# Added Value of Convection-Permitting ReAnalysis for IDF Estimation in Urban Areas


Milan Onderka[1,2], Roman Výleta[1], Silvia Kohnová[1]

[1]Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, SK-810 05 Bratislava, Slovakia

[2]Regional Climatological Institute, Plavecký Štvrtok 794, SK-900 68, Slovakia

✉ milan.onderka@stuba.sk


## INTRODUCTION

Frequency of rainfall extremes originating from convective processes is highly relevant for hydrology in small watershed and urban areas. These events are typically inadequately captured by coarse-resolution re-analyses and climate model simulations that rely on parameterized convection. In Europe, intense precipitation associated with organized convective systems represents a major contribution to hydrological extremes, yet its representation in traditional modeling frameworks remains limited due to the multiscale nature of deep convection and its strong coupling with microphysical, boundary-layer, and large-scale atmospheric processes. In contrast, numerical weather prediction and regional climate models can operate at kilometer-scale grid spacing, allowing deep moist convection to be represented explicitly rather than through parameterization. Such convection-permitting models (CPMs) offer a substantial improvement in simulating convective rainfall intensity, structure, and spatial variability.

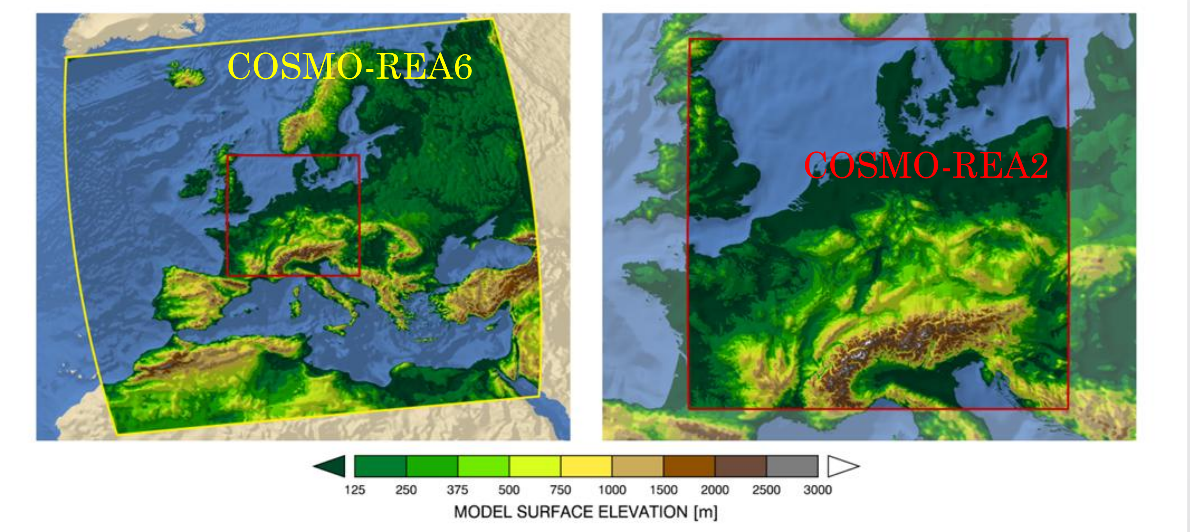


**FIG. 1** Model domains and topography of COSMO-REA6 (left) and COSMO-REA2 (right) adopted from Wahl et al. (2016).

## ANALYZED DATA

The COSMO-REA2 convection-permitting regional reanalysis was developed by the Hans-Ertel Centre for Weather Research in cooperation with the German Weather Service framework. It is based on the COSMO numerical weather prediction model. Its spatial resolution is 0.018° (2 km) compared to 6 km in COSMO-REA6.. COSMO-REA2 comprises of of 150 variables (2D and 3D fields) with hourly temporal resolution. For the purposes of our analyses only the Total Precipitation product was used. The analyzed dataset covers the period 01/2007 – 12/2018.

## OBJECTIVE

- Apply the Generalized Extreme Value (GEV) distribution to annual maximum series of rainfall accumulations for durations of 1, 2, 3, 6, 12, 24, 48, 72, and 120 hours derived from the COSMO-REA2 regional reanalysis.
- Estimate extreme rainfall quantiles and construct intensity–duration–frequency (IDF) curves for return periods between 1 and 20 years.
- Extract location-specific IDF curves for selected cities in Central Europe from the gridded reanalysis dataset.

