SPACE ENVIRONMENT LABORATORY

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Space Environment Laboratory

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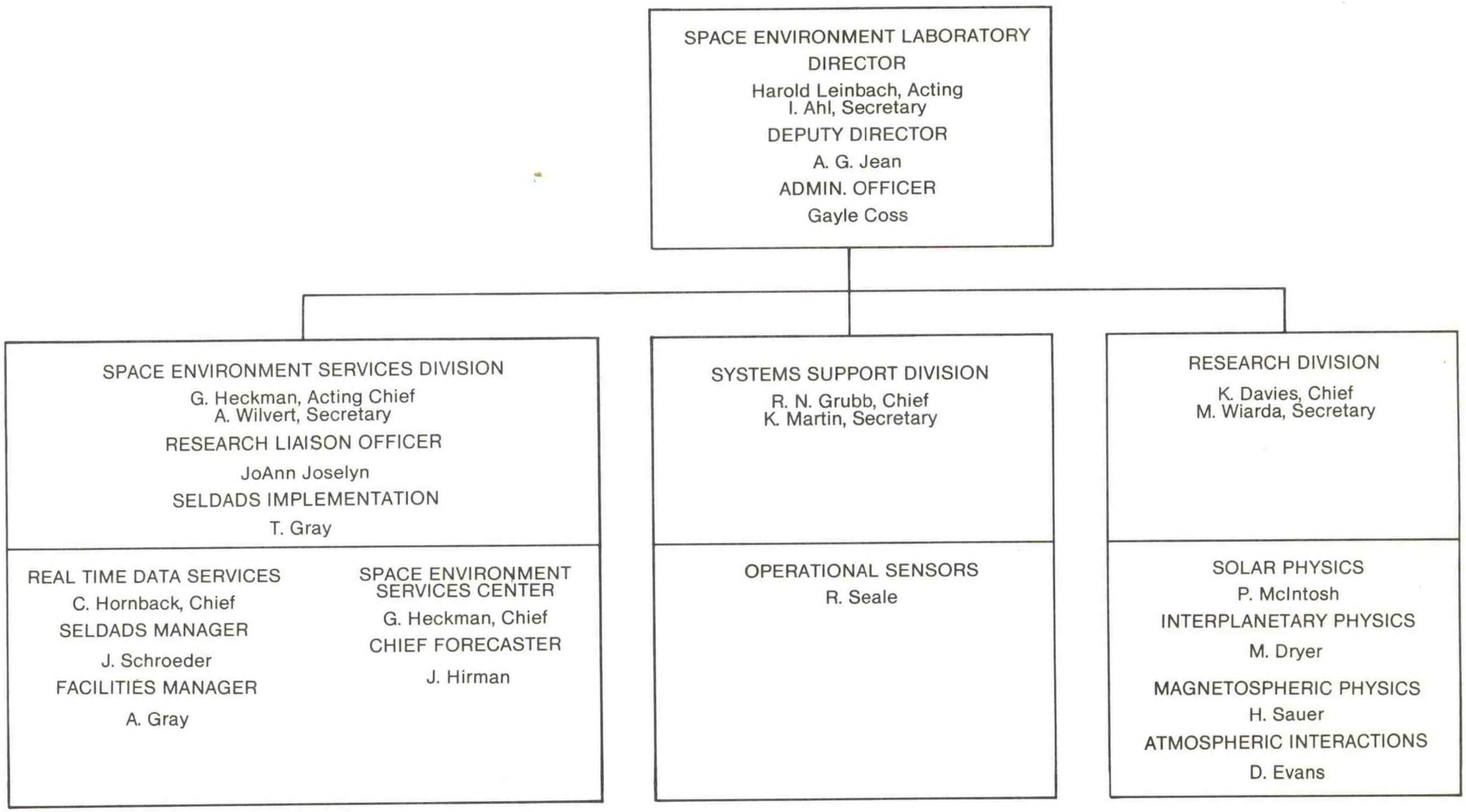

Figure 1 Space Environment Laboratory Organizational Chart

INTRODUCTION

The Space Environment Laboratory (SEL) is unique within NOAA's Environmental Research Laboratories in providing both real-time services to meet national needs, and research and support activities to improve these services. SEL is a national center for providing around-the-clock forecasts and warnings of solar and space disturbances, an activity which requires a substantial fraction of its resources. The rest of its efforts are devoted to studying and analyzing solar and terrestrial disturbances, and to developing systems to improve monitoring, understanding, forecasting, and analysis of disturbances.

The genesis of the mission of SEL is traceable to activities of the U.S. Government during the World War II, when the Interservice Radio Propagation Laboratory (IRPL) was formed in the National Bureau of Standards (NBS). At that time there was a strong requirement to support ionospherically propagated communications to the European Theatre, which could be severely disrupted during times of solar and geomagnetic disturbances. In 1946, the Central Radio Propagation Laboratory (CRPL) was formed in NBS to place the work of IRPL on a permanent basis. In the early 1950's, CRPL moved to the new NBS facilities in Boulder. From these beginnings, the radio propagation work moved to the Environmental Science and Services Administration, and still later the space environment services and research activities moved to NOAA when it was established.

The modern era of providing space environment services dates from 1965, when SEL (then the Space Disturbances Laboratory) established a real-time forecast and warnings center. The needs for these services have grown and diversified, extending well beyond ionospheric communications to include such problems as radiation hazards to astronauts, increased drag on navigation satellites during magnetic disturbances, upsets of geostationary satellite electronics and other systems, induced currents in long lines, and the impact of geomagnetic activity on geophysical exploration by air-borne magnetometers.

Major terrestrial space disturbances are traceable to three different types of solar activity: large solar flares, coronal mass ejections (some of which are associated with eruptive filaments), and high speed solar wind streams emanating from coronal holes. The time required for disturbances to reach the Earth ranges from the immediate effects of X-rays associated with flares, to 10's of minutes to hours for energetic solar protons from major flares, to 1 to 5 days for shock waves and plasma clouds from solar flares and the solar wind disturbances which are a result of coronal mass ejections. Disturbances associated with a given high speed solar wind steam tend to affect the Earth every 27 days, as the stream overtakes the Earth due to solar rotation. Only the flare X-rays reach the Earth unperturbed by the intervening medium. The propagation of both the energetic particles, and the shock waves and mass ejections can be profoundly influenced by the solar wind and its magnetic fields.

The terrestrial impacts of solar activity of concern to users include

- radiation hazards to astronauts and high flying aircraft (energetic solar protons)
- surface charging and deep charging of satellites (enhanced plasma environment and energetic solar protons)
- disturbed ionospheric communications (solar X-rays, solar protons, magnetospheric particle precipitation)
- disturbances of the external geomagnetic field (ionospheric currents associated with particle precipitation, ring current in the inner magnetosphere)
- induced currents in long lines (temporal variations of the magnetic fields from ionospheric currents)
- upper atmosphere heating (joule heating by ionospheric currents) .

(The sources of the problems are given parenthetically.)

The forecasts, warnings, real-time data, and summary information provided by SEL's Space Environment Services Center are generic products designed to serve the entire set of users concerned with these problems. Several methods of distributing these products are used, including commercial satellite broadcasts.

The thrust of research activities within SEL is to increase man's understanding of solar activity and consequent disturbances at the Earth, and to develop techniques for improving man's capabilities to monitor, forecast, and analyze solar-terrestrial disturbances.

SEL staff make important contributions to defining, procuring, and implementing the real-time monitoring systems used by the SESC, particularly the space environment monitors (SEM's) on the TIROS/NOAA and GOES satellites.

The following sections of this report discuss the FY 85 activities of SEL in detail. The reader will note that many projects, such as SELDADS II, cross the three-division administrative structure of the Laboratory (Space Environment Services Division, Systems Support Division and Research Division). Where this is the case the activity has, for convenience, been grouped under one division with the contributors noted.

SPACE ENVIRONMENT SERVICES

Introduction

The Space Environment Services Division contains the Space Environment Services Center (SESC) and Real-Time Data Services (RTDS). SESC, operated jointly by NOAA and the U.S. Air Force Weather Service, provides predictions, alerts and real-time information describing solar activity and solar-induced geophysical disturbances to users throughout the United States. In addition, it is the designated World Warning Agency for the International Ursigram and World Data Service (IUWDS), which is operated under the International Council of Scientific Unions. RTDS collects and processes monitoring data from NOAA satellites and ground sensors operated by cooperating agencies from other countries, both through IUWDS and through bilateral exchange agreements. The data collected include solar images and measurements of other parameters that characterize the Sun, measurements in the interplanetary medium, and information about the Earth's magnetosphere and ionosphere.

Solar-activity forecasts, geomagnetic forecasts, and warnings of events in progress, as measured by real-time observations, are valuable to a great variety of users. For example, the NASA Space-Shuttle program uses this information in orbit planning and planning for astronaut safety. Ionospheric communications, including the low-frequency navigation systems such as Omega, are disturbed during strong flares, proton events and geomagnetic storms; the space environment forecasts and warnings help users to anticipate and cope with ionospheric disturbances. The orbits of navigational satellites may be modified by increased density of the heated upper atmosphere during magnetic storms. The U.S. Navy issues corrected satellite ephemerides based on the forecast or observed level of magnetic activity. The same magnetic activity can induce strong voltage and current transients in electric power distribution lines, leading to possible system outages. In long pipelines, the induced currents may upset cathodic corrosion protection systems. In these situations, customers utilize geomagnetic forecasts and warnings to minimize adverse effects on systems. Many geophysical prospecting companies that use airborne magnetometers will avoid flights during the magnetically disturbed conditions that would affect measurements.

Space Environment Products and Services

The products and services listed below were provided throughout the year in accordance with an interdepartmental agreement on standard products and services required "to meet the multiple needs of various Federal agencies and public users" (National Plan for Space Environment Services and Supporting Research, 1983–1987, Federal Coordinator for Meteorological Services and Supporting Research, NOAA, FCM–P10–1983).

Monitoring Reports
- Solar–geophysical indices (broadcast)
- Daily High–Frequency Radio–Propagation Report
- Solar–Geophysical Activity Summary (daily)
- Solar Region Summary (daily)
- 7– and 27–day outlook (weekly)
- Solar and geophysical alerts and warnings (as required)
- Preliminary Report and Forecast of Solar–Geophysical Data (weekly)
- Primary Report on Solar and Geophysical Activity (daily)
- Multi–purpose data base (SELDADS)

Alerts
- Solar X–ray index (2 thresholds)
- Geomagnetic K index (4 thresholds)
- Geomagnetic A index (3 thresholds)
- Sudden commencements of magnetic storm
- Solar protons (2 thresholds)
- High–altitude radiation hazard (1 threshold)
- 10.7–cm solar radio flux (1 threshold)
- 245–MHz solar radio flux (2 thresholds)
- Type II and Type IV solar radio bursts

Forecasts
- Proton events
- Geomagnetic variation
- X–ray flares
- 10.7–cm flux
- General level of solar activity
- Smoothed sunspot number

In addition to the standard services provided to Federal agencies, universities, research groups, commercial users, the general public, and cooperating foreign countries, reimbursable special support was provided to the NASA Solar Maximum Mission at NASA's Goddard Space Flight Center and to the Spacelab 2 and 3 missions at the NASA's Johnson Space Center.

