Forecasting systems in Russia: current status and development

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WGNE30, College Park, USA

23-26 March 2015

Computer facilities at Roshydromet (WMC Moscow)

Computer	Vendor (country)	Rpeak, TFlops	cores/ cores per node
~~SGI Altix 4700~~	SGI(USA)	11	1664/128
SGI Altix ICE8200	SGI(USA)	16	1408/8
RSK Tornado	RSK(Russia)	35	1536/16
SGI Altix ICE-X	SGI(USA)	14	720/20
SGI Altix UV2000	SGI(USA)	2	96/96

Modification of the computer system (~1 PFlops) is delayed by a year and now is planned to 2016

Data assimilation: global 3D-Var system

- Based on a parametric spatial-auto-regression covariance model
- Assimilates the following satellite data: AMSU-A, MHS, AMV (Geo, Polar, Leo-Geo), scatterometry (ASCAT), radio-occultation (COSMIC, GRAS)
- Works in real time both with the external background (6-h GFS forecast) and in the cycling mode with the RHMC semi-Lagrangian model SL-AV

Progress since March 2014:

- The inner-loop resolution has been increased from 167 km to 55 km (still mixed impact on forecast skill, not operational yet)
- An ensemble of 3D-Vars with perturbed observations is now up and running. Model-related perturbations – from the background error covariance matrix (B-matrix)

Next steps (2015-2016)

- **Development of a hybrid EnVar scheme**
  (has already started)
- ✓ **Assimilation of new data types**
  Hyper-spectral satellite data.
  GNSS ZTD satellite data
- **Work on accounting for satellite error correlations in the analysis**
- **Development of a new approach to EnKF and EnVar: Hierarchical Bayes Ensemble Filter (HBEF)**

For more information see

Tsyrulnikov M., Rakitko A. Hierarchical Bayes Ensemble Variational Data Assimilation. - World Weather Open Science Conference 2014, August 16-21, 2014, Montréal, Canada, Abstracts, p.170.

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A new approach to EnKF and EnVar: Hierarchical Bayes Ensemble Filter (HBEF)

The principal problem in EnKF and EnVar is an inevitably small affordable ensemble size, which results in a poor background error covariance matrix B. The common remedy: localization (of different kinds).

Small ensemble → Poor B matrix → Localization+ Cov.inflation → "True" B matrix

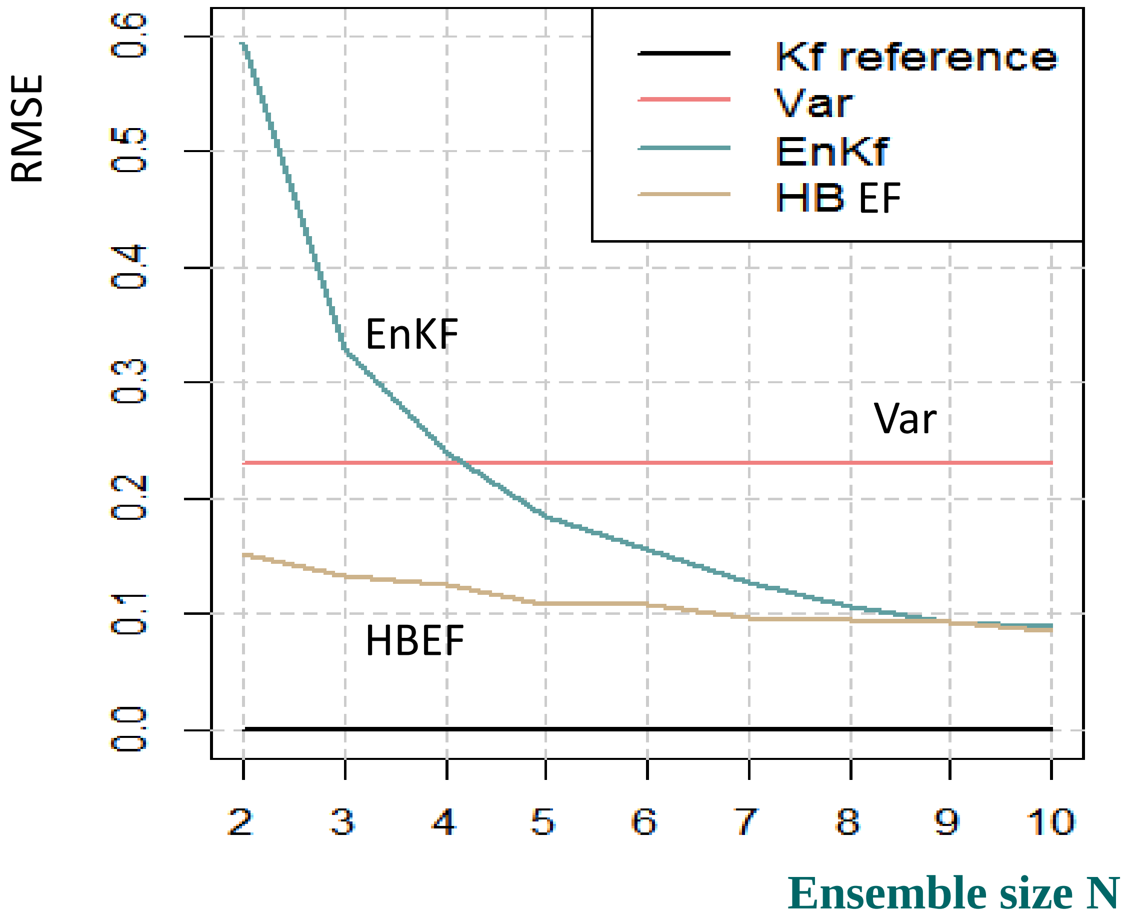
***Proposal*:**

- **Instead of using ad-hoc localization and artificial covariance inflation, explicitly admit that the B matrix is unknown and random and treat it as part of the control variable in an optimal hierarchical Bayes analysis**

- **In this update of both x and B, ensemble members are used as generalized observations on B**

Assume that B matrix is random and uncertain → Use ensemble members as generalized observations and assimilate them along with ordinary ones → Estimate the "true" B matrix

Results for a 1-D model of “truth”: (RMSE of analysis) minus (RMSE of reference-KF analysis)



- ✓ **HBEF significantly outperforms EnKF, except for very large ensembles (N=8 for the system with 1 degree of freedom is a *very large ensemble*).**
- ✓ **HBEF significantly outperforms Var for all N.**

The global SL-AV model

Semi-Lagrangian vorticity-divergence dynamical core (Tolstykh), mostly ALADIN/LACE parameterizations

- Operational medium-range fcst version: 0.9x0.72 deg lon/lat, 28 levels
- Seasonal forecast version: 1.4x1.1 deg lon/lat, 28 levels

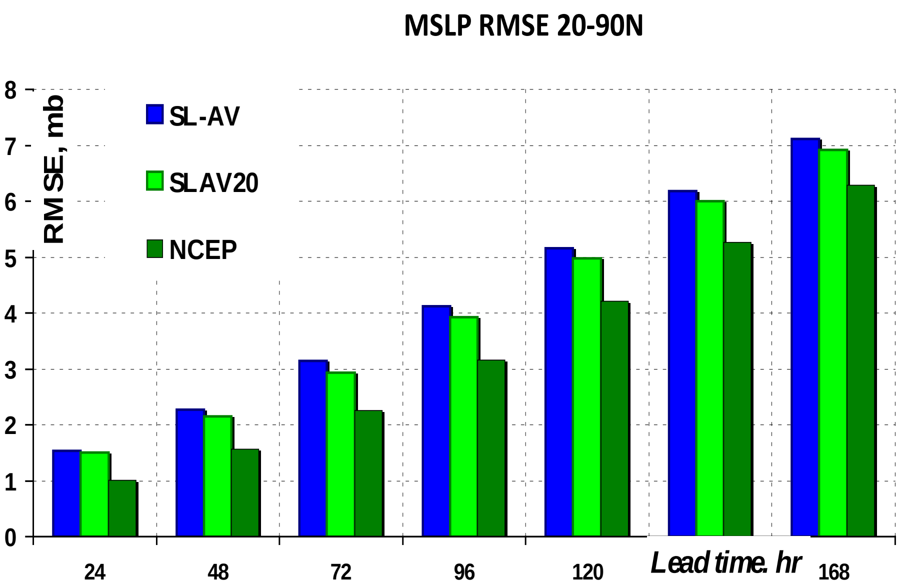
- A new medium-range fcst version (0.225x(0.18-0.23) deg, 51 levels, improved physics) is on operational trials