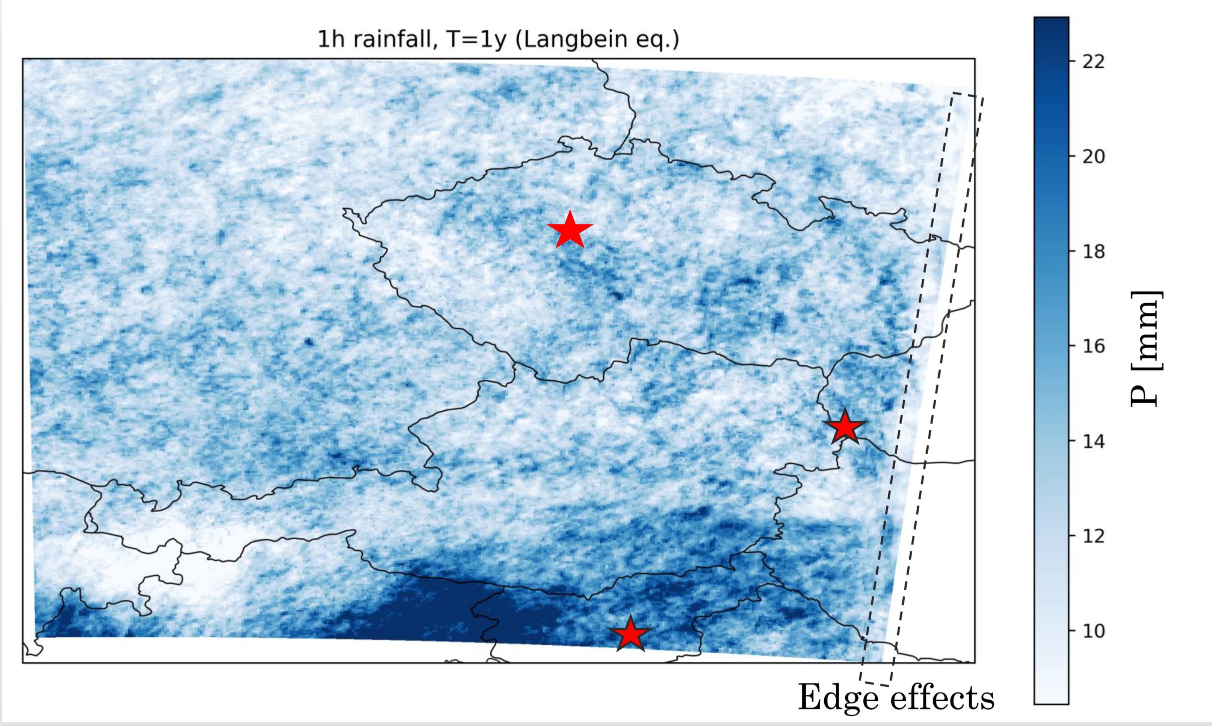


**FIG. 2 .** Quantiles of 1-hour rainfall corresponding to return period 1 year.

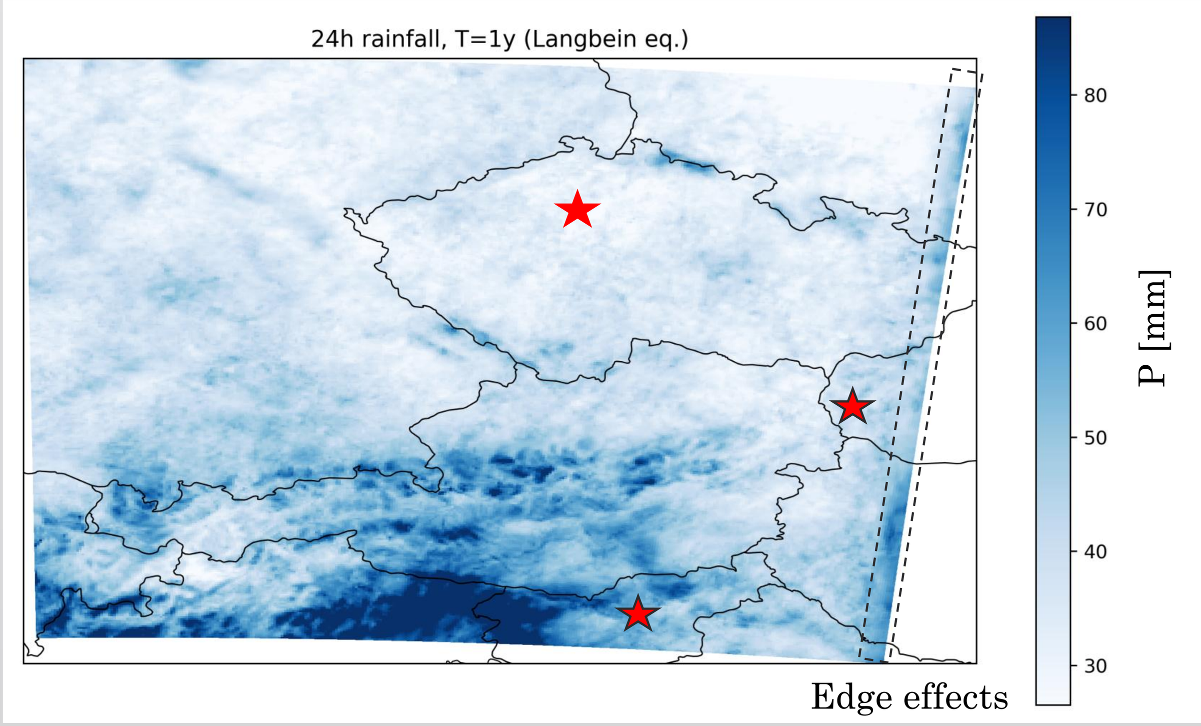


**FIG. 3**. Quantiles of 24-hour rainfall corresponding to return period 1 year.

## METHODS

Monthly maximum precipitation fields were first grouped by calendar year. For each grid cell and year, the annual maximum is computed as the maximum over 9 aggregation periods (1, 2, 3, 6, 12, 24, 48, 72, 120 hours).

### GEV Distribution and quantiles

Extreme precipitation was modelled using the Generalized Extreme Value (GEV) distribution. This produces a time series of annual maxima at each grid cell.
GEV parameters were estimated independently at each grid point using L-moments (probability-weighted moments). L-moment estimation is chosen for its robustness to outliers and small sample sizes, which is crucial for spatially distributed annual-maximum series.

