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Detecting Synoptic Patterns related to Freezing Rain in Montréal using Deep Learning

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Climate change is altering the Earth's atmospheric circulation and the dynamic drivers of extreme events. Extreme weather events pose a great potential risk to infrastructure and human security. In Southern Québec, freezing rain is among the rare, yet high-impact events that remain particularly difficult to detect, describe or even predict.

Large climate model ensembles are instrumental for a profound analysis of extreme events, as they can be used to provide a sufficient number of model years. Due to the physical nature and the high spatiotemporal resolution of regional climate models (RCMs), large ensembles can not only be employed to investigate the intensity and frequency of extreme events, but they also allow to analyze the synoptic drivers of freezing rain events and to explore the respective dynamic alterations under climate change conditions. However, several challenges remain for the analysis of large RCM ensembles, mainly the high computational costs and the resulting data volume, which requires novel statistical methods for efficient screening and analysis, such as deep neural networks (DNN). Further, to date, only the Canadian Regional Climate Model version 5 (CRCM5) is simulating freezing rain in-line using a diagnostic method. For the analysis of freezing rain in other RCMs, computational intensive, off-line diagnostic schemes have to be applied to archived data. Another approach for freezing rain analysis focuses on the relation between synoptic drivers at 500 hPa resp. sea level pressure and the occurrence of freezing rain in the study area of Montréal.

Here, we explore the capability of training a deep neural network on the detection of the synoptic patterns associated with the occurrence of freezing rain in Montréal. This climate pattern detection task is a visual image classification problem that is addressed with supervised machine learning. Labels for the training set are derived from CRCM5 in-line simulations of freezing rain. This study aims to provide a trained network, which can be applied to large multi-model ensembles over the North American domain of the Coordinated Regional Climate Downscaling Experiment (CORDEX) in order to efficiently filter the climate datasets for the current and future large-scale drivers of freezing rain.

We present the setup of the deep learning approach including the network architecture, the training set statistics and the optimization and regularization methods. Additionally, we present the classification results of the deep neural network in the form of a single-number evaluation

metric as well as confusion matrices. Furthermore, we show analysis of our training set regarding false positives and false negatives.