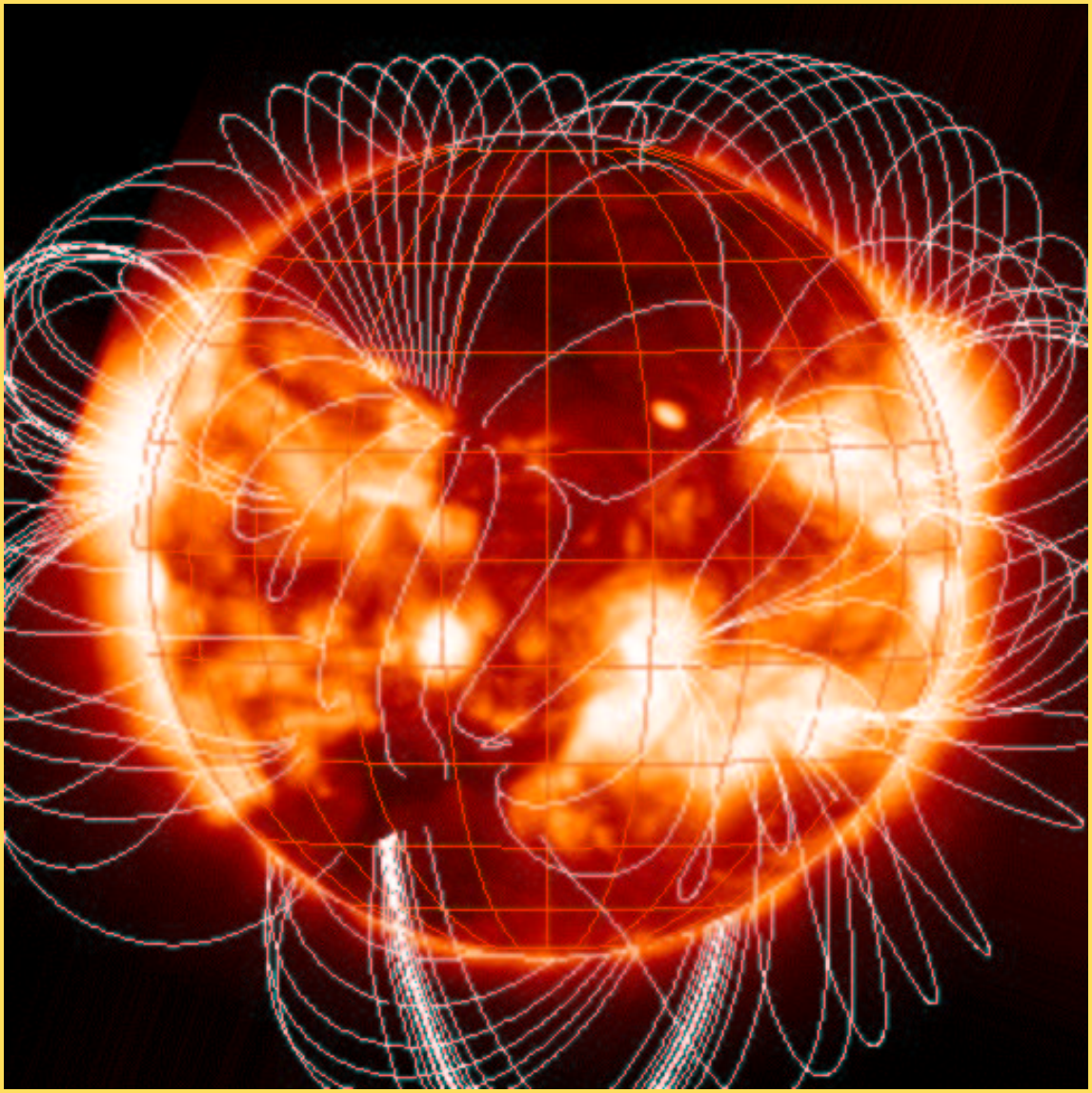
Space Environment Center 2002–2003



U.S. Department of Commerce

National Oceanic and Atmospheric Administration

February 2004

A Message from the Director

Funding

Funding for the years 2002 and 2003 has been remarkably complex and had serious effects on this Nation's civilian space weather service. Funding for FY02 fit the familiar pattern—a little less than the year before. FY03 funds were not appropriated until February 13, and the cut in SEC funding was dramatic.

The year 2003 was a scramble to find the funding to pay staff and to provide for only the most vital needs of the Space Environment Center. Bit by bit, pieces of funding were found or given, so that all SEC staff could stay, were paid, and could continue doing their jobs.

The current situation is rather brighter than it was three months ago. It appears that despite a reduced appropriation, funding has been identified to enable the Space Environment Center (SEC) to carry on in Fiscal Year 2004 at about the same level as in Fiscal Year 2003. We will continue to work for restoration (and even growth) of funding in Fiscal Years 2005 and 2006.

All of us at SEC are deeply grateful for the many letters and strong contacts that were directed to decision makers in Washington about the importance of space weather services and research. These calls and letters had a big effect, and helped set up the House Science Subcommittee Hearing in October 2003 on "Space Weather and Who Should Forecast It?"

Space Weather Program in NOAA

NOAA has identified several "Matrixed Managed" programs, which broadly cut across the agency. Fittingly, space weather is one of the matrixed programs. NOAA had many of its offices working together with SEC to instrument satellites, collect and process data, and archive and disseminate data. This new management brings the groups together in an organizational way that should strengthen the support of space weather. No units will change location or office, but the cooperation will be more real and will acknowledge space weather needs more directly.

Satellites

Happily, the long awaited Solar X-Ray Imager was turned on and became a "must have" operational instrument. While that accomplishment was celebrated, another effort began for a seriously needed instrument: a real-time solar wind monitor to replace our current source of data, NASA's ACE satellite. Upstream solar wind data are vitally needed by many industries, and we are now in the process of assuring that we will have data when ACE eventually fails.

Partnerships Remain Strong

Finally, while we have much to look forward to, we are especially appreciative of the support we get from our partners who work with us on new models, better products, and a new understanding of the space environment. Noteworthy in the last two years have been the establishment of modeling centers, the initiation of the NASA Living With A Star program, and completion of the shift of military space weather operations from Colorado Springs, CO to Omaha, NE. With our partners, we will provide better service to customers here on Earth, in Space, and on planets we have yet to visit.

Dr. Ernest Hildner, Director

Space Environment Center
325 Broadway
Boulder, CO 80305
303-497-3311, Fax 303-497-4006
Ernest.Hildner@noaa.gov

Space Environment Center

Cover: This figure is an example of the SXI imagery combined with magnetic model output showing the large-scale structure of the magnetic fields on the sun.

Welcome to Space Environment Center

As the Sun sets behind the mountains of Boulder, Colo., our telescope captured an enthusiastic SEC worker in silhouette.

The Space Environment Center (SEC), headquartered in Boulder, Colorado, is a part of the Department of Commerce National Oceanic and Atmospheric Administration (NOAA).

SEC is the national and world warning center for space weather disturbances that can affect people and equipment. The operations center, jointly operated by NOAA and the U.S. Air Force, provides forecasts and warnings, and real-time data about solar and geomagnetic activity to users in government and industry.

The SEC Mission Statement: SEC...

- continually monitors and forecasts Earth's space environment
- provides accurate, reliable, and useful solar-terrestrial information
- conducts and leads research and development programs to understand the environment and to improve services
- advises policymakers and planners
- plays a leadership role in the space weather community
- and fosters a space weather services industry.

SEC accomplishes the end-to-end tasks of developing requirements, acquiring sensors, doing data ingest, preparing products, and dissemination. SEC research scientists study the Sun, the region between the Sun and Earth, and Earth's magnetic field and upper atmosphere. From observations of these environments, scientists are able to improve understanding of the entire Sun-Earth connection and develop better forecasts of solar and geophysical disturbances.

New instruments and observing techniques continue to expand the amount of vital data, which are constantly being added to improve space weather monitoring and analysis. Because some of these data sets come from satellite observations, SEC takes a leading role in advocating and designing new sensors that will fly on government satellites.

Space Weather Forecasting

Space Weather Operations (SWO) continuously monitors, analyzes, and forecasts the environment between the Sun and Earth. Solar and geophysical data continuously flow into the Center in real-time from a large number of ground-based observatories and satellite sensors around the world. SWO forecasters use these data to predict solar and geomagnetic activity and issue worldwide alerts of extreme events.

What's SEC done lately?

To provide the best forecasts and services, SEC continually works to improve space-based instruments, from determining what space weather data to measure to working with contractors to build instruments, and interpreting the results. The Space Environment Monitors on the NOAA GOES and POES satellites are the real workhorses in satellite monitoring of the space environment.

Just made operational is the Solar X-ray Imager, an instrument that stares at the Sun and conveys what it sees to forecasters on the ground. This instrument is making possible a huge improvement in the forecasts of space weather at Earth.

Contents

Welcome to Space Environment Center . 1
SEC Past, Present, and Future 2
Space Weather Forecasting 3
Directed Research 5
GOES Acquisition 7
POES Acquisition 8
Product Development and Transition . . . 9
Satellite and Data Services 11
System and User Support 13
Environmental Literacy 14
Vision of SEC in 5 Years 15
Facts About SEC 16
SEC Staff list 18
Publications 19

SEC Past, Present and Future

History of Space Weather

Efforts have begun to write a book about the history of space weather from the perspective of work done by U.S. Government agencies who fostered and evolved into the Space Environment Center. Here is a small sample of the early history of the Space Environment Center.

SEC has been reorganized and renamed many times over the last 50 years. Groups that were predecessors of SEC are noted by (SEC).

- 1945—Space weather services were needed for radio communication and radars during WWII.
- 1946—During the buildup of the cold war and the resultant nuclear war dangers, key government agencies moved out of Washington. The Central Radio Propagation Lab (SEC) moved to Boulder, Colorado from Ft. Belvoir and began issuing daily warning/no warning forecasts.
- 1957—Sputnik was launched by the Russians. The CRPL Radio Physics Group (SEC) and National Center for Atmospheric Research High Altitude Observatory staff used their radio telescopes to track the satellite and provided the nation with predictions of the Sputnik Orbit for over a month.
- 1959—The CRPL Radio Physics Group (SEC) began their support for the planned NASA Mercury Missions, providing forecasts to enable reliable communications while Mercury was in orbit.
- 1963—President Kennedy declared that we would go to the Moon. Manned space flight is supported by CRPL (SEC) from then until the present.
- 1965—The Space Disturbances Lab (SEC) began routine forecasting services with the U.S. Air Force Air Weather Service.
- 1967—The Space Disturbances Forecast Center (SEC) is declared “operational,” that is, staffed continuously with a forecaster, an observer, and a communications operator.
- 1970—NOAA was created within the Department of Commerce. The Space Environment Laboratory (SEC) was incorporated (and renamed).
- 1995—SEL became one of the National Centers for Environmental Predication and was renamed Space Environment Center

NOAA Reorganizes its Processes

NOAA has worked in the last year and a half to find a better way of enumerating, selecting, funding and managing its tasks, directives and high-priority projects. We now have a combination of several interconnecting pieces.

1. A Planning, Programming, Budgeting and Execution System has been installed
2. A NOAA-wide Program Baseline Assessment has documented what we do and where programs fall short
3. An Office of Program Planning and Integration has been established to oversee the newly established Matrix Managed programs
4. An office of Program Analysis and Evaluation has been established to advise the Administrator regarding program resources and priorities.

The efforts to implement the plans represent a good start on a new system. Next year’s efforts will be easier.

SEC Operating Plan Organization

SEC worked hard to develop a Strategic Plan, consistent with NOAA’s and its Office of Oceanic and Atmospherics Administration’s strategic plans. Our annual operating plan guides us in achieving our strategic plan; it shows the effort expended and outcomes expected of each project in SEC.

This report is organized by the eight projects of SEC’s current annual operating plan:

- Space Weather Forecasting
- Directed Research
- GOES Acquisition
- POES/NPOESS Acquisition
- Product Development and Transition
- Satellite and Data Services
- Systems and User Support
- Environmental Literacy, Outreach, and Education

Space Weather Forecasting

The Space Weather Operations (SWO) Division of the Space Environment Center continued to provide space weather services to the nation on a 24 hour-a-day basis. SWO operates with three operations specialists, and one forecaster each day. The forecaster staff is augmented by two U.S. Air Force staff and two NOAA Corps officers.

