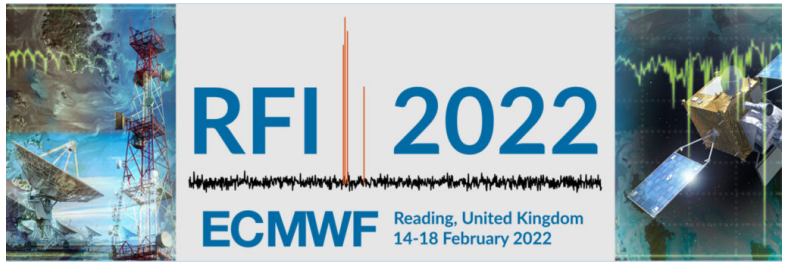
Deep Learning-Based RFI Detection and Mitigation for SMAP Using Convolutional Neural Networks

Ahmed Manavi Alam, Ali Gurbuz, Mehmet Kurum
Mississippi State University
Information Processing and Sensing Laboratory (IMPRESS)
Date: 02/15/2022
RFI 2022 Workshop



Presentation Outline

- Motivation
- Data Products
- Algorithm Flowchart
- Data Statistics
- Data Preparation
- Deep Learning Architecture
- Results
- Discussion and Future Work
- Acknowledgment

Motivation

- Active Wireless Technologies Expansion
- Jeopardizes Success of a Mission
- Interference Mitigation Techniques
- A Data-Driven Approach

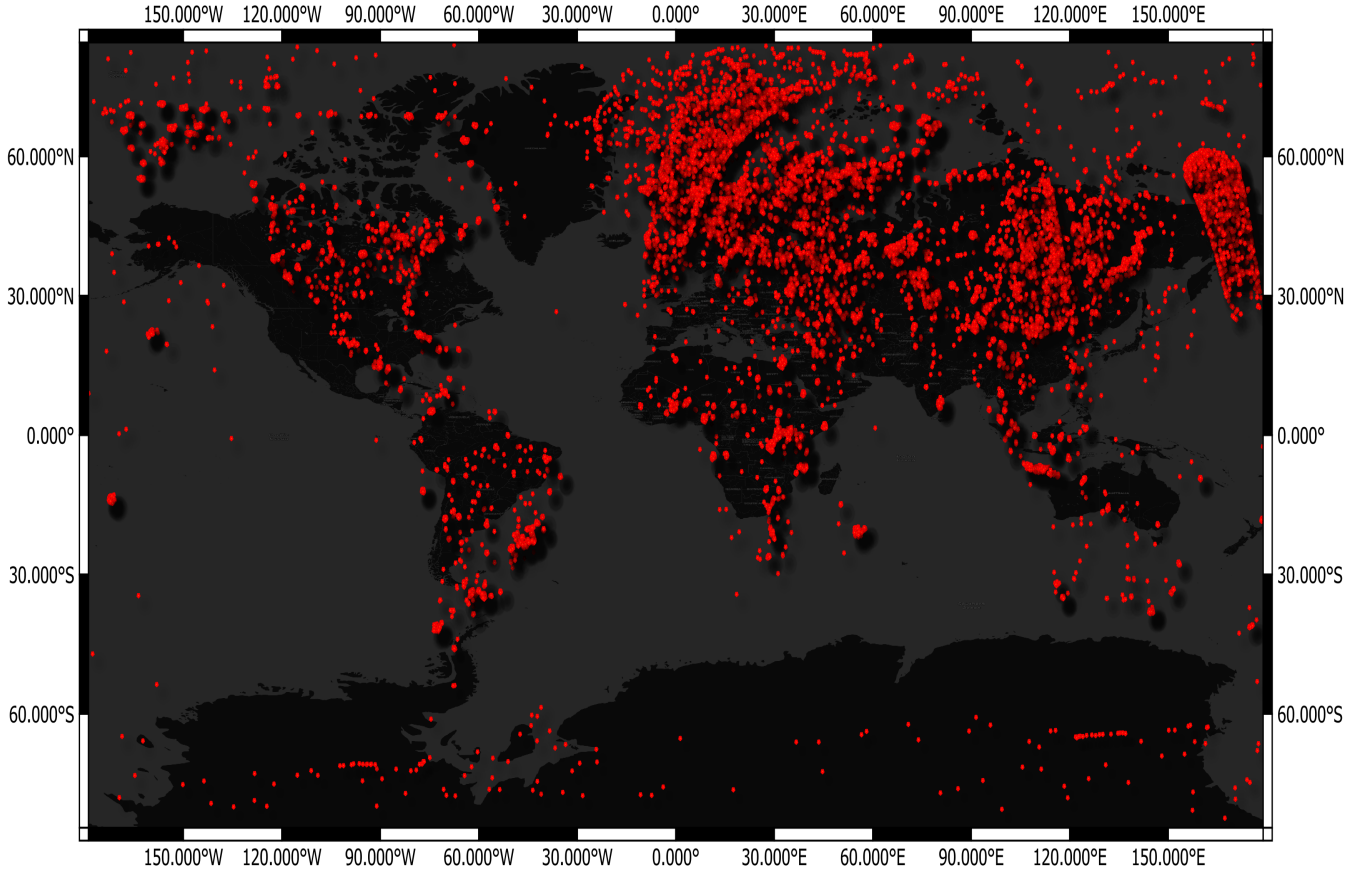


Figure: Global RFI cases from June 1 to June 4, 2017

Data Products

Level 1A data products – Antenna Counts
https://nsidc.org/data/SPL1AP/versions/2

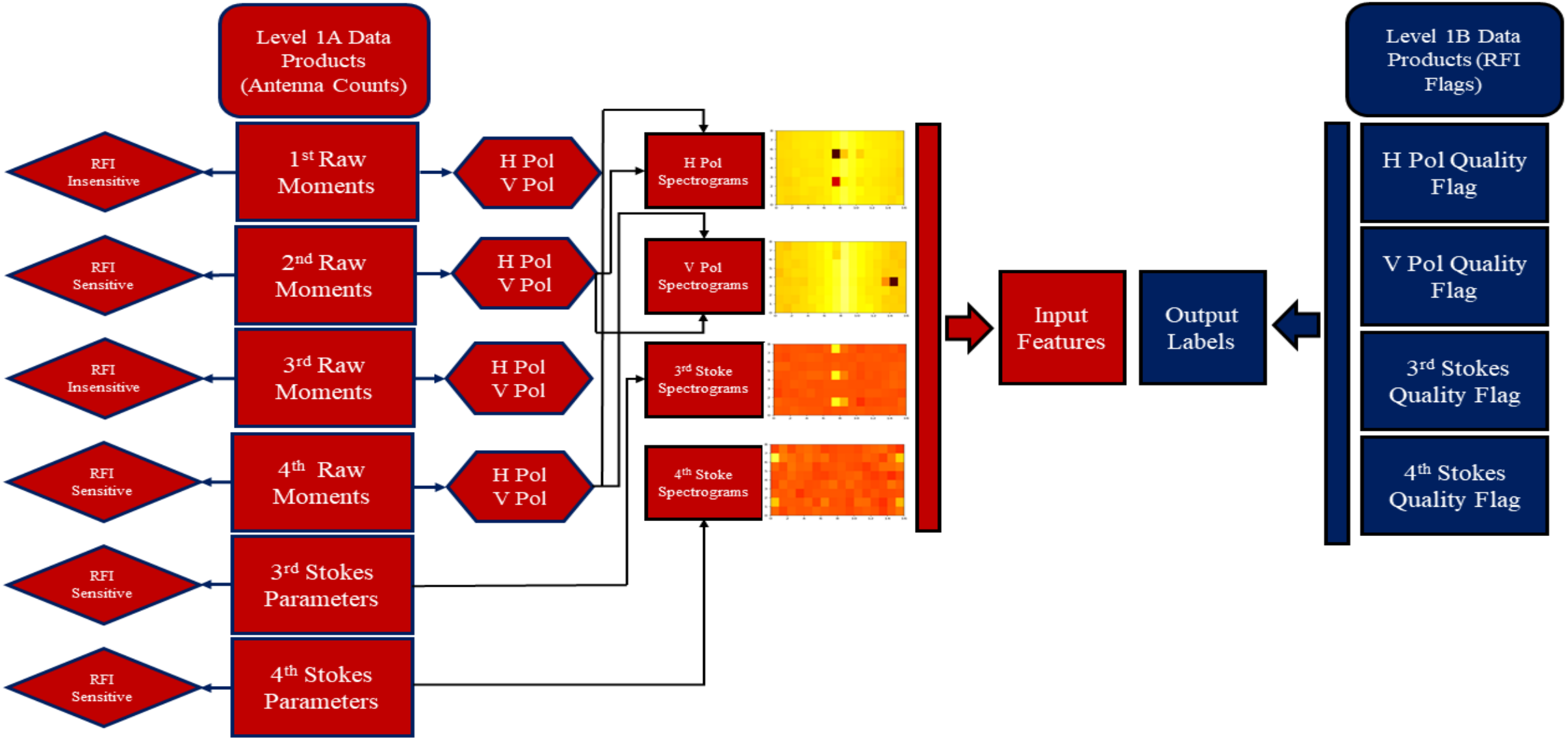
Antenna Moments (779×1931×16×4)
1st Raw Moment - $M_1 = \frac{1}{N}\sum_{1=1}^{N} X_1$
2nd Raw Moment - $M_3 = \frac{1}{N}\sum_{1=1}^{N} X_1^{\,3}$
3rd Raw Moment - $M_3 = \frac{1}{N}\sum_{1=1}^{N} X_1^{\,3}$
4th Raw Moment - $M_4 = \frac{1}{N}\sum_{1=1}^{N} X_1^{\,4}$

Stokes Parameters (779×1931×16)
3rd Stokes Parameters
4th Stokes Parameters

Level 1B data products – Brightness Temperatures
https://nsidc.org/data/SPL1BTB/versions/5

Quality Flags (779×241)
Horizontal Polarization
Vertical Polarization
3rd Stokes Parameters
4th Stokes Parameters

