LISN definition and Instruments

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OUTLINE

- **About distributed observatory. Concept, community needs, Distributed observatory vs. Cluster of Instruments, LISN.**

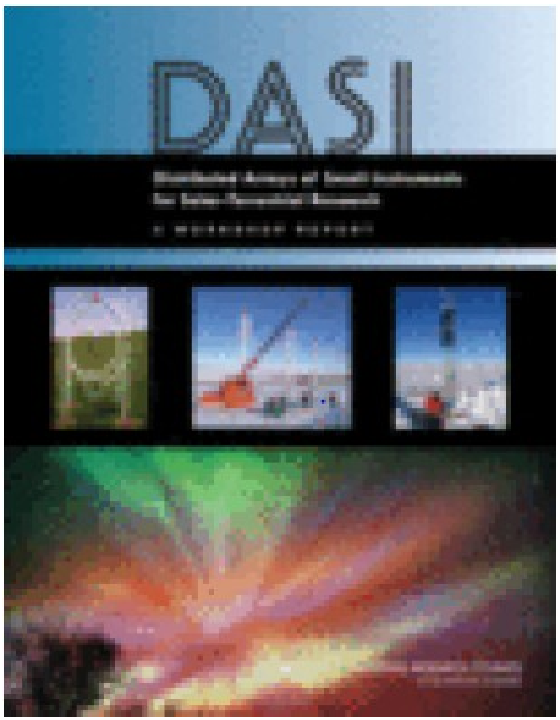
- **LISN: GPS observations, TEC variability. The August 3, 2010 Magnetic storm. Super fountain effects vs. wind effects. TEC empirical model.**

- **Magnetometer baselines – Electric fields. VIPIR ionosondes.**

- **Real-time Processing. Tomography. Forecasting using LISN data.**

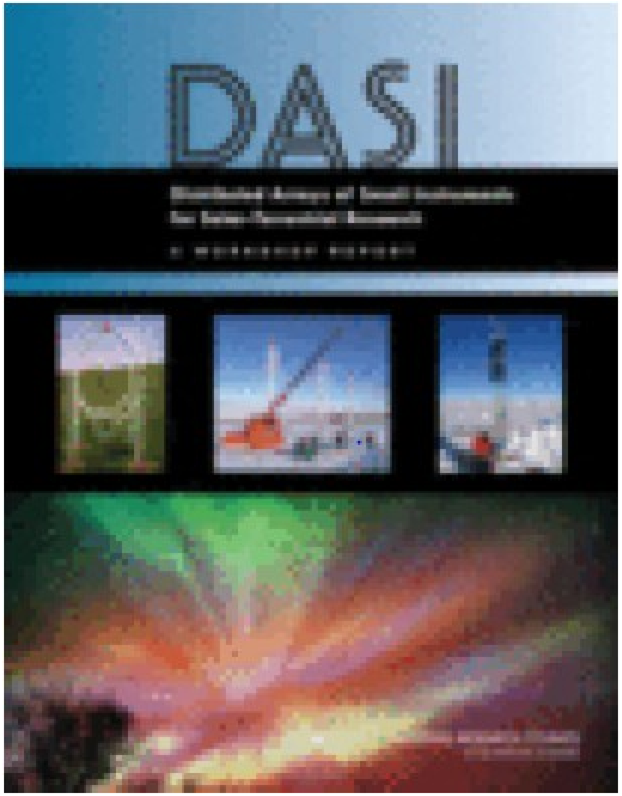
Initial efforts on Distributed Observatories

2002 Decadal survey: Understanding and monitoring the fundamental processes responsible for solar-terrestrial coupling are vital to fully explain the influence of the Sun on the near-Earth environment. DO can monitor these processes.



June 2004 workshop on Distributed Arrays of Small Instruments (DASI): A significant fraction of the flow of mass, momentum and energy in the M-I-T system occurs in a relatively small spatial scales and over a wide range of temporal scales. Elucidation of the fundamental coupling processes requires continuous coordinated, real-time measurements from a distributed array of diverse instruments.

More about DASI

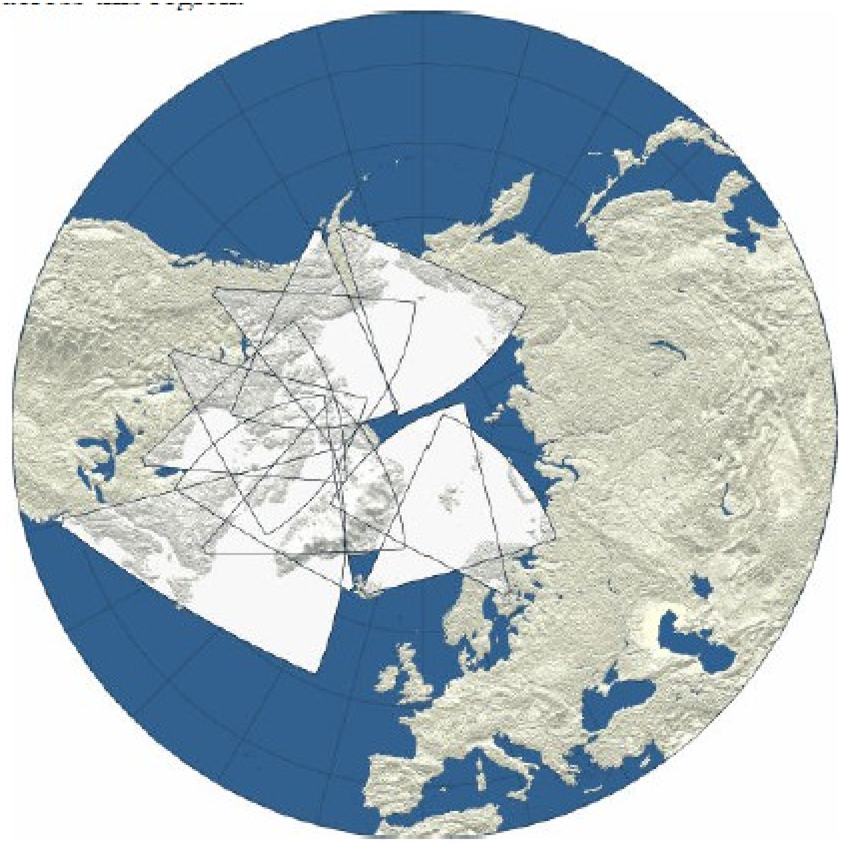


It offers a cost-effective means of performing original and critically important science.

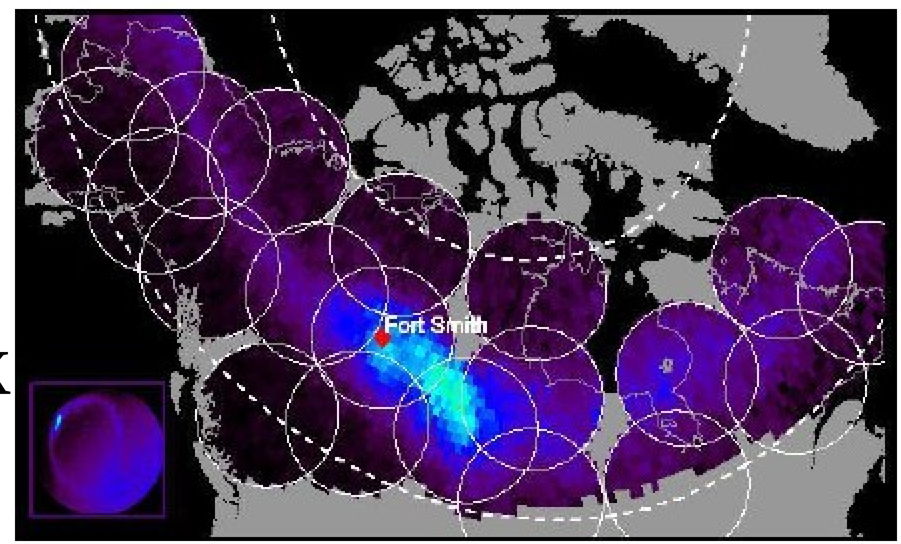
DASI will provide a global context to understand in-situ and remote sensing observations.

There is a inadequate spatial distribution of ground-based measurements.

Due to the importance of cross-scale coupling in plasma processes, there is a need to resolve both high and low spatial scales.

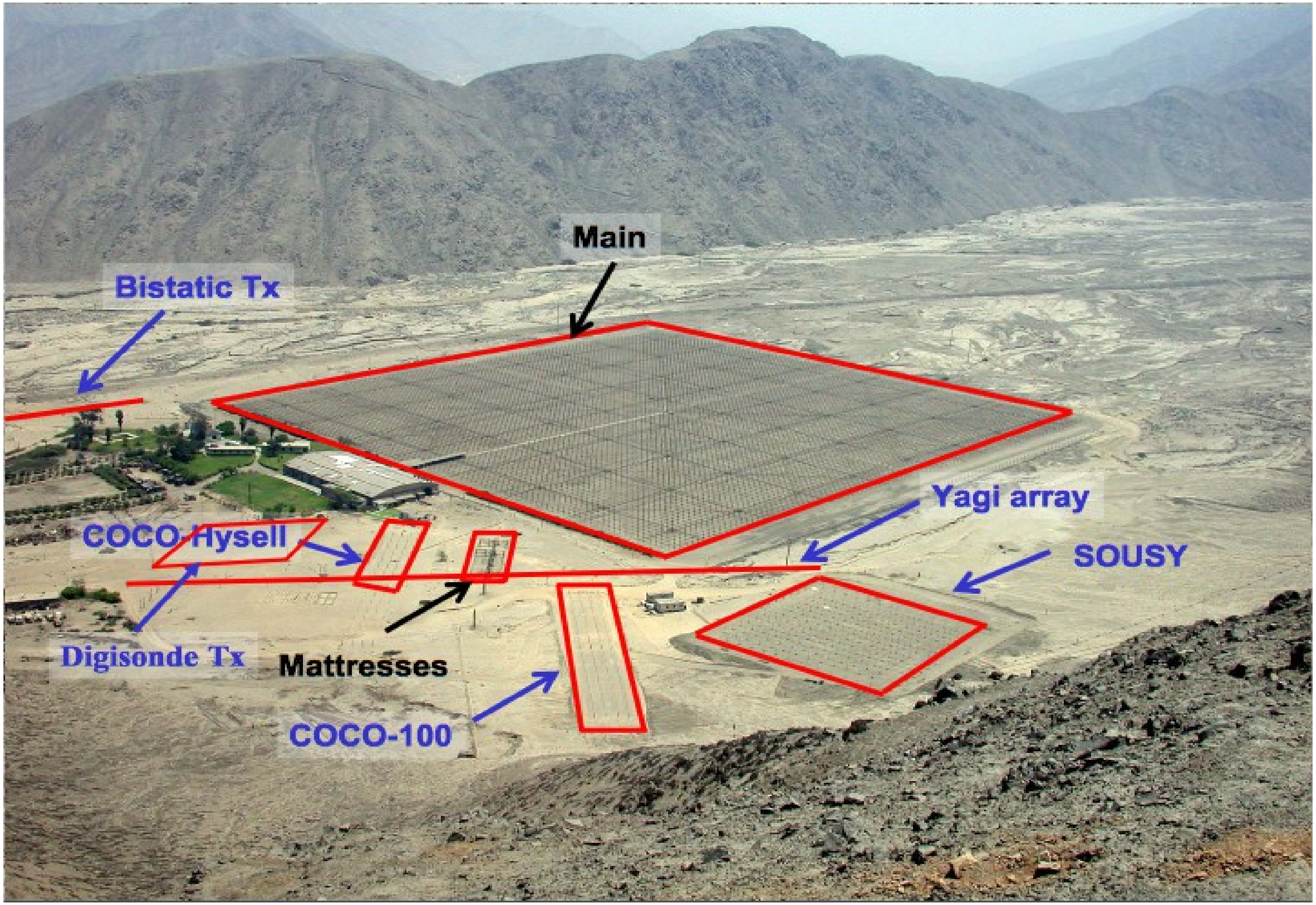


Field-of-view of the SuperDARN network of coherent radars that exist in the northern hemisphere. A similar network exists in the southern hemisphere. This system monitors the electric fields.



Distributed array of auroral imagers deployed in North America for the THEMIS MIDEX mission to provide a near-Earth image of the development of substorm.

Jicamarca antennas & radar systems



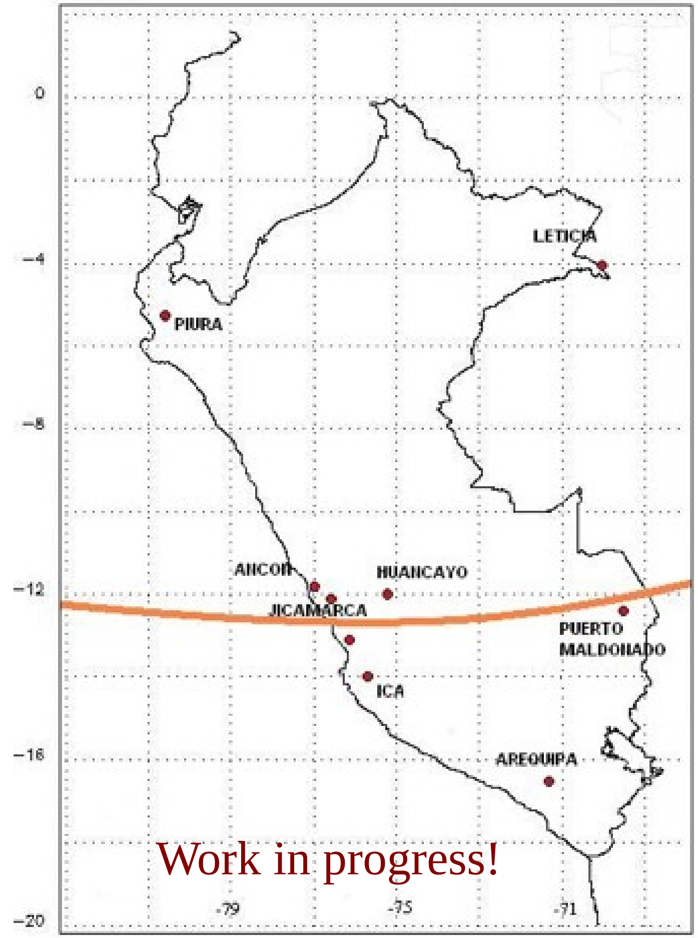
Jicamarca Optical Observatory (Since 2009)

Other Instruments near Jicamarca for Equatorial and Low-latitude Observations

- Tristatic HF Doppler Radar (G. Crowley, ASTRA)
- Beacon Rxs (P. Bernhardt, NRL)
- New VIPIR at JRO (J. Makela/E. Kudeki, UIUC)
- Mini JULIA at HYO (J. Urbina, PSU) (May 2013)
- SOFDI FPI at HYO (A. Gerrard, NJIT).

