Detection and Localization of Terrestrial L-Band RFI with GNSS Receivers

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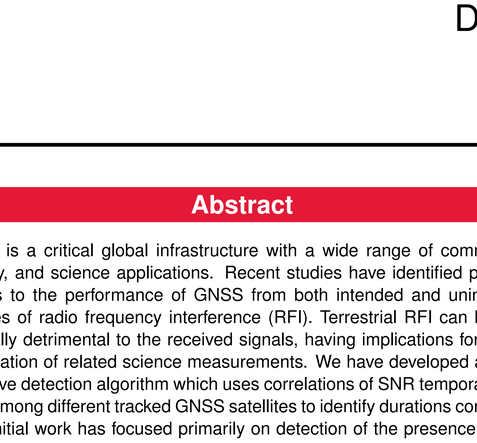
Abstract

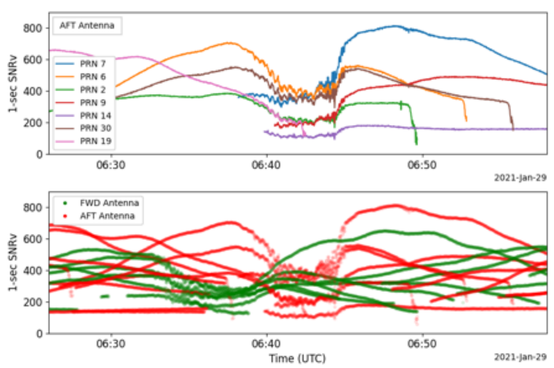
GNSS is a critical global infrastructure with a wide range of commercial, military, and science applications. Recent studies have identified potential threats to the performance of GNSS from both intended and unintended sources of radio frequency interference (RFI). Terrestrial RFI can be substantially detrimental to the received signals, having implications for the interpretation of related science measurements. We have developed a highly sensitive detection algorithm which uses correlations of SNR temporal variations among different tracked GNSS satellites to identify durations containing RFI. Initial work has focused primarily on detection of the presence of RFI, and uses the receiver's position to record the location of detection events. With this minimal amount of information, an inter-mission analysis using 20 years of data creates a unique record of global RFI with the potential for a) rigorously identifying the presence of interfering signals during science measurements, b) coarse geolocation of RFI sources, and c) characterizing the nature of the transmitted signal to better identify intent. Preliminary analysis has shown correlation with regional conflicts and other geopolitical events.

Effects of RFI on GNSS SNR_V

Terrestrial RFI can produce SNR variations similar to ionospheric scintillation, confusing interpretation of the measurement.

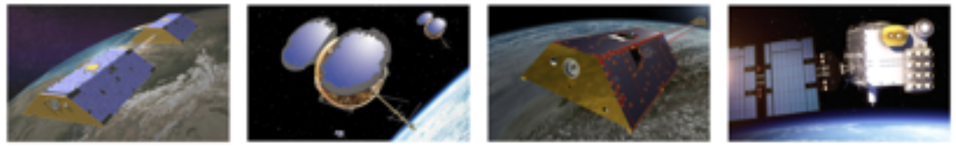


RFI is observed to degrade SNR_V of tracked signals, often reducing the tracked signal strength by a substantial fraction (plots from COSMIC-2).

