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A Conditional Generative Adversarial Network for Rainfall Downscaling

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Predicting extreme precipitation events is one of the main challenges of climate science in this decade. Despite the continuously increasing computing availability, Global Climate Models' (GCMs) spatial resolution is still too coarse to correctly represent and predict small-scale phenomena such as convection, so that precipitation prediction is still imprecise. Indeed, precipitation shows variability on both spatial and temporal scales (much) smaller than the current state-of-the-art GCMs resolution: the precipitation field can vary strongly on spatial scales of the order of the km or even less, whereas GCMs typical spatial resolution ranges from 50 to 200 km. Therefore, downscaling techniques play a crucial role, both for the understanding of the phenomenon itself and for applications like e.g. hydrologic studies, risk prediction and emergency management.

Seen in the context of image processing, a downscaling procedure has many similarities with super-resolution tasks, i.e. the process of enhancing the resolution of an image. In recent years this scope has taken advantage of the introduction of deep learning techniques, and in particular Convolutional Neural Networks (CNNs). In our work we exploit a conditional Generative Adversarial Network (cGAN) to train a generator model to perform precipitation downscaling. This generator, a deep CNN, takes as input the precipitation field at the scale resolved by GCMs, adds random noise, and outputs a possible realization of the precipitation field at higher resolution, preserving its statistical properties with respect to the coarse-scale field. Moreover, since the generator is appropriately conditioned by the coarse-scale precipitation field, also the spatial structure of the produced small-scale precipitation field is consistent with the structure prescribed by the GCMs prediction. The GAN is being trained and tested in a "perfect model" setup, in which we try to reproduce the ERA5 precipitation field starting from an upscaled version of it.

Compared to other downscaling techniques, our model has the advantage of being computationally inexpensive at run time, since the computational load is mostly concentrated in the training phase. Furthermore the approach is robust, as it does not depend on physical, statistical and empirical assumptions. For this reason it can be applied to any geographical area, including those whose morphology limits the performance of numerical models (such as areas with complex orography) or domains subject to local phenomena which are difficult to model properly (e.g. coastal territories). Lastly, the ability of the generator model to produce a whole set of possible realizations of the small-scale precipitation field compatible with the large-scale one provides us a straightforward way to model uncertainty of the prediction, a point of primary importance in the context of the extreme events prediction and disaster management.

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