

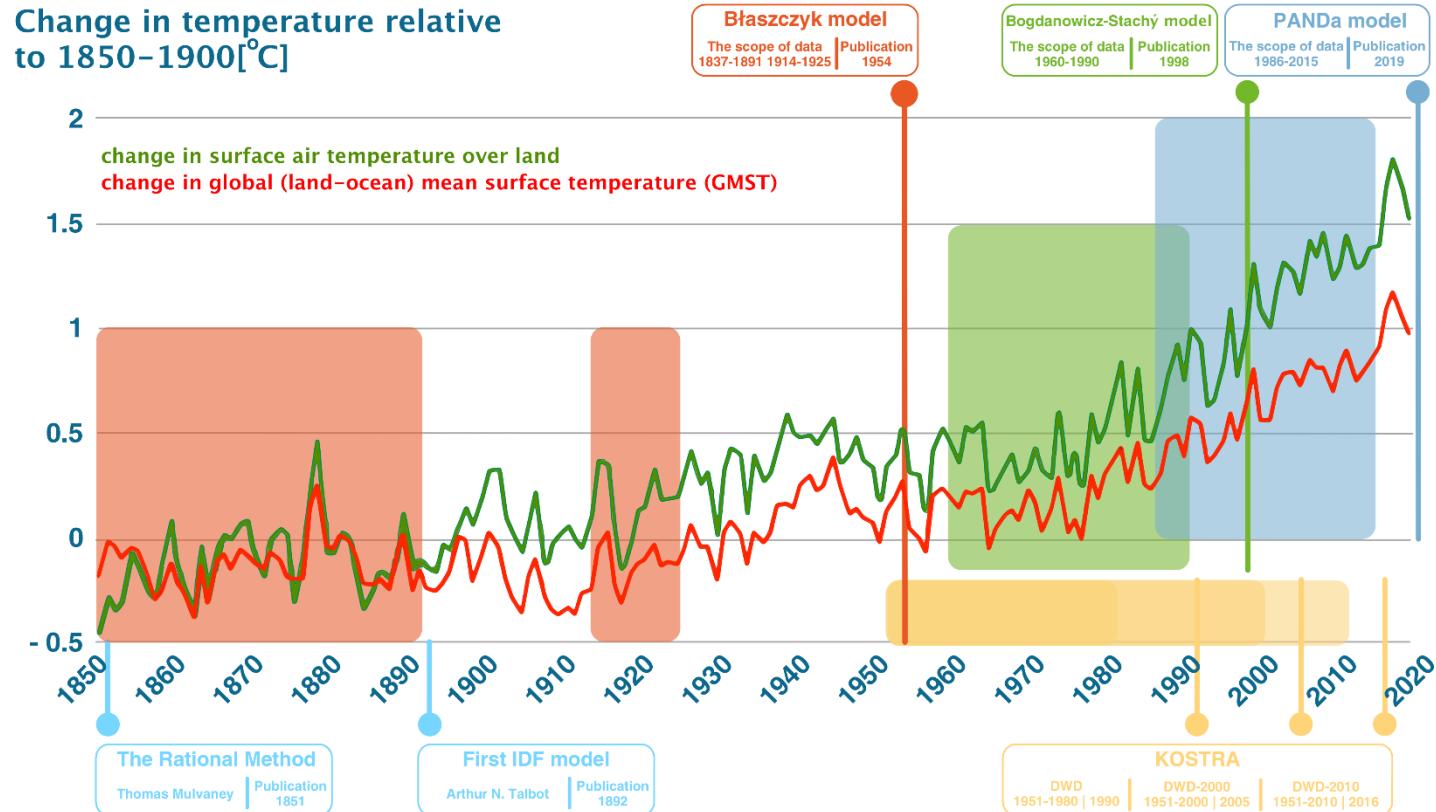


Going digital in stormwater management Polish Atlas of Rains Intensities (PANDa/PARIs)

Paweł Licznar

Faculty of Environmental Engineering
Wrocław University of Technology
Wrocław, Poland
Retencja.pl
Gdansk, Poland

Why to talk about extrems?



Could we make things better?

- ✓ Modern precipitation monitoring: electronic gauges, networks of gauges instead of single devices
- ✓ Alternative rainfall data sources - e.g. C-band weather radar products
- ✓ Fully digital rainfall series processing
- ✓ Geostatistics (geostatistical simulations) – allowance for spatial variability and uncertainty
- ✓ Statistical modeling of extremes – probabilistic DDF/IDF models
- ✓ Digital delivery of extreme precipitation models to end-users

PARIs (PANDa) project

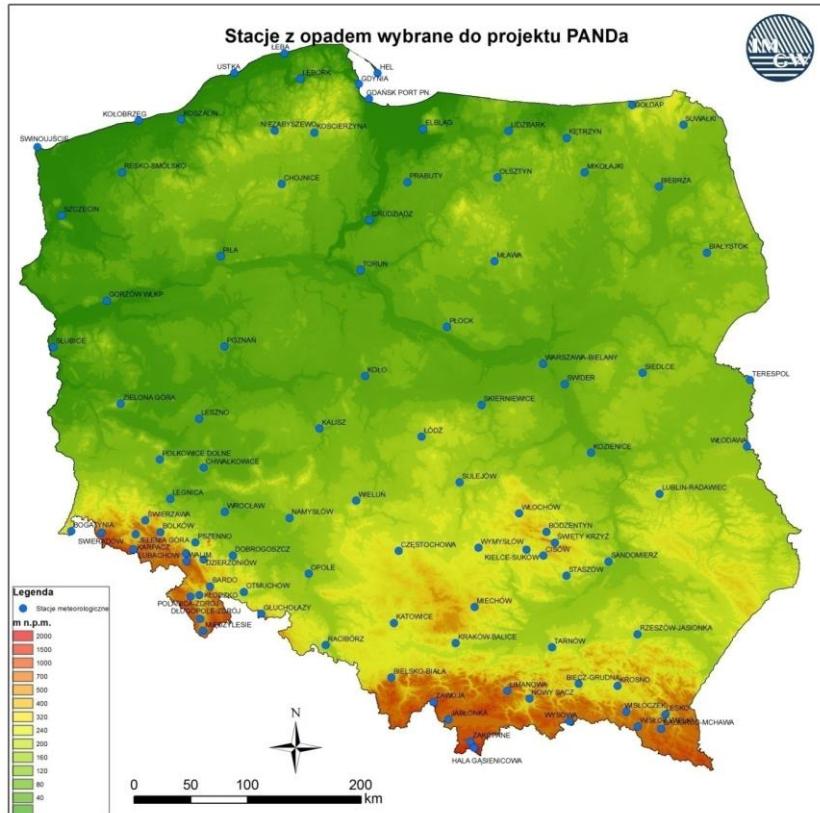
Project title: Development and introduction of the Polish Atlas of Rainfall Intensities (PARIs - PANDa)

Grant number POIR.01.01.01-00-1428/15

Operational Program of Intelligent Development 2014-2020



- ✓ 100 gauges
- ✓ a 30-year time series (1986-2015)
- ✓ high resolution time series (single minutes)

