The LISN distributed observatory: The Deployment Phase

Cesar E. Valladares, Boston College
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Vince Eccles, Space Environment Corp.
Erhan Kudeki, Univ. Illinois
Ronald F. Woodman, IGP
Bill Wright & Nick Zabotin, DSL

Objectives

- To build and install the first Distributed Observatory across the western half of South America. Provide real-time display of observables.

By using assimilation:

- To study the electrodynamics of the low-latitude ionosphere during magnetic quiet and disturbed conditions.

- To develop tools to forecast the initiation of equatorial spread-F (ESF) in a regional basis.

A distributed observatory to address aeronomy and space weather problems that will have a standard mode of operation, but at the same time special and campaign modes.
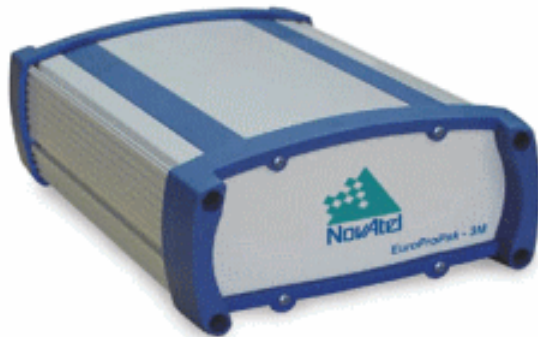
GPS selected for the LISN network

GPS **I**ONOSPHERIC **S**CINTILLATION AND **T**EC **M**ONITOR GSV4004B

- **SBAS capable (amplitude and phase).**
- **Tracks 10 GPS satellites and 3 SBAS.**
- **50 Hz amplitude and phase measurement for scintillations.**
- **Stable ovenized crystal oscillator.**
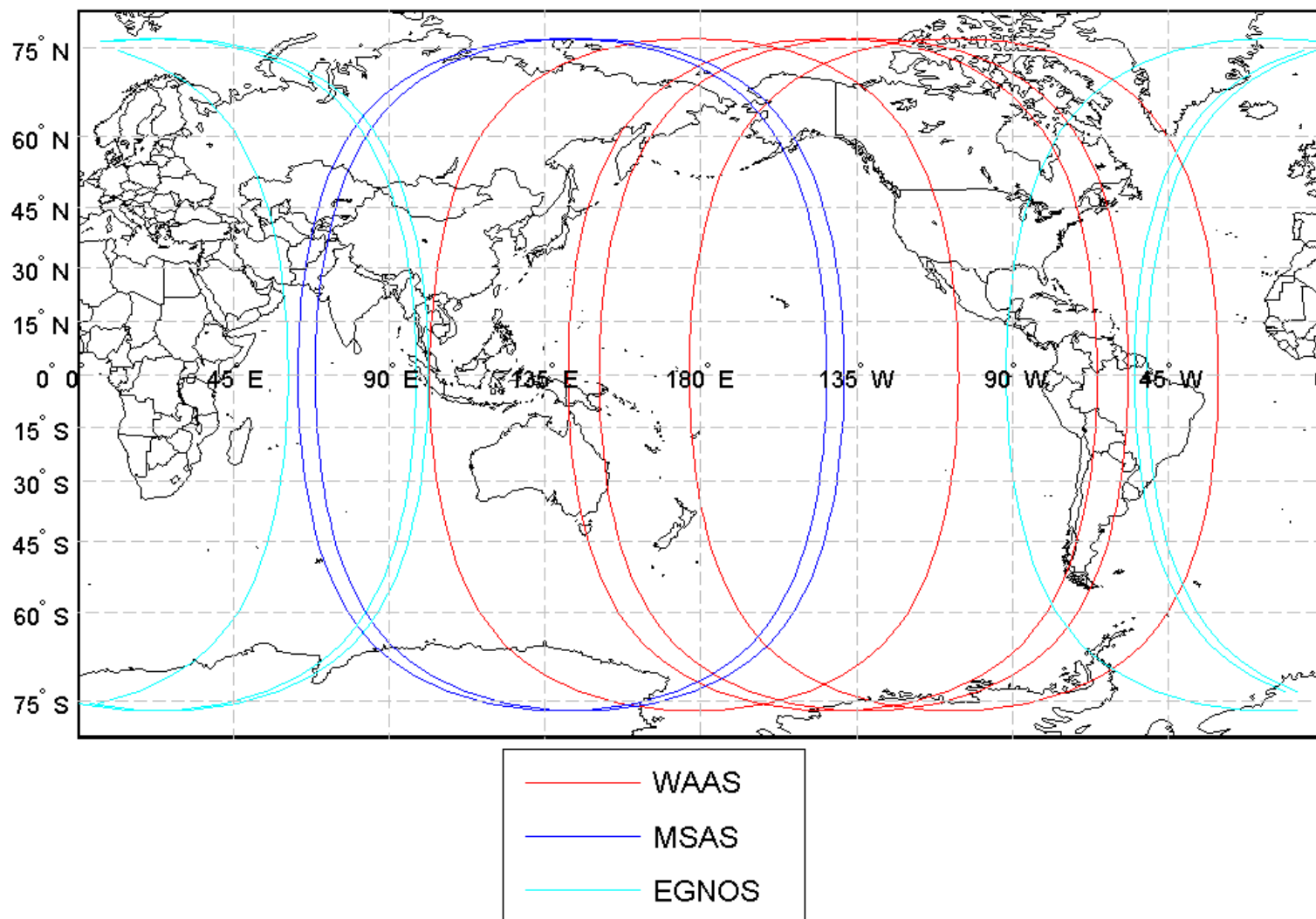

GSV4004B GPS IONOSPHERIC SCINTILLATION AND TEC MONITOR WITH

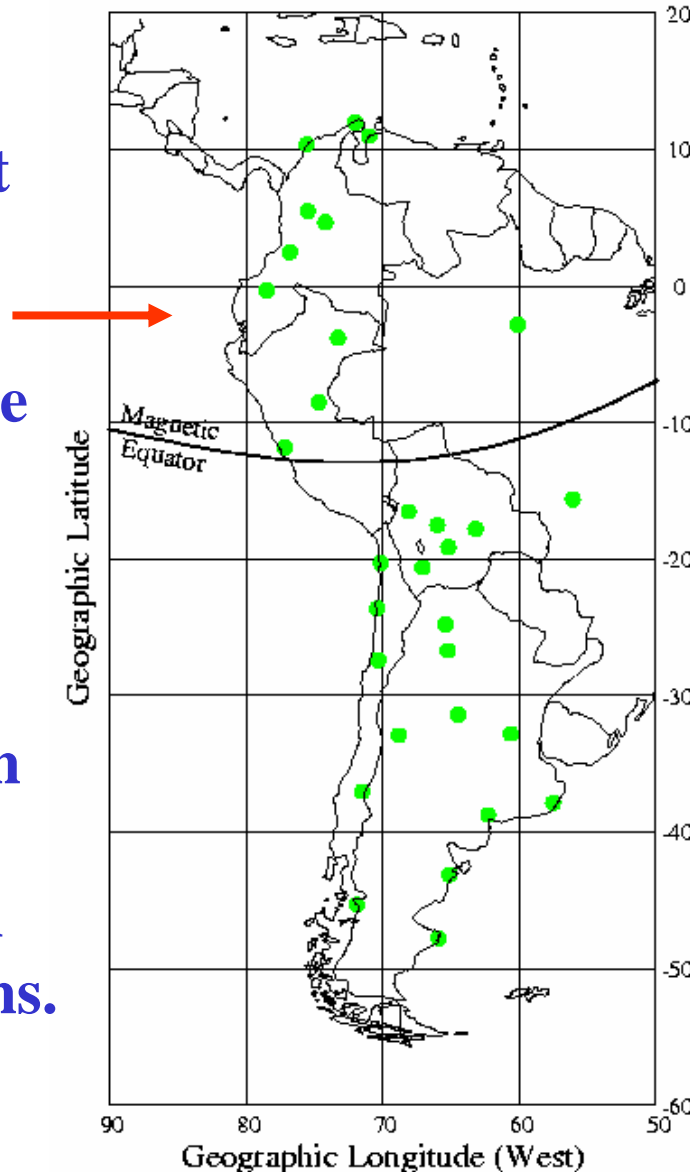# Worldwide SBAS GEO Coverage

GEO Footprints @ 5 deg Elevation Angle Mask

Legend:
- WAAS
- MSAS
- EGNOS

Existent GPS receivers in SA

Operating GPS receivers in SA that will become part of the LISN network. Their infrastructure is being upgraded.

All these receivers (30) will give TEC in real-time basis. In addition, 17 of them will give scintillations.

Receivers belong to BC(6), Mike Bevis OSU (9), Claudio Brunini UNLP (7), Victor Rios UT, Bob Smalley (2) UM, K. Groves AF (2), Hector Mora INGEOMINAS (2), NGA (1), Yogesh Sahai UNIVAP (1).

