APPLICATION OF LOCAL-AREA HELIOSEISMIC METHODS AS PREDICTORS OF SPACE WEATHER

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ABSTRACT

Space weather is of growing concern to our increasingly technological society. Here we discuss neural-network approaches to forecasting space weather, in which we plan to incorporate now-cast information about solar subsurface flows from local-area helioseismic analyses. This is part of onging work for monitoring and predicting solar activity for space weather.

Key words: Sun: activity, space weather.

1. INTRODUCTION

Many of the phenomena observed on the Sun are of magnetic origin. The solar wind, Coronal Mass Ejections and flares are all phenomena closely linked to Sun's magnetic field. The technology based society of today can be strongly influences by these phenomena. The high energetic particles emitted in connection with CMEs and flares are able to cause enough damage to satellites to render them useless. It is therefore of great interest to understand the physical processes behind these phenomena.

During the last three decades helioseismology has investigated the solar interior by measurements of the global eigenmode frequencies. The global nature of these data makes it impossible to resolve phenomena that are highly localized in the Sun. Within the last decade local-area helioseismic methods have emerged as powerful tools for investigating localized phenomena in the solar convection zone such as flows and magnetic activity. With these methods it has become possible to study structures around and below active regions. Observations have been made of flows and temperature variations surrounding and extending below sunspots thereby enabling the study of dynamical processes below the solar surface in active regions. These studies can help to understand the processes behind phenomena such as flares and CMEs which can influence the Earth. With local-area helioseismic methods a wealth of new information has or will become available, which hopefully can be used to increase the reliability of space weather predictions. With the data available from the SOHO satellite and the GONG network it is possible to monitor large-scale flows in the Sun in connection with magnetic active regions using local-area helioseismic methods. We propose to use these observed flows as indicators for future space weather. If observations of the magnetic configuration in active regions are supplemented with information of the flow fields surrounding the active region it might be possible to improve on flare prediction. To this end we propose to use a physics-based neural network to investigate whether the flow fields can be used to predict flares and space weather. The goal is to incorporate these data into the space weather-forecast models developed at the Swedish Institute of Space Physics in Lund. A space weather-forecast service prototype was developed within the ESA Space Weather Programme Study and an ESA Pilot Project is in progress. The Lund division of the institute also runs the RWC-Sweden of ISES. Here we outline this new approach of using helioseismic data.

2. FLARE PREDICTION SCHEMES

Current prediction schemes uses data such as the magnetic class (McIntosh 1990) of the region, the area of the region and the number of spots within the region. Examples of such prediction schemes include the expert system THEO (Shaw 1989), the BBSO Flare Prediction System based on historic flare probabilities of magnetic classes (Moon et al. 2001, Wheatland 2001), and an expert system implemented using a neural network (Aso and Ogawa 1994).

We plan to include estimations of the fluid flows surrounding the active regions in our scheme for flare predictions. As an example of the kind of helioseismic and photospheric magnetic data that could be used in flare prediction, we show in Fig. 1 a GONG magnetogram and a flow map in the vicinity of active region AR 10486 on

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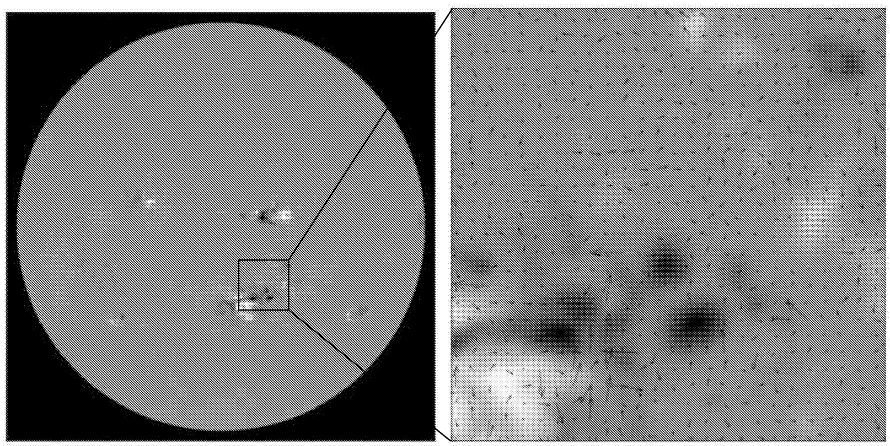

Figure 1. Left panel and background to the right panel show a GONG magnetogram. The right panel also shows a flow map obtained from the area indicated by the square on the full-disk magnetogram. The flow map was obtained directly from travel-time differences calculated using time-distance helioseismology (see e.g. Kosovichev et al. 2000). The travel times are for an offset of 15 Mm between a central point and surrounding annulus, and the data used were 8 hours of GONG Dopplergrams on October 29 2003.

October 29 2003 (a time of great solar activity late in the present cycle). The flow map was constructed from GONG Dopplergrams using time-distance helioseismology with a centre-annulus configuration. It should be possible to produce the required flow maps from only 8 hours of data (as in the present example), which could for instance come from just a single site of the GONG six-site network rather than delaying while data from all six sites are merged. At least initially, rather than use the full flow map we propose that the information in the flow maps be reduced to just a few scalar quantities by taking the curl and divergence of the flow. A representative measure of the curl or divergence for the active region is then taken. This could be the maximum or mean in order to represent the largest stress or the average stess the region is subjected to from the flow. This flow information is then used as input along with the magnetic class, the area and the number of spots.

