Report on activities and experiments at the Jicamarca Radio Observatory: Pushing the radar beyond its limits

Marco Milla
Radio Observatorio de Jicamarca - Instituto Geofísico del Perú

2016 Joint CEDAR-GEM Workshop
Session: Frontier research in equatorial aeronomy
June 19-24, 2016 - Santa Fe, New Mexico

Jicamarca Radio Observatory - Introduction

- A research facility dedicated to monitor and study the Equatorial ionosphere and upper atmosphere.
- It is located at ~20 km east of Lima, Peru. (11.95°S, 76.87°W).
- Operates a variety of instruments: radars, ionosondes, magnetometers, GPS receivers, Fabry Perot interferometers, etc.

Its main instrument is one of the largest incoherent scatter radars in the World.

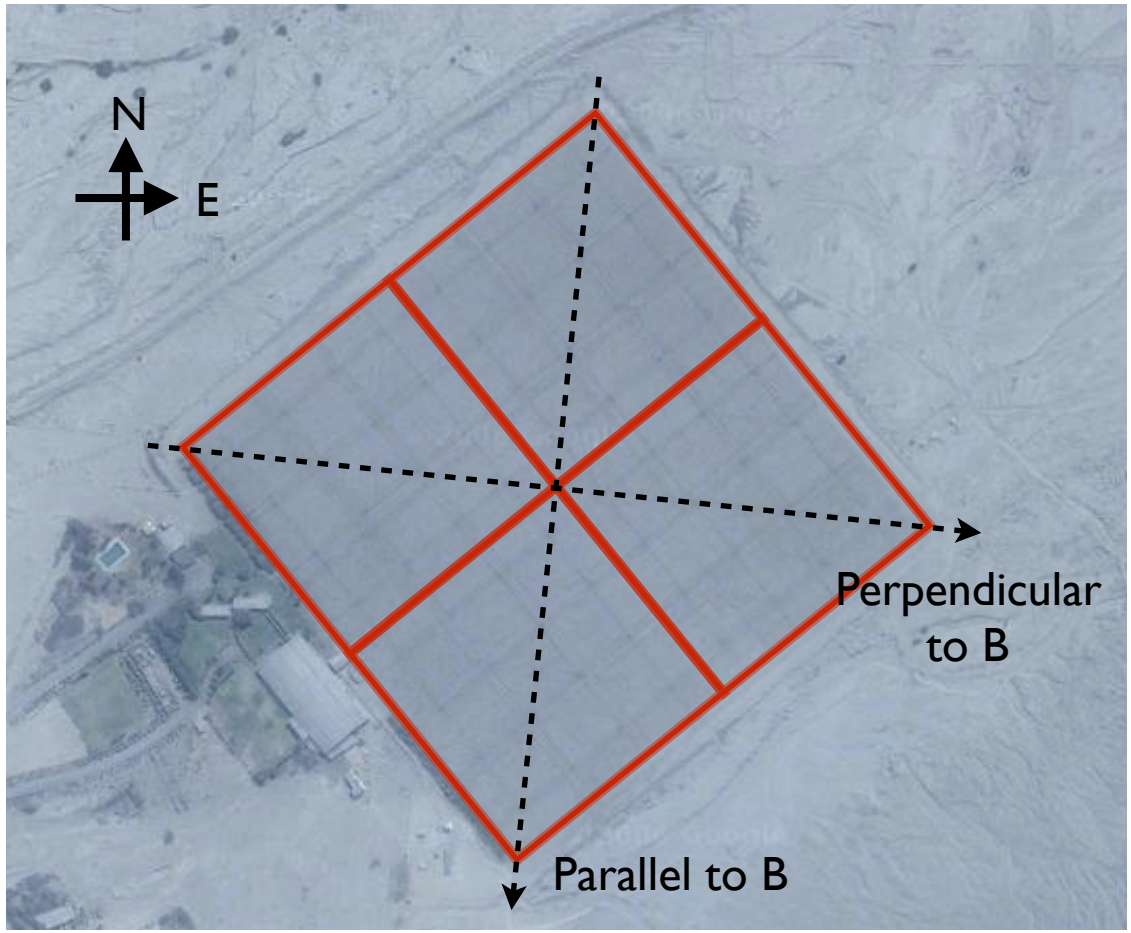
Outline

- Recent improvements & current capabilities
- Standard modes & new experiments
- Ideas for the future

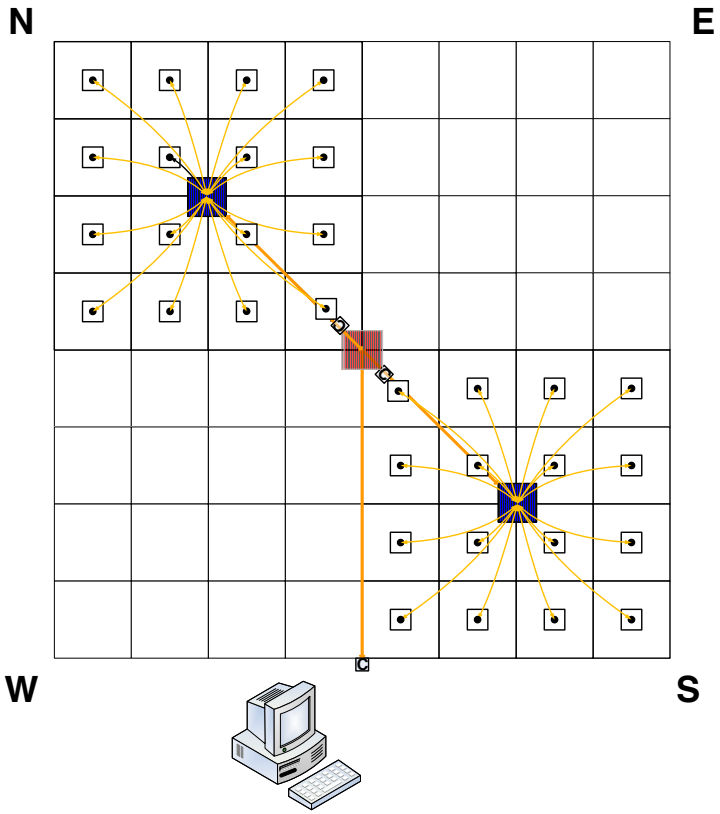
Recent improvements and current capabilities

Characteristics of the Jicamarca Radar

- Operating frequency: 50 MHz
- Antenna: array of 18,432 half-wave dipoles covering an area of 300 x 300 m^2.
- Grouped in 8x8 cross-polarized antenna modules (that can be combined in multiple ways).
- Pointing directions: within 3 degrees from on-axis.
- Transmitters: 4 x 1 MW peak-power with 5% duty cycle (2 under repair).
- Digital Receivers: 8 independent lines of reception (one per antenna quarter and polarization) + 8 lines for the imaging system.



