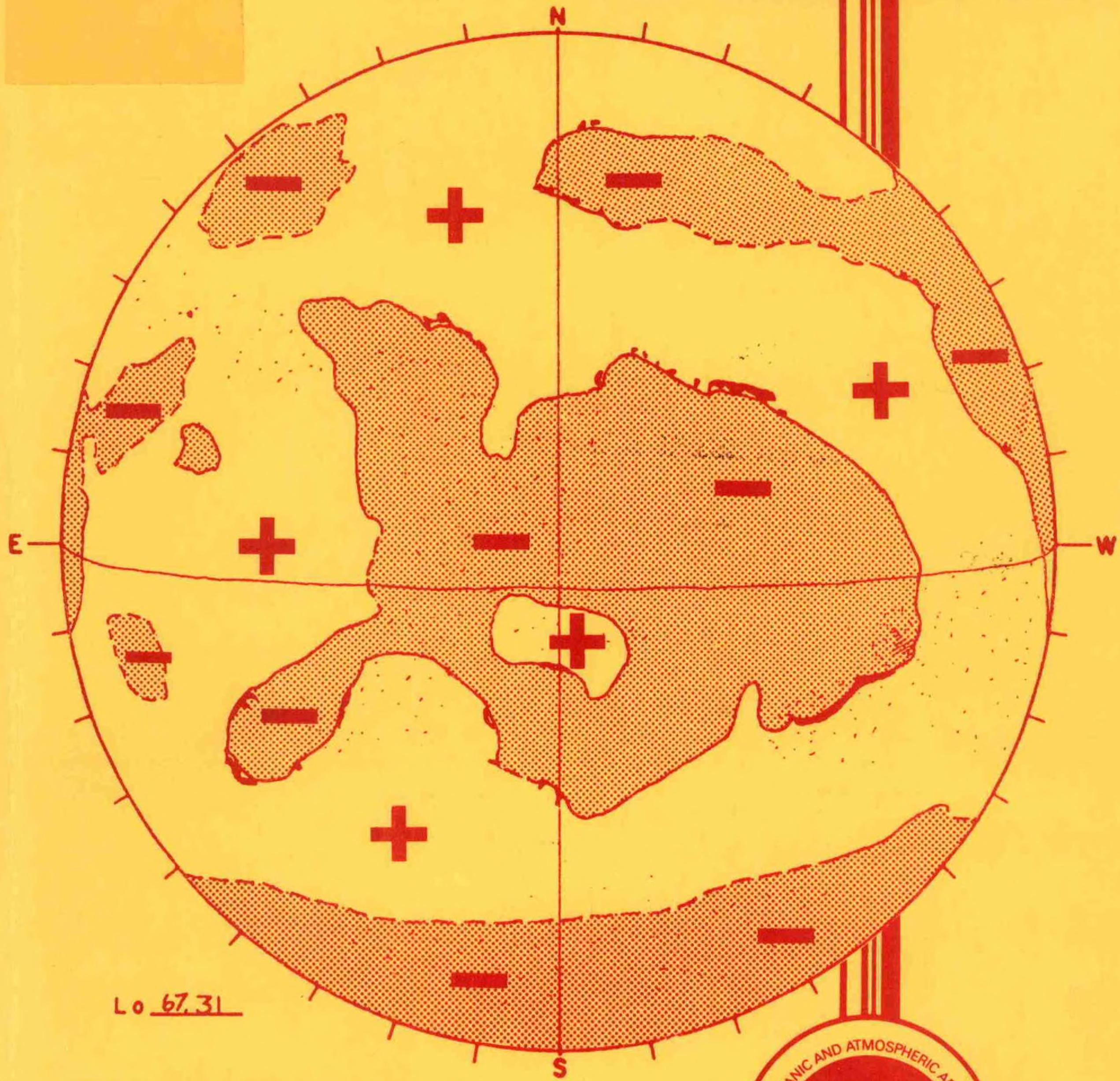
SPACE ENVIRONMENT LABORATORY

Environmental Research Laboratories

ANNUAL REPORT FY 1983



U.S. DEPARTMENT OF COMMERCE
National Oceanic
and Atmospheric Administration
Environmental Research
Laboratories

COVER

The cover figure presents a map of solar magnetic-field patterns used in the prediction of recurrent geomagnetic storms. The surface of the sun is covered with continents of weak magnetic fields in which the radial component is outward (+) or inward (-). These continents are mapped by the locations of filaments and other fine structures observed in H-alpha solar photographs. These giant patterns correspond in detail to the overlying structures in the solar corona, such as those recorded in X-ray images obtained by rockets and the Skylab manned space station. The interior of the continental-scale patterns, such as the "fish" in the center, are favored locations for coronal holes in which high speed solar wind originates. The western boundaries of these magnetic continents are favored locations for sunspot formation and flare occurrence.

S P A C E   E N V I R O N M E N T   L A B O R A T O R Y

ANNUAL REPORT - FY 1983

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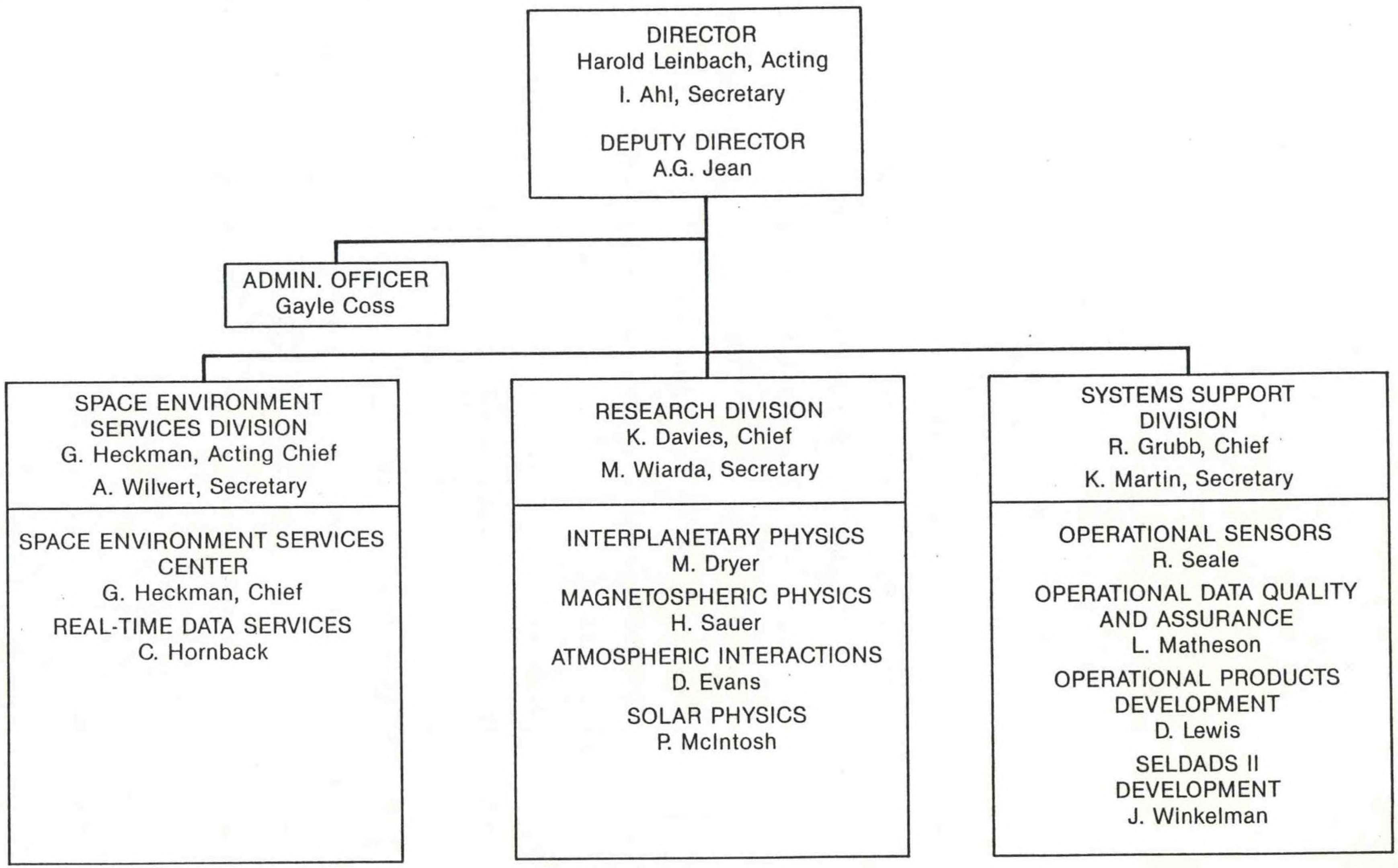
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INTRODUCTION

The Space Environment Laboratory provides real-time monitoring and forecasting services, develops techniques necessary for forecasting of solar-terrestrial disturbances and their subsequent effects on the near-Earth environment and conducts research in solar-terrestrial physics in support of the service mission.

The focal point for the nation's present solar-terrestrial services is in the Space Environment Laboratory 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.

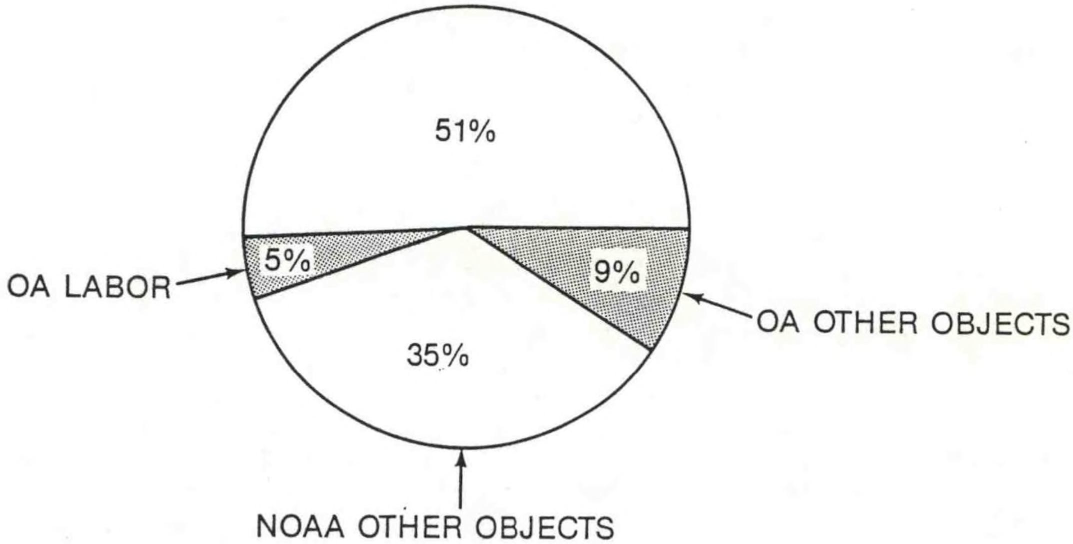
The laboratory had a very productive year; 65 publications were issued; a contract was placed for the new equipment to replace the obsolescent Space Environment Laboratory Data Acquisition and Display System (SELDADS); approval was received to pursue the development of the Solar X-Ray Imager to be flown on future GOES satellites; and the laboratory assisted in the completion of the "National Plan for Space Environment Services and Supporting Research" for the Federal Coordinator for Meteorological Services and Supporting Research.

The organization chart indicates that SEL is composed of the Space Environment Services Division, Research Division, and Systems Support Division. The activities listed in each Division are the key ones selected to accomplish the laboratory's main objective, namely; to meet the national needs for current solar-terrestrial information and to improve these services through research and technological advances.

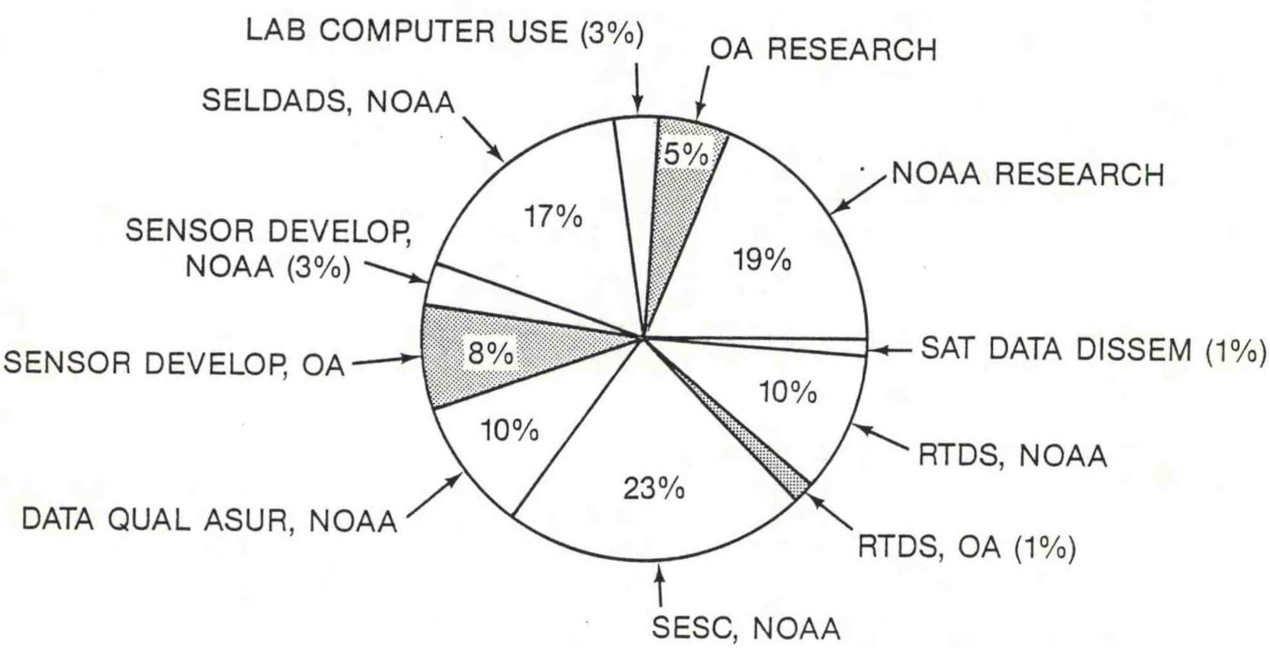
The first (pie) diagram shows the percentages of total laboratory funding received from NOAA (unshaded areas) and other government agencies (shaded areas). NOAA funding amounted to 86% of total laboratory funding, of which 51% was for labor and 35% was for other objects. Other Agency funding amounted to 14% of total laboratory funding, of which 5% was for labor and 9% for other objects.

