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TAKING THE PULSE
OF OUR PLANET FROM SPACE



C-band RFI contamination monitoring and operational mitigation in Sentinel-1 products



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1. Impact of RFI on Sentinel-1 data
2. Using noise measurements to detect S-1 RFI events
3. Aresys' C-band RFI monitoring website
4. S-1 operational RFI mitigation
5. Examples and statistics
6. Further material

Acknowledgements

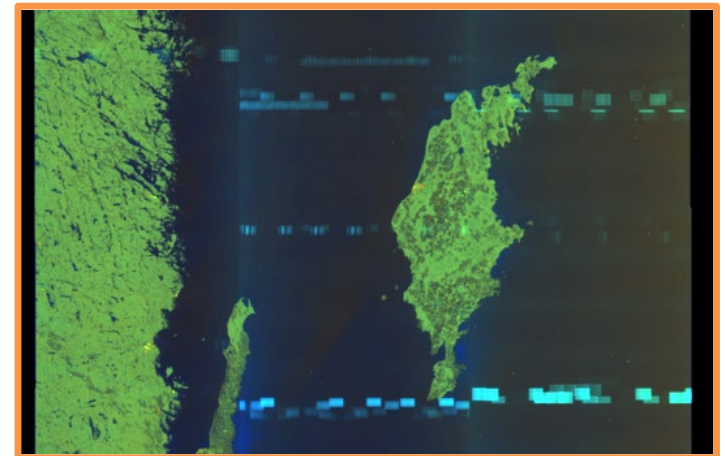
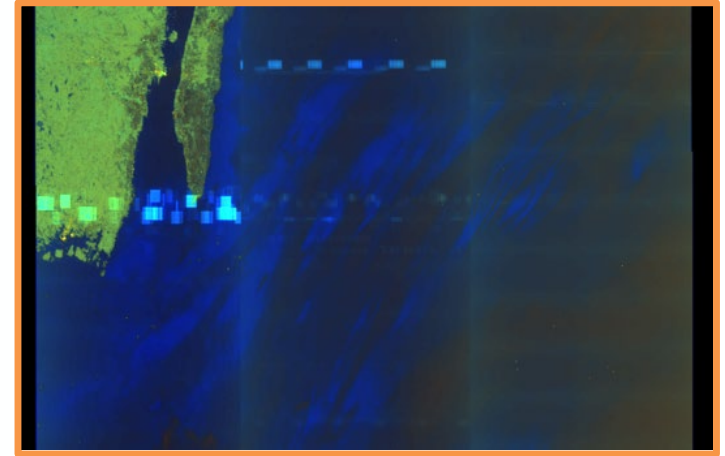
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SAR-MPC

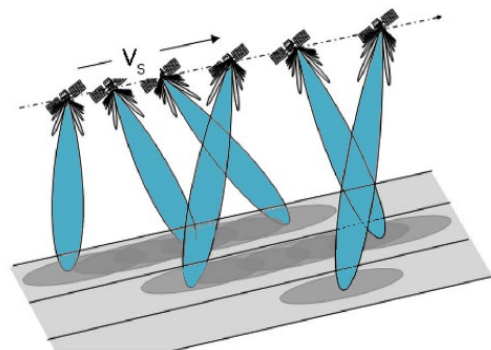
Impact of RFI on Sentinel-1 data

- Since the start of the mission, users reported local image degradations related to radio frequency interferences (RFI).
- Known sources of RFI include: military radars, meteorological radars and other spaceborne SARs
- In the future, new emitters could compete with C-band SAR:
 - agenda item 1.16 of WRC-19: RLAN deployment in the 5150-5925 MHz band → not successful;
 - potential migration of European meteorological radars from 5.6 GHz to 5365-5470 MHz → currently under consideration within the CEPT



