This presentation on the Trans-National Access (TNA) project titled

Validating the Swarm S4 index over Africa using the Eswua Database

(VSS4AED)

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TNA project, INGV Node

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SWMC team: Ola Abu Elzz and Ahmed Yassen (EJUST)

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Outline

Abstract

- The **amplitude scintillation index S4** is a measure of the intensity fluctuations of Global Navigation Satellite System (GNSS) signals caused by **ionospheric irregularities**.
- Recently, **The INGV** proposed and designed **a model to estimate S4** from the 16 Hz density data measured by the Swarm satellites.
- The model based **on Rino's theory** of weak scattering and **the NeQuick2 model** of the electron density profile.
- They used the **Swarm data** to **derive** the **spectral slope** and **the variance of the electron density** at the **peak of the irregularity layer**, which are the **key parameters for the scintillation model.**
- Then they used the NeQuick2 model to reconstruct the irregularity layer.
- <u>In this project, my contribution was to validate the INGV proposed model using Malindi observatory data that intersect with Swarm trajectories.</u>

The INGV proposed model can provide global information on scintillation, especially in areas where ground-based GNSS receivers are unavailable.

The WAM scintillation model approach for high latitudes and for low latitudes procrdure:

- Assume virtual GNSS satellites and ground GNSS receivers that are coincident with Swarm trajectories.

- Compute the profile of the electron density from the virtual GNSS receivers on the ground to the GNSS satellites at 20,000 km over and below the Swarm path and altitude.

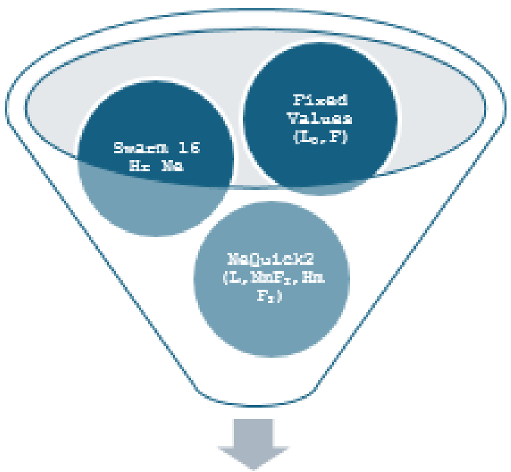
- The NeQuick electron density profile

is related to the ground-based Total Electron Content (TEC) measurements from the Madrigal database.

- The importance of this choice for reliable results,

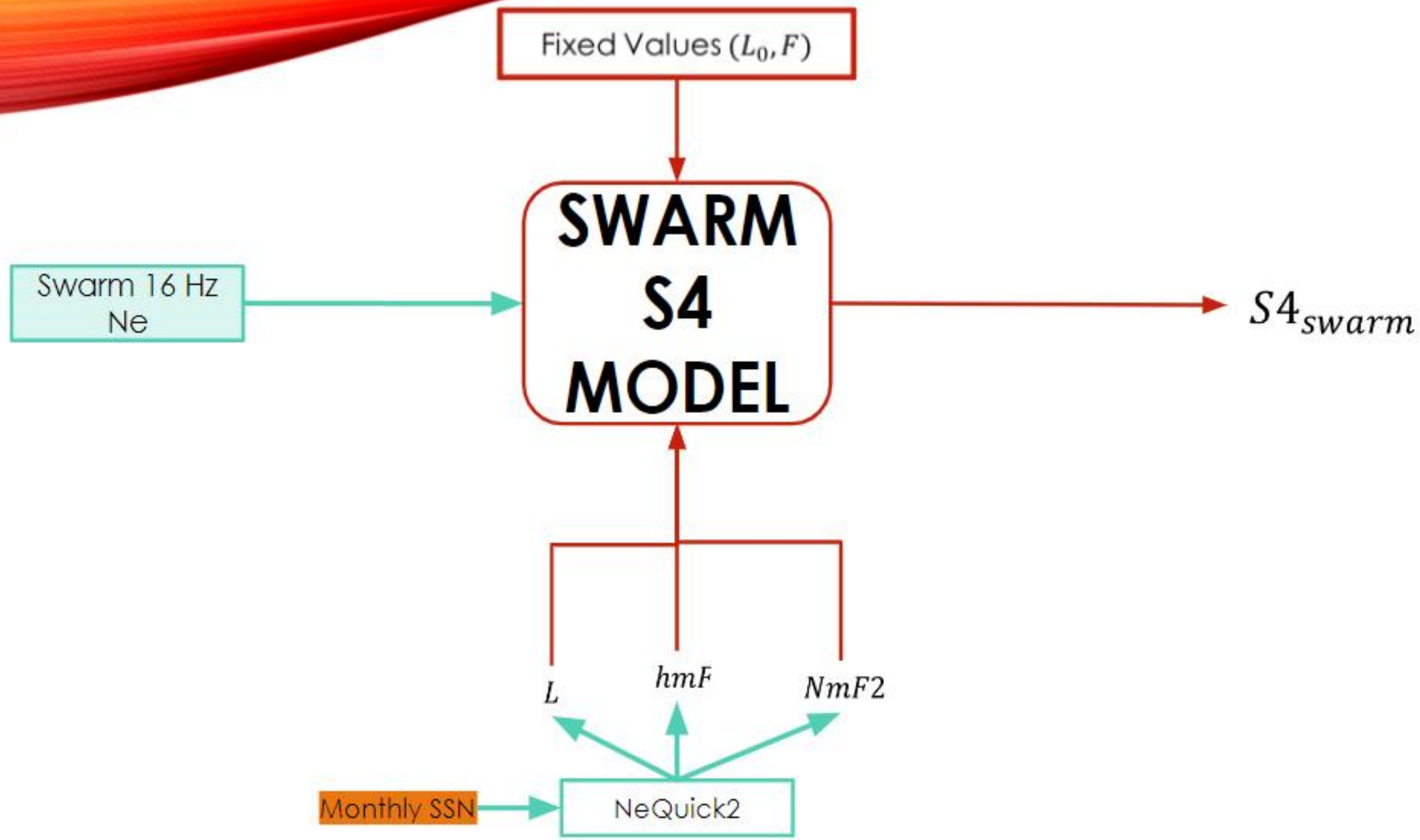
used for the validation.

use the same ray path that the ground-based GNSS scintillation receiver observed.



