EVALUATING THE SUITABILITY OF INTERNATIONAL GNSS SERVICE (IGS) STATIONS FOR GNSS-IR VEGETATION CONTENT ESTIMATION.

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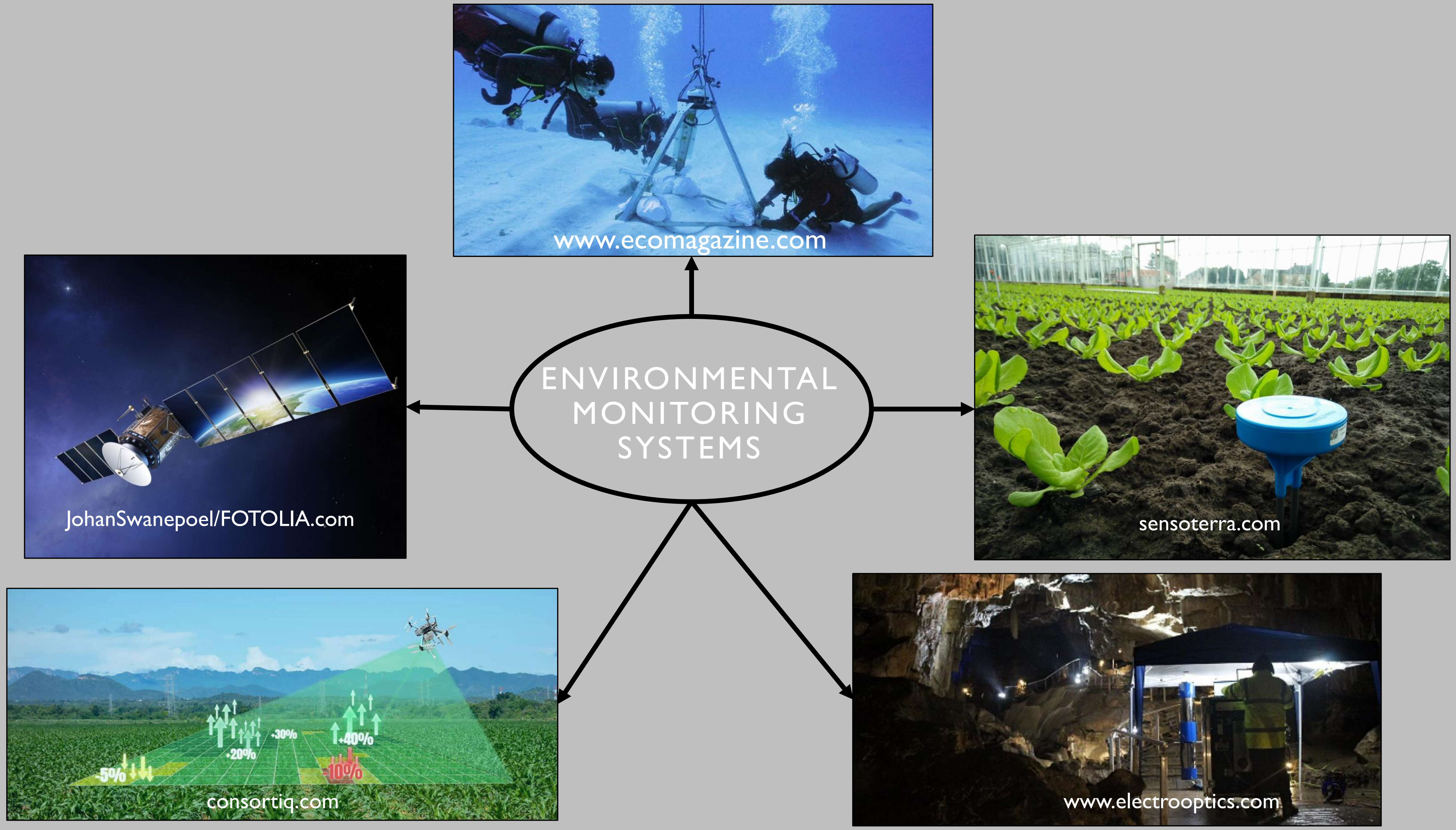
30 Years of IGS, 4th July 2024

CLIMATE CHANGE AND GLOBAL WARMING



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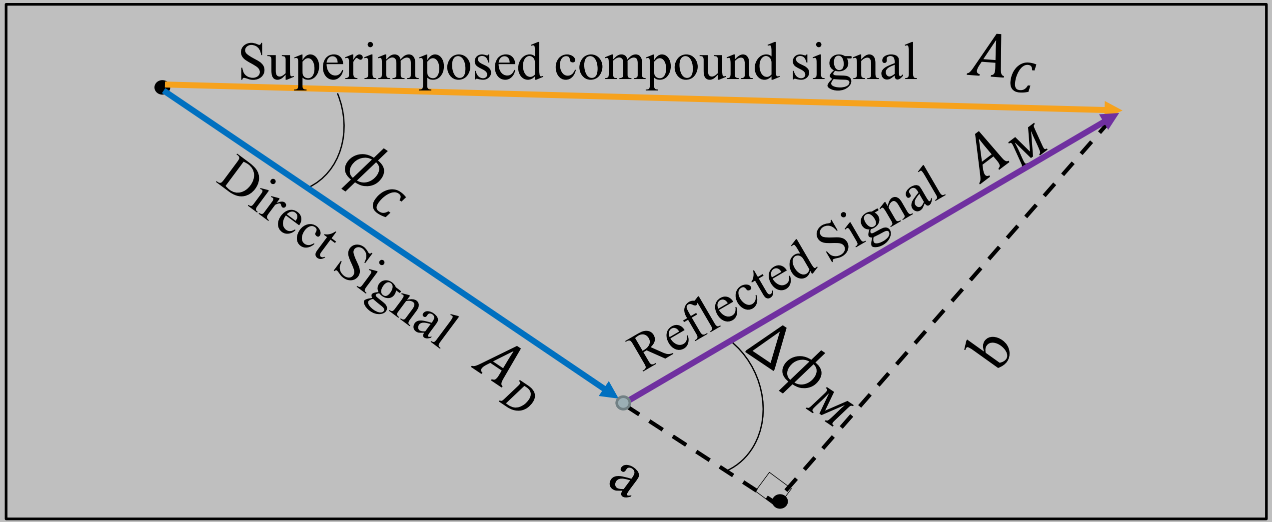
GNSS-IR

Global Navigation Satellite System – Interferometric Reflectometry

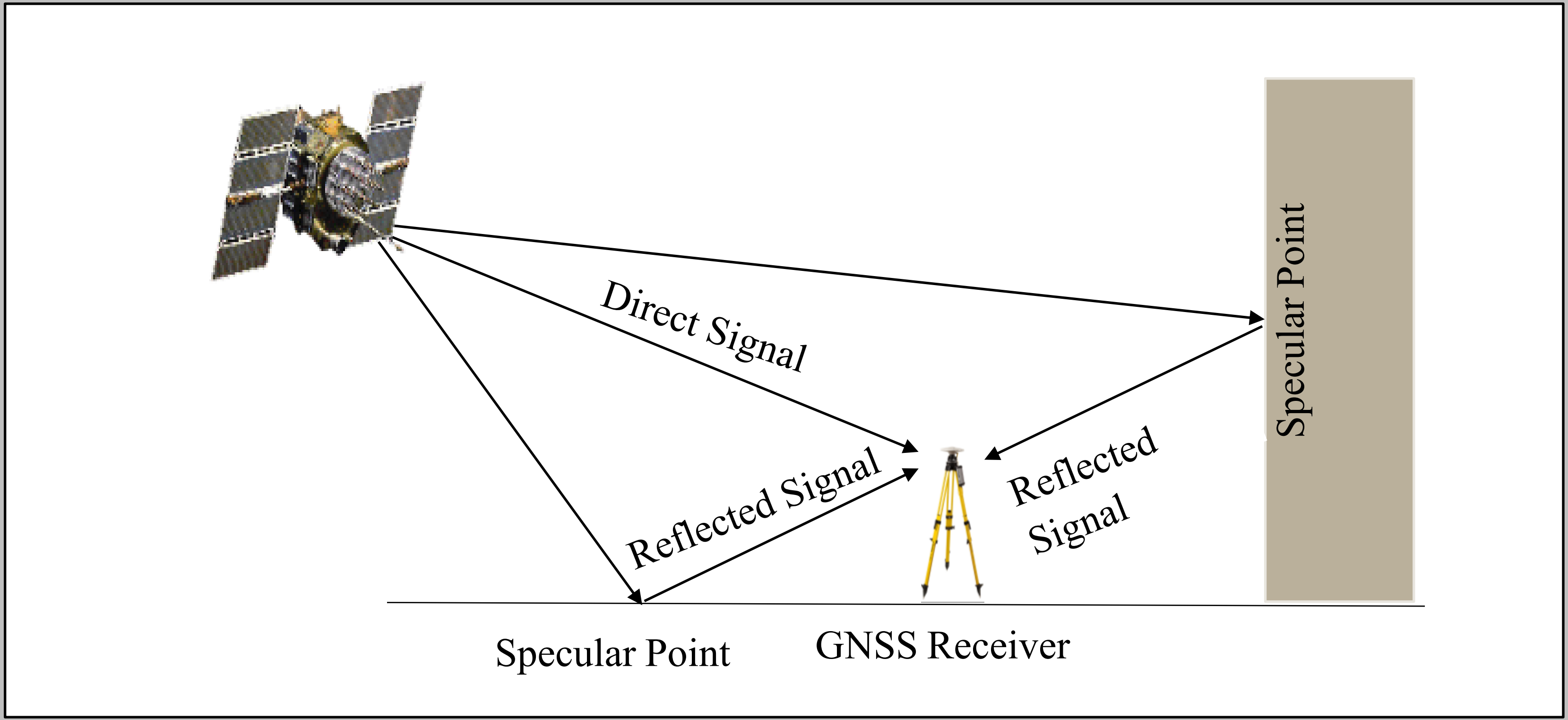
A technique which analyzes changes in the direct and reflected signals by looking at the interference pattern of the two.



