

## Improving the operational capabilities of vertically-pointing insect-detecting radars

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*This report is a summary of the work conducted for a Short Term Scientific Mission (STSM) in the COST Action ES1305 (European Network for the Radar surveillance of Animal Movement, [www.ENRAM.eu](http://www.ENRAM.eu)), as part of working group 3: Visualizing spatio-temporal patterns of animal movement.*

### Background

The STSM was carried out by Adj.Prof. Curtis Wood. The core work was done during 5–18 September 2014, mostly at Rothamsted Research (Harpenden, Hertfordshire) in the United Kingdom (UK), within the Insect Migration group led by Dr Jason Chapman, and supported by the group's radar engineer Jason Lim and expert colleague Dr Don Reynolds.

The principal outcomes were as follows:

1. **Production of near real-time visualisations for insect data collected by vertically-pointing radars.** Automated programs and scripts were developed to produce the required outputs i.e. daily visualisations of vertical profiles of migration intensity in terms of a) insect target numbers and b) a measure of 'total biomass' (from returned signal power). These outputs are needed to ensure that the continuous operational capacity of entomological radars is being utilised to the full, and important events (e.g. mass invasions, and interesting case studies of behaviour) are identified as soon as possible after the event. This also means that real-time dissemination of migration-intensity measures to interested stake-holders becomes a possibility (e.g. forecasts of pest invasions). We also note that in Summer/Autumn 2014, an ornithological radar was located at Rothamsted: so inter-comparison between the outputs of these units will be facilitated by the new visualisations.
2. **Advancing integration of atmospheric-boundary-layer (ABL) and entomological studies in the UK community.** In particular, two possible collaborations were identified. (i) The UK Met Office's Cardington research station has a suite of useful equipment which could support entomological studies, not least a 3.2 millimetre-wavelength radar and a Doppler-wind lidar (e.g. giving profiles of wind speed and direction, and estimates of ABL depth). (ii) A visit of Don Reynolds and Curtis Wood to Dr John Nicol at the University of Reading's Department of Meteorology (who works with e.g. cloud-radar data from Chilbolton Observatory in Hampshire) – this visit is expected to strengthen the interest in the interface of entomological and meteorological measurements in the ABL.

### Methods

The core instrumentation was the vertical-looking entomological radar (**VLR**; Chapman et al 2002, 2003; Wood 2007). The original visualization of these data was dubbed "Quickview" and another version "Quickview2". Hence the current work is dubbed "Quickview3". The core MATLAB function is called **quickview3.m**

The core data archive for end-users is normally .mdb files (i.e. Microsoft Access database), with one file for each month for each site (its creation has been detailed in Standard Operating Procedures at Rothamsted, written by Alan Smith). However, an alternative way into the data has become highly desirable (e.g. to

avoid difficulties with large file sizes in Excel). At least in recent years (e.g. 2010 onwards), this avenue is via processing of the .CSV and .AVD files stored on the radar computers (NB. there is simply a direct copy of that .CSV file into the “inpdata” table in the .mdb files).

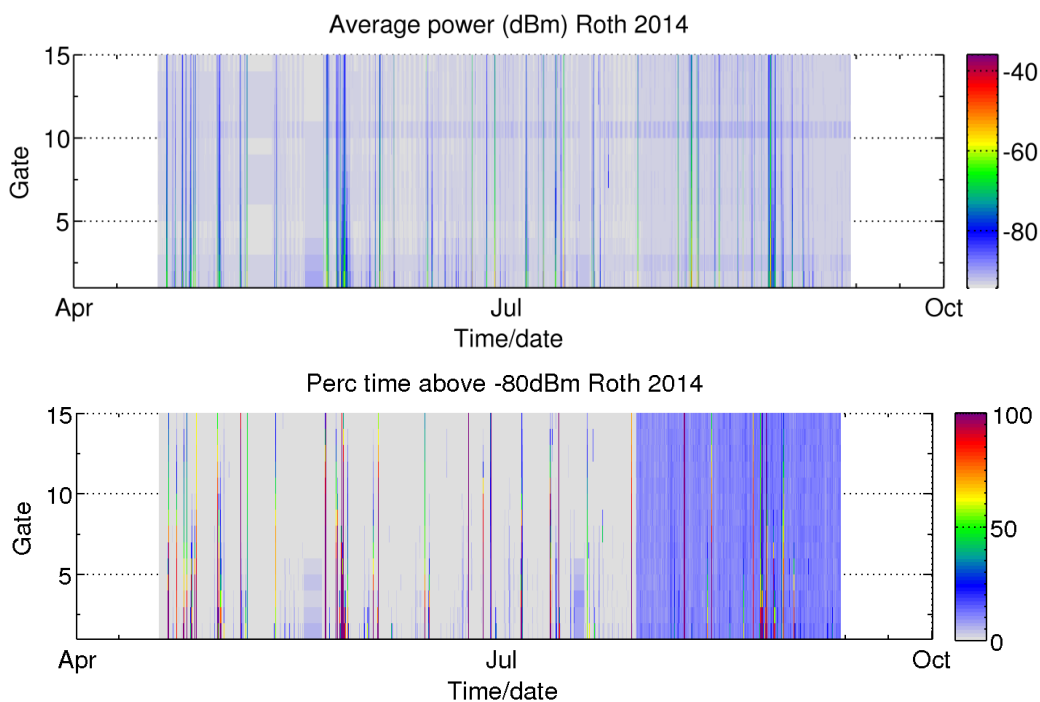
*(A) Pre-processing to obtain ‘average power’:*