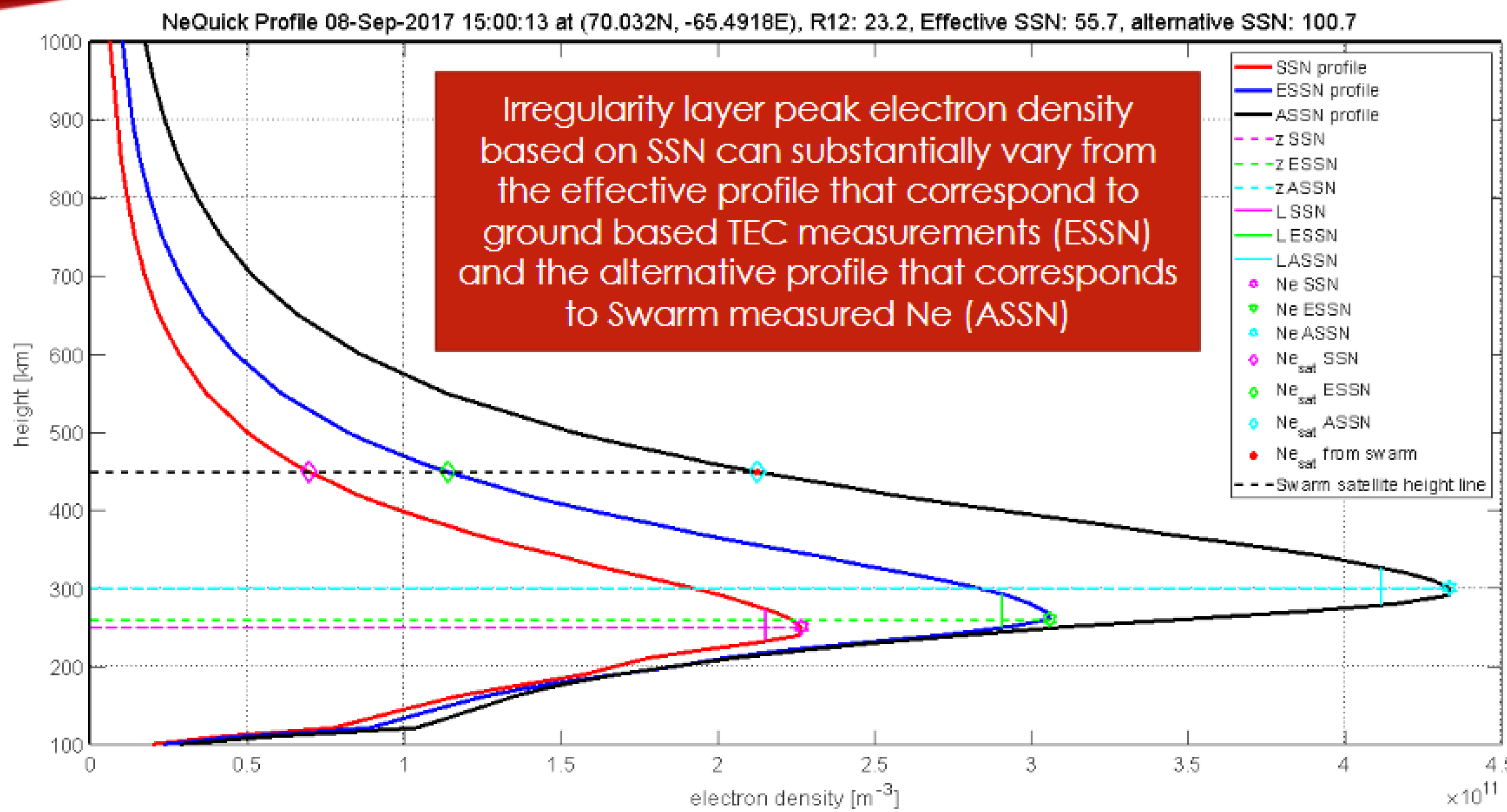
INGV proposed model to derive Swarm S_4

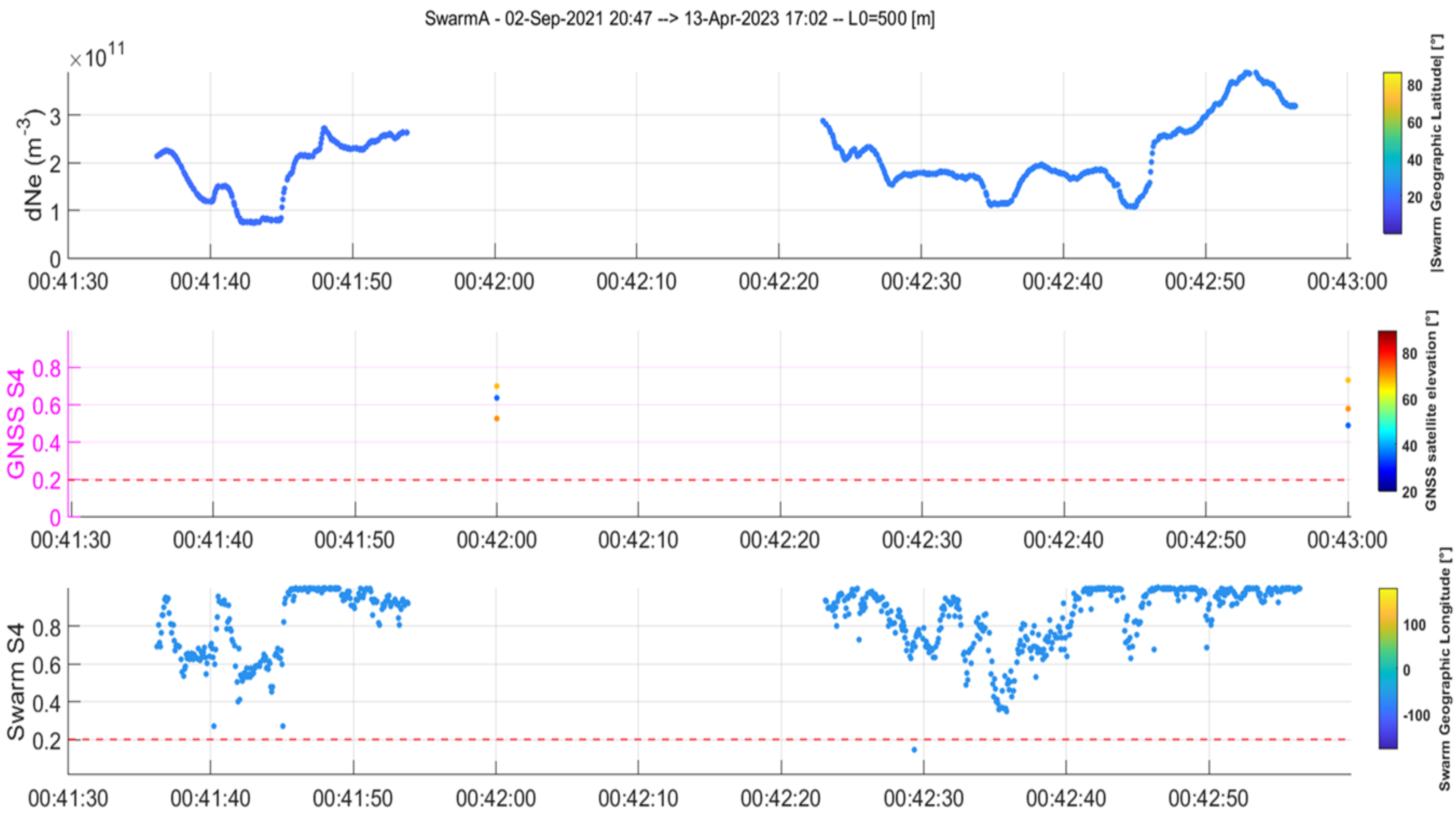
INGV Model's parameters

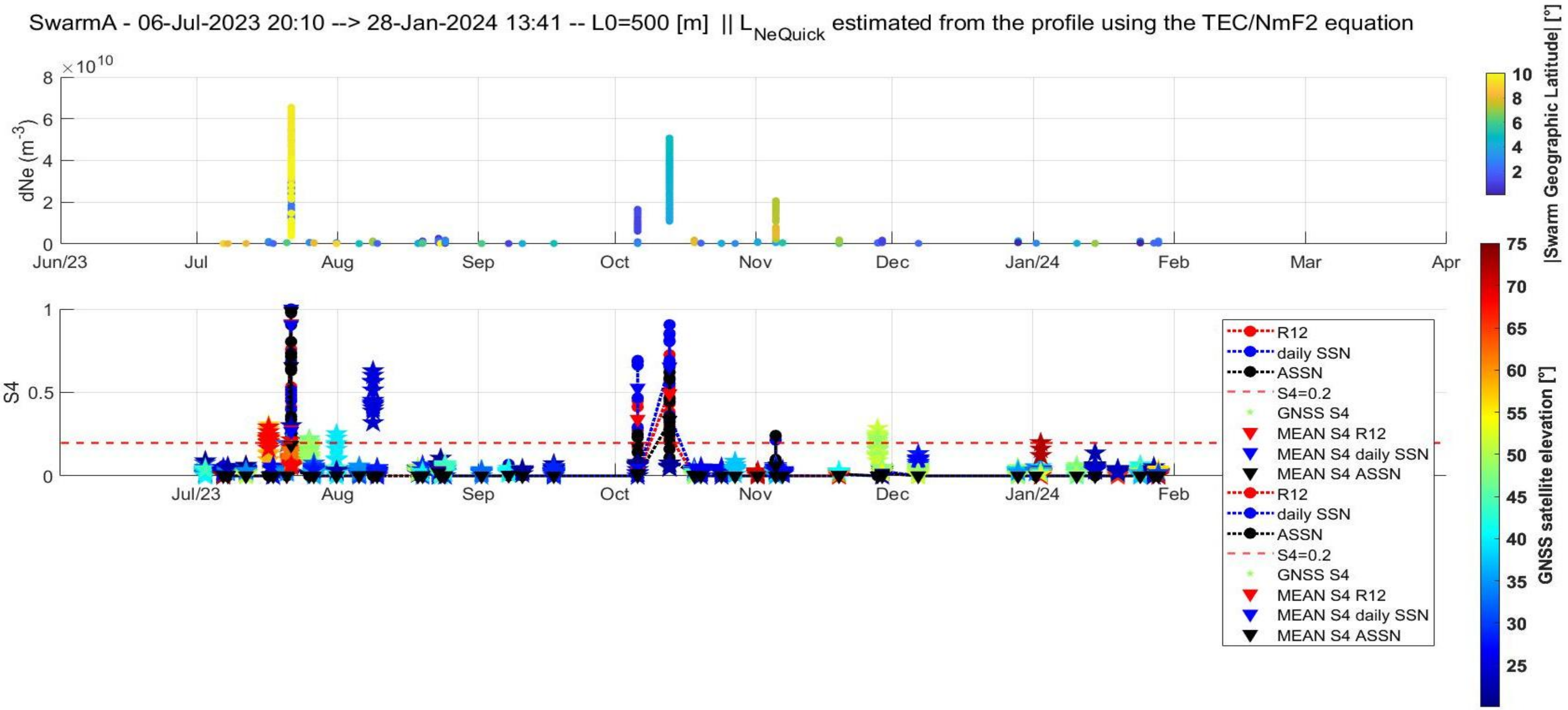


The Three NeQ-Ne profiles models

EXAMPLE OF NEQUICK2 PROFILES




SwarmA - 02-Sep-2021 20:47 --> 13-Apr-2023 17:02 -- L0=500 [m]
×10^11
dNe (m^-3)
0
1
2
3
00:41:30
00:41:40
00:41:50
00:42:00
00:42:10
00:42:20
00:42:30
00:42:40
00:42:50
00:43:00
|Swarm Geographic Latitude| [°]
20
40
60
80
GNSS S4
0
0.2
0.4
0.6
0.8
GNSS satellite elevation [°]
Swarm S4
Swarm Geographic Longitude [°]
-100
0
100

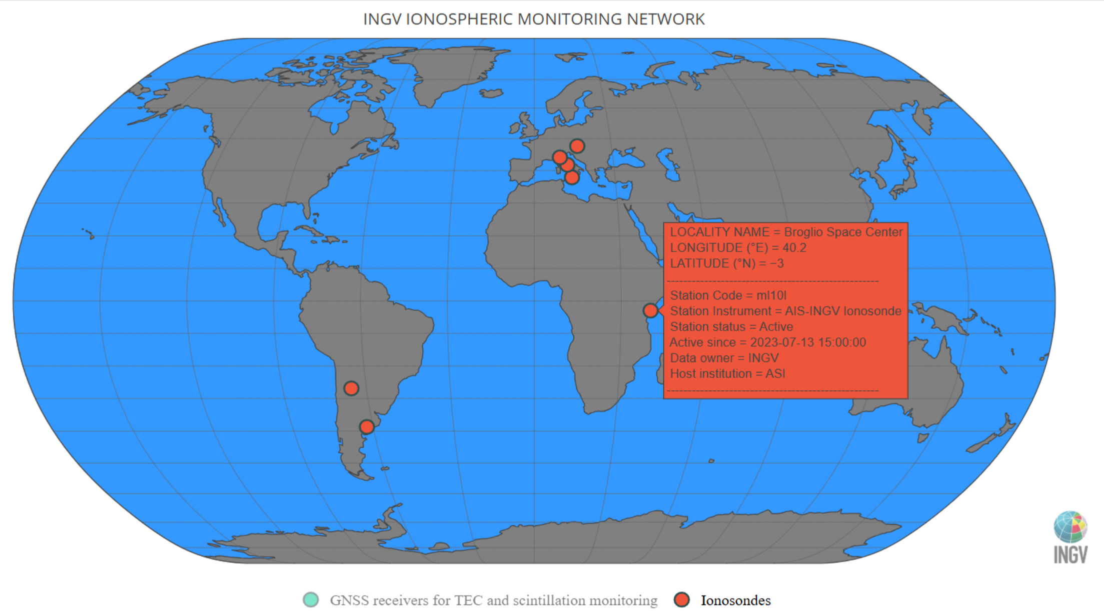


SwarmA - 06-Jul-2023 20:10 --> 28-Jan-2024 13:41 -- L0=500 [m] || L_NeQuick estimated from the profile using the TEC/NmF2 equation
