The WSR-88D Chaff Detection Algorithm

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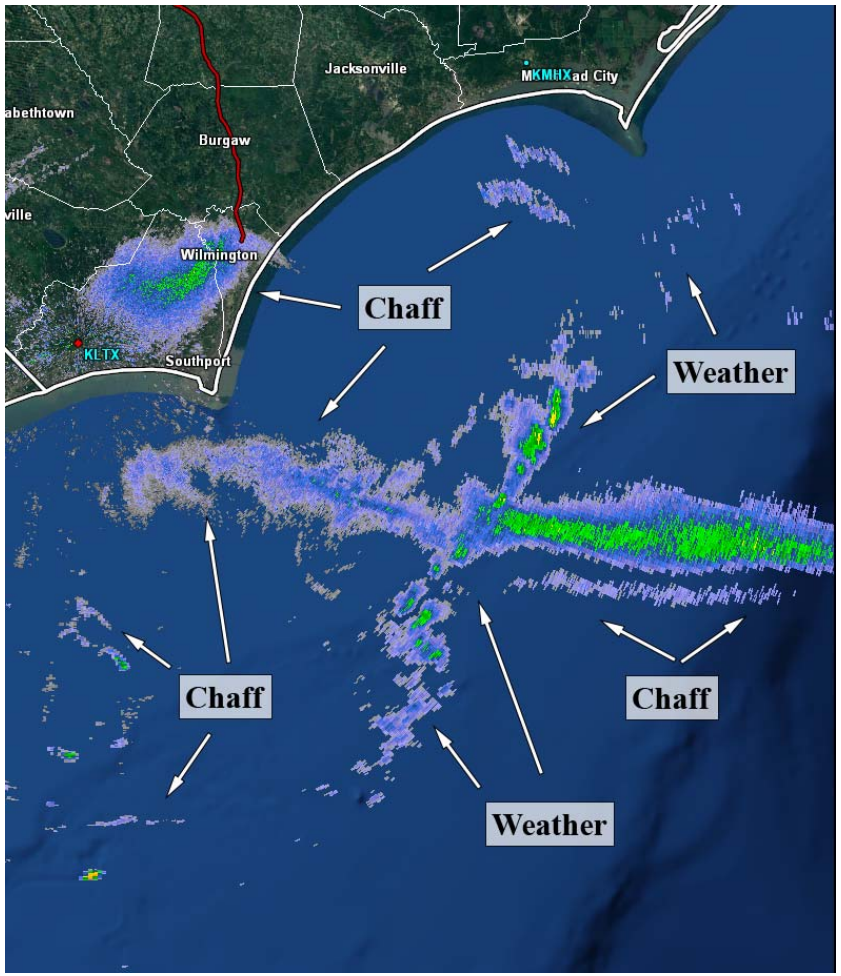
Chaff and Weather Radar

- False weather returns cause issues for radar users
- Co-existence of chaff and weather is particularly problematic
- Chaff "clouds" may be undesirable to fly through
- Mixed cases can be discerned via Z_{DR}, Φ_{DP}, and ρ_{HV}
- Flight controllers don't have access to polarimetric estimates



Reflectivity Factor (Z)

Z_{DR} = Differential Reflectivity
Φ_{DP} = Differential Phase
ρ_{HV} = Correlation Coefficient

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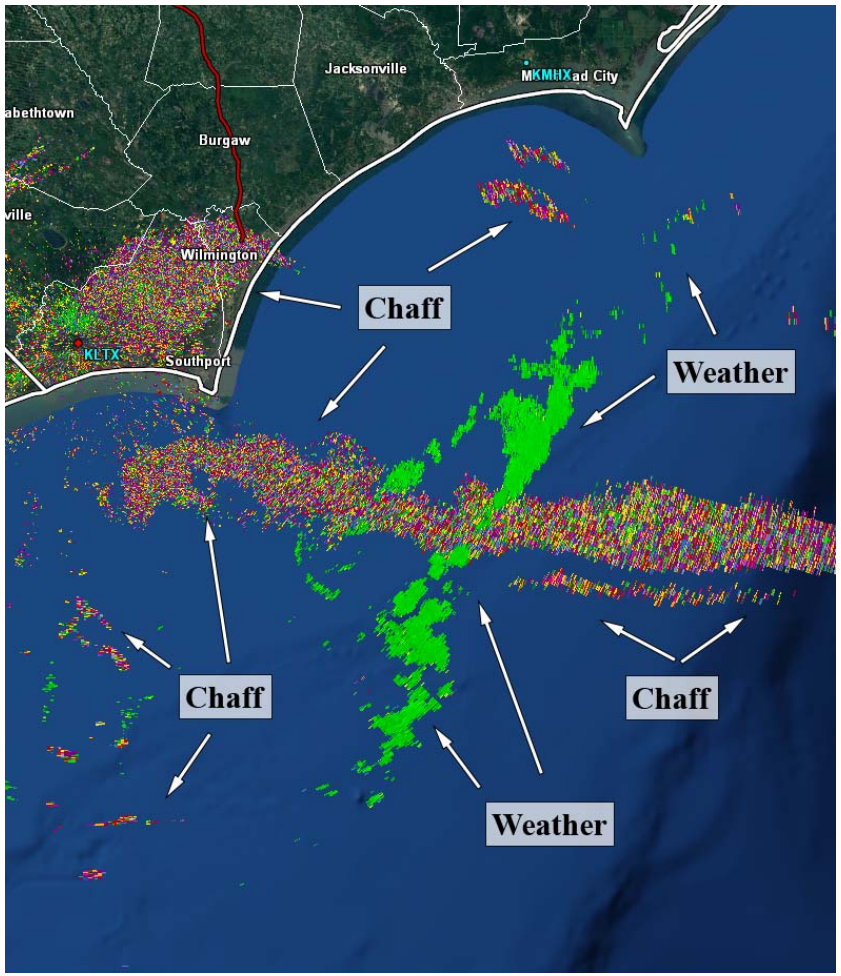
Effective chaff detection is a useful and desired tool



Differential Phase (Φ_{DP})

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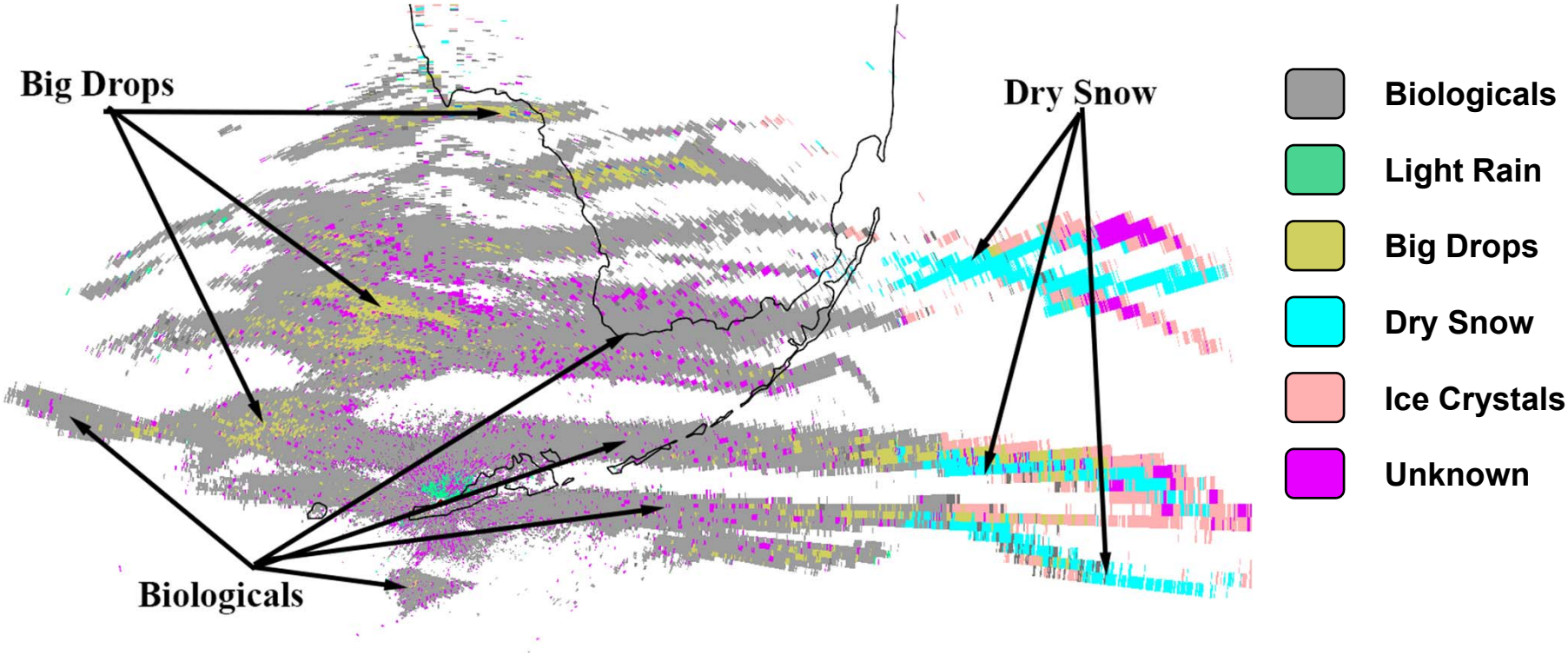
Current HCA Output for Chaff

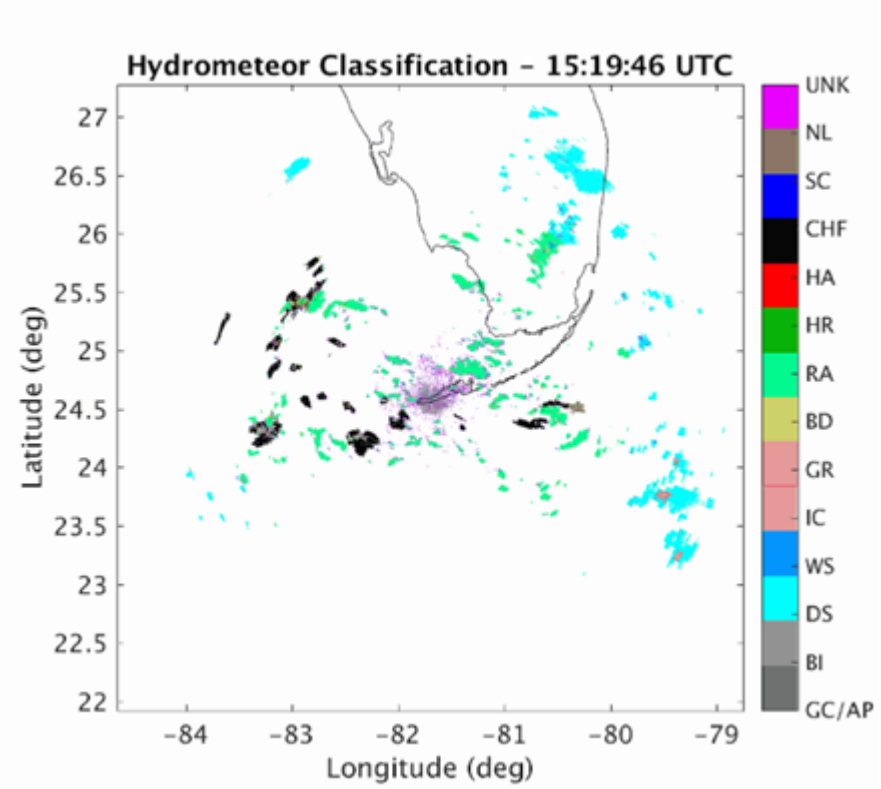


HCA output from the 12 February 2016 chaff event

HCA = Hydrometeor Classification Algorithm

CDA Approach and Goals

- Develop an "Aviation Classification Algorithm" (ACA) Product
- Include Inanimate (IN) class off human-truthed/trained data
- Cluster IN class and remove likely clutter/weather
- Use trained SVM for classification of clusters
- De-flicker using composite product
- "First-cut" design in MATLAB using ORPGSim
- Development in ORPG