Network of magnetometers in Peru

PIURA (-5.17 –80.67)	XYZ Fluxgate (Tromso-IGP)
ANCON (-11.77 -77.14)	XYZ Fluxgate (MAGDAS) HDZ Fluxgate (Tokyo Univ.-IGP)
HUANCAYO (-12.03 -75.32)	H,D,Z Eschenhagen (DTM) HDZ Fluxgate (GRL-Tokyo-IGP) XYZ Fluxgate (ERI Tokyo) PPM (OHBM)*
JICAMARCA (-11.56 -77.03)	XYZ Fluxgate (UCLA-IGP)
CAÑETE (-13.11 -76.38)	XYZ Fluxgate (KYU Univ.) CPMN Project
ICA (-13.98 -75.77)	XYZ Fluxgate (KYU Univ.) CPMN Project
AREQUIPA (-16.46 -71.49)	H,D,Z La Cour, Photographic, (UNSA)
PTO. MADONADO (-12.58 –69.18)	XYZ Fluxgate (LISN – IGP)

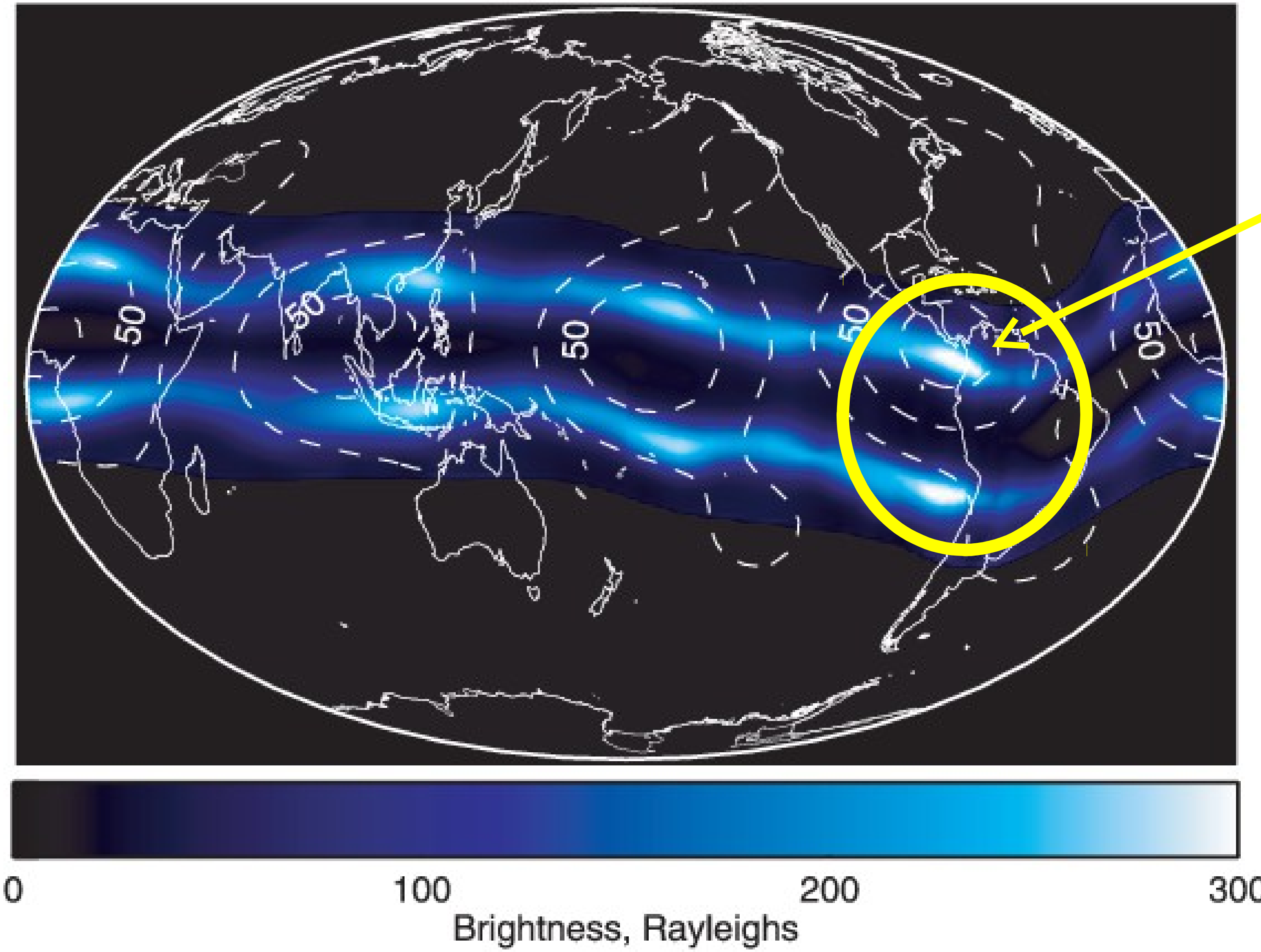


http://jro.igp.gob.pe/database/magnetometer/html/magdata.htm

JRO & Cluster of instruments

Instrument	Parameter	Region	Time Coverage	Annual Coverage	Regional Coverage
ISR	Ne, Te, Ti, Vz, Vx, %	Ionosphere	24h	1000 hours	JRO
MST	U,V,W	Troposphere, Stratosphere, Mesosphere	24h (T,S) Daytime (M)	> 10 days	JRO
JULIA	Irregularity intensity, Vz, Vx	Ionosphere	24h	4000 hours	JRO
JULIA-150	Vz	Ionosphere	Daytime	150 days	JRO
FPI (AQP, SOFDI, MRH)	U,V, Tn	Bottom F region	Nighttime Daytime (SOFDI)	> 100 days	Peru
Magnetometers (JRO, LISN)	Vz	Ionosphere	Daytime	365 days	77o, 75o, 69o, 56o West
LISN GPS	TEC, scintillations	Ionosphere	24h	365 days	South America
Ionosondes (JRO, LISN)	TEC, scintillations	Ionosphere	24h	365 days	77oW, 69oW
JASMET-Meteors	U, V	Mesosphere	24h	Campaigns	JRO, Piura, HYO (*)

Immel et al., GRL, 2006

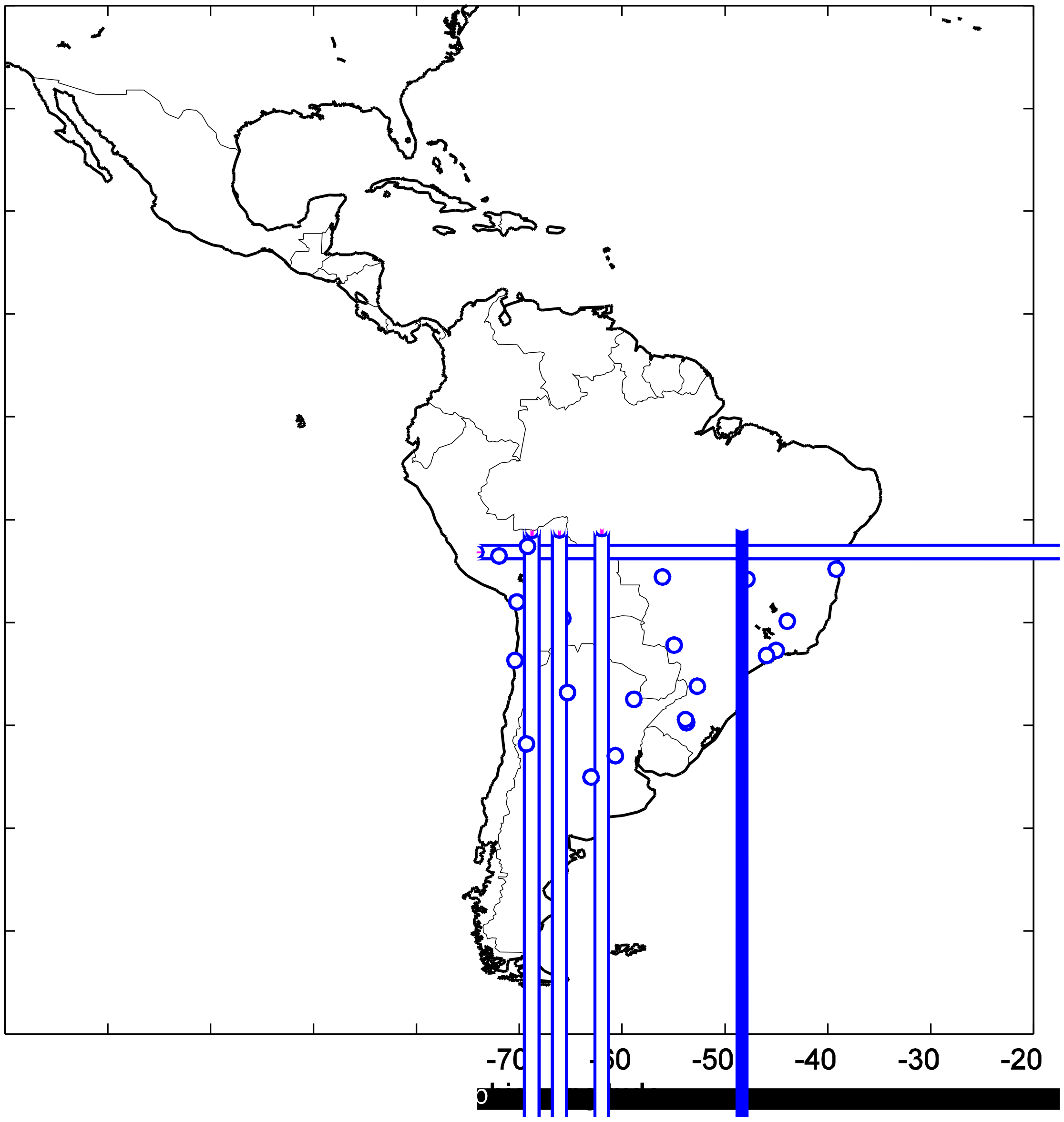


Node of 4-cell pattern seen on the western side of South America

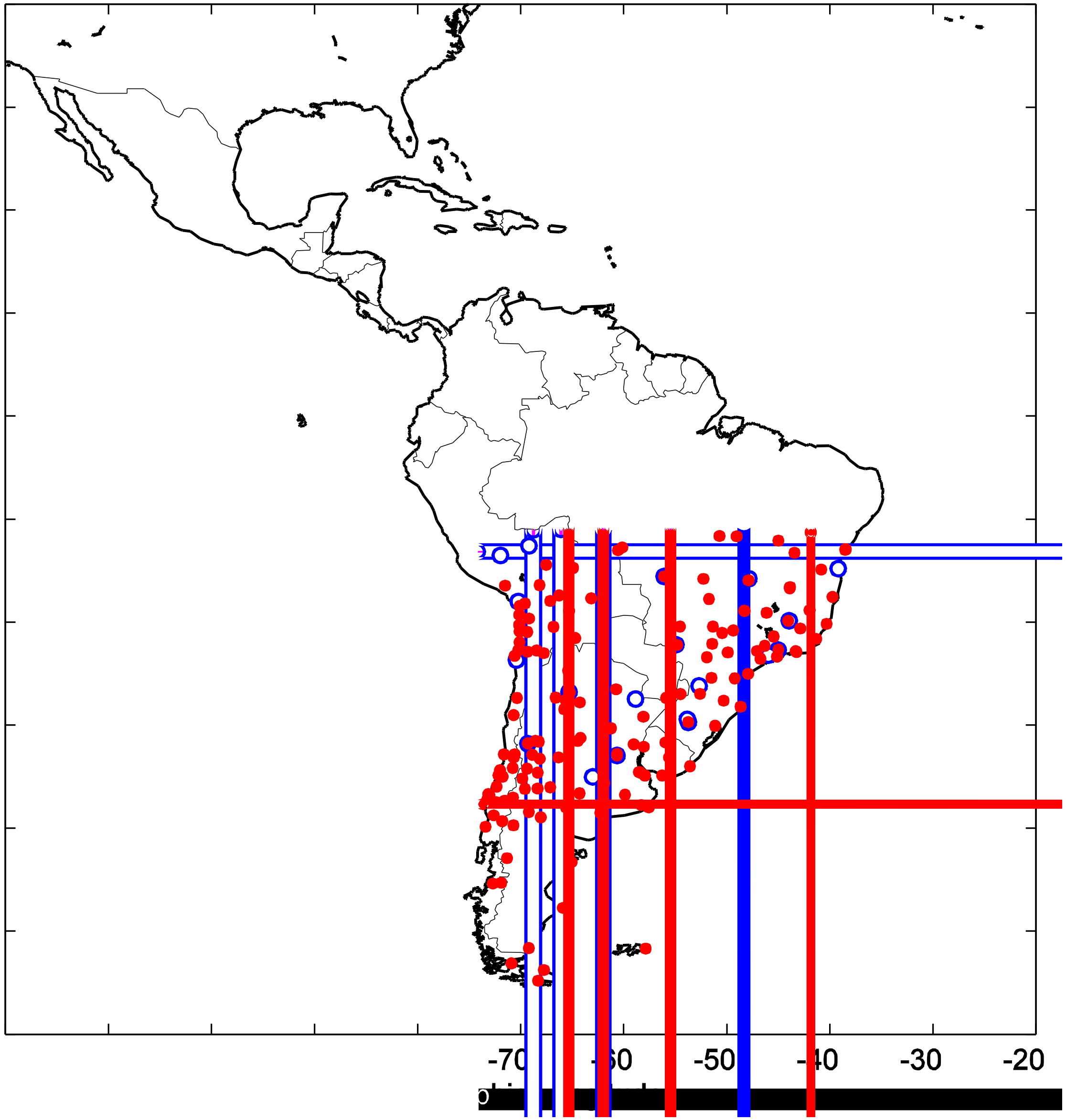
The Low-latitude Ionospheric Sensor network (LISN)

1. The instruments were selected to study I-T coupling and the electrodynamics of the low-latitude ionosphere, ESF, etc…
2. It consists of 47 dual-frequency GPS receivers to measure TEC, S4 scintillation index, TIDs, and TEC depletions, 5 tri-axis magnetometers that provide daytime electric fields, , and 2 VIPIR ionosondes that observed bottomside density profiles, drifts, ESF, TIDs and density gradients using interferometry.
3. Provide a nowcast of TEC, S4 index, and other derived parameters.
4. The network is expandable and all instruments are easy to relocate.
5. It operates continuously, but able to do campaigns.
6. It will be equipped with real-time assimilation tools to conduct forecasting of the low-latitude ionosphere.
7. The success of the project depends of the human network as many instruments are installed in small cities.

