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Cyclone Global Navigation Satellite System (CYGNSS) and Soil Moisture Product Prospects

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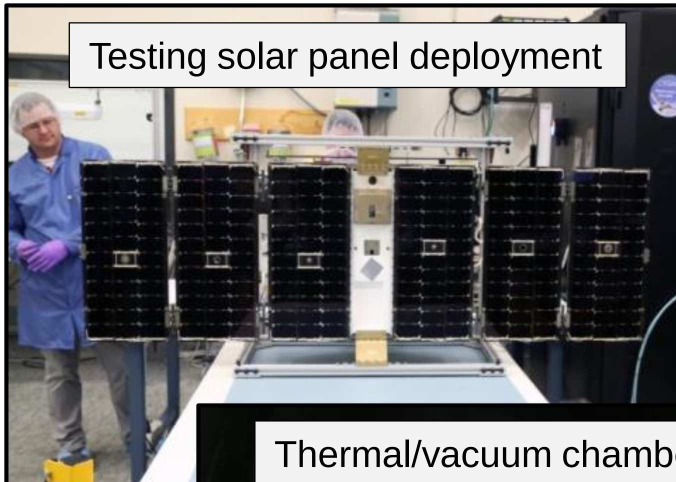
CYGNSS Mission Overview

- The NASA Cyclone Global Navigation Satellite System (CYGNSS) Mission consists of 8 microsatellites, each with a 4-channel GPS bi-static radar receiver
  - Mission lead/Science Ops (University of Michigan)
  - Spacecraft/Integration/Mission Ops (Southwest Research Institute)
- CYGNSS uses a new measurement technique and a new satellite mission architecture
  - Measure the distortion of GPS signals scattered from the ocean surface to determine ocean surface roughness and wind speed
  - Use small satellites so many can be flown to improve sampling
- The primary measurement objective is ocean surface winds in the inner core of tropical cyclones
- Measurements over land show sensitivity to soil moisture, flood inundation, and wetland extent

