WIND SPEED RETRIEVAL UNCERTAINTY > 20 m s\(^{-1}\). A histogram of the stepped-frequency microwave radiometer (SFMR) wind speeds measured during the overpasses is shown in Fig. ES1. The maximum wind speed in the histogram is 54 m s\(^{-1}\) (120 mph, category 3).

A scatterplot with all wind speed matchups between Cyclone Global Navigation Satellite System (CYGNSS) and SFMR is shown in Fig. ES2a. A histogram of the difference between each pair of wind speeds is shown in Fig. ES2b.
WIND SPEED RETRIEVAL UNCERTAINTY < 20 m s⁻¹. The buoys used for wind speed intercomparisons and performance assessments were sited throughout the tropical Atlantic, Pacific, and Indian Oceans, as shown in Fig. ES3. Also noted in the figure is the number of intercomparison samples available at each site. Histograms of wind speed measurements by CYGNSS and the full array of buoys for all intercomparison samples are shown in Fig. ES4.

SPATIAL RESOLUTION.
Figure ES5 illustrates the instantaneous field of view (IFOV) as a function of incidence angle for the high- and low-altitude limits of the CYGNSS orbit. Figure ES6 illustrates how spatial resolution affects the CYGNSS mean daily coverage.

The spatial resolution of CYGNSS reflections over land is a function of the terrain. For land surfaces where large-scale topography and small-scale (with respect to the ~19-cm GPS wavelength) surface roughness is significant, the received power is distributed over a surface region analogous to an ocean rough-sea glistening zone (with varying surface facets returning power from a potentially wide area). However, in cases where the surface roughness variation (i.e., the standard deviation of surface slopes) is small with respect to the 19-cm wavelength,
coherent surface reflections can result. In case of a coherent surface reflection, the surface spatial area contributing to the received power in the delay Doppler map (DDM) area (DDMA) pixels will be dominated by the first Fresnel zone (where local surface propagation paths within one-quarter wavelength (~5 cm) will constructively interfere). The first Fresnel zone size determined by the semimajor and semiminor axes of an ellipse is a function of the reflection incidence angle. Figure ES7 shows the area and the dimensions of the two ellipse axes as a function of incidence angle. The semimajor axis will generally align with the specular point direction of travel and increases faster than the semiminor axis with incidence angle.

![Figure ES4](image) Fig. ES4. Surface wind histograms (bin width: 1 m s⁻¹) for CYGNSS and buoys.

![Figure ES5](image) Fig. ES5. CYGNSS observation IFOV spatial resolution as a function of incidence angle for a range of observatory altitudes. The baseline requirement of 25 km met or exceeded below approximately 38°, while the threshold requirement of 50 km is always met.

A second factor determining spatial resolution (for both ocean and land measurements) is the 1-s integration performed for each DDM. This causes the first
**Mean Daily Coverage vs. Specular Point Incidence Angle**
Total Valid L2 Wind Speed Samples: 409,191,159
2017-03-18 - 2018-11-30

**Fig. ES6.** Relationship between CYGNSS mean daily coverage baseline and threshold requirements as a function of observation incidence angle for CYGNSS level 1 calibration, versions 2.1 and 3.0. The v3.0 calibration enables the inclusion of the GPS block type IIF satellites, which significantly increases the number of usable observations.

**First Fresnel Zone vs Incidence Angle**

*Fig. ES7. Area of first Fresnel zone and semimajor and semiminor axes of the surface ellipse. The semimajor axis generally aligns across track to the specular point direction of travel and increases at a higher rate than the semiminor axis as a function of incidence angle.*
Fresnel zone to be smeared across the surface for cases of land coherent reflection. How the 1-s integration maps to movement of the specular point across the surface is a function of the relative geometry and velocities of the CYGNSS observatory and GPS transmitter. Figure ES8 shows the distribution of specular point velocities for 10 days of measurements. The mean velocity of approximately 6 km s\(^{-1}\) results in the single-look surface area (glistening zone of Fresnel zone) being smeared over the surface on average by 6 km.

Figure ES9 shows an example of a coherent CYGNSS land reflection across a small lake.

**Fig. ES8.** The speed of the CYGNSS specular point motion across the surface is a function of the relative observatory and GPS transmitter vector velocities and can vary between 2 and 9 km s\(^{-1}\), with an average of approximately 6 km s\(^{-1}\).

**Fig. ES9.** An example of an integrated Fresnel zone for a coherent specular reflection from Big Creek Lake (Mississippi). For this relatively low-incidence-angle reflection (~15°) the Fresnel zone is a ~500-m-radius circle. The start and end 1-s integration Fresnel zones are shown as circles at the start and end of the integration. For this example, the total Fresnel spatial surface area for this measurement is ~3.15 km\(^2\) (0.5 km × 6.3 km). The fluctuations in the signal level (upper-right insert) clearly show the coherent reflection from Big Creek Lake originating within the first Fresnel zone.
in Mississippi. The 1-s integration starts and ends on either side of the lake. The first Fresnel zone is shown integrated across the surface, resulting in elongated spatial resolution. The coherent reflection of the small lake (roughly 1.5 km across the observation track) is clearly visible in the increased power received. The area of the integrated Fresnel zone in this case is approximately $3.15 \text{ km}^2 \left( 0.5\text{-km Fresnel radius } \times 6.3\text{-km time integration} \right)$. This clearly demonstrates the potential for significantly improved spatial resolution when the conditions for coherent reflection exist.

**TEMPORAL REVISIT.** Figure ES10 shows a histogram of the revisit times over the life of the mission.

![Fig. ES10. Histogram of CYGNSS L2 revisit times.](image-url)