SEL LABOR & OTHER OBJECTS FUNDED BY NOAA & OTHER AGENCIES, FY 1983

NOAA LABOR



SEL RESOURCES BY ACTIVITY, FY 1983



The second (pie) diagram shows the percentage of laboratory resources devoted to each of these key activities which are carried out with a high degree of inter-Division cooperation. The diagram indicates the percentages of NOAA and other government agency funding devoted to the following activities:

34% for the provision of solar-terrestrial services by the Space Environment Services Center (SESC) 22%, and the Real-Time Data Service (RTDS), 18%.

24% to advance understanding of solar-terrestrial physics and to make improvements in current services.

17% for replacement of SELDADS equipment for processing the solar-terrestrial data in real-time.

11% for the improvement of future satellite instrumentation including a solar X-ray imager.

10% to develop methods for assuring the quality of solar-terrestrial data to be processed by SELDADS.

3% for the laboratory use of the MASC Central Computer.

1% for satellite data dissemination tests.

To provide a comprehensive account of the laboratory accomplishment, this report describes the activities listed above without separately identifying the role of each Division.

Lists of laboratory staff and publications are given in the Appendix.

SPACE ENVIRONMENT SERVICES

Introduction

The Space Environment Laboratory, through the Space Environment Service Center (SESC), provides a common set of space environment services, including forecasting and warnings of solar and terrestrial disturbances, to a broad user community, consisting of other agencies (including NOAA, Departments of Defense, Transportation and Interior, National Aeronautics and Space Administration,) industry, universities and civilian customers. These military, public and private agencies are each affected, in some way, by disturbances of the space environment. Some of the affected systems and operations which are served by the Space Environment Service Center are listed in Table 1.

Table 1: Systems and Operations Served by the SESC

Military and civilian radio communications and telecommunications.
Military and civilian navigation systems
Military radars and surveillance systems
Electric power transmission grids
Pipeline flow meters and corrosion protection systems
Telephone long-line operations
Launch and orbit variations caused by satellite drag
Spacecraft charging anomalies
Geophysical exploration and mapping
Personnel and systems subject to solar cosmic radiation hazards
Biological systems influenced by magnetic activity
Scientific research campaigns
Questions posed by the general public

The SESC is jointly operated and staffed by SEL and the Air Weather Service, USAF. The SESC serves as the U.S. center for international exchange of real-time, solar-terrestrial data.

The foundation for the services is a cooperative program of observations, made by several government agencies, public institutions and foreign governments, which are collected and interpreted in a central location (Boulder) for use in producing a common set of products to meet the requirements of the user community. The primary activities and products that comprise the service function include:

1. Collection of Solar-Terrestrial Data.

2. Field Site Operations.

3. Communications for Data Collection.

4. Data Systems Operation (SELDADS).

5. Analysis and Interpretation - The Forecast Process

6. Service Products--A Description.

7. Distribution of Service Products.

8. Technique Development to Improve Services

These activities are centered within the Space Environment Services Center and the Real-Time Data Services of SEL, with additional support provided by the Research and Systems Support components of the laboratory. These activities, described in the following sections, are shared with other components of NOAA and other government agencies.

COLLECTION OF SOLAR-TERRESTRIAL DATA

The space environment services require a variety of observations from both ground-based and satellite borne sensors. These include:

Solar Optical Observations

Optical observations with solar telescopes provide information on the state of the solar atmosphere (quiet or disturbed), such as the presence of active regions and the global distribution of solar magnetic fields. The observations are analogous to the National Weather Service hemispheric cloud cover data obtained from a geostationary satellite. In much the same way that cloud cover data allow the detection of frontal activity, hurricanes, and other severe-storm centers, solar observations identify regions of high potential for solar flares, filaments with high probability of eruption, and coronal holes (sources of high-speed solar wind). The sources of optical observations are listed in Table 2 and shown in Figure 1.

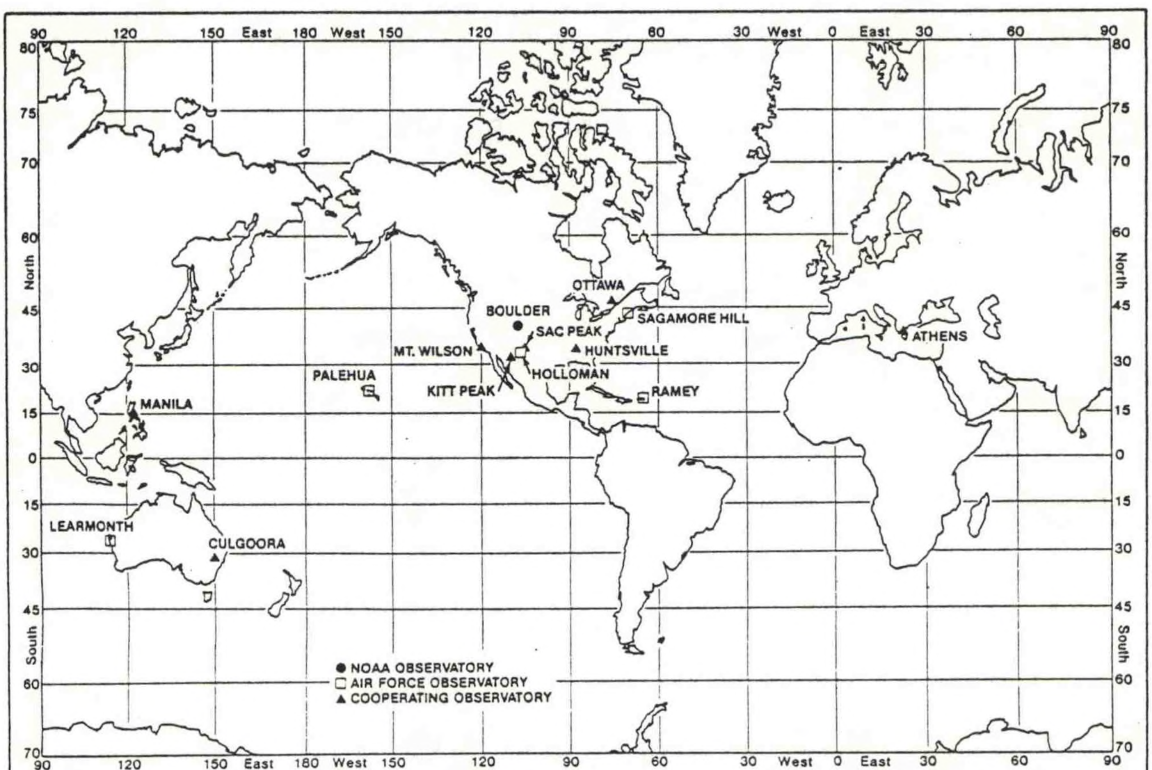


Figure 1: Solar observing network.

Table 2. Solar Optical Observatories

System (Type Image)	Location(s)	Operating Agency
Hydrogen-alpha, White Light	Boulder, CO	NOAA
	Athens, Greece	USAF
	Culgoora, Australia	Government of Australia
		NOAA
Hydrogen-alpha, White Light, Magnetogram (Solar Optical Observing Network--SOON)	Holloman, NM	USAF
	Ramey, PR	USAF
	Palehua, Hawaii	USAF
	[1]Learmonth, Australia	USAF
Magnetogram Helium 10830 Angstrom	[1]Kitt Peak National Observatory, AR	AURA, NOAA, NASA
Magnetogram White Light	Mt.Wilson, CA	Carnegie Institute
Hydrogen-alpha, Calcium K	[2]Sacramento Peak, NM	AURA, USAF
Magnetogram Hydrogen-alpha,	Huntsville, AL	NASA, NOAA

1. NOAA provides one observer to the Learmonth Observatory, which is operated jointly with the Australian Department of Science.

2. Associated Universities for Research in Astronomy, supported by the National Science Foundation.

Solar Radio Observations

USAF and NOAA conduct solar radio telescope observations, including some done through cooperative agreements with the Government of Australia, that provide an indication of the energetics of solar disturbances, acceleration of energetic electrons, and the passage of shock waves through the solar atmosphere. Additional observations are provided by the National Research Council of Canada.

Table 3 lists the operating agencies for the Radio Solar Telescope Network and associated observing stations.

Table 3. Radio Solar Telescope Network

System	Location(s)	Operating Agency
Radio Solar Telescope Network (RSTN)	Sagamore Hill, MA Palehua, HI Learmonth, Australia	USAF USAF USAF, GOA, NOAA
Radio spectrograph	Culgoora, Australia	GOA
Radio solar telescope	Athens, Greece Manila, Philippines	USAF USAF
Radio solar telescope	Ottawa, Canada	Government of Canada, National Research Council
Radio solar telescope	Fleurs, Australia	GOA

Geomagnetic Field Observations

USAF, NOAA, the Department of the Interior (USGS), and the NSF (through grants to the University of Alaska and the State University of New York) jointly conduct geomagnetic observations to provide quantitative information on the geographic extent and severity of the impacts of the solar wind on the earth's magnetosphere. Table 4 lists the stations and operating agencies for the Real-Time High Latitude Monitoring Network and the Geophysical Observing Network.

Table 4. Geomagnetic Observation Stations

System	Location(s)	Operating Agency
Real-Time High Latitude Monitoring Stations	Thule, Greenland Goose Bay, Canada Upper Heyford, England College, AK Loring AFB, ME	USAF
Geomagnetic observatories (supplying data through the NOAA Real Time Geophysical Observing Network (RGON))	Boulder, CO Anchorage, AK Sachs Harbor, Canada Cape Parry, Canada Inuvik, Canada Arctic Village, AK Ft. Yukon, AK College, AK Talkeetna, AK Mould Bay, Canada Norman Wells, Canada Ft. Simpson, Canada Lynn Lake, Canada Ft. Smith, Canada San Juan, PR Honolulu, HI	USGS, NOAA, NSF, University of Alaska, State University of New York,
	Narsarssuak, Greenland	Canadian Gov't. Dept.Of Mines, Energy Resources
Other geomagnetic observatories (supplying data in real-time or near real-time)	Fredericksburg, VA	USGS

Satellite Observations

NOAA satellites monitor solar X-rays, energetic solar particle emissions, magnetospheric particles, and atmospheric energy deposition from magnetospheric electrons and protons. Observations of the solar wind, the interplanetary magnetic field and other significant solar disturbances are provided by NASA satellites.

Solar X-Ray Observations

Continuous observations of solar X-ray emissions from the whole sun are provided by the NOAA Geostationary Operational Environmental Satellites (GOES). A range of hard X-ray emissions from the Sun are obtained from the NASA International Sun Earth Explorer (ISEE-3).

Energetic Particle Emissions

Solar emissions of high energy protons, electrons, and alpha particles may cause radiation damage to satellite systems and are potential health hazards to astronauts in space and to passengers in aircraft flying at high altitude. The same particles also cause outages on High Frequency (HF) radio circuits in polar areas and are correlated with errors in VLF navigation systems.

Observations of these energetic particles are made on the NOAA polar-orbiting and GOES geosynchronous satellites.

Upper atmosphere heating, a consequence of the magnetospheric particle precipation, is determined from the total energy deposition sensors (TED) on the NOAA polar orbiting satellites.

Geomagnetic Field Observations

Satellite observations of the geomagnetic field at the GOES are transmitted in real-time to the SESC to monitor the effects of solar disturbances in the Earth's magnetosphere.

Solar Wind Observations

By agreement with NASA, preliminary solar wind data from the ISEE-3 spacecraft is received in real-time by the SESC. These data include solar wind density and velocity and the interplanetary magnetic field direction and amplitude.

International Data Exchange

SESC acquires space environment data through international data exchange agreements. Such access is assisted by an international warning and a prompt solar and geophysical data exchange program designated the International Ursigram and World Days Service (IUWDS). Through participation in the IUWDS, (a permanent service of the International Council of Scientific Unions [ICSU]), the United States obtains data that would not otherwise be available. IUWDS data exchange is accomplished through Regional Warning Centers which collect the necessary data from observing facilities in their portion of the world, exchange the data with the other centers one or more times per day, and then redistribute the foreign data to users within their portion of the world. The SESC has been designated the World Warning Agency for the IUWDS.

Planned Improvements

Two special projects have been identified to improve collection of solar-terrestrial data. These are: 1) the definition of SESC's image handling requirements for the next five years and 2) development of a plan for interim optical imaging systems. The current system, used by SESC to collect solar images from the various observatories for use by the forecaster in making activity predictions, is over 15 years old and becoming unreliable and labor intensive to maintain. There is an immediate need for repair or replacement of portions of the system to keep it operating. An interim plan for obtaining solar images, to cover the years 1984-1988, will be developed. Functional requirements will be translated into a plan for procurement and upgrading of the system to maintain current forecast capabilities. A secondary objective will be incorporation of capability for automating some of the all-manual image handling system presently in use.

