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“Study of Equatorial Ionospheric Irregularities for the Assessment of Impacts on Communication/Navigation System (VII)”

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14. ABSTRACT

The main purpose of the study is to carry out a correlated study of global and seasonal scintillation morphology in the equatorial region using a coincident observation that occurred on 24 Mar 2000 between the irregularity structure observed by ROCSAT-1 and the scintillation experiment carried out at the Ascension Island. The two sets of data were studied separately first, and then compared correlatively for their causal relationship. The results show the reasonable scintillation level at coincident time to indicate a direct relationship between the irregularity structure and the scintillation in both temporal and amplitude variations. Second, since the ionospheric density irregularities are the source of ionospheric radiowave scintillation that affects space communication and navigation, in-depth investigation for the cause of ionospheric irregularities has been carried out. In conclusion, our analysis indicates that the seeding of deep atmospheric convection represented by OLR for the ionospheric irregularity occurrences has not happened as frequently as it was thought.

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1. Complete the study of "Study of a Coincident Observation Between the ROCSAT Density Irregularity and the Ascension Island Scintillation"

The detailed results of this study are published in:

"Global and Seasonal Scintillation Morphology in the Equatorial Region Derived from ROCSAT-1 In-situ Data," Liu, Yen-Hung; Liu, Chao-Han; Su, Shin-Yi, TERRESTRIAL ATMOSPHERIC AND OCEANIC SCIENCES Volume: 23 Issue: 1 Pages: 95-106 FEB 2012.

The main purpose of the study is to carry out a correlated study of a coincident observation that occurred on 24 Mar 2000 between the irregularity structure observed by ROCSAT-1 and the scintillation experiment carried out at the Ascension Island. The two sets of data were studied separately first, and then compared correlatively for their causal relationship. The scintillation statistics shows that the Nakagami distribution can portray the normalized intensity of the L-band scintillation at various S4 value, up to S4 equal to 1.4. Moreover, the departure of frequency dependence (between VHF and L band) on S4 predicted by weak scintillation is noticed due to multiple forward scattering effect. The coincident feature between the characteristics of irregularity structure and the scintillation variation do indicate that the causal relationship between the fluctuation of ion density and the scintillation variation existed. A numerical simulation using the parabolic wave equation was then carried out with the ROCSAT-1 data in space to compare with the ground scintillation observation. The results show the reasonable scintillation level at coincident time to indicate a direct relationship between the irregularity structure and the scintillation in both temporal and amplitudinal variations. This paper probably is the first attempt to verify the direct causal correlation between the irregularity structure in space and the ground scintillation observation. Although many correlated observations do indicate such causal relationship existed, a single space observation at a constant height (600 km in the case) cannot rule out other irregularity structure that existed at other altitude along the radiowave propagation path will also cause similar and/or additional scintillation observed at ground. We hope there will be more coincident observations for study to have a better understand of the causal relationship between the space and ground observations.

2. Complete the correlation study of the global distributions of density irregularity characteristics (ΔN, spectral slope, outer scale) with S_4 index.

Here in Figure 1, we plot the global distribution of density variation ΔN on the left and the spectral index on the right. The S_4 (weak and strong) maps are shown in Figure 2.

The density variation ΔN seen in Figure 1 is expected to have larger values around the EIA region because EIA region has a larger background density. When this is compared with the weak S_4 map shown in the left panel of Figure 2, no relationship between weak S_4 occurrence and the ΔN variation can be concluded. On the other hand, the strong S_4 map on the right does indicate so good correlation such that strong S_4 occurrence probability is higher when the ΔN variation is larger. However, the highest occurrence of large ΔN in the longitude region of 60°W does not correspond to the most frequent occurrence of strong S_4 around 60°E region even though the latitudinal distribution resembles to each other. It is possible that spectral shapes in the ΔN variation could have played a factor in the high strong S_4 occurrence rate. Unfortunately, the variation of spectral indices in the global distribution does not indicate any high contrast from one region to the other as seen in the right panel in Figure 1. The value of spectral indices does not change much so that no conclusion can be made at this moment. In fact, our coincident study between one irregularity structure and the ground scintillation experiment seems to indicate that ΔN, spectral index, and scintillation variation only exhibit some correlation in gross feature, without any detailed cross-correlation at one particular point or incident between the in-situ measurement in space and ground scintillation observation. This is due to the fact that the scintillation observed at ground is the result caused by all the irregularities along the radio propagation path so that observation made at any single point in the propagation path may not be able to represent the final scintillation effect at ground.

