AWARE: Appraisal of "Challenging WeAther" FoREcasts

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- *Prolongation accepted to complete Tasks and provide the related deliverables.*
- *The requested extension was until the January 2021.*
- *Problems with RHM participation in COSMO caused additional delay in some deliverables*

Deliverables: Available at http://www.cosmo-model.org/content/tasks/priorityProjects/aware/default.htm

- **The Final Project Report is to be submitted by the end of 2022**

Remaining PP AWARE (RHM) Tasks

Task 1.2. Approaches to introduce observation uncertainty (A. Bundel, RHM):

Delayed due to limited human resources. The overview is under preparation.

Task 2.3. Extreme Value Theory (EVT) approach, Fitting precipitation object characteristics to different distributions (A. Muraviev and A. Bundel, RHM):

Task finished. The final report is ready (see next slides)

Task 3.3. CRA and FSS analysis on intense precipitation (A. Bundel, RHM)

Task finished. Report is under revision (see next slides)

Task 4.4. Representing and communicating HIW forecast for decision making (A. Bundel and I. Rozinkina, RHM)

Delayed due to lack of resources.

The overview of the practices of issuing warnings globally and at RHM is under preparation.

A report summarizing the operational meetings with the RHM forecasters about warning issuing is under preparation.

It is planned to present as part of the report the warning value chain on the example of significant convective events.

Task 3.3: CRA and FSS analysis on intense precipitation

(A. Bundel, RHM)

- **The MODE method was used instead of CRA, due to its better flexibility and availability of software**
- **Task Finished. A paper is published in IOP, Conference Series (Russian).**
- **Report is under revision**

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Task 3.3: CRA and FSS analysis on intense precipitation

Data and verification setup

Model

- Research version of ICON-Ru2-EPS convection-permitting system with a horizontal resolution of about 2.2 km and 65 vertical levels
- Integration domain covers the Central Federal District of Russia (approximately 50-60°N, 29-43°E)
- IIC and LC conditions are obtained from the global ICON runs with a grid step of about 13 km and 90 vertical levels
- EPS comprised 11 members. Parameters of physical parameterizations of several processes like convection, turbulence, soil processes, etc. were stochastically disturbed. A set of variables to perturb was defined from model sensitivity experiments. The tuning parameters were perturbed within a meaningful range so that the forecast skill on average did not get worse.
- Forecast horizon was 48 hours starting from 00UTC for summer conditions (July 2021).

Observations

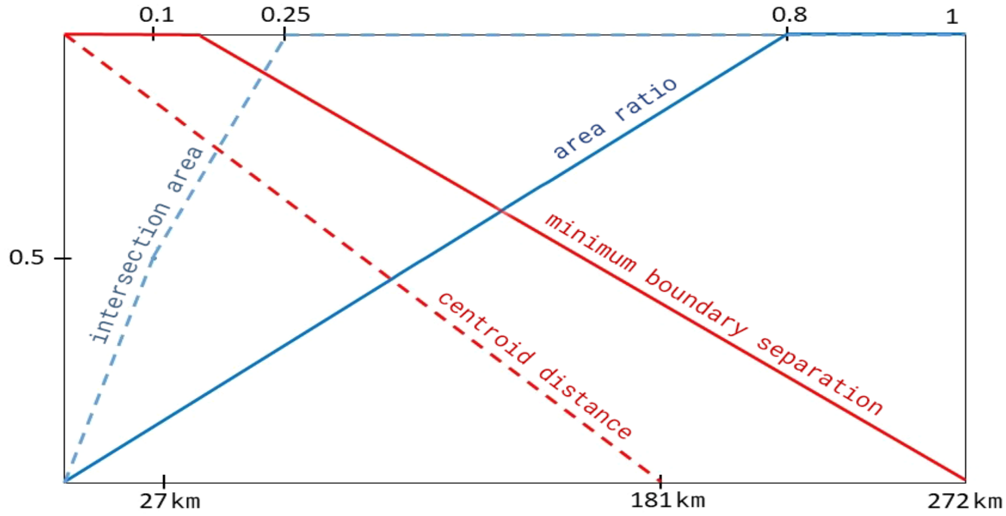
Radar composite over the Central Russia was used as gridded precipitation observation dataset.