FIELD SITE OPERATIONS

High-Latitude Monitoring Station (HLMS)

The HLMS acquires, processes, displays, and archives geophysical data observed from local and remote ground-based sensors located across Alaska and at Thule, Greenland. The site is jointly operated with the USAF Air Weather Service. A local HF propagation and magnetic forecast is prepared along with special products for the AWS needs. Data summaries are sent out every 15-minutes on the USAF-Astrogeophysical Teletype Network and by telephone each day to the SESC.

Current Progress

In addition to maintaining current operation, improvements were made in the magnetometer photo electric read-out and in the digital equipment for receiving digital data from Thule, Greenland.

Future Plans

Continue to maintain the present operation and develop programs for a backup microcomputer.

Table Mountain Observatory (TMO)

The TMO, located near Boulder, acquires and processes solar-terrestrial data from ground-based and satellite sensors through operation of the sensors and ground receiving stations for the GOES satellites.

Current Progress

The XDS 930 computer was up about 98.5% of the time for the year. Most of the down time was caused by commercial power outages. Modifications were made to the power-fail detector system to protect the standard clock during power failures. The site has been vexed by numerous air conditioner outages which are becoming more difficult to repair.

In order to receive signals from the GOES-6 satellite, which replaced GOES-4 in January 1983, the following activities were carried out: the dish antenna was recabled and the antenna polarization was adjusted to improve the received signal; attempts were made to locate the source of a radio signal which interferes with the reception of the GOES-6 signal; and software was prepared to receive the data.

Future Plans

The TMO operations will be continued with special emphasis on improving the reception of radio signals from the GOES satellites.

Boulder Solar Observatory

This solar observatory provides daily photographs of the Sun in Hydrogen-alpha and drawings of sun spots to the duty forecasters. In addition, weather permitting, closed-circuit TV images are transmitted to the SESC console for real-time monitoring.

Current Progress

Daily H-alpha pictures and spot drawings were supplied for approximately 85% of the period with weather hampering observation for the remainder of the time.

Future Plans

Continue H-alpha picture and spot drawing support to the duty forecaster.

Kitt Peak National Observatory

Through a joint program with NOAA and NASA, solar magnetographs and Helium 10830 Angstroms images, observed at Kitt Peak, are sent daily to the SESC.

Current Progress

The solar magnetograms and Helium 10830 Angstrom images were sent consistently with only minor interruptions due to weather.

In support of visitor programs, observations were performed a) to measure the relation between velocity and magnetic field in solar prominences, b) to detect photospheric shadowing by emerging magnetic fields, c) to study high resolution velocities in active region filaments.

Data processing, archiving and preparation of current synoptic rotation maps were continued during the year.

Future Plans

Continue the current synoptic and data processing programs.

Australian Observatories

Solar optical observations are conducted at Learmonth, Western Australia, and Culgoora Observatory, New South Wales, Australia. Both observatories have NOAA commissioned Corps Officers on assignment from SESC to assist the full observatory staff in providing solar optical and radio data to the SESC and to other users. The Learmouth Corps Officer also serves as a member of the senior management of the observatory, in cooperation with USAF and Australia Department of Science.

COMMUNICATIONS FOR DATA COLLECTION

The Space Environment Service operates communication links to collect data from NOAA satellites, observatories and monitoring stations. NOAA also provides data collection from the Real-Time Geophysical Observing Network which supplies geomagnetic data, using the Data Collection System on the GOES satellites as a collection point from the widely scattered observatories. (A Memorandum of Understanding between NESS and SEL signed in 1981 provides for such collection for 10 years.) Data from RGON and NOAA/TIROS Space Environmental Monitor and Energetic Particle instrument systems are relayed from the National Environmental Satellite Data and Information Service (NESDIS) at Suitland, Maryland, to Boulder. SESC receives required data from the USAF from the Air Weather Net at Carswell AFB. SESC provides a dedicated voice line to connect the SESC at Boulder, the Holloman AFB Solar Observatory, Sacramento Peak Observatory, Kitt Peak Solar Observatory, Offutt AFB, and the NORAD Missile Warning Center. NOAA and the USAF cooperate to maintain data communications from Greenland and Alaska via the High Latitude Monitoring System into Boulder.

The USAF provides communication lines to collect data from its own observatories and monitoring stations to a central point for relay to the Space Environment Services Center.

Current Progress

In addition to maintaining routine operations, the Data Collection platforms for the RGON were reprogrammed and certified to provide for revisions in the RGON network.

Future Plans

Routine operation of all systems will be maintained. In addition, old style networks now operated by the USAF will be replaced during the year by new high-speed digital networks requiring new terminals and interface software procedures in the SESC.

DATA SYSTEMS

The primary data system in the service operation is the Space Environment Laboratory Data Acquisition and Display System (SELDADS) to accept, process, and integrate data streams from all publicly available space environment observing systems of the DOC, DOD, DOE, DOI, and the National Science Foundation, as well as international data exchange programs. The services operation is responsible for procuring, operating, and maintaining equipment and procedures to update the data base routinely and rapidly 24 hours per day to meet the data needs of the SESC forecasters and all other users of the national space environment service program. This data base is accessible to all Federal agencies as a common service.

Current Progress

The primary accomplishment was maintaining the SELDADS I computer system in operation 95% of the year, even when major disk and card failures occurred. Staff of the Real Time Data Service are on call continuously and respond immediately to systems problems. They have done an outstanding job with a small staff and an old system. A diagram of SELDADS I is shown in Figure 2.

Future Plans

A major activity of the Laboratory will be the implementation of SELDADS II as discussed on page 25.

ANALYSIS AND INTERPRETATION - THE FORECAST PROCESS

The primary role of the SESC is the monitoring, analysis and interpretation of space environment data flowing in real time into the service center. Here the human factor becomes critical in the extraction of useful information from the several hundred raw data streams flowing continuously. Twenty-four hours per day, the data are monitored for quality, edited, combined and analyzed to form a synthesized picture of the space environment. From

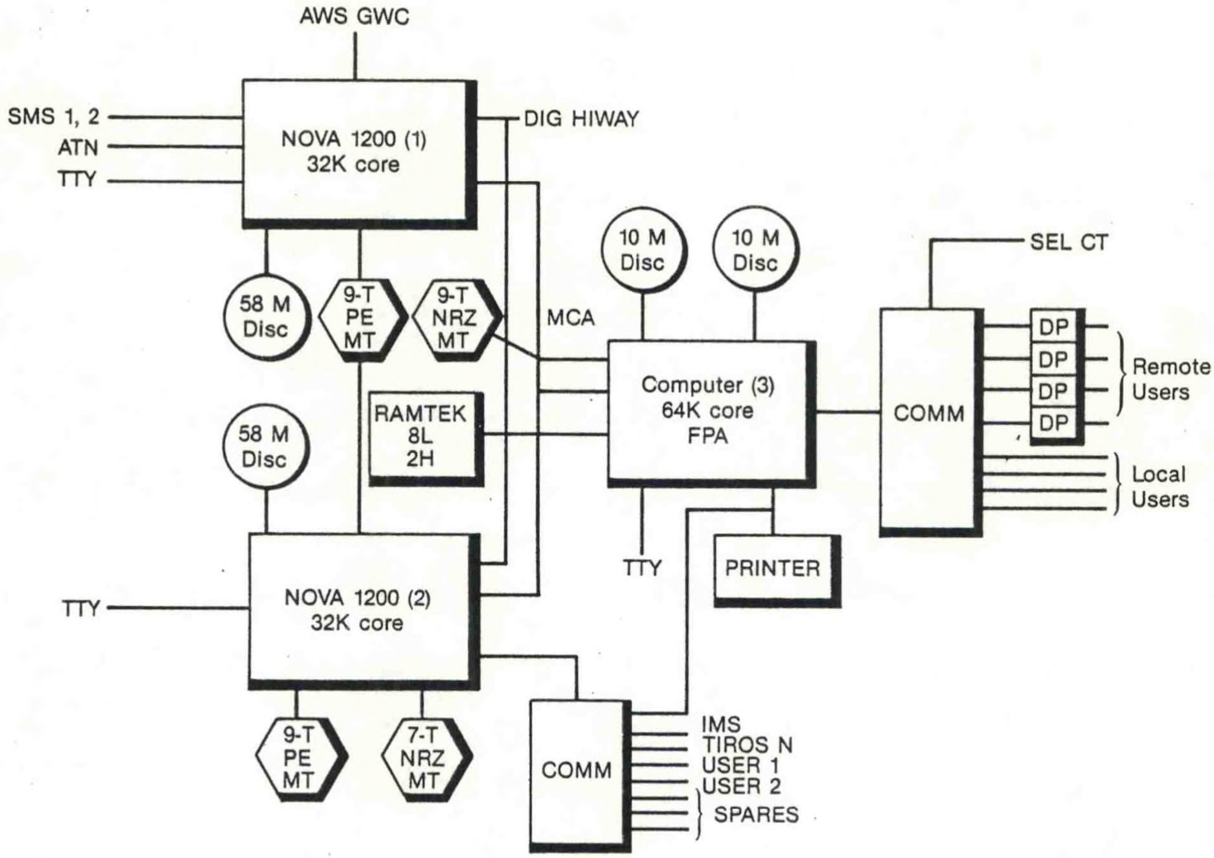


Figure 2: Configuration diagram of SELDADS-I

this process, indices and forecasts are derived to serve the SESC customers.

Current Progress

Forecasters, formerly responsible for the entire real-time operation, are now assisted by physical science technicians, designated Sol Techs; to assist in the increasing demands of data monitoring, editing and distribution of standard products. Though short in numbers, the Forecasters and Sol Techs have an outstanding record of reliability in insuring that the SESC functions are covered twenty-four hours per day, seven days per week without interruption.

Future Plans

In addition to maintaining the present level of operations, the operations team will participate extensively in designing new application software for SELDADS II, in evaluating the quality of the incoming data and outgoing services and working with data systems specialists, research scientists, and tchnique development scientists to improve the quality of services.

A system will be developed to define and maintain the documentation within SESC which describes the products, procedures, data sets and current projects.

GENERATION OF SERVICES PRODUCTS

Standard service products to meet the common needs of other government agencies and which can be distributed to non-government users as well are listed in Table 5.

Table 5. SESC Standard Service Products

- Daily report and forecast of solar-geophysical activity
- Daily solar-geophysical activity summary
- General purpose solar-geophysical disturbance alerts
- The weekly publication "Preliminary Report and Forecast of Solar and Geophysical Activity"
- 27-day outlook (including 10 cm and Ap forecast)
- Direct access to the SELDADS data base

Current Progress

No substantial changes were made in the common products. In order to provide improved information regarding the use of each of the products, planning began for a data base describing SESC users.

Future Plans

A substantial change is planned in the geomagnetic products. In order to better service geomagnetic users, who total approximately two-thirds of the SESC user base, a more detailed format for issuing one; two; and three-day forecasts will be developed. Rather than simply issuing a predicted value for a forecast period, an indication of the uncertainty in the forecast and information about latitudinal variations will be included.

Each forecast will contain a liklihood of the activity falling in each of six categories of disturbance, from very quiet to very stormy. Results have shown that geomagnetic activity has characteristic variations that are distinct in mid-latitudes, the auroral zone and in the polar cap. To supplement the current service, oriented to mid-latitude variations, a high latitude service will be added to the standard products.

DISTRIBUTION OF SERVICE PRODUCTS

Distribution of service products requires extensive communications facilities to reach the widely scattered users. The policy of the services operation has had two main objectives:

1. Cooperation with users to make the most use possible of the user's communication lines. The DOD, NASA and FAA all use their own networks to distribute the products within their agency and to their affiliates. Dedicated data lines distribute the products to the Global Weather Center of the USAF and to the US Navy in San Diego. A similar practice is extended to commercial users. For example, a single alert call for geomagnetic disturbances is made to one power company. That company then relays the alert over communications systems used by the industry to coordinate their power distribution operations. The American Radio Relay League also performs the same service for radio amateurs.

2. Where there are no available user networks, the policy is to distribute the products over systems that reach the maximum number of users at the least possible cost. Radio broadcasts on the shortwave time service WWV contain hourly announcements of space environment indices and predictions. Users can call a tape recorded message in Boulder at their own expense to obtain the same information.

Some services cannot be delivered by these methods. Alerts of disturbances are distributed by telephone to users who need such information in real time. Teletype messages that contain more information than can be included in verbal messages are sent on a collect basis to users who do not have access to other newtorks.

In its role as the World Warning Agency for the International Ursigram and World Days Service, the Services Center distributes its products to regional warning centers on each of the major continents for relay with those areas of the world.

Finally, a compilation of the primary indices, summaries and forecasts collected in the Services Center each week are printed and distributed as rapidly as possible using low cost publication methods for distribution by mail.

Current Progress

The primary effort in the past year has been the development and testing of a plan to replace much of the current distribution system with a satellite broadcast to serve those widely scattered users who have no access to agency communications, who need more timely and specific services or who can save money be replacing costly land lines. In addition, the objective has been to shift more of the cost of the communications over to the users, especially those who receive the telephone alerts and teletype mesages which are more costly or more labor intensive.

Future Plans

See the discussion of the satellite broadcast on page 3Ø.

TECHNICAL IMPROVEMENTS IN SESC SERVICES

New scientific research is fundamental to improved services but information in published papers is rarely in a form suitable for direct implementation. The translation of technical knowledge into improved space environment services requires a significant effort that includes the monitoring of areas of scientific advance pertinent to improved services, communication with customers to evaluate their evolving requirements for services, and the development and testing of algorithms and the training of forecast staff in the use of new algorithms and to maintain their continuing education.

