Analysis of Radio Frequency Interference (RFI) from 6.9 to 89 GHz in an NWP system

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Abstract

Although RFI has not yet affected key MW sounder bands, there is increasing pressure from telecommunications at 23 GHz and up. The sounder community needs to be ready with detection and mitigation strategies, applicable at a range of frequencies.

Unnatural emission in the microwave spectrum can be analysed using an NWP system, with the presence of RFI manifested as positive background departures (i.e. high O-B). The NWP model background is a source of significant a priori knowledge for analysis of RFI. Analysis with an NWP model thus serves as both a method of verifying observations flagged as potentially RFI-affected and a way to detect and possibly attribute RFI.

First, this study assesses externally-produced RFI flags from Zenithal Blue Technologies (ZBT) with departure-based analysis for the year 2022. As the ZBT method is model-agnostic, analysis of O-B statistics of flagged data validates its approach. The study focused on the AMSR2 and AMSU-A instruments, finding that there are significant direct and reflected sources of RFI at AMSR2 bands from 6.9, 7.3, 10.65, and 18.7 GHz. No significant sources of RFI are corroborated at AMSR2 or AMSU-A bands from 23.8 GHz and up.

Second, O-B at C-band frequencies on AMSR2 (6.9 and 7.3 GHz) are used to identify RFI. This simple O-B screening helps to remove C-band RFI prior to assimilation.

Third, some RFI signals over sea can be traced back to reflected RFI from geostationary broadcast satellites. To isolate these signals, O-B statistics were evaluated for glint conditions, allowing attribution of likely RFI source locations in GEO orbit. This knowledge can be used to screen affected observations prior to the assimilation.

