



Federal Service for Hydrometeorology
and Environmental Monitoring



Hydrometeorological
Center of Russia



SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
CARFFGS: Central Asia Regional Flash Flood Guidance Project

Status and availability of SWFDP-CA QPF for use in CARFFGS

Gdaliy Rivin, Inna Rozinkina
and SWFDP-CA team

Astana, 14 Sept. 2015



Status and availability of SWFDP-CA QPF for use in CARFFGS

1. WMO SWFDP
2. WMO SWFDP –CA: status
3. COSMO and COSMO-Ru
4. QPF by COSMO-Ru
5. Meteorological part of CARFFGS

SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
CARFFGS: Central Asia Region Flash Flood Guidance Project



Status and availability of SWFDP-CA QPF for use in CARFFGS:

1. **WMO SWFDP**
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SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
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WMO SWFDP GOALS

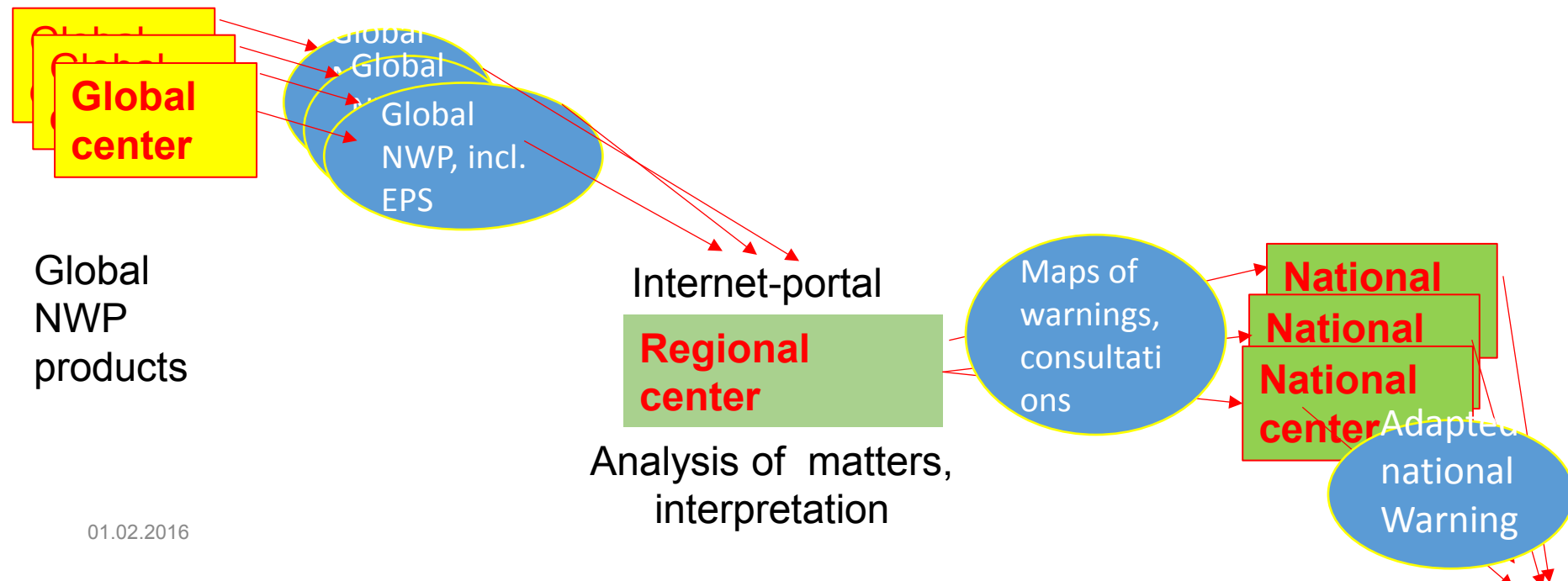
- 1. To improve the ability of NMHSs to forecast SEVERE weather events**
- 2. To improve the lead time of alerting these events**
- 3. To improve the interaction of NMHSs with Disaster Management and Civil Protection authorities (DMCPAs), the media, each identified user sector, before, during and after severe weather events**
- 4. To identify the gaps and areas for improvements**
- 5. To improve the skill of products from NWP Centres through FEEDBACK from NMHSs**



Principal concepts of WMO SWFDP (1)

- The more critical dangerous weather events happen frequently in the countries without own NWP development
- The centers that produce NWP products should be of great assistance
- The Cascadian exchange of NWP products is the methodical basis of SWFDP projects:

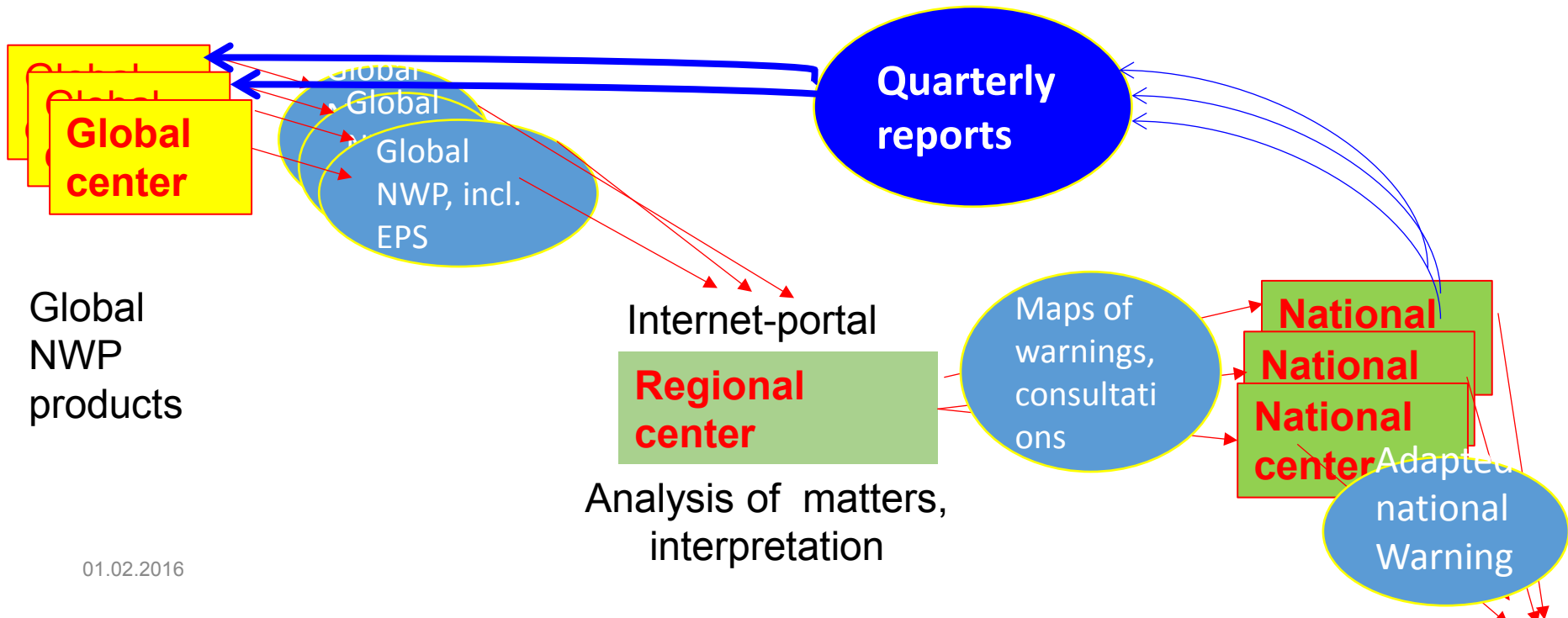
Global&NWP centers (NWP products)→Regional centers (interpretation, LAM products) → National centers (warnings)





Principal concepts of WMO SWFDP (2)

- The feed-back from RMC & NMC to NWP & global centers should be extremely useful for development of NWP and for the forecaster training experience exchange
- Every NMC (RMC) should observe the skill of NWP forecasts for severe weather events
- The trainings for forecasters concerning the optimal use of products are one of main components of WMO SWFDP

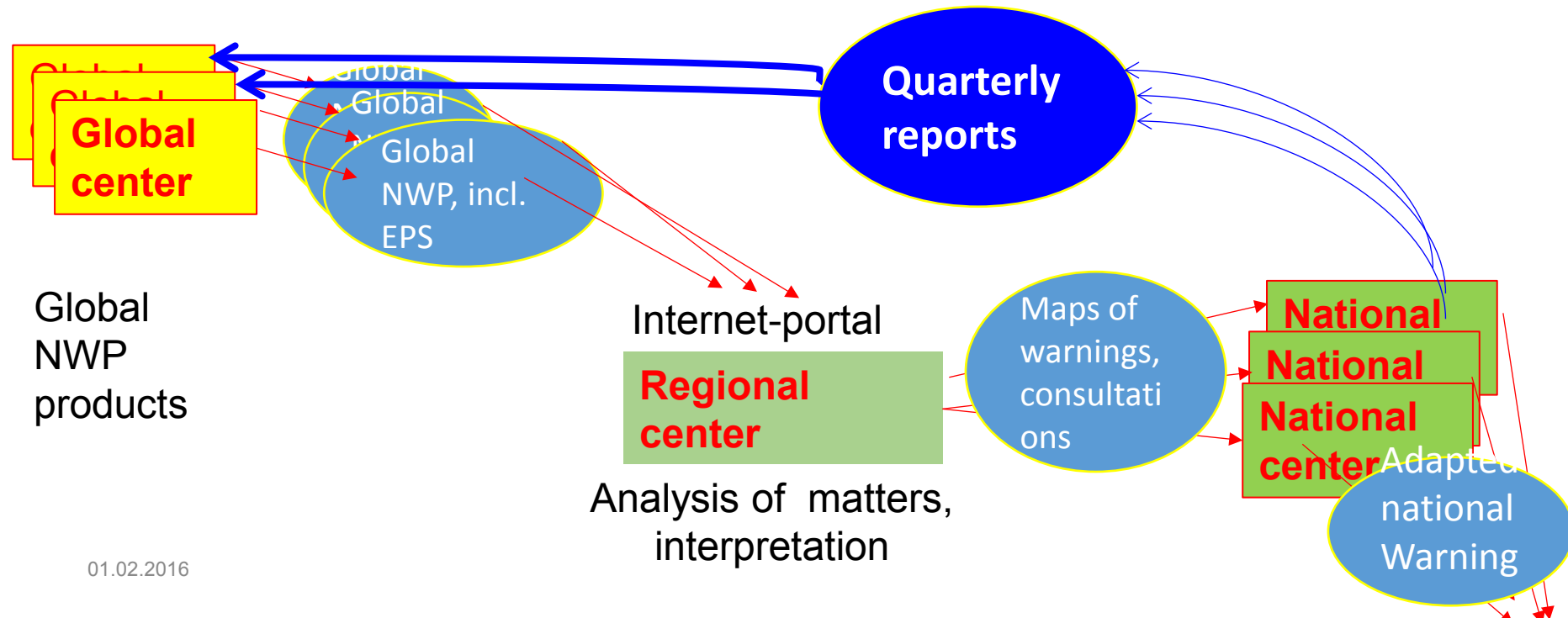




Principal concepts of WMO SWFDP (3)

Quarterly reports of NMC and RMC should consist to:

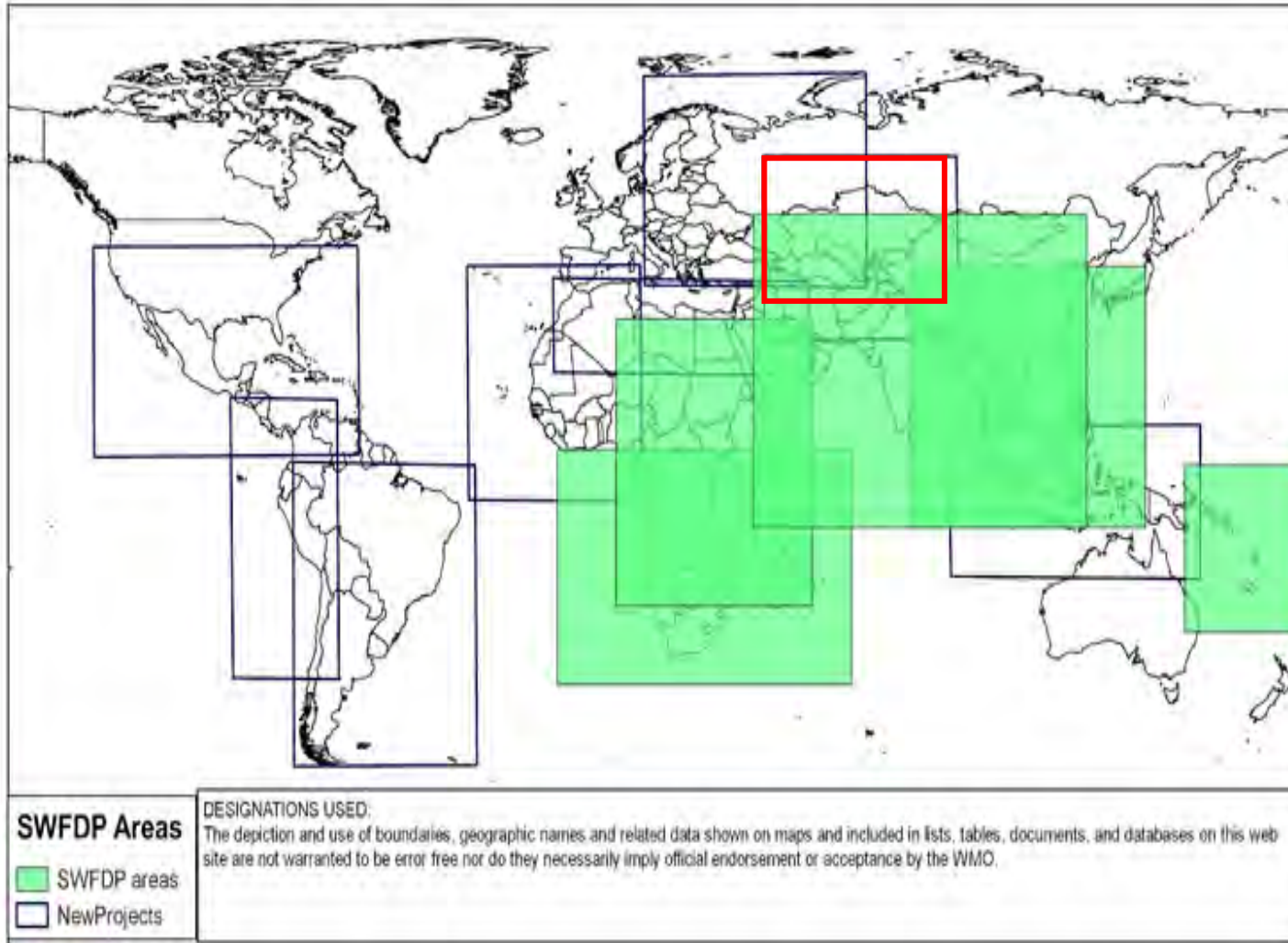
- Monitoring of severe weather events for each country
- Description of selected 1-2 Case studies (scale, origin, structure)
- Forecaster view about the more feasible kinds of NWP





WMO SWFDP areas,

<http://www.wmo.int/pages/prog/www/swfdp//>



SWFDP-CA
Is the first SWFDP without the ocean area and for extreme-continental subtropical conditions



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SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
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SWFDP –CA:

- **Started at April 2015,**
 - **Participants: Kazakhstan, Kirgizstan, Uzbekistan, Tadjikistan +Russia + COSMO**
 - **Participant centers of NWP:**
ECMWF, CMA, KMA, DWD, Roshydromet
- 2 directions:**
- **To realize the concept of SWFDP for CA region**
 - **To develop the Technology of HR LAM in region**



All geographic areas have their own unique forecasting challenge

Weather components typical features for CA region:

- Convection processes over flat terrains
- The significant influence of high mountains



The important potential of high resolution NWP



RSMC: TASHKENT (UZBEKISTAN)

NMC: Astana (KAZAKHSTAN), Bishkek (KIRGIZSTAN), Dushanbe (TADJIKISTAN)



RMC & Global centers:

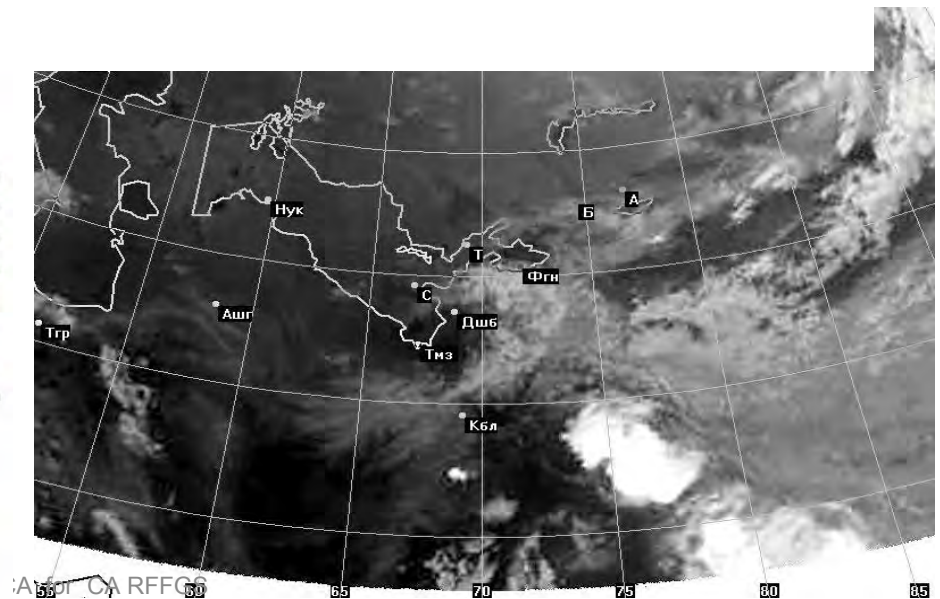
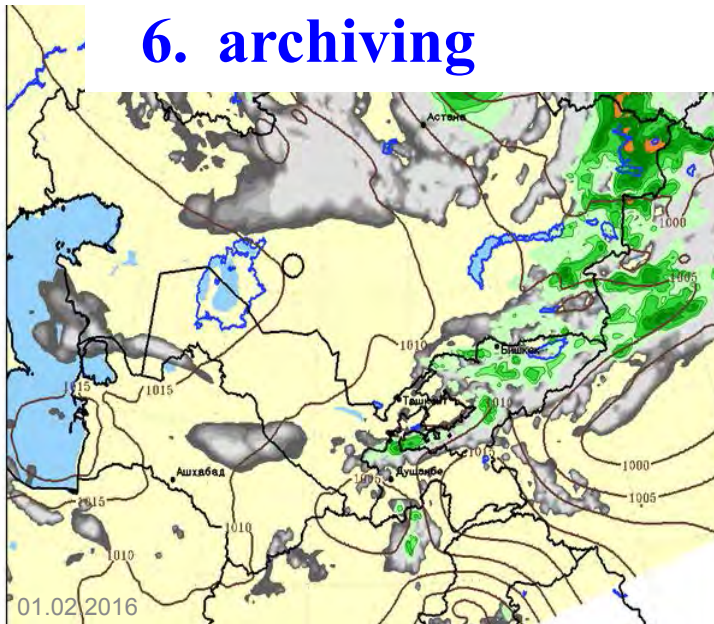


