Monitoring and forecasting airborne animal migration by radar meteorologists – a new task?

A talk about birds and insects

Felix Liechti – Swiss Ornithological Institute

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1. Short background

2. Recent use of radar for monitoring

   - **Birds**

   - Insects

3. Outlook

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Millions of bats, billions of birds and an infinite number of arthropods use the airspace for moving between their preferred habitats on a local, continental and worldwide scale.

The biology of most migratory animals is poorly understood because we have not been able to monitor their movement around the planet

Biological targets were detected from the beginning of radar

Figure 23. Exterior View of Radio Set SCR-584.

Angel targets during the 2nd world war

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Radar angels the start of radar ornithology

Pioneers of radar ornithology in the **1950ies**:
E. Sutter (Switzerland), D. Lack, W. G. Harper, E. Houghton, E. Eastwood (Great Britain)

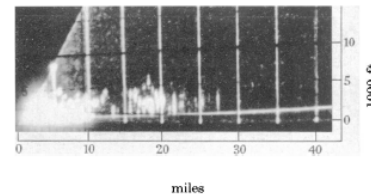Harper — Proc. Roy. Soc. B, volume 149, plate 16

FIGURE 5. The 10 cm range-height display on the occasion of figure 1, plate 15, 17.50 h G.M.T., 13 March 1957, 008°. The angels are spread in height up to 5000 ft., with one at 6000 ft. The intense echo on the baseline within the first 10 miles is from permanent echoes (see page 485).
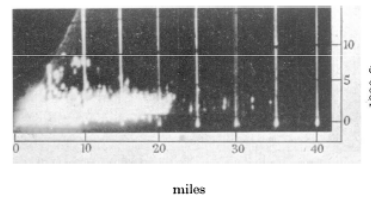
FIGURE 6. The heavy display on the occasion of figure 3, plate 15, 19.15 h G.M.T., 11 March 1957, 002°. Angels mainly concentrated at 2500 ft., but dense to 5000 ft., and scattered above this to 10000 ft. Permanent echoes again affect the first 10 miles on this bearing.
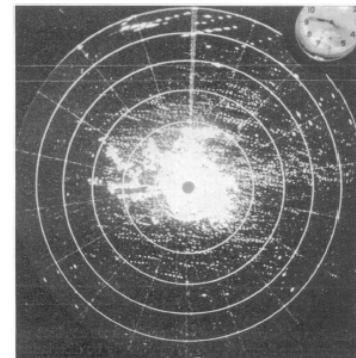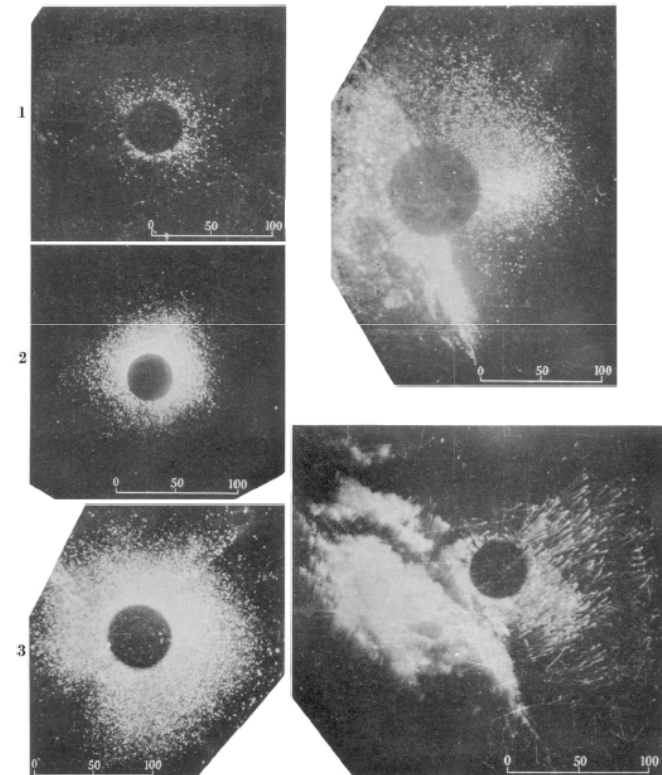
FIGURE 10. A time-lapse photograph of several sweeps of the plan-position display at roughly 1 min intervals. The angels are the weaker lines of dots scattered across the centre of the display, while the faster-moving echoes at the top of the photograph are aircraft (see page 491).

Tedd & Lack — Proc. Roy. Soc. B, volume 149, plate 17

Scales show nautical miles.

FIGURE 1. Light angels.
FIGURE 2. Medium angels.
FIGURE 3. Heavy angels.
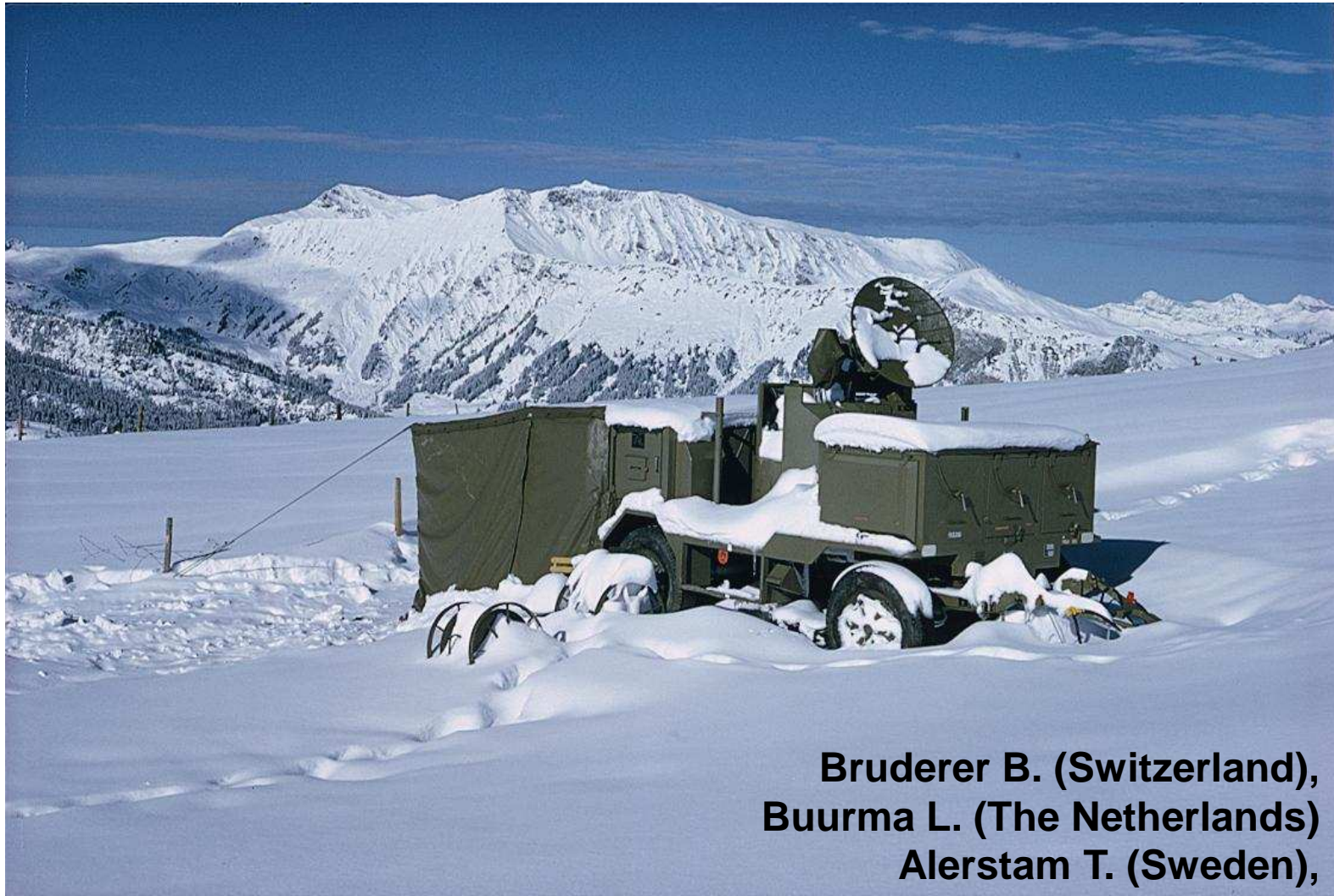FIGURE 4. Heavy angels to east, rain spreading from the west.
FIGURE 5. Time exposure for ½ h showing north-easterly track of angels. The belt of rain is travelling 10° east of north.

These photographs are 'Crown Copyright reserved, and are reproduced by permission of the Controller of Her Majesty's Stationery Office'.
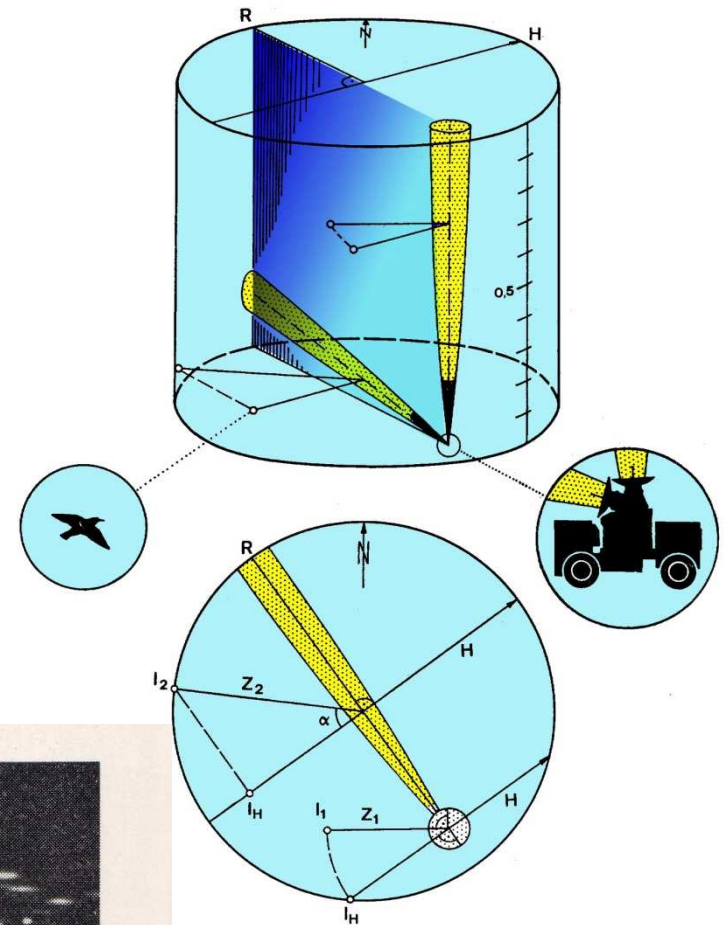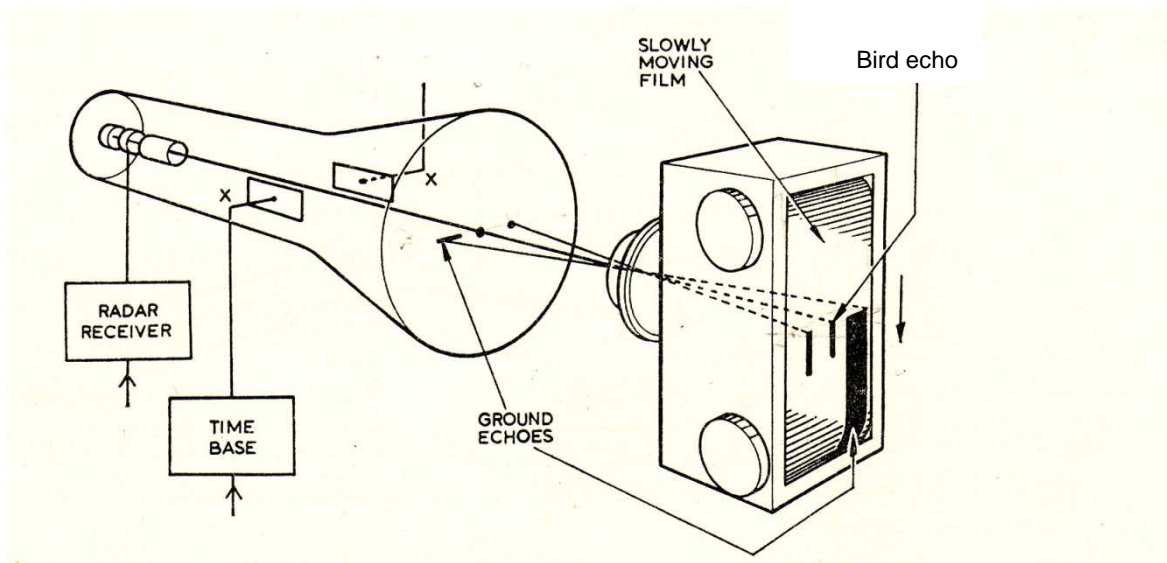
(Facing p. 504)

