SPACE ENVIRONMENT LABORATORY

Environmental Research Laboratories

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Director

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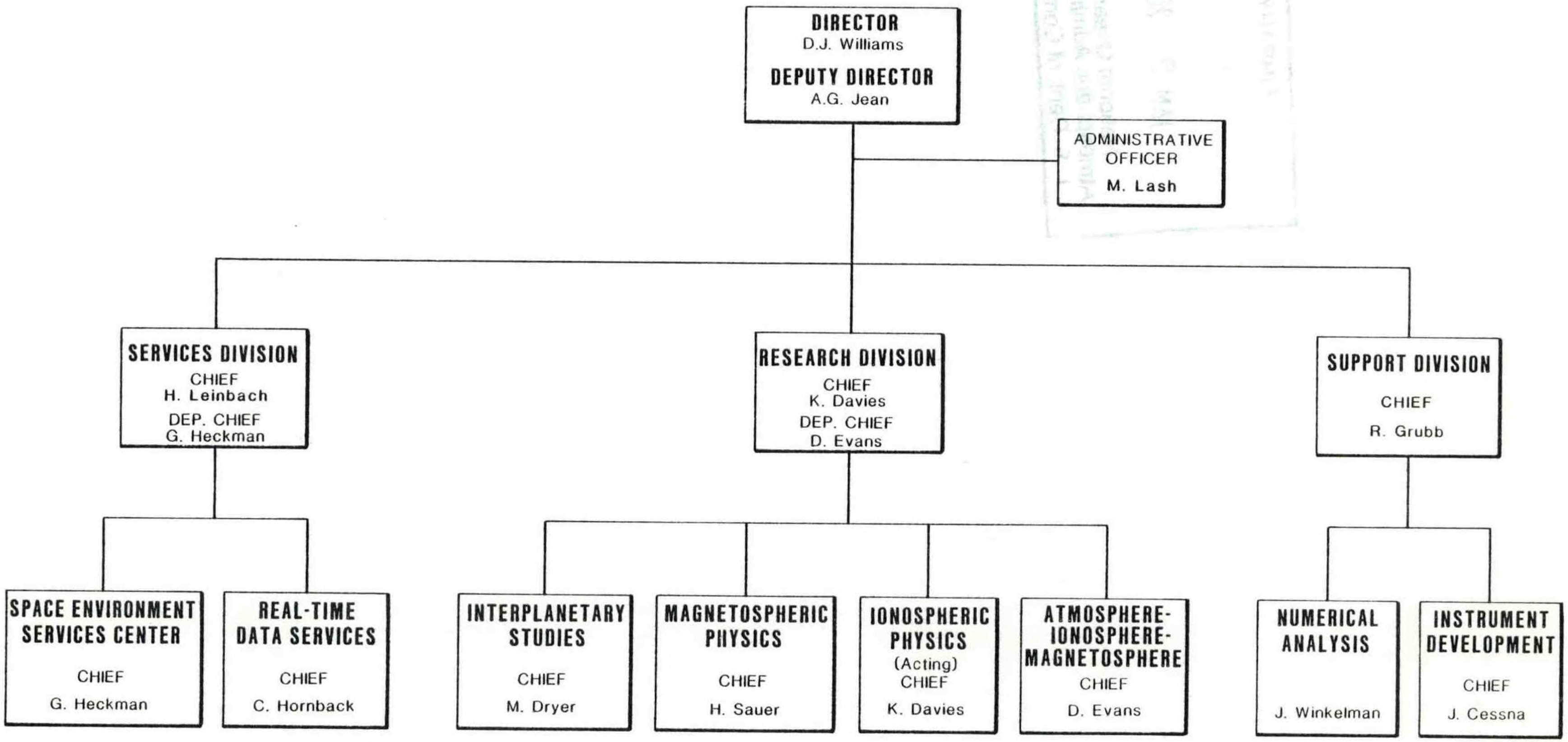
SPACE ENVIRONMENT LABORATORY

ORGANIZATIONAL CHART



INTRODUCTION

The Space Environment Laboratory conducts research in solar-terrestrial (ST) physics; develops techniques for forecasting solar disturbances and provides real-time environment monitoring and forecasting services.

The SEL is the contemporary component of the DOC which has provided ST research and services for four decades. NOAA and its predecessor organizations have provided such services since 1942 when military operations required ionospheric radio propagation predictions for communications purposes. Since then, the increased reliance of society on sophisticated technological systems, which are sensitive to perturbations in the solar-terrestrial environment, has created a growing need for an understanding of ST relationships and technically advanced solar-terrestrial services.

The focal point for the nation's present solar-terrestrial services is in the SEL at Boulder where, with the cooperation of the Air Weather Service, the monitoring and forecasting services are carried out to meet a wide variety of civilian, military, commercial and federal agency requirements. The scope of the services ranges from the real-time collection of solar-terrestrial data to issuance of forecasts, alerts and warnings of adverse solar-terrestrial conditions, to the archiving and processing of solar-terrestrial data from all over the world, to the development of an understanding of the behavior of the solar-terrestrial environment to yield significant service improvements.

Theoretical and experimental research studies are conducted on the fundamental physical processes responsible for the observed energy release in the form of electromagnetic and particle radiation from solar flares; the propagation of this energy through the interplanetary medium to the near-Earth environment; the transfer of this energy from the near-Earth interplanetary medium into the Earth's magnetic field, the magnetosphere; and the behavior and subsequent effects of this energy within the magnetosphere, the ionosphere, and upper atmospheric regions. Knowledge gathered from these studies is used to develop prediction techniques that can, with the extensive real-time data service maintained by the Laboratory, forecast solar events and their ground-based effects. Early warning and real-time information concerning the solar-terrestrial environment, especially the near-Earth environment, is provided to a variety of users.

ORGANIZATION

The organizational arrangement through 1981 is shown in the accompanying chart. Note that the Services Division consists of the Space Environment Services Center (SESC) and the Real Time Data Service (RTDS); the Research Division consists of the Interplanetary, Magnetospheric, the Ionospheric, and the Atmosphere-Ionosphere-Magnetosphere (AIM) groups; and the Support Division consists of the Numerical Analysis and the Instrument Development Groups.

Functionally, there is constant cooperation and interchange between staff in the three divisions and their branches to accomplish the goals of relatively short-term projects as well as the long-term goals of the

Laboratory. The interchange between the Research, Support and Services Divisions is evident in the "Activities and Plans" portions of this report and applies equally to activities funded by NOAA and by other government agencies and to national and international cooperative programs.

BUDGET AND FUNDING

Early in FY 1981 the SEL announced an anticipated deficit for that year, and an even larger one in 1982 unless corrective measures were taken. Extrordinary reductions were made in other objects expenditures to minimize the deficit in 1981 and permission was given for SEL to conduct a reduction-in-force to prevent a deficit in 1982.

Within the last few years, laboratories have not received funds for the full amount of the comparability pay raises, nor for overheads which must be paid on the increased labor costs, including 9.6% for personal benefits. The shortfall to SEL in 1981 was approximately $100 K. A few years of this practice will severely erode the laboratory's ability to maintain a level staff and there appears to be no alternative to reductions-in-force.

The good news is that 80% of the long-awaited FY 1981 initiative for improving the Services Division was received in March. These two actions, the reduction-in-force and the receipt of the Services initiative, were accompanied by a reorientation of the Laboratory's activities for the next several years.

Changes for 1982 and Beyond

In view of the budget problem outlined above, a decision was made to terminate the Ionospheric Research Group of the Laboratory. This choice was particularly difficult in view of the recent completion of several units of a modern digital ionosonde and the field demonstrations of its capabilities. Efforts are continuing at this time to assist other groups to continue a national program of ionospheric research using the digital ionosondes which were designed and produced in SEL under the joint NOAA/NSF sponsorship. The excellent and world-renowned accomplishments of the Ionospheric Group are hereby acknowledged.

The reduction-in-force and the receipt of the 1981 Services initiative signify significant changes in the Laboratory's activities over the next several years. The Services initiative will provide in FY 1984 a new ST data facility to better cope with the national needs which are expanding and also becoming more complex. After the new equipment is purchased and placed in operation, a technique development activity will be begun.

In the research area, which will be considerably smaller, high-quality research in appropriate ST areas will be stressed.

In order to conduct the necessary research in the face of a decreasing staff, the Space Environment Laboratory has benefited greatly from the participation of visiting scientists, the NOAA-NRC Post Doctoral Associateship program, guest workers and visitors. Persons working at the Laboratory during the year are listed in the Appendix with the SEL Staff.

Research Division K. Davies

Objective:

The objective of the Research Division is to conduct long-term research into those factors that affect the solar-terrestrial environment. This research covers emission processes on the sun, the propagation of disturbances through the solar wind, the impact of the solar wind on the Earth's magnetosphere and the energy coupling between the magnetosphere, the ionosphere and the neutral upper atmosphere. During the year the Division was organized into four Branches in the areas of Interplanetary Physics, Magnetospheric Physics, Ionospheric Physics and the new Atmosphere-Ionosphere-Magnetosphere Interactions (AIM) Branch.

INTERPLANETARY PHYSICS BRANCH M. Dryer

Objectives

A principal objective of the Interplanetary Physics Branch is the development of magnetohydrodynamic (MHD) models of the transfer of plasma mass, momentum, energy, and magnetic flux from the Sun to the Earth's magnetosphere. Simulation of the power in this solar wind will provide a scientific basis for the evaluation of the power transfer into the magnetosphere under both quiet and disturbed periods. An essential element of this theoretical and computer-oriented research is the testing of these models by direct confrontation of their predictions with spacecraft observations (such as ISEE-3) and operational forecasting statistics.

Staff member Dr. S. T. Suess spent most of FY 81 at the Institute for Plasma Research of Stanford University as a Visiting Scholar in order to learn the use of the computer algorithms required for inclusion of thermal conduction within locally-developed (NASA-Ames) implicit differencing techniques and to apply them to time-dependent solar wind models.

Another SEL staff scientist, Dr. R. F. Donnelly, joined the Branch at the start of FY 81. Donnelly is the leader of the Solar UV research project. The long-term objective of this project is to determine the intensity and time scales of variations in the ultraviolet radiation as a function of wavelength in the 100-400 nm range in terms of their significance to climate, molecular dissociation, atmospheric chemistry, upper atmospheric heating, and measurements of minor atmospheric constituents. The accomplishments of the Branch will be discussed under the following two headings: Solar Wind Physics Research and Solar UV Radiation Research.

ACCOMPLISHMENTS FY 81

Solar Wind Physics Research

The basis for the most advanced fluid equations describing the solar wind (with no magnetic field) was established (Cuperman, Weiss and Dryer,

1980) with higher moment equations in the time domain for a non-equilibrium, multicomponent solar wind plasma. This will enable extension of existing SEL computer codes to include the case of highly turbulent, three-specie (proton, electron, helium) solar wind with more realistic consideration of heat flux and departure of the distribution functions from the classical Maxwellian distribution. Work was started, with Tel-Aviv University, to combined effects of relative velocity among the species as well as highly-skewed distribution functions that represent double-streaming and plasma beams. A specific analysis using the classical 3-moments equations in a self-consistent form, was performed for the three species mentioned above (Cuperman, Metzler and Dryer, 1981).

Numerical simulation, with explicit consideration of magnetic fields, of transient activity in the lower corona (flares, eruptive prominences, etc.) has continued. These transients, most often observed by radio and white light techniques, follow the visible and x-ray manifestations of a solar flare. We extended our previous two-dimensional MHD model to allow for the existence of the accelerating solar wind for the highly-restricted case of a radial magnetic field (Wu, Steinolfson, Dryer and Tandberg-Hanssen, 1981). A model for coronal transients was proposed based on bouyancy due to plasma and magnetic gradients in the solar atmosphere (Yeh, 1980; Yeh and Dryer, 1981a; and Yeh and Dryer, 1981b). Work was initiated to extend the coronal two-dimensional model to include the third component of both plasma velocity and magnetic field. This results in a non-planar, quasi-three-dimensional MHD model of the solar corona.

Work was initiated, with the University of Alabama, Huntsville, and several visiting scientists to extend the coronal two-dimensional simulations to consider the third component of both plasma velocity and magnetic field resulting in a non-planar, quasi-three-dimensional MHD coronal model. The coronal transient problem was also approached, phenomenologically, on the basis of a synthesis of various kinds of observations (radio bursts, white light and spacecraft). This work suggests the association of the expanding shock wave with the enhanced density (i.e. coronal transient) observed by coronagraphs near the sun and by plasma probes in the interplanetary medium (Maxwell and Dryer, 1981; Maxwell and Dryer, 1980). Figure 1 shows a montage of a cross-sectional view through a flare-generated transient; the solid (dashed) contours are plasma density enhancements (rarefactions) computed from the two-dimensional MHD planar model. The interpretations of the various diagnostics are sketched-in and labeled as indicated by the arrows. This model has also been employed as the basis for the secondary acceleration of solar cosmic rays by the expanding shock wave (Dryer and Wu, 1981).

Work started on the simulation of the 1980 June 29 ($\sim$ 1800 UT) solar flare that is being examined by the SMY (Solar Maximum Year) STIP (Study of Travelling Interplanetary Phenomena) project. The input conditions of density and temperature at the flare site (as a function of time) will be provided by the Solar Maximum Mission (SMM) x-ray Polarimeter experiment. This work is being performed in collaboration with UAH, NCAR/HAO, NASA/Goddard, and Lockheed.

As part of the Study of Travelling Interplanetary Phenomena (STIP) a group of international scientists was organized to serve as coordinators for the five extensively-observed interplanetary events during the Solar Maximum Year. Dr. Dryer participated also in the planning for the SMY Workshop to be held in France in October 1981 and assisted the ERL Office by coordinating solar-terrestrial and other projects under the Special Foreign Currency program. A proposal was submitted to NASA/JPL on the utilization of the STIP project during the International Comet Halley Watch.

Substantial progress was made with the extension of the two-dimensional MHD model of the solar wind (with the University of Alabama) to include all three components of velocity and magnetic field -- starting at the Sun and extending to the Earth's orbit. The model was run successfully on NCAR's CRAY computer and is being programmed for NOAA's CYBER 750. An example of the propagation of a warped, interplanetary magnetic field topology is shown in Figure 2. This model will be the principal model for study of energy flow from the Sun to the Earth's magnetosphere.

Several earlier projects have been completed involving the one-dimensional and two-dimensional MHD models. The results of confrontation of spacecraft data and calculations have been published (Smith et al., 1981) for the case of Pioneer 10 measurements near 3 AU. In an application of the two-dimensional (planar) model it was shown (Dryer, Wu and Han, 1980) that the model was capable of simulating "magnetic bubbles" in the ecliptic plane. In another application (D'Uston et al., 1981) simulations were made of the azimuthal solar wind perturbations by solar-flare-generated shock waves of different strengths.

