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The effects of meteorological conditions on diurnal insect migration studied using vertical looking radar and numeric atmospheric simulations

Short Term Scientific Mission (STSM) report (COST-ENRAM action)

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A key question in the study of animal migration is concerned with the effects of atmospheric conditions on the abundance and distribution of migratory animals. In this STSM I coupled insect migration data from Vertical Looking Radars (VLR, see details in Figure 1) designed and operated by a team lead by Jason Chapman at Rothamsted Research, with numeric atmospheric simulations by means of the Regional Atmospheric Modeling System (RAMS) that was run by Nir Horvitz in Israel. During the course of the STSM I extracted data from two different radars located in Rothamsted and Malvern for the year 2003. I calculated two specific parameters, the diurnal migration intensity and the time of emergence for diurnal migration. We simulated the meteorological conditions encountered by migrating insects at the radar sites in high spatial (250 × 250 m^2) and temporal (1 min) resolution. The vertical resolution of the model varied by altitude, starting with a 50 m resolution from the surface, and increasing by a factor of 1.1 with altitude (e.g. the second vertical grid was 55 m high, from 50 to 105 m above-ground). RAMS input included European Center for Medium range Weather Forecasting (ECMWF) reanalysis data, sea temperature, radiation, land-use and topographic data of the study area. Output variables included temperature, barometric pressure, turbulence kinetic energy and the u (west–east), and v (south–north) components of wind velocity. We calculated tailwind and crosswind by calculating the projection of u and v components in the general direction of insect movement. Positive values of tailwind speed indicate that wind blew from the tail of the insects and negative values indicate that the insects encountered headwinds.