To create the unified information exchange

Whole region: unified web-site

Portal SWFPD-CA:

1. links to NWP centers websites
2. placement or links to synoptic map for CA region
3. placement or links to satellite images
4. interactive ALARM-CA system
5. placement of daily forecasts of NHMC
6. archiving





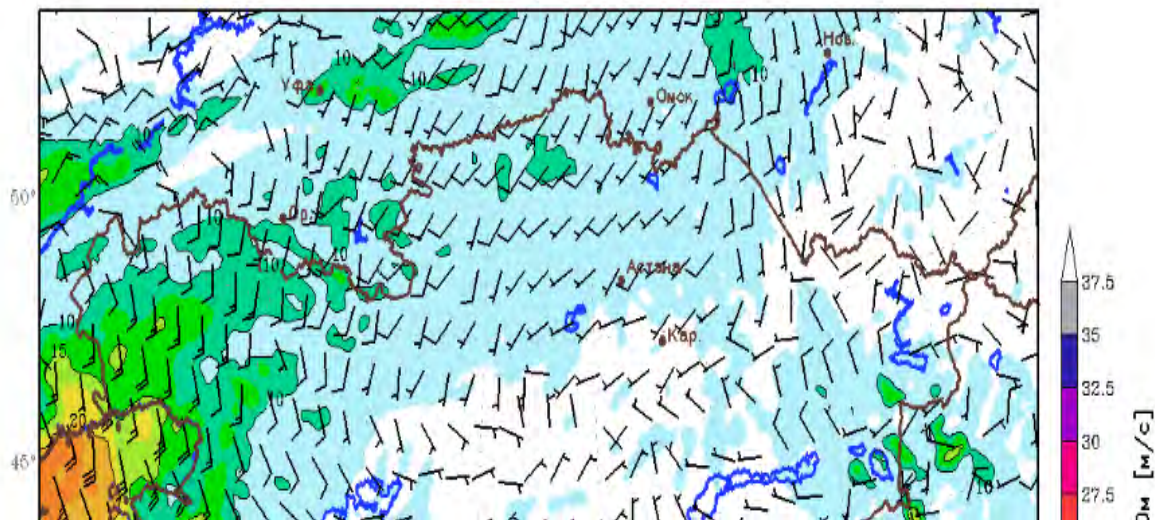
ЦЕНТР ГИДРОМЕТЕОРОЛОГИЧЕСКОЙ СЛУЖБЫ



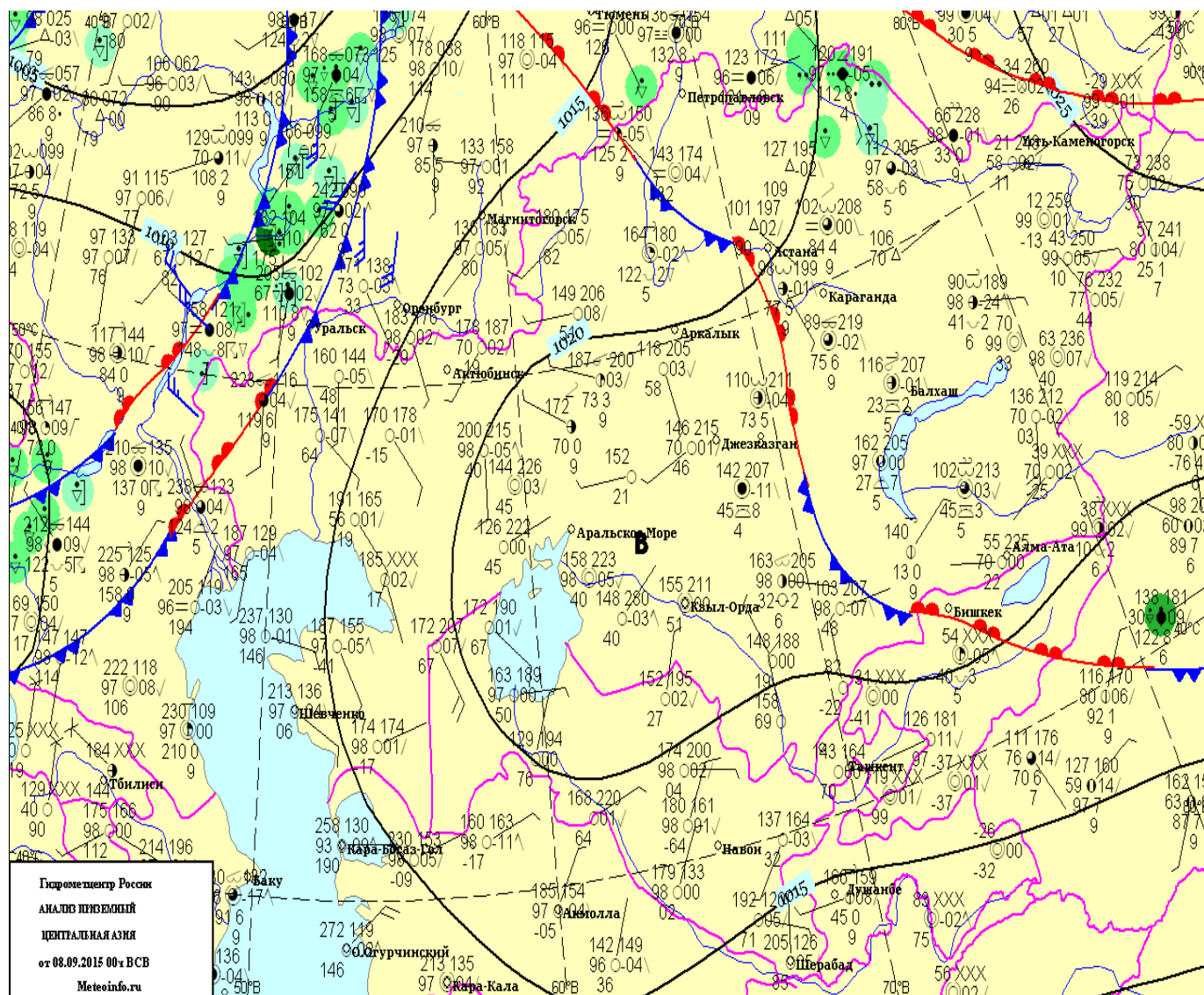
Продукция

Продукция прогнозов COSMO

03:00 09сен 2015 (UTC): Ветер на 10м



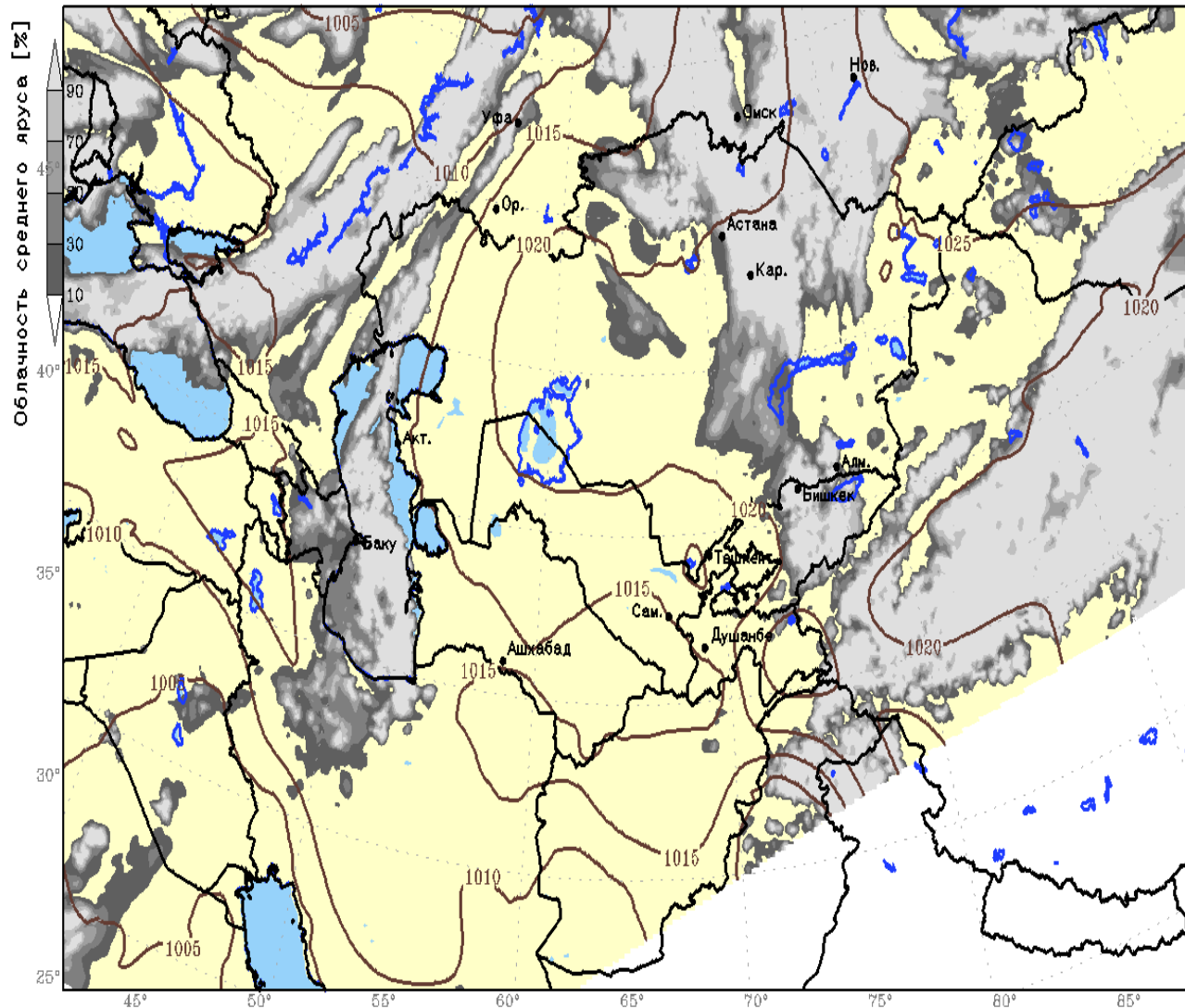
- [Карты прогнозов COSMO для расширенного региона ЦА](#)
- [Карты прогнозов COSMO для расширенного региона ЦА \(анимация\)](#)
- [Спутниковые изображения ЦА масштаба 1:20000000](#)
- [Карты прогнозов COSMO для ЦА](#)
- [Карты прогнозов COSMO для ЦА \(анимации\)](#)
- [Карты прогнозов COSMO для горных районов ЦА](#)
- [Карты прогнозов COSMO для горных районов ЦА \(анимации\)](#)
- [Прогноз по пунктам \(метеограммы\)](#)



01.02.2016



00:00 08сен 2015 (UTC):
Р ур. моря, облачность ср. яр., Осадки



Прогноз на 0ч. от 00:00 08сен 2015 (UTC)

01.02.2016

COSMO-RU 13.2км

— Давление на уровне моря



swfdp-ca.meteoinfo.ru - МетеоАларм

swfdp-ca.meteoinfo.ru/meteoalarm

FB2book.com - Эле... Snow Forecast, Sno... Greg Hakim's Annot... AMS Journals Onlin... Переводчик Google Pantene Russia - Yo...

SWFDP-CA

О проекте МетеоАларм Фактическая погода Прогнозы Семинары Библиотека Ссылки

МетеоАларм

2015-09-07 2015-09-08 2015-09-09

Прогноз на 2015-09-07

КЗ
KG
TJ
UZ

- Данные отсутствуют
- Оповещения о погоде не требуется
- Погода потенциально опасна
- Погода опасна. Имеется вероятность стихийных бедствий, нанесения ущерба
- Погода очень опасна. Имеется вероятность крупных разрушений и катастроф

<http://swfdp-ca.meteoinfo.ru/meteoalarm>



Seminars SWFDA-CA
6—10 и 8—14 July, 2015, Moscow

01.02.2016

SWFDP CA for CA RFFGS



SWFDP-CA components



Synoptic

Technological

Daily: NMC, RMC

RMC, NWP center

Analysis of all matters, incl. skill of NWP products

Placing on the site of daily forecasts for list of points

Placing pf ALARM CA data

Case-study

The SWFDP-CA reports

- **Development of SWFDP CA site**
- The goals of SWFDP SITE:**
 - **To provide the information for forecasters**
 - **To unify the efforts and the information from NMC**
 - **Development of systems of processing of LAM output**
 - **Trainings**
 - **Development of COSMO-LAM**

Technology in RSMC Tashkent



Table of recommended LAM NWP products in concept of SWFDP



Precipitation (3, 6, 12, 24 sum)

T2m,

Wind 10m

Wind gust

T max, T min (as postprocessing product)

MSPL

Cloudiness of middle and low levels

Bottom of convective cloudiness

Snow depth, SWE

New snow depth for 6 and 24 hours

Parameters on levels 925, 850, 700, 500 hPa: U,V, T, H, R%

Vertical velocity on levels 850, 700, 500

K index, CAPE, CIN, Showatler Index (+ others-?), SKEW-T

Meteogrammes



PT CACOIM (Central Asia COSMO Implementation) proposals



N	Period	Activities	FTE	Deliverables
1	DJF 2015-2016	Trainings for first stage: Preparing of matters, feed-back from 4 NMC	0.2	Extended and adapted Guidelines for first stage of COSMO licensed USERS (based the existing COSMO Education matters)
2	MAM 2016	Software development: postprocessing extension and tests (Indices for warnings)	0.2	Proposed, tested algorithms for indices calculation for Severe weather events Proposals for COSMO new products
3	JJA 2016	Analysis of skill of new COSMO products for subtropical continental conditions Development of adapted version COSMO-CA Trainings for NMC staff	0.1	Case-study results of comparison of importance of COSMO and ECMWF EPS products for some sub-tropical continental severe weather events
4	SON 2016	feed-back from 4 NMC Testing of COSMO-CA2 technology, trainings	0.1	Matters of trainings Guidelines for forecasters concerning use of COSMO LAM products for forecasting of different weather phenomena
5	DJF 2016-2017	Analysis of results Adaptation of COSMO-CA2 version.	0.2	Extended software of COSMO postprocessing in concordance with WMO requirements, Presentations on CUS and COSMO GM, Papers



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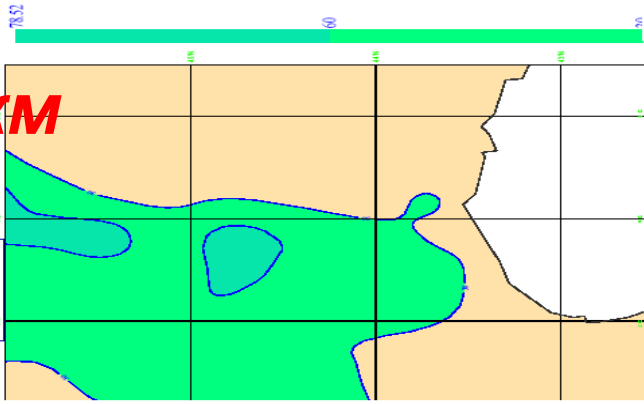


Роль разрешения модели

Осадки за вторые сутки прогноза, полученные по модели ECMWF с разными шагами сетки

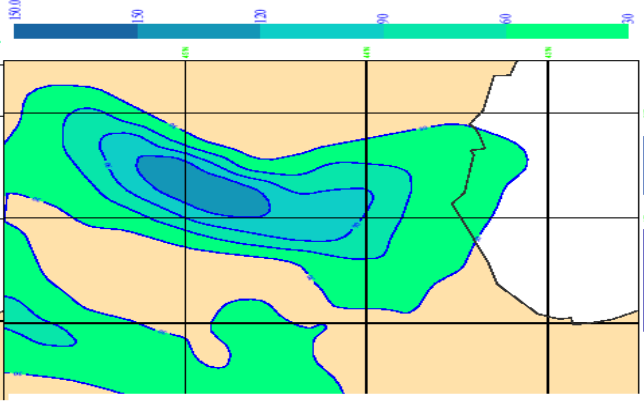
2002:
 $h = 40$ км

T511
max ~ 78mm



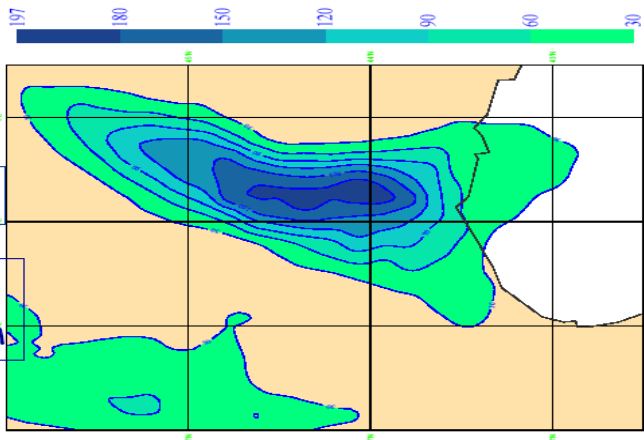
2010:
 $h = 25$ км

T799
max ~ 150mm



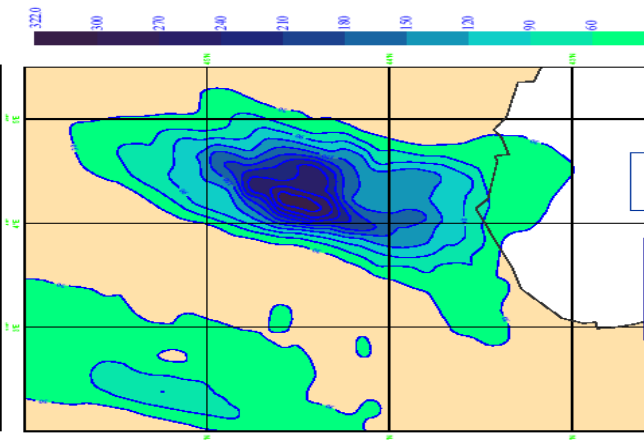
2012:
 $h = 16$ км

T1279
max ~ 197mm



2015:
 $h = 10$ км

T2047
max ~ 321mm





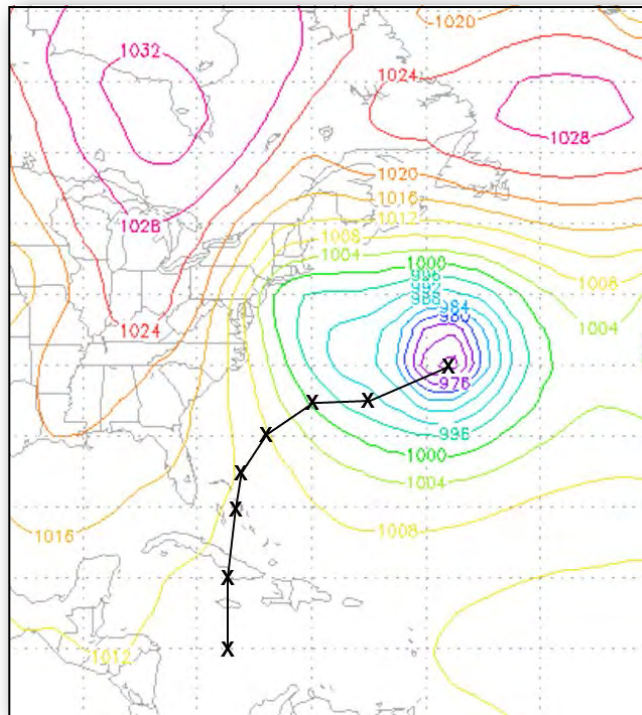
Increasing NCEP Global Model Horizontal Resolution Improves Hurricane Sandy Track Guidance