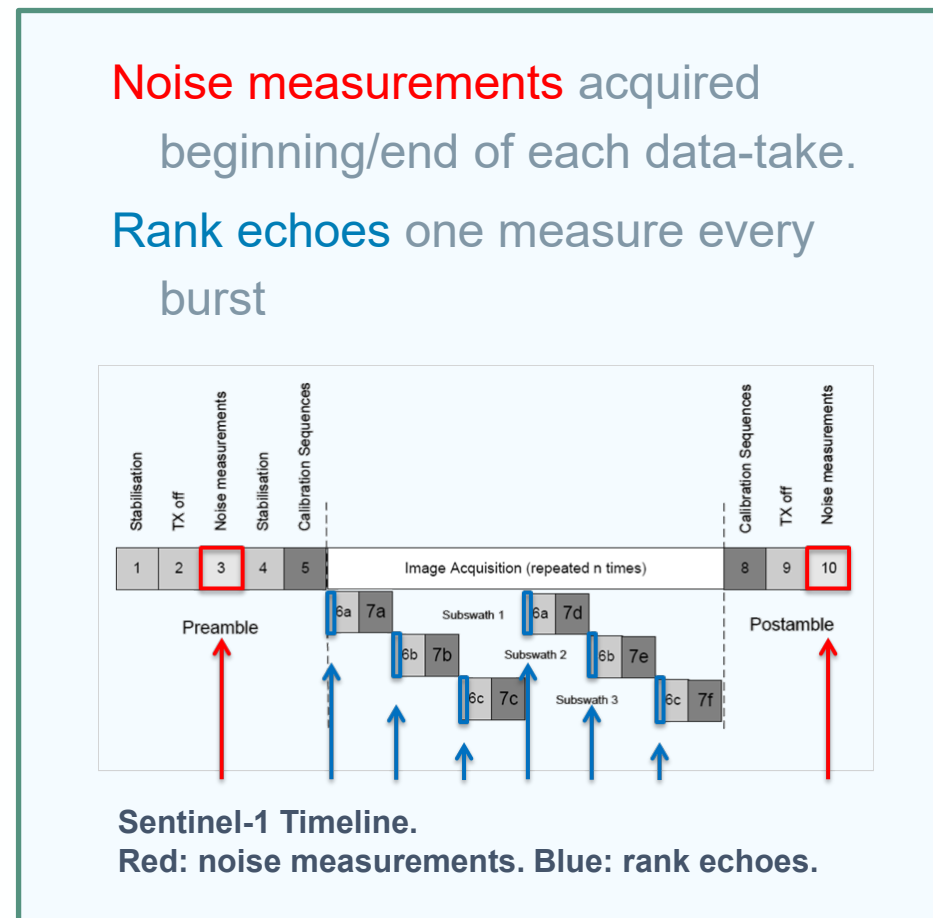
The power of noise echoes

- **Idea:** Sentinel-1 noise measurements can be used for RFI detection and monitoring.
- Too few noise measurements: take advantage of **rank echoes**.
- Challenges:
 - Cross-calibration of S-1 measurements using JAXA's GCOM-W1 (see next slide)
 - Find a suitable **RFI detection algorithm**¹



De Zan, Guarnieri (2006)

[1] Monti-Guarnieri, A.; Giudici, D.; Recchia, A. Identification of C-Band Radio Frequency Interferences from Sentinel-1 Data. Remote Sens. 2017, 9, 1183.

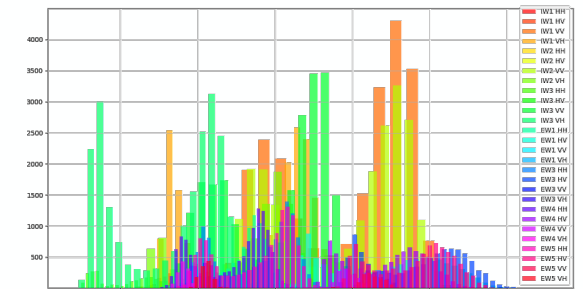
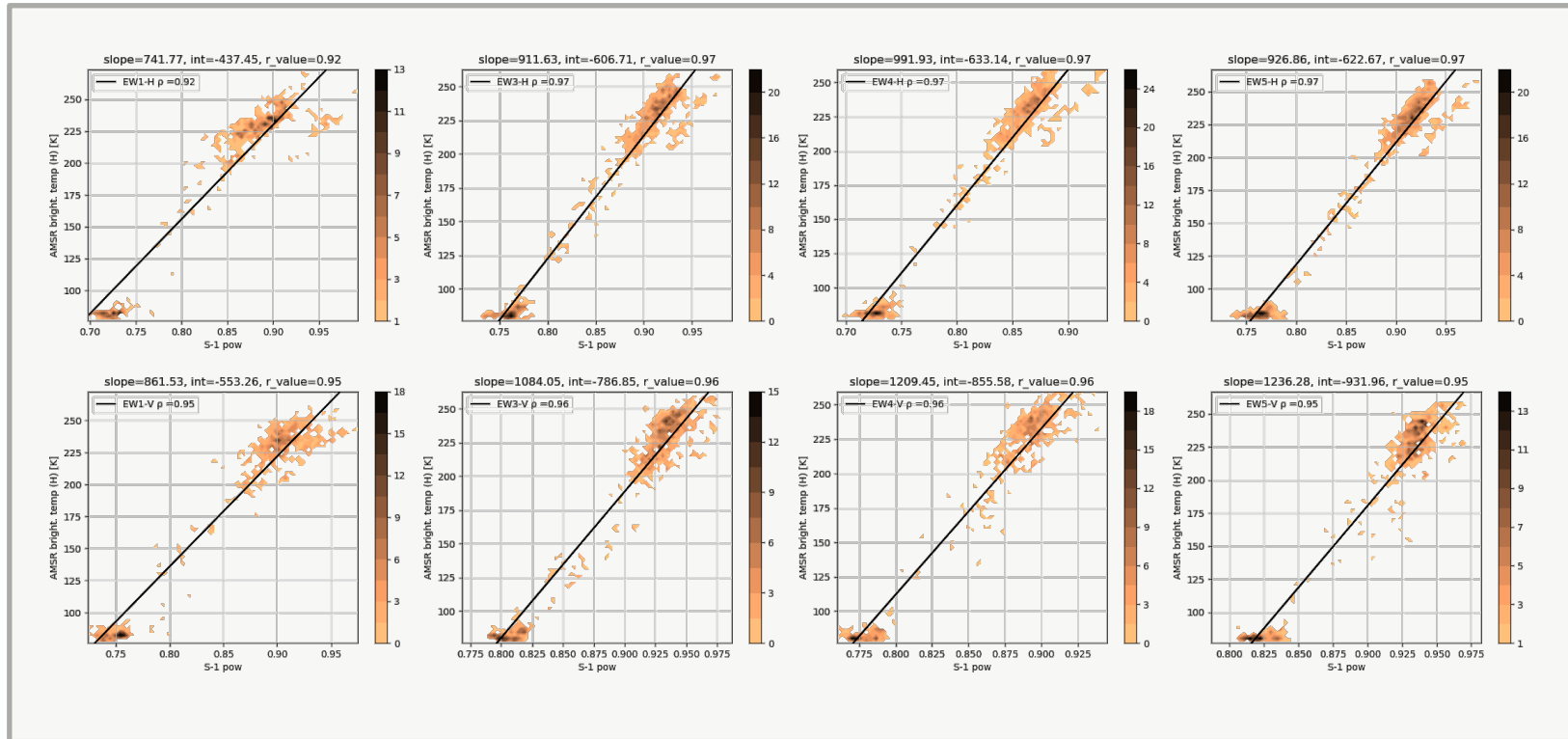