3. Complete the Study of Seeding for the Ionospheric Density Irregularities

Since the ionospheric density irregularities are the source of ionospheric radiowave scintillation that affects space communication and navigation, in-depth investigation for the cause of ionospheric irregularities has been carried out. The seasonal/longitudinal patterns of density irregularity (as well as scintillation) occurrences have been known to follow more or less the seasonal/longitudinal variations of the alignment of the sunset terminator with the local magnetic flux tube. However, the day-to-day variability of irregularity occurrences is so unpredictable that the latest investigations [see for example, Tsunoda, 2010 a, b, c, GRL; 2010 JGR] have indicated that the day-to-day variability of irregularity occurrences could be tied to the seeding mechanism originated from the upper atmospheric disturbances. The most likely seeding agent is the atmospheric gravity wave that is generated during the deep atmospheric convection period. The generated atmospheric gravity wave can propagate upward to the lower ionosphere to become a seed for the Rayleigh-Taylor instability process that generates the ionospheric density irregularities.

The current investigation adopts a statistical approach to study the correlation between the probabilities of the occurrences of deep atmospheric convection represented by the outgoing longwave radiation (OLR) observed by a satellite and the occurrences of density irregularities observed by ROCSAT. For an observed OLR below 200 w/m^2, a deep atmospheric convection is known to occur so as the occurrence of an atmospheric gravity wave. The current report investigates the statistical correlations between the distributions of irregularity occurrence and the OLR occurrence in seven different longitudinal regions based on different magnetic declination angles. Figure 3 shows the global averaged occurrence pattern of density irregularities observed by ROCSAT-1 in 1999 to 2004 in the top panel versus the occurrence pattern of OLR in the same period observed by the NOAA satellites. The seven geographic regions are given in a table shown in the lower part of the figure. At the first glance of comparison between the top two panels, we notice that except for the Africa continent and Atlantic region there is little correlation between the irregularity occurrences and the OLR occurrences. On the contrary, negative correlation between the occurrences of irregularities and OLR occurrences seems exist for the rest of five geographic regions.

Because the seasonal effect of irregularity occurrences is not considered in the result of Figure 3, the outcome of comparison could be misleading. Therefore, in Figure 4(a) and Figure 4(b), we show the seasonal variations of the two occurrence patterns. We notice that while the occurrences of irregularities are concentrated in the African and Atlantic longitudes in every season, the OLR occurrence pattern on the other hand seems to spread evenly in many longitude regions. Thus the correlation between the seasonal/longitudinal occurrences of irregularities and the OLRs seems lacking.

A final plot for the correlation between the monthly occurrences of irregularities and OLR is shown in Figure 5. Again, lack of correlation between the two occurrence patterns is very obvious.

In conclusion, our analysis indicates that the seeding of deep atmospheric convection represented by OLR for the ionospheric irregularity occurrences has not happened as frequently as it was thought. There could be by chances that a few deep atmospheric convections have been observed to produce ionospheric irregularities. However, the probability of such correlated occurrences seems very low. Other seeding agent originated from the electrodynamic origin, such as the bottomside sinusoid (BSS) in the bottomside ionosphere should be studied to understand the day-to-day variability of the irregularity occurrences.

The result of this work will be presented in the International CAWSES-II Symposium held in Nagoya, Japan, Nov 18 to 22, 2013.