LISN GPS Stations

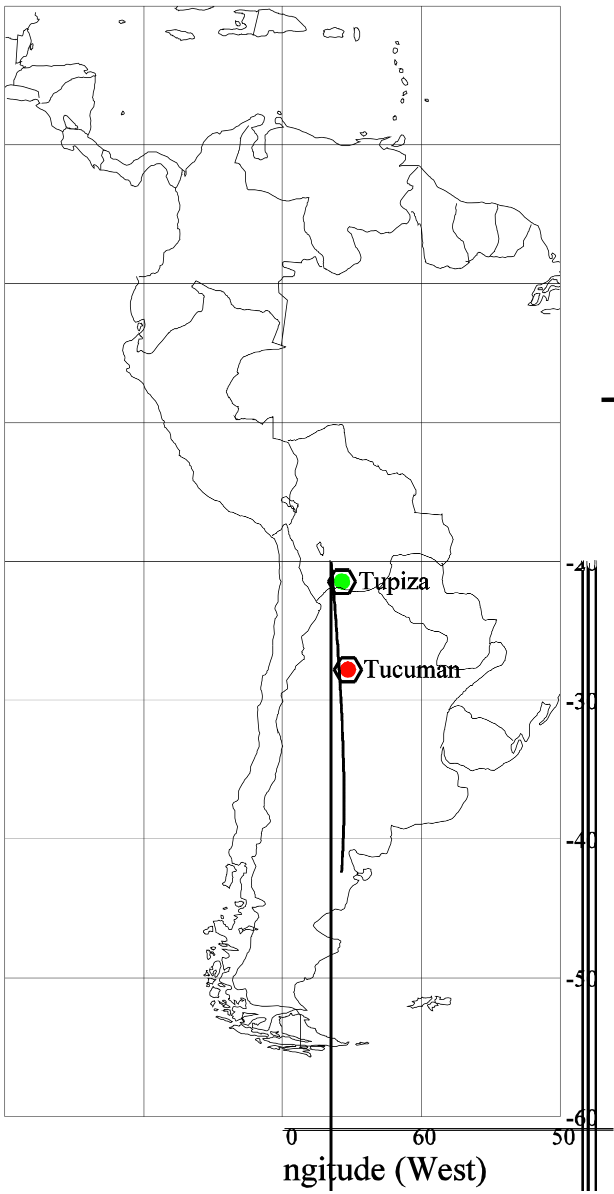


LISN and other GPS Stations in South and Central Americas

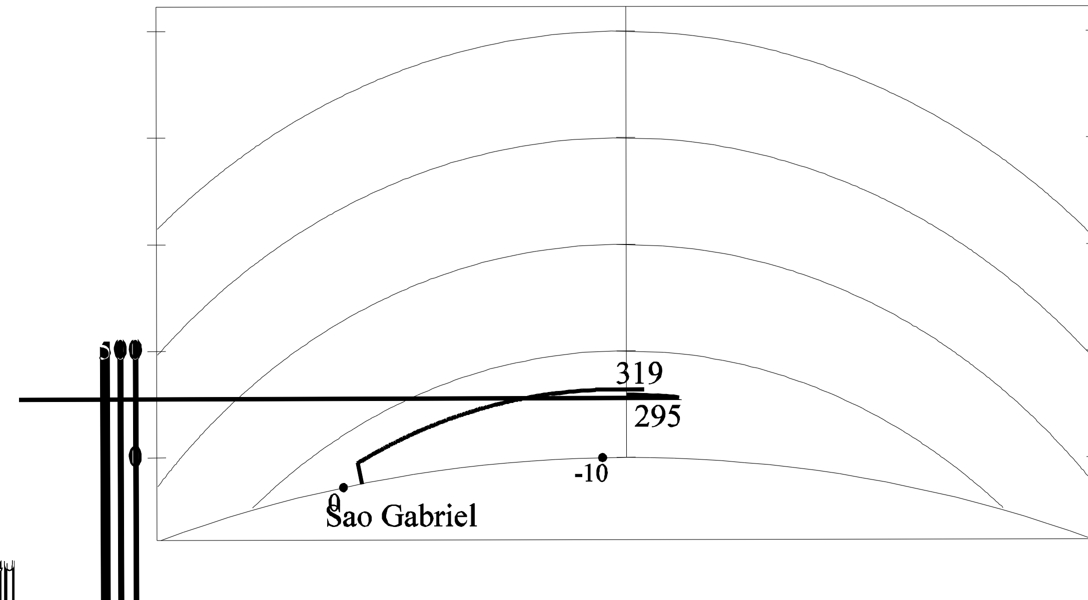


4 Magnetometer Baselines in SA; LISN (Green) and Others (blue)

SA Ionosondes (partial)

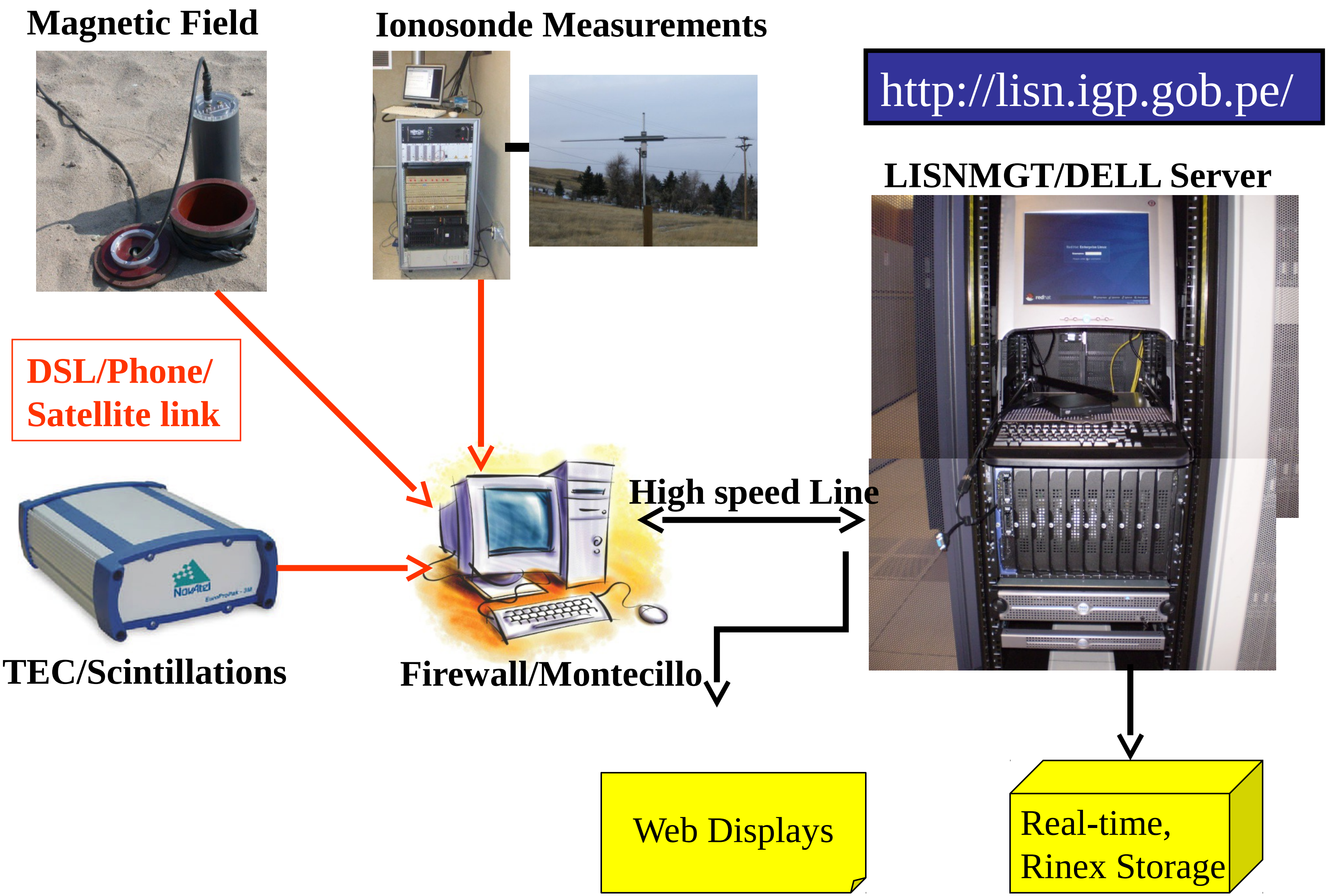


E Region and ESF



The field lines that intersect the E region over the cities of Sao Gabriel, Brazil and Tupiza, Bolivia map to between 295 – 320 km at the magnetic equator. We will be able to investigate: (1) role of Es layers on development of ESF. (2) role of equatorial and off-equatorial E region to balance pre-reversal currents.

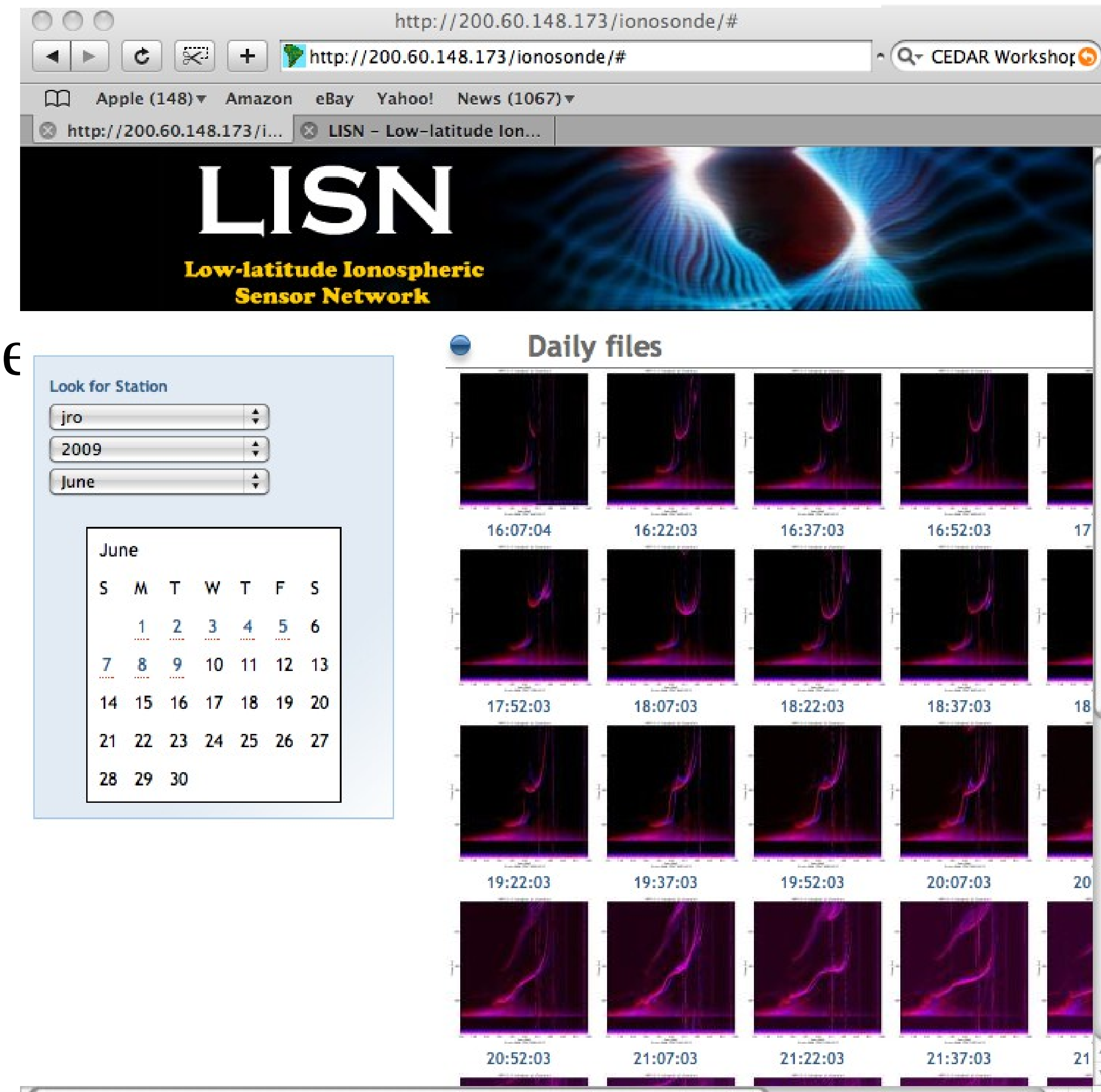
LISN - Data Flow Diagram



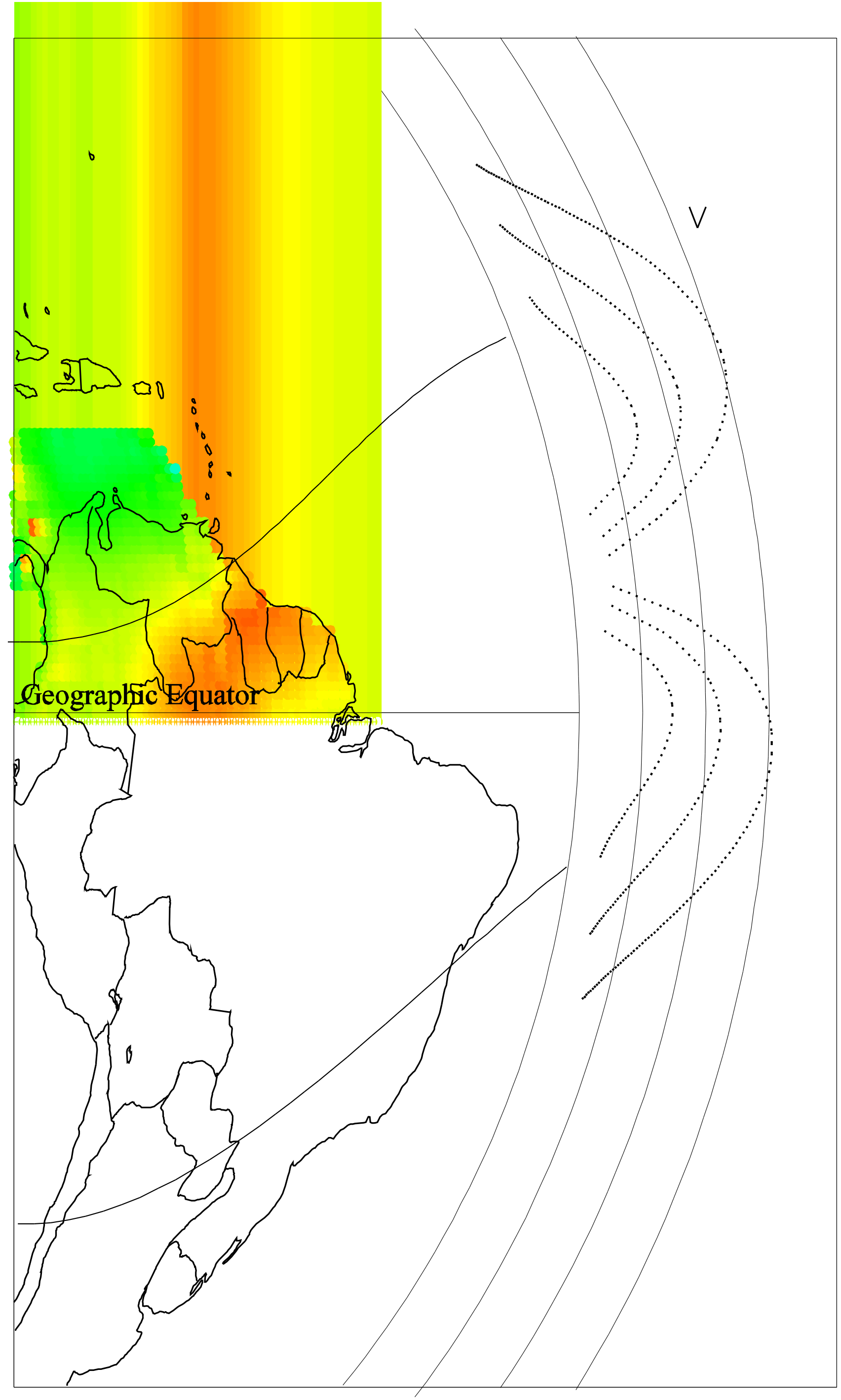
LISN VIPIR Database

http://lisn.igp.gob.pe/ionosonde

- Daily files
  - NCDF
  - IDL SAVE fil
- On-line plots
  - Power ionograms (O and X modes)

