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Microwave Radiometer RFI Detection Using Deep Learning

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NASA's Goddard Space Flight Center

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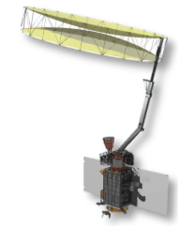
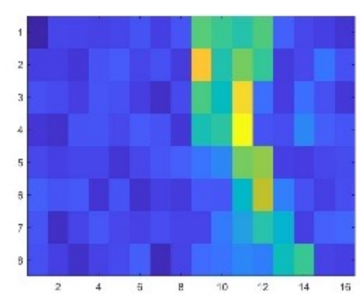
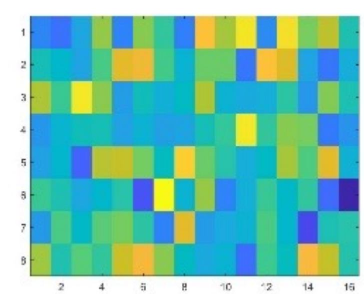


Motivation

- Radio frequency interference (RFI) remains a challenge especially with the advent of wideband receivers and spectrometers with interest in spectrum outside the designated bands
- Large amounts of accumulated data necessary for current techniques which require post processing
- Deep learning can be used to detect RFI in data represented as spectrograms, suitable for wideband receivers

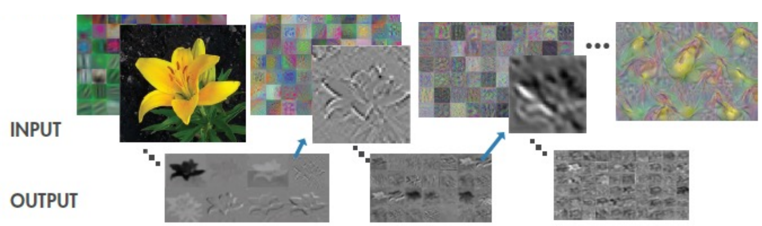




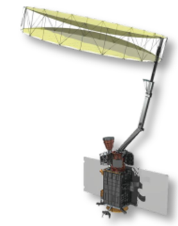
Deep Learning – How Does It Work

- Deep learning is a type of machine learning
  - Machine learning manually extract relevant features in an image
  - Deep learning, feed raw images directly to a deep neural network that learns features automatically
  - Deep learning requires 100s of thousands or millions of images for best results, computationally intensive

