

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

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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.

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

- Latitude: $20^{\circ}14'29.83''$ S
- Longitude: $67^{\circ}37'38.66''$ W
- Ellipsoindal Height: 3715.8 m
- Operated by UNAVCO
- Operational till Dec-2017

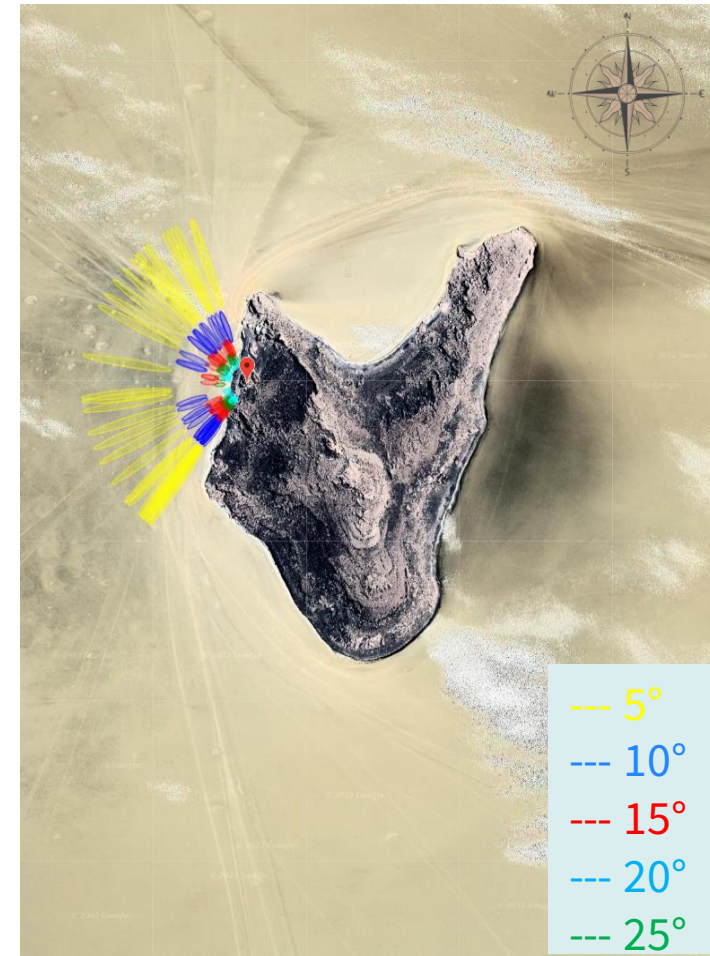
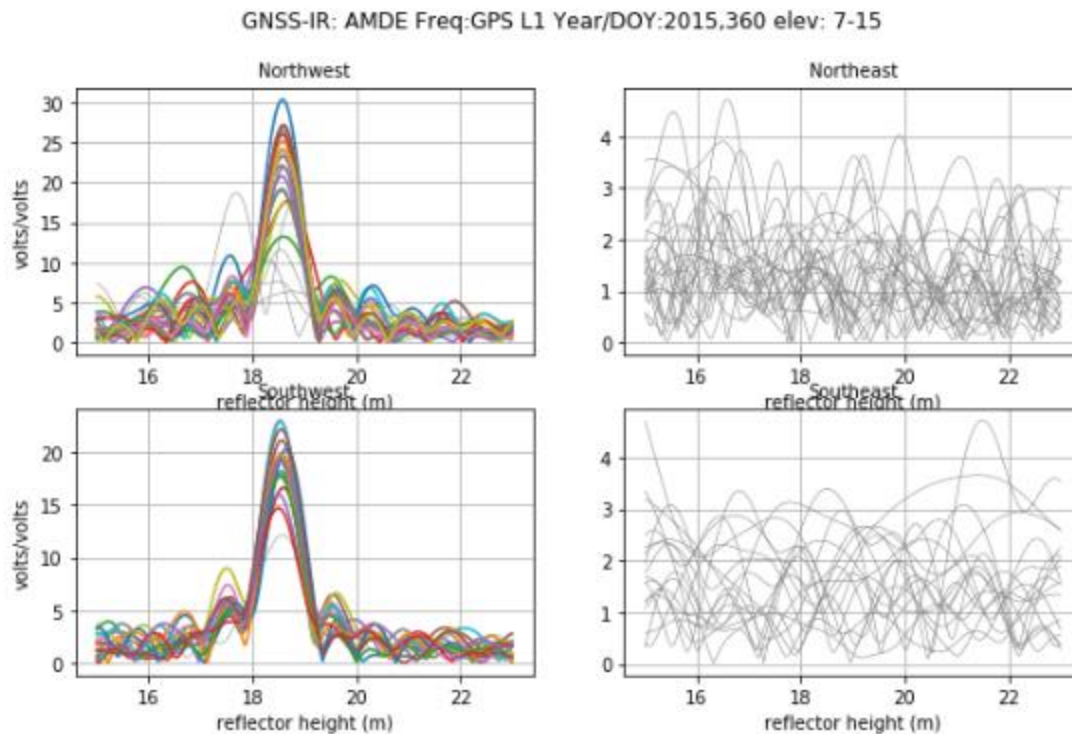
GNSS Receiver:

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

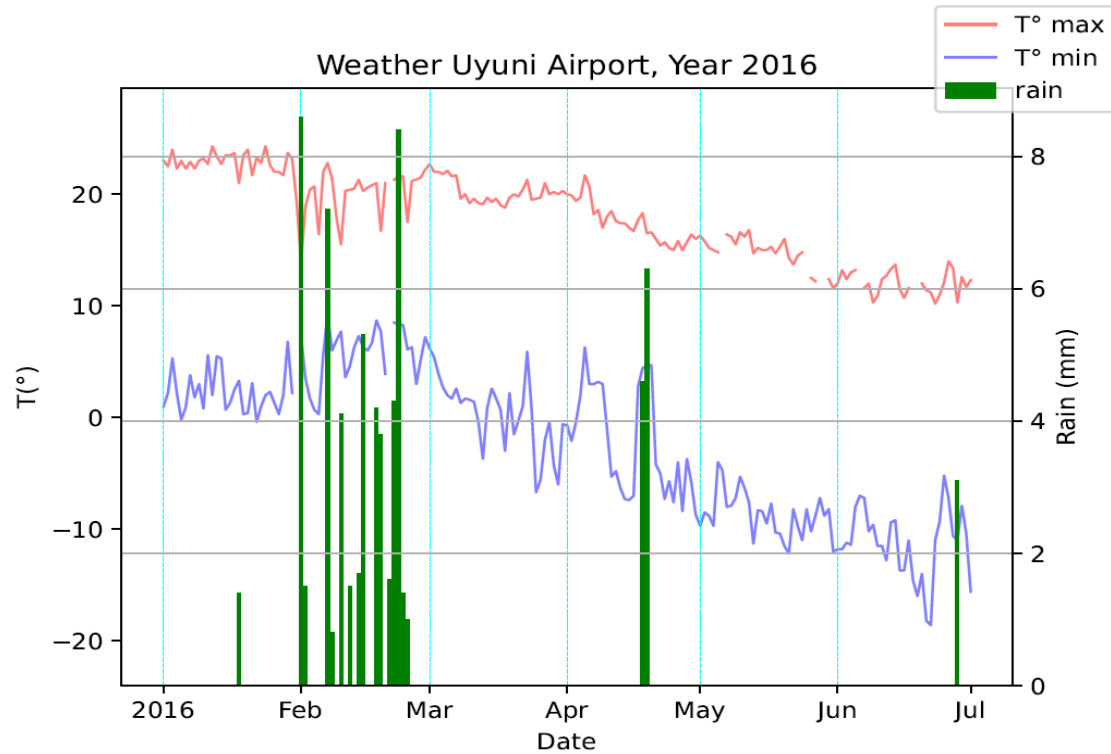


Fig 5: AMDE Station

- Begin : 01/01/2016
- End : 01/07/2016
- Reflection Height: 18.5 m
- Azimuth Angle: $215^{\circ} - 345^{\circ}$



