Accuracy assessment of heavy rainfall forecasting in the West Caucasus with the use of ICON-Eu regional atmospheric model for short-term flood prediction

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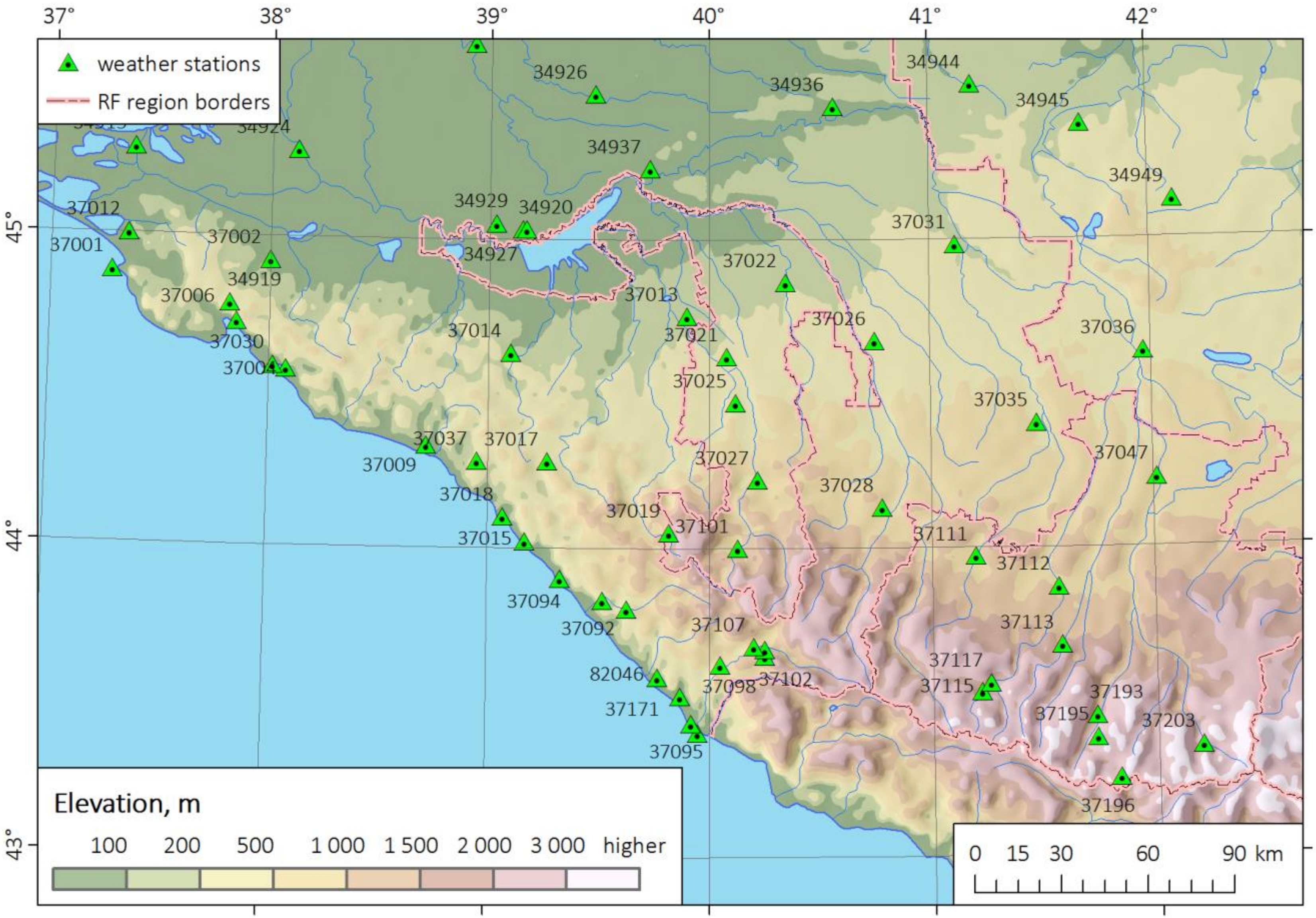
Scientific challenge

