DEEP LEARNING-BASED MODEL FOR RECONSTRUCTING INNER-CORE HIGH WINDS IN TROPICAL CYCLONES USING SATELLITE REMOTE SENSING

Xiaohui Li[1], Jingsong Yang[1], Guoqi Han[2], Xinhai Han[3], Peng Chen[1], Gang Zheng[1], Lin Ren[1], Lizhang Zhou[1], Romain Husson[4], Alexis Mouche[5], Bertrand Chapron[5]

[1] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, MNR, Hangzhou 310012, China
[2]Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada, V8L 4B2, Canada
[3]School of Oceanography, Shanghai Jiao Tong University, Shanghai 200240, China;
[4]Collecte Localisation Satellites, F-31520 Brest, France;
[5]Laboratoire d'Oceanographie Physique et Spatiale, Institut français de recherche pour l'exploitation de la mer, F-31520 Brest, France

Abstract

We propose a deep learning method using GAN (generative adversarial networks) to reconstruct inner-core high wind within tropical cyclones using satellite data. Our model combines dilated convolution and attention mechanisms to address underestimation issues in SAR data. To address the scarcity of SAR data, we developed a GAN model using HWRF data as a proxy to simulate missing SAR data via transfer learning. Comparison with SFMR data further revealed that the GAN model's stability is influenced by varying rainfall conditions.

Introduction

Over the years, several spaceborne SAR satellites have been launched, including the first and second generations of ERS1/2, Envisat-ASAR, and TerraSAR-X/TanDEM-X. However, heavy rain and high winds can disrupt the backscattered radar signals from C-band SAR images, leading to signal saturation and reduced retrieval accuracy of high winds and extreme winds.

The machine learning method is also widely used in SAR wind speed retrieval. However, their application to the reconstruction of cyclone structures from SAR images has so far been limited. Therefore, this paper describes a GAN framework for reconstructing the inner-core winds of tropical cyclone from SAR images based on transfer learning.

Aim

This study utilized SAR images from two satellite missions, Radarsat-2 missions and Sentinel-1A/B missions, covering the period of 2014 to 2021. Our study aims to use GAN to accurately reconstruct inner-core high winds within tropical cyclones using SAR data. Our aims to propose an effective machine learning model for extracting both local and global features from SAR. This model can be used to efficiently reconstruct typhoon wind fields, thereby enhancing the quality of SAR wind field data.

