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Towards a statistical model of the Southern ionospheric polar convection maps

I. Bertello[1,2], E. Amata[1], M.F. Marcucci[1], and I. Coco[1]

[1] Istituto di Fisica dello Spazio Interplanetario - INAF – Via Fosso del Cavaliere 100, Roma, Italy
[2] Dipartimento Scienze della Terra - Universitá di Siena – Via del Laterino 8, Siena, Italy
e-mail: igor.bertello@ifsi.rm.cnr.it

Abstract. The plasma in the high latitude ionosphere continuously undergoes $E \times B$ convection, organised in large scale cells, whose extension and number depend on IMF orientation. This paper briefly reviews the model of high-latitude ionospheric convection based on SuperDARN data from the Northern hemisphere and argues that a similar model should be developed for the Southern hemisphere. The method to derive such a model from SuperDARN radar data is described.

Key words. Methods: statistical – Magnetic fields – Plasmas – Convection – solar wind – solar-terrestrial relations

1. Introduction

The plasma in the high latitude Earth's magnetosphere is maintained in nearly continuous state of motion by the transfer of energy and momentum from the solar wind. This motion is observed down to the polar and auroral ionosphere, both in the Northern and in the Southern hemisphere, and can be described in terms of E x B plasma convection. The basic configuration of the plasma convection pattern consists of two cells, such that the plasma moves anti-Sunward over the polar cap and Sunward at lower latitudes. However, it has been found that, when B_z is positive and dominates over B_y, two reserved cells can develop and that, in general, the number, extension and rotation sense of the convection cells depend on the solar wind IMF orientation.

Send offprint requests to: I. Bertello

2. Early models of ionospheric convection and their application

There have been numerous attempts, dating back to over thirthy year ago, to describe the ionospheric convection patterns as a function of IMF through various empirical and theoretical models, in both numerical and pictorial form: Heppner (1972), Heelis et al. (1982), Hairston & Heelis (1990), Heppner & Maynard (1987), Rich & Maynard (1989), Rich and Hairston (1994). However, all such models were far from complete and did not have an easy-to-use digital representation.

The model of Weimer (1995) is the first such model that makes use of the spherical harmonics treatment of the experimental data. Its data base consists of electric field measurements collected between 300 and 1000 km of altitude by the Dynamics Explorer 2 satellite from August 1981 to March 1983.

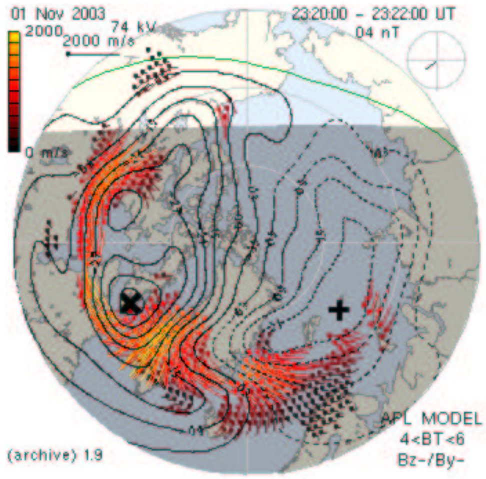

Fig. 1. Example of convection cells obtained from SuperDARN data.

The most recent model is by Ruohoniemi & Greenwald (1996). It makes use of the same spherical harmonics technique, applying it to convection velocities measured by the Goose Bay SuperDARN radar from September 1987 to July 1993. This model is strictly valid for the Northern hemisphere convection, but it is widely used as well for the Southern hemisphere. Thanks to this model, it is possible to compare the SuperDARN data with satellite data for the study of specific events. This is particularly interesting for the study of the effect in the ionosphere of reconnection at the magnetopause. Another application is the reconstruction in real time of the ionospheric high latitude convection. Moreover, it is possible to calculate in real time the cross polar cap potential, which is a proxy of the energy input from the solar wind to the magnetosphere.

There is clearly a need for a similar model to be derived from Southern hemisphere SuperDARN data.

