Detection of RFI in Sentinel-3 (STM) Microwave Radiometer data

Sous-titre

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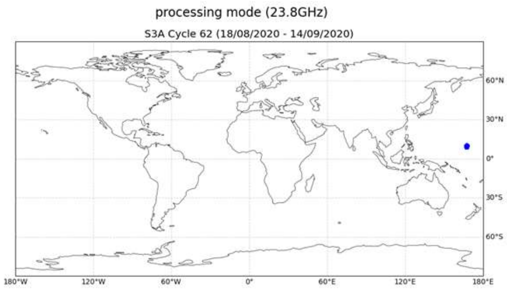
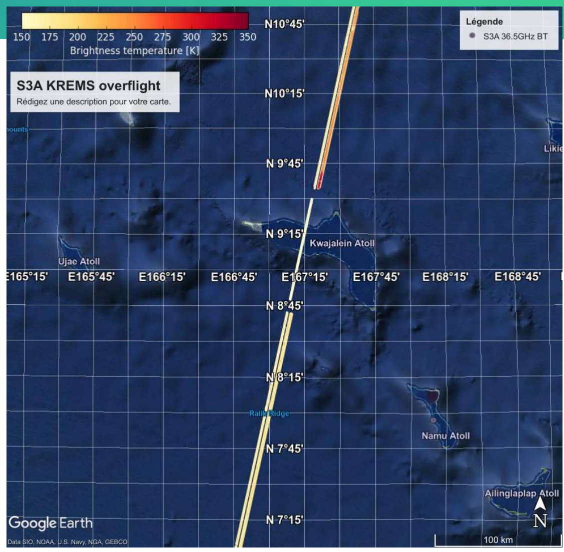
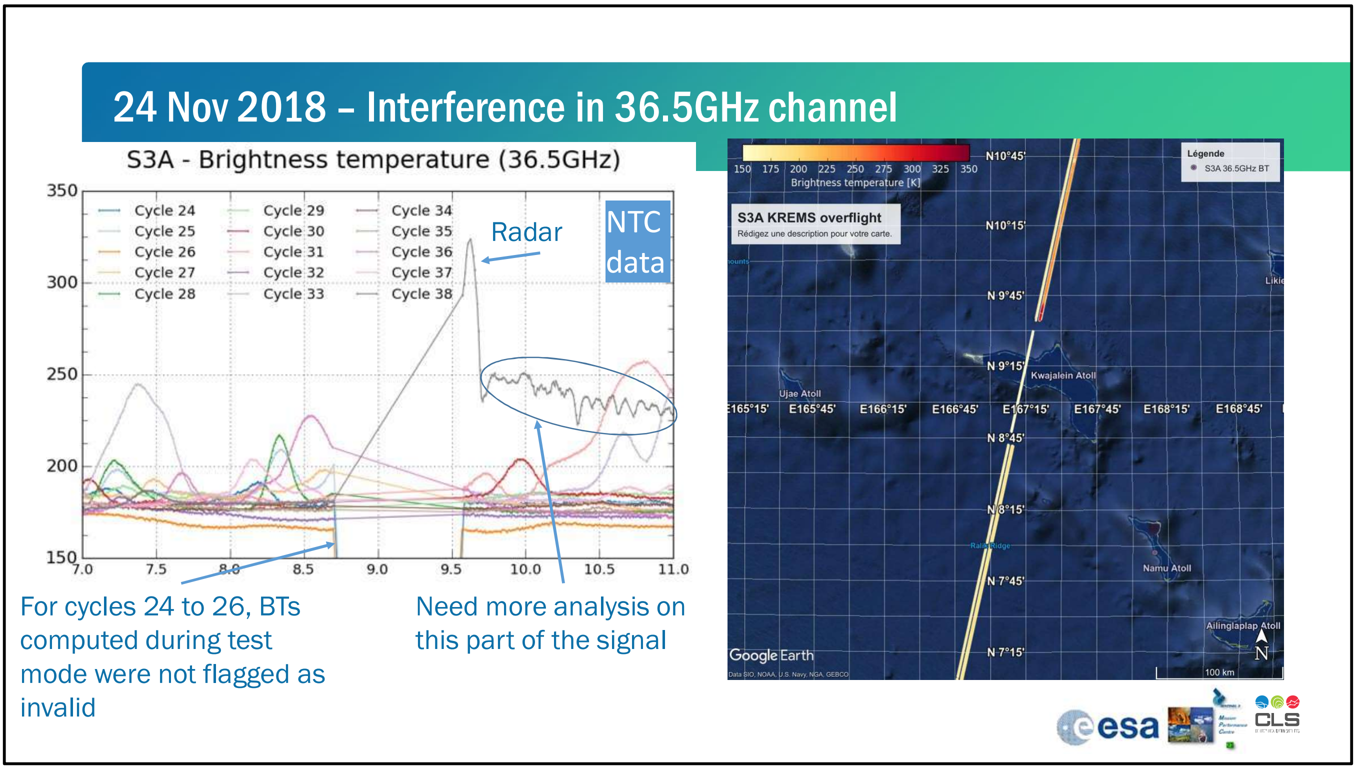
Context