Antenna Beam Switching & Solid state TRs



The electronic antenna beam switching system was finally implemented a year ago., though only for the North and South antenna quarters. This upgrade has increased significantly JRO capabilities.

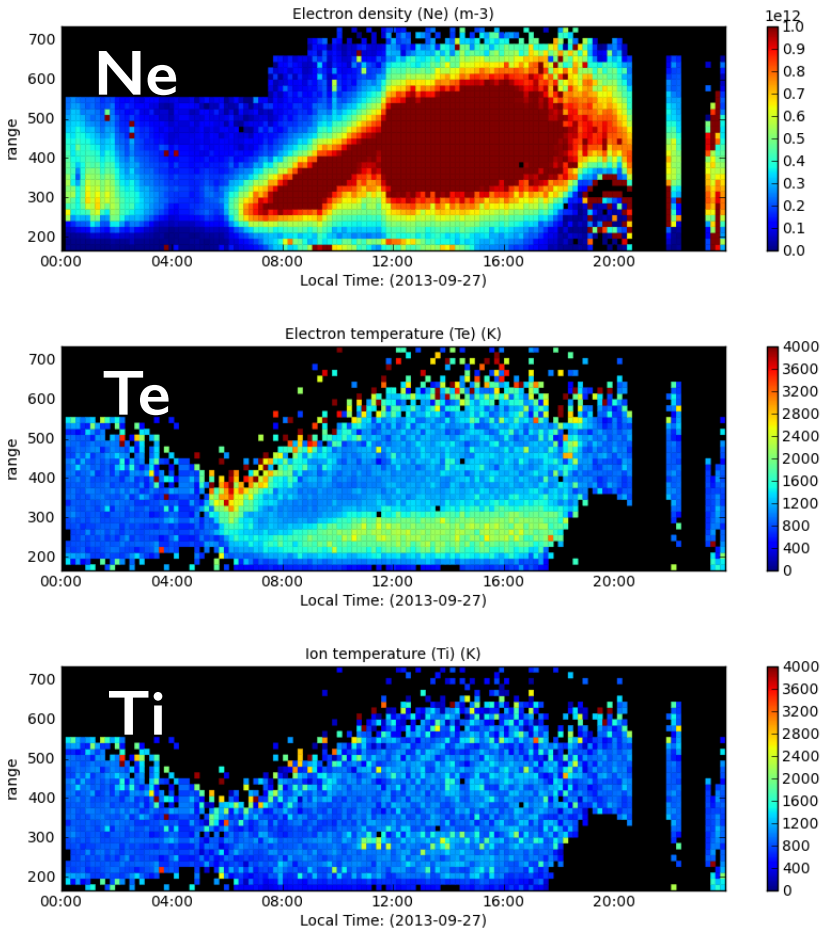
The old TR switches (spark-gaps) were replaced by solid-state TRs (diodes). This upgrade reduces pulse-distortion and noise contamination issues we had with the old TRs.

Cluster of Instruments for Equatorial and Low-latitude Observations (CIELO)

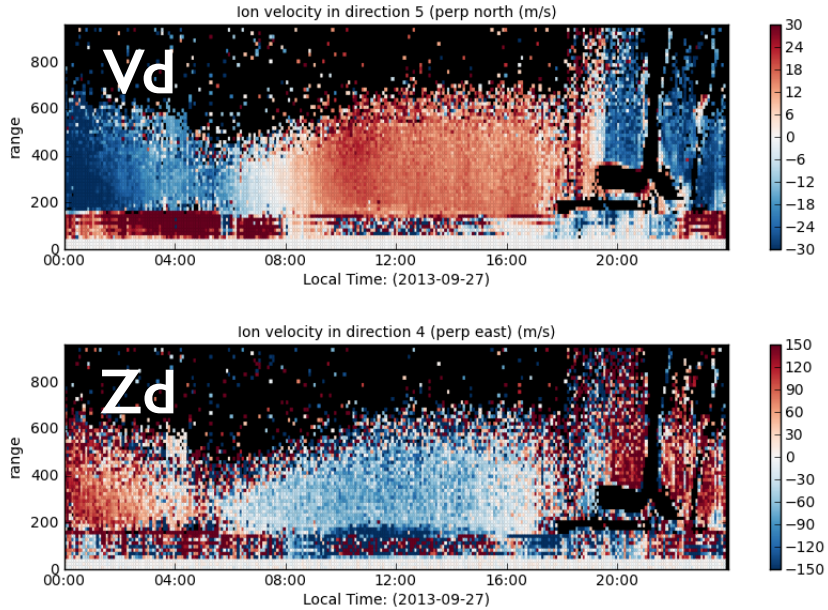
- LISN (C. Valladares, UTDallas)
- Magnetometer chain (O. Veliz, IGP)
- Digisonde (B. Reinish, U. Mass. Lowell)
- VIPIR (E. Kudeki, J. Makela, Illinois)
- Beacon RXs (P. Bernhardt, NRL, Tsunoda, SRI)
- GNSS RXs (J. Morton, MU)
- CIRI Huancayo (J. Urbina, PSU)
- AMISR14 (J. Arratia, UMET)
- FPI chain (A. Gerrard, NJIT)
- Airglow camera (C. Martinis, BU, G. Swenson,, Illinois)
- Multi-static HF radar (D. Hysell, Cornell)
- TIDDBIT (G. Crowley, ASTRA)

Standard modes and new experiments (pushing the radar capabilities)