Algorithm Flowchart



Data Statistics

Antenna Counts Domain		Spectrogram Images	Observed Footprints	Observed Antenna Scans
Vertical	2nd Raw	190,000	1,100,000	170,000
	4th Raw	190,000	1,100,000	170,000
Horizontal	2nd Raw	202,000	1,200,000	180,000
	4th Raw	202,000	1,200,000	180,000
3rd Stokes		71,000	900,000	150,000
4th Stokes		66,000	800,000	140,000

Data Preparation

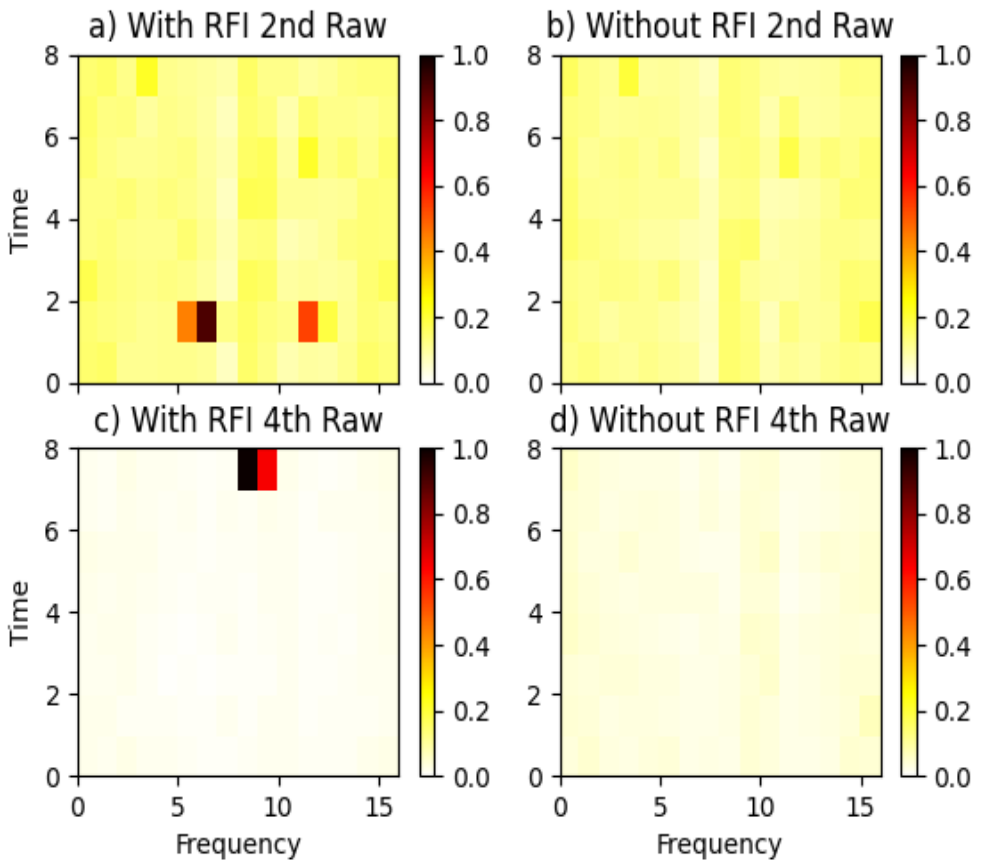


Figure: Spectrogram images from vertical polarization (Sensitive to RFI)

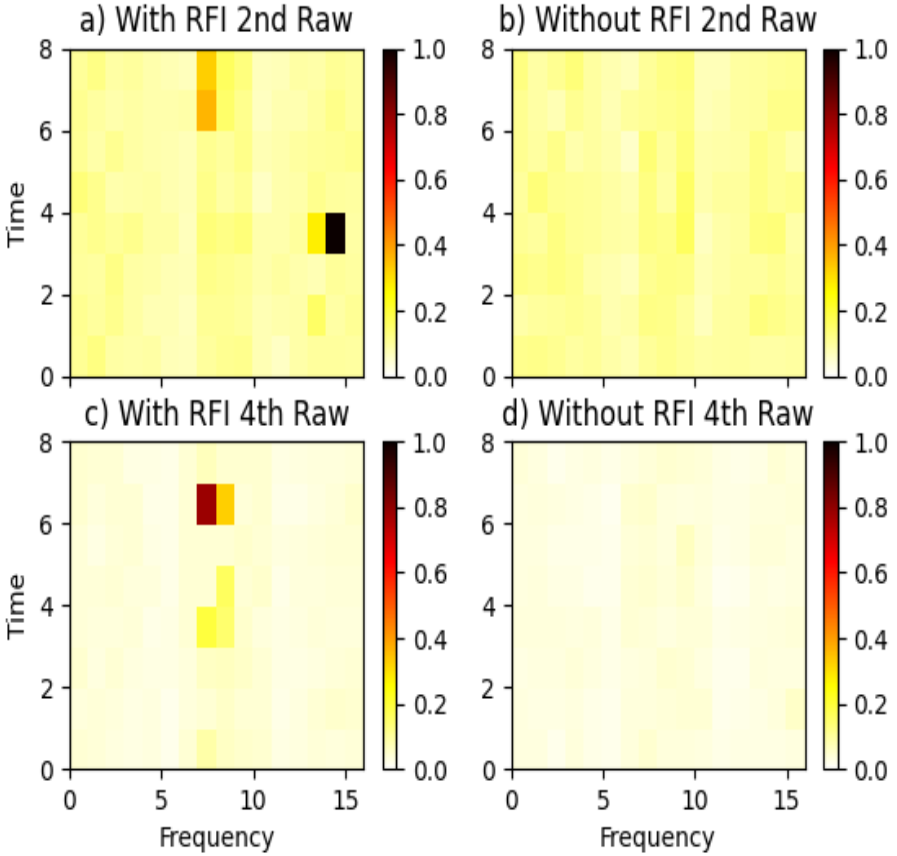


Figure: Spectrogram images from horizontal polarization (Sensitive to RFI)

Data Preparation

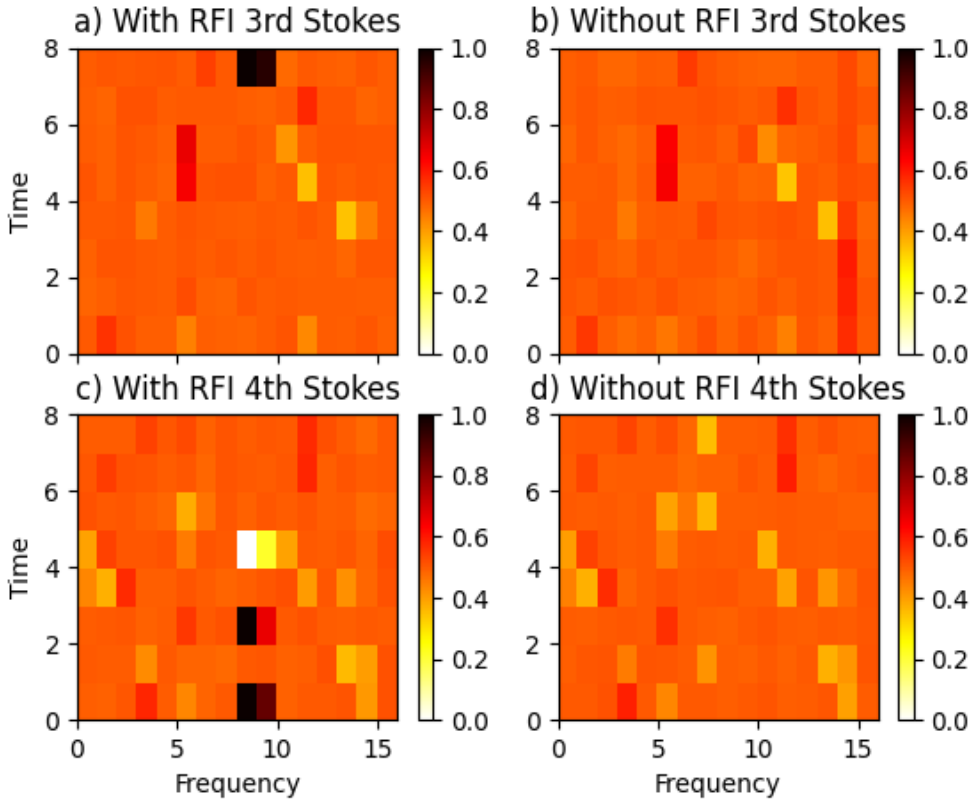


Figure: Spectrogram images from 3rd stokes and 4th stokes parameters (Sensitive to RFI)

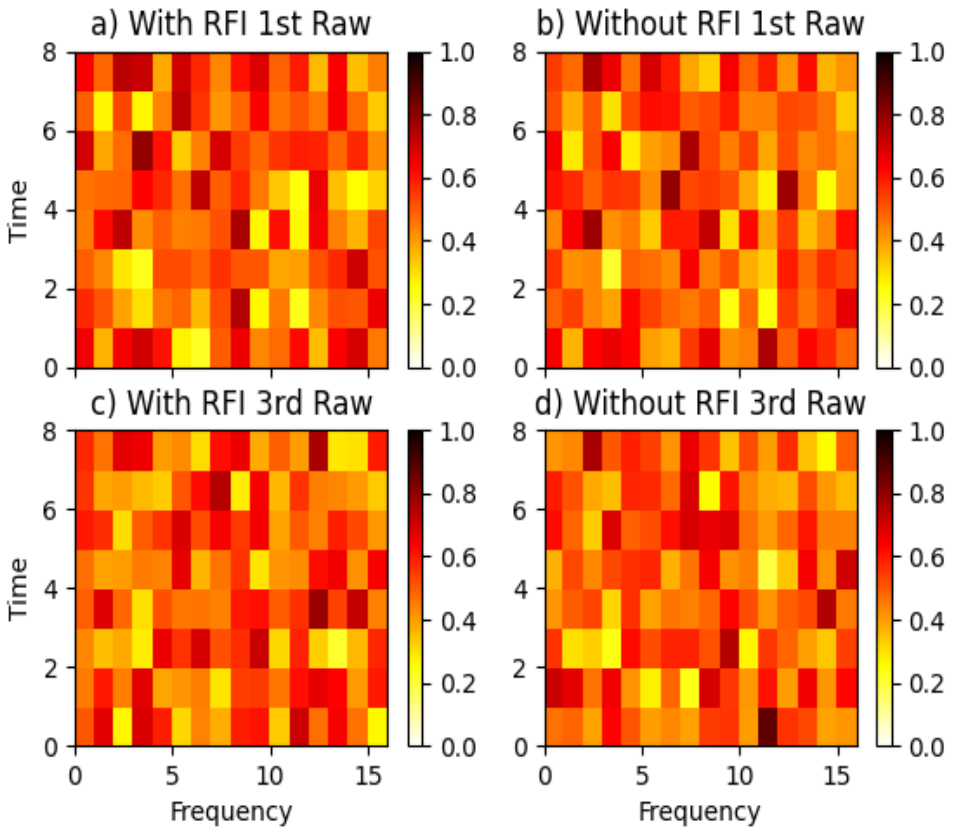


Figure: Spectrogram images from vertical polarization (Insensitive to RFI)