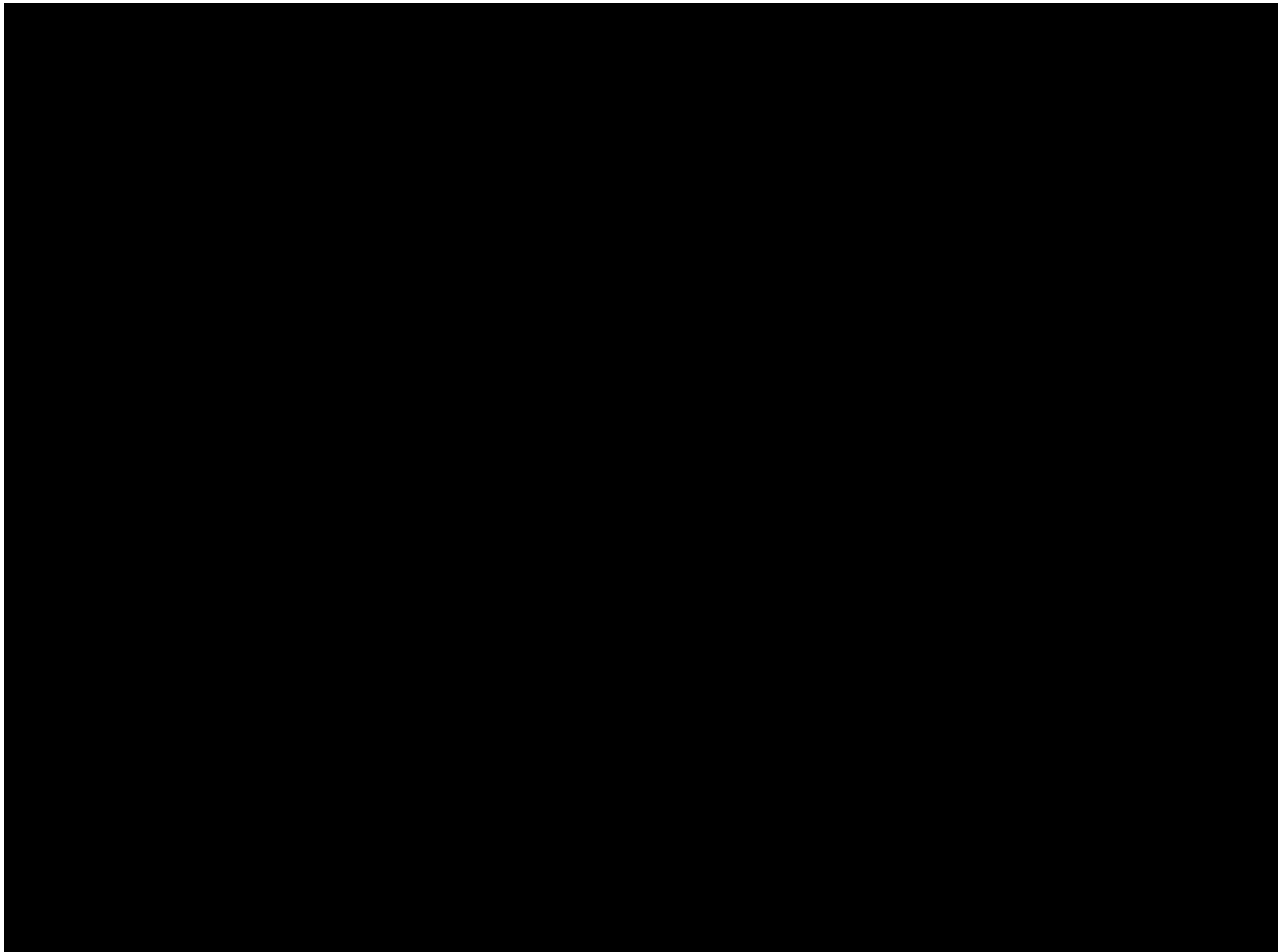
Observatory Integration and Test


Testing solar panel deployment


Thermal/vacuum chamber test


Vibration table with “full-stack”
In launch configuration

CYGNSS Specular Point Contacts and Spatial Sampling



CYGNSS Mission Timeline

PAST

- 15 Dec 2016 at 08:37 EST Launch
- Mar 2017: begin Science Mode with continuous science data taking
- May 2017: Provisional release of v1.0 data products to PO.DAAC
- Aug – Nov 2017: Initial cal/val of hurricane force winds using coincident P-3 SFMR matchups
- Nov 2017: Public (non-provisional) release of v2.0 data products to PO.DAAC
- Sep 2018: Release of v2.1 data products to PO.DAAC; Improved GPS characterization