Combo mode for simultaneous measurement of Ne, Te, Ti, Vd, and Zd

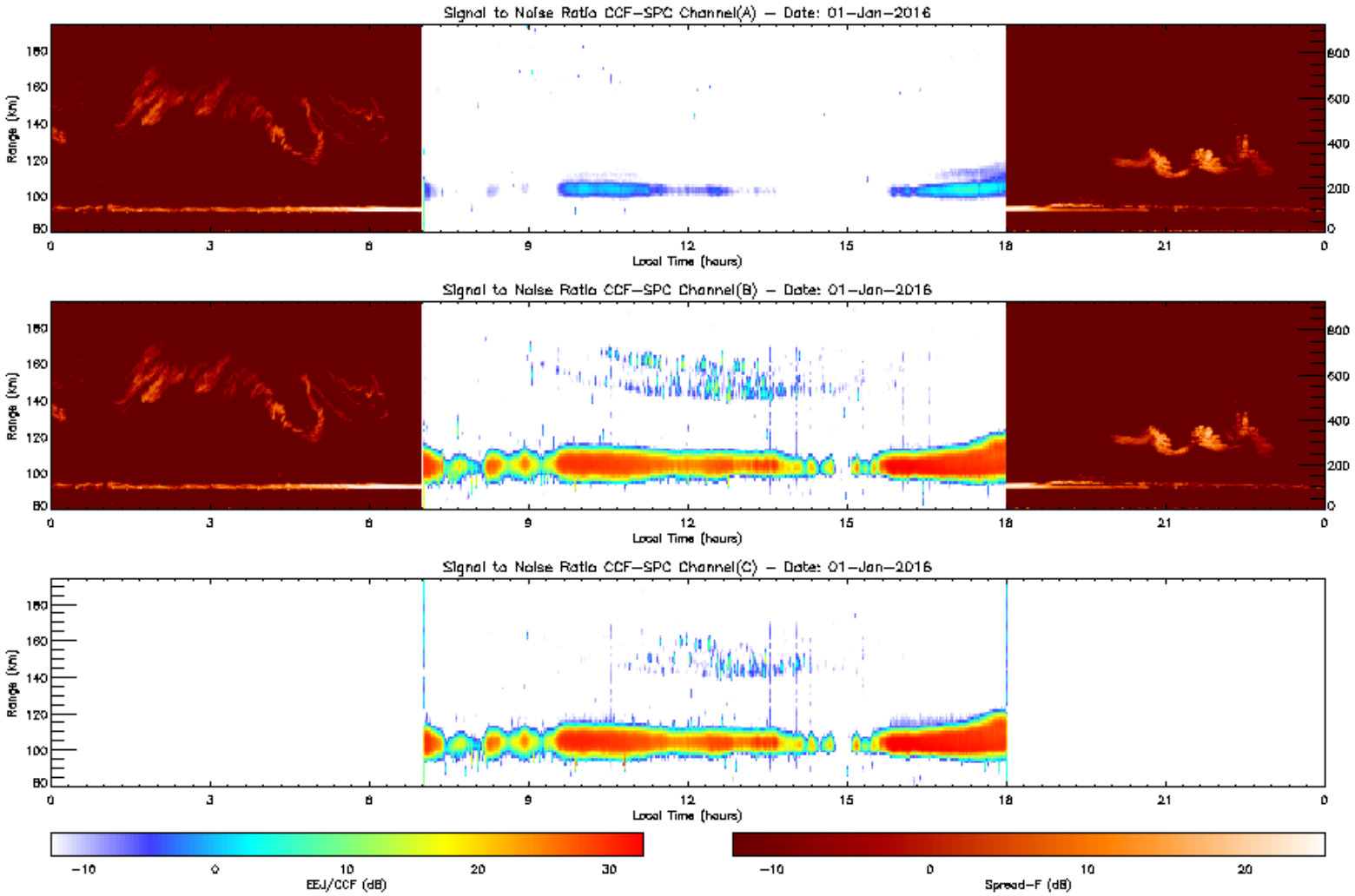


Simultaneous measurements of F-region densities, temperatures and drifts is now possible at Jicamarca applying a multi-beam radar technique that interleaves perpendicular-to-B and off-perpendicular observations.



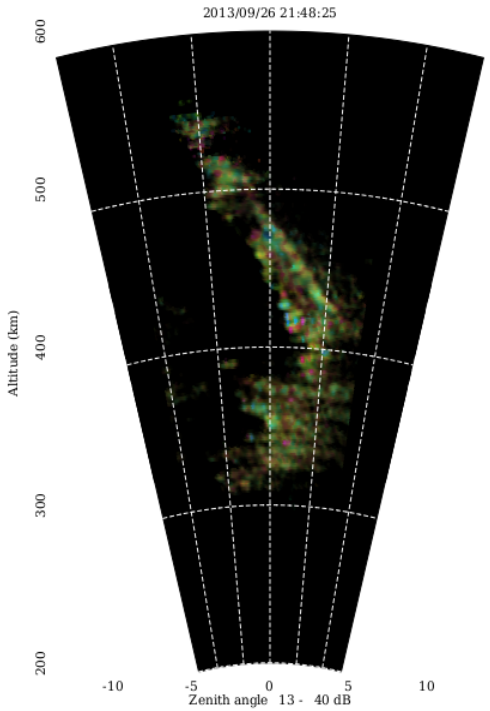
This mode is used in most of the ISR coordinated campaigns since 2013.

