Instituto Geofísico del Perú

Radio Beacon Satellite Receivers for rTEC study at Jicamarca / Blanketing Sporadic E observations

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PERÚ Ministerio del Ambiente

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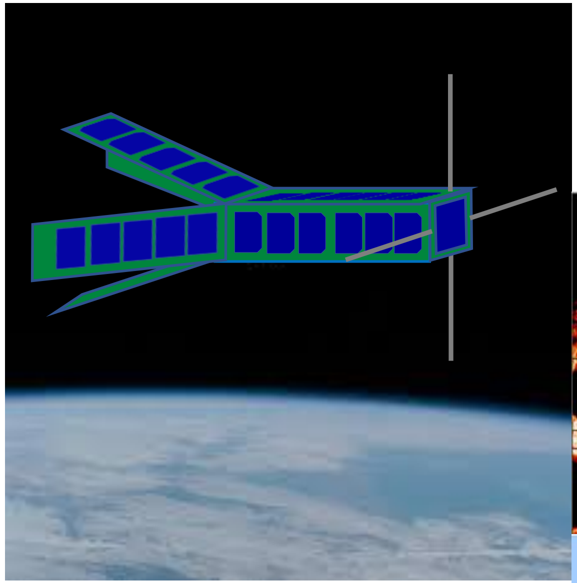
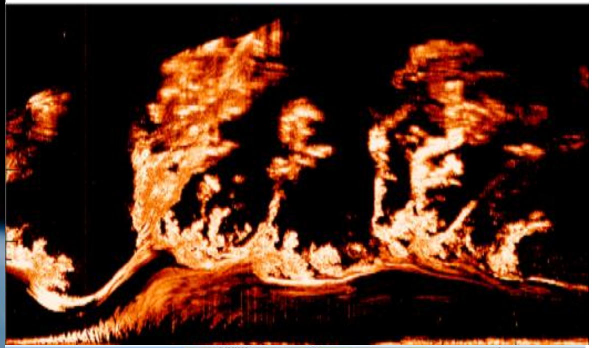
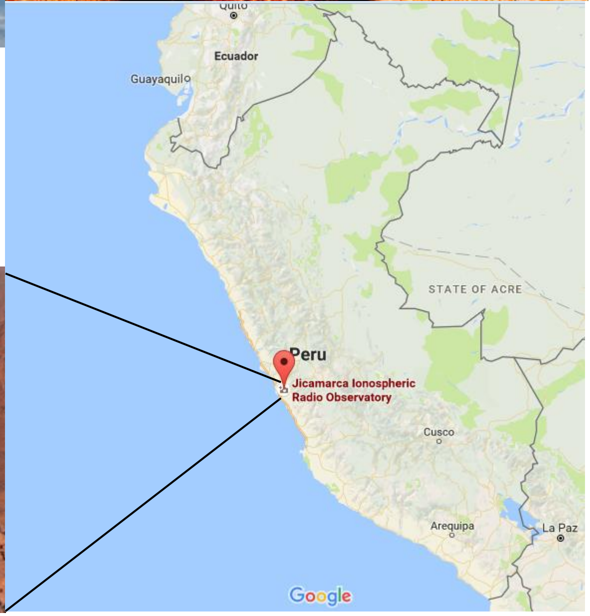
Motivation



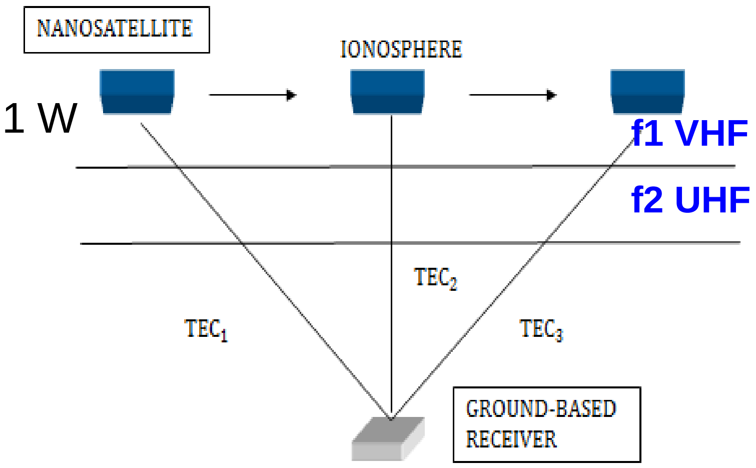


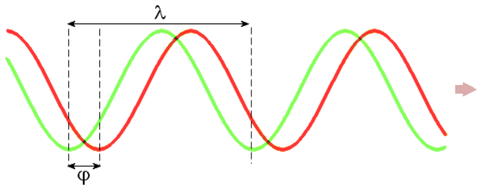


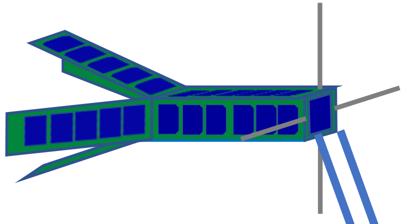
- Obtain **TEC measurements**.
- Investigate the **ionospheric variability** by using space-based instruments in addition to the ground-based radar measurements.
- Detect **irregularities**, spread F that affect communications and navigation signals.
- Combination with **Jicamarca measurements**.
- Extend network of receivers.
- Latitudinal and Longitudinal variability.

Main Concept

Power Tx ~ 1 W

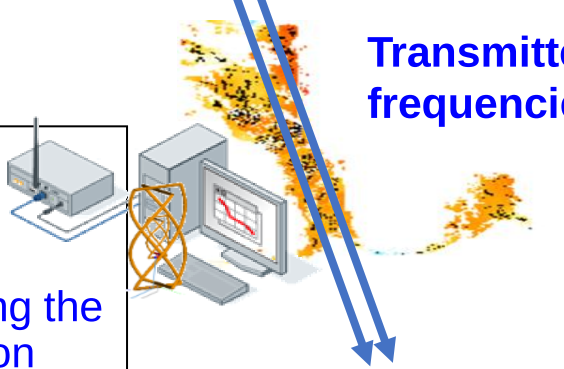






VHF	UHF
150 MHz	400 MHz

Transmitter frequencies:



Methodology:

The phase difference between the two received frequencies provides the information of total electron content along the line-of-sight between the receiving station and the space vehicle at any given instant.

[Bernhardt and Siefring, 2006], [Yamamoto, 2008, Vierinen et al. 2014].

