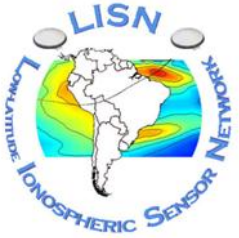
Expansion of the LISN network in Peru and South America (new digital receivers for multi-static ionosondes)

Cesar E. Valladares
cev160230@utdallas.edu
W. B. Hanson Center for Space Sciences

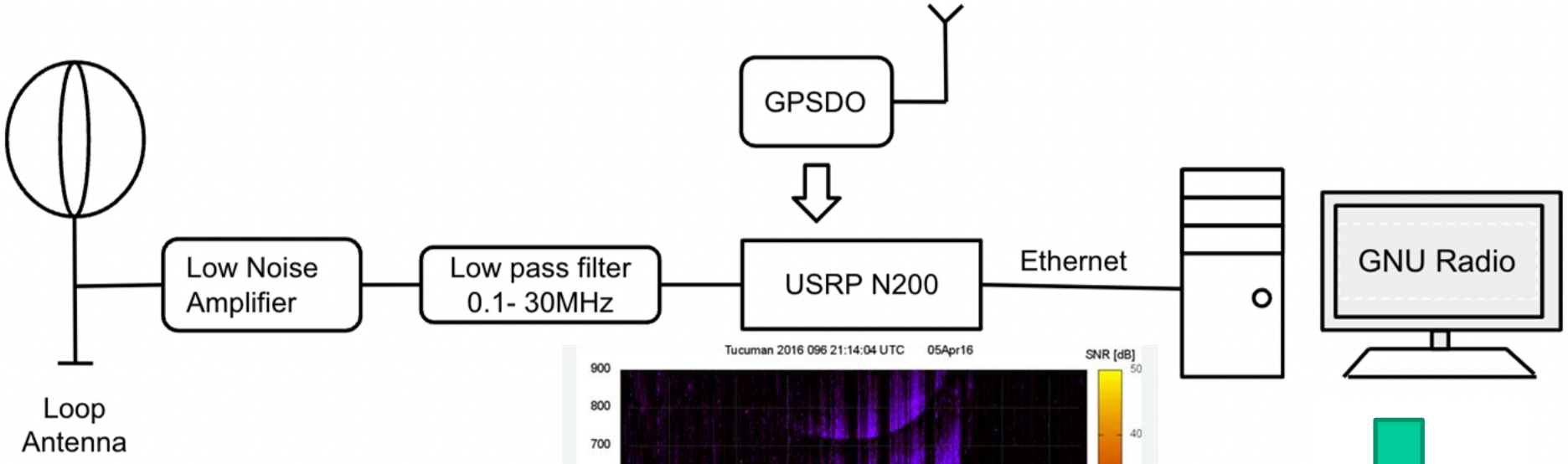
Collaborators: Marco Milla, Isaac Davila, Cesar de la Jara, Karim Kuyeng, Danny Scipion, Juan Espinoza.



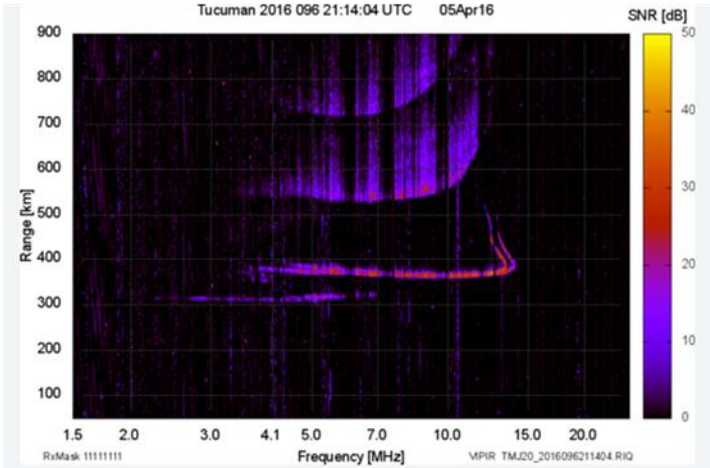
Research and technology development in Peru July27, 2022

UTD

(1) Purchase 34 Septentrio PolaRx5S GNSS receivers (receivers are tested at Jicamarca)
(2) design, construct, and install four (4) VIPIR ionosonde receiver stations

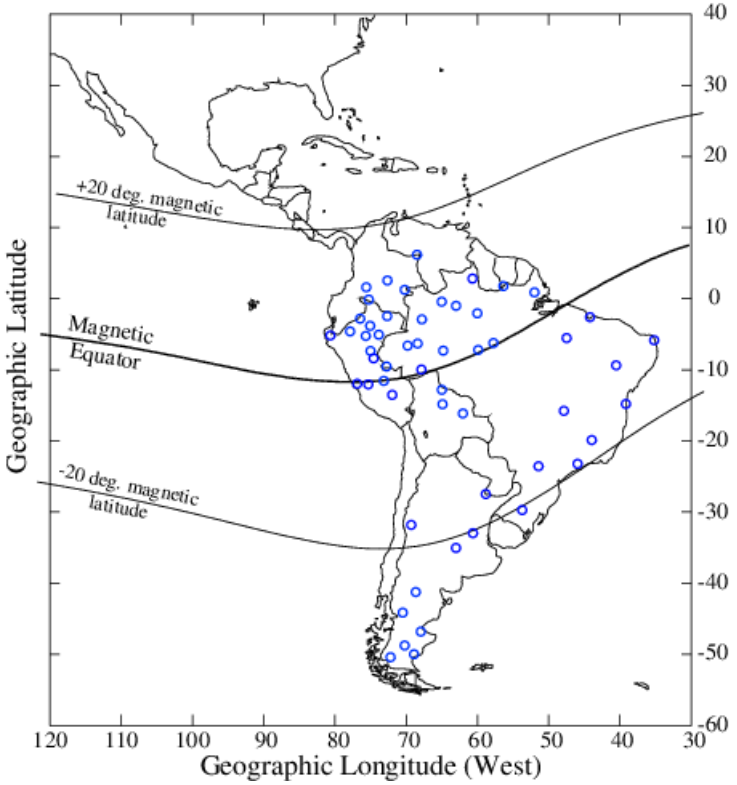


Oblique Sounding



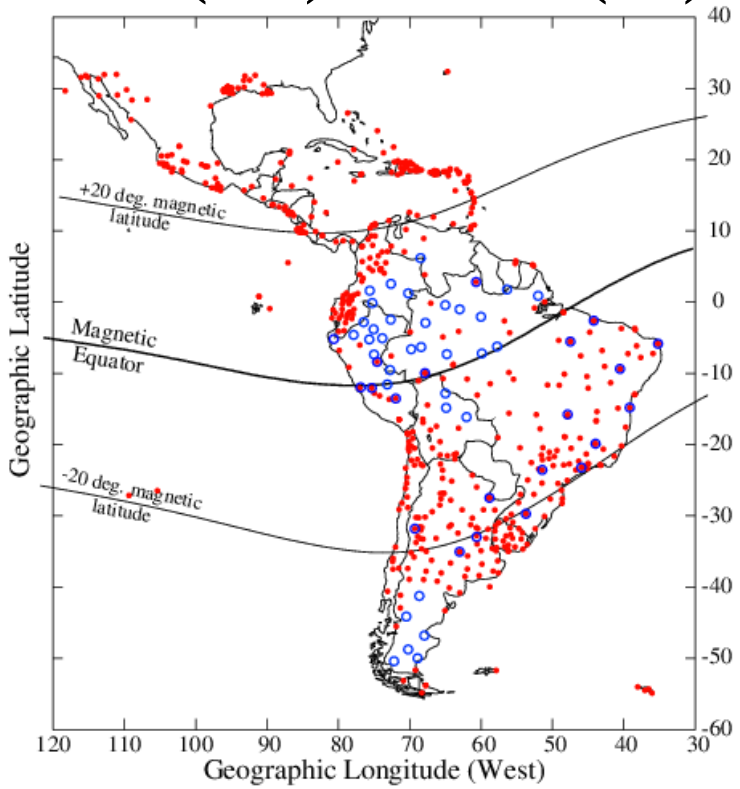
Joint Operations of GPS & GNSS receivers will start in September 2022

34 GNSS + LISN GPS



Real-time data to be upload every 15 min.

LISN (blue) + 800 GPS (red)

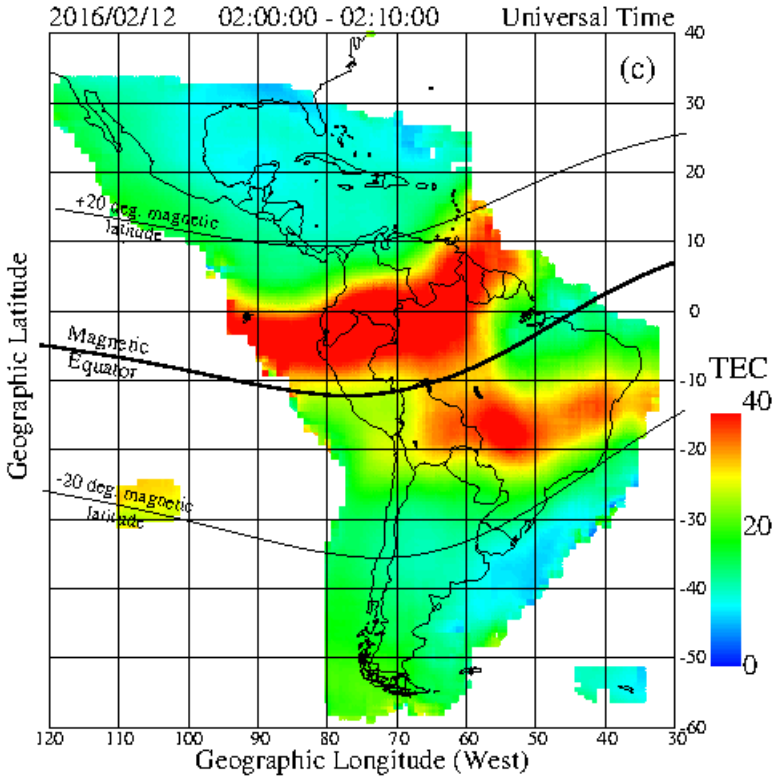


Red dots indicate location of 800+ receivers. Most of them provide data at UT=0.