Work was completed on a contribution to a report of the National Academy of Sciences entitled "Solar-Terrestrial Research in the 1980's" as was the publication of Solar and Interplanetary Dynamics (Dryer and Tandberg-Hanssen, 1980). A series of studies were initiated (with the University of Mexico) of the solar wind's viscous interactions with the Venusian ionosphere. The shock wave in the solar wind plasma interacts with the ionopause and strips off heavy ions such as O^+ that flow into the wake. The compression and expansion of the dayside ionopause in response to variable solar wind pressure was documented.

The analysis required for construction of a one-dimensional hydrodynamic model (no magnetic field) of the solar wind was successfully implemented on both Stanford University and NOAA/ERL computers. Furthermore, a general analysis for a two-dimensional MHD model, and a quasi-three-dimensional MHD model including solar rotation was completed as was work on the damping of lower coronal motions by thermal conduction. These models are part of the continuing effort to prepare for analyses of solar-wind data from the NASA/ESA International Solar Polar Mission.

The inclusion of magnetic field into a theory of coronal plumes was successfully completed (Suess, in press). This study showed that plumes, clearly visible in Hα and other wavelengths are magnetic features with magnetic field strengths typically two to three times the background strength with separations of from 50,000 km to 70,000 km. The relationship of coronal-hole size to magnetic field strength was successfully modeled (Steinolfson, et. al., in press) which showed that coronal-hole size was weakly dependent on field strength but does depend on the geometry of the photospheric magnetic field. This conclusion eliminates one of the variables hindering interpretation of solar cycle variations of the solar-wind structure and, therefore, interpretation of the cause of geomagnetic disturbance.

The structure of the magnetosphere of Mercury has been investigated to acquire an understanding of particle access from the solar wind which is analogous to the access of the solar wind to the Earth's magnetosphere. A topological model of the magnetic field of Mercury was published (Goldstein, Suess and Walker, 1981) showing that the observed helium exosphere of that planet is derived almost entirely from the solar wind.

Solar UV Radiation Research R. F. Donnelly

This research is concerned with the temporal scales of solar variability. These time scales include: (a) intermediate-term variations (days, weeks, months) involving active region evolution, solar rotation, sector boundary passages, etc., and (b) long-term variations (years to decades) involving sunspot cycle evolution and the 22-year solar magnetic field cycle. The research involves the following: (1) analysis of existing solar UV irradiance data through co-operative studies, e.g., analysis of NIMBUS 4 and 7 solar UV irradiance data in cooperation with NASA-GSFC, and Systems and Applied Sciences Corp.; (2) development of models to explain the observed UV variations in terms of the spatial structures and the full-disk chromospheric flux observed from the ground in the CaK solar absorption line with CIRES, NCAR, and Kitt Peak National Observatory; (3) development of data analysis for future solar UV irradiance measurements from the NOAA-NASA, (Solar Backscatter Ultra Violet (SBUV)/2 instruments that are currently being built by Ball Aerospace Corp.; and (4) design and development of an improved instrument for rocket-flight measurements of solar UV spectral irradiance. A detailed report of the progress on this work is available from NOAA-ERL-SEL (Donnelly 1981a). Accomplishments of this project in FY 81 are discussed below.

The analysis of NIMBUS-7 SBUV data was extended from six months to about two years of data, with the most extensive analyses of data completed for about a year of data by System and Applied Sciences Corp. under NOAA Contract No. NA80RAC00212, in cooperation with NASA-GSFC. Because of agreements about unpublished data, the figures below include only the first six month's data, which have been previously published (Heath, 1980). Figure 3 shows typical examples at three wavelengths of the temporal variations of UV flux normalized to the flux measured at the start of observations. Variations due to active region evolution and solar rotation ($\sim$ 27 days) dominate the temporal variations. Figure 4 shows the solar rotation variations as a function of wavelength obtained by averaging, over three cases, the ratio of the peak flux during a rotation to the flux at the next rotational minimum.

These were the first observations to show the existence of solar rotation variations in the 210-300 nm range and also to provide extensive high-quality quantitative results for the solar-rotation variation in the

180-210 nm range. The 175-205 nm Schumann-Runge band is particularly important in the photodissociation of O_2 and the subsequent production of O_3. Ozone plays an important role in the UV heating of the atmosphere by absorbing 230-292 nm solar radiation. The 195-210 nm range is also very important because it can penetrate the atmosphere to low altitudes ($\sim$ 20 km) where it dissociates chlorofluorocarbons to produce free radicals which can destroy ozone.

A model of solar UV spectral irradiance conceived at the U. S. Naval Research Laboratory, has been revised and extended to include more spatial information on active regions in order to better model the solar rotation and active region evolution variations and has included a term representing long-term variations in the chromospheric network. The model uses as input data two alternative types of ground-based observations made in the core of the strong absorption line of calcium called the Calcium K line (CaK). The first type involves highly accurate full-disk flux intensity measurements by NCAR and Kitt Peak National Observatory. The second type involves information on the area, location and approximate intensity of chromospheric plages in solar active regions. In effect the model uses the ground-based CaK to interpret the full-disk CaK flux in terms of chromospheric active region emission (intensity and solar location), the chromospheric quiet sun and the chromospheric network. The model then estimates the corresponding chromospheric UV emissions from these same components. The results already achieved include a great improvement in estimating the solar-rotation variations observed by the NIMBUS-7 SBUV experiment in comparison with the previously available model. The new model also indicates a somewhat larger solar cycle variation.

These models will be used to interpret those portions of the observed UV temporal variations that can be well explained by our current knowledge of solar physics and to help determine the characteristics of that portion of observations that remains unexplained, which may.also be useful in identifying any instrument-drift problems.

The progress in the Solar UV satellite observation program has been the designation of R. F. Donnelly as an official user of the solar UV spectral irradiance measurements to be made by the SBUV/2 instrument in the joint NOAA-NASA program for ozone and solar UV operational monitoring measurements from the TIROS-N series of satellites. Requests have been submitted to NOAA-NESS for those data pertinent to understanding these solar UV spectral irradiance measurements in order to start the process of setting up their soft-ware for a generation of solar UV data tapes. Because the intermediate-term variations (days, weeks, months) caused by solar-rotation and active-region evolution are comparable to the long-term variations, satellite solar UV measurements are currently required because rocket-flight and future shuttle measurements are too brief and infrequent. On the other hand, satellite measurements alone are insufficient for measuring long-term solar UV variations because of long-term instrument drift problems which are not a significant problem for the relative measurement of solar-rotations. Figure 5 shows the planned solar UV measurements for the coming decade as of August, 1980. The funding for the UARS program has not been approved and that program may be cancelled or appreciably delayed. The combination of the NIMBUS-7 and SBUV/2 measurements should be the dominant data sets during this decade. The NIMBUS-7 measurements started in November, 1978, during the final part of the rise, the peak and early decay of solar cycle 21. The SBUV/2 measurements will start near sunspot minimum and will continue into the rise of the next cycle. The measurements during the current decade are extremely important because in the 1990's research on the stratospheric and climate effects of solar UV variations will be complicated by the halocarbon-induced ozone depletion and CO_2 build-up problems. As these latter effects increase in importance in about 1990, it will be necessary to know how much of the observed atmospheric variations could be caused by natural solar UV variability. Our answers to that question will come mainly from the NIMBUS-7, SME and SBUV/2 with recalibrations based on rocket-flight and possibly shuttle-flight measurements.

In order to achieve rocket-flight measurements of the solar UV spectral irradiance with accuracies consistent with the required accuracy-goals, a program has just been initiated to design and develop a new spectroradiometer. Higher-accuracy measurements are needed to recalibrate the NIMBUS-7, SME and SBUV/2 measurements and to intercompare rocket-flight and future shuttle measurements, where in the latter case the effect of space contamination from the shuttle on high-accuracy UV measurements remains to be determined.

In anticipation of receiving the NIMBUS-7 solar UV data an analysis was made of the long term variations of solar soft x-rays, which are dominated by active-region emission and were already available from SMS-1 and -2, and GOES-1, -2 and -3. Two atlases of x-ray data were published (Donnelly, 1981b; Donnelly and Bouwer, 1981) as a by-product of preparing the data for time-series analysis. It was found that the relationship between solar soft x-rays and the daily 10.7 cm solar radio flux is greatly affected by the central meridian distance (CMD) of the prominant regions of solar activity because the 1-8A soft x-rays are optically thin in the corona while the coronal active region emission at 10.7 cm is not. Amazingly most of the literature involving comparisons of the 10.7 cm solar radio flux and solar soft x-ray flux have erroneously assumed that the radio source is optically thin, which is inconsistent with the solar radio literature published in the 1950's. The one paper that considered the radio sources to be optically thick neglected the dominant role played by temporal variations in the coronal emission measure and effective radio emission areas compared to the coronal electron temperature variations. Consequently, the CMD dependence had been missed.

A daily soft x-ray index was developed based on the daily average x-ray flux. We hope to use this measure of the solar corona in conjunction with concurrent NIMBUS-7 solar UV measurements, which varies predominantly because of related chromospheric variations, and with concurrent solar constant measurements, which vary because of related photospheric variations. The x-ray data from the different satellites have been compared in order to obtain a more homogeneous data set in preparation for time-series analyses.

Contracting arrangements

The research on solar UV and x-rays is carried out under the direction of one SEL employee (R. F. Donnelly) by contracts to universities and private industry. The solar UV irradiance model and the solar x-ray analyses were carried out by the Cooperative Institute for Environmental Sciences (D. Bouwer and J. Lean); the analysis of the solar UV data by Systems and Applied Sciences Corporation (H. Park, 1981), the rocket-flight UV spectroradiometer by H. Koskowski, improvement in calibrations by the Laboratory for Atmospheric and Space Physics (G. J. Rottman, 1981). Data for these studies have been provided by NASA-Goddard Space Flight Center (D. F. Heath) the National Center for Atmospheric Research (O. R. White and A. Skumanich), and Kitt Peak National Observatory (W. C. Livingston). A detailed report on this project is available (Donnelly, 1981).

PLANS FY 82

Solar Wind Physics Research

Fundamental equations will be formulated containing higher moments for model development. Computer algorithms will be prepared for the inclusion of these equations into models.

The non-planar, two-dimensional solar wind model will be put into production on the NOAA CYBER 750 computer. A description of the basic model, together with examples, will be published, as well a description of multi-spacecraft observations at differing solar longitudes. We will attempt to determine the energy flux at the magnetosphere.

The non-planar two-dimensional MHD model of coronal transients will be used to simulate the SMY-STIP event of 1980, June 29 ($\sim$ 1800 UT) based on soft x-ray observations on Solar Maximum Mission. In collaboration with the NCAR/HAO Coronagraph-Polarimeter team a paper will be published on a coronal transient that was observed sequentially in Hα and Fe X at Sacramento Peak Observatory then by the SMM (white light and a broadband Hα filter) and the PF8-1 (white light) coronagraphs. This will represent the first set of consistent photo-subtracted images that can be compared more directly with coronal transient model simulations.

The operational utility of using Pioneer-Venus-Orbiter solar wind plasma measurements at 0.7 AU to predict the same parameters at ISEE-3 (or IMP 8) will be examined. The PVO data will be used to compute the predictions, at 1 AU, via a steady state thermal conduction solar wind. The PVO data will be used also to study the closure of the shocked solar wind in the Venusian wake.

The one-dimensional solar wind model will be used to analyze coronal energetics, conductive damping of coronal notions, coronal stability and the general topic of stellar winds. A detailed analysis will be made and the program requirements assessed for application of the implicit algorithm method of equation solution to the case of the multi-dimensional MHD computations. This numerical technique will be applied to damping of coronal motions.

Participation will continue in national and international programs such as: the SMY Workshop in France, STIP Workshop in Ireland, the SMY Symposium in Canada, the International Astronomical Union General Assembly in Greece and certain of the Special Foreign Currency programs sponsored by NOAA.

Solar UV Radiation Research

The results of research on solar UV variability observed by the NIMBUS-7 satellite will be published. The variability of solar UV will be compared with the variability of the solar constant.

The model of solar UV spectral irradiance will be refined and compared with all available UV observations including NIMBUS-7 data.

Time series (frequency) analyses of the daily background solar soft x-ray flux will be made. The results of studies on the long-term variations of the solar soft x-ray flux (during the NIMBUS-7 solar-UV observing period) and on the CMD dependence of the relationship between the solar 10.7 cm radio flux and the 1 to 8 Å x-ray flux will be published.

MAGNETOSPHERIC PHYSICS BRANCH

H. Sauer

Objectives

The Magnetospheric Physics Branch conducts experimental and theoretical investigations of magnetospheric physics comprising the study of the geomagnetic field and the several particle populations within it, and the dynamics of the complex electromagnetic processes by which the particles interact. Emphasis is placed on analyses of satellite instrumentation data sets, obtained from both research and operational satellites. Multisatellite studies of magnetospheric dynamics continued with particular emphasis on the analysis of data from the Medium Energy Particle Experiment of the International Sun Earth Explorer (ISEE) A and B spacecraft launched 22 October 1977, together with associated theoretical studies.

Conventional wisdom in the magnetospheric research of the past decade has looked to the so-called collective behavioral characteristics in trying to explain the dynamics of the magnetosphere. While certain progress has been made in our understanding of magnetospheric processes such as the structure of the radiation belts and some significant effects of wave-particle interactions, progress toward and understanding of the principal energization processes operating in the magnetosphere has been halting. The success of the modelling of the dayside magnetosphere boundary through the development of the remote sensing technique, developed by laboratory scientists, and the modelling of an auroral particle acceleration mechanism, has stimulated an aggressive interest in re-examining the single-particle dynamics approach to magnetospheric dynamics. This approach has also been encouraged by some rather exciting and productive analytical and theoretical accomplishments this year.

ACCOMPLISHMENTS FY 81

Studies of the ISEE 1 particle data at this laboratory as well as studies at other institutions had shown that particle acceleration in the geomagnetic tail occurred primarily in a thin layer adjacent to the plasma sheet. Imaginative analysis of the ISEE data by laboratory scientists has indicated that the apparently complex behavior of these bursts of energetic particles observed near the plasma sheet could be explained and understood by invoking single-particle dynamics. From this perspective, the motion of a charged particle moving with a velocity V at an angle α (the pitch angle) with respect to the magnetic field may be characterized by a gyration in a circle about its average position or guiding center, with a velocity $V_{\perp} = V \sin \alpha$, and a motion of that average position or guiding center along the magnetic field direction with a velocity $V_{||} = V \cos \alpha$. Therefore, if one examines a group of particles with a relatively broad velocity or energy spread, all of which have approximately the same guiding center velocity $V_{||} = V \cos \alpha$, one can see that the lower energy (velocity) particles would have a smaller pitch angle, and higher energy particles would have a larger pitch angle. If one, therefore, were to observe the sequence of observations due to a burst of particles of a given energy occuring at some distance away from him on the same field line, he would first see the passage of particles of pitch angle zero, that is, those moving directly along the field line toward him. As time passes, he would see particles of increasing pitch angle with respect to the field line in a circle of directions looking very much like a "smoke ring" centered on the magnetic field direction -- the field direction would be devoid of particles because they had already passed.

