Regional NWP models and their application to operational weather forecasting in Ukraine

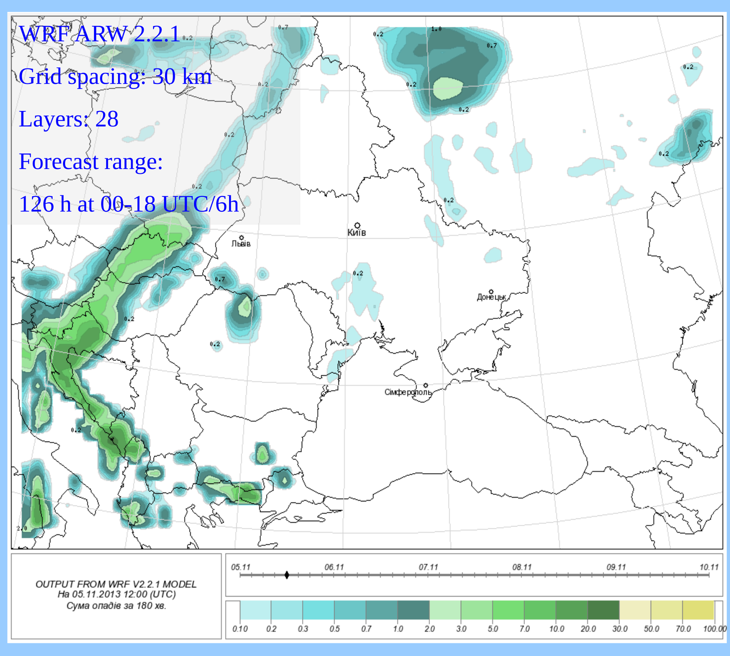
Vitalii Shpyg(1), Igor Budak(1), Valerii Mykhailovskyi (2),
Denys Pishniak(3), Lesia Katsalova (1) and Pavlo Poperechnyi (1)

(1) Ukrainian Hydrometeorological Institute, Kyiv (Vilal@rambler.ru)
(2) Ukrainian Hydrometeorological Center , Kyiv
(3) National Antarctic Scientific Centre of Ukraine, Kyiv

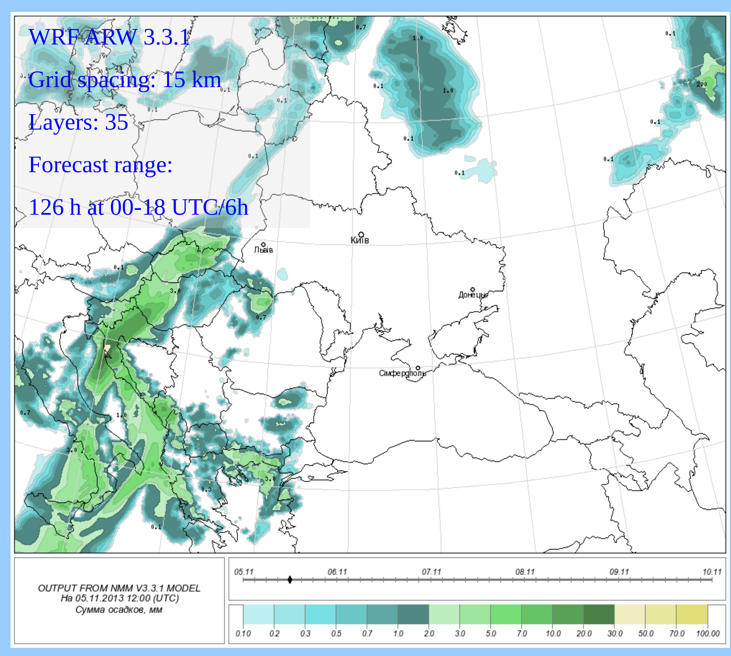
Weather forecasts are part of information about environment for which every living thing on Earth adapts including humans. For today, in connection to the development of weather forecasting technology, social resilience to adverse conditions had risen sharply. But at the same time even the most modern methods and forecasting technology in many ways are still far from the demands imposed by business and consumer spheres. Climate changes in modern period, seems not improve the accuracy of forecasts, particularly when use classic synoptic and statistical methods. Looking about the benefits of weather forecasts for different aspects of performance should not be forgotten, that in common case the expansion of their applications without accounting of necessary specifications may leads to increasing negative consequences, up to risks for humans life.

Over the last decades, numerical weather prediction (NWP) models established themselves as a highly effective way of weather forecasting in everyday operational practice in many hydrometeorlogical centers around the world. These are enable to significantly speed up and simplify the process of creating heterogeneous information for a wide range of users, which is also independent from the state of forecaster's health. The accuracy of these models is usually higher than the accuracy of the synoptic weather forecast, especially when it comes about their spacial and temporal detalization. The global atmospheric models have approached with their current temporal and spatial discretization to the mesoscale-gamma of atmospheric processes.