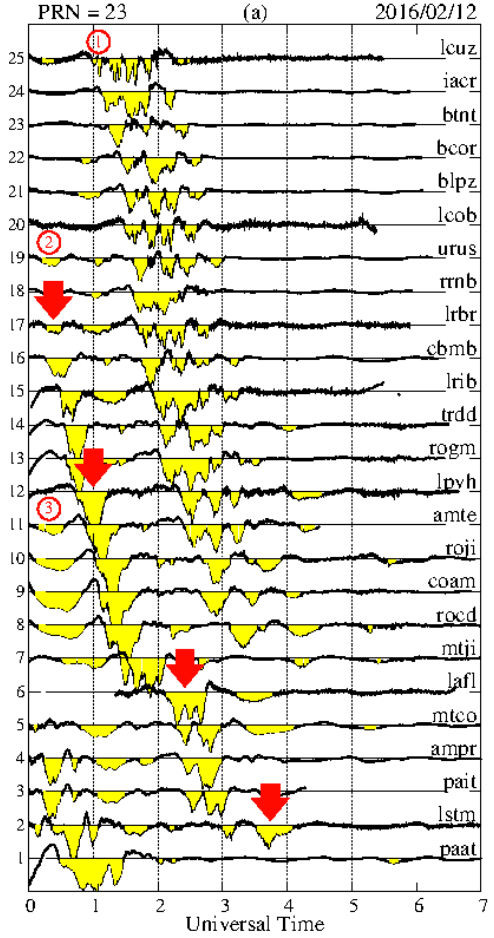
Networks:

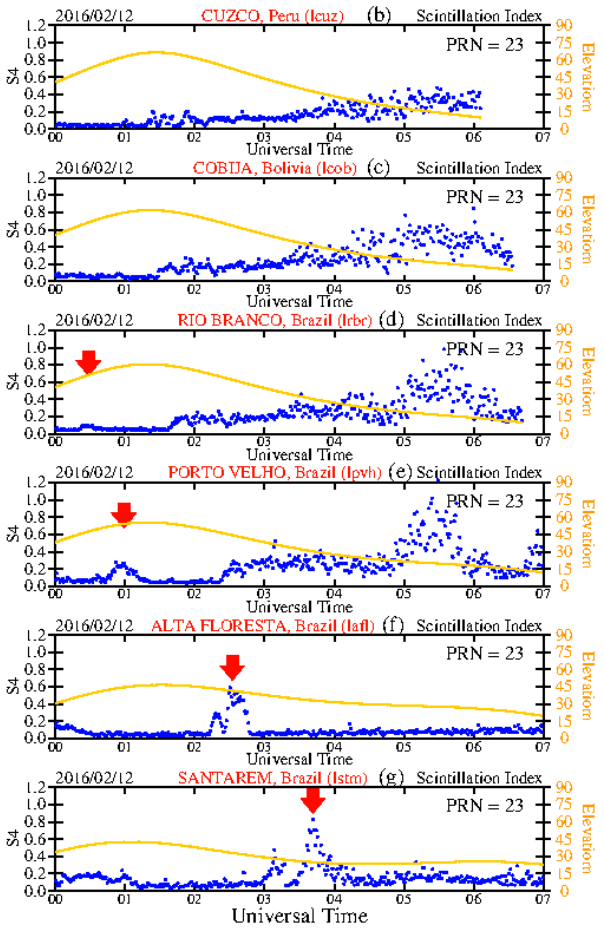
SOPAC https://garner.ucsd.edu
UNAVCO: https://data-out.unavco.org
CDDIS: https://cddis.nasa.gov/archive/
CHILE: gps.csn.uchile.cl
BRAZIL: ftp://geoftp.ibge.gov.br/informacoes_sobre_posicionamento_geodesico/rbmc/dados/
ARGENTINA: 186.33.227.179
LISN: lisn.igp.gob.pe
Other networks at Peru, Ecuador, Bolivia, and Colombia.

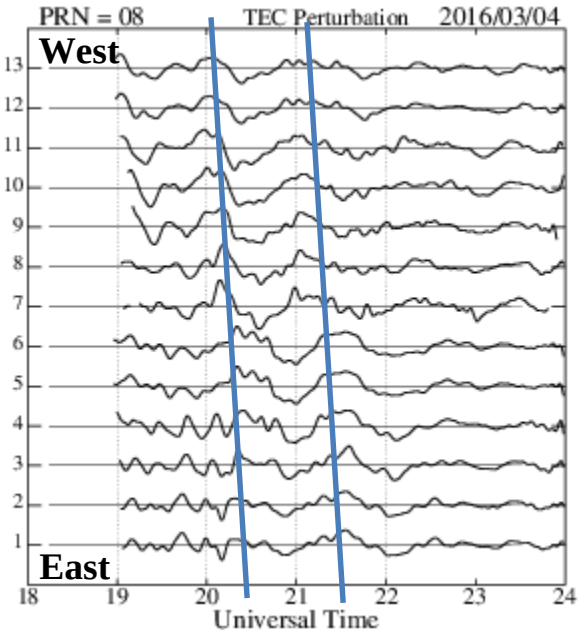
Near real-time TEC plots & derived products



LISN GNSS receivers will provide TEC values every 15 min. At UT= 0 (sunset near Lima) we will get RINEX files from most of the GPS receiver that operate at Argentina, Brazil, Peru and Chile







TEC depletion/bubble identification (after TEC calculation), scintillation S4 index (real time), and fading rate.

Calculation of TID characteristics. Here, TIDs are moving eastward two hours before sunset.

Tasks completed: System simulation, pulse generator development, and VIPIR and receiver synchronized

Programmable pulse generator, designed and built at the Jicamarca station.

USRP N200 built by Ettus Research

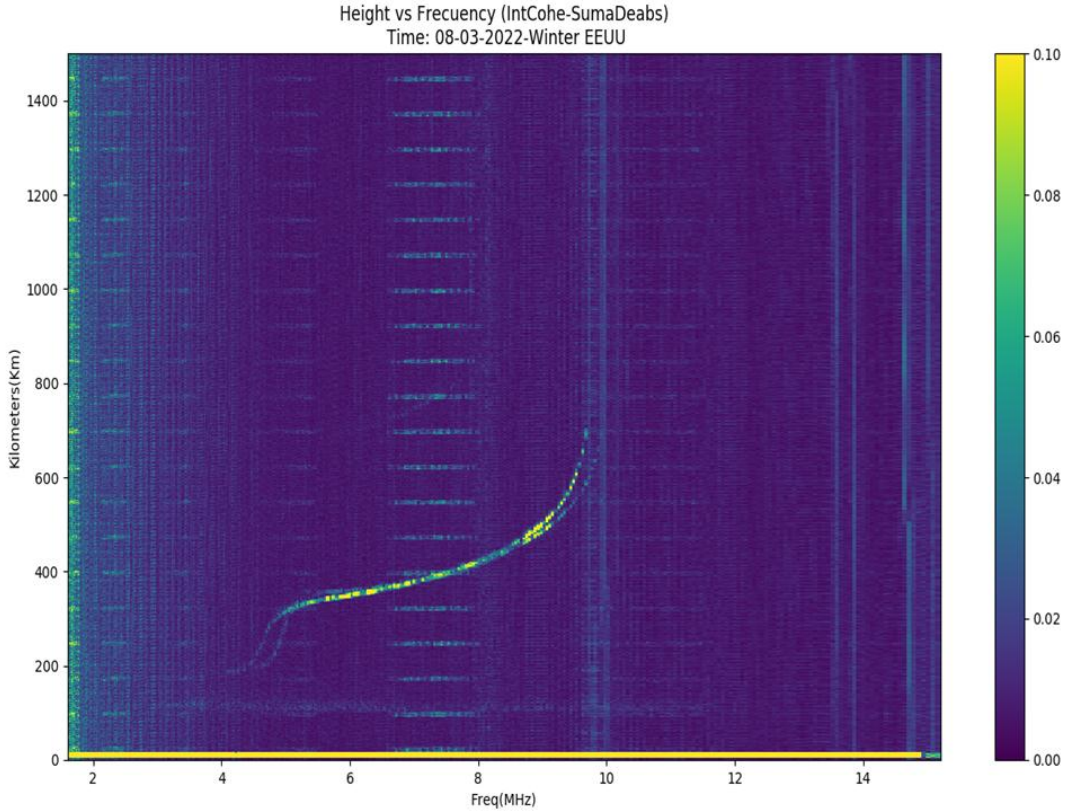
Antenna systems: ALA 1530 LN, MLA 30 from Wellbrook Communications

- The new system is a passive receiver that detects the signals transmitted by a VIPIR ionosonde.
- The receiver is based on an SDR device: USRP N200. It uses double polarization loop antennas and GNU radio for data acquisition.
- This relatively low-cost receiver will be employed in oblique sounding, taking advantage of the VIPIR ionosondes from the LISN distributed observatory already operating in South America.

