SCATSAT-1 HIGH WINDS GEOPHYSICAL MODEL FUNCTION AND ITS WINDS APPLICATION IN OPERATIONAL MARINE FORECASTING AND WARNING

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ABSTRACT

In this paper we develop high wind portion of a Geophysical Model Function (GMF) for Scatsat-1 scatterometer measurements. Starting with NSCAT4 GMF the high wind portion has been modifying by utilizing measurements obtained by IWRAP instrument on board of NOAA P3 aircraft within tropical and extratropical cyclones. The A_0 coefficient in NSCAT4 GMF was modeled so its slope is a linear function of a logarithm of wind speed and its first derivative of it equals to zero at saturation wind speed for particular incidence angle and measurements frequency as it was measured by IWRAP. The calibrated measured sigma0's from Scatsat-1 shows good agreement with the new GMF named NSCAT4.H at the high winds. The respective wind retrievals are higher and much better aligned with ASCAT high winds while the global winds statistic performance of ScatSat-1 winds remained unchanged. The new ScatSat-1 wind products produced by NSCAT4.H GMF has been implemented in NOAA's operational marine forecasting and warning applications and examples are presented here.

Index Terms— Scatterometer, High Winds, Geophysical Model Function

1. INTRODUCTION

The ocean surface wind vector measurements have been produced in near real-time from the Scatsat-1 scatterometer satellite mission at the National Oceanic and Atmospheric Administration (NOAA) [1]. The Scatsat-1 was launched into a sun-synchronous low Earth orbit on 26th September, 2016 and is capable of providing about 90% coverage of the ocean surface winds observation daily. The satellite was developed, launched and is operated by the Indian Space Research Organization (ISRO). NOAA has been receiving Level 1 normalized radar cross section (sigma0) from ISRO in the near real-time. The ISRO Level 1B sigma0 product [2] has been utilized to produce the earth-gridded sigma0 Level 2A (L2A) products in 12.5 km and 25 km sampling. From there Level 2B (L2B) wind vector products at 12.5 km and 25 km have been then produced respectively using the wind retrieval algorithm methodology based on the Maximum Likelihood Estimation (MLE) and the new high wind GMF (NSCAT4.H) together with Two-Dimensional Variational Ambiguity Removal (2DVAR) scheme [3].

A Geophysical Model Function (GMF) establishes a relationship between the sigma0 and wind vectors (speed and direction) as well as its measurement geometry (incidence and azimuth angles) for a given frequency and polarization. The GMF is an important tool not only in the wind retrieval algorithm but also in the determination of the sigma0 calibration and validation as well. In this paper, we focus on the derivation of the GMF at high wind speed for ScatSat-1 instrument. Scatsat-1 instrument is operating at 13.61 GHz (Ku-band) and acquiring measurements at dual-polarization, VV and HH.

Traditionally, the GMF is derived from the sigma0 measurements collocated with ground truth surface wind sources such as Buoys, Numerical Weather Prediction (NWP) model or remotely sensed satellite observations. This methodology establishes good relationship between wind vector and sigma0's for low to moderate wind speeds for about up to 20-25 m/s. However, the high wind observations are rarely available and reliable, it is especially hard to collect enough high wind speeds with a uniform wind direction distribution for GMF derivation. To overcome this problem we have derived high wind GMF for ScatSat-1 measurements by utilizing an existing NSCAT4 GMF [4] and modifying the high wind portion of it so that its trend matches high wind scatterometer GMF developed from the Imaging Wind and Rain Airborne Profiler (IWRAP) measurements regularly flown on NOAA P3 aircraft in tropical and extratropical cyclones [5]. The GMF development and validation are presented in section 2 and 3 respectively. In section 4, examples of Scatsat-1 high winds applications in support of operational marine forecasting and warning are discussed. Conclusions are given in section 5.

2. HIGH WINDS GEOPHYSICAL MODEL FUNCTION APPROACH

The high wind ScatSat-1 GMF developed originates from NSCAT4 GMF [4]. The GMF can be written in a generic form as:

$$\text{sigma0} = A_0 \cdot [1 + A_1 \cdot \cos(\varphi) + A_2 \cdot \cos(2\varphi)] \quad (1)$$

where φ is the relative wind direction and A's coefficients are wind speed and incidence angle dependent. The A_0 is a first-order wind speed dependent term while the other higher harmonics determine the wind direction characteristic.

