Radio Frequency Interference in the SMAP Radiometer

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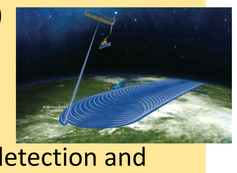
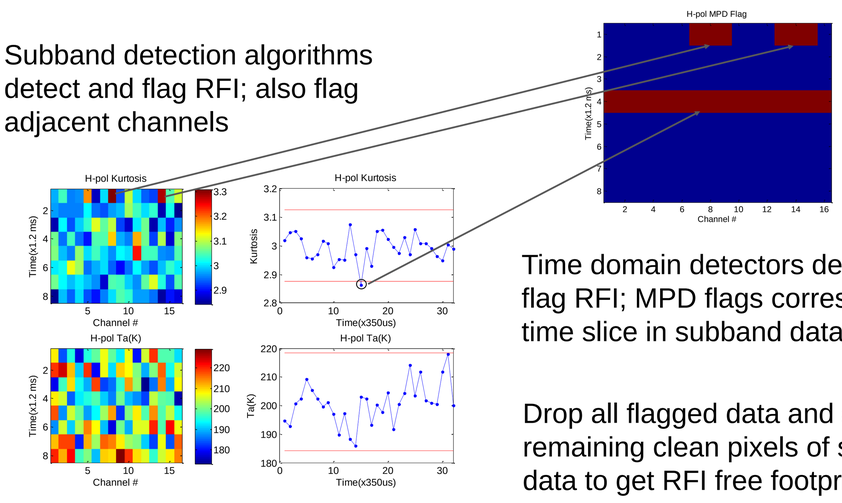
Introduction

- SMAP (Soil Moisture Active Passive) was launched by NASA January 31, 2015, to measure soil moisture of the Earth's land surface
- The SMAP radiometer operates in the L-band protected spectrum (1400-1427 MHz) that is known to be vulnerable to radio frequency interference (RFI)
  - SMOS and Aquarius provided a good indication of the RFI environment at L-band
- On orbit results show that RFI is indeed a problem
  - RFI increases brightness temperatures
  - Can lead to dry biases in soil moisture retrievals if undetected
- SMAP radiometer includes a digital backend enabling multiple RFI detection and mitigation capabilities; detection and mitigation processing performed on ground



SMAP RFI Detection and Filtering

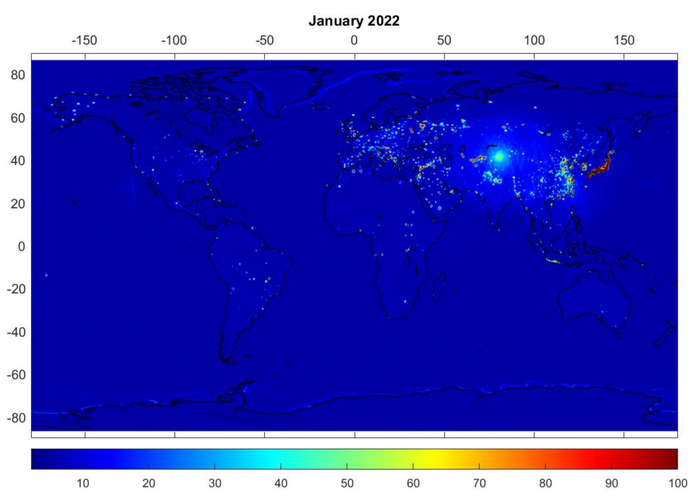
Subband detection algorithms detect and flag RFI; also flag adjacent channels



Time domain detectors detect and flag RFI; MPD flags corresponding time slice in subband data

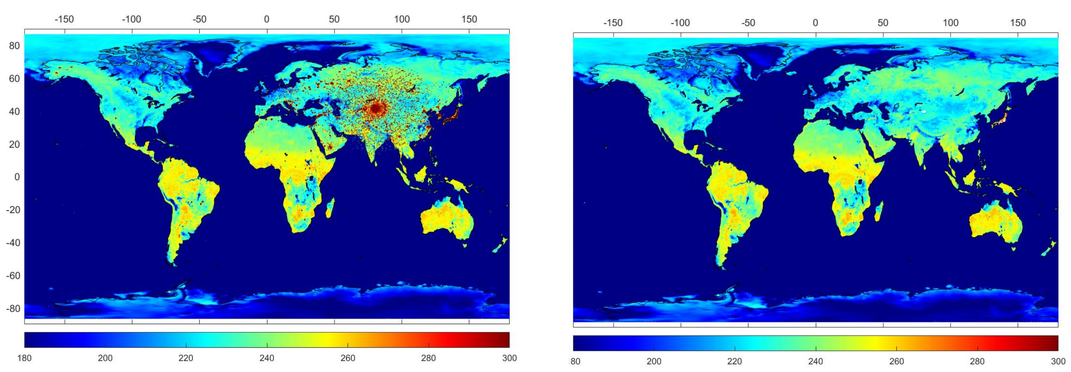
Drop all flagged data and average remaining clean pixels of subband data to get RFI free footprint, T_A

