Correction of hourly radar precipitation data based on rain-gauges values: what is the most efficient method for hydrologic modeling purposes?

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UNIVERSITÀ DEGLI STUDI DI MILANO

THE CYPRUS INSTITUTE
RESEARCH•TECHNOLOGY•INNOVATION

EGU General Assembly 2023

LINK TO THE ABSTRACT:

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METHOD

RESULTS

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

METHOD

RESULTS

LINK TO THE ABSTRACT:

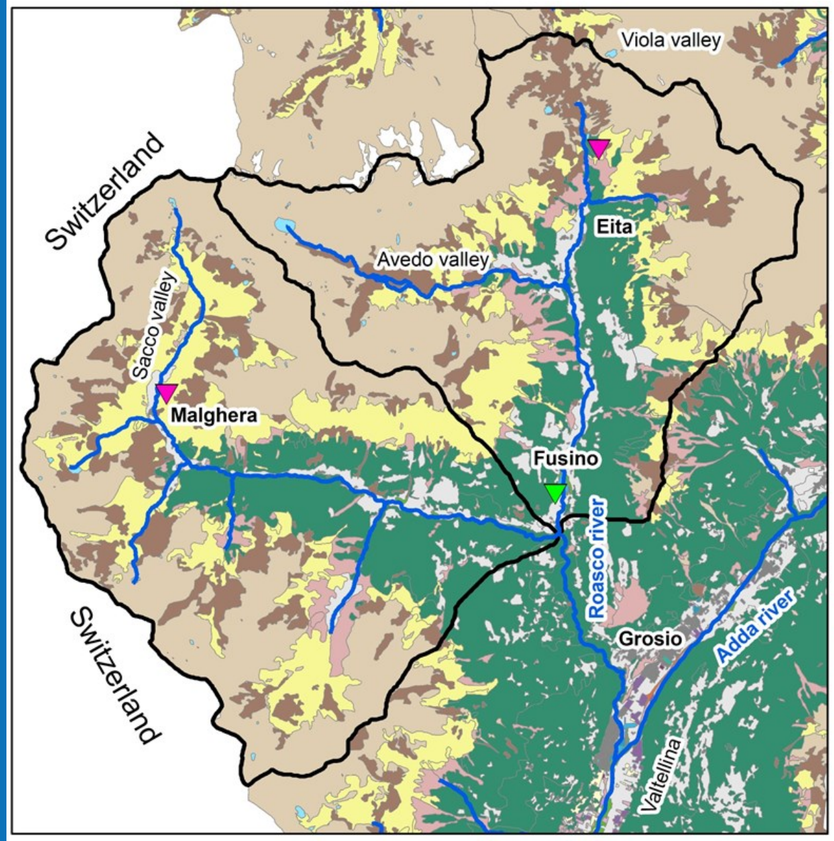
Research goals

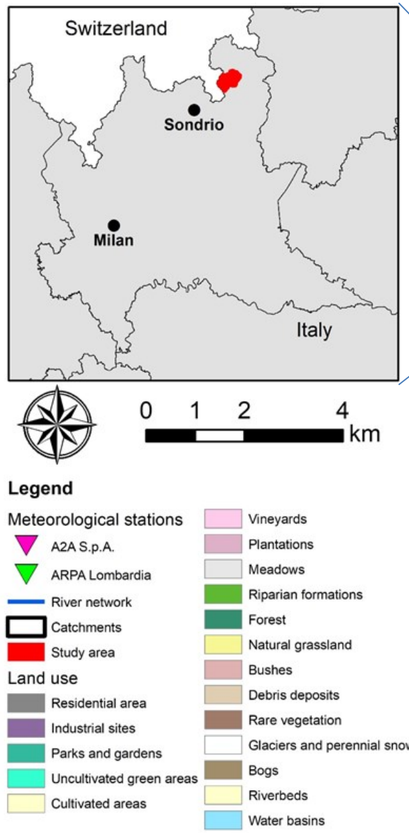
Radar data corrections

Hydrologic model runs

Most efficient radar correction method for hydrologic purposes

Study area





Sacco catchment: 71 km^2 (1030.0 ÷ 3260.6 m a.s.l., mean value of 2249.6 m a.s.l.)
Eita catchment: 62 km^2 (1030.0 ÷ 3370.0 m a.s..l., mean value of 2254.9 m a.s.l.)

The climate is of **central-alpine type**, with medium-low precipitation (800-1000 mm), more consistent in spring and summer(max of 1700 mm/y).

The main lithotypes are represented by **micaschists and gneisses** with local lenticular intercalations of quartz and greyish micaceous quartzites → **Runoff>>Infiltration**

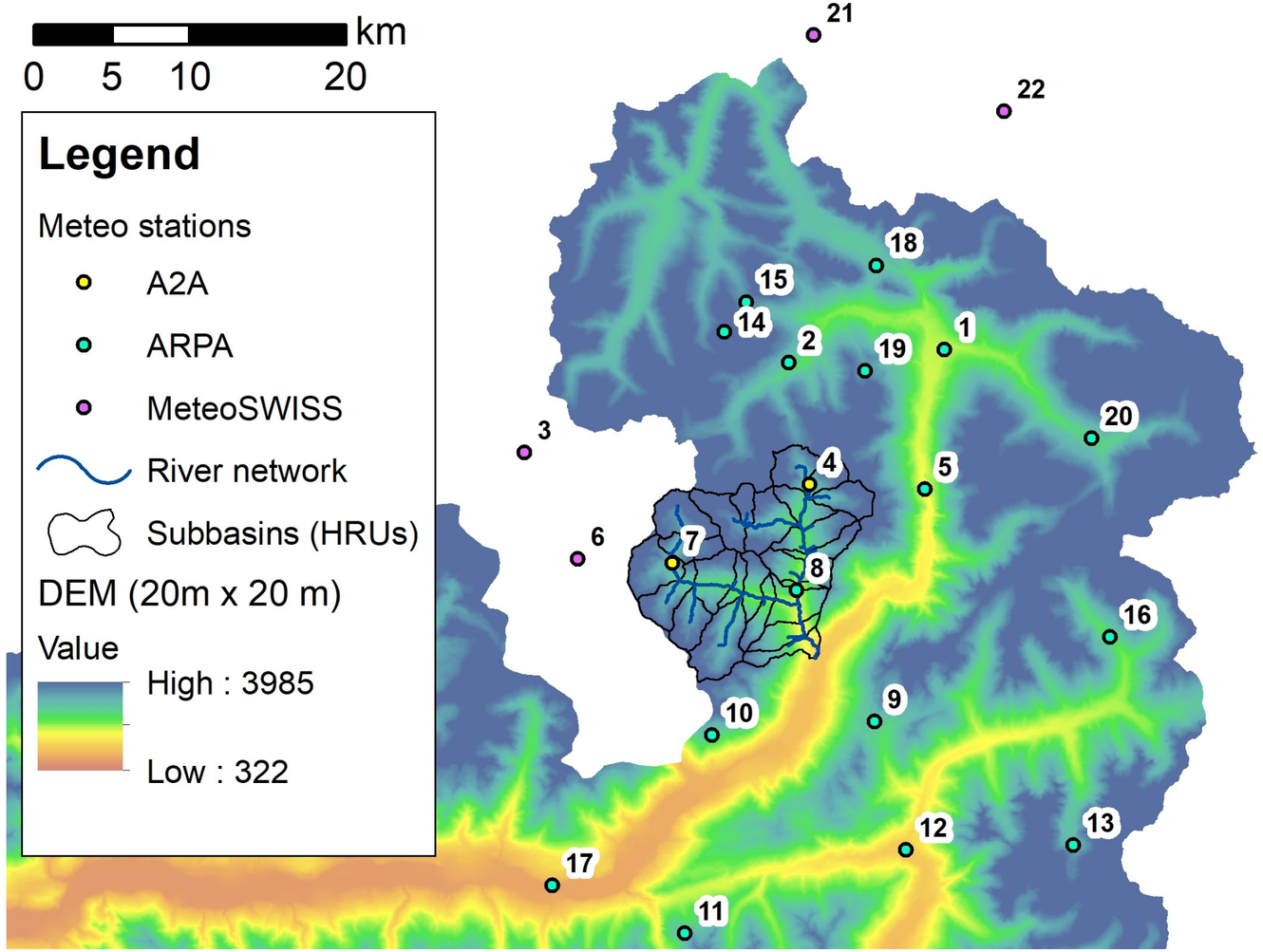
METHOD

RESULTS

LINK TO THE ABSTRACT:

Available data

1- Bormio, Frodolfo;
2- Valdidentro, Arnoga;
3- Passo del Bernina;
4- Eita;
5- Valdisotto, Arginone;
6- Poschiavo/Robbia;
7- Malghera;
8- Grosio, Fusino Dam;
9- Monno;
10- Tirano, M. Masuccio;
11- Aprica;
12- Edolo, Ist. Meneghini;
13- Edolo, Pantano Avio;
14- Livigno, la Vallaccia;
15- Livigno, P. Foscagno;
16- Ponte di Legno;
17- Teglio, S. Giacomo;
18- Valdidentro, Cancano;
19- Valdisotto, Oga;
20- Valfurva, S. Caterina;
21- Buffalora;
22- S. Maria/Val Mustair



Hourly Precipitation dataset from 22 rain-gauges.
Period from 01-10-2010 to 30-09-2020

