

S. Derghazarian, D. L. Hysell, K. Kuyeng and M. Milla  
High Altitude Echoes in the Equatorial Topside Ionosphere

CEDAR 2020

# Equatorial High Altitude Echoes

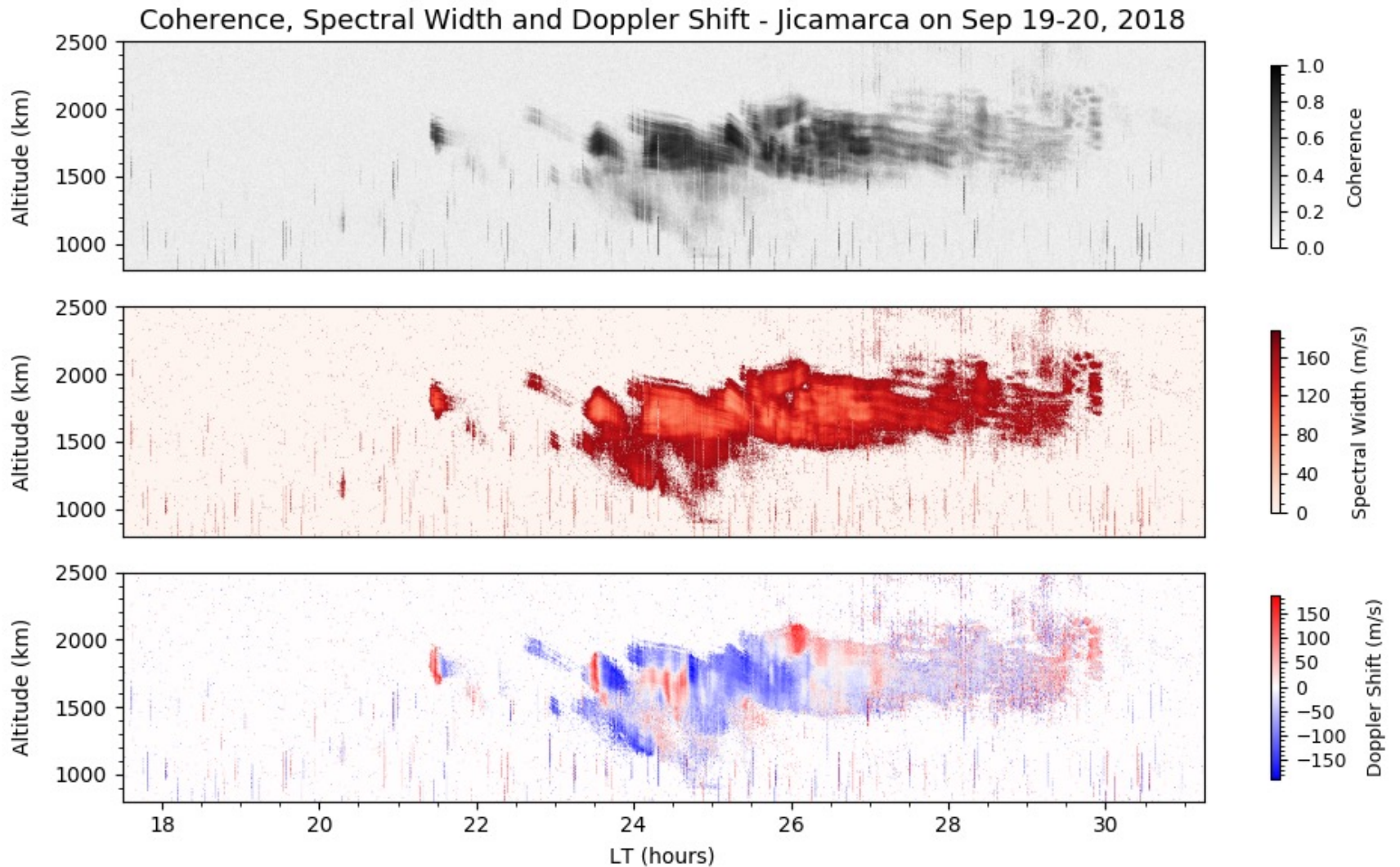
## Characteristics

- Irregularities appear in the post-midnight/pre-dawn sector at altitudes ranging from 1200km-2200km
- Thin layers rather than convective plumes
- Observed only during low solar-flux conditions
- Irregularities dissipate entirely before local sunrise
- Exhibit strong sidebands at the lower-hybrid frequency for protons
- Large increase in relative intensity of sidebands between 0400—0500 LT

