Convolutional Neural Networks for Hydrometeor Classification Using Dual Polarization Doppler Radars

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Introduction

Radar echoes from dual-polarization radars are widely used to discriminate between meteorological and non-meteorological scatters and to distinguish between various types of hydrometeors (like rain, hail, graupel, snow, etc.). Traditional fuzzy logic hydrometeor classification algorithm is a common way to classify precipitation type for dual polarization doppler radar. We develop a new deep learning method to effieiently classify hydrometeors using various radar moments (horizontal reflectivity (Z_H), differential reflectivity (Z_{DR}), correlation coefficient (ρ_{HV}) and specific differential phase (K_{DP})). In this study we analyze data collected by NEXRAD at Vance AFB facility at the first elevation angle from January 1st, 2015 to October 1st, 2018. Four deep learning architectures were explored to classify hydrometeors into four target categories (Ice Crystals (IC), Dry Snow (DS), Light and/or Moderate Rain (RA) and Big Drops (rain) (BD)).

Method

Convolutional neural network (CNN) models were developed to mine the non-linear relationship between the four selected radar observations and hydrometeor types. We explored four CNN architectures (AlexNet, VGG, ResNet, and DenseNet) with layers ranging from 8 to 121. CNN networks were modified and optimized for dual polarization doppler radar data.

