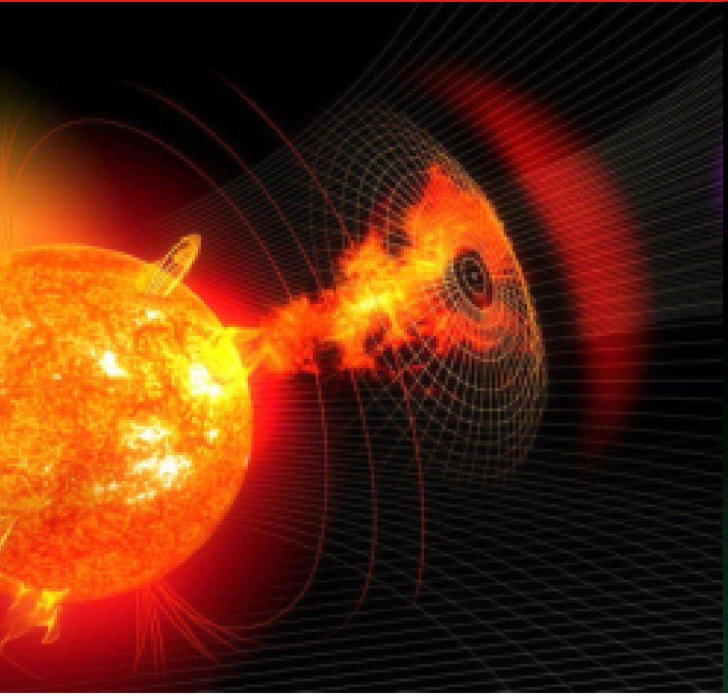
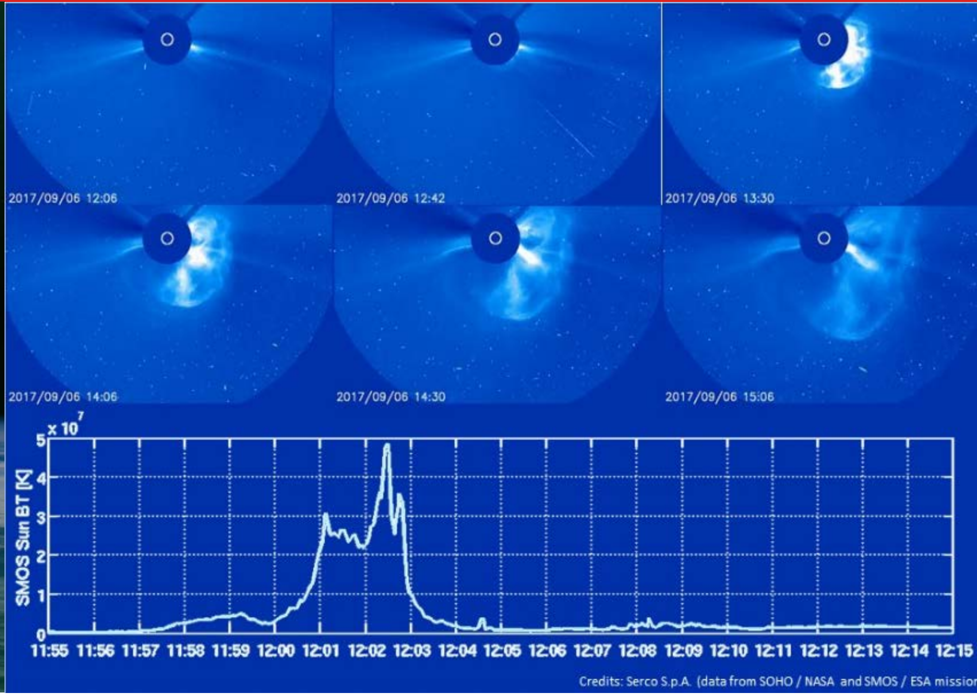
L-band Solar Flux derived from SMOS L1B v724 operational products





Solar Radio Burst as detected by SMOS on 6 September 2017

Presentation to:

SMOS for Space Weather 1st workshop 14 November 2022 (ESA-ESRIN)

Presented by:

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SMOS ESL WP160: Support to new SMOS data products ESA | SMOS ESL2020+ ESA contract number 4000130567/20/I-BG.

Outline

About exploration of a “noise” signal for new mission application

- Soil Moisture Ocean Salinity (SMOS) mission overview
- How MIRAS instrument (SMOS payload) sees the Sun
- Retrieval of Solar flux from SMOS L1B v724 dataset
- SMOS Solar flux validation results
- Why SMOS Solar flux ?

SMOS Mission (2009 ->) overview

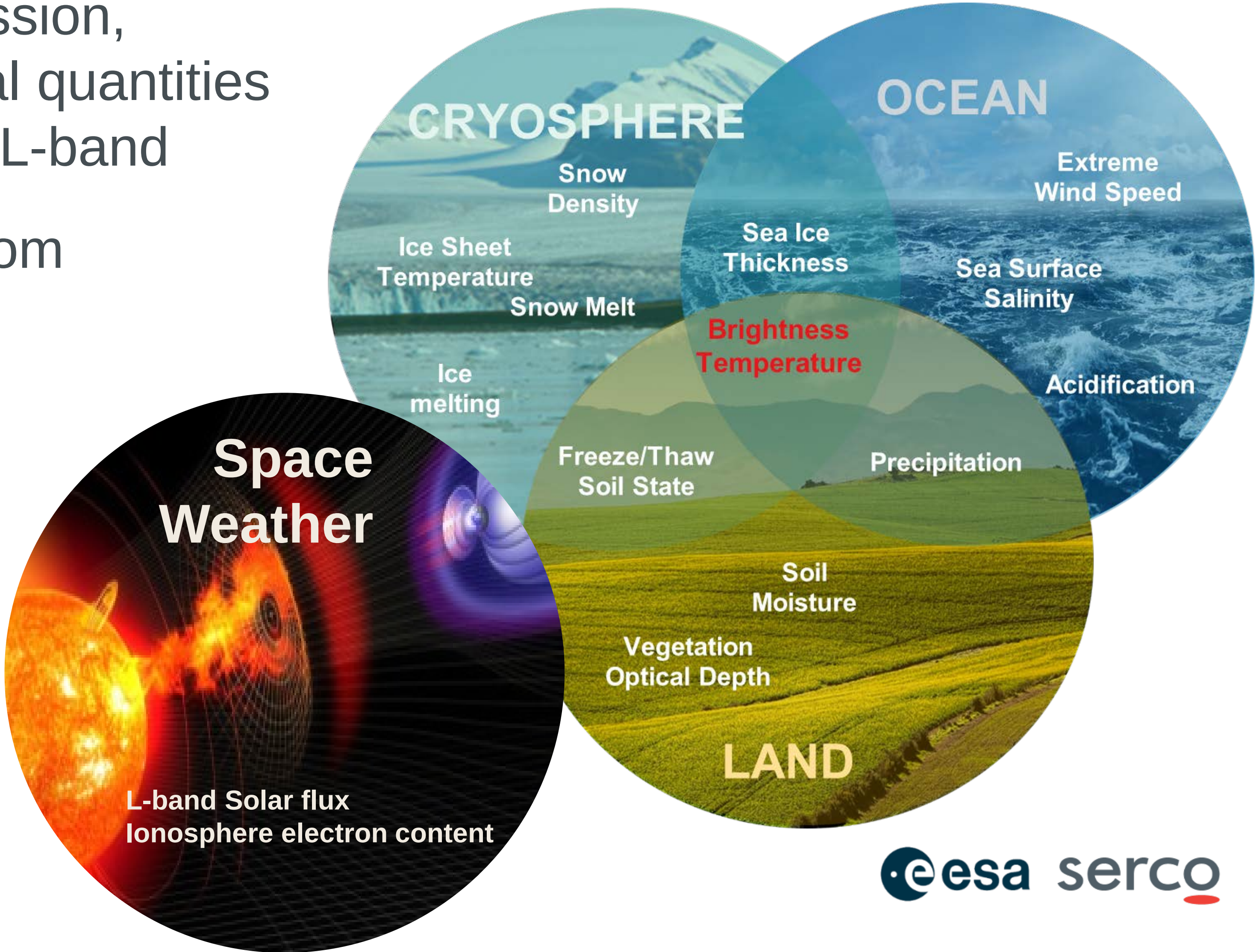
- **WHAT**: Soil Moisture Ocean Salinity (**SMOS**) is one of the ESA's Earth Explorer dedicated to capturing "Brightness Temperature" images of Earth surface.
- **APPLICATIONS**: It is the first mission to provide global observation of the temporal and spatial variability in soil moisture and sea surface salinity, which are driven by the continuous exchange in Earth's water cycle between the oceans, atmosphere and land.
- **INNOVATIVE**: SMOS carries the first spaceborne Microwave Imaging Radiometer using Aperture Synthesis (**MIRAS**) instrument to measure Earth's surface radiation at 1.4 GHz.
- **WHEN**: Launched 2 November 2009, initially designed as a five-years mission, it is still delivering key information to advance science and data used in various practical application. Platform and sensors are in very good status with operation planned till end 2025 and possible next.

