Acta Oceanol. Sin., 2017, Vol. 36, No. 11, P. 1–3
DOI: 10.1007/s13131-017-1133-9
http://www.hyxb.org.cn
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Cover Story

The first quantitative joint observation of typhoon by Chinese GF-3 SAR and HY-2A microwave scatterometer

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Received 1 August 2017; accepted 25 August 2017

The typhoon, as a mature tropical cyclone that develops in the western part of the North Pacific Ocean with high wind speed and heavy rainfall, is one of the most lethal and costly of natural disasters for the densely populated countries of East Asia. It can be easily detected by space-borne sensors operated at microwave, visible or infrared bands (Liu et al., 2014). Synthetic Aperture Radar (SAR) is a kind of active imaging radar, which can detect the targets with high resolution at one-meter level. SARs can be used to extract the sea surface wind and the eyes of typhoons or hurricanes (Friedman and Li, 2000; Zhang and Perrie, 2012; Li, 2015; Jin et al., 2014; Liu et al., 2014). As a pioneer project of Haiyang-3 (HY-3), the Chinese C-band SAR satellite of Gaofen-3 (GF-3) was launched in August 2016 under China High-resolution Earth Observation System (CEOS). GF-3 carries a multi-polarized C-band SAR with a highest spatial resolution of one meter, the most imaging modes in the word of twelve and a long designed lifespan of 8 years. Haiyang-2A (HY-2A), which was launched in August 2011, is the first Chinese marine dynamic environment satellite with a main payload of Ku-band microwave scatterometer (Jiang et al., 2012; Ye et al., 2015). One of the objectives of HY-2A scatterometer (HY-2A SCAT) is monitoring sea surface wind field of global ocean.

The SAR image shown in Fig. 1 is the first GF-3 VH-polarized SAR image of a typhoon. It was acquired at 21:24 UTC on August 4, 2017 and covered the typhoon of Noru in the Northwest Pacific by ScanSAR wide mode with a swath width of 500 km and a spatial resolution of 100 m. One can see in the SAR image shown in Fig. 1, fine structure of the typhoon, including typhoon eye, rainfall zoon and wind streak, is seen clearly. Comparison of the typhoon image shown in Fig. 1 with RARDASAT-2, a Canadian SAR satellite, the quality of GF-3 SAR images in detection of typhoons is nearly the same as RARDASAT-2 (see the typhoon images of RARDASAT-2 shown in Fig. 5–33 in Ye (2017)). It is interesting that the first Sentinel-1 SAR image of typhoon also covers the same place as GF-3 (Fig. 2 in Li (2015)). Sentinel-1 is also the C-band SAR satellite operated by European Space Agency (ESA).

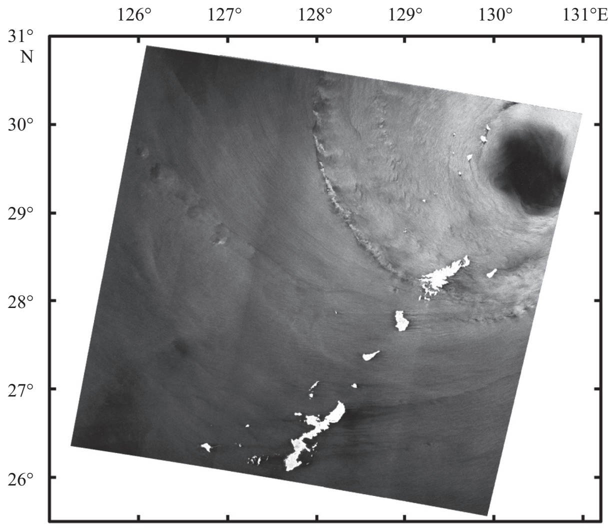

Fig. 1. GF-3 SAR image (C-band, VH polarization) acquired at 21:24 UTC on August 4, 2017 over the typhoon of Noru in the Northwest Pacific.

