Sensitivity of hydrological response of a small mountainous catchment to the spatial resolution of precipitation field

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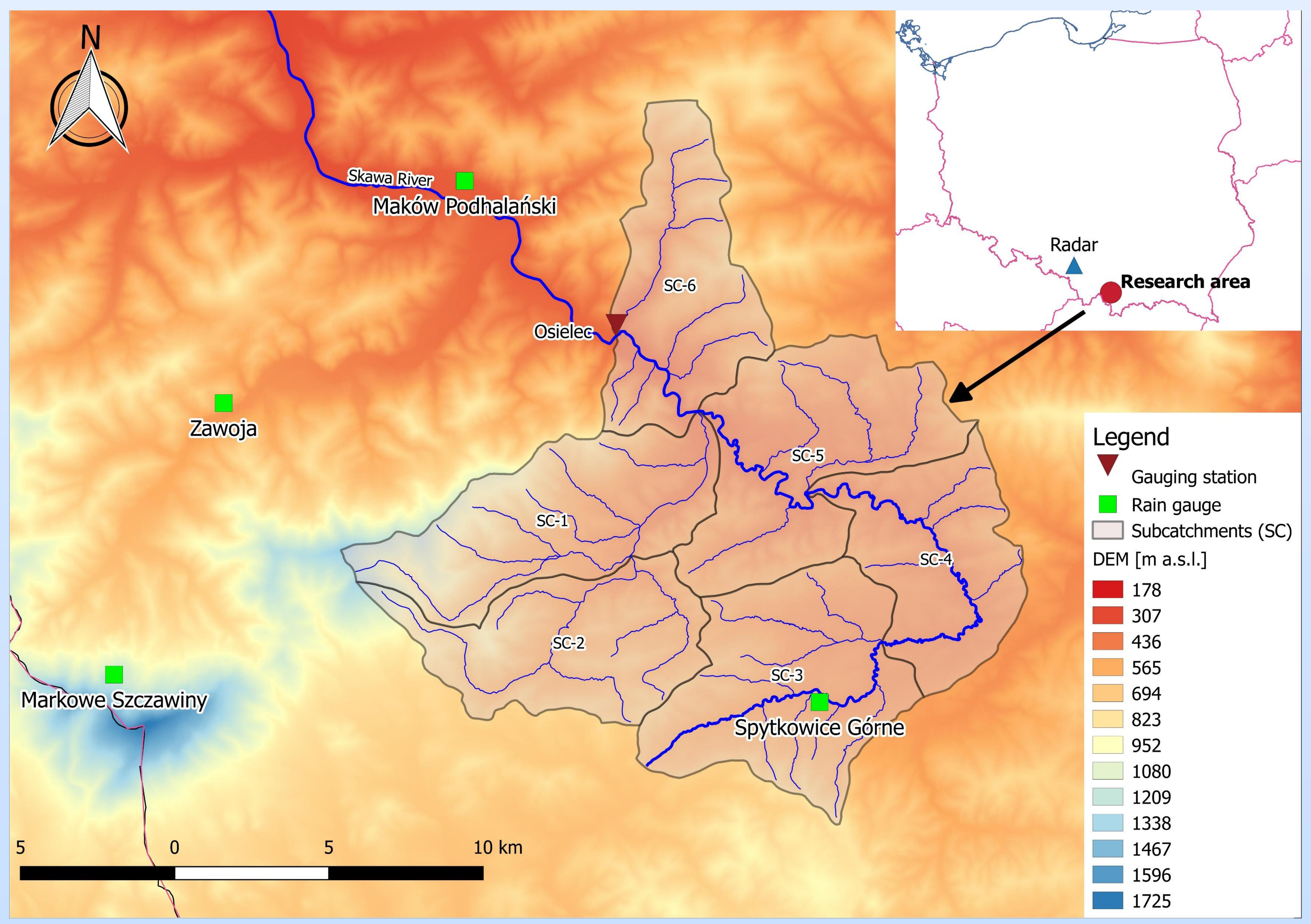
1. Context

The quick hydrological response of **mountainous** watersheds is one of the primary reason for flooding. The reaction itself depends on the meteorological forcing and physical characteristics of the catchment.

