SWFO - National Centers for Environmental Information

National Environmental Satellite, Data, and Information Service

15 April 2024

William Rowland, C. Bethge, J. Darnel, G. Dima, K. Hallock, F. Inceoglu, B. Kress, P. Loto'aniu, J. Machol, N. Merati, A. Pacini, L. Rachmeler, R. Redmon, J. Riley, J. Rodriguez, D. Schmit, X. Wei, et al.

National Centers for Environmental Information (NCEI)

Acquiring, Preserving, Monitoring, Assessing, and Creating Authoritative Environmental Data

The science-based NCEI organization produces and archives authoritative environmental data to enable individuals, businesses, and governments to make informed decisions.

In the SWFO and SW Next Program, NCEI will:

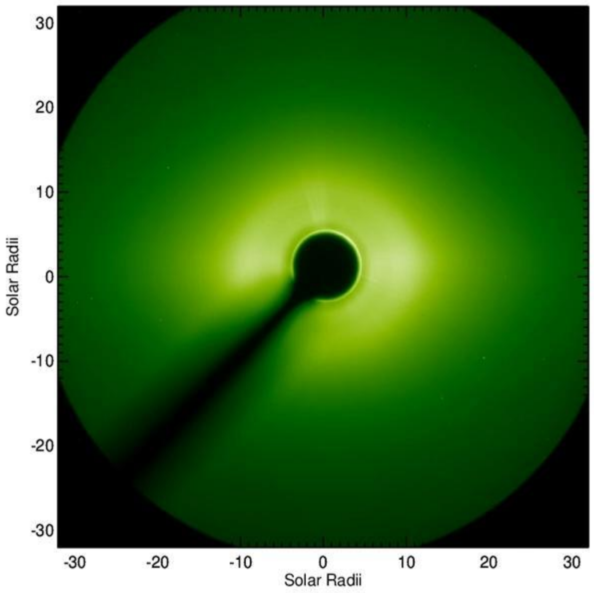
- Provide scientific, instrumental, and product expertise.
- Calibrate, validate, and ensure scientific accuracy of all SWFO and SWO data products.
- Develop and maintain the scientific product creation algorithms for SWFO, and both the scientific and operational product creation algorithms for future SWO missions.
- Archive operational and science-quality SWFO and SW Next data products.
- Develop and manage the Space Weather Science Center, with the DSCOVR data portal as heritage. This provides public access for non-operational users—scientists, researchers, general public, educators, etc.

SWFO Product List (Archive)

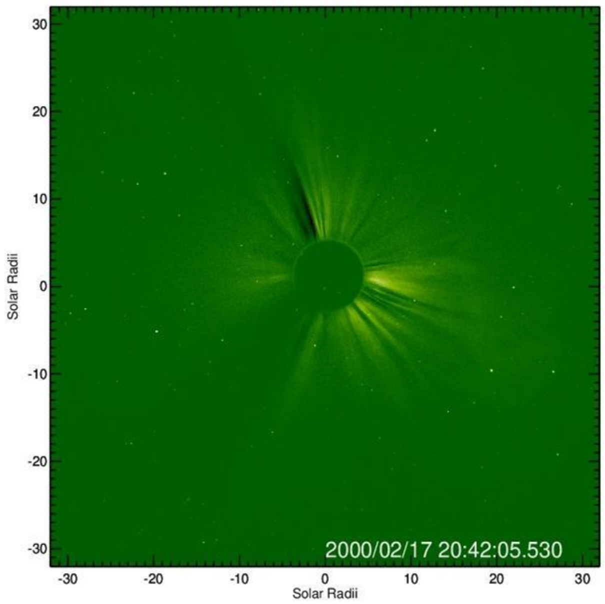
Instrument	Operational from SWPC	Reprocessed/Scientific from NCEI	Total Data Volume
CCOR-1 (GOES-U)	Day files: L0, L0b, L1a, L1b, L2, L3+ Tiers 1 and 2	Day files: L1a, L1b, L2, L3+ Tiers 1 and 2	Ops = 1.3 TB/yr Scientific = 0.9 TB/yr
CCOR-2	Day files: L0, L0b, L1a, L2, L3+ Tiers 1 and 2	Day files: L1a, L2, L3+ Tiers 1 and 2	Ops = 1.3 TB/yr Scientific = 0.9 TB/yr
SWiPS	Day files: L0, L0b, L1a, L1b, L2, L3+ Tiers 1 and 2	Day files: L1b, L2, L3+ Tiers 1 and 2	Ops = 0.2 TB/yr Scientific = 0.2 TB/yr
STIS	Day files: L0, L0b, L1a, L1b, L2, L3+ Tiers 1 and 2	Day files: L1b, L2, L3+ Tiers 1 and 2	Ops = 0.2 TB/yr Scientific = 0.1 TB/yr
MAG	Day files: L0, L0b, L1a, L1b, L2, L3+ Tiers 1 and 2	Day files: L1b, L2, L3+ Tiers 1 and 2	Ops = 0.2 TB/yr Scientific = 0.1 TB/yr

Example of Data Levels

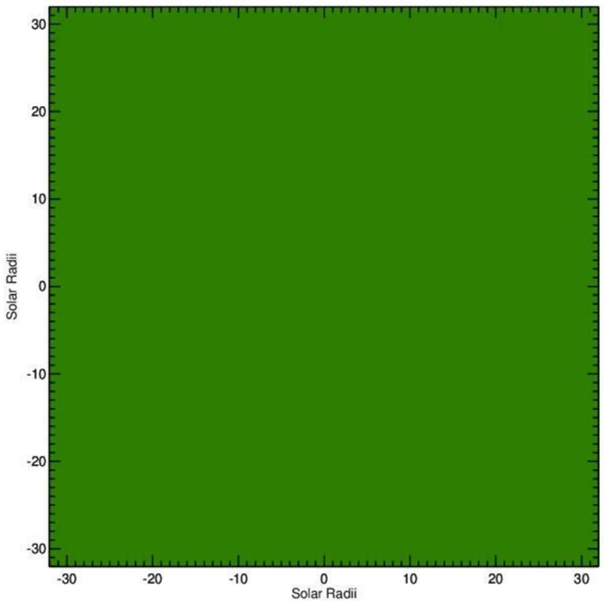
SWFO L1a
LASCO L0



SWFO L2
LASCO L0 - 1month background



Fixed Diff



SWFO-equivalent data levels using LASCO data
Credit: NCEI, NRL

SWFO - National Centers for Environmental Information *Calibration and Scientific Product Development*

William Rowland, C. Bethge, J. Darnel, A. Davis, G. Dima, K. Hallock, F. Inceoglu, B. Kress, P. Loto'aniu, J. Machol, N. Merati, A. Pacini, L. Rachmeler, R. Redmon, J. Riley, J. Rodriguez, D. Schmit, X. Wei, et al.

National Environmental Satellite, Data, and Information Service

15 April 2024

NCEI's Space Weather Team

Branch Chief: Stephanie Herring
Section Chief: Laurel Rachmeler

<u>Stewardship & Development</u>
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Rob Allsop
Stefan Codrescu
Liam Kilcommons
Ann Marie Mahon
Vicente Salinas
Xue Wei

Josh Riley (Data Management Lead)
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Pamela Wyatt

<u>Data Analysts (multi-discipline)</u>
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Fadil Inceoglu
Alison Jarvis
Elysia Lucas

<u>Solar</u>
Janet Machol (SWx CIRES Lead & Irradiance lead)
Don Schmit (Imagery lead)
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Gabe Dima
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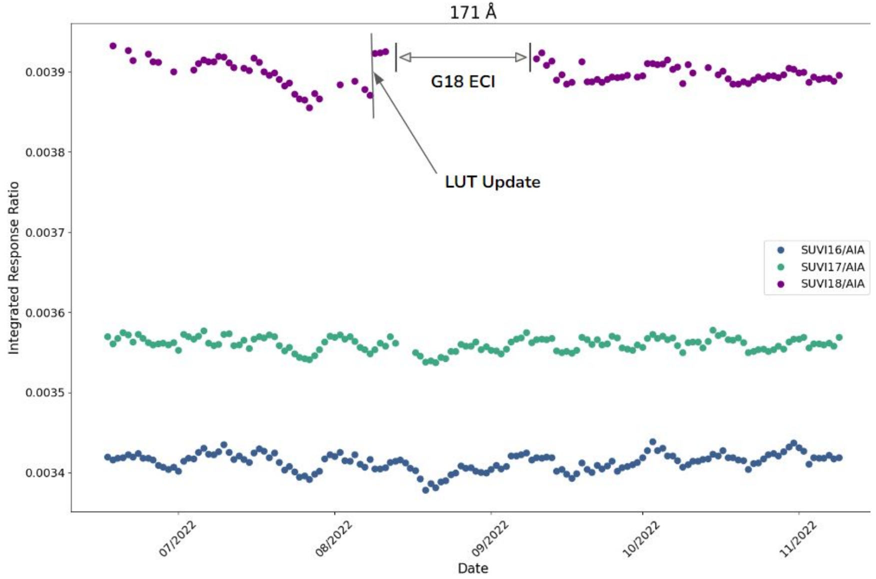
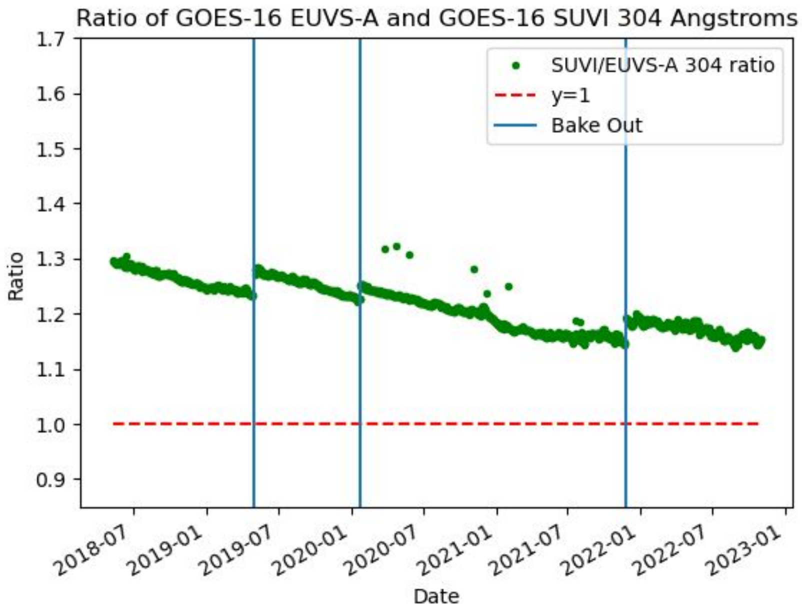
<u>Federal</u>
William Rowland (Space Weather Systems Architect, Calibration Working Group Lead)
Alessandra Pacini (Heliophysics Data Steward)

<u>NCAI</u>
Rob Redmon (NCAI Lead, Space Weather Scientist)

Blue Text - Federal Employee
Black Text - Cooperative Institute Affiliate

Cal/Val - SUVI Degradation





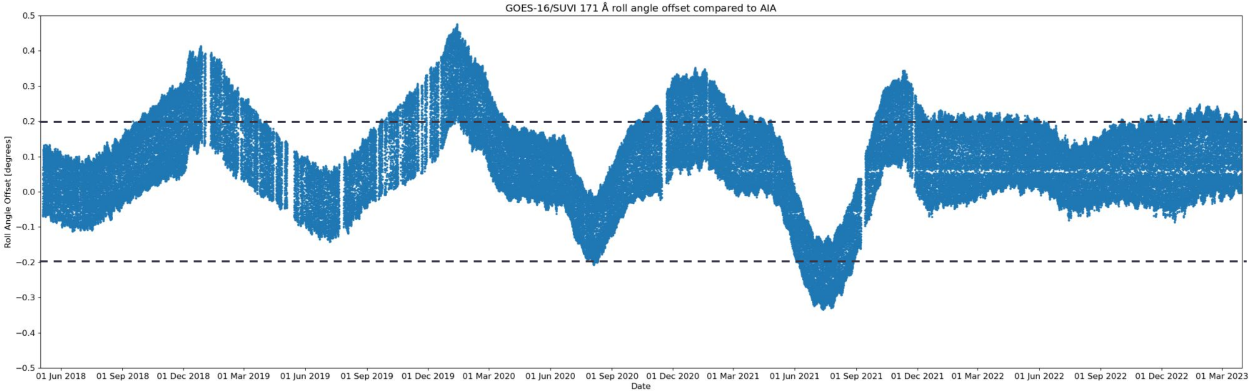
NCEI uses comparable solar instruments (NASA's SDO-AIA and NOAA's EXIS-EUVSA) to track the relative performance degradation of the SUVI instruments.

GOES-18 SUVI Provisional PS-PVR, J. Darnel et. al

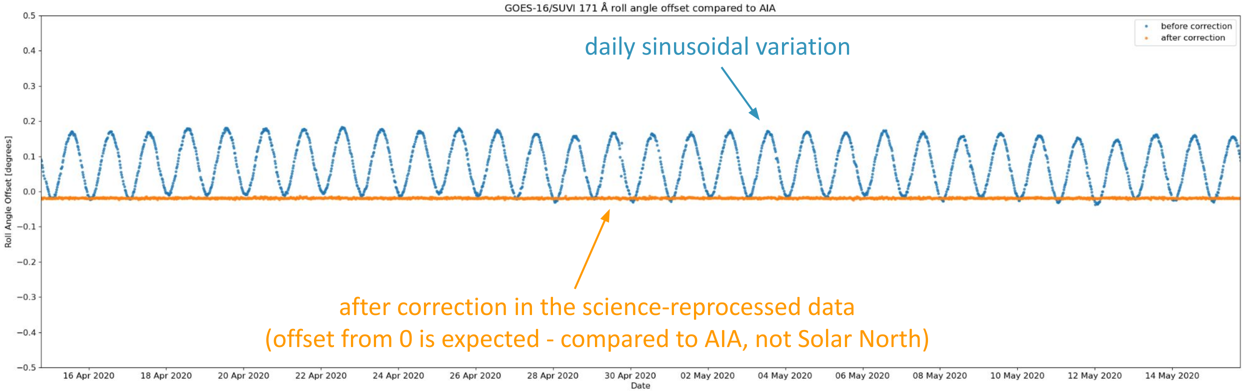
Cal/Val - SUVI Roll Angle

GOES-16/SUVI uncorrected roll angle variation compared to AIA (May 2018 - March 2023)

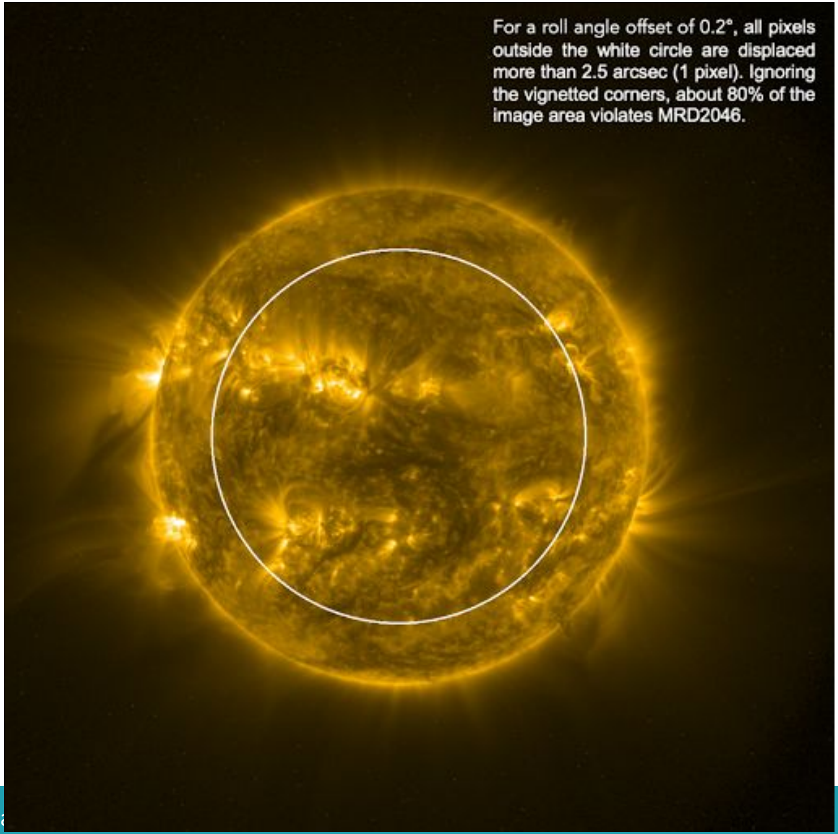
Impact of a .2 degree variation (i.e. outside of dashed lines) is shown on the next slide.



Zooming in on 15 April - 15 May 2020

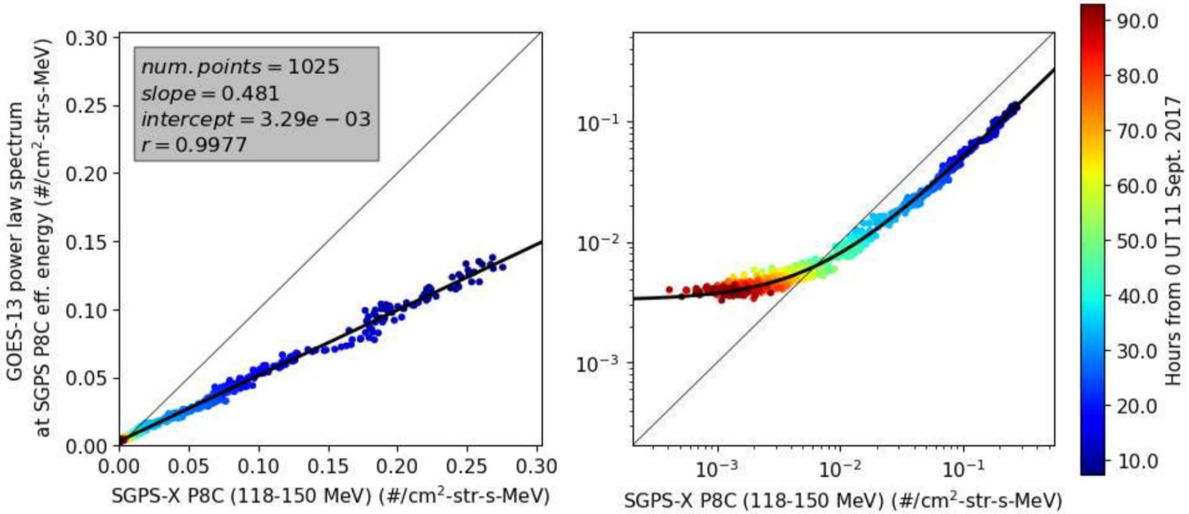


Cal/Val - SUVI Roll Angle Impacts



GOES-R Series Solar and Galactic Proton Sensor (SGPS) Cross Instrument Comparisons with Legacy GOES Energetic Particle Sensors (EPS)

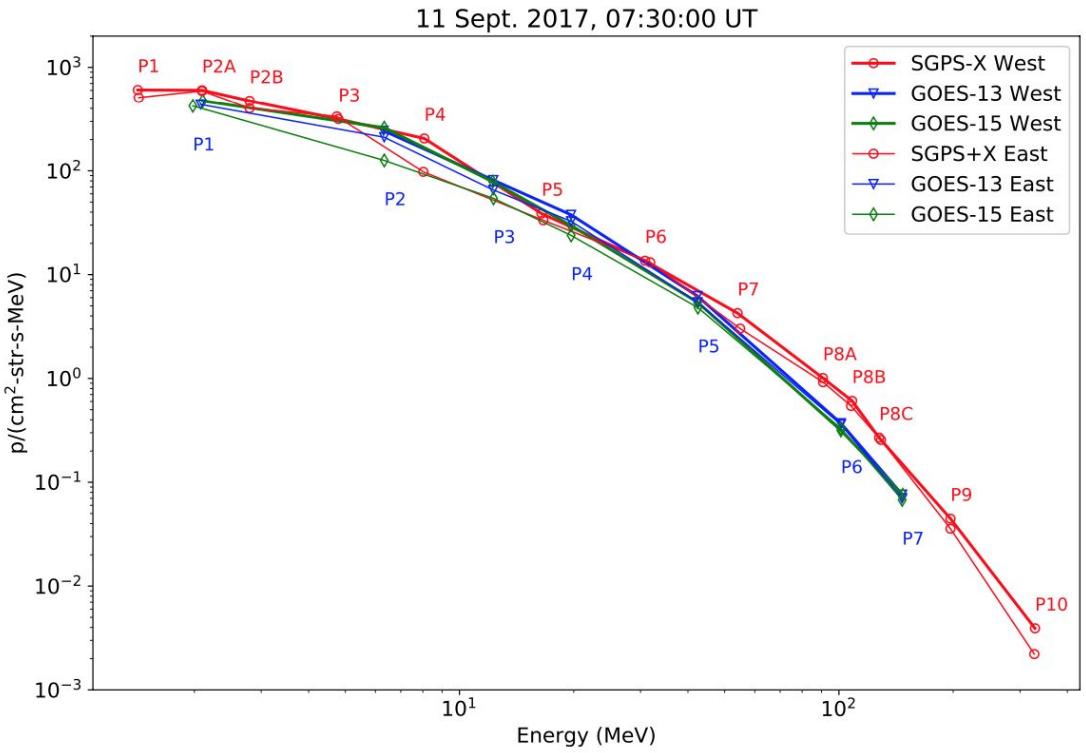
- These cross-satellite comparisons reveal systematic differences between SGPS and EPS measurements.
- They are critical for establishing continuity with legacy NOAA measurements and understanding changes in long-term trends in Solar Particle Event fluxes.
- They are also important for accounting for changes in space weather model results where legacy GOES energetic particle measurements have been used as model inputs.



GOES-13 West Energetic Particle Sensor (EPS) vs. GOES-16 Solar and Galactic Proton Sensor -X P8C scatter plots of simultaneous 5 min averages from 11-16 Sept. 2017 using linear and log scales. A power law is fit to the EPS fluxes, and comparisons with the EPS spectrum are made at SGPS channel effective energies. The same data and OLS fit is shown in both panels. The SGPS fluxes exceed the EPS measurements by approximately a factor of two [Kress et al., 2021, doi:10.1029/2021SW002750].

Example of Comparison of spectra from GOES-16 Solar and Galactic Proton Sensors and GOES-13 Energetic Particle Sensors.

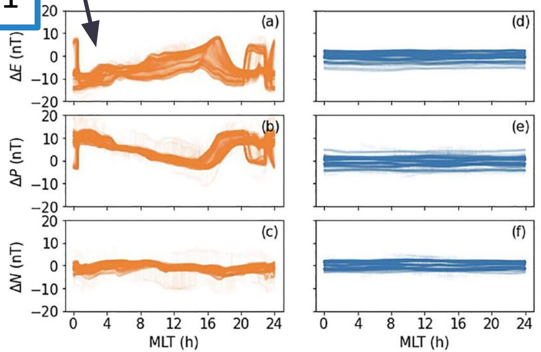
Comparison of spectra from Geostationary Operational Environmental Satellites (GOES)-16 Solar and Galactic Proton Sensor (SGPS), GOES-13 Energetic Particle Sensor (EPS), and GOES-15 EPS at 7:30 UT near the event peak flux during the September 2017 GLE. GOES-16, GOES-13, and GOES-15 measurements are shown with red, blue, and green traces, respectively. East and west fluxes are shown by the thin and thick traces, respectively.



Correcting Geosynchronous Magnetic Field using Transfer Learning

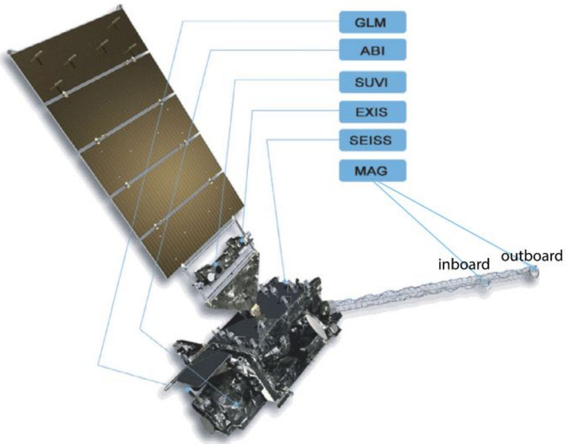
Errors

1



Outboard - Inboard time series for the E-component (ΔE), the P-component (ΔP), and the N-component (ΔN) for GOES-16 (a–c) and GOES-17 (d–f)

2

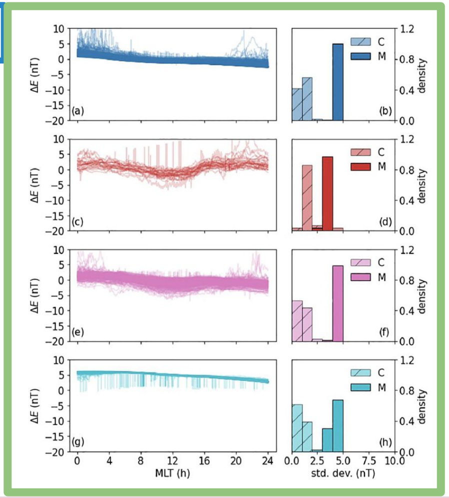


Four clusters of anomalous data detected in the Earthward-component of the magnetic field data.

…**due to Earth shadowing of the spacecraft during eclipse seasons**

Transfer Learning

3

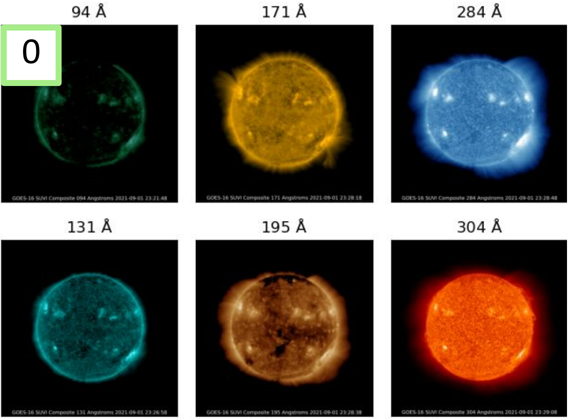


Correction via LSTMs using transfer learning from GOES-17. The left panel shows the difference between GOES-16 measured OB and corrected IB E-component magnetic field values for each cluster. On the right panel, we show the standard deviations calculated for the offsets between the measured OB and IB (darker colors) and also the standard variations in the differences between the measured OB and corrected IB (hatched bars).

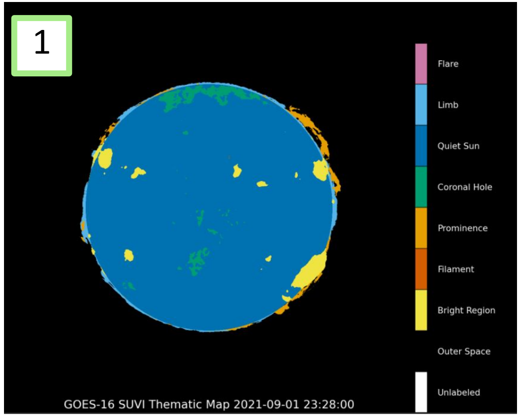
Inceoglu and Loto'aniu, Space Weather, 2021
https://doi.org/10.1029/2021SW002892

Advancing AI Research to Operations (R2O2R)

Characterizing the Sun with GOES-16 Solar Ultraviolet Imager



Random Forest

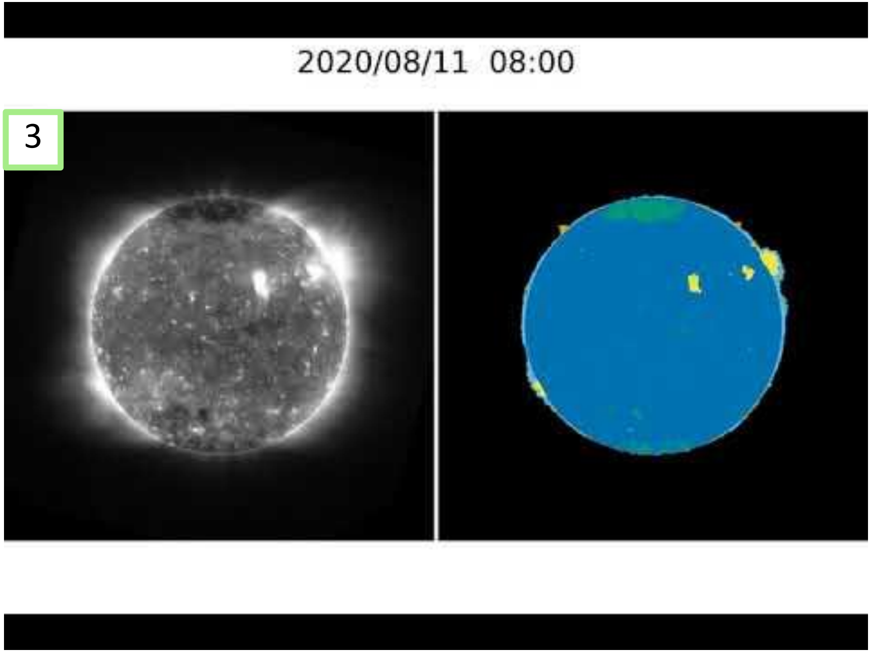


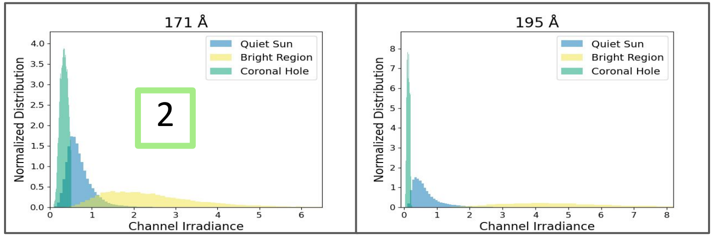
Thematic maps provide automatic, real-time classification of solar features, which is useful for space weather forecasters. These maps enable both real-time event monitoring / prediction and long-term statistical studies.

GOES-16 Solar Ultraviolet Imager (SUVI) composite images, observed in **six extreme ultraviolet** wavelengths, are input to a random forest algorithm to generate a thematic map.

As seen in the histograms below, irradiance distributions for different themes overlap in certain wavelengths, but have distinct, separate profiles in others. A random forest is an ideal solution to approach the complexity of wavelength combinations that can be used to isolate a given theme.

For some themes, such as flares and filaments, irradiance information alone is insufficient for classification. For these, we are investigating other forms of machine learning incorporating temporal and spatial information, such as CNNs.

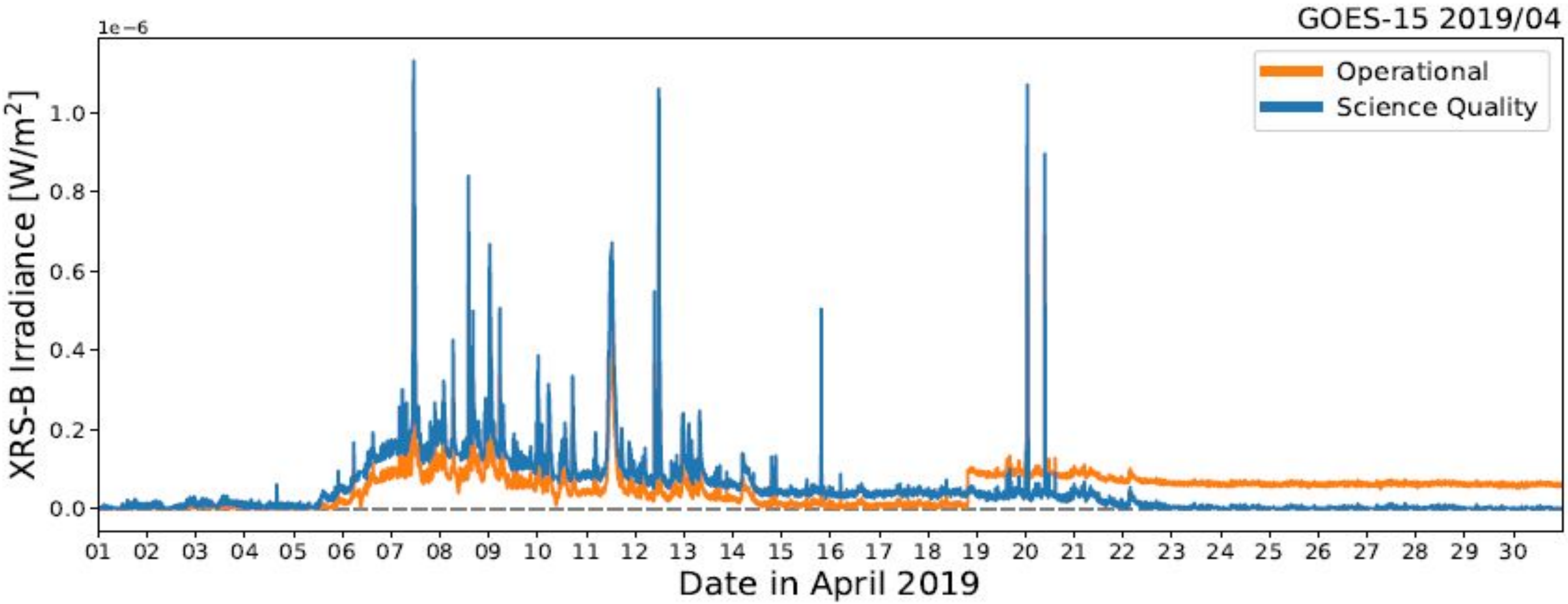




Thematic maps are **publicly available** on the GOES-R Space Weather Page, with **example code** to display the data. The work of Hughes et al. describes the problem and previous algorithms, and the code used to produce these results can be found at github.com/jmbhughes/thmap.

Please contact Alison Jarvis (alison.jarvis@noaa.gov) or Chris Bethge (christian.bethge@noaa.gov) with any questions.

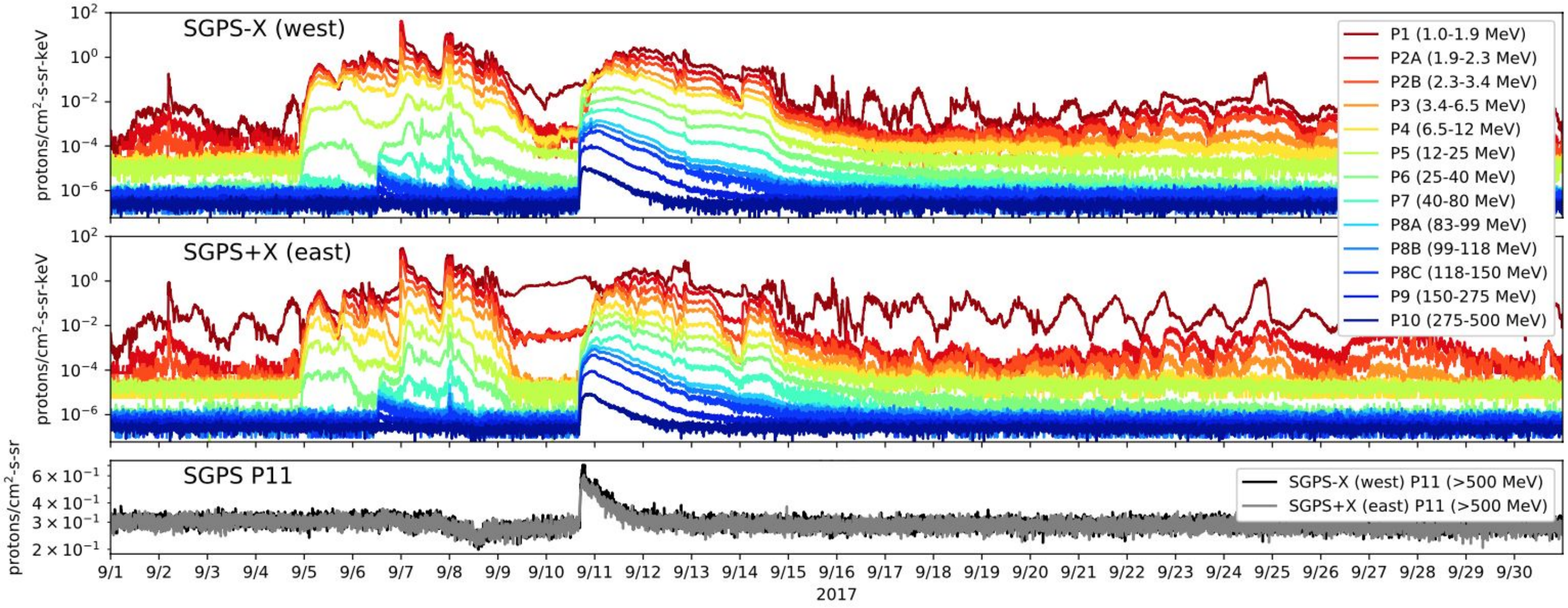
Scientific Stewardship



Additional information available at **Poster Sessions on Tuesday, 04/18**, "Solar and Interplanetary Research and Applications," 9:35-10:45AM and 2:45-3:45PM. ***"50 Years of GOES XRS Science-Quality Data"***, *J. Mothersbaugh et. al*

GOES-16 SGPS 5-minute Averaged Fluxes from the September 2017 Solar Particle Events

Full Solar and Galactic Proton Sensor (SGPS) September 2017 data set available from the NOAA - National Centers for Environmental Information Geostationary Operational Environmental Satellites-R website, including P1–P10 (differential) and P11 E (500 MeV) integral fluxes from east- and west-facing SGPS units. The complete September 2017 SGPS data set is available from the NOAA-NCEI website at https://www.ngdc.noaa.gov/stp/satellite/goes-r.html.

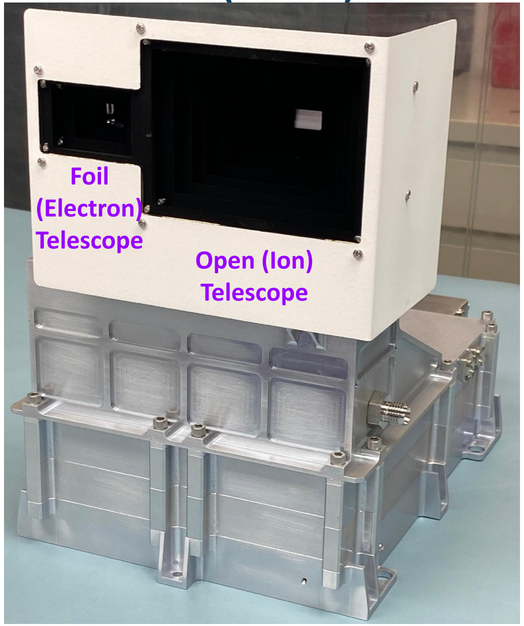


Backups

MAG

<table>
<tr><th colspan="3">Requirement</th><th>Performance</th></tr>
<tr><td rowspan="2">Range</td><td>In-situ</td><td>±250 nT</td><td>±440 nT</td></tr>
<tr><td>Ground test</td><td>± 20 μT</td><td>± 20 μT</td></tr>
<tr><td rowspan="3">Accuracy</td><td>|B| ≤ 100 nT</td><td>≤ ±0.5 nT</td><td>≤ ±0.26 nT</td></tr>
<tr><td>|B| > ±100 nT |B| < ±250 nT</td><td>≤ ±0.5%</td><td>≤ ±0.24%</td></tr>
<tr><td>|B| ≥ 250 nT</td><td>< ±1000 nT</td><td>< ~300 nT</td></tr>
<tr><td>Noise</td><td>Integrated [0.05, 0.5] Hz</td><td>0.137 nT rms</td><td>0.015 nT rms</td></tr>
<tr><td rowspan="2">Quantization Error</td><td>|B| ≤ 250 nT</td><td>≤ 0.05 nT</td><td>≤ 0.03 nT</td></tr>
<tr><td>|B| ≤ 20,000 nT</td><td>≤ 13 nT</td><td>≤ 4.0 nT</td></tr>
</table>

Suprathermal Ion Sensor (STIS)



Credit: University of California, Berkeley, Space Sciences Laboratory

Prior to IOC, cross-calibration planned with ACE/EPAM for operational continuity and with SWFO-L1/SWiPS for data accuracy

Suprathermal Ion Sensor products:

Telescope FOVs: 80 x 60 deg, centered 50 deg off the Sun-Earth line in the ecliptic plane in the 'ahead' direction

Proton fluxes are produced from Open telescope count rates. Corrected for electron contamination using Foil telescope observations.

Electron fluxes are produced from Foil telescope count rates although they are not a SWFO-L1 requirement.

Product levels:

- L0b: counts, 2-s cadence
- L1a: count rates, 2-s cadence
- L1b: differential fluxes, 2-s cadence
  - Protons: 0.025-6 MeV, 38 energy bands
  - Electrons: 0.025-0.3 MeV, 17 energy bands
- L2: differential fluxes, 2-s cadence, ACE/EPAM-like energy bands
  - Protons: 0.047-4.8 MeV, 8 energy bands
  - Electrons: 0.045-0.3 MeV, 4 energy bands
- L3: 1-minute averages of L1b and L2 fluxes

Note: channel count & definitions are subject to revision as the calibrations are refined

Solar Wind Plasma Sensor (SWiPS)

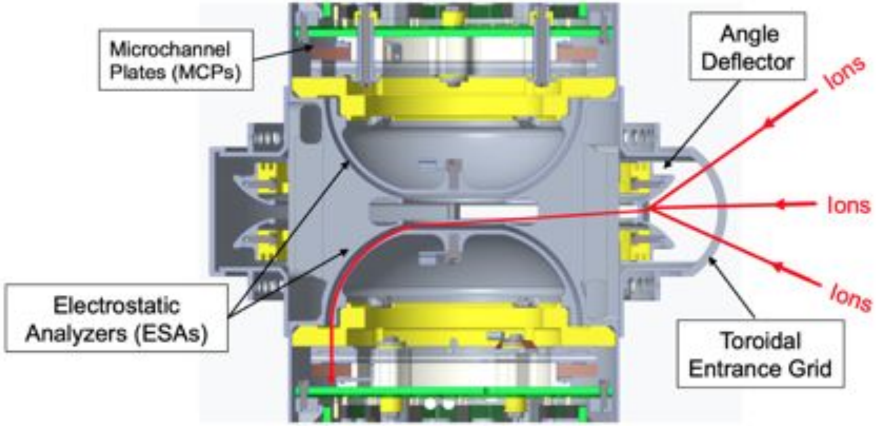


Image credit: Ebert et al., 2022 AGU Fall Meeting, SH46B-08.

- Two oppositely oriented top-hat electrostatic analyzers (ESAs) with a common toroidal entrance aperture
- Both used for measuring solar wind ions. One is used operationally, while the other is in standby mode.
- The standby ESA is used for periodic cross calibrations with the operational ESA, to monitor changes in the operational sensor performance.

SWiPS measures solar wind density, velocity and temperature to characterize interplanetary structures such as coronal mass ejections (CMEs), co-rotating interaction regions (CIRs), interplanetary (IP) shocks, and high-speed streams associated with coronal holes. SWiPS will provide early warnings of changes in the interplanetary medium which are a source of geomagnetic storms and elevated radiation belt fluxes.

SWiPS Measurement Requirements

Cadence	60 seconds
Density	0.1 - 150 cm^{-3} $\pm$10%
Velocity	200-2500 km/s $\pm$10%
Temperature	40,000 -2,000,000 K $\pm$10%
SW Dynamic Pressure	1 - 100 nPa (Consistent with ranges for n and V)

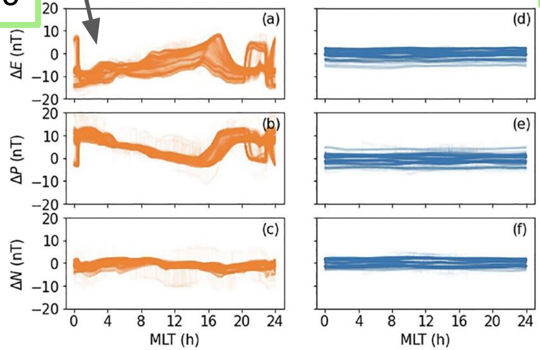
Advancing AI Research to Operations (R2O2R)

Correcting Geosynchronous Magnetic Field using Transfer Learning

Errors

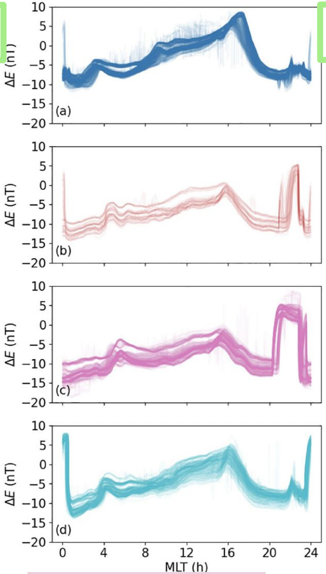
GOES-16 GOES-17

0



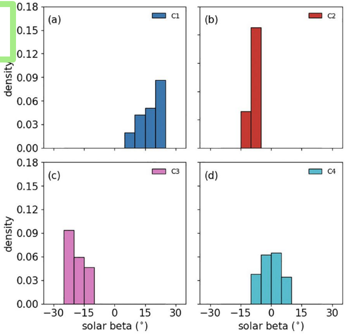
Outboard - Inboard time series for the E-component (ΔE), the P-component (ΔP), and the N-component (ΔN) for GOES-16 (a–c) and GOES-17 (d–f)

1



Four clusters from k-Shape, C1 (a), C2 (b), C3 (c), and C4 (d), detected in the GOES-16 OB-IB E-component magnetic field data.

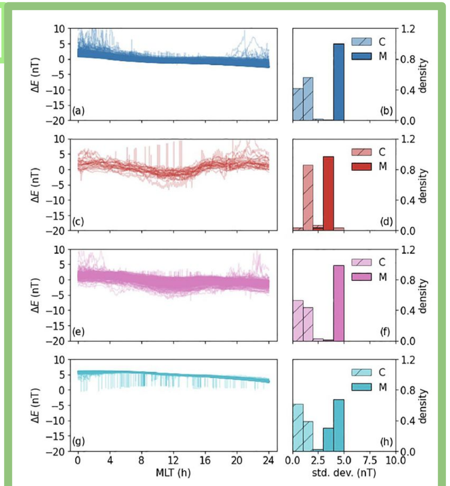
2



Distribution of the solar beta angles in C1 (a), C2 (b), C3 (c), and C4 (d). The solar beta is a measure of the amount of time that a satellite is in direct sunlight. The ΔE trends for each cluster are consistent with thermally induced contamination **due to Earth shadowing of the spacecraft during eclipse seasons** as defined by β, and due to spacecraft shadowing of the boom.

Transfer Learning

3



Correction via LSTMs using transfer learning from GOES-17. The left panel shows the difference between GOES-16 measured OB and corrected IB E-component magnetic field values for each cluster. On the right panel, we show the standard deviations calculated for the offsets between the measured OB and IB (darker colors) and also the standard variations in the differences between the measured OB and corrected IB (hatched bars).

Inceoglu and Loto'aniu, Space Weather, 2021
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