Analysis of different wind gust forecast approaches

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Approaches to estimate wind gusts

Statistical:

- Distribution at the location

+ accurate

+ can be used for constractions loads calculations

- need of long term observations

- limited usage for forecast

Dynamic-statistical:

- Predictors of extreme events

+ can be used for forecasts

- need of long term observations

- predictors≠events

Dynamical:

- Using model forecasts calculate constant gust factor
- Stability dependent gust factor
- Turbulence estimation
- Reflection from upper layers
- …..

+ can be used for forecasts and uses model products

+ physicaly based

- not always good accuracy

Methods for wind gust estimations

1 Gust factor

$$wge = k \cdot U$$

k depends on surface roughness

2 Brasseur

$$wge = \max[U(z_p)]$$

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

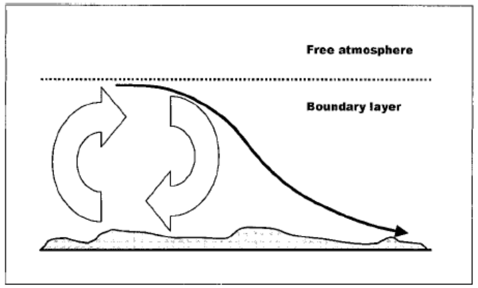


FIG. 1. Proposed mechanism explaining gusts observed at the surface: turbulent eddies are triggering the deflection of air parcels flowing in the boundary layer downward to the surface.

Gust = wind +dispersion

$$wge = U + \alpha\sigma$$
$$\alpha = 3$$

3 $$wge = U + \alpha \cdot 2.4u_*; \quad \alpha = 3$$

4 $$wge = U + 3\sigma = U + 3\sqrt{q}$$

5 q represent maximum wind deviation

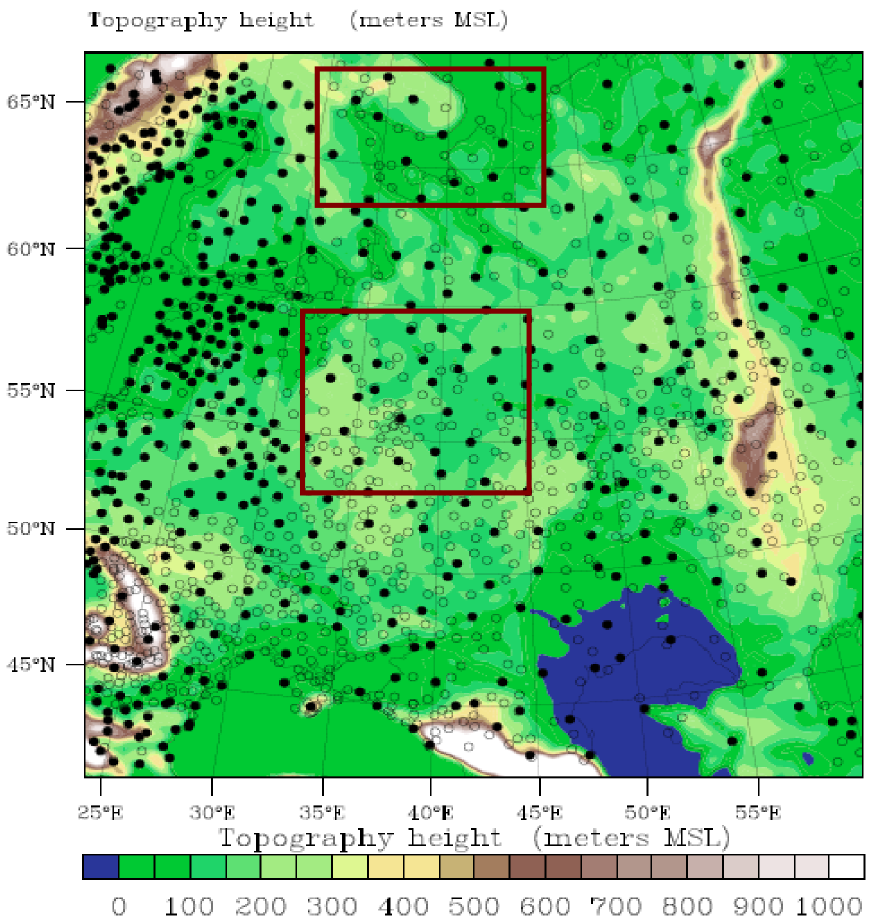
$$wge = U + \sqrt{2q}$$

Brasseur, O., 2001: Development and Application of a Physical Approach to Estimating Wind Gusts. *Mon. Wea. Rev.*, **129, 5–25**
K. Born et al., 2012: Wind gust estimation for Mid-European winter storms: towards a probabilistic view. Tellus A 2012, 64, 17471, DOI: 10.3402/tellusa.v64i0.17471
Schulz, J.-P. 2008. Revision of the turbulent gust diagnostics in the COSMO model. COSMO Newslett. 8, 17–22. Online at: www.cosmo-model.org

Observation data

- Synoptic stations reports
- Ultrasonic thermoanemometers USA-1, placed in Lomonosov Moscow State University, Moscow, Russia, with measurement frequancy: 50 Hz
- Microwave temperature profiler MTP-5

