living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Inter-comparison of Soil Moisture Ocean Salinity (SMOS) derived Solar flux with on-ground radio telescope observations for the 11-years Solar cycle

Raffaele Crapolicchio, Lorenzo Di Ciolo
Serco Itala S.p.A. / Redlab

25 May 2022
A6.01.2 Geospace System Science: Thermosphere, Ionosphere, Magnetosphere and Their Coupling - 2

Outline

About exploration of a noise signal for new mission application

SMOS mission overview

How SMOS' payload MIRAS instrument sees the Sun

SMOS Solar flux algorithm

SMOS Solar flux validation results

Why SMOS Solar flux ?

SMOS Mission (2009 →) Overview

esa

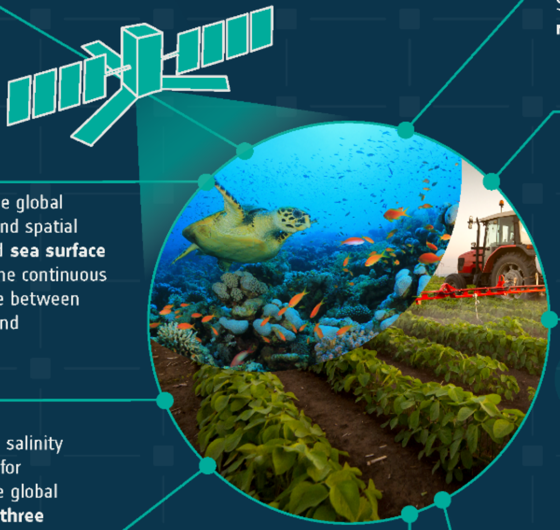
About SMOS

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



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

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

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**

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

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

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)**

SMOS Mission (2009 →) Overview

About SMOS

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

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**

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

Data and Users

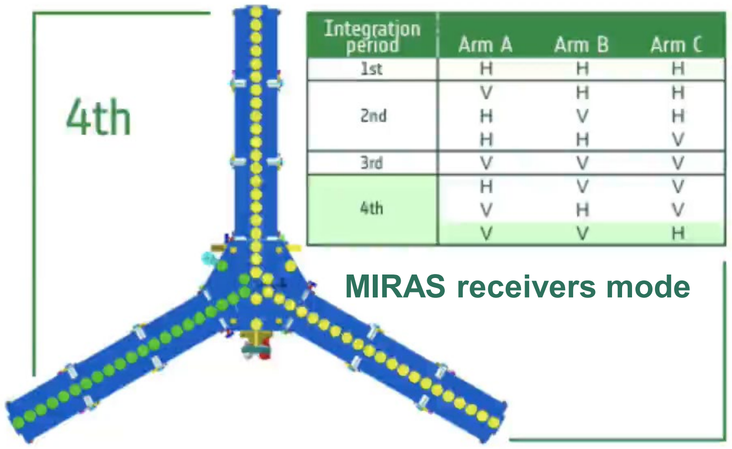
Since the beginning of the SMOS mission, around 24.2 million products have been downloaded from ESA's SMOS dissemination service, by more than 1700 active users, for a total volume of 920 TB of data

Data Access

https://smos-diss.eo.esa.int/oads/access

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)**



Integration period	Arm A	Arm B	Arm C
1st	H	H	H
2nd	V	H	H
	H	V	H
	H	H	V
3rd	V	V	V
4th	H	V	V
	V	H	V
	V	V	H

MIRAS receivers mode

Polarisation map: Horizontal Vertical

SMOS Mission (2009 →) Overview

About SMOS

What?

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

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

Benefits?

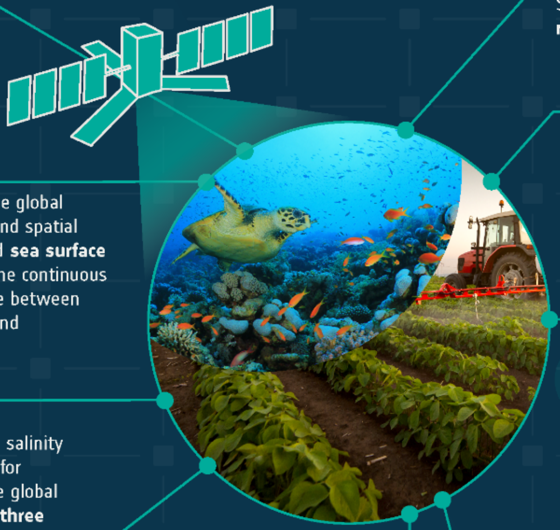
These **key geophysical parameters**—soil moisture for understanding hydrometeorological processes and salinity for understanding of ocean circulation—are both vital for climate change studies. Its images are used to derive global maps of soil moisture and sea surface salinity **every three days**, at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

