Spatial distribution of extreme wind speeds statistics over the Sakhalin Island based on observations and high-resolution modelling data

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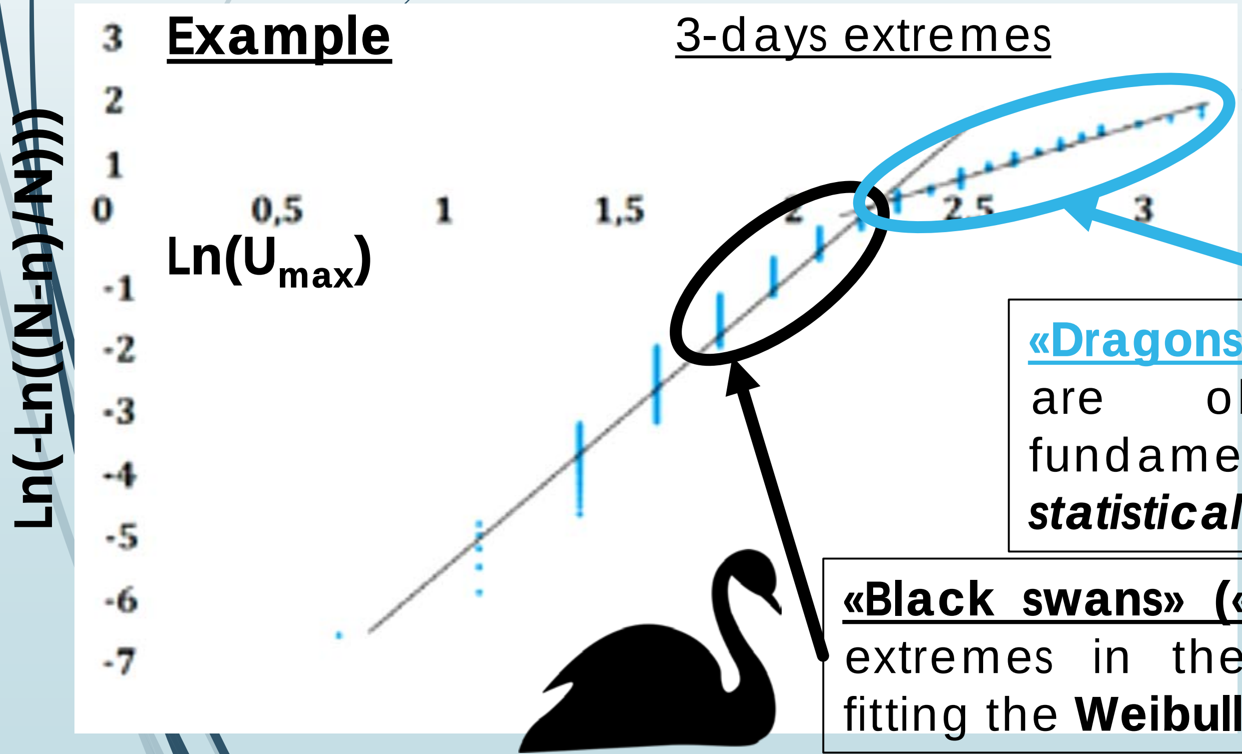
Extreme wind speed statistics approach

- **Extreme wind speeds** are common very important features of Russian Far East and Sakhalin island regions affecting infrastructure, facilities, navigation, oceanic waves, storm surges etc.
- In this work we use **Weibull approach** to describe ***statistical properties*** of wind speed extremes
- For Arctic stations, In [Kislov, Matveeva, 2016] it was shown, that the set of wind speed extremes obtained from observations is a ***mixture of two different subsets*** each described by the Weibull distribution.



<u>**Weibull law** and coordinates (**k** and **A** coefficients)</u>

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

$$ln\left(-ln\left(\frac{N-n}{N}\right)\right) = ln\,A + k\,ln\,U \Rightarrow$$

$$\Rightarrow y = k * x + A$$

<u>**«Dragons» («Ds»)**</u> – extremes are obeying to the fundamentally ***different statistical law*** [Sornette, 2009]

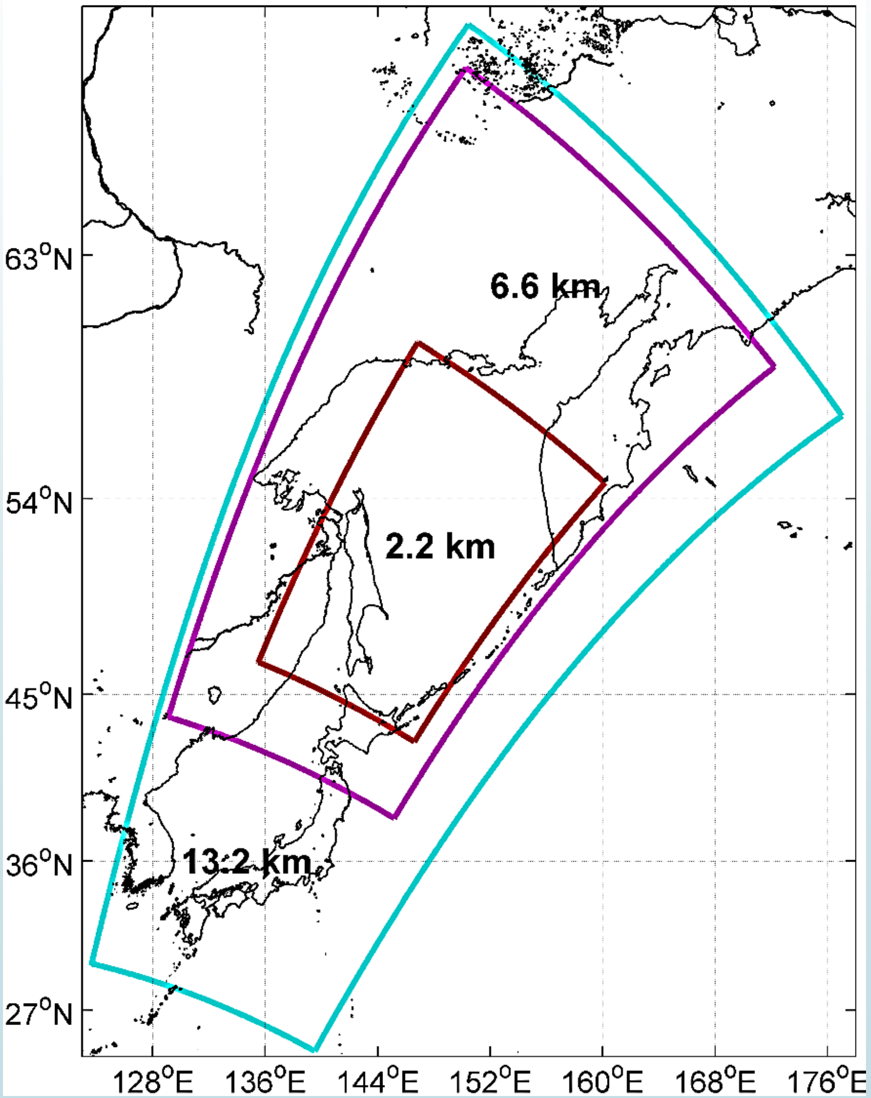
<u>**«Black swans» («BSs»)**</u> – the most extremes in the current sample fitting the **Weibull law** [Taleb, 2010]

<u>**This statistical structure doesn't reproduced by global climate models (e.g., INM-CM4)!!!**</u>

Modelling approach

- The next approach to investigate these statistical features and its potential physical mechanisms is the **mesoscale long-term simulation**.
- The created **long-term (1985-2014)** meteorological archive over the ***Okhotsk Sea and Sakhalin island*** region was described in [Platonov et al., 2017]. We have applied this archive for statistical investigation of wind speed extremes.
- **COSMO-CLM model**; three-steps **dynamical downscaling** (**13.2**-6.6-2.2 km); using spectral nudging technique.

