X1.141

Numerical modeling of wind gusts of different origin

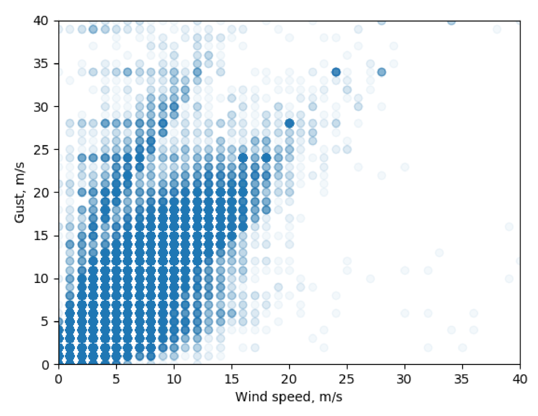
Maria Kurbatova *, *Konstantin G Rubinstein*

Hydrometeorological Research Centre of Russian Federation,
Nuclear Safety Institute of the Russian Academy of Sciences

* e-mail **marja1702@gmail.com**

Introduction


Wind gusts are extreme events which can cause severe damage. Numerical atmospheric models are designed to represent average winds, not gusts. There are several parameterization or models of wind gusts based on atmospheric models output. They are often used to determine effects of climate change on severe wind gusts occurrence. However their ability to represent gust of different origins and formation mechanisms was not investigated.



Wind gusts depending on wind speed using synoptic stations data over European part of Russia

Wind gusts formation mechanisms and methods to estimate them

Mechanical turbulence

TKE usage

Assuming TKE (turbulent kinetic energy) is wind speed dispersion measure:

$$Wg_{estimate} = U + 3\sqrt{q}$$

Assuming model estimates maximum value of TKE (Born, 2012):

$$Wg_{estimate} = U + \sqrt{2q}$$

More complex distributions (Schreur, 2008)

Convection

Air particle reflection from upper levels

Method by (Brasseur, 2001) :

$$Wg_{estimate} = \max[\sqrt{U^2(z_p) + V_p^2(z_p)}]$$

for z_p satisfying (1)

$$\frac{1}{z_p}\int_0^{z_p} E(z)\,dz \geq \int_0^{z_p} g\frac{\Delta\theta_v(z)}{\Theta_v(z)}\,dz, \qquad (1)$$

Speed from immediately above the boundary layer (Bradbury,1994)

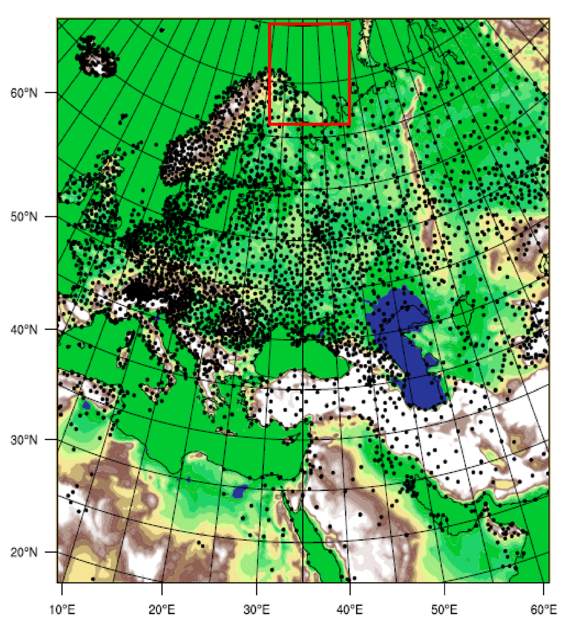
Inclusion of vertical motion (Nakamura, 1996)

Hybrid method

Convection—air particle deflection—Brasseur method
Mechanical turbulence—TKE method

$$wge = \begin{cases} U + 3\sqrt{q}, & Ri > 0 \\ \max[U(z_p)], & Ri \leq 0 \end{cases} \quad \text{where } z_p\text{:} \quad \frac{1}{z_p}\int_0^{z_p} q(z)dz \geq \int_0^{z_p} g\frac{\Delta\theta_v(z)}{\Theta_v(z)}dz$$