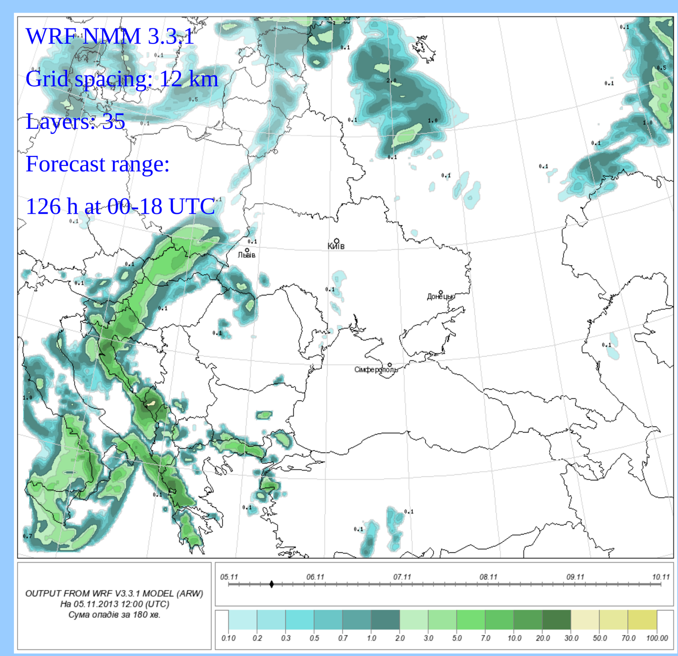
Ukrainian Hydrometeorological Center (UHMC) provides different types of forecasting information for all governmental institutions of Ukraine using various internal and external sources of data. Ukrainian hydrometeorlogical Institute (UHMI) works over investigation of regularities of atmosphere physical processes, study of mechanisms of regional climate formation, trends of climate fluctuations, numerical modeling of regional climate, relation with global climate change, development of numerical and physical-statistical methods for weather forecast, development of agrometeorological forecasts, study on physical mechanisms and regularities of influence of the atmosphere and underlying surface on vegetation growth and etc. UHMI provides additional support and scientific maintenance of UHMC and other governmental organization in matters of hydrometeorology. One form of such activity is NWP. WRF ARW v.2.2.1 was a first mesoscale model of new generation in UHMI which started use since February of 2008. During last 5-6 years the list of NWP models, which were operated in UHMI, included: mesoscale atmospheric model of UHMI, WRF ARW (since 2008), ETA (2008/2009) , WRF NMM (since 2009) and COSMO (since 2011/2012). Real time runs are provided by supercomputer Altix-4700 and a few number of servers on the basis Xeon-type processors.