Forecast model



WRF-ARW

•Horizontal resolution:
18-6-2 km

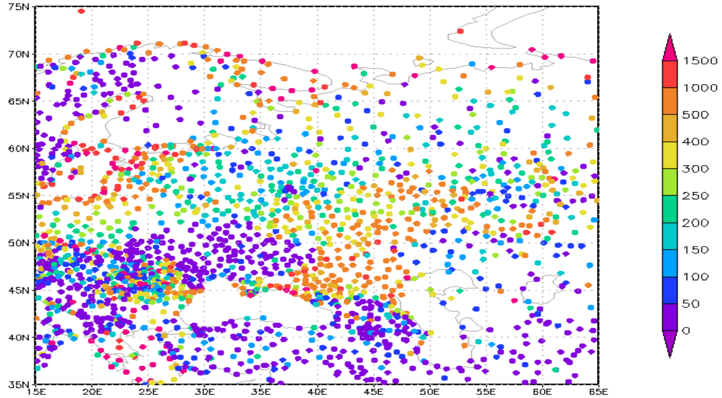
•Vertical resolution:
41 vertical levels

•Input data:
GFS 0.5 deg input forecasts

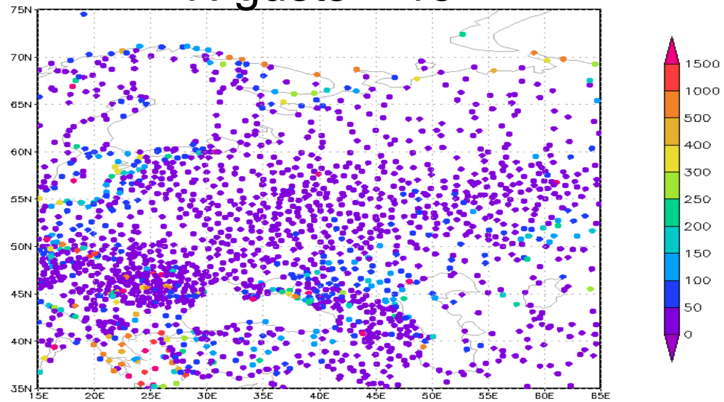
•Parametrization:
✓RRTM radiation,
✓MYNN boundary layer,
✓Noah sflay,
✓varying convection