- The West Caucasus is one of the most flood-impacted areas in Russia
- Short-term forecasting of rain flood formation in West Caucasus is challenged due to the local nature of heavy precipitation events and low density of precipitation gauging network.
- Mesoscale numerical weather prediction (NWP) models are widely used as the initial data sources to drive runoff formation models.
- Horizontal grid size of global NWP models has been reduced to 9-13 km, that allow partially resolve a deep convection.
- Among publicly available sources of precipitation forecasts, the ICON-Eu model is of greatest interest due to its high spatial resolution (6.5 km).

- The aim of this study is to assess the applicability of short-term precipitation forecast according to the ICON-Eu regional NWP model and the possibility of its use as input precipitation data for event-based rainfall-runoff model KW-GIUH

Study area


weather stations
RF region borders
Elevation, m
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2 000
3 000
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Heavy rainfall reports

- The data from 57 weather stations of Roshydromet have been used
- 189 heavy rainfall events (≥ 30 mm/12 h) have been reported between January 2019 and July 2020
- 66 days with heavy rainfall events
- 61 events with precipitation amount ≥50 mm/12 h, and two ones with precipitation amount ≥100 mm/12 h
- Highest number of heavy rainfall events have been reported at Aug 17, 2019 (11 reports, including 7 ones with precipitation amount ≥ 50 mm/12 h) and February 4, 2020 (13 reports, including 9 ones with precipitation amount ≥ 50 mm/12 h).

NWP models data

NWP Model	Developers	GRID resolution, km	Number of vertical levels	Output data grid resolution	Output data time step	Initial conditions for start the model
ICON-Eu	Deutscher Wetterdienst (DWD), Germany	6.5	60	6.5 km	1 h	
WRF – ARW*	(NCEP) and Penn State University U.S.	3.0	64	3 km	1 h	ERA-5 reanalysis
Cosmo -RU*	International Consortium for small-scale modelling	7	?	7 km	3 h	ICON-Global

*The model was used only for the event August 17-18, 2019

Assessment of forecast accuracy

- The CSI and EDI metrics were calculated based on the contingency table of predicted and observed heavy rainfall events.

$$SCI = TP/(TP + FP + FN)$$

$$EDI = \frac{\log F - \log H}{\log F + \log H}$$

- To calculate EDI values, it is needed to preliminary calculate the number of true positive (H) and false alarms (F)