dNe (m^-3)
×10^10
Jun/23
Jul
Aug
Sep
Oct
Nov
Dec
Jan/24
Feb
Mar
Apr
|Swarm Geographic Latitude| [°]
S4
Jul/23
R12
daily SSN
ASSN
S4=0.2
GNSS S4
MEAN S4 R12
MEAN S4 daily SSN
MEAN S4 ASSN
GNSS satellite elevation [°]

Malindi Ionosonde

- The Swarm S4 index using GNSS data collected from Malindi station in Africa, where ionospheric irregularities are more pronounced due to geomagnetic equatorial effects.

Ionosonde Station	Latitude	Longitude
Malindi	-3° N	40.2° E



The New Observatory for Real-time Ionospheric Sounding over Kenya- NORISK project (http://norisk.rm.ingv.it/)

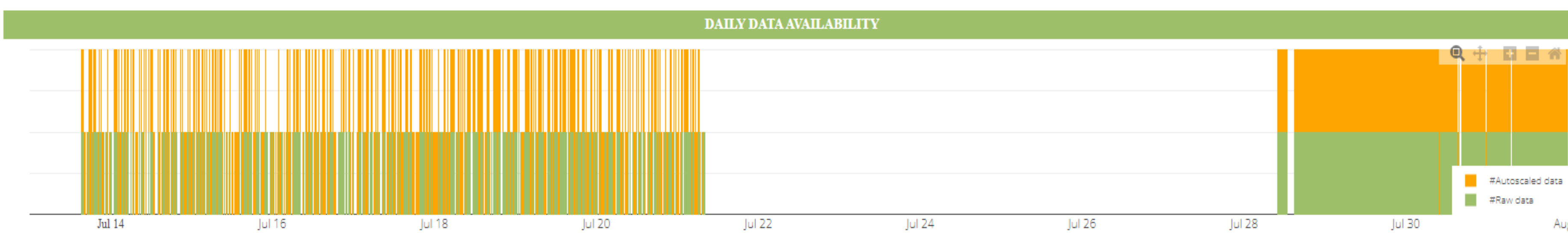
Data availability

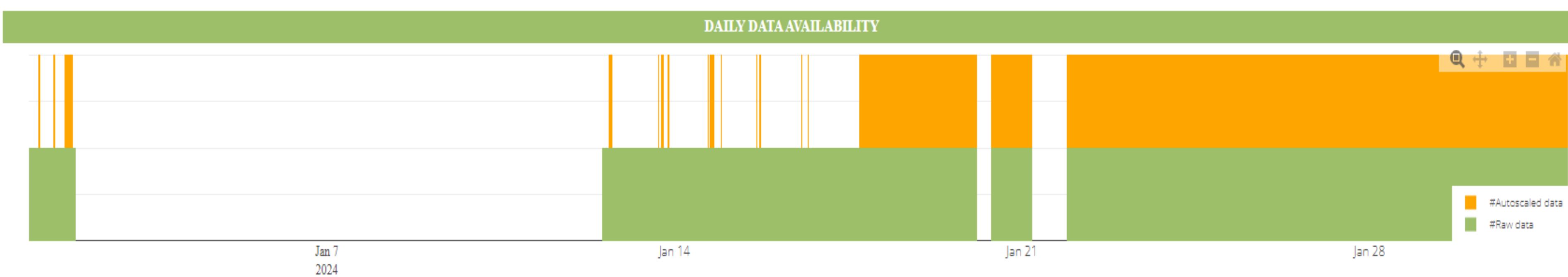
- Malindi Ionosonde data started on 13/7/2023 up to now.