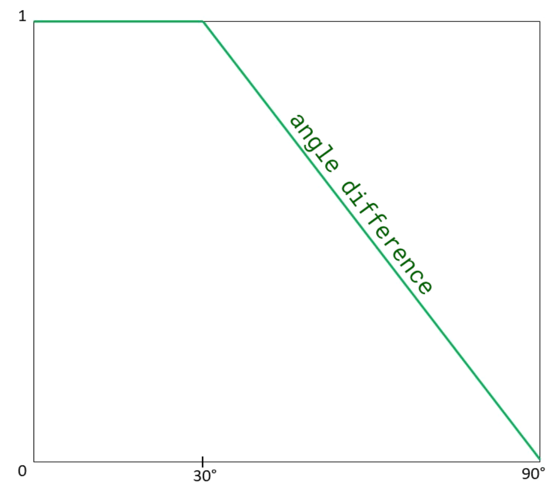
Composite data with 1 km grid mesh were interpolated to the model grid with 2.2 grid mesh using the nearest grid point approach. 10-min accumulations were summed up to obtain 1h accumulations

Software

MET verification package (https://dtcenter.org/community-code/metplus) was used.

MODE setup: Fuzzy logic functions in the interval [0, 1] for the attribute differences used in this study





The interest values I are calculated for each attribute i and object pair j, and the total interest (TI) value is computed.

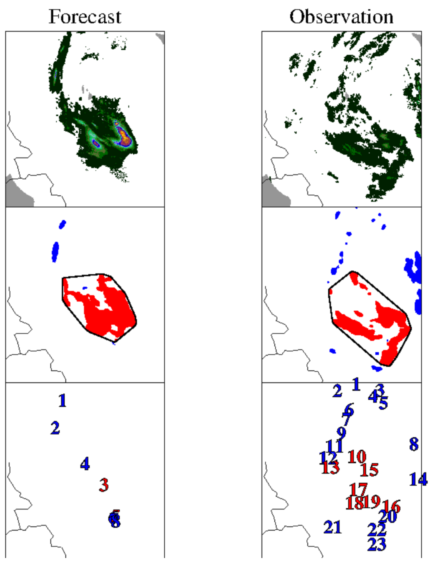
$$I_{ij} = F_{ij} w_i c_i$$

$$TI_j = \frac{\sum_i I_{ij}}{\sum_i w_i c_i}$$

Fuzzy engine weights w	
Centroid distance	2.0
Minimum boundary separation	4.0
Angle difference	1.0
Area ratio	1.0
Intersection area ratio	2.0

MODE results for 2021.07.01, 02h UTC (Test case 1), Precipitation threshold > 0.1 mm/h

MODE for EPS control member,
Black contour indicates object clustering,
numbers correspond to identified objects



Fcst	Obs	Interest
3	18	0.9116
3	16	0.8967
3	10	0.8761
3	17	0.8708
3	15	0.8608
3	13	0.8428
5	18	0.8033
3	19	0.7663
7	20	0.6825
1	2	0.6625
4	13	0.6525
5	22	0.6480
5	19	0.6413
7	18	0.5992
7	22	0.5920
4	12	0.5914
5	20	0.5861
4	15	0.5802
3	12	0.5774
4	11	0.5660
6	18	0.5626
2	11	0.5602
7	19	0.5519
1	9	0.5437
8	18	0.5369
3	20	0.5283
2	9	0.5216
8	22	0.5183
4	10	0.5177