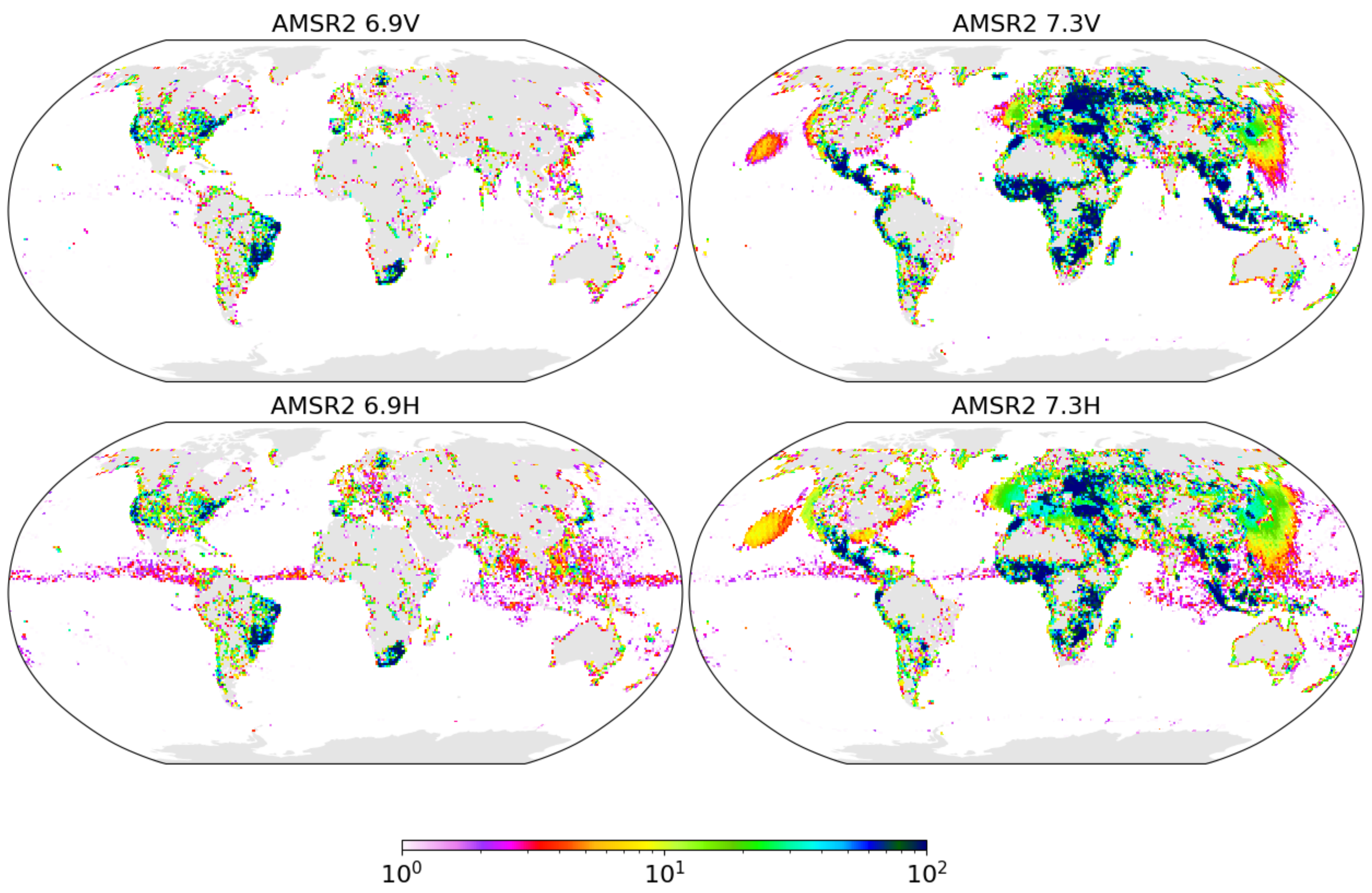
2. Spectral Differences at C-band

AMSR2 has a 7.3 GHz channel to aid in RFI detection at 6.9 GHz

- By using O-B differences at C-band, we can isolate small (~1K) observed anomalies between these channels
- RTTOV simulations at these nearby bands are nearly identical even in deep convection
- Our interest is in 6.9 GHz, but can apply for detecting 7.3 GHz RFI too
- Detected RFI has positive difference due to RFI signals being positive in observations (e.g. here for 6.9V):

$$\Delta_{RFI} := (O_{6.9v} - B_{6.9v}) - (O_{7.3v} - B_{7.3v})$$

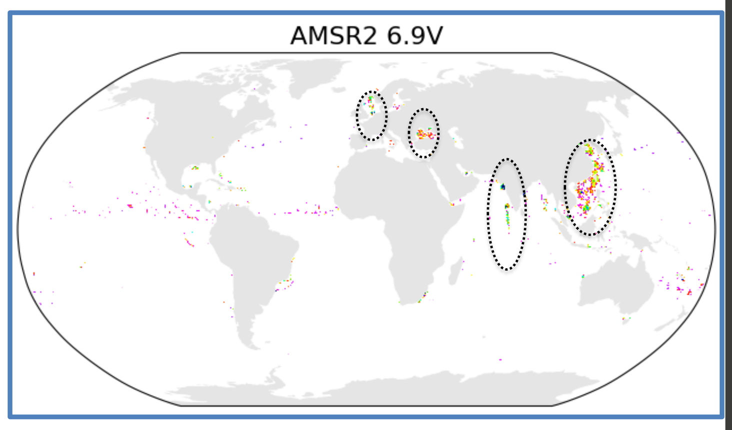
- Set a nominal threshold of 2K
- Need to balance instrument noise, false positives, and desired RFI sensitivity



Frequency of flagging for AMSR2 observations using 2K threshold. Data from summer 2022.

Conclusions

- C-band contamination is widespread over most populated regions, with 7.3 GHz RFI especially prevalent
- Reflected RFI common at 7.3 GHz (seen in Wu et al. 2020)
- Some false positives in deep convection at H-pol in particular – these may be due to non-linearity correction of AMSR2 observations
- *Method is effective at isolating 6.9 GHz point sources over sea, the one C-band channel and surface type assimilated in IFS*



As above but showing data over sea only. Areas highlighted for significant RFI include the North Sea, Maldives, South China Sea, and Black Sea.

Conclusions

- No corroborated RFI found at key MW sounder frequencies (yet), but the period of study was 2022 – *more up-to-date knowledge is needed for the operational community as pressure increases from telecommunications*
- Spectral difference method is simple way to mitigate C-band RFI on AMSR2, and will be applied to X-band on AMSR3 (with extra 10.25 GHz band) in the future
- Attribution analysis of reflected RFI permits sophisticated mitigation for MW imagers at ECMWF, though new sources would require manual analysis and intervention
- As ECMWF moves to active assimilation of 6.9 and 10.65 GHz channels from AMSR2 and GMI in late 2025, *RFI mitigation is now a necessary consideration to allow use of these key SST frequencies*

