Observations of Red Line Emission and Ion Upwelling during Pulsating Aurora

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Background

- **Pulsating Aurora:** Post midnight, common event visible as patches which vary in brightness periodically, often embedded in diffuse background. Electron spectrum for pulsating aurora is ~ 10s of keV. Pulsating period 2-20 seconds is typical. Whole events usually 1.5 hours, though can be very long, up to 15 hours (Jones et al, 2013).
- **Ion Upwelling:** Part of the outflow process, ionospheric plasma increases in scale height up to ~ 400 km where they may undergo a secondary energization process and outflow. This study focuses on Type II outflow, meaning the upwelling process is driven by electron heating and ambipolar fields (Strangeway, 2005).
- A soft component of electron precipitation has been shown to exist in pulsating aurora, which may be due to secondary/backscatter electrons caused by the high energy precipitation. (Evans, 1987; Liang, 2016, references therein). Soft (100s of eV) electron precipitation is known to cause heating in the F-region which could drive ambipolar fields and lead to ion upflow.

Experiment

Poker Flat, AK on February 5, 2017

- **Poker Flat Incoherent Scatter Radar (PFISR) "TopsideUpflow2":** Ran from 12:00 - 16:00 UT, consists of 7 beam positions indicated in figure 1. Constructed to give very good F-region and topside ionosphere statistics. Beams 3-7 form a fan in plane of constant magnetic longitude through zenith. Beams 1 and 2 pointed northwest and northeast for estimation of vector velocities.
- **All Sky Imagers (ASI):** Filtered ASI data are provided by UAF (557.7, 630.0, 427.8 nm emission lines) and NASA GSFC (557.7 nm emission line). The UAF camera system consists of and EMCCD with three filters cycled on a 12.5 sec cadence. The Multi-spectral Observatory of Sensitive EMCCD (MOOSE) observatory data provided by NASA GSFC provides 557.7 nm emission line data at a rate of 3.3 frames/sec. Both ASIs generate 512 x 512 pixel images.

