Survey of RFI contamination in Earth Observation passive frequency bands

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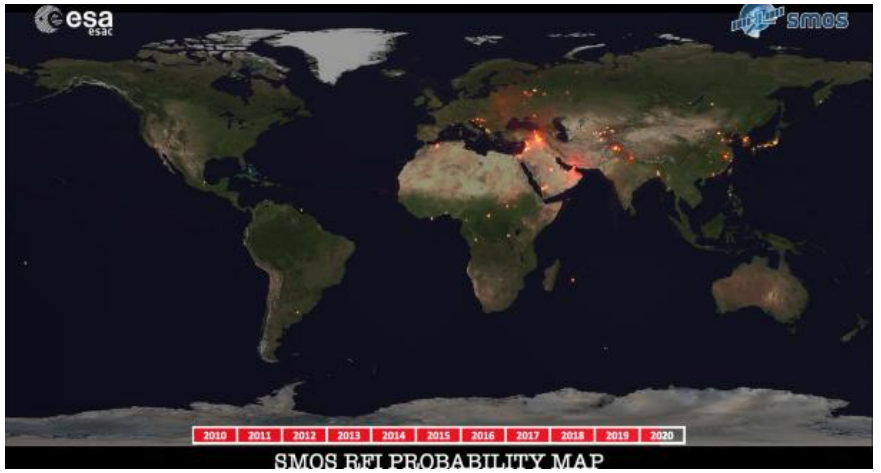
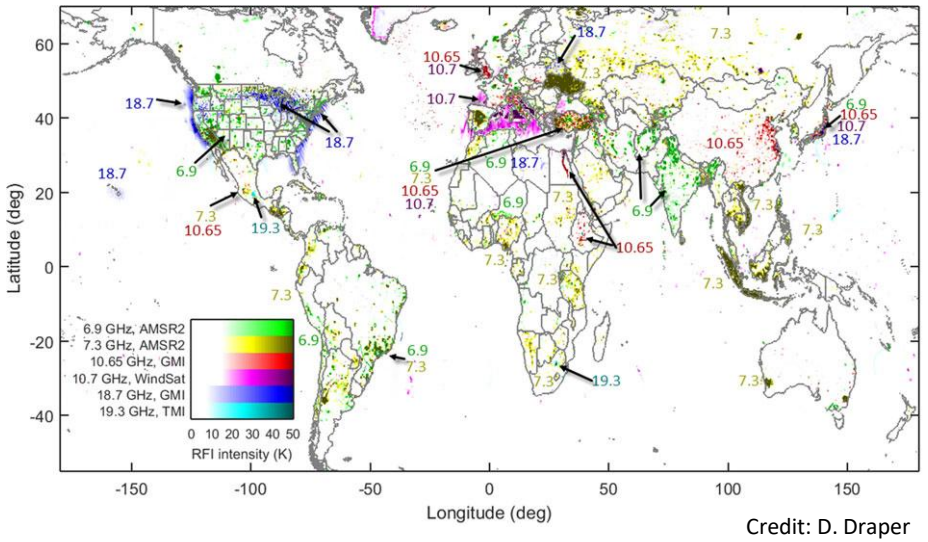
RFI workshop 2025, 21 October 2025

RFI current environment

- Low frequency channels are known to have RFI contamination
  - SMOS has been dealing with RFI contamination since mission was launched and collaborated with authorities to shut down RFI sources
  - Multiple missions (TMI, Windsat, GMI, AMSR2) bands have shown RFI contamination in other bands:
    - 6.9 GHz, 7.3 GHz, 10.7 GHz, 18.7 GHz
    - Some bands are shared with other services
  - RFI contamination found up to 18.7 GHz



