Press Releases

December 19, 2018
JAMSTEC
Kyushu University
Japan Science and Technology Agency

Artificial Intelligence (AI) helps to detect precursors of tropical cyclones

Overview
A research group led by Dr. Daisuke Matsuoka from the Center for Earth Information Science and Technology of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and Professor Seiichi Uchida at Kyushu University has successfully presented a deep learning[*1] approach for identifying tropical cyclones and their precursors.

In a conventional approach, prediction of tropical cyclones such as typhoons and hurricanes has usually been carried out with model-driven methods[*2] using climate models based on observational data and monitoring of cloud development from satellite data. In this study, the research team has applied a data-driven approach[*3] to detect the precursors of a developing tropical cyclone from a vast amount of simulation data using deep learning and examined the detection accuracy.

To ensure accurate identification in deep learning, a vast amount of data exceeding several thousand examples per category is required. So, the scientists first applied a tropical cyclone tracking algorithm to 20 years of climate simulation data generated by NICAM (Nonhydrostatic ICosahedral Atmospheric Model)[*4] and created 50,000 cloud images of precursors of tropical cyclones and developing tropical cyclones. They also created 10 training data sets from the aforementioned 50,000 cloud images combined with 1 million images pf clouds that did not develop into tropical cyclones, thereby making a total of 1,050,000 images. A total of 10 types of classifiers with different characteristics were formed from machine learning using a deep convolutional neural network[*5]. As a result of building an ensemble classifier for making final judgment by comprehensive evaluation of the results of the 10 different types of classifiers, it was found that precursors of tropical cyclones using climate simulation data from NICAM can be detected with higher accuracy.

To predict actual tropical cyclones before they occur however, it is still necessary to further improve the training method and data, and ensure the same level of detection capability for cloud images from satellite observation and/or real-time simulation data with data assimilation. By adopting AI technology with deep learning in this field, it is expected to lead to a new development of big data analysis for marine and earth science with combination of data-driven and model-driven approaches.

This work was supported by JST, PRESTO Grant Number JPMJPR1777, JSPS KAKENHI Grant Number 16K13885, 26700010, and 17K13010.

The above results were published in *Progress in Earth and Planetary Science* issued by Japan Geoscience Union on December 19, 2018.
https://progearthplanetsci.springeropen.com/articles/10.1186/s40645-018-0245-y

Title:Deep Learning Approach for Detecting Tropical Cyclones and their Precursors in the Simulation by a Cloud Resolving Global Nonhydrostatic Atmospheric Model
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*1 Deep learning: A machine learning technique that uses multi-layered neural networks (deep neural networks). Deep learning has given rise to major breakthroughs in fields such as image recognition, speech recognition, natural language processing, and human activity recognition, thereby allowing past performances to be far surpassed. In addition to the accumulation of large amounts of data due to the recent development of the Internet and computer technologies, deep learning is based on innovations in multi-layered technologies of neural networks that make complex tasks possible and the development of computer technologies (particularly GPU) that accelerate this process; it recently attracted a large amount of attention for sparking a third artificial intelligence boom from 2012 onward.

*2 Model-driven methods: Methods that attempt to derive solutions deductively using physical models in which natural phenomena are modeled based on theory. Simulation models based on physical equations, such as NICAM, fall under this category, and they have been used as the main research method in meteorology and other natural sciences.

*3 Data-driven methods: In contrast to model-driven methods, data-driven methods attempt to inductively derive the laws and relationships governing phenomena through statistical processing of acquired data. In this study, a data-driven method was applied to simulation data obtained by model-driven methods.

