Wideband Radio Frequency Interference Study

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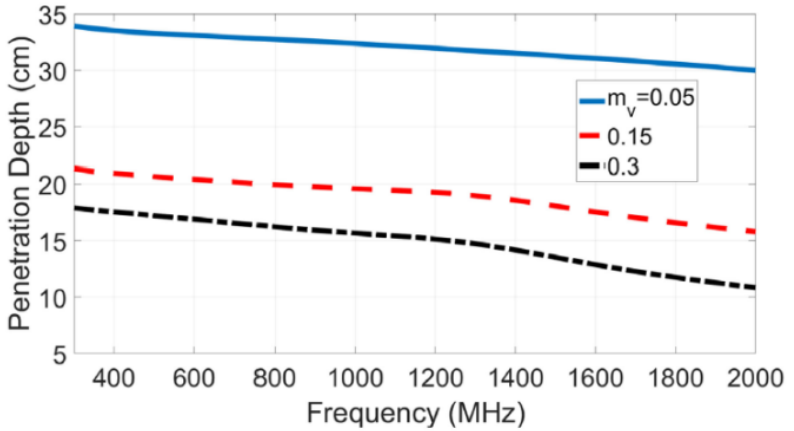
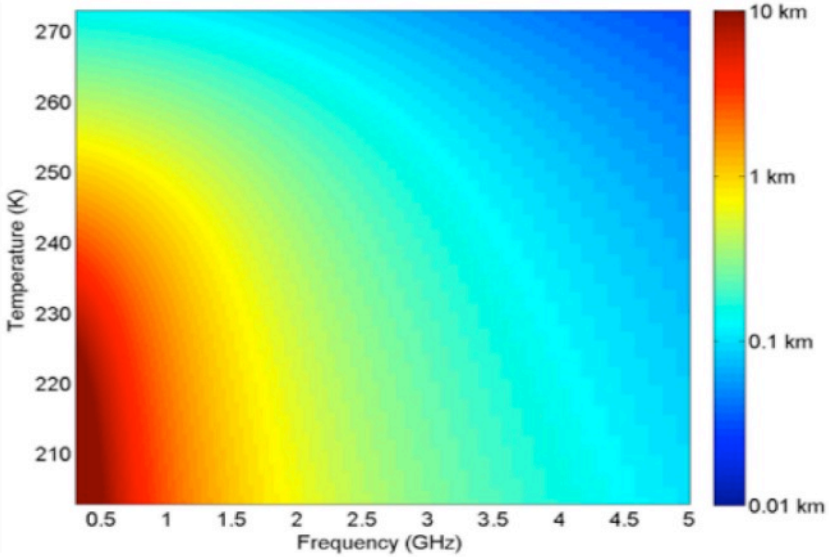
Microwave Radiometry from 500 MHz to 2 GHz

- Sensing at greater depths of vegetation, soil moisture and ice, increased sensitivity to sea surface salinity with Freq < 1400 MHz
- Advancement in RFI detection and filtering techniques enables consideration of measurements in shared or unprotected spectrum
- Radio spectrum 500 to 1400 MHz heavily occupied
- Understanding the global RFI is key to risk reduction

Figures from J. T. Johnson *et al.*, "Microwave Radiometry at Frequencies From 500 to 1400 MHz: An Emerging Technology for Earth Observations," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 14, pp. 4894-4914, 2021, doi: 10.1109/JSTARS.2021.3073286.



Penetration depths in soil as a function of freq and volumetric soil moisture



Penetration depth in laboratory-grown ice as a function of freq and ice temp

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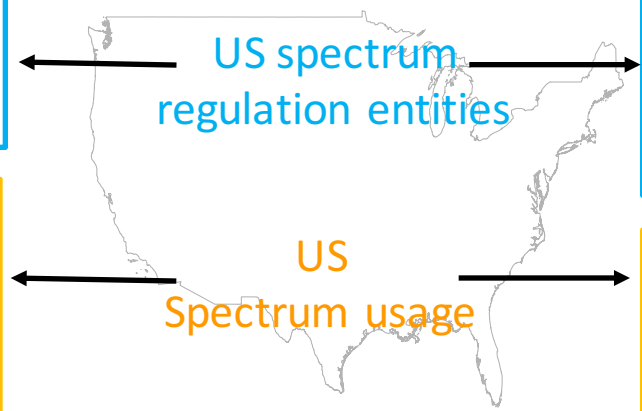
Interference Study – 500 to 2000 MHz

FCC (Federal Communications Commission)

NTIA (National Telecommunications and Information Administration)



FCC oversees non-Federal use – state local government, commercial private, internal business, personal use

NTIA manages spectrum for Federal use – Army, the FAA (Federal Aviation Administration), FBI (Federal Bureau of Investigation)

- Sources obtained from the NASA spectrum office via FCC and government databases
- Licensed transmitters in the US and Canada
  - ~100 000 sources from 1000 to 2000 MHz
  - ~800 000 sources from 500 to 1000 MHz
- Information of licensed transmitters – location, maximum transmit power, gain, frequency, BW and transmitter type

US Spectrum Allocations 1000 to 2000 MHz

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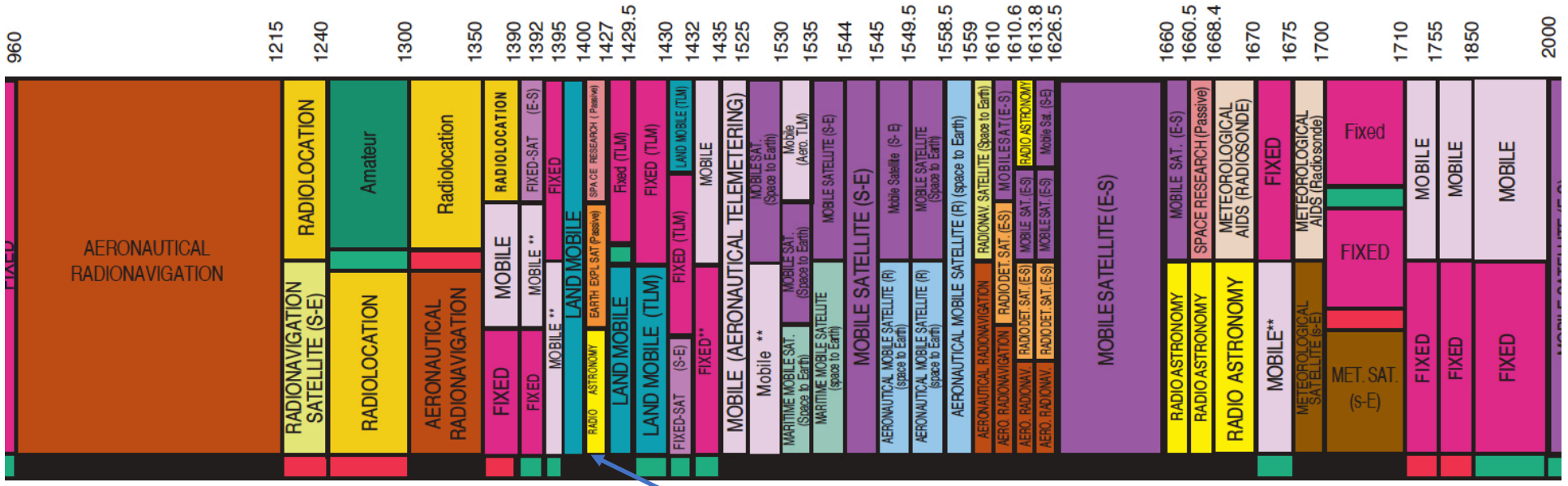