- S3A orbit is such that it flights over KREMS radar facility in the Kwadjalein atoll (Pacific Atoll)
- For safety reason, MWR is switched to a specific mode, 50km before and after the radar facility



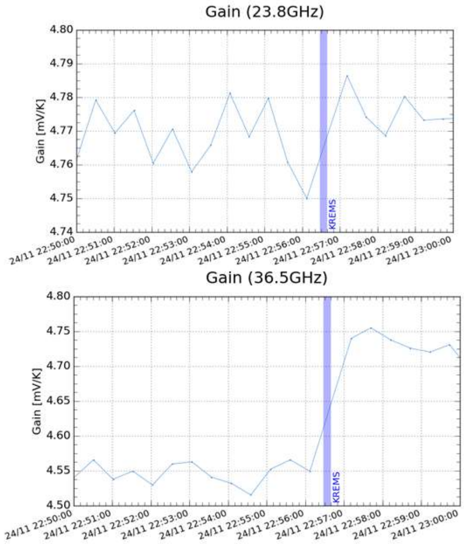


S3A orbit is such that it flights over the KREMS radar facility in the Kwadjalein atoll in the Pacific Atoll. The map shows the position of facility. To avoid any interference and damage to the instrument, the MWR is switched to a specific mode at a given distance before and after the radar facility. At the beginning of the mission, the MWR was switched 50 km before and after the facility.

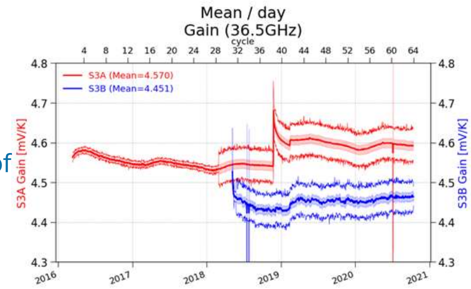


Unfortunately, the 24th November 2018 an interference of the 36.5GHz channel was detected on the brightness temperature. As you can see in the figure on the left panel, the brightness temperature for the previous cycles is consistent with geophysical signals. However for cycle 38, the signal is clearly not geophysical with high frequency oscillations at the facility approach and a peak value higher than 320K. The highest values has a gaussian shape, conistent with a radar interference.