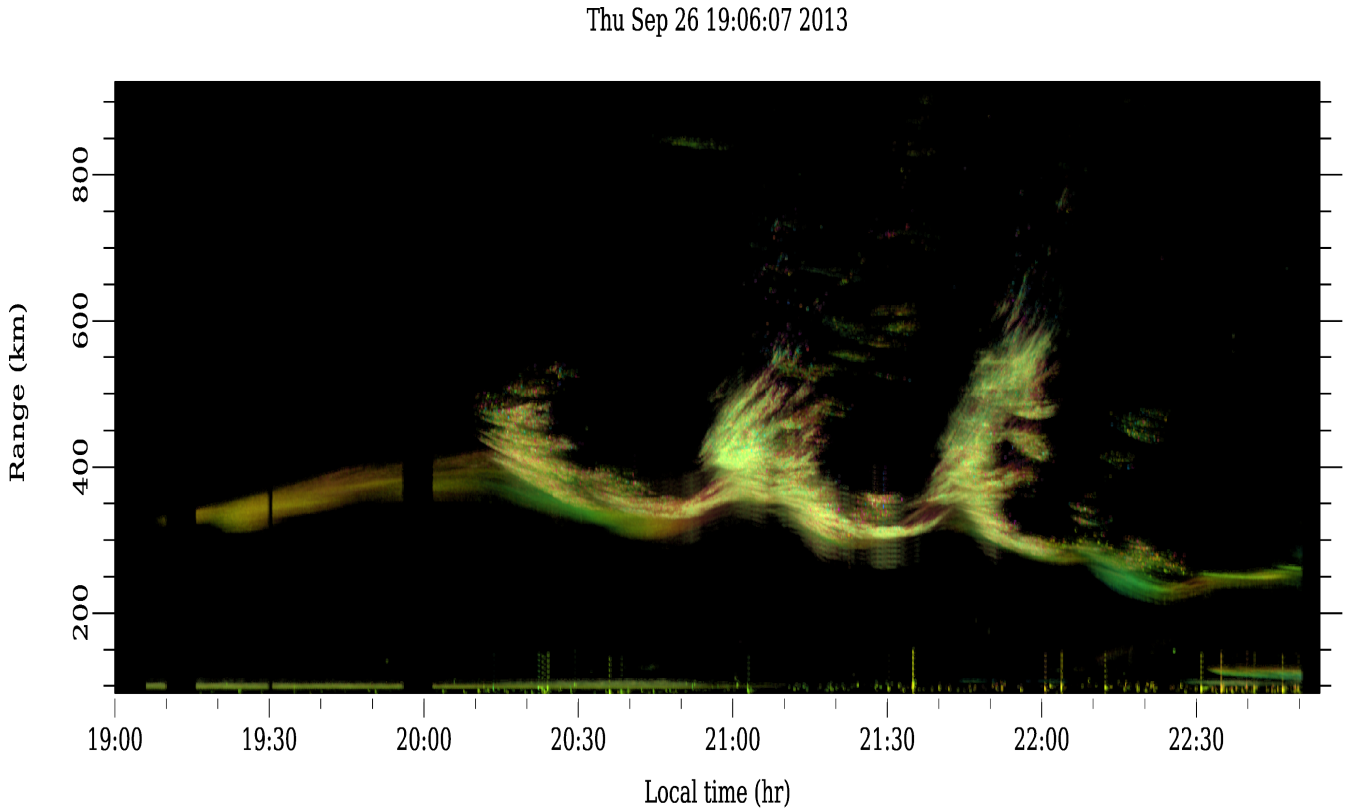
JULIA : EEJ + 150km + Spread-F observations



More than 4000 hours per year of plasma irregularities observations: EEJ, 150km echoes and Spread-F. Data available in Madrigal.

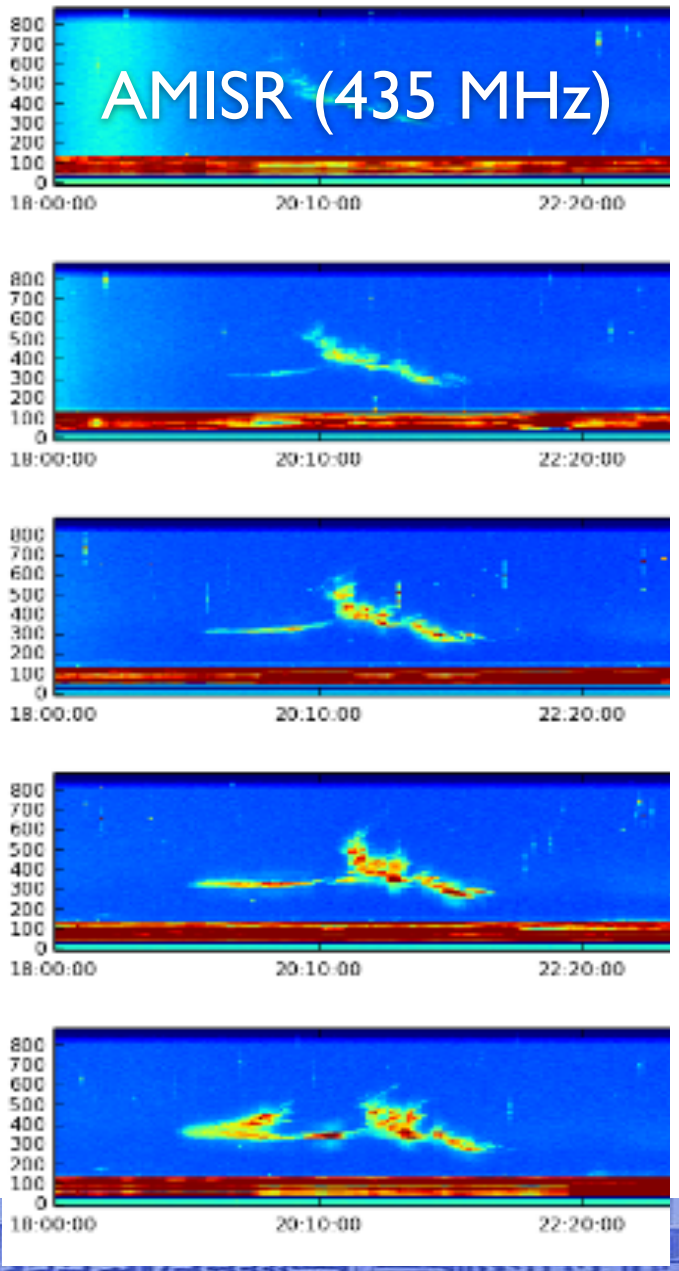
Radar imaging of ionospheric irregularities

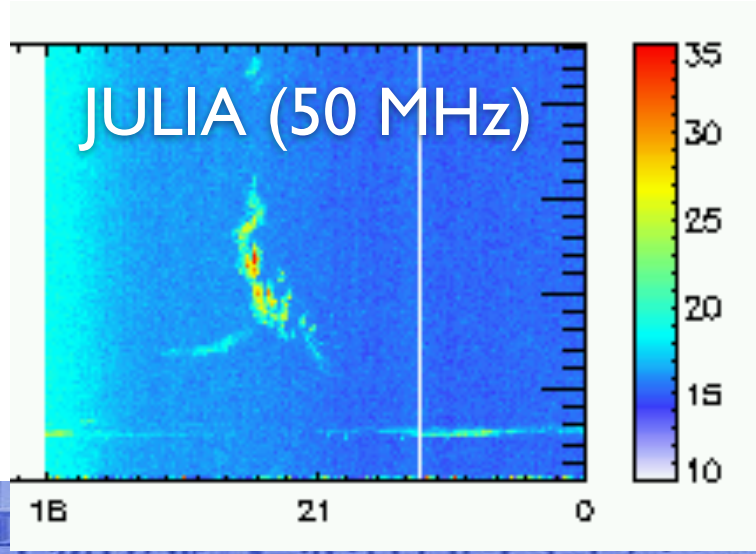




Applying a radar imaging technique we can conduct 2-D observations of ionospheric irregularities, e.g., Spread-F. This type of observations are used to conduct forecasting and simulation studies of the occurrence of such irregularities in the equatorial ionosphere (e.g., Hysell et al [2014]).