Figure 6 shows from left to right, four "snapshots" in time sequence, at four increasing energies from top to bottom, the observations of particle fluxes by instruments aboard the ISEE-1 spacecraft while it was adjacent to the plasma sheet in the geomagnetic tail. The detector look directions are plotted with azimuth angle on the horizontal axes, elevation angle on the vertical axes, while intensity is indicated by color. Looking at the lowest energy channel of the first snapshop (upper left frame) we can see a "fuzzy" smoke ring in the right half of the frame representing at that moment in time, particles of about 45° pitch angle moving toward the earth, with a hole in the center (the field direction) because particles moving along the field had already passed ISEE -- in fact we find these "hole" particles in the left half of the figure returning from the opposite direction along the field, having reflected from the much stronger magnetic field near the Earth. As we look at the simultaneous response at a higher energy (next lower frame) the earthward smoke ring has expanded (higher energy particles arrive at ISEE and have the same parallel velocity at larger pitch angles) as has the reflected particle smoke ring in the left of the frame, returning from the Earth. This is just what would be predicted by the analysis of the previous section. Calculations can be made to deduce the distance of the source from the observation point, confirmed by the character of the reflected particle response from the earth, which is a known distance away.

It is pointed out that the scientific insight which recognized the signature of single-particle dynamics in the data owes much to the development of imaginative data displays such as those illustrated by Figure 6. A further theoretical study has realistically modelled the plasma sheet configuration and, using single-particle dynamics, has shown that transport of magnetospheric particles into the plasma sheet and their subsequent acceleration by electric fields known to exist there is able to predict the fluxes of energetic particles observed to precipitate into the auroral regions of the earth. Figure 7 illustrates the remarkably good fit of the predicted particle distribution indicated by the solid curve, to the measured tail flux values of several workers. There is a strong indication that this process represents a major mechanism for the transport of solar-wind energy into the auroral atmosphere, and may also represent a significant source for the maintenance of the particle populations of the Earth's radiation belts.

Rather than exhaustively catalog the diversity of studies and accomplishments of the Magnetospheric Physics Group, it was felt appropriate to high-light a few specific investigations in which a laboratory developed perspective has resulted in genuinely exciting results at the forefront of magnetospheric research. As the publication list would indicate, significant results continue in the area of magnetospheric boundary wave studies, ion composition and dynamics studies, and studies of the inner magnetosphere and its dynamics.

PLANS FY 82

Continued analysis of data relevant to acceleration processes in the geomagnetic tail.

Further characterization of the magnetospheric boundary and associated boundary regions and wave structures.

Further characterization of the particle populations of the inner magnetosphere (trapped particle population and ring currents).

Further studies of the heavy ion magnetospheric population and its dynamics.

Initiation of studies of entry of energetic particles into the Earth's polar caps, and the implication with respect to high latitude magnetospheric topology.

ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE INTERACTIONS D. Evans

The AIM group within SEL was formed on Oct. 1, 1980, for the dual purposes of, first, understanding the transfer of energy from the magnetosphere into the earth's upper atmosphere by treating the atmosphere, ionosphere, and magnetosphere as a single coupled system and, secondly, to understand the consequences of this energy input upon the ionosphere and upper atmosphere.

ACCOMPLISHMENTS FY 81

During the year, a major effort has been directed toward the reduction and analysis of data from the "Total Energy Detector" (TED) which since Nov. 1978 has been flown as part of the Space Environment Monitor on board the TIROS/NOAA series of spacecraft. This instrument measures the energy input to the upper atmosphere by the precipitation of auroral particles over the polar regions. The energy input by particle precipitation represents about 30% of the total energy input to the upper atmosphere from the magnetosphere, the remainder being the Joule heating associated with dissipative electrical currents flowing in the ionosphere. For point of reference, the total energy input to the polar atmosphere above 90 km by magnetospheric processes regularly exceeds, by a large margin. The energy input to the same region of space by solar irradiation. The dynamical behavior of the ionosphere and neutral upper atmosphere in the polar regions is controlled largely by the energy input from the magnetosphere and, occasionally, disturbances propagate from the polar regions to middle and low latitudes.

The importance of this energy input was the basic motivation for including the TED instrument on board the TIROS/NOAA satellites. It was believed that these measurements, particularly the magnitude, location, and extent of the energy input, would provide an excellent guide to the level of geophysical activity and, thus, be immediately useful to the Space Environment Services Center. In addition, it was felt that the availability of a long term, continuous measure of the particle energy input to the polar atmosphere would be of great value to the understanding of the response of the atmosphere to this very dynamical and important source of energy.

Processing of the TIROS/NOAA data tapes began in July, 1980, and the entire backlog of some 30 satellite months of data was cleaned up in seven weeks. Since then, the data processing has continued on a regular basis.

During the past year a great deal of preliminary analysis of the TED data has been done. A correlation was performed between the location of the equatorward boundary of auroral particle precipitation and the magnetic K_p index. There was a good association between the two parameters in the sense that the precipitation boundary moved to lower latitudes during periods of high K_p value, the scatter in the correlation was very large. Whether the location of the auroral precipitation boundary represents a valid index of geophysical activity (at least as valid as K_p) is a question that will be addressed. It is important to establish the true relevance of this parameter because the SESC has a desire to utilize the boundary location both as am activity index and as a predictor of auroral disturbances at local times and longitudes not sampled by these spacecraft.

The total energy input observations were used also to obtain an estimate of the amount of power input to the entire polar cap by the auroral particles. The method utilized data from an entire satellite pass (see Figure 8) over the polar regions (taking about 25 minutes) and a numerical integration technique which weighted the magnitude, location, and geographical extent of the energy input. The critical assumption that the particle precipitation was homogeneous in longitude had to be made in order to convert what is essentially a line integral along the satellite path to the estimate of the power input to the entire hemisphere. The degree of error introduced by this assumption is unknown, but the existence of several satellites making energy flux measurements simultaneously at different longitudes will allow the degree of longitudinal inhomogeniety to be investigated.

This estimate of power input can be made each time the satellite passes over the polar regions, 28-29 times a day. A correlation between a daily averaged hemispherical power input (which ranges from 3×10^9 watts to 10^{11} watts or 2.5×10^{14} to 9×10^{15} Joules per day at the extremes) and the planetary Ap index of activity. The results of this correlation again showed a good association between the two parameters but, also, a large degree of scatter. However, it would seem that a direct measure of the particle energy deposition into the atmosphere would be a better indicator of geophysical disturbance than the Ap index which is based upon a level of magnetic disturbance as monitored at a limited number of ground stations. Based upon this reasoning, the daily averaged power input to the polar hemisphere is routinely calculated for each available satellite, and these results have been published each month since Oct., 1980, in the "Summary of Solar and Geophysical Activity" issued by SESC.

The TIROS/NOAA energy input data were used also in several internal and collaborative research projects during the year. Potentially, one of the more important involved using the data to model the perturbed ionosphere, in particular the ionospheric conductivity, produced beneath the satellite by the precipitating particles. This research was begun in collaboration with European groups in an effort to determine the pattern of enhanced ionospheric conductivity for specific satellite passes which could then be associated with simultaneous geomagnetic field perturbations observed near the satellite ground track.

While this research was begun as a specific problem, it is natural to extend the program to deduce the pattern of ionospheric conductivity on a global basis and as a function of magnetic activity. Such an extension is extremely useful as the global conductivity patterns can be merged with ionospheric electric field patterns to infer the magnitude of the Joule heating which is the other major energy input from the magnetosphere.

During the past year AIM scientists, in collaboration with scientists at the National Center for Atmospheric Research, have continued to develop a computer model which simulates the global interaction between the thermosphere, the ionosphere, ionospheric level electric fields, and electrical currents flowing in the ionosphere. Preliminary results of the model show that during geomagnetically quiet days the major portion of the ionospheric current system in middle and low latitudes is driven by winds created by in-situ solar heating of the thermosphere. However, the results of the model also show that the effects of tidal motion propagating upwards from the lower atmosphere should be taken into account and, for cases of higher magnetic activity, a more realistic treatment of the high latitude thermospheric structure and the auroral energy input will be necessary before achieving good agreement between the simulations and observations.

In an effort to improve this simulation model, the TIROS/NOAA energy flux data are being used, in collaboration with NCAR, in the analysis of the atmospheric response to the exceptionally large energy inputs recorded during the great magnetic storm of 13 April 1980. On this day aurora was observed from geomagnetic locations far south of 45°, a doubling of the gas temperature at 200 km over Boulder was recorded, and the atmospheric drag on the shuttle orbiter Columbia was unexpectedly large. All these effects were caused by the massive energy input to the atmosphere from the magnetosphere, and the objective of the study is to account from them in a quantitative fashion.

PLANS FY 82

1. We shall commence a program to determine the global pattern of enhanced ionospheric conductivity using the TIROS/NOAA auroral particle precipitation measurements. Knowledge of this pattern will aid in estimating the energy input to the upper atmosphere by Joule heating.

2. Research will be conducted to model the three-dimensional ionospheric current system. This program will be carried on in collaboration with groups in Europe and with visiting scientists who spend limited periods of time at SEL. This program, which is directed toward understanding the current system which links the ionosphere to the source of electromotive force in the magnetosphere, utilizes magnetic field data from a dense grid of magnetometers in Scandinavia, electric field data from radar instruments also located in Scandinavia, and, possibly, inferences about the ionospheric conductivity as obtained from auroral particle measurements.

3. Analysis of the TIROS/NOAA total energy flux data will continue. Perhaps most important will be a program, in collaboration with the academic community, to determine whether the total energy flux measurements can be used to create a geophysical activity index which might be more quantitative and more physically meaningful than the commonly used K_p and A_p magnetic indices.

4. A research study will start to model the generation and propagation of infrasonic atmospheric waves. Infrasonic waves are acoustic waves in the frequency range below 2 Hz. They are often created in the polar upper atmosphere by auroral processes and, because of their wavelengths, can propagate long distances in the earth's lower atmosphere.

5. The Space Environment Services Center is organizing a workshop concerning the prediction of atmospheric drag on satellites orbiting at less than 1500 km altitudes. One of the SESC's major customers are those groups who use current and predicted indices of magnetic activity in order to calculate atmosphere gas densities at satellite altitudes and, thence, the drag on satellites. Experience has shown that these calculations are often unsatisfactory, particularly during periods of high geomagnetic activity and for high inclination (near polar orbiting) satellites. The purposes of the workshop are to first identify the reasons for unsatisfactory satellite-drag predictions and, second, to begin work on alternative methods; either better atmospheric model calculations or the use of more valid indices of activity in the models. The AIM group will be participating in this workshop and will contribute to both objectives.

IONOSPHERIC PHYSICS K. Davies (Acting)

The ionospheric research includes theoretical and experimental studies of the physical processes that govern the ionosphere such as ion production and loss, plasma motions and the influence of the neutral atmosphere and the plasmasphere. The experimental research includes measurements by digital ionosondes and satellite radio beacons.

ACCOMPLISHMENTS FY 1981

The total electron content measurements made at Boulder, Colorado during Phase I of the ATS6 Radio Beacon Experiment (June 1976 through May 1975) have been physically modelled using a model that includes electromagnetic drift, neutral winds and O^+ ions only. By suitably adjusting the diurnal neutral wind it was possible to obtain good agreement between calculated and observed maximum electron density (Nmax) but the calculated total electron content was smaller than the observed content. Indications are that the deficit in electron content, which is largely in the topside, results from the absence of molecular ions (O_2^+, NO^+ etc.) in the model.

This computer model has been used also to simulate equatorial anomaly variations over a 24 hour period. The equatorial anomaly refers to the latitudinal distribution of maximum electron density near the magnetic dip equator where the peak densities occur, not at the subsolar point where production is a maximum but, around 15° north and south of the dip equator. This phenomenon is a manifestation of the important role of electric fields in lifting ionization over the magnetic equator followed by transport to higher latitudes. The ion production was calculated using the 10.7 cm radio flux and models were assumed for the diurnal variation of the meridional neutral wind (which is not as critical in low geomagnetic latitudes as in middle latitudes) and the vertical electromagnetic drift. It was shown that the combined effects of electromagnetic drift and neutral winds gave a good representation of the maximum electron densities for March 1971 at Raratonga and at Hawaii which are conjugate locations both geographically and geomagnetically.

A model study was conducted to calculate the F region critical frequency which can be used to improve the prediction of ionospheric parameters over regions of the earth which are inaccessible to ground-based soundings. Input parameters (e.g., neutral wind, electromagnetic drift) were adjusted so that agreement was achieved between calculated and observed maximum penetration frequency foF2 (proportional to $\sqrt{N_{max}}$) as a function of local time at two stations and then it was assumed that these parameters were valid at intermediate locations where the major difference is the geomagnetic-field configuration (Anderson et. al., 1981).

Reviews of progress made in the prediction of ionospheric parameters for radio propagation applications were submitted for publication (Davies, 1981a, b).

In the ionospheric sounding program, field campaigns were conducted at Cleary, Alaska; Brighton, Colorado and at Arecibo, Puerto Rico. In the Cleary campaign, simultaneous digital (F2 region) ionograms, conventional photographic ionograms and incoherent scatter radar data from Chatanika, Alaska showed good agreement. For summer conditions the F2 layer penetration frequencies (foF2) obtained with the three techniques agree to within ± 0.2 MHz.

The NOAA digital sounder was designed to be a versatile control center for a variety of ionospheric experiments. In its basic operating modes it functions as an interferometer measuring angles of arrival and Doppler frequency shifts of radio frequency pulses reflected from the ionosphere. During the year the sounder was developed for operation in other modes, including partial reflection from the D region, multifrequency riometry and spectrum surveillance. At Cleary, the first results were obtained when operating in the spectrum surveillance and multifrequency riometer modes. At Brighton, Colorado the sounder has been used in the partial reflection mode to investigate the mechanism of radio scattering by irregularities in the D-region. Although the signal-to-noise ratio was low the measurements indicate that the scattering irregularities are associated with atmospheric waves e.g. gravity waves and/or infrasound.

During the past five years the NOAA digital sounder has been developed into the Middle-Atmosphere Image Forming Radar (MAIFR). During FY 81 most of the hardware was completed and contracts were let for the remaining hardware that will not be built by SEL. When completed the MAIFR will enable investigations of meteorological conditions (e.g. winds and waves) in the mesosphere.