Forecast model and measurements



Model domain (18 km), domain 6 km in red and synoptic stations

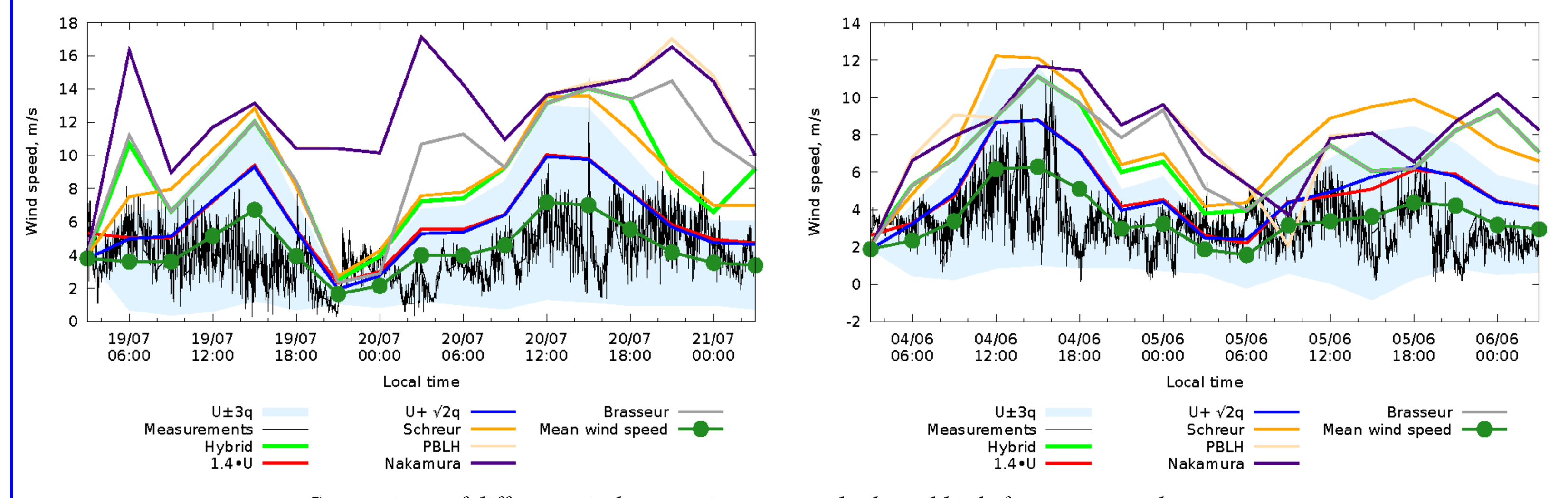
Gusts were calculated using WRF-ARW V3.8.1 model forecasts covering Europe with 18 km resolution. Some experiment were done using inner domain covering Murmansk region with 6 km resolution. As observations two data sets were used:

- Synoptic stations reports from more then 2000 points
- Ultrasonic thermoanemometers USA-1, placed in Lomonosov Moscow State University, Moscow, Russia, with measurement frequency: 50 Hz

Area was divided into cells 1 ° x1 ° in latitude and longitude. The value in the cell was the maximum value of gusts from all stations that got into it, and from all nodes of the computational model grid that got into it.