Model Initialized at 00UTC 24 October 2012

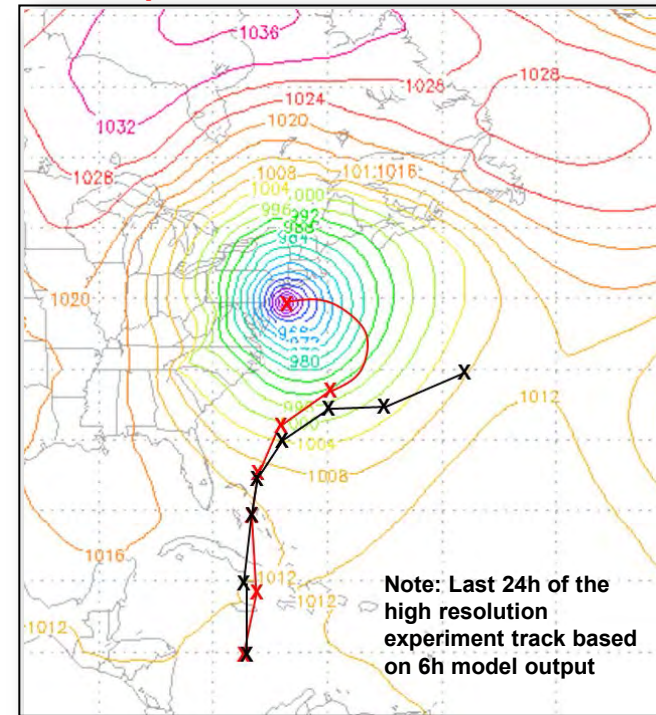
7-Day Sea level Pressure (mb) Forecast valid at 00UTC 31 October 2012

Hurricane Position Shown Every 24h

Operational (T574~ 27km)



Experiment (T1500~ 13km)

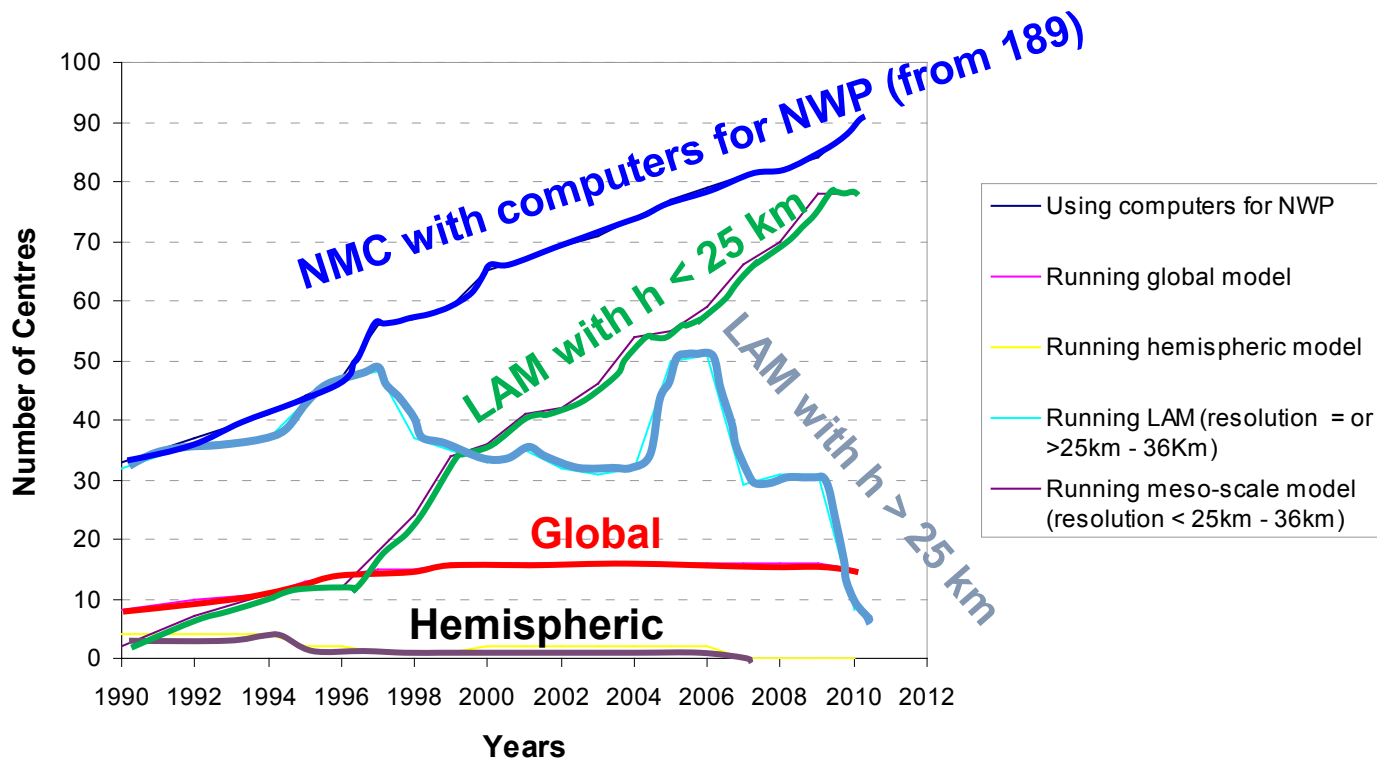


Hypothesis: Increased horizontal resolution resolves complicated Atlantic blocking pattern, slows simulated hurricane, and allows it to curve toward the East Coast



STATUS OF WMO FORECASTING CENTRES RELATIVE TO NUMERICAL MODELS

WMO Forecasting Centres using Global or Limited Area NWP Models (Last update 11/2011)





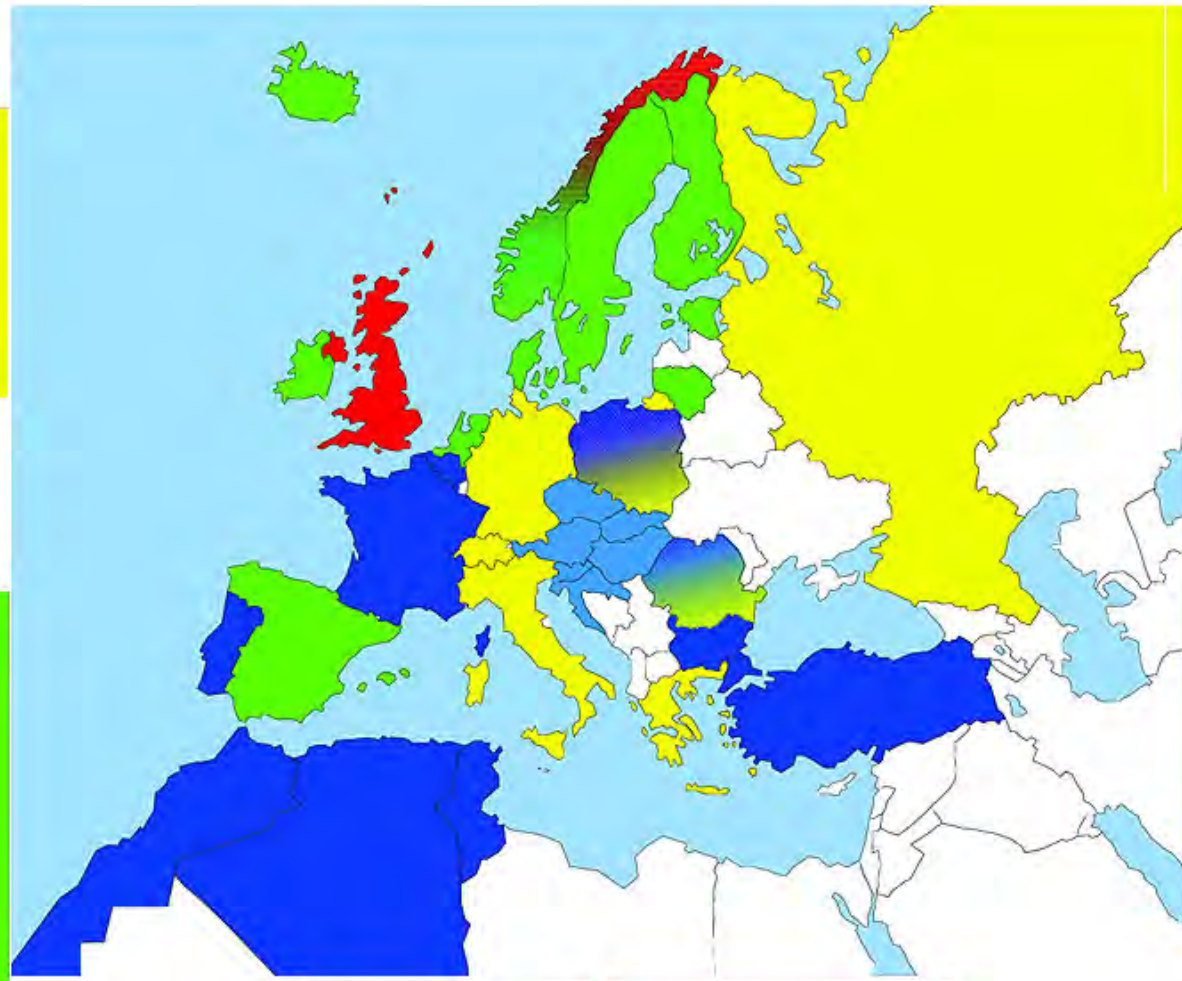
Short-Range Numerical Weather Prediction Consortia in Europe



- Germany
- Greece
- Italy
- Poland
- Romania
- Russia
- Switzerland



- Denmark
- Estonia
- Finland
- Iceland
- Ireland
- Lithuania
- Netherlands
- Norway
- Spain
- Sweden

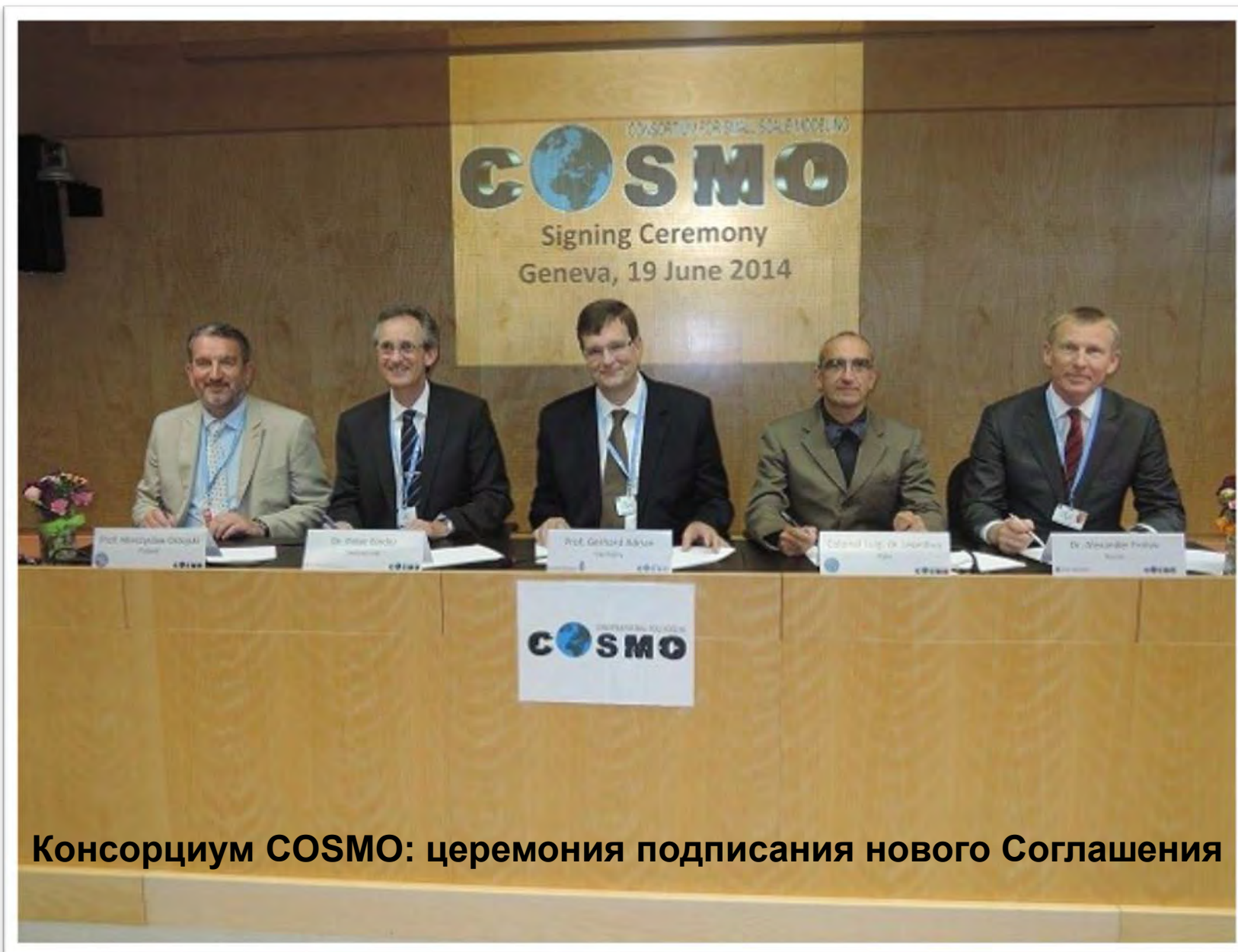


- Algeria
- Belgium
- Bulgaria
- France
- Morocco
- Poland
- Portugal
- Tunisia
- Turkey

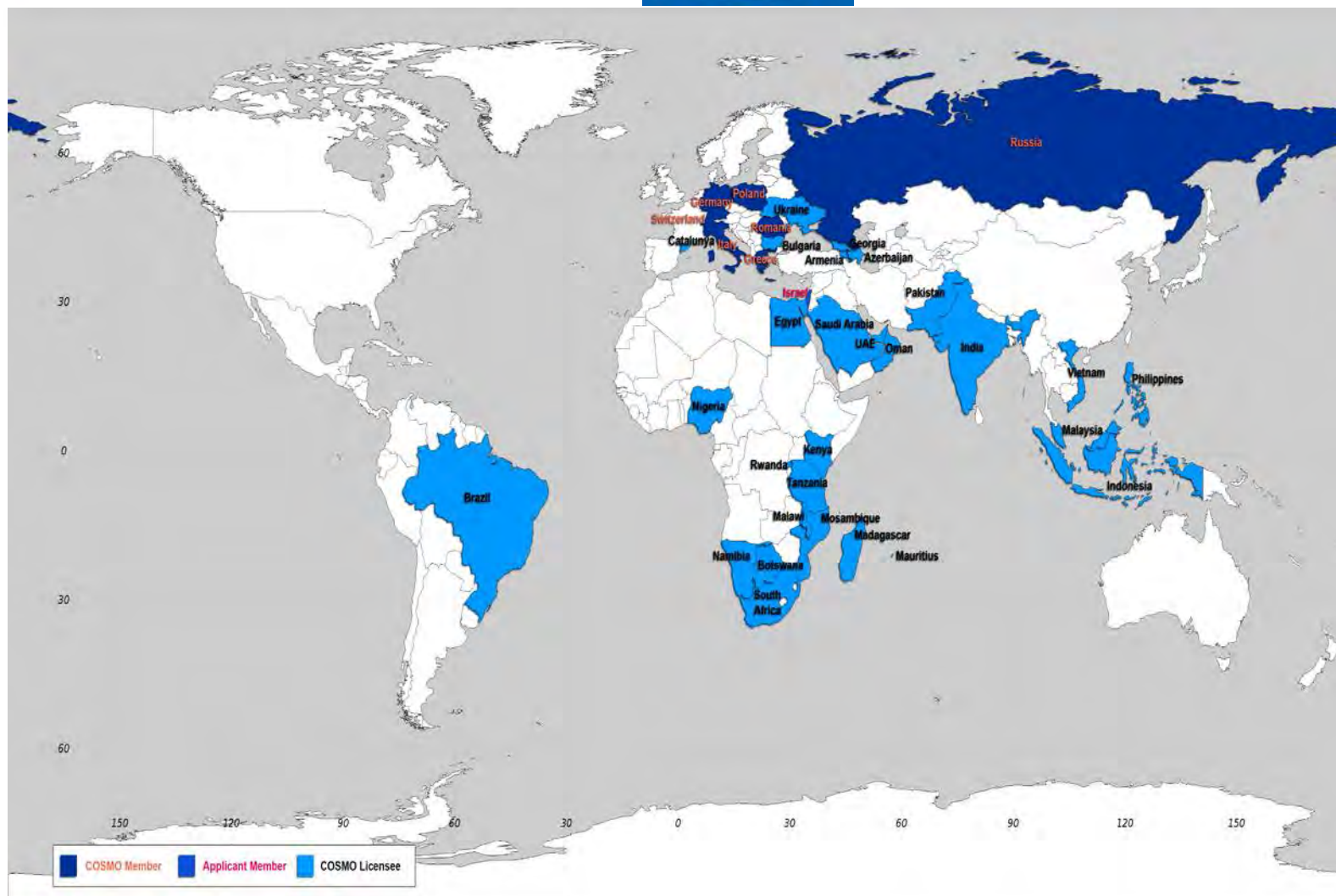
- Austria
- Croatia
- Czech Rep.
- Hungary
- Romania
- Slovakia
- Slovenia



<http://srnwp.met.hu/>



Консорциум COSMO: церемония подписания нового Соглашения



COSMO-Model Worldwide distribution

8 licensees in 2015 (new: Saudi Arabia), each paying 20.000 € annual license fee.
Free usage of COSMO model in developing countries and at universities.



COSMO-Model



New global **ICO**sahedral **N**onhydrostatic model - **ICON**

ICON is joint development project of German Weather Service (Deutscher Wetterdienst – DWD) and Max-Planck-Institute for Meteorology (MPI-M) for next-generation global Numerical Weather Prediction and climate modeling system.

Operational use for NWP at DWD **from January 2015**.

