# Mesoscale high-resolution modeling of extreme wind velocities over the western water areas of Russian Arctic

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# OUTLINE

- *Goal*
- *Methods and observational background*
- *COSMO-CLM model and experiments description*
- *Modeling results*
- *Conclusion and perspectives*

**GOAL** - investigation of genesis and modeling extreme wind speeds over the western sector of Russian Arctic.

# METHODS data

Observational data analysis of extreme wind speeds has shown <u>many interesting features of the describing Weibull distribution function</u>.

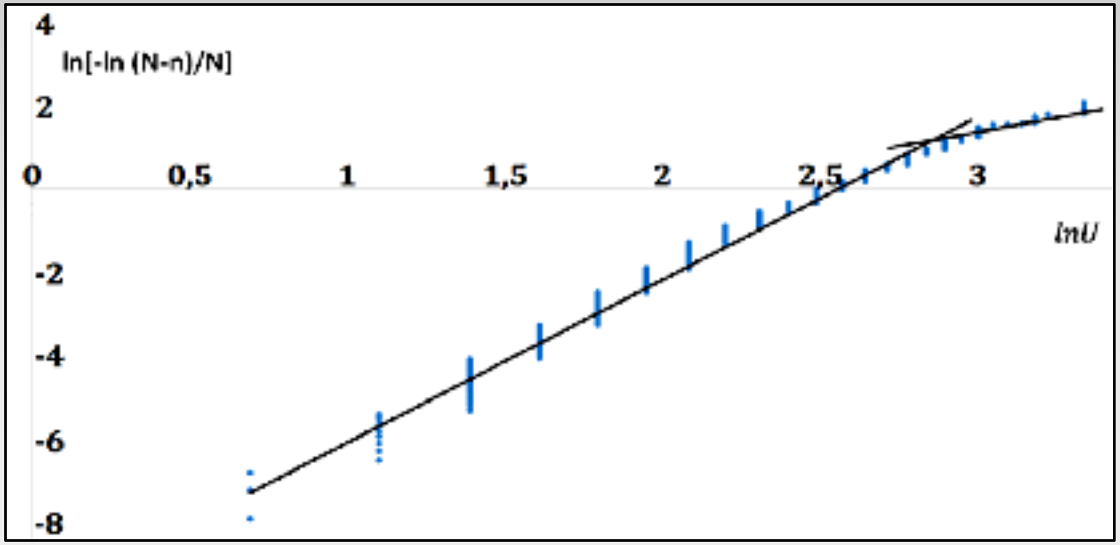



Fig. Example of empirical wind speed pdf on **Marresale** station (1936 - 2013), on a *Weibull coordinate grid* ( $\ln\left[-\ln\frac{N-n}{N}\right], \ln U$ )

It seems, extremes are belonging to **different statistical populations.**

These two sets of extremes were named as "black swans" (BS) and "dragons" (D), following to accepted terminology from *[Taleb, 2010]* and *[Sornette, 2009]*

**References:**

1. Kislov A., Matveeva T., Platonov V. Wind speed extremes in Arctic area. (In Russian) Fundamental and applied climatology, 2015, vol. 2, pp. 63 – 80.
2. N.N. Taleb. The black swan: the impact of the highly improbable fragility. New York, Random House, 300 p., 2010
3. Sornette D. Dragon-Kings, Black Swans and the prediction of crises. IJTSE, №2, pp. 1 – 18, 2009

**Examples of U(0.99) quantiles for cold season for many Arctic stations**

| Station | "BS" | "D" | "BS"/"D" |
|---|---|---|---|
| **Teriberka** | 23 | 29 | 0.83 |
| **Marresale** | 19 | 22 | 0.86 |
| **Malye Karmakuly** | 28 | 40 | 0.70 |

# METHODS model

In [Kislov et al., 2015] it was shown, that extremes as "**BS's**" and "**D's**" couldn't reproduced by global climate models (e.g., INM-CM 4.0). Therefore, its investigation is reasonable using *mesoscale models* only.

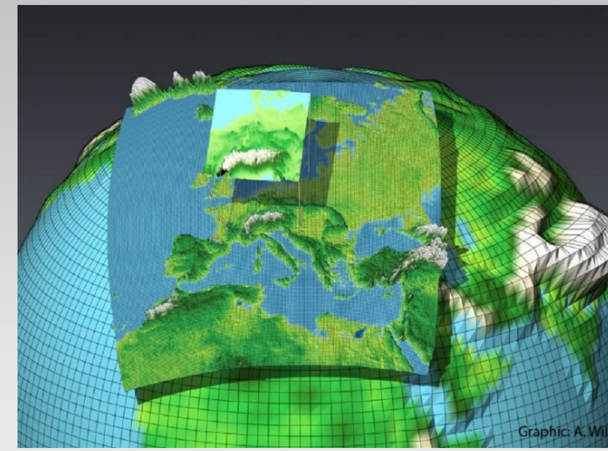
Simulation of extreme winds over the western Arctic basin was performed using **COSMO-CLM** regional model.


It is climate version of the well-known non-hydrostatic regional atmospheric model COSMO developed by German Weather Service (DWD) and CLM-Community (http://www.clm-community.eu/)

# METHODS experiments

**COSMO-CLM model configuration.**

- COSMO-CLM model, version 5.0 (from 09.2015)
- Rotational grid with tilted pole
- Arakawa C-grid, Lorenz vertical grid staggering
- Runge-Kutta integration scheme with 5$^{th}$ advection order
- 40 vertical levels (height based hybrid Gal-Chen coordinate)
- Prognostic TKE-based scheme for turbulence




**Detailed surface information (soil type, albedo, surface height, roughness length etc.)**
**External parameters (EXTPAR tool)**

**Initial and boundary conditions – from global driving models (netCDF-4):**
**- Reanalysis** ERA-Interim

**Nonhydrostatic regional climate model COSMO-CLM**


**Computational resource: MSU Supercomputer "Lomonosov"**


Most applicable resolutions:

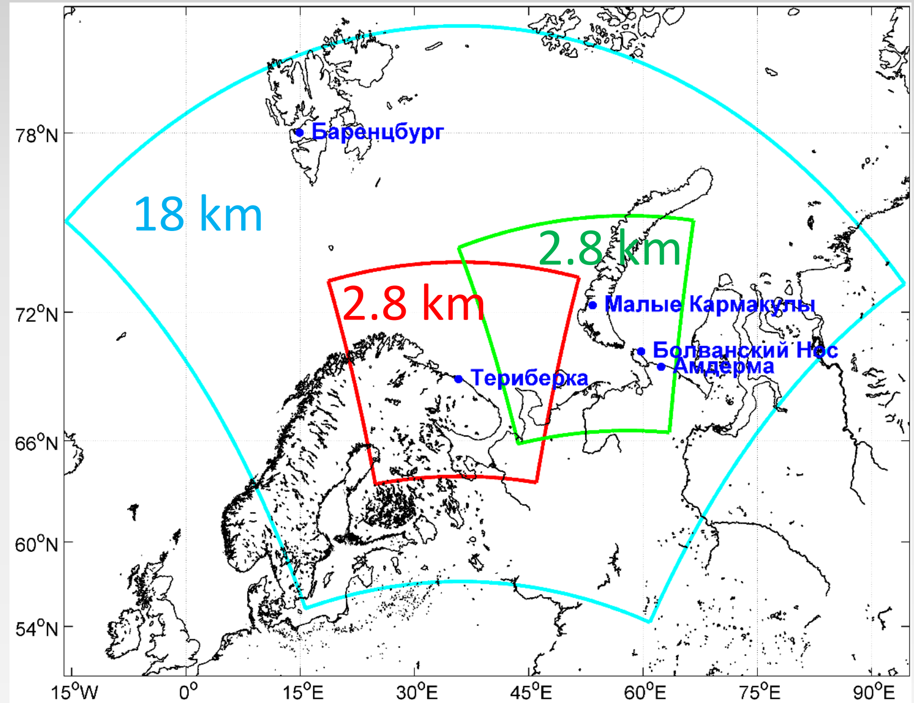
| | | | | |
|---|---|---|---|---|
| $0.44^0 \sim 48$ km | $0.165^0 \sim 18.3$ km | | $0.12^0 \sim 12$ km | $0.025^0 \sim 2.8$ km |
| $0.22^0 \sim 24$ km | $0.15^0 \sim 16$ km | $0.0625^0 \sim 7$ km | $0.02^0 \sim 2.2$ km | $0.01^0 \sim 1.1$ km |

