SOLERS22 **Working Group 1 Report**

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SOLERS22 Working Group 1 had extensive discussions of current and future space and ground-based observations of total solar irradiance as well as near-UV, visible, and infrared irradiances during the l-day SOLERS22 meeting held at the IAU Colloquium No. 143 on June 25, 1993. The list of WG1 members attending this session is given at the end of this report.

1.) Observations of solar irradiance

Considerable research efforts have been made to detect and understand the variations in the entire spectral band and in the near-UV, visible and infrared spectral bands since the SOLERS22 1991 Workshop. Besides the ERB on NIMBUS7 and the ERBE experiments on ERBS, NOAA9 and NOAA1O satellites, additional space experiments provided data for total irradiance. The ACRIM II radiometer on board the Upper Atmospheric Research Satellite (UARS) has been measuring total solar irradiance since October 4, 1991. Two radiometers, SOVA1 and SOVA2, were placed on the European Retrievable Carrier (EURECA) satellite to monitor totalsolar irradiance. The EURECA experiment was lunched on July 31, 1992 and it was retrieved on July 1, 1993. The SOVA experiment operated from August 10, 1992 until May 16, 1993. Irradiance observations were made simultaneously by the SOVA1 absolute radiometer CROM from the Royal Meteorological Institute of Belgium and by the SOVA2 absolute radiometer PM06 from PMOD/WRC at Davos, Switzerland. An ACR absolute radiometer from the Jet Propulsion Laboratory and SOLCON, a copy of SOVA1, operated together on the ATLAS1 and ATLAS2 space shuttle experiments. A summary of these space experiments is given in Fig. 1 (from Willson, 1993) .

Data from the different experiments have been compared to each other and to various solar activity indices. Interesting noise features were observed in the radiometric data as well as in the different sun-photometer channels of SOVA. The SOSP experiment on EURECA , ATLAS1 and ATLAS2 measured the solar spectral irradiance from 180 to 3200 nm with 1 nm resolution below and 20 nm above 800 nm. The results show good agreement with previous measurements taken during the Spacelab I mission and the Labs & Neckel spectrum. The long duration of the EURECA mission allows to analyze the solar variability as a function of wavelength and to establish proxy data like the Mg II h & k core-to-wing ratio.

2.) Results gained from the current irradiance observations

The total irradiance observations of ACRIM II, SOVA1 and SOVA2 radiometers clearly show the influence of solar active regions (sunspots and faculae) on total solar irradiance. Papers presented at IAU Colloquium No. 143 have demonstrated that the effect of sunspots on total solar irradiance changes with the phase of the solar activity cycle; however it is not clear as yet whether this is related to the 11-year solar cycle or is a longer term variation (Fröhlich et al., 1993; Romero et al., 1993; Pap et al., 1993). Current results of sunspot photometry, carried out at the San Fernando Observatory (Northridge, California) and at the Kiepenheuer Institute (Freiburg, Germany) confirm that the former Photometric Sunspot Index (PSI) overestimates the effect of sunspots on total irradiance by up to 40% (Chapman, 1993; Brandt et al., 1993) . A new PSI index was developed by Fröhlich et al., 1993, that takes into account the area dependence of the sunspot contrast among other effects, such as the latitude dependent rotation of the spots , different limb-darkening functions, and screening for outliers . Mainly the screening for outliers improves significantly the homogeneity of the data set. Brandt et al., 1993 have also included the area dependence of sunspots in their PSI calculations.