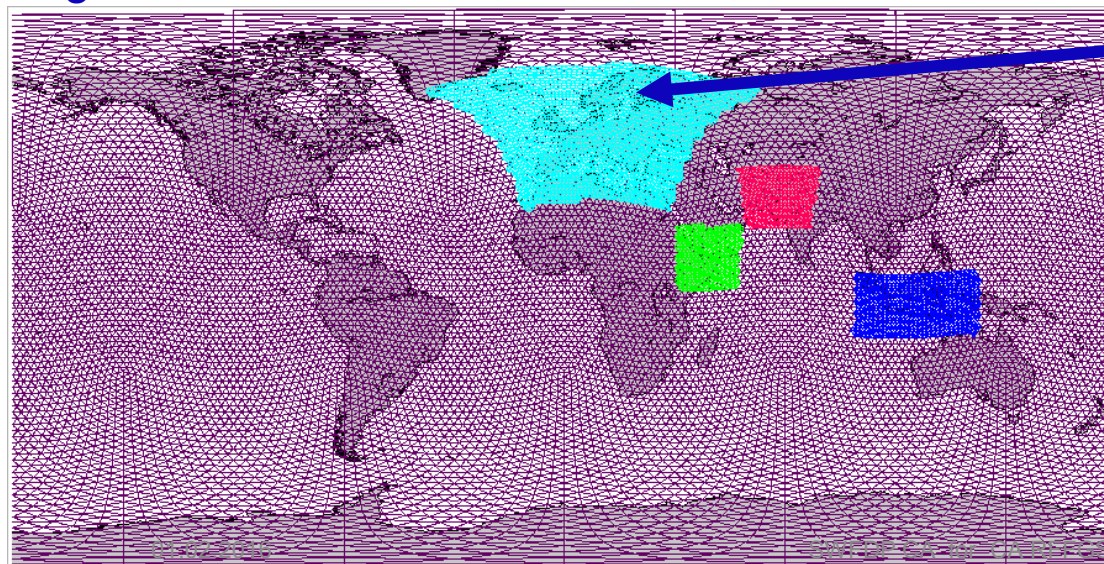
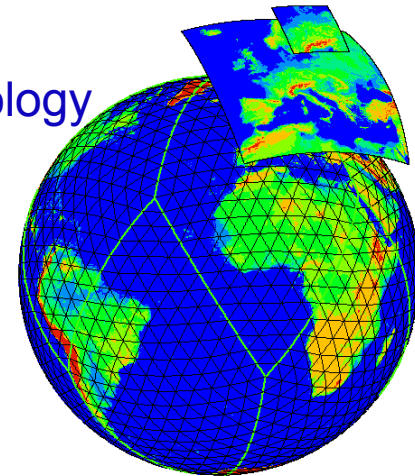
Global mode

Grid spacing: 13 km

Layers: 90

Forecast range: 174 h at 00 and 12 UTC // 78 h at 06 and 18 UTC

1 grid element: 173 km²



ICON zooming area Europe

Grid spacing: 6.5 km

Layers: ~ 60

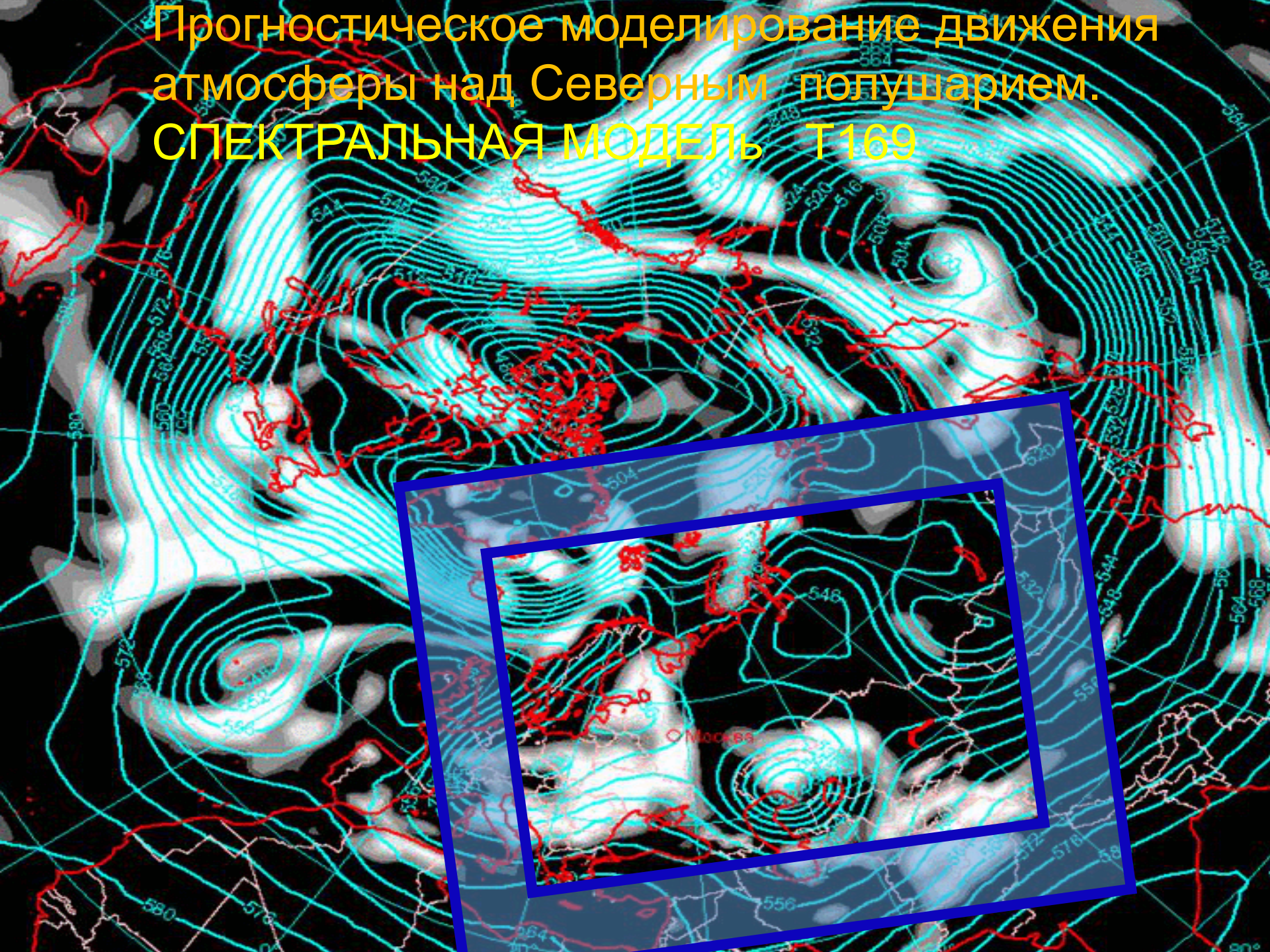
Forecast range:

78 h at 00, 06, 12 and 18 UTC

1 grid element: 43 km²

plus 3 other zooming areas

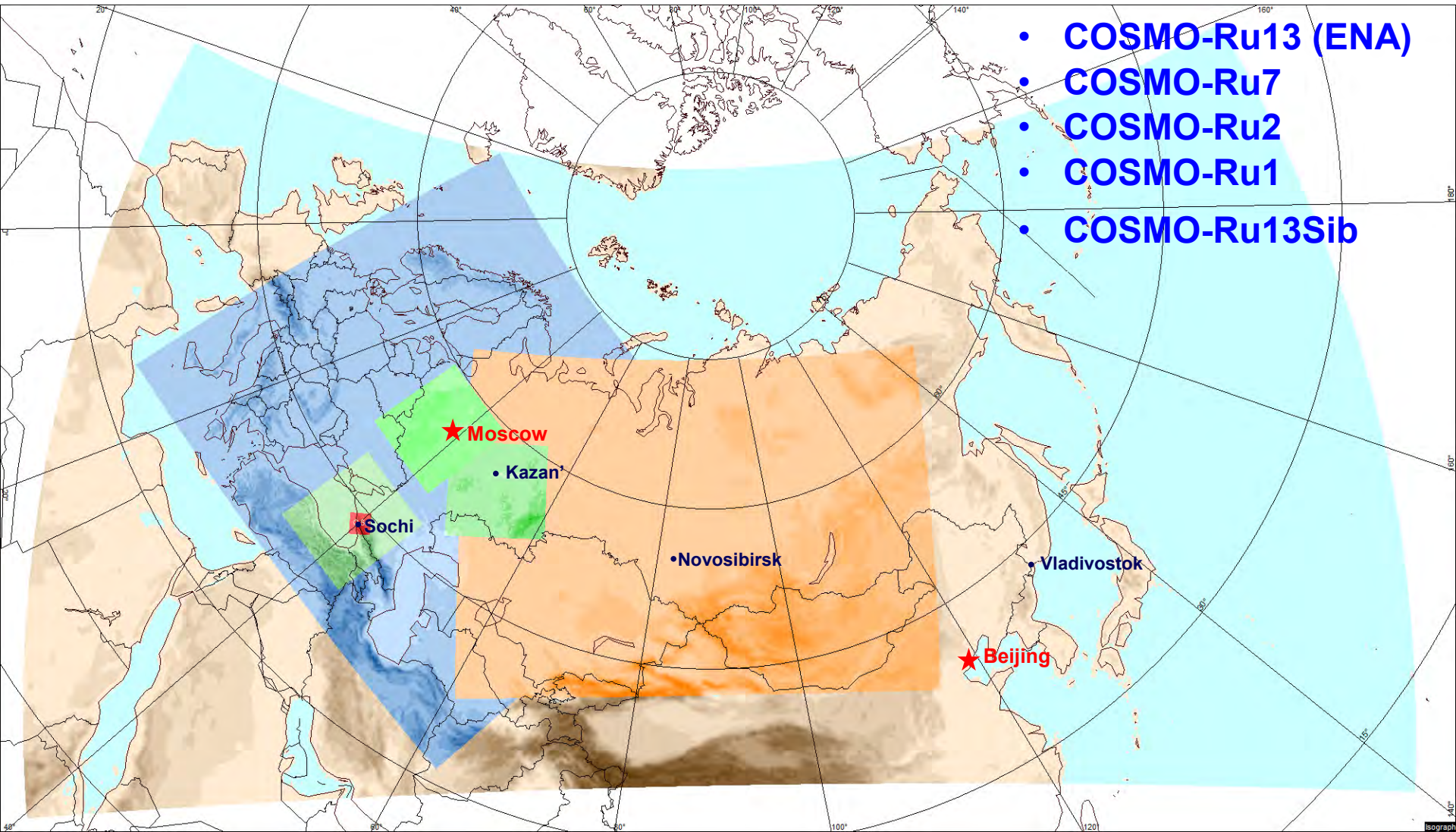
Прогностическое моделирование движения
атмосферы над Северным полушарием.
СПЕКТРАЛЬНАЯ МОДЕЛЬ T169





COSMO-Ru system

COSMO-Ru domains used for operational NWP





УРОВНИ

COSMO-Ru7 / Ru13-SIB / Ru13-ENA

АТМОСФЕРА - 40 уровней

N ρ, mm z, m

0,5 20 23589

1 30 22300

8,5 203 11879

17,5 499 5569

Пограничный слой

27,5 830 1546

35,5 975 214

39,5 997 20

40 998 10

40,5 1000 0

n-1/2

w, z

n

T, u, v, p₀

n+1/2

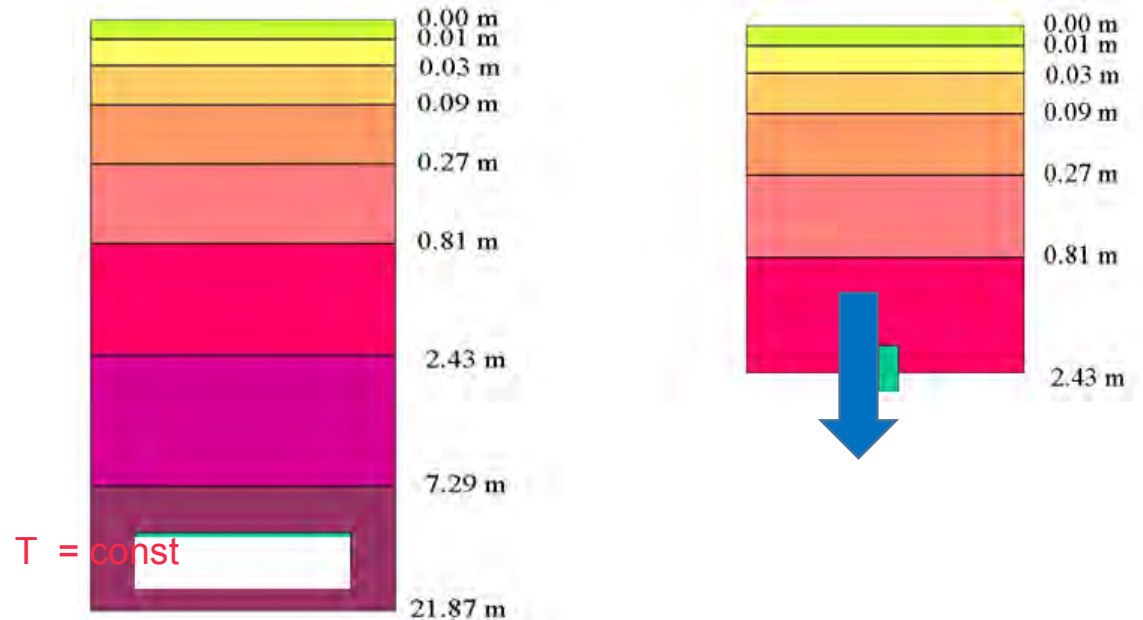
w, z



ПОЧВА: 7 – уровней

БАЛАНС ЭНЕРГИИ

ВОДНЫЙ БАЛАНС





УРОВНИ

COSMO-Ru2 / Ru1

АТМОСФЕРА: 50 уровней

N	p, mm	z, m
0,5		22000
....	
12,5		11807
до 1550 м - 13 уровней		
24,5		5162
Пограничный слой		
36,5		1450
до 550 м - 8 уровней		
42,5		500
49,5		20
50		10
50,5		0

n-1/2
n
n+1/2

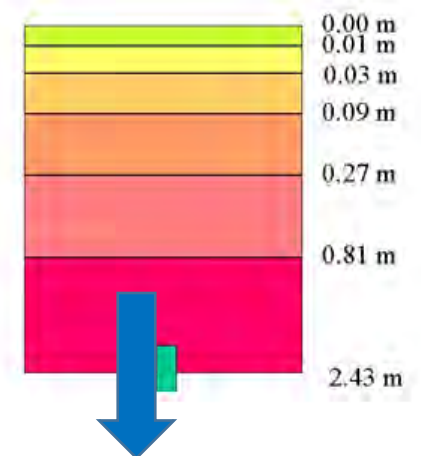
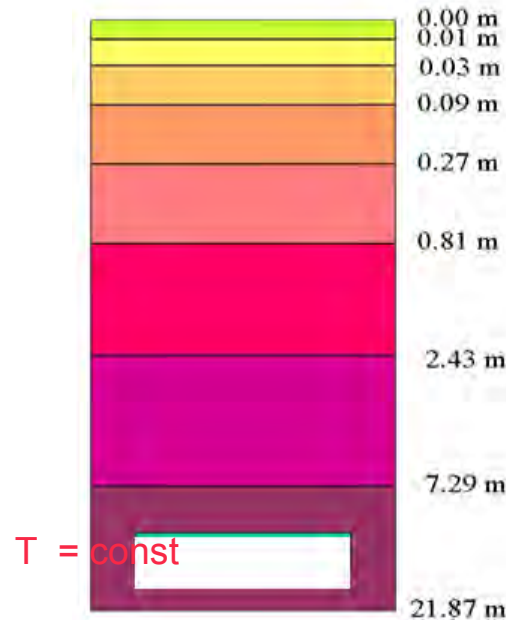
w, z
T, u, v, p₀
w, z



ПОЧВА: 7 – уровней

БАЛАНС ЭНЕРГИИ

ВОДНЫЙ БАЛАНС





COSMO-Ru system

COSMO-Ru team

- A staff of **8** full-time and **12** part-time
- Among them **6** young (under 30 years old) graduates (2 PhD and 4 PhD students) and **3** students of the Meteorology and Climatology Department, Geographical Faculty of Moscow State University

Work in collaboration with

- departments of Hydrometcenter of Russia
- departments of Moscow State University
- Scientific organization “Taifun”
- Central Aerological Observatory
- ...





COSMO-Ru system



Forecast activity

- 7 domains with different grid size from 13 km to 1 km;
- Operational run 4 times per day;
- More than 8000 meteo charts and 1000 meteographs are produced every day;
- All products are automatically sent to forecasting centers and posted on the web-site;
- Model output verification.

Research activity

- Data assimilation;
- Preprocessing (initial field correction for T2m, Tsoil, SWE);
- Ensemble forecasts;
- COSMO-ART;
- Forecast postprocessing (fresh snow, KF);
- Severe weather forecast (case studies);
- Boundary layer processes;
- Surface and soil (lakes, marshes);
- Verification.

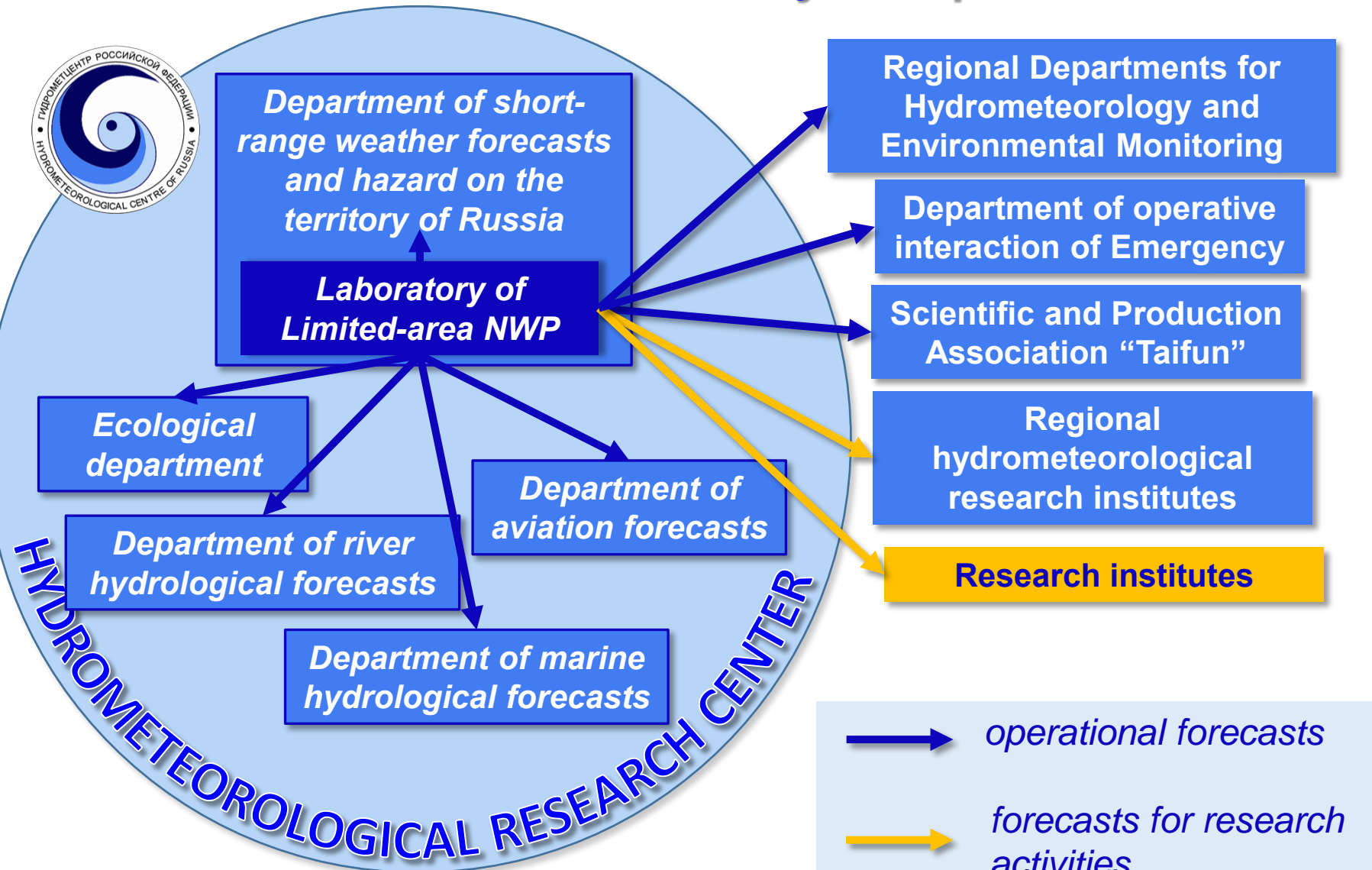
Participating organizations

- Hydrometeorological Center of Russia
- Main Computer Center of Roshydromet
- Siberian Regional Hydrometeorological Research Institute (Novosibirsk)
- Geographical faculty of Moscow State University



