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COVERAGE OF TROPICAL CYCLONES REVEALED BY CYGNSS DATA

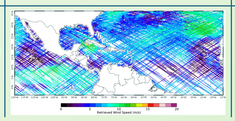
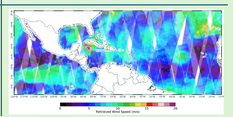
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BACKGROUND

- The CYGNSS (Cyclone Global Navigation Satellite System) constellation of eight smallsats was launched in December 2016 (Ruf et al. 2016) and continues to operate today
  - Communication with one of the eight satellites was lost in late November 2022
- Utilizes "signals of opportunity" from the existing GPS constellation that reflect off the ocean surface and are received by the CYGNSS antennas
- Two major advantages of GNSS reflectometry:
  - retrieve wind speeds through precipitation (because of the longer wavelength)
  - more frequent revisit times in the tropics (because of the lower-inclination orbit)
- These advantages over conventional scatterometers (such as ASCAT) make it well-suited to analyze tropical waves and cyclones. In practice, CYGNSS is a proof-of-concept mission and the data have a multi-day latency

	CYGNSS	ASCAT
Retrieved quantity	Ocean surface wind speed	Ocean surface wind speed and direction
Median Revisit Time in Tropics	3 hours	12 hours
Instrument	Passive 19 cm wavelength (L-band)	Active 5 cm wavelength (C-band)
Orbital Inclination	35°	99°
Effect of Precipitation	Not contaminated or attenuated by rain	Contaminated and attenuated by rain
Data Range	0-70 m/s but 2 GMFs diverge at ~ 20 m/s	0-50 m/s
Daily Coverage Example		

Mayers, D.R., C. S. Ruf, and A. M. Warnock, 2023: CYGNSS Storm-centric Tropical Cyclone Gridded Wind Speed Product. *J. App. Meteor. Clim.*, **62**, 329-339.

McNoldy, B. D., B. Annane, S. J. Majumdar, J. Delgado, L. Bucci and R. Atlas, 2017: Impact of Assimilating CYGNSS Data on Tropical Cyclone Analyses and Forecasts in a Regional OSSE Framework. *Mar. Tech. Soc. J.*, **51**, 7-15.

Morris, M., and C.S. Ruf, 2017: Estimating Tropical Cyclone Integrated Kinetic Energy with the CYGNSS Satellite Constellation. *J. App. Meteor. Clim.*, **56**, 235-245.

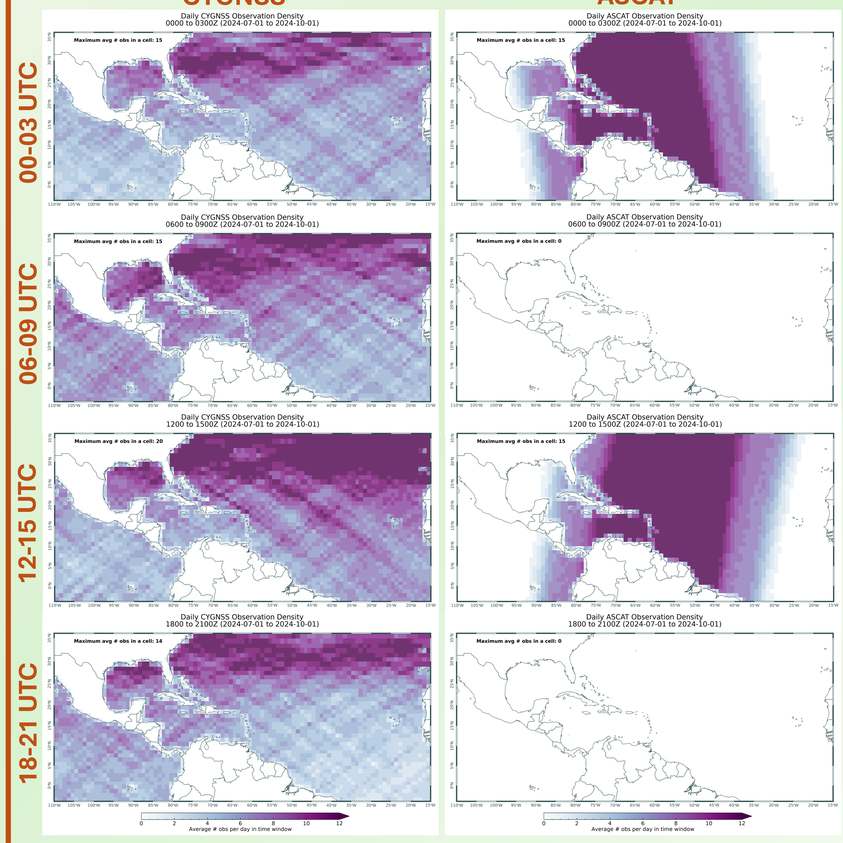
Ruf, C.S., and Coauthors, 2016: New Ocean Winds Satellite Mission to Probe Hurricanes and Tropical Convection. *Bull. Amer. Meteor. Soc.*, **97**, 385-395.

