SMOS FLARES - SMOS Sun Flux Product for Space Weather

SMOS FLARES Team

14th of November 2022

Table of Contents

SMOS Sun Flux Product for Space Weather

- **Key objective: develop and generate a first version of a dedicated SMOS Product for Space Weather and Solar Science.**
- **Timeline:**
  - SMOS FLARES - Study (2019 - 2020),
  - SMOS FLARES CR1 - Prototype version (2021 – 2023)

- **Prime:**
  - **Deimos Space Romania (DMR):** Ionut Grozea, Suzana Vladescu, Gabriel Graur
- **Subcontractors:**
  - **Research and Development in Spatial Imaging (RDIS):** Ali Khazaal
    – Algorithm development
  - **University of Alcalá (UAH):** Consuelo Cid, Manuel Flores
    – Science team
  - **Research and Development in Aerospace (RDA):** José Barbosa
    – SMOS support team
  - **Royal Observatory of Belgium (ROB):** Christophe Marqué
    – calibration and reference data team

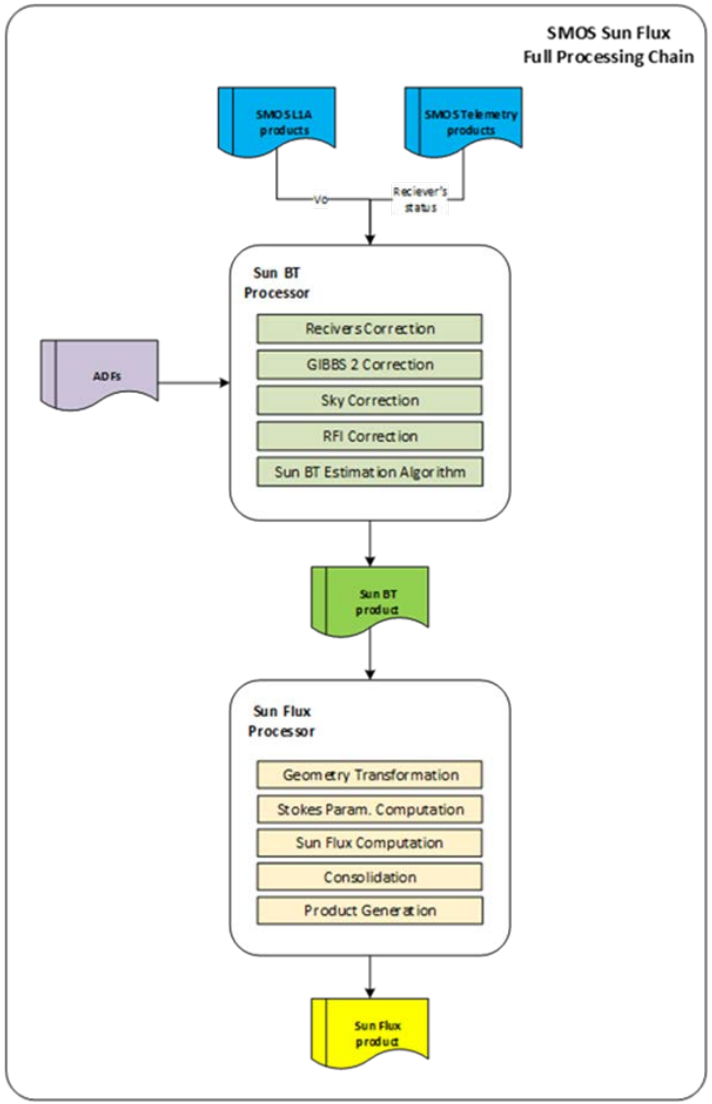
- **SMOS has the potential of being a unique instrument** if it provides:
  - Full polarimetry
  - Observations 24 hours a day
  - Near real-time observations

- For space weather **SMOS could provide**:
  - Continuous monitoring of solar interferences affecting GNSS, radar and L-band wireless communications (e.g., mobile telephony)
  - Post event analysis of yet not fully understood incidents
  - Early assessment of mass ejections

- In order to provide optimal solar radio observations some **problems need to be addressed**:
  - Not properly flagged (non-solar) RFIs
  - Inconsistencies depending on data extraction method
  - Lack of calibration
  - Reference frame for polarimetry should be the Sun, not the antenna

- **Objectives**
  - **generate a set of prototype SMOS Solar Flux products** based on SMOS v724 L1A inputs
  - **disseminate** them to space weather and solar science users
  - **get feedback** from community
  - consider **operational service for future use**