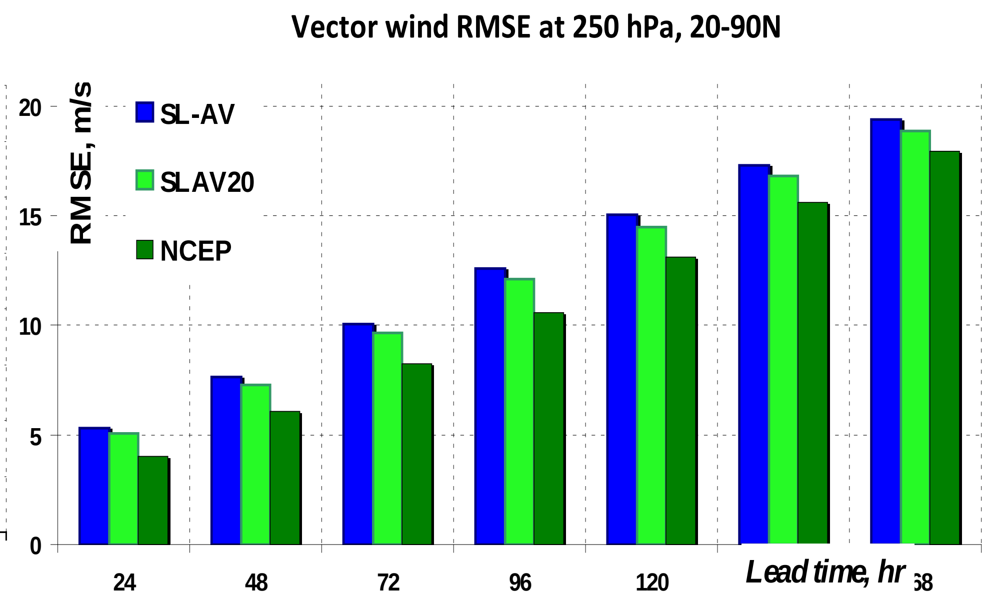
Developments since the last WGNE session:

- a new snow albedo scheme ((Dutra et al) + Verseghy scheme south of 60S + solar zenith angle (Dickinson et al))
- tests of reduced lat-lon grid with the SL-AV dynamical core
- improved hindcasts in the seasonal version
- development of a unified version, suitable for both NWP and climate simulations

Operational version (~75 km) vs new (~25 km) version (on operational trials) of SL-AV models and GFS

(April, 11 –September 11,2014)





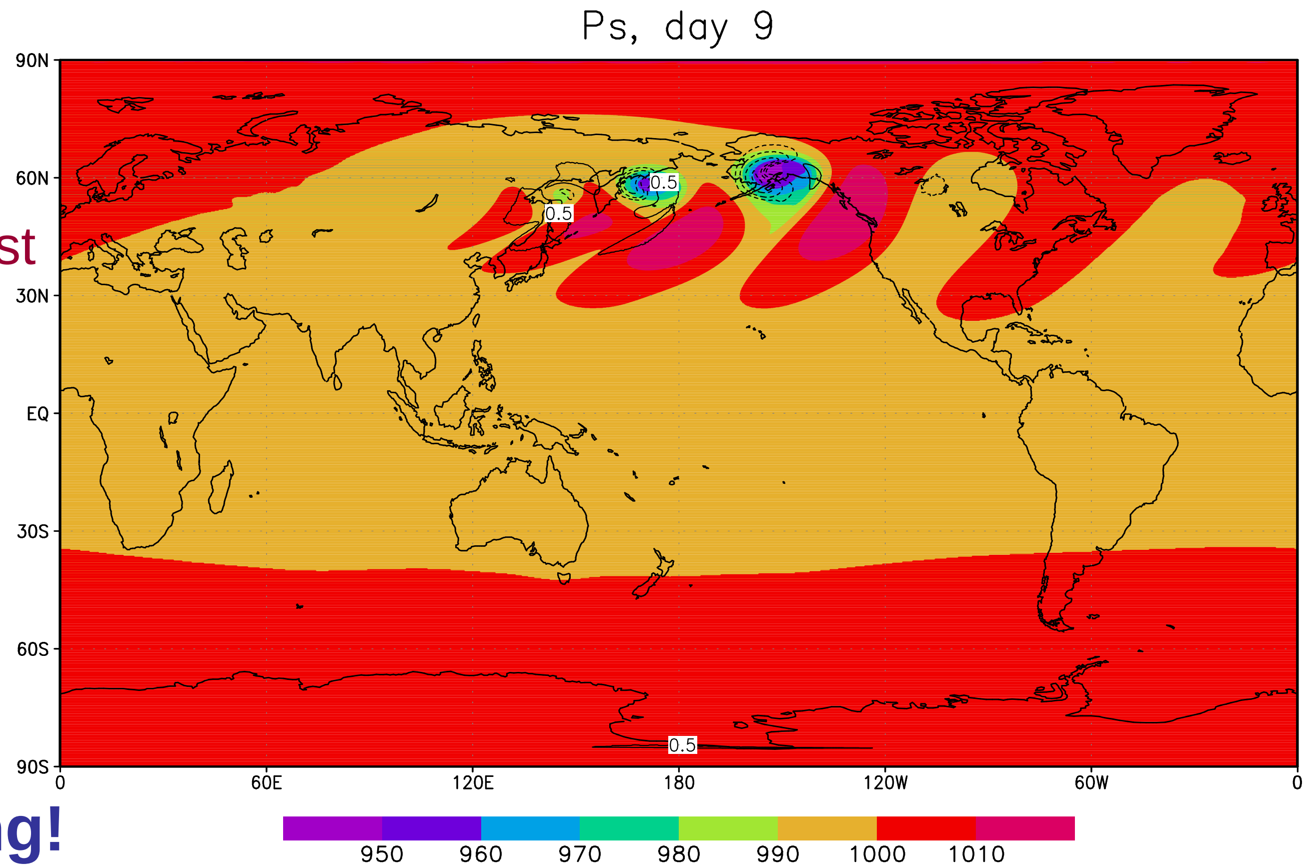
N.B.: the horizontal resolution of RHMC analysis is just 1.5 degrees

Reduced lat-lon grid for SL-AV model (Tests)

(algorithm: Fadeev, 2013, Russ.comp.math &math.phys)

- Mountain-induced Rossby wave (Jablonowski et al 2008)
- Rossby-Haurwitz wave 4

Baroclinic instability test (Jablonowski, Williamson 2006)



New SL-AV version

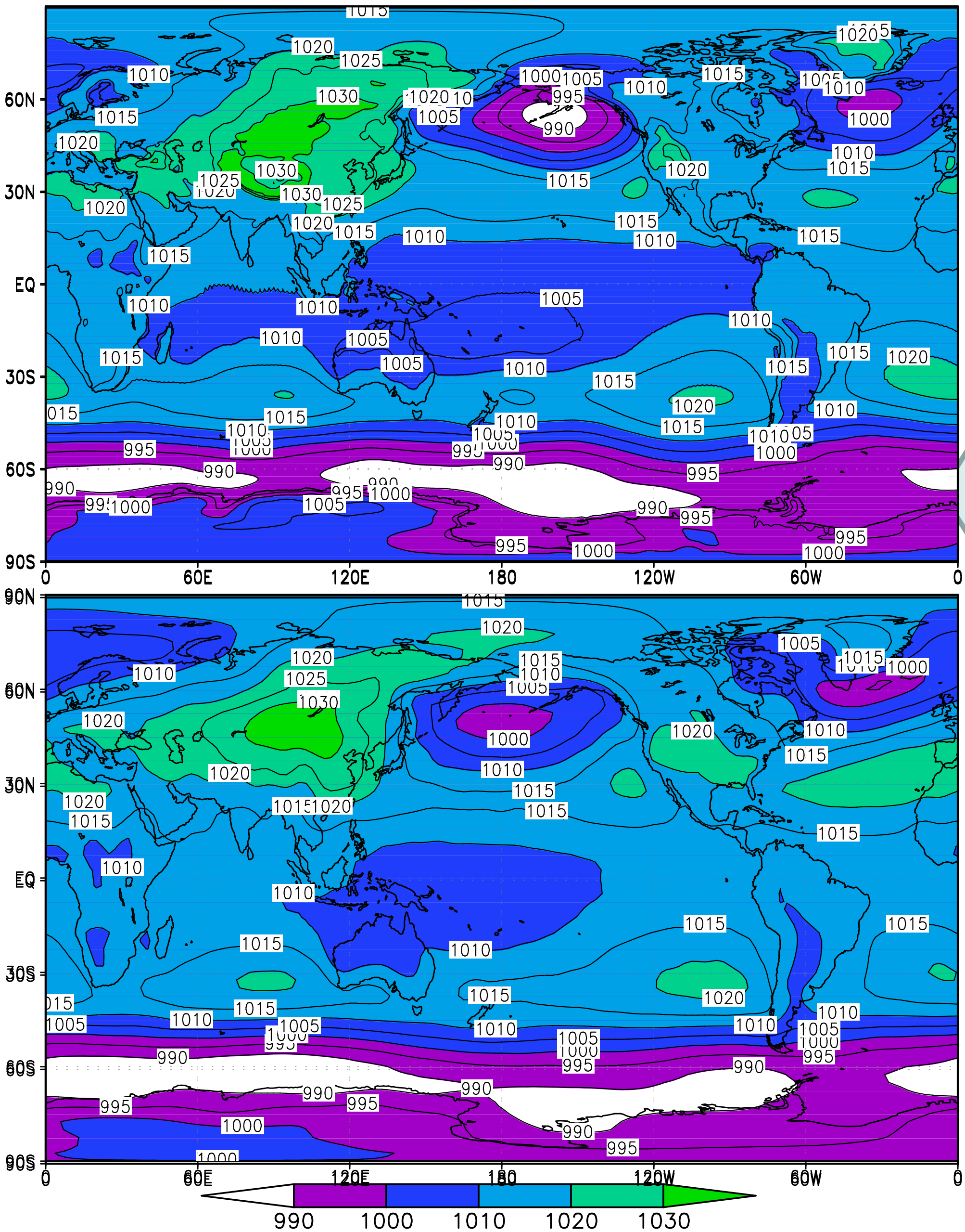
No grid imprinting!

