

SMOS and RFI

Yann Kerr

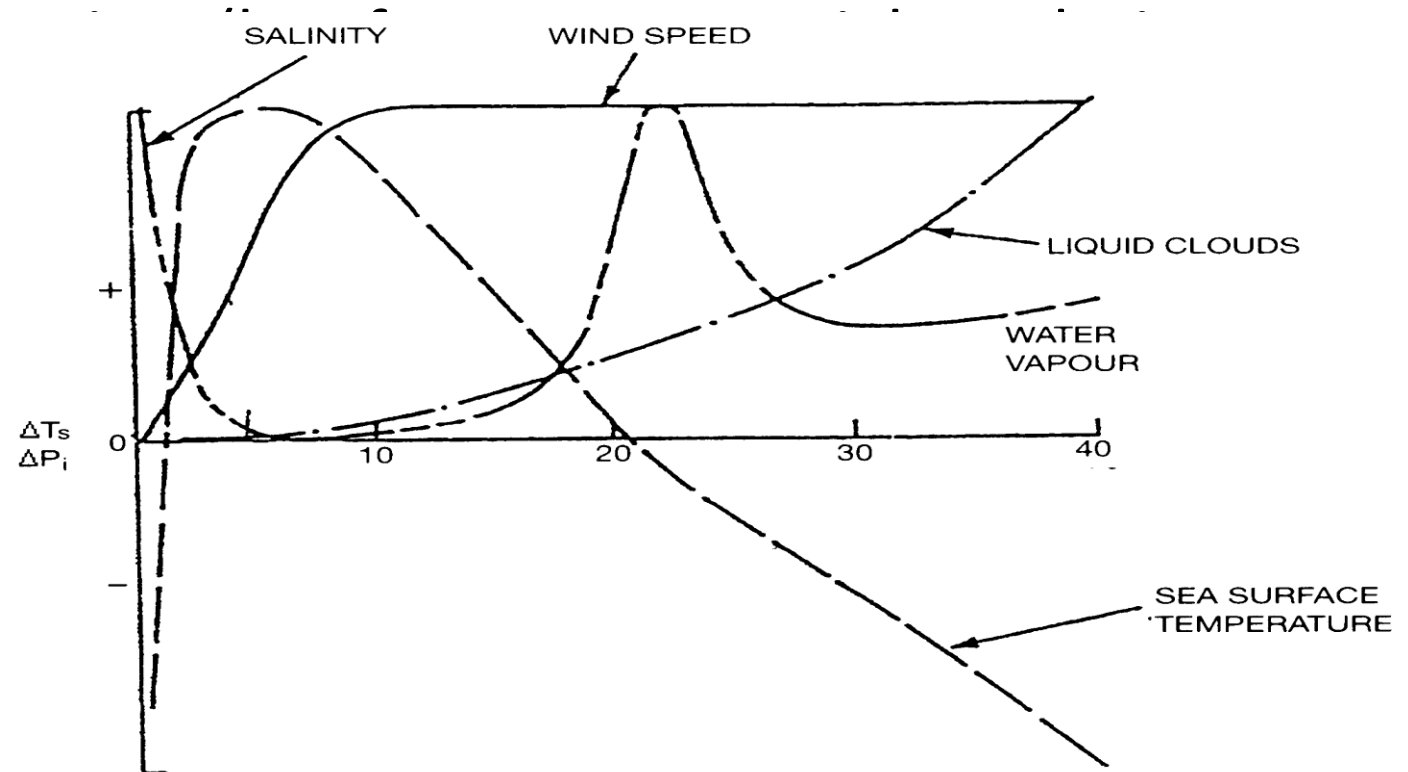
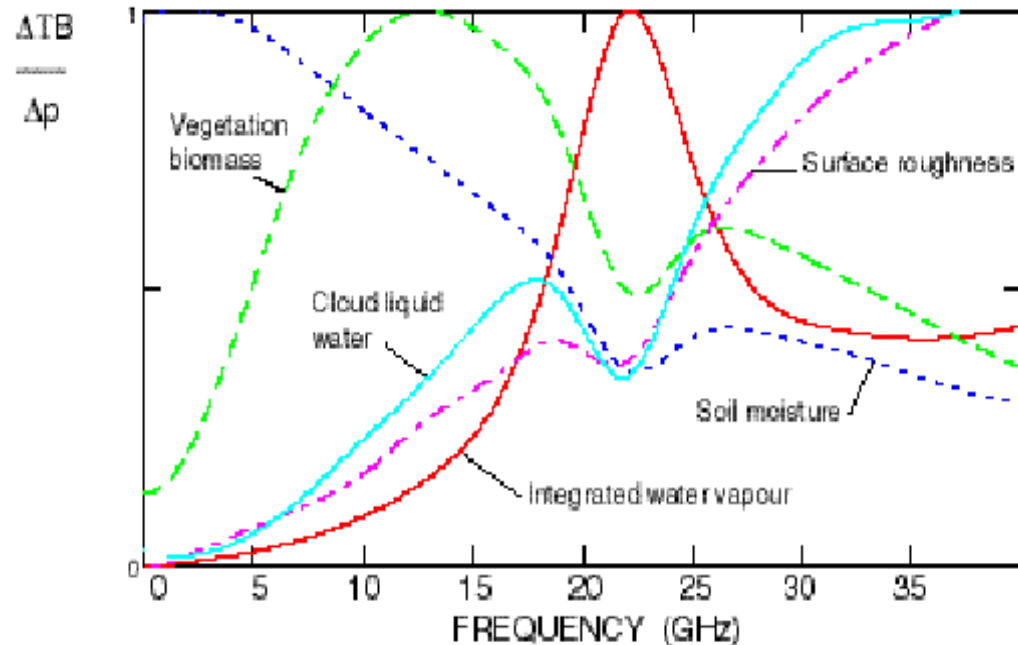
CESBIO

Layout

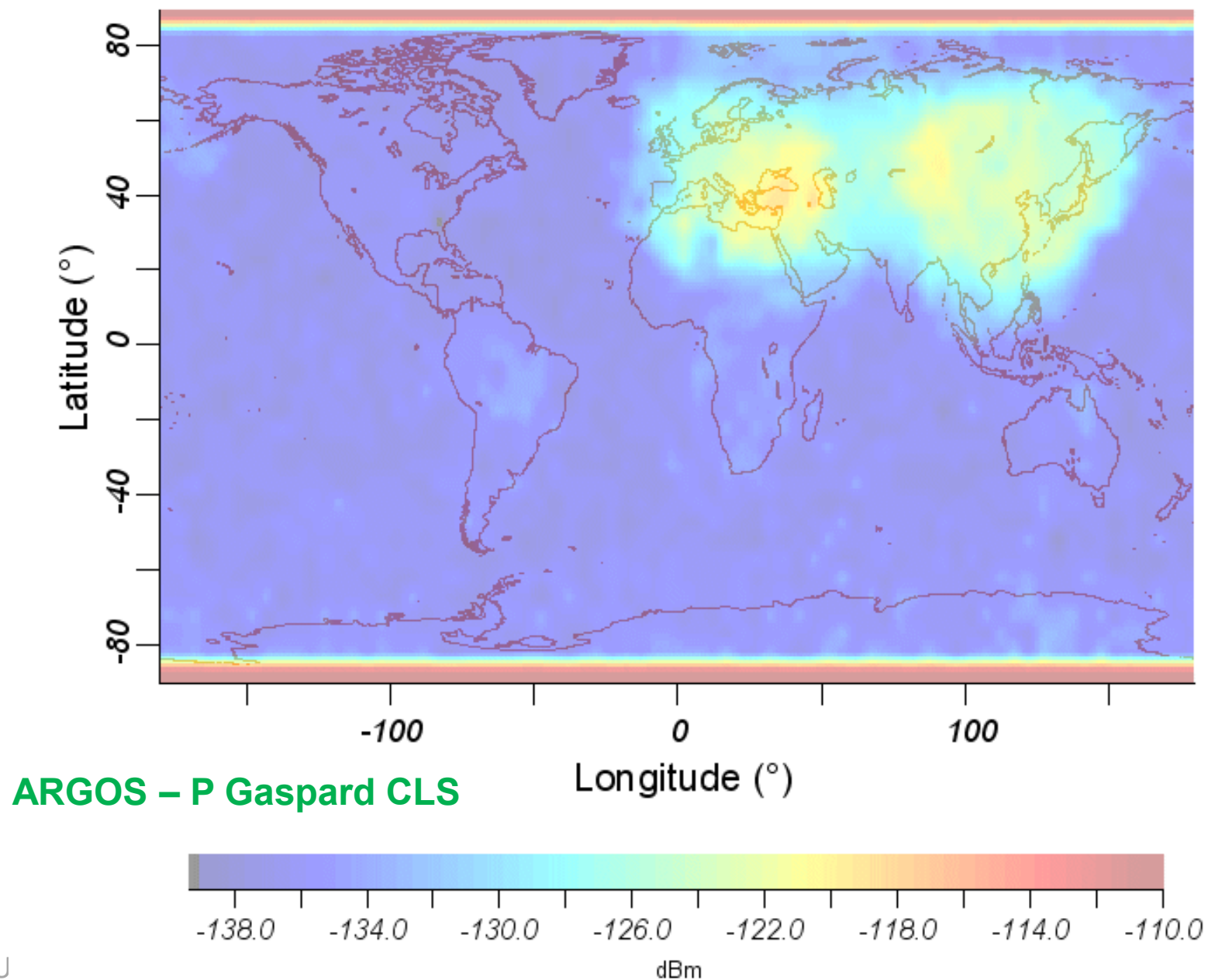
- Brief historical background
 - SMOS in a nutshell
- What we saw after launch and salient features
 - Current status
 - Way forward

Brief historical background

- ❑ Need for Soil moisture and Ocean Salinity measurements from space
- ❑ Best approach: **low frequency radiometry**



LDR Minimal received power (dBm) [4.96 day(s)]