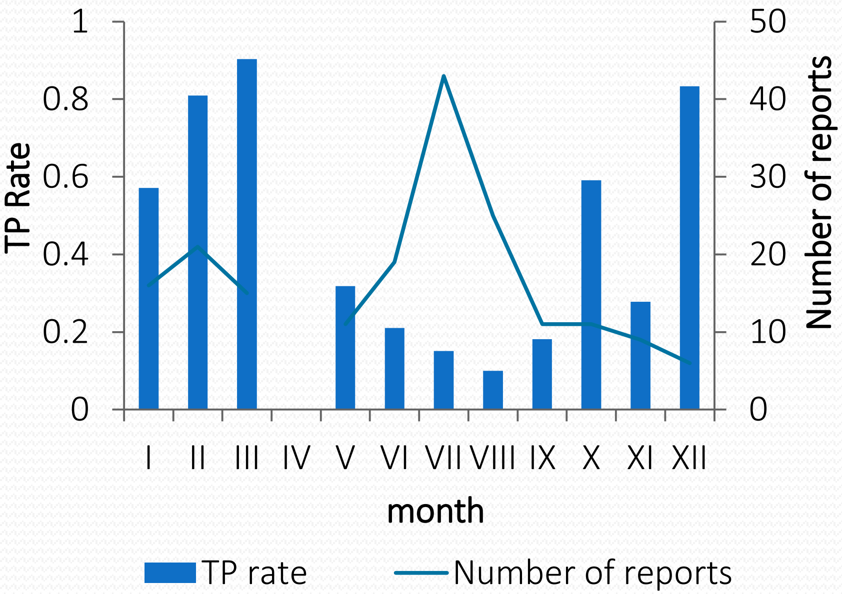
$$H = TP/(TP + FN)$$

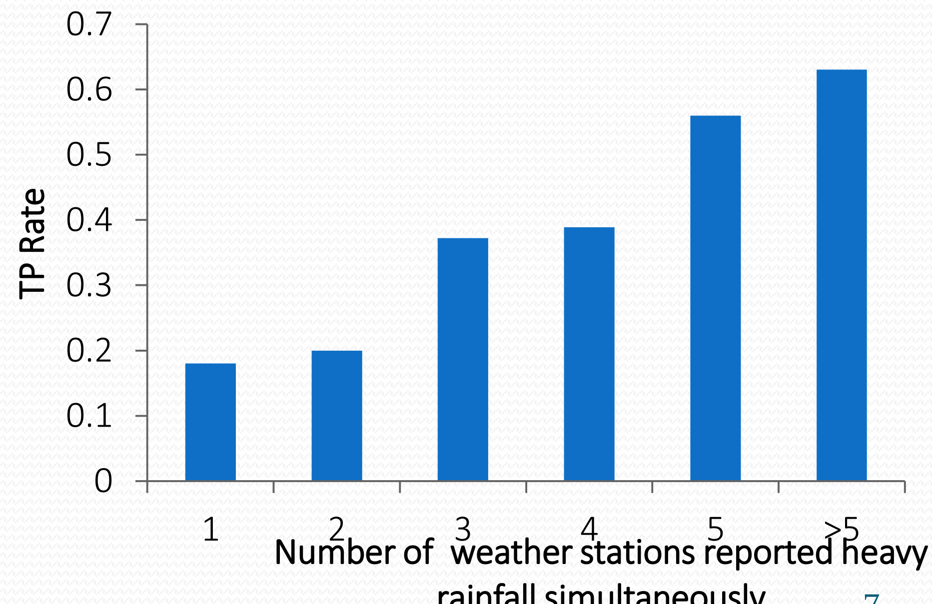
$$F = FP/(FP+TN)$$

- Where *TP* is the number of true positive forecasts, *FN* – the number of false positive forecasts, *FP* – the number of false alarms and *TN* – the number of true negative forecasts.