# METHODS experiments

| Parameters of experiments | Two model domains using downscaling | |
|---|---|---|
| Experiment's duration | Approx. 7 days | |
| Horizontal resolution | $0.165^0$ (~18 km) | $0.025^0$ (~2.8 km) |
| Domain size (number of points) | 164*146*40 | 380*400*40<br>326*364*40 |
| Time step, s | 100 | 40 |
| Initial and boundary conditions | ERA-Interim (~$0.75^0$) | COSMO-CLM 18 km |

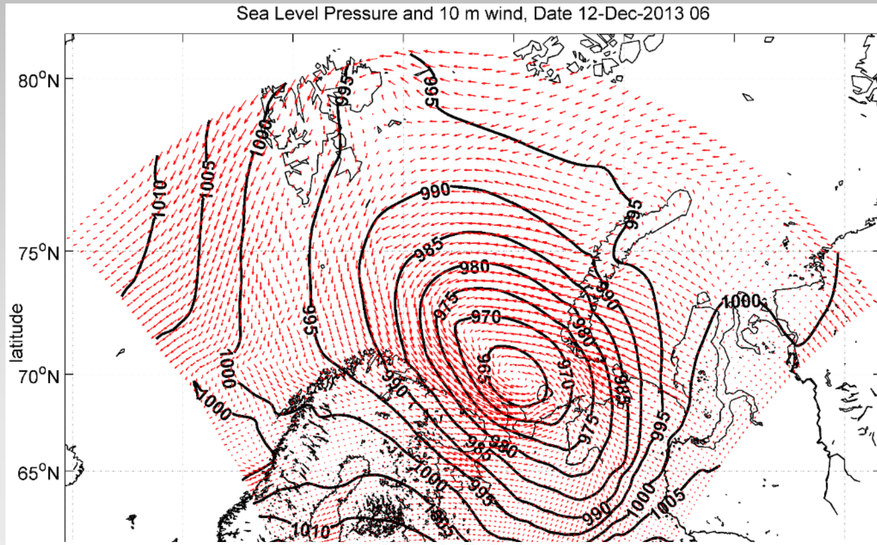
**Dates of extreme wind speeds for experiments**

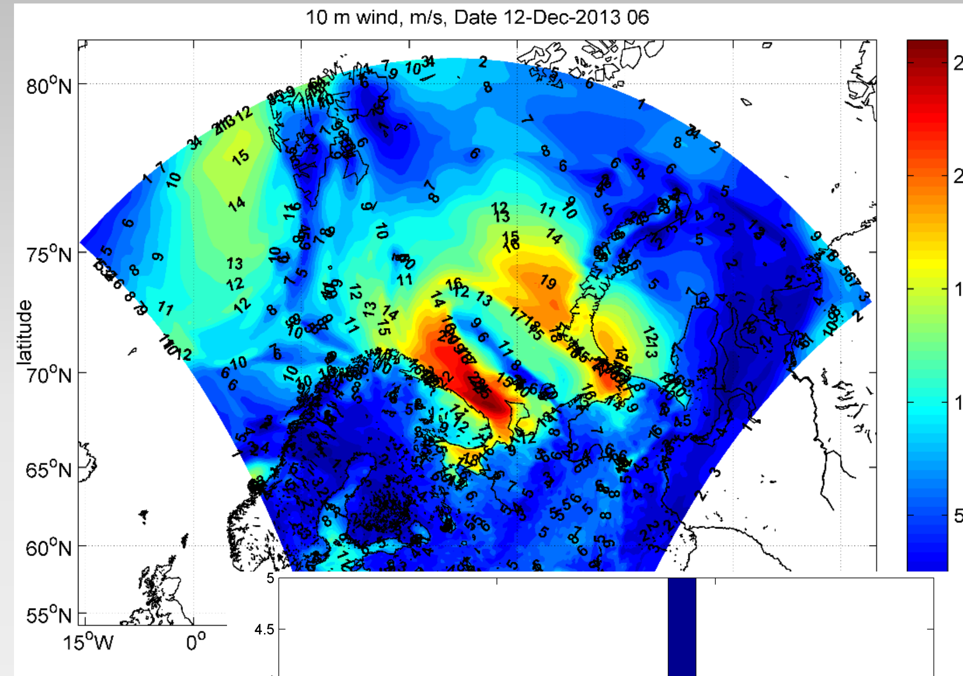
| *"Black swans"* | *"Dragons"* |
|---|---|
| 15.12.1997 | 17.12.1997 |
| 29–30.10.2000 | 05.02.2003 |
| 26.01.2002 | 22.11.2010 |
| 28.12.2003 | 12.12.2013 |
| 11.01.2010 | |