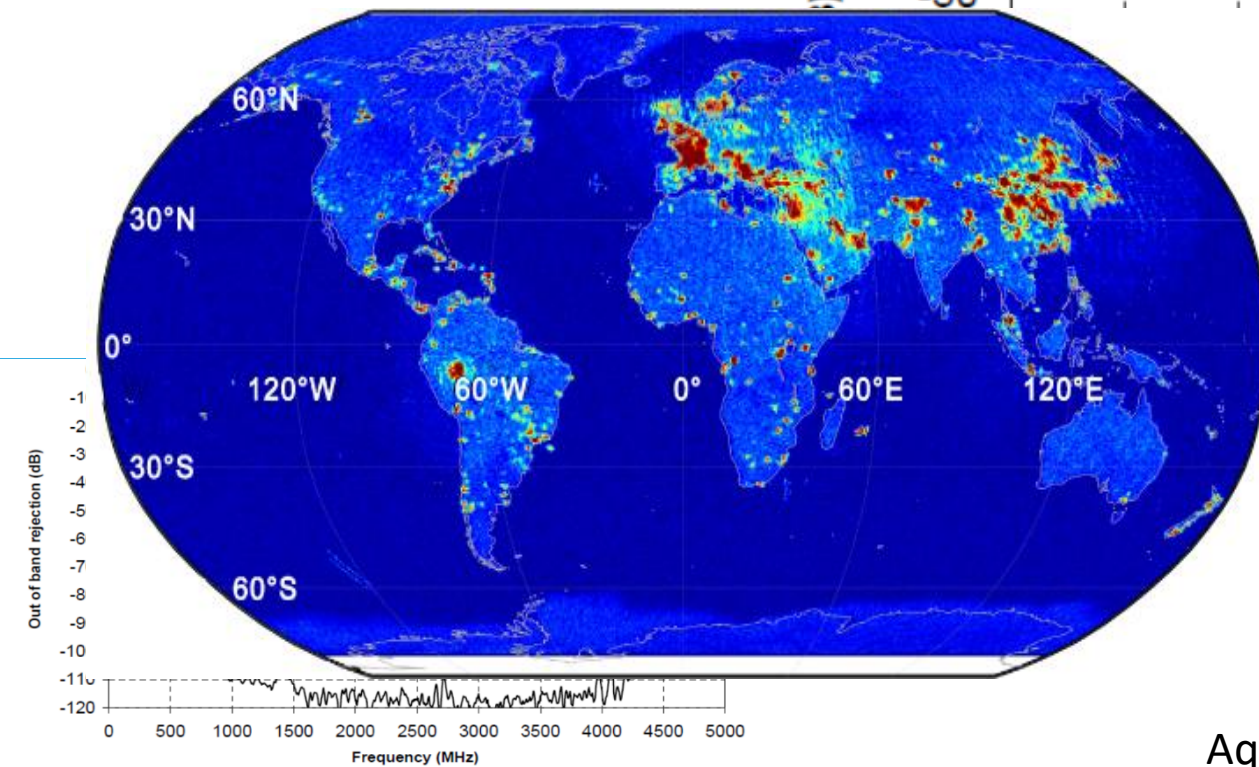
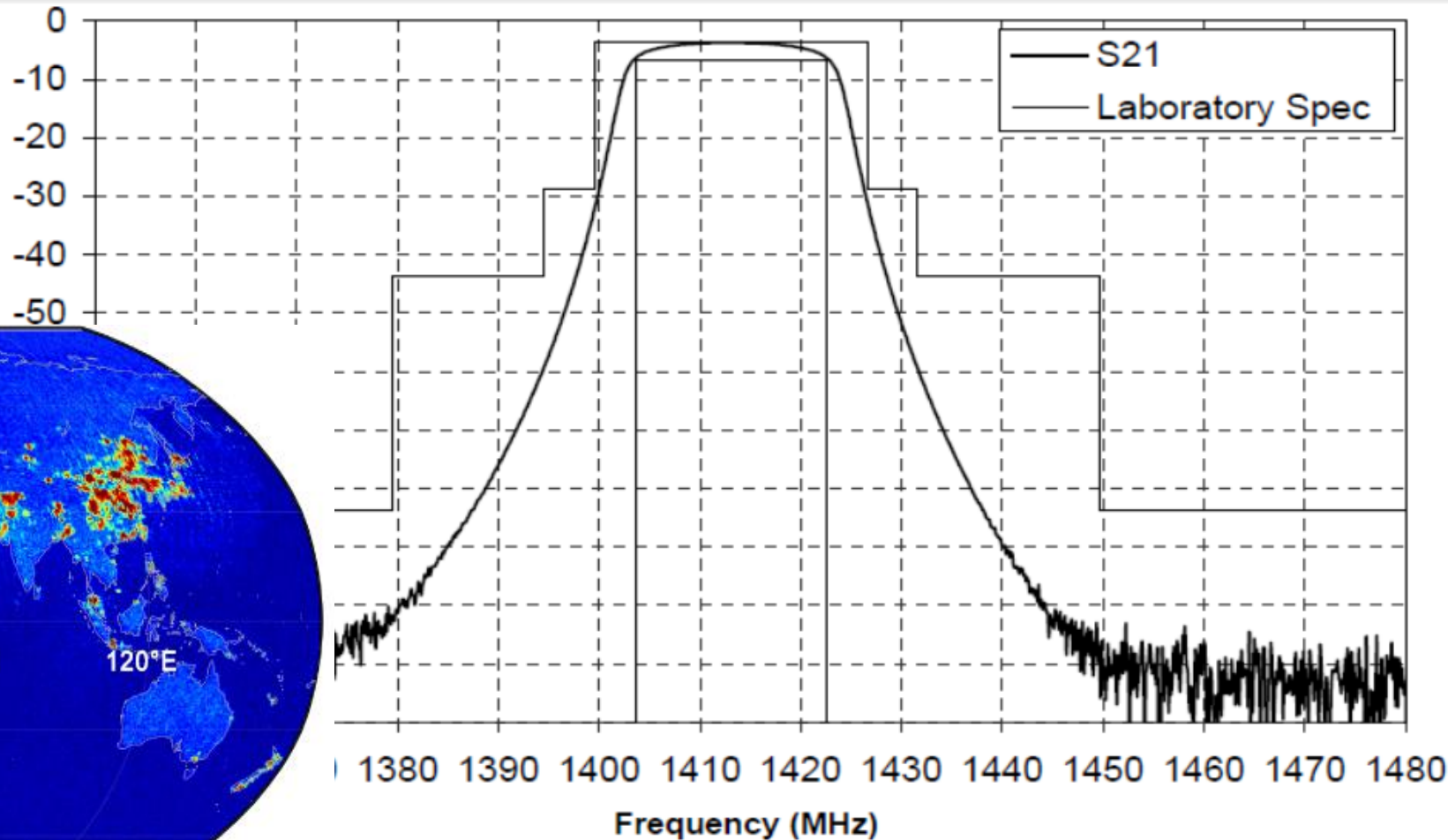


links to Guy Rochard
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Keeping in the protected area: SMOS filters

□ SMOS RF BANDPASS pass filter response :

- Center freq 1413.5 MHz
- -3dB bandwidth 20 MHz
- See graph L(dB) vs F(GHz)



Aquarius D Levine

SMOS in a nutshell

- ❑ EE 2 proposed in 1998 and in operation since 2010 (launched in November 2009) Radio astronomie heritage
 - ❖ 1st L Band radiometer in orbit
 - ❖ 1st interferometer in space
 - ❖ 1st direct measurements of soil moisture and sea surface salinity
 - which are global, continuous and absolute
 - **Science GAP filler**, no other mission covered such measurements as L band radiometry provides unique measurements
 - ❖ 1st multiangular acquisitions in microwaves
 - ❖ Only L band continuous data set and this for more than 16 years
- ❑ Operational uses started as soon as 2011!
 - ❖ Near real time dissemination and assimilation at **ECMWF** and other NWP centres
 - ❖ Strong winds, fire risks, freeze thaw, space weather [TEC,Sun], boat routing at high latitudes etc...
- ❑ Continuous emergence of new products
 - ❖ Six ECV for Climate Change
 - ❖ Led to new science and a wealth of **operational uses**
 - ❖ Strong winds, rainfall, snow, carbon, GHG...
 - ❖ A record publication rate
- ❑ **Longest ESA EO satellite**, followed by **Aquarius** (2011-2015) and **SMAP** (2015...)

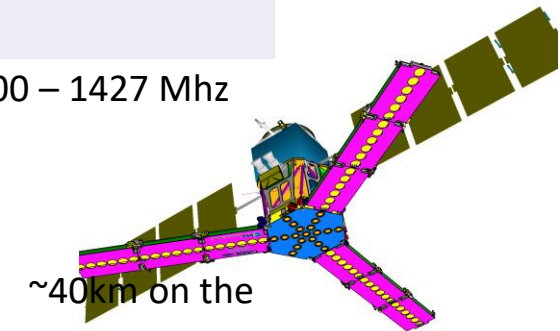


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SMOS Specificities

The SMOS mission and observation system in brief

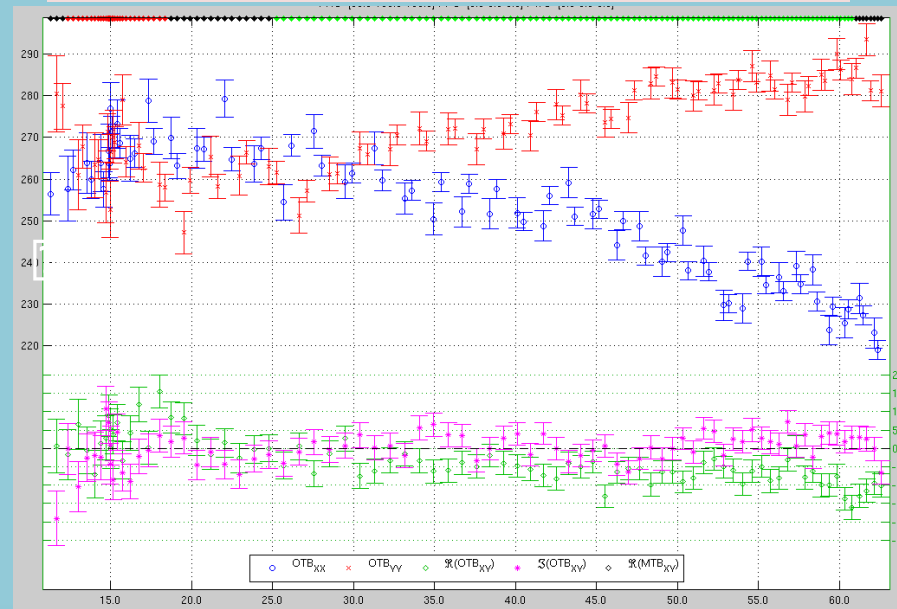
- Radio-interferometer operating in the L-band @ 1413MHz within the ITU protected 1400 – 1427 Mhz band (ITU RR 5.340)
- 69 dishes antennas (LICEF) distributed along a Y shape arms
- LICEF $\sim 70^\circ$ beam =
- The image reconstruction of Earth at 755 km altitude
 - $\Rightarrow$ Allows Brightness Temperature (BT) mapping with a footprint of ~ 40 km on the Earth's surface
 - $\Rightarrow$ Full polarization
 - $\Rightarrow$ 2.5K to 5K of BT
 - $\Rightarrow$ Recollected p
- Boresight tilted 32°



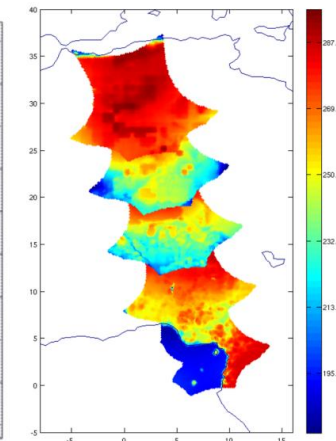
~40km on the Earth's surface

BTs full polarized incidence angles profiles
One of very unique feature provided by SMOS
A key input of Level Soil Moisture processing