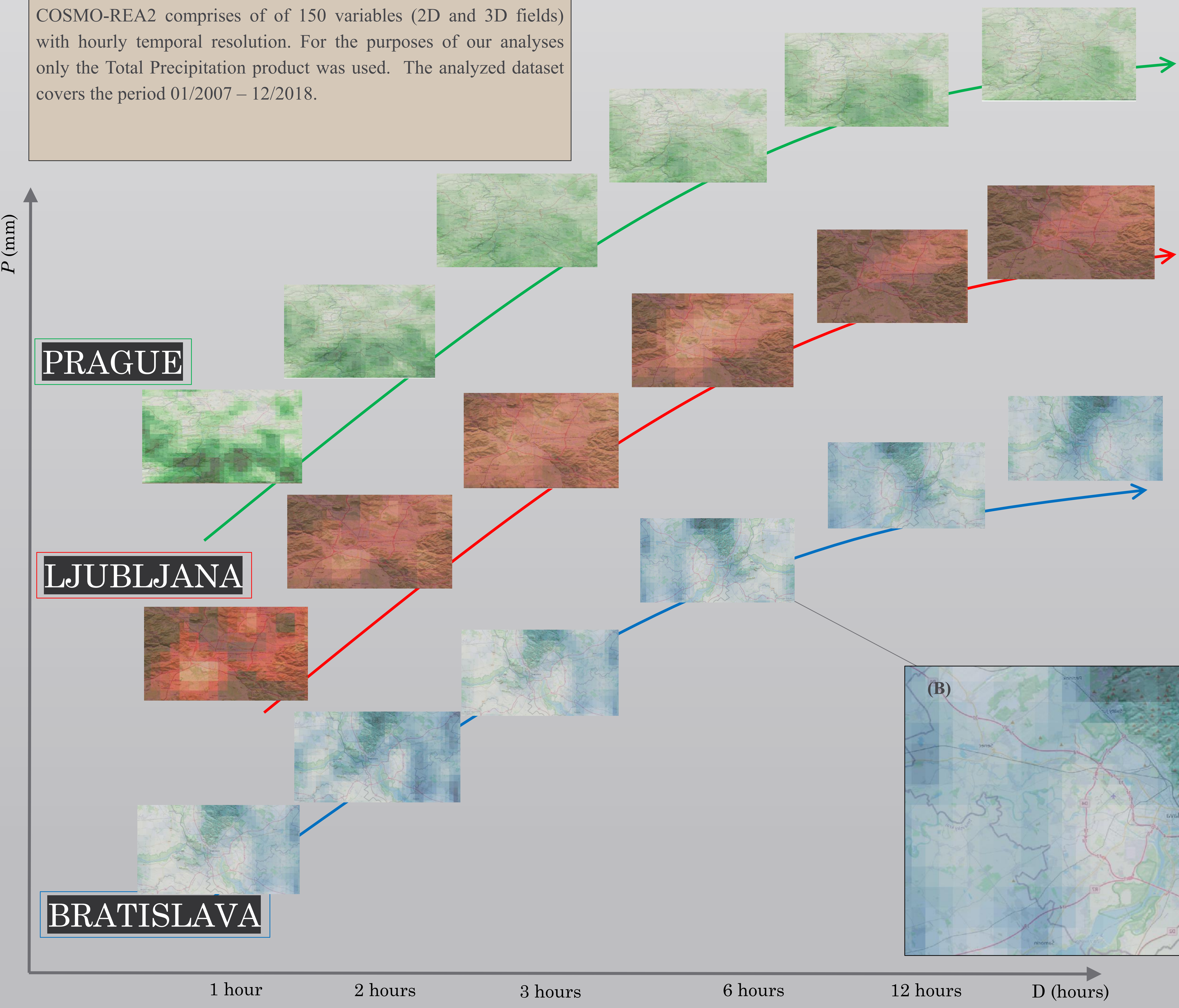


**FIG. 4.** Visualization of maps of rainfall quantiles (return period 1 year) at selected European cities.

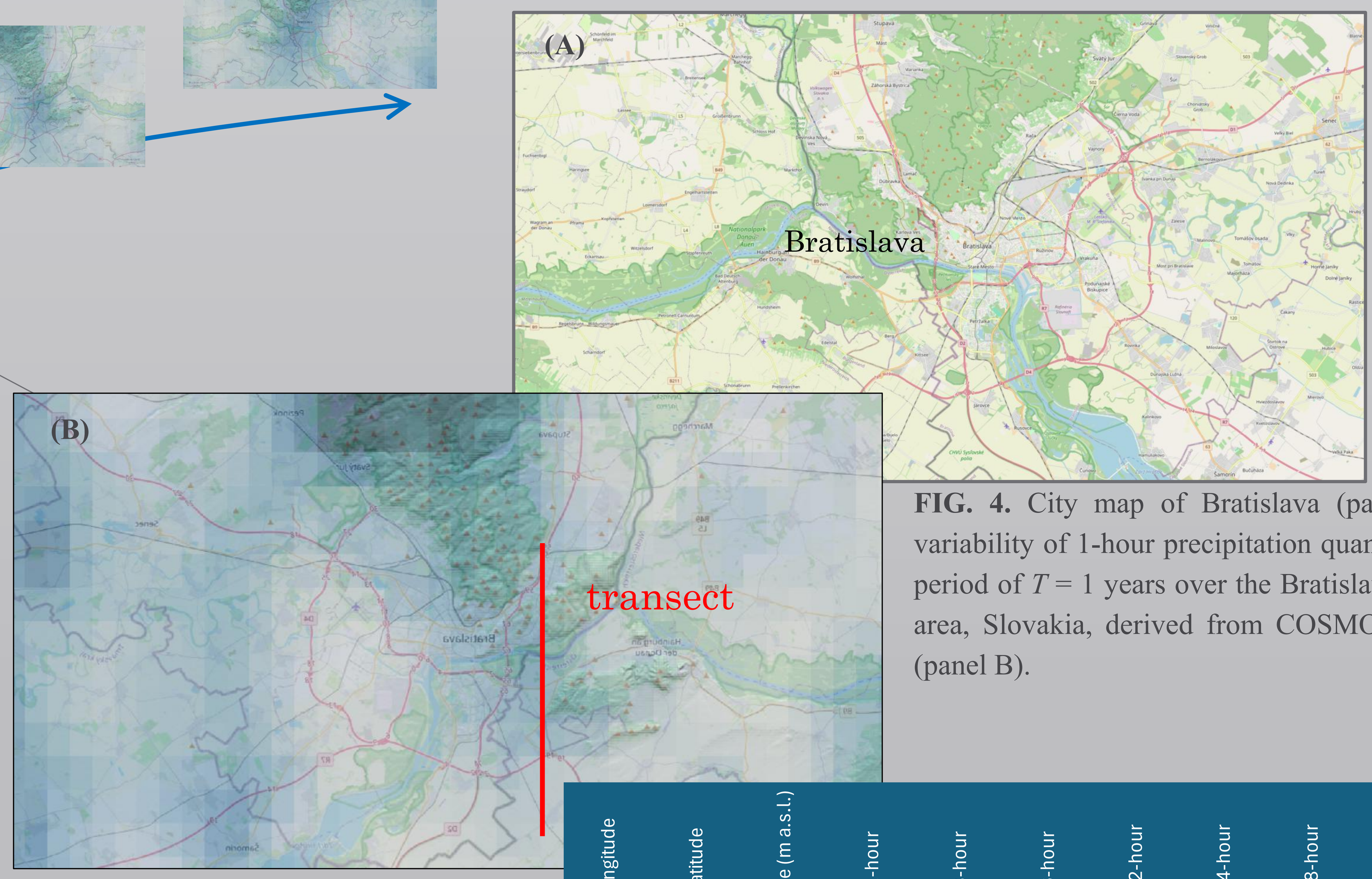


**FIG. 4.** City map of Bratislava (panel A); spatial variability of 1-hour precipitation quantiles for return period of $T = 1$ years over the Bratislava metropolitan area, Slovakia, derived from COSMO-REA2 dataset (panel B).

| Longitude | Latitude | Altitude (m a.s.l.) | 1-hour | 3-hour | 6-hour | 12-hour | 24-hour | 48-hour | 72-hour | 120-hour |
|---|---|---|---|---|---|---|---|---|---|---|
| 17.0995 | 48.2560 | 404 | 13.8 | 18.6 | 22.3 | 26.5 | 35.6 | 42.3 | 58.0 | 67.3 |
| 17.1019 | 48.2340 | 402 | 13.3 | 18.4 | 22.5 | 26.5 | 33.2 | 39.8 | 56.2 | 65.4 |
| 17.1044 | 48.2120 | 338 | 14.2 | 20.5 | 23.8 | 27.4 | 33.2 | 40.1 | 57.7 | 65.9 |
| 17.1069 | 48.1900 | 262 | 15.3 | 20.2 | 23.3 | 27.9 | 35.5 | 41.8 | 58.4 | 66.0 |
| 17.1094 | 48.1680 | 237 | 14.7 | 19.4 | 23.1 | 26.5 | 34.1 | 41.2 | 60.6 | 67.6 |
| 17.1119 | 48.1460 | 137 | 14.6 | 18.8 | 22.1 | 24.9 | 32.8 | 40.6 | 60.4 | 66.6 |