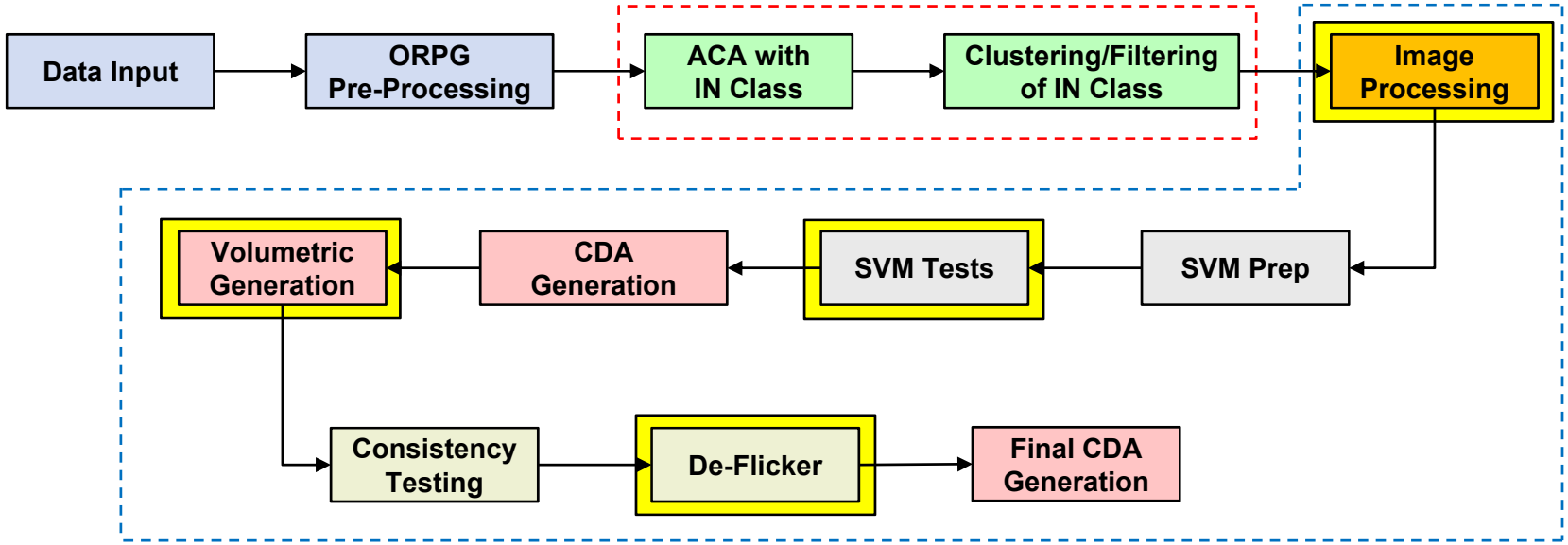


MATLAB-Based ORPGSim ACA Output
from 08/02/2016 KBYX Chaff Event

CDA = Chaff Detection Algorithm
ACA = Aviation Classification Algorithm
IN = Inanimate Class in ACA

SVM = Support Vector Machine
ORPG: Open Radar Product Generator
ORPGSim: ORPG Simulator

CDA Flow Diagram



ORPG Base Functions

HCA/ACA Functions

Image Processing Functions

SVM Functions

Product Generation

De-Flicker Functions

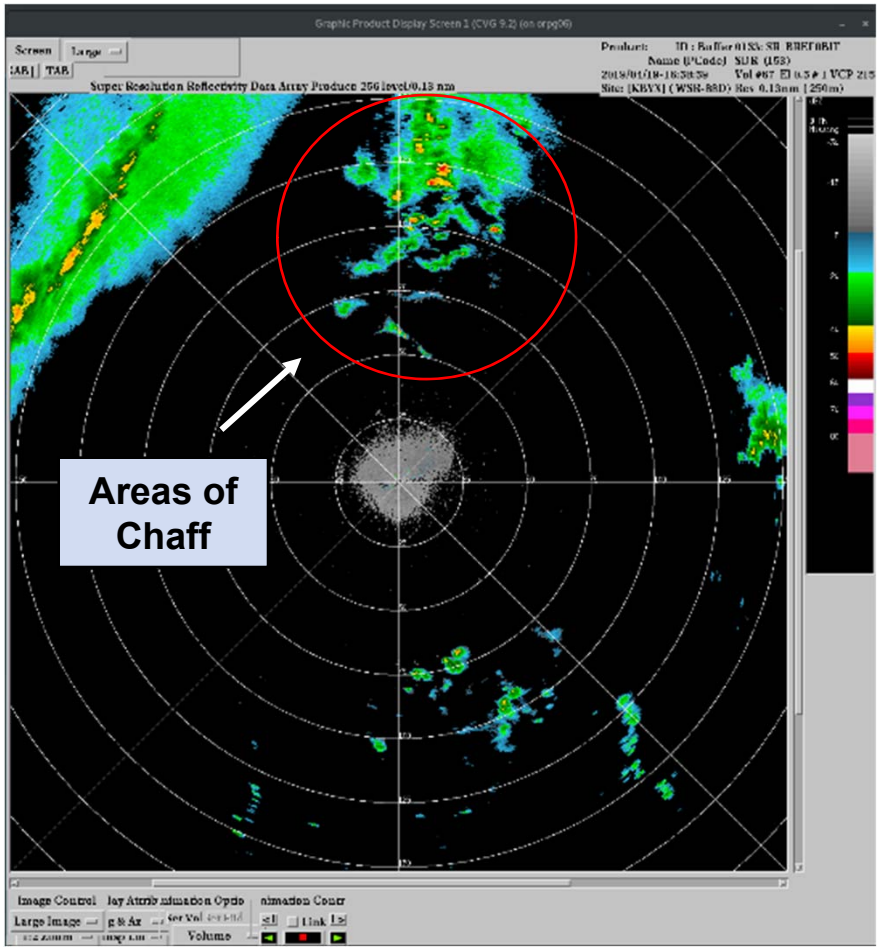
CPC 023 / Task 1301

CPC 022 / Task 1093

Highlight Areas for this Talk

Steps Through a Case: 4/19/19 - KBYX

Horizontal Reflectivity Factor (dBZ)



Aviation Classification Algorithm

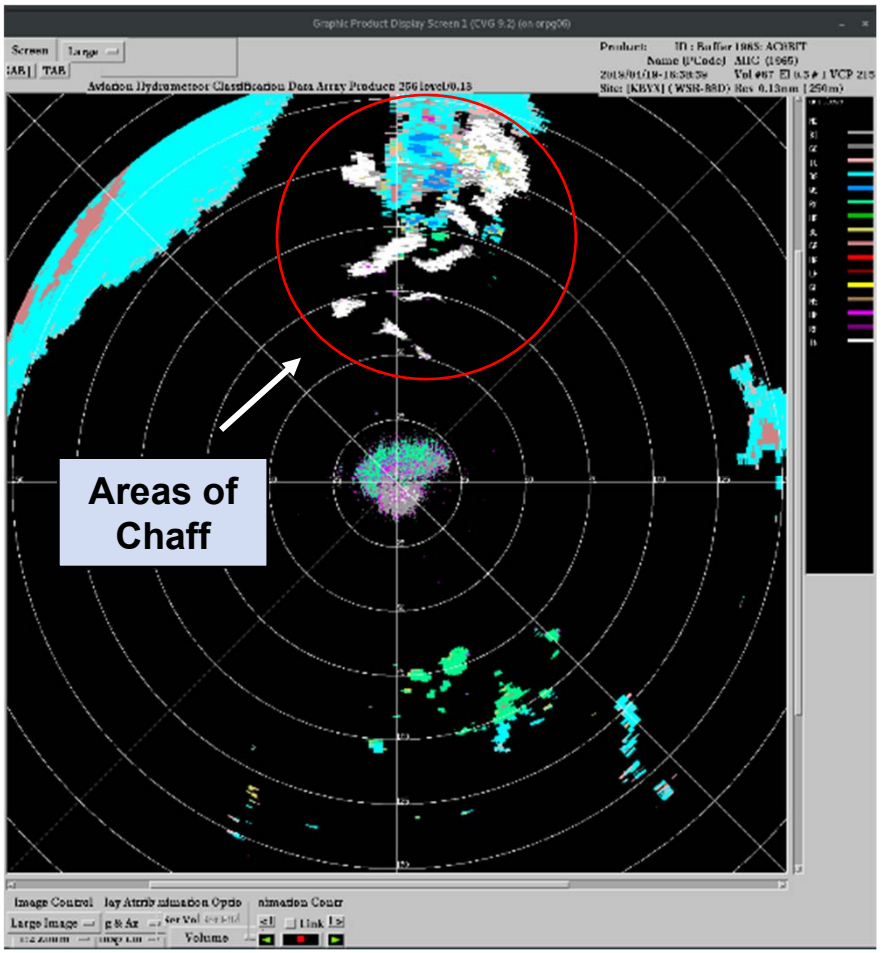
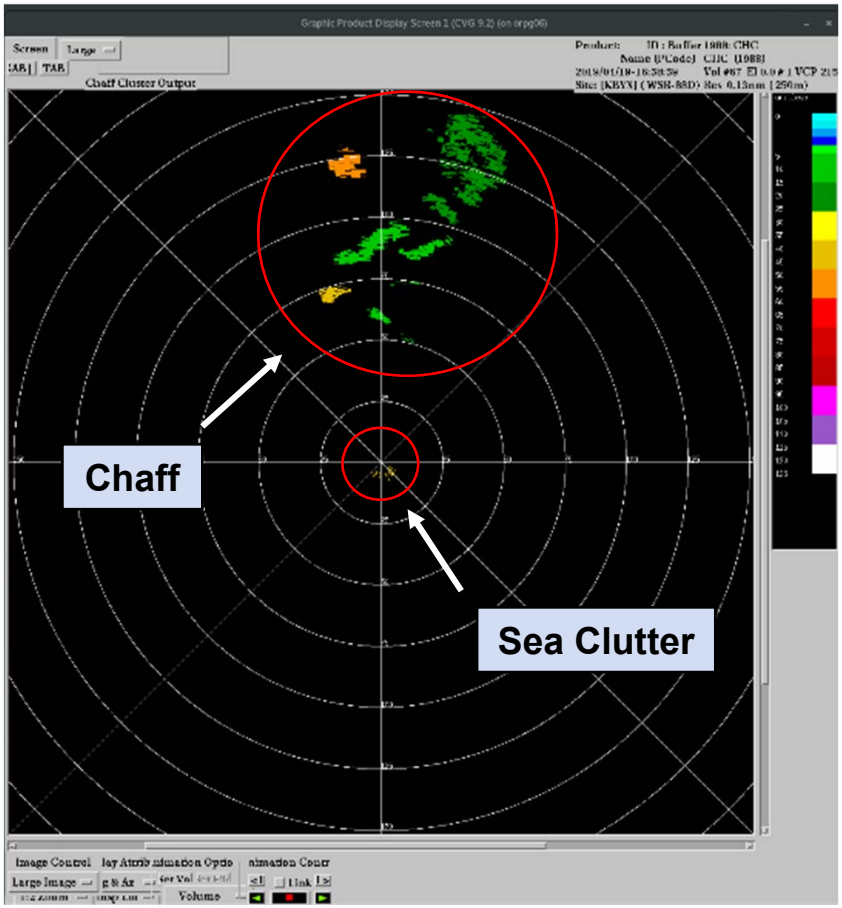


Image Processing Algorithm

- Desire for a smooth product
- Processing consists of 7 steps:

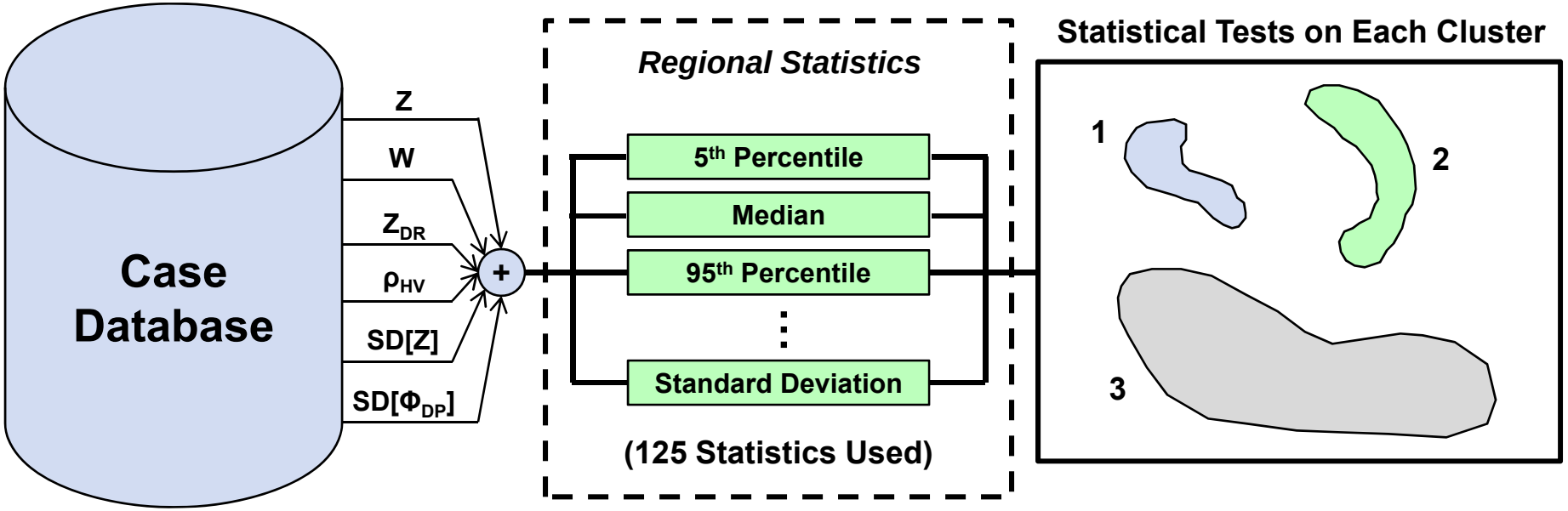
1. Calculate ACA output including new chaff class
2. Separation of IN and non-IN
3. Median filtering
4. Dilation and Closing
5. Clustering and Thresholding
6. Filtering of Wet Classes
7. Dilation and Closing

Goal is to transform sparse IN detections into operable clusters

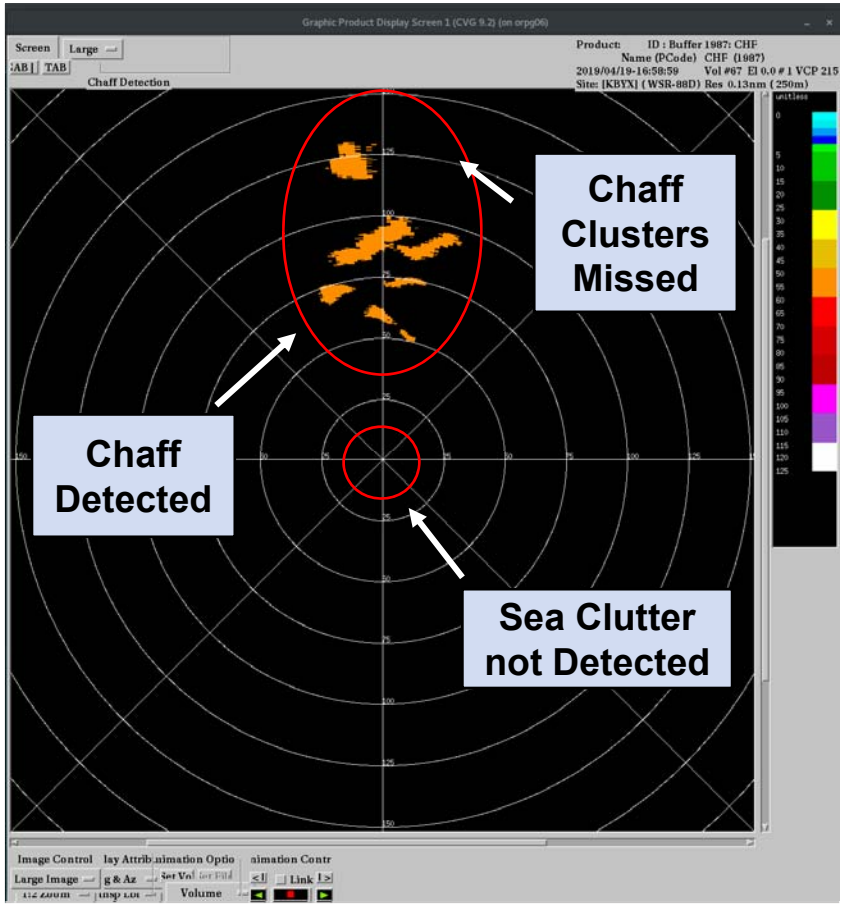


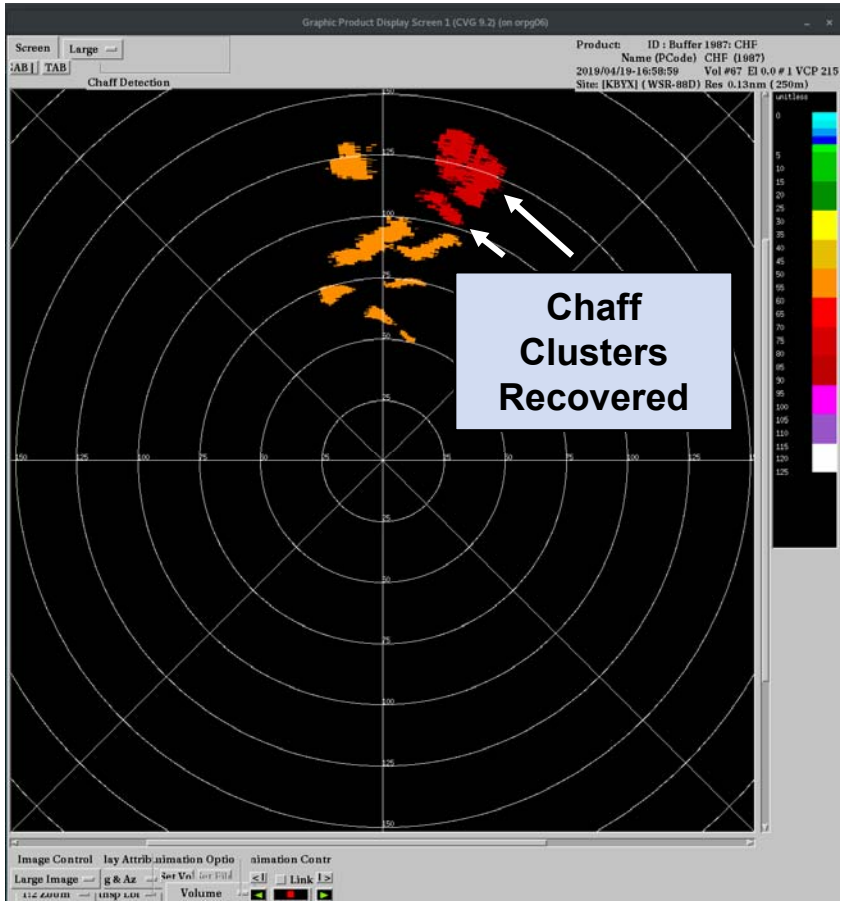
SVM Framework

- Human-truthed chaff and clutter cases
- Data are clustered into cells for analysis as a group of pixels
- An SVM framework of cells is used for training
- The SVM output is applied to new cells for classification