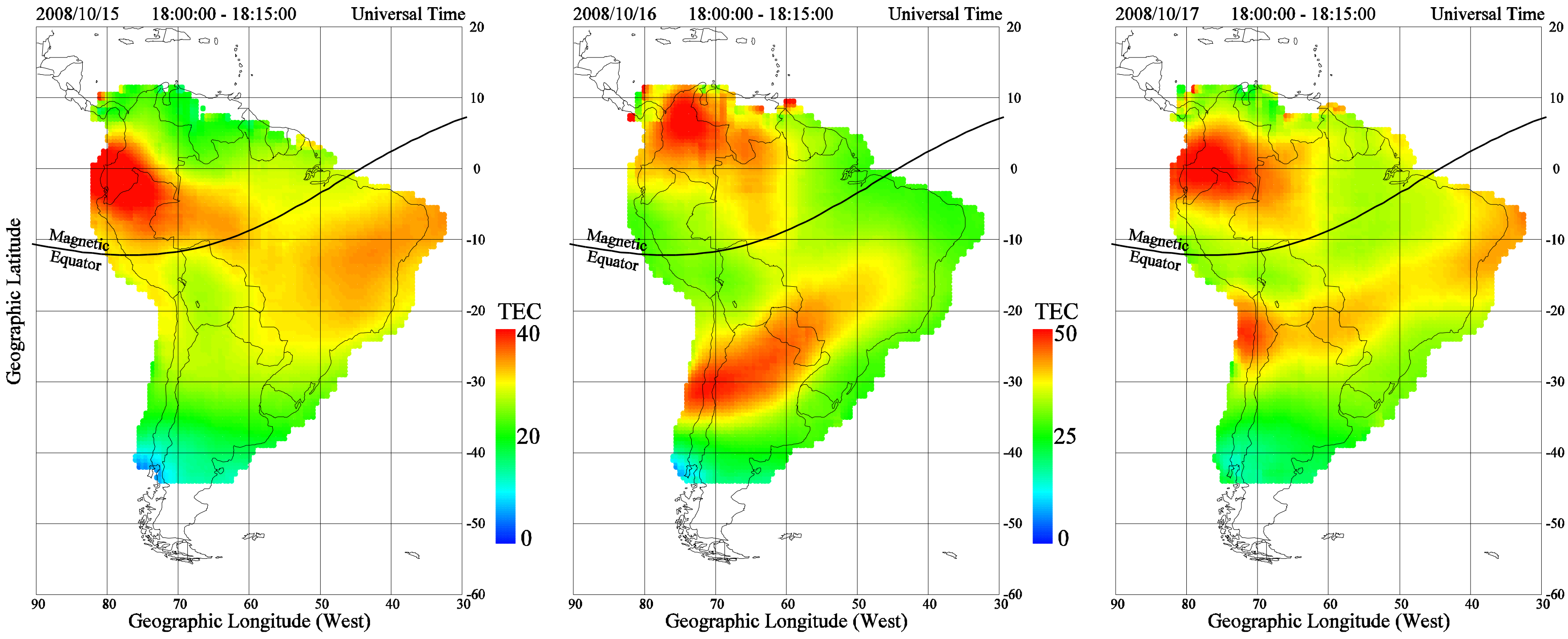


The combination of upward, daytime ExB drift velocity perpendicular to B and downward diffusion parallel to B by gravity and pressure gradient forces create crests in ionization at +/- 15 to 20 degrees magnetic latitude known as the equatorial anomaly. If the daytime, ExB drift velocities are significantly lower or are absent, then the crests in ionization are significantly closer to the magnetic equator or are absent



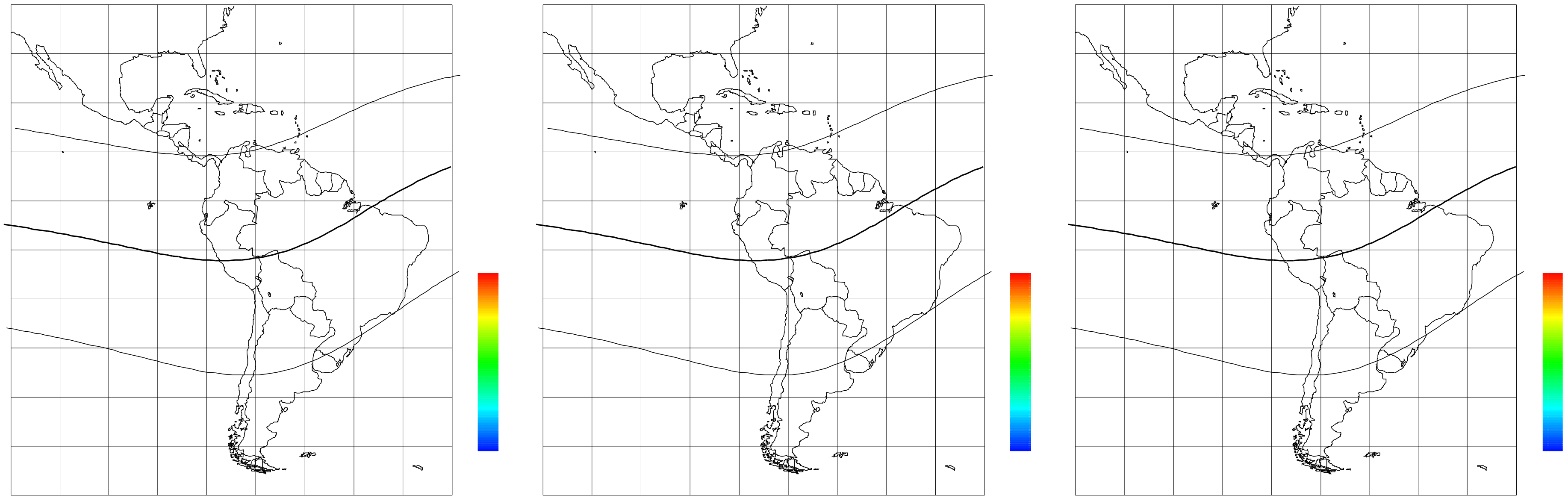
TEC variability

TEC values observed on 3 consecutive days (Oct 15-17, 2008) at same local time (2 PM at 60° W)

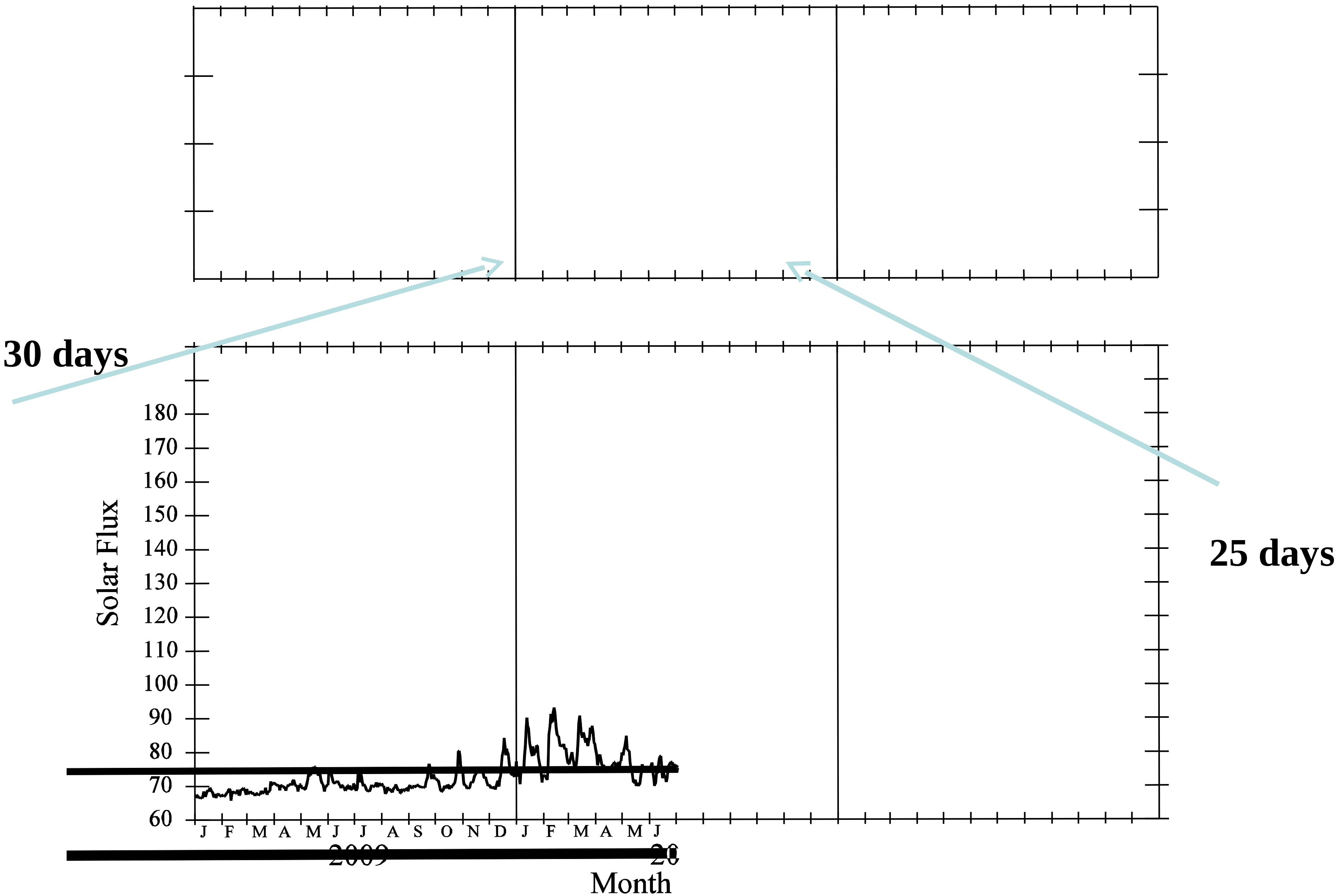


More on TEC variability

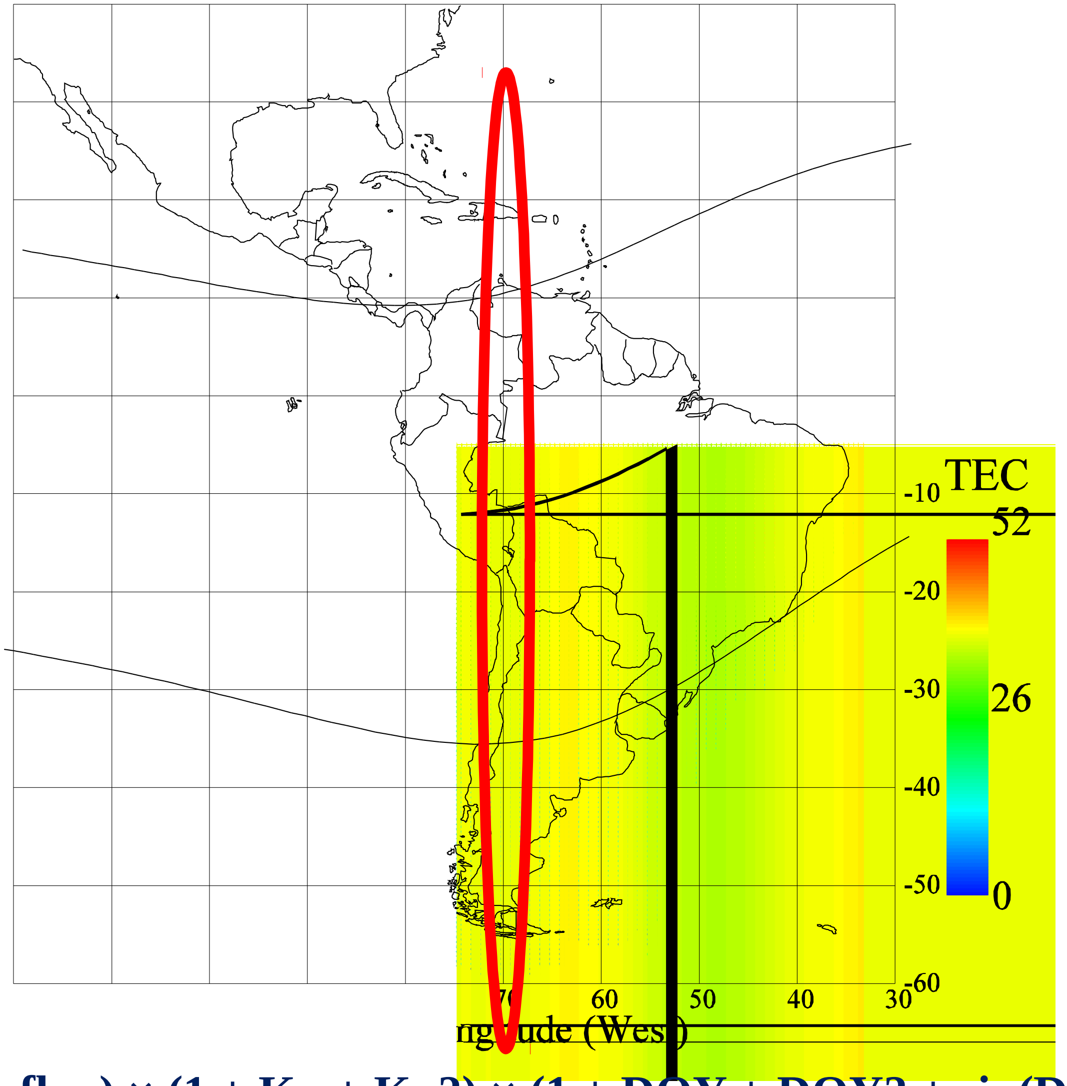
TEC values observed on 3 consecutive days (Dec 24-26, 2011) at ~ 1 PM local time



