A detection algorithm for scale analysis of post-sunset low-latitude plasma depletions as observed by the Swarm constellation mission

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Poster in Session ST3.1
EGU2016-6318

**M O T I V A T I O N**

ESA’s constellation mission Swarm was successfully launched on 22 November 2013. The three satellites achieved their final constellation on 17 April 2014 and since then Swarm-A and Swarm-C orbit the Earth at about 470 km (flying side-by-side) and Swarm-B at about 520 km altitude. The satellites carry instruments to monitor the F-region electron density with a sampling frequency of 2 Hz.

We present an algorithm for detecting the low-latitude post-sunset plasma irregularities (bubbles) using local minima and maxima to detect depletions directly from electron density readings of Swarm. Our analyses were performed in the magnetic latitude (MLat) and local time (MLT) coordinate frame.

We discuss the global distribution of depletion depth and width of plasma irregularities and its seasonal and local time dependence for all three Swarm satellites.

**Data and Processing**

- **Observations**: Apr/2014 – Sep/2015
  - Swarm A, B, and C data
  - Swarm B and C: similar to Swarm A
  - Depletion detection: local minima based
  - Depletion width: left and right local maxima of local minimum
  - Bubble merging mechanism
    1. Left and right local maxima are same for two neighbor depletions
    2. And minimum is always smaller than final left and right maxima
  - Depletion depth: the amplitude of depletion (after merging)
  - Savitzky-Golay filter: polynomial order 3 and frame sizes 9 (4.5 s) and 201 (100.5 s)
  - Assumption: minimum depletion depth
    - $4 \times 10^4$ cm$^{-3}$ (for Swarm A, B, and C)

**Data binning**

- MLat (Magnetic Latitude), MLT (Magnetic Local Time), and GLon (Geographic Longitude)
- Bin size: $5^\circ$ in MLat and GLon; 1 h in MLT
- Mean values: for each beam

**Seasonal subdivisions**

- December solstices:
  - Jan, Feb, Nov, and Dec
- Combined equinoxes:
  - Mar, Apr, Sep, and Oct
- June solstices:
  - May, Jun, Jul, and Aug

**Bubble detection algorithm**

- Used data: 18 - 04 MLT and -37.5° - 37.5° MLat
- Depletion detection: local minima based
- Depletion width: left and right local maxima of local minimum
- Bubble merging mechanism
- Depletion depth: the amplitude of depletion (after merging)

**Conclusions and Summary**

- MLT distribution shows an inverse relation between the depletion depth and width of bubbles. This is true for all seasons and for all Swarm satellites. The bubble depth (width) is decreasing (increasing) from post-sunset to post-midnight for December solstice (Jan, Feb, Nov, and Dec) and combined equinoxes with about the same amplitude values.
- Bubble depth: decreases from post-sunset to post-midnight for December solstice and equinoxes with about the same amplitude values.
- Bubble width: increases from post-sunset to post-midnight for December solstice and combined equinoxes with about the same amplitude values.
- Bubble depth and width for June solstices: less deep and do not change significantly throughout the evening.
- The bubble occurrence maximum is around the equator between $15^\circ$ MLat, but the deepest depletions occur at about $10^4$ MLat. This is true for all seasons and satellites.
- The latitude of the deepest depletions correspond to the latitude of maximum occurrence of magnetic signatures.