NOAA National Centers for Environmental Information

Space Physics and Geomagnetism Activities

Historical Perspective and Future Directions

(WDS for Geophysics)

R. J. Redmon

W. F. Denig, E. A. Kihn, A. Chulliat, S. McLean
NOAA / NCEI / CCOG / Solar Geophysics Branch and Geomagnetism Team

(Contact Rob.Redmon@noaa.gov, +1 303 497 4331)

SCOSTEP-WDS
Sept. 28, 2015
NiCT, Tokyo, Japan
Abstract

The NOAA Solar Geophysics Branch and Earth and Space Magnetism Team within the Center for Coasts, Oceans and Geophysics of the US National Centers for Environmental Information (NCEI) are dedicated to the observation and characterization of the natural environment from Sun to Earth. NCEI’s environmental data sets from ground to orbital platforms are vast in both space and time, with worldwide contributions of solar imagery, geomagnetic and ionospheric measurements and interpretations dating long before the 1957/1958 International Geophysical Year (IGY). With technological advancements, continuous operational measurements of the near earth space environment have trended towards the use of fully instrumented space based assets. Space platform measurements in NOAA’s current archive provide (non-inclusively) irradiance measurements of the solar disk and plasma and magnetic properties of the equatorial radiation belt charged particle environment sensed by the Geosynchronous Operational Environmental Satellites (GOES), similar plasma properties and upper atmosphere energy inputs sensed by the low earth Polar Orbiting Environmental Satellites (POES) and European Meteorological Operational (MetOp) and Defense Meteorological Satellite Program (DMSP; multi-institution collaboration) satellites. NOAA’s strong observational continuity continues with two flagship programs: the Deep Space Climate Observatory (DSCOVR) (launched February 2015) which will provide NOAA with a new operational solar wind monitoring capability and GOES-R (first launch 2016) which will advance our GEO radiation environment monitoring. The aggregated expertise within NCEI provides a powerful arsenal supporting many key, internationally valuable activities. These include leadership roles in the development of the standard International Geomagnetic Reference Field (IGRF), the World Magnetic Model and its Extension (WMM and EMM), the new Satellite Anomaly Initiative, NOAA’s foray into the Big Data arena, and numerous contributions to the operations and research communities. We present on NOAA’s past, present and future space physics and geomagnetism activities.
Outline

Organizational Structure
NOAA NCEI CCOG
Solar Geophysics Branch
Earth and Space Magnetism Team

Historical Perspective
From ground to space assets...

Future Directions
Sunpots Make the Aurora Gleam...

Adapted by Denig (F-AGU 2015), adapted from Trenton Times Advisor (September, 1941).
Organization - Synopsis

NOAA
National Environmental Satellite Data & Information Services (NESDIS)

Centers for Coasts, Oceans and Geophysics (CCOG)
Director: E. Kihn

Centers for Weather and Climate
Director: M. Tanner

NOAA
National Centers for Environmental Information (NCEI)
Director: T. Karl

Geophysical Science Division
S. McLean

NOAA
National Weather Service

Space Weather Prediction Center (SWPC)

Solar Geophysics Branch
W.F. Denig

Earth and Space Magnetism Team
1942 Interservice Radio Propagation Lab. (IRPL) formed to publish and disseminate ionospheric data.

1946 Central Radio Propagation Lab. (CRPL) formed in DOC to centralize research and predictions.

1954 CRPL moves to Boulder, Colorado.

1957 World Data Center A (WDC-A) system of international data centers in the United States established in support of the International Geophysical Year.