GNSS-IR

There are five parameters that characterize a multipath signal relative to the direct signal:

1. **Relative amplitude**
2. Relative delay
3. Relative phase
4. Relative phase rate
5. Relative polarization



REFLECTED AMPLITUDE ESTIMATION

Vegetation Content: The amplitude of the reflected signal is affected by the moisture of the vegetation growing at the specular point. Information about the vegetation content is important to monitor the health of farmlands, assessing flood effects or in many applications where filtering out vegetation effects is important.

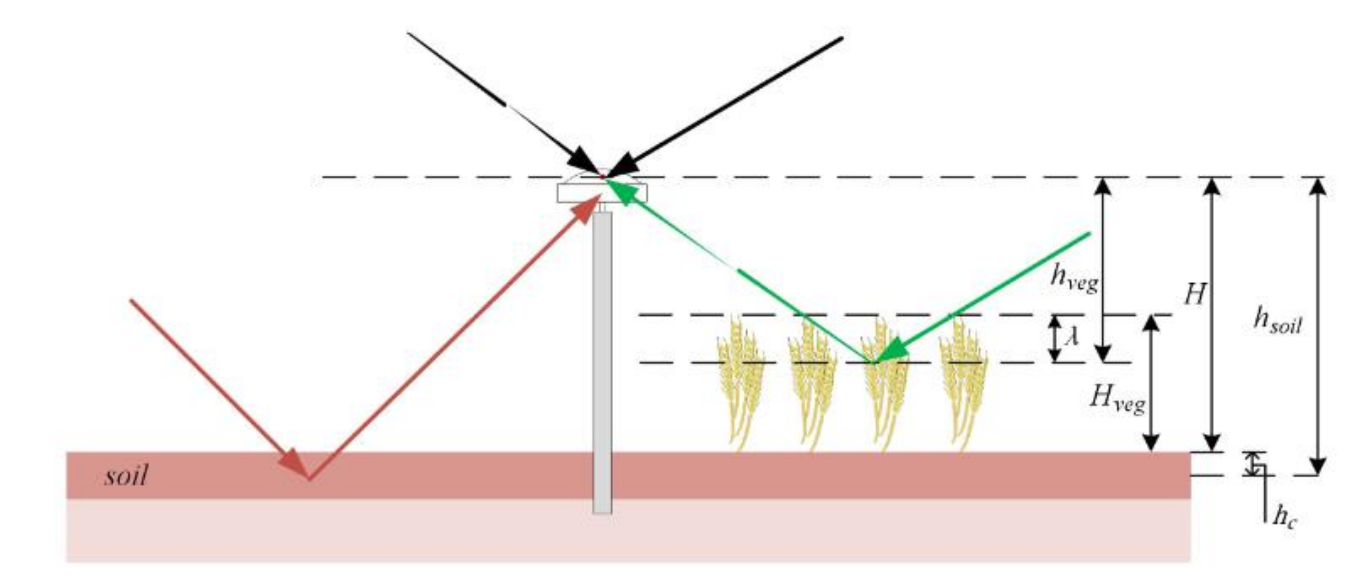


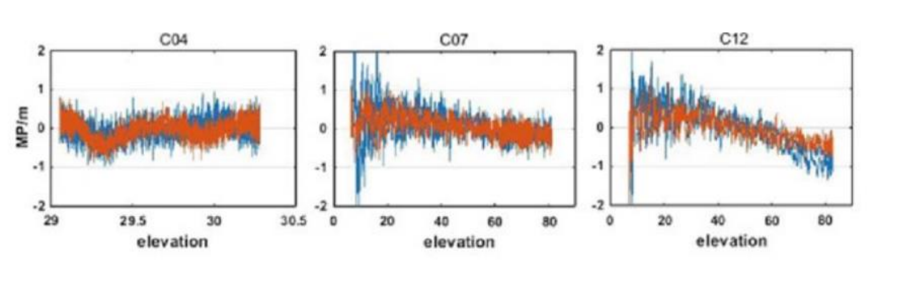
Image: Zhang et al., 2021 (Remote Sensing, 13(13), p.2442.)

GNSS-IR METHOD WORKFLOW

STEP 1: GNSS data collection and filtering out data with elevation angles outside the [5,35]° range.

STEP 2: Acquisition of the SNR (Signal-to-Noise ratio) of the reflected signal.

STEP 3: Adjusting the value of the amplitude of the reflected signal using the SNR observations.



Graph: Wang et al., 2017

REFLECTED AMPLITUDE ESTIMATION

We adjust the phase ϕ (and amplitude A) shift values using Least Squares for the following model:

$$SNR_{indirect} = A \times \cos\left(\frac{4\pi H_o}{\lambda}\sin(E) + \phi\right)$$

where H_o is the reflector height (usually equal to antenna height since signals don't penetrate the ground any deeper than a few centimeters), E is the satellite elevation angle, and λ is the GPS wavelength.

