

NEWARK  
"NEW-ARCH"

# AEROECHOLOGY AUG 2024

Q1. HOW DOES RADAR WORK

MY GUESS: LIKE A BAT. SENDING OUT SONAR SIGNAL & BOUNCING BACK  
✓ AT DIFFERENT RATES BASED ON WHAT IT RUNS INTO?

• MICROWAVE

WE HAVE: FREQUENCY & TIMING

• DAN SHELDON → UMASS

KYLE HOLTON → U. COLORADO

ASSIST.  
MINTIE?

• DR. ADRIAN DOKTER →

JEFF KELLEY → U. OKLAHOMA

• YUTING DENG

JEFF BEULER → U. DELAWARE

ELSAE TIELENS

KELLEY → U. LEEDS

PPI = PLANNED POSITION INDICATOR  
& (TOM KUNZ)

DR. SID GORTHO → FATHER OF RADAR + ORNITHOLOGY

## LECTURE 1:

RESEARCH QUESTION: CAN RADAR BE USED TO MEASURE VAR OF EMISSIONS?

• ATMOSPHERIC CONDITIONS CREATE FREQUENCIES, NETWORKS, ETC (FAFAR)

MICROSCALE RADAR INTERACTION → MY INTEREST

ECHOLOGY QUESTIONS:

• POPULATION • HABITAT • PHENOLOGY • BEHAVIOR • ECOSYSTEM SERVICE

↓  
BIO SCATTER

$$\eta = \frac{1}{\Delta V} \sum_{vol} \sigma = N_{BIO} \sigma$$

• SCATTER CROSS SECTION USED TO IDENTIFY SPECIES

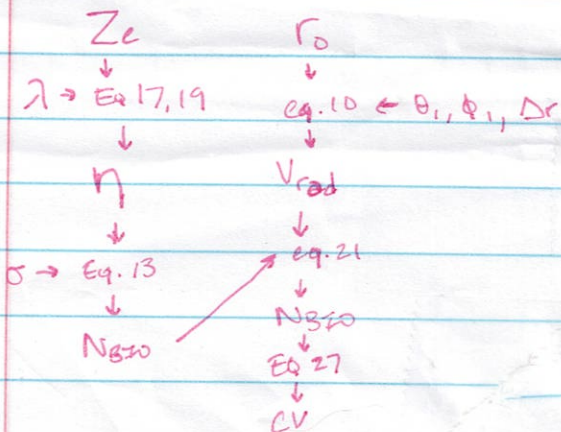
• CAN MEASURE BIRDS + INSECTS

• SONG SPRAWL (STRUCTURE?)

• STOP OVER MAPPING

• TEMP & NET PRODUCTIVITY CHANGES  
INSECT FLIGHT

• THE AIRSPACE IS HABITAT





## PHENOLOGY

- VAR OF ROOSTING TIME - 2 DAYS PER DECADE
- BEHAVIORAL DATA
  - BIRDS IN HIRTLANE
- BIRDS 40% FASTER IN SPRING
  - BC HIGHER WINDSPEED (28%) + FLYING FASTER

- REFLECTIVITY
- RADIAL VELOCITY
- COEFFICIENT

## METHODOLOGY → ME!

### LESSON 2: INTRO TO RADAR DATA

RADAR = RADIO DETECTION & RANGING

- PULSE OF EM WAVES
- REFLECTORS ARE "ISOTROPIC" (SEND ENERGY IN ALL DIRECTIONS)
- RADAR IS AN ACTIVE REMOTE SENSING PLATFORM
  - LANDSAT IS PASSIVE BC IT RELYS ON SUNLIGHT

RADAR WAVELENGTH ( $\lambda$ ) → SAME AS FREQUENCY

$$\lambda = \frac{c}{v} \quad c = \text{SPEED OF LIGHT} \quad \& \quad v = \text{FREQUENCY (OSCILLATIONS/SEC)}$$

(299,792,458 m/s)