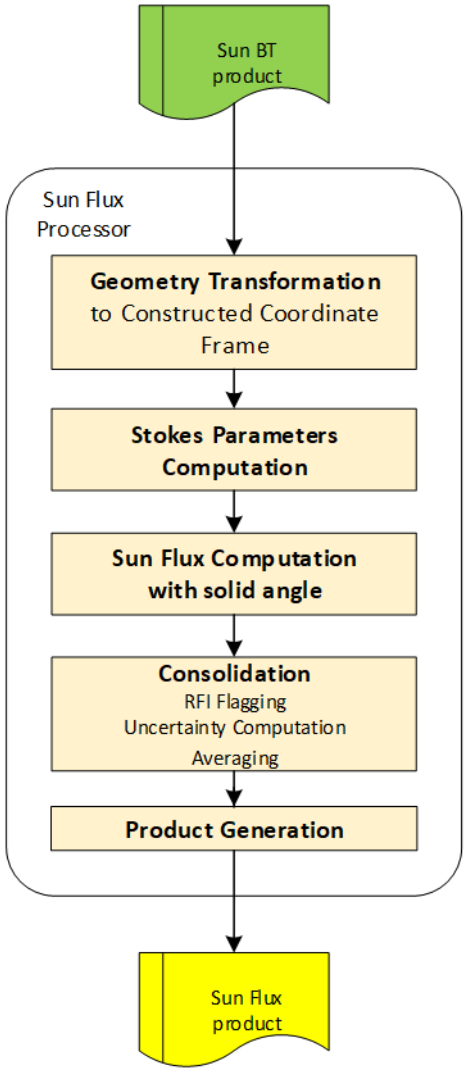
SMOS Sun Flux Product for Space Weather – SMOS Sun Flux Processing Chain



The **SMOS Sun Flux Full chain** is composed of two independent processors, interfaced strictly via files:

- **SMOS Sun BT Processor** (RDIS) – covered in a previous presentation
- **SMOS Sun Flux Processor** (DMR)

SMOS Sun Flux Product for Space Weather
SMOS Sun Flux Processing Chain



❑ Sun Flux Steps:

- ➢ Geometry Transformation
- ➢ Stokes Parameters Computation
- ➢ Sun Flux Computation
- ➢ Consolidation
- ➢ Product Generation

SMOS Sun Flux Product for Space Weather - Outputs

Sun Flux Output Flavors

User-friendly formats for the final product:

- **TXT – human readable format** with first line representing the column head/name
- **JSON – machine optimized format**

Sun Flux full cadence: Fast rate using the actual SMOS rate of one value every 1.2 seconds

Sun Flux Averaged: Daily / monthly average based on fast rate data

Sun Flux "Imaging files": Datasets containing information about the distribution of the Sun BT over the entire Sun Disk, in the CCS, in a right ascension and declination grid, at each time stamp.

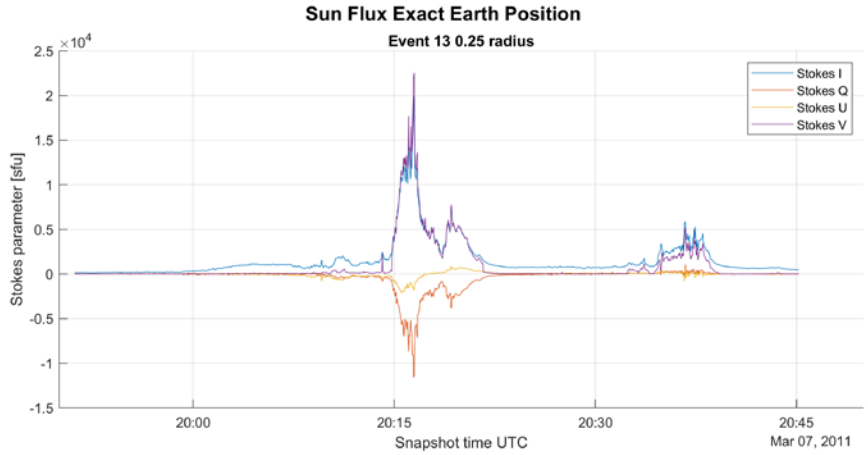
Sun BT Files: Fast rate Sun BT estimation product, for calculation and reference