24 Nov 2018 – Interference in 36.5GHz channel

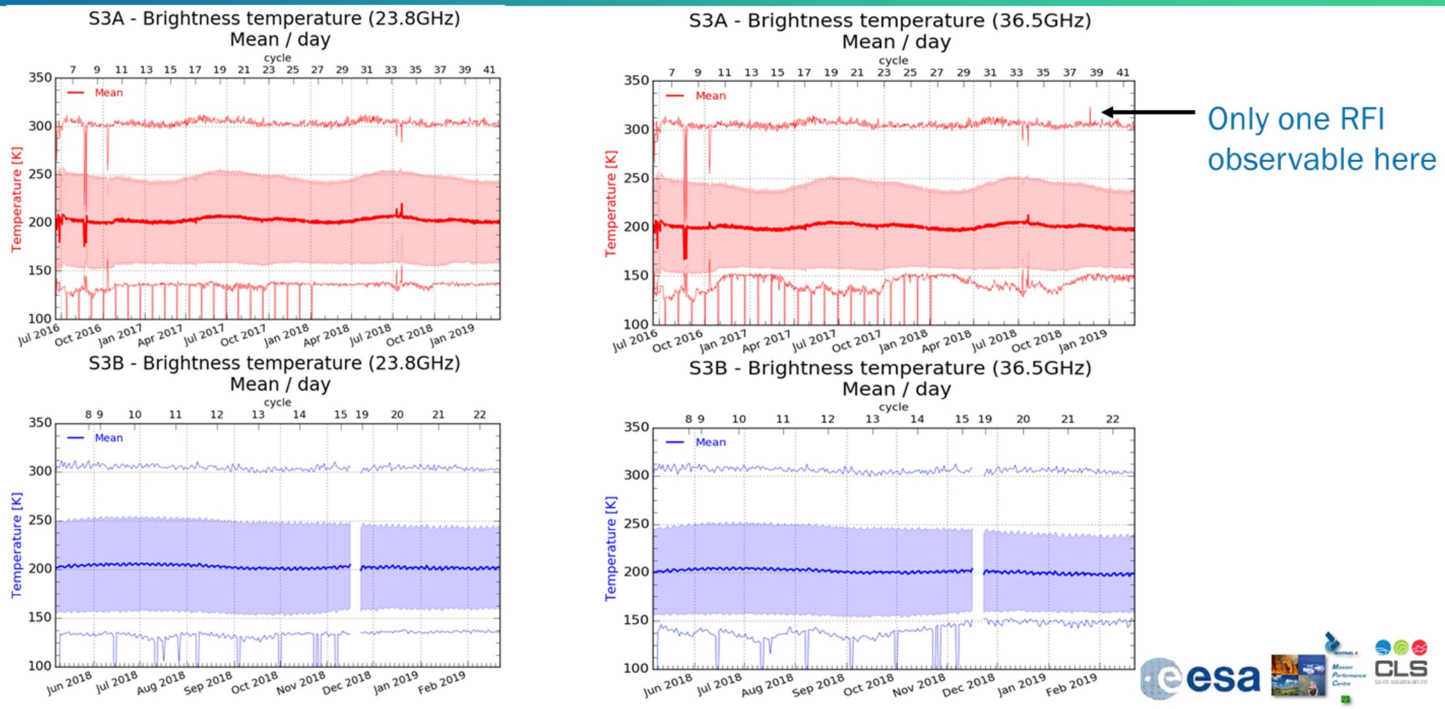


- 36.5GHz receiver gain is the calibration parameter the more impacted
- The gain is changed on a long-term point of view



Calibration parameters for the 36.5GHz channel were impacted by the interference. The recever gain of this channel has a different level after the interference. After the intereference, the operating point is different than before. Moreover the long-term monitoring did not get back to its initial state. The analyses carried out did not highlight any impact on the brightness temperature, confirming that the instrument is still correctly calibrated with the in-flight two-points calibration. The instrument has been stressed by this interference, and fortunately, there was no impact on data quality. However, the instrument could not suffer too many of these interferences before suffering irremediable damage. Consequently, actions were taken to protect the instrument, consisting in the enlargment of the safing zone.

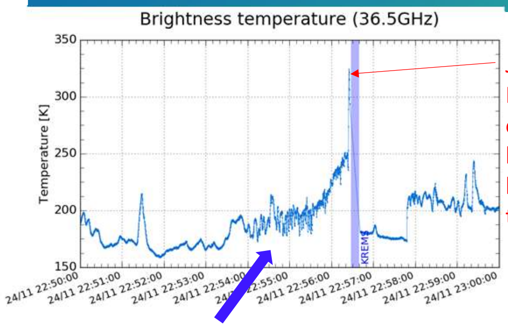
Monitoring of S3 BT (L1 - 7Hz)



This event was the first of its kind on Sentinel3 data as confirmed by these plots. Daily statistics of the brightness temperatures are presented here for both channels of S3A and S3B. On these graphs, the average is shown with the bold line, the shade representing the standard deviation; finally minimum and maximum are represented by the lower and upper light lines. Only one event is noticeable for channel 36.5GHz channel of S3A.

This event was of exceptional amplitude but we can wonder if there has been other interferences of smaller amplitude. If there have been some, these events would not be as dangerous for the instrument, but they could degrade data quality by adding an artifical signal to the geophysical one.