LISN GPS receivers to be installed

Installation to be conducted under the collaboration of (agreements signed with):

Dr. J. Chau, JRO, Peru

Dr. C. Brunini UNLP, Argentina

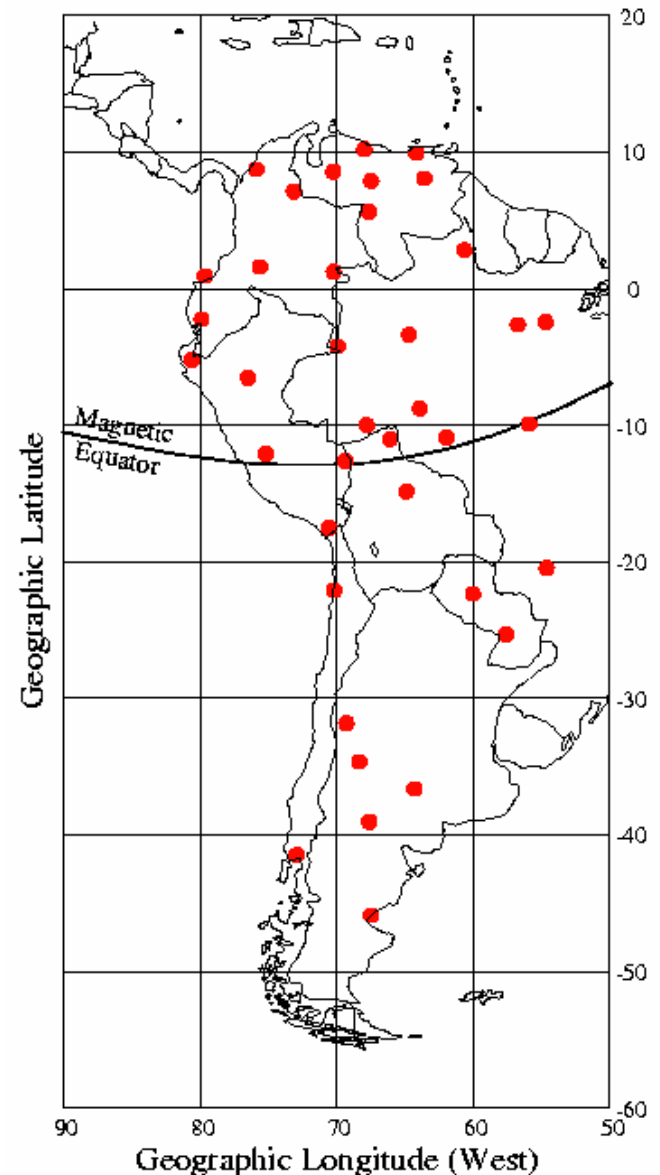**Dr. E. DePaula, INPE, Brazil**

Dr. J. Villalobos, UNC, Colombia

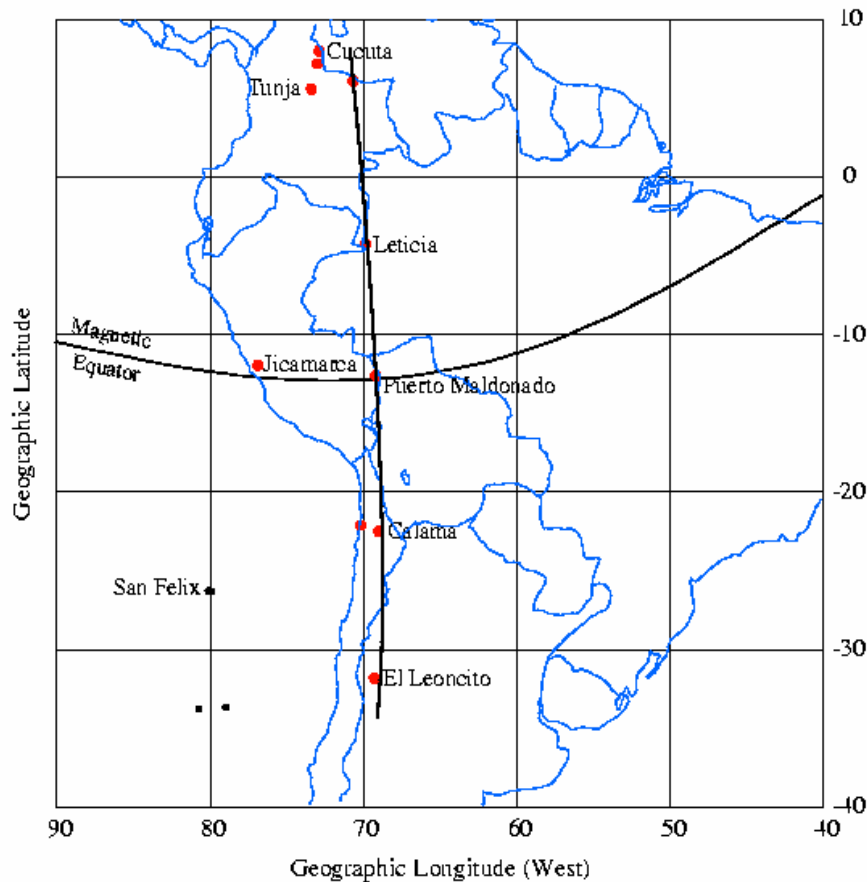**Dr. H. Mora, INGEOMINAS, Colombia.**

Dr. J. Araya, UCN, Chile.

Dr. A. Tierra, EPE, Ecuador.

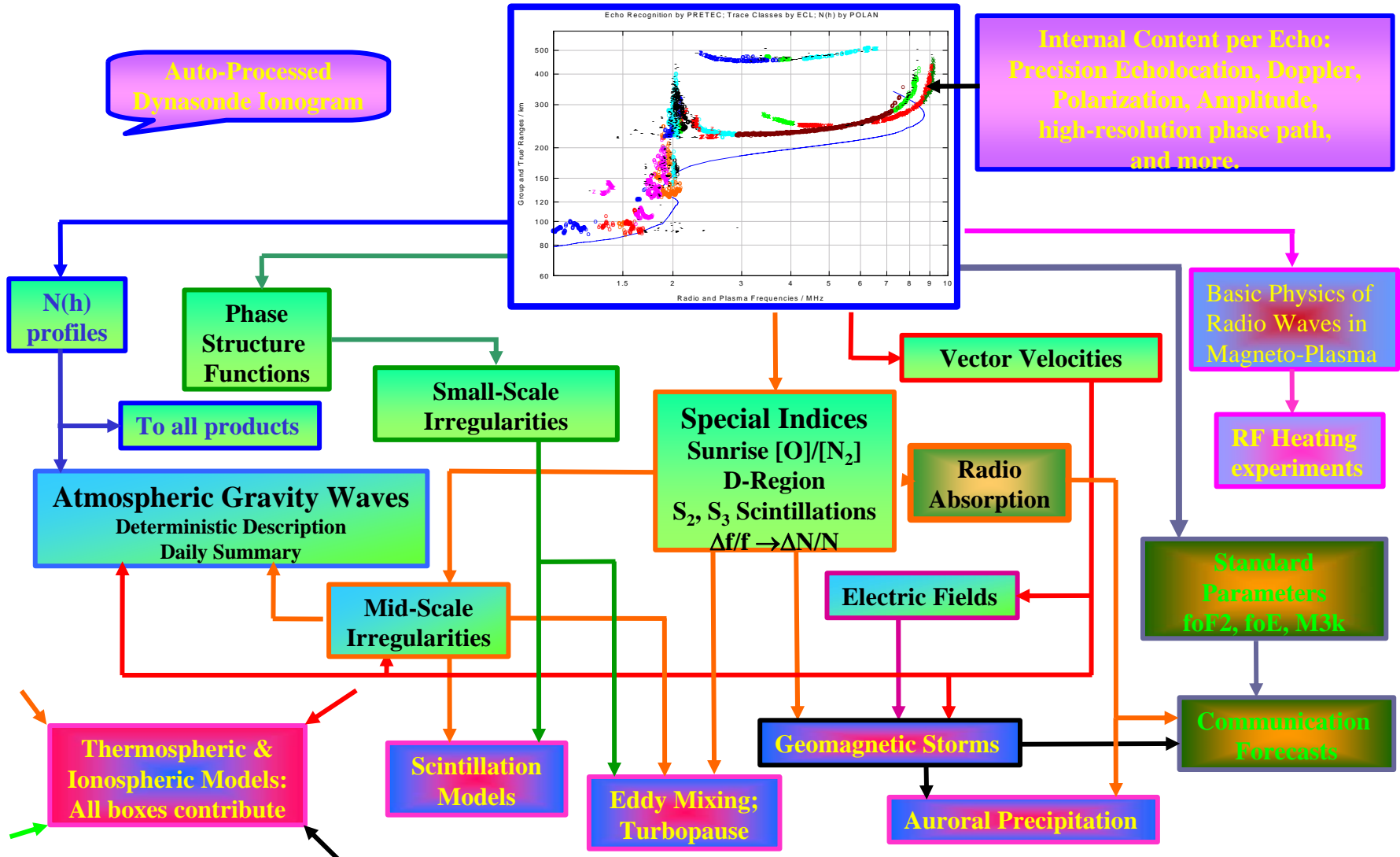**Dr. M. Bevis will help with the installation in Bolivia.**

5 dynasondes to be paced at El Leoncito, Carmen Alto, Puerto Maldonado, Leticia & northern Colombia

5 Dynasondes designed by Terry Bullett, Bob Livingstone (hardware) and Bill Wright (software).

1. High-frequency radar hardware system.
   Eight receiver channels.
   Eight active antenna preamplifiers.
   Real-time control/data acquisition PC.
   GPS timing module for bistatic operation.
   Linux O/S with radar control interface.
2. Transmitter power amplifier, Tomco.
   Four KW
3. Receiver dipole array with eight non-resonant dipole antennas.