1970 National Oceanic and Atmospheric Administration (NOAA) established within DOC.

1972 National Geophysical and Solar and Terrestrial Data Center (NGSDC) begins archive of DMSP auroral imagery.

1974 SMS/GOES space environmental monitor (SEM) archive begins.

1978 TIROS/NOAA SEM archive begins.

1982 NGSDC is renamed the National Geophysical Data Center (NGDC).

1994 Space Physics Interactive Data Resource (SPIDR) begins WWW-based data services.

1999 STP Division begins real-time data services for ionospheric and geomagnetic data.

2001 GOES-12 Solar X-Ray Imager archive begins.

2011 WDC-A for STP and WDC for Geophysics and Marine Geology merged to WDS for Geophysics.

2012 STP assumes responsibilities from SWPC; GOES-R SpWx sensors acquisition and operations.

2014 NGDC assigned responsibility for the archive of DSCOVR solar wind data.

2015 NGDC merges with other NOAA Data Centers to become the National Center for Environmental Information (NCEI); STP transitions to the Solar Geophysics Branch (SGB) within the Geophysical Science Division (GSD) of the Center for Coasts, Oceans and Geophysics (CCOG).

Solar & Terrestrial Physics Div. (Historically WDC-A)
Historical solar datasets include:

Historical Ha photos from the Boulder Solar (1967 – 1994) and other observatories.
Monthly Geophysical & Solar Indices Bulletins (pre 1985 – present) and other historical reports.
Composite drawings: Franhoeffer, Wendellstein

The **Solar and Geophysics Branch (SGB)** is responsible for a wide variety of environmental datasets from the sun’s surface to the upper atmosphere.

**Slate** - “Forty-Three Years of Hand-Drawn Maps of the Surface of the Sun, in One Mesmerizing Video”

Credit: Prof. Jeff Thompson, Program Director of Visual Arts and Technology at the Stevens Institute of Technology ([link](https://www.stevens.edu/)).
Historical: Ionospheric Sounding

NCEI-Boulder (was CRPL) innovated the Dynasonde vertical incidence sounder (D. Grubb, W. Wright)

Paper Records
- Approximately 15,572 station-months
- First record: Oct 1936 - Hiraiso
- Last record: Jan 1999 – Sodankylän

Film Records
- Approximately 17,000 station-months

1957 URSI/AGI Special Committee on WWS

Back row (left to right): Rivault, Rawer, R. Wright, Haulbert, Theissen, Becker; Front row (left to right): Belrose, JW2, Shapley, Piggott.

Photograph courtesy of Ray Conkright - taken in Lindau, 28-30 March 1957.
Current Ionospheric Sounding Team
Mission: Develop and Field Revolutionary Technologies for Advanced Ionospheric Sounding

Members:
- Terry Bullet (lead), Justin Mabie, James Manley, Dick Grubb, Nick Zabotin, Ray Conkright.

Actions:
- Acquire & disseminate to SWPC/AFWA real-time, ionospheric soundings from a global network of ground sensors. Data also disseminated to domestic and international partners.
- Demonstrate advanced capabilities for ionospheric sounding by VIPIR.
- Field new ground-based sensors in U.S., Africa and the Antarctic.
- Manage 70+ years of ionospheric sounding data. Key to understanding climate change impacts to geospace.

NCEI-Boulder (was NGDC) innovated the new-technology Vertical Incidence Pulsed Ionospheric Radar (VIPIR)

Recent/Ongoing Activities:
- Supported NASA Sounding Rocket Program.
- Install new Korean VIPIR at Jang Bogo Station, Antarctica
- Continued support to the Low latitude Ionospheric Sounding Network (LISN)
Magnetic measurements at NCEI date back to 1850’s. Data exist on analog and digital media. Also, Charles Schott collection: “History of Terrestrial Magnetism”.

Historical Perspective: Geomagnetism
Historical Perspective: Geomagnetism

Magnetic field declination for 1590 through 2020 was constructed by assimilating magnetic observations from ocean going vessels, ground, aero and space based observatories.

1590 to 1890 is given by the [GUFM-1 model](http://geomag.colorado.edu/historical-main-field-change-and-declination) of [Jackson et al. (2000)](http://geomag.colorado.edu/historical-main-field-change-and-declination).

