Soil Moisture Estimation using GNSS-IR for Salar de Uyuni, Bolivia

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Motivation

Goal:

- Estimation of soil moisture fluctuations using GNSS-IR for the Salar de Uyuni

Background:

- Studies have already demonstrated the relationship between the reflected signal of GNSS and the water content of the ground.

Salar de Uyuni

Location: Andes Mountains in south-western Bolivia

- Largest salt flat in the world
- Area: 10582 km2
- Landscape: entirely flat with small islands

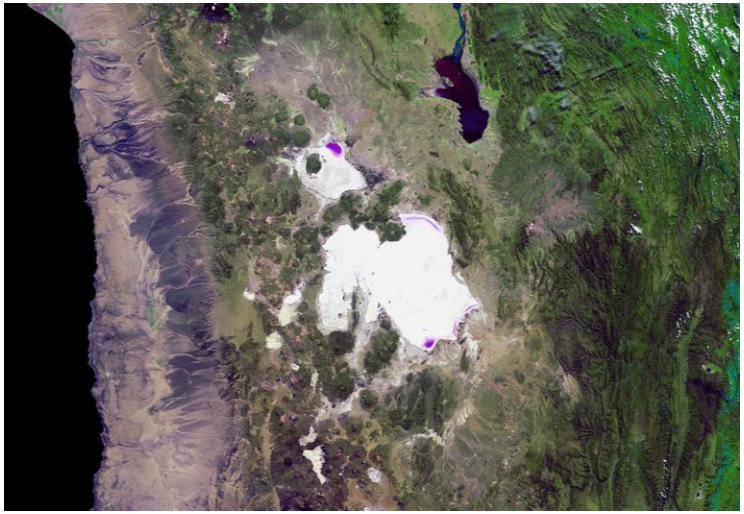


Fig 1: Satellite image Salar de Uyuni

Fig. 2: Salar de Uyuni during the dry season

Fig 3: Salar de Uyuni during the rainy season

AMDE Station

AMDE Station

- Latitude: 20°14’29.83“ S
- Longitude: 67°37‘38.66“ W
- Ellipsoindal Height: 3715.8 m
- Operated by UNAVCO
- Operational till Dec-2017

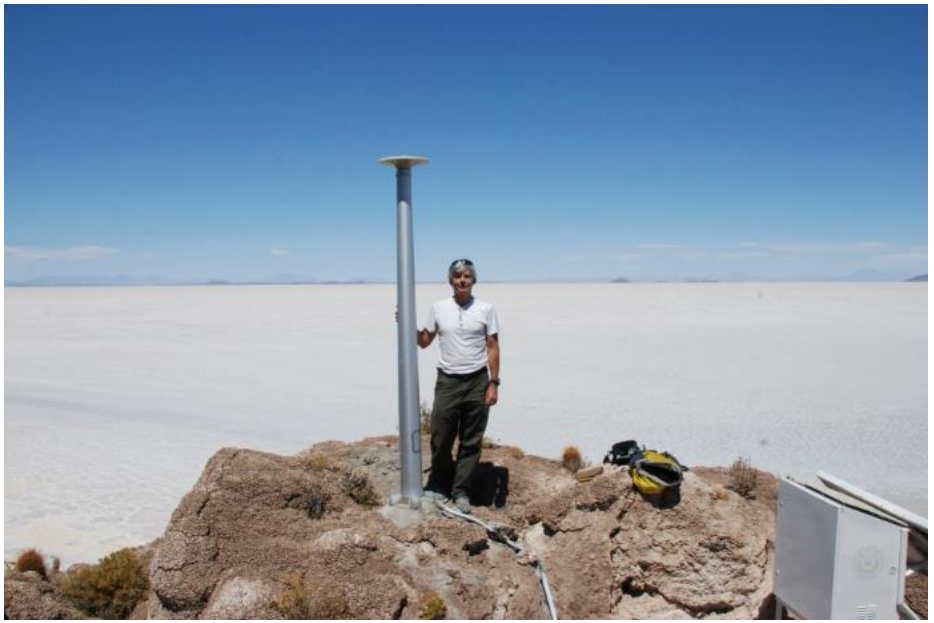


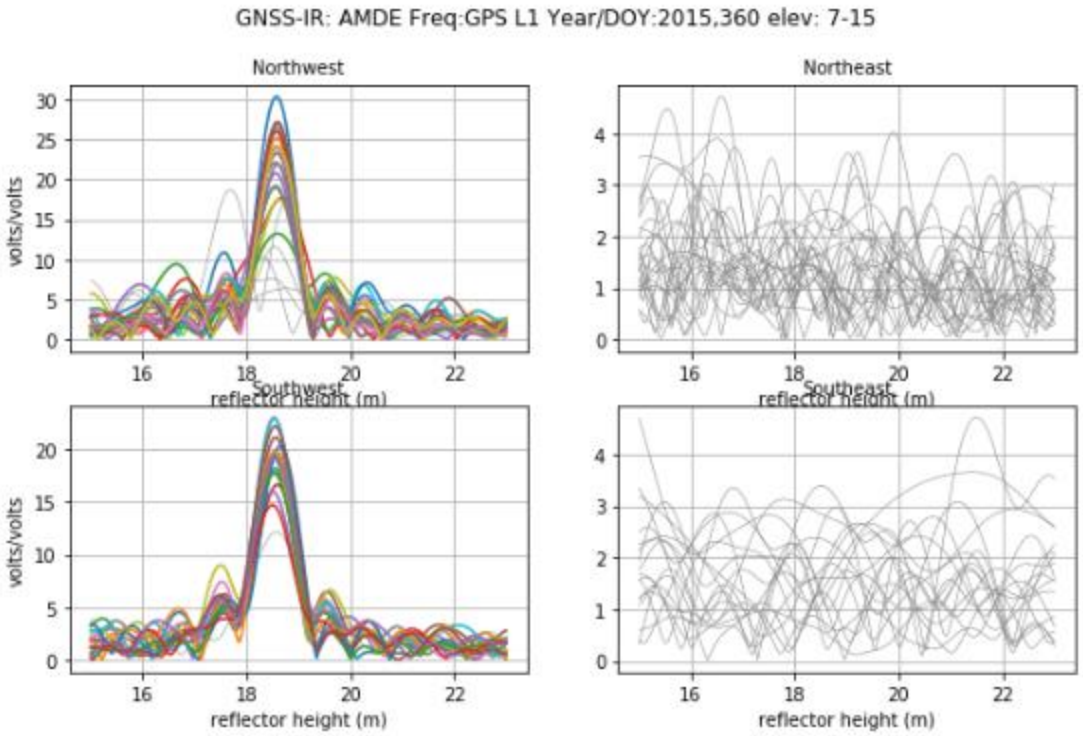
Fig 5: AMDE Station

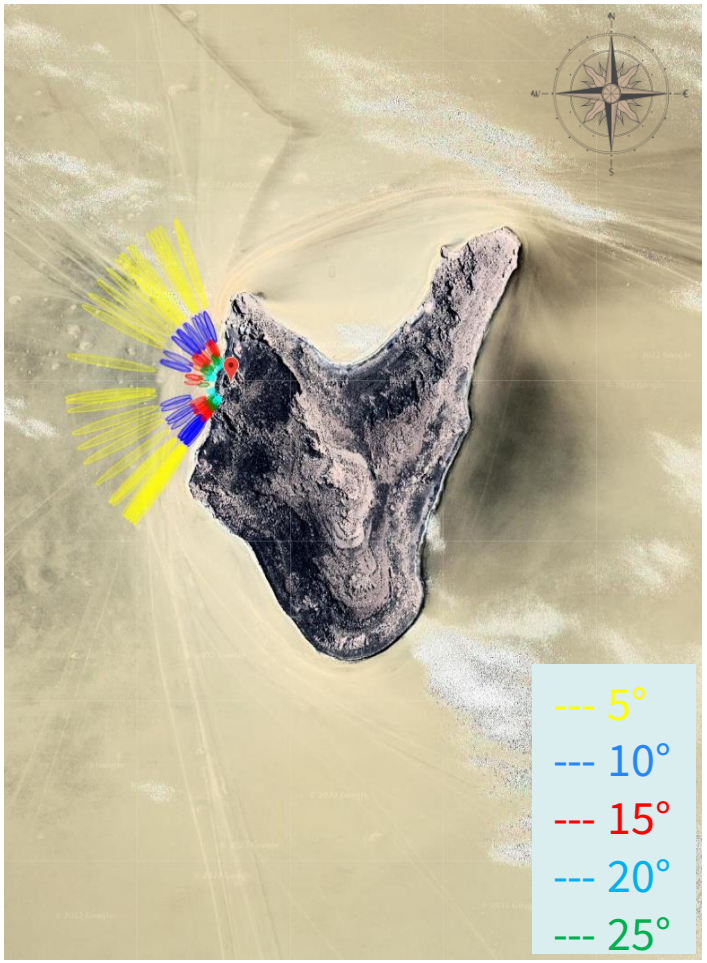
GNSS Receiver:

- Antenna: Trimble Zephyr 2
- GNSS Freq: GPS L1/L2/L5, Glonass, Galileo, BeiDou

Station Parameters

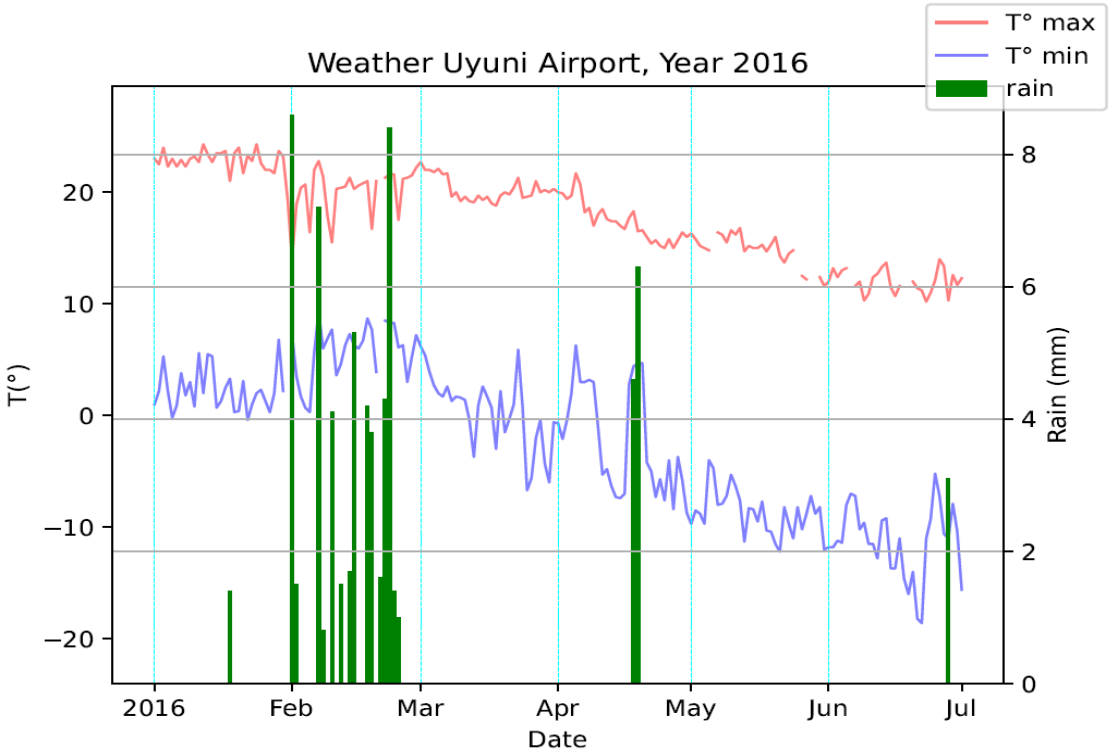
- Begin : 01/01/2016
- End : 01/07/2016
- Reflection Height: 18.5 m
- Azimuth Angle: 215° – 345°

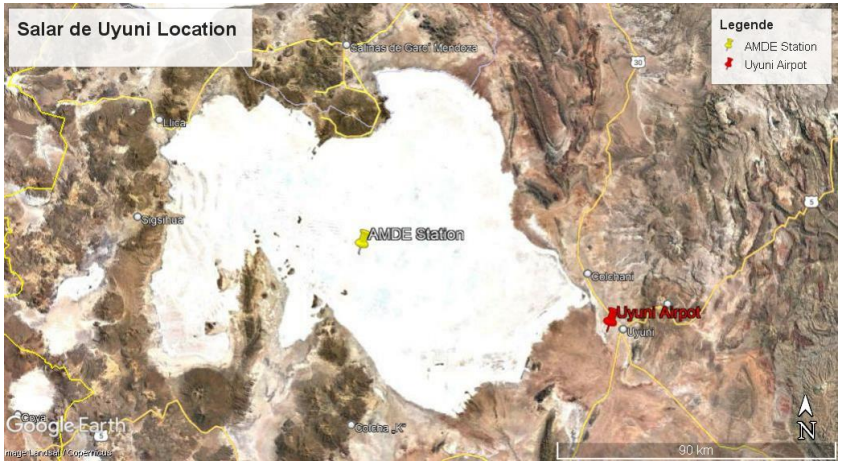




Periodogram Analysis

Climate Data

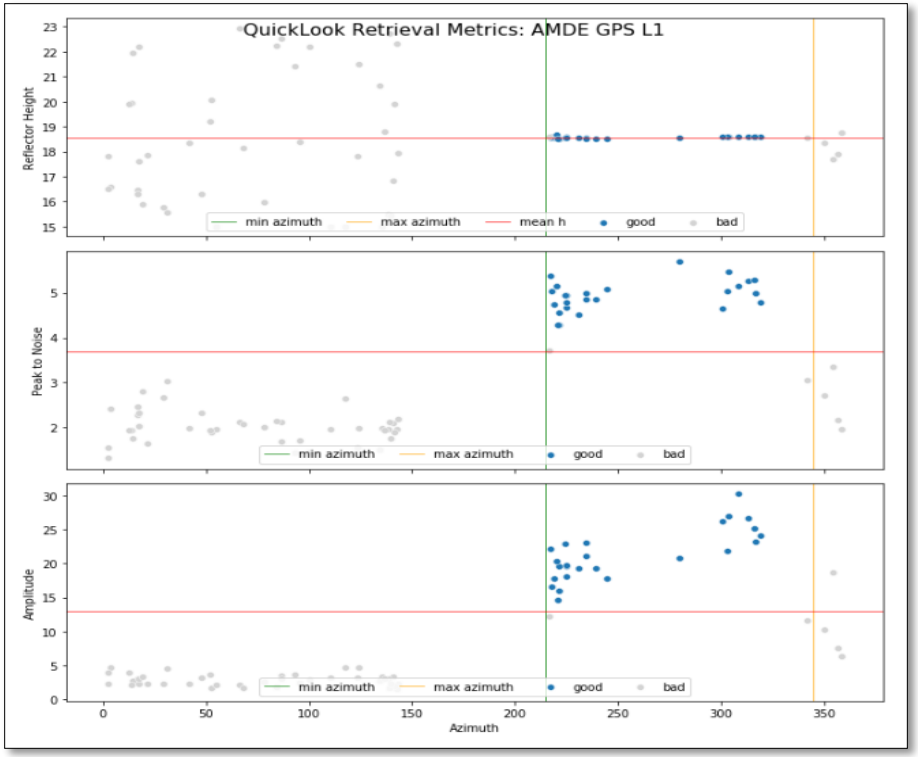


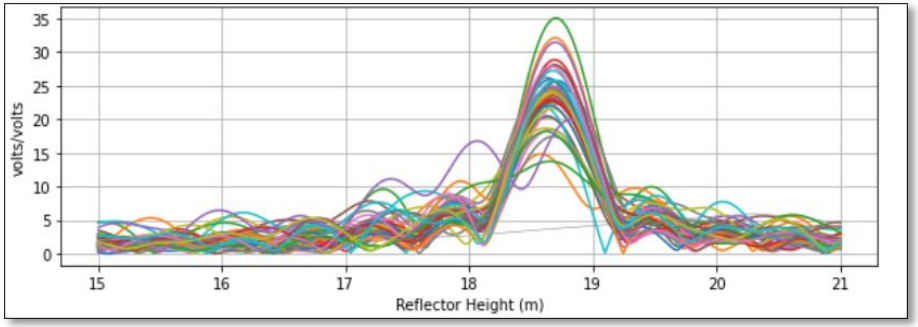


Climate station: Uyuni Aeropuerto
Source: Servicio Nacional de Meteorologia e Hidrologia de Bolivia
Source: https://senamhi.gob.bo/index.php/sysparametros

