

# SMOS, how an ESA Earth Observation mission can contribute to Solar activity monitoring



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# About SMOS

**When:** Launched in Nov. 2009

## Target:

Land products

(soil moisture, Soil freeze/thaw state)

Sea products

(sea surface salinity, sea ice thickness,  
Sea surface wind speed)

## Orbit:

sun-synchronous orbit  
(dusk-dawn 6am/6pm)

## Payload:

L-band Microwave Imaging Radiometer  
with Aperture Synthesis (**MIRAS**)



**What?**  
SMOS (Soil Moisture and Ocean Salinity) is one of ESA's Earth Explorers dedicated to capturing 'brightness temperature' images of Earth's surface

**Innovative**  
SMOS carries the first spaceborne microwave **interferometric radiometer (MIRAS)** to measure Earth's surface radiation at 1.4 GHz

**When?**  
Launched **2 November 2009**, initially designed as a five-year mission, it is **still delivering key information** to advance science and data used in various practical applications, such as weather forecasting

**Applications?**  
It is the first mission to provide global observations of the temporal and spatial variability in **soil moisture** and **sea surface salinity**, which are driven by the continuous exchange in Earth's water cycle between the oceans, atmosphere and land

**What's next?**  
Going way beyond its original scientific aim of delivering critical information to understand Earth's water cycle, **SMOS continues to demonstrate its suitability for new uses**. Some examples include:  

- providing information to **measure thin ice floating** in the polar seas accurately enough for **forecasting and ship routing**
- measurements of severe winds over oceans to support tropical **cyclone monitoring** and forecasting
- measuring the solar flux** to support space weather applications and solar science studies

**Benefits?**  
These **key geophysical parameters**—soil moisture for understanding hydrometeorological processes and salinity for understanding of ocean circulation—are both vital for climate change studies. Its images are used to derive global maps of soil moisture and sea surface salinity **every three days**, at a **spatial resolution of about 50 km**

**Where?**  
The PROTEUS spacecraft platform SMOS utilises was designed and built by **CNES and Alcatel Alenia Space**, while the **MIRAS** instrument was designed and built by a consortium of 20 European companies, led by **EADS-Casa Espacio (now Airbus)**

**Data and Users**  
Since the beginning of the SMOS mission, around 24.2 million products have been downloaded from ESA's SMOS dissemination service, by more than 1700 active users, for a total volume of 920 TB of data

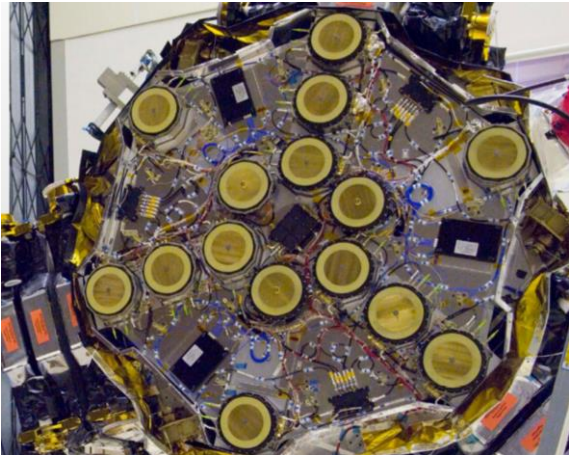
**Data Access**  
<https://smos-diss.eo.esa.int/oads/access>

**Data Access**  
<https://earth.esa.int/eogateway/missions/smos>

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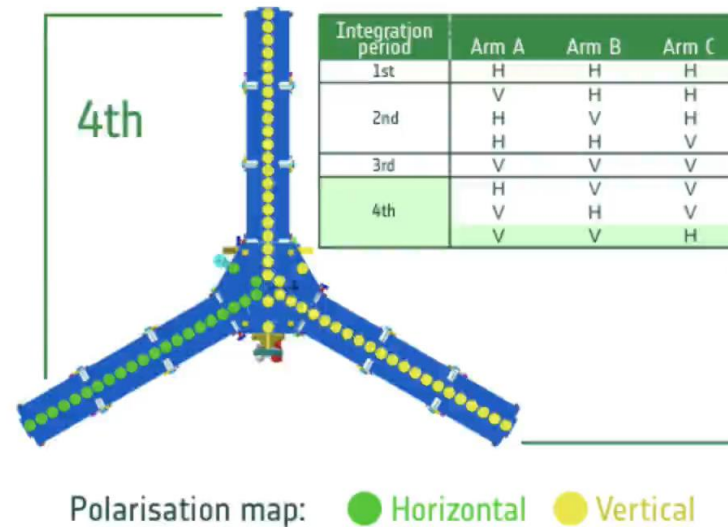
# About MIRAS Instrument

Passive microwave **2-D interferometric full polarization radiometer**, operating at **1.413 GHz** (freq. wavelength 21 cm at L-band) within the protected 1400-1427 MHz band.

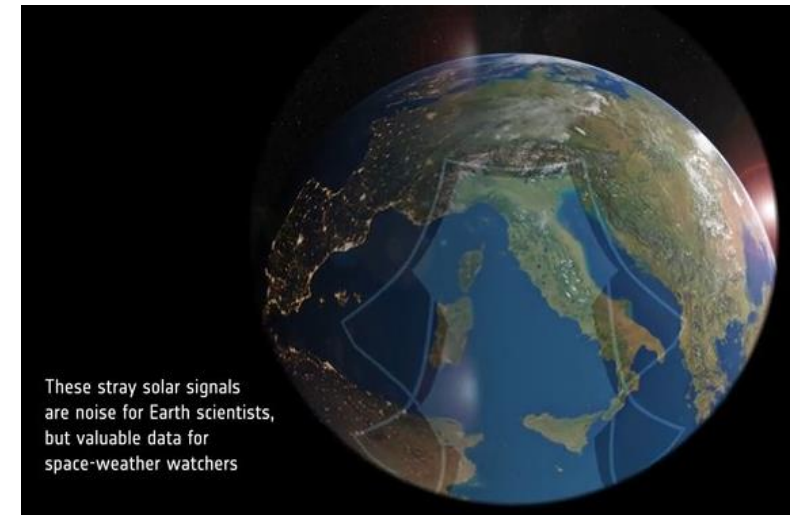


3 arms 120° apart with 23 equally spaced antennae each. Diameter 16.5 cm.