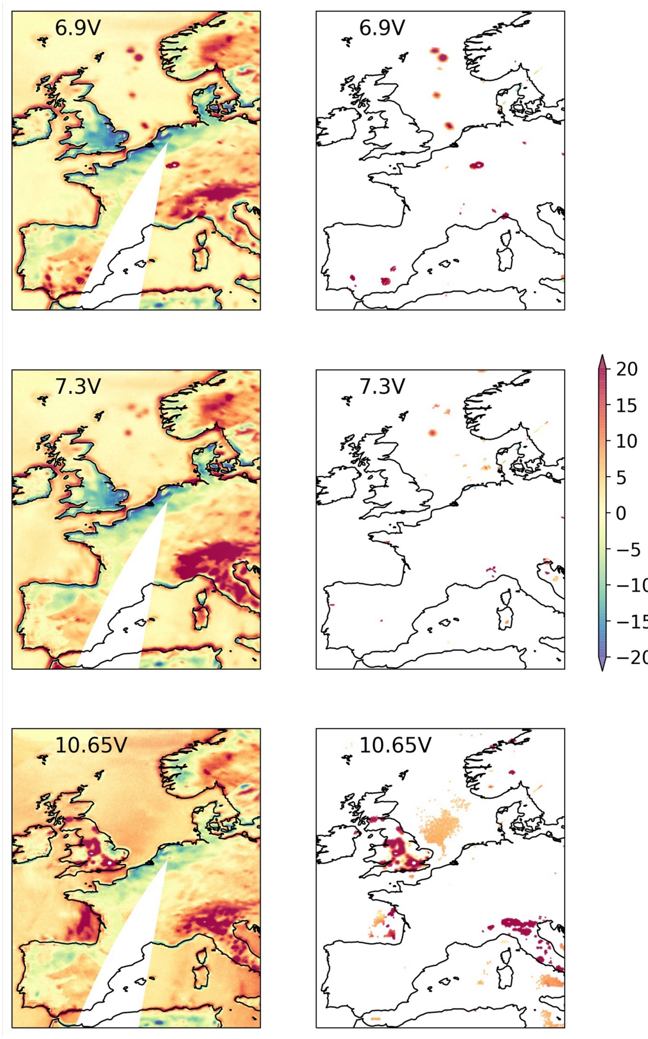
1. Assess External RFI Detection via NWP

Use O-B to validate EORFIScan detection algorithm

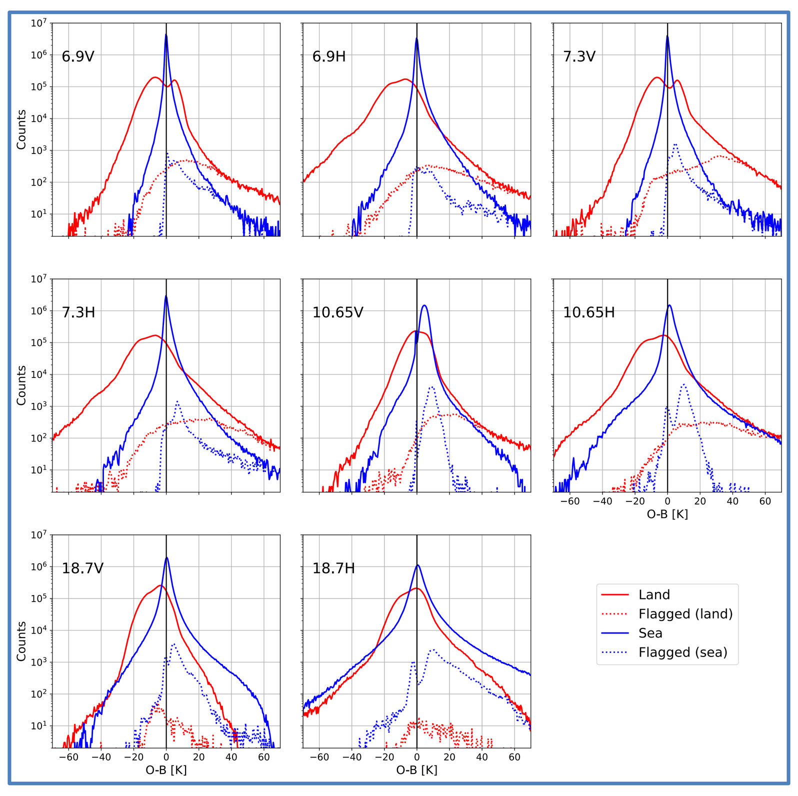
- Analysis of O-B for RFI-flagged data helps separate physical signals from artificial ones, as IFS background simulations do not include man-made sources
- For scenes with high confidence in IFS radiative transfer, use O-B to assess RFI flags quantitatively; frozen surfaces, high orography, etc. are excluded
- **Focus here is on AMSR2 6 to 18 GHz**, as no significant RFI was found in AMSU-A radiances or at 23+ GHz bands

