NEAR REAL TIME FORECASTING OF DYNAMICS OF LARGE SCALE MAGNETIC FIELD CONFIGURATIONS FROM MAGNETOGRAPH DATA

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ABSTRACT

Daily full-disk magnetograms measured at Stanford were taken separately to infer large-scale magnetic field configuration in framework of potential field theory. A regularization technique was applied to resolve spherical harmonics using daily large-scale magnetic field observations (see Ponyavin 1997). Sets of daily spherical expansion coefficients collected during few days of observations serve as input entries for training procedure. This training procedure was constructed to train coefficients and resolve trends in large-scale magnetic field evolution. Coefficients were than used to predict large-scale magnetic field changes just near the solar and source surface — the origin of the heliospheric current sheet and solar wind streams. Results of comparison between actual and predicted configurations of magnetic fields were presented and discussed.

Key words: Large-scale magnetic fields; superstorms; forecasting.

1. INTRODUCTION

It is well known that geomagnetic activity originates from the solar wind and interplanetary magnetic field (IMF) variations. Both the solar wind and IMF are controlled by the large-scale magnetic fields on the Sun and their dynamics. Geomagnetic storms have been widely recognized as recurrent or sporadic storms. This classification comes from the fact that the Sun rotates with a period approximately equal to 27 days. Recurrent storms occur from one solar rotation to another and originate from long-lived coronal holes formed by large-scale magnetic field configuration, which changes slowly. By contrast, transient events on the Sun are related rather with dynamics of large-scale magnetic fields resulting from changes of magnetic field configuration within a whole rotation period. It was established that transient events in the solar corona, i.e coronal mass ejections (CME), are stimulated by emergence of new magnetic fluxes on the photosphere of the Sun (Feynman & Martin 1995).

Therefore forecasting of short-term magnetic field changes on the Sun and their catastrophic consequences at the Earth named *superstorms* (see Ponyavin 1993; Bell, Gossenhoven & Mullen 1997) seems to be very important for the “Space Weather” community and all potential users.

Ideally spacecraft observing stations would be spaced around the heliosphere to monitor in real time such new magnetic field regions emerging on the back of the Sun (Hoeksema 1993). A project was proposed recently to locate spacecraft monitor on the other side of the Sun and provide regular observations of evolving magnetic structures using minimum Doppler magnetograph instrumentation (Ruzmaikin et al. 1998).

However, the cheapest way to resolve this problem at present is to develop some new extrapolation techniques using only earthside observations.

The purpose of this paper is to demonstrate some possibilities of reconstruction of the short-term evolution of solar large-magnetic fields from daily ground-based magnetograms.

2. OBSERVATIONS

Observations of the photospheric field with a resolution of three arc minutes began at the Wilcox Solar Observatory (WSO) at Stanford in 1976 and have continued through the present time. Since the data now span more than two solar cycles 21 and 22. Measurements of the mean magnetic field of the Sun averaged across nearly the all visible hemisphere of the Sun have been also conducted at that time.

A summary of day-to-day observations of the mean magnetic field seen as star are given using Bartels format display in the Figure 1. Besides the gradual evolution of large-scale magnetic fields resulting in slanted features with respect to 27-day period one could also observe relatively sudden amplification of magnetic fields near-simultaneously practically at all Bartels longitudes.

The corresponding patterns of geomagnetic recurrent activity presented by the global geomagnetic indices C9 and the time onset of superstorms are displayed in the Figure 2. It can be seen from the Figure 2 a clustering of superstorms around recurrent geomagnetic variations when intensification takes place. The re-