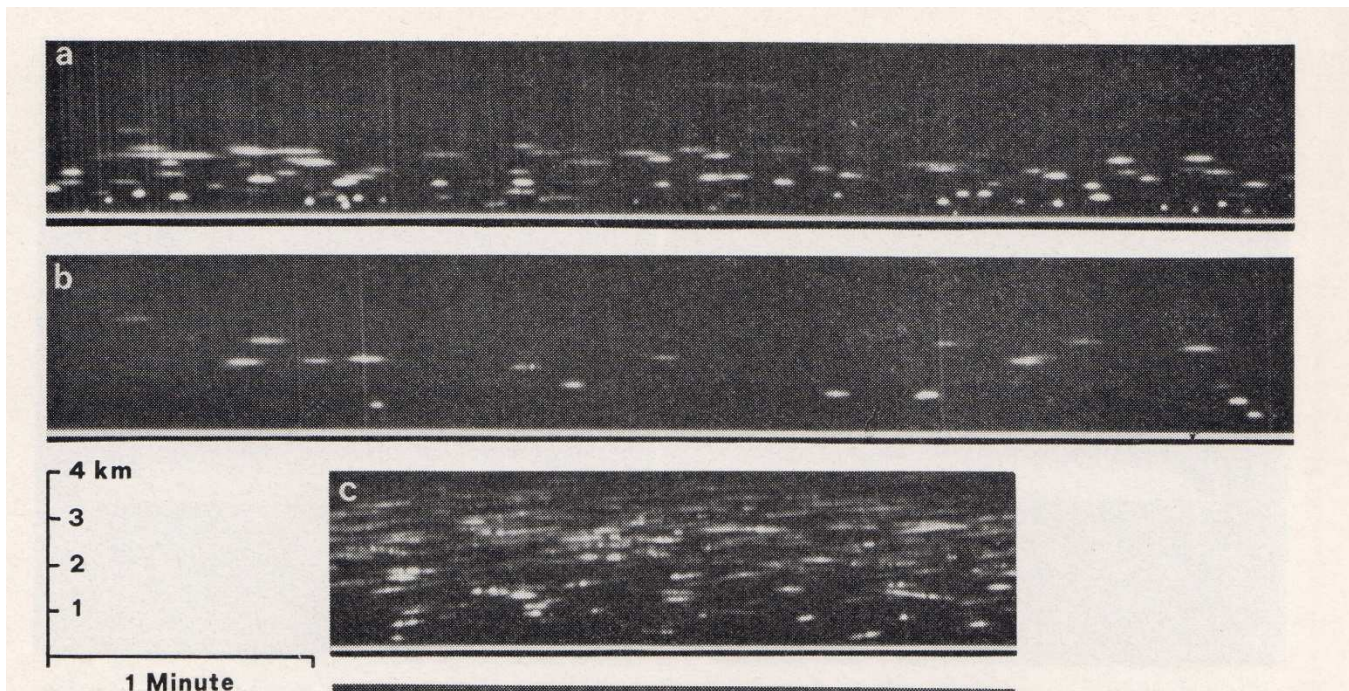vogelwarte.ch

From surveillance radar to tracking radar

Bruderer B. (Switzerland),
Buurma L. (The Netherlands)
Alerstam T. (Sweden),

SLOWLY
MOVING
FILM

Bird echo

RADAR
RECEIVER

TIME
BASE

X

GROUND
ECHOES

Echo identification?

R   N   H

0,5

R   N

I_2 Z_2 H

α

I_H I_1 Z_1 H
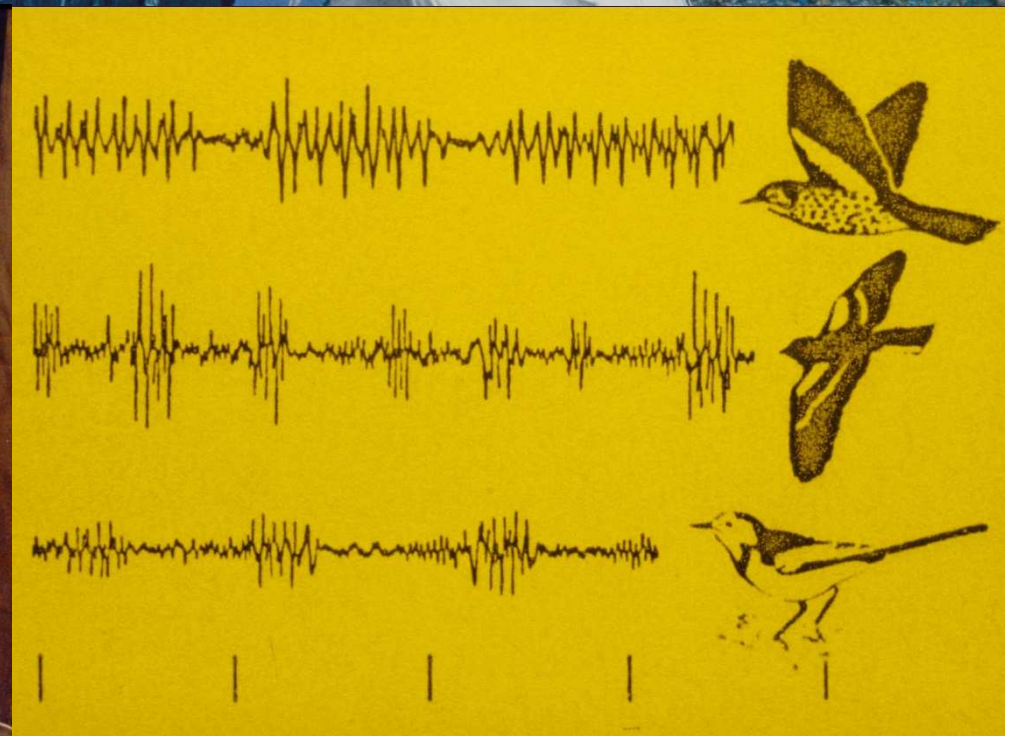
I_H

a

b

- 4 km
- 3
- 2
- 1

c

1 Minute

1968

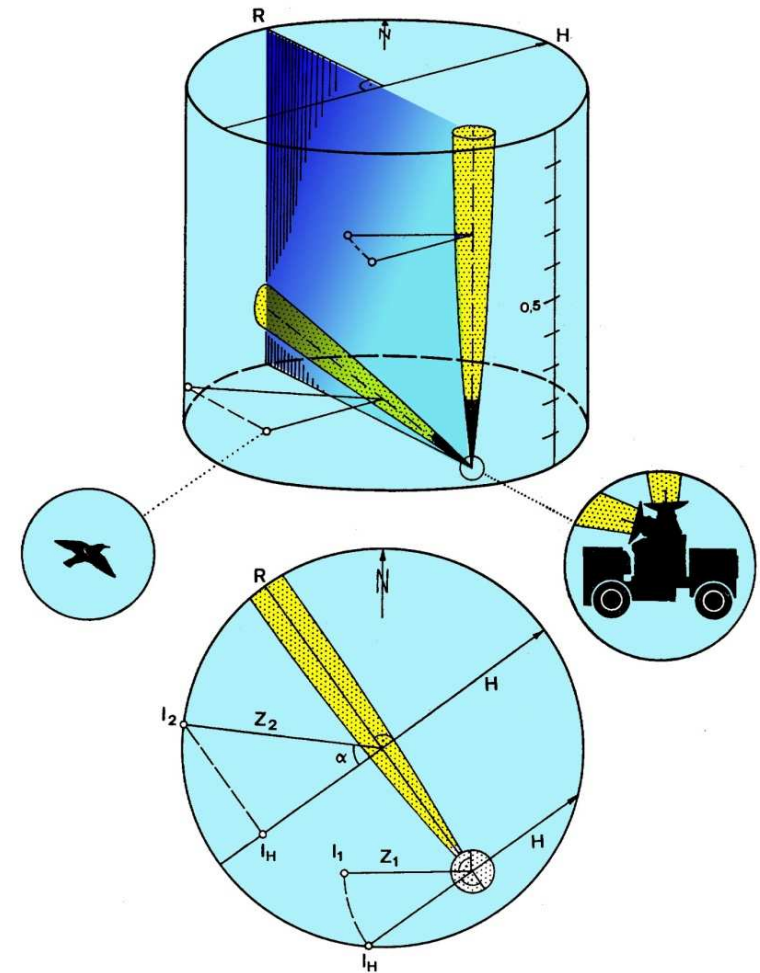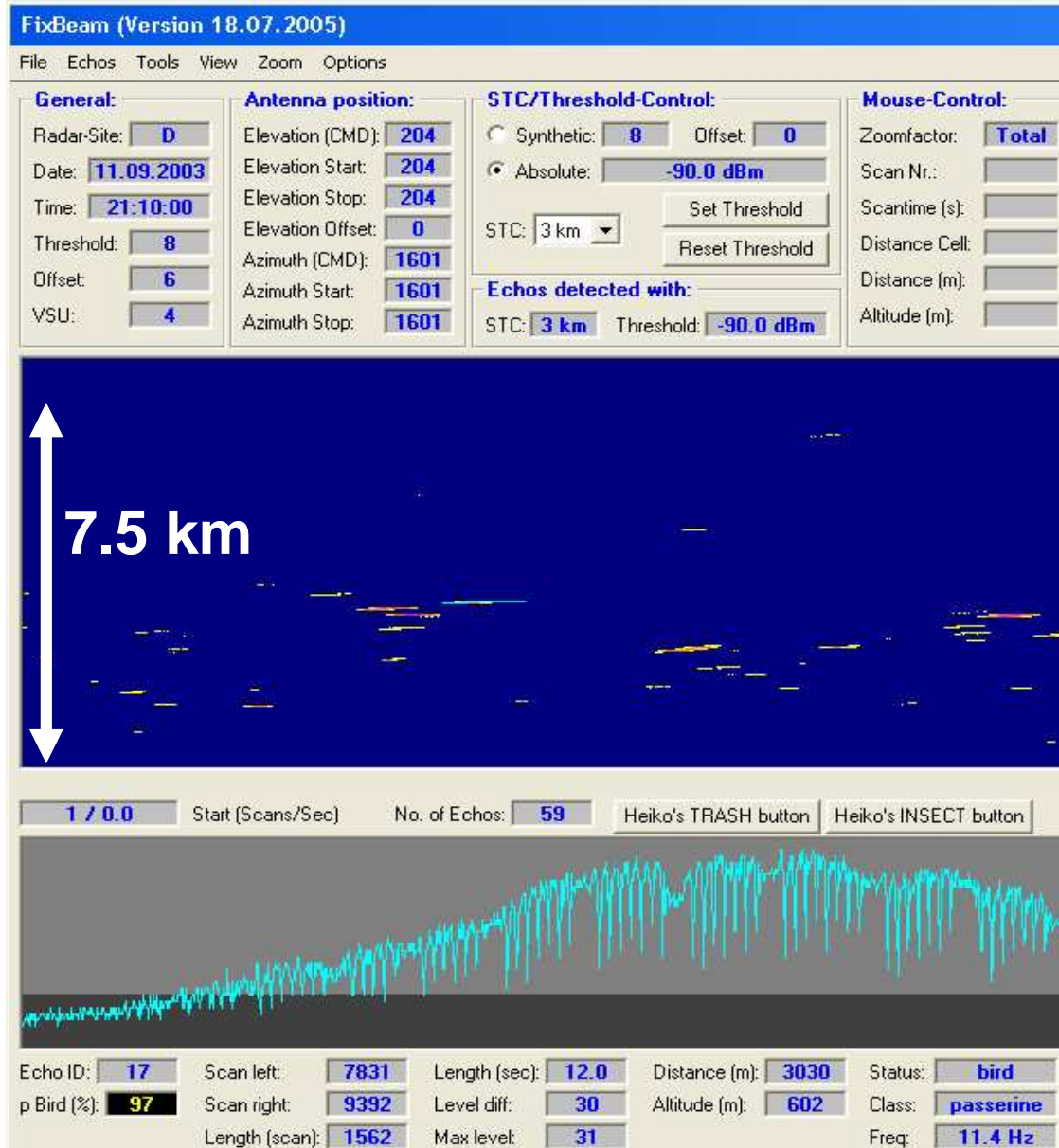Ornithologist

Meteorologist

Bruderer & Joss 1969

1969
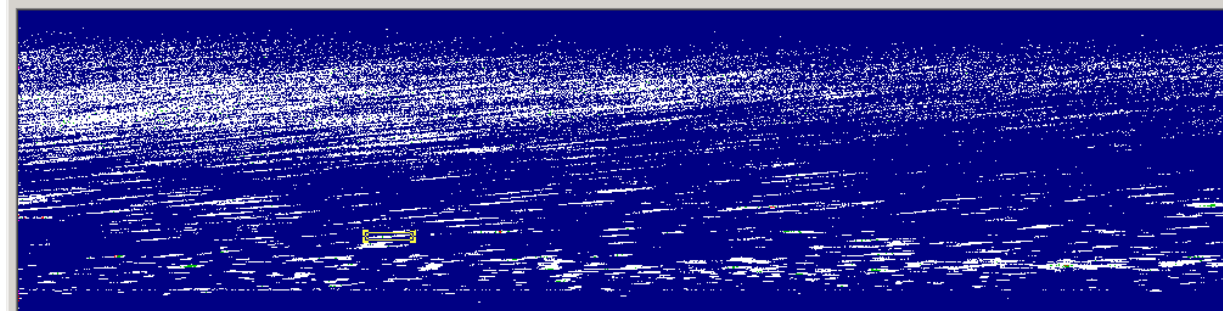
Echo signature provides wing beat pattern!
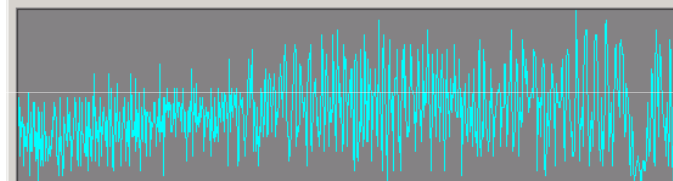
Recent use of radar for monitoring birds