| 17.1144 | 48.1241 | 133 | 12.7 | 16.1 | 19.6 | 24.5 | 32.3 | 41.0 | 57.3 | 64.0 |
| 17.1169 | 48.1021 | 132 | 11.7 | 14.9 | 18.6 | 23.8 | 31.9 | 41.7 | 55.8 | 62.8 |
| 17.1194 | 48.0801 | 131 | 11.1 | 15.4 | 18.8 | 22.9 | 30.1 | 39.1 | 51.2 | 57.5 |
| 17.1218 | 48.0581 | 131 | 11.0 | 16.0 | 18.5 | 22.6 | 29.1 | 37.1 | 49.1 | 55.9 |
| 17.1243 | 48.0361 | 131 | 10.9 | 16.1 | 18.1 | 21.9 | 28.7 | 37.3 | 49.2 | 56.8 |
| 17.1250 | 48.0314 | 130 | 11.0 | 16.0 | 18.2 | 21.9 | 28.4 | 35.7 | 48.3 | 55.6 |

**FIG. 5** Quantiles (return period 1 year) of precipitation totals $P$ (mm) for selected durations $D$ along the transect (from top to down) that is captured by the 2-km resolution of COSMO-REA2 dataset.

## RESULTS

The analyses demonstrate that the 2-km spatial resolution of COSMO-REA2 provides an added value for the estimation of design rainfall especially in urban environments and small catchments. At this resolution, fine-scale spatial gradients and localized precipitation extremes, typically smoothed out in coarser reanalyses (e.g. COSMO-REA6, ERA5-Land, ERA5), are resolved. With a grid spacing of 2 km, individual urban districts and small upper catchments can be distinctly resolved, allowing spatial variability of extreme rainfall to be represented at scales relevant for urban hydrology and local flood response.
This level of detail is particularly critical for hydrological modeling in small catchments and for stormwater system design, where small spatial displacements of rainfall maxima can lead to markedly different runoff responses. Unfortunately, due to the relatively short analyzed period the results are uncertain. Longer time series will be needed to capture more extreme values. The results further indicate that future work should include systematic comparisons with IDF estimates from rain-gauges.


**References:** Wahl, Sabrina & Bollmeyer, Christoph & Crewell, Susanne & Figura, Clarissa & Friederichs, Petra & Hense, Andreas & Keller, Jan & Ohlwein, Christian. (2016). A novel convective-scale regional reanalyses COSMO-REA2: Improving the representation of precipitation. Meteorologische Zeitschrift. 26. 10.1127/metz/2017/0824.



**Acknowledgment**

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