METHOD

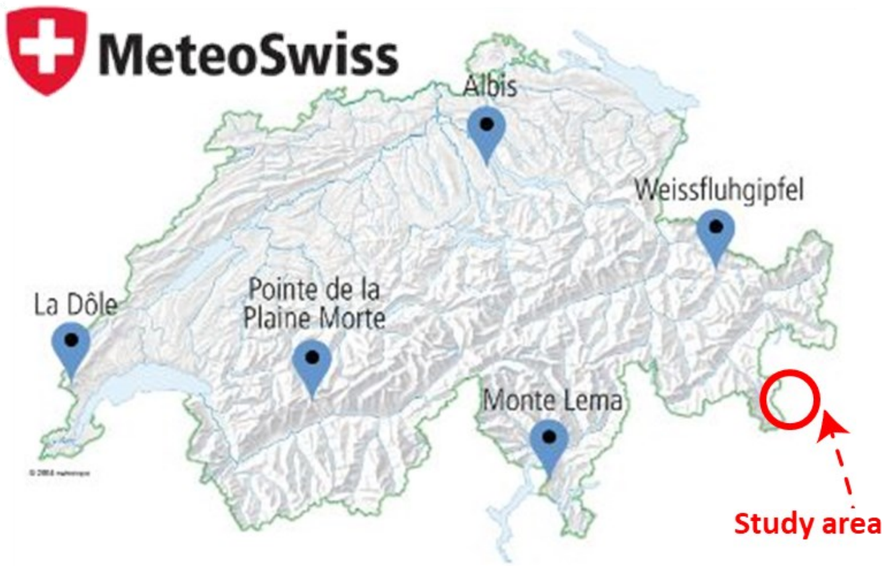
RESULTS

LINK TO THE ABSTRACT:

METHOD

RESULTS

LINK TO THE ABSTRACT:



The CombiPrecip (CPC) product provides information on hourly precipitation levels at ground level (1 km x 1 km resolution). Using a geostatistical method, radar estimates are combined with data from Swiss rain-gauges. The CombiPrecip products cover the entire area monitored by the Swiss weather radar network, which includes Switzerland and its neighboring regions.

Comparing the values in the cells where the 22 available stations are located, the radar underestimates the values by about 28% → It needs to be corrected for a hydrological application

Available data


Monte Lema - 1626 m a.s.l.
Credit: MeteoSwiss

Hydrologic model

METHOD

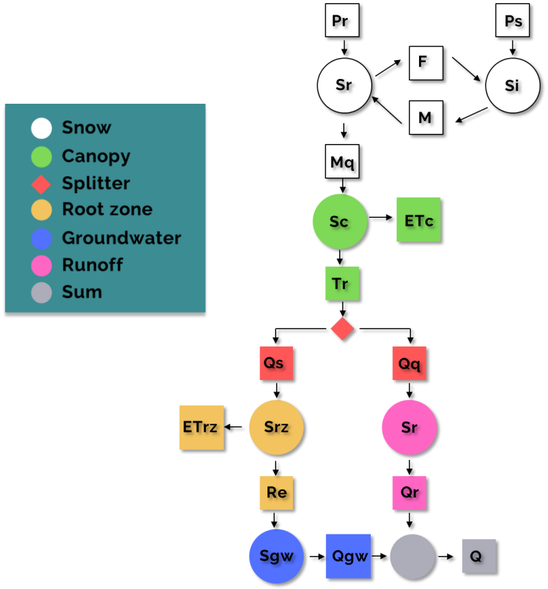
RESULTS

LINK TO THE ABSTRACT:

1 **HRU definition**

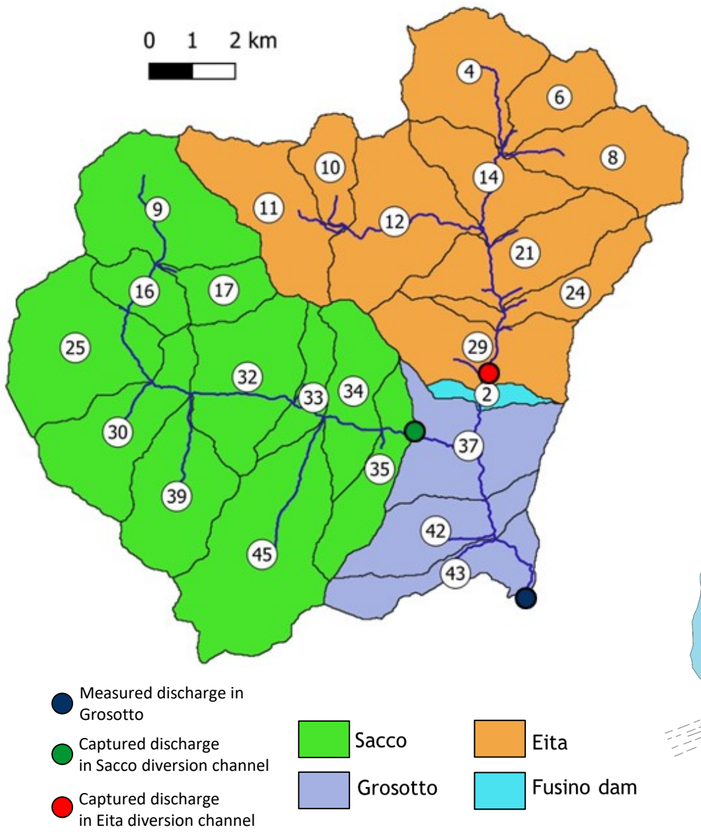
2 **Component computation**

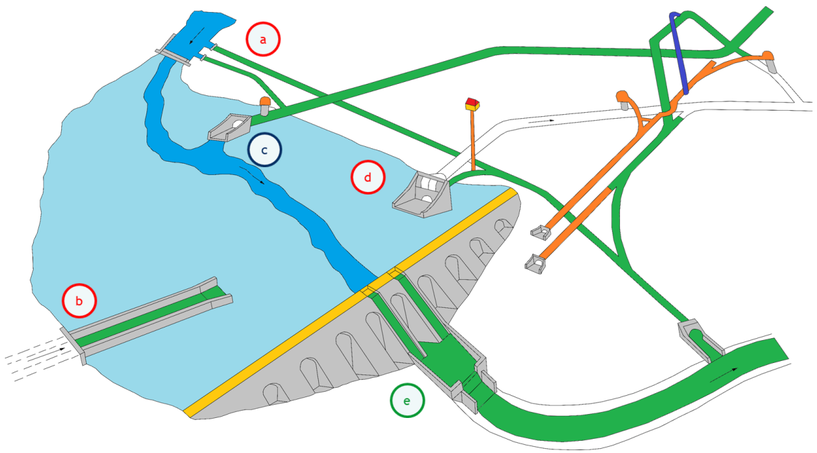
3 **Streamflow simulation following the topology scheme**



Pr – Rainfall;
Ps – Snow;
Sr - Rainfall storage;
Si – ice storage;
F – Freezing;
M – Melting;
Mq –Snowmelting /Rain;
Sc – Canopy storage;
Etc – Canopy evapotranspiration;
Tr – Throughfall;

Qs – Slow flow;
Qq – Quick flow;
Srz – Root zone storage;
Etrz – Root zone evapotranspiration;
Re – Groundwater recharge;
Sgw – Groundwater storage;
Qgw – Groundwater flow;
Sr – Runoff storage;
Qr – Runoff flow;
Q – Simulated streamflow.



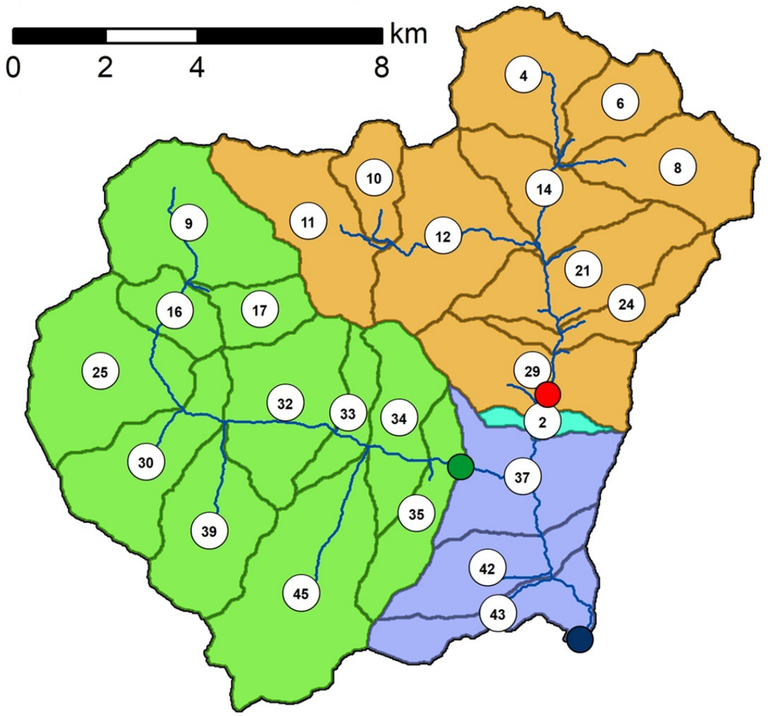


GEOframe

Formetta et al.(2014), Bancheri (2017)

It is an open-source hydrological modeling system developed by the University of Trento.
It is a partially distributed model formed by different components that simulate the streamflow and that can be used independently or in combination between them.