~960 – 1350 MHz
Radio navigation

~1350 – 1400 MHz
fixed, mobile

1400 – 1427 MHz
Protected band

~1700 – 2000 MHz
fixed, mobile

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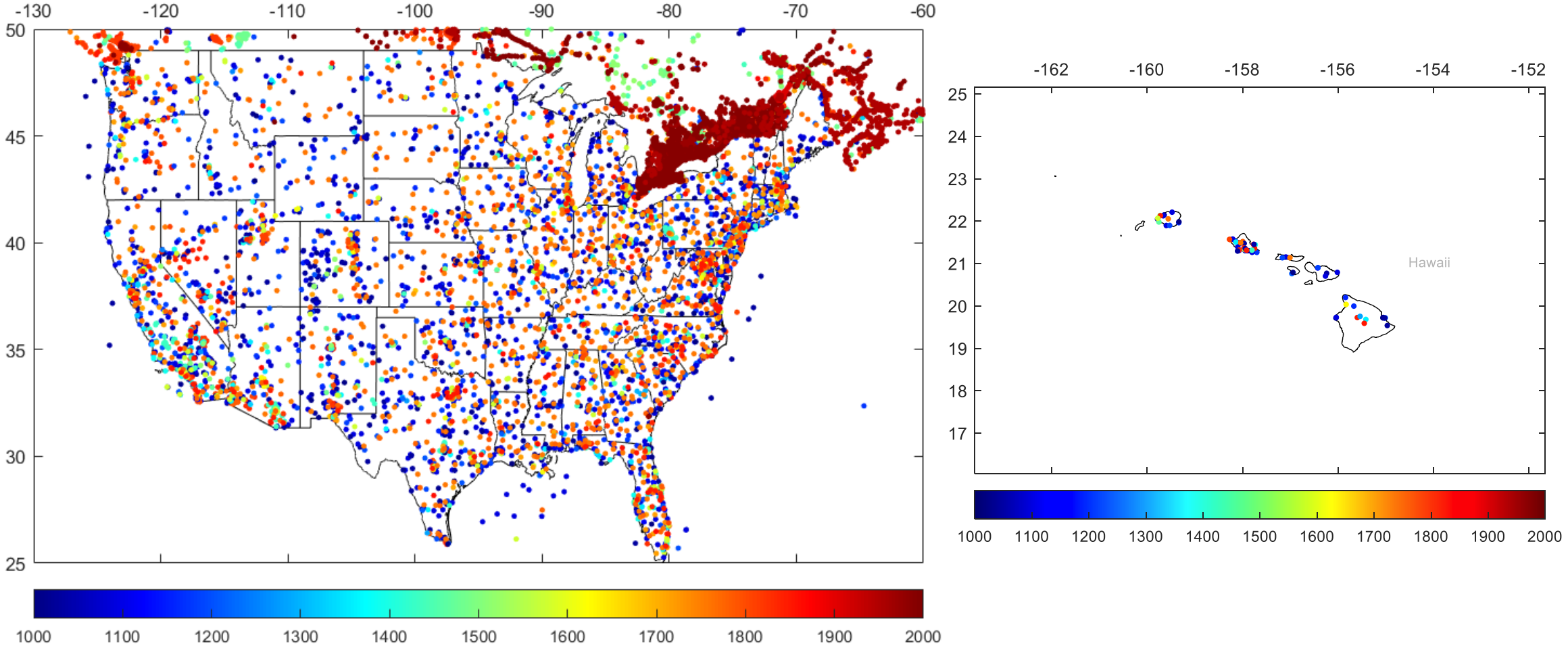
US Frequency 1000 to 2000 MHz



Map showing frequency at location of source in MHz

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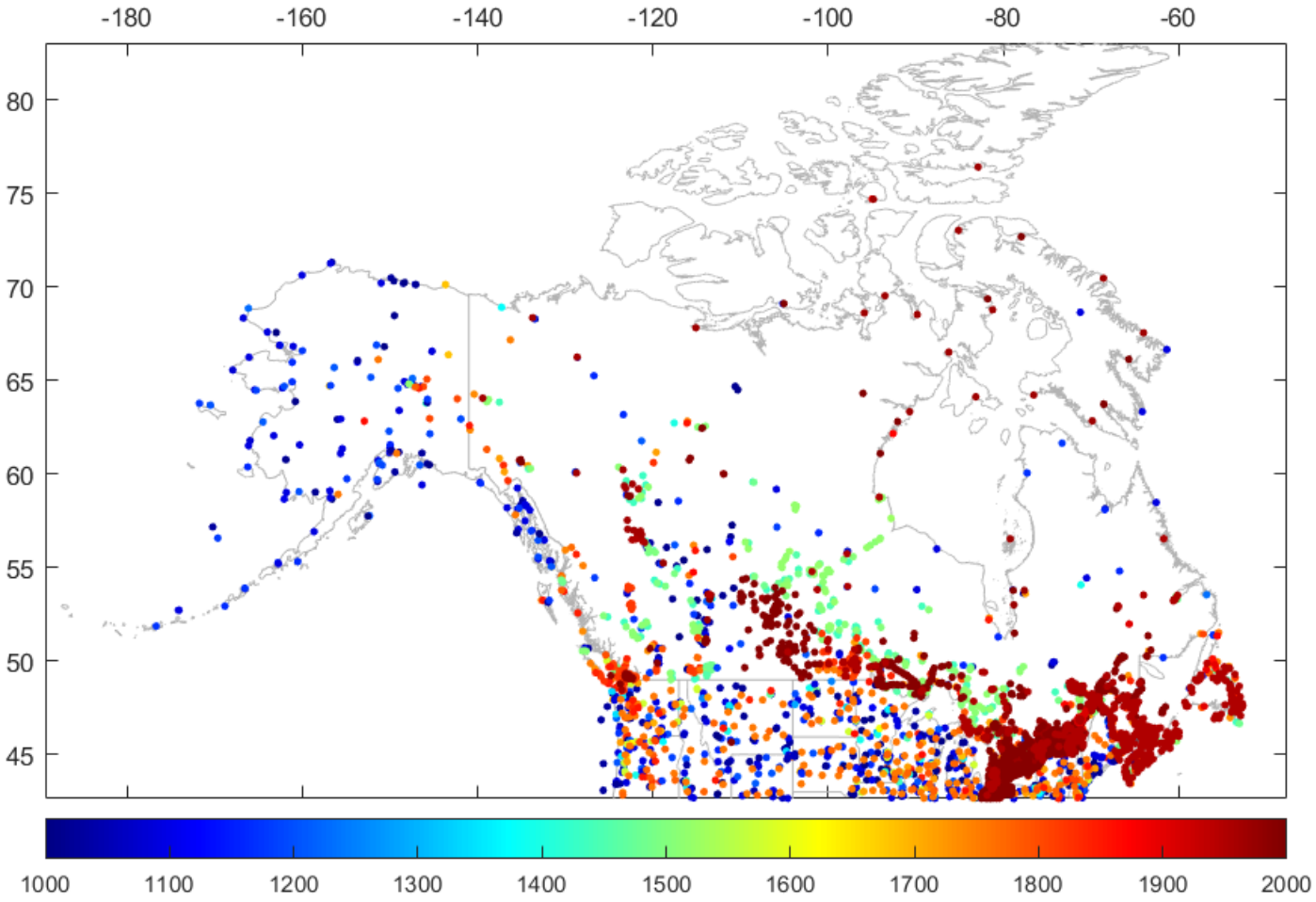
Canada Frequency 1000 to 2000 MHz



