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A TWO-STAGE MID-LATITUDE INSTABILITY PROCESS: GRADIENT-DRIFT AND KELVIN-HELMHOLTZ WAVES?

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1 INTRODUCTION

Many naturally occurring variations of electron concentration in the Earth's ionosphere on scales from meters to tens of kilometers have been interpreted as being caused by plasma instabilities. Differing circumstances of layer, latitude, altitude, geo-magnetic field strength or orientation, electric field strength or orientation, electric current strength or direction and spatial plasma distribution control which instabilities can operate. Sometimes multiple different instabilities occur at different wavelength scales[1]. Here, evidence is presented of a two-step instability process occurring in the mid-latitude F-layer ionosphere over Europe on 30th October 2003.

2 METHOD

The MIDAS 2.0 imaging algorithm[2] is used to reconstruct the ionosphere above Europe on 30th October 2003. A grid with spacing of 0.5º longitudinally, by 0.5º latitudinally, by 30 km vertically is used. The results for the day are divided into 72 individual sequential temporal segments that each assimilate 20 minutes of GPS data, using receiver data from the European Permanent Network (EPN)[3] and from dense networks in Belgium, the United Kingdom, France and Germany (see fig.1). The limits of the reconstruction are 30º to 70º in latitude, -10º to +40º in longitude and 100 to 790 km vertically. The output consists of one value of electron concentration for each voxel of the grid for each time period. The reconstruction is validated by comparison with the EISCAT UHF antenna measurements at 300 km above Kiruna. Measurements are taken by the radar every minute; in fig.2 the mean value for each twenty minutes is plotted against the single value from the imaging algorithm for the same twenty minutes. The error bars are set at $\pm 10^{-10}$ electrons m^{-3}.

3 RESULTS

The reconstruction shows a number of structures. The features highlighted by fig.3, Box A, (wave-like contours of Total Electron Content (TEC)) are interpreted as a primary plasma instability. It should be noted that these features always grow parallel to the background gradient in electron concentration, even though this direction varies with time of day. The features highlighted in fig.3, Boxes B and C, are interpreted as resulting from a secondary instability operating parallel to the primary instability.

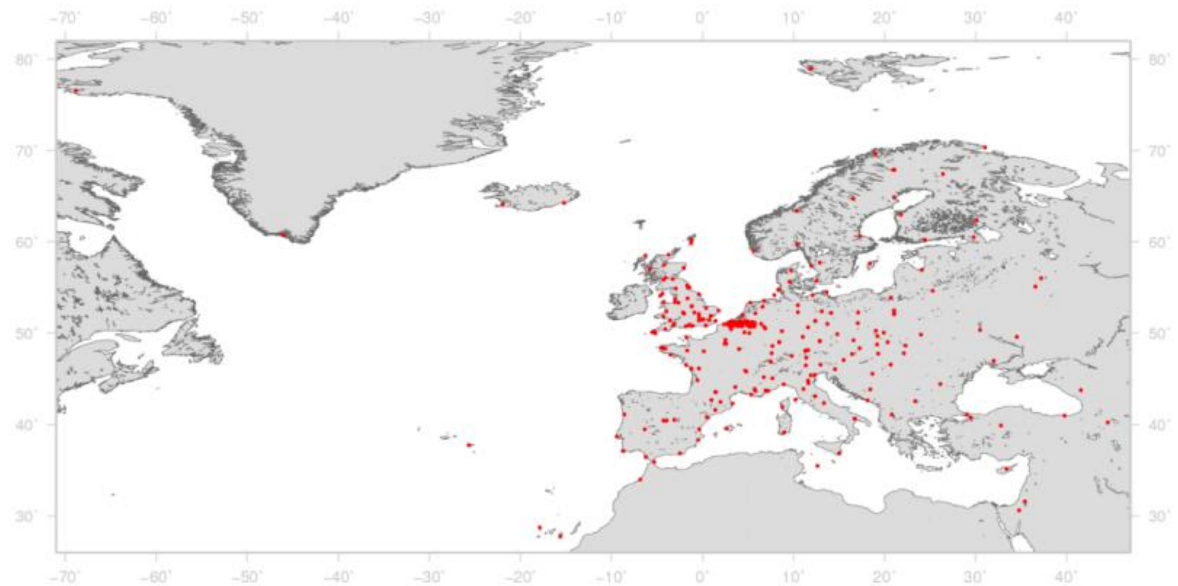

Figure 1: Locations of GPS Receiver Stations, data from which are used in the reconstruction.