For each track separately

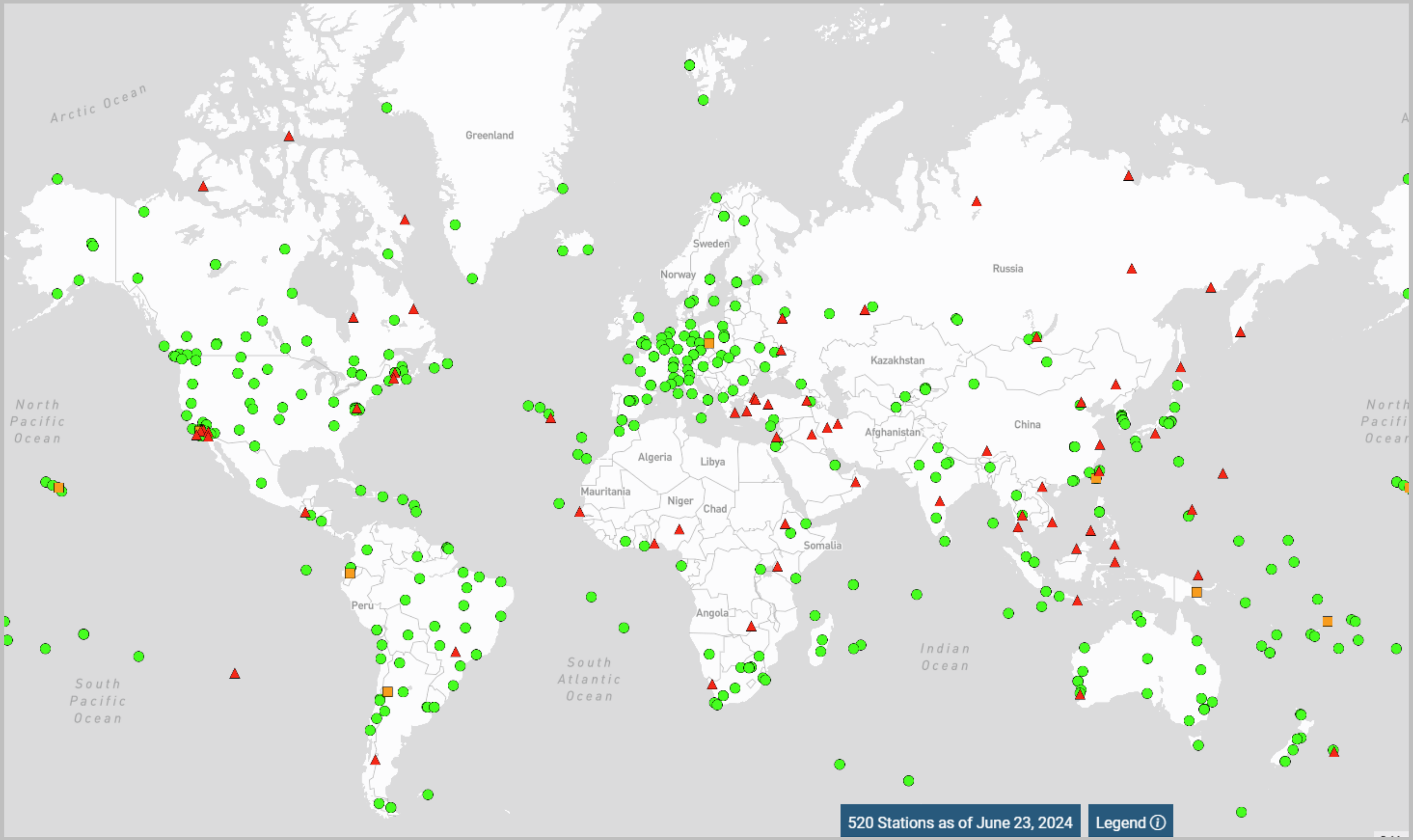
Daily

CHECKING INTERNATIONAL GNSS SERVICE (IGS) STATION SUITABILITY

We downloaded data and Log Files for each station.

We were able to check 489 out of 514 stations, as of January 2024 (95%).

All 520 Stations Belonging to the IGS Network (June 2024)



LEGEND

- Data received within the last 10 days.
- Data received within the last 30 days.
- No data for over 30 days.

[Source: IGS Network]

CHECKING INTERNATIONAL GNSS SERVICE (IGS) STATION SUITABILITY POTENTIAL

The following criteria were checked:

Condition 1

The antenna's height is roughly at least 1.5 [m]. Some exceptions for antennae at least 1.3 [m] tall placed in open fields were made.

Condition 2

The antenna is not placed on top of a building or is placed on a small building in an open field with no obstructions.

Condition 3

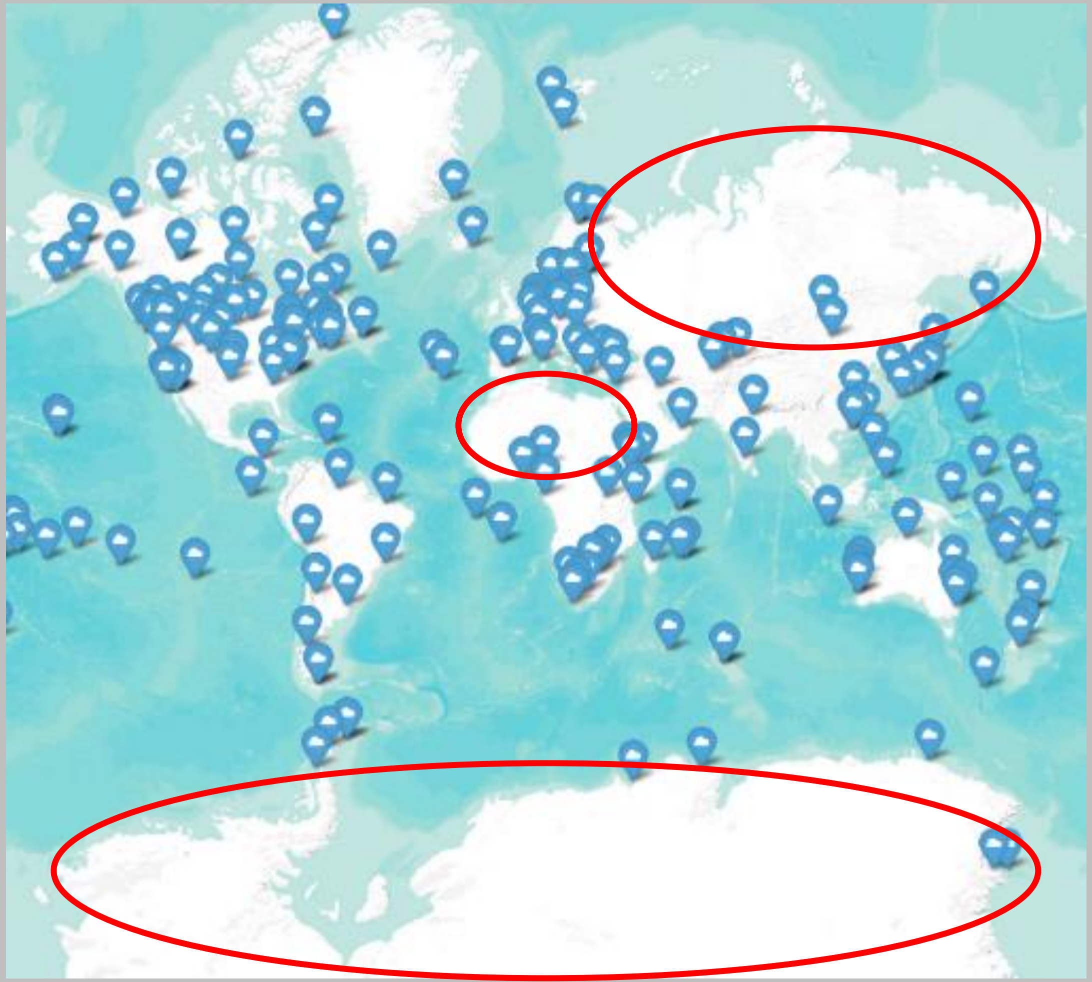
There are no significant obstructions around the antenna, such as large buildings or tall trees. If there are only small obstructions from a particular direction around it, the station is still considered for estimations, noting the need to filter out the signals from that direction.

Condition 4

The antenna is placed in a field of soil, sand, grass, natural rocks, or by a large water source. The topography type for each antenna is recorded.

CHECKING INTERNATIONAL GNSS SERVICE (IGS) STATION SUITABILITY

211 stations (43%) were found potentially suitable for GNSS-R environmental estimation.



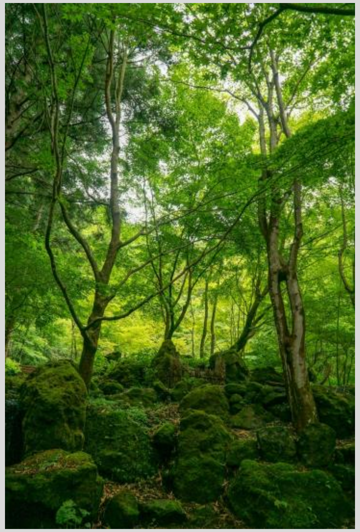
There is good global coverage!
But some areas are lacking.