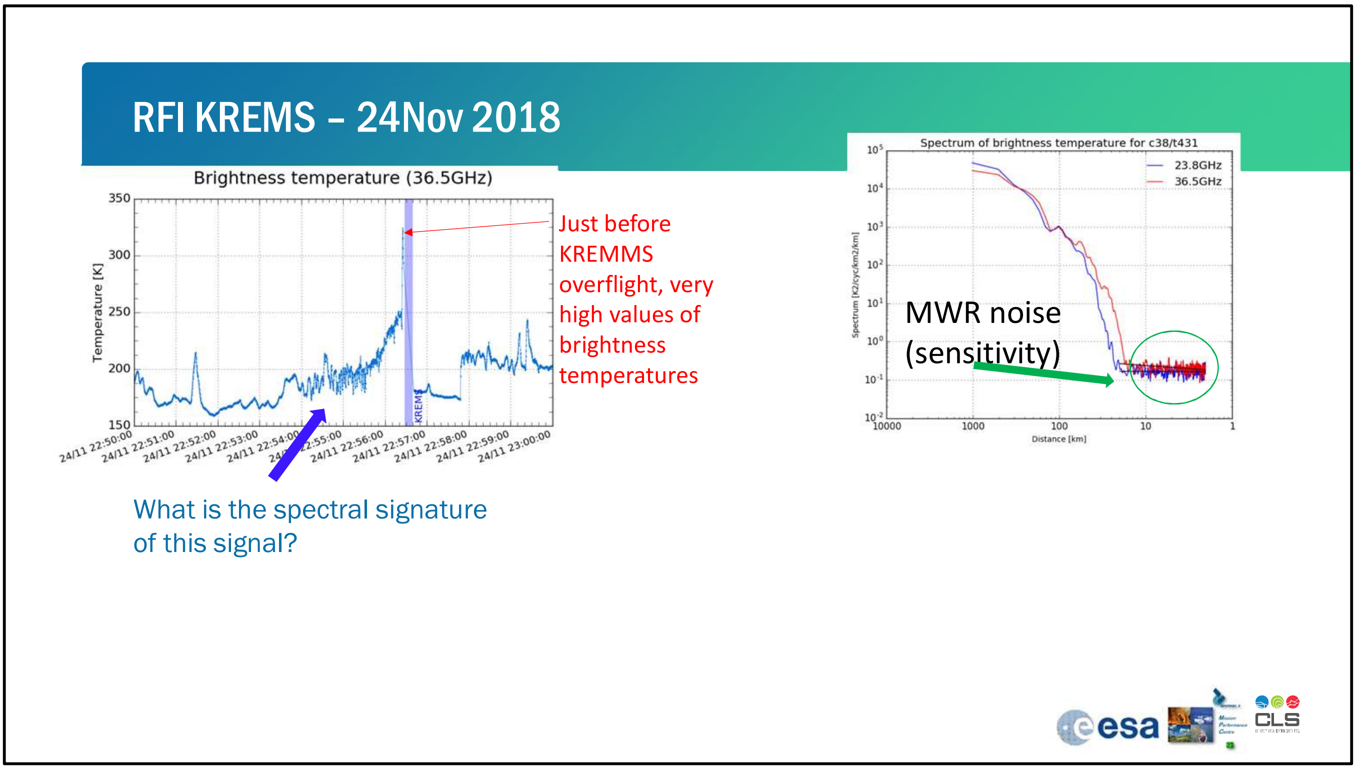
RFI KREMS – 24Nov 2018



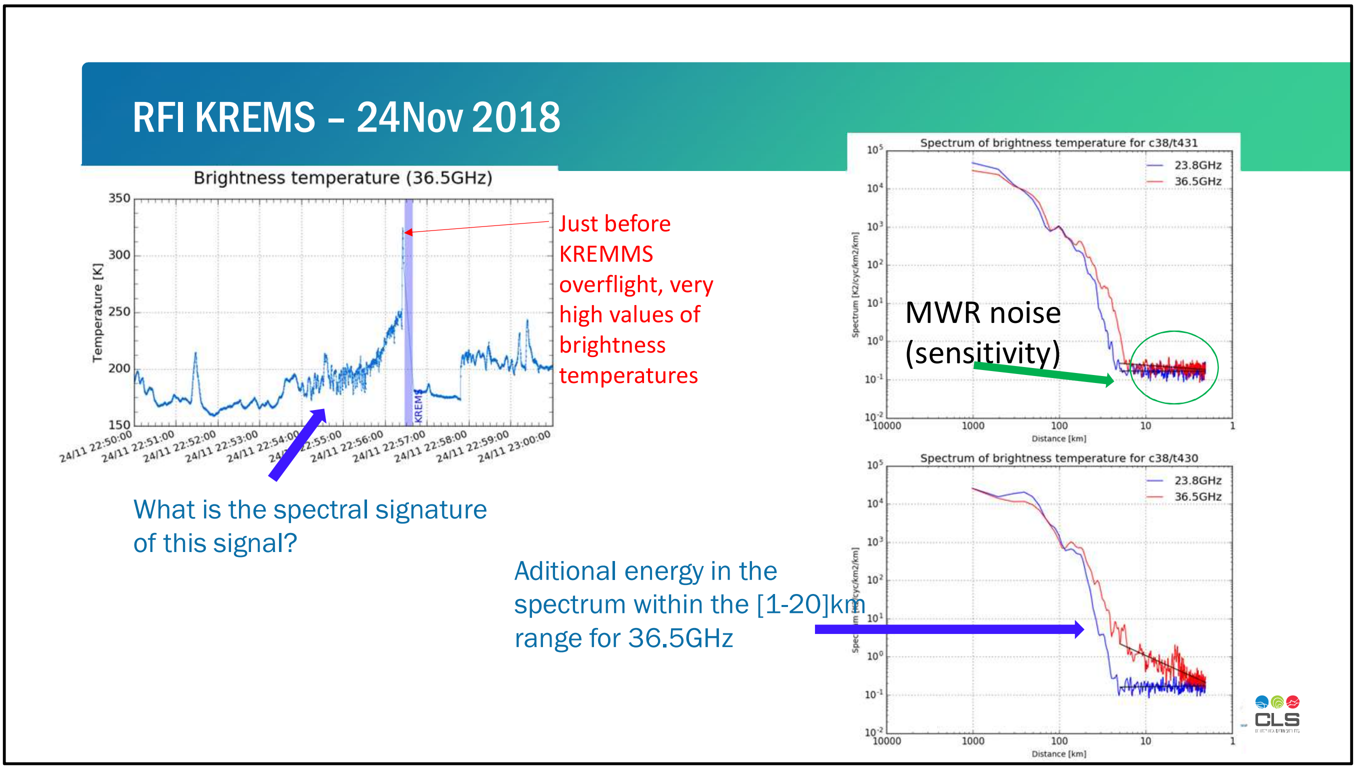
Just before KREMMS overflight, very high values of brightness temperatures

What is the spectral signature of this signal?

