

Remote Sensing for Offshore Wind Turbine Development

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Technologies

- Radar
- Video
- Transponders
- Telemetry (not covered, generally understood)



Application

- Pre-construction surveys
- Post-construction monitoring
- Mitigation



Pre Construction

- NEXRAD is used for first cut assessments on shore to see if biological targets are present and timing of large events
- Limited applicability offshore, movements maybe less dense (some species actively avoid overwater flights) and can be more limited in altitude distribution and hence not detected by this long range WX sensor



Broad Front migration

- NEXRAD can detect broad front migration
- Would you consider birds randomly spaced with an average separation of 300m to be broad front migration?



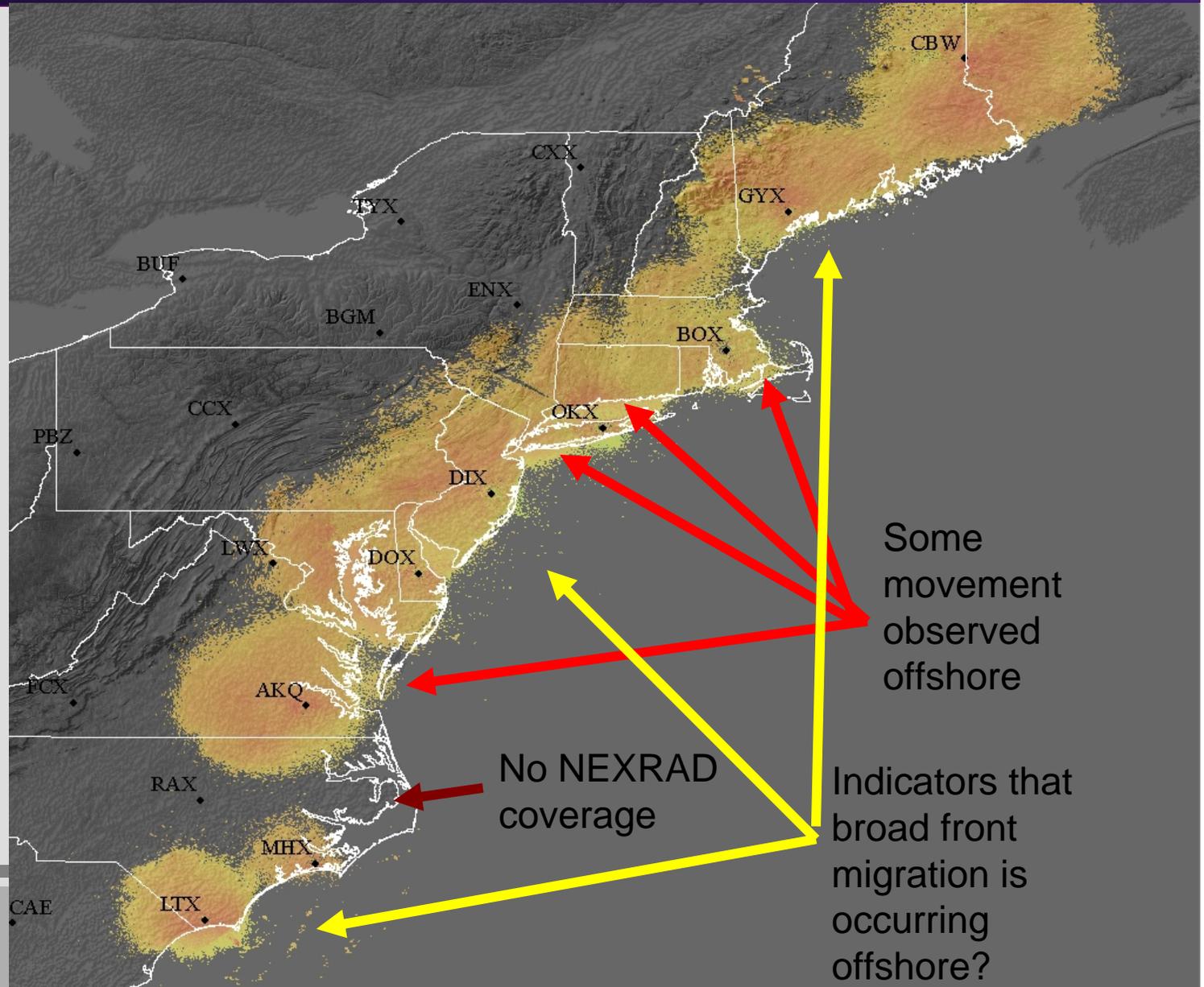
Point target rejection algorithm

- The point target rejection algorithm is a **logical filter** (which means all or nothing) and will eliminate broad front migration from the display until it reaches the level where there are similar values in second nearest 250m (500m long pulse) range bins.
- If the average spacing is greater than 250m then the point target rejection algorithm will cause the radar to show **NOTHING** when broad front migration is underway.
- If the average spacing is less than 250m but the reflected energy in adjacent cells fluctuates dramatically then the point target rejection algorithm will cause the radar to show **SOMETHING LESS** than the broad front migration that is underway.
- This is very important to understand for offshore applications
- **NOTHING** may not be nothing and **SOMETHING** maybe less that it really is!



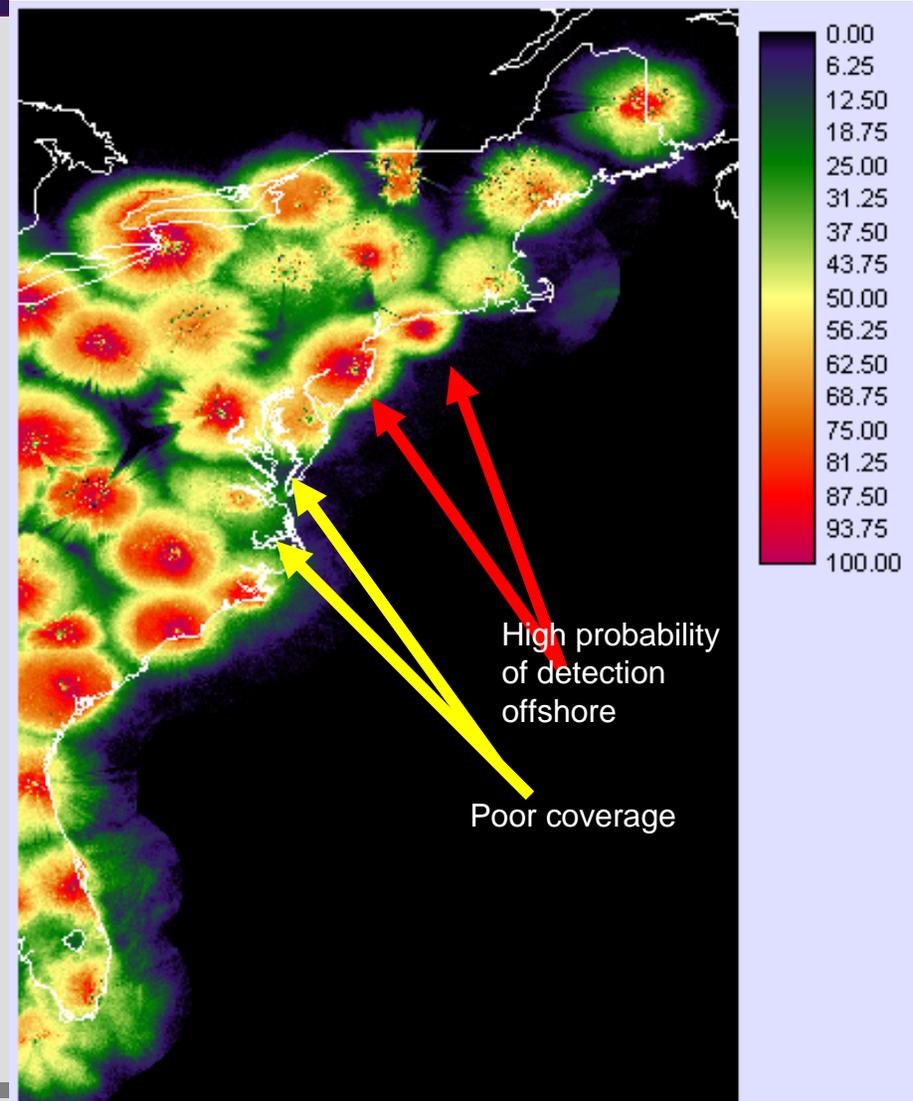
NEXRAD

- North East Coast NEXRAD Coverage
- Remember NOTHING on NEXRAD may not be **nothing** and SOMETHING maybe **less** that it really is!



NE Probability of detection maps

- Using very large number of bloom images we can determine the % probability of detection in each grid cell
- Generally blooms are less often detected offshore
- Lower rate of occurrence does not equate to no birds, perhaps just lower density, greater spacing

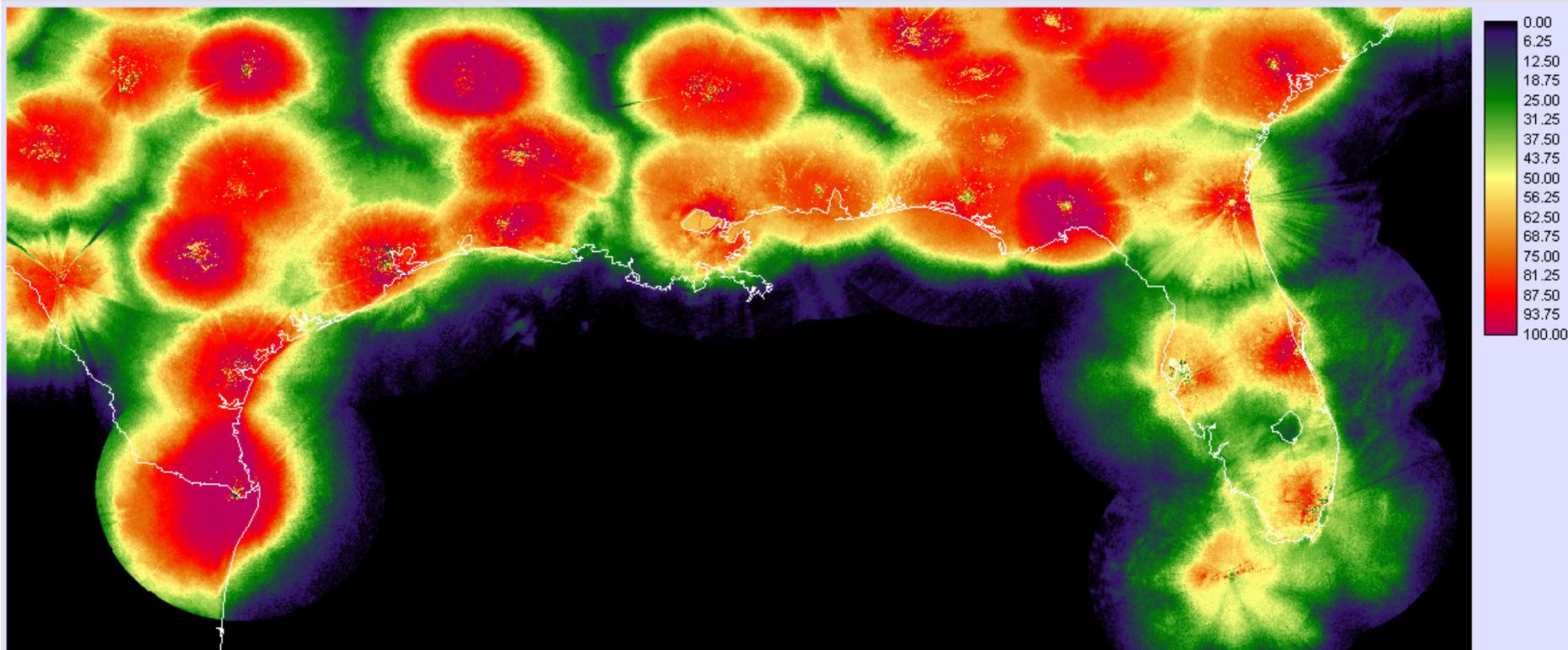


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SE Coast



- Asymmetry of detection is seen offshore
- Would anyone argue trans gulf migration does not occur?
- Just be careful with interpretation of low NEXRAD values offshore

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Mobile Radar

- Surveillance mode
- Vertical Scanning mode
- Limitations, when not digitally processed
observer bias, sampling bias
- Ground Clutter and Sea clutter can be minimized
digitally and physical hardware, but be very
careful of limitations off shore
- Weather blocks the radar at X band, birds can be
seen with digital processing at S Band