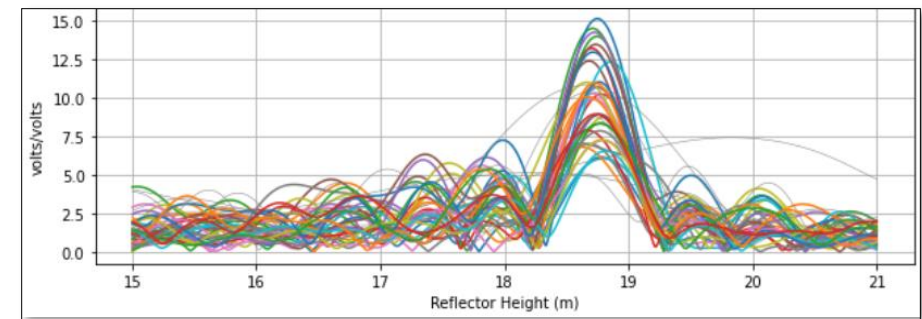
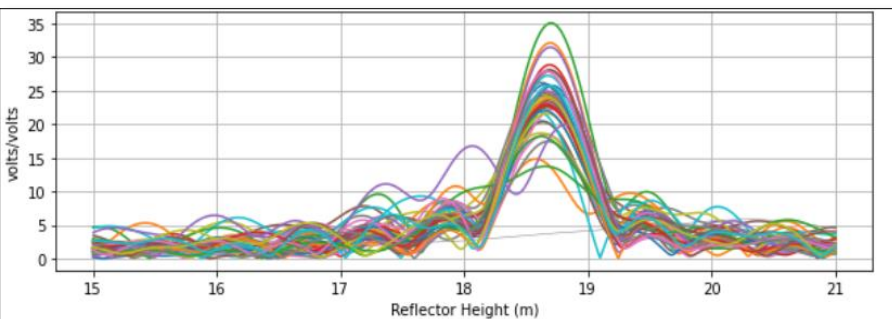
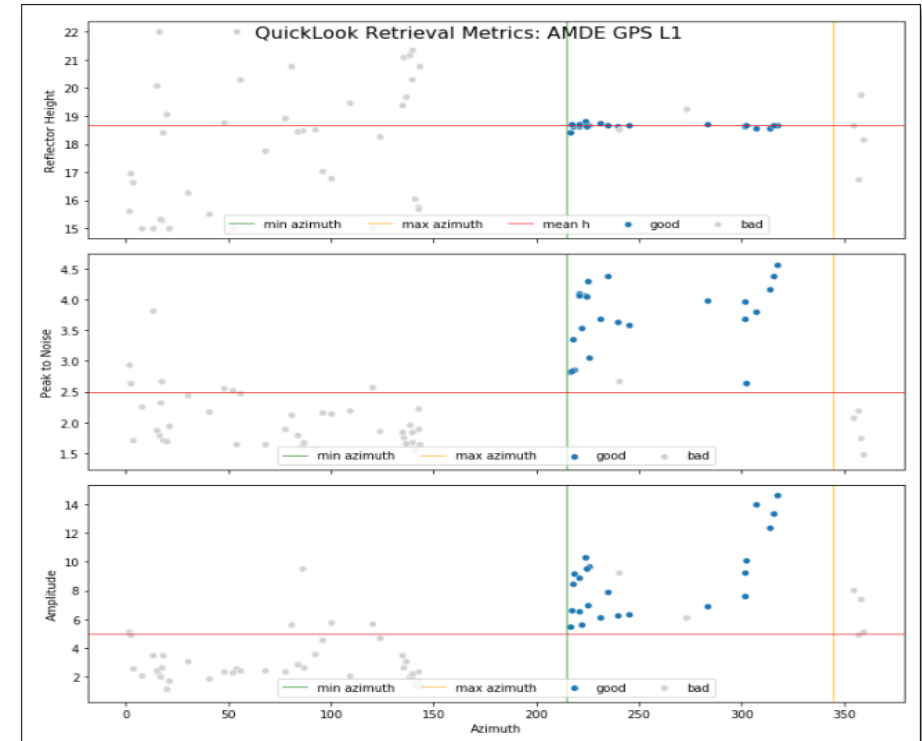
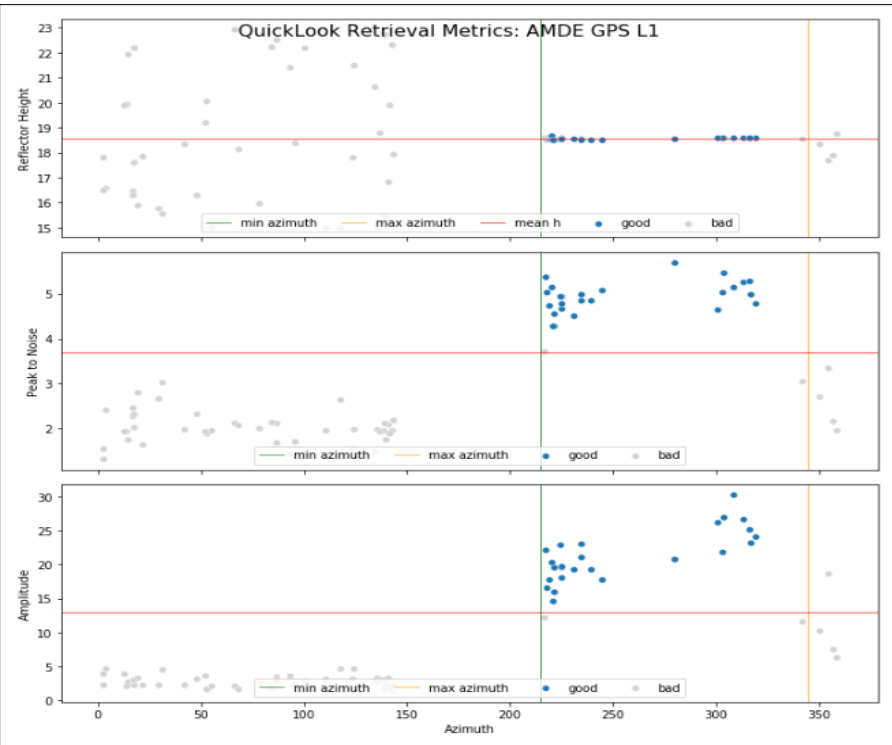
Periodogram Analysis



Climate station: Uyuni Aeropuerto
 Source: Servicio Nacional de Meteorología e Hidrología de Bolivia
 Source:
<https://senamhi.gob.bo/index.php/sysparametros>

Dry Day (Doy=1)