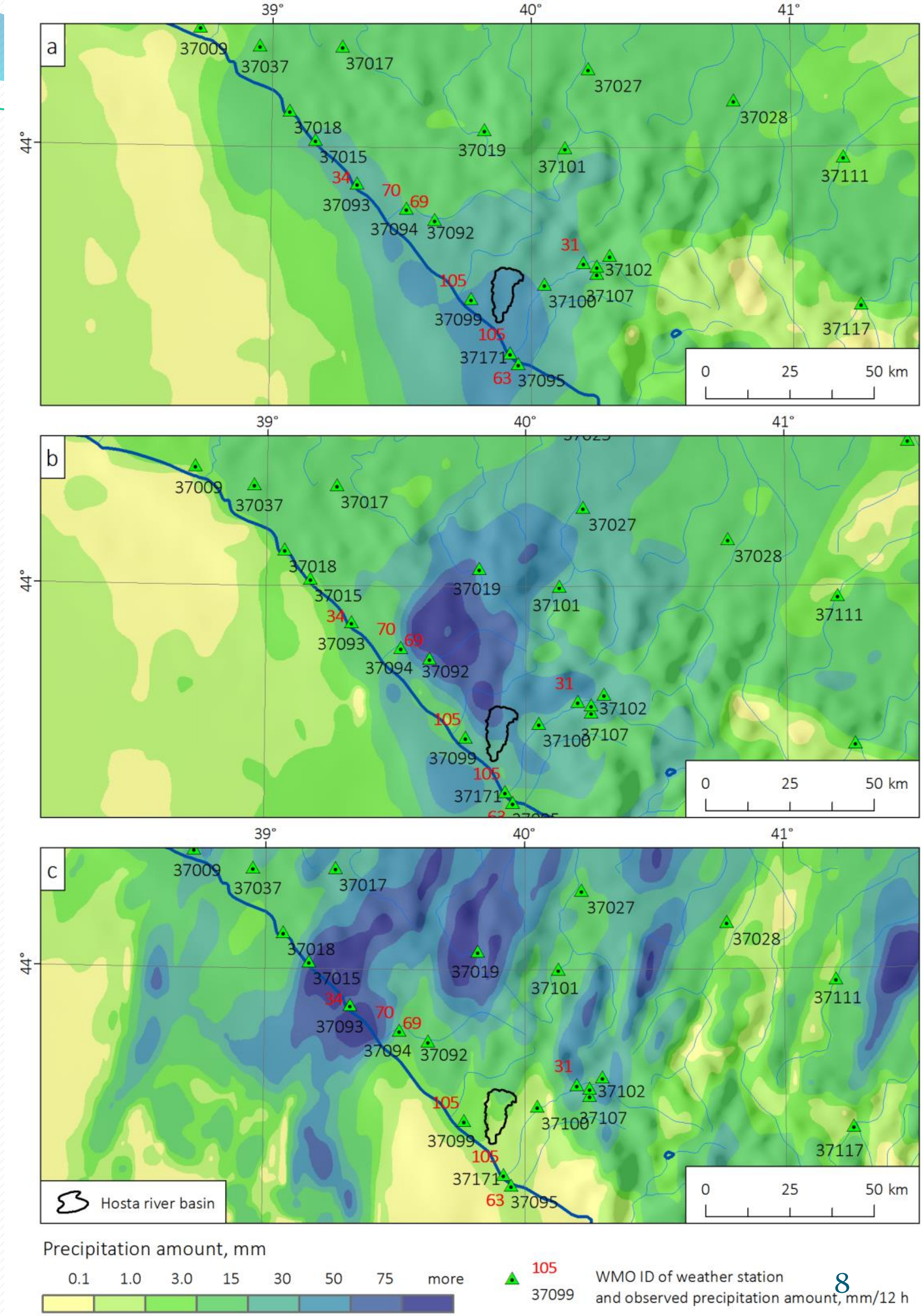
Assessment of forecast accuracy

Season	Model start time	TP	FN	FP	TN	SCI	EDI
All study period	00.00 UTC	66	119	51	3572	0.28	0.61
	12.00 UTC	74	112	71	3577	0.29	0.62
April – September (109 events)	00.00 UTC	16	93	22	2569	0.12	0.43
	12.00 UTC	21	88	11	2580	0.18	0.53
October –March (80 events)	00.00 UTC	53	26	59	1083	0.38	0.76
	12.00 UTC	57	24	65	1096	0.39	0.78



