AN OPERATIONAL ALL-WEATHER WIND SPEED FROM AMSR2

Suleiman Alsweiss[1,2], Joseph Sapp[1,2], Zorana Jelenak[1,3], and Paul Chang[1]

NOAA/NESDIS/STAR[1], Global Science & Technology, Inc. (GST)[2], University Corporation for Atmospheric Research (UCAR)[3]

ABSTRACT

The Advanced Microwave Scanning Radiometer-2 (AMSR2) on board the Global Change Observation Mission-Water (GCOM-W) launched in May 2012 by the Japan Aerospace Exploration Agency (JAXA) is acquiring electromagnetic radiation from the Earth for the purpose of monitoring its environmental and climate system. Among a suite of oceanic environmental data records (EDR), the Ocean Surface Winds Team of the Satellite Applications and Research (STAR) group at the National Oceanic and Atmospheric Administration (NOAA) has developed an all-weather wind speed (AWS) by exploiting AMSR2 brightness temperature (T_b) measurements. The new product provides wind speeds in normal and extreme weather conditions with minimal flagging and excellent accuracy. Validation results of this novel AMSR2 AWS product, represented in this paper, show a mean bias of 0 m/s and an rms error < 2 m/s when compared to numerical weather models under all weather conditions.

Index Terms— AMSR2, microwave radiometry, wind speed, all-weather, validation

1. INTRODUCTION

Over the last few decades, several advancements in microwave communications technology and high-performance computing have allowed data acquisition from space to play a bigger role in observing Earth. Spaceborne data acquisition systems allowed scientists to monitor the Earth's environment and climate system on both short- and long-term temporal scales with near global coverage (e.g. [1], [2]). Passive microwave radiometry is a special application of microwave communications technology for the purpose of collecting Earth's electromagnetic radiation.

The Advanced Microwave Scanning Radiometer-2 (AMSR2), aboard the Global Change Observation Mission - Water (GCOM-W), is part of the Japanese Aerospace Exploration Agency's (JAXA) broader commitment toward a global and long-term observation of the Earth's environment. The AMSR2 instrument, a follow-on to AMSR-E [3], is performing observations related to the global water and energy cycle. Another follow-on is planned by JAXA in 2023 to launch the Global Observation Satellites for Greenhouse Gases and Water Cycle (GOSAT-GW) with AMSR3 as the payload.

As part of the successful collaboration between JAXA and the National Oceanic and Atmospheric Administration (NOAA), the GCOM-W1 product development and validation project has been providing the scientific community worldwide with access to critical environmental data records (EDRs) derived from AMSR2 observations.

In this paper, we will focus on describing and evaluating the performance of a novel all-weather wind speed (AWS) product obtained from AMSR2 brightness temperature (Tb) measurements. We start with a brief description of AMSR2 and NOAA's GCOM-W acquisition system in Section II, and then a general description of AMSR2 AWS followed by validation results in Sections III and IV, respectively. Conclusions are presented in Section V.

2. AMSR2 INSTRUMENT DESCRIPTION

AMSR2 onboard GCOM-W1 satellite is a passive remote sensing instrument that acquires microwave emission from the surface and the atmosphere at 6.9, 7.3, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz. It conically scans the Earth's surface to obtain measurements along a semicircular pattern in front of the spacecraft. It operates at a nominal earth incidence angle (EIA) of 55° which results in a wide swath of 1450 km from its sun-synchronous orbit ~ 700 km away from earth.

AMSR2 has a 2.0 m aperture diameter antenna that completes one full rotation every 1.5 s with an instantaneous field of view (IFOV) spatial resolution that varies inversely with frequency. This conical scan mechanism enables AMSR2 to acquire a set of daytime and nighttime data with more than 99% coverage of the Earth every 2 days [4].

3. AMSR2 OCEANIC EDR

AMSR2 oceanic EDRs provide a suite of critical geophysical parameters that include total precipitable water (TPW), cloud liquid water (CLW), precipitation type/rate (PT/R) [5], sea surface temperature (SST) [6], and sea surface wind speed (SSW). In addition, two derived products are also provided to users: SST anomaly and TPW percentage normal.

The operational EDR's processing algorithms utilize the calibrated AMSR2 Tbs in a robust multi-stage regression-based retrieval algorithm [7]. A near real time demonstration of these advanced satellite data products can be obtained from [8]. The performance of NOAA's AMSR2 oceanic EDRs is comparable to other satellite products and meets the requirements detailed in NOAA's Joint Polar Satellite System (JPSS) Requirements Document Supplement [9]. In addition, the accuracy of these EDRs was validated using tropical cyclones composite fields and found comparable to inferred parameters from other satellites and weather models [10].