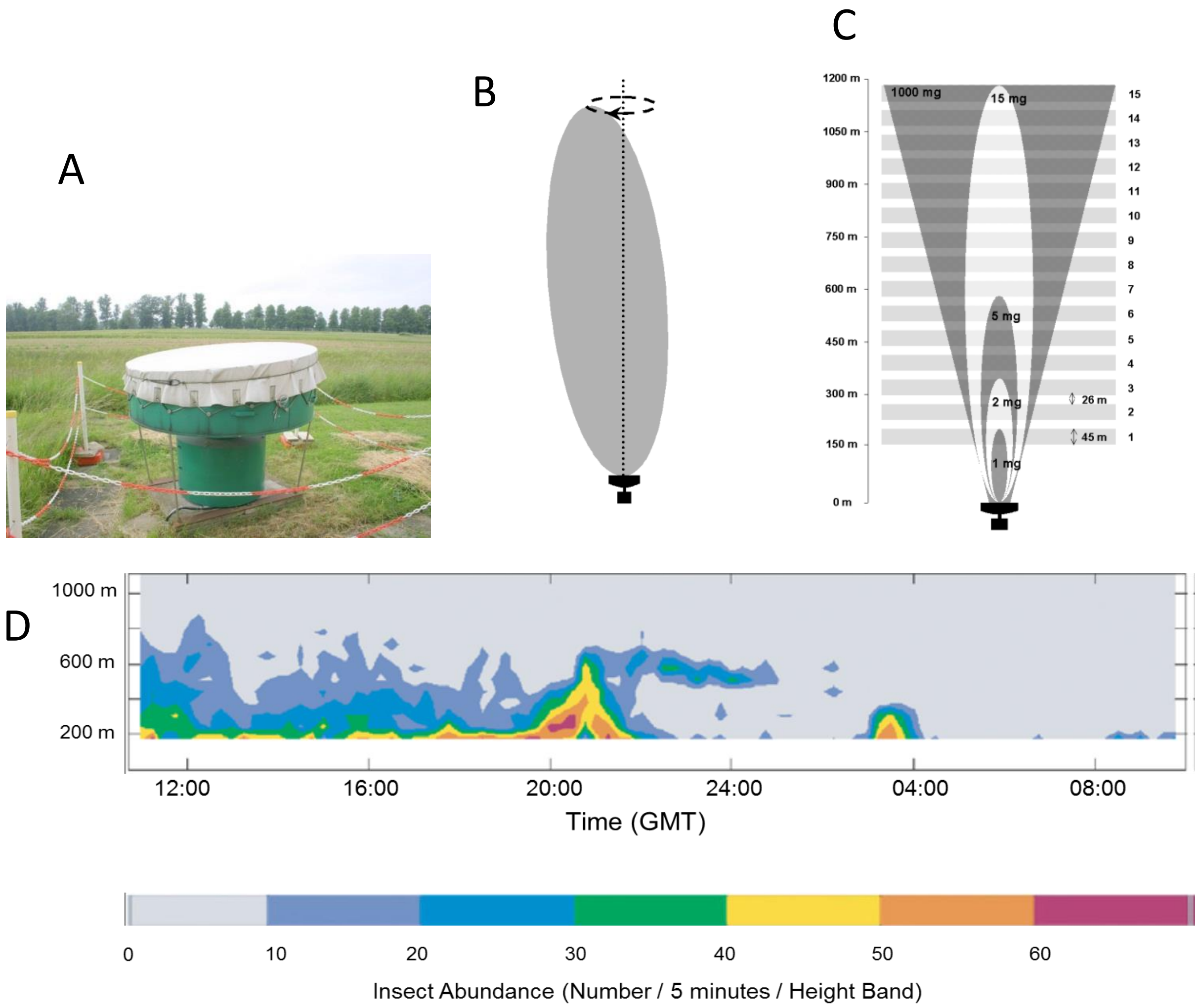

Figure 1. Vertical looking radar (VLR). A. Radar unit. B. Rotating radar beam allowing the extraction of different flight parameters. C. VLR range and lower limit of body masses that the radar is capable to detect at each height. D. A typical daily data of migrating insects, showing both diurnal and nocturnal insect migrations.

I found that albeit located about 150 km from each other, data from the two VLRs are highly correlated (Figure 2), suggesting that factors dictating insect migration are spatially extensive. Secondly, by matching the VLR and RAMS data, I was able to identify key atmospheric parameters affecting diurnal migration of insects.

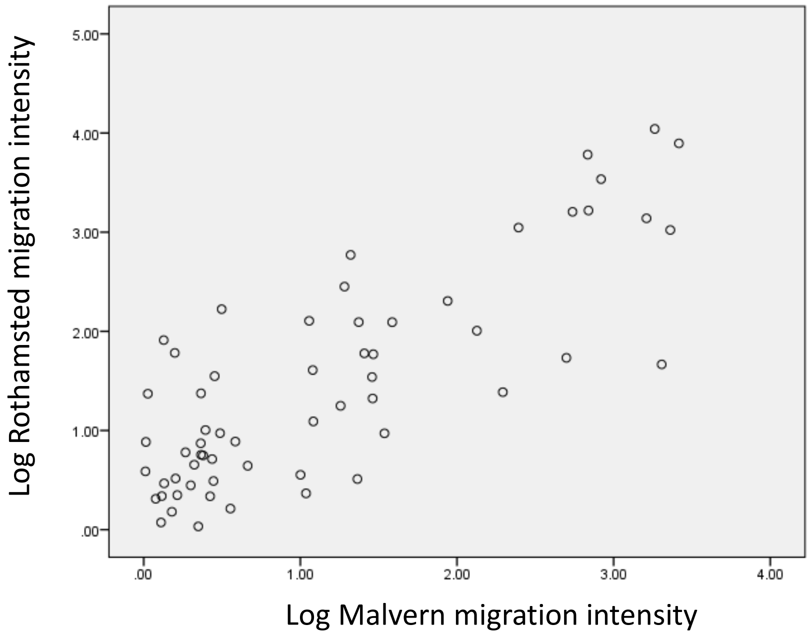

Figure 2. Insect migration intensity in two sites located 150 km apart. These data suggest a positive correlation between migration intensity in the two radar sites in which VLRs were positioned.

In addition, I found that diurnal migration intensity and the start time of insect migration during the morning are correlated, such that when migration starts earlier during the morning, the overall intensity of diurnal migration in that particular day is higher (Figure 3).

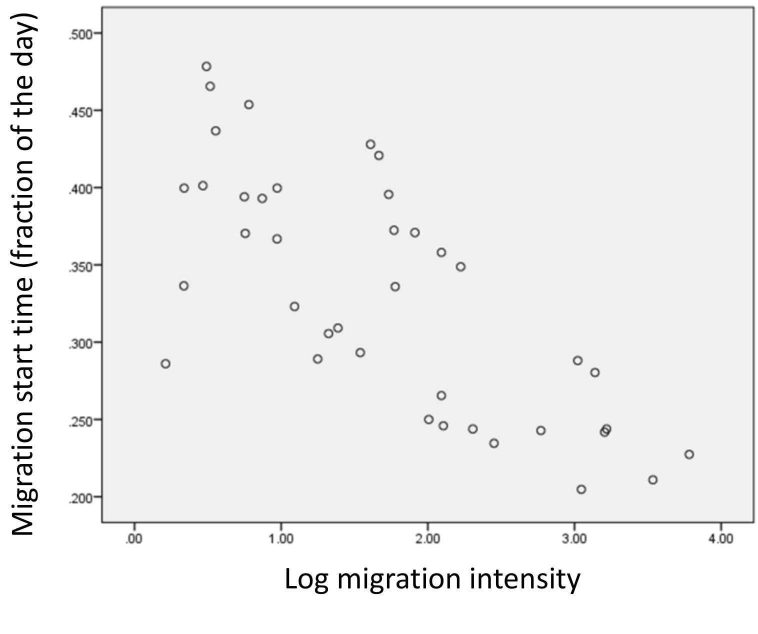

Figure 3. The relationship between insect migration intensity and start time (Malvern data). Note that when migration was more intense, migration start time was earlier.