Computer software programs were developed to exploit the high precision of the new sounder and enable detailed studies of ionospheric phenomena as for example: gravity wave effects, sunrise effects and sporadic-E phenomena. A system of off-line analysis methods for digital-structure was completed.

As part of a multi-technique campaign for studying the artificially radio-modified ionosphere the NOAA sounder was operated near Arecibo, Puerto Rico in June and July 1981. The campaign was organized by Rice University and sponsored by the National Science Foundation. A variety of diagnostic techniques were used for measuring the amount of modification by the high-power high-frequency heating facility as for example: airglow photometer, digital ionosonde, incoherent scatter. A major emphasis was to see whether there was agreement between the quantities (e.g. winds, electron density profiles) measured by the different techniques. Particularly important were the horizontal plasma drift motions and their relationship to the neutral winds and electric fields both during normal and during disturbed conditions. The experimental campaign was very successful.

PLANS FY 82

Because of insufficient funding of salary increases, the research aspects of the digital ionosonde program will be terminated on November 1, 1981.

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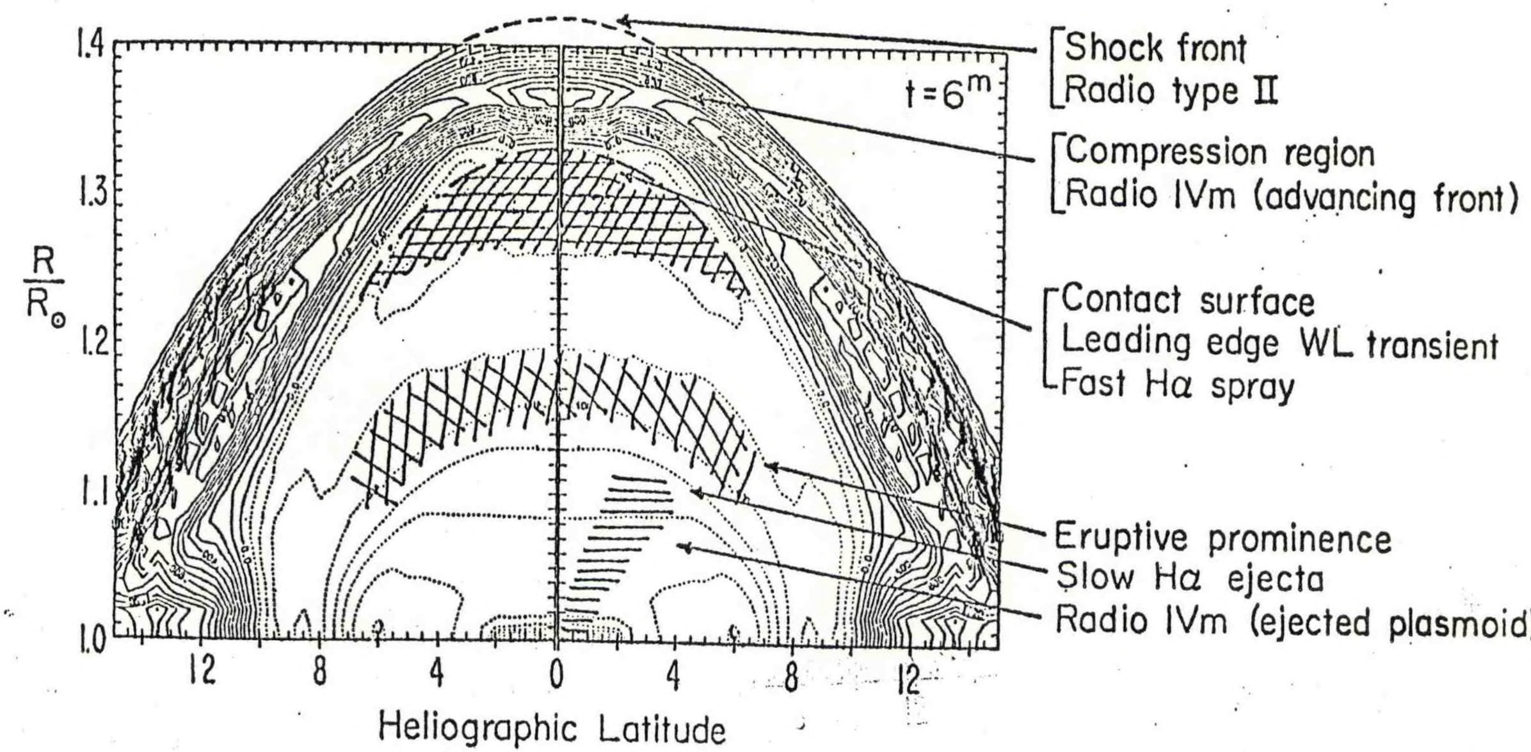


Fig. 1 A cross-section through a coronal transient as modelled by a two-dimensional, time-dependent MHD model. The transient is produced by a temperature pulse which simulates a solar flare. The thin solid lines show plasma density enhancements; the dashed lines, rarefactions. The thicker lines in this montage, labeled by the arrows, represent interpretations of various diagnostic observations (Hα, radio bursts, and white light). (Maxwell and Dryer, 1981).

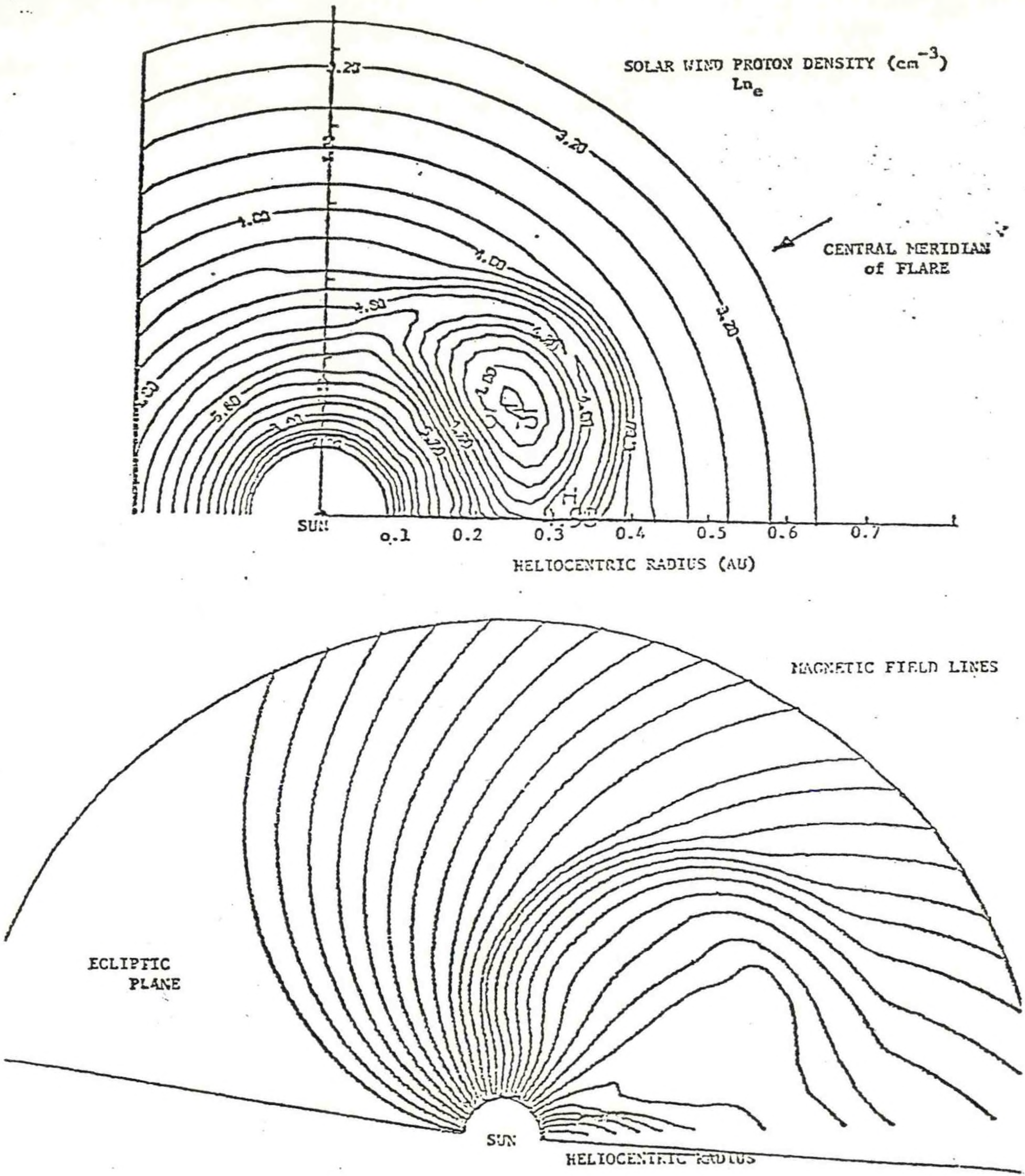


Fig. 2 An ecliptic plane projection of the interplanetary magnetic field's topological distortion following a simulated flare. The upper half of the figure shows density contours that correspond to the region affected at the time (20 hr after the flare) of this "snapshot". A pressure "high" occurs in the shocked region downstream of the propagating interplanetary shock wave. The compression is followed by an expansion into a moving pressure "low" in the 'eye' of the disturbance prior to achievement of a final steady flow.

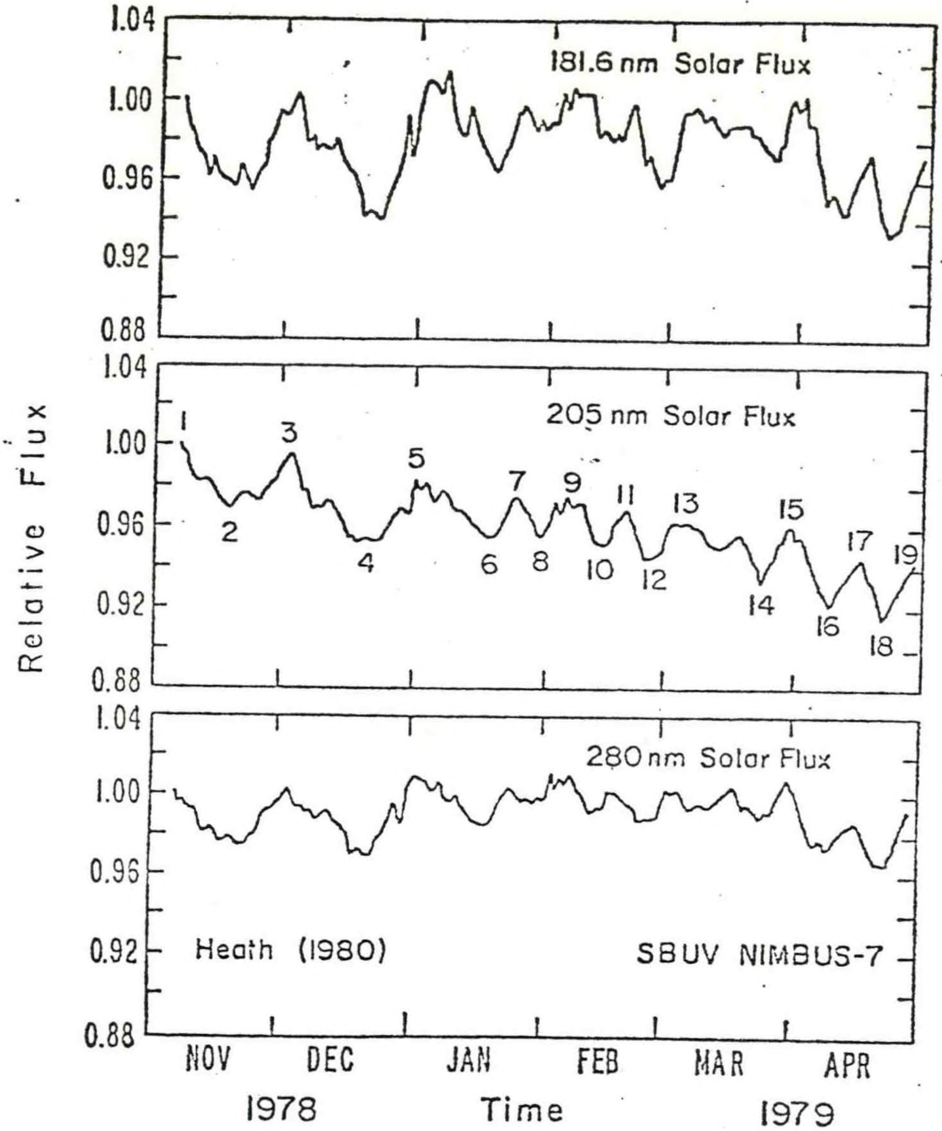


Fig. 3 Examples of the temporal variation of solar UV radiation. Note the high correlation between widely spaced wavelengths. Peaks like those numbered 1, 3 and 5 or minima like 2, 4, and 6 are caused by solar rotation of active regions that are very strong at certain solar longitudes. The change in period at peaks 7, 9, 11 and 13 is caused by two sets of strong solar active regions at nearly opposite solar longitudes. The time scales of active region evolution are comparable to the solar rotation period and the above figures involve mainly temporal variations due to both the solar-rotation of a nonuniform longitudinal distribution of solar activity and the temporal evolution of active regions (emergence, growth, peak and decay). Longer-term variations like that evident in the 205 nm curve are currently being researched to separate real solar variations from instrument degradation.

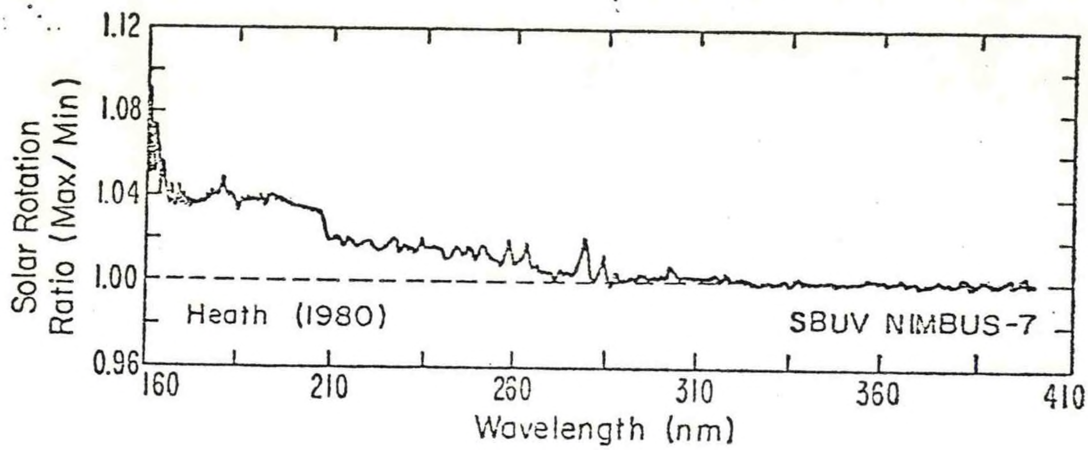


Fig. 4 Solar-rotation variation of the solar UV irradiance as a function of wavelength. The sharp decrease in variation with increasing wavelength near 200 nm corresponds to the aluminum absorption edge in the solar spectrum. The spikes near 280 nm are real and correspond to chromospheric absorption lines.