In the validation process:

- We started our analysis by using the Autoscaled ionograms.
- The data range is from 5/8/2023 to 28/01/2024.

http://www.eswua.ingv.it/





REFERENCE TIME (UTC) 2025-06-03 09:45:00

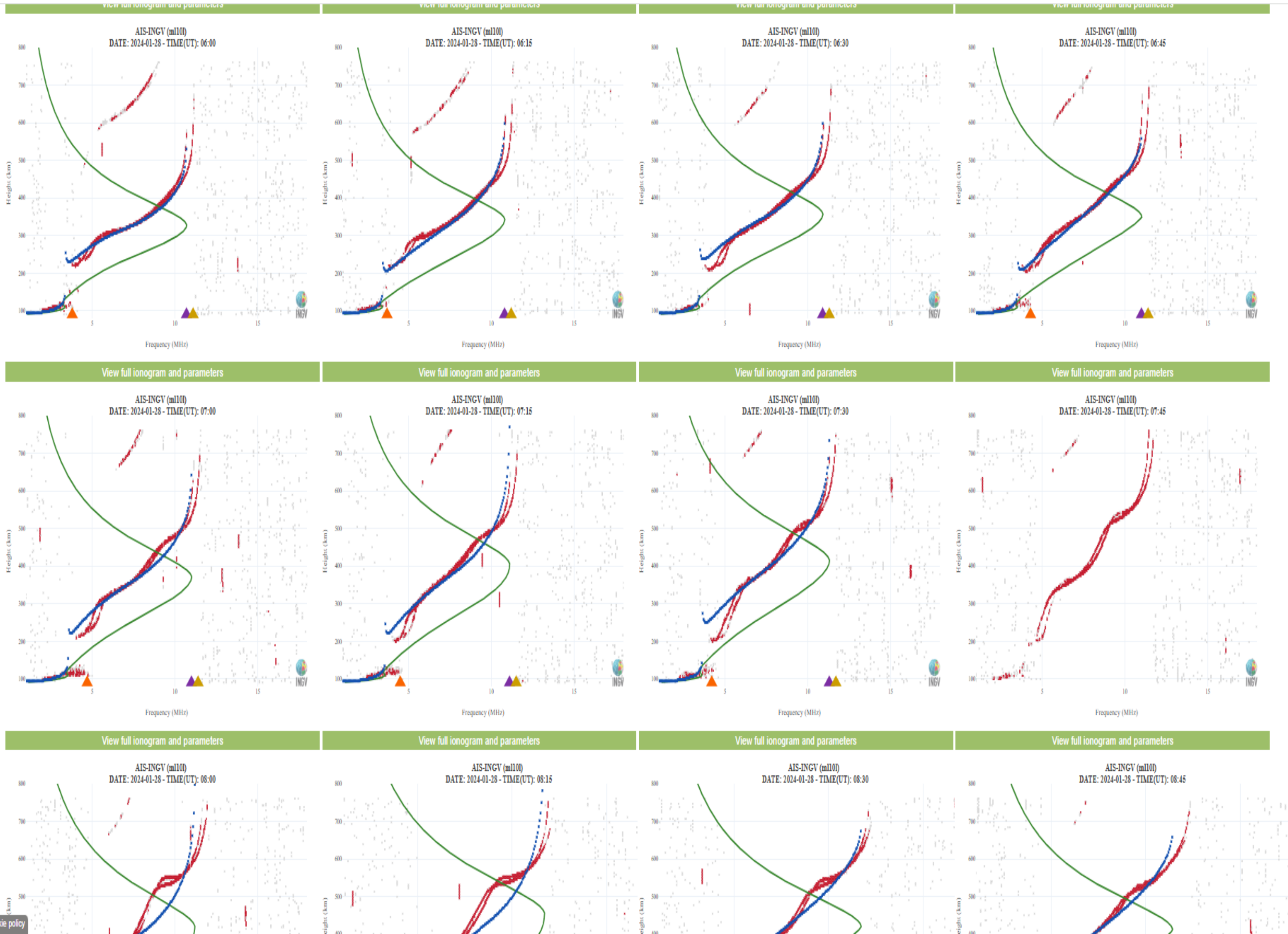
SELECT STATION: AFRICA - ml10l

Station info and data availability

TIME RANGE (UTC): 2024/01/28 00:00 - 2024/01/28 12:00

FILTER SPECIFIC INSTANT: undefined

APPLY FILTERS



Cookie policy

Model validation

Methodology

1- Finding the time Synchronization (matching) between the 3 different instruments.

2- Compute the NmF2, hmF2 from the Iononsonde (Malindi station).

3- Compute slap thickness (L) from the NmF2 (ionosonde) and TEC from GPS measurements.

4-Calculating the mean and standard deviation values from each parameter (NmF2, hmF2 and L).

Time Matching

Swarm Time measurements

Every 16 Hz

Ionosonde epocs

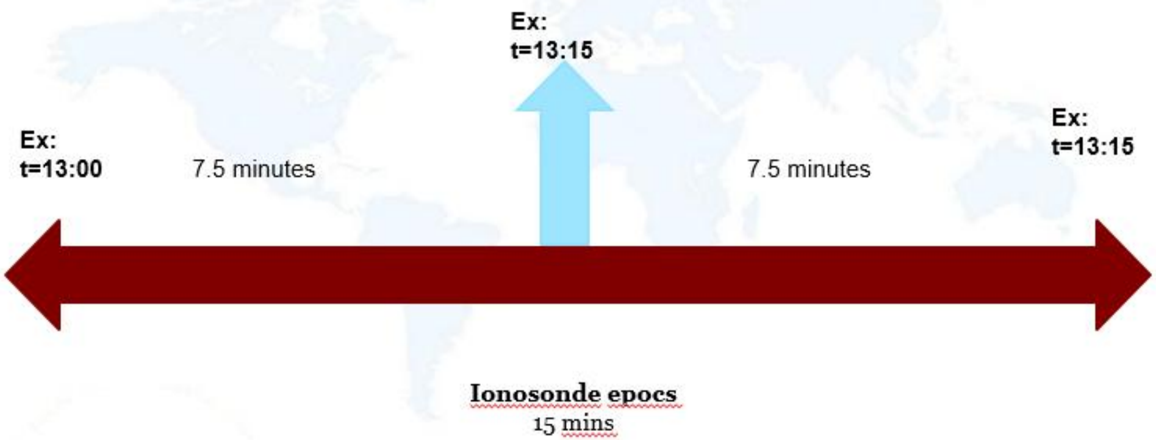
Every

15 mins

GPS Time measurements

Every 1 min

The reference time is the ionosonde epoch.