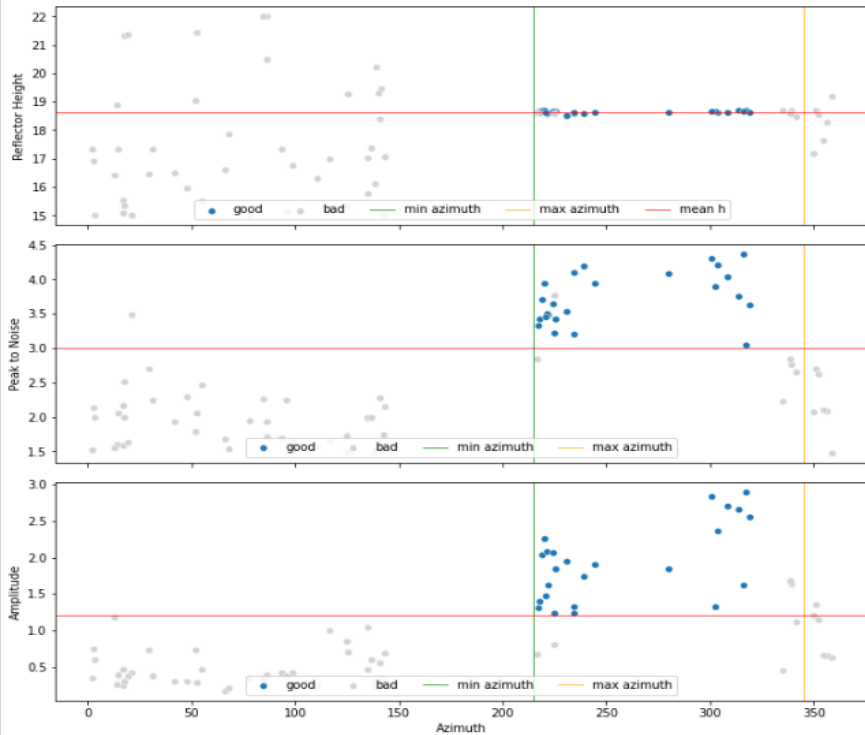
Rainy Day (Doy=60)



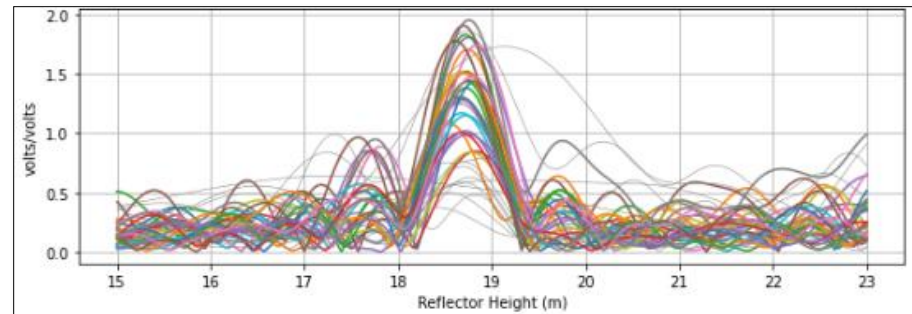
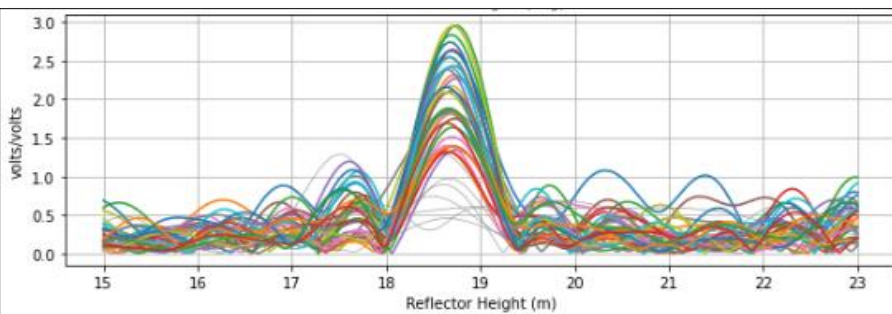
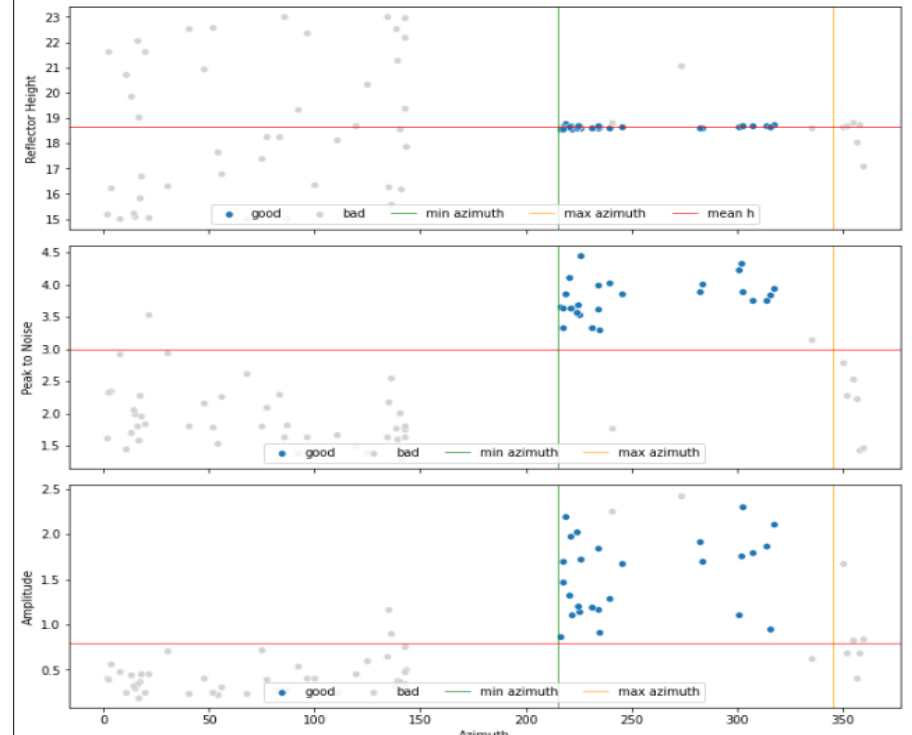
Dry Day (Doy=1)

Rainy Day (Doy=60)

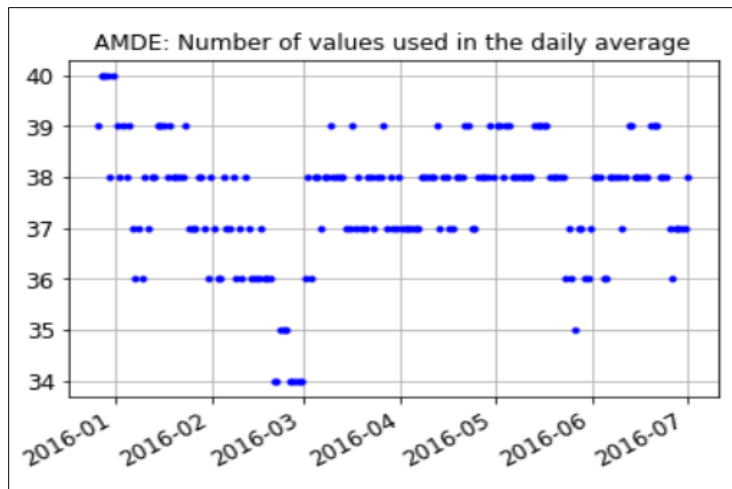
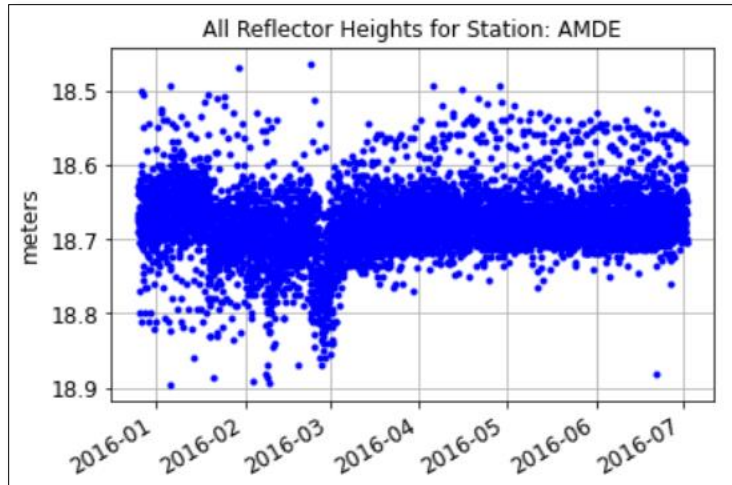
QuickLook Retrieval Metrics: AMDE GPS L2



