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Detecting spatio-temporal dynamics of western European heatwaves using deep learning

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Heatwaves over western Europe are increasing faster than elsewhere, which recent studies have attributed at least partly to changes in atmospheric dynamics. To increase our understanding of the dynamical drivers of western European heatwaves, we developed a heatwave classification method taking into account the spatio-temporal atmospheric dynamics. Our deep learning approach consists of several steps: 1) heatwave detection using the Generalized Density-based Spatial Clustering of Applications with Noise (GDBSCAN) algorithm; 2) dimensionality reduction of the spatio-temporal heatwave samples using a 3D Variational Autoencoder (VAE); and 3) a clustering of heatwaves using K-means, a Gaussian Mixture Model, and opt-SNE. We show that a VAE can extract meaningful features from high-dimensional climate data. Furthermore, we find four physically distinct clusters of heatwaves that are interpretable with known circulation patterns, i.e. UK High, Scandinavian High, Atlantic High, and Atlantic Low. Our results indicate that the heatwave phase space, as found with opt-SNE, is continuous with soft boundaries between these circulation regimes, indicating that heatwaves are best categorized in a probabilistic way.