XSWATH ~ 150 km



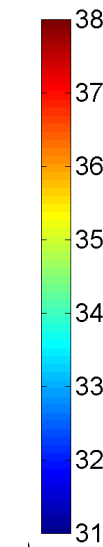
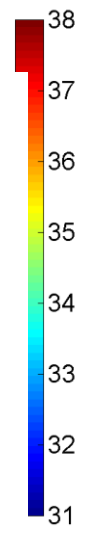
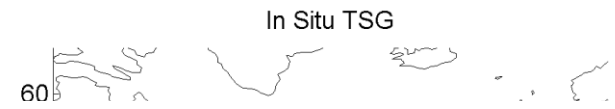
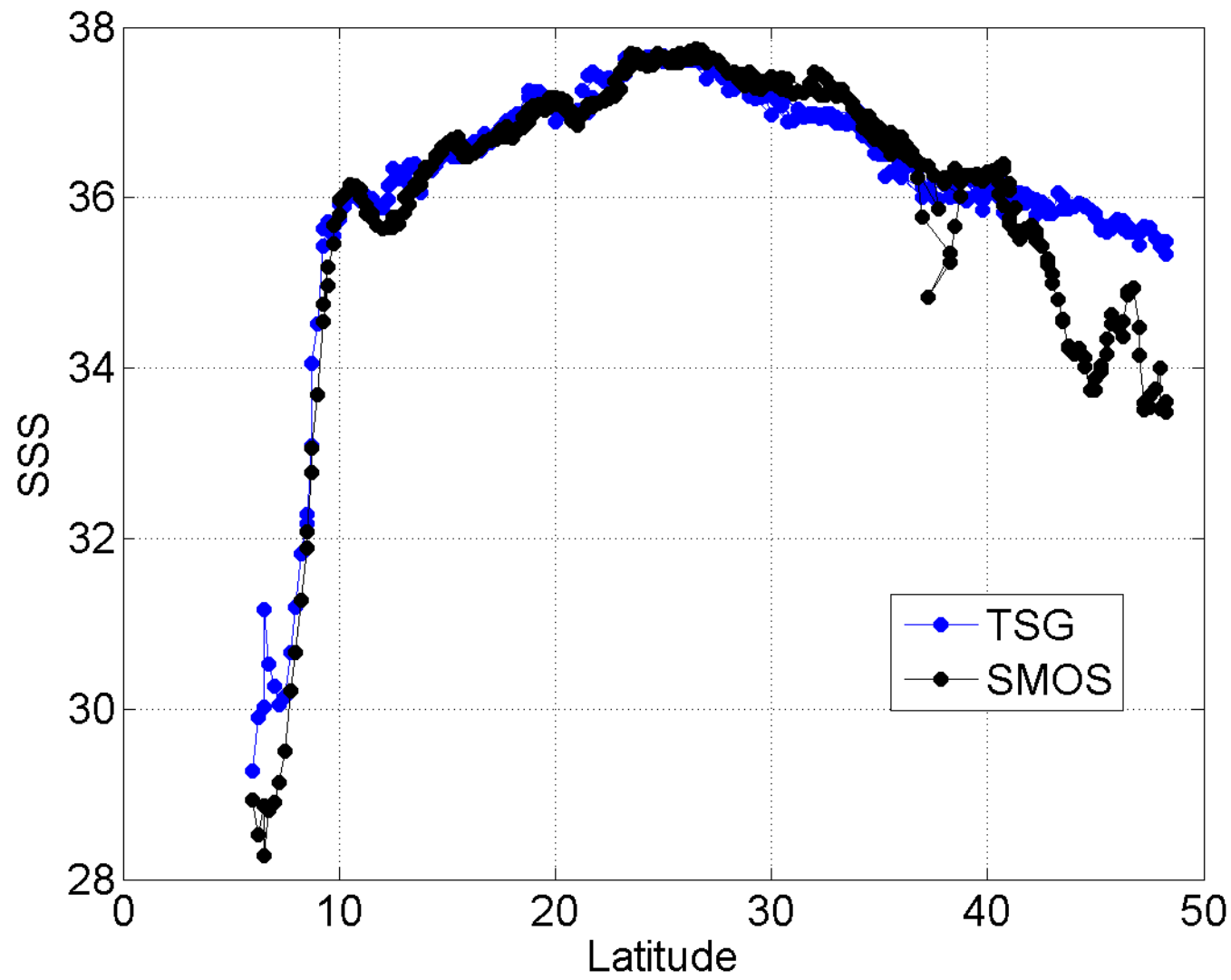
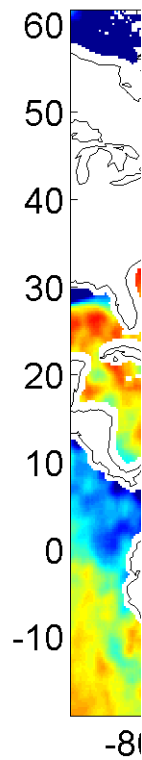
Earth horizon
Boresight



Daganzo et al

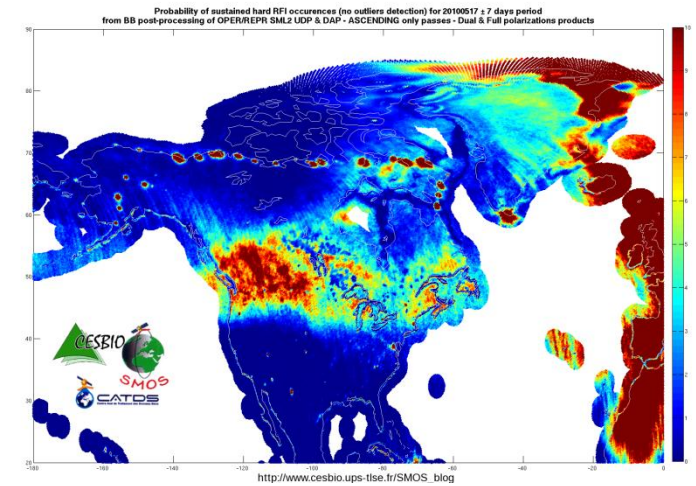
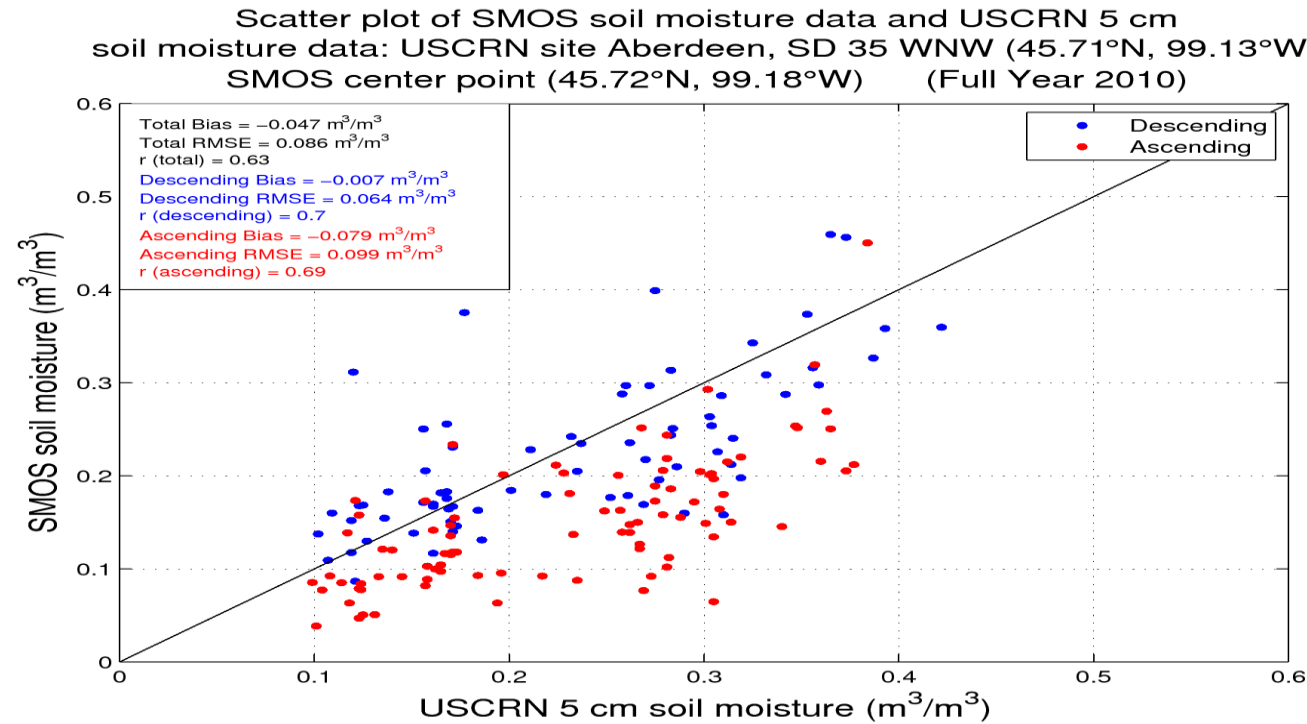
BUT

- ☐ Strong RFI impacting the measurements identified from day 1
- ☐ Impacting measurements and results



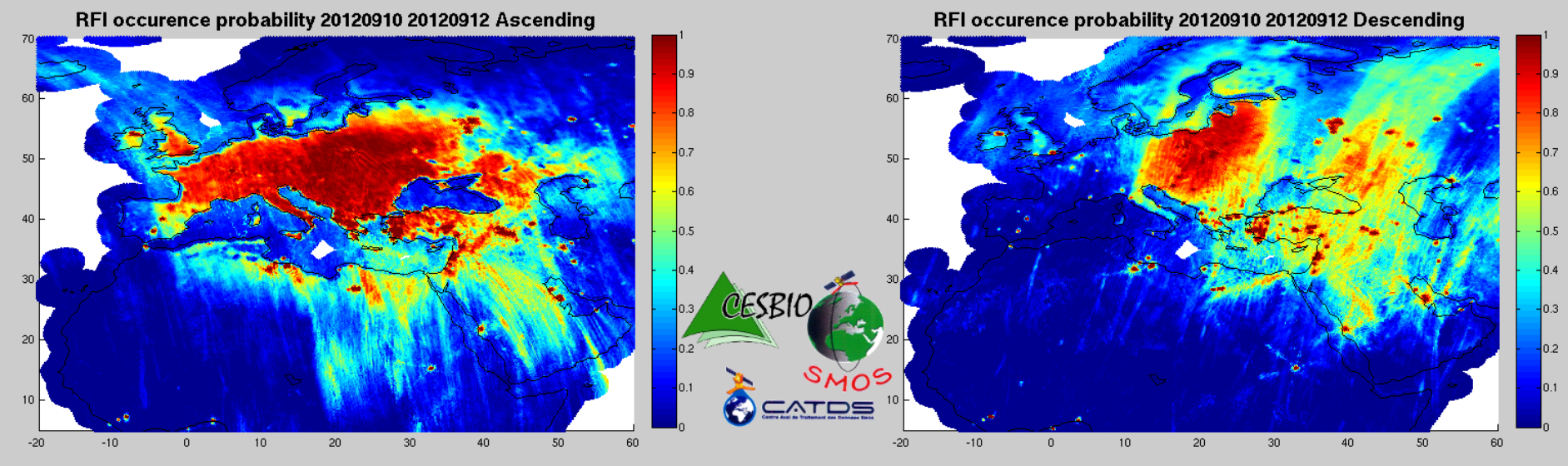
N. Reul

Collow & Robock



Impact of a single strong RFI source in Poland retrievals and wrong values

Almost no soil moisture retrieval in Europe for ascending orbits and dubious for descending'