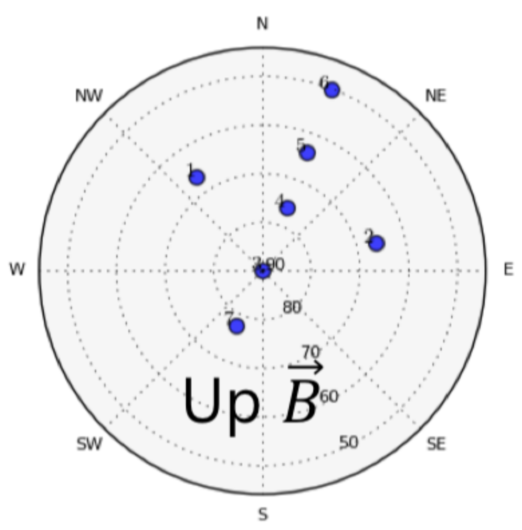

Figure 1: Beam positions for PFISR TopsideUpflow2 Experiment

Observations

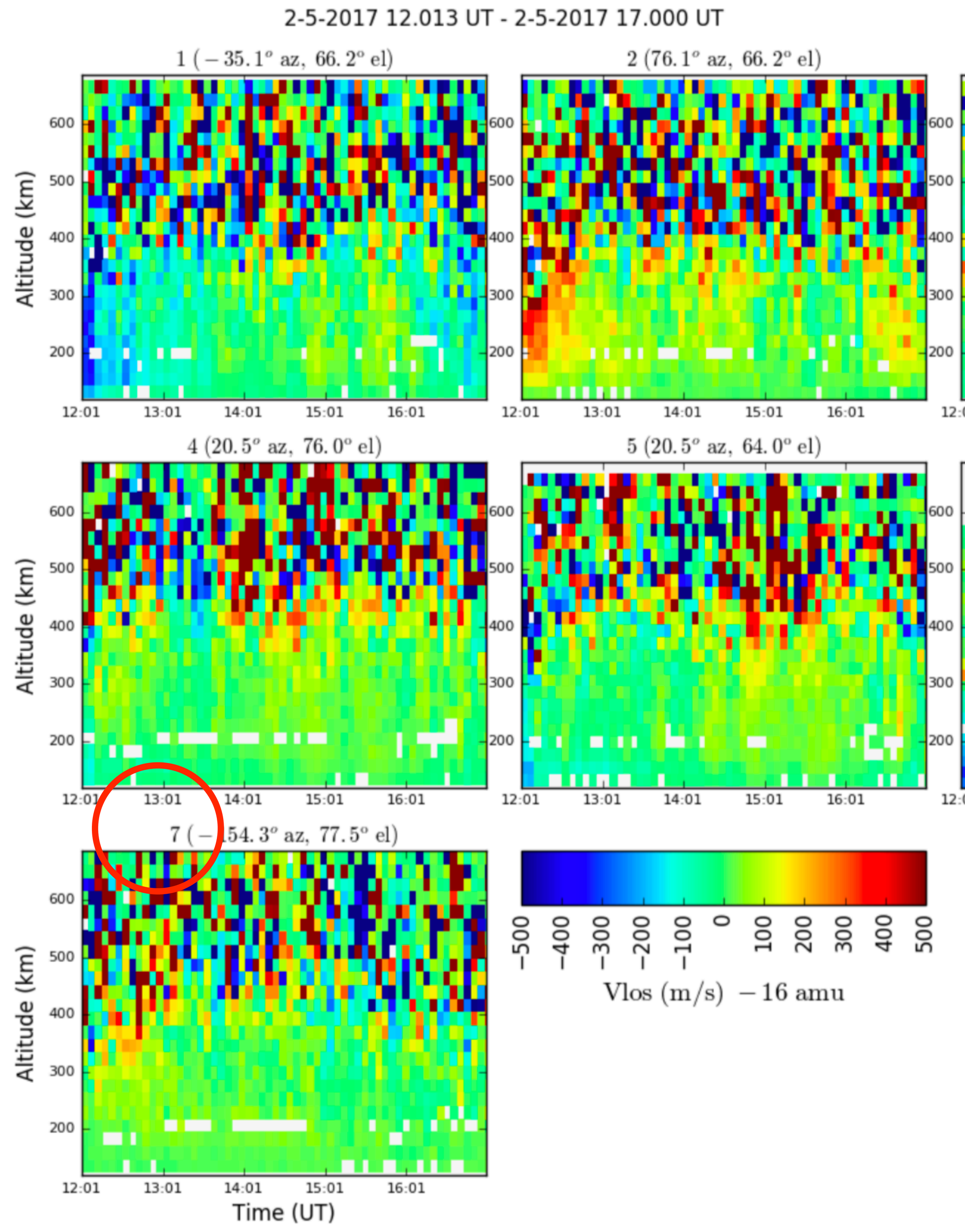

Figure 2 (7 panels above): Line-of-sight ion velocity data are shown for each PFISR beam. Positive indicates ions moving away from the beam. A single column in the plot represents a 5 minute integration time. Panels 1,2 show an eastward flow for first which weakens through the first hour, and may indicate that convection is being "shorted" by increased electron densities. Bottom panel (beam 7, mag. zenith) shows ion upflow signature (red circle).