7.5 km

FixBeam (Version 24.07.2003)

File View Options

General:
Radar-Site: M
Date: 14.09.2003
Time: 20:40:00
Threshold: 18
Offset: 3
VSU: 1

Antenna position:
Elevation (CMD): 150
Elevation Start: 146
Elevation Stop: 146
Elevation Offset: -5
Azimuth (CMD): 2009
Azimuth Start: 2009
Azimuth Stop: 2009

Threshold-Control:
Synthetic 18
Absolute (dBm) -90.0
Set Threshold
Reset Threshold
Meat in the air

STC:
2 km
3 km
4 km

Mouse-Control:
Scan Nr.:
Scantime (s):
Distance Cell:
Distance (m):
Height (m):

Level-Control:

Data files:
M-030914-2000.FF1
M-030914-2005.FF1
M-030914-2010.FF1
M-030914-2020.FF1
M-030914-2025.FF1
M-030914-2030.FF1
M-030914-2040.FF1
M-030914-2045.FF1
M-030914-2050.FF1
M-030914-2100.FF1

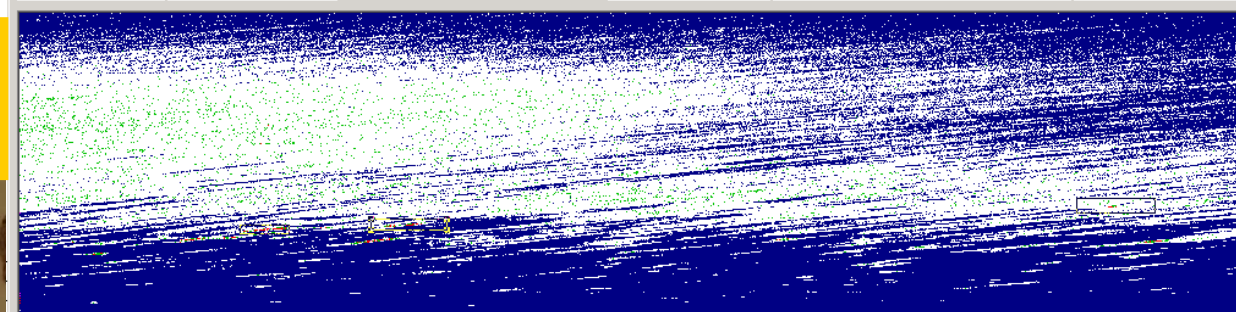0.0 Total 1:1 1:2 1:4 1:8 1:16 No. of echos
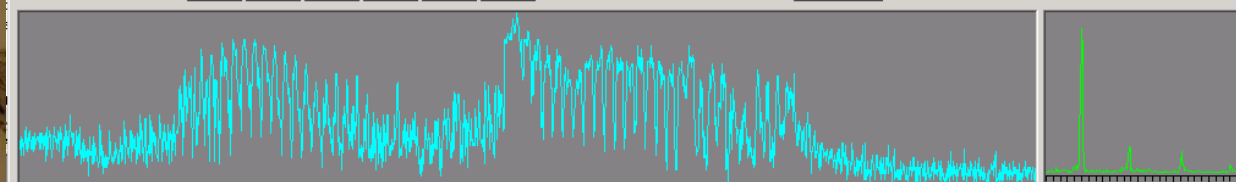
0 Define wingbeat pattern

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M-030914-2020.FF1
M-030914-2030.FF1
M-030914-2040.FF1
M-030914-2045.FF1
M-030914-2050.FF1
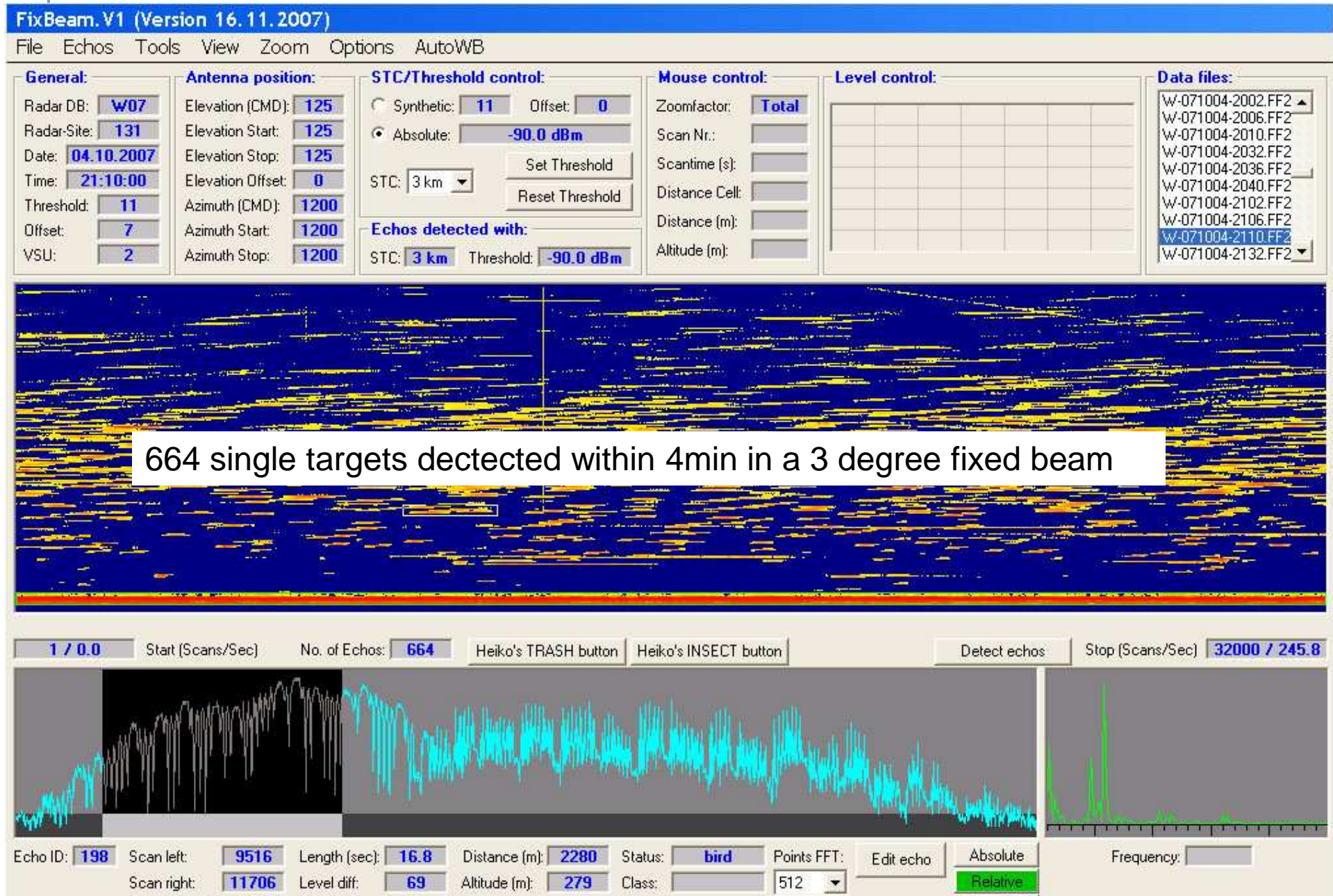M-030914-2100.FF1

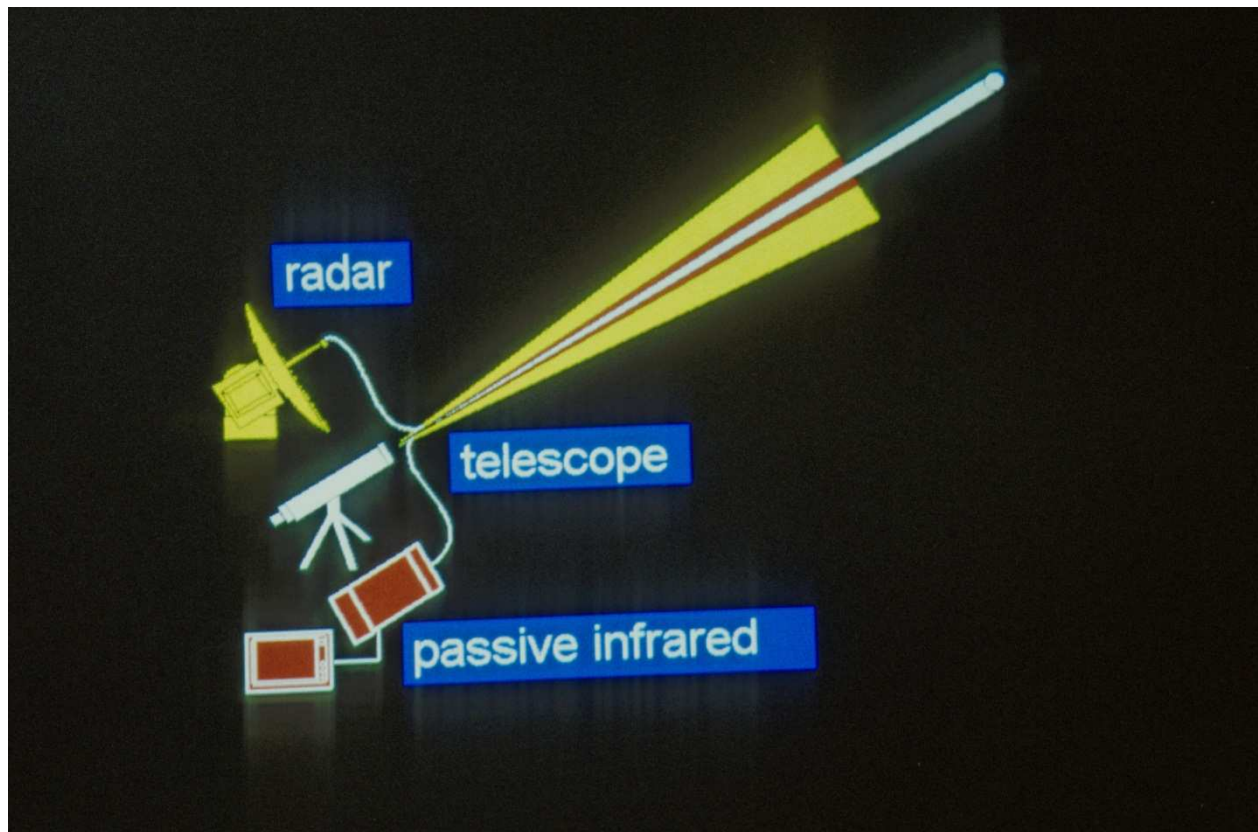0.0 Total 1:1 1:2 1:4 1:8 1:16 No. of echos detected: 3 Reset Echos 245.8

0 Define wingbeat pattern Wingbeat freq.: 14.2 1024 0.13 Hz
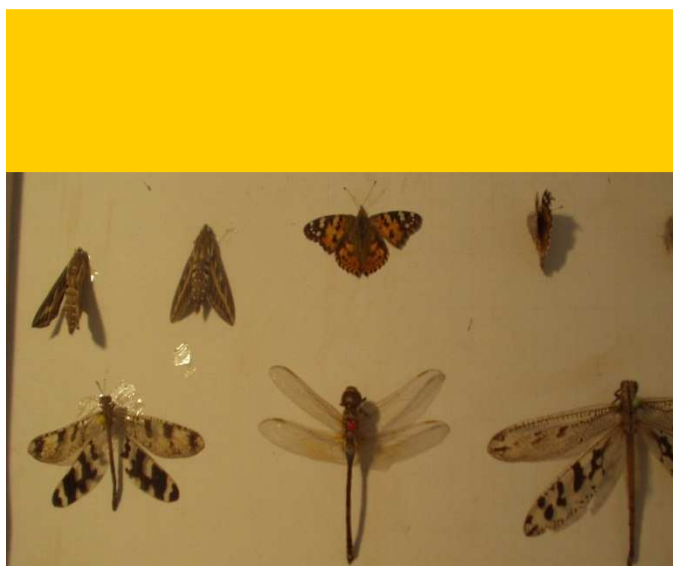
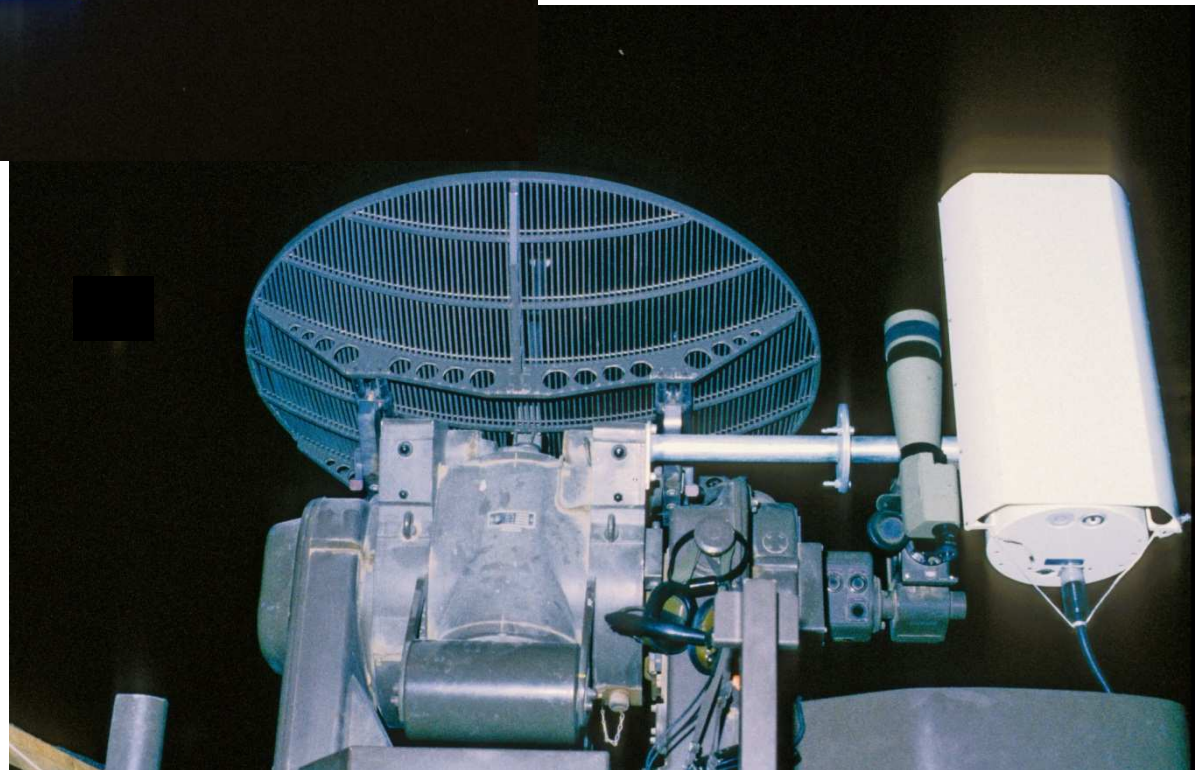# Example of intensive nocturnal bird migration (Belguim 2007)