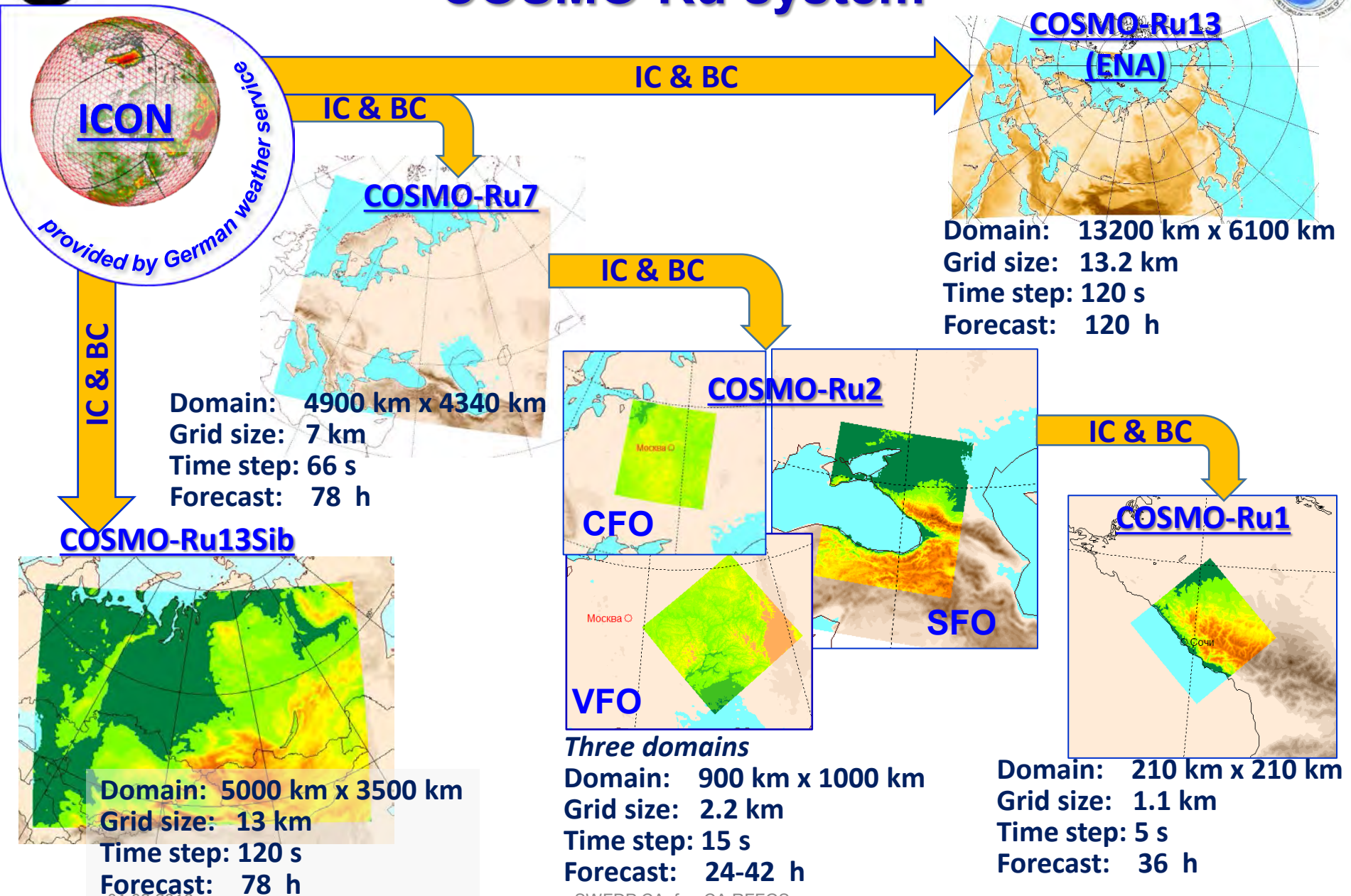
COSMO-Ru system

Users of COSMO-Ru system products





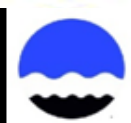
COSMO-Ru system



01.02.2016

SWFDP CA for CA RFFGS

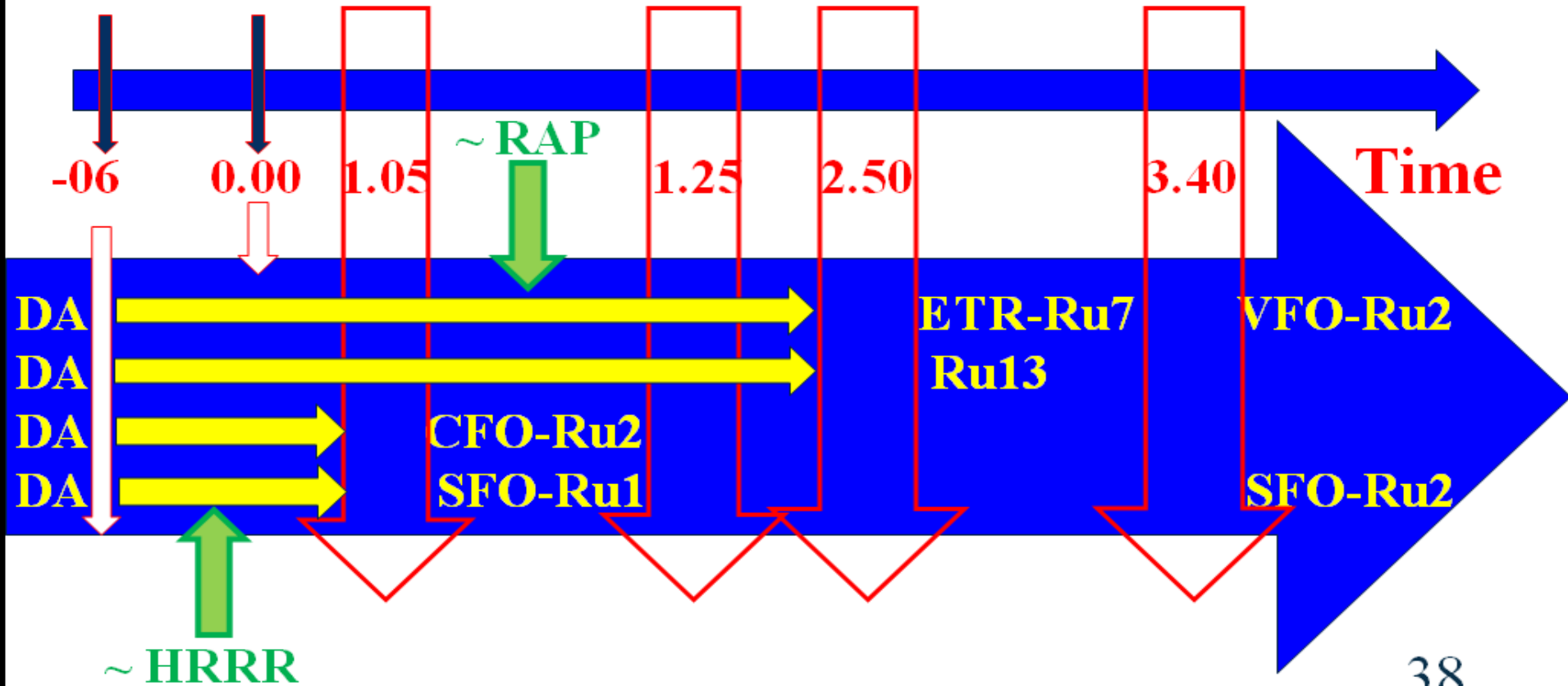
IC & BC – initial and boundary conditions



TECHNOLOGICAL LINE of COSMO-Ru



- ~ RAP (RAPid refresh)
- ~ HRRR (High Resolution Rapid Refresh)
- DA (Data Assimilation)



~ HRRR

Москва, семинар ИТКиЭ

38

17.06.2015



COSMO-Ru system products

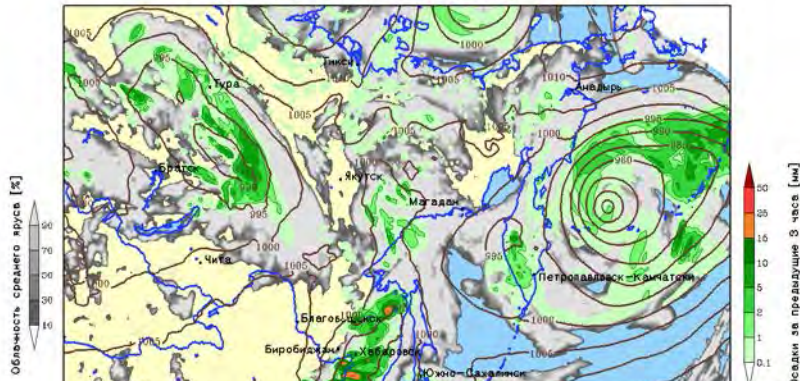


Forecast charts

- ☐ single characteristics
- ☐ combination of characteristics
- ☐ whole domain
- ☐ particular region (e.g. Moscow region, Baltic sea, Far East etc.)

part of COSMO-RU domain: "Baltic Sea"
 whole domain COSMO-RU
 combination of char. - Streamlines and PMSlidity
 single char. - Dew point temperature

15:00 22мая 2015 (UTC+0):
 Р ур. моря, облачность ср. яр., Осадки

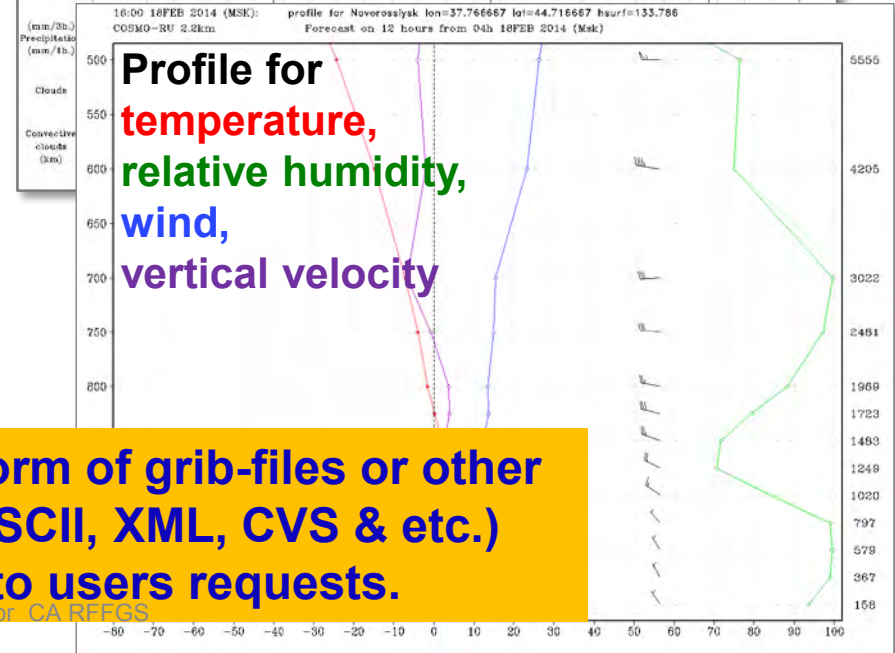
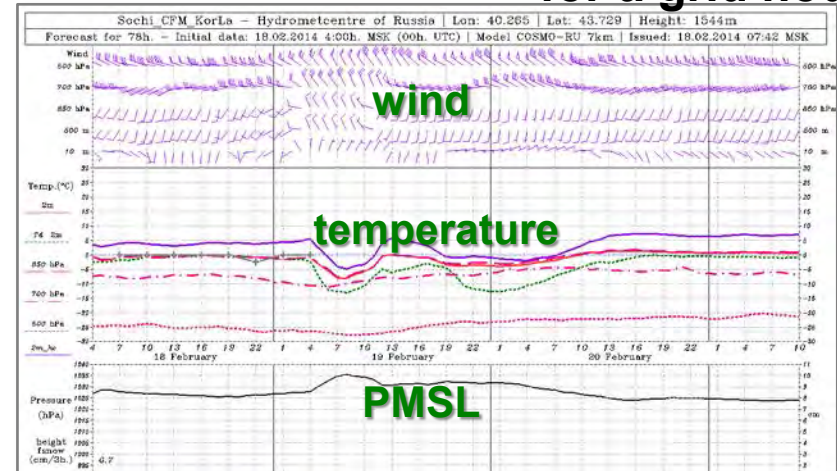


Прогноз на 99% от 12:00 18мая 2015 (UTC+0)
 COSMO-RU 13.2km

— Давление на уровне моря

Meteographs

for a grid node



Additionally: In form of grib-files or other special form (ASCII, XML, CVS & etc.) according to users requests.

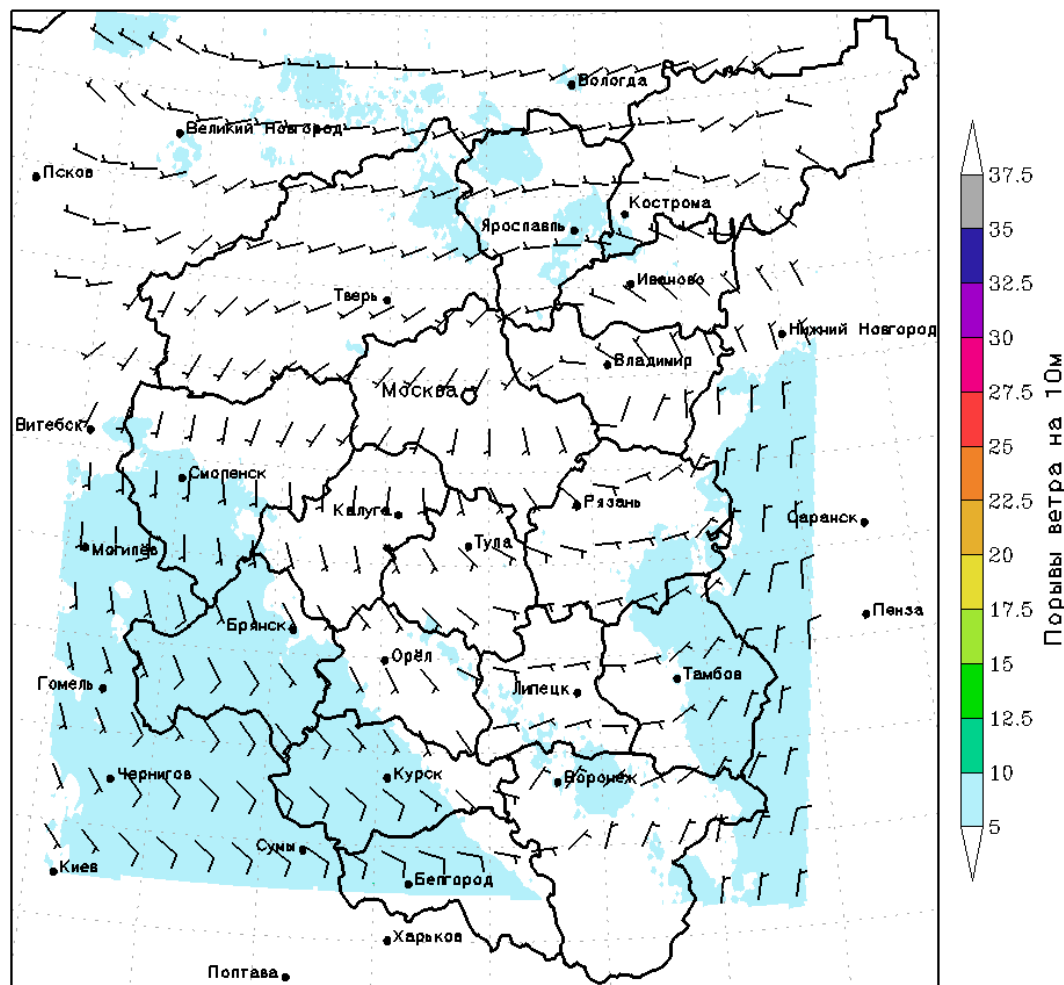


ПОРЫВЫ ВЕТРА

04:00 01мая 2012 (МСК): Ветер на 10м

**COSMO-Ru-
02 км.**

**Прогноз на
24 часа
по данным за
01 мая 2012 г.
00 UTC**



Прогноз на 0ч. от 04:00 01мая 2012 (МСК)

COSMO-RU 2.2км

ветер на 10м

COSMO-Ru2 (420 • 470 • 50) для ЦФО

SWFDP CA for CA RFFGS



В настоящее время ежедневно

(для 00, 06, 12 и 18 часов ВСВ)

**через 3 часа 40 мин. после срока наблюдения
система COSMO-Ru7/2/1/13км:**

- **за сутки подготавливает около 8000**
прогностических карт и 1000 метеограмм,
- **автоматически рассылает их в**
прогностические учреждения
Росгидромета,
- **выкладывает около 70 гб файлов в коде**
GRIB на ftp-серверы (за месяц > 2 Тб).