Color: surface pressure field

Isolines: the difference between full and reduced grid simulation

The unified SL-AV version: applicable to climate modelling

- Much more scalars; much more fields in I/O; parallel I/O).
- Mass-conserving version is already developed (Shashkin, Tolstykh, GMD 2014)



Validation with 7-yr AMIP2 simulation (0.9˚x0.72˚, L28)

Averaged MSLP in AMIP-2 model simulation (top) and reanalysis (bottom) (1980-1985)

Global SL-AV model: Plans for further development

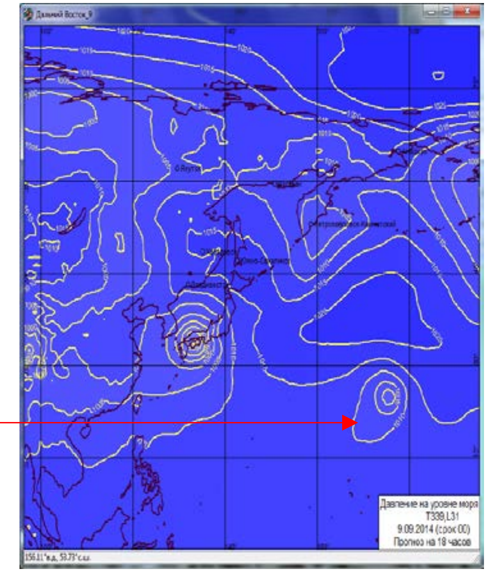
- Implement hybrid vertical coordinate instead of sigma, increase the model atmosphere top (from 5 to 1 hPa).
- Run AMIP2 for 25 years after some model refinements and analyze the results.
- Couple to INM global ocean models and run CMIP.
- Implement full 3D version with physics at the reduced lat-lon grid.
- Implement EKF soil initialization scheme for multilayer soil model.

RHMC Global spectral model

A new operational version T339L31 was implemented in June 2014 (after 2-year trials)

- **Increased horizontal resolution (T169 → T339)**
- **New external data sets**
- **Upgraded radiation parameterization**
- **Modified soil model (thermal conductivity of soil)**
- **Modified post-processing**

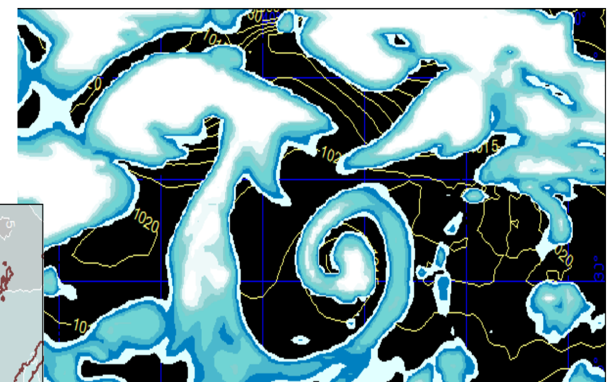
Improved description of atmospheric evolution by the new version (T339 vs T169)



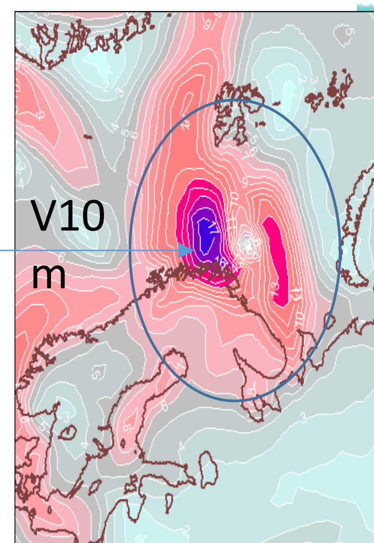
In the tropics :

- ✓ **Generation of new cyclones after 2-3 day forecasts**
- ✓ **Better simulation of wind fields and cloud systems**
- ✓ **Explosive situations in ITCZ became rarer**

In Mid- latitudes:



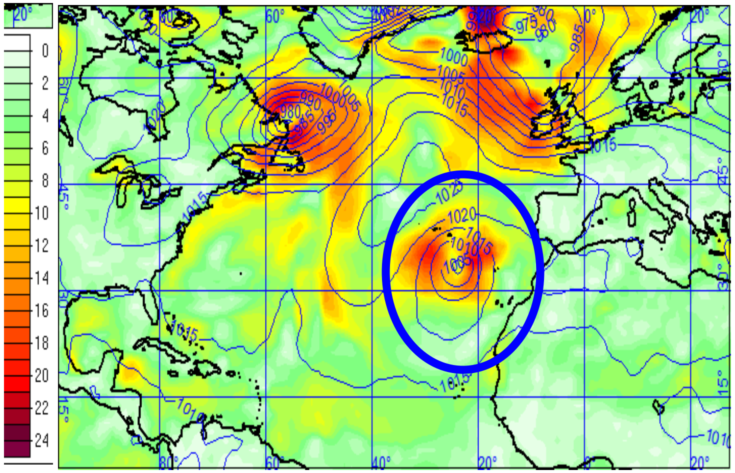
- ✓ **Better location of precipitation zones near the fronts**
- ✓ **More exact cyclone depths**
- ✓ **Strong wind zones over the sea are described better**
- ✓ **The wind maximums in the upper troposheric jet are better reproduced**
- ✓ **Better T2m in mountains**



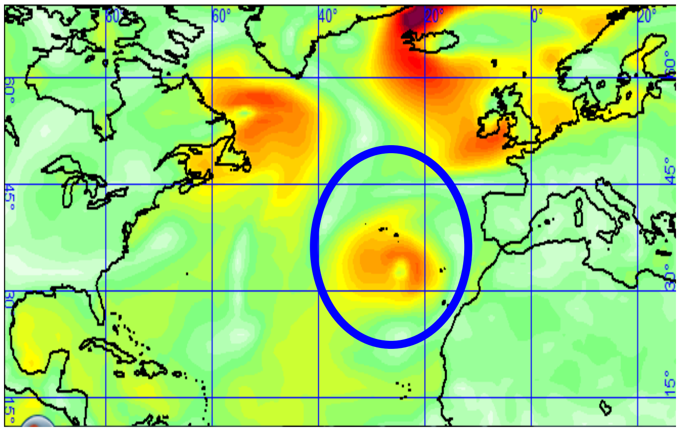
In the Polar and Arctic latitudes:

- ✓ ***Better description of*** **polar cyclogenezis**

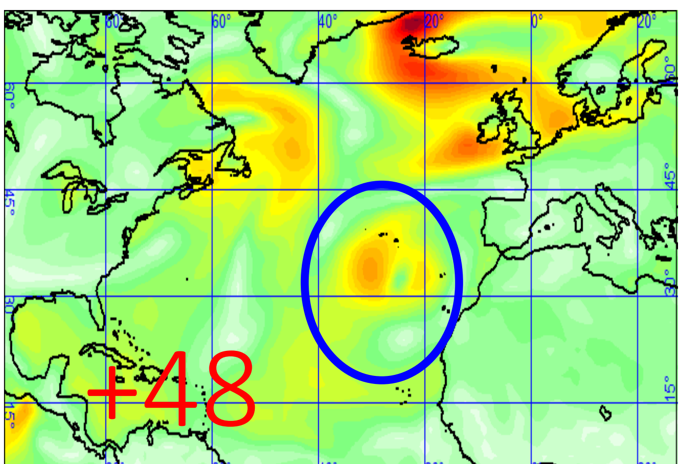
Generation of a new tropical cyclone after 48h forecasting: T339 vs T169