1900 to 2020 is given by the 12th generation of the [International Geomagnetic Reference Field](http://geomag.colorado.edu/historical-main-field-change-and-declination).
Objective: The Earth and Space Magnetism Team provides scientific data analysis, processing, and management of archive and dissemination systems for magnetic field models and ground, aero and space based measurements. We develop internationally utilized magnetic field models and related applications, and conduct applied research. We provide magnetism subject matter expertise from the Earth's core to the outer magnetosphere.

Members:
Arnaud Chulliat and Rob Redmon (co-leads)
Manoj Nair, Paul Loto’aniu, Patrick Alken, Adam Woods, Brian Meyer, Rick Saltus, Nir Boneh, Neesha Schnepf

Current Team Efforts:
Model development: W/EMM, IGRF.
IGRF co-chair (P. Alken)
Instrument support to GOES-R, DSCOVR, DMSP, and SWARM magnetometers.
Historical Perspective: Satellite Obs

Space Environment Overview: 1983-01-01 - 2014-12-31

- Monthly Smoothed Sunspot Number:
- Daily Sunspot Number:
- Moscow - Cosmic Rays, R = 2.46:
- GOES X-Class Flares, XL (1-8 nm) > 10-4 W/m²2
- GOES X-rays - Daily Means: XL
- GOES Ion Storms, > 10 MeV Proton PFU > 10^7
- GOES Protons - Daily Means: P3, P5, P7
- Max Ap^ - Geomagnetic Storm Index > 40
- GOES Magnetometer - Daily Means, Hpc, Hpe

<table>
<thead>
<tr>
<th>Solar Cycle 22</th>
<th>Start Date</th>
<th>Max Date</th>
<th>End Date</th>
<th>C-Class Flares</th>
<th>M-Class Flares</th>
<th>X-Class Flares</th>
<th>Ion Storms</th>
<th>Mag Storms Ap^ &gt; 40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1986-03</td>
<td>1989-07</td>
<td>1996-06</td>
<td>12,447</td>
<td>2,021</td>
<td>151</td>
<td>73</td>
<td>191</td>
</tr>
<tr>
<td>Solar Cycle 23</td>
<td>1996-06</td>
<td>2000-03</td>
<td>2008-01</td>
<td>13,102</td>
<td>1,437</td>
<td>126</td>
<td>92</td>
<td>158</td>
</tr>
</tbody>
</table>

- We are far from the end of Solar Cycle 24 so these numbers should be considered a progress report rather than a final grade. Event totals are through November 2014.
Future Directions: GOES-R
New Instrument Capabilities

**EXIS XRS, EUVS**

**SUVI**

**SEISS**

**MAG**

**Improvements:**
- Rate 10 Hz
- Bandwidth 2.5 Hz

**New Applications:**
- Coordinate frames
- Comparison to Models
- Magnetopause Crossing

**Solar X-Ray Sensor (XRS)**

**Solar Extreme Ultra-Violet Sensor (EUVS)**

**Solar Ultra-Violet Imager (SUVI)**

**Space Environment In-situ Sensor Suite (SEISS)**

**Magnetometer (MAG)**

- Two boom mounted 3-axis, flux gate magnetometers
- Sample rate of 10 Hz
- Spectral bandwidth of 2.5 Hz
Future: GOES-R Products
GOES-R Selected Product
Thematic Maps

The SDO/AIA is the heritage sensor for SUVI

Pixels are classified from probability distributions created from training sets using all six bandpasses.