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1. WMO SWFDP
2. WMO SWFDP –CA: status
3. COSMO and COSMO-Ru
4. QPF by COSMO-Ru
5. Meteorological part of CARFFGS

SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
CARFFGS: Central Asia Region Flash Flood Guidance Project



Heavy rainfall caused extreme flood on the Kuban



July, 6-7, 2012

171 dead
34600 affected
5000 houses destroyed





COSMO-Ru system products

COSMO-Ru7

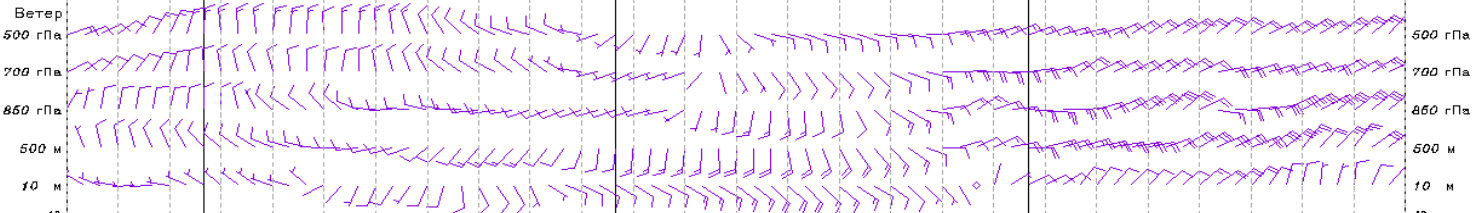


Heavy rainfall caused extreme flood

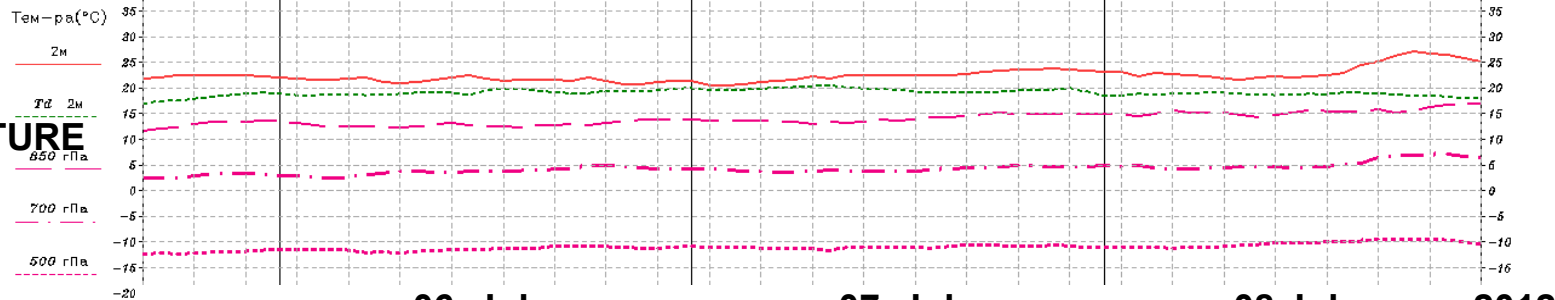
Meteographs for Gelendjik
05/07/12, 12 UTC, fc+78 h

Sochi_Gelendjik W — Предоставлено: ГУ "Гидрометцентр РФ" | Долгота: 37.935
 Прогноз на 78 часа(ов) от 05.07.2012 16:00 МСК (12ч. UTC+0) | Модель COSMO-RU / 7m | Период: 05.07.2012 16:00 МСК

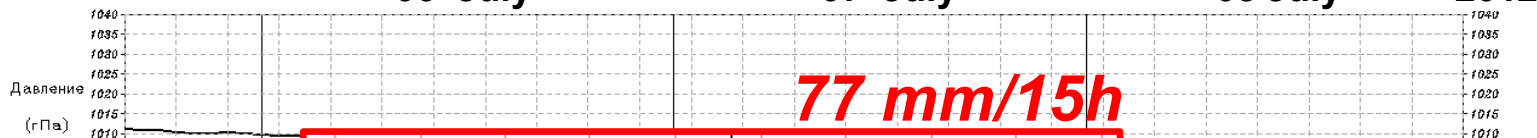
WIND



TEMPERATURE

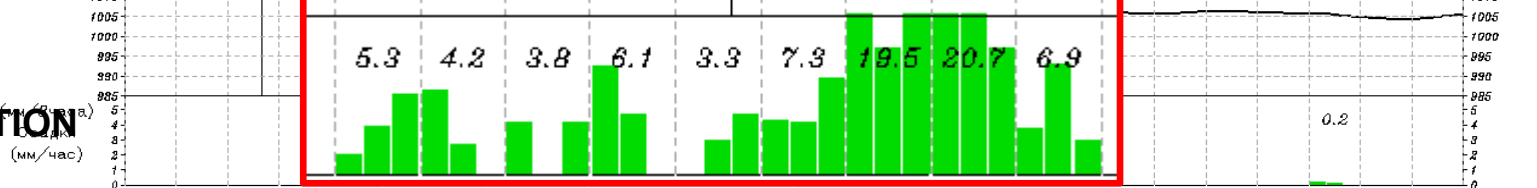


PMSL



77 mm/15h

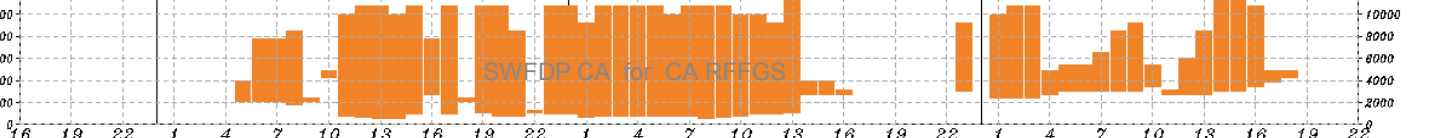
PRECIPITATION



CLOUD COVER



CONVECTIVE CLOUDS

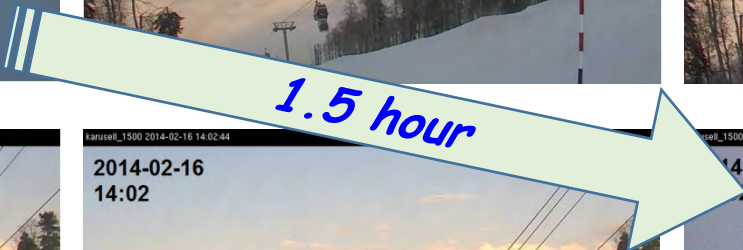
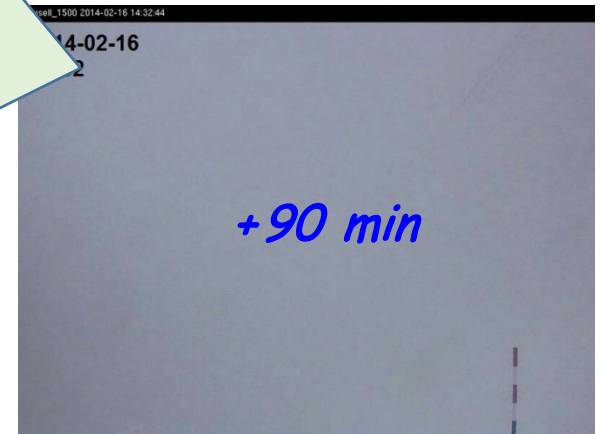
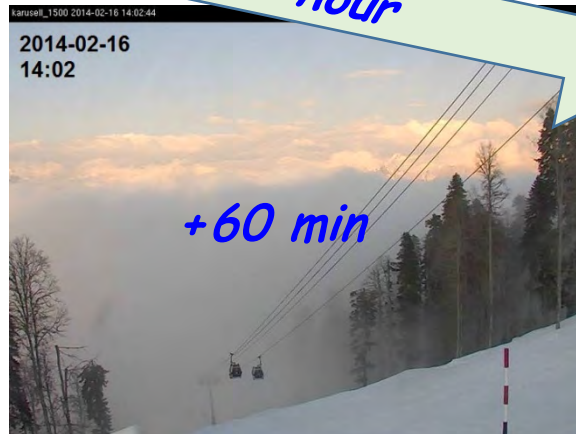
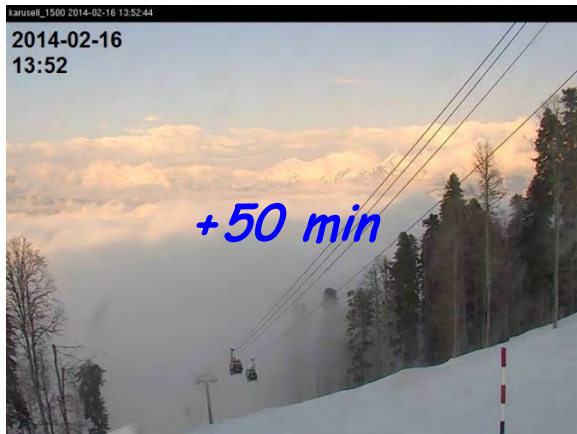
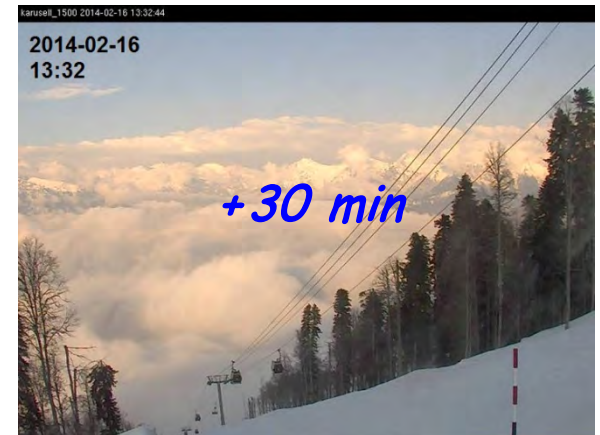
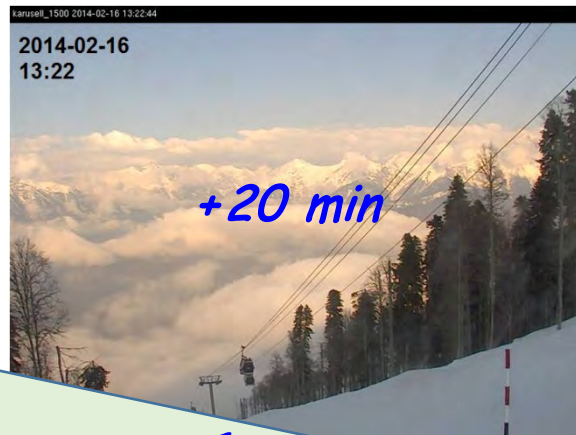
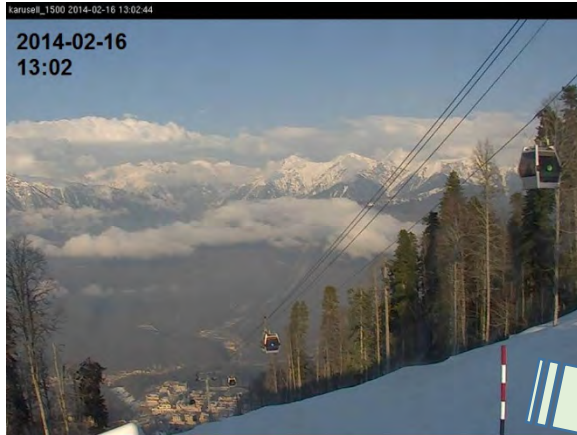




Low visibility event

Cloudiness formation due to adiabatic cooling of the moisture air during its rise along the slope of the valley

February, 16-17, 2014



Camera shots at Gornaya Karusel-1500



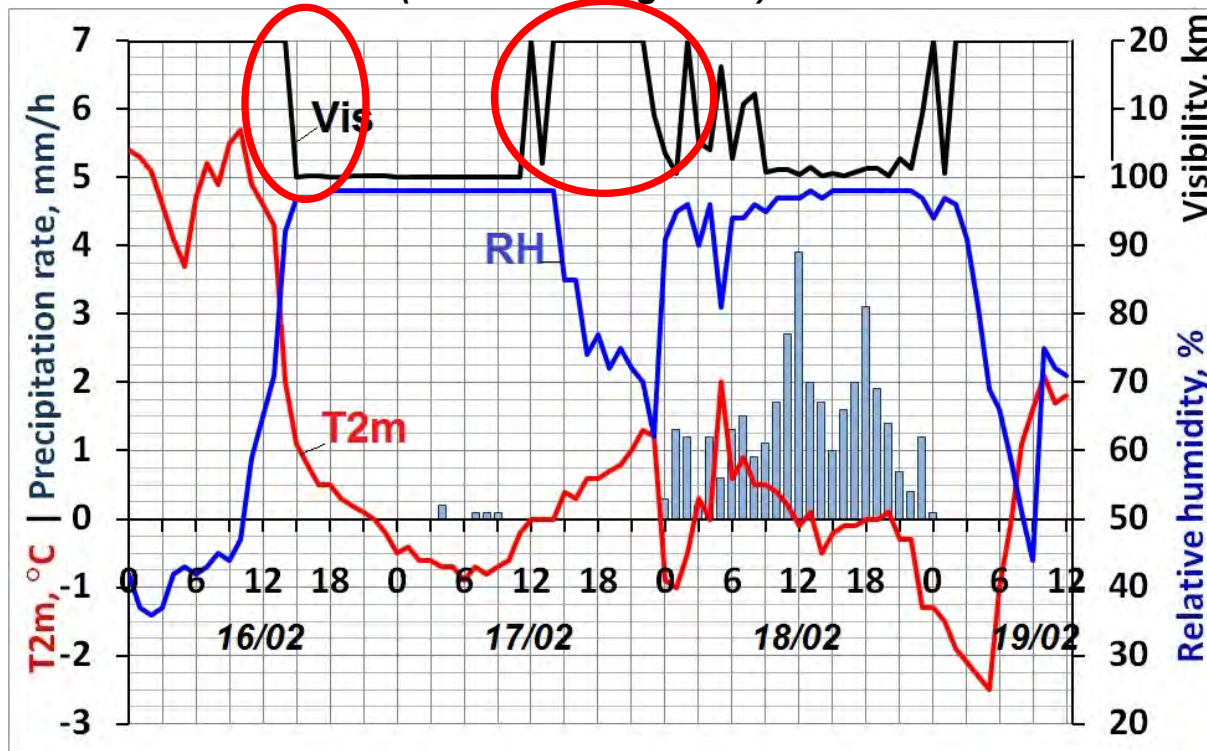
Low visibility event

At an altitude of 1000 -1500 m low visibility was observed during 21-23 hours on February, 16-17, 2014. Observed minimum visibility values: **25 – 59 m**.

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

On February, 18, 2014 heavy snowfall caused decreased of the visibility again. Maximum snow rate was **3.9 mm/h**.

Observation at Biathlon Stadium (h=1455 m, highland)





COSMO-Ru system products

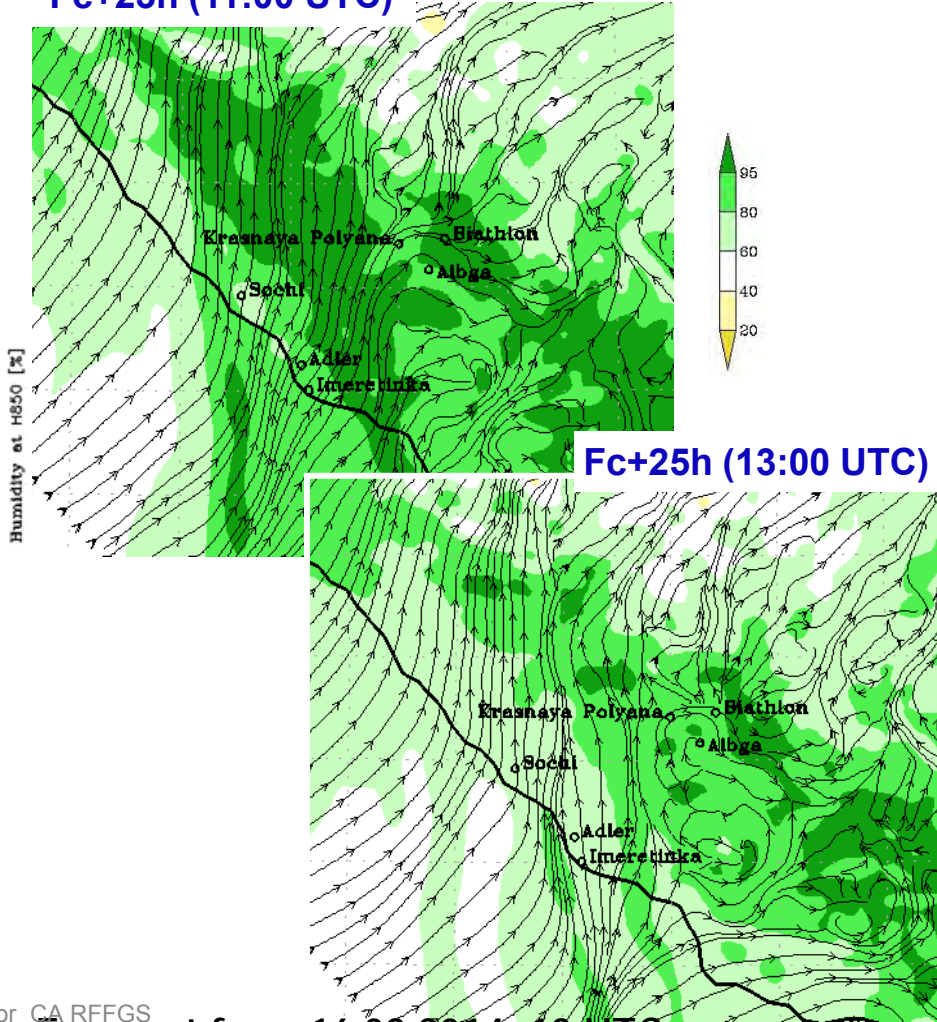
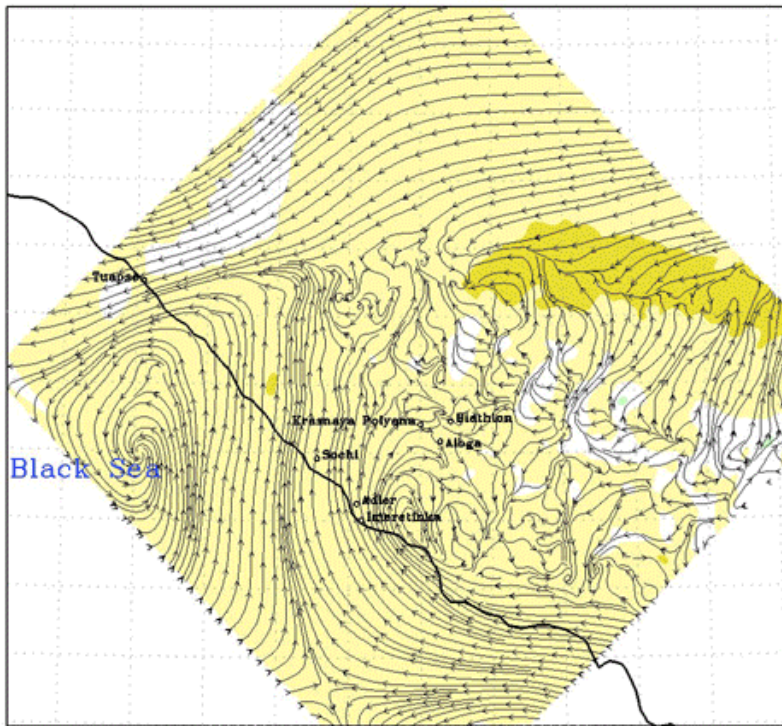
COSMO-Ru1

Low visibility event during Sochi Olympics

Stream lines and relative humidity at 850 hPa

Fc+23h (11:00 UTC)

04:00 16FEB 2014 (MSK):
Wind direction, Relative Humidity at H850



Forecast on 0 hours from 04h 16FEB 2014 (Msk)
COSMO-RU 1.1km

→ Wind direction

Forecast from 16.02.2014, 00 UTC

Forecast from 16.02.2014, 12 UTC



COSMO-Ru system products

COSMO-Ru1

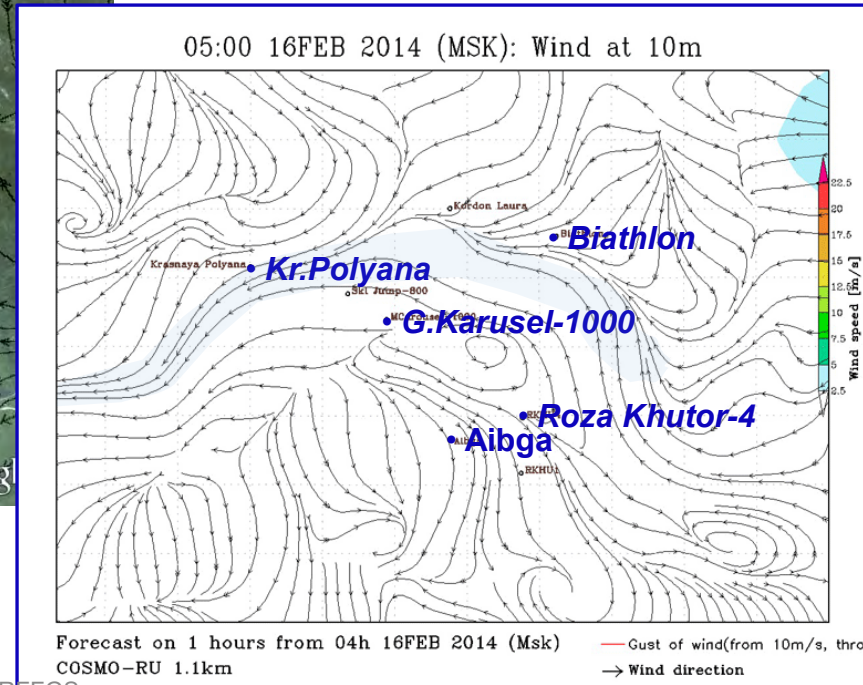
Low visibility event during Sochi Olympics