Gust occurrence over European part of Russia

N gusts ≥ 12

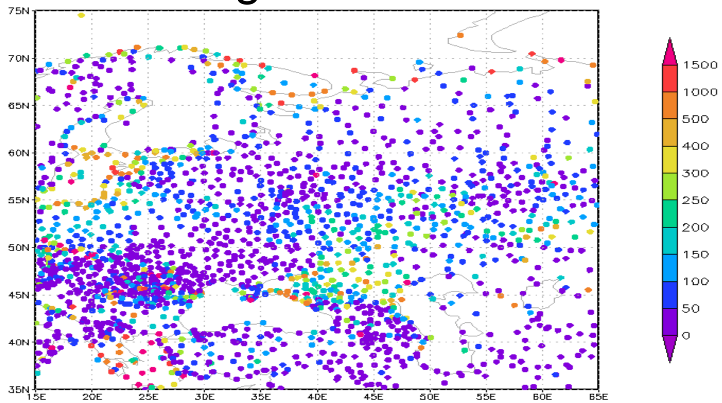


N gusts ≥ 18

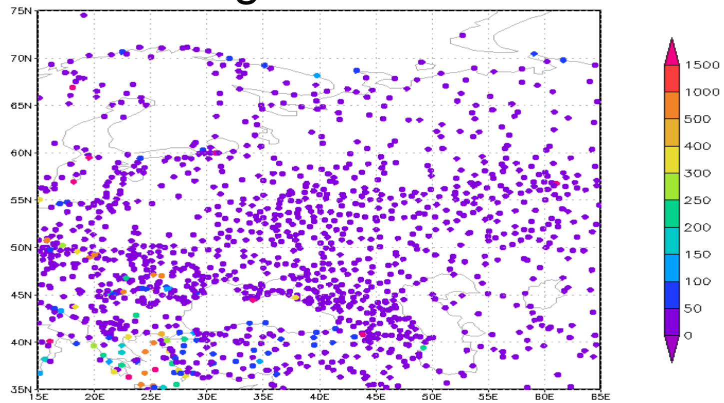


GrADS: COLA/IGES

N gusts ≥ 15



N gusts ≥ 24



GrADS: COLA/IGES

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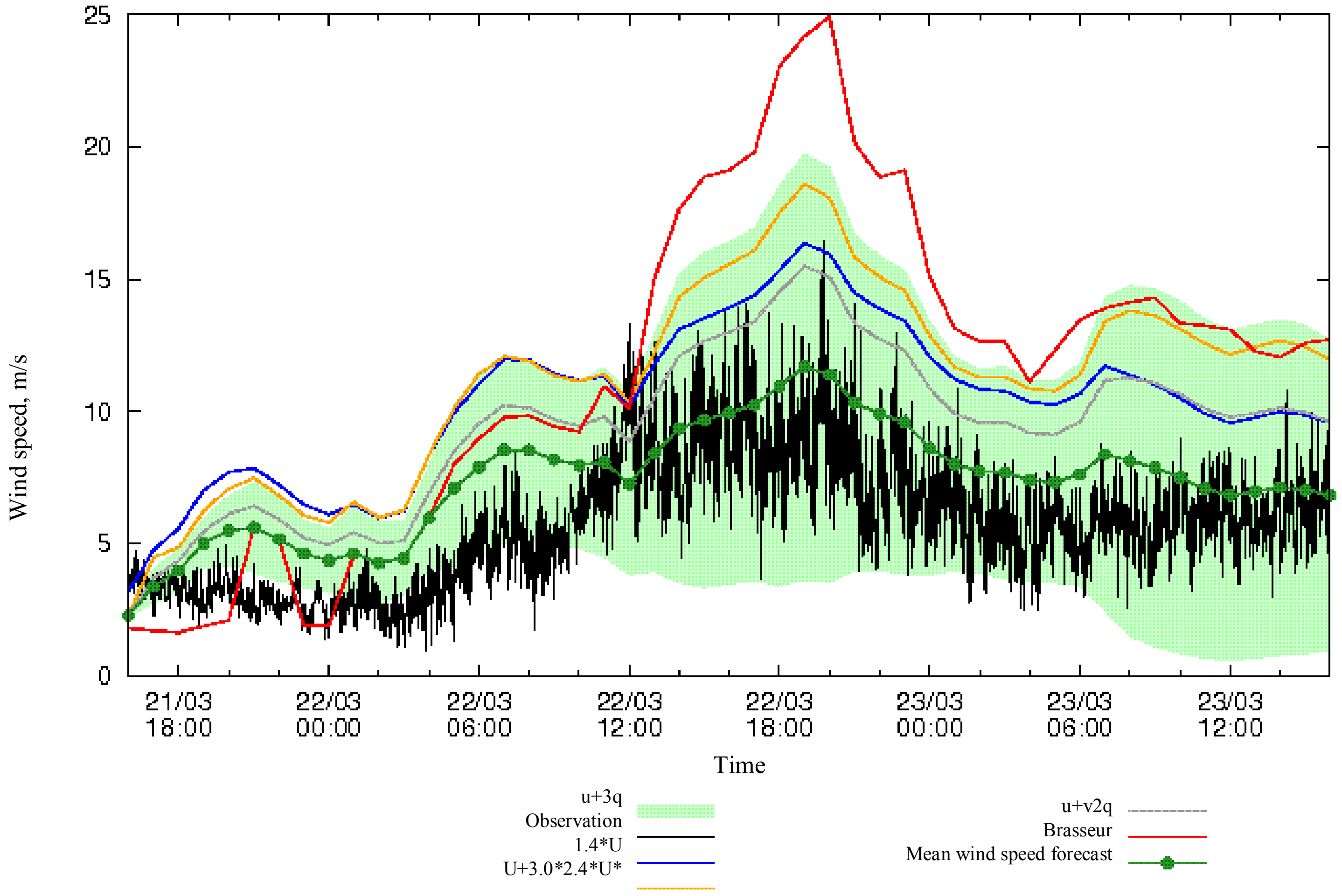
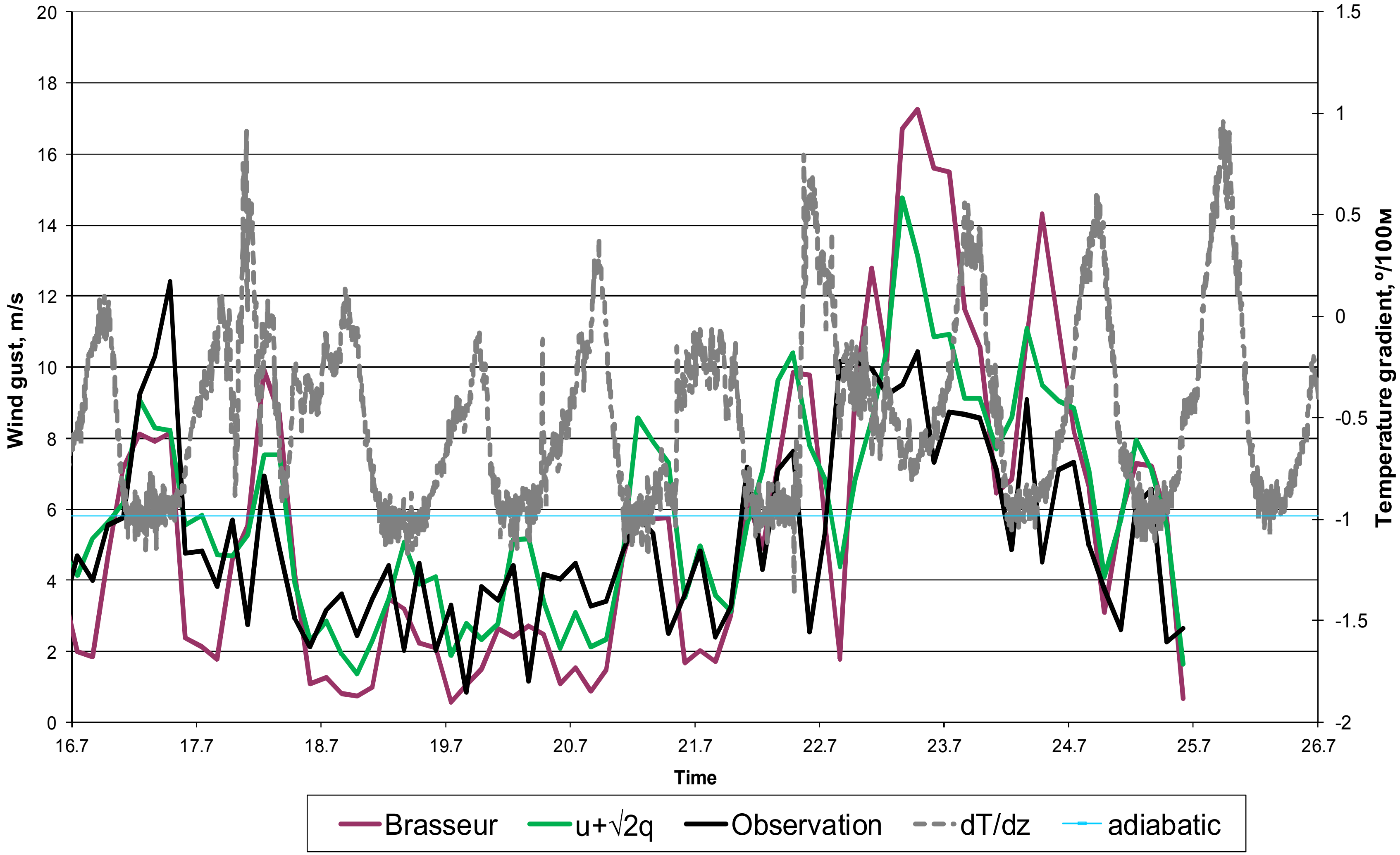
Wind gusts using different methods