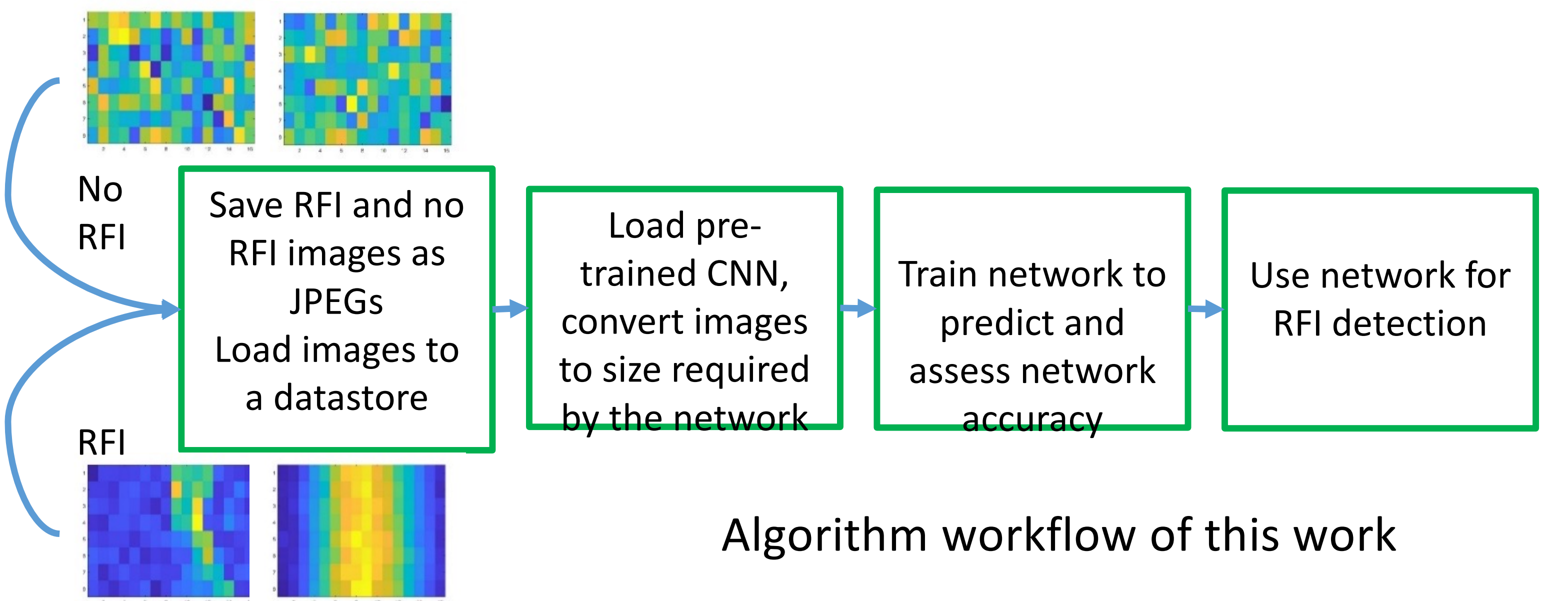
DL network learns directly from data



Transfer Learning



- Transfer learning uses an existing network trained on millions of images
- Pre-trained network fine-tuned, learned features transferred to new task using a smaller number of training images



Algorithm workflow of this work

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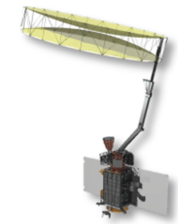
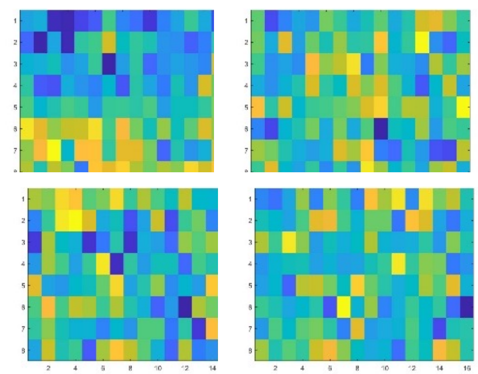


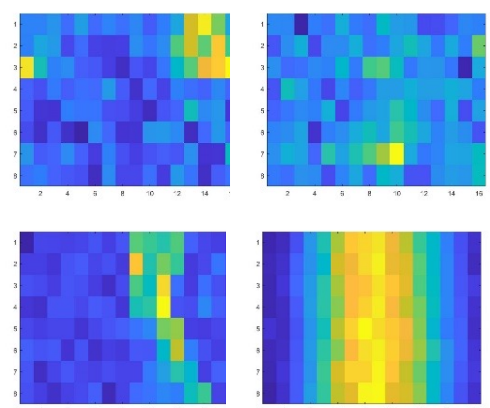
Experiments

- Used pre-trained networks Alexnet, GoogleNet, ResNet-101
- Training input 2507 images of RFI, 2507 images of no RFI
- No RFI cases taken over Antarctica, the ocean and Australia with the conditions that RFI level < 2 K and number of pixels flagged < 50 %
- RFI cases taken from all parts of the globe, high level, low level, different types, RFI > 5 K or > 50% of spectrogram blanked
- 80 % of data used for training, 20 % validation

- Object is to classify image as RFI or no RFI



No RFI examples



RFI examples

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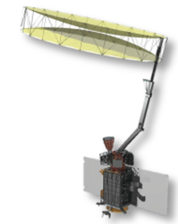
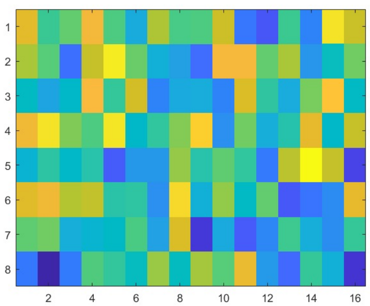