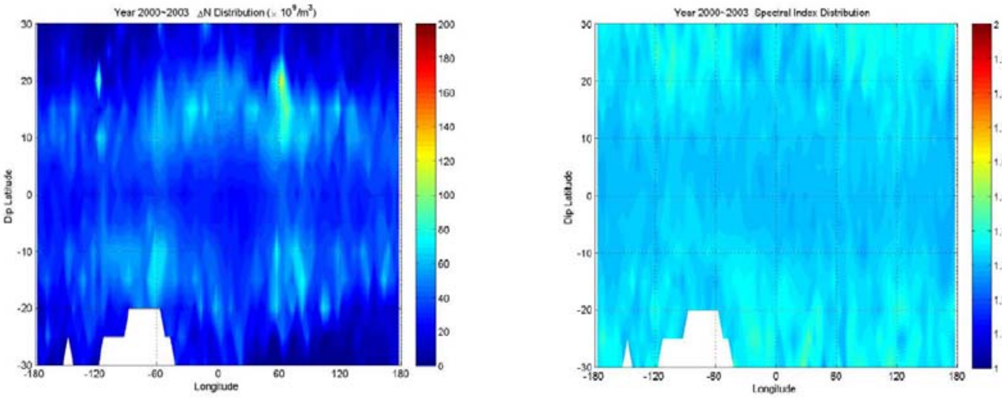


Figure 1. Global distribution of ROCSAT observed density variation ΔN in the irregularity structure is shown in the left panel. The distribution of the spectral index of density variation ΔN is shown in the right panel.

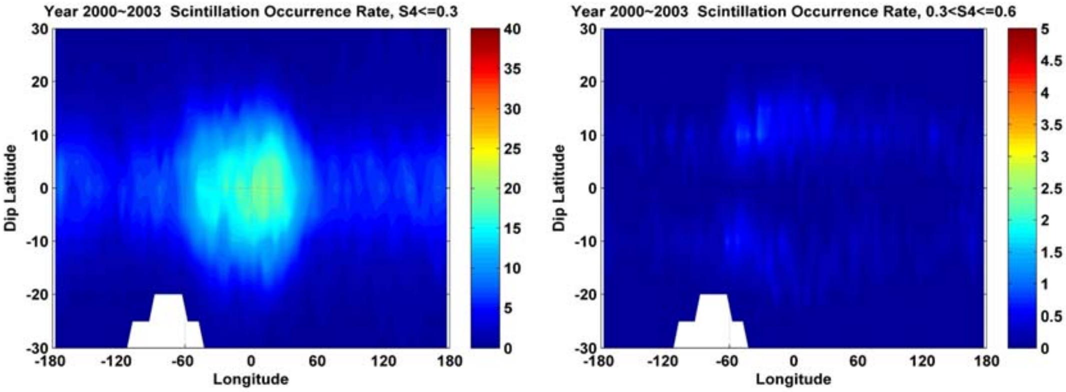
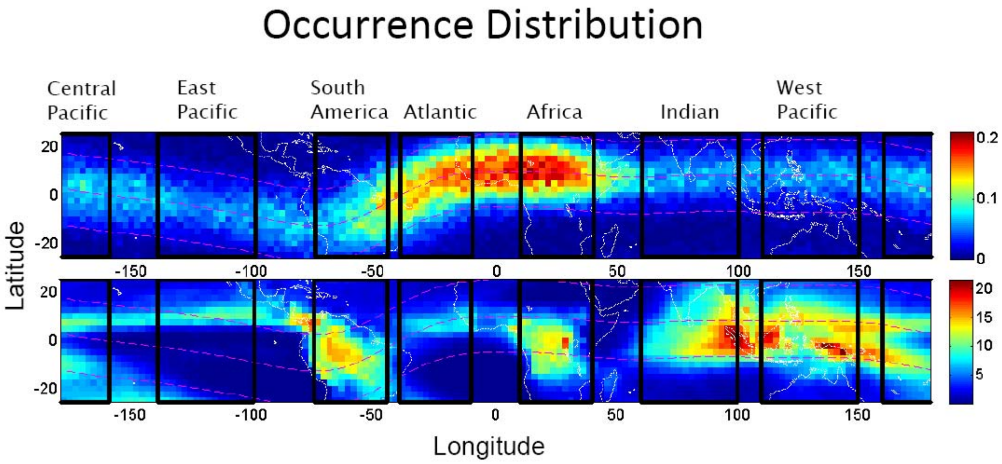


Figure 2. Global distribution of calculated scintillation S_4 index from the thin phase screen model using ROCSAT measured density data.



