Global Distribution and Characteristics of Equatorial Plasma Bubbles

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Abstract

Data recorded during the seven year period from 2008 to 2014, a period that spans more than one half of a magnetic Solar cycle and includes solar minimum and a moderate solar maximum, by the Ion Velocity Meter (IVM) as part of the Coupled Ion Neutral Dynamics Investigation (CINDI) aboard the Communication/Navigation Outage Forecasting System (C/NOFS) satellite is used to study equatorial plasma bubbles (EPBS) from 17:00 to 5:00 in altitudes from 350 to 850 km. Here EPBs are identified by profiles in the plasma density, and each may be described by its width in apex longitude, relative density reduction, and the number of local minima within it providing a simple measure of the structure. Here we describe EPB parameters as a function of location and season with the goal to discover the relationships between these parameters and the generation and evolution of the depletions.

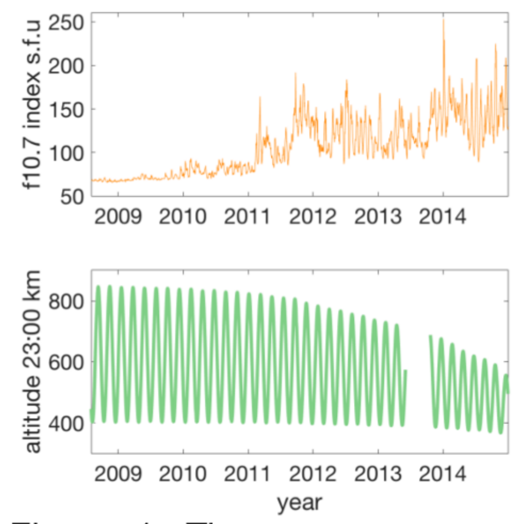

Figure 1. The orange curve on the top is the f10.7 solar flux index for the duration of the data used here. Below that is the altitude of the satellite at 23:00 over that same period of time. This pattern is produced by the precession of the satellite's orbit.

Introduction

-Atmospheric gravity waves and a collisional shear instability in the bottomside F region are both able to produce initial perturbations that can grow under the action of the Rayleigh Taylor instability [Hysell et al, 2005; Vadas & Fritts, 2004].

-When the duskside terminator aligns with the geomagnetic meridian, longitudinal gradient in Pedersen conductivity increases causing the growth rate for EPBs to rise rapidly after sunset making their detection more likely [Tsunoda, 1985], and produces an expected seasonal and longitudinal occurrence.

-More information about the nature of the original perturbations and the conditions leading to their growth might be extracted from an examination of the bubble size, depth and shape in the topside ionosphere.

-Here we examine the characteristic scale sizes of EPBS observed in the topside ionosphere by the C/NOFS satellite. We describe the changes in EPB appearance in longitude and local time as a function of solar activity from 2008 to 2014.

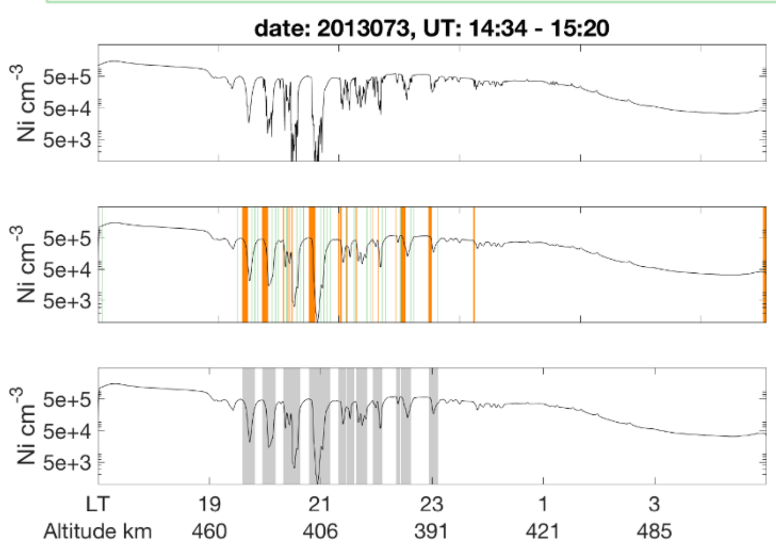

Figure 2. These three plots are a demonstration of the data processing used here. The top panel is the original data from the CINDI data. The second panel shows the filtered data with the detected edges overlayed, orange lines are leading edges, and green are trailing edges. The bottom panel shows the EPBS that are recorded as shaded regions over the filtered density data.