Accuracy of wind gust estimations using high-frequency observations

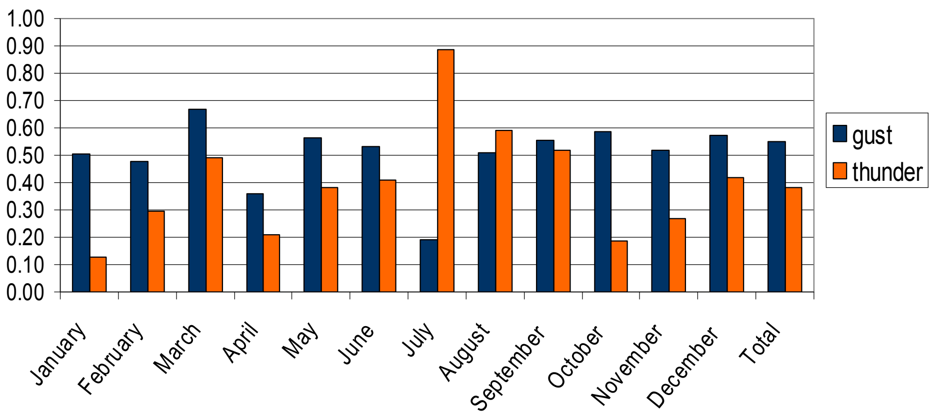
		Wind speed	Wind gust				
			1.4*u	u+3.0*2.4U*	Brasseur	u+3q	u+√2q
BIAS	April	0.82	0.86	2.20	1.02	2.88	0.91
	July	0.53	0.50	1.94	-0.06	2.72	0.77
	October	0.76	0.72	2.22	1.87	2.83	0.73
ABIAS	April	1.46	1.89	2.64	2.45	3.21	1.77
	July	1.31	1.74	2.46	2.13	3.15	1.68
	October	1.43	1.73	2.59	2.73	3.14	1.62
Relative	April	0.59	0.48	0.64	0.54	0.77	0.45
	July	0.55	0.47	0.65	0.51	0.82	0.46
	October	0.49	0.38	0.58	0.53	0.69	0.37
R	April	0.63	0.68	0.73	0.71	0.72	0.72
	July	0.57	0.59	0.65	0.60	0.64	0.65
	October	0.61	0.71	0.72	0.72	0.72	0.72

