

*2019 Earth Science Technology Forum (ESTF2019)*

*June 11-13, 2019, NASA Ames*

# Next Generation GNSS Bistatic Radar Receiver

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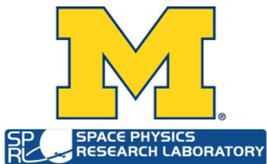
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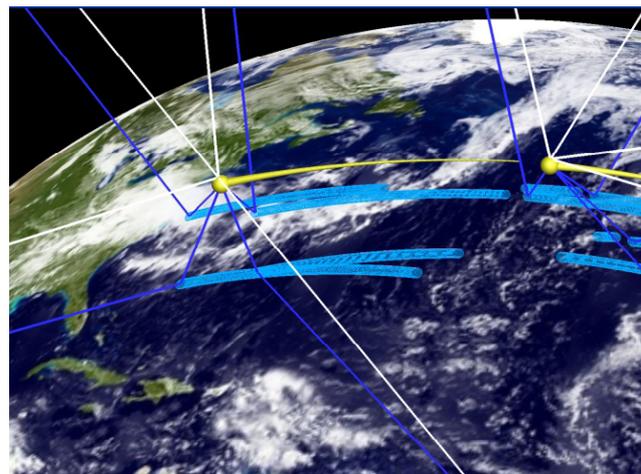
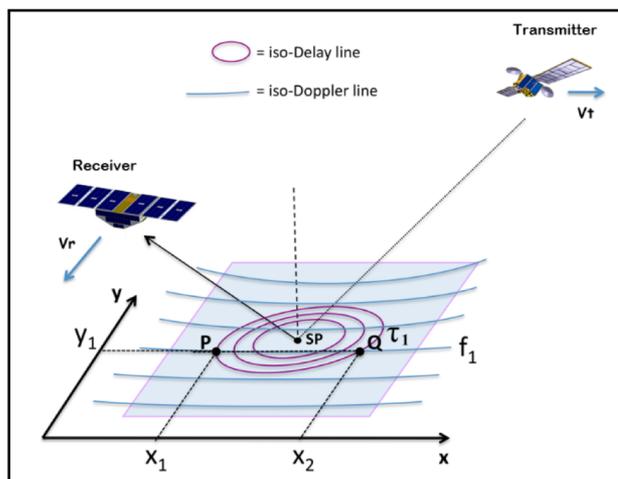
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# Overview of NGRx Project

- Develop a next generation GNSS bistatic radar receiver capable of processing signals transmitted by both GPS and Galileo satellites, including both low (L1/E1) and high (L5/E5) bandwidth signals



- Raise technology readiness from TRL-4 to TRL-6

# First Gen GNSS-R is CYGNSS Payload

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- Limited to GPS L1 C/A signal reception (co-pol only)
- Limited to 4 parallel receive channels by digital processor capacity
- Limited to static coherent/incoherent real time digital signal processing
- Navigation and reflection processing not optimized due to legacy code development

