Interpolating intraday precipitation data with radar background information

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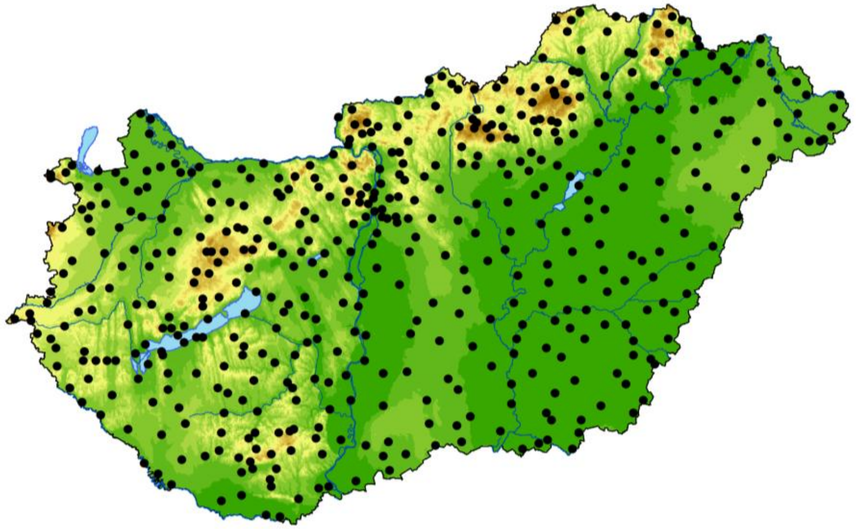
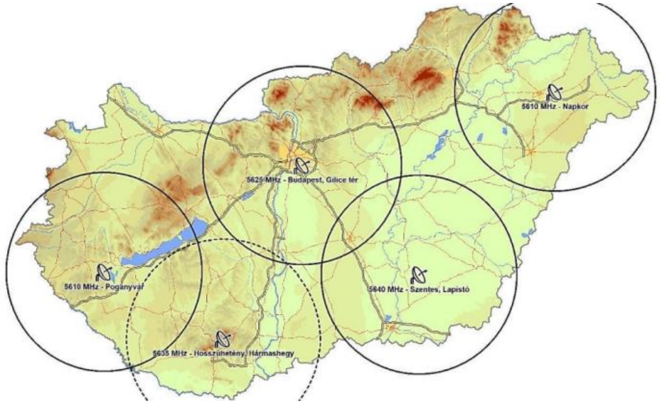
HUNGARIAN NATIONAL LABORATORY

ORSZÁGOS METEOROLÓGIAI SZOLGÁLAT

- Precipitation data are interpolated with MISH in OMSZ. Daily, monthly, seasonal annual etc...
- hourly? ten-minute?
- Accurate rainfall estimates are needed for hazard warning, for insurance companies to settle claims and of course for the public to justify the damage.
- Plan:

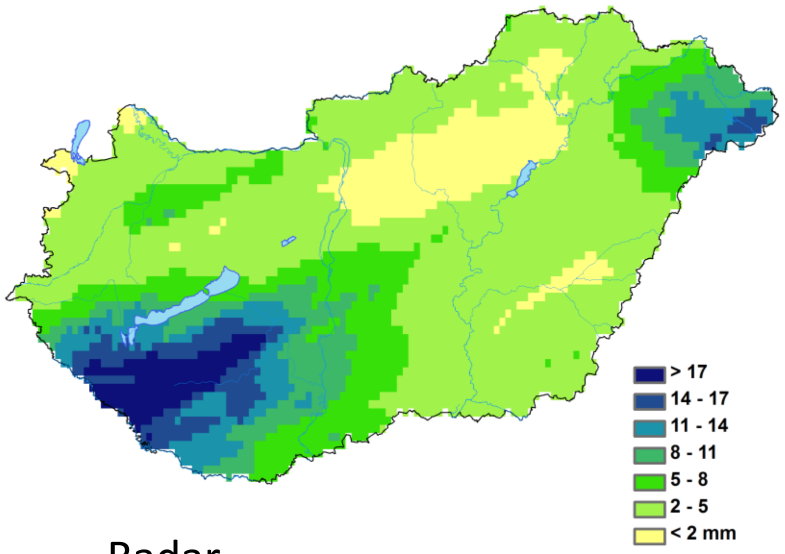
MISH, Radar and MISH with radar background information to be operationally displayed hourly



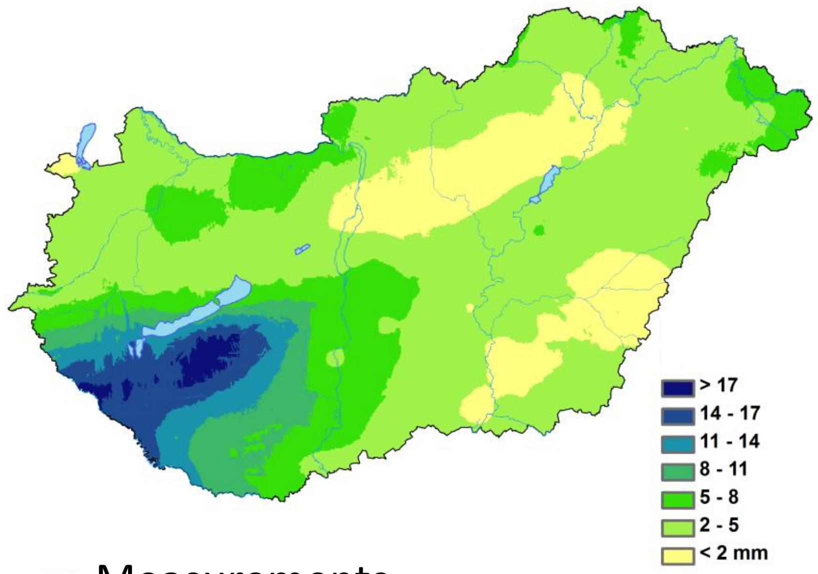


1.Problem

It is a common phenomenon that a small but significant precipitation cell or supercell passes between two measuring stations, resulting in an inadequate record of the daily precipitation amounts of up to 100 mm falling on a small area between the measurements and observations.