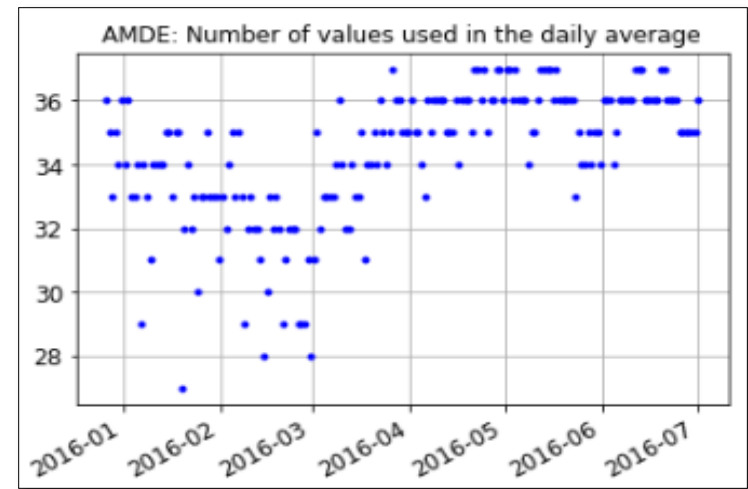
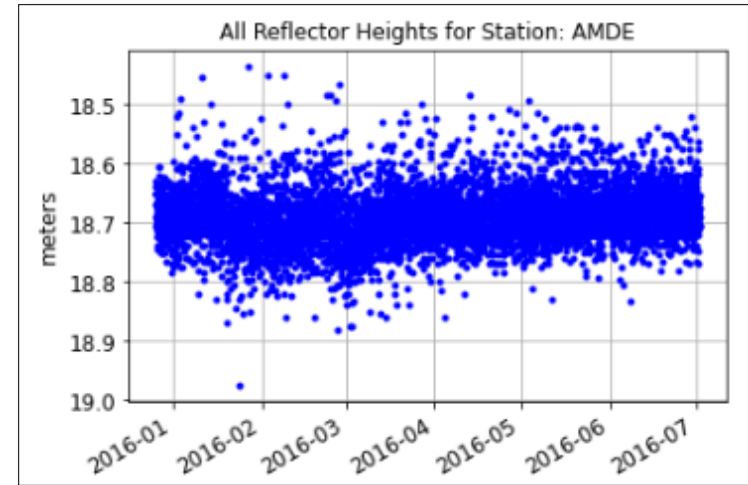
QuickLook Retrieval Metrics: AMDE GPS L2