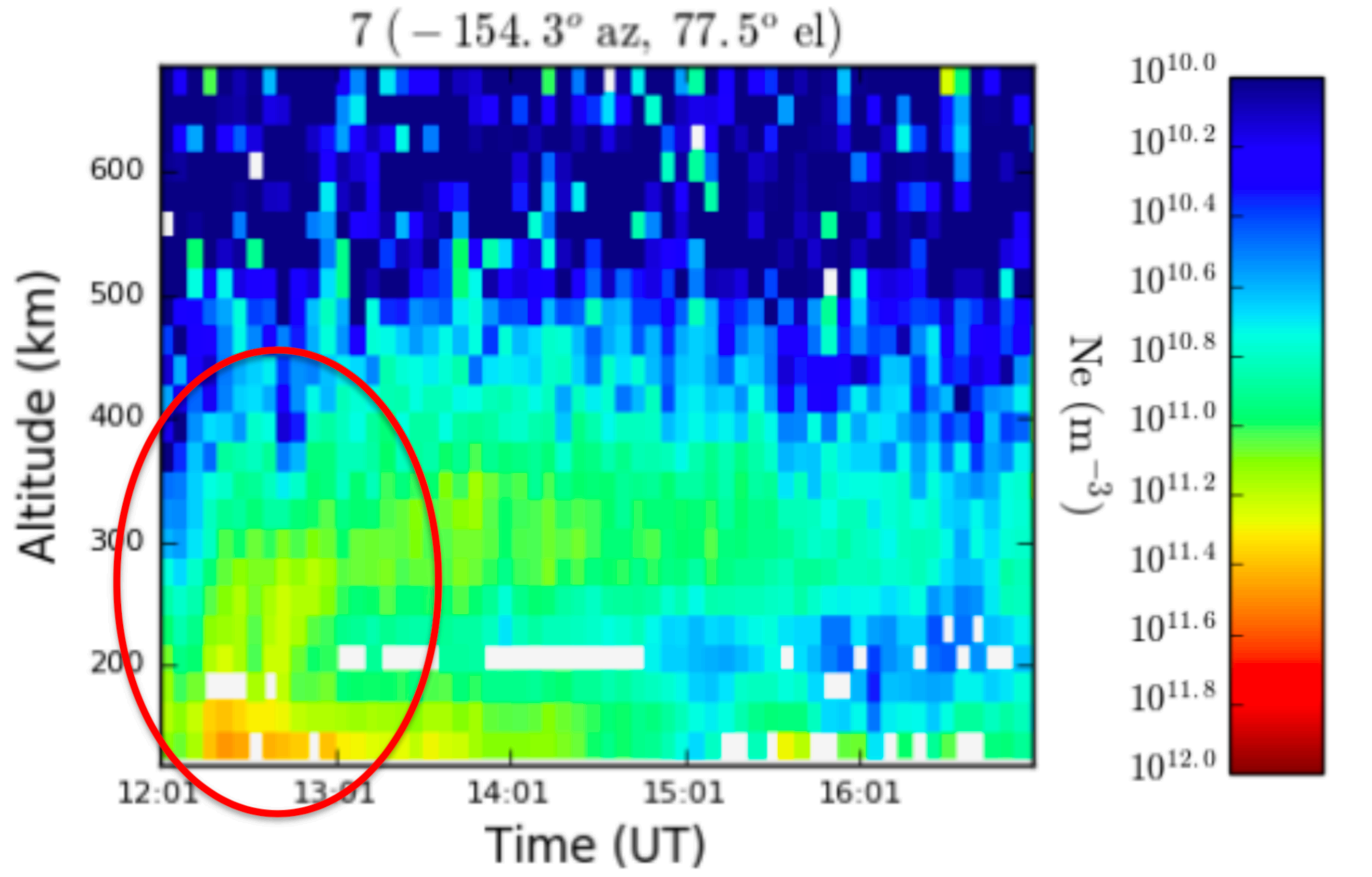

Figure 3 (above): Electron number density for beam 7 (mag. zenith). D-region ionization present at start of pulsating aurora. Electron density "plume" rises from D-region up.