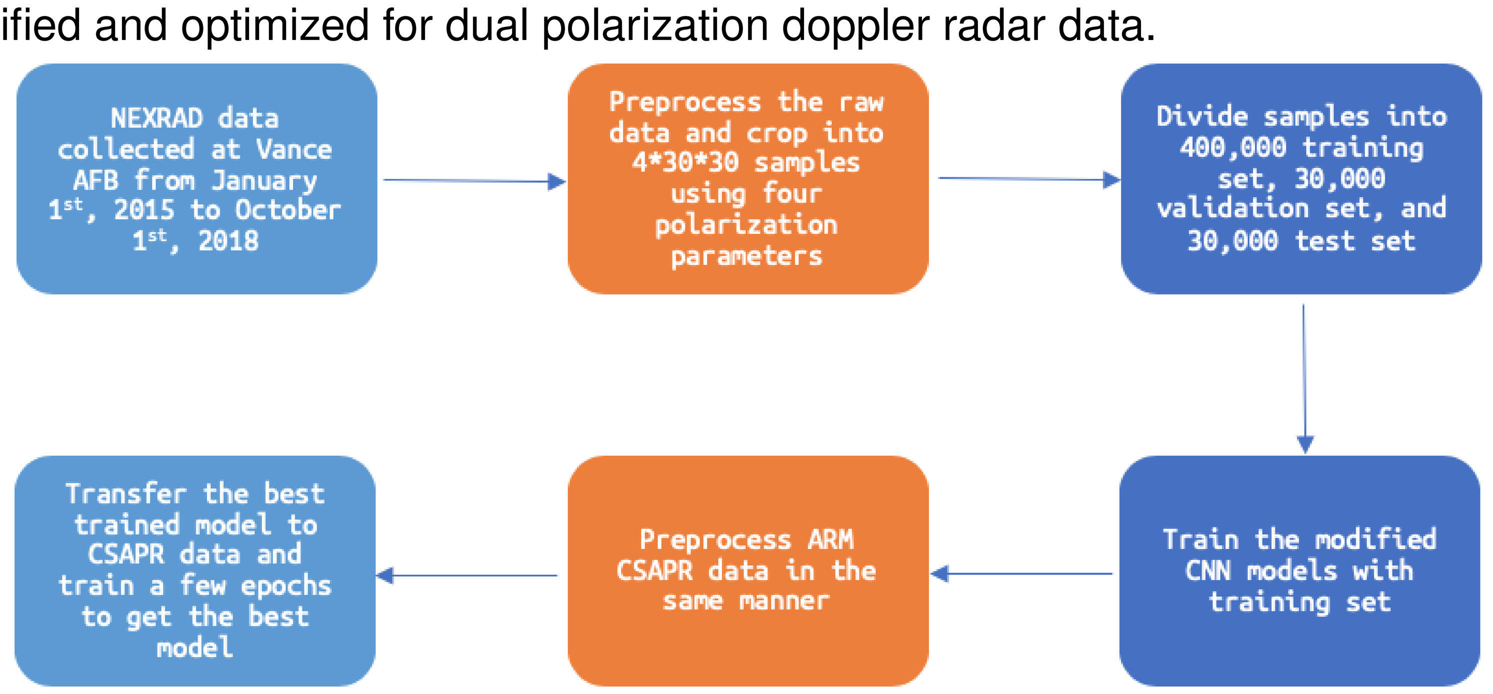


Figure 1: Training workflow

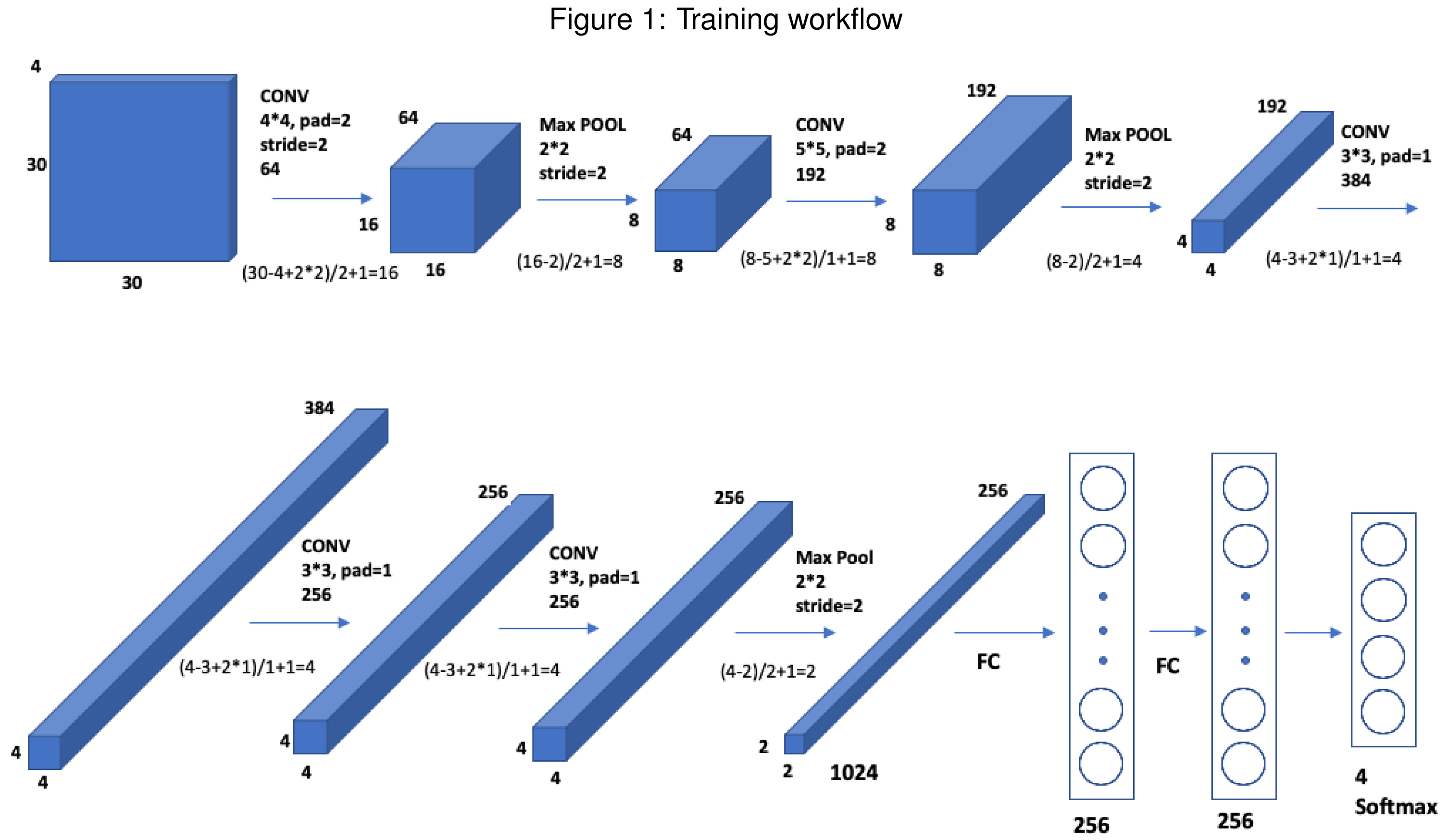


Figure 2: Modified AlexNet architecture for NEXRAD data. All CNN models were implemented in *PyTorch*. Using *PyART* we also implemented our own dataset class for radar data for data loading and processing.