Event-based hydrological modeling can be a useful tool in the flood risk management. However, modeling over mountainous areas is challenging due to the topography and the problems which come out it, e.g., rainfall estimation.

2. Study area

The upper Skawa catchment is a **small** 240,4 km^2 mountainous catchment located in southern Poland. Most of it is covered by non-irrigated arable lands (32,7%) as well as coniferous and mixed forests (45,1%).



Due to its landform and **heavy rain events** this region is endangered to struggle from **flash floods** particularly during spring and summer time.

In the catchment area, there are **four rain gauges** and one of them is directly on-site. The meteorological **radar** is located around 100 km away.

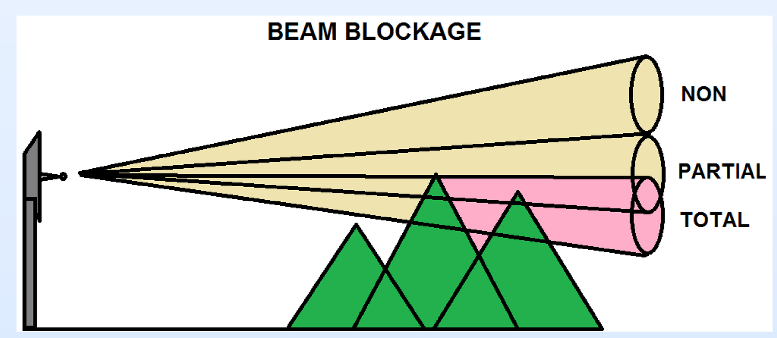
3. Materials & Methods

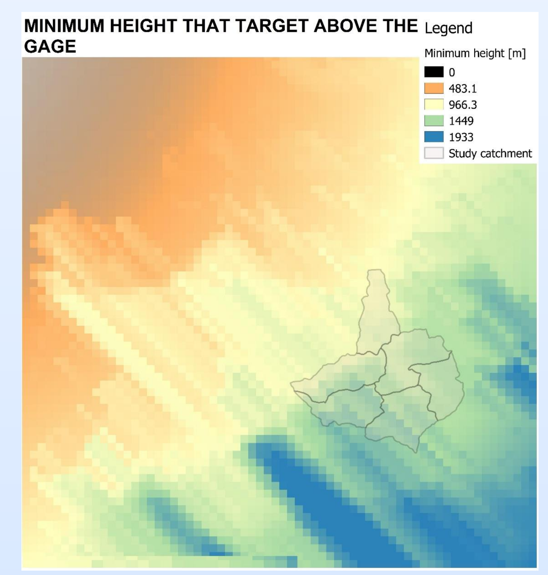
In the study, **two** rainfall input data sources were investigated.

Data	Spatial resolution	Temporal resolution	Description
Rain gauge	Point	10 min	Data collected from the three nearby rain gauges by tipping buckets
Radar	5 x 5 km	10 min	Rainfall intensity measured by the nearby meteorological radar located in Ramża

Altogether the data from the **rain gauges** were used as a reference input for simulating the runoff. The inverse distance weighting method was used for the data interpolation.

Application of **radar data** in the mountainous area is challenging due to e.g., **beam blocking**. Therefore the radar estimates must not be used without the adjustment process.





The radar estimates were **adjusted** using the weighted multiple regression method which can be written as:

$$lg\frac{R}{G} = a_1 \cdot lgDR + a_2 \cdot MH + a_3 \cdot HS + a_4 \quad \textbf{(1)}$$

where: R – radar-derived rain-amount [mm], G – time-accumulated rain gage amount [mm] , DR – distance between the radar and the gauge [km], MH – minimum height that target above the gage [m], HS – height of the gage [m a.s.l.], a_1-a_4 – regression coefficients [-].