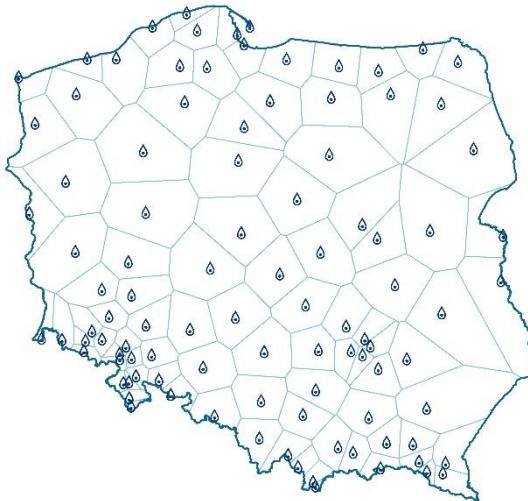


PARIs (PANDa) project milestones

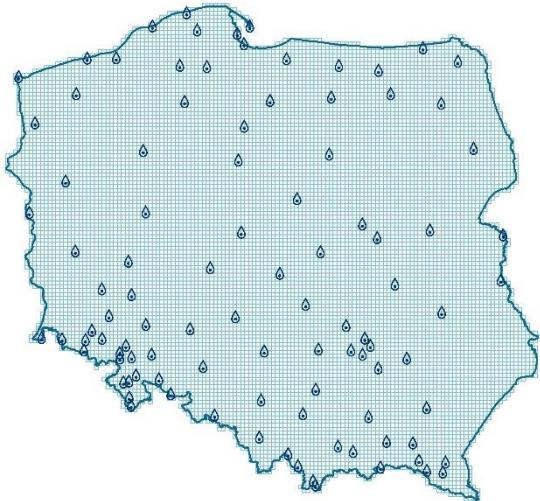
- 1) Rainfall digital database
- 2) Selection of maximum precipitation depths and best fitting distributions
- 3) Geostatistical simulations and digital platform on web



2016

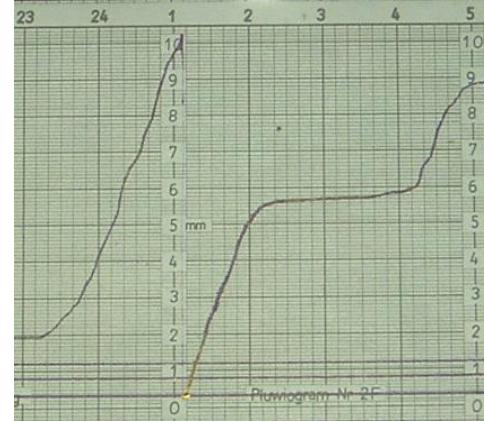


2018



2019

Raingauges yesterday and today



Pluviograph



RG-50 SEBA



Met One
Instruments 60030

Digitalization of rainfall records

59% of database
1782 out of 3000 years

The screenshot shows a software interface for digitizing rainfall records. On the left, there's a toolbar with various drawing and selection tools. The main area features a graph of rainfall data over time, with a red box highlighting a specific section. Below the graph is an Excel spreadsheet with columns labeled A through O. The first few rows of data are as follows:

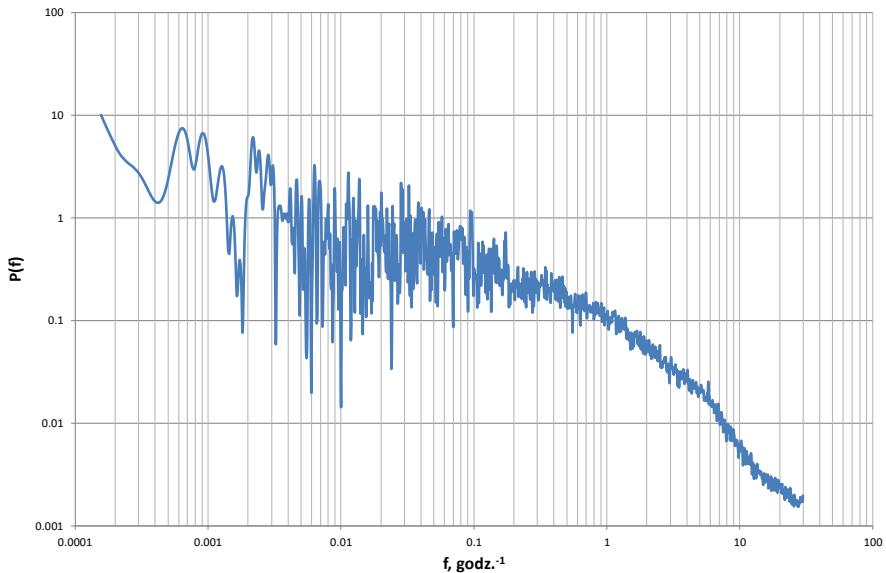
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Data i godzina	Przyrost czasu	Przyrost opadu	Warstwa opadu	Uwagi									
2	12-05-89 00:00:00			0.0	początek rejestracji									
3														
4	13-05-89 4:05:19	8.85E-02	0.35299813	0.4										
5	13-05-89 4:08:36	5.49E-02	0.744372698	1.1										
6	13-05-89 4:14:42	0.10445586	1.6883904	2.8										
7	13-05-89 4:20:49	0.2089105	1.4097000	4.3										
8	13-05-89 4:40:04	0.195906468	1.13933171	6.4										
9	13-05-89 4:46:07	0.100837746	1.823908702	7.2										
10	13-05-89 4:52:39	0.109010532	1.04967881	8.3										
11	13-05-89 5:01:01	0.109010531	0.54196949	8.8										
12	13-05-89 5:23:10	0.215687726	0.29815773	9.1										
13	13-05-89 5:31:15	0.134465158	0.186693025	9.3										
14	13-05-89 5:38:27	5.78E-02	0.631887498	9.9										
15	13-05-89 5:43:27	7.69E-02	0.4461600487	10.4										
16	13-05-89 5:43:04	0.344218481	0.136915199	10.5										
17	13-05-89 6:03:43													
18	13-05-89 16:00:00	0												
19														
20	14-05-89 16:13:28	3.96E-02	9.28E-02	10.6										
21	14-05-89 16:28:41	0.263747995	8.47E-02	10.7										
22	14-05-89 16:33:34	8.13E-02	0.645326271	11.6										
23	14-05-89 16:37:31	0.109010531	0.44796949	12.0										
24	14-05-89 16:48:34	0.150910673	0.122745259	12.1										
25	14-05-89 16:52:50	7.12E-02	2.683256729	14.8										
26	14-05-89 16:57:58	0.63E-02	1.793363301	16.6										
27	14-05-89 17:02:16	0.109010531	0.165678306	16.8										
28	14-05-89 17:51:22	0.757403074	1.21E-02	16.8										
29	14-05-89 18:29:57	0.643104966	0.115562015	16.9										
30	14-05-89 21:25:19	2.922639799	2.45E-02	16.9										

Below the table is a line graph showing the cumulative rainfall over time from May 14, 1989, to May 15, 1989.