New synchronization scheme

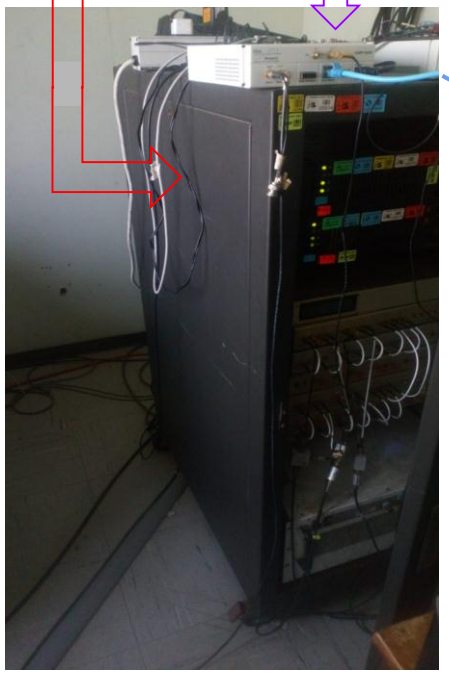
Second system: Using a synchronization circuit and a GPSDO

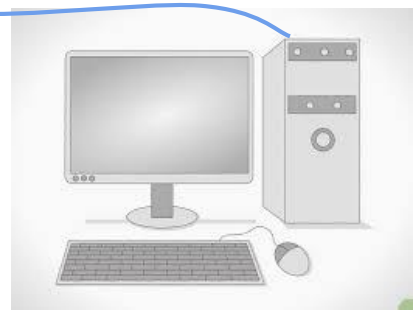
- This system is based on an FPGA that uses the PPS of a GPS receiver to generate the pulse that initiates the VIPIR transmisión and a GPSDO to initiate the USRP
- We also used a GPSDO and a USRP N200 for the data acquisition.



Synchronization flow diagram

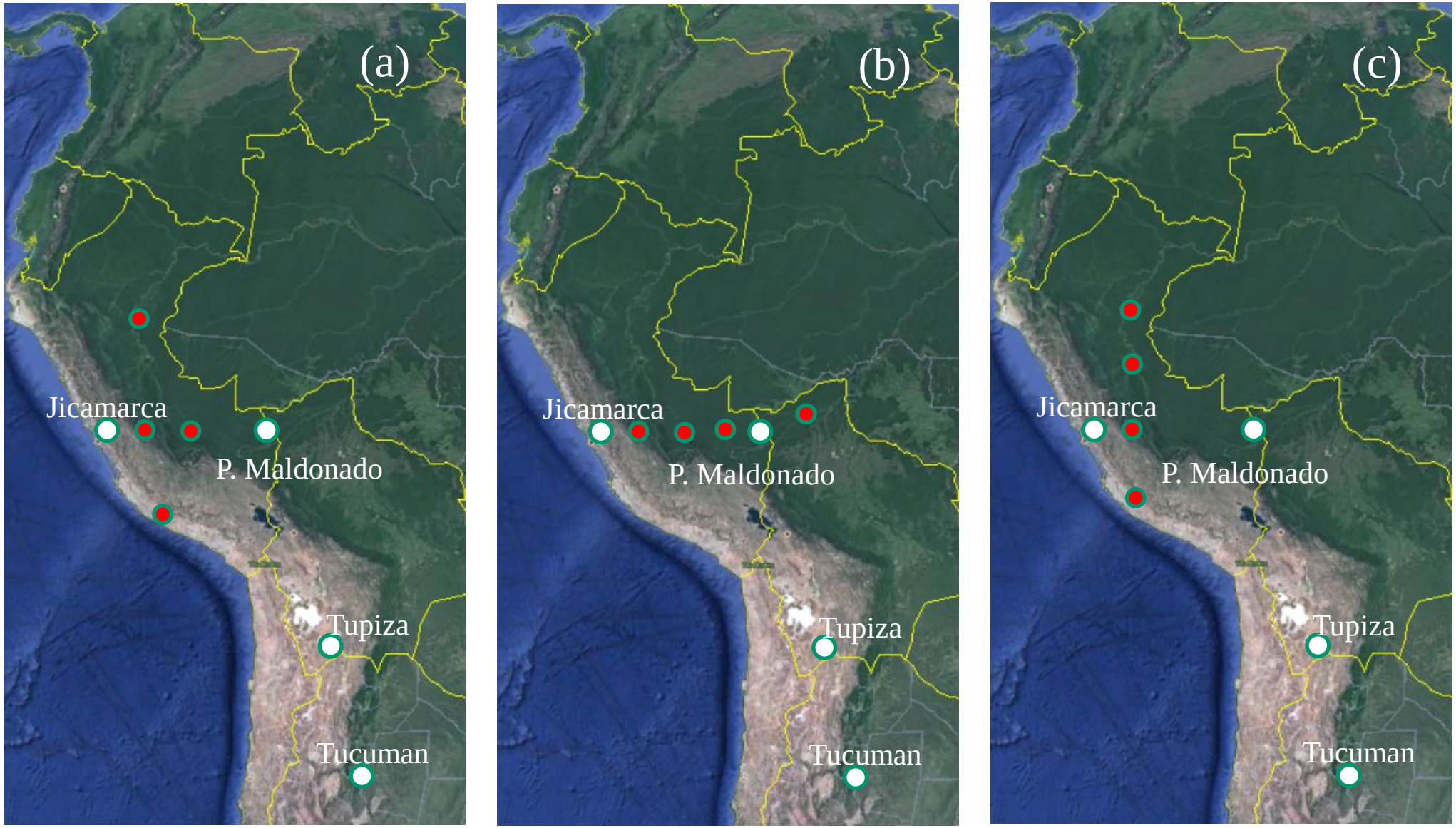
GPSDO





Four ionosonde receivers (red dots) will be added to four existing LISN VIPIR ionosondes (white dots) operating on the western side of SA

Different receiver configurations will be implemented during different years.
These receivers (in red) will provide oblique ionograms



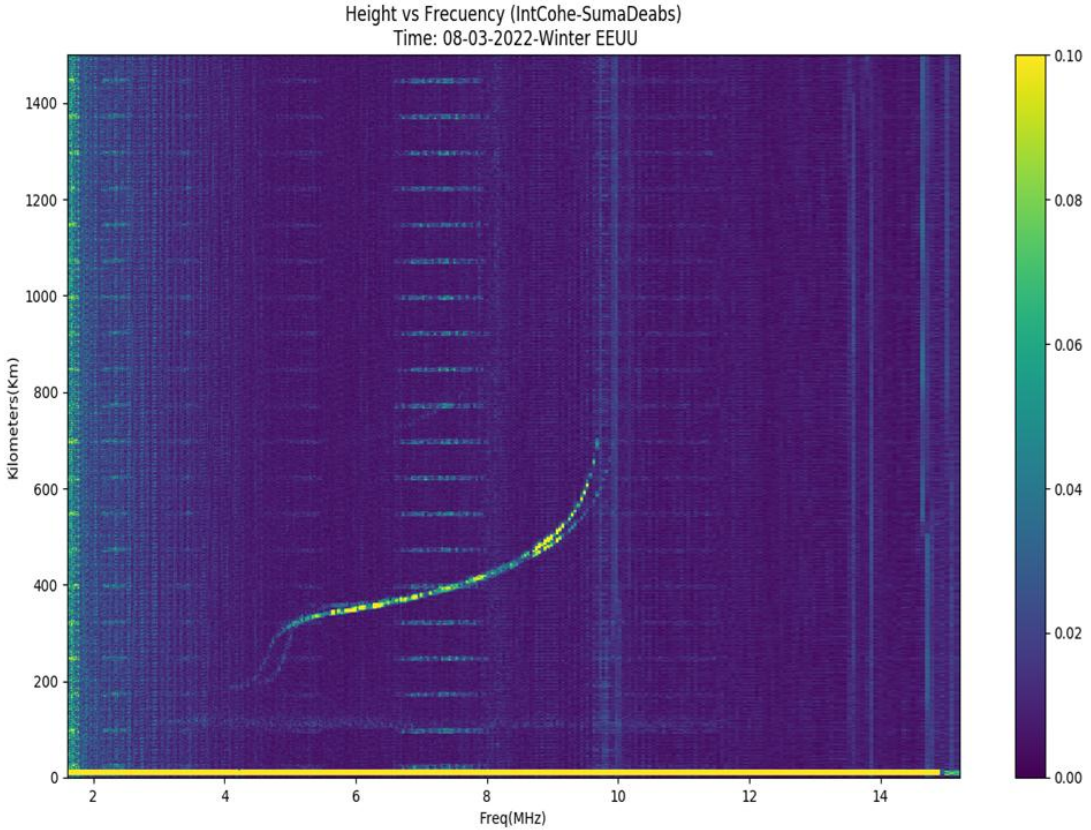
Tasks to be delivered between July 2022 – July 2024

