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A review is presented of the activities of the Solar Working Group. The major problems of solar activity prediction include the solar cycle size and duration, the occurrence of major active regions, flares, and the injection of high energy particles into the interplanetary medium. New data bases and predictive techniques are identified and advocated.

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LEURA SOLAR-TERRESTRIAL PREDICTION WORKSHOP

SOLAR WORKING GROUP REPORT

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1. INTRODUCTION

The Leura Solar-Terrestrial Prediction Workshop convened during a period of exceptionally high solar activity. The sequence of activity initiated by the 19 October 1989 proton event resulted in a proton flux that approached the flux recorded during the August 1972 events, and a high energy fluence that exceeded the fluence of the August 1972 events. The August 1972 sequence of activity is given as a reference point since these events have long been identified as a "worst case" scenario for spacecraft hardware and manned missions. In fact, the outstanding flares of 1989 have considerably increased the awareness of potential users of the importance of solar-terrestrial predictions.

As in previous solar-terrestrial workshops (Boulder, 1979 and Meudon, 1984) the Leura workshop has offered an opportunity to work with researchers and forecasters specializing in a wide range of fields, to review the progress of our scientific knowledge of the Sun and interplanetary medium, and to discuss related applications. The workshops, because of their interdisciplinary character, have attracted many scientists not directly involved in solar-terrestrial predictions.

Within the Solar Working Group, four sessions covered the following sub-topics: the solar cycle (chaired by E. Hildner), active regions (chaired by P. McIntosh), flares (chaired by D. Neidig), and proton events (chaired by M. Shea). An additional session, combining the Solar Group with Geomagnetic and Space Environment Group, was devoted to the interplanetary medium (chaired by R. Schwenn), and a general discussion session was chaired by D. Webb.

2. MAJOR QUESTIONS TO BE ANSWERED

2.1 The Solar Cycle

- How may theoretical models help to define new prediction methods?
- What are the skills and the limits of the different classes of prediction methods now in use?

2.2 Active Regions

- What are the sources of temporal variations in solar indices over periods of weeks to months?
- Is the 153-155 day period in solar activity real, and is it a basis for making effective medium-term solar predictions?
- In what way can the slow evolution of large-scale magnetic field patterns assist in making medium-term solar predictions?
- What is the source of magnetic flux associated with the "active network" component of solar irradiance?

2.3 Solar Flares

- What similarities and differences exist between flares, filament eruptions and coronal mass ejections?
- How can we improve observations and physical diagnostics of the corona at the site where the flare energy storage and initiating instability are located?
- How can we develop physical models on which to base flare predictions?

2.4 The Interplanetary Medium

- What can be predicted about the solar wind at 1 AU based on observations of the Sun and measurements in space?
- What are the solar wind critical parameters for geomagnetic activity predictions?

2.5 Proton Events

- What is the role of coronal structures in proton propagation and how to model it?
- What parts are played respectively by coronal acceleration and shock wave acceleration in the proton events observed at the Earth?
- How can we predict particle propagation characteristics from solar and interplanetary observables?

3. WORKING GROUP DISCUSSION

3.1 The Solar Cycle

The central point of discussion was the comparison of the different kinds of prediction methods; e.g. methods analyzing possible long-term periods in past sunspot records; statistical methods; and "physical" methods. The latter type is mostly based on geomagnetic observations (as initially proposed by Ohl) as proxy-data for the solar polar magnetic fields measurements. The relevance of the present solar activity indices was also the subject of lively discussions. Sunspot number and 10.7 cm flux indices have the advantage of being available over long time periods, and thus they should not be interrupted. Nevertheless, it is urgent to monitor sunspot area and EUV solar flux in particular, so as to be as close as possible to phenomena directly involved in solar-terrestrial physics.

3.2 - Active Regions

The source of most solar activity appears connected to emerging magnetic fields; therefore, considerable attention was given to the observation and explanation of erupting flux. The large-scale solar activity patterns are a promising way for predictions and, in cooperation with theorists, their understanding is of great interest. Regarding the temporal aspect of solar activity, the 153 to 155 day period in solar activity was a subject of discussion. Also of particular note were the different times given for solar cycle maximum depending on the observations, 10.7 cm flux and coronal emissions peaking late in the maximum phase relative to the sunspot number maximum.

