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Ozone deposition at a polluted site in the English Midlands

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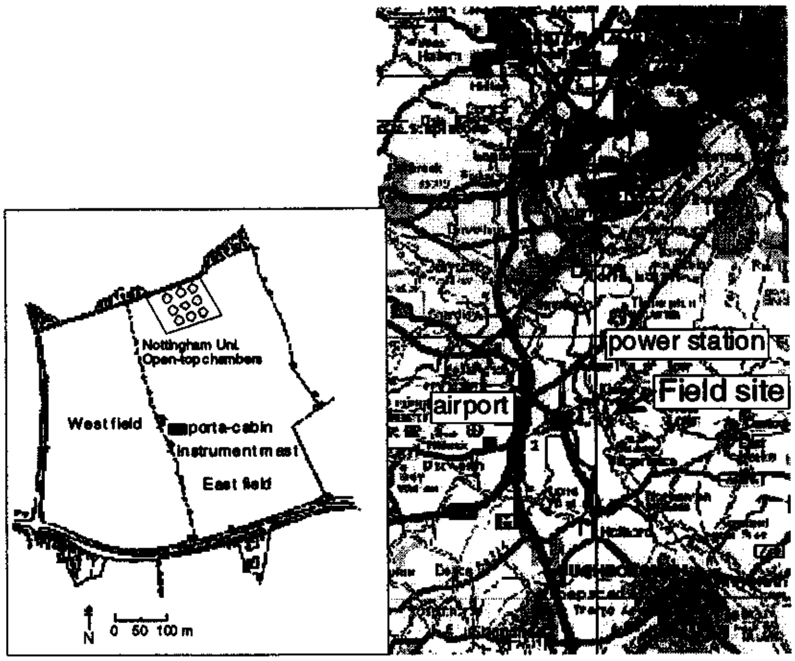
Measurements of ozone deposition, using the aerodynamic flux/gradient method, started on the 1st of May 1998 at Sutton Bonnington in the English Midlands, and have been made continuously since then. The field is split into two halves from north to south, which are planted with different commercial crops, although they are not physically separated (Figure 1a). In 1998 the west field was planted with sugar beat and the east with wheat whereas during 1999 wheat was in the west field and oats in the east.

Fetch requirements are well met for wind directions in the ranges 190° to 300° and 70° to 170° of the measurement mast. The area is mainly agricultural, although the region is quite densely populated, and there are several sources of NO_x and SO_2 near to the field, such as: Ratcliffe coal fired power station 3 km north, the M1 motorway to the west and the East Midlands Airport about 4 km to the south west, see Figure 1b.



A, from Biscoe *et al* 1975

B, Bartholemews UK Road Map CD v 3 (50 km x 50 km grid)

Figure 1. Location of the Sutton Bonnington dry deposition monitoring site

The background concentration of NO_x is between 8 to 16 ppb. This level of NO_x and episodes of higher concentrations lead to significant reductions in the ozone concentration being observed at Sutton Bonnington, potentially causing errors in the calculated fluxes. Hence the NO_x concentration is also monitored to allow corrections to be made to the ozone flux.

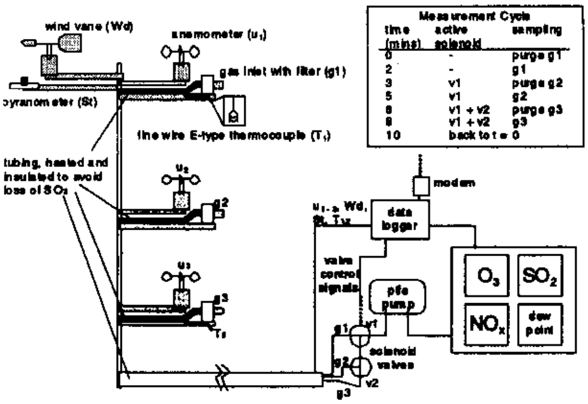


Figure 2. Configuration of the measurement mast.

Measurements of O_3 and NO_x concentration are made at the 3 heights in sequence, as described in Figure 2. The top height is fixed at ~3 m, the middle and bottom heights are moved so that log spacing is maintained with the bottom inlet just above the canopy, in the inertial sub-layer. The prevailing wind direction is from the west (Figure 3) and so the majority of measurements suitable for flux analysis are obtained from the westerly fetch. Hence, only the ozone deposition measurements over sugar beet in 1998 and wheat in 1999 are considered here. Figure 4 shows the monthly data capture of ozone and NO_x in total and for the westerly fetch.

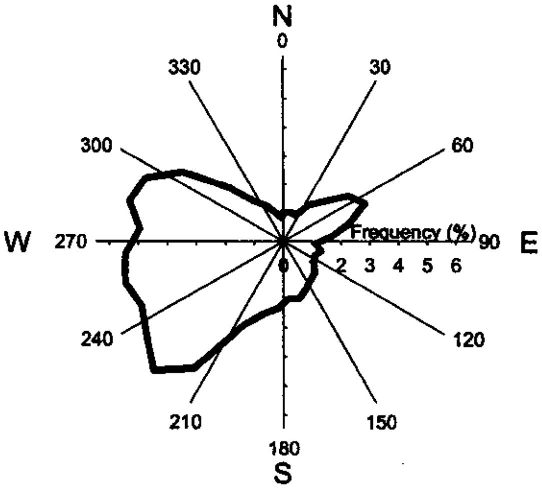


Figure 3. Wind rose of %frequency of wind direction (3/3/98 to 26/8/99).