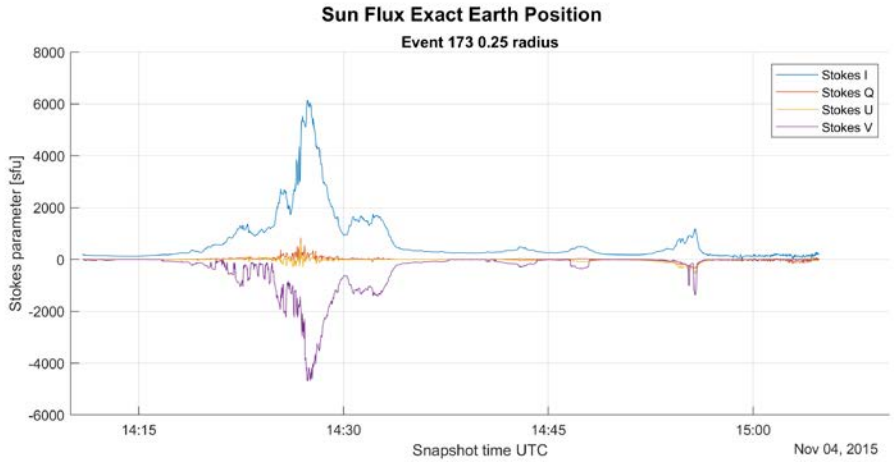
SMOS Sun Flux Product for Space Weather - Outputs

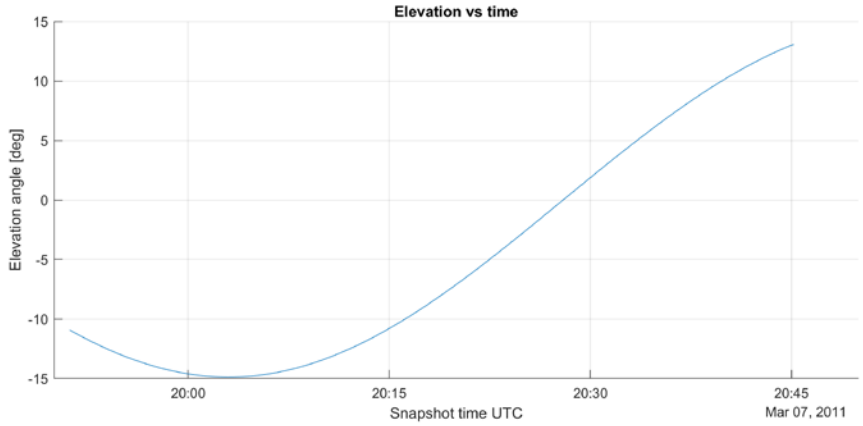
- **Sun Flux Product, for fast rate** = Sun Flux calculated data for each snapshot, using the actual SMOS rate of one value every 1.2 second, in the rotated frame
- Dedicated user product
- Flagging

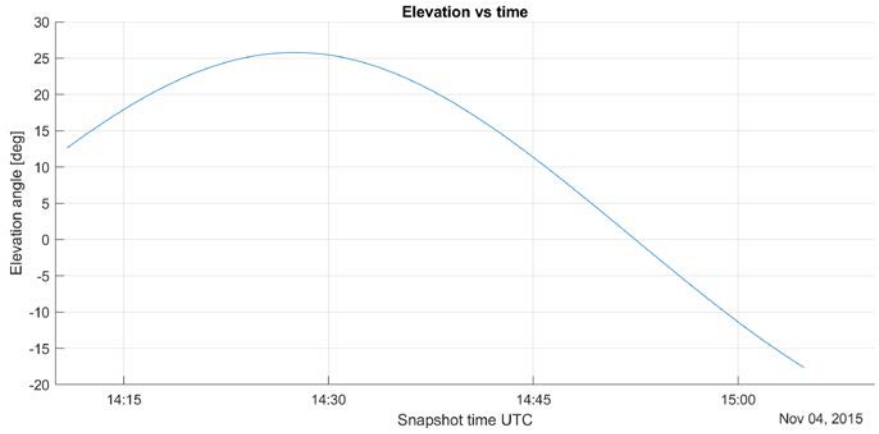
Sun Flux Field	Field Description
SUN_FLUX_Sample_Counter	Number of SUN_FLUX_Sample data set record structures
Snapshot_Time	UTC time at which the HV polarization was taken, in the format YYYY-MM-DD hh:mm:ss
Solar_Flux_Earth_Stokes_I	Solar flux on Earth for Stokes I
Solar_Flux_Earth_Stokes_Q	Solar flux on Earth for Stokes Q
Solar_Flux_Earth_Stokes_U	Solar flux on Earth for Stokes U
Solar_Flux_Earth_Stokes_V	Solar flux on Earth for Stokes V
Solar_Flux_1AU_Stokes_I	Solar flux on at 1AU from the Sun for Stokes I
Solar_Flux_1AU_Stokes_Q	Solar flux on at 1AU from the Sun for Stokes Q
Solar_Flux_1AU_Stokes_U	Solar flux on at 1AU from the Sun for Stokes U
Solar_Flux_1AU_Stokes_V	Solar flux on at 1AU from the Sun for Stokes V
Solar_Flux_Uncertainty	Uncertainty calculated using the uncertainty function, depending on elevation angle
Elevation_Angle	The elevation angle of the Sun relative to SMOS. The elevation angle is considered to be 0 at the transition, negative in the back and positive in front of SMOS.
RFI_flag	RFI flag defined as stop light with possible values: LOW/MODERATE/HIGH
Eclipse_flag	Eclipse flag defined as 1 when the Sun is eclipsed by Earth, and 0 when not