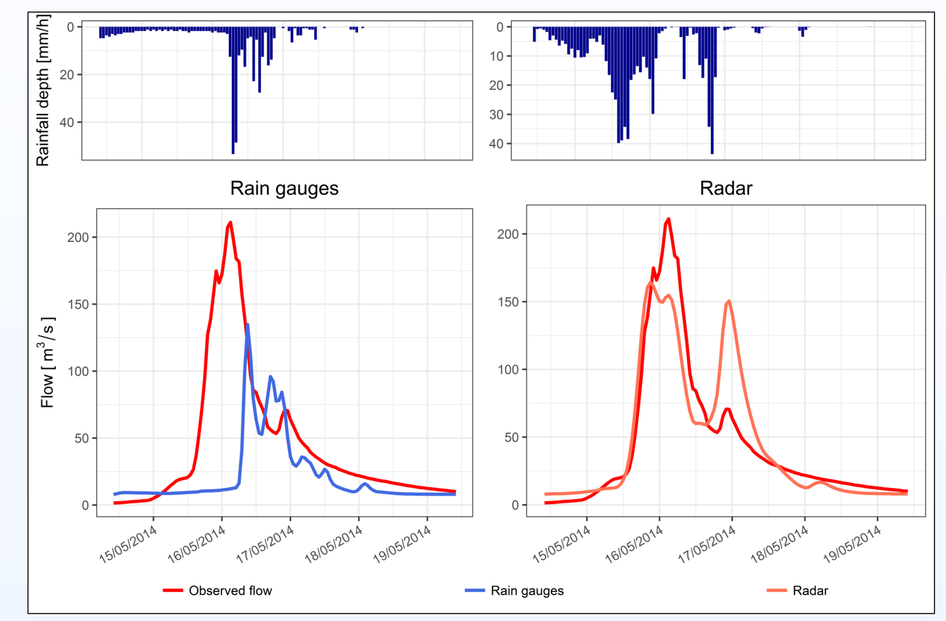
When all radar-gage data pairs were regressed for a **three year period** (2014-2016) using eq. 1 the following coefficients were obtained:

$$lg\frac{R}{G} = 4{,}48 \cdot lgDR - 4{,}8^{-4} \cdot MH - 2{,}5^{-5} \cdot HS - 7{,}34 \quad \textbf{(2)}$$

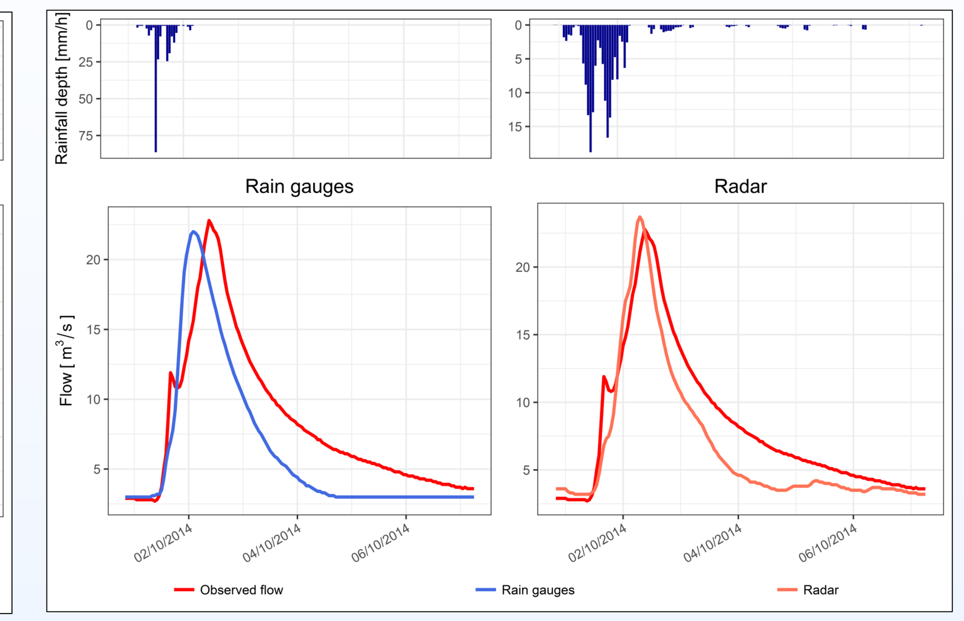
The radar-derived estimates were adjusted using eq. 2 and assimilated to the **semi-distributed hydrological model** in HEC-HMS as individual hyetograph representing a mean value from the radar cells for each of the subcatchments.