Observation site in Moscow

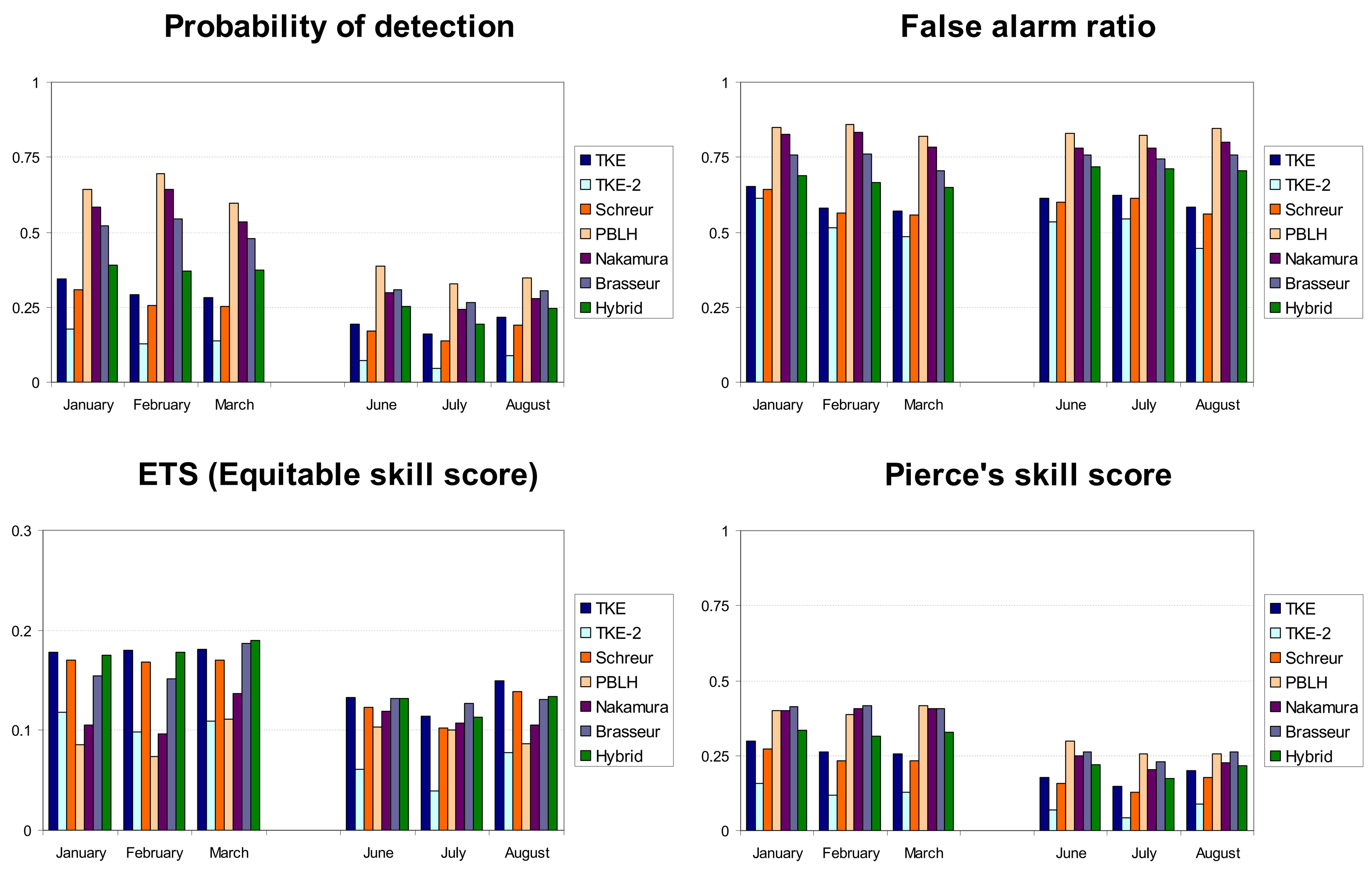
Examples of wind gusts forecast



Comparison of different wind gust estimation methods and high-frequency wind measurements