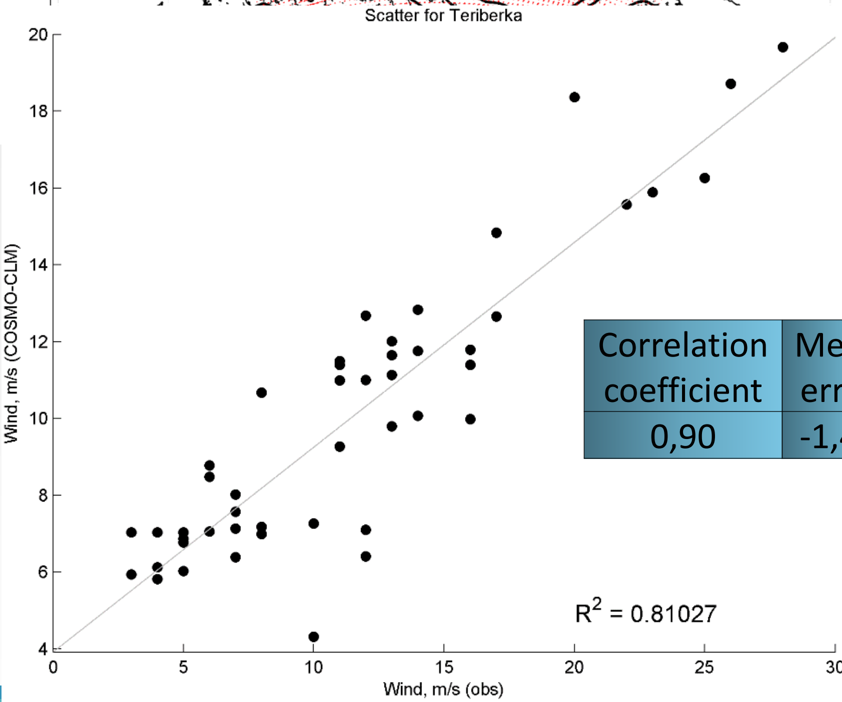



**Model domains and stations (using downscaling)**

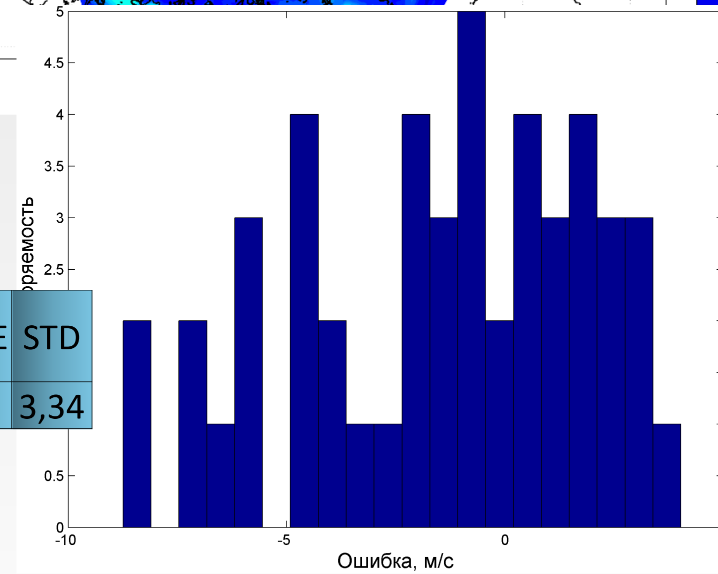
# RESULTS 12.12.2013 18 km



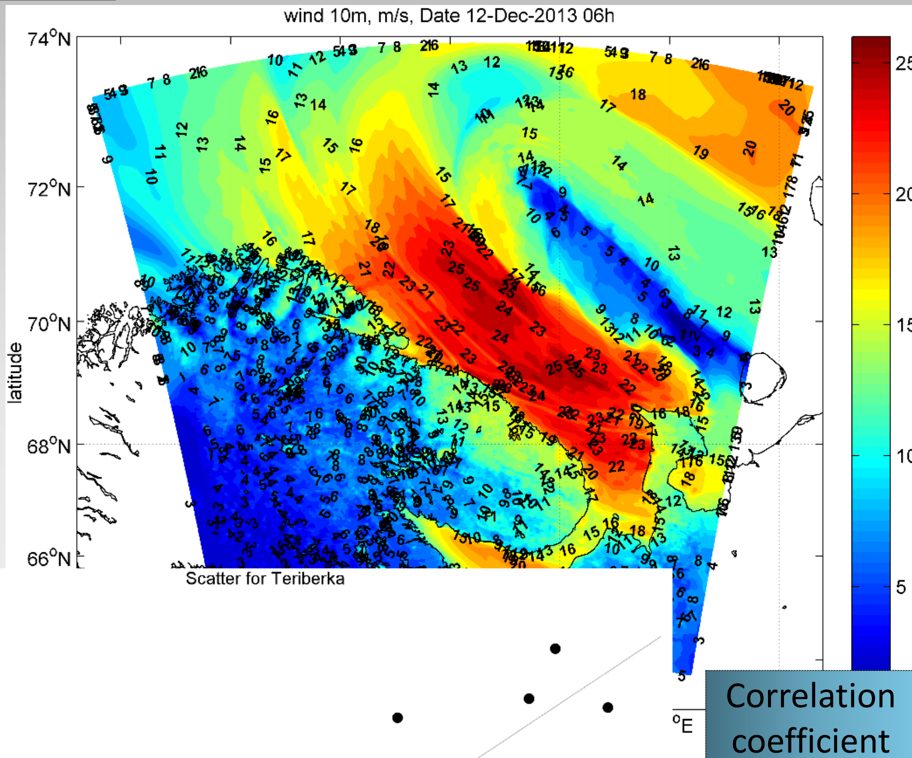



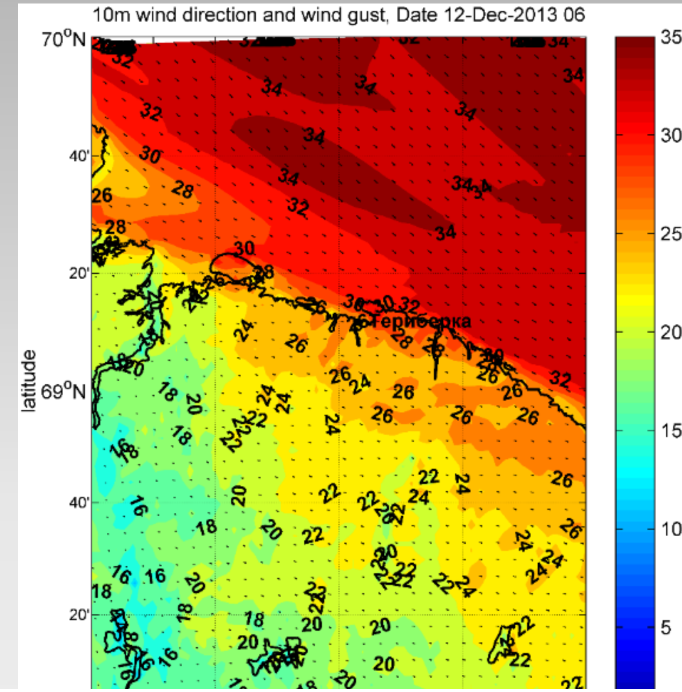

| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,90 | -1,49 | -1,00 | 3,63 | 3,34 |

