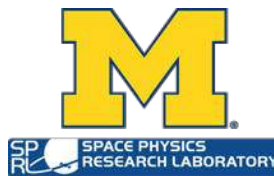


International Ocean Vector Wind Science Team Meeting
Salt Lake City, UT
29-31 May 2024

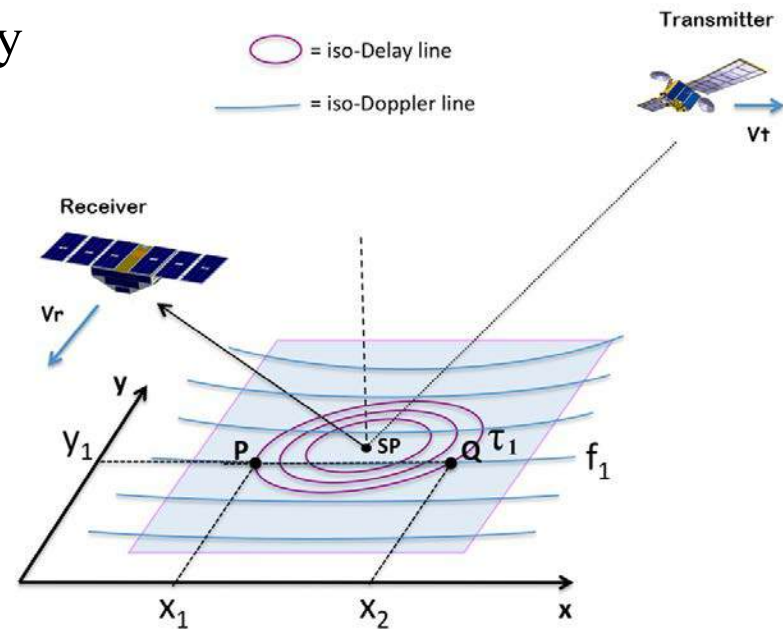
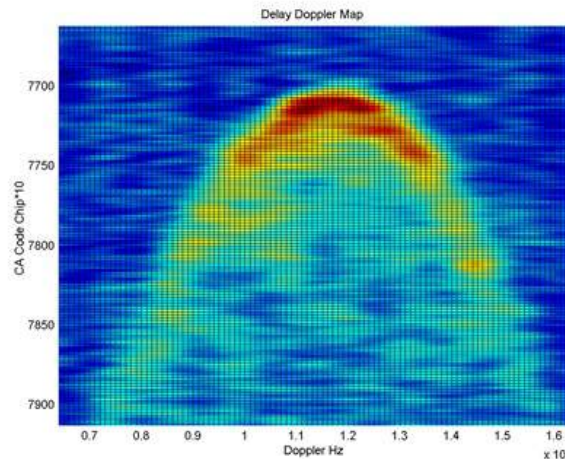
Review of GNSS-R Winds

Chris Ruf
University of Michigan



GNSS-R Measurement Methodology

- Global Navigation Satellite System (GNSS) is the generic name for GPS, Galileo, BeiDou, ... navigation satellites, which operate at L-Band (1.2-1.6 GHz)
- GNSS Reflectometry (GNSS-R) is a remote sensing method which measures GNSS signals scattered in the forward (specular) direction from the Earth surface. It is essentially an L-Band bistatic radar.
- GNSS-R measurement of the Delay Doppler Map (DDM)



Relationship between GNSS-R Measurement and Ocean Surface Conditions

- Bistatic link equation gives scattered power received as a function of ocean surface scattering cross section, σ_0

$$P_g^R(\tau, f) = \frac{\lambda^2}{(4\pi)^3} \iint_A \frac{(P_T G_T) \sigma_0 G_R}{(R_{x,y}^R)^2 (R_{x,y}^T)^2 L_{a1} L_{a2}} \Lambda_{x,y}^2(\tau) S_{x,y}^2(f) dx dy$$

- Scattering cross section is related to the mean square slope of surface height (R is Fresnel reflection coefficient)