Snow Depth

Ice Thickness

Soil Moisture

Vegetation Content



Desertification

Sea Level Altimetry

IGS STATION CATEGORIZATION FOR ENVIRONMENTAL PARAMETER ESTIMATION

IGS STATION CATEGORIZATION FOR ENVIRONMENTAL PARAMETER ESTIMATION

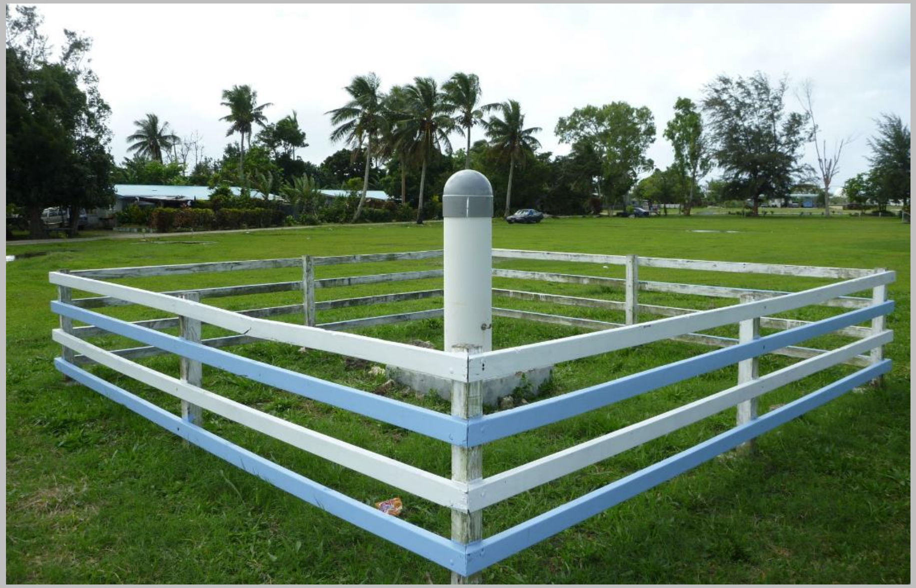
Parameter	Number of Potentially Suitable Stations	Percentage out of 489 Stations
Soil Moisture	147	30.1%
Sea Level Altimetry	31	6.3%
Desertification	69	14.1%
Vegetation Content	161	32.9%
Snow Depth	70	14.3%
Ice Thickness	19	3.9%

IGS STATION CATEGORIZATION FOR ENVIRONMENTAL PARAMETER ESTIMATION

Vegetation Content

The IRKJ Station in Irkutsk, Russia.

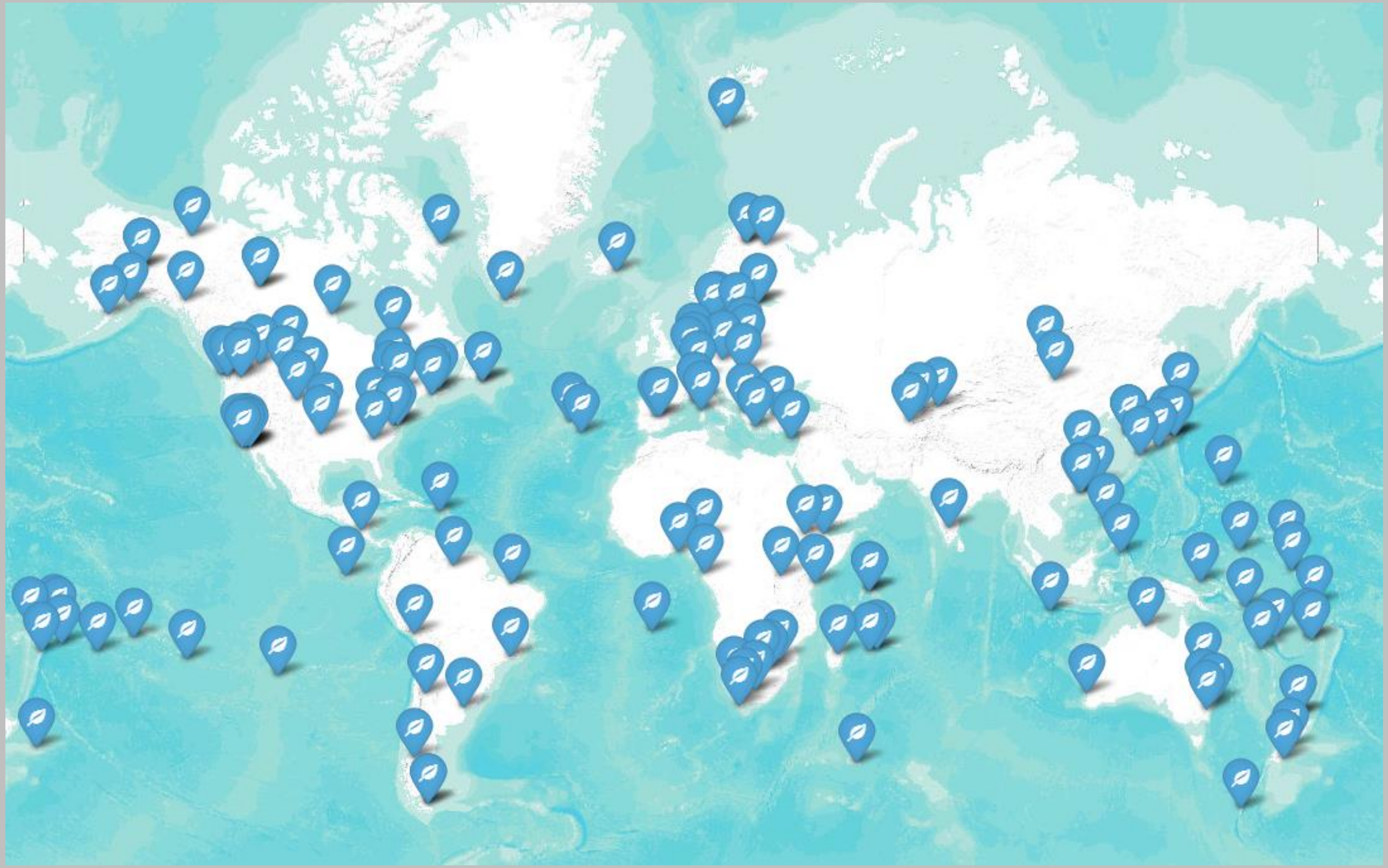
The BREW Station in Brewster, Washington, USA.



The TONG Station in Tonga.

CHECKING INTERNATIONAL GNSS SERVICE (IGS) STATION SUITABILITY

IGS Stations Potentially Suitable for Vegetation Content Estimation– 161 Stations



VEGETATION CONTENT EXPERIMENT

<u>Motivation:</u>

DUND Station, Dunedin, New Zealand

- Test the potential of IGS GNSS stations in environmental parameter estimation via GNSS-IR.

- Estimate Vegetation Content using GNSS-IR and compare its results with established remote sensing techniques (NDVI).

