# Statistical downscaling of results of the forecasting system MM5–Ukraine using neural net technology.

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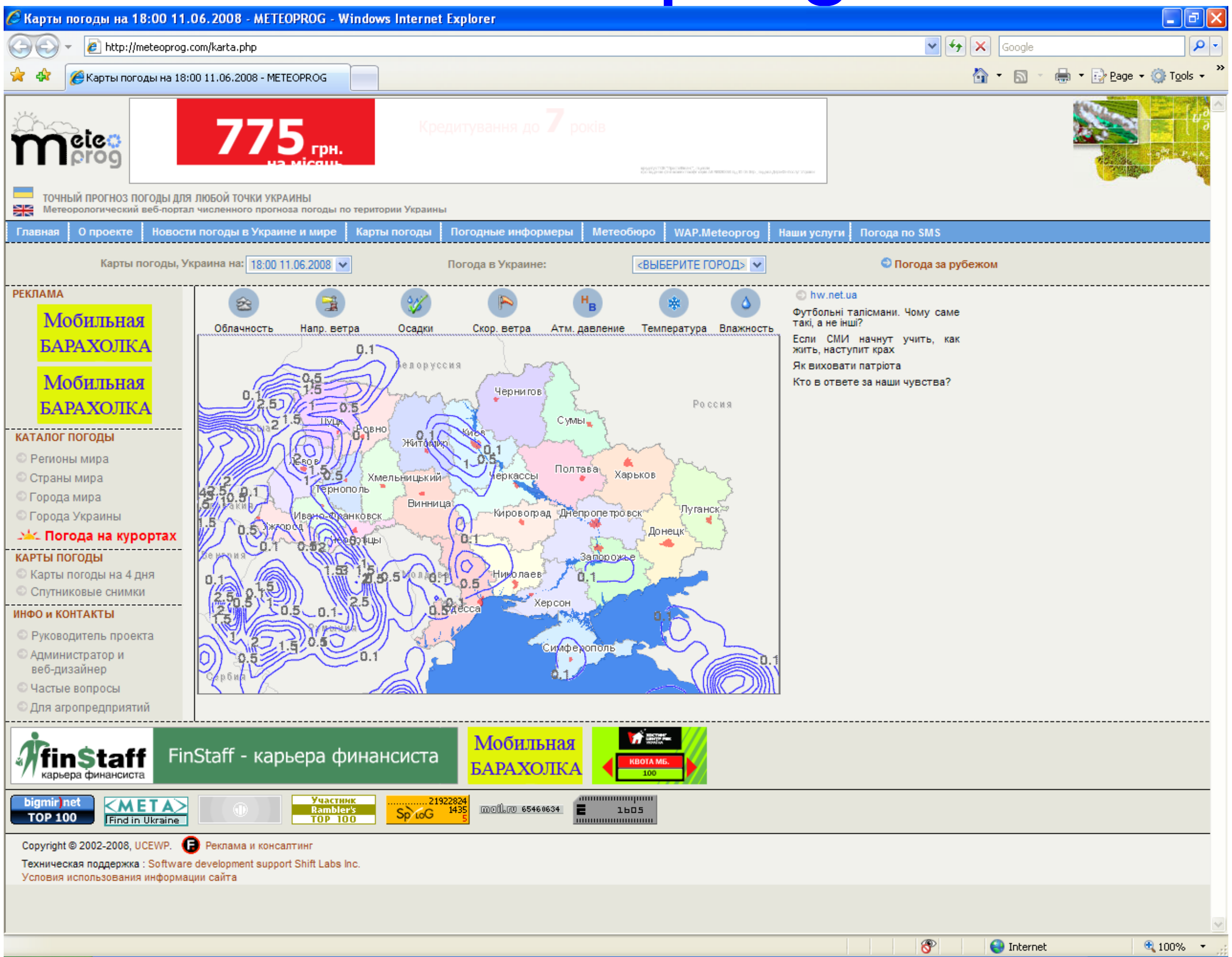
# NWP in Ukraine

# www.meteoprog.ua



# Current configuration of system MM5-Ukraine

- Grid 30 km x 30 km (covers Ukraine) nested in grid 81 km x 81 km.
- Data from Global meteorological model provided by National Center for Environmental Predictions of USA (NCEP, http://nomad5.ncep.noaa.gov/) is used for initial and boundary conditions of the model.
- Geospatial data is taken from Geological service of USA (USGS), spatial resolution is 5’.
- Parameterizations (for description of all available options, please, see http://www.mmm.ucar.edu/mm5/documents/tutorial-v3-notes-pdf/mm5.pdf ):
- **Explicit Moisture Schemes IMPHYS = “4,4”** (4 – simple ice)
- **PBL Schemes IBLTYP=”5,5”** (5-MRF, see Hong and Pan (1996) for details)
- **Cumulus Parameterizations ICUPA=“3,3”** (3 – Grell, see Grell et al. (1994))
- **Radiation Schemes IFRAD=“4,4”** (Rapid Radiative Transfer Model long-wave scheme)

