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Insects, weather and climate; 18 March 2009, Imperial College

Applications of atmospheric science are relevant to a range of themes within science and society; application to entomology was the main focus of this meeting organised by Dr Curtis Wood (University of Reading). This meeting was held jointly with the Royal Entomological Society. The talks were designed to appeal to the broader scientific community by showcasing topics near the join of the two disciplines. The audience heard about exciting topics within weather and climate change, how they are applied to entomological science and how insects can be used to advance atmospheric science. The meeting included the 2009 *Margary Lecture* given by Prof. Philip Mellor (Figure 1) from the Institute for Animal Health (IAH) at Pirbright.

First, one might question why one needs to know about insect movements. Beyond a more fundamental understanding of insect ecology, there are impacts on many parts of society. Dr Jason Chapman (Rothamsted Research) highlighted that many insects have well-developed migration strategies that enable them to travel many hundreds of kilometres in just a few days (e.g. the diamond-back moth in Chapman *et al.* 2002) and this is important since many insects can be pests of crops. In particular, Dr Chapman discussed the detection and understanding of the mass emigrations at spring and autumn (northwards and southwards respectively) observed in data from UK entomological radar.

The research into insect-vectored parasites and viral diseases (e.g. malaria and bluetongue carried by mosquitoes and midges respectively) was presented by Dr Andrew Morse (University of Liverpool) and Prof. Mellor (Mellor *et al.* 2000). Temperature is a powerful determinant in the transmission of viruses and other pathogens both within vectors themselves and their host animals, in addition to strongly affecting insect migration itself. UK media and politicians have paid great attention in recent years on the spread of bluetongue into northern Europe via certain *Culicoides* midge species; the first UK case was discovered on 21 September 2007. A quote was underlined from the Prime Minister's Romanes Lecture in Oxford on 27 February 2009: "*…when British scientists used meteorological data to predict that midges bearing bluetongue virus would be carried to specific parts of the UK from the continent—they enabled selective vaccination of livestock and saved nearly £500 million, together with 10,000 jobs*". Without doubt, society benefits from the Met Office working with DEFRA and IAH in this integrated approach. Laboratory work at Pirbright was emphasized since Pirbright is an international reference laboratory for many viral diseases (e.g. bluetongue, foot-and-mouth, African horse sickness).

Classic entomological techniques of ground-level trapping have been running for many decades. For example the Rothamsted Insect Survey's (www.rothamsted.ac.uk/insect-survey) first trap started in 1933, and netting studies have been operating for a similar length of time (Chapman *et al.* 2004). Recently, at Rothamsted Research, the flight simulator technique (Mouritsen and Frost 2002) is being used so that flight behaviours—such as insect orientation phenomena—can be studied under controlled conditions.

Since the development of radar for entomological purposes in the '60s, papers on the detection of insects at high altitude have developed into a large literature (see the radar entomology website, www.pems.adfa.edu.au/~adrake/trews). In particular, vertical-looking entomological radars (VLRs) have been operating operationally in the UK since 2000 and are presently located at Rothamsted and Chilbolton; an example of such VLR output of aerial concentrations of macro-sized insects is shown in Figure 2. Dr Susan Rennie (University of Reading) showed how understanding the movement of insects detected in the UK network of *precipitation radars* could be used to infer information about winds and thus improve short-term weather forecasts by including this extra information in data assimilation systems (Rennie *et al.* 2008; see also Wood *et al.* 2009 for obtaining insect echoes from cloud radars). Such information will be most useful at short lead-times (of order minutes to hours) in the development of convective precipitation.

John Gloster (IAH-Pirbright and the Met Office) discussed the joint development by the Met Office's Atmospheric Dispersion Group and IAH-Pirbright of the Numerical Atmospheric-dispersion Modelling Environment (NAME) for use in the biological community (foot-and-mouth in Gloster *et al.* 2003 and bluetongue in Gloster *et al.* 2008); see Figure 3. The NAME technique includes a vital non-deterministic approach: since the model is Lagrangian in nature, the numerous trajectories show the breadth of pathways insects/particles could follow from a given take-off location. Furthermore, the need for a non-deterministic approach was echoed by Dr Morse, who showed work from ECMWF weather prediction ensembles and the resulting malaria forecasts (see also Thomson *et al.* 2006).

A large range of spatial scales were discussed at this meeting: (i) at larger spatial scales, atmospheric flow and temperature affect aerial insect migrations (e.g. see Drake and Farrow 1988); (ii) at the scale of metres to kilometres, micrometeorology and local insect habitats were discussed by Prof. Chris Thomas (York University, Thomas *et al.* 2004) who emphasised the difficulty of downscaling global climate-model data into the effects at the microscale; and (iii) at the molecular scale, Prof. Mellor talked about the virus within the insect itself and the effect of temperature on virus transmission.