We found that several atmospheric parameters affected migration intensity. A univariate analysis done on August data suggested that barometric pressure and temperature have a positive effect on migration intensity, while wind speed has a negative effect on migration intensity (Figure 4). This result can be explained by the positive relationship between fair weather conditions, characterized by high temperature and barometric pressure, and insect migration.

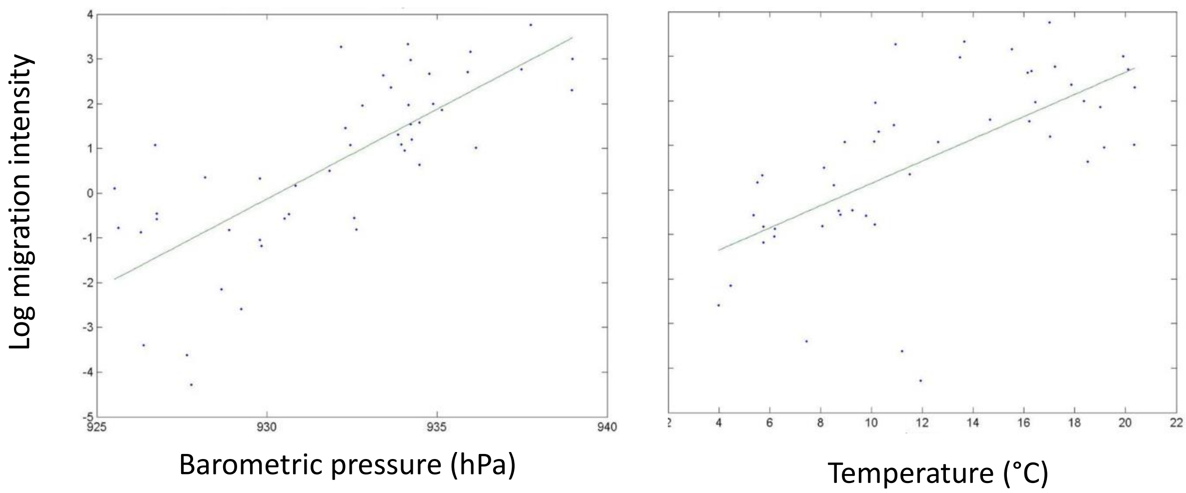

Figure 4. The effects of barometric pressure (left) and temperature (right) at 1,400 m above the surface on insect migration intensity (R^2 = 0.57 for barometric pressure and R^2 = 0.42 for temperature). Insect intensity data include the two radar localities.

We additionally found that wind speed had a negative effect on migration intensity, but this effect depended wind direction. When winds blew from the south to the north, presumably representing headwinds for the migrating insects during the fall (August), migration intensity was low, while when winds blew from the north to the south (tailwinds), insect migration was intense (Figure 5).