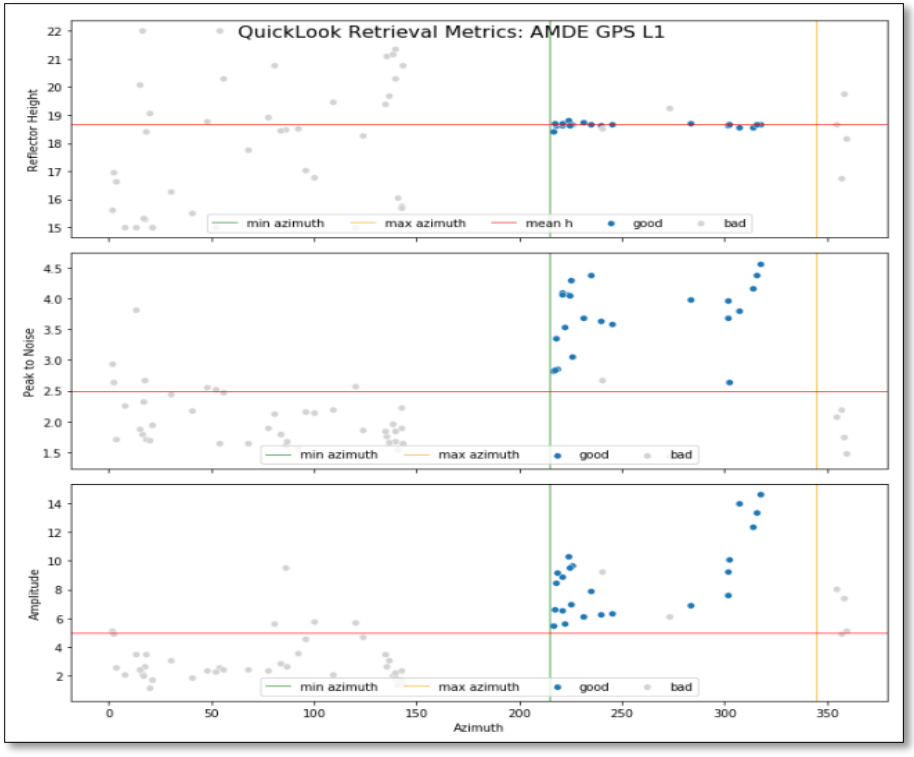
Lomb-Scargle Periodogram for L1

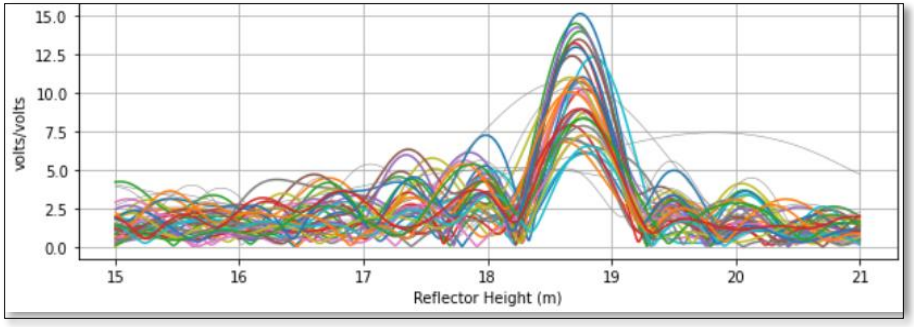
Dry Day (Doy=1)





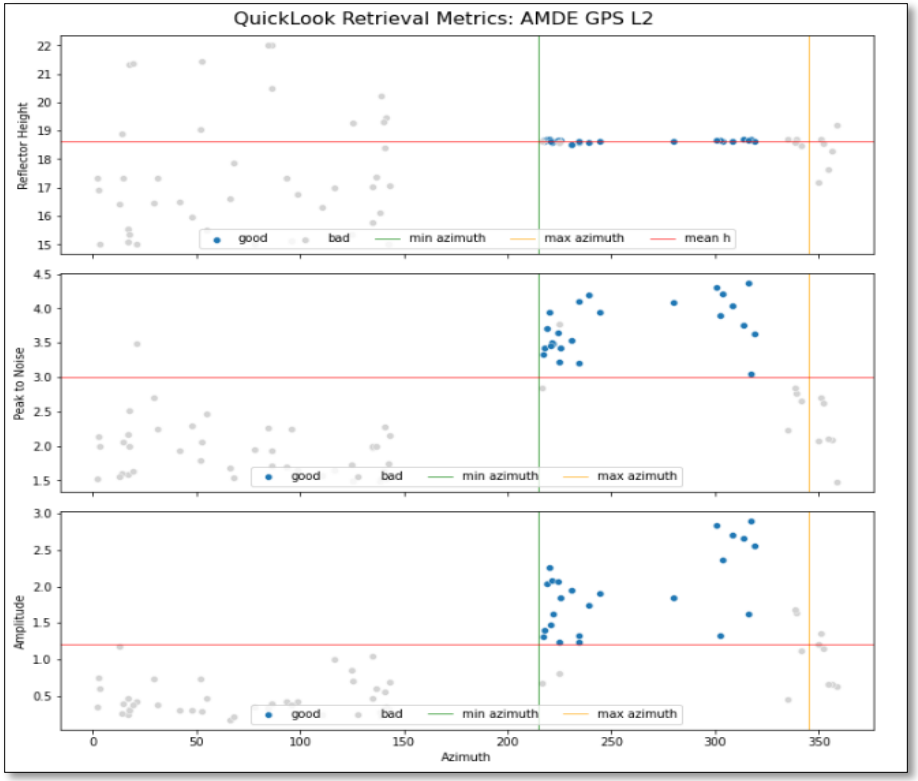
Rainy Day (Doy=60)