Individually Normalized Spectra

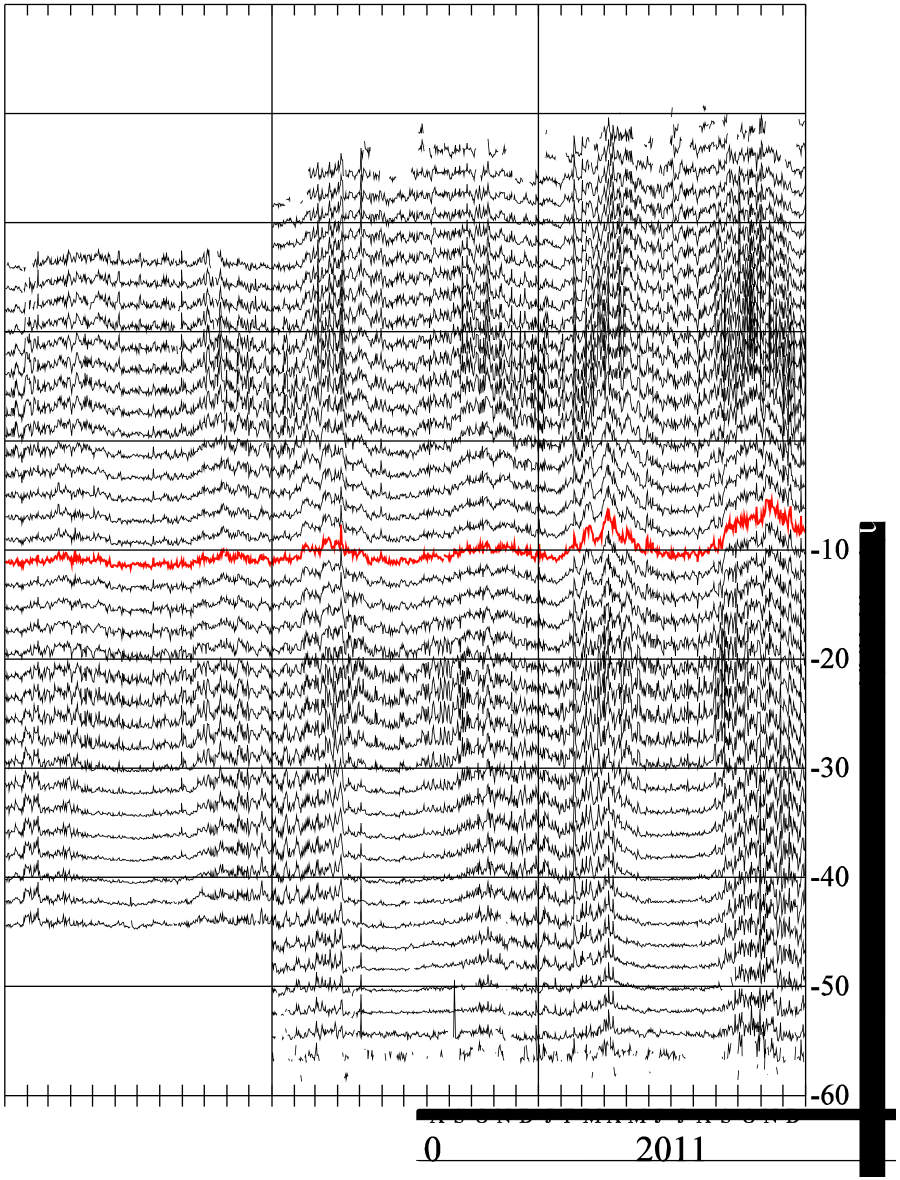


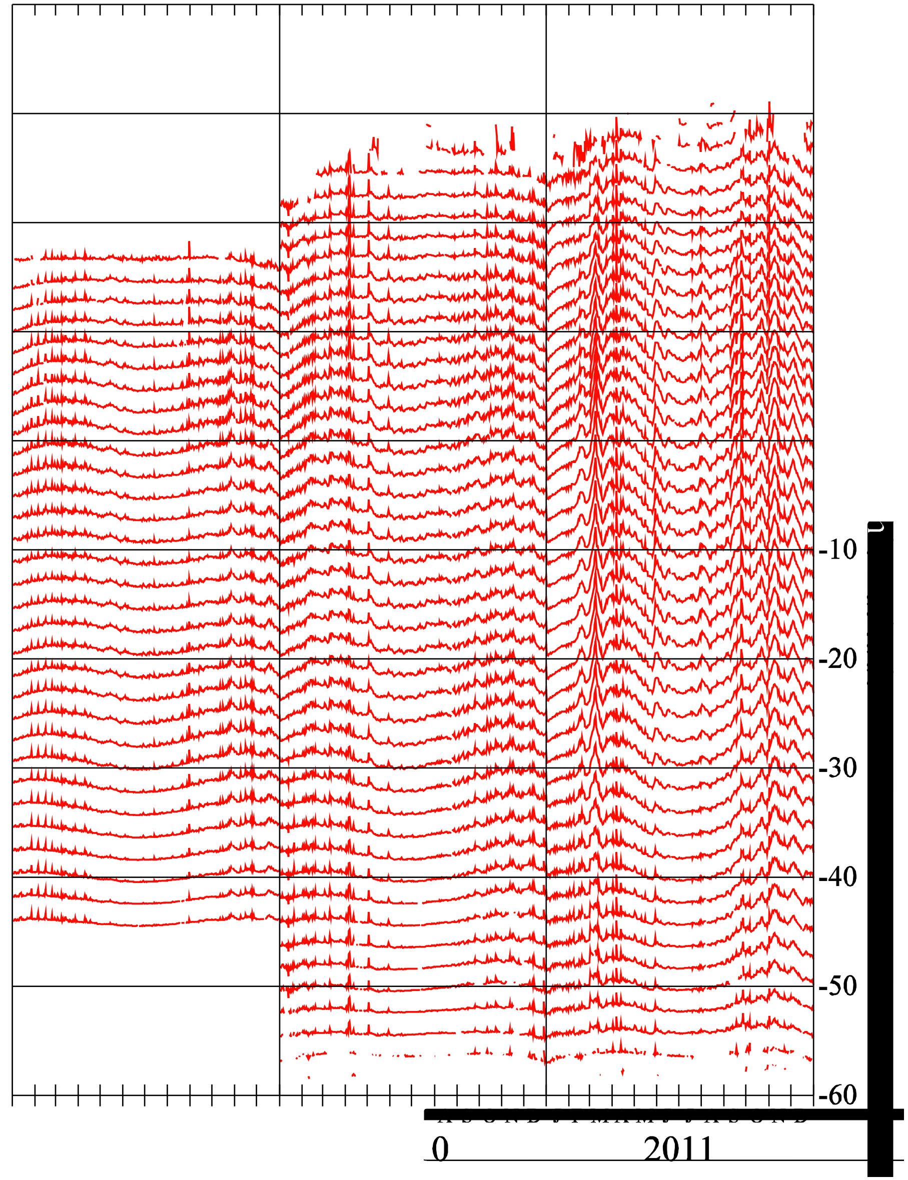
Numerical fitting for each Pixel of the plot and each 30 min interval



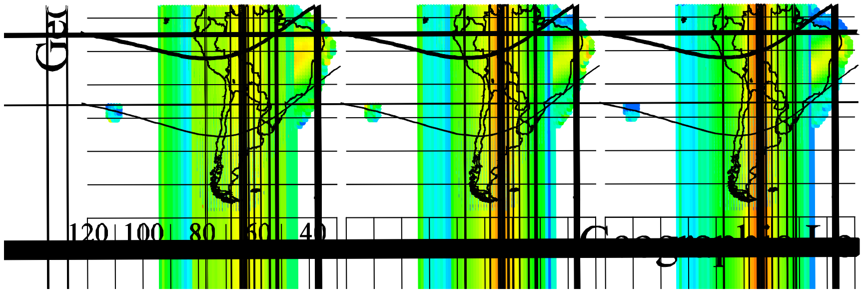
TEC = (1 + solar flux) × (1 + Kp + Kp2) × (1 + DOY + DOY2 + sin(DOY) + cos(DOY))

Measured and Fitted values fro longitude = 69 W and 17 UT





Empirical Model of TEC for Kp = 2o, solar flux = 145 units and December 21



Projects to be conducted with VIPIR ionosondes

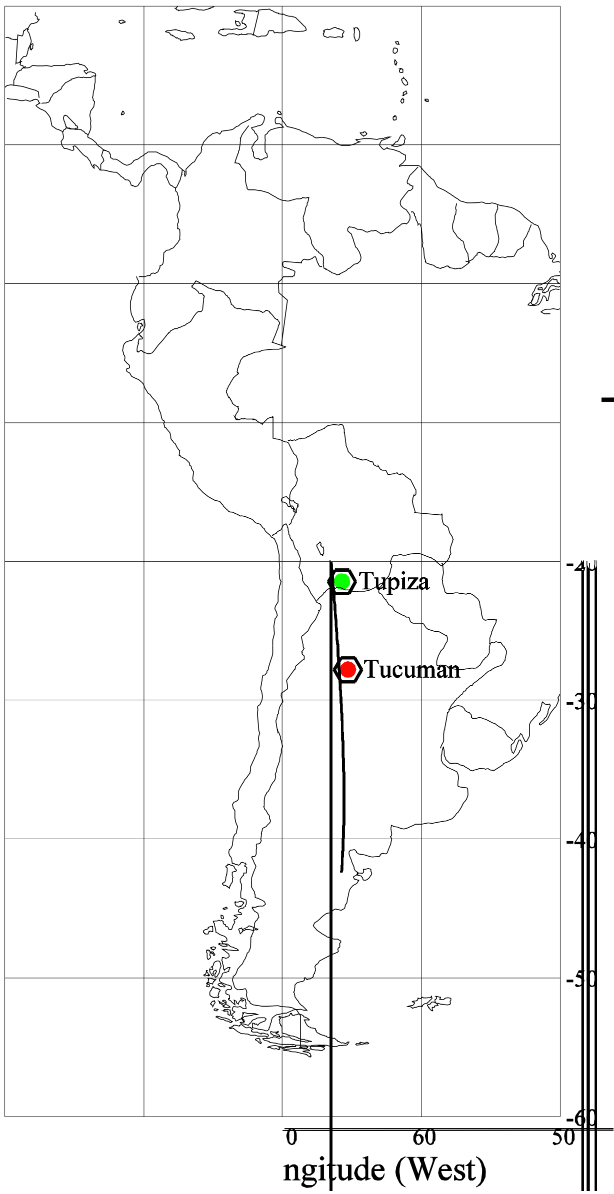
To use VIPIR measurements of E and Es layers provided by two ionosondes placed at nearly conjugate locations, ~11-12° on both sides of the magnetic equator, and to study the role of Es layers on the onset and dynamics of ESF.

To calculate the value of the meridional winds using the LISN ionosondes and compare these values with measurements conducted in South America using Fabry-Perot interferometers and other techniques.

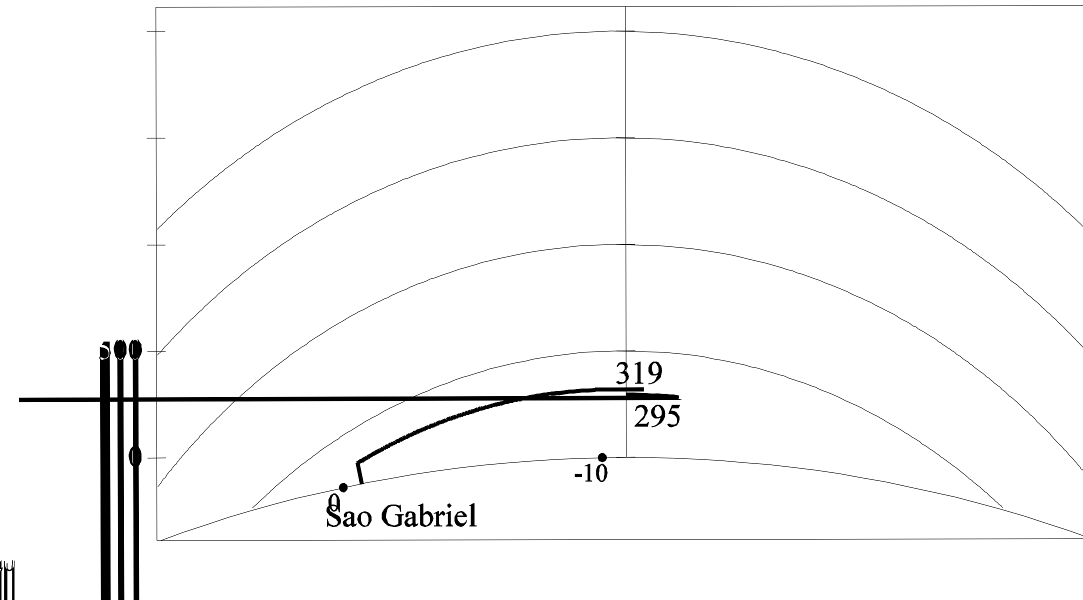
To use data from GPSs and VIPIRs and numerical techniques to calculate plasma density profiles along the LISN meridian (~67° W).

Compare Fof2 values from P. Maldonado at the magnetic equator and Jicamarca also at the mag. eq, but separated by 800 km to observe longitudinal variability.

SA Ionosondes (partial)



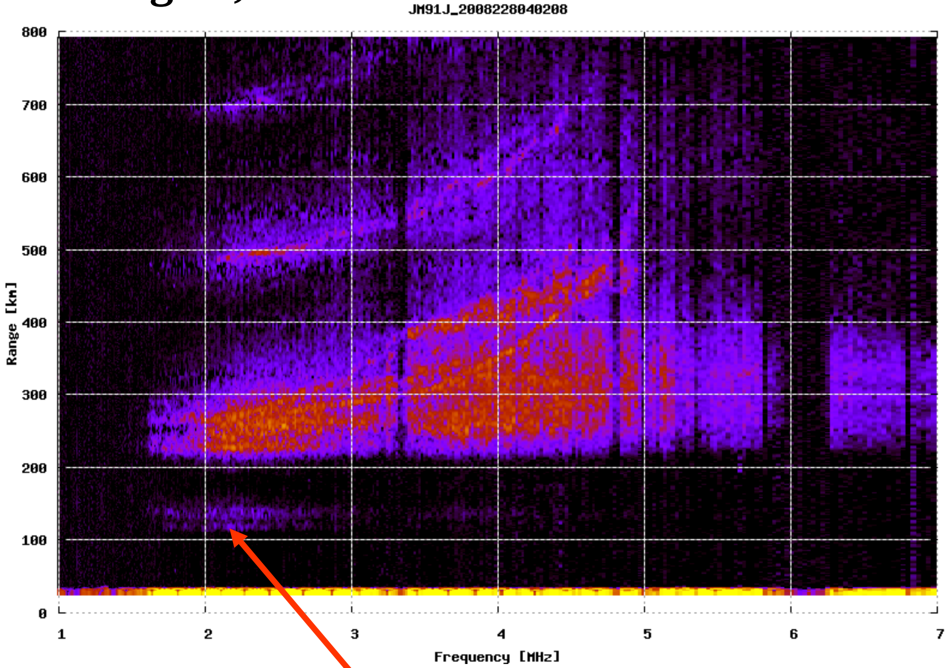
E Region and ESF

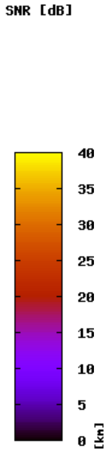


The field lines that intersect the E region over the cities of Sao Gabriel, Brazil and Tupiza, Bolivia map to between 295 – 320 km at the magnetic equator. We will be able to investigate: (1) role of Es layers on development of ESF. (2) role of equatorial and off-equatorial E region to balance pre-reversal currents.