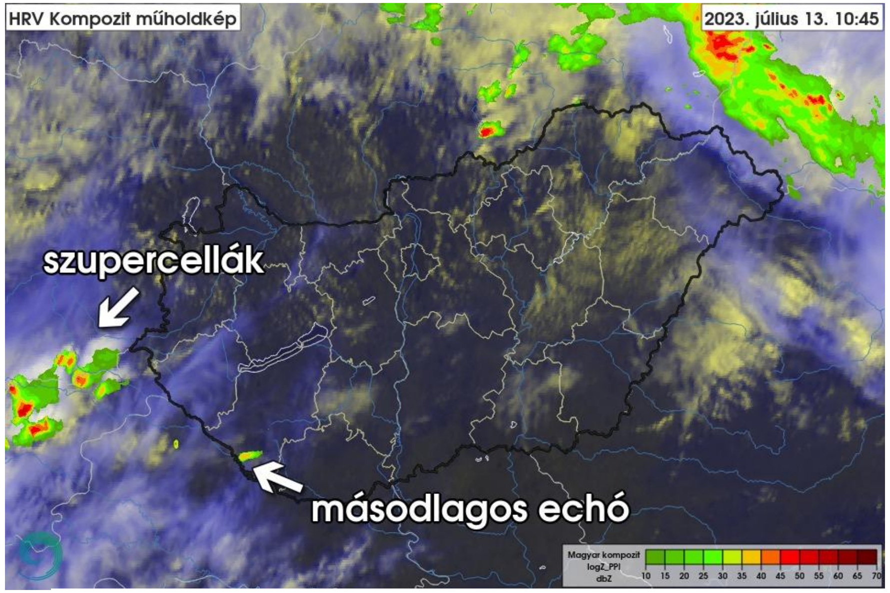


Radar

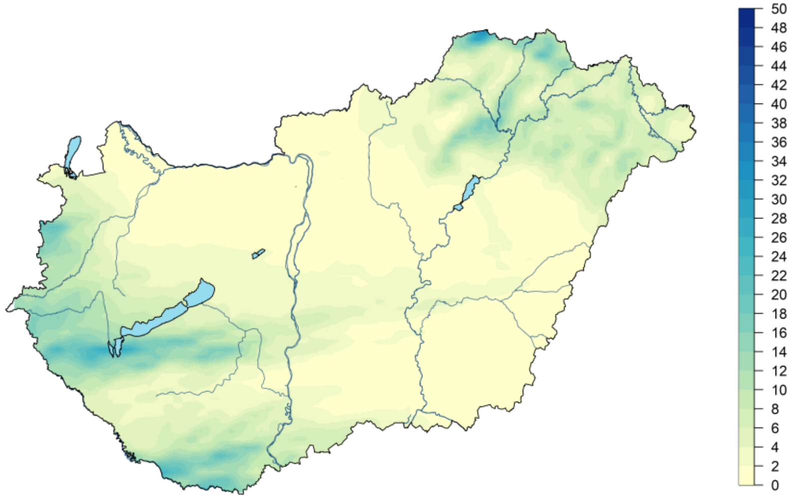


Measurements

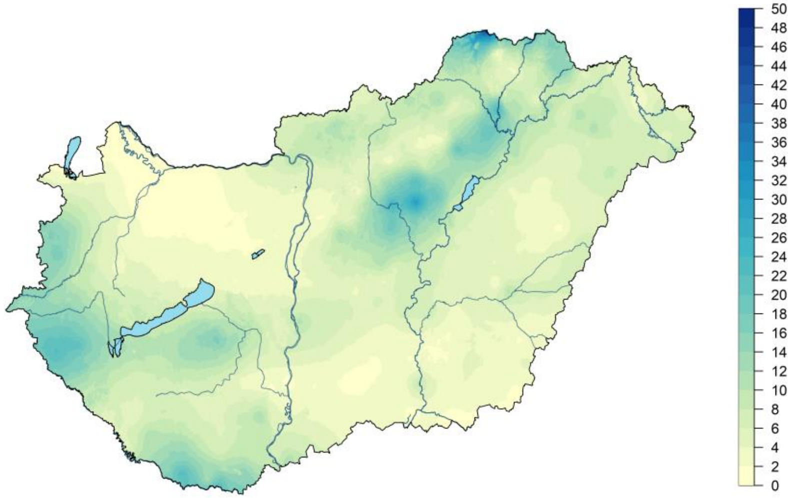
Correlation= 0.559



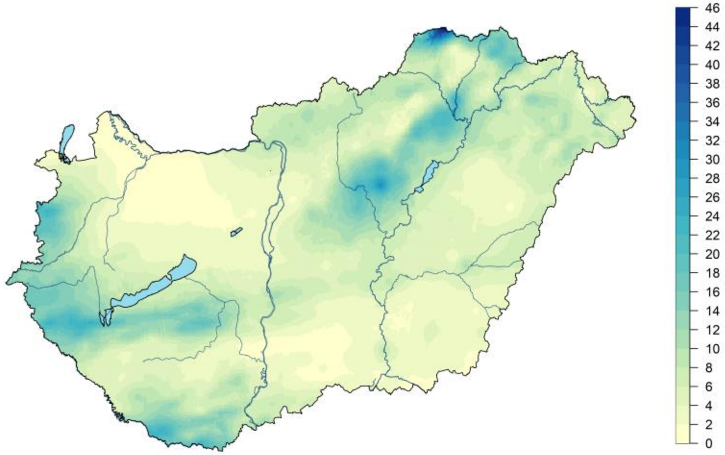
Radar



Measurements

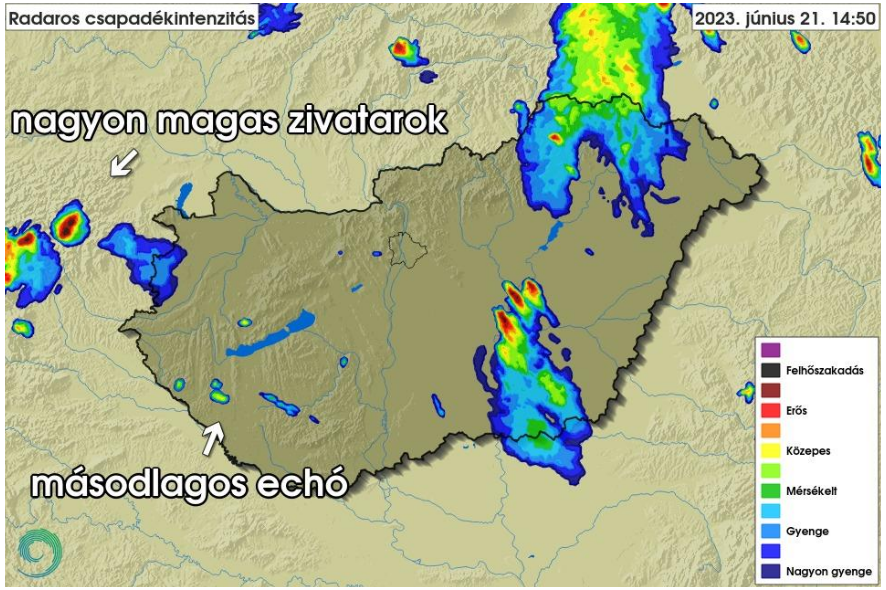


Measurements+Radar

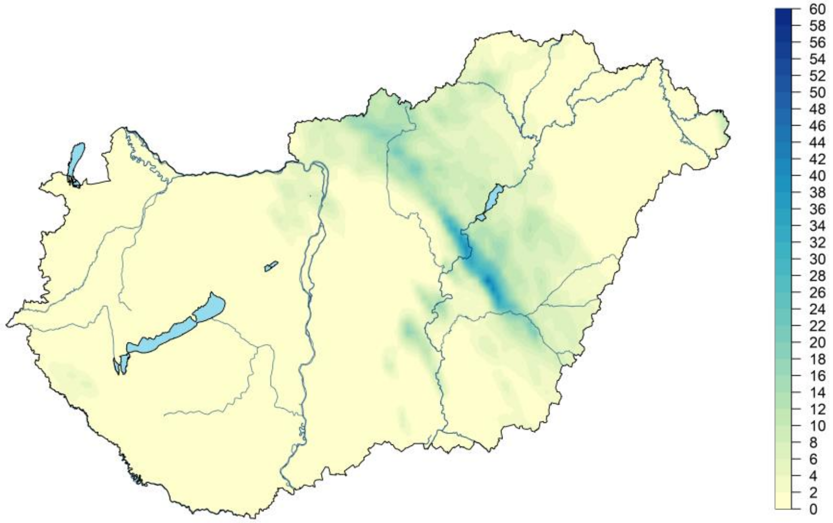


13.07.2023

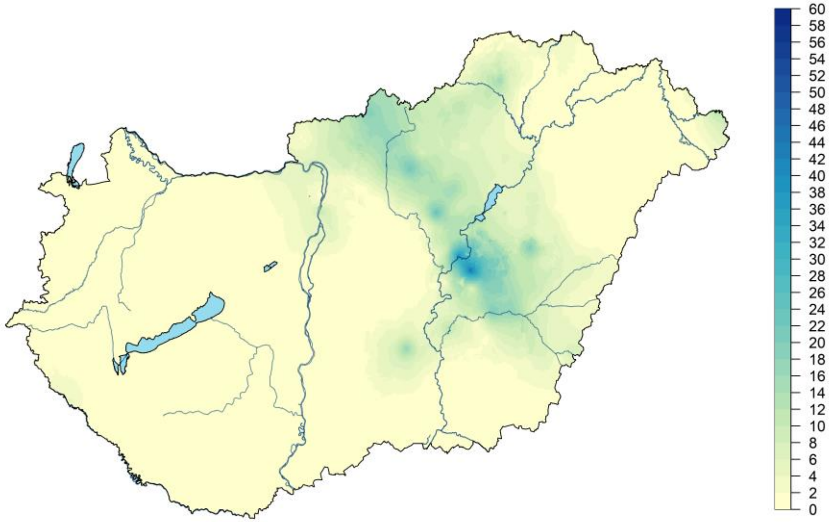
21.06.2023



Radar