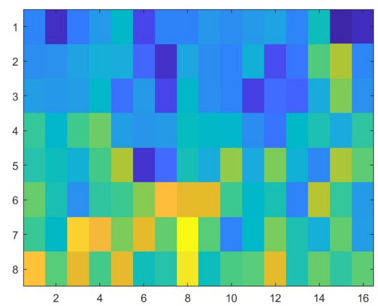
Experiments

- Training performed twice on each network
  - Experiment 1: RFI free images contained coastlines
  - Experiment 2: RFI free images excluded coastlines

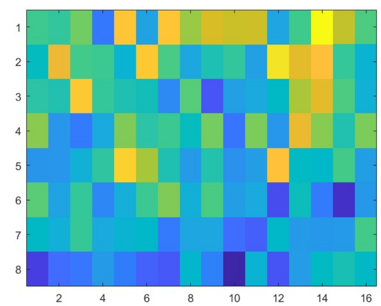
No RFI



Coastline

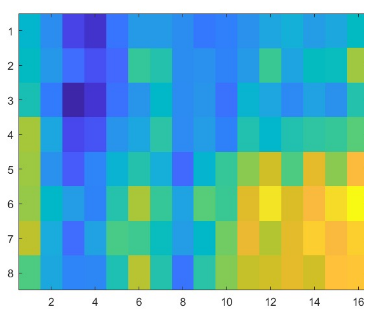


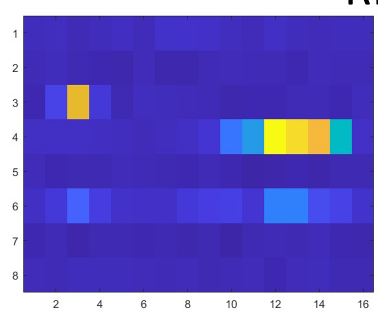
Coastline



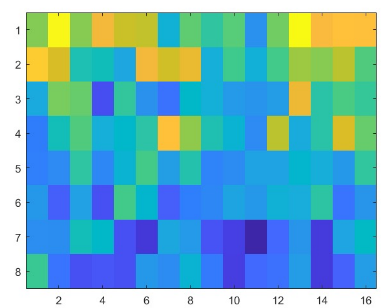
Excluding coastlines in training images can result in false alarms along the coasts

RFI





RFI looks like a Coastline



Including coastlines in training images can result in missed detections

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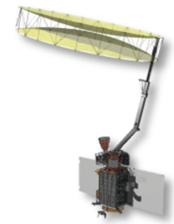
Training Results and SMAP Agreement



Network	Accuracy 1 (%)	Accuracy 2 (%)	Training Time 1 (Hr)	Training Time 2 (Hr)
AlexNet	98.50	96.51	7.73	7.10
GoogleNet	97.80	98.30	16.21	16.19
ResNet-101	98.60	98.90	31.62	31.00

Network	Europe Orbit Agreement with SMAP detection (%)	Middle East Orbit Agreement with SMAP detection (%)
AlexNet	97.58	88.31
AlexNet (no coast)	98.85	92.23
GoogleNet	95.89	82.10
GoogleNet (no coast)	96.84	85.03
RestNet-101	96.09	85.77
Restnet-101 (no coast)	97.09	88.05