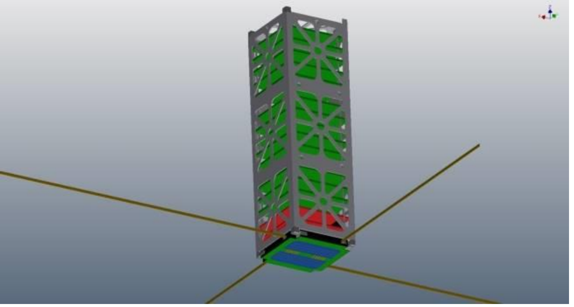
- Phase difference method
- Equations

$$\Delta\phi_f = \frac{\phi_1}{q_1} - \frac{\phi_2}{q_2} = \frac{80.6\pi N_T}{c f_0}\left(\frac{1}{q_1^2} - \frac{1}{q_2^2}\right) = \frac{8.447\times10^{-7} N_T}{f_0}\left(\frac{1}{q_1^2} - \frac{1}{q_2^2}\right) \text{ rad}$$

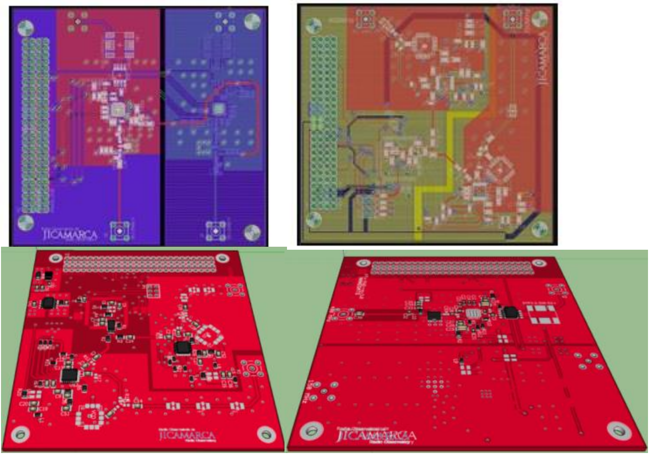
- Differential phase $\Delta\varphi_f$ measures the time delay by comparing the phases φ_1 and φ_2 of two signals on widely separated frequencies $f_1 = q_1 f_0$,and $f_2 = q_2 f_0$ when they are translated to a common reference frequency f_0.
- N_T is total electron content TEC along the path.

Radio waves emitted by the transmitter onboard the CubeSat will be received by ground-based stations.
TEC will be obtained after processing the signals received by detecting the phase difference of the received radio waves.

Receivers based on Universal Software Radio Peripheral (*USRP*)



Transmitter Block Diagram



General overview

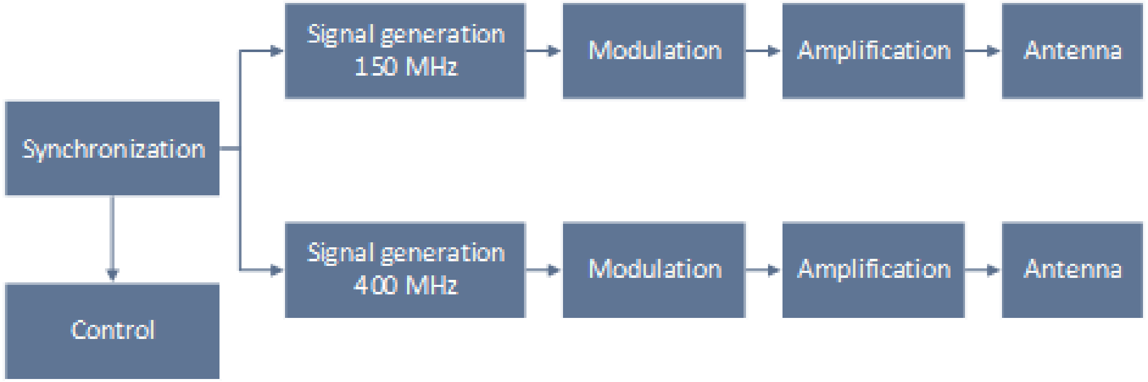
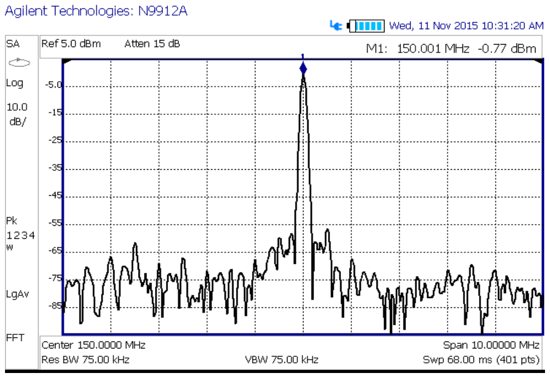


Figure 1. Block diagram of the general overview



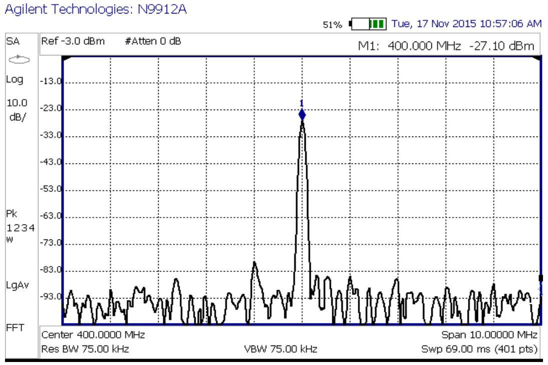
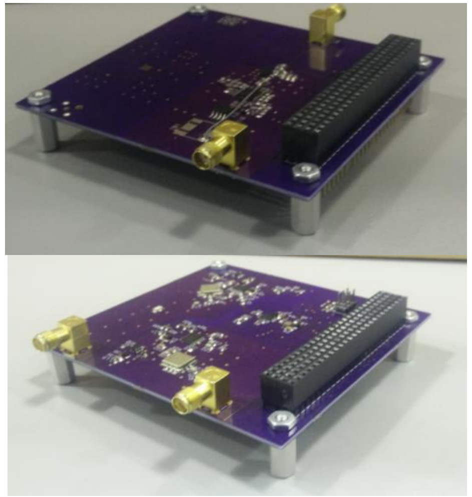