Results

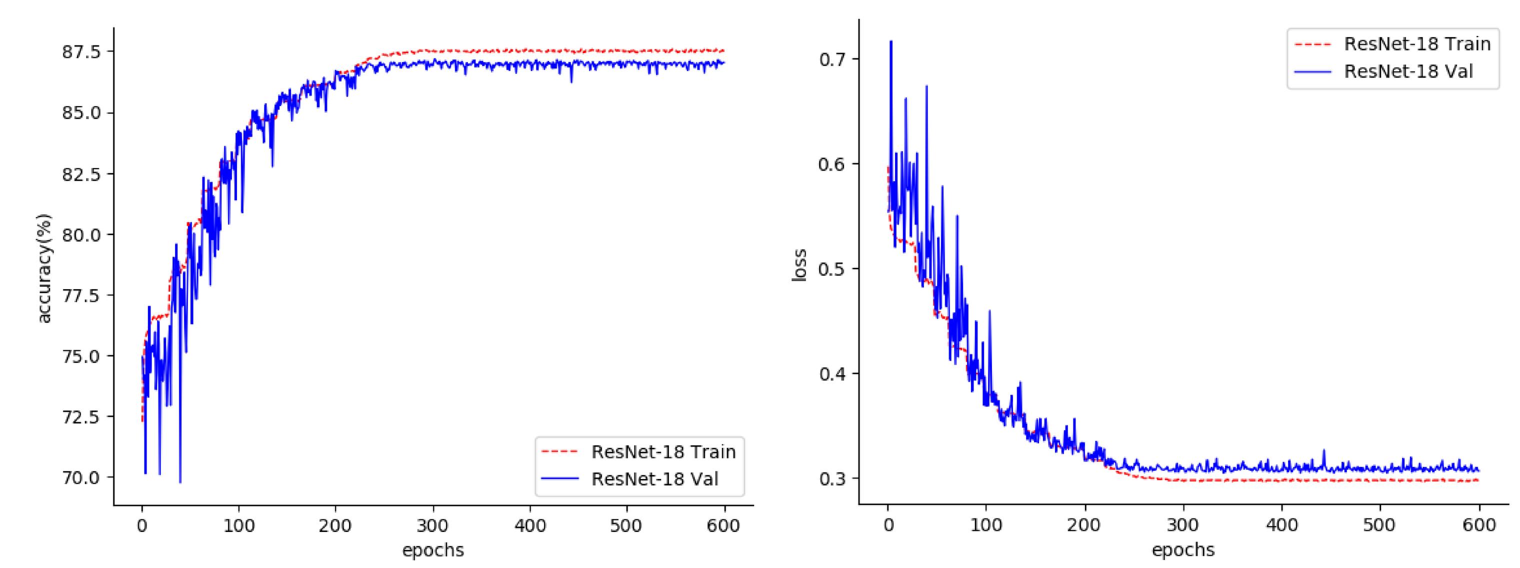


Figure 3: Training and validation accuracy and loss of ResNet-18. NEXRAD raw datasets are preprocessed on ORNL CADES platform. Training and testing of the CNN models are performed on NVIDIA DGX-2 station.