Alerts, Warnings, and Watches

SEC's forecast center, a joint operation with the USAF, provides a number of daily space weather products, and special alerts, warnings, watches and advisories. These are a few of the key products produced by SWO:

- The Solar-Geophysical Activity Report and Forecast, which provides users with a daily summary of important activity during the previous 24 hours and a forecast of expected conditions for the next 3 days.
- Watches issued if conditions appear to be favorable for enhanced space weather conditions. This provides users significant lead time prior to the onset of the activity.
- Warnings issued if adverse conditions are imminent, with high probability.
- Alerts issued once adverse conditions are actually observed.
- SWO issues occasional advisories to inform the public and the media of the special circumstances and to increase awareness of the potential effects of space weather.

A major upgrade to SWO alert, warning, and watch services was implemented on March 12, 2002. At that time, a number of alerts and alert procedures were redefined to provide near-real-time notification of significant activity. A new type of product, called a summary, was also implemented; it fills in details about the alert and is issued after all the data are collected. The formats of the messages that are issued for the watches, warnings, alerts, and summaries were revised to be more readable, by both people and computers, and were expanded to include additional event information. New messages were also introduced that correspond to the NOAA Space Weather Scales, and some redundant products were eliminated. Geomagnetic warnings were improved to distinguish between a persistence warning (how long current activity will continue) and an onset warning (imminent increase in conditions). Geomagnetic alerts were improved by issuance in near-real time. In addition, a new warning was implemented to notify users when a shock is observed at the ACE solar wind spacecraft. Proton alerts were expanded, in response to user requests, to follow the NOAA S-scale hierarchy. Details of the SEC alerts services are now fully documented at http://www.sec.noaa.gov/alerts.

Space Weather Activity

Solar Cycle 23 has been in decline during 2002–2003 as we moved from the season of flares to the season of persistent high speed solar wind streams. Though sunspot number maximum was in April 2000, the Sun continued to be very active. Some particularly noteworthy intervals were these:

- high activity intervals in the middle of April 2002 and in late May 2002.
- a series of major flares during July and August 2002.
- major flares with geophysical effects in late May 2003.
- a series of major flares during June 2003.
- a record-breaking round of activity from the middle of October to early November 2003.

Regardless of these pulses of enhanced solar activity, high-speed solar wind streams from persistent coronal holes became the dominant features, especially during 2003, as we observed a recurring pattern of minor to major geomagnetic storm level activity in response. We expect solar minimum and the season of increased low-energy electrons (causing spacecraft charging) to be in the 2006–2008 time frame.

Keeping Us On Our Toes

The remarkable interval of solar-geophysical activity between October 19 and November 7, 2003, included 17 major solar flares, six strong interplanetary shocks, six significant injections of energetic particles, and extreme levels of geomagnetic storming on October 29 and 30. Among the more spectacular events were an ~X28 flare observed by the GOES XRS sensor on November 4, which may be the biggest ever seen by GOES (the sensors could not record the highest level); a severe energetic particle event on October 29, with peak fluxes making it the fourth highest observed in records going back to 1976; and an extreme geomagnetic storm which ranks as the sixth most intense since 1932, based on the running Ap index. This stormy interval provided unique

challenges and resulted in a number of success stories for space weather forecasting and nowcasting services. The intense activity affected a wide range of users and was well-covered by the media. There has been a significant increase in the number of users requesting various SWO products since these events.

The forecast center made use of a new and valuable forecasting tool during the October–November 2003 period of activity. The major events database allows forecasters to query historical events from the last three solar cycles (1970–present), using up to approximately 30 different query parameters (e.g. X-ray class, spot class, longitude and latitude, date, NOAA Scales, maximum Ap-index, etc.). After each major flare during the October–November 2003 activity, the database was queried for similar events. Having instant access to historical events aided in forecasting of CME transit times, maximum proton levels and geomagnetic response. A second version of the major event program is due in early 2004. The new version has many more features, including a space weather impacts section.

Solar Imaging

Significant progress has been made in the development of solar image acquisition and display tools in the operations center. SEC has convenient access to images that are now automatically ingested from several sources. Mauna Loa Observatory and the Big Bear Solar Observatory contribute to SEC. Image display and animation software has been developed with a convenient graphical user interface that enables forecasters and operations specialists to monitor sequences of images and to study specific historical intervals in the recent past. Software that allows forecasters to make direct measurements of the apparent speed of coronal mass ejections, and solar-rotation chart software that enable forecasters to study the slow evolution of recurring features on the Sun was also developed.

The Solar X-ray Imager (SXI) on GOES-12 was turned on in January 2003 and immediately began supplying once–a–minute images to SWO. The latest image and the past 24-hour movie sequence are routinely displayed in the forecast center, providing the operations staff with immediate knowledge of the current and recent location and morphology of solar activity. Image display, movie display, and real-time event display software allows operations staff to carry out more detailed observations using SXI. The availability of SXI images was particularly timely, given the closures of the USAF Ramey Solar Observatory (April 2003) and the Kitt Peak Vacuum Telescope (September 2003).

Verification

A major update to the SEC verification web pages (www.sec.noaa.gov/forecast_verification) was completed in September 2003. Effective use of SWO warnings and forecasts requires knowledge of their capability and limitations. Verification statistics and other quality information are now available on these web pages. The majority of the forecasts in the SWO primary daily forecast product—the Joint USAF-NOAA Report of Solar and Geophysical Activity (SDF)—are covered, as well as the SWO short-term geomagnetic K6 warning. The pages include a glossary of verification terms and a verification bibliography. More verification results for other routine SWO forecasts and warnings will be added along with new charts, analysis and other supplemental resources.

The Space Weather Operations is staffed all the time.

Directed Research

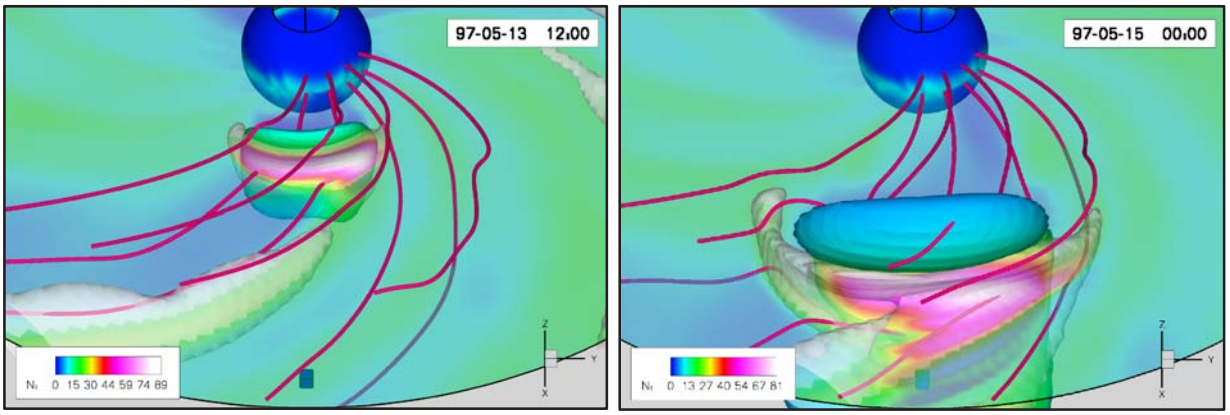
Directed research at SEC identifies research results suitable for transition into operations through collaborations with interagency and international partners and improves our understanding of the space environment and its effects. The space environment we study extends from the solar surface, through the heliosphere and interplanetary space, through Earth's magnetosphere, ionosphere and thermosphere. Researchers at SEC have expertise in all of these regions, so we are able to understand the Sun to Earth linkages that are crucial for developing new Space Weather products and services. SEC is the sole research entity within NOAA conducting space weather research. Because research and operations staff work together, our ability to transition research into operationally useful services is greatly enhanced.

Solar-Heliosphere Research

The participation of SEC in the development of sophisticated Sun-Earth models is a key element in the Center for Integrated Space Weather Modeling (CISM) and Multi-disciplinary University Research Initiatives (MURI) projects. SEC researchers provide empirical solar magnetic analyses, and play a strong role in developing the interplanetary models used to simulate coronal disturbances (executed by SAIC in San Diego and University of California at Berkeley). A model replication of a real-life coronal mass ejection (CME) event is shown below.

Another area of solar research involves solar eruptions that are dominated by the conversion of magnetic energy into thermal and mechanical (kinetic and gravitational potential) energy. Understanding this conversion process and its observable signatures will likely improve forecast accuracy substantially. Ongoing work at SEC includes examining magnetic energy converted to thermal energy in solar flares. Observations from the GOES SXI, along with other instruments such as the GOES XRS, SOHO EIT, and Yohkoh SXT are being used to refine our understanding of the formation and cooling of flare loops. The rapid cadence of SXI observations in multiple wavelength bands has enabled a precise chronology to be constructed for a major coronal mass ejection. Coronagraph observations, combined with SXI data have shown that in this eruption the magnitudes of flare thermal energy and CME mechanical energy are remarkably well correlated during the solar eruption's impulsive phase.

Using multiple wavelength bands from two different satellite instruments, GOES SXI and SOHO EIT, this false color composite shows cooling flare loops (bluish−green) and a hot, fan−like source above the loops (orange) to provide a new understanding of solar erruptions.



Visualization of a solar wind flow simulation for the halo CME event of May 12−15, 1997. In the left panel, the disturbance has just been ejected from the corona. At right, the strongly interacting stream and disturbance structure is about to impact Earth (location indicated by the blue box in both panels) Odstrcil et al.

Magnetospheric Research

One focus of SEC's magnetospheric research is to understanding the structure and dynamics of the radiation belts. The electron radiation belt is an important element of space weather, contributing to the radiation dose received by astronauts on the International Space Station and causing anomalous behavior and damage to spacecraft systems. Understanding the processes responsible for the observed rapid loss and regeneration of radiation belt electrons is a high priority for space weather operations and for space environment research.

We are developing techniques for determining the spatial structure of the radiation belts, and we are characterizing the solar wind and geomagnetic conditions that lead to rapid variations in the electron flux levels. This research will be important for the development of physics-based models of the space environment that will lead to improved predictions of hazardous space weather conditions.

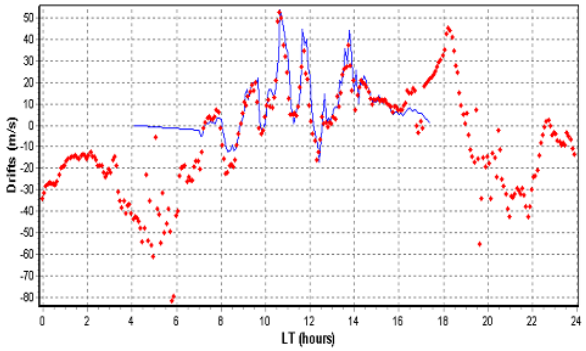
Ionosphere-Thermosphere Research

Variations in the state of the ionosphere are the source of many of the space weather impacts at ground level. Research at SEC over the past two years has been directed at understanding and predicting the changes in electrodynamics of the ionosphere at low latitudes. The results of this work explain the source of a significant fraction of the equatorial electrodynamic variability on Earth's nightside.

Research has also been conducted to develop ways to predict electrodynamic drift. The daytime equatorial electrojet is a narrow band of enhanced eastward current flowing in the 100 to 120 km altitude region within $\pm$ 2 degrees latitude of the dip equator. The strength of the vertical drifts is directly correlated to the development of ionospheric irregularities that already affect satellite communications and GPS navigation. The following figure shows the excellent agreement between the modeled drift (blue line) with the observed drift (red dots) on April 17, 2002, validating this technique.

Advocacy, Planning, and Service

SEC serves as a focal point for the space weather research, observation and forecasting efforts in our nation. The directed research effort at SEC has the important responsibility of providing interagency and international leadership and advocacy for the space weather part of NOAA's overall mission. This includes a large effort to collaborate with interagency and international activities and to ensure that NOAA and the public benefit from these activities. SEC provides services to worldwide research and development efforts, we collaborate with external researchers, and we direct activities outside of NOAA toward the needs of users of space weather services. Our close interaction with colleagues improves our research, and it helps focus their activities on needed space weather services.