4. Results

May 2014 observed peak flow 211,1 m^3/s



September 2014 observed peak flow 22,8 m^3/s



Evaluation metrics:

NSE: Nash-Sutcliffe efficiency

$$NSE = 1 - \frac{\sum_{t=1}^{N}(Q_{t,obs} - Q_{t,sim})^2}{\sum_{t=1}^{N}(Q_{t,obs} - \overline{Q_{obs}})^2}$$

rVE: relative volume error

$$rVE = \frac{V_{sim} - V_{obs}}{V_{obs}} \cdot 100$$

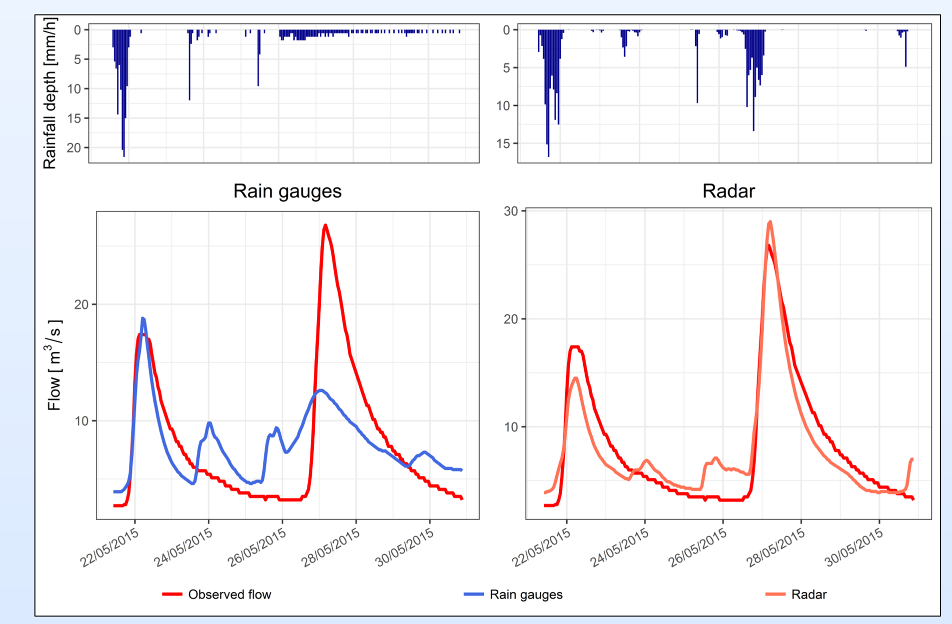
PFD: peak flow difference

$$PFD = \frac{Q_{p,sim} - Q_{p,obs}}{Q_{p,obs}} \cdot 100$$

PTD: peak time difference

$$PTD = t_{p,sim} - t_{p,obs}$$

May 2015 observed peak flow 27,9 m^3/s



Measure	May 2014		September 2014		May 2015	
	Rain gauges	Radar	Rain gauges	Radar	Rain gauges	Radar
NSE [-]	-0,13	**0,80**	0,64	**0,81**	0,46	**0,88**
rVE [%]	-51,27	**0,39**	-22,49	**-18,46**	-2,13	**-3,32**
PFD [%]	-36,2	**-22,4**	-3,2	**4,2**	-30	**8,1**
PTD [h]	6	**6**	7	**2**	119	**1**

5. Conclusion

- **rainfall-runoff model** based on the adjusted **radar-derived rainfall** estimates perform **significantly better** for event-based modeling than a model based on the **gauging network**
- the proposed approach for the radar data assimilation can be **easily replicable** in any other catchment

Acknowledgements

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