Hydrologic model calibration-validation



Grosotto

Sacco

Eita

Measured discharge in Grosotto

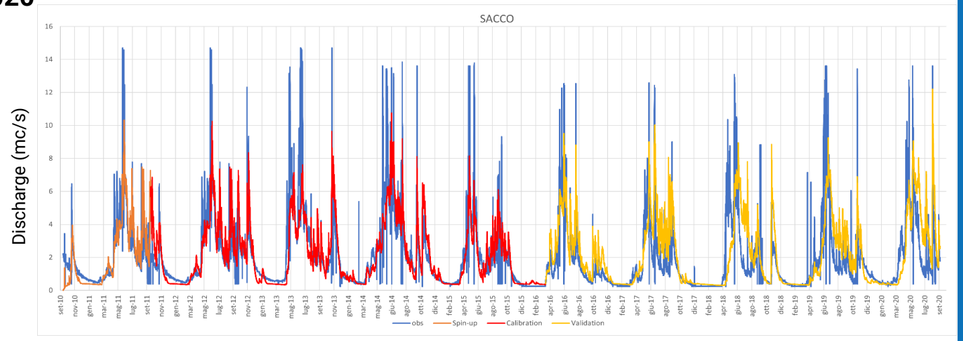
Captured discharge in Sacco penstock

Captured discharge in Eita penstock

Sacco → Period from **01-10-2010** to **30-09-2020**

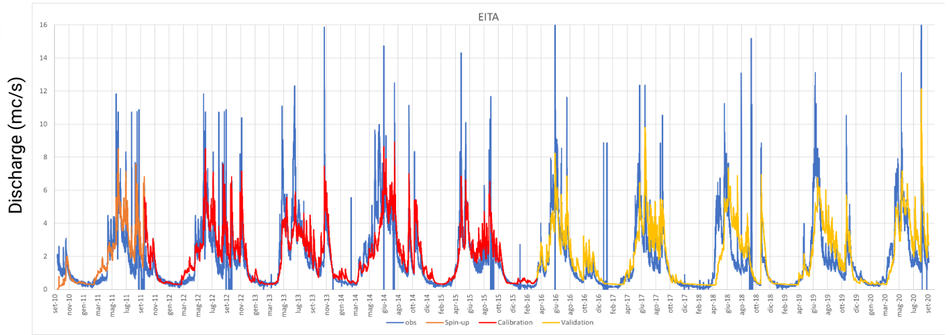
NSE		hourly	daily	Log_h
Calibration	01/10/2011 31/03/2016	0.64	0.67	0.75
Validation	01/04/2016 30/09/2020	0.48	0.50	0.64

May-Oct MEF = 0.406 m^3s^{-1}
Nov-Apr MEF = 0.266 m^3s^{-1}



Eita → Period from **01-10-2010** to **30-09-2020**

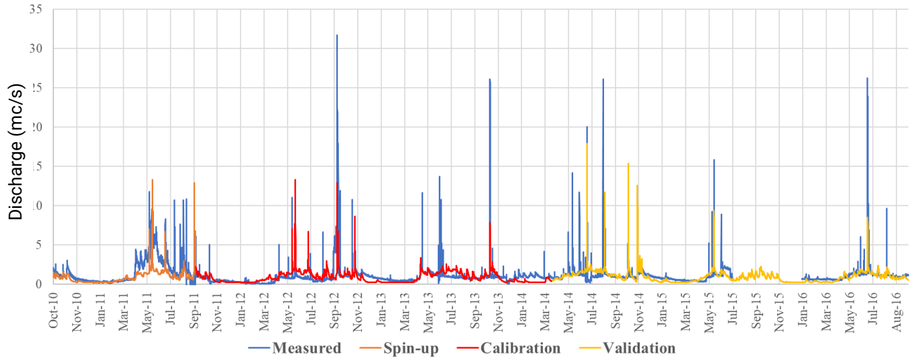
NSE		hourly	daily	Log_h
Calibration	01/10/2011 31/03/2016	0.66	0.67	0.78
Validation	01/04/2016 30/09/2020	0.63	0.64	0.76



Grosotto → Period from **01-10-2010** to **30-09-2016**

NSE		hourly
Calibration	01/10/2011 31/03/2014	0.15
Validation	01/04/2014 30/09/2016	0.16

Control data → Measured discharge in Grosotto hydrometer (from 01-10-2011 to 30-09-2016)



METHOD

RESULTS

LINK TO THE ABSTRACT:

Method

INPUT

- Hourly rain-gauge dataseries from Oct 2010 to Dec 2020
- Hourly radar dataseries from Oct 2010 to Dec 2020

Point-based corrections exploiting the Triangular Irregular Network TIN:

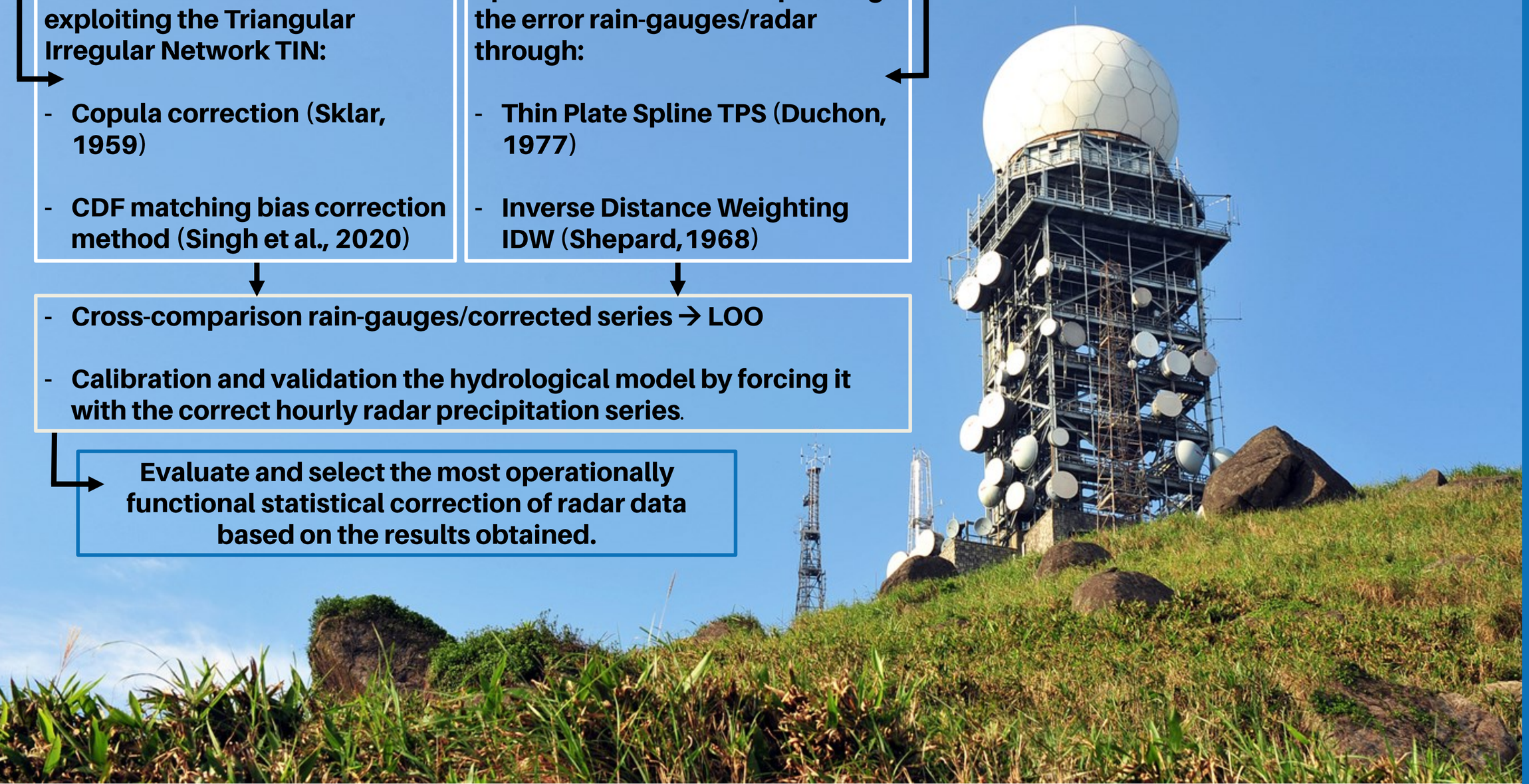
- Copula correction (Sklar, 1959)
- CDF matching bias correction method (Singh et al., 2020)

Spatial corrections interpolating the error rain-gauges/radar through:

- Thin Plate Spline TPS (Duchon, 1977)
- Inverse Distance Weighting IDW (Shepard,1968)

- Cross-comparison rain-gauges/corrected series → LOO
- Calibration and validation the hydrological model by forcing it with the correct hourly radar precipitation series.

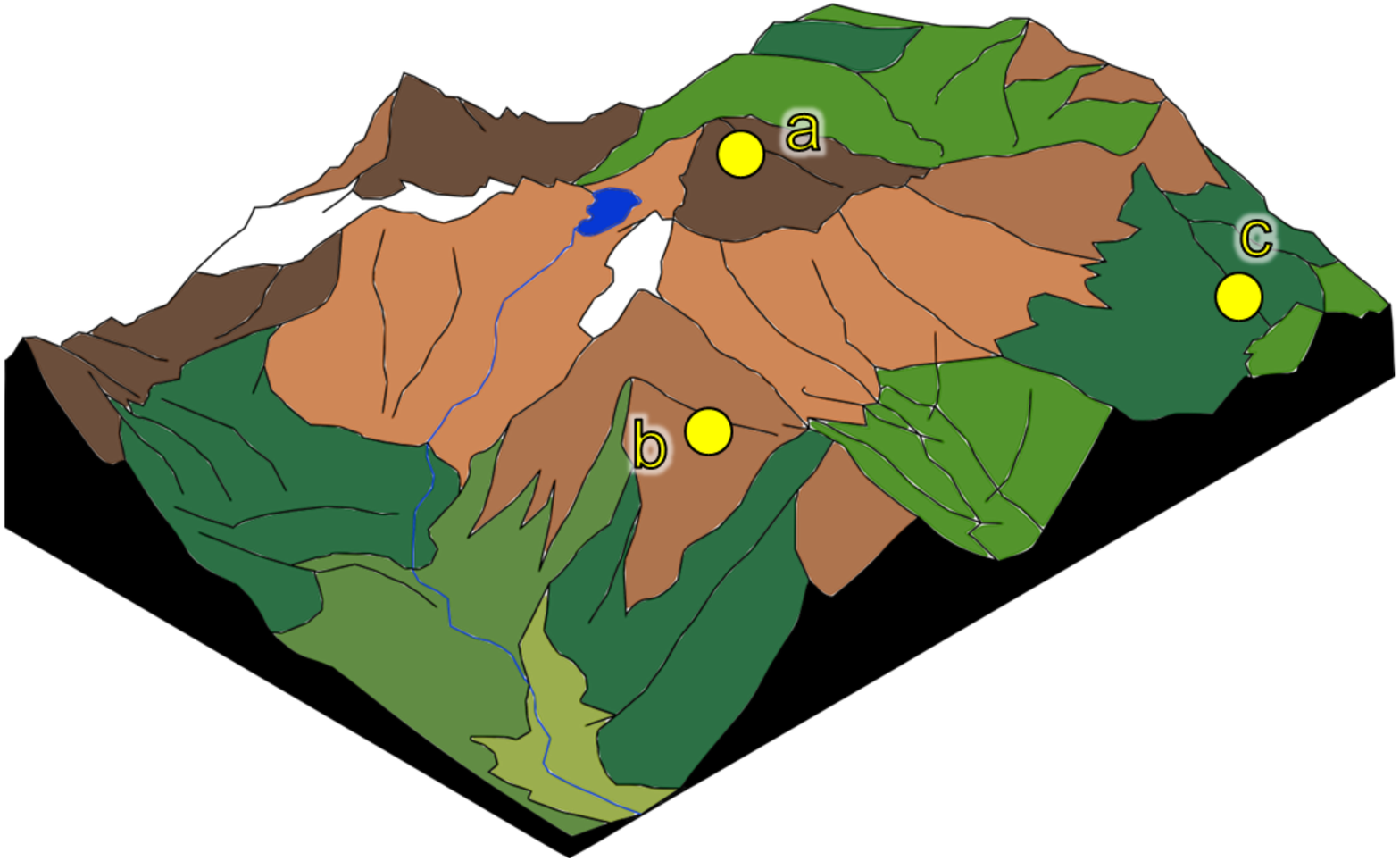
Evaluate and select the most operationally functional statistical correction of radar data based on the results obtained.