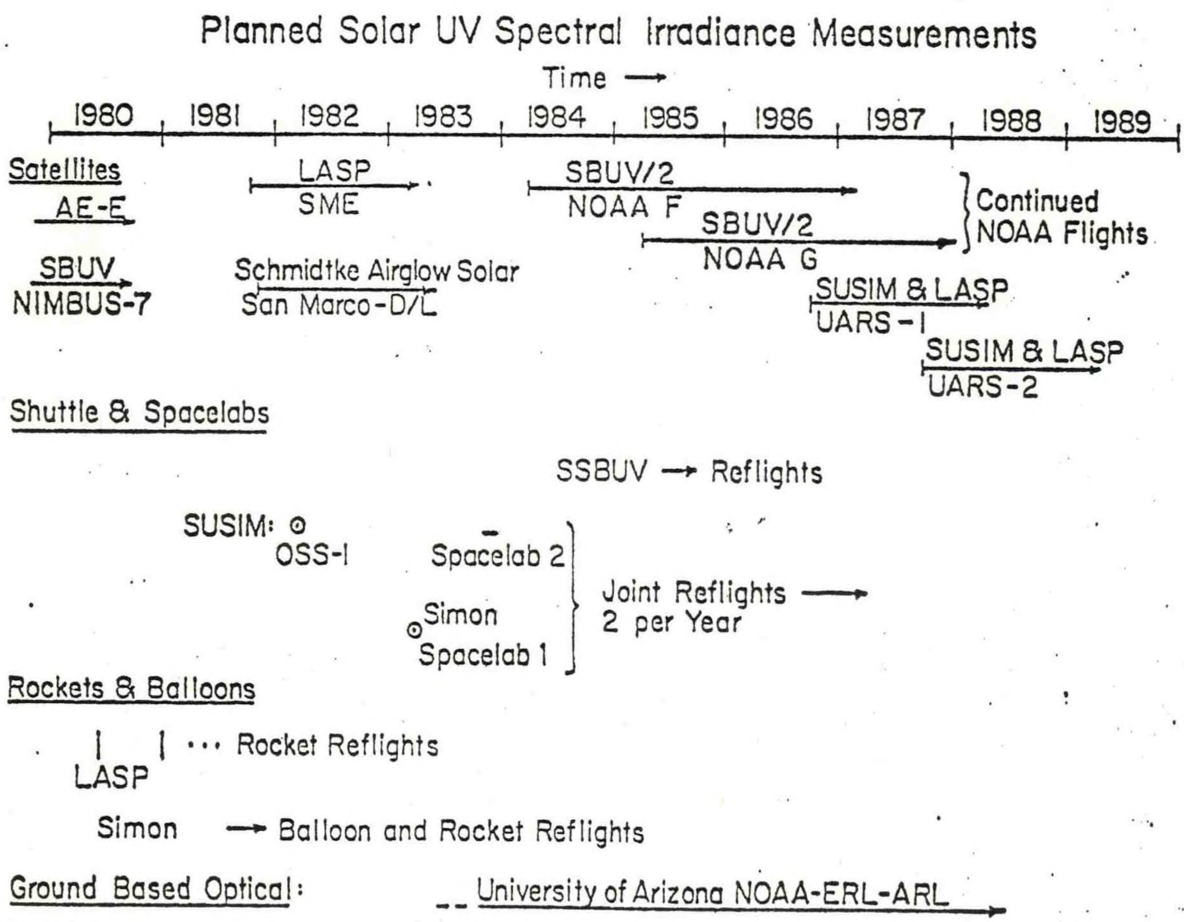


Fig. 5 Planned solar UV-irradiance measurement programs.

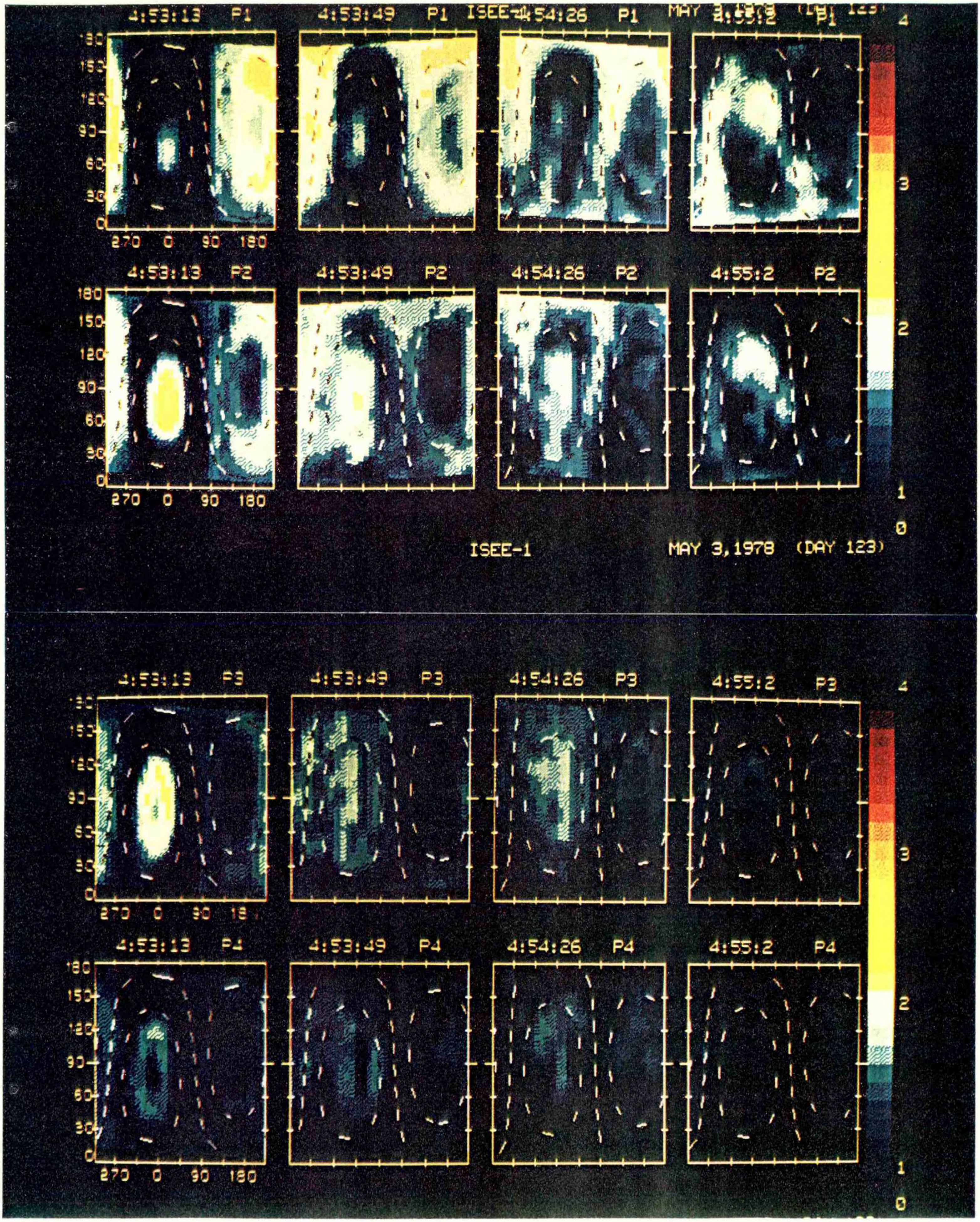


Fig. 6 Color display of ISEE particle distributions.

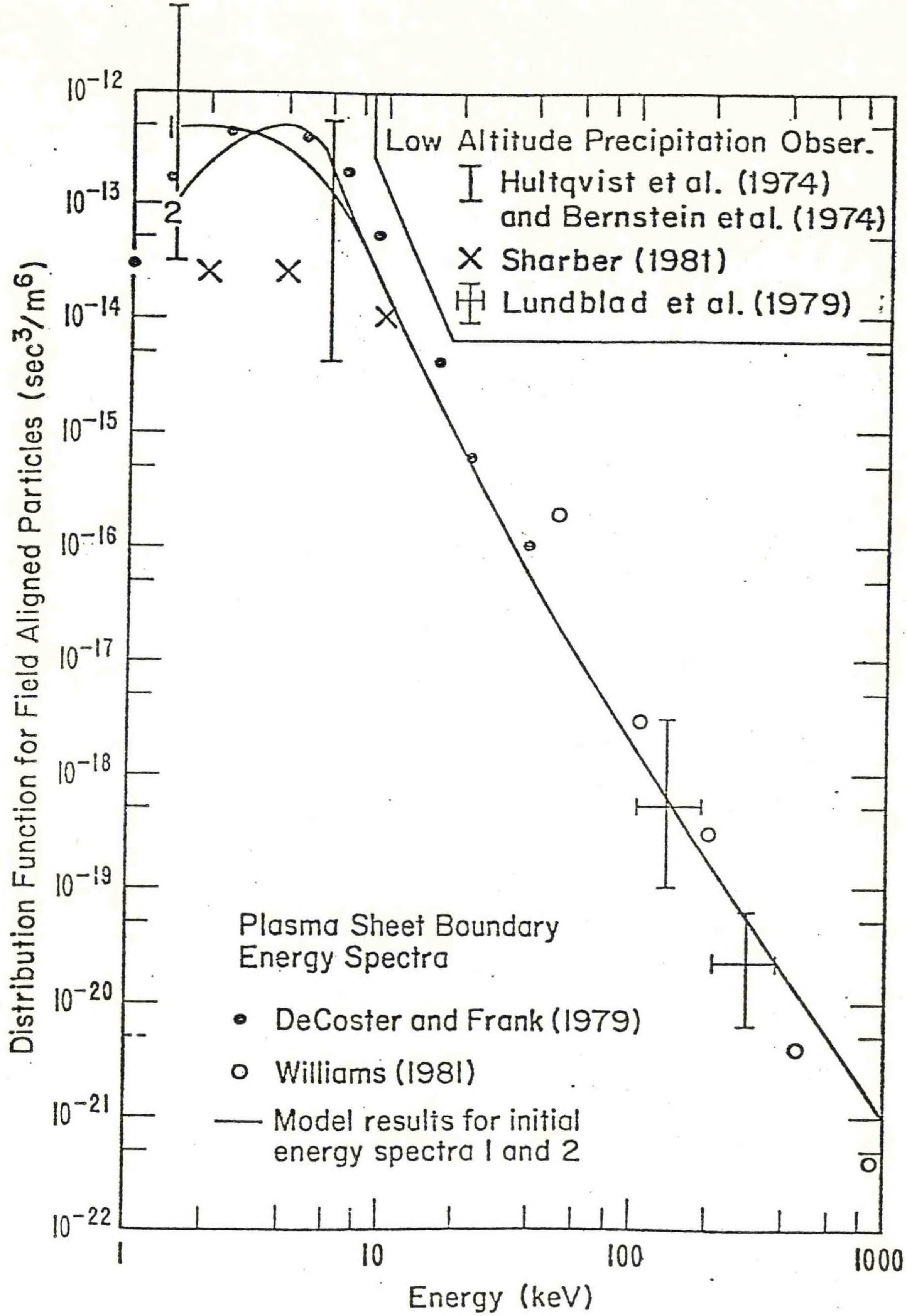
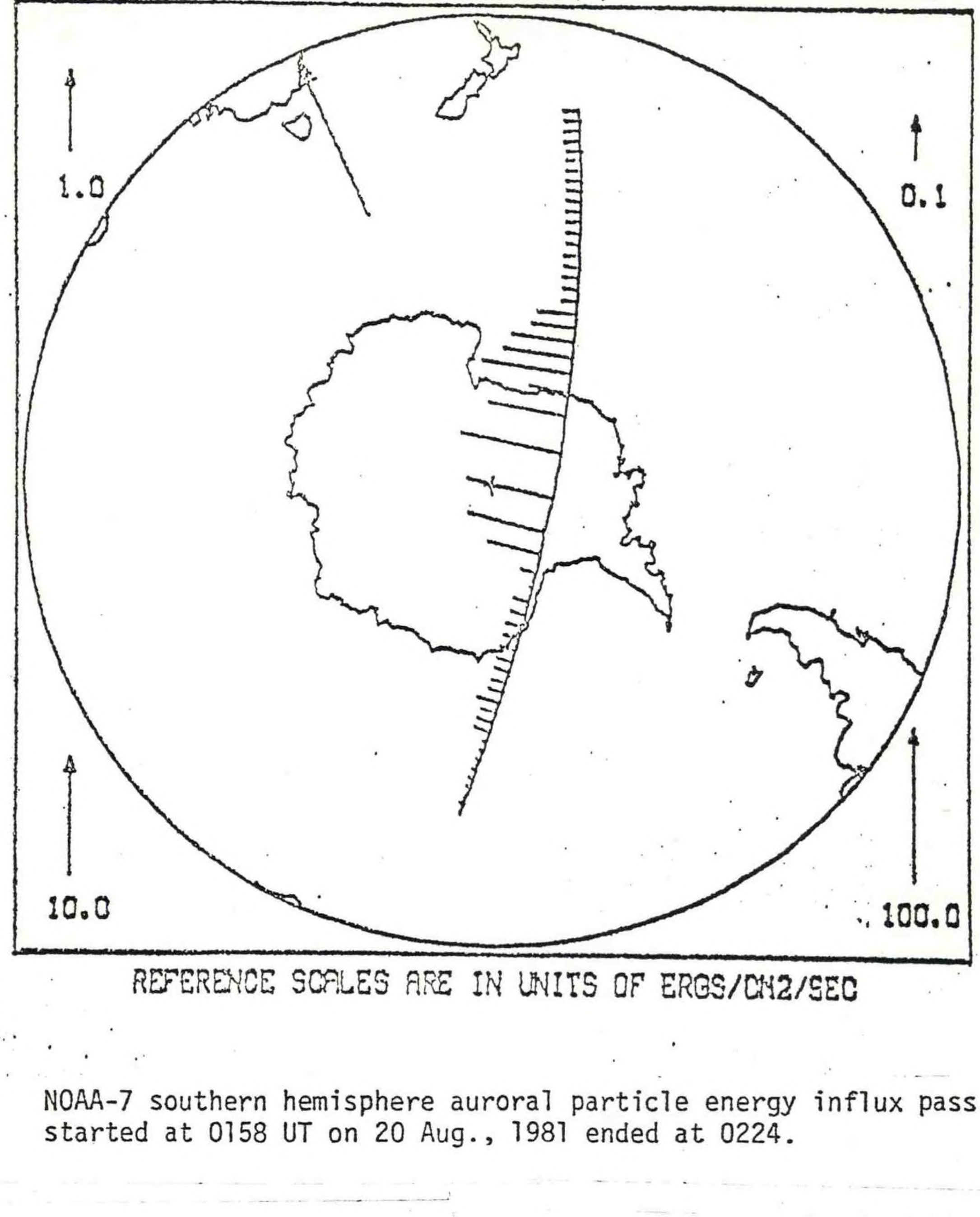


Fig. 7 Distribution function for field aligned particles (sec^3/m^6).