2.1. Saturation Wind Speeds

The A_0 term, derived from the Hurricane Hunter aircraft measurements, of IWRAP GMF [5] is plotted as a function of wind speed at various incidence angles for the Ku-band VV and HH (Fig. 1). Here the A_0 was normalized by A_0 at 25 m/s to depict differences in high wind sensitivities for different incidence angle ranges. From plots it is apparent that the A_0 increases with wind speed until certain wind and then it either starts to saturate or decrease. The saturation wind speed is dependent on the incidence angle, polarization and measurement frequency. The saturation wind speed, U_{10sat}, tend to increase with incidence angles.

With an assumption that a saturation wind speed should be the same regardless of the sigma0 measurement resolutions if we have a uniform wind distribution at appropriate aircraft or satellite resolution, our goal was to modify the NSCAT4 GMF A_0 trend at the high winds to match that of IWRAP GMF. We have achieved this by matching A_0 slopes at U_{10sat}. Since U_{10sat} from IWRAP measurements was measured only at a certain incidence angles, we first interpolated U_{10sat} across NSCAT4 GMF incidence angles interval 16-66 degrees as shown in Fig. 2. The high wind A_0 term for NSCAT4.H was then derived for all those incidence angles.

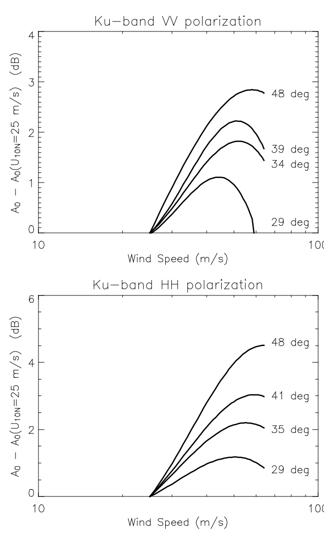


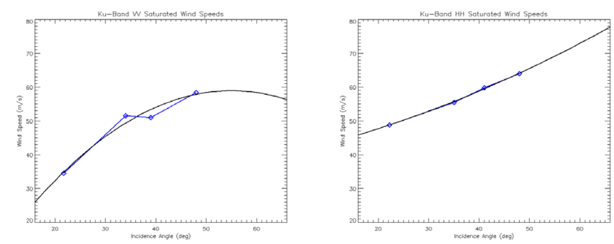
Fig. 1. Normalized A0 wind speed and incidence angle dependence for IWRAP Ku-band VV and HH.

The approach for new high wind A_0 term derived here follows a similar approach that was implemented for CMOD5.H GMF [6] in which the A_0 at high wind portion (>10 m/s) was modified so that its slope is a linear function of a logarithm of wind speed and that it has a zero slope at U_{10sat} (maximum A_0 at U_{10sat}).

2.2. High Winds A_0 Derivation

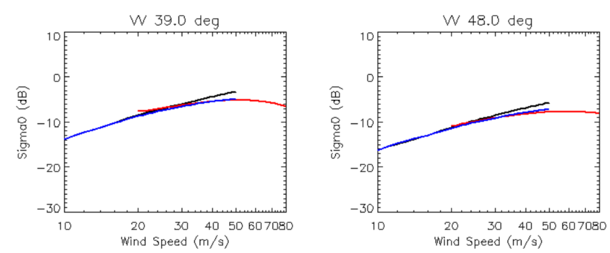
The resulting new A_0 with respect to the original A_0 and IWRAP A_0 are presented in Fig. 3 as a function of wind speeds and selected incidence angles.

From (1), the original A_0 was replaced with the new high winds A_0 and then the final GMF was converted back into a look-up table form to complete our high winds GMF for Scatsat-1.



(a) (b)

Fig. 2. Saturated wind speed, U_{10sat}, for (a) VV and (b) HH for incidence angle [16, 66] degrees. The symbols represent U_{10sat} at the IWRAP incidence angles.