LINK TO THE ABSTRACT:

Point-based corrections

- Three rain-gauges a, b, and c

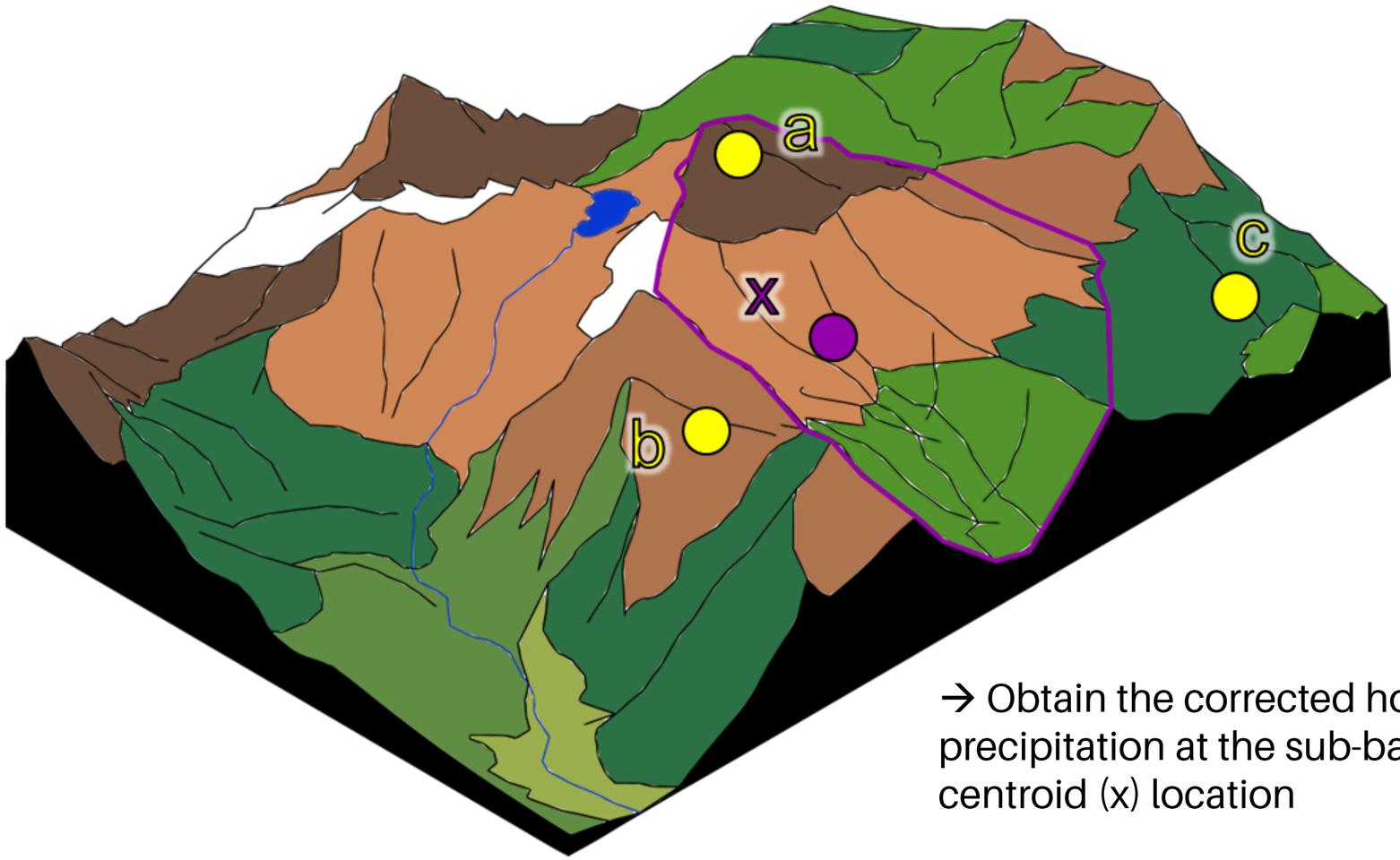


Rain-gauge

LINK TO THE ABSTRACT:

Point-based corrections

- Three rain-gauges a, b, and c



Rain-gauge

Centroid sub-basin

Sub-basin

→ Obtain the corrected hourly precipitation at the sub-basin centroid (x) location

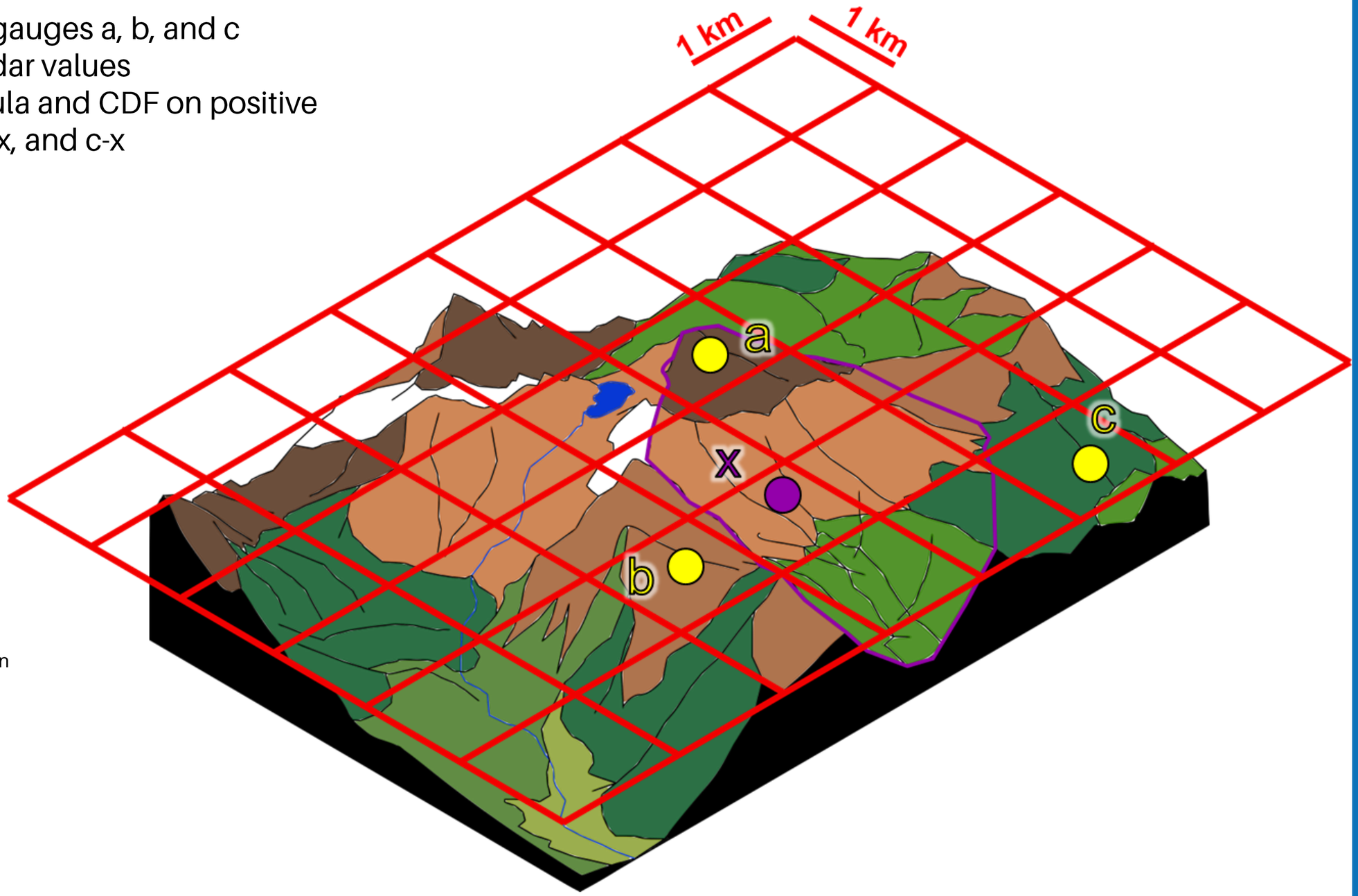
METHOD

RESULTS

LINK TO THE ABSTRACT:

Point-based corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Apply Copula and CDF on positive pairs a-x, b-x, and c-x



Rain-gauge

Centroid sub-basin

Sub-basin

Radar cell

METHOD

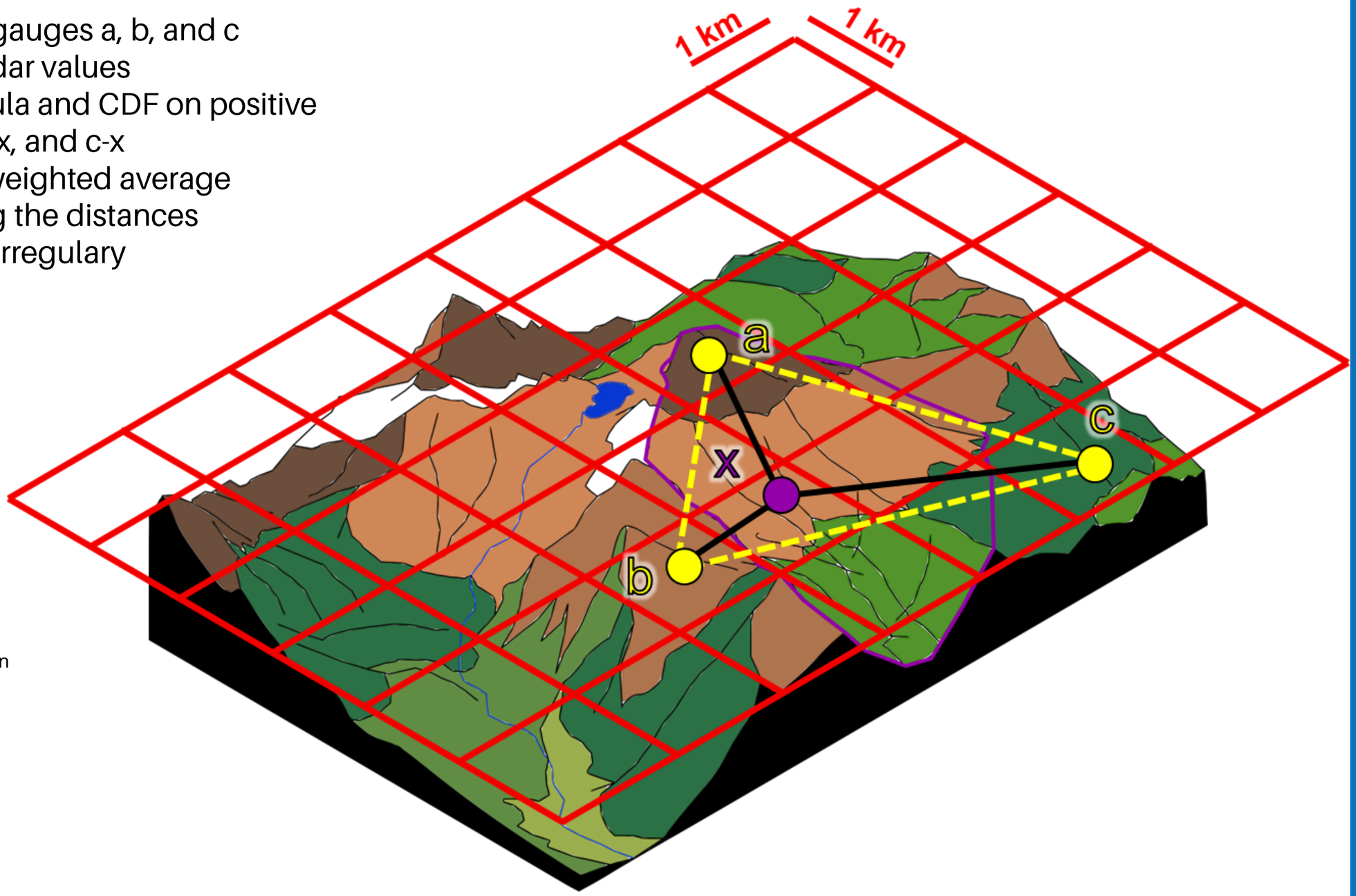
RESULTS

LINK TO THE ABSTRACT:

Point-based corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Apply Copula and CDF on positive pairs a-x, b-x, and c-x
- Perform a weighted average considering the distances

→Triangular Irregulary Network TIN



Rain-gauge

Centroid sub-basin

Distance

Triangle side

Sub-basin

Radar cell

METHOD

RESULTS

LINK TO THE ABSTRACT:

Point-based corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Apply Copula and CDF on positive pairs a-x, b-x, and c-x
- Perform a weighted average considering the distances

→Triangular Irregulary Network TIN

$$coef_a = \frac{sum\_dist}{dist_1\left(\frac{sum\_dist}{dist_1} + \frac{sum\_dist}{dist_2} + \frac{sum\_dist}{dist_3}\right)}$$

$$coef_b = \frac{sum\_dist}{dist_2\left(\frac{sum\_dist}{dist_1} + \frac{sum\_dist}{dist_2} + \frac{sum\_dist}{dist_3}\right)}$$

$$coef_c = \frac{sum\_dist}{dist_3\left(\frac{sum\_dist}{dist_1} + \frac{sum\_dist}{dist_2} + \frac{sum\_dist}{dist_3}\right)}$$

Rain-gauge

Centroid sub-basin

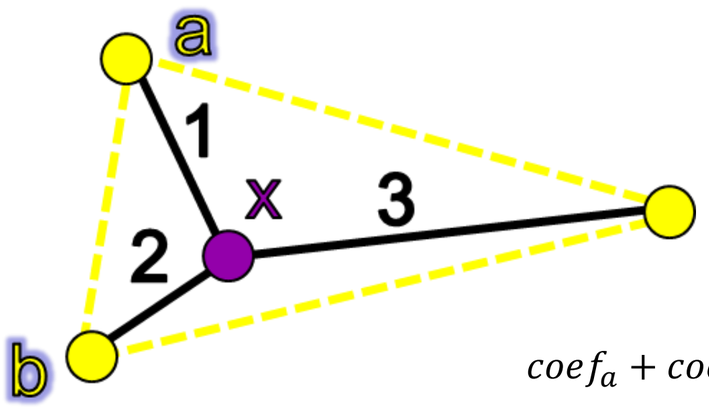
Distance

Triangle side

Sub-basin

TIN-Copula (Lazoglou et al., 2019; 2022)

Copula → a multivariate cumulative distribution function used to describe/model the dependence (inter-correlation) between random variables



$$coef_a + coef_b + coef_c = 1$$

The series obtained from **CDF correction** is given by the solution to

$$cdf_{rg}(x') = cdf_{rad}(x)$$

where x is the radar value and cdf_{rg} and cdf_{rad} are the cdf's of the rain-gauge and the radar, respectevely.

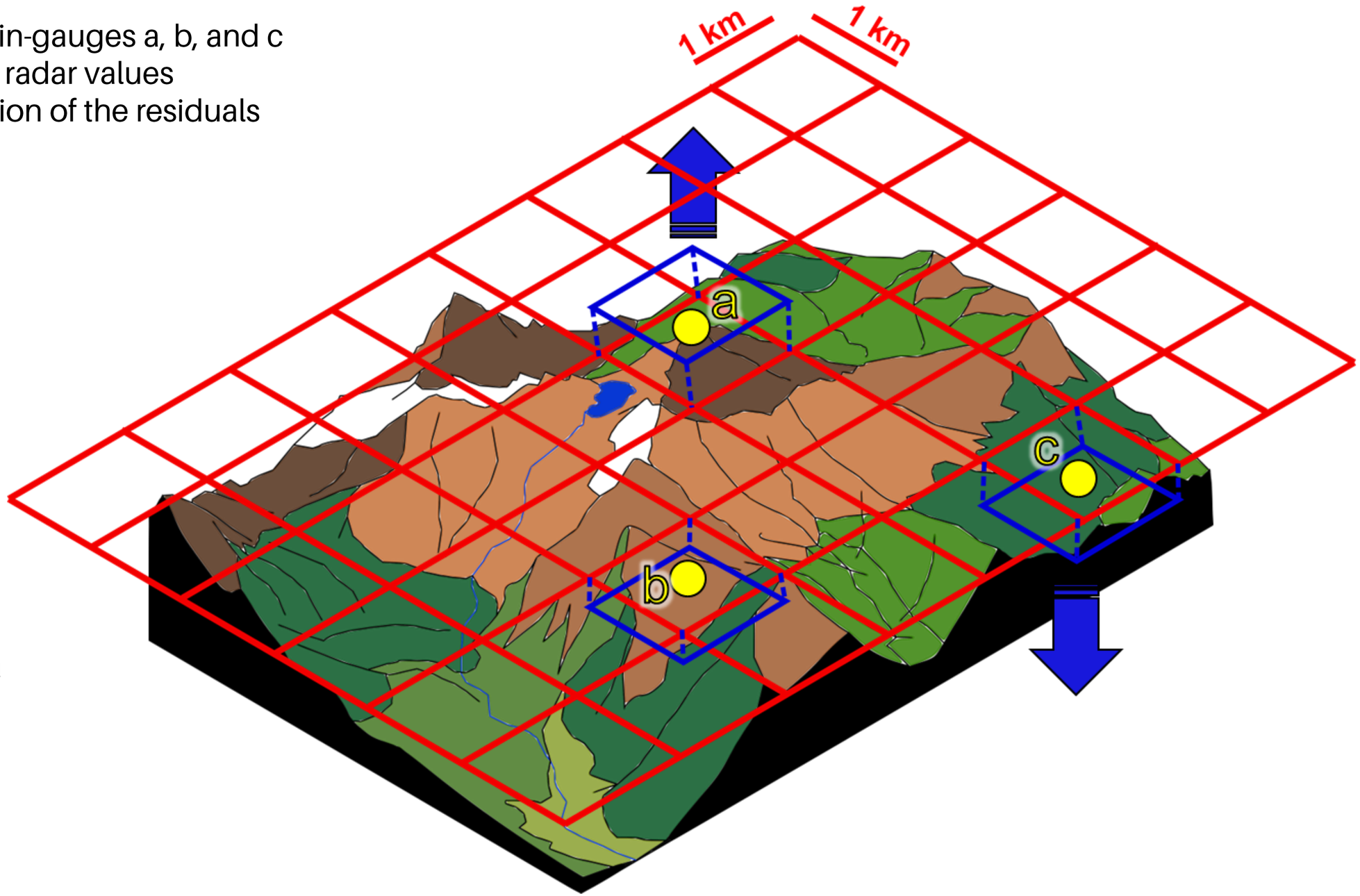
METHOD

RESULTS

LINK TO THE ABSTRACT:

Spatial corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals



Rain-gauge

Residual cell

Radar cell

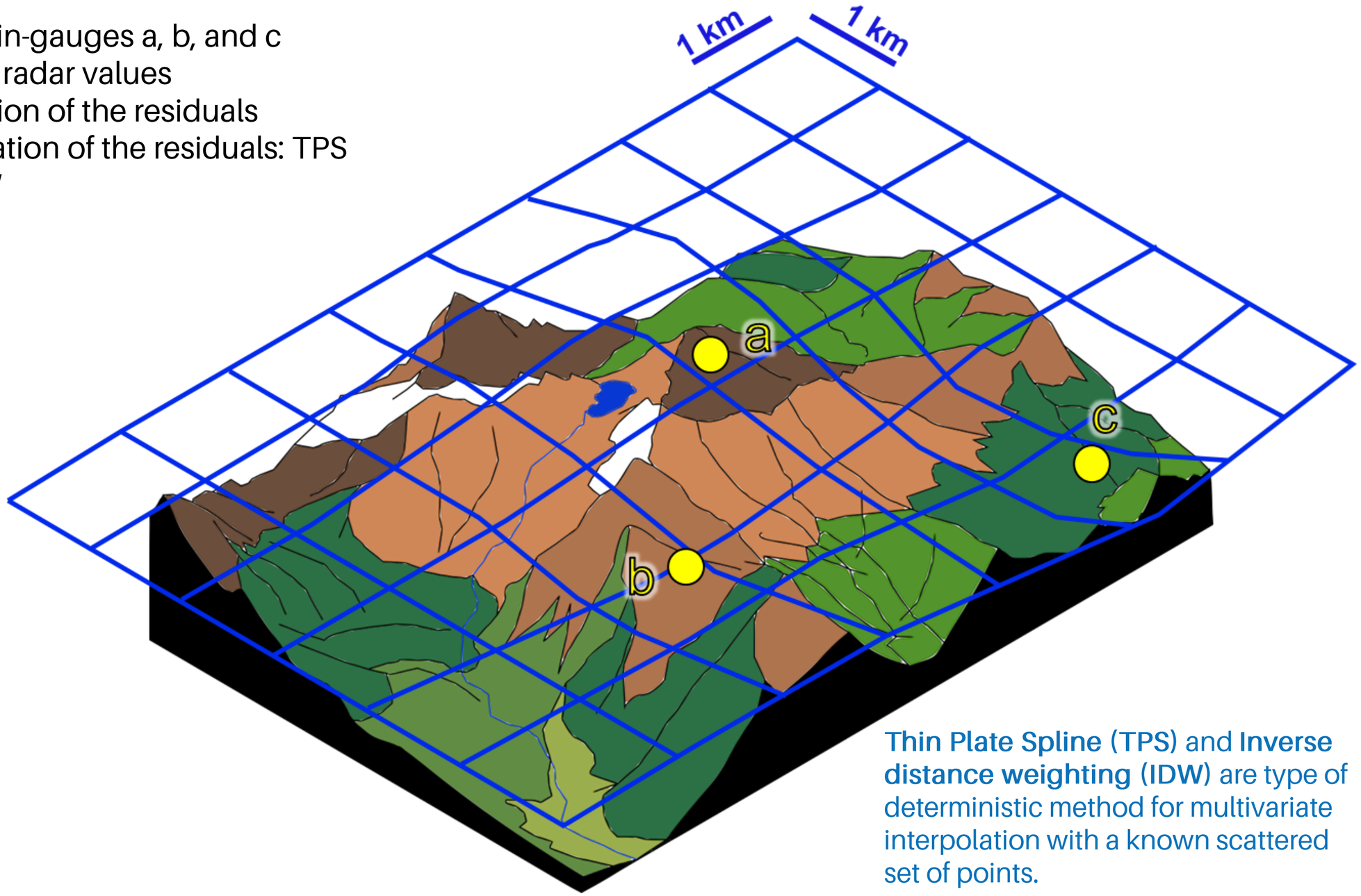
METHOD

RESULTS

LINK TO THE ABSTRACT:

Spatial corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals
- Interpolation of the residuals: TPS and IDW



Rain-gauge

Residual cell

Thin Plate Spline (TPS) and **Inverse distance weighting** (IDW) are type of deterministic method for multivariate interpolation with a known scattered set of points.

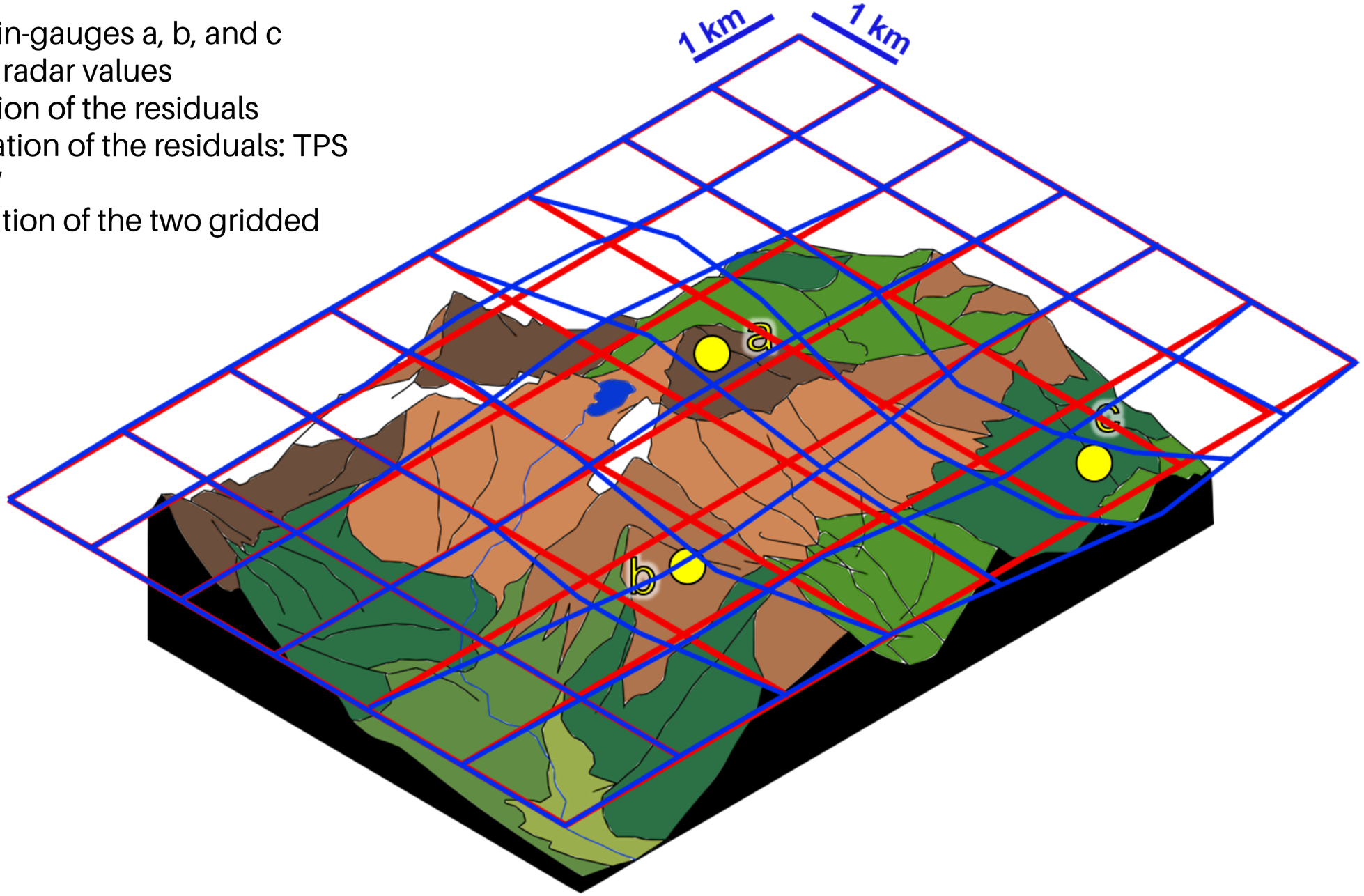
METHOD

RESULTS

LINK TO THE ABSTRACT:

Spatial corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals
- Interpolation of the residuals: TPS and IDW
- Aggregation of the two gridded dataset



