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Data-driven Climate Models Based on Recurrent Neural Networks

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Nowadays recurrent neural networks (RNNs) are one of the most interesting and rapidly developing branches of the artificial intelligence. RNNs find their application in the wide range of challenging tasks from robot control to speech recognition. Mathematically being the dynamical systems, RNNs are successfully used for short-term prediction and attractor reconstruction of large spatio-temporal chaotic systems from time series. In our recent works [1-2] we proposed the RNN with special structure for data-driven modeling and prediction of complex systems from spatially distributed data. This RNN-based model projects the observed high-dimensional data into a low-dimensional subspace and models a dynamical system in this subspace. Thus it provides retrieving the key modes underlying the observed dynamics.

In this work we demonstrate the abilities of proposed RNN in climate system modeling. First, we apply our RNN to investigation of dynamical regimes of the quasi-geostrophic three-layer (QG3) model of the Earth's atmosphere with natural orography [3], describing dynamics of synoptical vortexes. We demonstrate that full complex QG3 model dynamics can be described in terms of data-driven modes with different spatial and temporal scales. Second, we apply RNN to analysis of real climate data measurements – satellite data of sea surface temperature (SST). We construct RNN from the SST data with an explicit accounting of external forcings, e.g. seasonal cycle, solar activity and concentration of carbon dioxide in the atmosphere, which may influence interannual and decadal climate variability. The interpretation of the resulting model in terms of internal and external (forcing-induced) dynamics is discussed.

References

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