*4 NICAM: A global climate model that implements highly accurate calculations through the direct calculation of cloud formation/behavior across the globe. Conventional global climate models require some assumptions to be made about the relationships between cloud systems and large-scale atmospheric circulations, such as high-pressure/low-pressure systems, and these assumptions are a major cause of uncertainty. The NICAM is primarily applied at a horizontal resolution of 870 m to 14 km. When used at extremely high resolutions of 870 m to 3.5 km, it is called a global cloud-resolving model, and when used at resolutions from 7 km to 14 km, it is called a global cloud-system-resolving model. The ability of the NICAM to simulate typhoons is high, and so far, it has yielded numerous results in typhoon research.
(Reference: http://www.jamstec.go.jp/e/about/press_release/20150120/)

*5 Convolutional neural network: One of the deep neural network models specialized in image recognition. It is also applied to the recognition of faces or objects photographed in images, automatic driving technology, anomaly detection in factory production, and cancer cell detection from CT scan data. Conventional image recognition requires human intervention to apply feature values (image shading patterns, etc.) to represent the target object that needs to be recognized, but with deep learning, the feature values can be automatically learned from large amount of data, which has vastly improved the recognition capability.

Figure 1. Examples of cloud images of tropical cyclones and precursors (outgoing longwave radiation) created by applying a tropical cyclone tracking algorithm to 20 years of NICAM simulation data. Each image shows 1,000 km^2 (64 × 64 grid).