SMOS Mission (2009 ->) overview

SMOS is truly Earth Explorer Mission, providing a variety of geophysical quantities from Earth Surface emissivity at L-band

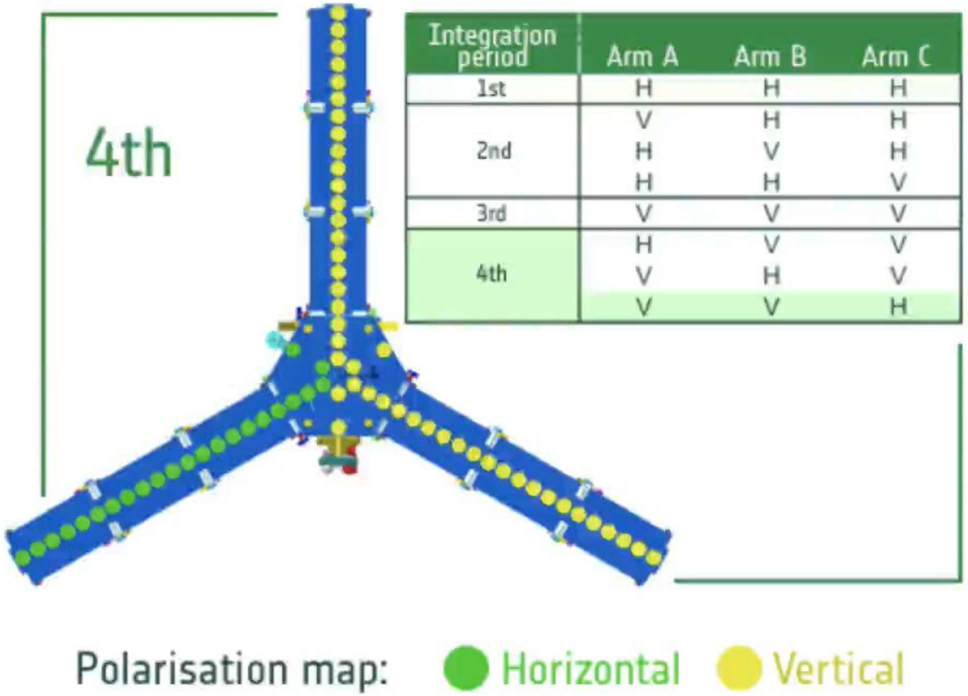
…next, geophysical quantities from Ionosphere and Sun

SMOS mission overview of operational and experimental products

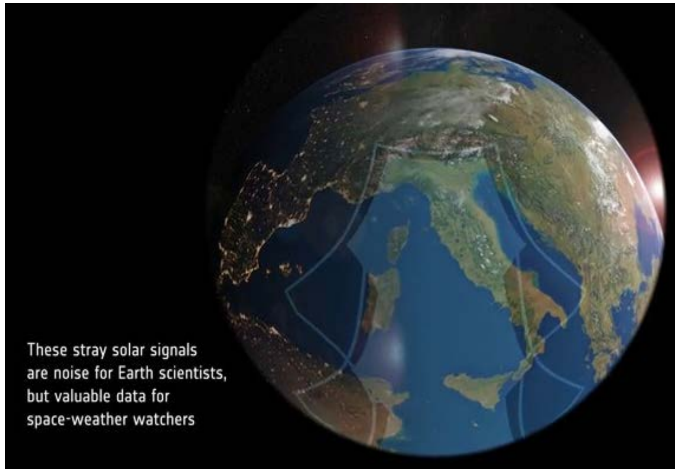


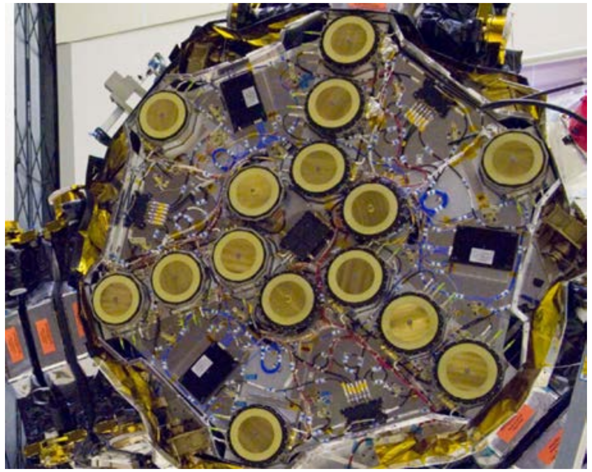
SMOS payload: MIRAS

- The SMOS mission is based on a **sun-synchronous** orbit (dusk-dawn **6am/6pm**)
- The payload of **SMOS** consists of the Microwave Imaging Radiometer using Aperture Synthesis (**MIRAS**) instrument, a passive microwave **2-D interferometric full polarization radiometer**, operating at **1.413 GHz** (wavelength of 21 cm) within the protected 1400-1427 MHz band.
- The **MIRAS** instrument antenna array is formed by three arms 120° apart, with 23 equally spaced **LICEF** (Lightweight Cost-Effective Front-end) receivers each.
- A full polarimetry measurement is acquired in four integration period i.e. **4.8 seconds**.

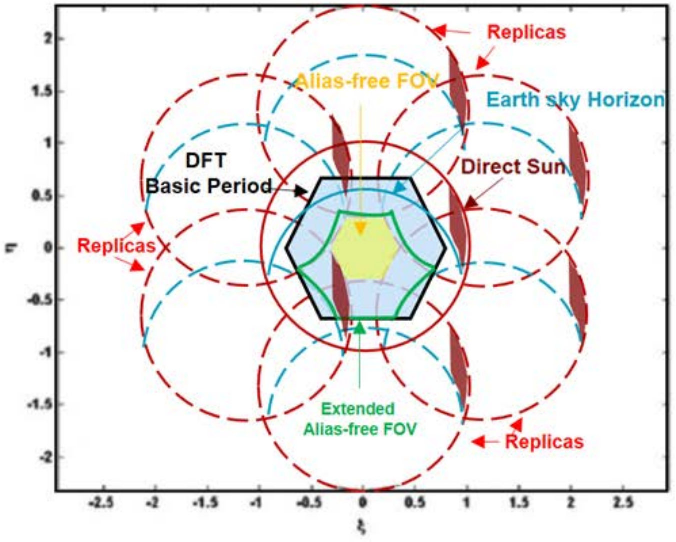


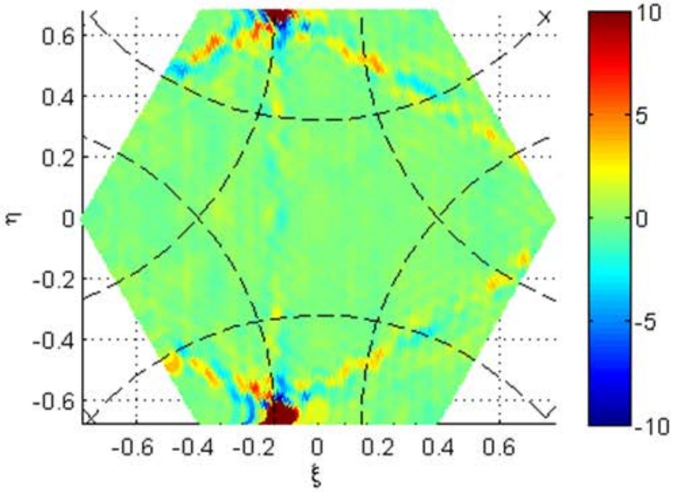
How MIRAS instrument is sensing the Sun





- Due to antenna size (diameter equal to 16.5 cm) and frequency wavelength (21 cm at L-band) the instrument's field of view (FoV) is large and includes full **Earth-disk** and part of the surrounding **Sky including the Sun**.





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.

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L-band solar flux retrieval algorithm

- Ancillary information derived by the Sun removal algorithm annotated inside L1B (BT_{Unc}^{sun}) are corrected by obliquity factor and converter in flux unit. The final Solar flux is derived with a linear regression model.

L1B

$$BT_{CorEl}^{sun} = \frac{BT_{Unc}^{sun}}{cos\left(\frac{\pi}{2} - e\right)}$$

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

$$F = \frac{2\,K_b BT_{CorEl}^{sun}}{\lambda^2}\,\Omega_{Sun}$$

$$Solar\ flux = F * m + q$$

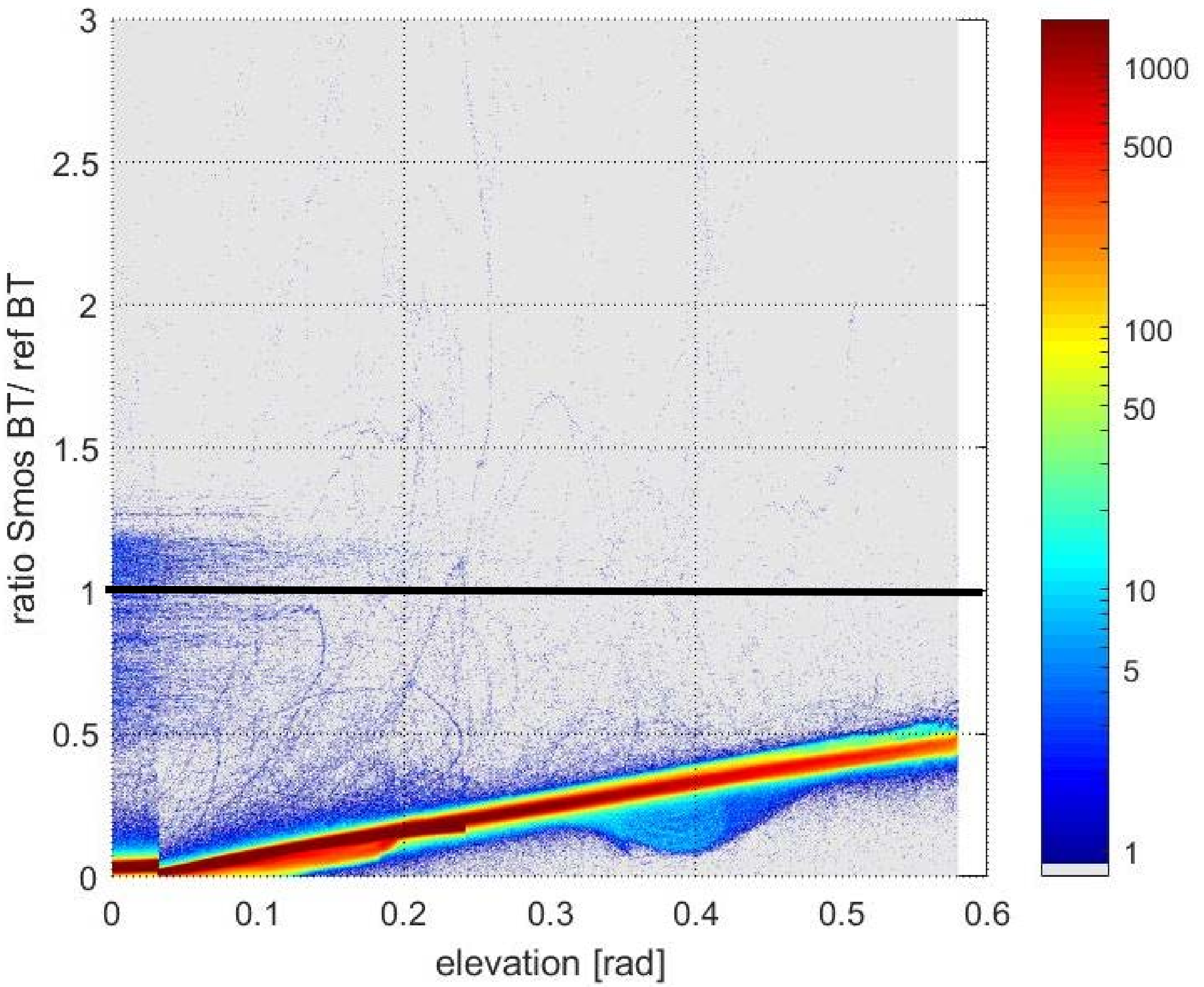
Flux

- **m,q** coefficients are based on linear regression model between **calibrated Solar flux from radio-telescope** measurements and SMOS Sun removal ancillary information F.
- **m,q** are derived for both Sun position in front and in the back of the antenna plane (xi, eta) along the satellite orbit allowing about 24h continuous estimation of the Solar flux.

