Unusual spectral and temporal characteristics of equatorial electrojet irregularities observed with the Jicamarca VHF radars

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## Equatorial Electrojet (EEJ) Irregularities





#### EEJ Observations: Geometry





- Wide beam (COCO array)
  - Main beam points ~45° West with a vertically oriented sidelobe.
  - For ranges > 120 km, angle and altitude information are mixed, and range represents mainly elevation angle

$$\cos\theta = \frac{\sqrt{r^2 - h^2}}{r}$$

- Narrow beam (Yagi array)
  - Narrow beams at 37° (main), 67° (first sidelobe) and 90° (second sidelobe).
  - For ranges > 120 km, ranges provide altitude information. Given the narrow beams (~1.2° HPWF) angular contribution will depend on range resolution.

#### Usual Observations with Oblique Beams



# Pure Two-Stream Waves During Counter EEJ





EEJ echoes from FB waves moving at expected ion-acoustic speed. Main Doppler shows cosine dependence (range dependence on wide beam observations). At low elevation angles, spectra are of type I, becoming type-II like at higher angles. Similar results have been obtained for the auroral electrojet [*Bahcivan et al.*, 2004] and simulations [Oppenheim, 2005, in prep]

[from Woodman and Chau, 2002]

#### EEJ Observations with Narrow beams





TSTI

## Double-peaked Doppler Spectra: First Observations



- Fejer et al. [1980] reported the first observations of Type I Double peaked spectra
- Observations were reported only west of Jicamarca/Huancayo.
- Doppler separation of ~270 m/s was attributed to a "blanketing" sporadic E layer, with sharp gradients below (smaller Doppler) and above (larger Doppler)

[from Fejer et al., 1980]

Fig. 4. A set of spectra observed at Huancayo showing the bifurcation effect. From left to right, the scattering volumes are those labeled 5, 7, and 9, in Figure 3. The integration time was  $\sim 80$  s. The integrations at 38°, 62°, and 67°, began  $\sim 160$  s, 240 s, and 320 s, respectively, after the times listed at the left.

Double-peaked Doppler Spectra: What produces the spectral splitting?

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- Winds. It will require wind differences of ~300 m/s in less than 4 km.
- Temperatures. A velocity difference of a factor of 2 implies a temperature difference of almost a factor of 4.
- Density gradients. Large density gradients are required.



Fig. 8. The effect of an electron density gradient on the type 1 threshold phase velocity for 3-m irregularities near the center of the electrojet scattering region. The length  $L_N$  is  $N_0(dN/dh)^{-1}$ , and the electrons are assumed to be drifting to the west (daytime conditions; upward electric field).

[from Fejer et al., 1980]

### Double-peaked Doppler Spectra: East and West Observations



- During a magnetic storm in Sep 22 1999, again type I Doublepeak Doppler spectra were observed.
- This time, it was also observed to the East (not as clear as the West observations, though).



## Double-peaked Doppler Spectra: Halloween Storm (12:50)



## Double-peaked Doppler Spectra: Halloween Storm (13:50)



### Double-peaked Doppler Spectra: Halloween Storm (14:50)



## Double-peaked Doppler Spectra: Halloween Storm (16:20)



### Double-peaked Doppler Spectra: Halloween Storm (16:40)



#### Multi-Instrument Observations: EEJ all-in-one



- VHF Radar Observations
  - Radar Imaging [e.g., Hysell and Chau, 2005]
  - Bistatic experiments to get *E* region densities [e.g., *Hysell and Chau*, 2001].
  - Multi-beam Narrow Oblique EEJ observations to measure *E* region zonal wind profiles [e.g., *Hysell et al.* 2001; *Shume et al.* 2005]
  - 150-km observations to get F region vertical drifts [e.g., Chau and Woodman, 2004].
- Multi-beam UHF Radar Observations using a AMISR-7 system (small version of full AMISR).
- Other instruments: Magnetometers, Ionosonde.
- Modeling and Theory.
- Simulations



[Chau, Drexler, Hysell, Oppenheim, 2005]





- Type I Double-peak Doppler spectra from recent observations:
  - These type of spectra are also observed to the East.
  - Combined effects of density gradients and zonal winds
    - Zonal winds are evident in the range dependence of Type I Doppler, particularly in the slower type I peak.
    - Density gradients are evident in the type of echoes observed (GD, TSTI, FB).
    - Are these effects related to the large day-to-day variability of type I Doppler shift?
- These and other EEJ features are being studied with different instruments and techniques (imaging, multi-frequency radars, multi-beam configurations, etc.)