Detection and Imaging of Microplastics from Space

ISAP2021 - RIVERINE MICROPLASTICS POLLUTION IN ASEAN COUNTRIES (TT11)

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Overview

- Satellite radar observations of ocean surface roughness anomalies are found to be highly correlated with ocean plastic concentrations
- Estimates of plastic concentration from the satellite observations produce time-lapse images of plastic concentration dynamics
- The correlation between roughness anomaly and microplastic concentration may not be direct, but rather may result from the suppression of roughness by surfactants acting as tracers for the microplastics
- Laboratory experiments are currently underway to understand the connection between roughness suppression and the presence of microplastics and surfactants
- Extension of this method from open ocean to rivers may be possible

CYGNSS and MSS

NASA Cyclone Global Navigation Satellite System

- Launched in Dec 2016
- Eight microsatellites; Latitude range of 38˚N – 38˚S
- Bistatic radar system
- Measures direct and reflected GPS signals

CYGNSS Measures Ocean Surface Scattering Cross Section (σ_0)

- Mean Square Slope (MSS) is a statistical measure of ocean surface roughness derived from σ_0 and Fresnel reflection coefficient $\Re(\theta)$

$$MSS = \frac{|\Re(\theta)|^2}{\sigma_0(\theta)}$$

- MSS results from wind roughening of the ocean surface

Compute MSS anomaly, the deviation of measured MSS from model predicted value given local wind speed

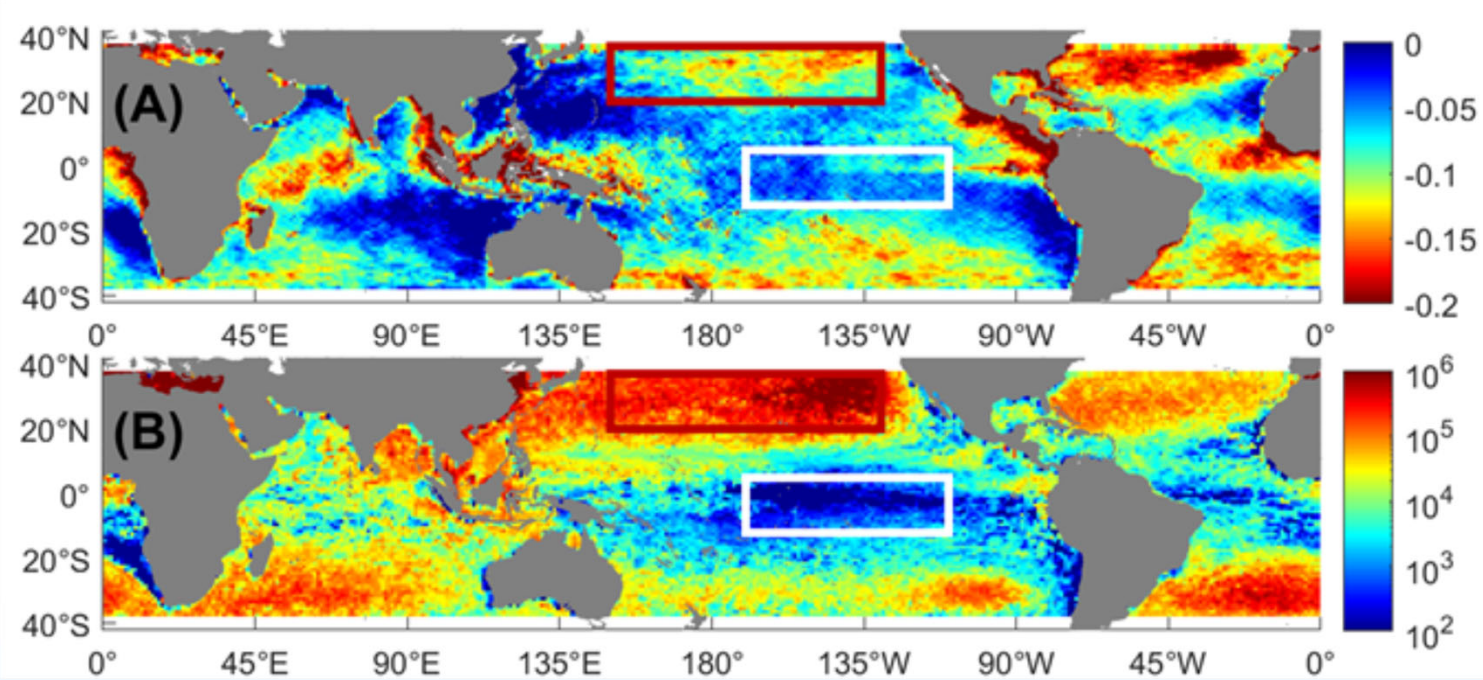
Evans, M. C., C. S. Ruf (2021), Towards the Detection and Imaging of Ocean Microplastics with a Spaceborne Radar. IEEE Trans. Geosci. Remote Sens., DOI: 10.1109/TGRS.2021.3081691.