- <u>Experiment Time Frame:</u> 2013-2023

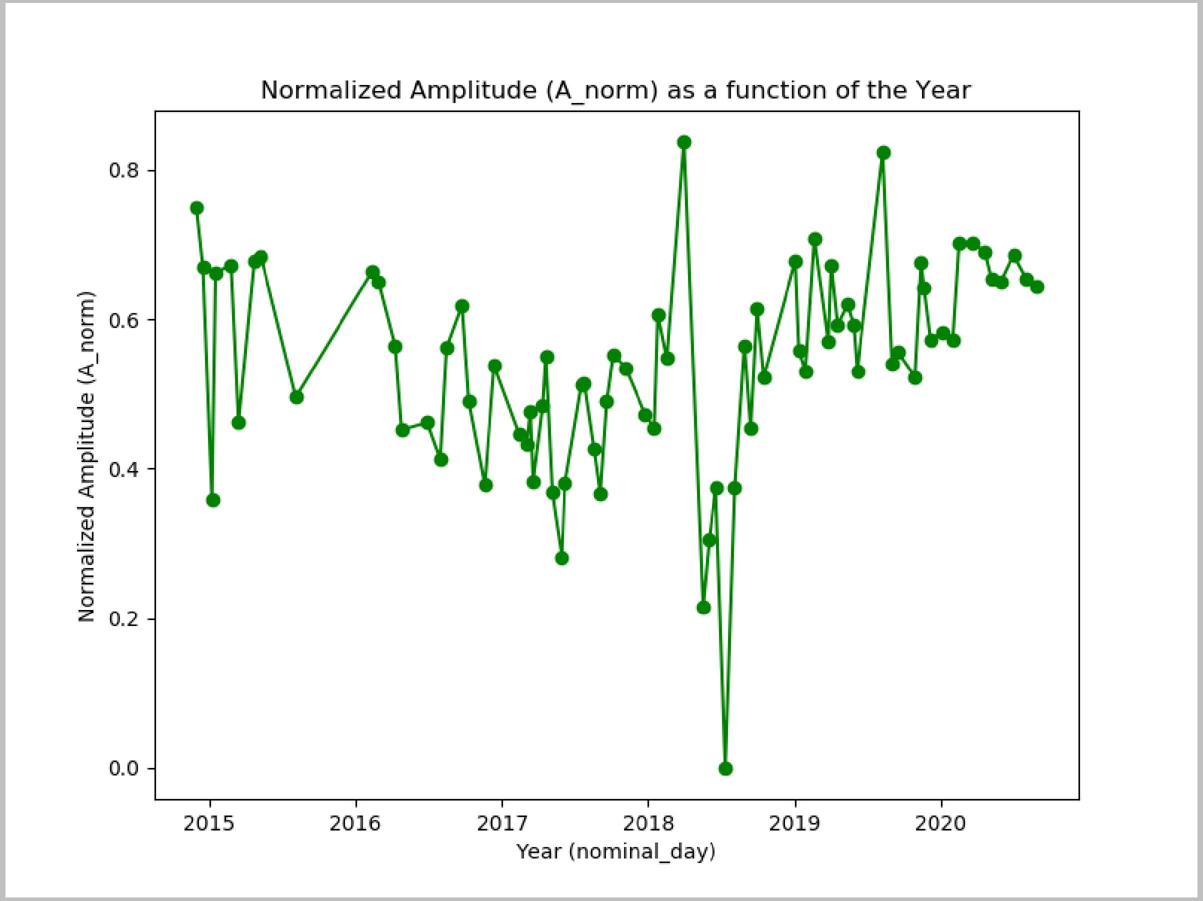
VEGETATION CONTENT EXPERIMENT

Data Sources:

Data	Source
O-Files and N-Files	The NASA site, urs.earthdata.nasa.gov.
GNSS antenna height	Antenna log files (IGS Site)