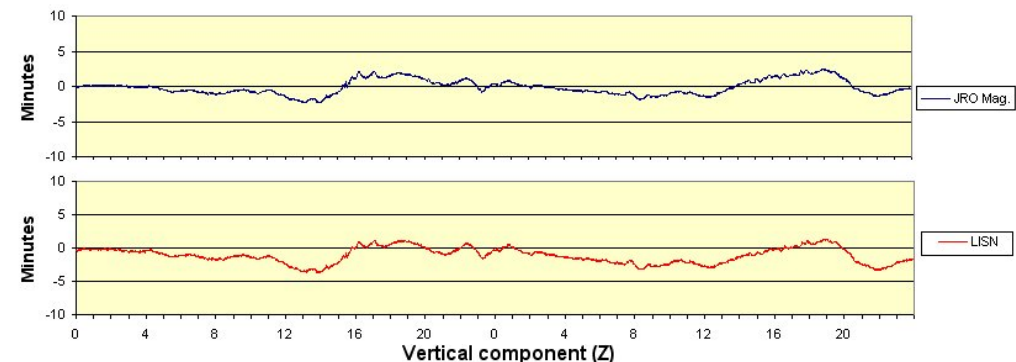# Dynasonde design done by: Terry Bullett, Livingston, Wright, and Zabotin

Echo Recognition by PRETEC; Trace Classes by ECL; N(h) by POLAN

Auto-Processed Dynasonde Ionogram

Internal Content per Echo: Precision Echolocation, Doppler, Polarization, Amplitude, high-resolution phase path, and more.

Group and True Ranges / km

Radio and Plasma Frequencies / MHz

N(h) profiles

Phase Structure Functions

To all products

Small-Scale Irregularities

Vector Velocities

Basic Physics of Radio Waves in Magneto-Plasma

RF Heating experiments

Special Indices
Sunrise $[O]/[N_2]$
D-Region
S_2, S_3 Scintillations
$\Delta f/f \rightarrow \Delta N/N$

Radio Absorption

Atmospheric Gravity Waves
Deterministic Description
Daily Summary

Mid-Scale Irregularities

Electric Fields

Standard Parameters foF2, foE, M3k

Thermospheric & Ionospheric Models: All boxes contribute

Scintillation Models

Eddy Mixing; Turbopause

Geomagnetic Storms

Auroral Precipitation

Communication Forecasts

Development of a prototype magnetometer

Comparison of UCLA magnetometer and new Jicamarca (LISN) prototype.
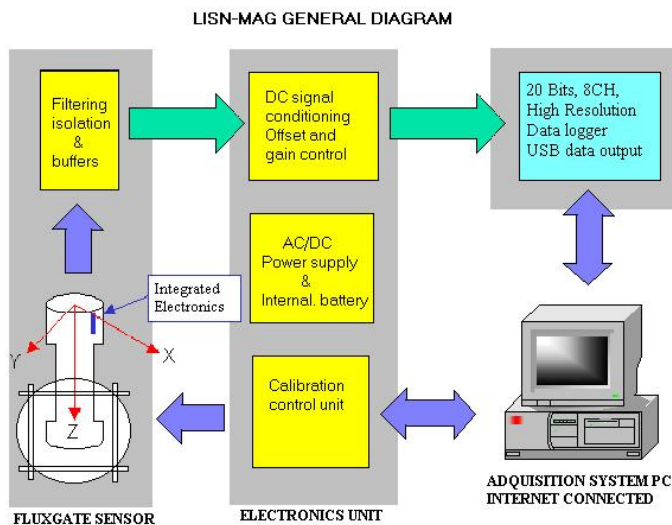
Horizontal Component (H).
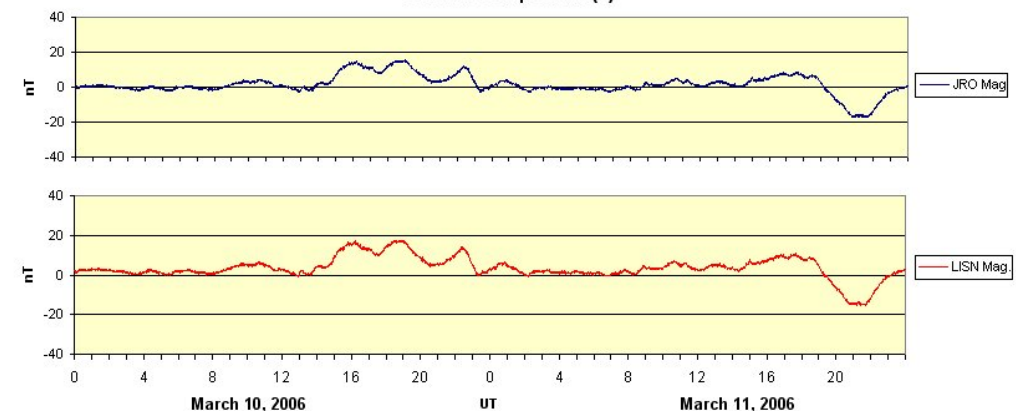
Declination Componente (D)

Vertical component (Z)

LISN-MAG GENERAL DIAGRAM

Magnetometer Design by Oscar Veliz

LISN Web Page
http://jro.igp.gob.pe/subwebs/lisn/

Username: userlisn
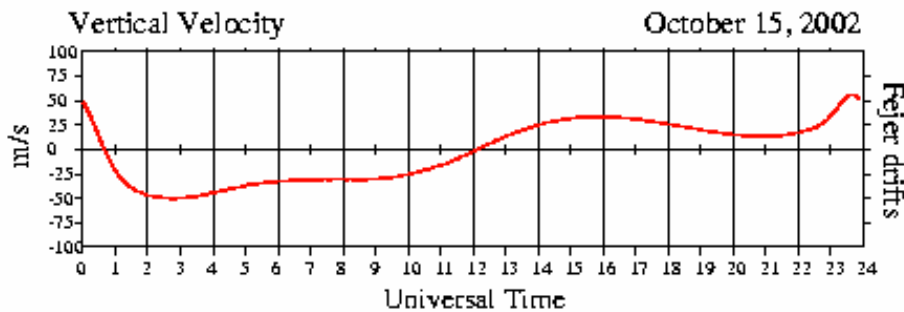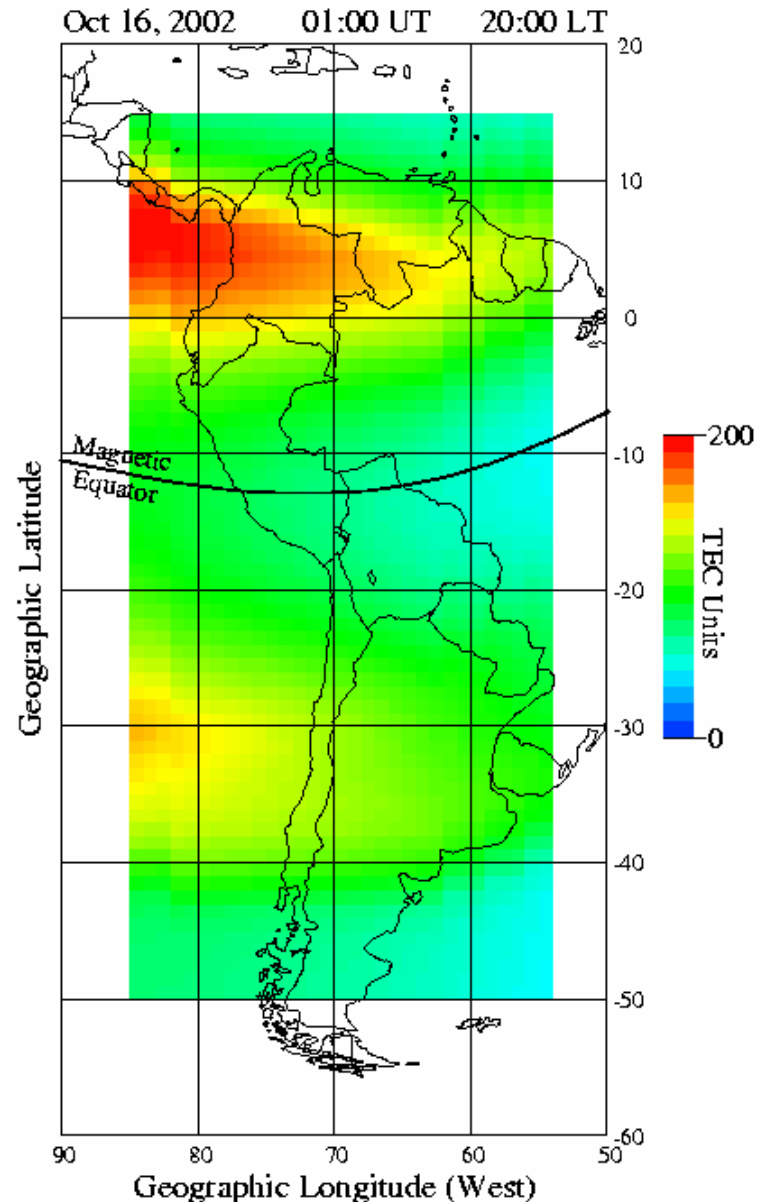
Simulation of the LISN TEC display
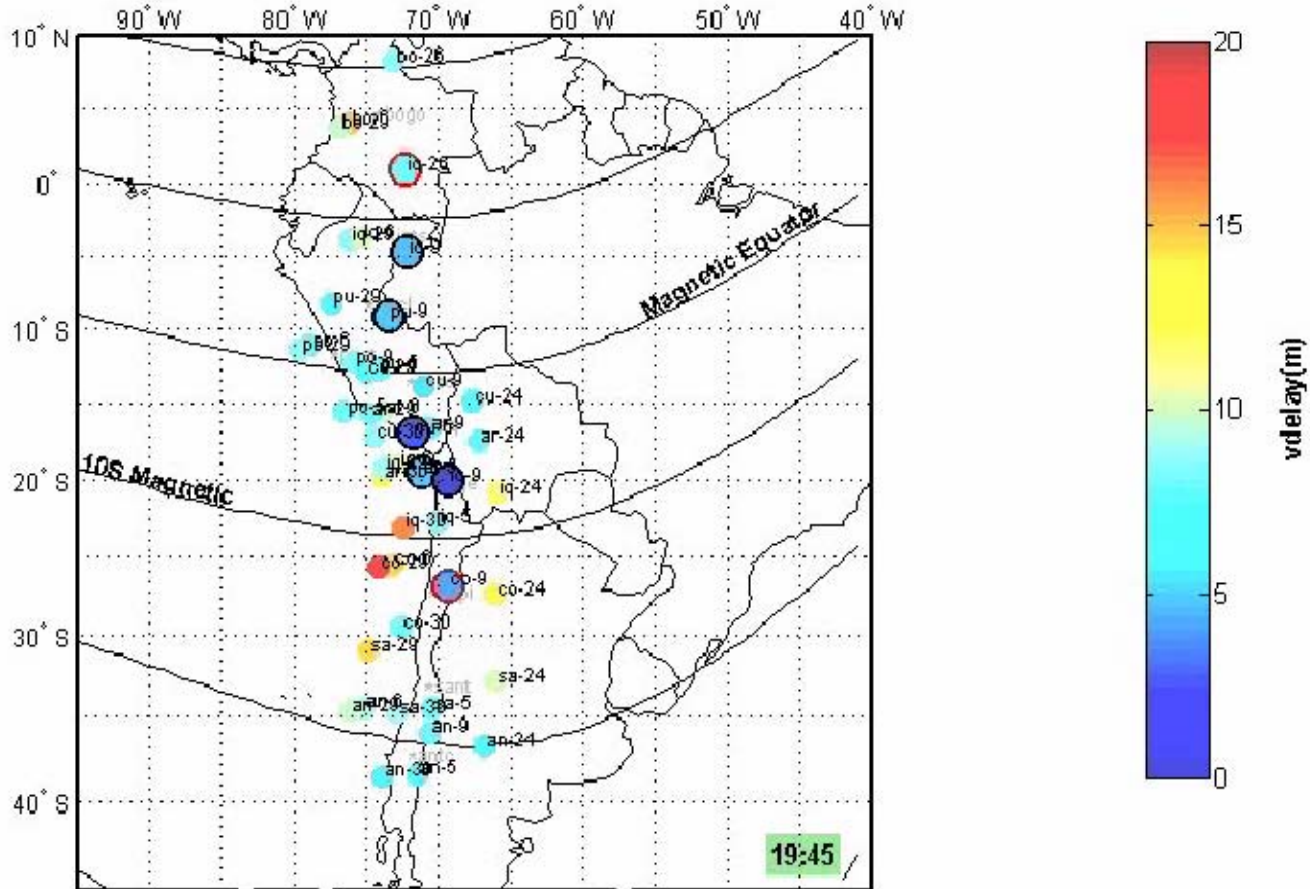
Fejer's drifts multiplied by a factor dependent on longitude. 1.3 at 85°W and 0.7 at 55°W.