L-band solar flux retrieval algorithm

Annotated SMOS Sun BT V724 divided by Sun BT from radiotelescope as function of the Sun elevation angle on the antenna frame

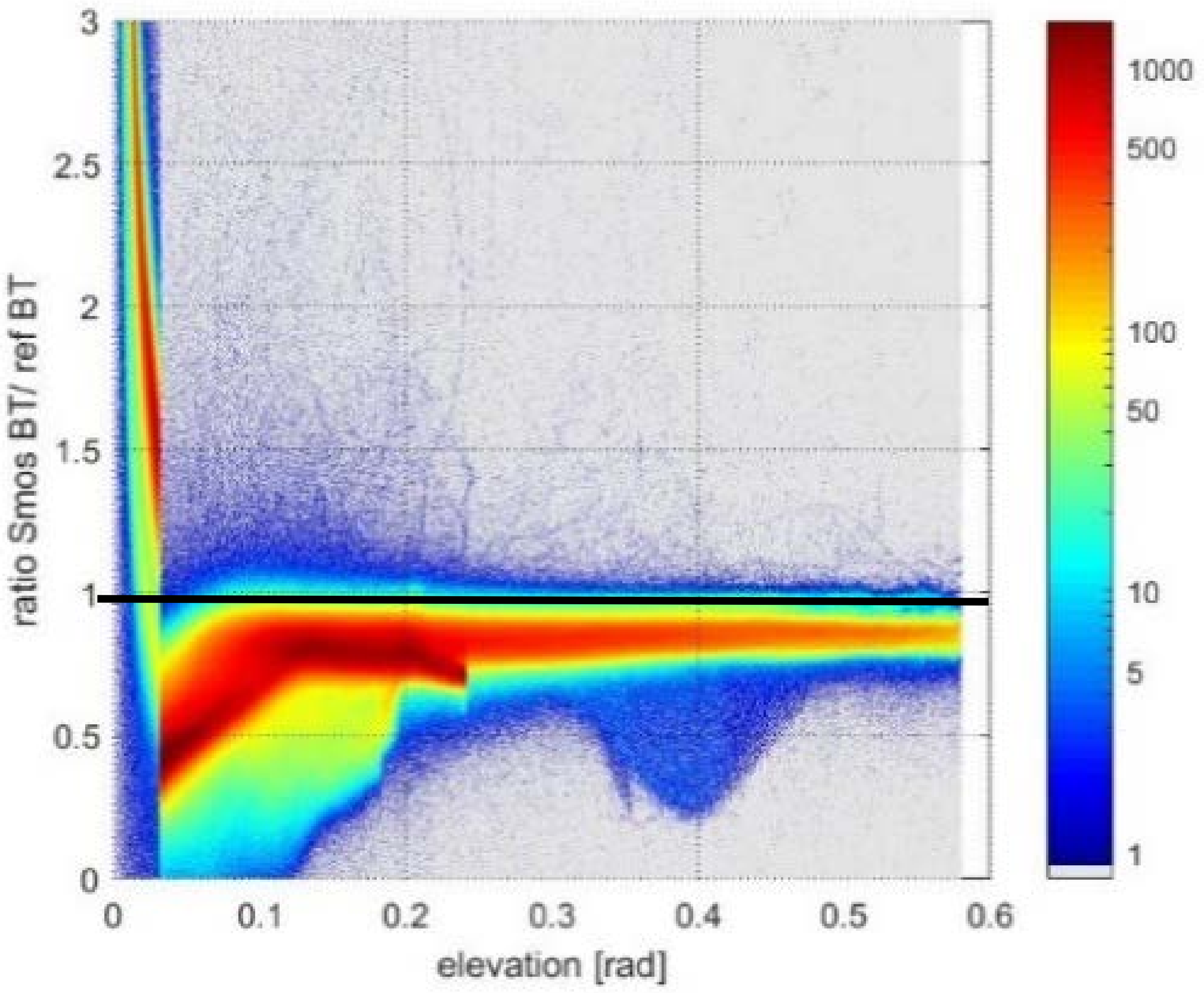
- Not aligned to 1
- Clear trend as function of the elevation angle
- Discontinuity for very low elevation angle (around 0.04 rad)



L-band solar flux retrieval algorithm

SMOS Sun BT V724 corrected for the obliquity factor sin(el) and divided by Sun BT from radiotelescope as function of the Sun elevation angle on the antenna frame

- Towards alignment to 1
- Trend as function of the elevation angle reduced,
- Discontinuity for very low elevation angle (around 0.04 rad) clear evident due to antenna pattern interpolation between front and back antenna plane.

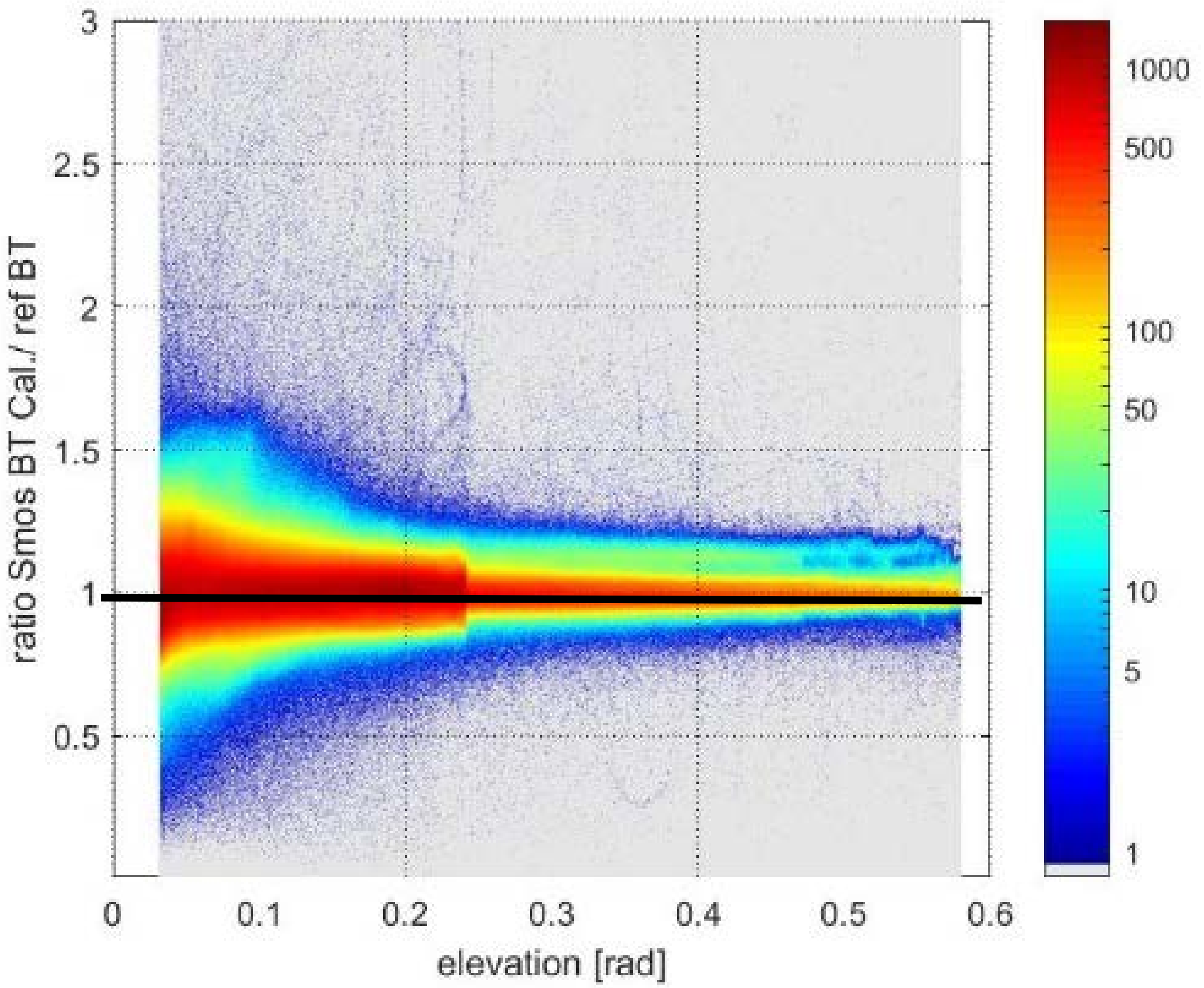


REDLAB

L-band solar flux retrieval algorithm

Sun BT V724 calibrated and divided by Sun BT from radiotelescope as function of the Sun elevation angle on the antenna frame

- Alignment to 1 very good for elevation angle above 0.25 rad.
- Trend as function of the elevation angle removed, eclipse effect removed
- Data in the discontinuity for very low elevation angle (around 0.04 rad) cannot be calibrated

