Hydrological validation of H–SAF precipitation products on Polish basins from different regions (lowland, upland, mountainous catchments)

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ECMWF/ H-SAF and HEPEX Workshops on coupled hydrology

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The main goals of hydrological validation

The main goals of HV

OE 5100

Product interfacing and utilization improvement

Make software for blended products

Perform the analysis of possible product utility for hydrological tasks

Development of tools to assimilate soil moisture and snow cover products to hydrological models

Development of tools (software) for data format conversion acceptable by hydrological models

Sensitivity analysis – influence of each product on final output data

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OE 5200

Impact studies and hydrological validation

Hydrological validation of Products

Satelital data assesment and model calibration

Case studies

Hydrological Validation

Hydrological validation of operational or pre-operational H-SAF products:

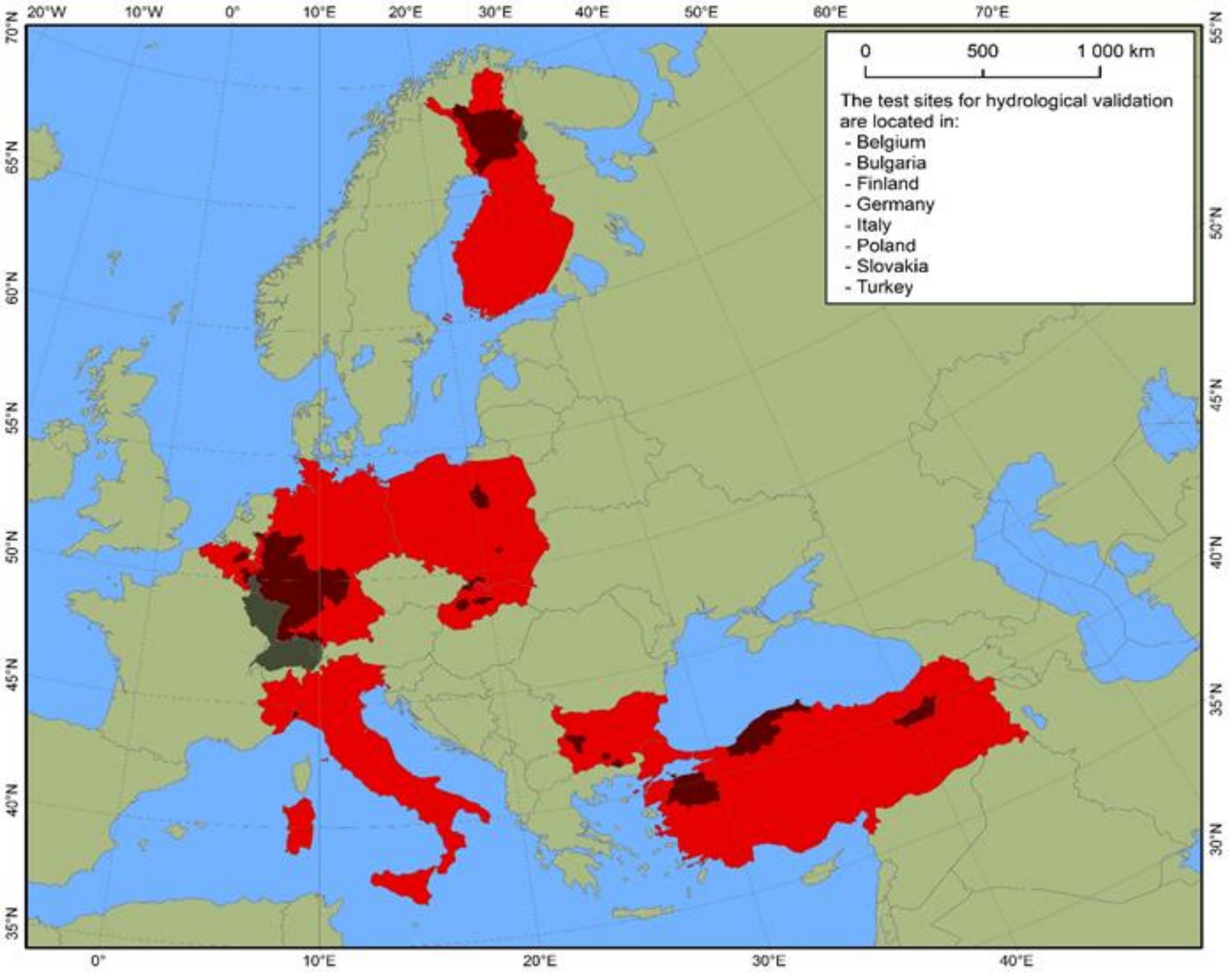
- PR: H03; H04; H05
- SM: H08; H14
- SN: H10; H12; H13

Results are presented in
Hydrological Impact Validation Report (HVR)

Validation Teams, test sites, models

Country	Test site	Hydrological model
Belgium	Demer-Scheldt	SCHEME (SCHEldt and model)
	Ourthe-Meuse	
Bulgaria	Iskar River	Artificial Neural Networks (ANN)
	Varbica river	Mike-11/NAM (Nedbør-Afstrømmings Model) and Isba-Modcou model
	Chepelarska	
Finland	Ounasjoki	Variable Infiltration Capacity (VIC) Model version 4.1.2f
Germany	Rhine	HBV (Hydrologiska Byrans Vattenbalansavdelning model), LARSIME (Large Area Simulation Model)
Italy	Orba	Continuum Model
Poland	Soła	HBV (Hydrologiska Byrans Vattenbalansavdelning model), SRM
	Raba	
	Czarna and Lagowianka	
	Wkra	
Slovakia	Nitra	Hron-NAM (Hron and Nedbør-Afstrømmings Model)
	Kysuca	
	Hron	HBV (Hydrologiska Byrans Vattenbalansavdelning model)
Turkey	Susurluk	HEC-HMS (The Hydrologic Engineering Center – Hydrologic Modeling System)
	Western Black Sea	
	Upper Euphrates	SRM (Snowmelt Runoff Model)
	Kırkgöze	HBV (Hydrologiska Byrans Vattenbalansavdelning model)

Validation Teams, test sites, models



Status of validation

Country		Product							
		H03	H04	H05	H08	H14	H10	H12	H13
Belgium		-	-	YES	-	-	-	-	-
Bulgaria		-	-	YES	-	YES	-	-	-
Finland		-	-	-	-	-	-	-	YES
Germany		-	-	YES	~	~	~	~	~
Italy		YES	-	YES	YES	YES	-	-	-
Poland		YES	YES	YES	-	~	~	~	~
Slovakia		YES	YES	YES	YES	-	-	-	-
Turkey	ITU	-	-	YES	-	-	-	-	-
	AU	-	-	-	-	-	YES	~	YES
Hungary		-	-	-	-	-	-	-	~

-	not validated
~	validation in future
YES	validated

Validation period and products

Period

- from 1/7/2012 to 30/6/2013

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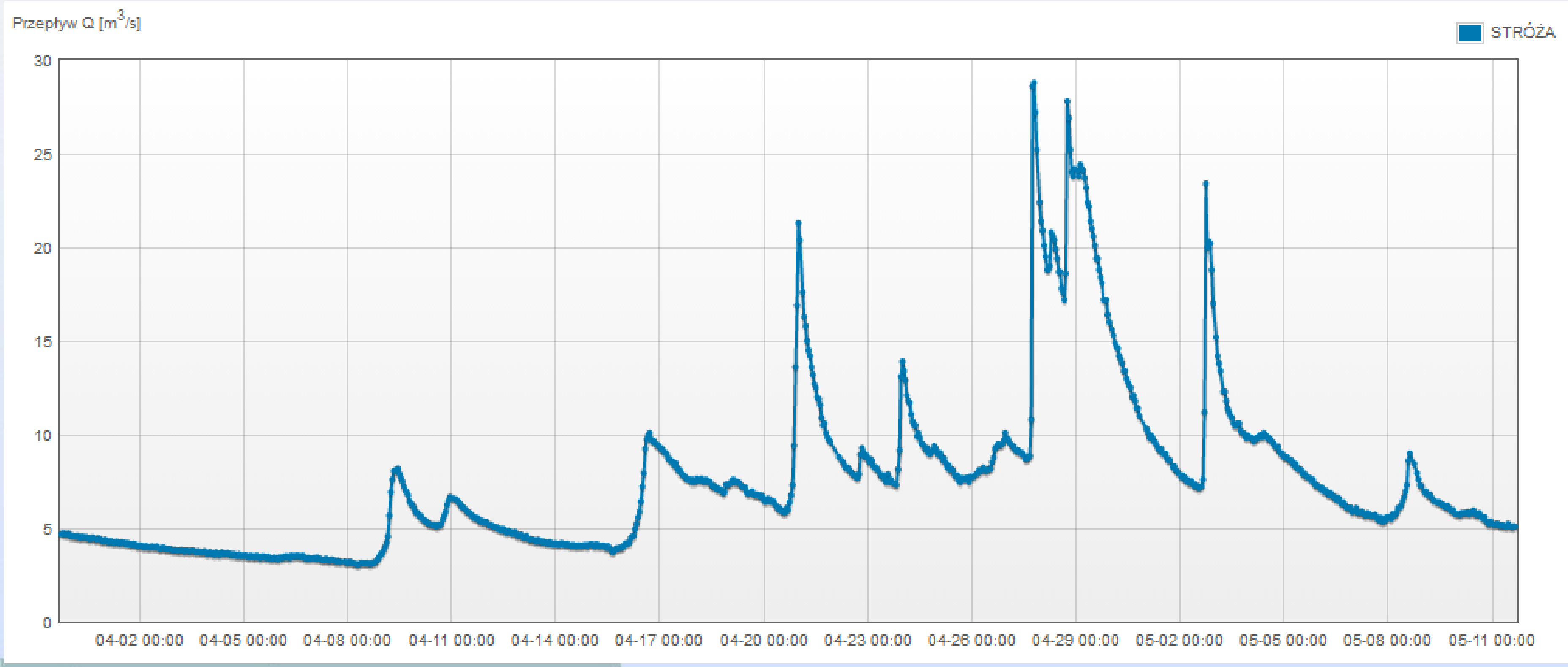
Precipitation products

Product		Resolu tion	Cycle
H03	Precipitation rate at ground by GEO/IR supported by LEO/MW	~ 8 km	15 min
H04	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)	~ 8 km	3 hours
H05	Accumulated precipitation at ground by blended MW and IR	~ 8 km	Each 3 hours: MW+IR integrated over the previous 3, 6, 12 and 24

