NASA CYGNSS Competed Science Team

Project Title: User-Oriented Level 4 Ocean Wind Products from the CYGNSS Wind Retrievals

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Project Focus

The NASA CYGNSS satellite constellation measures ocean surface winds using the existing network of the Global Navigation Satellite System (GNSS), through the innovative use of ocean surface reflectometry [1,2]. The research mission was designed with the goal of providing critical and frequent wind measurements in the core of Tropical Cyclones (TCs). The CYGNSS spatial sampling configuration, with multiple thin tracks with spatial/temporal gaps in between, makes it hard for the users to easily extract a snap-shot of information about a storm at a specific time.

The objective of this investigation has been to verify that the CYGNSS wind measurements are consistent with the wind measurements from other satellite sensors, and provide a satellite-based, user-friendly dataset which includes the CYGNSS wind speeds, with wind direction from ancillary dataset. For this purpose, we added the CYGNSS wind measurements into a satellite-based wind analysis, the Cross-Calibrated Multi-Platform (CCMP) wind vector [3,4]. CCMP is run in near-real time at Remote Sensing Systems (RSS) and includes wind retrievals from 7 satellite wind sensors now in operation.

An important step of the investigation has been therefore to assess the ability of the CYGNSS wind products to provide reliable and accurate retrievals at all wind regimes compared to mature microwave satellite sensors datasets processed at RSS: the radiometers AMSR2, WindSat, SMAP, and the scatterometer ASCAT[5–7]. The validation at low-to-moderate regimes uses radiometer/scatterometer dataset from algorithms with global validity. We devoted special attention to assess CYGNSS wind products at high wind and in TCs, using radiometer data from algorithms specifically developed at RSS at TC-conditions and in rain: the TC-winds[8]. All these radiometer datasets have been extensively validated at all wind speed regimes [9–11].

Despite the CYGNSS mission objective being wind measurements in TCs, the CYGNSS retrievals at high winds proved to be extremely challenging. Soon after launch, unforeseen calibration and methodology issues emerged [12]. Multiple wind datasets were released over time by the Science Team investigators to improve algorithms or correct for the observed calibration deficiencies. The datasets processed at the Science Operation Center (SOC) at the University of Michigan include Science Data Records (SDR) with short latency, and a long-latency bias-corrected Climate Data Record (CDR), and a storm-centric dataset for TC analyses [13,14]. The SDR and CDR datasets include a product for low-to-moderate winds speeds (FDS), one suitable for high winds (YSLF). An additional wind product from NOAA applies a track-wise bias correction method to minimize calibration biases, and is suitable in all wind regimes [15].

Within our investigation, significant efforts were devoted into assessing the accuracy of each wind product released over the course of 2018-2021, with special focus of measurements in TCs.

Conclusions

The most important conclusions of our investigations are:

- The CYGNSS high wind products processed at the Satellite Operation Center (YSLF, SDR and CDR datasets) display significant biases in TCs and very large uncertainties. They are not of sufficient quality for studies of tropical storms.
- Similar biases and large uncertainties were found with the storm-centric wind product, which nonetheless displays promising features, provided future versions are developed using L2 wind datasets with better quality at high winds, like the NOAA winds.
- The NOAA winds show promising skill in TCs, approaching a level suitable for tropical meteorology studies. At the global level, the NOAA winds are overall unbiased at wind regimes from 0-30 m/s. They were selected for a test assimilation into a global wind analysis, CCMP.
- A user-friendly L3 wind vector satellite-based analysis including CYGNSS data (CCMP_CYGNSS) has been processed and released to the public, directed to users interested in air-sea interaction studies, wind variability in the tropical convective regions, such as investigations into the Madden Julian Oscillation or diurnal cycle, and genesis of TCs. The CCMP winds also depend on wind measurements from other satellites (scatterometers and radiometers) as well as the NCEP GDAS background field. The dataset is freely available here:
  https://data.remss.com/research/cygnss/CCMP_CYGNSS
- The analysis of the storm-centric CYGNSS dataset developed aggregating winds in storms from the SDR V3.0 dataset displayed that it has great potential for storm forecasters, but the product is still in the early stages of development and suffers from biases and excessive noise. A similar storm-centric dataset aggregating the NOAA V1.1 would likely be of much better quality.
- The following manuscript summarizing the analyses and results of our investigations has been submitted to the open-source journal Remote Sensing, for a special issue on GNSS-R. It will be shared here when published.

Ricciardulli, L., C. Mears, A. Manaster and T. Meissner: Assessment of CYGNSS wind retrievals in Tropical Cyclones, submitted to *Remote Sensing*, November 2021.

Data Product: Integration of CYGNSS winds into the CCMP wind analysis

The Cross-Calibrated Multi-Platform (CCMP) wind analysis is a spatially-complete wind product constructed using satellite measurements of surface wind combined with a model-derived background field. A variational analysis is used to minimize the difference between the measurements, the background field, and the final analyzed vector-wind product. One of the weaknesses of CCMP is the relative paucity of satellite observations in the tropics (and in tropical storms) due to the presence of moderate to heavy rain. Since the CYGNSS observations are only minimally affected by rain, they present the possibility of filling data gaps in the measurements made by other satellites.

A test assimilation of the CYGNSS retrievals within tropical latitudes was developed in the context of this investigation. It provides an opportunity to investigate the impact of filling the radiometer/scatterometer gaps with actual satellite observations from CYGNSS, rather than a numerical model wind. The impact of assimilating the NOAA CYGNSS V1.1 into a version of CCMP_CYGNSS (years 2017-2020) can be assessed with comparisons with the control version CCMP V2 (available at https://www.remss.com/measurements/ccmp). The CCMP_CYGNSS wind analysis was developed for users dedicated to air-sea interaction studies and provides insight into the wind structure in convective regions such as investigations into the Madden Julian Oscillation[16], and genesis of TCs [17,18], and diurnal wind variability [19].

The CCMP_CYGNSS are distributed here as netCDF files with 6-hourly gridded surface wind vector maps for the period 2017-2020.

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