Cross-calibration with AMSR-2 data

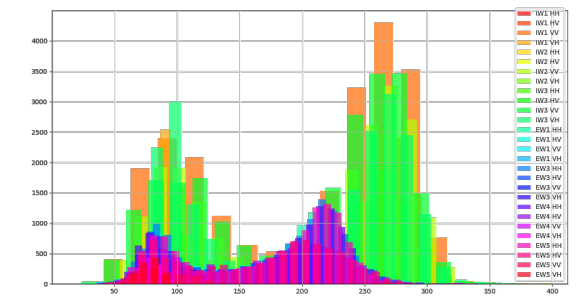
Goals: eliminate beam-to-beam bias; give physical significance to the measures,

S-1 noise data was cross-calibrated using AMSR-2 radiometer aboard JAXA's GCOM-W1.

Despite AMSR-2 @ 6.93GHz and S-1 @ 5.4GHz, high correlation coefficients (**r=0.92-0.97**) are found.

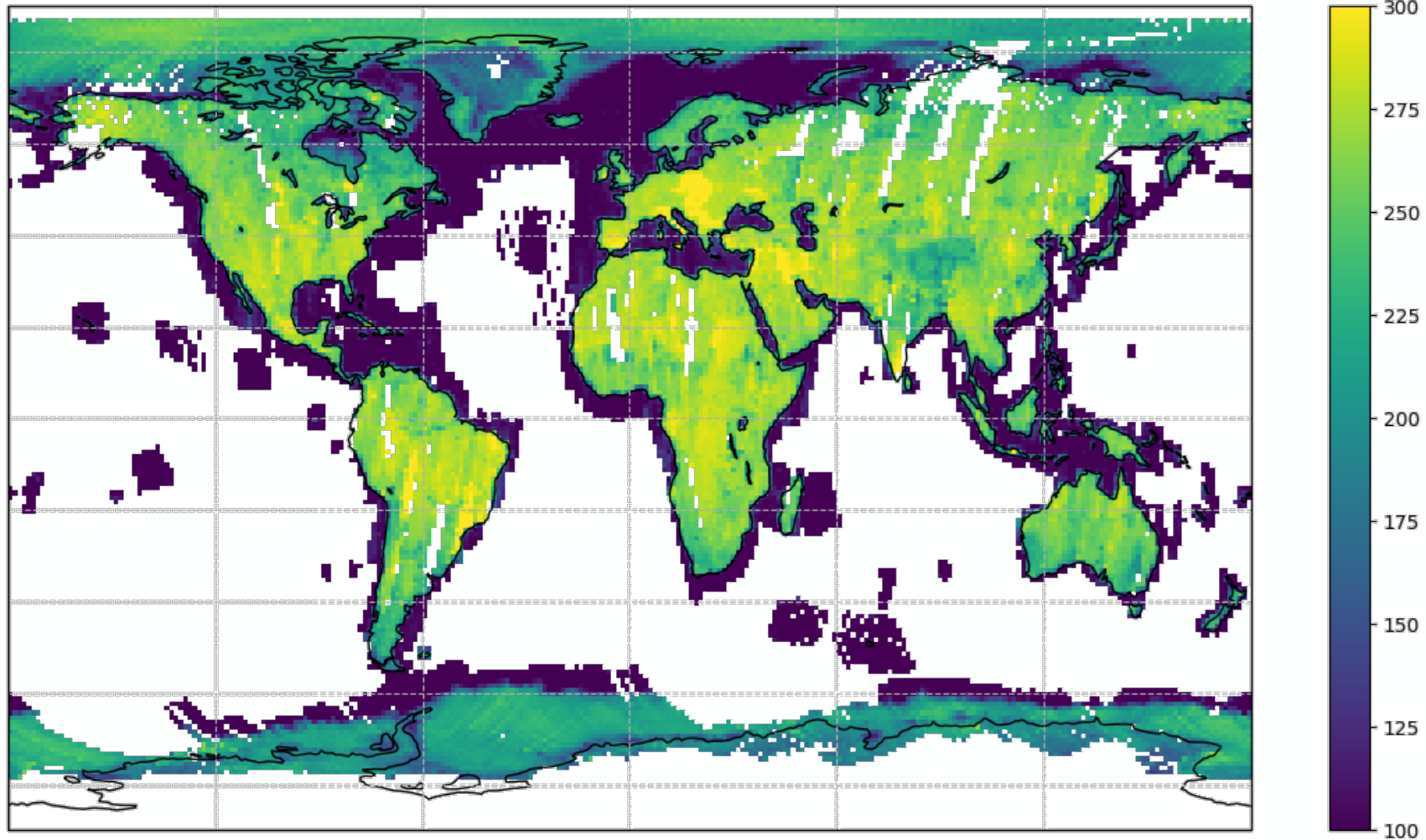


Sea Ice Land



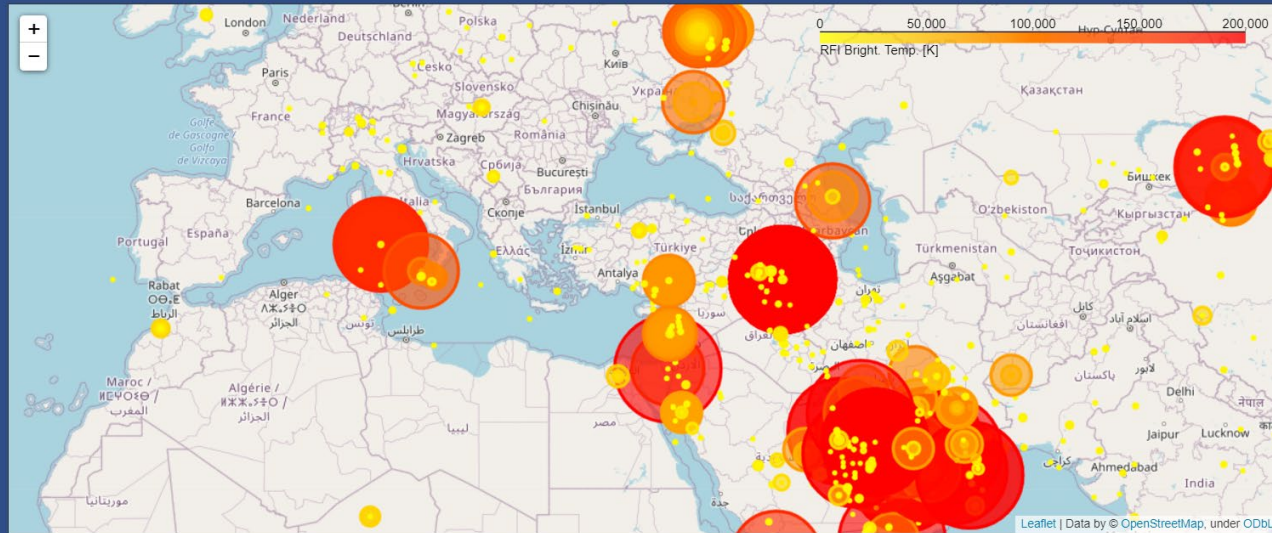
Sentinel-1 as a Passive Radiometer

S-1 noise power captures Earth emissivity



