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# A CYGNSS TROPICAL CYCLONE INTEGRATED KINETIC ENERGY (IKE) SCIENCE DATA PRODUCT

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## 1. INTRODUCTION

Recent studies have shown that the maximum surface wind speed ($V_{max}$) is not always a good indicator of a tropical cyclone's (TC) destructive potential, especially when considering TC storm surge (Powell and Reinhold, 2007; Irish et al. 2008). A better indication can be determined from a TC's integrated kinetic energy (IKE), defined as

$$IKE = \int_V \frac{1}{2} \rho U^2 dV \quad (1)$$

where $\rho$ is air density, and $U$ is near-surface wind speed.

The CYclone Global Navigation Satellite System (CYGNSS) constellation of eight, small satellites, to be launched in late 2016, will provide unique observations of ocean surface wind speed under all precipitating conditions (Ruf et al. 2016). An IKE product derived from CYGNSS level-2 wind speed data is developed in this paper.

## 2. DATA

A mission simulator is used to simulate CYGNSS observations. As an initial test, noise-free simulated CYGNSS level-2 wind speed data for Atlantic basin storms from 2010 – 2011 are used to develop and test the CYGNSS-IKE algorithm. HWRF wind fields are used to derive the true IKE for each test case.

## 3. METHODOLOGY

The sampling patterns of CYGNSS are unique because they rely on signals of opportunity from GNSS transmitters. Consequently, there will be coverage gaps over a TC wind field. The gaps are filled in using a parametric wind model fit to the available CYGNSS observations before calculating IKE.

The wind parametric model used is given by (Emanuel and Rotunno, 2011)

$$v(r) = \frac{2r\left(R_{max}V_{max} + \frac{1}{2} fR_{max}{}^2\right)}{R_{max}{}^2 + r^2} - \frac{fr}{2} \quad (2)$$

where $R_{max}$ is the radius of maximum wind, $V_{max}$ is the maximum wind speed, $r$ is the radial distance from the storm center, and $f$ is the Coriolis parameter. This model has a sufficient balance between simplicity and accuracy (Lin and Chavas, 2012). An example of the radial wind dependence is plotted in Fig.1.

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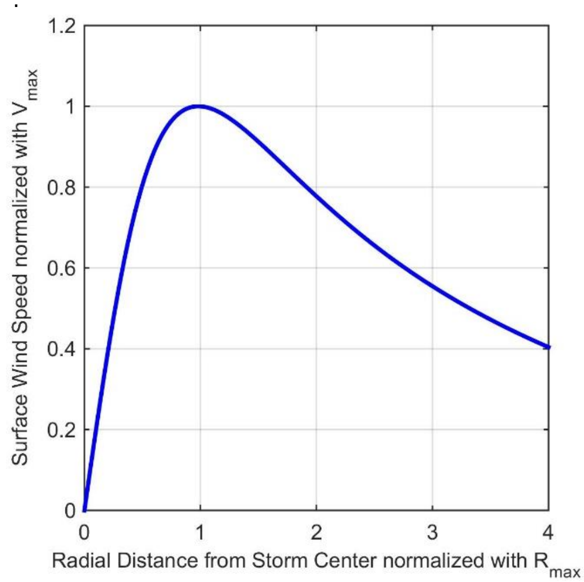


Figure 1: A normalized wind profile computed from (2). The surface wind speed is normalized by the maximum surface wind ($V_{max}$) in (2) and plotted with respect to radial distance from the storm center, normalized by the radius of maximum winds ($R_{max}$) in (2). This profile is computed at a latitude of 15˚.

The two free parameters of the model, $R_{max}$ and $V_{max}$, are estimated by least squares minimization of the difference between the model winds and all available CYGNSS wind speed data collected over three hours within 200 km of the storm center. Using a CYGNSS end-to-end simulator, the noise-free level-2 wind speed data are simulated from HWRF model output. Figure 2 gives an example of the model estimated from these simulated data for Hurricane Igor (2010).

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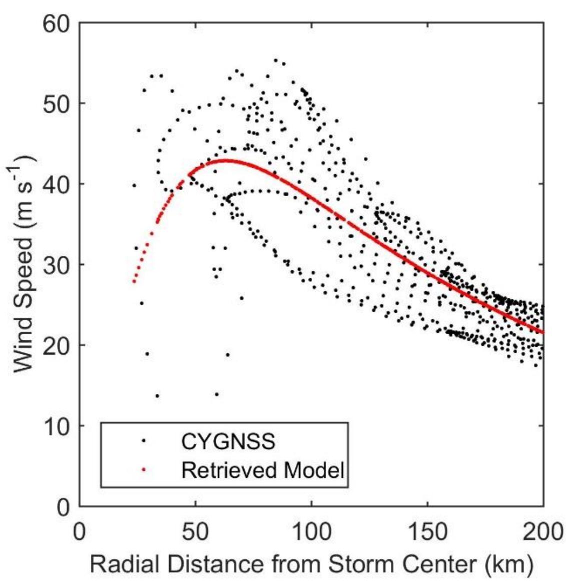


Figure 2: Parametric wind profile (red) estimated from CYGNSS observations collected over three hours and within 200 km of the Hurricane Igor (2010) storm center (black).