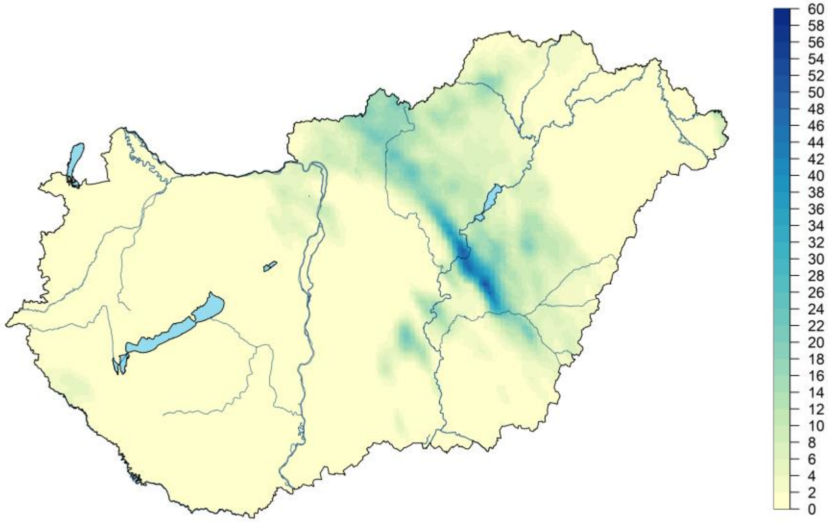


Measurements



Correlation= 0.919

Measurements+Radar



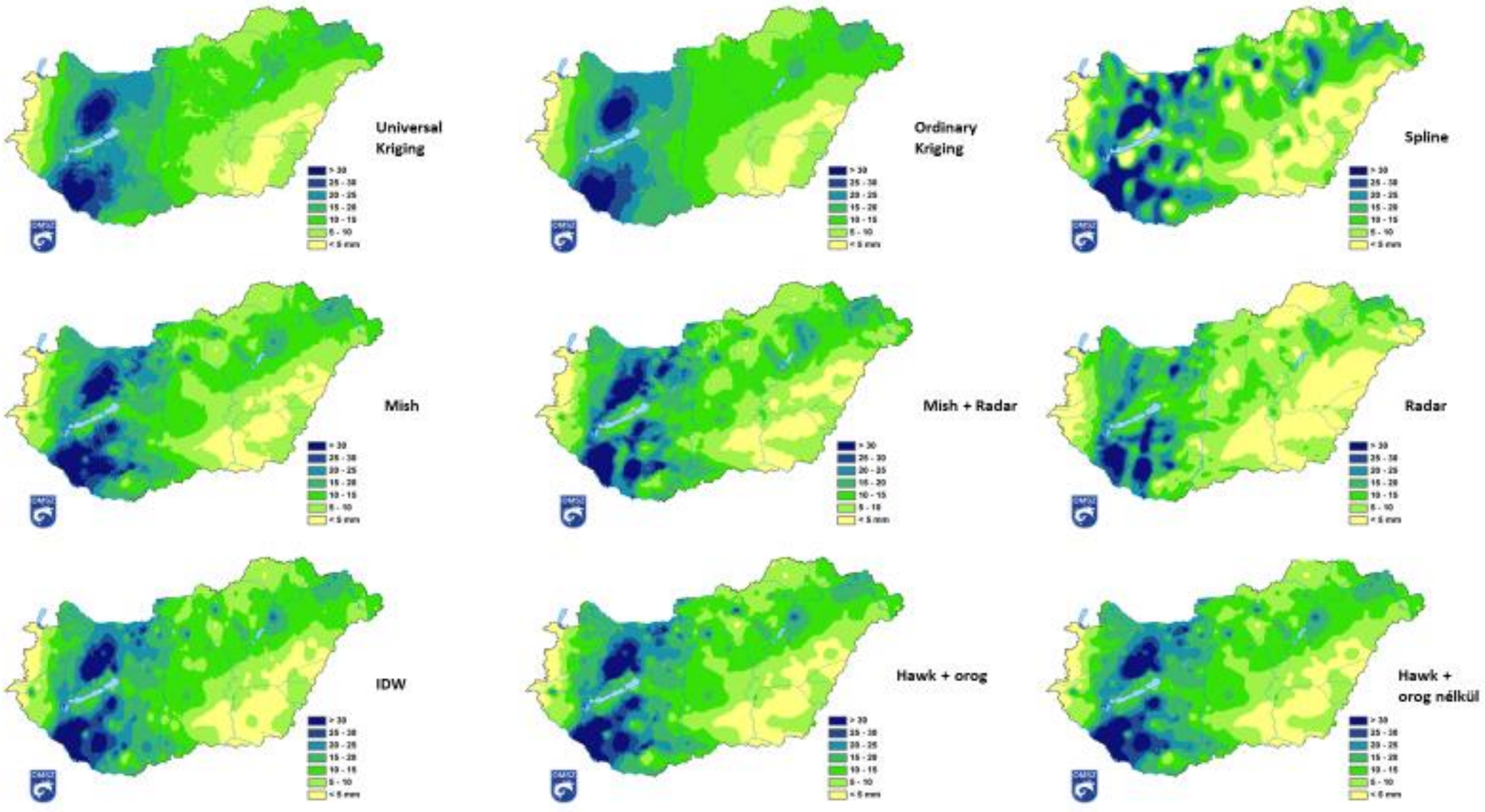
Interpolating precipitation data

Inverse Distance Weighted (IDW) Ordinary Kriging (OK)
KED: radar , KED: many years average+hight
Aurelhy+residual kriging MultiLinear Rregression+IDW
thin-plate smoothing splines Ensemble…..etc.

deterministic and
stochastic
(geostatistical)
methods

?

