ON-ORBIT TRENDING OF CYGNSS DATA

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ABSTRACT

Shortly after its launch in December of 2016, the Cyclone Global Navigation Satellite System (CYGNSS) constellation began producing estimates of sea surface wind speeds. With its unique remote sensing method and use of eight satellites, the constellation is able to produce winds with shorter revisit times and in more intense weather than other sea surface wind missions. As a part of the CYGNSS calibration and validation (cal/val) process, these estimates are routinely compared to other estimates in order to understand their uncertainties as well as to diagnose and develop corrections for calibration issues. This paper presents trending of CYGNSS data, focusing primarily on comparisons to numerical weather forecast model analysis wind speed estimates and inter-comparison of simultaneous observations within the CYGNSS constellation.

Index Terms— sea surface winds, GNSS-R, calibration, validation, small satellites.

1. INTRODUCTION

NASA's CYGNSS mission consists of eight small satellites in 35° inclined orbits making GNSS reflectometry (GNSS-R) measurements of ocean surface roughness in order to produce estimates of 10 m referenced ocean surface winds [1]. GNSS-R enables observations of the ocean surface even through the intense precipitation often found in Tropical cyclones. The use of eight satellites within the mission shortens the revisit time for any given location relative to a mission relying on a single satellite.

The mission started releasing wind speed estimates to the public in May of 2017 via NASA's Physical Oceanography Distributed Active Archive Center. As a routine part of mission operations, these estimates are monitored to check for self-consistency (trending to detect anomalies/outliers relative to estimates to-date) as well as constancy with other independent wind estimates (e.g., model analysis fields and other remote sensing estimates). From the data gathered during the first hurricane season observed by CYGNSS, assessment of CYGNSS calibration accuracy and stability, as well as estimates of CYGNSS wind speed uncertainties have been made and reported in the literature [2, 3].

2. EXAMPLE ON-ORBIT TRENDING

As anomalies within the CYGNSS data arise, they are investigated to determine if a root cause can be found and corrected. This process has resulted in a number of updates to the calibration and wind retrieval algorithms used for the mission. The data shown in the figures below use CYGNSS v2.1 data. These anomalies can take the form of outliers in a time series of wind speeds, or outliers in lower level data, such as the normalized bistatic radar cross sections (NBRCS) from which winds are derived [1, 3]. An example is shown below in Figure 1. This is a time series of the mean monthly root mean square (RMS) difference in wind speed estimates between CYGNSS and the Global Data Assimilation System (GDAS) sea surface wind speed estimates [4] collocated in time and space to within 1 hour and .25° of latitude and longitude averaged across the CYGNSS constellation broken down by GPS transmitter (designated by GPS PRN). Note the spike in April, 2018. For this month, the wind speed estimates across all eight CYGNSS satellites appear biased with respect to GDAS. Examination of the data reveals that the biases are primarily from the block IIR-M GPS satellites. During April, 2018, the "flex-power" mode integrated into this generation of GPS satellites was being tested, which allows the GPS operators to dynamically change the transmit power of these satellites, which in turn affects the CYGNSS observed NBRCs and hence the CYGNSS derived winds. This same flex-power mode is integrated into the block IIF GPS satellites, which in addition to flex-power also show significant variability in power as a function of relative azimuth, and as a result were eliminated from the CYGNSS v2.1 data. While CYGNSS maintains control over the receiver portion of the mission, the transmitters are operated independently. Future versions of the CYGNSS calibration algorithm will use on-board estimates of the GPS transmission power to address this issue.