Sampling rate is 1.2 sec  
 A full polarimetry measurement is acquired in four integration period i.e. **4.8 seconds**.



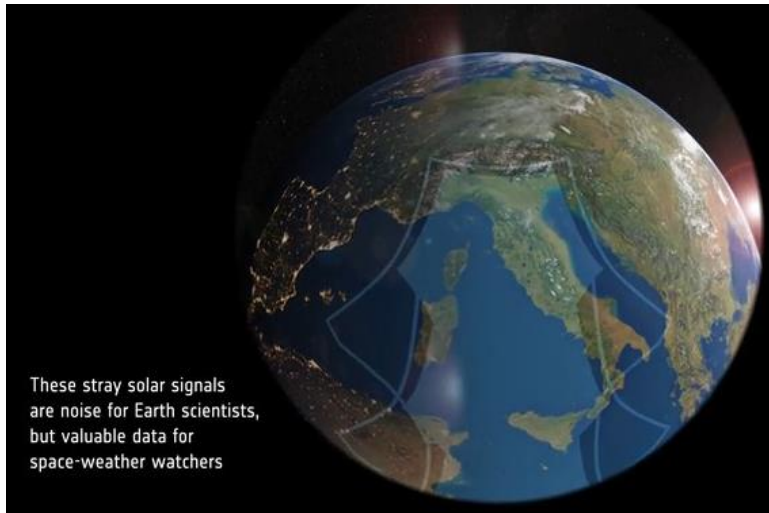
Due to antenna size and freq. wavelength, the instrument's field of view (FoV) is large enough to include full Earth-disk and part of the surrounding Sky including the Sun.



These stray solar signals are noise for Earth scientists, but valuable data for space-weather watchers

# About MIRAS L1B data

Due to antenna size and freq. wavelength, the instrument's field of view (FoV) is large enough to include full Earth-disk and part of the surrounding Sky including the Sun.

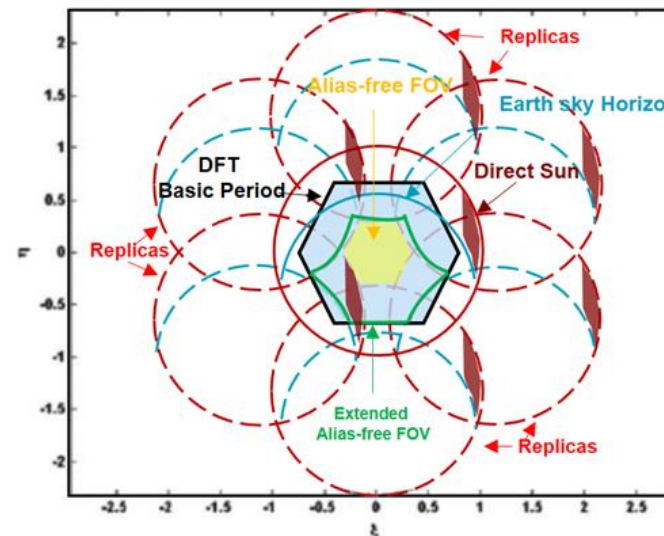


The ancillary parameters from the “Sun removal” algorithm available in the operational L1B v724 products can be used to derive the Sun Brightness Temperature for the entire Stokes vector (Sun BT)

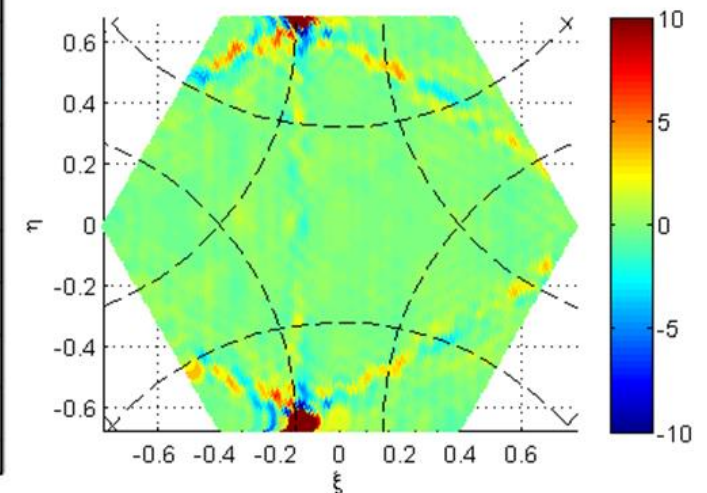
Antenna spacing is 0.875 wavelengths. Part of the FoV is affected by aliasing.

Direct Sun signal appears as a replica in the SMOS image disturbing the sensing of Earth surface emission.

**This signal is “removed” by the L1 processor, the result of this removal is annotated in L1B product.**



SMOS Field of view and image alias



SMOS image with Solar signal

# SMOS Solar Flux daily product algorithm

Sun BT from  
SMOS L1B data

- **Data aggregation**  
*semi-orbit merging on daily basis*
- **Filtering**  
*(RFI, Eclipse, Sun position Front/Back, Sun elev. angle threshold <0.2 rad)*
- **Earth-Sun distance correction**  
*normalization to 1AU*

**Correction for obliquity factor**

$$BT_{Corr El.} = BT / \cos\left(\frac{\pi}{2} - e\right)$$

Where  $e = \arccos(\sqrt{xi^2 + eta^2})$

**LUT (Look Up Table) Calibration**

$$BT_{Corr El.}^{LUT cal} = BT_{Corr El.} * m + q$$

## Resampling

*linear interpolation for X and Y polarization to resample to a common timeline based on Snapshot Time*