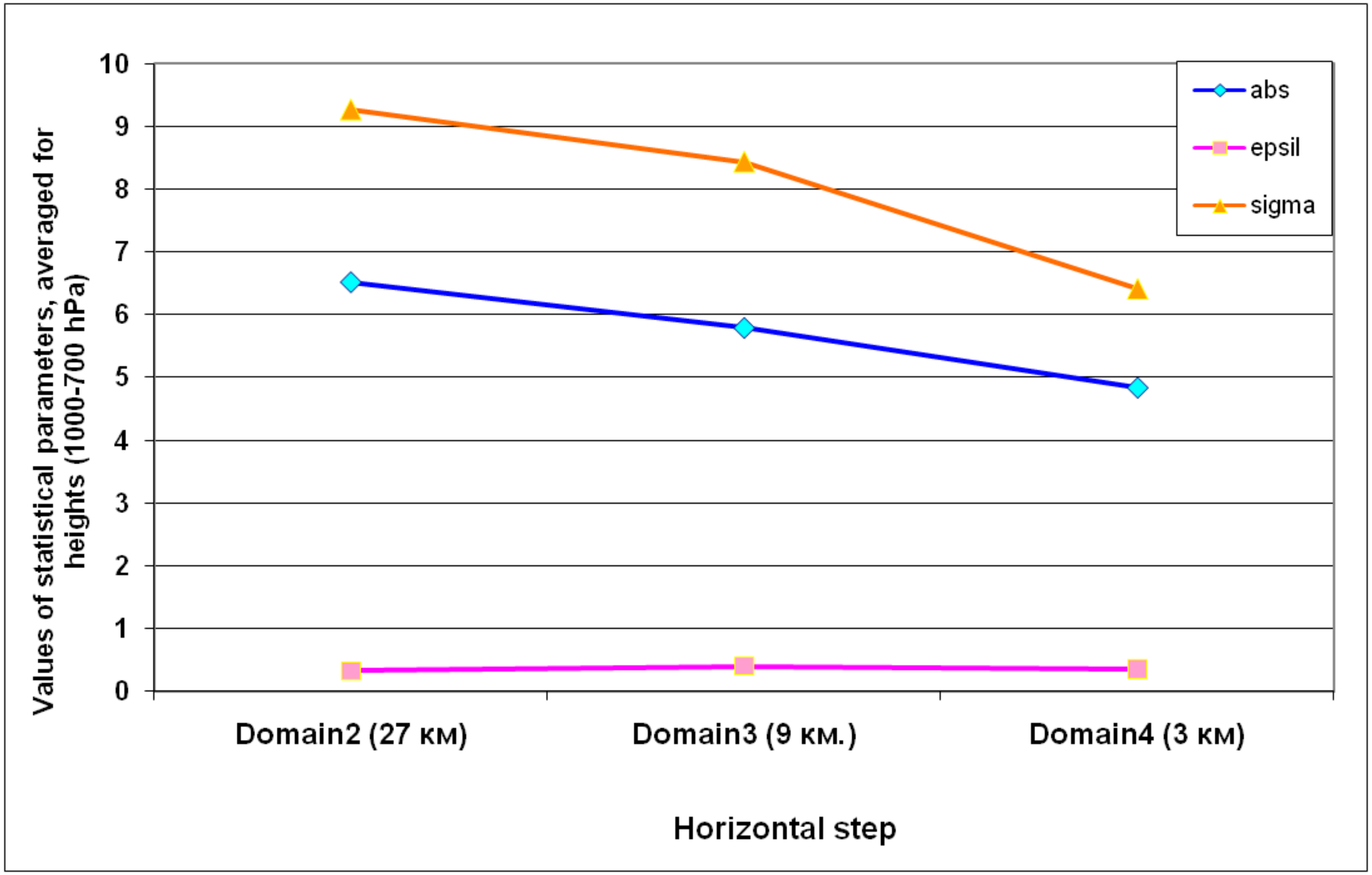
## *Quality of temperature forecast at 925-700 hPa (°K)*

| Type of synoptic situation | | Number of occurrences, % | rms error of prognosis |
|---|---|---|---|
| 1 | Axis of crest, anticyclone | 27.6 | 1.7 |
| 2 | Axis of cavity, cyclone | 5.2 | 3.5 |
| 3 | Rear part of cavity, cyclone | 8.6 | 2.7 |
| 4 | Front part of cavity, cyclone | 5.2 | 2.6 |
| 5 | Rectilinear isobars | 5.2 | 2.8 |
| 6 | Saddle, low gradient field | 41.4 | 1.5 |
| 8 | West periphery of crest, anticyclone | 3.4 | 1.7 |
| 9 | periphery of crest, anticyclone | 3.4 | 1.5 |
| ***net*** | | ***100*** | ***1.9*** |