Different methods give different results!



SPATIAL INTERPOLATION

According to the interpolation problem the unknown predictand $Z(\mathbf{s}_0, t)$ is estimated by use of the known predictors $Z(\mathbf{s}_i, t)$, $(i = 1, \ldots, M)$, where the location vectors $\boldsymbol{s}$ are the elements of the given space domain $\boldsymbol{D}$ and t is the time. The type of adequate interpolation formula depends on the probability distribution of the meteorological element.

Precipitation: Log-normal-, Gamma-, Gumbel, Weibull-,

Log-Pearson type-III distribution…..

Assuming quasi-lognormal distribution (e.g. precipitation sum) the multiplicative formula is adequate, that is, the estimate may be written as

$$\hat{Z}(\mathbf{s}_0) = \vartheta \cdot \left(\prod_{q_i \cdot Z(\mathbf{s}_i) \geq \vartheta} \left(\frac{q_i \cdot Z(\mathbf{s}_i)}{\vartheta} \right)^{\lambda_i} \right) \cdot \left(\sum_{q_i \cdot Z(\mathbf{s}_i) \geq \vartheta} \lambda_i + \sum_{q_i \cdot Z(\mathbf{s}_i) < \vartheta} \lambda_i \cdot \left(\frac{q_i \cdot Z(\mathbf{s}_i)}{\vartheta} \right) \right)$$

$$\vartheta > 0 \; , \; q_i > 0, \qquad \lambda_i \geq 0 \; (i = 1, \ldots, M) \qquad \sum_{i=1}^{M} \lambda_i = 1$$

Interpolation parameters :

$$\vartheta = m(\mathbf{s}_0), \quad q_i = \frac{m(\mathbf{s}_0)}{m(\mathbf{s}_i)}$$

Interpolating intraday precipitation data

Also in this case, the optimal interpolation parameters are clearly determined by certain climate statistical parameters - local statistical parameters, stochastic relationships!

Interpolating precipitation data with MISHv.1.03

I. Modelling system for climate statistical parameters in space

(expected values, standard deviations, spatiotemporal correlations)

- **Based on long homogenized data series and model variables.**
- **Modelling procedure must be executed only once before the interpolation applications.**

II. Spatial interpolation system

- Additive (e.g. temperature) or multiplicative (e.g. precipitation) model and interpolation formula can be used depending on the climate elements.
- Daily, monthly, annual values and many years' means can be interpolated.
- Capability for application of background information such as satellite, radar, forecast data.
- Capability for gridding of data series.

Szentes, O., Lakatos, M., and Pongrácz, R.: *Long-term homogenized and gridded precipitation data for Hungary*, EMS Annual Meeting 2023, Bratislava, Slovakia, 4–8 Sep 2023, EMS2023-376, https://doi.org/10.5194/ems2023-376, 2023.

Modelling of Monthly Climate Statistical Parameters for a half minutes grid (Szentimrey, 2014)

First step of modelling by using model variables

The monthly climate statistical parameters belonging to the stations $\mathbf{S}_k \; \left(k=1,..,K\right)$ can be used for modelling. The basic principle is as follows. Let $P(\mathbf{s}), Q(\mathbf{s}), r\left(\mathbf{s}_1, \mathbf{s}_2\right) \left(\mathbf{s}, \mathbf{s}_1, \mathbf{s}_2 \in D\right)$ be certain model functions depending on different model variables with the following properties:

(a) Modelling of correlations: $r\left(\mathbf{S}_{j1}, \mathbf{S}_{j2}\right) \approx \mathrm{corr}\left(Z(\mathbf{S}_{j1}, t), Z(\mathbf{S}_{j2}, t)\right) \quad \left(j_1, j_2 = 1,..,K\right)$

(b) Modelling of difference of means (E): $P\left(\mathbf{S}_{j1}\right) - P\left(\mathbf{S}_{j2}\right) \approx E\left(\mathbf{S}_{j1}\right) - E\left(\mathbf{S}_{j2}\right)$

(c) Modelling of ratio of st. deviations (D): $\dfrac{Q\left(\mathbf{S}_{j1}\right)}{Q\left(\mathbf{S}_{j2}\right)} \approx \dfrac{D\left(\mathbf{S}_{j1}\right)}{D\left(\mathbf{S}_{j2}\right)}$

The model variables may be distance, height, topography.

Szentimrey, T. & Bihari, Z. (2014) *Manual of interpolation software MISHv1.03*. Hungarian Meteorological Service, 60.

Second step of modelling by interpolation

Predictand location: $\mathbf{s}_0$, predictor station locations: $\mathbf{S}_{0i}\ (i=1,\ldots,M)$.

The weighting factors can be calculated where $\mathbf{r}$, $\mathbf{R}$ contain the modelled predictand-predictors, predictors-predictors correlations.

Modelling of means, expected values (E) by additive interpolation:

$$E(\mathbf{s}_0)=\sum_{i=1}^{M}\lambda_i\left(P(\mathbf{s}_0)-P(\mathbf{S}_{0i})\right)+\sum_{i=1}^{M}\lambda_i E(\mathbf{S}_{0i})$$

Modelling of st. deviations (D) by multiplicative interpolation:

$$D(\mathbf{s}_0)=\prod_{i=1}^{M}\left(\frac{Q(\mathbf{s}_0)}{Q(\mathbf{S}_{0i})}\cdot D(\mathbf{S}_{0i})\right)^{\lambda_i}$$

Interpolation with Background Information

Background information can decrease the interpolation error.
For example: forecast, satellite, radar data

$Z(\mathbf{s}_0, t)$: predictand

$\hat{Z}(\mathbf{s}_0, t) = \lambda_0 + \sum_{i=1}^{M} \lambda_i Z(\mathbf{s}_i, t)$: interpolation

$\mathbf{G} = \{ G(\mathbf{s}, t) \mid \mathbf{s} \in D \}$: background information on a dense grid