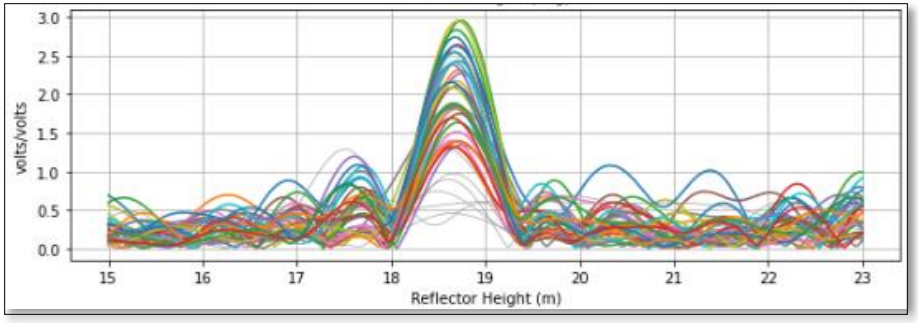




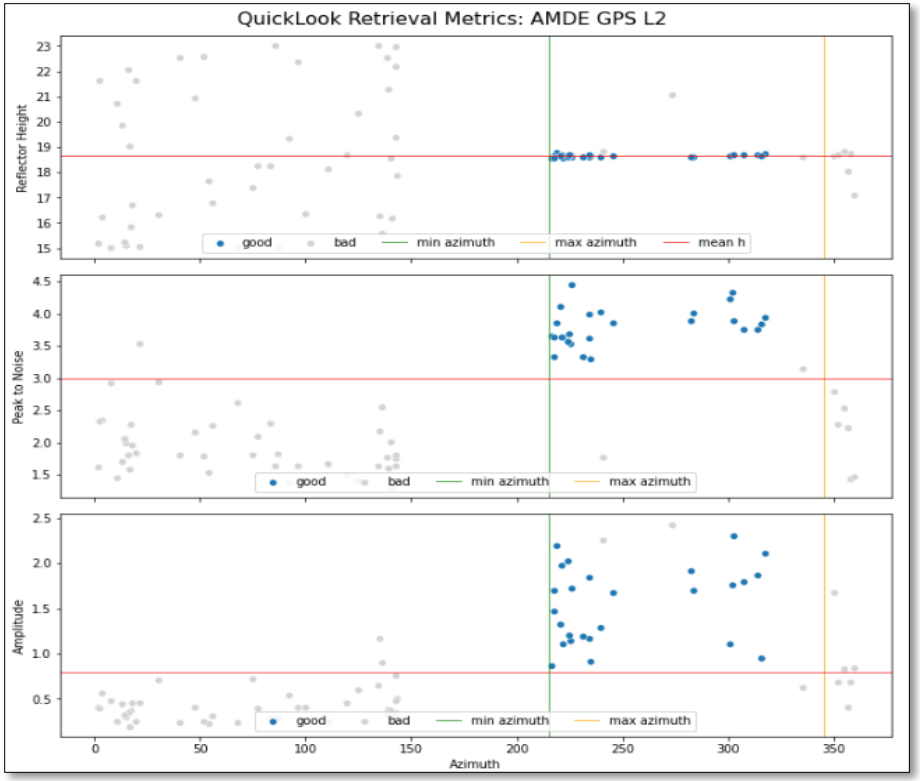
Lomb-Scargle Periodogram for L2

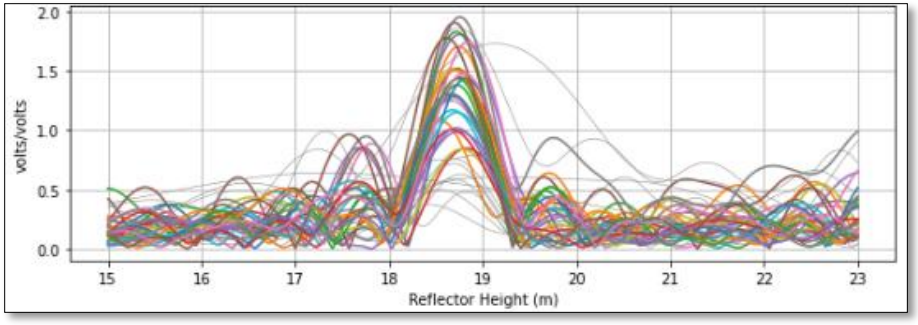
Dry Day (Doy=1)





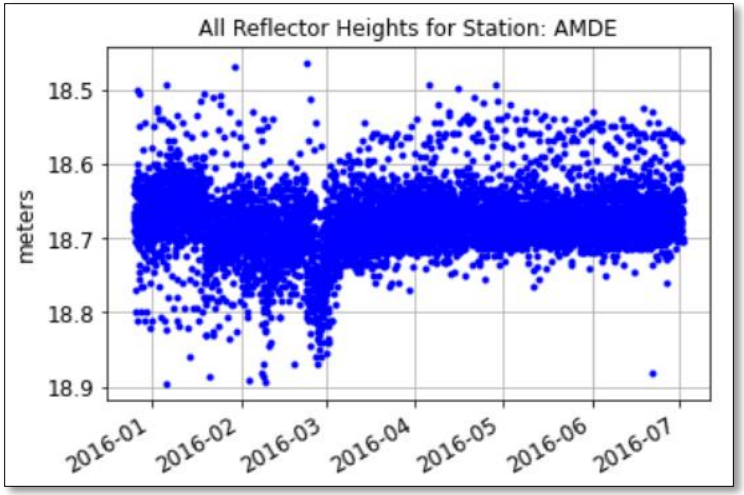
Rainy Day (Doy=60)