Current Progress

Primary results this year have been in two areas: 1) improved use of hardware to automate tedious manual tasks and do more comprehensive automatic monitoring for solar geophysical events and 2) development of technical advisories to provide forecasters with quick reference material in areas where research has developed new information about geophysical disturbances; but the information is not so well developed to be usable in forecasting algorithms. Examples of new advisories included techniques in using the lower energy particle detectors of

GOES to differentiate between protons coming from solar flares and protons accelerated in the magnetosphere. An example of automation of manual tasks was the development of new software to automatically punch teletype paper tapes rather than cutting messages by hand.

Other work in this area included the beginning of an applied research program, supported partially by the USAF, to develop indices to give objective measures of the amount of shear occurring within sunspot groups. Research has shown such shear is proportional to the energy stored in the Sun's magnetic field which is available for release in solar flares. Work continued in the clarification of the relation between eruptive solar filaments and geomagnetic disturbances.

Future Plans

In addition to the SELDADS II work discussed elsewhere, new communication networks to replace the current rather antique systems will allow elimination of all paper tape processes by use of direct interface between the SELDADS computers and the new communication lines. Work will continue on use of the shear index as a flare predictor and disappearing filaments as sources of geomagnetic activity. In support of the proposed new geomagnetic forecast format discussed in the preceding section, climatoligical geomagnetic forecast information will be developed for the use of the forecasters and verifiction of the forecasts against the climatology will be implemented.

OPERATIONAL SATELLITE INSTRUMENTATION

Introduction

The operational Space Environment Monitor (SEM) subsystems on the NOAA GOES and TIROS series spacecraft are a vital part of the real and near real-time data base used by the SESC to support the National Space Environment Services. The performance requirements for these instruments are set by SEL staff working closely with the NASA project staff to monitor the contractors producing the instruments and check out the performance in orbit. It has also proved necessary to provide more direct support for the instruments in some cases. The current instrument for the TIROS series of spacecraft was built by a contractor in one batch of instruments. At the present rate of spacecraft launch the last instrument in this batch will be launched some years after it was produced by the contractor. With this long storage period it is to be expected that some instrument repairs and recalibrations will be necessary. As the original contractor was not interested in maintaining a capability for a contingency which might not arise, SEL was asked by NASA to carry out any work which proved to be necessary using facilities which the laboratory already possessed by virtue of its previous participation in scientific spacecraft programs. During FY1983 one TIROS instrument was repaired and retested after it failed acceptance testing at RCA, the TIROS contractor.

In addition to the repair work, SEL has also been requested by NASA to complete the assembly of one High Energy Proton and Alpha Detector (HEPAD). This instrument was originally a part of the TIROS SEM subsystem but was subsequently transferred to GOES for operational reasons. One more instrument was required for the current GOES spacecraft program and sufficient government-owned spare parts and contract residual material were available to assemble another instrument.

Current Progress

Two operational spacecraft, NOAA-8 and GOES-6, were launched during 1983. In both cases, SEL participated in the check out of the SEM subsystem prior to the handover of the spacecraft for operational service.

In order to carry out the repair and assembly work some facility improvements were made during 1983. An existing small clean room area was upgraded and thermal control was added to an existing vacuum test chamber.

Approximately half of the required assembly on the HEPAD instrument has been completed during FY83 and the instrument is expected to be completed, tested and delivered during FY84.

The laboratory has worked closely with NASA GSFC during the year to prepare specifications for the procurement of the SEM instruments for the GOES NEXT series of spacecraft.

Future Plans

We will continue to support the operational spacecraft program and the provision of SEM instruments as needed to maintain the capabilities of the SESC. This is expected to include in 1984 the check out of further NOAA TIROS type spacecraft and the support of the GOES NEXT procurement and subsequent contractor supervision. The future health of the service and most of the opportunities for significant improvement all depend on the use of the NOAA spacecraft to provide improved operational data on our Space Environment.

SELDADS II

Introduction

The Space Environment Service Center (SESC) depends on receiving a continuous stream of real-time and near real-time data for its operation. Since 1974 this data has been processed and displayed by a system of minicomputers known as the Space Environment Laboratory Data Acquisition and Display System (SELDADS). Several years ago it became clear that in spite of the continuous expansion of the original system (SELDADS I) it would be difficult to continue to provide for the increasing data flow and the more sophisticated data analysis support programs which were being developed. Simultaneously, the original equipment was becoming obsolete and very difficult to maintain in operation. It was therefore decided to plan for a new system which would support the SESC operation through the decade of the 1980's. New funding was requested and approved for this program starting in 1981.

The major design objectives for the new system were the following:

1. To provide the capacity to accept the existing satellite and ground-based sensor data plus the capability to expand to accept the data flow anticipated by 1990.

2. To provide "fail soft" operation and some protection against power failures.

3. To provide the capacity to maintain an extensive historical data base with a high level interface which does not require the programmer to understand the file structure in detail.

4. To provide the capacity to handle application programs written in high level languages by non-programmers which access the data base and graphics systems.

The system concept adopted to achieve these objectives is shown in Figure 3. Each of the major data streams is handled by a separate preprocessor. These are high level microcomputer systems which are operated from uninterruptable battery backed power supplies. The power supply permits operation for approximately 15 minutes or until the building standby power becomes available. During the time the main power and the central processor are unavailable the preprocessors provide a basic data display capability and can store up to several hours of data onto their own hard disk systems.

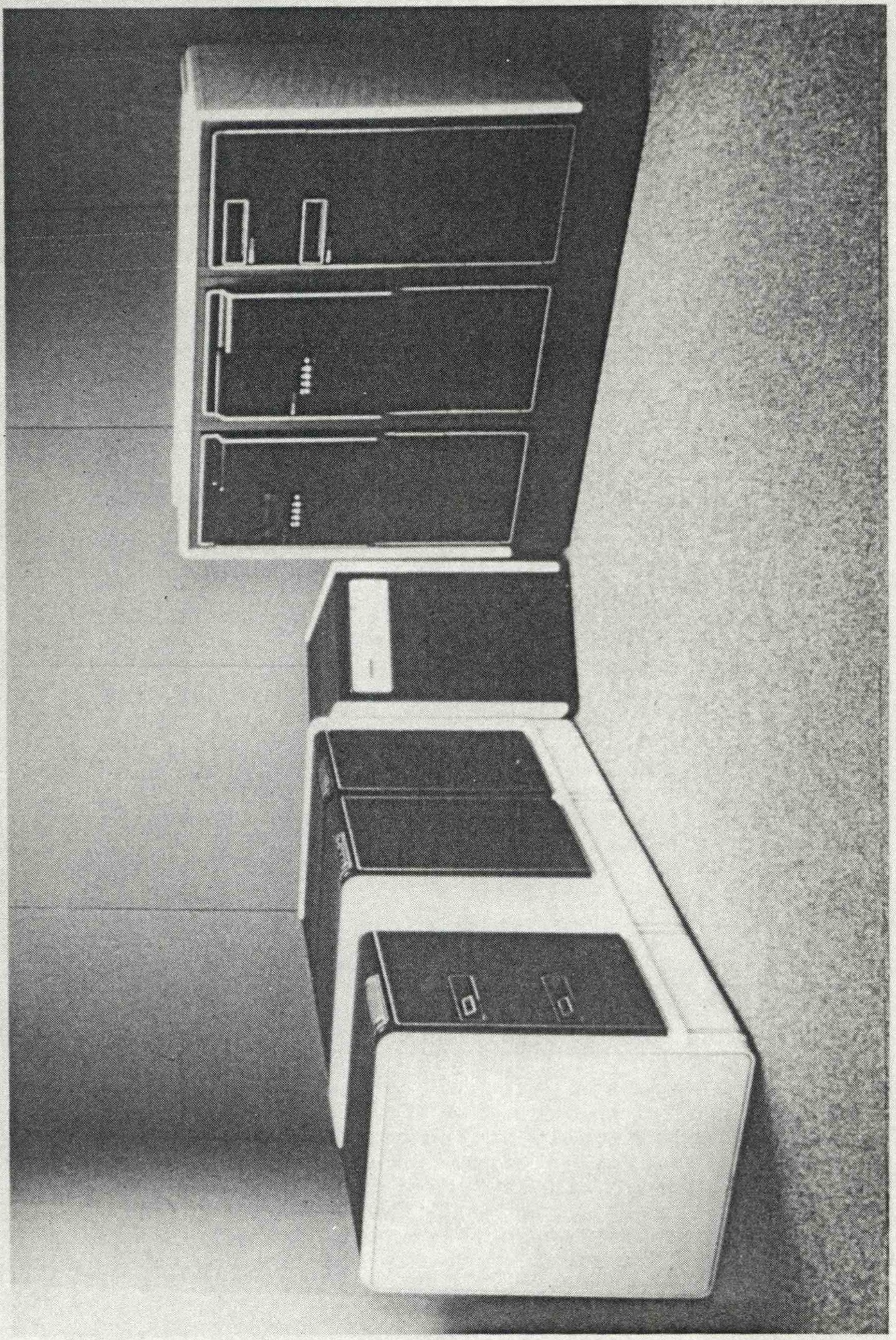


Figure 3

Each preprocessor takes its input data stream and performs the necessary synchronizations and handshaking with the source. It then puts the required data into a standard format which in normal operation is passed to the central processor. In addition, the preprocessors will carry out event detection and maintain dedicated communications with certain continuous users such as the USAF.

The central processor manages the main data base, provides the high level graphic display capability, maintains the main SESC forcaster data and status displays, writes archive tapes and provides for all SESC application support programs for analysis and prediction to be run as required on a scheduled or demand basis. In addition, the capacity will be available to provide for new product development and specialized customer support.

Current Progress

Considerable progress has been made in implementing the new system during FY83. The microcomputer systems for the preprocessors were received at the start of the year and in spite of problems with the immaturity of the system software, good progress is now being made in realizing the preprocessor programming.

Specifications were completed early in the year for the central processor system. This includes the hardware for multiple graphic displays, workstations and standard computer peripherals. It also includes the specialized software to interface with the preprocessors, and manage the data base and the graphics system. A Request for Proposals was issued in May and proposals were received in July. After evaluation an award was recommended, approved, and made to Minicomputer Systems Inc. in September. The company will supply a Data General MV10000 32 -bit super minicomputer system (Figure 4) with 16 megabytes of main memory, 2 gigabytes of on-line storage, together with tape transports, graphic displays and workstations. This hardware will be delivered to the contractor in early 1984. They will then proceed to integrate the hardware and write the specialized software. The overall system will then be formally handed over for acceptance testing in the fourth quarter of 1984.

Working groups have been set up to plan the details of the data flow through the new system and the standard displays and basic application programs which will be needed to bring the new system on line.

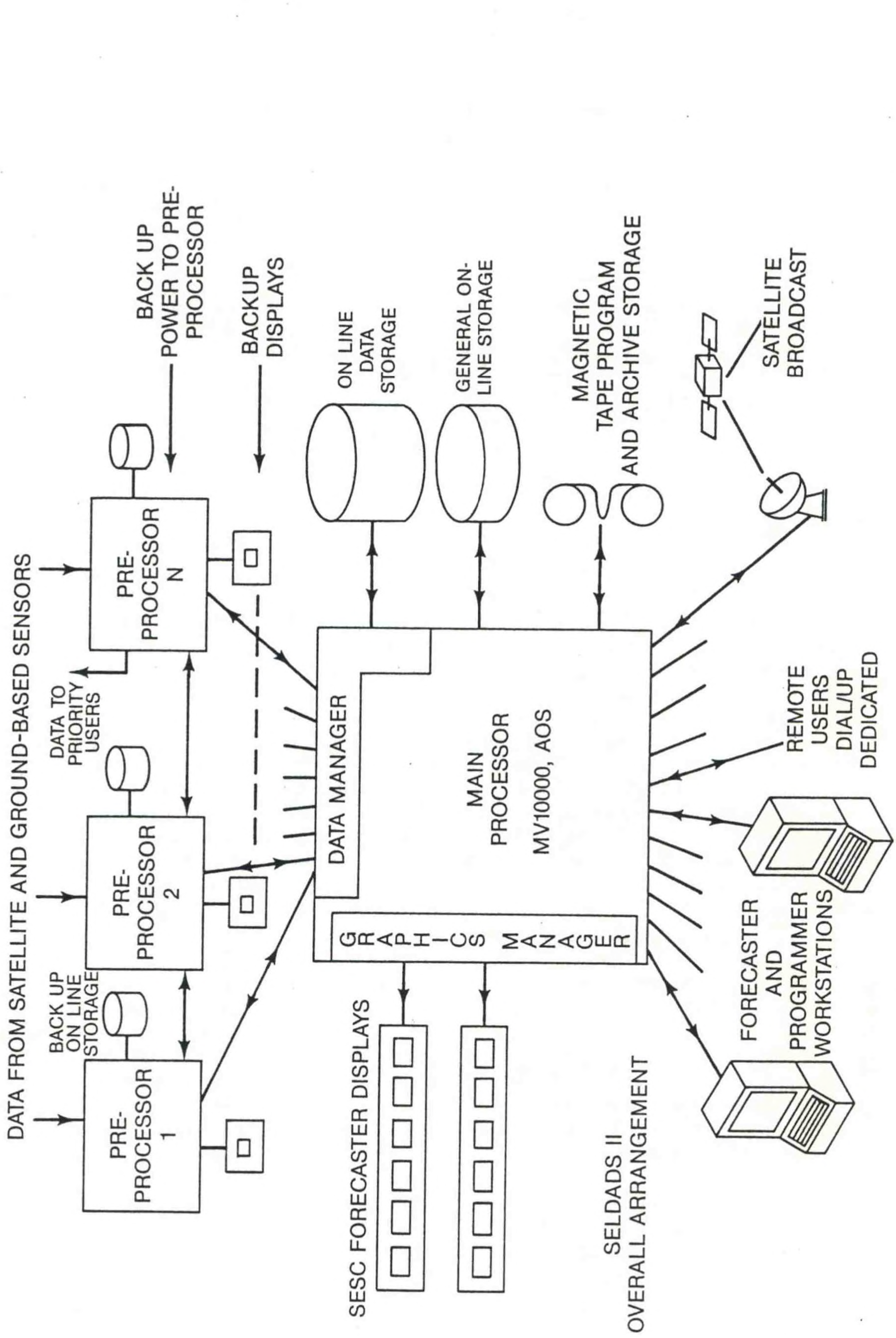

DATA FROM SATELLITE AND GROUND-BASED SENSORS
PRE-PROCESSOR 1
PRE-PROCESSOR 2
PRE-PROCESSOR N
BACK UP ON LINE STORAGE
DATA TO PRIORITY USERS
BACK UP POWER TO PRE-PROCESSOR
BACKUP DISPLAYS
ON LINE DATA STORAGE
GENERAL ON-LINE STORAGE
MAGNETIC TAPE PROGRAM AND ARCHIVE STORAGE
SATELLITE BROADCAST
DATA MANAGER
MAIN PROCESSOR
MV10000, AOS
GRAPHICS MANAGER
REMOTE USERS DIAL/UP DEDICATED
FORECASTER AND PROGRAMMER WORKSTATIONS
SESC FORECASTER DISPLAYS
SELDADS II
OVERALL ARRANGEMENT

Figure 4

Preliminary work on the physical space for the new computer system and for a new SESC forecaster console was carried out in 1983. Now that the equipment configuration is known, this work will be completed during 1984 prior to final installation.