Comparison between predicted drift from ground-based magnetometer observations and Jicamarca incoherent scatter measurements.

The numerous activities in which SEC staff have participated include: Space Weather Week organization, participation on the National Academy of Sciences Decadal Survey panels, research conducted with the DoD Multi-disciplinary University Research Initiatives, participation on the steering committee and working groups of the interagency Community Coordinated Modeling Center, participation on NASA Living With a Star mission definition teams and panels, collaboration in the NSF supported Center for Integrated Space Weather Modeling Science and Technology Center, participation on national and international planning and review committees, and hosting numerous meetings. Through these activities, SEC maintains an active involvement in the research community. Through this active participation in interagency and international activities, SEC is able to benefit from the worldwide investment in space weather and to help direct this broad effort to the benefit of customers for space weather services.

GOES Acquisition

GOES Space Environment Monitors

Geostationary Operational Environmental Satellites (GOES) Space Environment Monitor (SEM) instruments on the NOAA GOES satellites are the foundation for many of the space weather forecasts, alerts, and warnings; they also provide the measures used for two of the three NOAA Space Weather Scales (Solar Radiation Storms and Radio Blackouts). The SEMs include measurements of solar and galactic energetic particles, solar X-rays (both whole-disk integrated and solar images), energetic particles in Earth's magnetosphere, and geomagnetic field variations. To assure that the GOES instrumentation, the ground system, and data processing meet all requirements, the GOES Acquisition Project at SEC includes activities to improve and sustain the high-quality GOES instrumentation and data. We work closely with the satellite group (NESDIS) within NOAA, and with NASA and its contractors.

The current GOES series of satellites includes GOES-8, 9, 10, 11, and 12. At this time, GOES-10 and 12 are operational, GOES-11 is in on-orbit storage waiting to be activated when it is needed, and GOES-8 and 9 are located near Japan, with GOES-8 being used by the Japanese meteorological community. In September 2002, SEC held a major GOES Project Review that provided an overview of the project status and accomplishments.

GOES-N,O, and P Sensor Development, Data Processing System, and Ground Data System

The next series of GOES satellites, referred to as GOES-N, O, and P, which will become GOES-13, 14, and 15 after launch, are currently under development at Boeing Satellite Systems. In preparation for the launch of GOES-N in December 2004, SEC staff are monitoring instrument development, testing, and integration, and are designing and developing the systems needed at SEC for the ingest, processing, validation, distribution, archive, and display of the GOES SEM data.

The GOES-N, O, and P spacecraft will include improved SEM instruments to better support our growing space weather customers. The improvements include:

- two magnetometers (currently there is one)
- solar X-Ray Sensor (XRS) combined with a new Extreme UltraViolet sensor (EUV),
- sensors to measure a broader energy range and directionality of energetic particles,,
- a new Solar X-Ray Imager (SXI) that will have improved sensitivity and spatial resolution.

GOES-N will launch in December 2004, the first of the the GOES-N, O, and P series spacecraft built by Boeing Satellite Systems.

Work has begun on the GOES-N, O, and P SEM data processing algorithms, data access, and data storage for these new instruments. New products are also being investigated. Unlike the development of the GOES-12 SXI data system, which took place as an isolated project within the established GOES 8-12 SEM architecture, the SXI data system will be fully integrated into the GOES-N, O, and P data system. It will take full advantage of new and redesigned architectural elements and system infrastructure.

To improve SEC capabilities to track GOES and other satellites, SEC has begun an effort to upgrade and improve its ground system tracking and receiving resources. While we normally receive the GOES SEM data directly through antennas located in Boulder, we occasionally rely on new methods to receive GOES data in near-real time over land-line from the NOAA SOCC (Satellite Operations Control Center). This improved capability also provides us an important alternative pathway to receive GOES data. Other improvements include several new communications lines.

GOES R+ Planning

SEC staff has made major contributions to planning for the GOES-R series of satellites that will be launched around 2012. We have written the GOES SEM Operational Requirements Document and participated in the development of documents such as the GOES-R Program Requirements Document (GPRD) and Mission Requirements Document (MRD). Significant effort has been devoted to developing the draft requirements for the sensors on GOES-R, including SEC hosting two requirements workshops: one for Energetic Particles and the other for Solar EUV measurements. The information from these workshops has been used for the refinement of requirements for the formulation phase studies for the SEM instruments.

POES Acquisitions

POES Space Environment Monitor

The Polar Orbiting Operational Environmental Satellite (POES) Space Environment Monitor (SEM) instruments monitor the particle radiation environment just above Earth's atmosphere. These particles produce local heating of the upper atmosphere, enhance the electron density of the ionosphere, and collide with the atmosphere at high latitudes to produce the aurora. The areas impacted by the radiation environment include radio communication and navigation, satellite operations, astronauts and the passengers and crew on high altitude aircraft. The POES products include measures of the total energy flux into the high latitude regions and statistical maps of the aurora. A product mapping the high energy particle flux has been developed for use by the airline industry to indicate regions of enhanced or severe particle flux that often results in loss of air-to-ground communications.

POES Solar Backscatter Ultraviolet Sensor

The POES Solar Backscatter Ultraviolet Sensor (SBUV) instruments are primarily used for measuring ozone profiles, but on a daily basis, they also measure the solar flux. These data are used to calculate the Mg II Index, a long-term record of solar variability. This index is used in modeling the stratosphere, thermosphere, and ionosphere. The index is also used to model total solar irradiance, which is in turn used in models of long-term climate change.

POES Satellite and Instrument Status

The SEM instruments on the NOAA POES-14, 15, and 16 satellites continue to provide excellent coverage of the near-Earth space environment. The NOAA-16 SBUV is presently the primary sensor for collecting the Mg II core-to-wing ratios that make up the MGII index. The launch of NOAA POES 17 occurred in February 2002 and the satellite was made "operational" in July 2002. The NOAA-17 SBUV exhibited some degradation in sensitivity early in the mission but has stabilized and is fully functional. The NOAA POES-N satellite is ready for launch and is expected to launch sometime after July 2004. The POES-N' satellite met with an untimely demise while still on the ground. Replacement of the POES-N' satellite is under consideration as are many options to augment the POES program with data from other Low-Earth-Orbit satellites. This issue has not been resolved.

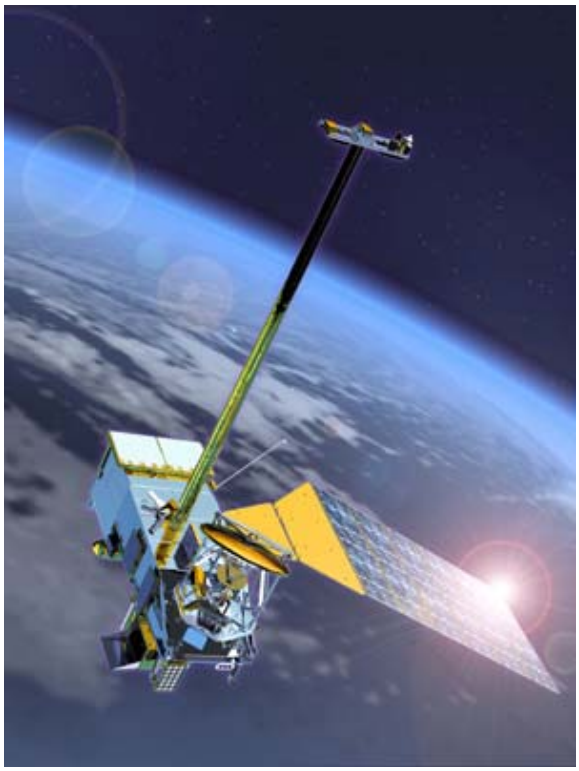
SEM Instrument Contract:

SEC manages the contract for the construction of SEM instruments for POES and the European METOP program. There were a total of 9 SEM-2 instruments purchased from GE Panametrics under this contract, including the Engineering model. SEMs are now on orbit on the NOAA-14, 15, 16, and 17 spacecraft and are performing well. The last SEM-2 should be delivered by the end of March 2004 and will likely be used as the POES-N' replacement instrument.

National Polar Orbiting Operational Environmental Satellite System

The National Polar Orbiting Operational Environmental Satellite System (NPOESS) program is designed to combine the civilian POES and the military Defense Meteorological Satellite Program (DMSP) into one program beginning in about 2010 and having spacecraft in three orbits. The Space Environment Sensor Suite (SESS) on NPOESS is intended to combine and enhance elements of the POES and DMSP space environment sensors. The implementation of SESS on all POES satellites is in jeopardy question due to considerations of phasing while DMSP is still flying and due to budgetary constraints.

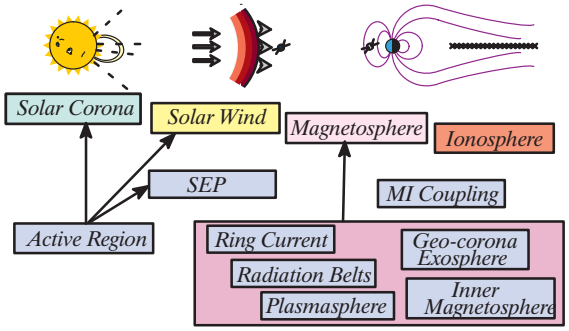
Artist's rendition of NPOESS in orbit



Product Development and Transition

The development of new products and the transition of research models and data into operations are necessary for SEC to continually improve space weather services for its customers. SEC manages the Nation's "test bed" for space weather products. What follows are but a few examples of recent new products and projects currently being prepared for operational transition.

Research to Operations Opportunities



This figure diagrams the complex set of coupled models being developed and integrated by CISM.

SEC is a partner in the Center for Integrated Space Weather Modeling (CISM), which is funded by NSF. CISM is dedicated to building a comprehensive physics-based numerical simulation model that describes the space environment from the Sun to the Earth. SEC is also a consortium member of the Community Coordinated Modeling Center (CCMC) along with many other government agencies. The CCMC is a facility designed to develop and test coupled models of the space environment.

Transition Candidate Evaluation and Selection

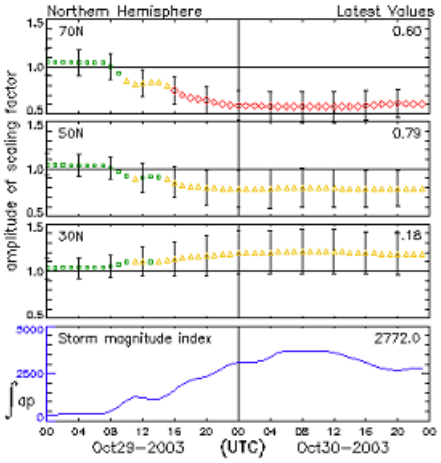
SEC recently developed an objective process to prioritize new models and data. This process facilitates the transition of new models and data into operations and maximizes the effectiveness of limited SEC resources. This iterative process is one that involves the evaluation and scoring of transition candidates by a diverse team of scientists, developers, operators, and users. Prioritization of the candidate is based on strategic importance, operational significance, and implementation readiness. The process has been exercised three times and has resulted in three models either fully transitioned or actively being developed.

Recent Model Transitions and Works in Progress

Specification of an operations concept, software development, integration into operational systems and data, validation in an operational environment, preparing extensive documentation, and training for users and support staff are only a few of the tasks required to make a model fully operational. Nevertheless, SEC has made steady progress in recent years bringing new models on-line and the experience gained with each transition has served to further streamline the process. Below are a few examples of recently transitioned models and ones that are currently being considered:

Storm-Time Empirical Ionospheric Correction Model (STORM)

STORM is the most recent model to become fully operational at SEC (summer of 2003). This empirical model provides a useful, yet simple tool for estimating the changes to the ionosphere in response to geomagnetic activity



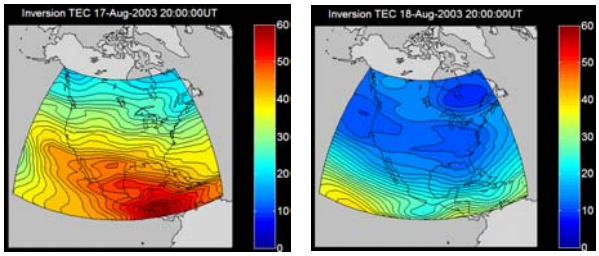
This figure of the northern hemisphere output of the STORM model shows the estimated scaling factor required to adjust the F-region critical frequency from normal during the large geomagnetic storms on October 29–30, 2003.