ANAL



T339



T169

10m wind speed over the Atlantic ocean

Global ensemble prediction at RHMC

Models: spectral T169L31, semi-Lagrangian SLAV

Membership: 14 members, 12 perturbed T169L31,

2 controls T169L31 and SLAV

Resolution: ~70 km

240h forecast once a day at 12 UTC

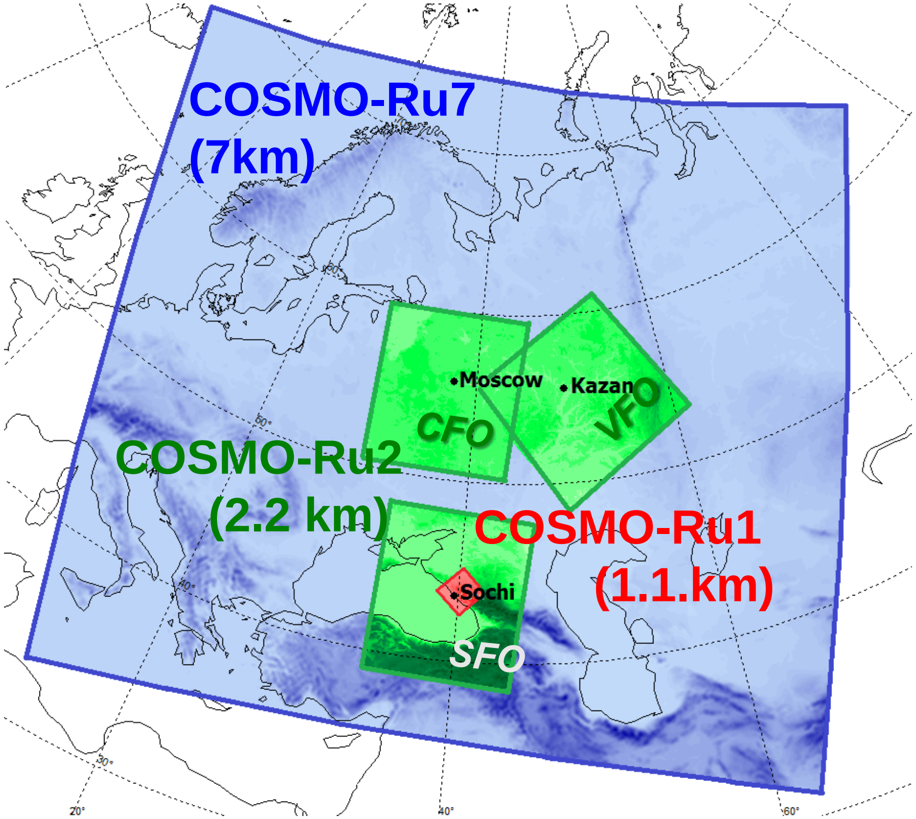
Operational since January 2015

Plans:

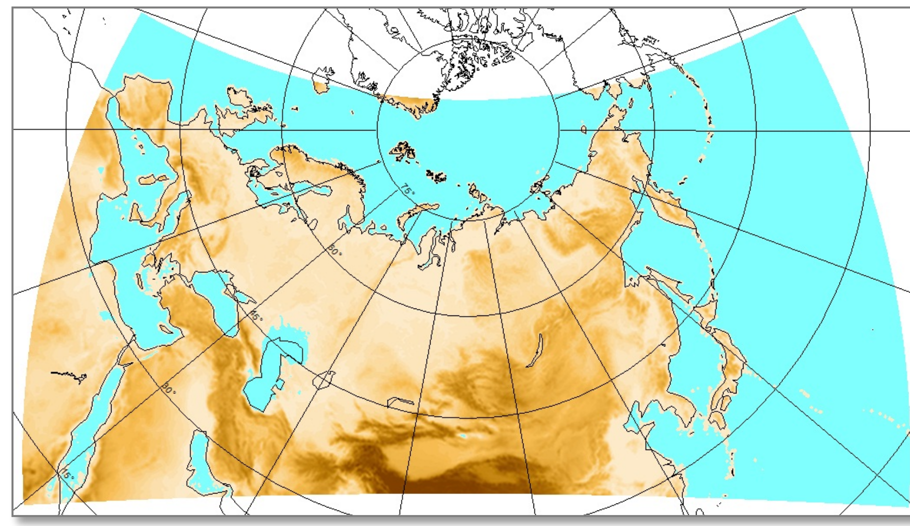
- Introduction of high-resolution control runs (~25-30 km) (2015)
- Increase of EPS size (greater contribution of SLAV) (2015, a greater increase in 2016 after a new computer is installed)
- Introduction of SPPT (2015-2016)
- Development of the system based on EnVar DA (2016)

OPERATIONAL WEATHER FORECAST SYSTEM COSMO-RU

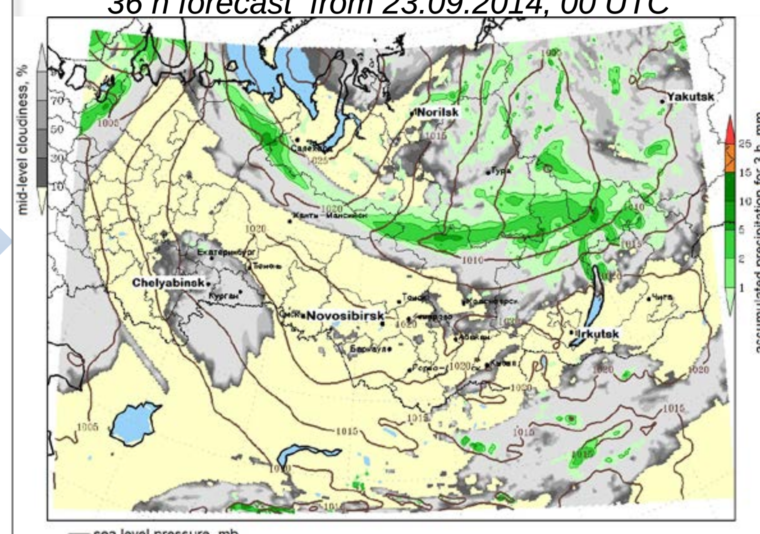
Driven by ICON (DWD) since Jan2015 ***NEW!***



ENA (Europe – North Asia) (13 km) ***NEW!***



Pressure, mid-level cloudiness and precipitation 36 h forecast from 23.09.2014, 00 UTC



COSMO-RuSib runs operationally in the WMO Regional Meteorological Center (Novosibirsk)

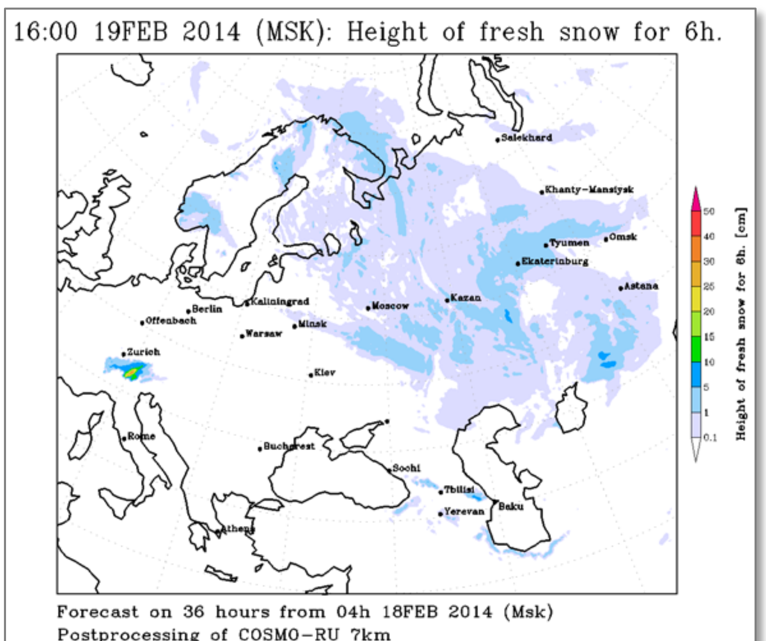
Grid:	360 x 250 x 40
Grid size:	14 km
Time step:	80 sec
Forecast:	78 h

OPERATIONAL WEATHER FORECAST SYSTEM COSMO-RU

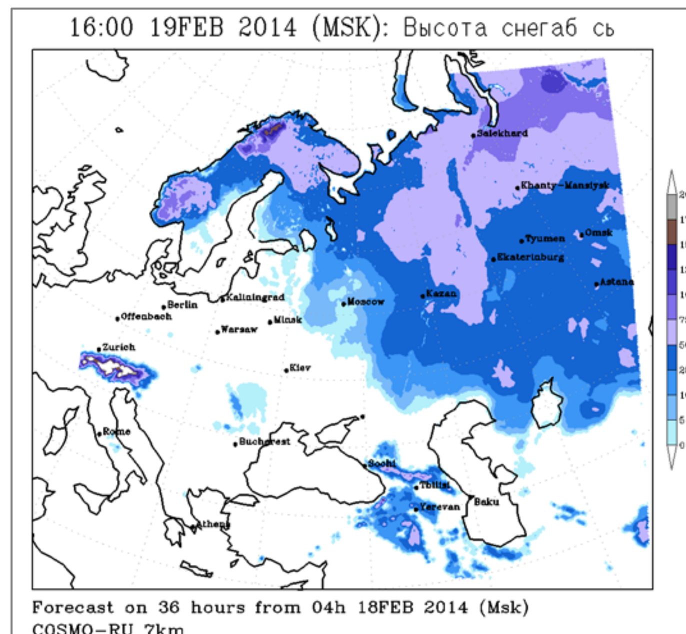
FRESH SNOW POSTPROCESSING SCHEME

- represents the amount of newly fallen snow as a column with elements
- uses the formula for density calculation from CLASS
- takes into account compaction due to gravity
- the number of elements in the column depends on the input sum precipitation
- gives depth of newly fallen snow and its density for 6 h intervals