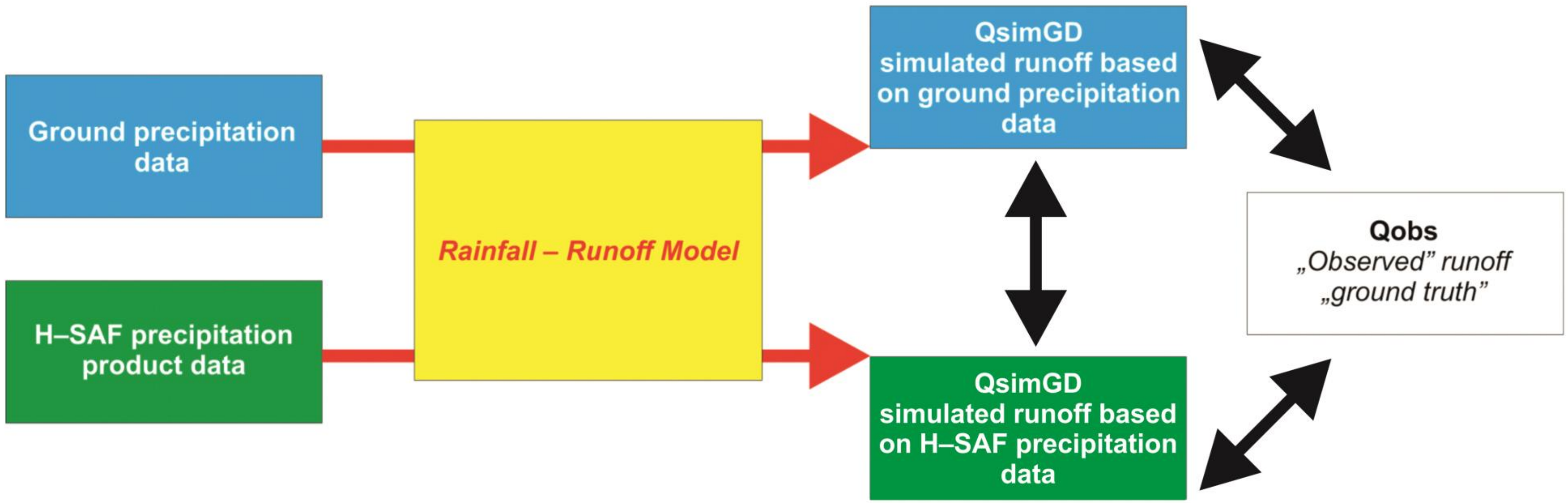
Methods

Methods: General idea of HV

How to define „*ground truth*”?



Methods: General idea of HV



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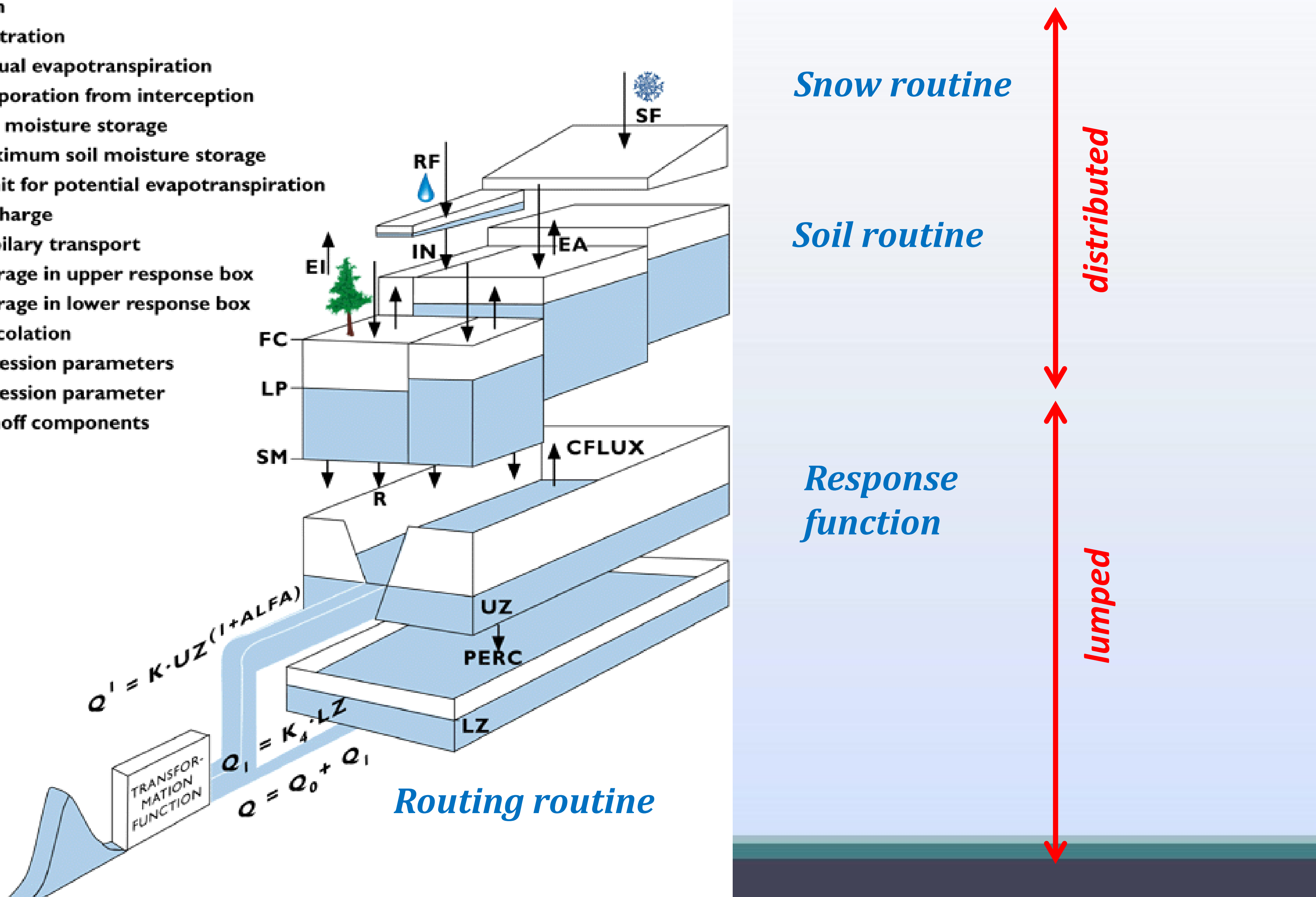
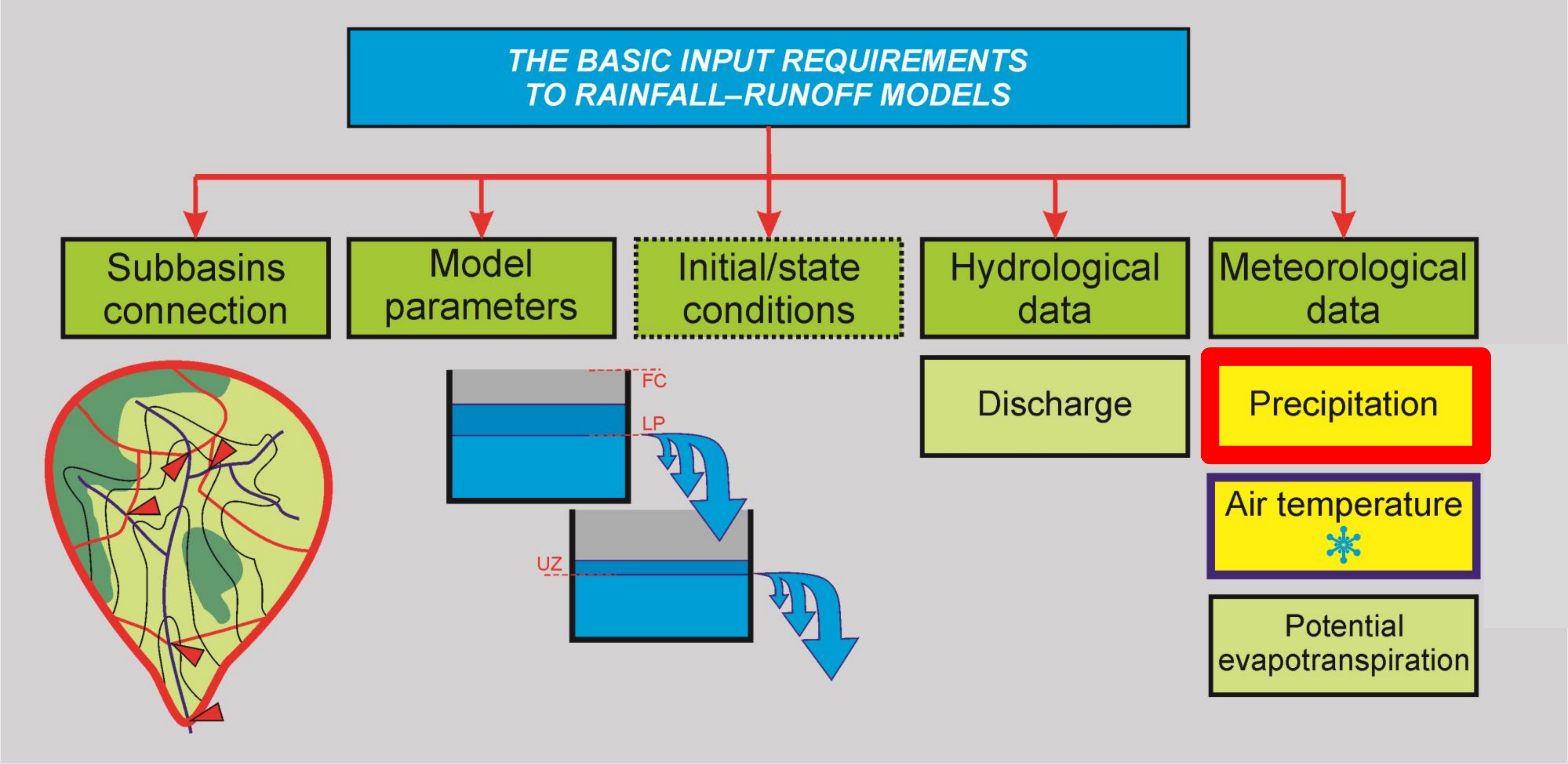
Methods: HBV model

SF = Snow
RF = Rain
IN = Infiltration
EA = Actual evapotranspiration
EI = Evaporation from interception
SM = Soil moisture storage
FC = Maximum soil moisture storage
LP = Limit for potential evapotranspiration
R = Recharge
CFLUX = Capilary transport
UZ = Storage in upper response box
LZ = Storage in lower response box
PERC = Percolation
K,K4 = Recession parameters
ALFA = Recession parameter
Q0,QI = Runoff components



Methods



THE BASIC INPUT REQUIREMENTS
TO RAINFALL–RUNOFF MODELS
Subbasins connection
Model parameters
Initial/state conditions
Hydrological data
Meteorological data
FC
LP
UZ
Discharge
Precipitation
Air temperature
Potential evapotranspiration

Methods

Precipitation
- Weighted mean
- Elevation zones

Temperature
- Weighted mean
- Elevation zones

Data for stations
The time step is
ONE HOUR

Potential evaporation*
- Penman-Monteith/Thornthwaite equation
- Usually long-term monthly mean values

Discharge observations are used to calibrate the model, and to verify and correct the model before a runoff forecast.