Constant meridional wind equal to +60 m/s (northward)

TEC-Depletion detection from 10 Sites in the Western Side of South America, March 19, 2002

Circles indicate the presence of TEC depletions.

Measurement of <u>differential TEC</u> using 2 GPS receivers

SBAS Satellite

We plan to use the SBAS phase from 2 GPS receivers to obtain dTEC = Phase$_1$ – Phase$_2$ + bias Phase error equal to 0.1 radian, that is equivalent to 0.02 TECunits.

Ionosphere

Multipath contribution can be calculated exactly given that the SBAS satellites are geo-stationary.
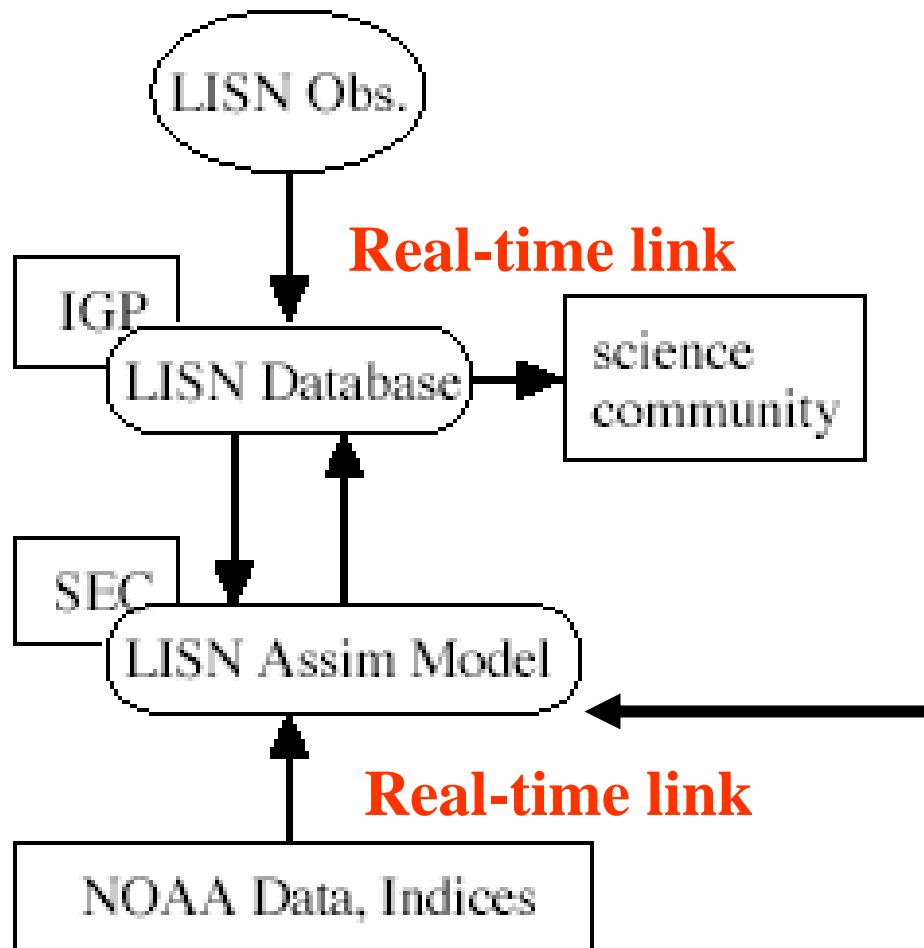
receiver 1   receiver 2

50 km

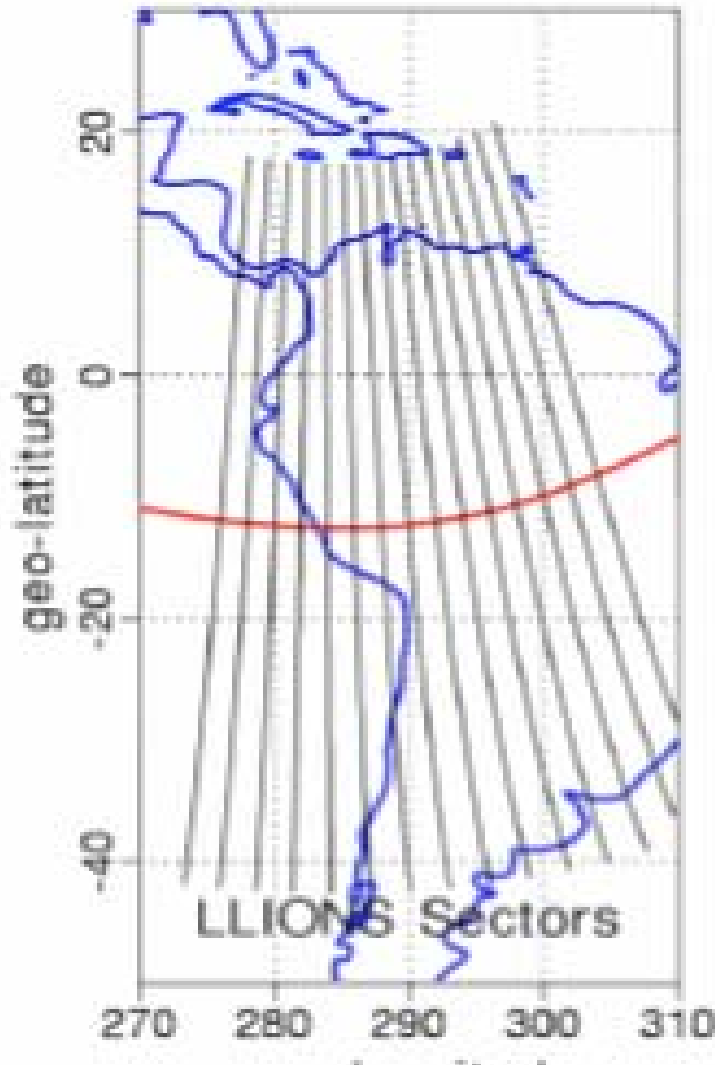**Two-month campaign in the Peru sector using 2 or 4 receivers.**

Real-time data flows of LISN data and assimilation

Real-time link

Real-time link

(1) **Low-latitude Ionospheric model, (2) low-latitude electrodynamics model, (3) model of ground-based magnetic perturbations for a 3-D current system (4) Kalman filter program.**

A Complementary Aspect of LISN

The LISN project includes an assimilative physics-based model designed to "nowcast" the ionosphere above the same geographic region. The model will use a Kalman filtering technique to assimilate the data and the LLIONS model developed by SEC.

Jicamarca will be used to validate results, but also its data will be later assimilated into the assimilation string We can use the high altitude resolution of the Jicamarca meas. to extend this resolution along a meridian. Ingest Jicamarca temperatures.