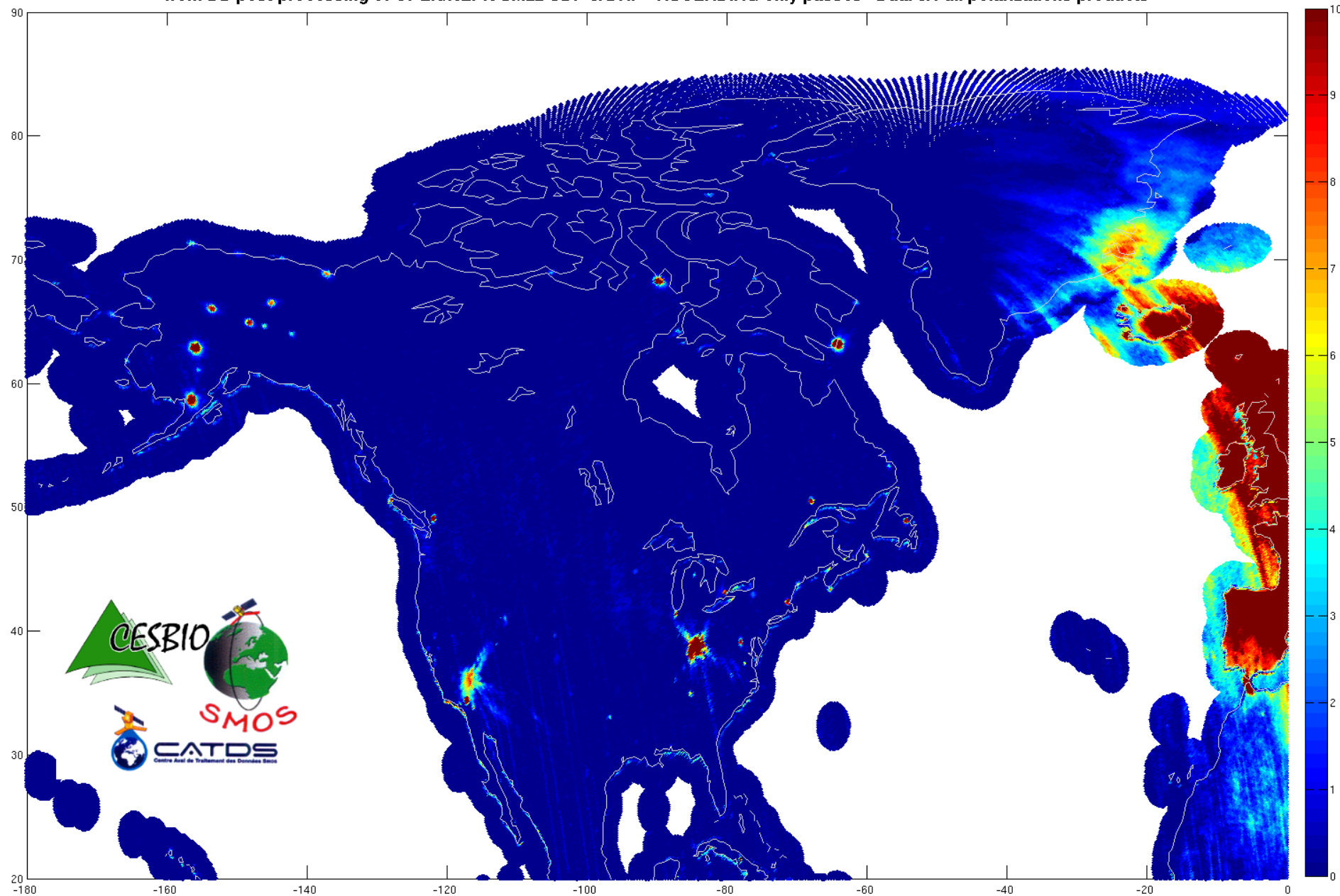


P. Richaume

BUT

- ☐ Strong RFI impacting the measurements identified from day 1
- ☐ Impacting measurements and results
- ☐ Developing techniques to reduce impact at the cost of poorer measurements
- ☐ Setting up a hunting team
- ☐ Two pronged approach
 - ❖ Publish maps showing culprits
 - ❖ Go through formal channels
 - Identify and localise RFI sources
 - With teams on the ground
 - Using switching on and off approaches
 - Reporting them to ITU and pointing them to local agencies for quick removal
 - ❖ Some successes

Probability of sustained hard RFI occurrences (no outliers detection) for 20120517 $\pm$ 7 days period
from BB post-processing of OPER/REPR SML2 UDP & DAP - ASCENDING only passes - Dual & Full polarizations products



P. Richaume

http://www.cesbio.ups-tlse.fr/SMOS_blog

- ❖ Actual RFI Location
- ❖ Intervention distance
- ❖ Interfering equipment
video transmitter
- ❖ Interfering equipment
transmitter
- ❖ Interfering equipment
(Transmitter)
- ❖ Any other additional
transmitter. It
Baba, Ali Express

Spectrum Use for Meteo

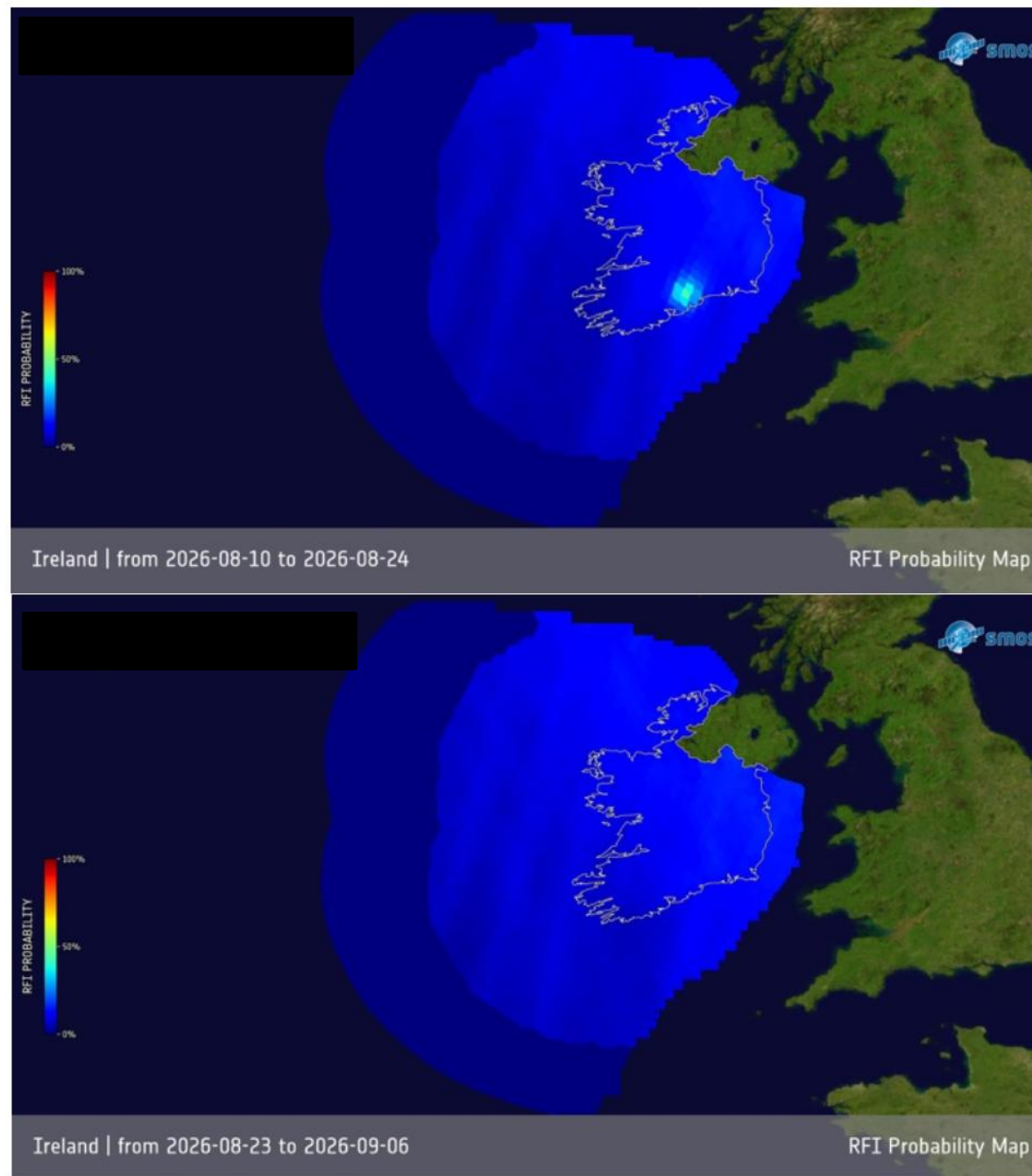


Figure 18. 15-day probability maps of Ireland for 2026-08-24 and 2026-09-06.

975°

Wireless audio and

ply), Unbranded

only), None found

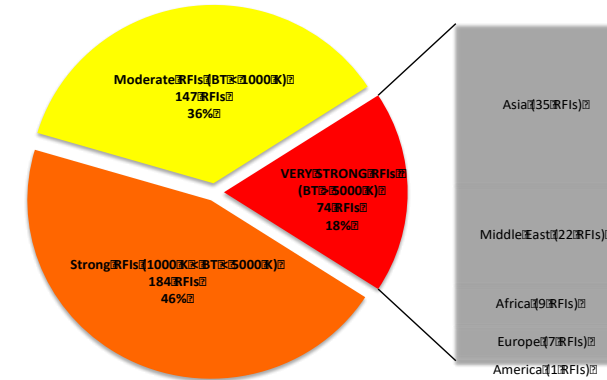
er found for the
sites including Ali-

E. Uranga
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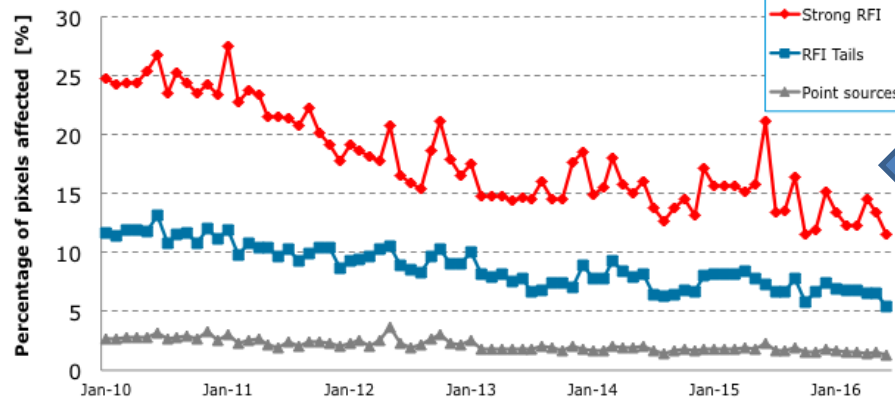
RFI before (2021)

RFI CONTAMINATION WORLDWIDE MUCH REDUCED Currently more than 75 % of the RFI sources detected have been switched-off, mostly as a consequence of reporting the RFI case to the Spectrum Management Authorities. Currently, there are approximately 400 active RFI sources worldwide, with strengths varying from moderate (BT < 1000 K) to very strong (BT > 5000 K), the latter being mainly located in Asia and the Middle East