Models of total solar irradiance have been developed to study the long-term irradiance variations. The current irradiance models use the improved PSI for describing the effect of sunspots and various indices, such as the 10.7 cm radio flux, He-line equivalent width (Fröhlich, 1993; Brandt et al., 1993) and the Mg II h & k core-to-wing ratio (Pap et al., 1993, Fig. 2) as proxies for the bright magnetic elements, including faculae and the magnetic network. These models significantly underestimate the observed total solar irradiance at the time of maximum and during the beginning of the declining portion of solar cycle 22, a discrepancy which is much larger than the one found during the maximum of cycle 21. These new results clearly demonstrate that the discrepancy between irradiance observations and their model estimates, which was first noted by Foukal and Lean (1988) for the maximum of solar cycle 21, is a real solar, rather than instrumental, effect. This disagreement between the observed total irradiance and its model estimates asks, as for the sunspots, for a time dependent model which removes the discrepancies but has no physical interpretation as yet (Fröhlich, 1993) . This whole issue is one of the current outstanding problems in solar physics and is indicative of the fact that we do not understand the physical origin of the variability observed in the solar radiative output.

3.) **Discussions of proxy data available for irradiance studies**

3.1. Sunspot data

SOLERS22 WG1 held extensive discussions on the availability of sunspot data. Helen Coffey and John McKinnon from the National Geophysical Data Center described the available data sources. The position of sunspots and area of both umbrae and penumbrae of sunspots are published in the Greenwich catalogue between 1874 and 1976; the Greenwich data are extended to December 1981 by Doug Hoyt using the Boulder sunspot observations. Additional data sets are available from Rome (1958-1990), Taipei (1964-1992), Yunnan (1981-1992), and Catania (1978-1987) . The Taipei data set contains both the projected and corrected area of umbrae and penumbrae. The U.S. Air Force Solar Observing Optical Network (USAF SOON) data are available at the National Geophysical Data Center on CDROM from December 1981 to present. This data set is compiled from observations at Learmonth, Holloman, Rainy, Palehua, Boulder, and San Vito.

András Ludmány and Tünde Baranyi represented the Heliophysical Observatory at Debrecen, where the continuation of the Greenwich Catalogue is compiled. András Ludmány described the current status of the publication of the Catalogue. The original goal of the Debrecen Observatory was to analyze and follow the evolution of each single sunspot. The new direction to be achieved at Debrecen is to measure and publish the position and area of sunspots because the real time to study the evolutionary effects of sunspots has led to the considerable delay of the publication of the catalogue. SOLERS22 WG1 underscores the urgent need of publication of the area and position of sunspots for the time interval of 1979-1981 (maximum of solar cycle 21) where considerable discrepancies exist between irradiance observations and model estimates. As András Ludmány explained, the progress at Debrecen can be expedited considerably by mid-1994.

SOLERS22 WG1 also discussed the direction of the current PSI calculations . WG1 members have agreed that the results of sunspot photometry must be incorporated into the current PSI models and changes of sunspot contrast on both active region and solar cycle time scales must be examined. PSI calculations have currently been taking place by various groups (Fröhlich et al., 1993; Brandt et al., 1993; Cugnon, 1993). The calculation of PSI by Fröhlich et al., 1993, and Brandt et al. , 1993 is essentially based on the original method developed by Hudson et al. , 1982. The Prompt Photometric Sunspot Index (PPSI) is developed by Pierre Cugnon at the Observatoire Royal de Belgique. In the PPSI calculations preliminary sunspot region data from the SELDADS system and additional data from Catania and Kislodovsk are used. Since considerable differences exist between the 'classic' PSI and PPSI data, further investigations and comparisons of PSI and PPSI are recommended by WG1. In addition, a clear description of the method of calculating the PPSI is requested. Furthermore, WG1 emphasizes the need of the publication of a unified and homogeneous PSI function in the SGD catalogue.

3.2. Faculae

One of the largest uncertainties in the irradiance models, especially on long time scales, originates from the lack of knowledge of the effect of faculae principally because of the lack of high quality synoptic data. Although more than 90% of total irradiance is emitted from the photosphere, most of the irradiance variations related to faculae and the network are modelled by proxies, such as the Ca II K plages, the Mg c/w ratio, the He-line equivalent width at 1083 nm, and 10,7 cm radio flux, which originate in the chromosphere or even higher. Detailed discussions of the problems with these proxies are given in the previous WG1 report (Pap and Wehrli, 1992), by Pap et al., 1993, and by Fröhlich, 1993.