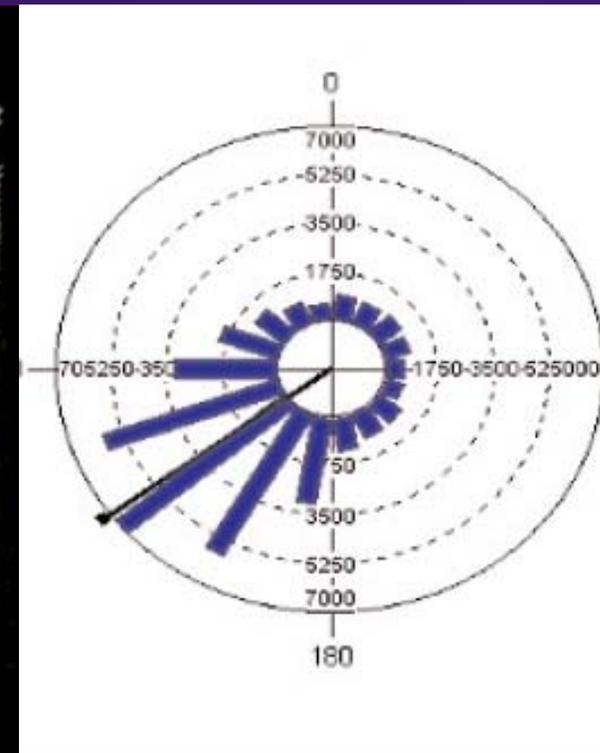
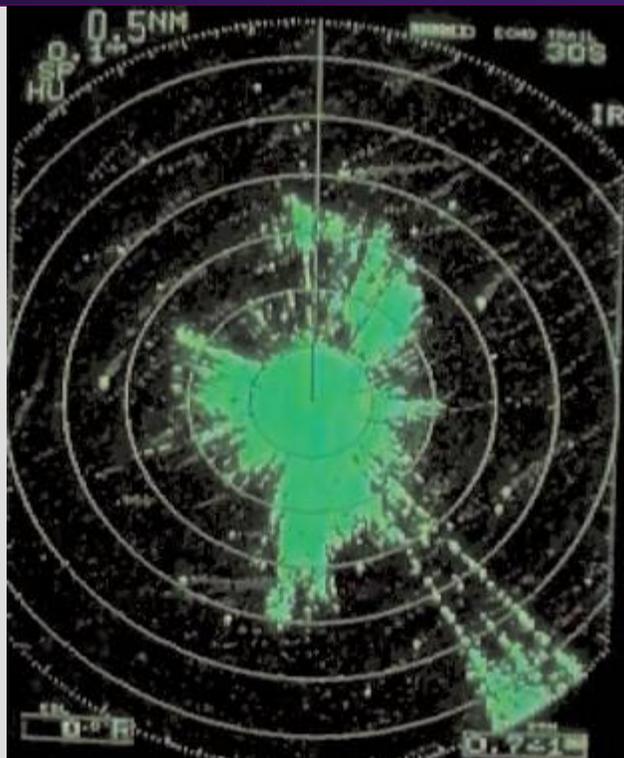
Costs

- Radar studies are not cheap, focusing field time with NEXRAD and automation reduces costs
- Operating radar offshore for bird studies is even more expensive than onshore, but has been done
- Operations from lift platform (high rental cost, USA), oil platform (Scotland), research platform (Netherlands), dedicated platform (Denmark and Netherlands)
- Almost all radars we operate have a remote data link, NASA full remote management, Netherlands and Scotland have operated unmanned



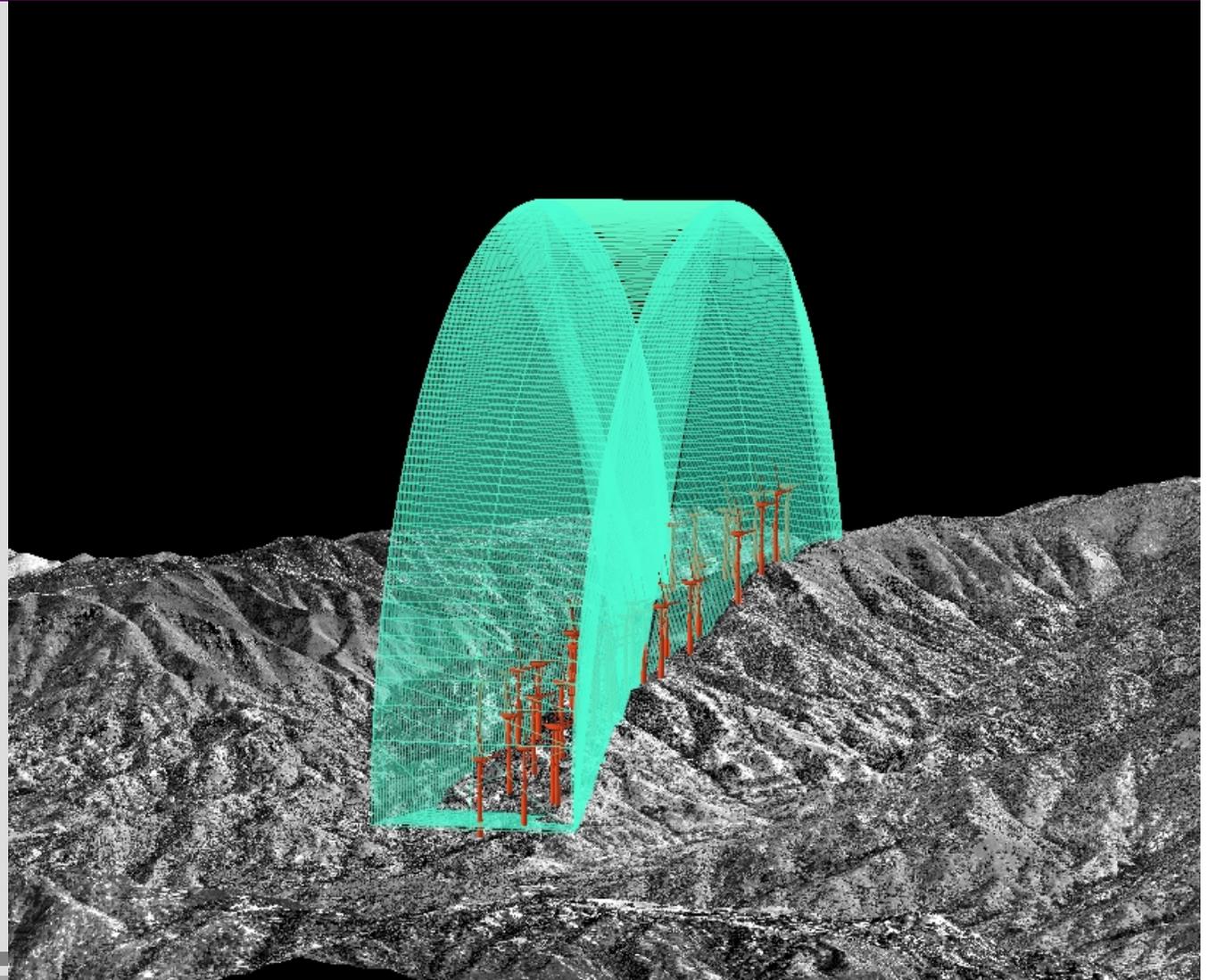
Surveillance mode

- Images from Woodlot Alternatives, Inc
- Provides data on numbers and heading
- Ground and Sea Clutter are an issue unless digitally processed
- WX issue unless S Band
- No altitude



Vertical Scan Mode

- Marine radar spins like a windmill to count birds and measure altitude



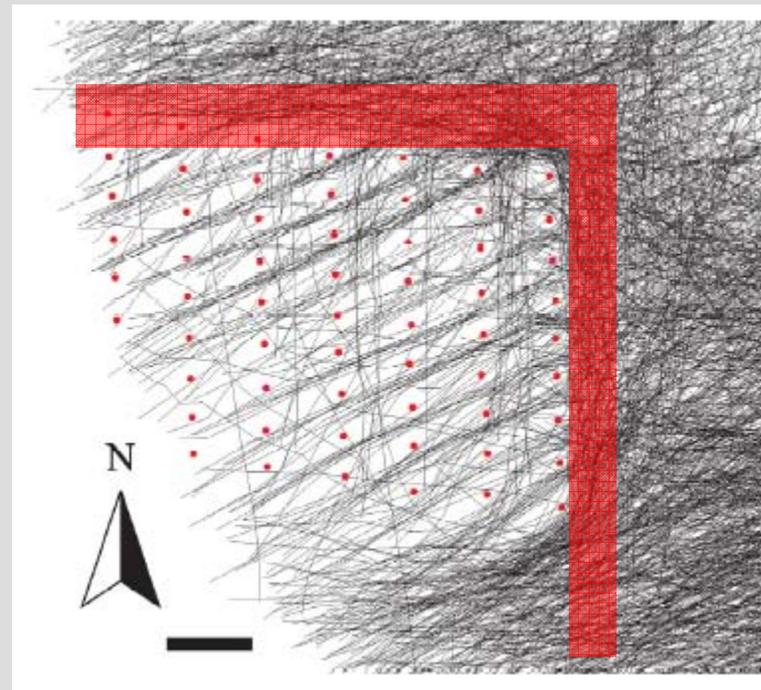
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Radar Study Denmark

- Be careful with the Danish offshore study by Desholm and Kahlert
- 3cm X band radar only works in dry conditions
- Maneuvering in close proximity to outside turbines may be high risk locations in low visibility
- Night was considered poor visibility, not actual low visibility from obscuration
- Birds “see and avoid” at night very well in good visibility



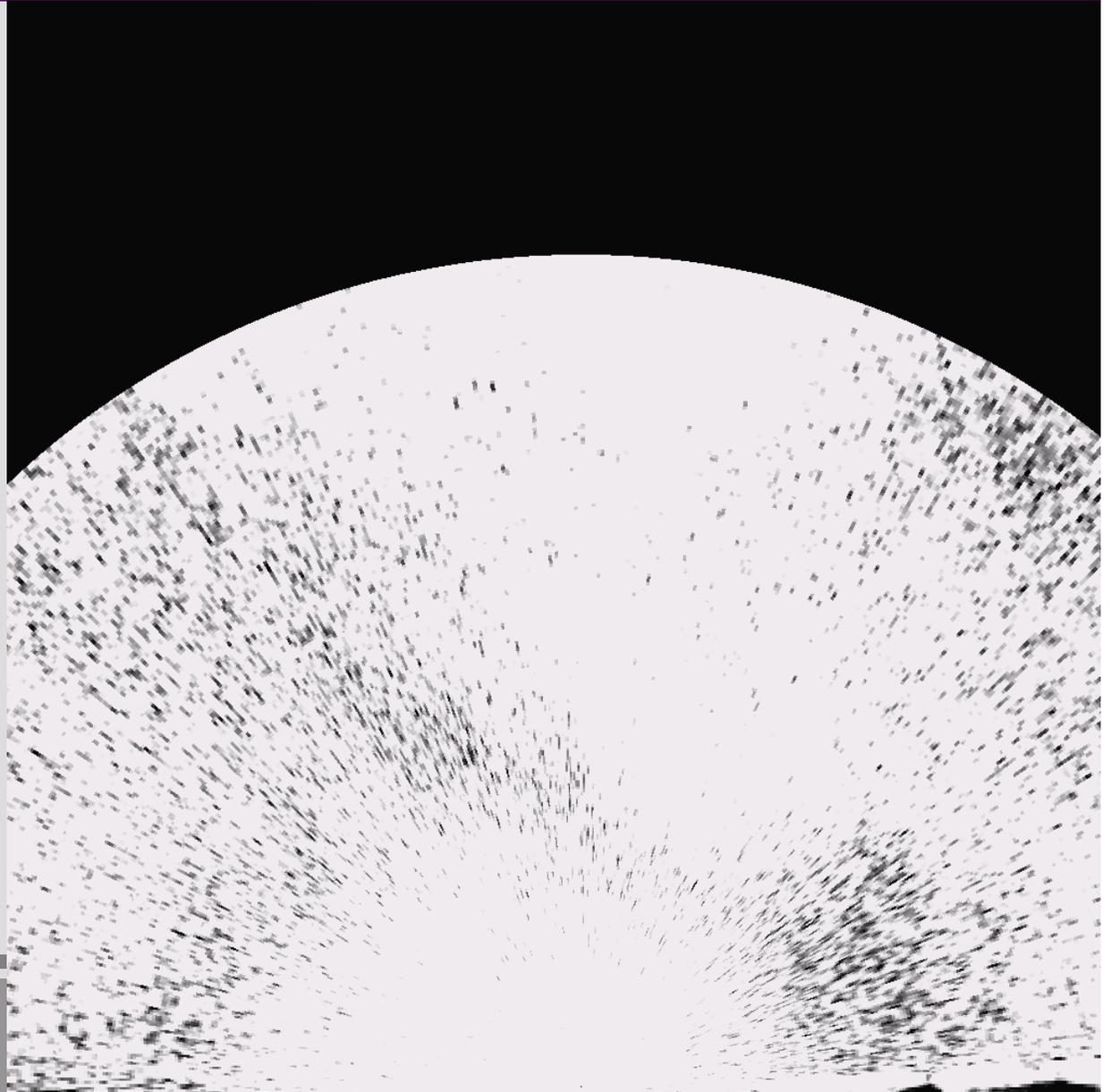
Vertical Scan Mode

- Birds in clear air on vertical radar (X band, 3cm wavelength)