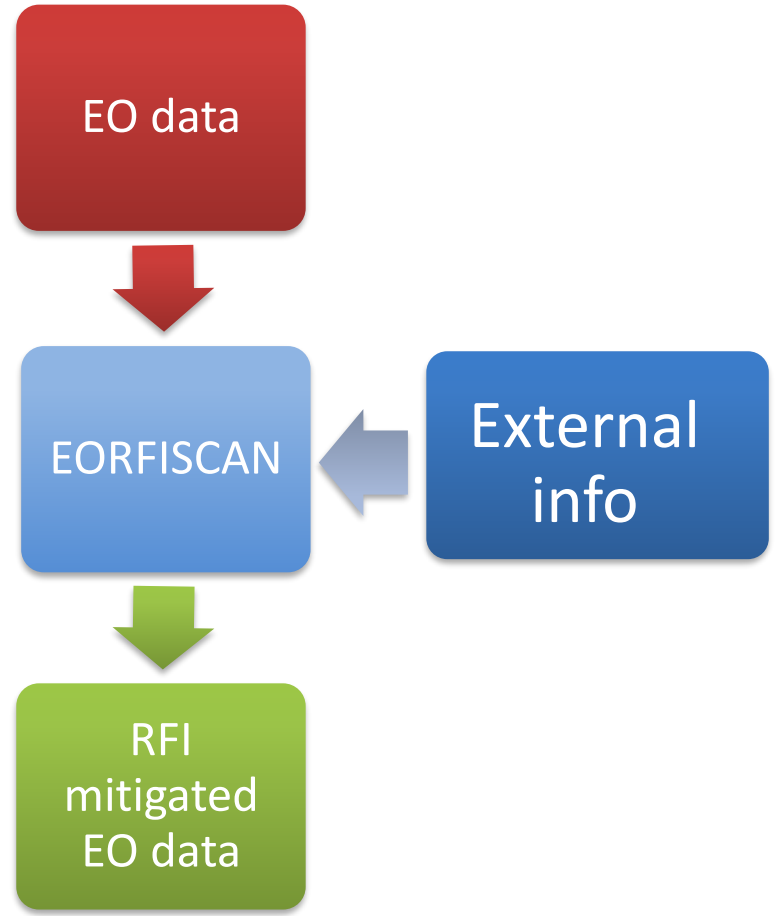
Credit: ESAC SMOS RFI team



Credit: D. Draper

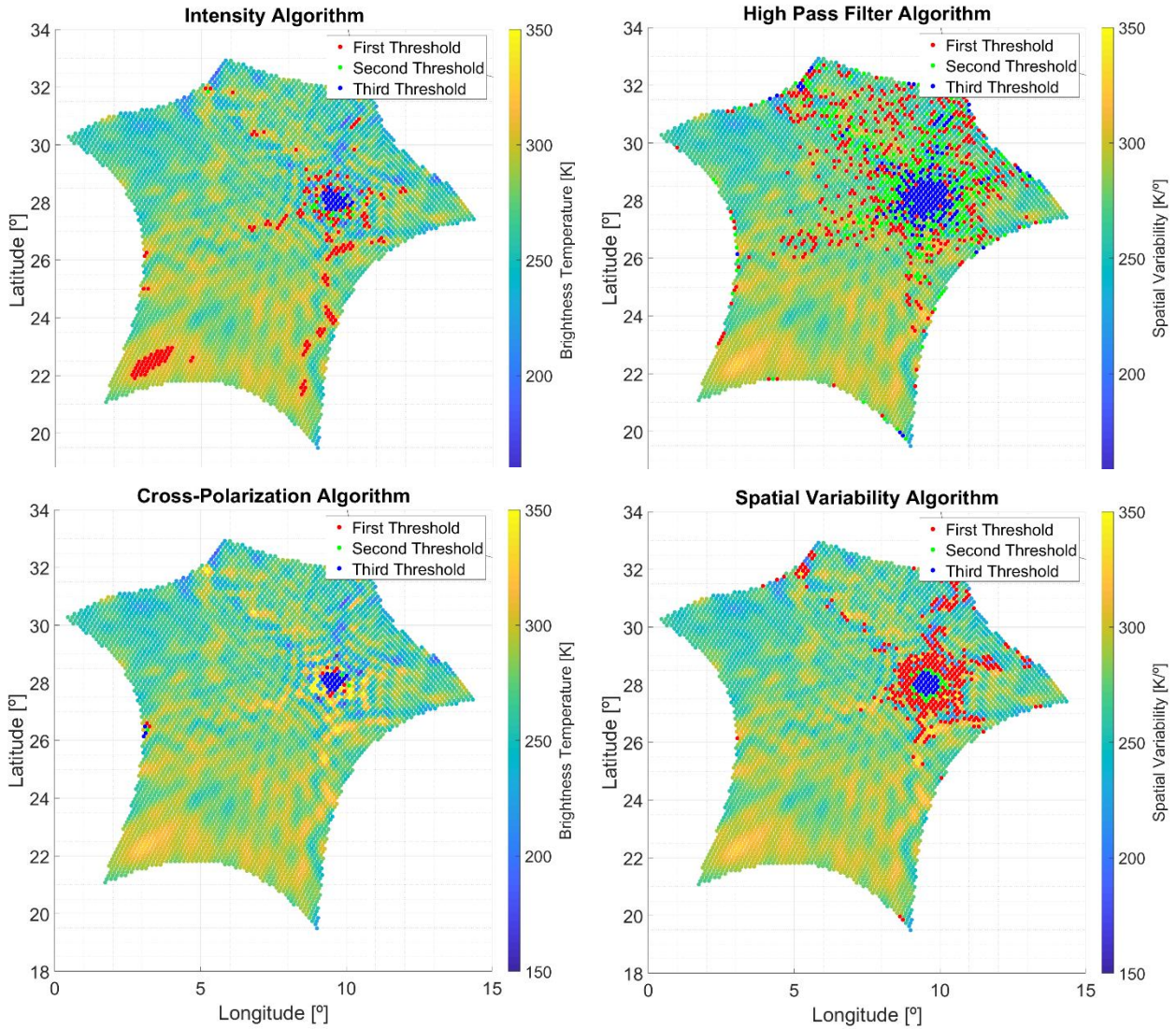
EORFISCAN concept

- Develop a flexible system with flexibility able to ingest data from any EO passive microwave mission
- It makes use of a library of RFI detection algorithms and external and internal information to detect presence of RFI.
- It allows to configure the level of flagging to set the user preference between missing RFI and false alarm detection, and to change configuration to adapt to new events.
- It can run in parallel processing in cloud services to allow for processing large data amounts and NRT applications.



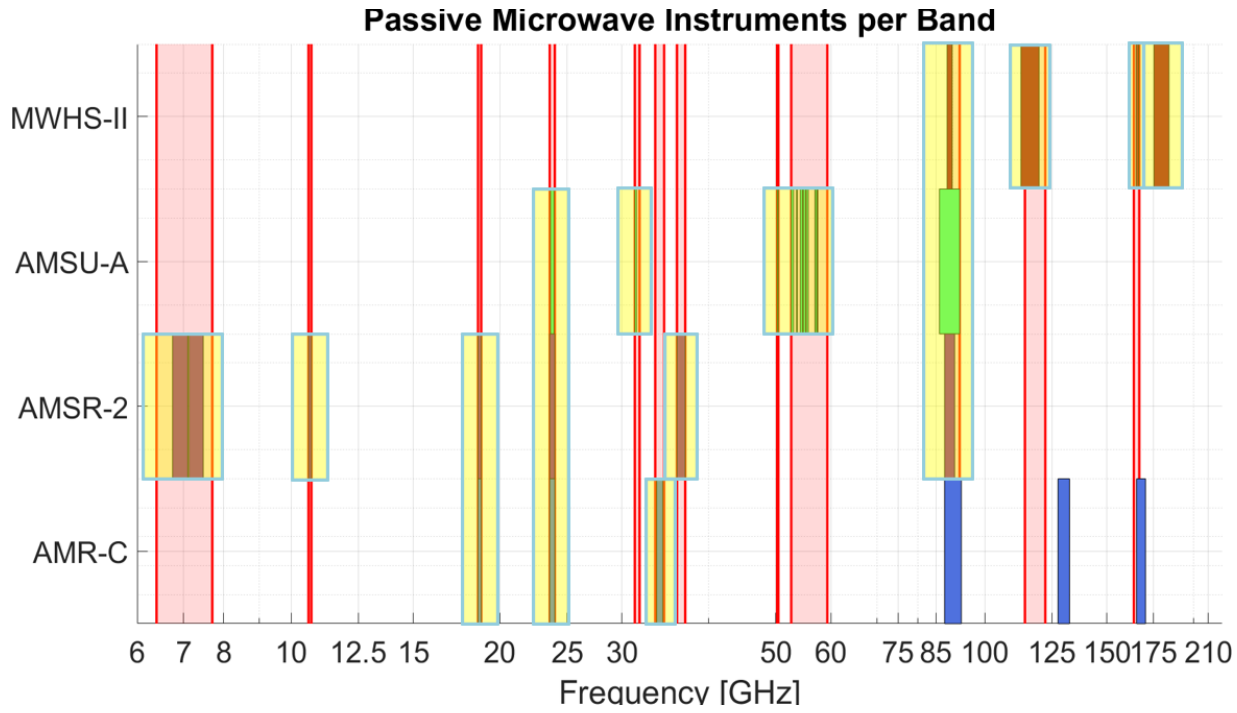
Several RFI Detection techniques applied