Let's get back to the event of 24th November 2018 and look at the signal. One can notice a high frequency signal just before the peak value. This signal is not a natural signal, and shall have a signature. What is the spectral signature of



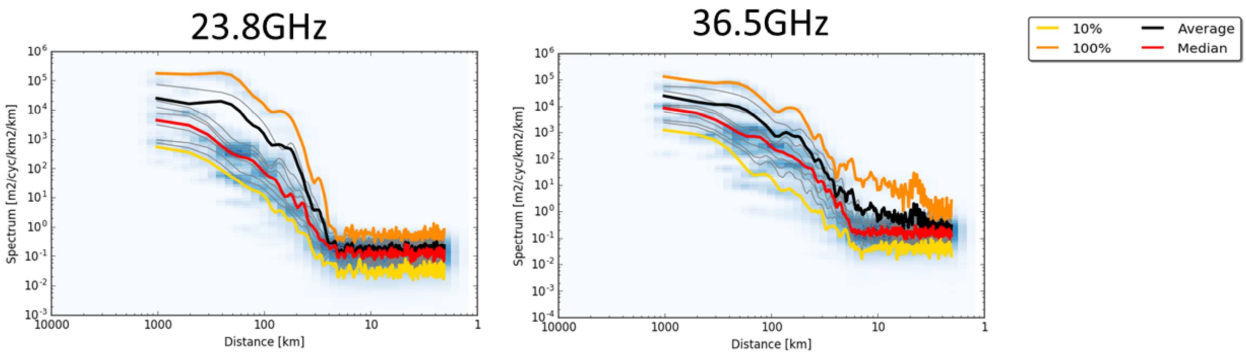
Let's get back to the event of 24th November 2018 and look at the signal. One can notice a high frequency signal just before the peak value. This signal is not a natural signal, and shall have a signature. What is the spectral signature of this signal?
First let's have a look at the spectrum of brightness temperatures of a normal situation with data of pass 431 for both channels. For this diagnosis it is important to have the MWR data at the sampling of 7Hz, ie data not averaged., to have access to the noise plateau. On a normal signal, we observe a decrease of energy for scales up to the resolution of the MWR pixel. Below the resolution of the pixel, only noise is expected which is the sensitivity.



Now looking at the particular event of 24th Nov (pass 430), we observe that the 36.5GHz channel represented with the red line is not flat as expected but presents a slope, highlighting additional energy in these scales, where only noise is expected.

Detection of lower impact RFI?

- Spectra for pass 430 of cycle 38 (RFI over KREMS)

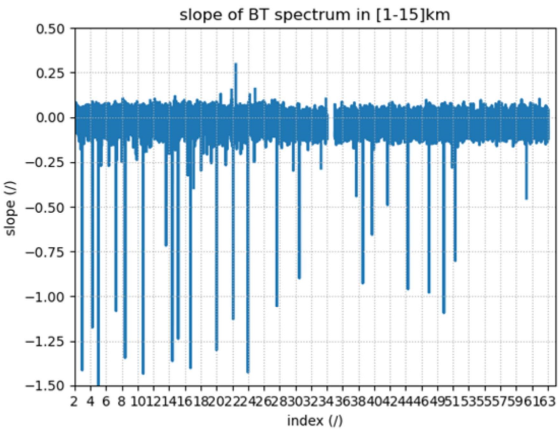


- 23.8GHz as expected: flat average spectra for distance from 5 to 20 km (noise of the MWR)
- 36.5GHz : high energy from 5 to 20 km – median spectra not impacted but average spectra is !
- Can we detect other RFI using the slope of the spectrum?
- Can we find the segments impacted by the RFI?

The computation of the spectrum for each pass is performed by splitting data in segments. The spectrum is computed for each segment, and then averaged to reduce the noise. thus we can look at the envelop defined by all the spectra, and the percentile statistics . The average is shown with the black bolld lines and the median with the red lines. For the 23.8GHz channel, spectra of all segments are flat in the 5-20km scales, while for the 36.5GHz all spectra are not flat. We can see that the average and median spectra are different, the average spectrum being impacted with some very energetic segments.
Using this diagnosis, we can wonder if we will be able to detect other RFIs ? And if we will be able to locate the segments impacted by the RFI?