PRESENT & FUTURE

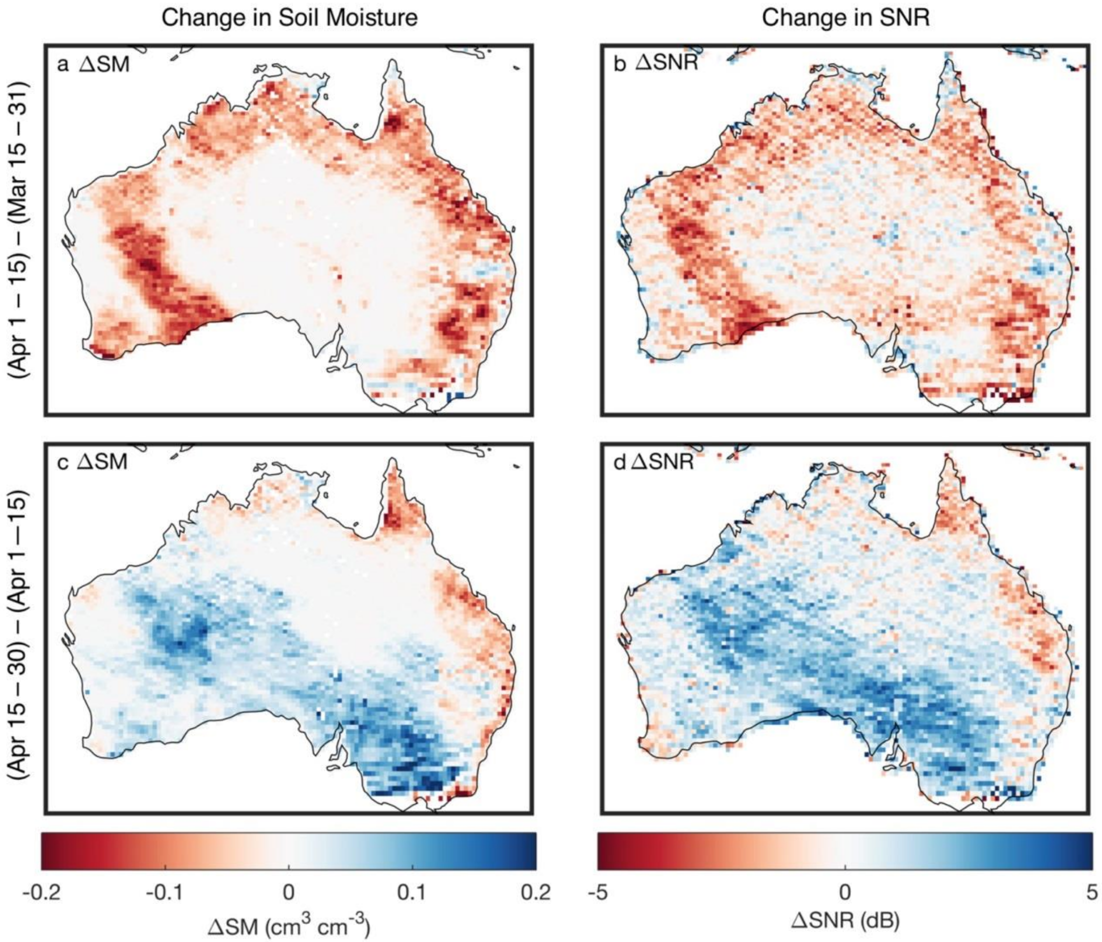
- Assimilation of observations into TC prediction model (HWRF); forecast skill impact assessment (results at AMS Annual Meeting in Jan'19)
- New land applications

CYGNSS Mission Science Requirements

Rqmt #	Requirement	Verification Status
1	3 m/s to 70 m/s at 5 km x 5 km resolution	verified < 54 m/s
2	Operation in presence of rain	✓ verified
3a	10% retrieval uncertainty for winds > 20 m/s	verified @ 11.3%
3b	2 m/s retrieval uncertainty for winds < 20 m/s	✓ verified @ 1.4 m/s
3c	Spatial Resolution of 25 km x 25 km or better	✓ verified @ 15 km
4a	100% duty cycle during science operations	✓ verified
4b	Mean temporal resolution less than 12 hours	✓ verified @ 7.5hr
4c	24 hour spatial sampling covering 70% or more of the cyclone historical track	✓ verified @ 74%
5	Calibrate and validate CYGNSS data in individual wind speed bins above and below 20 m/s	✓ verified
6	Support operational hurricane forecast community	✓ verified

CYGNSS Sensitivity to Near-Surface Soil Moisture

- Change in soil moisture retrieved by SMAP (left) and change in SNR imaged by CYGNSS (right) during Mar'17 (top) and Apr'17 (bot)