In order to get any quantities based on power returns, one must use the primarily the .AVD (binary raw data) file as the data source, and also useful is the .CSV (ASCII target information) file. Based on a previous script (of Shane Hatty and Jason Lim), in the current STSM a new MATLAB function was developed:

**av\_power.m**. It is presently designed to run from MATLAB within unix (at the time of writing this only operates on some computers due to the differences in reading binary data using lower-level methods, e.g. encoding UTF-8) using the following example format:

`av_power('Roth', 2014, '/media/VLR/quickview3')`. The function performs these actions:

- The .AVD files for the given year are recursively searched for within the entire given directory/path.
- Each of those files is sequentially loaded (using `fread`).
- As well as average power, a variable “percentage of time the received signal is above  $-80\text{dBm}$  threshold” (**%thresh**) is made.
- These are stored in an array at the 5(15)-min intervals (NB. the radar samples for 5 minutes every 15 minutes; with 10-minute non-sampling interval in between).
- Each file is saved in ASCII format (.AVD.pow and .AVD.per) in the csv/AVD folder.
- Next, all those ASCII data-files for the given year are concatenated to give a YEAR's data into one file, e.g. csv/AVD/Roth2014\_pow.csv.
- The average (i.e. median of 1760 values per 5 minutes) returned power (e.g. Fig 1a) and %thresh are made into a png figure for the year (e.g. quickview/AveragePower\_Roth\_2014.png; Fig 1b).