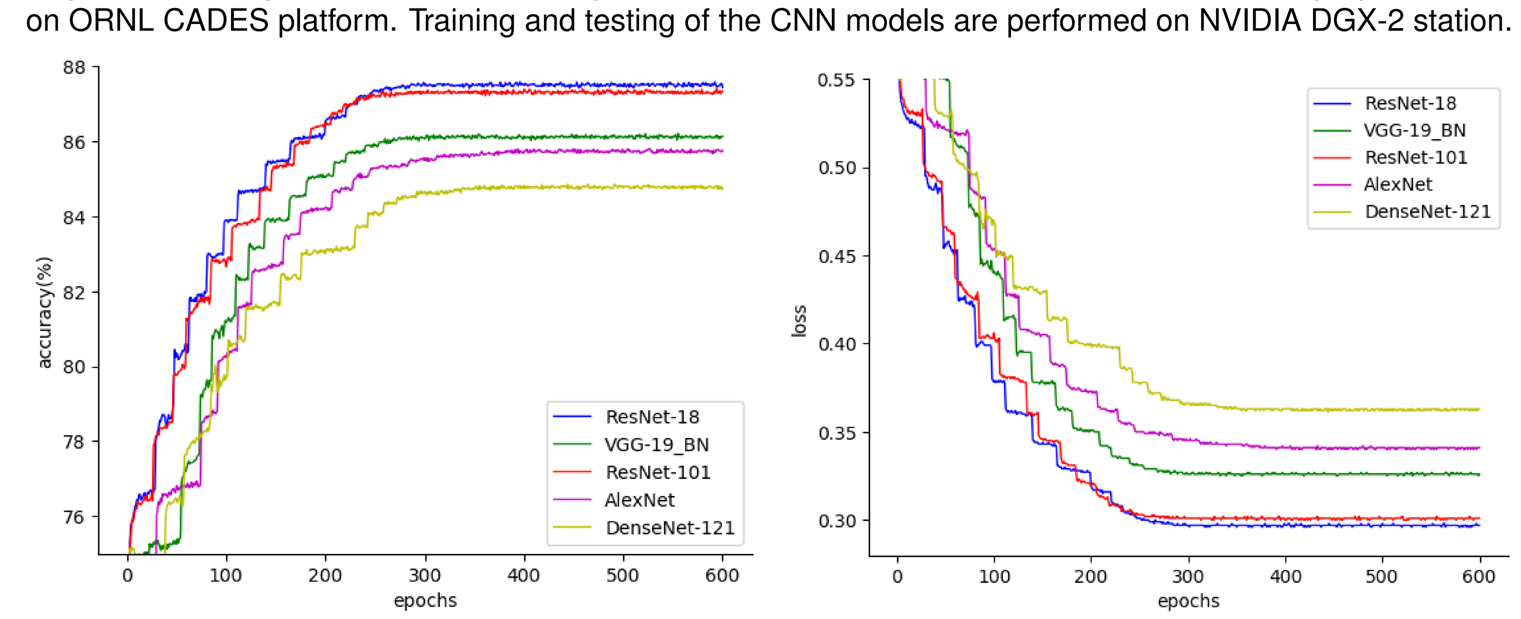


Figure 4: Training accuracy and loss of all five models. ResNet-18 reaches its peak earlier than other models with the highest accuracy, while DenseNet-121 reaches its peak later than others and has the biggest loss.