L1



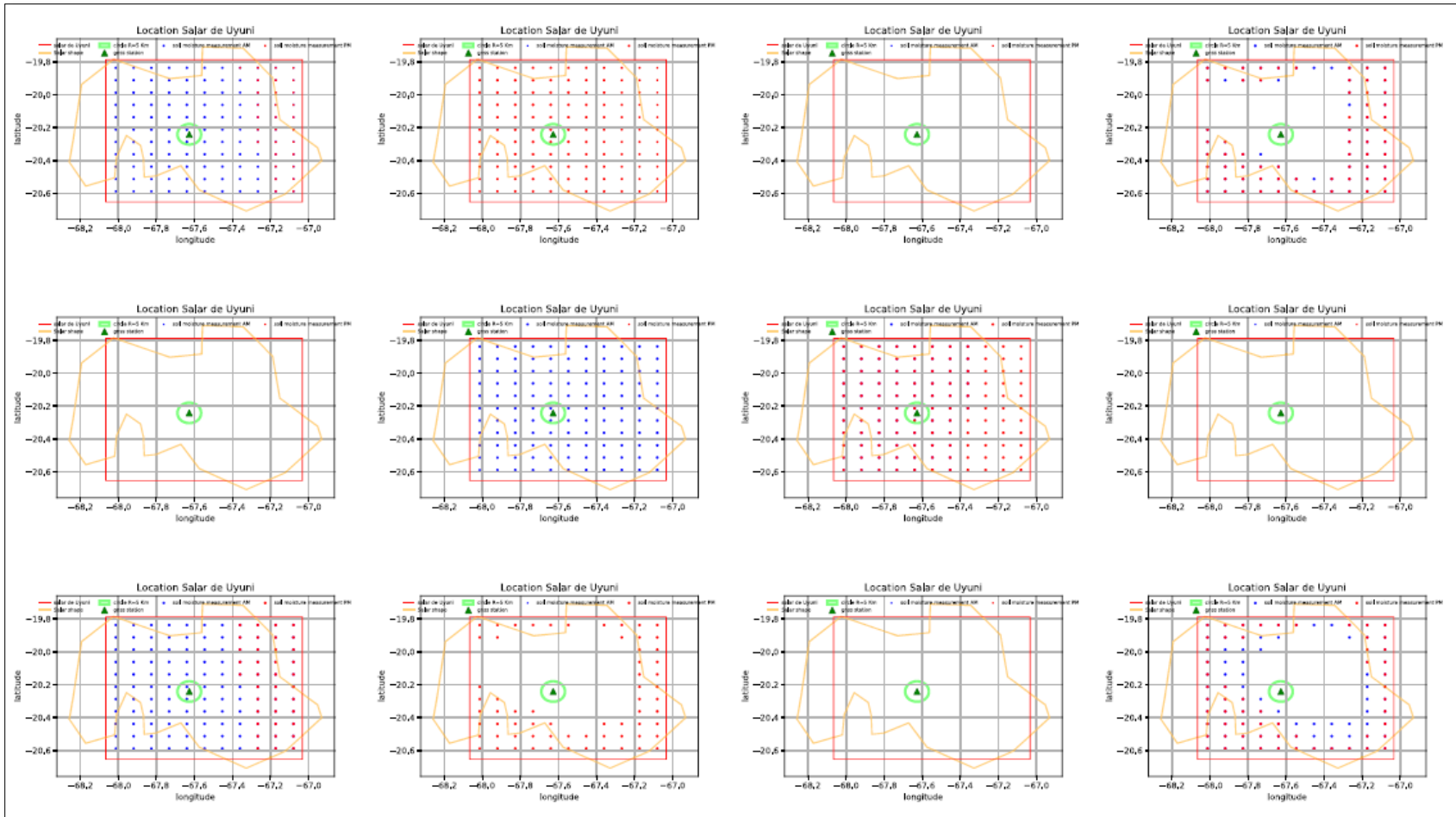
L2



Results

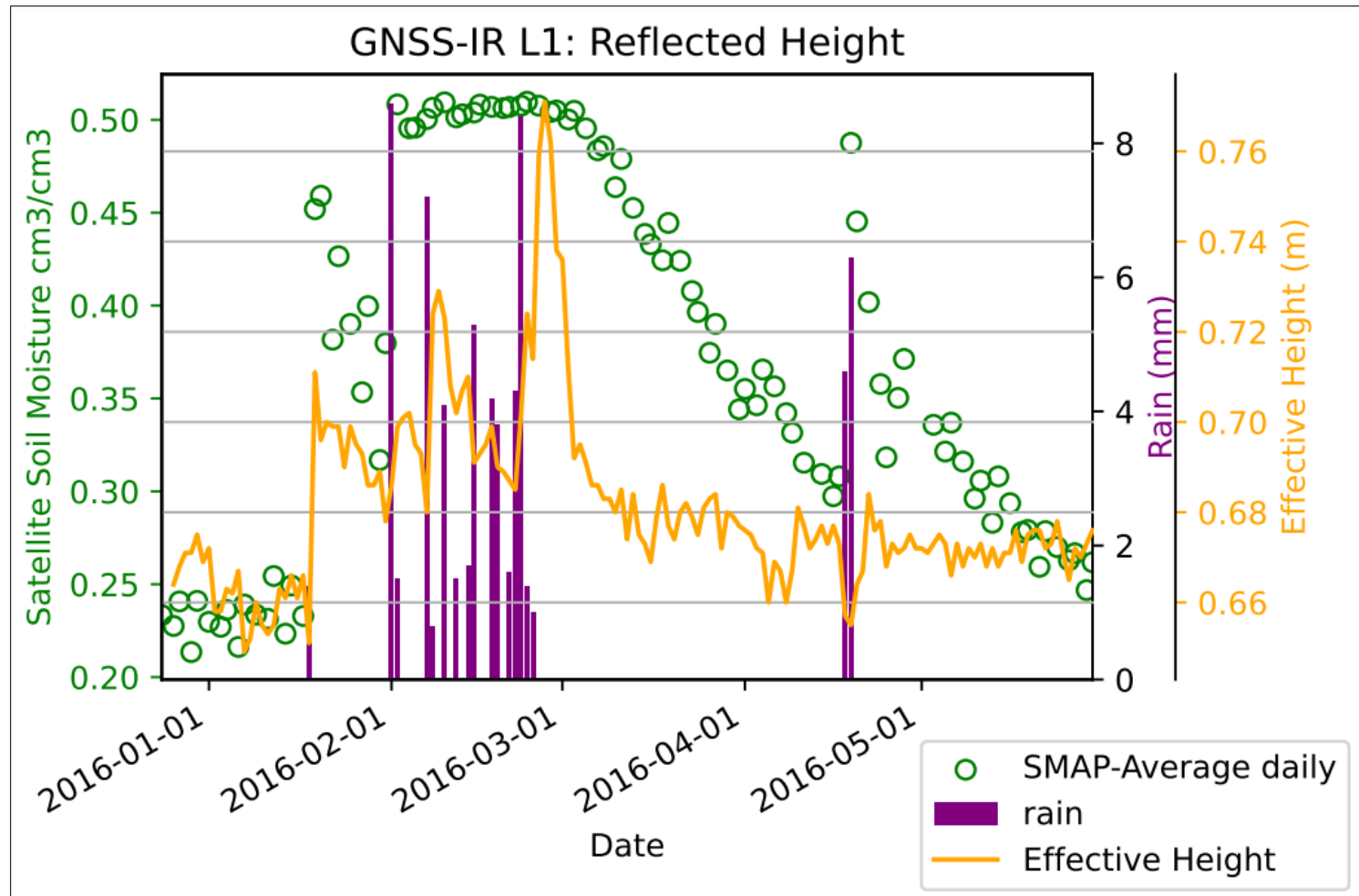
SMAP-Version 5: Soil Moisture Active Passive Satellite mission of NASA [4]

