Estimation of wind speeds inside Super Typhoon Nepartak from AMSR2 low-frequency brightness temperatures

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Abstract Accurate estimations of typhoon-level winds are highly desired over the western Pacific Ocean. A wind speed retrieval algorithm is used to retrieve the wind speeds within Super Typhoon Nepartak (2016) using 6.9- and 10.7-GHz brightness temperatures from the Japanese Advanced Microwave Scanning Radiometer 2 (AMSR2) sensor on board the Global Change Observation Mission-Water 1 (GCOM-W1) satellite. The results show that the retrieved wind speeds clearly represent the intensification process of Super Typhoon Nepartak. A good agreement is found between the retrieved wind speeds and the Soil Moisture Active Passive wind speed product. The mean bias is 0.51 m/s, and the root-mean-square difference is 1.93 m/s between them. The retrieved maximum wind speeds are 59.6 m/s at 04:45 UTC on July 6 and 71.3 m/s at 16:58 UTC on July 6. The two results demonstrate good agreement with the results reported by the China Meteorological Administration and the Joint Typhoon Warning Center. In addition, Feng-Yun 2G (FY-2G) satellite infrared images, Feng-Yun 3C (FY-3C) micro-wave atmospheric sounder data, and AMSR2 brightness temperature images are also used to describe the development and structure of Super Typhoon Nepartak.

Keywords microwave radiometer, sea surface wind retrieval, AMSR2, Nepartak, SMAP

1 Introduction

The northwestern Pacific Ocean is one of the most active ocean basins, as tropical cyclones strike the most frequently therein. A typhoon, as a type of severe tropical cyclone, can produce fierce winds and heavy rains as well as high waves and damaging storm surges that can produce dramatic impacts on the safety of both life and property. Using a combination of forecast models, satellite imagery, and data analysis, tropical cyclone tracking and forecasting have achieved remarkable advancements over the last decades (Roy and Kovordányi, 2012). However, the accuracies of tropical cyclone intensity forecasts have seen much less progress over the same period.

Passive microwave radiometers have been used to retrieve ocean parameters (e.g., the wind speed, sea surface temperature, and sea surface salinity) for a long time (Goodberlet et al., 1990; Krasnopolsky et al., 1995; Wentz, 1997; Yueh et al., 2006; Zhang et al., 2016a). Previous research has demonstrated that microwave radiometers can be used to retrieve wind speeds with an accuracy of approximately 1 m/s when the weather conditions are clear. Retrieval algorithms can be divided into two categories: statistical algorithms and physical-based algorithms. Statistical algorithms always employ regression or neural networks (NN) techniques to retrieve wind speeds with matching brightness temperatures (Goodberlet et al., 1990; Krasnopolsky et al., 1995; Wentz, 1997; Yueh et al., 2006; Zhang et al., 2016a). Physical-based algorithms use a radiative transfer model that relates brightness temperatures to retrieved geophysical parameters, such as the wind speed and sea surface temperature (Wentz, 1997). However, the performances of these algorithms break down completely when rain is present (Meissner and Wentz, 2009). Rain increases the atmospheric attenuation, especially at higher frequencies (e.g., 37 GHz). In fact, the brightness temperatures at higher frequencies are nearly saturated near the eyes of hurricanes (Yueh, 2008). In addition, it is very difficult to accurately model brightness temperatures under rainy conditions because of the high variability within rainy
atmospheres and the complicated dielectric properties of the ocean surface (Meissner and Wentz, 2009; Zabolotskikh et al., 2015).

One of the most important applications of radiometers is the study of severe ocean weather systems (Quilfen et al., 2007). Previous investigations noted that brightness temperatures from low-frequency channels (such as the L-band and C-band) can be used to retrieve wind speeds under extreme conditions such as tropical cyclones (Shibata, 2006; Uhlhorn et al., 2007; Yan and Weng, 2008; Meissner and Wentz, 2009; Reul et al., 2012). The Stepped Frequency Microwave Radiometer (SFMR), which is a typical airborne sensor onboard National Oceanic Atmospheric Administration (NOAA) aircraft, has been successfully used to estimate wind speed in hurricanes (Uhlhorn and Black, 2003). However, reconnaissance aircraft missions are mainly focused on the North Atlantic Ocean and the eastern Pacific Ocean. Little has been reported about the retrieval of tropical cyclone intensities over the northwestern Pacific Ocean.

The AMSR2 instrument is a conically scanning passive microwave radiometer on board the JAXA GCOM-W1 spacecraft, which was launched on May 18, 2012. AMSR2 provides TB observations at frequencies ranging from 6.9 to 89 GHz and is equipped entirely with dual-polarization channels. AMSR2 low-frequency brightness temperatures have been used to study wind speed retrievals in extratropical cyclones (Zabolotskikh et al., 2014). Super Typhoon Nepartak (2016), a Category-5 hurricane, struck the northwestern Pacific Ocean and had disastrous effects in Taiwan and Fujian. The AMSR2 sensor successfully captured four images when the development of Super Typhoon Nepartak was vigorous during July 5–7. In this paper, a new algorithm was established and used to retrieve wind speeds inside Super Typhoon Nepartak over the northwestern Pacific Ocean.

This paper is organized as follows. Section 2 describes the development and structure of Super Typhoon Nepartak. The retrieval algorithm is presented in Section 3. Section 4 tests the performance of the retrieval algorithm for Super Typhoon Nepartak and compares the retrieval results with the Soil Moisture Active Passive (SMAP) wind speed product. The conclusions are presented in Section 5.

2 Description of Super Typhoon Nepartak

The genesis of Super Typhoon Nepartak can be traced back to a low-pressure area that emerged from the south of Guam on June 30, 2016. After a period of slow development, it was estimated that a tropical depression formed on July 2. Shortly afterwards, the Joint Typhoon Warning Center (JTWC) issued a tropical cyclone formation alert. By 3 July, the Japan Meteorological Agency (JMA) upgraded the system to a tropical storm and named it Nepartak. The path of Nepartak is shown in Fig. 1, and the time series of the maximum wind speed and the minimum central pressure are also displayed in Fig. 1. Nepartak followed along a west-northwestward heading during its lifetime. On July 3, its forward speed was approximately 15–20 km/h. By July 4, it had started to accelerate up to 30 km/h under the influence of a subtropical ridge. At approximately 12:00 UTC on July 4, the JMA upgraded it to a severe tropical storm. Both the CMA and the JMA upgraded Nepartak to a typhoon on July 5; its annular characteristics can be found in Feng-Yun-2G (FY-2G) satellite infrared images displayed in Fig. 2(a). On the evening of July 5, due to a low vertical

![Fig. 1](image-url)  The best track positions, minimum central pressure, and maximum wind speed for Super Typhoon Nepartak during July 3–10, 2016, based on analyses from the China Meteorological Administration (CMA) typhoon website.