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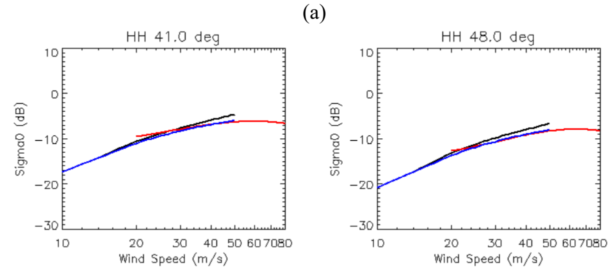


(b)

Fig. 3. High Winds A_0 (blue) with respect to the original (black) and IWRAP (red) A_0 as a function of wind speed for (a) VV and (b) HH.

3. GMF VALIDATION

To validation the high winds GMF, we compare the calibrated measured sigma0 from Scatsat-1 with the predicted sigma0 from the GMF as well as compare the NSCAT4 and NSCAT4.H wind retrievals. For Scatsat-1 sigma0 used in this study, we found the sigma0 calibration biases to be -0.11 dB for VV and +0.48 dB for HH. This bias has been added to Scatsat-1 sigma0's before any retrievals were processed. Using sigma0 measurements from Scatsat-1 passes over hurricane Dorian (Aug-Sep, 2019) and hurricane Lorenzo (Sep 2019), the calibrated sigma0 are compared to the NSCAT4 (blue) and NSCAT4.H (red) GMF in Fig. 4. The comparison was done at 58° incidence angle for VV and at 49° incidence angle for HH polarization while separating the relative wind direction into upwind (0°, top panel)), crosswind (90°, middle panel) and downwind (180°, bottom panel). The collocated ASCAT A/B/C winds were used as a ground truth for this analysis. As depicted on Fig 4 at higher wind speeds, the NSCAT4.H GMF compares much better with the measured sigma0. The resulting wind speed retrievals using NSCAT4 and NSCAT4.H GMF are presented in Fig. 5. It can be seen that winds produced by NSCAT4.H GMF compare much better with ASCAT wind retrievals for winds higher than 20 m/s while the overall global winds statistic remains the same.

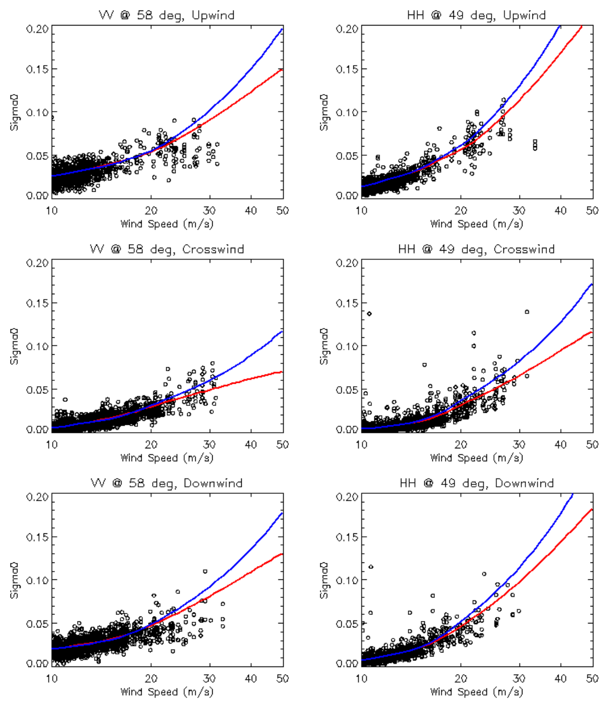
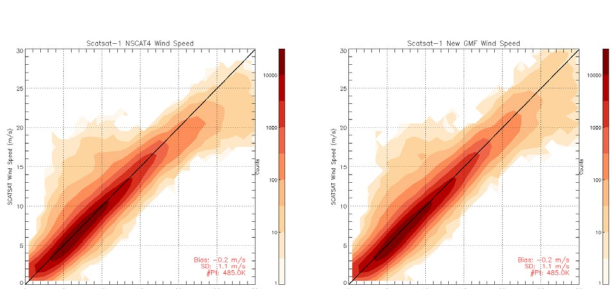


Fig. 4. Scatsat-1 calibrated sigma0 at upwind, crosswind and downwind in comparison with NSCAT4 (blue) and NSCAT4.H (red) GMF.