Map showing frequency at location of source in MHz

Distribution of Licensed Sources in the US 1000 to 2000 MHz

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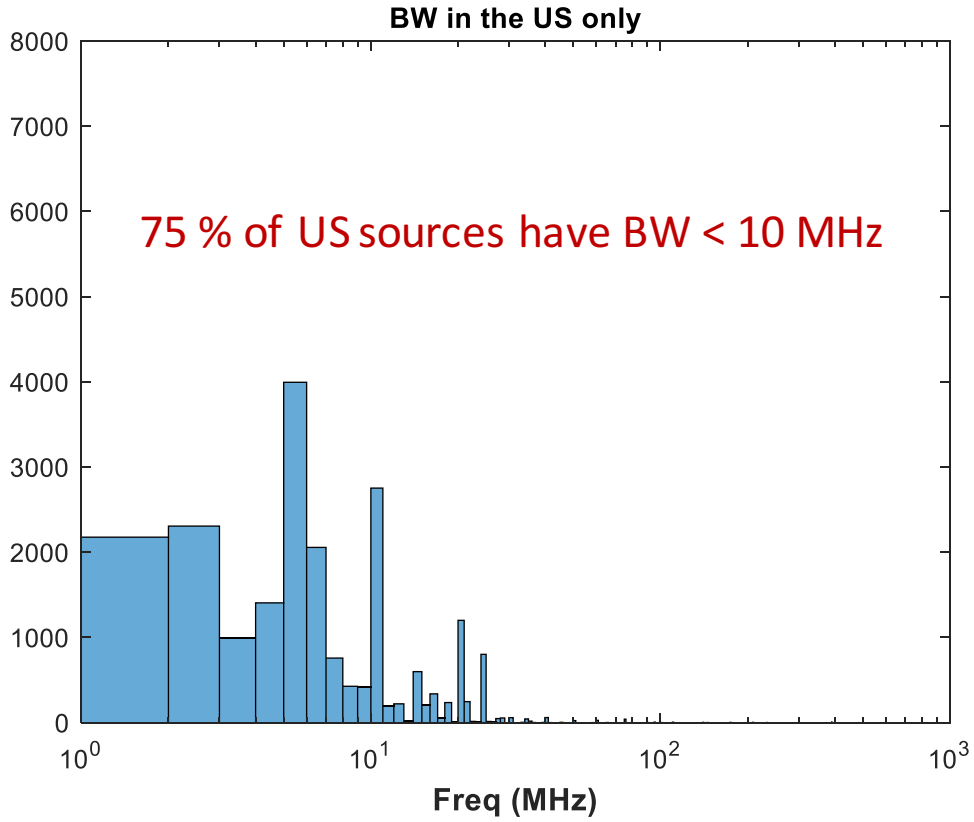
Frequency Range (MHz)	% sources with Center Freq in band US only
1000 – 1200	20.5
1200– 1400	11.1
1400 – 1427	0.04*
1427 – 1600	21.7
1600 – 1800	28.5
1800 – 2000	18.1

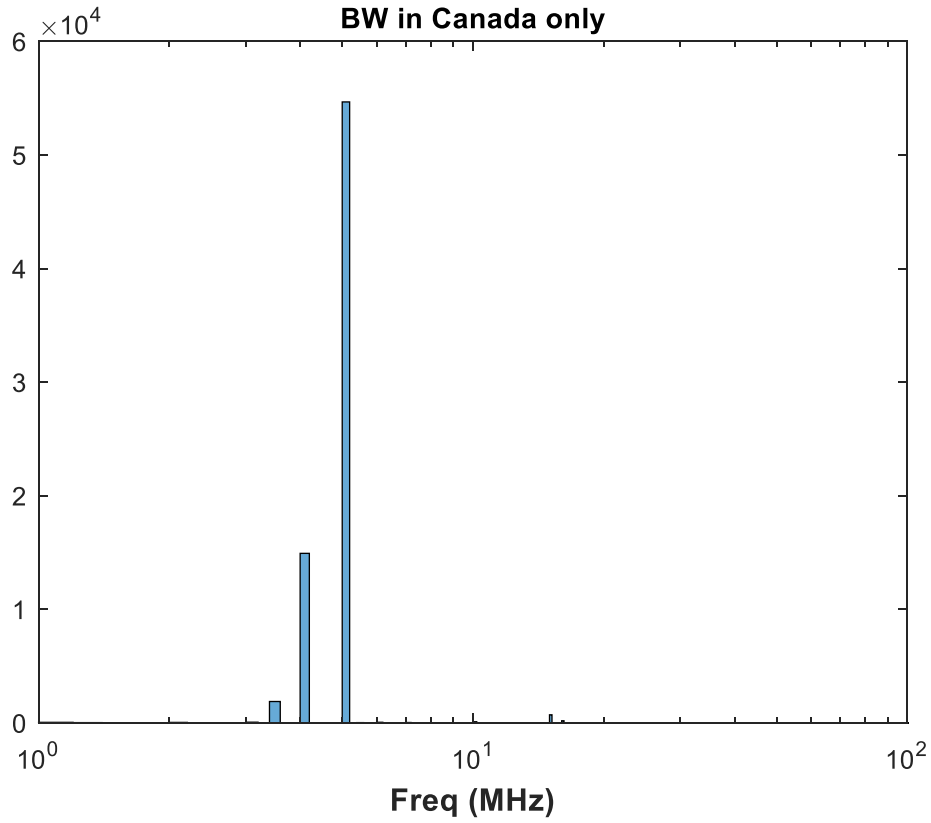


- *8 radars operating at 1400 MHz
- 2 government radars operating at 1410 MHz
- US sources somewhat evenly distributed