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



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

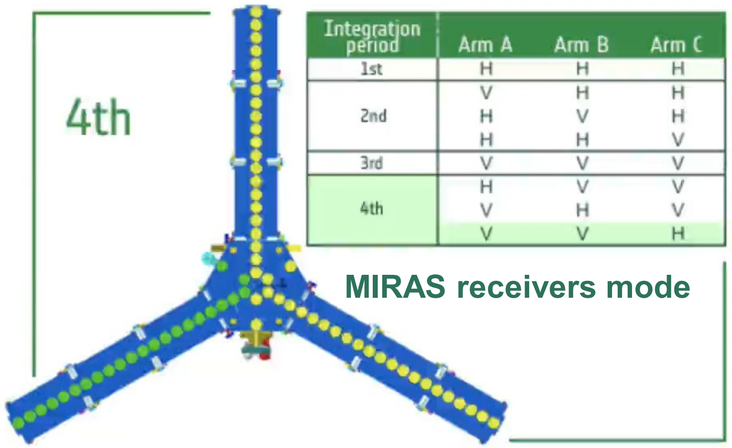
What's next?

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

Where?

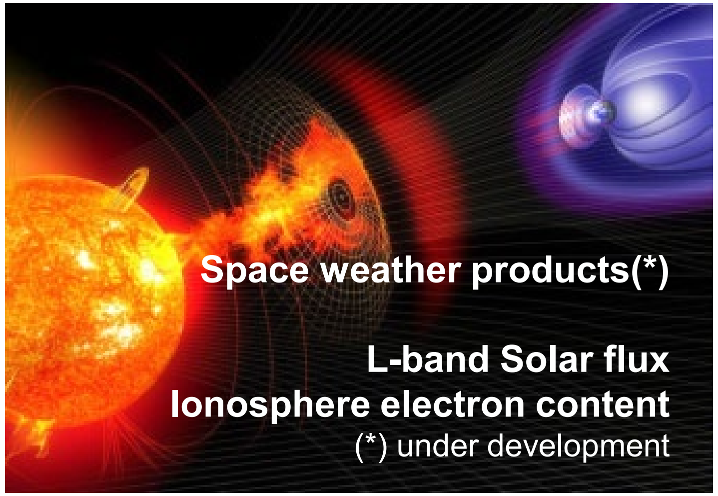
The PROTEUS spacecraft platform SMOS utilises was designed and built by **CNES** and **Alcatel Alenia Space**, while the **MIRAS** instrument was designed and built by a consortium of 20 European companies, led by **EADS-Casa Espacio (now Airbus)**



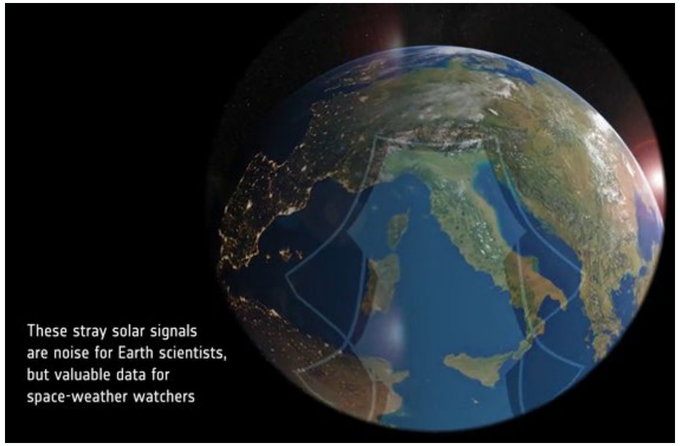
Integration period	Arm A	Arm B	Arm C
1st	H	H	H
2nd	V	H	H
	H	V	H
	H	H	V
3rd	V	V	V
4th	H	V	V
	V	H	V
	V	V	H