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

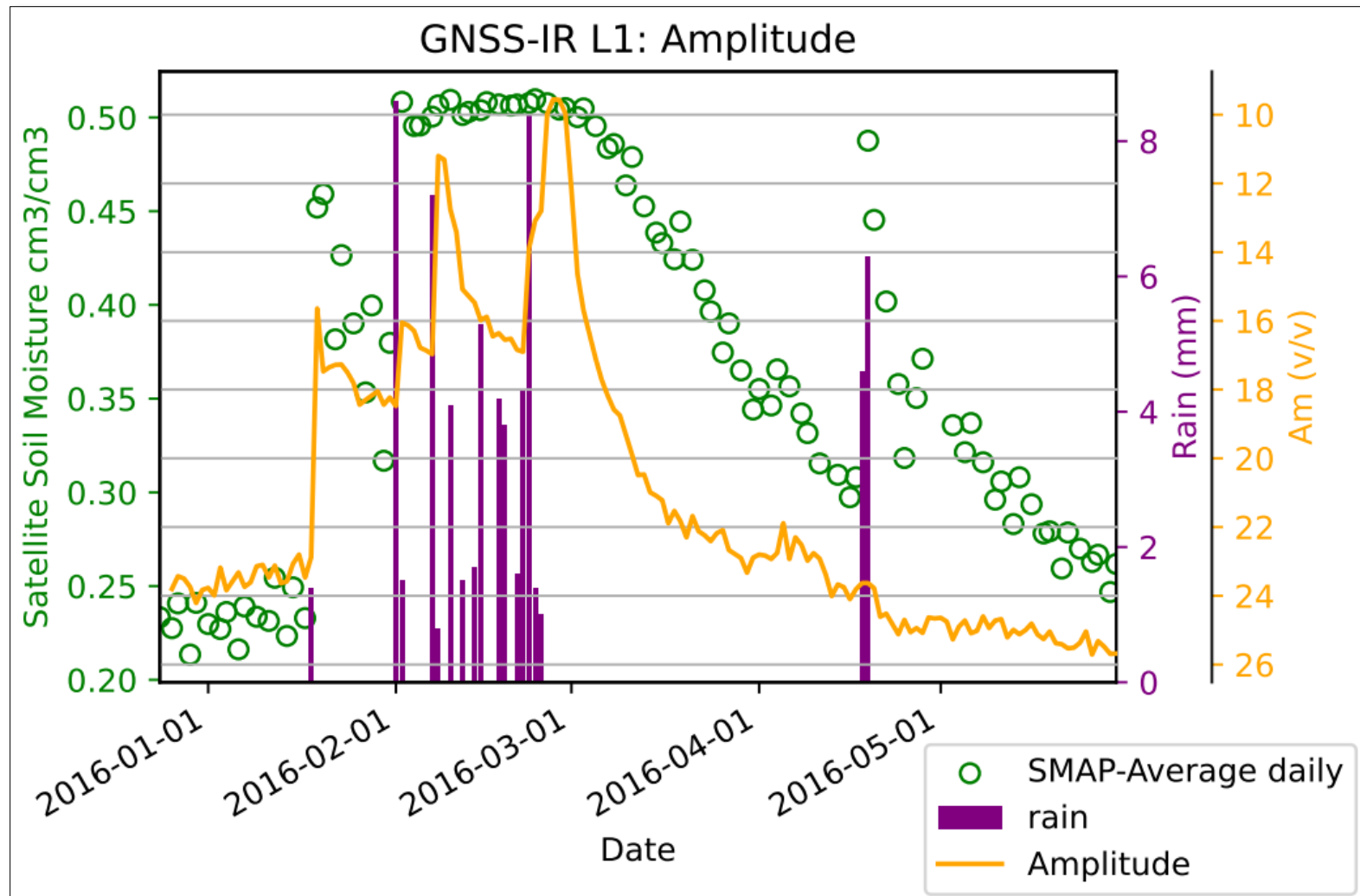


SMAP data for a period of 12 days

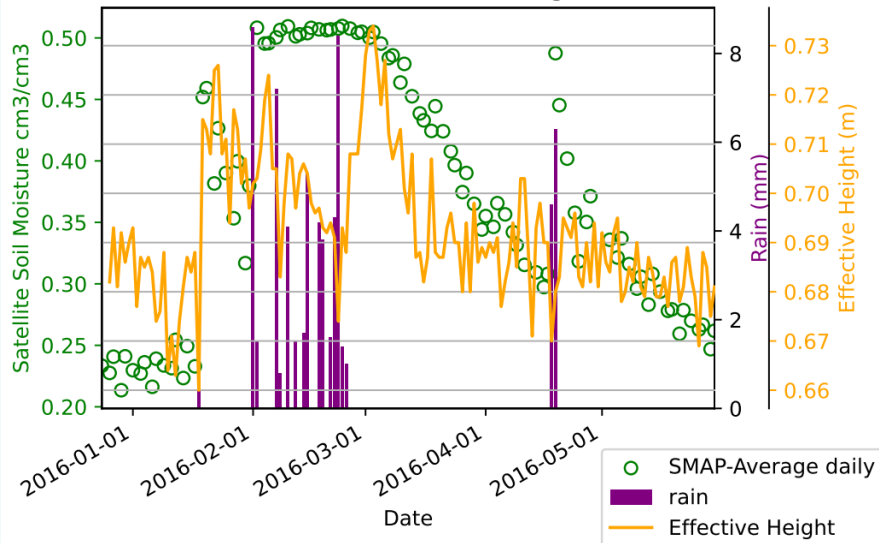
As the soil becomes wetter, the height estimated from the periodogram decreases [1]



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



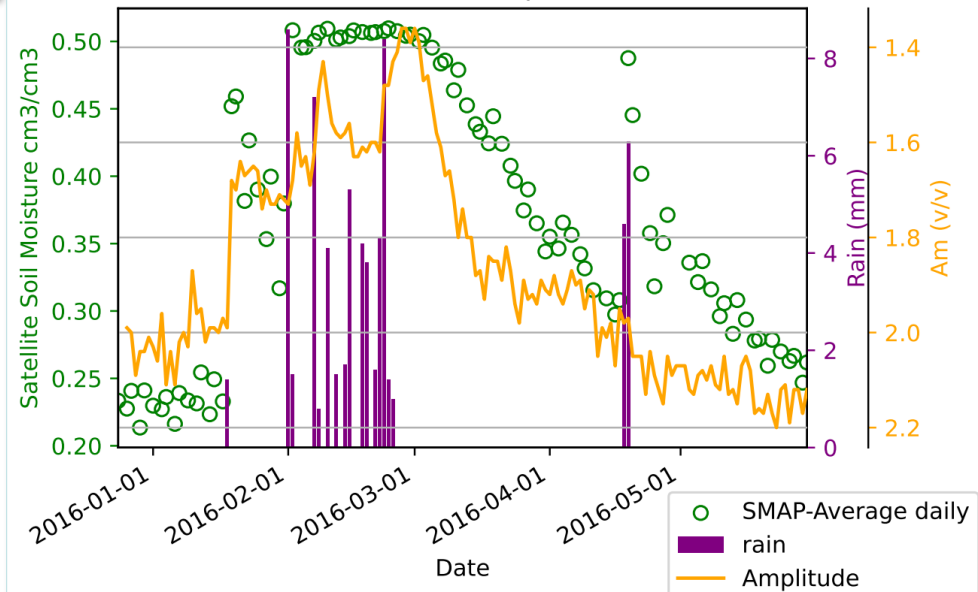
GNSS-IR L2: Reflected Height



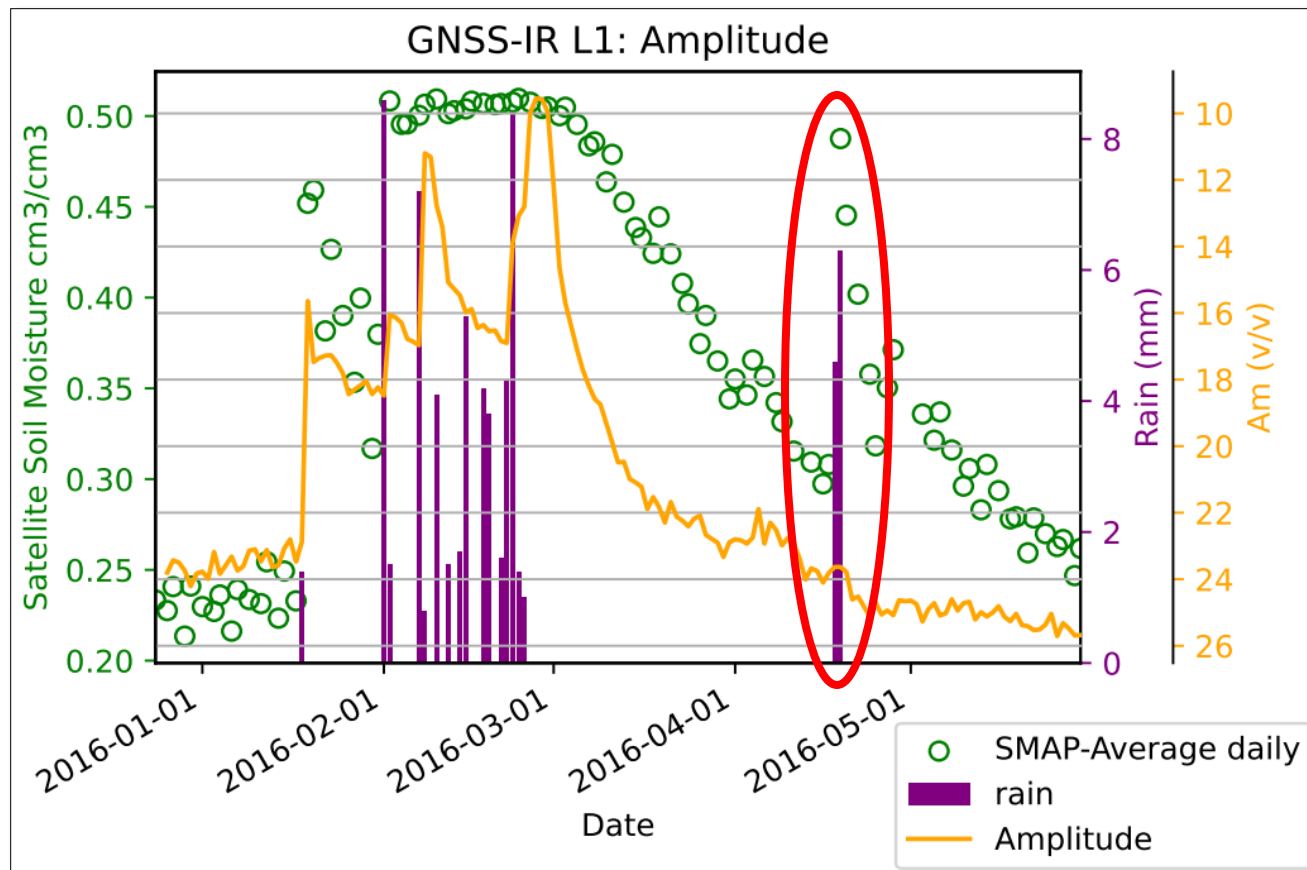
Changes in reflected heights have the same magnitude as L1