To compute an estimate of the facular contribution to the total irradiance we need photometrically accurate images, both in lines and continua. Ca II K is historically the basis for computation of a plage index from full-disk spectroheliograms or filtergrams . Narrowband K images ($\Delta\lambda \leq 1$Å are currently recorded at the National Solar Observatory at Sacramento Peak, San Fernando Observatory, Mt. Wilson Observatory, and Big Bear Solar Observatory. Both San Fernando Observatory and the National Solar Observatory at Kitt Peak record broadband (10Å) K filtergrams. These images are useful in irradiance studies only if they are analyzed to give plage areas and intensities, i.e. , a plage or facular index. Historically, the so-called plage index was computed from McMath-Hulbert Spectroheliograms, and this work continued at Big Bear Solar Observatory using their own data until 1987 when lack of funds stopped the data reduction. Reduction of the Mt. Wilson archive is now being in progress by Peter Foukal, and upon completion his work will yield the image time series for Ca II K spectroheliograms from 1908 to date. Similar reductions are under way at the Meudon Observatory using the Meudon spectroheliograms. The broadband K images from the National Solar Observatory at Kitt Peak and San Fernando Observatory are analyzed by a statistical technique introduced by Jun Nishikawa and Gary Chapman in their initial studies of solar images. This approach yields time series of a 'sunspot deficit' and a 'facular excess' that can be compared to total irradiance measurements.

Other lines such as H-et and HeI 1083 nm also show plages well, but only the HeI 1083 data from the National Solar Observatory at Kitt Peak are reduced to an irradiance index and useful as a surrogate. The HeI line is highly correlated with Lyman-u Ca II K, and Mg II K indices because of its sensitivity to plages and filaments.

It is also important to have continuum images as well. Jun Nishikawa used filters at 545 and 770 nm while Gary Chapman uses one band 672.8 nm as the basis for sunspot photometry. Their image analyses are based on the statistical technical method, But Gary

Chapman also does direct 'object' identification and analysis for sunspots and bright plages.

The existing analyses are all based on a small number of point measurements in the spectrum, i.e. , a particular line or continuum band. Now is the time to look carefully at placements of bands in the solar spectrum and define the optimum set if we are to generate a more accurate surrogate for the total irradiance. The only multi-band observations and analyses are done by our Russian colleagues (Makarova et al., 1993).

4.) Conclusions of SOLERS22 WG1

SOLERS22 WG1 emphasizes the necessity of combined research efforts between different groups using ground-based proxy data for solar irradiances. Comparison between different Ca K observations are required to make the time series comparable to each other. Development of homogeneous data sets for both sunspots and faculae are desired to enable the comparison of the results of data analyses carried out by different research groups. SOLERS22 WG1 also emphasizes that the limitation of irradiance models must be considered in climatic studies. The current models are developed with simple linear regression analysis and no adequate physical model exists for explaining the origin of irradiance changes.

Presentations at IAU Colloquium No. 143 have demonstrated that the terrestrial climate, radiative environment, and upper atmospheric chemistry are influenced by the varying irradiance of the Sun. SOLERS22 Working Group 1 has shared the increasing concern of the international research community regarding the possibility of the delay or even termination of forthcoming observations of solar irradiances. Both the presentations at IAU Colloquium No. 143 and the discussions during the SOLERS22 session have demonstrated the need of continuous long-term irradiance observations. SOLERS22 WG 1 supports very strongly the resolution released by the Scientific Organizing Committee of IAU Colloquium 143 (attached to the present report) .