Methods

Calibration of rainfall-runoff model
(using historical, long time series of ground data)

Validation

- runoff simulation using precipitation ground data as an input
- runoff simulation using satellite precipitation product as an input

Methods

- Results for each month and for the whole period
- Comparison the obtained run-offs with the measurements
- Evaluations of the H–SAF products were performed, in terms of discharges, by the calculation of the Nash–Sutcliffe model efficiency coefficient, the correlation coefficient, the RMSE and ME and MAE.
- Results: graphs, statistics scores

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Study area

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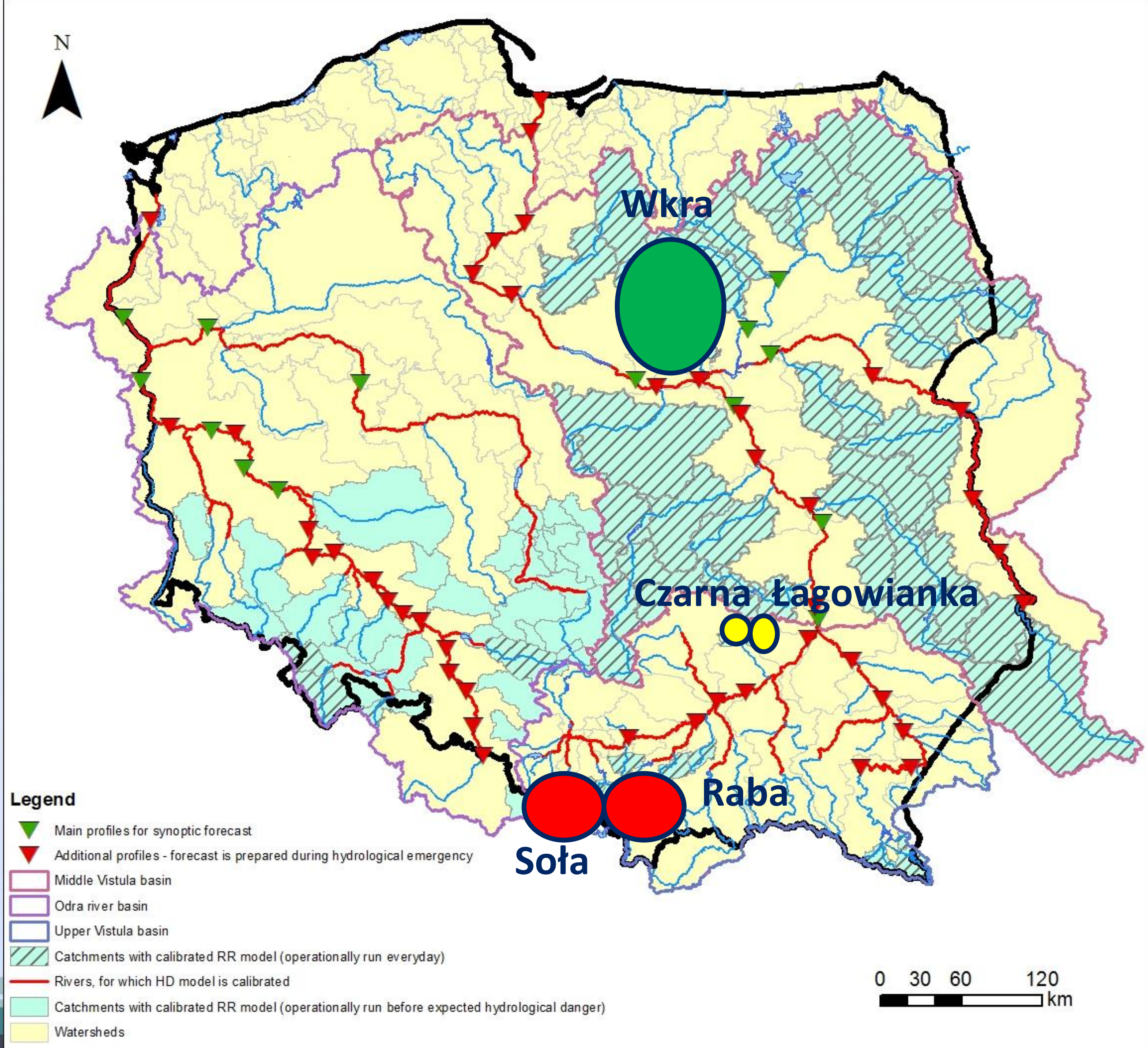
Study area