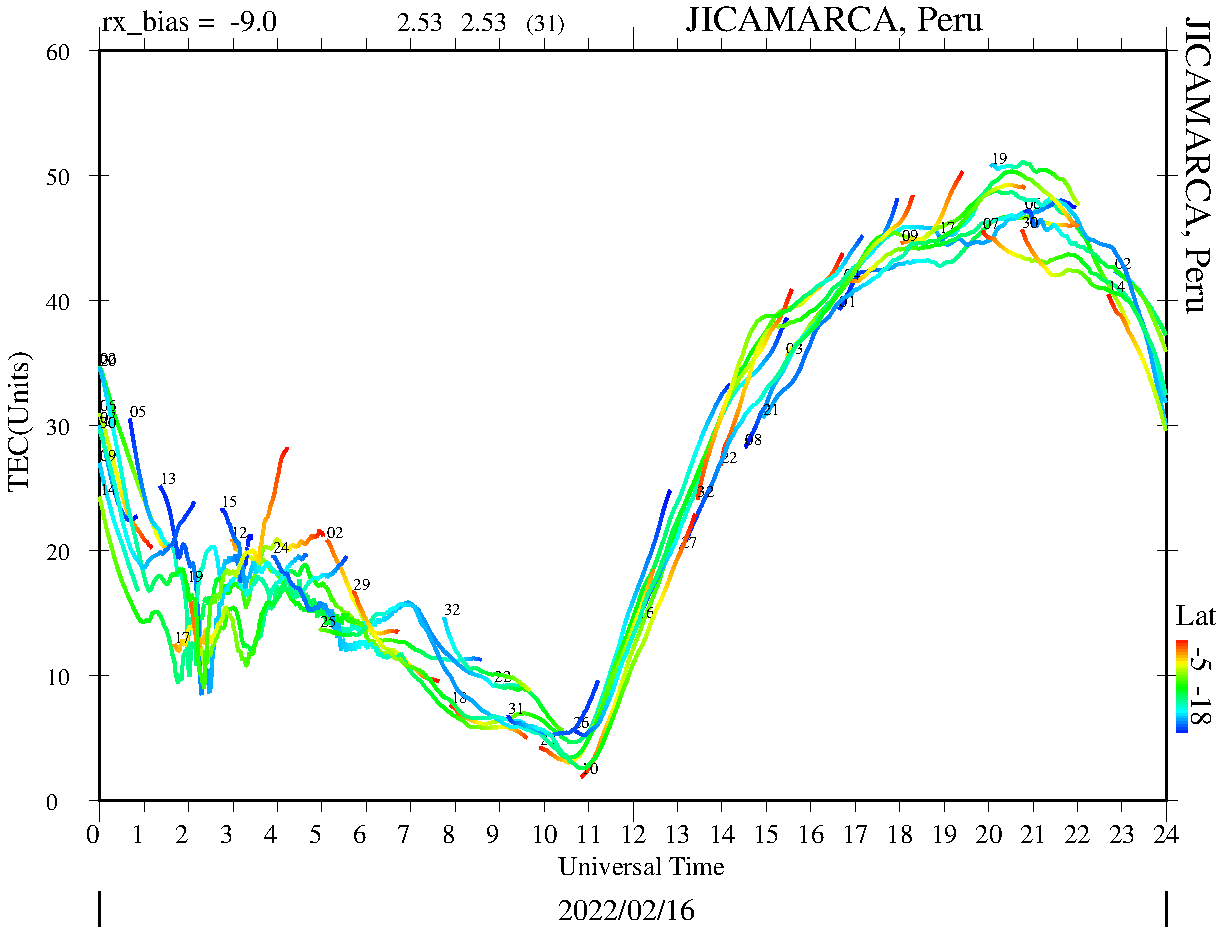
1. **We will use two VIPIR ionosondes (Jicamarca & Puerto Maldonado) doing vertical sounding and four VIPIR receivers for oblique sounding. This will provide a total of 10 density profiles every 5 minutes.**
2. **Real-time processing and display of TEC and scintillation S4 indices using ~50 GPS/GNSS receivers in South America.**
3. **Perform off-line tomographic reconstruction of density profiles in the area covered with GPS and VIPIR ionosondes. Density profiles provided by the vertical and oblique sounding will be used to regularize the tomographic reconstructions.**
4. **We will provide maps of TEC, TEC depletions, scintillations, and TIDs with a one min resolution using the LISN data.**

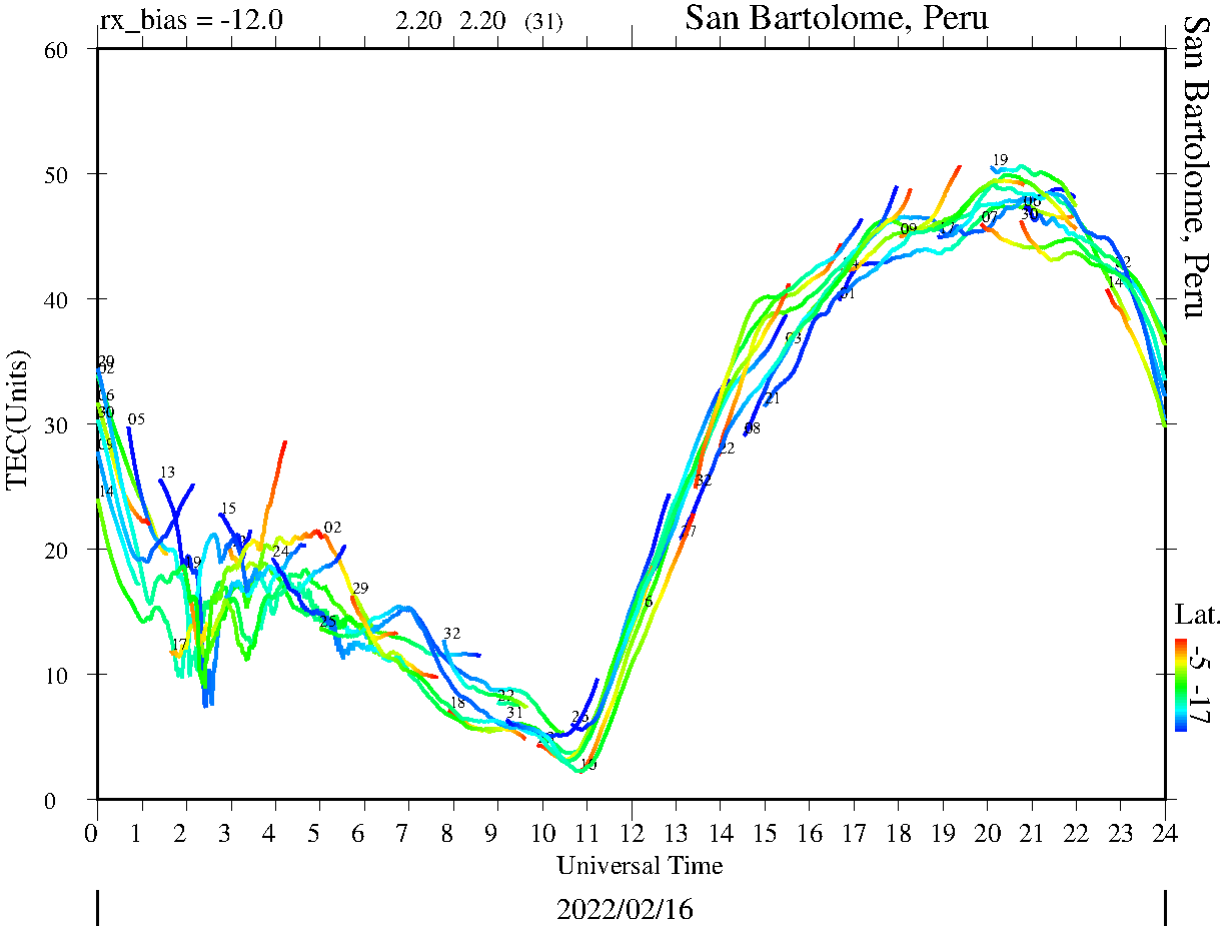
Different synchronization schemes

First system: Using a synchronization circuit.