664 single targets dectected within 4min in a 3 degree fixed beam

Cross-calibration:
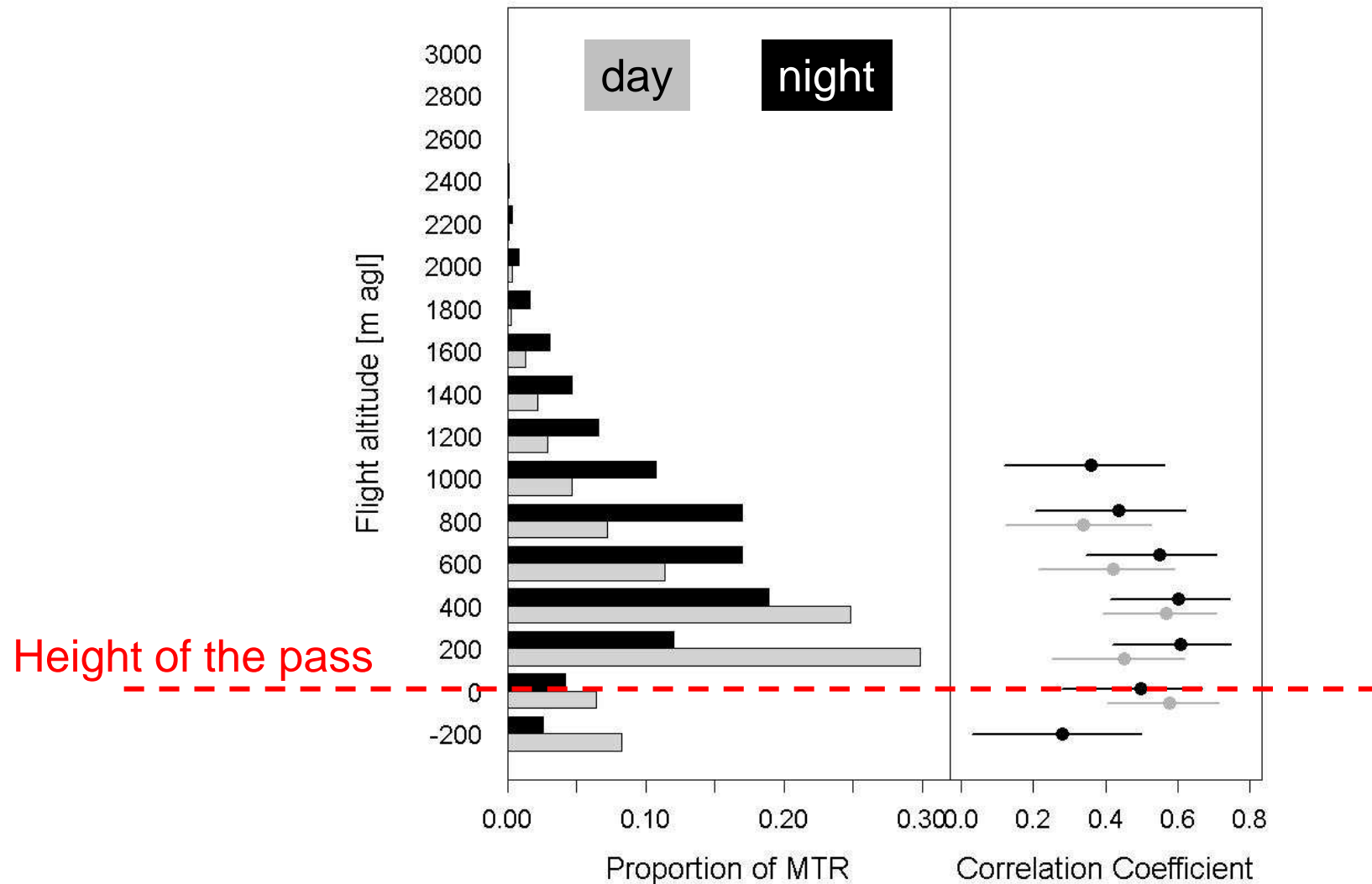
Radar
/ IR
/ Moon

Validation

Example: Height distribution and correlation with ground truthing
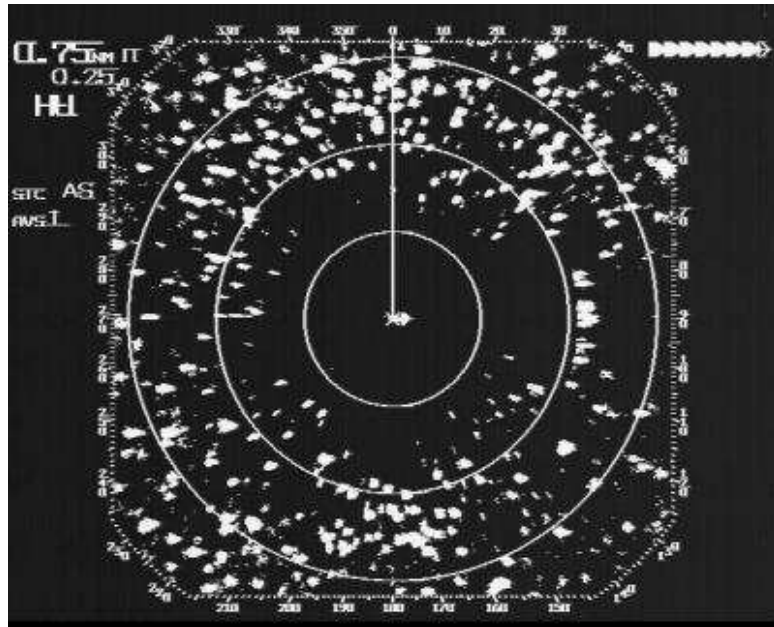
Val d'Illier – Col de Bretolet

Height of the pass

Radar entomology implemented already in 1949

Harmonic radar for tracking single bumble bees

Image provided by Don Reynolds

Locust movements
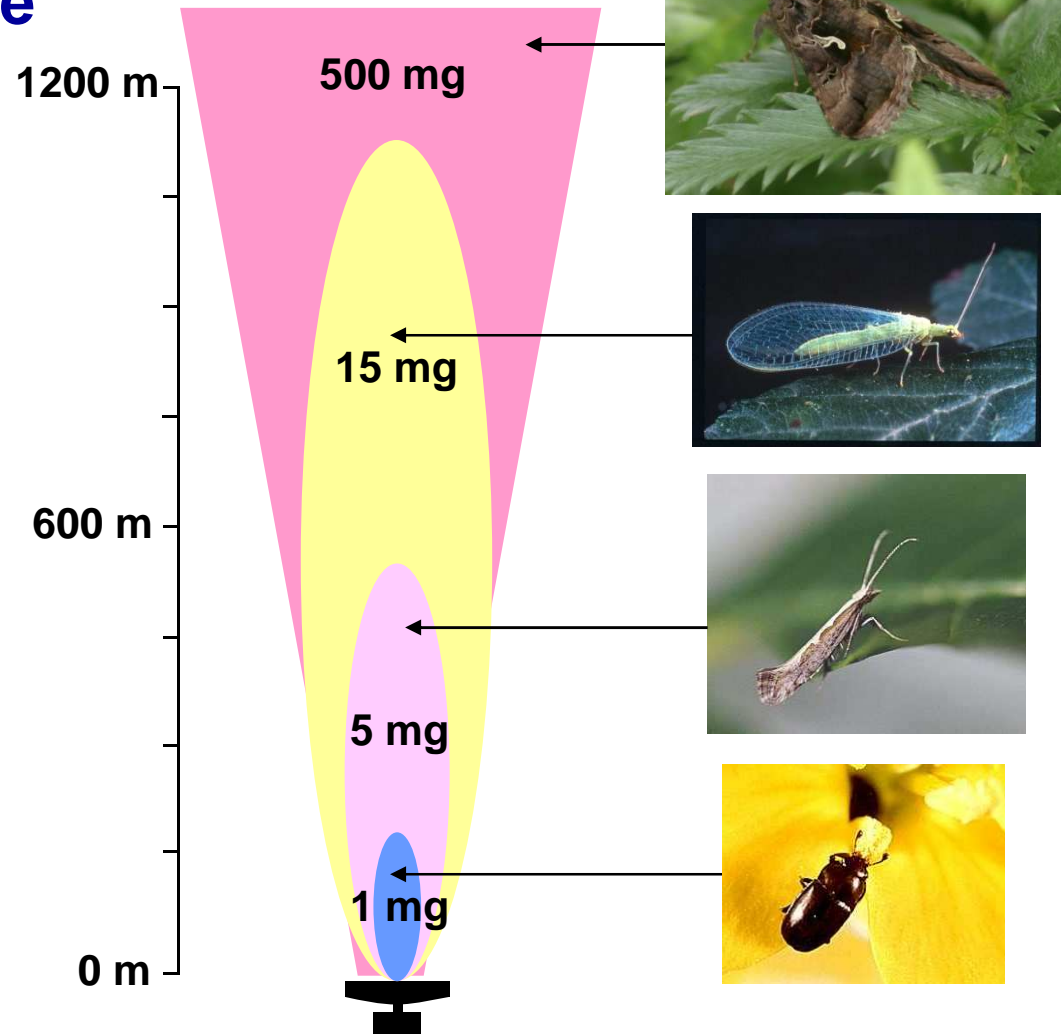

Image provided by Dr Kongming Wu.