Computation of **First half Stokes** parameter

$$BT = I/2 = \frac{BT(Xpol) + BT(Ypol)}{2}$$

*(representative measure of Sun BT)*

- **Orbital Data** time selection

*(from ANX to ANX)*

- **Moving window filter**  
*(to remove outlier and burst)*
- computation of Sun BT **mean and std** on orbit basis

conversion from Sun BT to  
**Solar Flux**

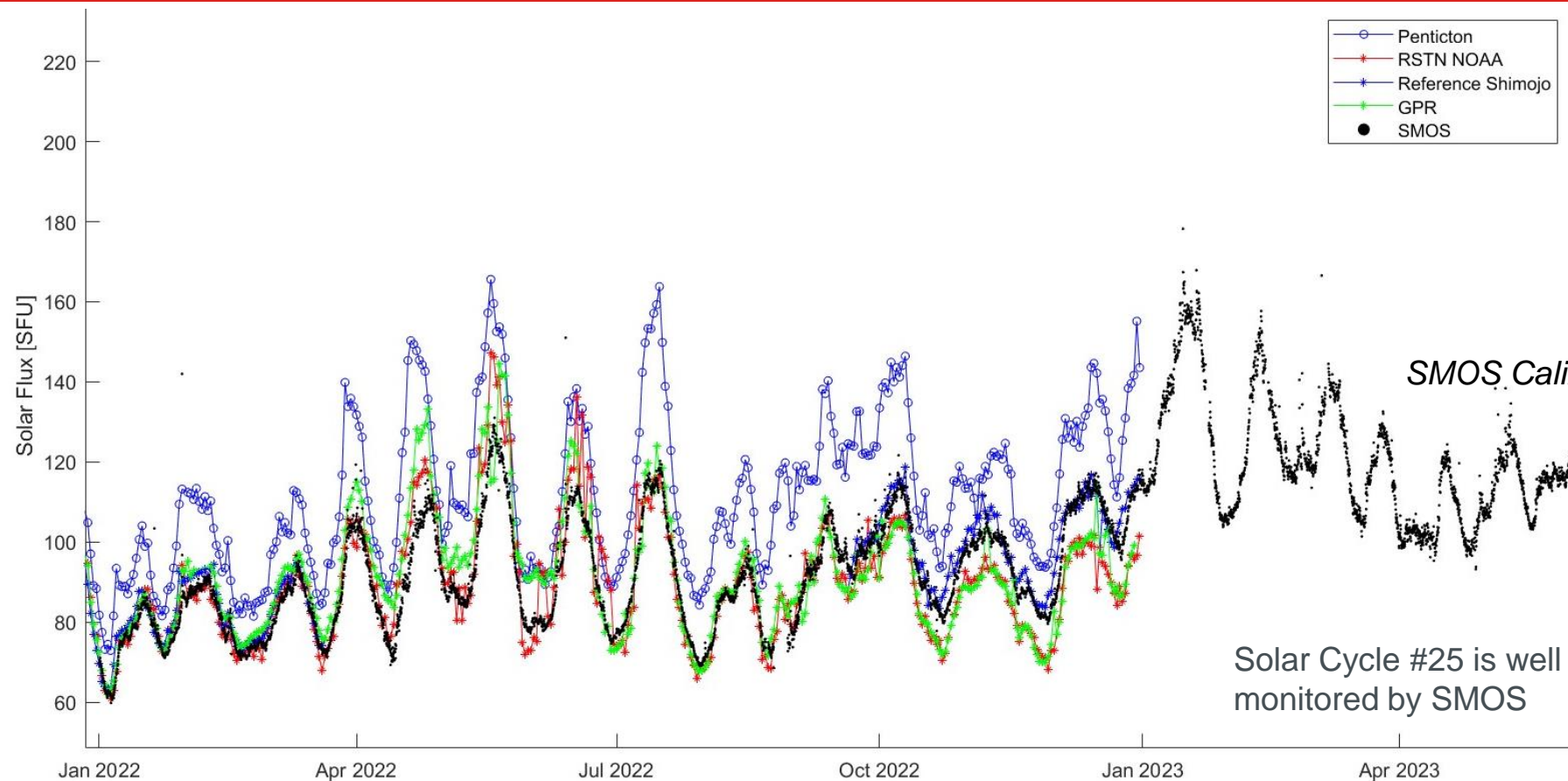
$$SF = BT_{CorEl}^{sun} \frac{2 K_b}{\lambda^2} \Omega_{Sun} (day)$$

SunFlux and SunBT Data  
distributed via **ftp**

Available **from BoM to 'yesterday'**  
File type: **ASCII**

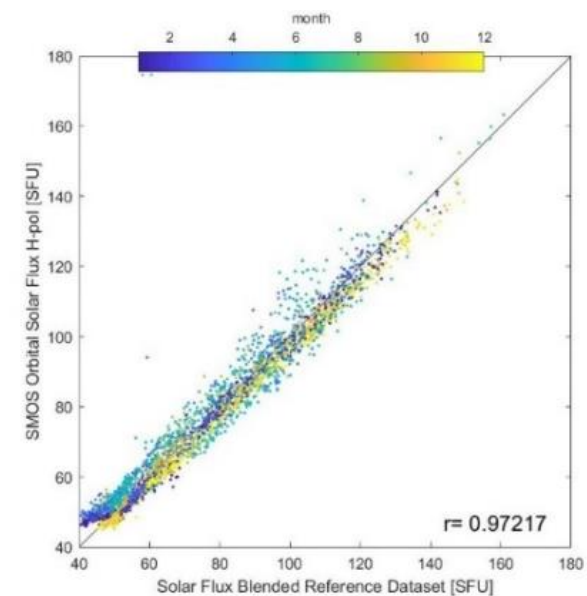
SF and BT value for each single orbit,  
separated between Front and Back  
(semi-orbit data with **~50 mins cadence**).

