CYGNSS CONSTELLATION INTERCALIBRATION

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ABSTRACT

The Cyclone Global Navigation Satellite System (CYGNSS) mission uses a constellation of 8 satellites to measure ocean winds in the tropics with high temporal resolution (~3 hr median, 7 hr mean revisit). Focusing on the measurement of winds in tropical cyclones, each satellite contains a Global Navigation Satellite System reflectometry (GNSS-R) receiver capable of measuring reflections from 4 Global Positioning System (GPS) satellite transmitters under all precipitating conditions over the full range of tropical cyclone winds. In order to provide wind estimates that are consistent from receiver to receiver, the data from each must be intercalibrated. This presentation describes the intercalibration method to be used for CYGNSS. Once the constellation is in operational mode (expected mid to late April 2017), on-orbit data will be used to provide intercalibration offsets between the receivers in order to provide consistent constellation wind estimates.

Index Terms— CYGNSS, GNSS-R, Calibration/Validation

1. INTRODUCTION

The CYGNSS mission will provide an unprecedented method for measuring winds in hurricane conditions. By using a constellation of satellites with GNSS-R receivers, CYGNSS will not only be able to provide continuous coverage of all tropical cyclones with high temporal resolution, but will be able to estimate winds even through the intense rain bands of the inner core [1]. These data will improve our understanding of the evolution of tropical cyclones as well as our ability to estimate their intensity.

The constellation will consist of 8 satellites, each of which carries a single GNSS-R receiver fed by two (starboard and port pointing) downward looking antennas. Each receiver will be capable of simultaneously measuring up to 4 GPS reflections for a total of up to 32 simultaneous wind speed estimates from the constellation. Once evenly spaced throughout the orbit, which will be low-inclination (~35°), the median revisit time within the constellation coverage area will be around 3 hours.

The basis of the CYGNSS wind estimates will be measurements of the normalized bistatic radar cross section (NBRCS) [2]. Calibrated NBRCS will be related to ocean wind speed through empirically derived geophysical model function (GMF) following the method of Clarizia et al. [3]. Calibration of the NBRCS will use observations of relatively stable and uniform open ocean winds as well as calibration of the receiver noise floor measured every 60 seconds using an on-board calibration target. The GMF will be empirically tuned once CYGNSS is in operational mode (expected mid to late April 2017).

While each CYGNSS receiver will be calibrated post-launch to ensure high quality observations, experience with the intercalibration of previous Earth observing constellations has demonstrated that even with calibration, instrument to instrument differences will remain [4, 5]. In order to produce consistent wind estimates from all receivers, the CYGNSS data will therefore undergo an additional intercalibration step described in the next section.

2. INTERCALIBRAITON METHOD

Once each receiver is calibrated, any remaining offsets amongst the CYGNSS instruments will be removed using the double difference intercalibration method [4]. The basis of the double difference (DD) method is the use of reference observations (Obs_{ref}) to compare measurements from instrument A (Obs_A) to estimates from instrument B (Obs_B):

$$DD_{A/B} = (Obs_A - Obs_{ref}) - (Obs_B - Obs_{Ref})$$

With these double differences, each pair of instruments in a collection can be compared to one another via a common reference. The point of the reference is to take care of any parameters that may differ between the two instruments upon which the observation depend. For example, the relationship between NBRCS and wind speed for CYGNSS will depend upon viewing geometry (incidence angle, azimuthal angle, satellite altitudes, etc.). CYGNSS data processing takes care of these dependences using spacecraft ephemeris, known relationships between these and NBRCS, and the GMF. As such these data processing modules could be used to produce Obs_{ref} to translate between observations of the same location from two different CYGNSS receivers to compare NBRCS from each. As another example, the wind speed estimates from two receivers could be compared using independent estimates from buoy, scatterometer, or model observations as Obs_{ref}.

Given the DDs between all instruments relative to some chosen observational standard (e.g., one receiver within the constellation, a weighted combinations of observations from all receivers, or an independent source of observations), all observations from all instruments can be de-biased respect to the chosen observational standard given the DDs with respect to the standard. For example, to shift instrument A to the observational standard OS, observations from A would be adjusted using DDA/S to map into observations from OS:

$$Obs_{OS} = Obs_A - DD_{A/OS}$$

Likewise, any other instrument can be shifted to this observational standard to provide a consistent basis for reporting observations. These comparisons could be done anywhere in the retrieval process from the raw count level, to NBRCS, to retrieved winds, given the right reference observations. From a practical standpoint, a validated end-to-end model exists to simulate observations of the standard CYGNSS level one products, and a GMF exists to translate these to level two wind speed estimates, so intercalibration will occur at the standard CYGNSS level 1 and 2 product levels.

5. CONCLUSIONS

In order to provide consistent wind speed estimates across the CYGNSS constellation, the double difference intercalibration method will be applied to calibrated CYGNSS observations. Initially, this will be performed to both level 1 observations as well as level 2 derived wind speeds. Intercalibration of basic instrument observables (level 1 data – e.g., NBRCS) are often very useful to track down and determine fixes for calibration issues with the instrument. Furthermore, once biases are removed in the level 1 data, they can used to retrieve consistent level 2 products – wind speeds). However, the consistency of the level 2 products from these de-biased observations depends upon the details of the retrieval algorithm. For example, some algorithms include empirical adjustments that correct for calibration issues for which intercalibration also corrects. Correcting twice for the same issue would re-introduce biases.

Once operational data are available, both level 1 and level 2 intercalibration will be performed in conjunction with optimization of the level 2 retrieval algorithms to determine the optimal level at which to intercalibrate CYGNSS. Likewise, an appropriate choice of reference data for the double differences will be chosen based upon the level at which intercalibration will occur. Results will be presented at the conference.

4. REFERENCES

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