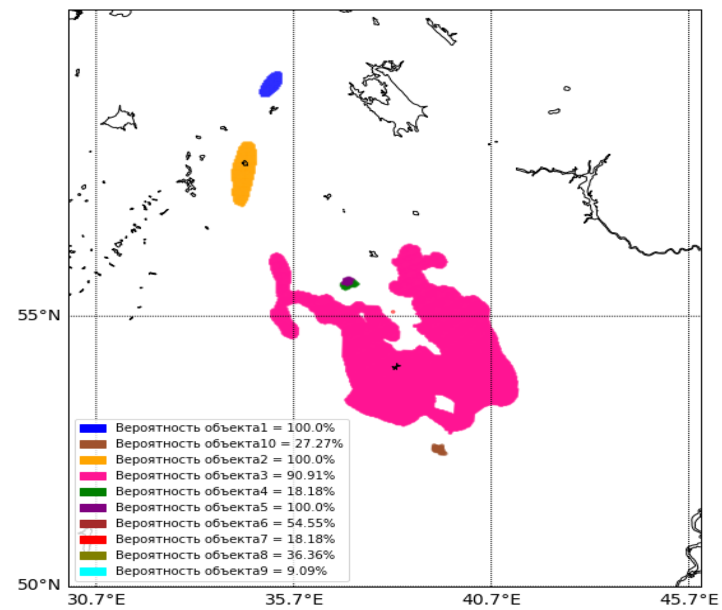
Matched

TI = 0.7

Threshold for object matching

Unmatched

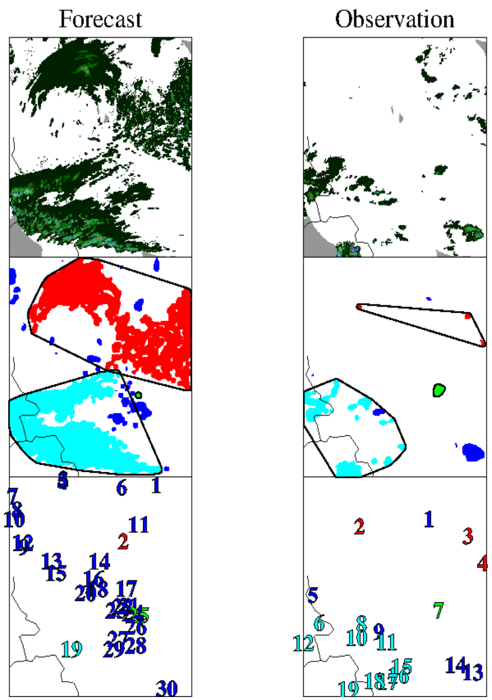
EPS pseudomember,
colors indicate probabilities



MMIF=0.64
MMIO=0.53
MMI=0.55

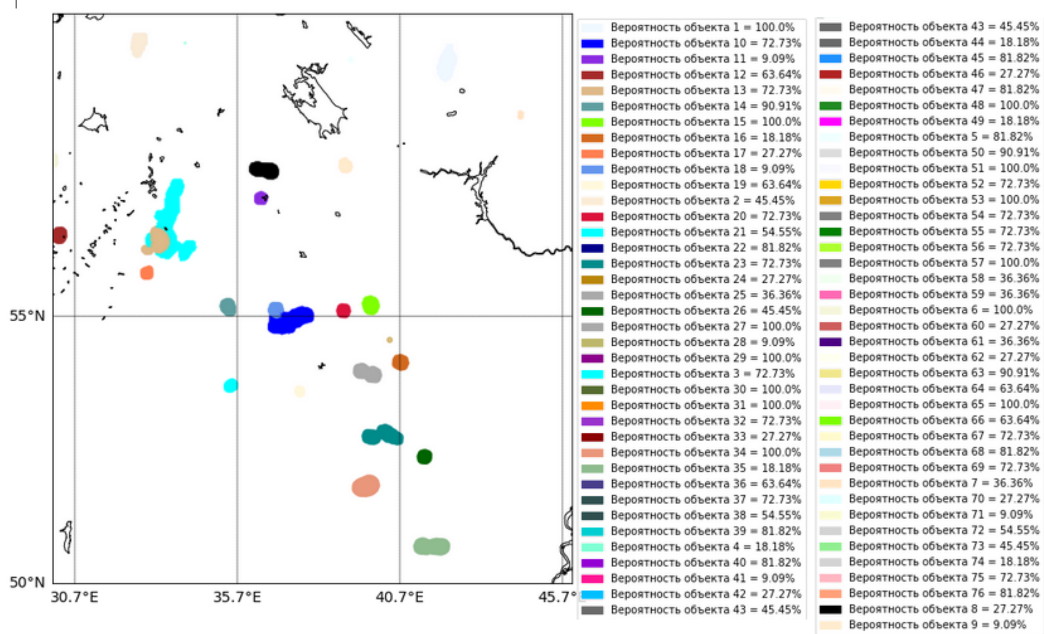
CLUS PAIR	CEN DIST	ANG DIFF	FCST AREA	OBS AREA	INTER AREA	UNION AREA	SYMM DIFF	FCST INT 50	OBS INT 50	FCST INT 90	OBS INT 90	TOT INTR
1	53.73	1.43	15354	11255	5495	21114	15619	0.37	0.32	2.58	1.29	0.9730