3. TWO NEURAL NETWORK APPROACHES

We suggest two different schemes for incorporating the helioseismic data into a neural network for flare prediction. The first is shown in Fig. 2 and utilises scalar input. The flow field bas been reduced to a scalar by taking the curl and divergence (as discussed above). Other inputs to the scheme are the the magnetic class of the active region, its area and the number of spots contained therein. Fig. 3 shows a second approach where the flow map is given directly to the neural network along with a magnetogram of the region. In this case the neural network should extract the relevant information from the magnetogram instead of being given it as in the first approach.

In the second approach, if the active region is sampled on a 50×50 grid, the number of input parameters is 7500 as opposed to 5 in the first approach, making the required neural network much larger in the second case than in the first.

In either case the output from the neural networks are the possibility of a flare of a given class (e.g. minor, major, severe) occurring within the next 24 hours.

4. OUTLOOK

This is an ongoing project. The next step is the development of an efficient computer code for calculating travel times and flow maps: this will be essential for nowcasting flow maps for space-weather predictions. We then aim to establish a database of flow maps obtained from the GONG data. With such maps we shall then implement and train a nearual network, initially based on the approach of using suitable measures of the curl and divergence of the flow field as helioseismic inputs to the neural network.

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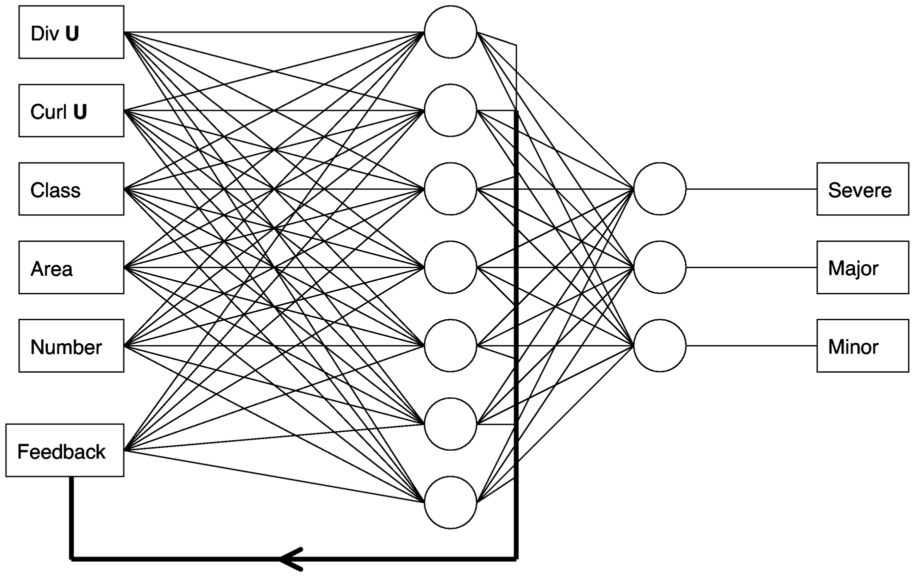

Figure 2. Outline of a Recurrent Neural Network for flare prediction, using scalar inputs. The outputs are probabilities for a flare of a given magnitude occurring. The exact classification of flares is a parameter of the system to be determined; but a starting point could be: Minor < M5, Major M5 – X5, and Severe > X5.

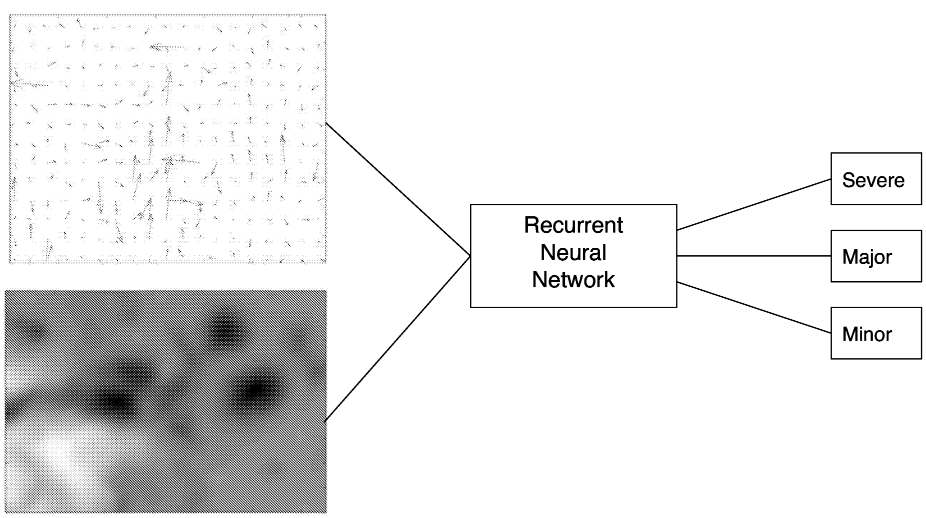

Figure 3. Outline of Neural Network for flare prediction using flow maps and magnetograms as inputs.

Space Weather". We are grateful to Gina Starr for help with producing the figures.

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