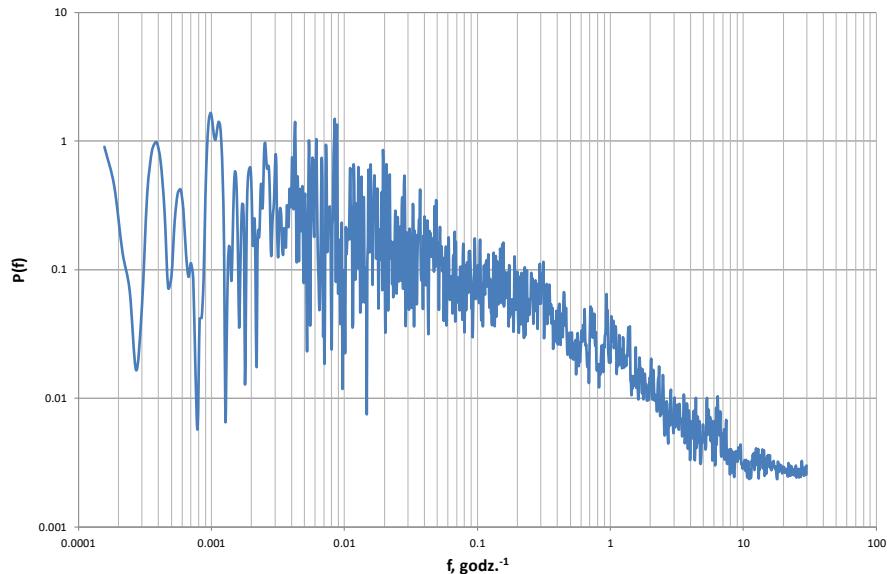
Verification of rainfall series structure

Fast Fourier Transform (FFT)

$$P(f) = f^{-\beta}$$

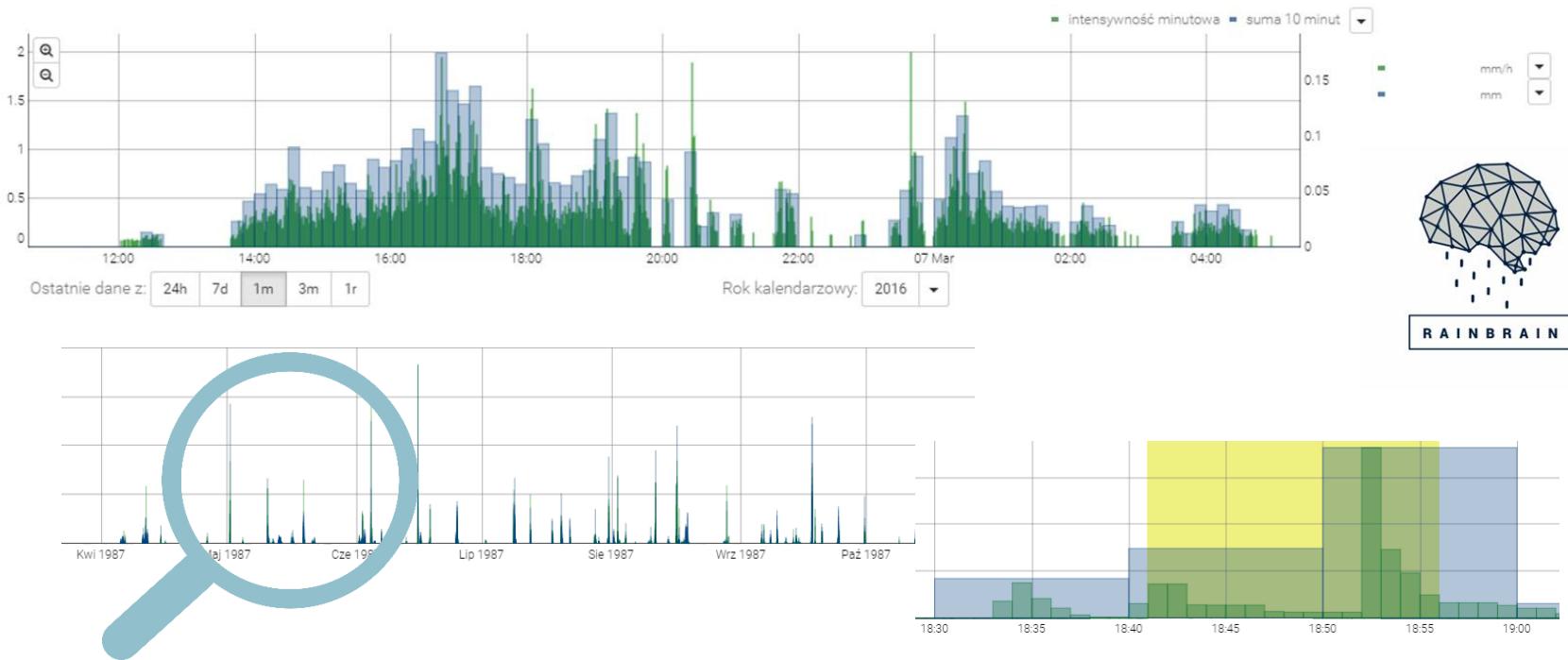


Digitized annual time series



Tipping bucket annual time series

Digital rainfall series processing - RAINBRAIN database



Years: 1986



AMS method:



POT method:



Extremes – maximum depths and rainfall intensities

26 czerwca 1988 20:11 UTC	
1138.58667	66
315.88260	25
313.54447	24
297.11666	21
296.66666	19
281.21387	18
280.00000	196.66667
267.35527	188.76470
266.66667	188.33333
263.00883	184.68713
259.91683	178.90732
249.50907	177.03235
246.66667	175.45258
240.00000	173.61222
239.12033	171.66667
231.81207	
230.00000	
220.66653	
220.41387	
213.89200	
210.00000	
210.00000	
206.66667	
203.33333	148.33333
201.97167	146.04348
201.80233	141.66667
197.63667	141.66667
196.66667	138.90081

		60. maksymalnych średnich natężień I, l/s/ha dla okresu (w min):																	
		15	30	45	60	90	120	180	360	720	1080	1440	2160	2880	4320				
1138.58667	66	443.81112	222.42811	148.32376	111.27159	75.43173	57.53217	38.69501	20.23148	10.11574	7.28395	5.99537	5.30864	4.03935	2.92438				
315.88260	25	190.59347	143.60547	108.51852	88.33333	65.92593	55.13889	36.85185	19.39367	9.89871	6.59914	5.17704	4.50617	3.98727	2.65818				
313.54447	24	183.67849	131.11111	107.77778	82.22222	60.55556	45.97222	31.66667	16.86027	9.49120	6.58273	4.97685	4.08060	3.12962	2.12787				
297.11666	21	182.22222	122.77778	98.45736	74.66036	52.69380	42.63778	29.53704	16.25350	9.21211	6.42540	4.94936	3.82781	2.90143	2.04307				
296.66666	19	170.00000	116.73533	90.50576	69.14689	49.88281	39.16667	29.50611	16.15741	8.19444	5.98765	4.81905	3.69067	2.76800	1.95851				
281.21387	18	154.44444	107.31244	77.82758	66.28815	49.29897	38.40005	28.97992	16.15741	8.10185	5.75617	4.36343	3.59568	2.71412	1.90972				
280.00000	196.66667	154.44444	100.55556	75.41428	58.96970	47.81608	37.66211	28.42593	15.46296	8.07870	5.46296	4.31713	3.49700	2.64749	1.90771				
267.35527	188.76470	150.33533	97.77778	69.62963	58.37370	45.37263	37.44056	26.57407	14.92519	7.73148	5.40123	4.25127	3.42684	2.57245	1.89043				
266.66667	188.33333	148.15452	90.72777	67.83803	55.83333	43.52467	36.44177	26.52827	14.72391	7.51842	5.33788	4.23611	3.21270	2.40953	1.85059				
263.00883	184.68713	146.66667	89.44444	67.40741	54.16667	41.11111	35.83144	26.45331	14.58333	7.50000	5.15432	4.16971	3.09115	2.32639	1.84534				
259.91683	178.90732	146.66667	88.33333	65.74626	53.70603	39.97937	34.58333	26.02508	14.42858	7.48262	4.99433	4.13290	3.04327	2.28296	1.72941				
249.50907	177.03235	145.68718	86.30810	64.89285	53.44930	39.83198	34.39080	25.80620	13.53161	7.37299	4.94765	4.05093	3.02165	2.26624	1.71296				
246.66667	175.45258	145.66872	86.18534	61.85185	52.25586	38.91982	33.25167	25.08207	13.42593	7.29678	4.93870	3.91204	2.96462	2.25113	1.60645				
240.00000	173.61222	131.77646	84.14216	61.17591	51.76271	38.19681	31.60282	24.96357	13.06050	7.13445	4.92269	3.89521	2.96126	2.24926	1.60214				
239.12033	171.66667	131.34774	83.88889	60.37037	51.11111	37.77778	29.19288	23.91094	13.00926	7.05254	4.90973	3.86574	2.90895	2.22095	1.58433				
231.81207																1.55093			
230.00000																1.54707			
220.66653																1.52963			
220.41387																1.52531			
213.89200																1.52392			
210.00000																1.52197			
210.00000																1.51572			
206.66667																1.50076			
203.33333	148.33333	117.55423	76.19233	55.40645	44.19598	32.77778	26.38889	18.98148	10.41667	6.46402	4.51054	3.62269	2.65432	2.06019	1.47948				
201.97167	146.04348	117.38598	76.15031	55.37494	43.54666	31.81938	25.97222	18.81123	10.12275	6.43519	4.47679	3.62143	2.57716	2.02546	1.45833				
201.80233	141.66667	114.44444	71.69184	55.20281	42.50000	30.98238	25.56821	18.24074	10.11863	6.40699	4.47531	3.61111	2.56903	2.01736	1.45361				
197.63667	141.66667	113.33333	69.21354	55.18519	42.19388	30.74074	25.30796	18.16021	10.04164	6.38889	4.45988	3.56648	2.50043	2.01389	1.44775				
196.66667	138.90081	112.28709	69.21109	53.51678	41.66667	30.37037	24.68541	18.14815	9.95370	6.37076	4.43460	3.54852	2.46405	1.99074	1.43133				