- 2 M/S FOR RADAR SIGNAL TO TRAVEL 300 KM & BACK
  - IF ANTENNA IS ROTATING 10 REVOLUTIONS PER MIN.
- THE ANTENNA MOVES  $1/10$  OF  $1^\circ$

| (GHz) | FREQ<br>$\lambda$ | WAVELENGTH | BAND           |
|-------|-------------------|------------|----------------|
| 1.5   |                   | 20 cm      | L              |
| 3     |                   | 10 cm      | S              |
| 6     |                   | 5 cm       | C              |
| 10    |                   | 3 cm       | X              |
| 16    |                   | 1.8 cm     | K <sub>u</sub> |
| 21    |                   | 1.4 cm     | K              |
| 35.3  |                   | 0.85 cm    | K <sub>2</sub> |

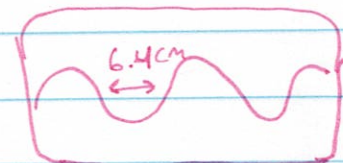
TYPICAL  
FOR PRECIP

RAIN  
FADING

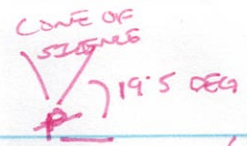
### MICROWAVE

- VACUUM TUBE
- WAVE GUIDE
- CHAMBER

TUNGSTEN  
THORIUM







MONOSTATIC VS. BISTATIC

TRANSMIT & RECEIVER

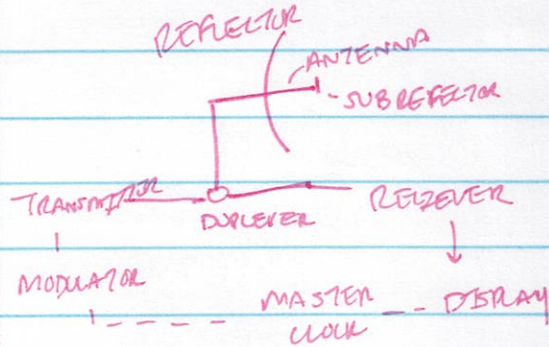
CONTINUOUS VS. PULSED WAVE

PHASED ARRAY → SOLID STATE TRANSMITTER

NO MOVING PARTS, MULTI-WISDOM

NEXRAD RADAR (6 PRODUCTS)

- CORRELATION COEFF.
- DIFFERENTIAL REFLECTIVITY
- DIFFERENTIAL PHASE



KLYSTRON TRANSMITTER

HIGH POWER

BEAM WIDTH

10 CONE  
 $\theta = 72.77 \lambda / D$

PULSE REPLICATION FREQUENCY (PRF)

+ # OF PULSES PER SEC

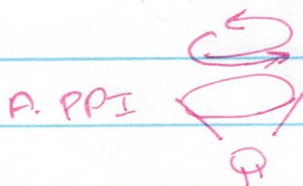
PULSE REPLICATION TIME (PRT)

• TIME B/W PULSES

$\lambda = c/f$

$\tau$  = PULSE DURATION

ANG  
300 KM  
MAX  
420 KM  
PRT



\* PULSE WIDTH

\* ANGULAR RESOLUTION

EX. X BAND

$\theta = 72.77 \cdot 0.03 / 3$   
 $\theta = 0.27^\circ$

S BAND

$\sim 3 \times$   
 $\theta = 72.77 \cdot 10 / 3$   
 $\theta = 0.94^\circ$

BIO:  
100 KM

PLANNED POSITION INDICATOR



RANGE-HEIGHT INDICATOR

POLAR COORD.





### LECTURE 3

#### WIND TURBINES, BIRDS EXPOSURE

##### PASSAGE THRU AIRSPACE

- TRAFFIC RATES
- HEIGHT PROFILES
- MIGRATION PHENOLOGY

##### LIFTOFF FROM STOPOVER

- DENSITY AT GROUND
- PHENOLOGY

- 24-41% OF BIRDS FLY THROUGH HRSZ

#### STOPOVER PREDICTORS:

|            |          |                   |         |      |
|------------|----------|-------------------|---------|------|
| LAND COVER | LOCATION | BI-MONTHLY PERIOD | WEATHER | YEAR |
| 16%        | 23%      |                   | 30%     | 8%   |

SPRING MIGRATION: MAY 1-30 (CONCENTRATED)

BIRDS CONCENTRATE W/IN 20 KM OF SHORELINE

#### SITING

#### CURTAINMENT

- PEAK SPRING
- CRESCULAR PERIODS

STOPOVER TO  
PASSAGE RATES (SPR)

#### PASSAGE BIOMASS

$$P = \frac{\text{cm}^2}{\text{km}^2 \text{ hr}} \times 75 \text{ km} \times \text{hr}$$

$\div 0.1$  ← cum. proportion  
OF DEPARTURE AT PEAK STOPOVER

MIGRATION  
TRAFFIC  
RATES

RADAR  
DOMAIN DIA.