Streamlines within the valley

Forecast chart overlaid on the relief image (fc+13h)



Forecast from 16.02.2014, 00 UTC





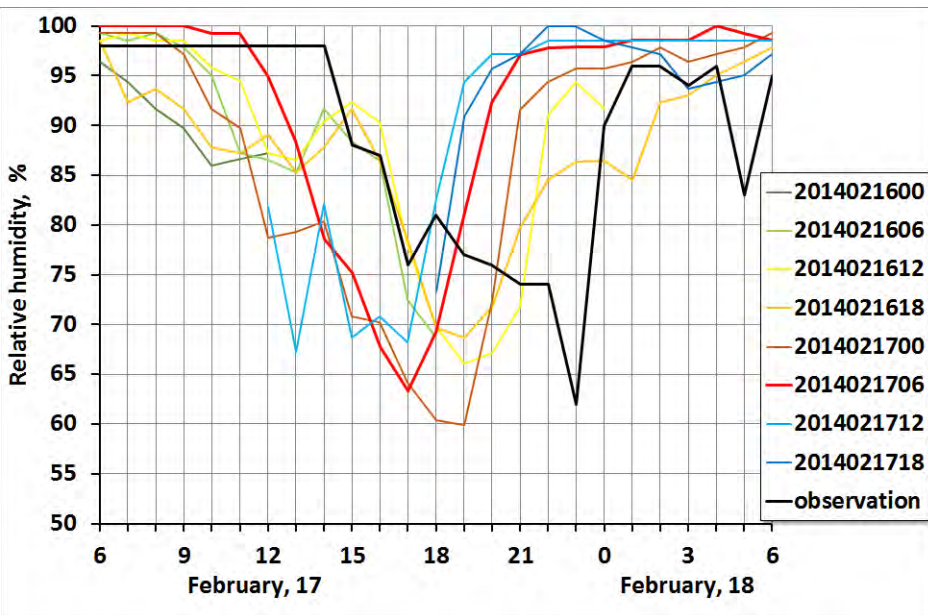
Low visibility event

COSMO-Ru1

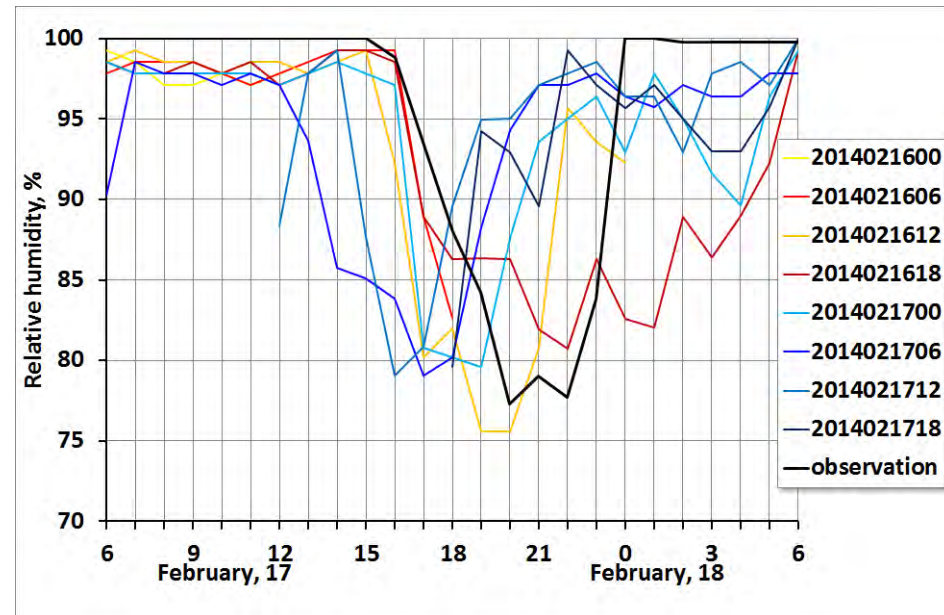
Low visibility event during Sochi Olympics

Relative humidity at 2m: series of the forecasts for the sites

Biathlon Stadium (1455 m)



Roza Khutor-4 (1580 m)



COSMO-Ru1 forecast for relative humidity and wind allowed forecasters to predict changes in visibility (“good visibility window”) and determine the time for the competitions.



Postprocessing: Fresh snow high

FieldExtra software

Visualization software

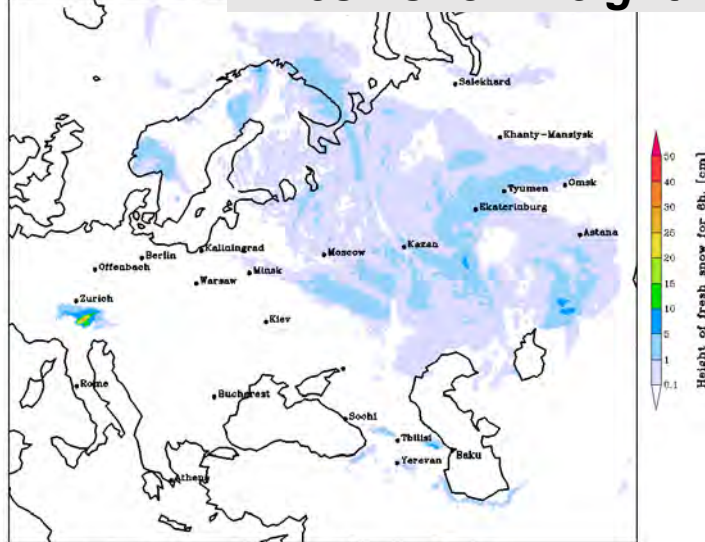
Maps of fresh snow height for 6 h intervals

Altitude correction of T2m

Algorithm of fresh snow height calculation

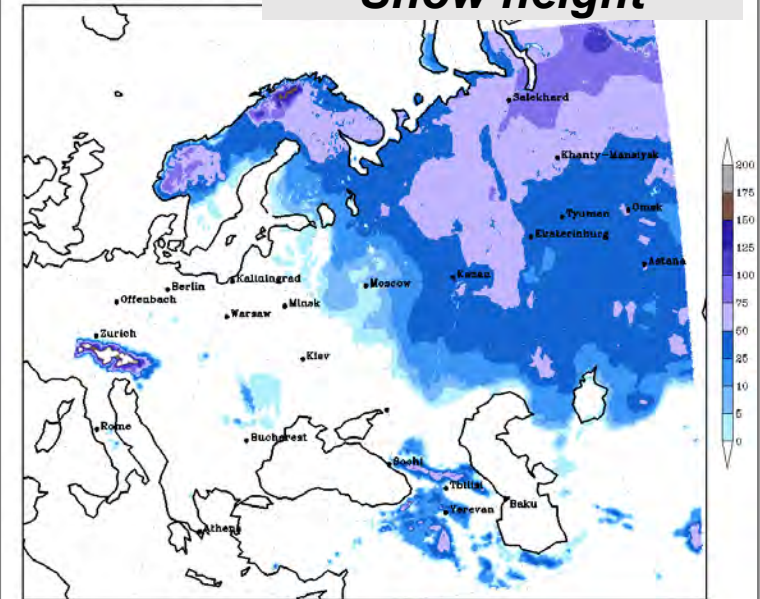
Meteographs

16:00 19FEB 2014 (1) **Fresh snow height**



Forecast on 36 hours from 04h 18FEB 2014 (Msk)
Postprocessing of COSMO-RU 7km

16:00 19FEB 2014 **Snow height**



Forecast on 36 hours from 04h 18FEB 2014 (Msk)
COSMO-RU 7km

For the Sochi region (mountain terrain) algorithm was tested and tuned with use the measurements of Sochi avalanche service

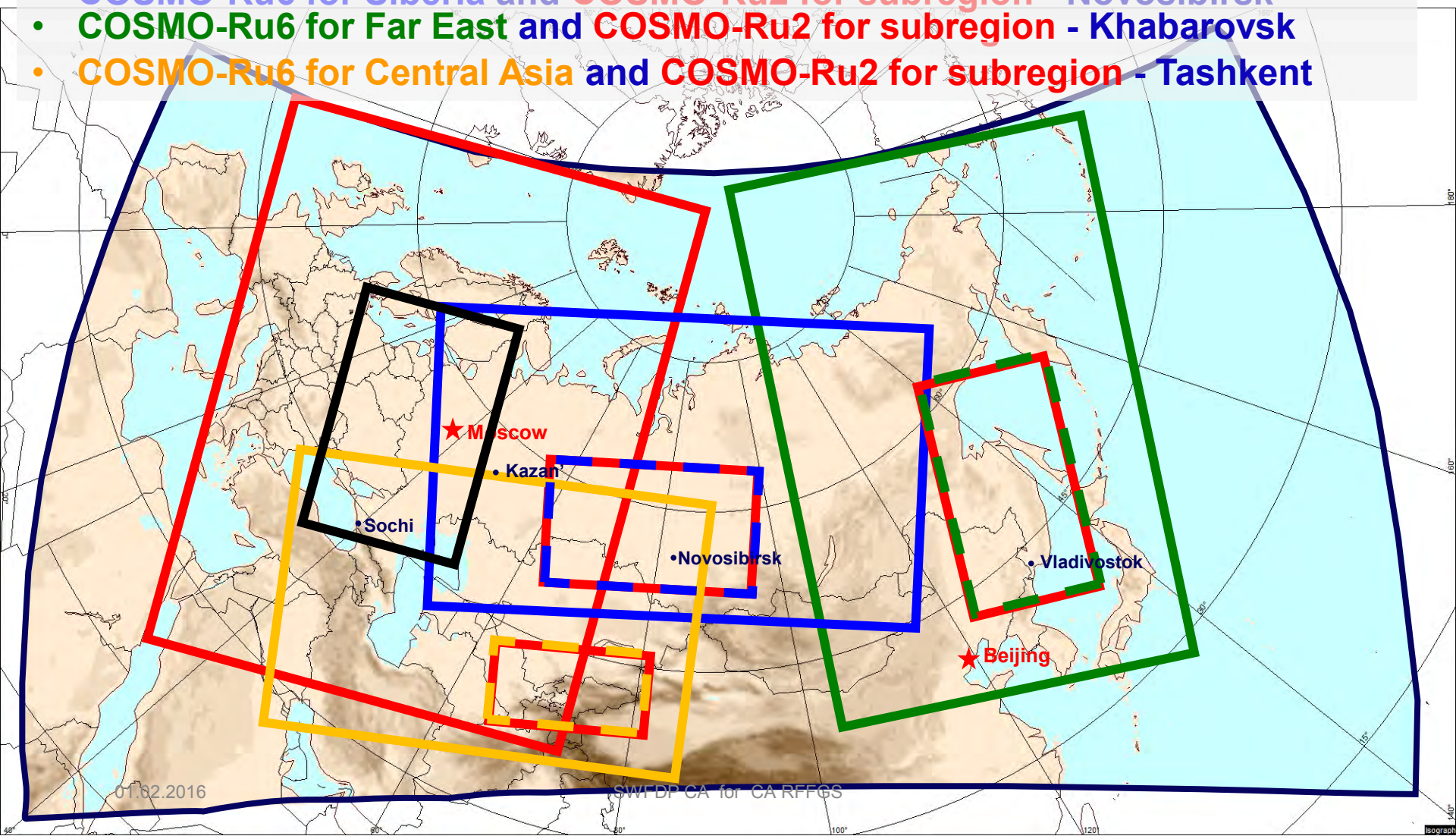


PLANS-2015/2017



Forecast activities

- COSMO-Ru6 (ENA) - Moscow
- COSMO-Ru2 for European part of Russia - Moscow
- COSMO-Ru1 European part of Russia - Moscow
- COSMO-Ru6 for Siberia and COSMO-Ru2 for subregion - Novosibirsk
- COSMO-Ru6 for Far East and COSMO-Ru2 for subregion - Khabarovsk
- COSMO-Ru6 for Central Asia and COSMO-Ru2 for subregion - Tashkent





PlansOutlook

Research activities



- **Data assimilation**
- **Preprocessing (initial field correction for T2m, Tsoil, Snow water equivalent)**
- **COSMO-Ru1 for Moscow region**
- **COSMO-Ru1 for enlarged domain for the Black Sea Coast**
- **Ensemble forecasts**
- **COSMO-ART**
- **Severe weather forecasts**
- **Soil and surface**
- **Case studies**
- **Verification**



COSMO-Ru system products

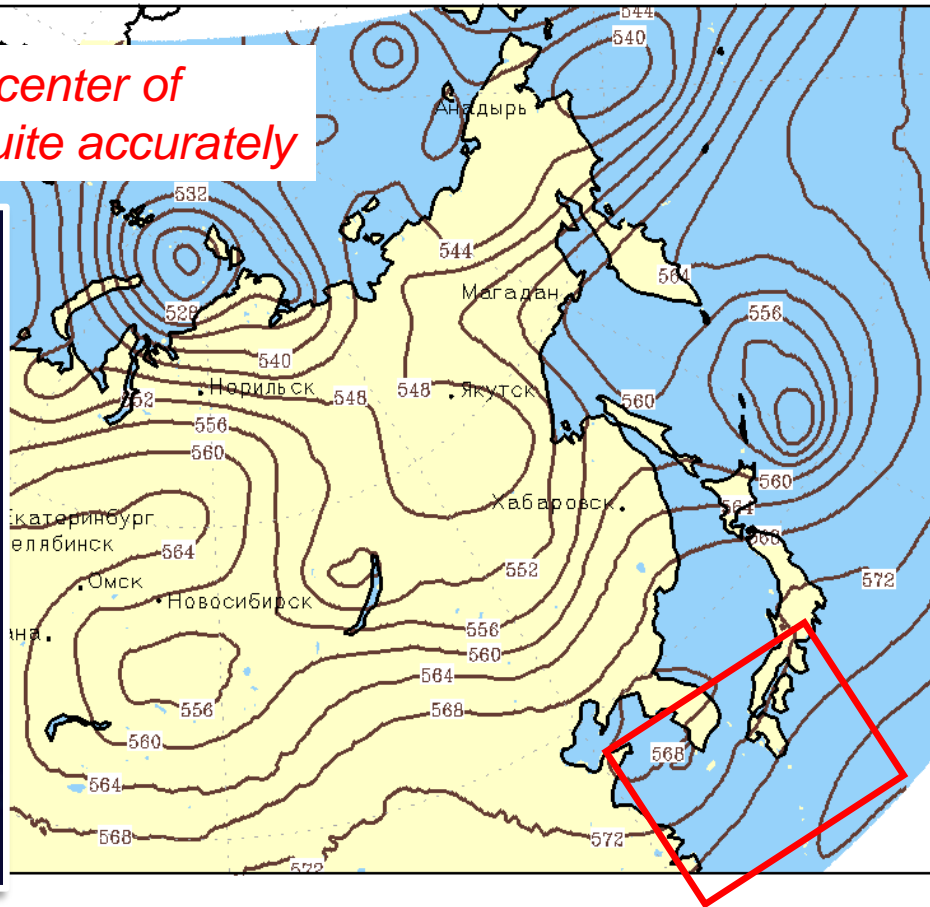
COSMO-Ru13

00:00 06июл 2014 (UTC+0): H500

Location and pressure in the center of the cyclone were predicted quite accurately

The track and intensity of the Typhoon Neoguri

The background image is from NASA.
Tracking data is from NOAA.



Lead time 0ч. от 00:00 06июл 2014 (UTC+0)

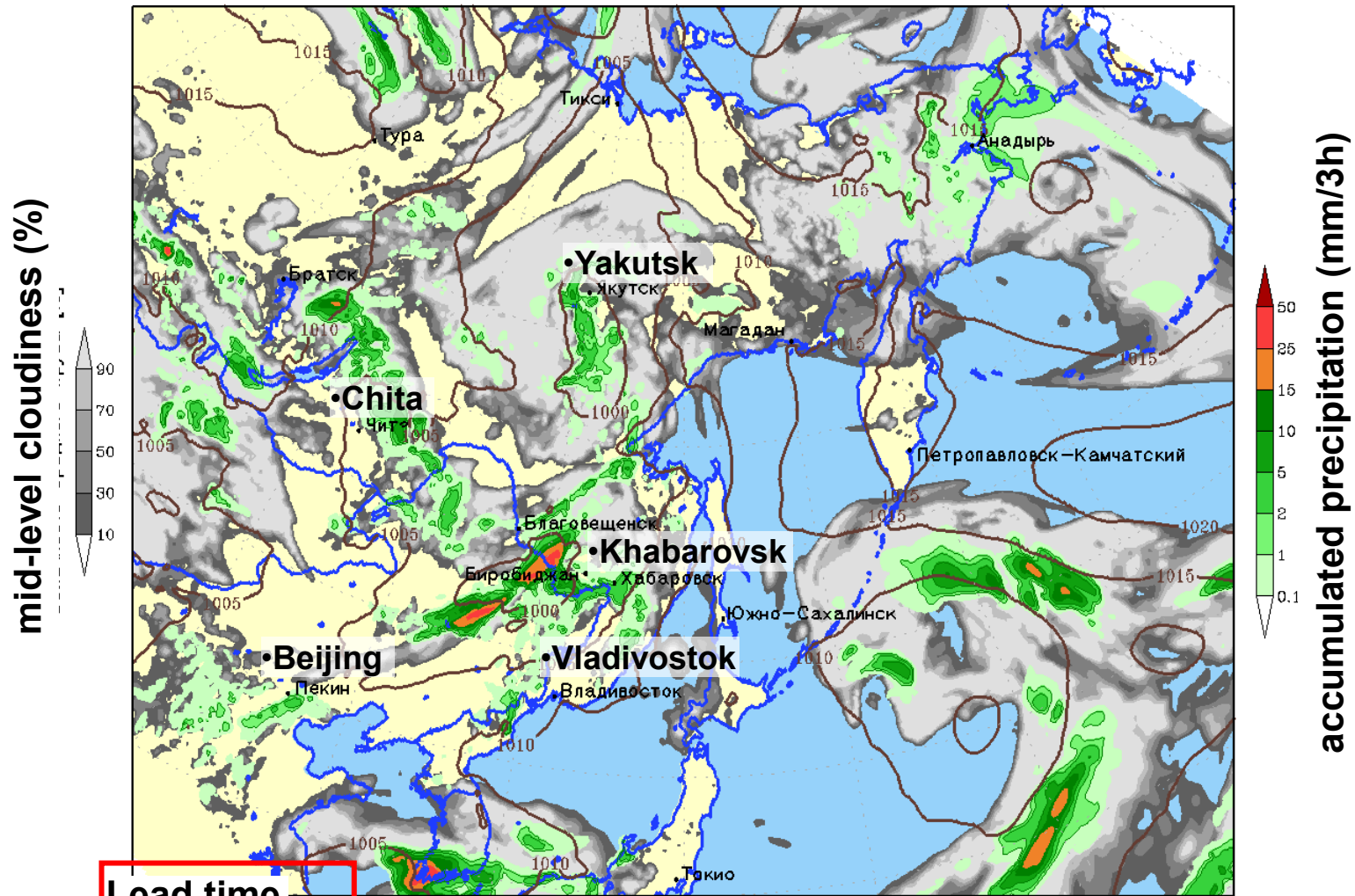
— H500



COSMO-Ru system products

COSMO-Ru13

03:00 06 июля 2014 (UTC+0): PMSL, mid-level cloudiness, precipitation
 1. уровень моря, облачность ср. яр., осадки