NOAA-7
SOUTHERN HEMISPHERE AURORAL PARTICLE ENERGY INFLUX
PASS STARTED AT 0158 UT ON 20 AUG, 1981 ENDED AT 0224



REFERENCE SCALES ARE IN UNITS OF ERGS/CM2/SEC

Fig. 8 NOAA-7 southern hemisphere auroral particle energy influx pass started at 0158 UT on 20 Aug., 1981 ended at 0224.

SUPPORT DIVISION

R. GRUBB

The Support Division assists all laboratory projects in using computers for acquiring and analyzing data through the Analysis Branch and in developing instrument hardware, engineering software, and data systems design through the Instrument Development Branch.

Typical contributions to laboratory research and services are the development of ground-based and satellite instrumentation for experimental- and observational-data collection and in the analysis of data used in research publications.

During the year a number of activites connected with the HF Radar Program were organized from the Support Division Office. These included liaison with the National Science Foundation and the other groups operating the equipment, Utah State University (USU, White Sands Missile Range (WSMR), the Max-Planck Institute for Aeronomy (MPIA), and the British Antartic Survey (BAS). Advice was provided on the operation and servicing of the systems. A field expedition to Puerto Rico by the SEL sounder was supported by program management and field installation. In August a training course was held in Boulder primarily to train operators for the BAS system which is at Halley Bay in the Antarctic and for the USU system which is moving to Siple, also in the Antarctic, in the fall of 1981. However, staff from WSMR, MPIA and the Geophysical Institute at Fairbanks, Alaska, also attended. The course consisted of one week of classroom instruction, given by Support Division staff from both the Instrument Development Branch and the Analysis Branch, followed by one or two weeks of practical training and experience using the SEL HF Radar at the Boot Lake field site.

In April of 1981 the laboratory was forced to make the decision to terminate the SEL Ionospheric Research Program which removed the primary raison d'être for the Support Division HF Radar Program. However, reorganizing the central support which was being provided by the division in the areas of programing and hardware, it is planned to gradually phase out SEL involvement with the other groups during FY82 in the expectation that they can become self supporting or make alternative arrangements before September 1982.

ANALYSIS BRANCH

R. GRUBB, ACTING

The Analysis Branch provides computer programming support to the rest of the Laboratory. It maintains a large library of experimenter data tapes from satellite and ground-based experiments, which are routinely processed and analyzed. Members of the Analysis Branch combine expertise in computer usage with general knowledge of the scientific requirements of the Laboratory and therefore provide advice and assistance to the scientists in the use of computer techniques to further their research.

ACCOMPLISHMENTS FY 1981

International Sun-Earth Explorer (ISEE). Data has been archived for the ISEE-1 satellite through data for September 11, 1979, when the Energetic Particle Detector became inoperable. Archiving for the ISEE-2 satellite has continued and archive tapes have been generated for data through April 1980. ISEE Quick-look Line Plots have been produced for all the data that has been archived as well as a complete set of ISEE-1 flux, magnetic, and spectral plots. Programs have been written to generate ISEE-1 pitch angle plots, gray code plots of ISEE-1 particle data, color plots of spectrograms and unit sphere displays, and plots of ISEE-1 plasma flow. Additional programs have been written to write ISEE data to magnetic tape in "standard CDAW format" and to write ISEE data to cassettes so scientists can analyze the data on the Tektronix mini-computers. In all, data plots in over 12 different formats have been provided, three of which are shown in Figures 9, 10 and 11.

Work has continued to support the SEL HF Radar (ionosonde) system with software. A more complete and flexible operating package has been designed. The Analysis Branch directly supported the field campaign in Puerto Rico.

Archive production continues for the TIROS series and the IMP-J satellite. Archive production continues for the IMS satellite. The Analysis Branch supported the Solar UV Radiation Research Project by providing computer access to the NIMBUS-7 data tapes sent by NASA/GSFC. Display of, and access to, SMS/GOES satellite series data continues. Design of a system for measuring soft x-ray bursts has begun.

The Branch has been actively supporting the 1982 ERL computer initiative both with representatives and in organizing the package of computer benchmarks.

PLANS FY 1982

With the exception of the HF Radar activities, the FY 1981 projects are expected to continue into FY 1981. ISEE-2 archiving will continue as long as the experiment is operational. Back-up tapes will be written for all the Bolder archive tapes. ISEE display programs will be run at the request of the scientists and new display programs will be generated as they become defined.

Programs to model the solar wind and the effects of solar-flare induced transients will be converted to the local CYBER 750 computer. These models will be expanded and improved.

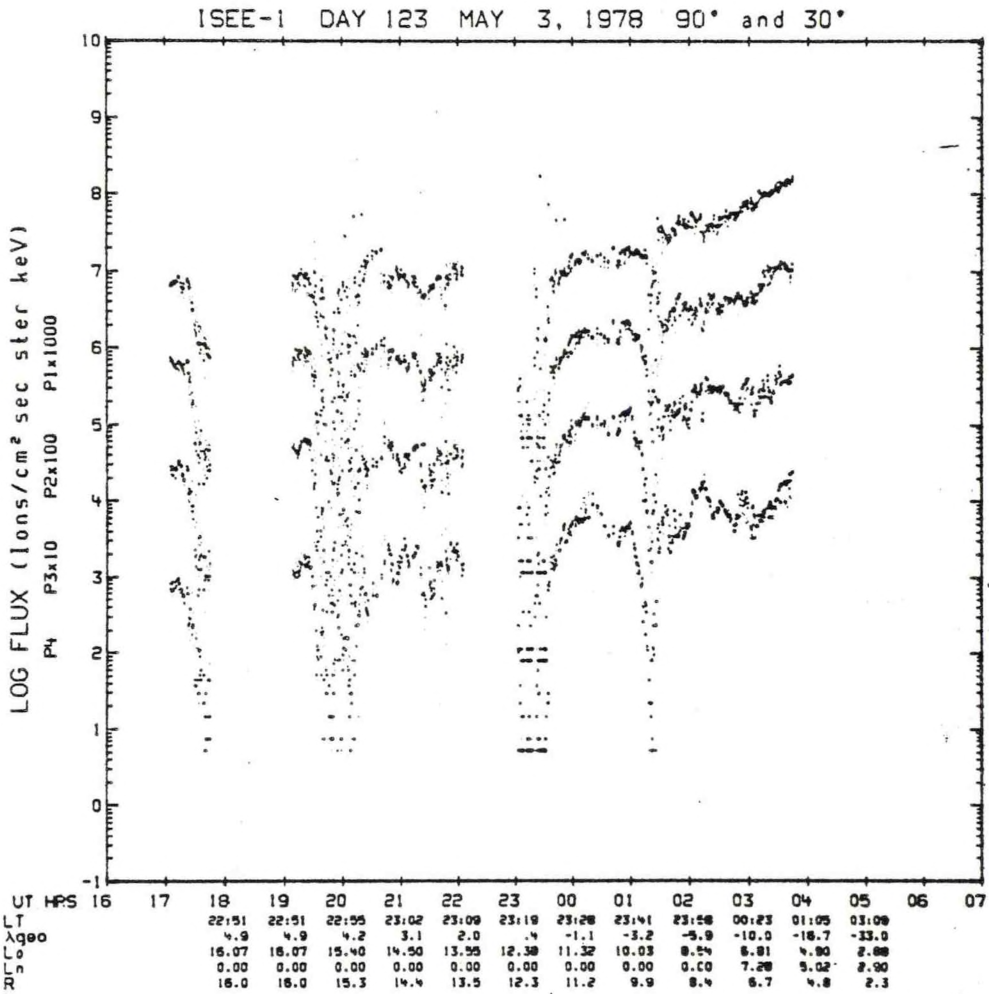


Fig. 9 ISEE 1 Flux Plot, Protons

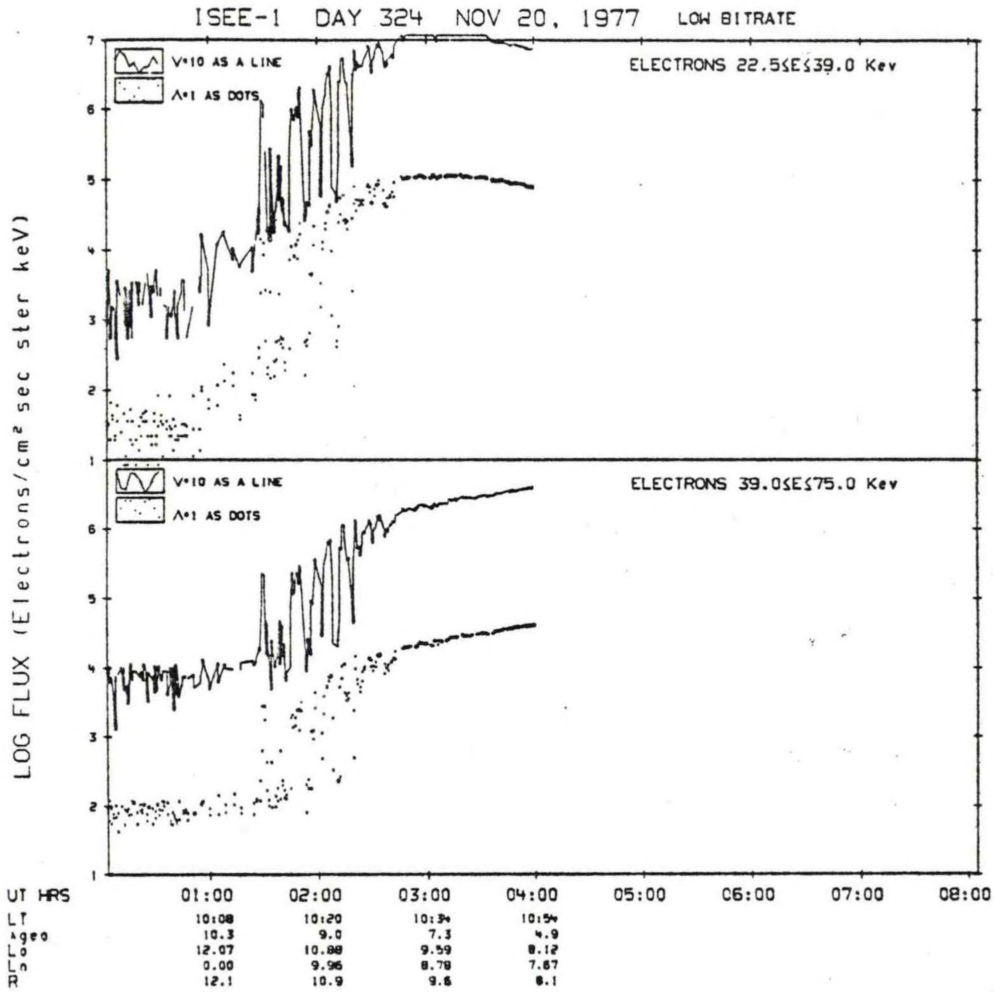


Fig. 10 Directional Flux Plot Through the Magnetotail

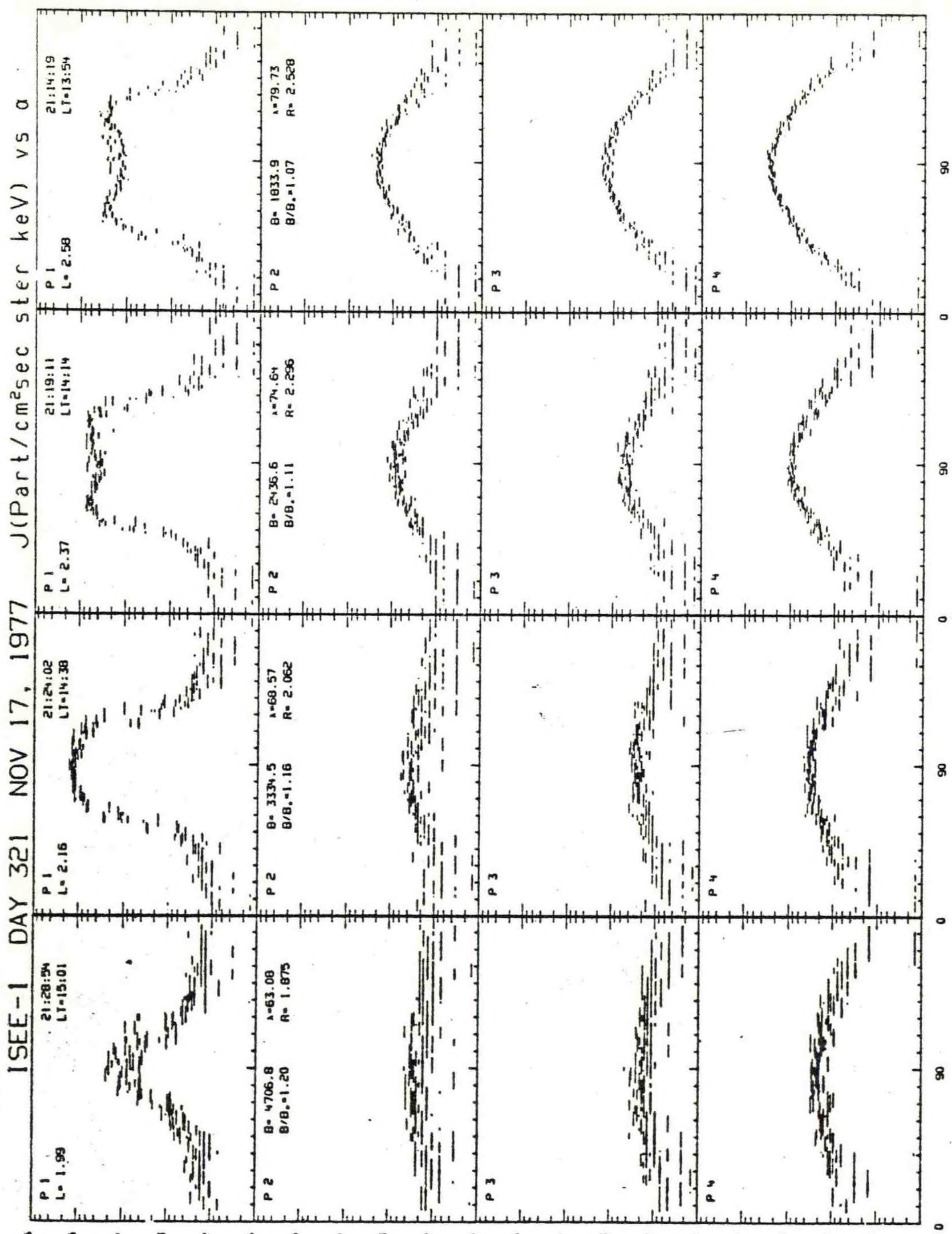


Fig. 11 ISEE 1 Pitch Angle Plots, Channels P1-P4

INSTRUMENT DEVELOPMENT BRANCH J. R. CESSNA

The Instrument Development Branch (IDB) provides general support to the Laboratory with instrument hardware, engineering software, and data system design. This support includes involvement throughout the lifetime of a laboratory program, often beginning with system conceptual development and proposal writing, continuing through design, fabrication, and test phases, to support in field deployment or launch operations and often involving continuing evaluation and consultation during data reduction and analysis. Program management and technical supervision of contractors are provided for larger programs.