As a continuation of NOAA's GCOM-W project efforts to improve the accuracy of the retrieved geophysical parameters under all weather conditions, a revised version of AMSR-2 SSW has been developed. The following section generally describes the development and validation of NOAA's AMSR2 all-weather SSW product (AWS). It is worth noting that a follow-on paper is in preparation to describe, in full details, the development and validation of NOAA's AMSR2 AWS product with special emphasis on extreme wind events such as tropical and extra-tropical cyclones.

4. AMSR2 ALL-WEATHER WIND SPEED

Microwave radiometers are sensors specialized in measuring Earth's electromagnetic radiation at the top of the atmosphere in the form of Tbs. For a specific microwave radiometer design and geometry, these Tbs are usually obtained at different frequencies and polarizations: vertical [V-pol] and horizontal [H-pol]. The measured Tbs then undergo a rigorous calibration and validation tests to quantify and account for any residual calibration biases or stability issues. All AMSR2 products, including the one described hereafter, exploit AMSR2 calibrated Tbs via inversion algorithms to infer the geophysical parameters of interest.

4.1. Algorithm description

AMSR2 AWS product is a statistical-based algorithm that consists of a multivariate regression followed by a set of empirical corrections. The inputs to the forward model are H- and V-pol AMSR2 calibrated Tbs from the 6–36 GHz channels.

The algorithm is trained with a hybrid dataset of numerical weather models from the Global Data Assimilation System (GDAS) and the Hurricane Weather Research and Forecasting model (HWRF) [11, 12]. The models were interpolated in space and time to AMSR2 location. This mix of GDAS and HWRF spans the whole range of wind speeds up to hurricane force winds. The inclusion of all wind speed regimes in the training dataset covers most of the variability encountered in the retrievals. 750 AMSR2 orbits from 2017–2019 were randomly selected to be used in the training dataset covering day/night and seasonal dependencies.

Afterwards, a set of empirical corrections are applied to account for other sensor, surface, and atmospheric parameters that affect the measured Tbs used in the retrieval algorithm, namely: latitude, SST, TPW, EIA, and relative azimuth. The Global Forecast System (GFS) was used to provide any ancillary data. All the corrections applied to the retrieved wind speed are in the order of ~10% combined.

Finally, a 3×3 median filter is applied to suppress noise. The retrieved AWS values have a spatial resolution of 0.1° similar to the reported AMSR2 Tbs.

4.2. Assessment & validation results

To validate the accuracy of AMSR2 AWS product, 350 AMSR2 orbits were used. The selected orbits were not part of the training dataset hence they are completely independent.

Figure 1 shows a 3-dimensional (3-D) scatter plot with GDAS wind speeds on the x-axis and AMSR2 AWS on the y-axis. Color denotes the density of points where warmer colors indicate more points. Histogram for the two quantities being compared are shown as well to indicate the distribution of wind speeds being used in the comparison.