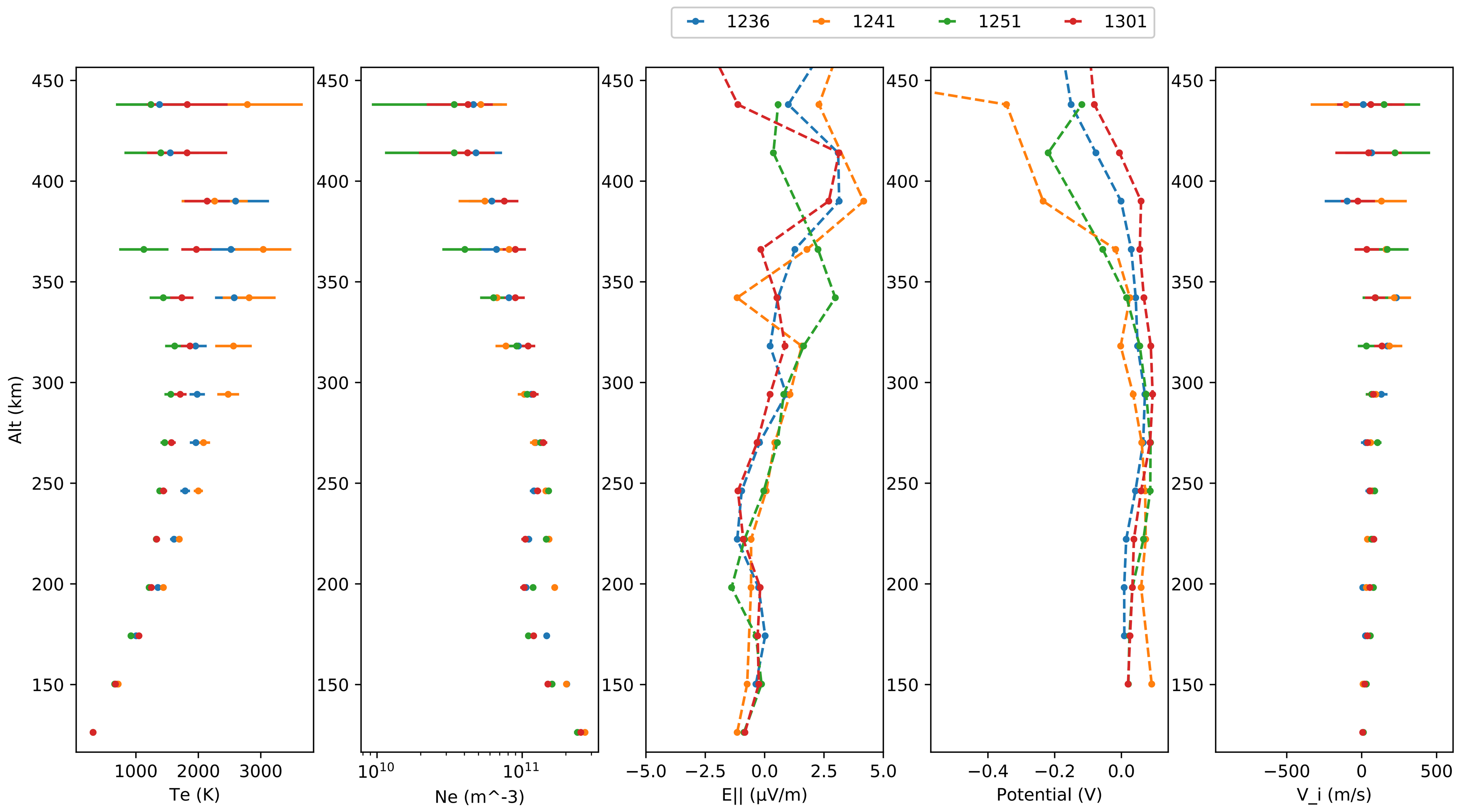

Figure 4: From left to right: electron temperature, density, ambipolar electric field, field aligned potential and line of sight ion velocity. Ambipolar field is calcualted as the gradient of electron pressure, then integrated to get the potential. These data and subsequent derivations are from the up-B direction (beam 7). The onset of red line emission coincides with the increase largest potential drop, and strongest signature of ion upflow. **Ambipolar field and ion upflow seem correlated with red line emission indicative of soft electron precipitation.**

