Scintillations climatology over low latitudes: statistical analysis and WAM modelling

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Abstract

Attempts of reconstructing the spatial and temporal distribution of the ionospheric irregularities have been conducted developing a scintillation “climatology” technique, which was very promising in characterizing the plasma conditions triggering L-band scintillations at high latitudes ([1.],[2.]) and further analysis on bipolar high sampling rate (50 Hz) GPS data are currently in progress for deeper investigations. The core of the scintillation climatology technique is represented by the maps of percentage of occurrence of the scintillation indices above a given threshold. The maps at high latitude are expressed in terms of geomagnetic coordinates (Magnetic Latitude vs. Magnetic Local Time) and their fragmentation depends on the available statistics. Typically the selected thresholds are 0.25° for the phase scintillation index σ_Φ and 0.25 for the amplitude one S4, which represent a good compromise between the need of a meaningful sample in each map bin and the necessity to distinguish moderate/strong scintillations. The scintillation climatology technique has been very useful in identifying the main areas of the ionosphere (from mid to cusp/cap latitudes) in which plasma irregularities could lead to scintillation phenomena on GPS signals and their dependence on different geomagnetic conditions of the ionosphere and on different level of the solar activity.

As the promising results achieved, we propose to apply the same approach to draw a first raw representation of the scintillations climatology over the Latin America sector. In the development of the study, it will be considered that, at low latitudes, scintillations effects are most severe around the magnetic equator and around the crests of the equatorial anomaly in the early evening hours. Moreover, the morphology of the ionosphere is different from that at other latitudes, because the magnetic field B is nearly parallel to the Earth’s surface, leading to different configurations, dimensions and dynamics of the ionosphere irregularities causing scintillation.

Scintillation climatology in geographic coordinates will be performed on scintillation data collected at the site of Presidente Prudente (Brazil, 22.12ºS, 51.41ºW) via a SCINTMON receiver [3.]. The SCINTMON receiver is developed by the space plasma physics group from Cornell University and designed to monitor the amplitude scintillations at the L1 frequency (1.575 MHz). The SCINTMON is capable of logging the signal intensity at 50 samples per second for up to 11 visible satellites simultaneously, then the data collected are post-processed via software, and for each 60 s interval of data the S4 scintillation index is computed for all satellites tracked during the observation nights (0900–2100 UT).

In relation with the aforementioned climatology, here we also discuss the extension to low latitudes of the empirical Wernik-Alfonsi-Materassi (WAM) [4.] model. This is a simple phase screen model of propagation of a plane wave through the irregular ionosphere. It ingests the electron density in situ satellite data to reproduce empirically the irregular medium. WAM was originally developed to model high latitude irregularities, and now

it is going to be extend to lower latitudes. The concept of such extension is here described. The low latitude scintillation climatology will be used for understanding the key points to be carefully explored to concretely envisage a reliable modelling.

The main innovative idea of the WAM model [4.] is that the statistics of the medium, giving rise to the irregular pattern formation called “scintillation” when crossed by an electromagnetic wave, should be constructed from *in situ* data instead of being assumed *a priori*. This is because the ionization fluctuations, due to a form of “dirty plasma” turbulence, are expected to show non-trivial statistics, often non Gaussian ones, due to the strong gradients possibly occurring in the ionosphere.

WAM was constructed as a phase screen model, good for climatological use, with the statistics of the phase fluctuations $\delta\phi$ directly calculated from the *in situ* data of the ionization fluctuations δN collected by the DE2 mission in the years 1981-1983. The S_4 scintillation index is predicted, along an assigned satellite-ground radio link, via the analytical formulæ for the weak scattering due to Rino [5.]. The location and thickness of the phase screen, and the value of the ionization maximum, all enter in Rino’s formulæ, and these are given in WAM by matching the background ionization as measured by the DE2 satellite with the ionospheric profile provided by some ionospheric background model. In its original form, WAM uses the IRI95 as a profiler [6.].

In its first release, described in [4.], the model predicts the S_4 climatology within high invariant latitudes (larger than 50°), and may calculate the most likely S_4 along a given radio link of identified geometry, time and geomagnetic conditions (represented through the K_p index).

The choice of high latitudes was due to some elements: being DE2 a polar orbiting satellite, its passes form a denser network around poles; real scintillation measurements to compare with are more abundant in the polar regions; the IRI95 profiler is an excellent tool for mid-high latitudes (with some suitable corrections for the topside at high latitudes).

In order to extend the WAM model to low latitudes as well, some changes to it must be done. First of all, low latitude in situ observations from DE2 are included, plus other similar data of a low latitude orbiting satellite (in the future, possibly ROCSAT data [7.]). The background ionosphere must be represented via some model which turns out to be more reliable than IRI95 to represent the so Equatorial Anomaly, which is the main feature of the low latitude ionosphere.

The successive developments of IRI95 represent improvements of the low latitude background, among the other things, but the choice here was to use the further development referred to as NeQuick model [8.], in its ITU-R version [9.].

Once the WAM model has been expanded to ±40° of latitude thanks to further *in situ* data and the NeQuick background model, it will be possible to predict a climatology of S_4 that will be tested against the real data of the scintillation climatology: this comparison will allow for operation of finer tuning in the low latitude extended WAM model.

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