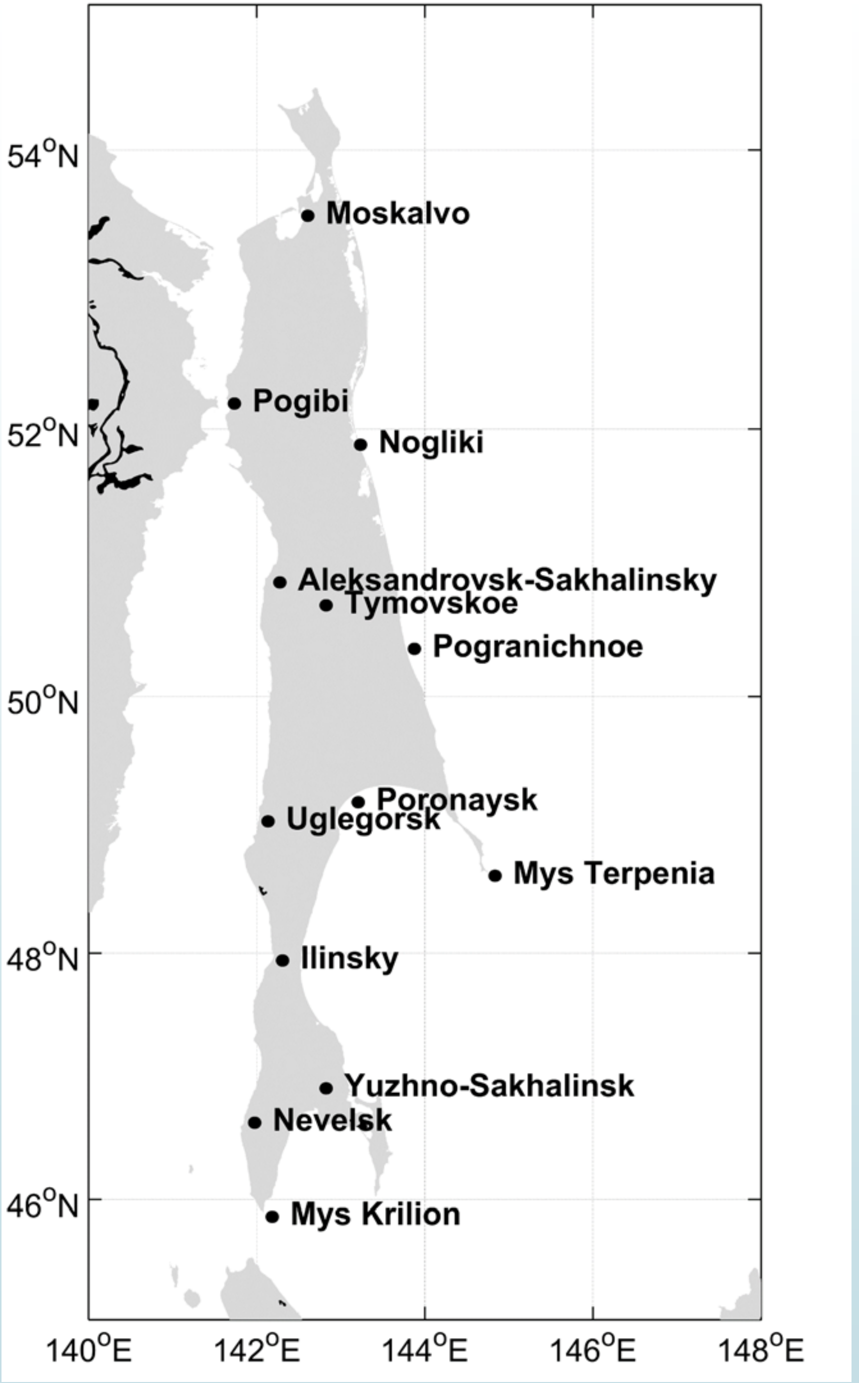
Model domains for 13.2, 6.6, 2.2 km resolution



Observations data analysis. Technique.

- The first task was to **verify** cited statistical features on the Sakhalin island **stations**.
- **13** meteorological stations, **1966 – 2014** years period, 10 m **wind speed** (10 minutes average) data.
- **3-days maxima wind speed** sampled to get statistically independence extremes. 3-days period chosen based on the e-folding autocorrelation function after 2-3 days.
- **Summer** (JJAS) and **winter** (NDJFM) periods analyzed separately.

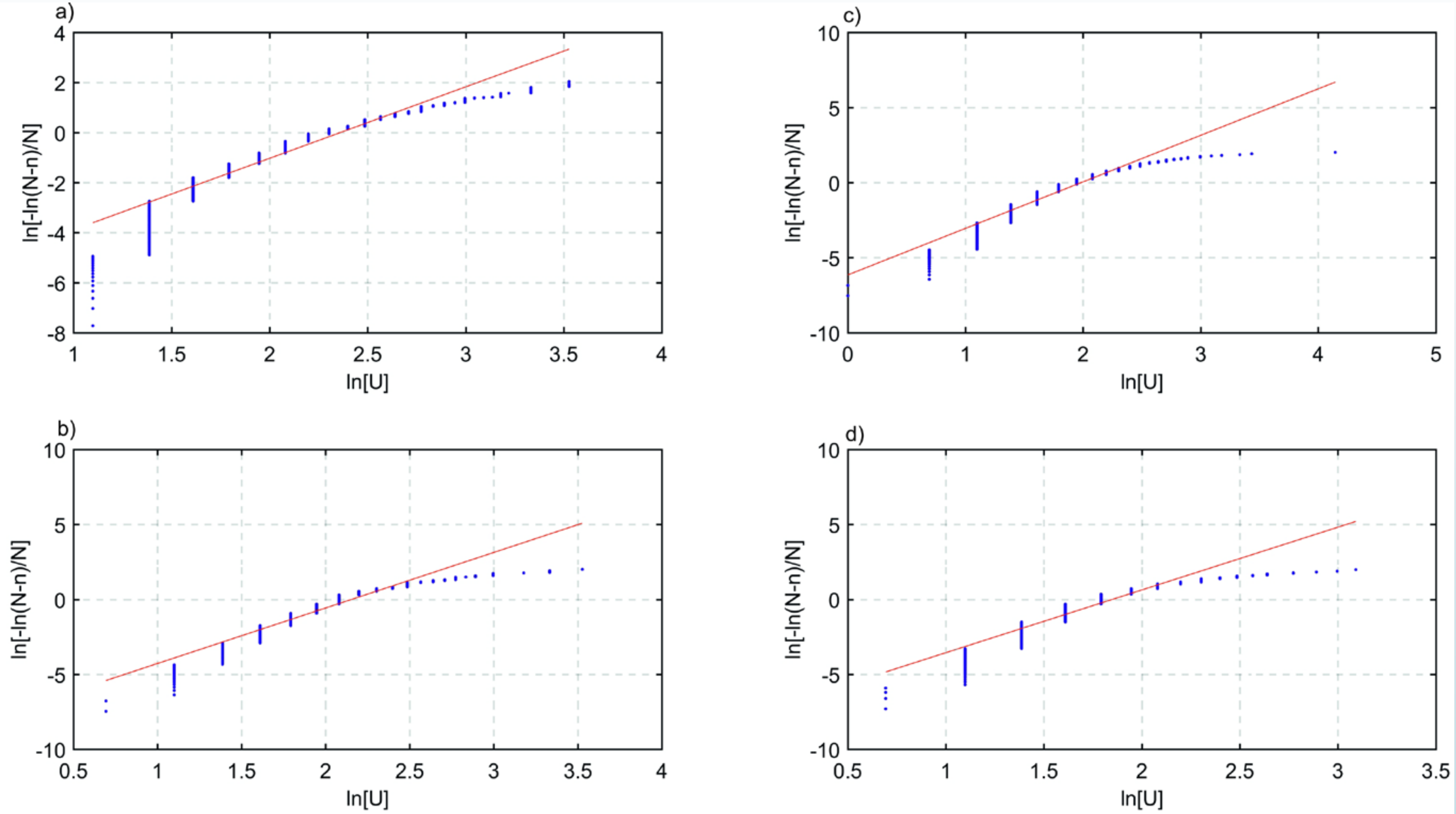
Stations used for statistical estimations