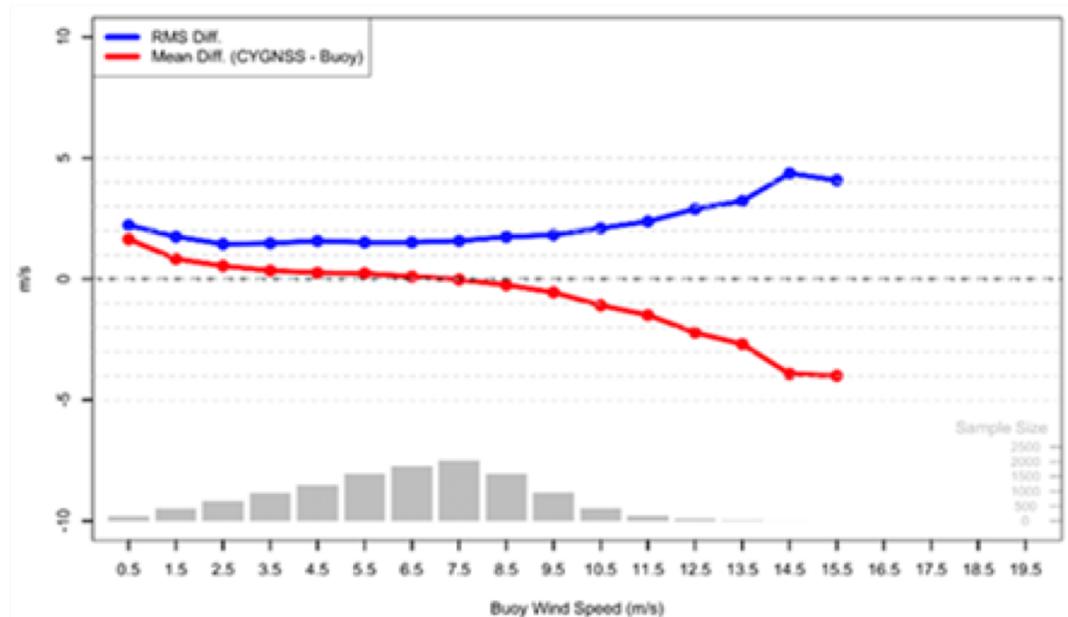
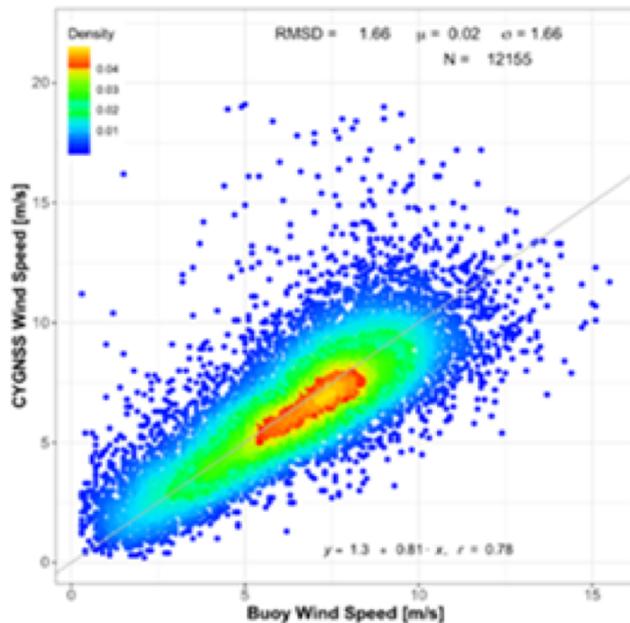
# CYGNSS Mission Timeline

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- Jun 2012 CYGNSS Earth Venture Mission Selected
- Jan 2014 Preliminary Design Review
- Jan 2015 Critical Design Review
- 15 Dec 2016 LAUNCH
- Mar 2017 Post Launch Commissioning Completed
- Mar 2019 End of Prime Mission/Beginning of Extended Mission

# Wind Speed Retrieval Uncertainty Below 20 m/s

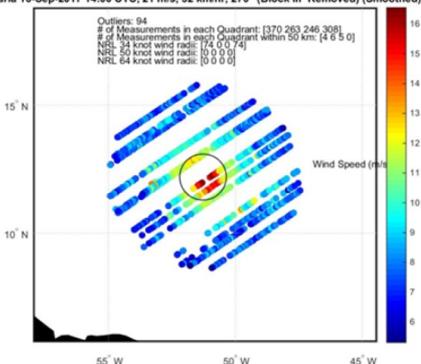
- Mar 2017 – Aug 2018 Matchups with 76 tropical moored buoys (12,164 samples)
- 1.7 m/s RMS difference between CYGNSS and buoys



