SCHUMANN RESONANCES AND THE TEMPORAL-SPATIAL DYNAMICS OF GLOBAL THUNDERSTORM ACTIVITY

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ABSTRACT: A two-dimensional computational ELF technique has been applied to interpret variations of peak frequencies of Schumann resosnances (SR) observed at the MIT experimental site (West Greenwich, Rhode Island). The spatial-temporal dynamics of global thunderstorm activity has been simulated on the basis of general meteorological data. It is shown that the proposed models provide a reasonable qualitative agreement between computed and observed variations for SR I to IV. Some inverse task diagrams has been constructed as an instrument for distinguishing between day-to-day thunderstorm scenarios.

INTRODUCTION

From the very beginning of the ELF research, the parameters of SR (peak frequencies and amplitudes as well as quality factors) have been considered as valuable information suitable for monitoring global thunderstorm activity. As a rule, the monitoring procedures have been based on spherically symmetrical (regular) models of the Earth-ionosphere wave-guide, in the limits of which models the SR parameters depend only on source's characteristics and the source-observer distance. But the analysis of ELF data accumulated at the Rhode Island site since 1994 shows that such a dependence is not sufficient, and some other factors are to be taken into account to interpret observed variations of the SR parameters. It was assumed that asymmetries of the wave-guide are also responsible for the observed phenomena.

PROPAGATION MODEL

The assumption has been tested by means of an approach suggested by *Madden and Thompson* [1965] and developed by *Kirillov et al.* [1997]. The method is based on a two-dimensional telegraph equation (TDTE)

$$\mathrm{div}\,[\mu_0 \mathrm{H_L}(\theta,\varphi)]^{-1}(\theta,\varphi)\mathbf{Grad}\,U(\theta,\varphi) + \omega^2\varepsilon_0[H_C(\theta,\varphi)]^{-1}U(\theta,\varphi) = \Lambda(\omega,\theta,\varphi,\theta^*,\varphi^*)$$

formulated in an arbitrary system of spherical co-ordinates (the right part of the equation being a two-dimensional analogue of a three-dimensional source) with propagation parameters in the form of complex characteristic altitudes which are analogous to those introduced by *Greifinger and Greifinger* [1972] for simplified determining ELF eigenvalues from aeronomical profiles. In its general formulation, the TDTE method is suitable for taking into account any asymmetries of the wave-guide, but some considerations listed by *Galejs* [1970] suggest that the most important are the differences between "grossly averaged day and night hemispheres". Exploiting such a model provides an additional advantage, since it allows keeping at least a limited (azimuthal) symmetry of the wave-guide, which, in its turn, permits to obtain an analytical solution realizable without any time-consuming numerical integration algorithms. Since there still is no reliable procedure of extracting ELF propagation parameters directly from experimental observations, we estimated them on the basis of representative day and night aeronomical profiles.