Matchup Between MSS Anomaly and Microplastic Concentration

(A) Annual mean MSS Anomaly observed by the CYGNSS radars

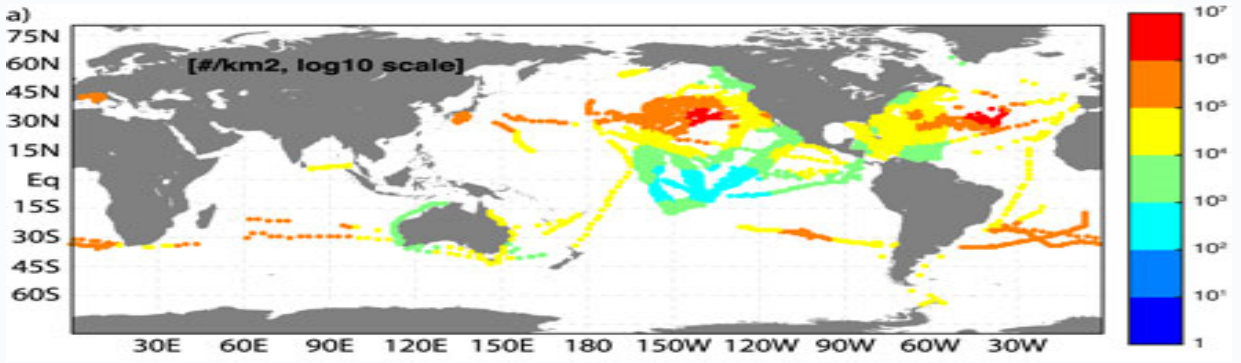
(B) Ocean microplastic concentration (#/km^2) predicted by the van Sebille model

Regions of high(red box) and low(white box) concentrations generally agree with regions of large and small negative MSS anomaly



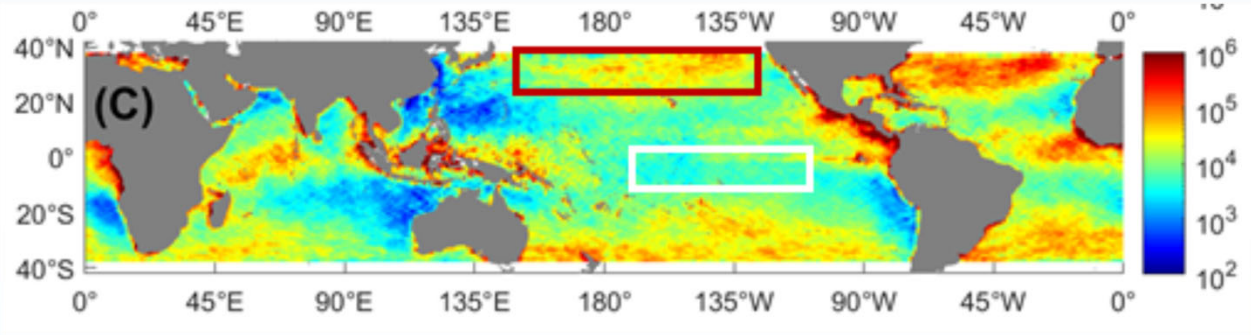
Comparison of Plastic Concentration Derived from CYGNSS to Net Trawl Data

(top) Composite of all Net Trawl Data from 1972 to 2015



(bottom) Annual Mean ocean microplastic concentration estimated from observed MSS Anomaly