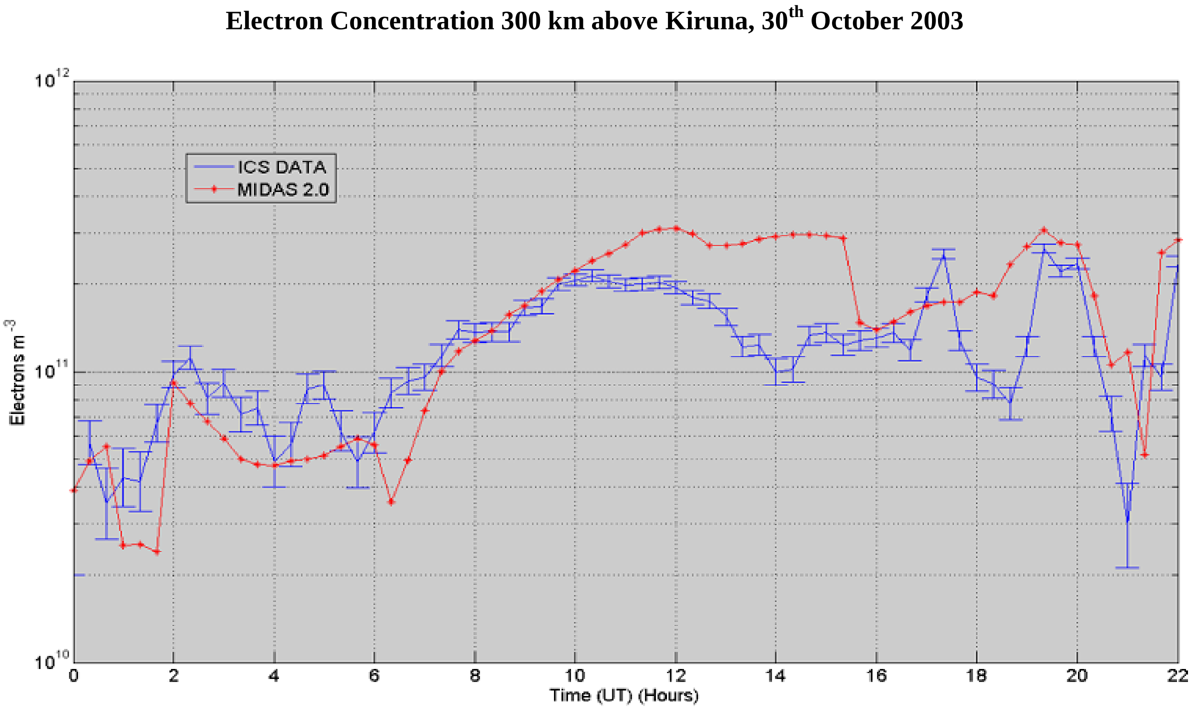

Figure 2: Comparison of EISCAT UHF antenna measurements 300 km above Kiruna with the imaging algorithm output for the same place, 30th October 2003.

4 CONCLUSIONS

The primary instability is considered to be the Gradient Drift Instability (GDI), which requires a vertical magnetic field, horizontal gradient of electron concentration and electric field perpendicular to both[1]. The geo-magnetic field has a vertical component across the latitudinal range of the reconstruction and a locally horizontal electron concentration gradient exists because of the latitudinal variation in time of exposure to sunlight. The necessary electric field could be caused by penetration of the polar-cap electric field to lower latitudes (a geo-magnetic storm is occurring on this date), or by a neutral wind, or by the charge separation of the initial seed perturbations[1]. There is no way to ascertain if such an electric field is present purely from the imaging algorithm, however.