Spectral remote sensing images	Landsat 8-9 Images (Band 4 and Band 5 Surface Reflectance Data) via Google Earth Engine

BILL Station, California, USA

GNSS-IR RESULTS – MCHL STATION, QUEENSLAND, AUSTRALIA



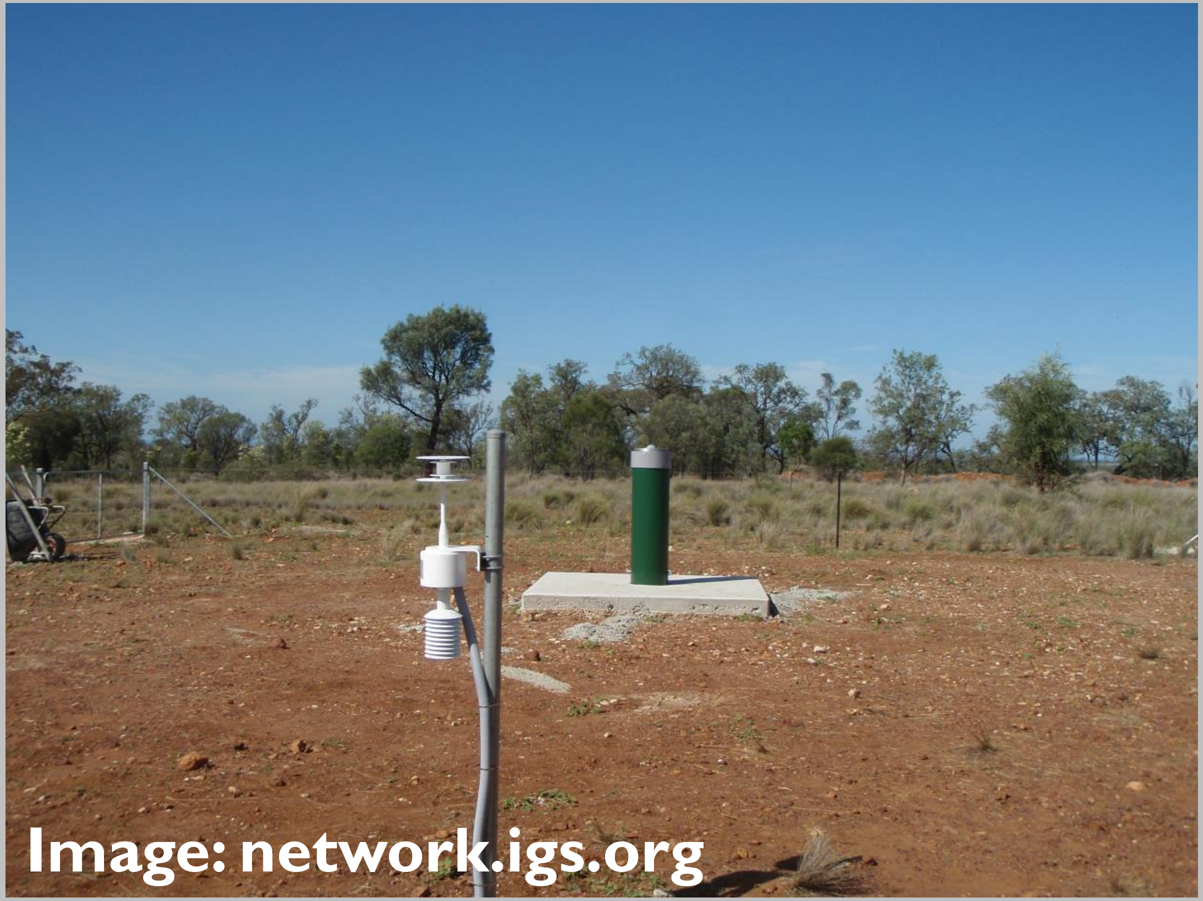
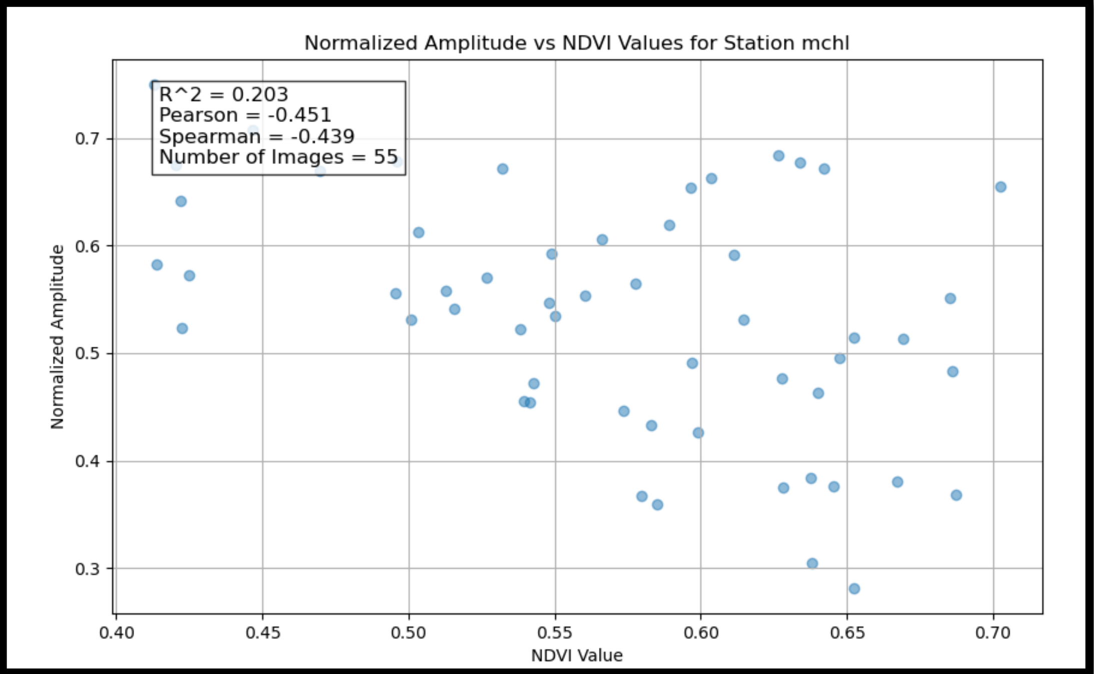
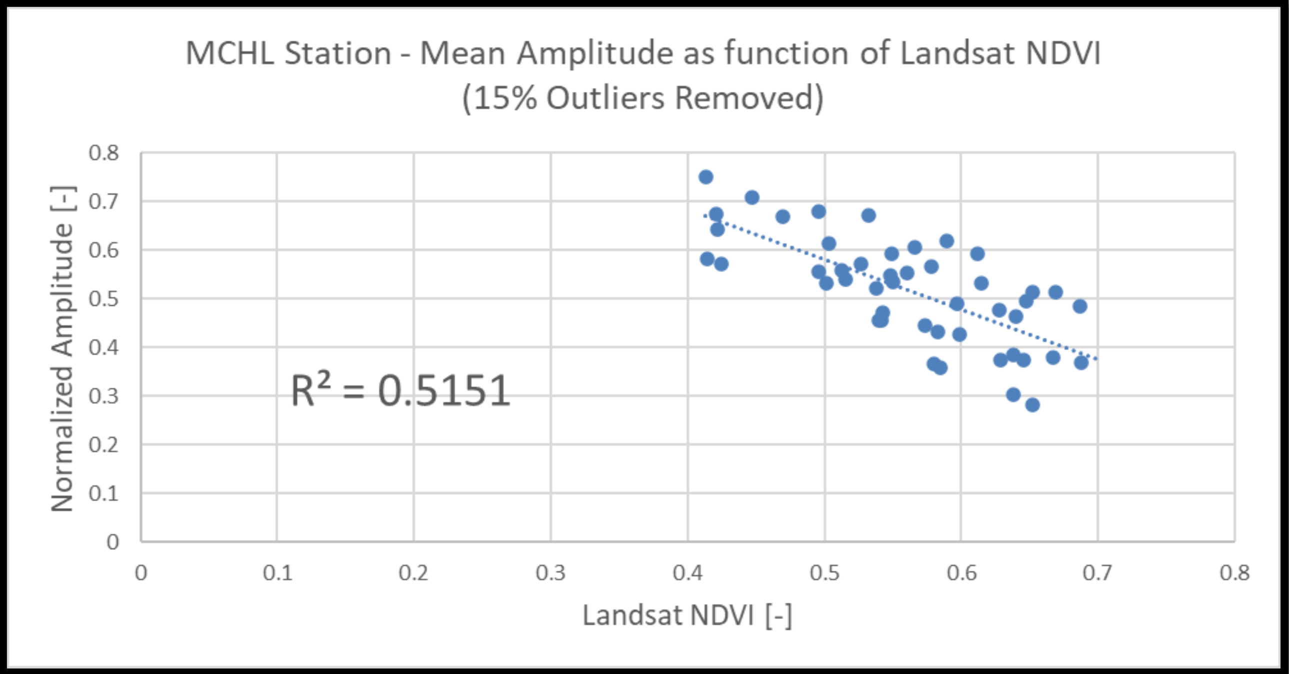