UPOS Real-Time Kp Model

SEC and the USAF are working towards the operational implementation of a new model that makes real-time estimates of the geomagnetic index, Kp. This model was initially developed through the University Partnering for Operational Support (UPOS) program. Operational transition of new geomagnetic products is expected this year.

Status of Global Assimilation of Ionospheric Measurements (GAIM)

The goal of GAIM is to characterize the state of the ionosphere-globally, regionally, and locally-providing both specification and forecasts. Recent work at SEC has concentrated on validation of the GAIM approach, and evaluation of its output with regards to accuracy and improvement over existing techniques. GAIM consistently shows accuracies 2 to 3 times that of the current empirical models.



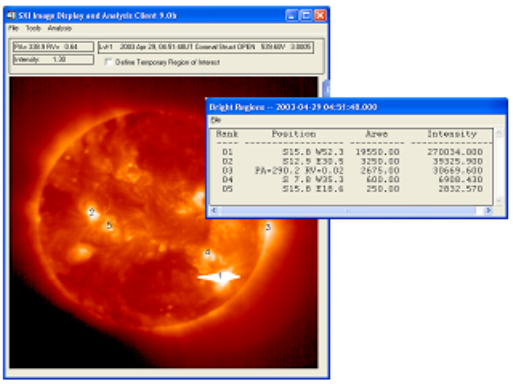
These figures show the response of the ionosphere over the CONUS in response to a geomagnetic storm in August 2003. The left figure shows the normal development of the peak total electron content during the day reaching values over 50 TEC units on August 17. On the storm day on August 18th, in the right figure, the geomagnetic storm wiped out the normal development of the dayside peak, leaving a trough in electron density (in cooperation with the National Geodetic Survey).

Solar2000 and Mg II Index Products

The NOAA MgII index continues to be used in the Solar 2000 operational product, developed by our CRADA (Cooperative Research and Development Agreement) partner, Space Environment Technologies, Inc. Increased security enhancements have been made to the data processing, by implementing the use of development and operational computers so there is dual processing of the data. In addition, changes to the data flow from SOCC to SEC have made the process more robust. The NOAA MgII index is available, updated daily, through SEC's web site.

GOES SXI Product Enhancements

Real-time images from the Solar X-ray Imager (SXI) became routinely operational in March 2003. These images enabled the creation of several new products and forecast analysis tools related to flare identification and reporting, active region tracking and analysis, coronal hole identification, and detection of various energetic events such as filament eruptions and CMEs. Future enhancements to existing SXI products include software to generate real-time region-of-interest light curves and the ability to combine model output to SXI images, such as to characterize the large-scale magnetic fields associated with the x-ray emissions.



An example of the SXI Image Display and Analysis client is shown above. This new tool allows the identification and tracking of active regions and other areas of interest.

New OUS Products

Most new SEC products eventually make their way to the SEC Outside User System (OUS), because the OUS has become one of the primary conduits for delivering SEC space weather services to our customers. Consequently, the OUS undergoes frequent updates and additions. Highlights of some of the new OUS products in this past year include:

- GOES SXI solar images and movie sequences.
- Near-real-time data lists and plots of the Boulder Magnetometer.
- Redesigned and updated Forecast Verification pages.
- D-Region Absorption Prediction animations
- More Ionospheric stations' data were added.

Some planned OUS products for the coming year include:

- An improved and expanded Mail Subscription Services.
- The addition of daily Solar Synoptic Maps and analyses.
- The output of new models transitioned into operations.

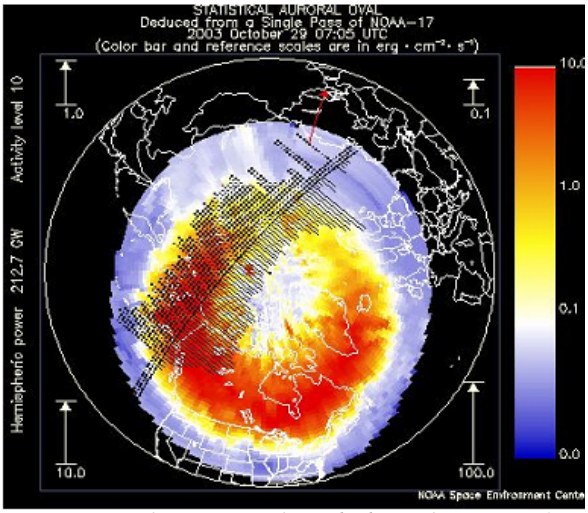
Satellite and Data Services

GOES SEM Data Processing, Verification, and Validation

The GOES Space Environment Monitor (SEM) data include measurements of solar x-rays, solar and galactic energetic particles, energetic particles trapped in the near-Earth space environment, and Earth's magnetic field. Substantial effort is dedicated to ensuring that these data are processed, verified, and validated for use by Space Weather Operations, SEC customers, the world-wide scientific community, the NOAA National Geophysical Data Center, and the NASA CDAWeb. Some of the recent accomplishments of SEC using the GOES SEM data include: changes to telemetry processing, SWO displays, web pages, and data products to accommodate GOES-12 replacing GOES-8 in April 2003. There were also changes to use GOES-11 proton data and to process correctly other GOES-12 energetic particle channels after the failure of some particle channels on GOES-12, end-of-life tests on GOES-8 to monitor the magnetometer calibration, model-data comparisons, and significant improvements to the magnetometer processing to remove signal contamination from spacecraft torquer currents.

POES Activities

NOAA-17 SEM data came on line at SEC in July, 2002. The instrument is operating well and complements the data from NOAA-14, NOAA-15 and NOAA-16 to provide unprecedented local-time and geographic longitude coverage of the near-Earth space environment. The NOAA-18 satellite is expected to be launched in mid-2004. Archiving NOAA-12 SEM data at SEC was terminated.



POES SEM data is posted regularly on the SEC web site (http://www.sec.noaa.gov/pmap) and often accounts for 30% to 40% of the outside accesses to SEC web servers.

During the last two years, SEC utilized POES SEM data to support a number of spacecraft anomaly studies. These included the ADEOS malfunction, anomalies on the NASA GALEX and RHESSI satellites, the Columbia shuttle accident, and a number of problems on DOD satellites.

Real-Time Solar Wind Data from ACE

The NASA Advanced Composition Explorer (ACE) satellite, launched in 1997 into a special orbit 1.5 million km (about 1 million miles) from Earth, began broadcasting a continuous flow of real-time solar wind data January 21, 1998. NOAA SEC developed an international partnership to track ACE 24 hours a day, collecting data from stations at Communications Research Laboratory in Japan, Rutherford-Appleton Laboratory in England, Indian Space and Research Organization in India, the NOAA stations located at Wallops Island, Virginia, and Boulder, Colorado, the Deep Space Network run by NASA, and the USAF network. While ACE reached the end of its design life in 2003, and has experienced some minor aging problems, it continues to broadcast reliable space weather data, and is expected to operate for many years to come, based on its fuel reserve.

These data have allowed SEC to develop and issue highly reliable alerts and warnings, with up to an hour lead time, of imminent geomagnetic storms. Such storms produce dramatic changes in the geomagnetic field of Earth, leading to problems in delicate technological systems on satellites, in electric power grids, and in navigational and communication systems. The real-time data are relied on and used throughout the United States by other federal agencies, commercial firms, scientists, and the general public. Additionally, the data and products are used throughout the world, as space weather storms can envelop much of the Earth within minutes, impacting all technologically advanced countries.

SXI on GOES

On January 22, 2003, the GOES-12 Solar X-Ray Imager (SXI) began imaging the Sun and had an immediate positive impact on forecasting. Almost immediately an extraneous source of light was evident when the filter was in the "OPEN" filter position. This source was attributed to a pinhole light leak in one of the entrance filters. The

effect was removed in ground processing of the images after a substantial effort by SEC staff, and the SXI formally entered operations on April 26, 2003, providing the forecast center with high cadence images of the Sun. The forecast center received real-time SXI data with an availability level of 97.7% from January to September. Two anomalies occurred in the fall:

- On Sept. 2, 2003, anomalies in the detector high voltage power supply forced the detector to be run only at lower voltages, but on October 28, SXI returned to operations, with only slightly degraded capabilities.
- On November 5, 2003, an apparent total failure of one of the entrance filters flooded the SXI telescope with too much sunlight, rendering the OPEN filter position unusable. This forced further degradation in the SXI capabilities.

The SXI has been operating continuously since November 12, 2003. In this difficult first year, the SXI saw setbacks as well as successes, and remains a great asset for the forecast center.

Data Display System

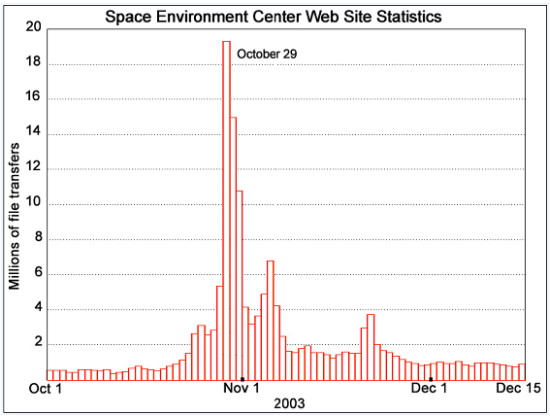
Release 1.3 of the Data Display System (DDS) software was developed over the last 2 years to correct software problems in previous releases, and to add new functionality and displays. SEC was unable to fully deploy this release because of staff resource limitations and competing priorities.

While the display components of the DDS remain under test, four new IDS clients and a data monitoring and alarm system (which provide audio alerts when selected thresholds have been exceeded) have been released in beta versions. SEC plans to release this software at the beginning of 2004.

SEC External Web Site Activities

Use of the SEC web site (*http://www.sec.noaa.gov*) increased by 50% in the last 2 years to an average 600,000 "hits" per day.

During the high solar activity and media attention of October and November 2003, SEC experienced record traffic (see following graph). SEC moved its web site to the NOAA web farm in Boulder, Colorado, just in time to serve nearly 20 million hits. SEC continues to use the NOAA web farm and plans further capacity, reliability, and bandwidth improvements through the use of other NOAA common internet services.



Common System Services

SEC spent significant effort in 2003 researching, designing and prototyping a new suite of software services that will improve SEC operational IT systems.

These services include both SEC developed and open source software:

- Directory Service—middleware services using a central directory lookup service.
- Bridge Service—safe interface to the SEC Database
- Logging Service—application log records.
- Messaging Service—distributed applications.
- FTP Servers—to provide public *ftp* for data providers and a dissemination service for external customers to SEC.

Database Migration

In 2002 and 2003, SEC began to migrate its space weather data from a legacy database to a data-storage system, SWDS (Space Weather Data Stores). SEC has verified and operationally deployed the following data within SWDS:

- GOES-8, 10, 11 and 12 SEM data
- ACE data
- Ionospheric SAO data

A new ground data system to acquire GOES-12 SXI image data was also developed by SEC during 2002 and 2003. The database portion of this system was developed utilizing the new SWDS relational and file store capabilities.

In the next 2 years, SEC plans to add GOES-N SEM, SXI, Ground Based Magnetometer, Ionospheric and derived product data to the SWDS system.