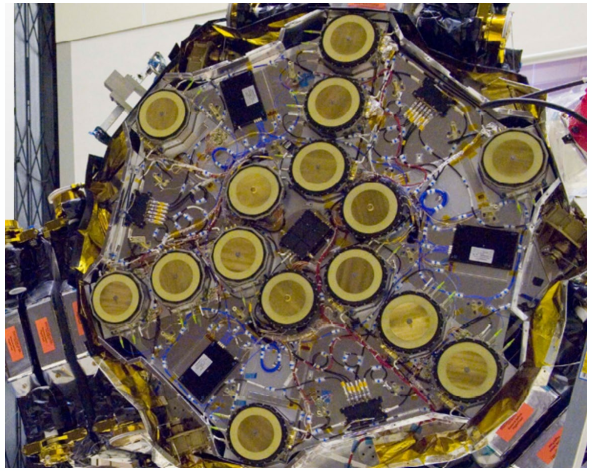
MIRAS receivers mode

Polarisation map: Horizontal Vertical

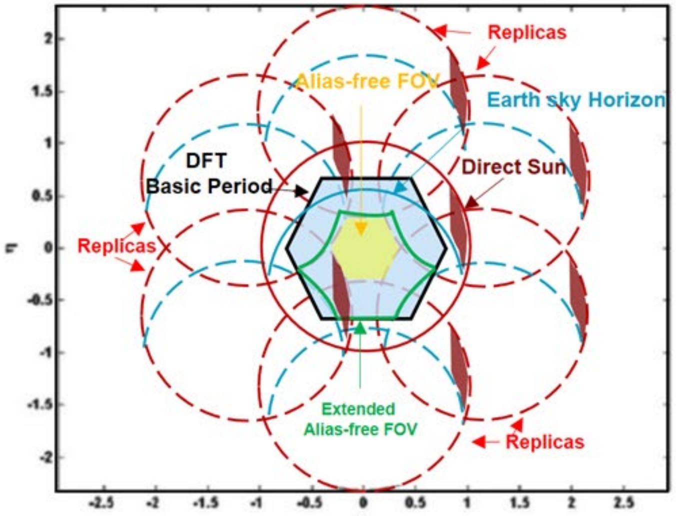


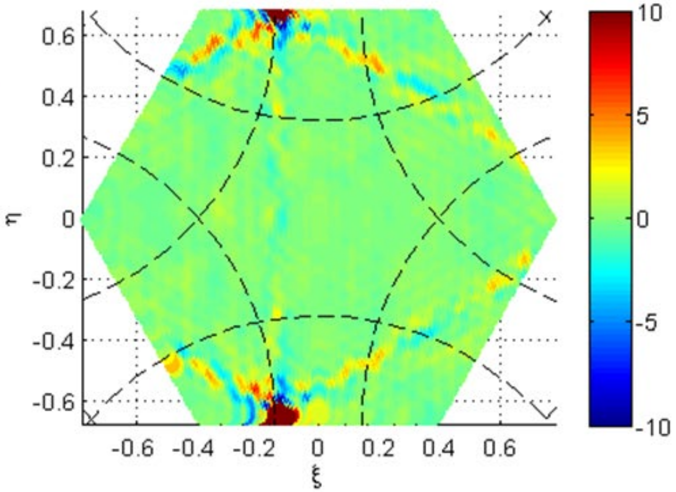
How MIRAS instrument is sensing the Sun





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**.





SMOS Field of view and image alias (left panel). SMOS image with Solar signal (right panel)

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 Solar flux algorithm overview

- 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 liner model

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

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

→

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

→

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

- **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 24h continuous estimation of the Solar flux

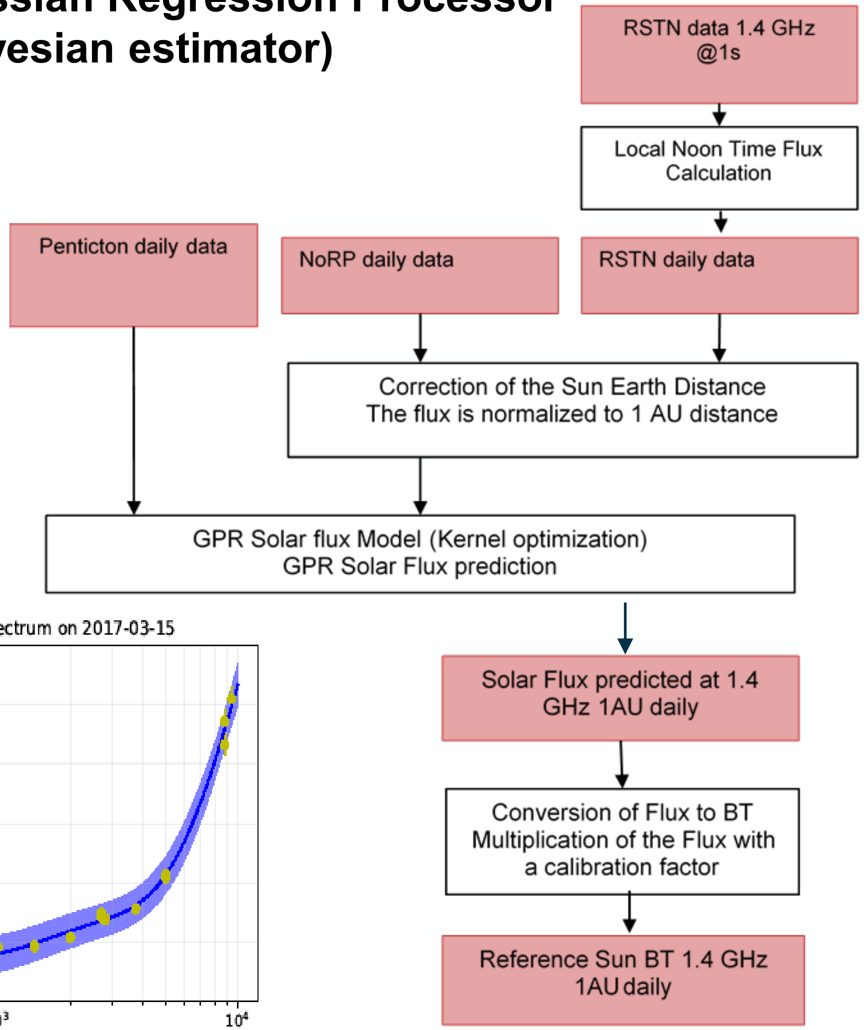
SMOS Solar flux algorithm: calibrated reference