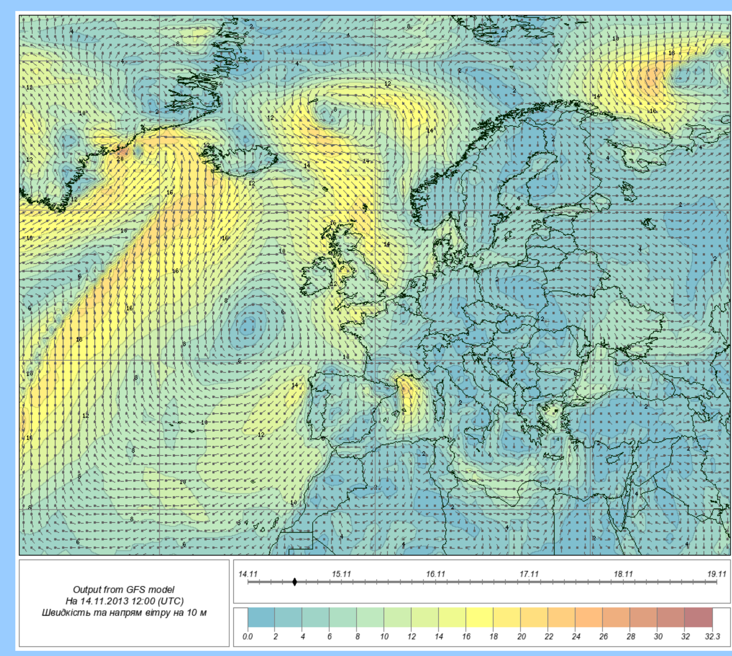
WRF ARW v.2.2.1 precipitation forecast



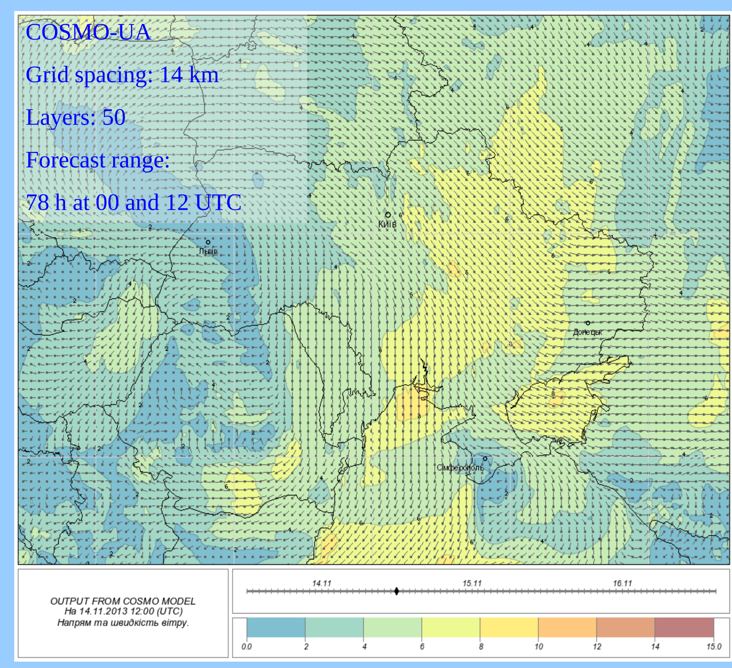
WRF ARW v.3.3.1 precipitation forecast



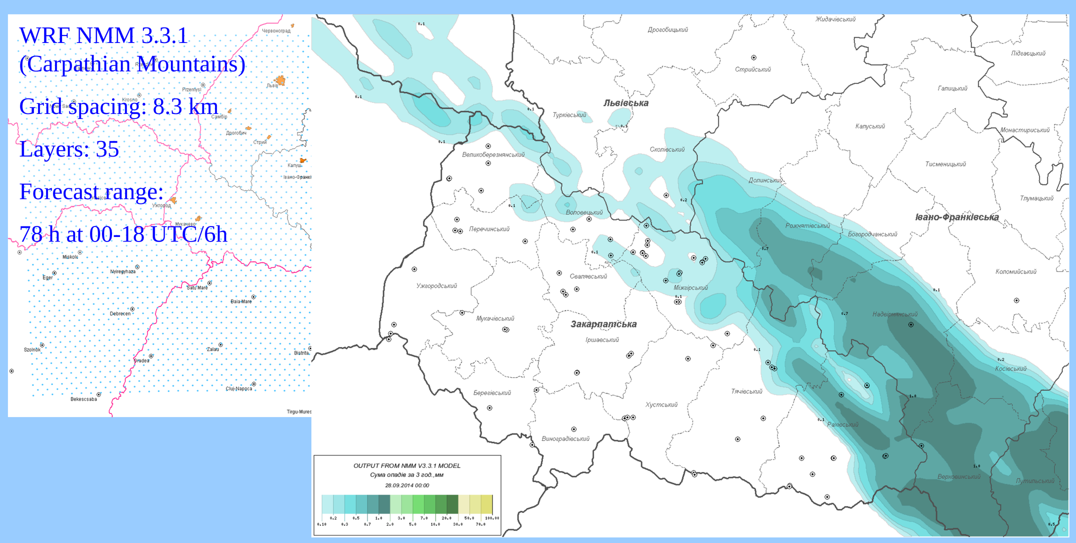
WRF NMM v.3.3.1 precipitation forecast



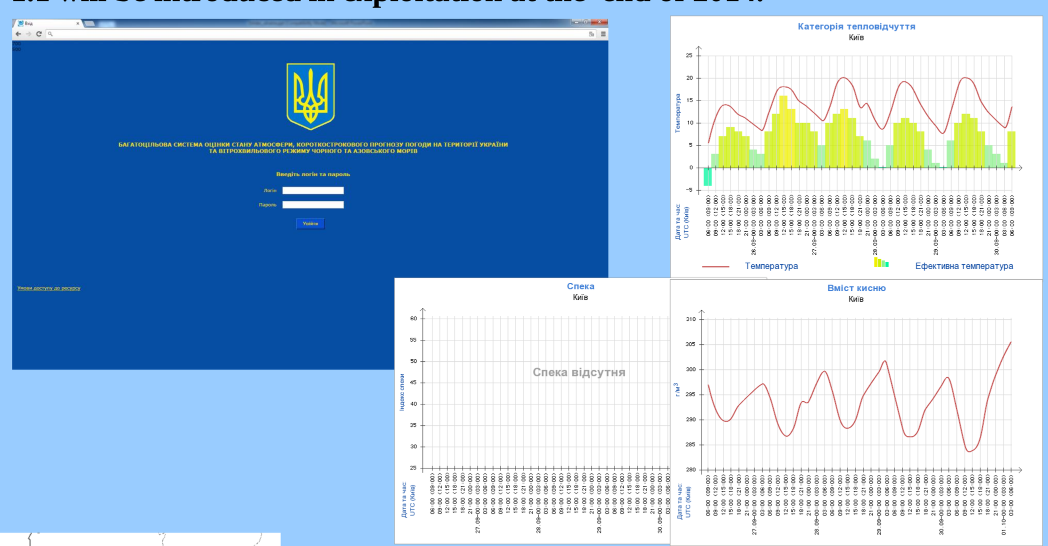
GFS NCEP (1 degree horizontal resolution) wind velocity and direction forecast