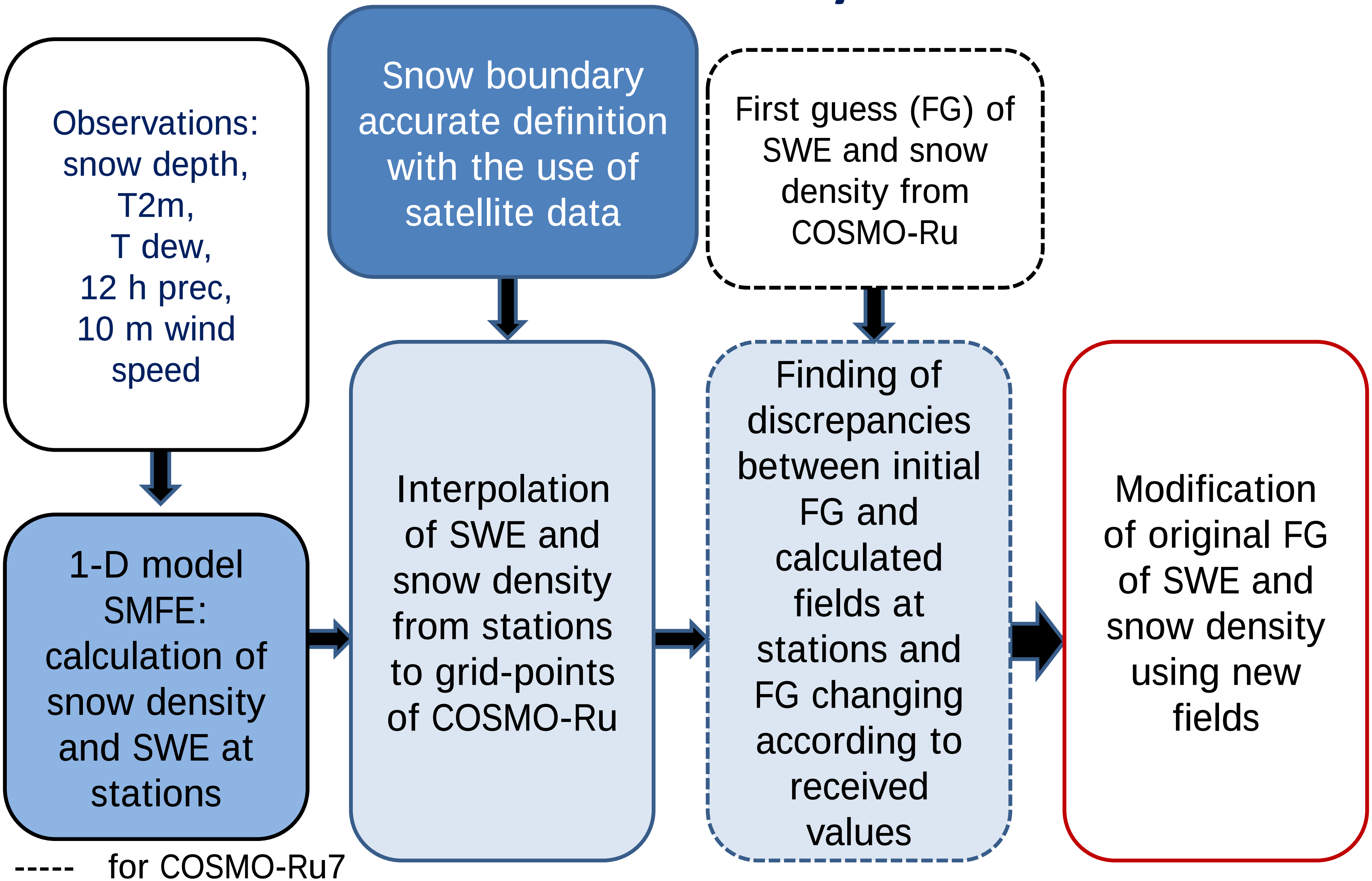
Fresh snow height



Snow height

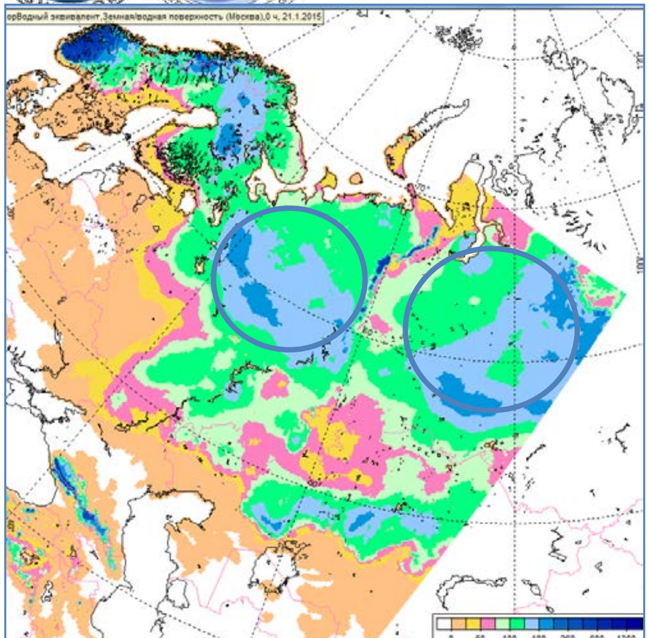


Initialization of Snow Water Equivalent (SWE) and Snow Density

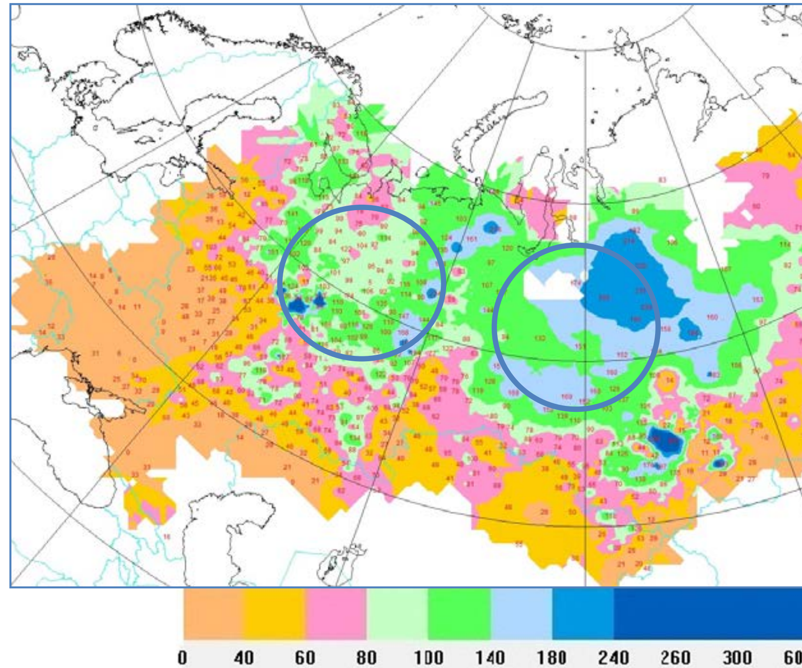


SWE fields. 20 January 2015

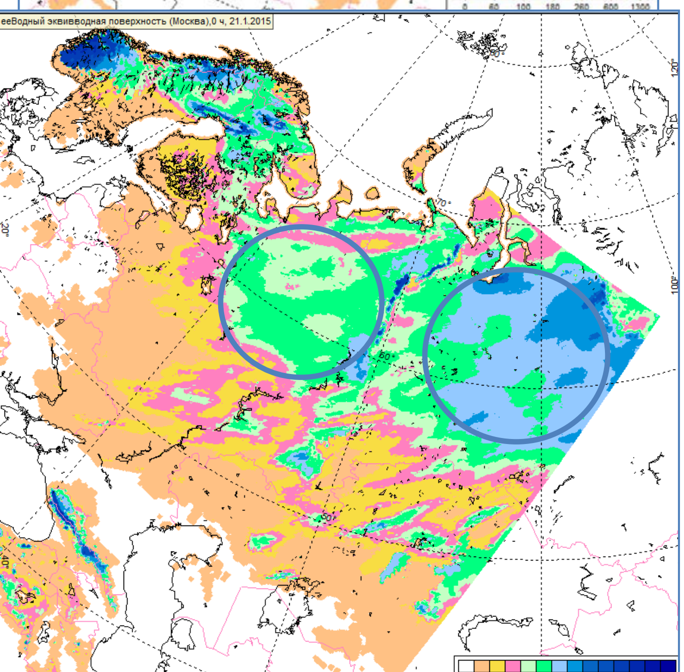
Old



Measurements

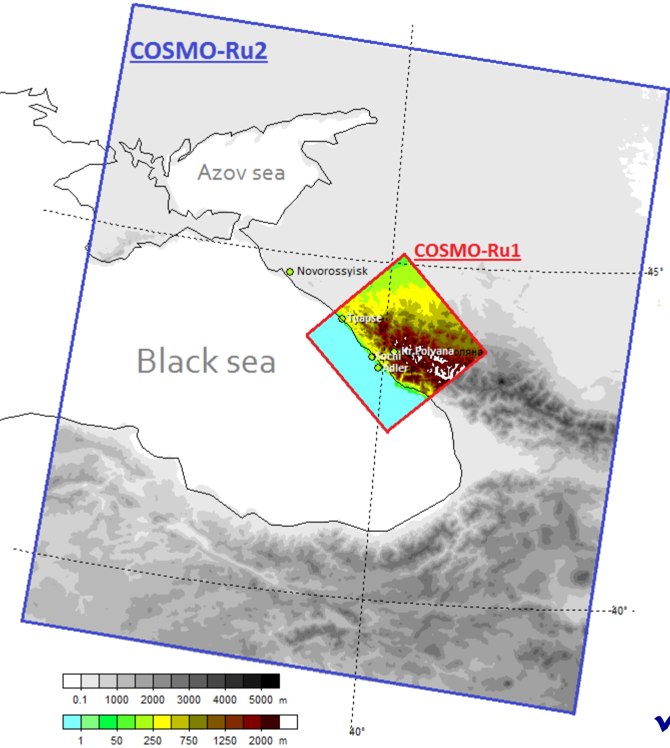


New



- Better T2m near the snow boundary during the snow-melt period
- More realistic T2m and cloudiness over the regions where much snow was accumulated

High-resolution model COSMO-Ru1



COSMO-Ru1 model's grid is nested to **COSMO-Ru2 for SFO** (region around Sochi)

COSMO-Ru2
(for the **S**outhern **F**ederal Area)
Domain: 900 km x 1000 km
Grid: 420 x 470 x 50
Space step: **2.2 km**
Time step: 20 s
Lead time: 48 h