Dependence on stability

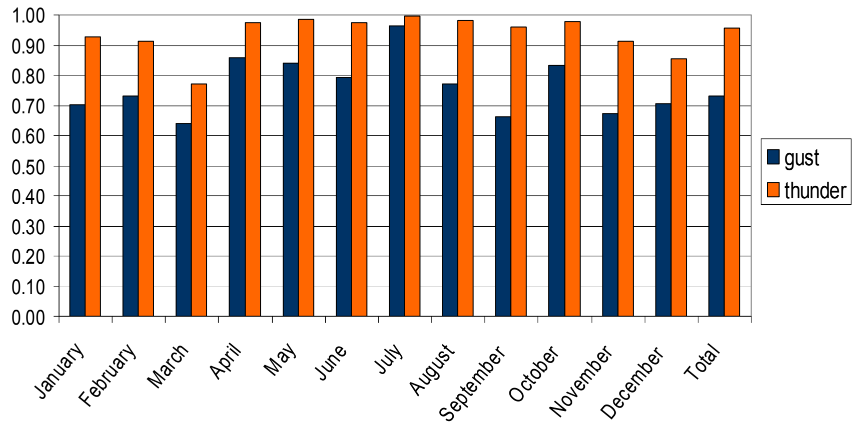


Comparison with thunderstorm forecasts

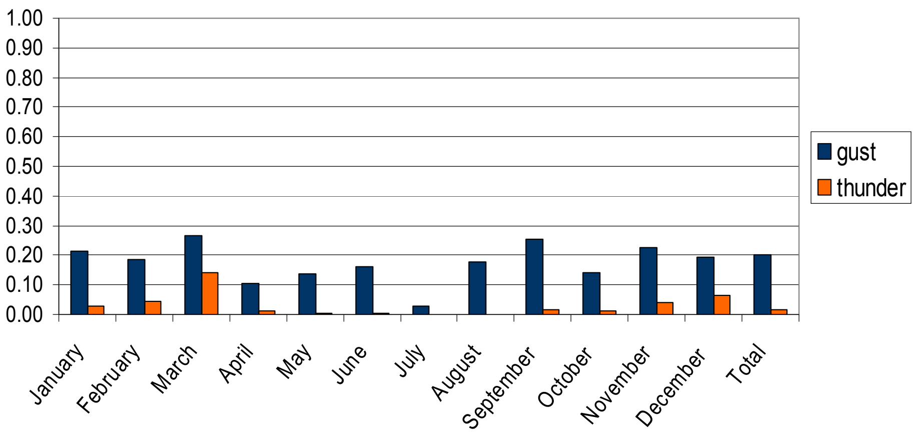
Probability of detection



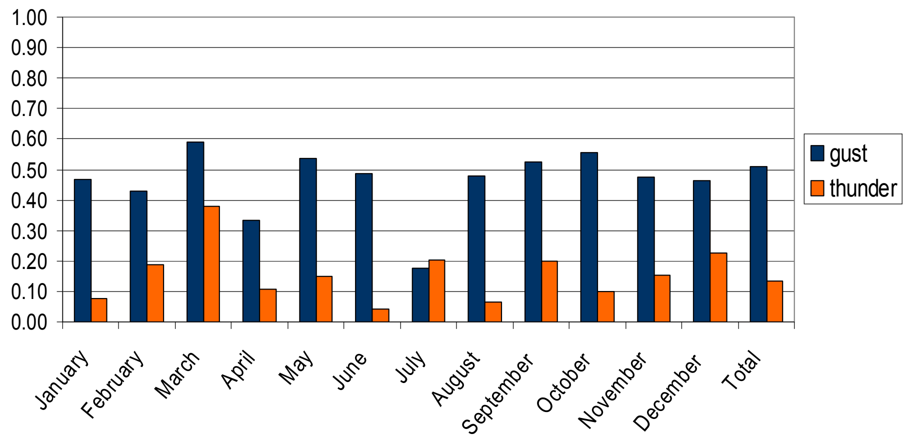
False alarm ratio



ETS (equitable threat score)



PSS (Peirce skill score)



Murmansk region, gust>15m/s, 2016

Hybrid method

- Summer—better results Brasseur method (convection)
- Autumn—better results TKE method (mechanical turbulence)

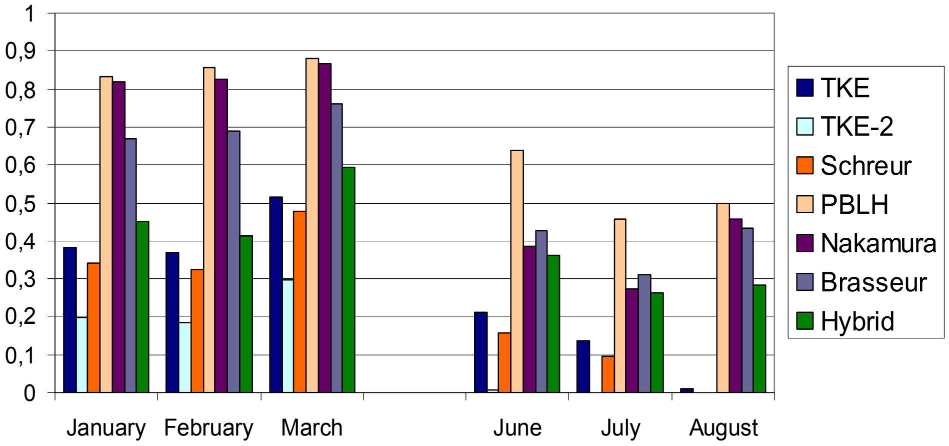
We propose a hybrid method. Gust calculation method depends on stability type of atmosphere:

$$wge = \begin{cases} U + 3\sqrt{q}, & Ri > 0 \\ \max[u(z_p)], & Ri \le 0 \end{cases}$$