Deep Learning Architecture

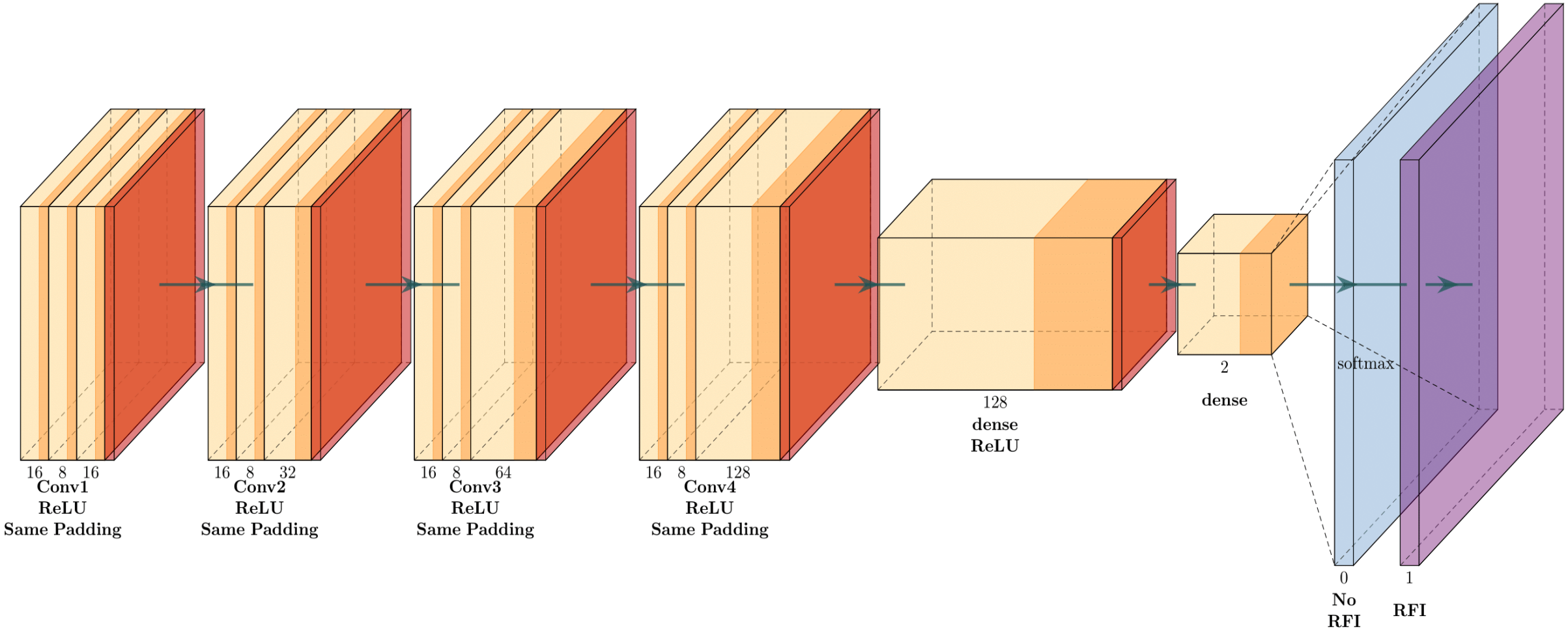


Figure: Deep learning architecture with 4 convolutional layers followed by a fully connected layer of 128 neurons

Hyper-Parameter Optimization of Deep Learning

Hyper-Parameter	Details
Input Size	?6×8
No. of Samples	1 million
Normalization	Max-Min
Padding	Same
Activation Function	ReLU
Optimizer	Adam
Loss Function	Binary Cross-Entropy
Kernel Size	?×?
Cross Validation	Train-Test Split & 5-fold
Epochs	60

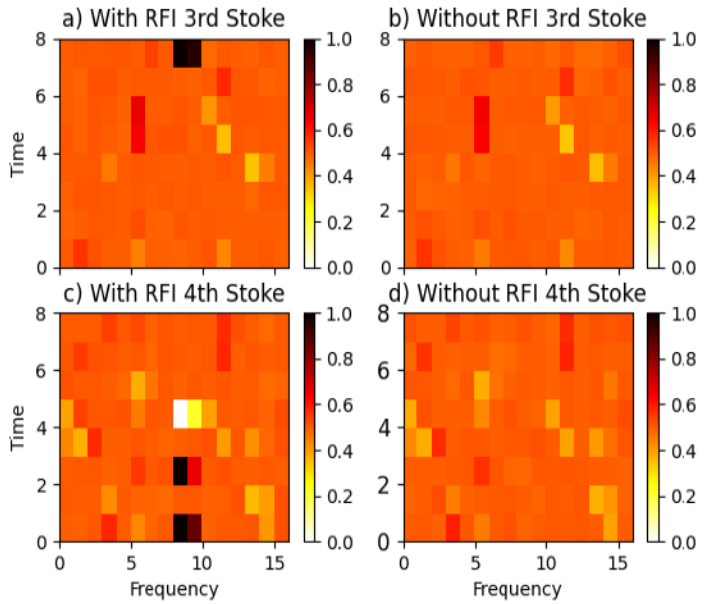
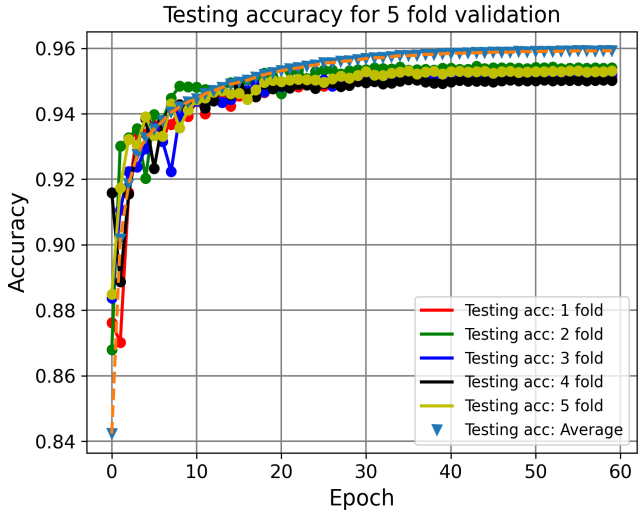


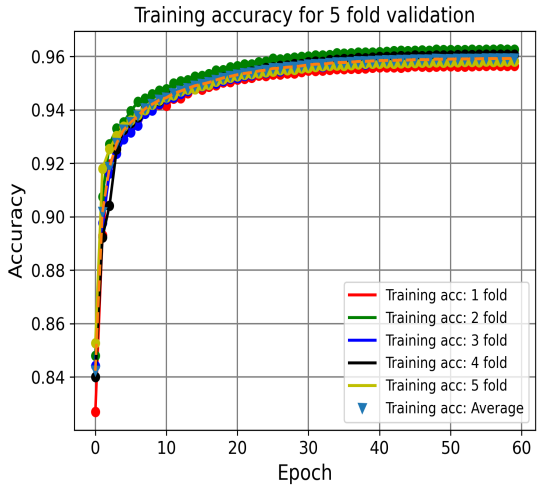
Figure: "Same" padding in convolutional layer helps to extract the features from spectrograms

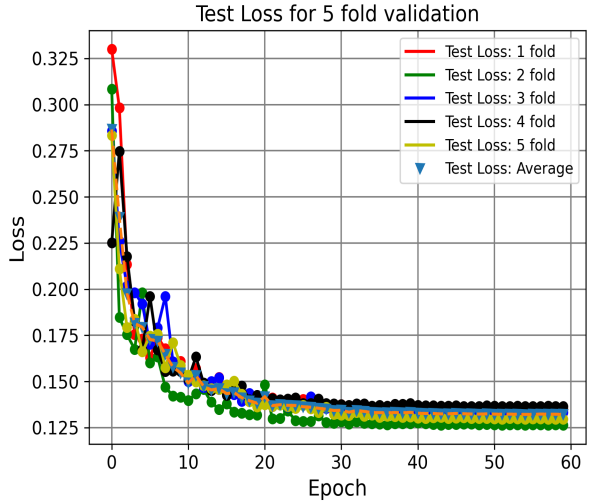
Results

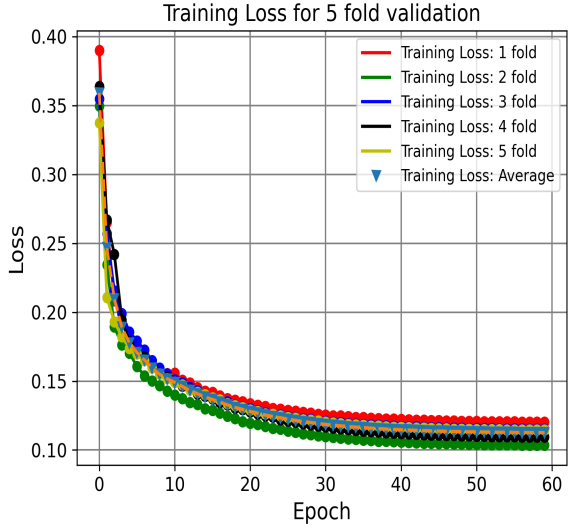
Antenna Counts Domain		Accuracy	Precision
Vertical	2nd Raw	95.1%	95.2%
	4th Raw	94%	93.8%
Horizontal	2nd Raw	94.3%	94.7%
	4th Raw	94.6%	94.7%
Thirds Stokes		93.6%	94%
Fourth Stokes		93.5%	93.7%

