Monitoring of EUV, UV, and Total Solar Irradiance from NOAA Satellites

Rodney Viereck
NOAA Space Environment Center
Boulder CO
(rodney.viereck@noaa.gov)

Larry Puga, Steve Hill, Vic Pizzo, Doug Biesecker, Matt DeLand, Gary Rottman, Greg Kopp, Jerry Harder, Many Others

LWS Workshop, March 2004, Boulder CO

Outline
Overview, status, and update on…
GOES XRS
GOES SXI
GOES EUVS
NOAA POES SBUV/2
NPOESS SIM
NPOESS TIM
GOES R+ Coronagraph
NOAA L1 Mission
NASA Strategic Plan
A few words extracted from the NASA Mission Goals

• Explore the solar system and the universe beyond,
• Explore the fundamental principles of physics, chemistry, and biology
• Enable revolutionary capabilities through new technology
• Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards

NASA’s Role:
Explore to Better Understand
NOAA Strategic Plan
A few words extracted from the NOAA Mission Goals

• Understand climate variability and change to enhance society’s ability to plan and respond.
• Serve society’s needs for weather and water information.

NOAA’s Role:
Understand to Better Serve

NASA Research
New Science
New Technologies

NOAA Operations
Long-Term Monitoring
Reliability and Heritage
NOAA Solar Observations

Motivation

- specify and predict space weather
- specify and predict terrestrial impacts
- satisfy customer requirements
- meet societal needs

NOAA Solar Measurements
X-Ray Irradiance Measurements

- **GOES X-Ray Sensor (XRS)**
  - Two Channels
    - 0.05 to 0.4 nm
    - 0.1 to 0.8 nm
  - 0.512 Second Cadence
GOES XRS

- Extends the observations made since 1974 of the disk-integrated solar x-ray emission in two wavelength bands
  - Short Channel 0.05 to 0.4 nm
  - Long Channel 0.1 to 0.8 nm
- Operational requirements for uninterrupted data requires two XRS instruments on separate GOES spacecraft
XRS Data 3 Second Data

Note:
Excellent signal to noise
Excellent agreement between XRS instruments

But:
There is saturation of the signal at high flux levels
XRS Data Products and Utility

- Initial warning of solar x-ray flare event and subsequent space weather
- Provides definitive measure of solar x-ray flare magnitude
- Provides a probability prediction of solar proton event
- HF Radio Absorption product shows solar X-ray flux affects ionosphere and radio propagation
- Scientific Research

**HF Absorption Product:**
http://sec.noaa.gov/rt_plots/dregion.html

**D-Region Absorption Prediction**
Presented by the NOAA Space Environment Center

Updated: 1999 Nov 01 1549 UT  Current X-ray Flux:B6.4

Use browser Refresh when returning to this page to ensure latest data. This page dynamically updates once a minute.

**Solar Proton Prediction Product:**
http://sec.noaa.gov/~sgreer/gprot/index.html
XRS Data Processing

• Data Products
  – 3 second
  – 1 minute
  – 5 minute
  – Daily background

• Archiving of Data
  – NOAA SEC
  – NOAA National Geophysical Data Center (NGDC)

• XRS Data Issue
  – Still applying multiplicative correction (Adjustment Factors)!
    • FAC_LONG = 0.70  (Data provided = Data Measured * Fac)
    • FAC_SHORT=0.85
      (note: X28 flare would have been an x40 flare without this factor)
XRS Instrument Status

- GOES 5-7 XRS (Spinning Spacecraft all retired)
- GOES 8 XRS About to be retired
- GOES 9 XRS Serving Japan
- GOES 10 XRS Operating (Primary Instrument)
- GOES 11 XRS On-orbit Storage
- GOES 12 XRS Operating (Secondary Instrument)
- GOES N XRS Launch in Dec 2004
- GOES O On Spacecraft (Launch when needed)
- GOES P Delivery in June (Launch when needed)
Future of GOES XRS Measurements

• GOES R+ (Launch-Ready in 2012)
• Preliminary RFP for “preformulation studies” went out last week (15 March 2004).
• Issue: Will we use older ionization cell detectors or new photodiode technology?
  – Older detectors…
    • are proven,
    • are stable
    • are resistant to energetic particles
    • will provide the same bandpasses
  – New detectors…
    • are smaller
    • are more readily available
    • will require serious consideration of bandpass and visible light rejection to match previous sensors.
Solar X-Ray Imager

- Steve Hill (NOAA SEC)
- Vic Pizzo (NOAA SEC)
- Doug Biesecker (NOAA SEC)
- Chris Balch (NOAA SEC)
Solar X-Ray Imager