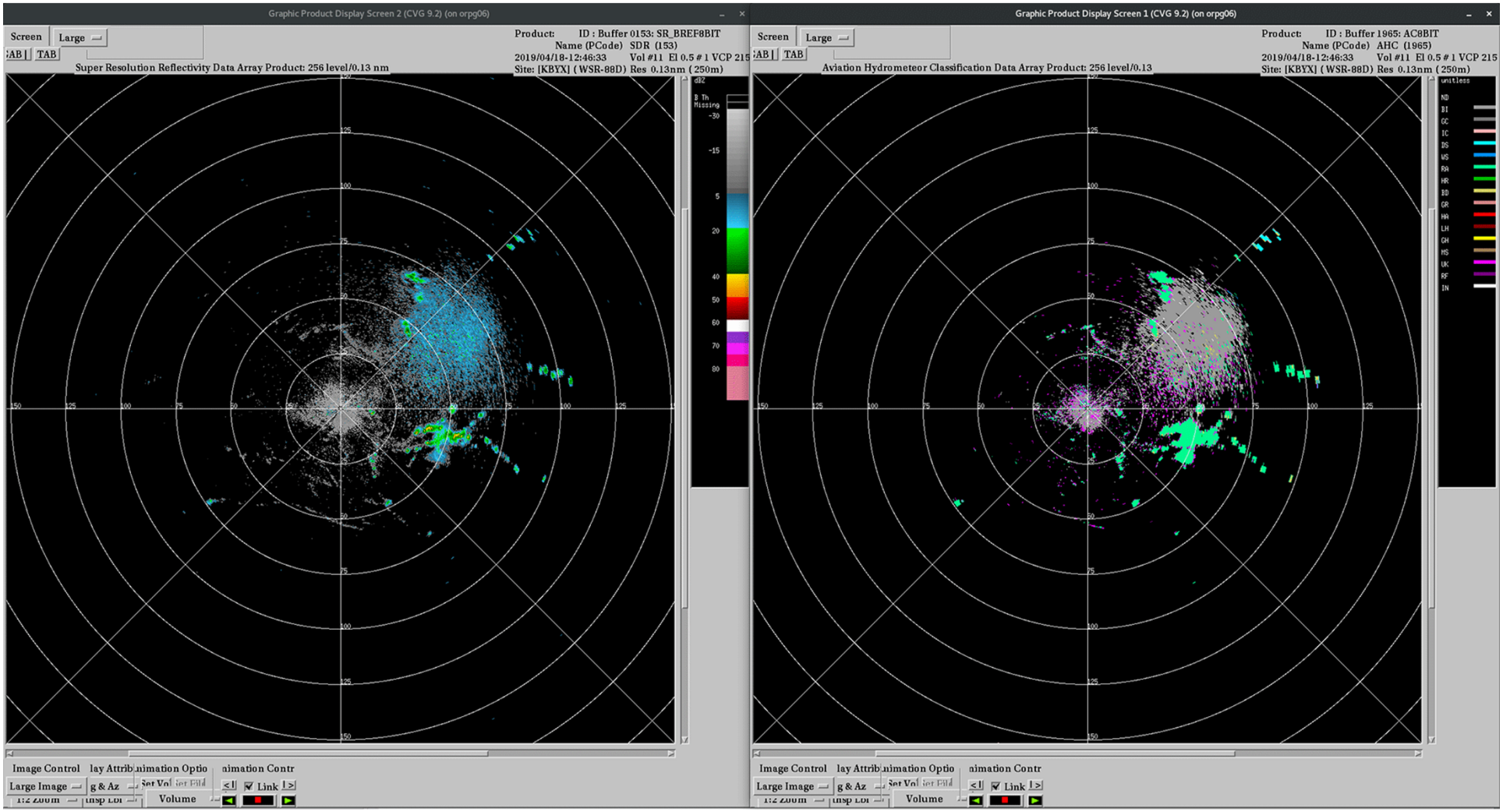


SVM Output and De-Flickering





Case Example: 04/18/2019 - KBYX



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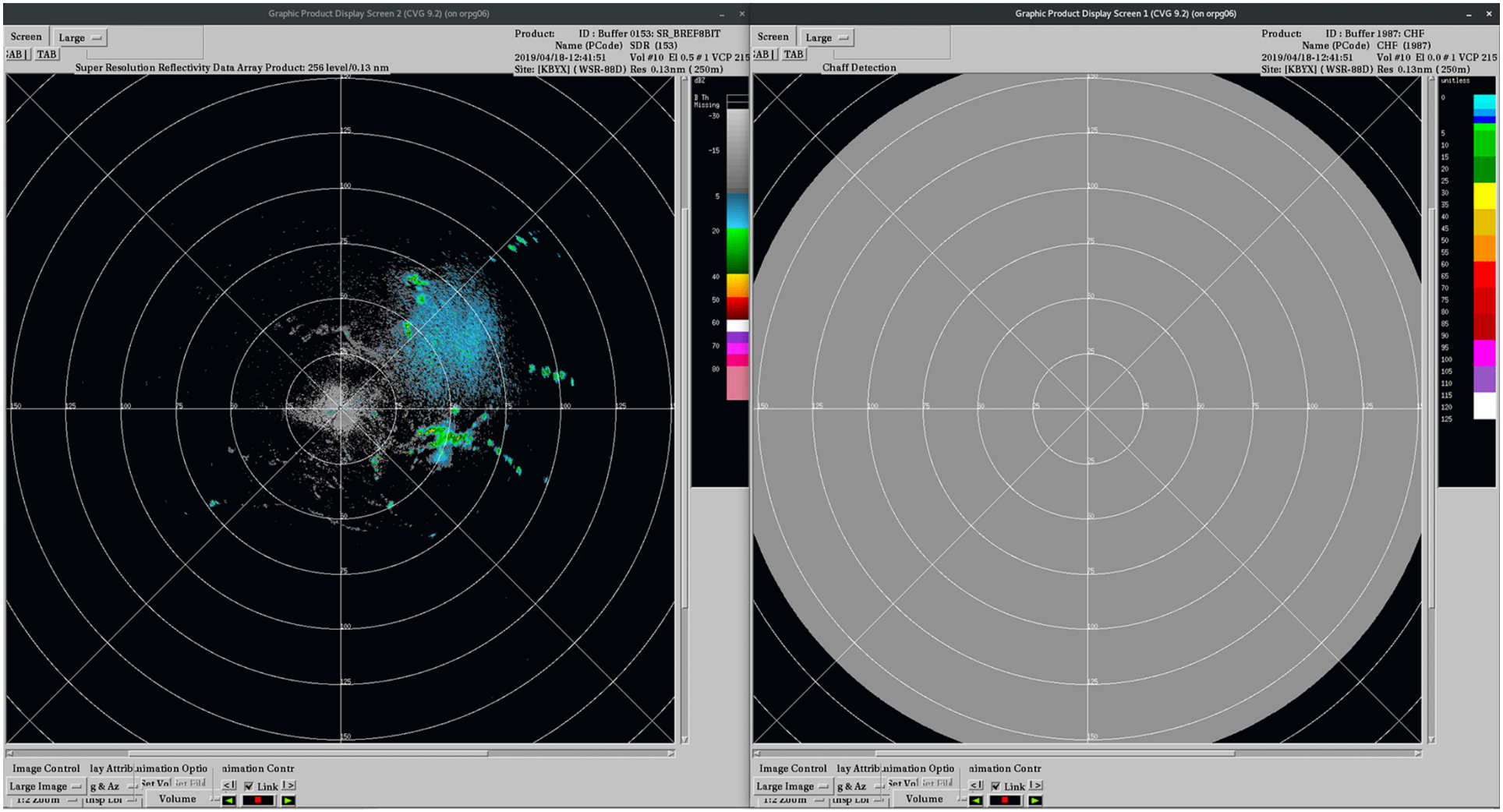
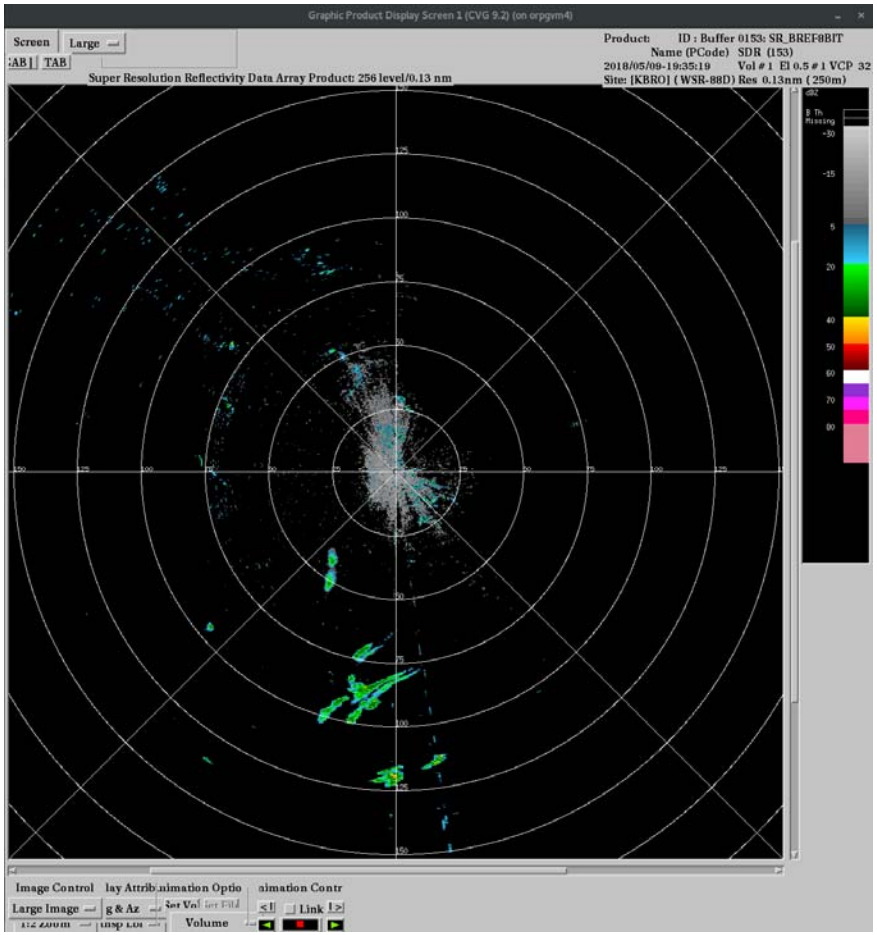
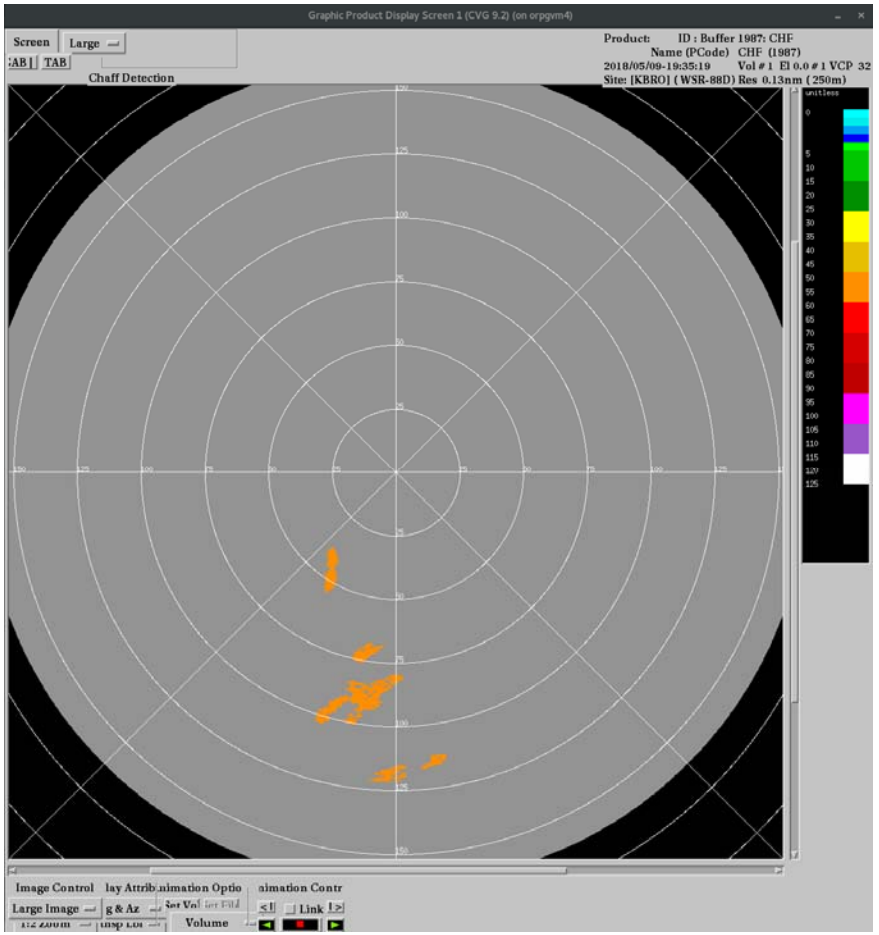
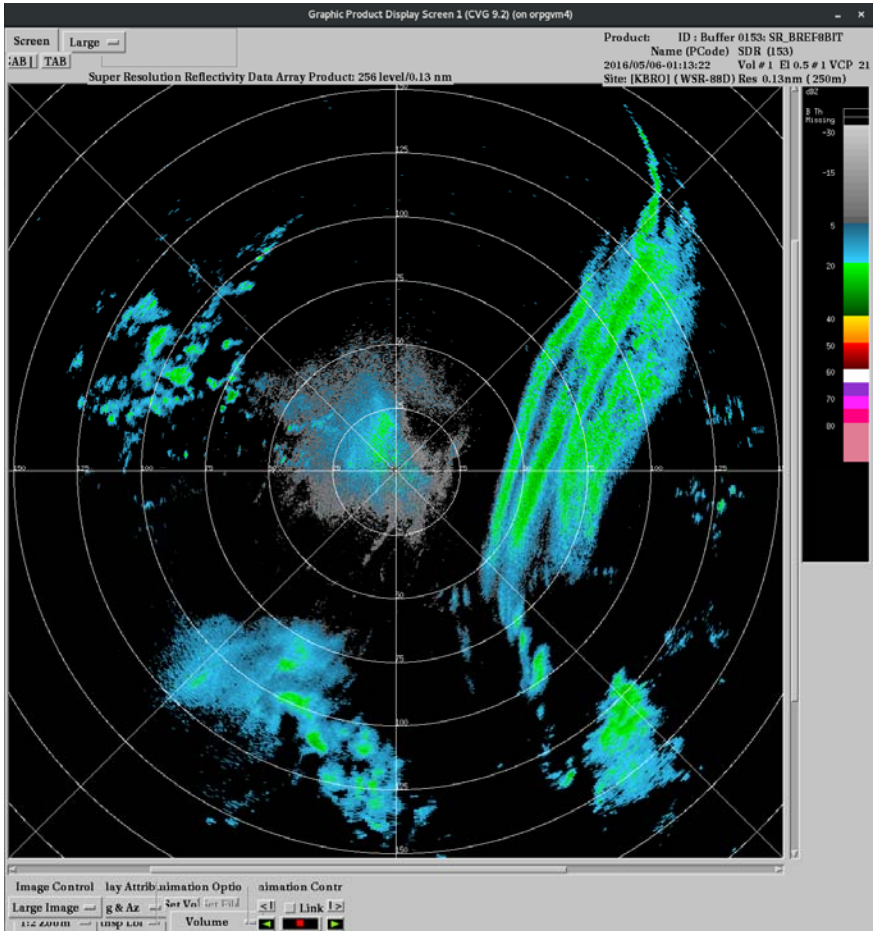