Maximum rainfall intensities (years 1986-2015) for time durations:
5, 10, 15, 30, 45, 60, 90, 120, 180, 360, 720, 1080, 1440, 2160, 2880, 4320 minutes

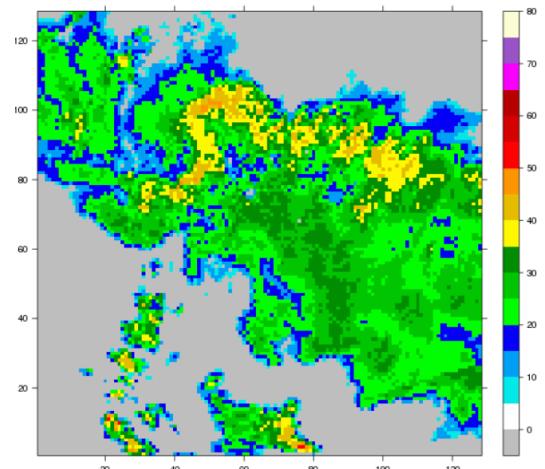
Dates are important for verification...

Verification of maximum rainfall intensities

- 1) Independent records of daily gauges
- 2) Synoptic records (eg. Climate Forecast System (CFS) wetter3.de/Archiv)
- 3) Weather radar data (2007-2015)



Radar precipitation, 06 Aug 2010 18:45





Verification: gauge vs radar series

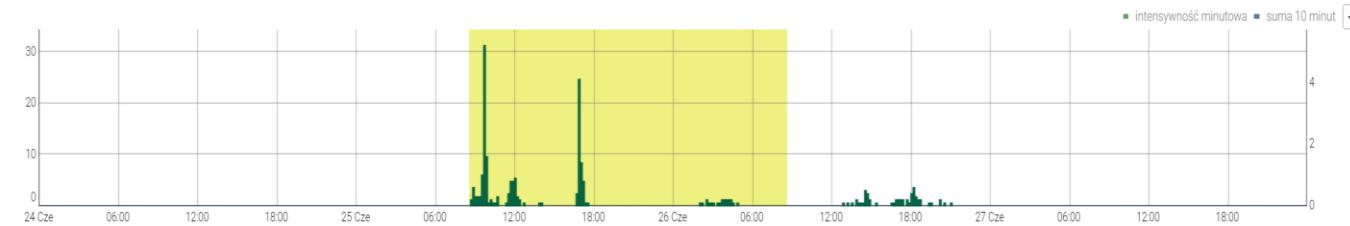
* Gdańsk-Port Północny

0.01 mm

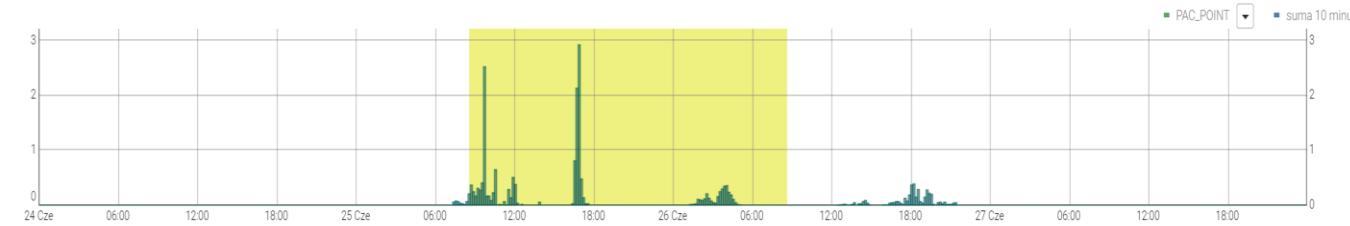
⌚ 2018-05-12 17:49:15 UTC ⌚ 2018-05-12 19:49:15 CEST

Status Analiza opadów Maksima opadów Dane radarowe Zdarzenia

Gauge



Radar PAC



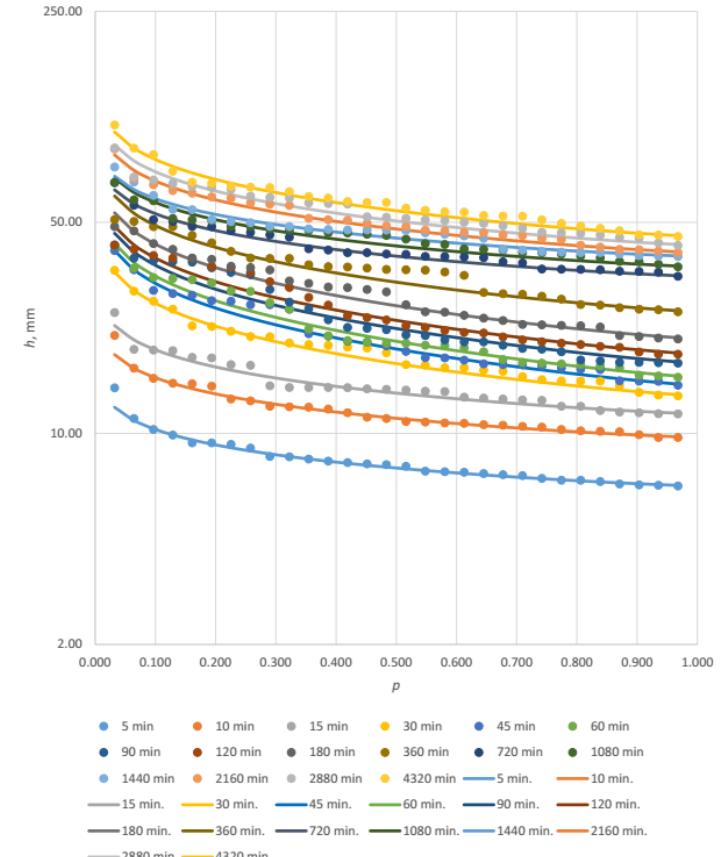
Radar QI



Fitting distributions – selecting the best distribution

16 time durations from 5 to 4320 min (each 30 maximum rainfall depths)