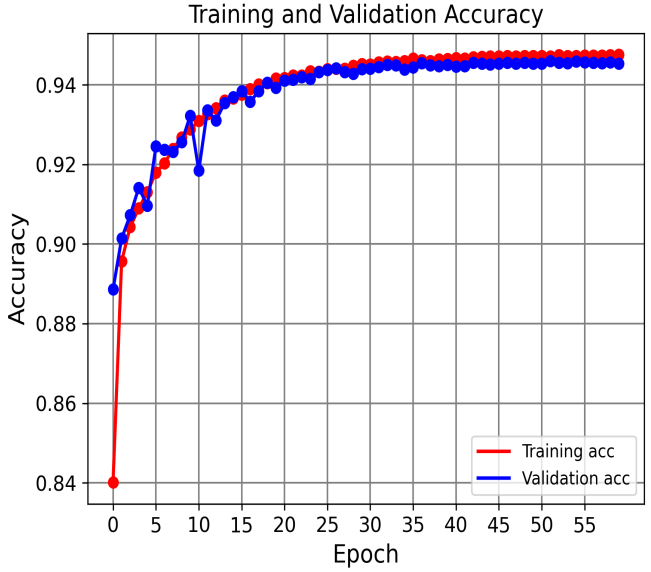
Prediction With 2nd Raw Moments of Horizontal Channel

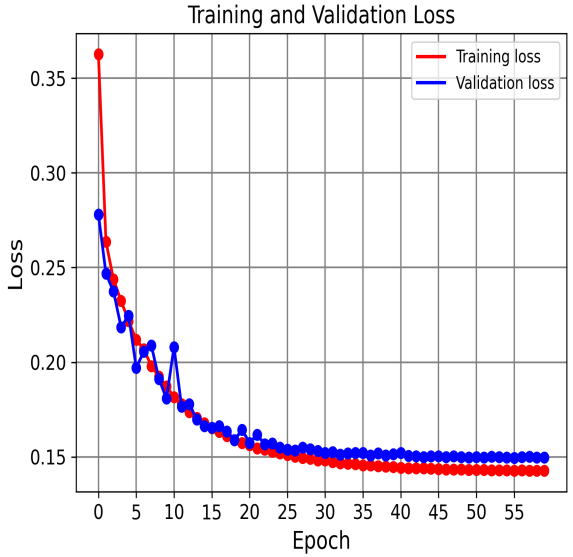


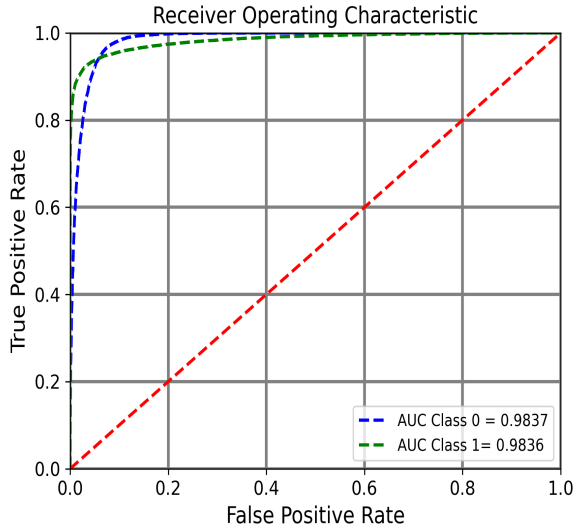


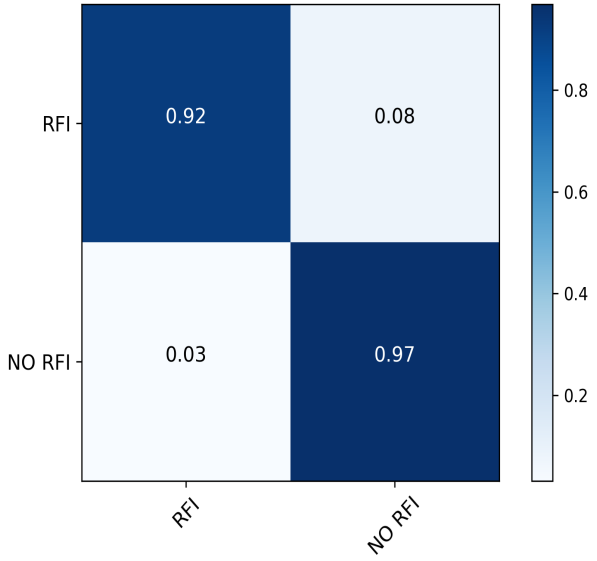




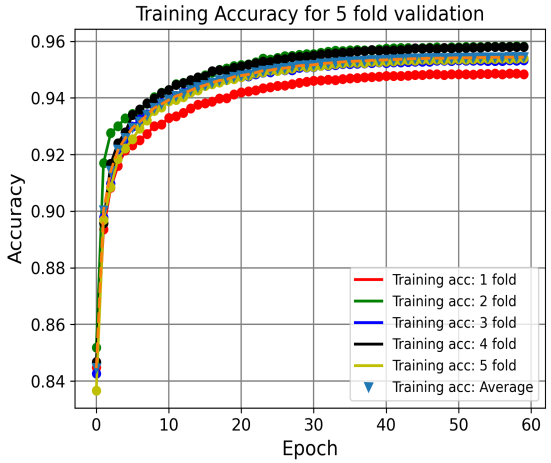


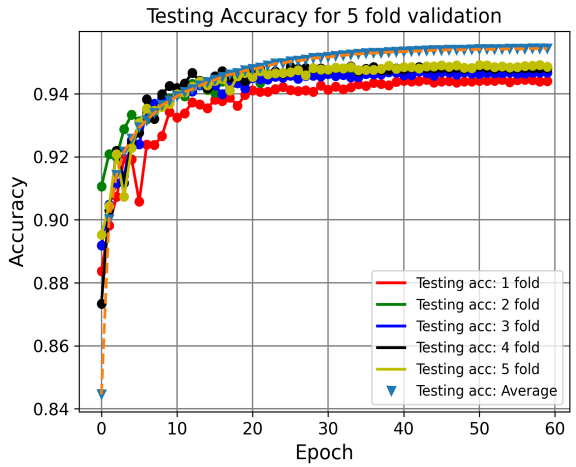


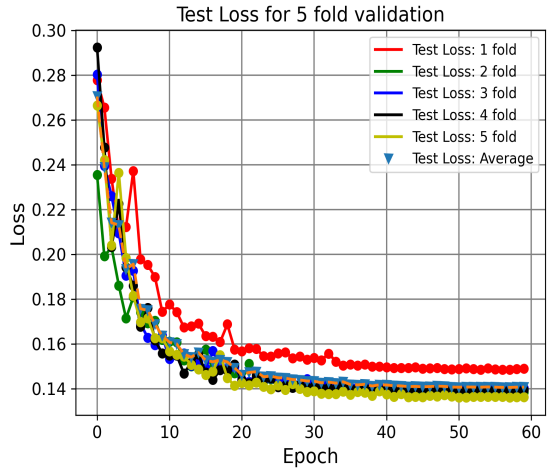


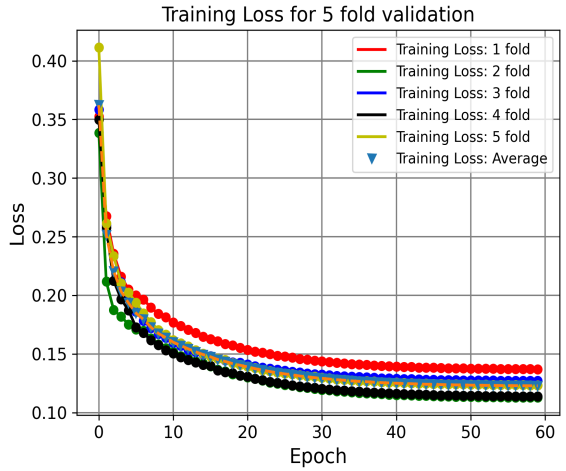


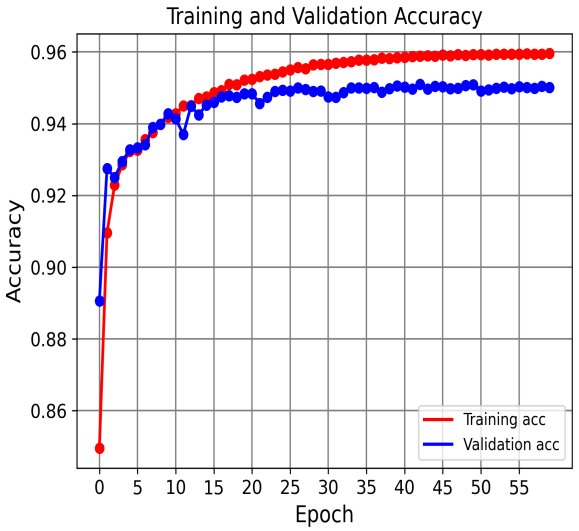
Prediction With 2nd Raw Moments of Vertical Channel

