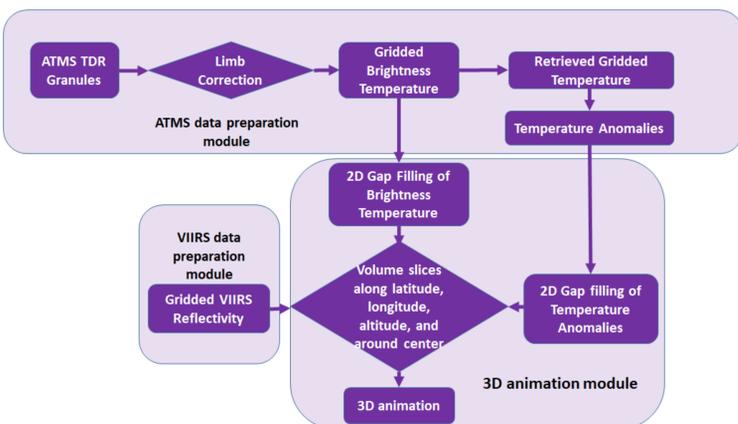


## Introduction

- Location of hurricane center is a key parameter in hurricane temperature anomaly calculation in the ICVS Hurricane Warm Core Animation System (HWCAS) with ATMS Sensor Data Record (SDR) observations (Yan et al., 2019). Currently, this information is provided by NOAA Hurricane Center (NHC) best track forecasts. However, the information from NHC is consistent with observations of ATMS because of certain time differences between the satellite observations and the model forecasts. NHC forecasts are also not always accurate.
- The purpose of this work is to improve ICVS-ATMS 3D-HWCAS by automatically locating hurricanes using deep Convolutional Neural Network (CNN).
- RGB channels of brightness temperature images of non-hurricane and hurricane in the Eastern North Pacific (85W-150W,0N-35N) region are used to train the deep CNN.
- The deep CNN used in this study has two convolutional layers and two pooling layers.
- Hurricane center is identified as the pixel which has the highest brightness temperature at channel 53GHz in the region identified as hurricane.

## STAR 3D Hurricane Warm Core Animation System Flow Chart



Gridded brightness temperature has a resolution of 0.25 degrees. Temperatures from 1000 hPa to 100 hPa pressure levels are retrieved from brightness temperatures at temperature sounding channels. Temperature anomaly is the difference between temperature at each pressure levels and mean temperature between 5-degree to 15-degree radii of the hurricane center.

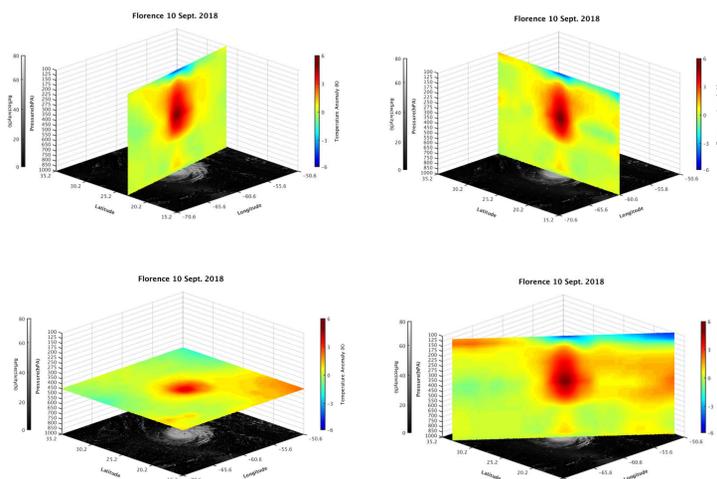
## Convolutional Neural Network

Flow chart below shows blocks used in the CNN in this study. The filters used in the first convolutional layer has a size of [4,4]. The filters used in the second convolutional layer has a size of [2,2]. Max pooling with same padding is used in this study. Gradient descent with adaptive moment estimation (Adam) is used in backpropagation to minimize cost function.