- Coronal Hole
- Prominence / Filament
- Space
- Corona Quiet
- Bright Regions
- Corona off-disk
- Flare
- Coronal Hole off-disk
## GOES-R Selected Product
### Improved Particle Obs

<table>
<thead>
<tr>
<th>Satellite Series</th>
<th>Electrons 0.03-30 keV</th>
<th>Electrons 30-600 keV</th>
<th>Electrons &gt;800 keV</th>
<th>Ions 0.03-30 keV</th>
<th>Protons 80-800 keV</th>
<th>Protons &gt;740 keV</th>
<th>Heavy Ions, &gt;10 MeV/n</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOES 8-12</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>He</td>
</tr>
<tr>
<td>GOES 13-15</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td>√</td>
<td>√</td>
<td>He</td>
</tr>
<tr>
<td>GOES R-U</td>
<td>√</td>
<td>√ (gap 30-50 keV)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>He, Z=4-29 (Be-Cu)</td>
</tr>
</tbody>
</table>

**Space weather application**
- Frame charging, charging signatures
- Frame and interior charging
- Interior charging, radiation belt alerts
- Frame charging signatures, ring current
- Surface damage
- SEP event alerts, surface damage
- Single event effects

Presented at Space Weather Workshop GOES-Next session, J.V. Rodriguez.
MP location is an important index for the state of the global space env. Compressed magnetosphere is often the first indicator of an impending geomagnetic storm. Large geomag storms may result in satellite anomalies, communications, navigations and ground electrical systems.

St. Patrick’s Day Storm - March 17, 2015
Continuity of LEO Measurements
An End of an Era (since 1978)

NOAA-19 (POES)
Launched: 08 Feb 2009

- NOAA-19 is the last NOAA satellite in polar LEO to provide operational SWx data via the Space Environmental Monitor (SEM).

- MetOp-C will be the last EUMETSAT s/c.
  - MetOp A – CY2006 – XXXX (SEM)
  - MetOp B – CY2012 – XXXX (SEM)

- DMSP F-19 launched in April 2015 (not fully checked out). F-20 is the final DMSP (launch date TBD).

- These data will notionally continue to be available via NOAA/NCEI through the end of these programs (Redmon et al., 2015), but there are problems (Denig et al., 2015).

http://www.ngdc.noaa.gov/stp/satellite/poes/index.html
DSCOVR
Deep Space Climate Observatory

Launch: 11 February 2015
Status: Early-orbit ops (all nominal)
Final Location: 1,500,000 km (L1)
Operations: L+105 days

Space Weather Sensor Suite
- Plasma-Magnetometer (PlasMag) measures solar wind for space weather predictions.

Launch Video
NCEI is ready to accept and disseminate DSCOVR data

Synchronous and Asynchronous Access are being merged into: [http://www.ngdc.noaa.gov/dscovr/](http://www.ngdc.noaa.gov/dscovr/)
Future Directions: WSA-ENLIL and GONG

GONG - Global Oscillation Network Group
6 ground stations: H-alpha images and Magnetograms
Operated by the Nat’l Solar Obs (NSO) since 1995. Will be transitioned to SWPC operations. (See Reinard et al., Fall-AGU SH021:74148)

WSA-ENLIL
Wang-Sheeley-Arge (WSA)
Radial magnetic field and flow velocity near SW source
ENLIL: Sumerian god of wind and storms
3-D MHD model estimates the SW evolution out to Earth
Will be archived at NCEI-Boulder. Web view similar to DSCOVR probable by Fall AGU.

Nominal conditions, adapted from SWPC WSA-ENLIL on Sep 13, 2015.
Future: Big Env. Data Initiative (BEDI)

Big Environmental Data Initiative (BEDI)

- Proposed multi-agency activity coordinated through US Group on Earth Observations (USGEO)

  *Improve discoverability, accessibility, & usability of data*

- Focus on "high value" datasets, e.g. from OSTP Earth Observations Assessment, USGCRP National Climate Assessment, NOAA Observing Systems of Record

Motivated by the executive Public Access to Research Results (PARR)


- Requires Agencies with $100M/yr research to ensure the direct results of scientific research are made available to and useful for the public, industry, and the scientific community.

International Collaborations

List of 2015 citations from SGB and ESM Team (32 so far…)


Questions?

“No one trusts a model except the [person] who wrote it; Everyone trusts an observation except the [person] who made it.” - Harlow Shapley