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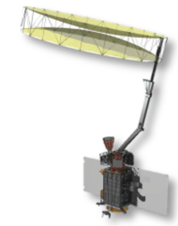
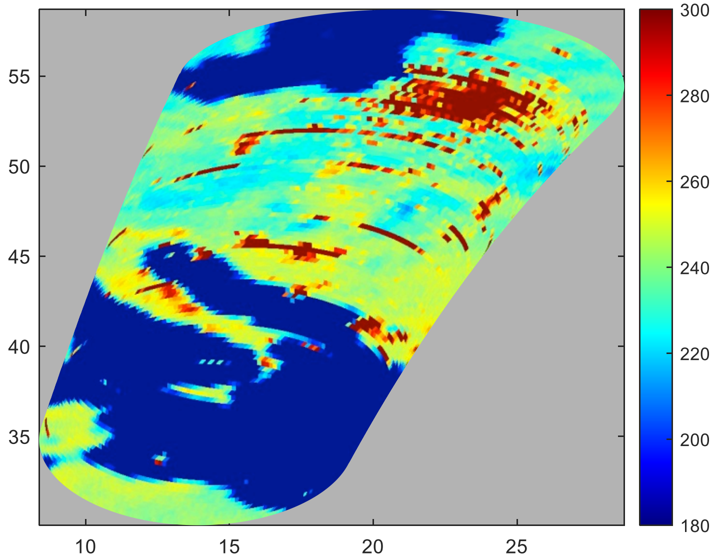
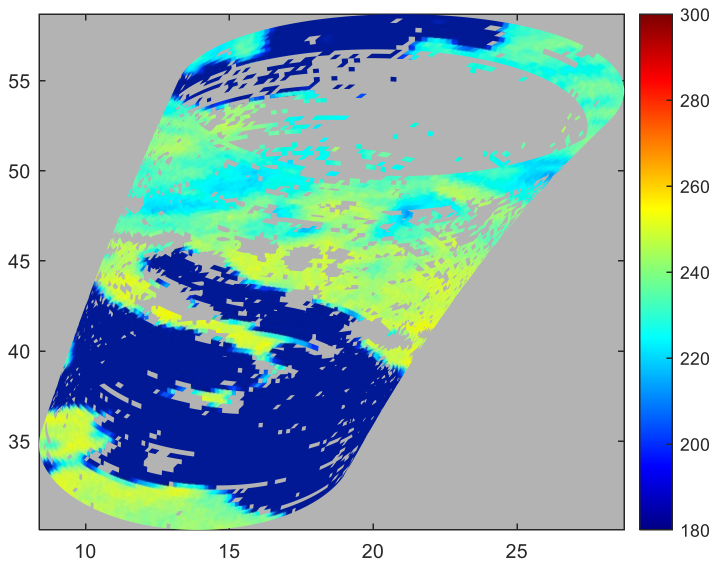
Results – Europe Pass



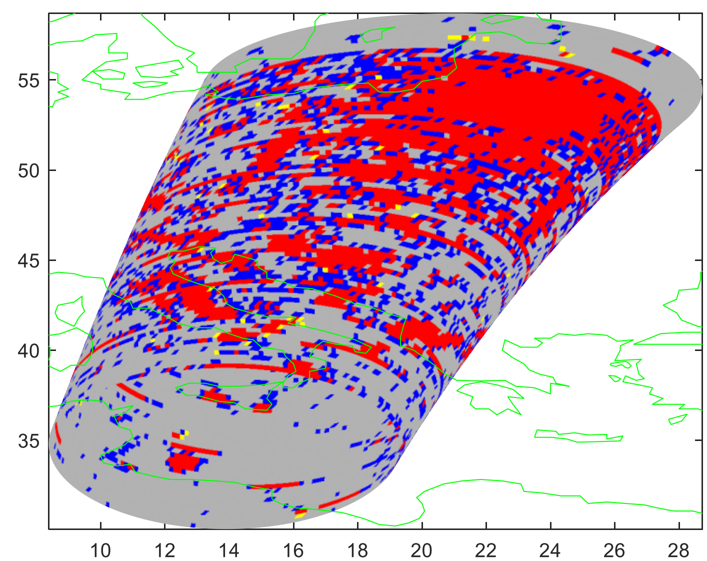
L1B_TB 28923_D



- 19405 footprints tested
- RFI > 5 K or > 50% of spectrogram blanked = 4088
- 7407 fps detected by deep learning
- Deep Learning agreement = 3989 or 97.6 %
- 256 fps detected by deep learning had 10 or less pixels detected by MAXPD , 1.3 %
- 4125 fps had RFI < 5 K