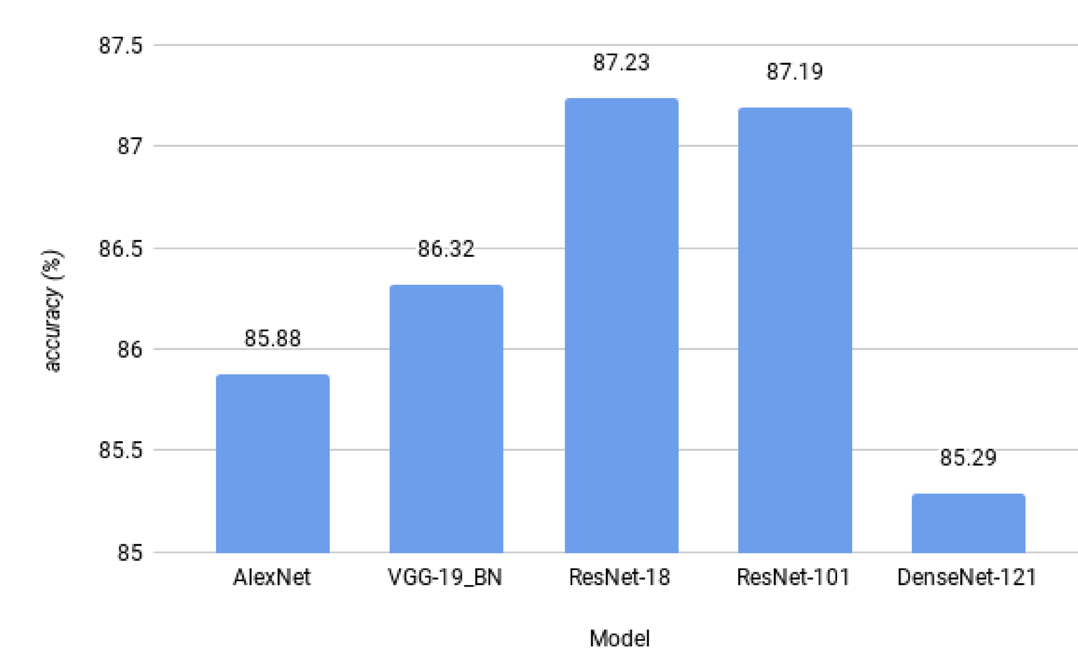
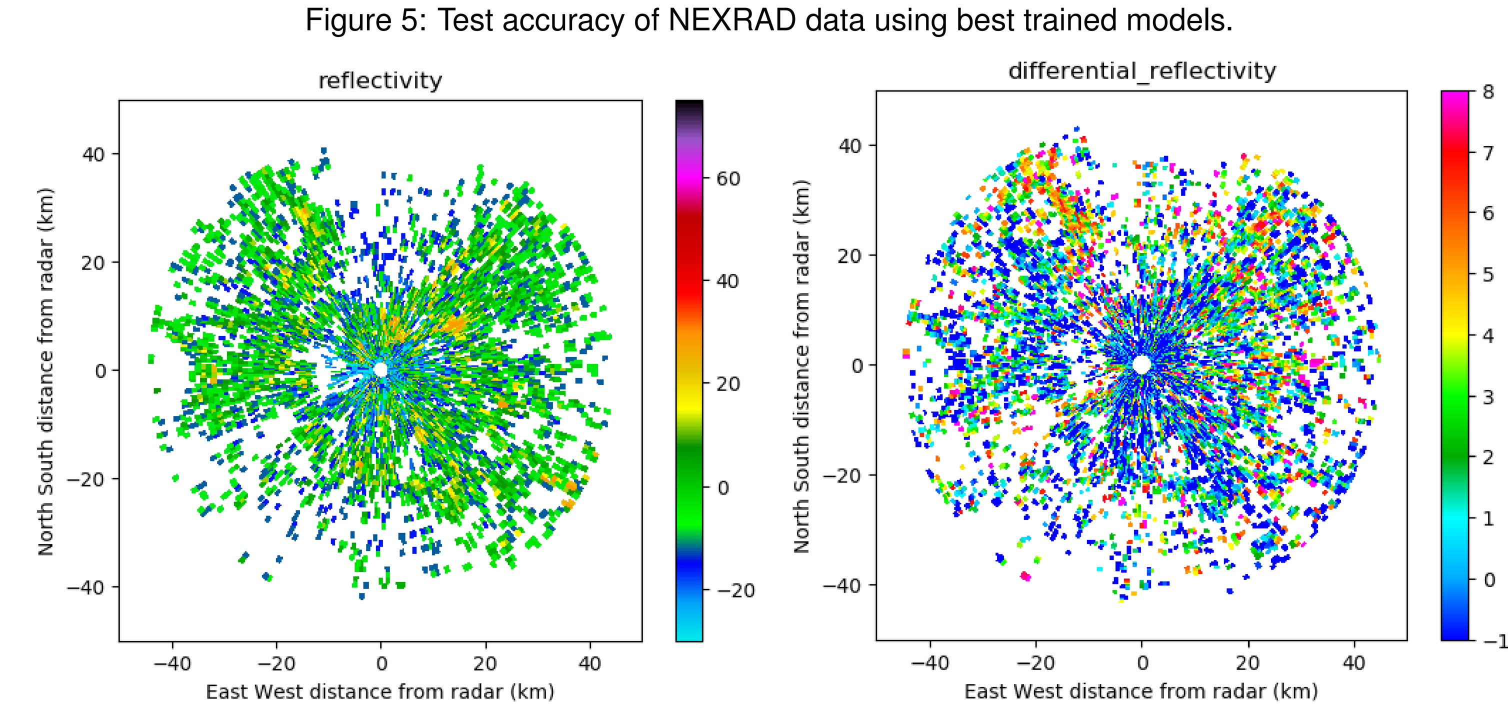


Figure 5: Test accuracy of NEXRAD data using best trained models.