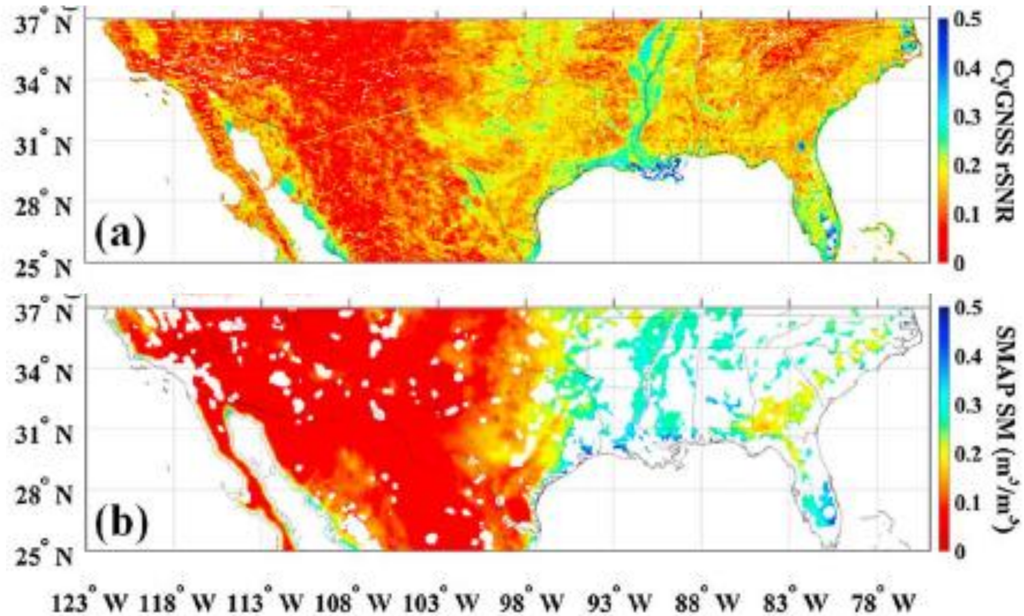


(courtesy C. Chew, UCAR)

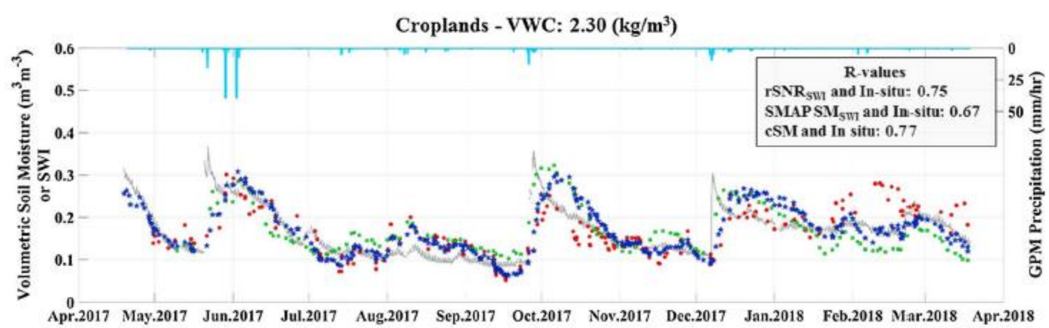
CYGNSS Soil Moisture Retrieval

Kim and Lakshmi, "Use of CYGNSS Observations for Estimation of Soil Moisture," Geophys. Res. Ltr., doi: 10.1029/2018GL078923, 2018.