Distributions tested: gamma (Pearsona typ III), Gumbela Max (Fishera-Tippetta typ I max), log-normal, Weibull (Fishera-Tippetta typ III min), generalized logistic, **generalized Pareto**, generalized extreme value (GEV), Wakeby



Statistical tests of Kołmogorow-Smirnow, chi-square (χ^2) and Anderson-Darling Akaike information criterion (AIC)

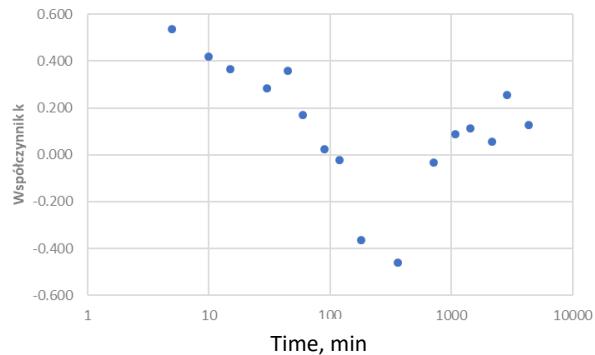
Generalized Pareto distribution

Generalized Pareto density function:

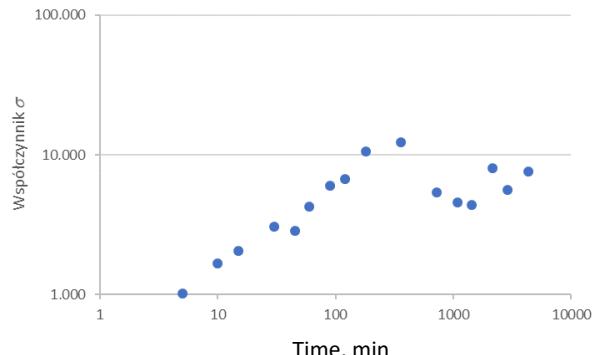
$$f(x; k, \sigma, \mu) = \begin{cases} \frac{1}{\sigma} \left(1 + k \frac{(x - \mu)}{\sigma}\right)^{-1-1/k} & k \neq 0 \\ \frac{1}{\sigma} \exp\left(-\frac{(x - \mu)}{\sigma}\right) & k = 0 \end{cases},$$

Generalized Pareto quantile:

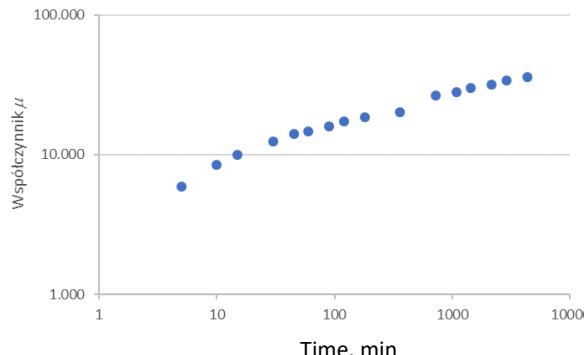
$$X_{(\mu, p')} = \begin{cases} \frac{\sigma(1 - (1 - p')^{-k})}{-k} + \mu, & k \neq 0 \\ -\sigma \log(1 - p') + \mu, & k = 0 \end{cases},$$



Shape parameter k

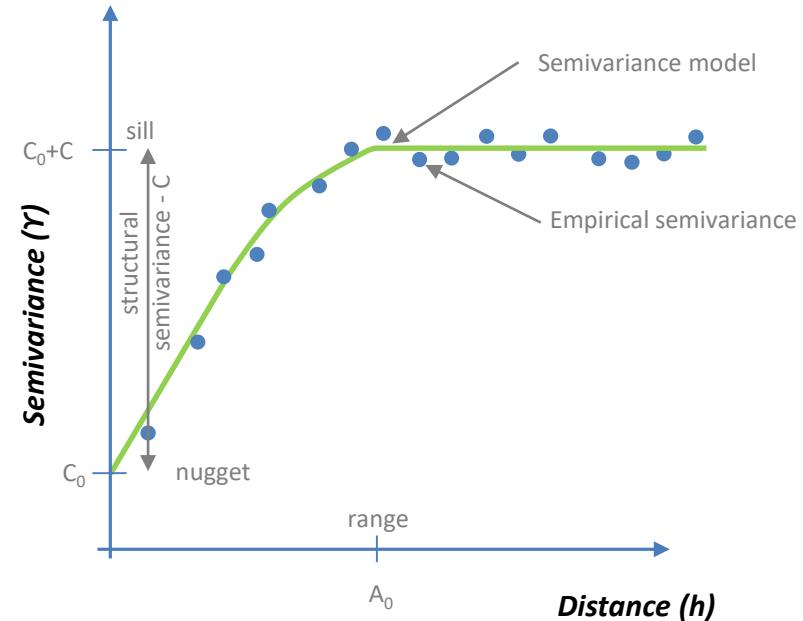
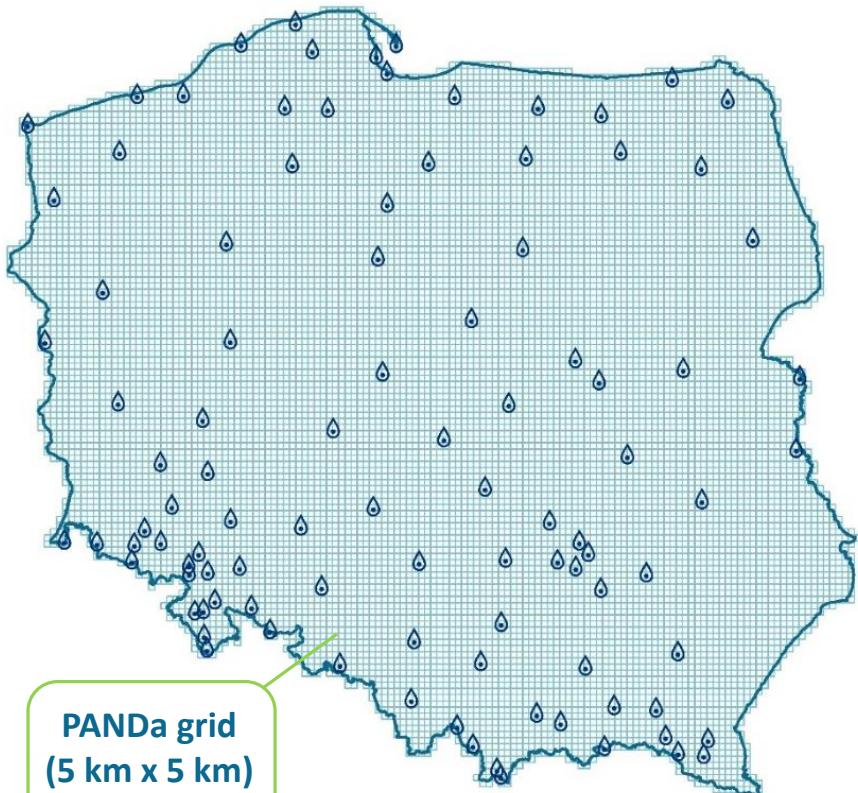