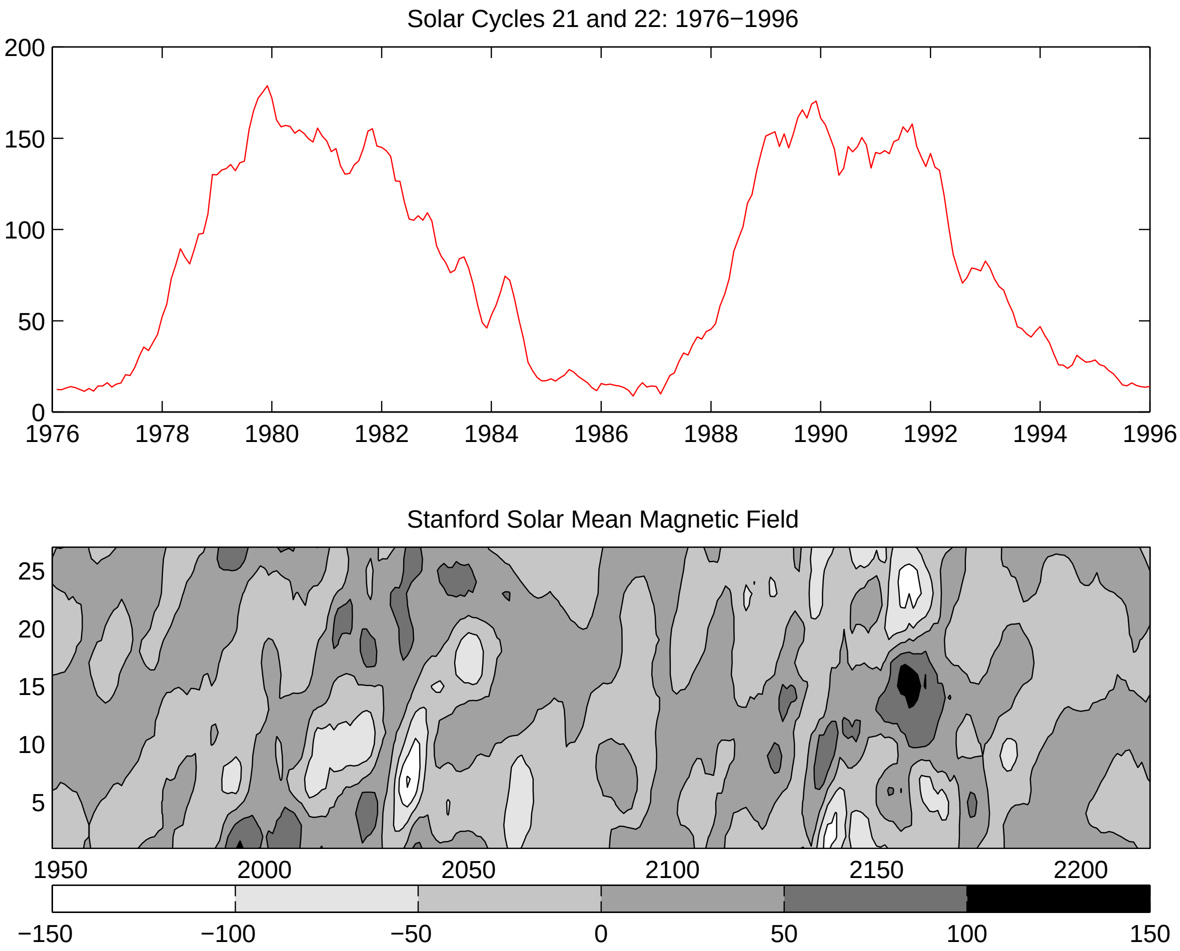


Figure 1. Bartels 27-day display of the mean magnetic field observed at Stanford (bottom panel) from 1976 to 1996 (Bartels Rotations 1948–2217). The data were smoothed to fill in the gaps. The polarity contours are shaded relative to levels: $0, \pm50, \pm100, \pm150$ *microtesla. The sunspot cycle activity presented by smoothed Wolf numbers at the same period as the mean magnetic field is displayed at the top.*

current pattern of geomagnetic activity roughly corresponds to the mean magnetic field behavior during a course of solar cycle.

The most interesting period is located around solar sunspot maximum when large-scale magnetic field configuration rapidly evolves due to new emerged magnetic fluxes. We have chosen for our analysis a period just close to the maximum of solar cycle 22 when the changes in magnetic fields are clearly pronounced.