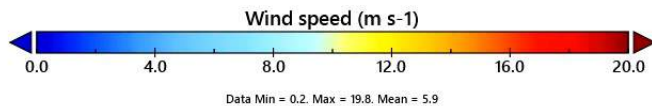
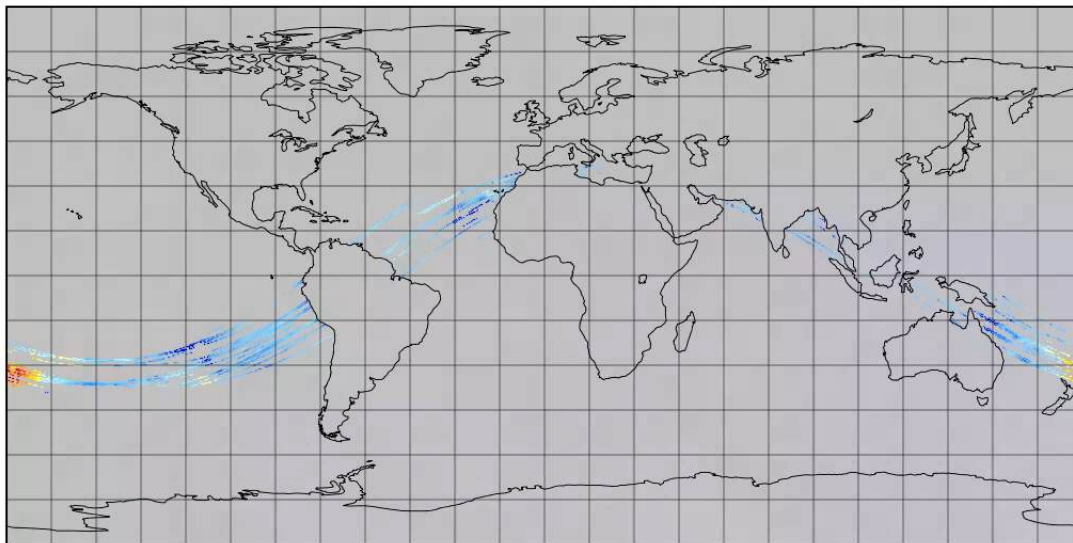
$$\sigma_0 = \frac{|R|^2}{mss}$$

- MSS is the second moment of the surface height spectrum

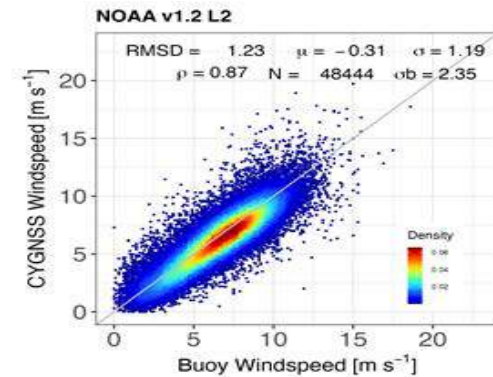
$$mss = \iint_{\kappa < \kappa_{\text{cutoff}}} \kappa^2 \Psi(\vec{\kappa}) d^2 \kappa$$

Examples of GNSS-R CYGNSS Wind Speed

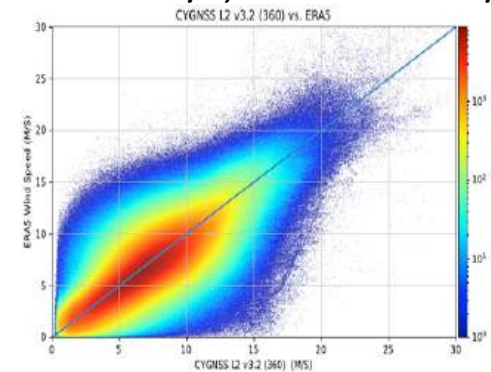
CYGNSS Level 3 FDS Wind speed (16 JAN 2022)
Reference time of file: 2022-01-16 00:30



Buoy comparison to NOAA v1.2
RMSD = 1.2 m/s, Bias = -0.3 m/s



ERA5 comparison to Project v3.2
RMSD = 1.7 m/s, Bias = -0.2 m/s



Practical GNSS-R Considerations and Differences from Scatterometry

- Scatterometers are primarily sensitive to the capillary wave portion of the roughness spectrum at the Bragg resonant wavelength of the backscattered microwave signal. Capillary waves are closely coupled to the local wind speed at the time of the radar observation.
- GNSS-R is sensitive to the integrated roughness spectrum over both capillary and longer swell waves
 - In fully developed seas, the shorter and longer portions of the roughness spectrum are in equilibrium and both GNSS-R and scatterometers are sensitive to the local wind
 - In young (underdeveloped) seas, GNSS-R is sensitive to longer portions of the roughness spectrum that are not forced by the local wind at the time of the observation, and a correction for this sensitivity is necessary (typically using ancillary SWH information from a model)
- GNSS-R is very weakly sensitive to wind direction
 - Poor ability to detect wind direction
 - Little dependence of wind speed error on wind direction