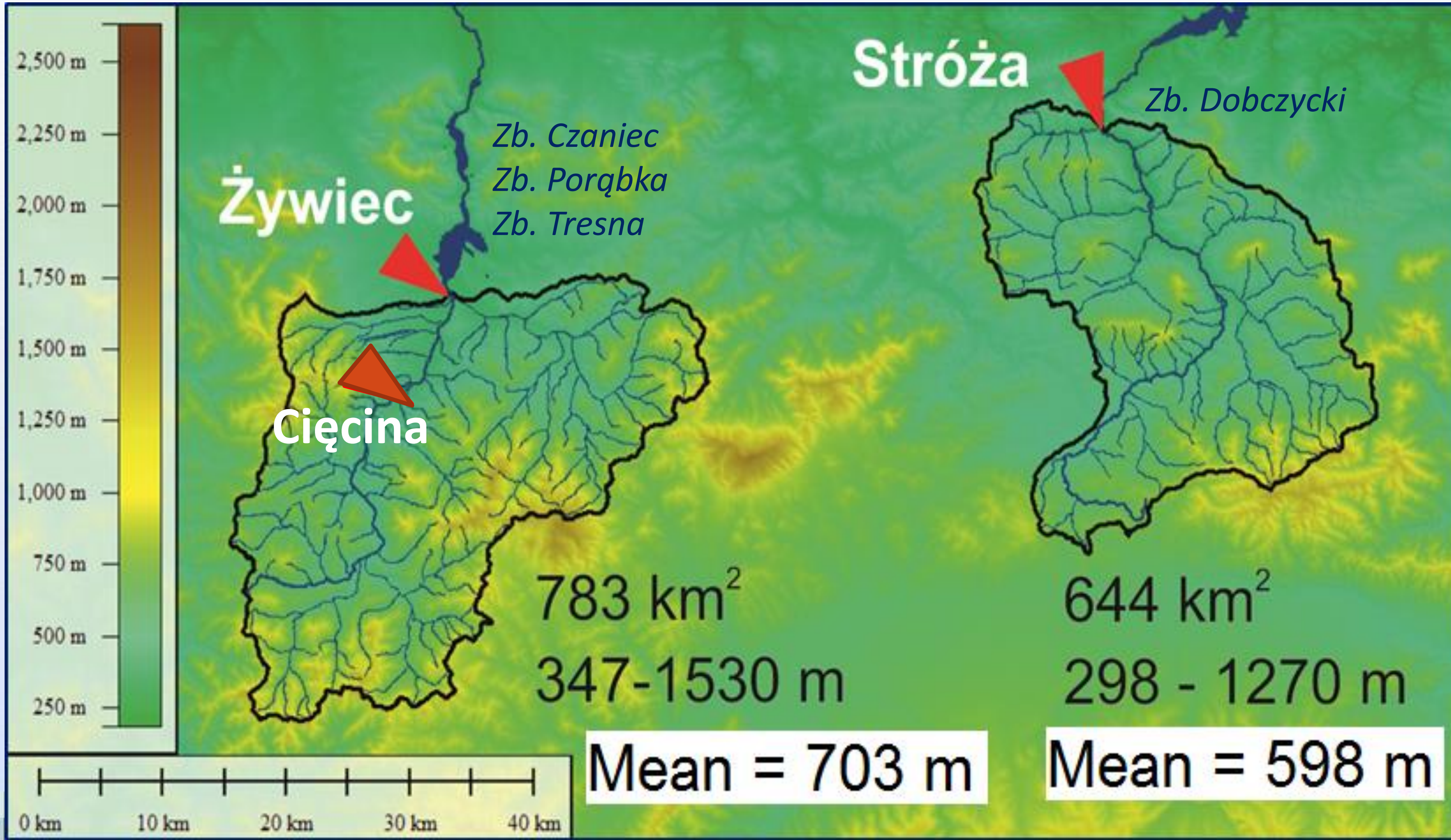
lowland

upland

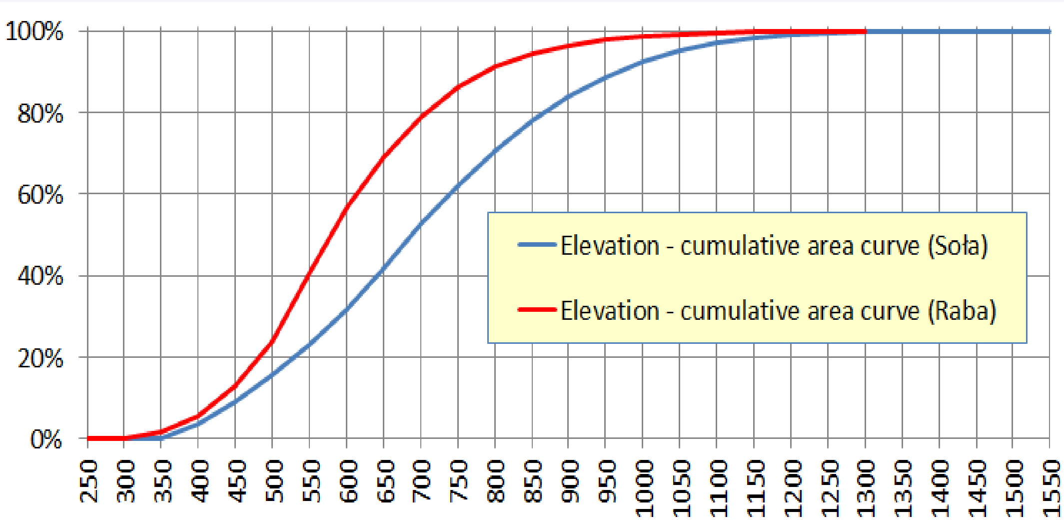
mountain

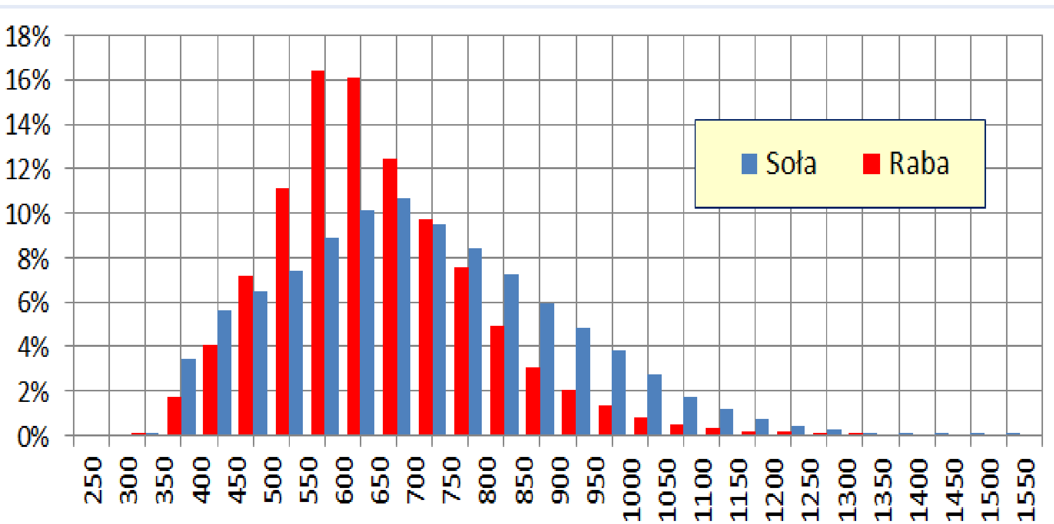


Study area

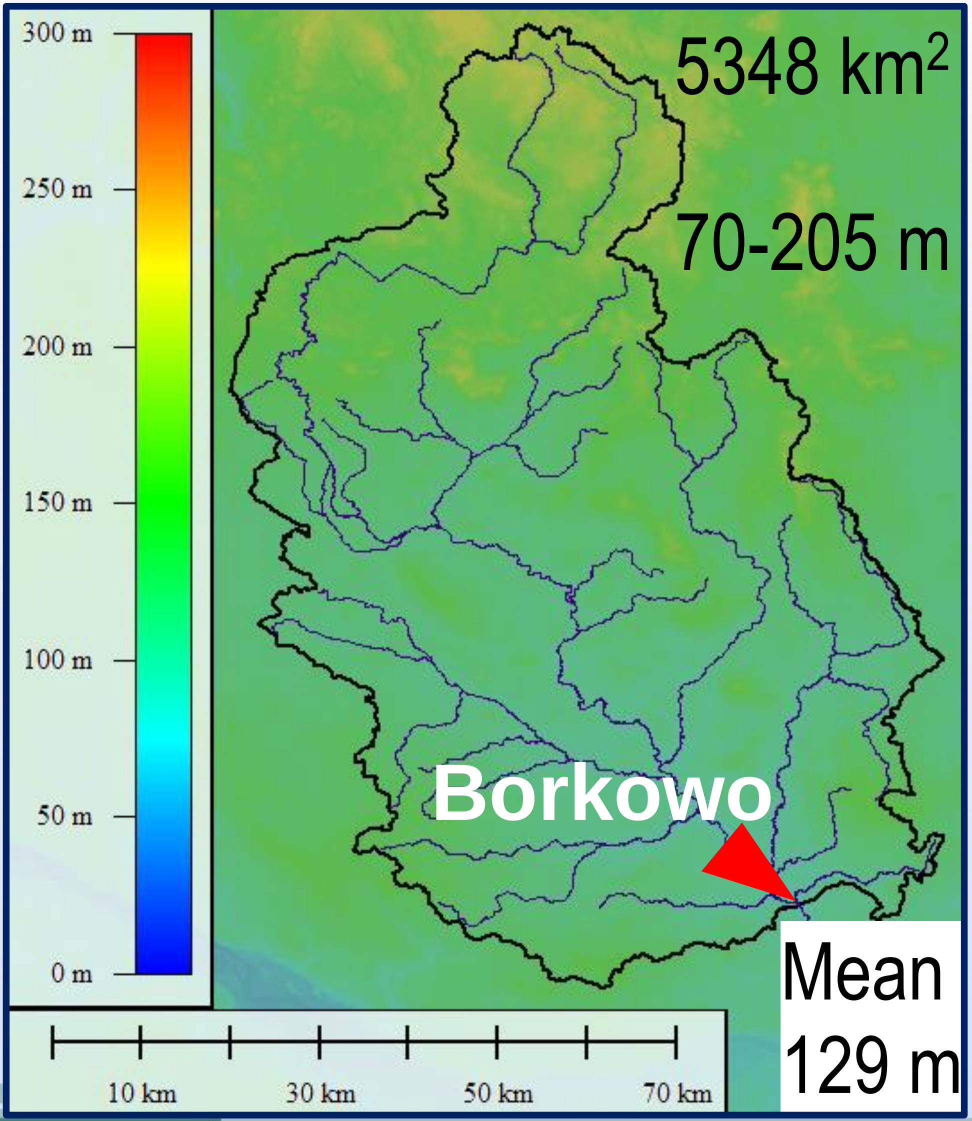

2,500 m
2,250 m
2,000 m
1,750 m
1,500 m
1,250 m
1,000 m
750 m
500 m
250 m
0 km
10 km
20 km
30 km
40 km
Żywiec
Zb. Czaniec
Zb. Porąbka
Zb. Tresna
Cięcina
Stróża
Zb. Dobczycki
783 km²
347-1530 m
Mean = 703 m
644 km²
298 - 1270 m
Mean = 598 m

Study area


100%
80%
60%
40%
20%
0%
250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550
Elevation - cumulative area curve (Soła)
Elevation - cumulative area curve (Raba)

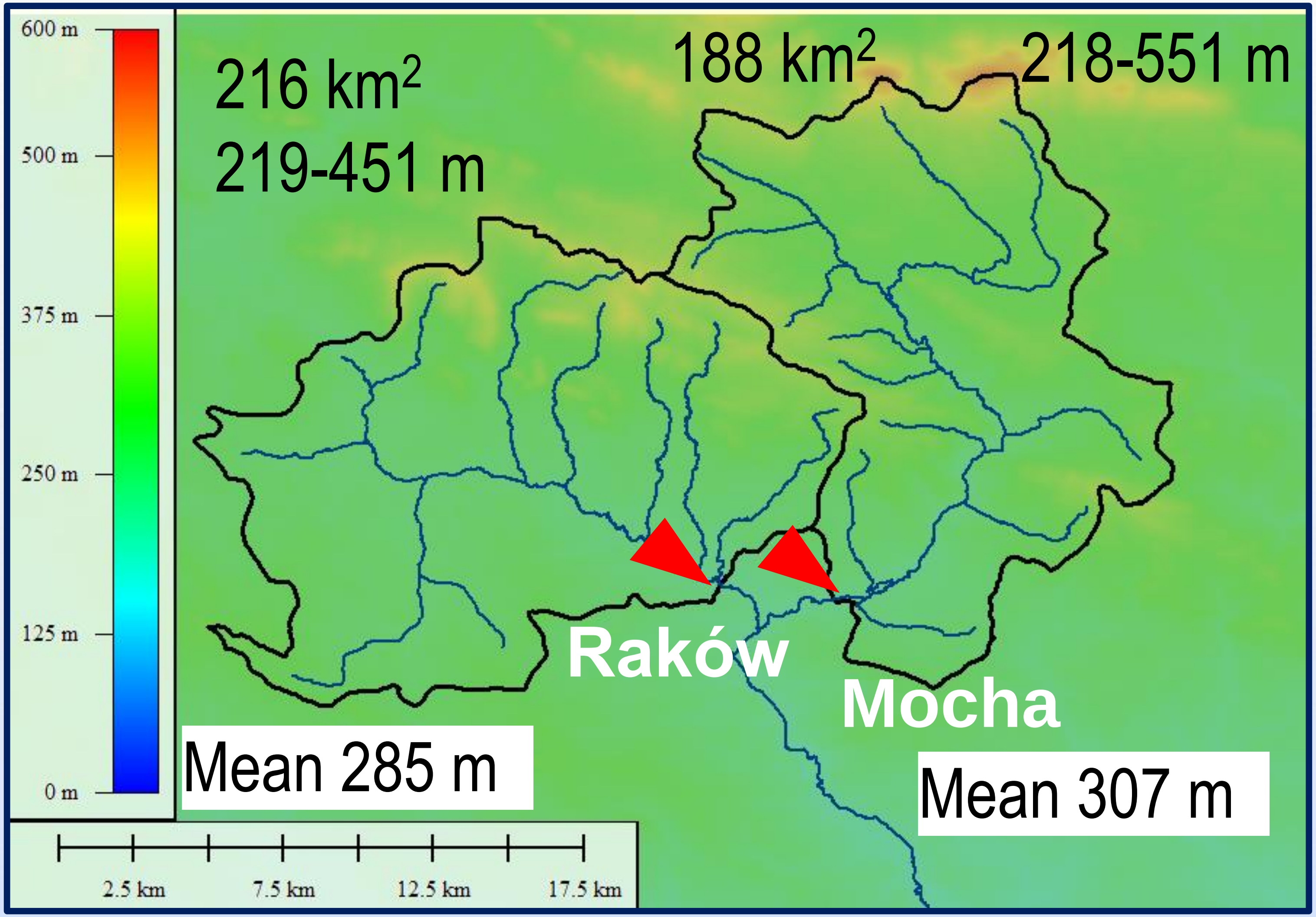

18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550
Soła
Raba

Study area



5348 km2
70-205 m
300 m
250 m
200 m
150 m
100 m
50 m
0 m
Borkowo
Mean
129 m
10 km
30 km
50 km
70 km

Study area


600 m
500 m
375 m
250 m
125 m
0 m
2.5 km
7.5 km
12.5 km
17.5 km
216 km2
219-451 m
188 km2
218-551 m
Raków
Mocha
Mean 285 m
Mean 307 m

Results

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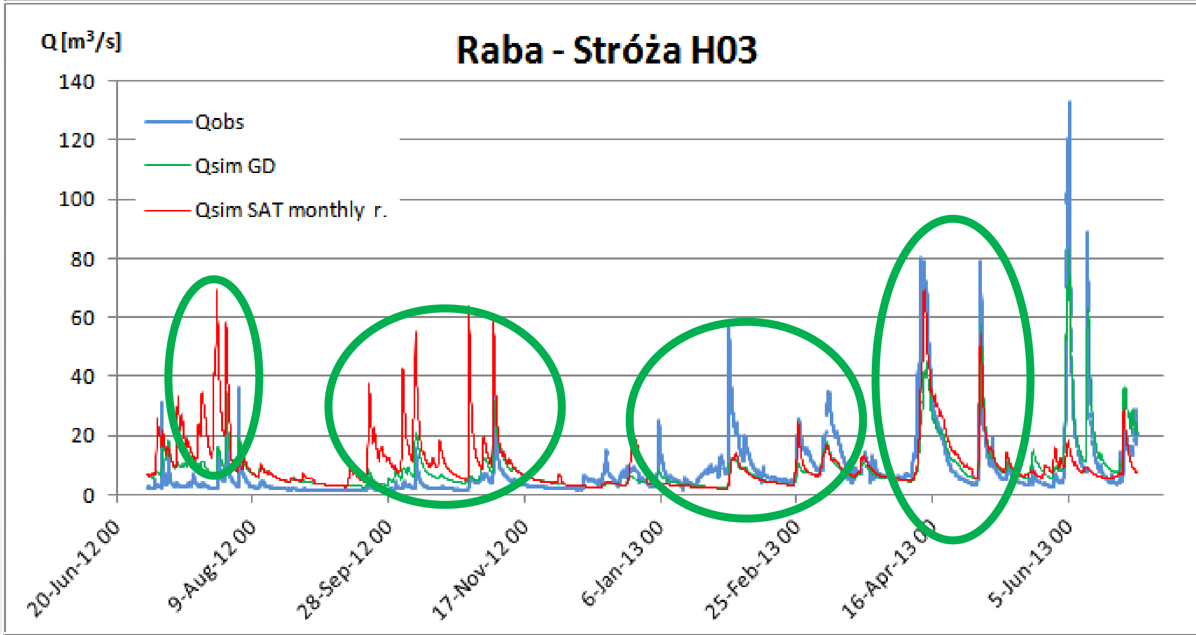
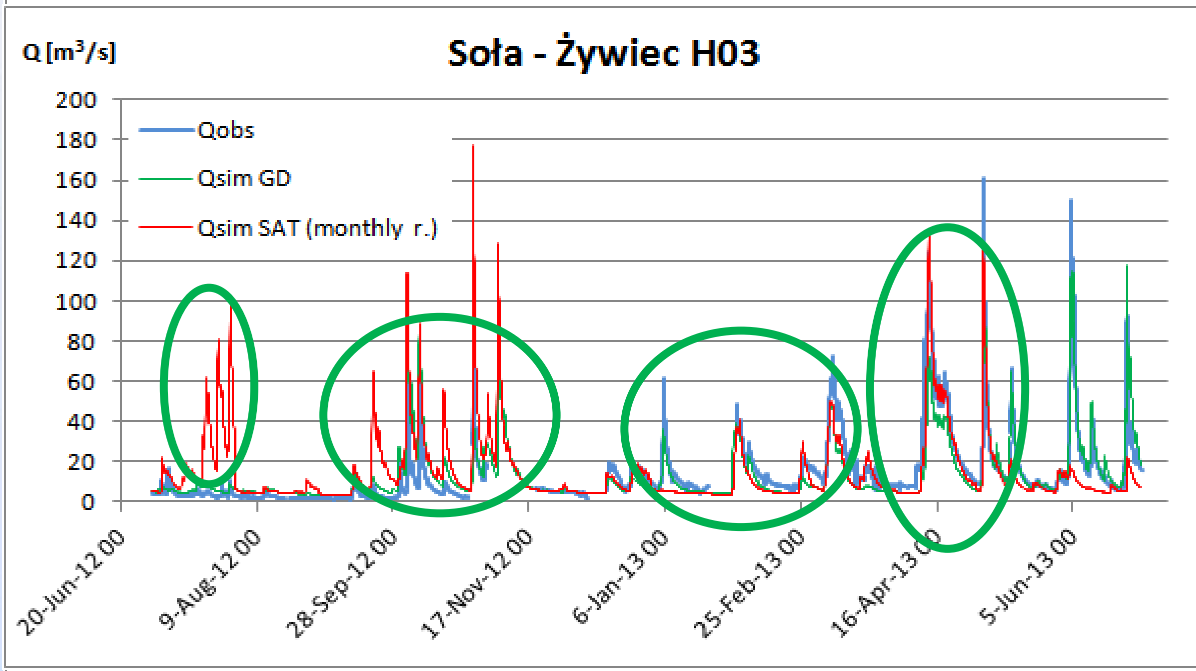
2012-2013