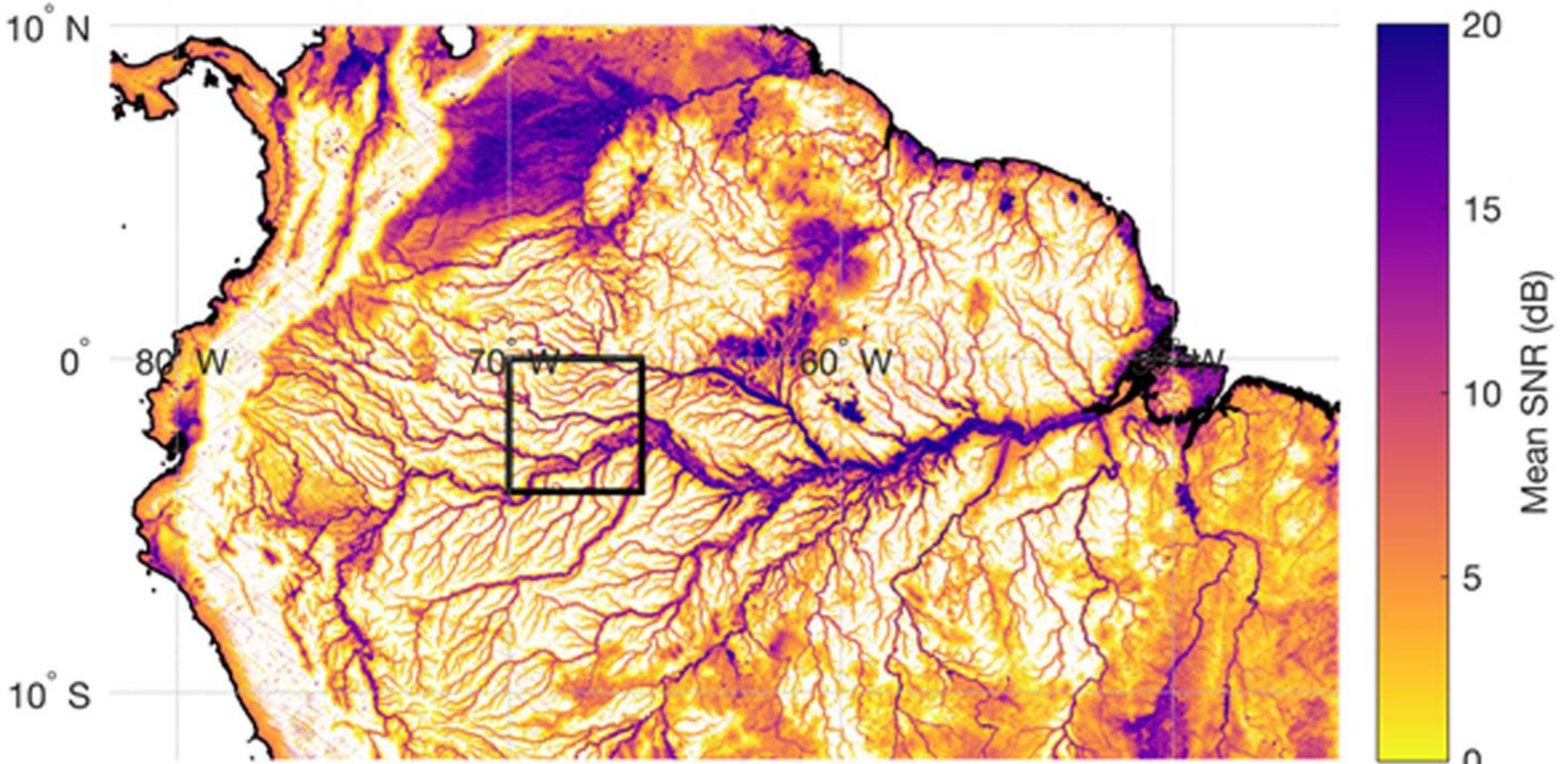
- Annual average CYGNSS SNR (top) and SMAP SM (mid) for 3/2017 – 3/2018



- SM time series from 4/2017 to 4/2018 retrieved by CYGNSS (red), SMAP (green), and in situ (grey) for cropland vegetation



CYGNSS Imaging of Inland Waterways



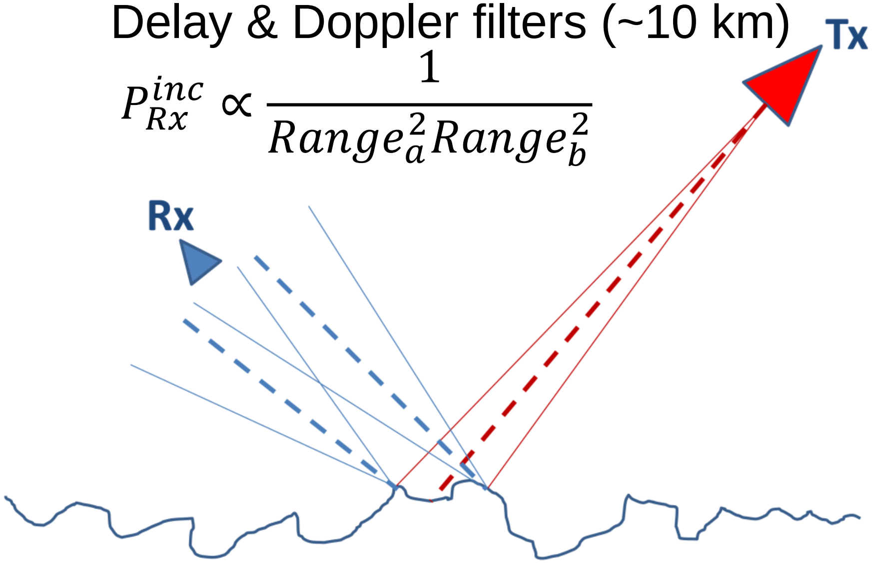
MichiganEngineering
Department of
Atmospheric, Oceanic and Space Sciences