Observations data analysis. Technique.

- Examples of Weibull **cdf**s based on observations
- Examples of **cdf**s separation onto two samples
- The **same features** were revealed for quite all stations and seasons
- Linear approximation by **Weibull distribution** parameters **k** (linear coefficient) and **A** (free)

$$y = k * x + A$$



Weibull cdfs for stations **Alexandrovsk-Sakhalinskiy** (left) and **Yuzhno-Sakhalinsk** (right), **cold** season (top), **warm** season (bottom)

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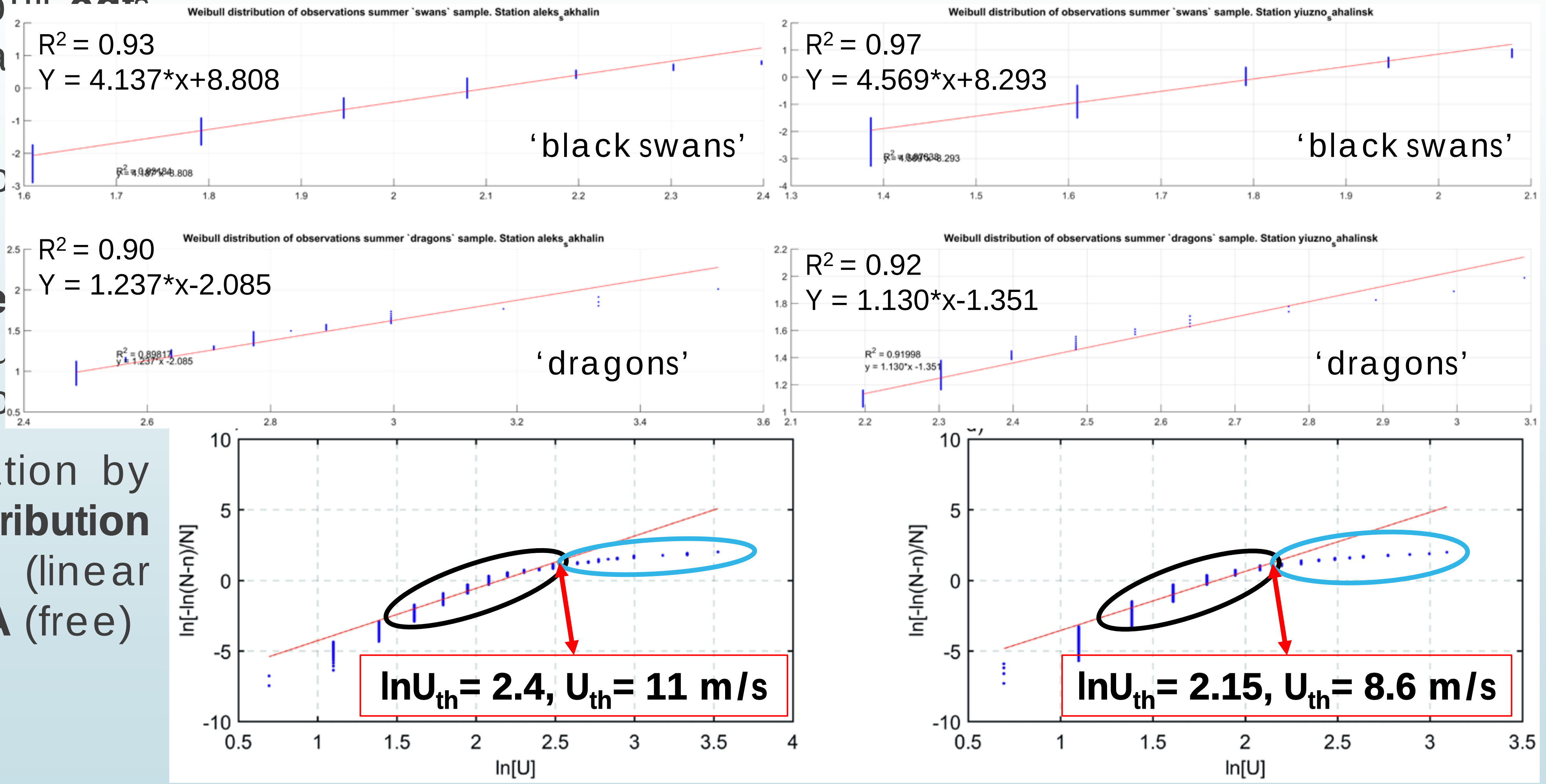
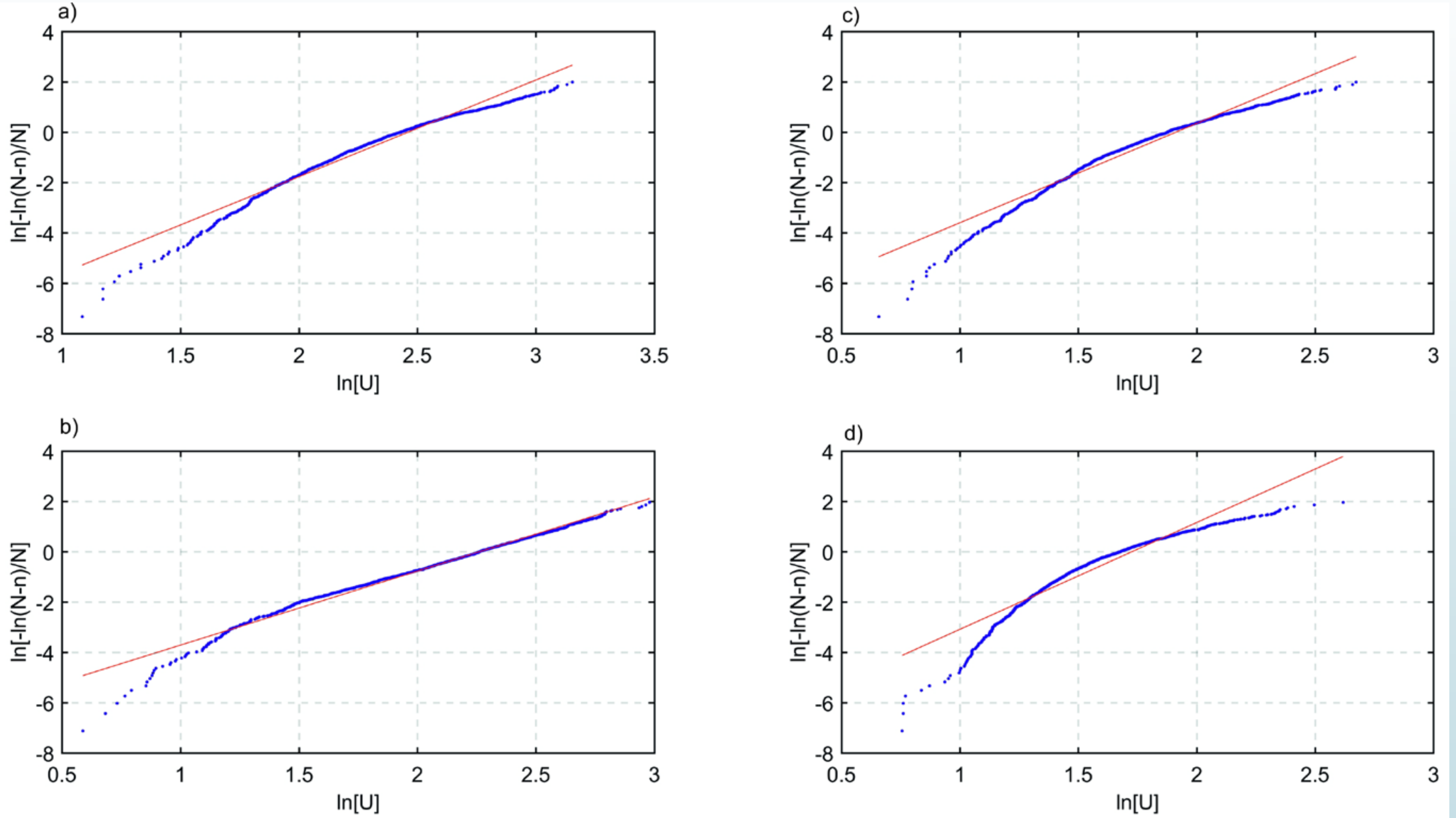