- For every EO measurement, it applies the most useful RFI detection techniques from a variety of techniques.
- It applies several thresholds at once, to customise for each user's needs.
- All detections are then combined to provide one single RFI flag per measurement and delivered to the user (NWP or science application)

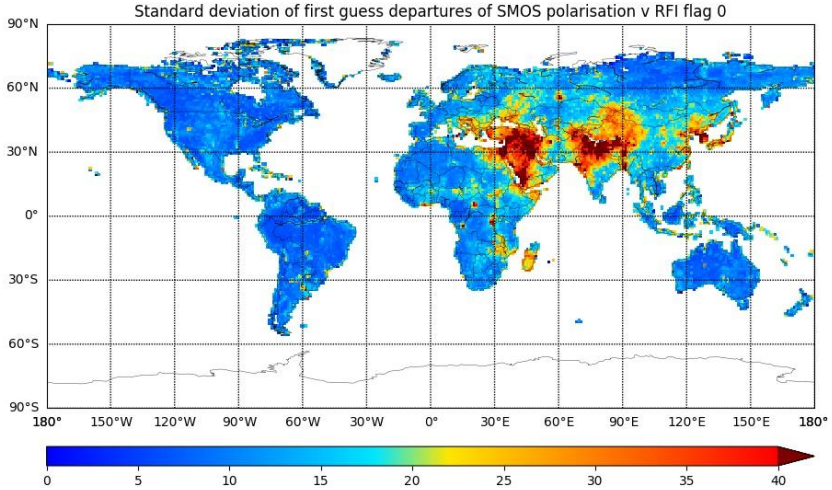


Frequency Bands

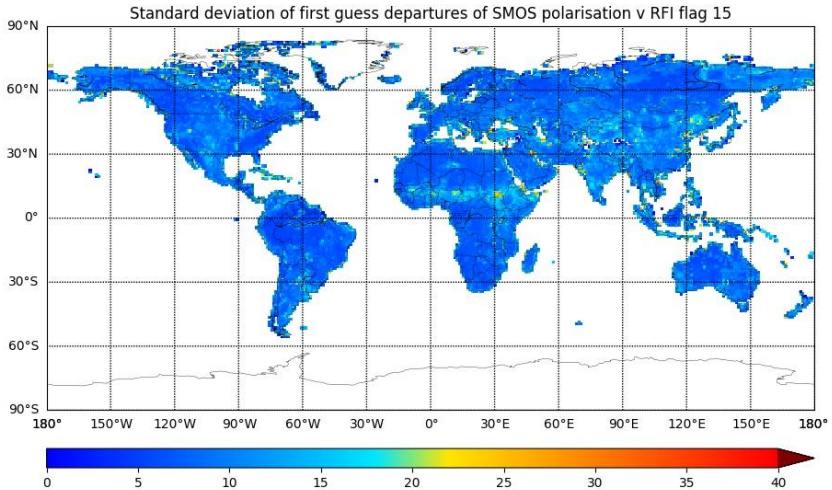
- Process data for 4 instruments to cover all passive bands
  - AMSR2
  - AMSU-A
  - MWHS-II
  - AMR-C
    - Only sensor covering 34 GHz at the moment
  - 23.8 and 89 GHz band observed by 3 satellites
- 2022 data for above missions was processed



- Data Results were sent to ECMWF for independent validation.
- ECMWF used their knowledge and expected statistical properties of the signal to quantify if the RFI filtering performed by EORFIScan was appropriate
- Initially done with SMOS L-band RFI sources
  - Results showed drastic reduction in contamination impact while keeping natural geophysical phenomena that differ from ECMWF models



Original SMOS data



After EORFIScan

ECWMF Validation

- ECMWF validation results were extended to the higher bands
- Filtering shows how the statistical properties of the First Guess Departure estimated values recover natural symmetric variation