ACCOMPLISHMENTS FY 1981

Operational Space Environment Monitors. NASA approved the IDB proposal to provide maintenance support for the TIROS SEM instruments. A clean room for use in the maintenance of existing space flight instruments and fabrication of new instruments was completed. All HEPADS were returned to SEL for replacement of a cable assembly which had been incorrectly assembled by the SEM manufacturer. SN006 HEPAD was returned to SEL for analysis and repair. Two failed components were replaced. The unit was then reassembled and retested.

NOAA 7 was launched on 23 June 1981 and GOES E was launched on 22 May 1981. Each subsystem was functionally checked for proper operations and calibration data taken. Except for the HEPAD on NOAA 7 which is exhibiting a presently unexplained anomaly, all sensors appear to be operating as predicted.

The IDB assisted RCA Corporation in trouble shooting a problem with the TED on NOAA D spacecraft. This problem was determined to be caused by a defective spacecraft cable assembly.

Thermal structural models of the SEM instruments were designed, fabricated, tested, and delivered to the spacecraft contractor. These units will be flown in place of the SEM instruments on alternate TIROS spacecrafts.

Solar X-Ray Imager Feasibility Demonstration. Preliminary laboratory tests have been completed on the CCD-based X-ray Imager prototype and TV display system using conventional white light optics. Excellent image spatial resolution was obtained, approaching very nearly the Nyquist limit for the 256 by 320 pixel array in use. The feasibility of electronic image despinning was demonstrated using a revolving mirror to simulate a spinning object field. Resolution for the despun image was not perceptibly degraded from that for the static case.

A cryogenic image array mount was under test at the end of this period. Preliminary results show that very significant background noise reduction and virtual elimination of dark current defects occur with cooling to -50°C or more.

HF Radar. In addition to general background technical support of the systems in the field, the IDB provided several new hardware developments.

A 1/20 scale model of a new log periodic transmitting antenna design was built and tested at Table Mountain. The Boot Lake antenna was modified according to the new design.

A parallel data interface was designed and built for the Book Lake HF Radar receiver allowing expansion of the number of receiving antennas used with the receiver.

The Boot Lake HF Radar receiver was modified so that it can be switched between wide and narrow bandwidths during soundings. An extra low-power transmitting circuit was also added to give quadrature RF outputs for transmitting circular polarization.

The design of a serial data interface for the HF Radar was begun. This interface will allow the central computer to switch antenna relays or control other devices at a distance of up to 1 km.

Galileo Energetic Particles Detector (EPD). During FY 81 the IDB continued to provide program management to the Galileo EPD team and engineering and fabrication responsibility for the time-of-flight (TOF) subsystem (see Figure 12, next page). The launch of the Galileo satellite has been delayed to April 1985. The EPD team has not changed the delivery schedule due to this slip however.

During FY 81 the EPD team component at JHU/APL, Laural, Maryland, experienced cost overruns that required the EPD team to review the development program and realign the development effort. The re-alignment included the dropping of the EPD engineering model as a total system and proceeding directly to the construction of the flight unit instrument. A number of the engineering model subsystems already existed and were being tested in the card cage assembly. The card cage assembly allows the testing of flight model subsystems prior to integration into flight unit. The IDB completed the construction of the engineering model TOF subsystem and delivered it to JHU/APL for integration and testing in the card cage assembly.

PLANS FY 1982

Operational Space Environment Monitors. Continuing support will be provided to the TIROS and GOES projects for SEM post-launch activation and checkout as required by the TIROS and GOES launch schedules.

IDB has committed to providing an instrument repair capability for the TIROS SEM and the GOES HEPADS. The in-house thermal/vacuum facility will be completed this fiscal year as part of this program.

IDB will continue to provide technical and project management support for the GOES SEM procurement.

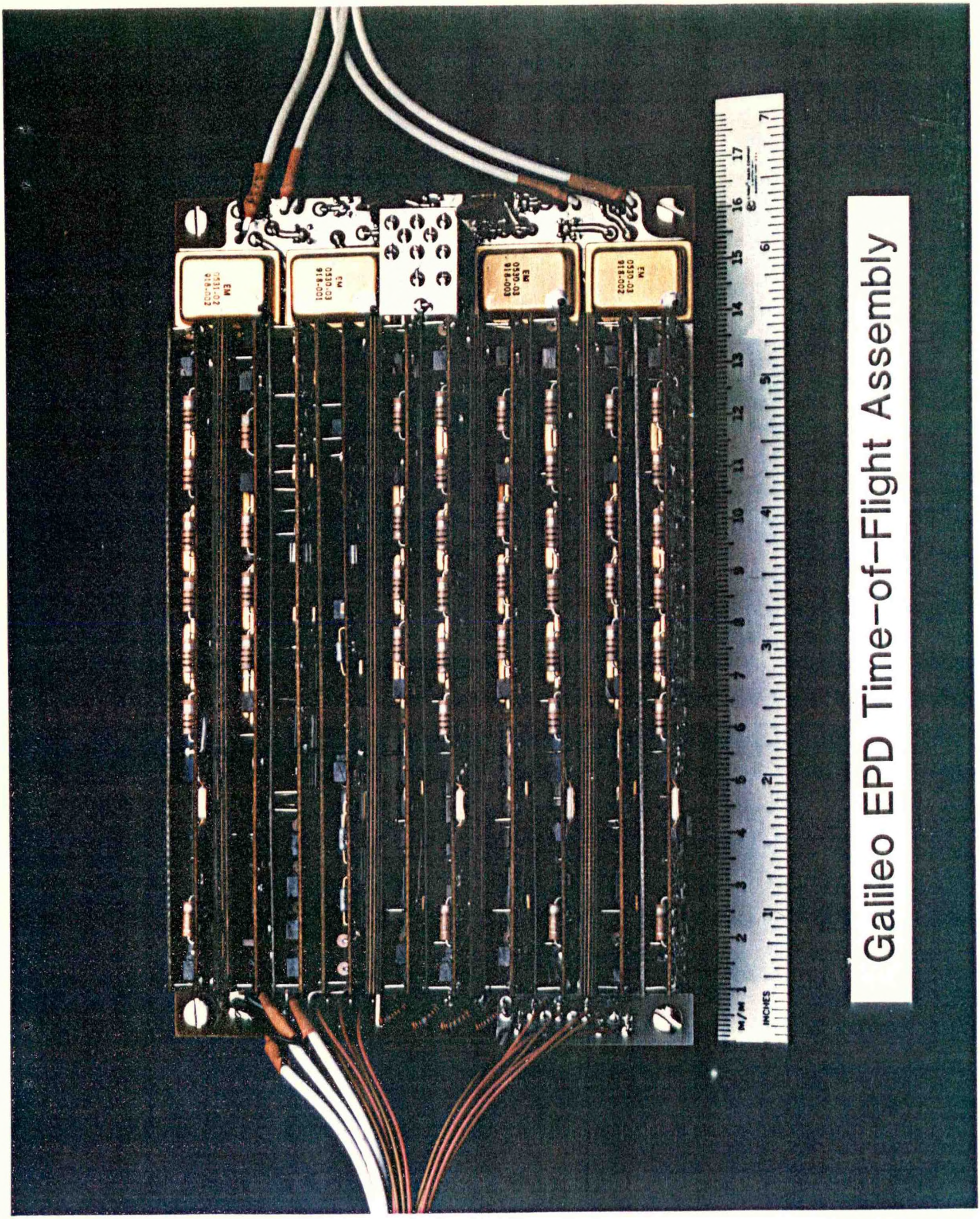


Fig. 12

Solar X-Ray Imager Feasibility Demonstration. In November, the Imager will be integrated with the x-ray optics which were developed through Marshall Space Flight Center. Extensive resolutions and sensitivity measurements will be made in white light followed in January by tests in the x-ray source chamber at Marshall Space Flight Center. In addition to x-ray resolution and sensitivity tests, multiple frame integration for low photon S/N improvement will be investigated.

Hardware and software modifications will be implemented to allow for remote operation and data analysis in the x-ray chamber. These will be tested during the November white-light tests.

Galileo Energetic Particles Detector (EPD). The EPD program plans for FY 82 include completion of the flight unit TOF subsystem at IDB, LEMMS subsystem at Max-Planck Institute, Lindau, West Germany, and the remainder of the flight unit subsystems at The Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland. Integration of all the subsystems will be accomplished at JHU/APL during the first half of FY 82. Environmental testing and calibrations will begin during the second half of FY 82.

Ion Composition Instrument. A detailed investigation into the timing characteristics of microchannel plates will be conducted. This effort is aimed at developing an improved ion composition measurement instrument employing an ultrathin, solid-state detector and using microchannel plates to collect secondary electrons from the ion interaction at the detector surfaces. This effort, funded by NASA, is expected to yield a sensor design for use on the NASA Origin of Plasmas in the Earth's Neighborhood Program, and other research and operational programs.

SERVICES DIVISION — H. LEINBACH

The Services Division provides a variety of services to a growing national and international community of users concerned with the effects of solar activity on the environment. The Real-Time Data Services Branch (RTDS) and the Space Environment Services Center (SESC) jointly constitute the major activity of the United States in solar-terrestrial monitoring, forecasting, and real-time data collection and dissemination. Many of the services are joint activities of NOAA and USAF.

ACCOMPLISHMENTS FY 1981

Mr. Thomas B. Gray, former Chief of the Services Division, resigned from government service on September 8, 1981. Under his leadership, the Division made important strides forward. He was the key figure in defining the new SELDADS II System. Dr. Harold Leinbach, formerly of the Research Division of SEL, was appointed Chief of the Division, effective May 31, 1981, allowing Mr. Gray to concentrate the remainder of his time on the SELDADS II procurement activities.

Mr. Tony Brittain, who had a lead role in preparing the requirements study and the Management Plan for the SELDADS II System, resigned effective August 28, 1981, in order to accept an attractive offer from private industry. Ms. Dolores Nottage left the Division office effective October 17, 1981, to accept a position with BLM in Cheyenne, Wyoming.

SELDADS II. SEL received an increase in base in early FY 1981, to improve the services offered by the Services Division, particularly those of SESC. The majority of these funds are being committed to acquiring a new SEL Data Acquisition and Display System (SELDADS II). The SESC staff has documented some 250 products which this new system must support. Based on these product definitions, the Requirements Study documentation was completed, and along with a Management Plan, was submitted through NOAA to the Office of Procurement and Automatic Data Processing Management, DOC. Following a meeting between representatives of SEL, NOAA/RD, NOAA/MB, and DOC/SEC in August, 1981, work was begun on writing the RFP for this procurement. The Source Evaluation Board and the Technical Review Committee of the SEB were appointed.

The RFP will be completed in early FY 1982. It is hoped that the RFP will be presented to prospective bidders early in FY 1983.

PLANS FY 1982

In the present climate of stringent budget constraints, some difficult decisions will have to be made on expenditures required to support the operations of the RTDS and SESC branches of the Division. A critical issue will be the support required to assure an adequate base of solar data and geophysical particles and fields data to support the forecasting and warning functions of SESC. The primary task of the Division Office will be to assure that an appropriate data base is secure.

The Space Environment Services Center (a joint operation of NOAA and the USAF Air Weather Service) continued to provide predictions, alerts, and data for a variety of users whose systems are affected by disturbances in the space environment or who are conducting scientific experiments to improve understanding of that environment. Predictions and summaries of activity are distributed daily to users throughout the United Sates and the world. Customers using the services include DOD, NASA, DOE, FAA, universities and research foundations, and industry and commercial users.

ACCOMPLISHMENTS FY 1981

The current eleven-year solar cycle reached its highest number of sunspots in late 1979, but one of the more energetic series of solar flares, magnetic storms and proton events occurred in the spring of this year. On April 13, brilliant aurora was reported over much of the United States as a geomagnetic storm in progress concentrated much of its effect on the Western Hemisphere. Effects were reported on electrical distribution equipment and communication systems. In addition to the increased normal workload imposed by this activity, the first Shuttle (Space Transporation System) mission was in progress. The geomagnetic storm produced a 47 per cent increase in atmospheric drag on the Shuttle while it was in orbit. The energetic proton flux was not as commensurately large as the rest of the activity, but it produced measurable levels of radiation enhancement on the Shuttle spacecraft. Although the activity was rated in the major category, it did not reach the "super" level seen in past cycles. The high sunspot number obtained in this cycle indicates we may still expect one or more very large events in the next year or two. (See Figure 13, next page.)

A major scientific research campaign, the Solar Maximum Year (SMY), was devoted to the study of solar activity and the release and propagation of disturbances from the sun through interplanetary space. SESC was closely involved through forecasting and monitoring activities in Boulder, communications coordination of the observing programs throughout the Western Hemisphere and much of the rest of the world, and especially in operating a dedicated forecast center on contract from NASA at the Goddard Space Flight Center, location of the control center for the Solar Maximum Mission Satellite (SMM). The SMY concluded in February and the SMM Control Center closed in June. NASA is considering a rehabilitation and reuse of the SMM Satellite in 1983 using rescue capabilities of the Space Transportation System (Shuttle).

Forecast Center

Operations were extended to 24 hours at the beginning of the fiscal year to meet service demands. New products were initiated, including an early morning forecast and activity summary intended to serve daytime users.