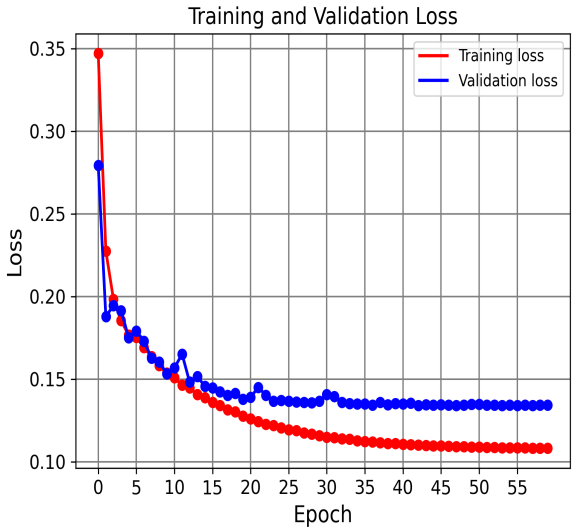


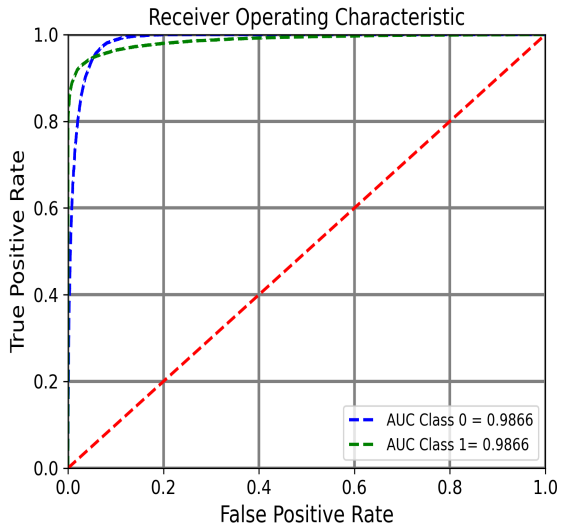


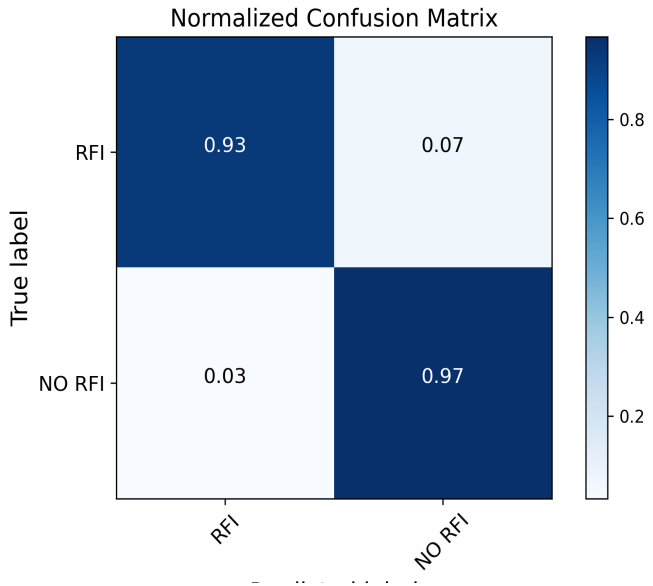




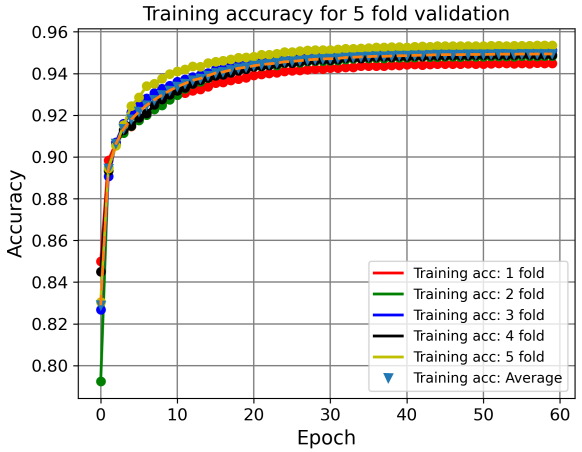


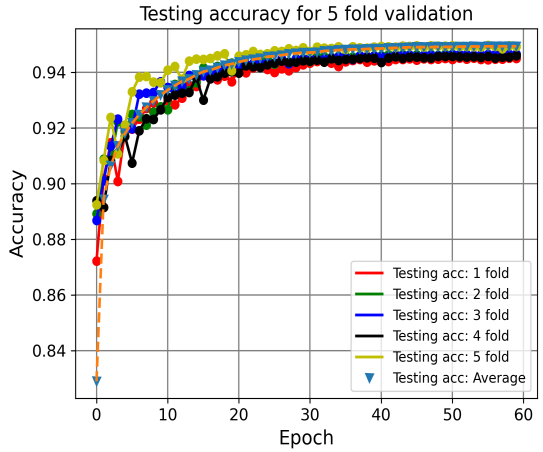


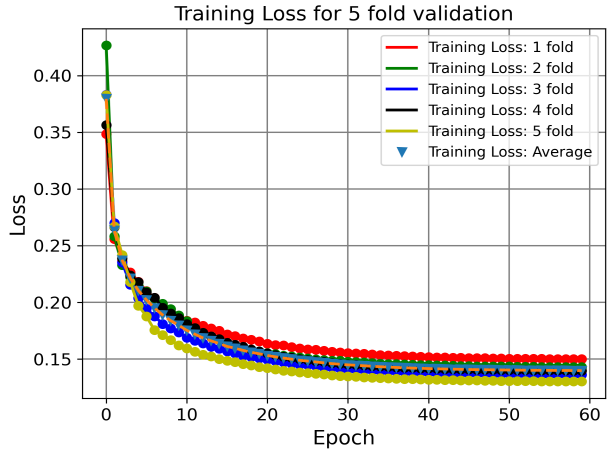


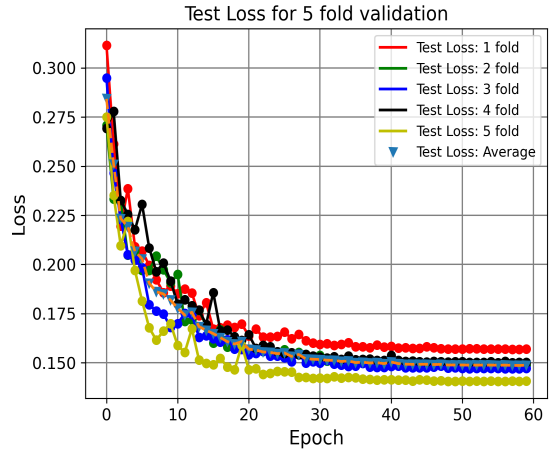


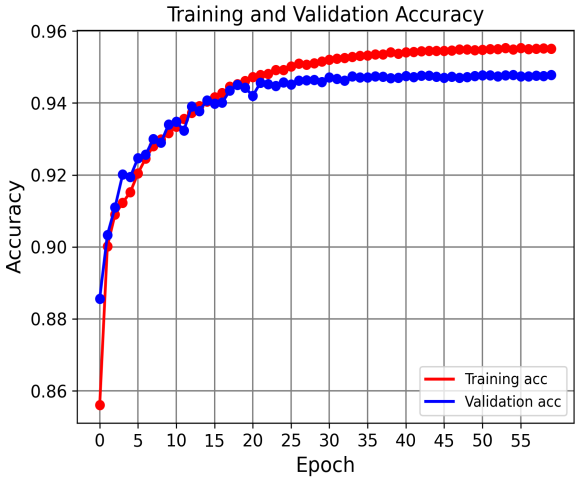
Prediction With 4th Raw Moments of Horizontal Channel