## New Phenomenon?

- *Echoes exhibit strong sidebands at the lower hybrid frequency*

# Double Pulse Barker Experiment – Sept 2018



## Experimental setup:

- 13 bit barker  $100\mu\text{s}$  baud width, transmitter  $\perp \mathbf{B}$

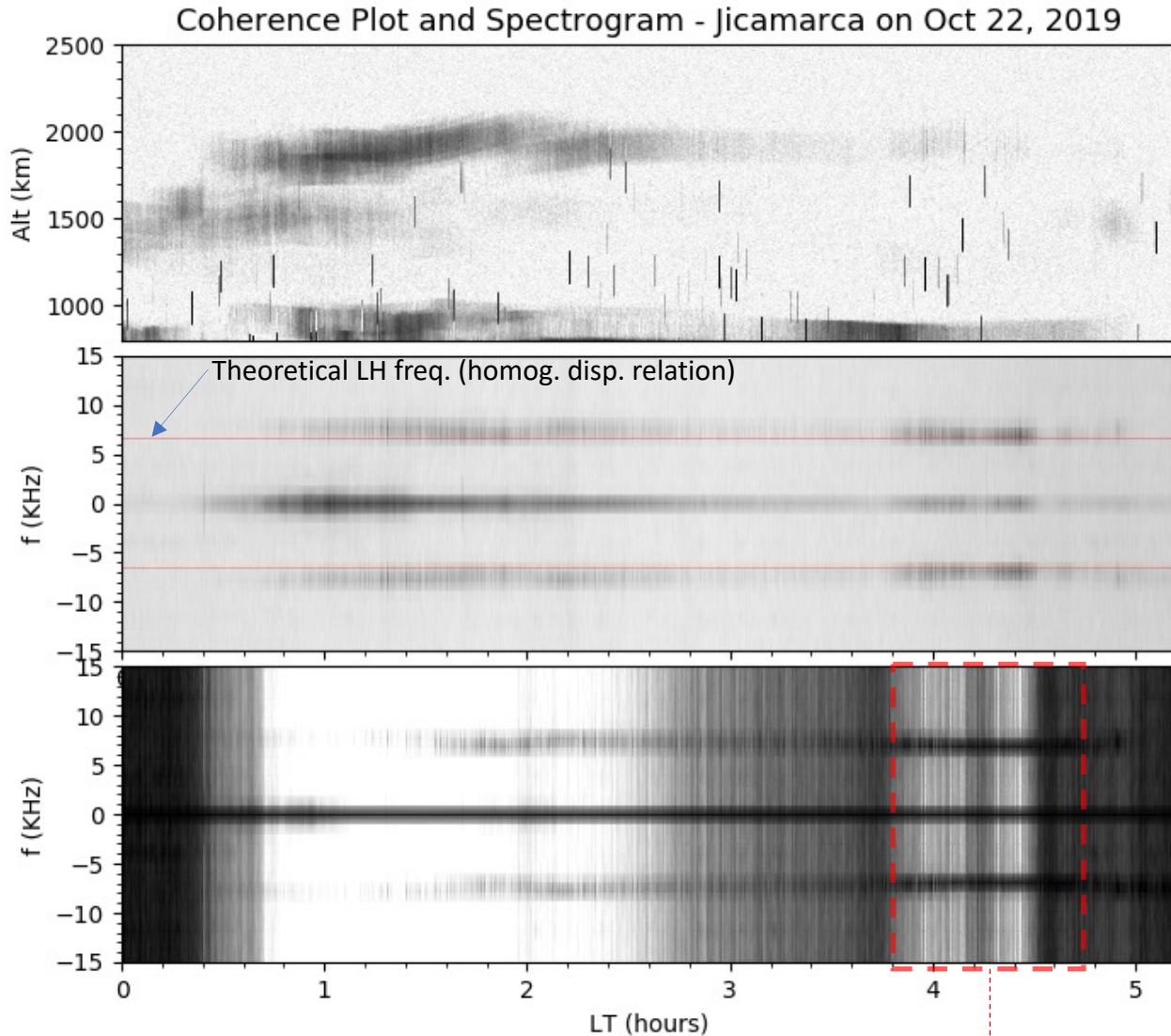
## Coherence:

- 4 ms lag product

## Key features:

- Thin layers rather than plumes
- Line of sight Doppler shifts change orientation frequently
- Dissipation before local sunrise