Detected RFI - S3A

- Slope of Brightness Temperature Spectrum, cycle 2 to 63 processed
- 23 RFI detected only for 36.5GHz channel

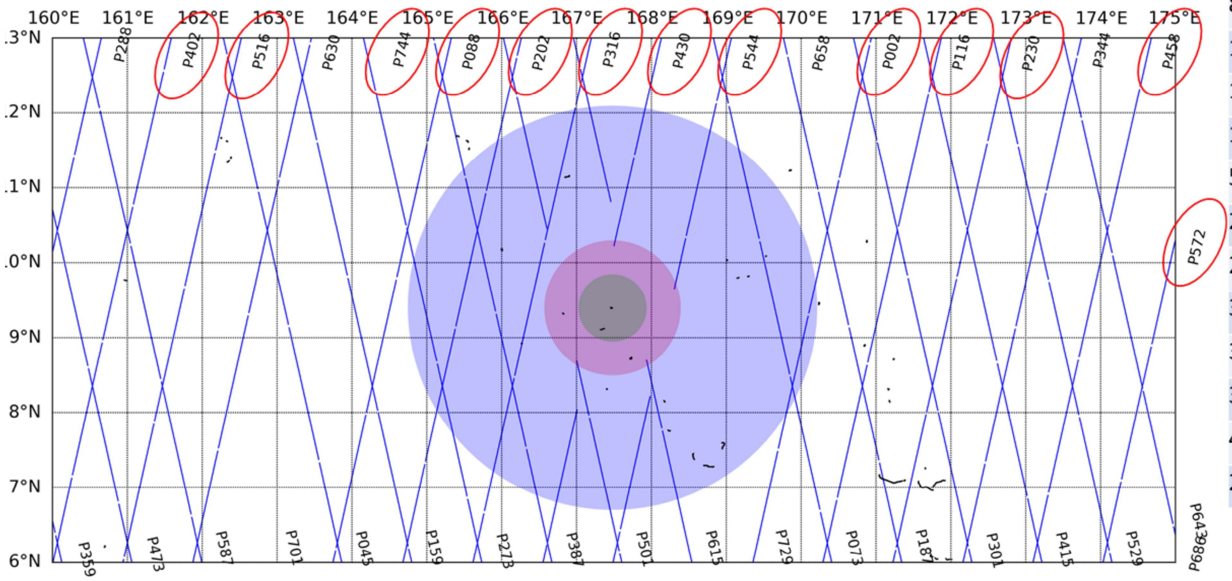


cycles	pass
4, 7	202
8, 14	316
10, 16, 20, 41	544
13	458
15	116
5, 20, 24	2
22	88
27	516
30	402
34, 37, 39	572
38	430
44	230
2, 46	744

S3A data were processed following the method described earlier. This method allowed the detection of 23 RFI from cycle 2 to 63, only for the 36.5GHz channel. The table on the right summarizes cycle and pass number of all events detected. Some wrong detection can be due to missing data in the pass.

Spectral analysis - S3A

- Slope of Brightness Temperature Spectrum, cycle 2 to 63 processed



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5, 20, 24	2
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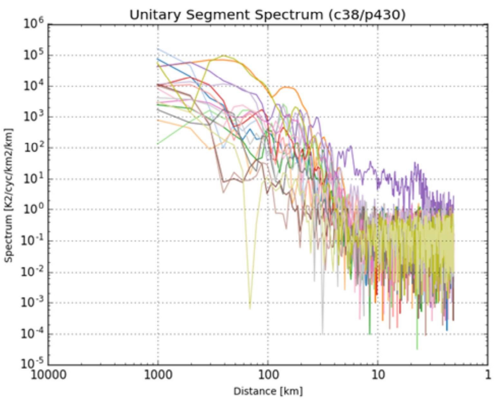
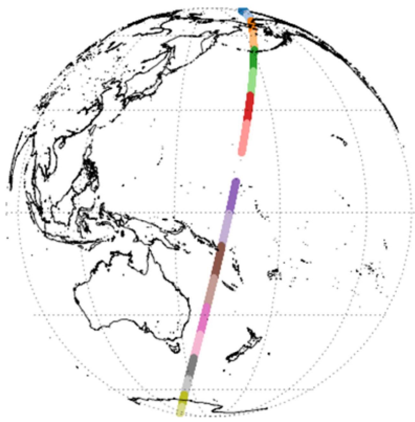
34, 37, 39	572
38	430
44	230
2, 46	744

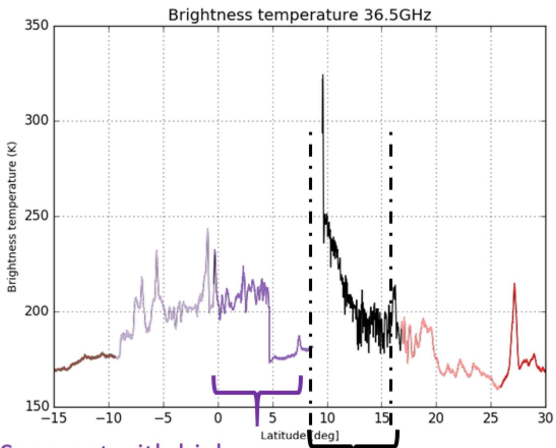
This map shows all the passes found to be impacted by interference. Around the radar facility are showed circles limiting the initial 50km safing area, 300km area defined after the interference of Nov 2018, and the final 100km safing area. The impact zone is quite large as you can see as passes several degrees in longitude can be impacted.