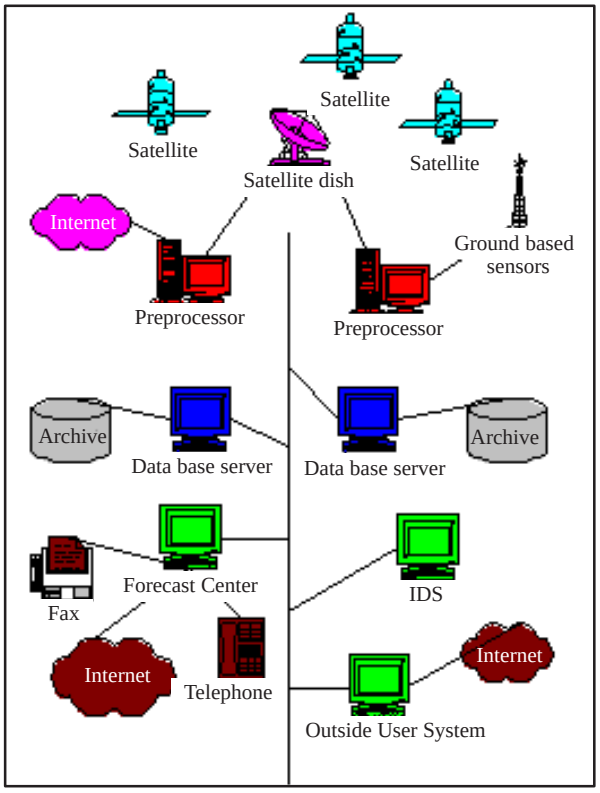
Systems and User Support

The primary goal of the Systems and User Support group is to provide the most reliable systems for SEC users and customers. Because the SEC computer systems are the lifeblood of nearly every task that is performed at the Center, the Systems and User Support personnel interface with every group and user in the Center.

Instrumentation

Instrumentation and data flow are two important priorities Systems Support. A 3-axis magnetometer was installed at the Table Mountain Observatory to provide back up, redundancy and verification of magnetic activity. This installation included excavation, installation, insulation, and calibration of the instrument and its corresponding preprocessor hardware.

The support group ensures that data from the primary GOES satellites are acquired, processed and delivered to all customers, including the SEC Space Weather Operations forecast center. Real-time solar wind data from the ACE (Advanced Composition Explorer) satellite is also received when it is within SEC's reception footprint. These data are received on a ground system that includes antennas, receivers, bit synchronizers, communication lines and preprocessor systems. All of this equipment is maintained and supported by SEC personnel.



End-to-end data acquisition, processing, and dissemination systems

Infrastructure

The ATM (Asynchronous Transfer Mode) backbone in the David Skaggs Research Center (DSRC, NOAA's building in Boulder) network was replaced by a Gigabit network. This replacement was performed in conjunction with and the cooperation of all the building tenants, including the NOC (Network Operations Center). The planning and preparation spanned several months and the actual switchover was accomplished in approximately 4 hours. Impacts to the SEC operational systems were kept to a minimum and very little data was lost.

System administration is provided to a wide variety of systems and platforms. These operating systems include Hewlett Packard HP-UX, DEC Ultrix, DEC UNIX, Microsoft Windows 2000, Microsoft Windows XP, Microsoft Windows NT 4.0, RedHat Linux, and Apple OSX. In addition domain name e-mail and web services are maintained and supported. All operational systems are supported at all times.

Customers

The systems maintained by the support group are used by everyone working at the Center, and are also utilized by a wide variety of customers who use SEC data. These customers include government agencies, like the U.S. Air Force, NASA, and FAA, and customers from the private industry sector. While most of the data are available on the Web, maintaining the Web services is only one type of support. Transfers of files and support for SEC-written software run by customers remotely are also part of the customer support.

IT Security

SEC has provided information to DOC and various parts of NOAA. Information from SEC has included security plans and self assessments, contingency plans, and responses to security alert actions. SEC will continue to respond to data calls and will continue to improve the security of our IT environment.

Computer Users Committee

As a way of ensuring good communication and responsive support for users, the CUC (Computer Users Committee) meets twice a month and reviews proposed changes to computer systems or suggestions users would like to offer. Policies, problems, recommendations, or joint efforts with other computer projects are frequently discussed and appropriately carried out.

Environmental Literacy

Environmental Literacy is a newly stated goal for NOAA. SEC efforts encompass two methods for achieving this goal: outreach and education. Environmental Literacy at SEC has taken on some remarkable roles in the last two years, both teaching and encouraging science education and also hearing back from the public and our customers.

Outreach

Space Weather Week

One of the most important outreach activities at SEC is the one that lets us communicate with our customers: the annual Space Weather Week conference. The 2003 conference, held May 19–22, drew record crowds of users, researchers, and industry and vendor representatives. In addition to the full agenda of solar activity reports, user effects, and research work on modeling the environment, several distinguished speakers gave us a view of the larger interest in Space Weather.

Space Weather Week is co-organized by the NOAA Space Environment Center, the Air Force Research Laboratory, the NSF Division of Atmospheric Science, and the NASA Sun-Earth Connection Program.

Who are our customers?

The most consistent answer to that question is that there are more and more of them. The sheer volume of them is reflected in the number of hits on our web site, an average of 600,000 per day, and as many a 19 million on a very busy day. Here are some examples of the industries that are inexorably linked to space weather

- U.S. power grid infrastructure
- Human space flight
- Spacecraft launch teams
- Commercial airline industry
- Telecommunications users
- Space commerce and transportation
- GPS users
- All Department of Defense units

For a short time, at least, one of our important new customers is the people who work for NOAA in the National Weather Service. Because SEC is joining the Weather Service, many of them will be learning about space weather, as we learn about how the meteorological side works.

Customer Survey

To answer the many questions that flooded us from Washington about our customers, our products and services, and our expenditures, we sent out an informal e-mail survey to some of our customers. The results were most helpful, and gave us a wealth of knowledge about how space weather information is used to mitigate problems or explain failures in various industries.

Outreach at the AMS

The first major presence of space weather at an American Meteorological Society (AMS) annual meeting in January 2004 was an unqualified success. Meteorologists enjoyed the exposure and saw space weather services as analogous to meteorological services.

Education

Students Here and There

Besides the many visits to classrooms our scientists make in a year to schools in the area (and sometimes neighboring states!), NOAA hosted 150 middle-school children from the Boulder Valley School District. Their "NOAA Science Day" was a pilot program created as part of a partnership between NOAA and the School District. The goal is to make it possible for all eighth graders in the district to attend a day at NOAA. The pilot visit was a great success. Children came away with lots of enthusiasm, knowledge, and interest. The teachers and scientists had ideas on how to make it even better.

The Denver Museum of Nature and Science

For the third year, SEC has been able to be a sponsor for the Museum with the NOAA Educational Partnership Program funds. This year, a diversity of students in the greater Denver area will be able to attend the newly opened wing of the museum called Space Odyssey. The subject matter is not only fascinating science, it covers the scientific parts of the NOAA Space Weather Program.

Vision of SEC in 5 Years

Considerable change occurred within NOAA the last 2 years as the Administrator introduced a new planning system called Planning, Programming, Budgeting and Execution System and established formal "programs" to carry out NOAA's work. This resulted in a direct and important impact on SEC and its future.

Evolved Customer and Partner Needs

Five years from now, we expect society will have an even greater dependence upon space weather services. New technologies have new vulnerabilities to space weather, especially when competition forces operating margins to shrink and risks due to space weather grow. At the same time, new data and models mean that space weather products will better serve users everywhere.

The Role of Space Weather in NOAA

SEC became the heart of NOAA's newly formed Space Weather Program, which included functions scattered throughout NOAA. Space Weather, and in particular SEC, became a visibly significant program in NOAA.

By FY08 SEC will be in the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP), will be issuing space weather aviation products through the NWS Aviation Weather Center and enhanced products through the NWS Family of Services, and will have models that run on the NCEP supercomputers alongside the tropospheric weather models. SEC will have expanded its involvement in the American Meteorological Society and continued to run its yearly Space Weather Week conferences, a melting pot that brings together, in one place at one time, forecasters, researchers, commercial users, vendors, and a far-ranging collection of international players.

Enhanced Guidance to Forecasters

Forecasts will evolve from today's once daily products to include rolling updates as conditions change. For instance, forecasts of communication and radiation conditions affecting airlines need to be updated more often than daily. In FY08 the next solar cycle will be ramping up, resulting in a shift from one dominant type of space weather activity to another, from recurrent high speed streams to large flares and solar storms. Forecasters will be using the first of a continuing and evolving string of physically based global models, producing regional and local specifications and forecasts of space weather conditions. This will be an evolutionary step up from the empirically based models run today. A number of models are under development within the larger space weather community with funds from NSF, NASA, and DOD, and they will be nearing their beginning transition phase. They range from the models involving the Sun and its output, to models dropping down to the stratosphere.

Expanded NOAA Space Weather Data

Considerable evolution also will have occurred in the data available from NOAA. The first of the new GOES satellites, N, will be supplying vast new streams of data, from instruments including an upgraded version of SXI, the first ever Extreme Ultraviolet (EUV) operational sensor, new instruments to measure the Earth's radiation belt particles, and expanded radiation detectors. The subsequent series of GOES, starting with GOES-R, with even more expanded instrumentation, will be in fabrication. A new series of Polar satellites, called NPOESS, will be in the building phase, with an expanded suite of space weather instruments. These spacecraft combine the former NOAA POES and DOD DMSP programs into one unified program.

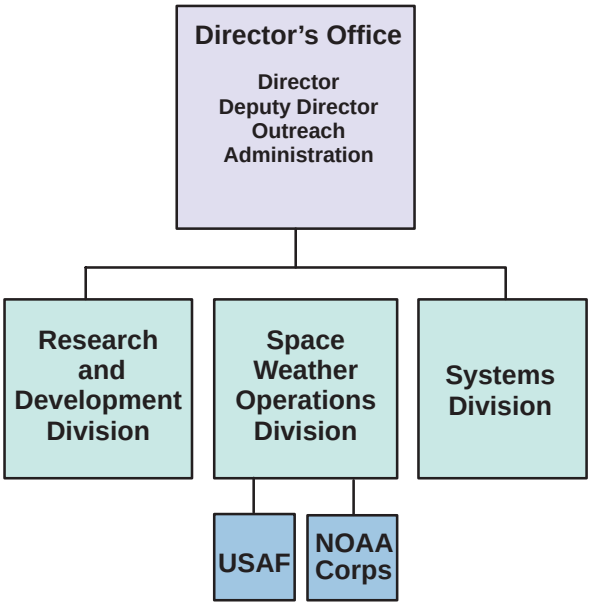
Beyond ACE, the Geostorms L1 Mission

SEC continues to strive to develop a mission to replace the current Advanced Composition Explorer (ACE) spacecraft as the source of needed real-time solar wind measurements. By FY08 it could be in development for launch before the next solar maximum.

Continued Acquisition of Data from Research Satellites

SEC will continue to take advantage of new sensors flown for research purposes by NASA, DOD and, where possible, by Europe and Japan. Two notable missions will be supplying real-time data to NOAA by FY08, the NASA missions STEREO and SDO. The STEREO mission will allow us to see, for the first time, the Sun and its solar storms from two directions simultaneously. The NOAA led ground station network will be tracking and gathering STEREO data in real time for use in operations. NASA's SDO (Solar Dynamics Observatory) will be supplying continuous solar data at a remarkably high time resolution, more than a factor of 10 beyond anything available today.

Facts about SEC



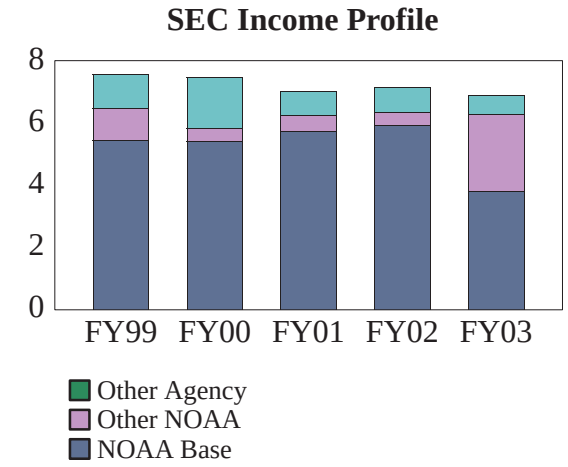
Center Organization—SEC continues to operate within a streamlined structure that minimizes organizational levels, but allows redeployment of resources quickly as situations change. Our staff works across organizational boundaries to support the many Center-wide tasks.

Program Planning—In 2003 SEC was identified as one of 41 programs within NOAA. This formalized our role as participants in NOAA's planning process. To accommodate this change in status, SEC has made a concerted effort to realign its projects with the official NOAA projects and themes. You can see the projects reflected in this report as subject heads.

