020***

* Experimental usage of statistical post-processing (model output statistic) to improve WRF-ARW ability to predict extreme surface air temperature for the points of Eastern Siberia and Far East.
* Experimental usage of diagnostic methods to predict hazard weather events for aviation (icing, turbulence in low level) based on output of WRF-ARW model for Eastern Siberia and Far East.

***6.1.2. Major changes in the operational DPFS expected in 2020-2022***

* Improved of numerical technologies to predict tropical cyclones for the territory of Far East.
* Development and improved of numerical technologies for meteorological forecasting for aviation.
* Development and improved of numerical technologies for marine forecasting:
  + Numerical model to predict sea level in south-west part of the Bering Sea.
  + Improved of numerical technology to predict wind sea waves (lead time is up to 5 days) for the seashore of the sea of Okhotsk.
  + Improved of numerical technology to predict wind sea waves for the seashore of Eastern Arctic.
  + Numerical technology to predict properties of sea ice for the Sea of Japan (lead time is up to 10 days).

**6.2. Planned Research Activities in NWP, Nowcasting and Long-range Forecasting and Specialized Numerical Prediction**

***6.2.1. Planned Research Activities in NWP***

* Improvement and development of the current WRF-ARW models to improve the quality and expand the amount of production.
* Refinement of coastal line and surface properties (soil and albedo) for the territory of Eastern Siberia and Far East is planned to improve quality of short-time numerical weather prediction of WRF-ARW model.

***6.2.2 Planned Research Activities in Nowcasting*** – not planned.

***6.2.3******Planned Research Activities in Long-range Forecasting***

Modernization and development of physical-statistical and analogous methods of long-range (from 1 month to 2 years) forecasting of the monthly average values of meteorological parameters and their anomalies.

***6.2.4******Planned Research Activities in Specialized Forecasting***

* Development and improvement of the numerical hydrodynamic model of the tropical cyclone evolution.
* Development and improvement of the forecasting model to predict sea level at the coastal line and offshore of Far Eastern seas.
* Development and improvement of methods for aviation meteorological service.

**7. References (2018-2019)**

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