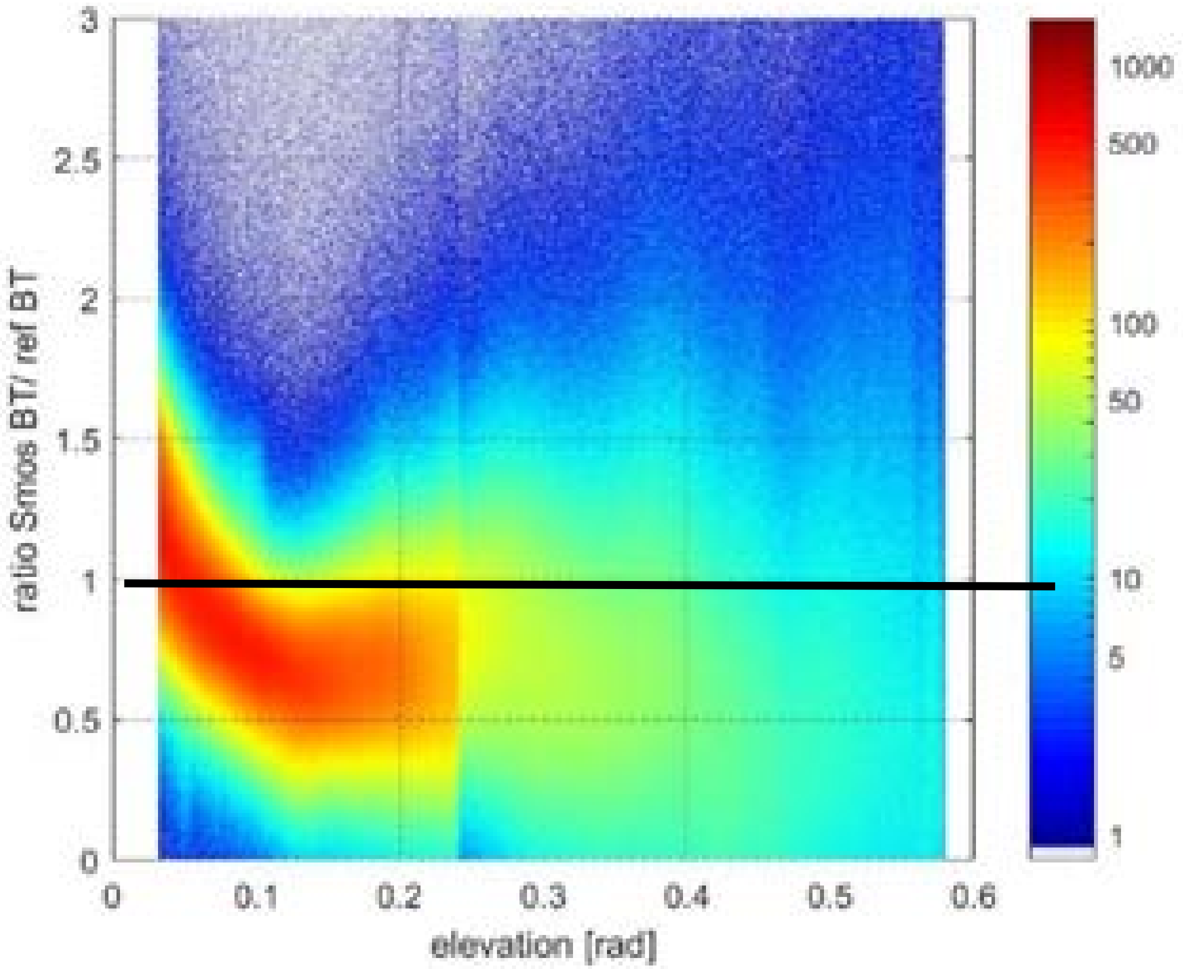


RedLab

L-band solar flux retrieval algorithm

SMOS Sun BT (Back) V724 corrected and divided by Sun BT from radiotelescope as function of the Sun elevation angle on the antenna frame

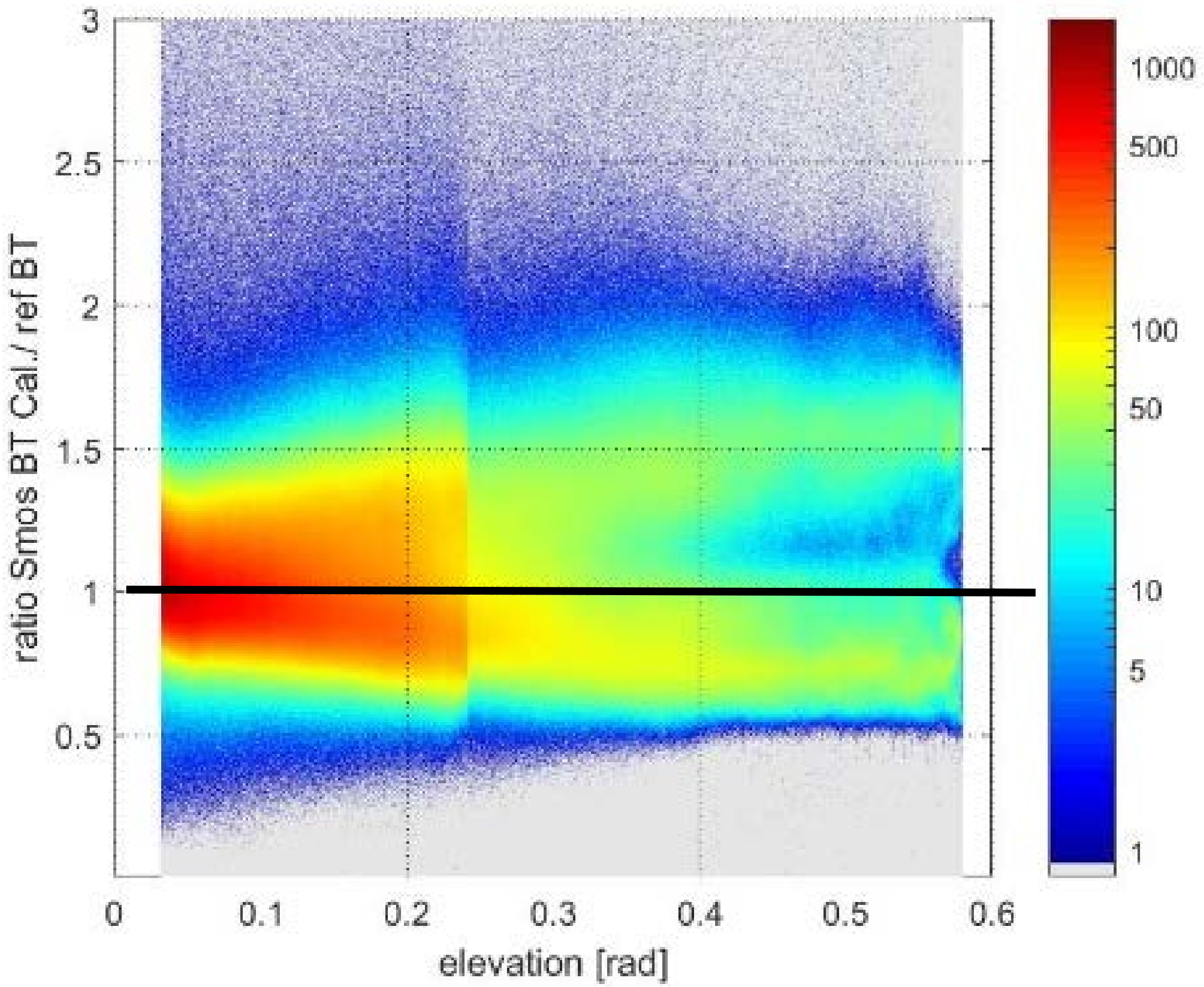
- Trend as function of the elevation angle.
- Discontinuity for very low elevation angle (around 0.04 rad) due to antenna pattern interpolation.
- No Sun signal for elevation angle above 0.25 rad



L-band solar flux retrieval algorithm

SMOS Sun BT (Back) V724 calibrated and divided by Sun BT from radiotelescope as function of the Sun elevation angle on the antenna frame

- Reduced trend as function of the elevation angle, better alignment to 1, more noisy if compared to Front.
- Discontinuity for very low elevation angle (around 0.04 rad) due to antenna pattern interpolation.
- No Sun signal for elevation angle above 0.25 rad