# SMOS Sun Flux calibrated with L-Band Ground Radio Telescope references



**SMOS Sun Flux is coherent with radio telescopes measurements**

- Good consistency among L-Band ground radio telescope references computed with different approaches (Blue line: Penticton observations at 2.8 GHz reported for info)
- Good consistency with NOAA L-band solar flux daily bulletin dataset (not inter-calibrated)
- **Good consistency between our inter-calibrated L-band solar flux reference and SMOS Mean Orbit value calibrated**



# SMOS Solar Radio Burst detection bulletin

- **BT correction**
- **calibration**
- **resampling** of X, Y, T3, T4 polarizations  
(Same as Sun Flux computation)

## Energy Computation

comparison between Energy computed as Solar Flux Integral on specified  $\Delta t$  and Solar energy reference computed from mean solar flux  
→ if difference exceed 4% → possible RB

Estimate of **burst peak time and duration**

False positive check

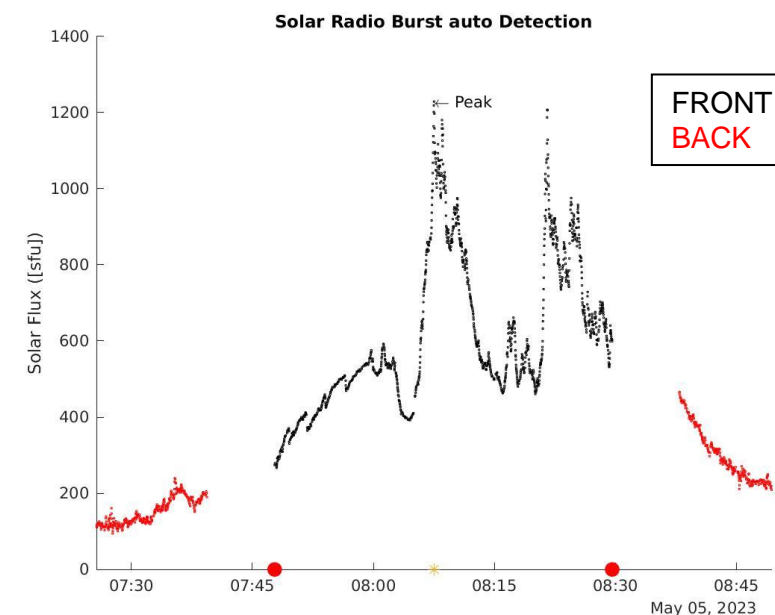
compute **Degree of Circular Polarization** from Stokes parameters (with corrected BT):

$$DoCP = V/I = -BT_4 / (BT(Xpol) + BT(Ypol))$$

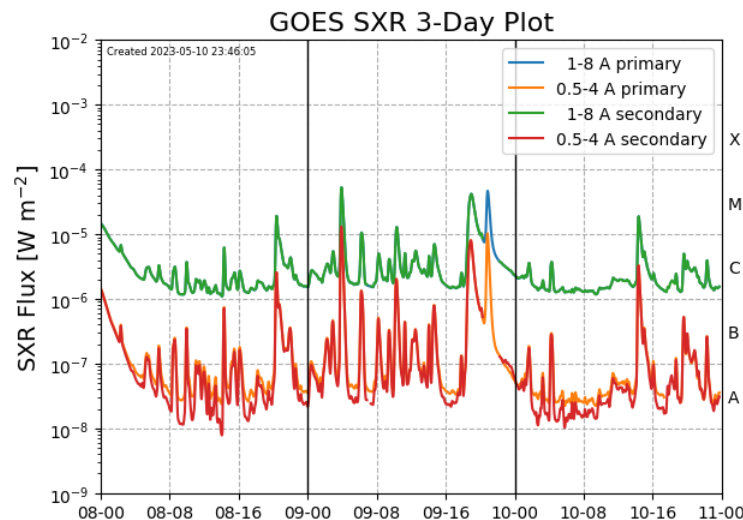
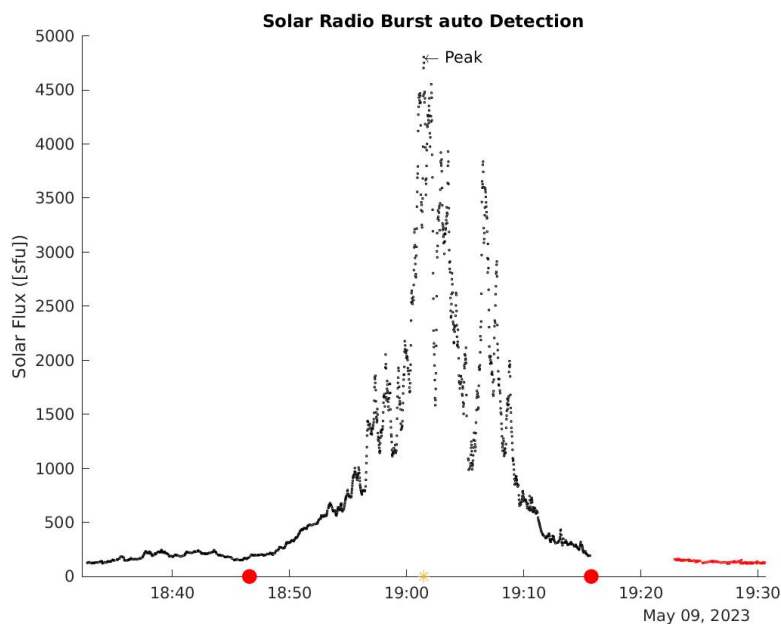
$$-1 < DoCP < 1$$

**Radio Burst warning product generation**

Data distributed via **ftp** upon **event detection**  
File type: **ASCII and JPG**  
Providing info on **RB event time, flux, DoCP**



# SMOS Solar Radio Burst bulletin validation



## SMOS RB detection verification:

- [www.spaceweatherlive.com](http://www.spaceweatherlive.com) – solar flares detection
- [www.solarmonitor.com](http://www.solarmonitor.com) – GOES X-rays observation
- [www.swpc.noaa.gov](http://www.swpc.noaa.gov) – Events report (RBR)

SPACE WEATHER PREDICTION CENTER  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Home > Products and Data > Reports > Solar and Geophysical Event Reports