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

GNSS-IR L2: Amplitude

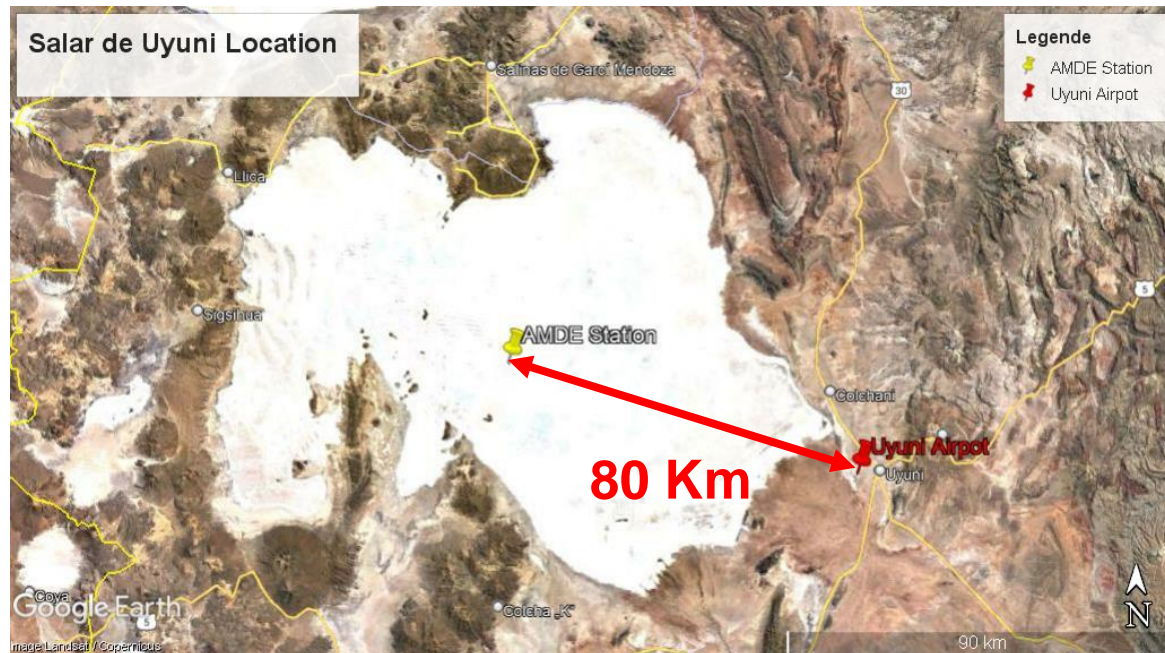


Why do the GNSS-IR results not match with the precipitation data?



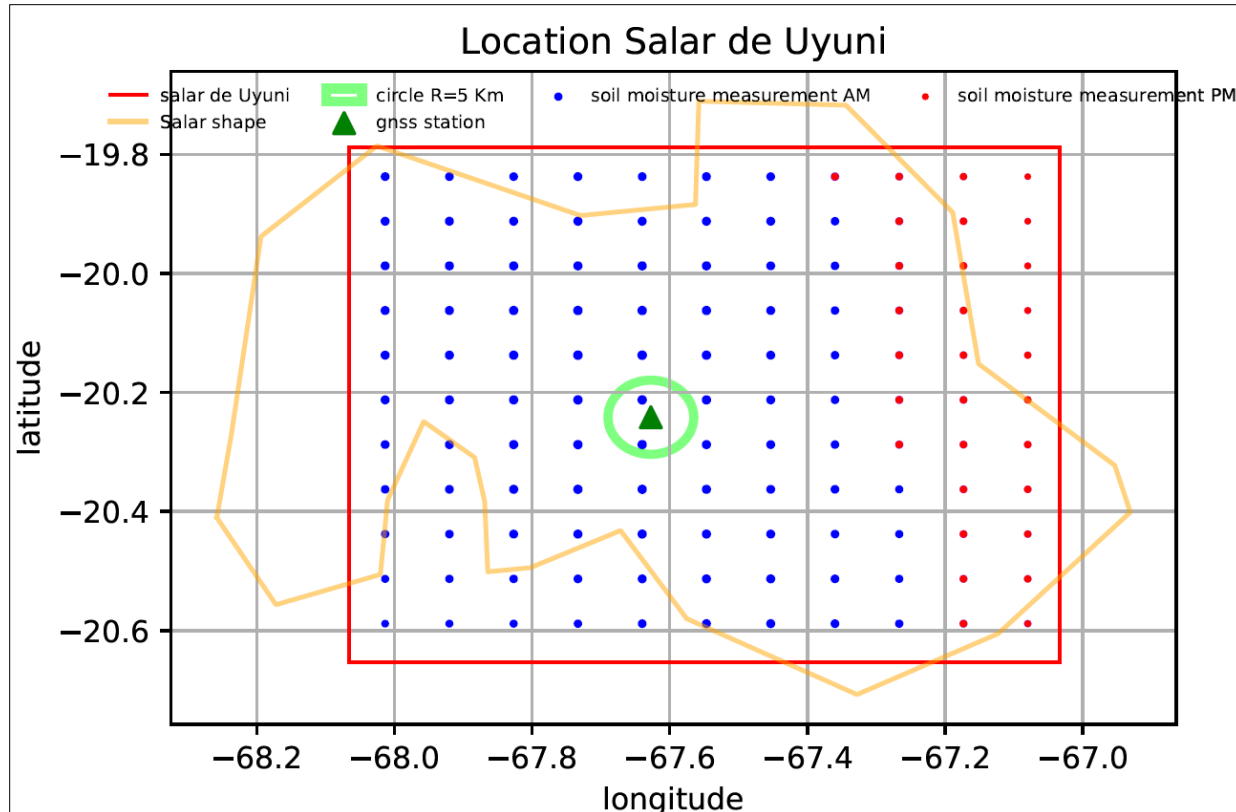
Why do the GNSS-IR results not match with the precipitation data?

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



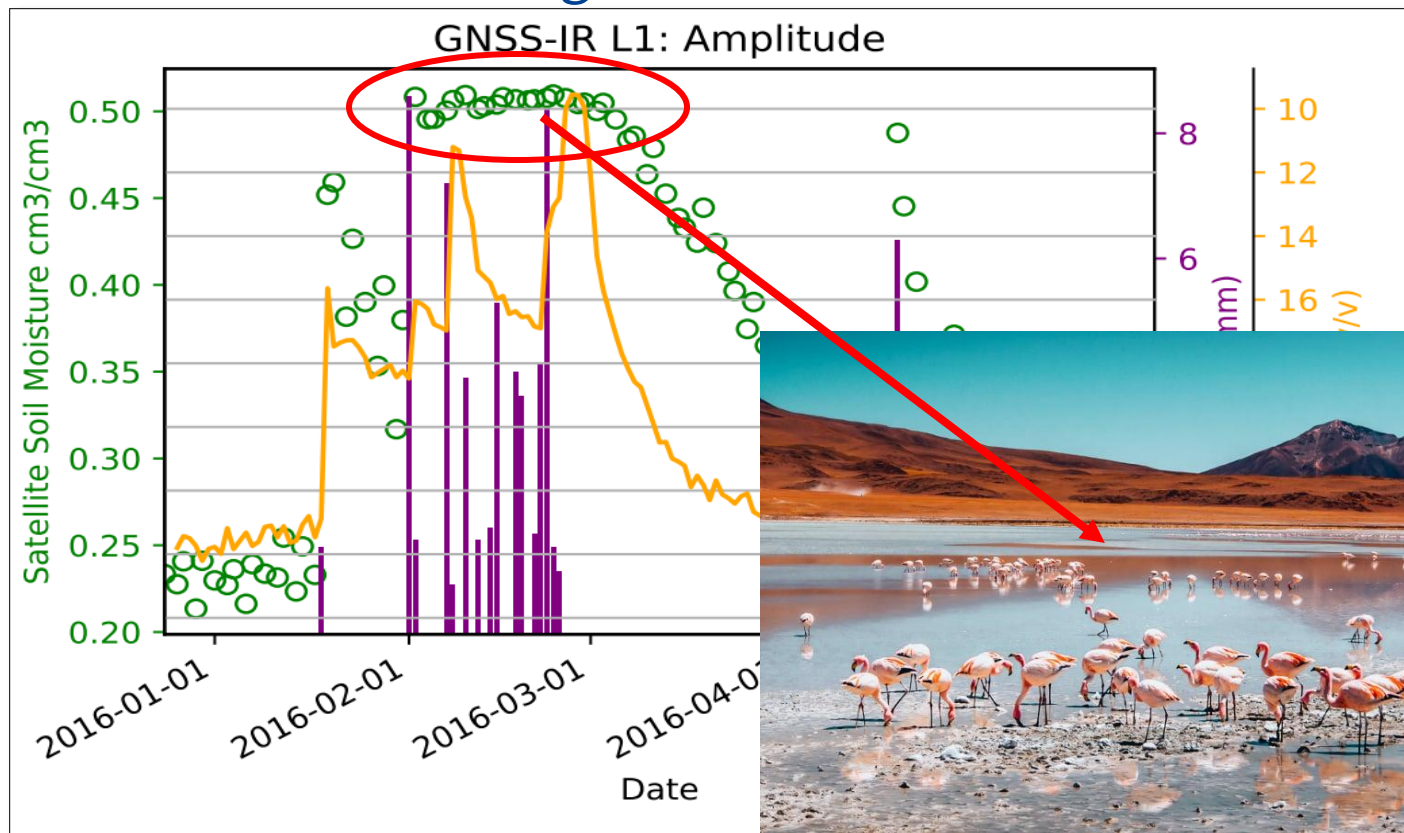
Why do the GNSS-IR results not match with the SMAP data?