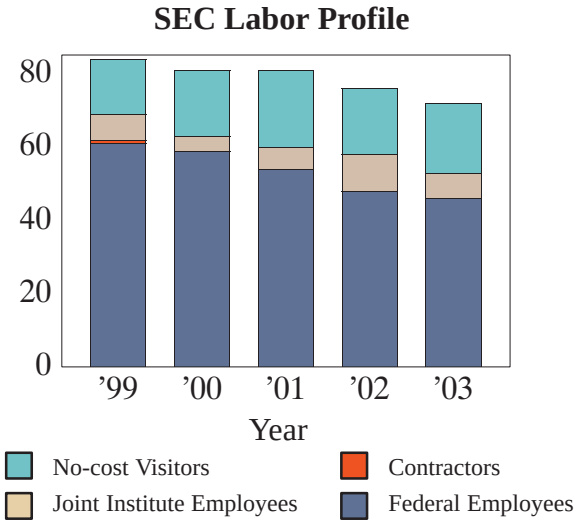
Funding—The major source of funding at SEC is through a direct appropriation from Congress; supplements to this base funding come from special NOAA programs and from other government agency sponsors. In the past few years NOAA and its Office of Oceanic and Atmospheric Research (OAR) have focused on trying to make Laboratory funds increase to offset increasing labor costs.

In FY03 SEC struggled through a reduced budget; through belt tightening and help from NOAA OAR we were able to make it through the year without losing staff.

Partners—SEC could not succeed without its partners. The SEC forecast center is a joint operation between NOAA and the USAF Weather Agency, which assigns three persons to SEC. Two NOAA Corps officers also work at SEC and another helps run the USAF solar observatory at Learmonth, Australia. Partnership with CIRES (Cooperative Institute for Research in Environmental Studies) at the University of Colorado is extremely beneficial. Finally, all federal agencies interested in space weather are loosely bound together in the National Space Weather Program, an organization which has successfully encouraged partnerships among the agencies.



Personnel—SEC continues to benefit from a wide range of Joint Institute employees, visitors, and various special guest workers on staff. SEC has been able to continue its high level of research, development, and operational activities through the use of this non-civil servant staff.



Personnel and Activities

EEO and Diversity—The Space Environment Center is committed to the principles of Equal Employment Opportunity and Diversity. Our greatest challenge in this regard is our lack of growth. For the past few years we have been shrinking in size and have had little opportunity for recruitments. Recognizing this, we have taken steps to create our own internal career mobility program. Staff members with aspirations for career enhancement have been encouraged to participate in the training necessary to move their careers forward. To date, we have been able to promote two employees from support positions into the professional IT career path. We also enjoy a broad representation of different cultures through our many international employees and visitors, and have devoted resources to the development of educational materials for elementary, junior and high school students.

Committee memberships, review boards, planning groups—SEC staff members played critical roles in the space environment community, authoring numerous scientific papers, participating in proposal and journal article reviews, leading professional organizations, and interest groups, and as members of numerous organizing committees of meetings. A few examples of SEC staff serving in critical roles follow:

- Co-chair of the National Space Weather Program governing Committee on Space Weather.
- Secretary, ISES; member, ISES Directing Board.
- Fellow, CIRES.
- Member, SHINE Steering Committee.
- Member, NASA Living with a Star Science Architecture Team.
- Member, Editorial Advisory Board, *GPS Solutions* Journal
- Members, NASA LWS Geospace Mission Definition Team.
- Member, National Solar Observatory SOLIS advisory group.
- Member, High Altitude Observatory Director's Advisory Committee
- Member, Coordinated Community Modeling Center Steering Committee
- Invited Lecturer, UCLA Slichter Lecturer, 2002
- Chair, COSPAR (Committee on Space Research) Panel on Space Weather.
- Secretary, American Geophysical Union Space Physics and Aeronomy-Solar Magnetospheric Section.
- Member, NSF Geospace Environment Modeling (GEM) Steering Committee.
- Member, SCOSTEP S-RAMP Committee on Space Weather.
- Member, National Solar Observatory Users Committee.
- Members of four of the National Academy of Sciences Panels for Solar and Space Physics.
- Members, several NASA Peer Review Panel for research proposals to the Living with a Star program.
- Member, Government Advisory Team for the NPOESS Space Environment Sensor Suite.
- Members, AMS Symposium for Space Weather organizing committee

Space Environment Center Staff and Associates

Staff who worked at SEC sometime during 2002–2003

Systems Division

Abeyta, Jim
Barsness, Steve
Cruickshank, Cheryl
Curtiss, Candice
DeFoor, Tom
Finelli, Dave
Ito, Dave
Lewis, Dave
Masten, Bob
McKillen, Kathleen, Sec'y
Prendergast, Kelly
Raben, Vi Hill
Sayler, Steve
Wolf, Carol

Guest Workers and CIRES

England, Marcus
Enney, Chris
Fedrick, Kelvin
Grubb, Dick
Husler, Mike
Padmanabham, Gopa
Stone, David
Taylor, John
Vickroy, Jim

SWO Division

Balch, Chris
Cohen, Norm
Combs, Larry
Crown, Misty
Doggett, Kent
Gajdys, Patrick
Kunches, Joe, Chief
McKillen, Kathleen, Sec'y
Miller, Warren
Murtagh, Bill
Nelson, Gayle
Real, Dan
Tegnell, Ken
Williamson, Court

NOAA CORPS

Hilton, Alan
Weaver, Mike, LCDR
Zezula, David, LT

U.S. AIR FORCE

Doser, Kelly, Capt
Jacobson, Rick, TSgt

Research and Development Division

Bergstedt, Pam
Biesecker, Doug
Detman, Tom
Evans, Dave
Garcia, Howard
Greer, Sue
Hill, Steve
Matheson, Lorne
Muckle, Alex
Newman, Ann
Onsager, Terry
Pizzo, Vic
Puga, Larry
Singer, Howard, Chief
Smith, Zdenka
Stewart, Rhonda, Sec'y
Vierick, Rodney

Guest Workers and CIRES

Akmaev, Rashid
Anderson, Dave
Anghel, Adela
Araujo, Eduardo
Arge, Nick
Codrescu, Mihail
Davies, Ken
Dryer, Murray
Faied, Dohy
Fraser, Brian
Fuller-Rowell, Tim
Green, Janet
Heaton, Amanda
Hood, Chris
Kiplinger, Alan
Koratova, Galina
Markel, Rob
Maruyama, Naomi
Mayer, Leslie
Minter, Cliff
Neupert, Werner
Odstrcil, Dusan
O'Loughlin, Karen
Romanov, Alex
Sauer, Herb
Singer, Kelsi
Speiser, Ted
Spencer, Paul
Wahl, Susan
Weigel, Robert

Administration

Crumly, Mike
Deitemeyer, Pat, Sec'y
Garcia, Nancy
Heckman, Gary
Hildner, Ernie, Director
Poppe, Barbara
Zwickl, Ron, Asst. Director

Guest Workers and CIRES

Aucone, Ryan
Bouwer, Dave
Joselyn, JoAnn

SEC Works Published in FY 2002 and 2003

FY02 Publications

Akmaev, R. A., Modeling the cooling due to CO2 increases in the mesosphere and lower thermosphere, *Phys. Chem. Earth*, v. **27**, 521–528, 2002.

Anderson, D., **A. Anghel**, K. Yumoto, M. Ishitsuka, and E. Kudeki, Estimating daytime vertical ExB drift velocities in the equatorial F–region using ground–based magnetometer observations, *Geophys. Res. Lett.*, **29**(12), 1596, doi: 10.1029/2001 GL014562, 2002.

Araujo–Pradere, E. A., **T. J. Fuller–Rowell**, **M. V. Codrescu**, STORM: An empirical storm–time ionospheric correction model 1. Model Description, *Radio Science* **37**, (5), 1070, doi:10.1029/2001RS002467, 2002.

Araujo–Pradere, E. A., Quality of STORM model predictions for a mid–latitude station *Geofisica Internaciona*, **41**, num. 2, pp. 195–201, 2002.

Araujo–Pradere, E. A., **T. J. Fuller–Rowell**, D. Bilitza, An example of validation of the STORM response in IRI2000, *Radio Science and, 2002 Ionospheric Effects* Symposium, p.202–209, 2002.

Arge, C. N., **E. Hildner**, **V. J. Pizzo**, and J. W. Harvey, Two solar cycles of nonincreasing magnetic flux, *J. Geophys. Res.*, **107**(A10), 1319, doi:10.1029/2001JA000503, 2002.

Arge, C. N., S. Wahl, J. Chen, S. Slinker, and **V. J. Pizzo**, Implementation and Verification of the Chen Prediction Technique for Forecasting Large Nonrecurrent Storms, in press Adv. in *Space Res*, *Proceedings of the COSPAR Colloquium on* Solar–Terrestrial Magnetic Activity and Space Environment, **14**, 393–396, 2002.

Baker, D. N., W. K. Peterson, S. Eriksson, X. Li, J. B. Blake, J. L. Burch, P. W. Daly, M. W. Dunlop, A. Korth, E. Donovan, R. Friedel, T. A. Fritz, H. U. Frey, S. B. Mende, J. Roeder, **H.J. Singer**, Timing of magnetic reconnection initiation during a global magnetospheric substorm onset, *Geophys. Res. Lett.*, **29**(24), 2190, doi: 10.1029/2002 GL015539, 2002.

Boudouridis, A., H. E. Spence and **T. G. Onsager**, Formation of the LLBL in the context of a unifying magnetopause reconnection mechanism, in The Low–Latitude Boundary Layer and its Dynamic Interaction With the Solar Wind and Magnetosphere, ed. P. T. Newell and T. G. Onsager, *American Geophysical Union*, 2002.

Boudouridis, A., H. E. Spence, **T.G. Onsager**, A new look at the pulsed reconnection model of the dayside magnetopause, *Advances in Space Research*, **30**, (10), 2295, 2002

Codrescu, M. V., Auroral E–field Variability Effects in the Ionosphere, *2002 Ionospheric Effects Symposium*, p. 107–113, 2002.

Codrescu, M. V, and Tomoko Matsuo, Auroral E–field Variability Effects in the Ionosphere, *IES2002 Proceedings*, p. 107–114, 2002.

Coumans, V., J.–C. Gérard, B. Hubert, and **D. S. Evans**, Electron and proton excitation of the FUV aurora: Simultaneous IMAGE and NOAA observations, *J. Geophys. Res.*, **107**(A11), 1347,doi:10.1029/2001JA009233, 2002.

Dryer, M., C. D. Fry, W. Sun, C. S. Deehr, **Z. Smith**, S. I. Akasofu, and M. D. Andrews, Prediction in Real–Time of the 2000 July 14 Heliospheric Shock Wave and Its Companions during the "Bastille" Epoch, *Solar Phys.*, **204**, 267–286, 2001, 2002.

Engebretson, M. J., W. K. Peterson, J. L. Posch, M. R. Klatt, B. J. Anderson, C. T. Russell, **H. J. Singer**, R. L. Arnoldy, and H. Fukunishi, Observations of two types of Pc 1-2 pulsations in the outer dayside magnetosphere, *J. Geophys. Res.*, **107**(A12), 1451, doi:10.1029/2001JA000198, 2002.

Evans, D. S., J. Lemaire, V. Pierrard, M. Roth, and J. De Keyser, Simulation of discrete auroral arcs, *Proceedings of the 6th International Conference on Substorms*, Ed. R. Winglee, 2002.

Fry, C. D., W. Sun, C. S. Deehr, **M. Dryer, Z. Smith**, S. I. Akasofu, M. Tokumaru, and M. Kojima, Improvements to the HAF Solar Wind Model for Space Weather Predictions, *J. Geophys. Res.*, **106**, 20,985–21,001, 2001, 2002.

Fry, C. D., W. Sun, C. Deehr, **M. Dryer, Z. Smith** and S.–I. Akasofu, "Real–time space weather forecasting driven by solar observations," in Solar–Terrestrial Magnetic Activity and Space Environment, H. Wang and R. Xu (eds), *COSPAR Colloquia* Series on Physics and Astronomy, Elsevier Science, pp 401–407, 2002.