Rain-gauge

Residual cell

Radar cell

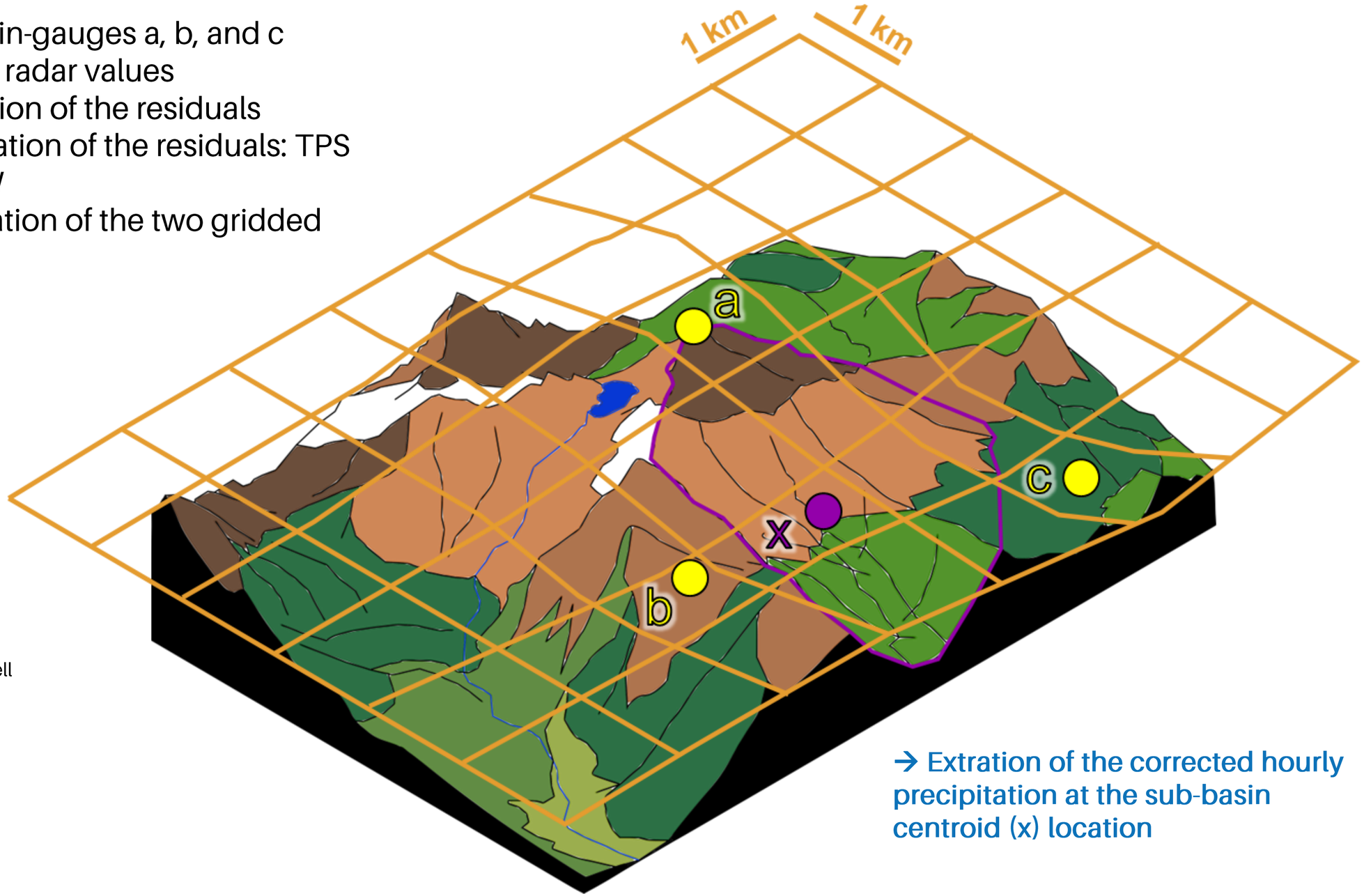
METHOD

RESULTS

LINK TO THE ABSTRACT:

Spatial corrections

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals
- Interpolation of the residuals: TPS and IDW
- Aggregation of the two gridded dataset



Rain-gauge

Corrected cell

→ Extration of the corrected hourly precipitation at the sub-basin centroid (x) location

METHOD

RESULTS

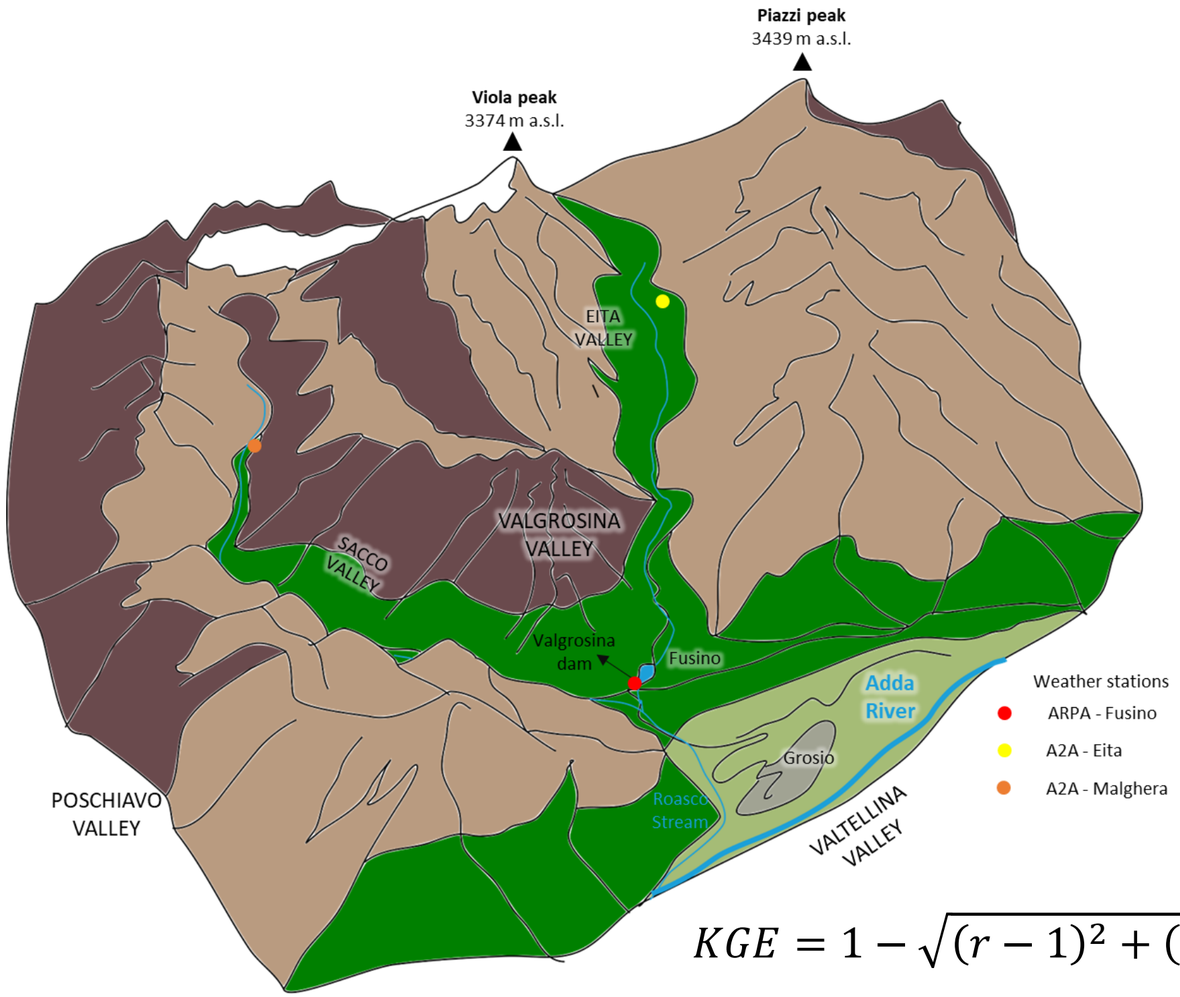
LINK TO THE ABSTRACT:

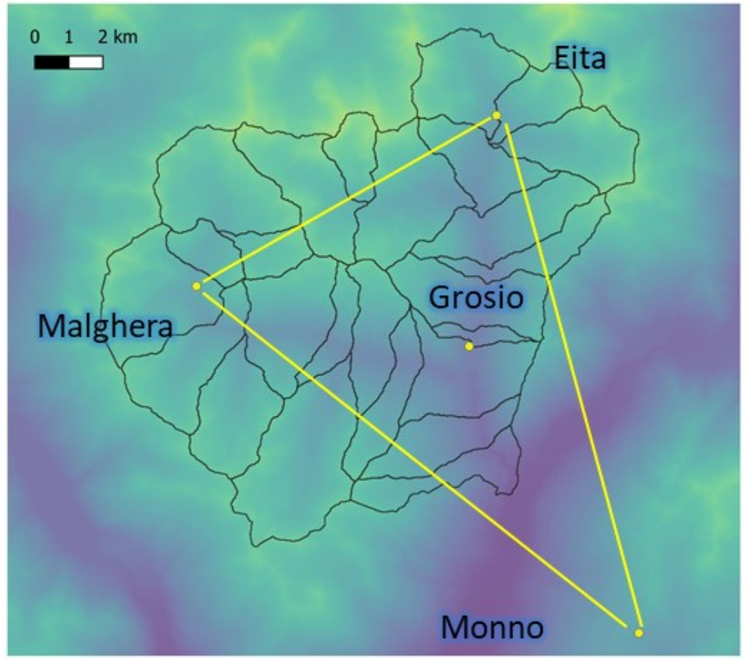
Radar correction evaluation

METHOD

RESULTS

LINK TO THE ABSTRACT:





LOO results compared with the 3 weather stations in the study area

$$KGE = 1 - \sqrt{(r-1)^2 + (\beta-1)^2 + (\gamma-1)^2}$$

KGE index (Gupta et al., 2009) is an expression of distance away from the point of ideal model performance in the space