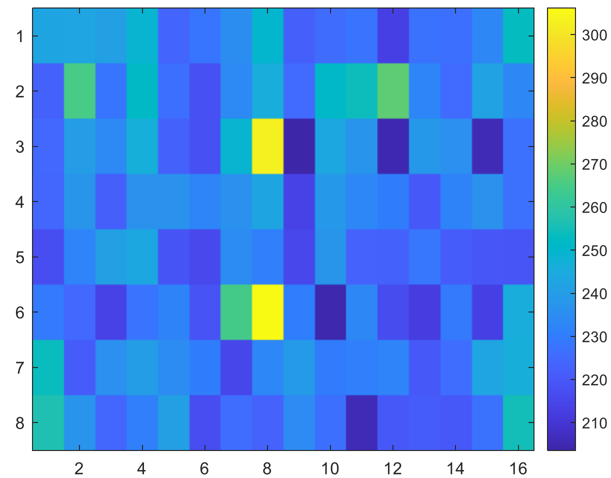
DL detection – AlexNet coastlines included



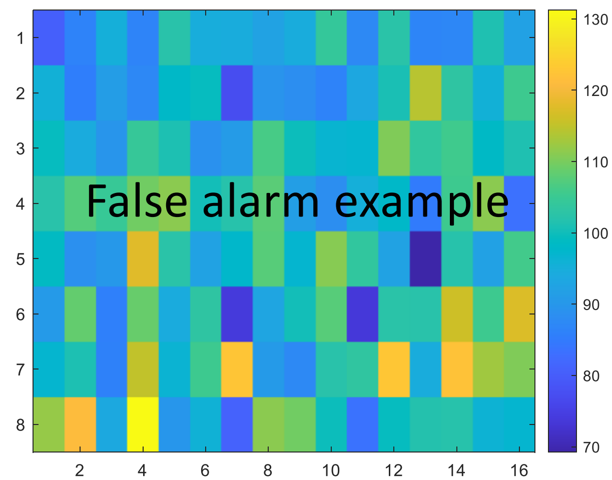
DL and SMAP detection agreement results

- Red: agree on RFI
- Grey: agree no RFI
- Blue: DL detects RFI but SMAP detection does not
- Yellow: DL does not detect RFI but SMAP detection does