## *Quality of temperature forecast at 1000 hPa (°K)*

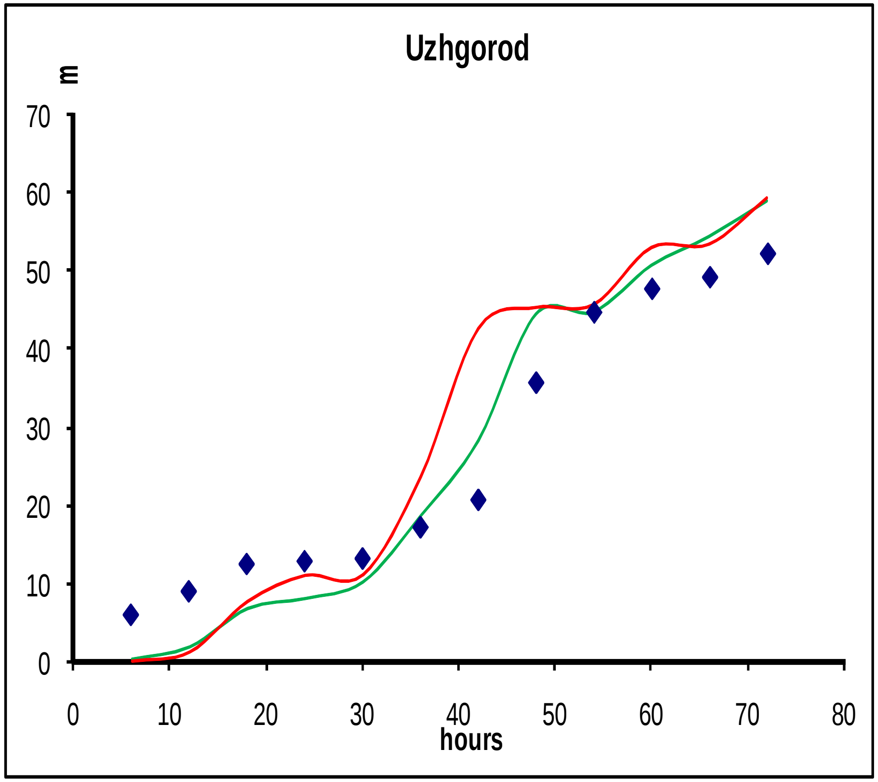
| Type of synoptic situation | | Number of occurrences, % | rms error of prognosis |
|---|---|---|---|
| 1 | Axis of crest, anticyclone | 27.6 | 3.50 |
| 2 | Axis of cavity, cyclone | 5.2 | 5.71 |
| 3 | Rear part of cavity, cyclone | 8.6 | 4.23 |
| 4 | Front part of cavity, cyclone | 5.2 | 5.13 |
| 5 | Rectilinear isobars | 5.2 | 4.63 |
| 6 | Saddle, low gradient field | 41.4 | 2.94 |
| 8 | West periphery of crest, anticyclone | 3.4 | 3.62 |
| 9 | periphery of crest, anticyclone | 3.4 | 2.47 |
| ***net*** | | ***100*** | ***3.56*** |

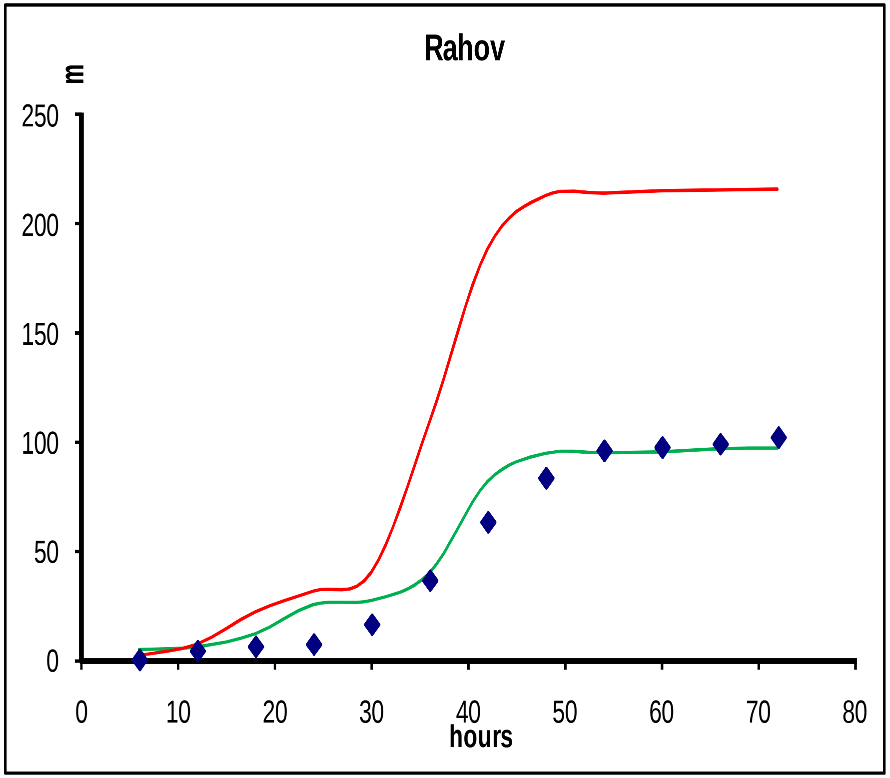
# Statistical characteristics of MM5-Ukraine forecast of geopotential as functions of horizontal step of the calculation domain.