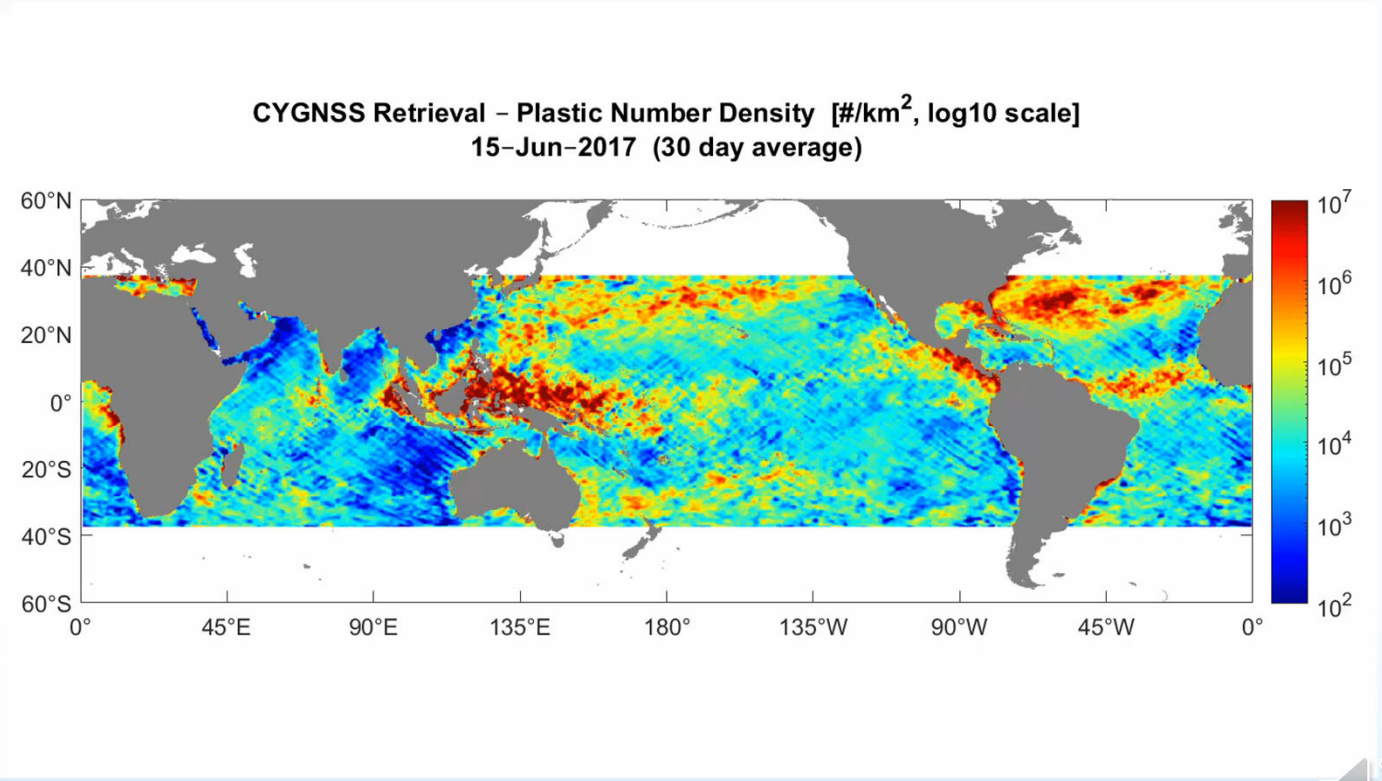
- (June 2017 – May 2018)



