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**Topic (Number ??): TC Analysis and Remote Sensing**

**Sub-Topic: New and Existing Methods to Estimate Tropical Cyclone Surface Wind Structure (Satellite Remote Sensing)**

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**Abstract:** The rapport describes and compares various existing and new methods to estimate tropical cyclone surface wind structure from spaceborne sensors. We discuss scatterometers, L-band radiometers, C-band synthetic aperture radar, reflectometers, microwave sounders. We describe the TC wind structure analysis at the JTWC and the DAV technique for determining wind radii.

## 1. Reflectometry

Global Navigation Satellite System-reflectometry (GNSS-R) is a remote sensing technique that uses navigation signals—specifically, those that reflect from a surface—opportunistically for science applications (Zavorotny et al. 2014). The Cyclone Global Navigation Satellite System (CYGNSS) mission employs a constellation of eight microsatellites, each with a 4-channel GNSS-R radar receiver capable of measuring Global Positioning System (GPS) L1 signals scattered from the surface (Ruf et al. 2016a,b; 2018). CYGNSS provides frequent observations of near-surface ocean wind speed in all precipitating conditions and represents the first science-driven GNSS-R satellite mission.

Contrasting the large swaths provided from scatterometers and radiometers, CYGNSS delivers wind speed observations via collections of tracks across the ocean surface (See Figure 1 below). (Ruf and Balasubramaniam 2018; Ruf et al. 2018) The sampling properties of the CYGNSS constellation are a function of the orbit properties of the spacecraft and GPS satellites, and are therefore a function of latitude, and time and space window choices (Bussy-Virat et al. 2018). Morris and Ruf (2017a,b) developed methods that objectively estimate TC intensity, wind radii, radius of maximum wind speed, and integrated kinetic energy from simulated CYGNSS level-2 wind speed estimates. Morris and Ruf's parametric model algorithm smartly interpolates across tracks of CYGNSS observations through a storm, leading to objective estimates of TC metrics. Using the

best-track datasets as validation, these methods are applied and validated using the first set of CYGNSS TC observations (Morris 2018; Chu et al. 2002; Landsea and Franklin 2013). Figure 1 shows a preliminary example of a CYGNSS storm overpass, with the resulting parametric model retrieval. In the example shown in Figure 1, Hurricane Florence is not completely sampled, but where there are observations, objective estimates of TC metrics are possible. Notably, CYGNSS wind speed estimates capture the storm structure asymmetry documented in the closest best-track analysis. The methods developed in Morris and Ruf (2017b) are currently being applied to on-orbit data, with one retrieval example shown in Figure 1.

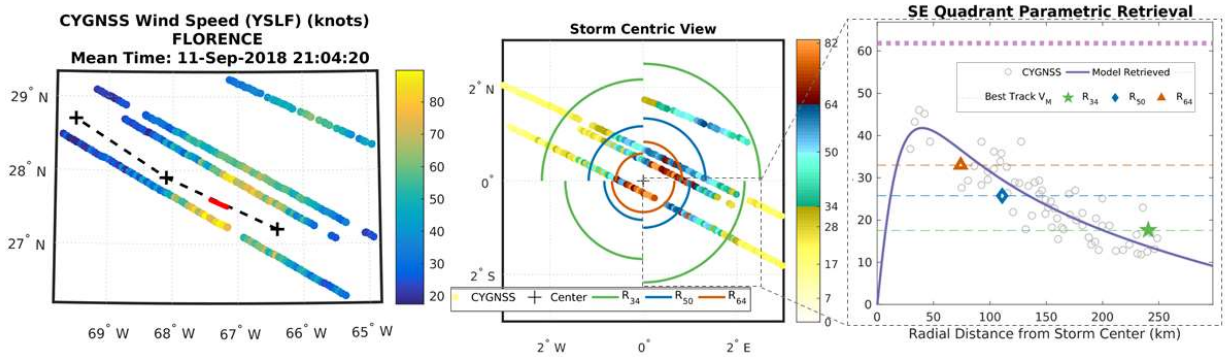


Figure 1: A CYGNSS overpass of Hurricane Florence on 11 September 2018. Left: In color, CYGNSS young seas limited fetch (YSLF) wind speed. A dashed-cross line denotes the best track center location, with the red dots denoting the interpolated center position at the CYGNSS coverage time for this plot. Middle: CYGNSS YSLF wind speed, again in knots, but projected in storm centric coordinates, with the closest-in-time best track wind radii estimates visualized for comparison. Right: An example of a CYGNSS parametric model retrieval in the SE quadrant.

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## 2. Summary and Conclusions

L-band radiometers (SMOS, SMAP) do not suffer from signal saturation at high wind speeds and are minimally affected by rain. Radiometers are an important spaceborne remote sensing tool for determining TC complimentary to the classical co-polarized scatterometers. Although reflectometry is a less mature technique compared to others, CYGNSS provides valuable rapid revisit, high resolution, near-surface wind speed data, which are uninhibited by rain contamination.

## 3. Recommendation

We recommend considering using wind fields from L-band radiometers (SMOS and SMAP) for determining intensity and 34-, 50, and 64 kt radii in TC. Proper scaling of the intensity of the satellite measurement to 1-minute sustained winds is necessary.

We recommend further investigation of the use of CYGNSS data for determining TC size, strength and structure. While CYGNSS data are currently not available with a latency to support real-time, operational activities, the Naval Research Laboratory, serving as liaisons to the Joint Typhoon Warning Center, plan to jointly validate and assess potential impact of CYGNSS-derived size and structure estimates if they were available in an operational, real-time environment.

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