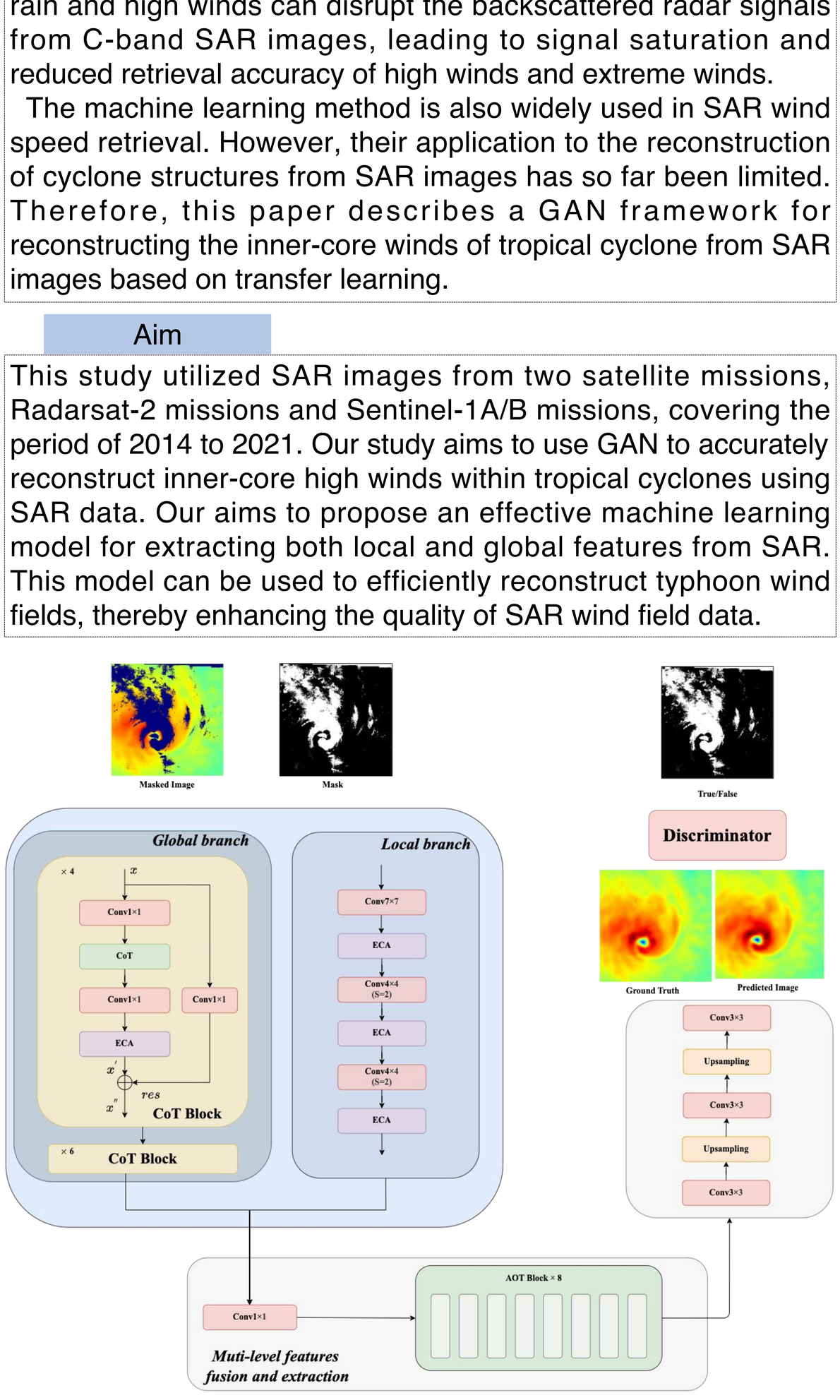

Fig. 1. Architecture of generative adversarial network (GAN) based on an encoder--decoder framework.

Methodology

Detailed information about TC-GAN is presented in Fig.1. It consists of a generator network and a discriminator network. The generator network follows the encoder--decoder structure with a special neck design. The encoder includes two branches, which can simultaneously learn global-level features by using the attention mechanism contextual transformer block (CoT) and local-level features by using a stack of convolutional layers and an efficient channel attention (ECA) module. The input is incomplete images and corresponding binary masks, and the output is the final reconstructed results of the tropical cyclone inner-core wind speeds.

Results

To test the performance and stability of our model in reconstructing tropical cyclone, the model showed promising results on HWRF validation set, with a bias of 0.03 m/s, an RMSE of 0.80 m/s, and an R of 0.997, indicating the effectiveness of the two branches in extracting both local and global features within the model.

Fig. 2 presents the scatterplot comparison between the reconstructed wind speed and SFMR based on the different mask conditions. The statistical metrics also indicate that as the rainfall intensity increases, the mask area decreases and the RMSE decreases (7.83 m/s to 5.84 m/s). It is important to note that the choice of masking conditions can also affect the performance of the model.

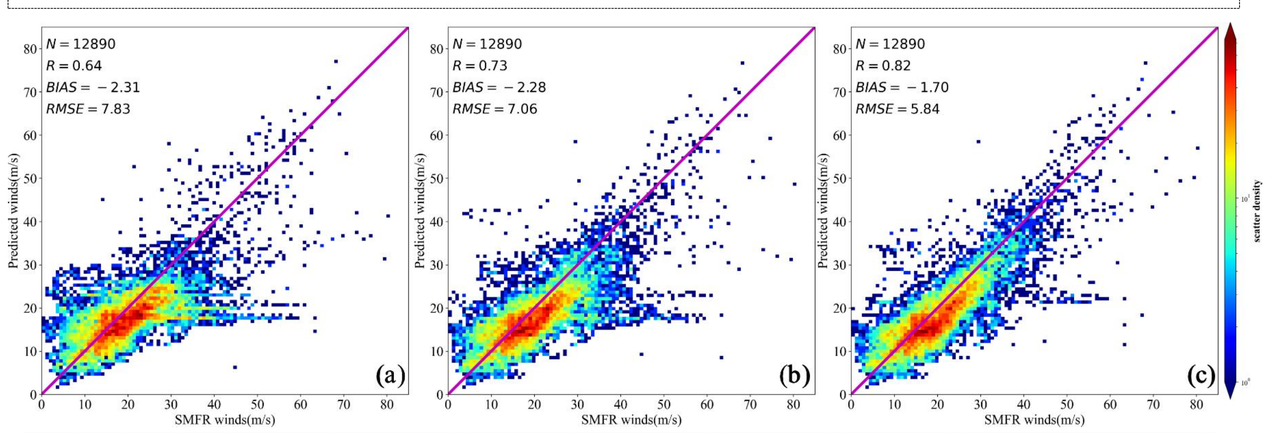

Fig. 2. The reconstructed tropical cyclone wind speed and SFMR scatter plots under different mask conditions created based on rainfall intensity. (a): All rainfall conditions. (b): more than 2.54 mm/hr. (c) more than 7.62 mm/hr.

Conclusion

Combining global and local information characteristics, this study developed an objective DL-based model for reconstructing the intensities and inner-core winds of tropical cyclones from Radarsat-2 and Sentinel-1A/B SAR imageries. Our model produces stable reconstruction results with a consistency with the measured data from SMFR, particularly performing well under heavy rainfall conditions with an RMSE of 5.84 m/s. This demonstrates the effectiveness of our model in repairing tropical cyclone data in SAR images.

Reference

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