Weather on Radar

- Precipitation on vertical radar (X band, 3cm wavelength)
- Horizontal X band radar display would be similar



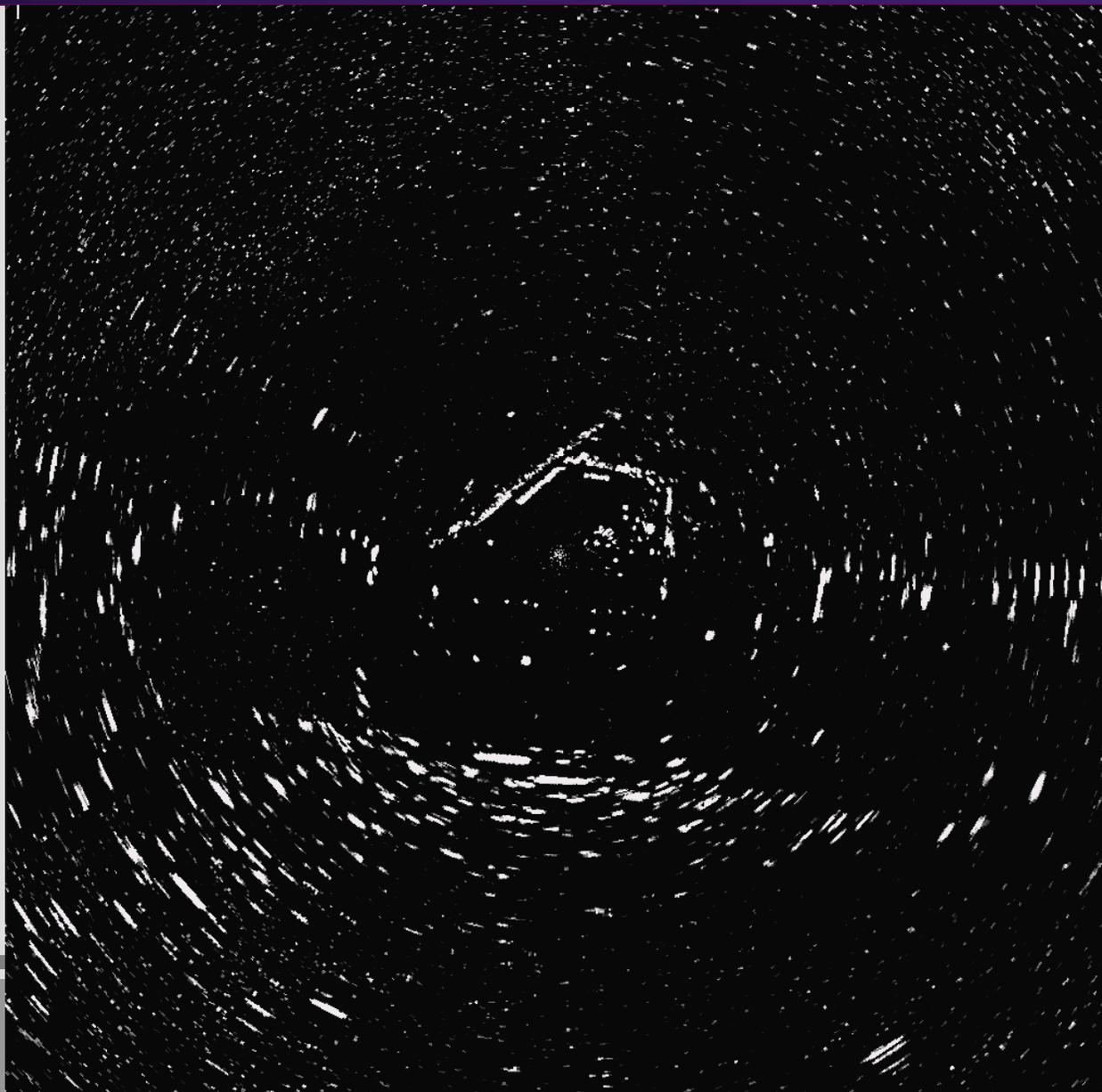
Weather on Radar

- Precipitation on horizontal radar (S band, 10cm wavelength)



Weather on Radar

- Precipitation on horizontal radar removed by CFAR to leave behind targets/clutter (S band, 10cm wavelength)



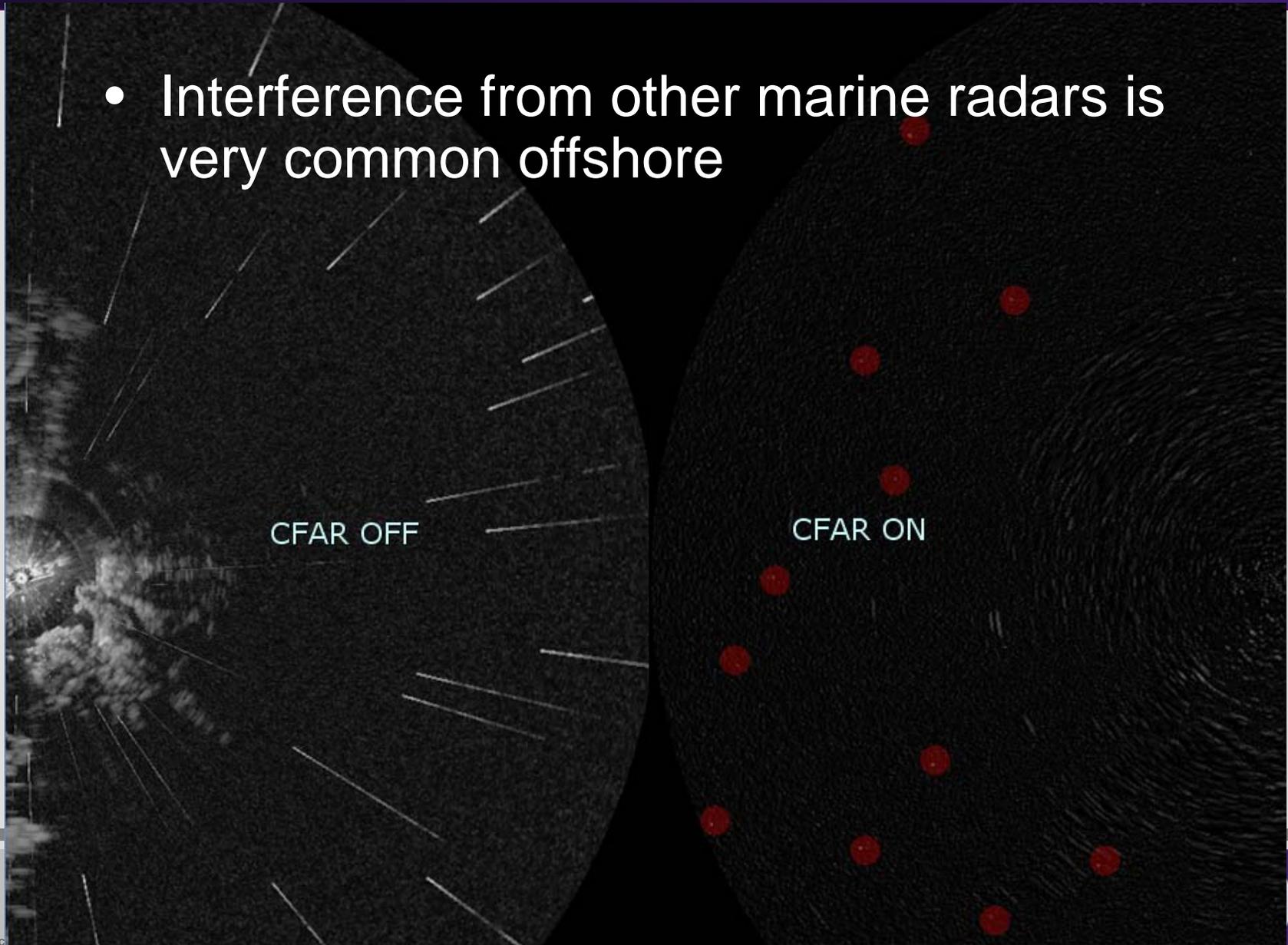
Weather on Radar

- Comparison with the previous scan shows which targets moved, these “Plots” can be fed to the tracking algorithm to correlate to tracks