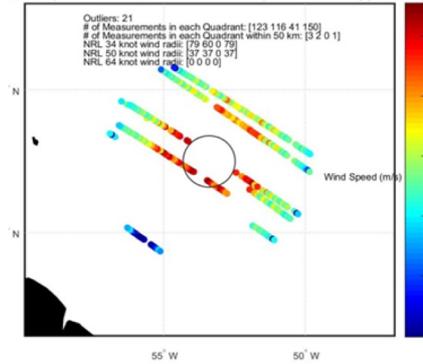
# Tropical Cyclone Overpass Examples

- Hurricane Maria overpasses centered on: 16 Sep @ 14:00, 17 Sep @ 00:00, 17 Sep @ 23:45, 20 Sep @ 14:45, 24 Sep @ 18:15, 25 Sep @ 18:30 UTC
- National Hurricane Center best track storm center in middle of black circle

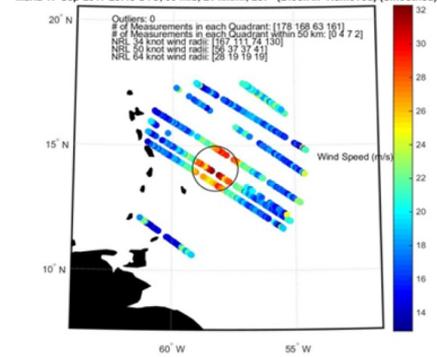
Maria 16-Sep-2017 14:00 UTC, 21 m/s, 32 km/hr, 270° (Block IIF Removed) (Smoothed)



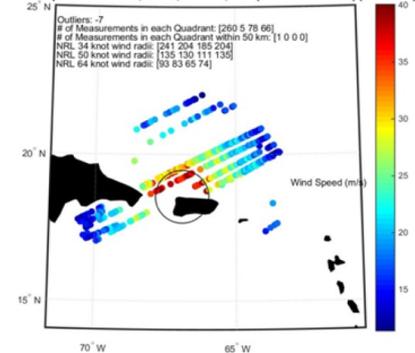
Maria 17-Sep-2017 00:00 UTC, 24 m/s, 25 km/hr, 289° (Block IIF Removed) (Smoothed)



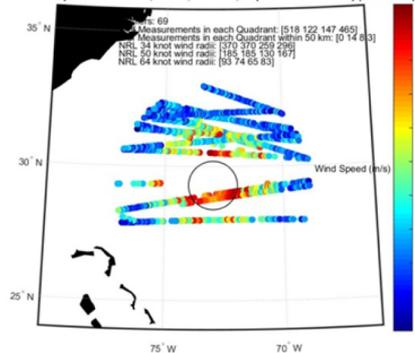
Maria 17-Sep-2017 23:45 UTC, 39 m/s, 21 km/hr, 287° (Block IIF Removed) (Smoothed)



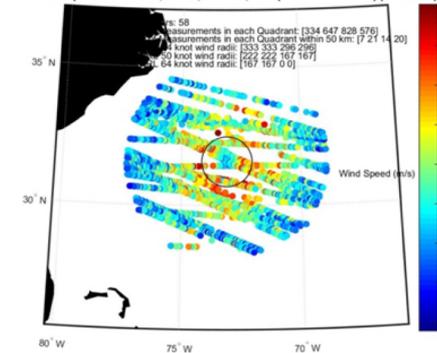
Maria 20-Sep-2017 14:45 UTC, 53 m/s, 13 km/hr, 295° (Block IIF Removed) (Smoothed)



Maria 24-Sep-2017 18:15 UTC, 46 m/s, 10 km/hr, 8° (Block IIF Removed) (Smoothed)



Maria 25-Sep-2017 18:30 UTC, 36 m/s, 12 km/hr, 120° (Block IIF Removed) (Smoothed)