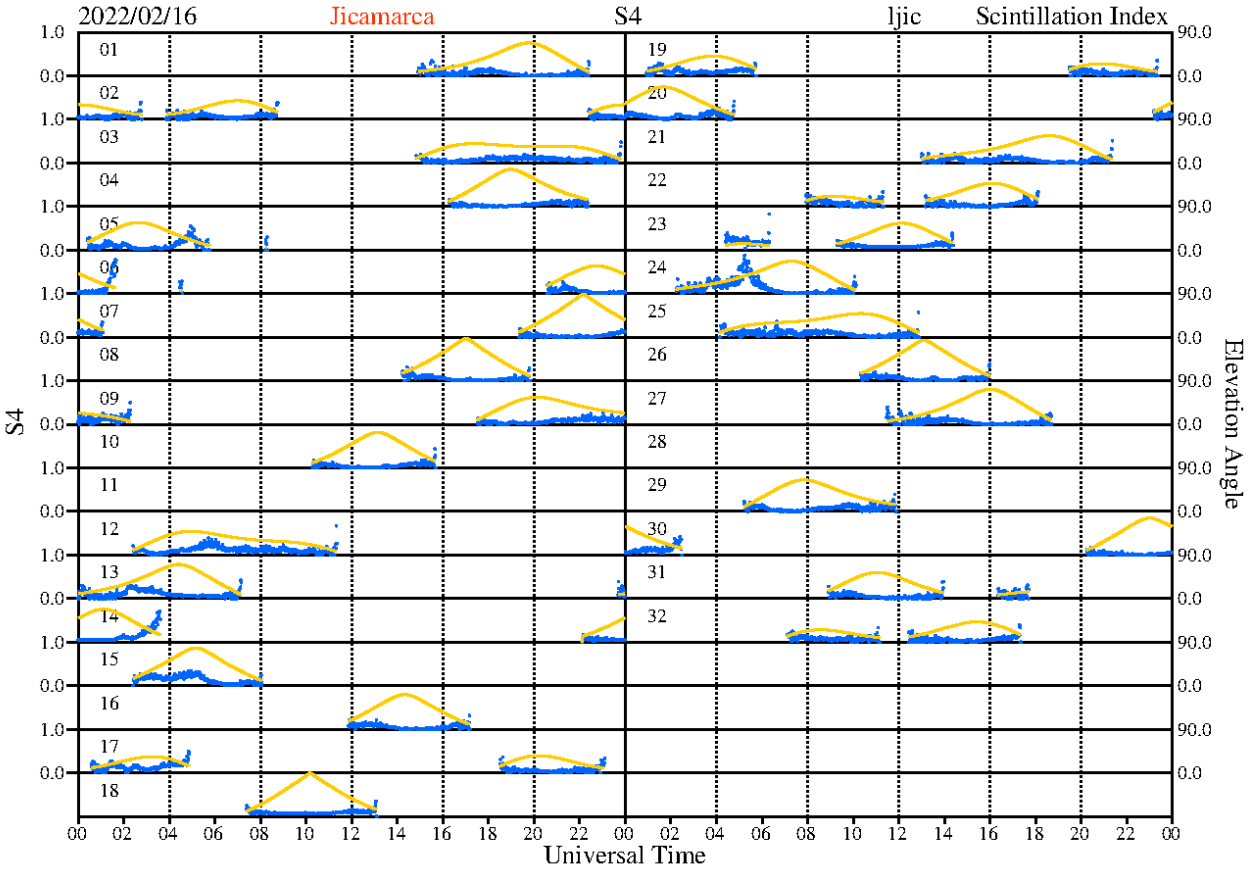
- We used an FPGA that is based on a PPS signal from a GPS receiver to generate a pulse to initiate the VIPIR transmisión as well as the USRP in the receiver. Both VIPIR and USRP are collocated, and the sync pulse is split and sent to both devices. For remote synchronization is necessary to use independent circuits.
- An USRP N200 and a GNU Radio were used during these initial tests.

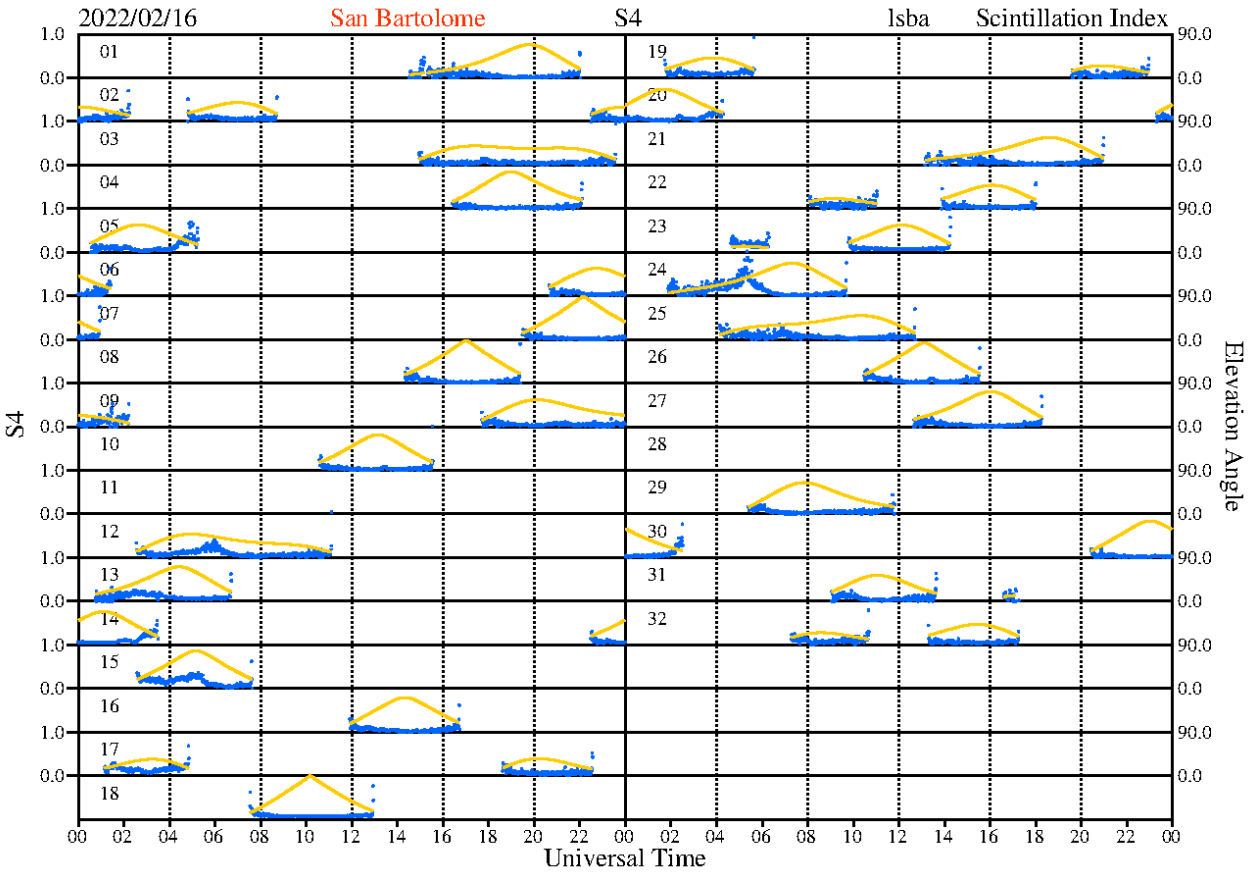



rx_bias = -9.0
2.53 2.53 (31)
JICAMARCA, Peru
TEC(Units)
Universal Time
Lat
-5 -18
2022/02/16


rx_bias = -12.0
2.20 2.20 (31)
San Bartolome, Peru
TEC(Units)
Universal Time
Lat.
-5 -17
2022/02/16

GPS Scintillations for Jicamarca and San Bartolome (50 km apart)





February 16, 2022

Description

- The new system is a passive receiver that detects the signals transmitted by a VIPIR ionosonde.
- The receiver is based on an SDR device: USRP N200. It uses double polarization loop antennas and GNU radio for data acquisition.
- A module in GNU radio has been developed to perform the frequency sweep from a table of frequencies generated by VIPIR ionosondes.
- This relatively low-cost receiver will be employed in oblique sounding, taking advantage of the VIPIR ionosondes from the LISN distributed observatory already operating in South America.

Goals:

(1) Purchase 34 Septentrio PolaRx5S GNSS receivers (receivers are tested at Jicamarca)

(2) design, construct, and install four (4) VIPIR ionosonde receiver stations

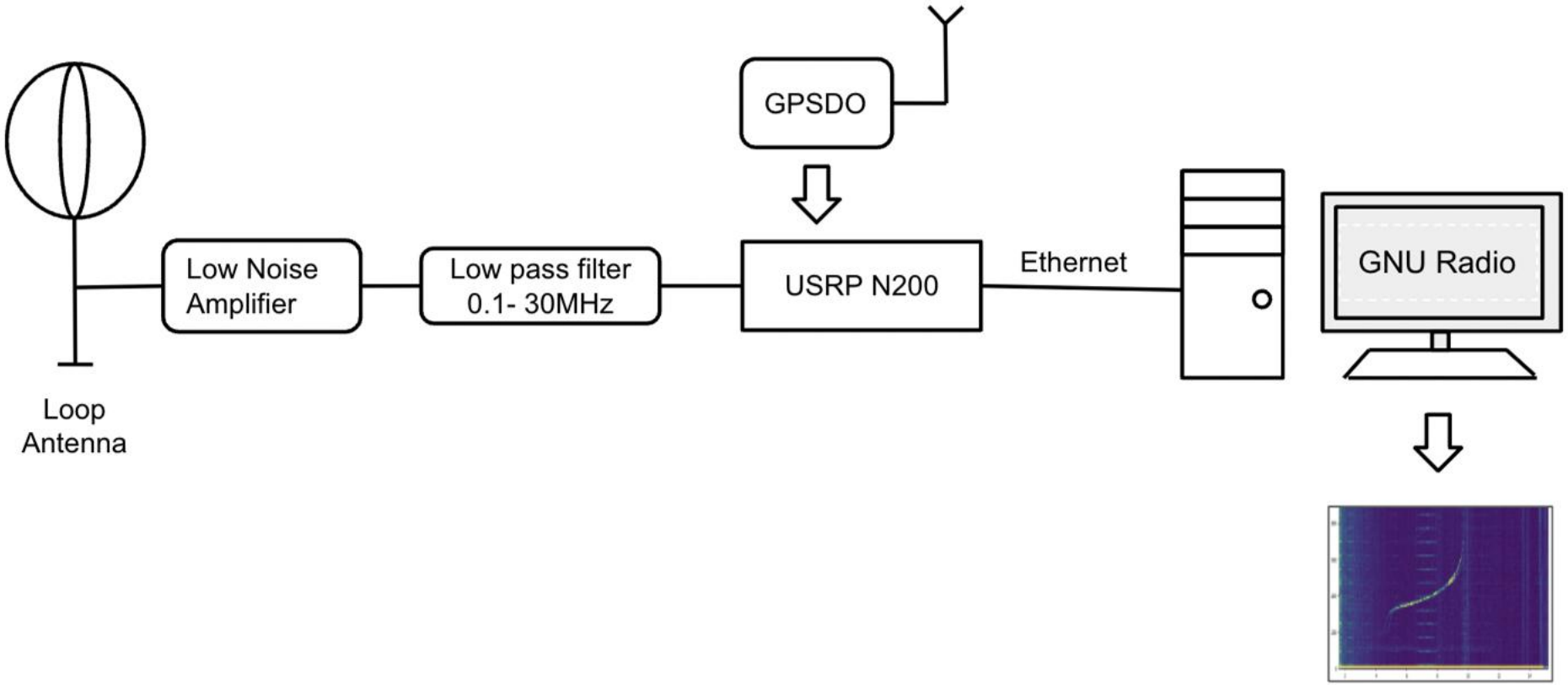
The PolaRx5S ionospheric monitoring GNSS receiver from Septentrio offers 544 channels that provide I&Q correlations, phase, code and carrier-to-noise at up to 100 Hz for all GNSS L-band frequencies. It features an ultra-low noise oscillator enabling precise phase scintillation monitoring with a phase noise standard deviation as low as 0.03 rad.