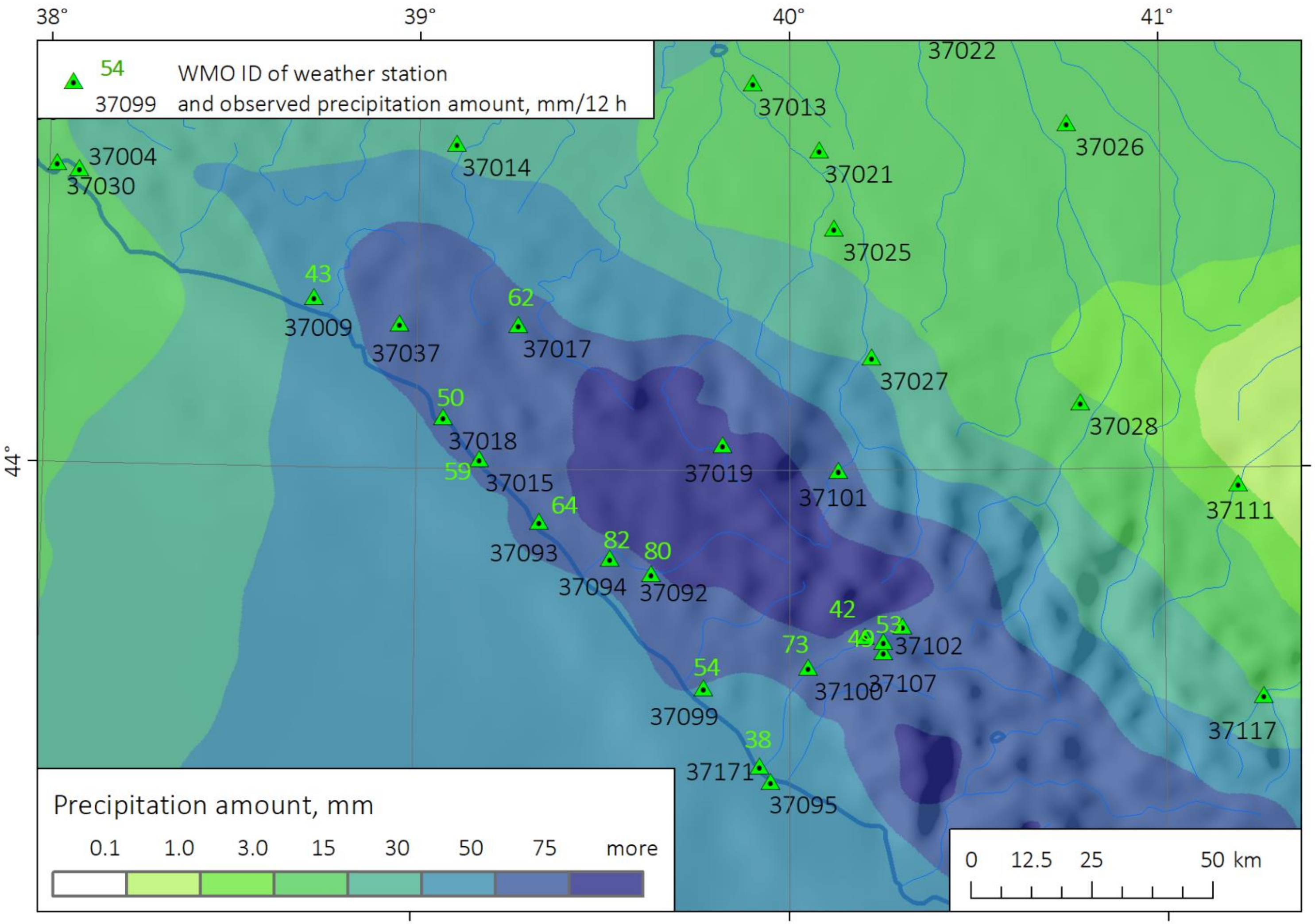


In a warm season, ICON-Eu model substantially underestimated precipitation amount comparing with observational data and other NWP models