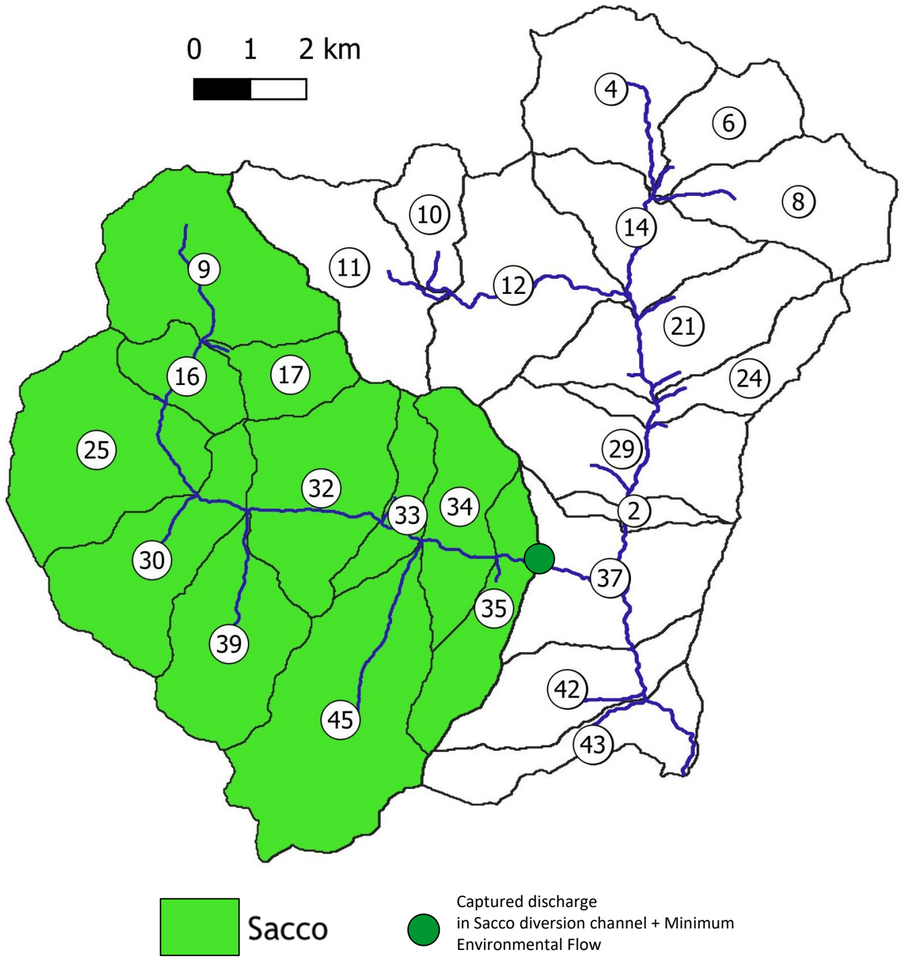
It varies $-\infty < KGE < 1$

Towner et al. (2019)
Andersson et al. (2017)

KGE>0.75 → GOOD!
KGE<0.50 → BAD!

Hourly data		KGE
Radar		0.27
Point-based methods	Copula	0.51
	CDF bias correction	0.39
Spatial methods	Radar+IDW	0.55
	Radar+TPS	0.51

Radar correction
Streamflow preliminary results



Hydrologic model results of Sacco section

Raw radar

Hourly		KGE
Calibration	01/10/2011 31/03/2016	0.55
Validation	01/04/2016 30/09/2020	0.44

Point-based corrections

KGE		TIN-Copula	TIN-CDF
Calibration	01/10/2011 31/03/2016	0.33	0.58
Validation	01/04/2016 30/09/2020	0.32	0.36

Spatial corrections

KGE		Radar+TPS	Radar+IDW
Calibration	01/10/2011 31/03/2016	0.69	0.71
Validation	01/04/2016 30/09/2020	0.64	0.64

METHOD

RESULTS

LINK TO THE ABSTRACT:

Final remarks

- After applying several correction techniques on the radar data, the spatial approach has proven to be the best fit. However, no substantial differences in application results between TPS and IDW are noted

- Spatial corrections are cost-effective and user-friendly compared to the point-based ones

- Good results were obtained in the coupling of the corrected radar data and the hydrological model

→Further calibration runs will be attempted to improve the robustness of the model

→The series corrected by spatial Radar+TPS approach will be used for statistical downscaling of Regional Climate Models

METHOD

RESULTS

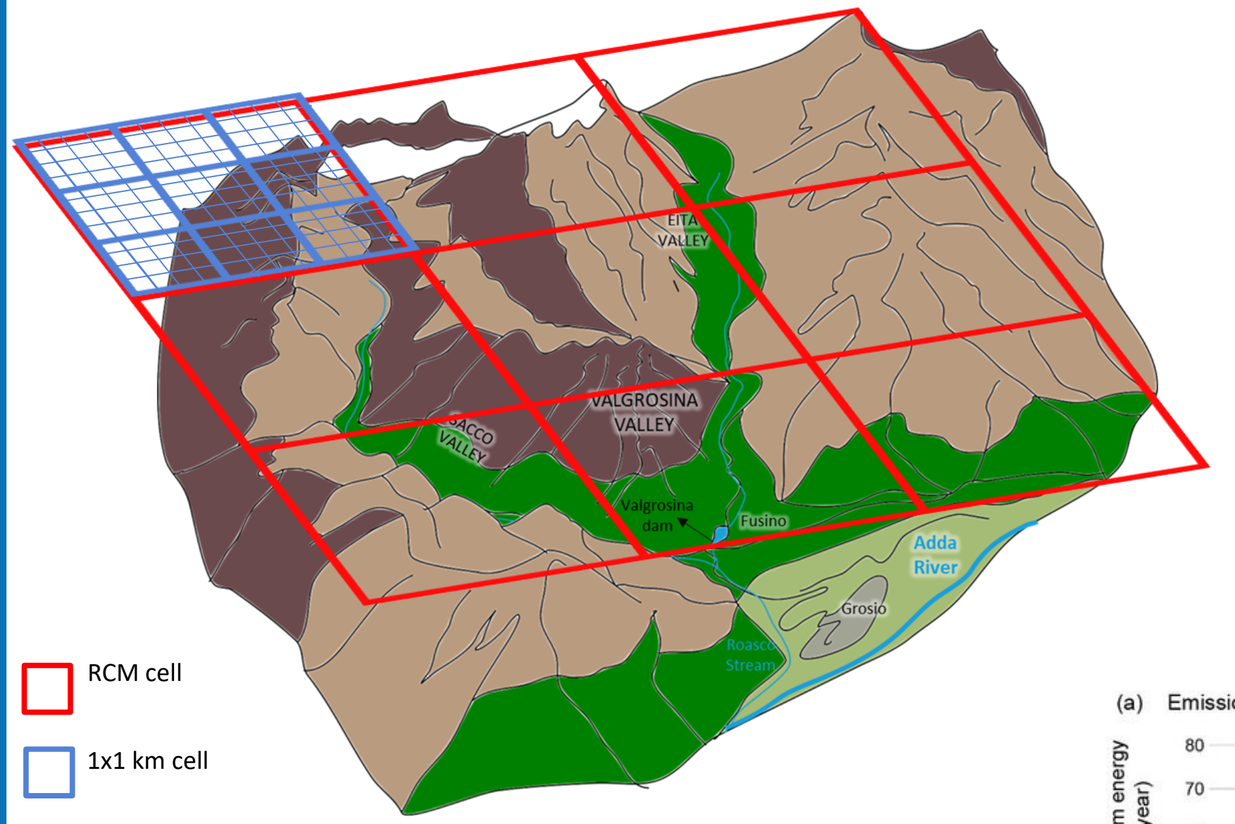
LINK TO THE ABSTRACT:

Ongoing work

METHOD

RESULTS

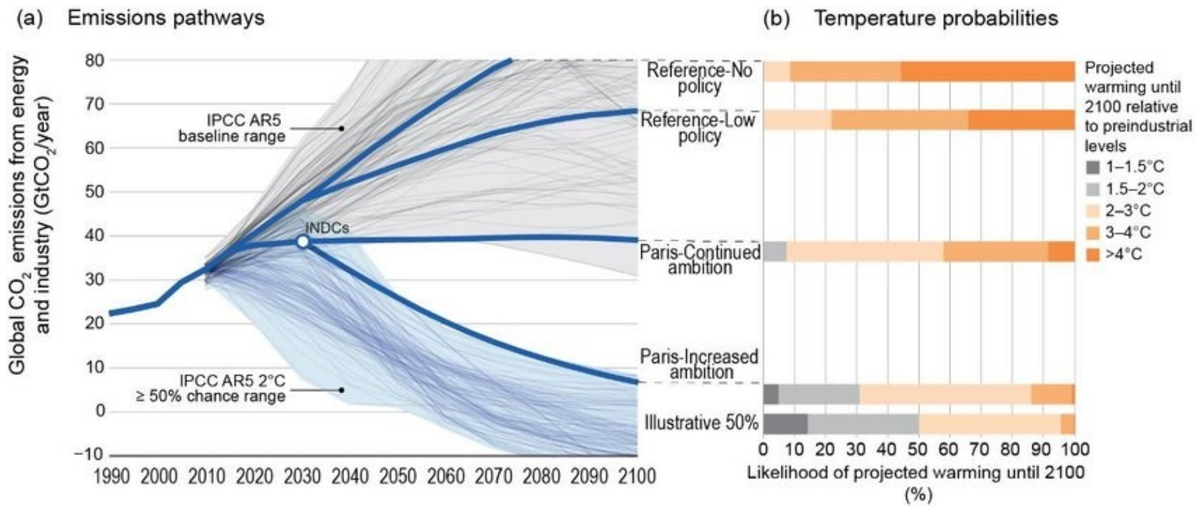
LINK TO THE ABSTRACT:



- Set-up of the daily-scale hydrological model
- 21 Regional Climate Models RCMs
- Statistical spatial downscaling → Quantile Delta Mapping (Cannon et al., 2015)

Downscaled RCM output to be used as input file into the hydrological model

Four different climate change scenarios (where available) will be considered: an increment of 1.5, 2, 3, 4°C above preindustrial temperatures, respectively.



Tiliakos & Marinoiu (2021)

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METHOD

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Thank you for your attention!

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Sharing is encouraged

METHOD

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