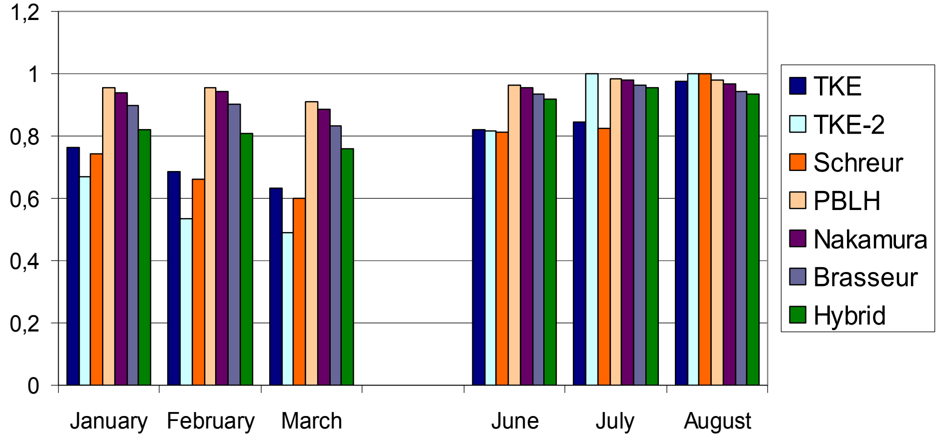
$$\frac{1}{z_p}\int_0^{z_p} q(z)dz \ge \int_0^{z_p} g\frac{\Delta\theta_v(z)}{\Theta_v(z)}dz$$

Different methods scores

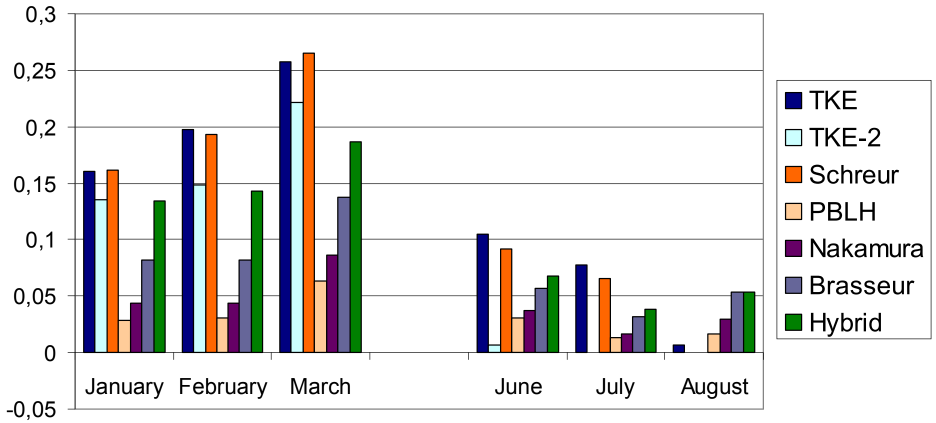
Probability of detection



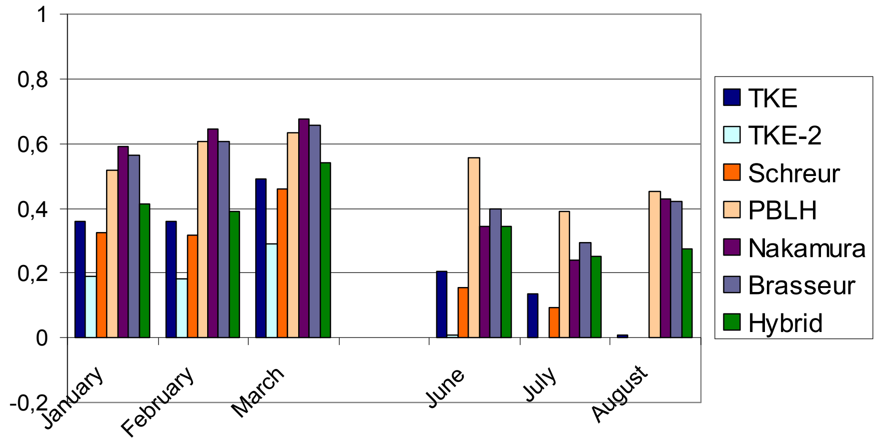
False alarm ratio



ETS (Equitable threat score)