Scale parameter σ



Location parameter μ

Spatial interpolation of extremes – geostatistics (kriging)



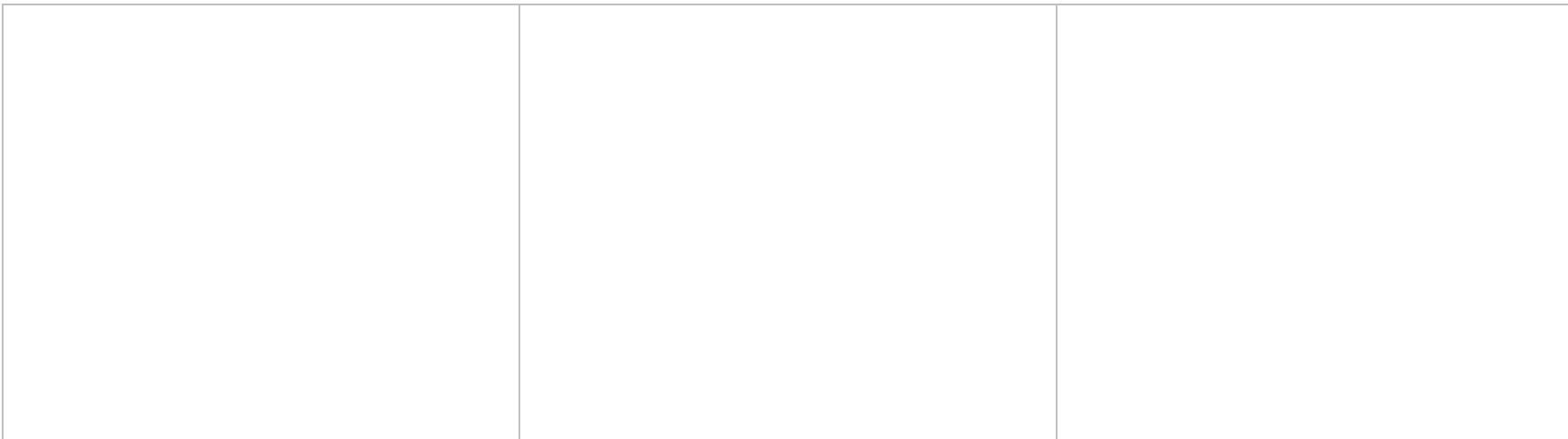
$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i + h) - Z(x_i)]^2$$

Spatial autocorrelation - semivariograms analysis

Points: 100+25 gauges

480 combinations: 16 time durations times 30 extremes

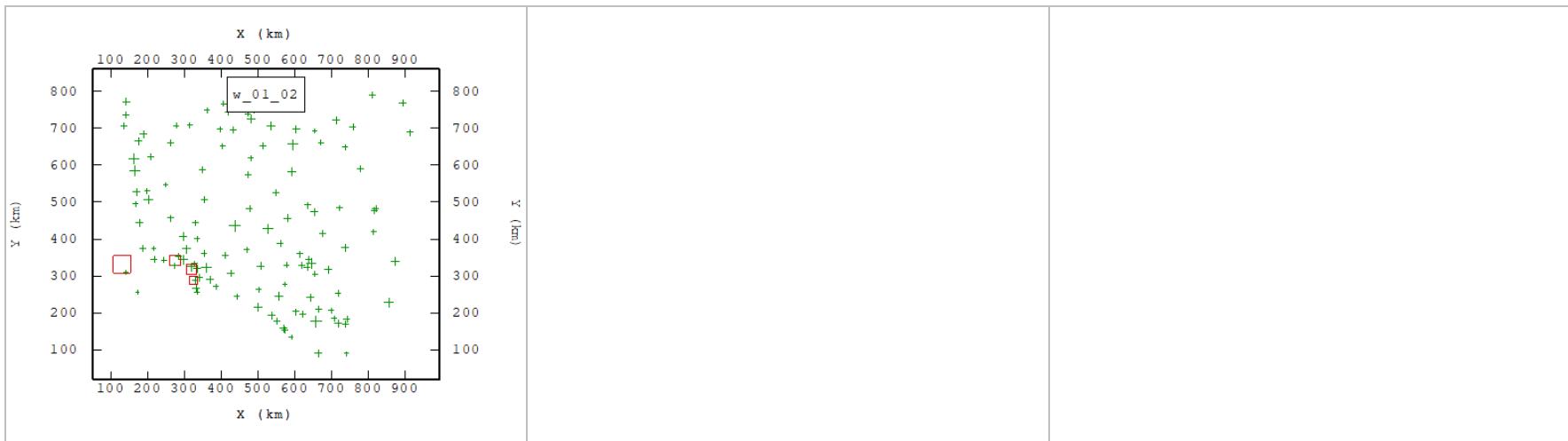
Example: maximum 10-min duration depths, 2nd maximum



Spatial autocorrelation - semivariograms analysis

Masking outliers

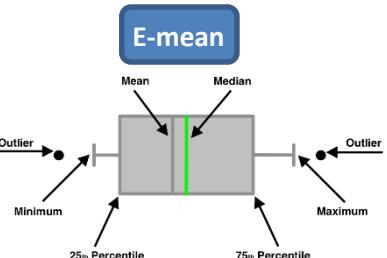
Combining semivariograms models: circular, spherical, exponential, gaussian, nugget – eg. N-S-S