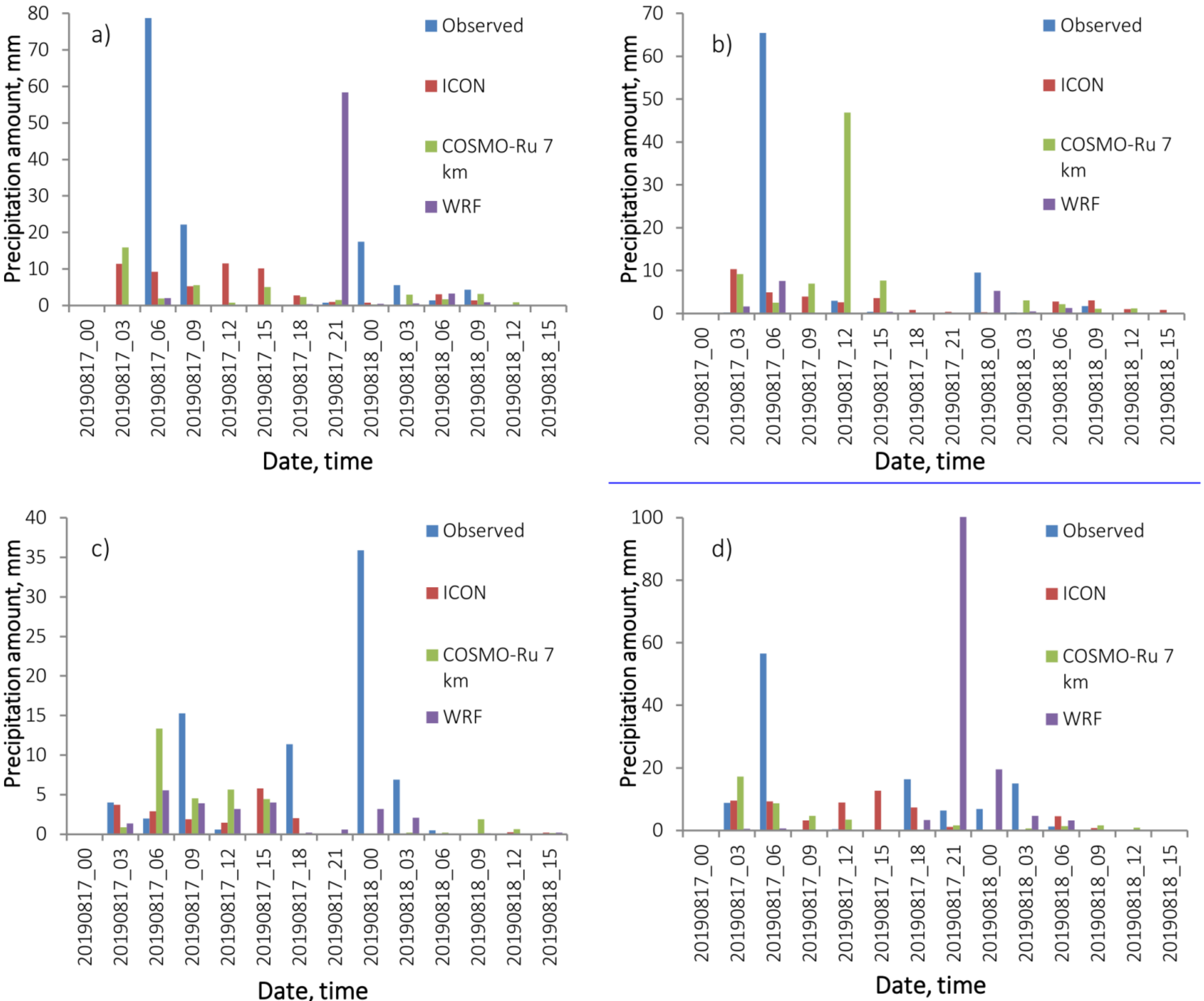
Accumulated precipitation amount between 03.00 and 15.00 UTC August 17, 2019 according to ICON-Eu (a), COSMO-Ru (b) and WRF (c) NWP models. Observed precipitation at the weather stations is also indicated

Accumulated precipitation amount between 15.00 UTC February 3, 2020 and 03.00 UTC February 4, 2020 according to the ICON-Eu models. Observed precipitation at weather stations is also indicated



In a cold season, heavy precipitation events are mainly associated with synoptic-scale processes, which are much more reliable reproduced by the model.