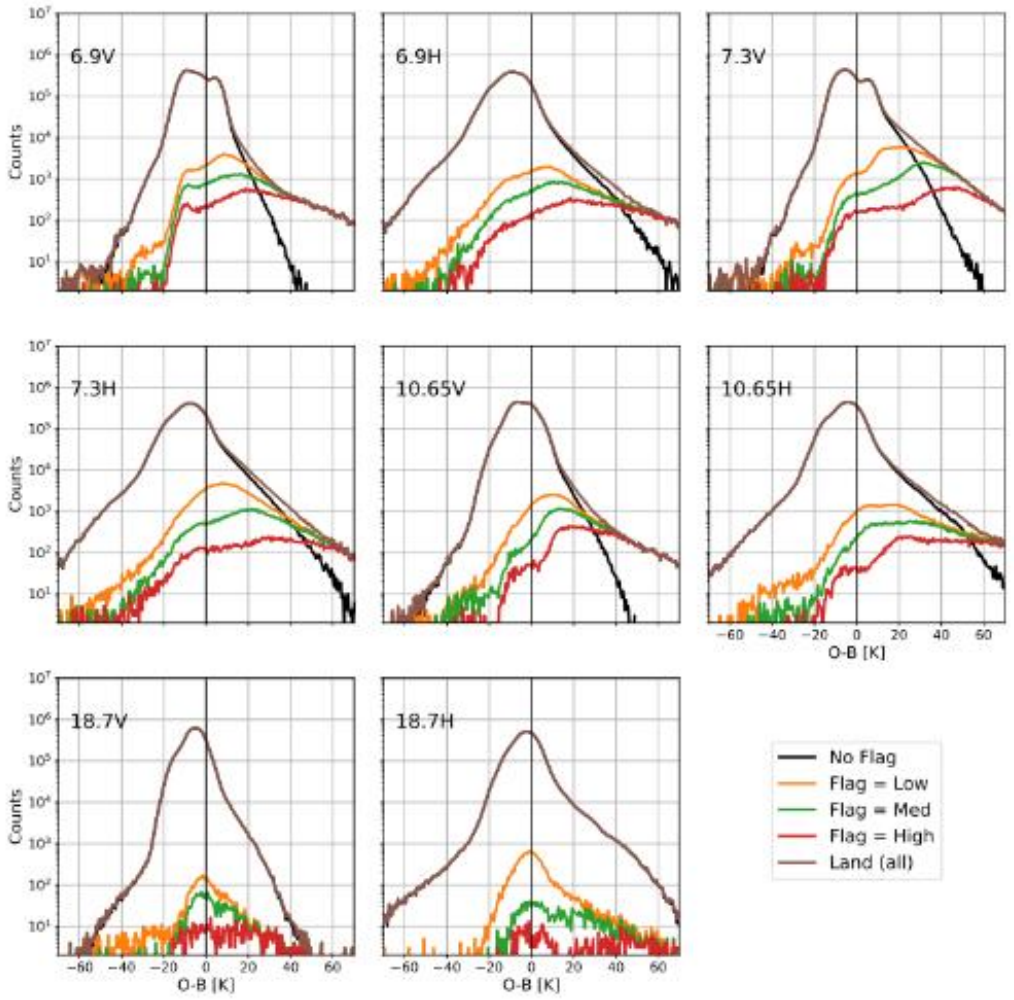


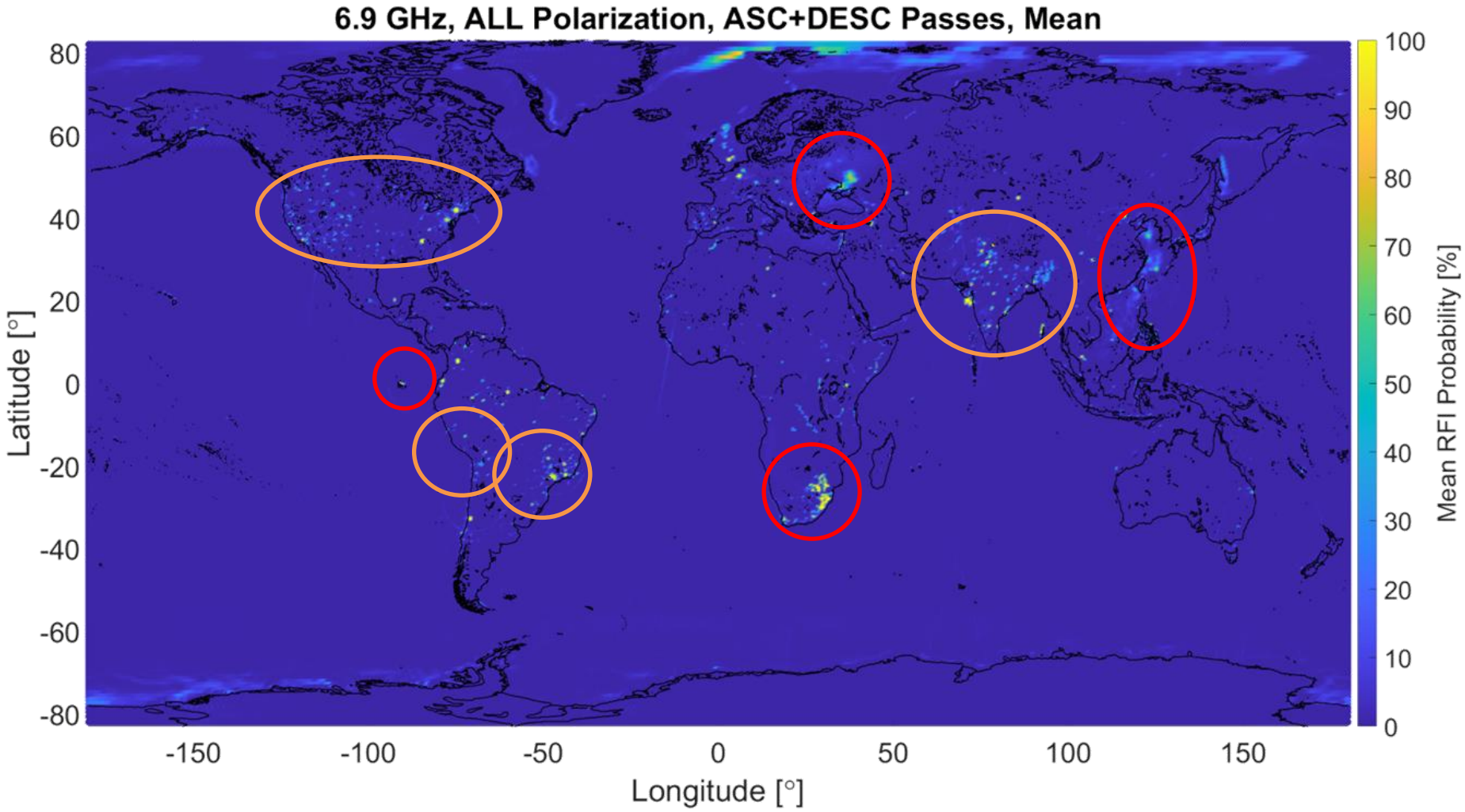
Figure 26: Histograms of departures for screened observations over land. The region covers North America and Europe, for the month of October 2022. Compare to the figure covering data over sea in Fig. 18.

Frequency Band 6.9 GHz

Results – 6.9 GHz – AMSR2

There is **no allocation** to EESS(passive) in this band, therefore, passive sensors cannot claim protection. RR No. 5.458 of the Radio Regulations simply recognizes the use of this band for passive microwave sensors:

"Administrations should bear in mind the needs of the EESS (passive) and Space research (passive) in their future planning of the bands 6425-7075 MHz and 7075-7250 MHz.