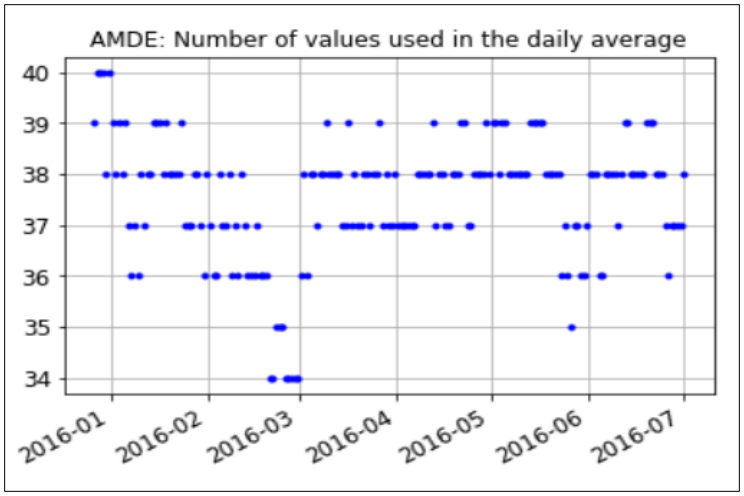




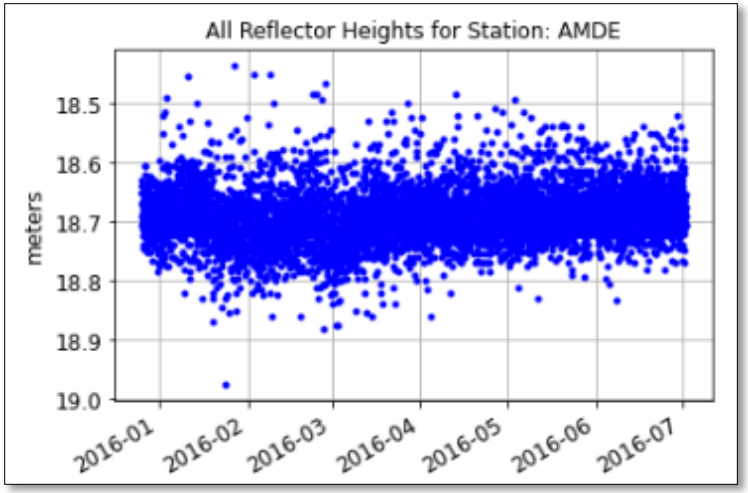
Daily Average

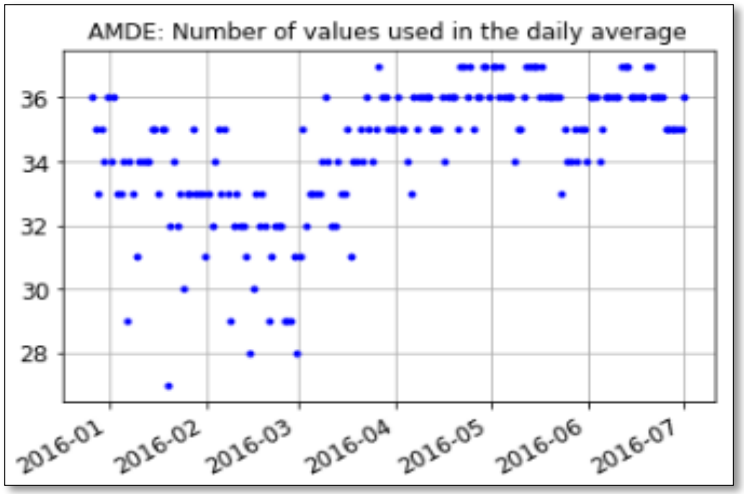
L1





L2



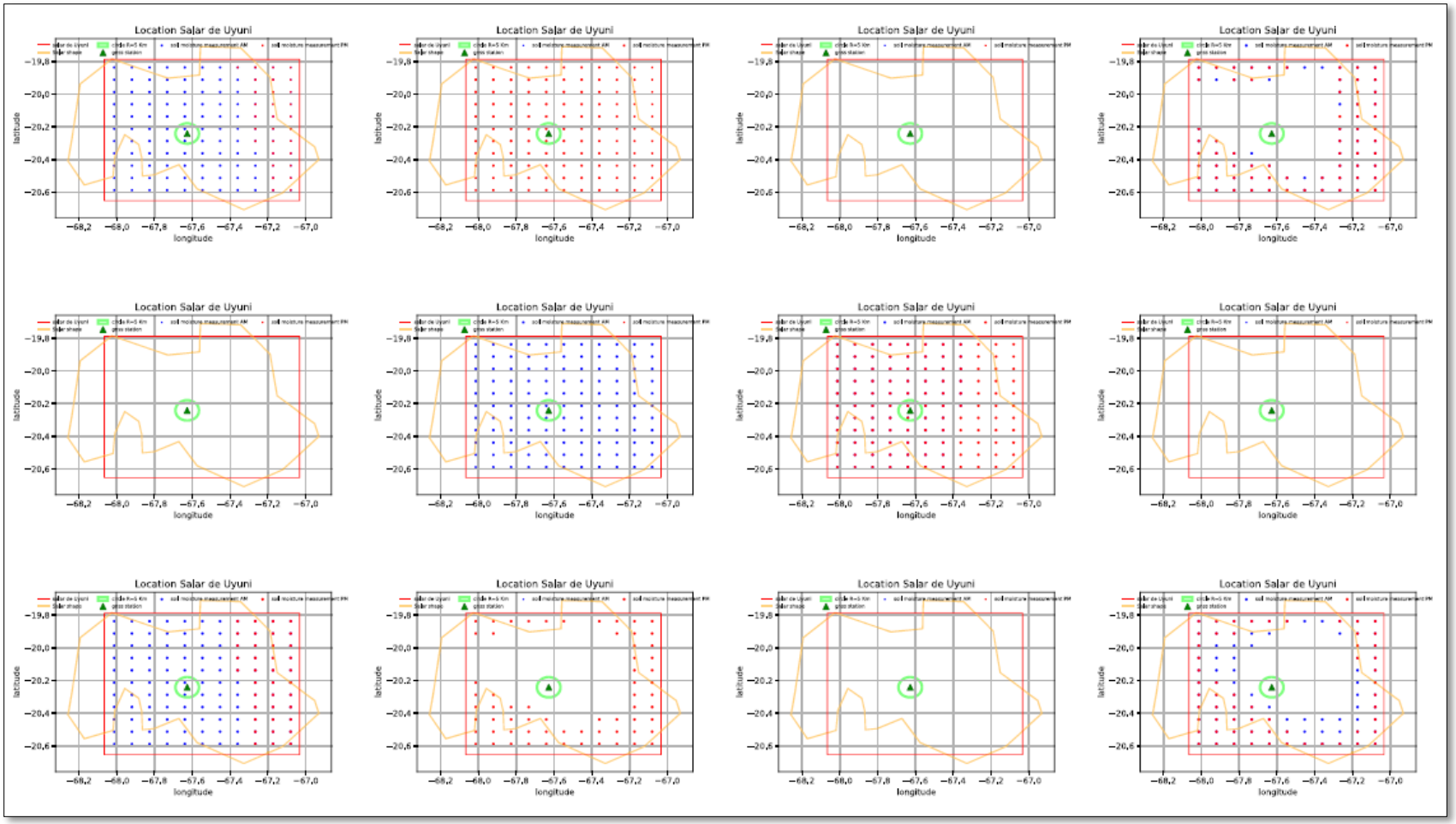


Results

Validation Data: Soil Moisture

SMAP-Version 5: Soil Moisture Active Passive Satellite mission of NASA [4]

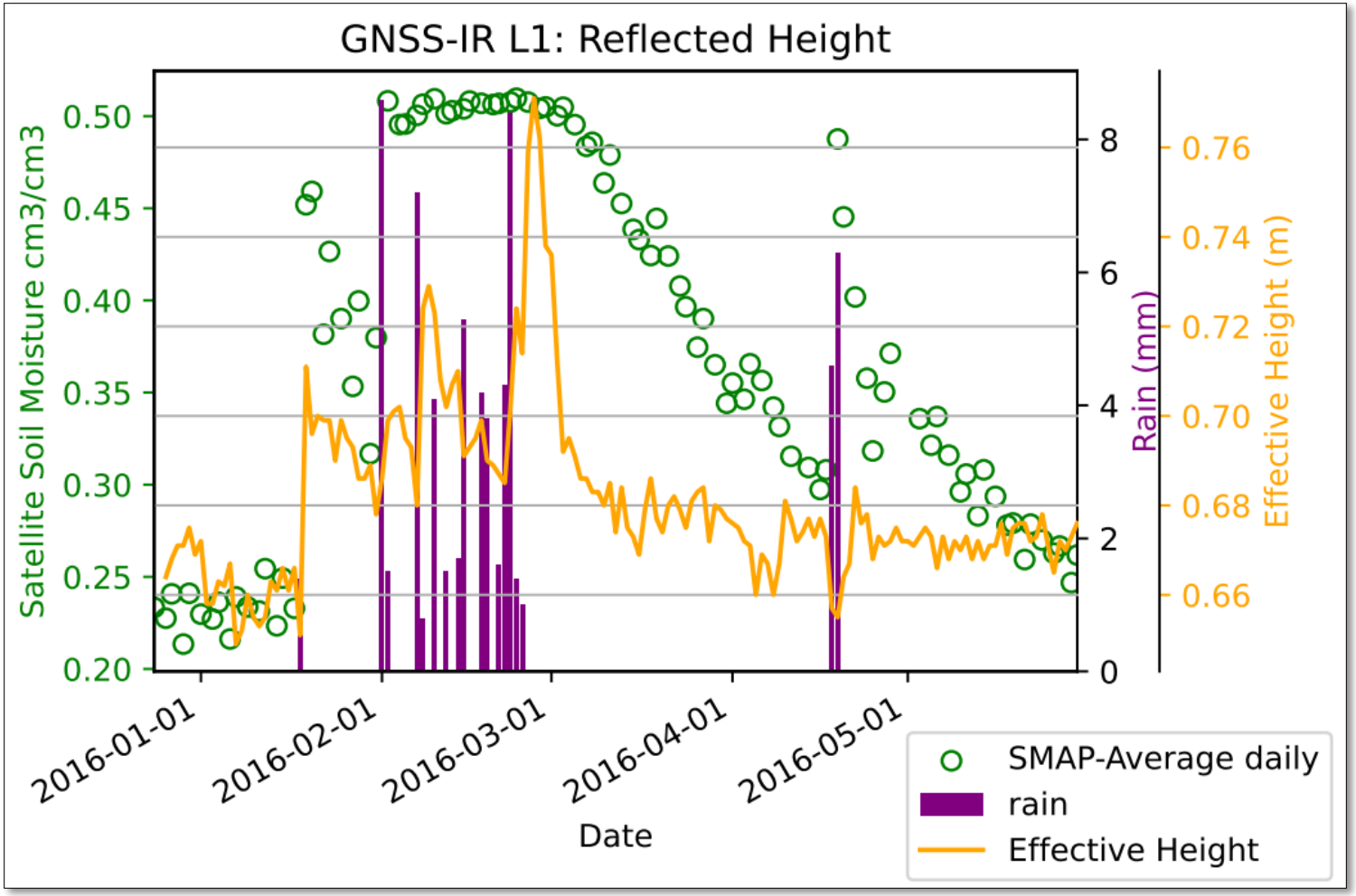
- L3 Radiometer Global and Polar Grid
- Resolution: Daily 9 km EASE-Grid Soil Moisture