Data sources used in operation of the SESC the previous year were continued (listed in ERL Programs and Plans 1984–1985). A study will be completed in FY 86 in cooperation with the U.S. Air Force, and recommendations will be made regarding the future of the High-Latitude Monitoring Station at Anchorage, Alaska, which is now jointly operated by the U.S. Air Force and NOAA. Coverage of solar wind disturbances from the NASA Satellite ICE (Interplanetary Cometary Explorer), useful at the beginning of the year, degraded as the satellite moved away from the Earth toward its encounter with the Comet Giacobini Zinner.

Current Progress

Projects

Mass Ejections and Coronal Monitor Studies

Statistical studies have shown that only 20 to 30% of observed solar activity (flares, coronal holes, erupting filaments) lead to disturbances in the terrestrial environment. Thus a major problem is differentiation of solar events which may cause disturbances. Important factors to consider include the nature of the solar activity, the coupling into the solar wind, and the propagation of the solar wind disturbance.

Research indicates that solar mass ejections may be a key to understanding whether solar activity of various kinds will produce geomagnetic storms. In a recent SESC/AF effort, near real-time data from the coronagraph on P78-1 were used to study coronal mass ejections, through the cooperation of NRL. The study was of short duration due to the loss of P78-1, and the number of cases was correspondingly small. Even so, an initial conclusion was that the coronal data reduced the number of false alarms of forecasted geomagnetic activity based only on observations of disappearing filaments.

Glossary of Solar-Terrestrial Terms

A glossary of over 2000 terms in use in the solar-terrestrial field was compiled and edited by the SESC staff. After initial distribution, the Office of the Federal Coordinator for Meteorological Services and Supporting Research proposed that the glossary be adopted as a Federal Standard, with subsequent issuance by that Office.

Information on the Satellite Environment

As an aid to the satellite industry, a space environment plot based on data from the GOES satellite and an Air Force ground-based network, has been added to the weekly "Preliminary Report and Forecast of Solar-Geophysical Activity."

The late phase of Solar Cycle 21, which is expected to end in 1987, has been marked by low levels of solar activity but by a persistently elevated level of geomagnetic activity. That activity has been accompanied by an increasing frequency of reports of operation anomalies on satellites. The anomalies typically occur at the time of disturbed space environment conditions, but one-to-one cause and effect have not been established. The SESC plots and information supplement the more complete but retrospective reporting and analysis available through the National Geophysical Data Center of NOAA.

Spacelab and SMM Support

SESC provided support to the NASA missions Spacelab 2 and 3, which were devoted in part to studies of the solar-terrestrial environment. Special analyses and forecasts of conditions on the Sun and in the space environment were prepared. SESC forecasters worked at the Johnson Space Center to provide the continuous and detailed support required by the Spacelab 2 mission. These activities in support of the Shuttle payload and operations were in addition to the standard radiation warnings and atmospheric drag parameters provided for all Shuttle missions.

Continuous and dedicated support to the Solar Maximum Mission Satellite (SMM) continued during the year, supported by a NASA contract.

Equipment and Systems

The SESC staff participated in working groups to help the U.S. Air Force define requirements for the next generation of satellite-borne solar monitors, and to define the requirements for and the benefits to be gained from an X-ray imaging telescope on the GOES satellite.

SELDADS II

Phase I of the implementation of the new Space Environment Laboratory Data Acquisition and Display System (SELDADS II) was completed; the system was installed and demonstrated much of the capability of the older SELDADS I. Software design is being driven by a set of service requirements developed by the operational forecast center staff. Design and implementation are being done by a group of analysts, engineers, and programmers from the RTDS and the Systems Support Division. Figure 2 illustrates the elements of SELDADS II in a block diagram.

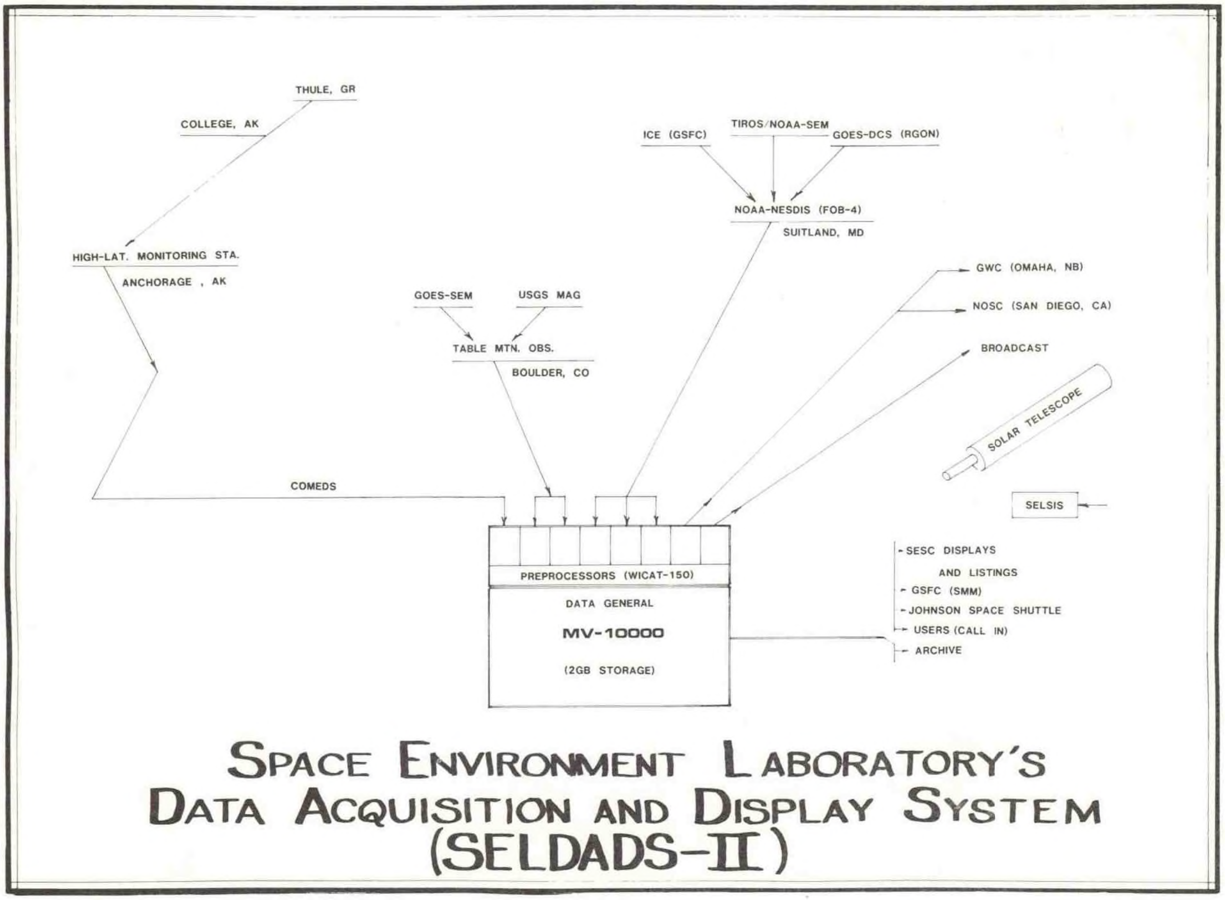

Figure 2. Block diagram of the SELDADS II system.

Capabilities will increase as software is implemented in Phases II and III. The system comprises eight micro-based computers networked with a Data General MV10000 super minicomputer to provide parallel, redundant processing for the collection, storage, editing, analysis, and transmission of data, forecasts, indices and alerts into and out of SESC.

The functions operational by mid-1986 will be sufficient to allow the shutdown of the old SELDADS I system after a period of parallel operation. Further developments of SELDADS II will provide numerical guidance programs, full real-time handling of all satellite and magnetometer data (exceeding the capacity of the old system), and a verification system for continuous evaluation of SESC forecasts and other forecast models.

SELSIS

A preliminary stage of the SEL Solar Imaging System (SELSIS), was used to support the Spacelab 2 mission. Digitized solar images were collected from Holloman AFB and Kitt Peak National Observatory and displayed at SESC and at the Science Area of NASA's Johnson Space Center, Houston, Texas. SELSIS is described in more detail in the next section.

A set of forecast requirements will be developed and incorporated in SELSIS software to analyze solar images, which is now done manually. New solar-forecast analysis procedures using digital image processing such as image-subtraction techniques will be added.

Communications Systems

Changes in communications included conversion from the obsolete Astrogeophysical Teletype Network to the modern Continental U.S. Meteorological Data System (COMEDS) network, and a growth in numbers of users of the SESC satellite broadcast network. This broadcast system permits users to receive SESC services directly on their own commercially available receivers as broadcast from a commercial satellite.

The advantages of the broadcast system to both SESC and the users are substantial. For example, alerts can reach all users at the same time, in contrast to telephone calls, where users are ordered by priority. Low priority users may find their alert delayed by as much as an hour or more. The satellite broadcast users also have access to some sets of real-time data, including the solar X-ray flux from the GOES satellite. They can construct real-time plots using a microcomputer that show the same information that is available at the Forecaster's console.

SYSTEMS SUPPORT

Introduction

The Systems Support Division plays a vital role in meeting the Laboratory's mission. The staff have responsibilities for design, procurement, and implementation of monitoring systems such as the satellite Space Environment Monitors (SEM's), and for the design of systems such as the SEL solar imaging system (SELSIS). The Systems Support staff interact with their counterparts in NASA and NOAA/NESDIS. The Division supports both operations and research projects in SEL.

Current Progress

Operational Satellite Instrumentation

Data from Space Environment Monitors (SEM's), which are carried on the TIROS/NOAA and GOES spacecraft, are essential to the operation of the SESC. Providing instruments to replacement spacecraft and developing new, or improving existing instruments for spacecraft is, therefore, a very important supporting activity.

Instruments are normally produced by contractors (or subcontractors) to NASA, which acts in turn to supply NOAA with the entire operational satellite. SEL sets the requirements for the SEM systems and assists with the technical supervision of the instrument contractor. In a somewhat different role, SEL has been asked by NASA to perform recalibration and repair on off-the-shelf instruments awaiting flight and also recently was asked to assemble for the GOES-H program one new instrument, a High-Energy Proton and Alpha Detector (HEPAD), from existing spare parts. This detector provides operational information on radiation hazards caused by very high energy solar particles during some solar-flare events. The new detector was substantially completed in FY 84. After acceptance testing and calibration, the instrument was delivered to the contractor for systems integration in January 1985.

The existing TIROS/NOAA instruments awaiting flight were supported as necessary. Two Medium-Energy Proton and Electron Detectors (MEPED) units were checked and requalified for flight. Repairs were necessary because of component failures in one of the MEPEDs and also in the GOES HEPAD. A new instrument procurement for TIROS/NOAA will be initiated in FY 86.

The GOES-Next program was supported by providing evaluations of the bidders' proposals for the SEM system. Unlike previous spinning GOES spacecraft, the new GOES satellites will be a three-axis-stabilized. This will require changes in the design of the SEM instruments, and it will be necessary to work closely with NASA and the contractor in the coming year to ensure satisfactory SEM performance. Support was also provided to the preparation of the SEL proposal for a solar X-ray imager to be carried on the GOES-Next series.

Off-line processing of data from the TIROS/NOAA and GOES spacecraft continued routinely during FY 85. The major programming effort was to realize the real-time processing of TIROS/NOAA and GOES data in the new SELDADS II system. An off-line data processing and data-quality-control system will be integrated into SELDADS II as this new system is brought into operational use.

SELSIS--SEL Solar-Imaging System

SELSIS will replace the present SESC system that handles solar image data in photographic form and transmits by analog wire photo systems. Data will be handled in digital form from the earliest possible stage. The benefits expected are greatly improved image quality and, most important, the ability to combine image data from more than one source and carry out quantitative image processing.