Geostatistical simulations – allowance for uncertainty

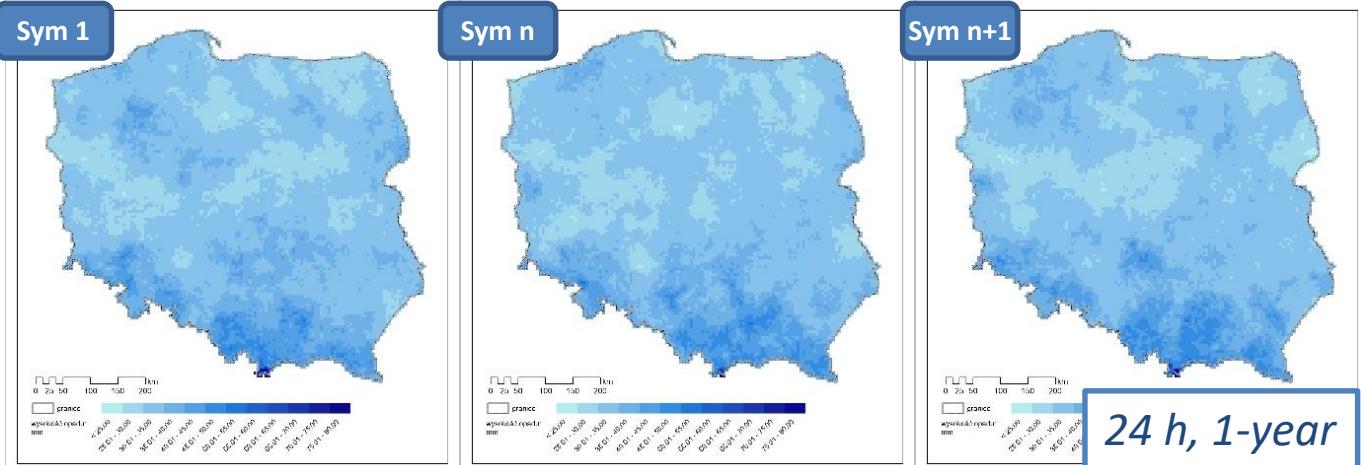


Direct Sequential
Simulation – DSSIM

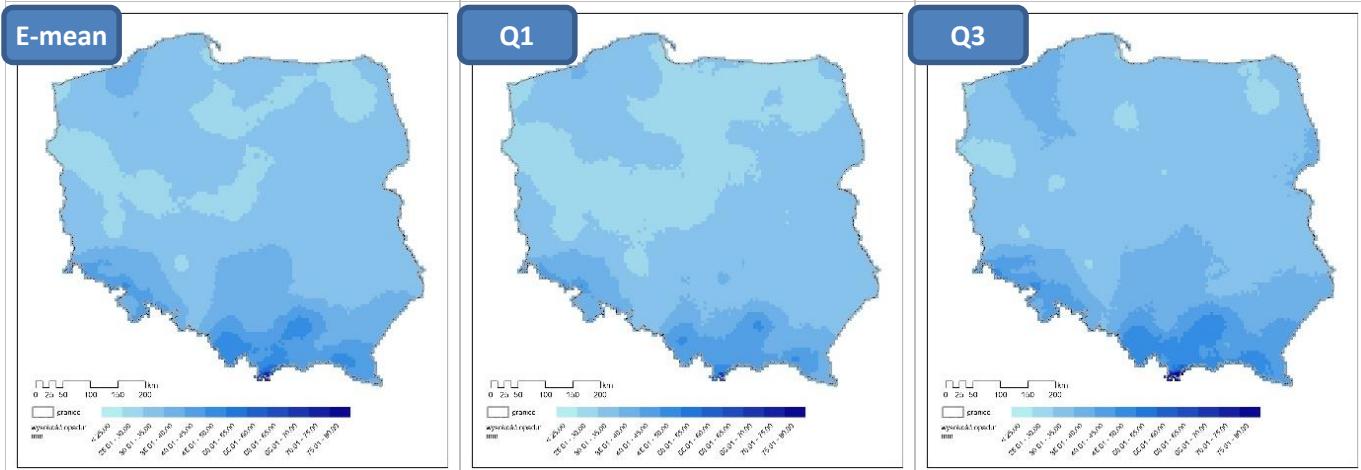


Q1

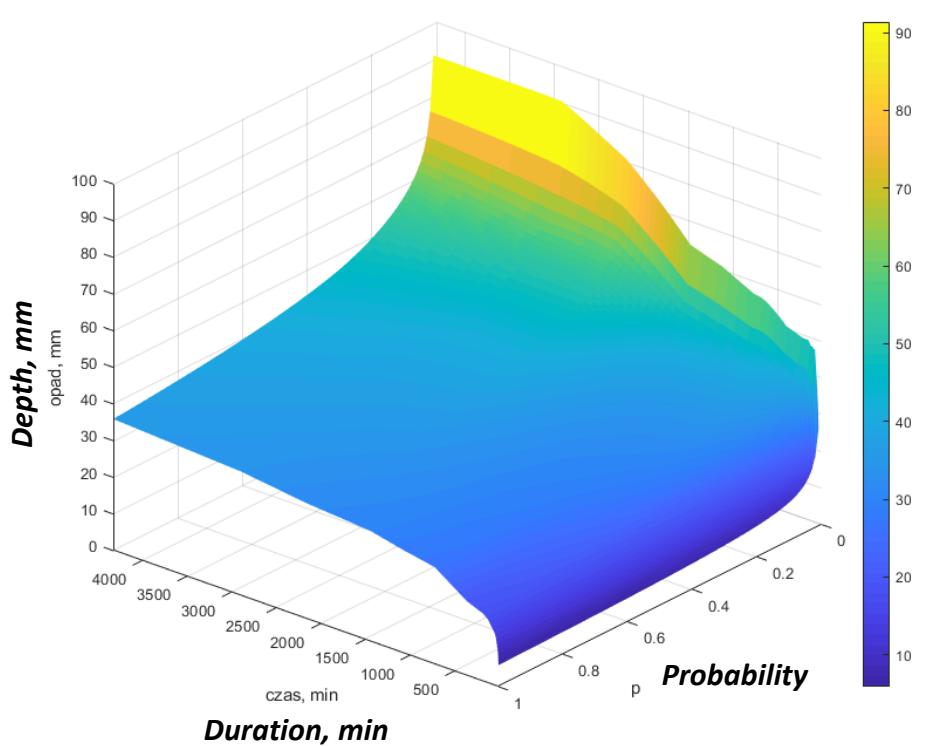
Q3



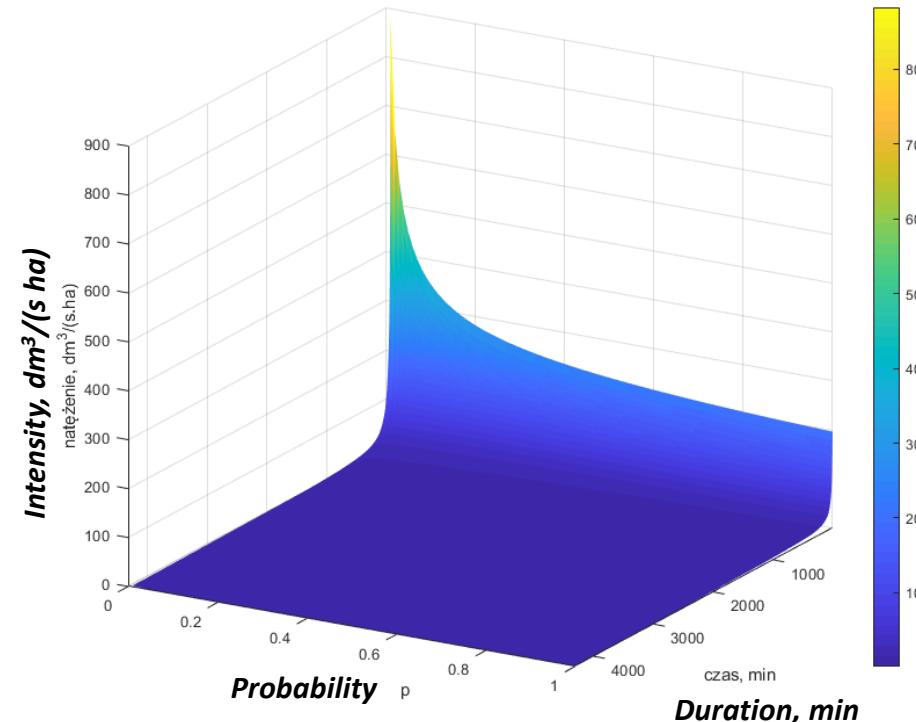
24 h, 1-year



Probabilistic DDF/IDF models

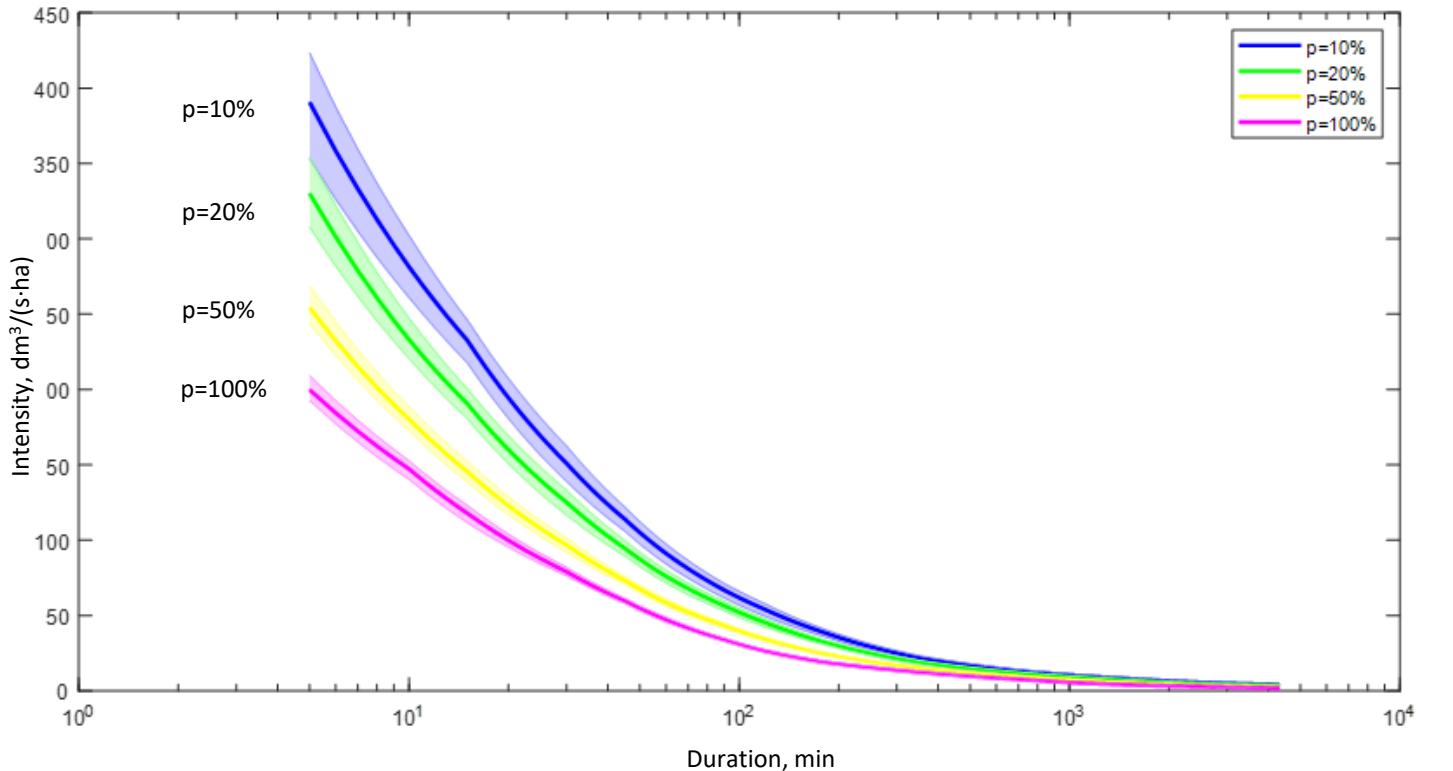


DDF model based on E-mean and generalized Pareto distribution (GPD)

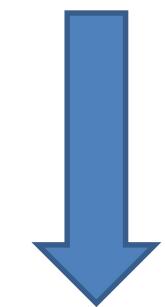
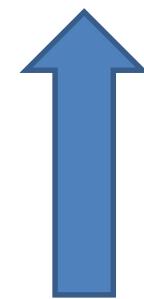


IDF model for frequencies from C=1 year ($p=1$) to C=100 years ($p=0,01$) and time duration from 5 to 4320 min

Selected (5km x 5km) pixel – IDF confidence intervals



shorter
more
violent



Less
confident

Selected (5km x 5km) pixel – IDF confidence intervals

Intensity, $\text{dm}^3/(\text{s}\cdot\text{ha})$

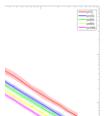
p= 1%

p=10%

p=20%

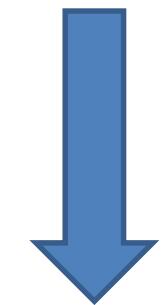
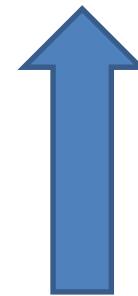
p=50%

p=100%



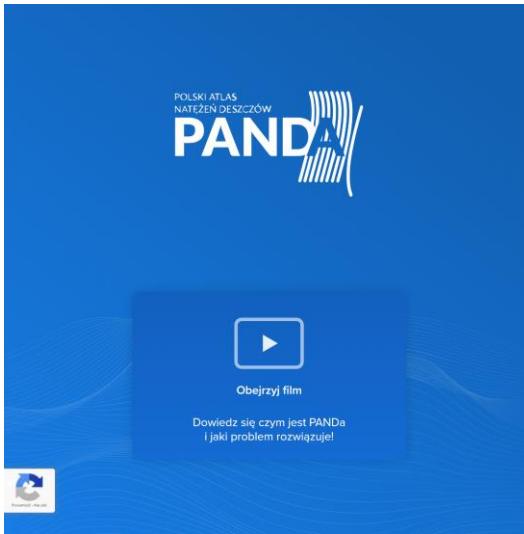
Duration, min

More
extreme



Less
confident