Distribution of Licensed Sources in Canada 1000 to 2000 MHz

Frequency Range (MHz)	% sources with Center Freq in band CAN only
1000 – 1200	0.7
1200 – 1400	0.2
1400 – 1427	0.001*
1427 – 1600	1.1
1600 – 1800	0.2
1800 – 2000	97.9

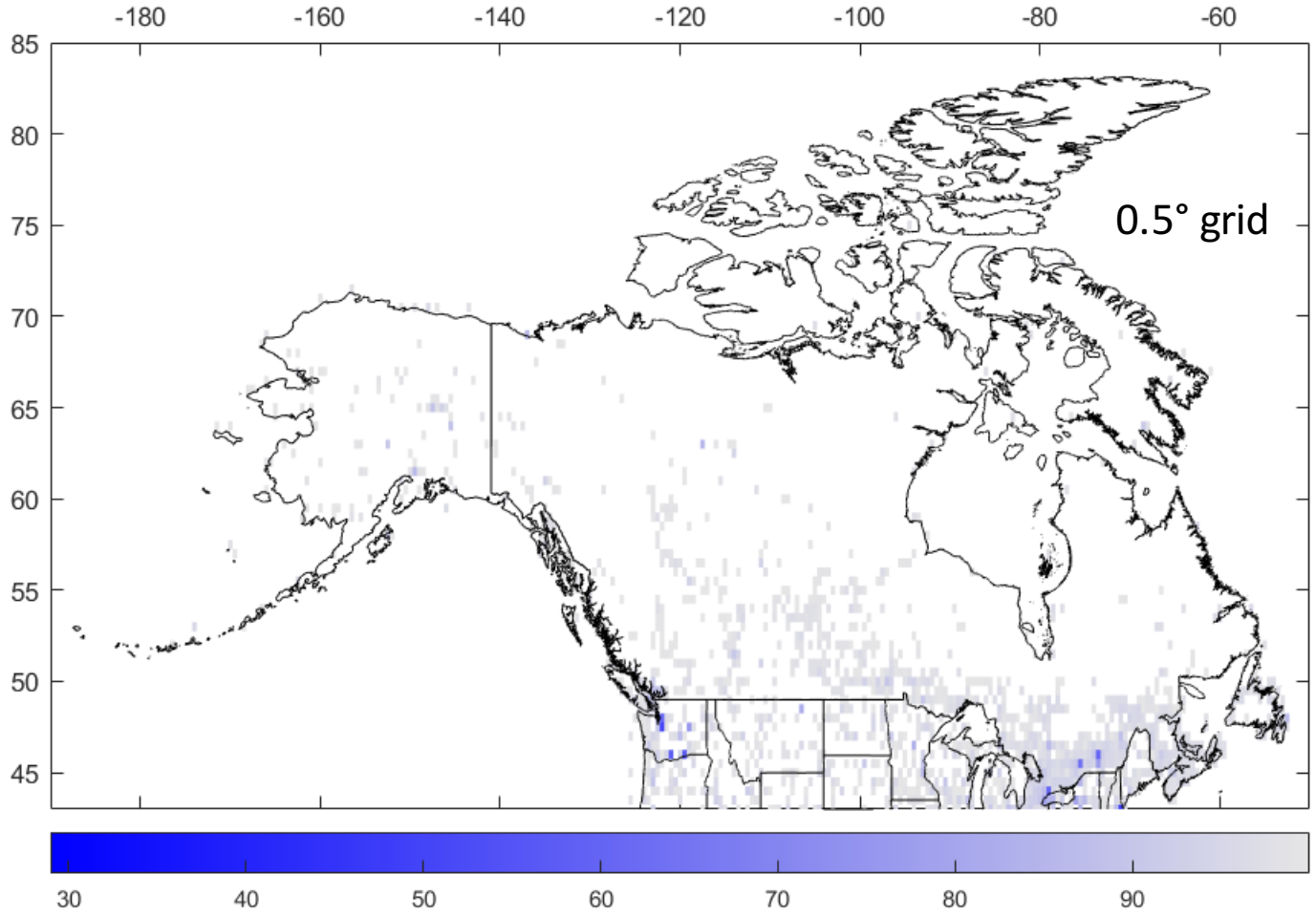
- *German PermASAR mission to operate from 1325 to 1475 MHz
- Most CAN sources are from 1.8 to 2 GHz and are PCS (personal communications services)



98.5 % of CAN sources have BW < 10 MHz

Percentage Available Spectrum 1000-2000 MHz

- In-band transmissions only (no out of band)
- White spaces mean no sources from databases in grid



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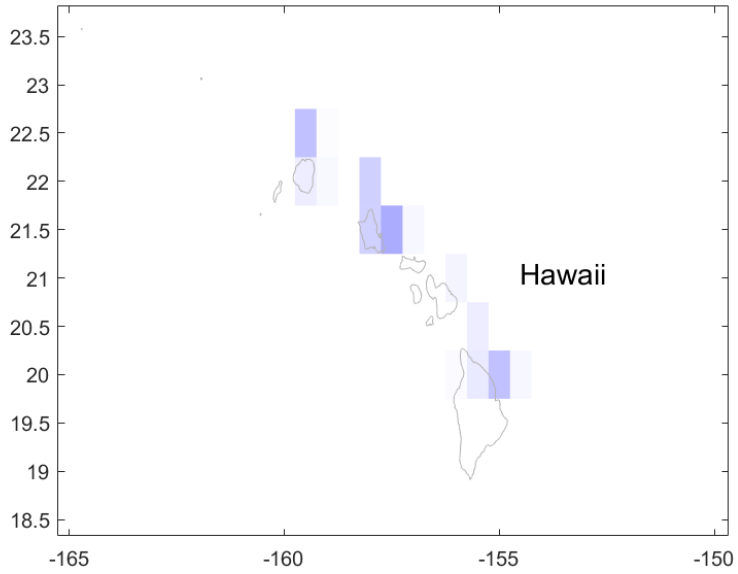