Seasonal Dependence of Observed Microplastic Concentration

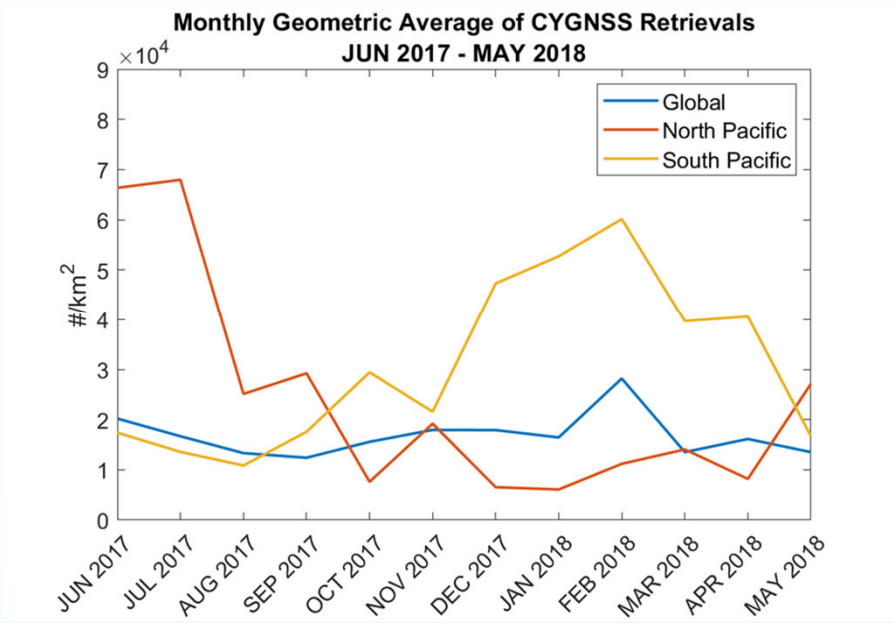
Higher summer concentrations in both Northern and Southern hemisphere Pacific Ocean at mid latitudes

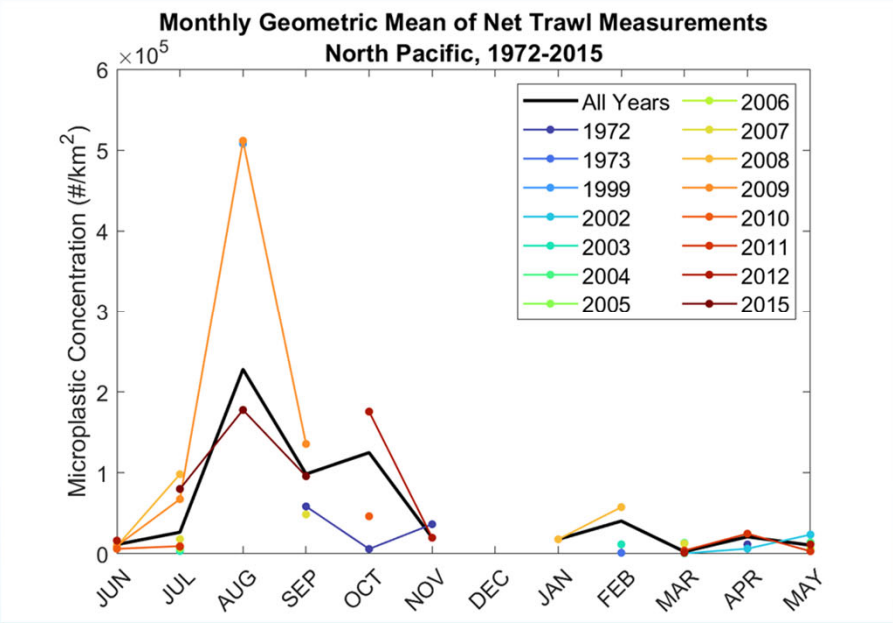
Mid latitude regions of the Pacific Ocean experience stronger currents and increased vertical mixing in the winter months of both hemispheres



CYGNSS vs.Net Trawls – Seasonal Dependence

Both CYGNSS retrievals and net trawls show **higher microplastic concentrations in the North Pacific Basin during summer months**