PolaRx5S can monitor 544 channels. **GPS:** L1CA, L1P, L2, L5. **GLONASS:** L1, L2, L3. **GALILEO:** E1, E5ab, AltBoc, E6. **BeiDou:** B1, B2, B3. **SBAS:** L1, L5.

Characteristics

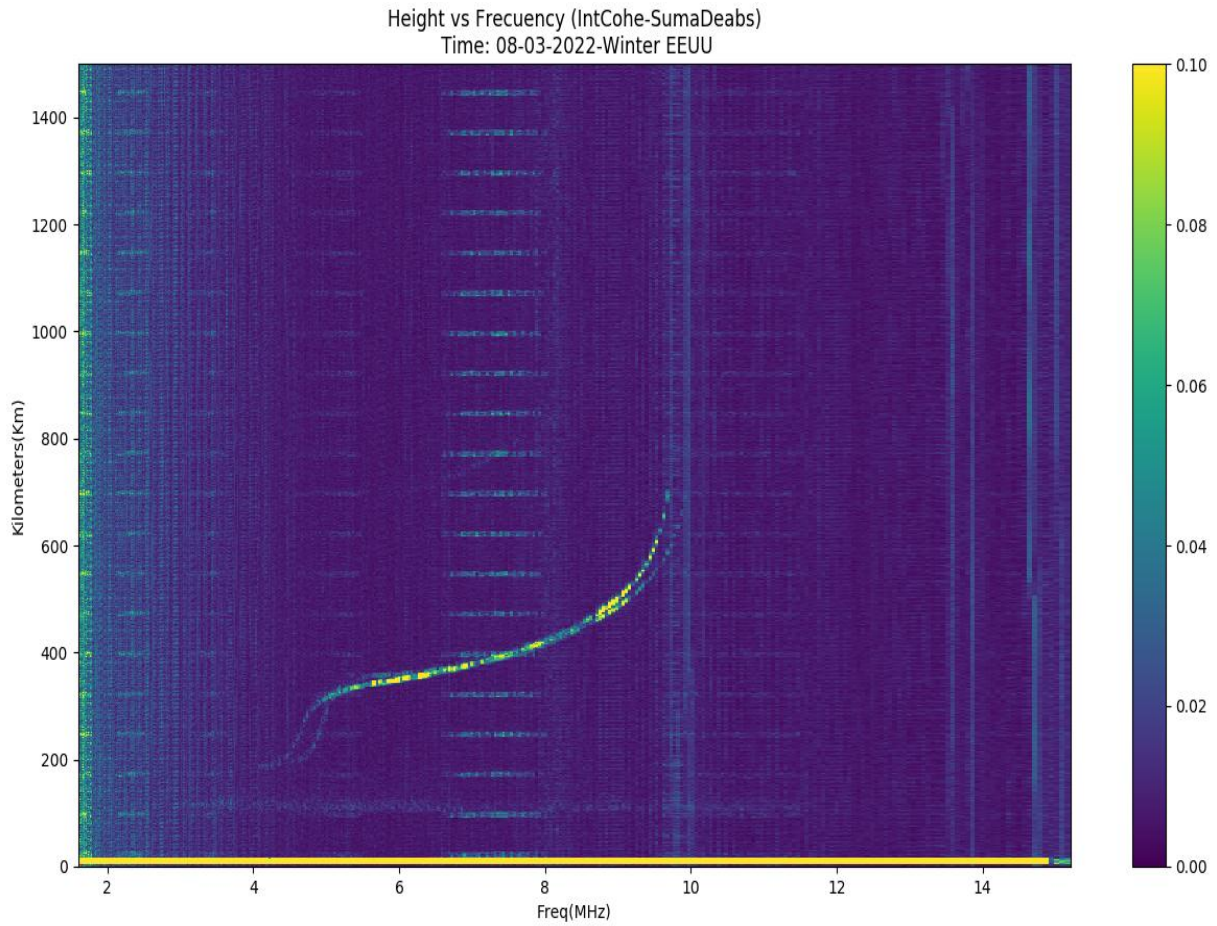
- Band width : 20 MHz
- Number of channels : 2
- Resolution : 1.5 km
- Synchronization : GPS
- Interface : GNU Radio (open source)
- Raw data : Digital RF (HDF5)
- Proc data : NGI

Block diagram



Ionograma adquirido utilizando el circuito de sincronización.

IPP: 10ms,
Rango de frecuencias: 1.601 Mhz- 15171.986 Mhz
Crecimiento exponencial con razón de: 0.5%
Repeticiones: 4
Rampas: 4



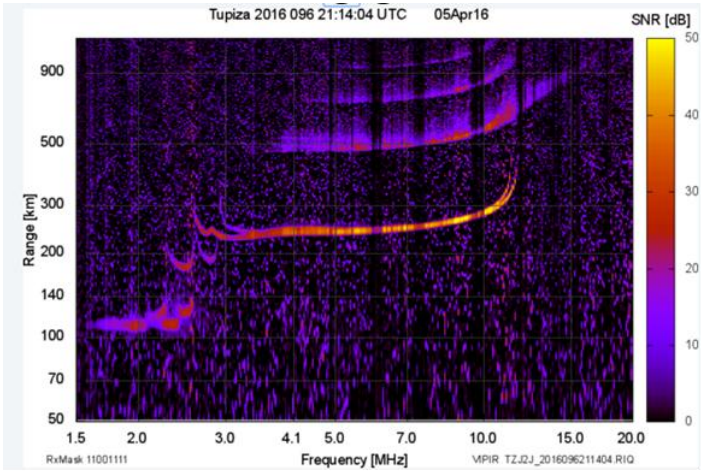
Design and construction of four VIPIR ionosonde receiver stations
Tasks completed: System simulation, pulse generator development