Label	Longitudes limit	Label	Longitudes limit
Africa	10°-40°E	East Pacific	100°-140°W
Indian	60°-100°E	South America	45°-75°W
West Pacific	110°-150°E	Atlantic	10°-40°W
Central Pacific	160°E-160°W		

Figure 3. Top panel in the upper part of the figure shows the occurrence distribution of ROCSAT observed density irregularities from 1999 to 2004. The lower panel shows the occurrence distribution of outgoing longwave radiation (OLR) representing the deep atmospheric convection observed by NOAA satellites in the same period. The table in the lower part of the figure shows the longitudinal regions that are used to study the correlation between the occurrences of density irregularities and OLR.

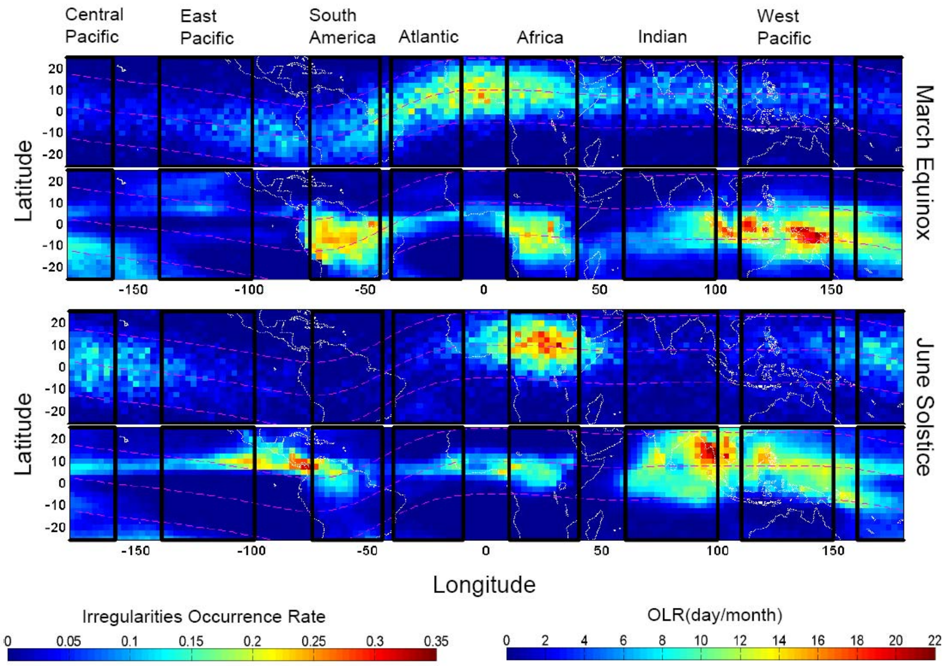


Figure 4(a). The seasonal distributions for the occurrences of density irregularities and the occurrences of OLR for the March equinox and June solstice.