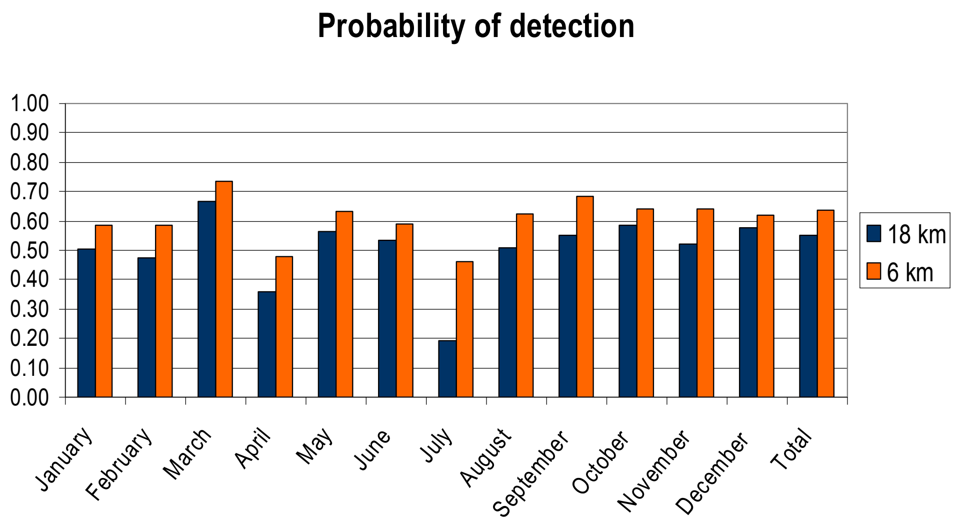
Peirce's skill score

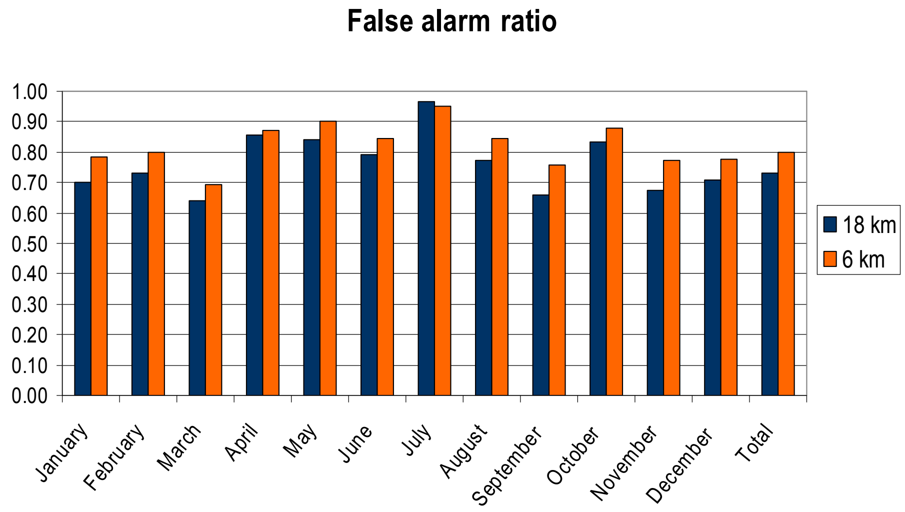


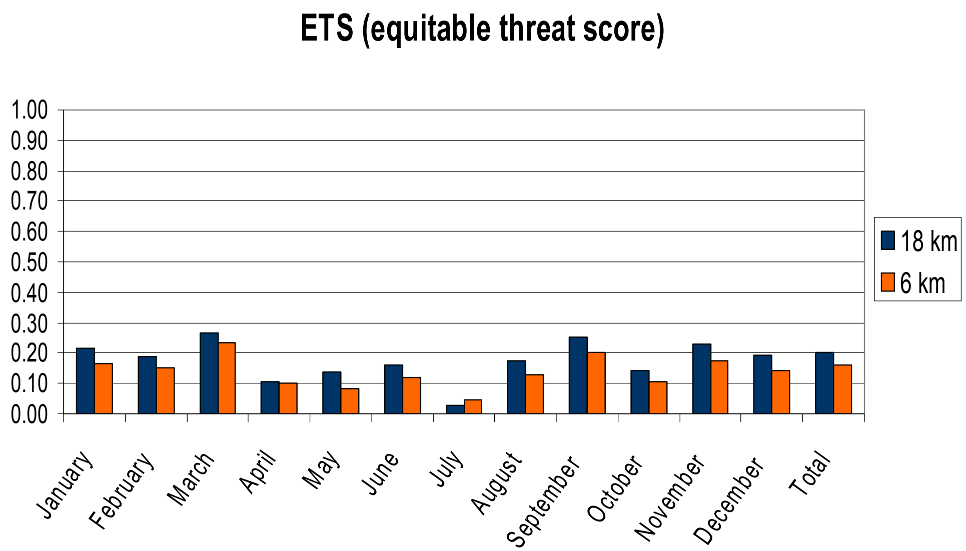
Influence of convection parametrization

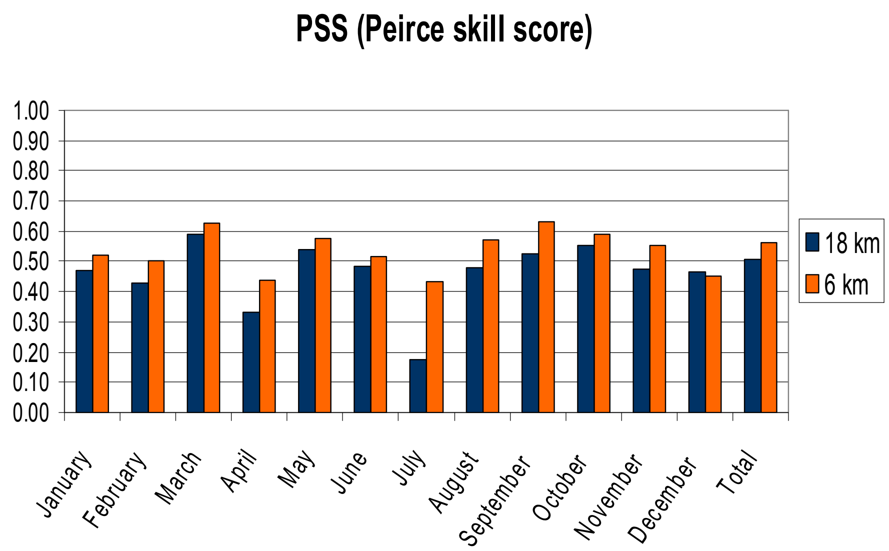
Convection parametrization	predicted gusts	unpredicted gusts	Predicted but absent gusts	predicted gusts absence	overall accuracy	predictability	Mean wind vector error
Kain-Fritsch	77	67	189	2905	92.1	53.5	2.6
Betts-Miller-Janjic	74	70	160	2934	92.9	51.4	2.3
Grell-Freitas	66	78	152	2942	92.9	45.8	2.6
Zhang-McFarlane	28	116	36	3058	95.3	19.4	3.4
Tiedtke	78	66	194	2900	92.0	54.2	2.7
Arakawa-Schubert	58	86	139	2955	93.1	40.3	2.4