Frequency Band 7.3 GHz

Results – 7.3 GHz – AMSR2

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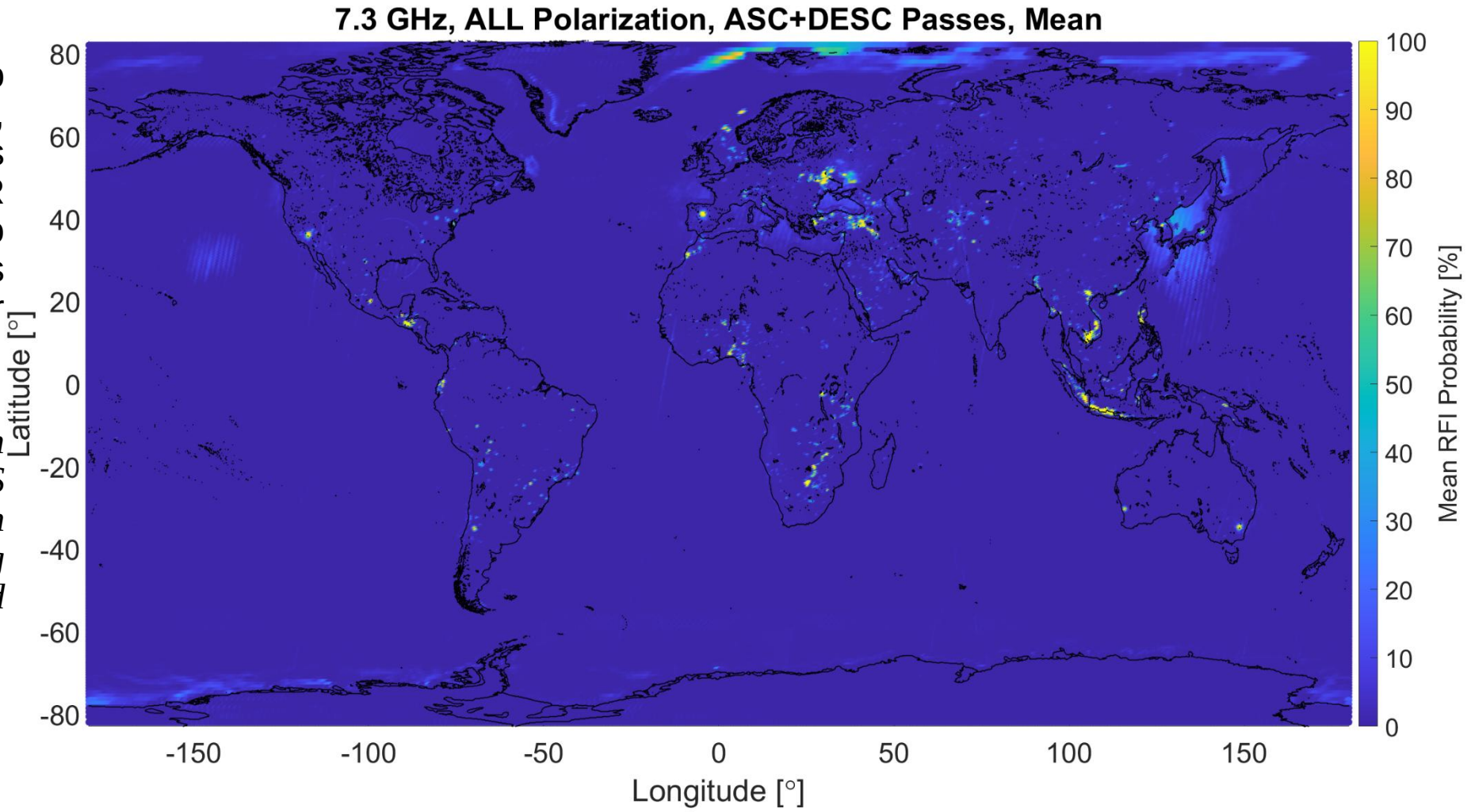

Results – 7.3 GHz – AMSR2

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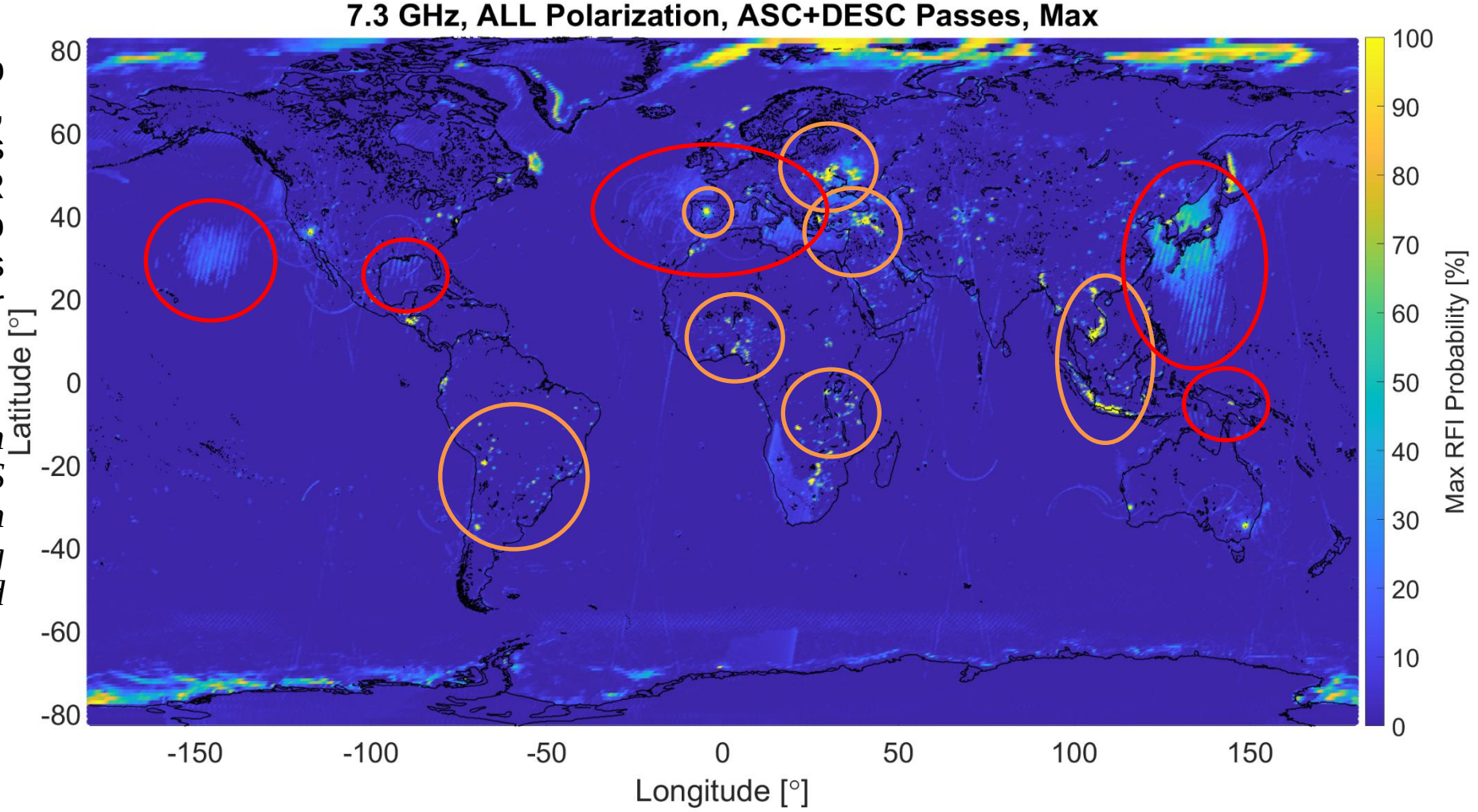