(a) (b)

Fig. 5. Global wind speed scatter plots comparison between the wind speeds retrieval using (a) NSCAT4 and (b) NSCAT4.H GMF.

4. APPLICATION IN OPERATIONAL MARINE FORECASTING AND WARNING

The scatterometer high wind products have been traditionally used in NOAA operations in support of the National Weather Service (NWS) marine forecasting and warning function. The latest addition to the scatterometer high wind products is the Scatsat-1 winds produced from the new NSCAT4.H GMF. An Extra Tropical Cyclone and Typhoon Bualoi winds observed by morning and evening Scatsat-1 passes on October 24th and 25th as displayed in an operational surface analysis tool are presented in Fig. 6. Scatsat-1 high winds were used in complementary way with other scatterometers for forecast verification purposes by Ocean Prediction Center (OPC). On Fig 7th we show another example of the Scatsat-1 (a) and ASCAT-A/B (b) scatterometer passes over hurricane force ETC on 27 October 2019 at 13:00 UTC and 23:00 UTC respectively. These winds were used as an input for surface wind field analysis issued by the OPC and valid on 28th of October 2018 @ 12UTC.

5. CONCLUSION

NOAA has been producing Scatsat-1 winds product in near real-time using the high winds Geophysical Model Function (GMF) NSCAT4.H since March 2018. The high winds GMF was derived from NSCAT4 GMF by modify the high winds portion of the A_0 coefficient to match IWRAP GMF high wind trend. NSCAT4.H slope is a linear function of a logarithm of wind speed that has a zero slope at U_{10sat}. The calibrated measured sigma0 from Scatsat-1 shows good agreement with the new GMF at high winds and the respective wind retrievals are higher without changing the global winds statistic. The NSCAT4.H high winds have been implemented in NOAA Scatsat-1 operational data stream in support of marine forecasting and warning by the NWS. The high wind validation and operational utilization of these winds will be presented during meeting.

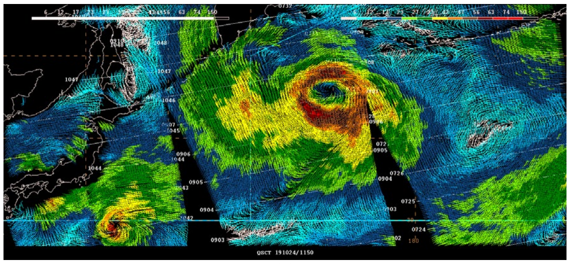
6. REFERENCES

[1] S. Soisuvarn, Z. Jelenak, F. Said, J. Park, Q. Zhu and P. S. Chang, "NOAA Scatterometer Wind Retrievals from the Scatsat-1 Mission," *IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium*, Yokohama, Japan, 2019, pp. 8039-8042, doi: 10.1109/IGARSS.2019.8900305

[2] SCATSAT-1 Data Products and Retrieval Team, "Algorithm and Theoretical Basis Document for SCATAT1 Data Products," ISRO/SAC, Dec. 2016.

[3] J. Vogelzang, "Two-dimensional variational ambiguity removal (2DVAR)," NWP SAF Document NWPSAF-KN-TR-004, Version 1.2, Sep. 2013.

[4] KNMI scatterometer team, "NSCAT-4 geophysical model function," http://projects.knmi.nl/scatterometer/nscat_gmf/



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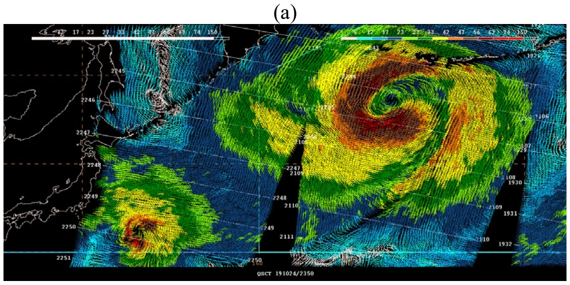

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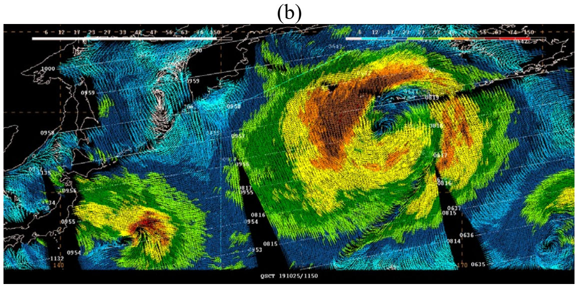