DURATION  
OF NIGHT

HIGH SPR  $\neq$  HIGH CONSERVATION  
PRIORITY

#### STOPOVER BIOMASS

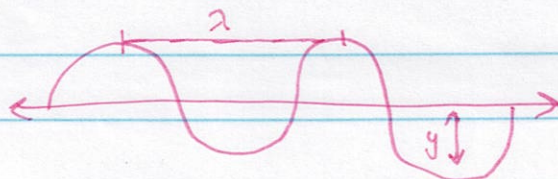
$$S = \frac{\text{cm}^2}{\text{km}^2} \times \text{km}^2 \div 0.1$$

MEAN BIRD  
DENSITY

HISTORICAL ENERGY BALANCE  
IN EA. GULF (FL)



# LECTURE 3: INTRO TO RADAR PRINCIPLES - ELSE TIELENS



PULSE WIDTH (T)

PULSE TIME (T)

$$\text{RANGE} = \frac{c \Delta t}{2}$$

RADAR COORD.

- RANGE
- AZIMUTH
- ELEVATION

RADAR POWER

• SIZE

• REFLECTIVE - MATERIAL  $m^2 km^{-3}$

REFLECTIVITY ( $\eta$ )

REFLECTIVITY FACTOR (Z)  $mm^6 m^{-3}$  (LOG SCALE: (DBZ))  
(METEOROLOGICAL USE)

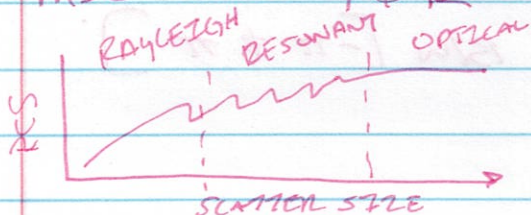
REFLECTIVITY = TOTAL BACKSCATTERING  
PER UNIT VOLUME

RADAR CROSS SECTION =

MIE THEORY & RCS

1/16  $\lambda$  = C-BAND

S-BAND



SUPERPOSITION = WAVES ADD

W/ RESPECT TO POSITION

ORIENTATION CAN CHANGE.

• CONSTRUCTIVE INTERFERENCE

AFFECT SCATTER

• DESTRUCTIVE INTERFERENCE

\* HOW REFLECTIVITY CONVERTS TO # OF ILLUMINATIONS

... NON-LINEAR TO OBJECTS SIZE (MIE CURVE)

PHASE = WHERE YOU ARE IN

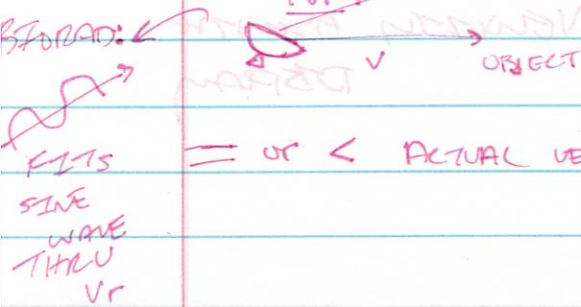
RADIAL VELOCITY

REGION WHERE RADIAL VELOCITY

IS PERPENDICULAR TO WIND DIRECTION

=  $\emptyset$  [ISODOP]

DISTANCE IS ALSO HEIGHT



= or < ACTUAL VELOCITY



CHANGING COLORS ACROSS HEIGHT ALONG  
SAME AZIMUTH?