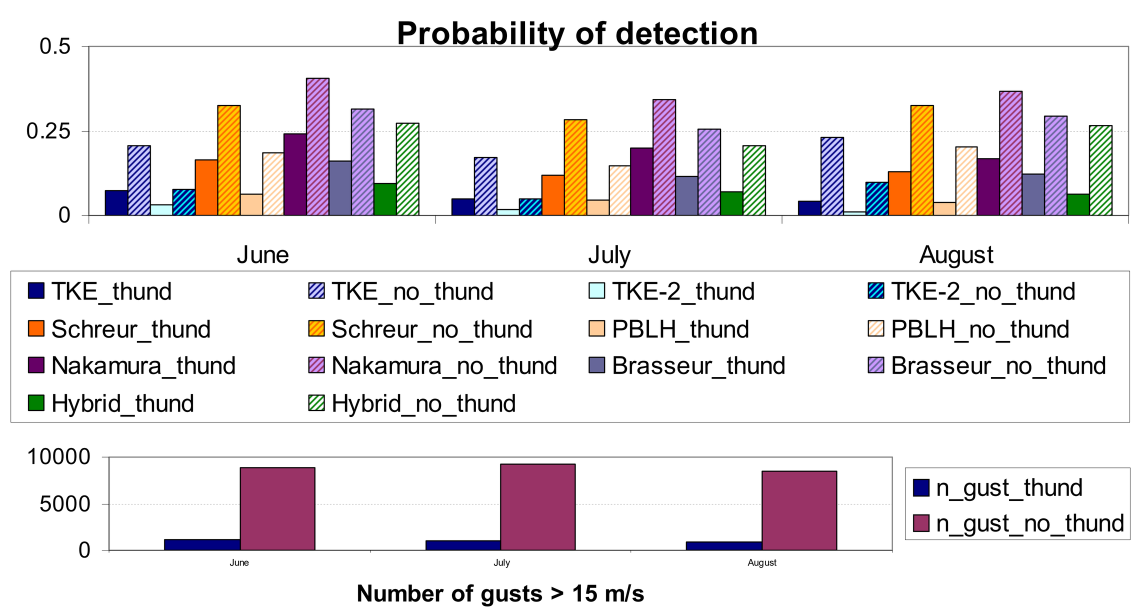
Most methods capture sole gust, but overestimate gusts major part of time

Different methods scores



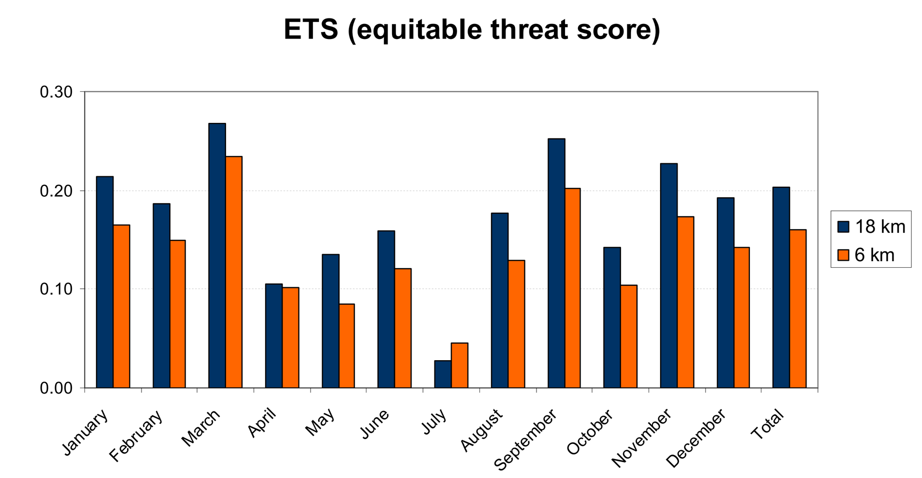
None of the existing methods provides high performance in every skill score. Despite the fact that the hybrid method does not show the best probability, it seems to be optimal from combination of all scores and gives stable results during the entire annual course.