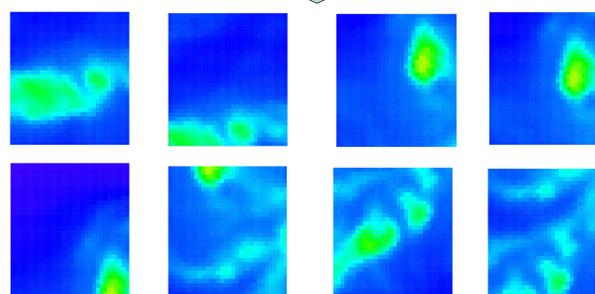
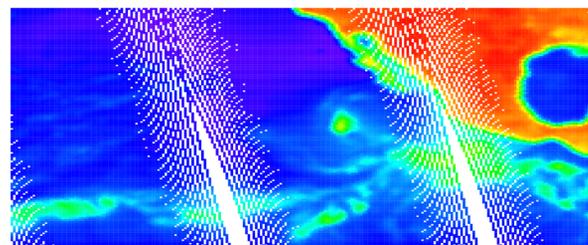
## Temperature Anomaly 3D Structure

Examples of temperature anomaly volume slices along latitude, longitude, altitude direction and around hurricane center for hurricane Florence on Sept. 10 2018. Temperature anomaly is retrieved from gridded NOAA-20 Advanced Technology Microwave Sounder (ATMS) brightness temperature of ascending mode using linear regression coefficients which are acquired by comparing ATMS brightness temperatures to European Centre for Medium-Range Weather Forecasts(ECMWF) analysis temperature field.



## Training Data Sets

More than 700 training images were acquired using a sliding window of 8 degrees x 8 degrees, that is 32x32 pixels, from gridded ATMS brightness temperature images with limb correction of Eastern North Pacific (85W-150W,0N-35N) region in June 2018. Figures below show ATMS images color coded by brightness temperature at 31.4GHz on 6/10/2018 with 8 examples of training images acquired from it. The right two training images on the first panel are labeled positive. The left two images on the second panel are labeled negative since we can not tell just from the training image what it is although they have part of the hurricane.



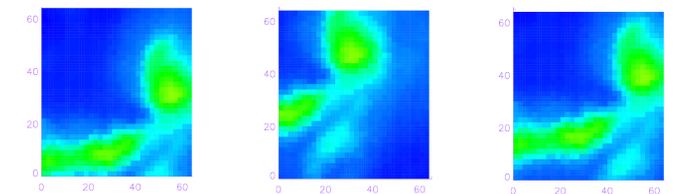
## Test Data Sets and Prediction Results

61 test images were acquired using the same sliding window from gridded ATMS brightness temperature images of Eastern North Pacific (85W-150W,0N-35N) region on 8/1/2018. 45 out of 61 are non hurricane images and 16 out of 61 are hurricane images. All non hurricane images are identified by CNN as non hurricane images. 10 out of 16 hurricane images are identified as hurricane and 6 of them are identified as non hurricane. The prediction precision (true positives/predicted positives) for the test data sets is 100%.

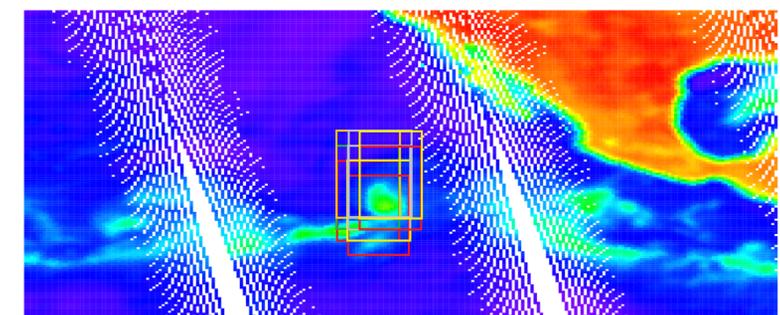
	Hurricane	Non Hurricane
Predicted Hurricane	10	0
Predicted Non Hurricane	6	45

## Analysis

The hurricane images that are not correctly identified by CNN do not have full hurricanes in the region. As long as precision is 100%, users can get correct hurricane center.



Hurricane images that are identified as non hurricane



ATMS images at 31.4GHz on 8/1/2018 with recognized hurricane windows highlighted

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