Weibull cdfs for stations **Alexandrovsk-Sakhalinskiy** (left) and **Yuzhno-Sakhalinsk** (right), **cold** season (top), **warm** season (bottom)

Modeling data analysis

- The same analysis was applied to model data archive
- Verification technique: model grid with ***minimal RMSE*** among the <u>4 nearest grid points</u> was chosen
- The **same features** were revealed for quite all stations and seasons.



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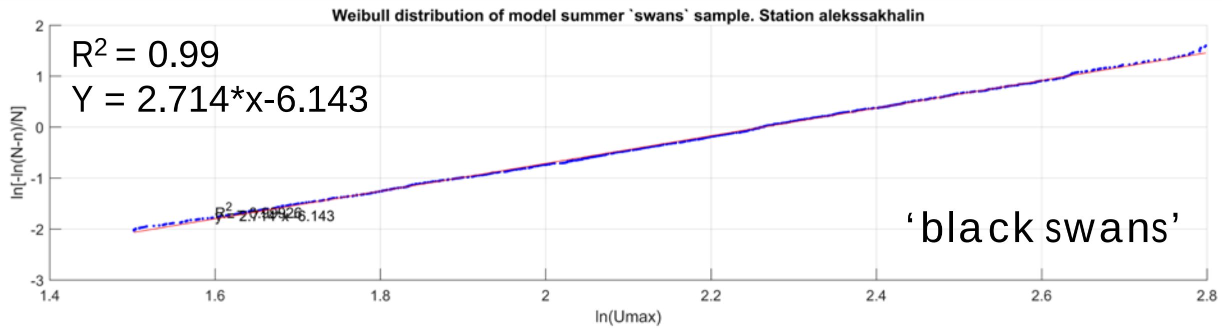