Figure 11Block diagram of control stage



Radio Beacon Transmitter
Signal generation
Power boards

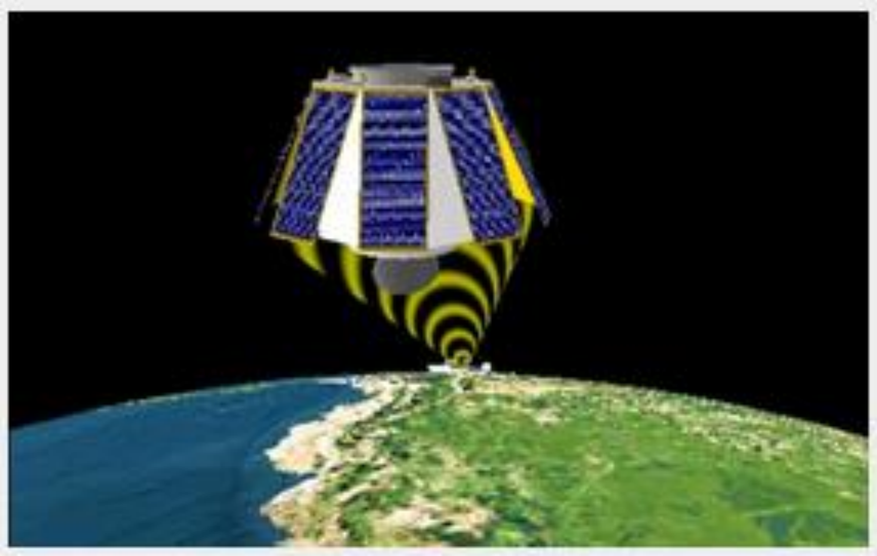
Receiver Block Diagram

DMSP F15

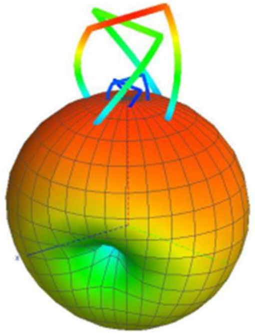
- The DMSP F15 satellite is in a near-circular, sun-synchronous, polar orbit. Temporal Coverage: 24 started January 2000
- Maximum altitude: 851km
- Minimum altitude: 837 km
- Inclination: 98.9 degrees
- Period: 101.8 minutes
- 150, 400 MHz

CASSIOPE

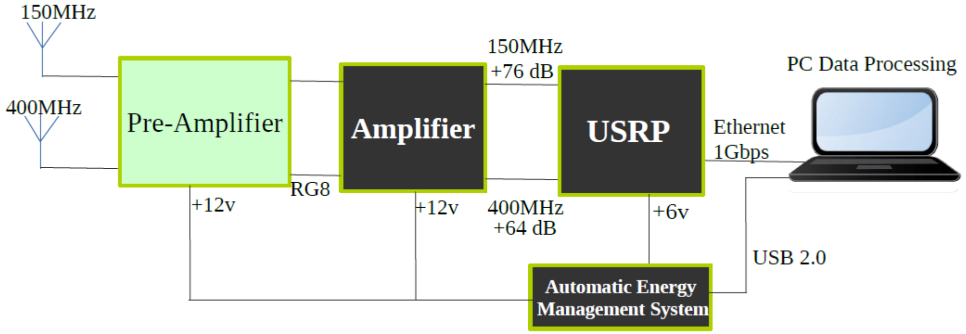
Orbit 325 x 1500 km, 80.99° inclination
Orbital Period 103 minutes (14 orbits per day)
e-POP scientific instruments
Coherent Electromagnetic Radiation tomography experiment (CER)
150, 400, 1067 MHz