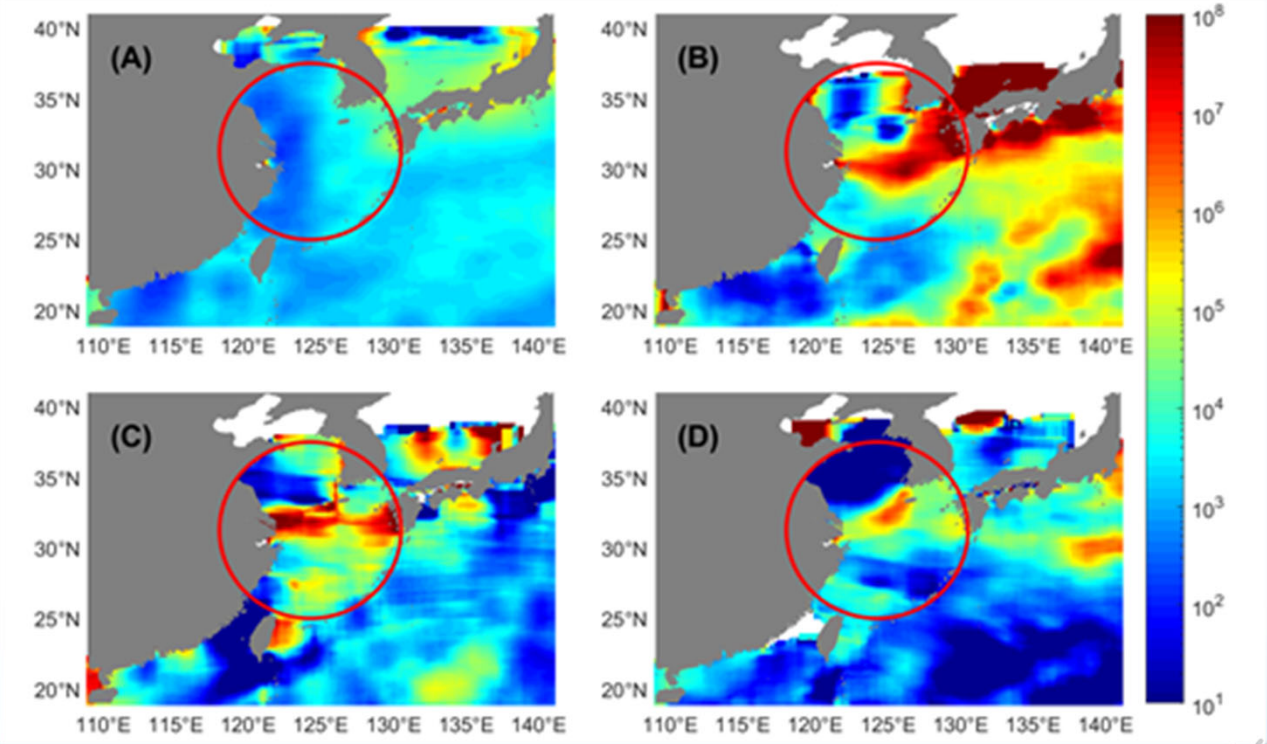
Qiantang & Yangtze River Outflow

An estimated 90% of plastic debris enters into the oceans through major rivers

- Yangtze is estimated to have the highest annual output of plastic debris (Lebreton, 2017)

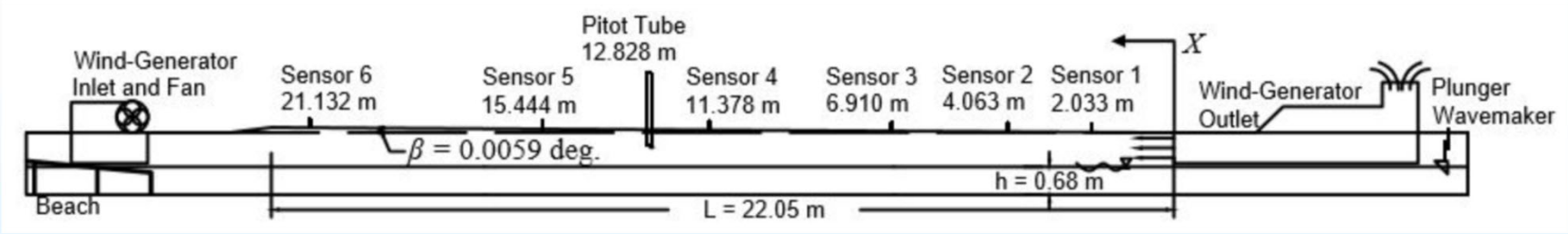
Plumes of high plastic concentration can be seen flowing from the river mouths into the East China Sea

- (A) Annual Average
- (B) 22–28 Jun 2017
- (C) 27 Oct – 2 Nov 2017
- (D) 2–8 Dec 2017