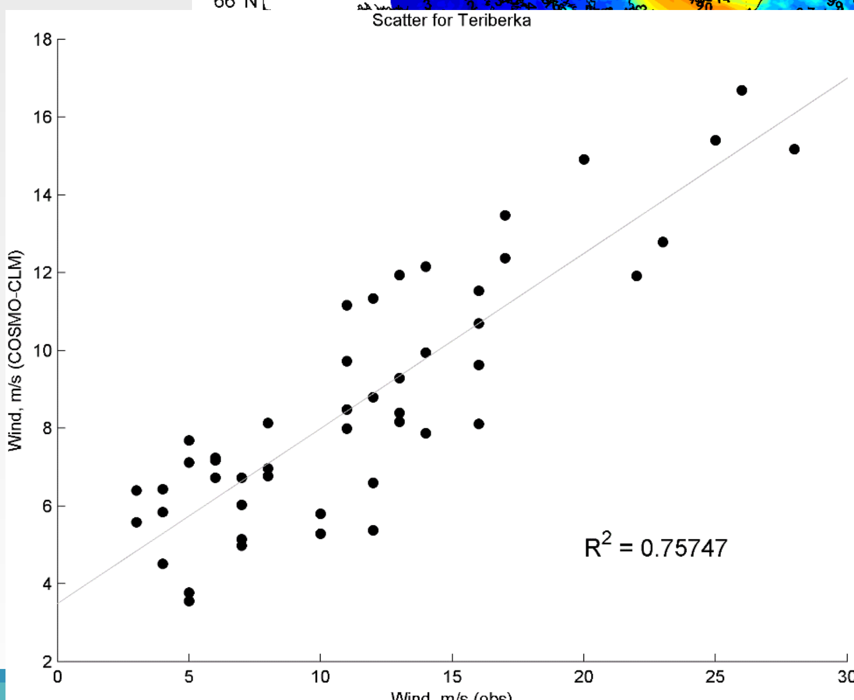


# RESULTS

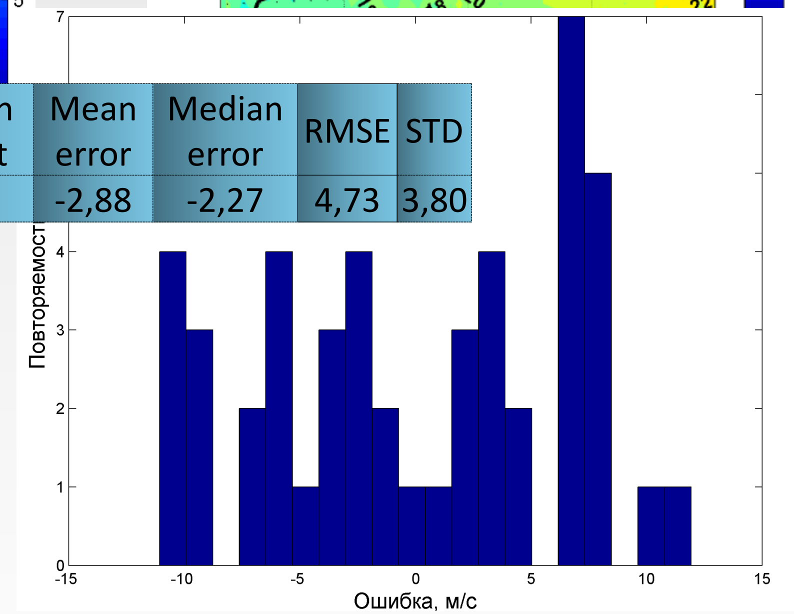
12.12.2013 2,8 km



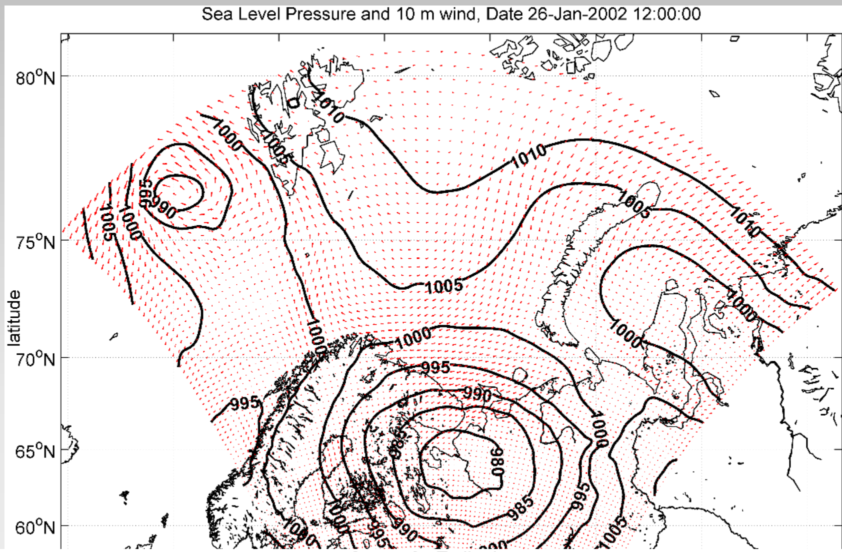



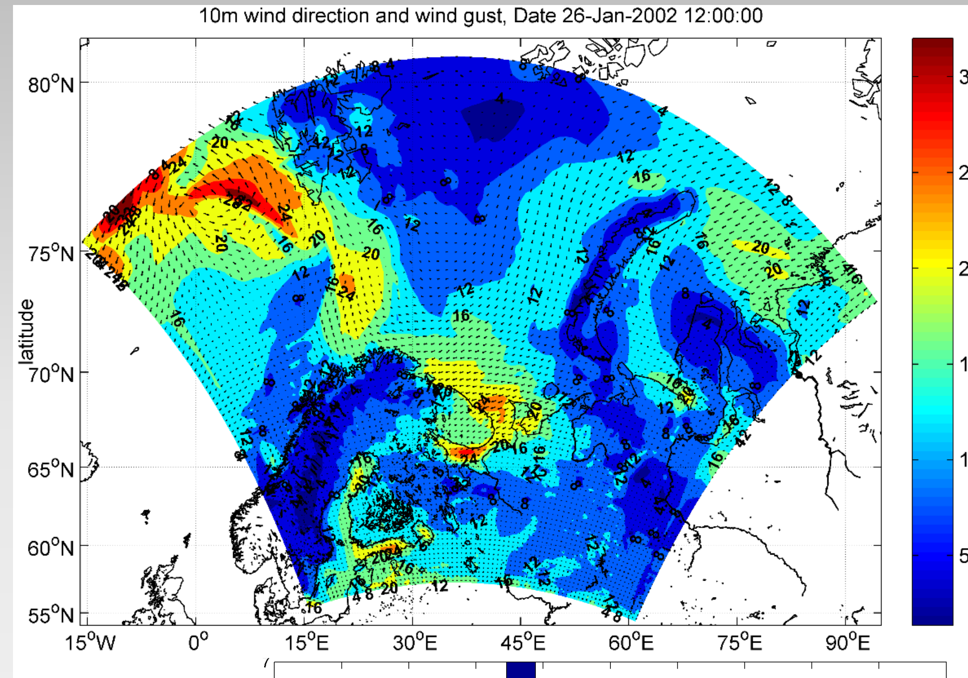

| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,87 | -2,88 | -2,27 | 4,73 | 3,80 |