The overall system will comprise (1) the observatory processors that collect the image data at the various cooperating observatories and make it available for transmissions to Boulder, and (2) the central SELSIS in the SESC, which collects and processes the image data, and makes them available to the SESC forecaster. During FY 85 the design of the observatory processor system was completed. It is based on standard personal computer hardware and advanced adaptive modem technology for dial-up lines. Observatory processors were installed at the AWS Holloman AFB solar observatory in New Mexico, and at Kitt Peak National Observatory in Arizona. An observatory processor was also installed in SESC as a temporary substitute for the more powerful SELSIS system. It permits the forecasters to obtain and view high-resolution digital images from the two observatories, although there is no processing or hard copy capability. During the recent shuttle-launched Spacelab 2 mission, a compatible system was installed at Johnson Space Center in Houston by Lockheed Research Laboratories. This enabled Spacelab scientists to receive the SELSIS imagery as an aid to planning the orientation of their high-resolution solar viewing experiments.

The first stage of the development of the central SELSIS system will be completed in mid-FY 86 and the system installed in SESC. This will permit incoming images to be scaled, rotated, and gridded so that the forecaster will have a uniform presentation and the capability of accurate position location. Software for the communications and for basic image display has already been completed. SELSIS will also include a high-quality laser printer system for producing hard copy.

A CCD detector system is being designed and built to provide digital image data from the SEL manual spectroheliograph instrument which has been used to supplement Hα observations for some years. The direct availability of the data through SELSIS and the automation of the instrument are expected to considerably enhance its operational and research value.

SEL Scientific Workstation System

The improvements in microprocessor technology now make it possible to have a desk top workstation with the computational power equivalent to today's super minicomputers. Combining this with tightly coupled high resolution graphics and networking to other workstations, mainframes and super computers make it possible for a scientist to carry out all his work through a single interface. The local computational capability provides a powerful user interface for local source code generation and debugging. The graphics system in conjunction with the local CPU permits rapid and interactive review of data as well as powerful text and illustration manipulation for the production of the final publications. The use of such systems significantly improves productivity for both research and system development.

During FY 85, three workstations, one with multicolor display and two with monochrome, were delivered and installed for individual users. A fourth multicolor-display workstation will be used for developing image-processing techniques for SELSIS. The workstations are networked with a 12 Mbit/second token-ring system, which permits transparent sharing of the network resources. A number of scientific applications requiring graphical output were successfully transferred to the workstation system and graphic display tools were developed.

Additional monochrome-display workstations will be added to the system next year, and network gateways will be installed to the SELDADS II MV10000 computer and to the DOC scientific computer system. Software will be made available for preparing technical documents, and communications will be added from the existing administrative and word-processing 8-bit microprocessor network.

RESEARCH

Introduction

The mission of the Laboratory encompasses a very large physical system, ranging from the surface of the Sun through interplanetary space to the magnetosphere, ionosphere, and upper atmosphere of the Earth. Disturbances anywhere in this system have potential consequences to the user community. The Laboratory operates sophisticated monitors for part of this system, including total solar X-ray flux, and the energetic particles and magnetic fields at the Earth. The small but active Research Division fulfills multiple roles in meeting the Laboratory mission, by providing scientific expertise for the monitoring systems, analyzing data obtained from these systems, and developing new techniques for improving forecasts and warnings. An important effort of the Research Division, in collaboration with the Systems Support Division, is to take a lead role in developing new monitoring instruments, such as the X-ray imager, and new techniques such as image processing, expert systems, and sophisticated numerical models.

The magnitude and number of research issues in solar-terrestrial physics is staggering, and no single group can treat more than a limited number of these problems. The SEL approach has been to concentrate on issues of most direct concern to improving the space environment services offered by the Laboratory. An important role for the researchers is to keep abreast of developments elsewhere, and to work cooperatively with other research groups on those problems of greatest concern to the SEL mission.

SEL's research efforts have been significantly enhanced by the presence of NRC postdoctoral fellows, and CIRES appointees and visitors.

In the following discussions, the major research efforts are summarized, beginning with the Sun, and moving to the upper atmosphere of the Earth.

Current Progress

Solar Physics

The objective of the Solar Physics Project is to improve medium and long-term solar predictions and to understand the structure and evolution of global solar magnetic fields and of the solar corona so as to improve prediction of solar disturbances. During the past year, the activities of the solar physics project were concentrated in the following areas.

Development of Expert Systems

Knowledge-based "expert systems" attempt to capture on computer the knowledge of a human expert in a limited domain and make this knowledge available to a user with lesser experience. Such systems can be used as a tool to assist forecasters and can be a powerful training device. In a pilot project during FY 85, members of SEL's Research Division and Systems Support Division collaborated with the Computer Science and Psychology Departments of the University of Colorado in Boulder to construct a small expert system emulating a methodology for sunspot classification and solar flare forecasting developed in SEL.

The rule-based system, called THEO, is based on a staff physicist's long experience in classification of the stages of development of sunspots as observed in white light, and the relation of probability of flaring with the sunspot structure and evolution. THEO has been made "user friendly" by incorporation of explanations of the various types of information which are to be entered by the forecaster. These are available when needed, using screen-prompting techniques. By making THEO self-contained, it also serves a useful function as a training tool.

The project convincingly demonstrated the possibilities of this type of computer assistance, which proved to be a useful tool for formally expressing a methodology and verifying its performance. In initial tests of the THEO, it performed as well as a skilled human forecaster using the same methods, and scored well compared with actual SESC performance in the period covered by the test data.

The pilot system will be extended next year to include additional solar data, such as the hydrogen alpha line features and magnetic characteristics of active regions. Other possible applications of knowledge-based expert systems to the SESC operation will be studied.

Solar X-rays – Total Flux Measurements

The SMS and GOES satellites have carried total solar X-ray flux detectors since 1974. These detectors measure the flux in two bandpasses, one covering the range of .5 to 4 Å, the other from 1 to 8 Å. The longer wavelength (lower energy) channel is the primary monitor for solar X-ray events, both because its wider bandpass makes it more sensitive, and the fact that the X-ray flux tends to increase as the energy decreases. However, the ratio of the high energy to low energy X-rays tends to increase during solar flares, so that the ratio becomes a qualitative indicator of the energetics of the flare. The X-ray flux measurements have become a primary real-time diagnostic of solar flares, since the peak fluxes and durations of X-ray flares are often symptomatic of the terrestrial effects of the flares. The Space Environment Center's classification of flares in terms of their peak X-ray fluxes has become a standard measure of the flare.

During the year, an analysis technique was under development to use the observed ratio of fluxes of the two X-ray channels, and its time variation during the flares, to quantitatively deduce the flare temperature and the emission measure (flare plasma electron density squared, multiplied by the volume of the flaring region). The model is based on a semi-empirical solution to an energy balance equation, incorporating the dominant "free-free" and "free-bound" transition mechanisms for generation of the flare X-ray fluxes. From the plasma temperatures and densities, related physical parameters can be derived, such as total thermal energy, gas pressure, and mass. The value of these studies to operations lies in the potential to sort out geophysically effective flares, including those accompanied by mass ejections.

As these analysis techniques are applied to real flares, a statistical data base will accumulate which will include the physical parameters for flares, as well as the standard X-ray indices such as the peak flux. This data base will provide the solar forecasters with statistical information on this new and quantitative diagnostic tool.

Work is continuing on this project, including testing the technique against other independent analyses of flare temperatures, and sorting out details such as the influence of the spectral bandpass of the detectors on the results of the model calculations.

Solar X-Ray Imager

SEL has proposed to add a Solar X-Ray Imager (SXI) to its Space Environment Monitoring detectors on the GOES-Next series of satellites. For the reasons outlined below, the X-ray imager will provide a breakthrough in capabilities to monitor major solar activity with terrestrial consequences. For example, X-ray images will significantly improve the monitoring and prediction of solar proton flares, as well as for other types of solar activity leading to geomagnetic activity. Figure 3 shows the evolution of remote sensing in the solar atmosphere.

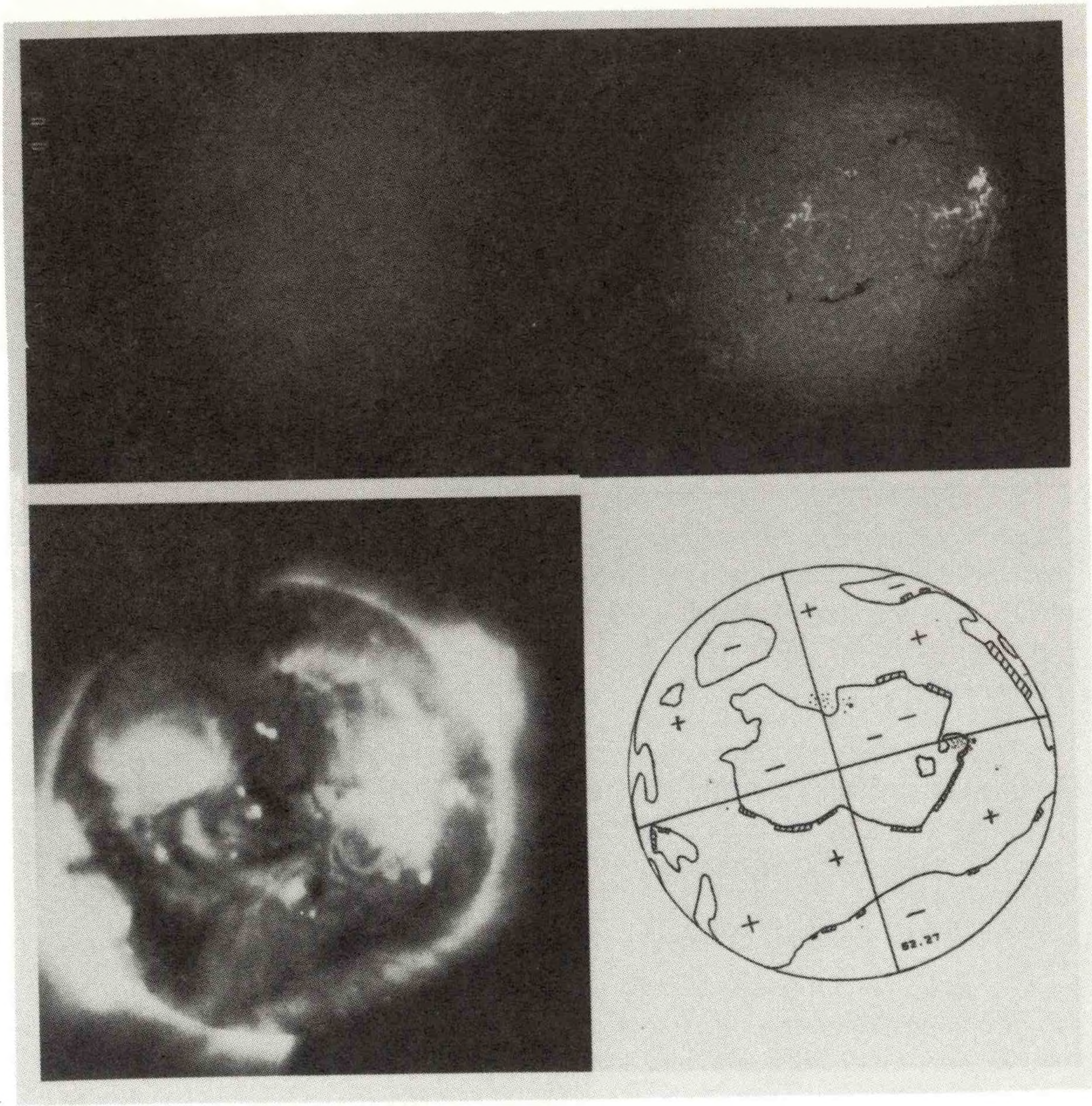

Figure 3. REMOTE SENSING IN THE SOLAR ATMOSPHERE. This figure is a montage of solar images (all from 28 May, 1973) which illustrates the development of observations of the Sun over the years. Similar to the case of remote sensing in the atmosphee of the Earth, spectral discriminatin of the various wavelengths of light provides additional information about the Sun.