Future Plans

Planning is under way for the cut over between the old and new systems. As the SESC provides a continuous 24-hour service this must be carried out in such a way that all services to the forecast center staff and to users are maintained. We plan to start to make the change over during 1985. the following priorities have been established.

HIGH PRIORITY

Products: Daily and weekly forecasts and summaries
Satellite broadcast
Event detection and notification
Flow of data to GWC
General display and quality control
IUWDS data interchange
GWC backup

Sources: GOES, ATN/COMEDS, USGS Boulder magnetometer
Autodin/Telex interface

MEDIUM PRIORITY

Products: Non-SESC user access and display
Archival
Forecast verification
NOSC data stream

Sources: ISEE, RGON, NOAA

LOW PRIORITY

Products: Administrative functions
New product development
Unique customer support

Sources: Historical data bases

We expect SELDADS II to make a very significant contribution to the improvement of the laboratory's services. Not only will it permit all the incoming data to be handled in a uniformly timely manner, but also for the first time it should permit new applications and techniques developed on off-line computers to be easily transferred to the operational system without the extensive recoding and rearrangement of programs which had become necessary due to the overloading of the existing system. This will greatly facilitate the application of research results to service products and therefore accelerate the whole process of service improvement.

SATELLITE BROADCAST

Introduction

The present dedicated Space Environment Services Center began operation in 1966 and predecessor radio propogation prediction centers in the Department of Commerce started during World War II in 1943. In that time, most of the technology associated with the services has changed extensively but the methods of distributing the products has remained virtually unchanged. Telephones, teletypes, the mail and radio broadcast on the short wave time service WWV are still the primary methods of delivering the service. However, the recent development of new technology to provide low-cost data broadcast capability from satellites greatly facilitates the distribution of information from a central location to widely scattered users. In cooperation with the user community, the Space Environment Services Center has developed a plan for using satellite communications to replace substantial portions of the present telephone and the teletype services. The proposed new service offers economical, technical and political advantages over the current methods.

Economically, the plan shifts the direct part of receiving space environment services from the SESC to the users. However, the cost is kept reasonably low so that it is affordable to mose users. The broadcast service and the receiving equipment are available from commercial sources, relieving SESC of responsibility of bookkeeping users' addresses, routing headers, or telephone numbers.

Technically, the plan provides users with a continuous, complete stream of indices, forecasts, and alerts. The information stream is both more timely and more complete than is possible with the current system. These products, directed to meet common national needs, can be tailored by commercial vendors to meet the special needs of specific users or groups of users. The receiving equipment is compact (24-inch dishes) and transportable with standard RS 232 interface to enable users to carry the equipment into the field and to link the received information to almost any computer.

<u>Politically,</u> the system is advantageous in that users, by being forced to make a modest investment in a receiver system, are indicating that they are serious about their use of the services and not simply taking advantage of a free public service.

Current Progress

In cooperation with representative users, a standard format has been developed and demonstration broadcasts made at several user group meetings. The concept is shown in Figure 5.

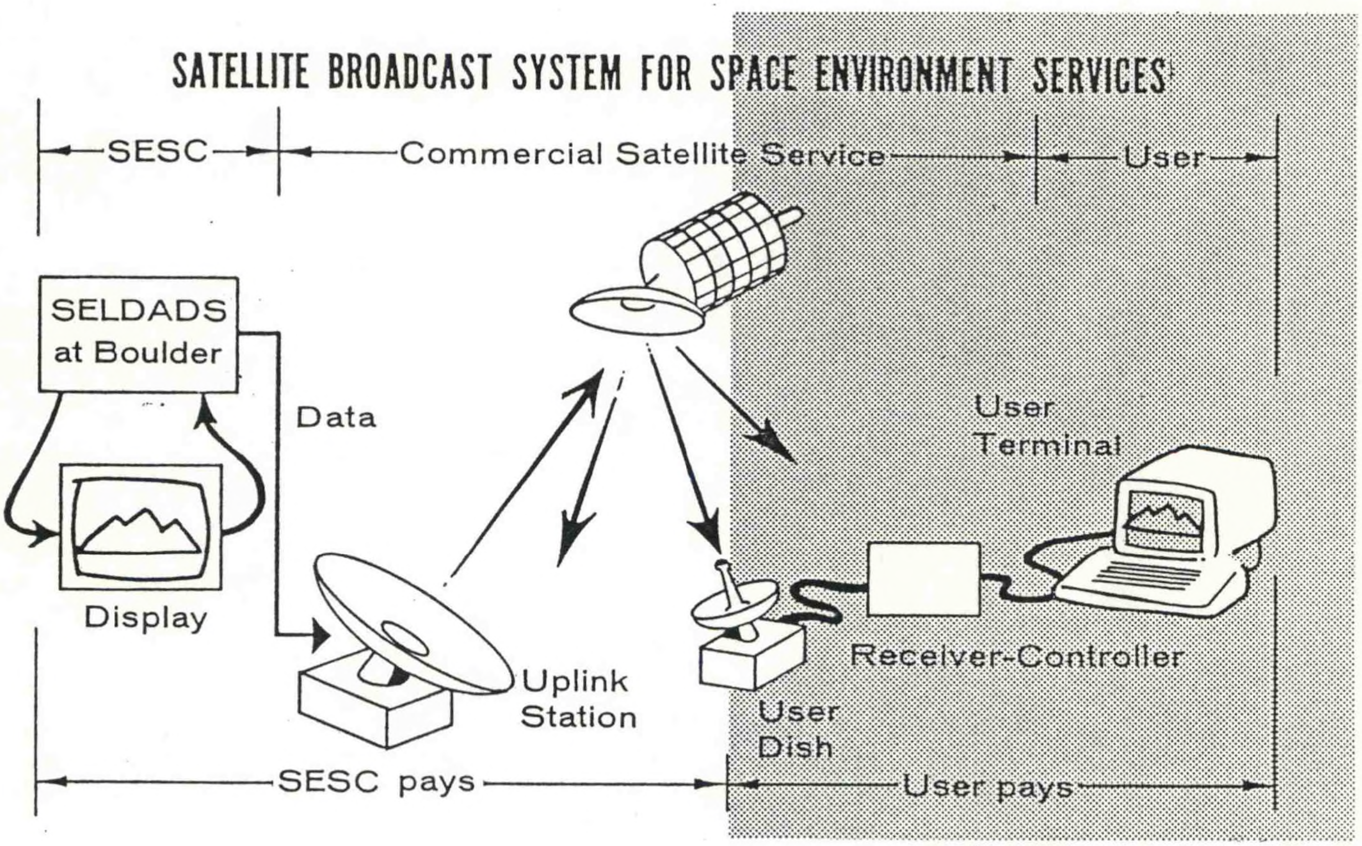


Figure 5

Future Plans

The service will become operational in 1984.

SOLAR X-RAY IMAGER

Introduction

It is clear that a fundamental improvement in forecasting solar activity and its terrestrial effects will come only from a combination of improved understanding of the physics of the whole Sun-Earth system and a considerable extension of our observational data base. Observation of the Sun from the Earth's surface is limited to the optical and radio "windows" in our atmosphere. For practical purposes ground-based, high-resolution observation of active regions in the solar atmosphere is limited to optical wavelengths and these provide information only on the lower temperature regions of the atmosphere close to the visible surface. As has been shown in the last 15 years by numerous rocket, unmanned satellite and manned Skylab missions, the important structure in the upper regions of the solar atmosphere (or corona), where the temperatures are much higher, can be observed properly only in the extreme ultraviolet (EUV) and soft X-ray regions of the spectrum. It is this coronal structure which modulates both the steady outflowing solar wind and the particle emissions from solar flares. Both of these are sources of significant terrestrial effects on man's activity. Important service benefits would be realized if the SESC had access routinely to operational solar X-ray imager data which shows the actual coronal structure instead of attempting to infer the structure from its footprints in the lower atmosphere.

Current Progress

SEL has placed an operational EUV and X-ray imager as its first priority for the enhancement of the present Space Environment Monitor system on the NOAA GOES spacecraft system. Because of the constraints of the present spacecraft design, this could only be done at the time a major redesign and enhancement of the spacecraft is undertaken. Such a redesign, known now as GOES NEXT, has been under study by NOAA and NASA for a number of years.

In preparation for an operational sensor SEL, in collaboration with NASA Marshall Space Flight Center (MSFC), has carried out a study of the major system components which would be required (i.e., the X-ray optics and the solid-state imaging detector). The final report on this work was published during the year, "The GOES X-Ray Imager Feasibility Demonstration," by J. R. Cessna, R. B. Hoover, R. W. Grubb and J. H. Taylor, NOAA Tech. Report ERL 423-SEL 41, February 1983, It was concluded that the technology exists for the realization of a suitable flight instrument with a high probability of success. In addition, SEL has been studying in greater detail the operational use of the imager data and the specific improvements in services which would be possible using the data. A report on this work has also been issued this year, "Operational Uses for a Solar Soft X-Ray Imaging Telescope," by S. T. Suess, NOAA Tech. Memo ERL SEL-66, July 1983.

Future Plans

At this time we expect a RFP for the GOES NEXT system to be issued by NASA on behalf of NOAA in the first quarter of 1984. In preparation for this RFP, the laboratory has prepared performance and interface specifications for an operational imager in collaboration with MSFC. The RFP will require the contractor to bid on the capability to accommodate an X-ray imager as part of the Space Environment Monitor. However, budgeting constraints may prevent an actual instrument being built for the early spacecraft in the series.

We plan to work closely with the Environmental Research Laboratories and NOAA administration and also with the other government agencies using the SESC services to achieve an operational imager at the earliest possible date.

RESEARCH

Introduction

The aim of the Research Division in FY 1983 was to conduct research into solar-terrestrial phenomena to improve the services provided by the Laboratory. This involves understanding emission of electromagnetic and particle radiation from the Sun, the propagation of matter and energy through the solar wind, and the interactions between the solar wind and the Earth's magnetosphere, ionosphere, and upper neutral atmosphere.

During the year the activities of the Research Division were organized into four projects: Solar Physics, Interplanetary Physics, Magnetospheric Physics, and Atmosphere-Ionosphere-Magnetosphere (AIM) Interactions.

SOLAR PHYSICS

Current Progress

The Solar Physics Project seeks improvements in solar-terrestrial services through studies of conditions on, and near, the Sun's surface. During the Fiscal Year 1983 studies were focused on: X-ray emissions from the Sun and on solar magnetic fields. The work can be viewed as addressing two distinct time scales: (a) the present and (b) the long-term future. In August 1983, the leadership of the project passed from S. Suess (who joined NASA) to P. McIntosh (acting).

In the "present" time scale Dr. H. Garcia developed techniques for inflight calibration of X-ray detectors on board the NOAA satellites to remove inconsistencies between detectors caused by telescope pointing and different sensitivities.

The long-term aspects include solar activities that change on time scales of weeks to decades. This involves mapping of solar activity and modeling the solar corona as it changes throughout the 11-year solar cycle. The mapping of solar activity includes patterns of solar magnetic fields. Solar mapping provides a means by which the effects of solar rotation and spherical geometry are removed in order to reveal the evolution of solar active regions as they relate to where and when solar events occur.

Solar mapping is a form of image processing. The images include, for example, the Sun seen in hydrogen-alpha, calcium K, magnetically-sensitive iron line and infra-red radiations and each represents a different picture of the Sun and its complexities. The structure of solar features indicates the presence of solar magnetic fields that "rule the sun." The information in these images provides data on the configurations of the magnetic fields. Figure 6 shows the superposition of large-scale patterns of neutral lines (along which the radial component of the field is zero) on an X-ray image of the Sun obtained from the Skylab satellite. The lower image is the same as the upper image but without the overlay. The complex structures in the X-rays are interpreted as loops of magnetic fields above the neutral lines. The large, dark coronal holes occur between neutral lines. Coronal holes are sources of high speed solar wind and turbulent magnetic fields that propagate through interplanetary space and affect the Earth's magnetic field.

The goal of the present effort is to replace labor intensive, hand drawn maps with maps and charts plotted from digital files stored on computers. Software developed this year enables computer production of the daily disk solar map. Provision is made for plotting of maps from data one or more days earlier in order to construct operational maps when solar data may be unavailable because of weather and/or equipment failure.