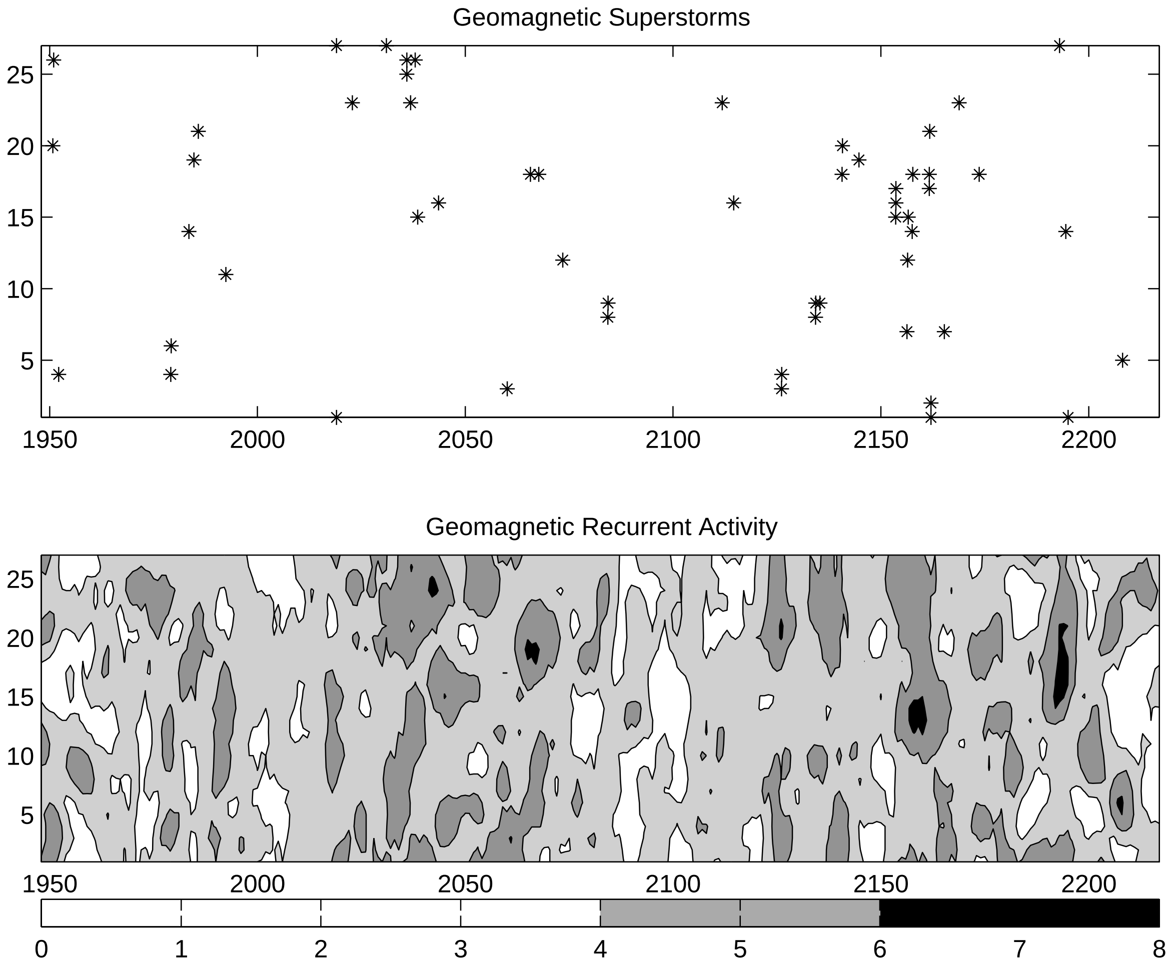
3. DATA ANALYSIS

Magnetograph data taken daily in Fe I λ5250 line at the Wilcox Solar Observatory at Stanford have been analyzed for the period from August 1990 to October 1990. 30 magnetograms of good quality are available during this period of observations. A quadratic fitting routine interpolates the original data onto a regular Carrington grid (Hoeksema 1984). The grid is centered on the even 5° longitude strip nearest central meridian and extends 55° east and west. In the north-south direction the field is determined at 30 points evenly spaced in sine latitude (this corresponds to even steps on the disk).

Three examples of original magnetograms are shown in the left side of the Figure 3. The time of Central Meridian Passage corresponds to the Carrington longitude just near 115°. It follows from the Figure 3 that magnetic field configuration change significantly from one solar rotation to another indicating the presence of new emerging magnetic fluxes during this period of observations.

I have applied a spherical harmonic analysis to the available data. Current free approximation means that magnetic field can be described by scalar potential and to find it we needs solve the Laplace equation with suitable boundary conditions corresponding to the available line-of-sight magnetic measurements. The solution of Laplace equation in spherical coordinates is expressed in spherical expansions coefficients.

However, because we deal with only daily magnetograms the problem to resolve harmonics cor-


Geomagnetic Superstorms

Geomagnetic Recurrent Activity

Figure 2. Bartels display of the daily geomagnetic activity indices C9. Data were smoothed to reveal recurrent geomagnetic activity. Superstorm onset time are labeled by asterisks at the same Bartels format as the bottom panel. Coverage of the geomagnetic data corresponds to solar data in the Figure 1.

rectly becomes ill-posed problem in absence of sufficient line-of-sight information around entire solar sphere. To choose the appropriate solution, closest to the real, the regularization procedure was applied (Ponyavin 1997). This regularization technique was based on the spectral characteristics of the spherical harmonics inferred from synoptic charts of large-scale magnetic fields.

As result sets of spherical coefficients could be obtained the day when the appropriate magnetogram is available. The sets of coefficients associated with any magnetogram, where then used as input entries to extrapolate observations for the next day and compare results with the actual. By using analytical extrapolation procedure one could restore the line-of-sight component of the magnetic field around the disk and construct the next-day magnetogram.