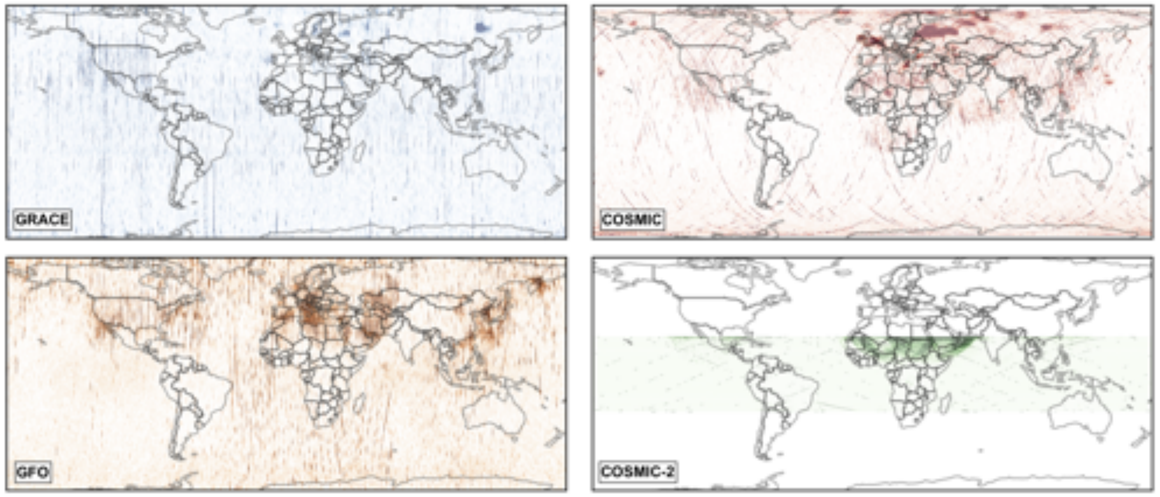


RFI appears as correlated degradation on tracks from the same antenna.

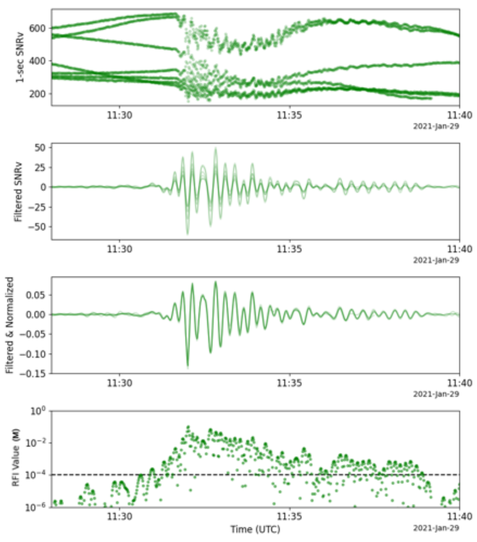
TriG/Blackjack Receiver Mission Characteristics



Mission	GRACE	COSMIC	GRACE-FO	COSMIC-2
Launch	March 2002	April 2006	May 2018	June 2019
End of Mission	November, 2017	September, 2018	Operational	Operational
Inclination	89°	72°	89°	24°
Antenna Boresight	Zenith	FWD/ AFT 15° above horizon	Zenith	FWD/ AFT 15° above horizon
Number of Satellites	2	6	2	6
RFI Sensitivity	Lowest	High	Low	Highest



RFI Detection Process

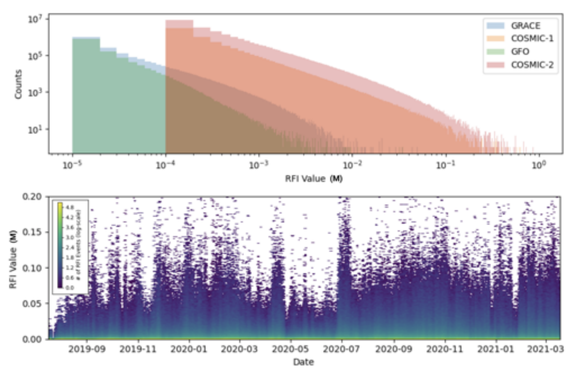


Technique uses the time varying nature of RFI within a certain periodicity range, correlated across tracks, for detection. Above from COSMIC-2.