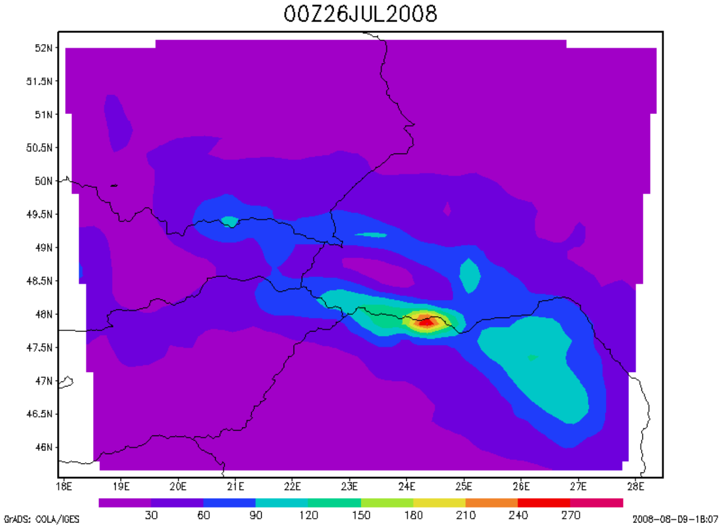
# Linearly interpolated precipitations accumulated from 00Z23JUL2008

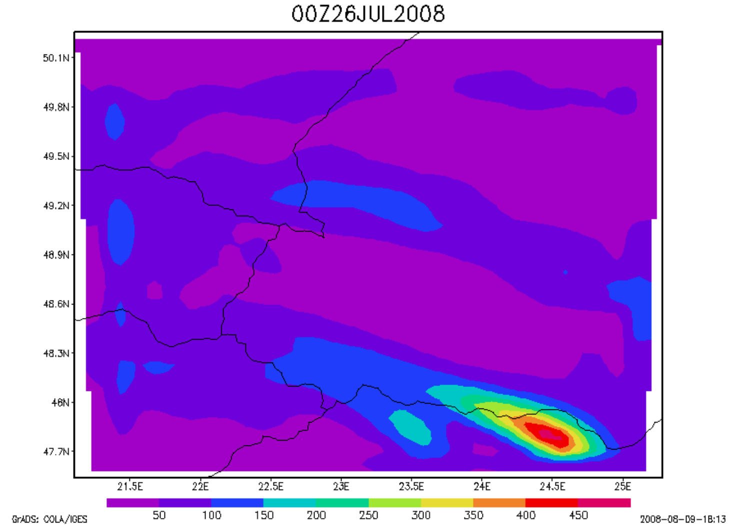
Blue points – measurements, red and green lines - MM5 forecasts on domains with steps 9 km and 3 km respectively.

