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# Classifying bird and insect echoes at S band

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## INTRODUCTION

### ECONOMIC IMPORTANCE OF BIRDS AND INSECTS

- 169,856 strikes were reported either as happened in the US or by US registered aircraft between 1990 and 2015
- 95.8% of strikes were birds
- Wildlife strike cost was estimated at $229 million USD in 2015

A UH-60 Black Hawk after collision with a common crane . From Patterson (2016)

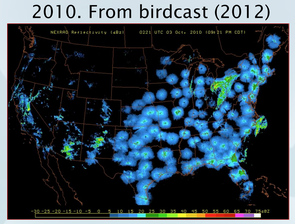

### CHALLENGES OF USING RADAR TO DETECT BIRD/INSECT ECHOES

- No current algorithm on NEXRAD for separating bird and insect echoes
- Birds and insects produce similar radar echoes
- Hydrometeor classification algorithm only defines a broad biological class
- Many studies of birds and insects are based on physical observation of few radar variables
- Radar variables are sensitive to position, aspect and range of target

### GOAL

The aim is to create a fuzzy logic algorithm for detecting birds and insects using the NEXRAD network

NEXRAD mosaic from 3rd October 2010. From birdcast (2012)



### FEATURES OF BIRDS AND INSECTS

| Birds | Insects |
|---|---|
| Birds are larger, faster and more active fliers than insects | |
| Birds migrate during the warm season in the great plains<br>• Spring (late Feb - early June)<br>• Fall (late Aug - November) | Insects migrate during the same period |
| Birds dominate nocturnal clear air echoes<br>• NOAA's Environmental Technology Lab routinely flags low level profiler data collected at night during migration season as contaminated (Martin, 2003) | Insects dominate most day time clear air echoes<br>• Kropfli (1986) deduced that clear air reflectivity was due to insects, seeds and particulates |

## DATA ANALYSIS

1. Migration period
   September 2017
2. Radar
   KTLX (WSR-88D)
3. Elevation
   Lowest 2 sweeps $(0.3^\circ - 0.5^\circ)$
4. Time of day
   Day 14 – 21 UTC (9 – 16 CDT)
   Night 2-9 UTC (21 – 4 CDT)
5. Range and time intervals
   - 10 – 100 km (10 km intervals) from radar
   - Analyzed data in 30 minute intervals
6. Selection of clear air days
   Mesonet data (Norman Station)
   22 days

### TEXTURE

$$\Delta Z_{a,b} = \frac{1}{N-1}\sum_{i=-1}^{1}\sum_{j=-1}^{1}\left|Z_{a,b-}\, Z_{a+i,b+j}\right|$$

### DATA QUALITY CONTROL

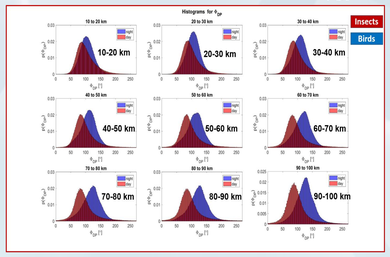
- Cells with no measurement or low SNR are excluded
- $\rho_{HV} > 0.8$ is excluded (Park et al, 2008)
- [-1,1] m/s is excluded

### DATA PROCESSING ALGORITHM

For radial at $20^\circ$, 10 – 20 km 09:00 – 09:30 UTC (30 mins)

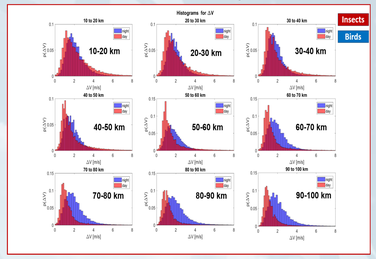
1. Calculate mean (median) of variable (texture) along the $20^\circ$ radial between 10 – 20 km
2. Accumulate all mean variables (median texture) from step 1 for all PPI's between 09:00 – 09:30 UTC
3. Mean (median) of all mean variables (median textures) in step 2 (MM variable)
4. Repeat for all azimuths, range and time intervals