Radar measurements of insect movements

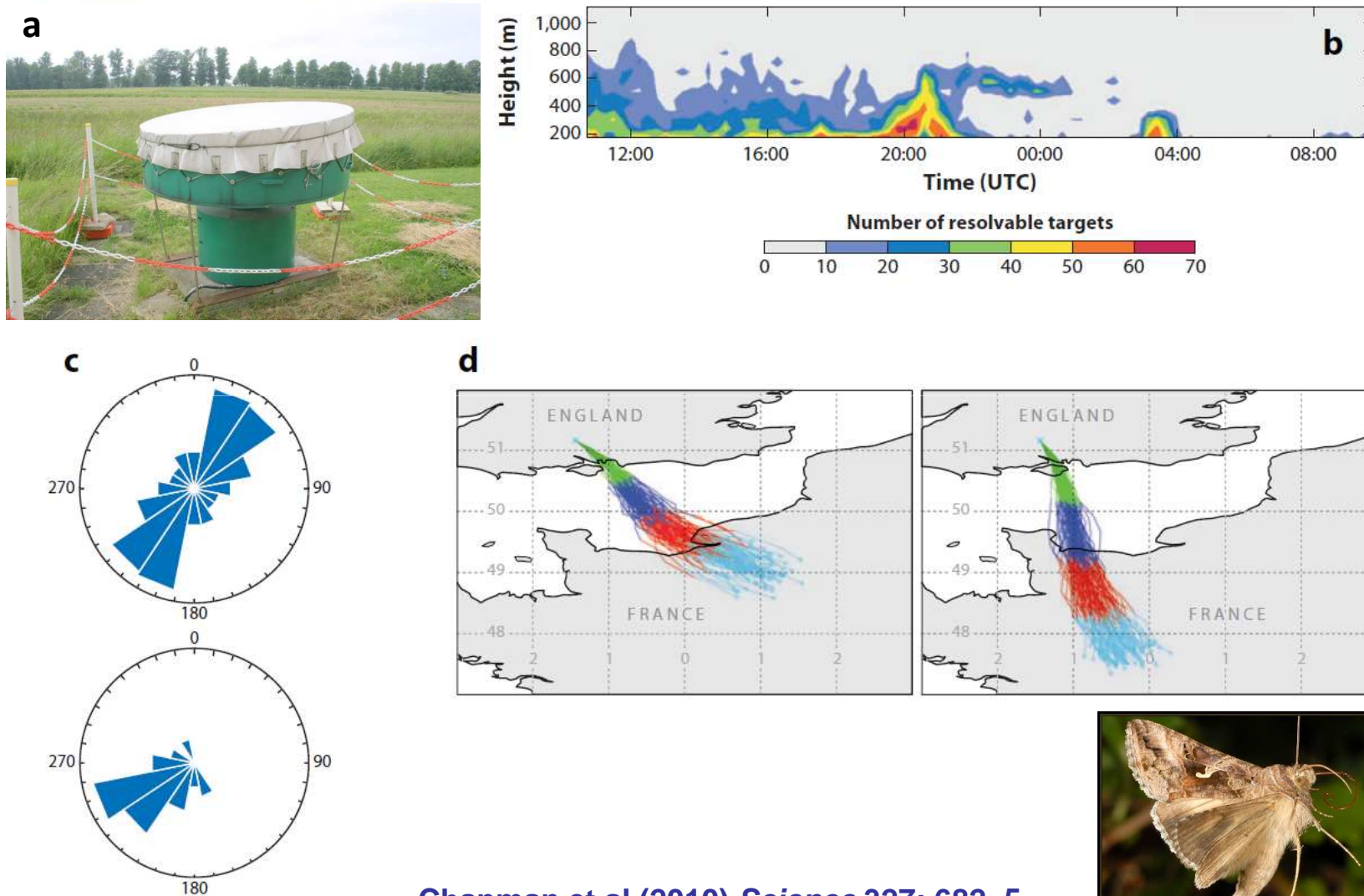## VLR Sampling Regime

Continuous coverage:
150 – 1200 m

Individual insects:
15 height bands

Parameters:
Speed & direction
Body Alignment
Mass
Shape

500 mg

1200 m

15 mg

600 m

5 mg

1 mg

0 m

Chapman, Drake & Reynolds (2011) *Annual Review of Entomology* 56: 337–356
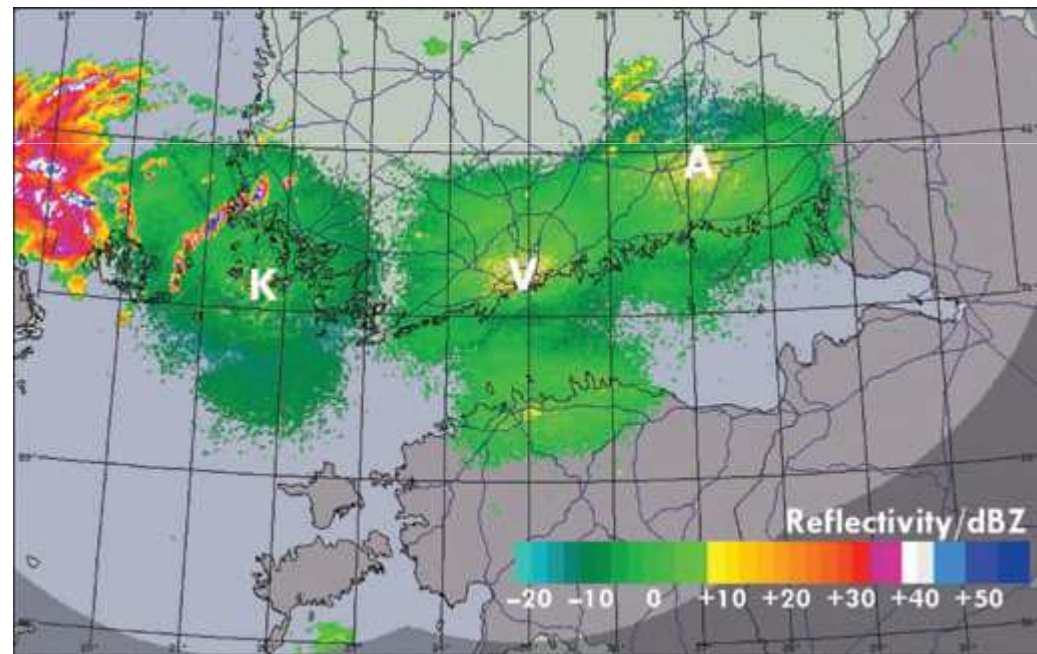
Radar measurements of insect movements

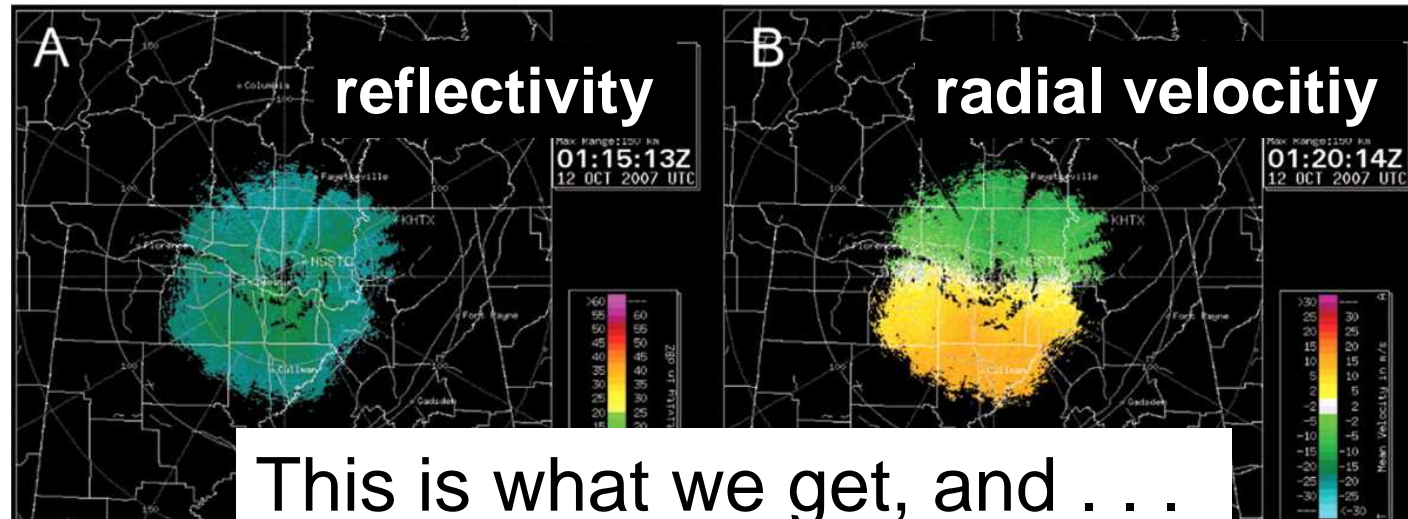Chapman et al (2010) *Science* 327: 682–5

Insect and bird movements studied with weather radar

Example: Pest insect immigration warning by an atmospheric dispersion model, weather radars and traps
M. Leskinen et al., J appl Entomology

Radar products used for detection and discrimination of fauna in weather radar

reflectivity — radial velocitiy

This is what we get, and . . .

Gauthreaux S A et al. Integr. Comp. Biol. 2008;48:12-23

. . . this is were it comes from!

Birds

precipitation

Clutter

Air turbulences

It's just a little air pocket, dear!

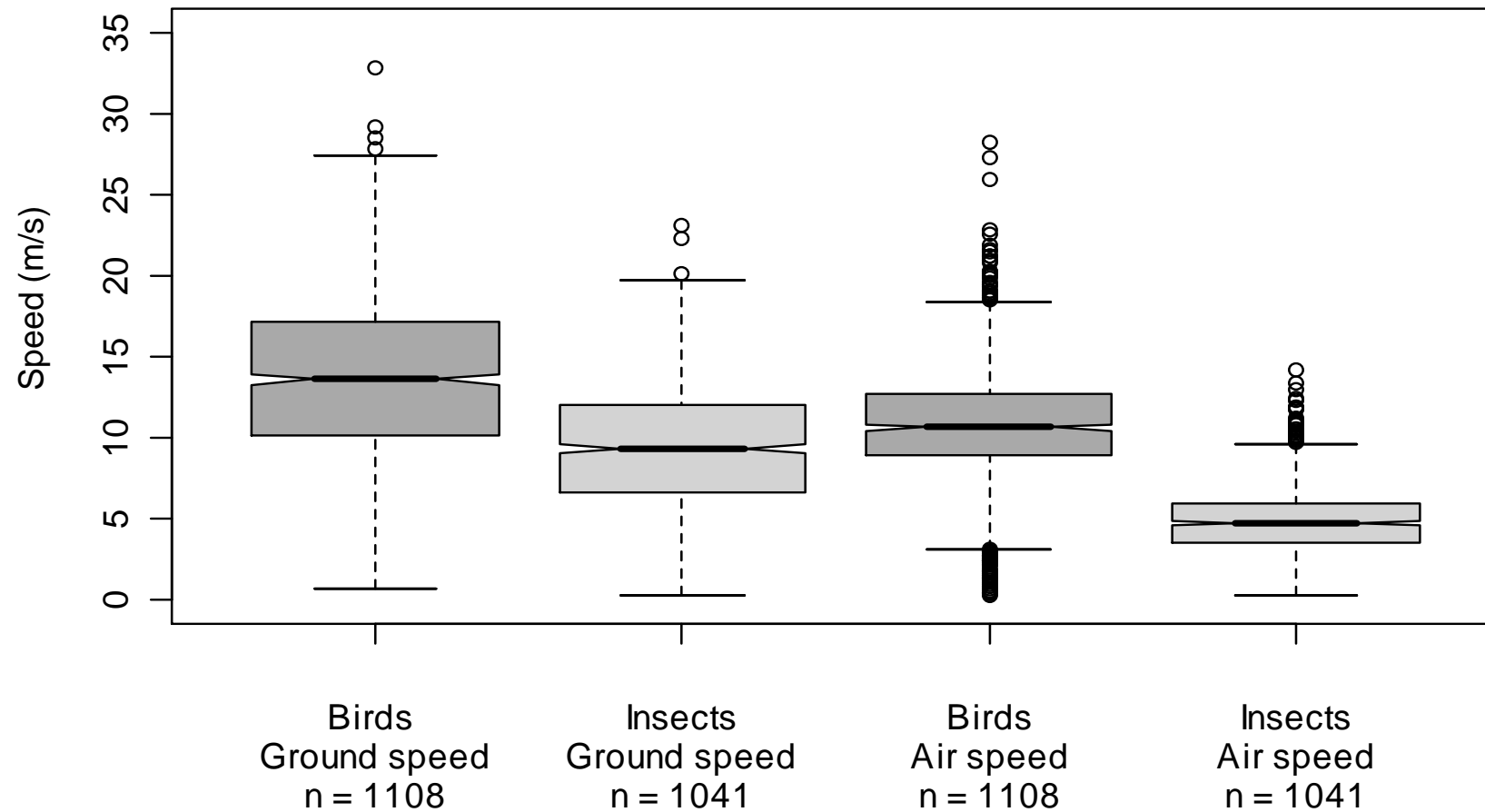**Bats**

Insects

UFOs

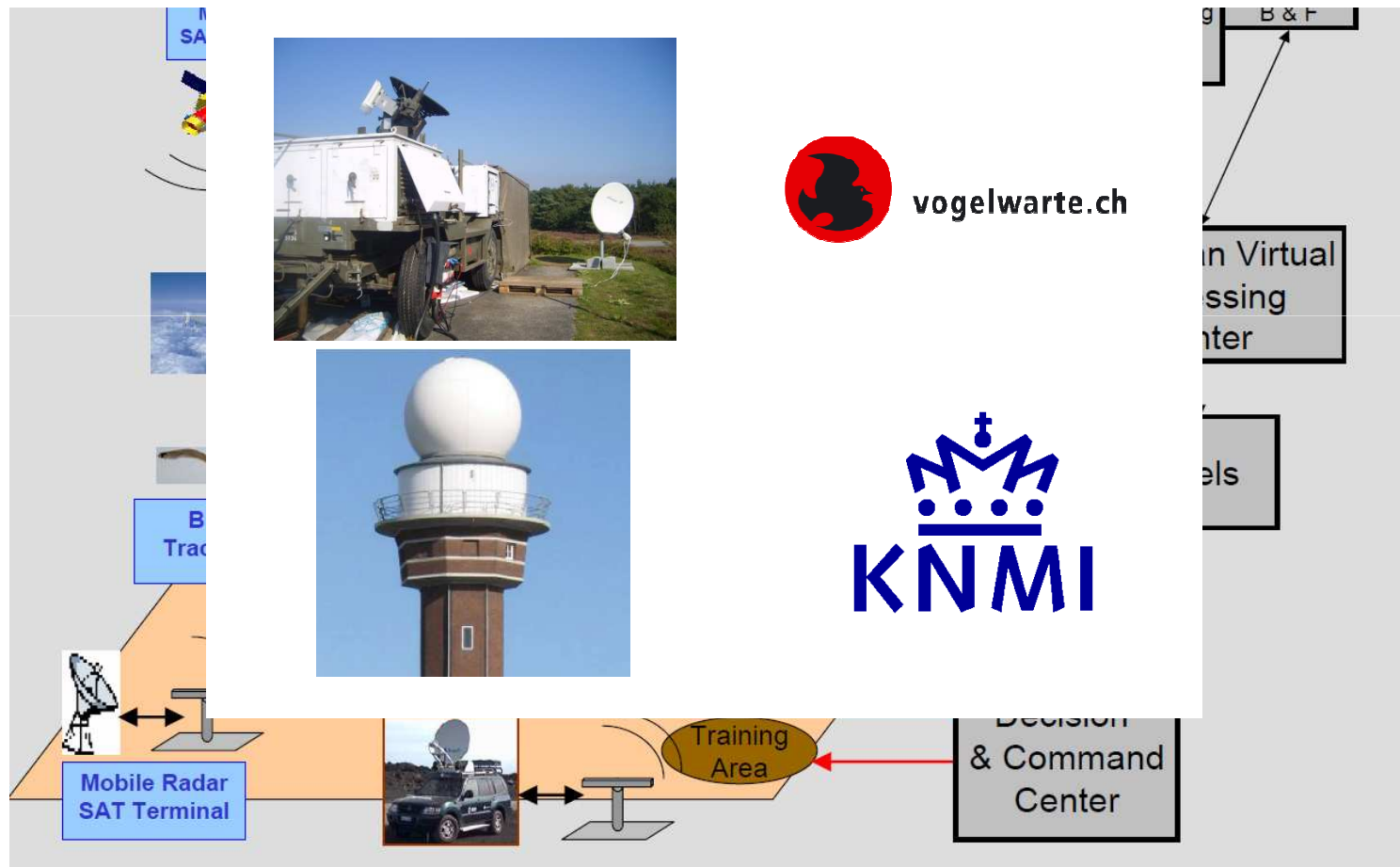➔ To differentiate between echoes is essential for all of us!