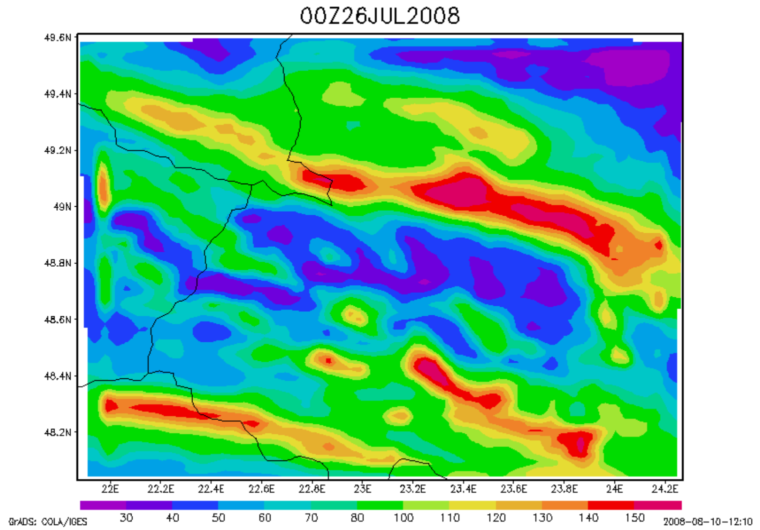


# Accumulated precipitations from 00Z23JUL2008, for horizontal steps 27, 9, 3 km



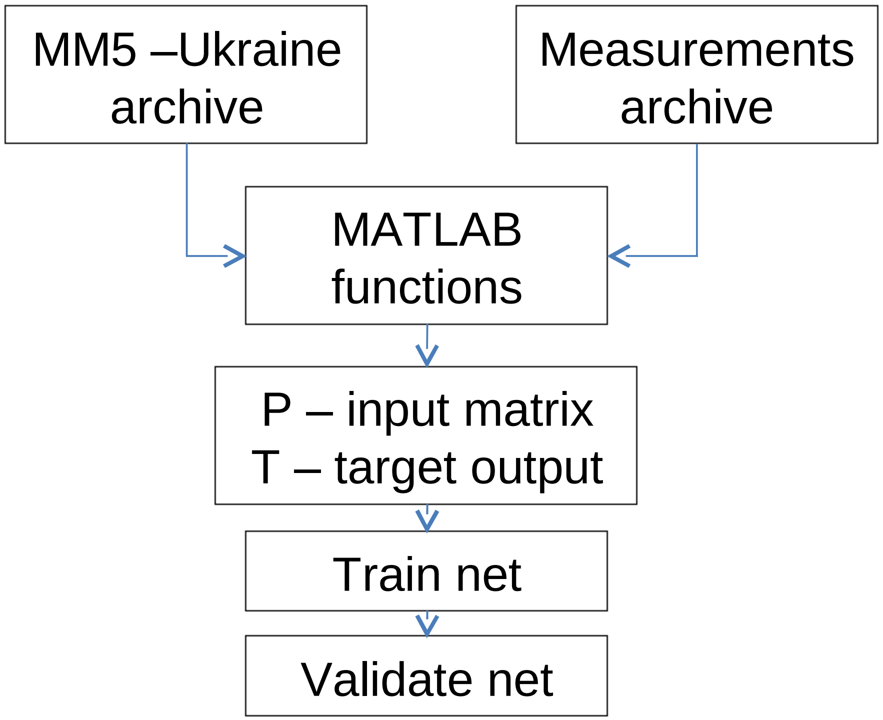



# Problems to solve

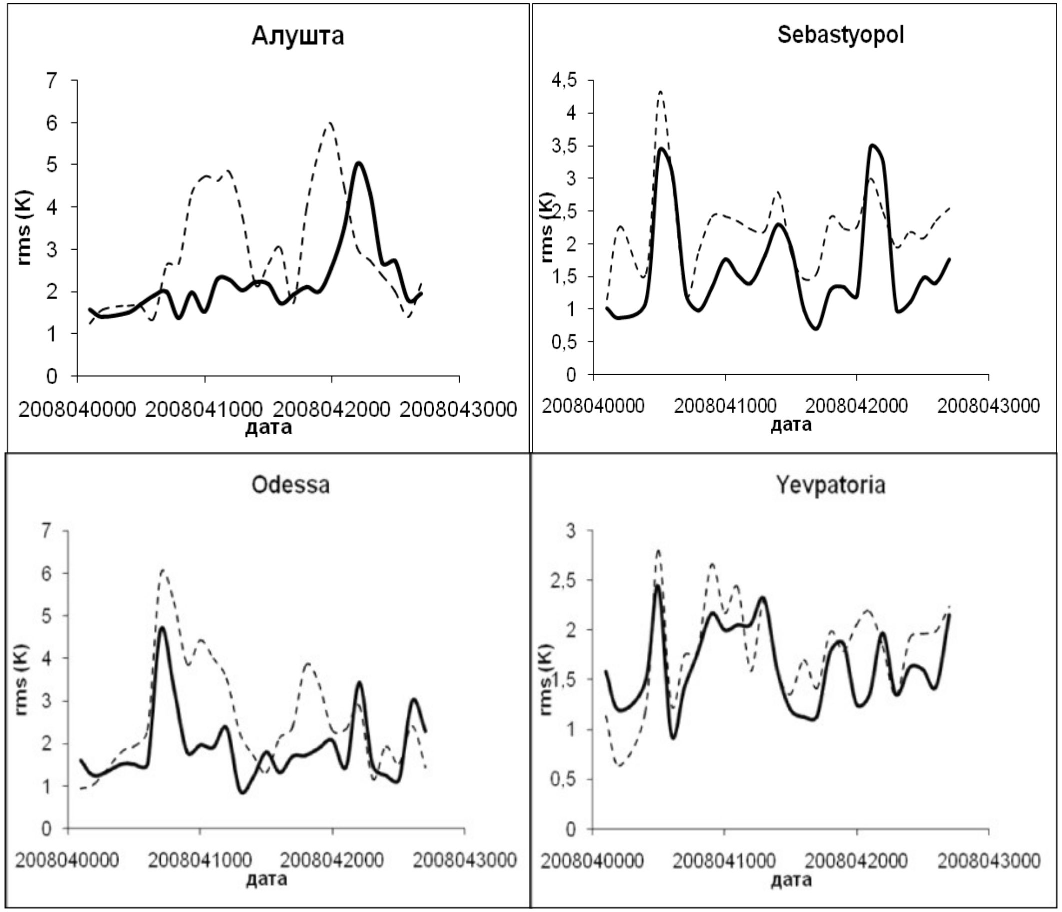
- Improve existing interpolation procedure.
- Explore errors of the improved system and compare them with errors of current system “MM5-Ukraine”.