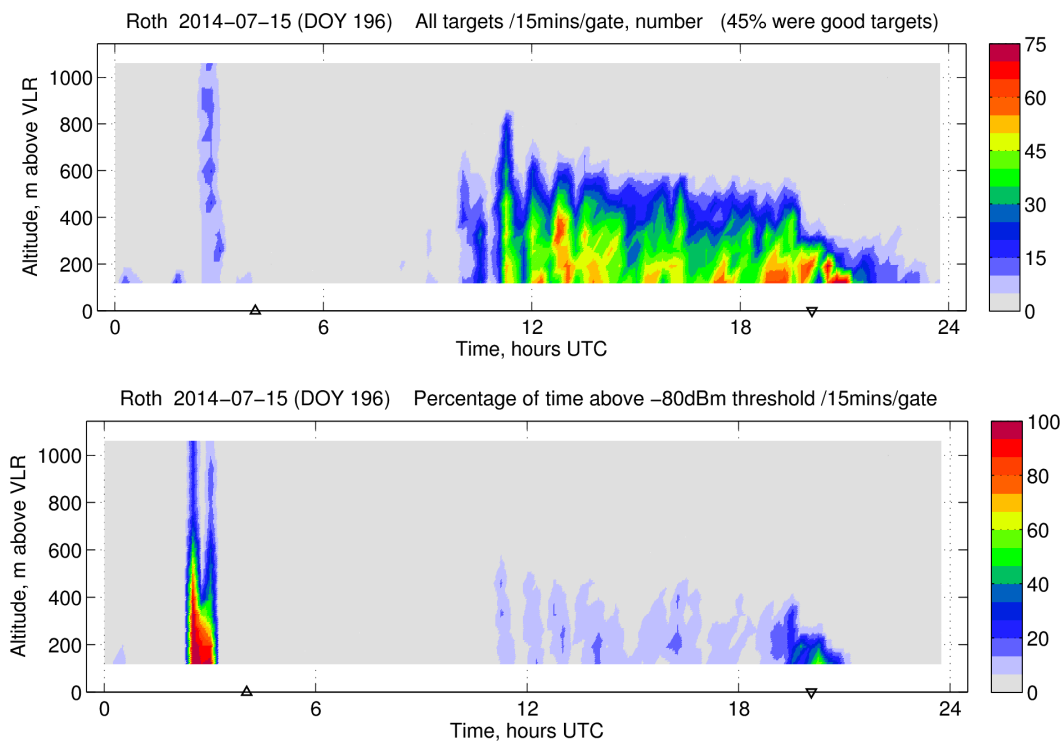


**Figure 1:** Summertime 2014 Rothamsted VLR data in terms of (a) average power in dBm, (b) %thresh. One can note an increase in ‘background’ power from 29 July onwards, presumably as a result of the presence of the ornithological radar at Rothamsted.

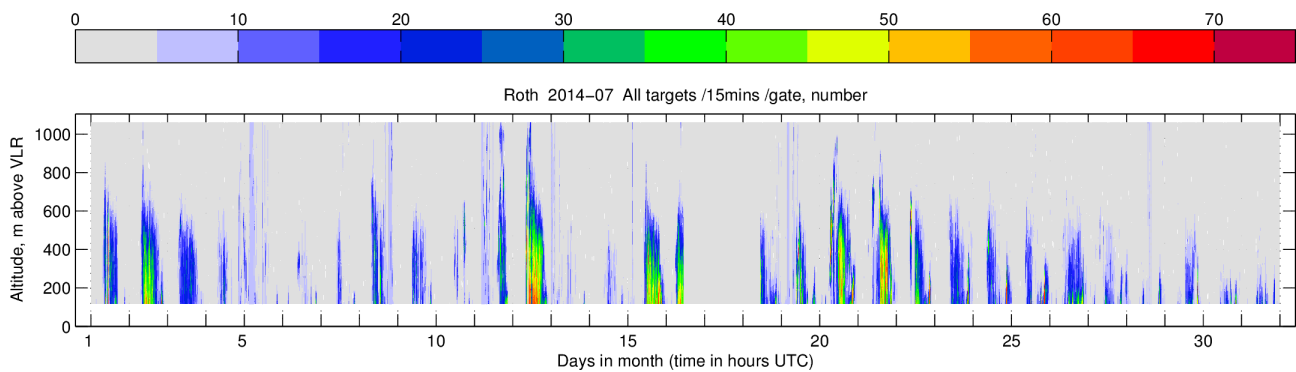
(B) Core processing:

The **quickview3.m** MATLAB function was designed to be run from Unix, using the following example format: `quickview3(2014,07,'Roth')` for Rothamsted in July 2014. The function's actions can be summarised as follows:

- For years <2010, we try to use the Access databases (.mdb) as the primary source.
- If not found, we look for the .CSV and .AVD files.
- If .mdb, we use Unix's "mdbtools" to convert .mdb datafile into a .csv datafile.
- Unfortunately there are changes in the primary data-table (e.g. Targets) in the .mdb file (e.g. slight differences in format/representation of date and time). So, some effort was required (invoking Unix's `sed` and `cut` commands) to get the generated .csv into a neat and consistent format for processing.
- When ready, the data can be loaded into MATLAB.
- 15-min averages are made with even times (:00, :15, :30, :45), regardless of radar operating schedule.
- All targets are shown: some of which will not be insects. But also the percentage of 'good' targets is written in the figure title (i.e. those exceeding 0.9 correlation coefficient as per the pre-calculated model; which means that insect mass and flight speed is known).
- A figure for each day is made (e.g. Fig 1a; `quickview/Targets_Roth_2014-07-15.png`) of target numbers.
- A file for each month (e.g. `csv/Targets_2014-07.csv`) is made of target numbers (this is similar to the previous 'Inspect' files), and a figure file for the whole month (e.g. Fig 3; `quickview/Targets_Roth_2014-07-ALL.png`).
- If possible, also png files are made for %thresh (e.g. Fig 2b). (At the time of writing, this step is not yet automated.)