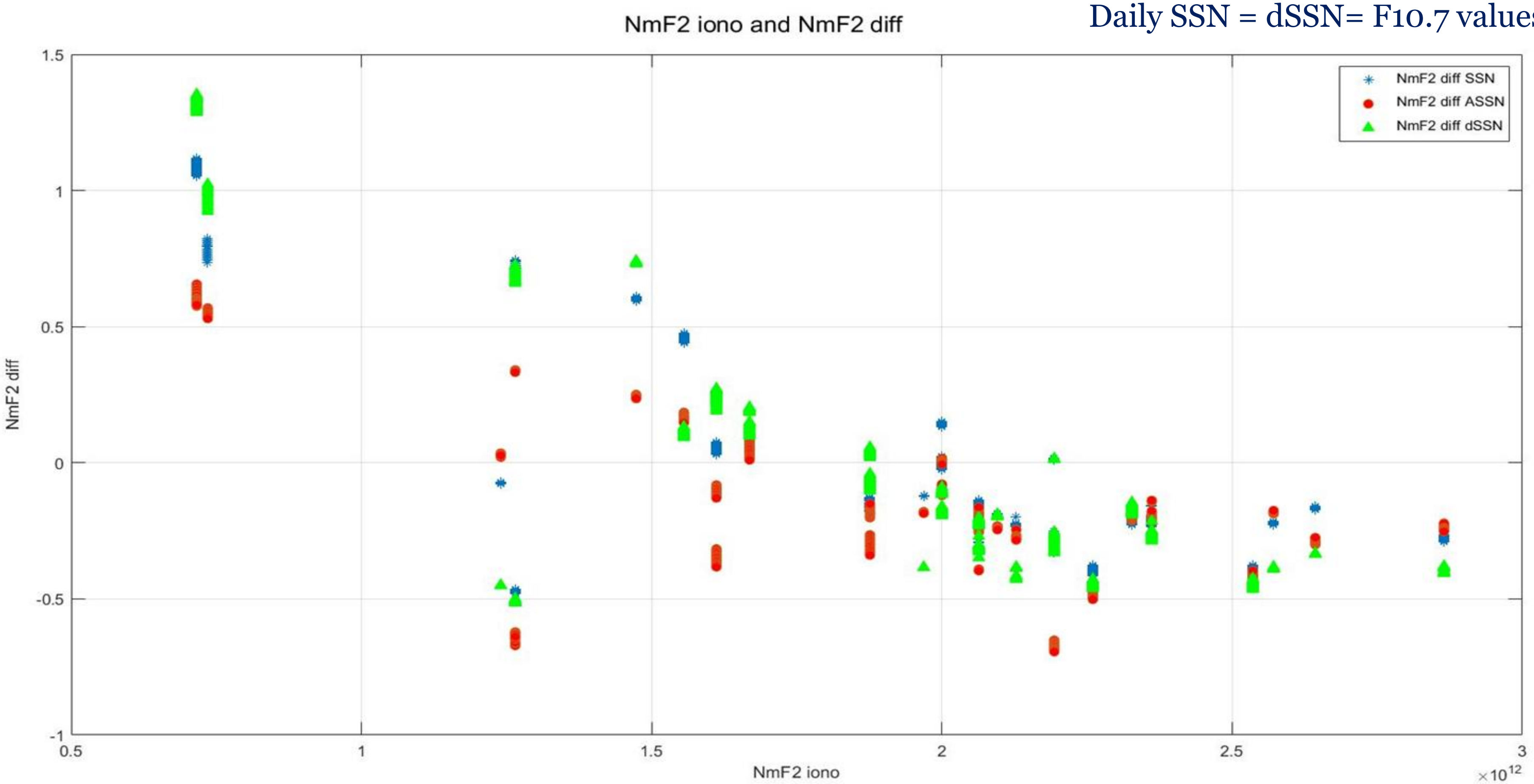


Comparing with the Autoscaled Ionograms

NmF2 Validation

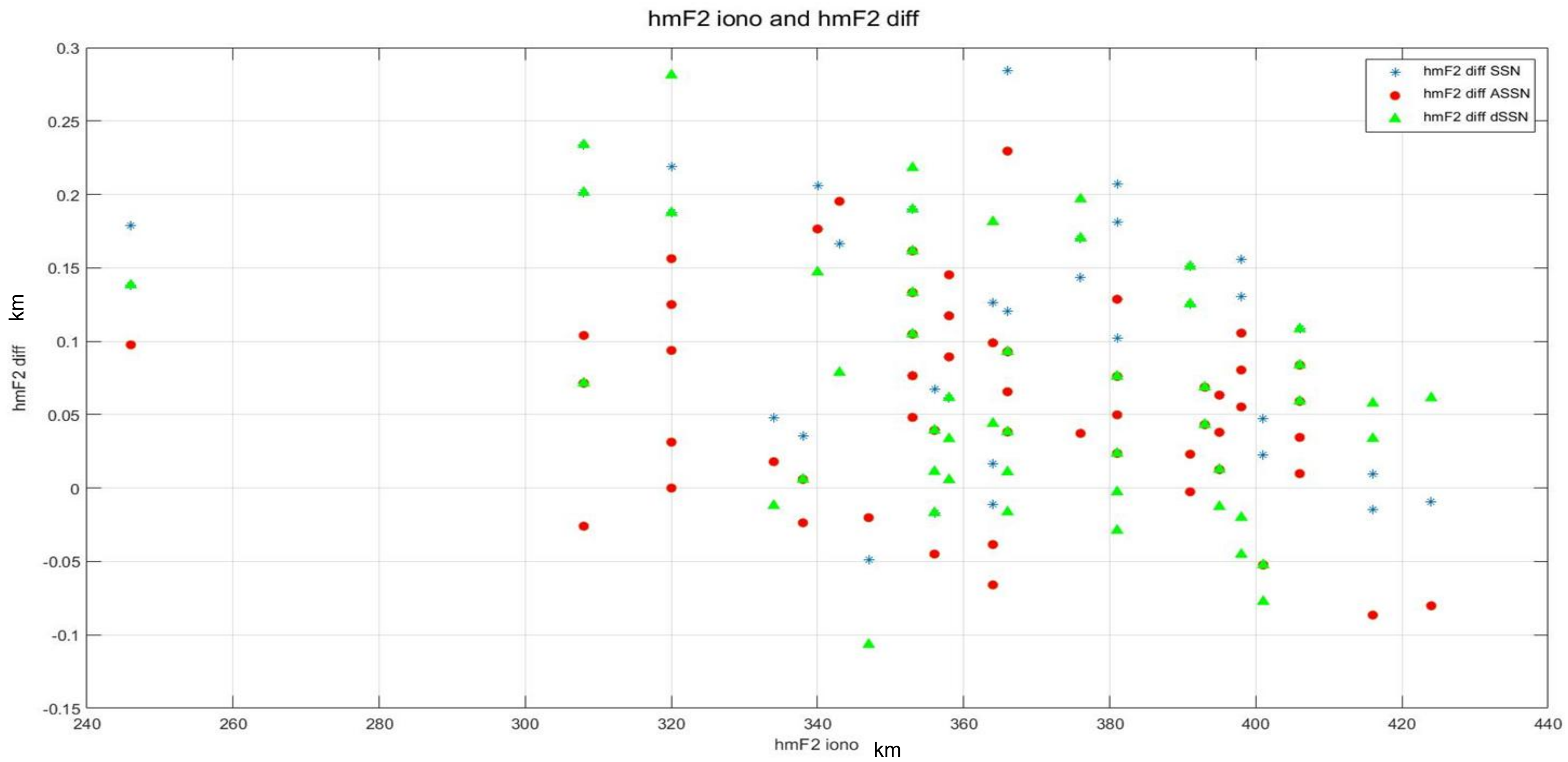
➢The distribution of the modelled NmF2 as calculated from 3 NeQ models with the NmF2 as observed from Malindi ionosonde.

Daily SSN = dSSN= F10.7 values



hmF2 Validation

- The distribution of the modelled hmF2 as calculated from 3 NeQ models with the hmF2 as observed from Malindi ionosonde.



