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

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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:

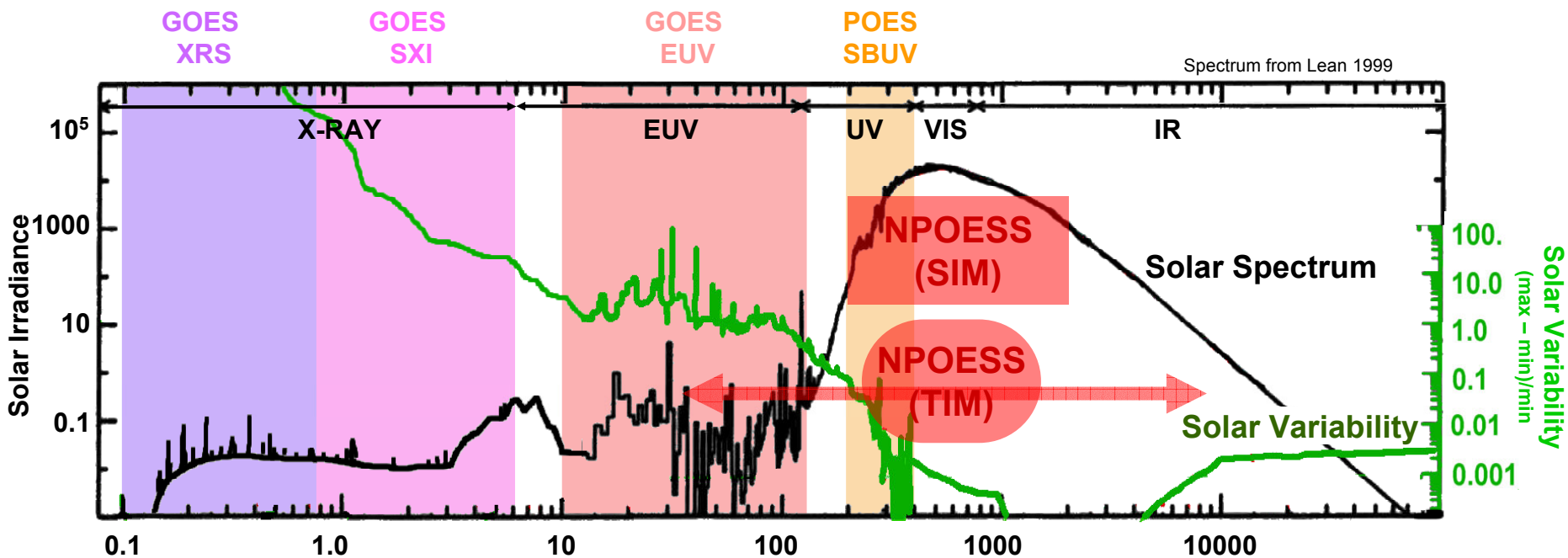
Understand to Better Serve

NASA Research New Science New Technologies	⟷	NOAA Operations Long-Term Monitoring Reliability and Heritage

NOAA Solar Observations

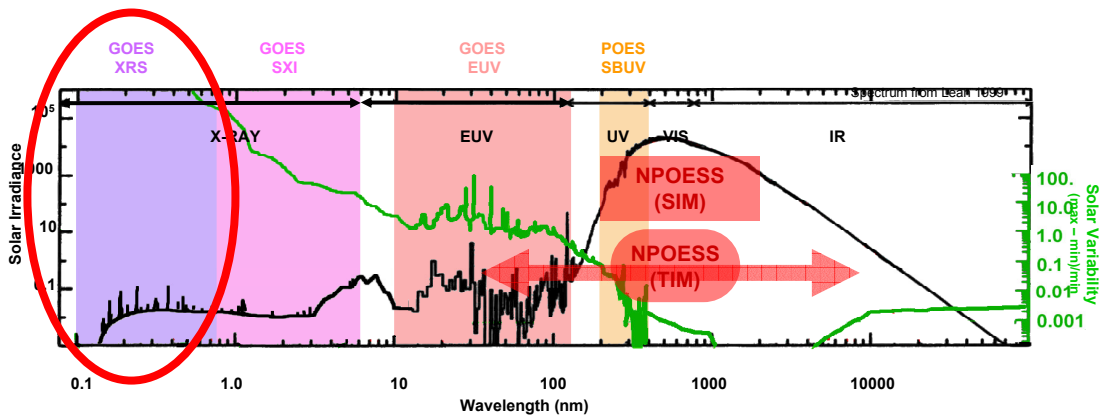
- **Motivation**
  - specify and predict space weather
  - specify and predict terrestrial impacts
  - satisfy customer requirements
  - meet societal needs