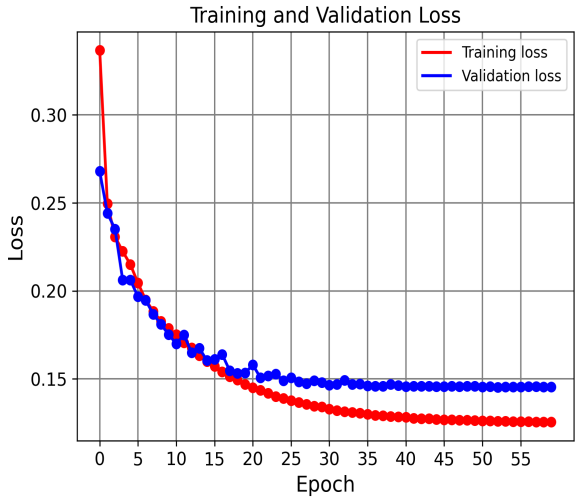


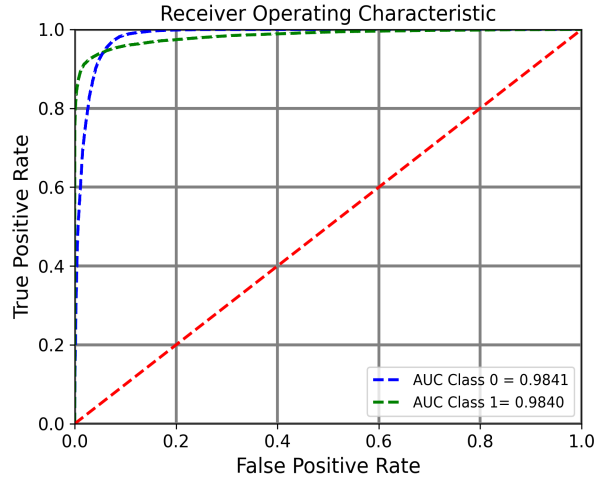


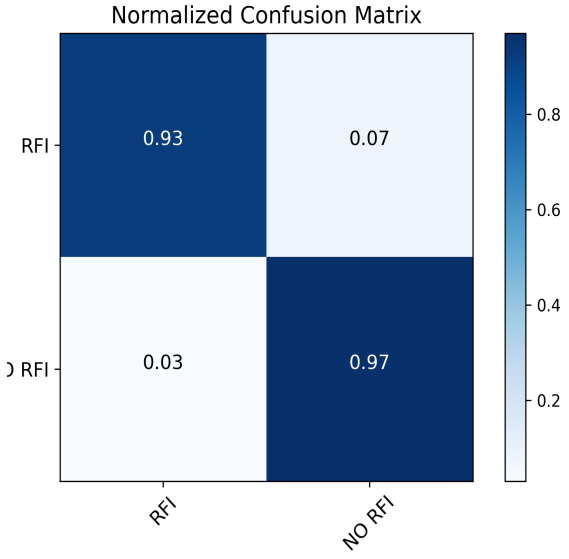




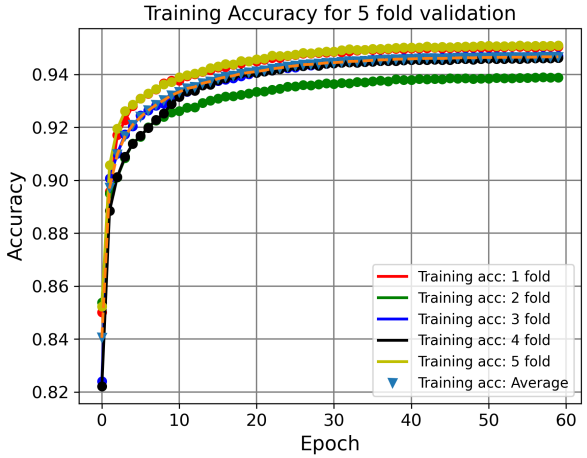


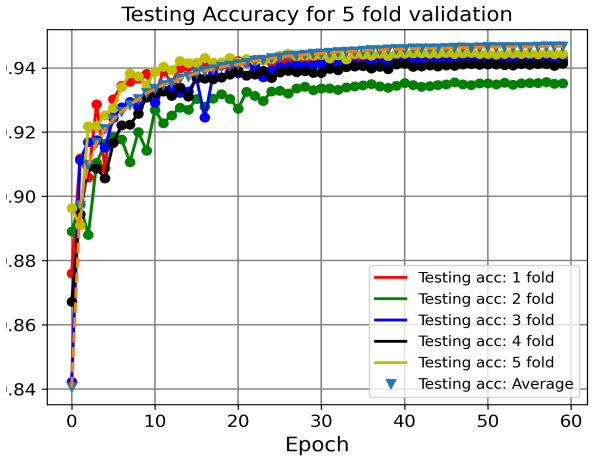


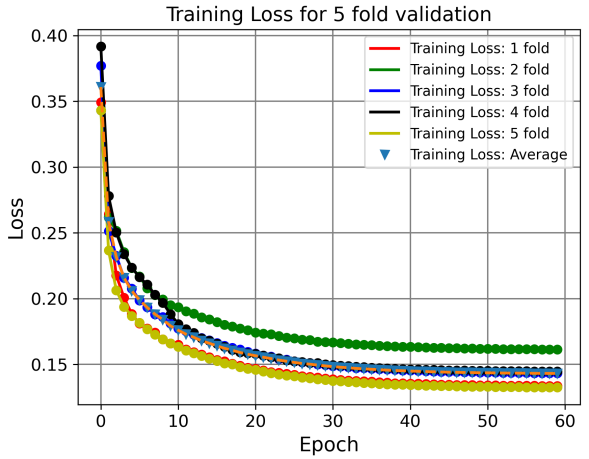


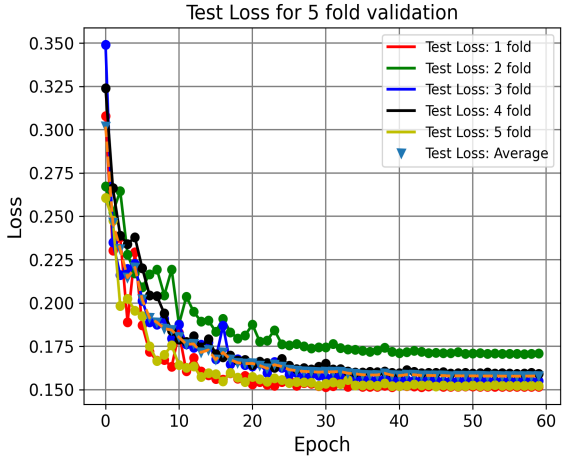


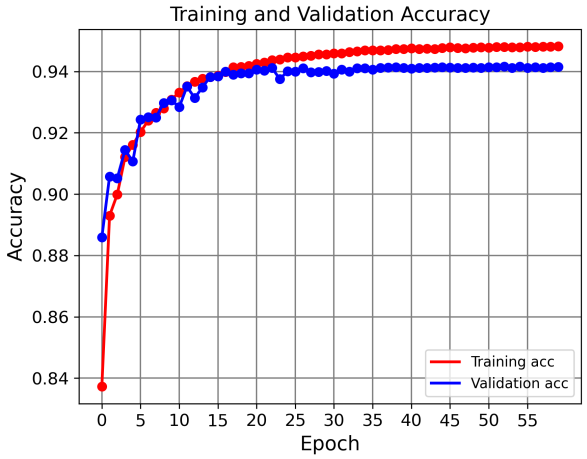
Prediction With 4th Raw Moments of Vertical Channel