RFI sources worldwide (August 2016)



RFI presence over land masses



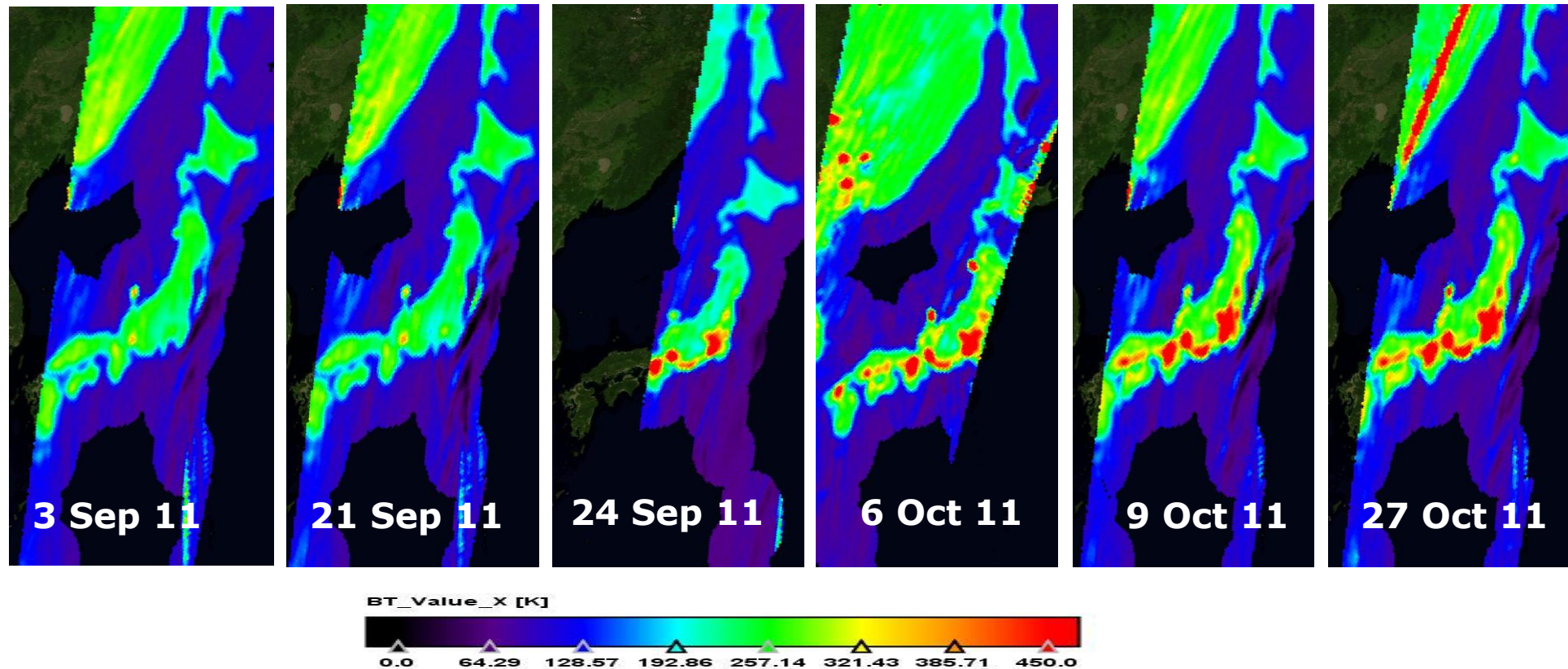
Percentage of the number of SMOS pixels over land affected by RFI for the 6 years of SMOS in orbit. **Pixels flagged with strong RFI have decreased by 11%** over the mission life time thanks to the efforts in detecting, geo-locating and reporting the RFI cases to the Spectrum Management authorities of the relevant administrations.

ESA has reported RFI cases to 40 administrations.

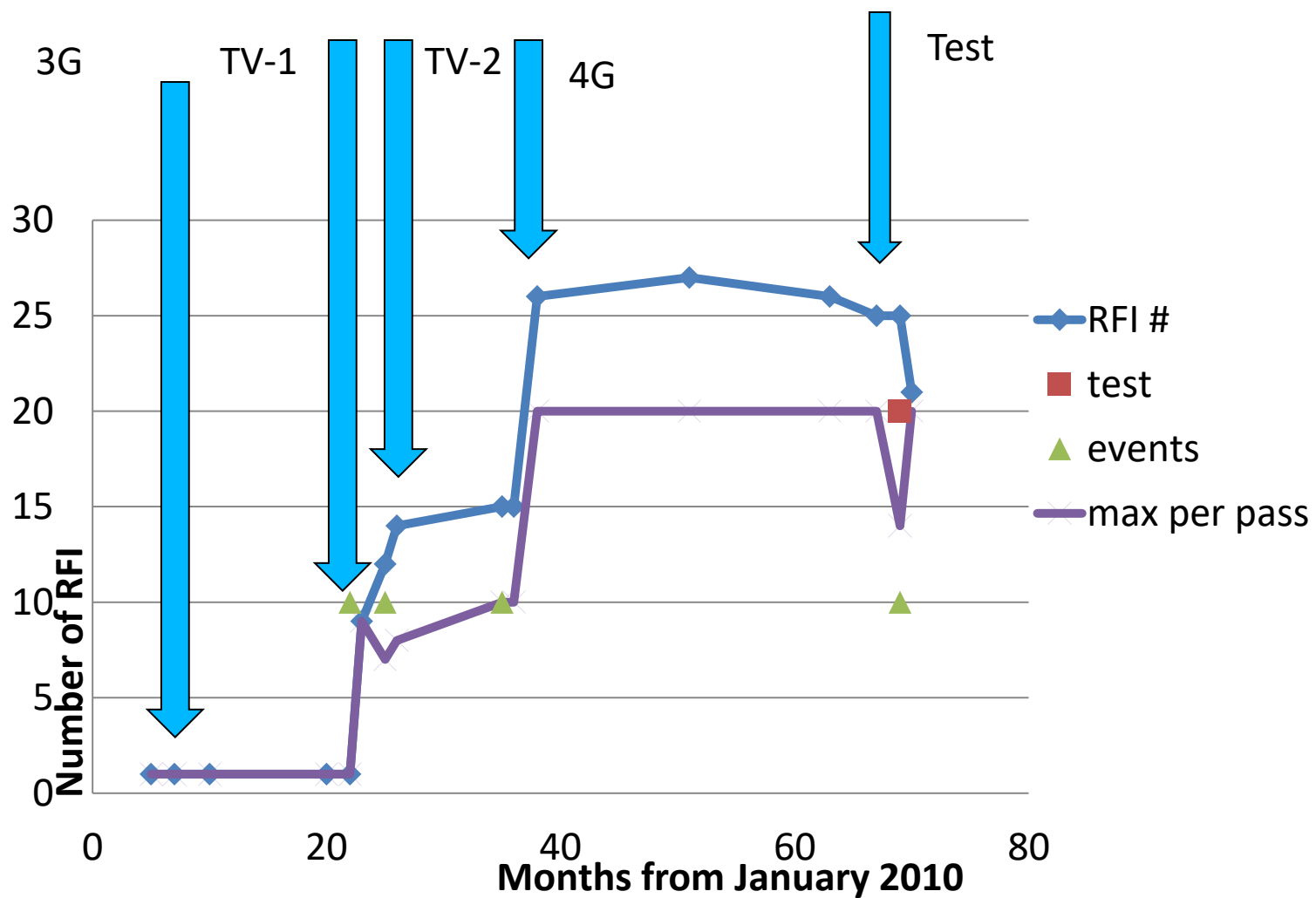
New RFI flagging in current Level 1 (v6) processor

SMOS Brightness Temperature observations in Japan

1. SMOS revisits Japan twice every 3 days (one in descending direction + one in ascending direction). A clear change was observed between the 21st September and the 24th September.



The Japanese RFI case



Accurate geolocation

- ❑ Assuming the source does not move, it is possible to assess its position with great accuracy by cumulating observations
- ❑ Spatial resolution 30-50 km, geolocation to a few hundred meters!
 - ❖ Pros → provides significant help to localise sources on the ground
 - ❖ Cons → requires lots of computing
 - ❖ Issues → when there are many sources within the pixel

Results and performances

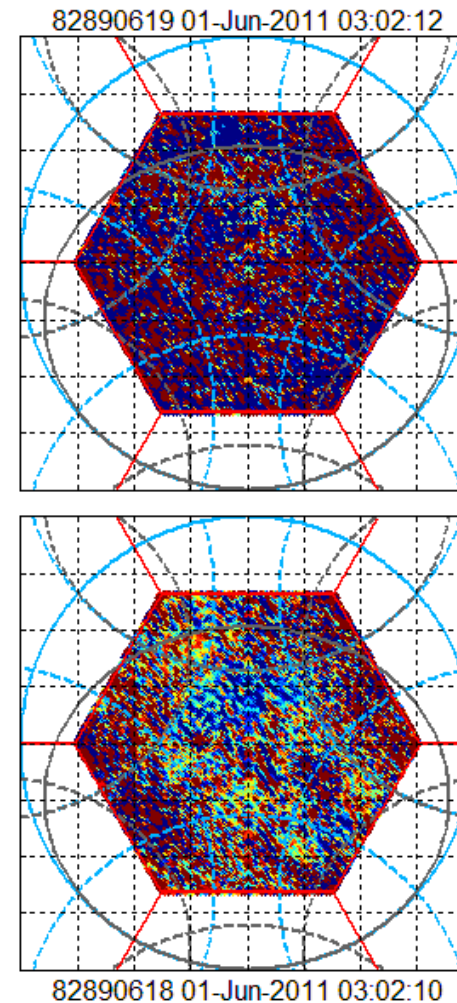
E. Anterrieu

❖ Practical exemple

➤ Asc orbit

01-JUN-2011

☹ *The conditions of detection are not those of the simulations; they vary from one snapshot to another.*

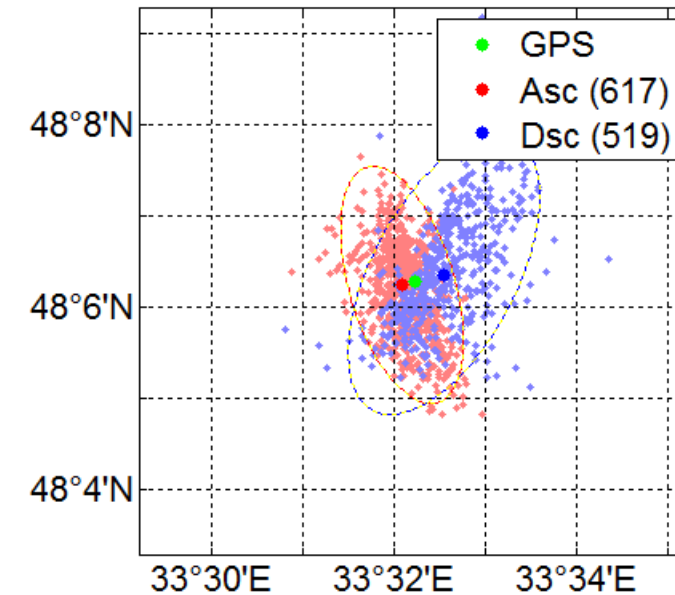


Results and performances

E. Anterrieu

❖ SMOS data June 2011

- Accuracy of location: **185 m**
420 m
- $\pm 2\sigma$ / 95% confidence ellipsis:
3333 m $\times$ 1425 m (-73°)
4155 m $\times$ 1967 m ($+62^\circ$)