IC&BC

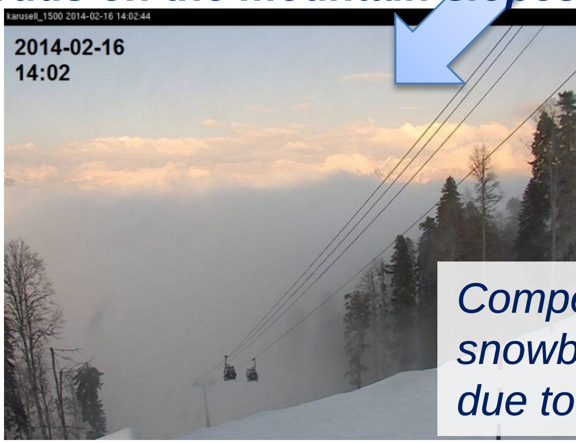
COSMO-Ru1
Domain: 210 km x 210 km
Grid: 190 x 190 x 50
Space step: **1.1 km**
Time step: 5 s
Lead time: 36 h

- ✓ A detailed orography based on ASTER data (Advanced Spaceborne Thermal Emission and Reflection Radiometer, resolution 1'' (~30m)
- ✓ A dynamic core with modifications by M. Baldauf
- ✓ Assimilation of HMS & AMS data using ***nudging method***

COSMO-Ru1 and COSMO-Ru2. Case studies.

Low visibility cases

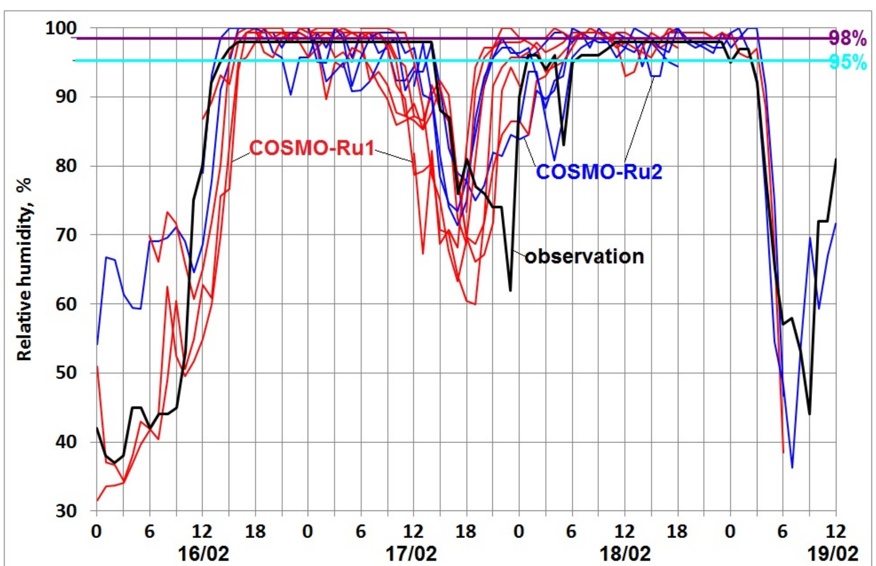
February, 16-17.
Clouds on the mountain slopes



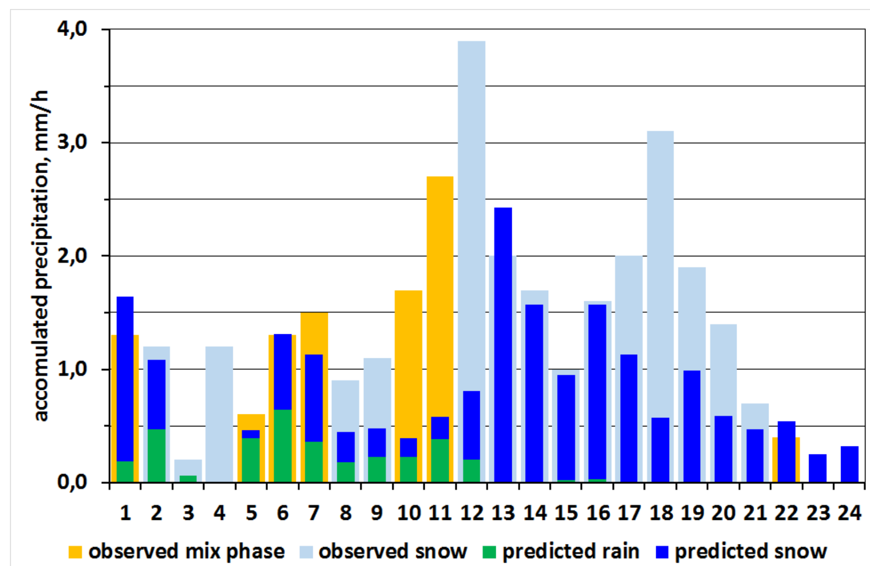
Competitions in biathlon and snowboard were postponed due to low visibility.

February, 18.
Heavy snowfall

Relative humidity. Observation, COSMO-Ru1 and COSMO-Ru2 forecasts.