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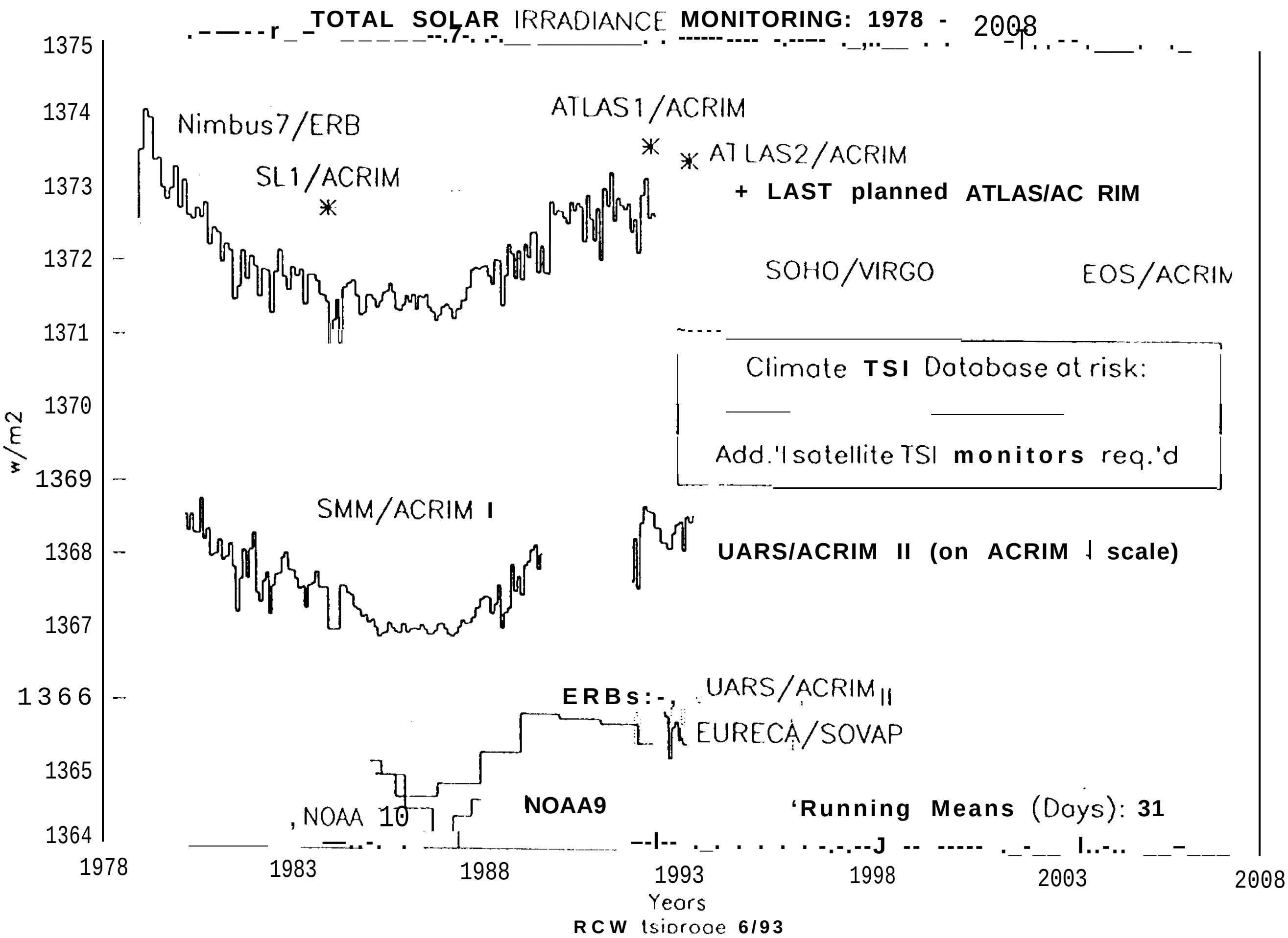

Fig.] . Past, current, and future space experiments and their results are presented. The figure is provided by R.C. Willson (1993).