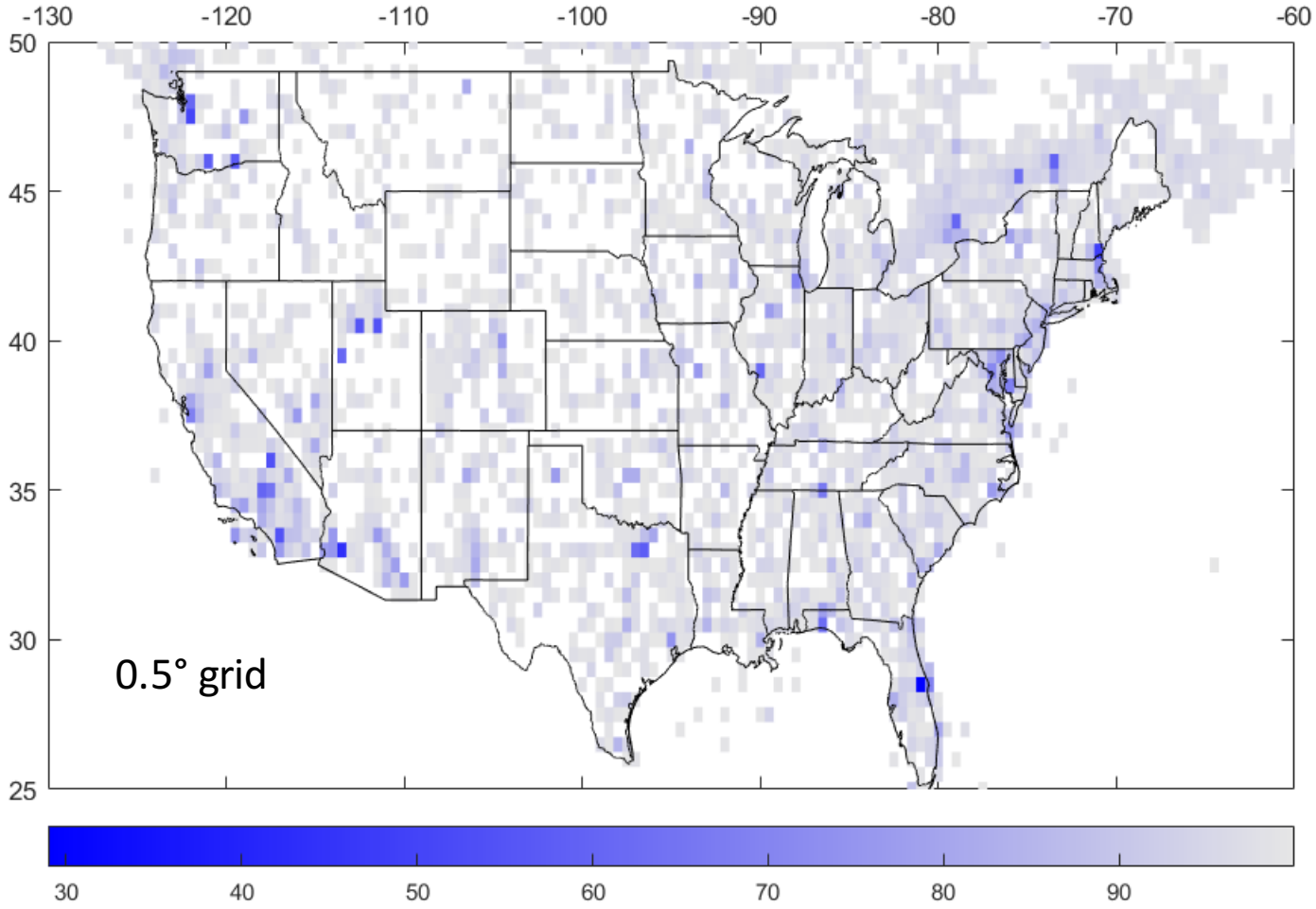

SMAP RFI and Licensed Sources

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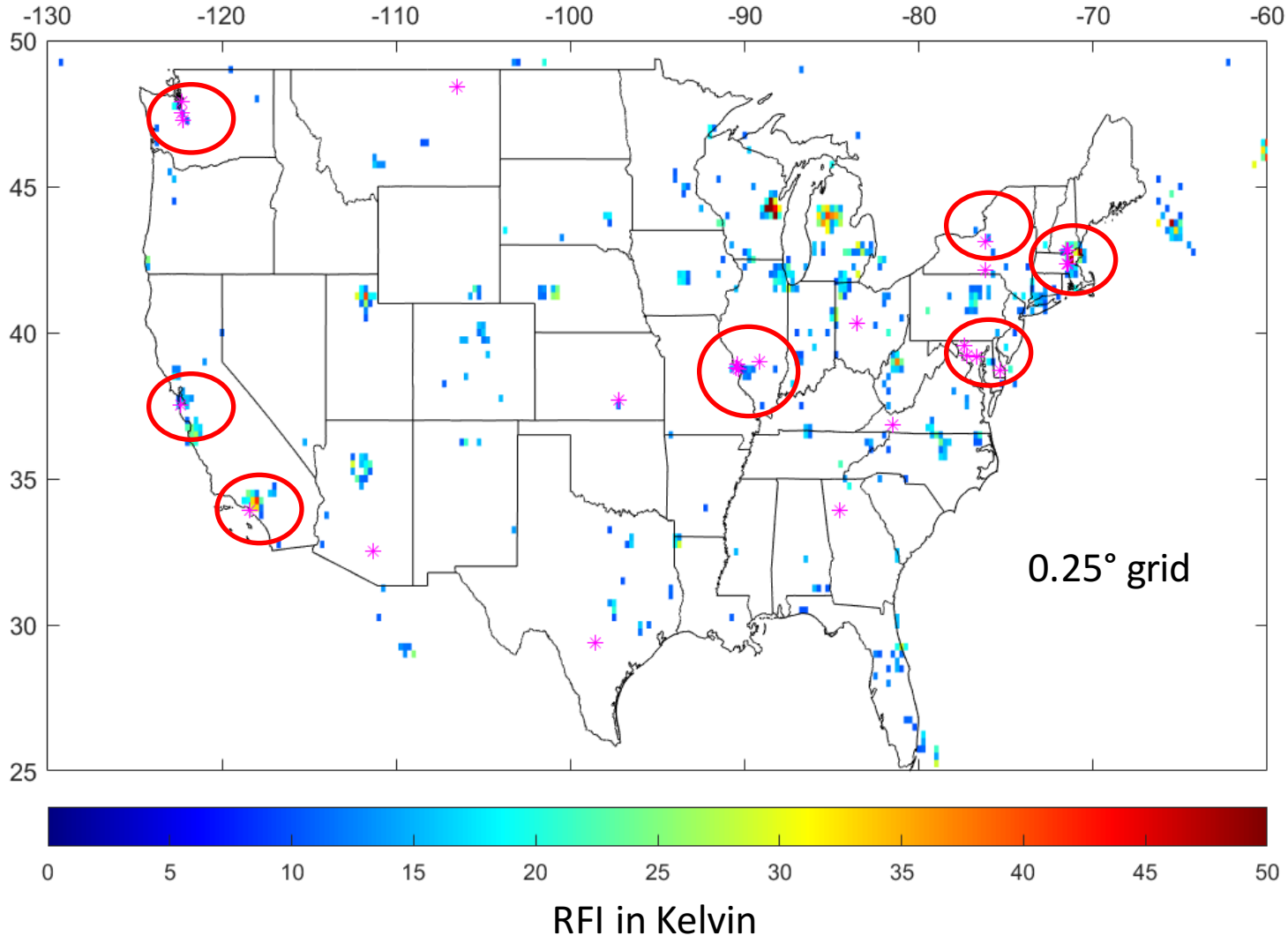
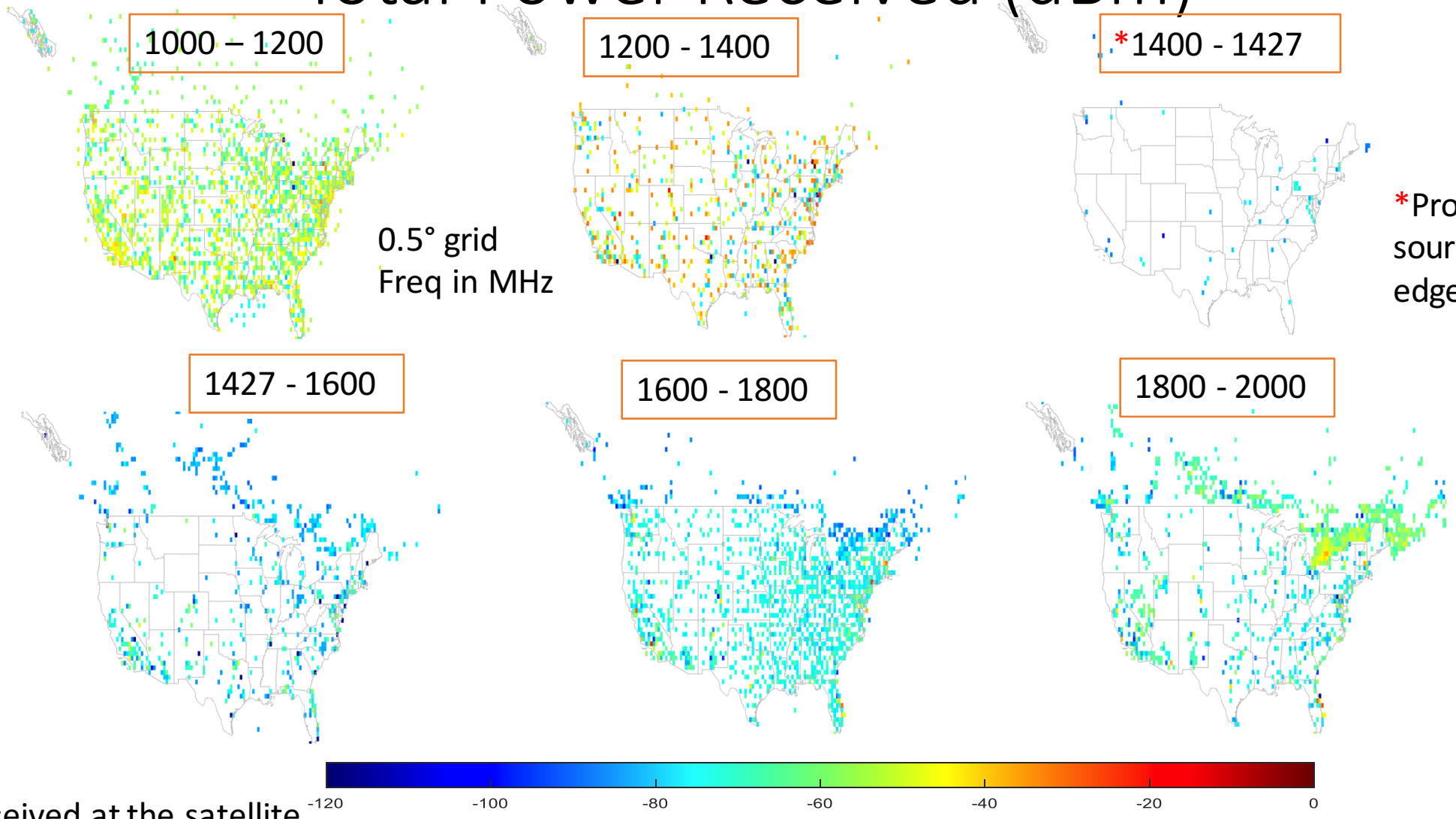
*Licensed sources at SMAP band edges that could be sources of RFI in SMAP data

RFI < 10 K omitted



Peak Hold SMAP RFI data