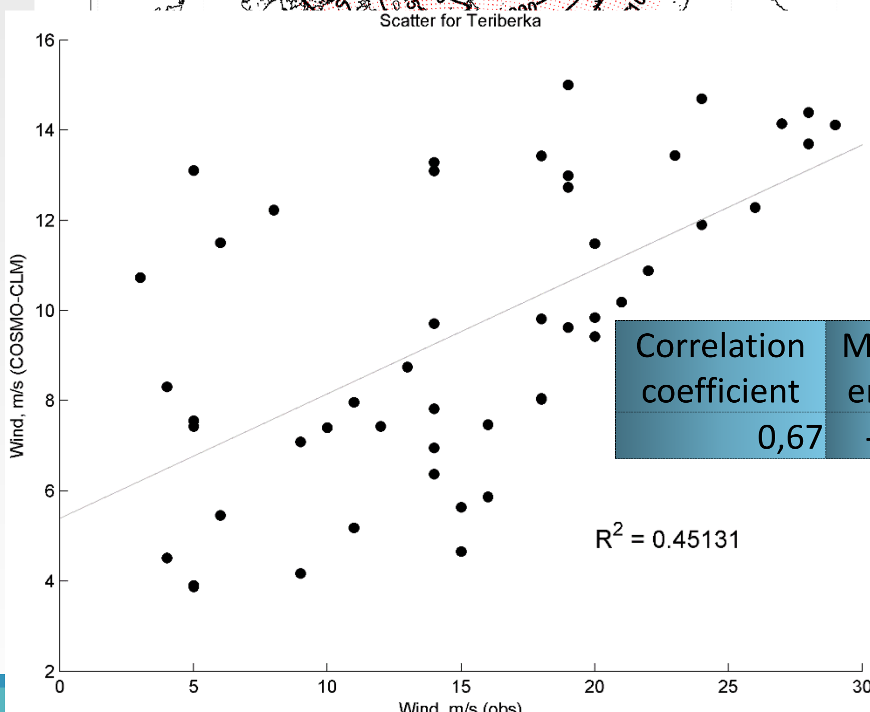


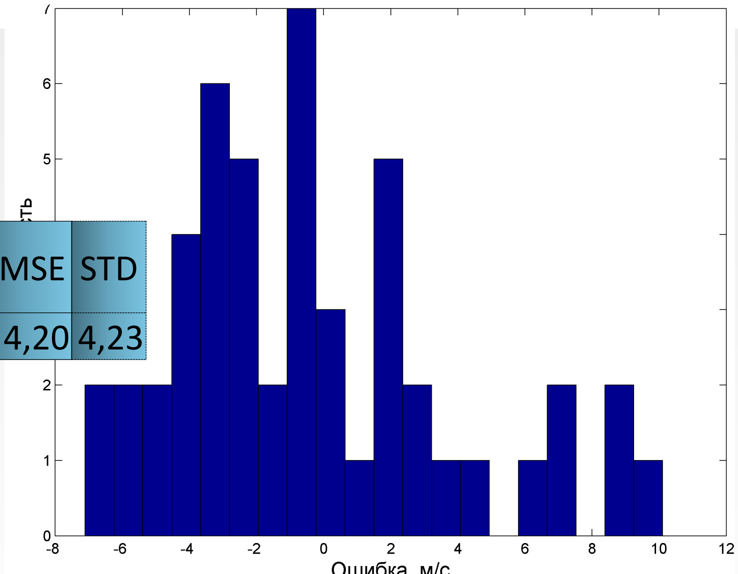
# RESULTS

## 26.01.2002 18 km



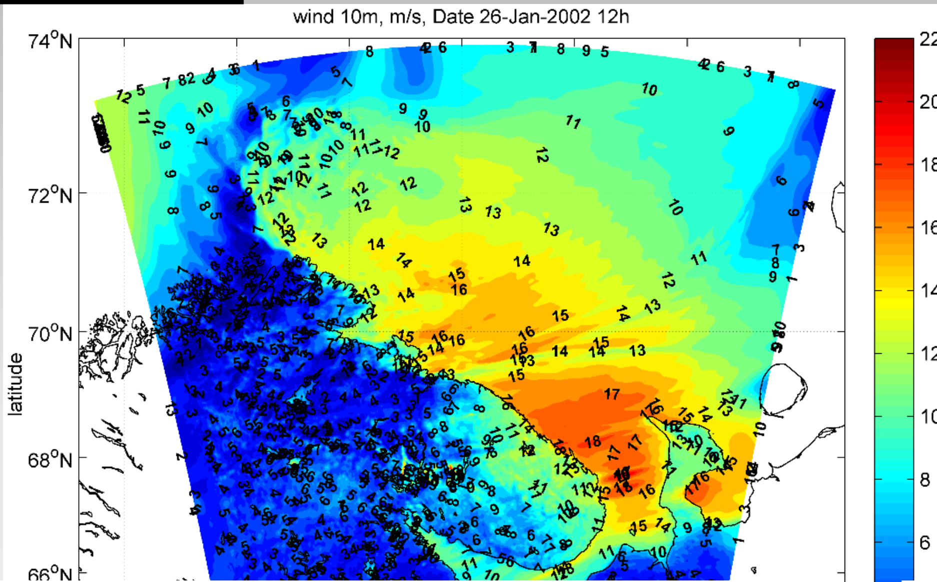



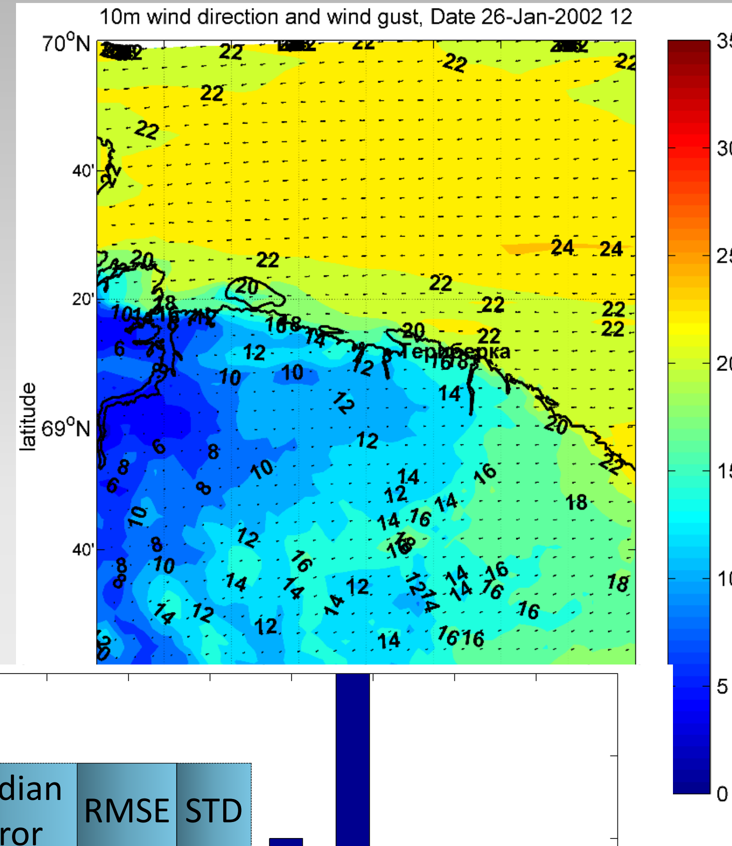



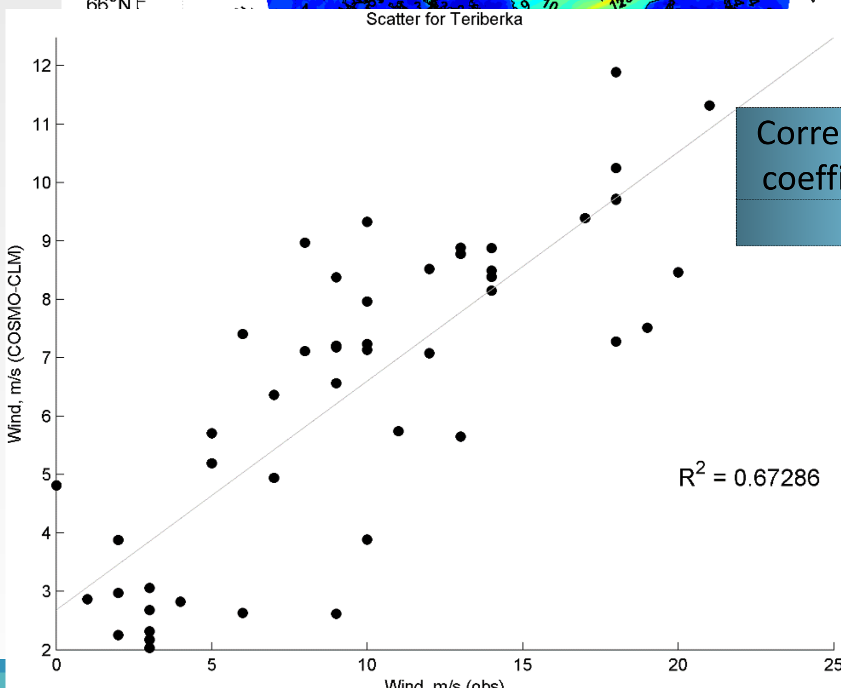

| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,67 | -0,31 | -0,60 | 4,20 | 4,23 |