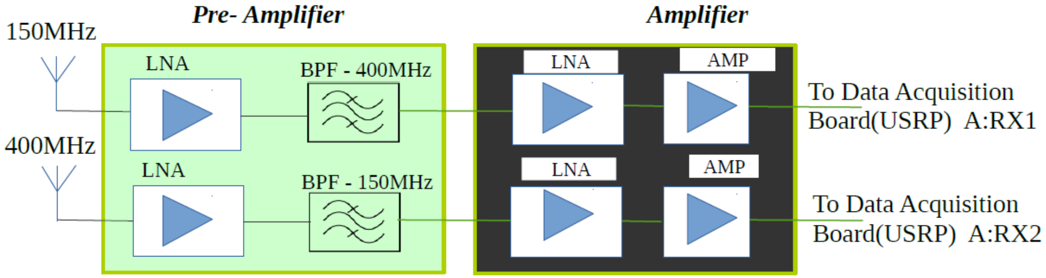


QFH antenna

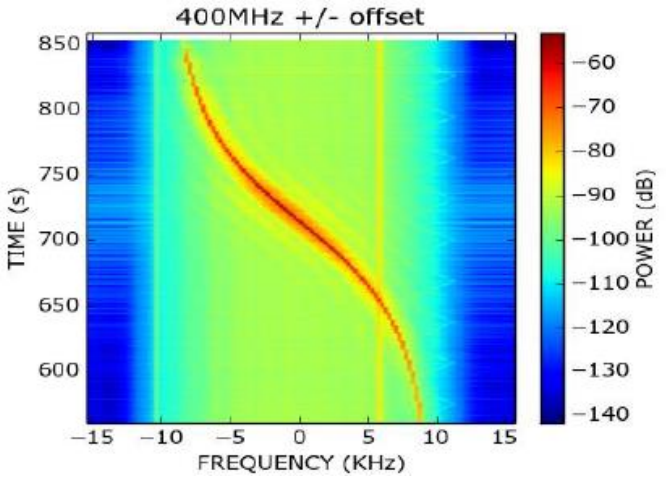


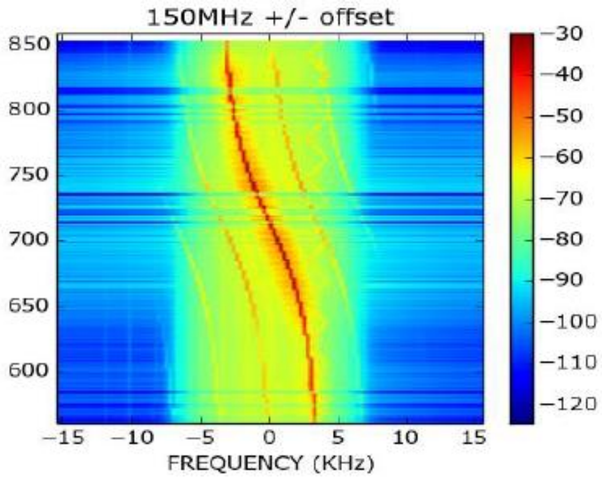
Receiver System Block Diagram





measurements at Jicamarca

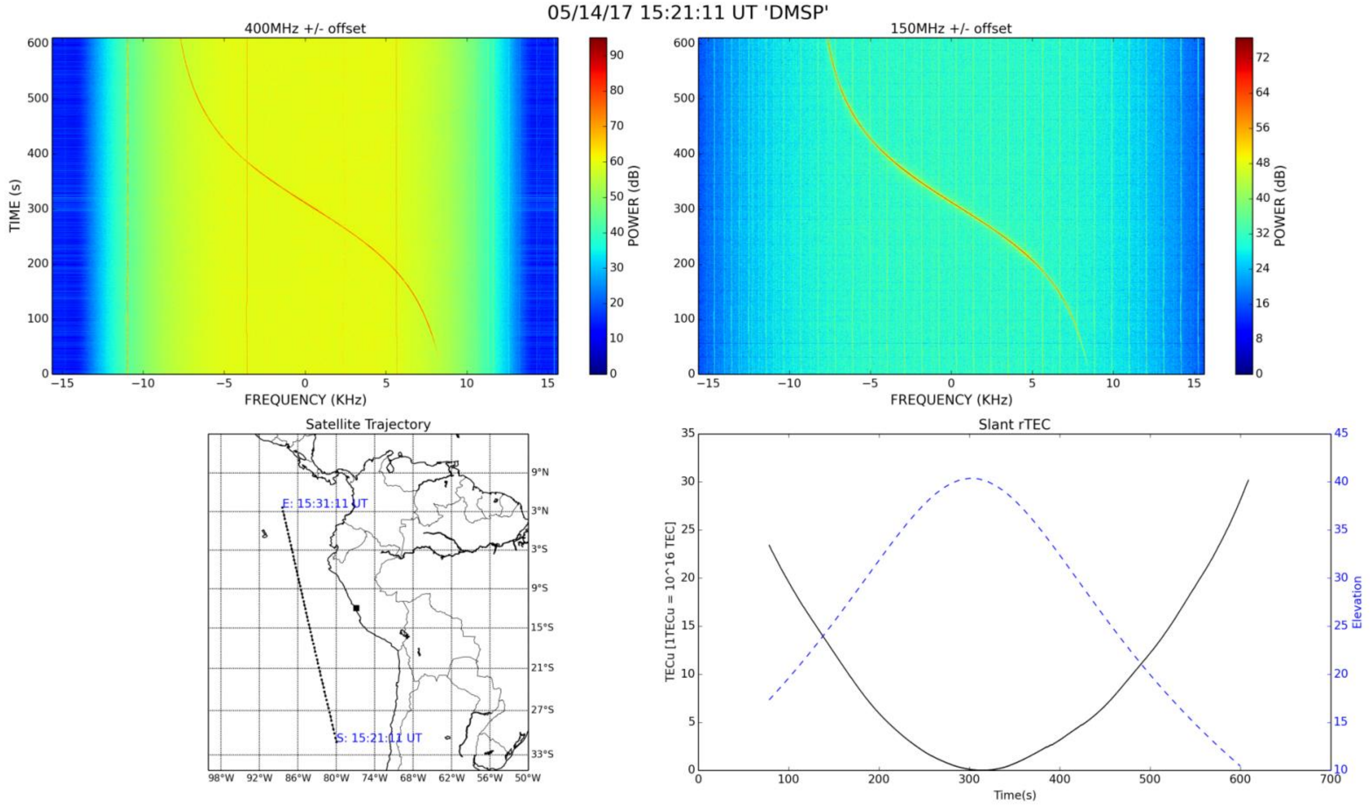




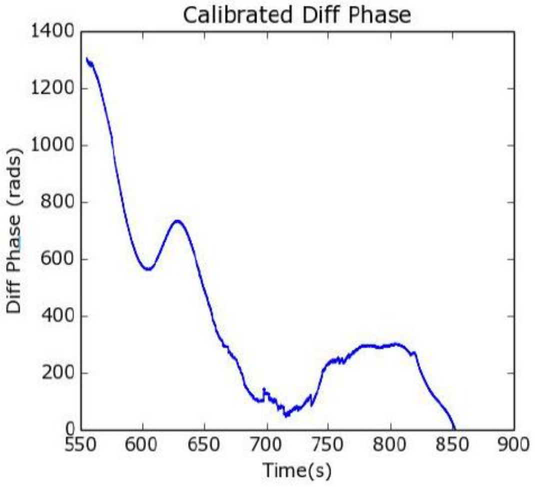
The frequency spectrum obtained by applying FFT to the RF signal is shown.

The Doppler effect is observed in the s-shaped curves.

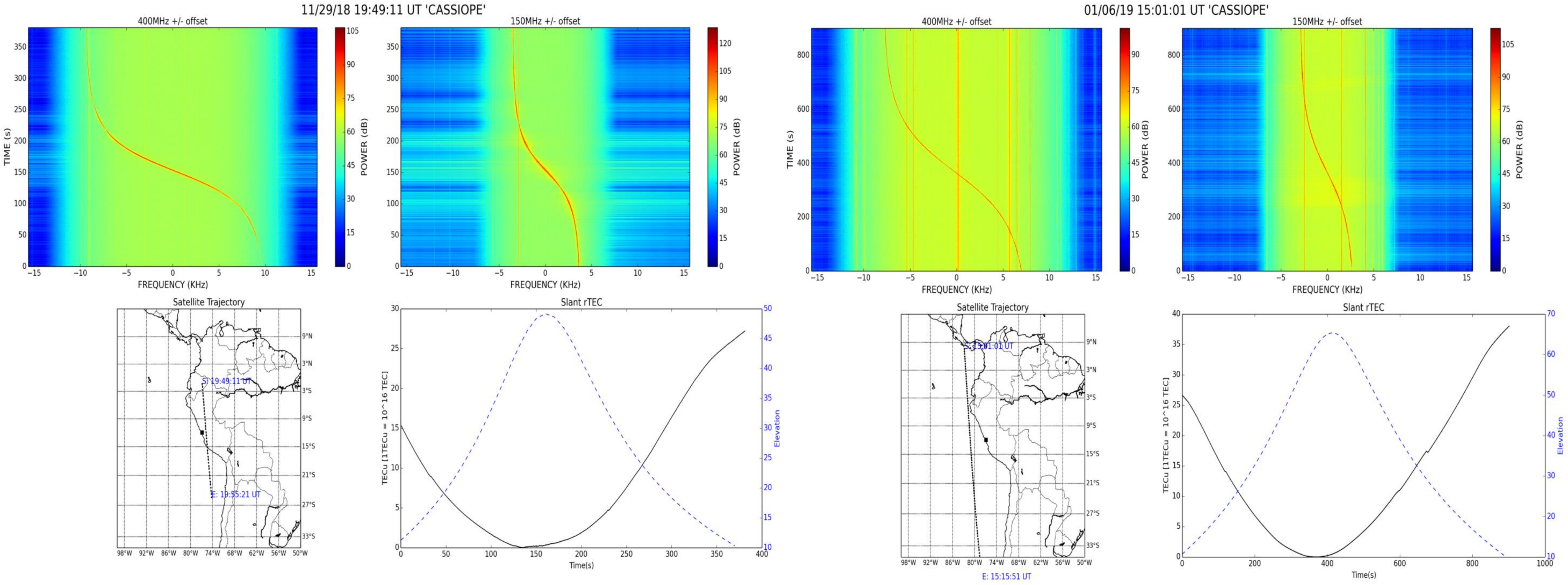
DMSP Satellite Plot data relative TEC results, from 14th May 2017 15:21 UT.