❑ Sun Flux – Stokes Parameters in sfu (2 events)









SMOS Sun Flux Product for Space Weather - Flagging

❑ RFI flagging

- ➢ RFI Flagging algorithm: 3 different thresholds used to define **1 unified RFI flag – LOW / MODERATE / HIGH**
- ➢ Calculation based on the following parameters: the Sun position relative to its tails, Sun Alias position inside the hexagon relative to the closest RFI sources, and information about the magnitude of the maximum RFI sources on the snapshot and closest RFI sources.
- ➢ Goal is to optimise for avoiding false-positives!

❑ Uncertainty Calculation

- ➢ Uncertainty calculation algorithm: **Polynomial function** depending on the elevation angle, estimated after the uncertainty on the range of the last 10 years of SMOS data: Tested on 1 set of data in all SMOS years, covering various elevation angle possibilities.
- ➢ Tests were done to determine instrument degradation.

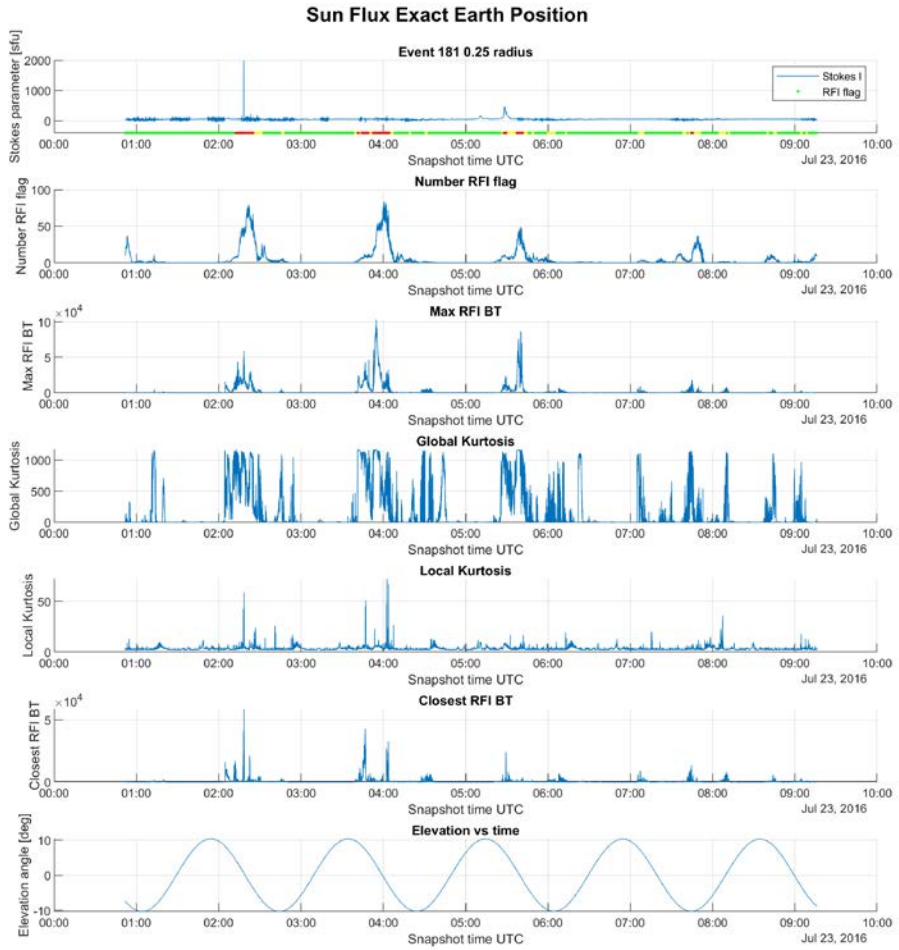
❑ RFI Contamination Flag

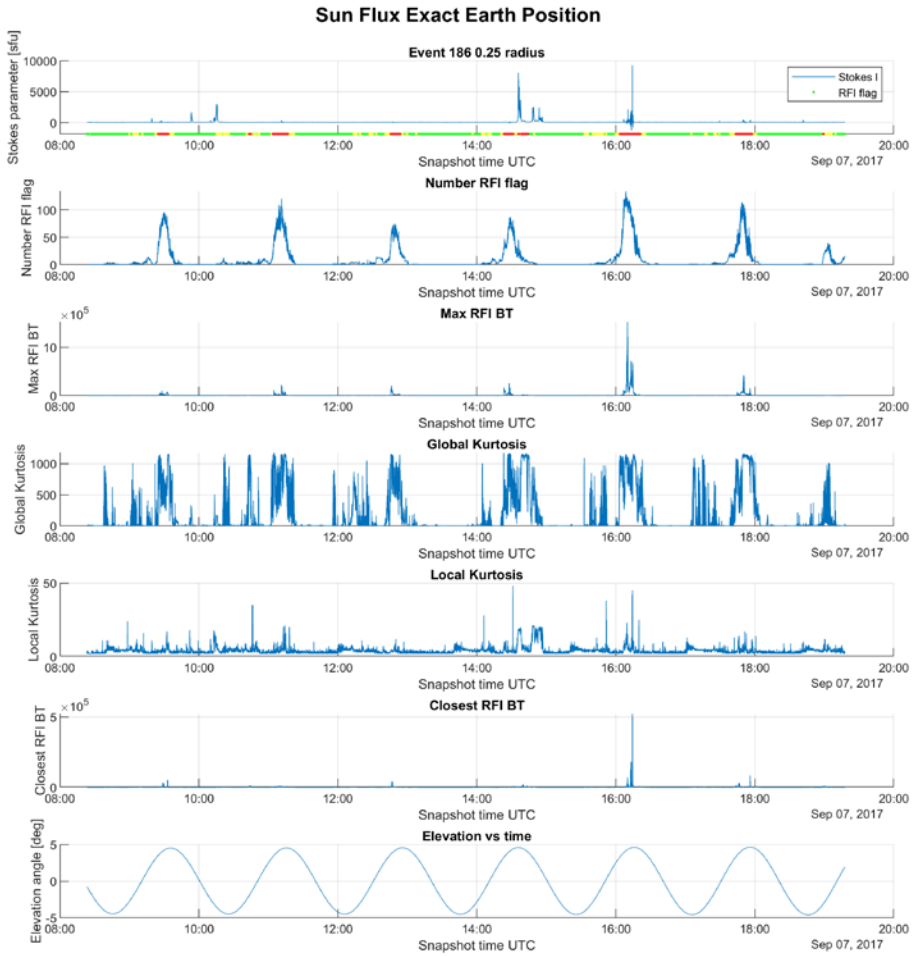
- Three levels available: LOW – green, MODERATE – yellow, HIGH – red
- If the flag is LOW, then we did not have contamination at all, or we had contamination in the vicinity of the Sun (or on its tails) with weak sources (BT < 1000K), marked as green.
- If the flag is MODERATE then we had contamination with medium sources (1000K < BT < 10000K) marked as yellow.
- If the flag is HIGH then we had contamination with strong sources (BT > 10000K) marked as red.