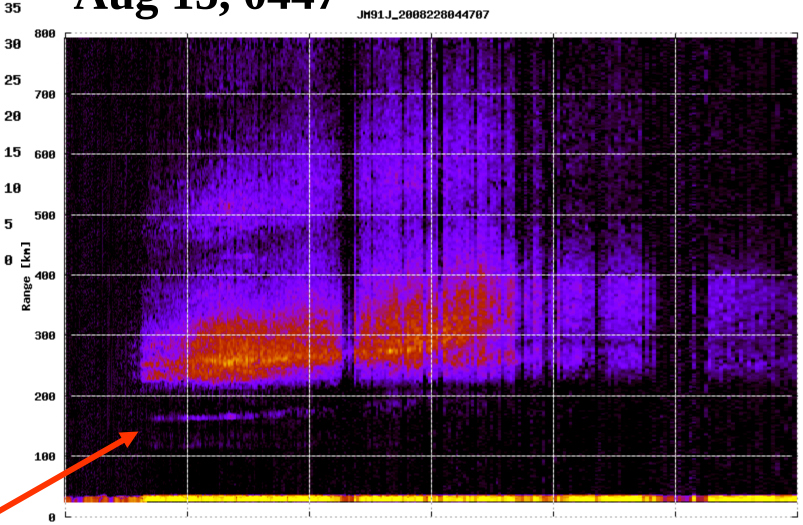
Capabilities of the VIPIR ionosondes

Aug 15, 0402



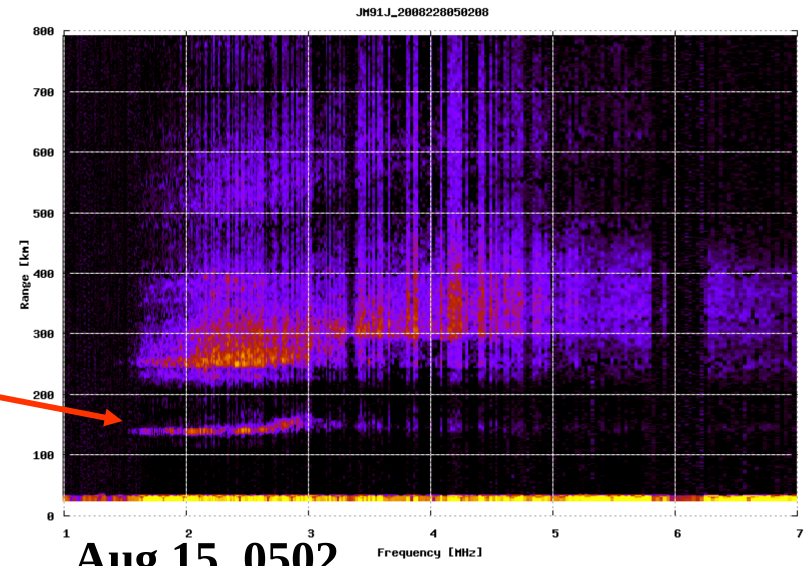


Aug 15, 0447



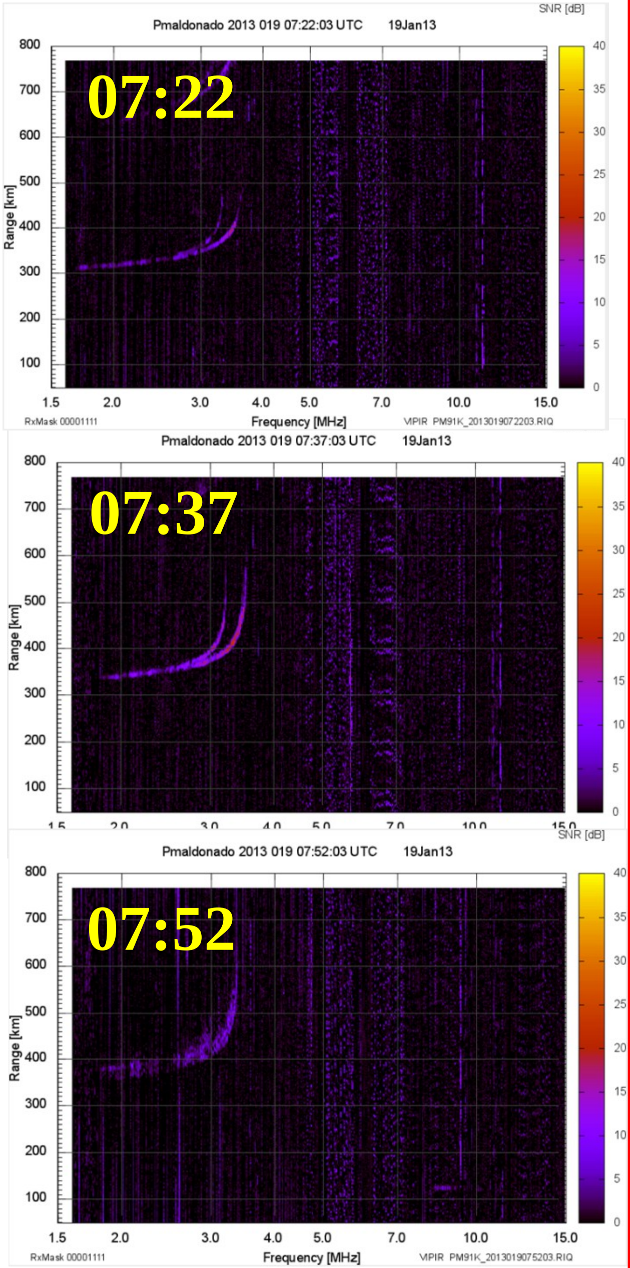
Double Es layer

Descending Es layer

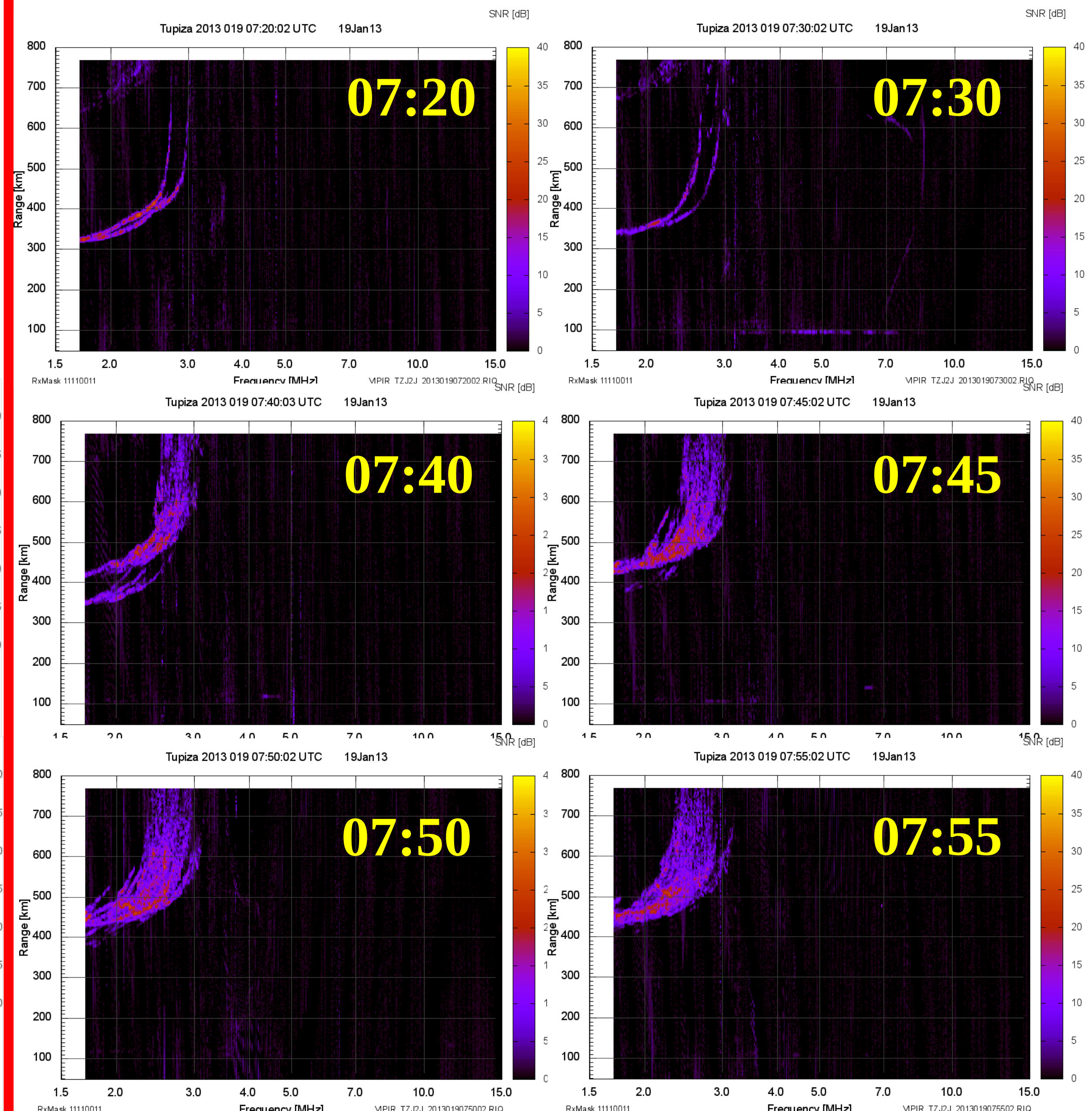


Aug 15, 0502

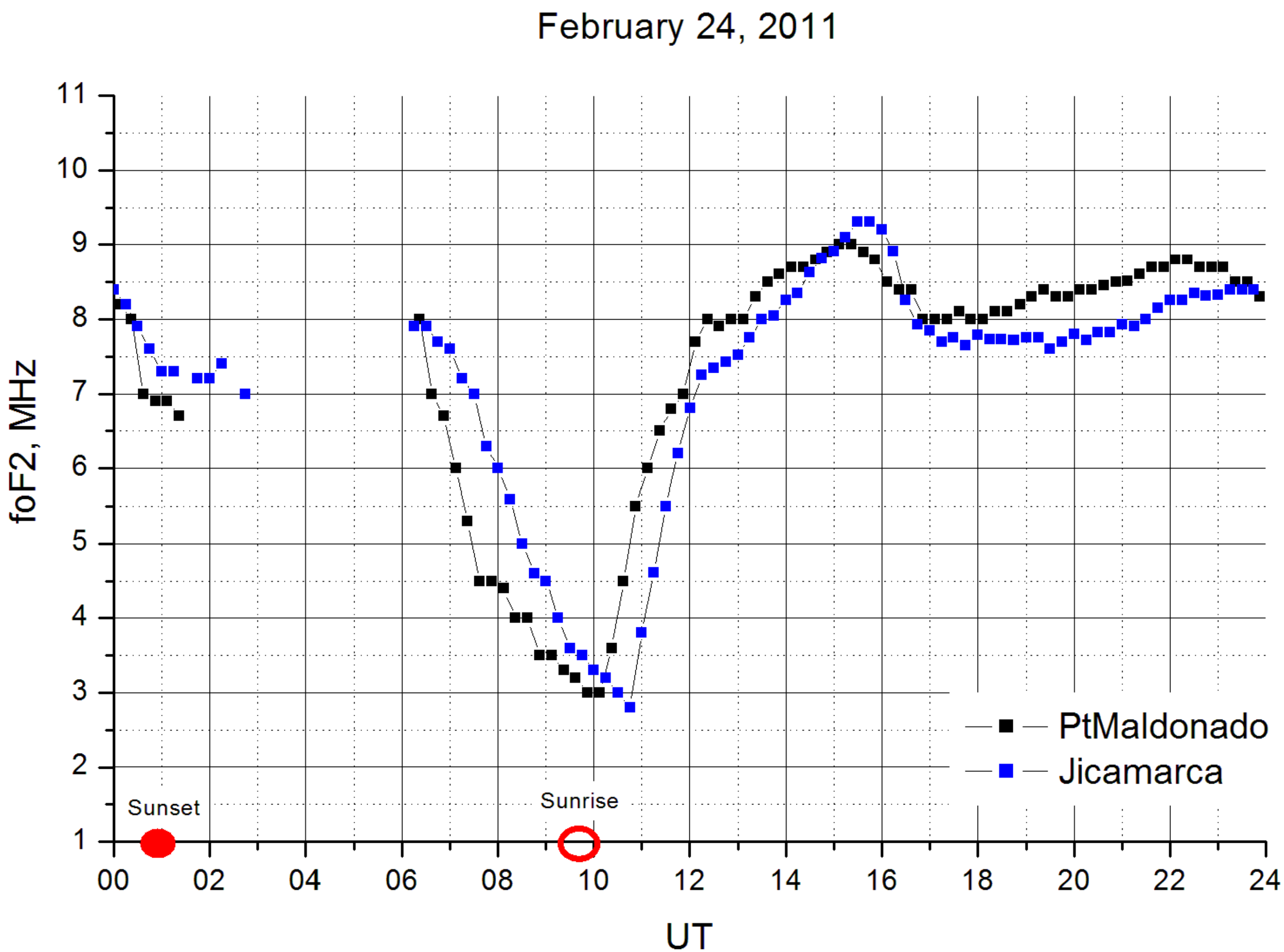
P Maldonado, Peru



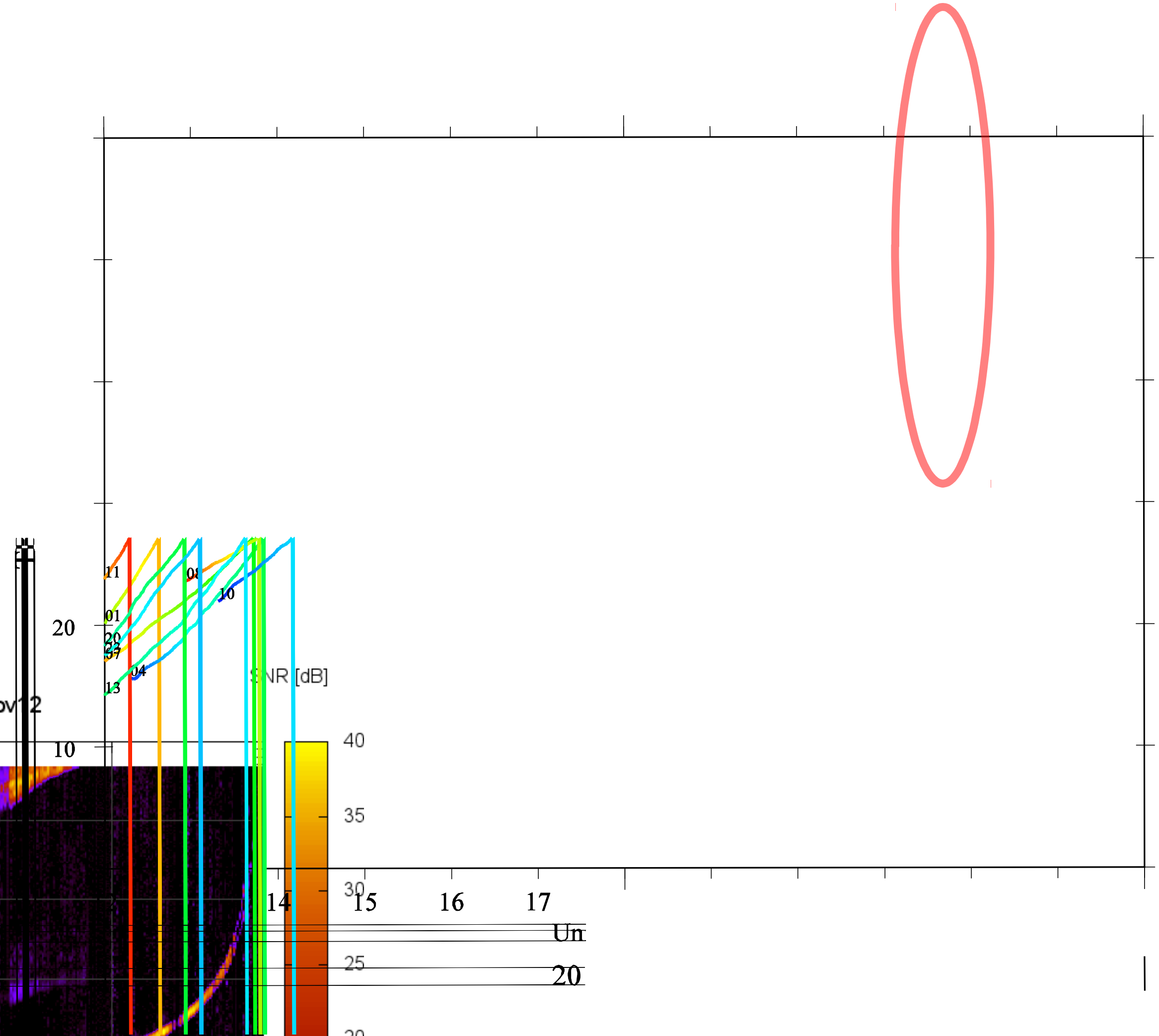
Tupiza, Bolivia – Jan 19, 2013

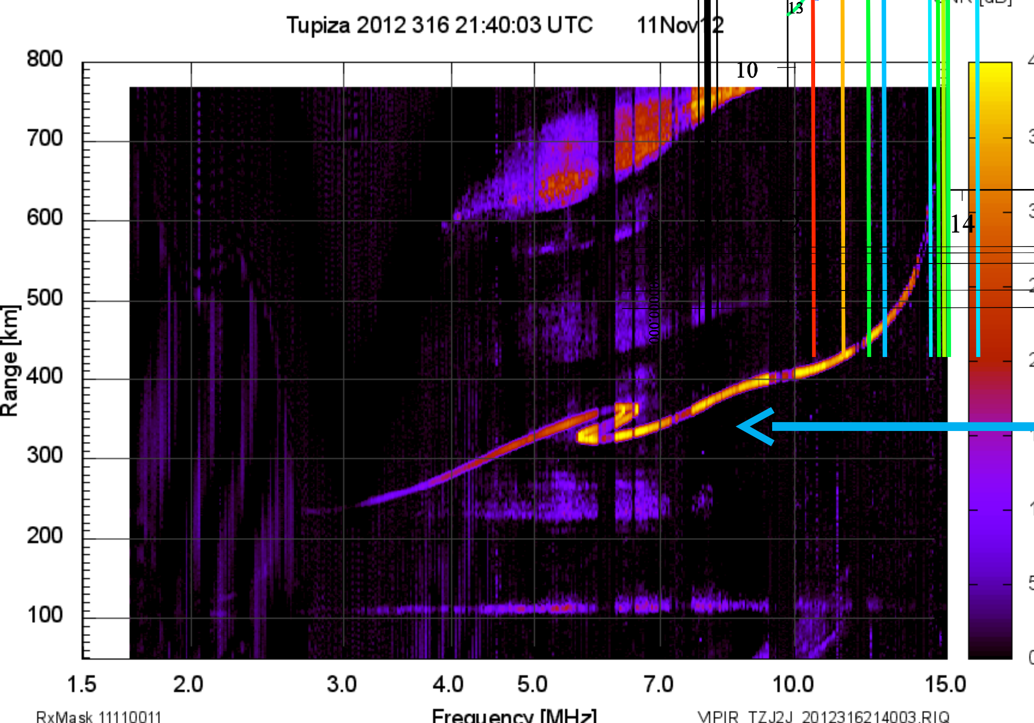


Jicamarca - Pto. Maldonado foF2 comparison



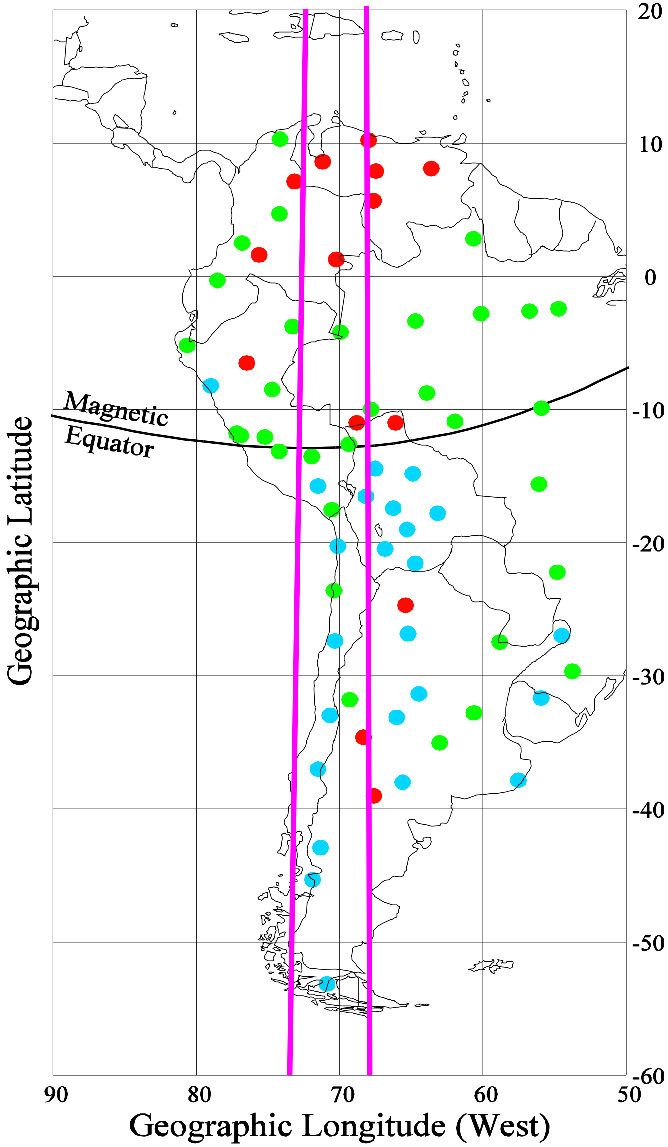
TEC perturbations associated with TIDs seen at the same time.



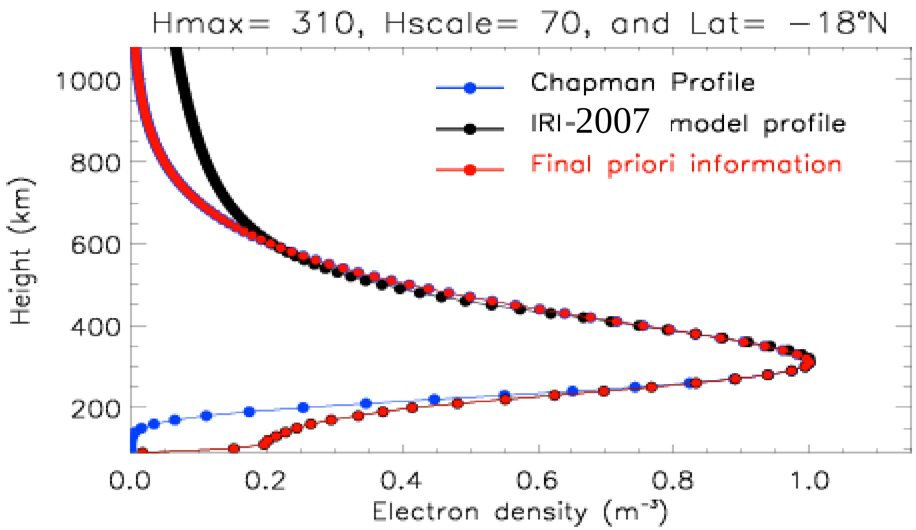


Due to passage of GW over field-of-view of VIPIR ionosonde.