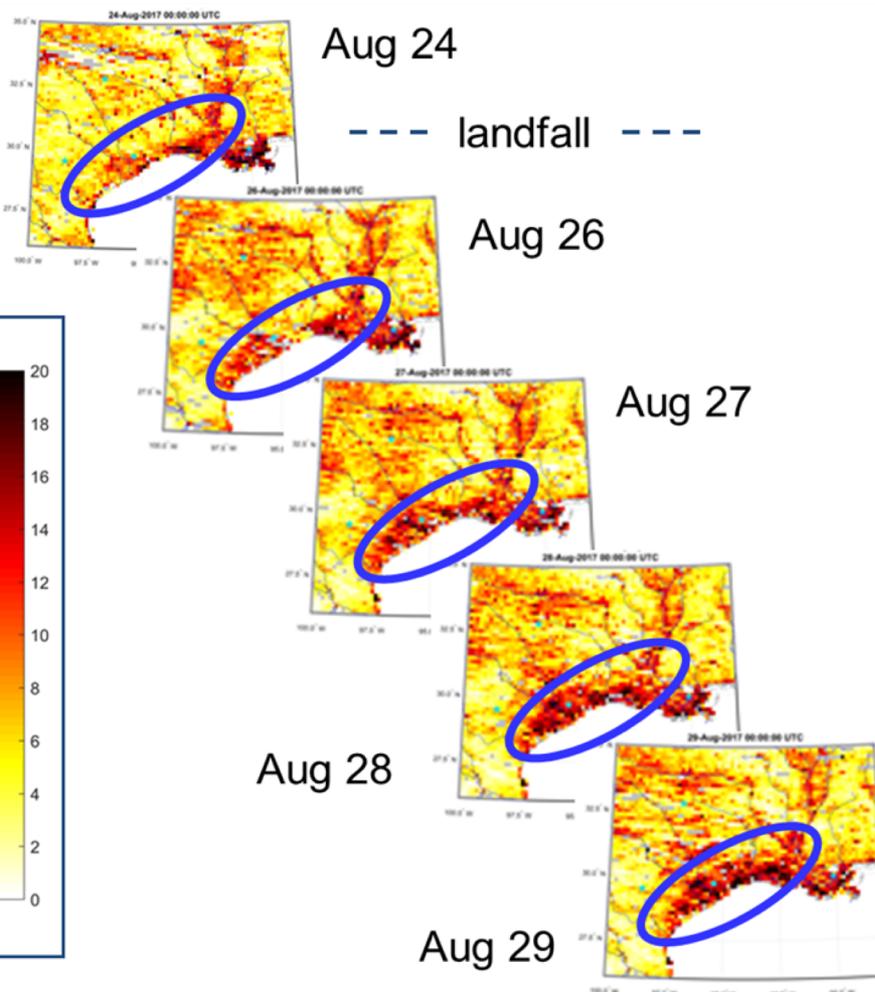
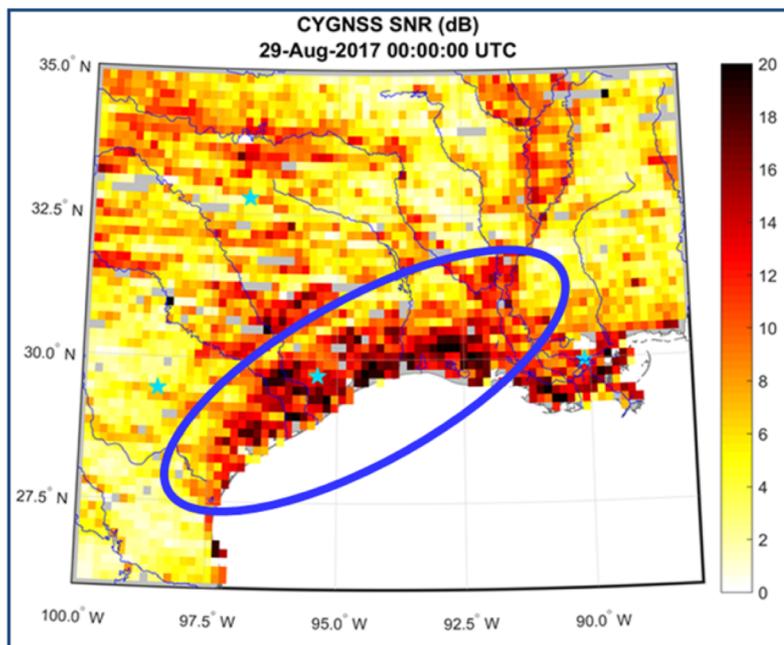
# CYGNSS Mission Science Requirements