Measure nighttime E-region density

Magnetic Equator

Unstable Plasma

F Region

Magnetic Field Lines

E Region

Earth
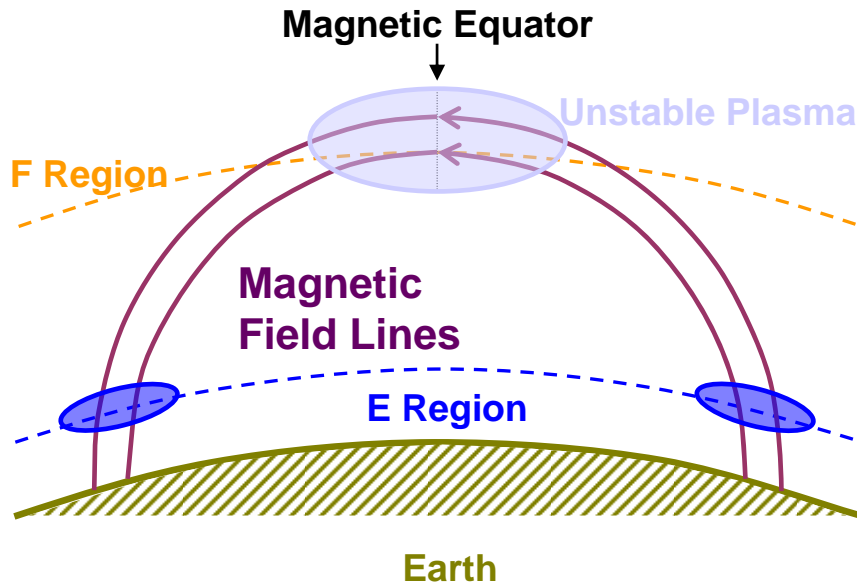
5 dynasondes will be placed along the field line that crosses the magnetic equator at 69° W. They will measure E-region densities during the onset of ESF.

The field lines that intersect the E region over the cities of Leticia and Carmen Alto map to 300 km at the magnetic equator. We will be able to observe: (1) times when E-region densities (sporadic E) "short out" electrodynamic instabilities. (2) role of equatorial and off-equatorial E region to balance pre-reversal currents.
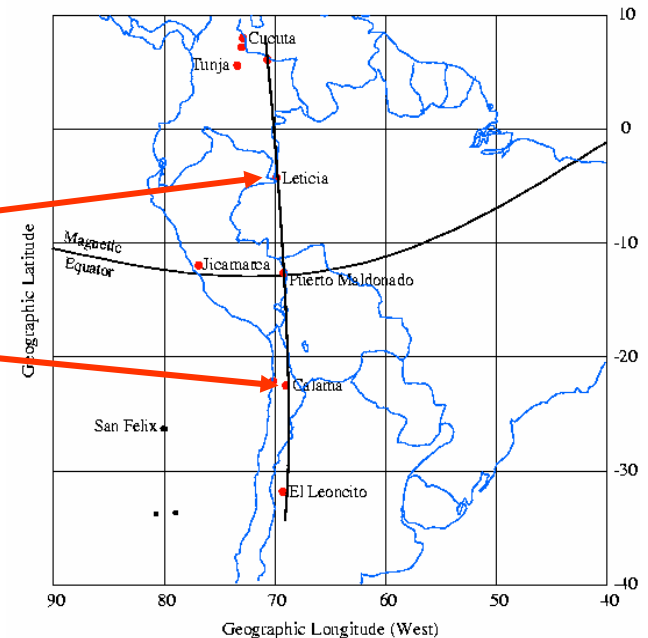
Concluding Remarks

- **I want to invite other members of the CEDAR community, who have instruments in South America to be part of LISN. A SuperLISN?**

- **This program is supported by the National Science Foundation and AFOSR to initiate collaboration with universities and research institutes from South America.**
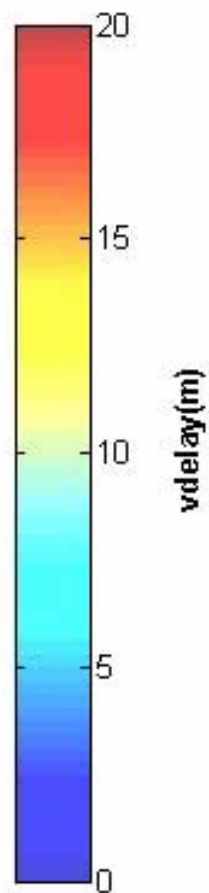
"Imagination is more important than knowledge"

Albert Einstein
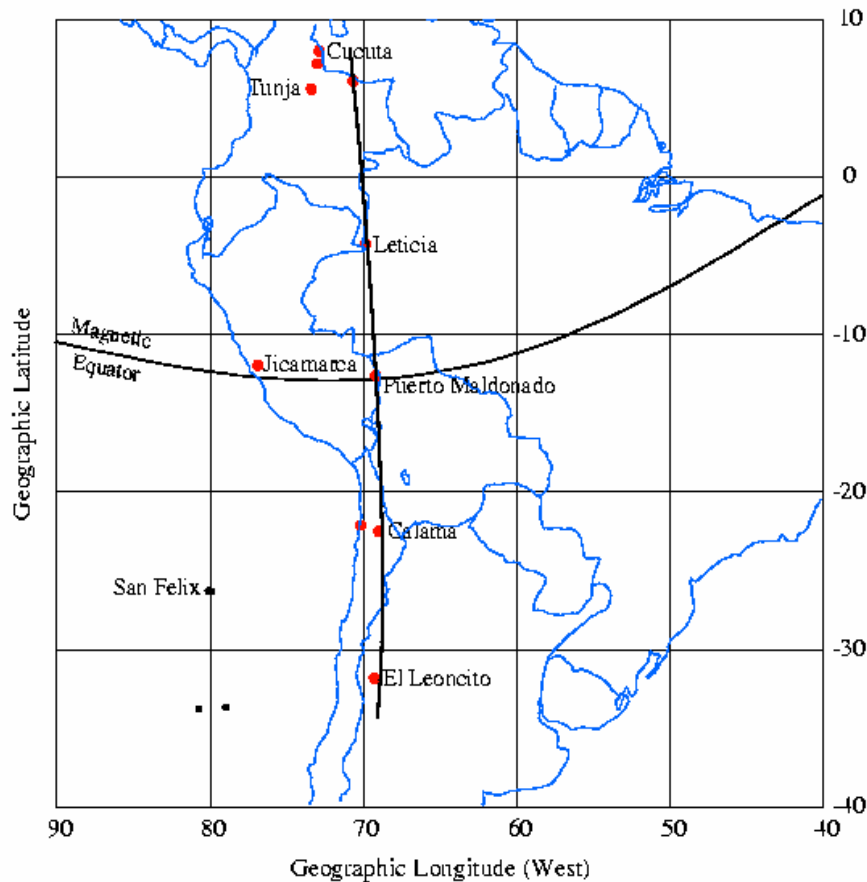
Oct 15, 2002   18:00 UT   13:00 LT
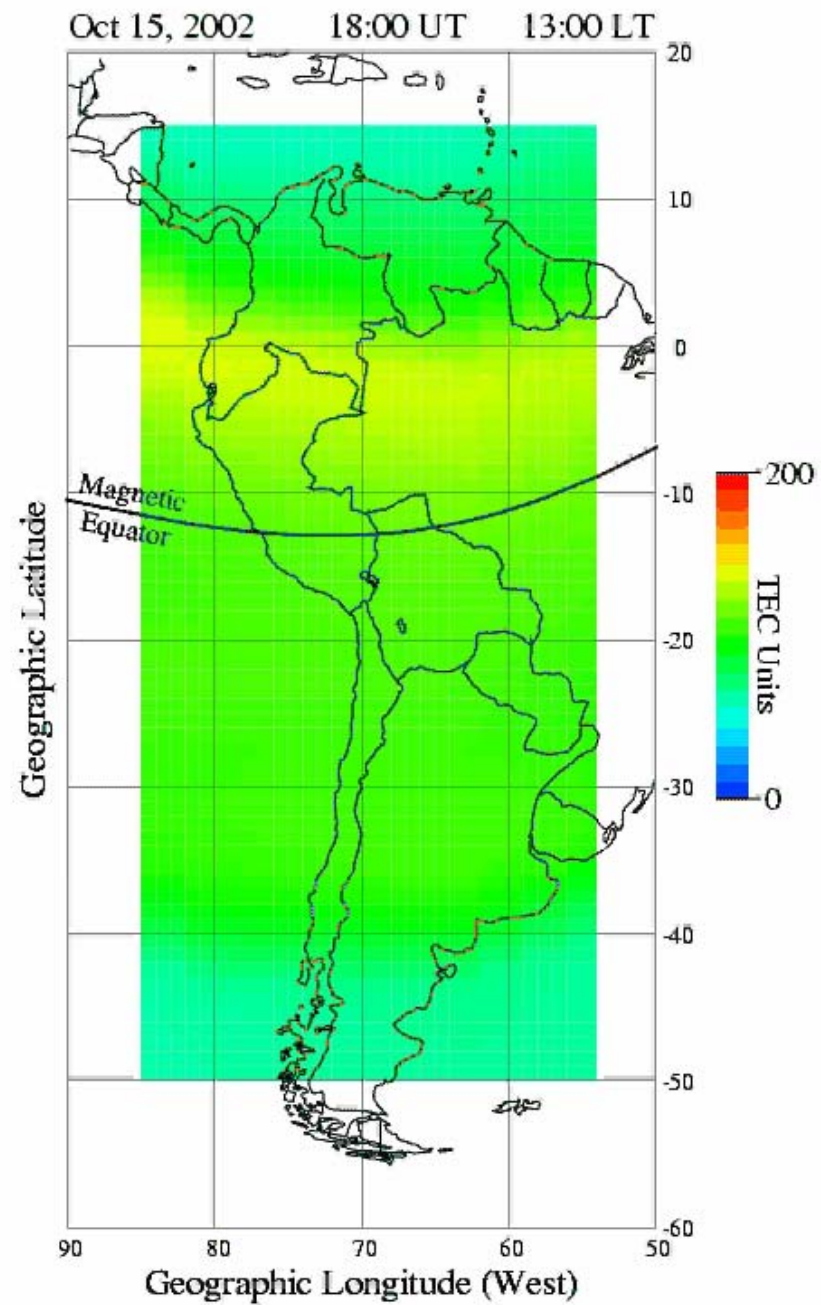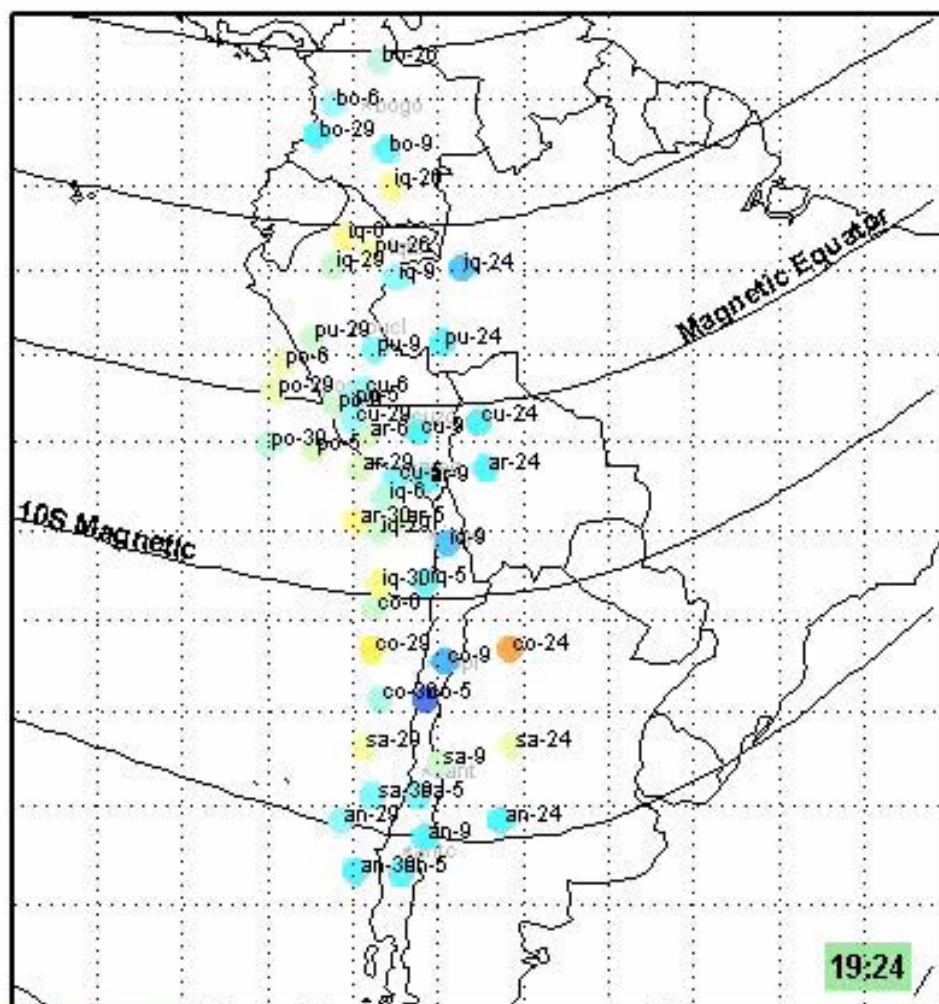
MITRE/CAASD
02/03/19