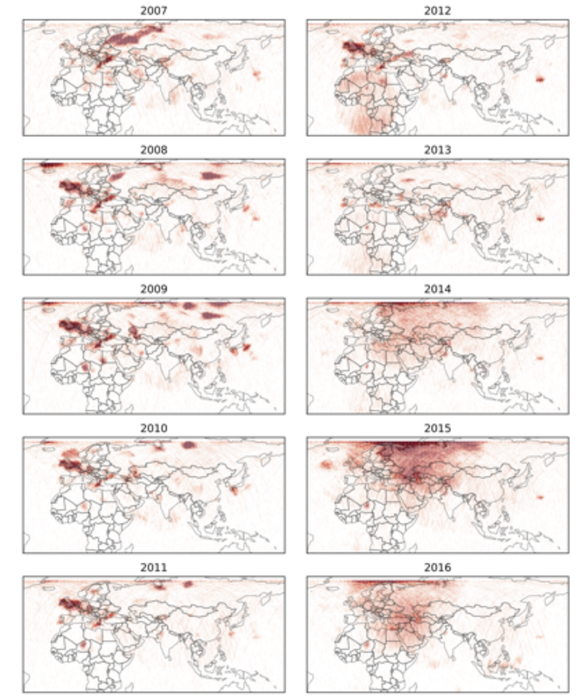
$$\mathrm{SNR_P} = \frac{S}{N+R} = \frac{S}{N+\tilde{R}+\tilde{R}} \qquad \frac{\tilde{\mathrm{SNR}}_\mathrm{V}}{\mathrm{SNR_V}} = \frac{\sqrt{N+R}}{N+R}\sqrt{\tilde{R}}$$

$$\frac{\tilde{\mathrm{SNR}}_\mathrm{P}}{\mathrm{SNR_P}} = \frac{\frac{S}{(N+R)^2}}{\frac{S}{N+R}}\tilde{R} = \frac{N+R}{(N+R)^2}\tilde{R} \qquad M(t) = \sum_{(i,j)}^{N}\sum_{\tau=0}^{T}\frac{\tilde{\mathrm{SNR}}_{\mathrm{V},i}(t)}{\mathrm{SNR}_{\mathrm{V},i}(t)}\frac{\tilde{\mathrm{SNR}}_{\mathrm{V},j}(t-\tau)}{\mathrm{SNR}_{\mathrm{V},j}(t-\tau)}$$

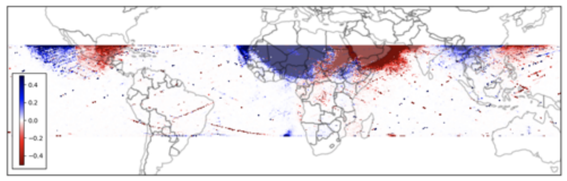
Distribution of RFI



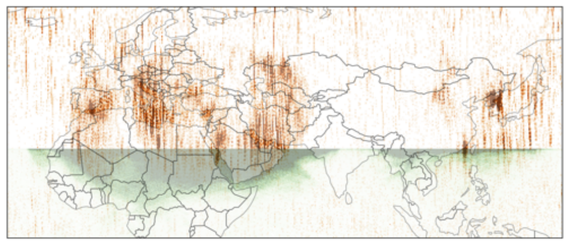
The RFI metric, $M(t)$, spans several orders of magnitude, displaying sensitivity to weak RFI. Time variation indicates changes in global RFI environment. Upper plots use full datasets from indicated missions, lower plot from COSMIC-2 using a sliding 60-day window.



Geographically binning values for different windows of time shows dynamics over certain regions of the planet, shown with 10 years of COSMIC data.



Differencing RFI measured between ram/anti-ram antenna on a COSMIC-2 spacecraft provides better localization of the source.



Combining detections between missions provides a more detailed picture of regional RFI environments, data from GFO in red, COSMIC-2 in green.

Next Steps

This preliminary work has explored the effects of RFI on L1 CA GPS signals collected by POD antennas. Expanding this to other signals, as well as using beam-steered RO antennas for improved RFI source localization, will be attempted. The application of this analysis to upcoming and additional past missions will also be performed to enhance the global RFI map. We will also study an interpretation of these RFI measurements to enhance related science measurements.

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