~~DIFFERENT HEIGHT~~

HORIZONTAL COLORS FOR INCLUSIVITY (COLOR BURNING)

ALIASING:

- ECHOS THAT RETURN AFTER NEXT PULSE IS SENT
- PRF DETERMINES MAX UNAMBIGUOUS RANGE

RADAR ASSUMES REAL PHASE SHIFT IS B/W  $[-\pi \text{ \& } \pi]$

NYQUIST VELOCITY

ALIASING OCCURS WHEN MAX V OCCURRING NEEDS RADARS  
MAX UNAMBIG. V

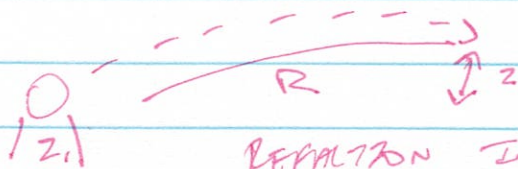
DOPPLER DILEMMA: MAX UNAMBIG. RANGE &

SPECTRUM WIDTH: VAR W/ Z RANGE GATE

$$PRF = \text{D\&RANGE} = \text{HEIGHT}$$



• VELOCITY AZIMUTH  
DOPPLER



REPETITION IN AMPLITUDE



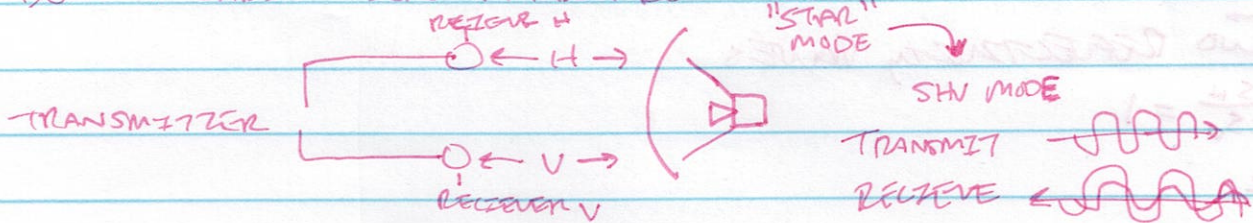
KOUN  
TEST  
RADAR  
IN OK

## LESSON 4: DUAL POLARIZATION FOR BIOLOGICAL APPS OF WEATHER SURVEILLANCE RADAR

KTOX  
FIRST  
NEXRAD  
DATA  
1991 (June 1)

- POLARIZATION OF EM WAVES CAN BE MANIPULATED

### DUAL-POLARIZATION HARDWARE



2013  
6 PRODUCTS  
W/ NEXRAD  
DUAL POL

- MOST BIRDS & INSECTS SCATTER MATRIX

ARE IN "RESONANT"  
MIE CURVE PHASE

$$S = \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix}$$

STAR JONES  
CALCULUS

### COHERENT INTERACTIONS

$$\gamma \ll \frac{\pi D}{\lambda}$$

$$\gamma \gg \frac{\pi D}{\lambda}$$

### RESONANCE INTERFERENCE

CONTROLLIES UNTIL  
DMSA

SIZE  
OF  
OBJECT

- MIE IS ONLY STRICTLY VALID FOR SPHERES

★ CANT EACH PLS HAVE ITS OWN CURVE THEN?

### DEPOLARIZATION: ONE ISSUE W/ IRREGULAR SCATTERS

- NO MEASURING OFF-DIAGONAL SIGNAL

~~LOOKS DO NOT JUST OBTAIN~~

### $Z_H$ & $Z_V$ REFLECTIVITY IN HORIZONTAL & VERTICAL PLANES

- RATIO OF RETURNED POWERS = DIFFERENTIAL REFLECTIVITY ( $Z_{dr}, dB$ )
- DIFFERENCE IN PHASE ( $\phi_{dp}$ , DEGREES)
- DIFFERENCE IN DIFFERENCES  $\rightarrow$  COPOLAR CORRELATION COEFF.

$$(C, P_{co}, P_{cv})$$

$$P_r = \frac{1.22^2 0.55^2 W^{-18} \pi^2 c}{1024 1090 c(2)} \frac{P_t Z_0^2}{24}$$

WEATHER & CLIMATE  
CLIMATE & WEATHER  
CLIMATE & WEATHER



TWO REFLECTIVITY VALUES

$$\frac{R_{CSH}}{R_{CSV}} = 1$$

EX. 2

DIFFERENTIAL REFLECTIVITY

$$Z_{DR} = 10 \log_{10} \left( \frac{Z_H}{Z_V} \right) = 0 \text{ dB}$$

$$Z_H = Z_V, \text{ and } Z_{DR} = \frac{Z_H}{Z_V} = 1$$

$$Z_{DR} = Z_H - Z_V$$

RAIN DROPS

2.7 mm

8.0 mm

NUAA.