S-1(A+B) Topsar data July 1-12, 2019. Resolution: 1deg lat., 1.5deg lon.

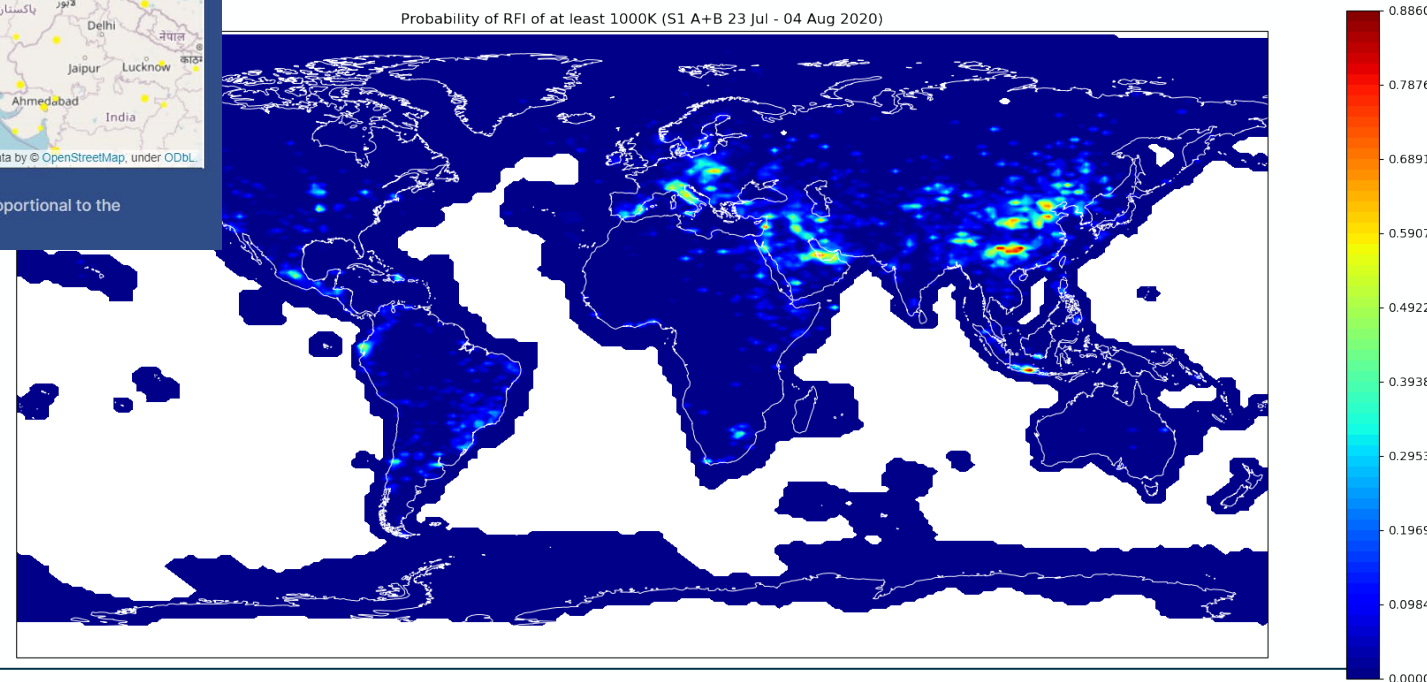
RFI events



Interactive map showing the main RFI events (>2500K) detected by Sentinel-1 during current orbit cycle. The colour/radius of the circle is proportional to the brightness temperature of the RFI event. Click on the circles to show additional information.

- Dedicated website created by Aresys for **RFI monitoring**.
- **Interactive maps** containing information about the major RFI events (BT>2500K).