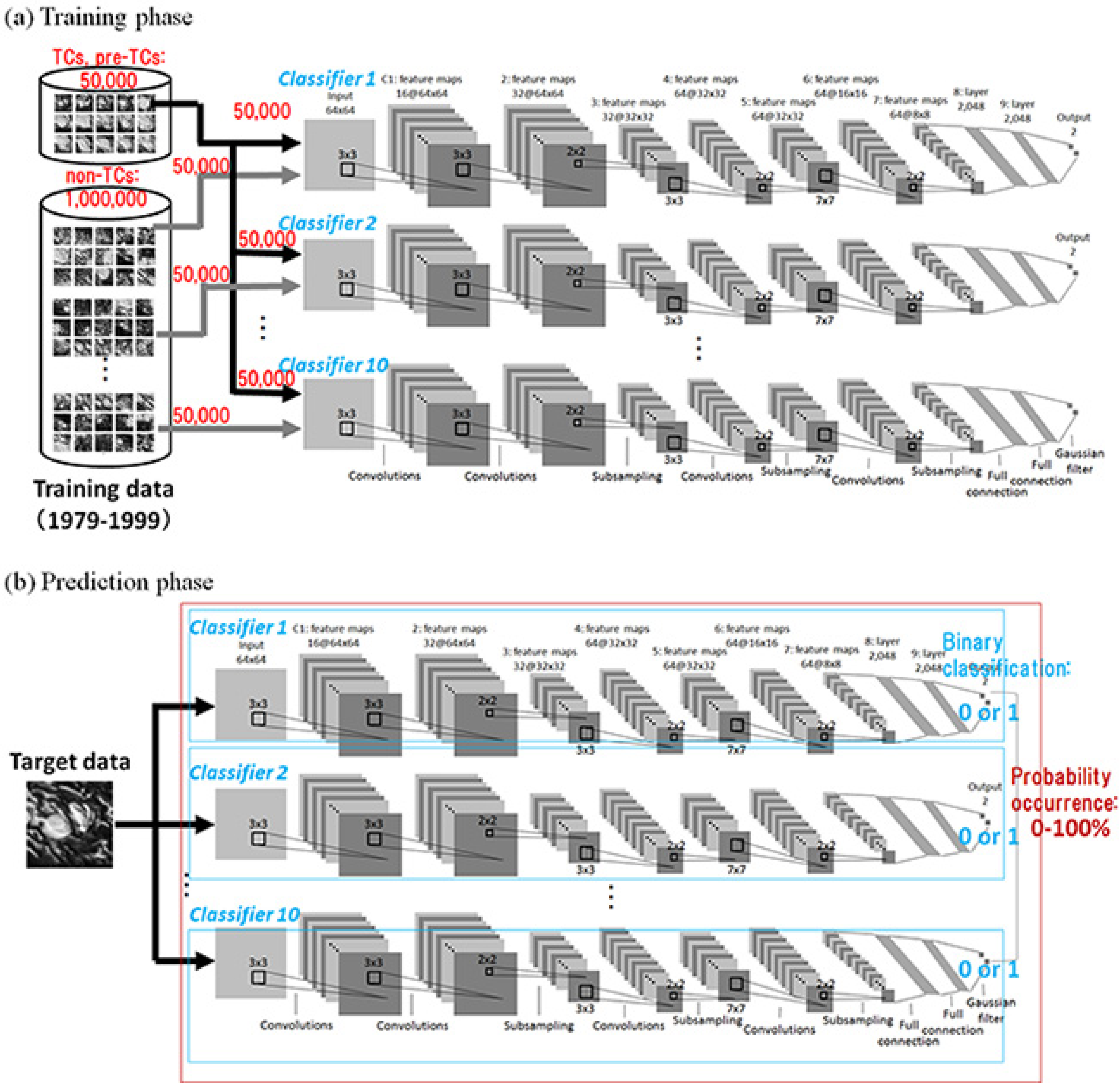

Figure 2. An ensemble classifier using deep convolutional neural networks (CNN). (a) In the training phase, 10 different CNN learn using different training data. (b) In the predicting phase, a single input image is classified into one of two classes by 10 different classifiers, and the weighted average is taken as the final probability of existence. In areas where the existence probability exceeds a previously assigned threshold, a tropical cyclone or its precursor is considered to be detected.