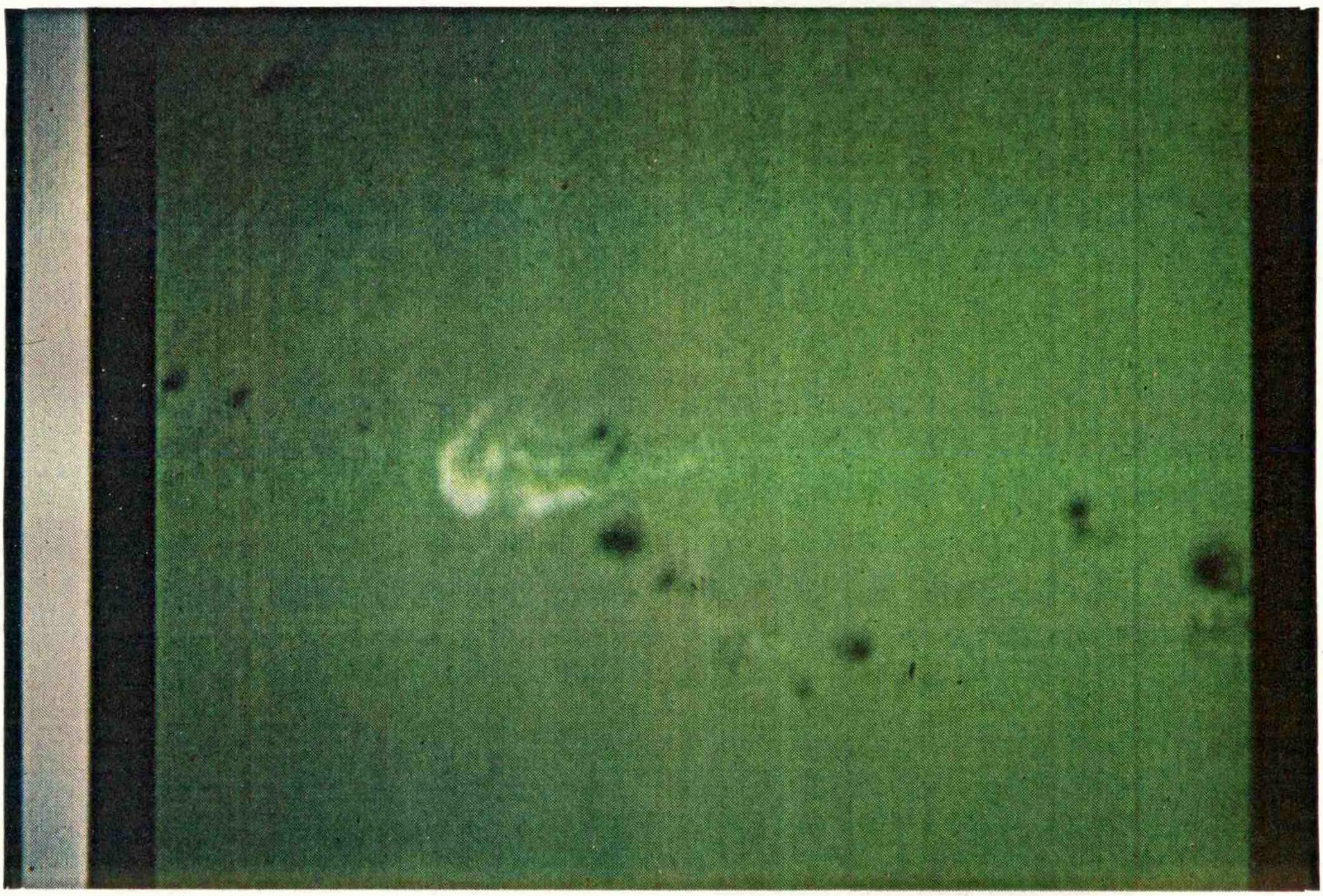


Fig. 13 Solar proton flare of April 10, 1981. Solar flares are usually monitored in the red light from the Hydrogen Alpha line. Intense flares are visible in other wavelengths as well, and may even give off continuum (white-light) radiation in exceptional cases. This photograph of the flare of April 10 was taken at Boulder in the green light of neutral and singly ionized iron, at a wavelength of 5169 Angstroms. This flare was responsible for the large magnetic activity and auroral displays of April 13, 1981. (Photographed with the SESC spectrohelioscope by H. Leinbach.)

As the Forecast Center has matured, new data sources have been added, there are more forecasters, customers have increased and new products have been introduced. As a result, there is an increasingly apparent need for standardization of procedures and programs. During the past year, the first steps were taken to develop a process that will produce standardized procedures and analysis and provide for uniform user documentation of all new programs.

A major improvement in detection and alert capability was introduced in the form of a shock detector operating on data from the ISEE-3 (International Sun-Earth Explorer) satellite, located about one million miles in front of the earth in the direction of the sun. As disturbances propagate outward from the sun, they are detected by the ISEE-3 as sharp discontinuities in the solar wind. The new automatic detector gives a 20 to 50-minute alert before the disturbances reach the earth and cause a sudden commencement, the normal beginning of a geomagnetic storm. (See Figure 14, next page.)

The launch of GOES-4 and 5 satellites, with a capability of monitoring very high energy solar flare particles (100 MeV to 1 BeV) significantly improves the ability to monitor hazardous radiation at high aircraft altitudes.

Alerts issued during the year totaled: Prestos, 142; Proton Events, 19; Radio Noise, 404; Magnetic Storms, 186; and Flares, 193.

Communications Center

The SESC Communications Center was established to provide communications services to the Boulder Laboratories as well as handle data flow into and out of the Forecast Center. The general communications function has continued to rely on standard teletype operation, while the SESC data flow has become increasingly automated, using computers as interface with the external networks. In order to improve both types of service while better utilizing available personnel, a contract was let with a commercial company to handle the general purpose communications and leave the civil service staff free to handle the increasingly heavy and specialized SESC data flow.

Observatories

Working relationships for real-time data continued with Kitt Peak, Marshall Space Flight Center, Mt. Wilson and Culgoora Solar Observatories. These data fill special purpose needs that are in addition to the data received from the Air Force SEON (Solar Electronics Observing Network), which provides the basic patrol and continual reporting functions required for real-time services.

Satellite data sources include GOES and NOAA weather satellites as well as the ISEE-3 satellite mentioned previously. The Total Energy Detector (TED) output from the NOAA polar orbiting satellites came into its own this year. The completion of routines that made the data available in near real-time and contributions from staff of the Research

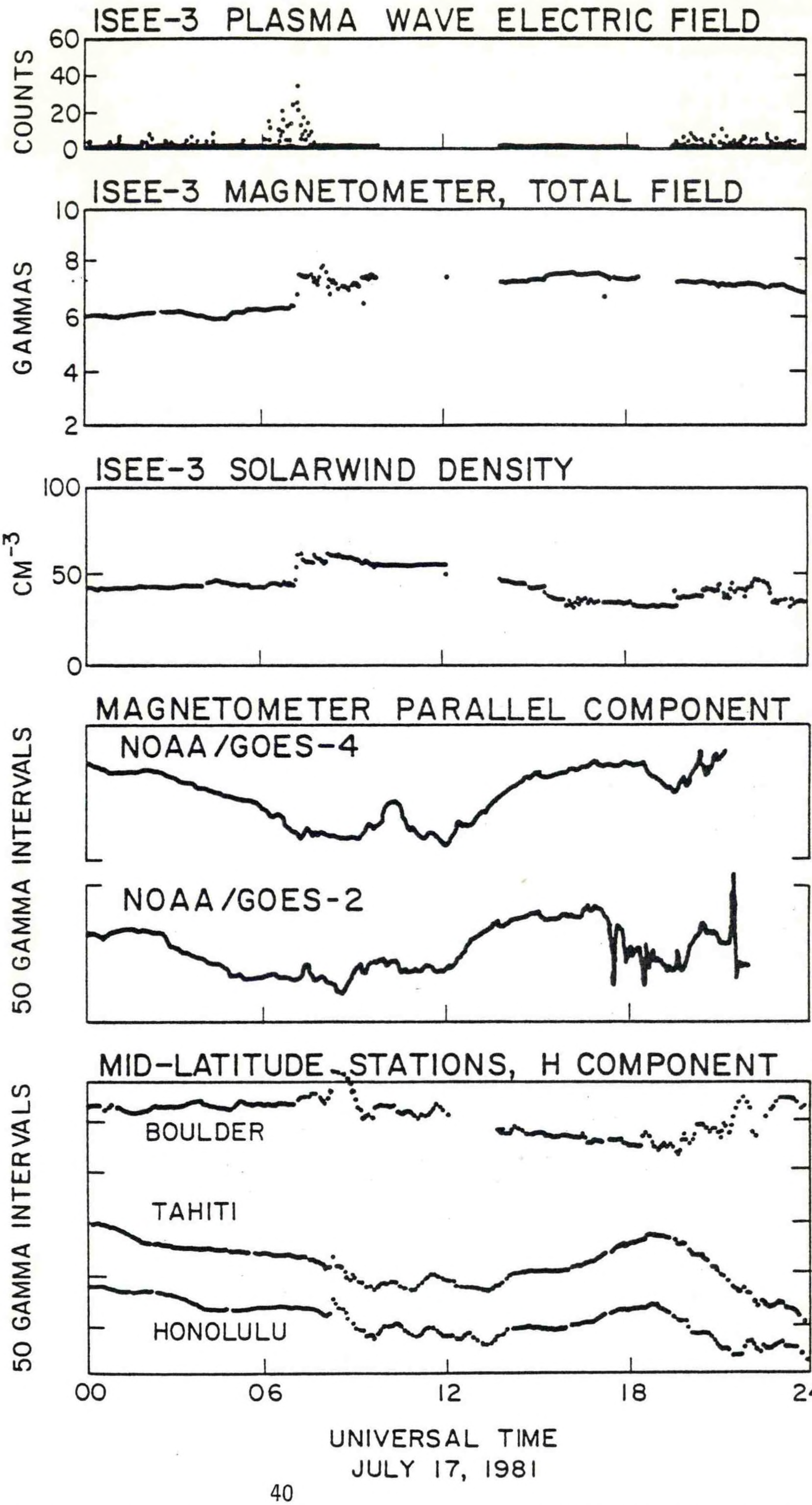


Fig. 14 Illustration of the detection of an expanding solar-interplanetary shock wave by the ISEE-3 satellite. Shortly after 0600 UT, plasma waves, running in front of the shock, are detected at ISEE. At 0709 UT, jumps in the total field and solar wind density at ISEE indicate the shock wave has reached the satellite. At 0803 UT, the disturbance reaches the earth and is evident in the sharp discontinuity in the magnetic field at Boulder, Tahiti, and Honolulu. A magnetic storm develops that is visible at these stations as well as on the GOES magnetometer.

Division assisted greatly in determining formats, content and use of the data in the services function.

Use of the International Magnetospheric Study (IMS) magnetometer network was made on several occasions when special processing enabled access to the data in real-time to support research campaigns and rocket launches. The same data are used in preparation of a Substorm Catalog included in the weekly publication, "Preliminary Report and Forecast of Solar Geophysical Activity."

Technique Development

Projects to improve services were carried out in the following areas: use of large-scale solar maps to anticipate areas of development of solar active regions; use of an automated routine for geomagnetic disturbance forecasting to record the basis for each forecast and provide continuity between forecast shifts; development of solar-active region indices as an aid in flare prediction; short-term (30 minutes to 1 hour) flare forecasting; use of interplanetary data in short-term geomagnetic forecasting; increased information about the probability of magnetic storms based on solar flare characteristics; longer range solar cycle forecasting; use of NOAA TED data for services; use of coronal hole information for geomagnetic forecasting.

PLANS FY 1982

Plans include maintenance of current services; preparation for bringing in the SELDADS II, including extensive documention of current routines and procedures; development of a Request for Proposal for a new video system to take, transmit, store, retrieve and process solar images; a Request for Proposal for design of a new forecast center layout; further technique improvement in many of the current areas; implementation of new data communication systems; and integration of the communication operations into the Forecast Center operation.

REAL-TIME DATA SERVICES BRANCH — C. HORNBACK

Real-Time Data Services (RTDS) operates systems that provide data from various solar and geophysical sensors for supporting the Space Environment Services (SESC) operations. RTDS has three operational components: (1) the Data Display System (DDS) in the Radio Building at Boulder, Colorado, (2) the Table Mountain Observatory (TMO) near Boulder, Colorado, and (3) the High-Latitude Monitoring Station (HLMS) at Anchorage, Alaska. The sites are manned during normal working hours; at other times personnel are on call for problems.

ACCOMPLISHMENTS FY 1981

The Space Environment Laboratory's Data Acquisition and Display System (SELDADS) consists of facilities to acquire, process, and display a wide range of solar geophysical data for use by the SESC forecaster for relay over a dedicated data link to the USAF Air Weather Service at

Offutt Air Force Base, Nebraska, and for direct use by a number of industrial, governmental and scientific groups. Data from this system are also supplied to the National Archives.

The Astrogeophysical Teletype Network (ATN), operated by the Air Weather Service, supplies data from observatories around the world including the High Latitude Monitoring Stations (HLMS) in Anchorage, Alaska. These data are decoded in SELDADS and stored for retrieval and display in SESC.

Data from the Space Environment Monitors on three GOES satellites were routinely received and sent to SELDADS where they were processed, displayed and archived. Data from GOES-4 and GOES-5 compare favorably with data from GOES-2. GOES-2 data are being recorded and sent to EDIS for archiving, and GOES-4 and GOES-5 data are being recorded for future reference.

Data from the NOAA-6 and NOAA-7 polar orbiting satellites are received at Boulder from NESS. The data are stored in a data base, displayed by the SESC, archived, and will be sent to the Global Weather Center (GWC) at Offutt Air Force Base, Nebraska.

SELDADS receives, processes, displays and archives the IMS magnetometer data from the U.S. Magnetometer Network via a satellite communications link. Because the data are received at SELDADS, there is a considerable amount of system monitoring and communications with USGS, University of Alaska, UCLA, and State University of New York, who maintain the magnetometer sites.

Data from the ISEE-3 electric field, solar wind, X-ray, and magnetometer sensors are received at Table Mountain. The data are processed and one-minute summaries are sent to SELDADS and displayed in real time by SESC. A solar wind "shock" alarm was implemented using the electron solar wind velocity data.

PLANS FY 1982

The routine data acquisition and processing will be continued. The development of the SELDADS II system will be supported.

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Capt. Bruce Springer

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Capt. Ghee Frye
S/Sgt. Warren West

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** COOP Students
*** Personnel no longer employed at SEL

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Sami Cuperman
Gary Gislason
Judith Lean
Michael Pitteway
Walter Spjeldvik
John Titheridge
Harold Trefall

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