基於類神經網路的數據劉維方程式與展期預報應用

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摘　要

大氣系統的渾沌特性限制了氣象預報的準確度與可預報度。系集預報（Ensemble Forecasting）透過產生大量成員來量化預報不確定性，藉此提升預報表現；然而，受限於計算資源，系集成員數量往往不足。劉維方程式（Liouville Equation）作為描述機率密度守恆的基礎方程，提供了一種從離散成員推演機率密度演變的理論框架，能有效克服系集規模受限的瓶頸。本研究利用歐洲中期天氣預報中心（ECMWF）的展期預報資料，發展一套基於類神經網路（Artificial Neural Networks）的數據驅動劉維方程式，旨在預測系集密度在相空間中的連續演變，並探討其於展期預報中的應用效益。

關鍵字：劉維方程式、類神經網路、歐洲中長期預報中心展期預報資料

Abstract

The chaotic nature of the atmosphere imposes inherent limitations on the accuracy and predictability of meteorological forecasts. Ensemble forecasting, which utilizes a large number of ensemble members to quantify predictive uncertainty, has been widely adopted to enhance forecast performance. However, such approaches are often constrained by limited computational resources, restricting the achievable number of ensemble members. The Liouville equation, which describes the conservation of probability density, offers a theoretical framework for evolving probability density functions from discrete ensemble members, thereby providing a pathway to overcome the bottlenecks associated with small ensemble sizes. In this study, we develop a data-driven Liouville equation based on artificial neural network, trained using extended-range ensemble forecast data from the European Centre for Medium-Range Weather Forecasts (ECMWF). This approach aims to predict the continuous evolution of ensemble density in phase space and evaluates its potential benefits for extended-range forecasting applications.

Key words : Liouville Equation, ANN, ECMWF S2S ensemble data