Such improvements in forecasts and warnings are becoming increasingly critical to users. For example, man-in-space activities are on the rise, including the upcoming manned missions over the Earth's polar caps, where radiation hazards can become very serious following major solar flares. Also, the incidence of reported space environment upsets of satellites has steadily increased during the past several years. The serious consequences of these upsets are now being realized by a majority of the satellite community. Information from the solar X-ray imager will be important for more accurate forecasting and warning of terrestrial disturbances, which will permit users to mitigate the undesirable effects on astronauts and space systems.

A prototype operational X-ray imager was developed several years ago by staff in the Systems Support Division. The Services and Research Divisions evaluated the operational utility of the imager. When the GOES-Next series of spacecraft were proposed SEL recognized an opportunity to install SXI's as adjoints to the on-going SEMS, based on a basic change in the satellite's configuration. Much of the FY 85 efforts were devoted to preparing FY 87 initiatives for the imagers. The hardware initiative was developed and advanced by the National Environmental Satelite and Information Service (NESDIS), with assistance from SEL staff.

In the *upper left* panel the Sun is seen in white light integrated over all visible wavelengths. Using white light, we "see" the deepest into the Sun, to a level where the temperatures are the coolest (5700K) and few features are evident. The only detail visible on this day in white light was a sunspot near the upper right edge of the solar disk.

In the 1940's, narrow wavelength filters were developed which passed only the light in individual spectral lines. The *upper right* panel is the solar image produced at 6563 Angstroms, the H-alpha line of neutral hydrogen. At these middle (chromospheric) layers of the Sun the temperatures approach 20,000K. Using spectral discrimination such as this, active regions, prominences, and flares may be seen. With H-alpha images available, the 1950's saw a flurry of flare research which perhaps peaked during the International Geophysical Year (1957-58). A principal element in the environment sensor systems used today remains the H-alpha telescope.

With the NASA flight of Skylab in 1973, images of the Sun were obtained in soft X-rays by the American Science and Engineering Corporation. At the *lower left* is the X-ray Sun for the day under discussion. In X-ray wavelengths, the highest layer of the solar atmosphere (the coronal) is sampled at temperatures exceeding 1,000,000K. For space environment monitoring, the X-ray region offers a significant signal-to-noise advantage -- bright emission is seen only from that pathology known as "solar activity." The AS & E X-ray Imager resembles that proposed for GOES.

In the *lower right* panel are traced the discernible large-scale magnetic field regions. When extrapolated out into the solar wind, maps like this can predict the direction of the interplanetary field with respect to that of Earth.

The accompanying research and technique development initiative for use of the X-ray image data was prepared by SEL. Throughout the year, staff members from the Research and Services Divisions presented numerous briefings on the imager and its uses to various offices in DOC, NASA, and DOD; as well as to a subcommittee of the U.S. House of Representatives. The initiatives were not accepted for FY 87 starts. Work has continued on resubmitting the initiatives in FY 88.

SEL staff and many others feel that the solar X-ray imagers would constitute a breakthrough in monitoring of solar activity, with valuable spinoffs to the missions of many agencies. However, the project is a major one in scope and costs, and support for the imagers will come through multi-agency interests and cooperation. Work on gaining such support will continue into FY 86.

The reasons why X-ray imagers will be so valuable to forecasts and warnings, and indeed to the fundamental understanding of solar disturbances, are straightforward. Disturbances which can affect the Earth either arise in, or pass through, the outer solar atmosphere called the corona. Conventionally, the corona has been observed using coronagraphs on high mountains, or now, on board satellites. But in order to observe either the visible wavelength coronal emissions, or the white light scattered by coronal electrons, the disk of the Sun must be artificially eclipsed. Thus only those coronal disturbances extending beyond the occulting disk can be observed. Coronal disturbances in the direction of the Earth are seldom observed by coronagraphs.

The corona also emits X-rays, since the coronal gases have temperatures in excess of one million degrees. The emissions are particularly strong in volumes of high density and temperatures. These are just the regions of the corona associated with solar activity. Furthermore, the surface of the Sun emits only a very small flux of X-rays, since its temperature ranges from a few thousand to a few ten-thousand degrees. Thus, the X-ray emitting regions of the corona are viewed against a dark solar disk, and can be seen anywhere across the solar disk, and extending beyond the limbs of the Sun. X-ray images thus permit a global view of all the geophysically important types of solar structures and activity, including solar flares, coronal mass ejections, and the coronal holes (portions of the solar corona which are dark in X-rays and are known to emit high velocity, low density solar wind streams).

The SEL X-ray imager will be based on the design so successfully used on the NASA Skylab missions of the early 1970's. The telescope will use grazing incidence optical surfaces to focus X-rays in a short wavelength bandpass of 10 – 20 Å and a longer wavelength passband of 20 – 60 Å. In addition, a channel in the EUV spectral range will provide images of the Sun at wavelengths which are important for heating the upper atmosphere of the Earth. Modern CCD technology will be used to construct the images. The image rate can be as high as one per minute, and the spatial resolution of the full disk images will be less than 10 arc sec.

Synoptic Solar Maps

The ability to prepare solar synoptic maps by computer, facilitated by acquisition of the scientific workstation system, has enabled high-resolution color graphics to be employed in the generation of maps and, more importantly, for the study of time series of maps. Solar maps for approximately 2 years were entered into the data base for use in the development and testing of computer programs for display and analysis of solar atmospheric dynamics. Both color and black-and-white versions of solar maps, with labels and legends, can be displayed on the workstation screens. The graphic displays are able to facilitate analysis of relationships between large-scale aspects of solar activity and the occurrence of solar sources of geophysical disturbances. For instance, solar maps have led to the introduction of a new model for the formation and evolution of sunspots, based on the fact that sunspots form in preferred locations with respect to the large-scale patterns of magnetic fields that precede sunspot formation.

Solar Magnetic Structures

A model of a solar prominence, based on eigenvalue solutions, was constructed. The model describes topologically different magnetic configurations with continuous magnetic field and finite magnetic energy. The thermodynamic parameters, including the total mass of a prominence as calculated by the model, agreed well with observations. The eigenvalue approach has been extended to a three-dimensional model of the solar atmosphere. Force-free electromagnetic oscillations were proposed as an important physical process in magnetized-ionized atmospheres. It was proposed also that, during solar flares, force-free electromagnetic solitons are formed.

Solar Activity

To study the evolution and persistence of solar active and inactive longitudes, a 14,000-item data set was created covering nearly three sunspot cycles (1956 to 1982). This data set consisted of all the calcium plage regions reported during the period, classified according to maximum optical flare importance reported from the regions. An earlier study had shown an abrupt change from domination of the solar disk by active longitudes to domination by inactive longitudes in one sunspot cycle. The specific objective of this study was to determine whether that abrupt change occurs during every sunspot cycle. A by-product of this effort is information on any asymmetry in major flare activity between the northern and southern solar hemispheres. This information was requested by mission planners working on Ulysses (the Solar Polar Mission).

Interplanetary Physics

The objective of the Interplanetary Physics Project is to develop forecasting models for the occurrence, duration, and severity of geomagnetic storms, using magnetohydrodynamic (MHD) models of the propagation of solar disturbances through the solar wind.

Propagation of Solar Wind Disturbances

Two interplanetary models have been developed: a 2 1/2-dimensional (2 1/2-D) model for disturbances in the ecliptic plane, and a 3-dimensional (3-D) model. By analogy with numerical weather forecasing models, these are called "Interplanetary Global Circulation Models" (IGCMs). The 2 1/2-D model was transferred to SEL's scientific workstation system, which provides a cost effective tool for two purposes: (1) sensitivity tests for solar input parameters, and (2) a test-bed for operational usage. The 3-D model, designed for eventual input of solar X-ray images, was tested on a CRAY-1 computer. The outputs of these models provide geo-effective parameters such as solar wind dynamic presssure, solar wind power, and the IMF polarity, all of which are crucial diagnostics for predictive capability. The 2 1/2-D model has already been used to simulate a complex series of solar and interplanetary events in August 1979. During this period, a series of eruptive prominences, solar flares, and magnetic storms took place. The international project, Study of Travelling Interplanetary Phenomena (STIP), headed by this group, acquired an extensive set of solar/interplanetary data that formed the basis for input to the 2 1/2-D model. The output of the model, shown in Figure 4 for one of the key interplanetary physical parameters (magnetic field magnitude), compares the simulation with the ISEE-3 observations.

As noted in the caption of Figure 4, it was demonstrated that improved input data (such as those from a soft X-ray imager and coronagaph) at or near the Sun are essential to better simulate the anomalous IMF behavior that couples the solar wind to the magnetosphere.

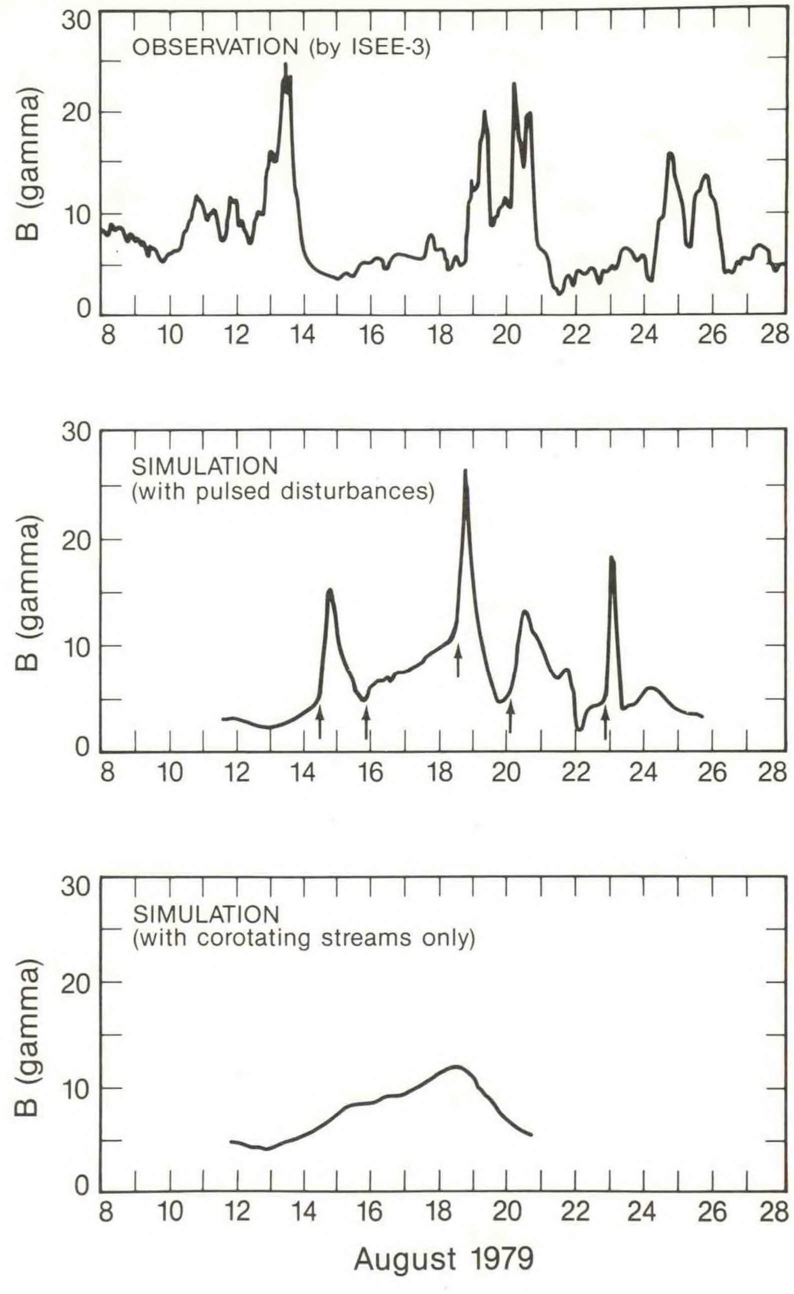

Figure 4. Comparison of interplanetary magnetic field (IMF) measurements at ISEE–3 in August 1979 (upper panel) with the 2 1/2–D Interplanetary Global Circulation Model (IGCM) predictions in the middle panel. The lower panel displays the IGCM predictions under the assumption that no solar activity took place; that is, with only a series of modulated high streams. Improvement of input data at the Sun was demonstrated to be essential for further progress with this model.