Fry C. D., **M. Dryer, Z. Smith**, W. Sun, C. S. Deehr, S–I. Akasofu, Forecasting solar wind structures and shock arrival times using an ensemble of models, *J.Geophys.R* vol **106** pp 20985– 21001, 2002.

Fuller–Rowell, T. J., G.H. Millward, A.D. Richmond, **M. V. Codrescu**, Storm–Time changes in the upper atmosphere at low latitudes, *PERGAMON–Journal of Atmospheric and solar–terrestrial Physics*, **64** p.1383–1391, 2002.

Fuller–Rowell, Timothy, **Cliff Minte**r, **Mihail Codrescu**, Data Assimilation for Neutral Thermospheric Species during Geomagnetic Storms, *2002 Ionopheric Effects Symposium*, p.239–247, 2002.

Ganushkina, N. Yu, T. I. Pulkkinen, M. V. Kubyshkina, and **H. J. Singer**, Comparative Study of Magnetospheric Configuration Changes During May 2, 1998 Moderate Storm and May 4, 1998 Intense Storm Events, *Proc, International Conference on* Substorms **6** (ICS–6), Ed. R.M. Winglee, 478, 2002.

Ganushkina, N. Y., T. I. Pulkkinen, M. V. Kubyshkina, **H. J. Singer**, and C. T. Russell, Modeling the ring current magnetic field during storms, *J. Geophys. Res.*, **107**(A7), 1092, doi:10.1029/2001JA900101, 2002.

Henderson, M. G., L. Kepko, H. E. Spence, M. Connors, J. B. Sigwarth, L. A. Frank, **H. J. Singer**, and K. Yumoto, The Evolution of North–South Aligned Auroral Forms into Auroral Torch Structures: The Generation of Omega Bands and Ps6 Pulsations via Flow Bursts, *Proc. International Conference on Substorms 6 (ICS–6)*, Ed. R.M. Winglee, **169**, 2002.

Hubert, B., J.–C. Gérard, **D. S. Evans**, M. Meurant, S. B. Mende, H. U. Frey, and T. J. Immel, Total electron and proton energy input during auroral substorms: Remote sensing with IMAGE–FUV, *J. Geophys. Res.*, **107**(A8), 10.1029/2001JA009229, 2002.

Huttunen, K. E. J., H. E. J. Koskinen, T. I. Pulkkinen, A. Pulkkinen, M. Palmroth, E. G. D. Reeves, and **H. J. Singer**, April 2000 magnetic storm: Solar wind driver and magnetospheric response, *J. Geophys. Res.*, **107**(A12), 1440, doi: 10.1029/2001 JA009154, 2002.

Kartalev, M. D., K. G. Grigorov, **Z. Smith, M. Dryer**, D. D. Fry, Wei Sun, and C. S. Deehr, Comparative Study of Predicted and Experimentally Detected Interplanetary Shocks, *SOLSPA: The Second Solar Cycle and Space Weather Euro conference* ESA SP–**477**, p.355, February 2002.

Kepko, L., H. E. Spence, **H. J. Singer**, ULF waves in the solar wind as direct drivers of magnetospheric pulsations, *Geophys Res. Lett*, **29** (8), 1197, doi: 10.1029/2001 GL014405, 2002.

Klobuchar, John A. and **Joseph M. Kunches**, "Eye on the Ionosphere: Report on the Ionospheric Effects Symposium, IES 2002," *GPS Solutions, Springer–Verlag*, Berlin, Vol. **6**, No. 1–2, pp 124–125, November 2002.

Korotova, G. I., D. G. Sibeck, **H. J. Singer**, and T. J. Rosenberg, Tracking transient events through geosynchronous orbit and in the high–latitude ionosphere, *J. Geophys.* Res., **107**(A11), 1345, doi:10.1029/2002JA009477, 2002.

Kunches, Joseph M. and John A. Klobuchar, "Eye on the Ionosphere: Tracking Geomagnetic Storms," *GPS Solutions, John Wiley and Sons, New York*, Vol. **5**, No. 3, pp 94–95, February 2002.

Lu, G., E. F. Donovan, T. Nagai, T. Mukai, D. Lummerzheim, G. K. Parks, L. A. Frank, **H. J. Singer**, M. B. Moldwin, J. L. Posch, M. J. Engebretson, and J. Watermann, Substorm Development as Seen Through Coordinated Multi–instrument Observations, *Proc. International Conference on Substorms 6 (ICS–6)*, Ed. R.M. Winglee, **63**, 2002.

Luhmann, J. G., Y. Li, **C. N. Arge**, P. R. Gazis, and R. Ulrich, Solar cycle changes in coronal holes and space weather cycles, *J. Geophys. Res*., **107**(A8), 1154, doi: 10.1029/2001 JA007550, 2002.

McKenna–Lawlor, S. M. P., **M. Dryer, Z. Smith**, K. Kecskemety, C. D. Fry,W. Sun, D. S. Deehr, D. Berdichevsky, K. Kudela and G. Zastenker, Arrival Times of Flare/HALO CME Associated Shocks at the Earth: Comparison of the Predictions of Three Numerical Models with These Observations, *Annales Geophys*., **20**, 917–935, 2002.

McPherron, R. L., M. G. Kivelson, K. Khurana, O. Amm, J. B. Baker, A. Balogh, H. Reme, M. Connors, F. Creutzberg, I. Dandouras, I. Mann, D. Milling, M. B. Moldwin, G. Rostoker, C. T. Russell, and **H. Singer**, Cluster Observations of the Postmidnight Plasma Sheet at 18 Re during Substorms, *Proc. International* Conference on Substorms **6** (ICS–6), Ed. R.M. Winglee, 478, 2002.

Moon, Y–J., **M. Dryer, Z. Smith**, Y. D. Park, and K.–S. Cho, A Revised Shock Time of Arrival (STOA) Model for Interplanetary Shock Propagation: STOA–2, *Geophys. Res.* Lett., **29** (10), 10.1029/2002 GL 014865, online, 22 May, 2002.

Odstrcil, D., and **V. J Pizzo**, Numerical simulation of interplanetary disturbances, in: *Proceedings of the Second Solar Cycle and Space Weather Euroconference, 24–29* September (2001), Vico Equense, Italy. Editor: Huguette Sawaya–Lacoste. *ESA* SP– **477**, Noordwijk: *ESA* Publications Division, ISBN 92–9092–749–6, 2002, p. 281 - 284, 2002.

Odstrcil, D., J. A. Linker, R. Lionello, Z. Mikic, P. Riley, **V. J. Pizzo**, and J. G. Luhmann. 3–D MHD simulations of CMEs by coupled coronal and heliospheric models In Solar variability: from core to outer frontiers, *Proc, 10th European Solar* Physics Meeting (Prague, Czech Republic), ESA SP–**506**, pp. 95–98, 2002.

Odstrcil, D., J. A. Linker, R. Lionello, Z. Mikic, P. Riley, **V. J. Pizzo**, and J. G. Luhmann, Merging of coronal and heliospheric numerical two–dimensional MHD models, *J. Geophys. Res*.,**107**(A12), 1493, doi:10.1029/2002JA009334, 2002.

Onsager, T. G., and J. D. Scudder, Low–latitude boundary layer formation by magnetic reconnection, in The Low–Latitude Boundary Layer and its Dynamic Interaction With the Solar Wind and Magnetosphere, ed. P. T. Newell and T. G. Onsager, *American* Geophysical Union, 2002.

Onsager, T. G., G. Rostoker, H.–J. Kim, G. D. Reeves, T. Obara, **H. J. Singer**, and C. Smithtro, Radiation belt electron flux dropouts: Local time, radial, and particle–energy dependence, *J.Geophys. Res.*, **107**(A11), 1382, doi:10.1029/2001JA000187, 2002.

Riley, P., J. A. Linker, Z. Mikic, **D. Odstrcil, V. J.Pizzo**, and D. F. Webb, Evidence of post–eruption reconnection associated with coronal mass ejections in the solar wind, *Astrophys J*., **578**, 972–978, 2002.

Roth M., J. De Keyser, and **D. S. Evans**, On the formation of discrete auroral arcs, *Physicalia Magazine of the Belgian Physical Society*, 2002.

Schunk, Robert W., Ludger Scherliess, Jan J. Sojka, Donald C. Thompson, **David N. Anderson, Mihail Codrescu, Cliff Minter, Timothy J. Fuller–Rowell**, Roderick A. Heelis, Marc Hairston, Bruce M. Howe, Global Assimilation of Ionospheric Measurements (GAIM), *2002 Ionospheric Effects Symposium*, p.50–61, 2002.

Slavin, J. A., D. H. Fairfield, R. P. Lepping, M. Hesse, A. Ieda, E. Tanskanen, N. Ostgaard, T. Mukai, T. Nagai, **H. J. Singer**, P.R. Sutcliffe, Simultaneous observations of earthward flow bursts and plasmoid ejection during magnetospheric substorms. *J. Geophys Res.*, **107** (A7), 10.10292000JA003501, 2002.

Smith, Z., **W. Murtagh**, C. Smithtro, Using solar wind energetic ion enhancements to forecast large geomagnetic storms, proc. "*SOLSPA: The Second Solar Cycle And Space Weather Euroconference*", Vico Equense, Italy, 24–25 September, 2001: ESA sp–**477**, p409, February 2002.

Smith, Z., **M. Dryer**, C. D. Fry, Wei Sun and C. S. Deehr, The Role Of Interactions Of Solar–Initiated Interplanetary Disturbances Within 1 AU In Real Time Predictions Of Shocks "*SOLSPA: The Second Solar Cycle And Space Weather Euroconference*", Vico Equense, Italy, 24–25 September, 2001: ESA sp–**409**, p.377, February 2002.

Søraas, F., K. Aarsnes, K. Oksavik, and **D. S. Evans**, Ring current intensity estimated from low–altitude proton observations, *J. Geophys. Res*., **107**(A7), 1149, doi: 10.1029/2001 JA000123, 2002.

Sun, W., **M. Dryer**, C. D. Fry, C. S. Deehr, **Z. Smith**, S.–I. Akasofu, M. D. Kartalev, and K. G. Grigorov, Real–time forecasting of ICME shock arrivals at L1 during the April fool's Day" epoch: 28 March–21 April 2001, *Annales Geophysicae*, Vol **20**, p. 937–945, 2002.

Sun, W., **M. Dryer**, C. D. Fry, C. S. Deehr, **Z. Smith**, S.–I. Akasofu, M. D. Kartalev, and K. G. Grigorov, Evaluation of Solar Type II Radio Burst Estimates of Initial Solar Wind Shock Speed Using a Kinematic Model of the Solar Wind on the April 2001 Solar Event Swarm, *Geophys. Res. Lett*., **29**(8), 10.1029/2001GL013659, online, 17April, 2002.

Sun, W., **M. Dryer**, C. D. Fry, C. S. Deehr, **Z. Smith**, S. I. Akasofu, M. D. Kartalev, and K. G. Grigorov, Annales Geophysicae, Real time forecasting of ICME shock arrivals at L1 during the "April Fool's day epoch 28 March–21 April 2001, *Annales Geophys*. **20**: 937–945, 2002.

Thompson, Richard and **Joseph M. Kunches**, "Eye on the Ionosphere: Solar Cycle 23 - A Progress Report," *GPS Solutions, Springer–Verlag, Berlin*, Vol**. 6,** No. 1–2, pp 121–123, November 2002.

Tsurutani B. T., L. D. Zhang, G. L. Mason, G. S. Lakhina, T. Hada, J. K. Arballo, and **R. D. Zwick**l, Particle transport in He–rich events: Wave–particle interations and particle anisotropy measurements, Annales Geophysicae (2002) **20**:427–444, European Geophysical Society 2002. File

Vandas, M., **D. Odstrcil**, and S. Watari, Simulation of magnetic cloud propagation in three dimensions, In: *Proc. Second Solar Cycle and Space Weather Euroconference*, 24–29 September 2001, Vico Equense, Italy, ESA SP–**477**, pp. 293–296, 2002.