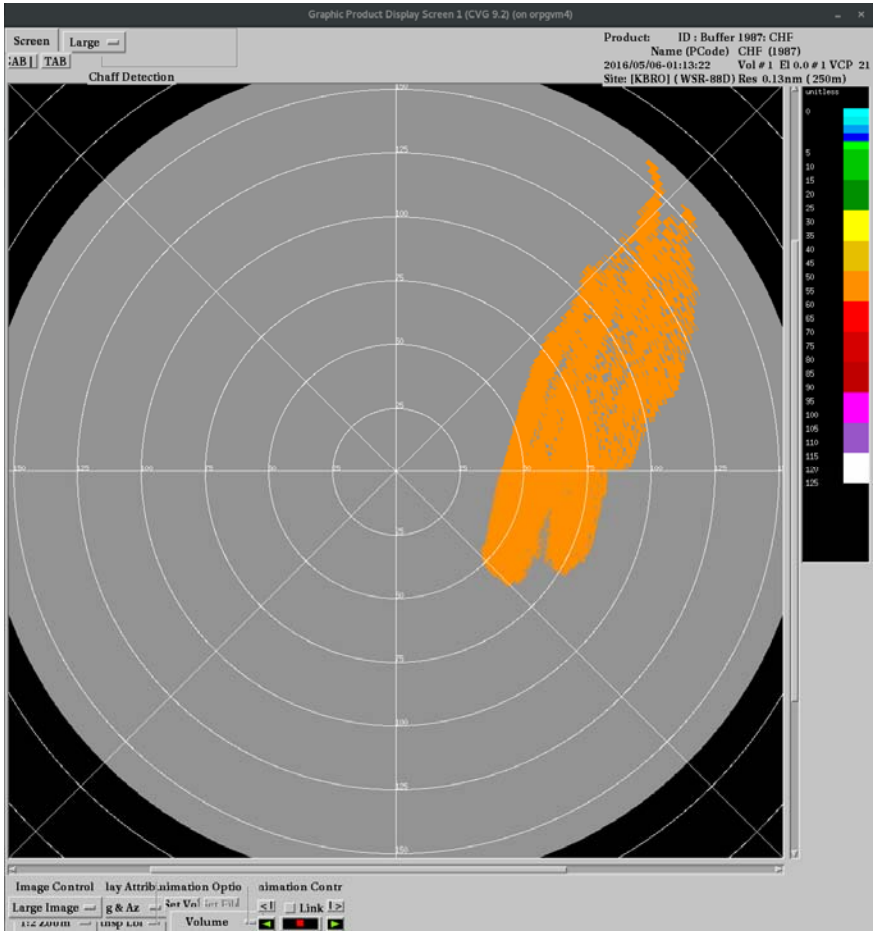
Case Example: 05/09/2018 - KNKX



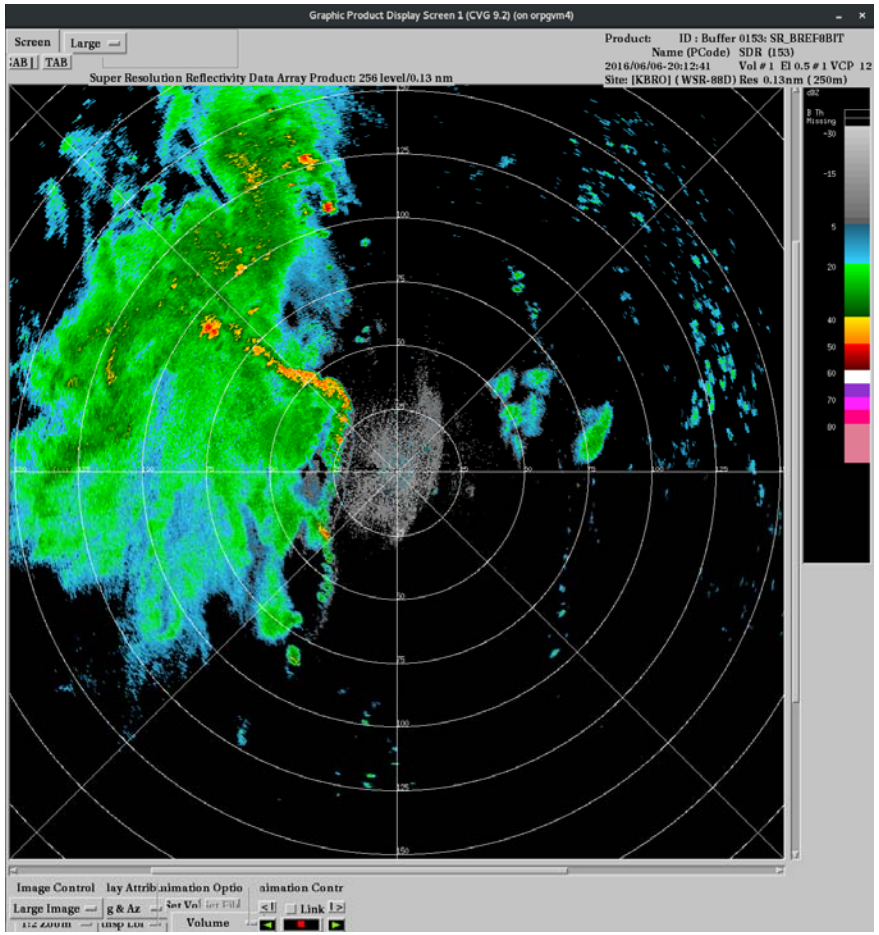


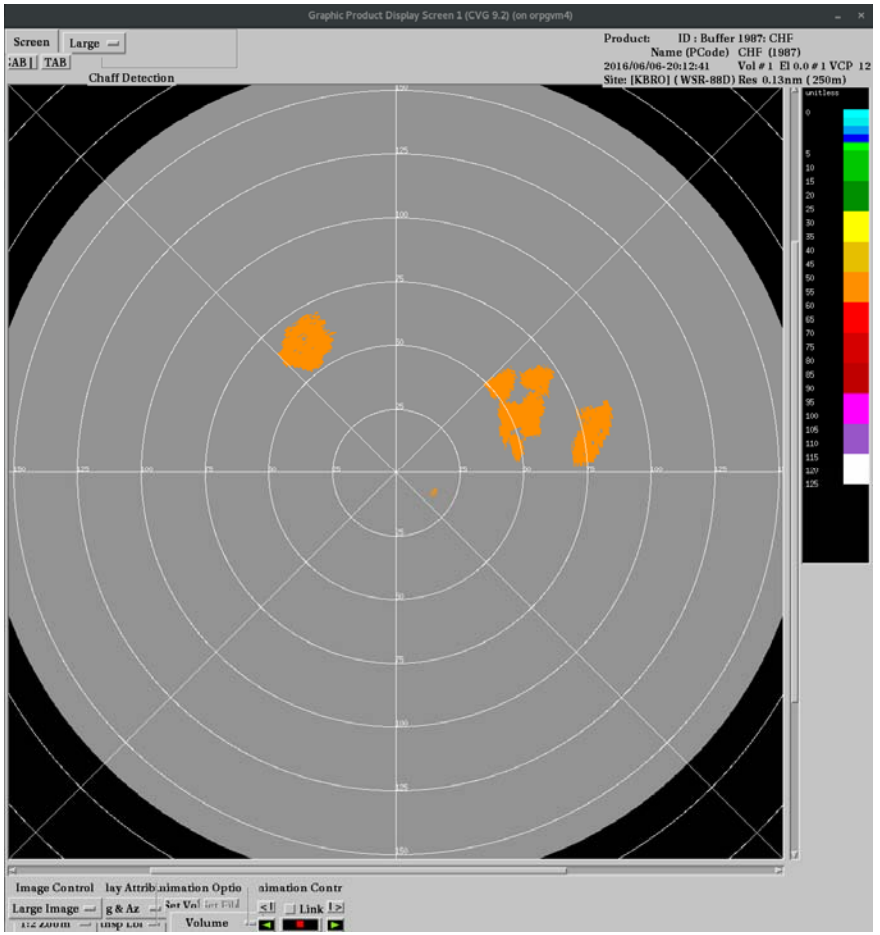
Case Example: 05/06/2016 - KDOX



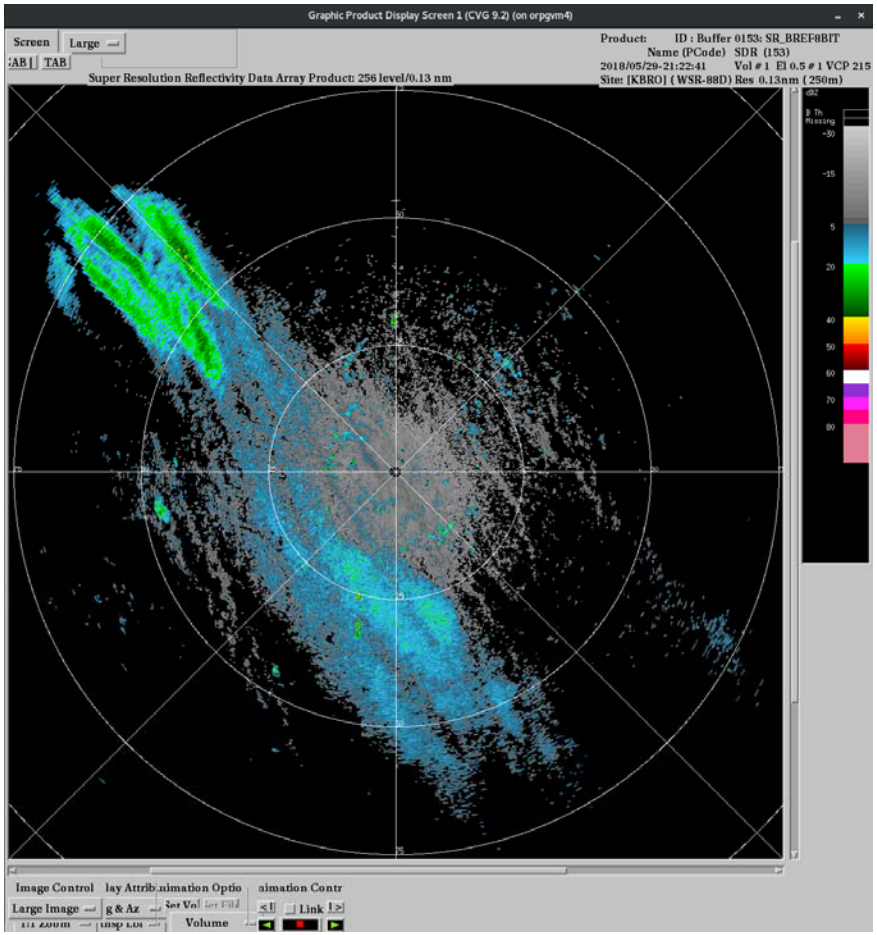


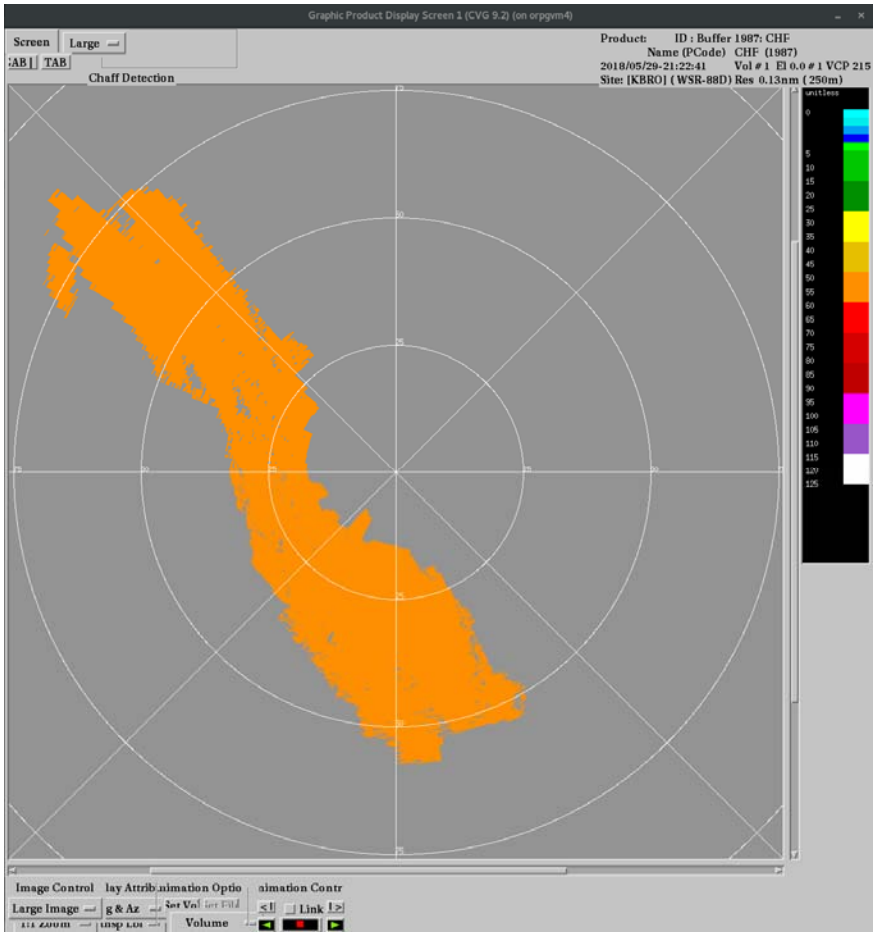
Case Example: 06/06/2016 - KAMX



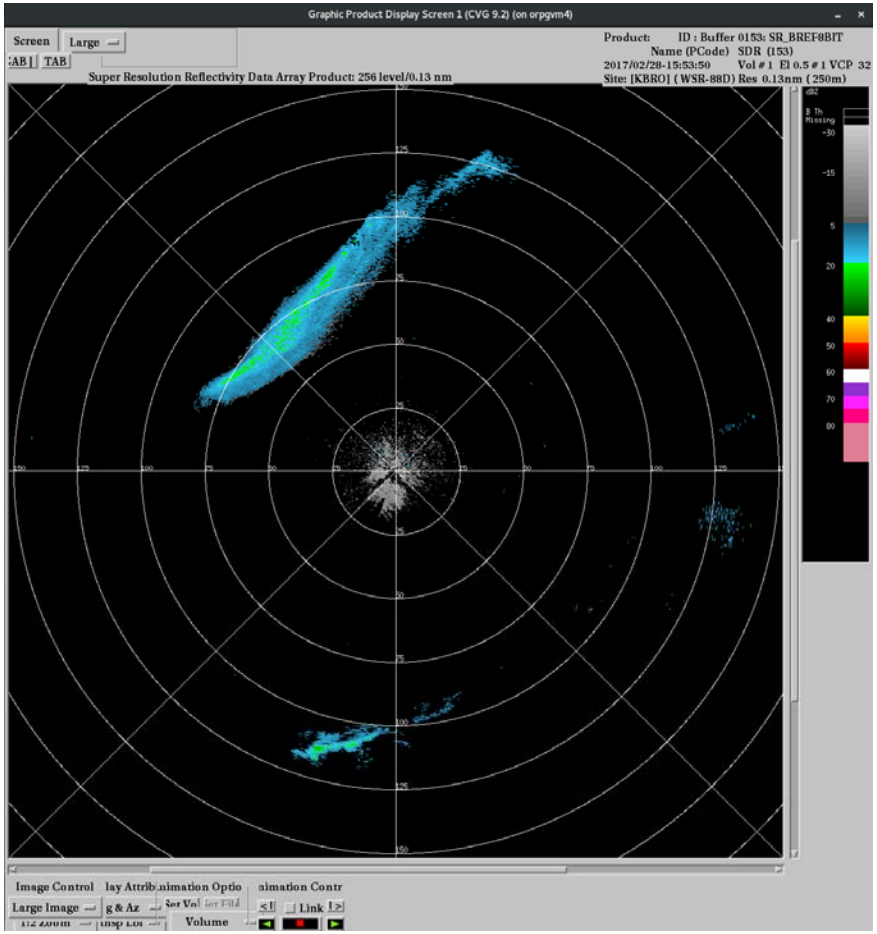


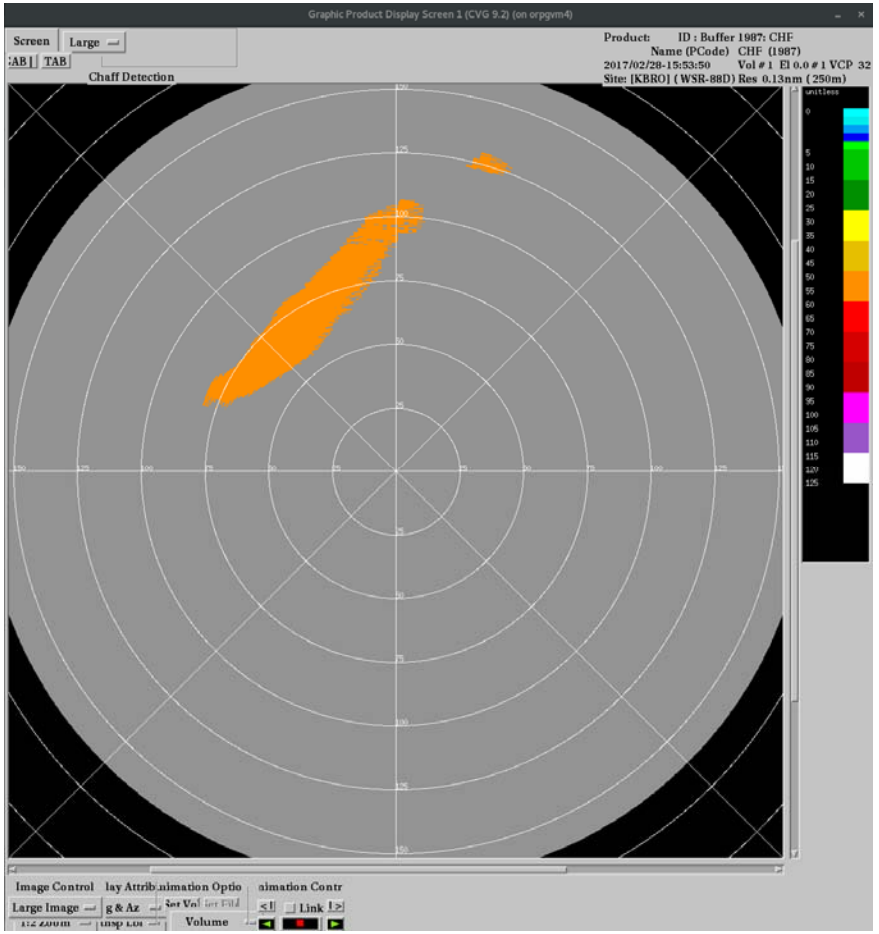