AMISR-14 in parallel with JULIA

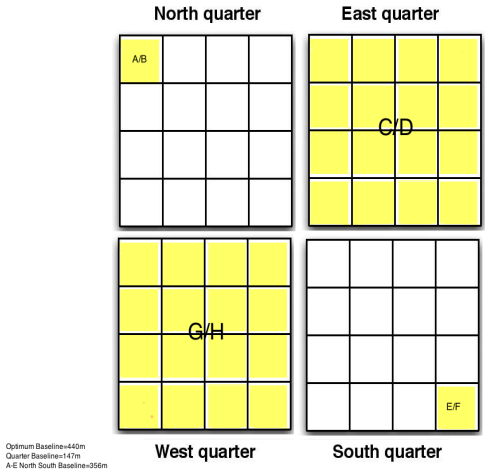




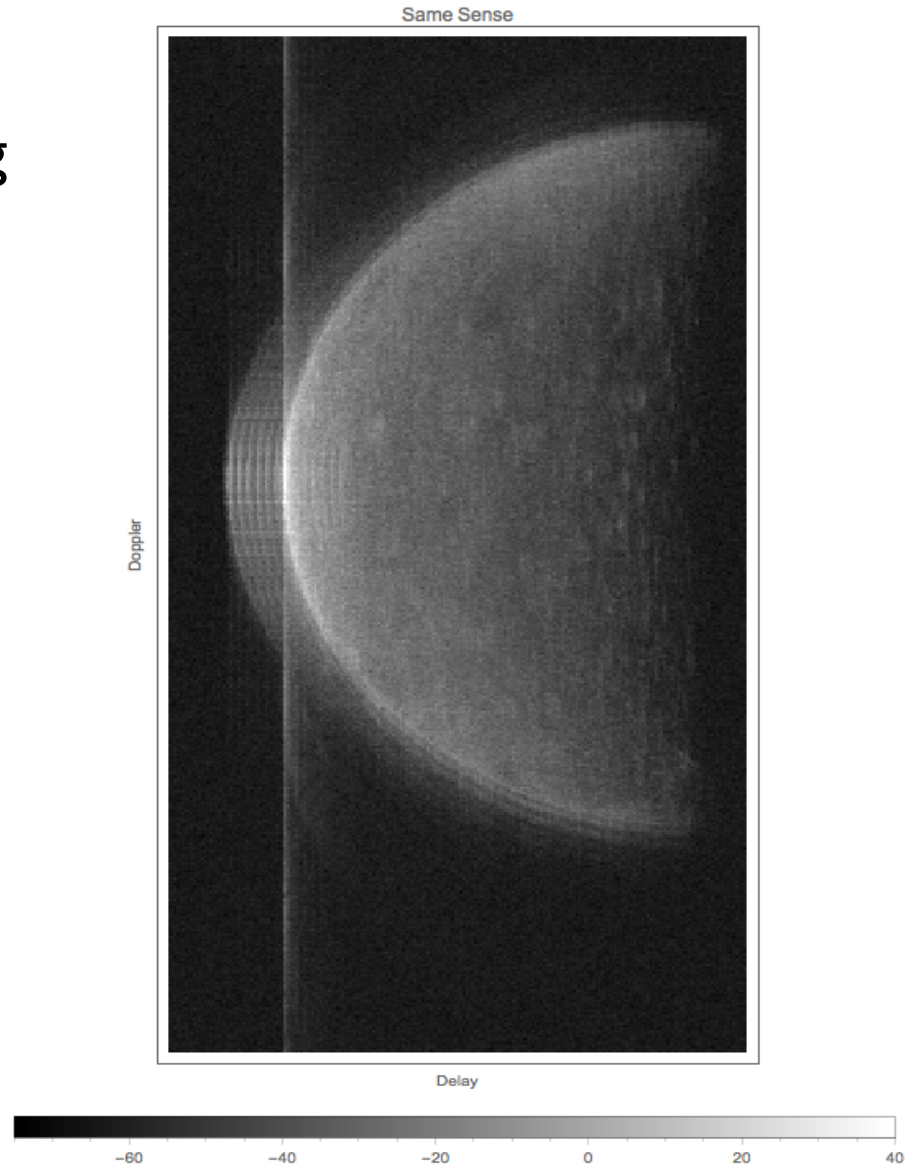
Since October 2015, AMISR-14 and JULIA operates in parallel for simultaneous EEJ and Spread-F observations.

Lunar imaging - Preliminary results

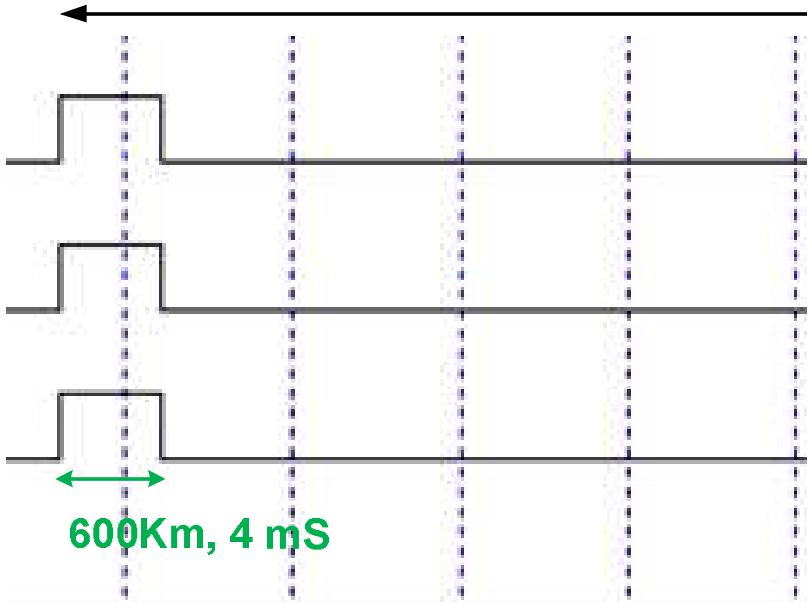
A particular radar configuration was used to image the moon in October 2015. Using the Jicamarca radar as a SAR system, maps of the lunar surface were computed to study its features and characteristics.