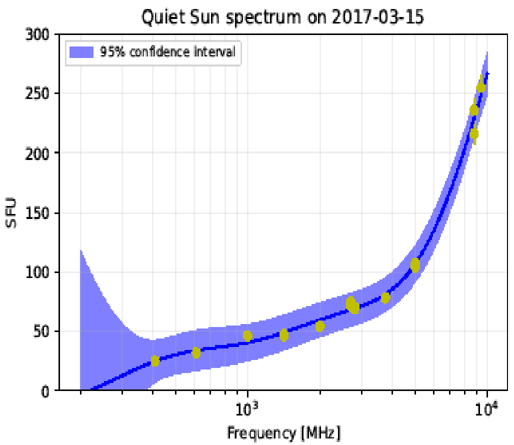
Issue: RSTN L-band radio-telescope dataset not inter-calibrated

Two methods developed to derive a calibrated L-band solar flux reference from multi-frequencies radio-telescope observations

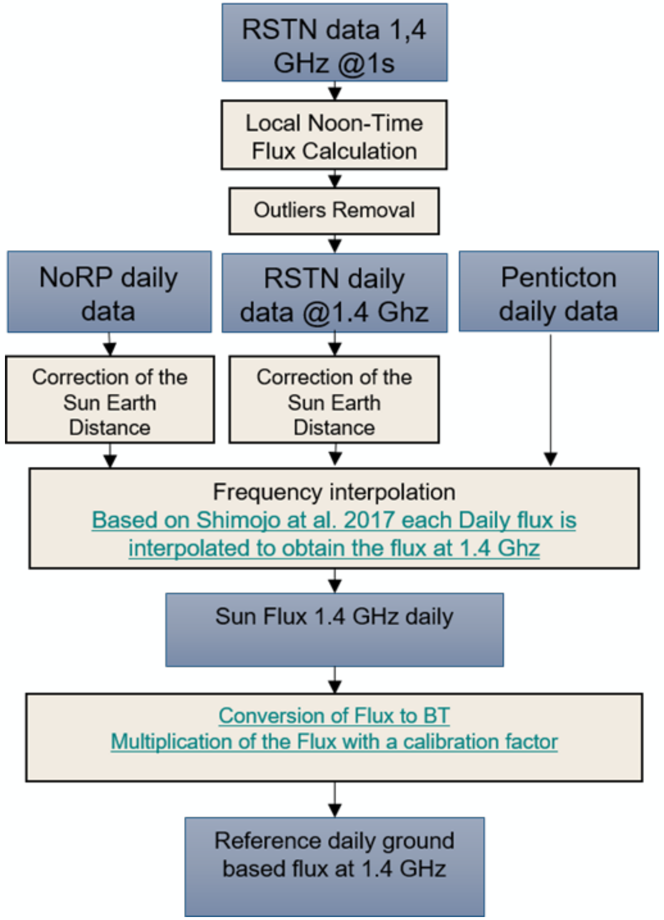
RSTN	Nobeyama	Penticton
0,24 GHz		
0,41 GHz		
0,61 GHz	1 GHz	
1.415 GHz		
2.69 GHz	2 GHz	2,8 GHz
4.99 GHz	3,7 GHz	
8.80 GHz	9,4 GHz	
15.4 GHz	17 / 35 /80 GHz	

Gaussian Regression Processor (Bayesian estimator)