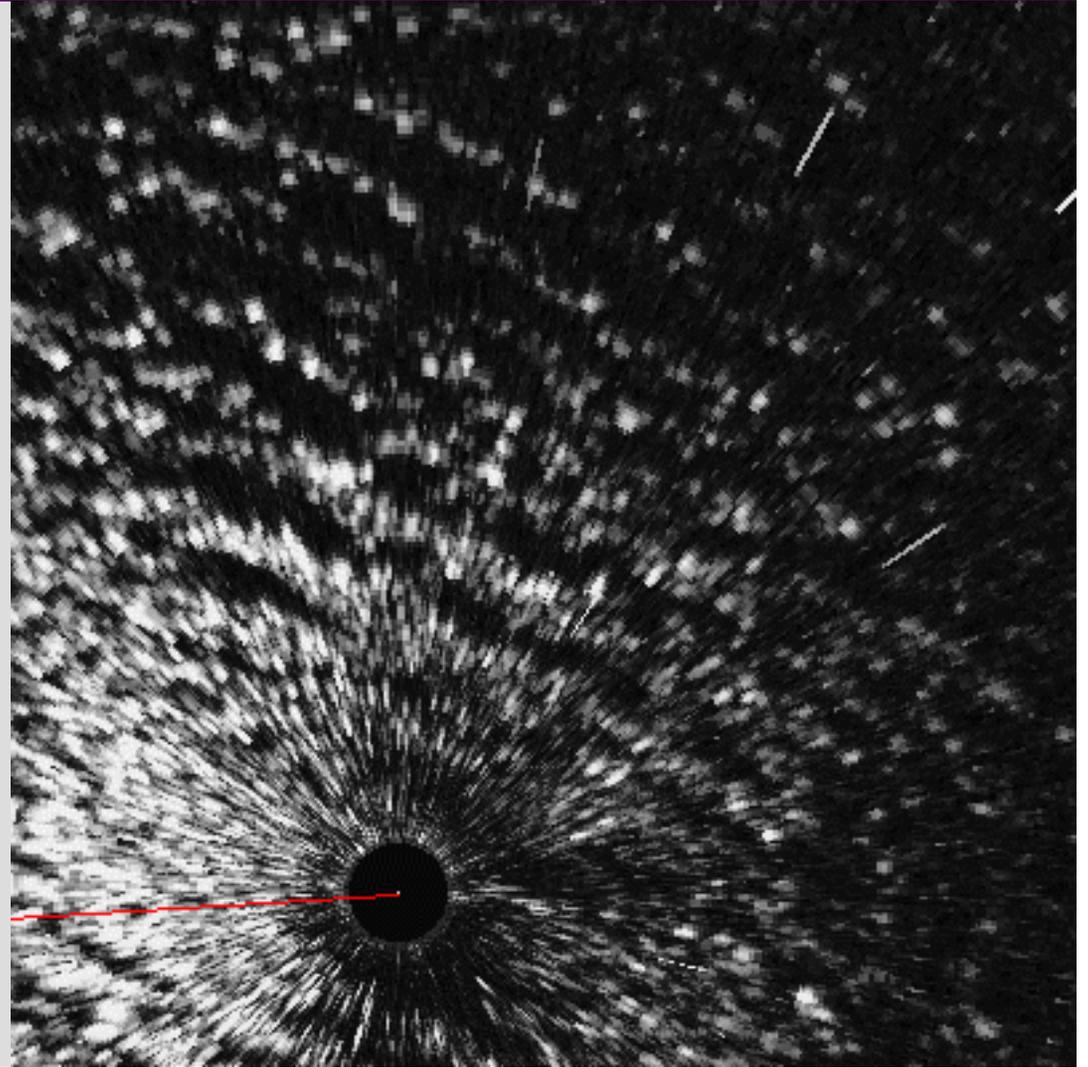
Interference

- Interference from other marine radars is very common offshore



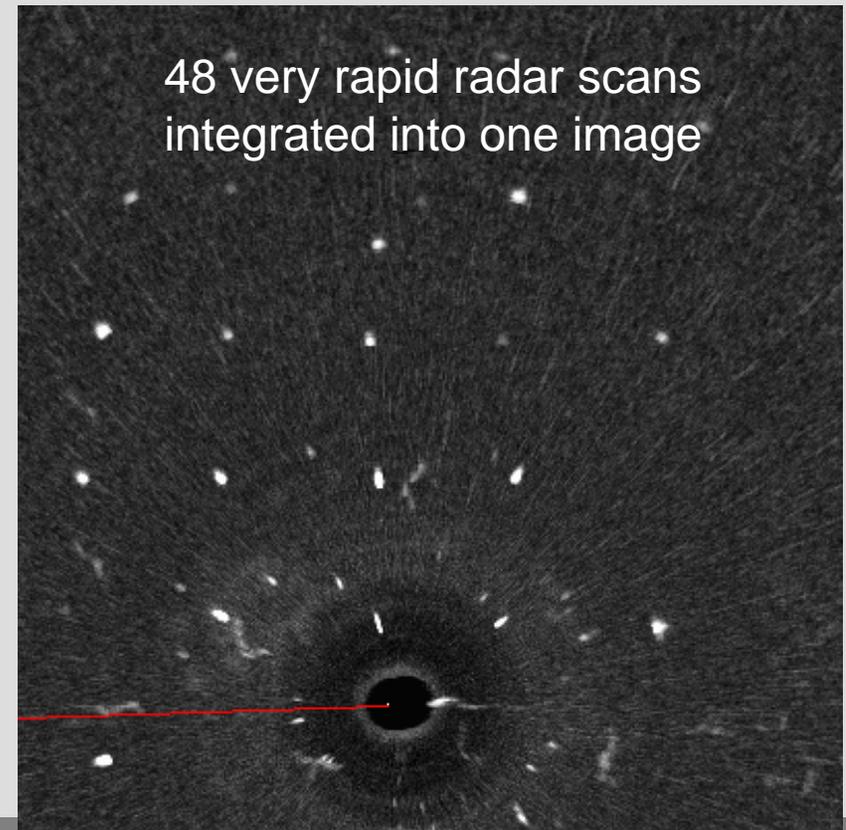
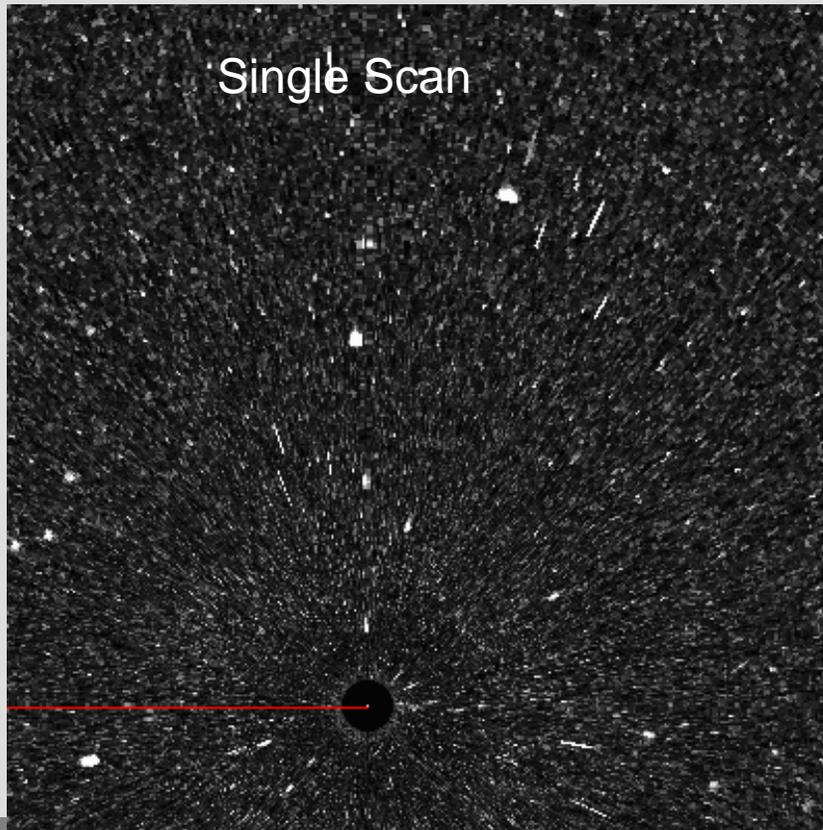
Sea clutter

- Waves are great radar reflectors
- Single Scan with high waves, point targets, interference from other radars (radial lines) and some receiver impulse noise



Waterfowl rafts

- Example of digital processing to find stationary rafts of waterfowl offshore

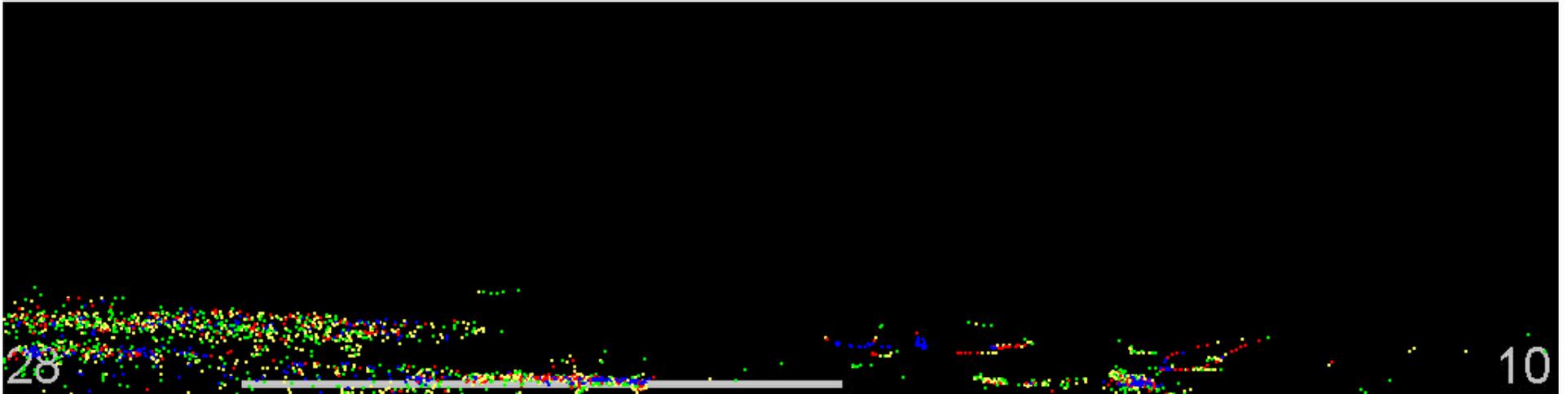


Data Products

- Decision making from time series plots

Vertical Radar

- Is height of movement an issue, data from vertical scan for the same movement



Vertical Profiler Radar

- First deployments of prototype radar to TN and NM
- Built to produce detailed density, altitude and target type information
- May be best offshore radar, no moving parts, no sea clutter can be used to validate NEXRAD



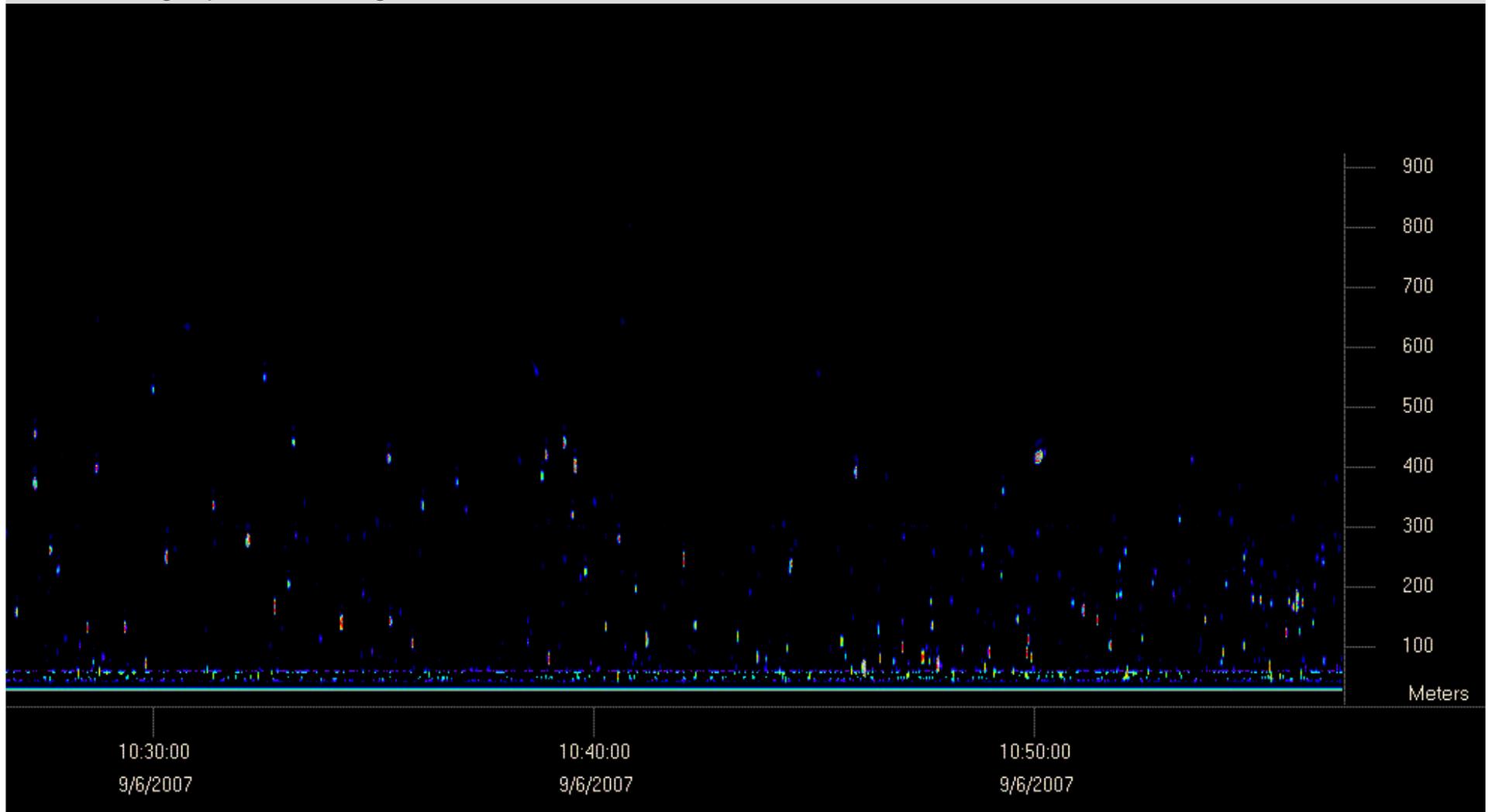
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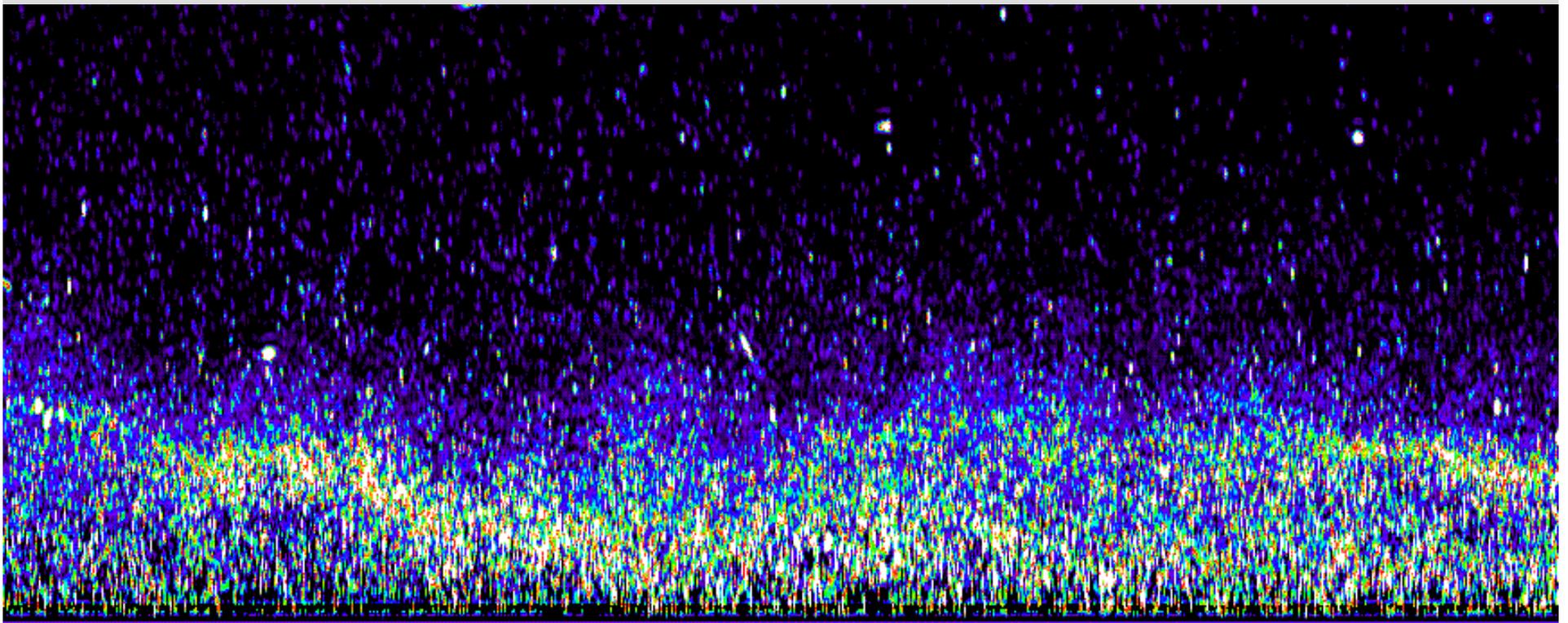
Point Targets