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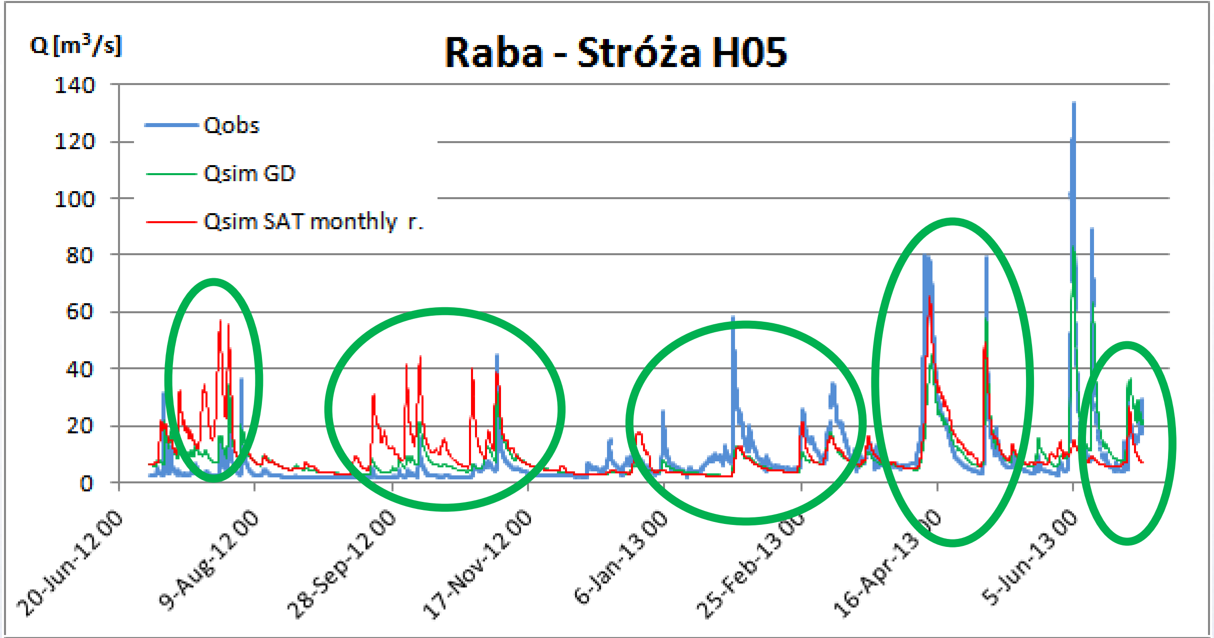
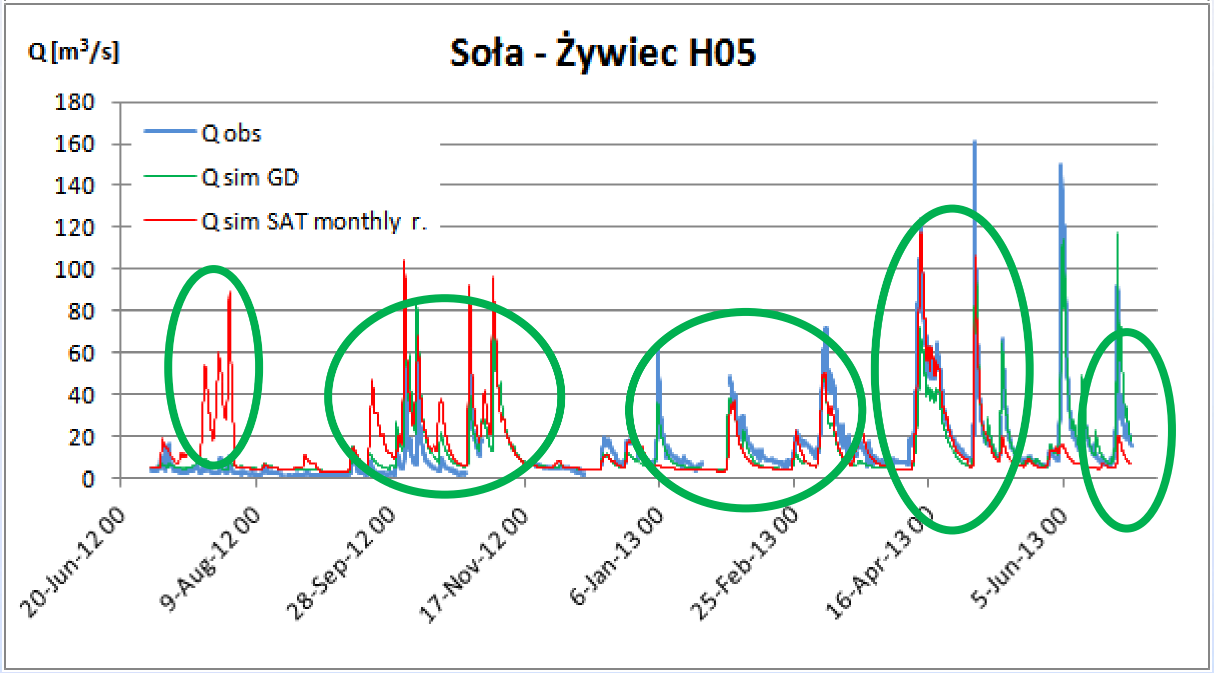
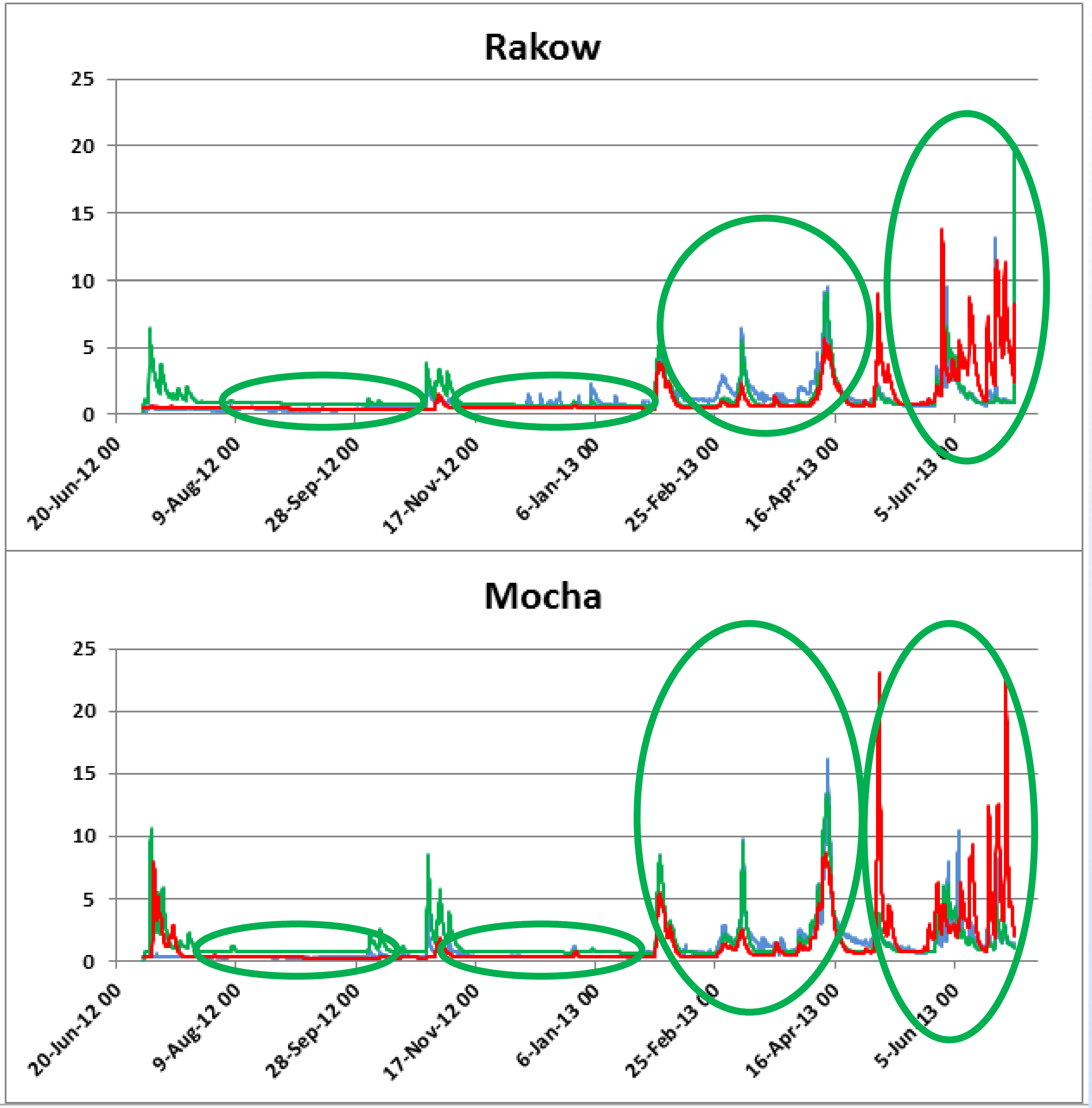
2012-2013