Influence of model resolution



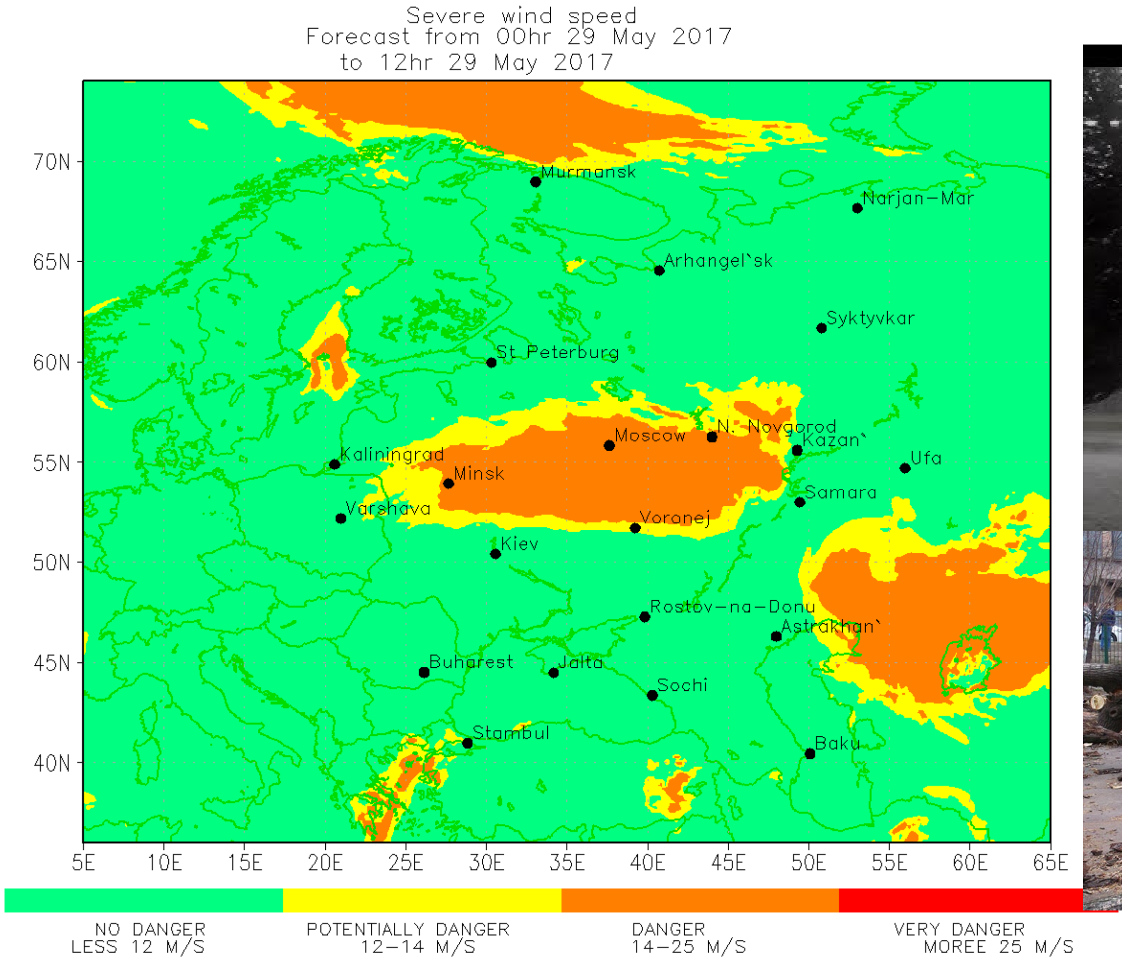






Murmansk region, gust>15m/s, 2016

Storm 29 May 2017 in Moscow



Conclusions

- Different gust estimation methods were applied to WRF-ARW forecasts and evaluated showing none of them is “good”
- Methods used for thunderstorm prediction (deep convection diagnostics) doesn’t suit for gust prediction
- New hybrid method was proposed that gives POD around 0.5 throughout a year
- Increasing model resolution results more gusts and more false alarms
- Gusts forecasts skills are more sensitive to model configuration (parametrization) then wind speed solely

Thank you for the attention!

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