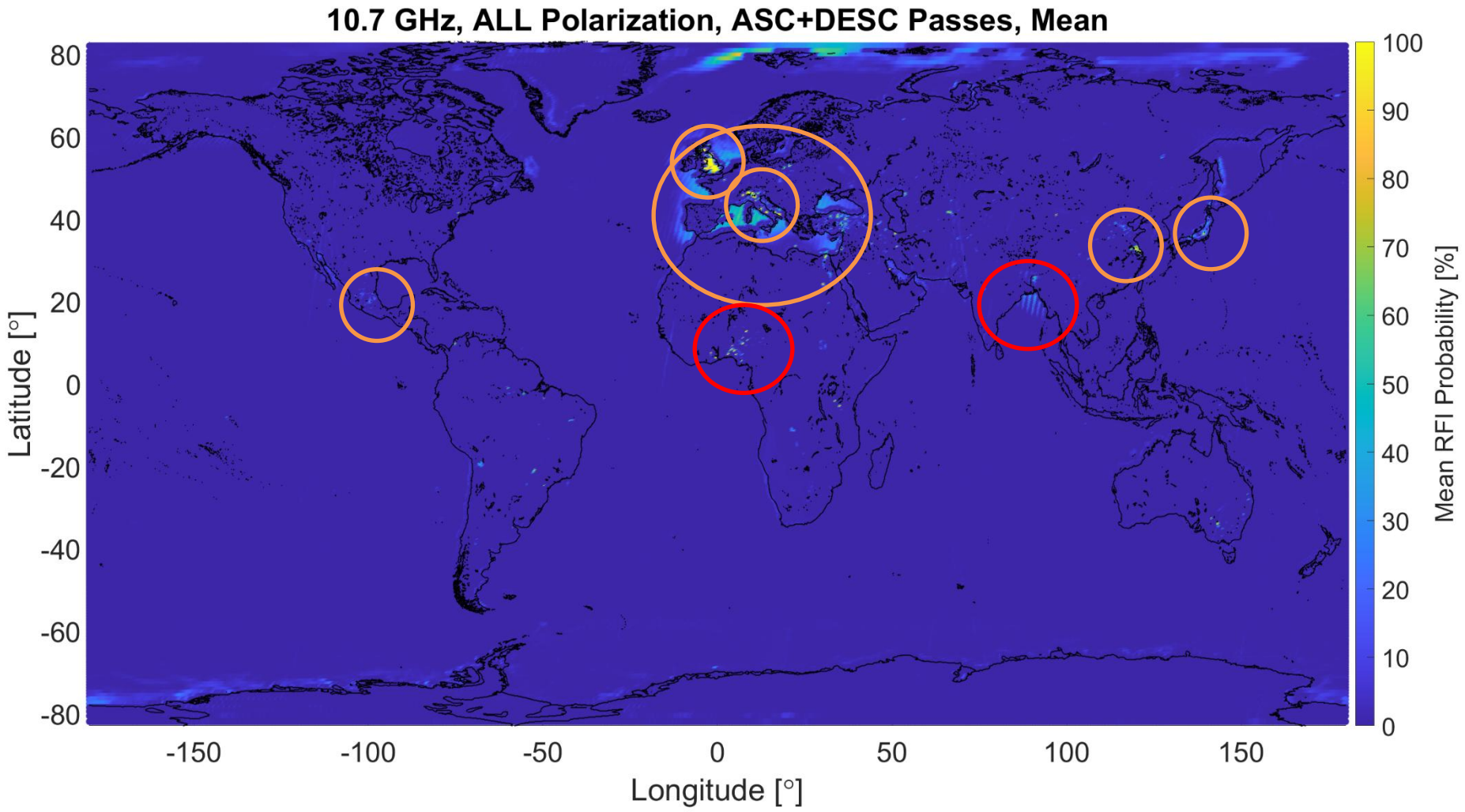
Frequency Band 10.7 GHz

Results – 10.7 GHz – AMSR2

The 10.6- 10.68 GHz band is **shared** with:

- Fixed and
- Mobile services,

whereas the band from 10.68-10.7 GHz is **exclusive** for Earth Observation (except those provided for by No. 5.484).