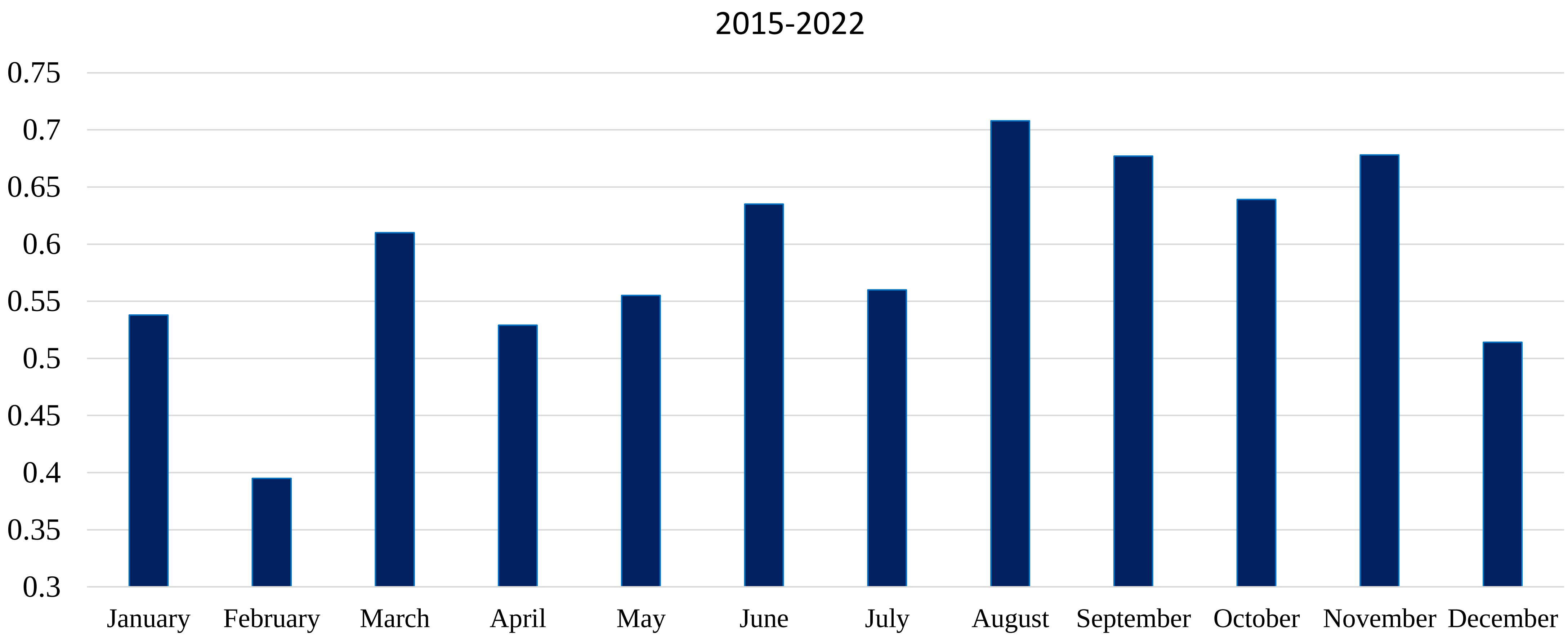
<u>Principle of interpolation with Background Information</u>

$$\hat{Z}_G(\mathbf{s}_0, t) = \hat{Z}(\mathbf{s}_0, t) + \mathrm{E}\left(Z(\mathbf{s}_0, t) - \hat{Z}(\mathbf{s}_0, t) \mid \mathbf{G} \right)$$

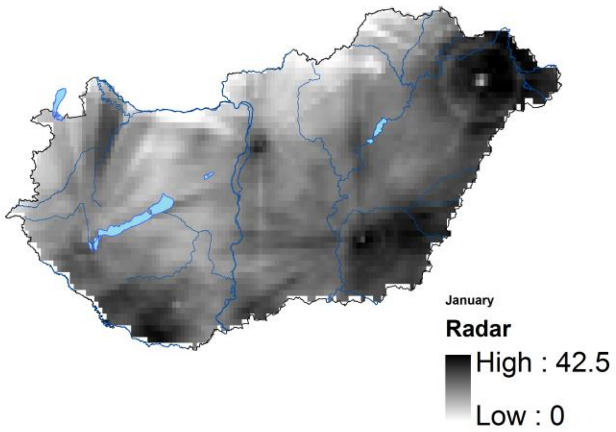
where $\mathrm{E}\left(Z(\mathbf{s}_0, t) - \hat{Z}(\mathbf{s}_0, t) \mid \mathbf{G} \right)$ is the conditional

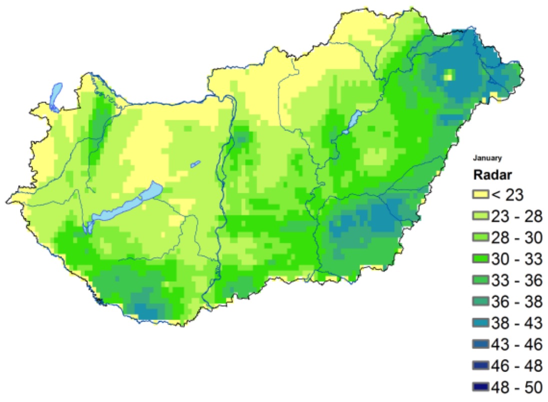
expectation of $Z(\mathbf{s}_0, t) - \hat{Z}(\mathbf{s}_0, t)$, given $\mathbf{G}$.

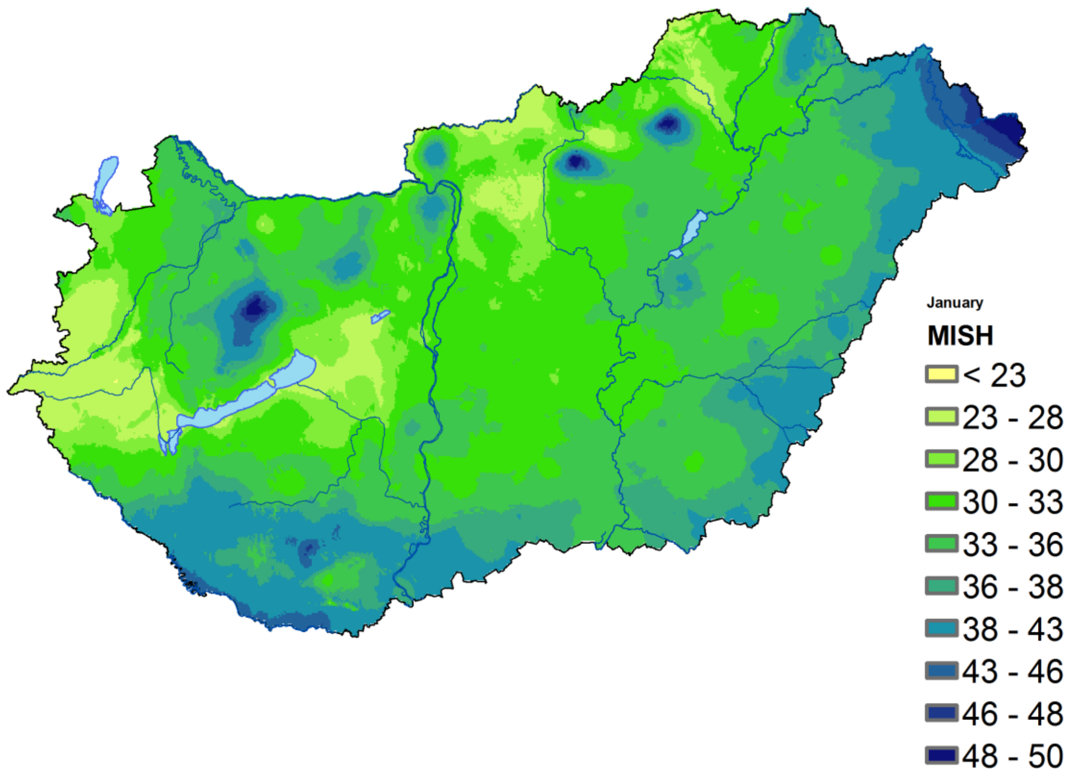
Correlation between measurements and radar information