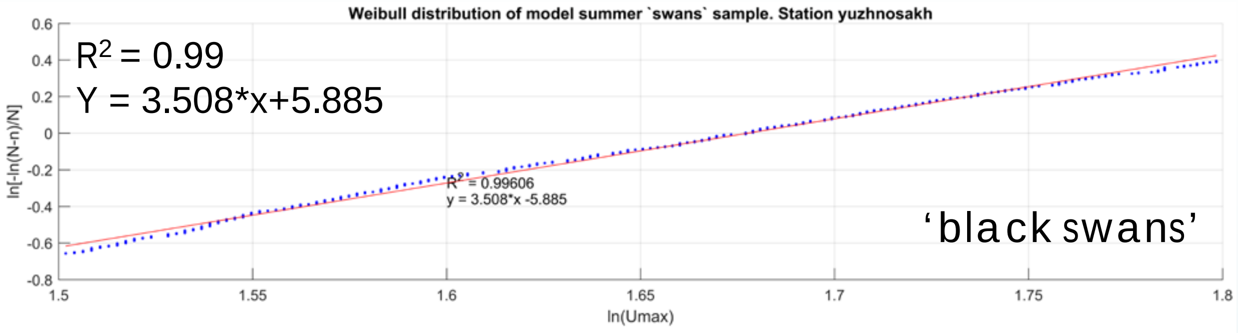

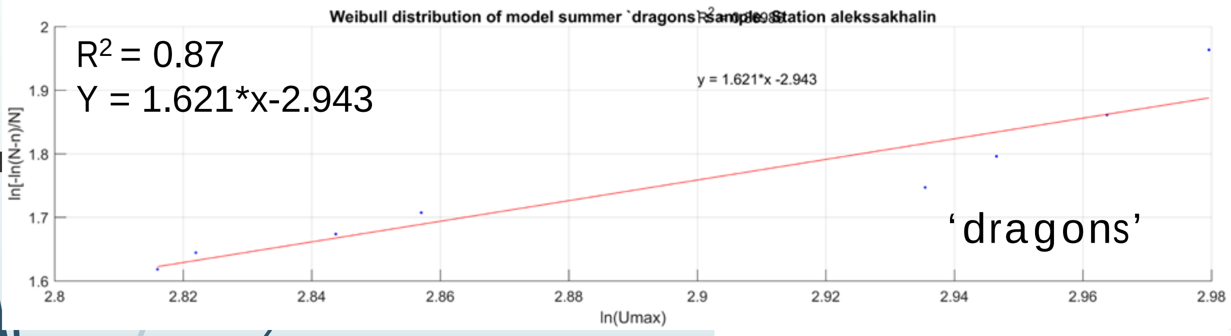

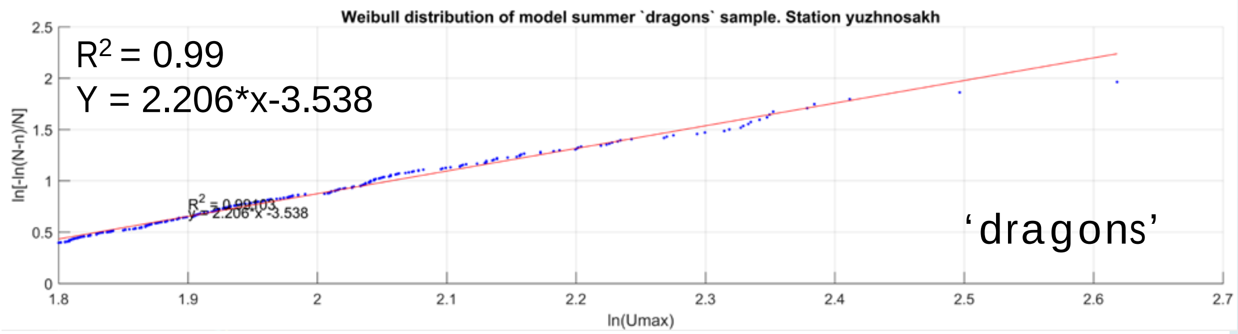

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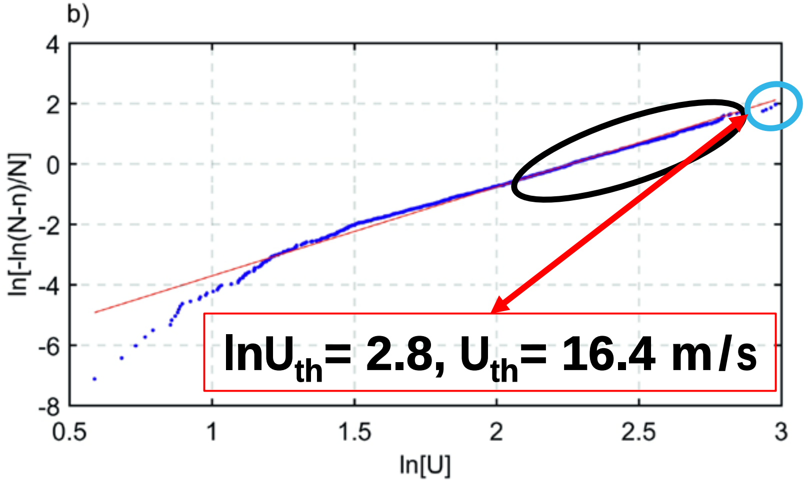
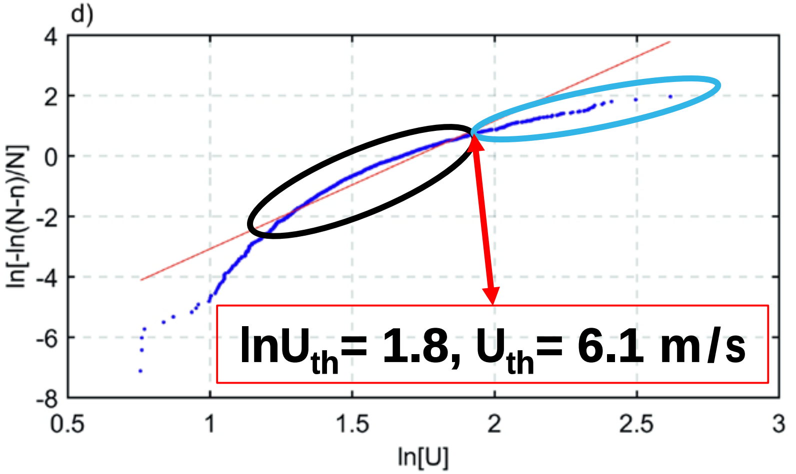
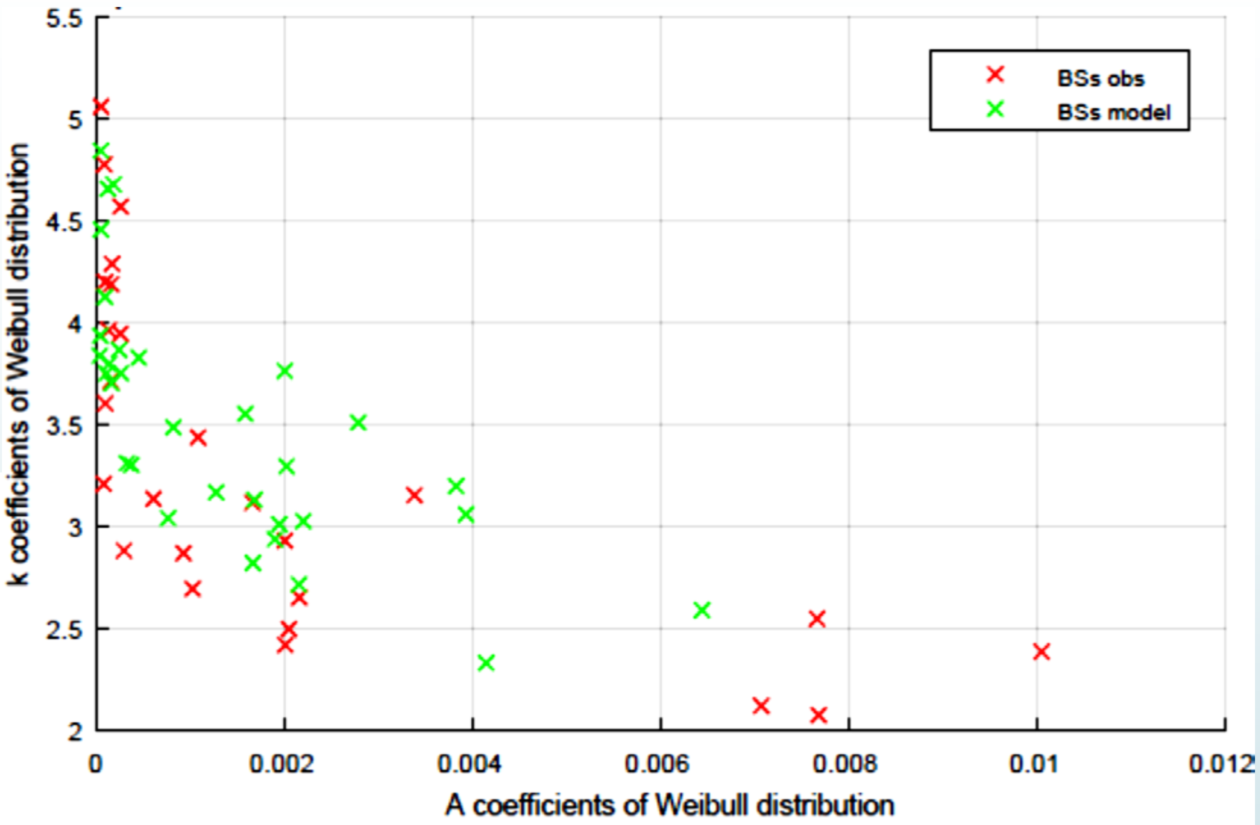