Case Example: 05/29/2018 - KCBW



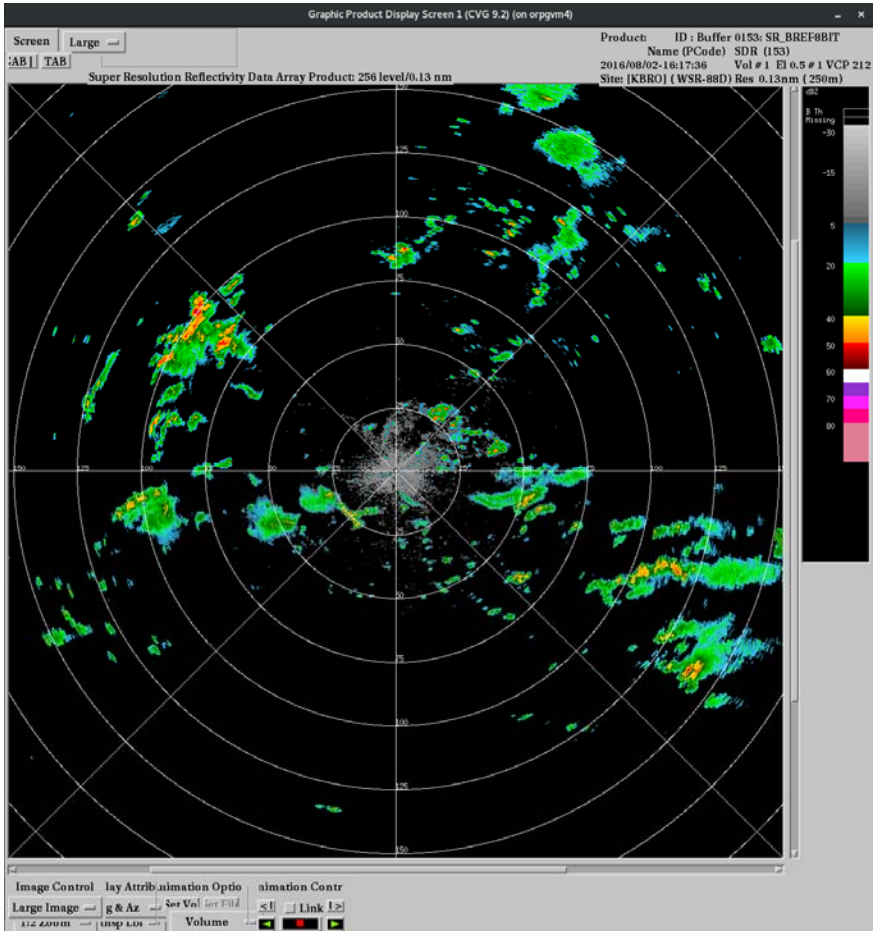


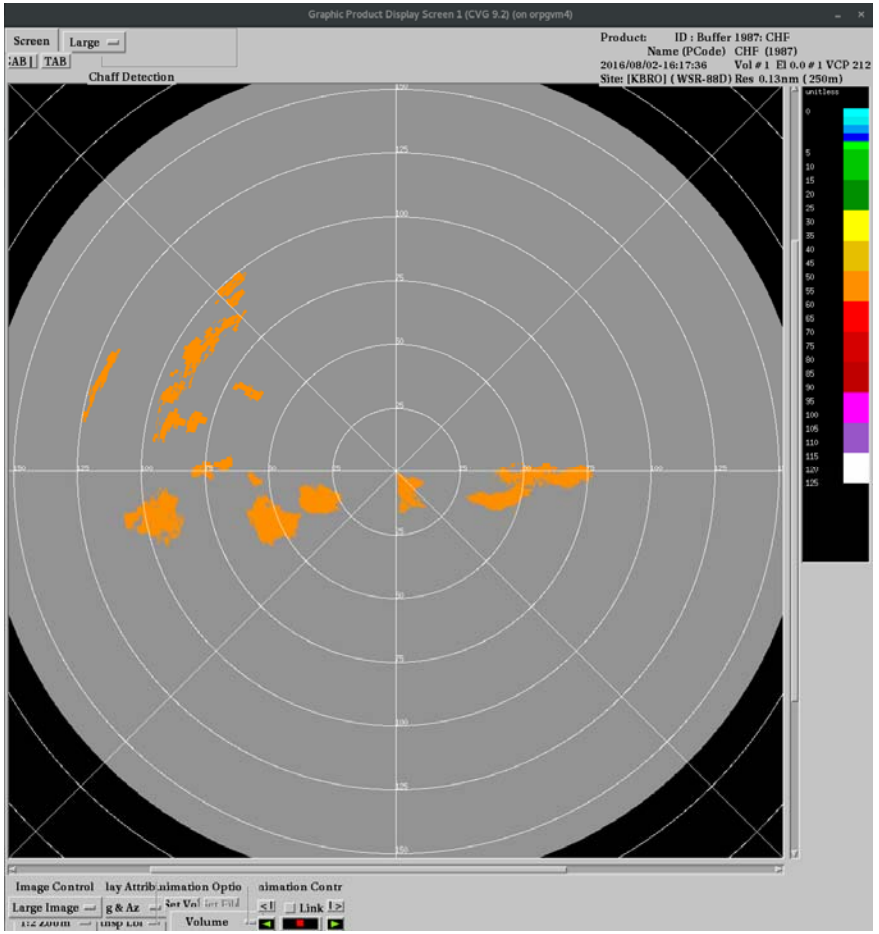
Case Example: 02/28/2017 - KLNX





Case Example: 08/02/2016 - KBYX





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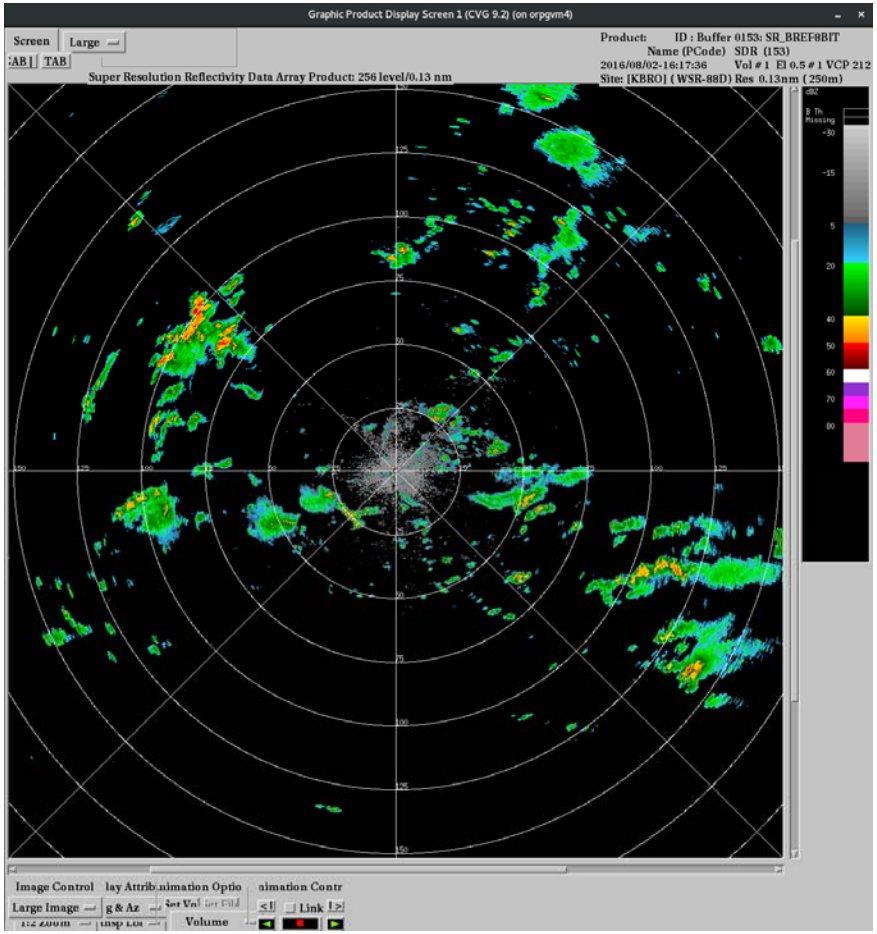
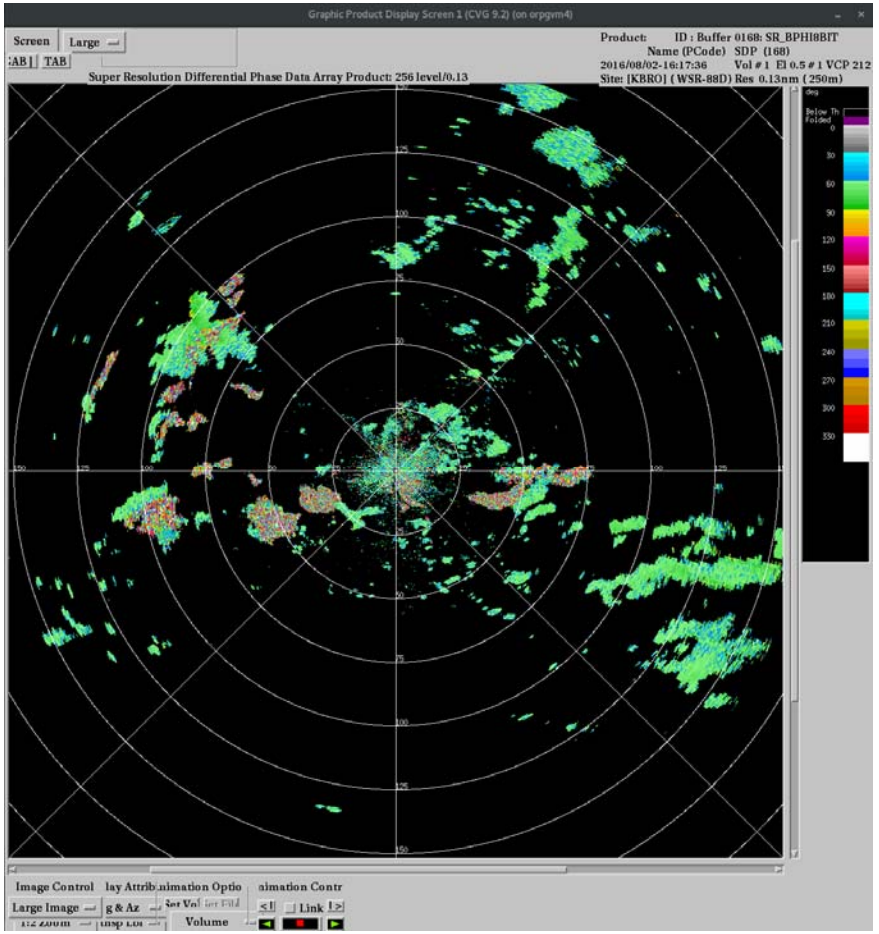
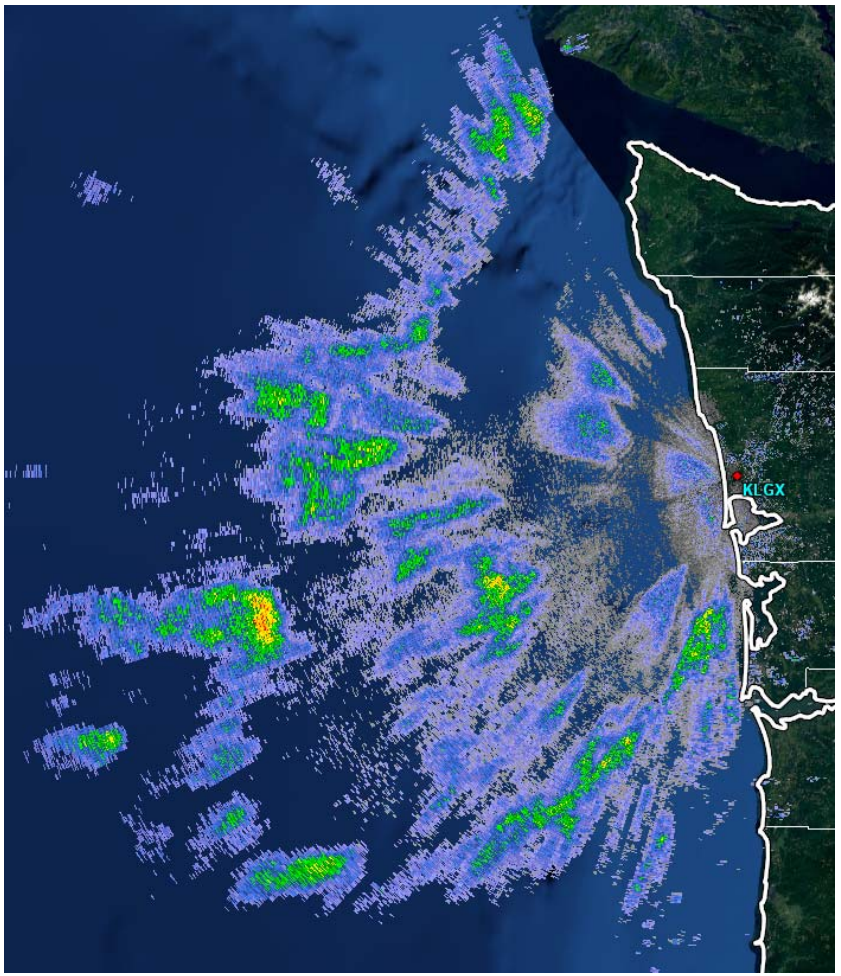




Sea Clutter and Weather Radar