**Figure 2:** 15 July 2014 in Rothamsted VLR data (a) Target (insect) numbers, (b) %thresh values. Also marked are sunrise/sunset on the time axis. The high intensity red patch around 3am is rain echo. Note also both daytime and crepuscular insect activity. Further, it would appear that target numbers are artificially low at dusk due to inter-target interference (given the high values given in %thresh at the same time).



**Figure 3:** July 2014 in Rothamsted VLR data, target (insect) numbers. It would appear a reasonably active month for daytime flight, with perhaps a little at dusk and dawn; but very little nocturnal activity was observed in this month.

*(C) Daily automation:*

A daily automated script (.bat) was made for Jason Lim's windows laptop, which runs every time the laptop is turned on. The script copies, via the Rothamsted network, from the 'rothvlr' PC the .CSV and .AVD files to a public FTP server (at FMI) via the internet. These files are thence auto-processed every day on a server chosen by Curtis Wood, and figures copied to <http://tinyurl.com/quickview3>

Summary and outlook

Basic functionality exists in the newly-developed MATLAB functions, and basic comments and documentation have been made. Importantly, almost all historical data have been processed. So, the STSM has allowed in most cases a quick first look at the data to identify potentially interesting migration events. However, this project is not 'complete' given the limited time available. Hence future possibilities include:

- Including more variables: mass, insect shape, orientation, speed, etc.
- Editing the .csv outputs to match the same output as was in historical the "Inspect" databases.
- Automating quantities taken from the average power (.AVD) files.
- Making the script more universal by adapting/removing Unix-dependent sections of the code.

References

Chapman JW, Smith AD, Woiwod IP, Reynolds DR & Riley JR (2002) Development of vertical-looking radar technology for monitoring insect migration. *Computers and Electronics in Agriculture*, **35**: 95–110

Chapman JW, Reynolds DR & Smith AD (2003) Vertical-looking radar: a new tool for monitoring high-altitude insect migration. *Bioscience*, **53**: 503–511

Wood CR (2007) *Biometeorology of high-altitude insect layers*. PhD thesis. University of Reading, UK.

Appendix

**Table:** Summary of data processed by quickview3 on this STSM. Shown are targets (T) and %thresh (P). Only May to September, inclusive, are processed. Missing data (-) normally means that the raw data was indeed available, but the data format varied in some way that the automated quickview3 cannot yet deal with – this also means that Malvern data have not (yet?) been processed in quickview3. (NB: In quickview1 all data from Rothamsted and Malvern 2000–2007 inclusive was processed).

YEAR/MON	Rothamsted	Chilbolton
2000/05	T	
2000/06	T	
2000/07	T	
2000/08	T	
2000/09	T	
2001/05	T	
2001/06	T	
2001/07	T	
2001/08	T	
2001/09	T	
2002/05	T	
2002/06	T	
2002/07	T	
2002/08	T	
2002/09	T	
2003/05	T	
2003/06	T	
2003/07	T	
2003/08	T	
2003/09	T	
2004	-	*
2005/05	T	-
2005/06	T	-
2005/07	T	-
2005/08	T	-
2005/09	T	-
2006/05	T	-
2006/06	T	-
2006/07	T	-
2006/08	T	-
2006/09	T	-
2007	-	-
2008/05	T	T
2008/06	T	T
2008/07	T	T
2008/08	T	T
2008/09	T	T
2009/05	T	T
2009/06	T	T
2009/07	T	T

2009/08	T	T
2009/09	T	T
2010/05	T	T
2010/06	T	T
2010/07	T	T
2010/08	T	T
2010/09	T	T
2011/05	T,P	T,P
2011/06	T,P	T,P
2011/07	T,P	T,P
2011/08	T,P	T,P
2011/09	T,P	T,P
2012/05	T,P	T,P
2012/06	T,P	T,P
2012/07	T,P	T,P
2012/08	T,P	T,P
2012/09	T,P	T,P
2013/05	T,P	T,P
2013/06	T,P	T,P
2013/07	T,P	T,P
2013/08	-	#
2013/09	-	
2014/05	T,P	
2014/06	T,P	
2014/07	T,P	
2014/08	T,P	
2014/09	T,P	

\* VLR moved Malv->Chil May/June 2004

# VLR broke