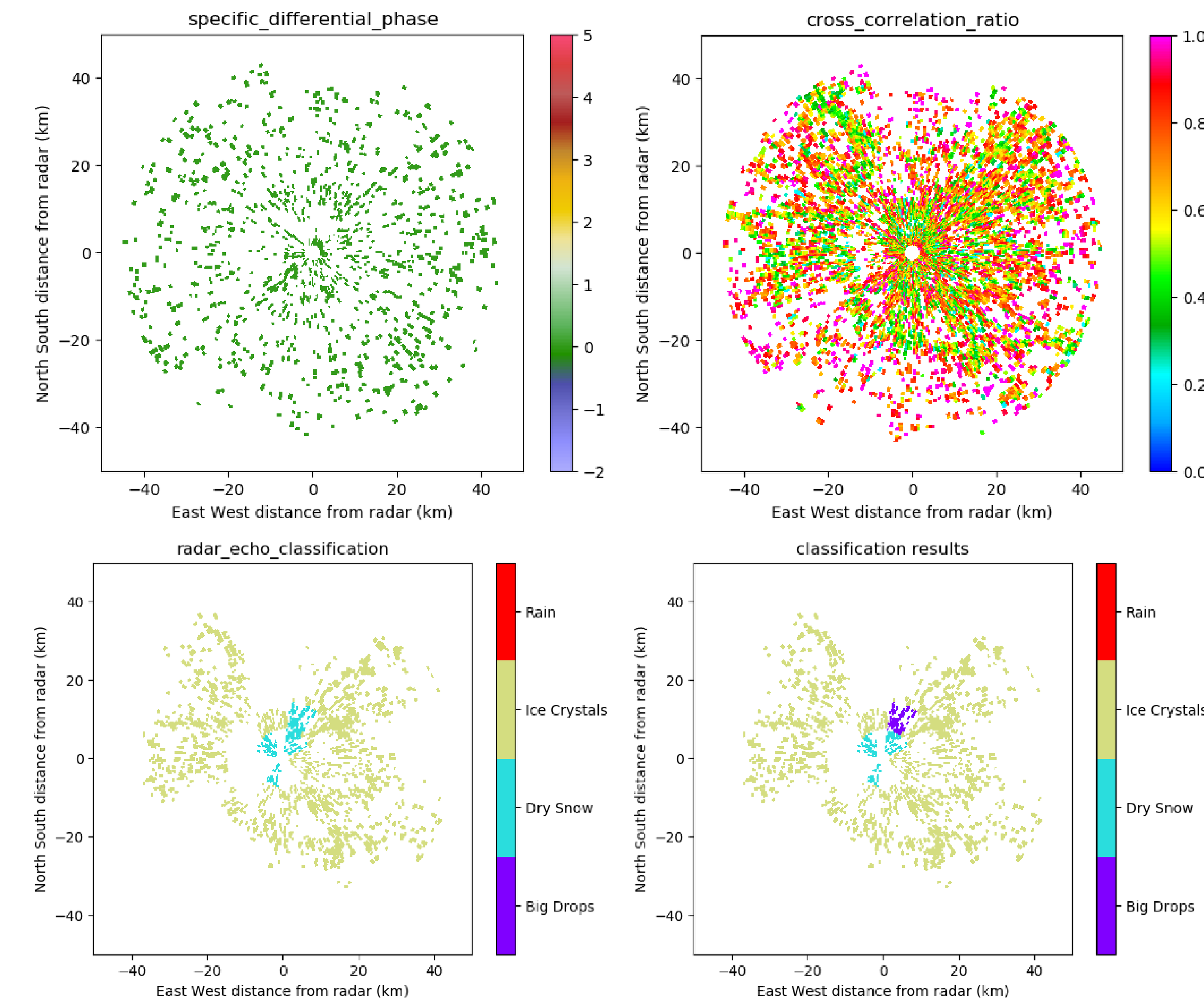


Figure 6: Visualization of five variables and classification result of an example NEXRAD dataset using best trained model from ResNet-18

Conclusions and Future Work

We developed models based on five modified CNN network architectures to classify hydrometeors using NEXRAD data. Our results indicate that CNN is an efficient tool to classify hydrometeors. Modified ResNet architecture with 18 hidden layers provided the best test accuracy of 87.23% for classification if hydrometeors in this study. As a next step we are working on a transfer learning approach to adapt and apply these trained models to CSAPR data collected at ARM Southern Great Plains (SGP) site.

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