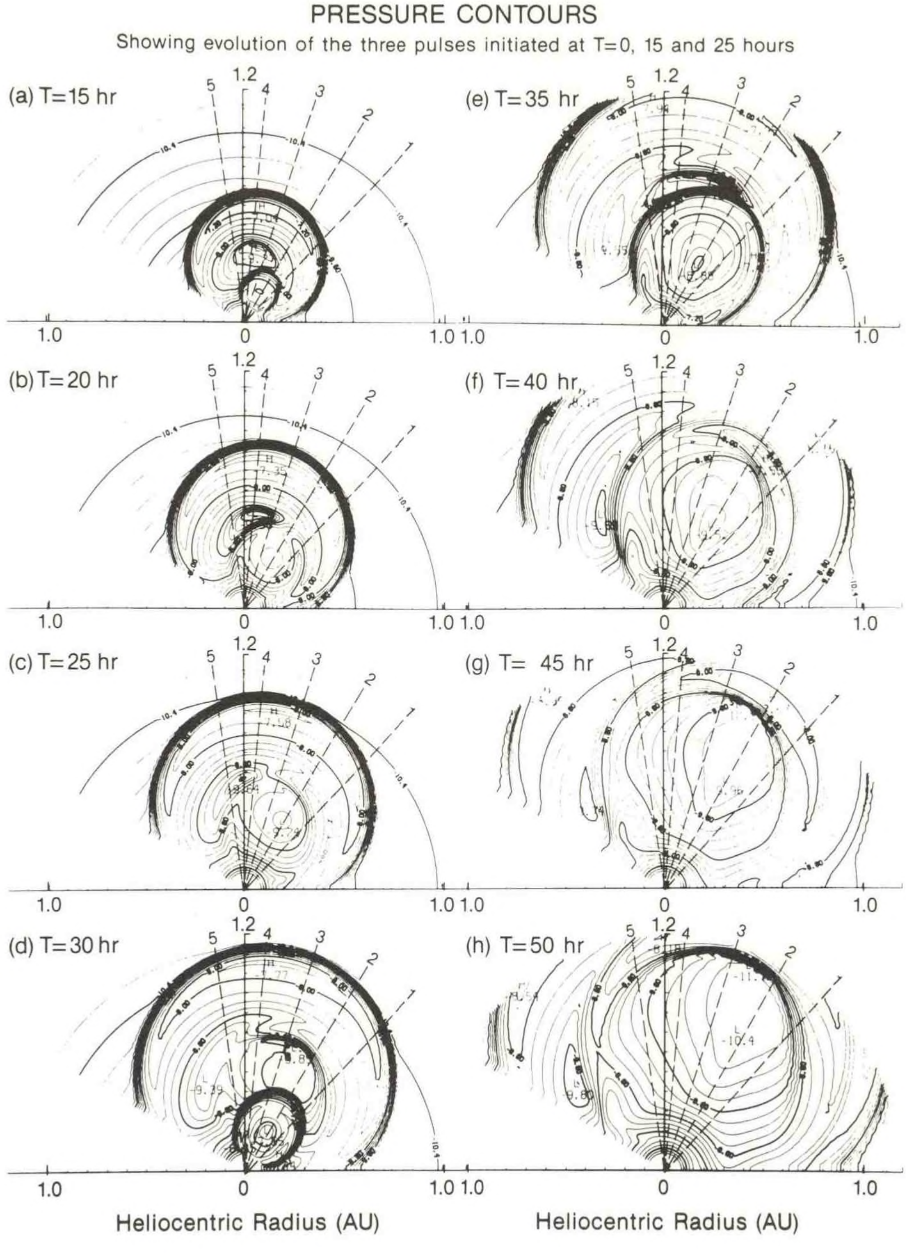

FIGURE 5. Multiple shock interactions in the interplanetary medium between the Sun and Earth following a series of solar energy outbursts and eruptive prominences. Note that both a "reverse" shock from Event #1 and a "forward" shock from Event #2 are attenuated after the collision shown in Figure 2(b). Interactions such as these can clarify the physics that might provide answers to questions concerning geo-effectiveness (or lack thereof) of certain flares.

The $2^1/_2$-D IGCM was also used to study the interaction of interplanetary shock waves as shown in Figure 5. The results shed light on the question of why some flares are geo-effective while others are not.

A full 3-dimensional MHD code has been developed with collaboration of scientists at the Universities of Alabama and Tennessee. Initial results from the 3-D code demonstrated the importance of latitudinal effects caused by activity such as coronal holes and eruptive pominences.

Arrival Times of Flare-Generated Shock Waves

An operational shock wave algorithm was developed with colleagues at AFGL in which real-time observations of the frequency versus time dispersion of Type II solar radio bursts from flares, detected by the USAF Radio Solar Telescope Network, are input to calculate the time-of-arrival of the shock at Earth. Impact of the shock wave on the Earth's magnetosphere can initiate a geomagnetic storm when the dynamic pressure of the solar wind and (or) the polarity of the interplanetary magnetic field (IMF) are appropriate.

Solar-Terrestrial Environment Model

With the collaboration of external scientists in the academic and private sectors and the Department of Defense, a strategy was developed that holds promise for tracking disturbances from the Sun to the auroral ionosphere and thermosphere. To demonstrate the physical solar-terrestrial linkage, a composite model was devised that inputs photospheric data in a 2-D chromospheric and coronal model and whose output serves as input to a 1-D interplanetary model. The output of the latter model provides the starting point at the Earth's magnetosphere for the propagation of a disturbance through the magnetosphere to the 300 km level of the auroral atmosphere. This permits calculation of the temporal profile of energy input to the thermosphere, which indicates possible atmospheric density increases by a factor of 10. The energy deposited into the auroral ionosphere agrees with that required to account for the short time (minutes) increases in the ultraviolet intensities observed by the Dynamics Explorer satellites. The neutral density increase at 300 km, over several hours, is sufficient to explain observed satellite drag.

Multi-Fluid Solar Wind Studies

To improve the existing models of the solar wind, two changes were introduced: (1) The spatial scales were reduced to 10^5 km over which the magnetic field in the solar wind can change polarity. (2) The importance given to multi-fluid structure (for example, from protons and electrons) was increased. The change permits short-time-scale processes caused by non-neutrality and results in coupling via electric fields. The results will be combined with earlier work that incorporates realistic dissipative effects such as thermal conductivity, temperature anisotropies, and non-Maxwellian energy distributions. The use of small spatial scales in the interplanetary models will result in more accurate prediction of IMF polarity changes and, therefore, more accurate predictions of the coupling of energy between the solar wind and the magnetosphere.

Magnetospheric Physics

The objective of the Magnetospheric Physics Project is an improved understanding of the dynamical processes by which material and energy are transported from the solar wind into the magnetosphere, stored, and eventually dissipated in the Earth's ionosphere. Both applications and research are pursued to improve the quality and utility of SEL's products and services.

Cooperative Programs

The University of Iowa ultraviolet imagers on the Dynamics Explorer, (DE) satellite have provided new perspectives on the occurrence of auroras, by providing images of the entire auroral zone, even extending into the dayside of the Earth. One new result, exemplified by the succcessive 12-minute images shown in Figure 6, is the detection of the so-called "Theta" aurora, marked by a sunward-directed band of emission extended across the interior of the auroral oval. The dawn-to-dusk orbital plane of the TIROS/NOAA satellites crosses the polar cap, and cuts the Theta auroras at approximately right angles. Detectors on these satellites measure charged particles in the energy range which can cause the observed auroral luminosity. A cooperative study of these data with scientists of the University of Iowa has detected particle influx into the southern polar cap at locations consistent with Theta aurora simultaneously observed in the Northern Hemisphere. This finding is of significance to understanding the magnetic field topology of field lines connecting into the polar caps.

A cooperative study was undertaken with members of the Middle Atmosphere Program (MAP), an international program to study the global characteristics of the stratosphere and mesosphere. A 7-rocket campaign during the winter of 1983-84 concentrated on providing data of a comprehensive assessment of middle atmosphere conditions in winter at high latitudes. SEL scientists examined the TIROS/NOAA energetic particle data for four of the rocket launches which closely corresponded in time to overflights by the satellites.