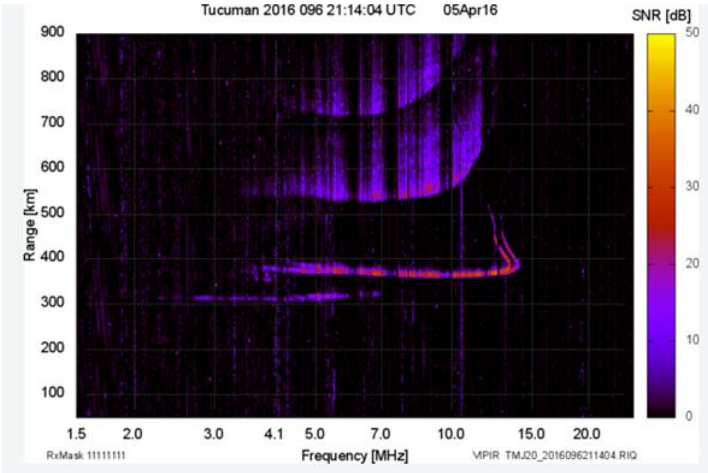
Simulation tests

Programmable pulse generator

USRP N200

vertical sounding & oblique sounding

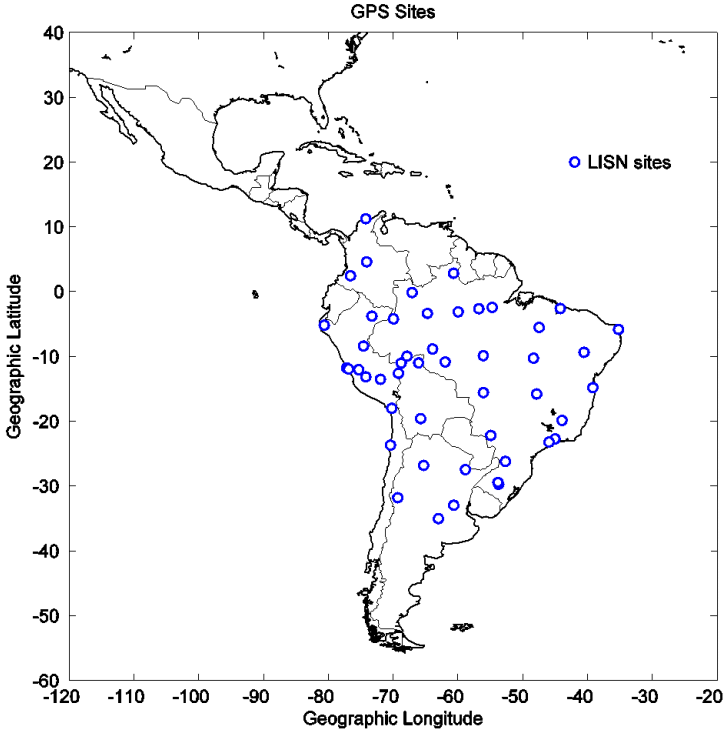




Antenna systems: ALA 1530 LN, MLA 30

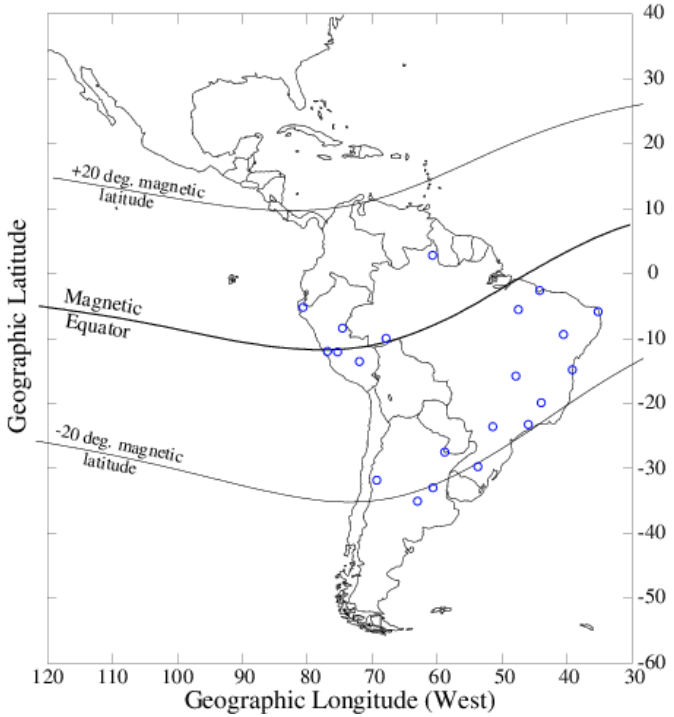
Low-latitude Ionosphere Sensor Network (LISN) of GPS/GNSS receivers