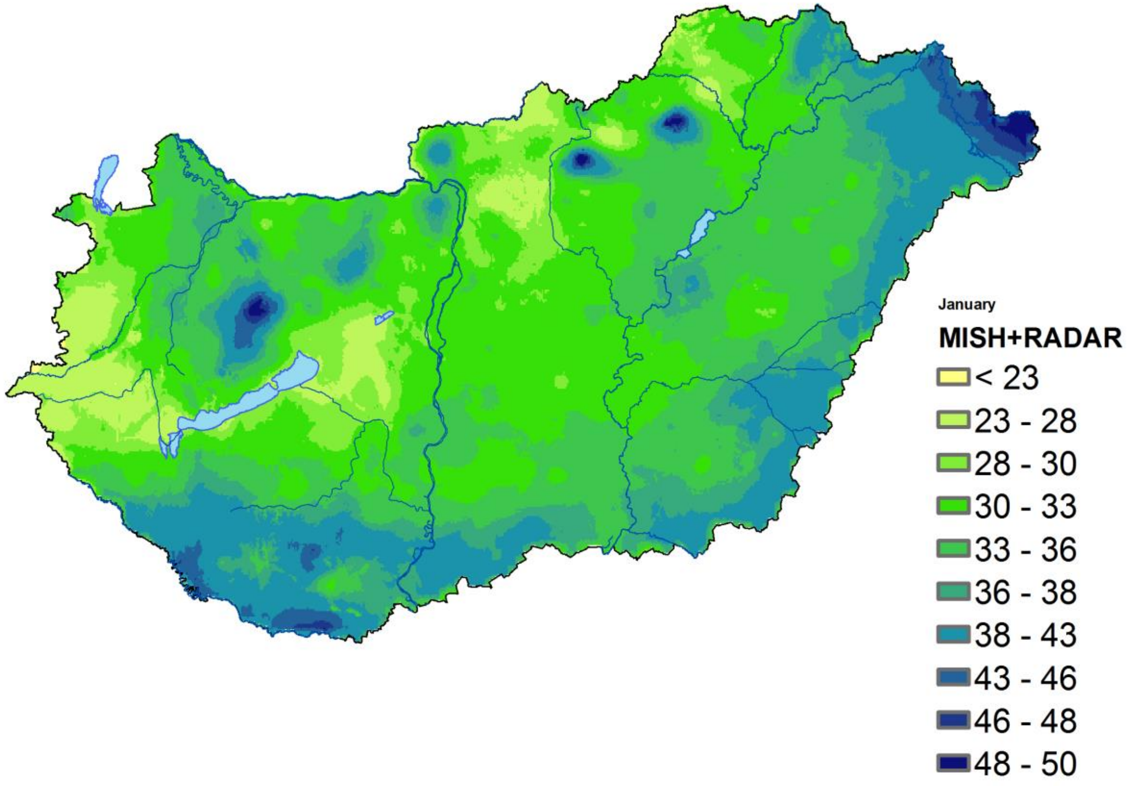


January average (2015-2022)