5 dynasondes to be paced at El Leoncito, Carmen Alto, Puerto Maldonado, Leticia & northern Colombia
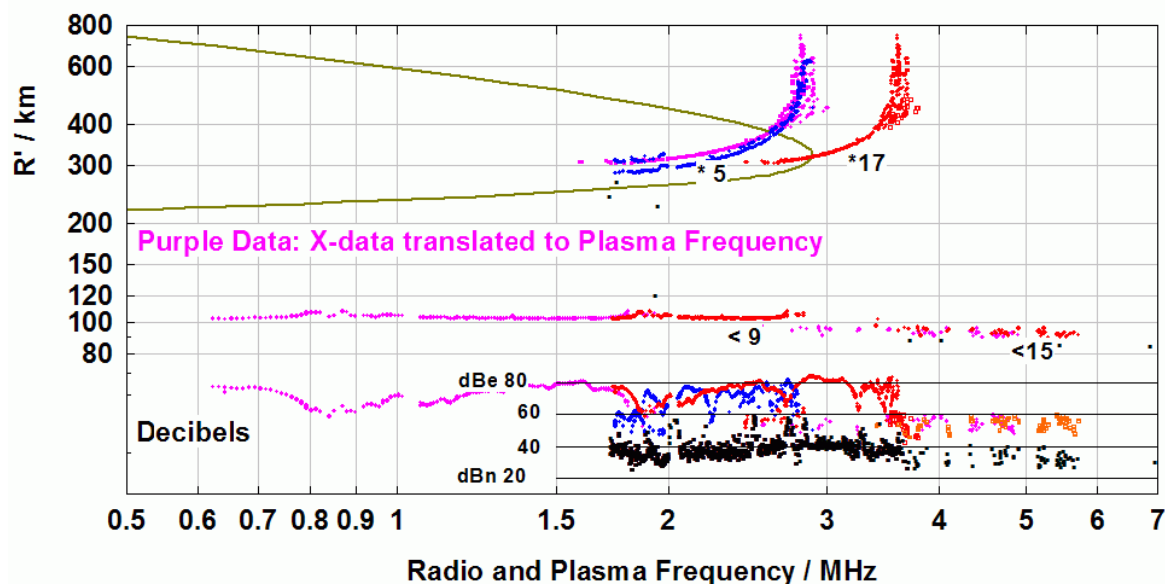
5 Dynasondes designed by Terry Bullett, Bob Livingstone (hardware) and Bill Wright (software).

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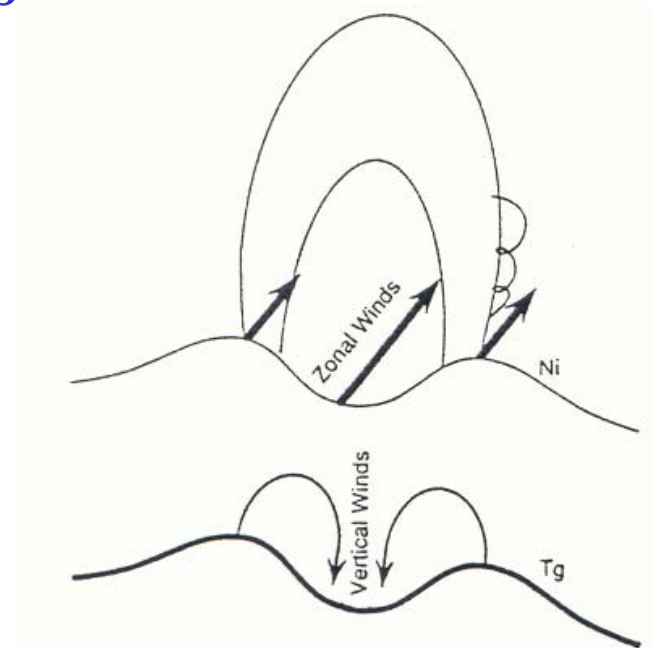# Conclusions

- **The LISN network and its assimilation effort will be able to provide:**
  (1) Number density, Conductivities, ExB drifts, neutral wind.
  (2) Map of TEC, GPS S4 scintillations, TEC depletions

- **Data from the Jicamarca radar will help to verify density profiles and later will be ingested into the LISN assimilation program. Measurements of the Fabry-Perot interferometers in Arequipa, Peru and Carmen Alto, Chile will be also assimilated.**