2012-2013

H04



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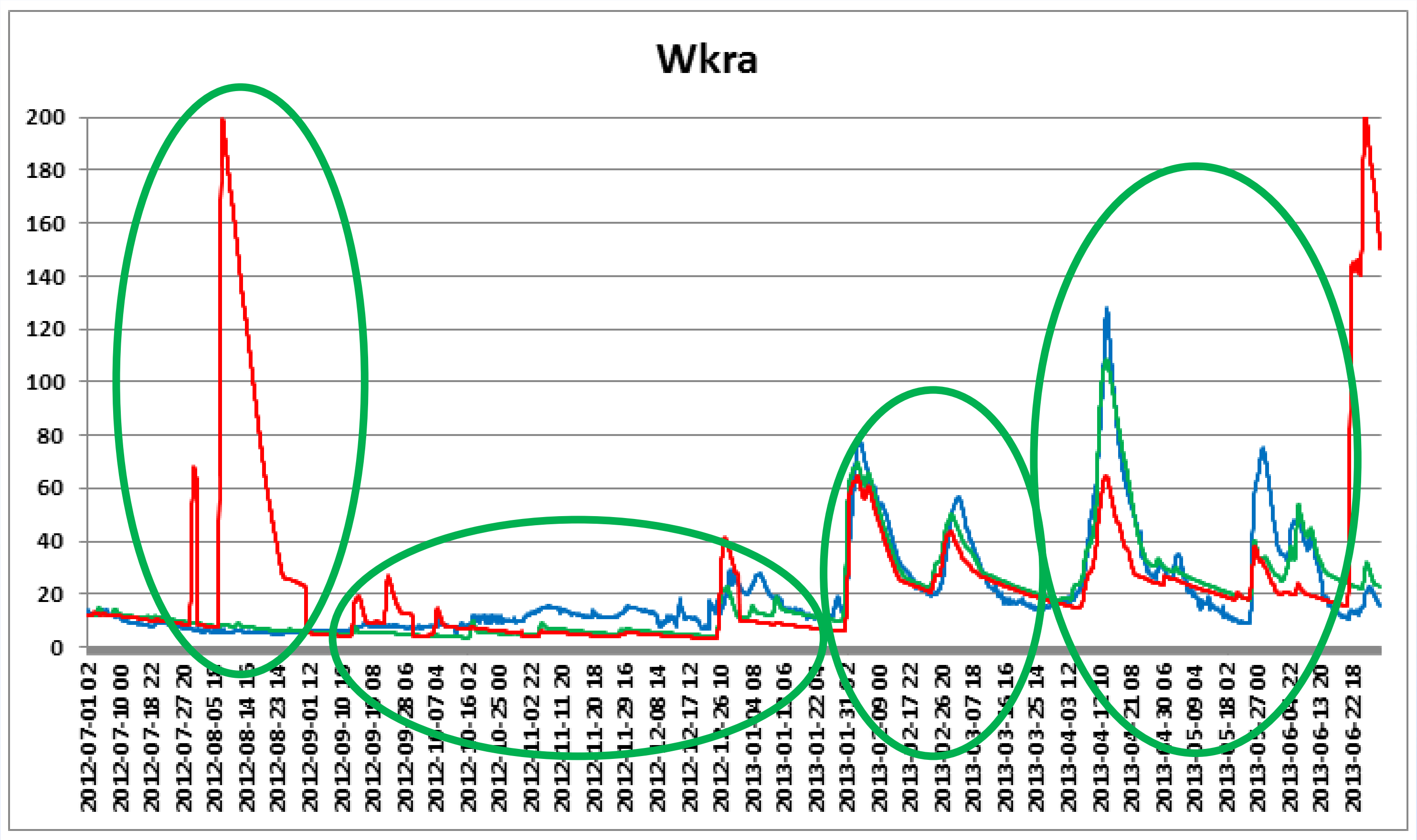
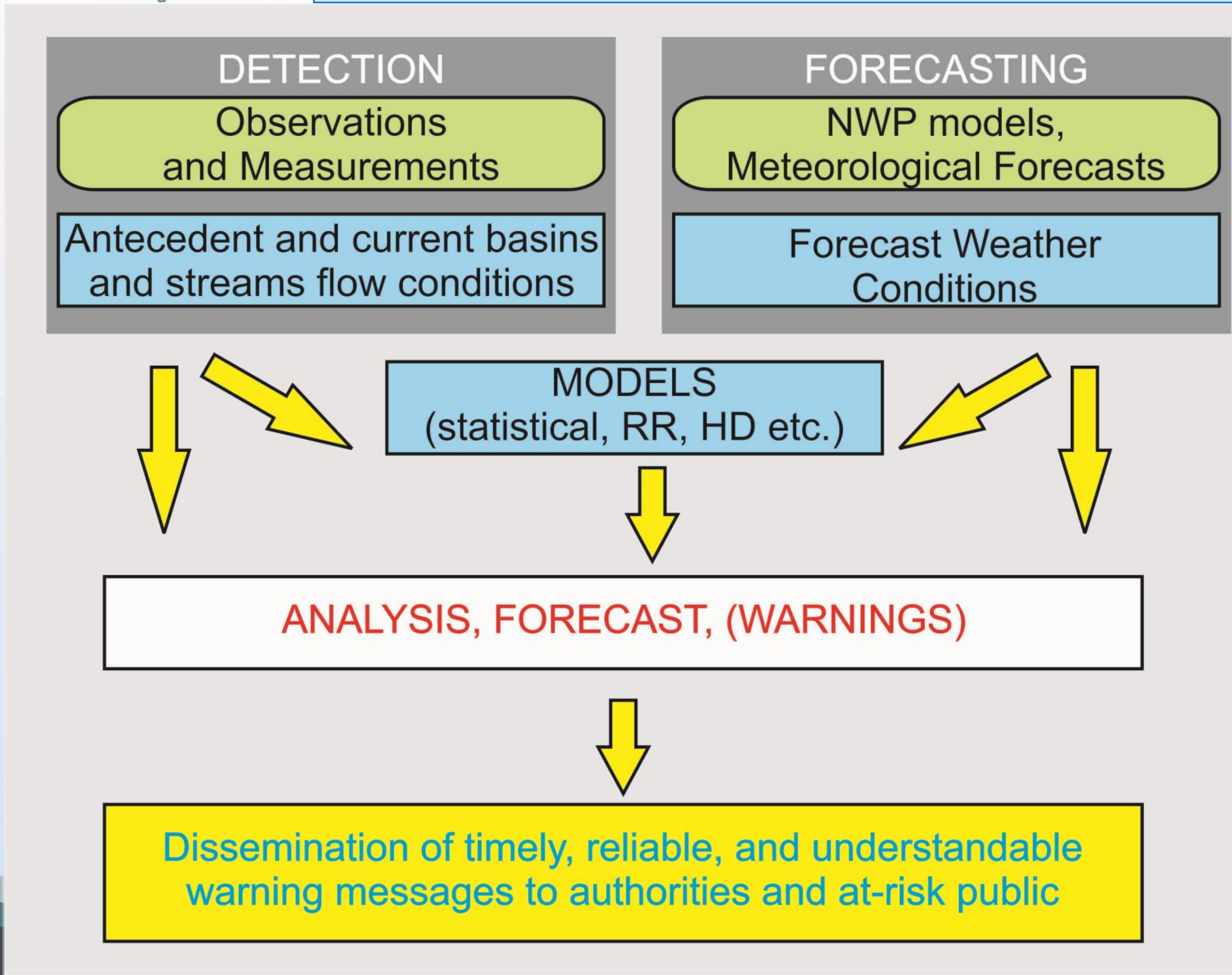
2012-2013
H04