RedLab

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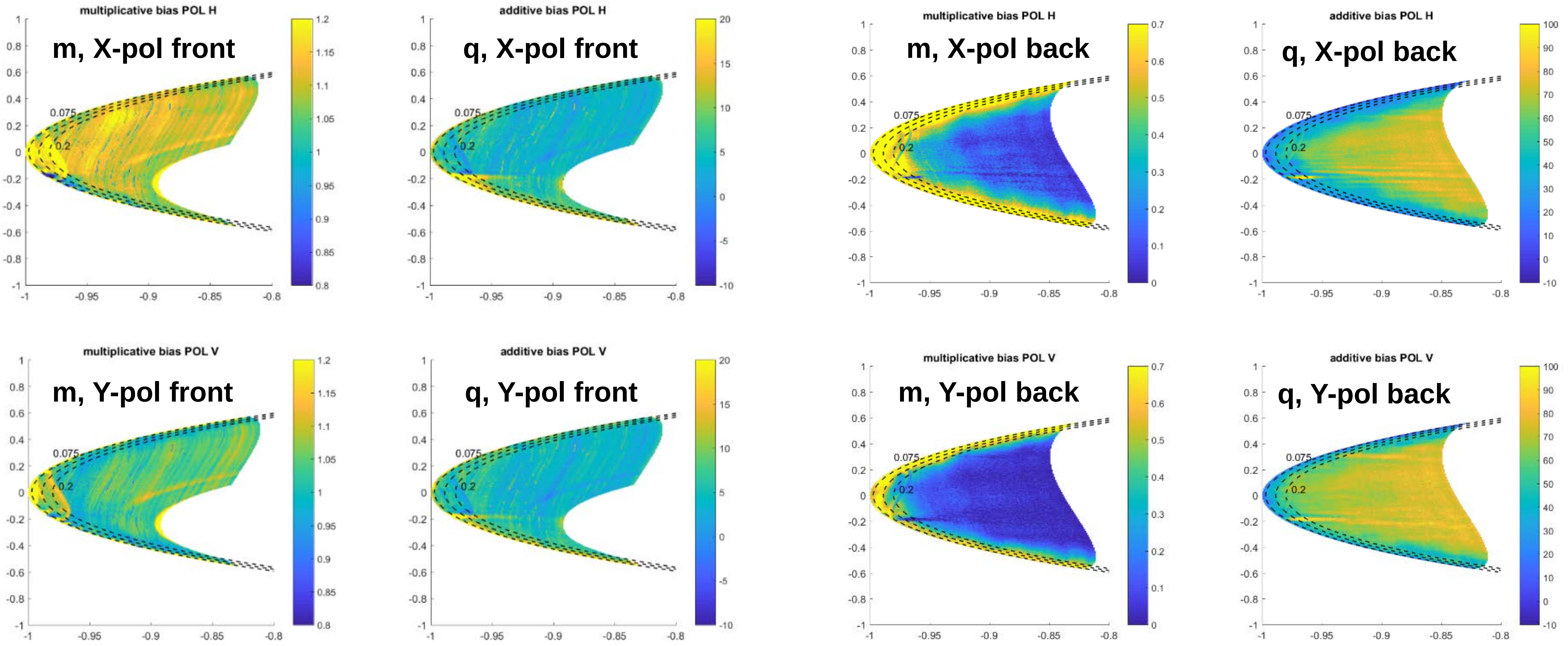
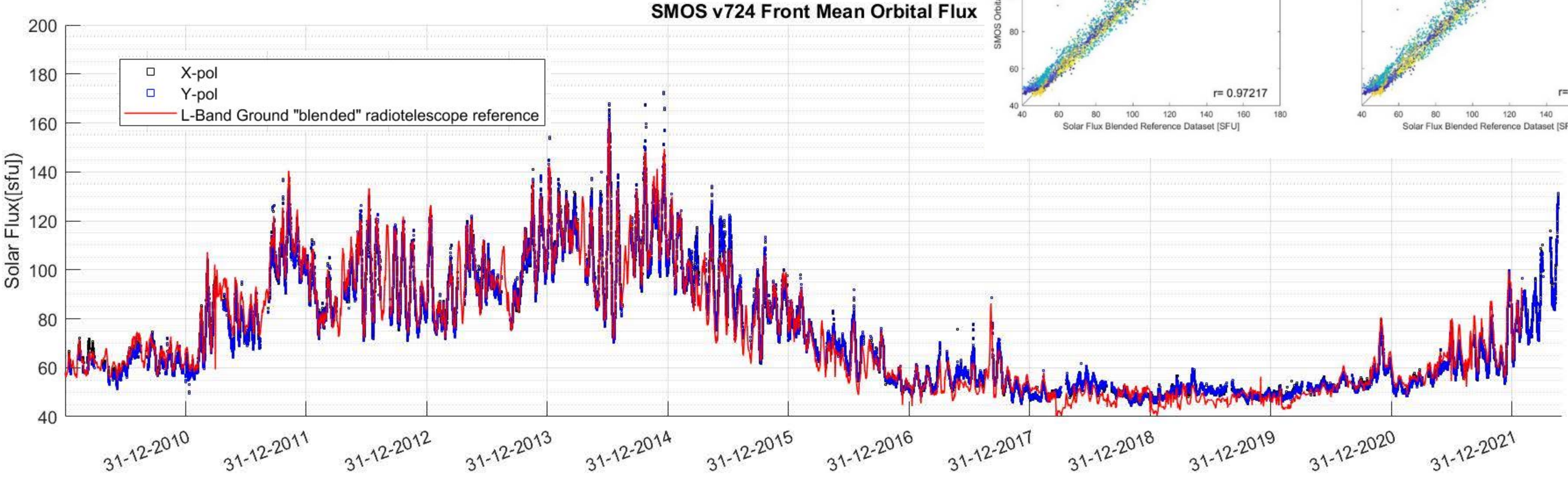
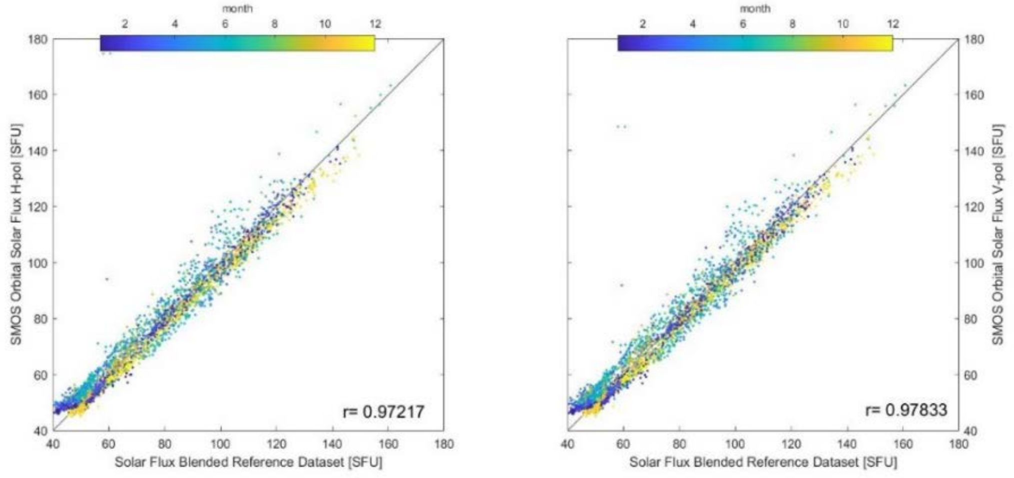
L-band solar flux retrieval algorithm



SMOS L-band solar flux years 2010 - 2021

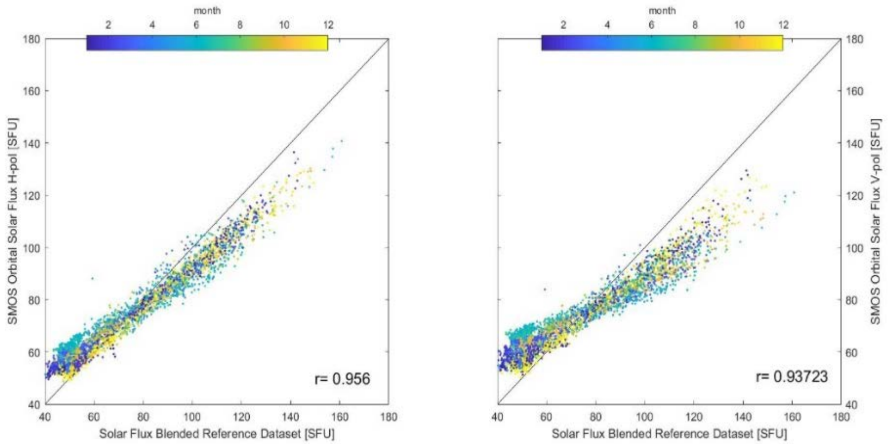
- Very good correlation (above 0.97) with calibrated radio telescope L-band flux reference along the entire 11 years Solar cycle. Solar rotation clear visible.

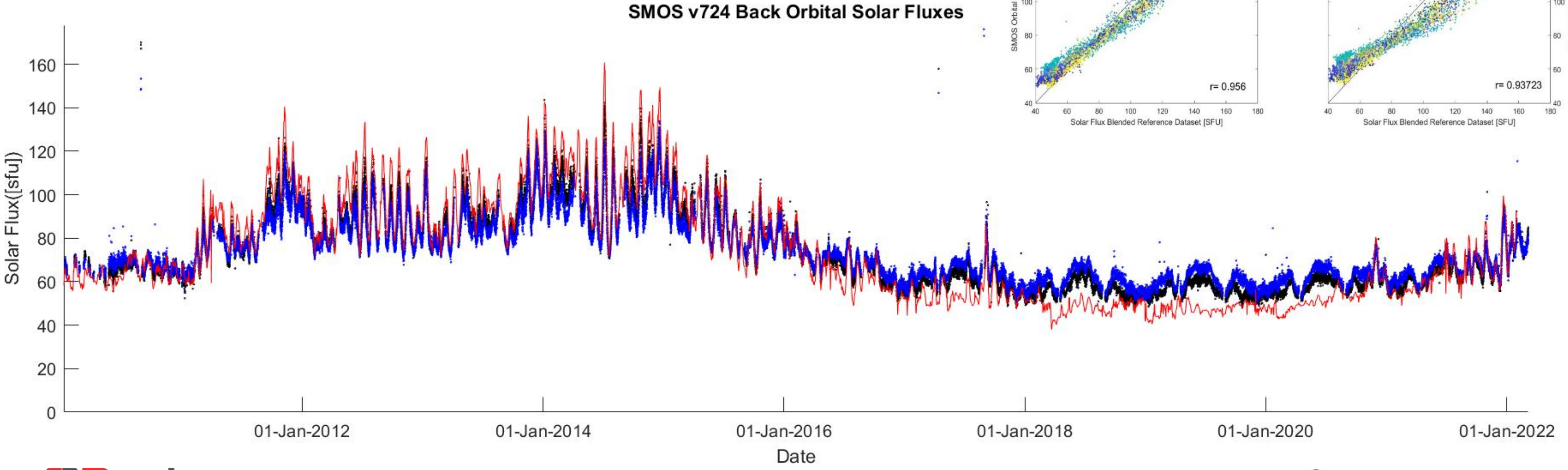




SMOS L-band solar flux years 2010 - 2021

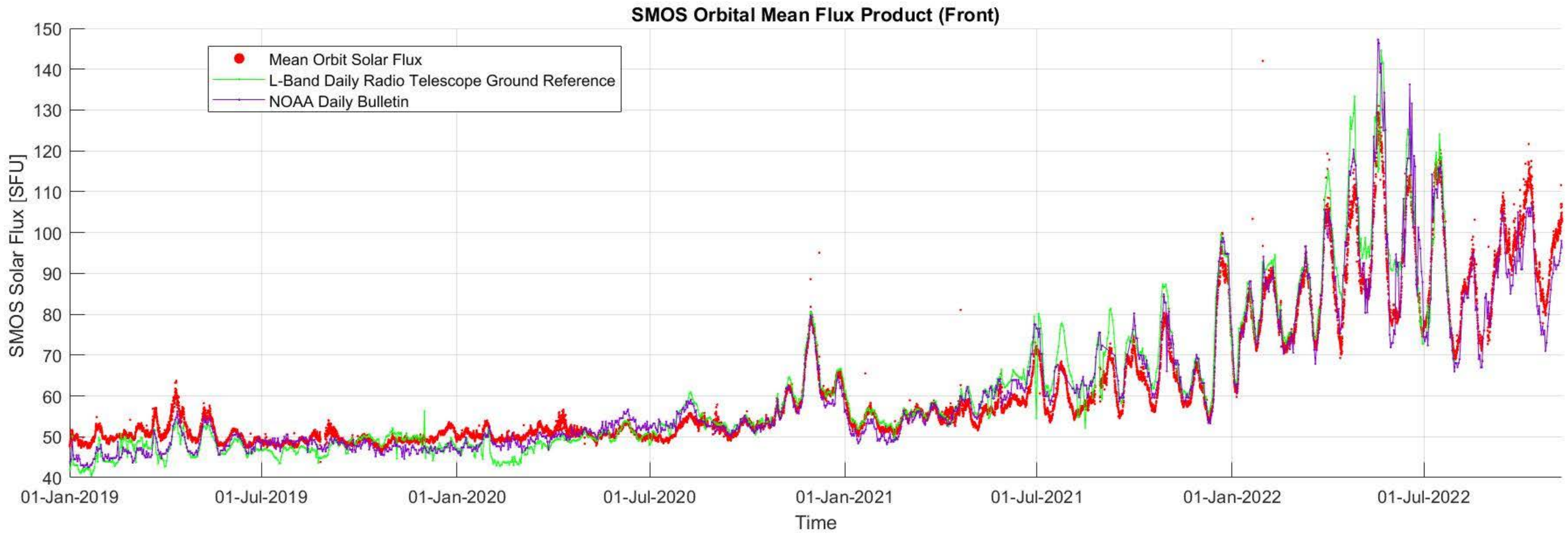
- Good consistency with calibrated radio-telescope along the entire 11 years Solar cycle also for measurements in the back. Better alignment during period with increased solar activity.