- Birds, bats and insects
- Weak targets blue, brighter shades are more reflective
- Time series vs altitude data birds each bird bat or insect here registers as single point, one dot, one target passed through the beam



Layering

- Layering of point targets has been detected during peak bat migration, similar patterns seen to that observed with the US Army FM-CW



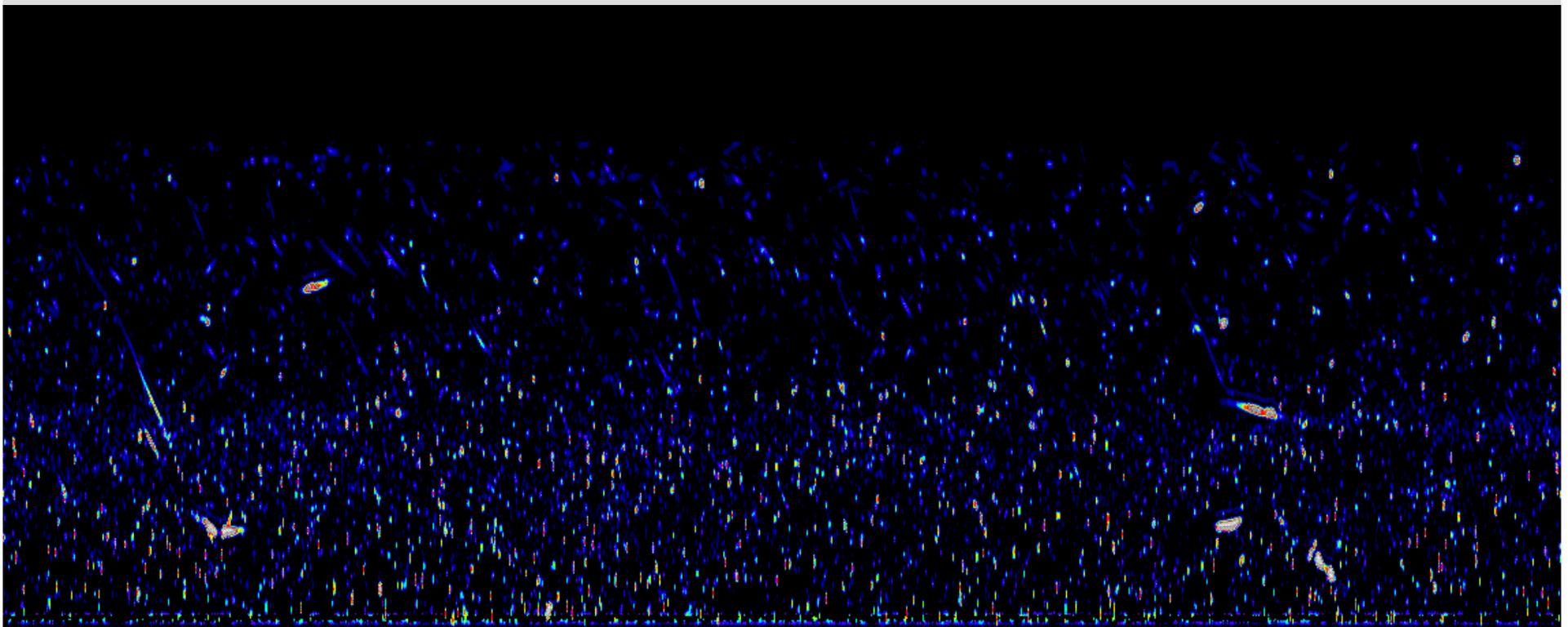
02:50:00
8/31/2007

03:00:00
8/31/2007

03:10:00
8/31/2007

Local Foraging?

- Target Dwelling – on occasions, in the early hours of the morning a small number of targets were seen to dwell in the beam, perhaps an indication of a switch to local foraging?
- An area for further investigation of the nature of these targets
- Target dwell has not been noted on the FM-CW radar



02:30:00
9/4/2007

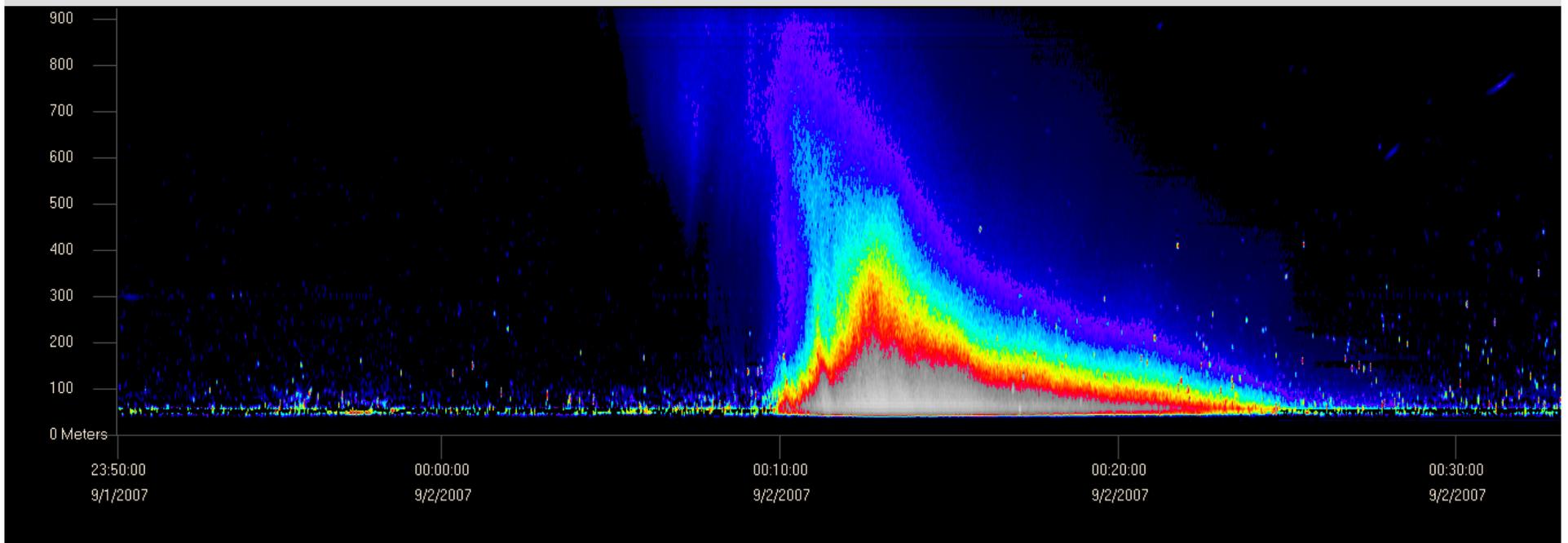
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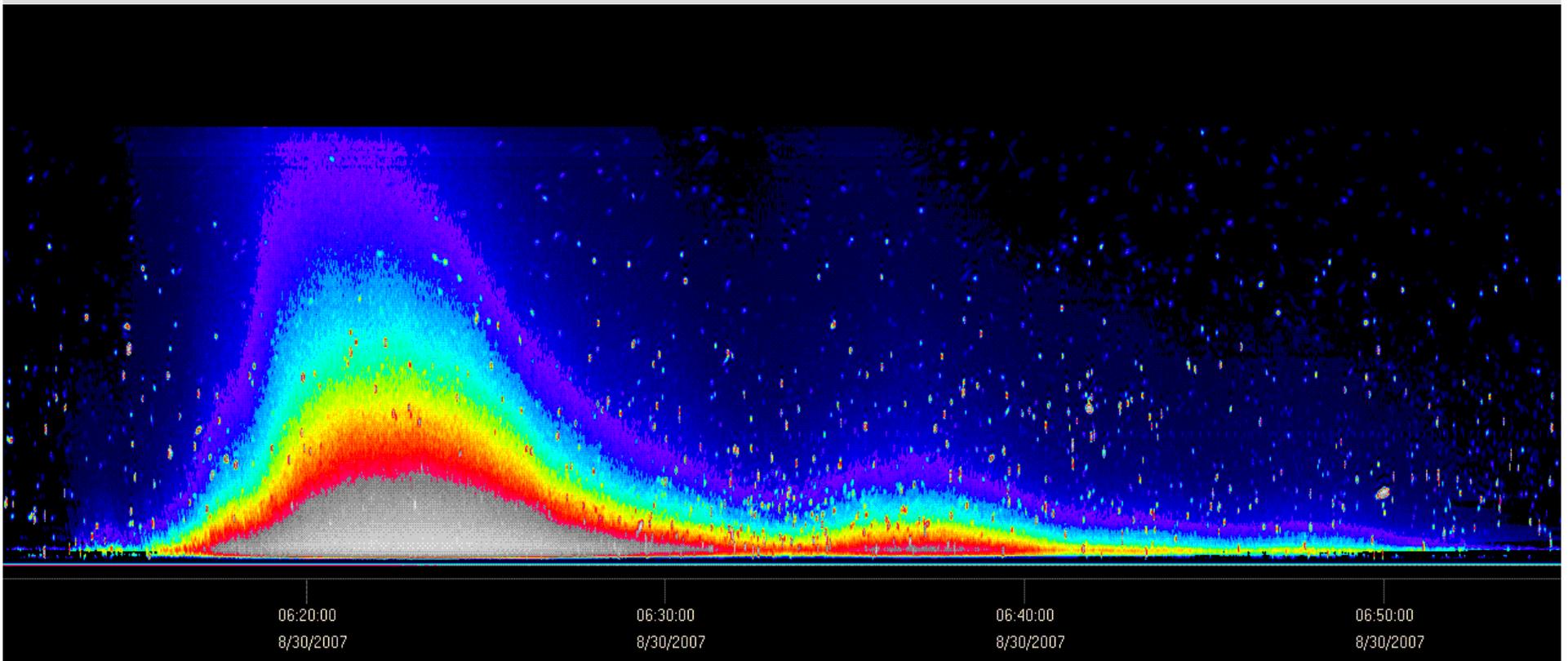
Rain event