❑ The RFI flag reports the conditions before RFI mitigation was applied

- The user will know if there was any disturbance to the data and its severity
- Mitigation is attempted in order to clean up the data in case the users decides to use it (e.g. just the low contamination epochs

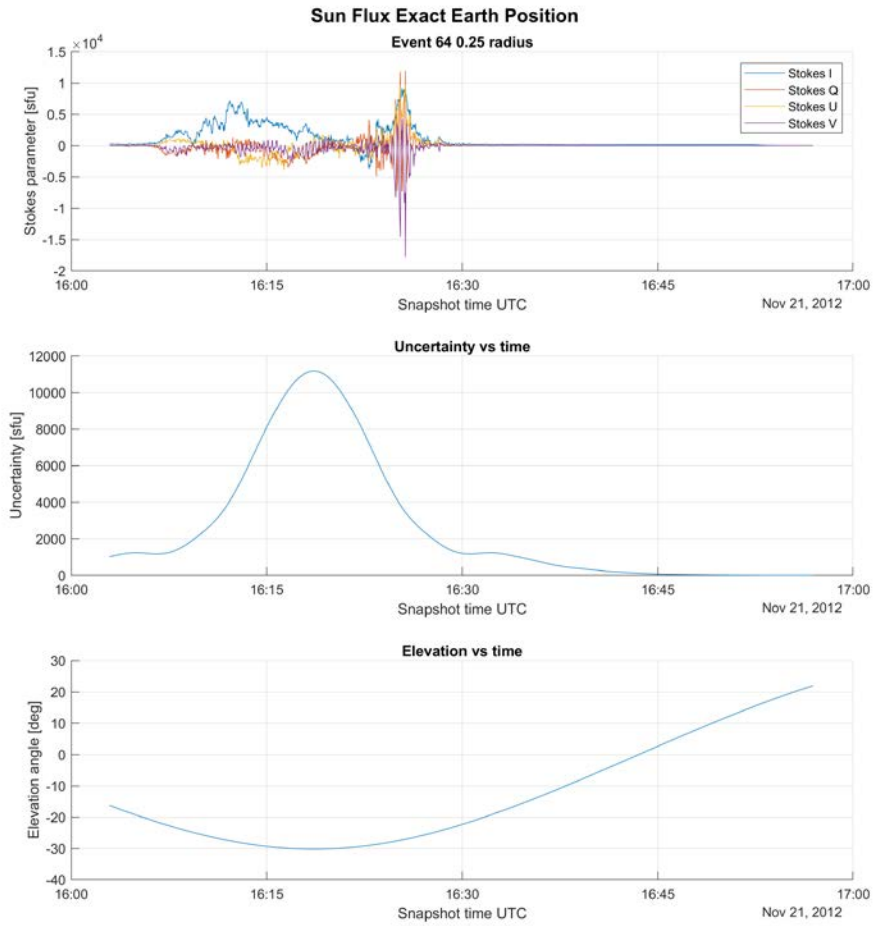
❑ RFI Contamination Flag (LOW – green, MODERATE – yellow, HIGH – red)