NOAA Solar Measurements



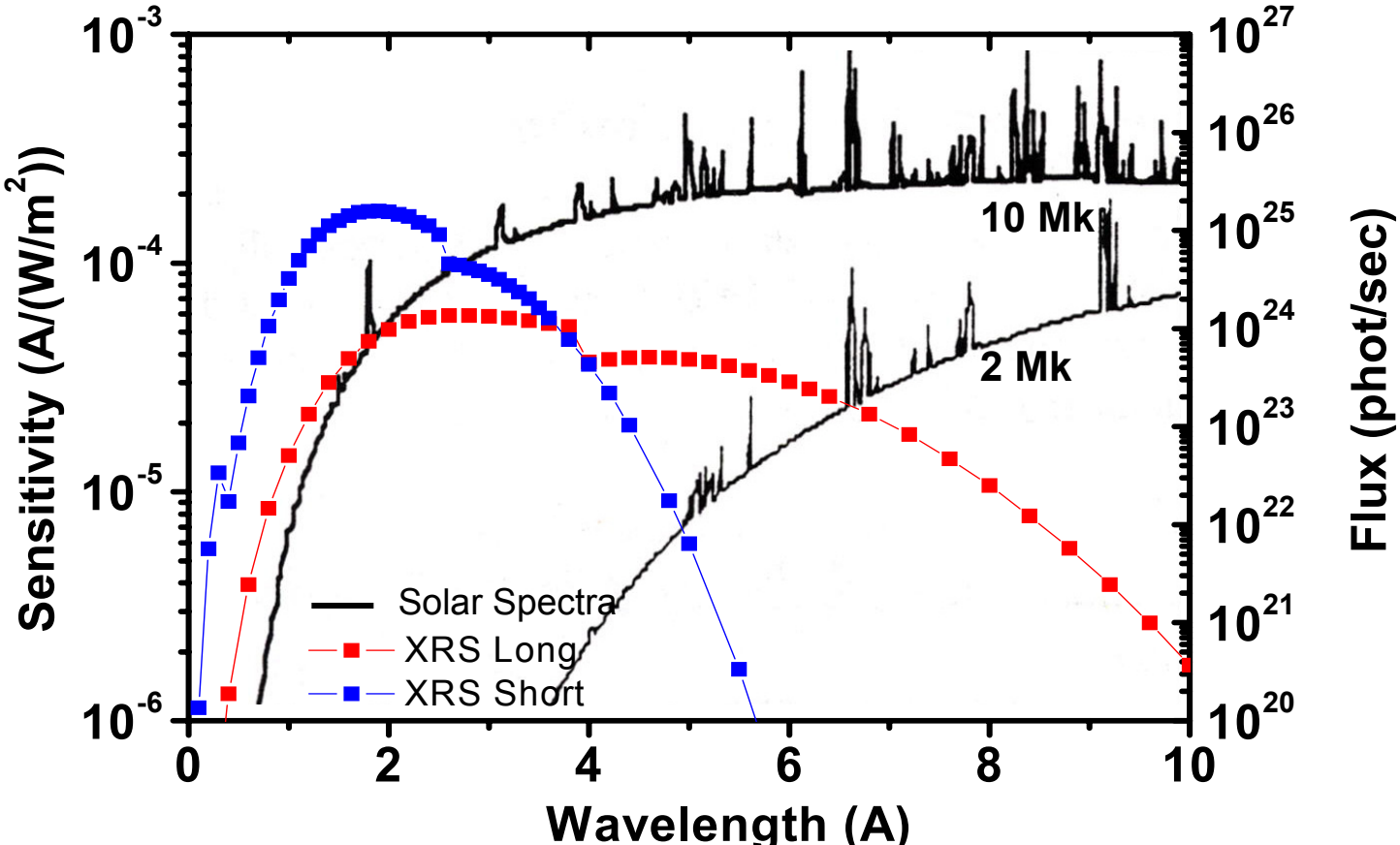
X-Ray Irradiance Measurements

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

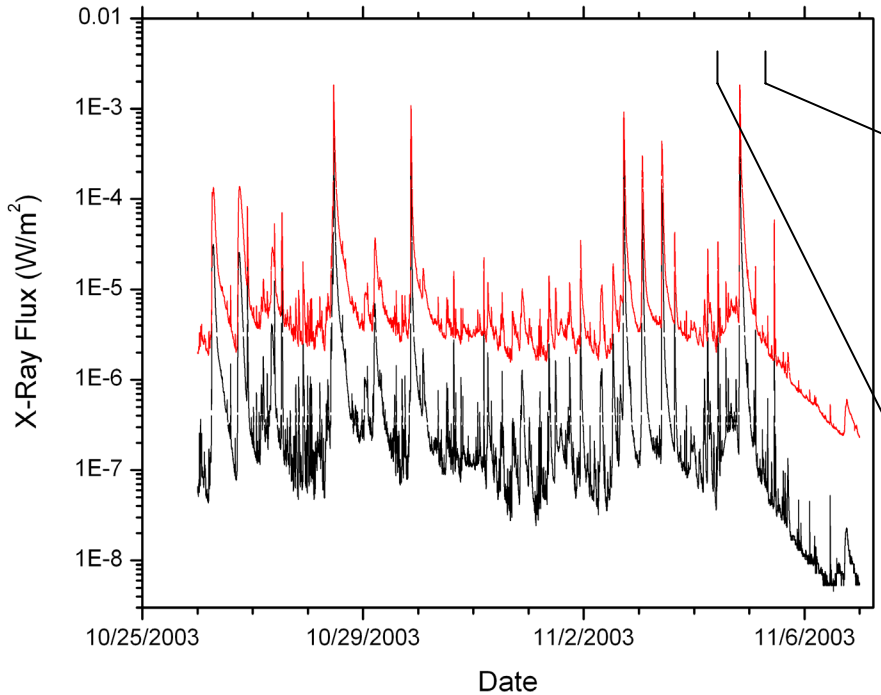


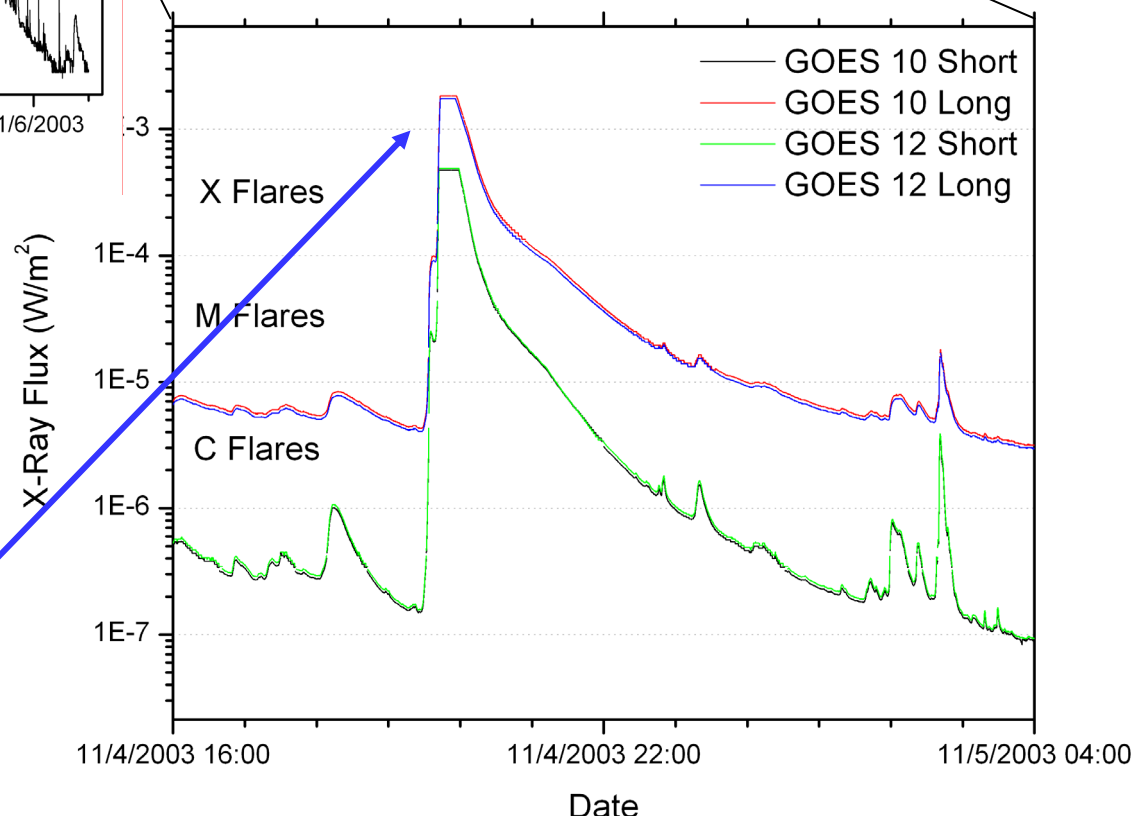
GOES XRS

- 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

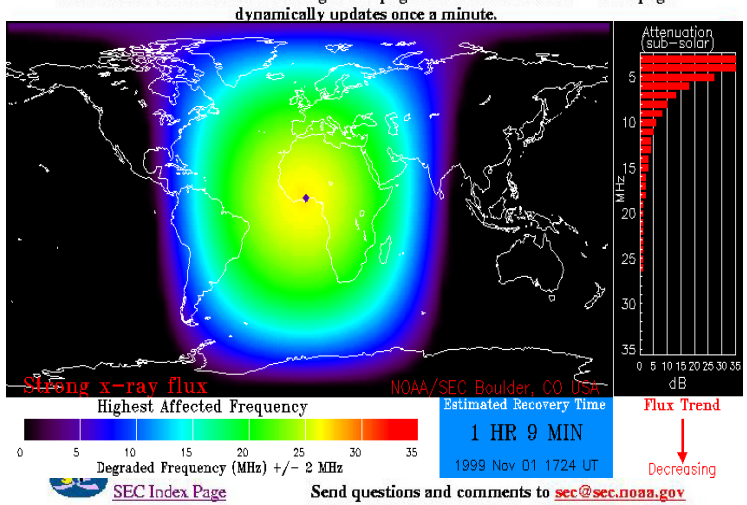
But:
There is saturation of the signal at high flux levels

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**

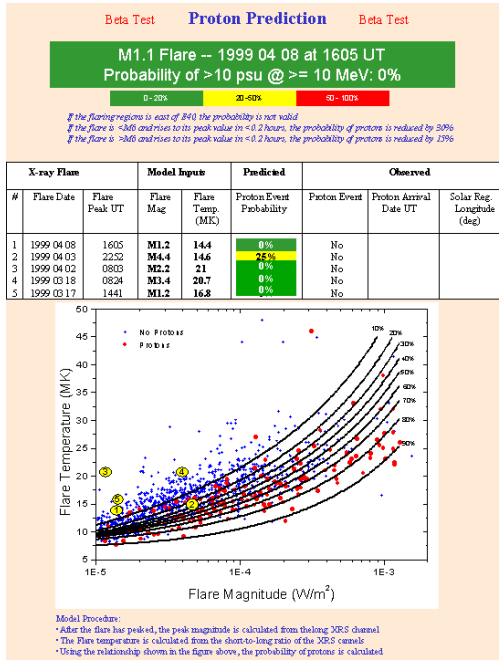
HF Absorption Product:

http://sec.noaa.gov/rt_plots/dregion.html



Solar Proton Prediction Product:

http://sec.noaa.gov/~sgreer/gprot/index.html



X-ray Flare			Model Inputs		Predicted	Observed		
#	Flare Date	Flare Peak UT	Flare Mag	Flare Temp. (MK)	Proton Event Probability	Proton Event	Proton Arrival Date UT	Solar Reg. Longitude (deg)
1	1999 04 08	1605	**M1.2**	**14.4**	0%	No		
2	1999 04 03	2252	**M4.4**	**14.6**	25%	No		
3	1999 04 02	0803	**M2.2**	**21**	0%	No		
4	1999 03 18	0824	**M3.4**	**20.7**	0%	No		
5	1999 03 17	1441	**M1.2**	**16.8**	0%	No		

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)

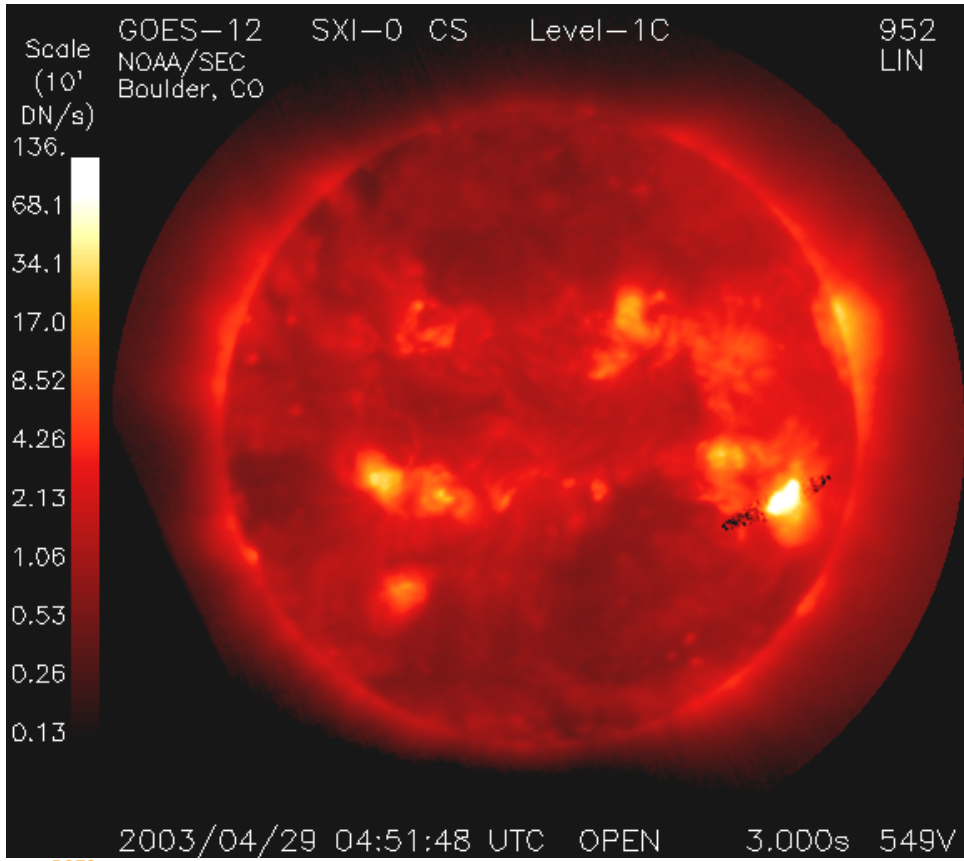
- GOES N XRS Launch in Dec 2004
- GOES O On Spacecraft (Launch when needed)
- GOES P Delivery in June (Launch when needed)