BEAR LAKE UTAH   DYNASONDE 05-07-31 1040UT 105W
4pB 6lt1 DoY=212.44444 File= 07311040.B_G

Blue data: O-polarization echoes
Red data: X-polarization echoes

Purple Data: X-data translated to Plasma Frequency

Radio and Plasma Frequency / MHz
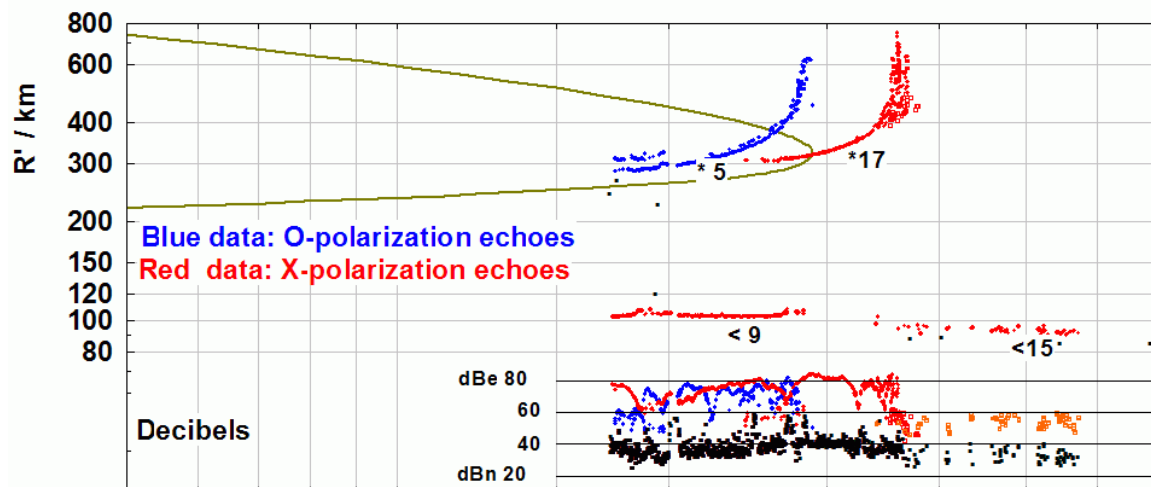
DE-2 electron density, zonal winds and vertical winds
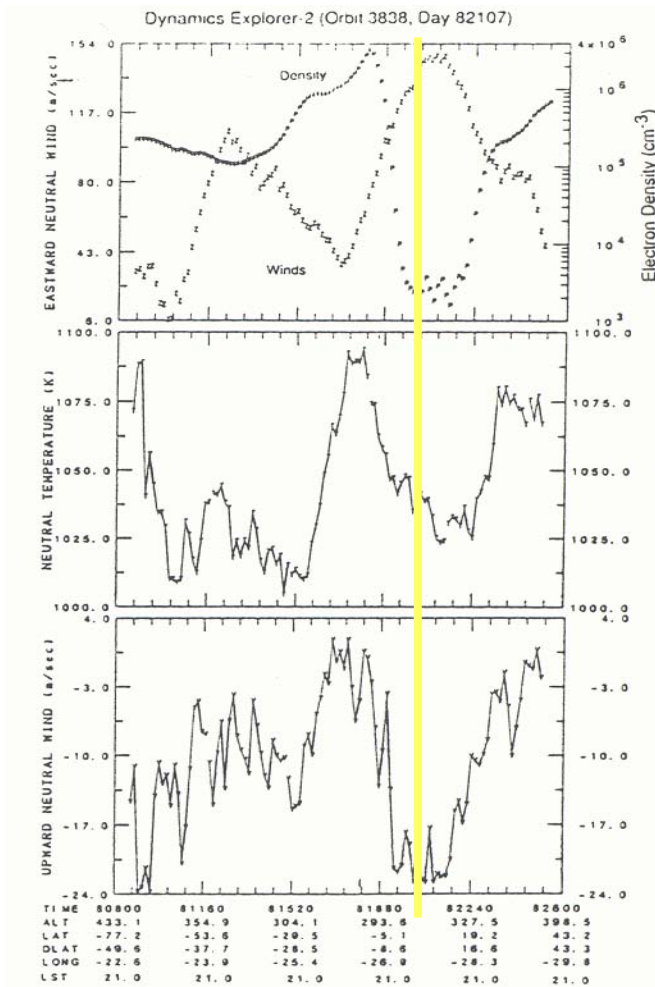
Schematic of the dynamic coupling process between the ionization anomaly and the thermosphere at low latitudes.

Prototype Magnetometer

- Overall Range: +/- 60,000nT.
- Dynamic Range: +/- 2000nT
- Resolution : 0.1nT
- Output: +/-2.5 VDC (analog signal)
- Digital outputs: USB, 5 output channels, X,Y,Z and 2 temperature sensors
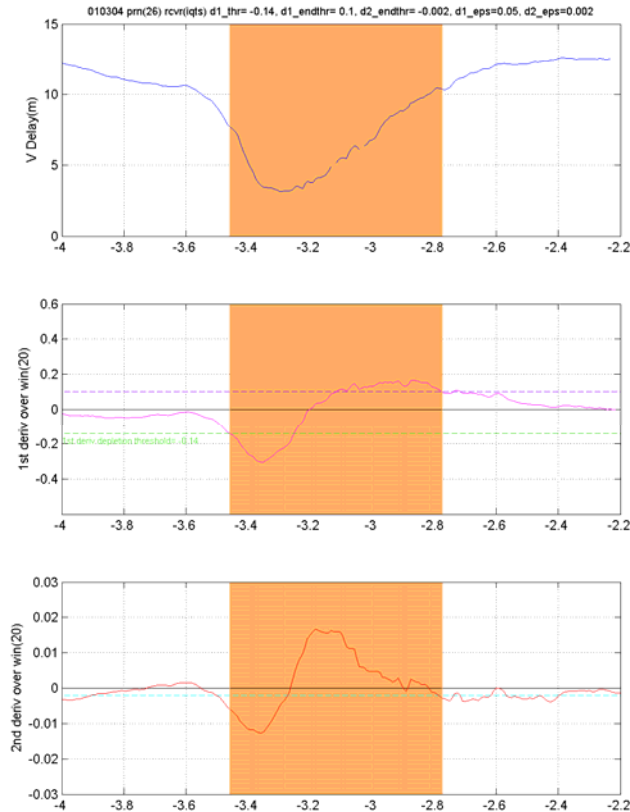- Internet data rate: 5min.

- Sensor : Triaxial ring core fluxgate.
- Sensor Module: PVC cylinder de 4" x 0.80 m, contains internal temperature sensor and 3 Helmholtz coils for periodic calibration.
- Electronic unit: AGC, fields cancellation and filters, including a data logger of high resolution : 20
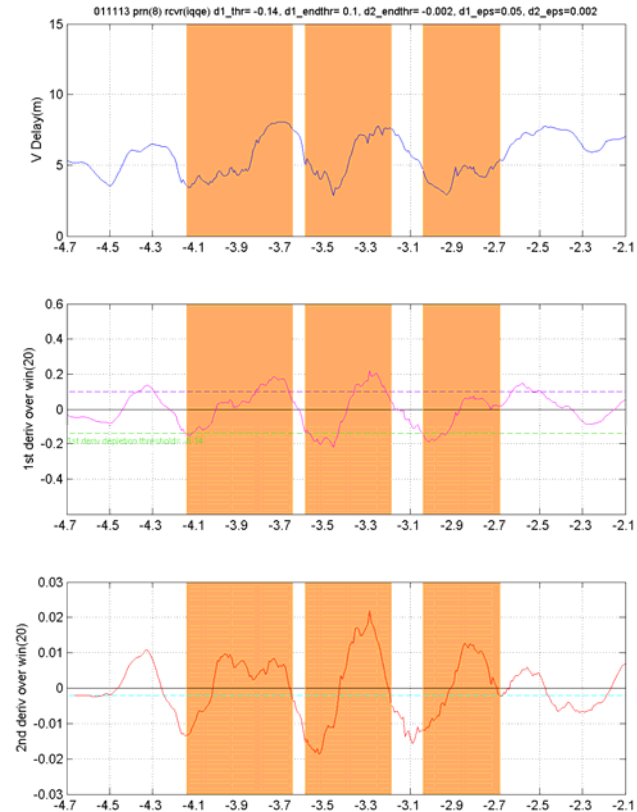
Examples of Detecting A Single Depletion and 3 Depletions

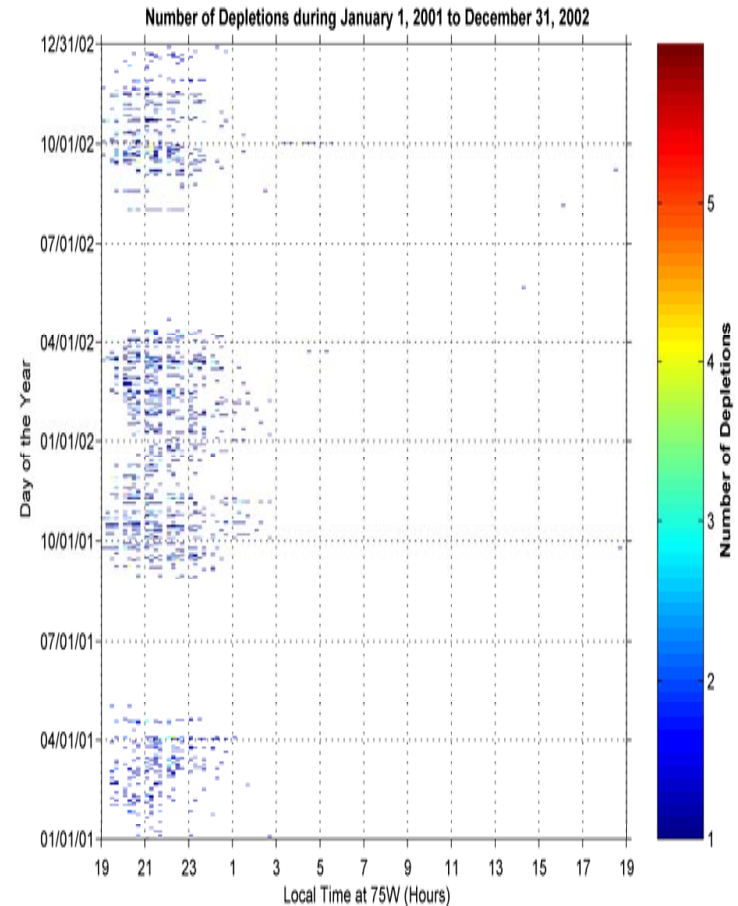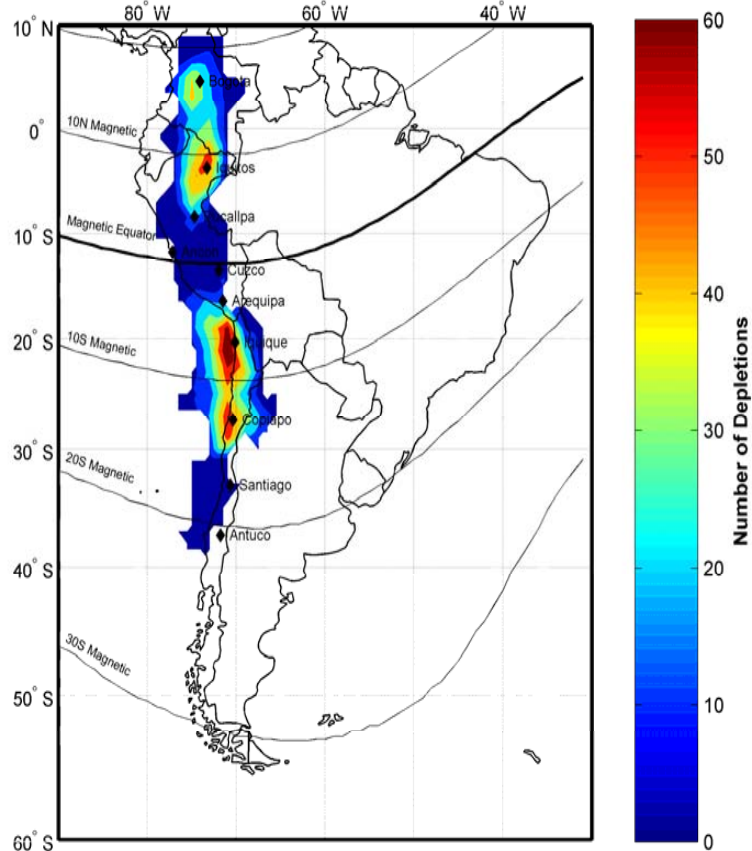PRN26 at Iquitos, Peru,
March 4, 2001