SMAP data for a perdiod of 12 days

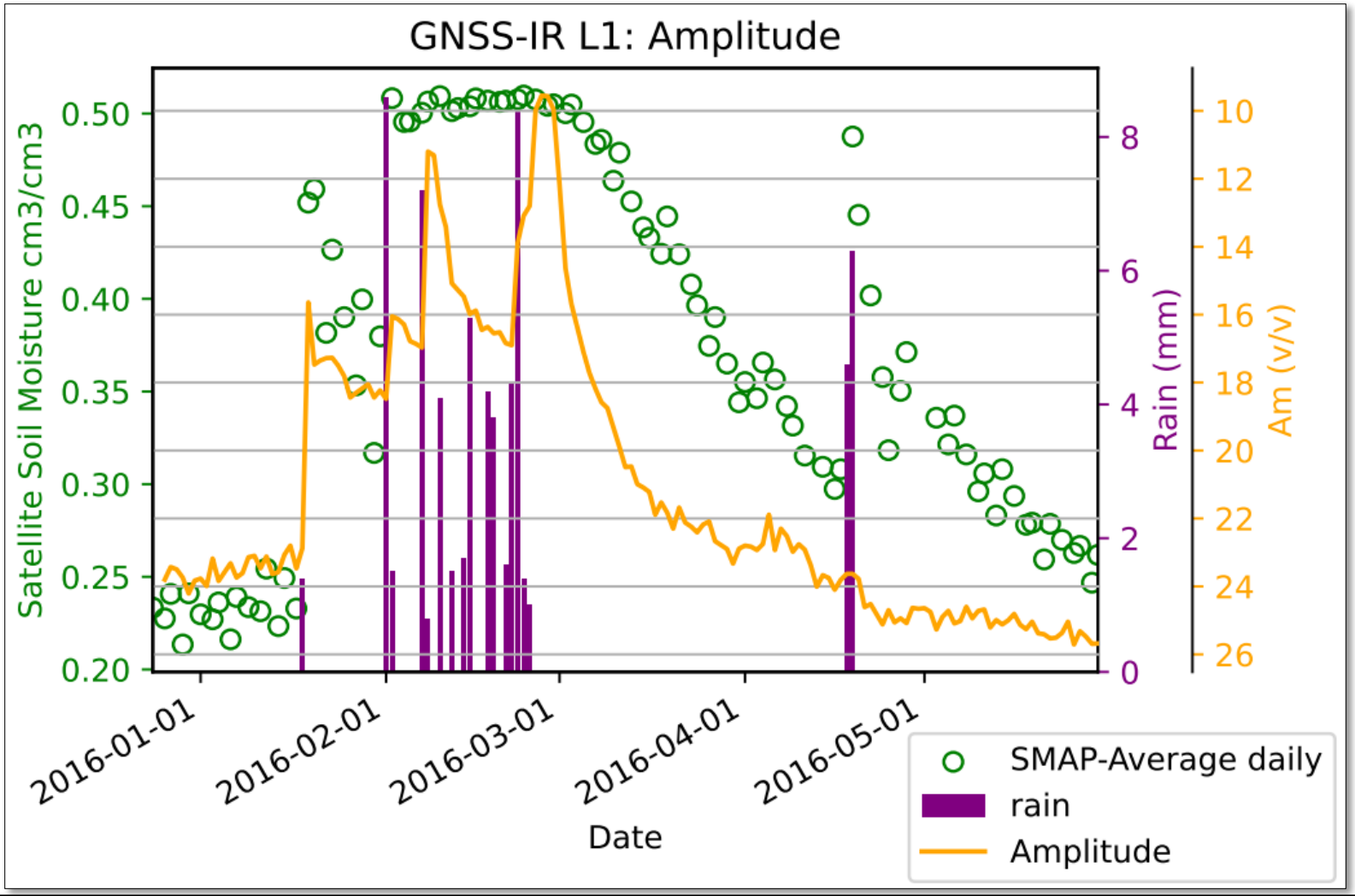
L1 Analysis: Reflected Heights

As the soil becomes wetter, the height estimated from the periodogram decreases [1]

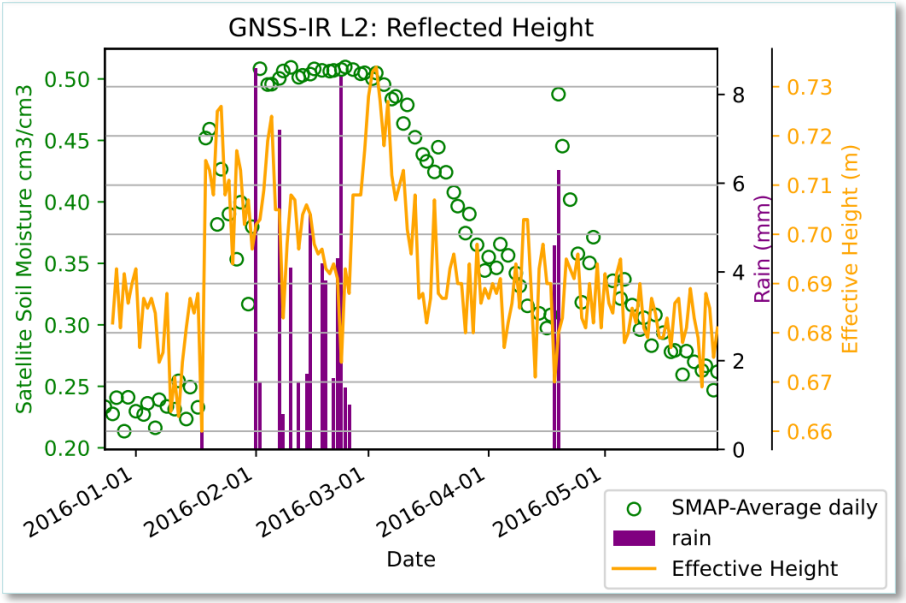


L1 Analysis: Amplitudes

Soil moisture (o) and amplitude of reflected signals (-) have a linear inverse relationship [1]

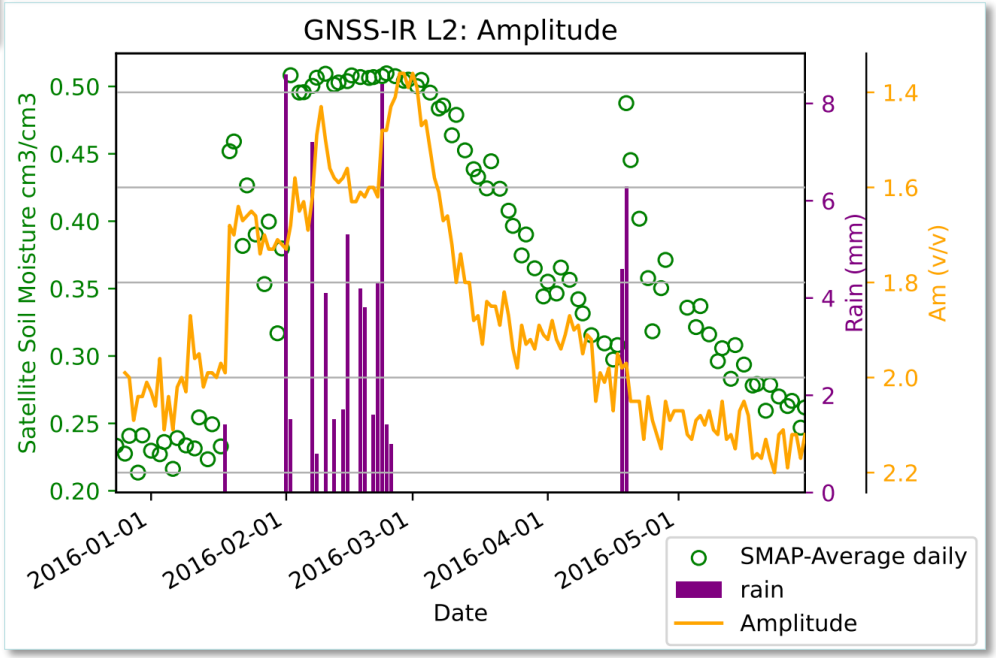


L2 Analysis



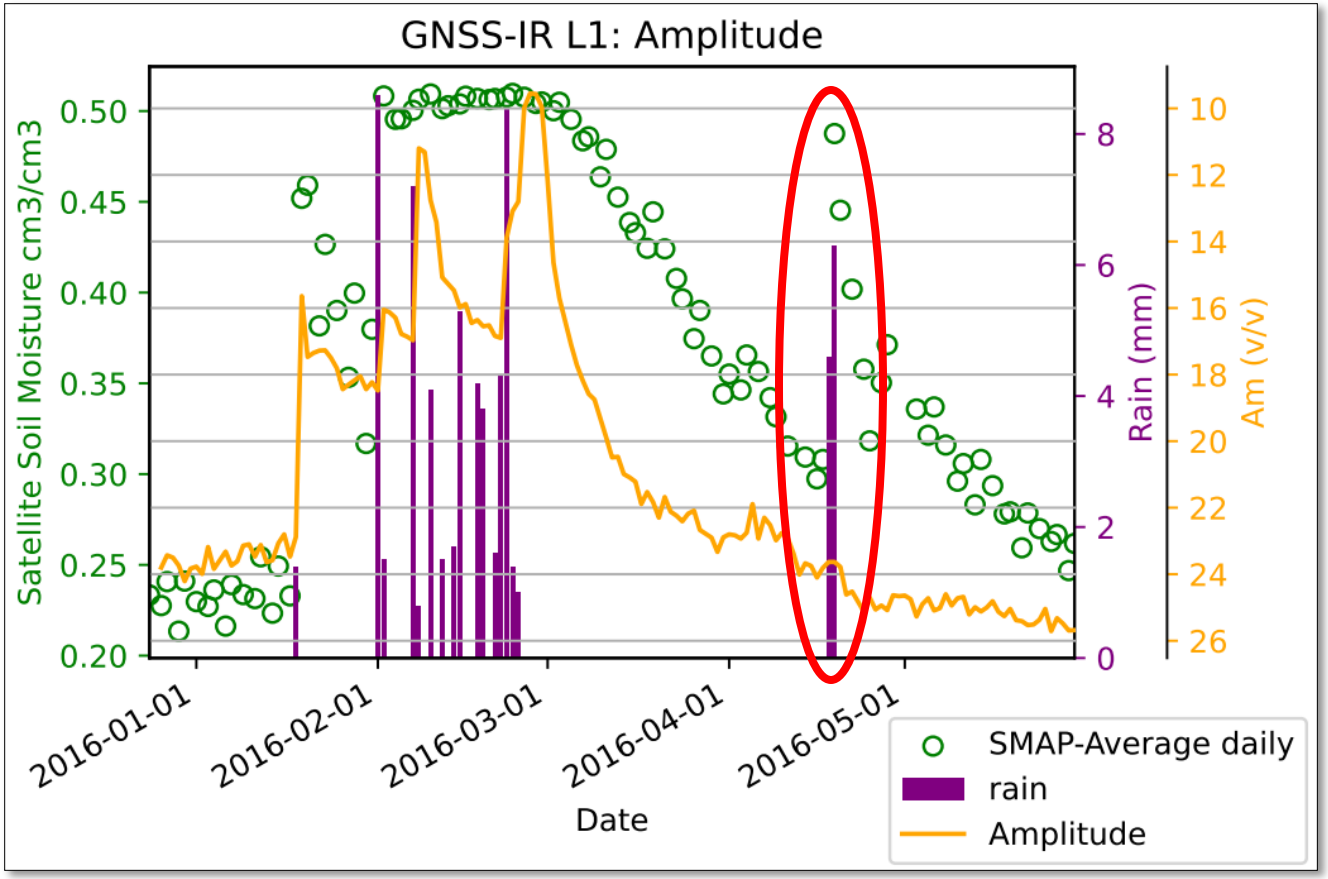
Changes in reflected heights have the same magnitude as L1