Why SMOS L-band solar flux ?

- Available in real time within 3 hours from acquisition
- Temporal resolution 100 minutes (or less) for Solar cycle studies and synergies with ionosphere/thermosphere modelling (proxy of solar activity)

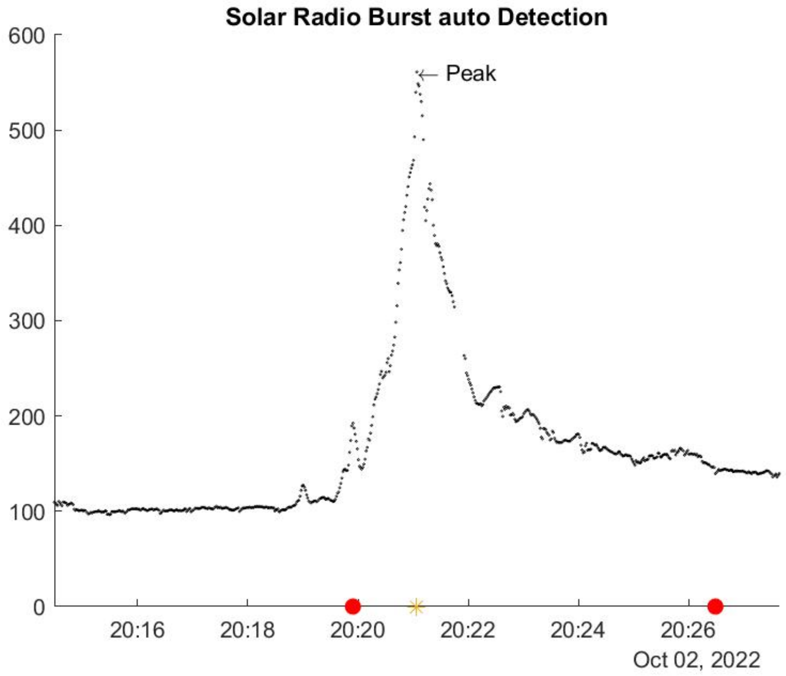


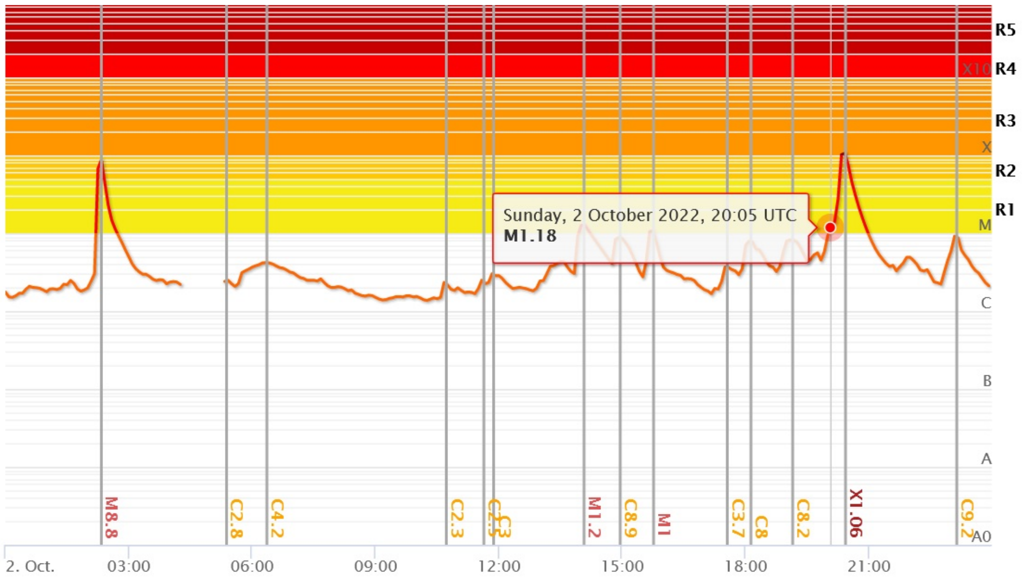
Why SMOS L-band solar flux ?

- Temporal resolution 4.8 seconds for Solar Radio Burst (SRB) studies and synergies with Solar flare/Coronal Mass Ejection monitoring/forecast

Data Center	Product Generation Time (UTC)	Processor Version	L1B input file used
RedLab	2022-10-04T10:27:20	724_1.0	SM_OPER_MIR_SC_F1B_20221002T014046_20221002T023443_724_001_1

Burst est. start time (UTC)	Burst est. stop time (UTC)	Peak time (UTC)	Peak Flux (sfu)	Integrated flux (10-19 erg*cm-2*Hz-1)	DoCP
2022-10-02 02:18:23.55	2022-10-02 02:21:40.35	2022-10-02 02:19:09.15	2.161608e+02	3.461398e+04	-7.8

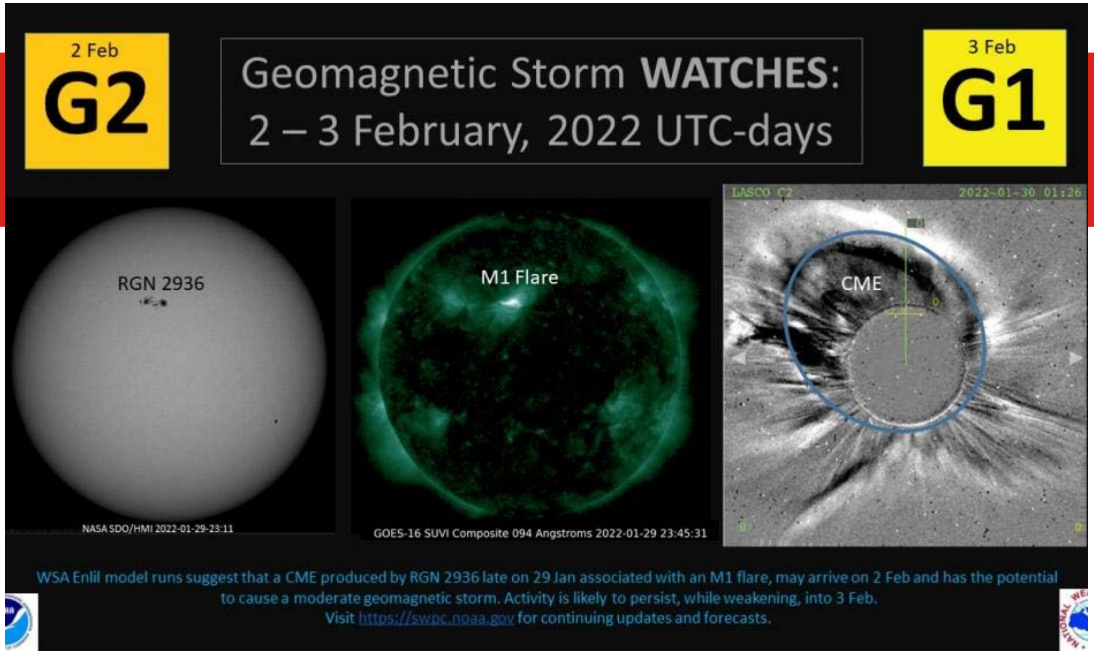


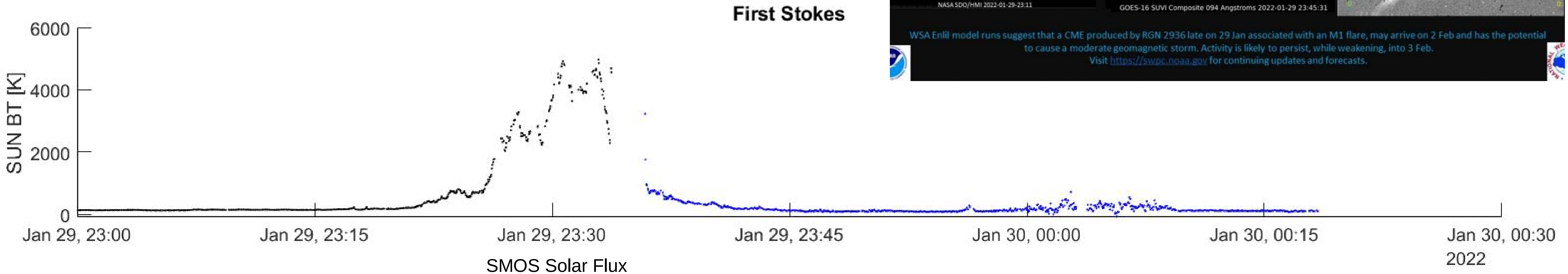


https://www.spaceweatherlive.com/en/archive/2022/10/02/xray.html

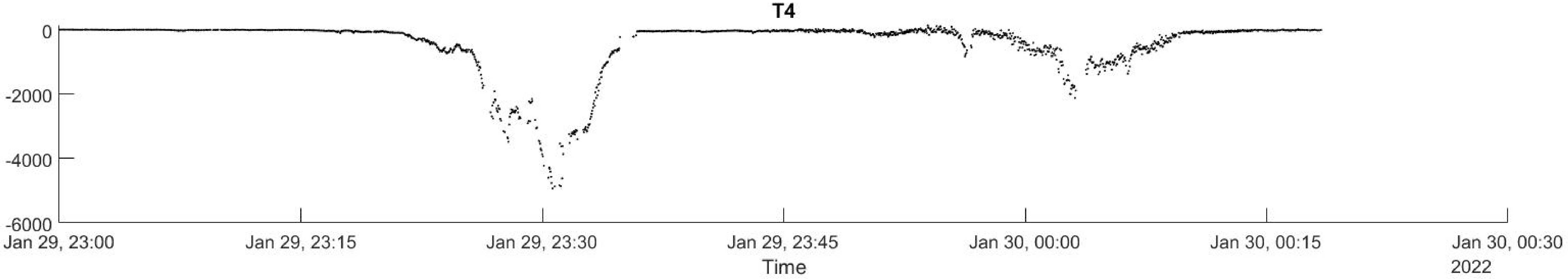
SRB 29 January 2022

NOAA/SWPC Region 2936 produced an M1 flare (R1-Minor Radio Blackout) on 29 January at 6:32 pm ET (29/2332 UTC). This flare was associated with an asymmetric, full halo coronal mass ejection (CME) as observed in NASA/SOHO LASCO coronagraph imager at 01:36 a.m. on 30 January. Predicted geomagnetic storm on 2 and 3 February 2022. Radio burst polarimetic information could provide information about the magnetic configuration during the flare and CME magnetic structure.