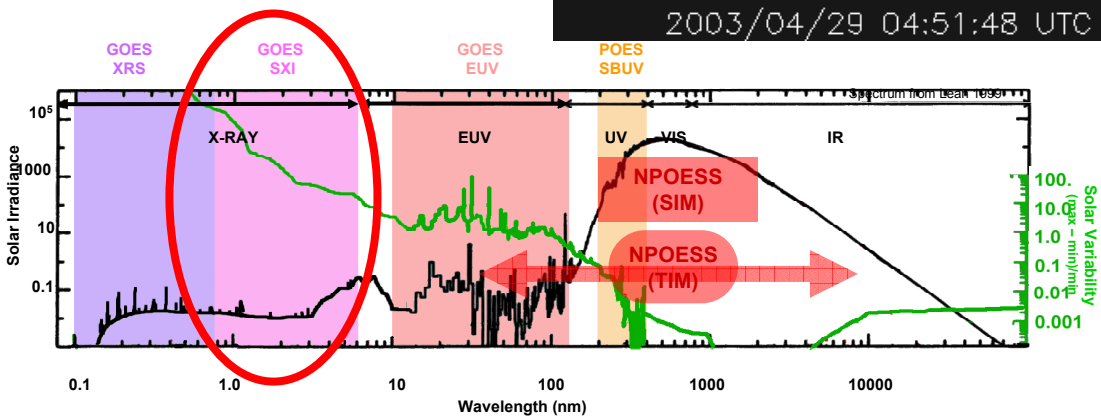
Future of GOES XRS Measurements

- 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)



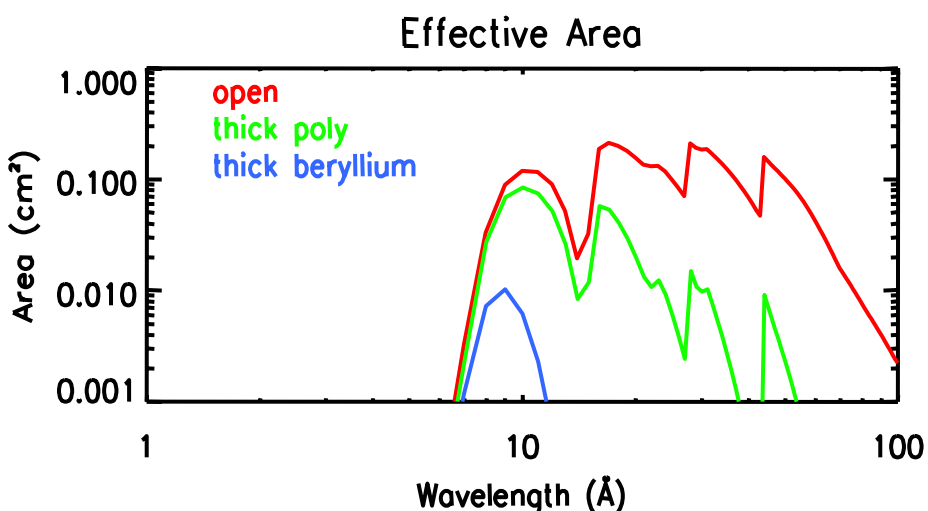


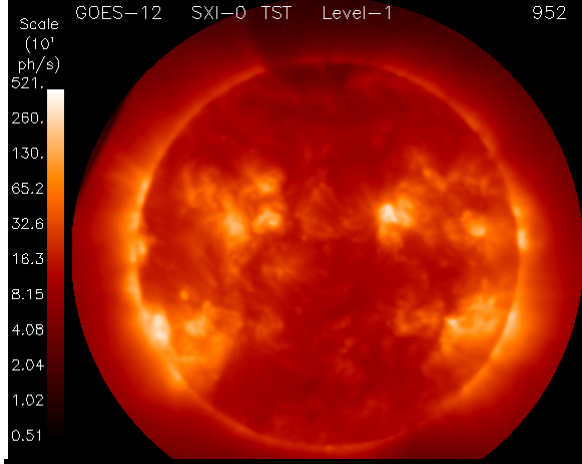
Solar X-Ray Imager

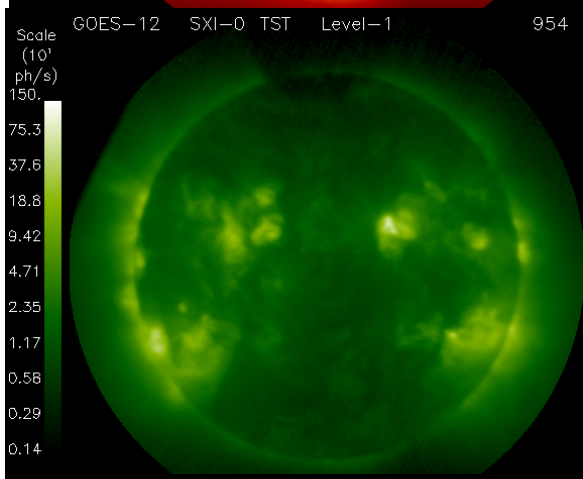
- Instrument Summary
  - X-ray Telescope
  - Geosynchronous orbit
  - Multiple spectral bands
  - One-minute cadence

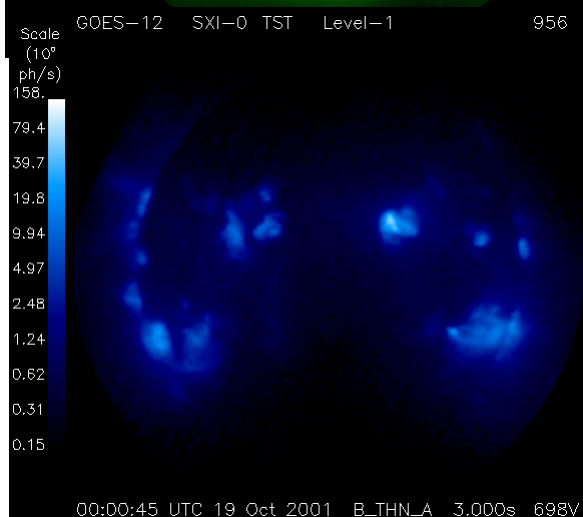
GOES 12 SXI presently has limited operational capabilities due HVPS problems

- 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)









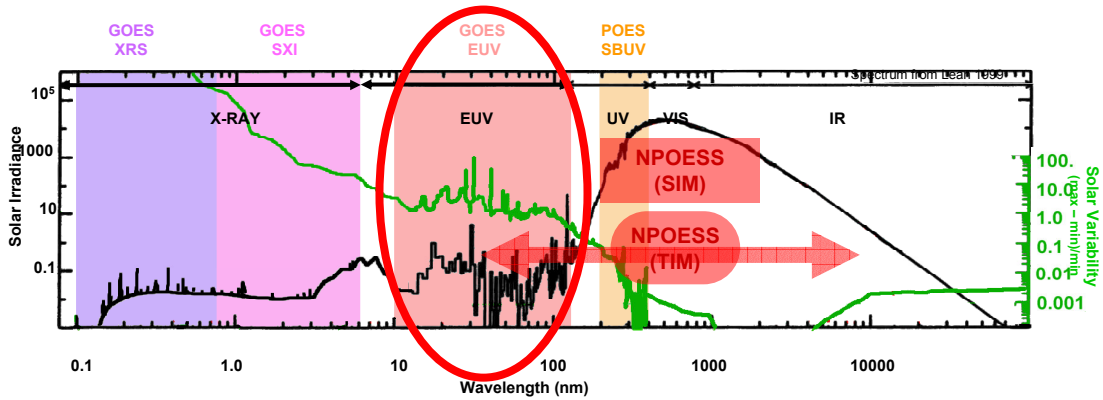
Future SXIs

- 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)