- Rain detection is possible like the FM-CW opening up the ability to study what biological targets do in response to rain
- Note point targets before, during and after the rain shower



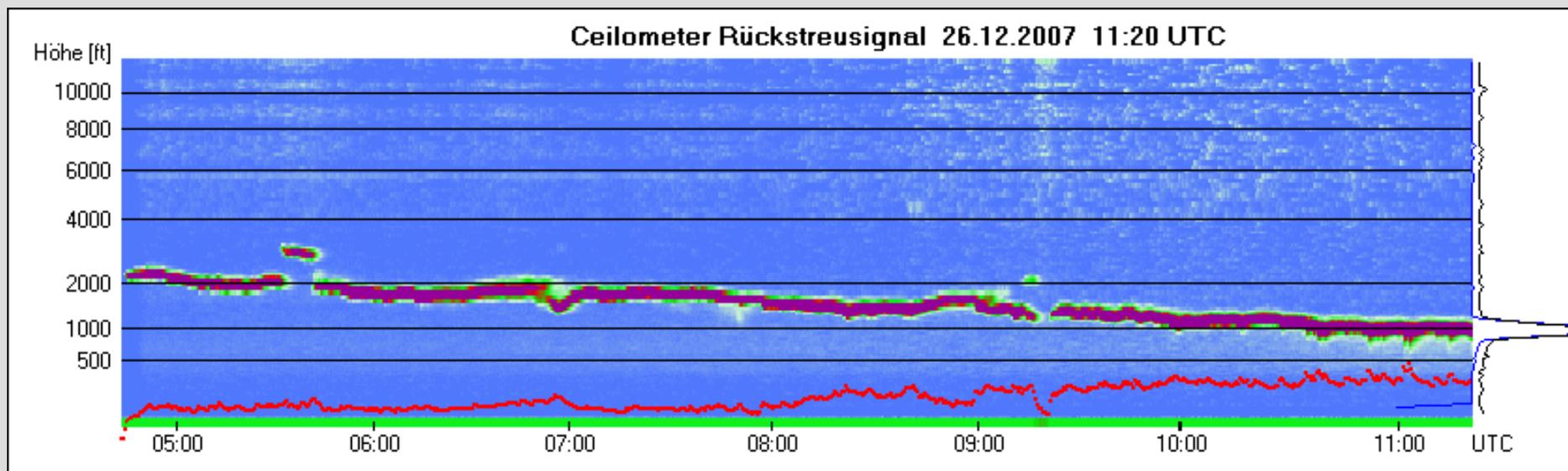
Particulate detection

- Particulate is different from rain as it arrives at ground level and goes up, not arrives at altitude and comes down
- Source of dust is vehicle traffic on site on dry evening with light to moderate winds
- Point targets visible in particulate
- Particulate detection is possible, but much more data is required to see if it can describe turbulence in the atmosphere as well as the FM-CW can from clear air scattering



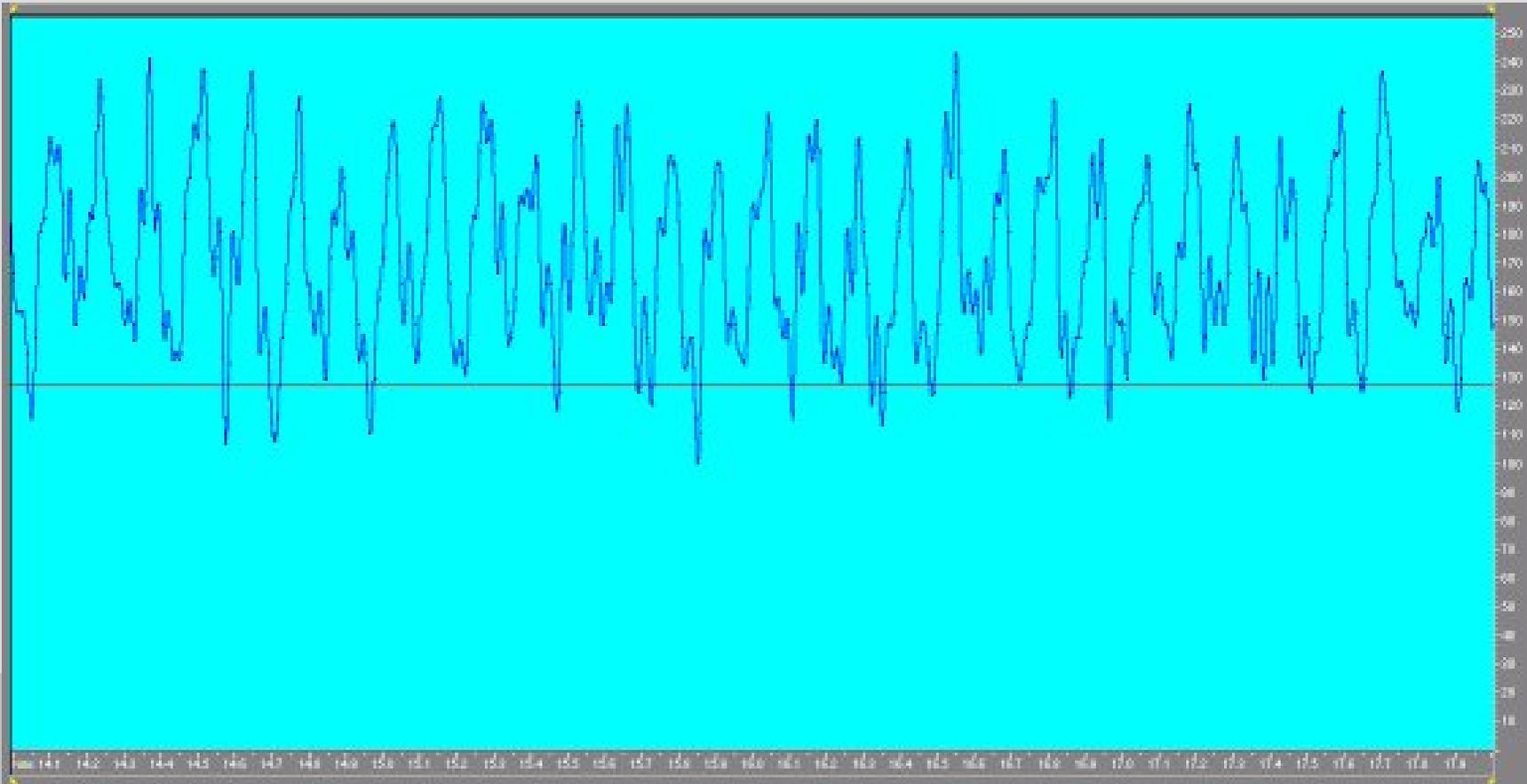
Data Matching

- Vertical profile data can easily be correlated to other time series / altitude data such as visibility (below), winds aloft, temperature etc



Species ID from Wing Beat

- As birds pass through a radar beam the amplitude of the signal varies with the wingbeat
- Wing beat frequency matches to size
- Pattern matches to types of target



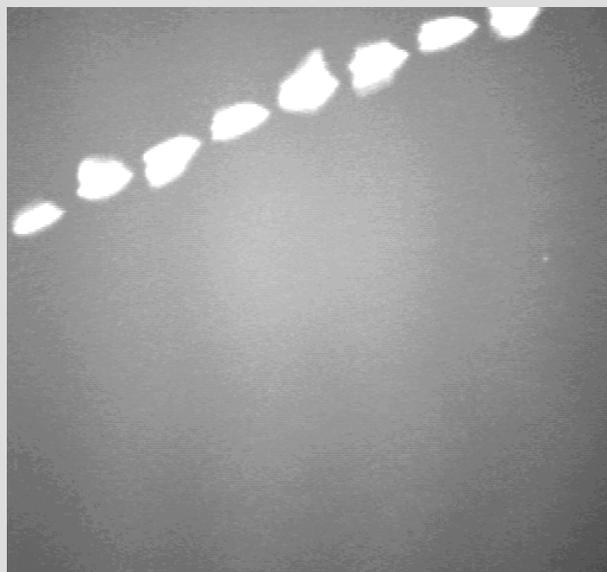
SCADA

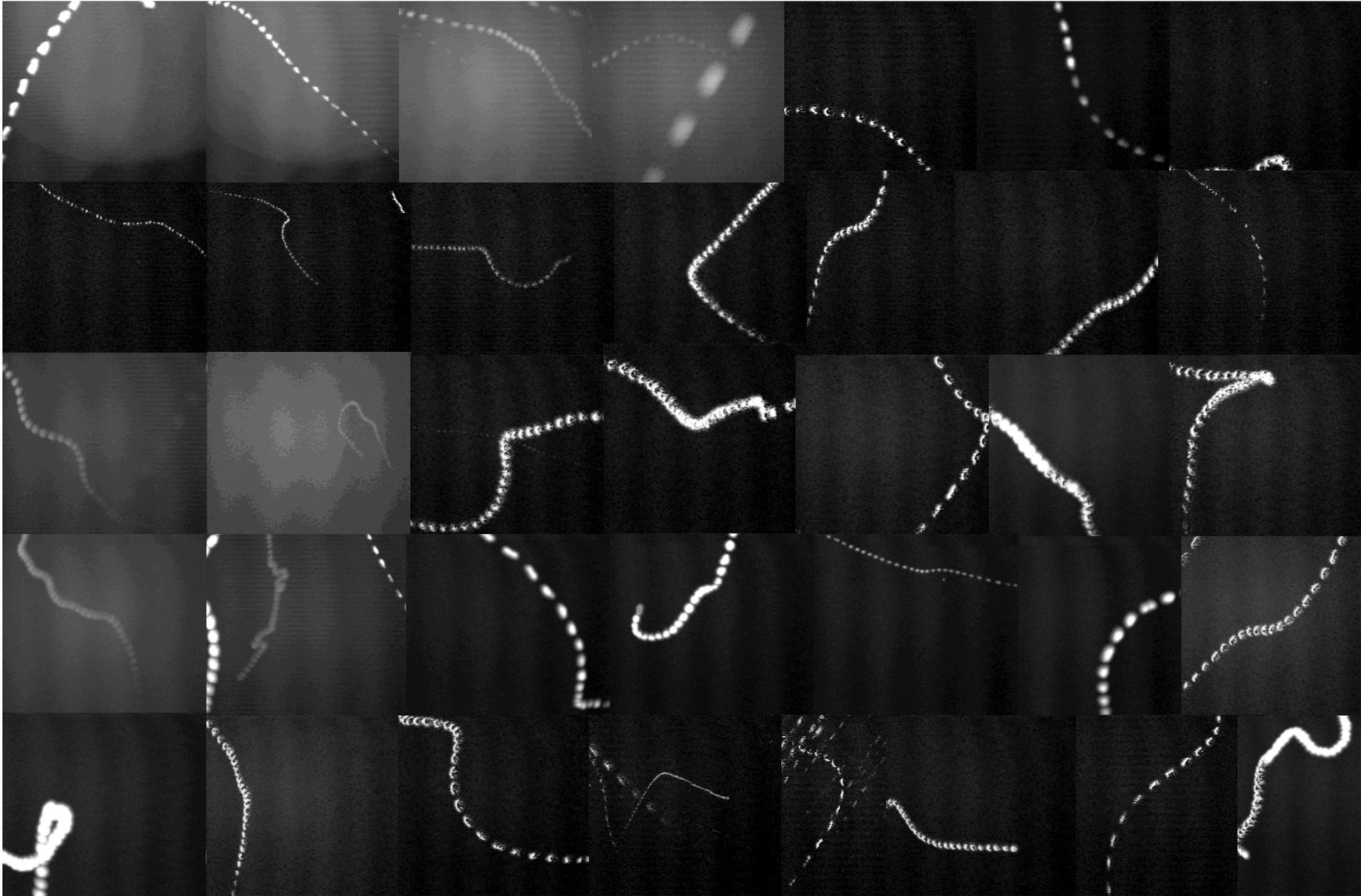
- Under development for deployment in 2008 is a SCADA system to automatically idle turbines if certain risk criteria are met
- System will be flexible to allow new rule sets to be introduced