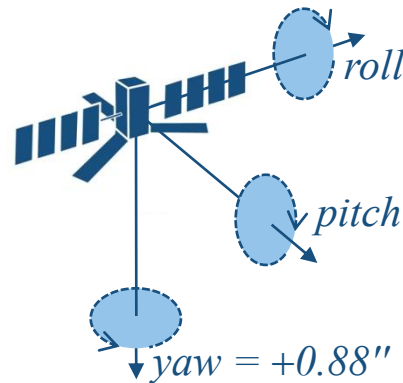
☺ *Simply averaging two estimations has no meaning...
...accounting for attitude of the platform is better!*

Results and performances

E. Anterrieu

❖ SMOS data June 2011

➤➤ Mispointing estimation



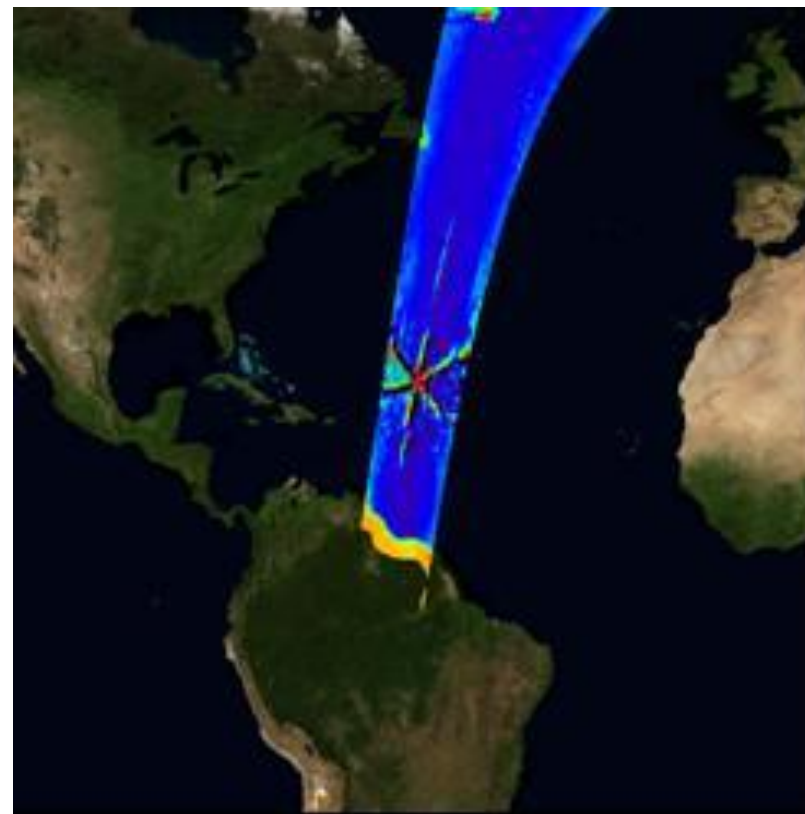
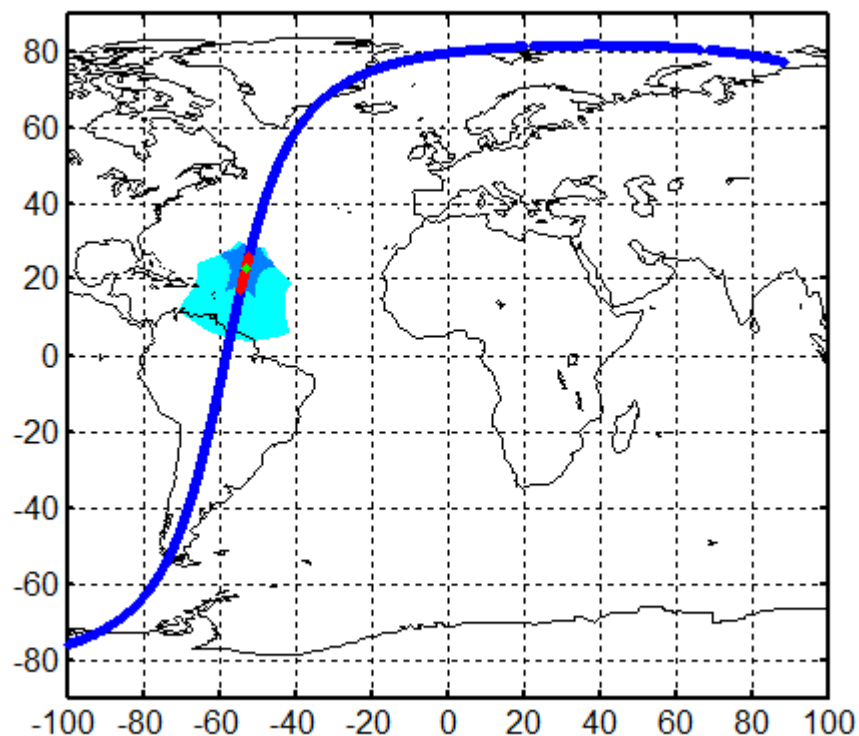
- Accuracy of location
- $\pm 2\sigma$ / 95% confidence
- $\pm 1\sigma$ / 68% confidence



Source in the Atlantic located short emission: 11 February 2010

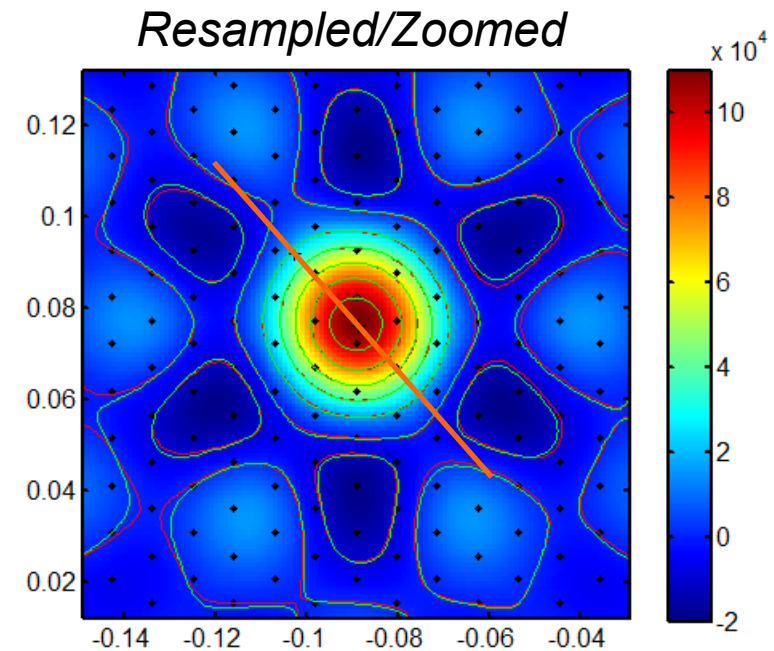
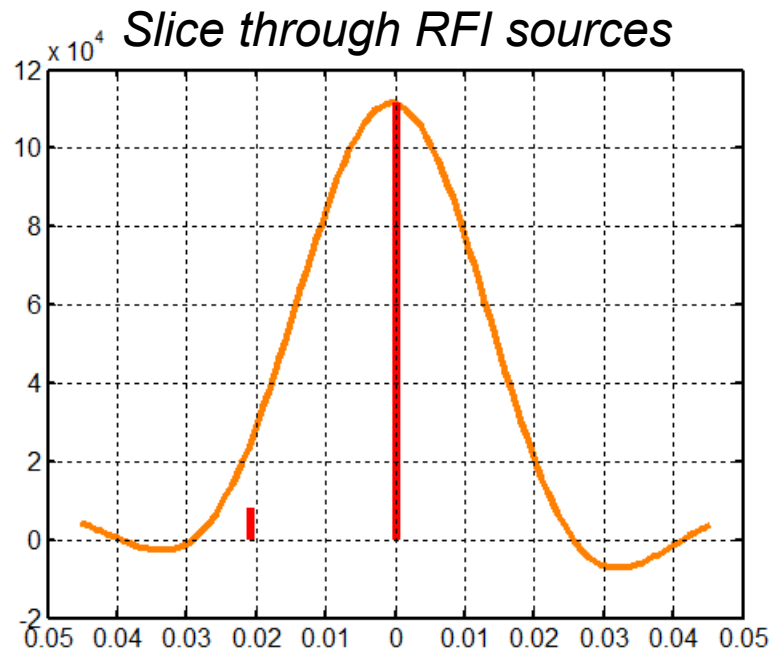
- SM_REPR_MIR_SC_F1A_20100211T212358_20100211T221759_346_001_5
- 31 snapshots with RFI in the EAFOV
- snapshot 14652559

E. Anterrieu



Actually 2 sources

❖ Snapshot 14652559: final with 2 sources



- ❑ Current model of RFI sources: $T_1 = 639631$ K located in $(\xi_1, \eta_1) = (-0.0888, +0.0762) \notin$ sampling grid and $T_2 = 47170$ K located in $(\xi_2, \eta_2) = (-0.1027, +0.0919) \notin$ sampling grid
- ❑ Comparison: — actual hot-spot in snapshot 14652559, — current model of RFI source
- ❑ The two RFI sources are resolved by SMOS ($\delta\xi_r = 0.0278$ rad) despite their close distance (0.0209 rad) and a small dynamic range (1:14)...