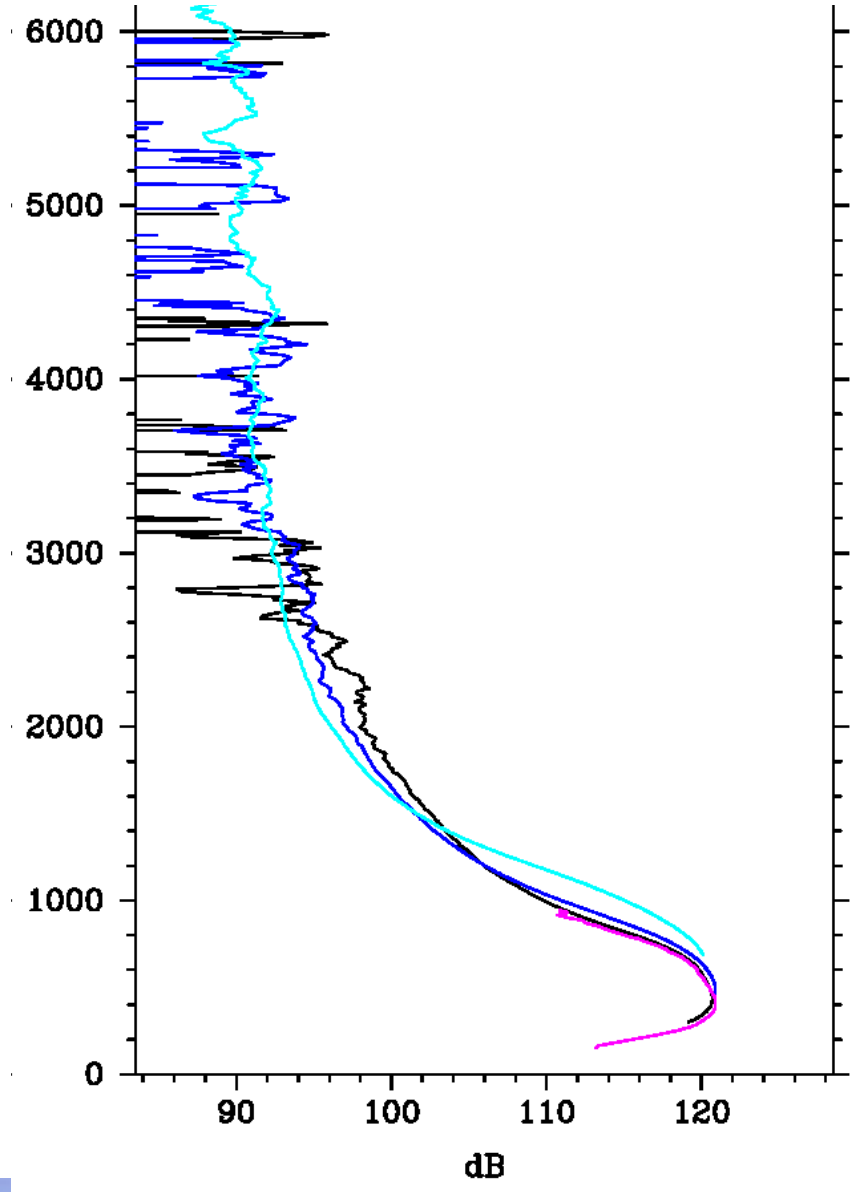


This is a preliminary reconstructed map. Artifacts due to coding issues still need to be removed.



Very long pulse experiment



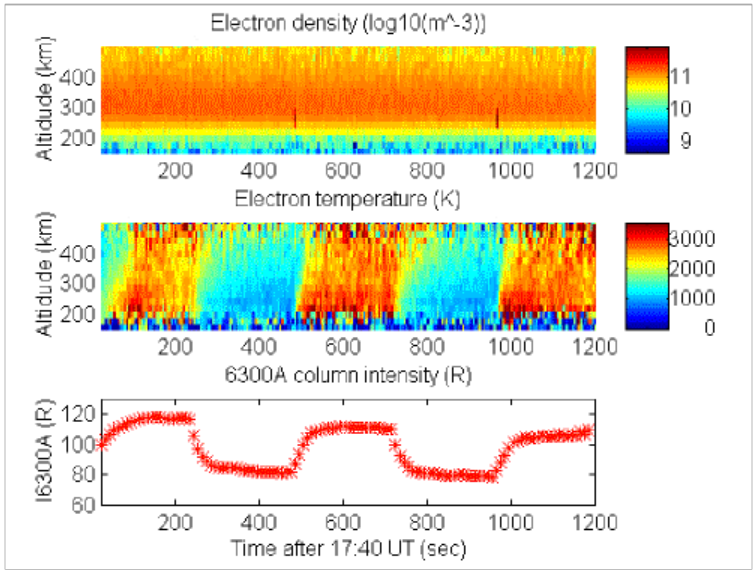


Pushing the radar to the maximum of its capabilities, we have transmitted a 4-msec pulse (600 km) to measure electron densities up to altitudes above 5000 km.