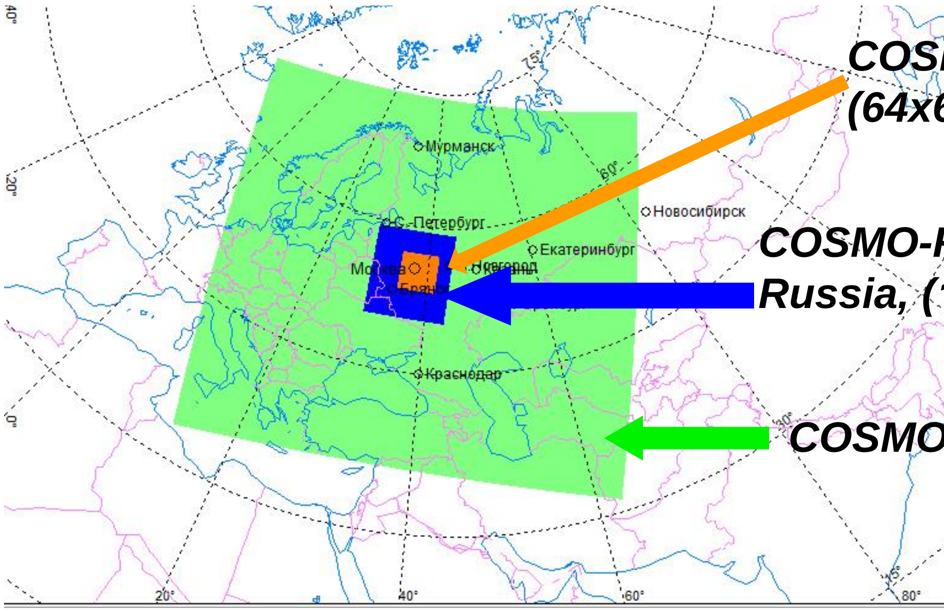


Precipitation and its phase.
Observation and COSMO-Ru1 forecast for Biathlon



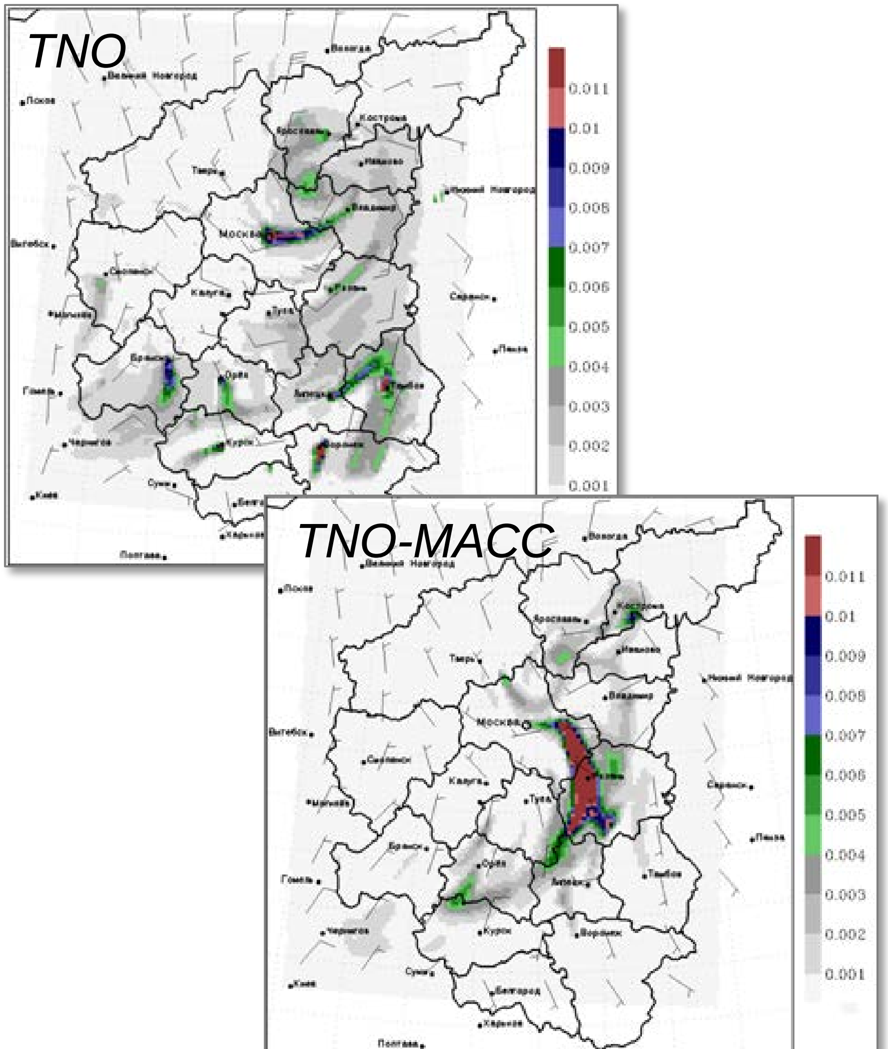
COSMO-RU-ART

- COSMO5.0-ART3.0 is used for 48-hours forecast of air pollutant's concentration over the center of the European part of Russia
- Forecast for the following substance *CO, SO_2, NO, NO_2, $PM10$, O_3*
- Updated emissions (TNO $\Rightarrow$ TNO-MACC)
- Calculation of the *meteorological potential* for atmospheric pollution
- Forecast of *fire pollution*
- Model *verification* in connection with meteorology, vertical profiles

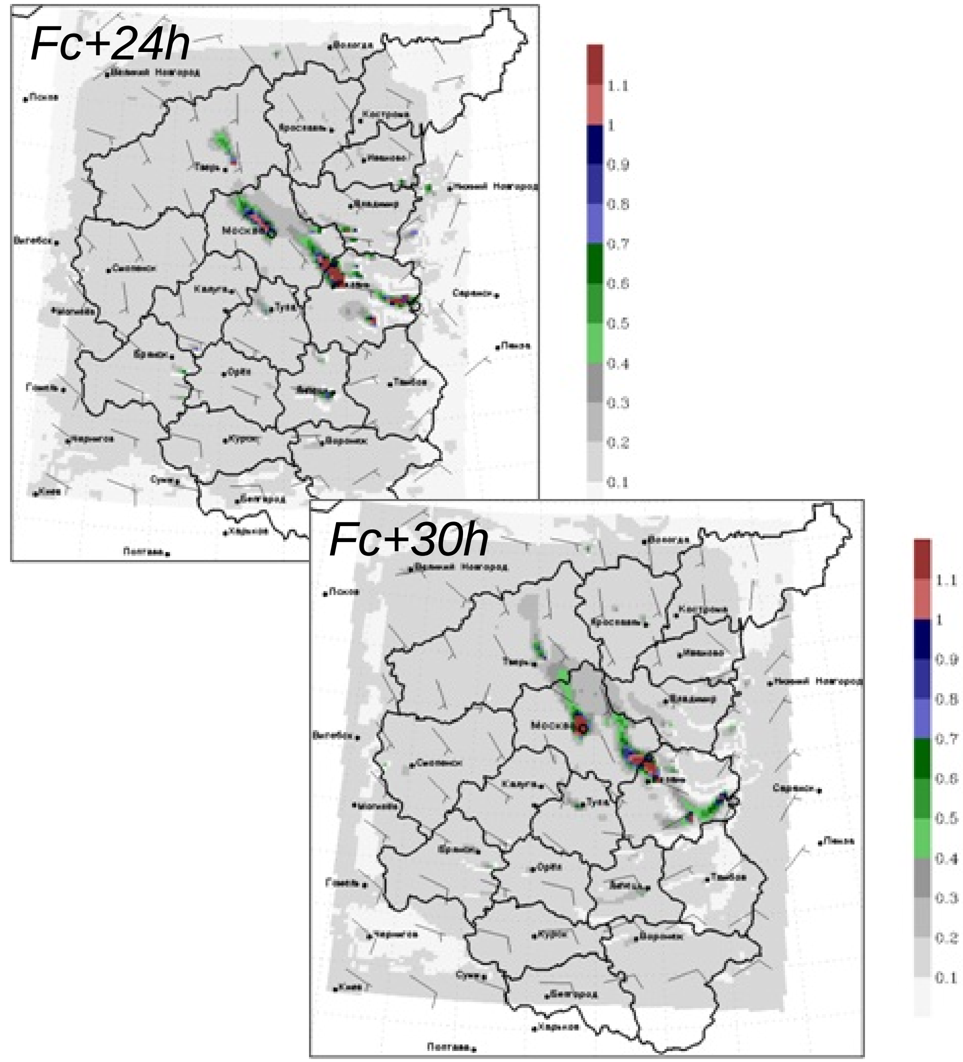


COSMO-RU-ART

NO concentration (ppm) 24h forecast from 02.09.2014, 00 UTC with different emissions



Wild fire event. CO concentration (ppm) forecast from 06.08.2010, 00 UTC

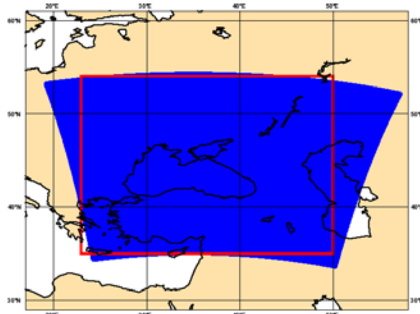


FURTHER WORK IN MESOSCALE MODELLING

1. Increase the resolution of COSMO-Ru7 from 700x620,7km, L40 to 800x700, 6.6km, L40 in 2015
2. Increase the vertical resolution to L60 in all versions in 2016
3. COSMO-Ru1 forecasts for the extended area and estimation the wind speed and wind gust forecast for the Novorossiysk bay (bora forecast) and Kerch Strait
4. Case studies for high resolution models (COSMO-Ru2, COSMO-Ru1) using observations archived during the Olympics / Paralympics (1.5 month) and trial period (2 previous years).
5. COSMO-Ru1 for Moscow region coupled with COSMO-ART.
6. COSMO-Ru1 for Moscow region coupled with URBAN model.