MODE results for 2021.07.02, 23h (Test case 3), Precipitation threshold > 0.1 mm/h



Fcst	Obs	Interest
19	11	0.8688
2	4	0.8676
19	15	0.8665
19	8	0.8653
2	2	0.8628
19	18	0.8464
19	6	0.8441
2	3	0.8349
25	7	0.8346
19	17	0.8333
19	10	0.8227
19	16	0.8145
19	12	0.8126
19	19	0.7819
21	7	0.6558
27	11	0.6437
24	7	0.6210
29	15	0.6158
27	9	0.5983
11	1	0.5895
29	11	0.5885
26	7	0.5835
19	9	0.5834
30	13	0.5720
28	15	0.5596
6	1	0.5539
27	8	0.5470
27	15	0.5416
27	7	0.5399

EPS pseudomember, colors indicate probabilities



Too many small objects, overestimating the precipitation area

Comparison of scores for 4 precipitation test cases

Ensemble scores (ME, RMSE for EPS mean) Precipitation threshold > 0.1 mm/h for 4 test cases				
	CRPS	**ME**	**RMSE**	**SPREAD**
1. 20210701_02	0.31	0.02	0.45	0.06
2. 20210701_23	1.96	1.67	4.31	3.61
3. 20210702_02	0.06	-0.01	0.15	0.01
4. 20210702_23	1.94	2.11	5.91	5.45

The best score among 4 cases is marked green, the worst red

Categorical and MODE scores for the control EPS member									
	FBIAS	**PODY**	**POFD**	**CSI (TS)**	**GSS (ETS)**	**HK (PSS)**	**MMI**	MMI-F	MMI-O
1. 20210701_02	0.97	0.31	0.06	0.18	0.14	0.25	0.59	**0.66**	**0.57**
2. 20210701_23	26.33	0.46	0.35	0.02	0.00	0.11	0.76	**0.62**	0.85
3. 20210702_02	0.12	0.01	0.00	0.01	0.00	0.00	0.49	0.76	0.47
4. 20210702_23	7.82	0.40	0.30	0.05	0.01	0.10	0.58	0.50	**0.83**

- ICON-Ru-EPS research version mostly overestimates precipitation.
- Case 1 is the best according to most of the scores, it can be also considered the best one according to subjective evaluation.
- However, MMI is the highest for Case 2, although it overestimates precipitation coverage. It is due to high MMI-O (analogue of the probability of detection PODY). It can be partially corrected by increasing the area ratio and area intersection ratio weights.
- The data also show the need to eliminate too small objects and to apply additional clusterisation (joining the objects within the isoline of smaller value than the threshold, e.g., 0.05 mm/h for a 0.1 mm/h threshold)

Task 2.3 Extreme Value Theory (EVT) approach –
Fitting precipitation object characteristics to different distribution

Verification of large contiguous precipitation areas using Generalized Pareto distribution, ***Anatoly Muraviev, Anastasia BundelRHM***