Probability of RFI of at least 1000K (S1 A+B 23 Jul - 04 Aug 2020)



- **RFI Probability maps** (BT>1000K) showing the most critical areas.
- Archive since January 2020.

Operational RFI pre-screening and mitigation modules

Operational filtering of RFI contamination in Sentinel-1 data was **activated on March 23, 2022**.

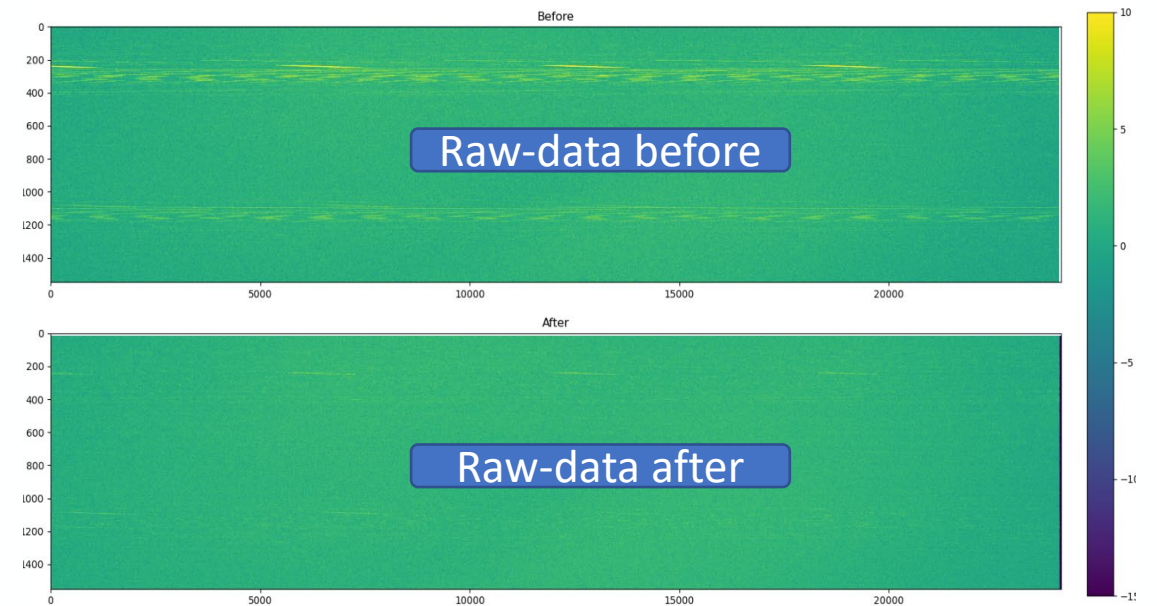
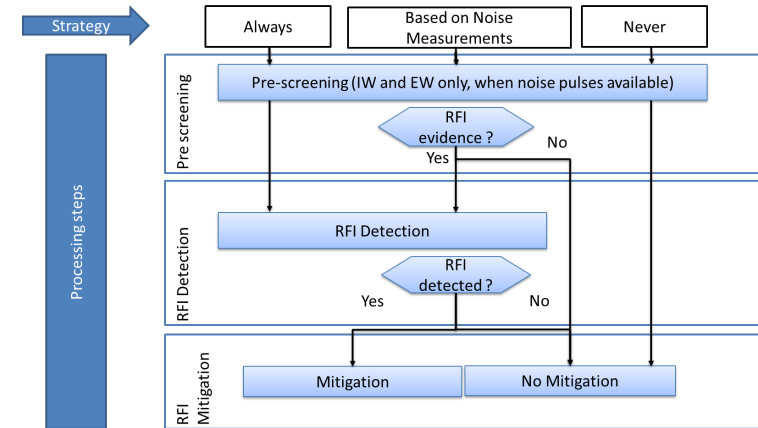
Two steps:

1. **Pre-screening** of noise measurements (few lines, fast)
2. If pre-screening positive, activation of the **detection/mitigation module** (pixel-by-pixel, slow)