**CURRENT SPACE WEATHER CONDITIONS** on NOAA Scales

**SOLAR AND GEOPHYSICAL EVENT REPORTS**

Product: 20230608events.txt  
 :Created: 2023 May 09 0357 UT  
 :Date: 2023 05 06  
 # Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center  
 # Please send comments and suggestions to SWPC.Webmaster@noaa.gov  
 #  
 # Missing data: ////  
 # Updated every 5 minutes.  
 # Edited Events for 2023 May 06  
 #

#Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars	Reg#
280	1921	1922	1922	PAL	G	RBR	245	250	
320	2016	///	2359	PAL	C	RSP	060-180	CTM/1	
290 +	2142	2157	2213	G16	5	XRA	1-8A	C4.7	5.5E-03 3299
290	2148	2156	2244	HOL	3	FLA	S08E40	SN	ERU 3299
300 +	2256	2257	2259	PAL	G	RBR	245	270	
300	2257	///	2359	LEA	C	RSP	050-180	CTM/1	

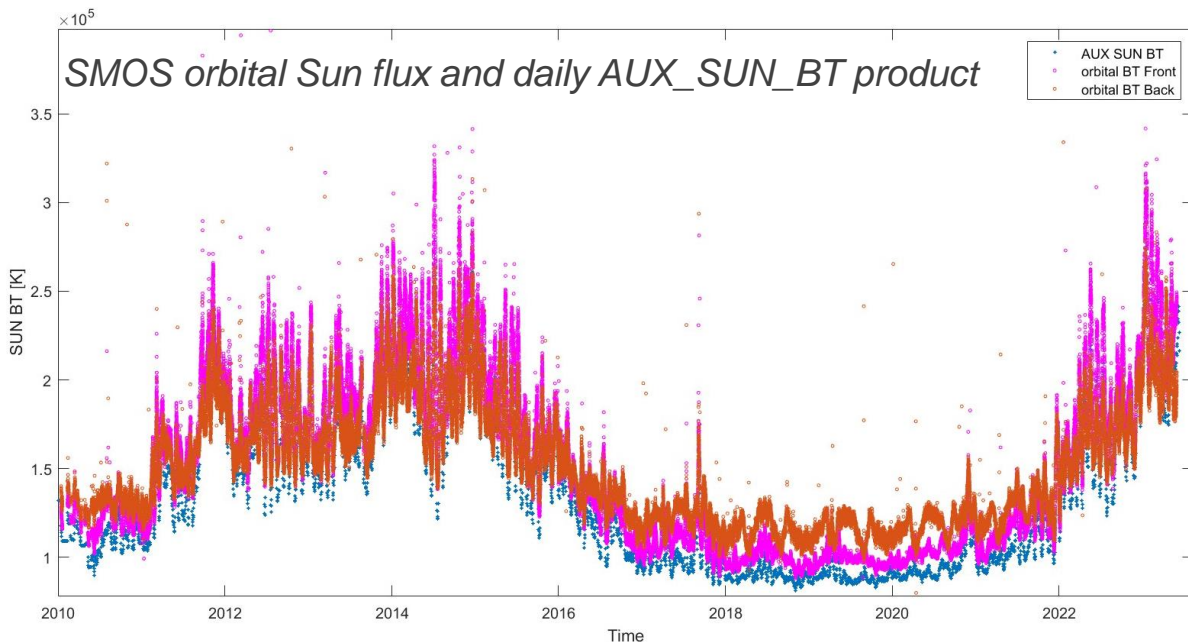
\*RBR = Fixed-frequency radio burst  
 RSP = Sweep-frequency radio burst



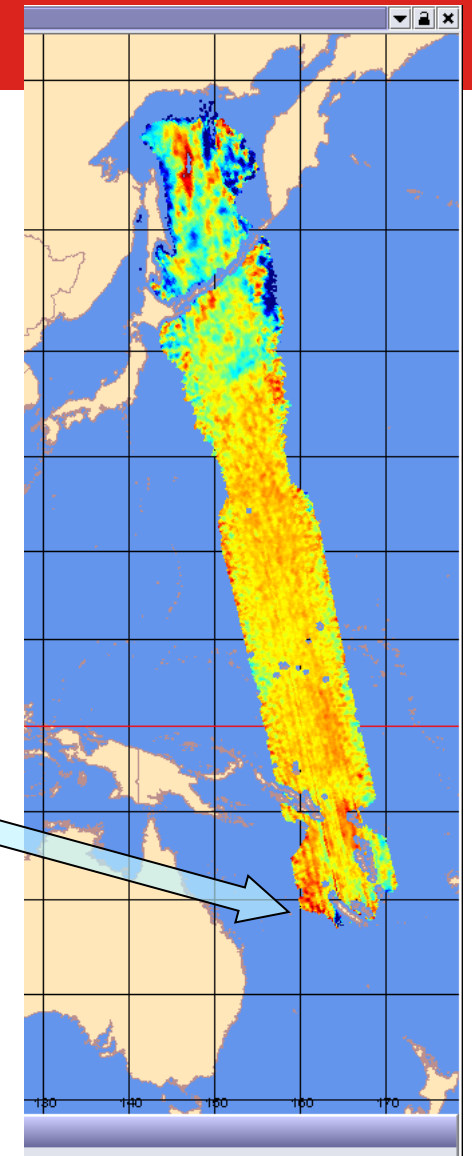
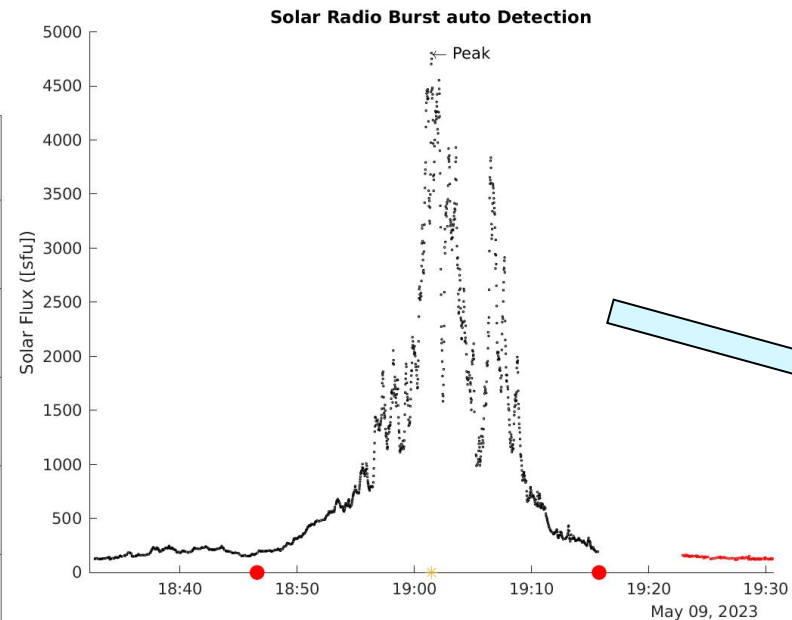
# Why SMOS for Solar flux?

