Equatorial Scintillation Characteristics During Solar Minimum: Observations from the SCINDA Network

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Abstract

The Communication/Navigation Outage Forecast System (C/NOFS) satellite was launched in April 2008 for the purpose of specifying and forecasting equatorial ionospheric scintillation. For the first two years on orbit the satellite operated in a period of very low solar flux and observed a significant occurrence of irregularities in the post-midnight timeframe while detecting an unexpectedly low level of disturbances in the post-sunset sector prior to midnight. Here we investigate the occurrence of irregularities as observed from the SCINDA network of ground sensors, comparing and contrasting differences and similarities.

1. Introduction

As space weather scientists and operational users anxiously await an increase in solar activity, satellite observations have led several investigators to report new ionospheric features purportedly unique to the low-latitude ionosphere during the recent prolonged solar minimum period. The most prominent of these is the occurrence of large-scale deep density depletions in the dawn sector first discovered from observations made by the Communications/Navigation Outage Forecast System (C/NOFS) equatorial satellite (O. de la Beaujardiere, private communication, 2010). Related discoveries suggest that the majority of solar minimum equatorial plasma bubbles occur post-midnight, in contrast to the typical post-sunset formation documented during previous solar cycles. The new observations demand new explanations and have stimulated activity to identify the physical mechanisms responsible. This paper addresses the climatology and physics of ground-based scintillation observations during the same extended solar minimum period.

2. Results

The results show that scintillation occurrence is largely consistent with observations from all phases of the solar cycles and little to no enhancement in post-midnight F-region irregularities occurs. This suggests that the physical processes leading to the formation of ionospheric irregularities during the extended solar minimum period are in fact the same processes that cause irregularities throughout the solar cycle. The amplitudes and rates at which these processes occur may, however, vary significantly with solar activity. The disparity in the space- and ground-based results may be explained by considering two factors.

First, the altitude bias of the in situ satellite observations results in a failure to detect irregularities below the satellite altitude. Direct radar observations of bubble formation indicate that bubble ascent rates and peak heights decrease during solar minimum. The reason for the decrease is a reduction in the amplitude of the electric field drivers that produce the vertical plasma drifts in the ionosphere. From both radar and satellite observations these drifts become so weak that it appears gravitational forcing (i.e., buoyancy) may in fact be the dominant mechanism in many cases. As a result, many bubbles simply do not progress above the F-region peak and even fewer reach typical satellite altitudes above 500 km during periods of extremely low solar flux. Those that eventually do, arrive later in local time due to lower vertical drifts. The altitude bias of space-based observations then results in a distribution of plasma bubbles that is both reduced in number and shifted to later local time.

Second, scintillation observations are sensitive to the absolute differences in density along the radio wave raypath, not the relative variations. If the background electron density becomes sufficiently low the structured plasma simply cannot cause scintillations even if 100% relative density fluctuations are present. Thus, scintillations may not occur during solar minimum in the low density post-midnight time period even though irregularities are present. A consideration of these factors leads to more consistent agreement between space- and ground-based observations during

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solar minimum and helps to identify what ionospheric characteristics are unique to the extended solar minimum of 2006-2009.

3. Conclusions

Consideration of ground-based scintillation observations suggest that low-latitude irregularity formation processes remain the same throughout the solar cycle including the recent period of extended solar minimum. The relative balance between upper atmosphere parameters, e.g., thermosphere density and winds, plasma density and electric fields, is a function of the solar cycle, however, and is responsible for differences in the occurrence rates, amplitude, duration and the spatial characteristics of the irregularities. The weakly-driven solar minimum conditions result in marked differences in space- and ground-based observations explained largely by a combination of decreased bubble heights and electron densities. It should be noted that these conclusions do not apply to space-based observations of very large scale post-midnight plasma depletions observed by C/NOFS, CHAMP and DMSP.