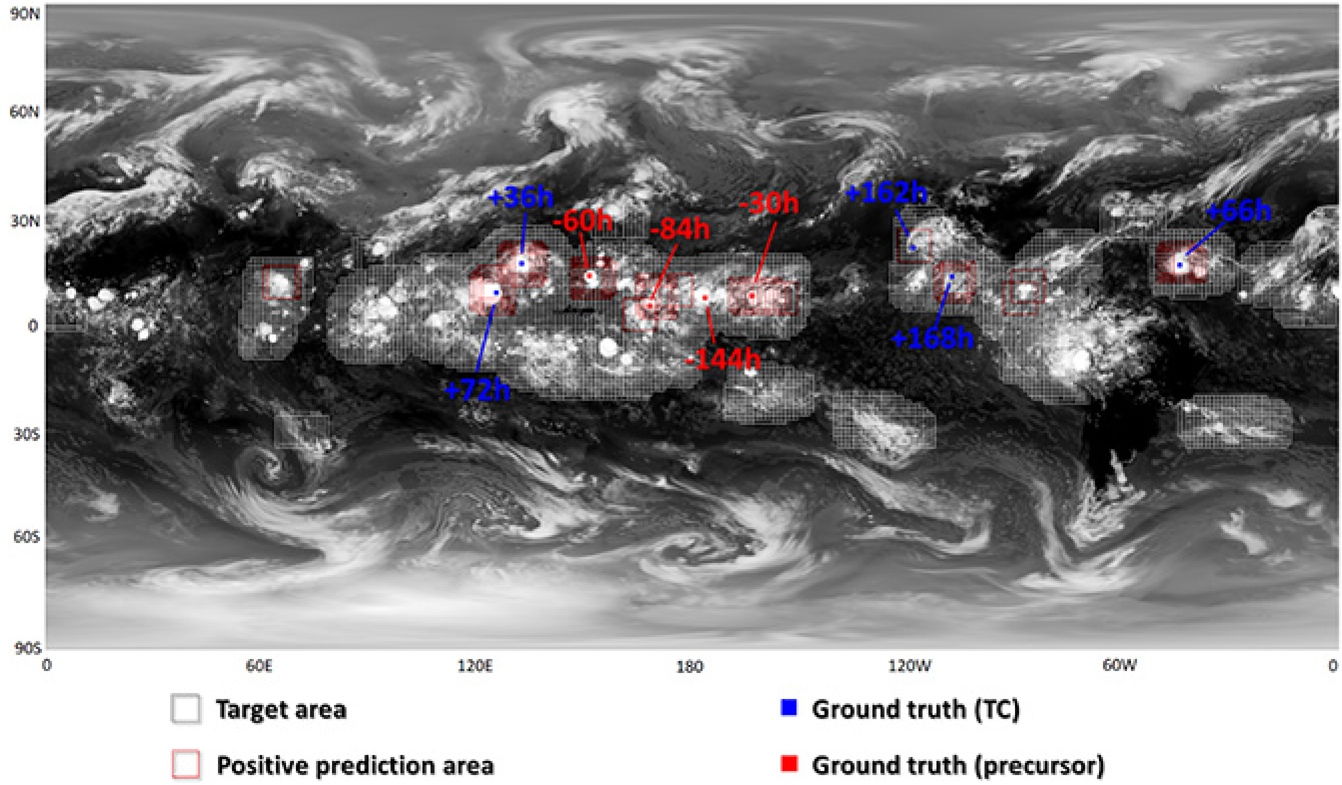

Figure 3. Example of detection results using the ensemble classifier on untrained data. Areas (1,000 km^2) with cloud cover of 30−95% are targeted for prediction, and are indicated by a white box. Areas targeted for prediction where the probability of existence of a tropical cyclone or precursor is predicted to be 100% (all 10 classifiers predict that a tropical cyclone or precursor exists) are indicated by a red box. The blue and red dots indicate the center points of correct answers for tropical cyclones and precursors, respectively, which are already evident from the tropical cyclone tracking algorithm.