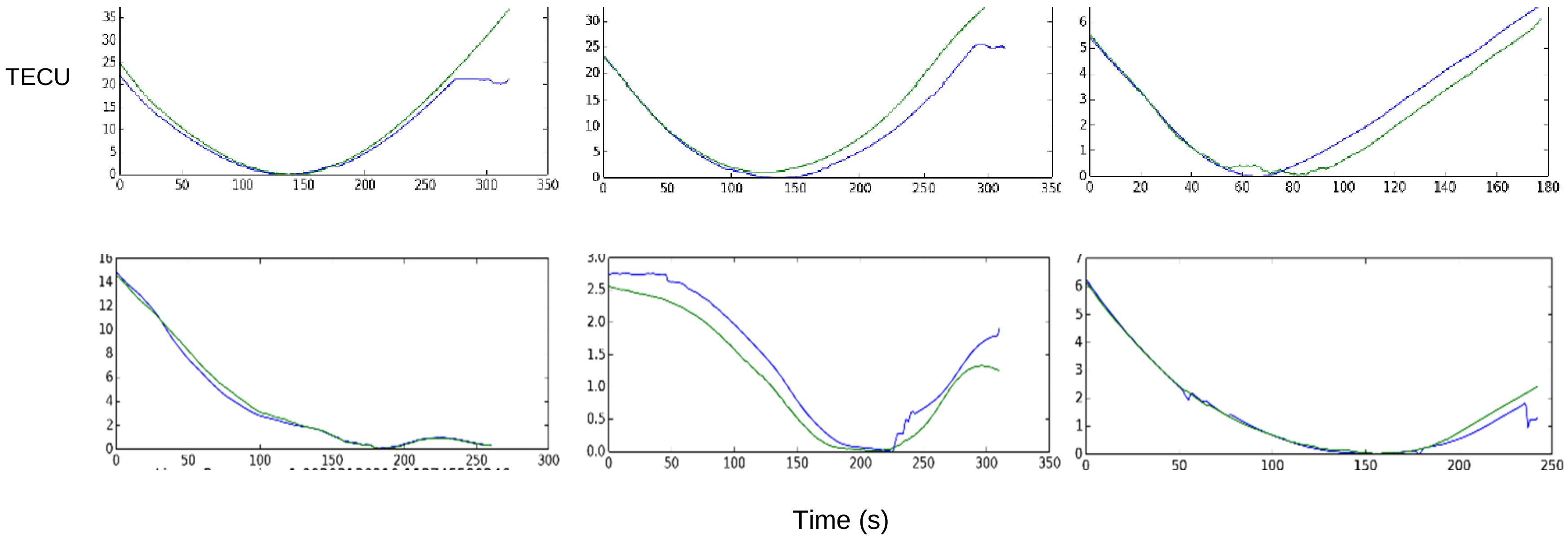
Cassiope Satellite Plot data relative TEC results, from 15th June 2016
1:17UT.



measurements at Ancon and Huancayo



Comparison of relative TEC measurements obtained from an analogic receiver NRL station and the obtained from the developed ground-based receiver



Comparison of relative TEC measurements obtained from an analogic receiver NRL station (blue curve) and the obtained from the developed ground-based receiver at the Jicamarca Radio Observatory (green curve) using CASSIOPE 150 and 400 MHz RF signals . (a) 2016-09-24, 00:04 UT, (b) 2016-09-23, 00:25 UT, (c) 2016-09-07, 02:22 UT, (d) 2016-08-31, 02:59 UT , (e) 2016-06-04, 03:28 UT , (f) 2016-06-03, 03:47 UT.

The resultant measurements show a very good agreement of the two receiver stations.

Future Work

- Payloads:
  Nanosatellite and rocket sounding probes
- Increase number of receivers> Tomography

Summary

- We are developed the implementation of ground-based receiver stations and a nanosatellite radio beacon transmitter for ionospheric investigation in the Peruvian sector.
- Total electron content (TEC) measurements will be obtained for studying the variability of the ionosphere and the occurrence of phenomena such as irregularities.
- The receiver station will be based on software-defined radio equipment and it will be capable of detecting not only the nanosatellite radio beacon signals but other radio beacons currently in operation that orbit above the Jicamarca Radio Observatory.

Blanketing sporadic E observations in the equatorial region over Jicamarca

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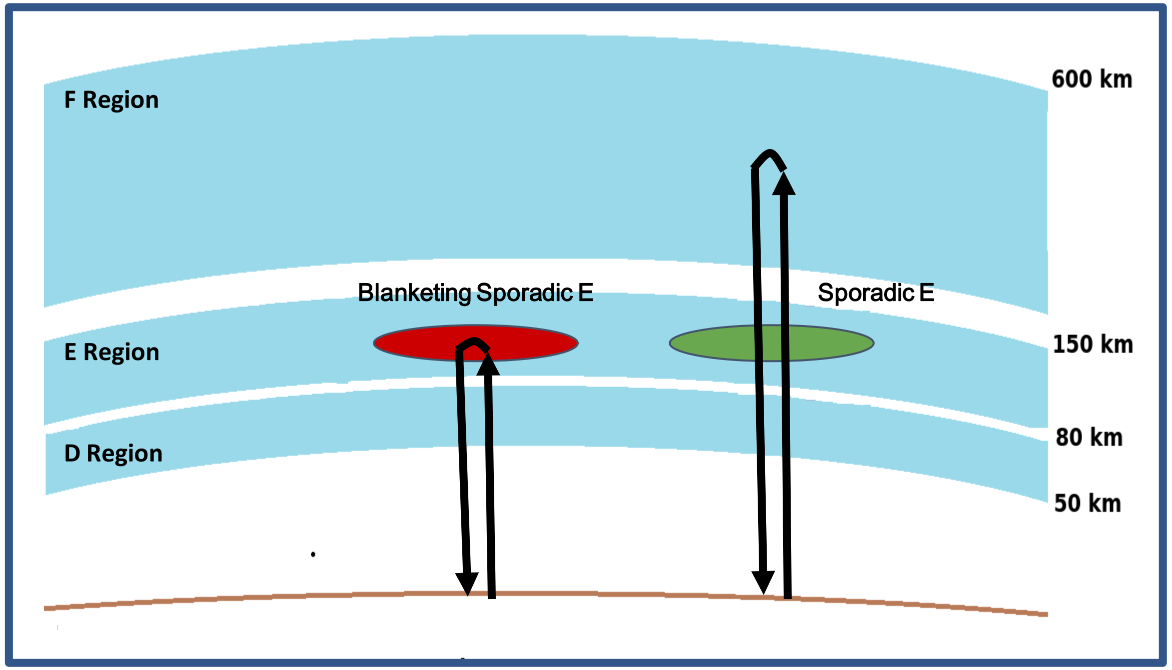
Introduction

• What are sporadic E layers (*Es*)?

"*Es*" are regions of increased electron density, observed between 90 and 130 km altitude and made up of metal ions as Mg^{+} , Si^{+} , Fe^{+} , Ca^{+} , Na^{+}.

