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Spatio-temporal AI downscaling of ERA5-land precipitation estimates

Luca Glawion[1], Julius Polz[1], Harald Kunstmann[1,2], Benjamin Fersch[1], and Christian Chwala[1]
[1]Institute of Meteorology and Climate Research - Campus Alpine, Karlsruhe Institute of Technology, Germany
(luca.glawion@kit.edu)
[2]Institute of Geography, University of Augsburg, Augsburg, Germany

Generative deep learning models have been proven to have great potential for precipitation nowcasting and downscaling applications. spateGAN [1] is a conditional generative neural network that we initially developed for spatio-temporal superresolution of radar-rainfall in Germany. Here, we apply the model for downscaling of ERA5-land precipitation estimates and discuss the specific challenges that arise in such an application.

While ERA5 data are vital in climate science, their limited grid size and temporal resolution (1 hour and 0.1°, ERA5 global: 0.25°) hinder accurate representation of e.g. convective rainfall events. To address these limitations, we trained a physical constraint spateGAN to enhance the resolution of time sequences of ERA5 land precipitation patches towards the resolution of RADKLIM-YW, a high-resolution (5 minutes and 1 km) rain-gauge-adjusted radar product tailored for Germany which we used as a training target. Additionally, for comprehensive validation, we assessed the Multi-Radar/Multi-Sensor (MRMS) radar product for the United States. The downscaled rainfields produced by spateGAN exhibit coherent spatio-temporal patterns and an improved representation of extreme values. Employing an ensemble approach, by generating multiple high-resolution solutions by shifting model input patches both pixel- and timewise, further enhances the quality of the downscaling product, quantified by Continuous Ranked Probability Score (CRPS), ensemble Fractions Skill Score (FSS), and rank histograms. Furthermore, our analysis of downscaled MRMS data highlights spateGAN's applicability for global downscaling applications and beyond its original training region.

In summary, our findings show the feasibility of generating a global high-resolution precipitation product based on ERA5. Such a product holds significant promise for various environmental applications, including in-depth analyses of rainfall variability on a fine-scaled global grid, impact assessments of extreme rainfall events, expanded possibilities for climate and hydrological model calibration and evaluation and as training data for AI weather forecasting models.

[1] Glawion, L., Polz, J., Kunstmann, H., Fersch, B., Chwala, C. (2023): spateGAN: Spatio-Temporal Downscaling of Rainfall Fields Using a cGAN Approach. Earth and Space Science. 10(10). e2023EA002906. https://doi.org/10.1029/2023EA002906.