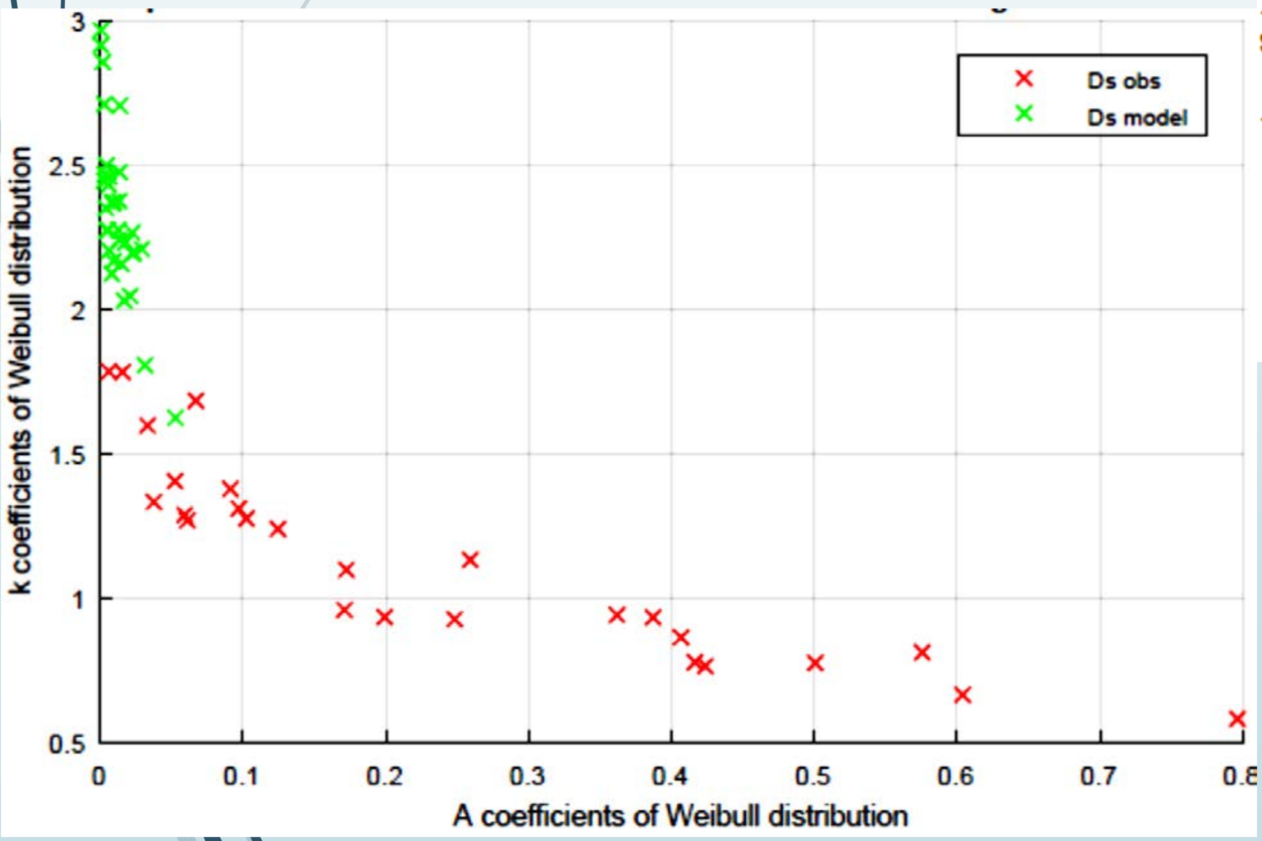


Weibull cdfs for stations **Alexandrovsk-Sakhalinskiy** (left) and **Yuzhno-Sakhalinsk** (right), **cold** season (top), **warm** season (bottom)

Analysis of statistical properties

- Scatter plot comparison **A** and **k** coefficients between model and observations (‘black swans’, ***BSs – right***; ‘dragons’, ***Ds – bottom***).