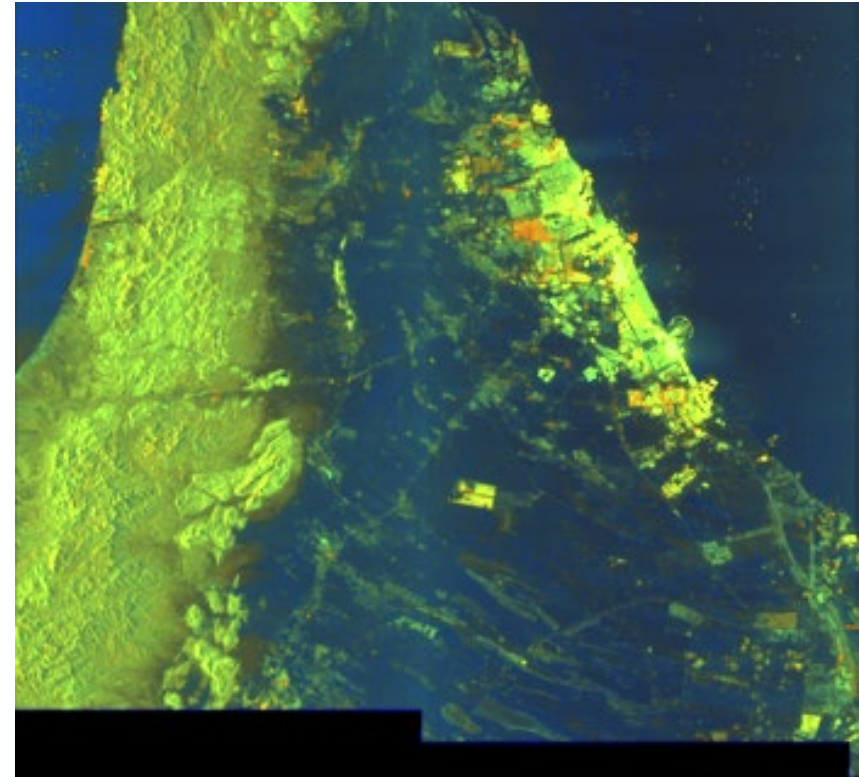
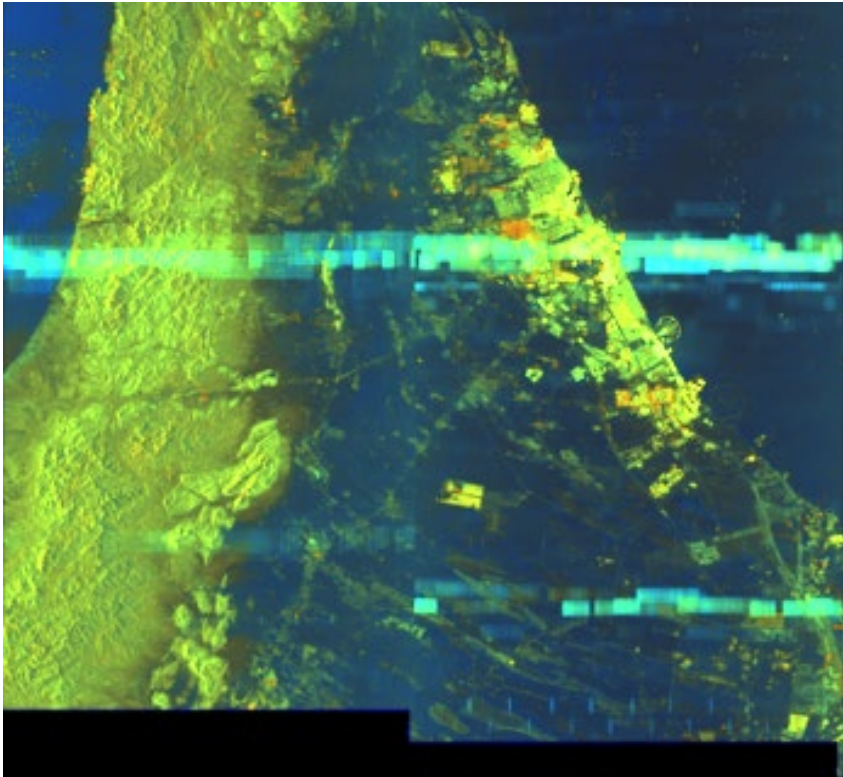
RFI Detection/mitigation module uses two independent algorithms in time-domain and in frequency domain.

Destructive step: it corrects unfocused (raw) data!

New annotation data file provides statistics about affected samples/lines and bandwidth.