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Velocity?

Ground and air speeds of tracked birds (dark grey) and insects (light grey):

vogelwarte.ch
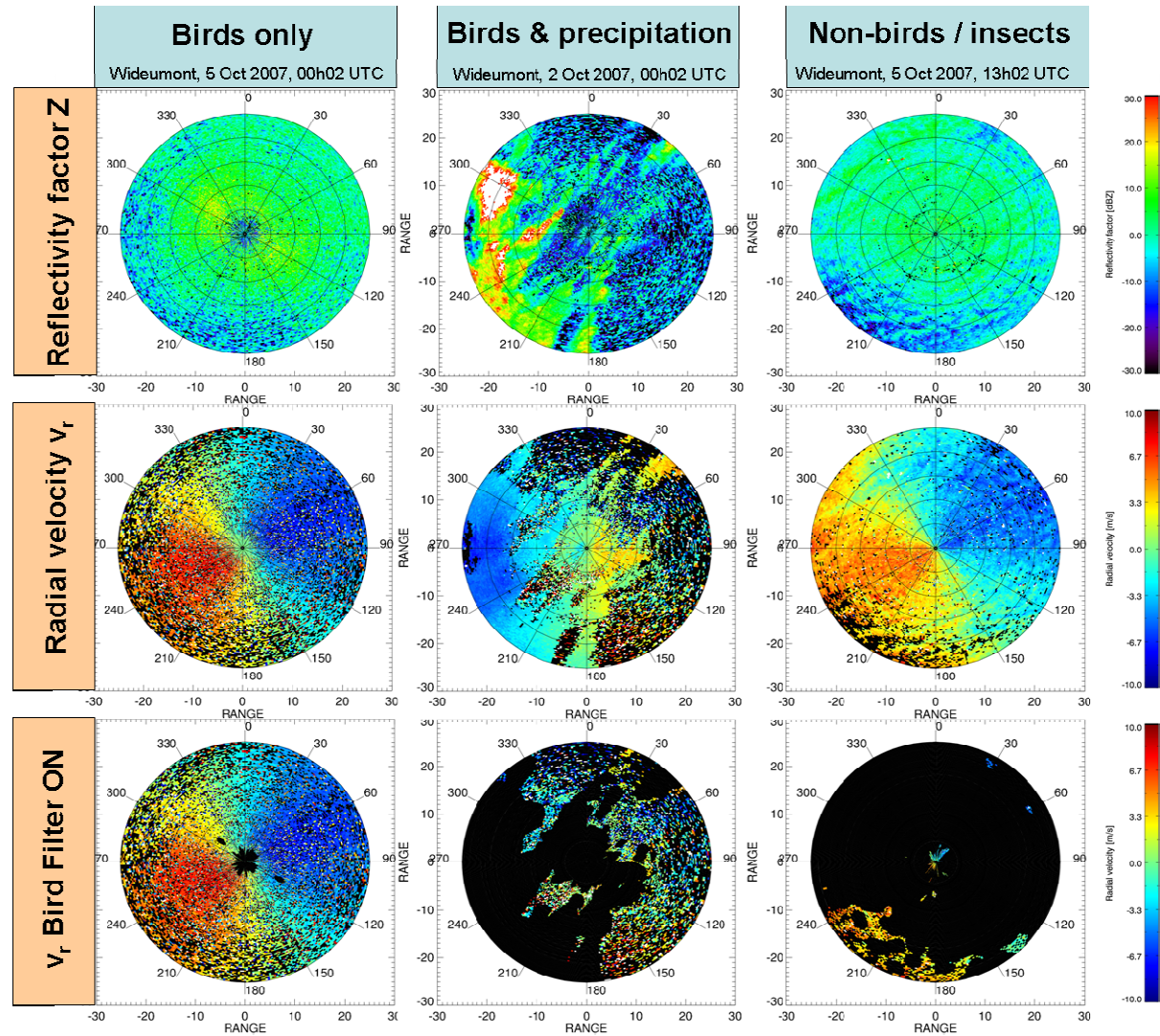
Validation of weather radars for automatic bird detections by a high precision Bird radar

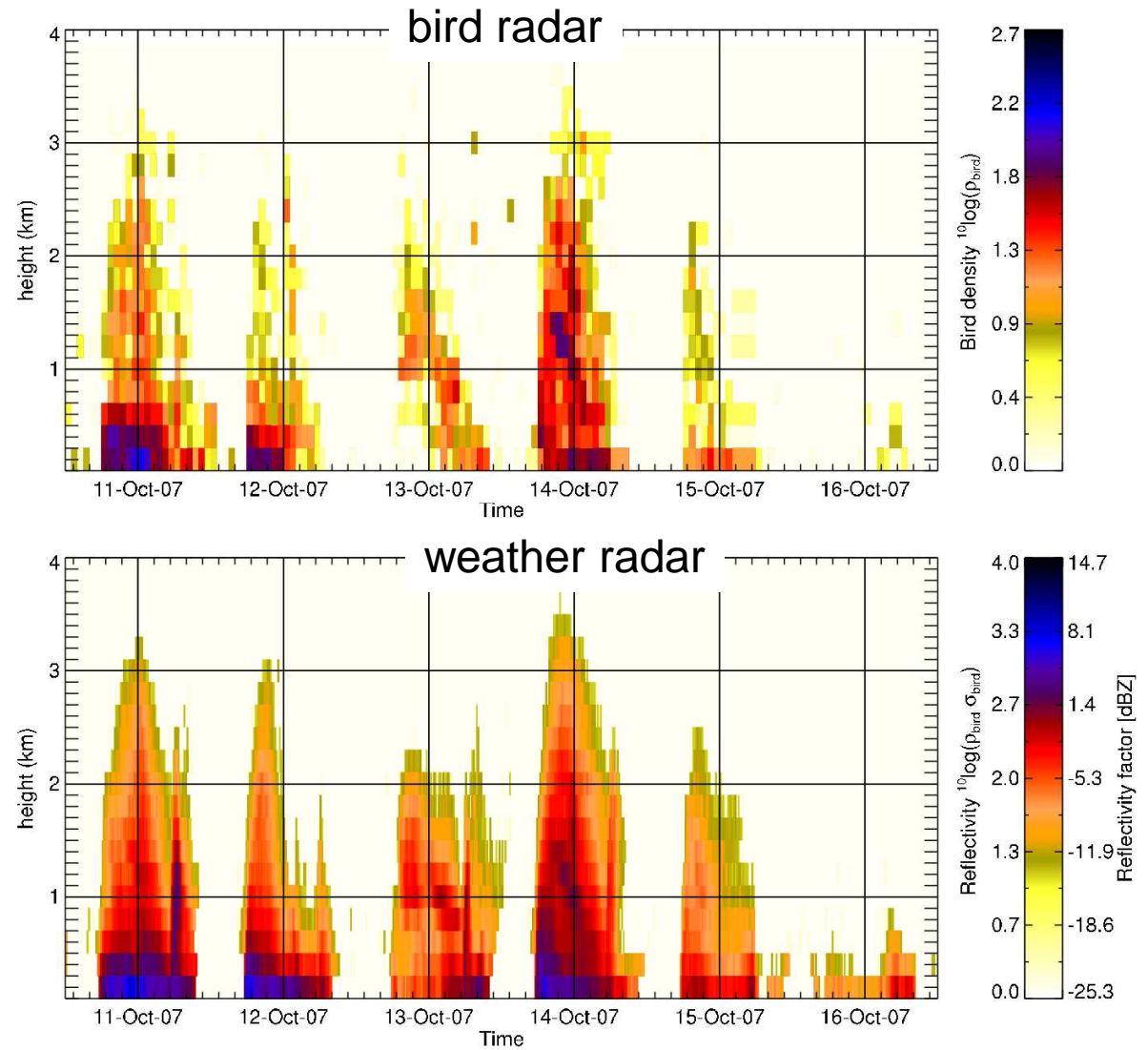# Doppler weather radar ➔ automatic extraction of birds

image pattern filtering
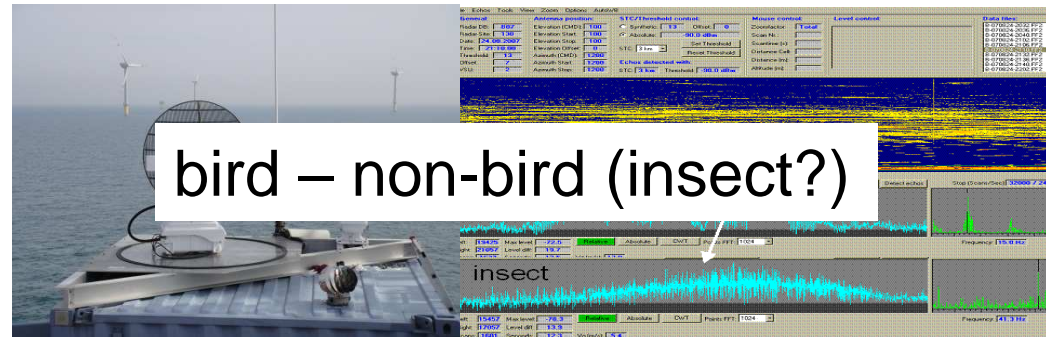

Dokter et al (2010). *J R Soc Interface*

Validation of weather radar with a «bird radar»
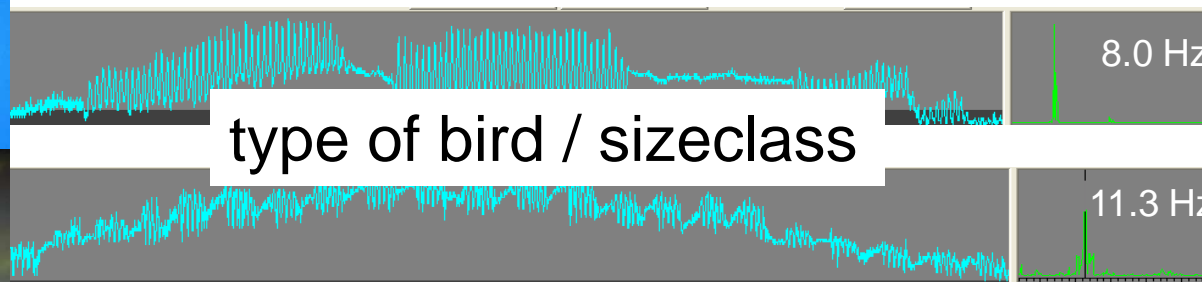
Height distributions at hourly intervals

Dokter et al (2010). *J R Soc Interface*

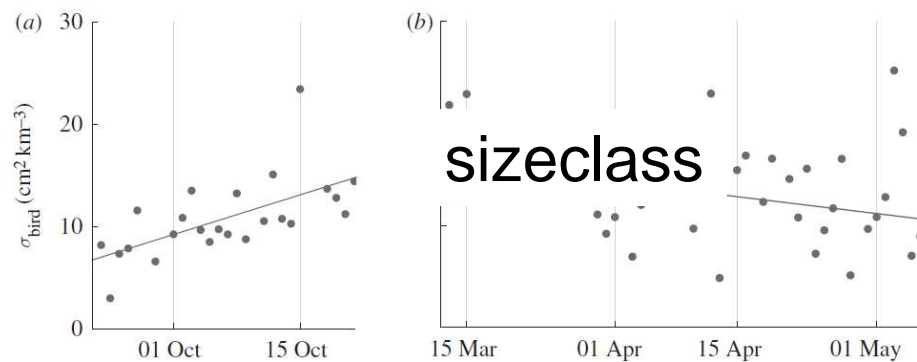# Automated target detection and identification

bird – non-bird (insect?)