Method

- Coupled Ion Neutral Density Investigation (CINDI) data from the IVM on C/NOFS satellite between altitudes of 365 to 850 km is used.
- Looking for bubbles with scale sizes >100km. A median filter of the ion density over ~50km is taken to remove features below the scale size of interest, and an average filter over ~100km is taken to reduce roughness on the walls of depletions.
- Leading and trailing edges in plasma density profiles are identified from the condition that $\Delta Ni/Ni < 0.35$ between points separated by 100 km.
- For a pair of edges to qualify as a bubble they must be spaced no farther than ~1600 km apart; the edges must have a percent difference less than 50%.
- Figure 2 details this process.
- In this initial study we examine the following key parameters for depletion regions observed in the nighttime sky from 17:00 to 5:00 within ±25° magnetic latitude and ±13° geographic latitude: Local Time, Longitude, date, Width in Apex Longitude, and the number of local minima.

Results

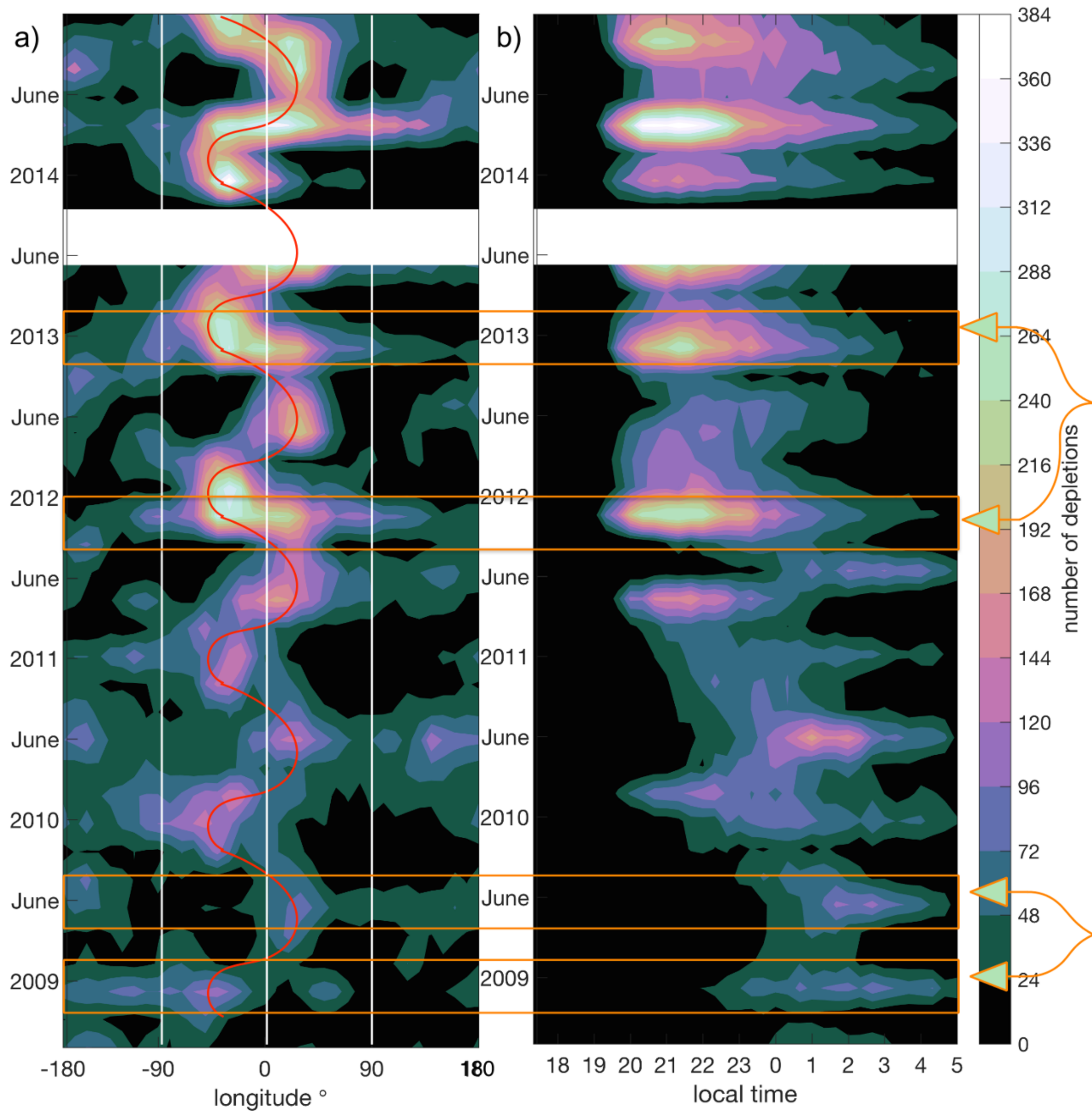

Figure 3.Seasonal occurrence of depletions in longitude and local time.[Green, 2011]