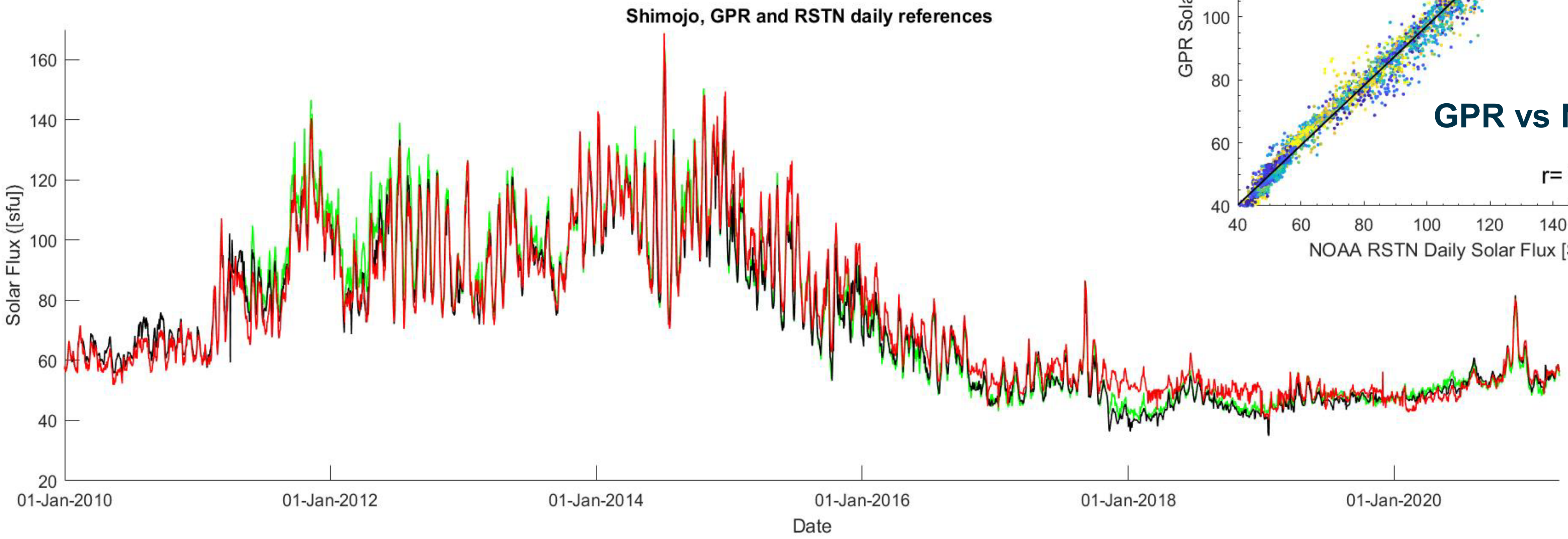


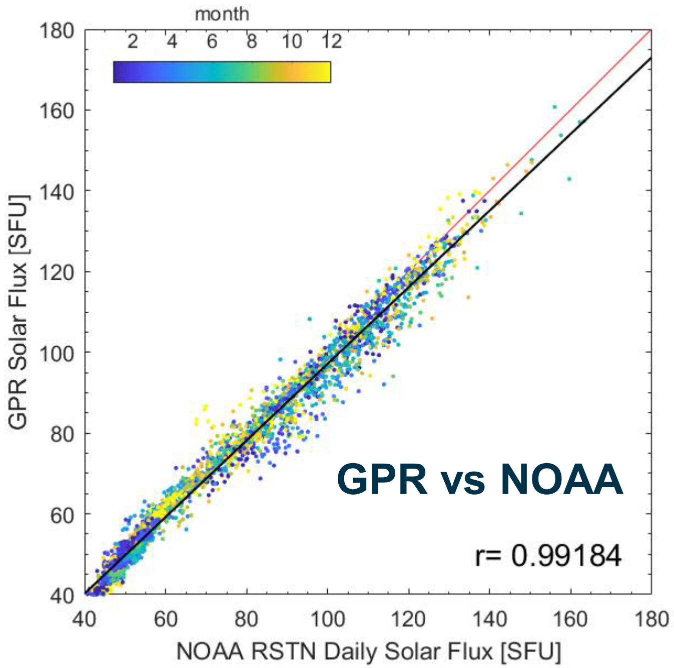
Shimojo linear interpolation