Software and communications were developed which permit daily transmission of disk maps of solar magnetic fields from Stanford University to SEL. These data are being used in real-time for evaluations of solar sector boundaries with respect to the sites of solar events that might affect the Earth. The Stanford maps are plotted on the same scale and format as the maps generated from other available solar images. These magnetic data are used to compute the three-dimensional forms of large-scale solar magnetic fields at heights above the solar surface where the fields are expected to couple directly to the interplanetary magnetic fields. This quantitative view of the solar corona will be the basis for advancing quantitative predictive models for propagation of solar disturbances from the Sun.

The data base of H-alpha synoptic charts (global maps of the Sun for each complete 27-day solar rotation) was maintained and prepared for archival publication in Solar-Geophysical Data. These edited charts have been used to construct time series of limited latitude zones of the Sun for monitoring long-term, large-scale evolutions. The formation of strong centers of sunspots and solar flares and the occurrence of large, stable coronal holes have been

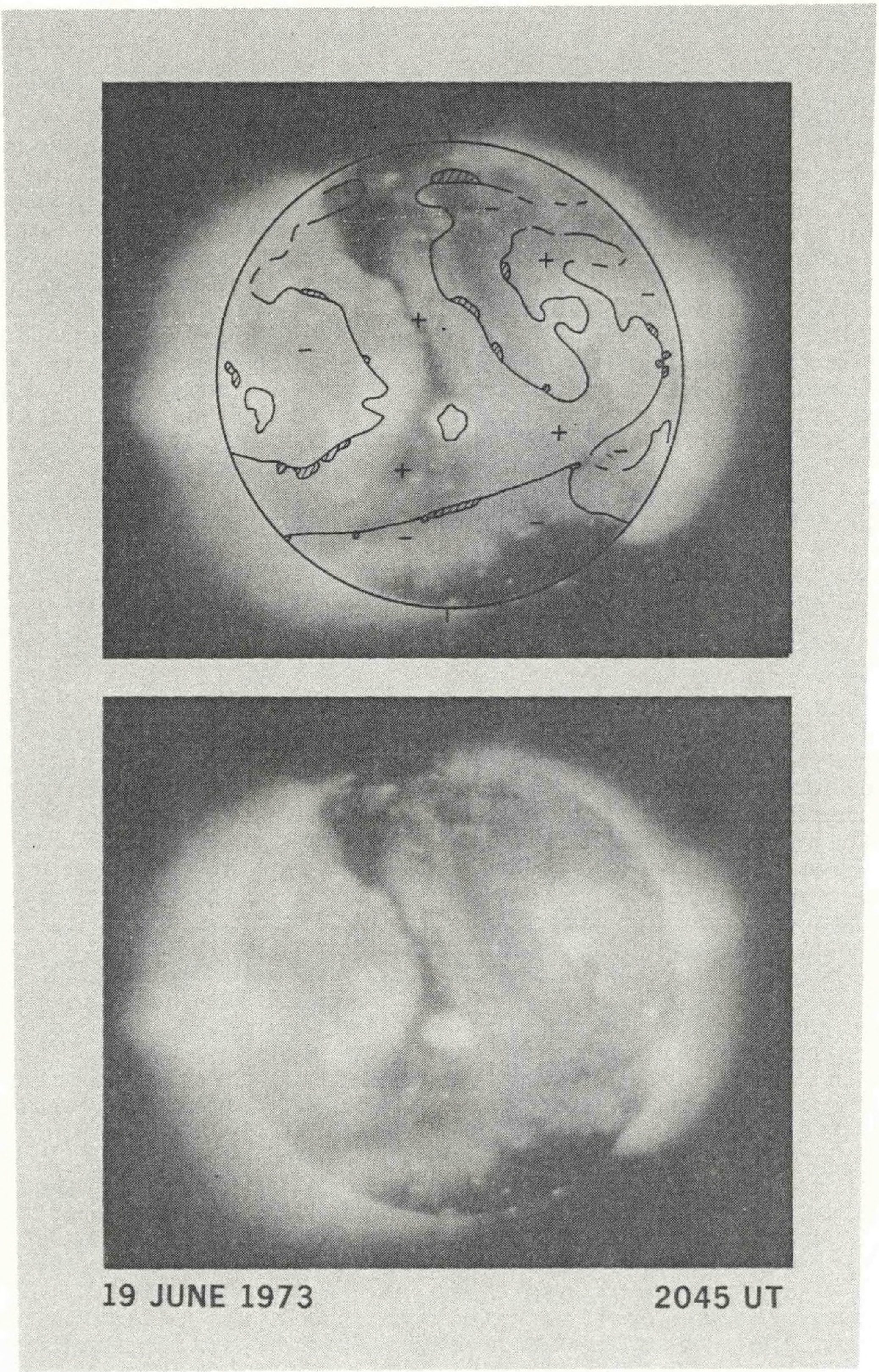


Figure 6: Lower figure is an image of the solar corona in soft x-rays and the same image (upper) with magnetic neutral lines.

tentatively associated with patterns of convergence and divergence, respectively, in the evolving large-scale patterns of magnetic fields. The maintenance of the data base on large-scale activity is a necessary prelude to developing practical methods for making 27-day solar-terrestrial predictions. These synoptic charts are the only maps which regularly combine large-scale patterns of solar magnetic fields with the locations of coronal holes as observed with infra-red data obtained daily from the Kitt Peak National Observatory. These maps reveal a close relationship between the H-alpha and infra-red features. A relationship has been established between the long-term, large-scale patterns of solar magnetic fields and to the locations of strong and persistent sunspot and flare activity. The relationships found between large-scale patterns from the H-alpha synoptic charts and the locations of the larger sunspot groups have been incorporated in a new model for the formation and structuring of sunspot groups. A catalog of outstanding active regions in terms of their X-ray flare production is being compiled. This data base is useful for tying solar active region formation to the large-scale solar evolutions.

The solar mapping and observation program has been complemented by theoretical work on modeling of polar coronal holes. Coronal holes appear, in X-ray pictures, as large-scale, cool, low-density areas with predominantly unipolar magnetic fields which extend from the Sun as diverging lines of force. Coronal holes are sources of high-speed solar wind streams that cause geomagnetic storms. A theoretical model of a polar coronal hole has been constructed based on quantum mechanics. The inputs to the model are: (1) the density distribution in the corona, above the pole and in the equatorial plane, observed during solar minimum and (2) the magnetic field strength above the pole (taken to be 9.8 gauss). The output of the model is the magnetic and thermodynamic structure of the polar coronal hole between two and five solar radii. With a magnetic field model consisting of a radial field plus a dipole-like field the boundary of a coronal hole is defined by a magnetic surface which separates open magnetic lines from those that return to the solar surface ("0" line in Figure 7). This boundary is clearly defined on X-ray images of the Sun. Solution of the magnetohydrostatic force balance equations in a magnetically dominated region ($1/2\,\rho\, v^2 \ll B^2/8\pi$) give the components of the magnetic field. The components of the outflow velocity, within the polar coronal hole are then found from the magnetohydrodynamic equations. The profiles of the radial component v_R, of the velocity above the pole $\Theta = 0^o$ and for $\Theta = 30^o$ and 45^o (polar hole boundary) are presented in Figure 8. Figure 8 shows that, between two and five solar radii, there is a fast radial acceleration of solar plasma. Above the pole the

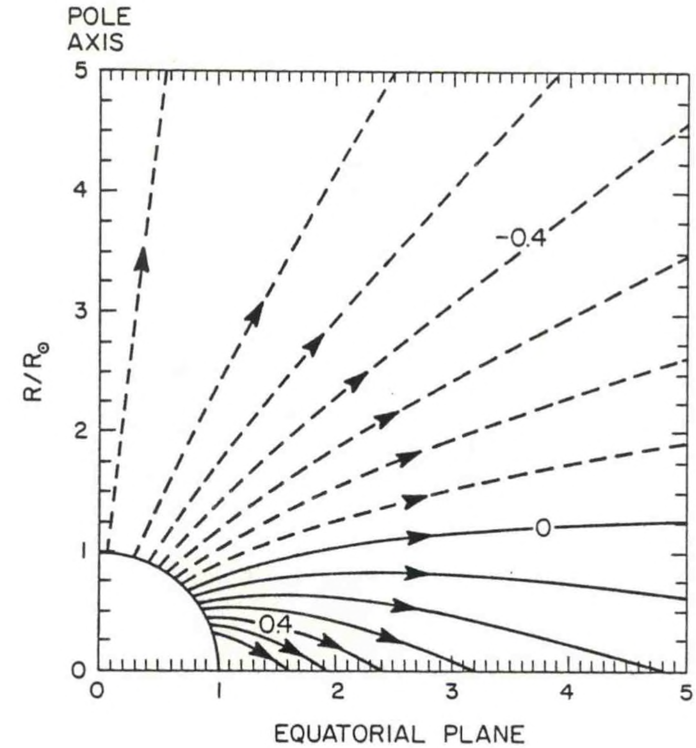


Figure 7: Model of solar magnetic field consisting of a combination of a unipolar field and a dipole-like field.

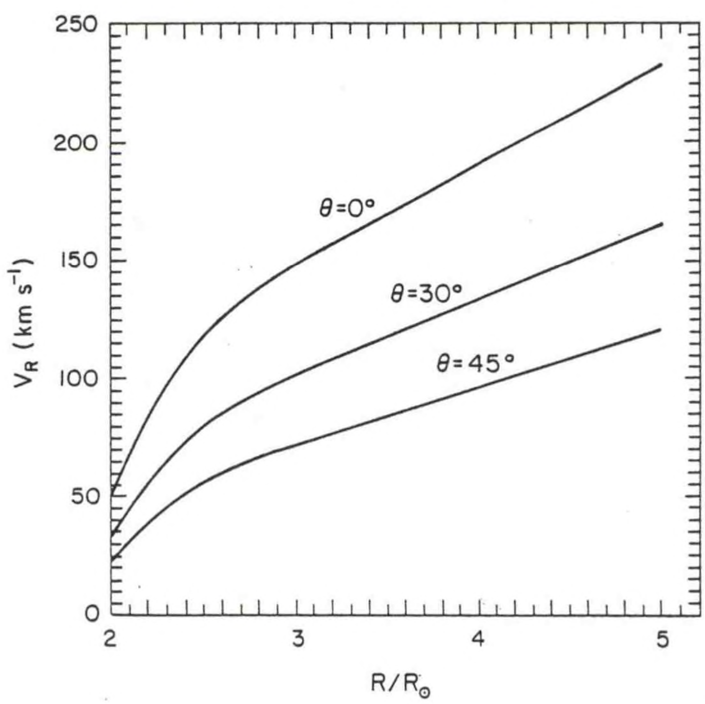


Figure 8: Variation with radial distance of the plasma velocity for three co-latitudes Ø°, 3Ø° and 45°.

radial velocity increased by a factor of five. The novel feature of the present model is the coupling between the magnetic and thermodynamic structures. Understanding of this coupling at the source of the solar wind is necessary for modeling of the propagation of plasma disturbances from the Sun to the Earth.

Future Plans

(1) Complete testing and refinements to the software for routine solar mapping and hand over to SESC.

(2) Use large-scale patterns of solar magnetic fields for 27-day (and longer) solar-terrestrial forecasts.

(3) Develop real-time, source-surface, magnetic field configurations for operational evaluation of solar events. Refine communication and display of Stanford solar magnetic maps.

(4) Extend coronal modeling to more complex conditions at solar maximum.

(5) Develop data bases for long-range solar activity predictions, including the time scale of the solar cycle (11 years). Investigate the epochal nature of solar activity (variations on scale of a few months) and test its predictability.

(6) Publish description of the McIntosh Revised Sunspot Classification in popular scientific journals to elicit wider use by the amateur solar astronomers who are taking on an increasing share of the burden of maintaining synoptic solar observations.

(7) Investigate the correlation between X-ray and 10 cm radio emissions in an attempt to improve the SESC forecasts of daily indices at both wavelengths.

INTERPLANETARY PHYSICS

Current Progress

A principal objective of the Interplanetary Physics Project 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 highly time-varying solar wind will provide a scientific basis for the evaluation of the power transfer into the magnetosphere under both quiet and disturbed conditions. An essential element of this theoretical and computer-oriented research is the testing of these models by direct comparison of their predictions with spacecraft observations. Another objective is to provide spinoff whenever possible for operational forecasting of geomagnetic disturbances.

The principal activities of the Interplanetary Physics project were linked in a two-fold objective: the development of multi-dimensional, time-dependent models of the solar corona, solar wind, and interplanetary magnetic field and to study the physics of the interplanetary medium. The near-term goal was the application of existing computer models (or simplified modifications thereof) with available real-time data as input to make verifiable predictions of occurrence, severity, and duration of geomagnetic disturbances.

Studies were started (with some NASA support) for a particular epoch (August 1979) during which there was substantial solar activity (solar flares, high-speed streams from coronal holes, and erupting prominences) as well as substantial geomagnetic activity. An empirical model, using solar synoptic H-alpha and magnetogram charts, was developed for this period. These data have been entered into the NOAA CYBER 750 computer as spatial and temporal input for our non planar MHD model of the solar wind in the ecliptic plane. A parametric study of variable shock and solar wind velocities was initiated in order to provide insight into what could be expected in the plane of the Earth's rotation around the Sun where the solar plasma and interplanetary magnetic field are highly variable in time and space.

Check-out tests of a fully, three-dimensional, time-dependent MHD model were conducted (in collaboration with Tennessee Technical University) on the NCAR CRAY computer. Propagation of a simulated flare-produced shock wave was satisfactorily demonstrated. Further development to decrease machine time for a complete run from near the Sun to one astronomical unit (presently about five hours) was started. This machine time, for reference, should be compared with physical transit times of 2-5 days.