CYGNSS Level 1 Mission Science Performance			
#	Requirement	CBE	Performance
1	Wind speed dynamic range at 5 km x 5 km resolution	1-54 m/s	Exceeds 40 m/s threshold
2	Operation in presence of rain	Yes	Meets baseline
3a	Retrieval uncertainty for winds > 20 m/s	11.3%	10% requirement
3b	Retrieval uncertainty for winds < 20 m/s	1.7 m/s	Exceeds 2 m/s baseline
3c	Spatial Resolution	25.4 km	Exceeds 50 km threshold
4a	100% duty cycle during science operations	Yes	Meets baseline
4b	Mean temporal resolution	9.1 hr	Exceeds 12 hr baseline
4c	Spatial sampling coverage of cyclone historical tracks in 24 hours	50-74%	Exceeds 50% threshold
5	Calibrate and validate CYGNSS data in individual wind speed bins above and below 20 m/s	Yes	Meets baseline

# CYGNSS SNR Images of Southeast Texas

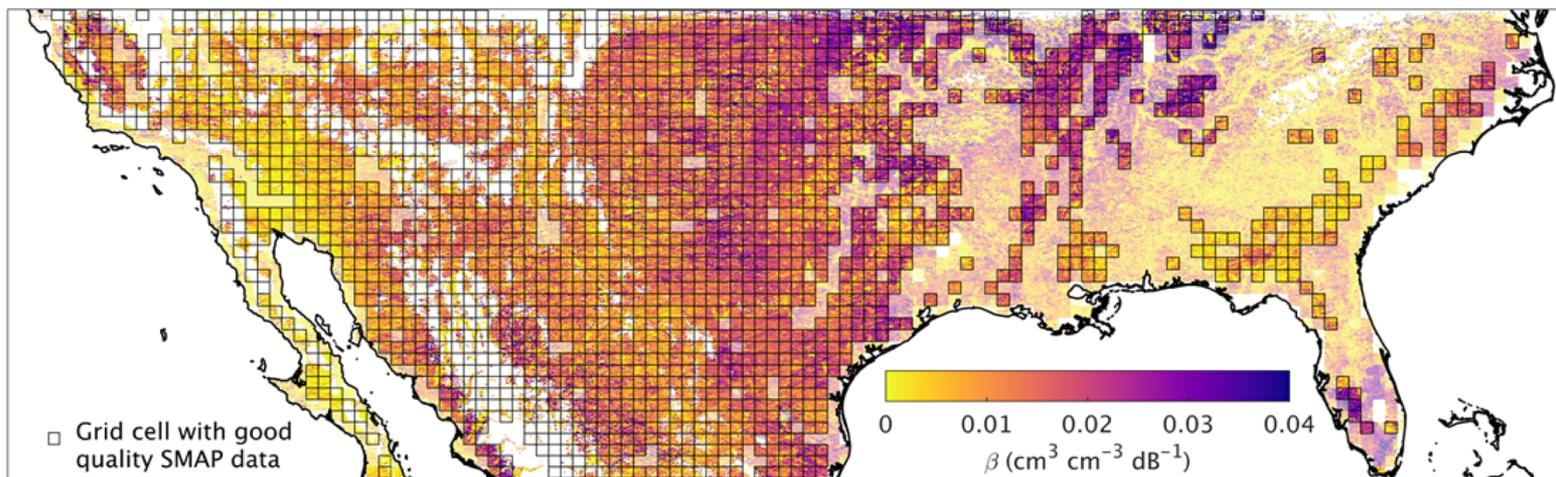
## Before & After Hurricane Harvey Landfall on Aug 25, 2017