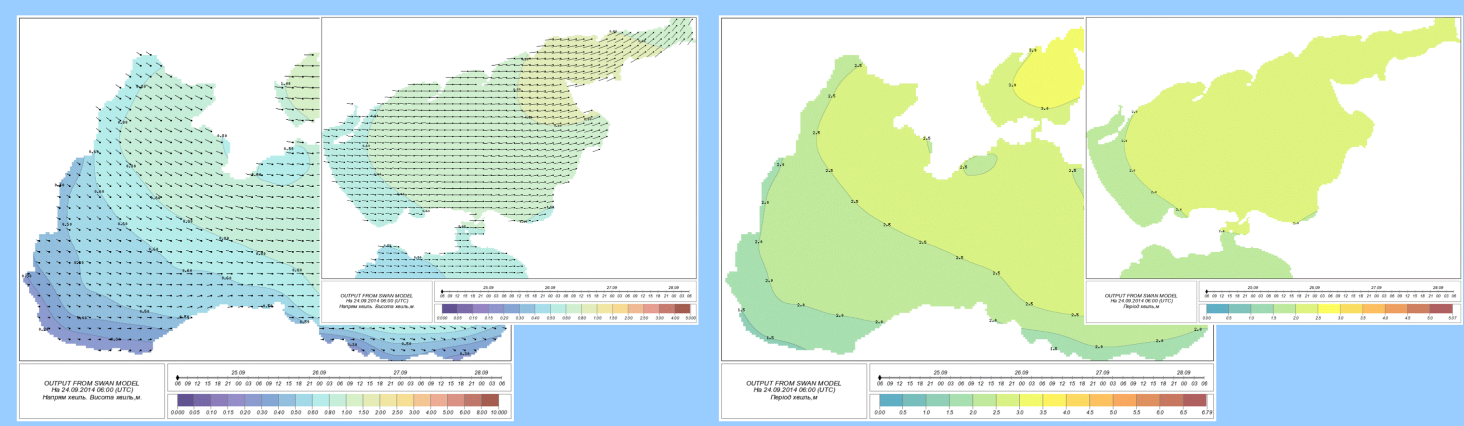


COSMO wind velocity and direction forecast



Version 1.0 of the Multipurpose system of evaluation of atmosphere state, wind and wave mode for the territory of Ukraine and of basins Black and Azov Seas was developed in 2012. Planned that Version 1.1 will be introduced in exploitation at the end of 2014.