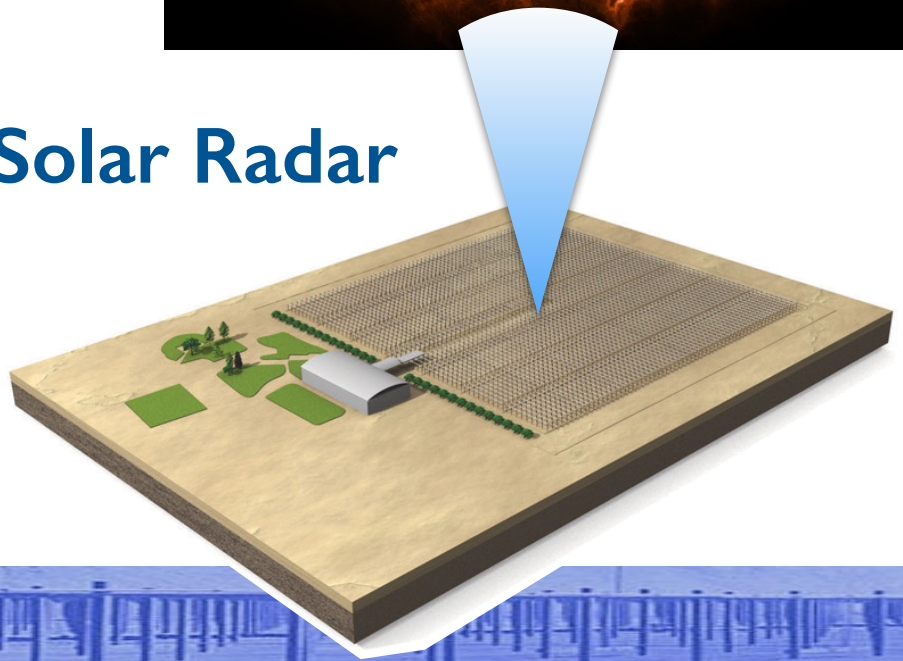
Stimulated Brillouin Scattering and Proton Gyroresonance experiments are being tested.

Ideas for the future:
More new experiments and upgrades

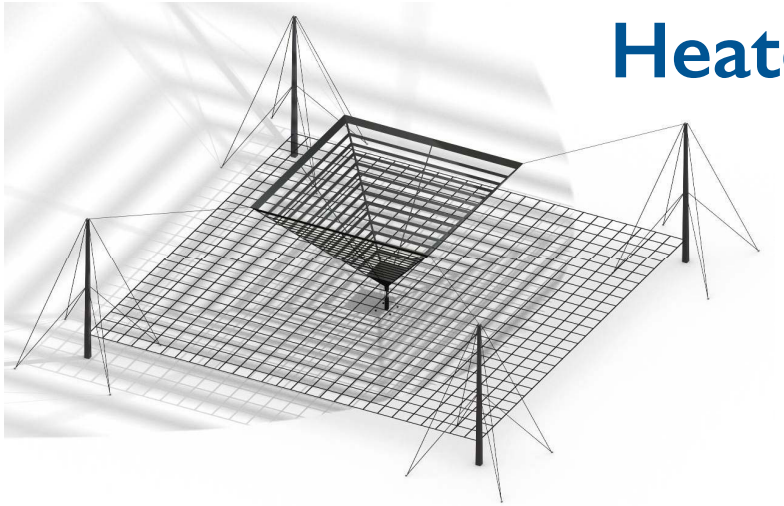
Ideas for new experiments at Jicamarca



Solar Radar

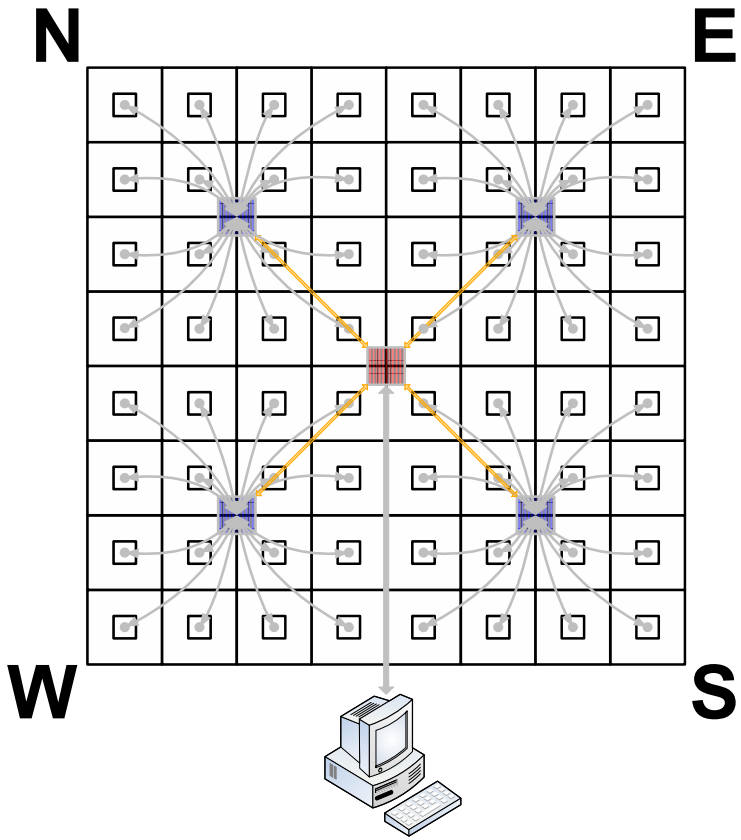


Ionospheric Heater



Short-term upgrades

- Complete the electronic beam steering system.
- Replace the antenna ground plane.



- Put fully operational the four high-power transmitters.
- Minimize cross-talk and local interference in the reception lines.

What is needed in the long-term?