• Instrument Summary
  – X-ray Telescope
  – Geosynchronous orbit
  – Multiple spectral bands
  – One-minute cadence

• Meeting Forecaster Needs
  – Forecast solar activity: Monitor active regions beyond east limb,
  – Forecasts recurring geomagnetic storms: Locate coronal holes,
  – Forecast flare probability: Assess active region complexity,
  – Forecast solar radiation storm effects: Locate flares, and
  – Forecast non-recurring geomagnetic storms: Monitor changes in the corona that indicate coronal mass ejections (CMEs)

GOES 12 SXI presently has limited operational capabilities due HVPS problems
Future SXIs

• **GOES N (Launch in Dec 2004)**
  - Much better spatial resolution (still 5 arcsec pixels)
  - Much better sensitivity (x10 over GOES 12)
  - Possible on-orbit storage 2005-?
  - At least one more SXI for GOES O or P

• **GOES R+ (Launch 2012)**
  - Preliminary RFP for “preformulation studies” went out last week (15 March 2004).
  - Considering trade study
    • grazing incidence optics (Yohko and SXI Like)
    • normal incidence optics (SOHO EIT Like)
Solar EUV Measurements from GOES

- New Solar EUV Sensor for GOES
  - First Launch, Dec 2004
  - Operational 2005?
Why Measure Solar EUV?

- Solar EUV flux is highly variable and is absorbed in the upper atmosphere
Effect of Solar EUV on the Atmosphere

- Solar EUV Flux is the primary source of energy and is a critical source of variability of the thermosphere and ionosphere.

![Graph showing daytime electron density from IRI and neutral density from MSIS models.](image)
Systems Impacted by Solar EUV Variability

- **Satellite Orbits**
  - Increased EUV flux causes an increase in the atmospheric density. This will add drag on LEO satellites. This affects...
    - Satellite tracking
    - Debris avoidance
    - Pointing stability
    - Satellite reboost schedules

- **Communications and Navigation**
  - Variability in the EUV flux cases variability in the ionosphere. This affects radio transmissions and radio navigations
EUV Sensor for GOES N-P

- Five EUV Bands between 5 and 125 nm
  - Bands selected to match wavelengths of atmospheric heating
GOES N EUV Sensor

• **Status**
  - GOES N (launch Dec 2004, Operational 200?)
  - GOES O (Launch when needed)
  - GOES P (Launch when needed)

**Mechanical Layout of the GOES EUV Sensor**

- There are three spectrograph units for the five EUV channels.
- The first optical element is a transmission grating made of very thin wires and spaces (up to 5000 ln/mm).
- The detectors are silicon diodes with thin-film filters deposited onto the diode.
Products GOES EUV Data

• EUV flux at each of the five bands at 10 second resolution.
• 1 minute, 5 minute, and daily averages of EUV flux
• Derived Products
  – Solar EUV Spectra (SOLAR2000 @ 1 nm resolution)
  – E10.7 (proxy for a proxy)
  – 1 Hour Cadence
• Inputs for EUV Models like GAIM (Global Assimilation of Ionospheric Measurements)
  – Requires Solar EUV Spectrum
  – 15 minute to 1 hour cadence
• Solar EUV Flare Product
  – 10 second cadence
Future GOES EUV Measurements

- GOES R+ (launch Ready 2012)
- RFP for “preformulation studies” released Last week (15 March 2004)
- Two GOES EUV sensor options being explored
  1. Broad Band Sensor Similar to GOES NOP
     - Complete coverage from 5 to 127 nm
     - Faces many of the same challenges as the GOES N EUVS
  2. Spectrograph similar to TIMED-MEGS and SDO-EVE
     - 0.5 nm resolution from 17 to 40 nm
     - Models provide the remaining spectral information
     - Requires additional validation from MEGS and EVE
Solar UV Measurements
from NOAA POES SBUV/2

- Matt DeLand (SSAI)
- Larry Puga (NOAA SEC)

Note: Gap in Coverage
Between 130 and 200 nm
Solar UV Irradiance

- **SBUV/2 Double Ebert-Fasti Monochromometer**
  - 1 nm resolution

- **Daily solar observations with NOAA POES SBUV/2 Sensor**
  - Primarily an ozone instrument
  - Ozone densities determined by taking the ratio of the downward solar flux and the upward (backscattered) flux
  - Measures Solar Spectra between 200 and 400 nm once a day
SBUV Solar Data Products

Measurements made once a day of...