PRN8 at Iquique, Chile,
November 13, 2001

Location and Frequency of Depletions for Two Years of Data

Number of Depletions during January 1, 2001 to December 31, 2002


Number of Depletions during January 1, 2001 to December 31, 2002

Basic Dynasonde Principles

- Phase differences among several (4-8) pulsed signals of a carefully designed pulse set, received through several (4-8) antenna/receiver channels, define, by a least squares solution, a radio "echo" with physical parameters:

  - "Doppler" or phase-path velocity V*, m/s

  - "Stationary-Phase Group Range" R´, km

  - Eastward XL and northward YL echolocations, km

  - Polarization rotation or "chirality" PP, degrees

  - The pulse set mean phase $\varphi 0$, degrees

  - A least-squares residual EP, degrees

  - An echo peak amplitude A, decibels, from signal magnitude

  - Possible 2nd order parameters with 8 antennas and receivers

An "Ideal" Dynasonde Antenna Layout
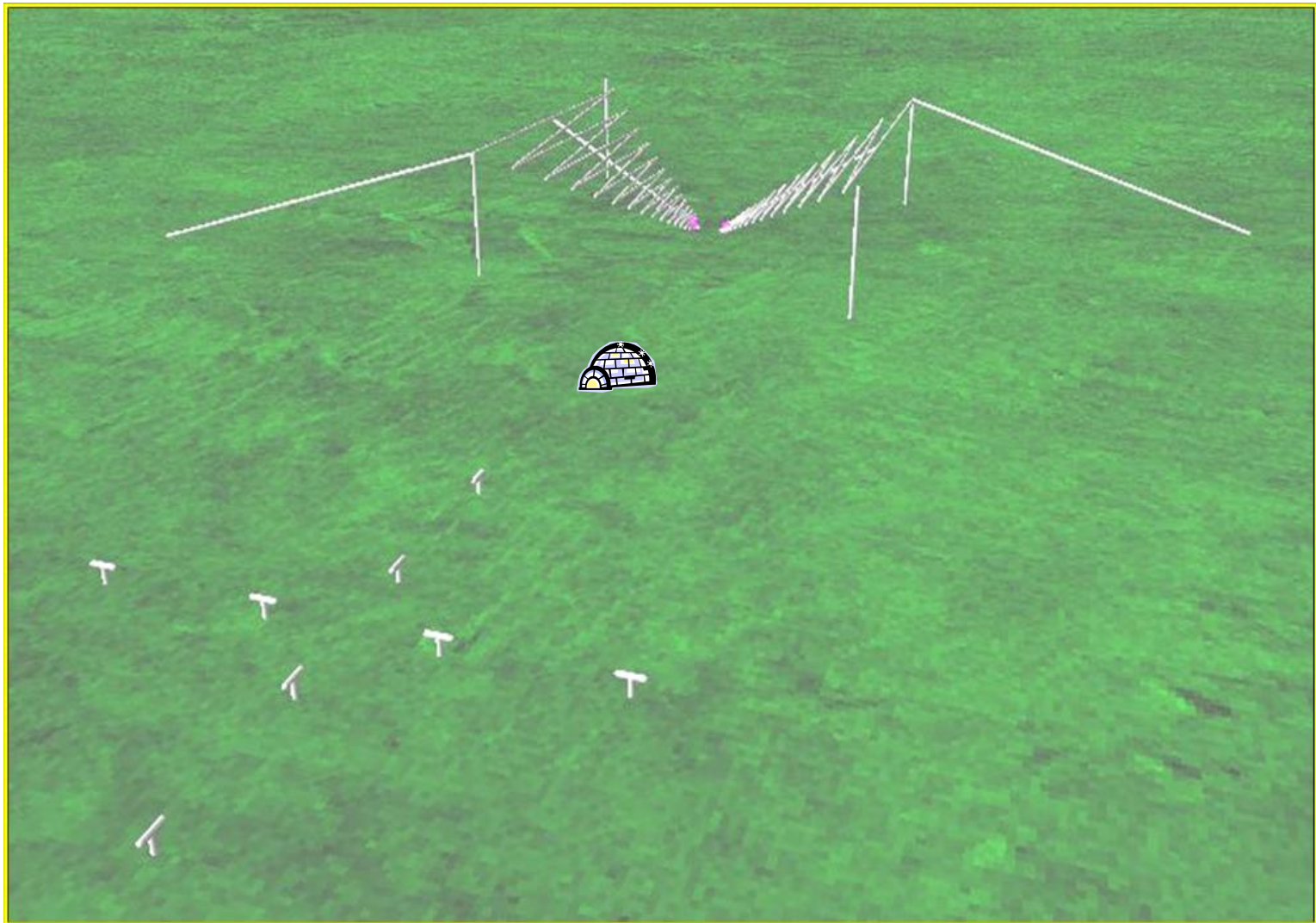
Key Features:

|		
Flat land	No competing antennas	Underground Power Lines
Tx, Rx separated	Instrument bldg. midway	Space for expansion
Underground coax	Non-conducting towers	Rotate Rx array 45°

Plan View of an "Ideal" Dynasonde Antenna Layout

In this example, the Tx Log Periodic is shown with 4 planes. Guys are shown for one of the four supporting towers: it is important that the guys be oriented as shown, to avoid the LPA curtains and for direct backward tension of the diagonal support ropes. Two opposing curtains are sufficient for most dynasonde purposes, but four provide better mechanical stability at little cost.

B
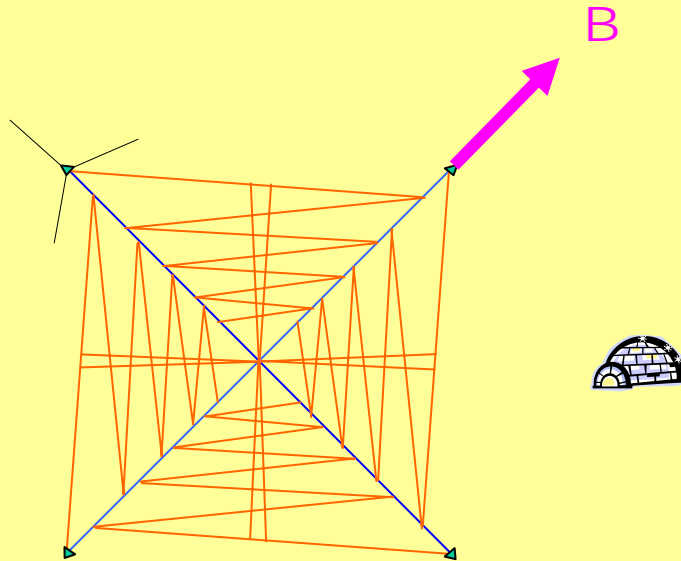
Tx 4-plane vertex-down LPA
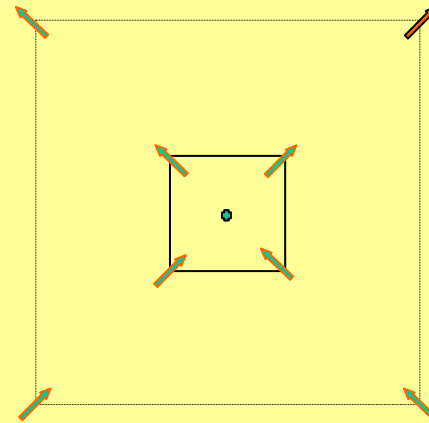
Rx 8-dipole array. Outer-square size controls precision of echolocation; inner square defines aliasing interval.

Placing the Tx and Rx arrays on either side of the instrumentation building maximizes their separation (good for RF isolation) and minimizes transmission-cable length (for economy and least signal loss). The 45 degrees between the Tx wires and the Rx dipoles also reduces radiation coupling between them. Magnetic-equatorial sites require that a diagonal of the Tx and Rx arrays be oriented along the magnetic field B, as shown, to put equal power into the Ordinary and eXtraordinary magnetoionic modes. Placing coax transmission lines in PVC tubing and underground avoids damage from traffic, animals and other users of the land.

Leticia Site

Carmen Alto Site

Site Location

El Leoncito Site