Lead time

01.02.2016 Прогноз на 3ч. от 00:00 06 июля 2014 (UTC+0) WRF-CM for CA RRF-03

COSMO-RU 13км

PMSL

— давление на уровне моря



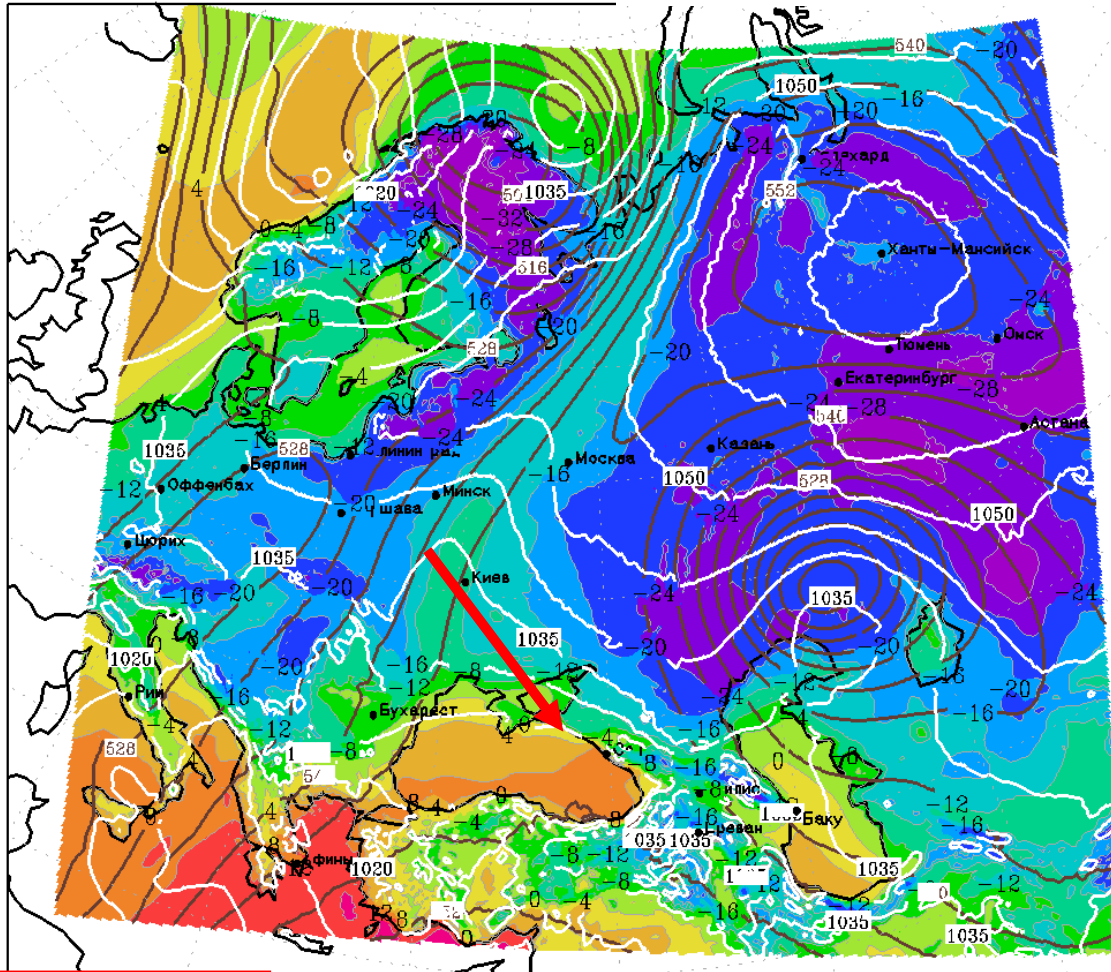
COSMO-Ru system products

COSMO-Ru7



Strong wind (Bora) in Novorossiysk

04:00 06 фев 2012 (MCK): H500, PMSL, T@2m



Lead time 0ч. от 04:00 06 фев 2012 (MCK)

01.02.2011 COSMO-RU 7km

— H500
SWFDP CA for CA RFFB PMSL



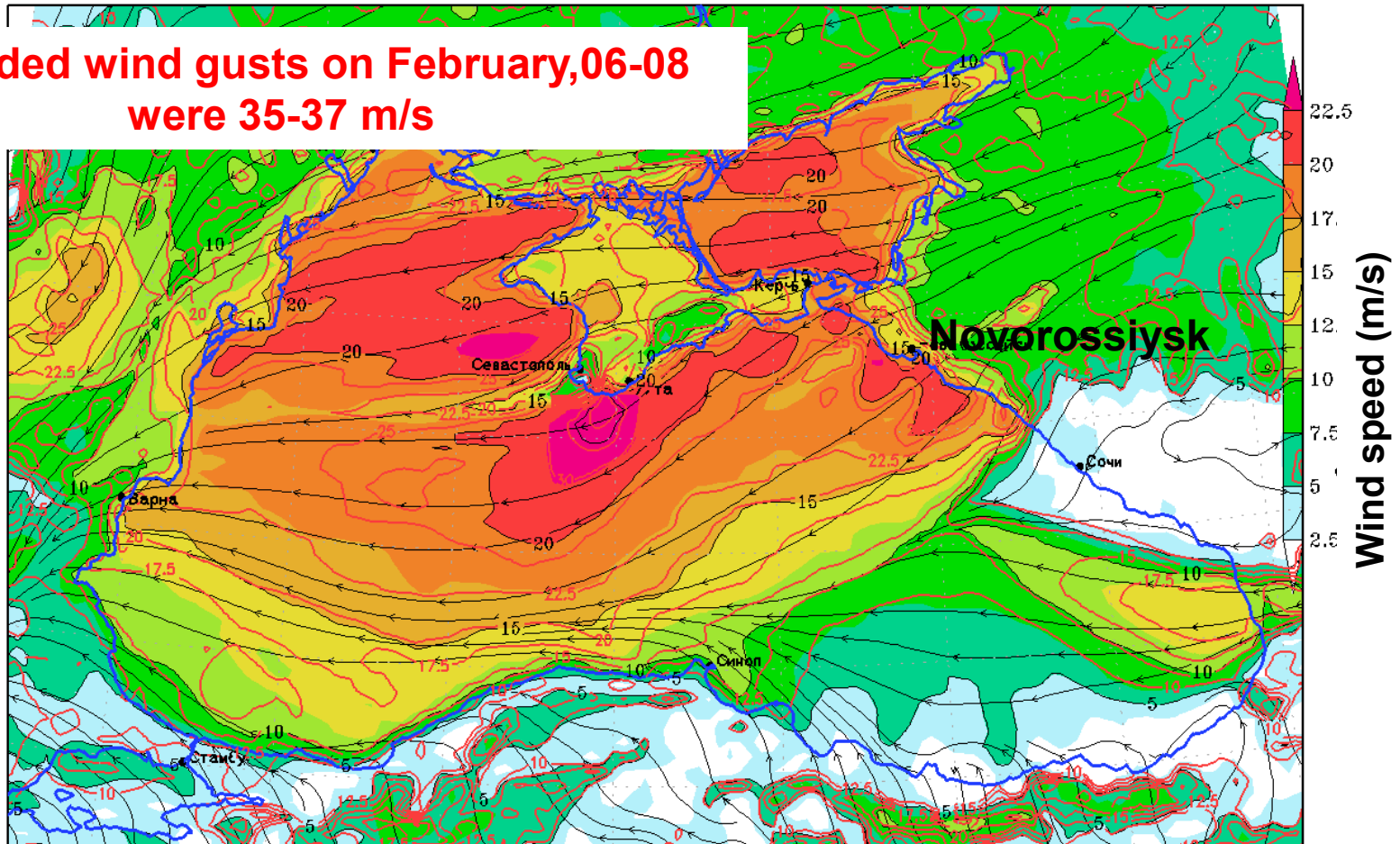
COSMO-Ru system products

COSMO-Ru7

Strong wind (Bora) in Novorossiysk

13:00 07 фев 2012 (MCK) Wind speed and wind gust at 10m

Recorded wind gusts on February, 06-08 were 35-37 m/s



Lead time λ 33 ч. от 04:00 06 фев 2012 (MCK)

— wind gust
→ wind direction

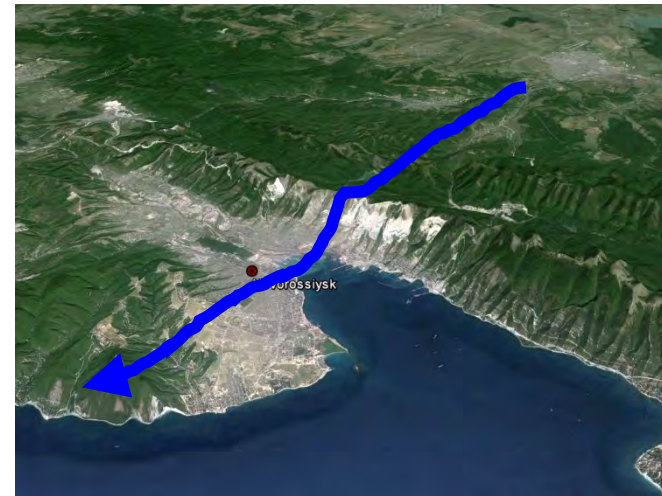
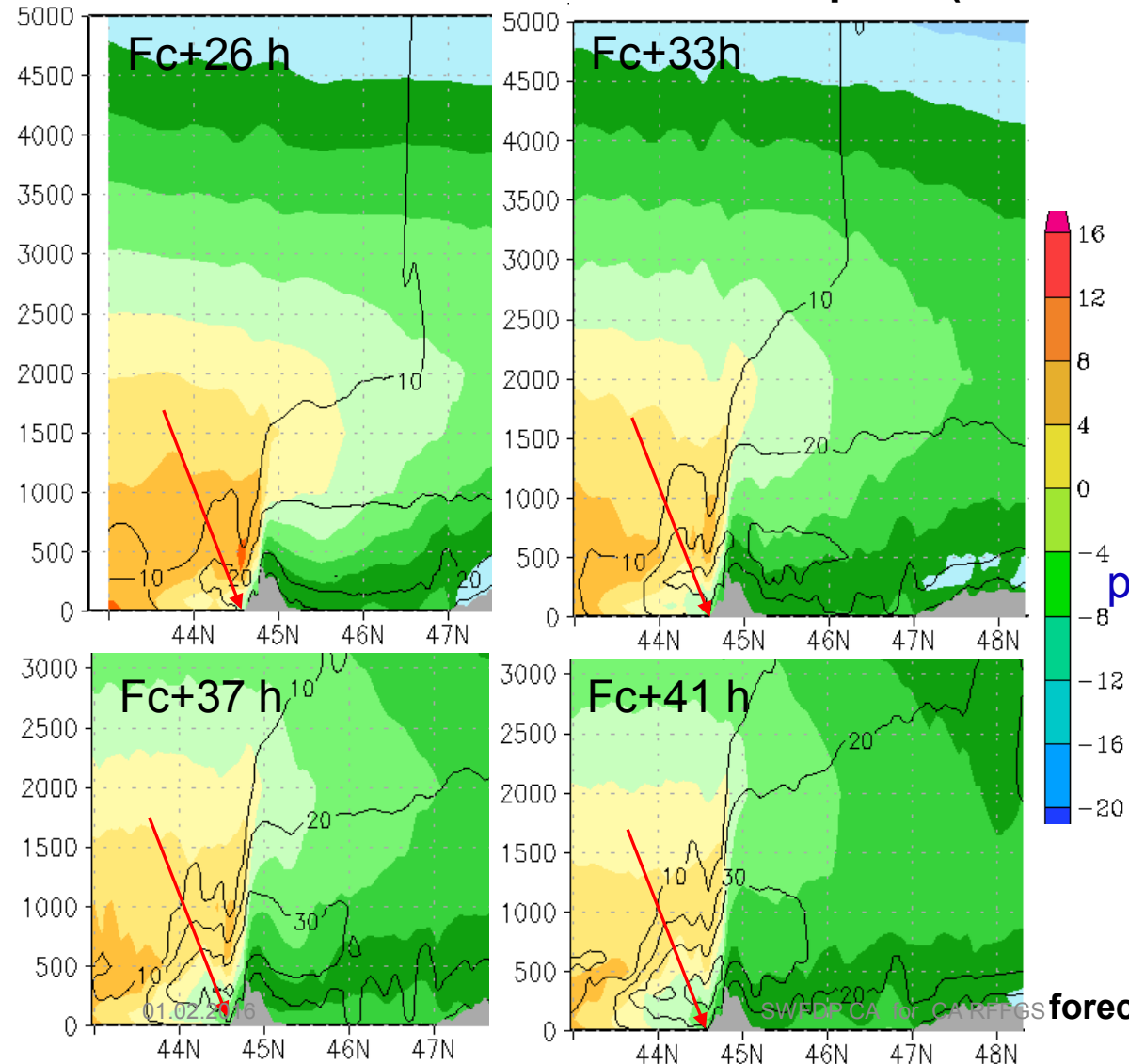


COSMO-Ru system products

COSMO-Ru2

Strong wind (Bora) in Novorossiysk

Meridional cross-section of wind speed (contours) and temperature (color)



Cold continental polar air passes Markhotsky Pass (435 m), creating strong north-east wind with a significant downward component near Novorossiysk bay .

forecast from 06.02.2012, 00 UTC



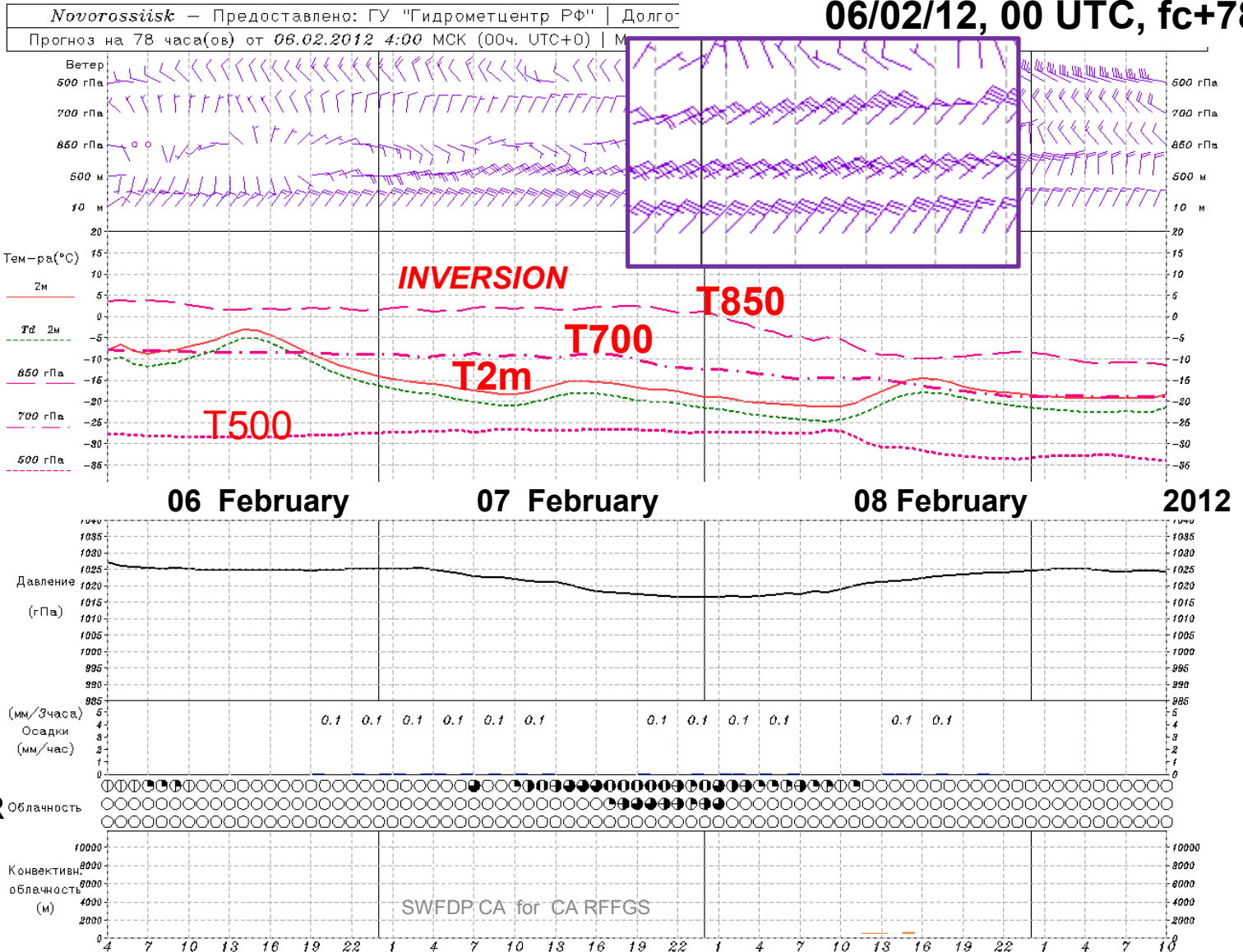
COSMO-Ru system products

COSMO-Ru7



Strong wind (Bora) in Novorossiysk

Meteographs for Novorossiysk
06/02/12, 00 UTC, fc+78h



04.02.2016



Status and availability of SWFDP-CA QPF for use in CARFFGS:

1. WMO SWFDP
2. WMO SWFDP –CA: status
3. COSMO and COSMO-Ru
4. QPF by COSMO-Ru
5. Meteorological part of **CARFFGS**

SWFDP-CA: Severe Weather Forecast Demonstration Project for Central Asia
CARFFGS: Central Asia Region Flash Flood Guidance Project



Meteorological part of **CARFFGS**

- 5.1. preparing of initial and boundary data for NWP and preparing flood-cases for 4 countries,**
- 5.2. numerical experiments with COSMO-CA with different grid sizes,**
- 5.3. hydrological forecasts,**
- 5.4. analysis of case study.**



	SGI ALTEX 4700	SGI ICE-X	РСК ТОРНАДО
Тип процессоров	Intel Itanium 2 (2-ядерный)	Intel Xeon (10-ядерный)	Intel® Xeon® E5-2600 (8-ядерный)
Узлов, ядер на узел, всего ядер	13 128 1664	36 20 720	96 16 1536
Опер. память на ядро, всего	4 Гбайт 6.6 Тбайт	3.2 Гбайт 2.3 Тбайт	4 Гбайт 4.6 Тбайт
Пиковая производительность	11 Тфлопс	14 Тфлопс	35 Тфлопс

**1 Тфлопс = 10^{12} операций в сек =
1 000 000 × 1 000 000 = миллион миллионов операций в секунду
35 тфлопс **==** 35 миллионов БЭСМ-6 !**



Спасибо за внимание !
Thank you!