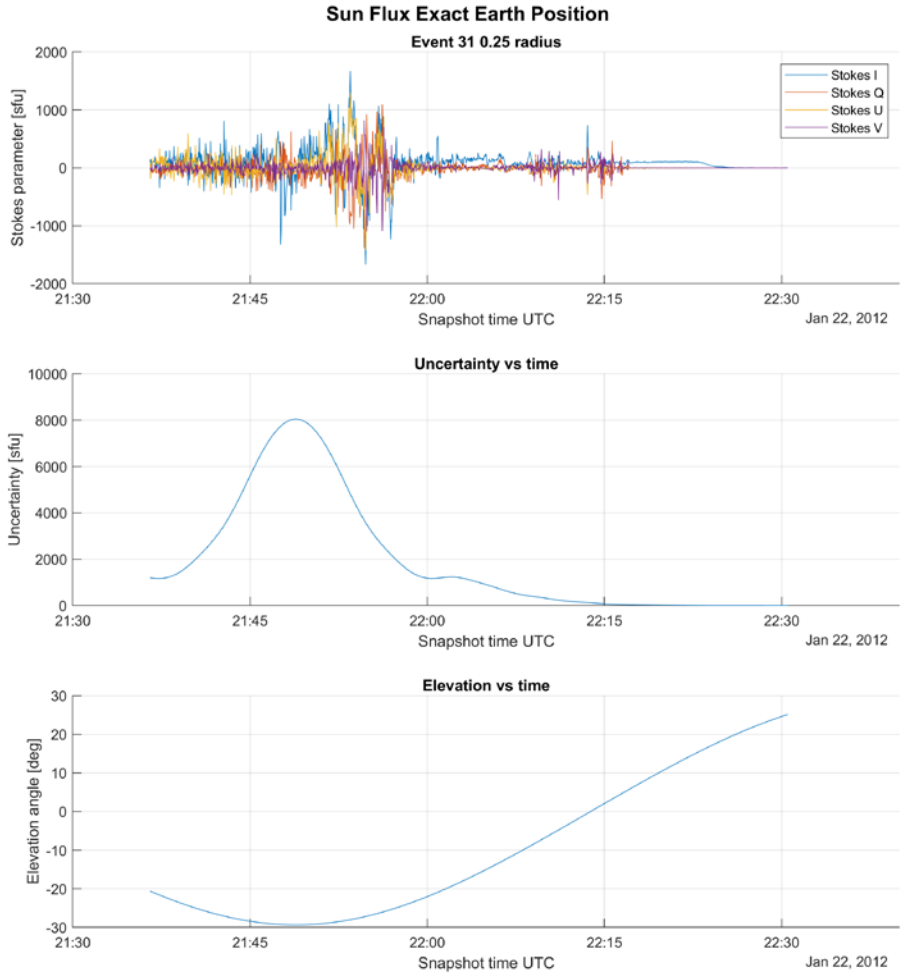




- ❑ 2 events showing the composition of the unified RFI flag

❑ Uncertainty





- Uncertainty for high elevation angles – noise increases with the decrease of elevation angle.

SMOS Sun Flux Product for Space Weather - Outputs

❑ Sun Flux Product, averaged dataset

= Sun Flux data, for the daily and monthly datasets, averaged, where averaging is proposed to be weighted, where the weight is defined by the uncertainty field.

Sun Flux Field	Field Description
SUN_FLUX_Sample_Counter	Number of SUN_FLUX_Sample data set record structures
Average_Type	Type of the average. Can be “daily” or “monthly”
Time_Period	Time period over which the average was taken. Depending on the Average_Type, Time_Period is in the format YYYY-MM-DD for daily averaging or YYYY-MM for monthly averaging
Solar_Flux_Earth_Stokes_I	Averaged Solar flux on Earth for Stokes I
Solar_Flux_Earth_Stokes_Q	Averaged Solar flux on Earth for Stokes Q
Solar_Flux_Earth_Stokes_U	Averaged Solar flux on Earth for Stokes U
Solar_Flux_Earth_Stokes_V	Averaged Solar flux on Earth for Stokes V
Solar_Flux_1AU_Stokes_I	Averaged Solar flux on at 1AU from the Sun for Stokes I
Solar_Flux_1AU_Stokes_Q	Averaged Solar flux on at 1AU from the Sun for Stokes Q
Solar_Flux_1AU_Stokes_U	Averaged Solar flux on at 1AU from the Sun for Stokes U
Solar_Flux_1AU_Stokes_V	Averaged Solar flux on at 1AU from the Sun for Stokes V
Solar_Flux_Uncertainty	Uncertainty calculated using the uncertainty function, depending on elevation angle
Elevation_Angle	The elevation angle of the Sun relative to SMOS. The elevation angle is considered to be 0 at the transition, negative in the back and positive in front of SMOS.
Averaged_RFI_flag	RFI flag defined as stop light with possible values: LOW/MODERATE/HIGH

