Geophysical Research Abstracts
Vol. 21, EGU2019-17539-1, 2019
EGU General Assembly 2019

Clustering of the Polar Vortex states using deep convolutional neural networks

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Profound understanding of the stratospheric wintertime dynamics and its climate changes are important for improving seasonal forecast skill.
The primary goal of this research of the wintertime Arctic stratospheric polar vortex (PV hereafter) is defining its states and their clustering. Manual classification is a highly time-consuming task suffering of researcher subjectivity. So we apply deep learning methods that let us cluster the PV states based on their spatial structure.
We used the particular kind of neural networks called sparse variational convolutional autoencoder (SpCVAE). We applied the state-of-the-art clustering algorithm to objects described by their embedded representation in convolutional autoencoder. Here objects are the PV states described by geopotential fields at 10 hPa level from JRA55 (Japanese 55-year Reanalysis). SpCVAE was built based on VGG-16 with the Transfer Learning technique applied. 96-dimensional embedded representation was found to be optimal with high samples reconstruction quality.
Using the convolutional autoencoder as a feature extractor and the agglomerative clustering with Ward inter-cluster distance measure, we have clustered PV states. The best number of clusters (12) were chosen based on "elbow rule" and topic-specific reasoning. The approach applied let us to automatically distinguish weak PVs of "displacement" and "split" types, as well as to isolate several strong vortex states of different shift directions. These results are only obtainable when one considers the spatial structure of the PV.
We have constructed the calendar of the PV states based on the clustering result. Clustered events of weak PVs were examined and demonstrated good correspondence with the calendar of sudden stratospheric warmings that have been built manually.

This research was supported by the Russian Ministry of Education and Science (agreement 14.616.21.0102, project ID RFMEFI61618X0102)