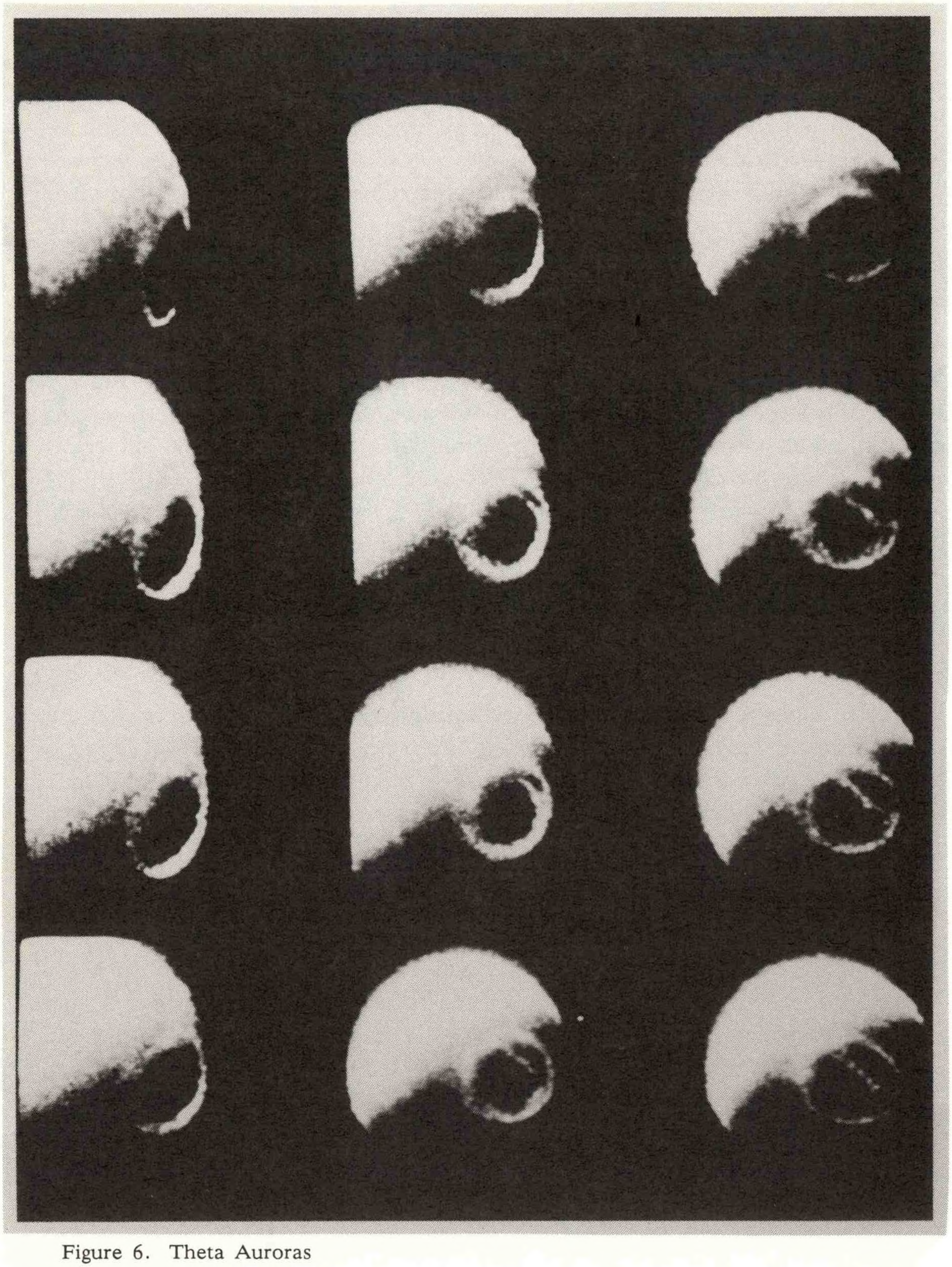

Figure 6. Theta Auroras

The observed particle fluxes, while enough to explain the auroral luminosity imaged by the Defense Meteorological Satellite Program (DMSP) satellite, were not intense enough to produce significant ionization and energy deposition below 90 km.

Theoretical Studies

Earlier theoretical studies of plasma phenomena in the magnetosphere relied on MHD approximations to ensure tractable equations. It has become clear that important physics may have been neglected in this approach. Therefore a new program of computer plasma simulations based on simulating the microphysics of individual plasma particles was initiated.

Experimental studies have identified the Earth's magnetospheric tail as being important for the transfer of electromagnetic energy to the particle populations, which on precipitation down field lines can subsequently modify the properties of the ionosphere. Simulation studies were undertaken to determine the particle behavior in the vicinity of x-type magnetic neutral point configurations which are expected to occur in the geomagnetic tail. Initial calculations confirmed the acceleration of particles by the mechanisms proposed earlier by SEL scientists, based on particle drifts in a plasma sheet with a cross-tail electric field, and a magnetic field with a component perpendicular to the plasma sheet. Further simulations are underway.

Magnetic Reconnection at the Magnetopause

It is universally accepted that the ultimate source of energy for the terrestrial magnetosphere is coupling from the solar wind. Magnetic reconnection at the dayside magnetopause is seen to be the process by which energy is coupled from the interplanetary medium to the magnetospheric system, a process by which solar wind magnetic fields are interconnected to the terrestrial magnetic fields.

Figure 7 schematically illustrates the reconnection process. Magnetic flux tubes are convected from the left by the solar wind toward the oppositely directed magnetic field within the magnetosphere. There they break and reconnect with corresponding flux tubes or the magnetospheric magnetic field, opening these flux tubes to the interplanetary medium, and permitting them to be swept back into the geomagnetic tail.

The dayside reconnection process was initially defined through its magnetic signature. Using data from the ISEE-1 (International Sun-Earth Explorer), the laboratory study found that:

1) the particle signature is a more sensitive indicator of the reconnection process and
2) the process is less localized in extent than is implied by the magnetic analysis.

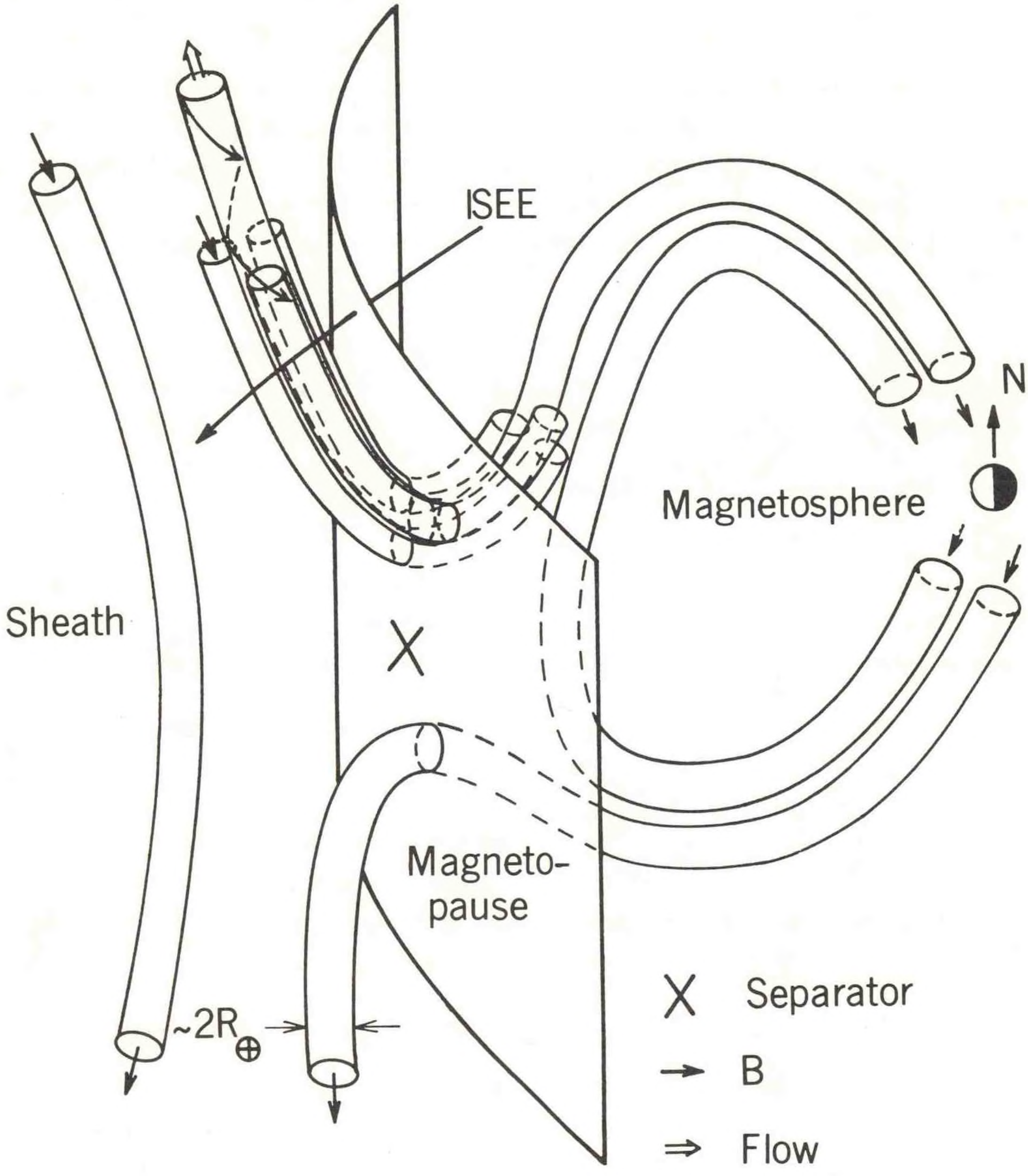

Figure 7. ILLUSTRATION OF RECONNECTION PROCESS TOPOLOGY. Magnetic flux tubes are convected from the left by solar wind flow to the magnetopause, where they interconnect with exterior flux tubes of the magnetospheric magnetic field.

Wave-Particle Interactions

Substantial effort also continues on the study of wave-particle interaction processes occurring in the magnetospheric plasma through which energy is internally transferred and which partially control the electrodynamic properties of the magnetospheric system.

For example, laboratory theoretical studies show that a beam-acoustic instability of the interaction of energetic particles at the plasma sheet boundary with the ambient plasma might provide a source for the heated plasma sheet particles found in the magnetospheric tail. The plasma sheet is considered to be the source of ring current particles, which partially control the geomagnetic field.

A clear understanding of this (and any other viable coupling mechanisms) is important to developing techniques for forecasting and warning of magnetospheric disturbances.

External Cooperation

The group will continue to provide support to assure the quality of real-time and non-real-time data and data processing. In addition, a data processing system for energetic particle data will be developed for use with a personal computer.

Laboratory scientists have engaged in a number of cooperative and consultative activities. Both data and consultation support continue to be provided to the Defense Nuclear Agency (DNA) for the conduct of its Long Wave Program to study ionospheric propagation of low-frequency signals. A data distribution system, for use with a personal computer, was initiated for easy exchange of satellite particle data in as near a universal and friendly format as possible.

Atmosphere-Ionosphere-Magnetosphere Interactions

The objectives of this project are an improved understanding of the transfer of electrical and mechanical energy from the Earth's magnetosphere into the upper atmosphere, and a characterization of the possible consequences of this input in the Earth's ionosphere and upper atmosphere.

Data Acquisition

Observations from instruments on board the TIROS/NOAA-6 and TIROS/NOAA-7 spacecraft continued to be obtained, processed, and used in both research and as a quantitative measure of geophysical activity. Because of the aging of the detectors, the quality and amount of these observations degraded during the year. Early in FY 85, spacecraft operational difficulties often reduced the flow of data from a normal 95% to less than 40%. Tracking of TIROS/NOAA-7 ended as TIROS/NOAA-9 (without an SEM) came into operation. The net result was that the amount of data now acquired is about 40% of that of a year ago, and the quality has deteriorated somewhat.

Data Studies

A thermospheric dynamical model to calculate changes in temperature, density, and composition as a function of energy input is being developed using TIROS/NOAA particle data. Several studies were carried out using the TIROS/NOAA total energy data. For example, a study was made of the symmetry, or conjugacy, of the energy input to the atmosphere occurring simultaneously in the Northern and Southern Hemispheres. Data from TIROS/NOAA and the Defense Meteorological Satellite Program show that considerable symmetry exists in the energy input over the equatorward and center portions of the auroral precipitation regions. This symmetry breaks down in high, polar cap latitudes where the energy input to one hemisphere may bear little resemblance to that in the other hemisphere.

A second example is a study of energetic particle precipitation in latitudes equatorward of the auroral zone, using data from TIROS/NOAA and the Stimulated Emissions of Energetic Particles experiment. This study showed that precipitation may be short lived but can extend over large distances. There is a possibility that the precipitation is triggered by lightning strokes and that a single stroke affects the energetic particle population over a wide region so that tropospheric phenomena may exert a significant control over the inner magnetosphere.

A third example is participation in the Global Thermospheric Modeling Study, a project directed toward the detailed analysis of the behavior of the Earth's upper atmosphere during three selected periods in 1984. Data from the TIROS/NOAA detectors were used to characterize the degree of geophysical disturbance (power input) and also provide information on the energy input (on an hour-by-hour basis) as a driving input to the models. The use of the power input as a measure of geophysical disturbance is gaining acceptance in the scientific community.