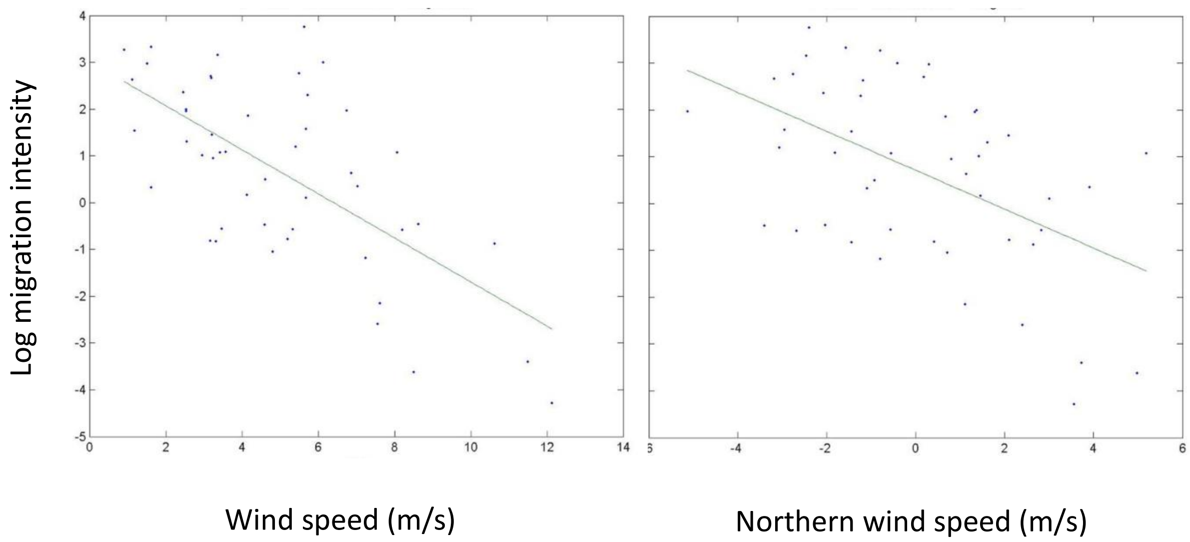

Figure 5. The effects of wind speed (left) and the speed of the wind that blew from south to north (right) on insect migration intensity (R^2 = 0.44 for wind speed and R^2 = 0.26 for southern wind component). Insect intensity data include the two radar localities.

Multiple linear regressions with two and three explanatory parameters explain most of the variation in insect migration intensity. The results of these regressions are presented in Table 1.

Model no.	Model equation	R^2
1	Log(intensity) = (-277.12)+ 0.299P -0.259W	0.67
2	Log(intensity) = 0.16 + 0.195T - 0.372W	0.67
3	Log(intensity) = (-151.61) + 0.115T + 0.163P - 0.297W	0.7

Table 1. Results of regressions with the dependent factor migration intensity (intensity) and several independent factors (T = temperature, P = barometric pressure, W = wind speed).

In addition, we found that temperature and barometric pressure strongly affected the daily migration start time (Figure 6).

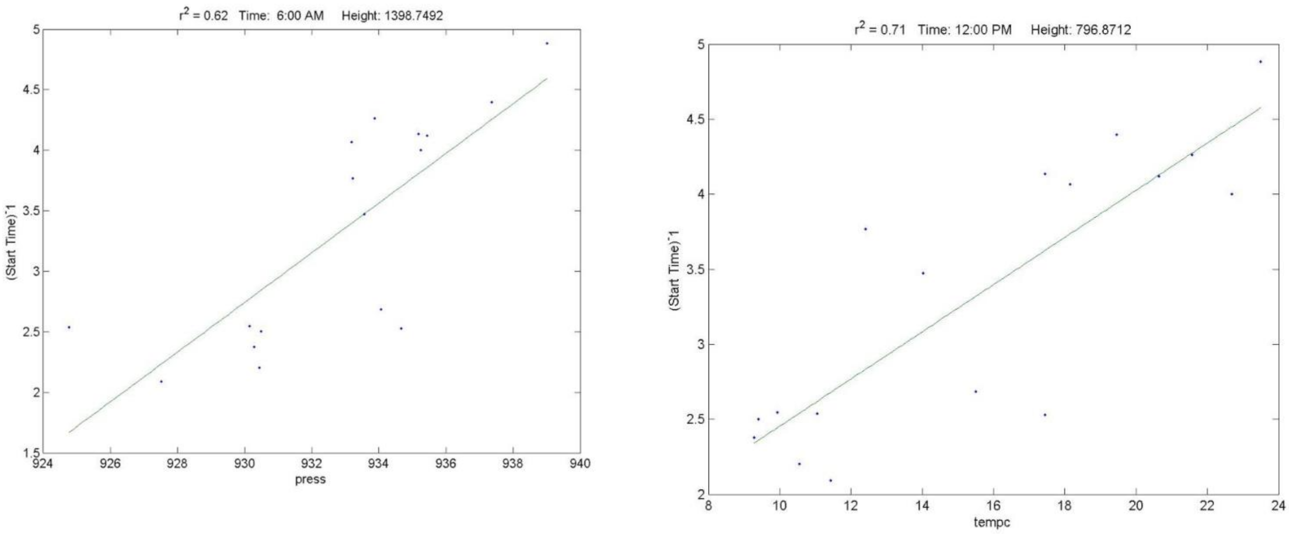

Figure 6. The effects of barometric pressure (left) and temperature (right) on the inverse of the daily timing of insect migration (R^2 = 0.62 for barometric pressure and R^2 = 0.71 for temperature). When barometric pressure and temperature were higher, the starting time of daily insect migration was earlier. Data is from Malvern radar.

The aim of this STSM was to analyse the effects of meteorological conditions on the migration of flying insects. I focused on diurnal migration, examined two parameters characterizing insect migration, and found that meteorological parameters explained most of the variation in migration intensity and daily migration timing. Using advanced technological methodologies (VLR and atmospheric modelling), I was able to explain the effects of atmospheric conditions on key migration properties. This work paves the way for more extensive examination of diurnal insect migration from additional years and localities, and may allow predicting migration of insects over a course of several days, including exploring applied consequences of insects migration related to the movement of crop pests.