The outputs of the MHD models are illustrated in Figures 9 and 10 which show the distortion of the interplanetary magnetic field by a solar-flare generated shock wave and effects on the Earth's magnetosphere. A highly-simplified version of the nonplanar (two and one-half dimensional) MHD model was developed. This software package was tested with shock velocities (from about 62 solar flares) obtained from Harvard University's Fort Davis Observatory and Air Force's Radio Solar Telescope Observatories. The test consisted in the complementary

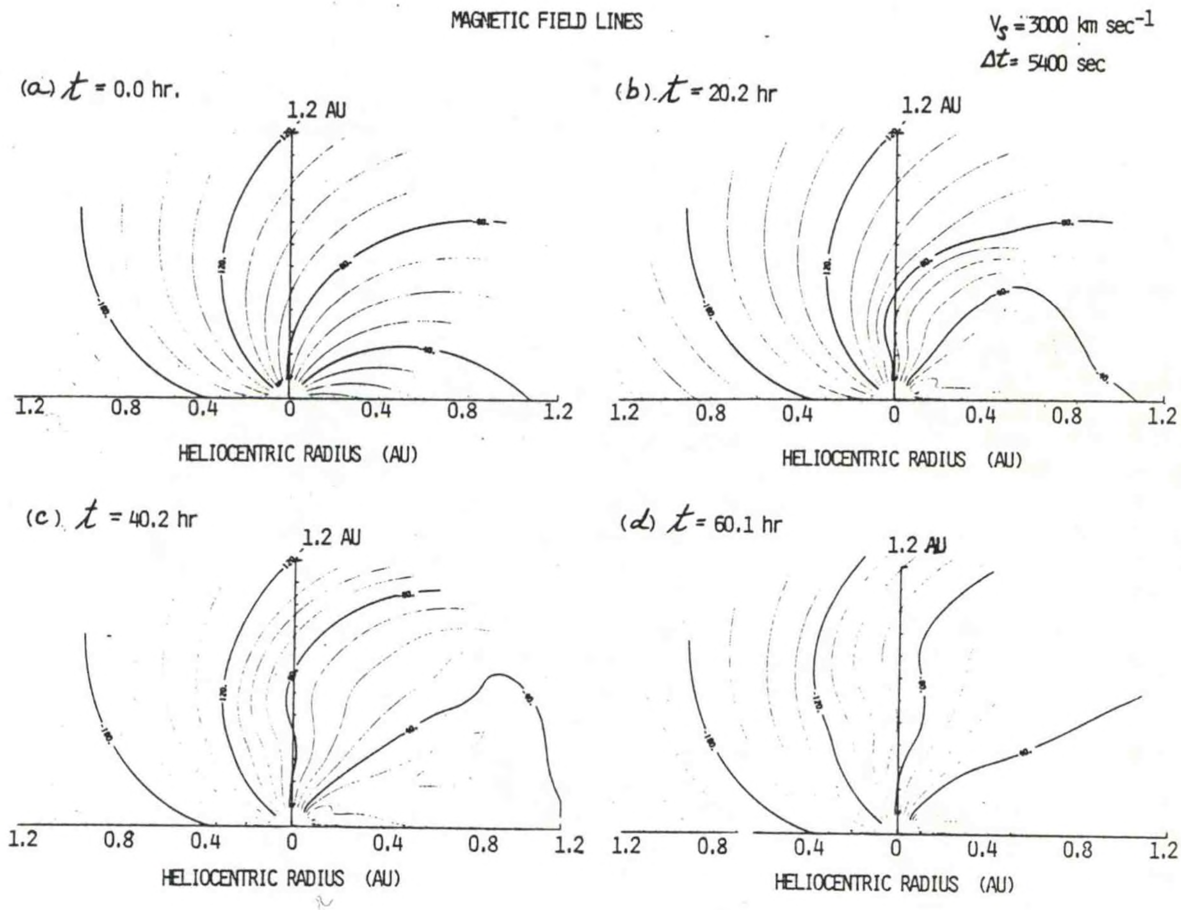


Figure 9: An MHD computation of the interplanetary magnetic field (IMF) lines as a solar flare-generated shock wave propagates through the solar wind. In this example, a narrowly-confined flare shock, 24^{o} wide in longitude and centered at 30^{o} measured counter-clockwise from the right side of each inset figure, is triggered at t = 0 hr. The deformation of the IMF takes place in the direction normal to the the figure as well as in the depicted ecliptic plane.

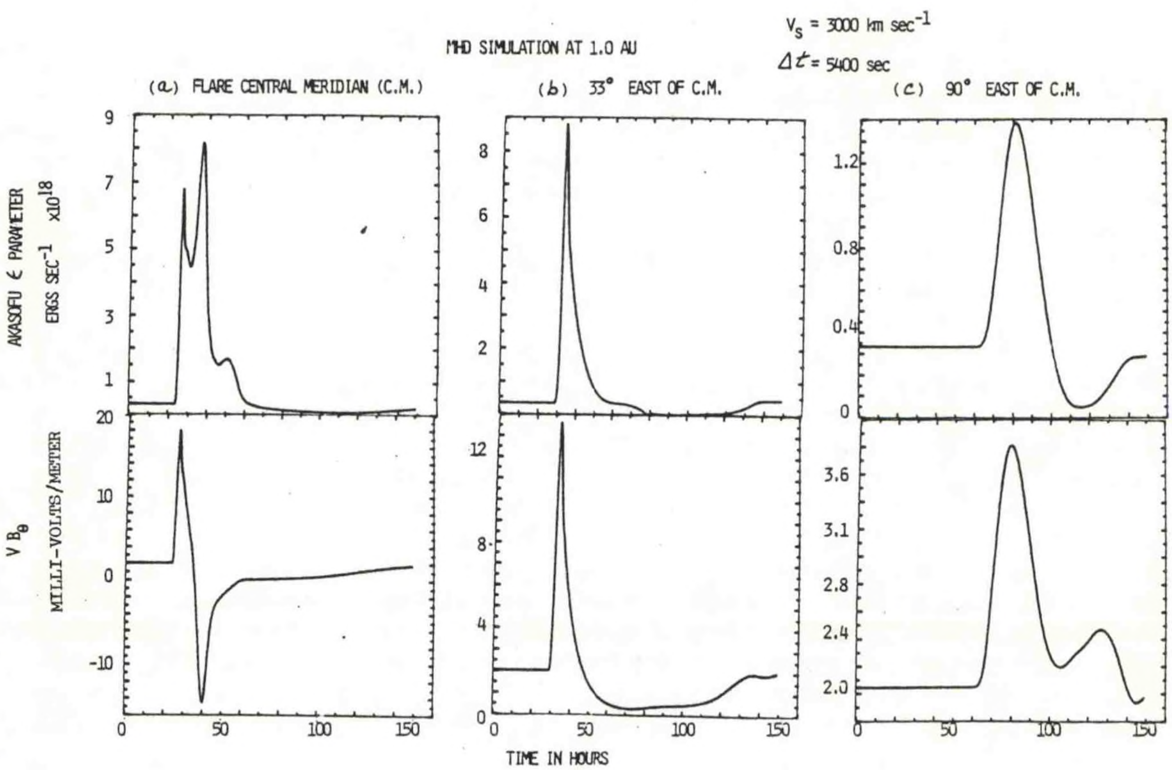


Figure 1Ø: The total power in the solar wind is shown in the upper row of figures as the solar flare-generated shock wave (from Figure 9) sweeps throughout the inner solar system. The earth's magnetosphere is assumed in (a) to be located at the central meridian (c.m.) of the flare and, at (b) and (c) at several other positions. The lower row of figures shows the magnetospheric cross-tail electric field which is believed to be involved in the energy transport from the solar wind into the magnetosphere.

input of solar optical and GOES soft X-ray data and the output of predicted shock arrival times at the Earth. This approximation to the MHD model considers only the flare-generated shock wave and its propagation under the piston-driven and subsequent blast wave approximations. Plans were made to use the algorithm for operational purposes with real-time shock velocity input from Air Force Observatories.

Research was conducted in the area of higher moment fluid equations that consider non-Maxwellian distribution functions of various ionized species, their relative streaming velocities, and their heat conduction properties. These effects are believed to be important in the presence of strong temporal and spatial gradients in the interplanetary medium. Plans were prepared to incorporate the basic ideas into the MHD models (nonplanar or purely three-dimensional versions).

Participation was continued, in a Guest Investigator status, in two NASA programs: Solar Maximum Mission (SMM) and Pioneer-Venus-Orbiter (PVO). This work contributed to SEL objectives in that the SMM activity was concerned with low solar corona activity associated with solar flares. The PVO activity was concerned with the explicit association of such activity (called "coronal transients"), via the solar wind, with spacecraft observations of their interplanetary and ionospheric consequences (Venusian, in this case). Several papers, including a comprehensive review article on coronal transients and their associated shock waves, were published in collaboration with a large, diverse group of spacecraft and ground-based observers. Guest workers and scientific collaborators included S. Cuperman, Tel Aviv University; S. M. Han, Tennessee Technological University; and T. Yeh, Eastern Enterprises, Inc.

Future Plans

(1) Test the nonplanar MHD model by inputing the August 1979 coronal data, first without simulation of flare-produced shock waves, and secondly with introduction of these shocks at appropriate times and locations.

(2) Pursue the development of a fully, three-dimensional, time-dependent computer model of the Sun-Magnetosphere "transmission line" by collaborating with others in the coronal and solar wind parts of this objective. A major goal will be the efficient design of the software package in order to reduce the CRAY time for a typical run from about five hours of machine time to about two hours.

(3) Predictions of shock arrival times (using real-time solar radio, optical, and X-ray data) will be compared

with both in situ spacecraft observations of shocks as well as with the recorded times of geomagnetic storm sudden commencements and sudden impulses at ground-based magnetometer stations.

(4) A "Users' Guide" will be distributed to all USAF observatories where solar radio spectral data are obtained from sweep frequency interferometers. This guide will provide explicit directions for obtaining and reporting (in real-time) the solar flare-generated shock velocities to SESC/Boulder. These data will then be incorporated into the USAF/SEL prediction algorithm for the forecasting of shock arrival times.

(5) Investigation of three-dimensional modeling of coronal transients and their associated shock waves will be pursued in collaboration with the University of Alabama at Huntsville. This work will be an expansion of earlier, nonplanar (two and one-half dimensional) interplanetary and coronal work. Eventually, this work would be combined with Item (2).

MAGNETOSPHERIC PHYSICS

Current Progress

In the past year, the project lost two senior scientists. Accommodations to, and recovery from this loss, will be an important part of the future.

The goals of the project are twofold:

(1) Provide direct support to the SESC and RTDS activities through operational data and system evaluation and supporting consultation.

(2) Applications research in Magnetospheric Physics directed toward enhancement of the scope, quality and utility of the laboratory products and services.

Among the support activities, the project has sponsored and participated in a number of intra-laboratory meetings to define the data management requirements for the production of reliable and scientifically valid space environment data which form a principle information base for the Space Environment Services Center. With the forthcoming implementation of the SELDADS II system, our understanding of the characteristics of the input data must be translated, via data processing techniques that efficiently reduce the data stream, to real "information" in the preprocessors.

Intercomparisons have been performed of the particle data from the Space Environment Monitors aboard the GOES-2, 4, 5, and 6 satellites and those aboard the NOAA/TIROS series of spacecraft. A number of prior software discrepancies were corrected, and new algorithms for the interpretation of the particle data were constructed; these algorithms are being used to produce new archival data sets. Upon certification of these procedures in the archival system, the procedures and algorithms will be transferred to the real- time system. In another study, a method has developed by which the adiabatic redistribution of magnetospheric particle population can be identified through examination of concurrent local magnetic field measurements. These particle redistributions cause changes in the particle fluxes observed at the GOES satellites that can mimic the start of an event, and therefore contribute to the "false alarm" rate of the warnings for particle event occurrence.

In response to concerns of the Omega Navigation System, the project had undertaken an examination of the polar radiation environment during periods of long-delayed (days) after-effects on VLF radio signals. The delayed recovery of the ionization level, following a polar cap absorption disturbance that is responsible for the Omega delayed response, results from either an additional particle ionization source, or ionospheric chemical processes. The relatively complete description of the polar particle radiation environment provided by the NOAA/TIROS and GOES instruments, allows a choice between these alternatives. Comprehensive observations were assembled of protons, alpha particles, and electrons precipitating into the polar ionosphere during and after five PCA events in 1982, along with corresponding observations of Omega phases advances. The ionospheric responses are currently being evaluated for comparison with those Omega records.

A major objective of the applied research is an understanding of those processes by which energy is transferred to the magnetosphere, stored therein, and ultimately dissipated in the Earth's upper atmosphere and ionosphere. Further effort was applied to a previously developed model of the acceleration of auroral particles in the magnetospheric tail by the crosstail electric fields observed here. The model calculations of individual particle responses to the electric field, produced predictions in excellent agreement with in-situ observations of auroral particle fluxes. Analytical expressions were derived for the principal characteristics of the acceleration mechanism, which simplifies the model's use. Beyond representing an important source for auroral particle precipitation, the acceleration mechanism may represent an important source for the development and maintenance of the

Earth's quiet-time ring current. Together, the auroral currents and ring currents represent the principal sources of ground geomagnetic disturbances.

An atlas of ion distributions throughout the magnetospheric trapping regions was produced with data obtained from the International Sun-Earth Explorer (ISEE) satellite. The energy range is from 24 keV to greater than 2 MeV, for all local times. The characteristics of the trapped-particle distributions, as depicted in this atlas, help to define those regions of the magnetosphere where specific dynamical processes are occurring, and thus help to direct the course of future inquiry. An algorithm has been constructed that simplifies analyses of magnetospheric processes, such as diffusion and charge exchange, which are important in magnetospheric energy transport.

Future Plans

(1) Conclude Omega study with comparison between the recovery of particle-induced ionospheric ionization and the recovery of delayed Omega VLF phase advance.