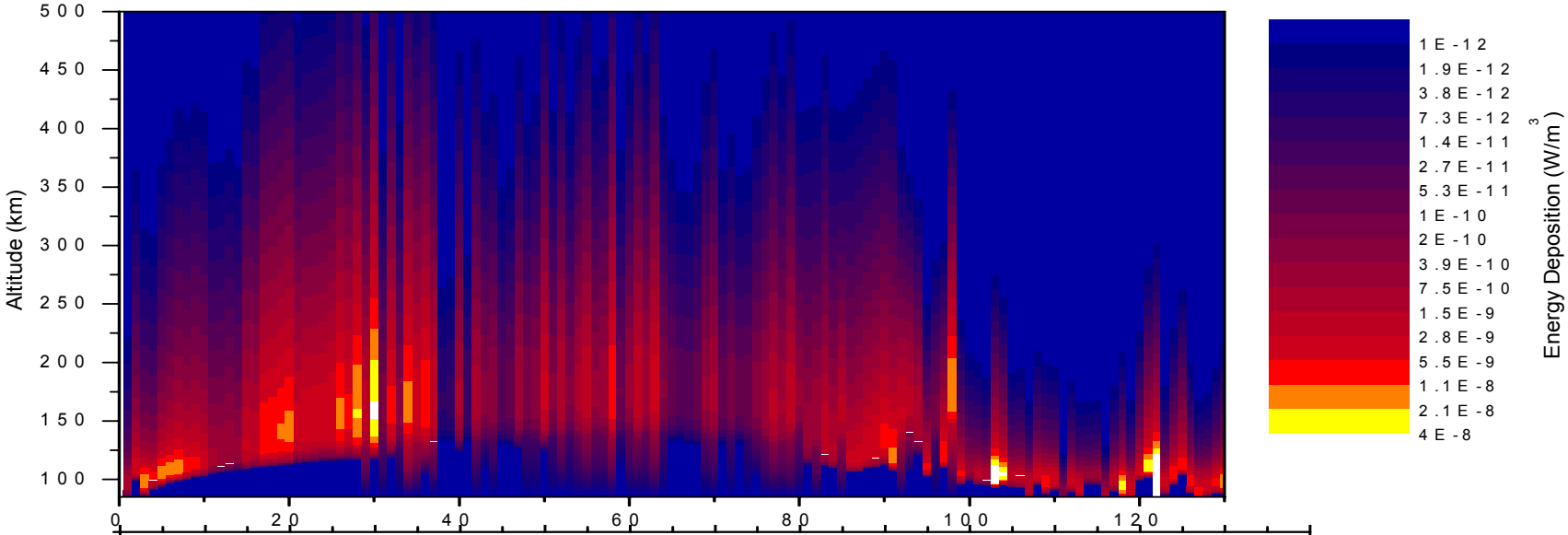
Solar EUV Measurements from GOES

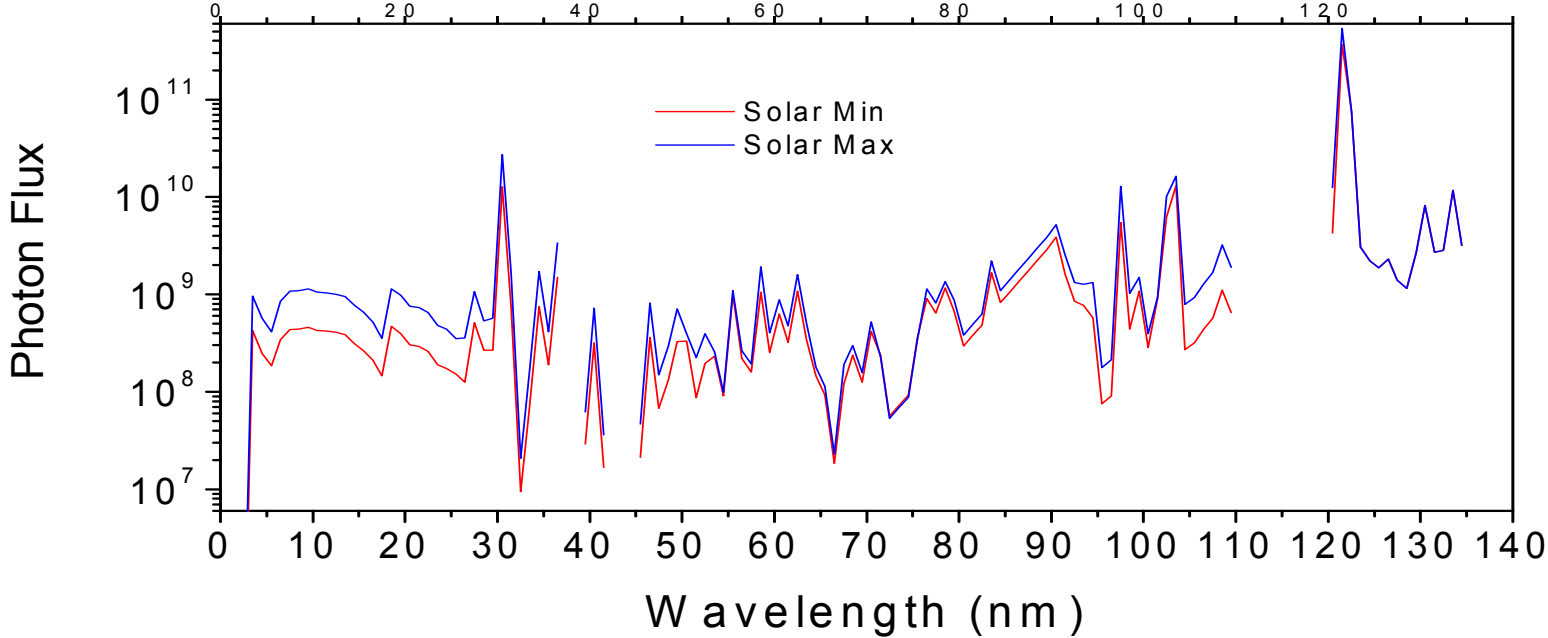
- **New Solar EUV Sensor for GOES**
  - **First Launch, Dec 2004**
  - **Operational 2005?**



Why Measure Solar EUV?

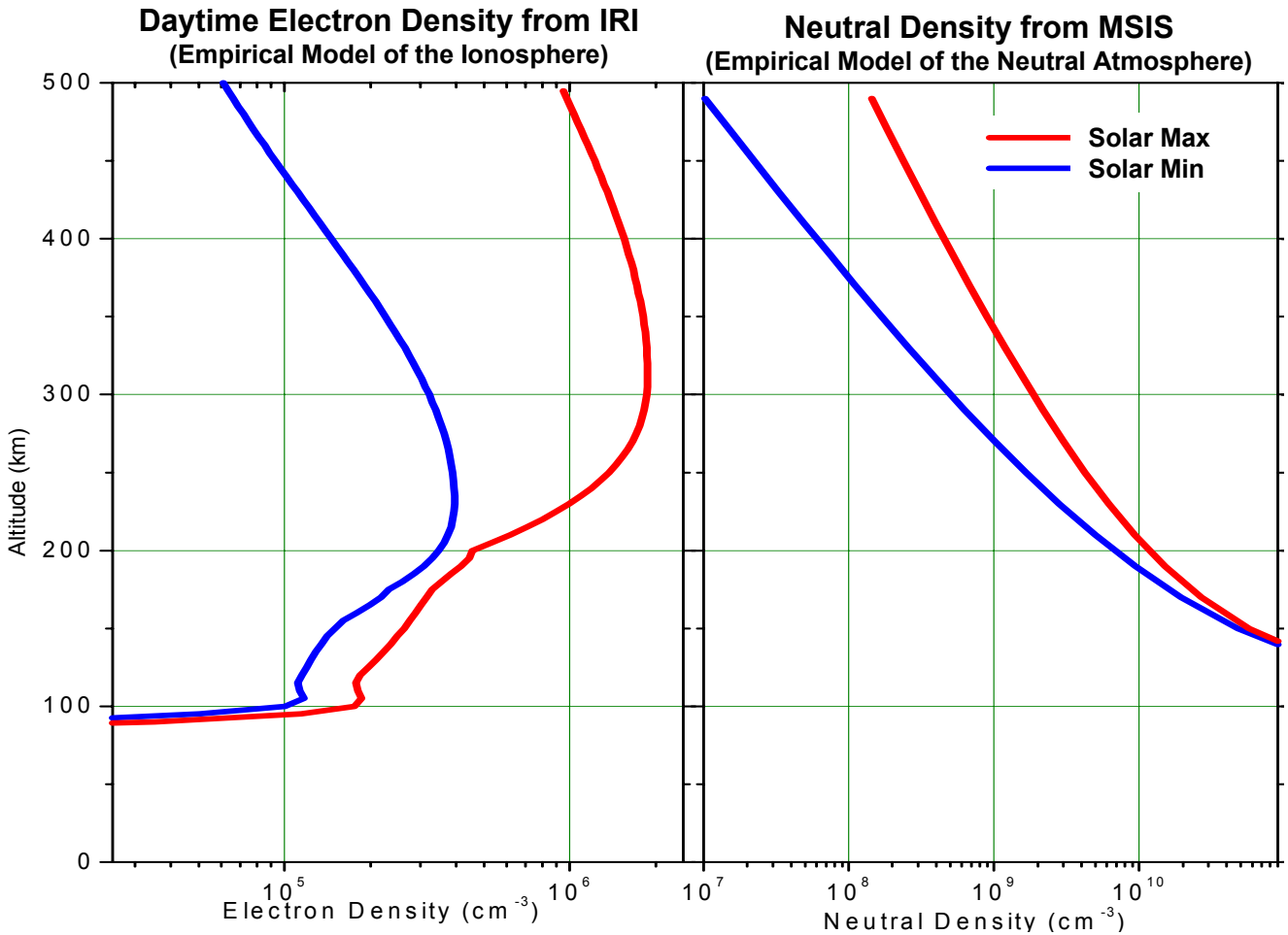
- **Solar EUV flux is highly variable and is absorbed in the upper atmosphere**





Effect of Solar EUV on the Atmosphere

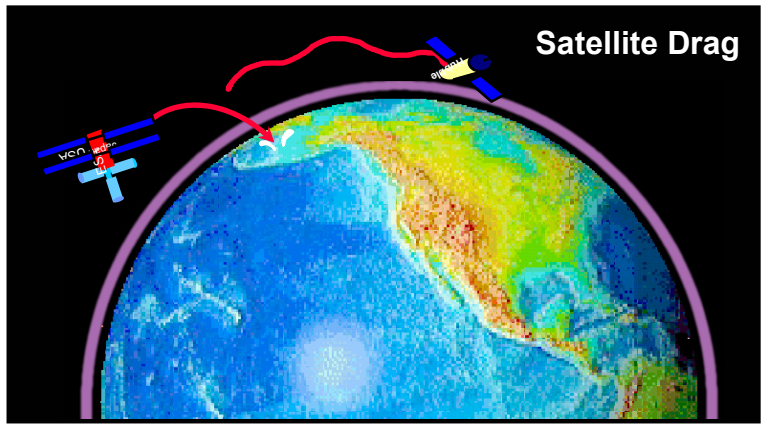
- **Solar EUV Flux is the primary source of energy and is a critical source of variability of the thermosphere and ionosphere.**