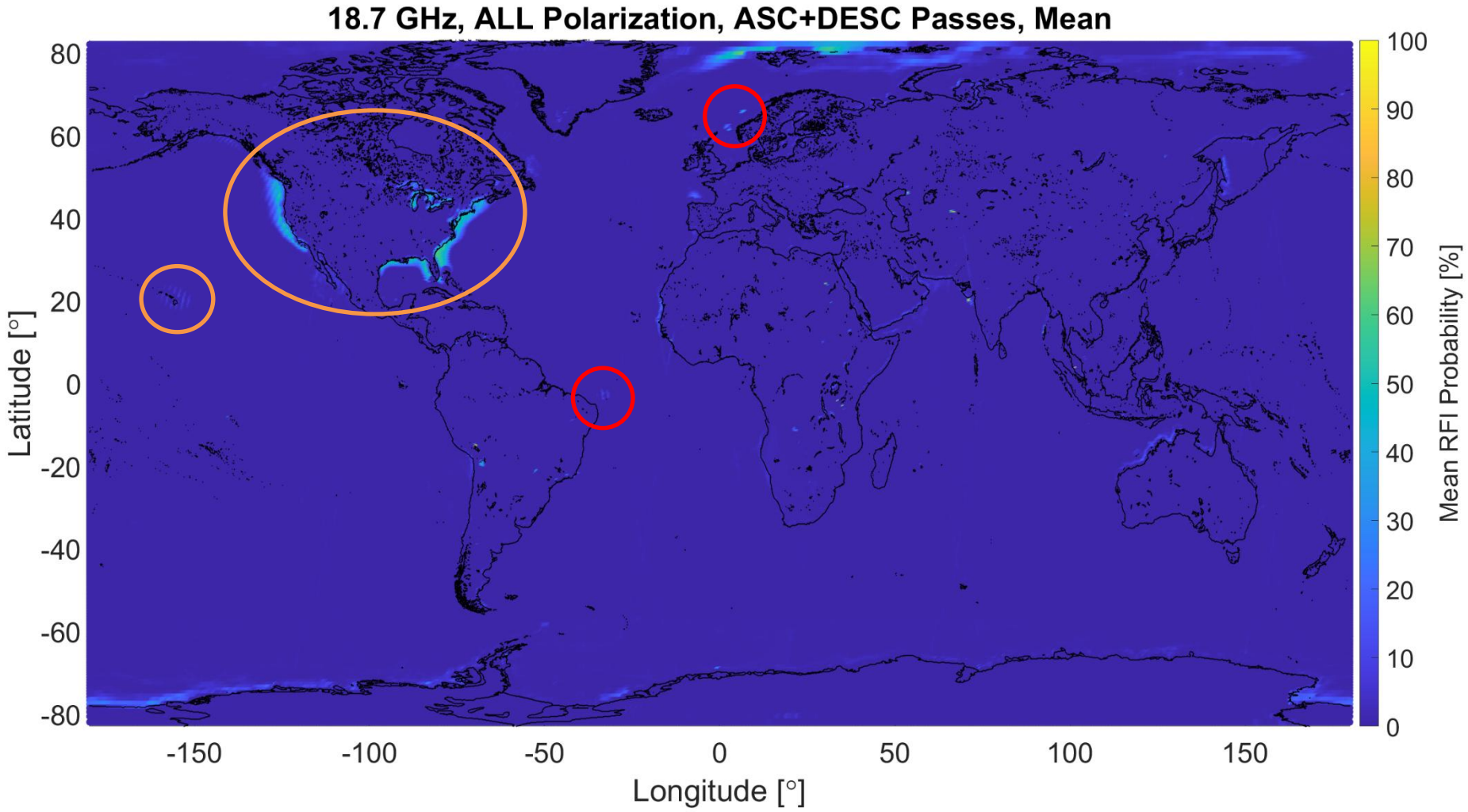


Frequency Band 18.7 GHz

Results – 18.7 GHz – AMSR2

The 18.6-18.8 GHz band **shares** a co-primary basis to:

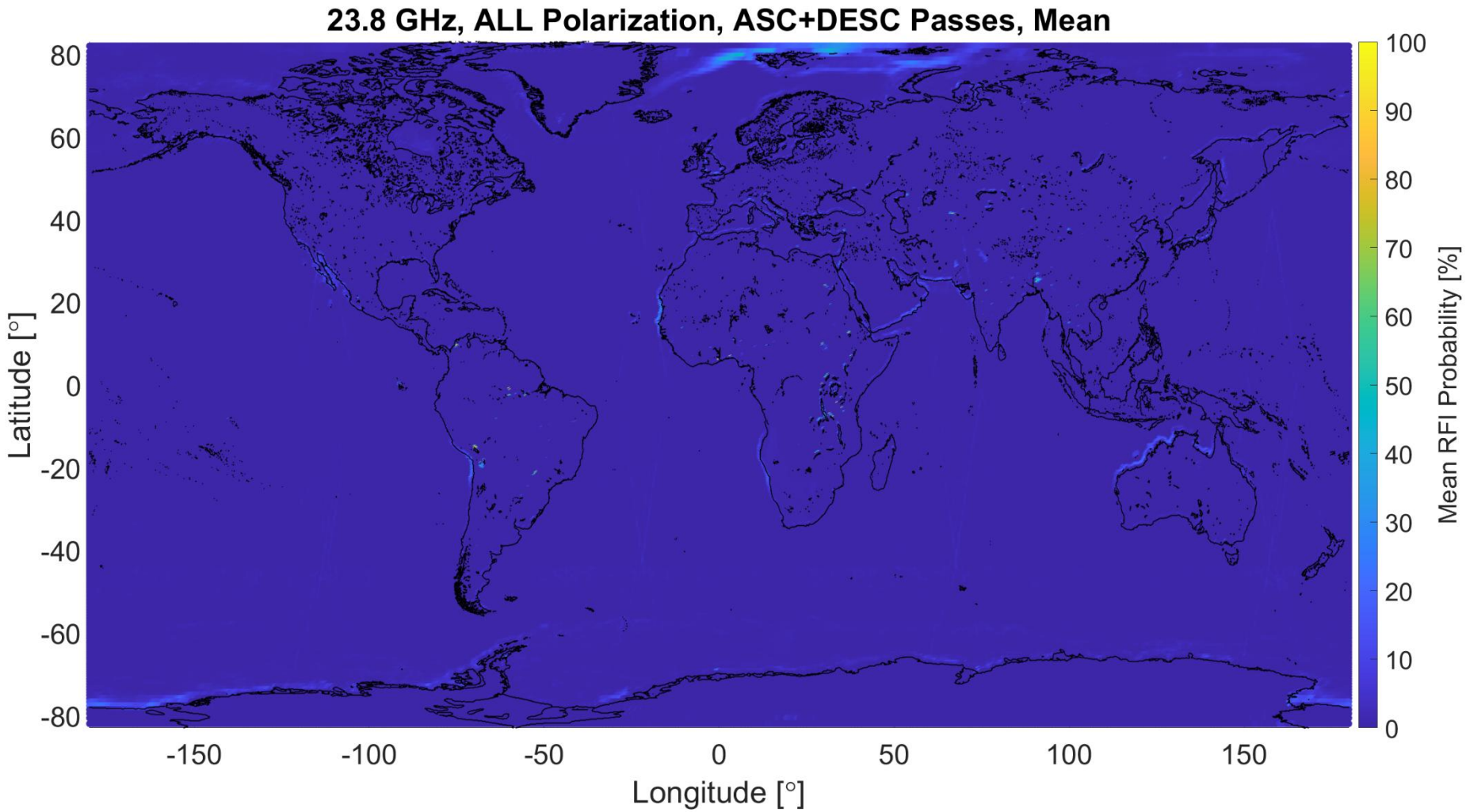
- fixed-satellite (FSS) (space-to-Earth),
- fixed, and
- mobile services.