Usage of these products as input for **Earth Observation** data, e.g. SMOS L2 sea surface salinity:

A data processing algorithm is already up and running on **Serco RedLab** machine and distributed to **SMOS Data Payload Ground Segment** to use SMOS derived Sun BT Auxiliary product as **input for SMOS L2 sea surface salinity retrieval**.



**Solar radio bursts detection is useful as they impact SMOS L2 OS products data quality and availability**

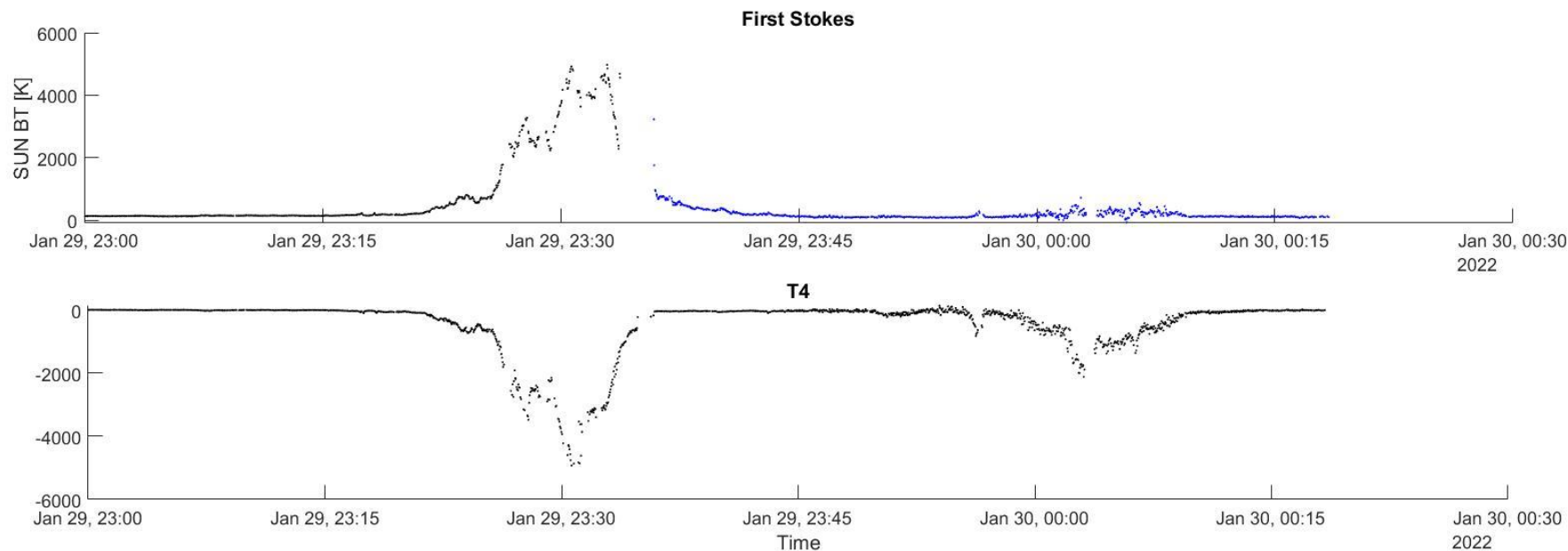


*Sea Surface Salinity map during the Solar radio Burst event on 9 May 2023 – visible degradation*

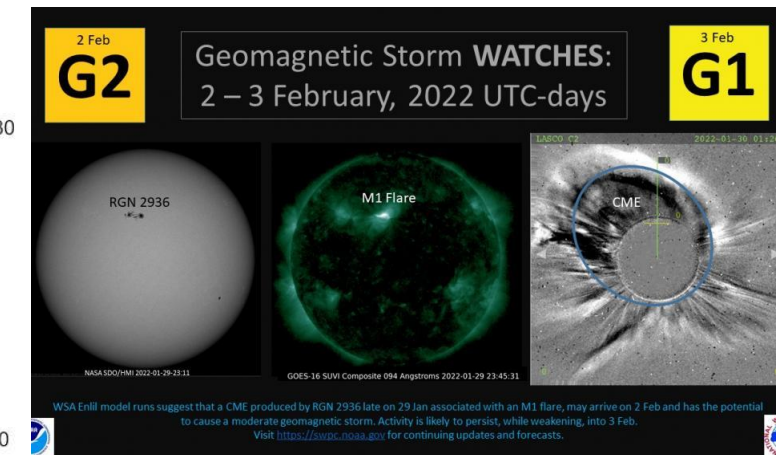
# Why SMOS for Solar flux?

Possible application of SMOS solar flux in **solar physics** and **space weather** studies:

- **Long coverage data:** 13+ years of observation → suitable for Space Weather models
- Could be available in **near-real time** within 3 hours from acquisition
- Different **temporal resolution:**
  - Orbital aggregation: **100 minutes** → suitable for Solar cycle studies and synergies with F10.7 for **ionosphere/thermosphere modelling** (proxy of solar activity)
  - **4.8 seconds** for **Solar RB** studies and synergies with **Solar flare/CME monitoring/forecast**



NOAA AR2936 produced an M1 flare (R1-Minor Radio Blackout) on 29Jan2022 at 23:32 UTC. Associated with asymmetric, full halo CME as observed in NASA/SOHO LASCO coronagraph imager.