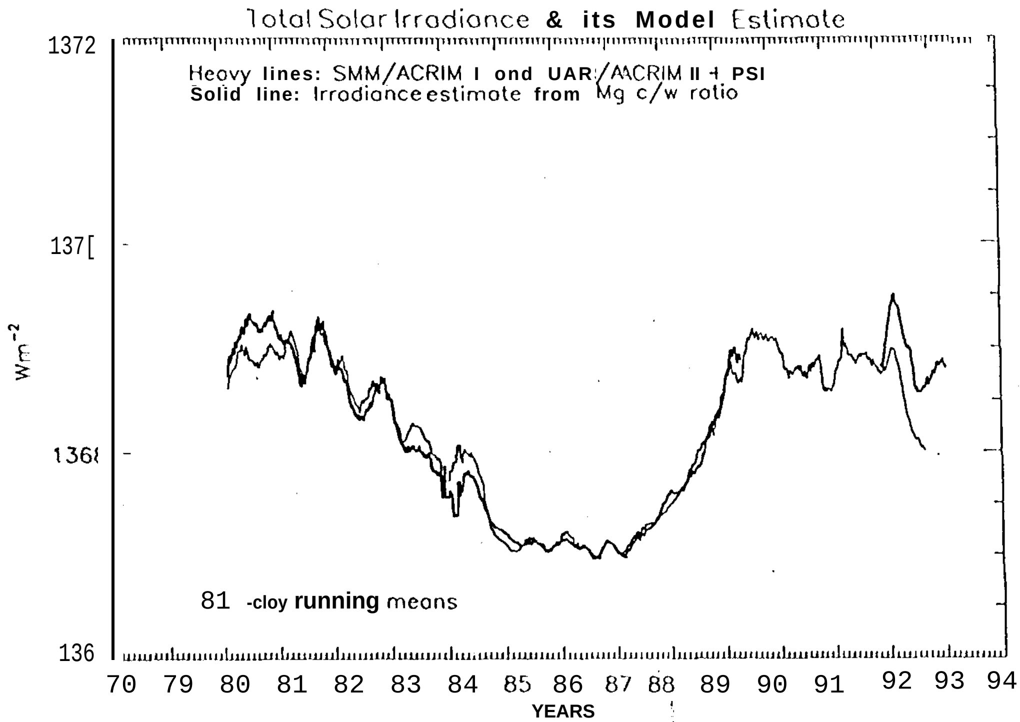

Fig.2a. The heavy line shows the 81-day running means of the SMM/ACRIM I and UARS/ACRIM II total solar irradiance values corrected for sunspot darkening. The solid line represents the 81-day running averages of the irradiance model. estimates.