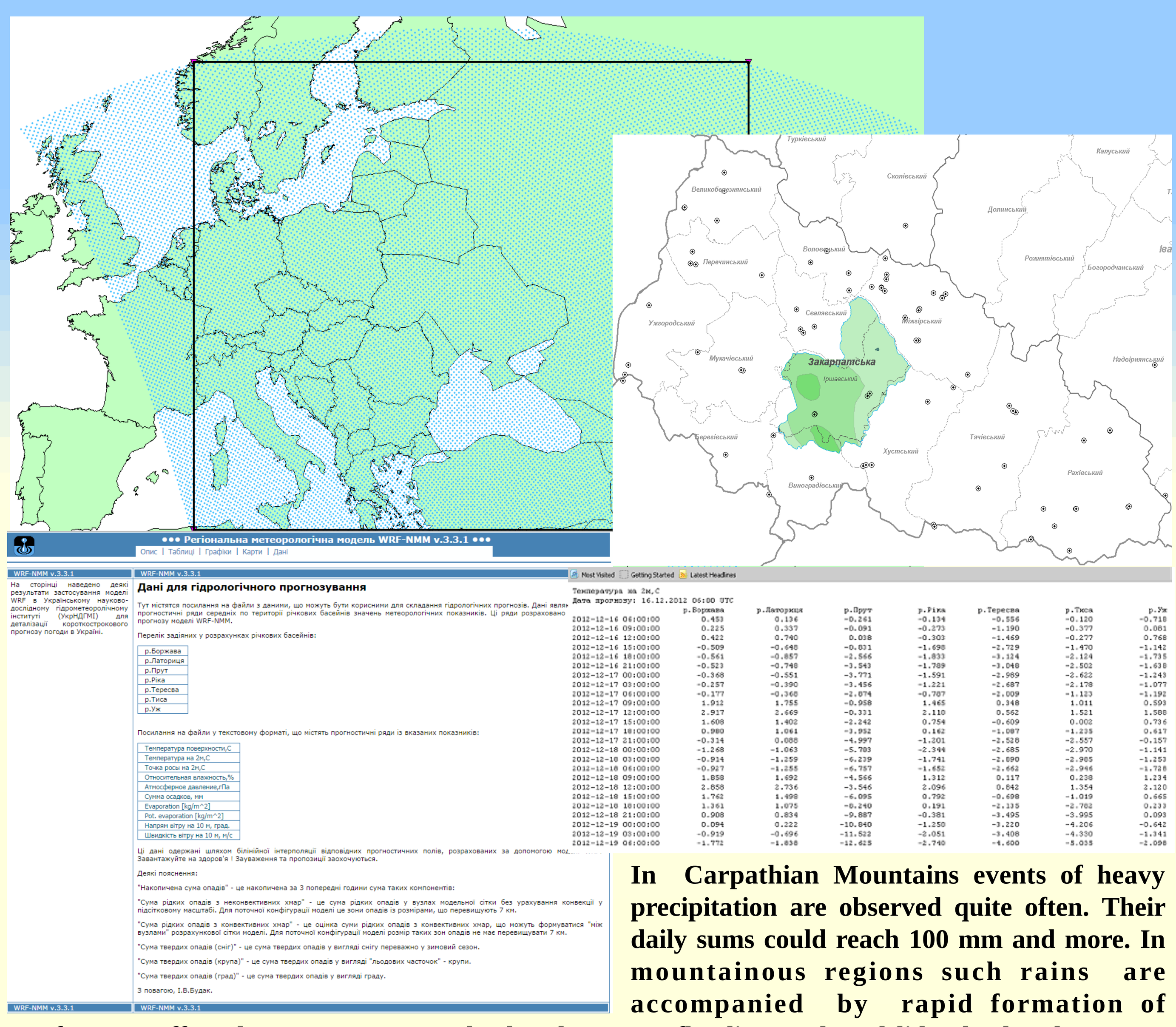




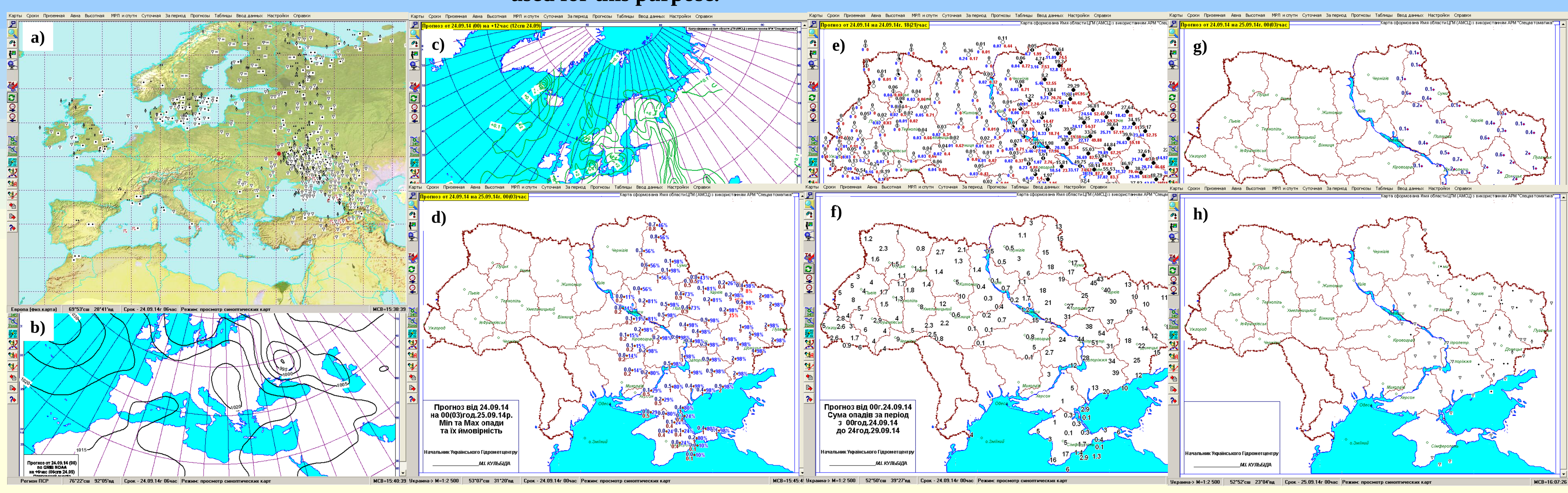
SWAN model simulating results: left side – height of sea waves and their direction; right side – period of sea waves

System contains: satellite images and products; data of numerical weather forecast; values of wind chill and human health indexes; O2 concentration; height of waves and their directions in Black and Azov Seas. Last products realized with the help modified in UHMI SWAN model.

Input data provided from mesoscale atmospheric model. Different versions of WRF NMM v.3.x were used for this purpose.



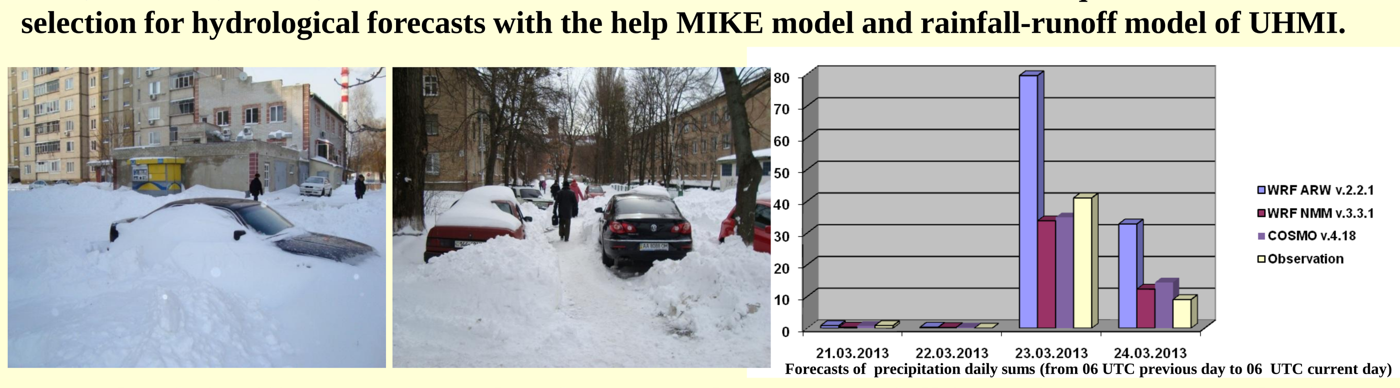
In Carpathian Mountains events of heavy precipitation are observed quite often. Their daily sums could reach 100 mm and more. In mountainous regions such rains are accompanied by rapid formation of surface runoff and, as a consequence, lead to dangerous flooding and mudslides. lead to dangerous flooding and mudslides. In connection to this, there is necessary to use modern weather forecast models with a detailed spatial and temporal discretization for solving problems in applied hydrology. As of the 2014 , forecast for the basin was realized for 7 rivers: Borzava, Latorica, Prut, Rika, Teresva, Tisza, Uzh. WRF NMM v.3.3.1 weather forecast and technique for further basins selection for hydrological forecasts with the help MIKE model and rainfall-runoff model of UHMI.