Linear inverse relationship between amplitudes of reflected signals and soil moisture values



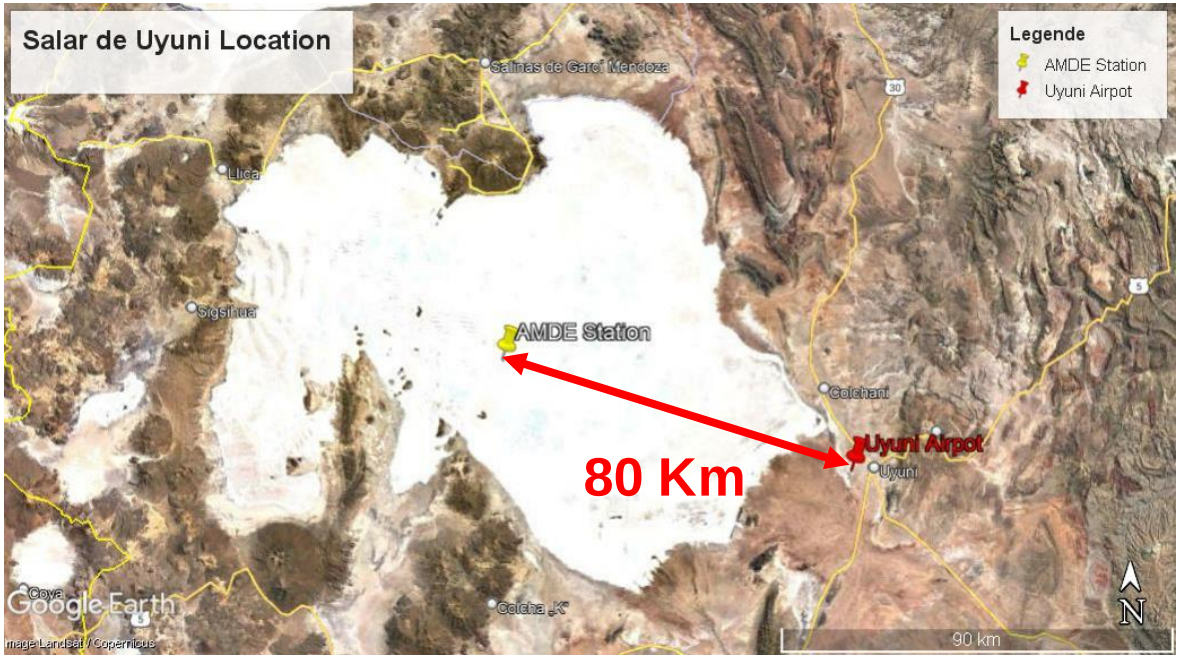
Result Analysis

Why do the GNSS-IR results not match with the precipitation data?



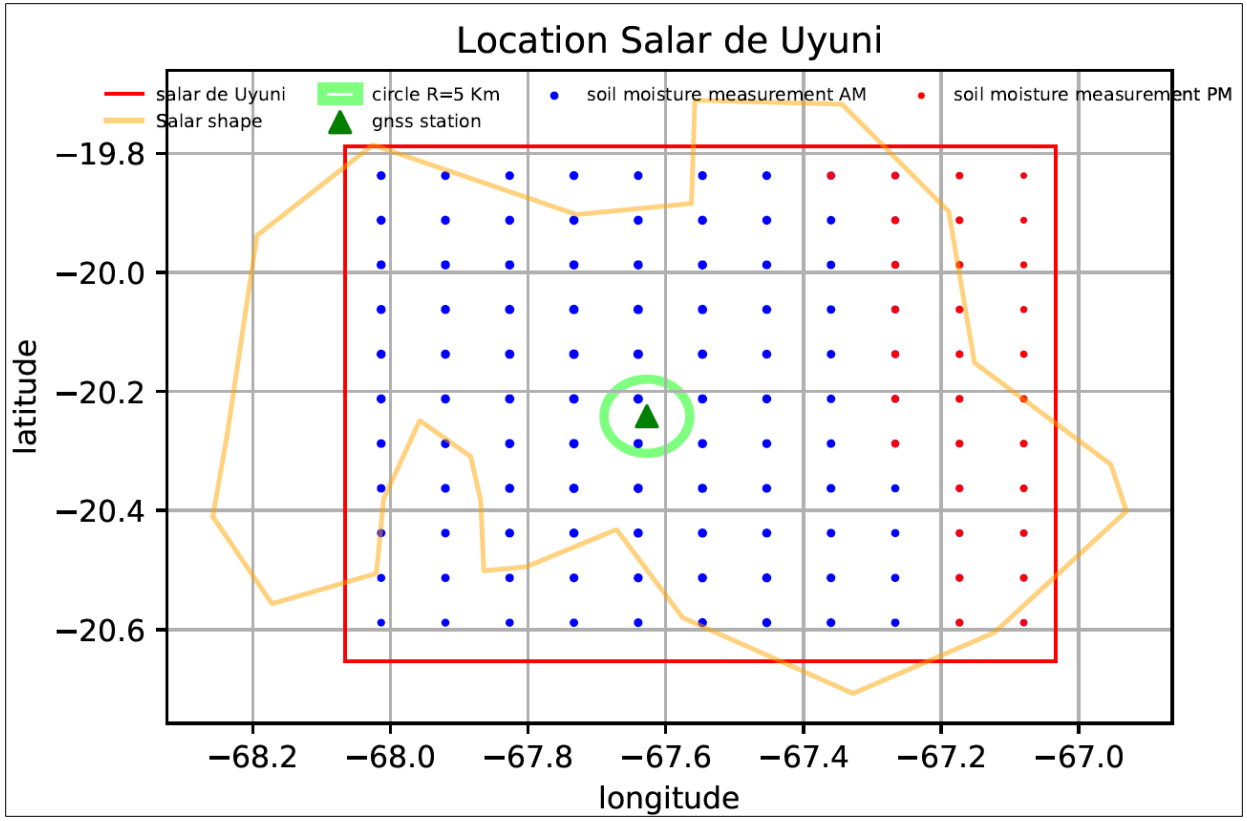
Why do the GNSS-IR results not match with the precipitation data?

- Climate station is located 80km away from the GNSS station



Why do the GNSS-IR results not match with the SMAP data?