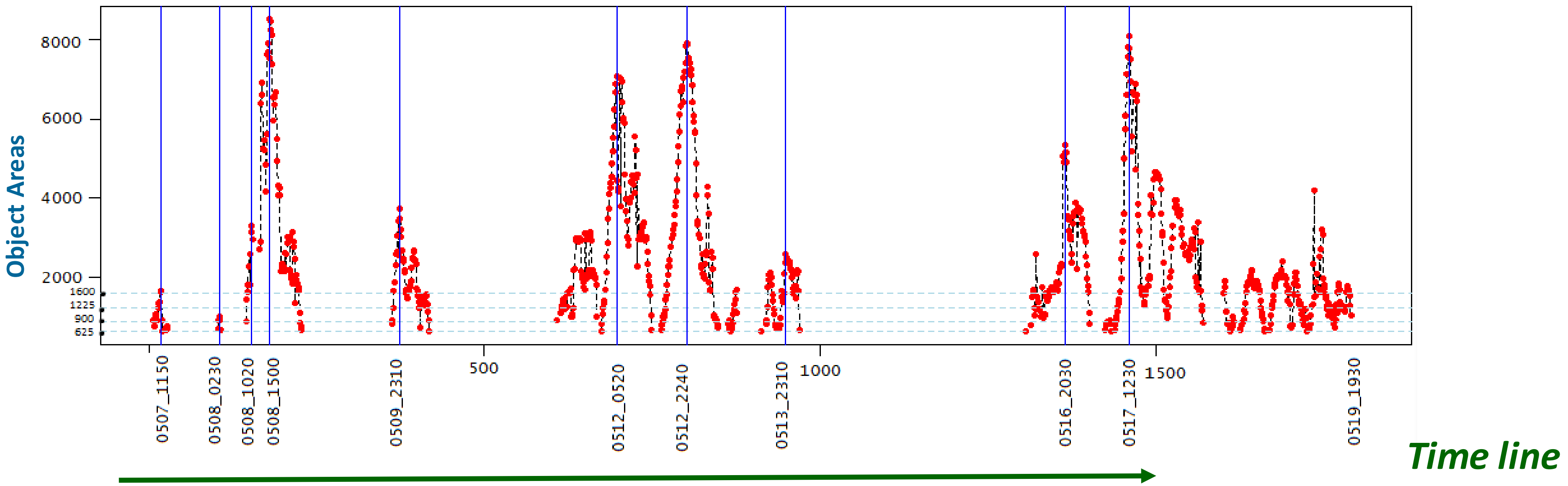
Finished. Report available. Short summary is under preparation for the Technical report. A paper is published in Hydrometeorological Research and Forecasting, in Russian, two papers are under revision in the same journal

Analysis setup

- The core of the system is the statistical STEPS scheme (Short Term Ensemble Prediction System) (*Seed 2003, Seed 2004, Bowler N. et al., 2006*)
- Verification period: Warm: May-September 2017
  Cold: November 2017-March 2018
- 9 radars in Central Russia used as observations
- 10 min time step until 3 h
- Grid size of about 2 km, 256x256 grid points domain
- R SpatialVx was used to identify objects (FeatureFinder)

Maximum areas of objects are under study

Example: Kursk radar fields from 5 to 19 May 2017. Blue lines indicate times of maximum areas within a precipitation situation for area threshold of 625 contiguous grid points



The Generalized Pareto distribution is an approximation of the Peaks over Threshold distribution, where the peaks are taken from the data of the generalized extreme value distribution. **The peaks on the time axis being the Poisson point process is the sufficient condition for satisfying the conditions of the first extreme theorem.** It was checked (using the R Poisson package) that **the times of the peaks in our data satisfy the conditions of the Poisson point process. Therefore, it justifies applying the Generalized Pareto distribution to precipitation object area maxima.**

Task 2.3 Extreme Value Theory (EVT) approach –

Fitting precipitation object characteristics to different distribution

Generalized Pareto (GP) distribution parameters were estimated using:

1. Generalized maximum likelyhood estimation (GLME)
2. Maximum likelyhood
3. L-moments
4. Bayes with Monte Carlo Markov Chain modeling