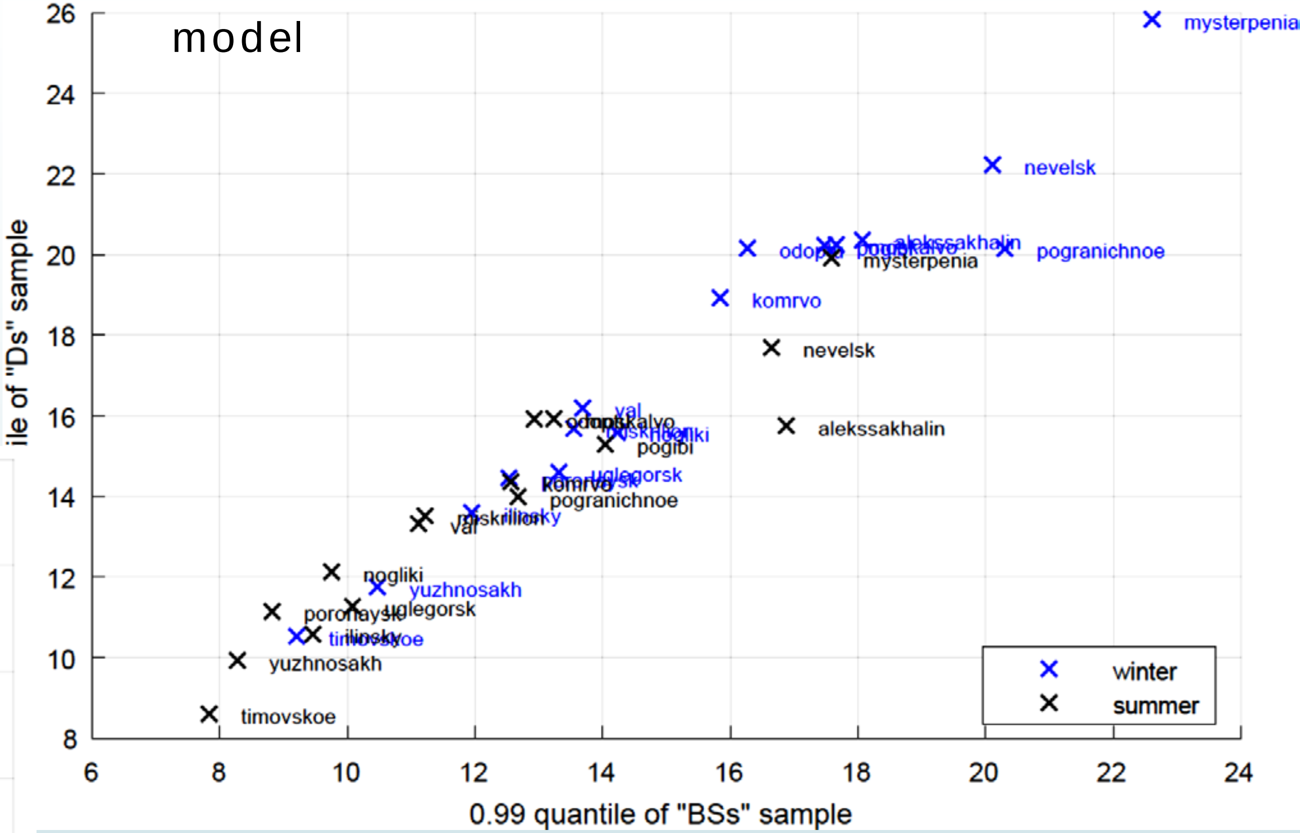


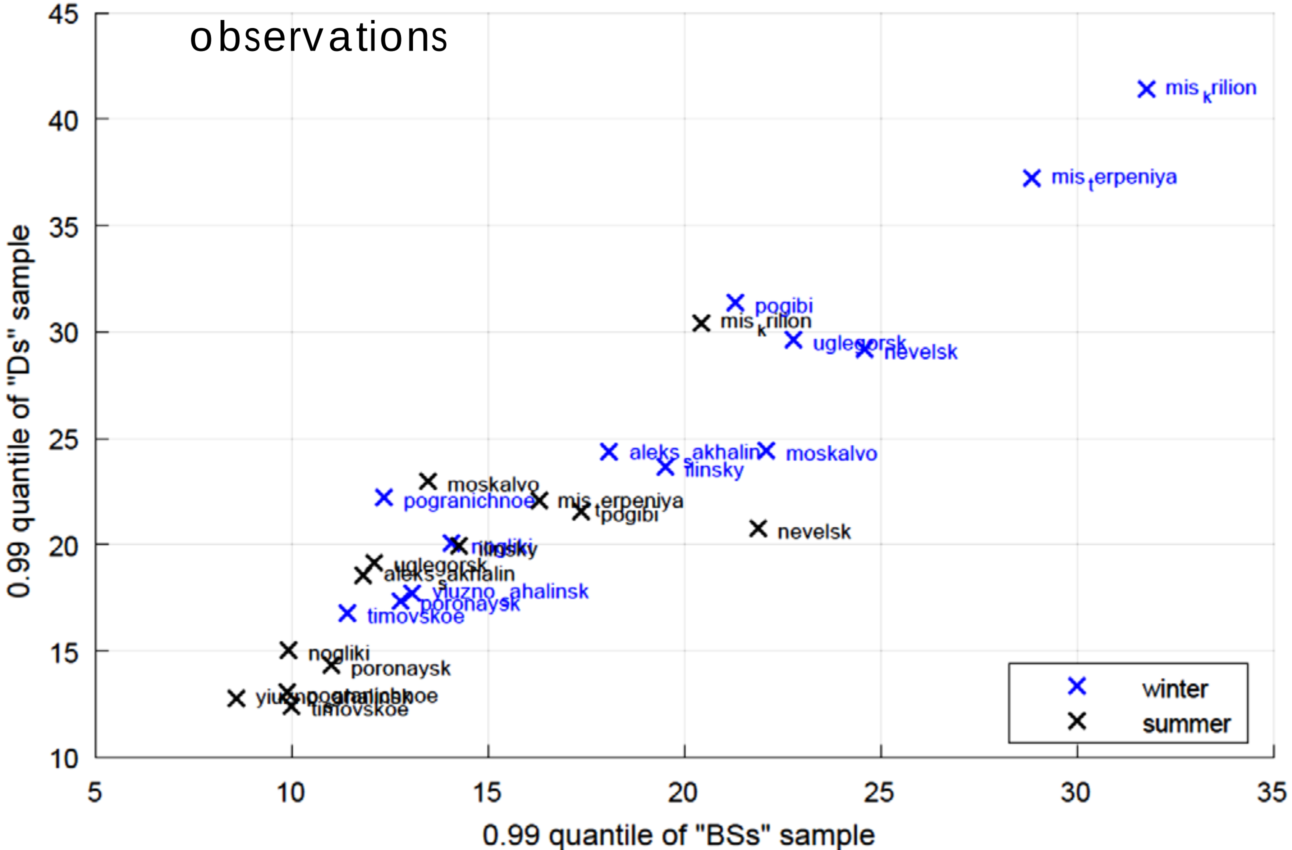


- For **BSs** model quite good reproduces the statistical characteristics, but for **Ds** model underestimates significantly **A** coefficients and overestimates **k** coefficients, i.e. ***underestimates the ‘extremity’ of sample***.

Analysis of statistical properties

- **q0.99** quantiles were calculated for each sample (**BSs** and **Ds**), each season, model and observations.