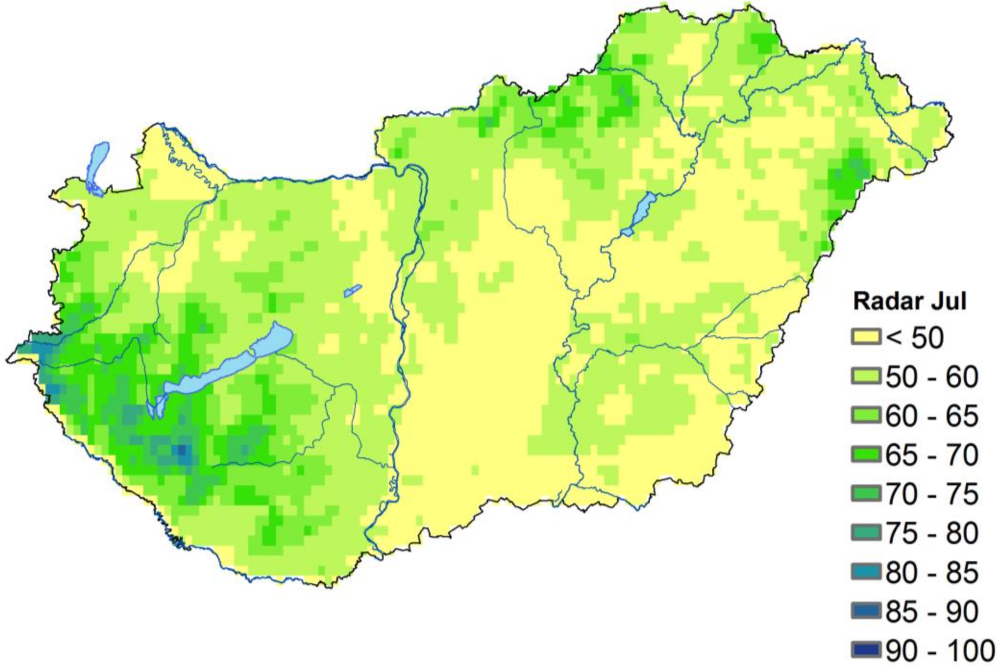


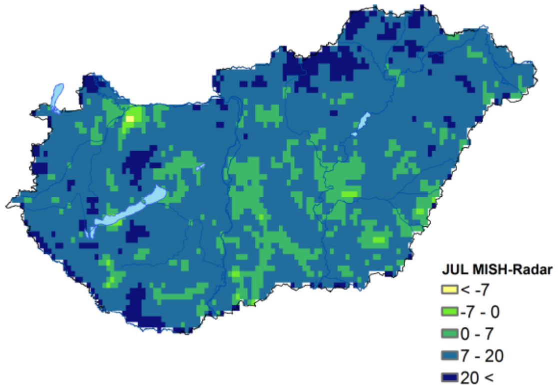


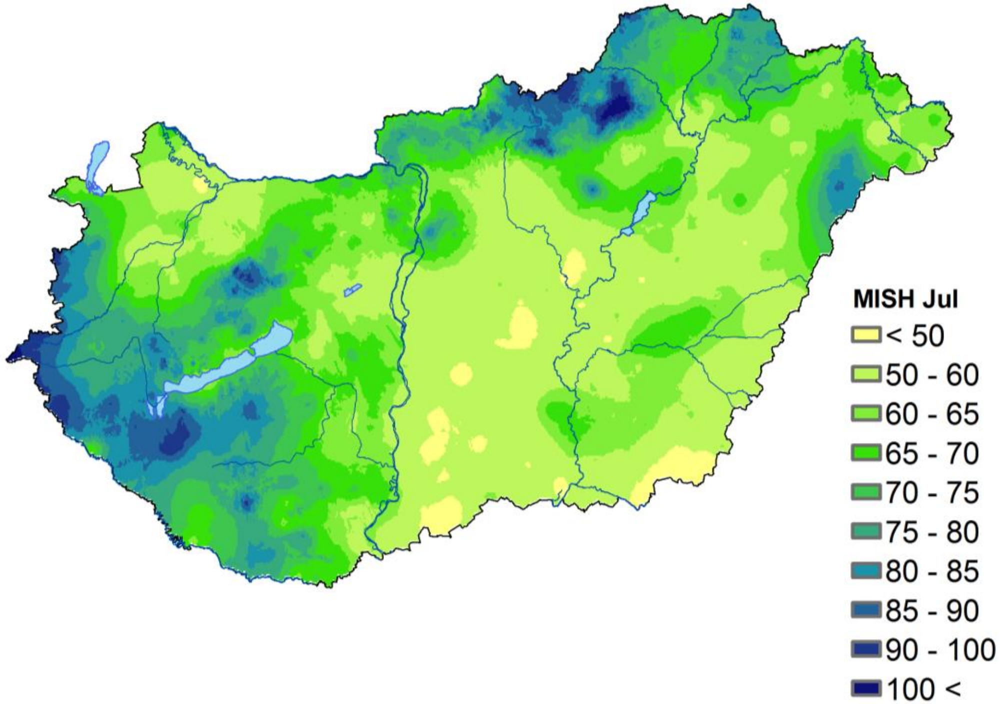


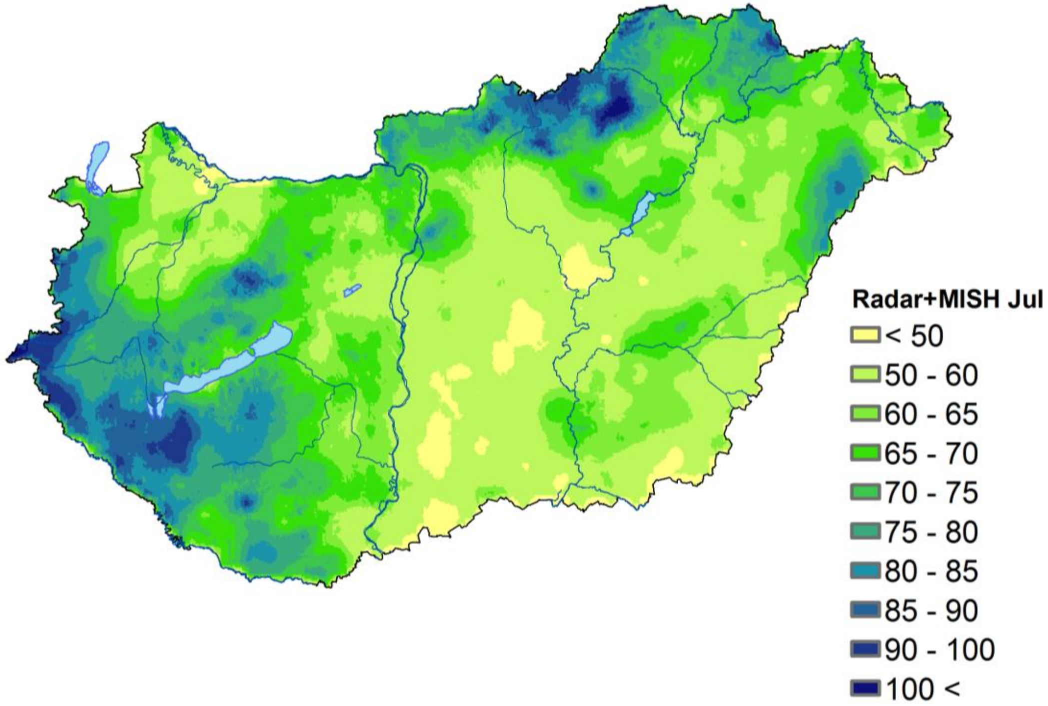


July average (2015-2022)





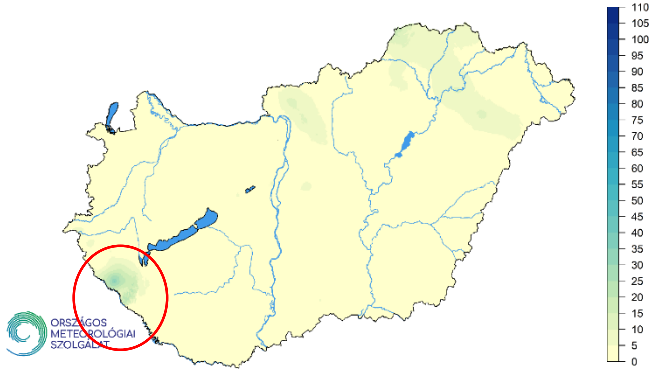


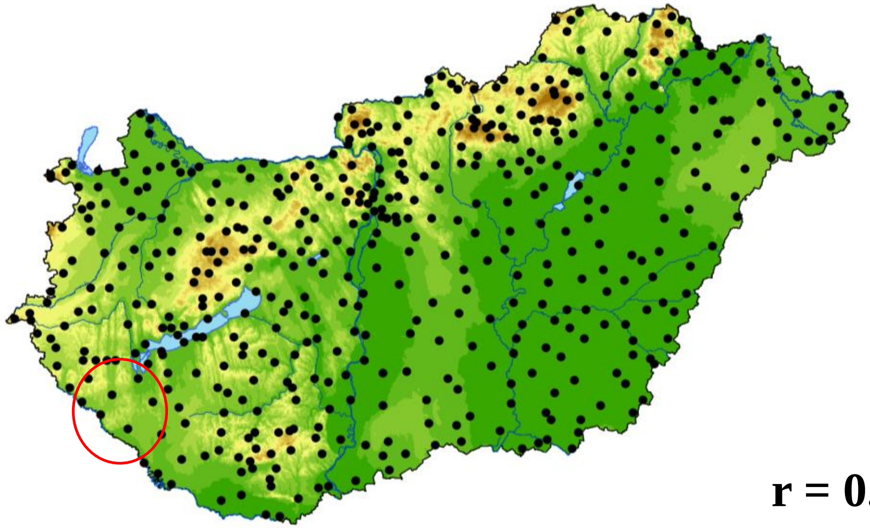


Flash flood

05.06.2021

Measurements 30mm?