Detected RFI: cycle 38/ p430

- Analyse of Slope of Brightness Temperature Spectrum : c38/p430







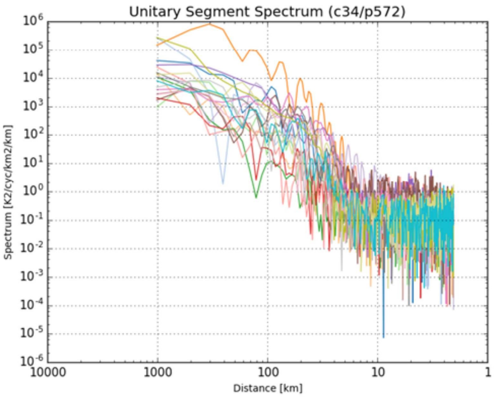
Segment with high energy spectrum

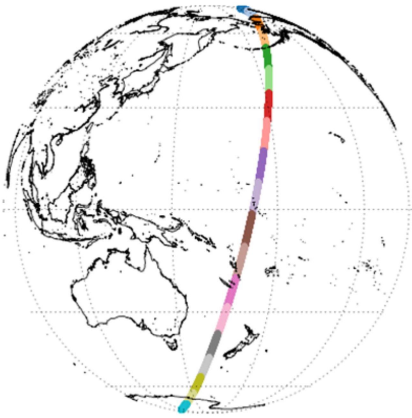
Incomplete segment due to area safing, no spectral analysis

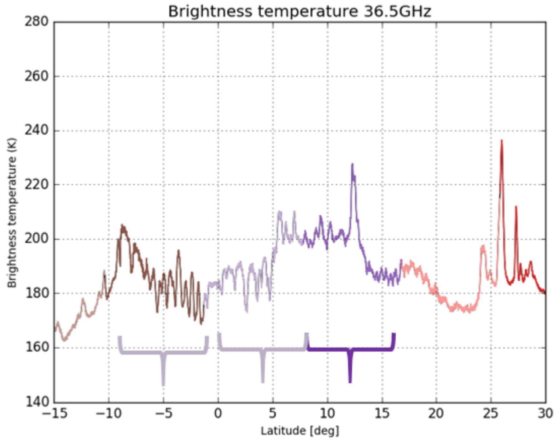
Now I show figures generated by the detection tool for some examples. The first one is the case of the 24 Nov 2018. The graph on the left represents all the unitary spectra computed for all segments along the pass. The unitary sepctra are noisy when taken one by one. But this is not what is important here as we are looking for some very different spectra. The middle graph provides their location, and the graph on the right the brightness temperature of the 36.5GHz. Each segment is associated with a color. We can see that a particular segment shows a very energetic spectrum, and that this segment is located near the KREMS facility location.

Detected RFI: cycle 34/ p572

- Analysis of Slope of Brightness Temperature Spectrum: c34/p572







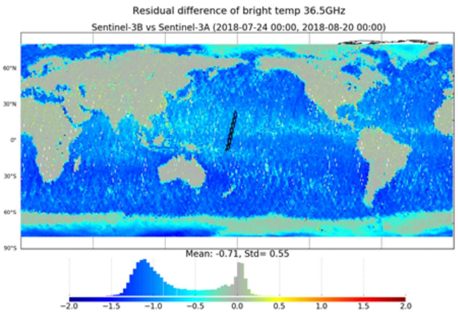
Segments with high energy spectrum

Here is another example. Again the high energetic segments are located close to the KREMS facility. But this example is also particular because it occurs during the tandem phase with S3B.