H-SAF products in Operational Hydrology

Precipitation products in OH



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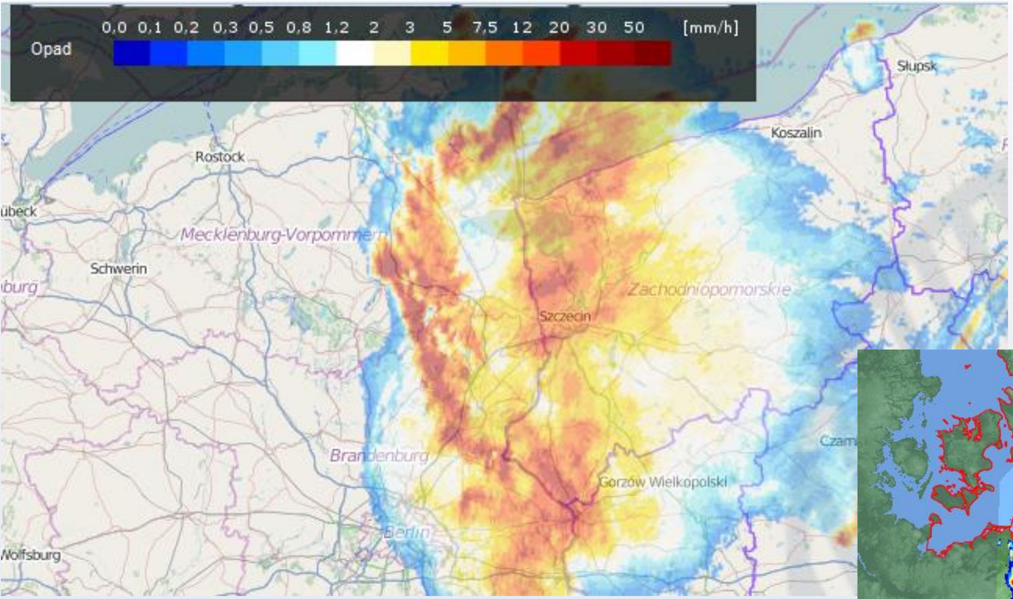
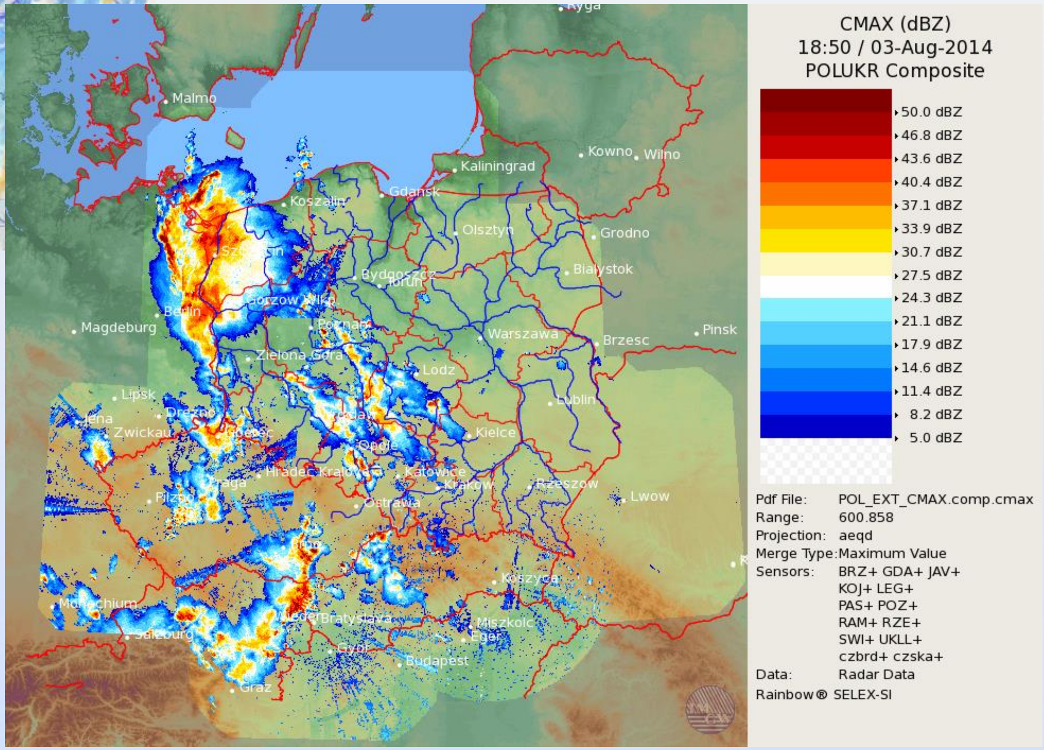
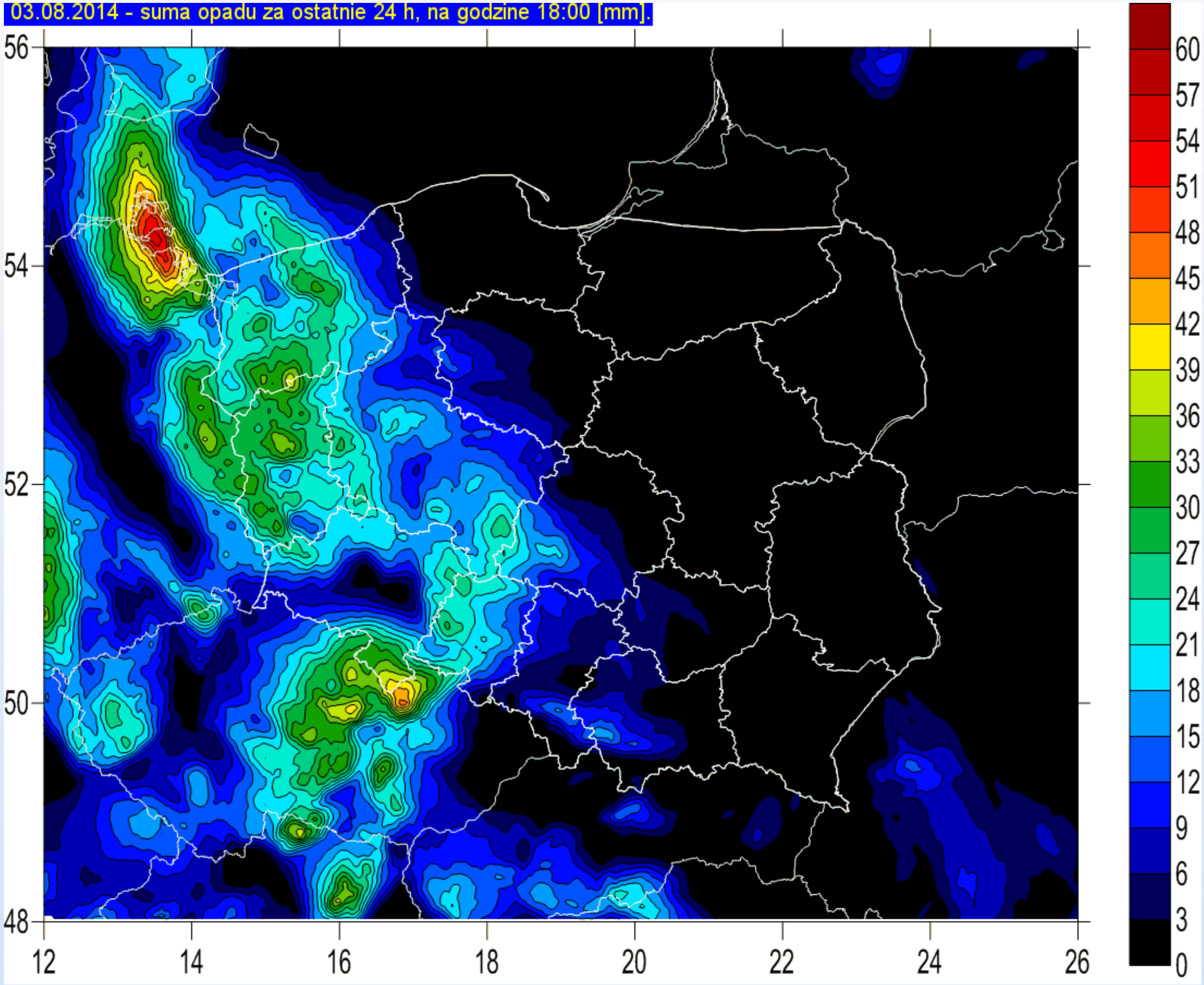
Precipitation products in OH



Radar Data



Precipitation products in OH



Satellite Data

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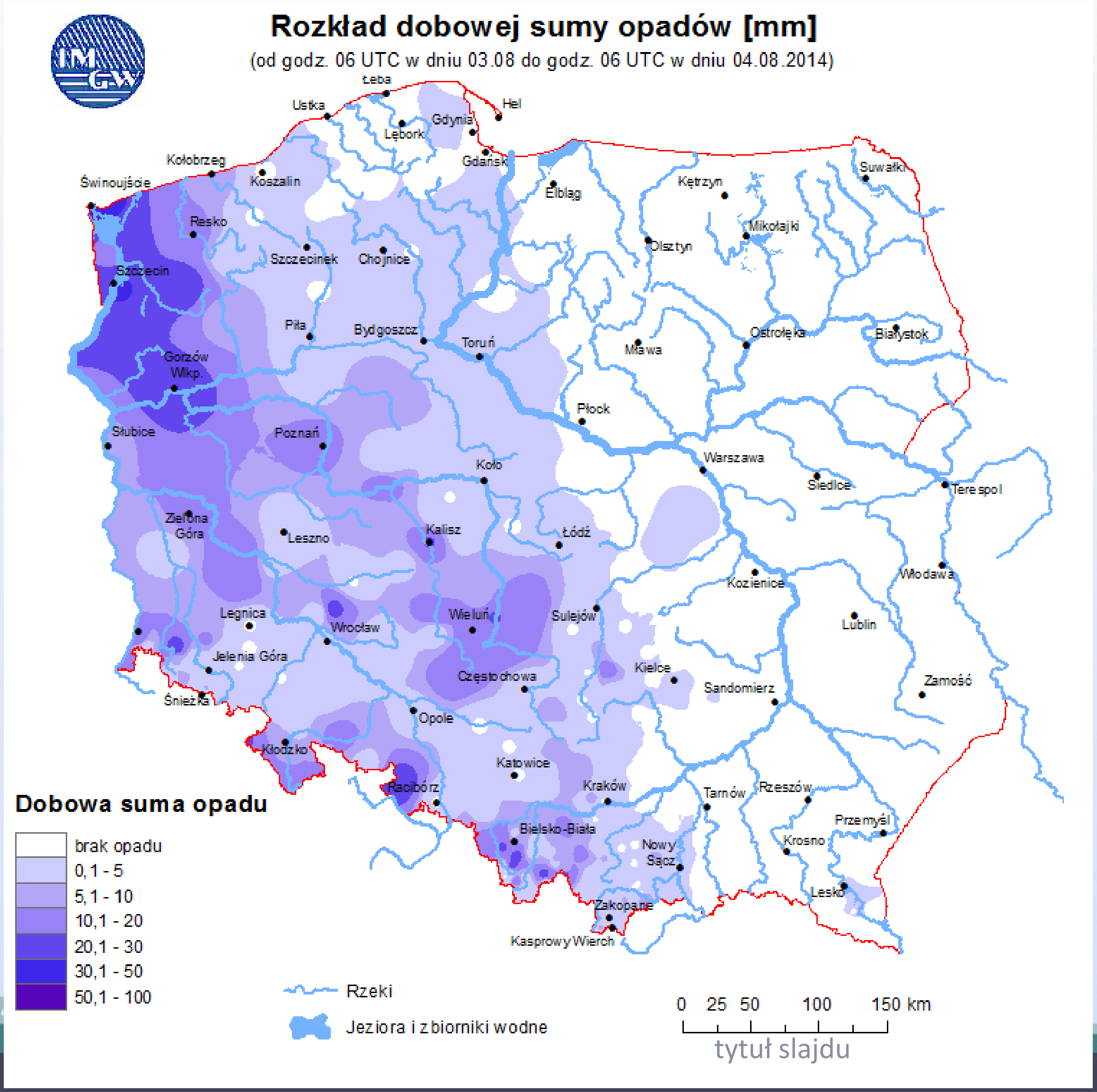
Precipitation products in OH



tytuł slajdu

Rain gauges

Bias-Correction

BIAS-correction

Satellite precipitation products have systematic errors called **bias,** which need to be corrected since the biases can affect the hydrological processing in the mathematical models…

- Problem to solve:

(…) to transform precipitation derived from H-SAF, to the observed precipitation

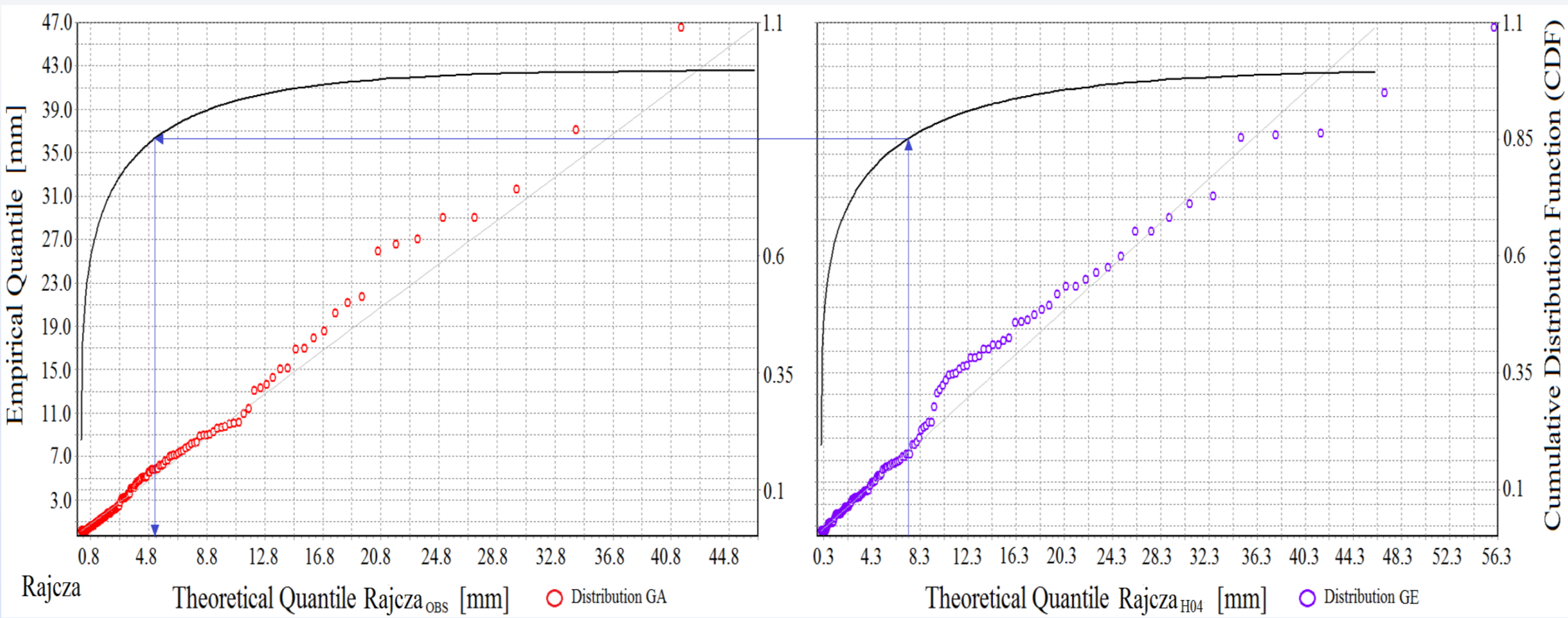
BIAS-correction: methods

- based on simple changes (Lehner et al., 2006), DELTA method
- parametric transformation (Piani et al., 2010; Maraun et al., 2013; Rojas et al., 2011),
- nonparametric transformation (Wood et al., 2004; Boé et al., 2007; Bennet et al., 2011),
- **distribution derived transformation** (Sharma, 2007; Salvi et al., 2011; Kurnik et al., 2012).

Distribution derived transformation

(…) to find the optimum function, that maps the modeled variable P_{MOD} from H-SAF precipitation Product in such way that a new distribution equals the distribution of the observed variable P_{OBS}, i.e.,

$$P_{OBS} = f(P_{MOD})$$


Empirical Quantile [mm]
47.0
43.0
39.0
35.0
31.0
27.0
23.0
19.0
15.0
11.0
7.0
3.0
1.1
0.6
0.35
0.1
0.85
0.8
4.8
8.8
12.8
16.8
20.8
24.8
28.8
32.8
36.8
40.8
44.8
0.3
4.3
8.3
12.3
16.3
20.3
24.3
28.3
32.3
36.3
40.3
44.3
48.3
52.3
56.3
Cumulative Distribution Function (CDF)
Rajcza
Theoretical Quantile Rajcza OBS [mm]
Distribution GA
Theoretical Quantile Rajcza H04 [mm]
Distribution GE

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Density and quantile functions for selected probability distributions

	gamma distribution	
GA	$f(x)=\frac{(x-\varepsilon)^{\lambda-1}}{\alpha^2\Gamma(\lambda)}\exp\left(-\frac{x-\varepsilon}{\alpha}\right)$ $\Gamma(\lambda)=\int_0^\infty t^{\lambda-1}\exp(-t)dt$ - gamma Euler function	λ>0 - shape, α>0 -scale, ε≥0 - lower left-side bound $\varepsilon \le X \le +\infty$
	generalized exponential distribution	
GE	$f(x)=\alpha\lambda\exp(-(x-\varepsilon)\lambda)[1-\exp(-(x-\varepsilon)\lambda)]^{\alpha-1}$ $x_p=\varepsilon-\frac{1}{\lambda}\ln\left[1-(1-p)^{\frac{1}{\alpha}}\right]$	α>0 - shape λ>0 - scale ε≥0 - lower left-side bound $\varepsilon \le X \le +\infty$

Sets of equations obtained by MLM method for GA, GE probability distributions.

GA	Initial values: $\alpha=1{,}0,\ \lambda=\left(3{,}0-c+\left[(c-3)^2+24c\right]^{\frac{1}{2}}\right)/12c,$ where: $a=\sum_{i=1}^{N}(x_i-\varepsilon),\ b=\sum_{i=1}^{N}\ln(x_i-\varepsilon),\ c=\ln\frac{a}{N}-\frac{b}{N}$ $\begin{cases}\ln\lambda-\psi(\lambda)=\ln\left(\frac{1}{N}\sum_{i=1}^{N}(x_i-\varepsilon)\right)-\frac{1}{N}\sum_{i=1}^{N}\ln(x_i-\varepsilon)\\ \alpha=\frac{1}{\lambda N}\sum_{i=1}^{N}(x_i-\varepsilon)\end{cases}$
GE	Initial value: $\lambda=\left[\frac{1}{N}\sum_{i=1}^{N}(x_i-\varepsilon-\bar{x})^2\right]^{-\frac{1}{2}}$ $\frac{N}{\lambda}-\left[\frac{N}{\sum_{i=1}^{N}\ln[1-\exp(-\lambda(x_i-\varepsilon))]}+1\right]*\left[\sum_{i=1}^{N}\frac{(x_i-\varepsilon)\exp(-\lambda(x_i-\varepsilon))}{1-\exp(-\lambda(x_i-\varepsilon))}\right]-\sum_{i=1}^{N}(x_i-\varepsilon)=0$ $\alpha=-\frac{N}{\sum_{i=1}^{N}\ln[1-\exp(-\lambda(x_i-\varepsilon))]}$

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Goodness-of-fit tests for probability distributions of random variables P_{OBS}, P_{H03}, P_{H04} and P_{H05}

Kołmogorow-Smirnow (K-S)	$D_N = \max\limits_{1\le i\le N}\left(\hat{\delta}_i\right)$, where: $\hat{\delta}_i = \max\left[\frac{i}{N} - F_0\left(x_i;\hat{\theta}\right), F_0\left(x_i;\hat{\theta}\right) - \frac{i-1}{N}\right]$, N – size of random sample, $F_0\left(x_i;\hat{\theta}\right)$ theoretical cumulative distribution, $\hat{\theta}$ - vector of parameters.
Anderson-Darling (A-D)	$A_N^2 = -N - \frac{1}{N}\sum_{i=1}^{N}\left\{(2i-1)\ln F_0\left(x_i;\hat{\theta}\right) + (2N+1-2i)\ln\left(1-F_0\left(x_{N+1-i};\hat{\theta}\right)\right)\right\}$
Liao-Shimokawy (L-S)	$L_N = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\frac{\max\left[\frac{i}{N} - F_0\left(x_i;\hat{\theta}\right), F_0\left(x_i;\hat{\theta}\right) - \frac{i-1}{N}\right]}{\sqrt{F_0\left(x_i;\hat{\theta}\right)\left[1-F_0\left(x_i;\hat{\theta}\right)\right]}}$
Kuiper (K)	$V_N = \max\limits_{1\le i\le N}\left(\hat{\delta}_i^+\right) + \max\limits_{1\le i\le N}\left(\hat{\delta}_i^-\right)$, gdzie: $\hat{\delta}_i^+ = \max\left[\frac{i}{N} - F_0\left(x_i;\hat{\theta}\right)\right]$, $\hat{\delta}_i^- = \max\left[F_0\left(x_i;\hat{\theta}\right) - \frac{i-1}{N}\right]$

- Statistical charactristics

Characteristic		Zywiec OBS	Zywiec MOD
Skewness	H03	3.277	3.936
	H04		4.371
	H05		3.608
Kurtosis	H03	12.529	21.390
	H04		26.283
	H05		17.036
Standard Deviation [mm]	H03	3.513	6.375
	H04		5.928
	H05		6.174
Variance [(mm)^2]	H03	12.343	40.637
	H04		35.147
	H05		38.116
Arithme-tic Mean	H03	1.693	2.918
	H04		2.641
	H05		2.919
Median [mm]	H03	0.200	0.300
	H04		0.100
	H05		0.100

Results of goodness-of-fit tests for P_{H03} H-SAF rate at ground and P_{OBS} for **Sola** sub-catchments (bolds refers to the best fitted theoretical probability distribution for Akaike Information Criterion (AIC) and underlying refers to the best fitted for Anderson-Darling (A-D) test. The symbol ✓ means, that the best fitted distribution was selected by Quantile theoretical-Quantile empirical (*Q-Q*)and probability plots analysis.

H03

Sub-catchment	Method of lower limit estimation	Distribution	L&S	K	K-S	A-D	AIC	Selected
Zywiec **OBS**	A-D	GA	3.5530	0.4863	0.3039	25.8521	**316.0350**	
		GE	3.5508		0.3028	25.7393	316.2770	✓
Zywiec MOD	AIC	GA	2.9672	0.4341	0.2715	19.9196	**97.2590**	✓
		GE	2.9972		0.2702	19.8280	97.5187	

H04

Zywiec **OBS**	A-D	GA	3.5530	0.4863	0.3039	25.8521	**316.0350**	
		GE	3.5508		0.3028	25.7393	316.2770	✓
Zywiec MOD	AIC	GA	3.8366	0.5165	0.3234	29.7588	**1.4314**	✓
		GE	3.8279		0.3224	29.6316	1.8855	

H05

Zywiec **OBS**	A-D	GA	3.5530	0.4863	0.3039	25.8521	**316.0350**	
		GE	3.5508		0.3028	25.7393	316.2770	✓
Zywiec MOD	AIC	GA	4.1661	0.5082	0.3167	30.3203	54.1876	
		GE	4.1500		0.3158	30.1451	**53.8405**	✓

Catchment of **Sola River**	Transformation function	
Zywiec	H03	$GE_{A\text{-}D}$-GA_{AIC}
	H04	$GE_{A\text{-}D}$-GA_{AIC}
	H05	$GE_{A\text{-}D}$-GA_{AIC}

H-SAF	root mean square error (RMSE)	Δ
H03	CORR_OBS MOD_OBS	-2.086
H04	CORR_OBS MOD_OBS	-1.752
H05	CORR_OBS MOD_OBS	-1.959

H-SAF	efficiency index	Δ
H03	CORR_OBS MOD_OBS	+1.444
H04	CORR_OBS MOD_OBS	+1.275
H05	CORR_OBS MOD_OBS	+1.350

H-SAF	maximum absolute deviation	Δ
H03	CORR_OBS MOD_OBS	-15.70
H04	CORR_OBS MOD_OBS	-21.64
H05	CORR_OBS MOD_OBS	-9.661

H-SAF	mean absolute error	Δ
H03	CORR_OBS MOD_OBS	-0.878
H04	CORR_OBS MOD_OBS	-0.557
H05	CORR_OBS MOD_OBS	-0.851

H-SAF	mean squared error	Δ
H03	CORR_OBS MOD_OBS	-17.778
H04	CORR_OBS MOD_OBS	-15.695
H05	CORR_OBS MOD_OBS	-16.620

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Summary

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Status of validation: Results

- The usage of precipitation products sometimes can improve the performance of the models...
- Some peaks are well simulated (some events were partly successfully simulated)...
- Precipitation products can be useful if there is no other information on precipitation amounts...
- Some „operations” can make precipitation products more useful in hydrological modeling („updating”)
- To make precipitation products more useful for hydrological purposes it is necessary to develop merge products/blended products (H-SAF products + ground data + radar data) and correction methods