Distribution of Differential Phase $\varphi_{DP}$

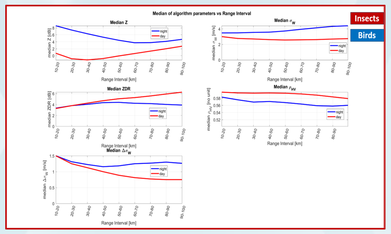


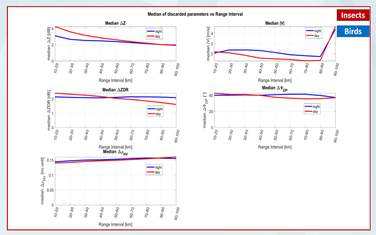

Variables that show good separation between day and night

Distribution of velocity texture $\Delta V$




Variables that show poor separation between day and night




7 parameters had the best separation between day and night echoes
$Z$, $\sigma_V$, $Z_{DR}$, $\varphi_{DP}$, $\rho_{HV}$, $\Delta V$ and $\Delta\sigma_V$

## FUZZY LOGIC ALGORITHM

### CLASSES

Birds and insects

### MEMBERSHIP FUNCTIONS

$$\hat{f}(y) = \frac{1}{n\sigma\sqrt{2\pi}}\sum_{k=1}^{n} exp(-\frac{(y-x_k)^2}{2\sigma^2})$$

where $\hat{f}(y)$ is the probability density function
$x_k$ is the $k$th observation of variable x
n is the total number of data points
$\sigma$ is the Bandwidth given by $1.06\, SD\, n^{-\frac{1}{5}}$ (Silverman, 1986)
$SD$ is the standard deviation of x

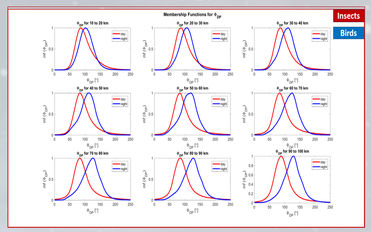
Membership functions $P^{(i)}(v_j)$ are gotten by normalizing $\hat{f}(y)$ so that the maximum is 1

### WEIGHTS

Defined as degree of overlap A between probability density functions $\hat{f}(y)$
$I$ is current variable index

$$W_I = \frac{1}{A_I}\sum_{j=1}^{N}\frac{1}{A_j}$$

Membership functions for Differential Phase $\varphi_{DP}$



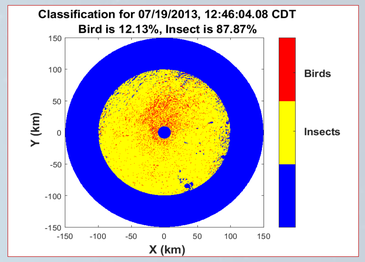

### AGGREGATION

$$Q_i = \frac{\sum_{j=1}^{7} W_{ij} P^{(i)}(v_j)}{\sum_{j=1}^{7} W_{ij}}$$

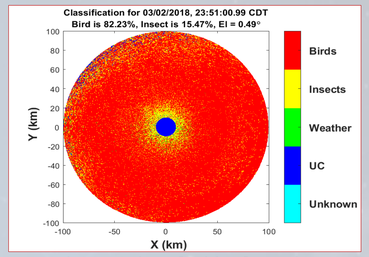
$j$ is variable index, $i$ is class index

## CLASSIFICATION RESULTS

Insect Case 19th July, 2013 using lowest 2 sweeps. From the US Department of Agriculture (USDA)

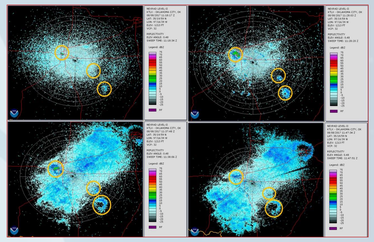


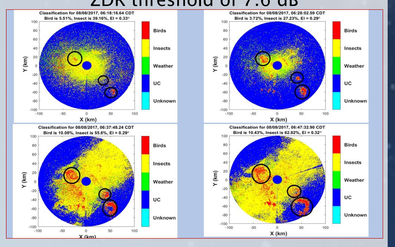

Bird Case (Provided by Phil Stephanian) using surveillance sweep and 7.6 dB ZDR threshold.




Bird rings identified by fuzzy logic algorithm using surveillance sweep and ZDR threshold of 7.6 dB

Bird rings from KTLX radar





## CONCLUSION AND FUTURE PLANS

- Insect case provided by USDA was identified as insect dominated with up 87.87% of classified echoes labelled as insects
- Bird migration case was classified as bird dominated with up to 82.23% of classified echoes labelled as birds
- Algorithm identifies birds as the cause of observed reflectivity rings
- Future work include further validation using more known cases, wind estimation by tracking insect movement and generalizing the algorithm to other KTLX WSR-88D radars