01/26/2022 – 02/01/2022

Total Power Received (dBm)



*Protected band, sources at band edges

- Power received at the satellite
- Calculated using SMAP like antenna in LEO

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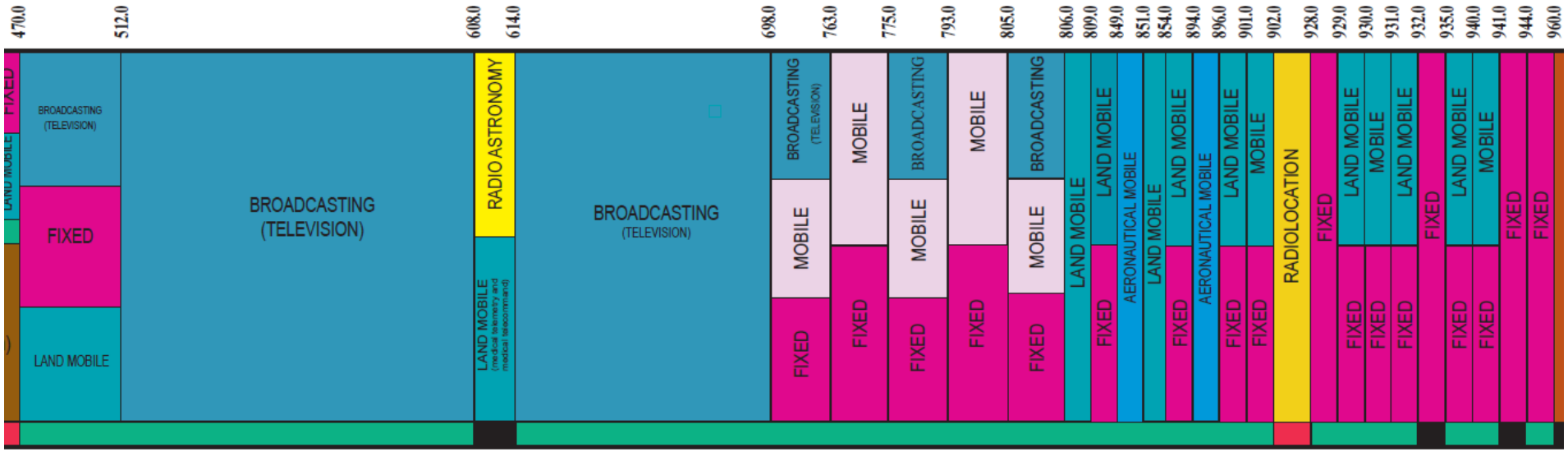
US Spectrum Allocations 500 to 1000 MHz