Examples of RFI-mitigated products



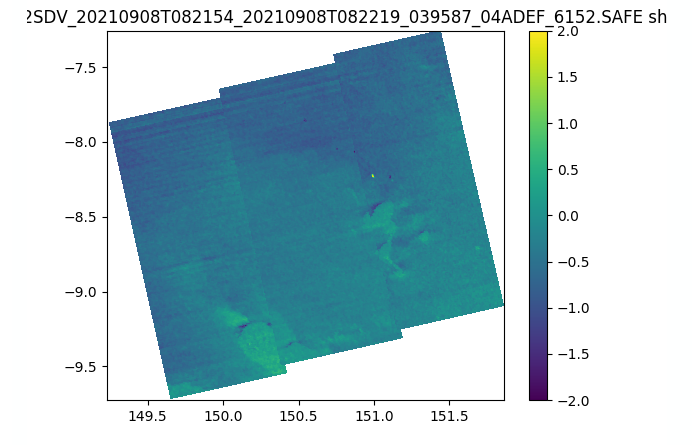
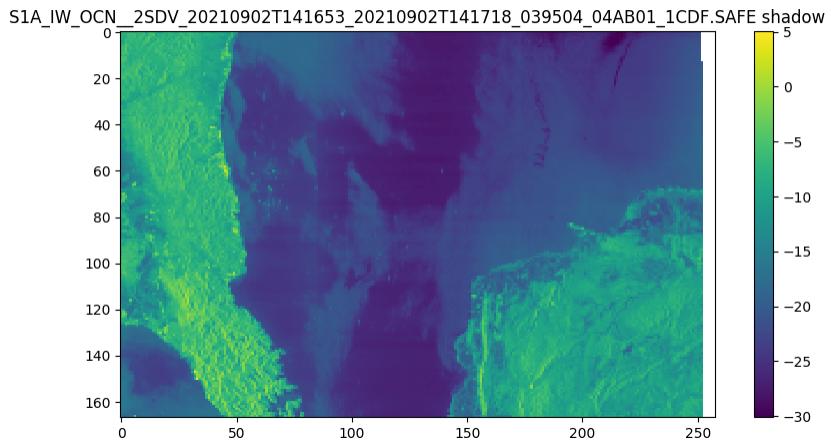
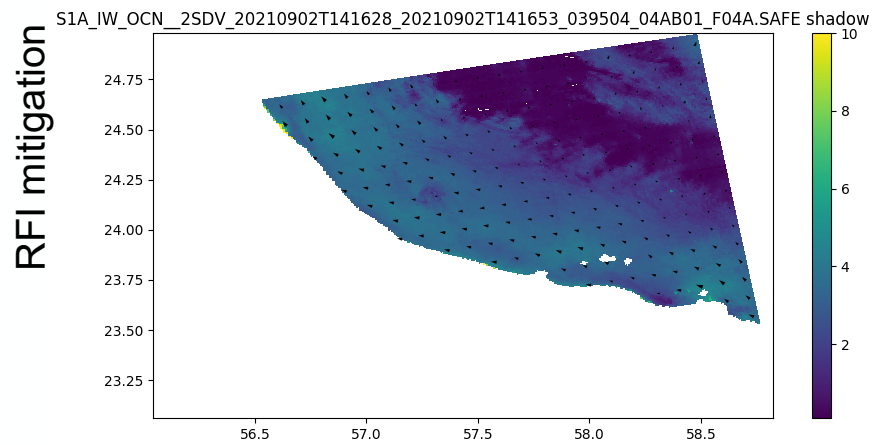
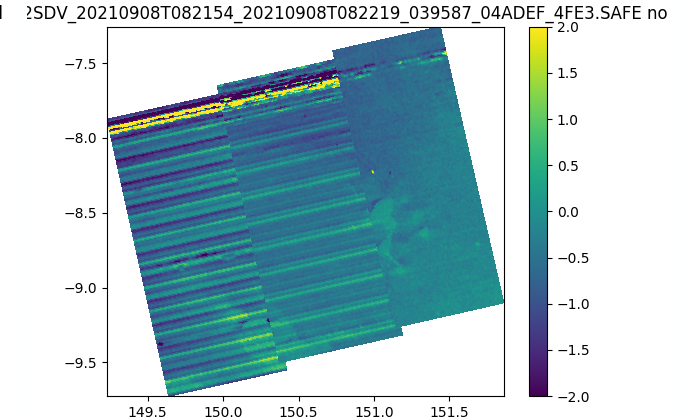
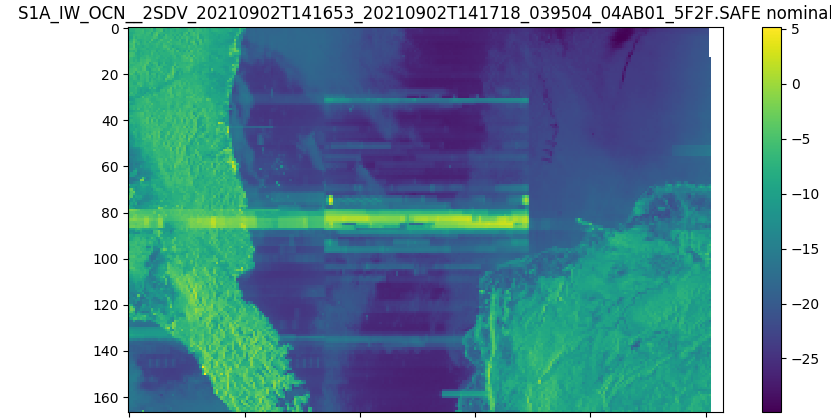
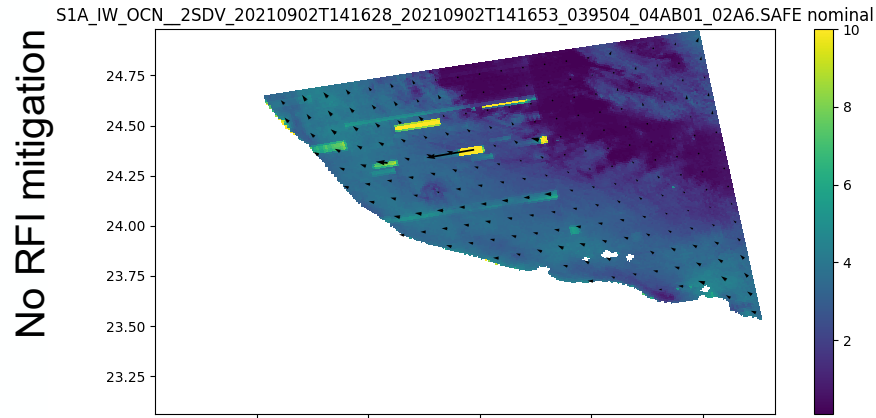
S1A_IW_GRDH_1SDV_20210922T021545_20210922T021608_039788_04B4BE_02A0

Examples of successful RFI mitigation (L2)

OWI wind speed

Intensity

RVL



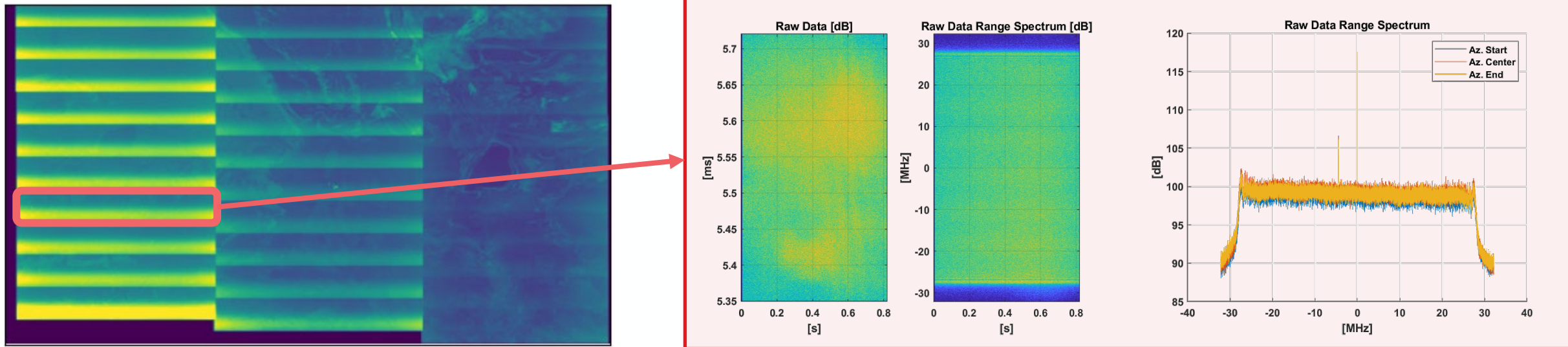
Unsuccessful example: space-to-space RFI