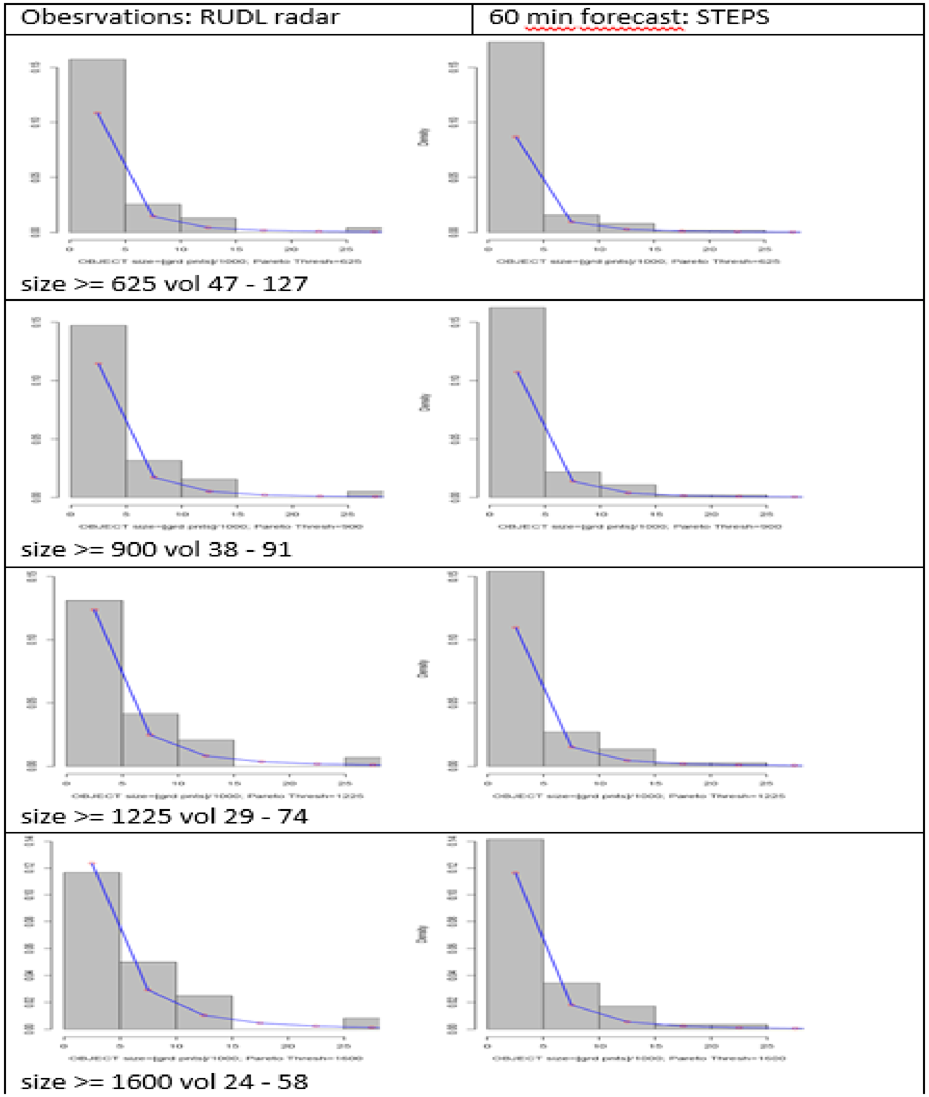
- Quality criteria (basically, Akaike and Chi-square) were calculated to estimate, which method of GP modeling is better
- **GLME was chosen as the basic method**

An example: Generalized Pareto distribution approximation of object sizes in precipitation fields in Smolensk radar observations and in STEPS for 60 min, cold period

Chi-square test values (the smaller the better) for assessing the quality of approximation by the Pareto distribution using GMLE				
Object area thresholds (in grid points)	**625**	**900**	**1225**	**1600**
Observations (Radars)	**3.604**	**3.020**	**2.056**	**1.888**
STEPS nowcasting	**12.928**	**4.424**	**3.651**	**2.909**