# Training of neural net for downscaling of precipitations and temperature.

1. Predictors: temperature at 2m height, soil temperature, dew point temperature, relative humidity, accumulated precipitations, wind speed, day time, month, day of month at 4 closest nodes of the calculation mesh. Forecast time up to 48 hours. Number of predictors 32.
2. Predicted quantities: 2m height temperature at desired point, accumulated precipitations during last 6 hours.
3. Training interval: January 2007 - March 2008 ( ~7000 training examples for temperature, ~1000 for precipitations)
4. Testing interval: April 2008
5. Type of the neural net: static/dynamic feed-forward, training function: ‘trainlm’ (which utilizes Levenberg-Marquard algorithm for error minimization), number of layers: 2, number of neurons: 16, activation functions ‘tansig’ for the first layer and linear for the second.
6. Implemented using MATLAB 7.0



**Root mean square errors of forecasts of bottom layer temperature for 48 h periods for April 2008.**
**(linear interpolation – hatched line, neural net – firm line)**



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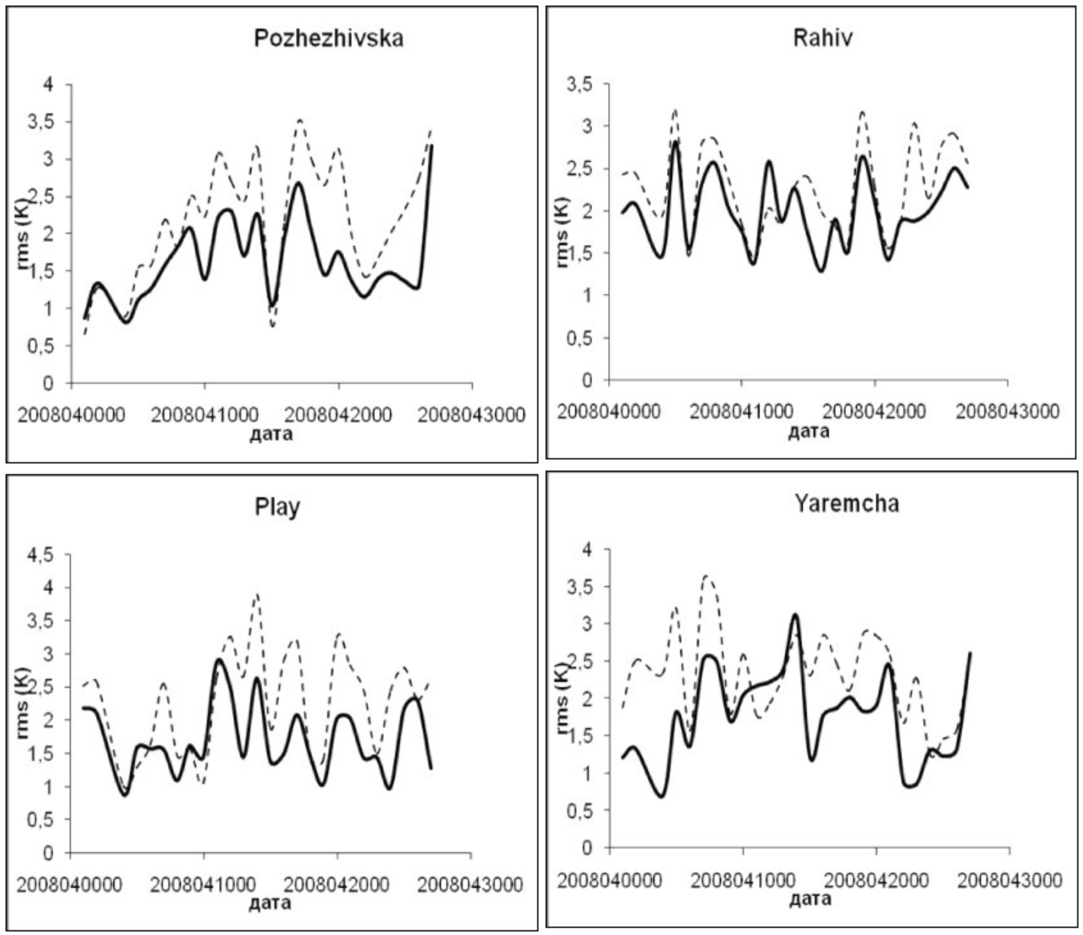
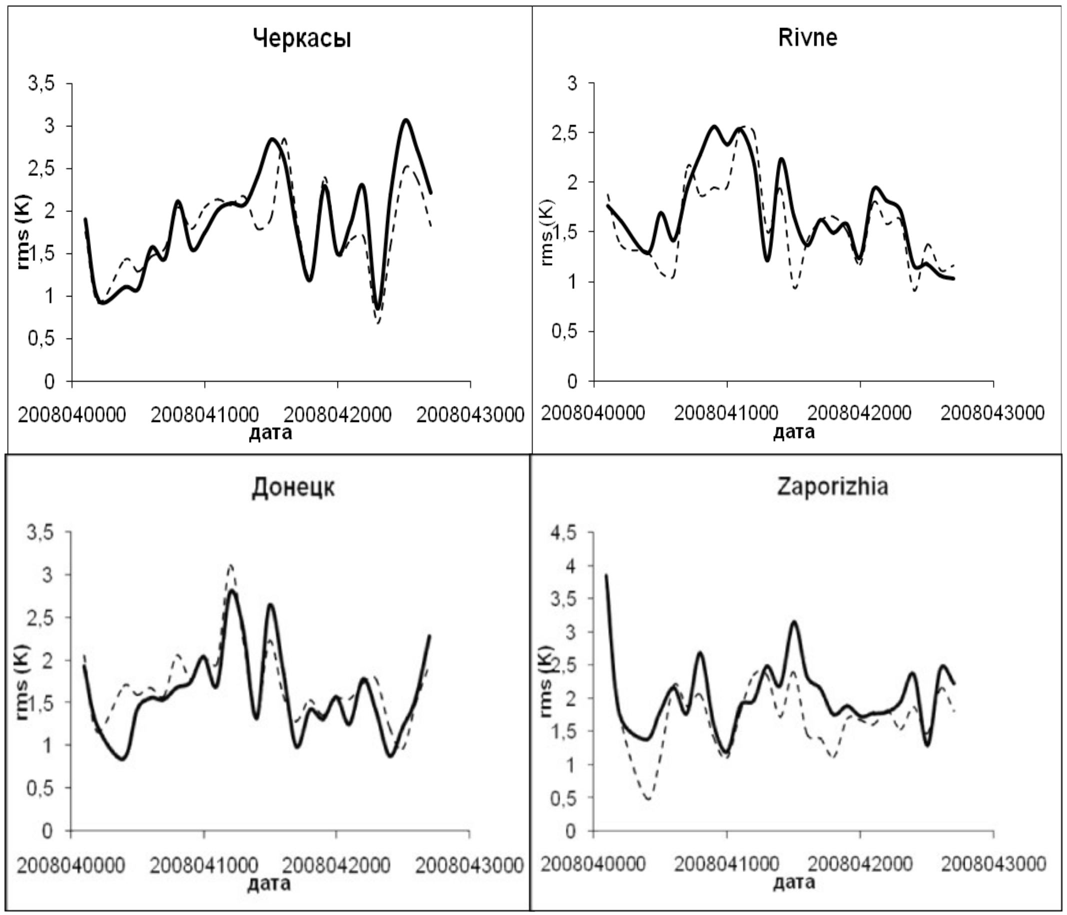