Coherent vs. Incoherent Bistatic Scattering

INCOHERENT

Spatial resolution determined by Delay & Doppler filters (~10 km)

$$P_{Rx}^{inc} \propto \frac{1}{Range_a^2 Range_b^2}$$

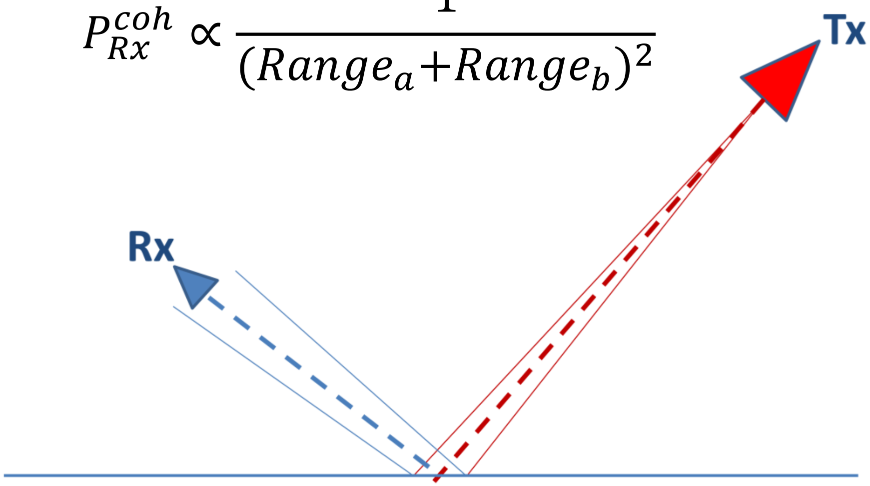


Incoherent (diffuse) bistatic scattering

COHERENT

Spatial resolution determined by First Fresnel Zone (~500m)