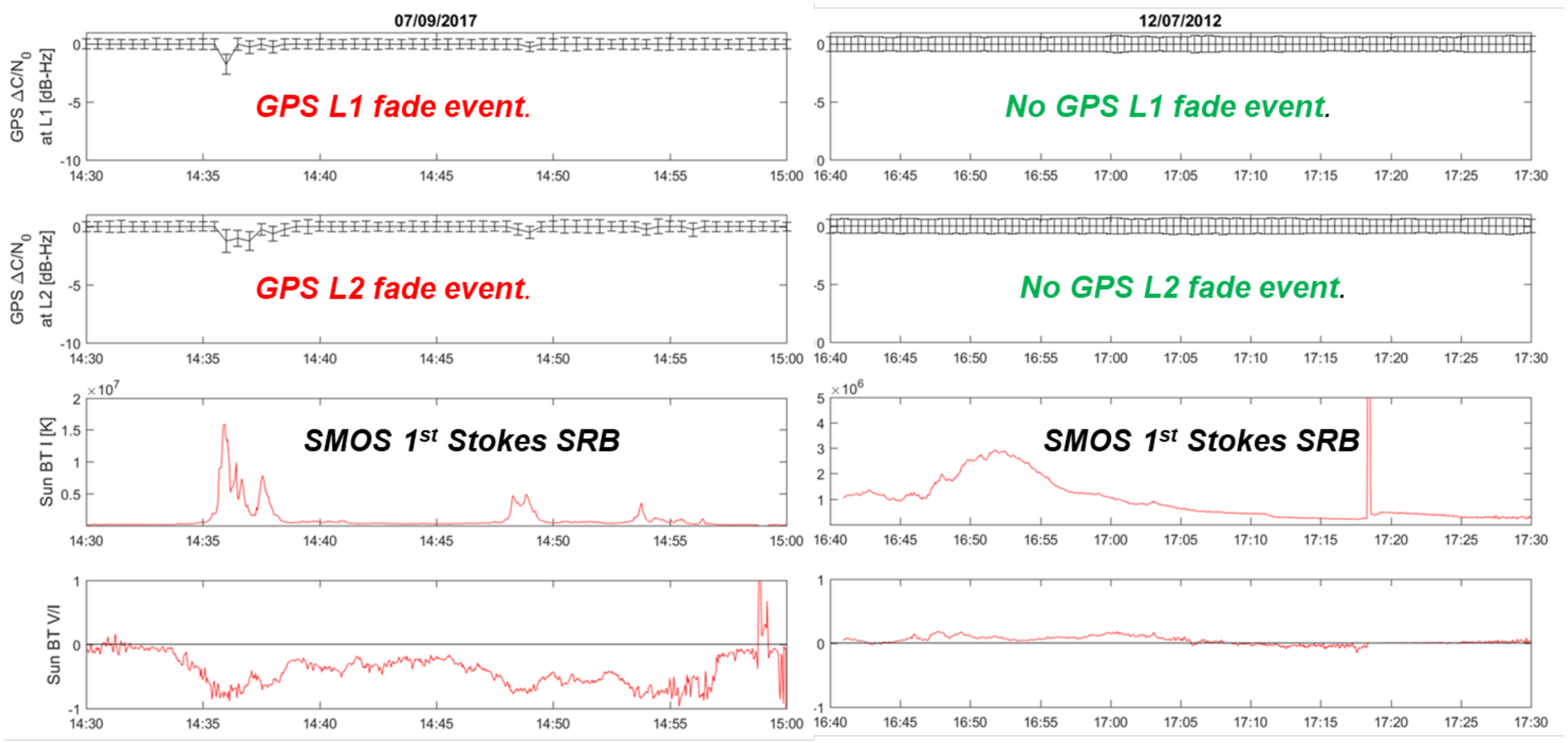


SMOS Solar Flux



Why SMOS L-band solar flux ?

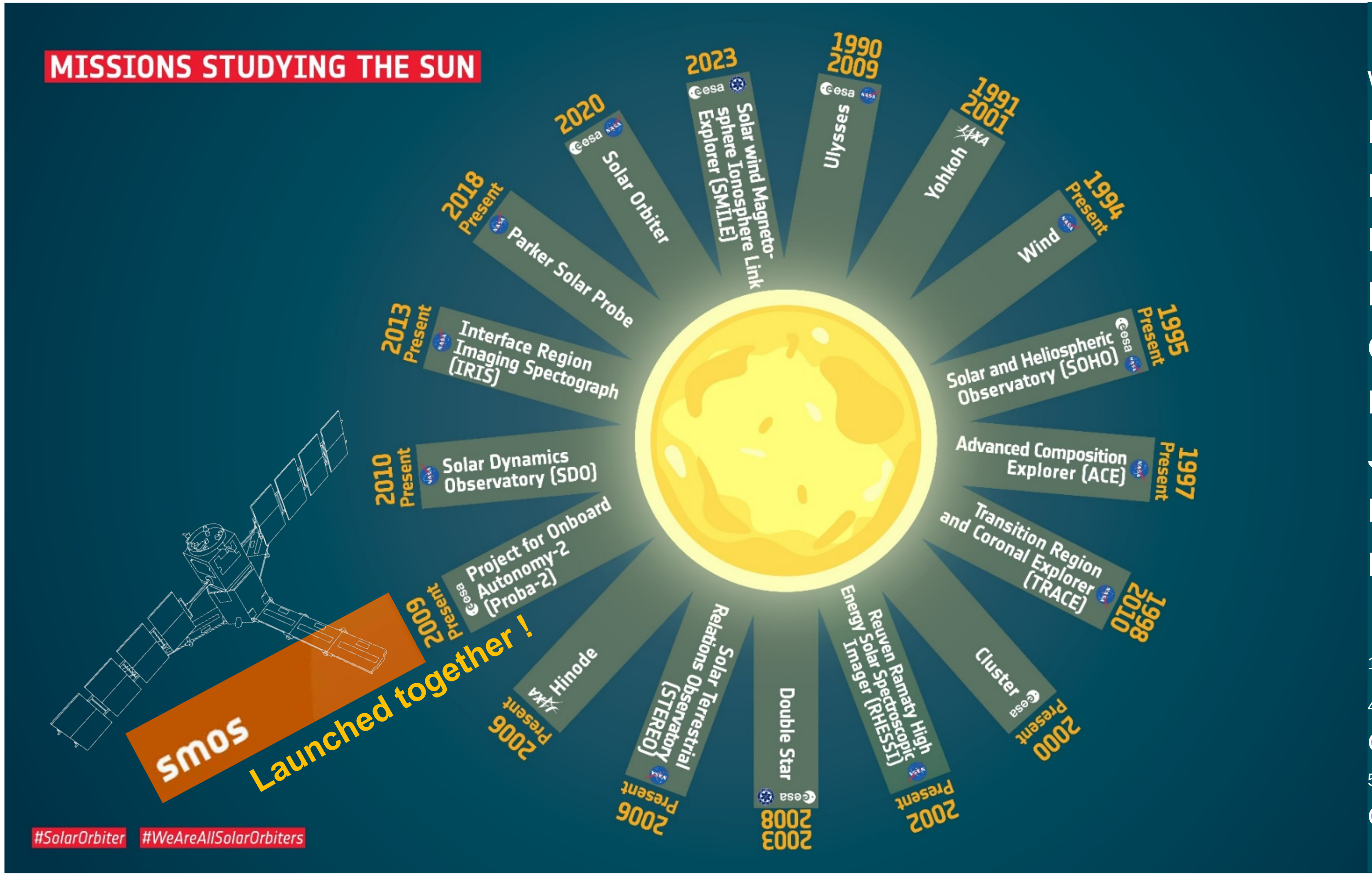
- Polarimetric dataset at L-band for study SRB circular polarization and synergies with GPS anomalies monitoring (MIRAS frequency is right in the middle of the two L1 and L2 GPS signal)