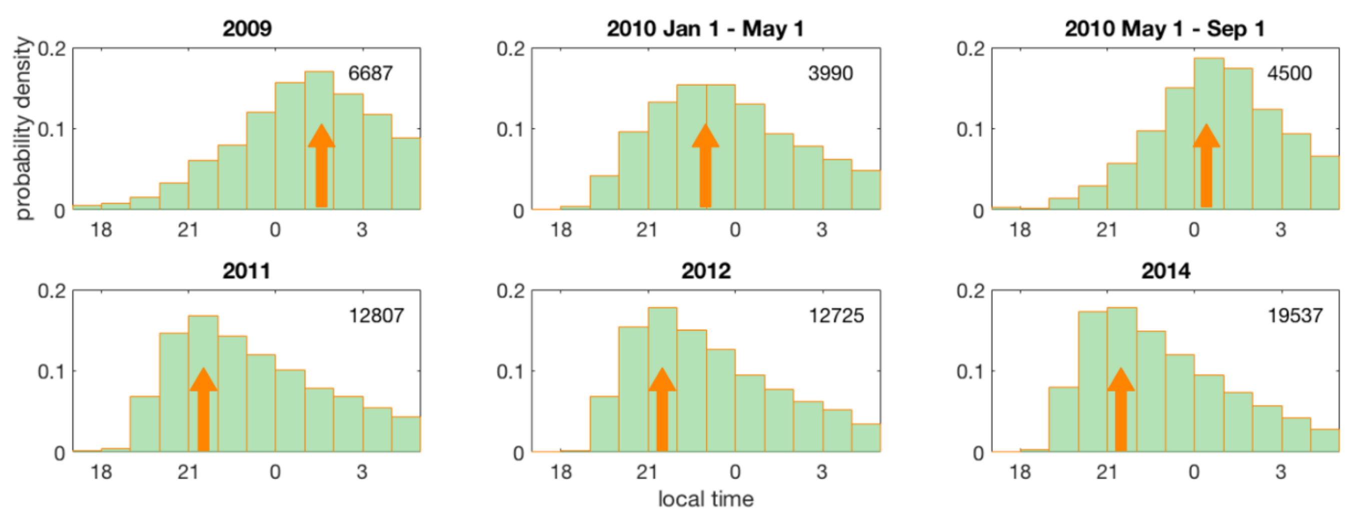

Figure 4. The histograms show the probability density distribution for the occurrence of depletions in local time, the number in the top right is the total number of depletions detected in that year or portion of year.

Local Time Dependence of EPBS

- **Peak occurrence changes from post midnight in solar minimum 2009 to post sunset in solar maximum 2014.** ***Transition occurs in 2010.***

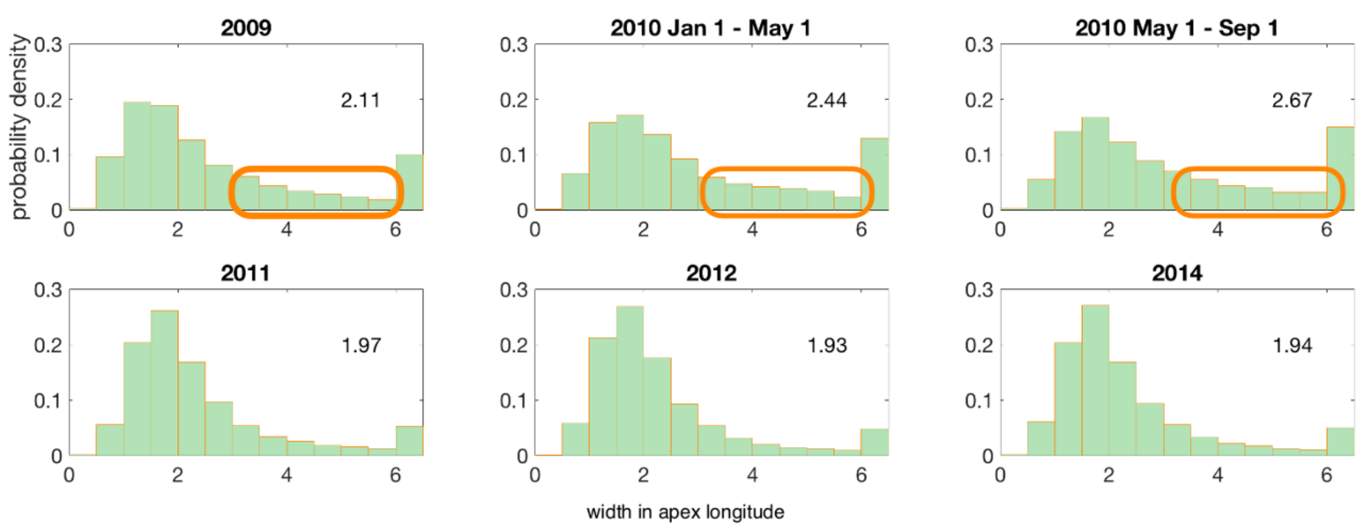

Figure 5.Probability density distribution for the widths of observed bubbles

Depletion Widths

- **Median widths near 2° apex longitude are *independent of solar activity.***
- **Wider distribution of widths at lower levels of solar activity.**