Slab thickness comparison

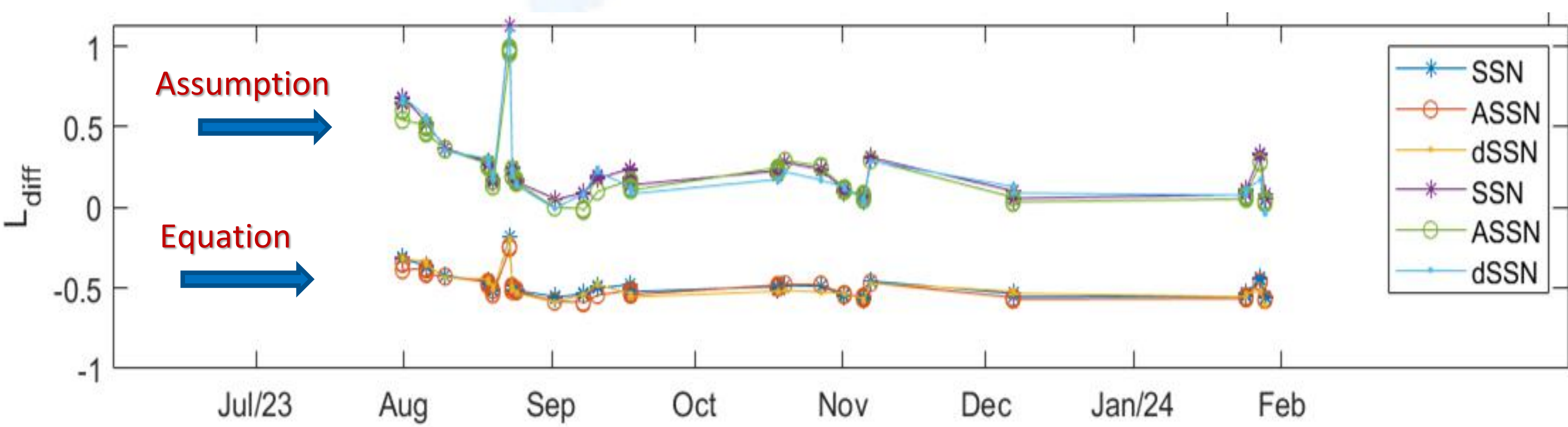
➢ The distribution of the modelled L as calculated from 3 NeQ models with the L as computed from L_assumption and L_equation (TEC_calculation).

Assumption 75%

L=NmF2*75%

TEC_calculation

L_eq= TEC/NmF2

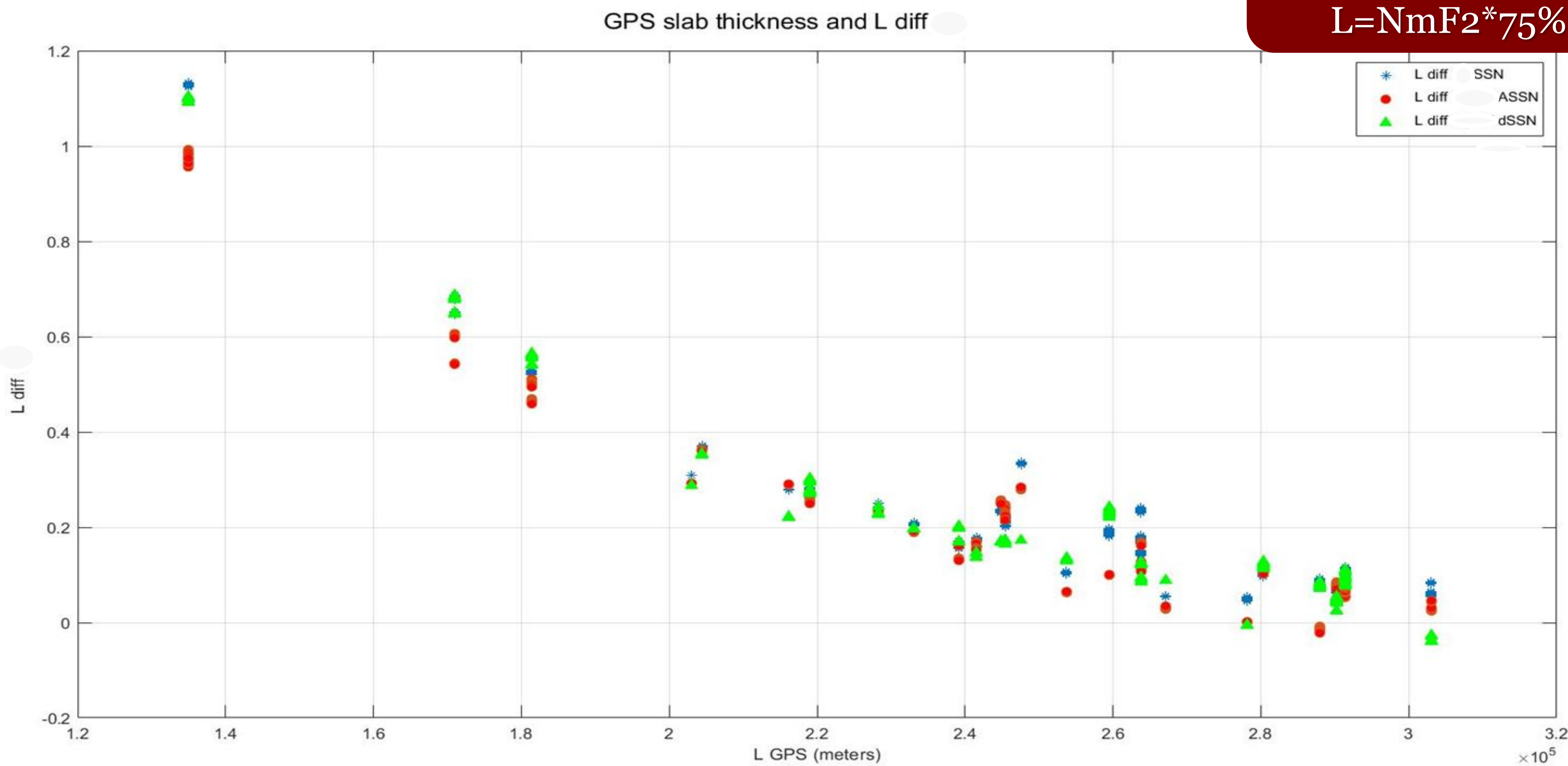


Slab thickness comparison

➢The distribution of the modelled L_diff (assumption) as calculated from the 3 NeQ models with the L_GPS as observed from Malindi ionosonde.

Assumption 75%

L=NmF2*75%

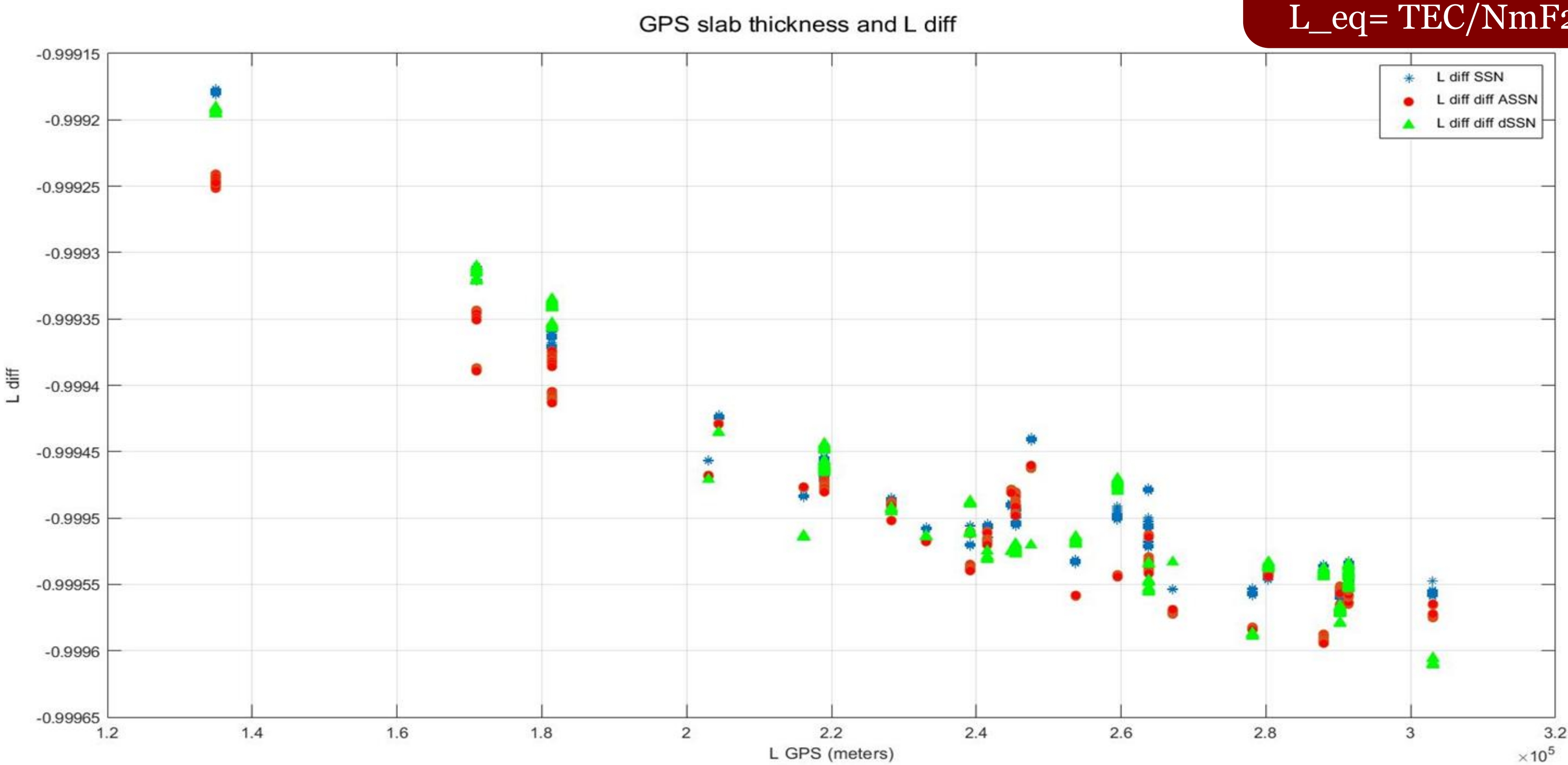


Slab thickness comparison

➢The distribution of the modelled L_diff_eq (TEC/NmF2) as calculated from 3 NeQ models with the L_GPS as observed from Malindi ionosonde.

TEC_calculation

L_eq= TEC/NmF2



Data comparing

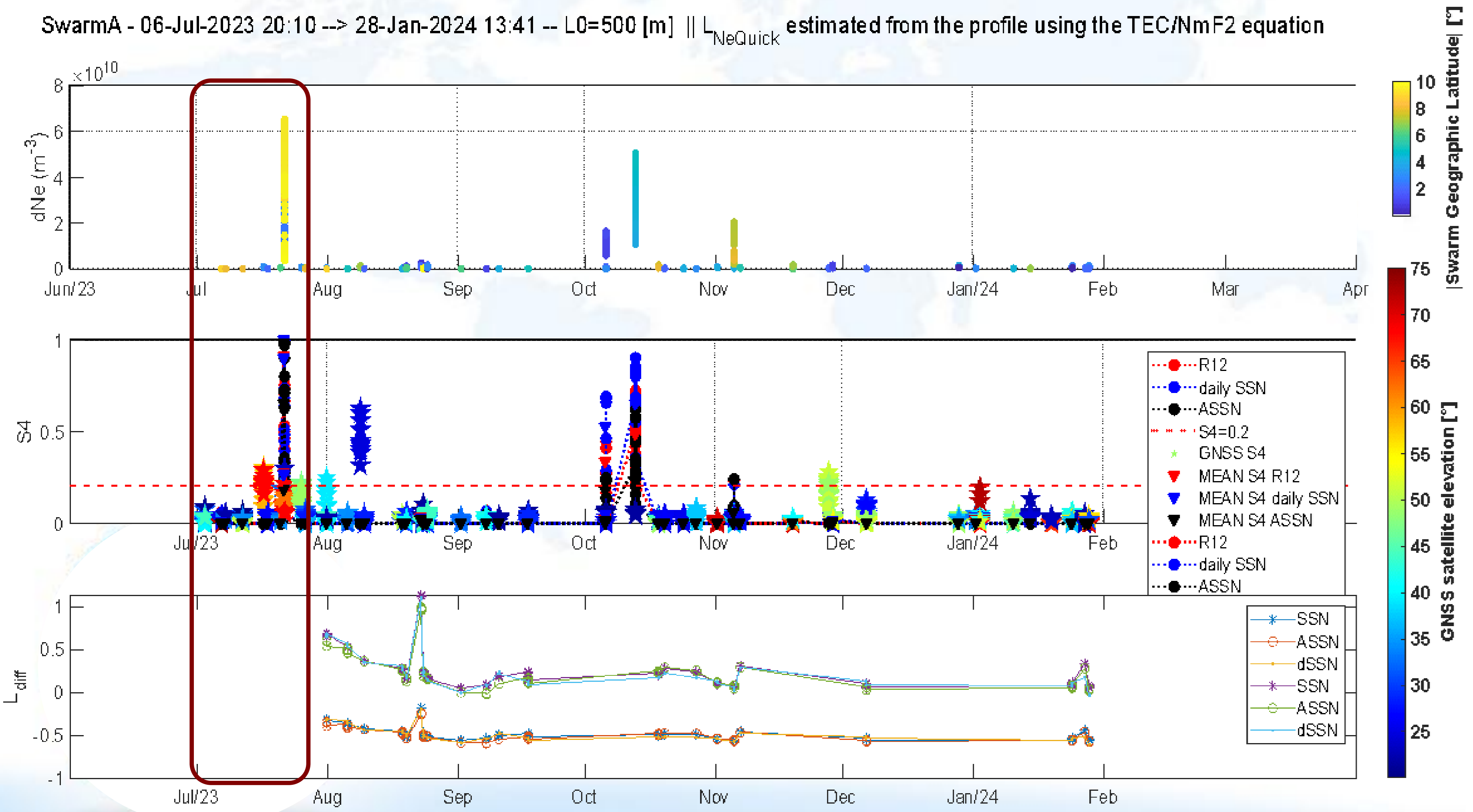
Three input model parameters (L,NmF2 and hmF2):

- Data comparing: the Auto scale data

Parameter	diff_SSN_mean	diff_ASSN_mean	diff_dSSN_mean
L_diff	-0.49707	-0.49707	-0.49178
L_diff_eq	0.2538	0.22242	0.23166
NmF2_diff	-0.019704	-0.13407	-0.06175
hmF2_diff	0.096985	0.057585	0.06853

Parameter	diff_SSN_std	diff_ASSN_std	diff_dSSN_std
L_diff	0.0913	0.0802	0.0960
L_diff_eq	0.2480	0.2224	0.2533
NmF2_diff	0.3696	0.2849	0.4486
hmF2_diff	0.0706	0.0729	0.0816

