

ARCTIC AND ANTARCTIC SEA ICE EXTENT FORECASTING USING HYBRID LSTM TECHNIQUES

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Abstract

Recent changes in global climate patterns have triggered the melting of polar sea ice, especially in Arctic regions. A decrease in the extent of sea ice is observed at a much faster rate than previously expected. The Antarctic region, on the other hand, has shown a stable sea ice pattern throughout the last few decades. However, the southern polar region is not completely unaffected. Recent studies of the Bellingshausen and Amundsen Seas have shown a downward trend in sea ice. The extent of sea ice is crucial for regulating global climate patterns, ocean circulation and human activities, including shipping and fishing. Hence, forecasting sea ice extent is vital for global economy planning and climatology studies. In this paper, time-series forecasting of 5 Antarctic and Arctic regions is evaluated using a hybrid convolutional long short-term memory (ConvLSTM) and a bidirectional long short-term memory (BiLSTM) and compared with a standalone long short-term memory (LSTM). This study uses regional sea ice extent data rather than considering the extent across entire hemispheres. With lower and stable RMSE scores across all lead times, the proposed hybrid BiLSTM model shows better performance in regional sea ice forecasting than does the standalone and ConvLSTM. The study also indicated that the climatic conditions of a particular region play a crucial role in forecasting efficiency, especially at longer lead times.

Keywords:

Sea ice extent, time series forecasting, long short-term memory (LSTM), bidirectional long short-term memory (LSTM), Arctic SIE, Antarctic SIE

1. INTRODUCTION

The increase in greenhouse gases, which has resulted in an increase in global temperature, has eventually caused notable changes in polar regions. The Arctic ice cover is declining at an accelerated rate, along with a significant reduction in its thickness [1]. Over the past few decades, an increase in the near-surface air temperature called the 'Arctic Amplification' has been observed [2]. The temperature increase and continuous melting have led to a feedback mechanism in the Arctic. This will result in additional ice melting. The Arctic is expected to be 'seasonally ice-free' once all layers of its multilayered ice are lost [3]. On the other hand, in contrast to its gradual increase in ice cover since the 1970s, Antarctica experienced a remarkable decline between 2014 and 2017. Over these four years, the reduction in the extent of Antarctic sea ice exceeded the total Arctic sea ice loss observed in the four decades from 1979 to 2018 [4]. However, after 2017, several recoveries were noted, but they have yet to reach the peak achieved in 2014, indicating a decreasing trend. The reason behind the irregular pattern of Antarctic ice remains a subject of debate. The climate change has a direct effect on polar sea ice extent.

The sea ice extent (SIE) is defined as the area of the ocean with a minimum of 15% ice concentration [5]. The reduction in the SIE commonly occurs during the summer

because of melting, followed by a rise in the SIE during the winter due to ice formation. The Antarctic SIE follows a seasonal pattern, with February as the month of minimum coverage and September as the month of maximum coverage [6]. Similarly, for the Arctic extent, March and September are the months with the maximum and minimum coverage, respectively [7]. The Arctic sea ice is more sensitive to climate change than the Antarctic sea ice [8].

As defined by [9], the Arctic is divided into 14 regions. As the entire Arctic region has experienced melting since the 1970s, these regions have shown a strong negative trend. A maximum negative slope is observed for the Kara and Barents Seas, Baffin Bay, Bering Sea and Greenland Sea [7] (Figure 1). While the Antarctic regions showed a positive trend until 2014, the trends during the decline were very different. A steep negative trend was observed for all regions except the Indian Ocean and a few parts of the Ross Sea [10], resulting in an overall negative trend (Figure 2).

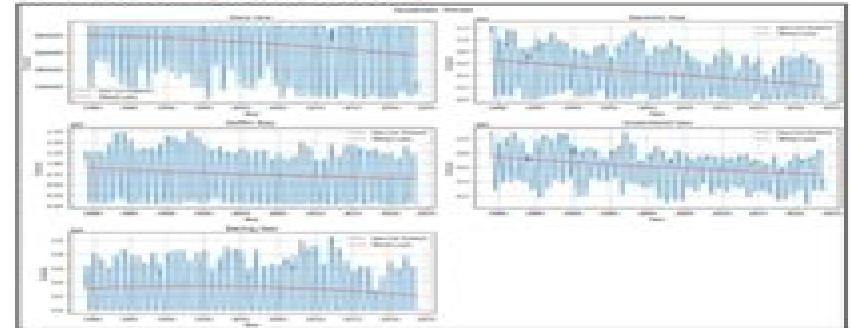


Fig.1. Time-series plots of the SIE (in km²) from 1979 to 2023 for five Arctic regions along with a quadratic regression trend line

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