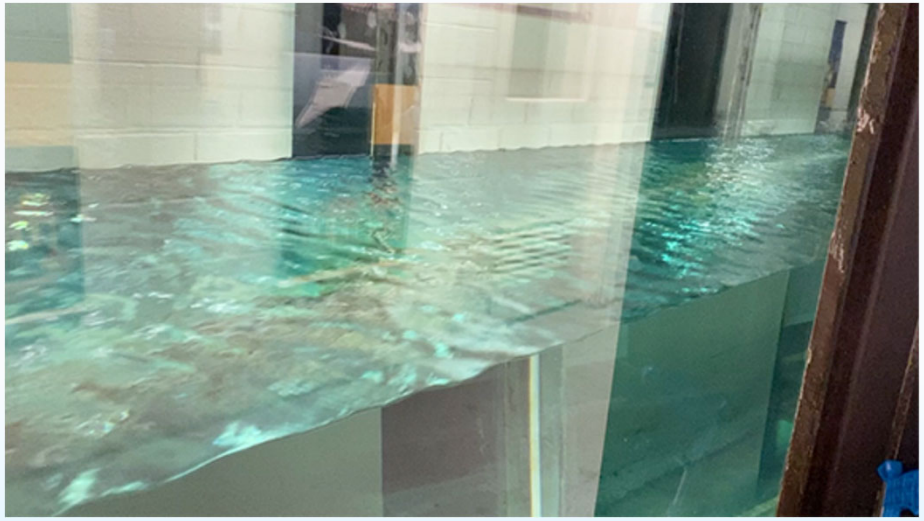
Wave Tank Experiment to Study Damping Effect on Wind Driven Roughening

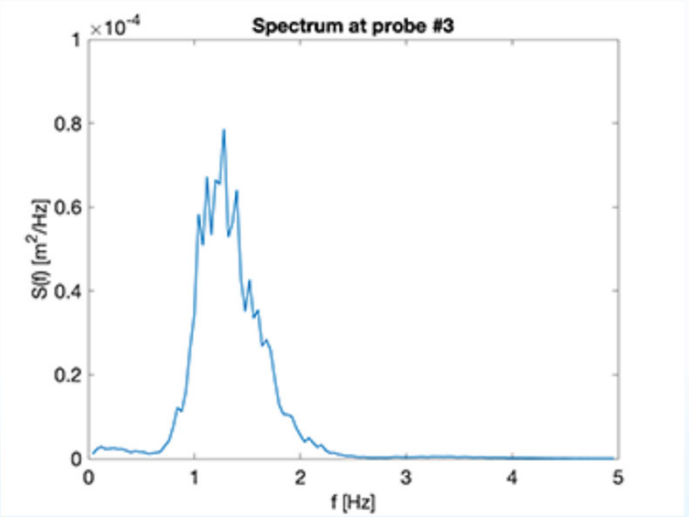
- Controlled experiment with wind-induced roughening and ultrasonic vertical surface height measurements
- Introduce variable concentrations of microplastics and surfactants
- Observe and quantify damping of roughening; equate changes in roughness to MSS anomaly using electromagnetic rough surface scattering theory



Wave Tank Experiment – Early Results

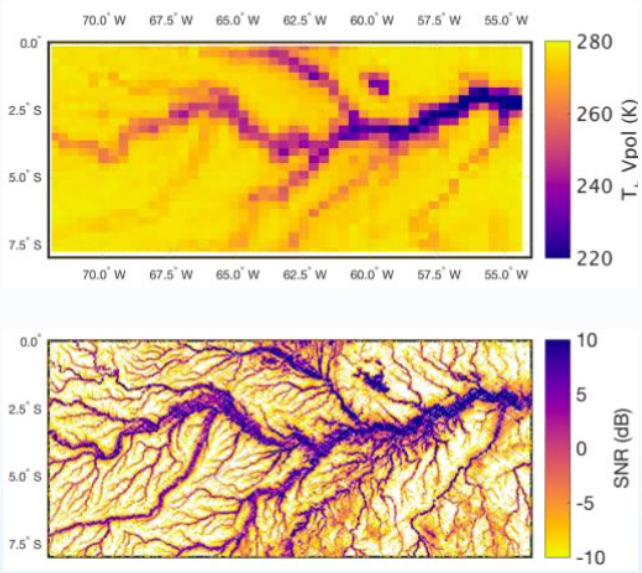
- Wind roughened surface at 7.1 m/s (clean water control case)
- Corresponding surface roughness power spectrum, from which MSS can be computed