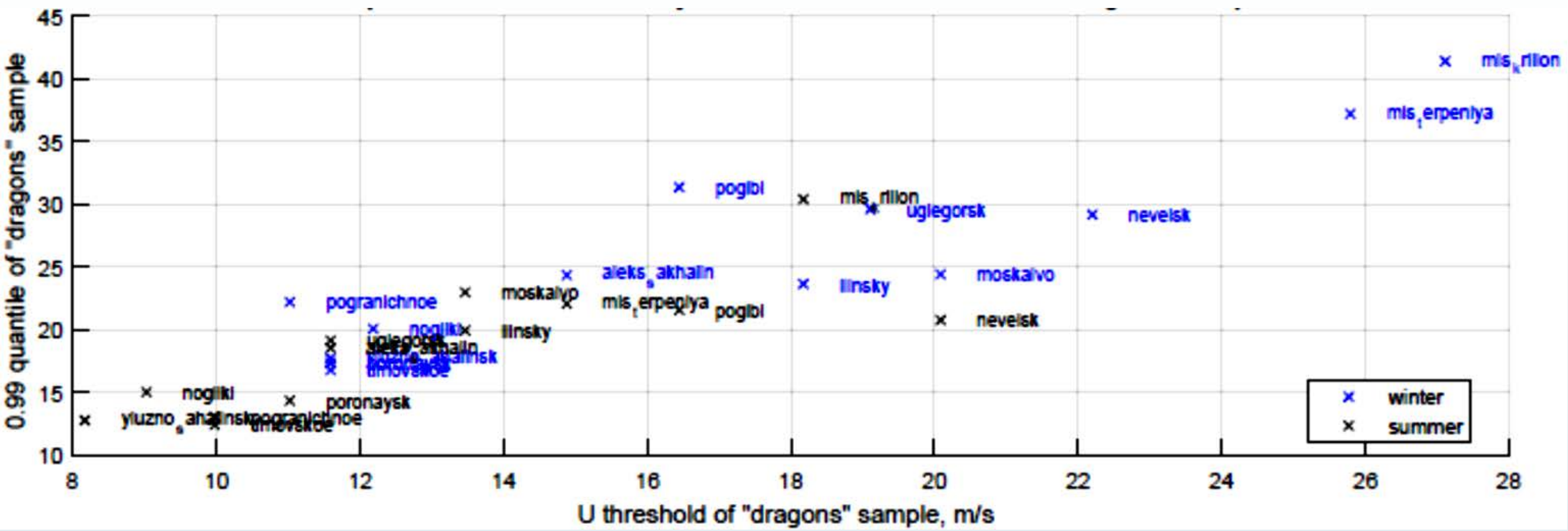


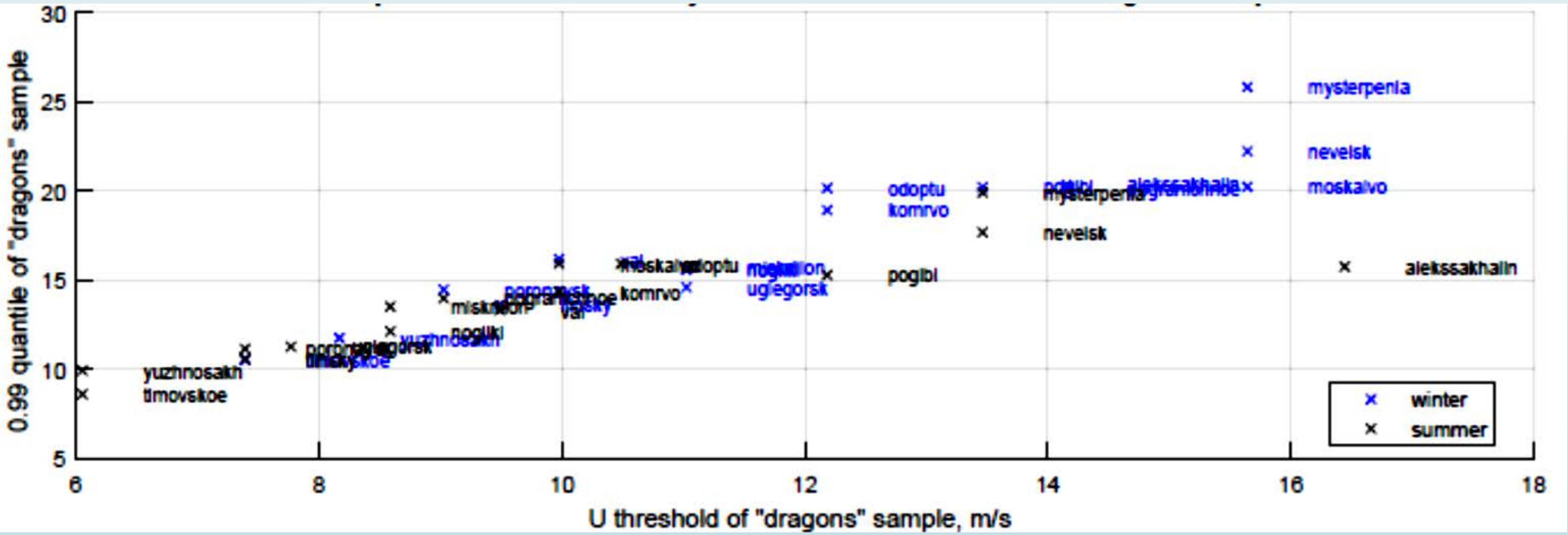


- Model reproduces the exceedance of the ***winter extremes*** over the summer ones, and mostly at the same stations (Mys Terpenia, Nevelsk, Mys Krilion).
- Model underestimates extremes in **BSs sample** by ***~25 – 30 %***, in **Ds sample** by ***30 – 40 %***.

Analysis of statistical properties

- Scatter plot of U_{th} and **q0.99** for **Ds** according to ***observations (top)*** and ***model (bottom)*** for winter and summer seasons.
- U_{th} is **<u>underestimated</u>** by model by up to 30 – 40 %, except for Aleks.-Sakh., summer.





Conclusion and perspectives

- **Mesoscale atmospheric model** succeeded to reproduce **statistical features** of wind velocity extremes, namely its dividing onto **"BS"** and **"D"**, ***unlike to the global models***.

- **«Extremity»** and distribution of ***'dragons'*** sample parameters are significantly **underestimated** by model, which may be due to model limitations, resolution, verification technique and geographical factors, etc.

- **Further study** will be dedicated to investigation of the specific situations attributed to the **«dragons»** type, to the detection of its formation mechanisms, to scaling problems and to the dependence of **statistical structure** on the **model resolution**.

- **References:**

- ***Kislov A.*** and ***Matveeva T.*** An extreme value analysis of wind speed over the European and Siberian parts of Arctic region. ***Atmospheric and Climate Sciences***, 6:205–223, 2016.

- ***Platonov V., Kislov A., Rivin G., Varentsov M., Rozinkina I., Nikitin M., Chumakov M.*** Mesoscale atmospheric modelling technology as a tool for creating a long-term meteorological dataset. ***IOP Conf. Ser. Earth and Env. Sci.***, 96, 2017.

- ***Kislov A., Platonov V.*** Extreme wind speed analysis: observations and mesoscale meteorological modelling data. ***Atmospheric and Climate Sciences, 2019, 9, 146-158***

Tables?

Station name	Observations, winter				Observations, summer				Model, winter				Model, summer			
	k BSs	A BSs	k Ds	A Ds	k BDs	A BSs	k Ds	A Ds	k BSs	A BSs	k Ds	A Ds	k BSs	A BSs	k Ds	A Ds
aleks_sakhalin	2,6497	0,0022	1,4023	0,0523	4,1865	0,0001	1,2366	0,1244	4,1865	0,0001	1,2366	0,1244	2,7143	0,0021	1,6214	0,0527
Ilinsky	2,8681	0,0009	0,9233	0,2481	3,9613	0,0001	1,2720	0,1023	3,9613	0,0001	1,2720	0,1023	3,5517	0,0016	2,4723	0,0135
mis_krilion	3,2078	0,0001	1,7821	0,0060	3,6026	0,0001	1,2659	0,0611	3,6026	0,0001	1,2659	0,0611	3,8268	0,0004	2,2385	0,0135
mis_terpeniya	2,8804	0,0003	1,3302	0,0375	3,7125	0,0001	1,5952	0,0331	3,7125	0,0001	1,5952	0,0331	3,0395	0,0008	2,1199	0,0081
moskalvo	2,4954	0,0020	1,7800	0,0156	4,1973	0,0001	0,7612	0,4237	4,1973	0,0001	0,7612	0,4237	3,0096	0,0019	1,8035	0,0313
nevelsk	2,4174	0,0020	0,9308	0,1993	2,0733	0,0077	0,5785	0,7964	2,0733	0,0077	0,5785	0,7964	2,8194	0,0017	2,1632	0,0092
nogliki	2,9292	0,0020	1,0953	0,1724	5,0588	0,0000	0,9384	0,3619	5,0588	0,0000	0,9384	0,3619	4,6550	0,0001	2,2289	0,0177
pogibi	2,1187	0,0071	0,9557	0,1710	3,1347	0,0006	0,6615	0,6039	3,1347	0,0006	0,6615	0,6039	4,1251	0,0001	2,7077	0,0029
pogranichnoe	2,5466	0,0077	0,7751	0,4164	3,1523	0,0034	0,8091	0,5757	3,1523	0,0034	0,8091	0,5757	2,5881	0,0064	2,0431	0,0210
poronaysk	3,1156	0,0017	1,3749	0,0911	4,2868	0,0002	0,9296	0,3872	4,2868	0,0002	0,9296	0,3872	4,6764	0,0002	2,1930	0,0233
timovskoe	3,4357	0,0011	0,8605	0,4067	4,7739	0,0001	1,6805	0,0669	4,7739	0,0001	1,6805	0,0669	3,7620	0,0020	2,7027	0,0137
uglegorsk	2,6937	0,0010	1,2851	0,0592	3,9439	0,0002	1,3076	0,0970	3,9439	0,0002	1,3076	0,0970	3,0589	0,0039	2,1907	0,0228
yiuzno_sahalinsk	2,3850	0,0101	0,7720	0,5007	4,5687	0,0003	1,1295	0,2591	4,5687	0,0003	1,1295	0,2591	3,5080	0,0028	2,2061	0,0291

Dates

- Comparison of **‘dragons’ dates** for Yuzhno-Sakh., summer (***observations – right, model - bottom***)