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

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

Thank you for your attention



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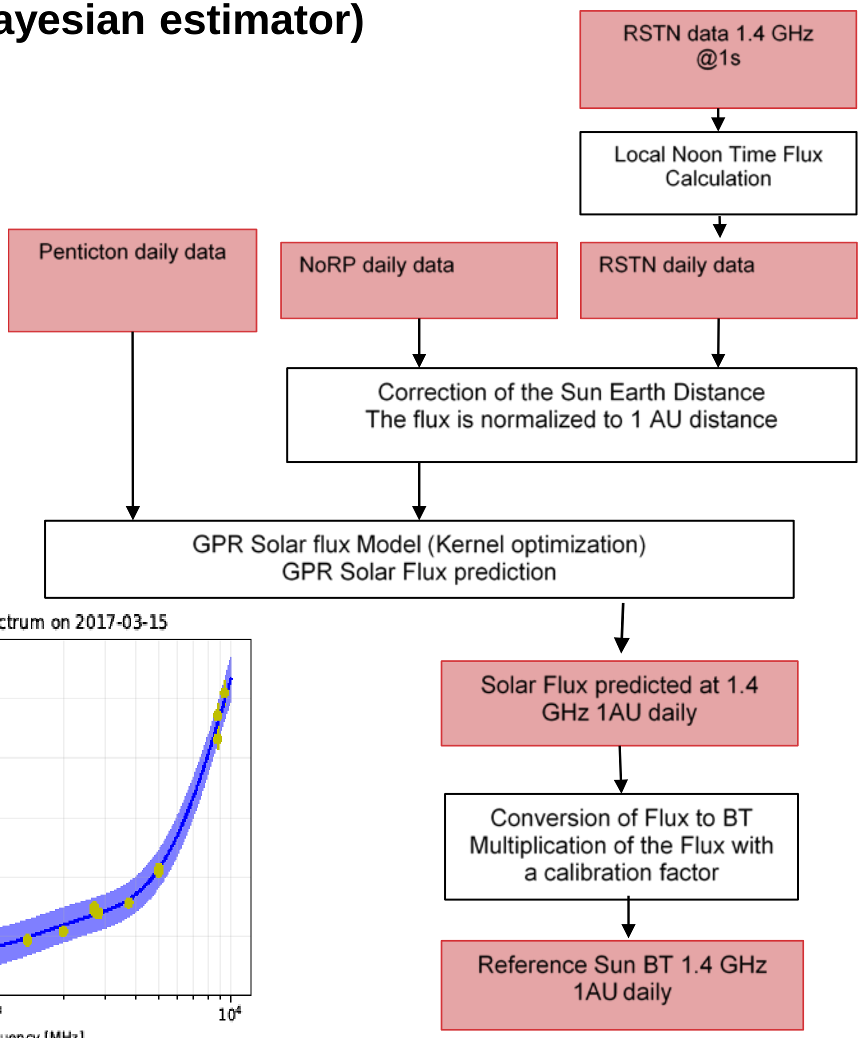
Backup slides

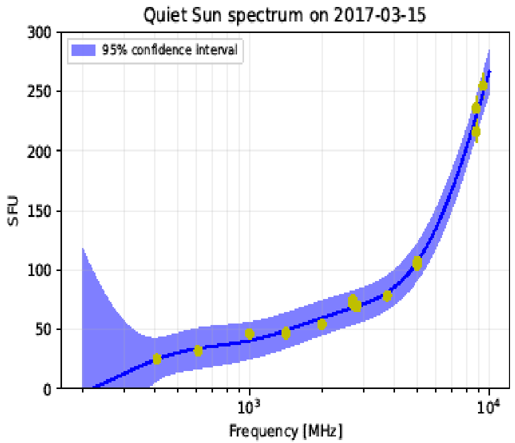
L-band solar flux daily references

- Issue: RSTN L-band radio-telescope dataset not inter-calibrated
- Two methods developed to derive a calibrated L-band solar flux reference from multi-frequencies radio-telescope observations

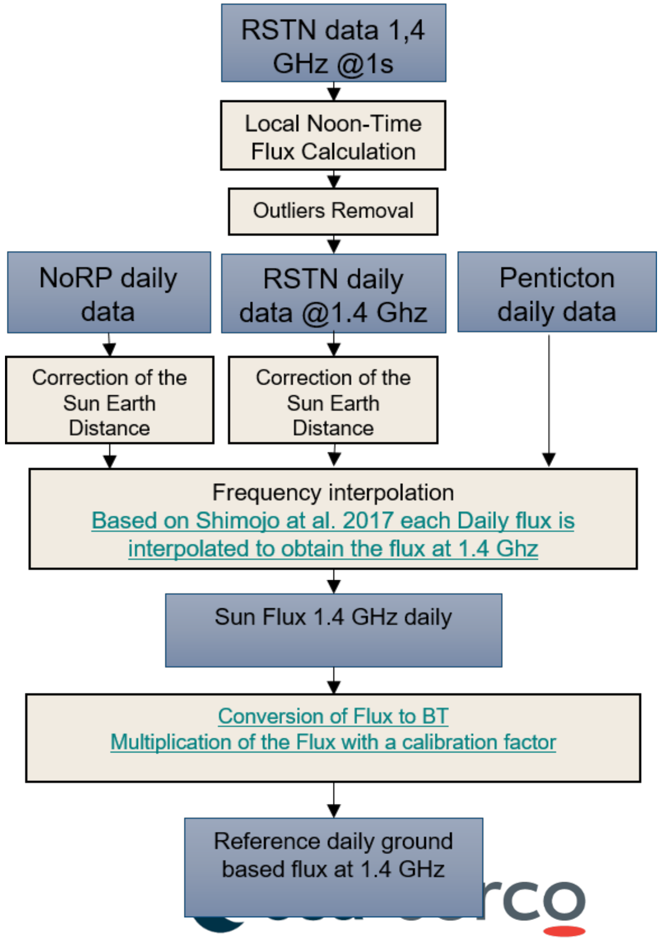
RSTN	Nobeyama	Penticton
0,24 GHz		
0,41 GHz		
0,61 GHz	1 GHz	
1.415 GHz		
2.69 GHz	2 GHz	2,8 GHz
4.99 GHz	3,7 GHz	
8.80 GHz	9,4 GHz	
15.4 GHz	17 / 35 /80 GHz	

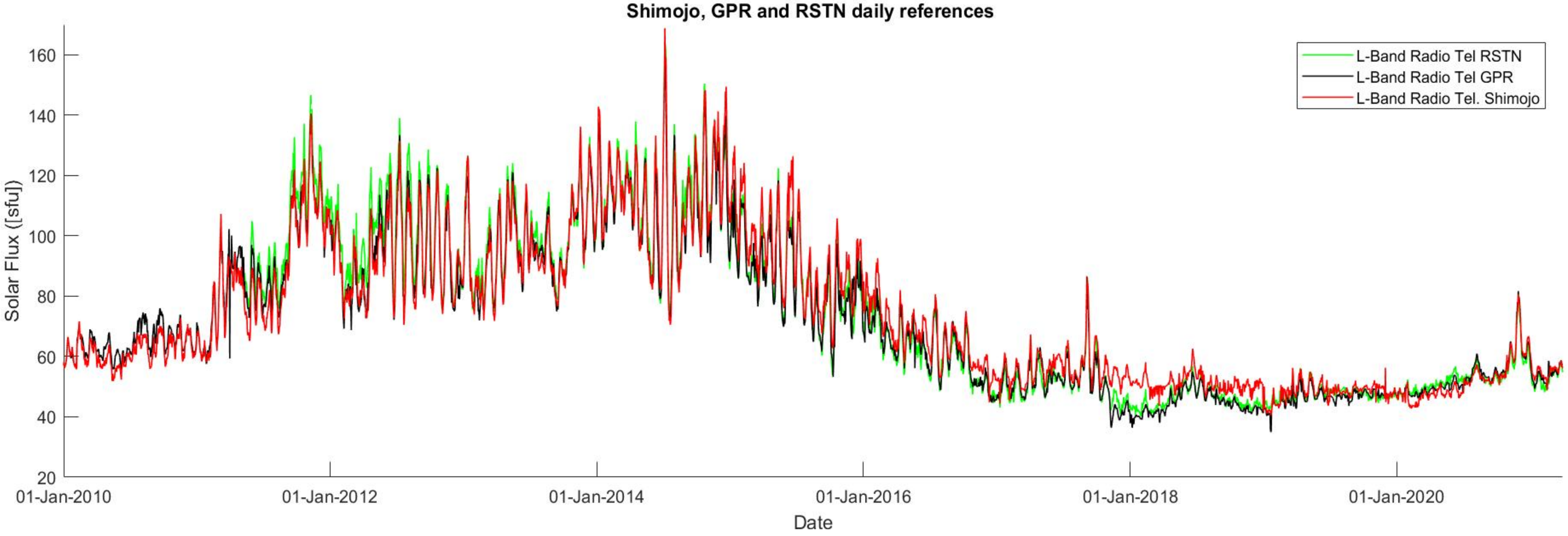
Gaussian Regression Processor (Bayesian estimator)

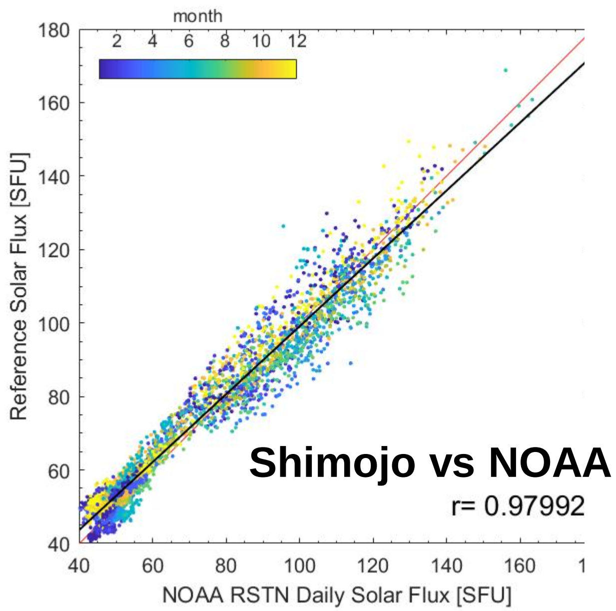


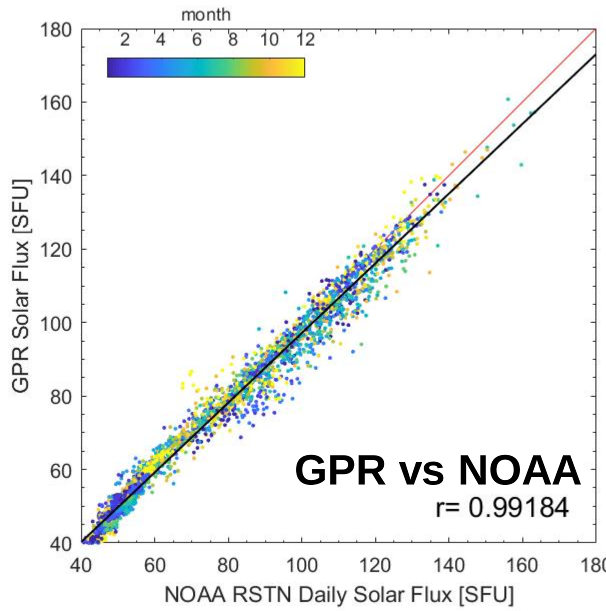


Shimojo linear interpolation









Good agreement among Solar flux references