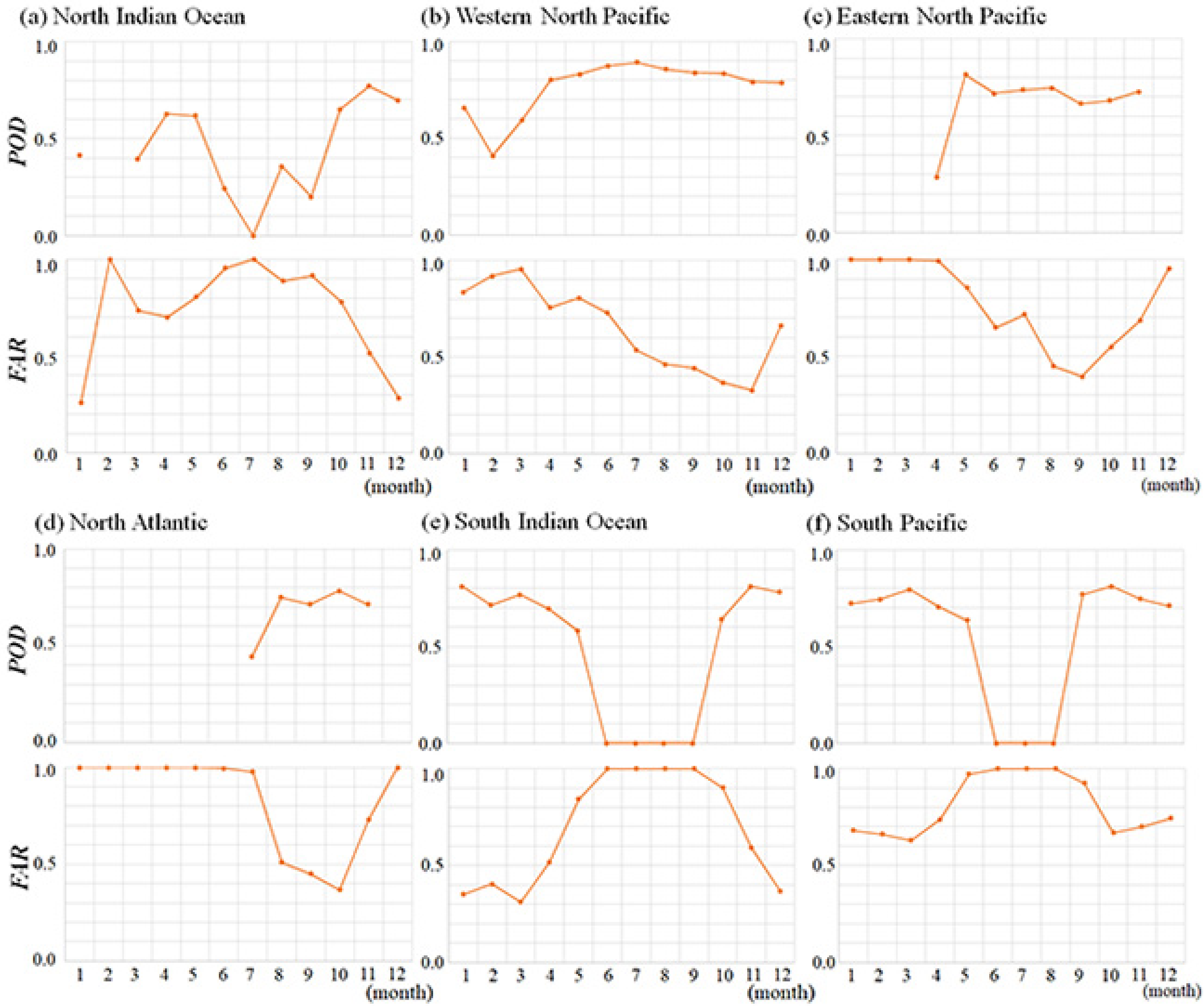

Figure 4. Monthly variations in probability of detection (POD) and false alarm ratio (FAR) in each basin (10-year average).

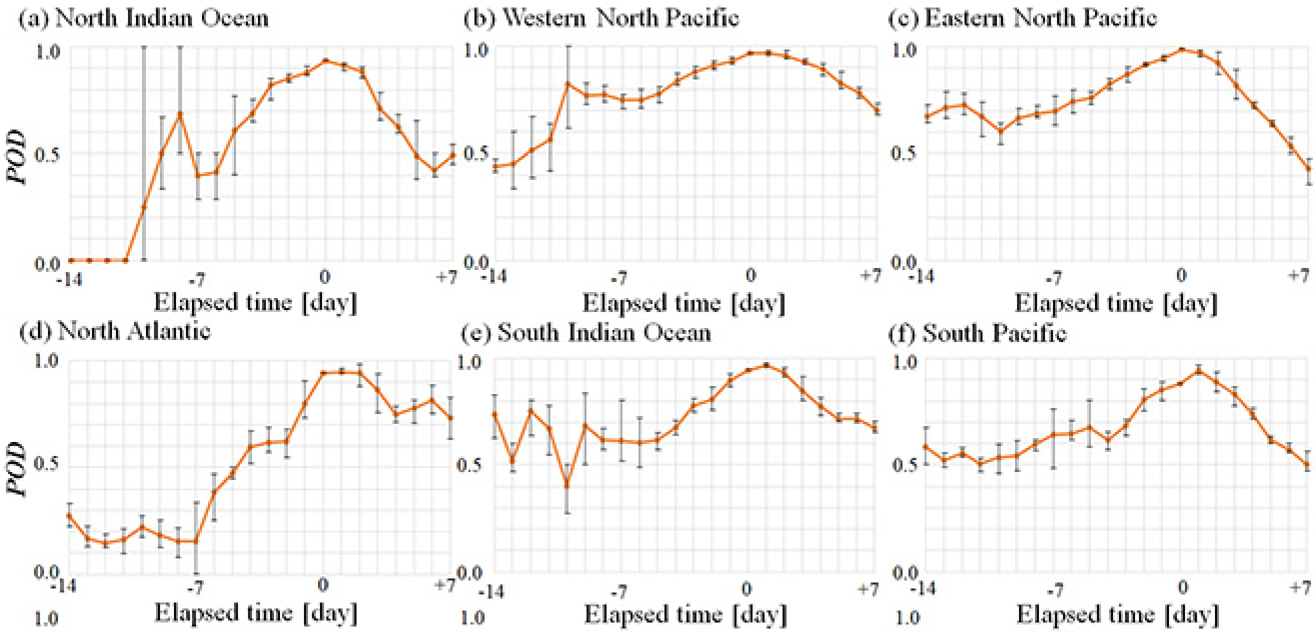

Figure 5. Probability of detection (POD) over time in each basin. Positive values of elapsed time indicate the number of days after tropical cyclone formation, and

negative values of elapsed time indicate the number of days until tropical cyclone formation.

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