Imaging Ocean Microplastic Dynamics from Space

Using the Cyclone Global Navigation Satellite System (CYGNSS)

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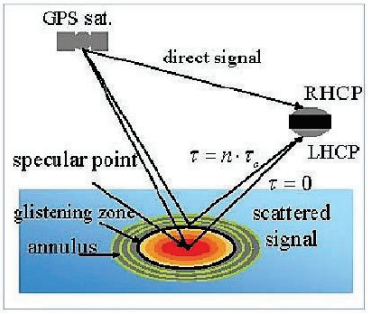
CYGNSS – CYclone Global Navigation Satellite System

- Originally launched in Dec 2016 to aid detection of tropical cyclones
  - Eight micro-satellites, mean revisit time of approx. 7 hours
  - Latitude range of 40˚N – 40˚S

- CYGNSS uses a bistatic radar system
  - Measures direct and reflected GPS signals
  - 19 cm wavelength enables signals to pass through heavy rain



- CYGNSS measures ocean surface roughness
  - Statistical measure of roughness is Mean-Square Slope (MSS)
  - MSS results from wind roughening of the ocean surface, among other factors
  - One day of CYGNSS measurements provides abundant samples of the ocean surface

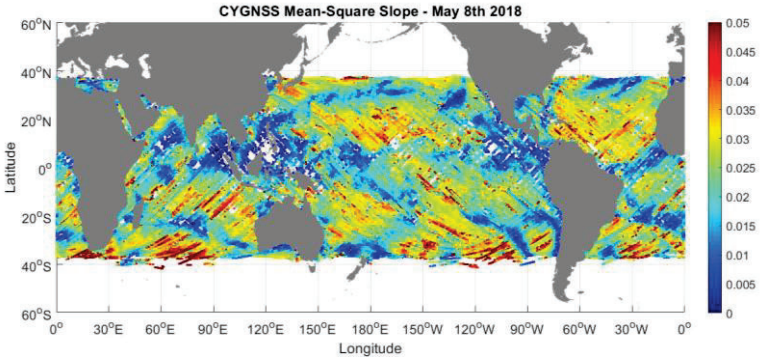


Fig 1. One day of MSS measurements performed by CYGNSS satellite constellation

Current Microplastic Detection Methods – Overview

- Current methods are limited to net-trawling and estimations from modelling based on ocean circulation patterns
- Infrequent samples offer little insight to microplastic dynamics
- Sparse global coverage of net-trawling samples, especially inadequate coverage of Southern Hemisphere and Indian Ocean
- Fig 2. shows the global distribution of plastic sampled via net-trawling
    - Time span: 1971 – 2013
    - standardized with respect to year of study, geographic location, and wind speed

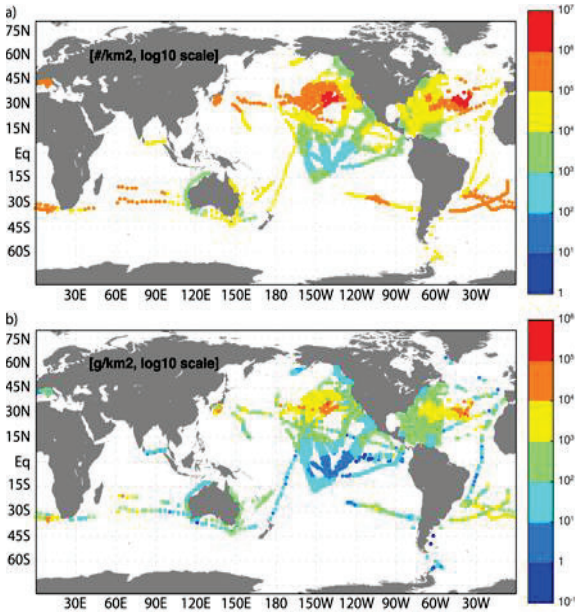


Fig 2. Standardized net trawl dataset (van Sebille, 2015)

Buoyant Plastic Debris Detection – Theory

- Small floating plastic debris (or other surfactants acting as plastic “tracers”) at the sea surface could attenuate wave energy and suppress wind-caused surface roughness
    - Small plastic spherical particles have been shown to dissipate wave energy and arrest waves in finite time in controlled environments (Sutherland, 2017)

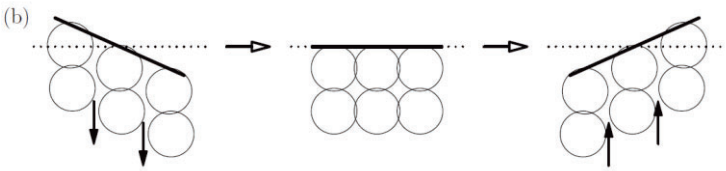


Fig 3. Mechanism for wave energy dissipation between particles (Sutherland, 2017)