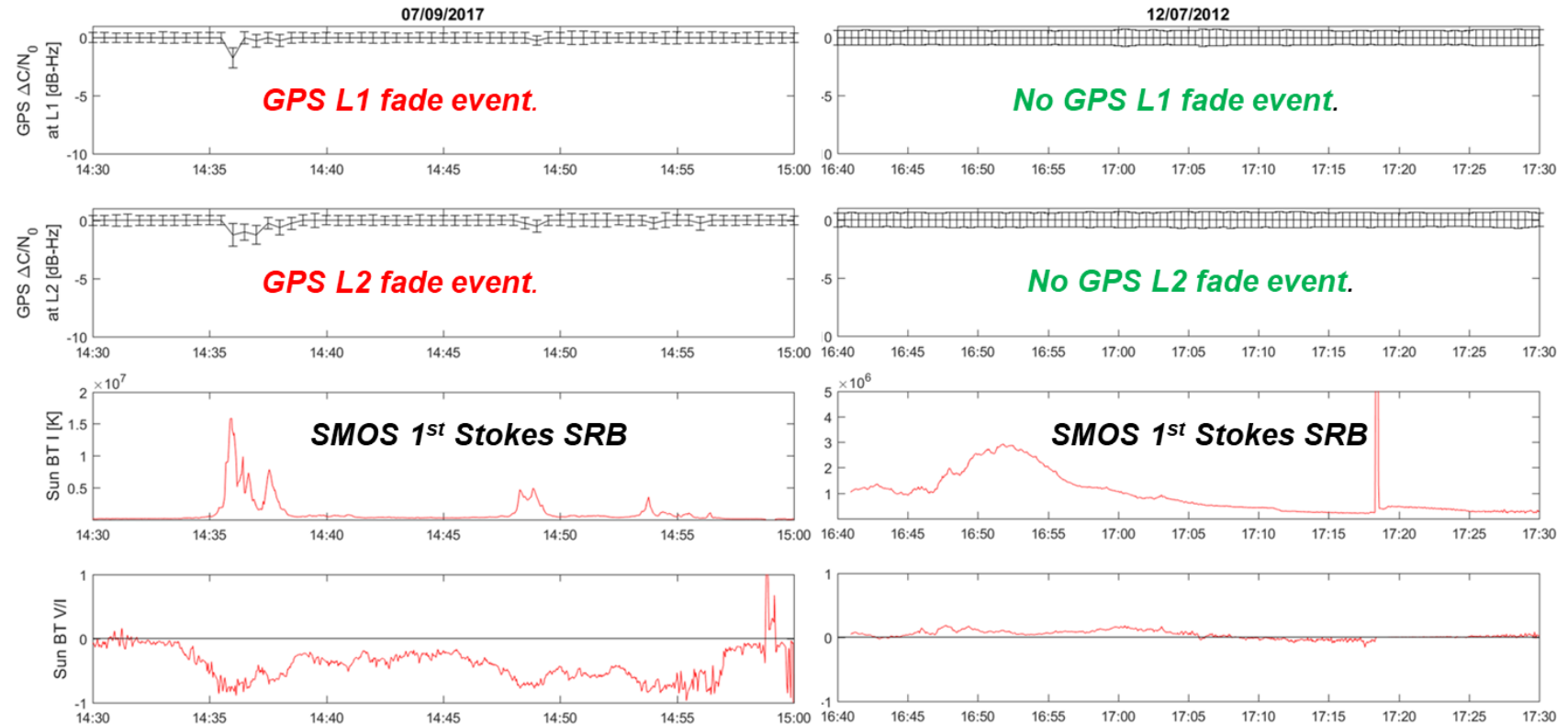
# Why SMOS for Solar flux?

Possible application of SMOS solar flux in **solar physics** and **space weather** studies:

Solar Flux in L-band → Useful to estimate impact on GNSS

Polarimetric data set at L-band are useful to analyse **circular polarization in Solar Radio Burst** which impacts **GNSS** signal reception. (SMOS frequency is right in the middle of the two L1 and L2 GPS signal)

Correlation between amount of Solar flux at L-band and the speed, angular width and kinetic energy of the CME is helpful for CME impact assessment



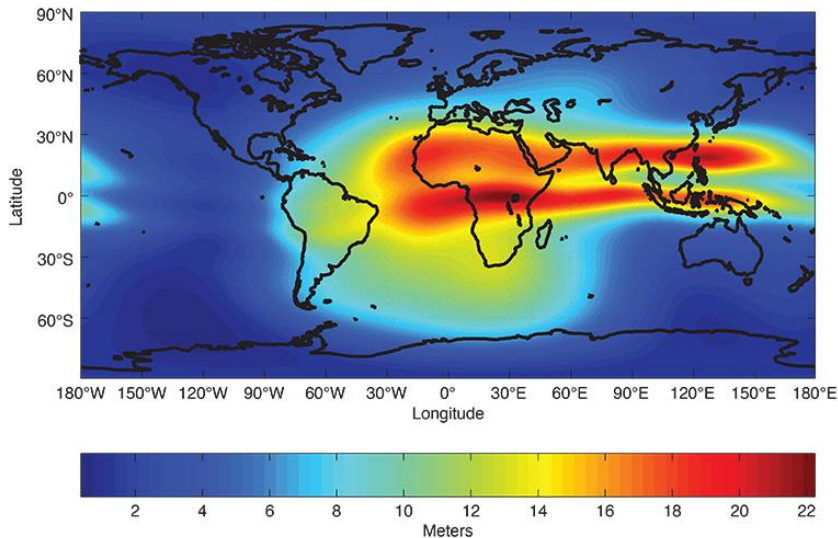
**SMOS degree of circular polarization in agreement with *GPS* fade event.**