LISN GPS 2007-2016



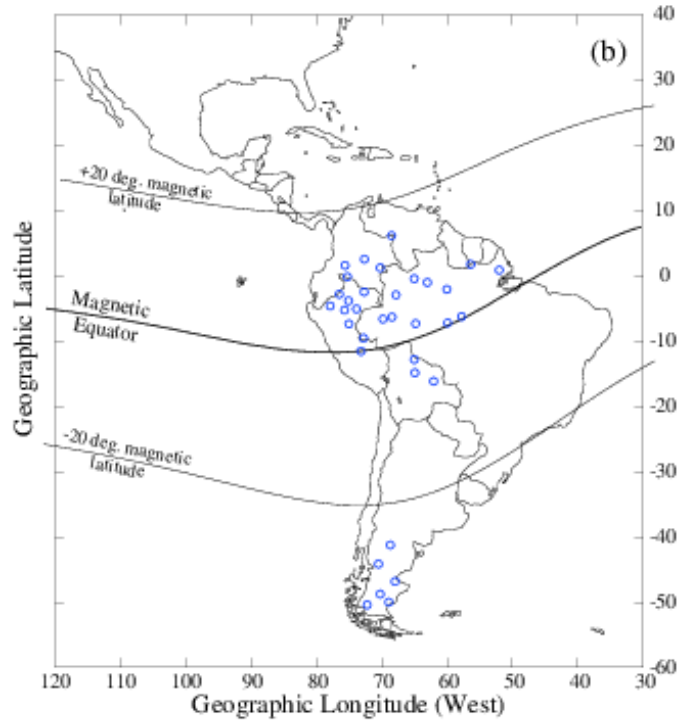
50 GPS Novatel rx

LISN GPS 2021



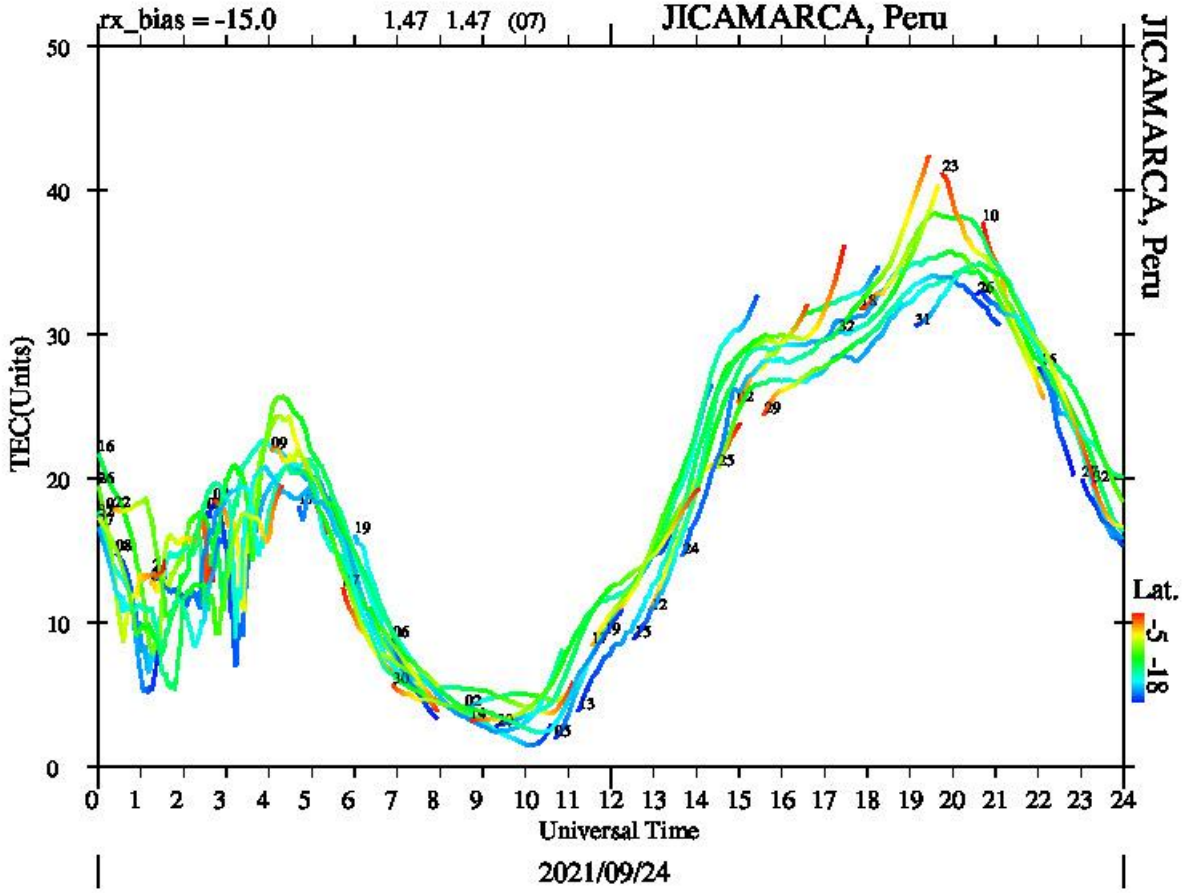
20 GPS receivers

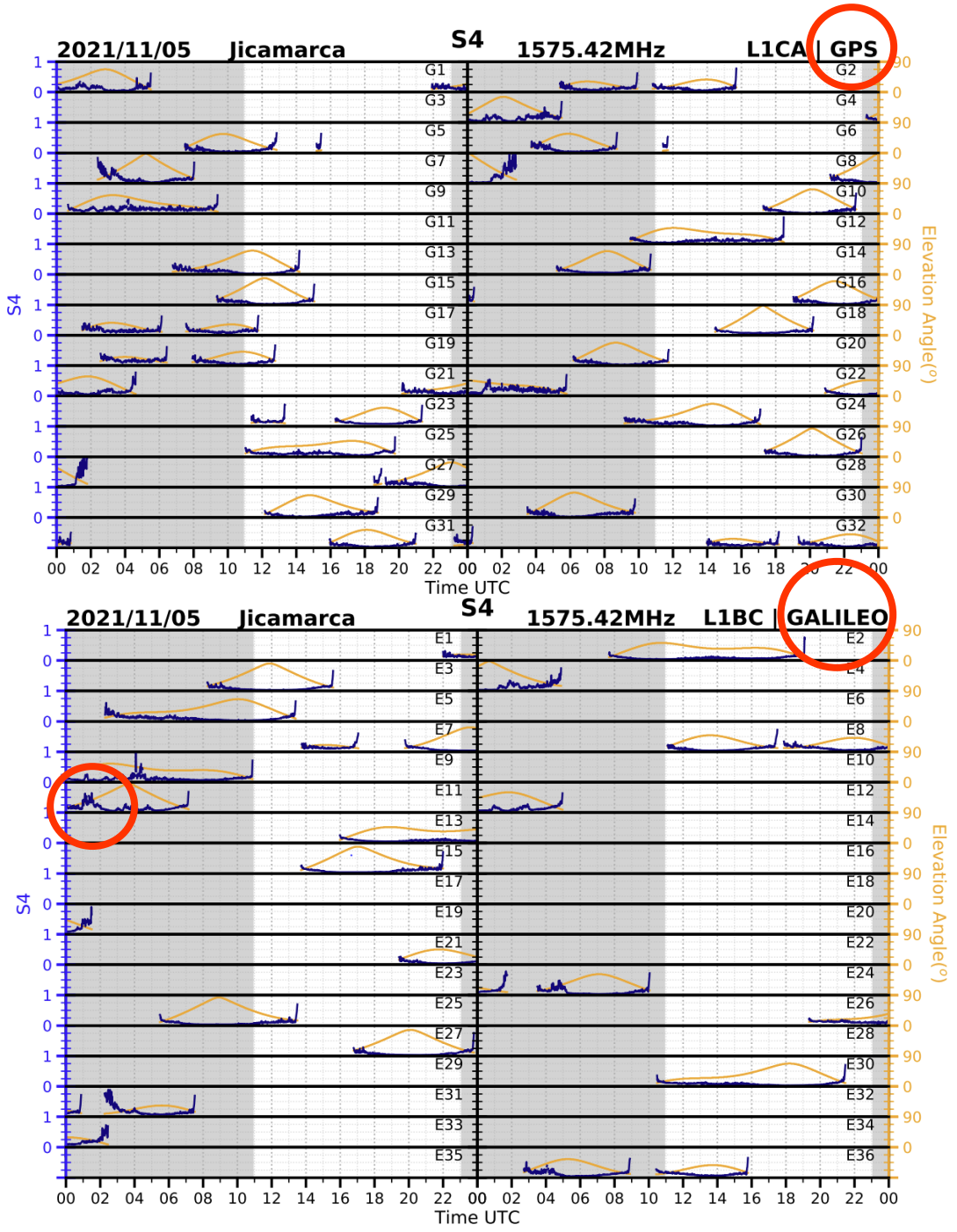
AFOSR DURIP Grant



34 GNSS Septentrio PolaRx5S

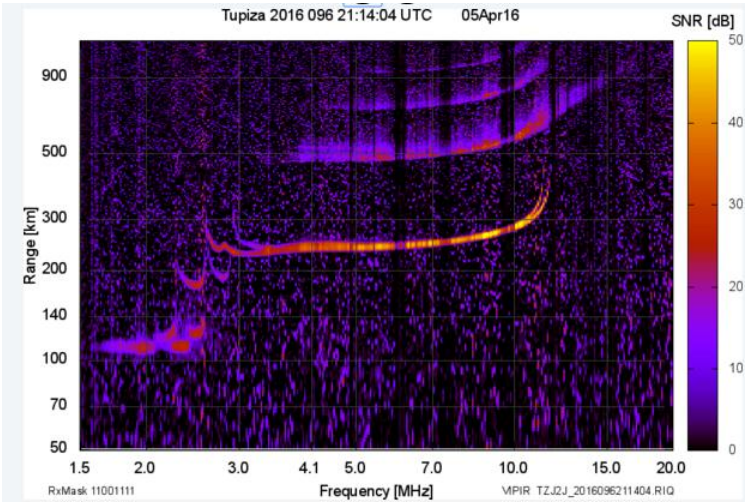
Two GNSS PolaRx5S receivers are already in operation at Jicamarca and San Bartolome (60 km away) for precise measurements of TEC gradients during plasma bubbles.



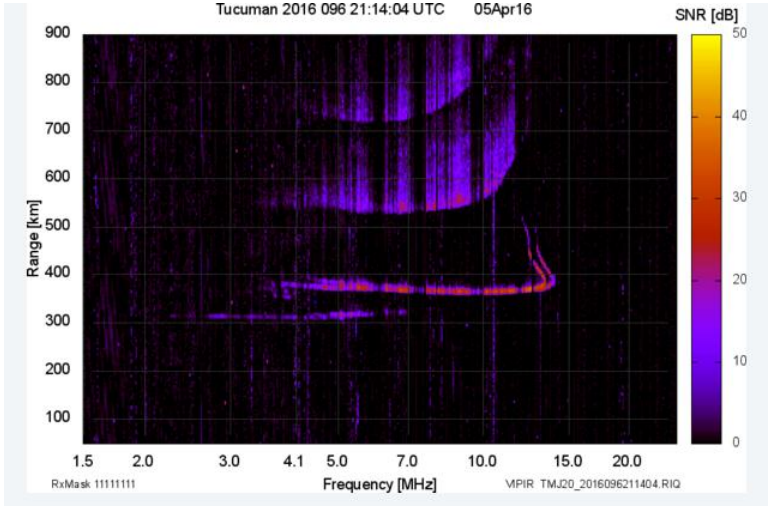


Additional VIPIR measurements

Tupiza: vertical sounding



Tucuman: oblique sounding

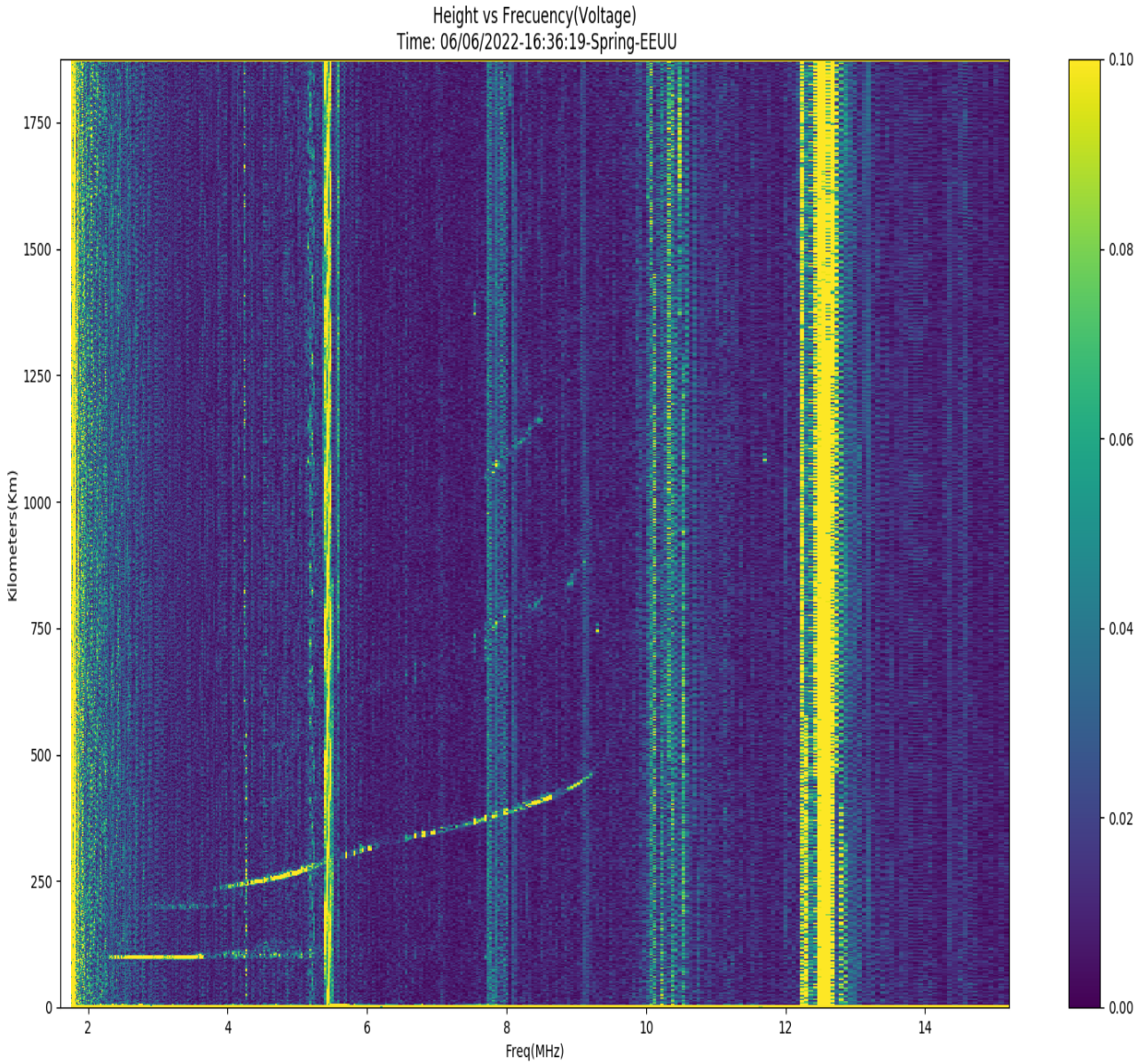


The plan is to synchronize the VIPIRs and conduct oblique sounding with these two VIPIRs.

Objetivos realizados

- Se realizaron las pruebas de sincronismo con un segundo GPSDO logrando obtener Ionogramas con altura inicial igual a cero.

- Se realizarán más pruebas para verificar si el error era el GPSDO.



- Se armó e instaló la antena Loop de doble polarización.

- Se utilizó unos prototipos en 3D para estabilizar la parte superior y se adquirió tornillos para ajustar la parte inferior.

- Se implementó el diagrama de bloques en GNU Radio para la etapa de recepción con la antena Loop en doble polarización.