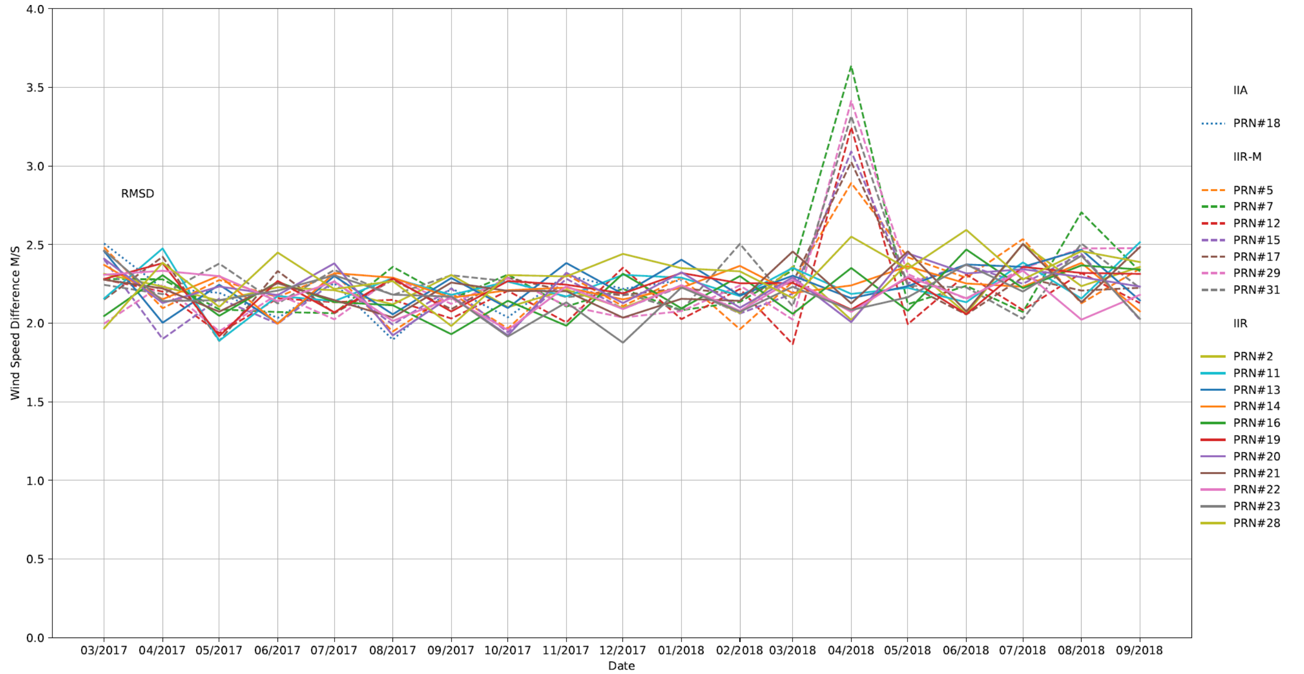

Figure 1. Time Series of monthly mean CYGNSS/GDAS RMS wind speed differences for each GPS satellite. The large spike around April, 2018 is from commanded power fluctuations in the block IIR-M GPS satellites outside of CYGNSS control.

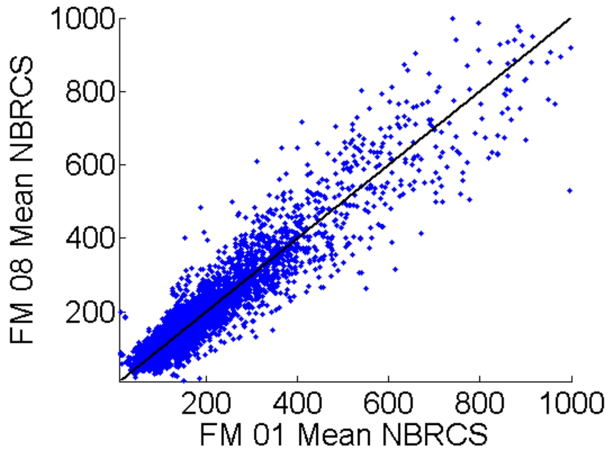

Figure 2. Collocated CYGNSS NBRCS for CYGNSS satellites 8 and 1. Data from other satellite pairs are very similar.

Another example of on-orbit trending data is shown in Figure 2. These data show collocations between two CYGNSS satellites within 30 minutes and 1° of latitude and longitude from the same GPS transmitter. If the calibration of the data is accurate, then observations from the two should be consistent to within the uncertainty of the measurements [1, 3]. There is good consistency between the two satellites, with the observations from both clustered around the one-to-one line and scatter within the expected noise in the observations. However, there are some outliers in the data. There are multiple potential sources for these, including (but not limited to) variability in the GPS transmitted signal, as observed with the previous case, as well as discrepancies between the assumed and actual CYGNSS antenna patterns used to calibrate the data. Significant updates to the antenna patterns based on early on-orbit observations were included in the version 2.0 algorithm updates. Future investigations will focus on the quality of the assumed CYGNSS antenna patterns to address this issue in future versions of the CYGNSS calibration algorithm as well.

5. CONCLUSIONS

The CYGNSS mission provides unprecedented observations of sea surface winds relative to other methods, with significantly reduced revisit time and enhanced ability in severe weather relative to other remote sensing missions. Comparisons of these observations to independent estimates have verified that CYNSS has met its primary mission objectives. Monitoring of the data with respect to these independent estimates as well as within the constellation have proven useful in identifying and determining the root cause of multiple. Monitoring of the data as well as use of these trending data to improve mission data quality will continue throughout the life of the mission. Updates from further data trending and algorithm upgrades will be presented.

6. REFERENCES

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