NEURO-FUZZY

HOW DATA

FOR METEOROLOGY  
IS CLEANED

CORRELATION COEFFICIENT

$P_{HV} = 1$  IF HIGHLY CORRELATED

$$|P_{HV}|_{e^{i\phi}} = \frac{\langle S^*_{hd} S_{hw} \rangle}{(\langle |S_{hd}|^2 \rangle \langle |S_{hw}|^2 \rangle)^{1/2}}$$

DIFFERENTIAL PHASE

← CUTTING EDGE OF  
CUTTING EDGE

$$\psi_{dp} = \psi_{HH} - \psi_{HV} = \sigma_{co} + \phi_{DP} + \psi_0$$

QC

- CLEARING → GROUND CUTTER, BEAM PROPAGATION
- CORRECTING BLAST DISTURBED DATA
- QUANT. EST. OF FINAL UNCERTAINTY ★



# LESSON 5: BIORAD

## VERTICAL PROFILING

RADAR\_FILE

READ\_PVO FILE

RADAR VEL.  
VRADH  
REFLECTIVITY  
DBZH

CALCULATE\_VP

VERTICAL PROFILE → PLOT

AWAY FROM RADAR: RED

TOWARDS RADAR: BLUE/GREEN

\* INSECTS & RAIN MAY W/ WIND \*

< .95 CORRELATION COEFF. IS RAIN

PRECIPITATION REMOVAL: DUAL POL

BIORAD OBJECT

PRECALCULATE

MISNET: PRECIP REMOVAL

PVO FILE

RADAR FILE

APPLY MISNET()

PVOL

POLAR VOLUME

GET\_SCAN(ELEV=0.5)

POLAR SCAN

PROJECT-AS-PPI

PPI

PLOT(PARAM="CELL")

↓ gplot

PLOT

VERTICAL PROFILING: ANIMAL DENSITY

$$\eta = \rho \sigma \quad \text{REFLECTIVITY} = \text{ANIMAL DENSITY} \times \text{RCS}$$

WEATHER  
RADAR  
EQN

RCS  $\sigma$

$D \ll \text{WAVELENGTH } \lambda$

$$\sigma_{\text{RANGE}} = \frac{\pi^5}{24} |K_m|^2 D^6$$

$K_m \& R_m$

ARE CONSTANTS  
DEPENDENT ON  
SCATTER

$$\sigma_{\text{NORMAL}} = |R_m|^2 D^2$$

$D_{\text{BIRO}} \sim \text{WAVELENGTH } \lambda$ : MIE SCATTER

$$\text{REFLECTIVITY } \eta(R) \approx \text{PBIRO } \sigma_{\text{BIRO}}$$

CALCULATE  $\eta$  FROM REFLECTIVITY FACTOR Z

$$Z(R) = \frac{1}{\pi} |K_m|^2 \eta(R)$$

BIORAD:

DBZ\_TO\_ETAC)

ETA\_TO\_DBAC)

FILES:

IRIS (NOT GRAN, ON GET) • ODEM • BIORAD



SUPERFLEDERMAUS - BIRD RADAR — CAN BE USED TO COMPARE

↳ WINGBEAT PATTERN DATA — REG. RADAR DATA

RCS SEASONAL VAR: USED TO EST. RCS BASED ON GIVEN MIGRATION

YEAR ROUND AVG:  $11 \text{ m}^2$

VERTICAL PROFILE: ESTIMATING ANIMAL VELOCITY



ALIASING

$$\text{MAX VELOCITY} = \text{PRF} (\text{RADAR WAVELENGTH}) / 4$$

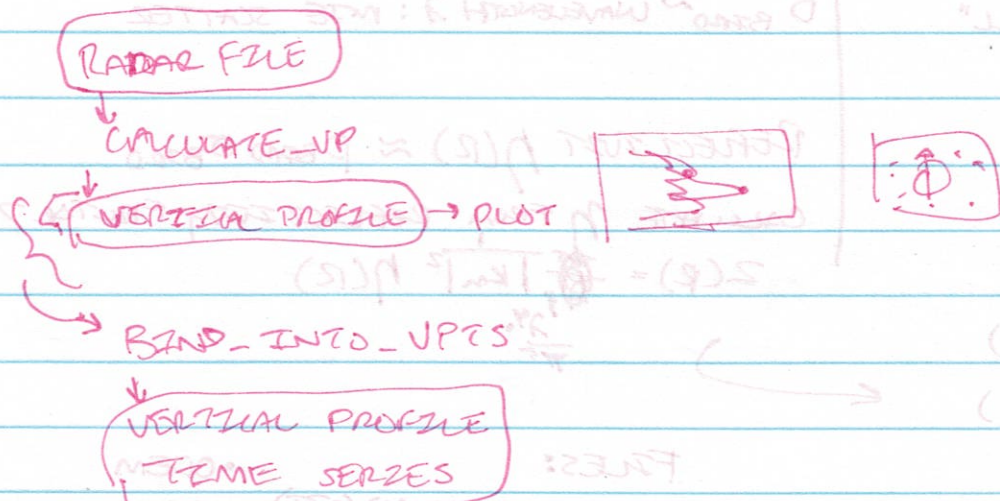
$$\text{MAX RANGE} = C / (2 \text{PRF})$$

$$\text{MAX RANGE} \times \text{MAX VELOCITY} = \text{CONSTANT}$$

"DOPPLER DILEMMA"

DEFAULT USING

"TORUS MAPPING"





## RADAR PROFILE

↓ CALCULATE-UP

VP ... , dual-POL=TRUE

DEALIAS=TRUE (ON AUTO)

HEIGHT INTEGRATION

VPTS

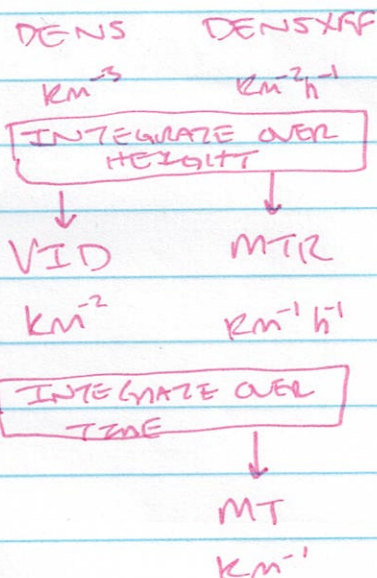
↓ INTEGRATE PROFILE

INTEGRATED  
VERTICAL  
PROFILE

PLOT  
→  
QUANTITY='VID'

$$VID = \sum \text{BIRDS}$$

## BIRD CAST



## MIGRATION TRAFFIC RATES (MTR)

BIRDS PER HOUR

$$MTR = \sum \text{HEIGHTS (BIRD DENSITY) (BIRD SPEED) (LAYER THICKNESS)}$$

$$\text{UNIT} = \text{BIRDS/KM/HR}$$

• TRANSECT STAYS PERPENDICULAR TO TRAVEL OF BIRDS

## MIGRATION TRAFFIC (MT)

• HOW MANY BIRDS HAVE FLOWN OVER HEAD

$$MT = \sum \text{TIMESTEPS}$$



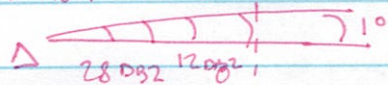
## LESSON 6: AERIAL INSECTS IN ANTHROPOCENE

- DAY FLYING INSECTS NOT IN DECLINE

## LESSON 7: USING WEATHER SURVEILLANCE TO MAP ANIMALS TO GROUND

RANGE BIAS

REFLECTIVITY DECLINES W/ RANGE



3 QS → WHEN TO SAMPLE → SUN ELEVATION  $-7^{\circ}$  TO  $-9^{\circ}$

WHERE IS RADAR BEAM

HOW ARE BIRDS DIST IN AIR?

SUB-REFRACTION NORM. (413 EAR. RADARS)



SUN ELEVATION BIAS

IN RADAR DOMAIN

~10M DIFF FOR 100KM RADARS

CAN HAPPEN AFTER SUNSET

NAR DATA

ATMOSPHERIC PRESSURE, TEMP, PARTIAL PRESSURE OF WATER VAPOR



Q31A

- ARE BIRDS NORM. DIST. WHEN MAPPING (JEFF)

- LETTERS TO A YOUNG SCIENTIST