$$P_{Rx}^{coh} \propto \frac{1}{(Range_a + Range_b)^2}$$

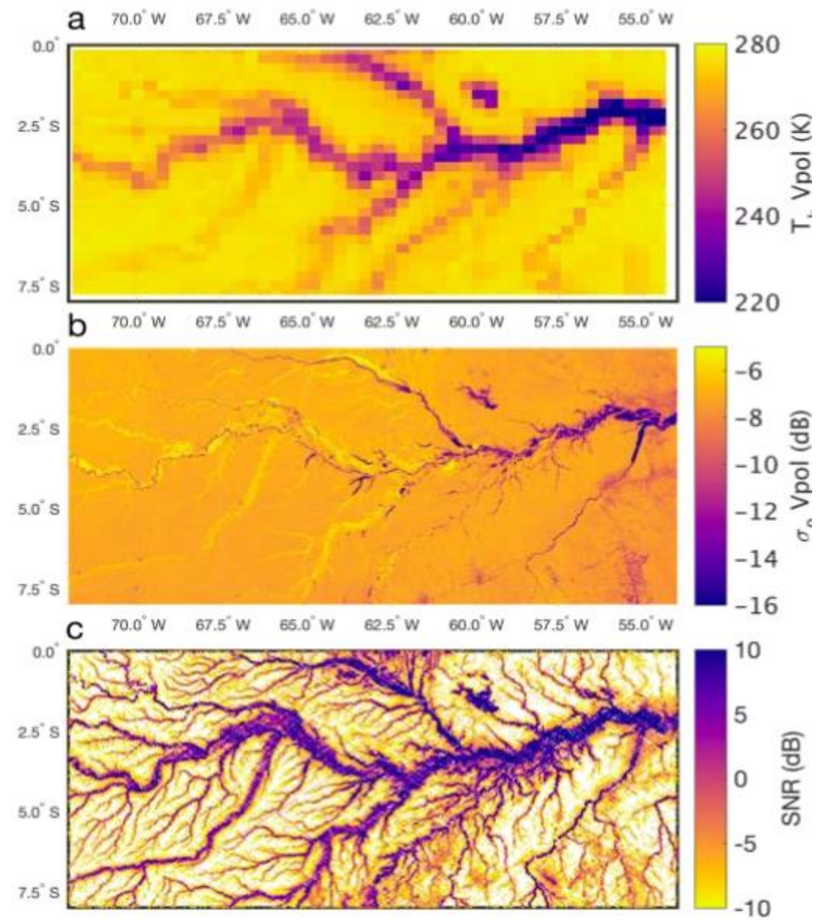


Coherent (specular) bistatic scattering

$Range_a$ = GPS-to-ground
$Range_b$ = ground-to-CYGNSS

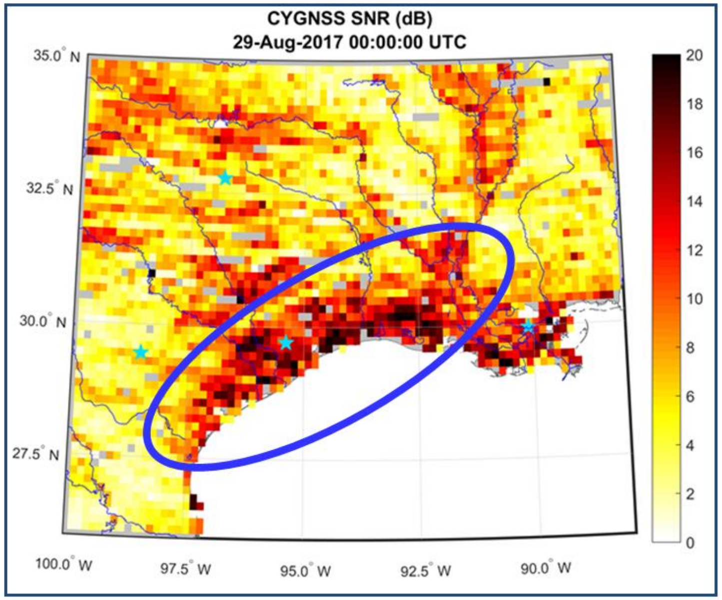
High resolution land imaging by CYGNSS resulting from coherent forward scatter

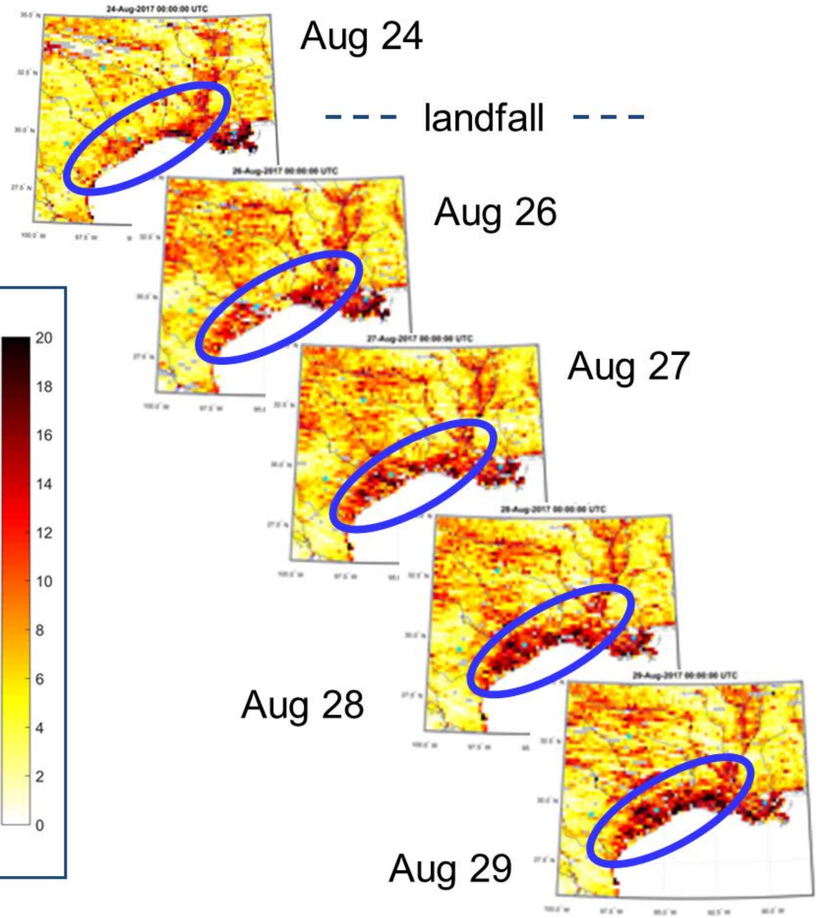
- Images of the same section of the Amazon River by:
  a) SMAP passive microwave
     ~30 km res
  b) SMAP active radar
     ~3 km res
  c) CYGNSS GNSS-R
     <500 m res)