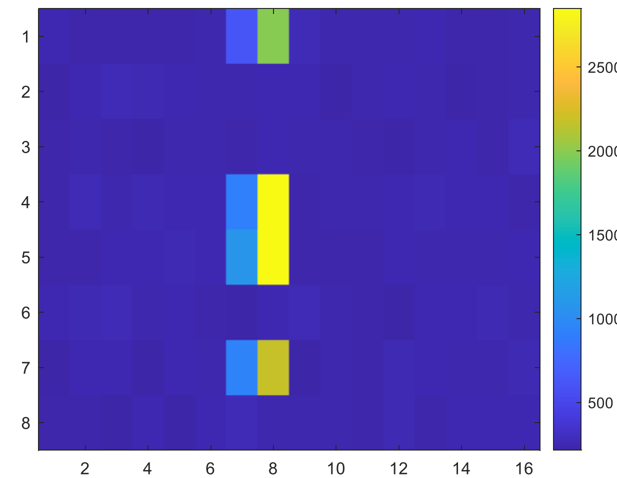
Results



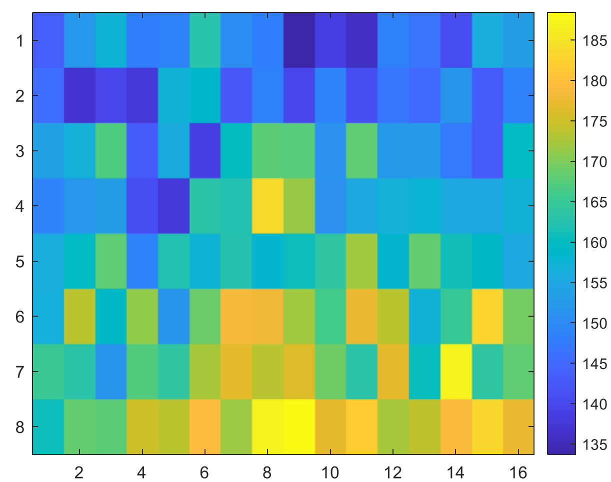
1.6 K



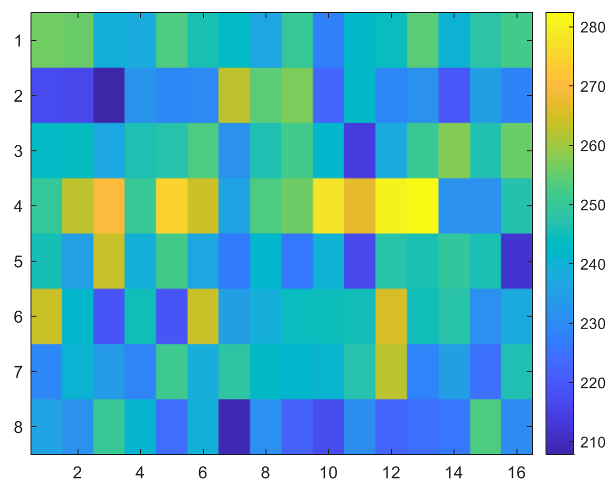
0.6 K, 9 pixels detected by SMAP



Example RFI



6.7 K

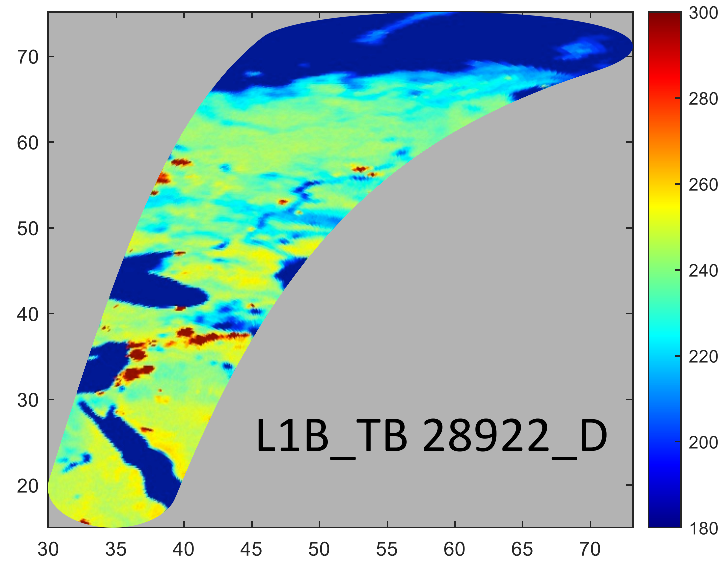


13.1 K

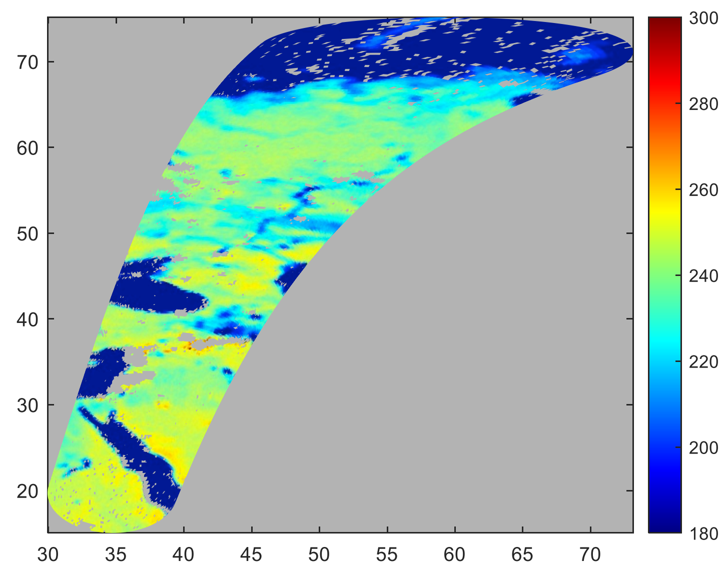
Example footprints missed by DL

More pulsed RFI in this orbit

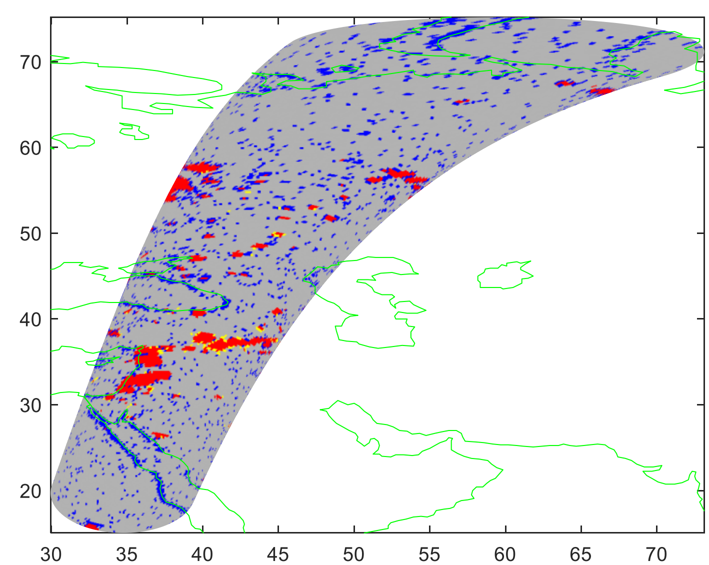
Results – Middle East Pass



- 98467 footprints tested
- RFI > 5 K or > 50% of spectrogram blanked = 3113