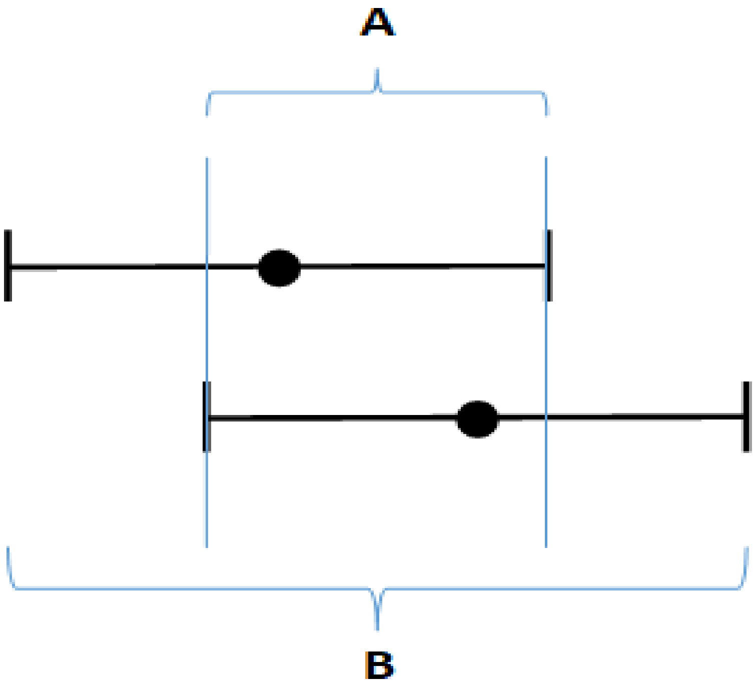
Red values reflect one of the most important condition of the second extremum theorem, ***threshold stability***: The larger the threshold, the more accurately the data is modeled by the GP distribution. In real samples of a limited size rapidly decreasing with increasing threshold, this phenomenon should be recognized as a rare success. It was not observed for all the radars, 625 and 900 points threshold were chosen as basic ones.

An example: Generalized Pareto distribution approximation of object sizes in precipitation fields in Smolensk radar observations and in STEPS for 60 min, cold period



Histograms and Pareto distribution approximation of object sizes in precipitation fields in Smolensk observations (RUDL, left column) and in forecasts (STEPS-60, right column) for 60 min. **The Pareto threshold is (from top to bottom) 625, 900, 1225 and 1600 field points.** Dimensions are given in size/1000 scale. **Blue lines are modeled Pareto distributions**

A measure of STEPS quality: intersection ratio (IR) of confidence intervals of Generalized Pareto parameters estimates (σ and ξ) in STEPS and in observations (radars)



intersection ratio (IR) = A/B
Ideal intersection ratio = 100%
IR >= 50% : chosen empirically as a useful skill level

The intersection ratio gives a diagnostic estimate of model ability to reproduce vast contiguous precipitation areas (or other extremes)