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



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



- 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]

- The code used for this study is available on my personal git account:

https://github.com/josemoragaposselt/gnssir_salar_uyni

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

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

Potosí Aeropuerto(Activo) ⊗



Variables

Precipitación



Tipo de dato

Diarios



Periodo

01/01/2016

01/07/2016



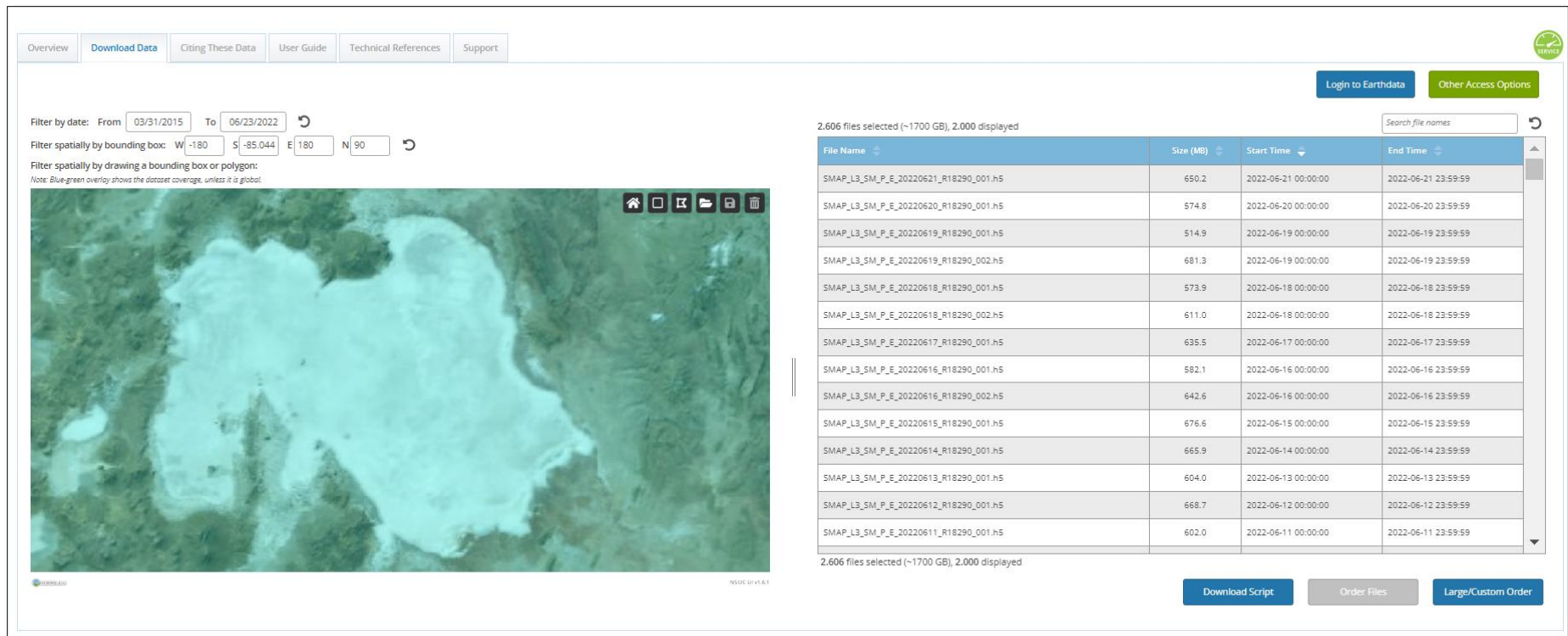
Ultimo dato registrado

Ver Potosí Aeropuerto(Activo)



Where to find the Data?

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



The screenshot displays the NSIDC data portal interface. At the top, there are navigation tabs: Overview, Download Data, Citing These Data, User Guide, Technical References, and Support. Below these, there are search filters for date (From 03/31/2015 to 06/23/2022) and spatial bounding box (W -180, S -85.044, E 180, N 90). A map of Antarctica is shown with a blue-green overlay indicating dataset coverage. To the right of the map, a table lists 2,606 files selected (~1700 GB), with 2,000 displayed. The table columns are File Name, Size (MB), Start Time, and End Time. Below the table, there are buttons for Download Script, Order Files, and Large/Custom Order.

File Name	Size (MB)	Start Time	End Time
SMAP_L3_SM_P_E_20220621_R18290_001.h5	650.2	2022-06-21 00:00:00	2022-06-21 23:59:59
SMAP_L3_SM_P_E_20220620_R18290_001.h5	574.8	2022-06-20 00:00:00	2022-06-20 23:59:59
SMAP_L3_SM_P_E_20220619_R18290_001.h5	514.9	2022-06-19 00:00:00	2022-06-19 23:59:59
SMAP_L3_SM_P_E_20220619_R18290_002.h5	681.3	2022-06-19 00:00:00	2022-06-19 23:59:59
SMAP_L3_SM_P_E_20220618_R18290_001.h5	573.9	2022-06-18 00:00:00	2022-06-18 23:59:59
SMAP_L3_SM_P_E_20220618_R18290_002.h5	611.0	2022-06-18 00:00:00	2022-06-18 23:59:59
SMAP_L3_SM_P_E_20220617_R18290_001.h5	635.5	2022-06-17 00:00:00	2022-06-17 23:59:59
SMAP_L3_SM_P_E_20220616_R18290_001.h5	582.1	2022-06-16 00:00:00	2022-06-16 23:59:59
SMAP_L3_SM_P_E_20220616_R18290_002.h5	642.6	2022-06-16 00:00:00	2022-06-16 23:59:59
SMAP_L3_SM_P_E_20220615_R18290_001.h5	676.6	2022-06-15 00:00:00	2022-06-15 23:59:59
SMAP_L3_SM_P_E_20220614_R18290_001.h5	665.9	2022-06-14 00:00:00	2022-06-14 23:59:59
SMAP_L3_SM_P_E_20220613_R18290_001.h5	604.0	2022-06-13 00:00:00	2022-06-13 23:59:59
SMAP_L3_SM_P_E_20220612_R18290_001.h5	668.7	2022-06-12 00:00:00	2022-06-12 23:59:59
SMAP_L3_SM_P_E_20220611_R18290_001.h5	602.0	2022-06-11 00:00:00	2022-06-11 23:59:59

- [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

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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