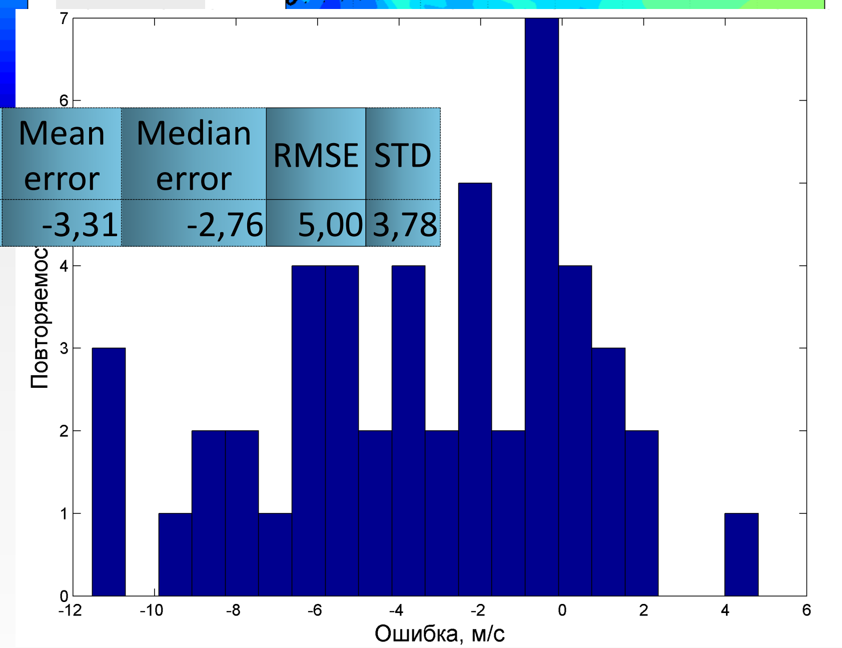
# RESULTS

26.01.2002 2,8 km



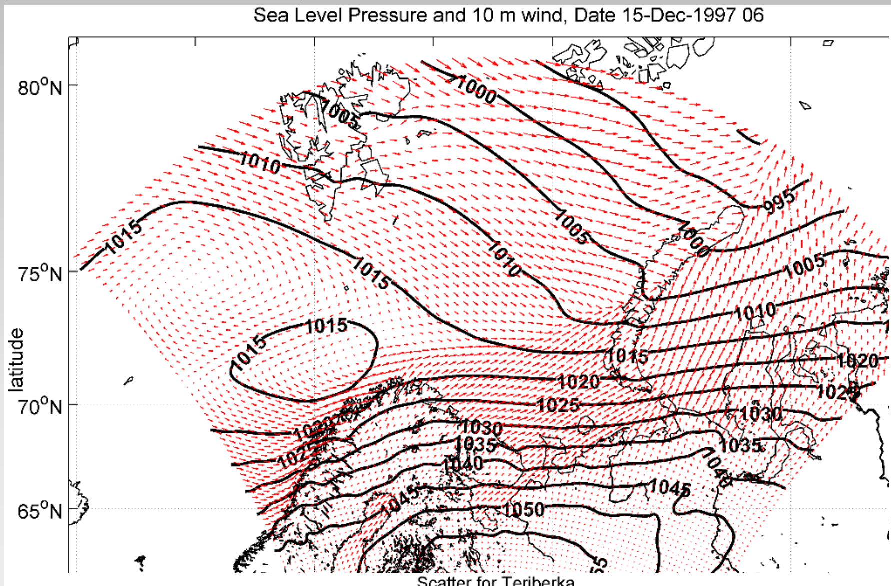



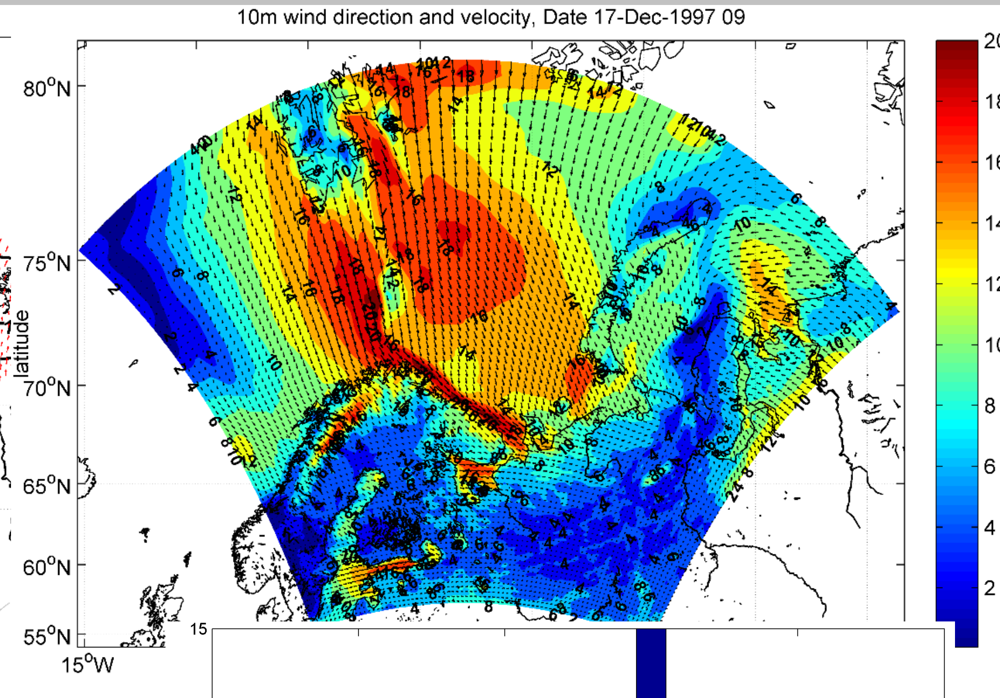



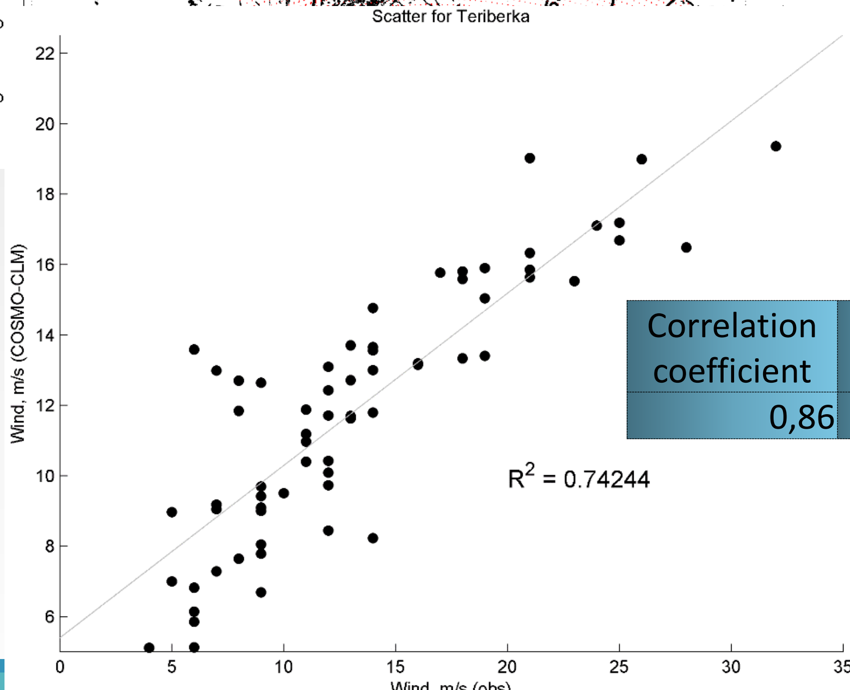



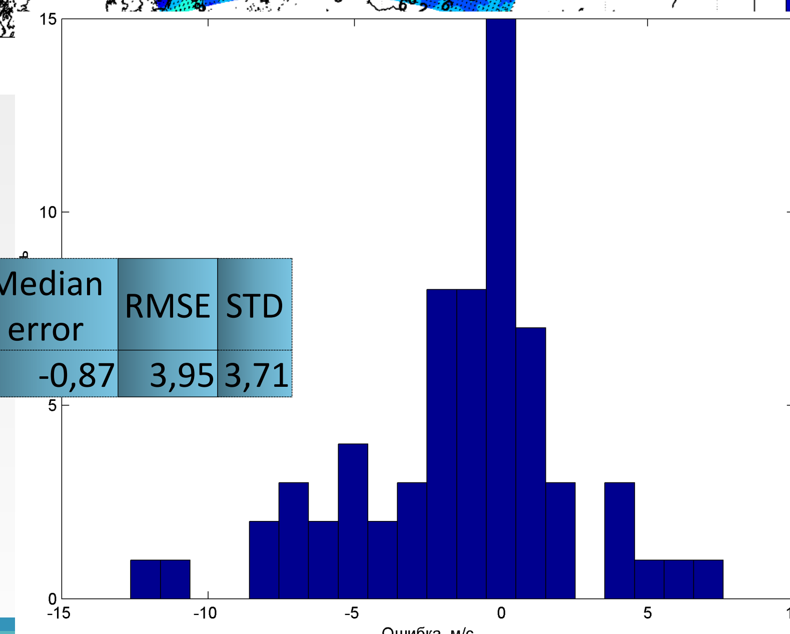

| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,82 | -3,31 | -2,76 | 5,00 | 3,78 |