Final IR table

RADAR	threshold\ lead time	IR (%) SCALE warm period 625	IR (%) SCALE warm period 900	IR (%) SCALE cold period 625	IR (%) SCALE cold period 900	IR (%) SHAPE warm period 625	IR (%) SHAPE warm period 900	IR (%) SHAPE cold period 625	IR (%) SHAPE cold period 900
RAKU	30	80	74	75	68	84 (+ +)	74 (+ +)	78 (+ +)	47 (0 +)
	60	83	77	50	63	85 (+ +)	76 (+ +)	68 (+ +)	44 (0 +)
	90	83	73	23	38	83 (+ +)	76 (+ +)	54 (+ +)	33 (0 +)
	120	79	68	21	20	80 (+ +)	72 (+ +)	54 (+ +)	23 (0 +)
RATL	30	39	27	62	78	74 (+ +)	41 (0 +)	78 (+ +)	87 (+ +)
	60	48	23	52	55	72 (+ +)	36 (0 +)	69 (+ +)	71 (+ +)
	90	35	17	47	53	66 (+ +)	32 (0 +)	67 (+ +)	69 (+ +)
	120	34	19	50	62	65 (+ +)	34 (0 +)	68 (+ +)	73 (+ +)
RAVO	30	54	38	70	76	78 (+ +)	40 (0 +)	76 (+ +)	71 (+ +)
	60	58	37	64	74	76 (+ +)	36 (0 +)	72 (+ +)	67 (+ +)
	90	56	46	61	63	77 (+ +)	38 (0 +)	66 (+ +)	63 (+ +)
	120	52	35	50	64	69 (+ +)	34 (0 +)	64 (+ +)	60 (+ +)
RUDB	30	92	88	75	78	93 (+ +)	91 (+ +)	72 (+ +)	72 (+ +)
	60	87	90	48	67	91 (+ +)	92 (+ +)	60 (+ +)	64 (+ +)
	90	81	94	46	56	92 (+ +)	94 (+ +)	56 (+ +)	57 (+ +)
	120	88	92	44	56	89 (+ +)	92 (+ +)	55 (+ +)	56 (+ +)
RUDK	30	78	85	69	73	80 (+ +)	79 (+ +)	75 (+ +)	70 (+ +)
	60	76	80	54	68	75 (+ +)	74 (+ +)	64 (+ +)	64 (+ +)
	90	80	82	50	60	76 (+ +)	74 (+ +)	60 (+ +)	57 (+ +)
	120	72	80	52	50	74 (+ +)	73 (+ +)	56 (+ +)	53 (+ +)
RUDL	30	75	63	47	52	80 (+ +)	76 (+ +)	72 (+ +)	71 (+ +)
	60	73	64	32	47	76 (+ +)	73 (+ +)	64 (+ +)	63 (+ +)
	90	68	57	40	45	73 (+ +)	69 (+ +)	62 (+ +)	61 (+ +)
	120	71	66	41	42	74 (+ +)	70 (+ +)	59 (+ +)	57 (+ +)
RUDN	30	78	85	87	70	89 (0 0)	80 (0 0)	87 (+ +)	89 (+ +)
	60	52	86	57	71	38 (0 +)	78 (0 0)	69 (+ +)	71 (+ +)
	90	38	83	54	58	30 (0 +)	79 (0 0)	65 (+ +)	63 (+ +)
	120	31	84	57	54	27 (0 +)	80 (0 0)	64 (+ +)	59 (+ +)

Particular attention is paid to the shape parameter, the positive sign of which indicates a heavy tail in the distribution: the larger the value of the shape parameter, the heavier the tail

Precipitation nowcasting system better predicts objects of extreme size in the cold season. The number of pairs (++) in the warm period according to the table is about half of the cases, and in the cold season, about 75%.

Only with a clear understanding of the theoretical prerequisites and using suitable statistical methods and reliable data processing tools, is the extreme value theory quite applicable to such objects of analysis and short-term forecasting as significant contiguous precipitation areas

ideas for PP-AWARE continuation

I. Stressing of observations role in HIW

✓ **new obs types use in the evaluation of forecasted phenomena (severe convection, fog).**

Obs Types:

Remote sensing. Use of satellite products (e.g. cloud oprical thickness, brightness temp, LWR, SWR) to evaluate characteristics of convection, NWC-SAF products for fog verification

Crowd-sourced data: third party and citizen met stations, smart phones, web & social media etc. usefulness for NWP predictions and evaluation - **Included in New PP idea presented by IMGW-PIB**

✓ **observation uncertainty and impact on scores**

II. Verification scheme for convection permitting ensemble forecasts

✓ **object-based approaches:** methodology and criteria for reduction/summarizing of object information, metrics for performance evaluation, visualisation

Long term activity of DWD though SINFONY project

✓ **build of a robust common verification framework for sensitivity tests**

Lack of participation does not allow in the present time for an organized PP on verification schemes, still a permanent activity within WG5. Special focus on EPS applications

Thank You

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