- Solar UV Spectra

- Mg II core-to-wing ratio: A proxy for chromospheric activity
SBUV Mg II Index

- Includes data from NIMBUS7, NOAA9, NOAA11, UARS SOLSTICE, UARS SUSIM, EUMETSAT GOME, NOAA 16, and NOAA 17.
- Proxy for EUV, UV, and Total Solar Irradiances
Future of NOAA Solar UV Measurements

• There will be SBUV/2 Instruments on
  – NOAA POES N (launch Sept 2004)
  – NOAA POES N’ (not yet decided if N’ will be fixed)

• Solar UV Measurements on NPOESS (launch 2010)
  – OMPS (Weekly solar measurements only)
  – Spectral Irradiance Monitor (SIM)
NPOESS UV, Visible, IR Measurements

Spectral Irradiance Monitor (SIM)

- Gary Rottman (CU LASP)
- Jerry Harder (CU LASP)
Spectral Irradiance Measurements

- Satisfies requirements from the Climate Community
- Required to understand the Sun’s influence on the Earth system
- Required to understand the wavelength dependence of solar variability.
- UV, Visible, and near infrared
- **Sufficient precision and accuracy to establish solar variability.**

![SORCE SIM Results](image)

ESR Full Scan
June 3, 2003

**Spectral Irradiance (W m⁻² nm⁻¹)**

Wavelength (nm)
NPOESS Spectral Irradiance Monitor (SIM)
Launch Ready in 2013

- One of the two instruments that make up the Total and Spectral Solar Irradiance Sensor (TSIS)
- Heritage based on the SIM instrument now flying on the NASA SORCE Mission
- Instrument Specs
  - Instrument Type: Dual Féry Prism Spectrometer
  - Detectors: Diodes and Electrical Substitution Radiometer
  - Wavelength Range: **200-3000 nm**
  - Wavelength Resolution: **0.25-33 nm**
  - Optics: Suprasil 300 prism
  - Detectors: ESR, 5 diodes
  - Absolute Accuracy: **300 ppm**
  - Relative Stability: **100 ppm/year**
NPOESS Total Irradiance Monitor (TIM)

- Gary Rottman (CU LASP)
- Greg Kopp (CU LASP)
NPOESS Total Solar Irradiance Monitor

- Requirements driven by climate community and long-term climate change
- Instrument Type: Cavity Bolometer
- Wavelength Range: All
- Detector: Cavity Electrical Substitution Radiometer (ESR)
- Absolute Accuracy: \textbf{0.01\% (100 ppm)}
- Long-term Accuracy: \textbf{0.001\% (10 ppm)}
- Heritage: SORCE TIM
- Pre-flight Cal. Std: NIST-traceable Volt and Ohm, apertures

**Key Technology**
- NiP black cones
- ESRs use phase-sensitive detection at shutter frequency

**Important Calibrations**
- Standard Watt (V, I)
- Aperture area
- Cone absorptance
SORCE TIM Data

TIM Irradiance

Minimum at 29-Oct-2003
0.34% decrease

Frohlich & Lean Composite Irradiance

SOHO/MDI Continuum
29-Oct-2003 08:00
Long-term Measurement Issue

- Continuous and overlapping measurements are critical in maintaining a long term data record.
  - The ability to identify and measure long term trends is severely compromised by gaps in the data
- SORCE (Launched in Feb 2003)
  - Going strong, All instruments functioning well
  - Life expectancy… 5-10 years????
- NPOESS TSIS Launch Ready in 2013
  - Another mission is required to avoid a gap
- NASA GLORY Mission (Launch 2007)
  - Includes TIM
  - Does not include SIM (data gap)
Choronagragh
(Hopefully)

Doug Biesecker (NOAA SEC)

• GOES R+ Launch 2012
  – Requirements well documented (DOD and DOC)
• Instrument Specifications
  – FOV and Resolution are between LASCO C2 and C3
  – Objectives
    • Identify CMEs
    • Determine CME propagation direction
    • Determine CME speed
NOAA Solar Wind Monitor
(Under Consideration)

• ACE Follow On
• NOAA GEOSTORMS Mission (L1 or better)
  – Requirements well documented (DOC and DOD)
    • Critical to forecasting geomagnetic and geoeffective events
  – Status: Funding for initial study for an ACE replacement has been proposed for the NOAA 2006 budget.
Summary

• NOAA continues to “monitor” the sun in many wavelengths
  – Measurements should continue indefinitely

• Gaps in Coverage
  – UV Irradiance in 130 – 200 nm (after SORCE)
  – Spectral Irradiance from 200 – 2000 nm (from 2007 to 2013)

• Two serious shortcomings in meeting NOAA’s Space Weather measurement needs
  – Coronagraph
    • NOAA GOES coronagraph being worked
    • STEREO?
  – Solar Wind Observations
    • NOAA GEOSTORMS mission to L1