- A common source of errors for the chaff algorithm
- Beam is refracted and returned from waves on water
- Motion of waves precludes Doppler filtering
- Similar characteristics in the polarimetric fields to chaff



Reflectivity Factor (Z)

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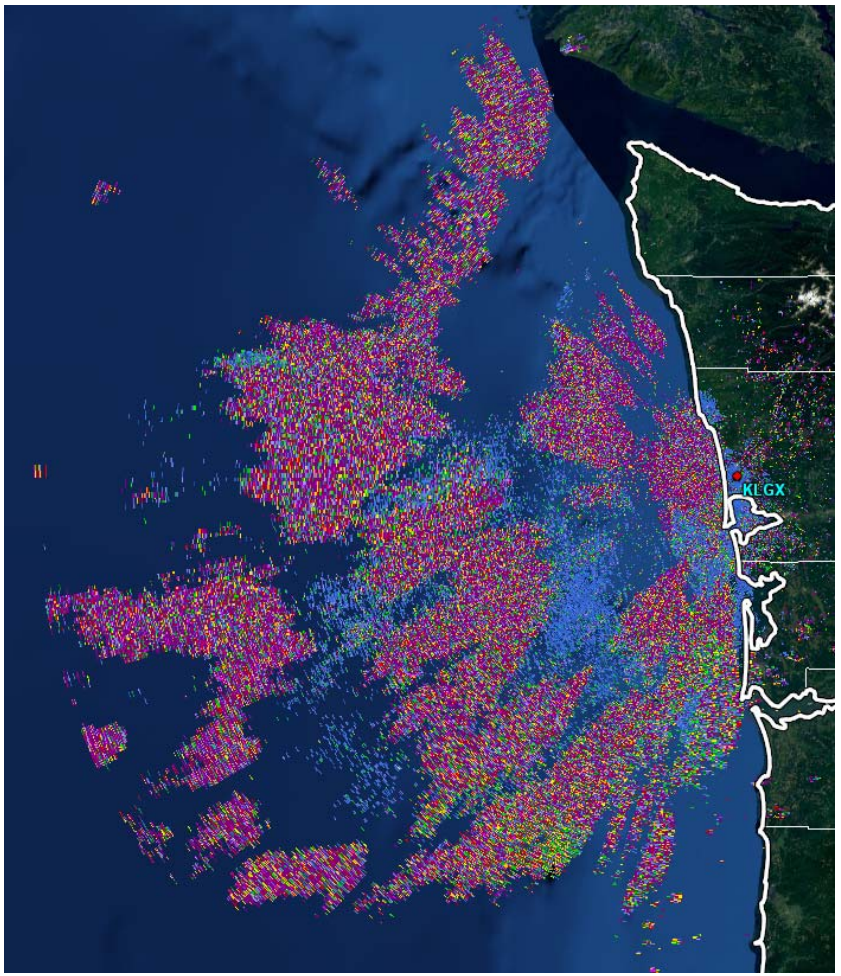
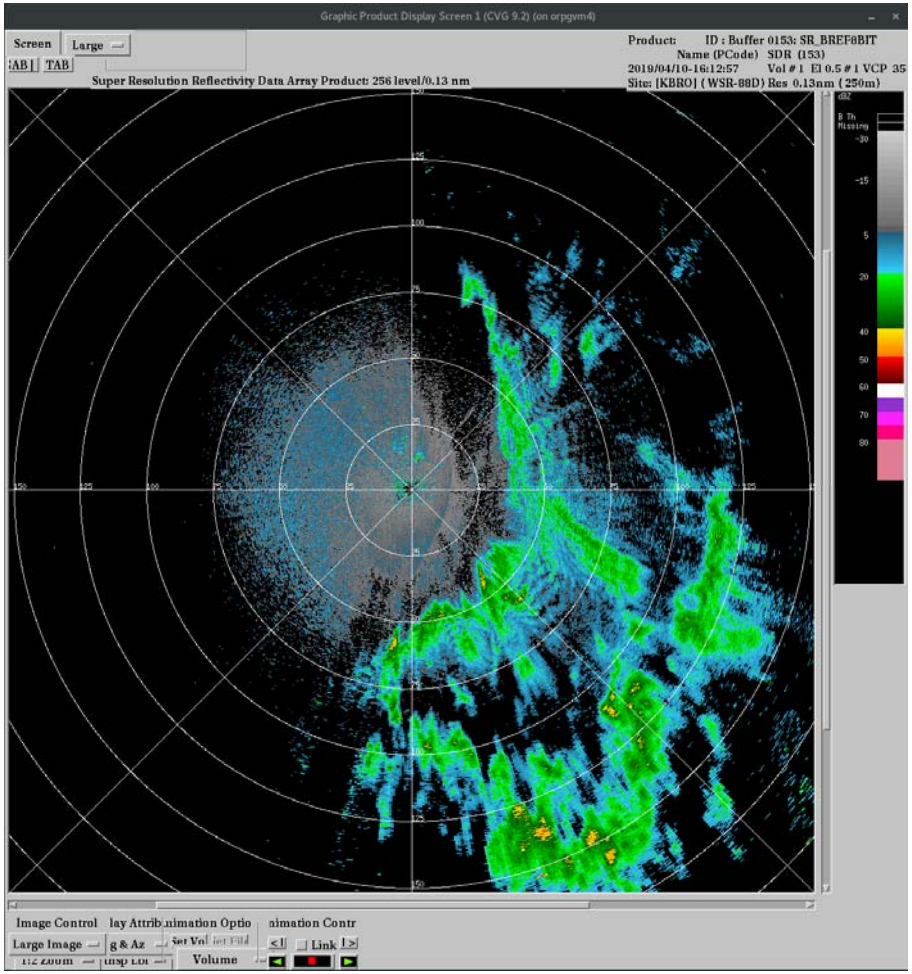
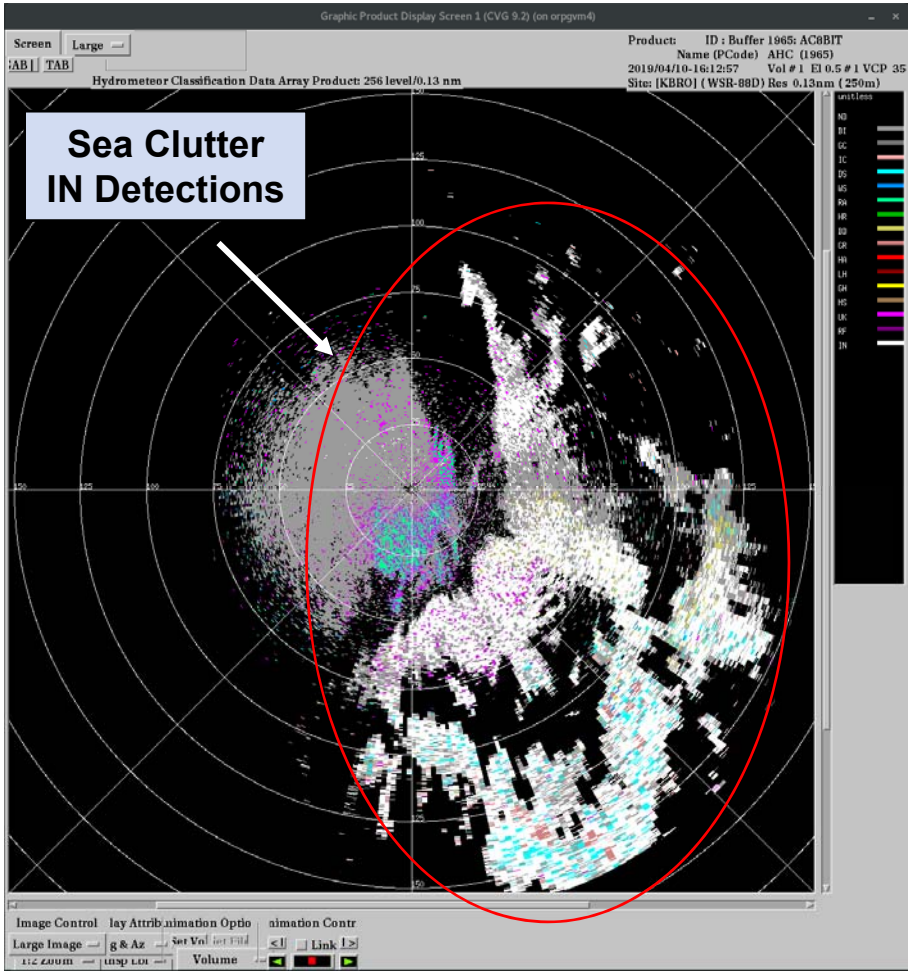