SMOS Solar flux algorithm: calibrated reference

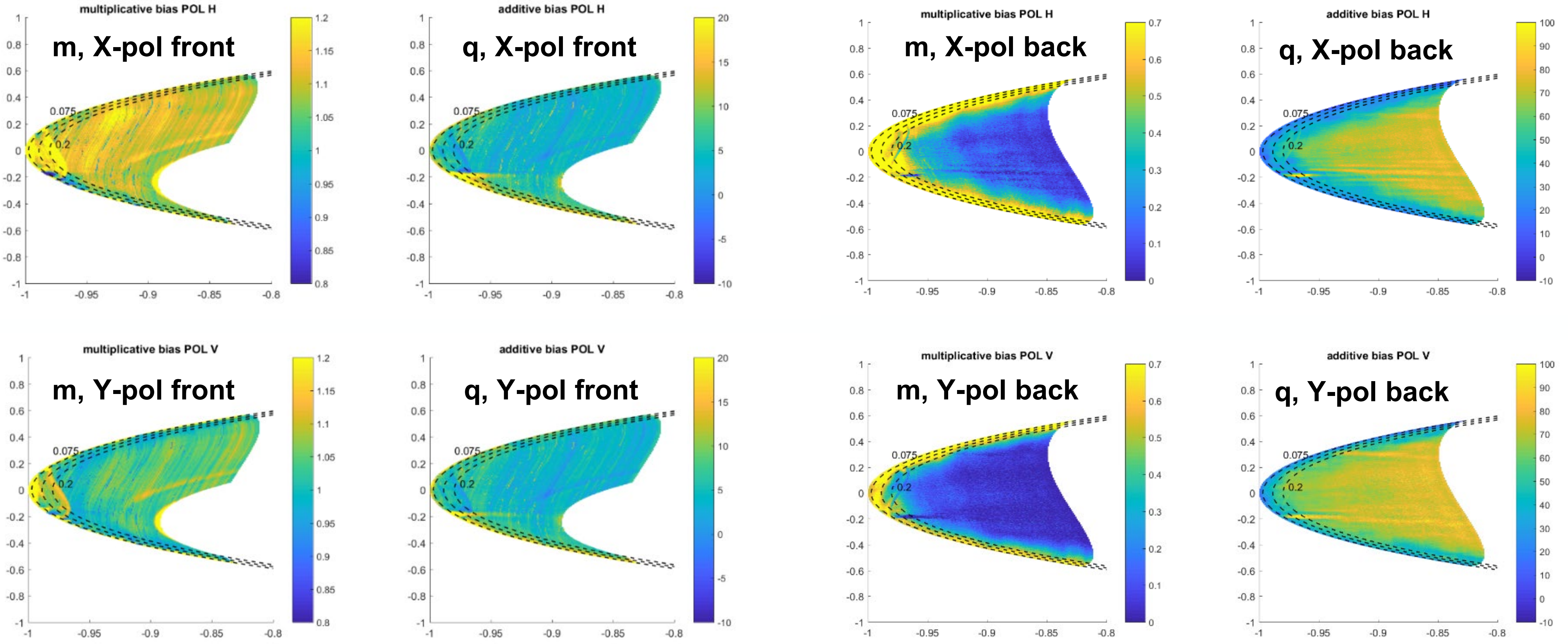
Good agreement between derived inter-calibrated reference