Mesoscale ensemble prediction at RHMC

Clusterization, interpolation



Interpolation

ECMWF-EPS
Globe
T779L61 (Δx~30 km)
M51, fc+14d
ECMWF computer

COSMO-S14-EPS
Sochi region
Δx~7km, L40
M10, fc+72h, ARPA-SIMC
ECMWF computer

COSMO-Ru2-EPS
Small Sochi region
Δx~2.2 km, L51
M10, fc+48h
Roshydromet computer

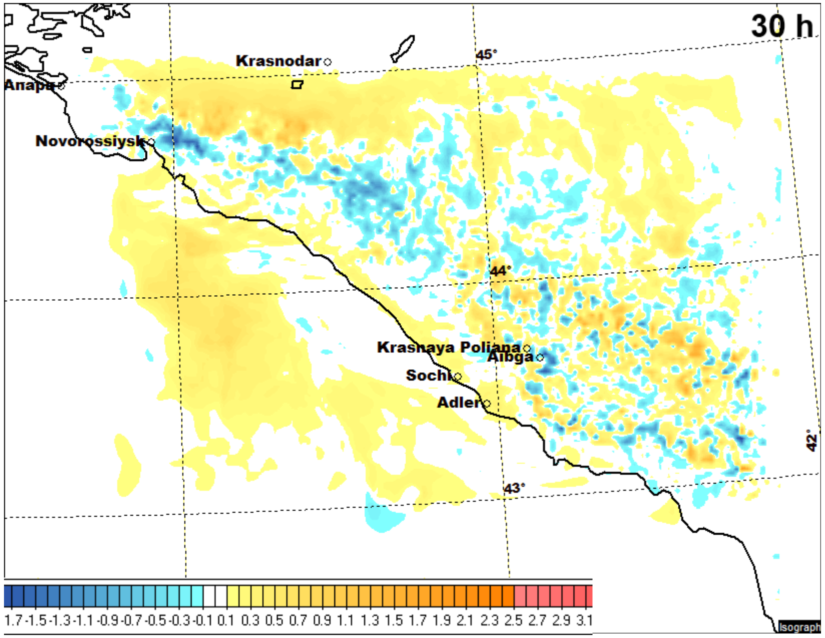
COSMO-Ru2-EPS has been developed for the Sochi region
and ran operationally from Nov 2013 to May 2014.
Used for meteorological support of the Olympic and Paralympic Games 2014

Research: SPPT effect on forecast skill and ensemble spread (using Sochi data)
Plans: development of convection-permitting EPS based on COSMO model for Moscow region (and for the polar region if computer available)

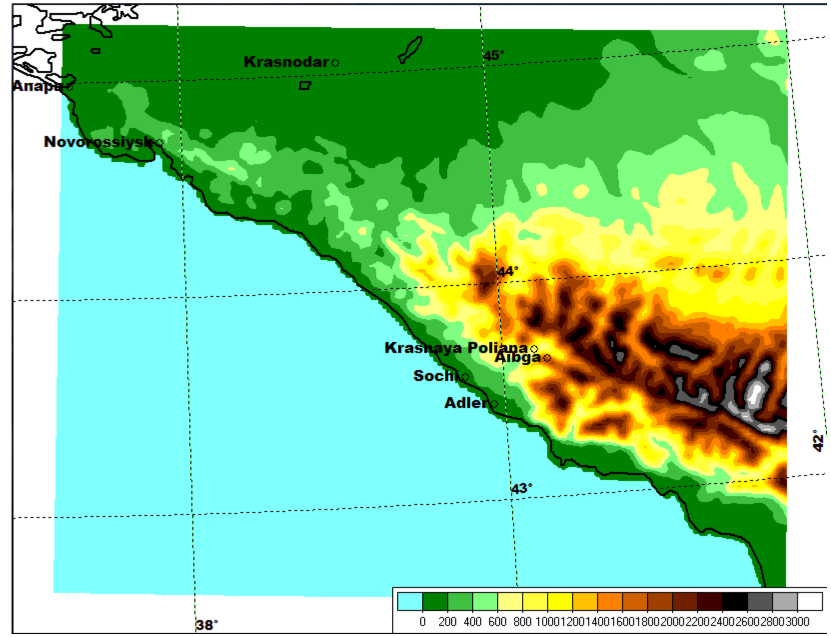
The SPPT effect on ensemble spread

COSMO-Ru2-EPS: T2m, 2014.02.06/00 UTC +30h

Spread change (SPPT - no SPPT)



Orography



The spread variations correlate with orography

The spread

- ✓ increases over sea and lowlands
- ✓ strongly increases over very high mountains
- ✓ decreases over lower mountains

SPPT sometimes improves precipitation forecasts

FROST-2014: Project Field Phase and Post-Olympics Life

(FROST = Forecast and Research in the Olympic Sochi Testbed)

• With the closure of the Olympics in March 2014 the project field campaign was mostly over.

• Today the focus of FROST-2014 activities is switched to analysis of results of the field campaign.

4th Meeting of the FROST-2014 participants
was held in Moscow 29-31 October 2014 to discuss the outcomes and preliminary results of the project field phase, lessons learned, potential joint studies, papers and further related activities.

FROST-2014 forecast data

- **Deterministic forecasts**:
  8 models, resolutions from 7 km to 250 m
- **Ensemble forecasts:**
  6 systems, resolutions from 11 to 2.2 km
- **Nowcasts:** 6 systems, mainly pointwise

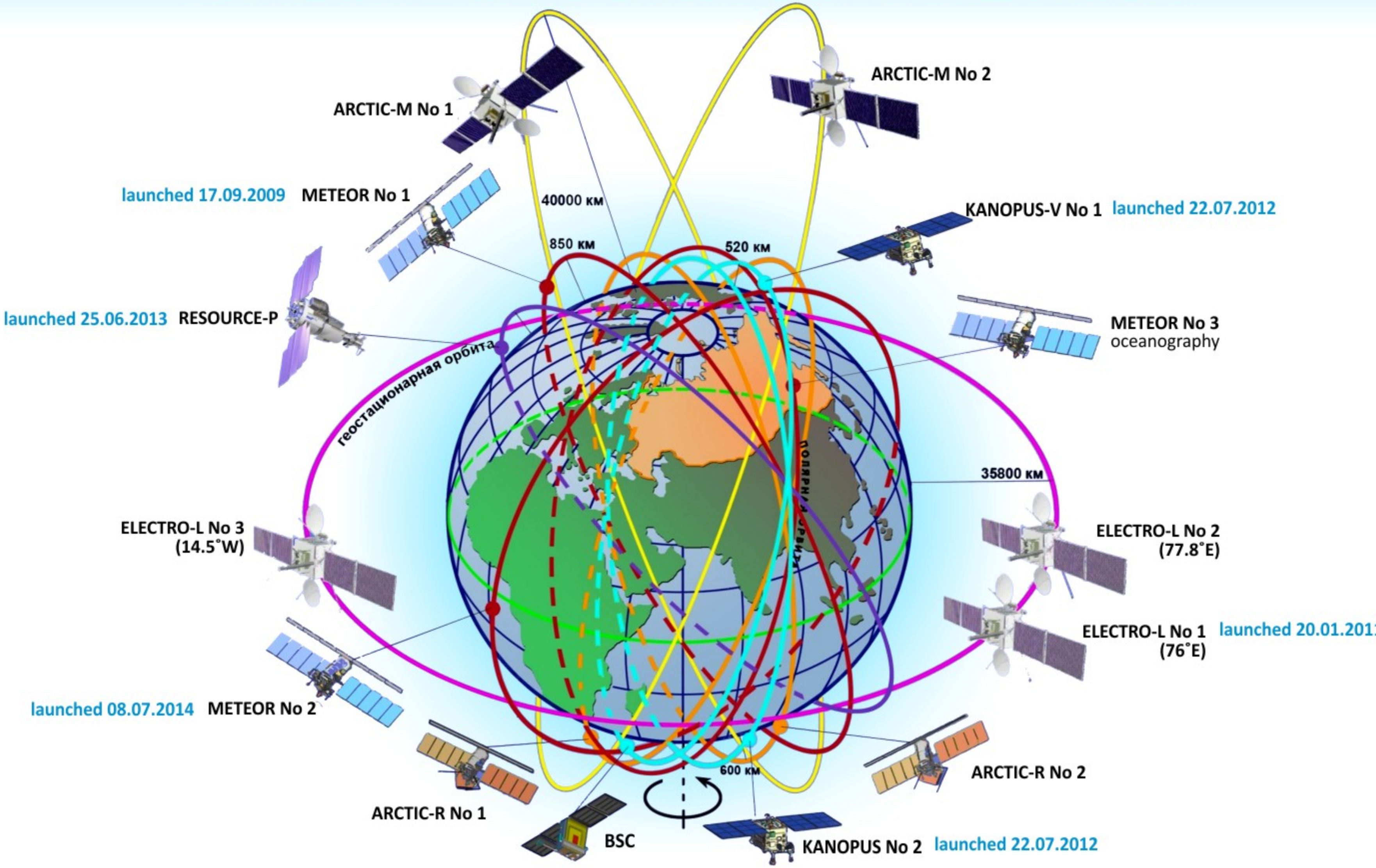
Forecast archives for the official testing period (15 Jan-15 March 2014 will be re-organized according to TIGGE-LAM standards (GRIB2)

FROST-2014 observation data

- AMS
- Temperature/humidity/wind profilers
- Vertical micro-rain radar profiles
- High-resolution upper air sounding profiles
- Special snow profile measurements
- Marine and meteorological data
  from the anchored sea buoy near the Sochi coast
- Raw radar data for 5 dual-pol Doppler radars
  (every 10 min)
- Radar graphical products, including composite maps
- Shots of 7 cameras (every 10min)
- Series of official forecast bulletins for 5 sport venues

http://frost2014.meteoinfo.ru

CONSTELLATION OF RUSSIAN EARTH OBSERVATION SATELLITES IN 2020



THANK YOU FOR YOUR ATTENTION!

СПАСИБО ЗА ВНИМАНИЕ!

Applying of aircraft-laboratory Yak-42D «Roshydromet»