Warnock, A.M., C. S. Ruf, A. Russel, M. M. Al-Khaldi, and R. Balasubramaniam, 2024: CYGNSS Level 3 Merged Wind Speed Data Product for Storm Force and Surrounding Environmental Winds. *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, **17**, 6189-6200.

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DATA COVERAGE

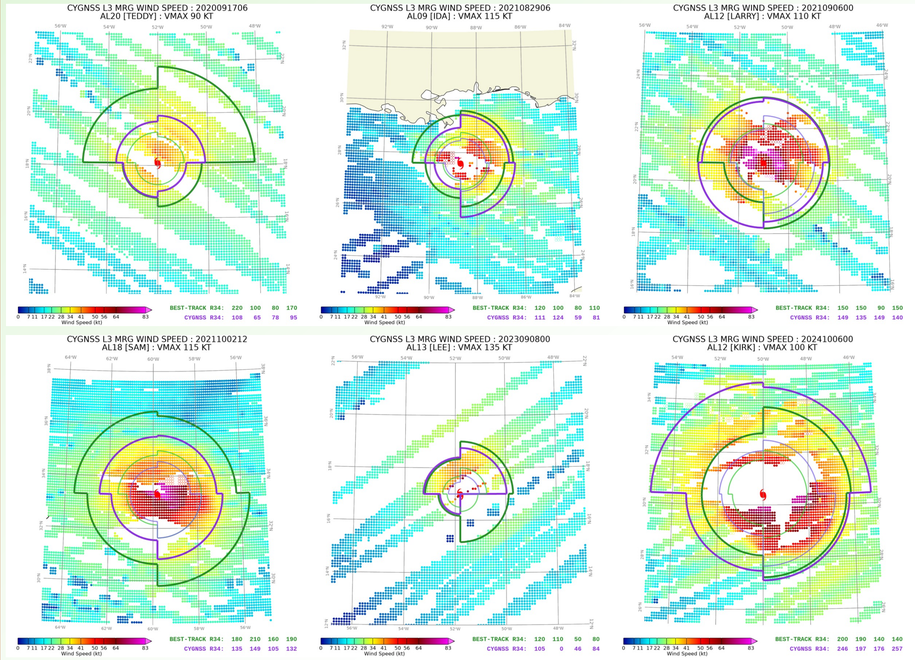
- Daily-average observation density of CYGNSS (left) and ASCAT (right) in 3-hourly and 1° bins during July-August-September 2024 are shown below
  - Three-hour periods end at 0300, 0900, 1500, and 2100 UTC, the nominal schedule of advisories from NHC
  - Level 2 data from all seven CYGNSS satellites are combined (v3.2 FDS)
  - Level 2 data from ASCAT-B and ASCAT-C are combined; their ground tracks are separated by approximately 1250 km and 52 minutes in the tropical Atlantic



- CYGNSS coverage is fairly well-distributed throughout the day, especially in the three-hour time windows leading up to NHC's advisory times
  - Coverage pattern at specific times is not a swath but rather a series of lines governed by a constantly-evolving bistatic radar configuration between the CYGNSS receivers and GPS transmitters
- In contrast, the two ASCAT instruments have significant data gaps at these times, though the area near Cabo Verde *is* well-covered in the 0900-1200 UTC (descending passes) and 2100-0000 UTC (ascending passes) time windows

WIND RADII FROM CYGNSS

- Although it does not provide wind direction, **CYGNSS provides structure information when ASCAT data are unavailable or between ASCAT swaths… and provides additional information when ASCAT data are present.**
- CYGNSS wind speed data can capture the structure, critical wind radii, integrated kinetic energy, and other storm properties well, with the added benefit of its frequent revisit times (McNoldy et al. 2016, Morris and Ruf 2017, etc.)
- Mayers et al. (2023) introduced a storm-centric gridded (SCG) ocean surface wind speed product using the CYGNSS "Young Seas with Limited Fetch" (YSLF) data around tropical cyclones (TCs)
- Warnock et al. (2024) introduced a merged product (MRG) that builds upon the SCG product by smoothly blending the TC area with global coverage of wind speeds provided by the CYGNSS "Fully Developed Seas" (FDS) data
  - The MRG v3.2 product contains quadrant estimates of the radius of tropical storm force winds (R34), but there are errors in how they are calculated. Here we calculate both R34 *and R50* from the best-track storm center and MRG wind speed data. A new release (v3.2.1) resolves the original R34 issues but is only available from mid-June 2024 onward. Additionally, it does not include R50 or R64 estimates
- Examples of six recent TCs with radii of tropical storm force winds (R34) and 50-kt winds (R50) are shown below on a 10°x10° domain. NHC values are in green and CYGNSS-derived values are in purple



- **CYGNSS has the potential to provide valuable estimates of critical wind radii**. We plan to investigate estimates of R64 (hurricane force wind radii), though retrievals of such wind speeds are limited in both scatterometry and reflectometry