Conclusions:

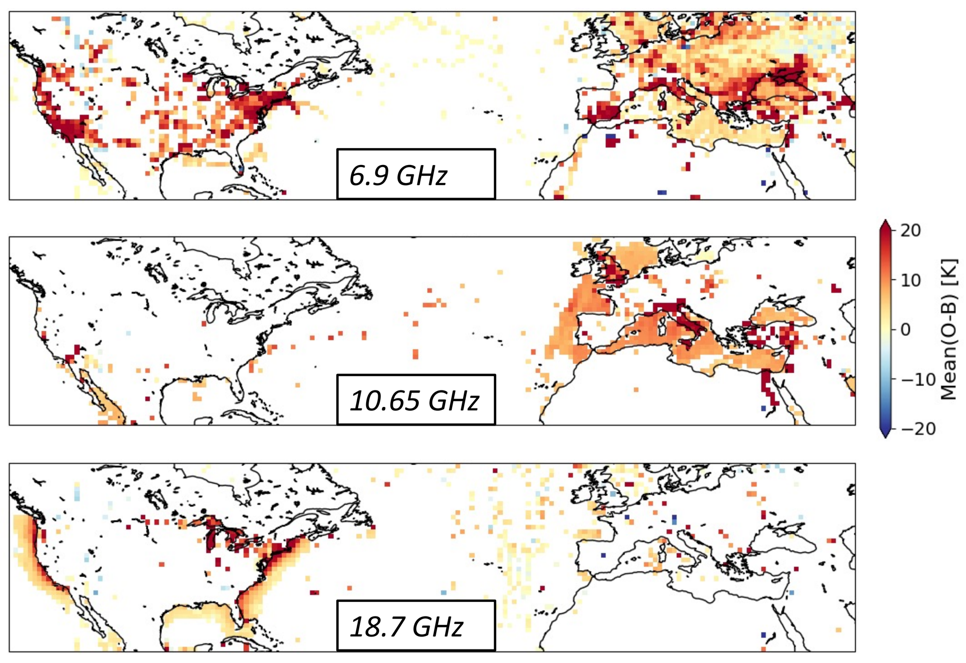
- Significant contamination found by EORFIScan at 6.9, 7.3, 10.65, and 18.7 GHz bands of AMSR2
  - *First documented point sources of 6.9 GHz RFI over sea*
  - Contaminated regions mostly match those in the literature
- NWP-based assessment finds positive mean departures for most observations flagged as RFI
- Detection struggles with coastlines and may be too conservative for some NWP usage where 2-5K sensitivity is needed
- *Analysis was for 2022 – real-time monitoring would be ideal to catch new sources of RFI contamination*



Swath-level O-B for all data (left) and RFI-flagged data only (right) from AMSR2 on March 2, 2022



Histograms of O-B for AMSR2 in March 2022, covering the region of North America and Europe seen on the right