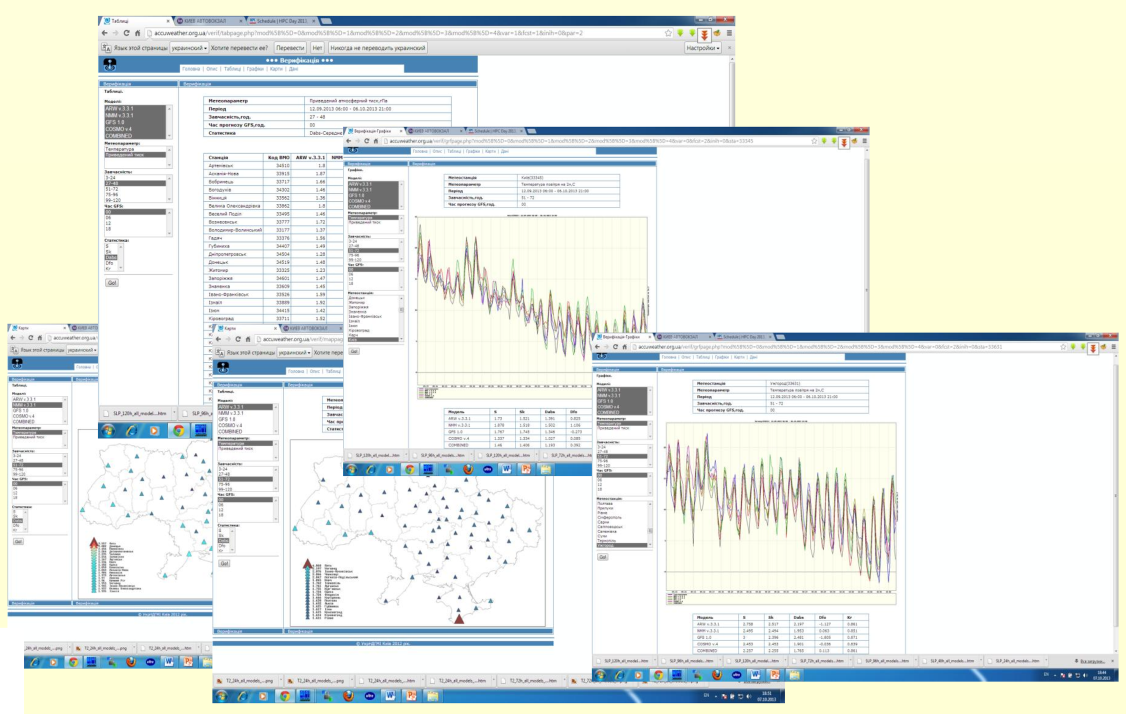
Examples of representation of forecast information with the help of Weather Forecaster Automatically Working Place, which is used by forecasters as basic information system and it was developed in UHMC

There is shown from left to right and top-down: a) weather chart, Europe 2014.09.24 06 UTC; b) forecast of MSLP by Global NOAA model on 2014.09.24 06 UTC; c) forecast of baric tendention by Global NOAA model on 2014.09.24 06 UTC; d) precipitation forecast provided by physic-statistical model of UHMC on 2014.09.25 00 UTC; e) daily forecast of precipitation by regional model of KNMI on 2014.09.24; f) forecast of precipitation on 5-days period from 2014.09.24 to 2014.09.29 by WRF NMM v.3.3.1; g) precipitation forecast provided by WRF NMM v.3.3.1 on 2014.09.25 00 UTC; h) observed precipitation on Ukrainian network of meteorological stations at 2014.09.25 00 UTC.