Frequency Band 23.8 GHz

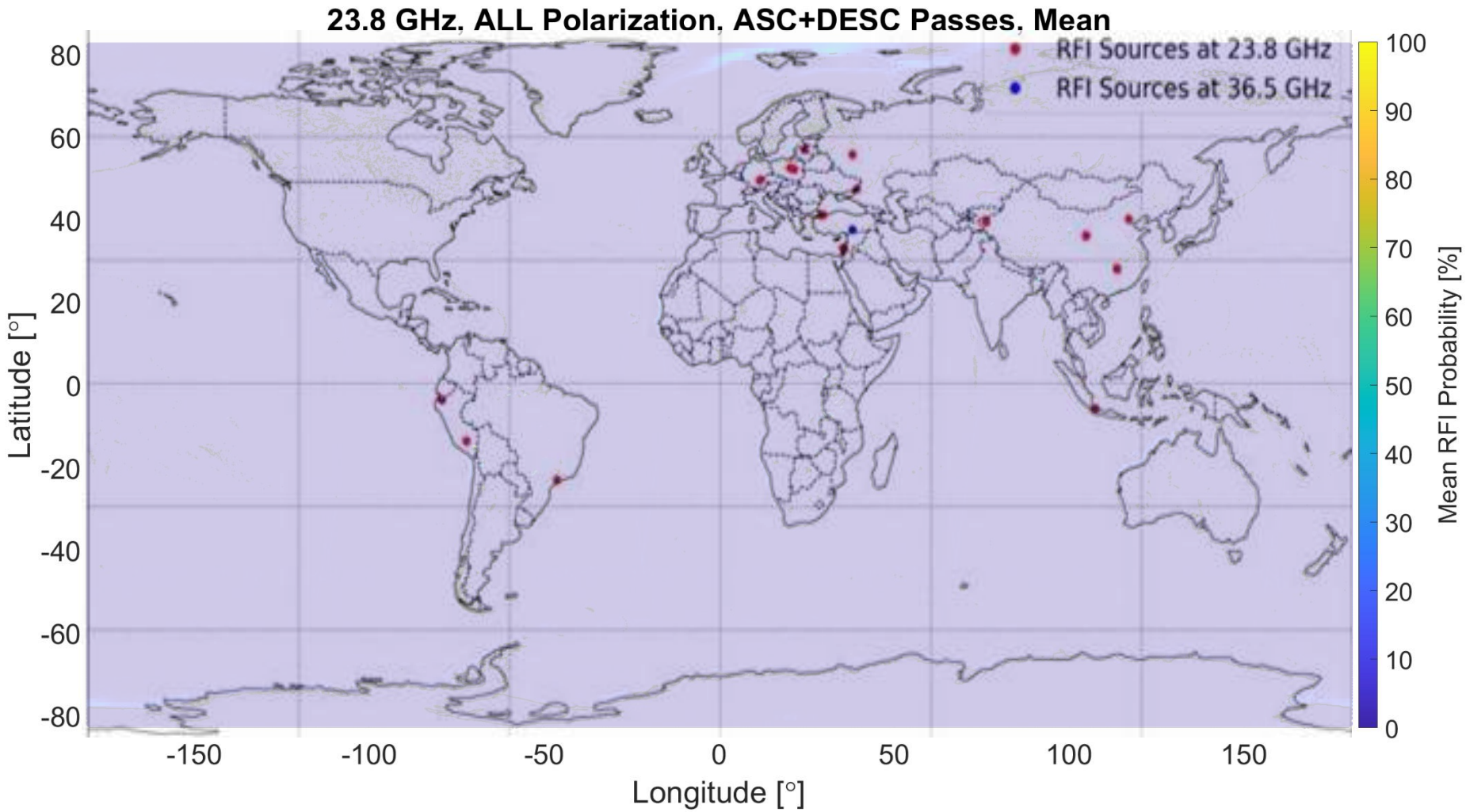
Results – 23.8 GHz – AMSR2

- The frequency band of 23.6 to 24 GHz is allocated **exclusively** to passive services.



Results – 23.8 GHz – AMSR2

- The frequency band of 23.6 to 24 GHz is allocated **exclusively** to passive services.



CONCLUSIONS (1/2)

- EORFIScan was developed to Detect RFI in most passive microwave sensors.

- Currently includes: SMOS, AMSR2, AMSU-A, MWHS-II and AMR-C and can use cloud computing for scalability and quick processing

- All passive frequency bands were analysed for 1 year of data **in fairly equal conditions**
- New RFI signatures have been observed
  - Hundreds of RFI contamination maps produced (frequency band, polarization, orbit direction, …) plus a database of contaminated observations

CONCLUSIONS (2/2)

- Types of RFI observed
  - Point sources spread over land: 6.9 GHz over the United States
  - Temporal RFI in marine traffic: 6.9 GHz in the Yellow Sea near China
  - Infrastructure deployment related RFI: 6.9 GHz in RDC
  - Reflected RFI over the sea: 7.3 GHz near Japan
  - Extended sources covering entire countries in shared telecommunication bands: 7.3 GHz in Indonesia
  - RFI in conflict areas: 7.3 GHz in Ukraine
  - Isolated RFIs present at 23.6 GHz and even at 36 GHz

Thank you for your attention!

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RFI Detection Techniques

- Threshold generation and RFI detection at slice level to optimize memory consumption
- SV and HPF implemented over the image in local coordinates, not geodetic
  - Convolution instead of interpolation
  - Implemented for AMSU-A after observing interpolation errors at high latitudes
  - Speed up processing
  - Thresholds recomputed
- AMR-C data is not an image but temporal 1-D signal
  - Only SV equivalent found, not HPF

Instrument	IN	CP	SV	HPF	RFI
AMSR2	X	X	X	X	X
AMSU-A	X		X	X	X
MWHS-II	X		X	X	X
AMR-C	X		X		X

RFI Detection Techniques

- Technique effectiveness depend on band and instrument
- AMSR2, 6.9 GHz:
  - Most effective technique:
    - RFI
  - Medium effectiveness:
    - HPF, SV, IN
  - Less effective technique:
    - CP