Imaging of Flood Inundation after Hurricane Harvey Landfall

- (right) Time lapse SNR images in Houston metro region
  - Large increases in SNR indicate flooding inundation
- (below) Aug 29 SNR image with coastal flooding circled

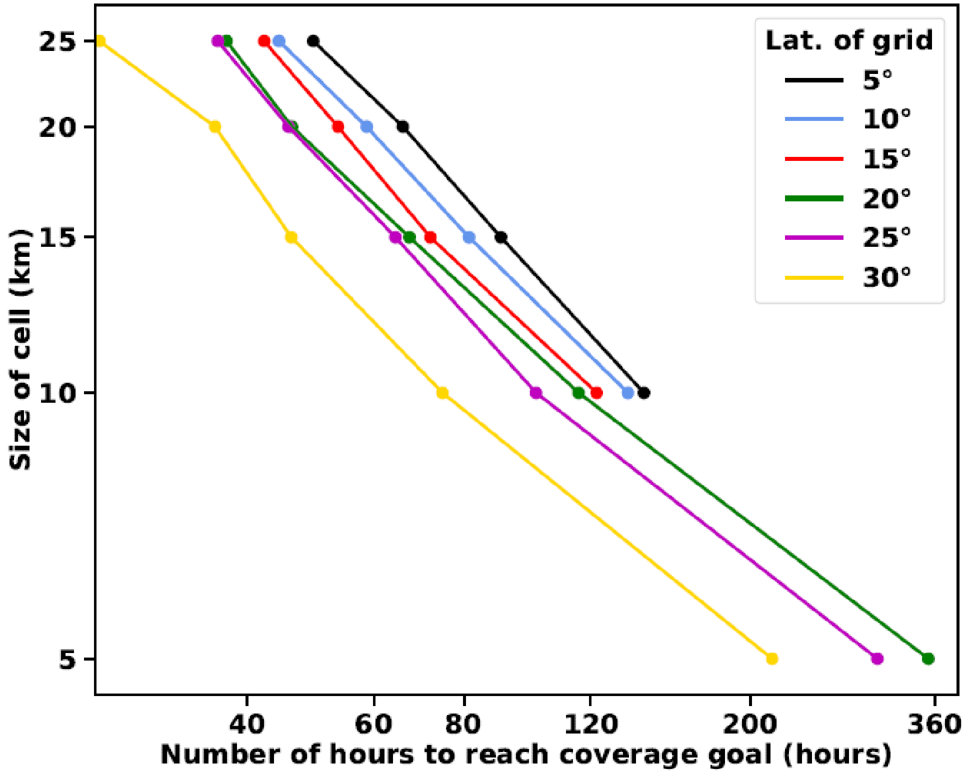




(courtesy Mary Morris, NASA/JPL)

GNSS-R Sampling Properties
Spatial Resolution v. Temporal Coverage

- GNSS-R sample locations are determined by geometry of Tx and Rx and images are inherently “gappy”
- Relationship between spatial resolution and time needed to sample 90% of the gridded Earth surface between 35º south and 35º north latitude



Current CYGNSS Land Applications Investigations

- Joel Johnson (Ohio State University)
  - Quasi-specular coherent scattering formulation
- Kyle McDonald (City College of New York)
  - Sub-canopy Inundation Dynamics in Tropical Wetlands
- Mahta Moghaddam (University of Southern California)
  - Retrieval of Surface and Subsurface Soil Moisture Profiles Over Diverse Landscapes
- Leung Tsang (University of Michigan)
  - Retrieval of Soil Moisture Using CYGNSS Based on Physical Models of Bistatic Scattering
- April Warnock (SRI)
  - Storm Surge Modeling and Algorithm Development
- Simon Yueh (Jet Propulsion Laboratory)
  - CYGNSS Soil Moisture Algorithm and Validation
- Cinzia Zuffada (Jet Propulsion Laboratory)
  - Dynamic Mapping of Tropical Wetlands and Inundations with CYGNSS

Thank You

for more information visit **http://cygnss-michigan.org**

or contact Chris Ruf, **cruf@umich.edu**