RFI Action status

☐ Continuous activities

- ❖ Regular updating of AUX RFI LST
- ❖ *Continuous update of maps on Blog*
- ❖ Continuous tracking of sources as per requests
- ❖ Monthly meetings
- ❖ *High accuracy localisation*

☐ Coordination with other entities

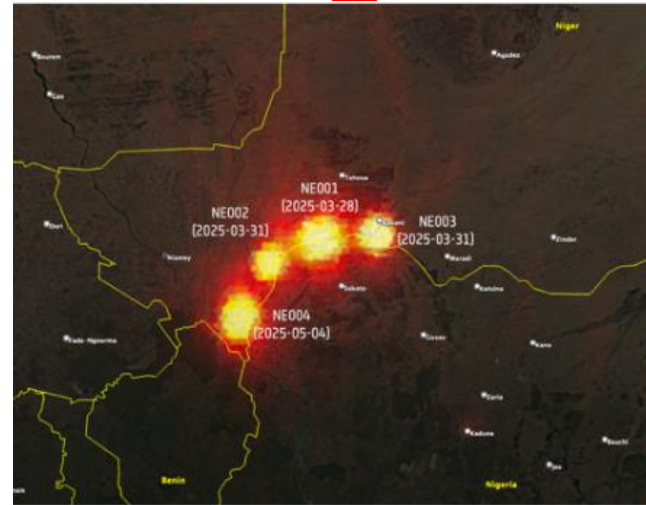
- ❖ NASA SMAP

☐ Search for improvements

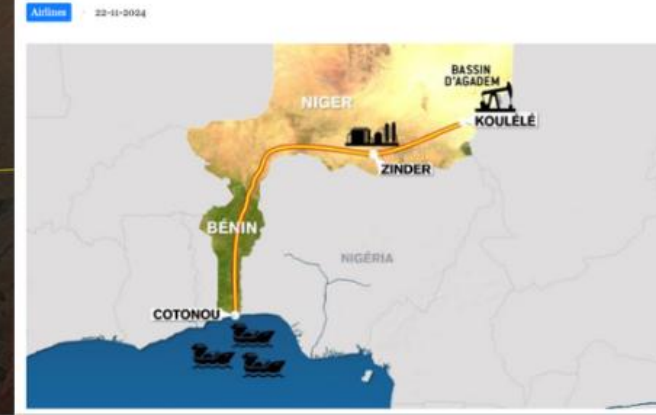
- ❖ RFI detection
- ❖ RFI filtering
- ❖ SMOS/SMAP merging

Pipe line in Niger

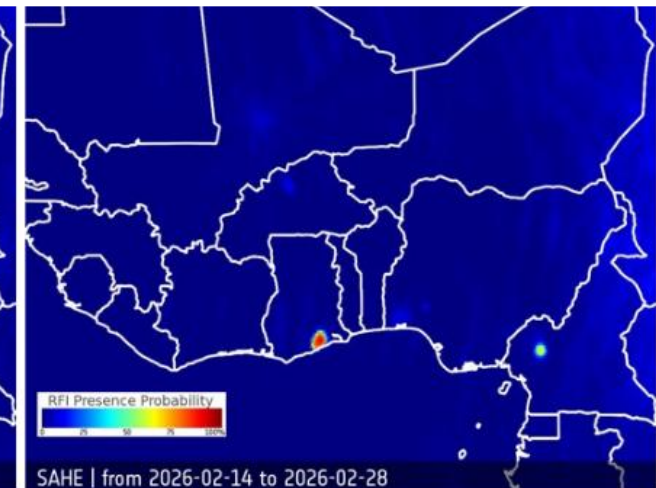
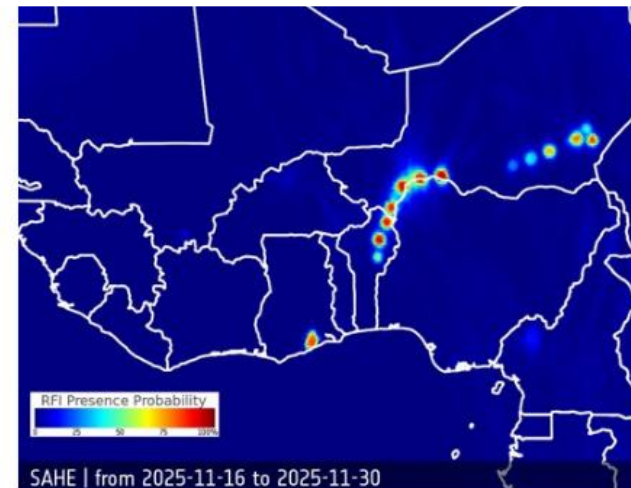
- Identification of numerous sources
- Jeopardising drought monitoringm rainfall monitoring, yield forecasting etc in Sahelian regions
- Identified, reported, suppressed



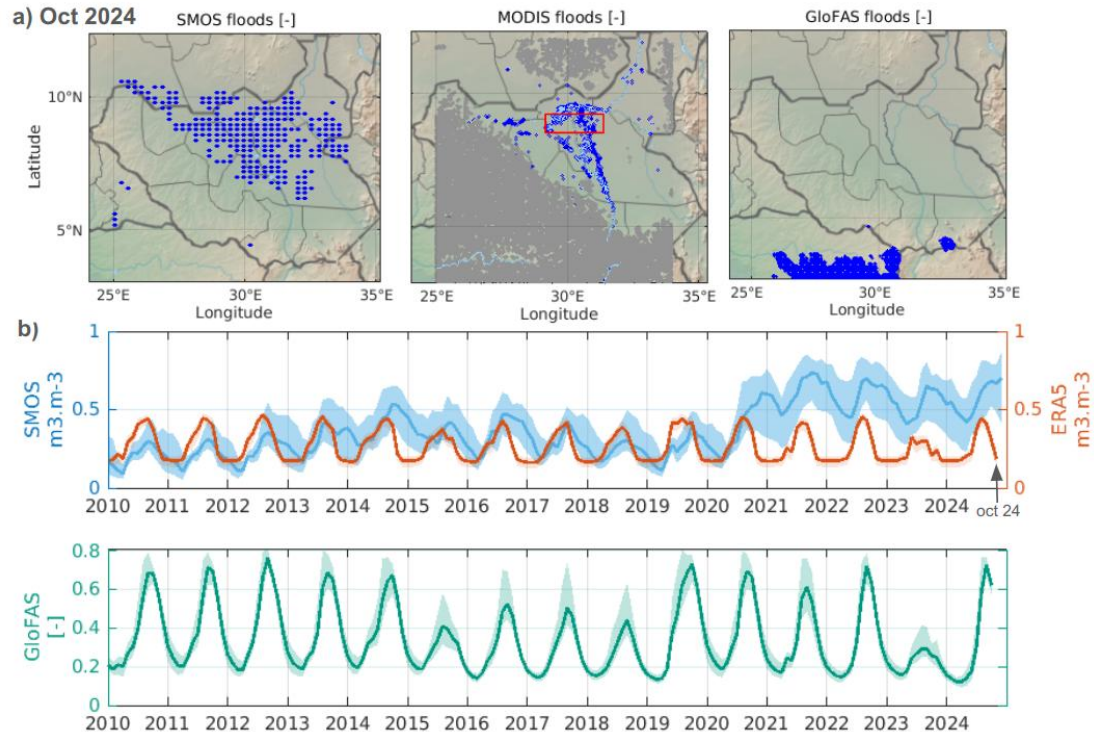
Niger Approves Construction of Four Private Airstrips Along Oil Pipeline to Benin



Figures 9 and 10. SMOS RFI Probability Map 2025-04-29 / 2025-05-13 centred in Nigeria-Niger border. Source: SMOS DPGS RFI Team (left). Niger approves four private airstrips along the oil pipeline corridor. Source: [newsaero.info](https://www.newsaero.info). (right)



Flood study : zoom in South Sudan



Flood maps (blue = flood, grey = lack of data), and time series (SMOS soil moisture, ERA5 volumetric water content, GloFAS soil wetness index) averaged over the red rectangle area

- Comparison of flood maps derived from optical-infrared data (MODIS), passive microwave data (SMOS, based on saturation threshold) and reanalysis data (ERA, GloFAS).
- Good agreement between satellite data (MODIS, SMOS), in line with the Global Water Monitor 2024 report and statements from the United Nation Office for the Coordination of Humanitarian Affairs.
- No event detection with reanalysis datasets (GloFAS and ERA5)

Current situation

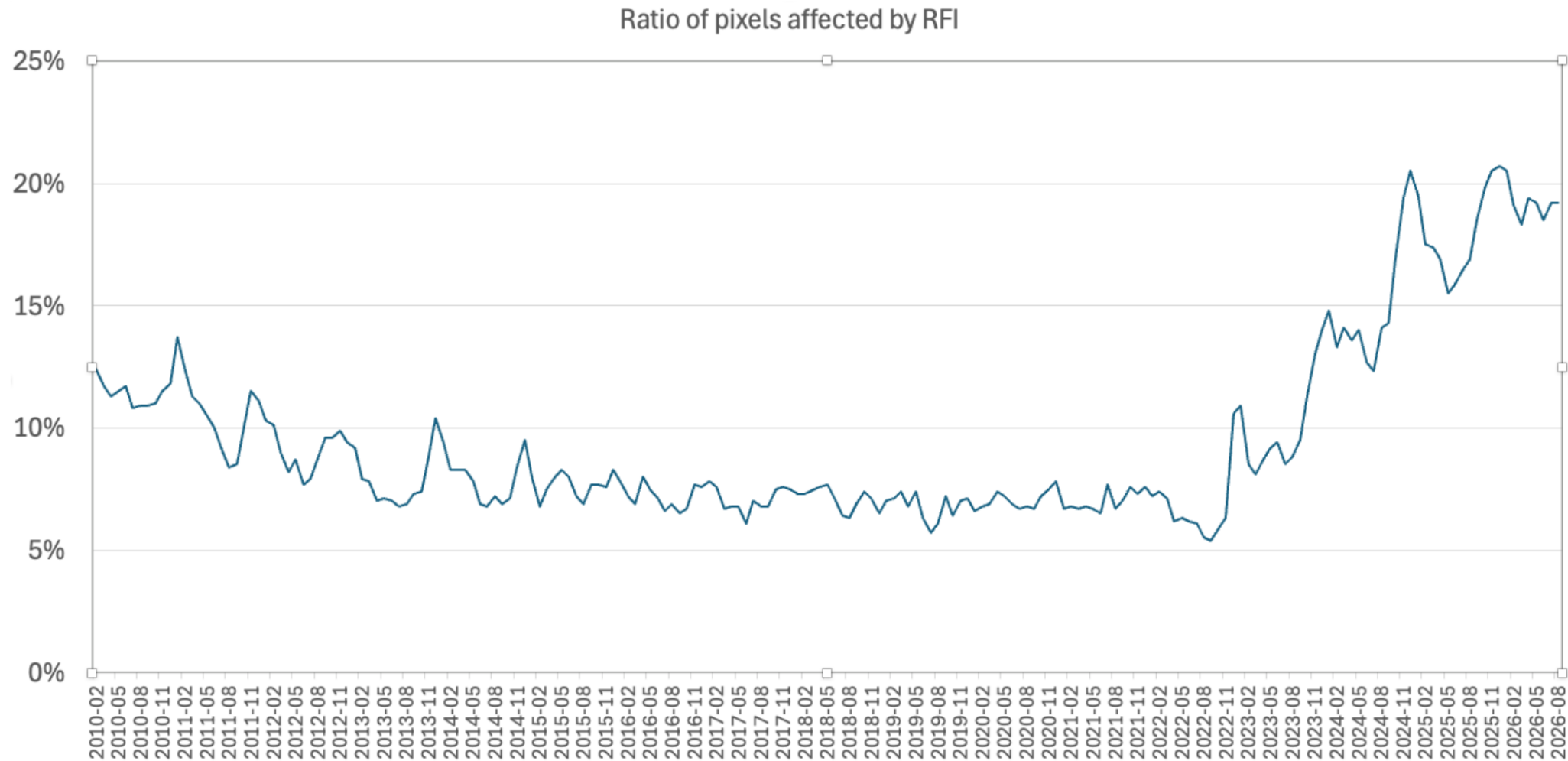
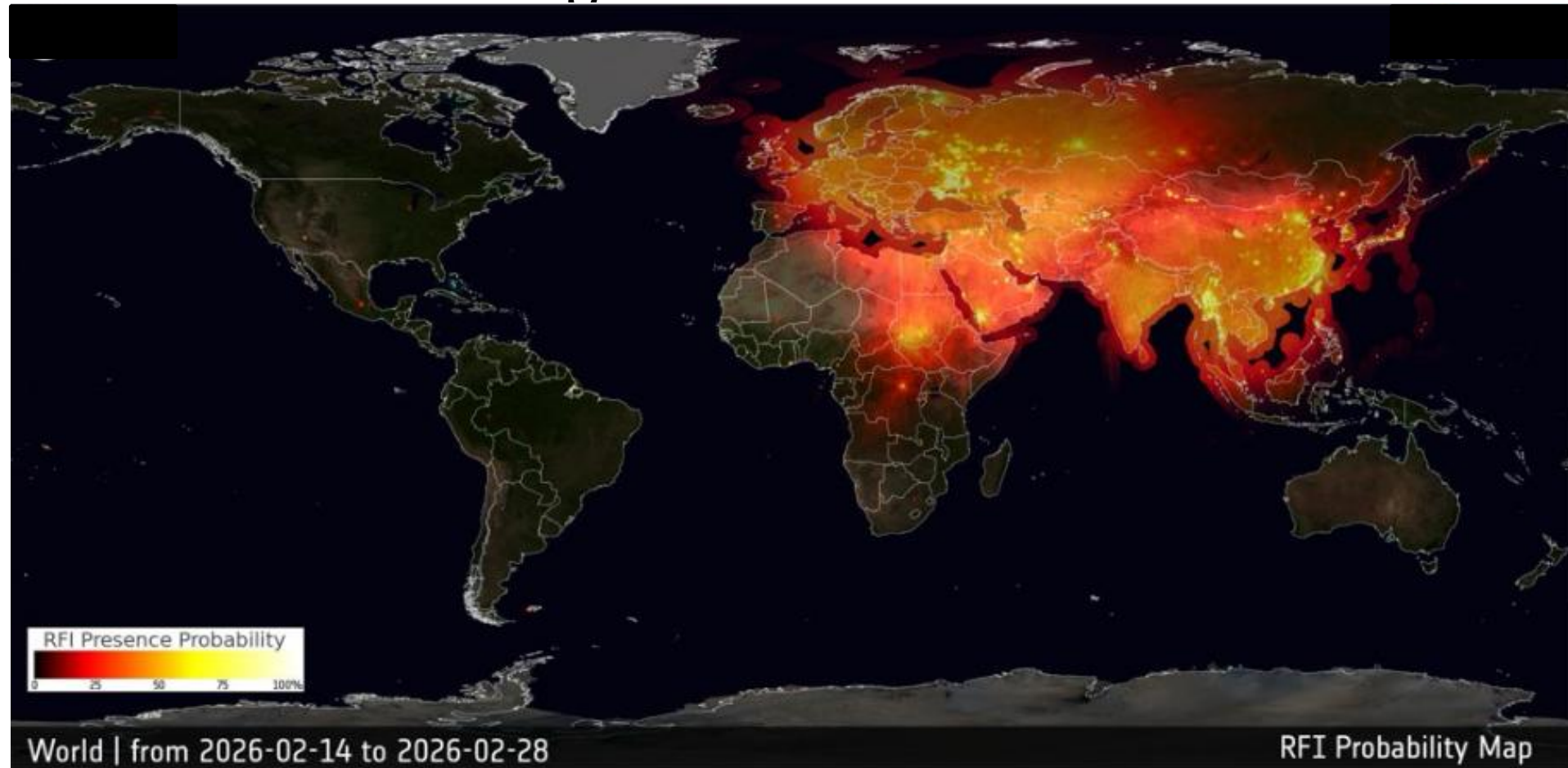