Differential Phase (Φ_{DP})

Sea Clutter False Alarm Example





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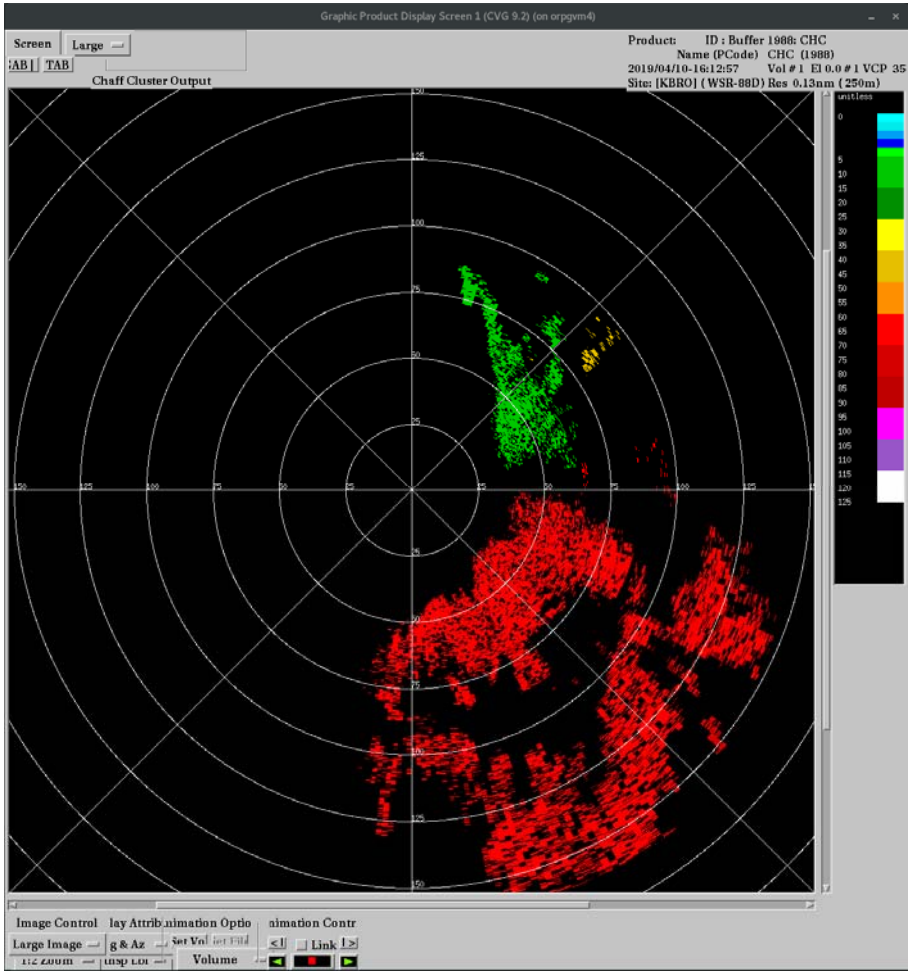
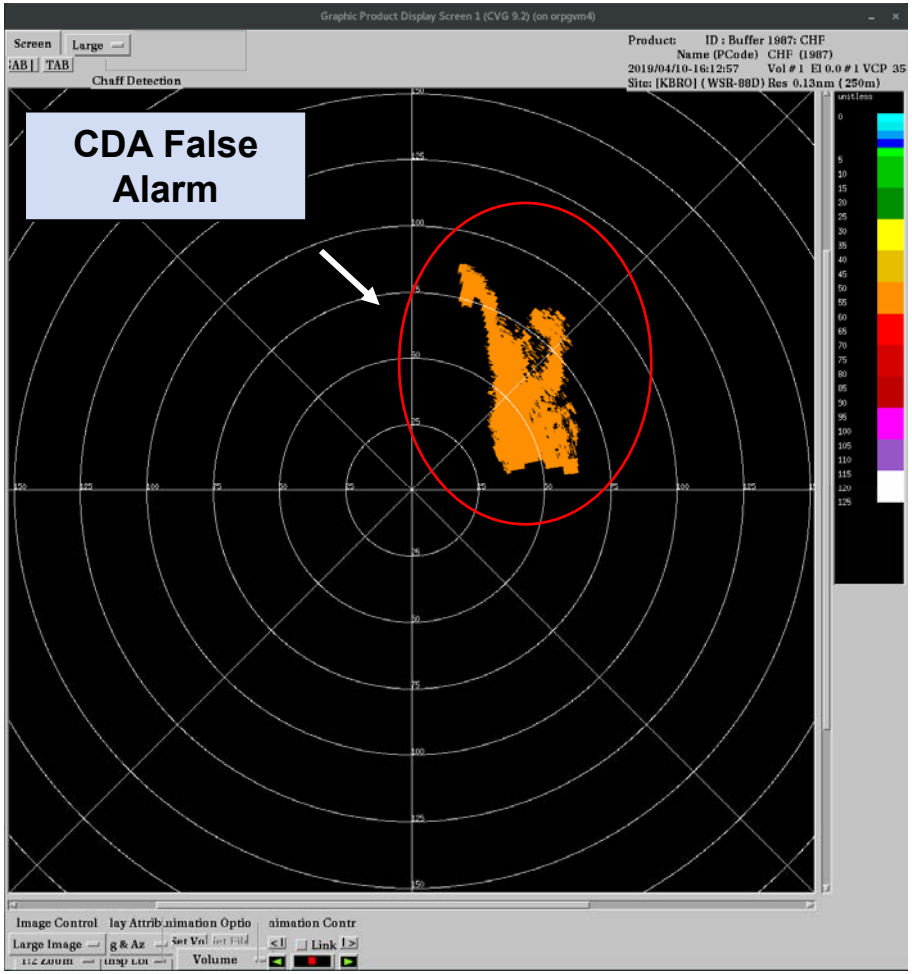
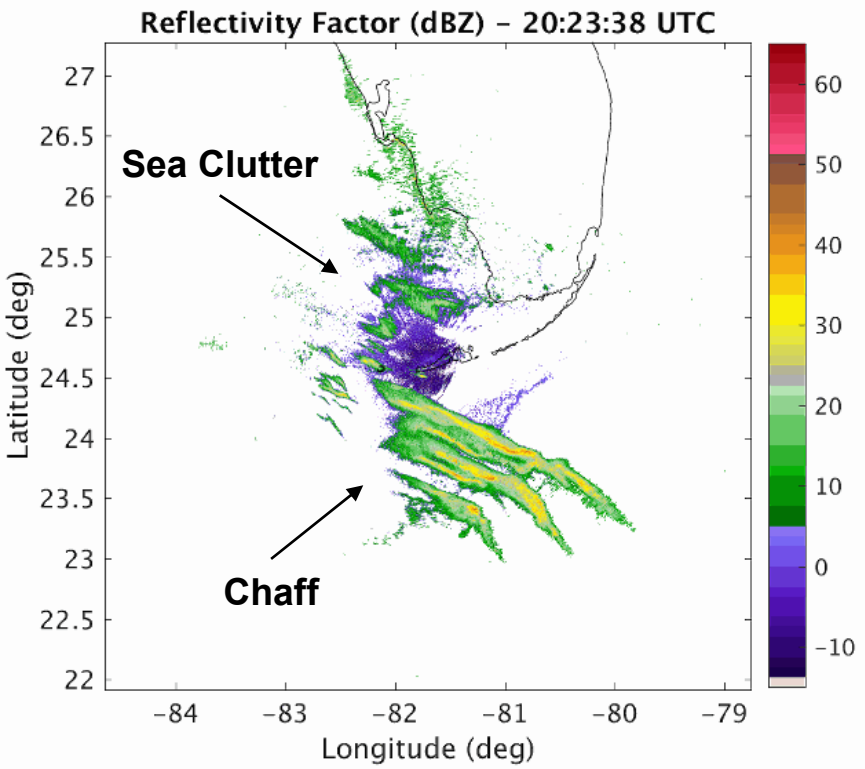
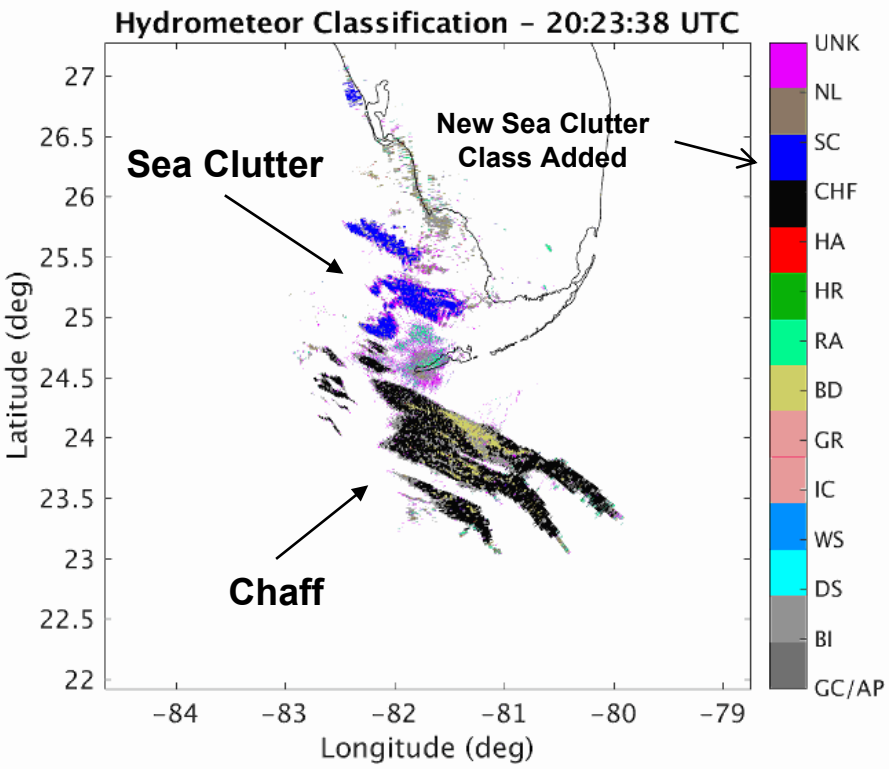




Sea Clutter Detection Algorithm in ORPGSim





Future work that Lincoln Laboratory is well-poised to take on

Summary

- Developed a chaff detector based on a modified HCA (ACA) and an image processing algorithm
- Compiled and analyzed chaff distributions
- Optimized IN class weights for ACA
- Implemented an image processing module for clustering and filtering
- Applied SVM classification to separate out clutter
- Designed de-flickering technique using a 5-volume-window composite chaff product
- Tested extensively on “live” ORPG sites with tremendous detection and some false alarms
- POD measuring at over 92%, FAR below 7% (initial testing with 15% SVM holdout)

POD = Probability of Detection
FAR = False Alarm Rate