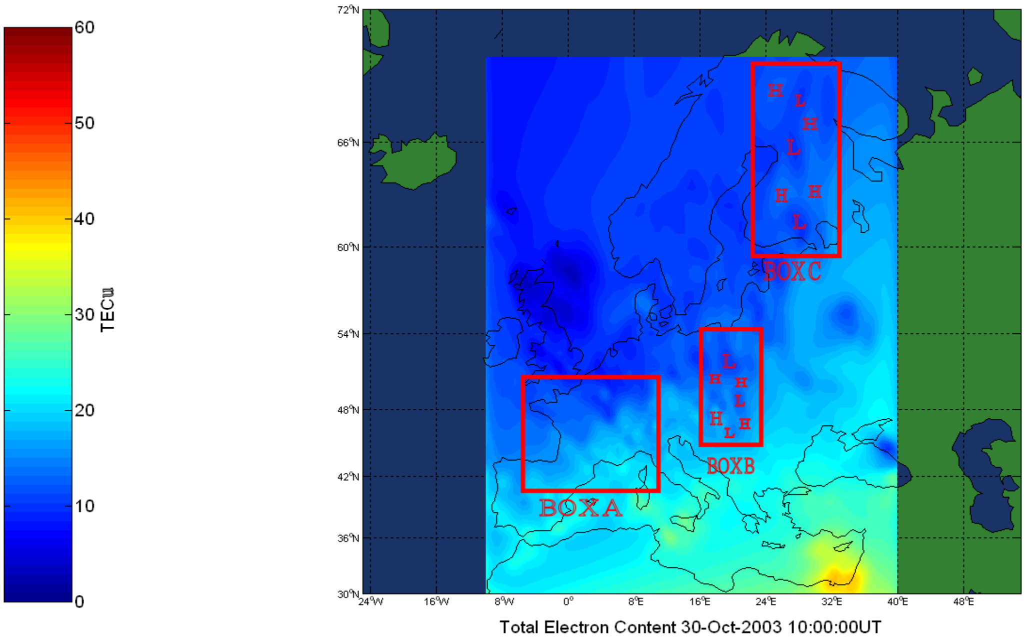

Figure 3: Reconstruction of the ionosphere over Europe, 10.00UT, 30th October, 2003. The area within Box A shows evidence of a primary instability (wave-like contours of TEC). The areas within Boxes B and C shows evidence of a secondary instability (regions of higher and lower TEC market "H" and "L" respectively).

Velocity Shear Creates Kelvin-Helmholtz Waves, Leading to Regions of Higher and Lower Vertical TEC

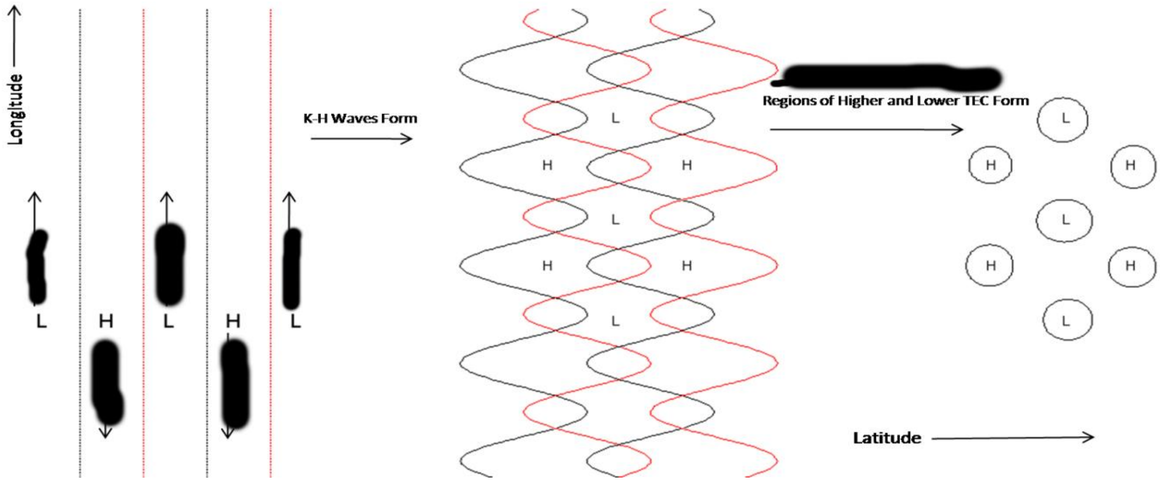

Figure 4: A velocity shears result in characteristic arrangement of regions of higher and lower TEC

The secondary instability is considered to be Kevin-Helmholtz (K-H) waves; this is the first recorded observation of such waves with locally horizontal amplitudes in the mid-latitude F-layer of the ionosphere. (Previously, vertical amplitude, E-region K-H waves have been reported[4,5], as have high-latitude K-H waves[6]). An idealized sequence of events is shown in fig.4, ending with a characteristic arrangement of regions of higher and lower vertical TEC. Comparison with the reconstruction shows similar features present in reality (fig.3, Boxes B and C). The necessary shear between regions of higher and lower electron concentration can only occur if a primary wave-like instability is operating but this interpretation is independent of the nature of that primary instability.

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