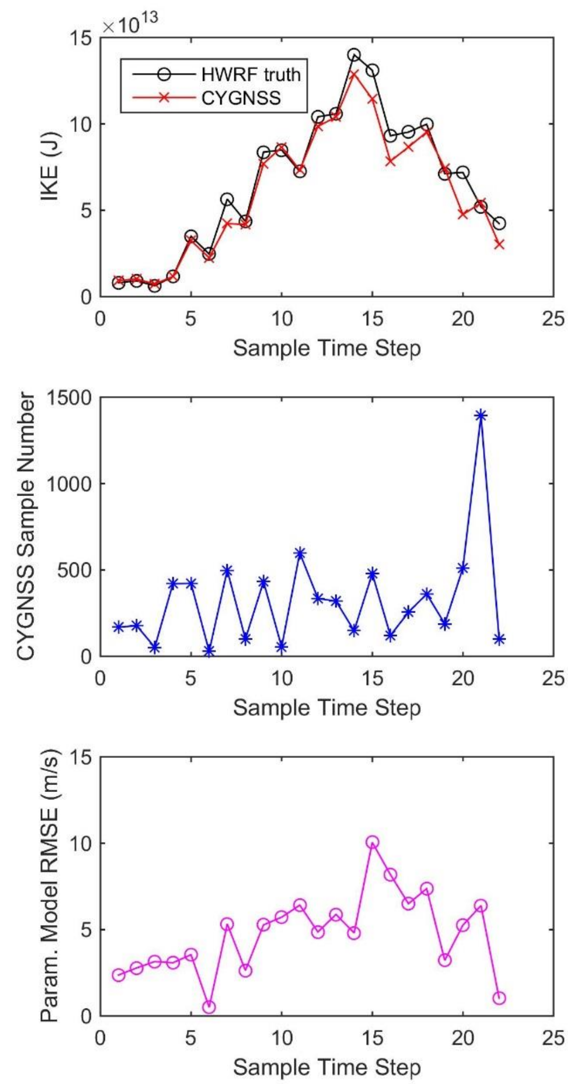


Figure 3: CYGNSS-IKE and related variables for Hurricane Igor (2010). Top: IKE calculated from HWRF (black) and CYGNSS observations (red). Middle: Number of CYGNSS observations used in a CYGNSS-IKE estimate. Bottom: RMSE in the parametric model fit to the CYGNSS observations.

## 4. RESULTS

Two examples of the CYGNSS-IKE estimates are presented in this paper, for Hurricanes Igor (2010) and Julia (2010). In each case, the CYGNSS-IKE over the complete life cycle of the storm is shown, together with the true IKE computed using HWRF winds. The performance of the CYGNSS-IKE likely depends on two variables. One is the number of CYGNSS observations used. The other is the RMS difference between the parametric wind model and the CYGNSS observations. Plots of these variables are included under each IKE plot.

Figures 3-4 show that the CYGNSS-derived IKE generally follows the trends and magnitudes in the HWRF-derived IKE. Figure 4 shows an example when the CYGNSS-IKE could fail. At sample time step 8, the CYGNSS-IKE estimate is far from the HWRF-derived estimate. Although the retrieved parametric model fit RMSE is low for this sample case, the CYGNSS-IKE is not representative of the true IKE. Since very few observations went into this estimate, the wind field structure may not have been adequately sampled for the IKE estimate to be accurate.

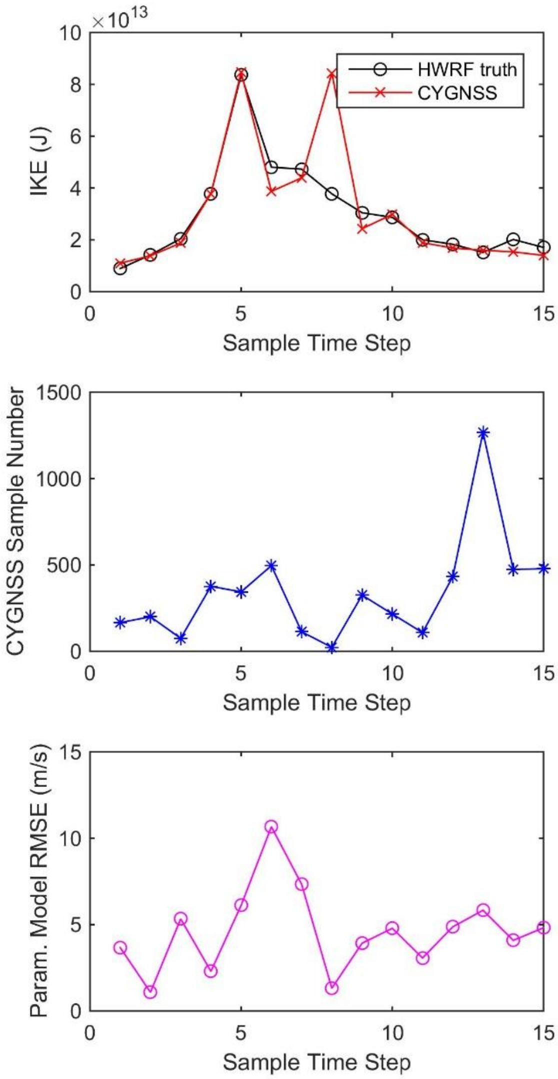


Figure 4: The same as Fig.3, but for Hurricane Julia (2010).

**5. SUMMARY AND FUTURE WORK**

The results from initial tests are promising. Future work includes developing and testing this algorithm with noisy simulated CYGNSS observations. A diagnostic tool for determining when CYGNSS-IKE is representative of the true IKE will be developed. Future work also includes decomposing all potential error sources in this algorithm: wind speed retrieval error, sparse sampling, and parametric model fit.

**6. REFERENCES**


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