SMAP RFI Detection



All figures 0.25-degree grid

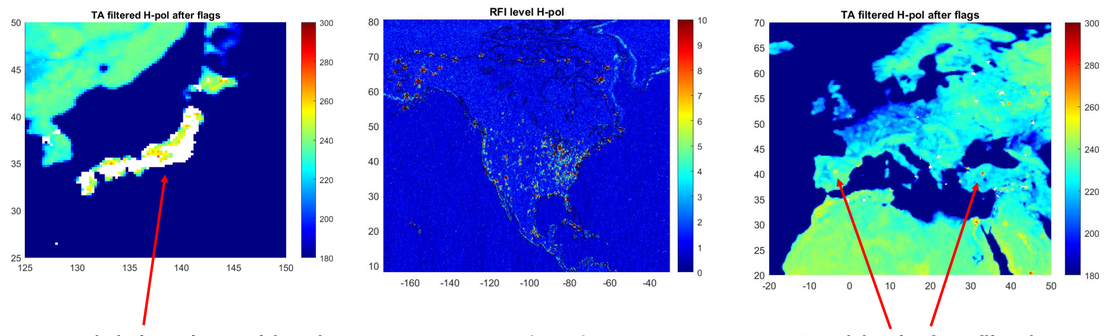
SMAP RFI Detection Rate



TA H-pol before and after filtering

Peak hold data 02/02/2022 to 02/08/2022

Different Types of RFI



High level resulting in denial of service

Low level

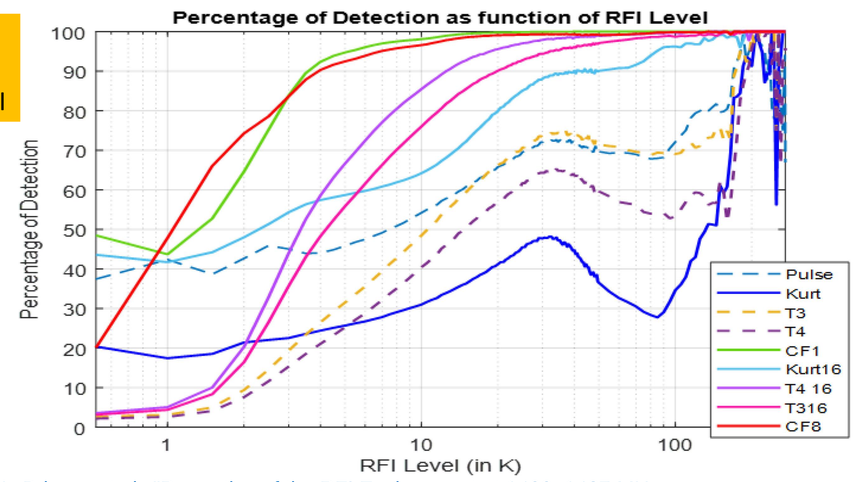
Residual after filtering

Peak hold data 02/02/2022 to 02/08/2022

SMAP RFI Detectors

Cross frequency appears to flag most types of RFI

Percentage of detection for each of the RFI algorithms as function of the RFI level for the five-year mission in V polarization

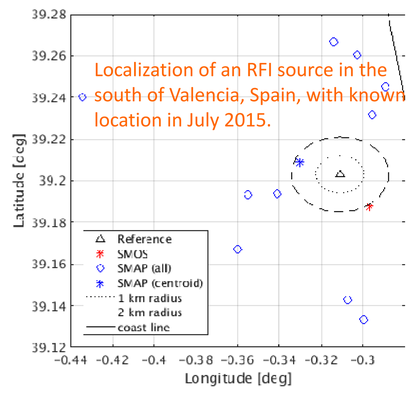


A. Bringer *et al.*, "Properties of the RFI Environment at 1400–1427 MHz as Observed by the Soil Moisture Active/Passive Mission Microwave Radiometer," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 14, pp. 7259-7267, 2021, doi: 10.1109/JSTARS.2021.3092996.