Vandas, M., **D. Odstrcil**, and S. Watari, Three–dimensional MHD simulation of a loop– like magnetic cloud in the solar wind, *J. Geophys. Res*., **107**, 10.1029/2001JA005068, 2002.

Wing, S., D. G. Sibeck, M. Wiltberger, and **H. Singer**, Geosynchronous magnetic field temporal response to solar wind and IMF variations, *J. Geophys. Res*., **107**(A8), 1222,doi:10.1029/2001JA009156, 2002.

Wu, S. T., H. Zheng, S. Wang, B. J. Thompson, S. P. Plunkett, X. P. Zhao, and **M. Dryer**, Three–Dimensional Numerical Simulation of MHD Waves Observed by the Extreme Ultraviolet Imaging Telescope, *J. Geophys. Res*., **106**, 25,089–25,102, 2001. FY 2002.

The LWS Geospace Storm Investigations: Exploring the Extremes of Space Weather, Report of the Living With a Star Geospace Mission Definition Team, Chair, Paul Kintner, Co–authors: Kintner, Lebair, Hoffman, Basu, Fennell, **Fuller–Rowell**, Germany, Ginet, Golightly, Heelis, Hudson, Meier, Mitchell, Pfaff, Reeves, Robinson, Schunk, **Singer**, Sojka, Thorne, Wolf, and Wygant, NASA/TM–202– 211613, September 2002.

FY03 publications

Akmaev, R. A., Comment on "Time series, periodograms, and significance" by G. Hernandez, *J. Geophys. Res*., Vol. **108**, No. A5, 1187, doi:10.1029/2002JA009687, 2003.

Akmaev, R. A., Thermospheric resistance to "greenhouse cooling": Effect of the collisional excitation rate by atomic oxygen on the thermal response to CO2 forcing, *J. Geophys. Res.*, Vol **108,** NO. A7, 1292, doi:10.1029/2003JA009896,2003.

Araujo–Pradere, E. A., **T. J. Fuller–Rowell**, and D. Bilitza, Validation of the STORM response in IRI2000, *J. Geophys. Res*., **108**(A3), 1120, doi:10.1029/2002JA009720, 2003.

Arge C. N., **D. Odstrcil**, **V. J. Pizzo**, and **L. R. Mayer**, Improved method for specifying solar wind speed near the Sun, In: *Proc. Solar Wind Ten*, AIP **679**, pp. 190–193, 2003.

Burke, Williams J. and **Joseph M. Kunches**, "Space Weather Conditions on February 1, 2003," *The Columbia Accident Investigation Report*, Vol.**2,** Appendix D.5, pp 133–144, U.S. Government Printing Office, Washington, DC, October 2003.

Cho, K.–S., K.–S. Kim, Y.–J. Moon, and **M. Dryer**, Initial Results of the Ichon Solar Radio Spectrograph, *Solar Physics* **212**: 151–163, 2003.

Dobrzycka D., J. C. Raymond, **D. A. Biesecker**, J. Li, And A. Ciaravella, Ultraviolet Spectroscopy of Narrow Coronal Mass Ejections, *The Astrophysical Journal*, **588**:586–595, 2003 May 1.

Fry, C. D., **M. Dryer**, **Z. Smith**, W. Sun, C. S. Deehr, and S.–I. Akasofu, Forecasting solar wind structures and shock arrival times using an ensemble of models, *J.* Geophys. Res., **108**(A2), 1070, doi:10.1029/2002JA009474, 2003.

Galand, M., J. Baumgardner, S. Chakrabarti, U. P. Levhaug, B. Isham, J. Jussila, **D. S. Evans**, F. Rich, D. Lummerzheim, Proton and Electron Aurora Over Eiscat: Optical Signature and Associated Ionospheric Perturbations, *Proceedings of the 30th annual* European meeting on Atmospheric Studies by Optical Methods, 2003.

Ganushkina, N. Yu, T. I. Pulkkinen, M. V. Kubyshkina, **H. J. Singer**, and C. T. Russell, Long term evolution of magnetospheric current systems during storms, *Annales* Geophysicae, 2003.

Hill, Steve; **Pizzo, Victor J**., Advanced solar imaging from the GOES–R spacecraft, Innovative Telescopes and Instrumentation for Solar Astrophysics. Edited by Stephen L. Keil, Sergey V. Avakyan . *Proceedings of the SPIE*, Volume **4853**, pp. 465–478 (2003).

Klobuchar John A., **Joseph M. Kunches**, Comparative range delay and variability of the earth's troposphere and the ionosphere, Eye on the Ionosphere, *GPS Solutions*, **7:55**–58 DOI 10.1007/s10291–003–0047–5, 2003.

Lamy, P., **D. A. Biesecker**, and O. Groussin, SOHO/LASCO observation of an outburst of Comet 2P/Encke at its 2000 perihelion passage, *ICARUS*, **163**, 142–149, 2003.

Li, X., T. E. Sarris, D. N. Baker, W. K. Peterson, and **H. J. Singer**, Simulation of energetic particle injections associated with a substorm on August 27, 2001, *Geophys. Res. Lett.*, **30**(1), 1004, doi:10.1029/2002GL015967, 2003.

Linker, J. A., Z. Mikic, R. Lionello, P. Riley, T. Amari, and **D. Odstrcil**, Flux cancellation and coronal mass ejections, *Phys. of Plasmas*, **10**, 1971–1978, 2003.

Linker J. A, Z. Mikic, P. Riley, R. Lionello, and **D. Odstrcil**, Models of coronal mass ejections: A review with a look to the future, In: *Proc. Solar Wind Ten*, AIP **679**, pp. 703–710, 2003.

Meurant, M., J. C. Gerd, B. Hubert, V. Coumans, V. I. Shematovich, D. V. Bisikalo, **D. S Evans**, G. R. Gladstone, and S. B. Mende, Characterization and dynamics of the auroral electron precipitation during substorms deduced from IMAGE–FUV, *J. Geophys. Res*., **108**(A6), 1247, doi:10. 1029/2002JA009685, 2003.

Moldwin, M. B., P. C. Liewer, N. Crooker, J. F. Fennell, J. Feynman, H. O. Funsten, B. E. Goldstein, J. T. Gosling, J. E. Mazur, **V. J. Pizzo**, C. T. Russell, and J. Weygand, Heliospheric Constellation: Understanding the Structure and Evolution of the Solar Wind, in *Solar Wind Ten: Proceedings of the Tenth International Solar ind* Conference, (M. Velli, R. Bruno and F. Malara, Eds.), American Inst. of Physics, Vol. **679**, pp. 842–845, 2003.

Odstrcil, D., Modeling 3–D solar wind structures, *Adv. Space Res*., 32(4), 497–506, 2003.

Odstrcil, D., P. Riley, J. A. Linker, R. Lionello, Z. Mikic, and **V. J. Pizzo**, 3–D simulations of ICMEs by coupled coronal and heliospheric models, In: *Solar Cycle* Studies, ESA SP–**535**, pp. 541–546, 2003.

Odstrcil, D.; Riley, P.; Linker, J. A.; Lionello, R.; Mikic, Z.; **Pizzo, V. J**., 3–D simulations of ICMEs by coupled coronal and heliospheric models, In: Solar variability as an input to the Earth's environment. International Solar Cycle Studies (ISCS) Symposium, 23 – 28 June 2003, Tatranská Lomnica, Slovak Republic. Ed.:A. Wilson. ESA SP–**535**, Noordwijk*: ESA Publications Division*, ISBN 92–9092–845–X, 2003, p. 541 - 546.

Odstrcil, D., J. A. Linker, R. Lionello, Z. Mikic, P. Riley, **V. J. Pizzo**, and J. G. Luhmann, 3–D MHD simulations of CMEs by coupled coronal and heliospheric models, In: *Proc. 10th European Solar Physics Meeting*, ESA SP **506**, pp. 95–98, 2003.

Odstrcil, D., M. Vandas, **V. J. Pizzo** and P. MacNeice, Numerical Simulation of Interacting Magnetic Flux Ropes, in *Solar Wind Ten: Proceedings of the Tenth* International Solar Wind Conference, (M. Velli,R. Bruno and F. Malara, Eds.), *American Inst. of Physics*, Vol**. 679**, pp. 699–702, 2003.

Riley, P., J. A. Linker, Z. Mikic, **D. Odstrcil**, T. H. Zurbuchen, D. Lario, and R. P. Lepping, Using an MHD simulation to interpret the global context of a coronal mass ejection observed by two spacecraft, *J. Geophys. Res*., **108**, doi:10.1029/2002JA009760, 2003.

Shanmugaraju, A., Y.–J. Moon, **M. Dryer**, and S. Umapathy, On The Kinematic Evolution of Flare–Associated CMEs, *Solar Physics* **215**: 185–201, 2003.

Sibeck, D. G., N. B. Trivedi, E. Zesta, R. B. Decker, **H. J. Singer**, A. Szabo, H. Tachihara, and J. Watermann, Pressure–pulse interation with the magnetosphere and ionosphere, *J. Geophys. Res*., **108** (A2), 1095, doi:10.1029/2002JA009675, 2003.

Skoug, R. M., M. F. Thomsen, M. G. Henderson, H. O. Funsten, G. D. Reeves, C. J. Pollock, J. M. Jahn, D. J. McComas, D. G. Mitchell, P. C. Brandt, B. R. Sandel, C. R. Clauer, and **H. J. Singer**, Tail–dominated storm main phase: 31 March 2001, *J. Geophys. Res*., **108**(A6), 1259, doi:10.1029/2002JA009705, 2003.

Soraas F., K. Oksavik, K. Aarsnes, **D. S. Evans**, and **M. S. Greer**, Storm time equatorial belt - an "image" of RC behavior, *Geophysical Research Letters*, **30** (2), 1052, doi:10.1029/2002GL015636, 2003.

Soraas F., K. Aarsnes, K. Oksavik, M. I. Sandanger, **D. S. Evans**, and **M. S. Greer**, *Journal of Atmospheric and Solar–Terrestrial Physics*, 7 May 2003.

Singer, H. J., Stormy weather in space, Book review on Storms from the Sun: The Emerging Science of Space Weather, *Nature*, vol **422**/6mar2003/p.21–22, 2003.

Smith, Zdenka, Demonstration of Method to Evaluate in the Operational Environment Space Weather Models that Predict Shock Arrivals and Geomagnetic Disturbances Using solar and Interplanetary Data for Input, *Proc. 10th. European Solar Physics* Meeting, "Solar Variability: Core to Outer Frontiers", Prague, Czech Republic, 9–14 September 2002 (ESA SP–**506**, December 2002).

Smith, Zdenka, W. Murtagh, T. Detman, **M. Dryer**, C. D. Fry, C.–C. Wu, Study of Solar–Based Inputs Into Space Weather Models That Predict Interplanetary Shock–Arrivals at Earth, *Proc. ISCS 2003 Symposium, "Solar Variability as an Input to the* Earth's Environment". Tatranska Lomnica, Slovakia, 23–28 June 2003.

Teriaca Luca, Giannina Poletto, Marco Romoli, and **Doug A. Biesecker**, The Nascent Solar Wind: Origin And Acceleration, *The Astrophysical Journal*, **588**:566–577, 2003 May 1.

Toivanen, P. K., D. N. Baker, W. K. Peterson, **H. J. Singer**, J. Watermann, J. R. Wygant, C. T. Russell, and C. A. Kletzing, Polar observations of transverse magnetic pulsations initiated at substorm onset in the high–latitude plasma sheet, *J. Geophys.* Res., **108**(A7), 1267, doi:10.1029/2001JA009141, 2003.

Tsyganenko, N. A., **H. J. Singer**, and J. C. Kasper, Storm–time distortion of the inner magnetosphere: How severe can it get?, *J. Geophys. Res.*, **108**(A5), 1209, doi:10.1029/2002JA009808, 2003.

Yahnina T. A., A. G. Yahnina, J. Kangas, J. Manninen, **D. S. Evans**, A. G. Demekhov, V. Uy. Trakhtengerts, M. F. Thomsen, G. D. Reeves, and B. B. Gvosdwvsky, Energetic particle counterparts for geomagnetic pulsations of Pc1 and IPDP types, *Annales Geophysicae* (2003) **21**:2281–2292 European Geosciences Union 2003.


DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA