United Nations Workshop on the International Space Weather Initiative: The Way Forward

First Steps
Towards developing a Nowcasting Algorithm for Amplitude Scintillations in Peru

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Outline :

1. Introduction :
    - Jicamarca Radio Observatory (JRO)
    - Peruvian Space Agency
    - Scintillations
2. Objective:
    - Description of the forecasting objective
3. Methodology:
    - Database
    - Algorithms
4. First results:
    - Predictions in different seasons
5. Next steps:
    - Ionosondes
    - Magnetometers
6. Summary

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Introduction

Jicamarca Radio Observatory (JRO) and LISN (Low Latitude Ionospheric Sensor Network)

- 50 MHz Radar-1.5 MW transmitters and an antenna array of 18,432 dipole elements.
- AMISR, SiMONE, digisonde.
- LISN: Distributed observatory 32 GNSS, 4 magnetometers and 4 ionosondes.

Fig 1. GPS receiver of LISN.

Fig 2. Main radar of Jicamarca Radio Observatory.

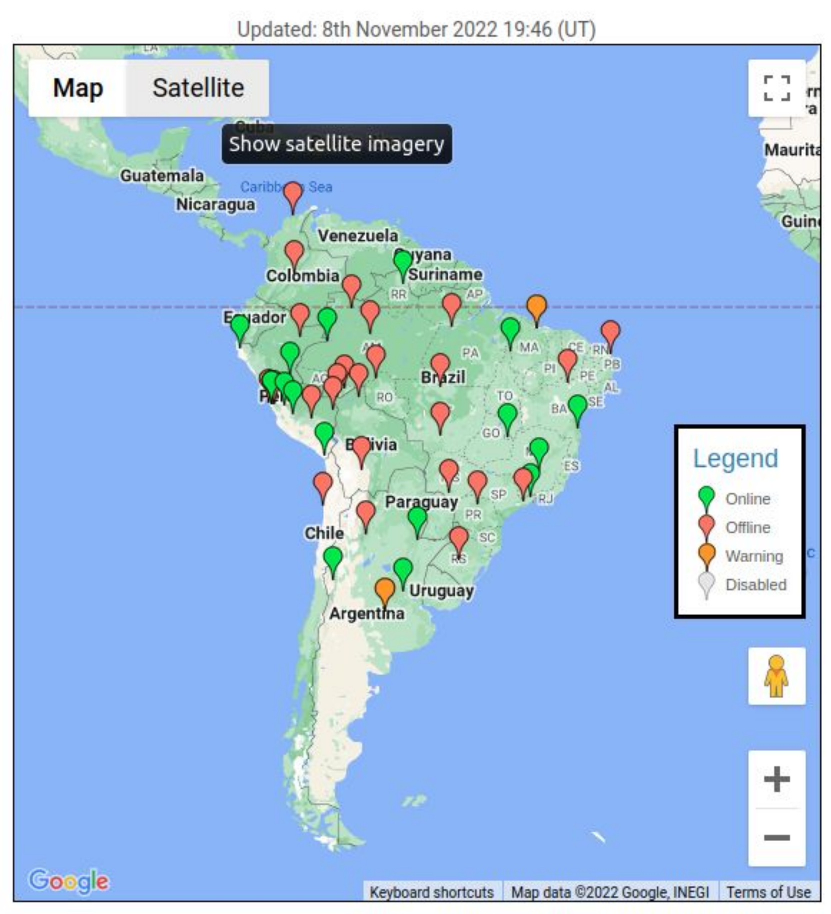


Fig 3. Location of LISN instruments in South America

Peruvian Space Agency (CONIDA)

Projects that CONIDA is working on:

- The Latin American Giant Observatory (LAGO) is an international network of water-Cherenkov detectors (WCD).
- South America VLF Network (SAVNET)

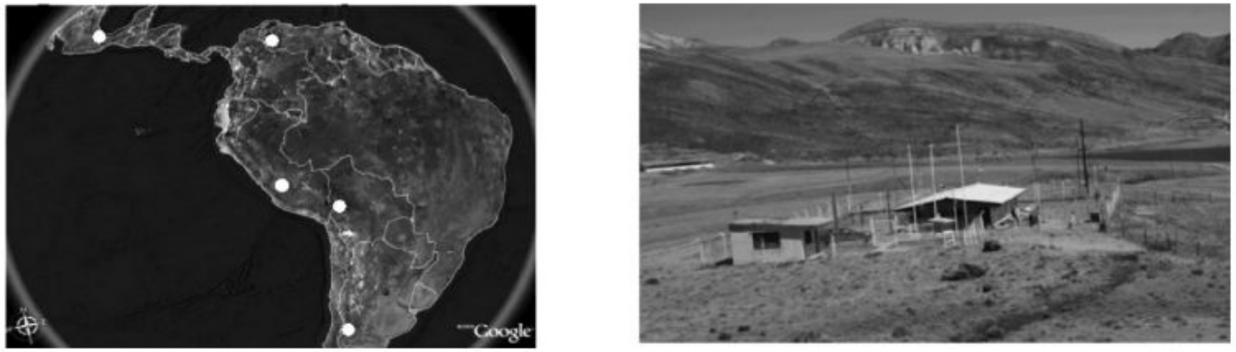


Figure 1. The left pannel hand picture shows the stations of LAGO in Sierra Negra (Mexico), Pico Espejo (Venezuela), Marcapomacocha (Peru), Chacaltaya (Bolivia) and Bariloche (Argentina) . The right pannel hand picture shows a view of the Marcapomacocha site.

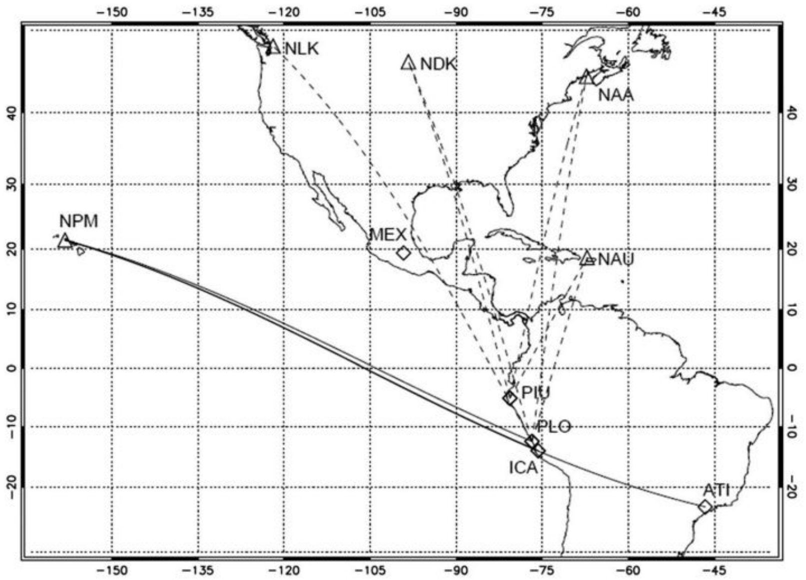


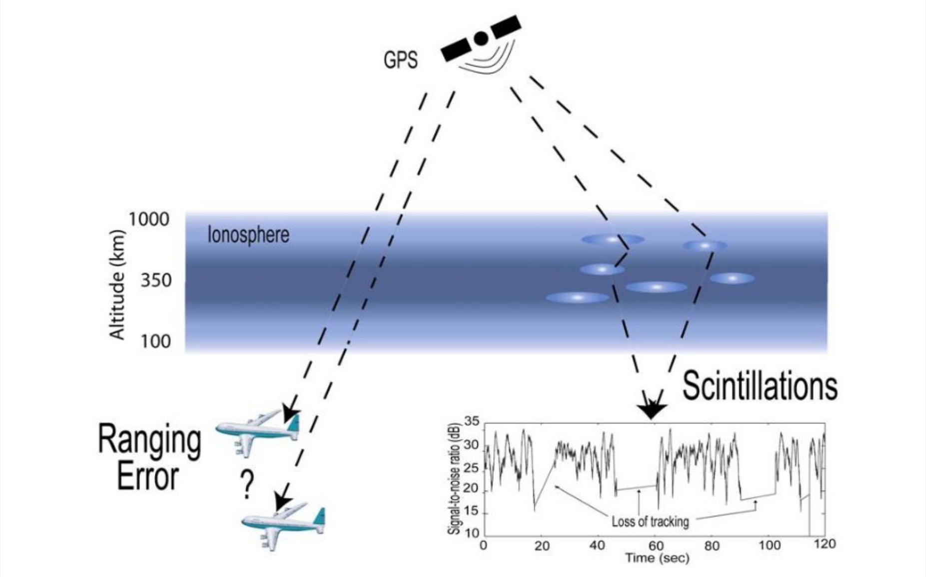
Figure 1. Examples of VLF propagation paths from transmitters NPM, NLK, NDK, NAA, and NAU (triangle symbols) to receiver stations of SAVNET (diamond symbols). The VLF propagation paths from NPM (Hawaii at 21.4 kHz) to receivers ATI (Brazil), PLO (Peru), and ICA (Peru) used in this work are shown with continuous black lines.

J. E. Samanes et al. 2015

Scintillation

$$S_4^2 = \left(\langle I^2 \rangle - \langle I \rangle^2\right) / \langle I \rangle^2$$

Ionospheric scintillation is the rapid modification of radio waves caused by small scale structures in the ionosphere.



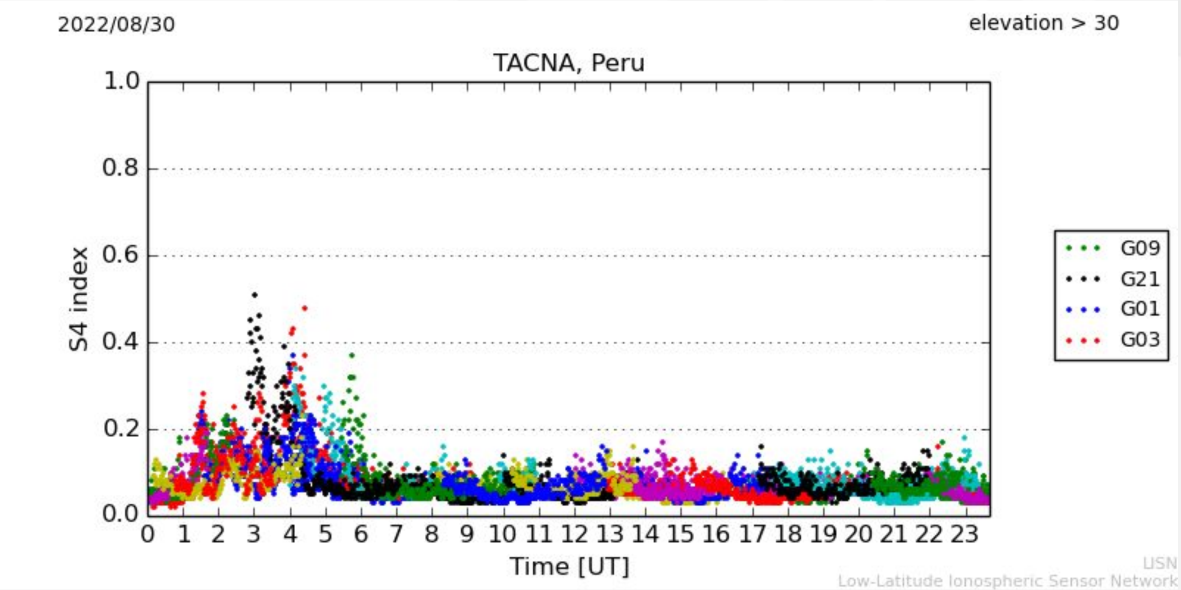


Figure 4. S4 registered in Tacna GPS receiver station (-18.004, -70.225)

Scintillation

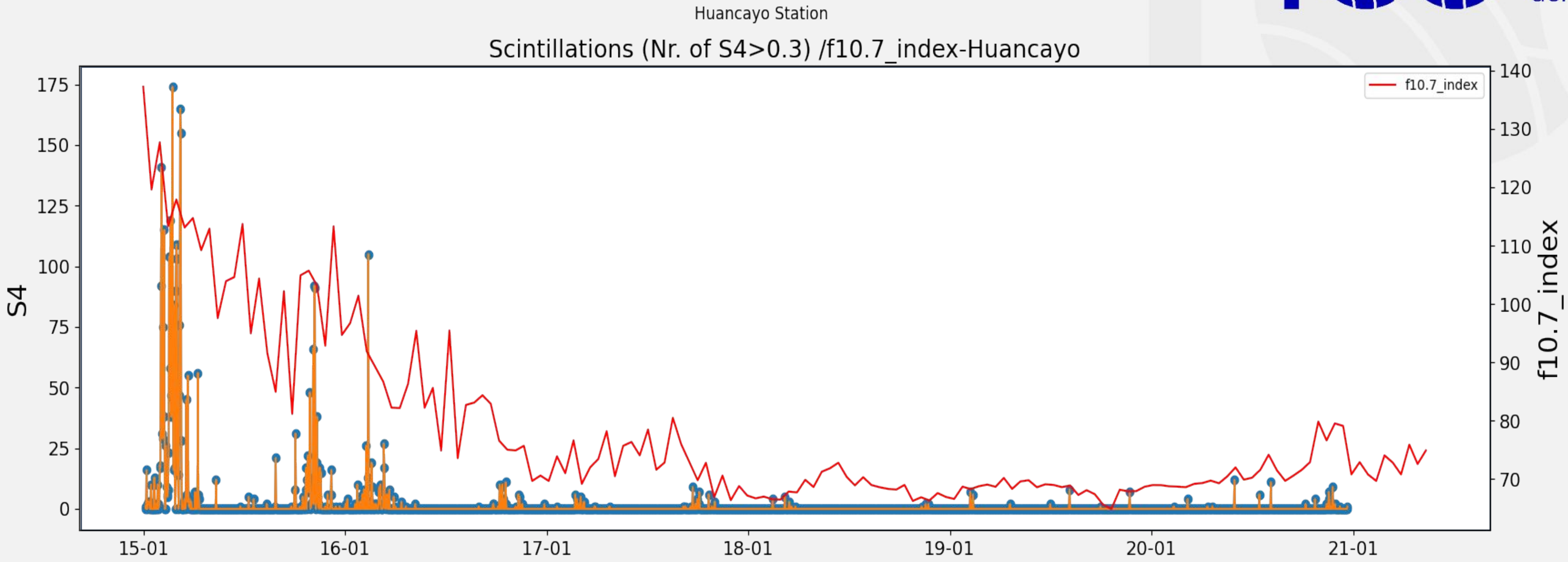


Figure 5. Number of ionospheric scintillations (S4>0.3) for Huancayo station between 2015 and 2020.

Scintillation

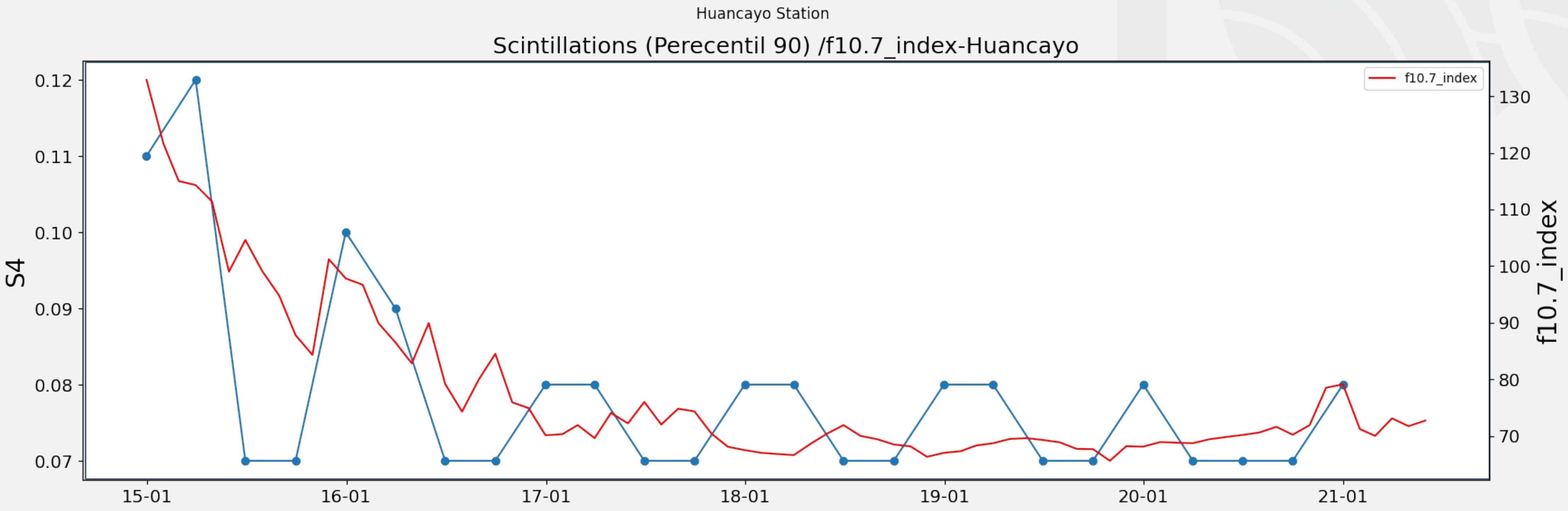


Figure 6. Ionospheric scintillations (S4 percentil 90) seasonally variation.

Scintillation

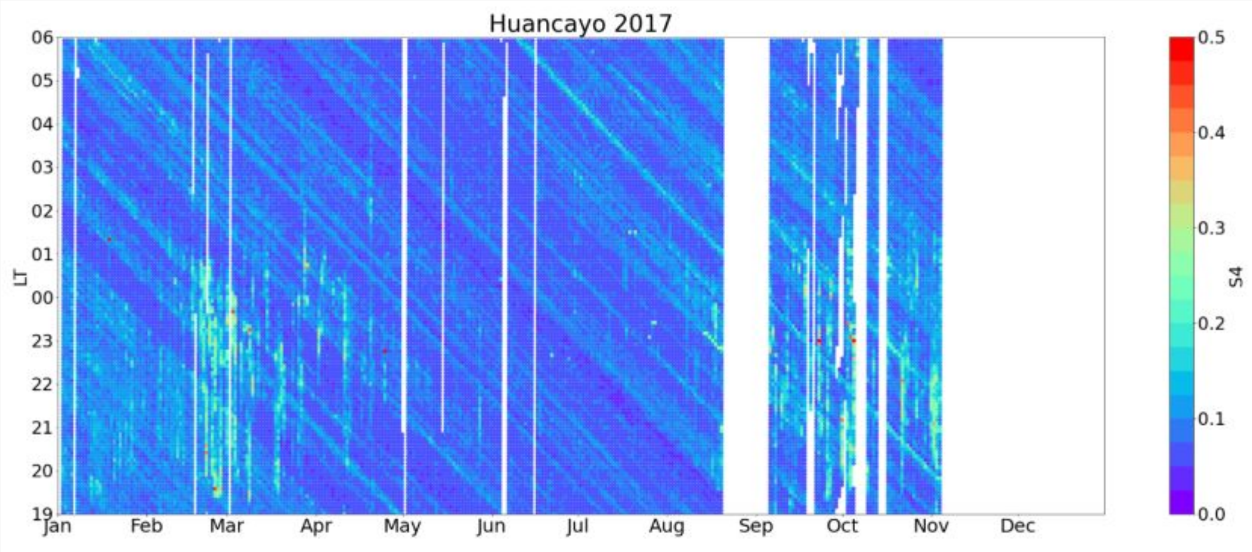


Figure 7. Climatology of ionospheric scintillations (S4) for the Huancayo for the year 2017. [-12.042,-75.321]

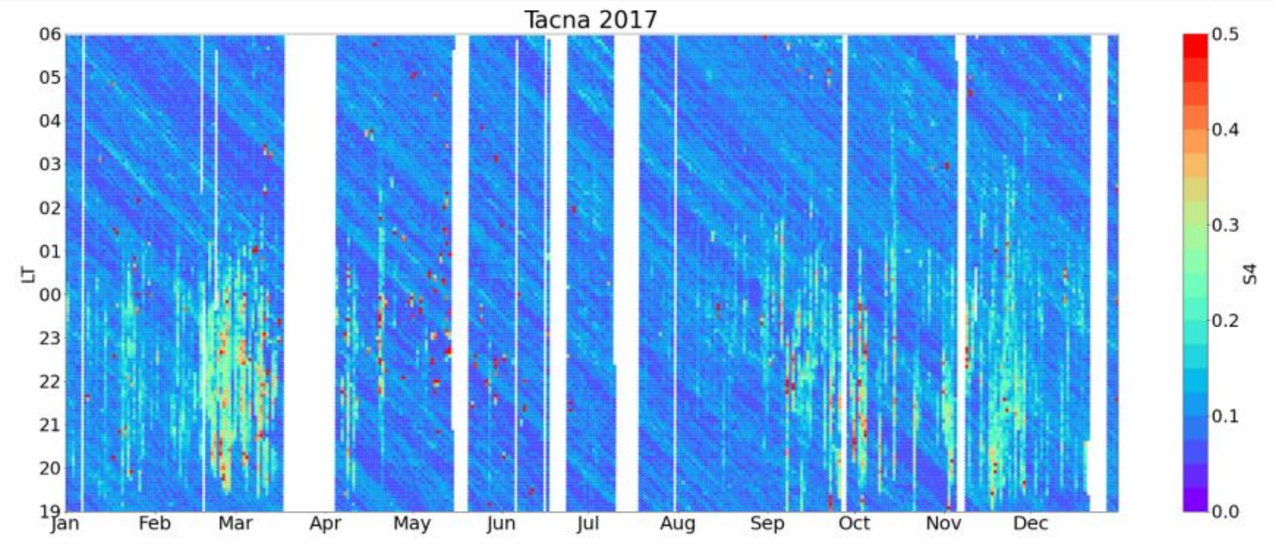


Figure 8. Climatology of ionospheric scintillations (S4) for the Tacna station for the year 2017. [-18.004, -70.225]

Scintillation and GPS error

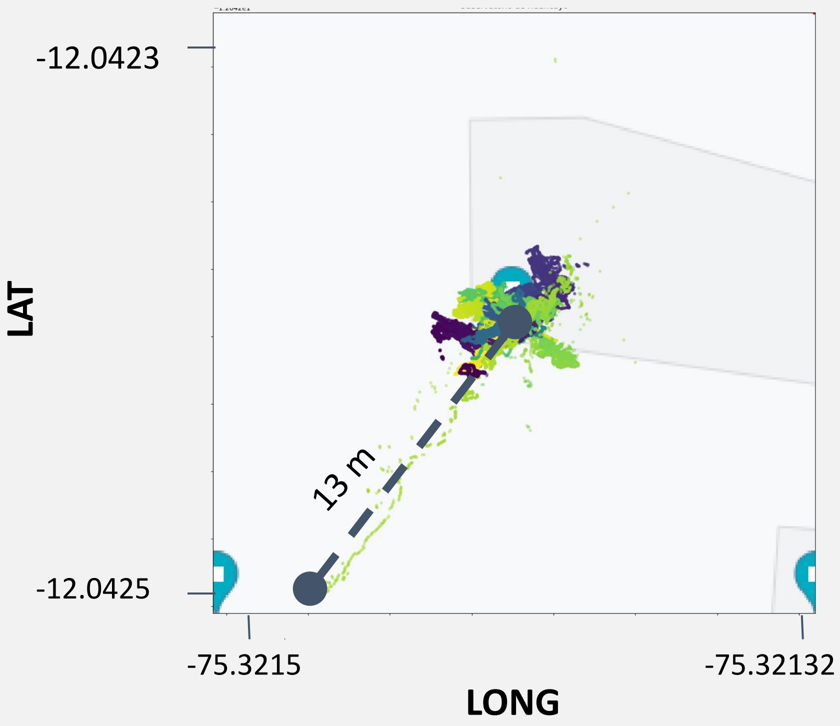


Figure 9. Position approximations (Latitude and Longitude) recorded by the Huancayo GPS receiver for March 16, 2015.

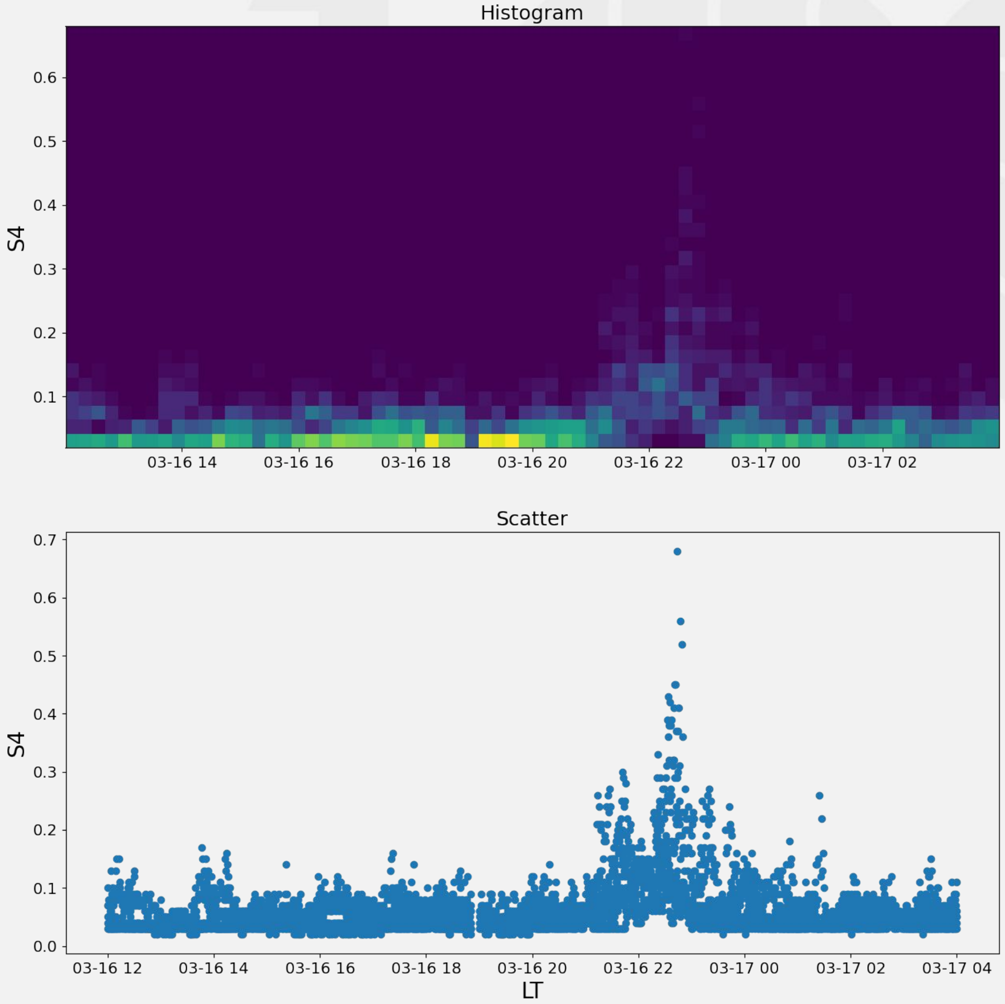
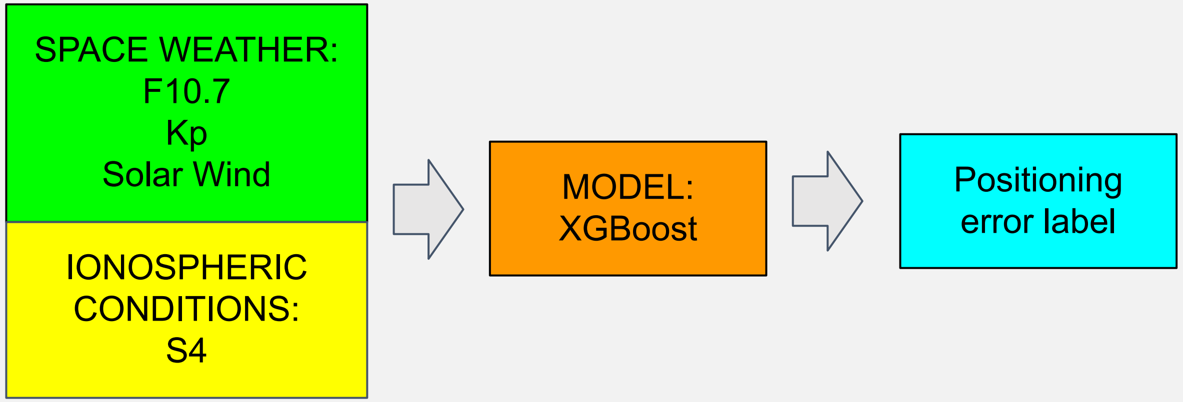
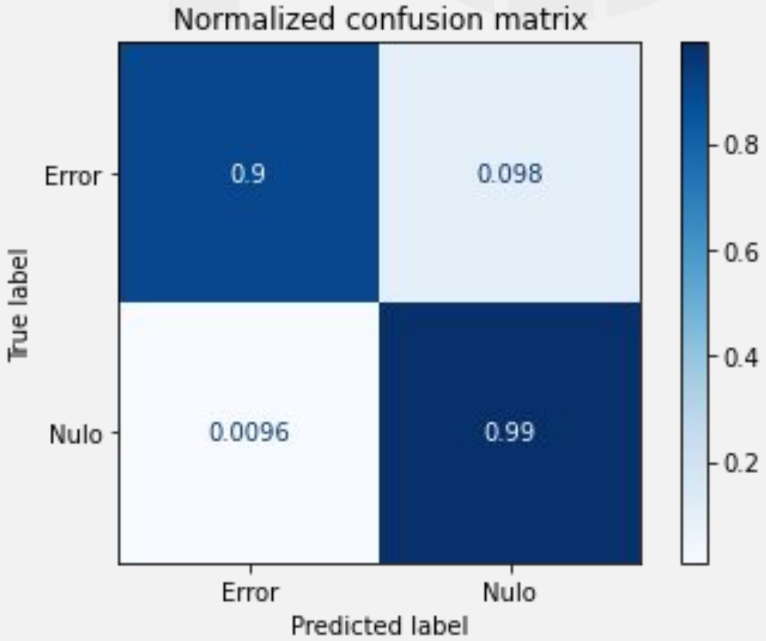


Figure 10. S4 activity as a function of local time for the recorded storm days (March 16–17,2015).

Scintillation and GPS error





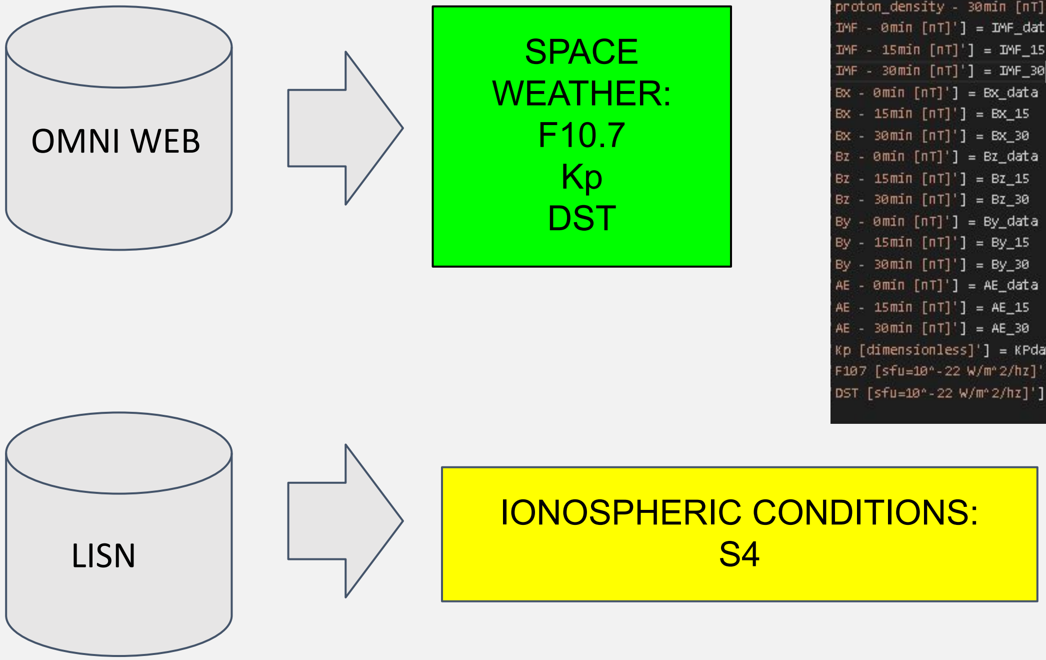
Objective

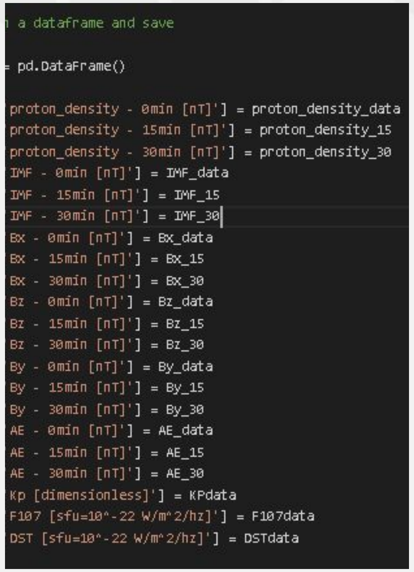
Develop an algorithm capable to predict the occurrence of amplitude ionospheric scintillation for different LISN GPS stations.

Methodology

Database

- Dataset from Omniweb and LISN server
- LISN Huancayo Station data from 2015-2019
- Multipath threshold=23.45° (Elevation angle)
- Super Observation- 5 min. average (McGranaghan et al. 2018)





```
n a dataframe and save

= pd.DataFrame()

'proton_density - 0min [nT]'] = proton_density_data
'proton_density - 15min [nT]'] = proton_density_15
'proton_density - 30min [nT]'] = proton_density_30
'IMF - 0min [nT]'] = IMF_data
'IMF - 15min [nT]'] = IMF_15
'IMF - 30min [nT]'] = IMF_30
'Bx - 0min [nT]'] = Bx_data
'Bx - 15min [nT]'] = Bx_15
'Bx - 30min [nT]'] = Bx_30
'Bz - 0min [nT]'] = Bz_data
'Bz - 15min [nT]'] = Bz_15
'Bz - 30min [nT]'] = Bz_30
'By - 0min [nT]'] = By_data
'By - 15min [nT]'] = By_15
'By - 30min [nT]'] = By_30
'AE - 0min [nT]'] = AE_data
'AE - 15min [nT]'] = AE_15
'AE - 30min [nT]'] = AE_30
'Kp [dimensionless]'] = KPdata
'F107 [sfu=10^-22 W/m^2/hz]'] = F107data
'DST [sfu=10^-22 W/m^2/hz]'] = DSTdata
```

Database

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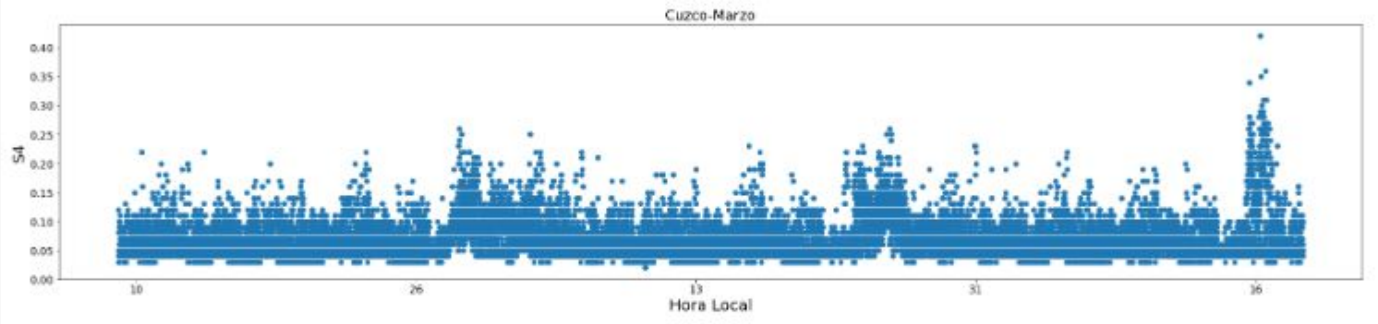
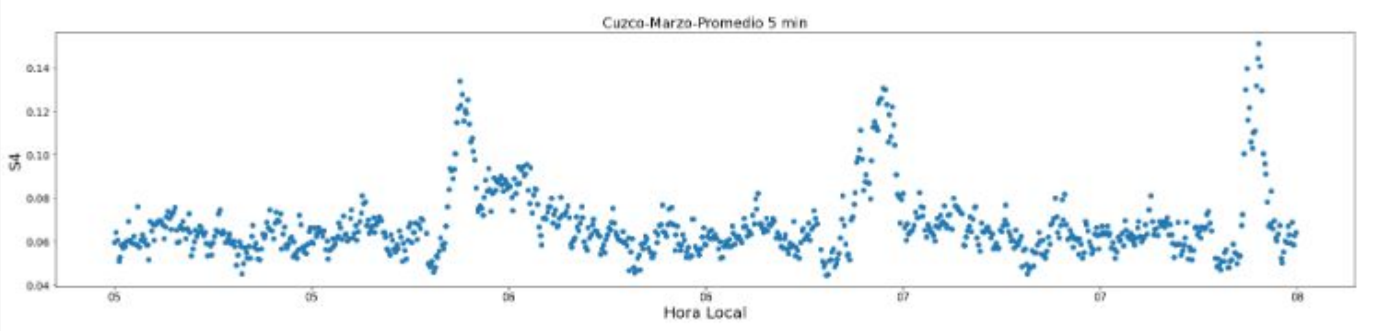
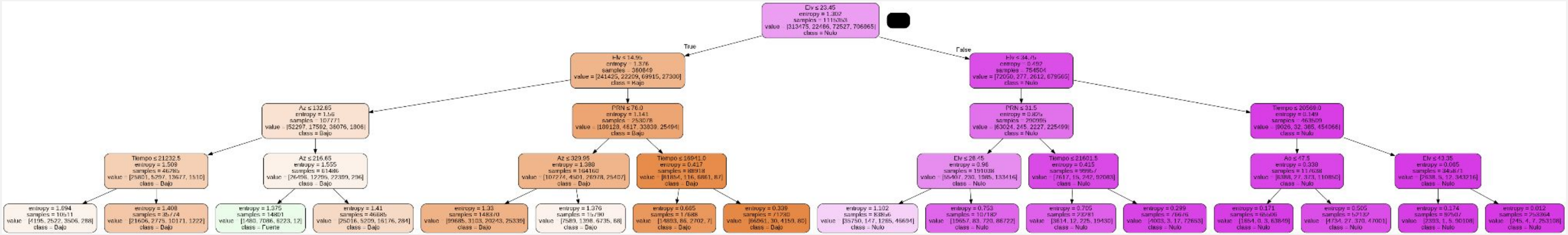




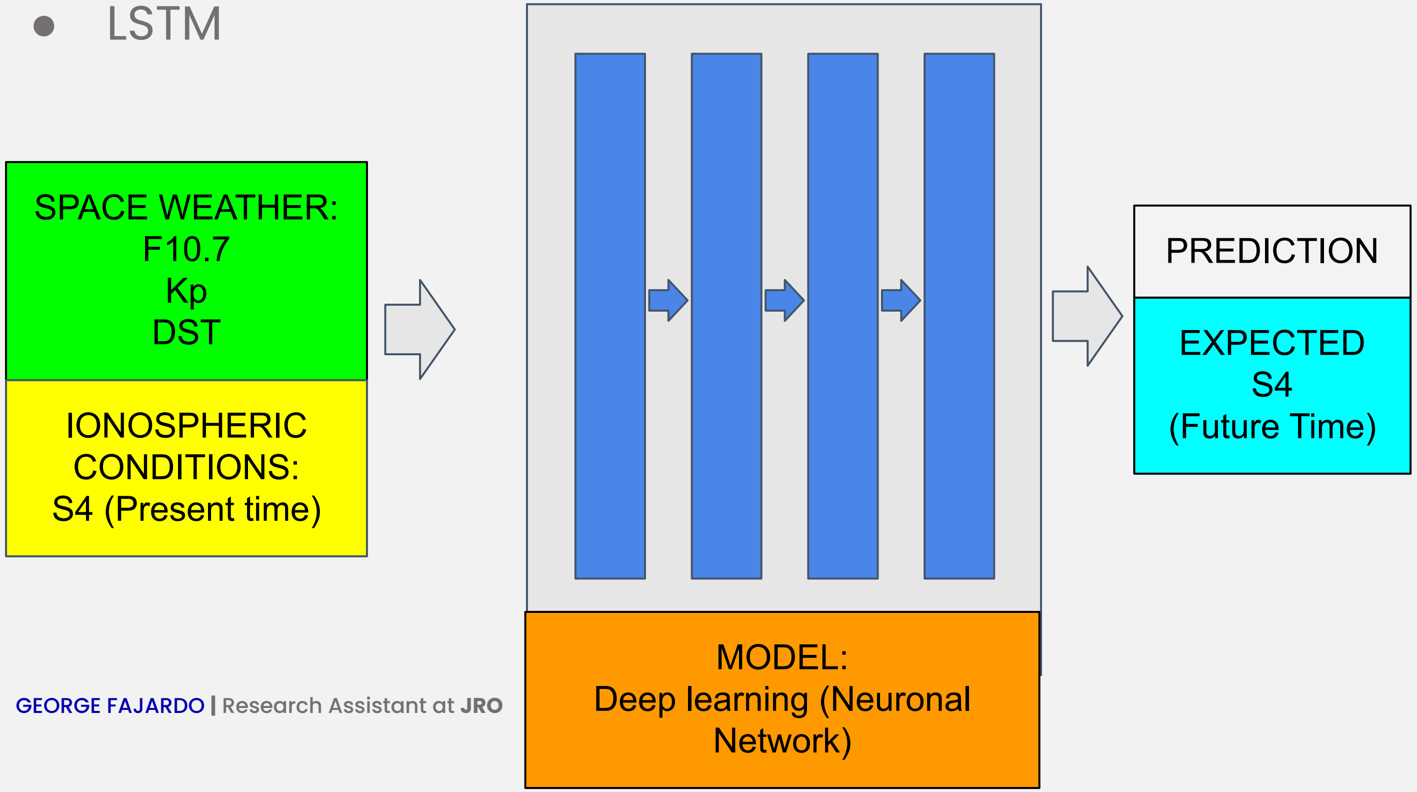


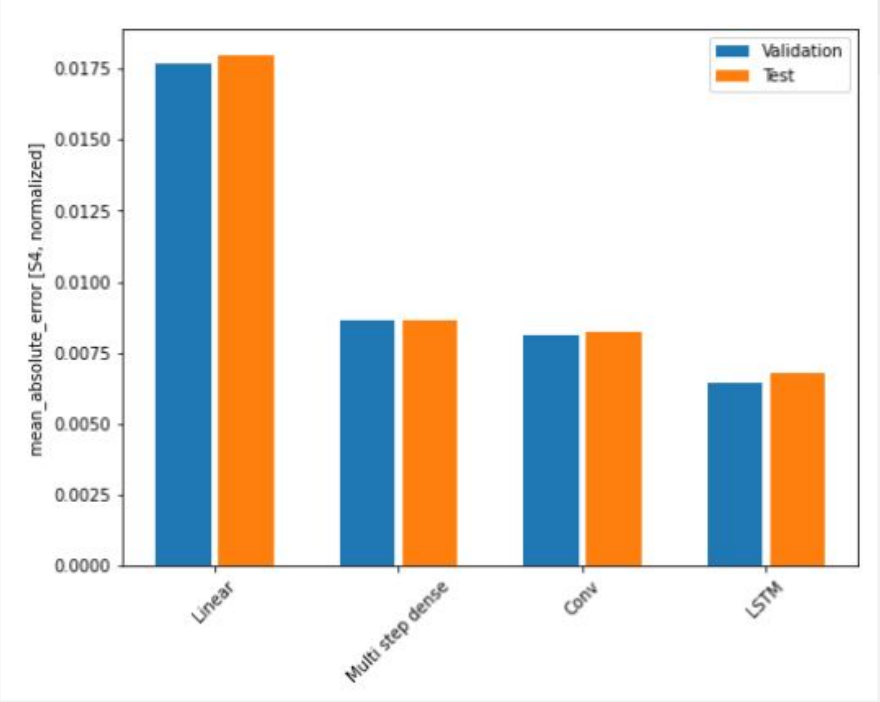
Model training

- Window of data [4 hours].
- 45 min prediction.

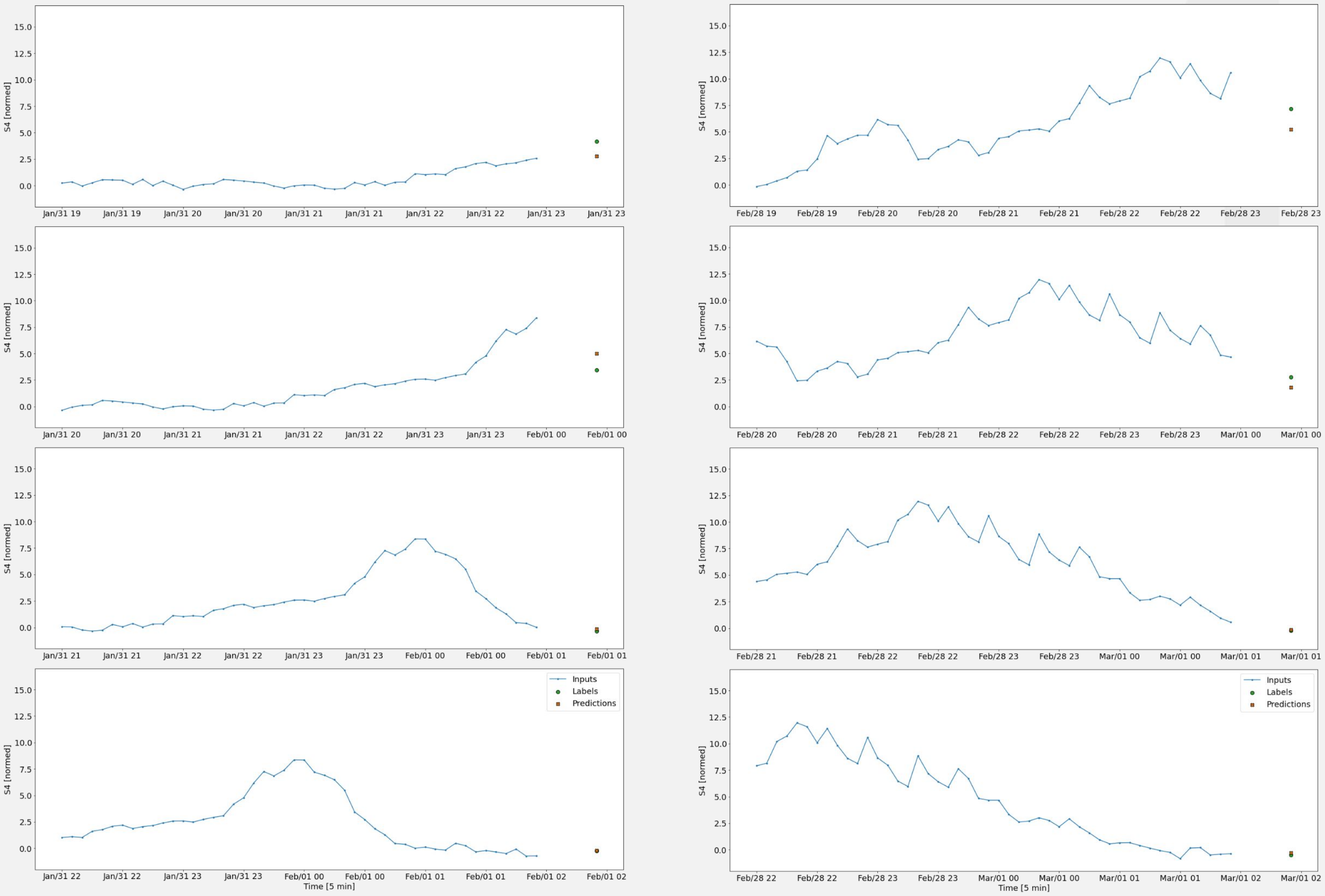
Models:

- Baseline (Linear)
- Multistep dense
- CNN
- LSTM





First Results


S4 [normed]
Time [5 min]
Inputs
Labels
Predictions

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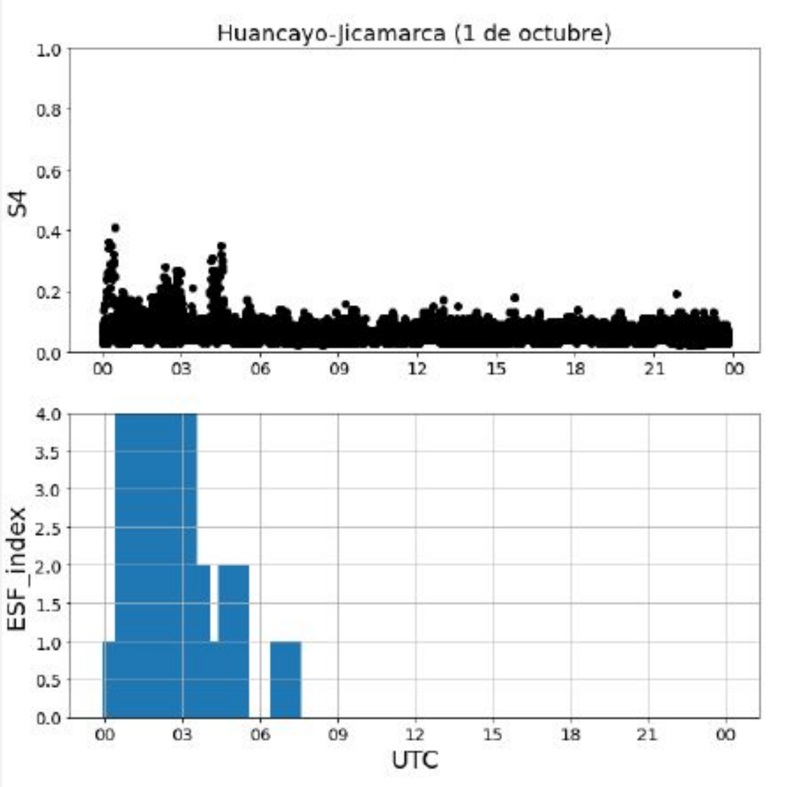
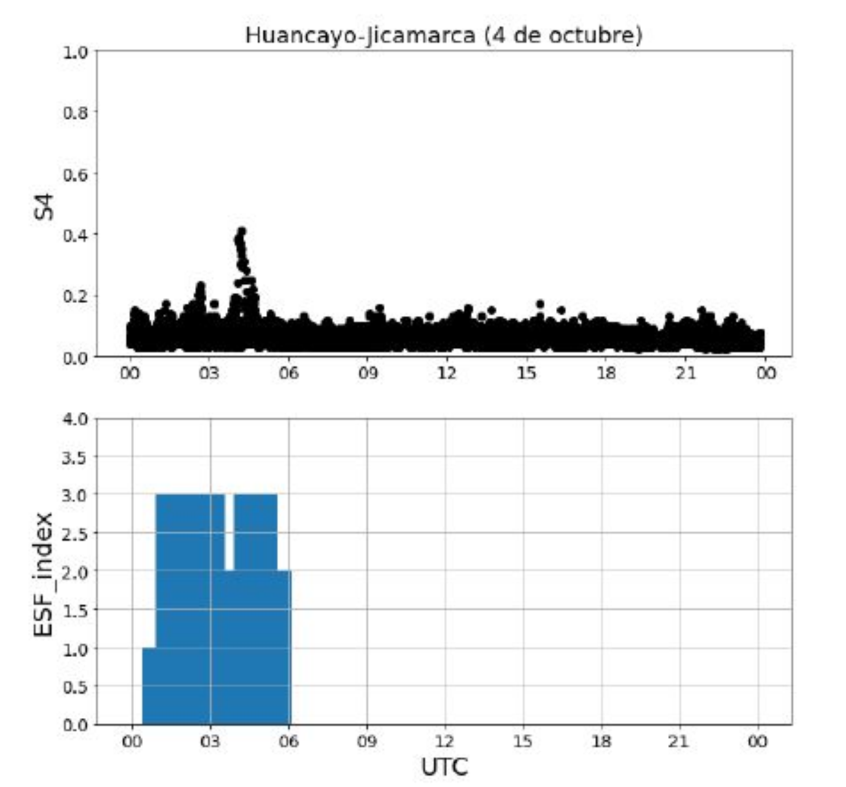
Next Steps

Ionosondes

- Ionosondes VIPIR
- Ionosondes SDR
- RSF, MSF, SSF - S4



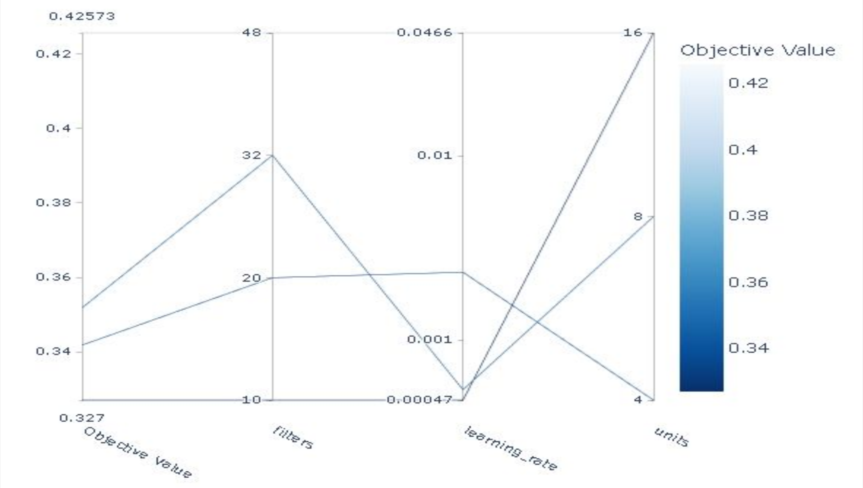


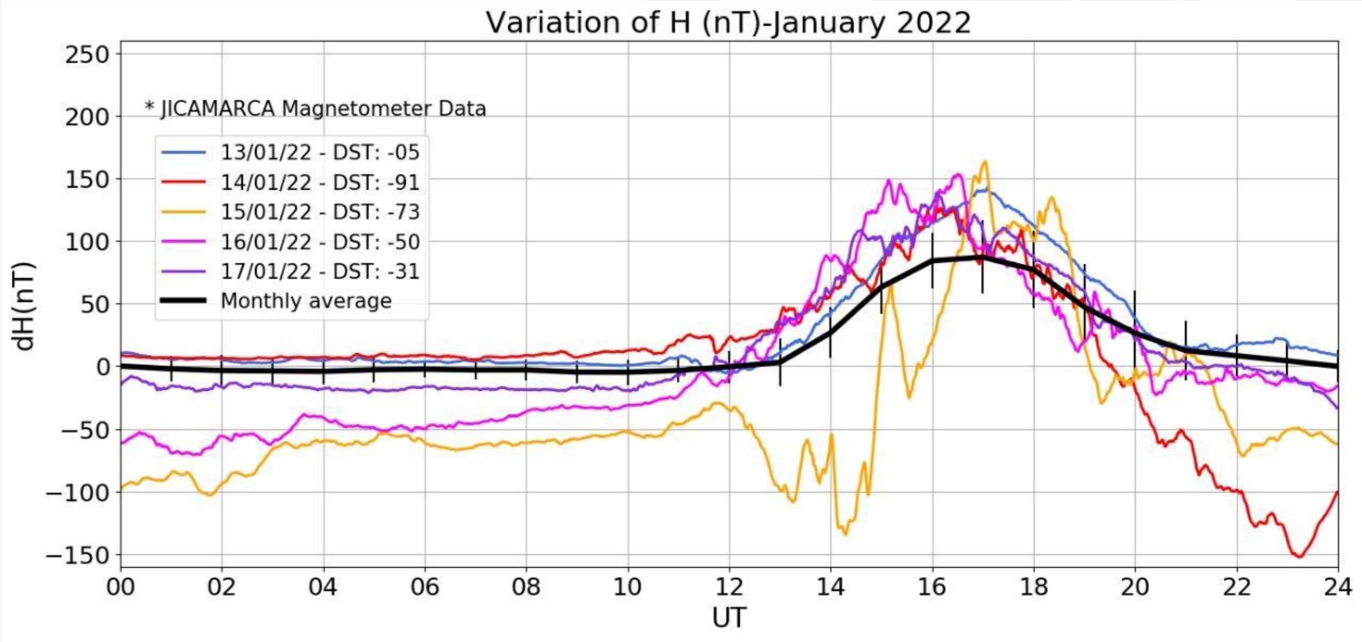
Parametrization optimization

- Optuna

Magnetometers

- LISN Magnetometers
- KSA (INPE)





Future works at Jicamarca

- The ionospheric scintillation error and forecast algorithm will continue to be developed.
- We intend to incorporate more satellite signal receivers for scintillation detection/measurement in the Peruvian region.

Summary

- GPS positioning error was analyzed and correlated with ionospheric amplitude scintillation.
- Scintillation events were analyzed in equatorial regions and close the equatorial anomaly.
- An algorithm was developed using neural networks that can predict the average s4 45 minutes in advance.
- The average GPS positioning error observed is between 3 and 5 meters in altitude at the Huancayo station.

Thank you!