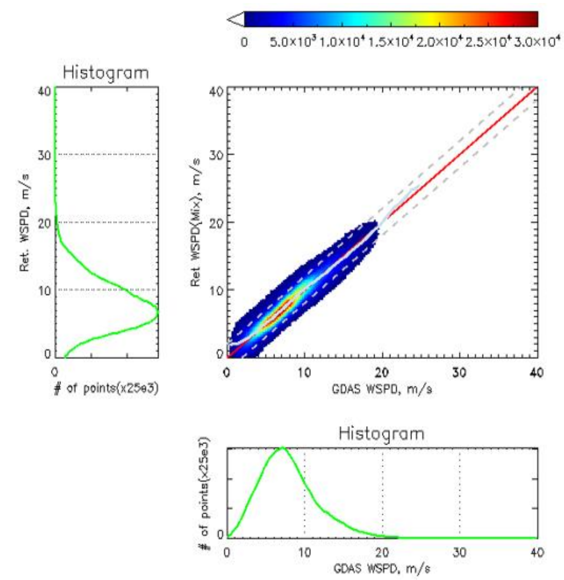
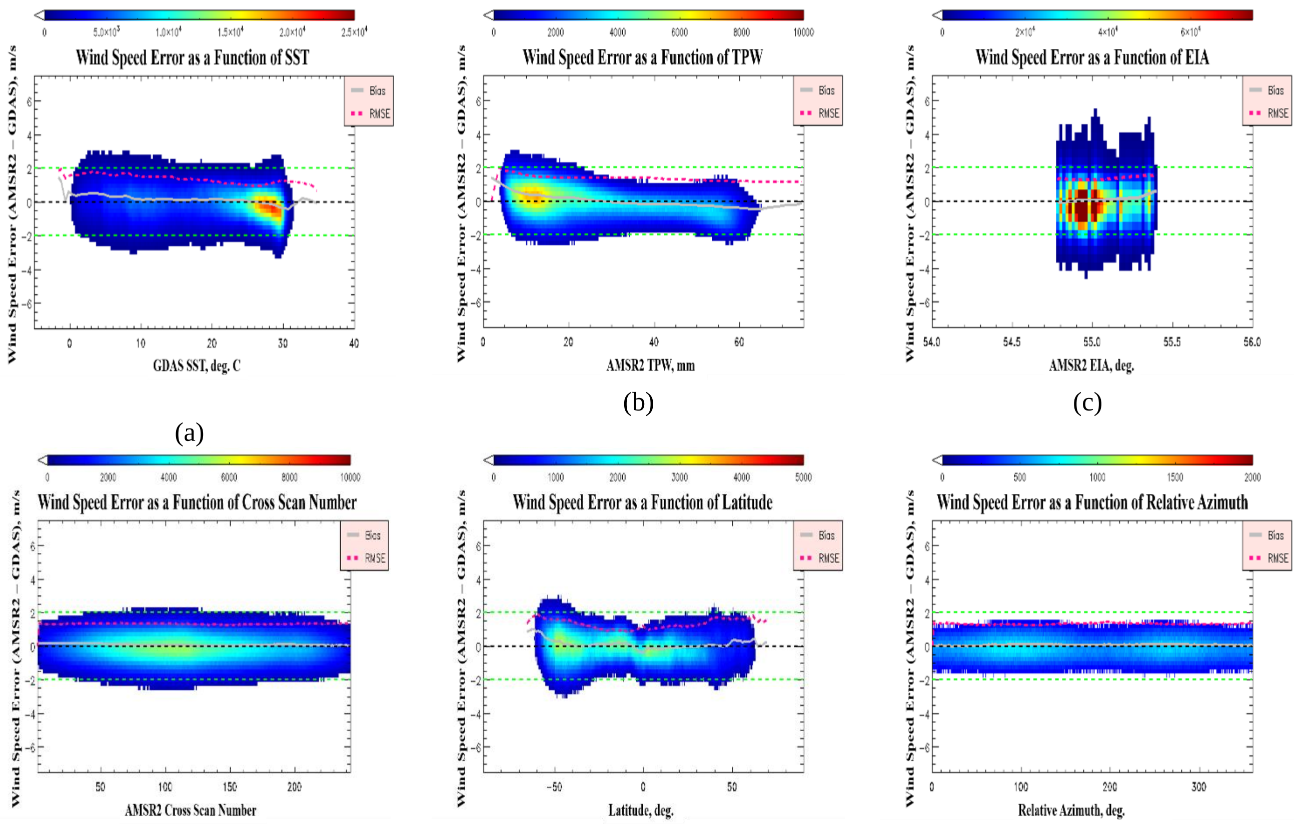


Figure1: 3-D scatter plot comparing AMSR2 AWS to GDAS. Colors indicate number of points.

Figure 2 shows the performance of AMSR2 AWS when compared to other surface and atmospheric parameters. The purpose of these comparisons is to identify any systematic biases that are a function of these parameters. The x-axis represents the parameter of interest, and the y-axis is the wind speed error ($AWS_{AMSR2} - GDAS$). As can be noted, the error is approximately 0 m/s with an RMS of < 2 m/s.

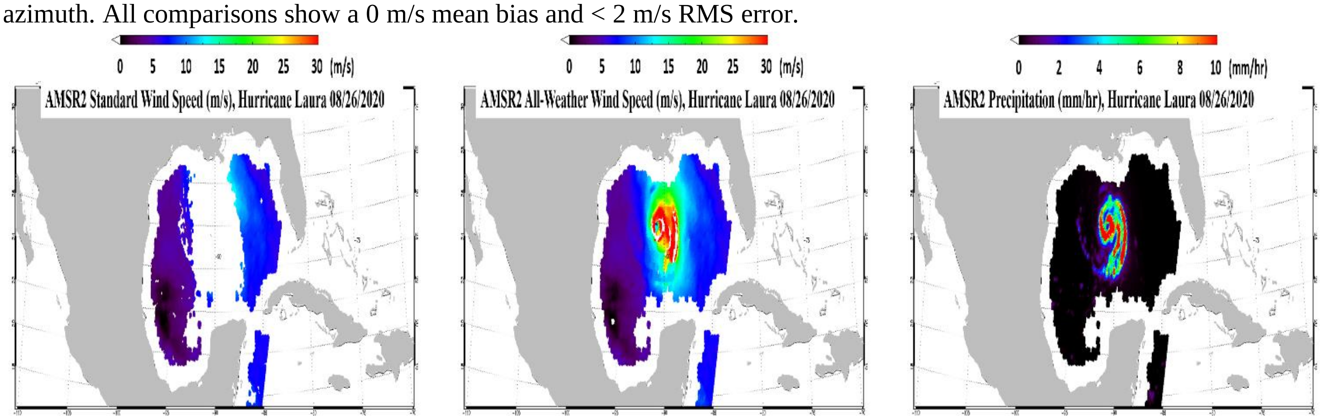
AMSR2 AWS is routinely used in the analysis of extreme wind events like hurricanes and tropical storms. It has the capability to estimate wind speeds in areas of the storm that were usually flagged due to high rain contamination. Figure 3 depicts snapshots of Hurricane Laura in August 2020 as seen by AMSR2. Panel a shows the standard wind speed retrieval from AMSR2, panel b shows