Ionospheric Conductivity Maps

The total energy deposition data base was used to construct maps of the electrical conductivities in the ionosphere at the polar regions. Constructed for different levels of auroral activity, the maps use the same activity parameters as those used to construct the patterns of particle energy influx, that is, hemispheric power input. Plots can be made of disturbed ionospheric conductivity patterns as a function of the geophysical activity parameter, using the particle energy patterns from the TIROS/NOAA total energy detector data. The maps are important because the major source of heat to the auroral upper atmosphere is the heat generated by currents flowing in a resistive ionosphere. A combination of conductivity maps with patterns of electric fields, together with energy input by the particles themselves, allows the total heat input to be determined. This leads to a better assessment of the magnitudes of the perturbations resulting from the heating.

Correlation Studies

A correlation study was performed between the estimated hemispherical power-input activity, the conventional magnetic-activity indices, and parameters of the interplanetary medium that are thought to control geophysical activity. Correlation was good (coefficient approximately 0.75) between the power input and magnetic indices, but it had a large variance. This suggests that the two parameters may be measuring different aspects of geophysical activity and (or) that neither is a good measure of activity. Furthermore, an association between power input and the interplanetary magnetic field showed reasonable agreement as, for example, with the north-south component of the IMF, but again the variance was large, suggesting the absence of a cause-and-effect relationship.

Operational Aspects

In addition to their use in the above studies, TIROS/NOAA data were made available for operational purposes. For example, an extensive data set, concerning the very largest energy fluxes, was made available to the Jet Propulsion Laboratory for the purpose of specifying the particle environment that will be encountered by polar-orbiting shuttles. Data from the TIROS/NOAA total energy detector will continue to be made available as appropriate.

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Akasofu, S.-I., W. Fillius, W. Sun, C. Fry, and M. DRYER. A simulation study of two major events in the heliosphere during the present sunspot cycle. Journal of Geophysical Research 90(A9):8193-8211 (1985).

Baumjohann, W., G. Gustafsson, E. Nielsen, H. Ranta, and D. S. EVANS. Latitude-integrated Joule and particle heating rates during the Energy Budget Campaign. Journal of Atmospheric and Terrestrial Physics 47(1-3):27-39 (1985).

CARRAN, K. L. SESC satellite broadcasting 10-year plan. NOAA Technical Memorandum ERL SEL-70 (PB 85-163541/GAR), 35 pp. (1985).

Clauer, C. R., and Y. KAMIDE. DP 1 and DP 2 current systems for the March 22, 1979 substorms. Journal of Geophysical Research 90(A2):1343-1354 (1985).

Cuperman, S., and M. DRYER. Generalized expression for the heat conduction in non-Maxwellian two-component spherically symmetric pelletlike plasmas. Physical Review A 31(5):3470-3472 (1985).

CUPERMAN, S., I. Tzur, and M. DRYER. Numerical investigation of fluid models with full electron and proton thermal conduction equations for the quiet solar wind. The Astrophysical Journal 286:763-771 (1984).

DAVIES, K., and C. M. Rush. High-frequency ray paths in ionospheric layers with horizontal gradients. Radio Science 20(1):95-110 (1985).

DAVIES, K., and C. M. Rush. Calculation of high-frequency ray paths in model layers simulating the sub-auroral trough and the equatorial anomaly. In Effect of the Ionosphere on C^3I Systems, John M. Goodman (Ed.-in-chief), Library of Congress #85-600558, NTIS, Springfield, VA: 74-83 (1985).

DAVIES, K., and C. M. Rush. Reflection of high-frequency radio waves in inhomogeneous ionospheric layers. Radio Science 20(3):303-309 (1985).

De La Beaujardiere, O., V. B. Wickwar, G. Caudal, J. M. Holt, J. D. Craven, L. A. Frank, L. H. Brace, D. S. EVANS, J. D. Winningham, and R. A. Heelis. Universal time dependence of nighttime F-region densities at high latitudes. Journal of Geophysical Research 90(A5):4319-4332 (1985).

DRYER, M. Examples of two- and three-dimensional time-dependent simulation of solar flare generated shock waves. In Recent Advances in the Understanding of Structure and Dynamics of the Heliomagnetosphere during the Current Maximum and Declining Phase of Solar Activity, Joint U.S.-Japan Seminar:87-93 (1984).

DRYER, M., and D. F. Smart. Dynamical models of coronal transients and interplanetary disturbances. Advances in Space Research 4(7):291-301 (1984).

DRYER, M., S. T. Wu, G. Gislason, S. M. Han, Z. K. SMITH, J. F. Wang, D. F. Smart, and M. A. Shea. Magnetohydrodynamic modelling of interplanetary disturbances between the Sun and Earth. Astrophysics and Space Science 105:187-208 (1984).

DRYER, M., and S. T. Wu. Comments on "density distribution in looplike coronal transients: a comparison of observations and a theoretical model" by D. G. Sime, R. M. MacQueen, and A. J. Hundhausen. Journal of Geophysical Research 90(A1):559-561 (1985).

DUSENBERY, P. B., and L. R. Lyons. Generation of Z mode radiation by diffuse auroral electron precipitation. Journal of Geophysical Research 90(A3):2915-2920 (1985).

EVANS, D. S. The characteristics of a persistent auroral arc at high latitude in the 1400 MLT sector. In The Polar Cusp, J. A. Holtet and A. Egeland (eds.), D. Reidel Publishing Company, Boston, 99-109 (1985).

Friis-Christensen, E., Y. KAMIDE, A. D. RICHMOND, and S. Matsushita. Interplanetary magnetic field control of high-latitude electric fields and currents determined from Greenland magnetometer data. Journal of Geophysical Research 90(A2):1325-1338 (1985).

GARCIA, H. A., and W. N. SPJELDVIK. Anistropy characteristics of geomagnetically trapped ions. Journal of Geophysical Research 90(A1):347-358 (1985).

GARCIA, H. A. GOES X-ray sensor inflight relative calibration. NOAA Technical Memorandum ERL SEL-72 (PB 85-221091/AS), 24 pp. (1985).

Gergely, T. E., M. R. Kundu, S. T. Wu, M. DRYER, Z. SMITH, and R. T. Stewart. A multiple type-II burst associated with a coronal transient and its MHD simulation. Advances in Space Research 4(7):283-286 (1984).

Gliner, E., V. OSHEROVICH, and I. Tzur. The possible role of electrical currents in coronal phenomena. Proceedings of the Fourth European Meeting on Solar Physics, "The Hydromagnetics of the Sun," Noordwijkerhout, The Netherlands, 1-3 October 1984, ESA SP-220:261-262 (1984).

Gustafsson, G., D. S. EVANS, H. Ranta, R. Pellinen, G. Schmidtke, A. Steen, and H. Lauche. Energy input and spectral variations of precipitated particles during three nights of the Energy Budget Campaign. Journal of Atmospheric and Terrestrial Physics 47(1-3):73-88 (1985).

Harrison, R. A., P. W. Waggett and R. D. Bentley, K. J. H. Phillips, M. Bruner, M. DRYER, and G. M. Simnett. The X-ray signature of solar coronal mass ejections. Solar Physics 97:387-400 (1985).

Hasselmann, K., R. K. Raney, W. J. Plant, W. Alpers, R. A. Shuchman, D. R. Lyzenga, C. L. RUFENACH, and M. J. Tucker. Theory of synthetic aperture radar ocean imaging: a MARSEN view. Journal of Geophysical Research 90(C3):4659-4686 (1985).

HILL, V. J., D. S. EVANS, and H. H. SAUER. TIROS/NOAA satellites space environment monitor archive tape documentation. NOAA Technical Memorandum ERL SEL-71 (PB 85-187900/AS), 50 pp. (1985).

JOSELYN, J. A., AND K. L. CARRAN. The SESC satellite broadcast system for space environment services. In Effect of the Ionosphere on C3I Systems, Based on Ionospheric Effects Symposium in Old Town, Alexandria, Va., 1-3 May 1984, J. M. Goodman (Ed.-in-Chief), NTIS, Springfield, Va., 252-254 (1985).

JOSELYN, J. A. The automatic detection of geomagnetic-storm sudden commencements. Advances in Space Research 5(4):193-197 (1985).

JOSELYN, J. A., and R. N. GRUBB. The space environment monitors onboard GOES. In American Insitute of Aeronautics and Astronautics 23rd Aerospace Sciences Meeting, January 14-17, 1985, Reno, Nevada, AIAA-85-0238, New York (1985).

Kamide, Y., D. S. EVANS, and J. C. Cain. A comparison of field-aligned current signatures simultaneously observed by the MAGSAT and TIROS/NOAA spacecraft. Journal of Geomagnetic Geoelectricity 36:521-527 (1984).

Kroehl, H. W., and Y. KAMIDE. High-latitude indices of electric and magnetic variability. Journal of Geophysical Research 90(A2):1367-1374 (1985).

LEINBACH, H. Space Environment Laboratory Annual Report, FY 1984. U.S. Dept. of Commerce, NOAA, Boulder, CO. NOAA Report Series (1985).

Lyons, L. R., and T. W. SPEISER. Ohm's law for a current sheet. Journal of Geophysical Research 90(9):8543-8546 (1985).

MARTIN, R. F., JR. Energetics of the aligned pulsar magnetosphere. Astrophysics and Space Science 105:339-356 (1984).

MARTIN, R. F., JR. On the existence of an exterior toroidal region in the nonaligned pulsar magnetosphere. The Astrophysical Journal 288:665-671 (1985).

Maxwell, A., M. DRYER, and P. McINTOSH. A piston-driven shock in the solar corona. Solar Physics 97:401-413 (1985).

McINTOSH, P. S., and P. R. Wilson. A new model for flux emergence and the evolution of sunspots and the large-scale fields. Solar Physics 97:59-79 (1985).

OSHEROVICH, V. A., E. B. Gliner, and I. Tzur. Theoretical model of the solar corona during sunspot minimum, II. Dynamic approximation. The Astrophysical Journal 288:396-400 (1985).

OSHEROVICH, V. A., E. B. Gliner, I. Tzur, and M. L. Kuhn. The magnetic and thermodynamical structure of a coronal hole. Solar Physics 97:251-266 (1985).

OSHEROVICH, V. A., I. Tzur, and E. B. Gliner. Magnetic and thermodynamic structure of the solar corona during sunspot minimum. In Measurements of Solar Vector Magnetic Fields, NASA Conference Publication 2374:66-77 (1985).

RUFENACH, C. L., L. S. Fedor, J. R. Apel, and F. I. Gonzalez. Surface and internal ocean wave observations. In Advances in Geophysics 27, B. Saltzman (ed.), Academic Press, Orlando, 141-196 (1985).

RUFENACH, C., and C. Smith. Observation of internal waves in LANDSAT and SEASAT satellite imagery. International Journal of Remote Sensing, 6(7):1201-1207 (1985).

SARGENT, H. H., III. Recurrent geomagnetic activity: evidence for long-lived stability in solar wind structures. Journal of Geophysical Research 90(A2): 1425-1428 (1985).

SAUER, H., W. N. SPJELDVIK, and F. K. Steele. OMEGA long-term phase advances. NOAA Technical Memorandum ERL SEL-73 (PB 85-233211/AS), 52 pp. (1985).

SMITH, Z. K., M. DRYER, and R. S. Steinolfson. A study of the formation, evolution, and decay of shocks in the heliosphere between 0.5 and 30.0 AU. Journal of Geophysical Research 90(A1):217-220 (1985).