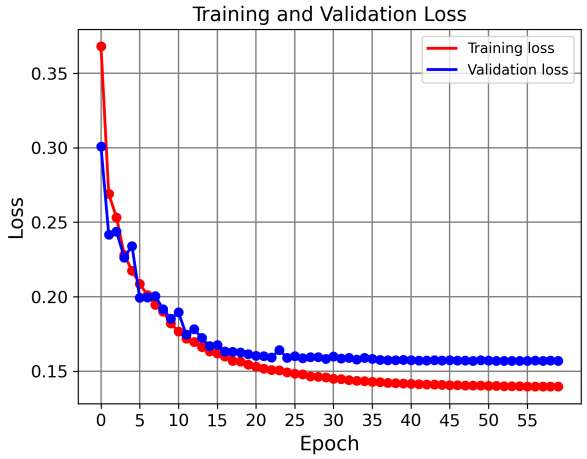


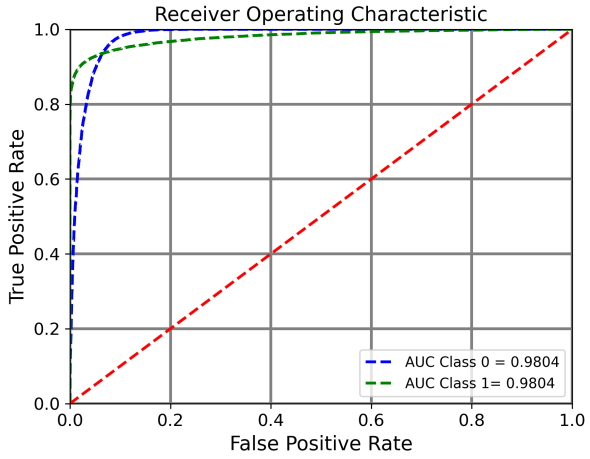


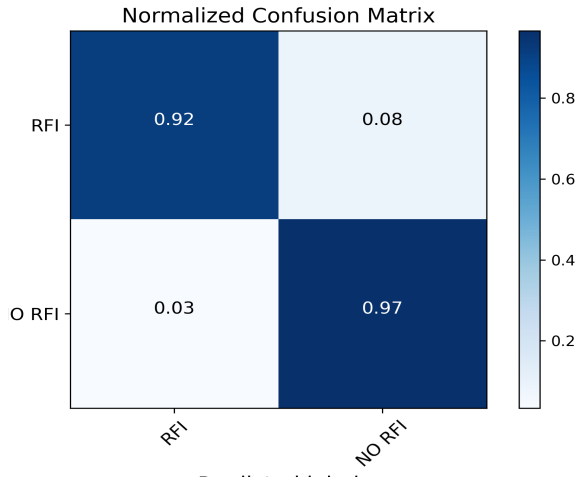




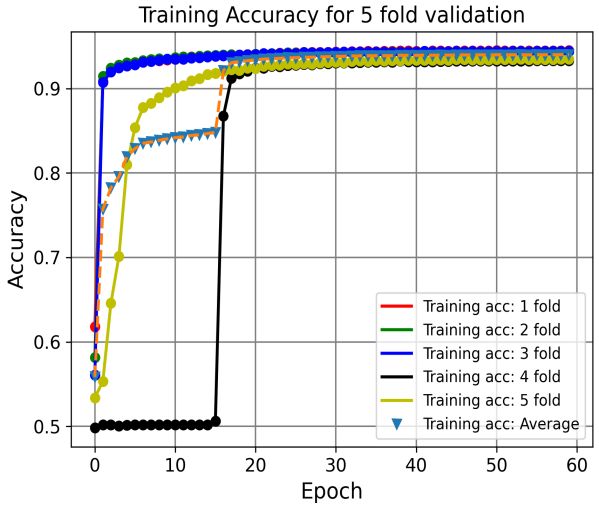


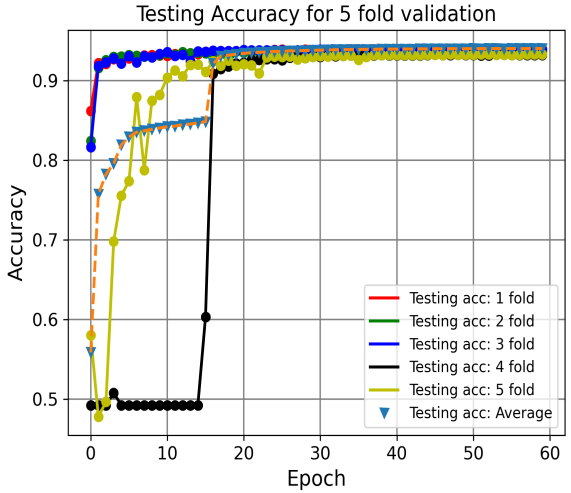


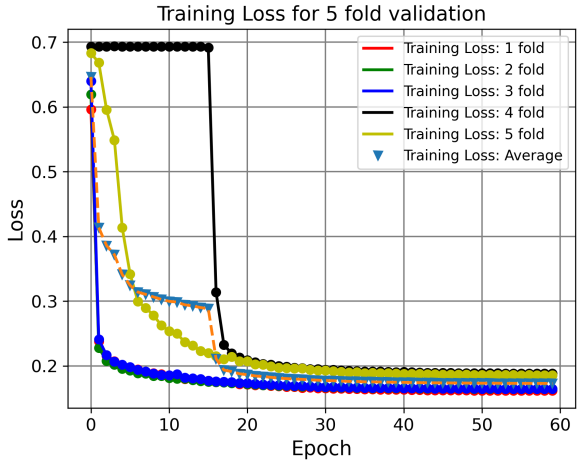


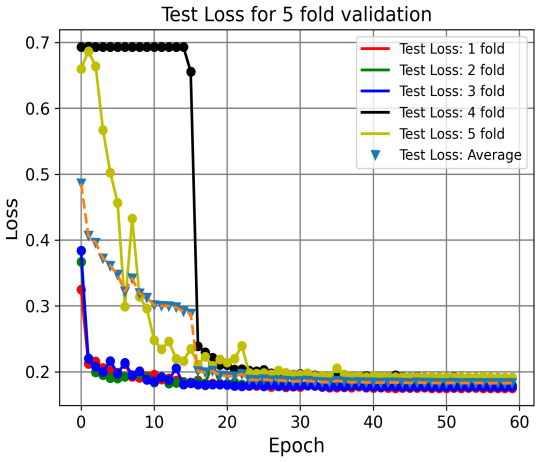


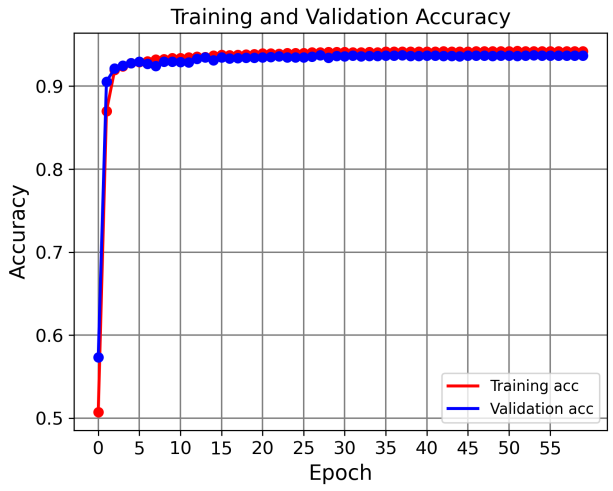
Prediction With 3rd Stokes Parameters

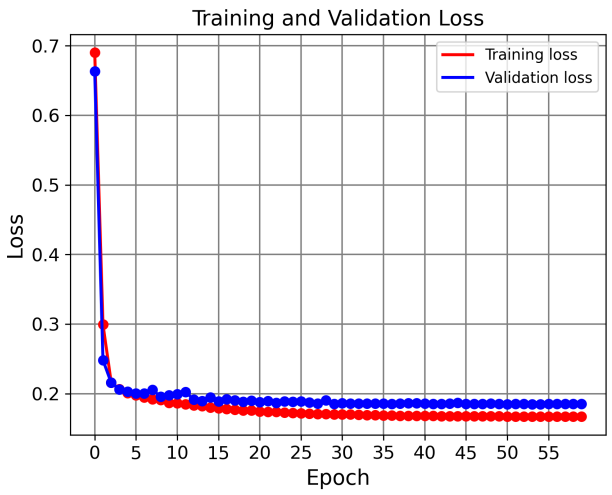


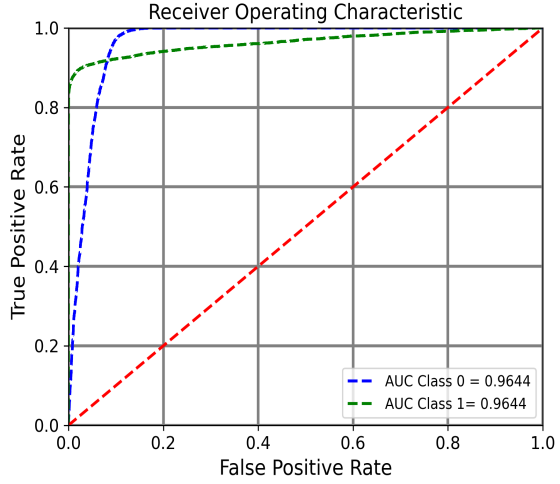


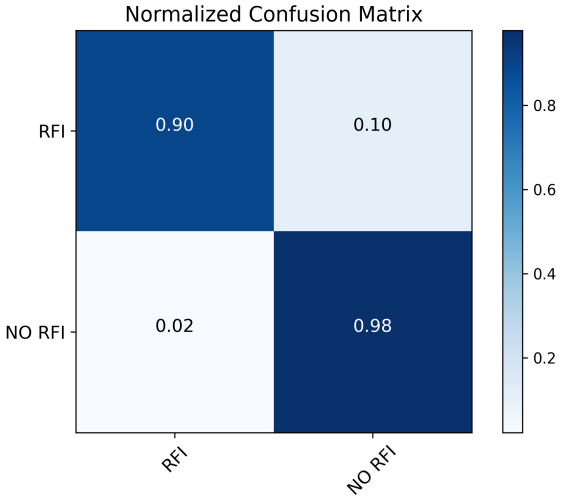




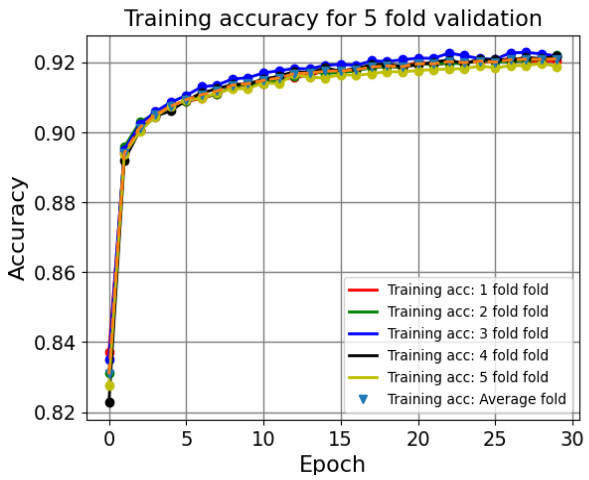


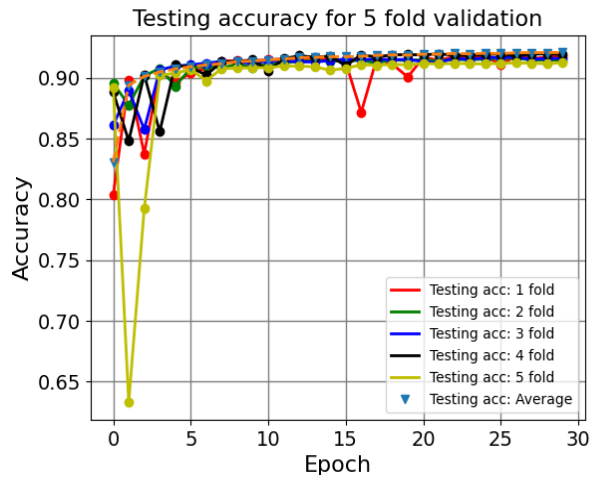


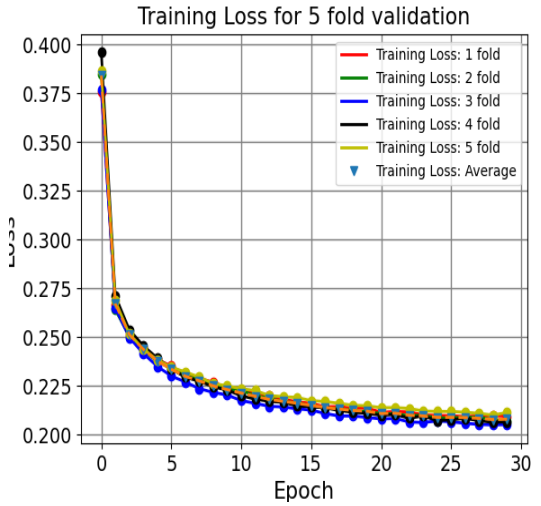


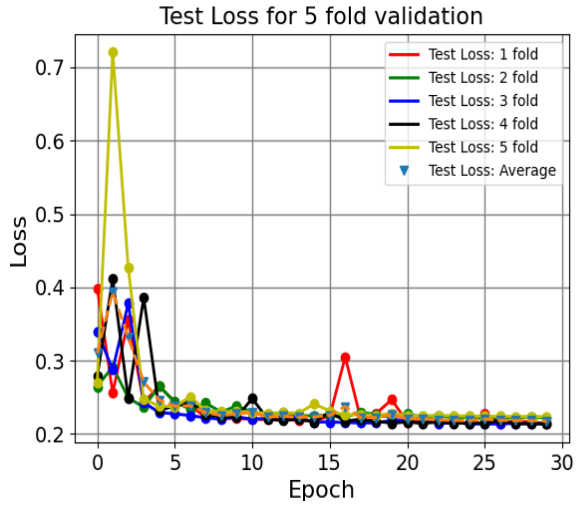


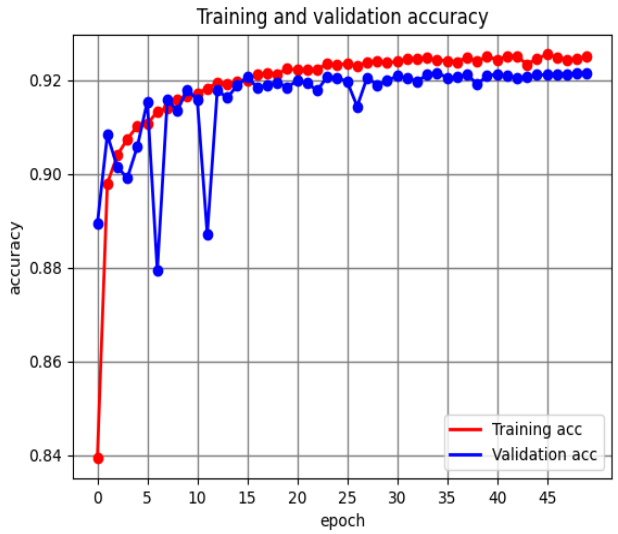
Prediction With 4th Stokes Parameters

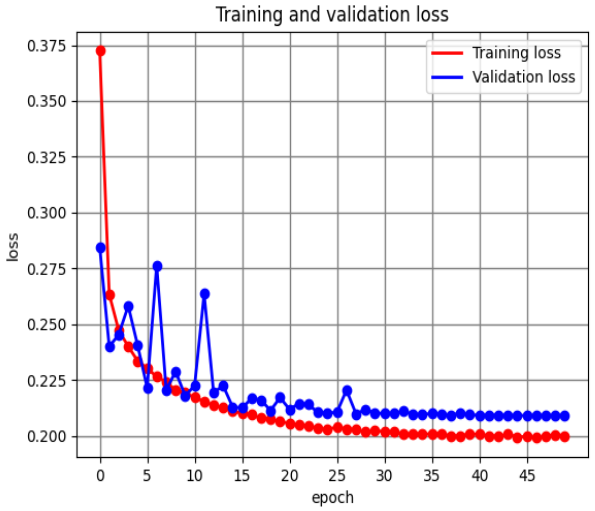


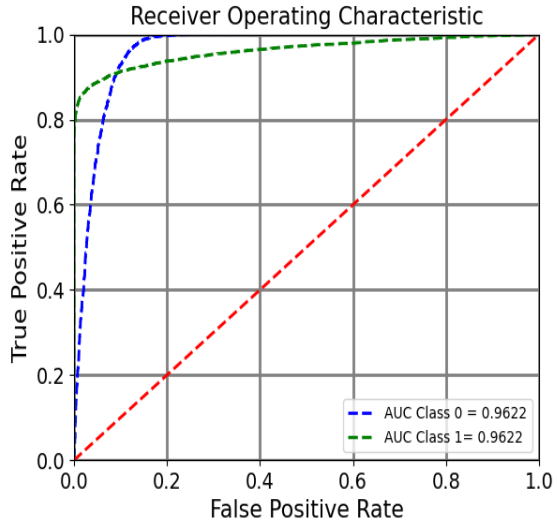


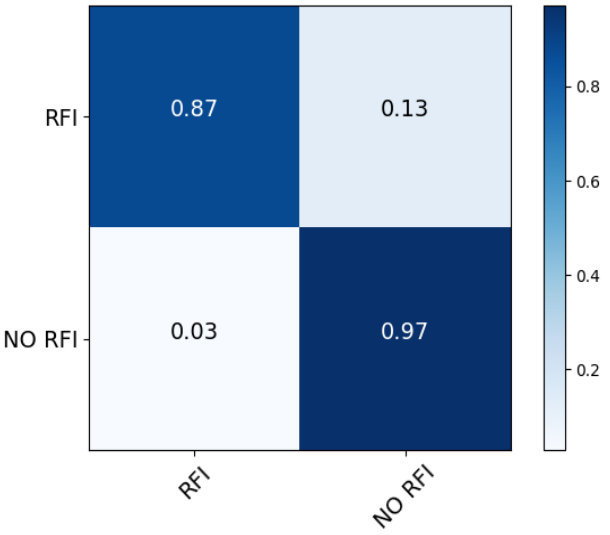