(a) (b) (c)

(d) (e) (f)

Figure 2: AMSR2 AWS comparisons with (a) SST, (b) TPW, (c) EIA, (d) cross-scan location, (e) latitude, and (f) relative azimuth. All comparisons show a 0 m/s mean bias and < 2 m/s RMS error.



(a) (b) (c)

Figure 3: AMSR2 overpass of Hurricane Laura (08/26/2020) where (a) shows AMSR2 standard wind speed product, (b) shows AMSR2 AWS, and (c) shows AMSR2 precipitation.

AMSR2 AWS, and panel c shows AMSR2 precipitation for the same time and location of the storm. Unlike AMSR2 AWS, it is clear how the aggressive flagging, required by the standard wind speed product, results in removing parts of the storm where high wind speeds are associated with high rain rates.

5. CONCLUSIONS

AMSR2 calibrated brightness temperatures were used to derive a suite of environmental data record. In this paper, we described and demonstrated the validation of a new AMSR2 all-weather wind speed product. The retrieval algorithm is statistical based and trained using 750 AMSR2 orbits from

2017–2019 using a mix of GDAS and HWRF data. Subsequently, an empirical set of corrections has been applied to account for the effect of other surface and atmospheric parameters on the measured Tbs. Validation results from independent data demonstrated the efficacy of the retrieval algorithm under different wind speed regimes with 0 m/s mean bias and < 2 m/s RMS error when compared to numerical weather models. AMSR2 AWS will complement the set of standard satellite data products and will help scientists and forecasters to further analyze parts of the storms that were previously challenging.

6. ACKNOWLEDGEMENT

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

7. REFERENCES

[1] N. C. Grody, “Remote sensing of atmospheric water content from satellites using microwave radiometry,” IEEE Trans. Antennas Propag., vol. 24, no. 2, pp. 155–162, Mar. 1976.

[2] T. T. Wilheit and A. T. C. Chang, “An algorithm for retrieval of ocean surface and atmospheric parameters from the observations of the scanning multichannel microwave radiometer,” Radio Sci., vol. 15, pp. 525–544, 1980.

[3] T. Meissner and F. Wentz, “Intercalibration of AMSR-E and Windsat brightness temperature measurements over land scenes,” in Proc. IEEE Int. Geosci. Remote Sens. Symp. (IGARSS), Jul. 2010, pp. 3218–3219.

[4] JAXA’s Earth Observation Research Center GCOM-W1 webpage: https://suzaku.eorc.jaxa.jp/GCOM_W/w_amsr2/whats_amsr2.html

[5] P. C. Meyers and R. R. Ferraro, "Precipitation from the Advanced Microwave Scanning Radiometer 2," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 9, no. 6, pp. 2611-2618, June 2016, doi: 10.1109/JSTARS.2015.2513666.

[6] S. O. Alsweiss, Z. Jelenak, and P. S. Chang, “Remote Sensing of Sea Surface Temperature Using AMSR2 Measurements,” IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 10, no. 10, pp. 3948–3954, 2017.

[7] S. O. Alsweiss, Z. Jelenak, P. S. Chang, J. D. Park, and P. Meyers, “Intercalibration results of the advanced microwave scanning radiometer-2 over ocean,” IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 8, no. 9, pp. 4230–4238, 2015.

[8] NOAA’s GCOM-W program products webpage: https://manati.star.nesdis.noaa.gov/gcom/datasets/GCOM2Data.php

[9] NOAA JPSS program web page: http://www.jpss.noaa.gov

[10] S. Alsweiss, J. Sapp, Z. Jelenak and P. Chang, "Validation of AMSR2 Oceanic Environmental Data Records Using Tropical Cyclone Composite Fields," IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium, Valencia, 2018, pp. 3078-3081, doi: 10.1109/IGARSS.2018.8517426.

[11] National Center for Environmental Prediction GDAS webpage: https://www.emc.ncep.noaa.gov/gmb/gdas/

[12] National Center for Environmental Prediction HWRF webpage: https://www.emc.ncep.noaa.gov/gc_wmb/vxt/HWRF/index.php