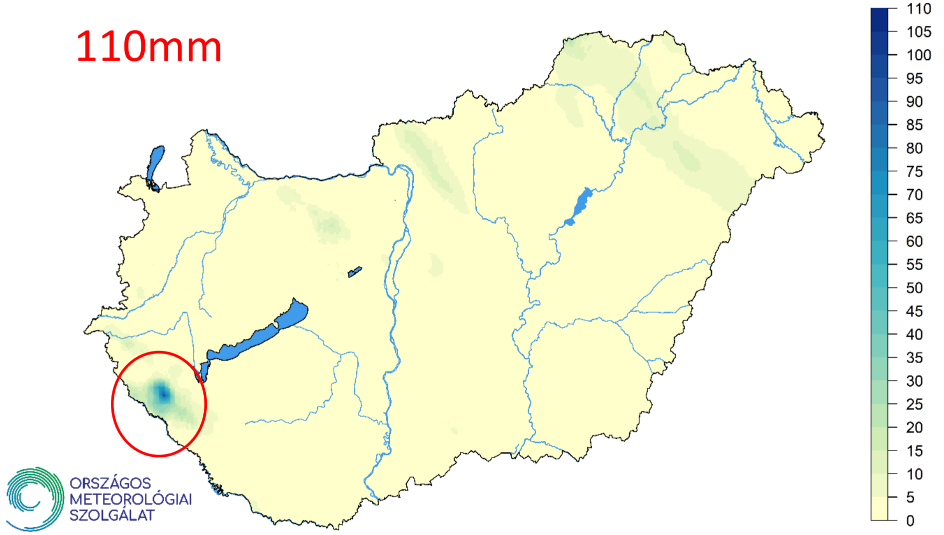


r = 0.889

The spatial variability of the radar data was found to be much smaller than that of the measurements (about 480 stations are available.) This resulted in a regression coefficient of **1.134** (the coefficient of the spatial trend of the precipitation data on the conditional expected value of the radar data.)

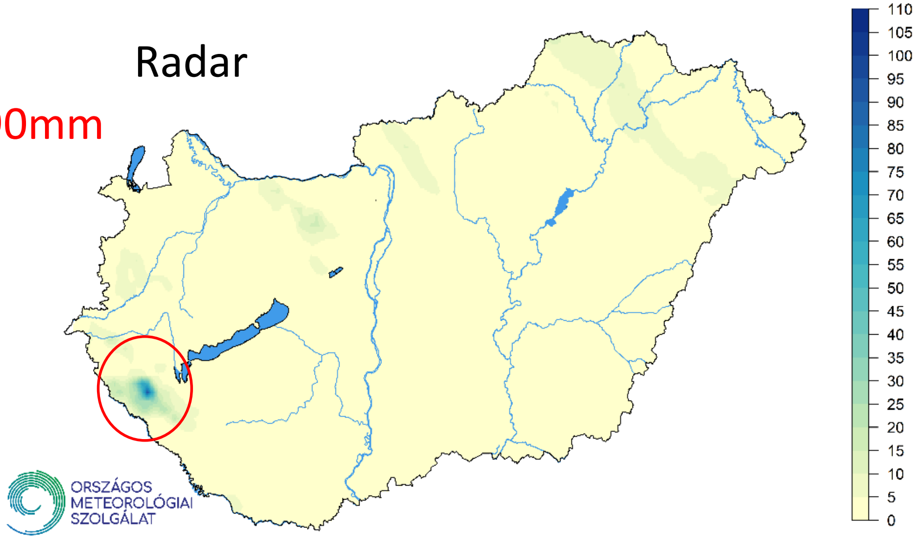
Measurements+Radar

110mm



Radar

90mm

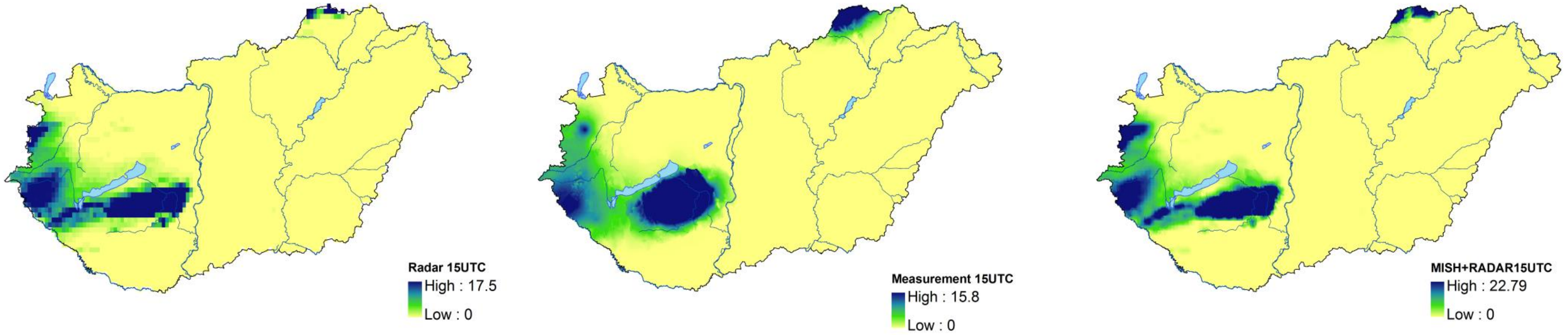


EXAMINATION OF BACKGROUND INFORMATION 15 UTC

Correlation: **0.981**

Constant: 0.000

Coefficient: 1.247

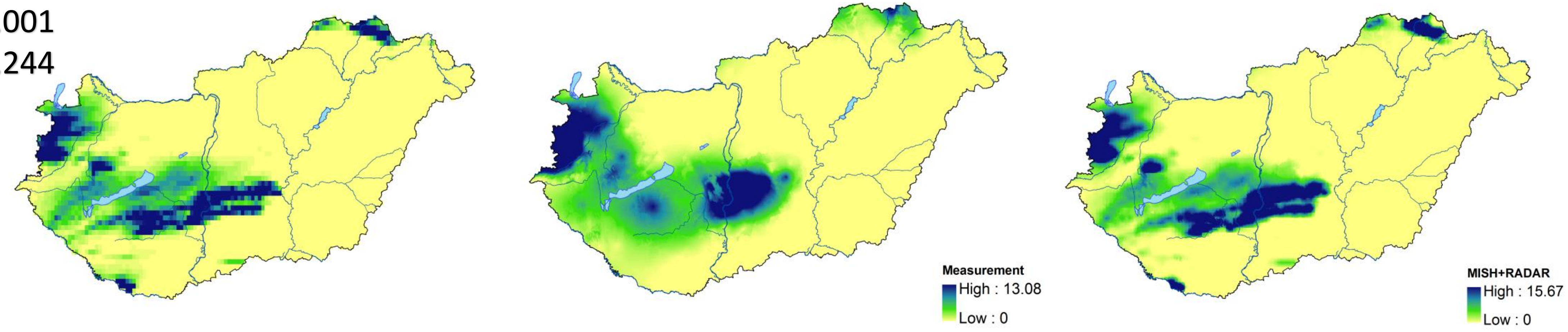


EXAMINATION OF BACKGROUND INFORMATION 16 UTC

Correlation: **0.908**

Constant: -0.001

Coefficient: 1.244



Conclusion

- Interpolation of rainfall data based on short period measurements is also possible with MISH software thanks to the quasi-multiplicative formula.
- Radar data cannot replace measurements!
- In fact, the MISH interpolation of measurements with radar background information can be understood as the transformation of radar data into precipitation data, which is called downscaling.
- In the following years (in test mode), not only daily data will be interpolated with radar background information, but also intra-day (one hour) precipitation sums.
- *The research presented was carried out within the framework of the* ***Széchenyi Plan Plus program*** *with the support RRF-2.3.1-21-2022-00008 project.*

Thank you for your attention!