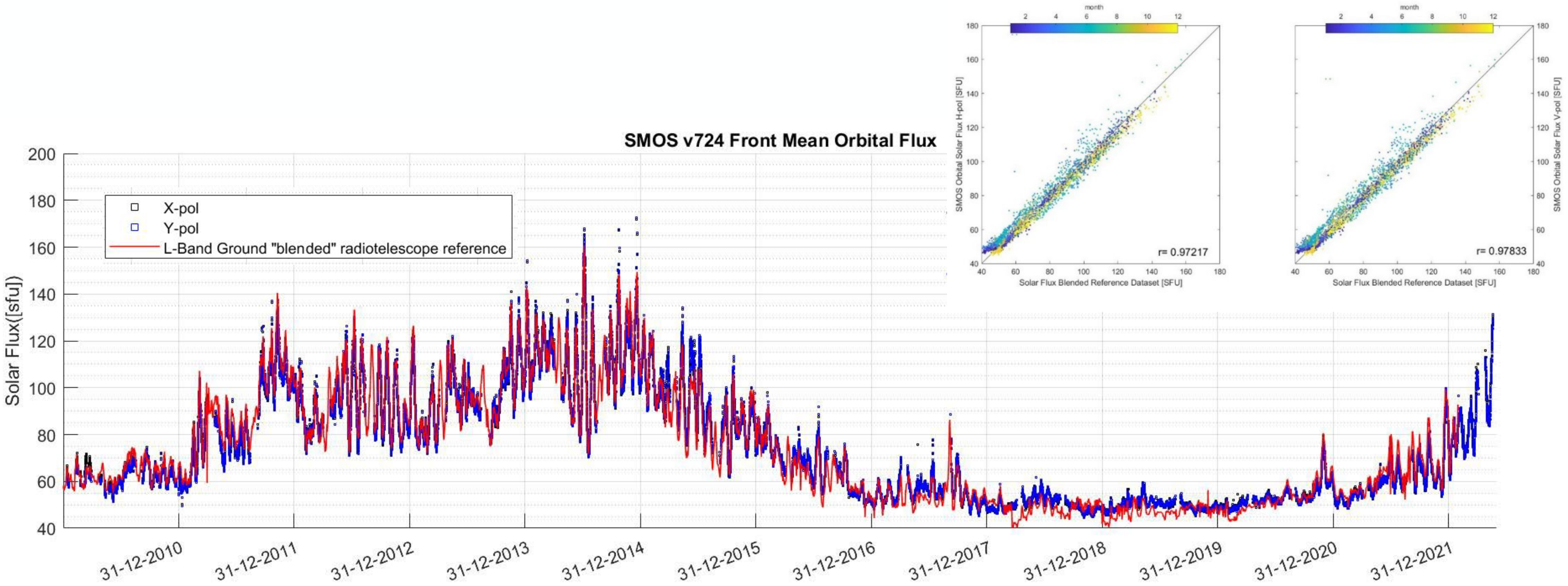
serco REDLAB

SMOS Solar flux algorithm: regression model



SMOS Solar flux results

Full monitoring of solar cycle-24 with excellent agreement with radio-telescope

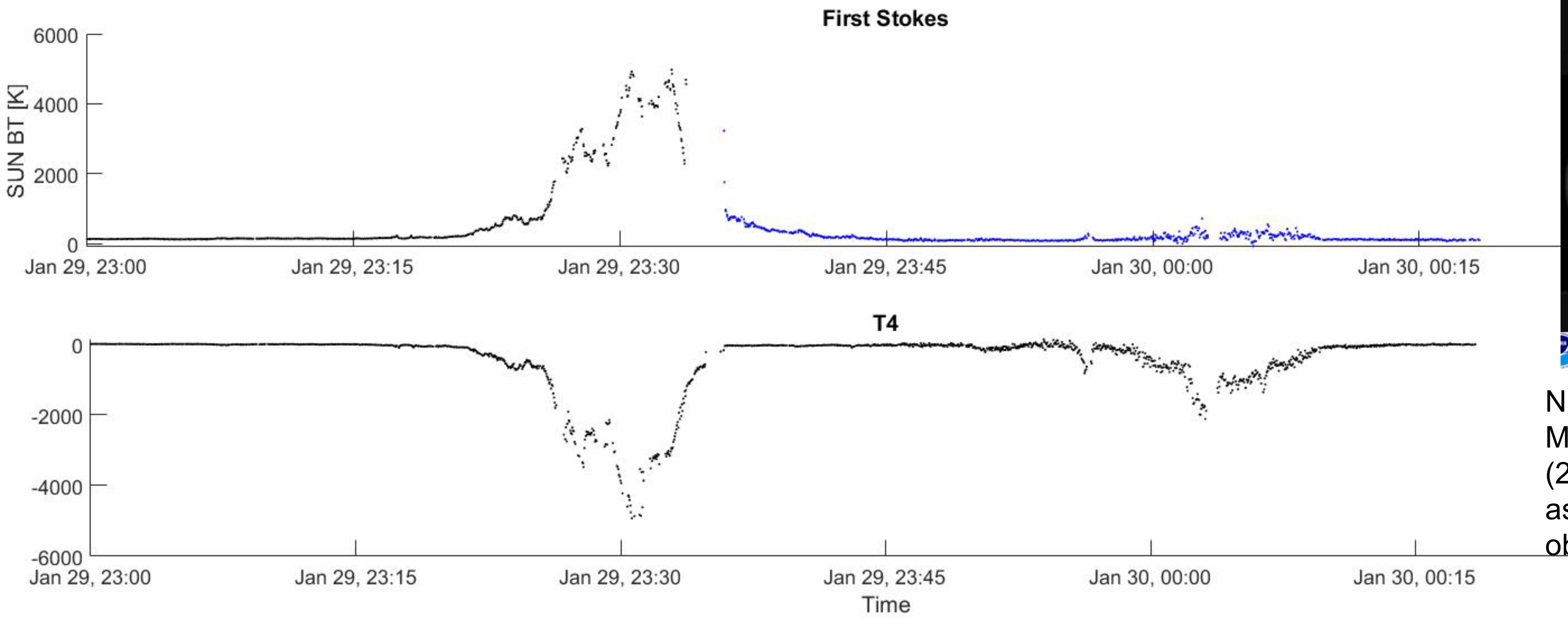


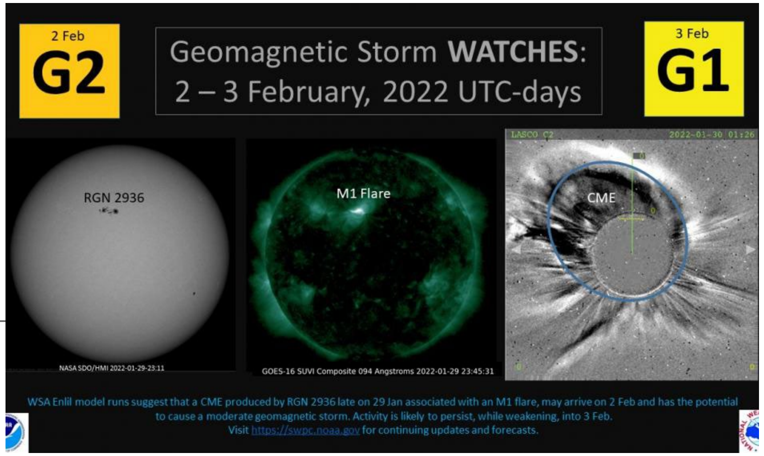
Why SMOS Solar flux ?