- 11232 fps detected by deep learning
- Deep Learning agreement = 2871 or 92.2 %
- 4470 fps detected by deep learning had 10 or less pixels detected by MAXPD , 4.54 %
- 8667 fps had RFI < 5 K



DL detection – AlexNet coastlines excluded



DL and SMAP detection agreement results

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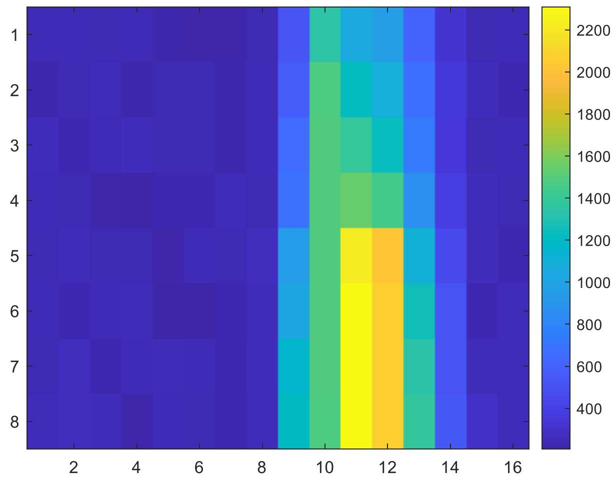
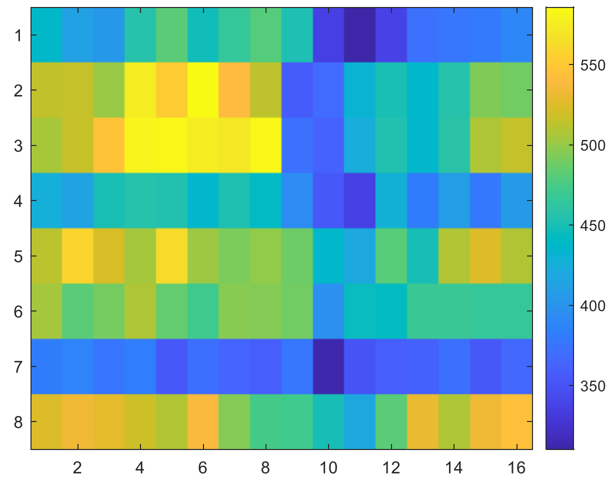
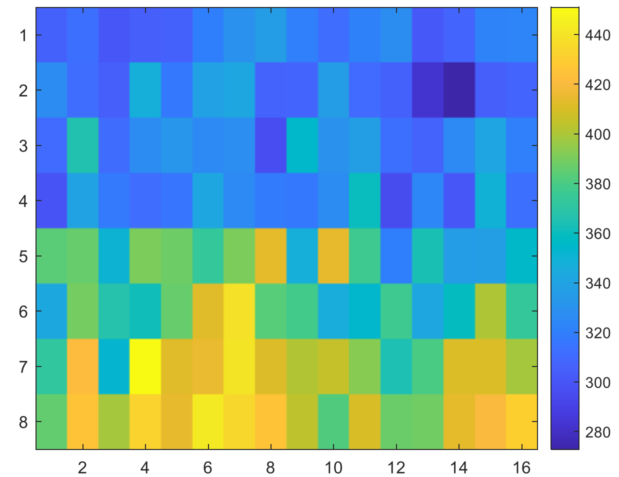
Results – Middle East Pass