RFI **originated by a space emitter** (likely C-band SAR) operating in a BW almost completely overlapped with S-1

Affected channels are IW1 and IW2 VH only (satellite transmitting in H pol)

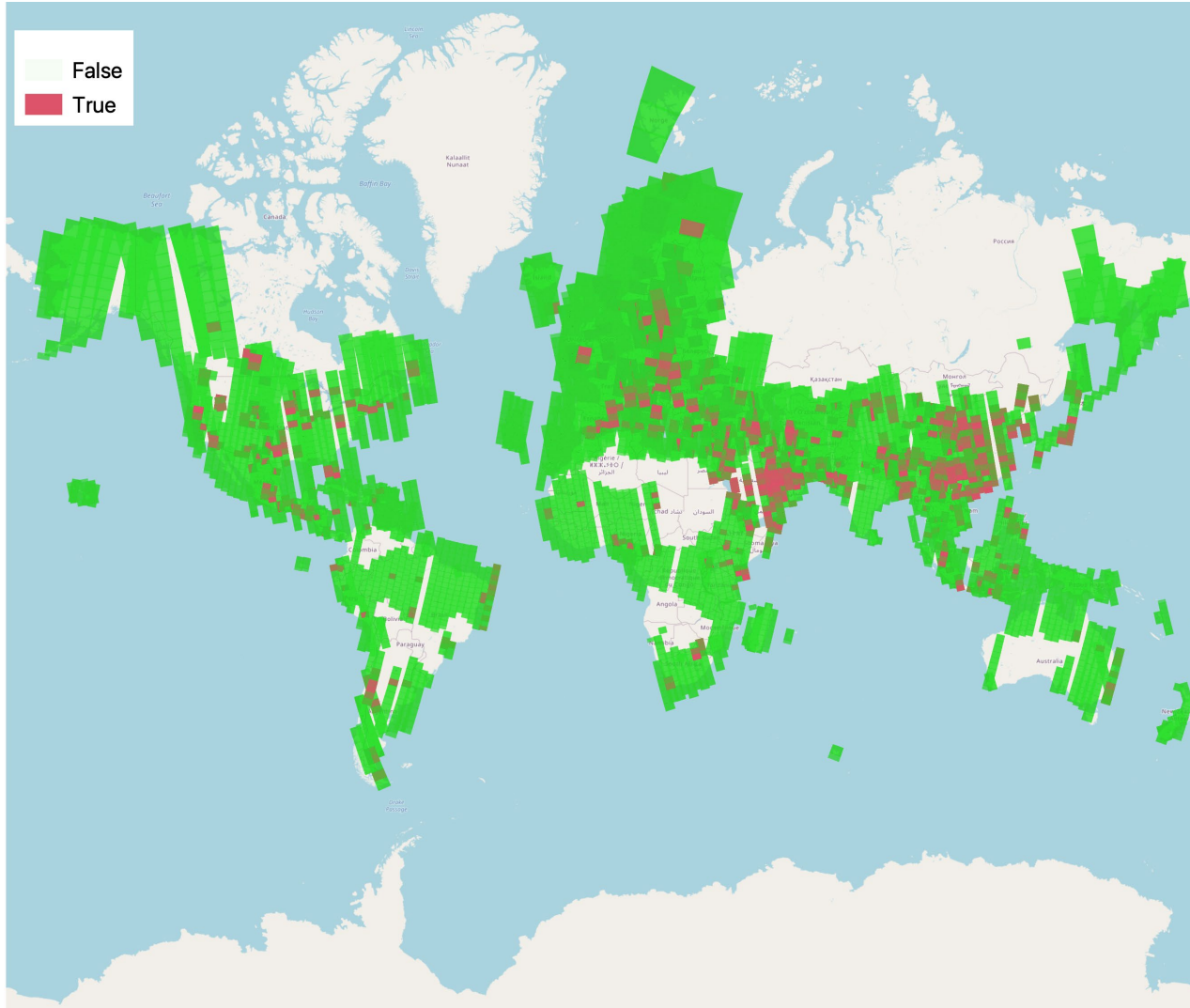
Received RFI signals have characteristics very similar to random noise: RFI pre-screening from rank echoes does not identify them.

In any case, RFI detection/mitigation module **unsuccessful due to the SAR-like characteristics** of the received RFI signals.



S1A_IW_RAW__OSDV_20220403T135746_20220403T135818_042610_051550_BAF8.SAFE

RFI monitoring: statistics of occurrences



S1A SLC products

	IW	EW
Number of product channels	36564	1150
% bursts with RFI detected from noise (pre-screening)	1.17%	0.02%
% mitigated products	17.65%	1.74%

Further reading

Further documentation on RFI detection and mitigation available on Sentinel Online:

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/document-library>

- **Detailed processing model:**
 - explaining how the processor detects and mitigate the RFI
- **S-1 RFI technical note:**
 - Description of RFI related format and usage
- **S-1A & B annual performance report:**
 - Provide examples of RFI and list of known space to space source with location of possible occurrences

