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Echo State Networks for Nowcasting a Simplified Model of Atmospheric Convection

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Abstract

Echo State Networks (ESNs) are an adaptation of recurrent neural networks, specialised for time-accurate prediction of chaotic dynamical systems. ESNs utilize a unique reservoir framework, where a fixed, sparsely connected reservoir of nodes transforms the input into a high-dimensional space. This study explores the use of ESNs for short-term forecasting, or nowcasting, of atmospheric convection and storm initiation. Nowcasting refers to the current state of the weather and predictions for the near future, typically 0-6 hours ahead. Prediction of convective storms within this time frame is challenging. Traditional nowcasting has established methods which are effective at tracking the movement of convective cells, however predicting the initiation and decay of cells has proven more difficult.

This research investigates convective initiation by simulating a simplified model for moist convection known as the Rainy-Bénard model, which extends classical Rayleigh-Bénard convection. In this model, convective initiation is influenced by gravity waves, which play a role in the triggering and organisation of convection. Our objective is to evaluate the predictive capability of ESNs on this simplified model of convection and to enhance our understanding of gravity wave initiation. Our results demonstrate that ESNs trained on global parameters of the system exhibit good skill in predicting the timing of convective events.

Keywords:

Convection, Echo State Networks, Nowcasting, Predictive Modelling, Nonlinear Systems