Image: network.igs.org

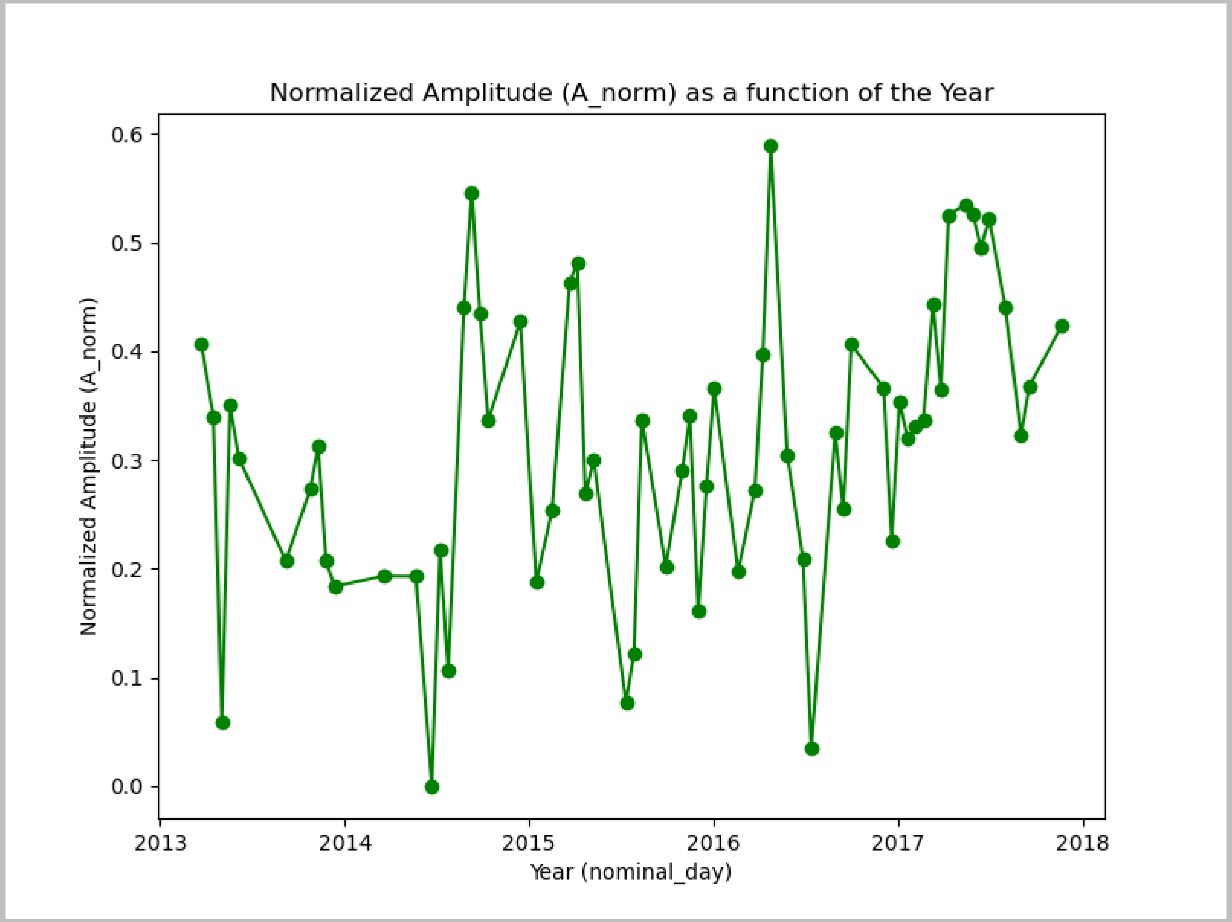
GNSS-IR AND NDVI RESULTS – MCHL STATION, QUEENSLAND, AUSTRALIA

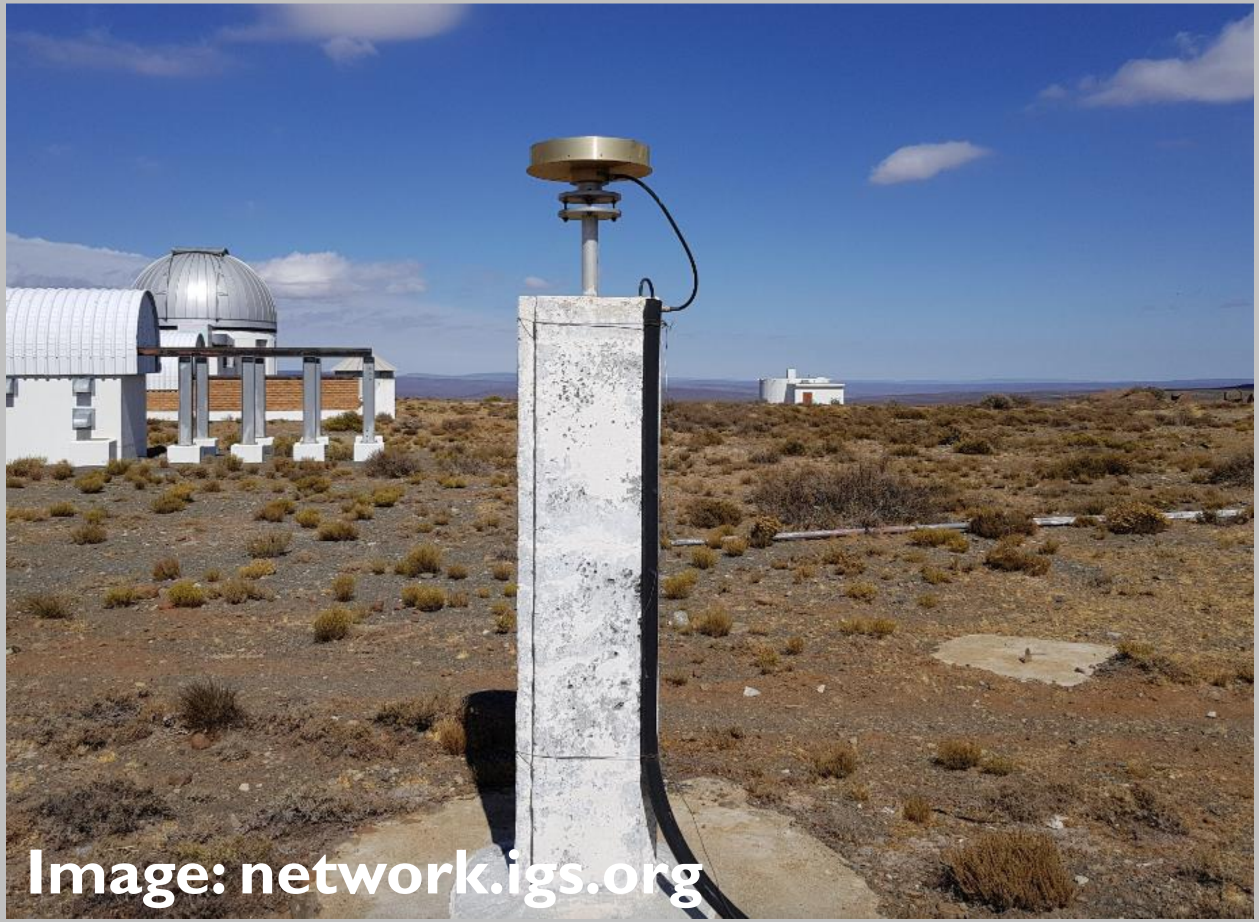




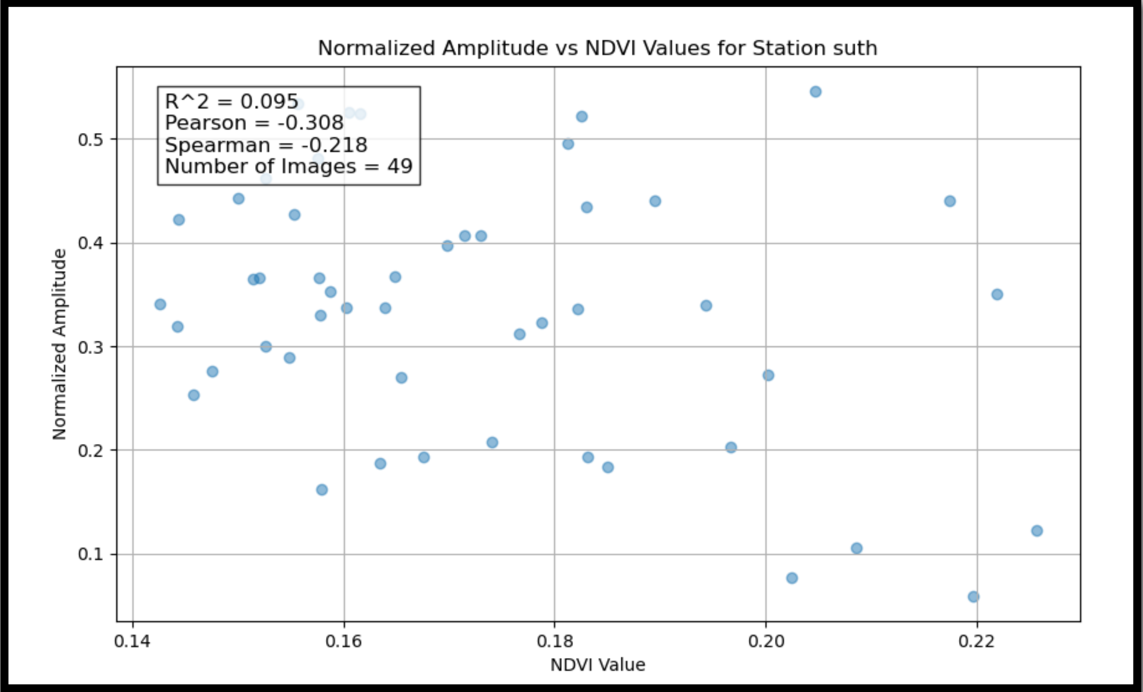
The R^2 correlation coefficient (0.51 [−]) and the Pearson (−0.45) and Spearman(−0.44) coeffcieints all indicate a moderately strong relationship between the normalized amplitude and the NDVI.

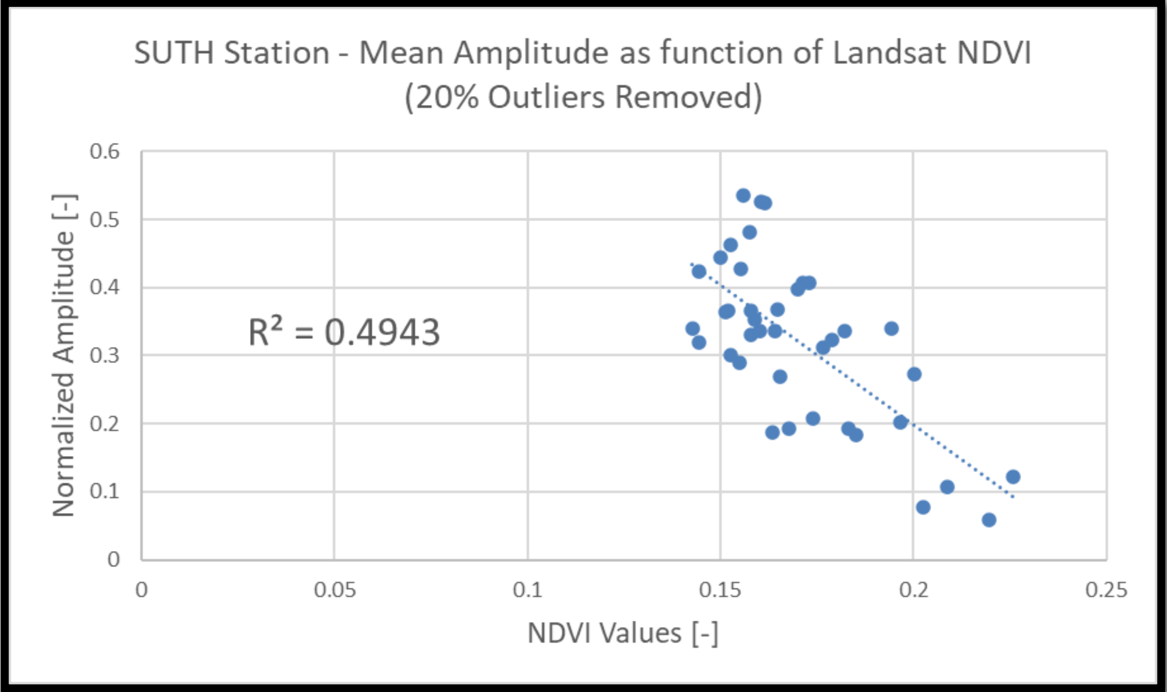
GNSS-IR RESULTS – SUTH STATION, SUTHERLAND, SOUTH AFRICA