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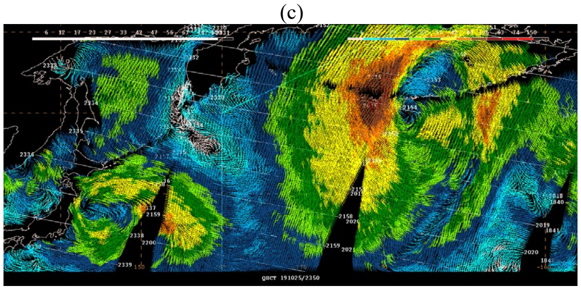
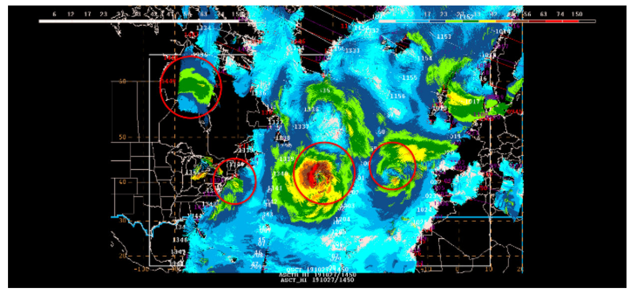


(d)

Fig. 6. Typhoon Bualoi and Extratropical cyclone (ETC) in Western Pacific as captured by ScatSat-1 passes and displayed in the NWS operational setting on October 24th (a,b) and 25th (c,d) 2019. Scatsat captured rapid intensification and dissipation of both typhoons and ETC wind field.

[5] J. Sapp, P. Chang, Z. Jelenak, S. Frasier, and T. Hartley, "Sea-surface NRCS observations in high winds at low incidence angles," in Geoscience and Remote Sensing Symposium (IGARSS), 2015 IEEE International, Milan, Italy, 2015, pp. 1199–1202, doi: 10.1109/IGARSS.2015.7325987.

[6] S. Soisuvarn, Z. Jelenak, P. S. Chang, S. O. Alsweiss and Q. Zhu, "CMOD5.H—A High Wind Geophysical Model Function for C-Band Vertically Polarized Satellite Scatterometer Measurements," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 51, no. 6, pp. 3744-3760, June 2013, doi: 10.1109/TGRS.2012.2219871



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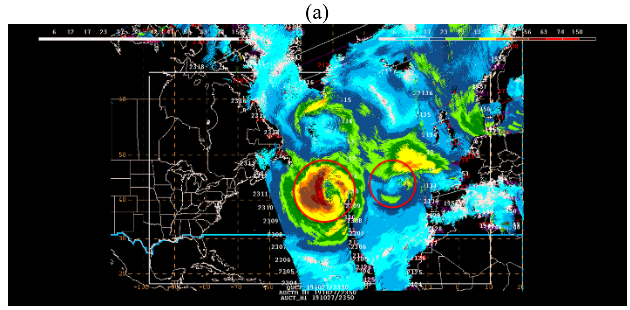

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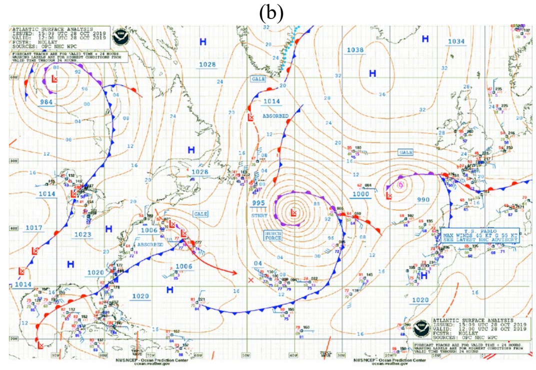

(c)

Fig. 7. Scatsat-1 winds used in operational in complementary of other scatterometers by ASCAT-A/B from (a) morning orbits and (b) night orbits helps validate the Hurricane force winds forecast by the Ocean Prediction Center (OPC) in (c).