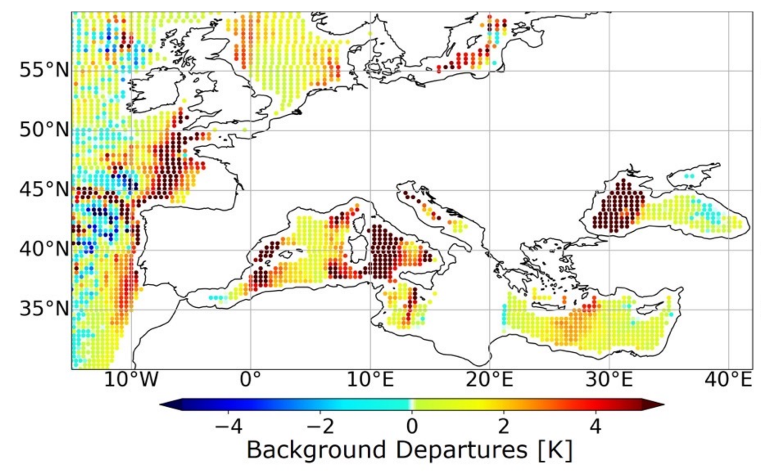


AMSR2 V-pol mean O-B for March 2022, RFI-flagged data only

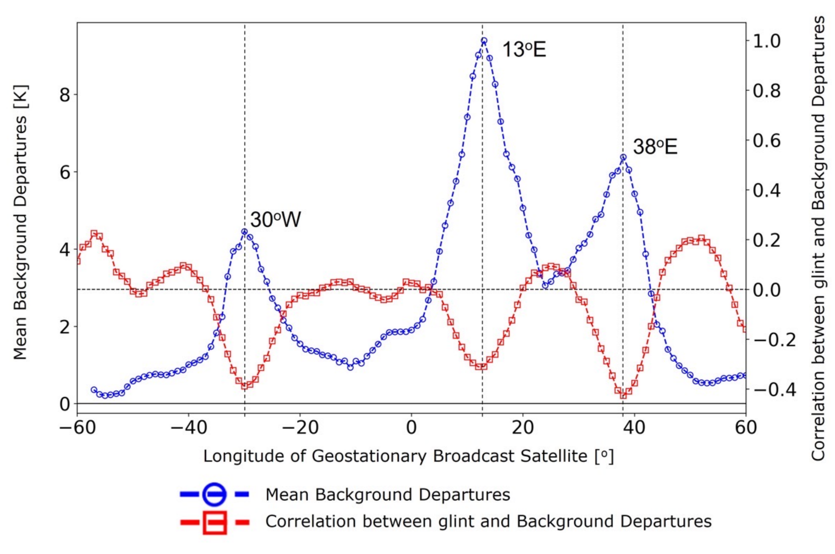
3. Find Reflected RFI Sources at X-band

Reflected RFI due to geostationary broadcast satellites over Europe is a known problem

- This is an issue for assimilation of AMSR2 10.65 GHz, key for use in the SST analysis
- RFI manifests in descending orbits at specific glint angles
- 'Scars' of positive O-B in swath-level data (see right)
- *Normal QC procedures not enough to remove harmful signals*



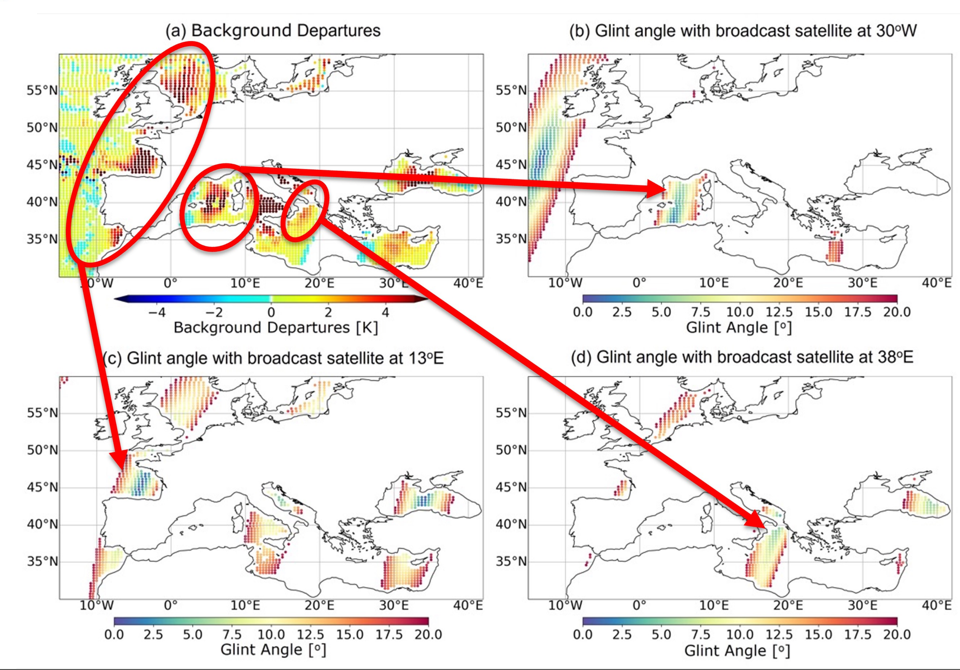
AMSR2 10.65V O-B, June 2nd 2022



Mean O-B from theoretical GEO transmitters spaced at 1deg intervals, considering glint angles < 3° only. Correlations consider glint angles < 10° only.

Link signals to theoretical emitters in GEO orbit

- Using departure-based analysis, find correlation between positive O-B and some GEOs at low glint angles
- Analysis finds 3 peaks over Europe: 30W, 13E, 38E



Conclusions

- New IFS screening uses glint angle threshold for these known sources of contamination from GEO
- *This removes systematic positive increments in SST over Europe that were present before RFI screening*
- For more details see Scanlon et al. (2024)

References

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