Ground truth

- Low light Video/TI slaved to radar
- Typical time exposure bat tracks

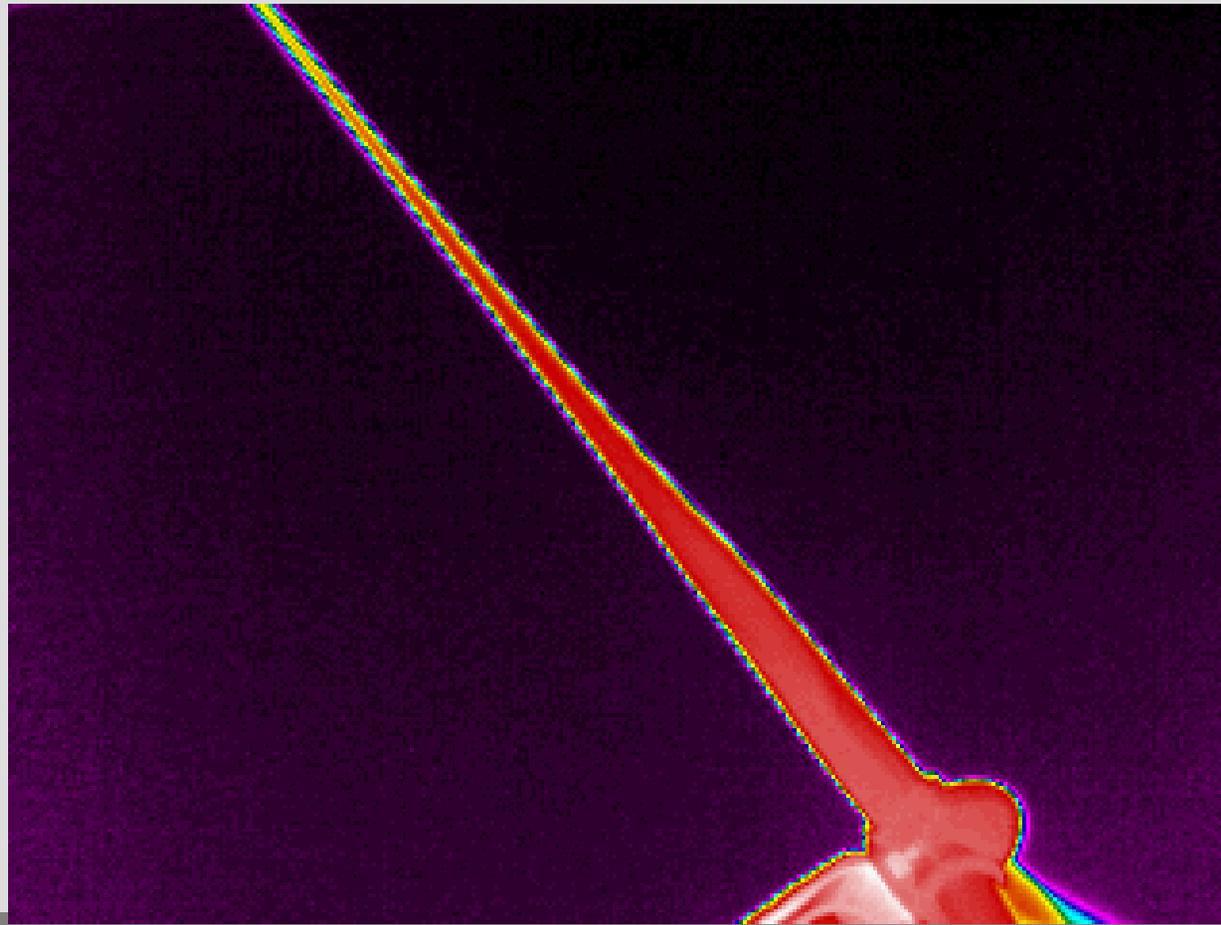




- How close does avoidance occur?

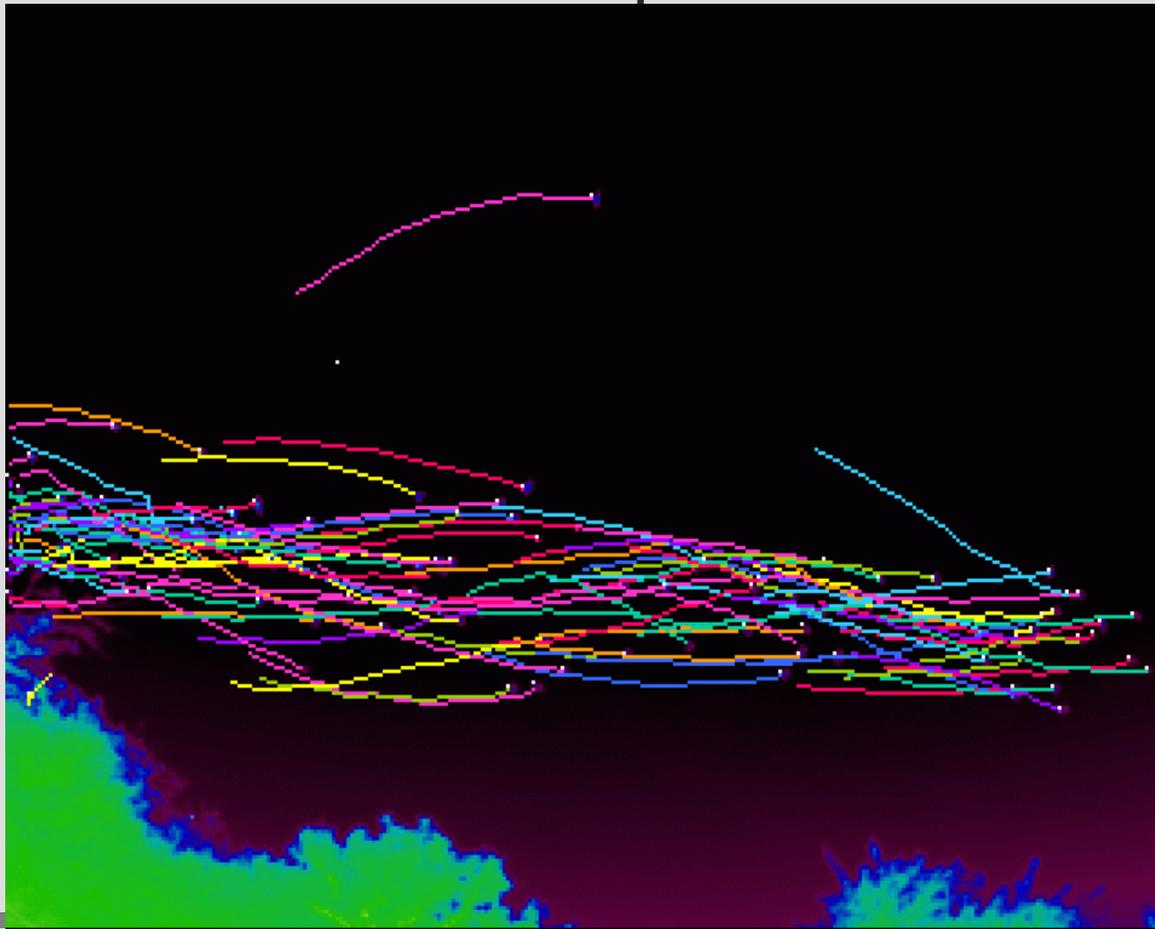


- To close?