Longitude/Seasonal Dependence of EPBS

South American Sector

- **Peak during winter**
- Increases over mission lifetime due to increase in solar activity and increase in sampling region where EPBS occur.

African Sector

- **Peak with spring/summer/fall modulation.**
- **Only a summer peak in solar minimum years.**
- Spring and Fall peaks increase over mission lifetime as before.
- **EPBS extend into the Pacific sector in spring and fall equinox.**

Local Time/Seasonal Dependence of EPBS

- **EPBS observed in northern winter (South American sector) and fall (African sector) have peak in post-sunset period.**
- **At low solar activity post-midnight EPBS observed in northern winter and summer.**
- Post midnight peaks appear in Africa and Pacific
- ***Summer peaks are not observed at higher levels of solar activity.***

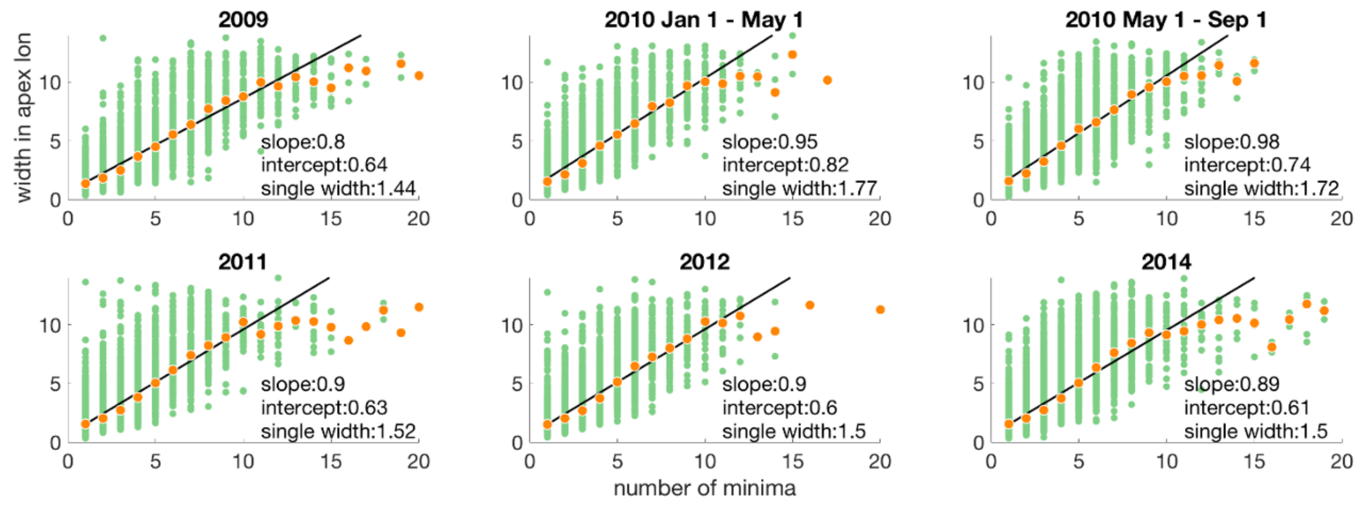

Figure 6.Widths of depletions organized by the number of local minima contained by each bubble.

Multiple Bubble Structures

- **Bubble width strongly correlated with number of local minima within bubble**
- **Linear fit suggests that bubble width is an *integer multiple* of single-minimum bubble width**
- **Excess of wider bubbles that do not represent a train of single minimum bubbles**

Conclusions

- Bubbles are primarily characterized by a single core width that is not strongly dependent on solar activity.
- Bubbles appear as single features or as groups of up to 10 core bubbles appearing as a train of embedded depletions.
- Wider depletions that do not conform to a train of embedded features are more prevalent at solar minimum.
- A post midnight peak in plasma bubbles is seen in the summer months during periods of low solar activity and is not seen during periods of moderate solar activity.
- For this dataset, increased solar activity and increased time in fertile altitudes occur at the same time requiring isolation of these parameters to understand individual contributions to increased observation of EPBS over the course of the C/NOFS mission.

References

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