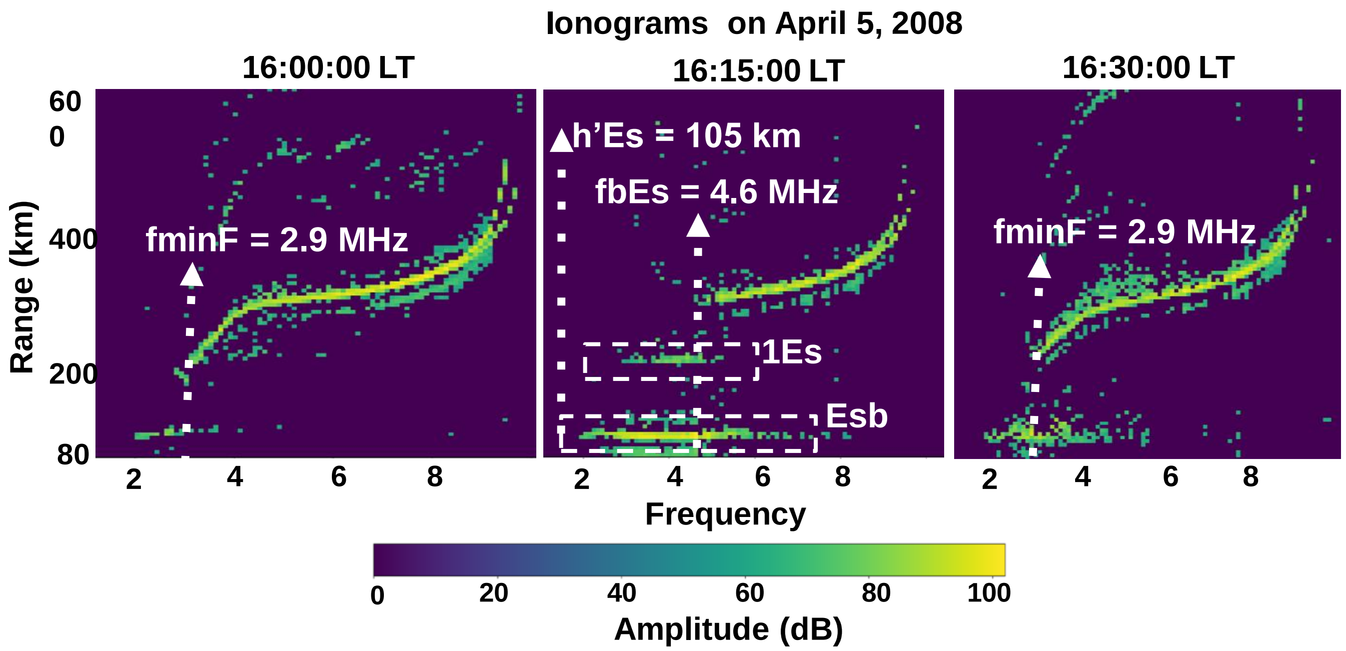
• What are blanketing sporadic *E* layers (*Esb*)?

"*Es*" are blanketing type layers (*Esb*) when they can partially or completely block the radio waves at the frequencies transmitted by the ionosonde for the sounding of the upper ionosphere (between 1.0 MHz and 14.0 MHz).



Blanketing sporadic E (*Esb*) events

How are *Esb* layers studied?

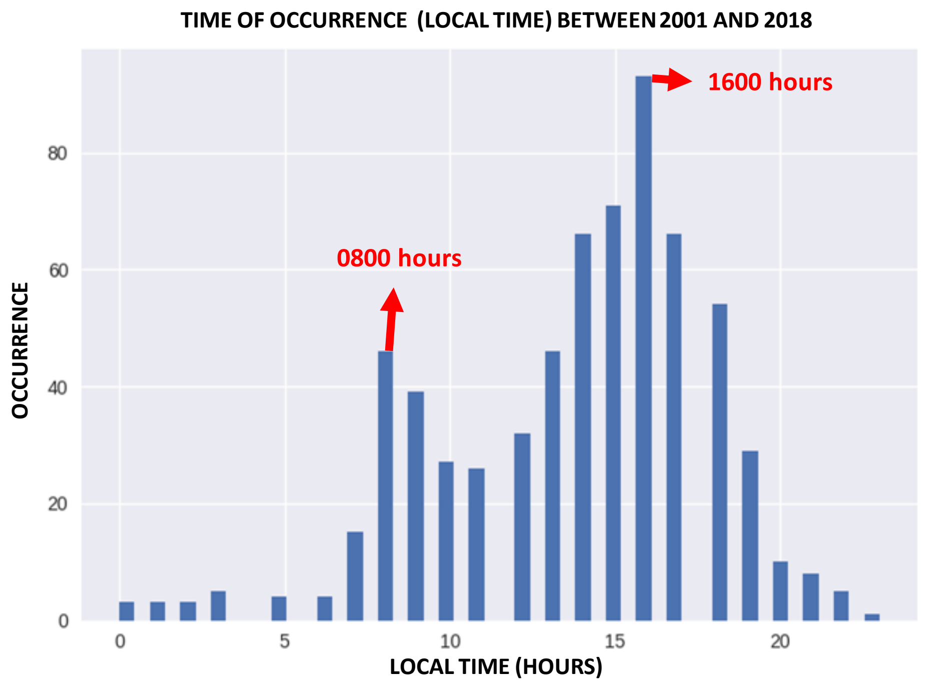


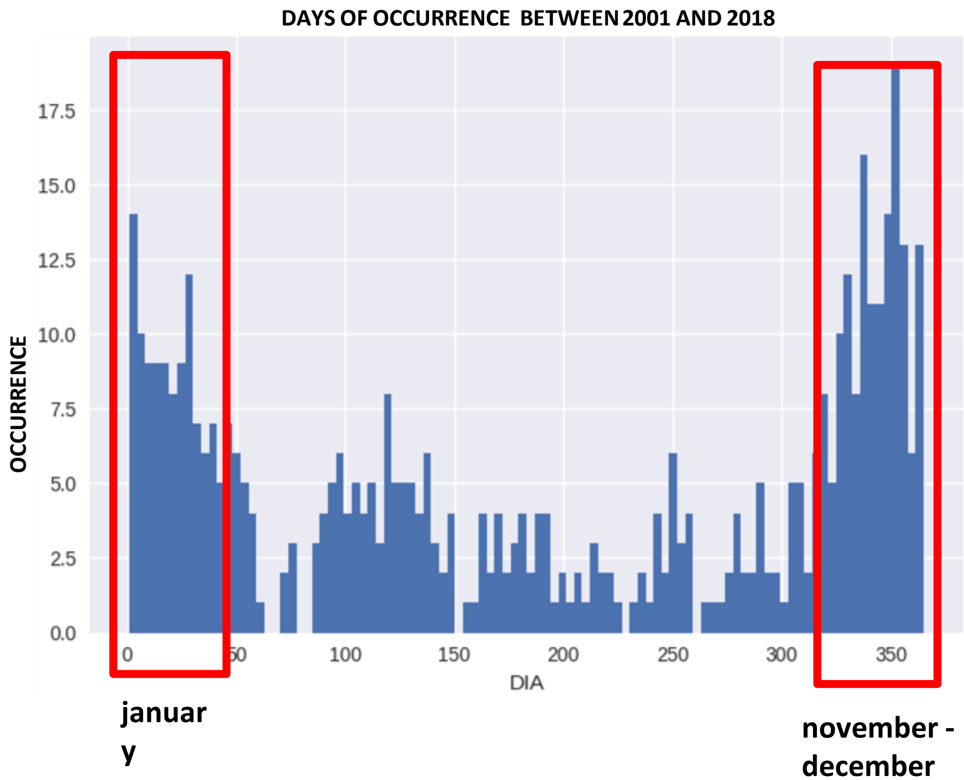
- Ionograms with presence of Esb layer and its parameters. Ionograms observed on April 5, 2008.