A completely rebuilt antenna array

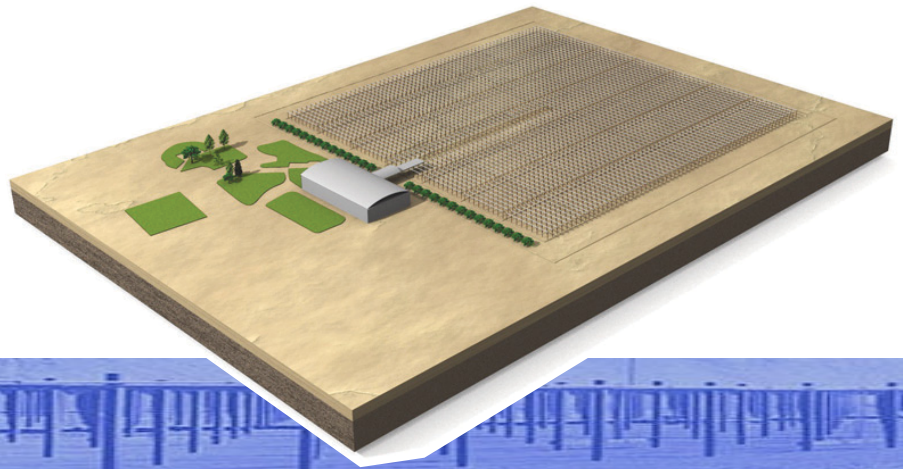
Some considerations for the new array

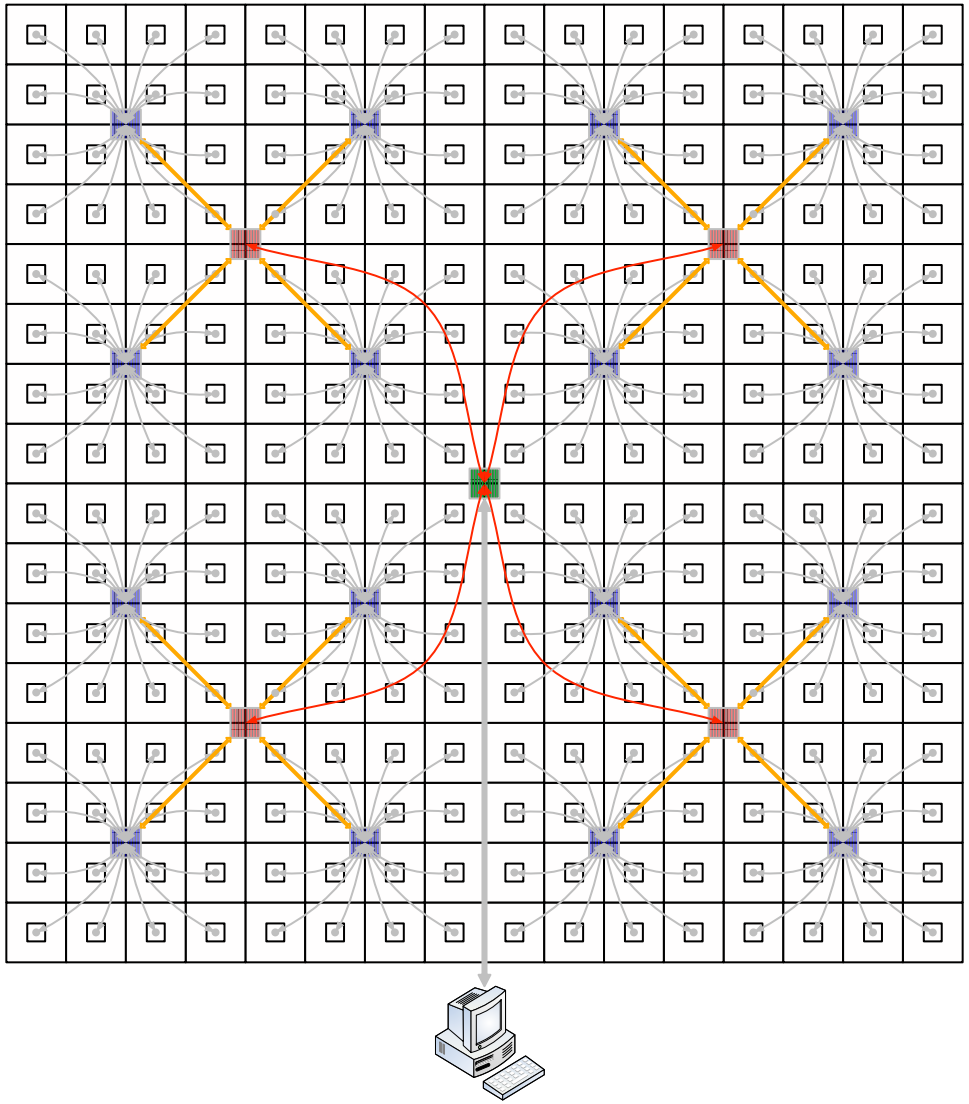
- To keep pointing perp-to-B, we need to increase angular coverage from +/-3 deg to +/-10 deg.
- To improve the quality of estimated physical parameters or to increase altitude coverage, we need to deliver more power and use narrower beams.
- To track the Sun or any other object, we need to change the beam position from pulse to pulse.
- To improve our observational capabilities, we need to transmit different waveforms and antenna patterns.

Antenna upgrades I

To increase angular coverage and be able to keep pointing perp-to-B,

- We need to increase the number of antenna modules from 64 to at least 256.
- We also need to reduce the size of an antenna module from 12x12 elements to 8x8 or even better to 6x6 elements.





Antenna upgrades 2

To improve the quality of our drift estimates, or to increase altitude coverage.

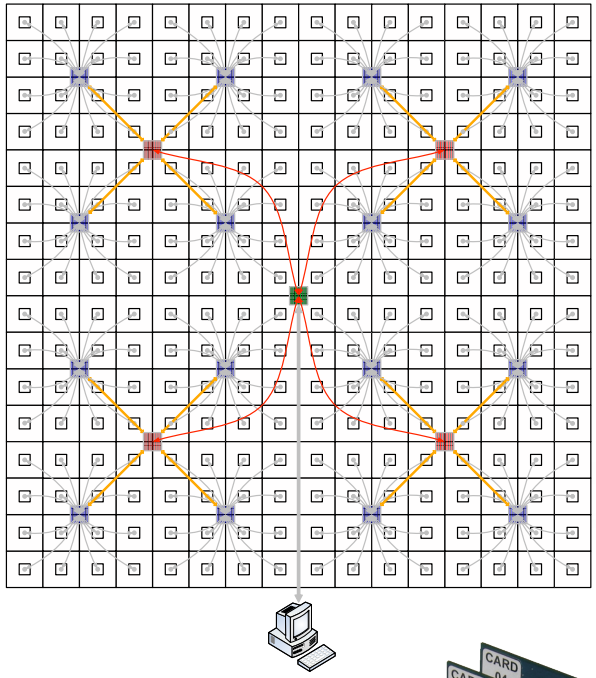
- A larger antenna array (from 300x300m2 to 400x400m2)

To track the sun or any other object.

- A new ABS system that changes beam position from pulse to pulse.

To transmit different waveforms and antenna patterns.

- A distributed power transmission system (i.e., one solid state 20 KW TX per module per polarization).
- Digital receivers in each antenna module.



Conclusion:

The Jicamarca incoherent scatter radar is a robust and flexible system that is often pushed to the maximum of its capabilities. However, in order to offer further possibilities, an important antenna upgrade should be conducted.


Thanks for your attention!