- (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

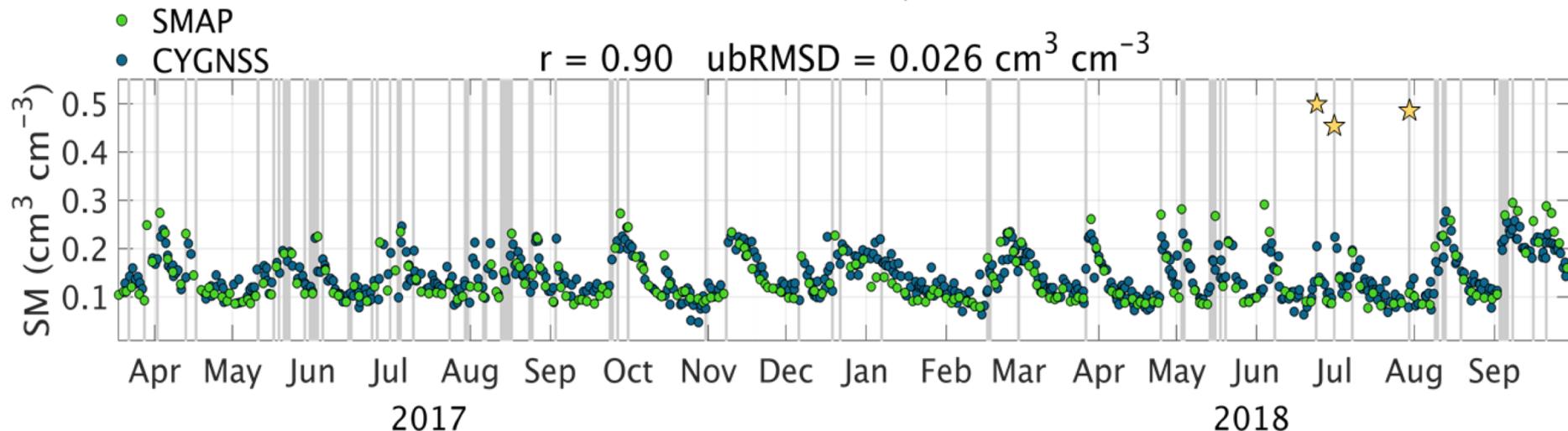


(courtesy Mary Morris, NASA/JPL)