# Long Pulse (2ms) Experiment – Oct 22, 2019



## Experimental setup:

- $1\mu\text{s}$  sampling, 2ms long pulse, 40ms IPP,  $\perp \mathbf{B}$

## Coherence:

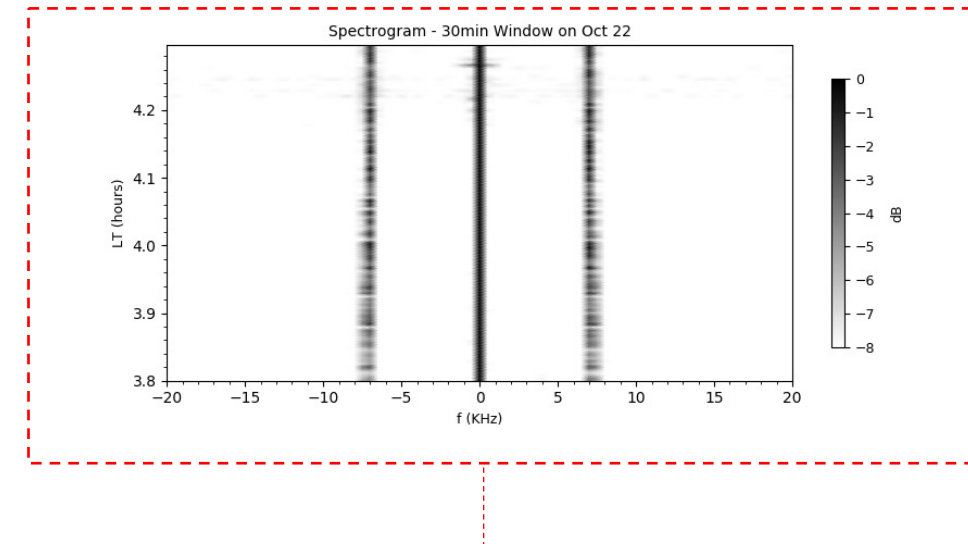
- $800\mu\text{s}$  lag product

## Spectrogram features:

- 1KHz freq resolution
- 15 sec temporal resolution

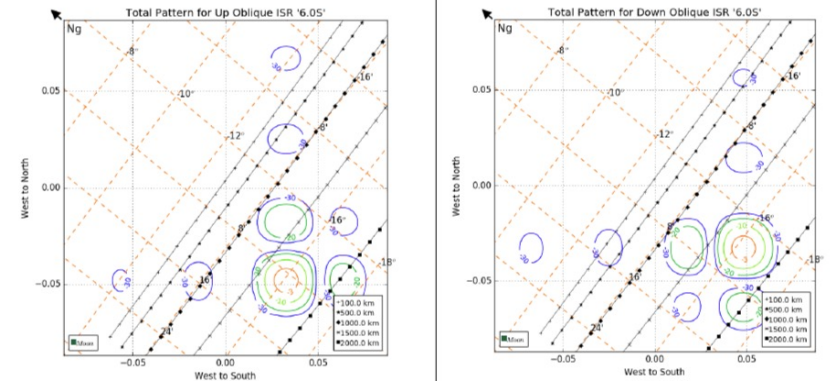
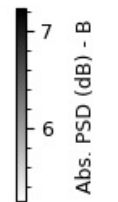
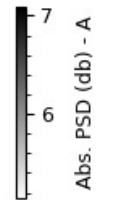
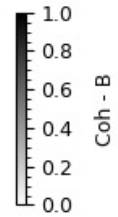
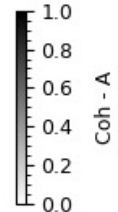
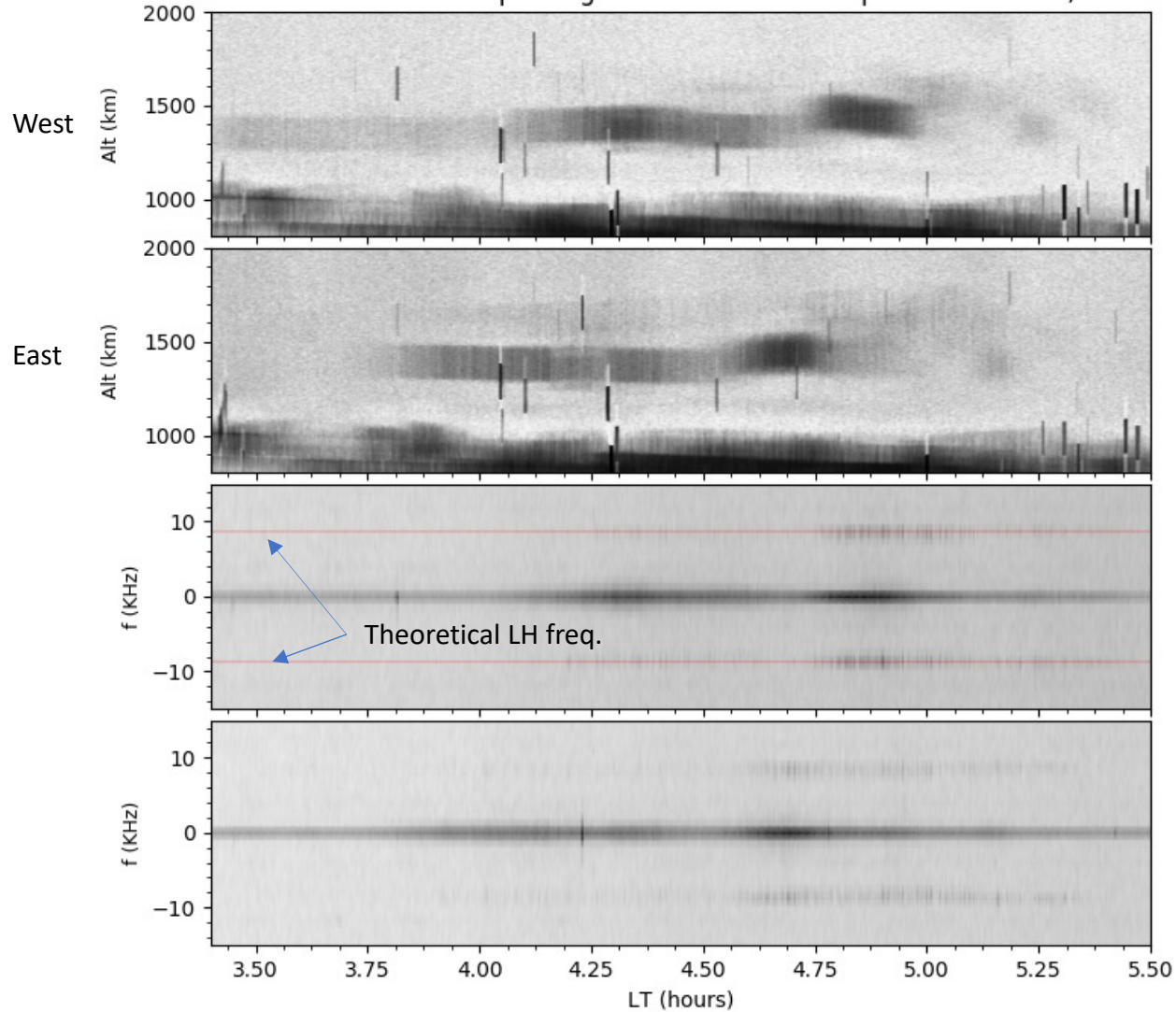
## Relative amplitude:

- High between 3.8 – 5 am
- Persistent fluctuations in LH bin amplitude



# Dual Beam Long Pulse (2ms) Experiment – Oct 23, 2019

Coherence Plots and Spectrograms - Dual Beam Experiment Oct 23, 2019



Antenna A and B separated  $\perp$  B by  $\sim 1.5^\circ$

**Longitudinal Dimension:  $\sim 270$ km**  
**Drift Speed: 45 -- 50 m/s westward**

**Spectrogram features:**

- 1KHz freq resolution
- 15 sec temporal resolution

# Phenomena associated with LH wave production

- Lower Hybrid Solitary Structures (LHSS)
  - Spatially localized structures elongated along magnetic field lines
  - Transverse dimensions: several thermal ion gyroradii (10-100m)
  - Dimensions along field lines: several to 100's of km
  - Large amplitude bursts of LH waves having frequencies slightly above and below the lower hybrid resonance
  - Reside within density depletions that vary from a few percent to several tens of percent of background  $N_e$
  - Linear theories (ex: mode conversion) – generally agree with satellite data
- Lower Hybrid Drift Instability
  - Temperature and/or density gradients in inhomogeneous plasma create diamagnetic drift which couples with a drift wave leading to a lower hybrid instability through inverse Landau damping [Huba et al., 1981]

# Future Work

## Future Experiments:

- Steerable radar (ex: ALTAIR) for zonal mapping of structures
- Coded long pulse experiments
  - Finer range resolved spectra in altitude
- Radar interferometry and imaging [Hysell and Chau, 2006] for 3D visualization
- Shorter wavelength radars (ex: ALTAIR, TRADEX)
  - Investigate cross-scale coupling mechanism between irregularities
- Bistatic radar system
  - Measurements of bulk drifts and dimensions along field lines
- Sounding rocket campaigns launched simultaneously with radar
  - In-situ electron density
  - Background VLF or other electromagnetic waves

# References

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