FIG.1a. Peak Frequency vs. UT, SR I

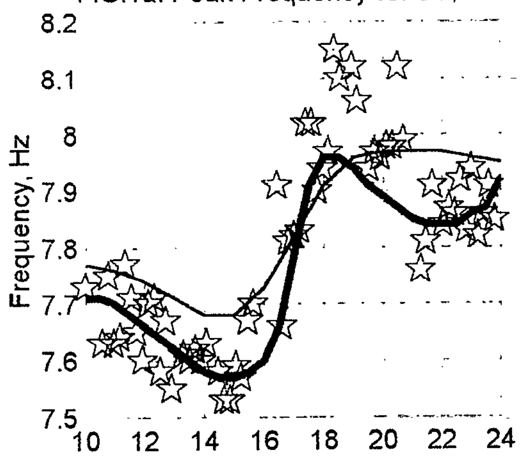


FIG.1b. Peak Frequency vs. UT, SR III

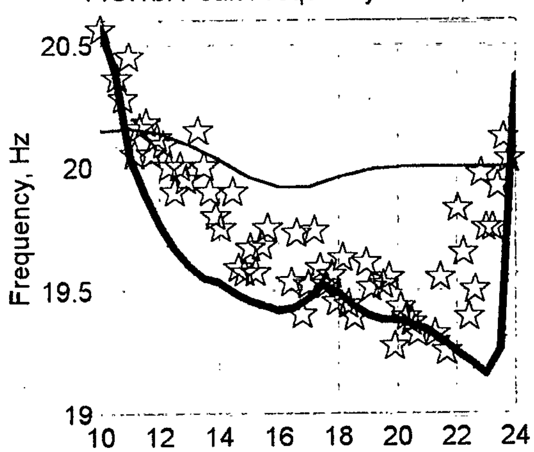


FIG.1c. Peak Frequency vs. UT, SR IV

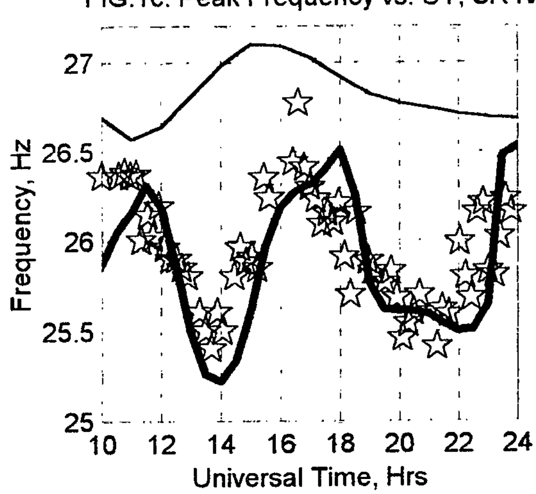


FIG.2a. Inv.Task Diagram, 2000 UT, SR I

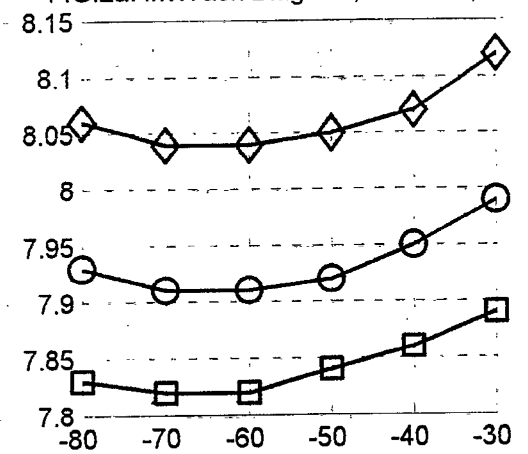


FIG.2b. Inv.Task Diagram: 1600 UT, SR III

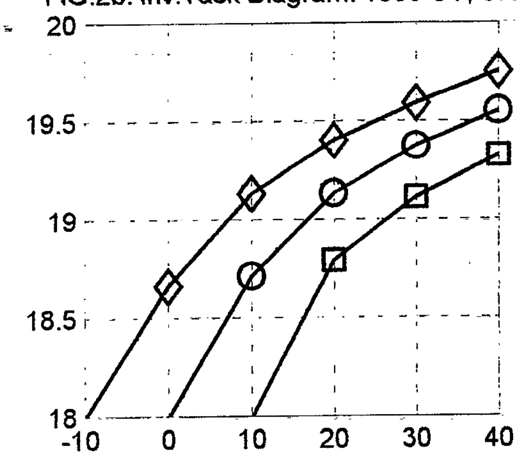
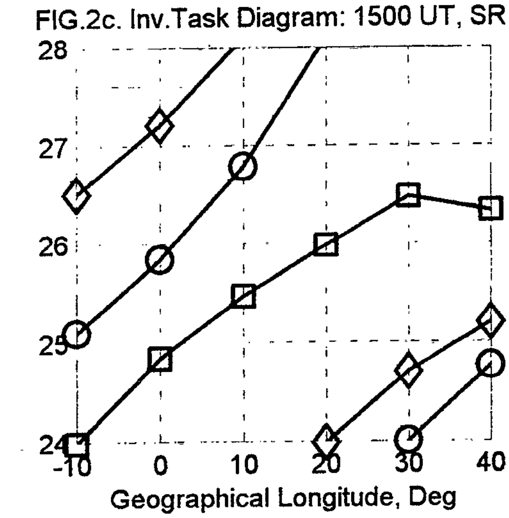


FIG.2c. Inv.Task Diagram: 1500 UT, SR IV



GLOBAL THUNDERSTORM ACTIVITY MODEL

The model of the activity has been constructed taking into account the most general features of the spatial-temporal dynamics of this geophysical process, namely: the presence of three major global thunderstorm areas; the presence of kernel thunderstorm regions moving predominantly westward within each of the areas during its prevailing activity; latitudinal migration of the major areas with season, and an approximately Gaussian-like dependence of the total activity of each major area on the local time. The parameters of the model (the geographical limits and seasonal latitudinal migration of the major areas as well as the sizes, relative activities and longitudinal dynamics of the kernel regions) have been estimated on the basis of available meteorological, satellite and VLF data.

THEORY AND EXPERIMENT CONCLUSIONS

A series of modeling simulations has been carried out to test the influence of the day/night asymmetry of the Earth-ionosphere wave-guide on the diurnal-seasonal variations of Schumann resonanses. Since the peak frequencies (PF) are the most susceptible to the source position and, therefore, are of the main interest from the point of view of monitoring global thunderstorm activity, special emphasis has been laid on these parameters. It was found that during the period of prevailing contribution of Asian activity there was rather a poor agreement between the observed and calculated dynamics of PF, which can be caused by two factors. Firstly, the Asian area is the most remote from the RI site, so it is essentially 'shielded' by the background activity even during its maximum intensity; secondly, geophysical properties of this land-maritime-archipelago area are too specific to be adequately described by the above-mentioned model. On the contrary, the continental - African and American - major areas produce PF variations which are in a qualitative (and, sometimes, also quantitative) agreement with simulated ones. An example (December 13, 1996; SR I, III-IV; the vertical electric component) is shown in Fig.1: pentagrams – experimental results, bold curves – simulations with a day/night model of the wave-guide; for comparison there are also shown simulations with a spherically symmetrical wave-guide (thin curves). In Fig.2 are shown some examples of inverse task diagrams – December values of peak frequencies vs. the longitude of the center of the American (Fig.1a) and African (Fig.1b, 1c) kernel regions for three latitudinal levels: 20°S (diamonds), 10°S (circles), and at the equator (squares).

Reasonable qualitative agreement between theoretical results and experimental observations shows that the proposed models satisfactorily reflect the most general features of generating SR in the Earth-ionosphere cavity. Nevertheless, to be used in an inverse task procedure, the propagation parameters need to be specified in a more adequate manner (for instance, on the basis of analyzing transients produced by lightnings reliably localized by means of some independent – satellite or meteorological - technique).

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