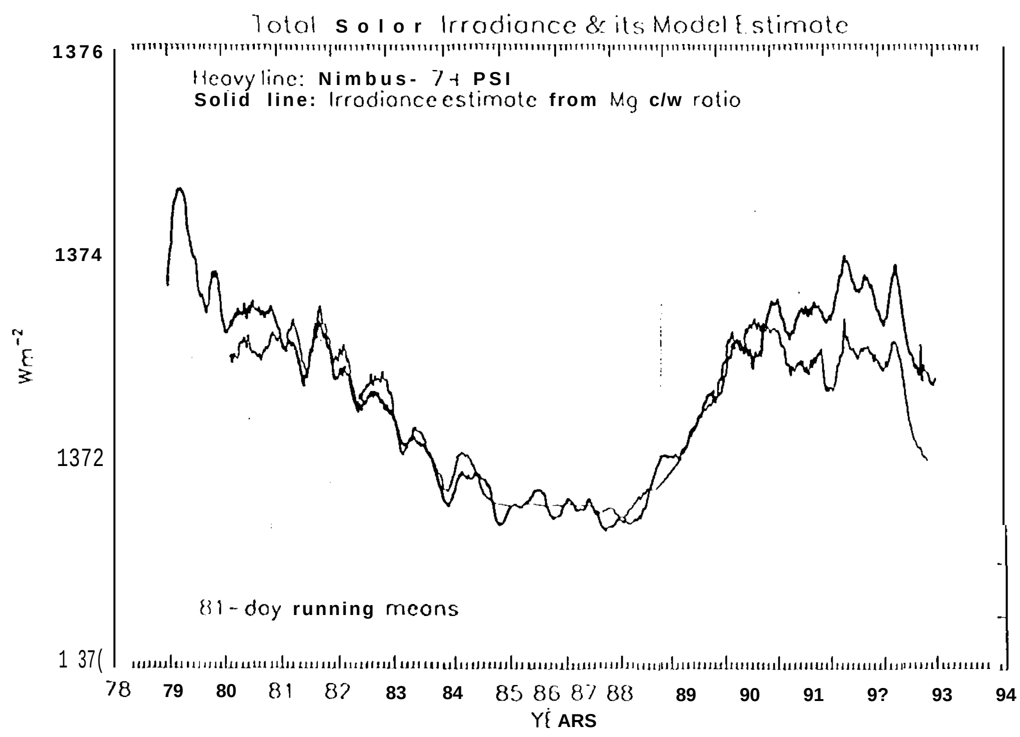

Fig.2b. The heavy line gives the 81-day running means of the Nimbus-7/ERB total irradiance corrected for sunspot darkening. The 81-day running means of the model led irradiance values are shown by the solid line.

Local and Scientific Organizing Committees

COLLOQUIUM NO. 143

The Sun as a Variable Star:

Solar and Stellar Irradiance Variations

Statement from the Scientific Organizing Committee of Colloquium No. 143 of the International Astronomical Union

It is now established by a variety of studies that the terrestrial climate, radiative environment, and upper atmospheric chemistry are strongly influenced by the varying luminosity of the Sun. The human consequences are such that quantitative study over the solar magnetic cycle is imperative for societal planning. The solar variability together with the accumulation of anthropogenic pollutants determine the human milieu of the future. We note that the World Climate Research Program has expounded a full scientific study of these problems.

The scientific presentations at the IAU Colloquium No. 143 make it, clear that the forthcoming termination of essential scientific measurements of solar irradiance places these studies in serious jeopardy. One of the most important aspects of the study is the long-term variation of the Sun, which we have reason to believe to be significant. However, the present understanding of the basic physical mechanisms of irradiance variations does not yet allow us to develop adequate irradiance models. Moreover, the limitations on" absolute calibration of instruments, the large short-term variability of the Sun, and the inadequacy of theory conspire to make it impossible to establish long-term trends if there are gaps in the observations. Therefore we note:

(NASA)

1. High precision observations of solar total and spectral irradiance from UARS and Atlas are required for one full solar 11-year cycle to achieve progress in understanding key issues of climate change and ozone variation.

2. Future flight opportunities on EOS for continuous monitoring of the solar radiative outputs urgently need to be maintained, to study the longer-term trends of potential importance to global change. Failure to achieve overlapping continuous measurement sets from successive satellites will reduce the usefulness of the excellent data already obtained (since 1980) addressing these issues.

(ESA)

Considering the results obtained from measurements of solar total and spectral irradiance of the Sun from the ultraviolet to the infrared, a second flight of EURECA would provide a unique opportunity to extend the measurements carried out by UARS and EURECA-1, to fill the gaps before and after the launch of SOHO. This proposal is in line with the general objectives of the European Community with respect to the Global Change Program.

(ISAS and NASDA)

The contributions of Yohkoh to studies of solar global properties are recognized, and the participants of IAU Colloquium 143 recommend and encourage continued analysis of Yohkoh data, and of the development of future Japanese solar and applications satellites that can extend our research knowledge in these important directions.

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