CYGNSS Microplastic Imaging Results

- We have found that oceanic gyres, where large concentrations of microplastics accumulate, are associated with reduced roughening for a given wind speed
    - Other wave-attenuating factors such as algal blooms are less abundant in open ocean, implying better detection ability
- The majority of gyres in CYGNSS estimates show remotely detected plastic number density concentrations of $10^5 – 10^6$ #/km^2
    - Consistent with standardized net trawl data (van Sebille, 2015)

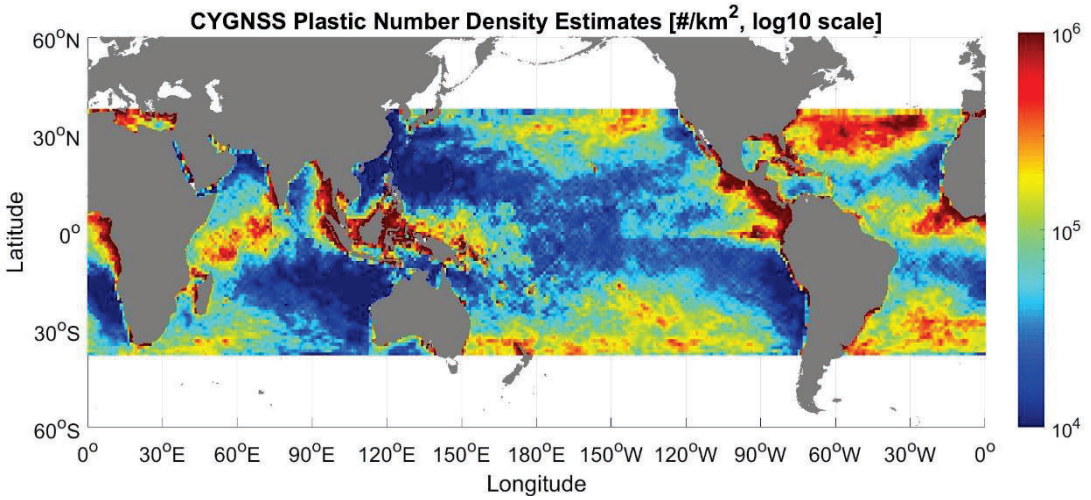


Fig 4. CYGNSS plastic concentration estimates (averaged over one year of satellite data)

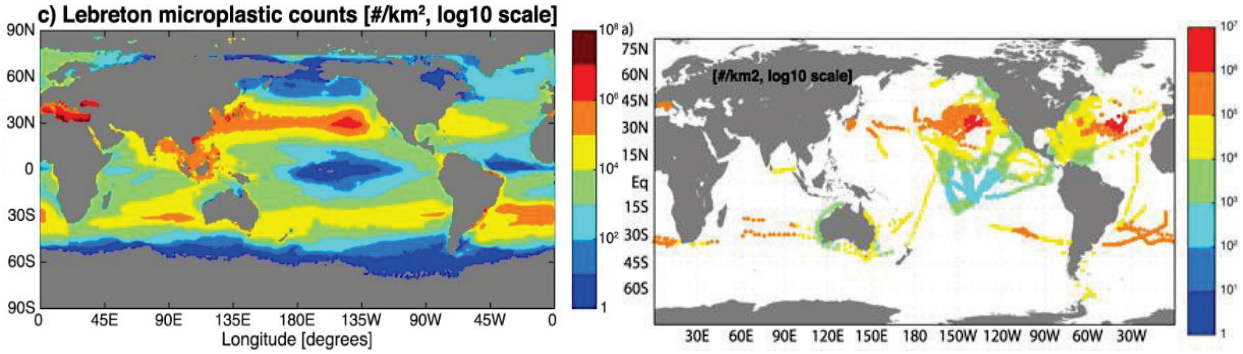


Fig 5. Plastic number density concentrations: (A) model based on Lebreton ocean circulation model, (B) standardized net-trawl dataset (van Sebille, 2015)

- CYGNSS data and Lebreton model disagree the most in the Southern Hemisphere and Indian Ocean
    - CYGNSS detection may be picking up heavier surfactant concentrations in Southern Hemisphere
    - Lack of data in the South Pacific and Indian Ocean due to sparse net-trawl sampling leave standard concentrations in these regions unestablished
- Discrepancies between CYGNSS-derived, Net Trawl-measured, and Global Circulation-modeled concentrations need to be evaluated and explained

References

Sutherland, B. R., & Balmforth, N. J. (2019). Damping of surface waves by floating particles. *Physical Review Fluids*, *4*(1). doi: 10.1103/physrevfluids.4.014804

Van Sebille, et al. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*, 10(12). doi: 10.1088/1748-9326/10/12/124006