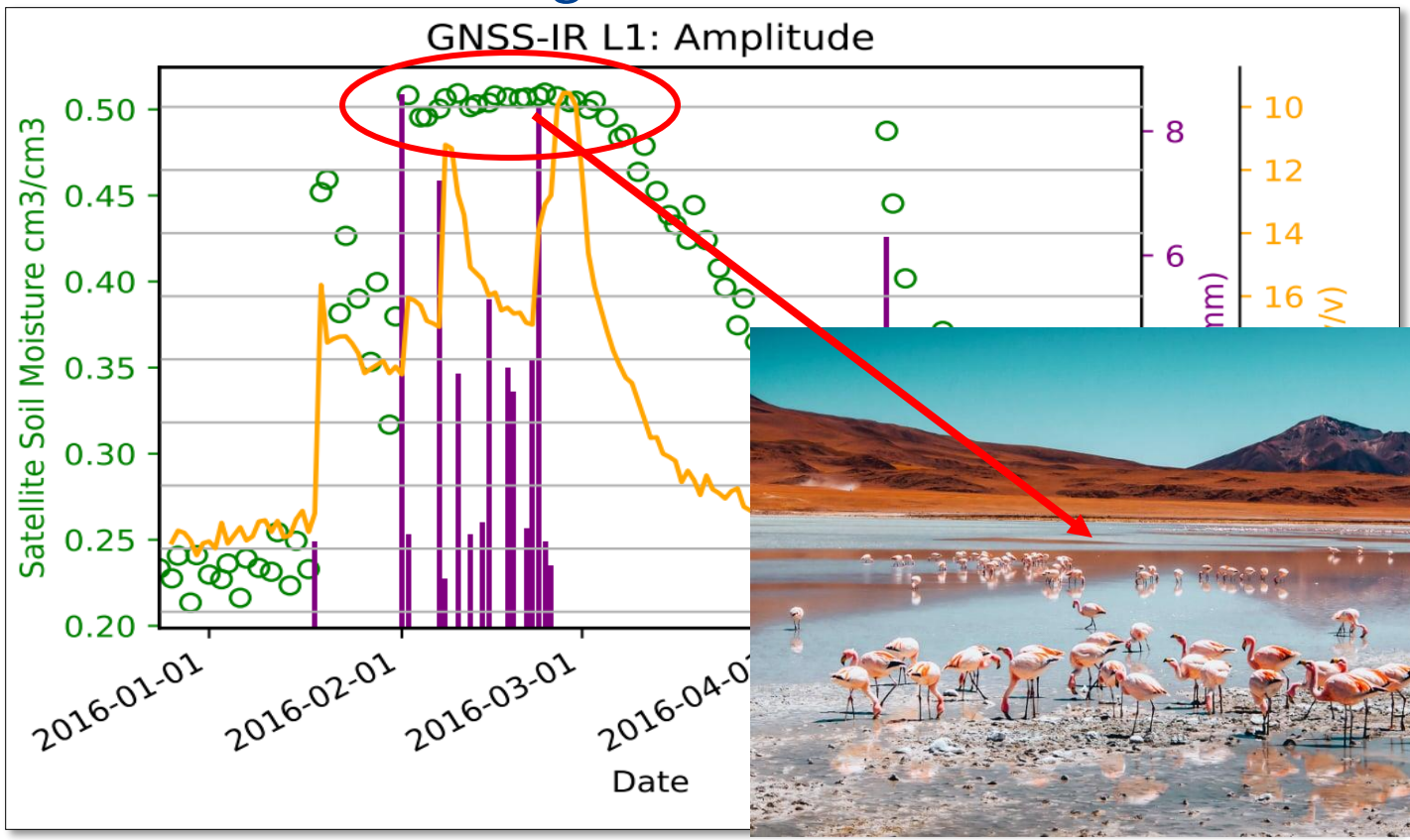
- The validation data is the average soil moisture value over the whole salar surface!



Result Analysis

Why do the GNSS-IR results not follow the shown trend by SMAP values?

- When there is water on the surface, the soil moisture value taken from SMAP goes to its maximum



Resume

- The characteristics of the reflected signals changes as soil moisture [2]
- Soil moisture and amplitude of reflected signals have a linear inverse relationship [1]
- As the soil becomes wetter, the height estimated from the periodogram decreases [1]

Where to find the data?

- The code used for this study is available on my personal git account: https://github.com/josemoragaposselt/gnssir_salar_uyuni

- The basic structure of this project was taken from https://www.unavco.org/gitlab/gnss_reflectometry/gnssrefl_jupyter

Where to find the data?

Where To find the Data?

Clima data: https://senamhi.gob.bo/index.php/sysparametros

INFORMACIÓN NACIONAL DE DATOS HIDROMETEOROLÓGICOS

Seleccionar tipo de exportación

Municipal

Seleccione el area

Potosí

Estaciones

Potosi Aeropuerto(Activo)

Variables

Precipitación

Tipo de dato

Diarios

Periodo

01/01/2016 01/07/2016

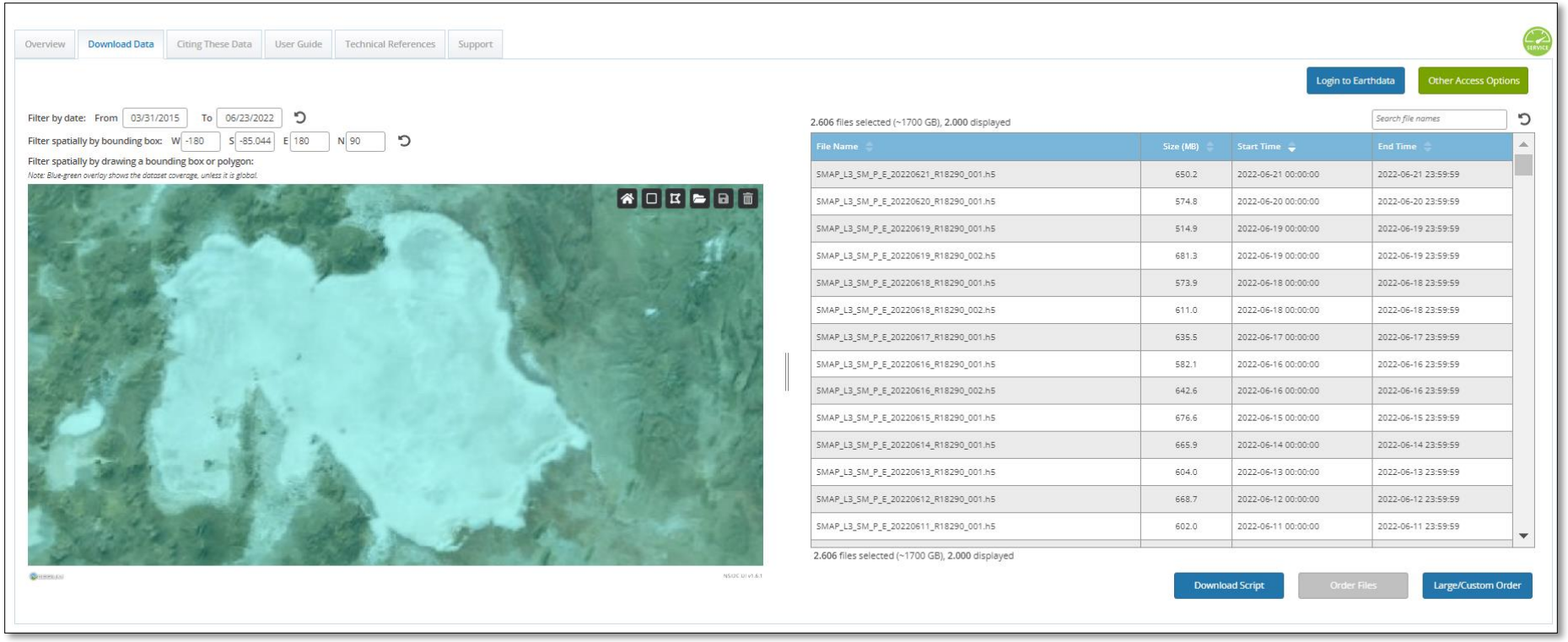
Ulimo dato registrado

Ver Potosi Aeropuerto(Activo) >

Where to find the data?

Where to find the Data?

Satellite Mission: https://nsidc.org/data/SPL3SMP_E/versions/5



References

[1] Larson, Kristine and Small, Eric and Gutmann, Ethan and Bilich, Andria and Axelrad, Penina and Braun, John (2008) “Using GPS multipath to measure soil moisture fluctuations: Initial results”, doi=10.1007/s10291-007-0076-6

[2] Larson, Kristine and Small, Eric and Gutmann, Ethan and Bilich, Andria and Braun, John and Zavorotny, Valery and Larson (2008) “Use of GPS receivers as a soil moisture network for water cycle studies”, doi = {10.1029/2008GL036013}

[3] Bilich, Andria and Larson, Kristine and Axelrad, Penina (2008) „Modeling GPS phase multipath with SNR: Case study from the Salar de Uyuni, Boliva “, doi=10.1029/2007JB005194

[4] Chew, C. and Small, Eric and Larson, Kristine and Zavorotny, Valery (2014) “Effects of Near-Surface Soil Moisture on GPS SNR Data: Development of a Retrieval Algorithm for Soil Moisture”, doi=10.1109/TGRS.2013.2242332

[5] Chew, C. and Small, Eric and Larson, Kristine (2015) “An algorithm for soil moisture estimation using GPS-interferometric reflectometry for bare and vegetated soil”, doi=10.1007/s10291-015-0462-4

References

Figures:

[1] Satellite image Salar de Uyuni, source: https://www.esa.int/
[2] Salar de Uyuni, Source: https://www.beautifulworld.com
[3] Salar de Uyuni Climate, Source: www.salardeuyuni.com
[4] Reflection Zone AMDE station, Source: https://gnss-reflections.org

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