echo signature

type of bird / sizeclass

8.0 Hz

11.3 Hz

radar cross section

sizeclass

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Application
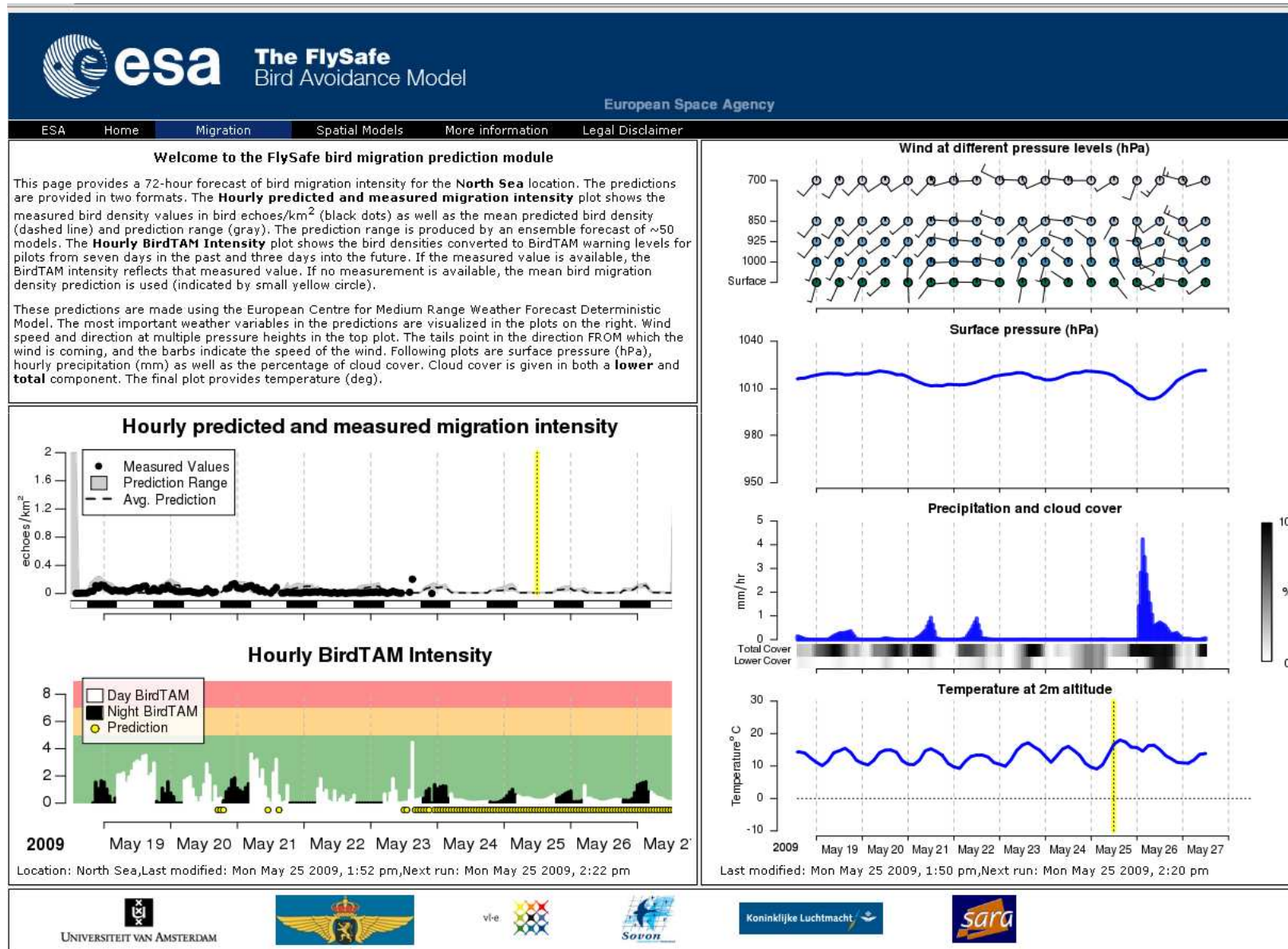
New Year's Eve in The Netherlands

Shamoun et al. 2012
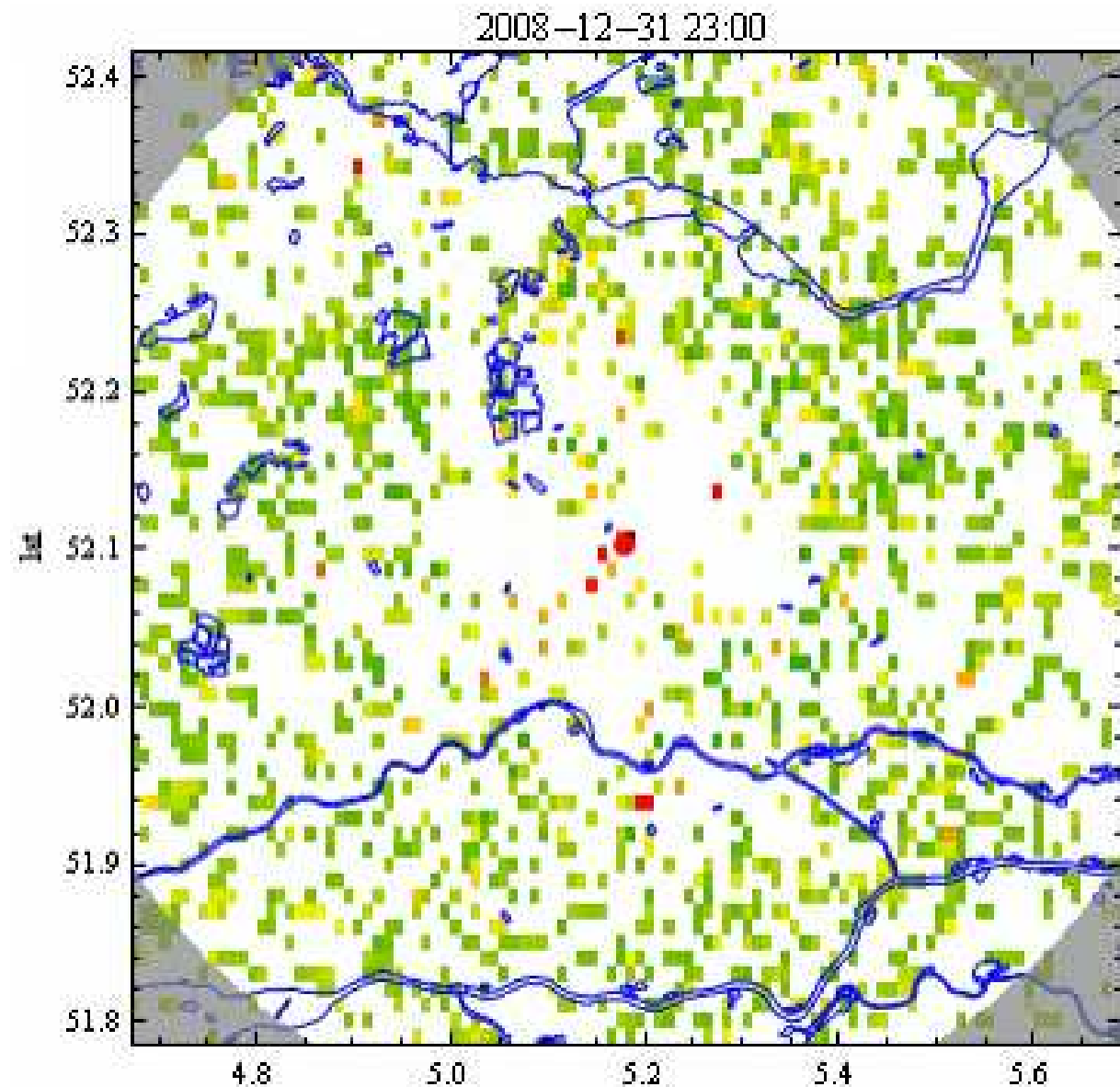
Wing beat pattern of Swifts (Apus apus)
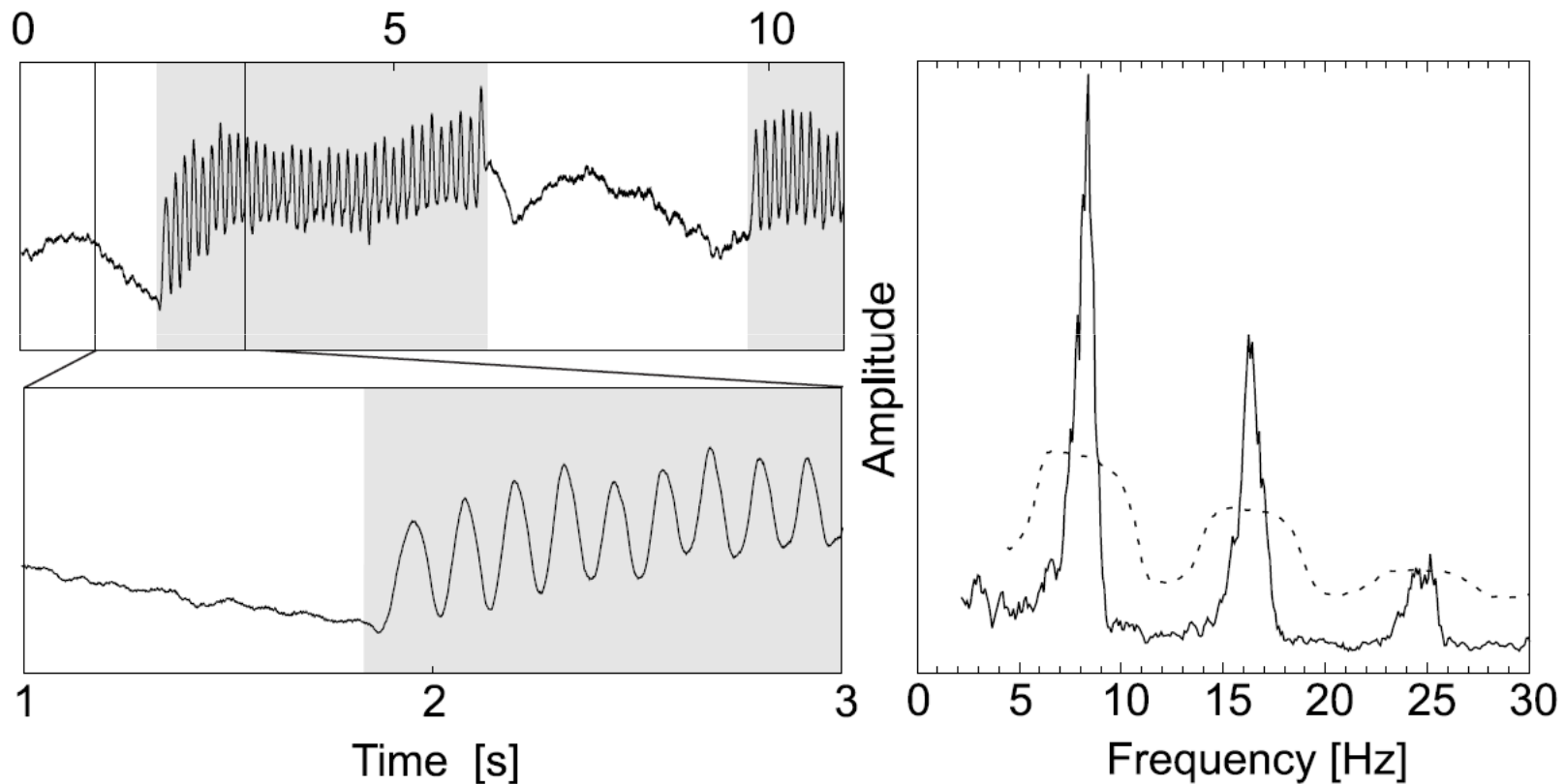
A. Dokter pers. comm.