Example RFI cases in this orbit

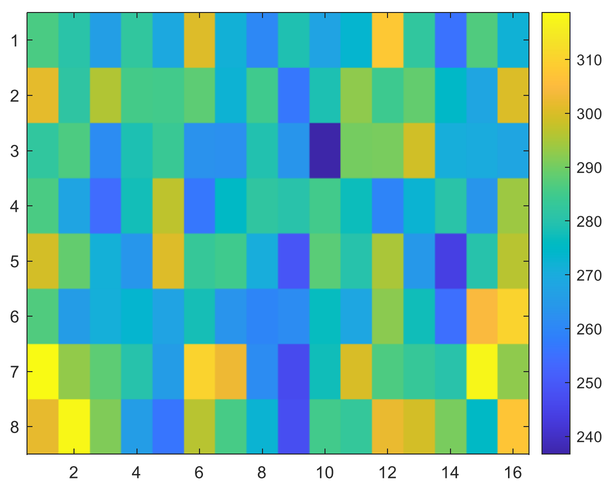


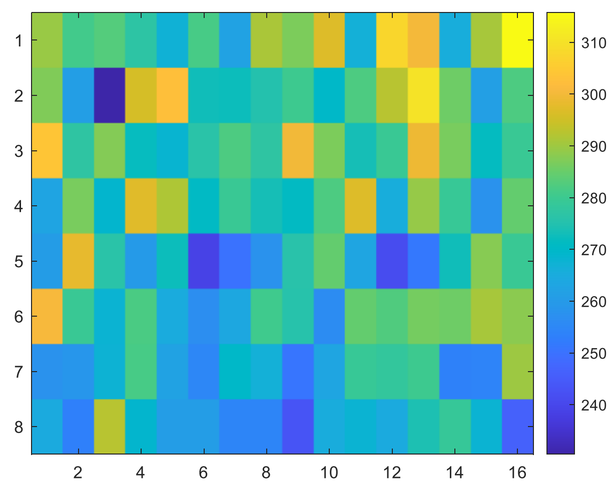




More wideband and continuous RFI in this orbit

DL missed detection footprints





All pixels flagged by SMAP

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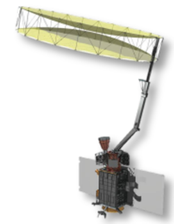

Conclusion

- Deep Learning has high performance at detecting RFI localized in time and frequency and lower performance for broadband RFI
- Classification is highly dependent on input data as demonstrated by the coastline/no coastline experiments
- To improve detection especially for broadband RFI improved ground truth can be used such as simulated data