Comparison Between Deep Learning Architecture and SMAP

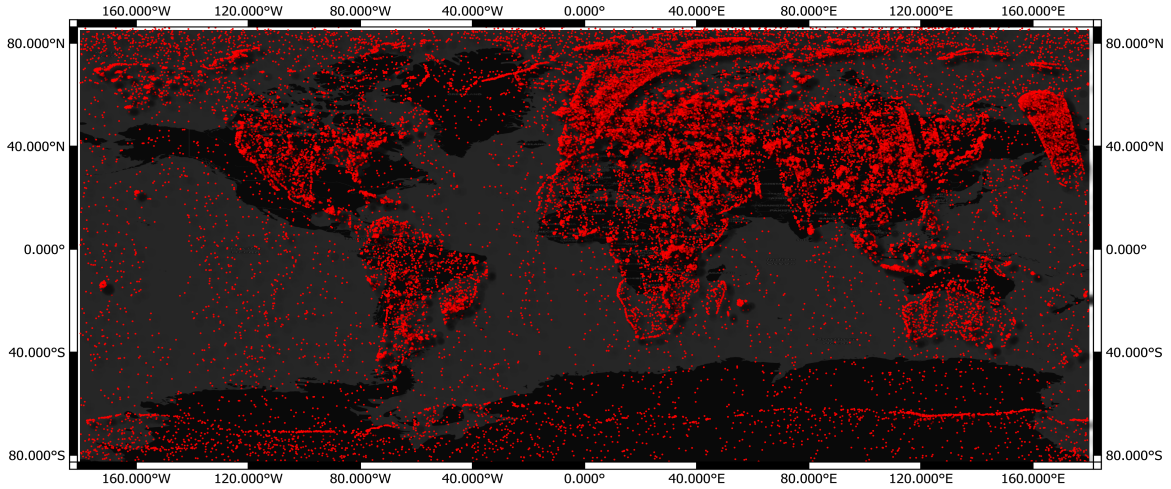


Figure: RFI prediction with deep learning vertical polarization

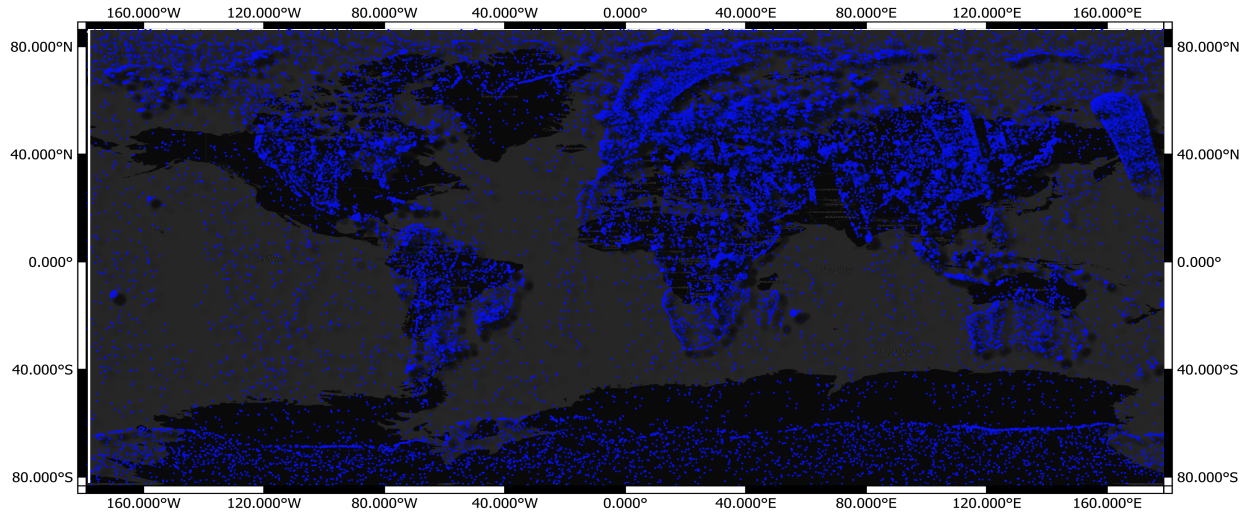


Figure: RFI prediction with SMAP quality flags

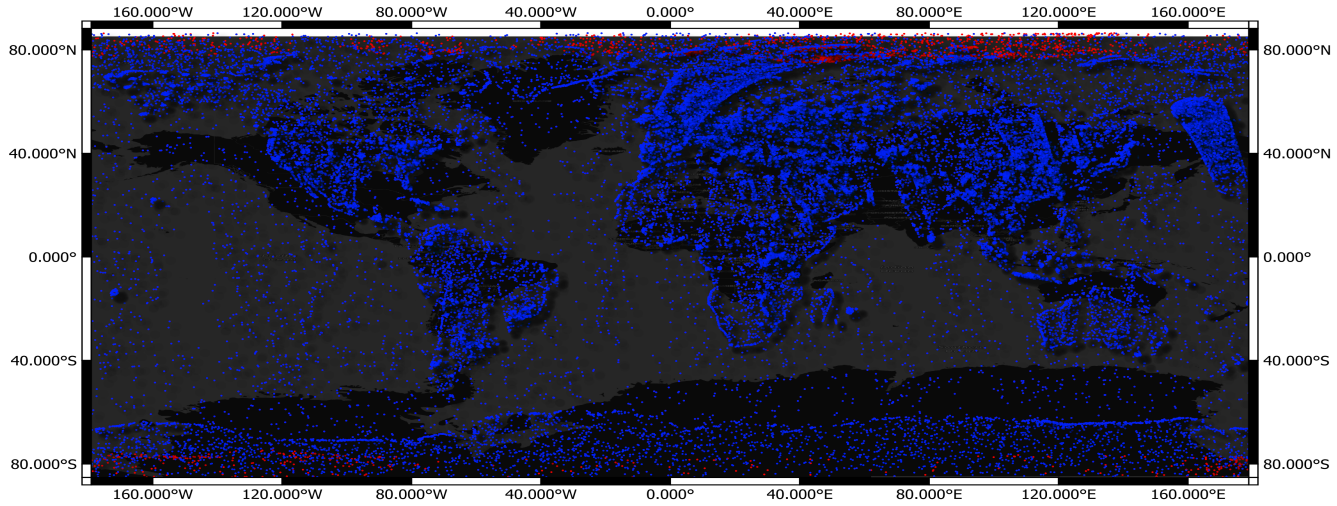


Figure: A comparison between SMAP and deep learning

Discussion and Future Work

- *In-situ* RFI contaminated sample collection is very challenging. To label the dataset for this study, SMAP's level 1B data quality flags have been used. So, there is less control over the dataset
- Future work aims to incorporate synthetically generated RFI into SMAP data products to have greater control over the dataset
- This will be helpful to distinguish lower and higher level RFI scenarios as well as single and multiple sources RFI

Acknowledgement

- This work was supported by National Science Foundation under Grant no. 2030291 and 204771

Thank You