Discussion

Much of the weather and climate change work performed ultimately needs end-users. The entomological community is one that is a substantial user of many weather and climate products (perhaps primarily because, since insects are cold-blooded, many entomological problems require temperature data). Indeed, all research presented at this meeting included atmospheric data that were needed in order to conduct the research.

Dr Rennie's work is part of the Flood Risk from Extreme Events (FREE) programme, where researchers are looking at the causes and propagation of floods to help to forecast and quantify flood risk, and inform society about the likely effects of climate change. FREE brings researchers in the hydrological, meteorological, terrestrial and coastal oceanography communities together in an integrated research programme.

The presentations and subsequent questions provoked interesting dialogue, which included the long-standing debate on the spectrum from passive-to-active flight. In brief, at the lower end of the spectrum dust/seeds/spores are often assumed to be completely passive (or perhaps with gravitational settling) and can be transported hundreds of kilometres; next on the spectrum are wingless arthropods (who might be able to affect their movements by curling their bodies or secreting silk drag-lines); next are small insects (whose flight strongly depends on atmospheric conditions); and finally the self-propelled flight of large insects and birds appreciably affect their tracks. There was reference made to Reynolds & Reynolds (2009), whereby even small insects like aphids clearly are not completely passive tracers of the wind. As further evidence of the insects' non-passiveness, evidence of the common orientation phenomenon was shown by Drs Rennie and Chapman (in this effect most insects' bodies are not aligned with the wind but modify their flight path by flying at an angle to the wind).

Further discussion took place around posters that were presented by Laura Burgin (Met Office), Rebecca Nesbitt (Rothamsted Research) and Dr Wood. There was also an interview with BBC Radio Berkshire, who talked with Prof. Paul Hardaker (RMetS Chief Executive) and Dr Wood on the highlights of the meeting.

This report is not a full representation of the meetings' output, but merely summarises some of the work presented. Copies of the speakers' presentations can be found on the RMetS website (at http://www.rmets.org/events/abstract.php?ID=407).

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Figures and captions

Figure 1: Vice-president Philip Eden (right) presented Philip Mellor (left) with a certificate and gift for giving the annual Margary lecture.

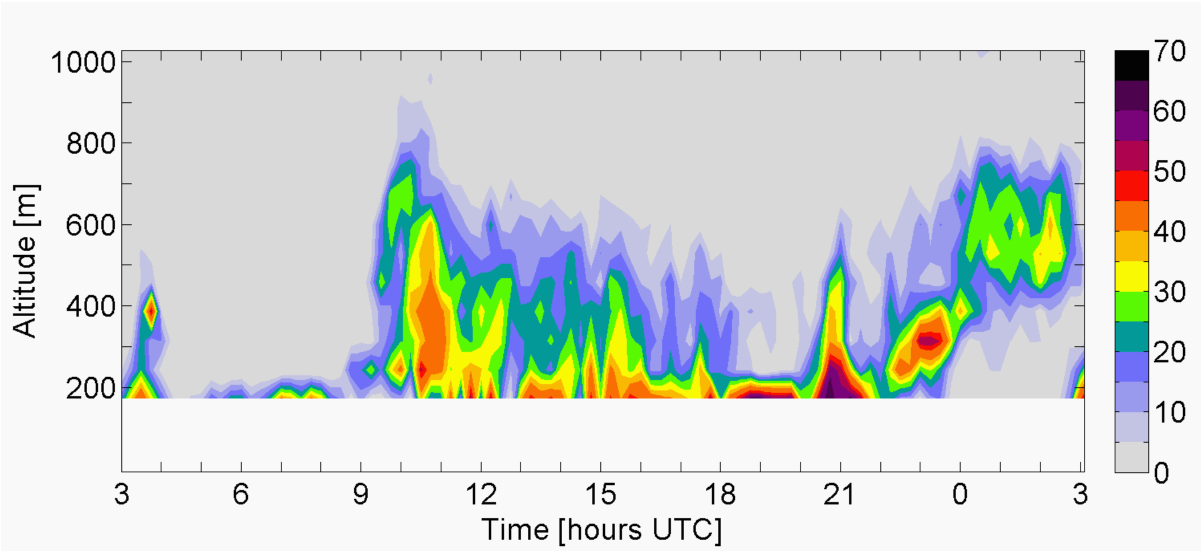

Figure 2: Macro-insect numbers per 5-min sampling period per range-gate (see colour key) on 16–17 June 2000 at the Malvern radar. This diurnal cycle shows many of the features seen in the vertical profile (see also Wood *et al.* 2009). In the period shown the end of civil twilight and sunrise were at 02:59 and 03:48 respectively, sunset and the end of civil twilight were at 20:31 and 21:20 respectively. No data was available for heights below 150 m above the radar.

Figure 3: Example of output from the Met Office's NAME (Numerical Atmospheric-dispersion Modelling Environment) issued to DEFRA on 7 August 2007 of the risk of virus vectors to the UK, taken from Gloster *et al.* 2008.