SPEISER, T. W. Current sheet particle acceleration: theory and observations for the geomagnetic tail. Advances in Space Research 4(2-3):439-448 (1984).

Strong, K. T., J. B. SMITH, JR., M. K. McCabe, M. E. Machado, J. L. R. Saba, and G. M. Simnett. Homologous flares and the evolution of NOAA active region 2372. Advances in Space Research 4(7):23-26 (1984).

Sun, W., S.-I. Akasofu, Z. K. SMITH, AND M. DRYER. Calibration of the kinematic method of studying solar wind disturbances on the basis of a one-dimensional MHD solution and a simulation study of the heliosphere disturbances between 22 November and 6 December 1977. Planetary Space Science 33(8):933-943 (1985).

Taylor, H. A., Jr., P. A. Cloutier, M. DRYER, S. T. Suess, A. Barnes, and R. S. Wolff. Response of Earth and Venus ionospheres to corotating solar wind stream of 3 July 1979. Earth, Moon and Planets, 32:275-290 (1985).

Taylor, H., P. Cloutier, M. DRYER, S. Suess, A. Barnes, R. Wolff, and A. Stern. Corotating interplanetary streams and associated ionospheric disturbances at Venus and Earth. Advances in Space Research 4(7):343-346 (1984).

Uberoi, M. S., and T. R. DETMAN. Free-stream turbulence near a wall. Physics of Fluids 28(5):1566-1568 (1985).

WAGNER, W. J., and G. R. HECKMAN. Solar Activity Monitoring Satellite (SAMSAT): Impact on space environment services. NOAA Technical Memorandum ERL SEL-69 (PB 85-165066/GAR), (1985).

Walker, D. N., and E. P. Szuszczewicz. Electrostatic wave observation during a space simulation beam-plasma discharge. Journal of Geophysical Research 90(A2):1691-1697 (1985). SEL Contract Report.

Williams, D. J., and T. W. SPEISER. Sources for energetic ions at the plasma sheet boundary: time varying or steady state? Journal of Geophysical Research 89(A10):8877-8884 (1984).

Woodgate, B. E., M.-J. Martres, J. B. SMITH, JR., K. T. Strong, M. K. McCabe, M. E. Machado, V. Gaisaukas, R. T. Stewart, and P. A. Sturrock. Progress in the study of homologous flares on the Sun - Part II. Advances in Space Research 4(7):11-17 (1984).

YEH, T. Hydromagnetic buoyancy force in the solar atmosphere. Solar Physics 95:83-97 (1985).

Addendum - FY 1984

Han, S. M., S. T. Wu, Z. K. SMITH, and M. DRYER. Numerical study of two-dimensional non-plane MHD wave propagation in a supersonic, superalfvenic magnetohydrodynamic flow. American Institute of Aeronautics and Astronautics, AIAA-85-1598 (1984).

HECKMAN, G., J. HIRMAN, J. KUNCHES, and C. BALCH. The monitoring and prediction of solar particle events - an experience report. Advances in Space Research 4(10):165-172 (1984).

HECKMAN, G. SESC Glossary of Solar-Terrestrial Terms. DOC Special Document (1984).

JOSELYN, J. A. Proposed major format change to geomagnetic activity reports and forecasts produced by the SESC, Boulder, Colorado, U.S.A. Geophysical Surveys 6(3/4):419-424 (1984).

OSHEROVICH, V. Magnetic flux tube in a stratified atmosphere under the influence of the vertical magnetic field. Solar Physics 94:207-217 (1984).

OSHEROVICH, V., E. B. Gliner, and I. Tzur. Observations of electron density in the solar corona during sunspot minimum and global electric currents around the sun. Advances in Space Research 4(8):133-139 (1984).

Steinolfson, R. S., and M. DRYER. Propagation of solar generated disturbances through the solar wind critical points: one-dimensional analysis. Astrophys. and Space Science 104:111-120 (1984).

WALDEN, D., J. WINKLEMAN, L. MATHESON, and L. SCHULTZ. High frequency radar software reference manual for product one. NOAA Technical Memorandum ERL-SEL 67 (PB 84-194884), 250 pp. (1984).

WALDEN, D., J. WINKLEMAN, L. MATHESON, and R. N. GRUBB. High frequency radar software reference manual for product two. NOAA Technical Memorandum ERL-SEL 68 (PB 84-210079), 250 pp. (1984).

Dryer, M., "Examples of Two- and Three-Dimensional, Time-Dependent Simulation of Solar Flare-Generated Shock Waves." Joint U.S.-Japan Seminar on Recent Advances in the Understanding of Structure and Dynamics of the Helio-magnetosphere during the Current Maximum and Declining Phase of Solar Activity, Kyoto, Japan, November 5-9, 1984.

Dryer, M., "Three-Dimensional Modeling of the Solar Wind." SEL Seminar, Boulder, Colorado, December 18, 1984.

Dryer, M., "Three-Dimensional, Time-Dependent, MHD Model of a Solar Flare-Generated Interplanetary Shock Wave." 19th ESLAB Symposium, Les Diablerets, Switzerland, June 4-6, 1985.

Dryer, M., "A Transient, Three-Dimensional MHD Model for Numerical Simulation of Interplanetary Disturbances." 1985 STIP Symposium on Retrospective Analyses and Future Coordinated Intervals, Les Diablerets, Switzerland, June 10-12, 1985.

Dryer, M., "A Simulation Study of Two Major Events in the Heliosphere During the Present Sunspot Cycle." 1985 STIP Symposium on Retrospective Analyses and Future Coordinated Intervals, Les Diablerets, Switzerland, June 10-12, 1985.

Dryer, M., "Empirical Technique for Predicting Times of Arrivals of Shocks from Powerful Flares." 1985 STIP Symposium on Retrospective Analyses and Future Coordinated Intervals, Les Diablerets, Switzerland, June 10-12, 1985.

Dryer, M., "Overview of STIP Intervals I-XIV." 1985 STIP Symposium on Retrospective Analyses and Future Coordinates Intervals, Les Diablerets, Switzerland, June 10-12, 1985.

Dryer, M., "MHD Simulation of Multiple Interplanetary Disturbances During STIP Interval VII (August, 1979)." Solar Maximum Analysis Symposium, Irkutsk, USSR, June 17-21, 1985.

Dryer, M., "The Solar Interplanetary-Magnetosphere-Ionosphere Connection: A Strategy for Prediction of Geomagnetic Storms." AAS/AIAA Astrodynamics Conference, Vail, Colorado, August 12-14, 1985.

Evans, D., "Comparison of Simultaneous Chatanika and Millstone Hill Observations with Ionospheric Model Predictions." 1985 Spring AGU Meeting, Washington, D.C., May 29, 1985.

Evans, D., "The Conjugateness of Aurora." 1985 Spring AGU Meeting, Washington, D.C., May 29, 1985.

Evans, D., "On the Simultaneous Existence and Motion of the Theta Aurora Over the Two Polar Caps." 1985 Spring AGU Meeting, Washington, D.C., May 29, 1985.

Gao, Meiqing, "A Comparison of Solar and Geomagnetic Activity from the 13th to the 21st Solar Cycle." Chapman Conference on Solar Wind-Magnetospheric Coupling, Los Angeles, Calif., February 15, 1985.

Gao, Meiqing, "A Comparison of Soalr and Geomagnetic Activity from the 13th to the 21st Solar Cycle." SEL Seminar, Boulder, Colorado, March 12, 1985.

Garcia, H. A., "Decay Phase and Implications, for Time Dependent Temperature Variations." AGU Fall Meeting, San Francisco, Calif., Dec. 3-7, 1984.

Garcia, H. A., "Flare Plasma Density Determination Using Observed Temperature Profiles." Solar Flare Workshop, Sunspot, Arizona, August 23, 1985.

Heckman, Gary R., "Solar Porton Event Prediction in Solar Cycle 21--An Experience Report." National Council on Radiation Protection and Measurement Scientific Committee 75, Bethesda, Md., January 16, 1985.

Joselyn, JoAnn, "Geomagnetic Services: Real-time Alerts and Disturbance Predictions." Society of Exploration Geophysicists, 54th Annual International Meeting and Exposition, Atlanta, Ga., Dec. 3, 1984.

Joselyn, JoAnn, "The Space Environment Monitors aboard GOES." 23rd Annual Meeting of American Institute of Aeronautics and Astronautics, Reno, Nevada, January 15, 1985.

Joselyn, JoAnn, "Real-Time Prediction of the Geomagnetic Field." Chapman Conference on Solar Wind-Magnetospheric Coupling, Los Angeles, Calif., February 15, 1985.

Joselyn, JoAnn, "Numerical Guidance for Geomagnetic Forecasts." Chapman Conference on Solar Wind-Magnetospheric Coupling, Los Angeles, Calif., February 15, 1985.

Joselyn, JoAnn, "Geomagnetic Forecasting at the Space Environment Services Center." SEL Seminar, Boulder, Colorado, March 12, 1985.

Joselyn, JoAnn, "Geophysical Alerts and Forecasts: A Global Interest." International Association of Geomagnetism and Aeronomy, Fifth Scientific Assembly, Prague, Czechoslovakia, August 13, 1985.

Leinbach, Harold, "Space Environment Laboratory Overview Presentation." ERL Director's Seminar, Boulder, Colorado, May 7, 1985.

Leinbach, Harold, "The Zeeman Effect and Observations of Solar Magnetic Fields." SEL, SESC Talk, Boulder, Colorado, May 30, 1985.

Martin, R. F., "Charged Particle Dynamics Near a Magnetic Neutral Line." Plasma Physics Seminar, University of Colorado, Boulder, Colorado, March, 1985.

Martin, R. F., "An Alternative View of the Pulsar Magnetosphere." JILA Colloquium (Joint Institute for Laboratory Astrophysics), Boulder, Colorado, May 13, 1985.

Martin, R. F., "Single Particle Acceleration in a Magnetic Neutral Line Field." AGU Chapman Conference on Ion Acceleration in the Magnetosphere and Ionosphere, Wellesley, Mass., June 3-7, 1985.

McIntosh, P. S., "The Polar Crown During Two Solar Cycles." 165th American Astronomical Society Meeting, University of Arizona, Tucson, Arizona, January 16, 1985.

McIntosh, P. S., "What Have H-Alpha Synoptic Charts to Say About Solar Magnetic Fields?" R. G. Giovanelli Commenmorative Colloquium, Sunspace Ranch, Oracle, Arizona, January 18, 1985.

McIntosh, P. S., "Theo, Forecaster's Apprentice: An Initial Phase Solar Flare Prediction Expert System." SEL Seminar, Boulder, Colorado, August 28, 1985.

Osherovich, P. S., "The Eigenvalue Approach in Modeling Solar Magnetic Structures." SEL Seminar, Boulder, Colorado, February 26, 1985.

Pinter, S., "Flare-Generated Shock Wave Propagation Characteristic and Forbush Decreases." SEL Seminar, Boulder, Colorado, March 5, 1985.

Smith, Z. K., "Interplanetary Shock Collisions." AGU Spring Meeting, Baltimore, Maryland, June 27-30, 1985.

Wagner, W. J., "Solar Activity Monitoring Satellite (SAMSAT)." 4th Weather Wing, Peterson Air Force Base, Colorado Springs, Colorado, December 19, 1984.

Yeh, T., "Relationship between Polarity Neutral Lines on the Solar Surface and Magnetic Structures in the Corona." SEL Seminar, Boulder, Colorado, February 12, 1985.

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