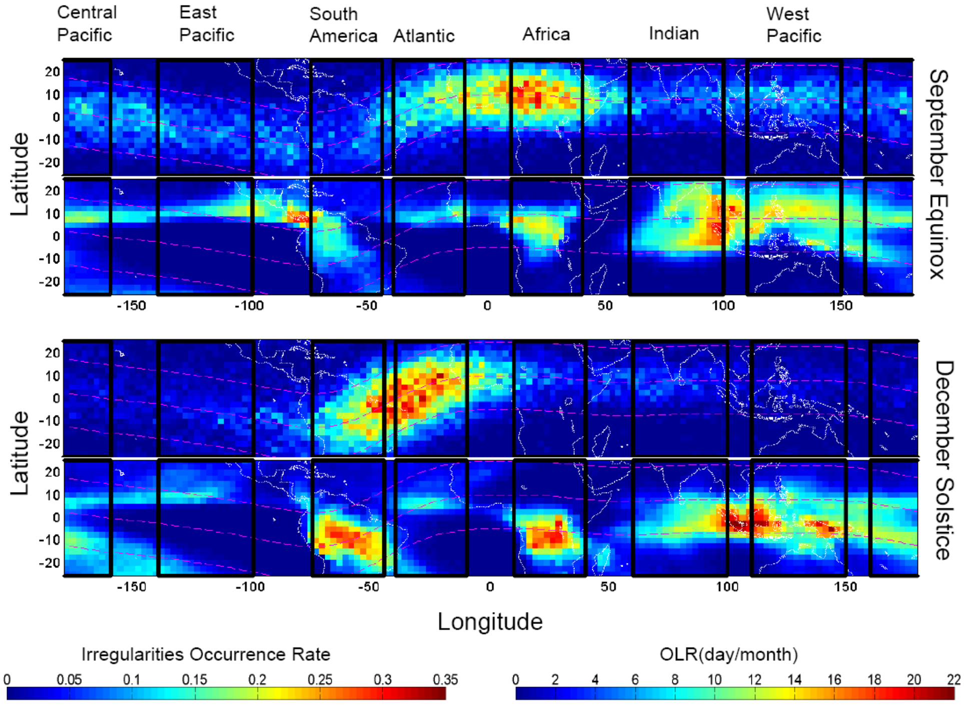


Figure 4(b). The seasonal distributions for the occurrences of density irregularities and the occurrences of OLR for the September equinox and December solstice.

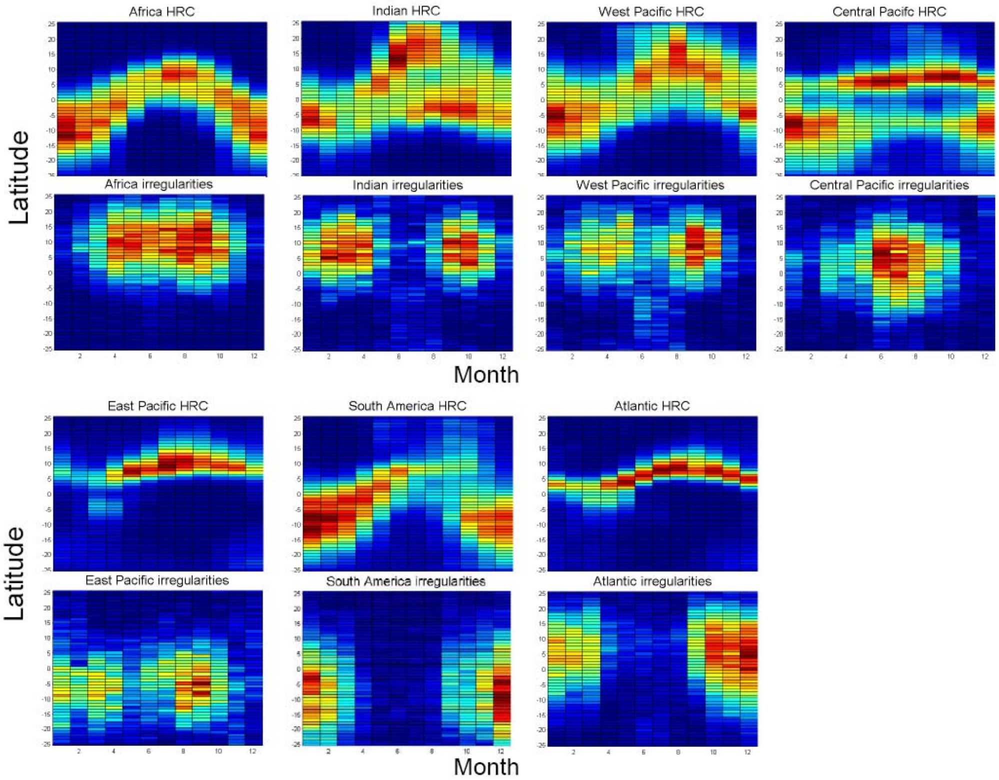


Figure 5. The monthly distributions of occurrences of OLR and density irregularities in the seven longitudinal regions.