Prediction of Gusts of different origin



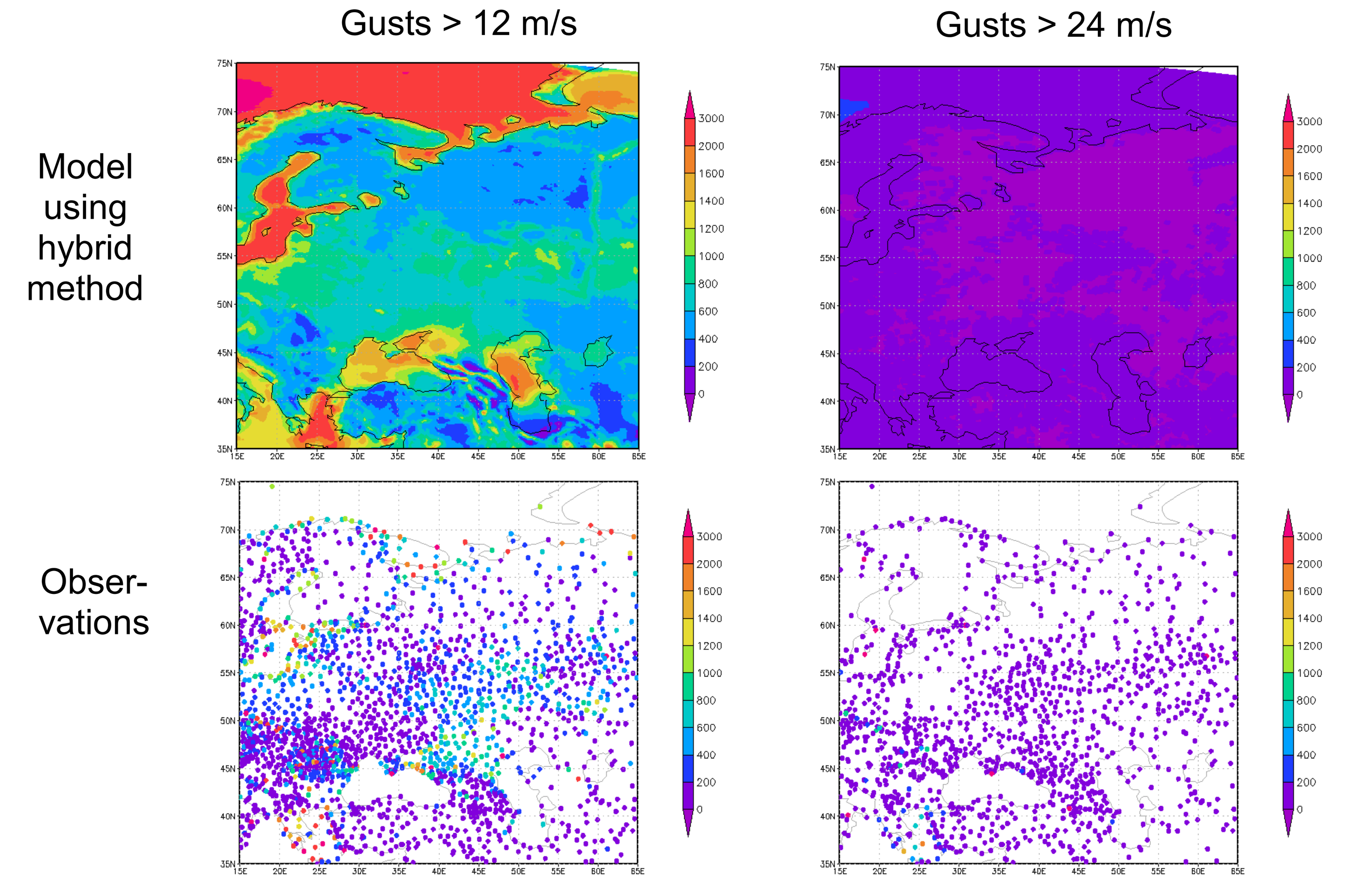
We divide all gust into two groups depending on whether thunderstorm was observed at the same station. Thunderstorms are characterized by deep convection and often associated with strong convective gusts. Gusts associated with mechanical turbulence are better reproduced by all methods.

Influence of model resolution



Gusts in summer are most often associated with the development of convection, which can not be solved by a numerical model with a step of 18 km. Contrary to expectations, an increase in the model resolution from 18 to 6 km did not improve the quality of the wind gusts forecast: the number of predicted phenomena increased, but the number of false alarms raised greatly too.

Gust frequency



Number of gusts over 12 and 24 m/s for three years (2014-2016) based on model using hybrid method and on each synoptic station

Major part of small gusts (12-18 m/s) are along seashore, strong gusts (20 m/s and more) are connected with individual station location characteristics. Wind gusts are generally encountered more often in the model results than in observations. Main features of the frequency distribution are reproduced across the territory. There are notable differences in the territory of the Caucasus, which may be due to topography effects.

Conclusions

- Seven methods for wind gust estimation were realized using WRF-ARW model output. New hybrid method was proposed. It gives more stable results throughout a year comparing to other methods.
- Increase in the model resolution results growth in the number of predicted phenomena, but also raising of false alarms
- Gusts associated with mechanical turbulence are the easiest to reproduce.

The conducted research shows the necessity of further studying the mechanisms of formation and methods for forecasting of wind gusts.

Acknowledgements

The authors acknowledge the support of the Russian Foundation for Basic Research according to the research projects №16-05-00822, 16-05-00704, 18-35-00044.