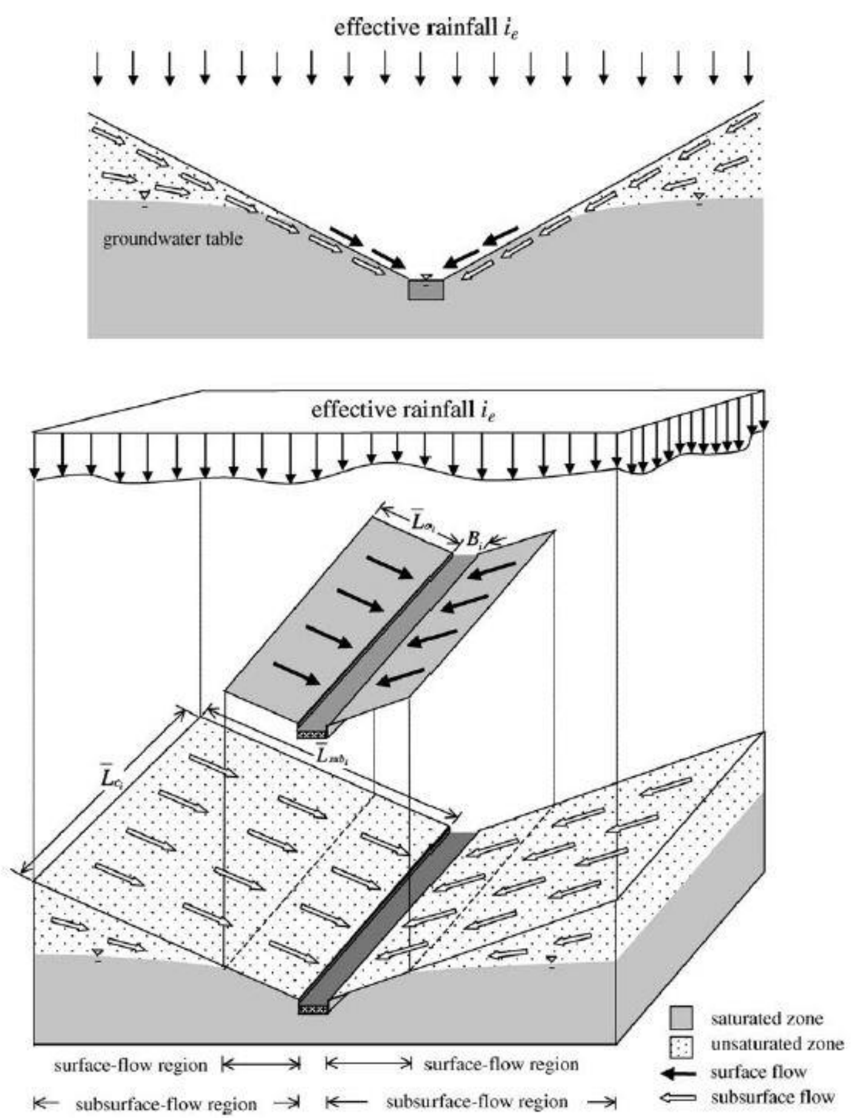
Rainfall intensity forecasting



Observed and simulated 3-h rainfall intensity at the weather stations: 37099 (a), 37092 (b), 37102 (c) hydrological gauge Khosta 82046 (d) at 17-18 August 2019