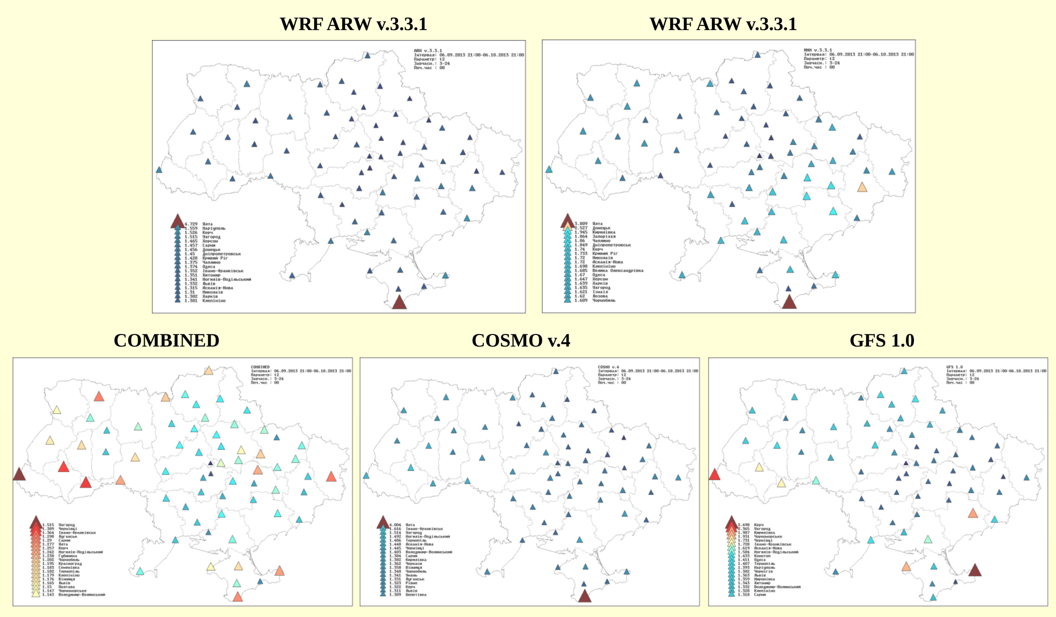
UHMC uses results of global weather forecasts, which are produced by NCEP, United States Navy's Fleet Numerical Meteorology and Oceanography Center, DWD and Met Office (Bracknell), and regional atmospheric models (physic-statistical model of UHMC, regional model of KNMI, both WRF version 3.3.1 and COSMO from UHMI)



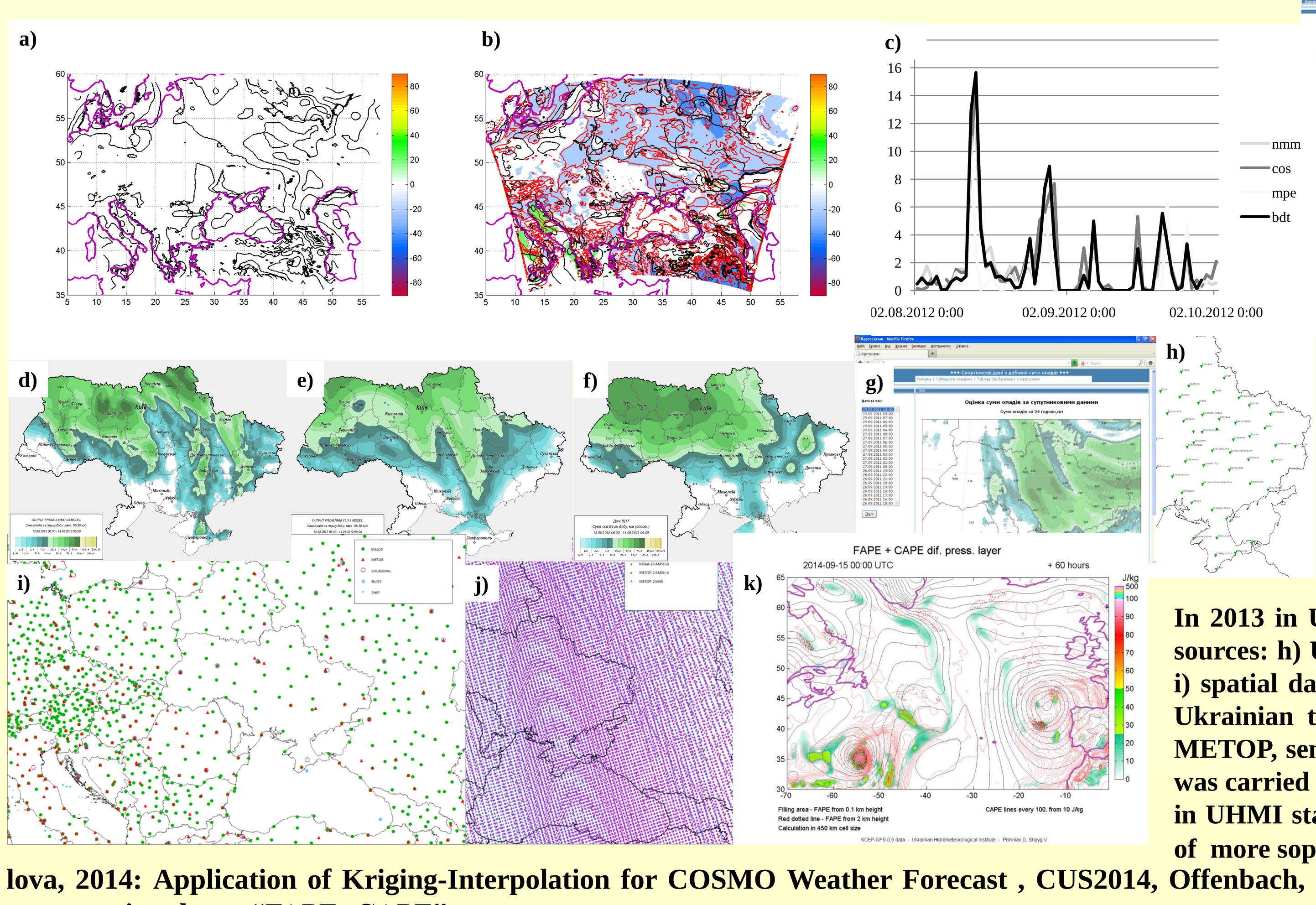
Example of significance of weather forecasts (heavy snowfall in Kyiv, 22-25 March of 2013)