# CYGNSS-Derived Soil Moisture Time Series (C. Chew, UCAR)

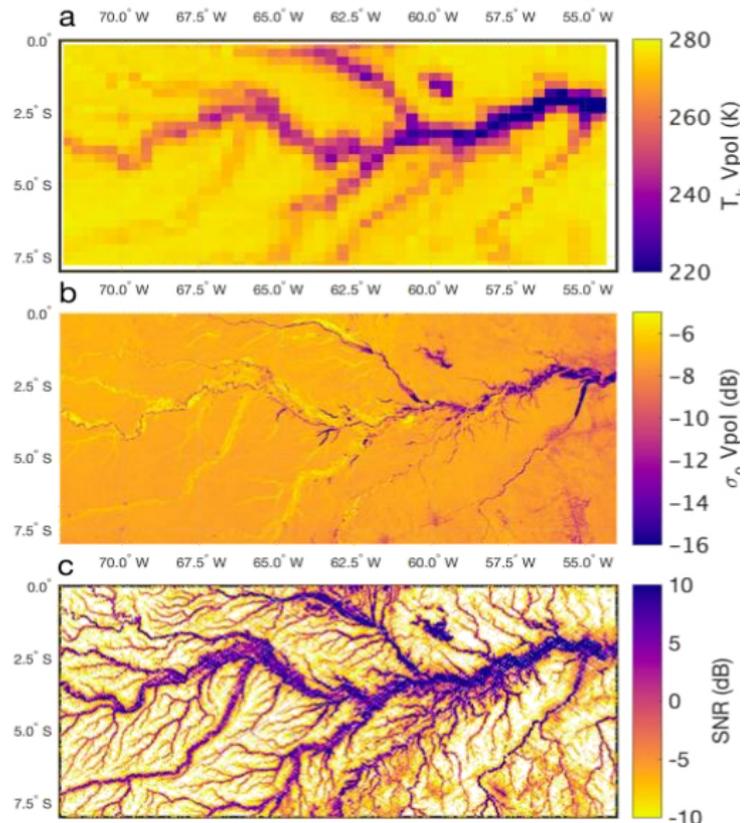


west of Dallas, Texas



# CYGNSS Spatial Resolution Over Land

- High res land imaging from coherent forward scatter
  - First Fresnel zone for CYGNSS is  $\sim 500$  m
- Images of the same section of the Amazon River by:
  - SMAP passive microwave  $\sim 30$  km res
  - SMAP active radar  $\sim 3$  km res
  - CYGNSS GNSS-R  $< 500$  m res



# IIP NGRx Enhancements

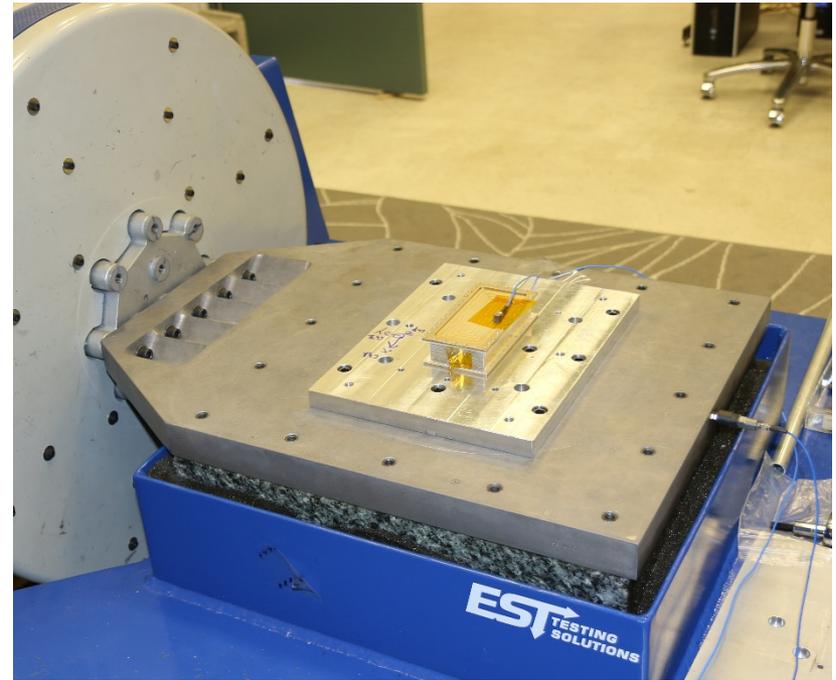
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- Engineering Design
  - GPS L1&L5, Galileo E1&E5
  - 20 simultaneous receive channels
  - Co- and X-pol antenna
- Science data products
  - 2 hr mean revisit (8 s/c constellation)
  - Co- and X-pol scattering cross section

# IIP NGRx Subsystem Development



Antenna testing in anechoic chamber with spacecraft mock-up



Receiver testing on vibration table

# Status and Next Steps

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- TRL-5 functional testing completed for antennas and receiver (analog) front end
- TRL-5 functional testing underway for receiver (digital) back end
- TRL-6 environmental testing later in 2019
- Possible airborne flights for demo in scientifically relevant environment
- Possible cubesat flight for demo of signal processing in relevant flight environment
- Possible inclusion in upcoming NASA DO mission