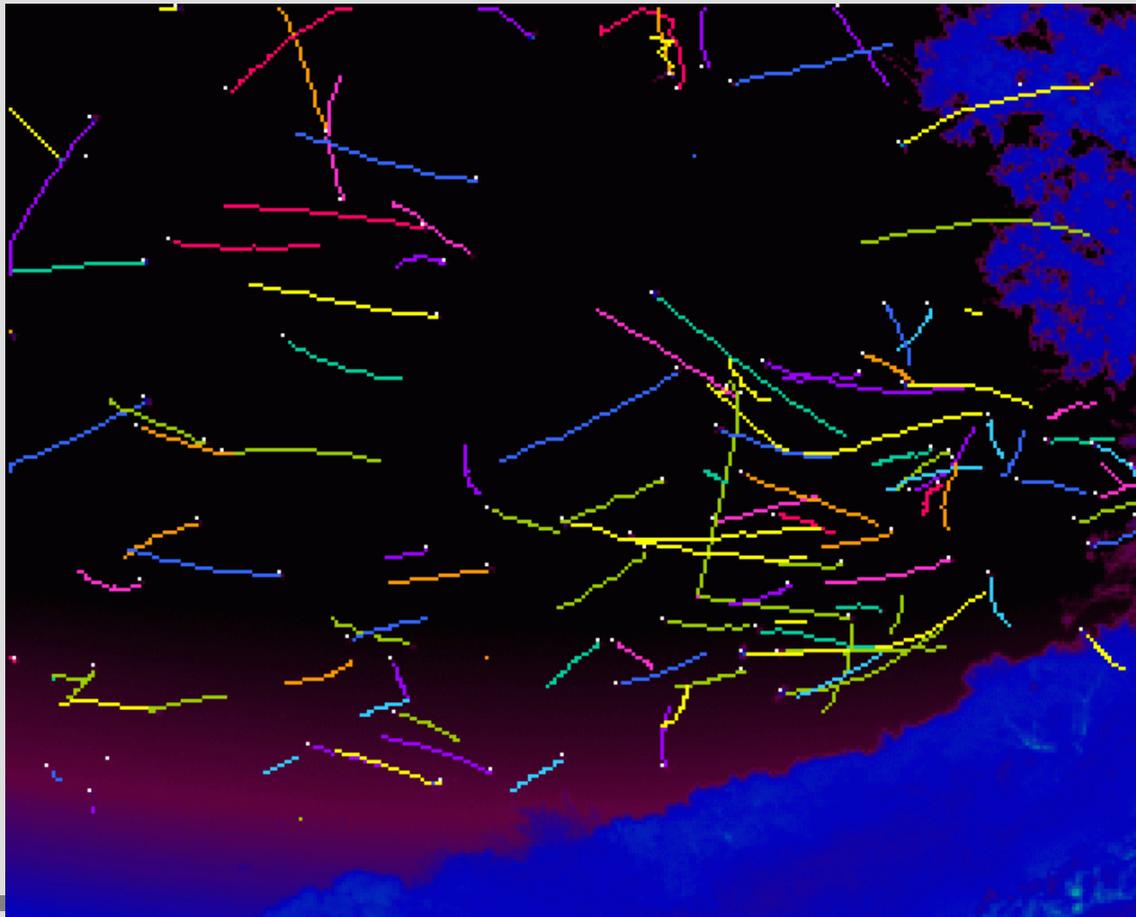
TI Tracking

- Free Tailed Bat Roost Departure



TI Tracking

- Foraging free tailed bats



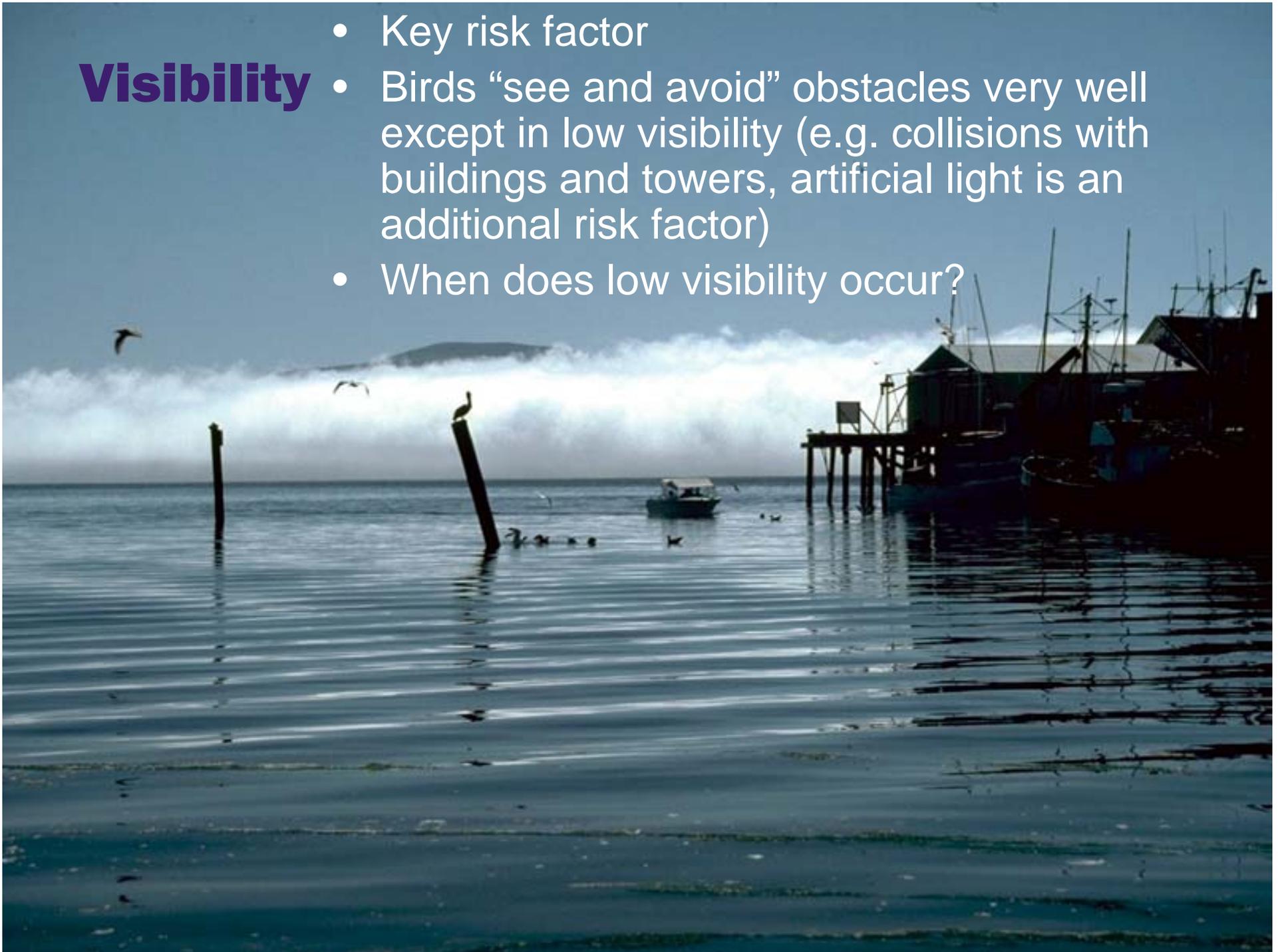
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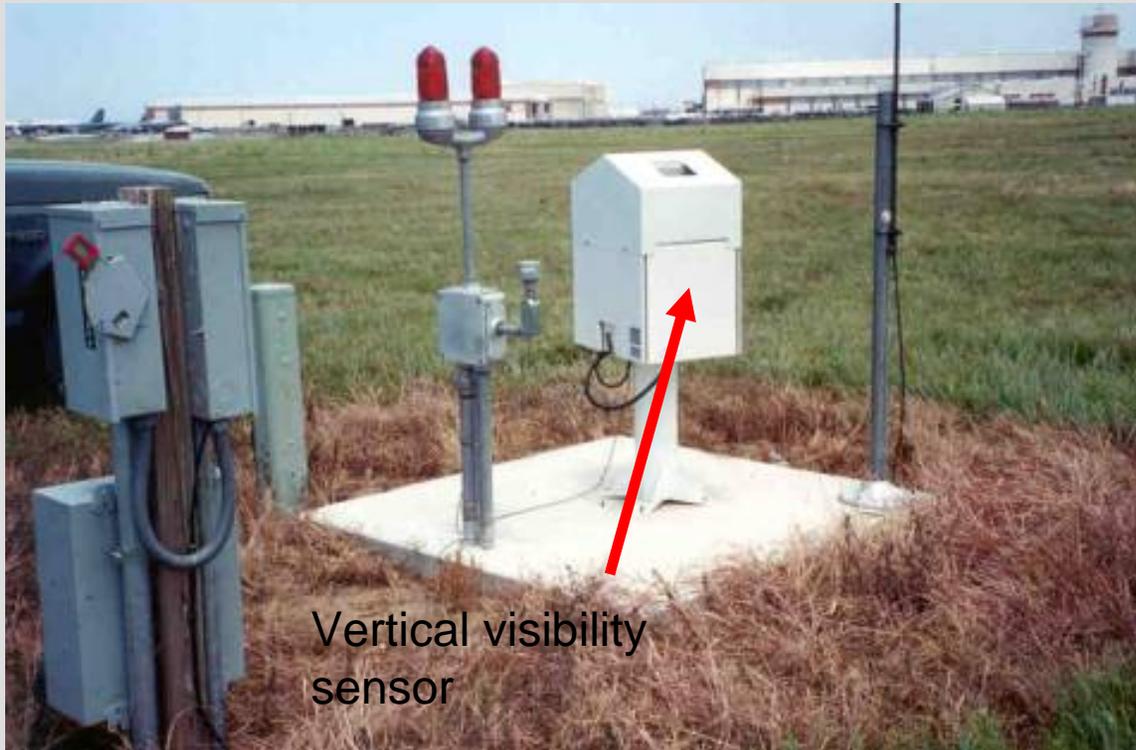
Visibility

- Key risk factor
- Birds “see and avoid” obstacles very well except in low visibility (e.g. collisions with buildings and towers, artificial light is an additional risk factor)
- When does low visibility occur?

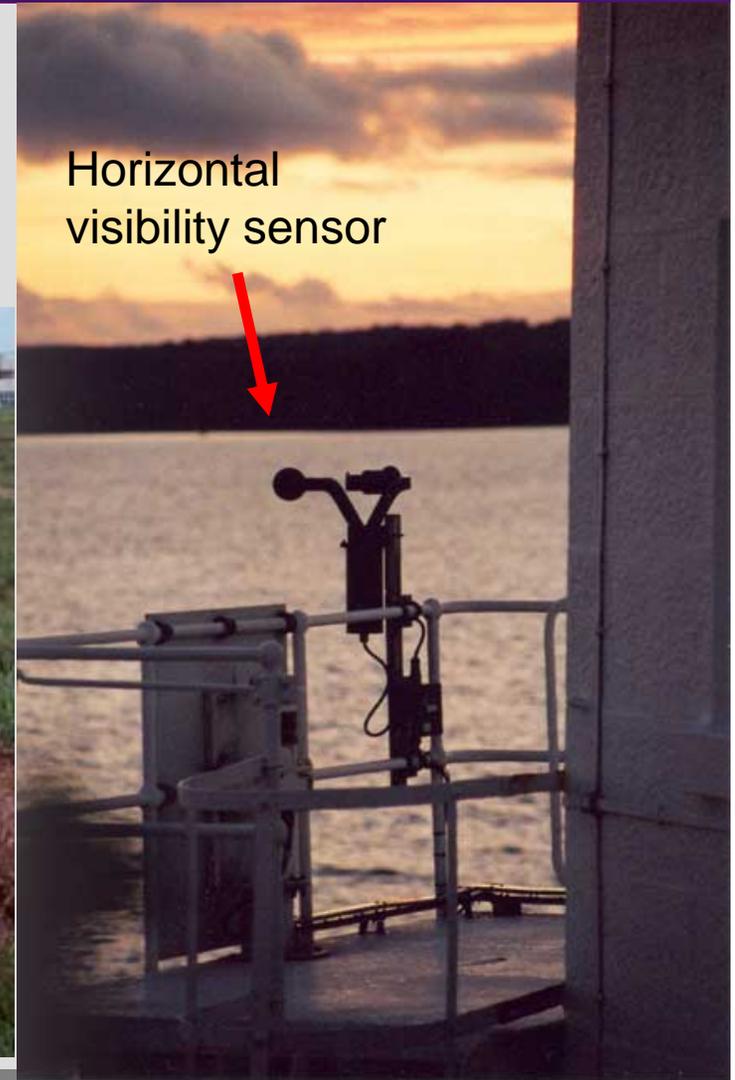


Sensors

- Visibility sensors are common place items in meteorology and can be added to “met towers” pre-construction
- Aid in finding high risk times



Vertical visibility sensor



Horizontal visibility sensor

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Post Construction Monitoring

- How do you detect mortality offshore?
- Difficult on shore
- Currents or scavenging will quickly remove carcasses
- Data vital to confirm preconstruction assessments and to refine mitigation techniques



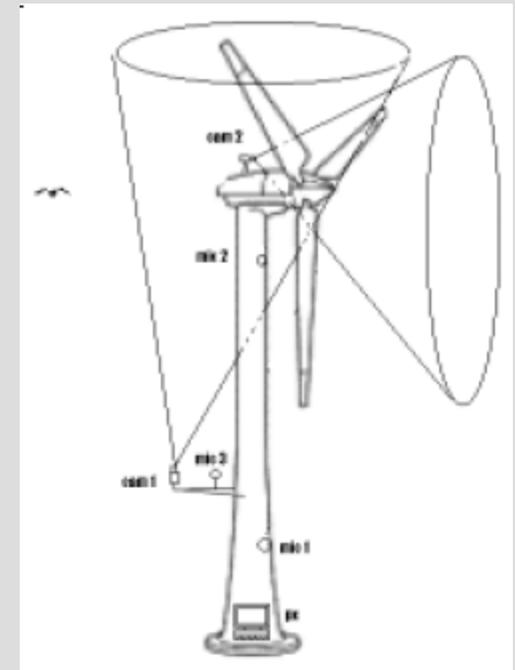
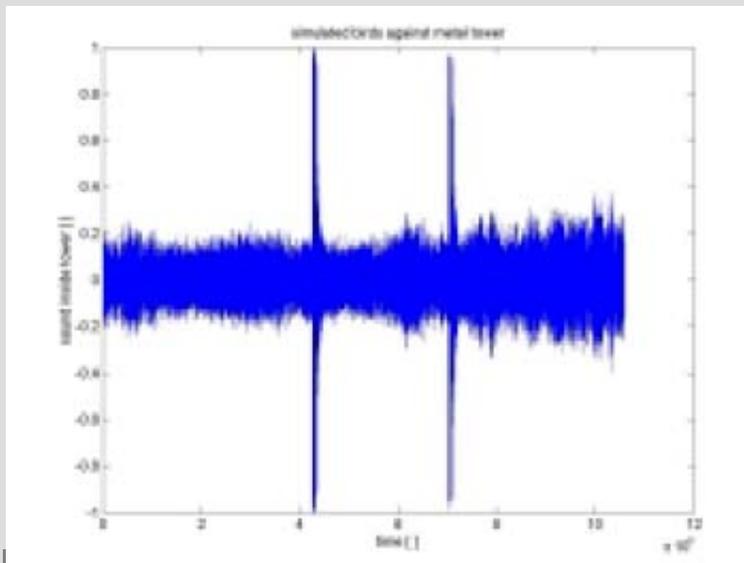
Impact monitoring

- Thermal Infrared sensors
- Danish “Thermal Animal Detection System” (TADS) is essentially a heat-activated infrared video camera that watches a wind turbine around the clock
- One kill detected not sure if it was a bird or bat



Impact Detection

- Dutch system “WT-Bird” video and acoustic impact monitoring
- Takes image when impact event detected
- Does not record close calls



Acoustic monitoring aloft

- Prof McCracken University of TN
- Monitored bats with bat detectors to 1200m with lifting kite, instruments placed at intervals on the lines
- Limitations, you must have wind
- Strengths, gets sensors to the height you need them
- Launch from boats
- Safety
- Wind noise issue solved



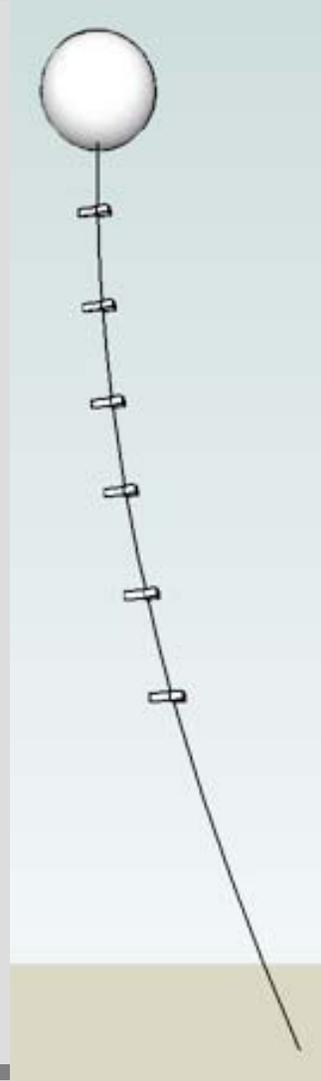
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Balloons for Monitoring aloft

- Weather balloons work in light winds when kites wont
- Limitations high winds
- Balloons are not very robust
- Next generation balloon with fabric outer skin is more robust but MUCH more expensive



Transponders

- Transponders and harmonic radars
- Range currently .5km, may get to 1.5km in the next 2-3 years due to the types of advances made with the vertical profiler radar
- Very lightweight
- Track known individuals
- No ground or sea clutter on the radar



Questions???

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