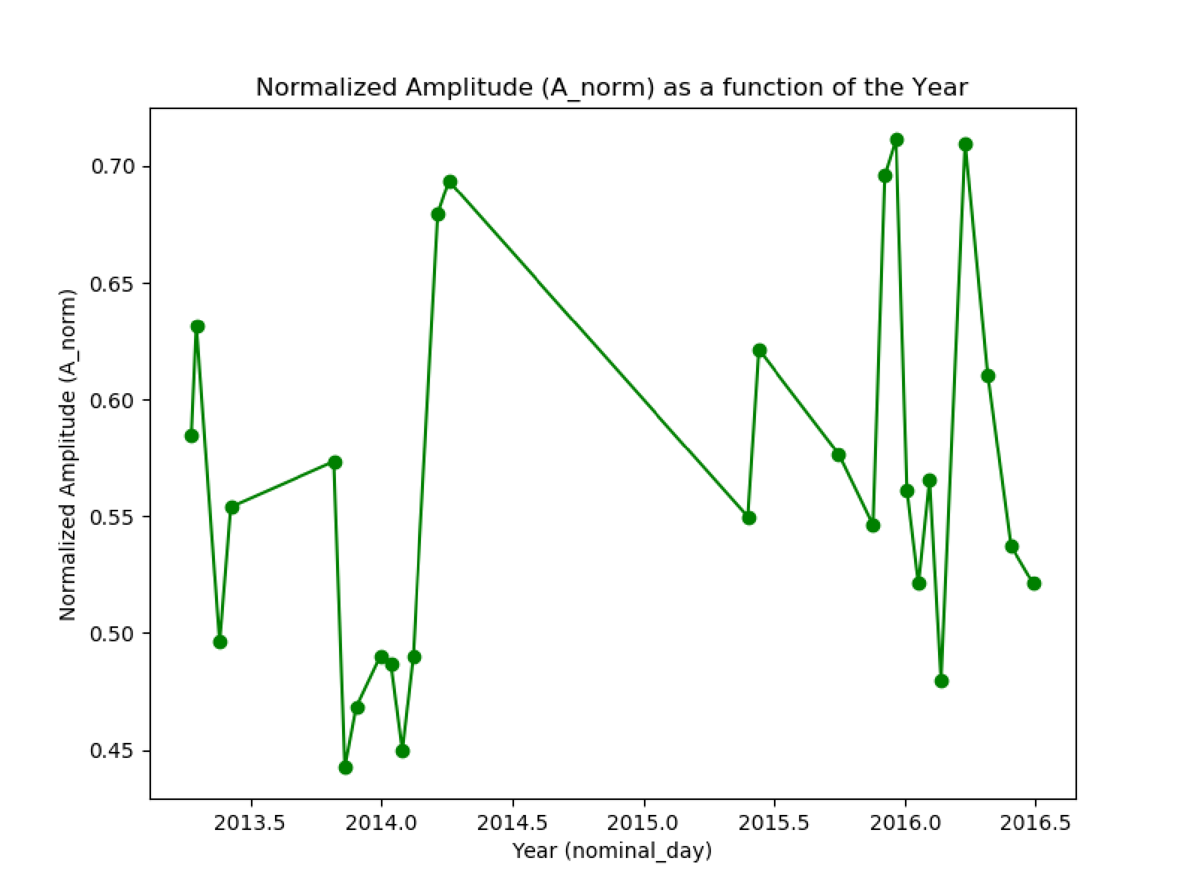


GNSS-IR AND NDVI RESULTS – SUTH STATION, SUTHERLAND, SOUTH AFRICA

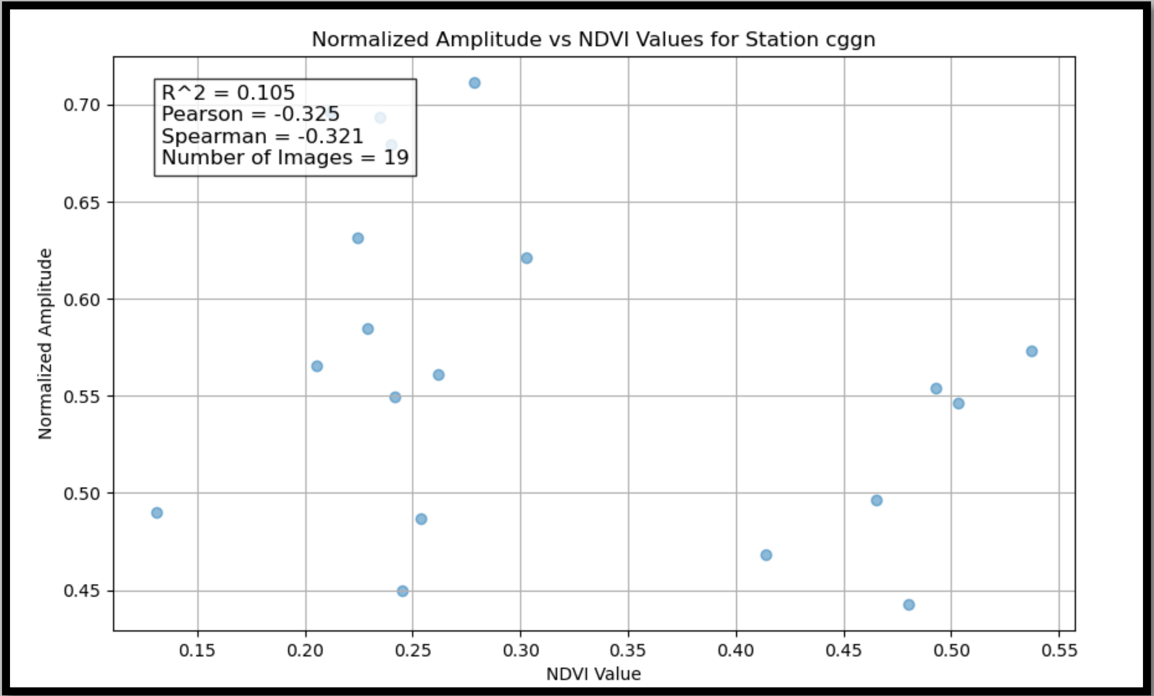


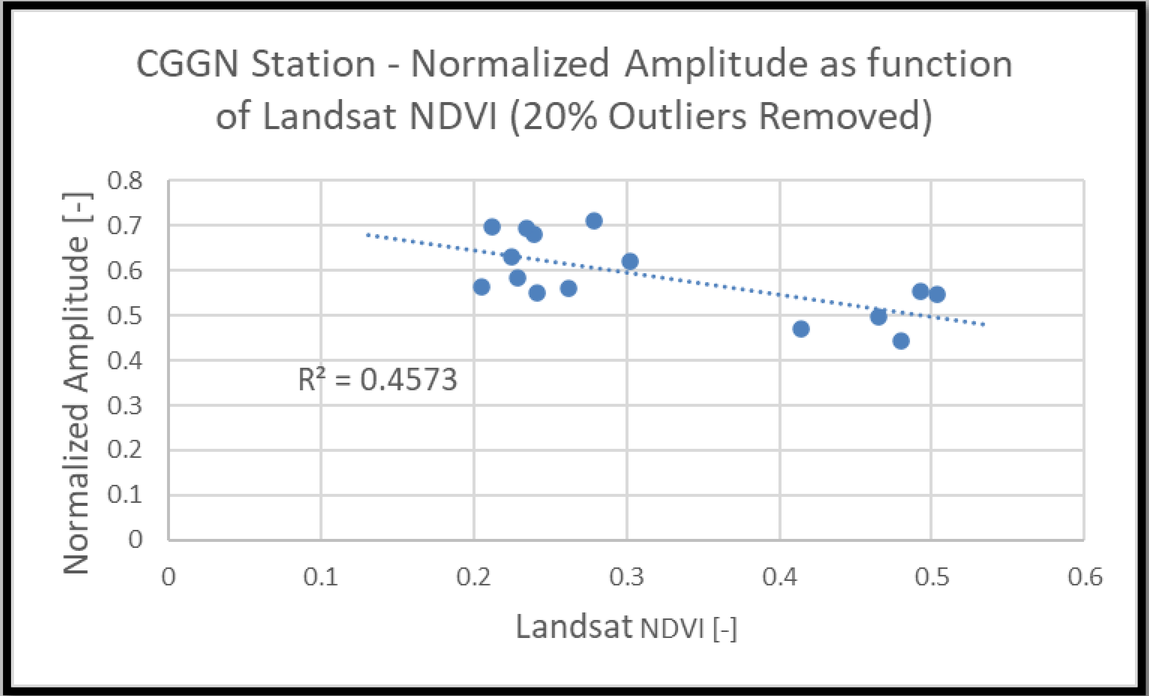


GNSS-IR RESULTS – CGGN STATION, TORO, NIGERIA



GNSS-IR AND NDVI RESULTS – CGGN STATION, TORO, NIGERIA





CONCLUSIONS

1. 43% of the IGS network stations can potentially be used for GNSS-R estimations for several parameters: soil moisture, vegetation content, desertification, snow depth, sea level altimetry and ice thickness.
2. The normalized reflected amplitude of multipath signals shows moderately strong correlations with NDVI, which has been used to track the health and content of vegetation for years.
3. The IGS's coverage shows decent potential to estimate and monitor environmental parameters as part of a global monitoring network, but more research regarding different parameters should be made.

FUTURE WORK

1. Expand the experiment to a global state and a longer period.

2. Numerically determine which IGS Stations are suitable for Vegetation Content Estimation which would in turn help understand the criteria that makes a station suitable for such estimations.

3. Assess other environmental parameters such as soil moisture, ice thickness and snow depth.

QUESTIONS?