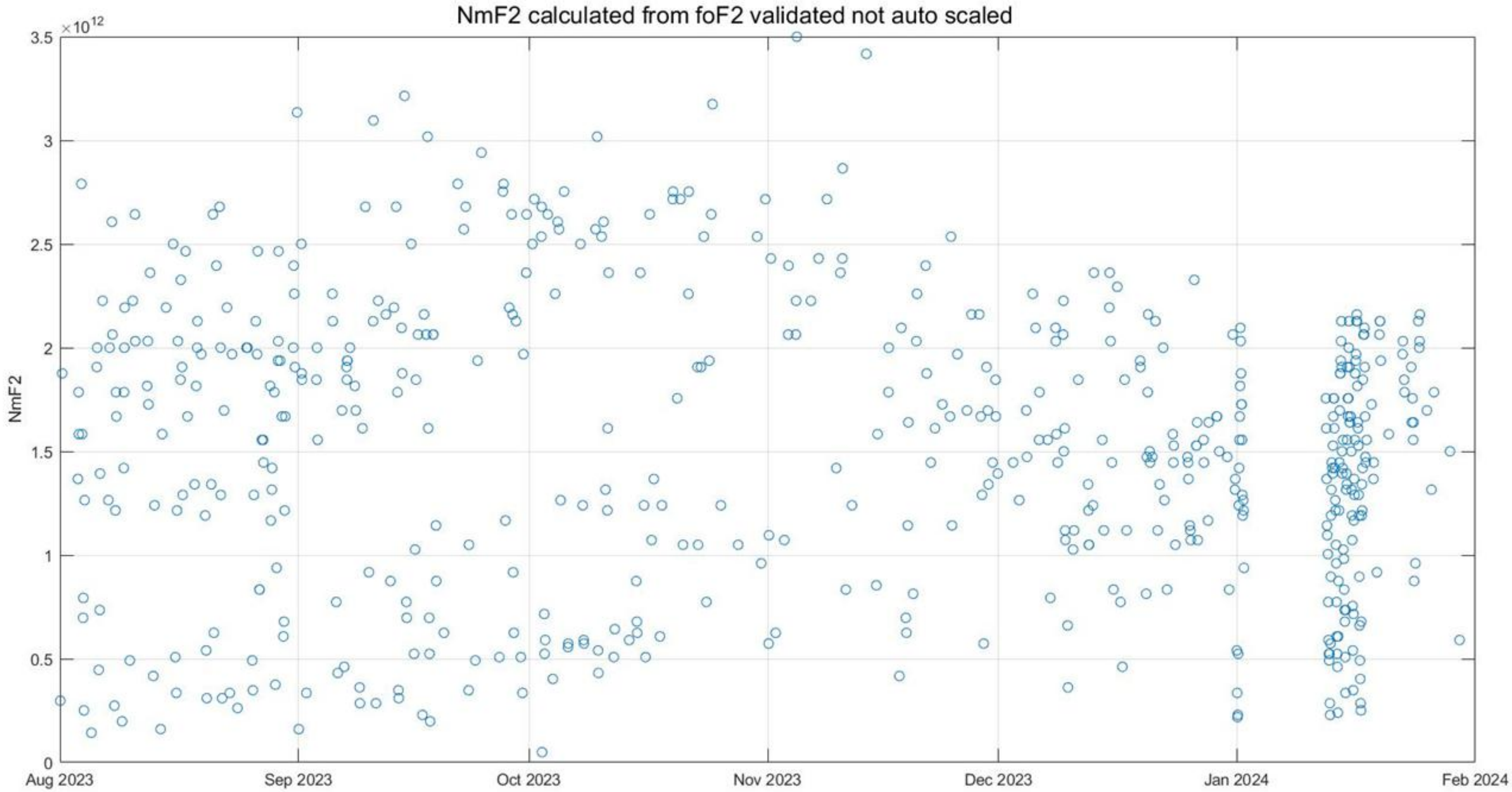
Why we are thinking to include the manual scale data ?



Comparing with the manual scaled ionograms

Manual scaled ionogram

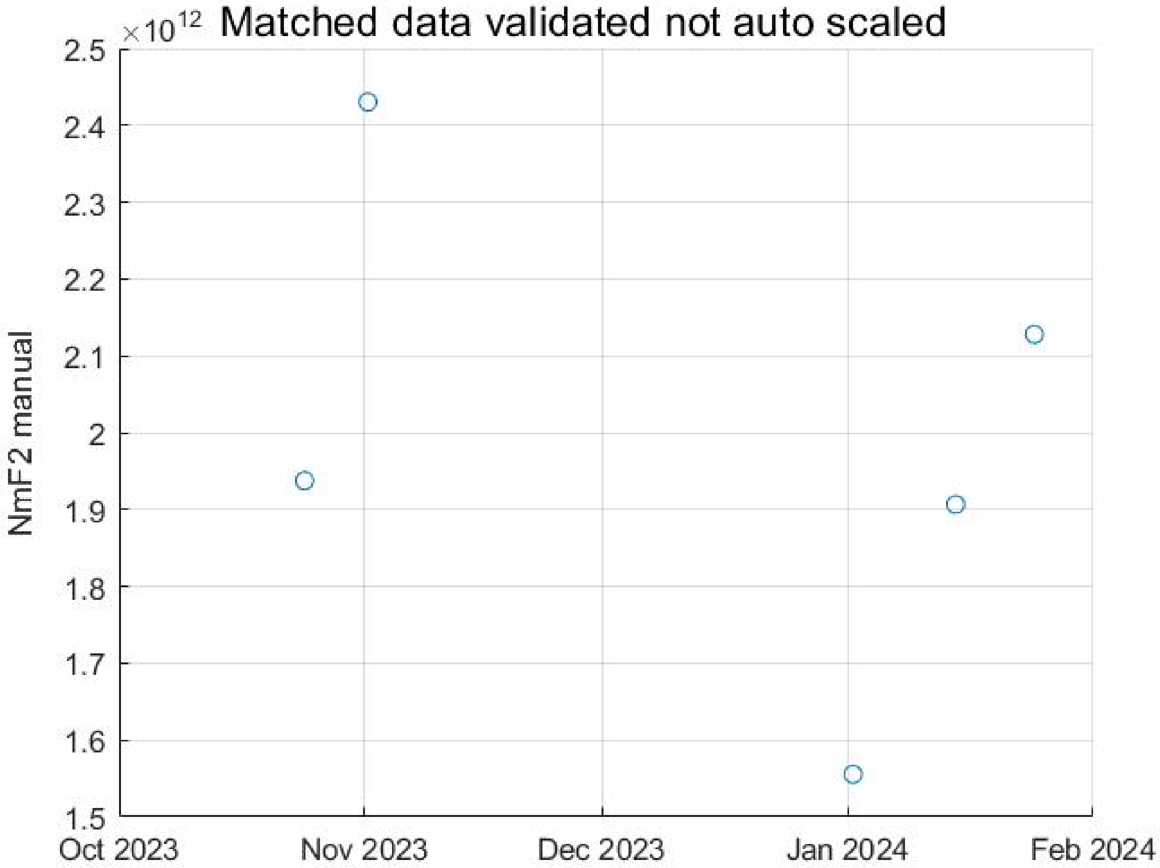
- NmF2 as calculated from the validated ionograms, but not autoscaled.



Number of manual scaled ionogram= 566

Manual ionogram data

- Matching manual scaled ionograms with Swarm measurements



Number of matched data between ionosonde with swarm = 5

Conclusion

- **For the Auto scaled ionograms:**
- ✓ The diff_ASSN_mean of three NeQ parameters (NmF2_ ASSN,hmF2_ ASSN, and L_ ASSN) give the smallest values.
- ✓ The L_diff_ SSN values are similar to the L_diff_ASSN values.
- ✓ The diff_ASSN_std for the three NeQ parameters is the smallest value except for the (hmF2).

- **For the Manual scaled ionograms:**
- ✓ Due to the few matched ionograms with the swarm trajectories, we couldn't compute the statistical analysis on the data.

Research outcome

Publications:

1. Validating the amplitude scintillation index from Swarm satellites faceplate measurements against the GNSS scintillation receiver measurements in Malindi, Conference paper, SIF National Congress 2024, Rome, Italy, 9 - 13, September 2024.

1. Validating Swarm S4 index from the faceplate electron density measurements over a pair of collocated ionosonde and GNSS receivers in Sharjah, UAE, and Malindi, Kenya. Conference paper, Conference of 4th URSI Atlantic Radio Science Meeting, AT-RASC 2024, Gran Canaria, Spain, 19-24 May 2024. DOI: 10.46620/URSIATRASC24/PFRO1041

The Role of PITHIA-NRF in My Project

The Trans-National Access (TNA) is one of the objectives of the PITHIA-NRF project.

- I have attended two TNA calls:
  - ✓ in 2024 at the INGV node (project: VSS4AED) and
  - ✓ in 2025 at the NOA node (project: CATNPRO).
- PITHIA-NRF infrastructure was important in the successful accomplishment of my project, primarily by providing access to high-quality data, computational resources, and expertise that were otherwise difficult to access.
- The collaboration of the PITHIA-NRF TNA programme enhanced communication and the exchange of ideas and experience between researchers from different institutes.

Acknowledgement

- I acknowledge the research infrastructures and the access provider TNA Node of INGV of the PITHIA-NRF project (https://www.pithia-nrf.eu/). The PITHIA-NRF project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007599.