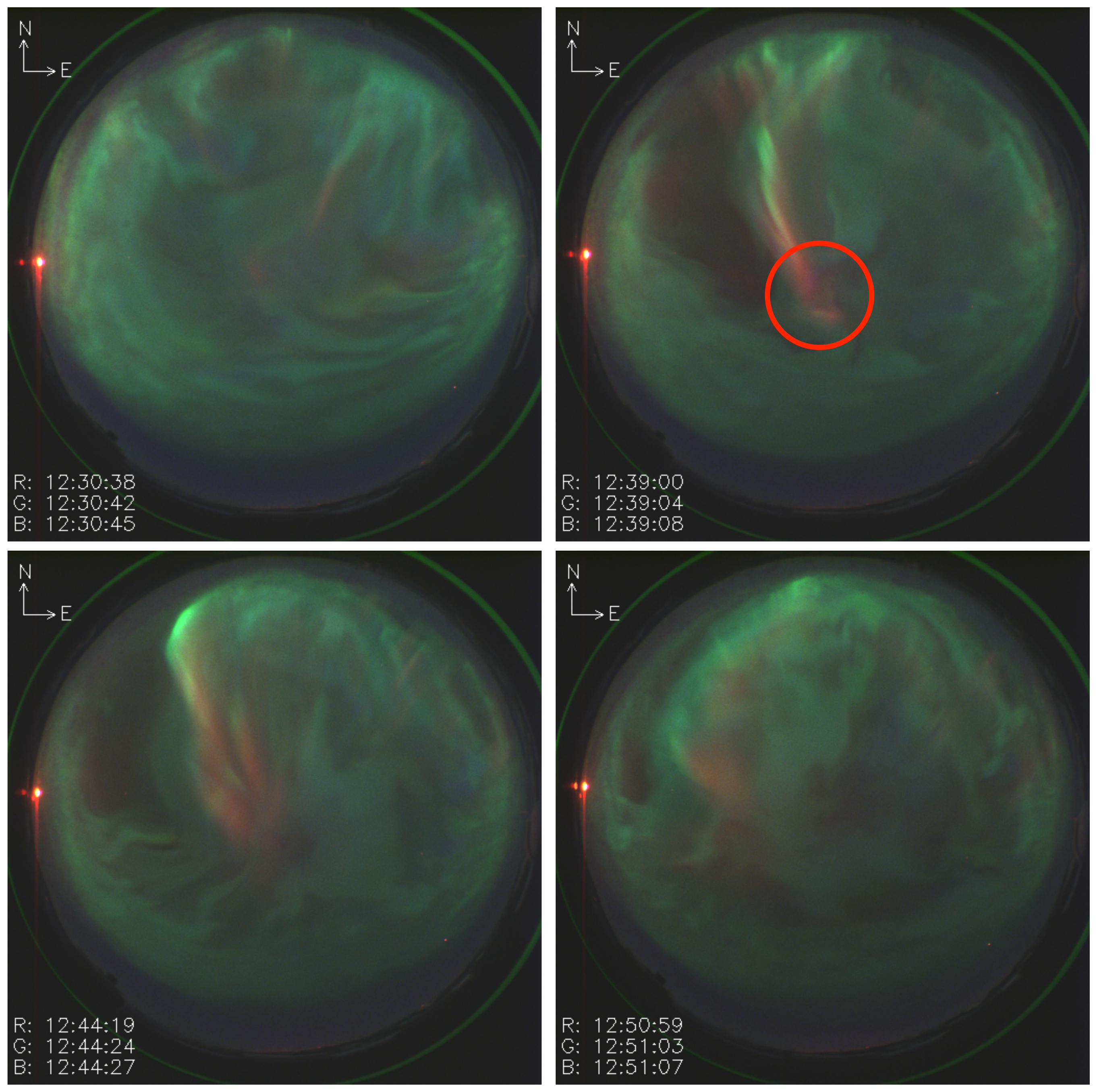

Figure 5: Composite images of 557.7, 427.8 and 630.0 nm emissions from UAF ASI. Pulsating patch structures are most visible in 557.7 (green) emissions. Sudden increase in 630.0 nm (red) emission coincides with incrase in field aligned potential drop and strongest ion upflow signature. Subsequent fading of red line coincides with return to decreased potential and upflow. Red aurora is localized, seems tied to black aurora and edge of pulsating region. Up-B direction is indicated by the red circle.

Conclusions

Using ASI and PFISR data, we have shown observations of ion upwelling embedded in pulsating aurora. This upwelling event coincides with a sudden increase in 630.0 nm emission which is often associated with soft electron precipitation. Just after the red line increase, the field aligned potential reaches a maximum. A summary and characterization of this event is as follows:

1. **Aurora begins to pulsate**
2. **High energy pulsating aurora creates electron density increase at low altitude and diminishes eastward convection**
3. **Soft precipitation begins, evidenced from the red aurora. This may be a pulsating behavior overlaid on a nonpulsating arc. The source of this arc is unknown. Some portion may be due to backscatter/secondary electrons as suggested by the small red line modulations which coincide with green line pulsations.**
4. **Ambipolar field lifts ions, causing enhanced velocity along local magnetic field seen in radar data as positive line of sight velocity.**