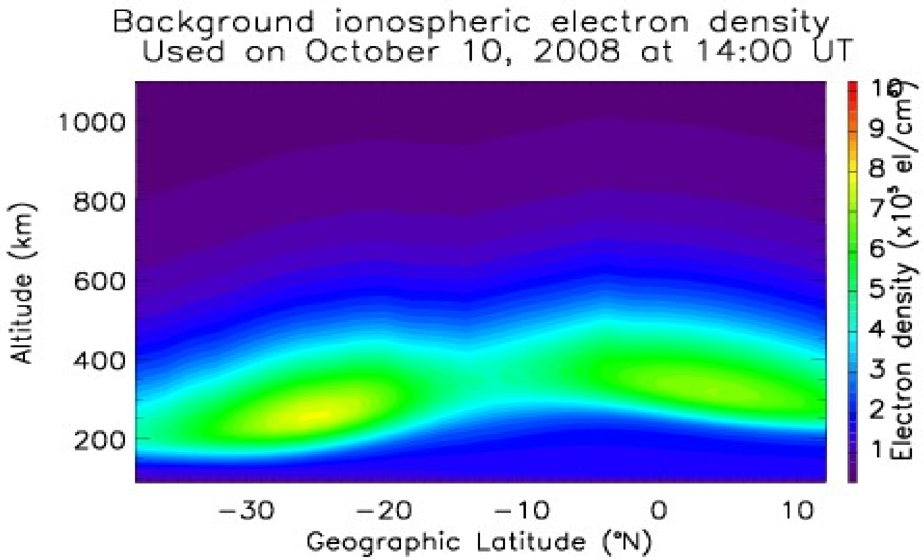
Ionospheric Tomography



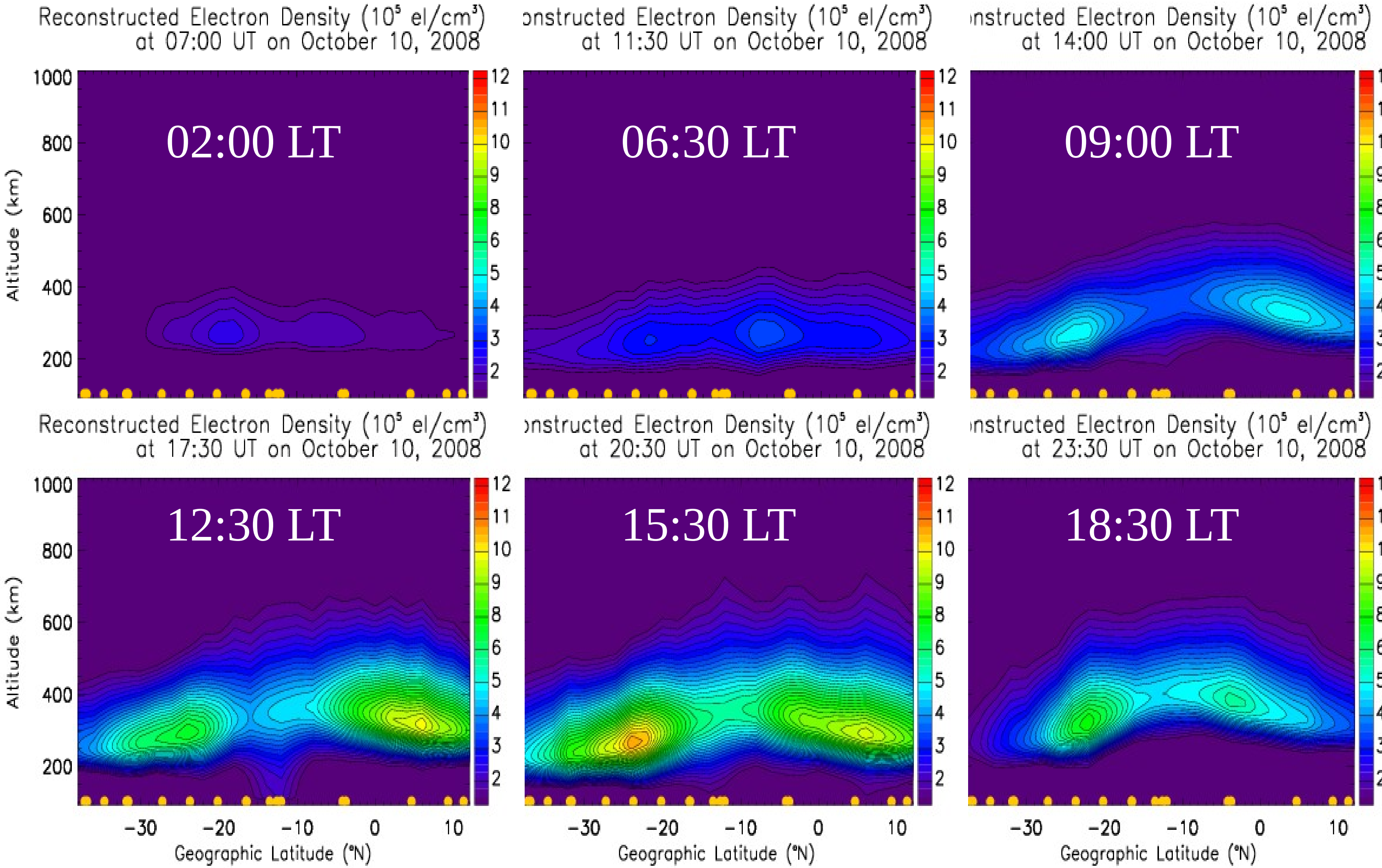
Harmonic background profiles



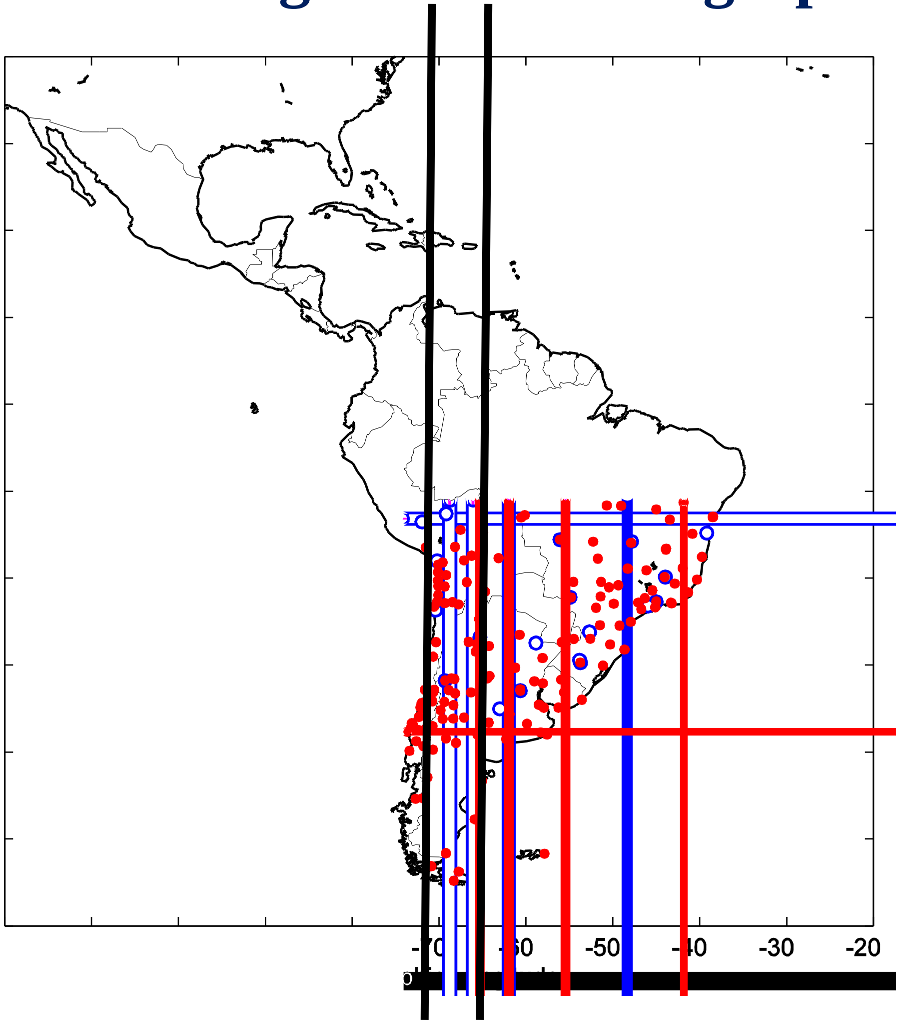
Background profiles

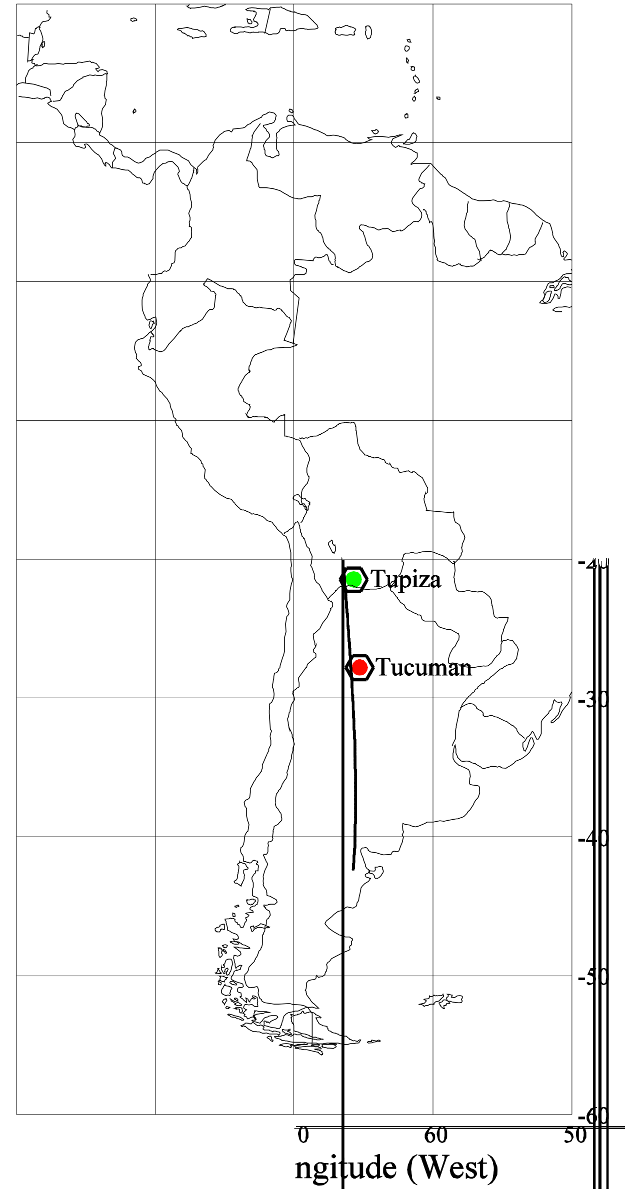


Tomographically Reconstructed Density Profiles



Regularized Tomographic Reconstruction



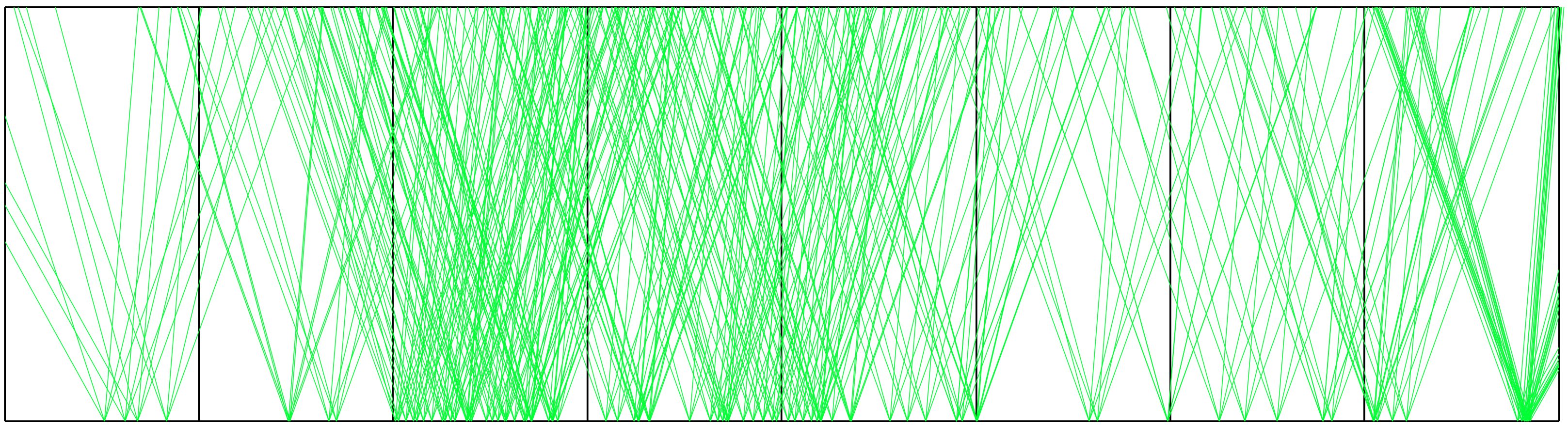


$$J(\mathbf{x}) = \|\mathbf{y} - \mathbf{H}\mathbf{x}\|_2^2 + \alpha_1 \|\mathbf{D}_1 \mathbf{x}\|_p^p + \alpha_2 \|\mathbf{D}_2(\mathbf{x} - \mathbf{x}_0)\|_p^p,$$

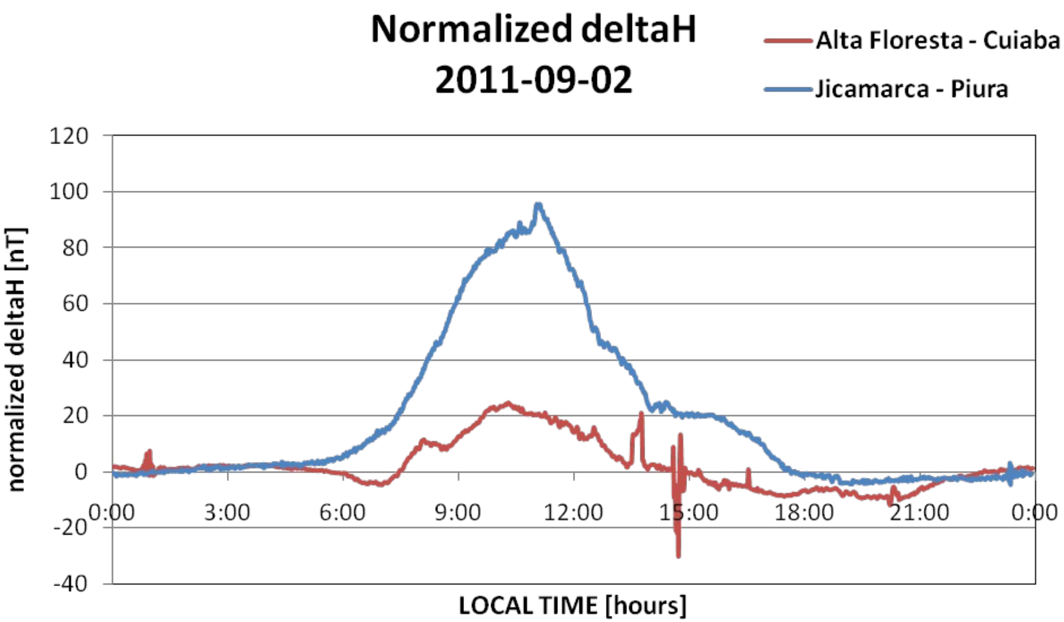
Cost function that includes two penalty terms in the horizontal and vertical directions, where D1 and D2 are the regularization matrices, and p = 2.

More on tomography

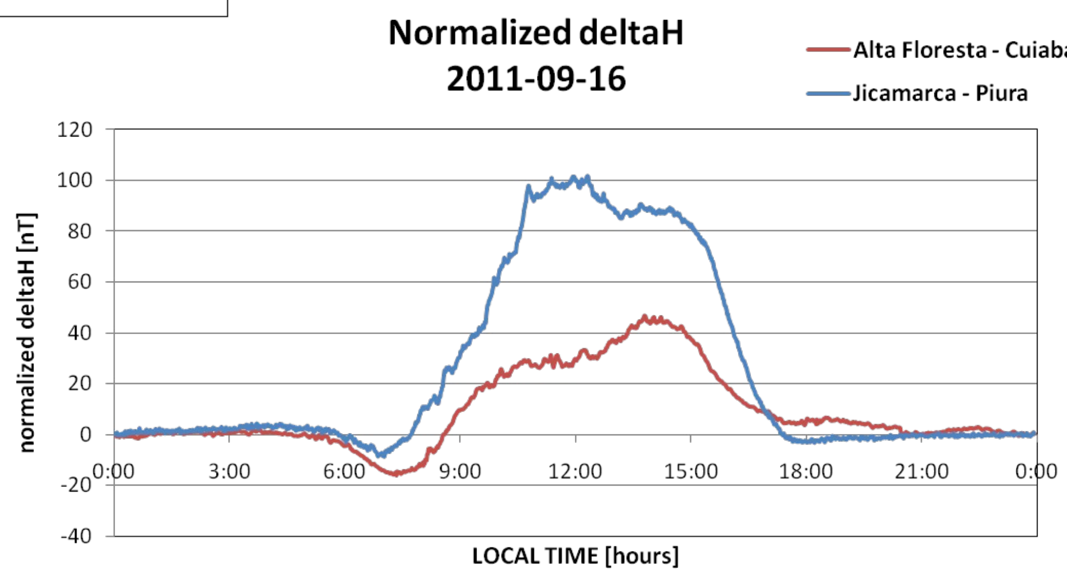
We will use TEC values measured by 95 GPS receivers that are operating between 72° W and 65° W longitude and 2 VIPIR ionosondes that measure density profiles with a 5 min cadence time. The bottom line of Figure 5 shows the geographic location of the GPS receivers and the upper edge of the Figure indicates the latitude of the VIPIR ionosonde locations.



Delta H Comparisons Between Jicamarca and Alta Floresta Longitude Sectors for September 2 and 16



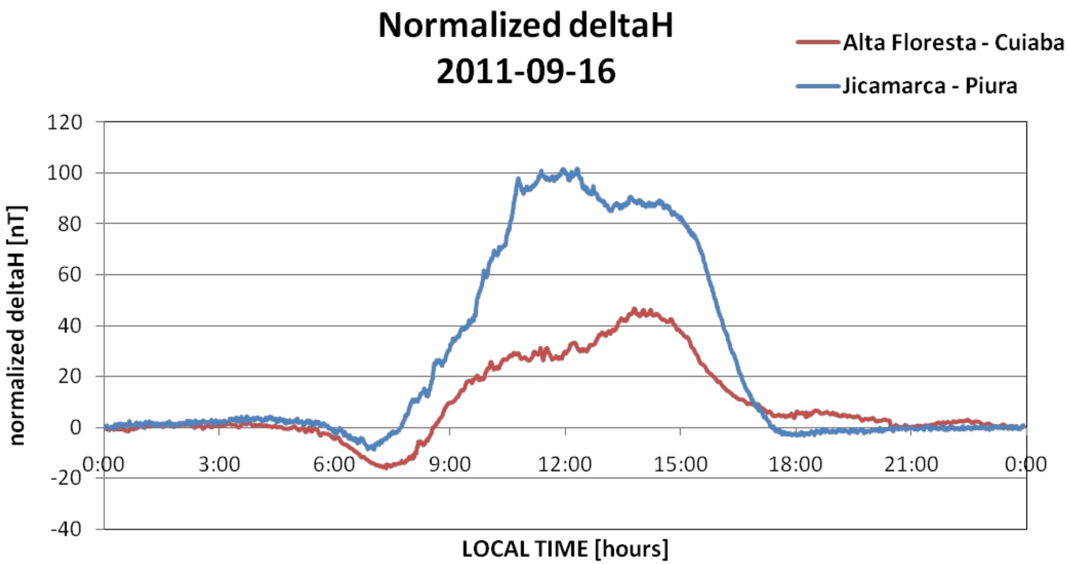
Assuming an ExB vs delta H linear slope of 0.31 m/sec/nT, the peak ExB drift velocity for Jicamarca-Piura is ~ 28 m/sec and for Alta Floresta-Cuiaba is ~6.5 m/sec.