Figure 4. Ratio of pixels affected by RFI worldwide from the beginning of the mission.

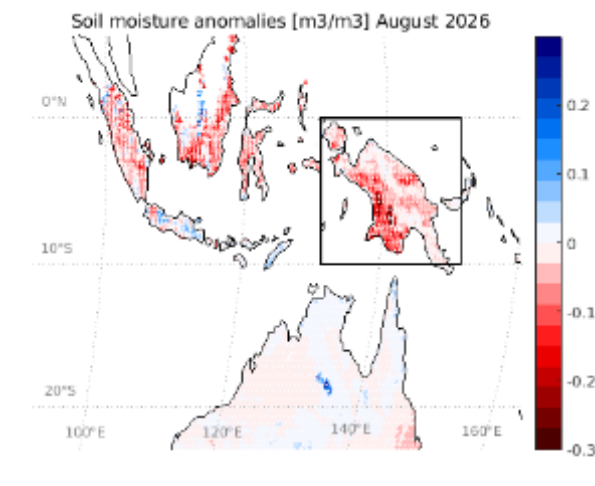
The big picture

- ❑ No retrievals over most of Europe and a good part of Asia....Impact on NWP, thin sea ice, Freeze thaw, SWE, hurricanes, permafrost, flood fire risks, droughts and water management.....



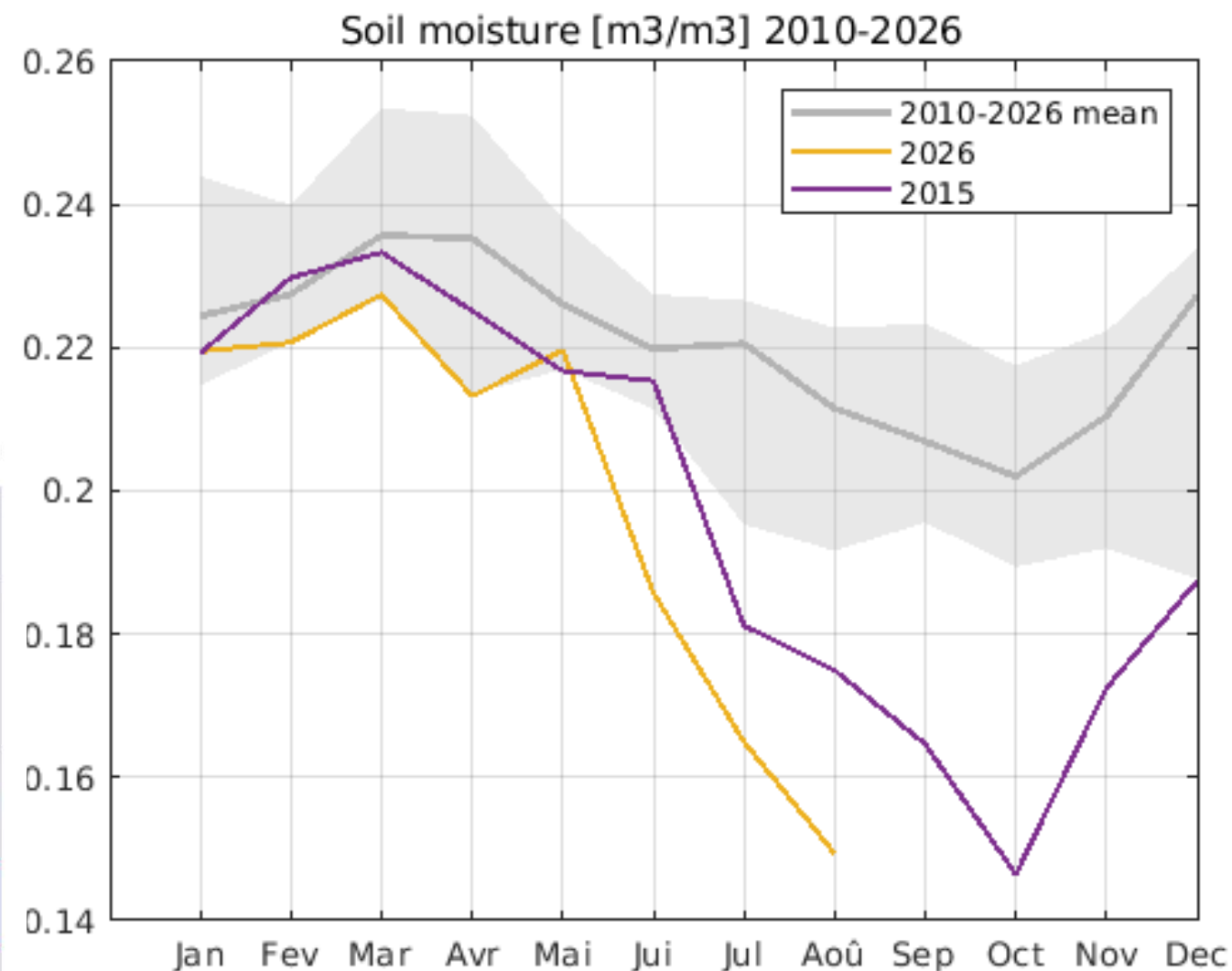
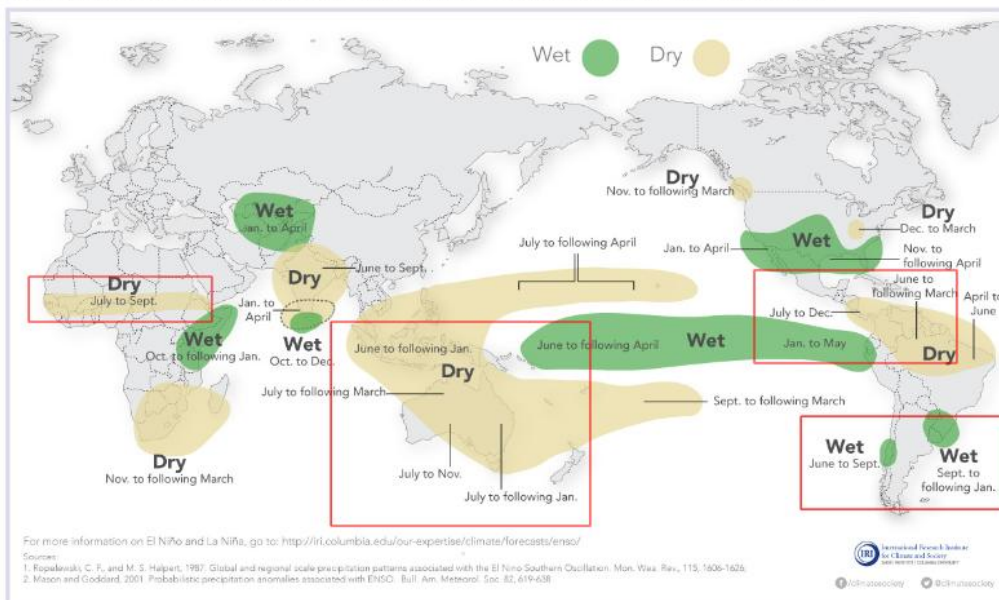
E. Uranga

When El Niño is coming



El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.



Summary

❑ Although all emissions are prohibited in the 1400-1427 MHz band (RR 5.340), L band is not clear of RFI, far from it, and operational applications – through SMOS – suffer from them.

- It can **jeopardise important measurements** (NWP, Fire / flood risks, extreme events (hurricanes)
- Mitigation is no solution as measurements are either damaged or eradicated

❑ It is thus very important to help identifying and shutting the RFI (adequate funding?)

❑ And mapping them is very useful

- ❖ Following evolution for quick action
- ❖ Letting users know how affected are their measurements
- ❖ Helps a lot shutting them down

❑ **It is thus crucial to keep the 1400-1427 MHz protected band clean of emissions and respect the recommendations for OoB emissions levels**