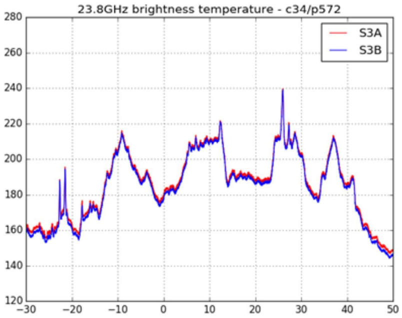
Detected RFI: cycle 34/ p572

- Analysis of Slope of Brightness Temperature Spectrum: c34/p572

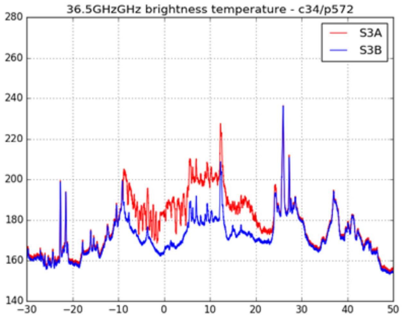
  This pass was already noticed during S3A/S3B tandem phase (S3B c11/p572)



Map of the residuals of the difference S3B-S3A



TB 23.8GHz for S3A&S3B
Cycle 34/ p572



TB 36.5GHz for S3A&S3B
Cycle 34/ p572

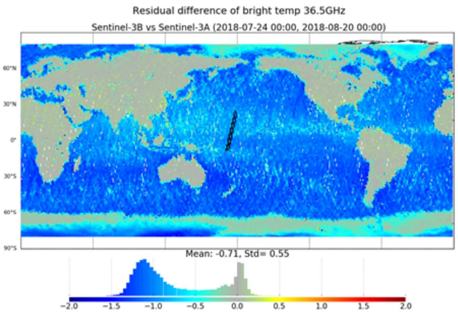
Here you can see a map of the residuals of the difference S3B-S3A, after calibration of S3B, for cycle 34 of S3A (cycle 11 of S3B). We can notice two black lines in the Pacific close to the location of the KREMS facility. One of these lines corresponds to the pass 574 of cycle 34. The two graphs on the right show the brightness temperatures for both channels for S3A and S3B. For the 23.8GHz channel, the signals are nearly identical for both instruments. However for the 36.5GHz, the S3A signal is different of S3B for a part of the track. For this example, the interference increase the brightness temperature of about 20K. The total temperature is still within validity thresholds, but will of course degrade the restitution of the wet troposphere correction of several centimeters.

Detected RFI: cycle 34/ p30

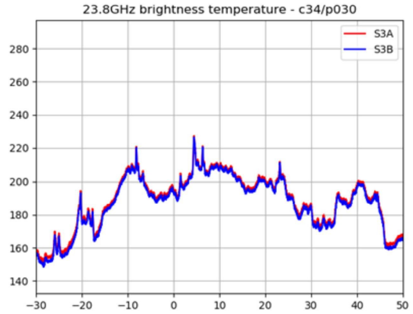
- Analysis of Slope of Brightness Temperature Spectrum: c34/p30

Not detected

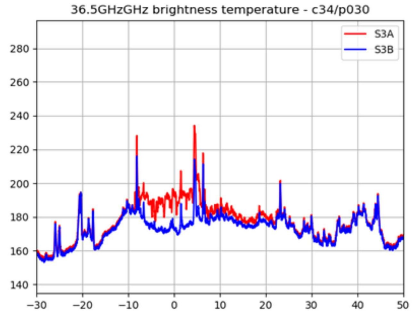
This pass was already noticed during S3A/S3B tandem phase (S3B c11/p30)



Map of the residuals of the difference S3B-S3A



TB 23.8GHz for S3A&S3B
Cycle 34/ p30

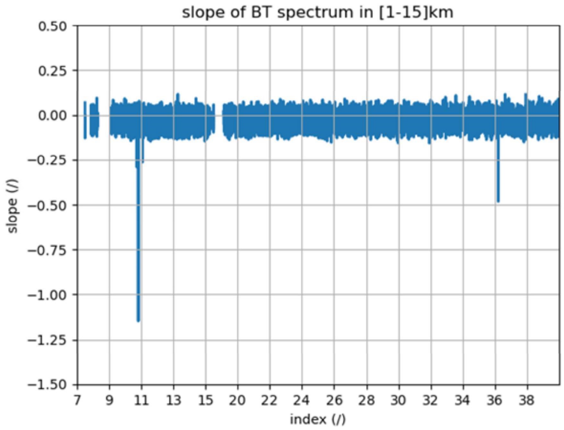


TB 36.5GHz for S3A&S3B
Cycle 34/ p30

However the second interference noticed on the map was not detected using the slope of the spectra. You can see that the additional signal in the brightness temperatures is smaller than in the previous example but still significant.

Spectral analysis - S3B

- Slope of Brightness Temperature Spectrum, cycle 998 to 28 processed



Only cases with incomplete data

S3B have been processed also and no RFI have been dectected with this technic. Only cases with incomplete data has been found.

Conclusion

- S3A has known an interference of exceptional amplitud which change its operating point
- A method of detection of interferences with smaller amplitude has been developed and allowed to detect 23 other cases,

- Some of them occured during the tandem phase, that allowed to confirm the interference
- But also showed that some are not detected

- Impacted data shall be flagged in the product in order to inform users of the degraded quality of the wet troposphere correction