# RESULTS 15-17.12.1997 18 km



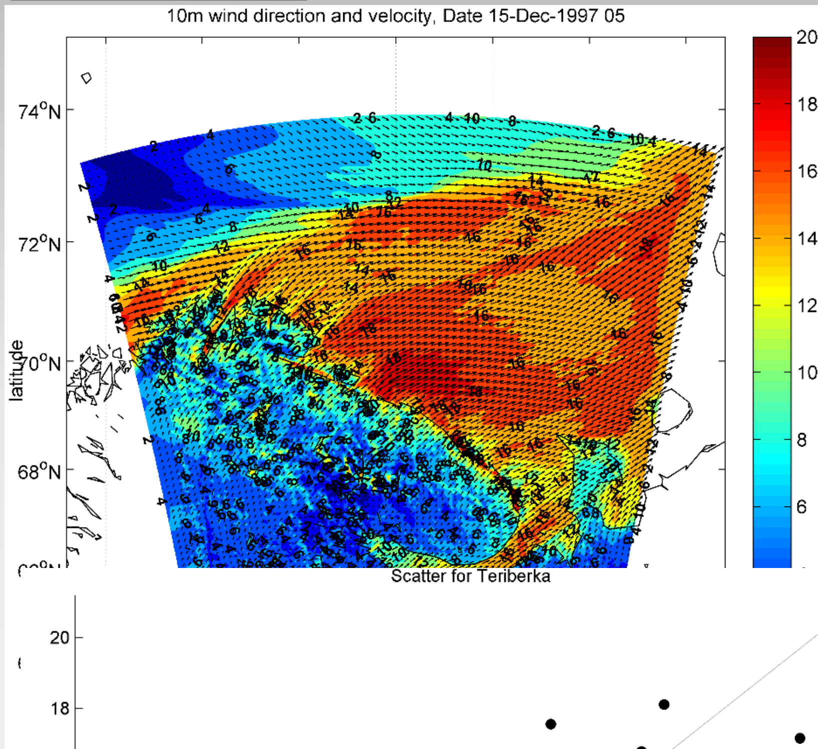



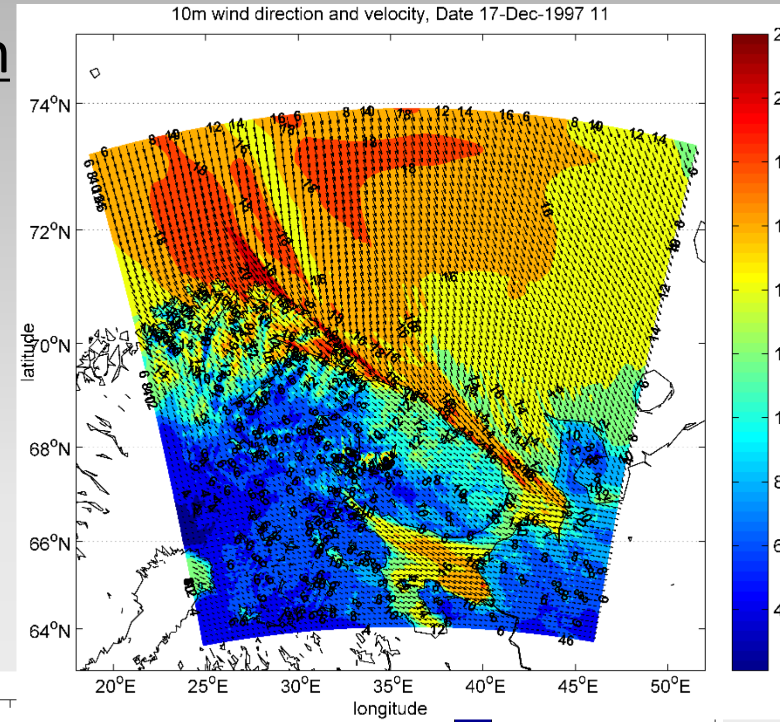



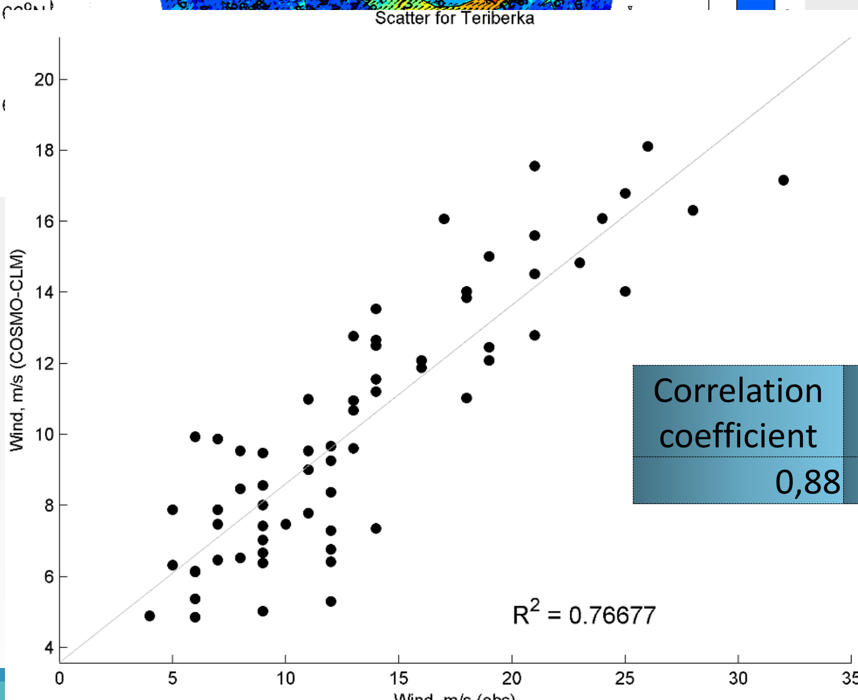

| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,86 | -1,43 | -0,87 | 3,95 | 3,71 |

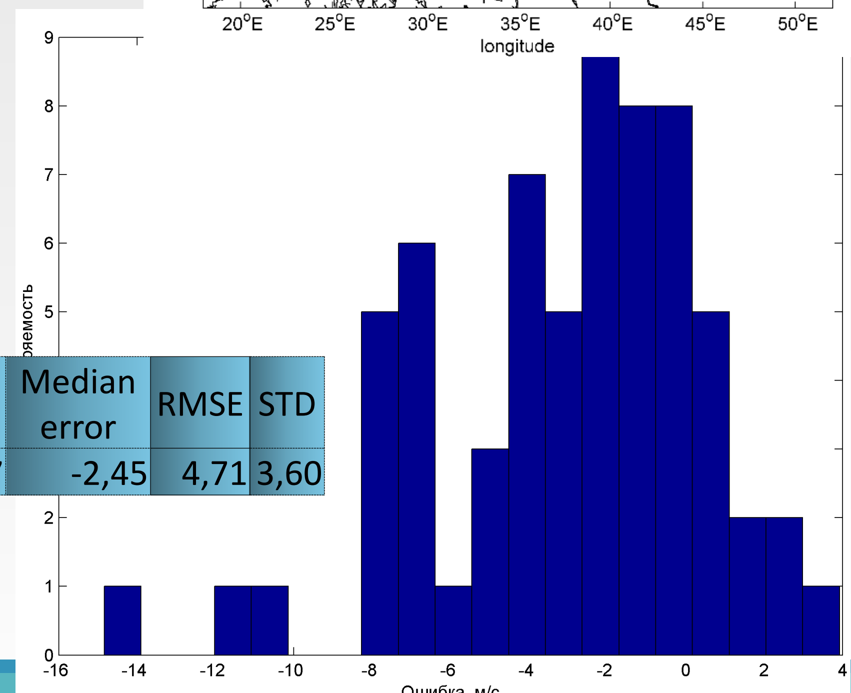
# RESULTS

15-17.12.1997 2,8 km




| Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|
| 0,88 | -3,07 | -2,45 | 4,71 | 3,60 |

# CONCLUSION AND PERSPECTIVES

## Overall statistics for 3 cases

| Station Teriberka | Correlation coefficient | Mean error | Median error | RMSE | STD |
|---|---|---|---|---|---|
| 2013 18 км | 0,90 | -1,49 | -1,00 | 3,63 | 3,34 |
| 1997 18 км | 0,86 | -1,43 | -0,87 | 3,95 | 3,71 |
| 2002 18 км | 0,67 | -0,31 | -0,60 | 4,20 | 4,23 |
| | | | | | |
| 2013 2,8 км | 0,87 | -2,88 | -2,27 | 4,73 | 3,80 |
| 1997 2,8 км | 0,88 | -3,07 | -2,45 | 4,71 | 3,60 |
| 2002 2,8 км | 0,82 | -3,31 | -2,76 | 5,00 | 3,78 |

The COSMO-CLM model reproduces the synoptic-scale dynamics and general synoptic-scale wind velocity patterns well as both with the $0.12^0$ (18 km), and ~3 km resolutions.

Model with **2.8 km resolution** succeed to reproduce detailed spotty wind pattern, caused by local orography or/and dynamic factors.

Statistics doesn’t show define result regarding an improvement of extreme wind speed reproduction.

# CONCLUSION AND PERSPECTIVES

These statistics results may be due to many features of assessment.

- Model underestimates observed mean values and wind gusts over seashores up to 2 - 4 m/s systematically.
- It could be interpreted as follow: such extreme speeds of air particles (15 – 20 m/s and more) doesn't make much physical sense to focus on wind velocity at a certain point. Therefore, we can consider wind velocity values for some surrounding area, according to the distance, corresponding to wind velocities.

With respect to revealing many differences between *"black swans"* and "*dragons"* situations, there were found out no clear distinctions.

- We can assume it caused by the rare overlay of the large-scale synoptic factors and many local meso- and microscale factors (surface, coastline configuration etc.).
- Generally, COSMO-CLM model reproduces wind velocity pattern quite adequately.

**Future work**: fine-tuning and adaptation of the model configuration to the Arctic basin, more precise estimation methods, more case-studies, etc.