<https://portal.atlaspanda.pl/login>



Logowanie

Adres e-mail

Hasło

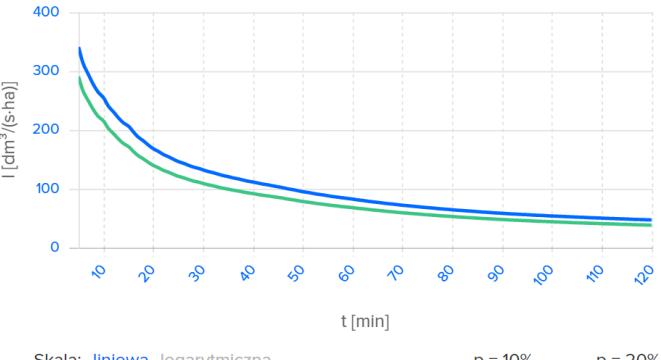
Zapominałeś hasła?

ZALOGUJ

Nie masz jeszcze konta? [Zarejestruj się](#)



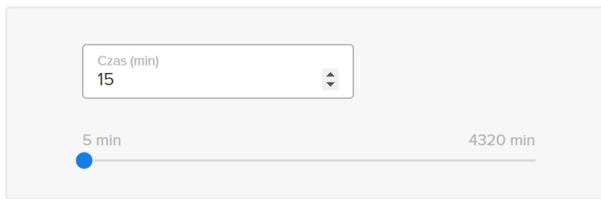
Natężenie deszczu I dla różnych czasów trwania t wg modelu PANDa



Skala: liniowa logarytmiczna

p = 10% **p = 20%**

Obszar wykresu



Natężenie deszczu miarodajnego o czasie trwania 15 min dla wybranych prawdopodobieństw (wraz z przedziałem ufności)

10%

206.1 $\text{dm}^3/(\text{s}\cdot\text{ha})$ ⓘ
(200.6 - 212.2)

20%

171.4 $\text{dm}^3/(\text{s}\cdot\text{ha})$ ⓘ
(167.7 - 175.6)

The background image shows a wide-angle view of a city, likely Vienna, Austria, from a high vantage point. The foreground is filled with lush green trees and grassy fields. In the middle ground, the dense urban landscape of the city is visible, with numerous buildings, roads, and a river. The sky above is a vibrant blue, dotted with large, billowing white clouds. On the right side, darker, more turbulent clouds suggest an approaching storm.

Thank you for your
attention