This step-by-step prediction procedure was applied to the available data and examples of actual and predicted magnetograms are presented in the Figure 3.

4. CONCLUSIONS

This is just a first attempt to apply the extrapolation procedure to predict magnetograms by using data previously observed. We need however further investigations in improving the prediction procedure by using neural network approximation capabilities.

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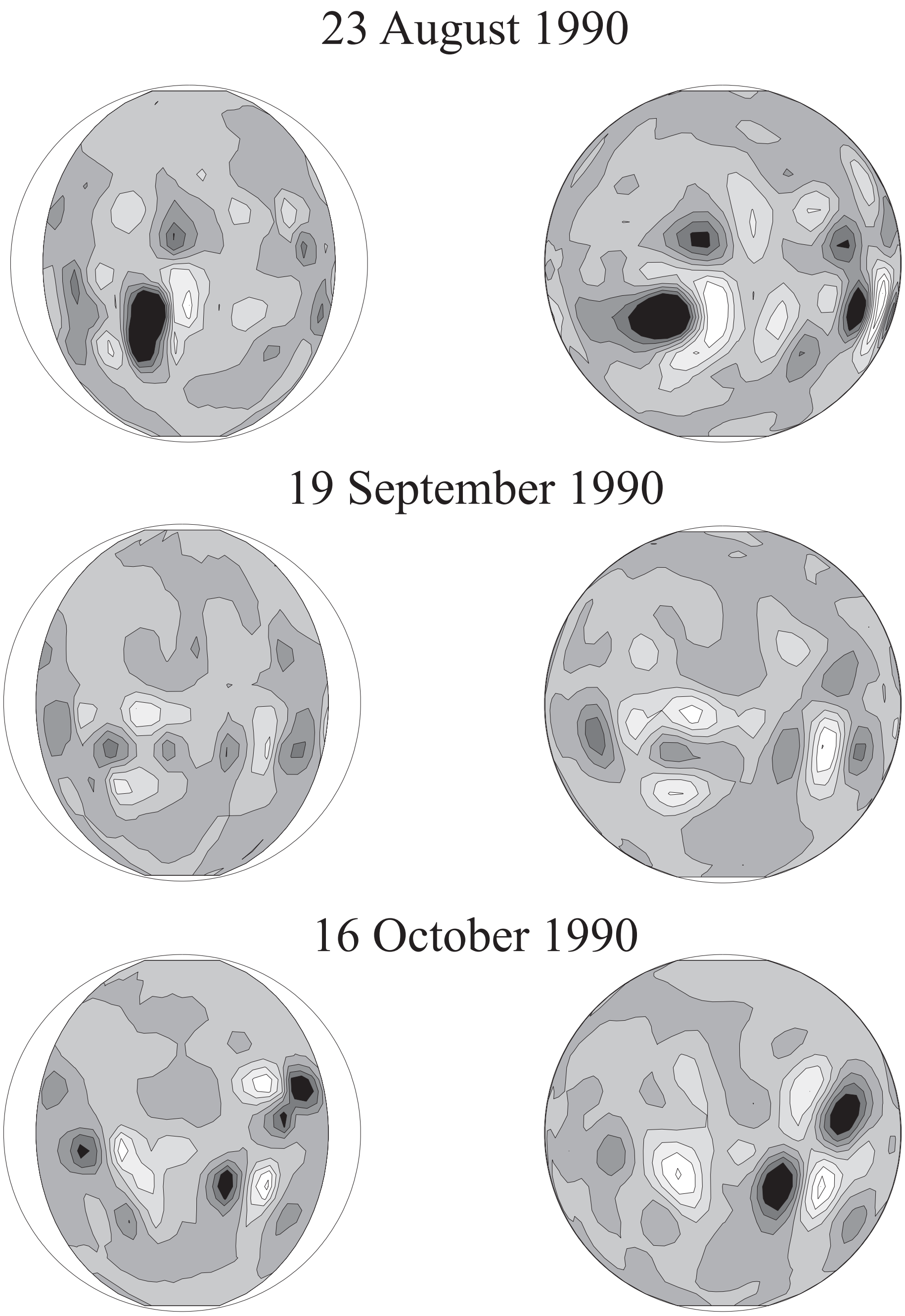

Figure 3. Actual (left) and predicted (right) magnetograms during three consecutive Carrington Rotations. The negative polarity is shaded more darkly. Isolines correspond to the levels: $0, \pm 500, \pm 1000, \pm 1500, \pm 2000$ *microtesla*

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