~500 – 700 MHz broadcast TV

~700 – 960 MHz fixed, mobile

Full spectrum allocation chart

https://www.ntia.doc.gov/page/2011/united-states-frequency-allocation-chart

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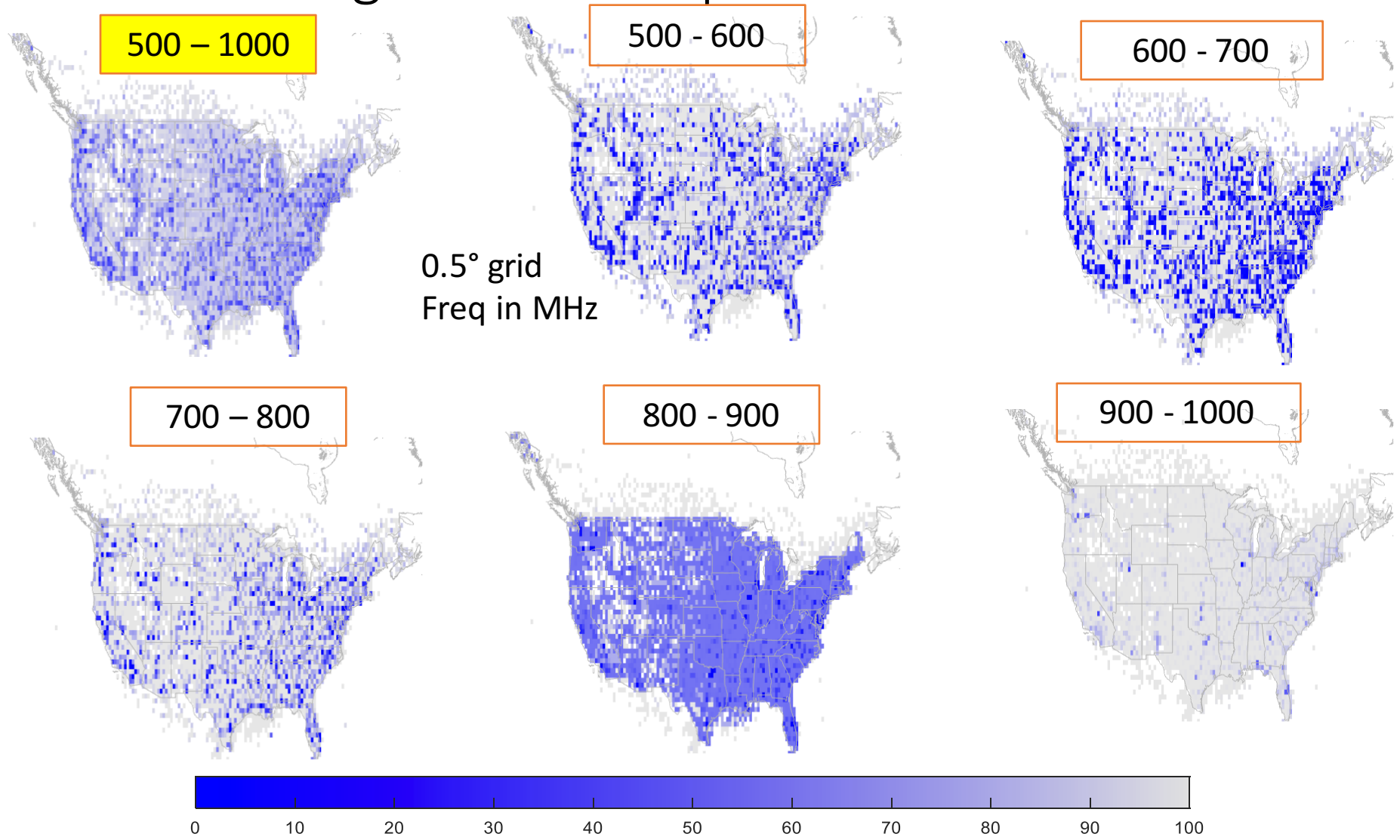
Percentage Available Spectrum 500-1000 MHz