Data

- **Ionograms recorded between 2001 and 2018 of DPS-4 digisonde.**
- **Location: Jicamarca Radio Observatory (11.95° S, 76.87° W and dip angle ~1°)**

Result of identification and observations of *Esb* occurrence

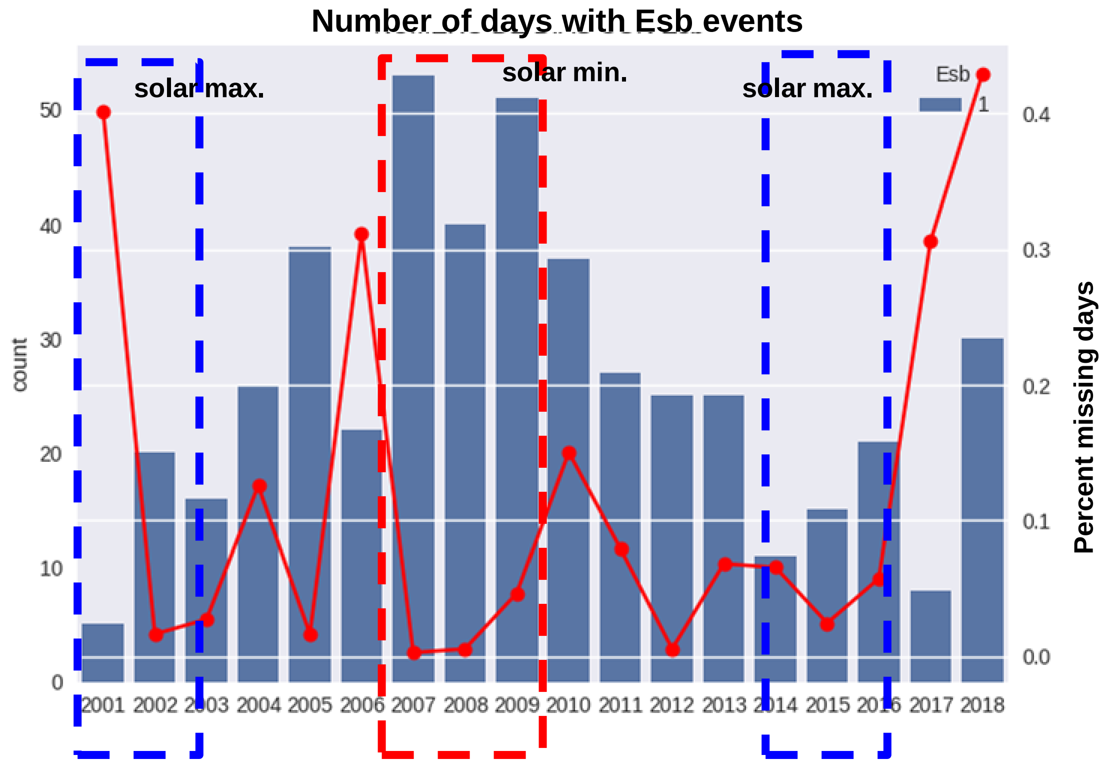




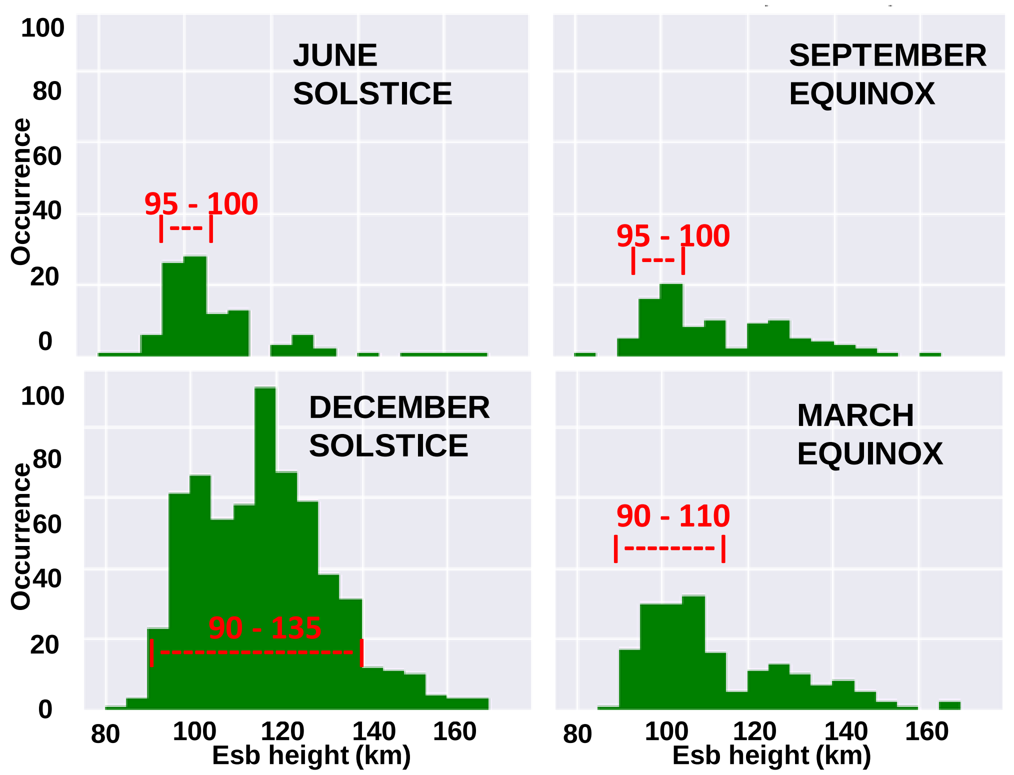
- Esb occur mainly between 0700 and 2000 hours local time
- There is a maximum peak at 1600 hours local time,
- and a second minor peak around 0800-0900 local time.