3.3 Solar Flares

Four major points were discussed in connection with flare predictions:

a. Present data bases are definitely inadequate, and are lacking in temporal and spatial resolution, consistency, and coverage at short (UV and X-ray) and long (IR and radio) wavelengths.
b. In addition to the limitations suggested above, the full predictive potential of existing data bases has not been exhausted, and might be extracted by new means of data analysis. Recent work in active region morphology and evolution, and in applications of expert systems, suggest that this may be true.
c. Forecasters and researchers alike strongly endorse routine observations of transverse magnetic and velocity fields as a means of acquiring additional predictive information.
d. Substantial improvements in flare prediction may incur large costs. This brings the attending questions of who will pay these costs and how can sufficient advocacy and justification be developed within the forecasting community.

3.4 The Interplanetary Medium

The importance of coronal mass ejections was pointed out many times during the discussions. The loss of the P78-1 satellite with the SOLWIND coronograph on board and the demise of the Solar Maximum Mission satellite have considerably reduced the possibilities of CME monitoring. The application of interplanetary scintillation techniques to monitor solar wind disturbances seems fully recognized, even if the interpretation of the results is still a subject of controversy. Critical issues in terms of the physics of magnetic storm prediction were also extensively discussed.

3.5 Proton Events

Reliable data bases of proton events with spectral and time resolution are a necessity for proton event studies. The lack of simultaneous multi-spacecraft observations at different solar longitudes is prejudicial to the understanding of the propagation effects. Better understanding of coronal propagation effects would improve present prediction methods.

Owing to the possible serious consequences of large proton events on spacecraft and on manned missions, proton event prediction is one of the areas where the space industry is waiting for significant progress from the scientific research community.

4. RECOMMENDATIONS

4.1 General

There is overall agreement among participants that prediction techniques should be based on the physics of the underlying activity mechanisms. In order to achieve this, it is necessary to closely follow scientific progress and to take part in the broader scientific activities of the solar and interplanetary community. In the case of highly specialized techniques like statistical algorithms, for example, cooperation with specialists in these fields is a demonstrated necessity.

4.2 Observational Data

A universal recommendation of forecasters and flare researchers is acquisition of improved solar magnetic field data, particularly vector magnetic fields with spatial resolution of 2 arcsec or better.

Routine study and monitoring of the corona may be of great importance in resolving many, as yet unanswered, questions. For example, the quiet corona (heliosheet structures and coronal holes) determines the solar wind regime; magnetic field configurations above active regions are important for flare onset and proton propagation; and coronal mass ejections and their relation to filament eruptions and flares are central to many solar-terrestrial physics problems. Coronal observations must thus be continued and intensified by means of ground-based and space coronagraphs as well as by radio observations. After two decades' absence of systematic X-ray images, the GOES Soft X-Ray Imager, now under preparation, appears as one means of filling this data gap.

The interplanetary medium should also be monitored more efficiently. Opportunities to develop interplanetary scintillation techniques, mass ejection imagers similar to the Helios photometer, solar wind monitors at the Lagrangian L1 point, satellites located three days east of the earth-sun line and multi-spacecraft proton observations must not be missed. Access to scientific space instruments for applied research on solar-terrestrial predictions must also be considered.

4.3 Data Bases and Computer Techniques

Because data bases are essential for further progress in various sub-fields, the work already done in many countries (including the United States, the Soviet Union and China) in establishing and maintaining solar-terrestrial data bases is to be commended. Nevertheless, efforts in validation, standardization, and rapid accessibility of these data bases seem necessary. The availability of data with higher spatial, temporal, and spectral resolution is recommended. Graphical data including solar images, are also highly desirable.

Evaluation of the techniques of artificial intelligence and other cognitive systems is encouraged. Application of an expert system as a forecast algorithm is now being tested at SESC (Boulder); the benefit to forecasting is not yet clear and additional refinements are in progress.

Lastly, it is recommended that the worth of objective, computer-generated prediction algorithms be investigated in forecasting centers generally, and tested in parallel with conventional techniques.

4.4 Dissemination of Results

The problem of publishing technical papers directed towards forecasting the solar-terrestrial environment was also discussed. The publication of these Solar-Terrestrial Prediction Workshop Proceedings was considered extremely valuable; however, we could not identify an appropriate journal for publishing similar papers between these Workshops. Most scientific journals, particularly those that customarily publish new scientific results, generally do not consider applied science papers. This is particularly true if approximation factors must be used to obtain a forecast, since many of these approximations are based on statistical studies and practical experience - not on first principals. Journals that concentrate on applied sciences usually cover many subjects and generally do not include a mix of basic research and applications in their articles. In addressing this problem it was felt that this prediction community should consider the solar-terrestrial area as a whole instead of individual disciplines. It was agreed that queries would be made to various editors and publishers who might consider publishing these type of solar-terrestrial research and application papers.