3. Construction of the statistical model for the Southern hemisphere

There are 15 SuperDARN radars, 9 in the Northern and 6 in the Southern hemisphere. Every 2 min, each radar performs 1200 measurements of the line-of sight velocity, over 75 range gates and 16 azimuthal beams (see Greenwald et al. (1995)).

For the determination of the Southern hemisphere convection pattern model we shall make use of data from the South hemisphere SuperDARN data between 1997 and 2002. The work will be actually done as follows.

In the first step, all 2-D speeds are binned in a Λ-MLT grid. Then, for each Λ-MLT cell an average 2D velocity is calculated.

Both steps can be repeated for various IMF and magnetospheric conditions.

Each such run produces a Λ-MLT grid of velocities, which can be represented in polar form as shown in fig. 2.

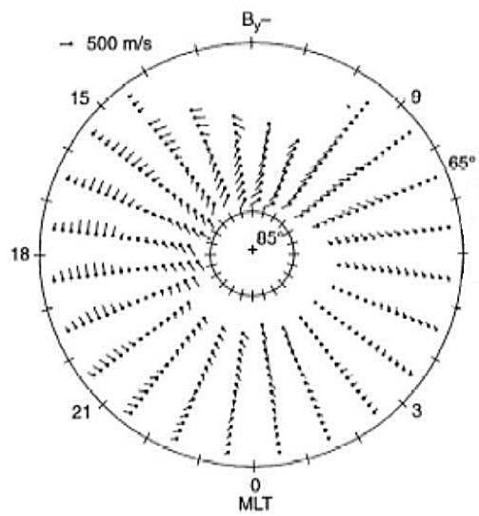

Fig. 2. An example of average velocities plotted over the Λ-MLT grid for negative B_y. Sun is at the top.

The vector velocities provide a set of electric field estimates through

$$E = -v \times B$$

where v is the grid averaged measured plasma velocity and B is the geomagnetic field. From such estimates we derive the electric potential by using

$$E = -\nabla \Phi$$

To achieve that, we express the electric potential in terms of a polynomial expansion in latitude and a Fourier expansion in MLT as follows

$$\Phi(x, \phi) = \sum_{n=0}^{N} \sum_{m=0}^{M} \phi_{nm} P_n(x) e^{im\phi}$$

where

$$x = (2\Lambda - \Lambda_a)/\Delta\Lambda, \qquad \Lambda_a = \Lambda_{min} + \Lambda_{max},$$
$$\Delta\Lambda = \Lambda_{max} - \Lambda_{min}$$

For each Λ-MLT cell a value of E is obtained. This allows to calculate

$$D = \sum_i | E_i - \nabla\Phi |^2$$

where the sum extends over the whole Λ-MLT grid. Moreover, the condition that Φ goes to zero at low latitude is added. By minimization of D, the complex coefficients ϕ_{nm} and the Legendre polynomials are determined.

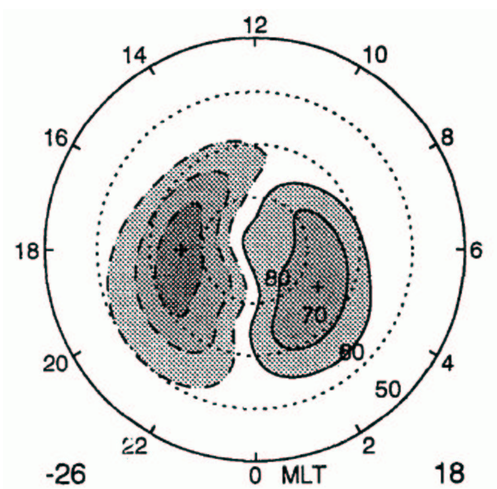

Fig. 3. An example of convection pattern produces through the process described in the text.

At the end of the process, this model will allow to build convection patterns for the South hemisphere such as the example shown in Fig. 3, which refers to the North hemisphere. The work plan for the future is to complete the calculation of the model for the Southern hemisphere. In addition, it is planned to study:

- the dependence on solar activity (i.e. at solar max and solar min);
- the seasonal dependence;
- the effect of the IMF Bx.

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