Towards a possible resolution of the 150-km riddle

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Abstract

The *150-km riddle* refers to VHF radar echoes detected from the upper E-regions heights during daytime in the low latitude ionosphere. The phenomenon is a daily occurring feature above the Jicamarca Radio Observatory (in Peru) independent of the strength of electrodynamic forcing and has also been reported from other low latitude stations in recent years. The 150-km VHF radar echoes point to the existence of meter scale structuring of the electron density distribution in the height range above about 140 km and the diurnal variation of the echoing regions exhibit an intricate necklace shaped feature on radar range-time-intensity maps first shown in *Kudeki and Fawcett* (1993). Although the first reporting of the phenomenon dates back to *Balsley* (1964) no physical mechanism explaining successfully the production of the meter scale 150-km electron density irregularities has been found to date.

Kudeki and Fawcett (1993) examined a possible production mechanism of 150-km irregularities by a gravity-wave driven interchange instability process but concluded that the mechanism is unlikely to be operative given the weak electron density gradients expected for the background at upper E-region heights (as confirmed by rocket soundings in the region). Radar interferometric studies of the irregularities reported in *Fawcett* (1999) indicate that the irregularities are field aligned and furthermore their groupings (responsible to the temporal signatures seen in intensity maps) are only possible in the meridional direction --- zonal groupings are ruled out by simultaneity of short-period signal enhancements observed by multiple radar beams split in the zonal direction. Finally, the irregularities are found to advect with ExB drift indicating that the density irregularities exhibit no propagation in the reference frame of the plasma.

The mechanism producing the 150-km irregularities with the properties summarized above remains a mystery. However, some new hints about the phenomenon have recently become available at Jicamarca that may help towards to resolution of the problem: *First*, there is now direct evidence from *incoherent scatter radar* and *digital ionosonde* observations that the background densities (at scales large compared to meter waves) in the region are more structured than believed earlier on (*Chau and Woodman*, 2005). Layers of field-aligned 150-km backscatter appear to be co-located with regions exhibiting upward or downward density gradients. *Second*, Jicamarca incoherent scatter observations have revealed the presence of an additional collection of meter scale waves in the region not exactly aligned with the ambient geomagnetic field (*Chau*, 2004; *Chau et al*., 2009). These "off-perpendicular" waves have the same Doppler spectral shapes as the ion-line of ionospheric incoherent scatter from the same altitude region. They are detected by radar beams pointed a few degrees off the direction of perpendicularity to the ambient geomagnetic field and most intensely at altitudes slightly *displaced* from the centroids of the layers exhibiting field-aligned returns in the direction of increasing electron density. Overall they are weaker in intensity than he field aligned waves. At this stage it is thus tempting to interpret the off-perpendicular waves as a non-linear consequence of field-aligned meter scale waves. As for the generation of meter-scale field-aligned waves, the cause could be an interchange-type instability, as originally suggested in *Kudeki and Fawcett* (1993), now that the presence of larger-scale electron density variations in the background have been confirmed using incoherent scatter and ionosonde techniques.

The recent results summarized above shifts the burden of explanation of 150-km irregularities from the regime of meter scale density irregularities to kms scale density variations seen in incoherent scatter and ionosonde data. A natural candidate to explain the latter would be gravity-wave imposed dynamics of the geomagnetically constrained plasma in the low-latitude upper E-region. In the presence of the geomagnetic field, divergence-free gravity wave motions of the neutrals would force the partially magnetized ions (and their neutralizing electrons) in the upper E-region into divergent flow patterns compatible with the density structures observed at km or larger scales. Such an explanation would also be compatible with the gravity-wave scale temporal variability of the observed 150-km layers. Recent Jicamarca observations pertinent to waves and oscillations in the 150-km altitude range will be presented and discussed.

References

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