- In general, it occurs most frequently in the months near to the summer solstice,
- that is, in November, December and January

Result of identification and observations of *Esb* occurrence



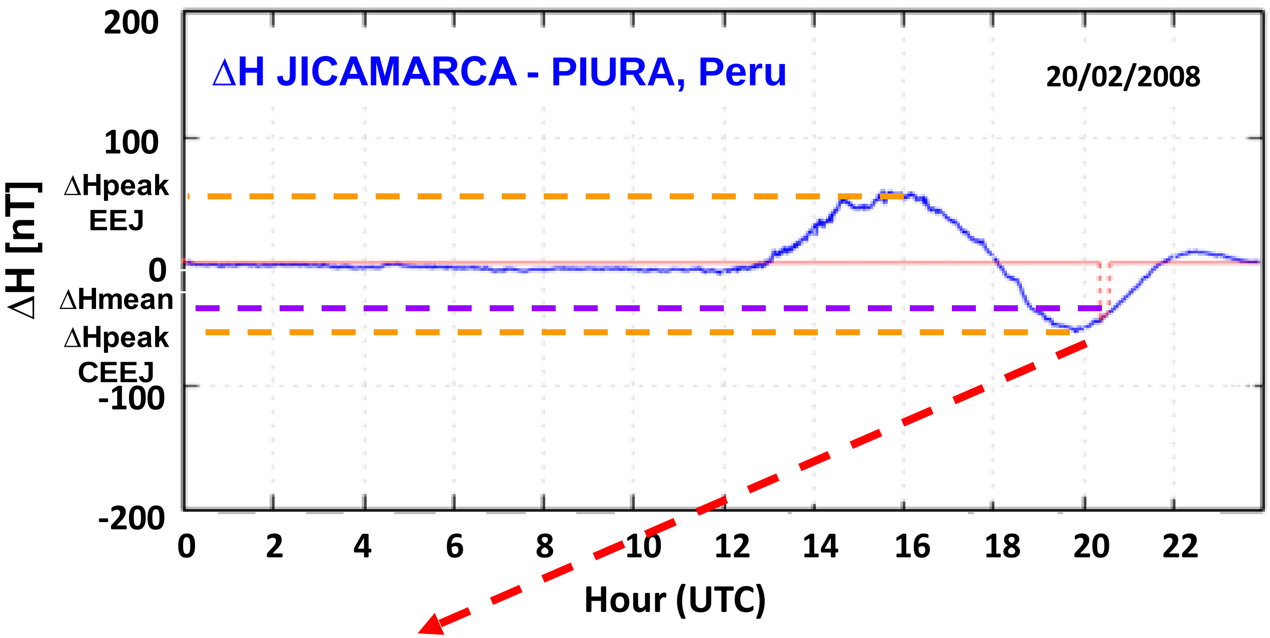
- Highest occurrence during the years of minimum solar activity



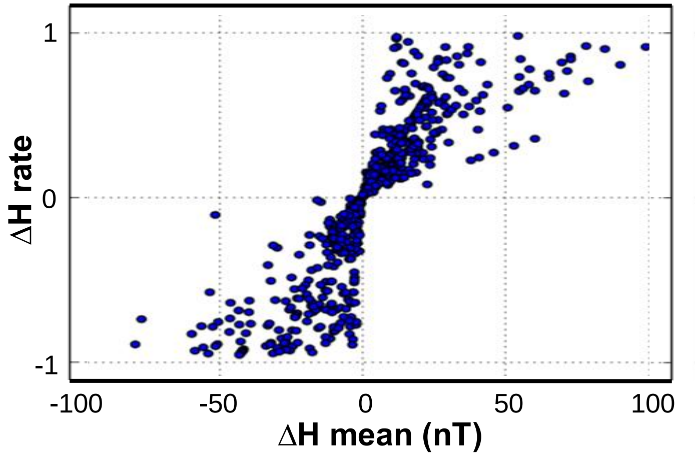
- During June solstice and equinoxes occur mostly in a range of 95 and 110 km
- During December solstice is mostly between 90 and 135 km

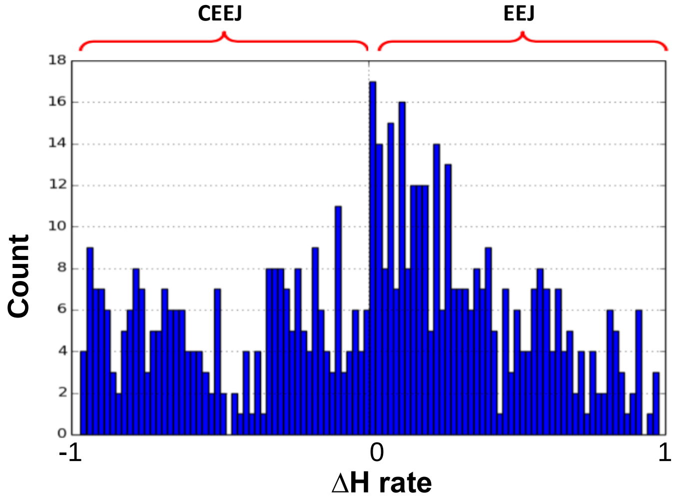
Result of identification and observations of *Esb* occurrence

Magnetograms in Esb occurrence: ΔH between Jicamarca (station at the magnetic equator) and Piura (station outside the magnetic equator) stations during days when Esb occurred.



Esb 20:30:00 UT
ΔH mean = -42.8 nT
ΔH peak(CEEJ) = -55.6 nT
ΔH rate = ΔH mean/|ΔH peak(EEJ or CEEJ)|= -0.77





- **Comparison occurrence of Esb layers in CEEJ conditions (ΔH mean less than 0 nT) and weak EEJ (ΔH mean**
- **between 0 and 25 nT, and ΔH rate less than 0.5).**

Summary

- We obtained the first long-term statistical study of Esb occurrence over the Jicamarca Radio Observatory using digisonde data from 2001 to 2018.
- In this work, it has been developed and implemented the first algorithm for automatic Esb identification over equatorial regions from ionograms, taking into account the absorption of the D region.
- In terms of occurrence, Esb can be classified as rare events over the Jicamarca Radio Observatory.
- Our observations have shown similar results obtained in other equatorial stations (Yadav et al., 2017; Devasia et al., 2006). Esb events occur more frequently during the summer solstice and years of minimum solar activity, also there is a main peak of occurrence at 1600 LT and a second peak around 0800 − 0900 LT.
- Three conditions have been proposed that favor the formation of these Esb layers in equatorial regions: Adequate presence of meteoric dust particles, sufficient level of ionization, and a weak EEJ or CEEJ generated by a weak main Electric Field.