European
  Network for the
    Radar Surveillance of
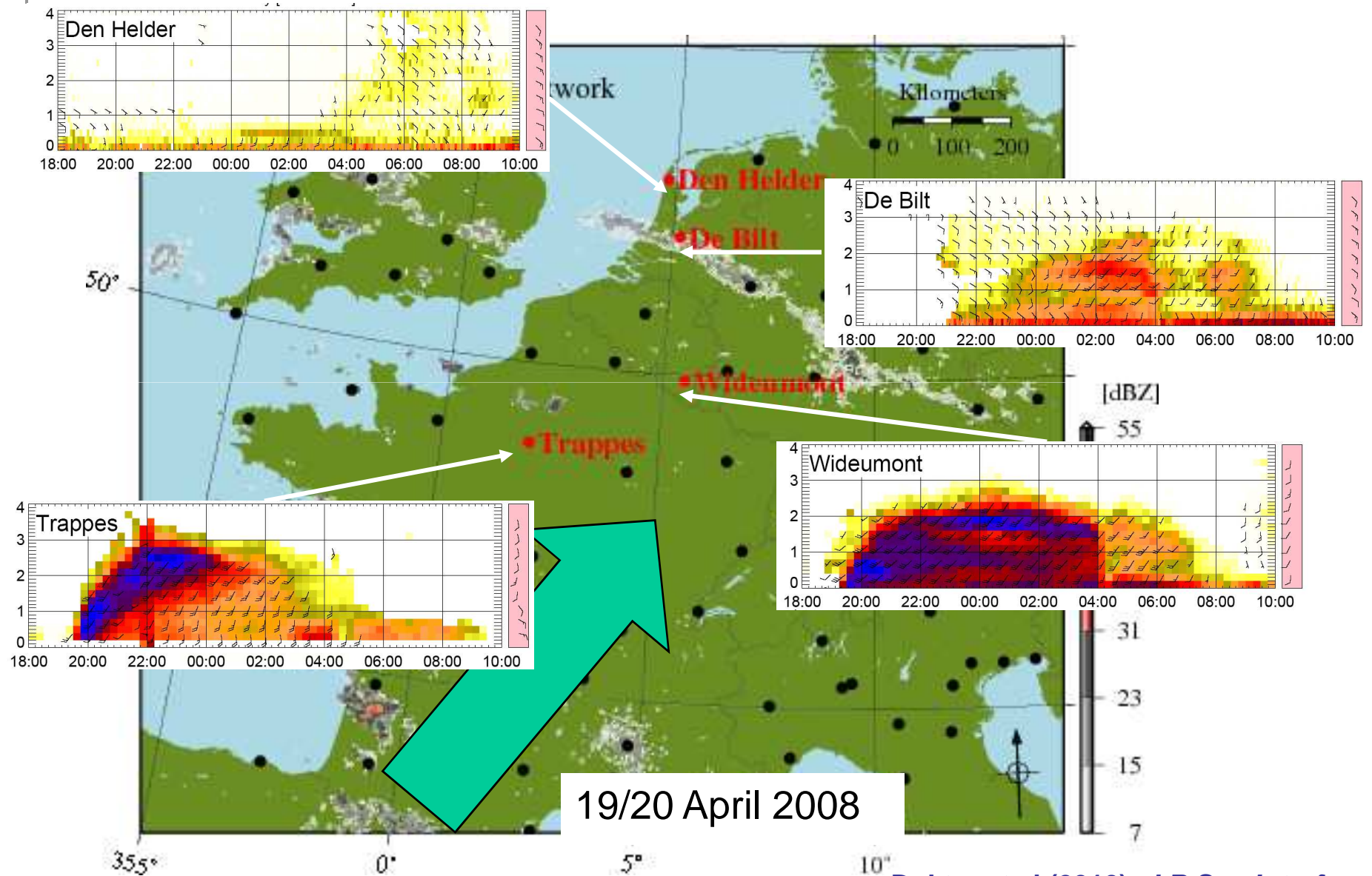   **A**nimal
        Movements

First aim: Consistent and prolonged periods of simultaneous measurement of animal movements
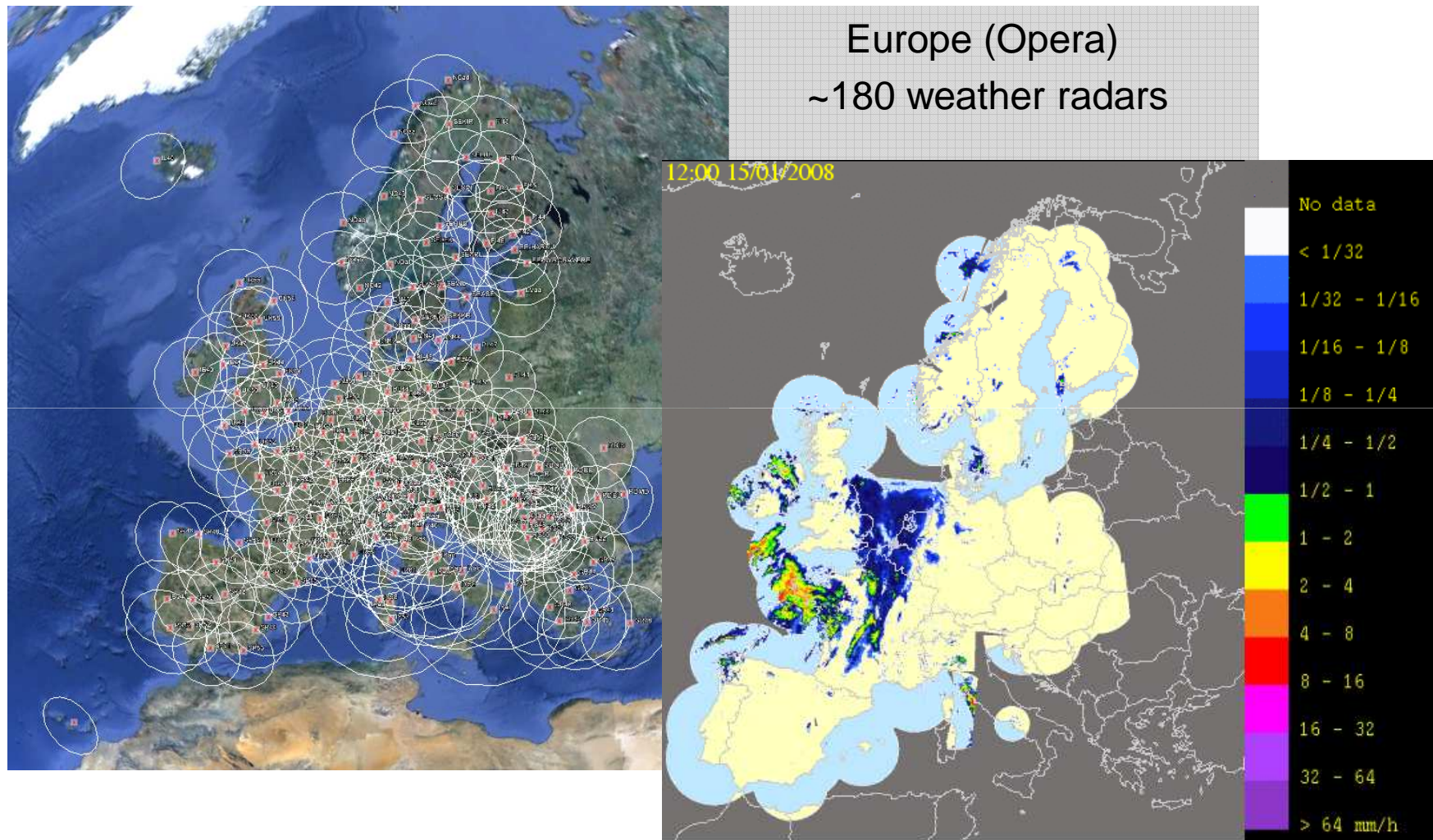
Amsterdam, Nov. 2010

Radar network for bird migration study – first example

19/20 April 2008

Dokter et al (2010). *J R Soc Interface*

OPERA – European weather radar network

Europe (Opera)
~180 weather radars

	No data
	< 1/32
	1/32 - 1/16
	1/16 - 1/8
	1/8 - 1/4
	1/4 - 1/2
	1/2 - 1
	1 - 2
	2 - 4
	4 - 8
	8 - 16
	16 - 32
	32 - 64
	> 64 mm/h

12:00 15/01/2008

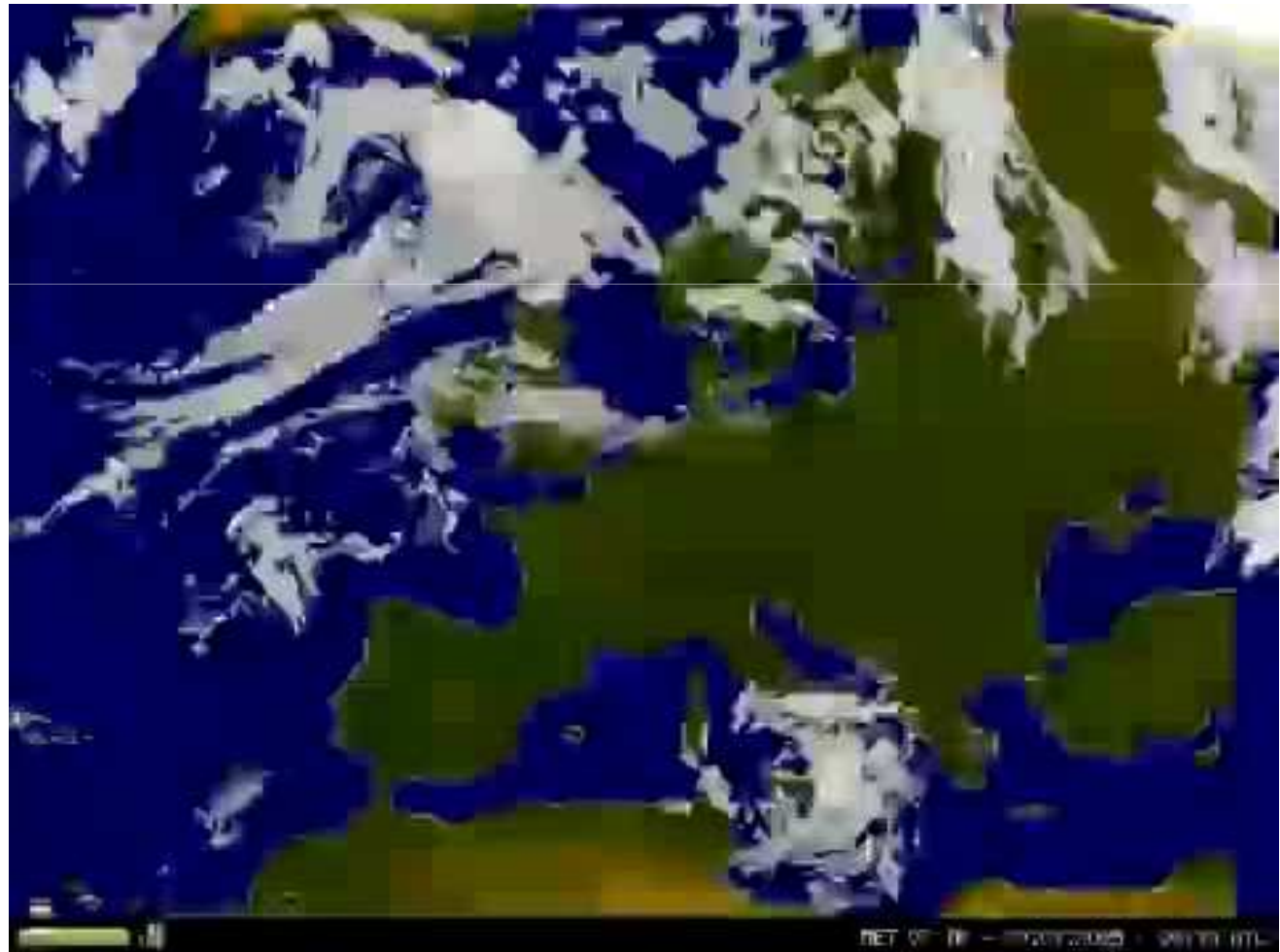Example of weather radar composite as produced at the pilot datahub of OPERA.

NEXRAD ➔ similar network in North America

Outlook

Real time monitoring of
➔ bird and insect movements across Europe

European
  Network for the
    Radar Surveillance of
      Animal
        Migration

By monitoring free ranging animals and forecasting their movements, the network will provide invaluable data and support for the rapid progress in disciplines such as climate change research, ecosystem stability, land utilization planning, air safety, natural disaster prediction and disease dispersion.

To make a step forward to understand our planet as one big network of ecosystems, we need to understand not only the flow of the physical components in the atmosphere, but also the movements of the living organisms therein.

For this challenge, radar meteorology has one of the most valuable tools in its hands.
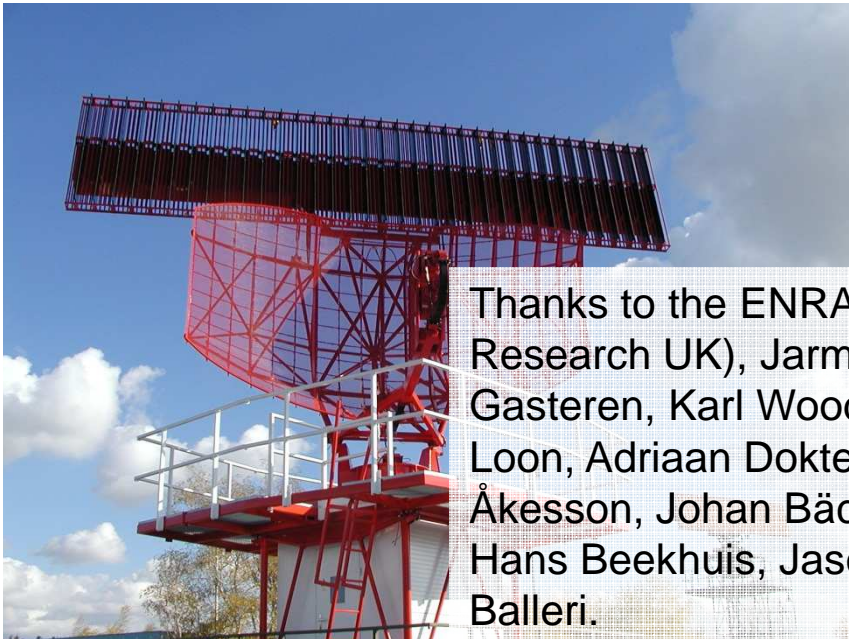
Thank you for your attention!

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Bird detection by operational weather radar

Adriaan M. Dokter[1], Felix Liechti[2], and Iwan Holleman[1]

[1]Royal Netherlands Meteorological Institute, De Bilt, The Netherlands
[2]Swiss Ornithological Institute, Sempach, Switzerland
November 20, 2009

Executive summary

Within the Avian Alert System of Systems (SoS) initiative of the EuropeanSpace Agency (ESA), we have explored the potential of operational C-band Doppler weather radar as a bird migration sensor. A bird migration recognition algorithm has been developed, extracting bird density, speed and direction as a function of altitude. The weather radar data have been validated against simultaneous and co-located bird density measurements by a high precision bird radar, provided by the Swiss Ornithological Institute (SOI). This mobile tracking radar . . .