FINAL REPORT

SOLAR PREDICTION ANALYSIS

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16. Abstract

BACKGROUND: Solar Activity prediction is essential to definition of orbital design
and operational environments for space flight. This task provides the necessary
research to better understand solar predictions being generated by the solar community
and to develop improved solar prediction models.
TASKS: The contractor shall provide the necessary manpower and facilities to perform
the following tasks:
1. Review, evaluate, and assess: (a) the time evolution of the solar cycle to
provide probable limits of solar cycle behavior near maximum end during the decline
of solar cycle 22, and (b) the forecasts being provided by the solar community and the
techniques being used to generate these forecases.
2. Develop and refine prediction techniques for short-term solar behavior flare
prediction within solar active regions), with special emphasis on the correlation of
magnetic shear with flare occurrence.

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I: INTRODUCTION

The purposes of this proposal/contract were twofold: (1) Ongoing monitoring of solar cycle indices, as indicators of the level of solar activity during Cycle 22, evaluation of Cycle 22 behavior, and extrapolation/prediction of medium-term and short-tern variations and trends in solar activity, and (2) the continuation of the early phase of operational development of a short-term prediction technique, toward objective algorithm development and improved short-term solar flare predictions utilizing indicators of free energy storage (magnetic shear) in the active region magnetic field.

(1) Space missions in progress and others in their early planning phase rely on solar cycle predictions and consequent thermospheric density expectations. Decisions to base mission planning on the expected behavior of the solar cycle (and resultant thermospheric densities) have appeared to result in the recovery of a major experiment package (LDEF), recovered earlier than initially scheduled, and orbital planning to avoid adverse effects of high densities during an extended solar maximum.

Statistical methods have traditionally been applied to predicting/ extrapolating the running mean of solar activity indices, and have met with some, but very limited, success. Precursor techniques (correlative) have also been used, but the product(s), with variable accuracy, have been only the magnitude of the solar maximum, with no timing information, and no predicted cycle shape or duration of a maximum level of activity. There is, additionally, a requirement for "medium term" (months) predictions, not of a smoothed mean, but of monthly values, and even of the daily values in one rotation (approximately 27 days) predictions. These requirements invite development, testing, refinement of techniques for such medium-term predictions, and evaluation of cycle (smoothed mean) prediction techniques.

(2) It is now generally accepted that the active region's magnetic field and, more specifically, the free energy stored in the non-potential magnetic field, is the source of the energy released in solar flares. The availability of vector magnetograms of solar active regions has made possible evaluation of measurements of the (observed) shear, and quantitative case studies of selected parameters and events have shown significant correlation of shear and field strength with major solar flares. Progress in a more comprehensive study, utilizing additional parameters and analysis of a large number of cases, along with the development and testing of an objective/ quantitative prediction algorithm, is the goal of this effort, in combination with preceding and following work.

II. ACTIVITIES AND SUMMARY

Improvement in medium-range prediction has historically been given less attention than long-range and short-term predictions. The requirement clearly exists for evaluating and improving the forecast techniques. It is suggested that forecasts and their evaluation should be a continuing activity.

The evaluation/analysis accomplished under this contract indicate strong justification for large scale correlation of available vector magnetic field

derived parameters with the occurrence of solar flares and determining the value of these input parameters in improving flare predictions. The results should be compared with predictions made utilizing only traditional data.

II. A - CYCLE MONITORING AND PREDICTION

At the beginning of the contract period, Solar Cycle 22 had been rising at a rather spectacular rate, with concern being expressed by some cycle watchers that the cycle maximum would reach record (since quantitative observations began) levels. However, there were by then early indications that a "plateau" of near maximum values (with large short-term variations) had been reached. Our evaluation of then current behavior, and comparison with the historical data base, led to the expectation that, in the long term (cycle), we could expect three to four years of values averaging near the smoothed maximum. Later in the year, the solar behavior had further indicated that the "roll over" in the indices was real, and that, with large short-term variations to be expected, the sun was in its Cycle 22 "Maximum Phase". Solar behavior during the contract period seemed to confirm this interpretation.

Efforts were then toward analysis and prediction of short-term to medium-term mean flux and variations. The resultant product(s) were the peak and minimum daily 10 cm flux values in a solar rotation, and the expected monthly mean F10.7 (10 cm flux). These efforts met with some success, but with limited improvement with time. Quantitative evaluation of techniques over a significant period of time is suggested.

II. B - SHORT-TERM PREDICTION TECHNIQUE DEVELOPMENT

The concept of some indicator (index), or indicators, of the amount of free energy stored in the non-potential magnetic field of the active region, utilizing primarily vector magnetic field data in the analysis of shear, guides the study. Additionally, any measurement reflecting the relative stability of the field (the likelihood of eminent energy release in flares, is believed of value in the proper evaluation of flare probability. Proposed objective/quantitative input parameters were defined, and variations were considered. Qualitative and subjective parameters were, in general, found to be too dependent on interpretation, and did not lend themselves well to analysis. Unless objectively defined, they were dropped from the study. The initial input parameters (or some subset), derived from vector magnetograms, to remain in the study are:

(1) The Length of the affected Neutral Line (where flux
     and/or shear angle exceeds selected values,
(2) The Maximum angle of shear along the Neutral Line,
(3) The Maximum Flux along the Neutral Line,
(4) The Sum or average flux along the neutral line,
(5) The Sum or average shear along the Neutral Line,
(6) The Maximum gradient of the magnetic field near the NL,
(7) Average Magnetic gradient along the selected NL segment,
(8) Orientation of the Spot Group and Neutral Line,
(9) Complexity (if objective determination defined).

The "traditional" (not from vector magnetograph measurements) parameters selected for incorporation are:

(1) Magnetic Classification (from B Longitudinal),
(2) Sunspot Classification (McIntosh-Zurich three letter),
(3) Sunspot area,
(4) Emerging Flux,
(5) Persistence,
(6) (H-alpha derived parameters were found to be too subjective).

Initial selection and occurrence criteria were defined and case selection initiated. (Due to time and resource constraints, minimal tests were done, and no meaningful statistical analysis was accomplished.) All cases in which Active Region magnetograms of satisfactory quality were available are to yield parameters for evaluation in a 24 hour forecast for the active region. Detailed analysis will follow for all those regions satisfying one or more of the vector magnetic field criteria (shear, field strength along neutral line, gradient) leading to a possible large flare prediction, or the occurrence in the active region of a large flare in the preceding or following 24 hour period.

The continuing study will incorporate analysis of the selected cases, test the selected parameters and select those most valuable in prediction of and correlation with major solar flares, and lead to predictions for the regions for which data are available. The predictions utilizing information about sheared magnetic fields will be compared with predictions using only traditional input parameters, and with predictions incorporating both sets of predictors.