Foundation item: The National Key R & D Program of China under contract No. 2016YFC1401000; the Joint Foundation of National Natural Science Foundation of China and the Marine Science Center of Shandong Province under contract No. U1406404; the National Natural Science Foundation of China under contract Nos 1506206 and 41476152.
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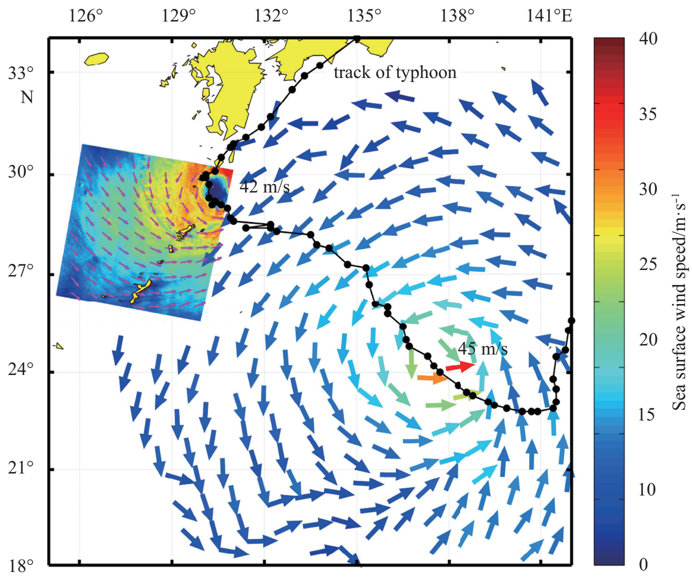

Fig. 2. Sea surface wind retrieved from GF-3 SAR image (continuous color-coded map with magenta arrows, at 21:24 UTC on August 4, 2017) and HY-2A SCAT (color-coded arrows, at 9:12 UTC on August 1, 2017). The black line is the track of Typhoon Noru and the labeled texts are the highest wind speed at the observation time of GF-3 SAR and HY-2A SCAT, respectively.

Sea surface wind speeds can be retrieved from calibrated SAR data. In this study, we used the VH-polarized GF-3 SAR image data (shown in Fig. 1) to retrieve the high wind speeds using the model developed by Zhang et al. (2014). Figure 2 is the composite figure of sea surface wind speeds retrieved from GF-3 SAR image (continuous color-coded map with magenta arrows, at 21:24 UTC on August 4, 2017) and HY-2A SCAT (color-coded arrows, at 09:12 UTC on August 1, 2017). The typhoon track of Noru (black line) with the highest wind speed (labeled texts) at the observation time of GF-3 SAR and HY-2A SCAT is also drawn in it. The data of Typhoon Noru's track and highest wind speed are downloaded from Chinese typhoon web, Chinese central meteorological station (http://typhoon.nmc.cn/web.html). The directions of the arrows shown in Fig. 2 represent the wind directions. The wind directions of SAR wind are derived from the wind streaks on the image itself. From the joint observation of typhoon by GF-3 SAR and HY-2A SCAT shown in Fig. 2, the following quantitative information is easily derived. (1) The center (i.e., typhoon eye) of Typhoon Noru located at about 24.2°N, 137.5°E at 21:24 UTC on August 4, 2017; meanwhile it located at about 29.5°N, 130.4°E at 9:12 UTC on August 1, 2017. These locations are almost in the track of Typhoon Noru. Another five HY-2A SCAT typhoon observation results (figures not shown here) also indicate the same conclusion. (2) The propagation direction and distance of the Typhoon Noru is northwestward and about 950 km during the time period from August 1 to 4, 2017. (3) The sea surface wind speeds distribution can also be derived from the observation results. Though we can get these typhoon features from single sensor, the more sensors we use, the more accurate information we can get from the joint observation. Especially, we can get the high spatial resolution structure of typhoon from SAR images (tens of meters for SAR, 25 km for scatterometer).

Both GF-3 and HY-2A satellites have been working effectivly to provide SAR images and sea surface wind filed products in application of marine meteorological forecast, ocean fishery, disasters and objects detection. National Satellite Ocean Application Service (NSOAS), States Oceanic Administration (SOA) of China offers these data and products to public for free. The website of data distribution system is http://dds.nsoas.org.cn. The SAR data of GF-3 and microwave scatterometer products of HY-2A will significantly increase the data sources in geography, meteorology, oceanography application and research in the next several years.

Acknowledgements

The authors thank An Dawei from National Satellite Meteorological Center, China Meteorological Administration, Chen Qi and Peng Yongzhao from China Centre for Resources Satellite Data and Application for the assistance of SAR image processing.

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