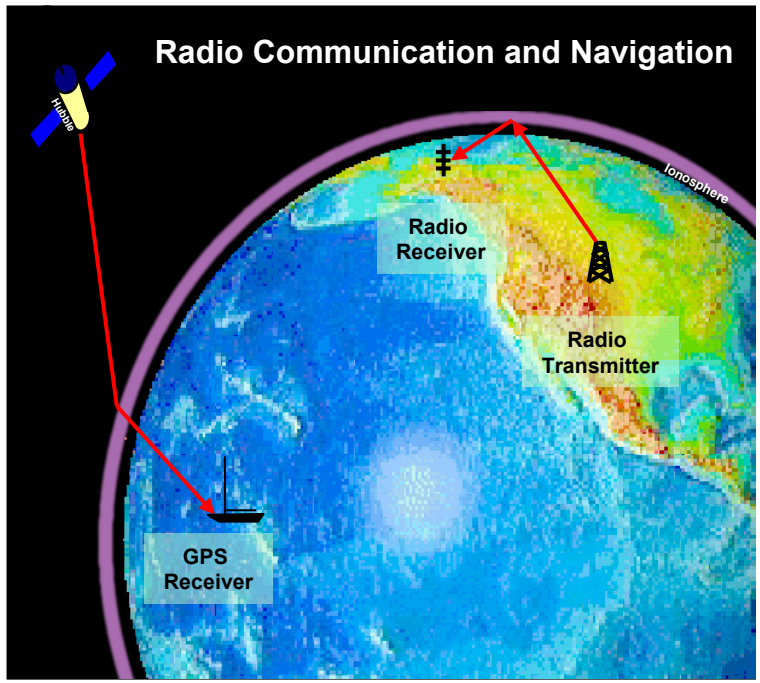


Systems Impacted by Solar EUV Variability

- **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

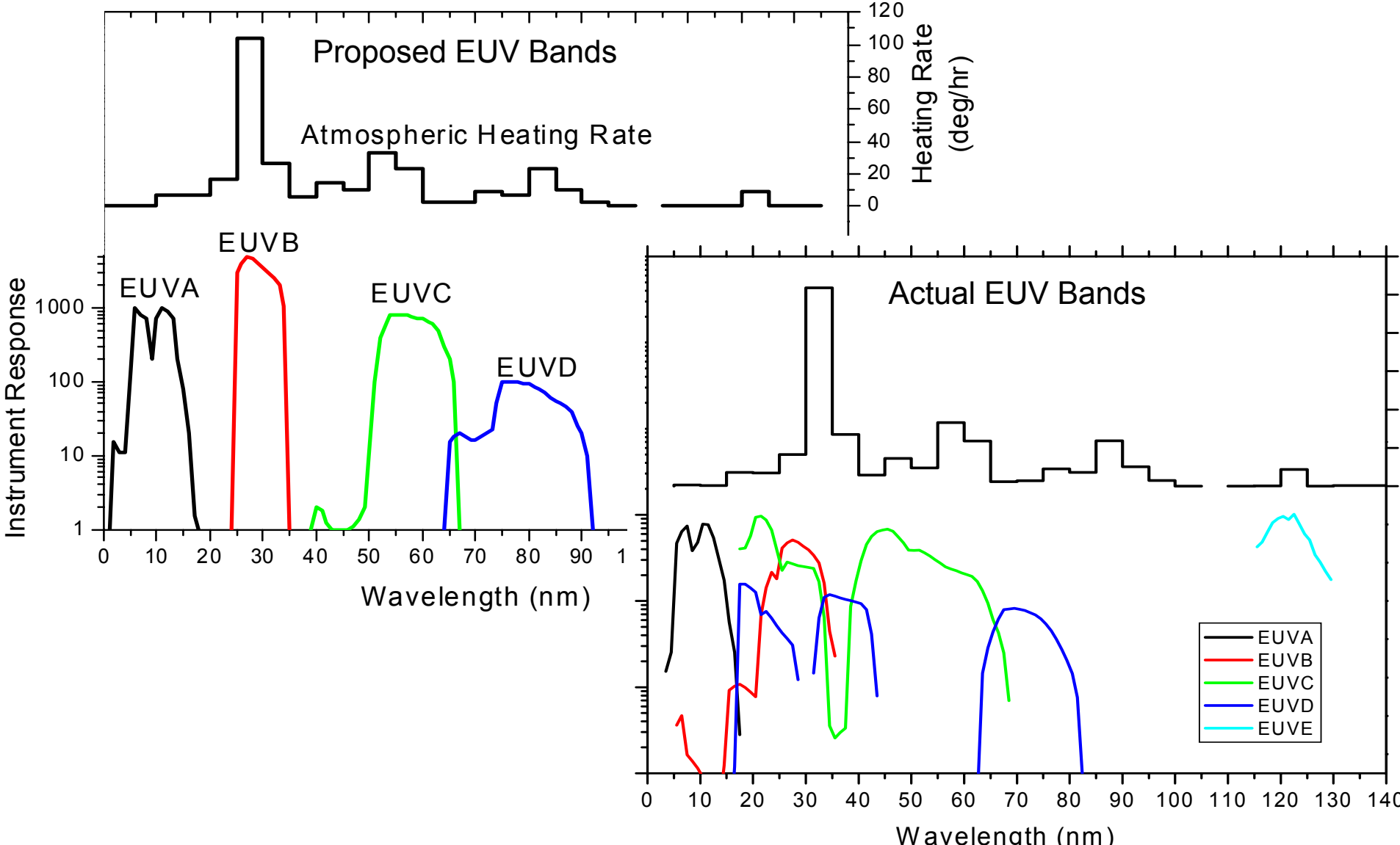
- **Communications and Navigation**
  - Variability in the EUV flux cases variability in the ionosphere. This affects radio transmissions and radio navigations





EUV Sensor for GOES N-P

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

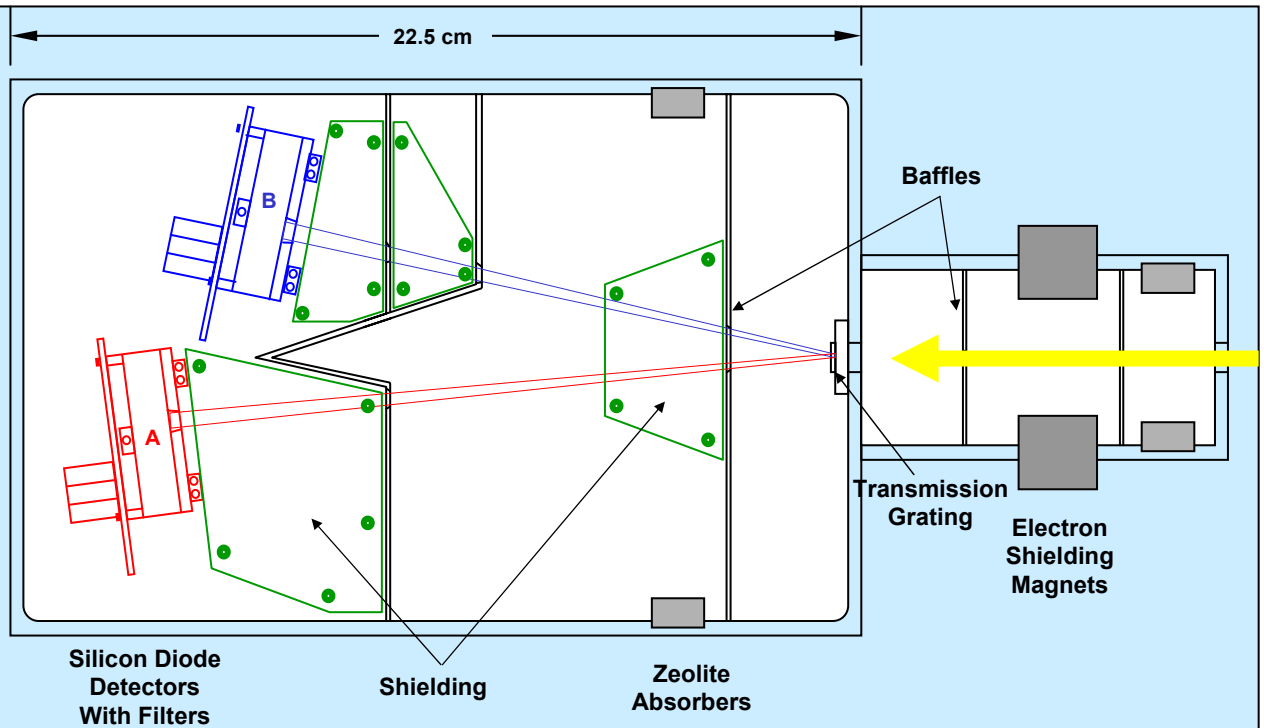


GOES N EUV Sensor

- **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

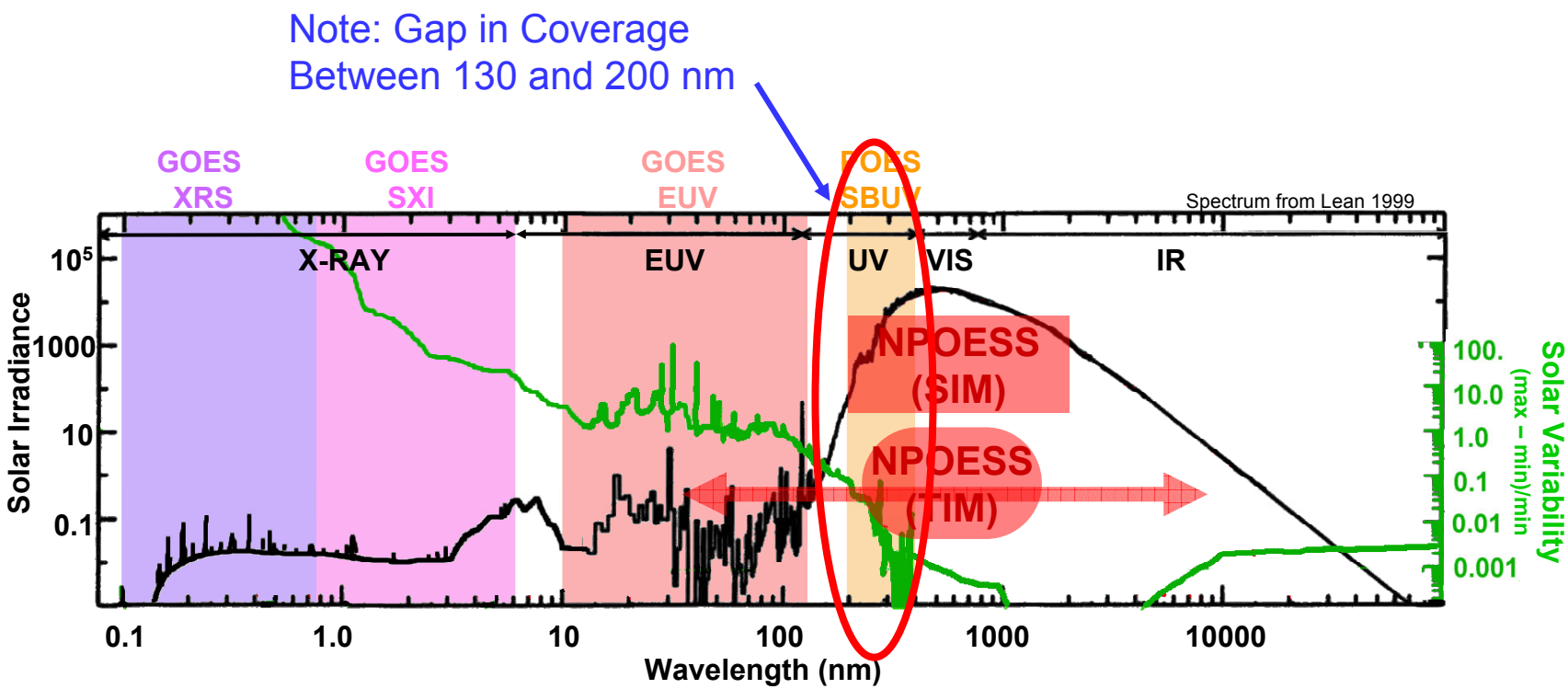
- EUV flux at each of the five bands at 10 second resolution.
- 1 minute, 5 minute, and daily averages of EUV flux
- Derived Products
  - Solar EUV Spectra (SOLAR2000 @ 1 nm resolution)
  - E10.7 (proxy for a proxy)
  - 1 Hour Cadence
- Inputs for EUV Models like GAIM (Global Assimilation of Ionospheric 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)



Solar UV Irradiance

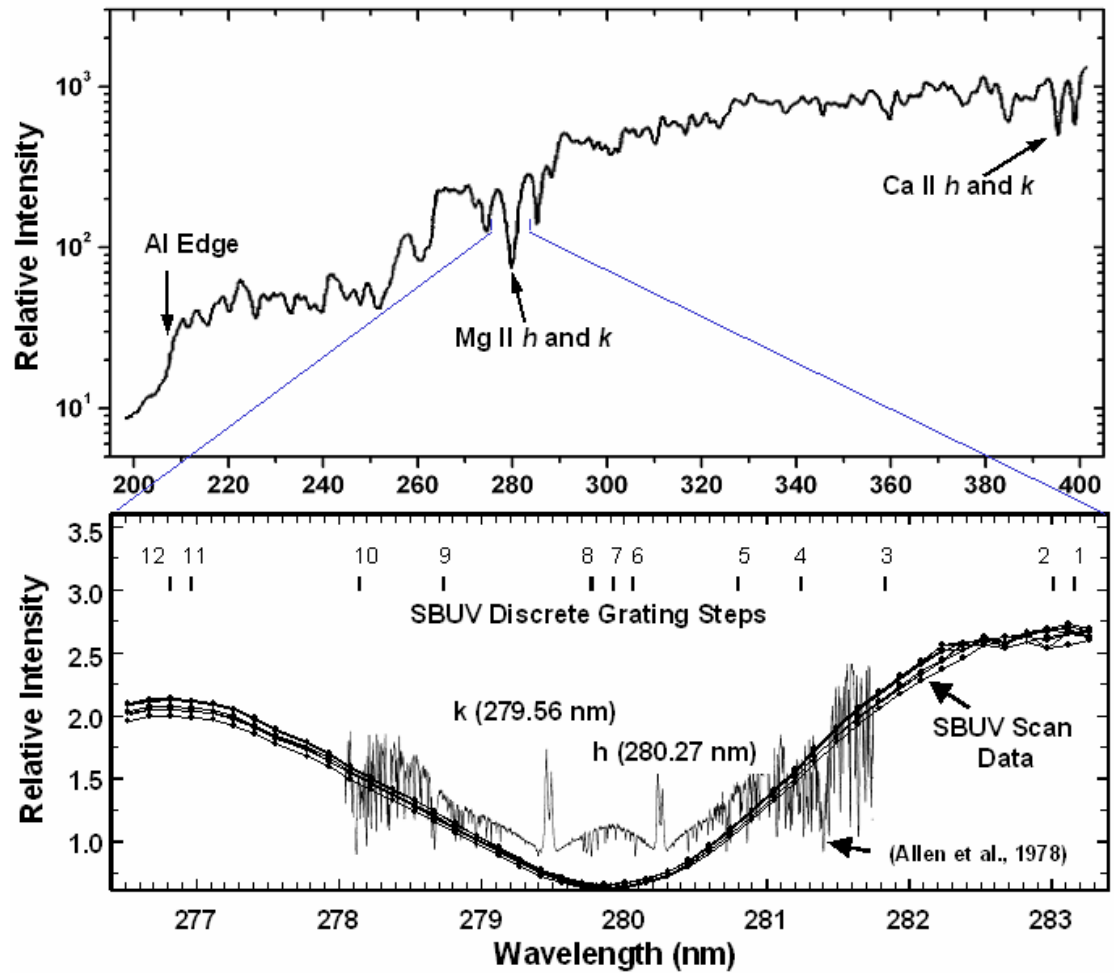
- SBUV/2 Double Ebert-Fasti Monochrometer
  - 1 nm resolution
- Daily solar observations with NOAA POES SBUV/2 Sensor
  - Primarily an ozone instrument
  - Ozone densities determined by taking the ratio of the downward solar flux and the upward (backscattered) flux
  - Measures Solar Spectra between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

SBUV Solar Data Products

Measurements made once a day of…

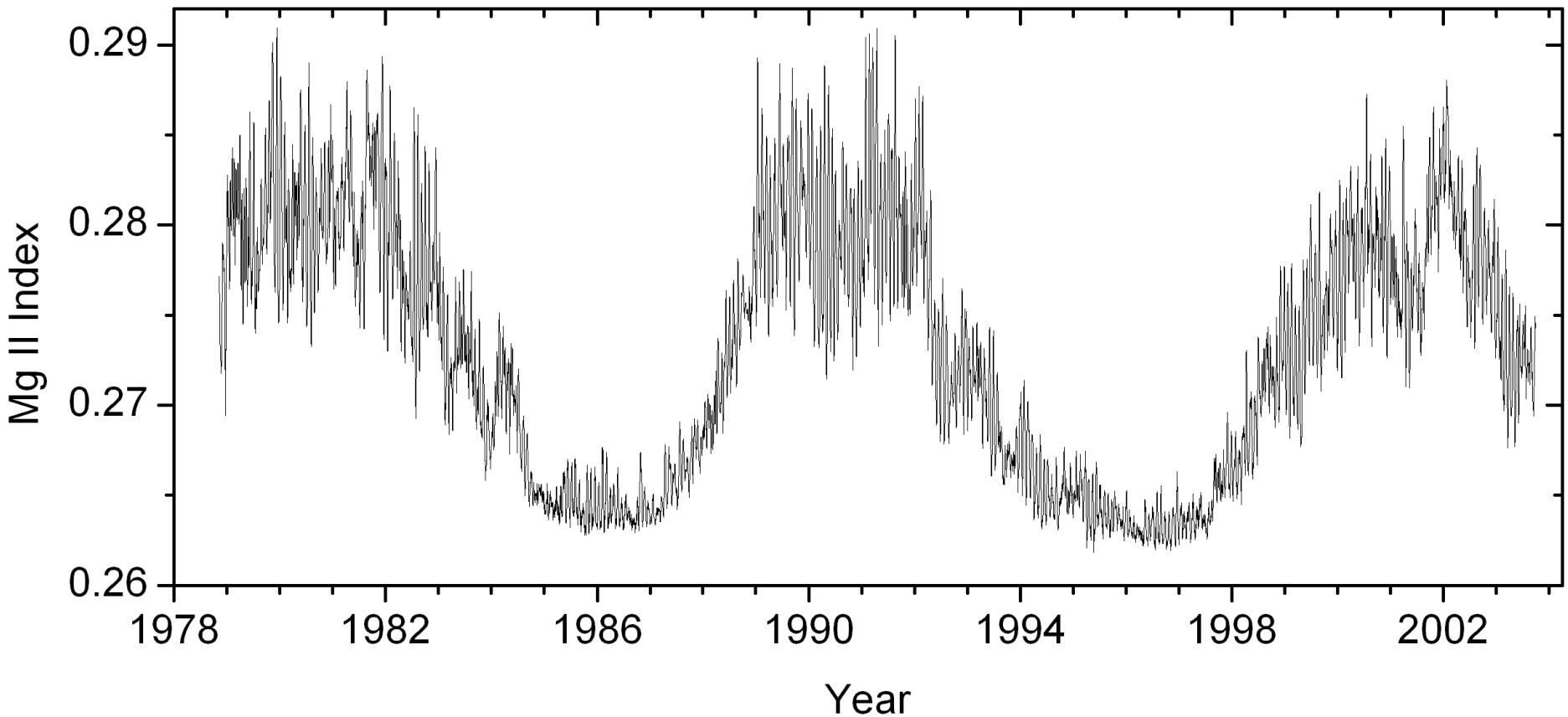
- **Solar UV Spectra**

- **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



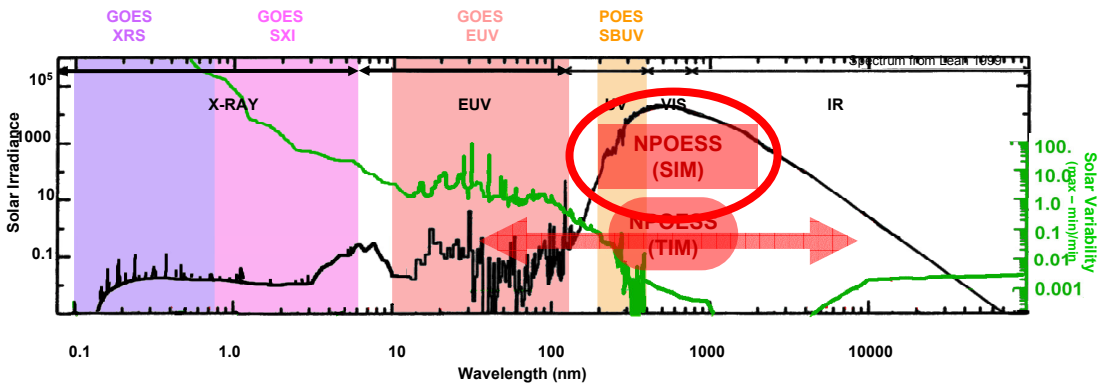
Future of NOAA Solar UV Measurements

- **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

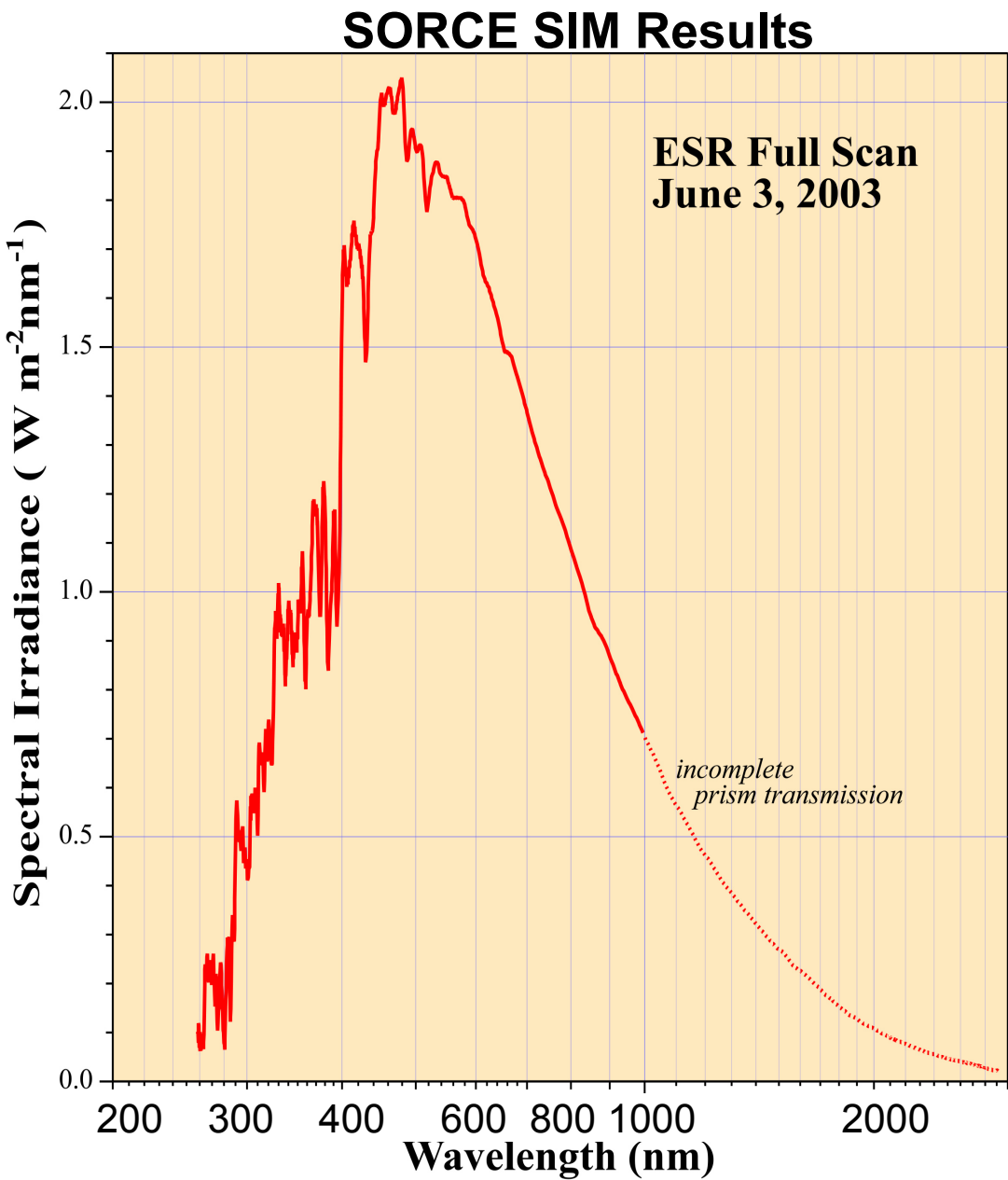
Spectral Irradiance Monitor (SIM)

- 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.**

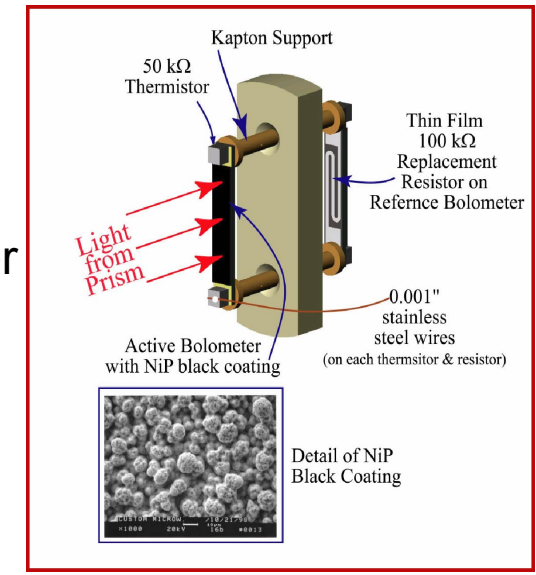


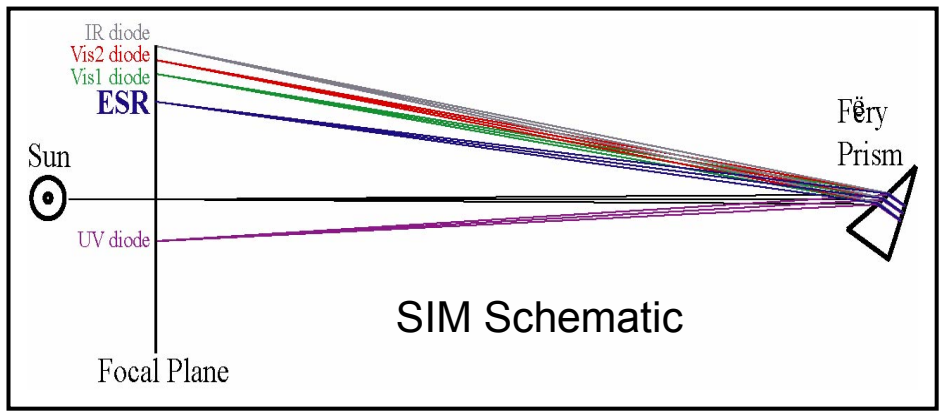
NPOESS Spectral Irradiance Monitor (SIM)

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**

ESR Detector

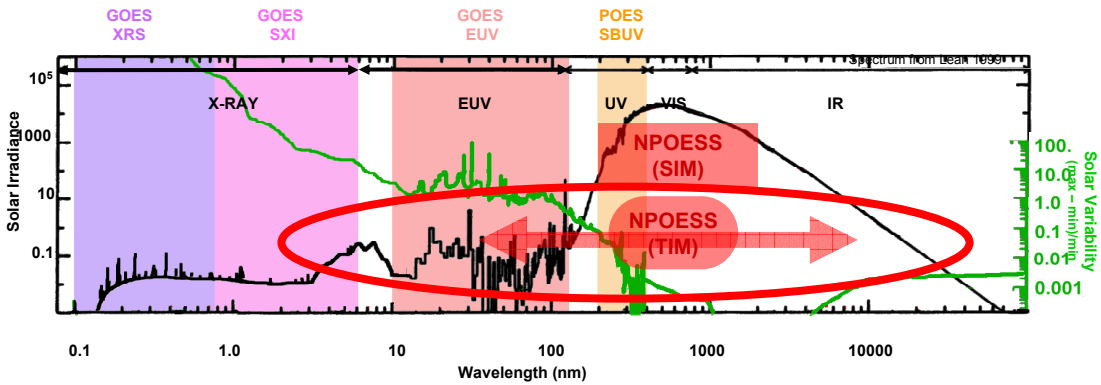




SIM Schematic

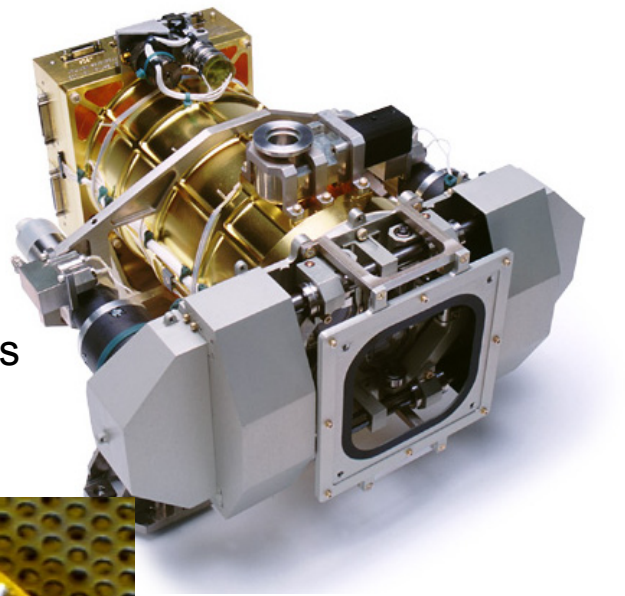
NPOESS Total Irradiance Monitor (TIM)

- Gary Rottman (CU LASP)
- Greg Kopp (CU LASP)

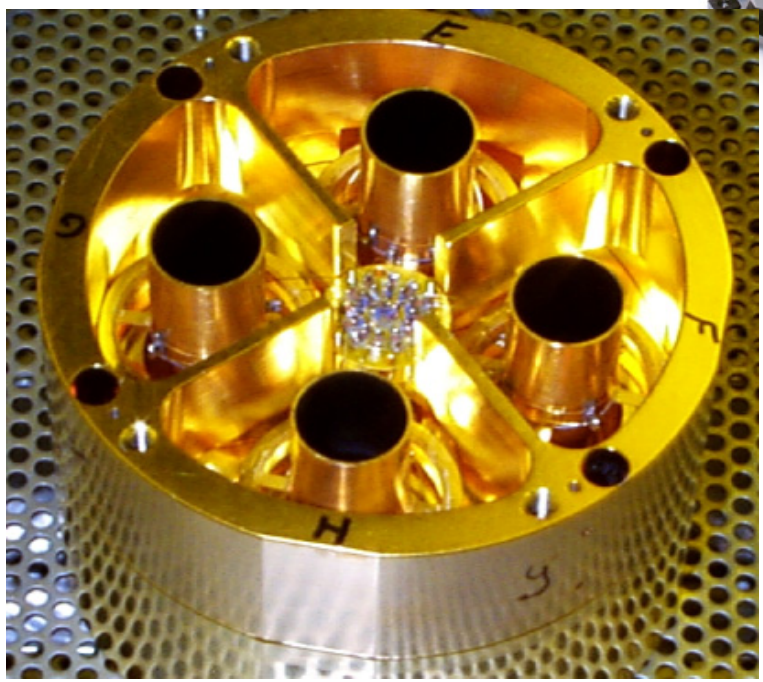


NPOESS Total Solar Irradiance Monitor

- 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: **0.01% (100 ppm)**
- Long-term Accuracy: **0.001% (10 ppm)**
- Heritage: *SORCE* TIM
- Pre-flight Cal. Std: NIST-traceable Volt and Ohm, apertures

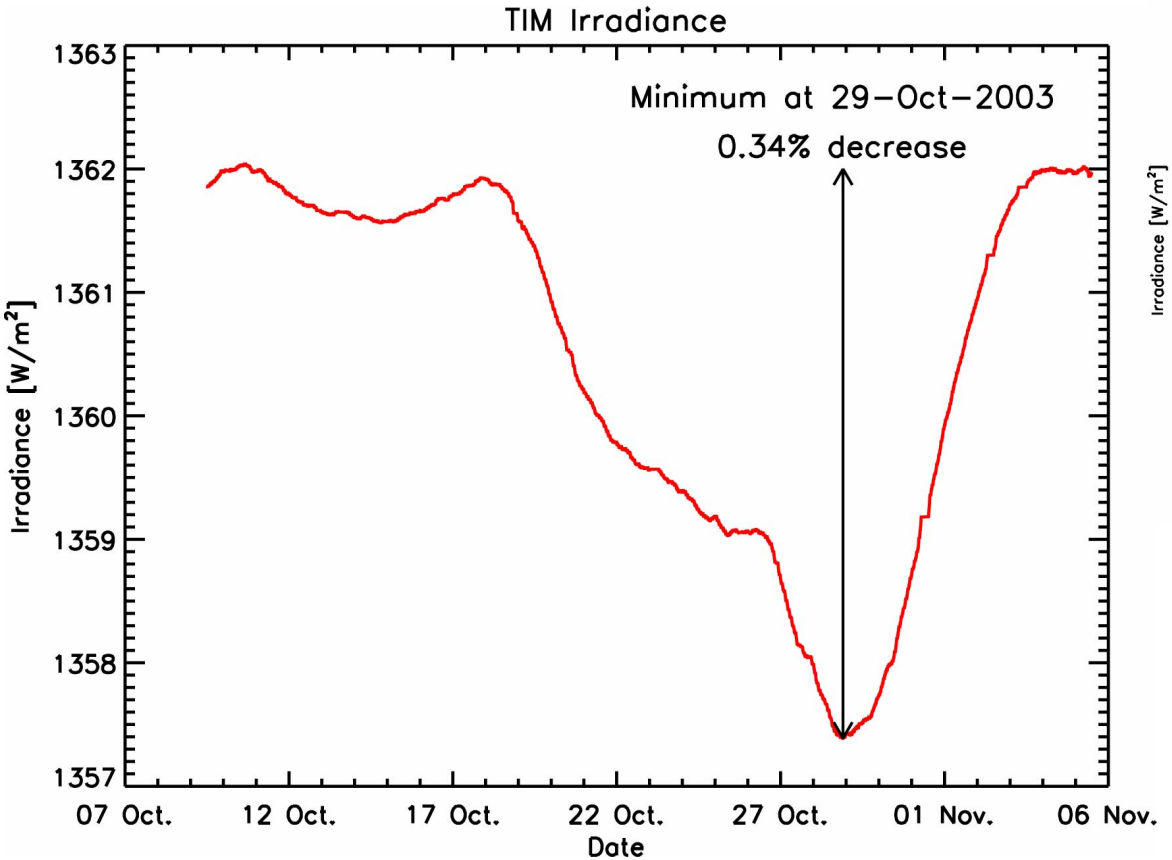


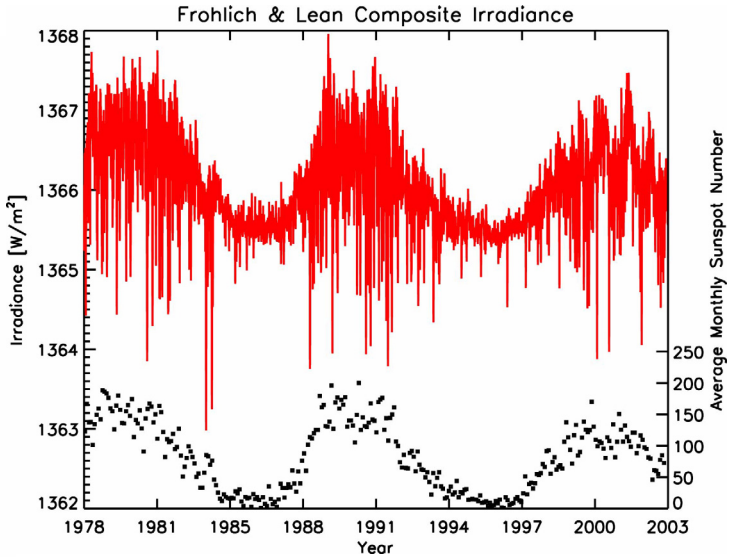
Key Technology
NiP black cones
ESRs use phase-sensitive detection at shutter frequency

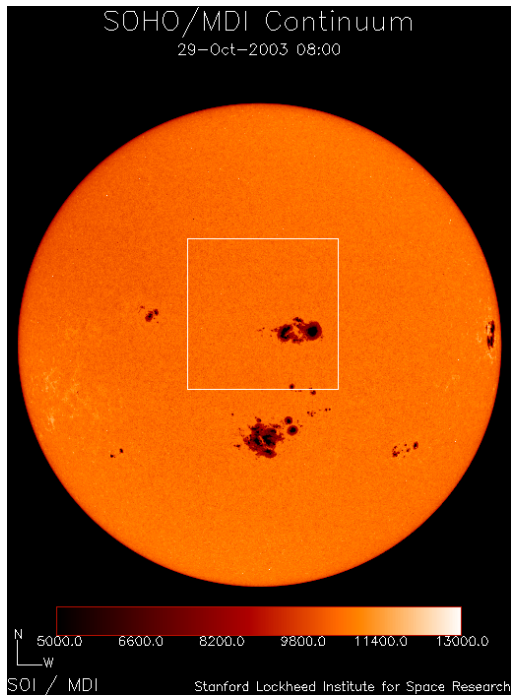


Important Calibrations
Standard Watt (V, I)
Aperture area
Cone absorptance

SORCE TIM Data

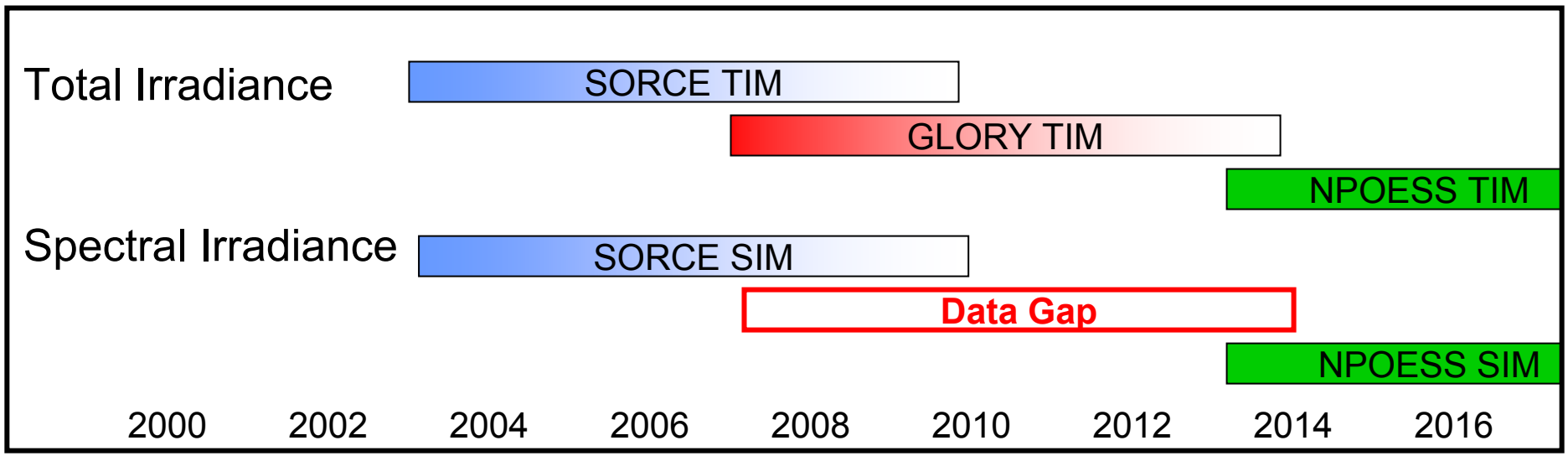






Long-term Measurement Issue

- **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 200? 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