SMOS Sun Flux Product for Space Weather - Outputs

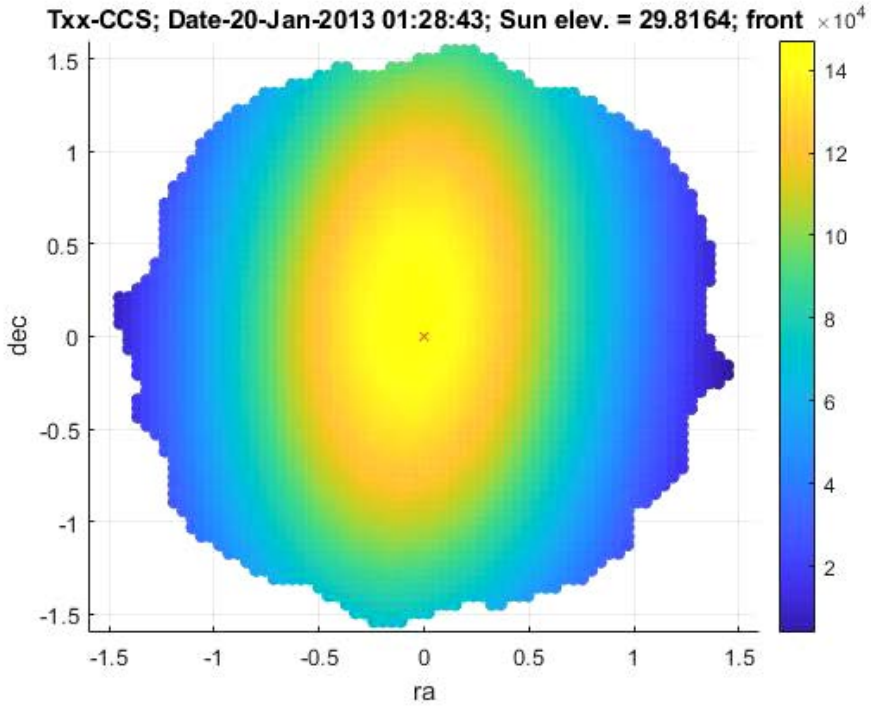
❑ Sun Flux Support File, image dataset

= image data file containing the estimated rotated Sun BT to the Sun frame written for the oversampled grid. Defined as a file containing all necessary data to generate image files

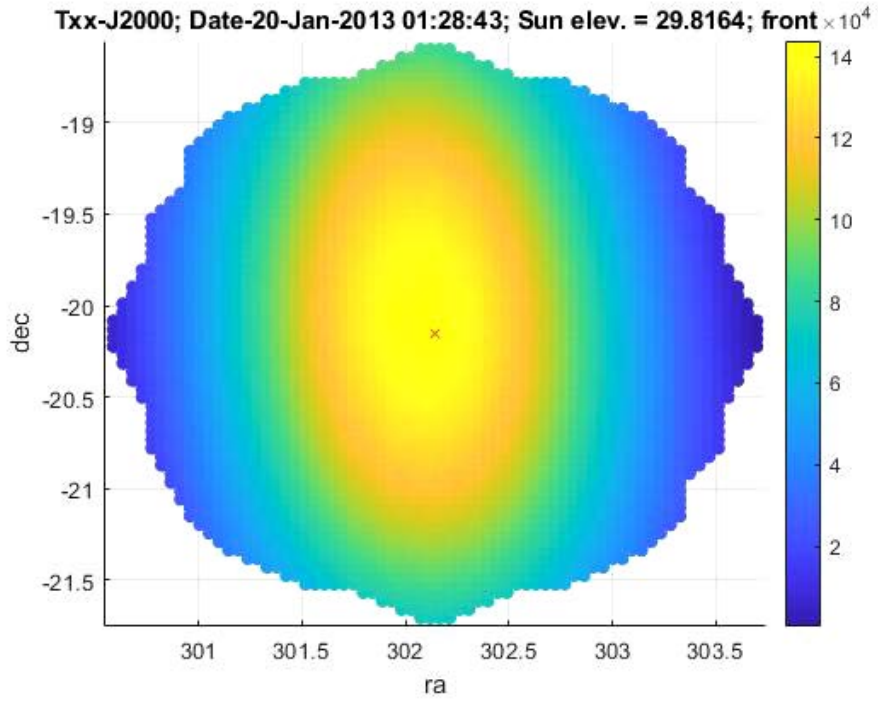
Sun Flux Field	Field Description
SUN_BT_Sample_Counter	Number of the SUN_BT_snapshots
Snapshot_Time	UTC time at which the snapshot was taken YYYY-MM-DD hh:mm:ss
Sun_Right_Ascension	The Right Ascension of the Snapshot grid points in the Sun Frame. The reference for Right Ascension and Declination is the Constructed Coordinate System
Sun_Declination	The Declination of the Snapshot grid points in the Sun Frame. The reference for Right Ascension and Declination is the Constructed Coordinate System
Polarisation_flags	Flag representing the polarisation of the snapshot. It could be: 0 – for HH polarisation, 1 – for VV polarisation, 2 – for HV polarisation
Real_Sun_BT	The real Part of the rotated Sun BT values to the Sun frame
Imag_Sun_BT	The imaginary Part of the rotated Sun BT values to the Sun frame. In the snapshots with HH or VV polarisation it will be set to 0.
Elevation_Angle	The elevation angle of the Sun relative to SMOS. The elevation angle is considered to be 0 at the transition, negative in the back and positive in front of SMOS.

❑ Sun Flux Support File, image dataset

= image data file containing the estimated rotated Sun BT to the Sun frame written for the oversampled grid. Defined as a file containing all necessary data to generate image files



❑ Txx rotated frame, for quiet sun



❑ Txx satellite frame, for quiet sun

! considered experimental.
The data taken in the back of the antenna is unreliable and the values close to the transition front/back of the antenna plane are also less reliable.

Thank you

www.elecnor-deimos.com