Automatically system of forecast's quality monitoring of UHMI



Examples of charts of spatial distributions of RMSE of different models which were built for part stations of Ukrainian surface observation network (time of initialization: 00 UTC; forecast: 24 h)



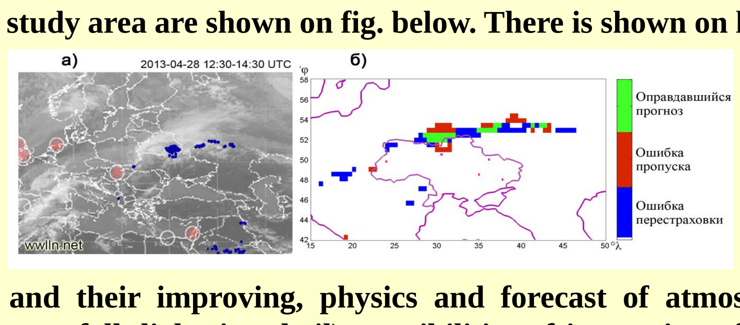
In UHMI many aspects of consistency (together with experts of UHMC) and quality (UHMI, see below) of NWP models' forecast are estimated: a) WRF NMM v.3.3.1 objective analysis of specific humidity in the range of domain and spatial errors on fifth (b) days of its forecast; c) comparison of precipitation sums provided by WRF NMM v.3.3.1 (nmm), COSMO v.4.18 (cos), satellite (mpe), surface observation (bdt) during August-September 2012; d) spatial field of daily precipitation sums of COSMO v.4.18 forecast; e) spatial field of daily precipitation sums of WRF NMM v.3.3.1 forecast; f) reduced of observed daily precipitation sums from surface network to standard grid points of visualization system of UHMI; g) estimation of precipitation sums by satellite data for the previous 3 hours (on the basis of EUMETSAT data)

In 2013 in UHMI data assimilation technology was realized with using of 3 data sources: h) Ukrainian stations which are correspond to requirements of WRF DA; i) spatial data set of observations, which is used including GDAS; j) Covering of Ukrainian territory according to satellite observations. Platforms - NOAA and METOP, sensors - AMSU-A, AMSU-B and MHS. Series of numerical experiments was carried out and obtained first results. Operative exploitation is put off. In 2013 in UHMI started researches about possibility of improving forecast through using of more sophisticated interpolation procedure (see, Vitalii Shpyg and Lesia Katsalova, 2014: Application of Kriging-Interpolation for COSMO Weather Forecast , CUS2014, Offenbach, Germany). Created new product of forecast on the data of GFS: comparative charts "FAPE+CAPE".

For the purpose of confirming our assumptions we express the proposed idea as a frontal parameter FAPE, which implies a positive part of relative potential energy (ОПЭ), calculated on a scale of 450 km and contained in the atmospheric column (calculated from all vertical levels):

$$ОПЭ_i = m_i g \int_{h_Z}^{h_E} \frac{\overline{p}T_i - p_i\overline{T}}{p_i\overline{T}}|dh| = m_i g \int_{h_Z}^{h_E} \frac{\theta_i - \overline{\theta}}{\overline{\theta}}|dh| \qquad FAPE_i = \frac{1}{m} g \int_{1}^{L} \int_{h_L}^{h_E} \frac{\theta_i - \overline{\theta}}{\overline{\theta}}|dh|\,dm$$

Calculations was conducted on the base of forecast data of GFS global model with a resolution of 0.5° latitude-longitude grid, 0-48 hours in advance, for the period from April to September 2013. Results are compared with data of thunderstorm detection of the World Wide Lightning Location Network. In general, there is frequent coincidence FAPE accumulation zones and frontal thunderstorm cells. Example of spatial comparison and the study area are shown on fig. below. There is shown on left side lighting detection and on right comparison of its results with FAPE more than 20 J/kg (green is hits; red is misses, false alarms).



Future plans

More researches in area of the atmospheric energy, forecasts estimation and their improving, physics and forecast of atmospheric phenomena (heavy rain and snowfall, lightning, hail), possibilities of improving of numerical weather forecast through using of physics post-processing developed on output NWP model data in coastal regions.