**SMOS degree of circular polarization in agreement with *No GPS* fade event.**

# Why SMOS for Solar flux?

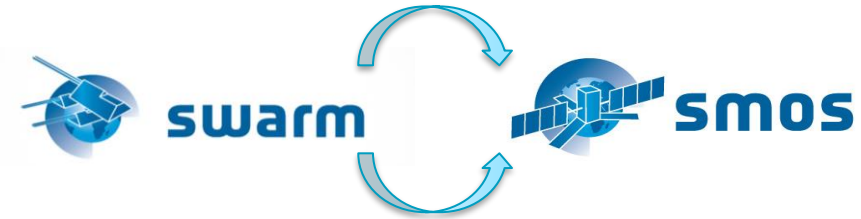
- Possible usage of SMOS AUX in **NeQuick** model: **quick-run ionospheric electron density model**, for trans-ionospheric propagation applications.  
*NeQuick-G: adapted for Galileo real-time single-frequency users, to compute ionospheric delay corrections.*

The model values depend on solar activity (given by monthly-mean sunspot number, **solar radio flux F10.7**), season and time.



*The NeQuick package includes routines to evaluate the **electron density along any ground-to-satellite straight line ray-path** and the corresponding **Total Electron Content (TEC)** by numerical integration.*

- Possible **multimission** applications: usage of SMOS\_SUN\_FLUX as input for **Swarm** products

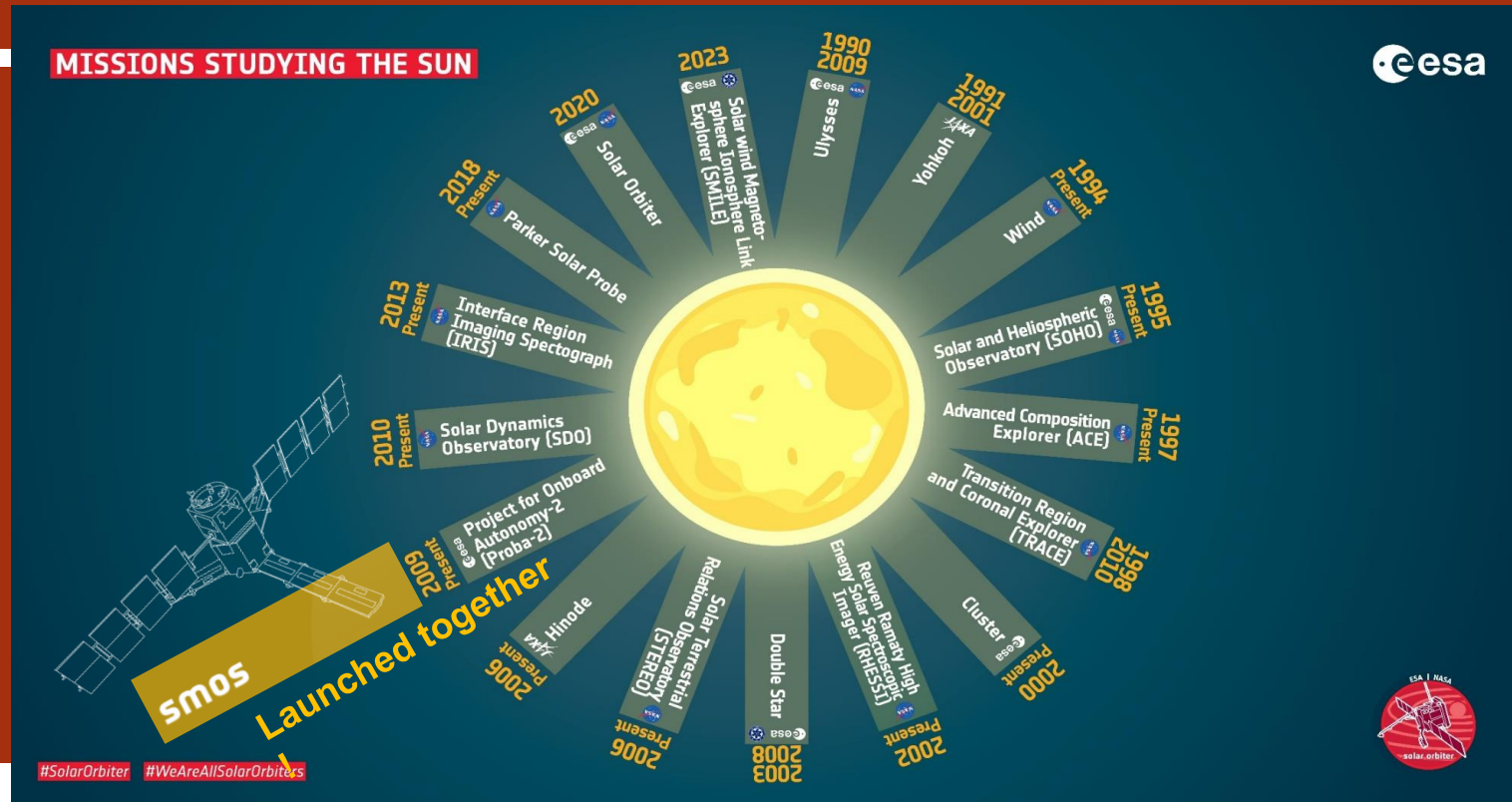


SUN\_FLUX product can be used for **Swarm L2 models**: Many of these models use F10.7 as proxy for solar EUV (main source of ionospheric ionization, and thus plasma density / conductivity in non-polar regions), with 3-months average.

Could be interesting to better describe the day-to-day variability of

- Solar quiet current (Sq)**;
- EEJ current (Equatorial ElectroJet**, that uses equatorial electric field, 1 value per orbit);
- MIO Model** (Model of non-polar daily geomagnetic variation caused by ionospheric currents, including their variability with season and solar flux);
- Etc...

# THANK YOU !



To access SMOS Solar Flux data contact:

[redlab-oper@eo-sppa.org](mailto:redlab-oper@eo-sppa.org)