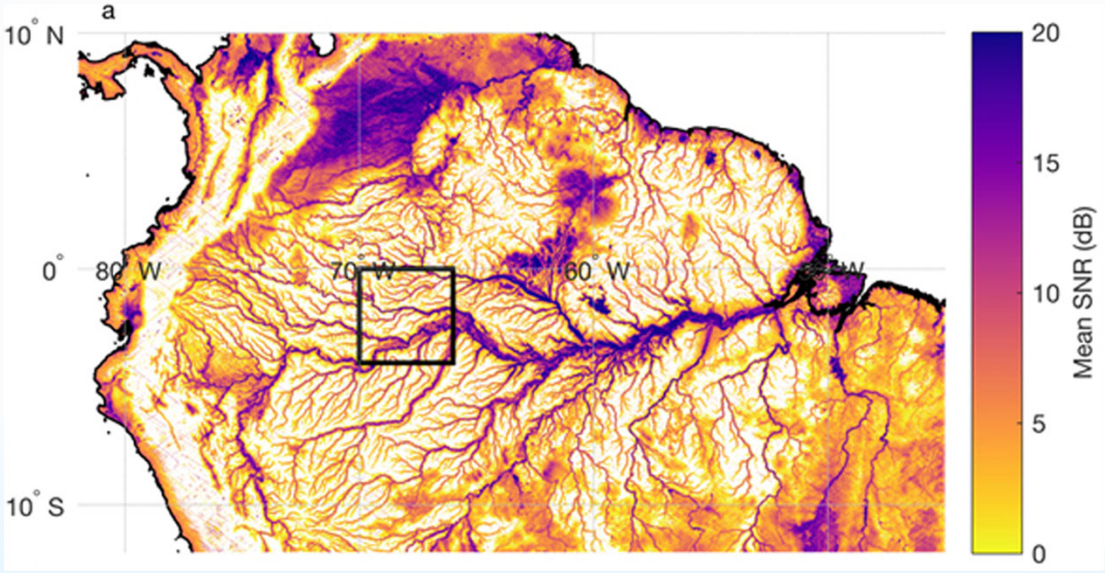




Observations over Inland Waterways

- CYGNSS bistatic radar scattering from rough ocean surfaces is typically incoherent, with 15-25 km spatial resolution (varies with incidence angle)
- Scattering from inland waterways is typically coherent, with 300-1000 m resolution



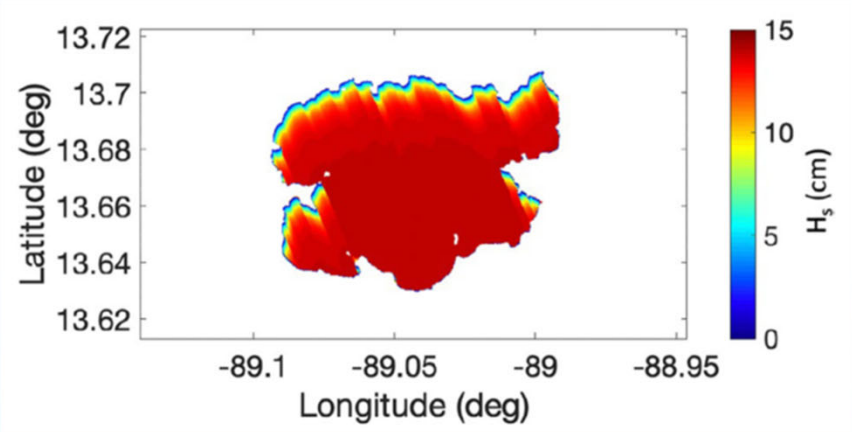


Observations of Wind-roughened Lakes

- Wind roughening of a lake surfaces reduces its scattering cross section without transitioning to incoherent scattering. **High spatial resolution is maintained**.
- Significant wave height can be estimated. Detection of roughness suppression is possible.
- Loria etal. (2021). Towards Wind Vector and Wave Height Retrievals over Inland Waters using CYGNSS. Earth and Space Science, DOI:10.1029/2020EA001506.

Lake Ilopango, El Salvador

Significant wave height retrieved by CYGNSS



Summary and What's Next

- Summary
  - Satellite observations of ocean surface roughness anomalies are highly correlated with ocean microplastic plastic concentration
  - Seasonal fluctuations in concentration noted in major northern and southern hemisphere ocean gyres
  - Episodic outflow bursts noted from major rivers into the ocean
  - Preliminary indications are that extension of method from open ocean to confined rivers may be possible
- What's Next
  - Ocean microplastic data product release scheduled for later in Fall 2021 by NASA PO.DAAC
  - Wave tank experiments to confirm physical mechanism for roughness suppression
  - Extension of method to other satellite radars with higher latitude coverage
- ***THANK YOU!***