However, in general it can be argued that further studies of the extreme wind speeds genesis in the Arctic, such as the "black swans" and "dragons", necessary to focus on **nonhydrostatic high-res. (5 km and less) modeling using downscaling techniques.**

# ADDITIONAL SLIDES…

$$\frac{n}{N} \approx F(U) = 1 - e^{-AU^k}$$

$$\ln\left[-\ln\frac{N-n}{N}\right] = k\ln U + \ln A$$

**Weibull** distribution and coordinates

$$U(p) = \left(\frac{1}{A}\ln\frac{1}{1-p}\right)^{1/k}$$

(threshold *p* was accepted as *p=0.99*)

$$\Phi(U) = 1 - \left(\frac{U_{th}}{U}\right)^{\Upsilon}$$

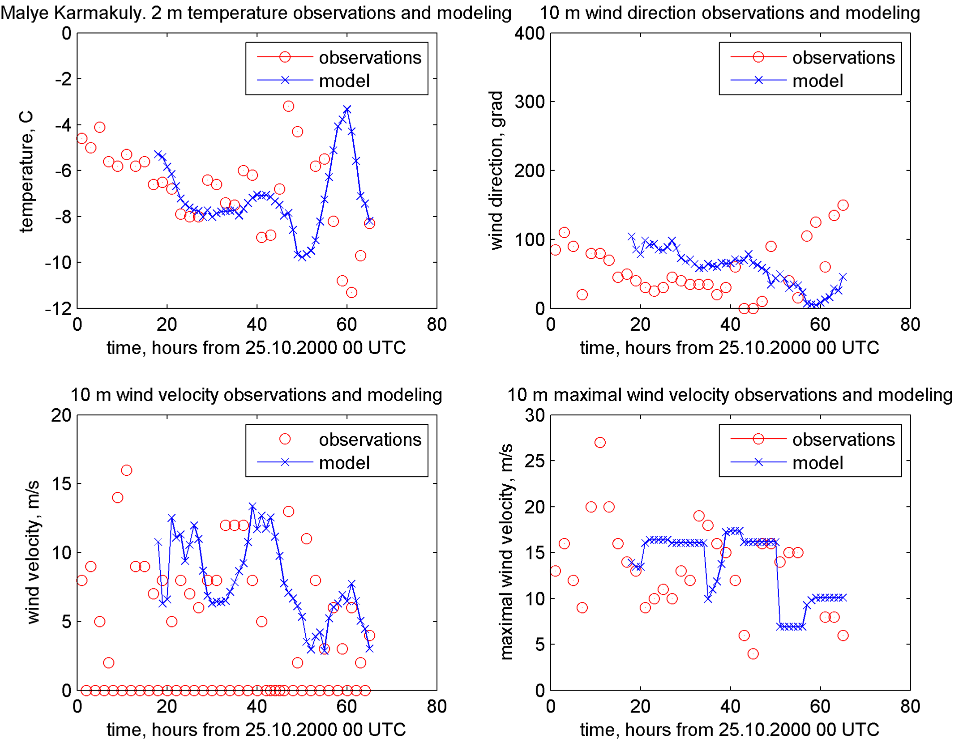
**Pareto** distribution with $U_{th}$ (threshold)

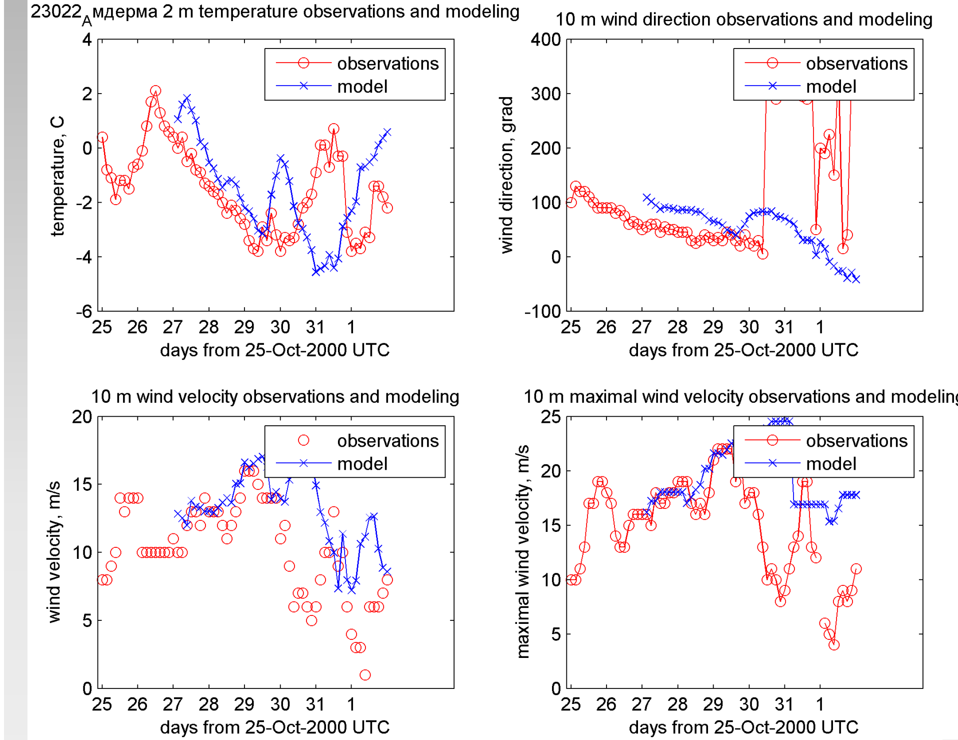
*COSMO scheme for diagnosis near-surface wind gusts ([Schulz, Heise, 2003]):*

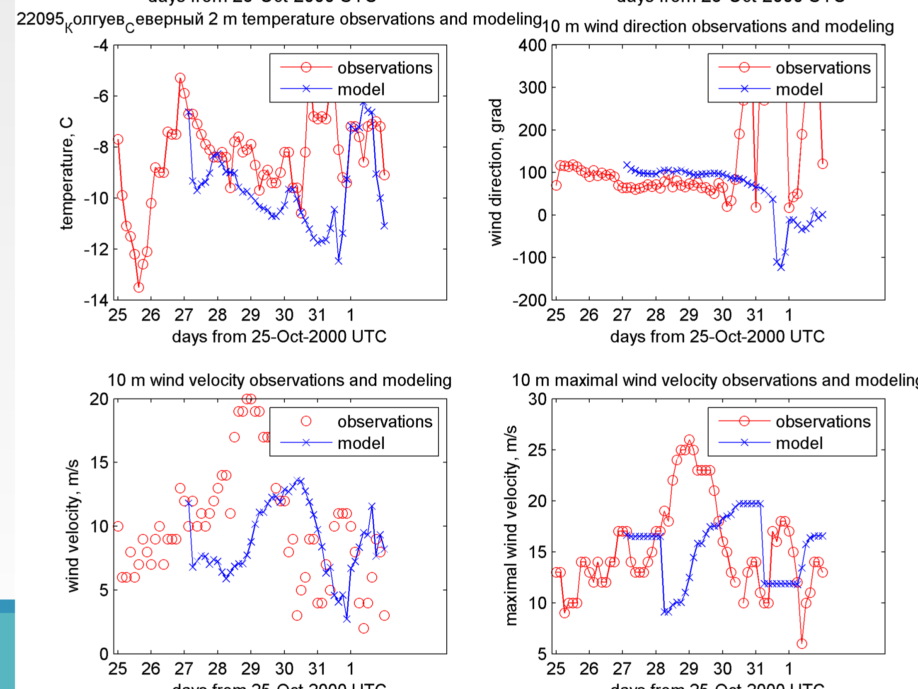
$$V_{\mathrm{turb}} = (1 + \alpha\sqrt{C_{\mathrm{m}}})V_{\mathrm{KE}}$$

$$V_{\mathrm{conv}} = \sqrt{\beta\int_0^H 2g\frac{\Delta\Theta}{\Theta}\mathrm{d}z + V(H)^2}$$

$$V_{\mathrm{gust}} = \max(V_{\mathrm{turb}}; V_{\mathrm{conv}})$$




# ADDITIONAL SLIDES…