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Wave decomposition of energy transport using deep-learning

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Energy transport in the atmosphere is accomplished by systems of several length scales, from cyclones to Rossby waves. From recently developed Fourier and wavelet based methods it has been found that the planetary component of the latent heat transport affects the Arctic surface temperatures more than its dry-static counterpart and the synoptic scale component of the latent heat transport.

However, both the Fourier and wavelet based methods require enormous amounts of data and are time consuming to process. The Fourier and wavelet decompositions are computed from 6 hourly data, throughout the whole vertical column of the atmosphere. The data required are usually only available from reanalysis archives, or possibly from climate model experiments where a goal is to examine the decomposed energy transport. However, the vast CMIP5 and CMIP6 archives are out of reach for the exact computations of the Fourier and wavelet decompositions. Even if all the data were available in the CMIP archives, it would be a computationally, and storage-wise, intensive task to compute the Fourier and wavelet decompositions for a large selection of the CMIP experiments.

Here we suggest a deep-learning approach to approximate the decomposed energy transport from significantly less data than the original methods. The idea is to train a convolutional neural network (CNN) on ERA5 data, where we have already computed the Fourier decomposition of the energy transport. The CNN is trained on data at 850hPa in the atmosphere on a daily temporal resolution. The required data are only a small fraction of the data required to compute the exact Fourier decompositon of the energy transport. Once the CNN is trained, the model is tested on data from the EC-Earth climate model. For EC-Earth we have an ensemble of model runs where the energy transport is decomposed using the Fourier method, hence the CNN may be evaluated on the EC-Earth dataset.

The CNN based energy transport decomposition matches well with the classically computed energy transport from EC-Earth.The CNN captures the mean meridional transport well, and the projected changes from the 1950s to the 2090s in EC-Earth. Additionally the CNN model captures the day to day variability well, as regressions of temperature on the transport from the CNNcomputations and the classical Fourier decomposition are similar. Further we may investigate how the decomposed energy transport changes in a range of CMIP models and experiments