Available in real time within 3 hours from acquisition with different temporal resolution

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 Radio Burst (SRB) studies and synergies with **Solar flare/Coronal Mass Ejection monitoring/forecast**

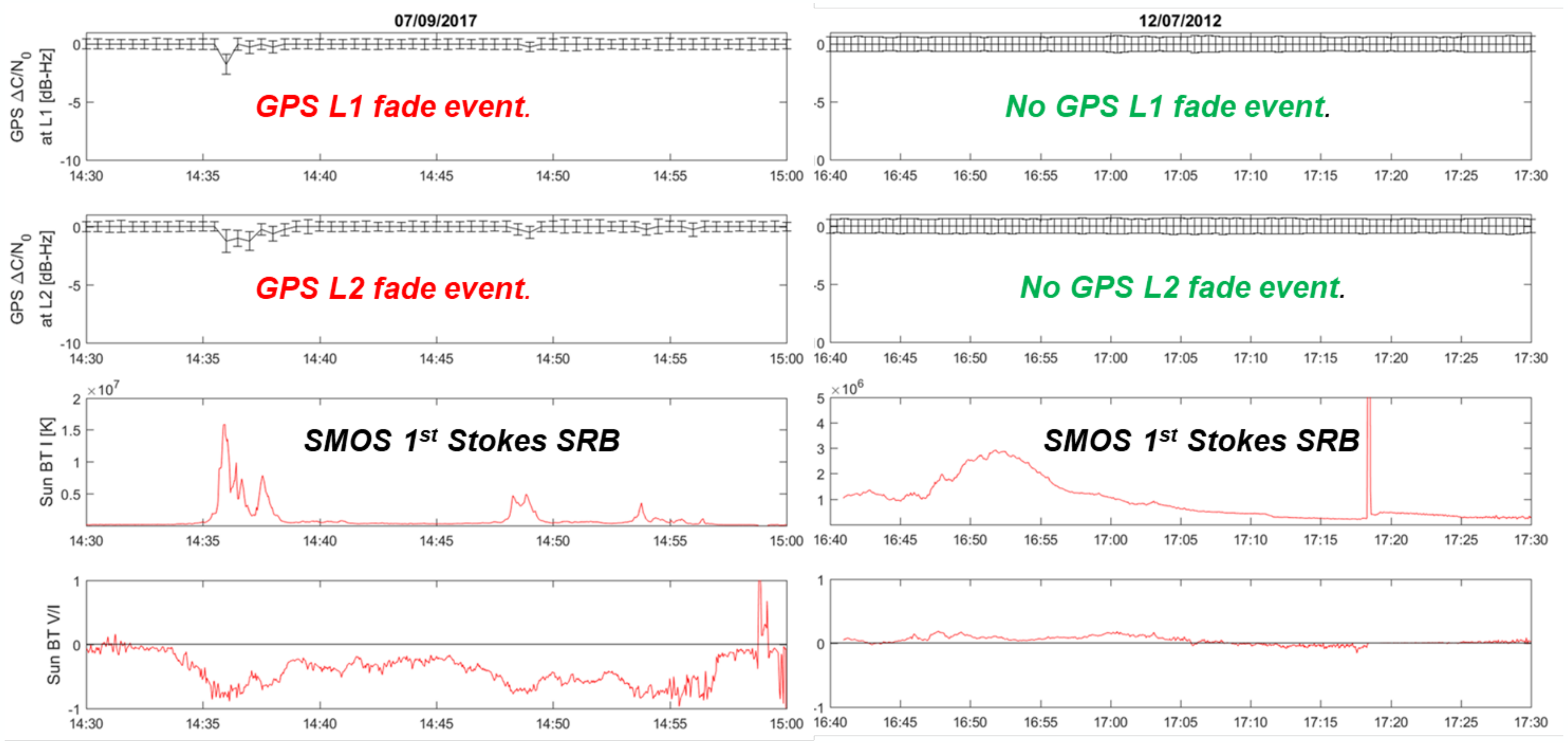




NOAA/SWPC Region 2936 produced an M1 flare (R1-Minor Radio Blackout) on 29 January at 6:32 pm ET (29/2332 UTC). This flare was associated with an asymmetric, full halo coronal mass ejection (CME) as observed in NASA/SOHO LASCO coronagraph imager

Why SMOS Solar flux ?

Polarimetric data set at L-band for study **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)



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 Solar flux ?

Space weather application: correlation between amount of Solar flux at L-band and the speed, angular width and kinetic energy of the Coronal Mass Ejection (CME) helpful for CME impact assessment

Poster session

A6.01 Geospace System Science: Thermosphere, Ionosphere, Magnetosphere and Their Coupling

Poster board 480

Space weather operations with the SMOS mission: what an Earth observing satellite can tell about solar activity (Manuel Flores-Soriano et al.)

Thank you for your attention

To access SMOS Solar Flux prototype dataset contact:

redlab@serco.com