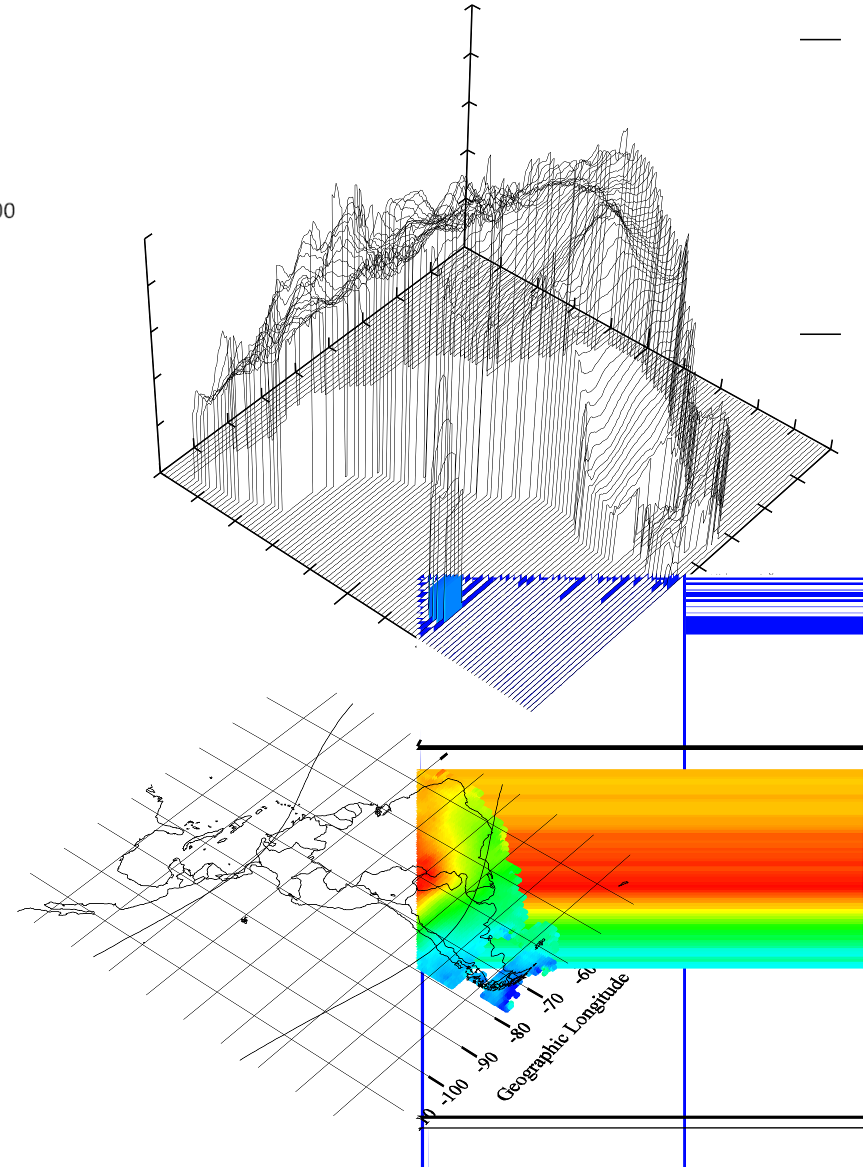


On September 16, the peak ExB drift velocity is ~ 31 m/sec in the Jicamarca longitude sector and ~ 13 m/sec in the Alta Floresta longitude sector.

Provided by D. Anderson

Comparison of E×B drifts and TEC values over South America





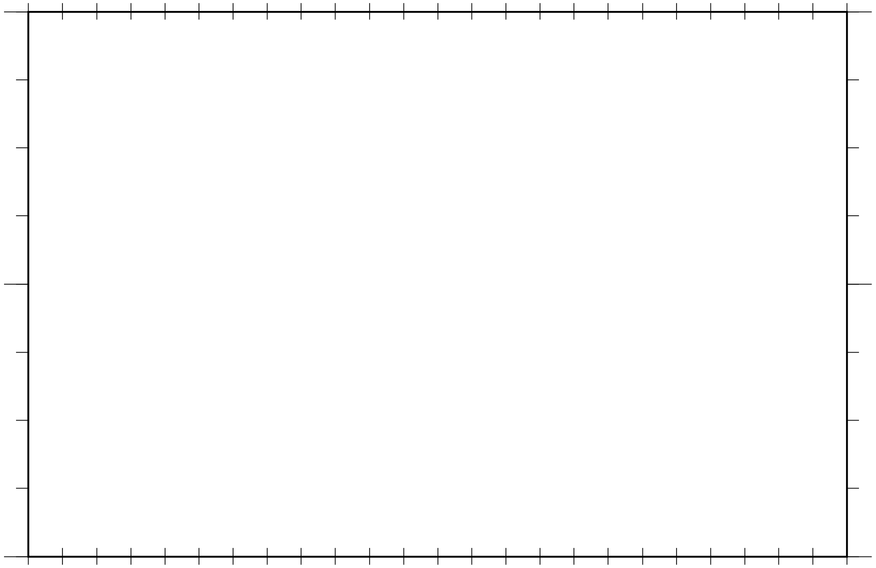
Physics-Based Model-data Inversion for the LISN region (V. Eccles)

- A physics-based, self-consistent model of the ionosphere is combined with data from the Low-latitude Sensor Network (LISN) to discern the neutral winds and tides. These winds are input to a model of the electrodynamics to generate the electric fields.
  - LLIONS low-latitude ionospheric sector model
  - NRL MSIS atmosphere.
- Ensemble of runs.
- Additionally, it is also possible to extract the lunar tides variation which also folds into the variability of the neutral wind and E field.

Conclusions

- **Distributed observatories are the best tool to study space weather issues.**
- **LISN offers the possibility to initiate new projects as tomography reconstructions of density profiles, maps of TEC depletions and TIDs.**
- **LISN is a distributed observatory to study some aspect of space weather (plasma bubbles, ESF). It provides regional coverage of the day-to-day variability of the ionosphere over South America.**

Comparison of h'F2 between Puerto Maldonado (equator) and Tupiza (11° S magnetic latitude).



foF2 values for P. Maldonado and Tupiza for the same day.