



From ERA5 to Precipitation Extremes: Global km-Scale, Sub-Hourly Downscaling with Generative AI

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Global reanalysis products such as ERA5 are indispensable for climate and hydrological studies, yet their coarse spatial and temporal resolution limits the representation of localised and short-lived precipitation extremes. Building on our earlier work [1], we now present the published and ready-to-use version of spateGAN-ERA5, a generative AI framework for global spatio-temporal downscaling of ERA5 precipitation to kilometre and sub-hourly scales (2 km, 10 min) [2].

The model, trained using gauge-adjusted radar observations over Germany, generates realistic high-resolution precipitation ensembles conditioned on ERA5 inputs. We demonstrate robust performance across multiple climate regimes through independent evaluations over Germany, the United States, and Australia, showing clear improvements in spatial structure, temporal coherence, and extreme rainfall representation compared to native ERA5 fields. Ensemble generation further enables probabilistic uncertainty quantification.

To facilitate broad adoption, we provide a public, easy-to-use downscaling tool [3] that enables on-demand generation of high-resolution precipitation for any region and time period worldwide. The approach is computationally efficient and applicable on modest GPU hardware, making it suitable for both regional studies and large-scale applications. spateGAN-ERA5 thus establishes a practical pathway toward global high-resolution precipitation products for climate impact analysis, hydrological modelling, and AI-based weather and climate research.

[1] Glawion, L., Polz, J., Kunstmann, H., Fersch, B., & Chwala, C. (2023). *gdUhY; 5B. GdUh]c hYa dcfU` Xck bgWV`]b[cZ fU]bZU` Z]Y`Xg i g]b[U W 5B UddfUWX. 9Ufh\ UbX GdUWV GVVYbWVž%\$, e2023EA002906. <https://doi.org/10.1029/2023EA002906>*

[2] Glawion, L., Polz, J., Kunstmann, H., Fersch, B., & Chwala, C. (2025). ; `cVU` gdUh]c hYa dcfU` 9F5) dfYV]d]hUh]cb Xck bgWV`]b[hc_a UbX gi V \ci f`mgWV`Y i g]b[[YbYfUhj] Y 5 . bd^7`]a UhY UbX`5ha cgd\ Yf]WGVYbWVž, , 219. <https://doi.org/10.1038/s41612-025-01103-y>

[3] https://github.com/LGlawion/spateGAN_ERA5