91 % of all sources have BW < 10 MHz

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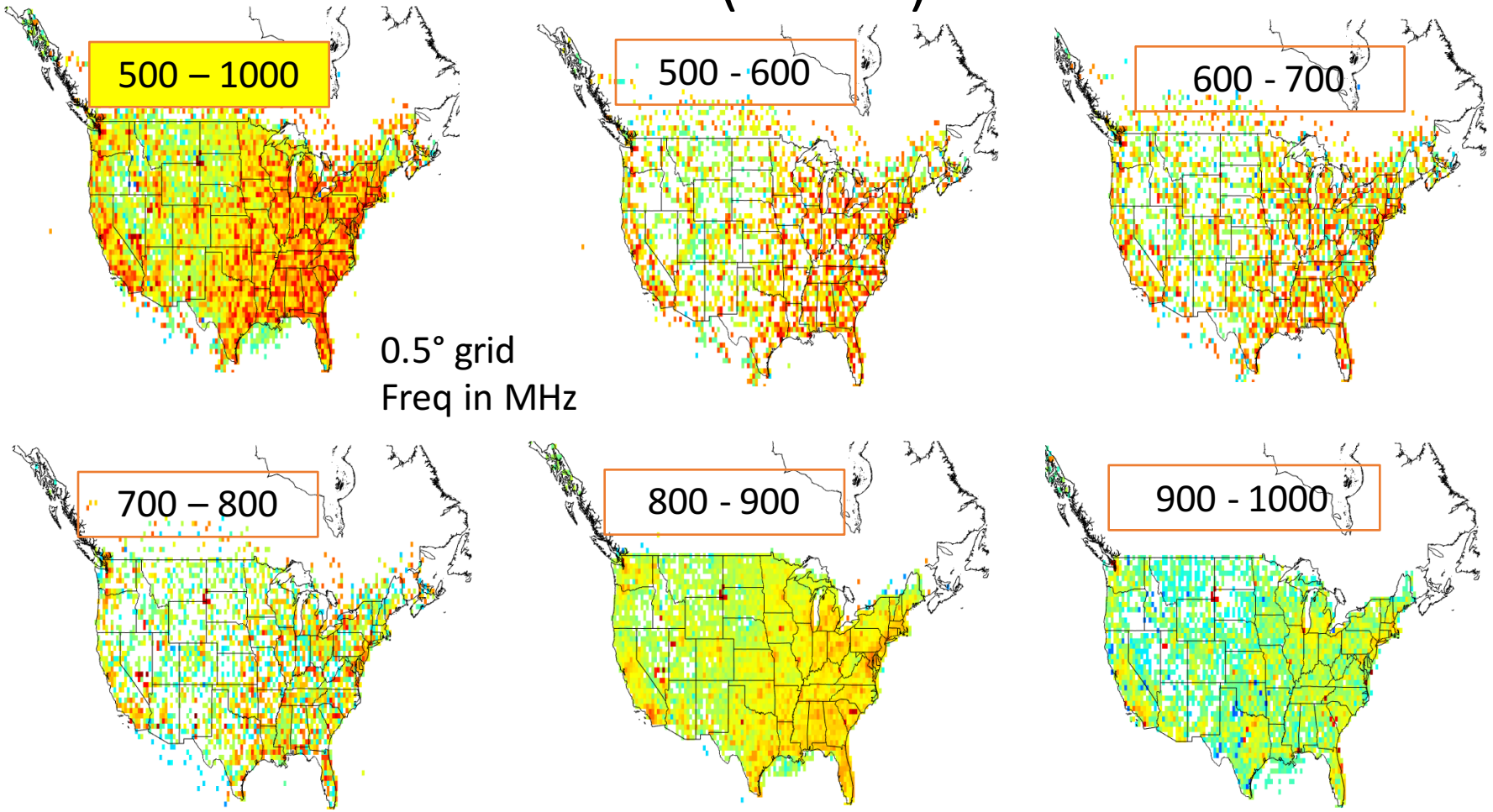
EIRP (dBm)



Total Effective Isotropic Radiated Power (on the ground) in each band

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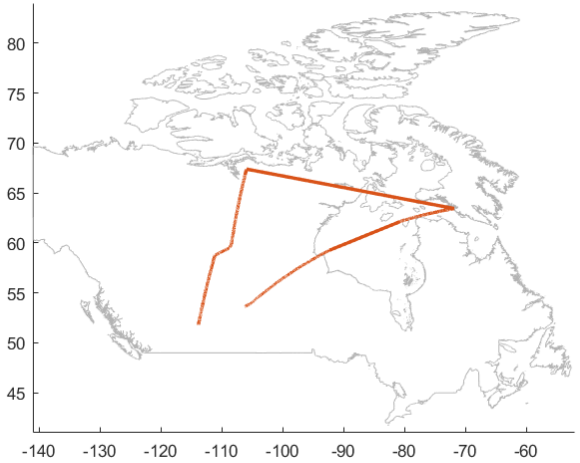
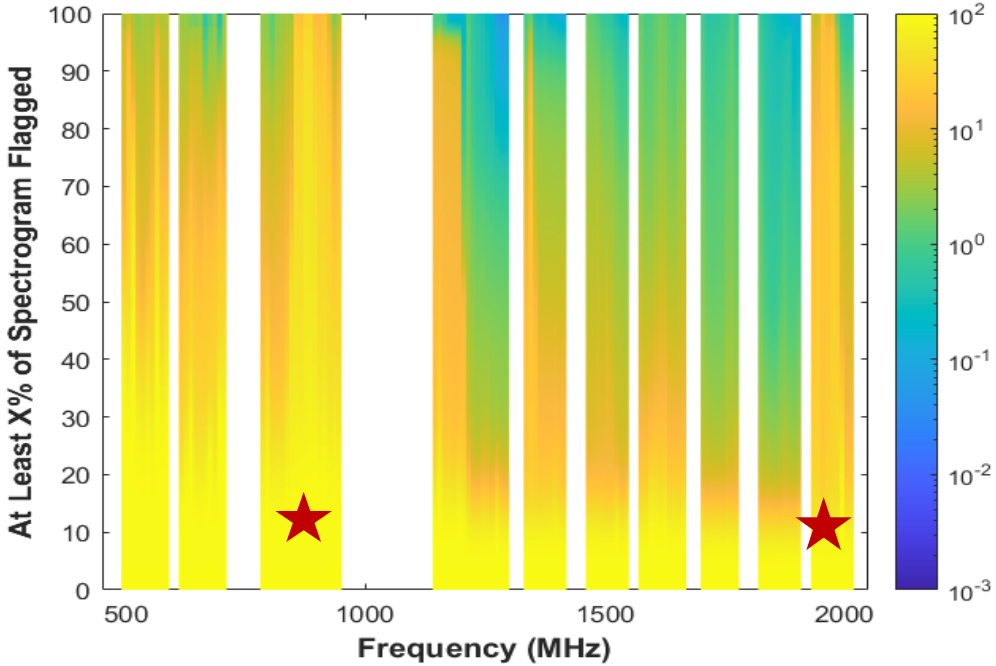
Comparison to Canada Airborne Data





- Flight path and data showing percentage of flagged data along with the percentage of time the data was flagged
- Airborne over Canada data shows spectrum below 1 GHz more heavily flagged than most regions from 1 to 2 GHz
- Most flagged data in the 850 - 950, and 1930 – 1990 MHz ranges
- Database shows most Canadian sources in 1800 to 2000 MHz range

M. J. Andrews, J. T. Johnson, M. Brogioni, G. Macelloni and K. C. Jezek, "Properties of the 500-2000-MHz RFI Environment Observed in High-Latitude Airborne Radiometer Measurements," in *IEEE Transactions on Geoscience and Remote Sensing*, doi: 10.1109/TGRS.2021.3090945.

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Conclusions

- Many science applications using observations outside protected spectrum
- Database study shows spectrum more heavily occupied at 0.5 to 1 GHz compared to 1 to 2 GHz
- Database information is limited and does not account for intermodulation products and unlicensed sources
- Airborne data complements database study
- Need airborne and spaceborne monitoring to fully characterize RFI environment
- Database study is a good starting point