Time Series Forecasting with LSTM Network Based Model for ENSO

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Abstract

We applied LSTM networks to study El Niño Southern Oscillation (ENSO) in this paper, which can been viewed as a time series forecasting problem on climate change field. We designed different experiments to testify the effectiveness of prediction models with different time series steps. the result showed that the LSTM networks have the ability to capture the long dependencies between the SST data, then forecast the ENSO phenomenon of 15~16 successfully, which show great potential as the supplement with the conventional prediction models, especially with longer multiple steps forecast ahead.

1 Introduction

The El Niño-Southern Oscillation (ENSO) is an irregularly periodic variation during the eastern equatorial Pacific, which is considered as the dominant mode of interannual climate variability observed globally (Wunsch 1990). ENSO is associated with many climate changes globally (Fraedrich 1994; Wilkinson et al.1999), so a skillful prediction of ENSO is highly desired.

So far, both dynamical and statistical models are applied for forecasting ENSO (Barnston 2012). The dynamical models use physical equations of the ocean and atmosphere to forecast ENSO and the statistical models use mathematical formulations to learn from the observed data to forecast ENSO. However, ENSO is not predicted well enough up to 6 months due to the existence of predictability barrier (Goddard et al., 2001), and the computationally are very expensive while applying those climate models. Those two points remain room for further study for this problem.

Recently, some researchers have attempted to apply machine learning methods for this problem, especially deep learning methods. LSTM networks have been applied to predict sea surface temperature (SST) (Zhang 2017) and tropical cyclones (Li 2017), which are highly related to ENSO phenomenon (Hong 2001; Catto 2012). A hybrid model with ANN and ARIMA model have also been used to predict ENSO, and the result is slightly better than an ensemble prediction model (Nooteboom 2018). Those preliminary results show great potential with LSTM networks for studying ENSO case, which will be discussed further in this paper.

The structure of this paper as follow: Section 2 formalizes the ENSO forecasting problem, which we transferred as a time series problem here. In Section 3, we discussed the data and applied model details. The experiment result and detailed parameters setting are reported in Section 4. The paper concludes with a summary and discussion in Section 5.

2 Problem Formulation

To quantify ENSO, there exist several indices to monitor the tropical Pacific, all of which are based on SST anomalies averaged across a given region (Figure 1). Among those different NINO indices, NINO3.4 index is the average SST anomaly in the region bounded by 5°N to 5°S, from 170°W to 120°W. This region has large variability on ENSO time scales, and is close to the region where changes in local SST are important for shifting the large region of rainfall typically located in the far western Pacific. NINO3.4 index is one of the most commonly used indices to define ENSO phenomenon, we use NINO3.4 index as the predictand in this paper. The prediction of ENSO can be regarded as a problem of predict NINO3.4 index with different time steps ahead.

Concretely, we list the observed NINO3.4 indices as a time series sequence as input (training data) to train our model, then use the model to predict the next several monthly NINO3.4 indices with different predict steps, and then compare the result with reality and result of climates models. It is worth mentioning that the length of prediction is critical here, as a prediction with lead times up to 1 year, is high desired (Nooteboom 2018).

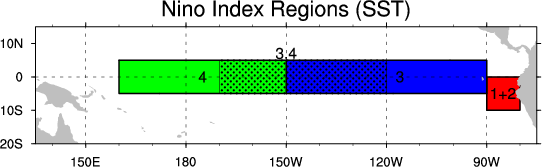


Figure 1: Different Nino index Regions

3 Data and Model

Dataset Description

1.Data source 🡪   
<https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Nino34/> （From 1870~2018 May, we use from 1870.01~2017.12 ）  
2.Some data Analysis (why no need normalization and pre-processing)

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“The training sequences are sliding windows”

MIMO Time Series Forecasting

Introduction of multiple input and multiple output and why we need multiple steps for ENSO case.

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LSTM Network

Brief introduction of LSTM networks

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4 Experiment

Tools introduction(Kears), parameter setting, metric(MSE)…

Compare with Convention Neural Networks

Detailed

Compare with Climate Models

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Prediction of ENSO during 2015~2016

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5 Conclusion

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Applied LSTM for ENSO case and compare the result with classical models, the result show great potential for this problem.

Works todo :

1.more complex data setting (considering the inner Dynamics mechanism) ;  
2. Single is not enough to cover all ENSO information, grid dataset is a optional;

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