**Root mean square errors of forecasts of bottom layer temperature for 48 h periods for April 2008.**
**(linear interpolation – hatch line, neural net – firm line)**

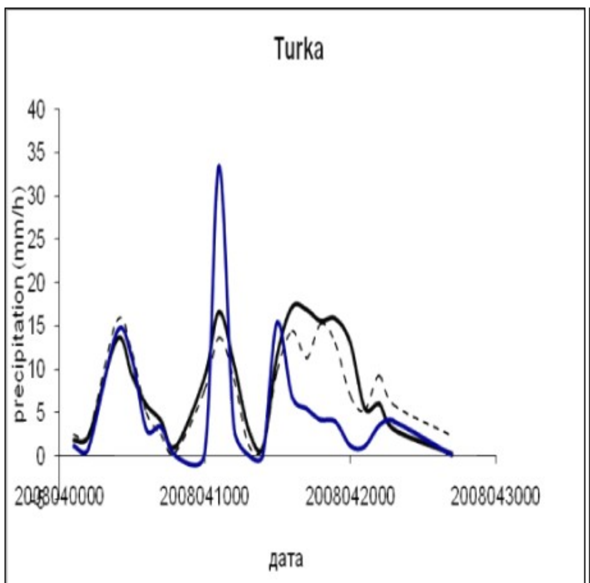


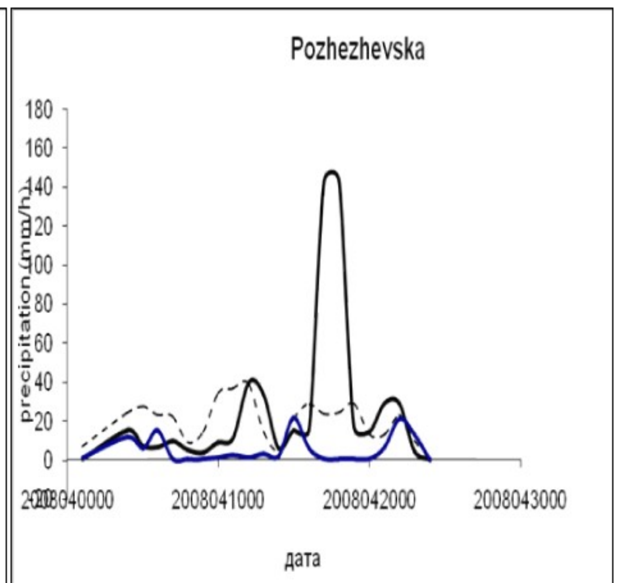
| Station | Linear interpolation. ( rms,K) | Neural net (rms, K) | Linear interpolation. (bias, K) | Neural net (bias, K) |
|---|---|---|---|---|
| Киев | 2.12 | 1.9 | -0.56 | 0.1 |
| Рахов | 2.32 | 2.04 | -0.79 | -0.4 |
| Черкассы | 1.85 | 1.98 | 0.22 | 0.33 |
| Никополь | 1.87 | 1.90 | -0.01 | 0.24 |
| Алушта | 3.34 | 2.42 | 1.63 | 0.1 |
| Межгорье | 2.36 | 2.14 | 0.50 | 0.49 |
| Николаев | 1.90 | 2.2 | 0.12 | 0.66 |
| Одесса | 2.96 | 2.11 | 1.32 | 0.95 |
| Пожежевка | 2.35 | 1.75 | 0.70 | 0.58 |
| Ровно | 1.64 | 1.75 | -0.26 | -0.6 |
| Селятин | 3.05 | 2.40 | 1.37 | 0.68 |
| Турка | 2.56 | 2.02 | 0.36 | 0.43 |
| Донецк | 1.77 | 1.70 | -0.1 | 0.0004 |
| Запорожье | 1.84 | 2.11 | 0.09 | 0.45 |
| Коломыя | 1.97 | 2.13 | 0.19 | -0.31 |
| Севастополь | 2.32 | 1.83 | 0.42 | 0.39 |

| Station | Linear interpolation. ( rms,K) | Neural net (rms, K) | Linear interpolation. (bias, K) | Neural net (bias, K) |
|---|---|---|---|---|
| Ангарский перевал | 2.24 | 2.0 | -0.55 | 0.1 |
| Беловодск | 3.05 | 2.63 | 0.45 | -0.29 |
| Дебальцево | 1.82 | 1.97 | -0.11 | 0.14 |
| Джанкой | 1.7 | 1.89 | 0.25 | 0.6 |
| Изюм | 2.42 | 2.44 | -0.11 | 0.32 |
| Керчь | 1.58 | 1.65 | 0.27 | 0.25 |
| Кировоград | 1.66 | 1.62 | 0.17 | 0.51 |
| Луганск | 2.19 | 2.12 | -0.09 | 0.35 |
| Нижний Студеный | 2.17 | 1.96 | 0.16 | 0.19 |
| Плай | 2.39 | 1.78 | 0.87 | 0.5 |
| Славское | 2.48 | 2.29 | 0.54 | 0.25 |
| Сватово | 2.7 | 2.44 | -0.4 | -0,1 |
| Яремча | 2.40 | 1.88 | -1.29 | -0.18 |
| Евпатория | 1.88 | 1.7 | 0.057 | 0.5 |

# Precipitations  forecast calculated by MM5-Ukraine

| Station | Bias NN (mm/6 h) | Rms NN mm/6 h) | Bias lininterp (mm/6 h) | RMS lininterp  Bias NN (mm/6 h) |
|---|---|---|---|---|
| **Коломия** | -0.48667 | 2.2698 | -0.63399 | 2.3314 |
| **Межгорье** | 0.19988 | 2.2181 | -0.24912 | 2.5552 |
| **Нижн. Студеный** | 0.39655 | 1.3685 | -0.10539 | 1.4884 |
| **Плай** | 0.3714 | 2.4059 | -0.77843 | 2.8367 |
| **Пожеживка** | -0.99693 | 17.6889 | -4.0474 | 18.4053 |
| **Рахов** | 0.54398 | 4.814 | -1.246 | 4.4311 |
| **Селятин** | 0.96231 | 2.2593 | -0.071117 | 2.0012 |
| **Славске** | 1.37 | 3.85 | -0.7 | 3.5 |
| **Турка** | -0.16793 | 1.5779 | -0.66177 | 3.2252 |
| **Яремча** | -0.28186 | 3.7529 | -1.8773 | 4.1105 |




Black firm line – measurements

Dark blue line– linear interpolation

Hatch line – neural net

# Conclusions

- Results of validation show that it is better to use finer grid for precipitation and bottom layer temperature forecasts. But since it requires too much computational resources for this scale, it is wise to use statistical post- processing.
- Subsystem was created for statistical downscaling of operational forecasts of the system MM5-Ukraine based on neural net.
- The use of neural net allows to lower the error of bottom layer temperature forecast for stations with rms > 2 K. For some 48 h periods the error decrease reaches 5 K. Especially this concerns mountain and coastal stations.
- The error decrease is not so significant for precipitations. It is caused by lack of predictors (vertical wind speed is not presented in the archive data) and smaller size of training set. Required size of training set is O(N/e), where N is a number of parameters, e – desired error. So in our case we need ~ 5000 training examples to train the net with the error less than 10%.
- The system is recommended for use in flood prediction for mountain regions.

Thank you for attention.