Locating Sources with SMAP Data

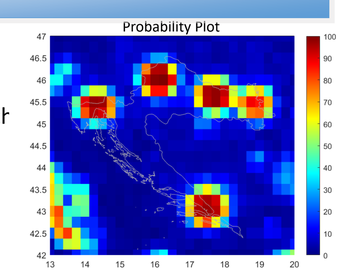
- Each blue diamond is found by clustering RFI footprints from a single pass (half orbit)
- Centroid (blue star) is found using all the clusters from several passes
- The black triangle is the known source location
- Algorithm used to find sources and geolocated sources are included in RFI reports filed

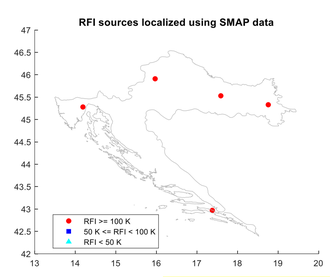
Y. Soldo *et al.*, "Location of Radio-Frequency Interference Sources Using the SMAP L-Band Radiometer," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 56, no. 11, pp. 6854-6866, Nov. 2018, doi: 10.1109/TGRS.2018.2844127.

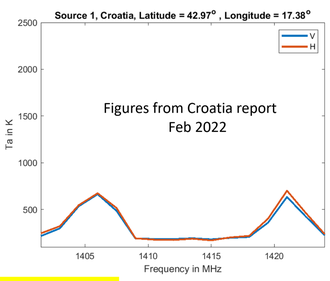


RFI Reporting

- RFI reported to authorities through NASA spectrum office
- Report a different country/region every month
- SMAP and SMOS agree to report on the same country every month
- Report for each source contains
  - Location coordinate
  - Brightness temperature in K
  - Estimate of EIRP of transmitting source
  - # of observations of source over analysis period
  - Date source was last seen
  - Spectral plot of each source, peak hold plot and probability plot of country being reported







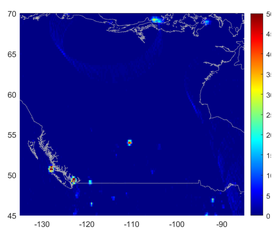
45 reports filed with 31 administrations

Sources turned off in Canada and UK due to RFI reporting

RFI Over Canada

RFI UK

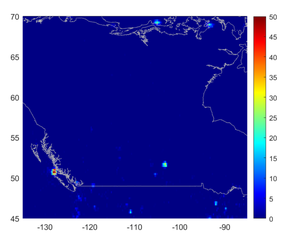
January 2021 | January 2022



CCTV camera | surveillance camera

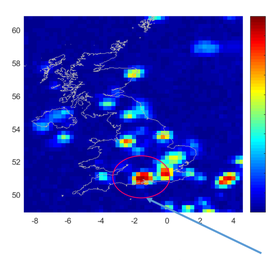
Sources identified and turned off due to the reporting process

January 2022



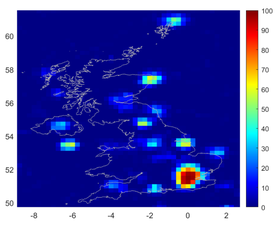
0.25° x 0.25° grid with a detected RFI level of 5 K or more in the horizontal polarization. Vertical polarization shows similar results.

02/19/2020 to 05/18/2020

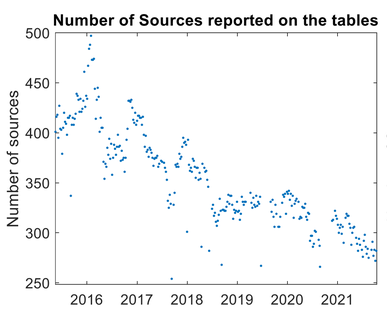


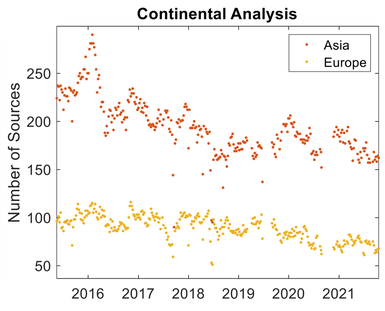
Video transmitter operating at 1.4 GHz confiscated from this location; other sources still present in current data

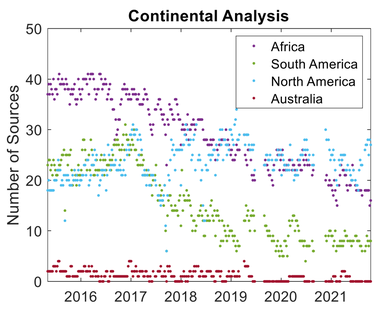
January 2022



SMAP RFI Environment







- Because the number of RFI sources are large, 2 criteria were defined to select the sources that have been reported:
  - RFI level > 10 K
  - Persistent in time i.e., present in at least 25% of SMAP overpasses during a month
- A table is generating every week using the information of the 4 previous weeks:
- Over the 6 years of SMAP missions, 300 tables were generated
- Their analysis allow to track RFI changes temporally and spatially