(2) Continue study of tail acceleration mechanism to investigate effects of multiple traversals of the tail acceleration region by mirroring particles.

(3) Continue exploitation of NOAA/TIROS data by comparing enhancements of medium-energy particle precipitation over the polar caps with the occurrence of interplanetary disturbances and geomagnetic activity.

ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE INTERACTIONS

Current Progress

The primary objective of research in this project is to understand the transfer of electrical and mechanical energy from the Earth's magnetosphere into the upper atmosphere and to characterize the consequences of that energy input on the ionosphere, the upper atmosphere and sea-level environment.

Studies were conducted to establish a real-time index of high-latitude activity, based on data from the Real-Time Geomagnetic Observing Network. Geomagnetic activity is essentially a manifestation of large energy depositions into the high latitude upper atmosphere caused, in turn, by magnetospheric processes ultimately traced back to the solar wind. The magnitudes of the energy involved are small compared to the total radiative energy delivered to the

Earth's atmosphere by the Sun. The ratio is about 10^{-5} at best. However, within the altitude range over which the magnetospheric source delivers its energy (above 90 km), it dominates its solar radiative competitor. Local heating rates of 10,000° K per day from this source are not unusual while the solar radiative component typically produces heating rates of 100° K per day.

The energy deposition occurs in two forms. The first and, in terms of magnitudes, the more important, is the resistive heating caused by electric currents flowing in the upper atmosphere. The magnetic signature of these currents defines magnetic activity. The other form is the precipitation of charged particles. The two forms are not totally independent because the particle precipitation produces the atmospheric ionization which carries the electrical currents. The atmosphere responds to this energy deposition in a variety of ways. The electrical, Joule dissipation is very efficient in heating the neutral gas and expanding the atmosphere upwards to the extent that number densities at 1000 km altitude may increase by over an order of magnitude. The energetic particle influxes: (a) introduce significant compositional changes through ion-chemical processes, (b) contribute to the neutral gas heating, and, (c) most important, produce large amounts of ionization in the upper atmosphere.

A major effort continued in the analyses of observations from the Total Energy Detector on board the TIROS/NOAA series of polar orbiting spacecraft. This detector regularly measures the energy carried into the polar atmosphere by auroral particles (both electrons and protons) with energies up to 20 keV. A second complement of charged particle detectors monitors the particle population with energies from 30 keV to solar protons with energies greater than 1000 MeV. For operational purposes, these measurements provide an excellent guide to the general level of geophysical activity. Scientifically, the measurements are important because auroral particles are a major source of energy into the upper atmosphere above 90 km and, therefore, dominate the dynamics of the polar upper atmosphere. Measurements of the energy input to the atmosphere may be a better indicator of atmospheric heating (and, therefore, of satellite drag) than the conventional geomagnetic K and A indices. Localized measurements of energy input can now be extrapolated to estimate the total rate of energy input over an entire polar hemisphere which is of the order of two gigawatts for quiet times and more than 300 gigawatts for an active period.

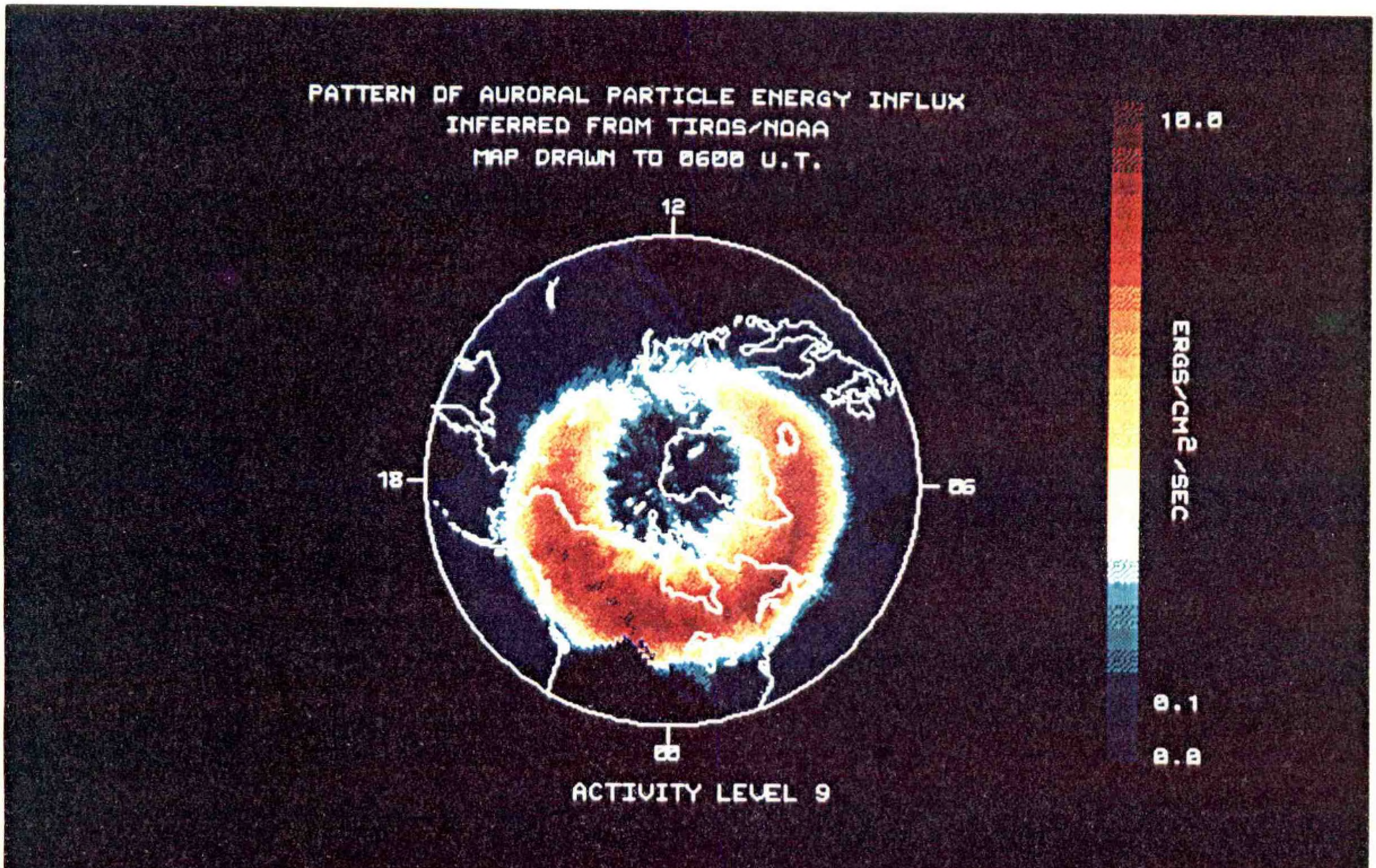
Single pass, local observations are often useful for certain work, particularly studies of specific geophysical events. However, as it stands, data in this form are of little direct use to the services. What might be of use is the global energy input from a single pass of the satellite over the polar regions and, beyond that to quantitatively assess the effects of that energy input: for example, the amount of atmospheric expansion that would result. To this end, a technique was developed to estimate the power input to an entire hemisphere from data obtained during a single pass of the satellite. Basically, this involves a line integral of the energy fluxes measured along the satellite pass suitably weighted to account for the inhomogeneity of particle precipitation around the Earth as determined statistically.

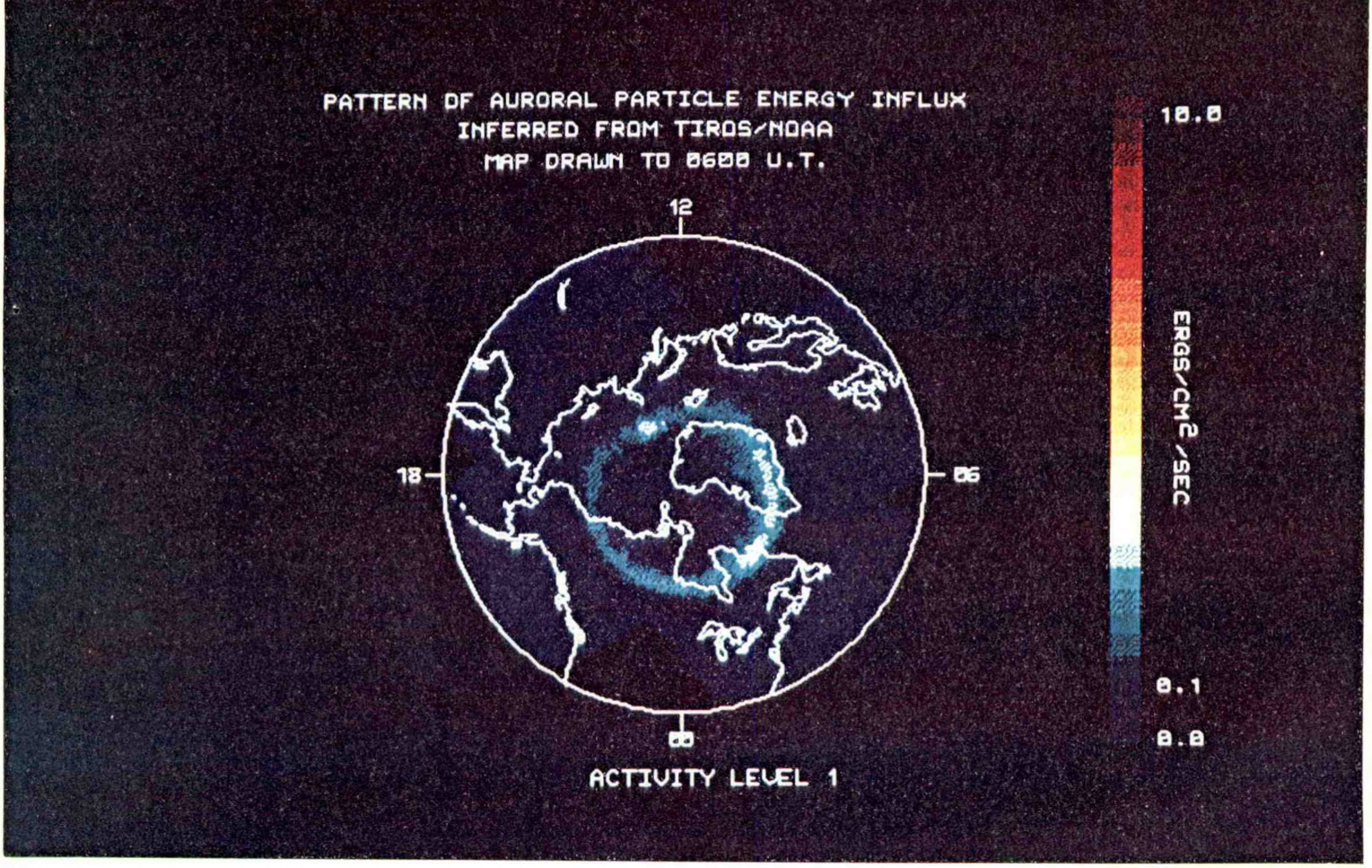
As a first step toward attaching a quantitative physical interpretation to the estimate of the power input to the polar hemisphere, all available TIROS/NOAA data, about 60,000 passes, were parameterized by the power input and maps of the average local energy flux to the atmosphere as a function of latitude and magnetic time were prepared for nine ranges of hemispheric power input.

Two maps showing the energy input into the northern hemisphere under very quiet conditions (activity level 1) and very disturbed conditions (activity level 9) are presented in Figure 11 for 0600 universal time. For activity level 1 the energy input is contained in a ring which does not extend in latitude below central Canada. The average energy fluxes for this level of activity do not exceed 0.25 erg/cm^2/sec; so low that there would be little effect on the upper atmosphere. In contrast, the map for activity level 9 shows that the pattern has expanded equatorward to engulf the northern part of the United States and the local energy fluxes have increased to more than 10 ergs/cm^2/sec. Energy fluxes of this magnitude can have a dramatic effect on the upper atmosphere. Currently the validity of these inferred energy input maps are being verified by cross comparisons with simultaneous measurements made by other satellites, (for example DMSP) and with radar measurements of the ionosphere.

Equivalent maps of upper atmosphere conductivity can be constructed as a function of "hemispheric power input" using the TIROS/NOAA particle observations. These conductivity patterns can then be merged with model, or observed, electric field patterns to obtain maps of the electrical power input to the atmosphere -- the unmeasured 70% of the total power input. At that time it may be possible to determine the electrical and mechanical response of the upper atmosphere to these energy inputs which is the ultimate goal of this work.

Figure 11: The global patterns of particle energy flux to the atmosphere constructed from TIROS/NOAA data for periods of low activity (bottom panel) and high activity (top panel).


PATTERN OF AURORAL PARTICLE ENERGY INFLUX
INFERRED FROM TIROS/NOAA
MAP DRAWN TO 0600 U.T.
12
18
06
00
ACTIVITY LEVEL 9
10.0
ERGS/CM2/SEC
0.1
0.0


PATTERN OF AURORAL PARTICLE ENERGY INFLUX
INFERRED FROM TIROS/NOAA
MAP DRAWN TO 0600 U.T.
12
18
06
00
ACTIVITY LEVEL 1
10.0
ERGS/CM2/SEC
0.1
0.0

Future Plans

(1) Develop a practical, useful, and fully automatic method of characterizing geomagnetic activity using real-time data sources such as the GOES satellite and Remote Geophysical Observing Network.

(2) Utilize the TIROS/NOAA particle observations available since late 1978 to develop maps of ionospheric conductivity as functions of magnetic local time, magnetic latitude, and activity as parameterized by the hemispheric power input.

(3) Explore the feasibility of monitoring upper-atmosphere density and composition by inference of energy input from TIROS/NOAA observations.

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