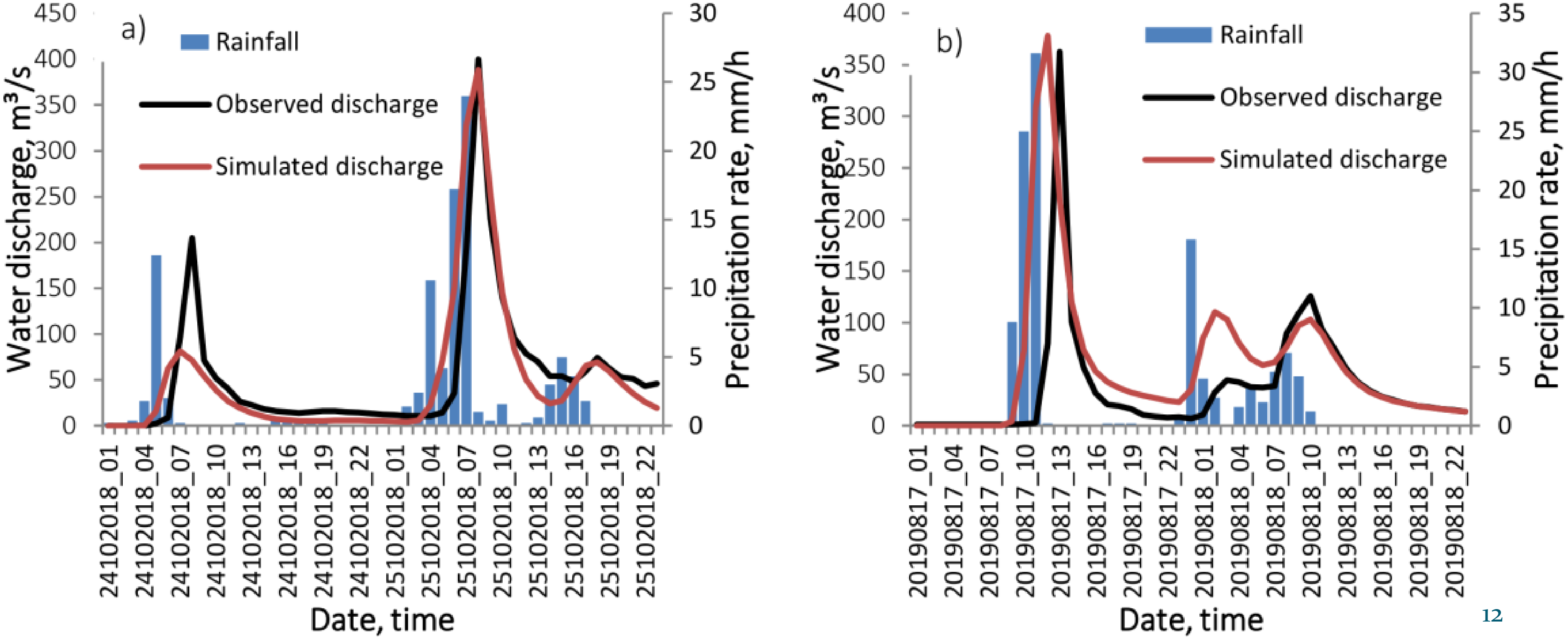
HYDROLOGICAL MODELLING

- We examined water discharge of the Khosta river at the Khosta gauging station (basin area of 98.5 km^2) on 17-18 of August 2019 as there was formed the highest flood among others during the study period (January 2019 – July 2020).
- An event-based rainfall-runoff KW-GIUH (Kinematic-Wave-based Geomorphological Instantaneous Unit Hydrograph) model was applied to simulate the Khosta river flood and to demonstrate model possibilities for flash flood forecasting using various meteorological forcings.



FLOOD SIMULATION

Observed and simulated water discharge at the Khosta river and observed precipitation at hydrological gauge Khosta, a) at 24-25 October 2018 and b) at 17-18 August 2019



Conclusions

- ICON-Eu model systematically underestimates (by 2-3 times) precipitation amount in a warm season (April - September) and almost never reproduces local convective heavy rainfall events (reported at 1-2 weather stations). So, the use of its forecasts for short-term prediction of rain flood events will have low efficiency.
- The ICON-Eu model several times underestimates the maximum intensity of precipitation, on the example of heavy rainfall event occurred August 17, 2019.
- In a cold season (October - March), the ICON-Eu model adequately reproduces most of heavy precipitation events, with some underestimation of the maximum precipitation amount and overestimation of the coverage area. These data can be used to improve short-term forecasting of rain floods on the rivers of the Black Sea coast of the Caucasus during the period from October to March.
- In warm season (April – September) real-time radar data and nowcasting could improve predictability of flash floods with the event-based hydrological model KW-GIUH. The KW-GIUH model is able to satisfactory simulate floods using observed precipitation. Further analysis of observed and simulated floods is needed for more sustainable parameter estimation.

Thank you for your attention

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