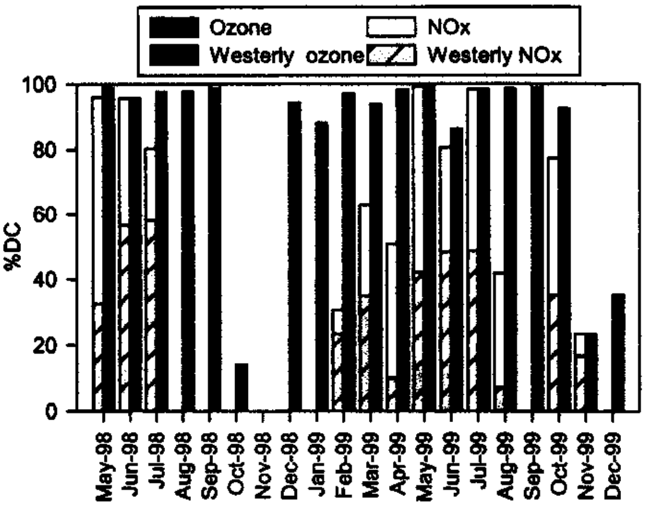
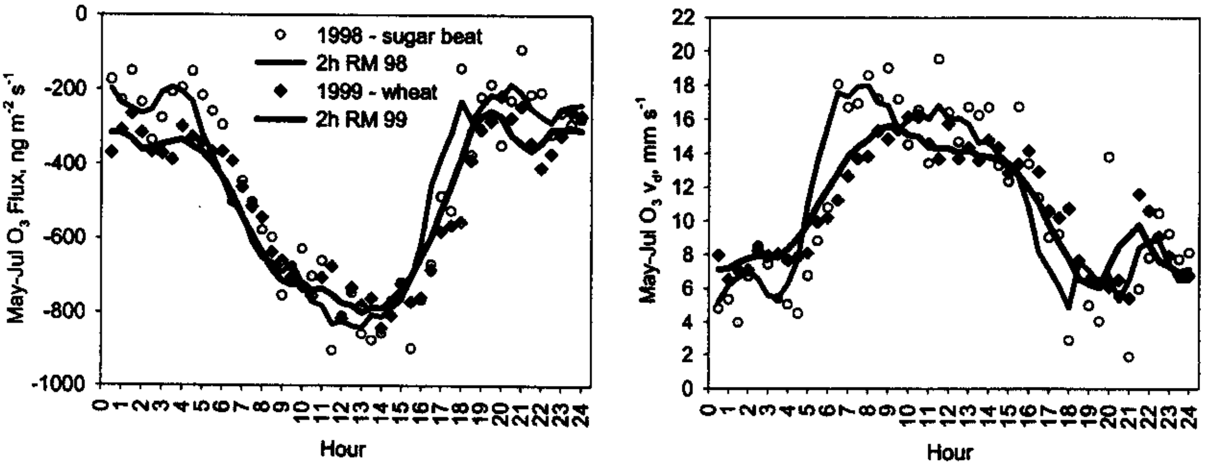


Figure 4. Monthly total and westerly %data capture.

The aerodynamic gradient method used to calculate the ozone flux is described in Sutton 1990 and Sutton *et al* 1993. Where coincident ozone and NO_x measurements have been made the calculated ozone fluxes are corrected for the O_3-NO-NO_2 and other reactions using the empirical method of Duyzer *et al* 1995. The corrections are typically between 0.1 to 2%. These are smaller than expected and further analysis, with different correction methods are in progress.

Figure 5 shows plots of the diurnal cycle in ozone flux and deposition velocity during the two growing seasons. Pronounced diurnal variations in ozone flux, deposition velocity and canopy resistance are evident in the measurements throughout the year. Diurnal patterns in flux and deposition velocity are similar for wheat and sugar beet. Nocturnal deposition to wheat is greater than that to sugar beet, 200 ng m^{-2} s^{-1} *vs* 300 ng m^{-2} s^{-1}, due to differences in canopy resistance.



a.

b.

Figure 5 May to July (a) ozone flux and (b) deposition velocity at 1m. 1/2 hourly average and 2 hour running mean averages for sugar beet in 1998 and wheat in 1999.

Plots of average ozone flux, deposition velocity (v_d) and median canopy resistance (R_c) for both growing seasons and January to March 1999, when the field was practically bare, are shown in Figure 6. Nocturnal winter ozone deposition fluxes (average -232 ng m^{-2} s^{-1}) exceed summer nocturnal fluxes (average -153 ng m^{-2} s^{-1}) as a consequence of higher wind speeds during the winter. May-July daytime canopy resistances (average 34 sm^{-1}) are substantially smaller than those for Jan-March (average 175 sm^{-1}) as a consequence of the stomatal uptake of ozone. During May-July stomatal and non-stomatal ozone deposition fluxes are of similar magnitude. During the winter most of the ozone deposited is non-stomatal.

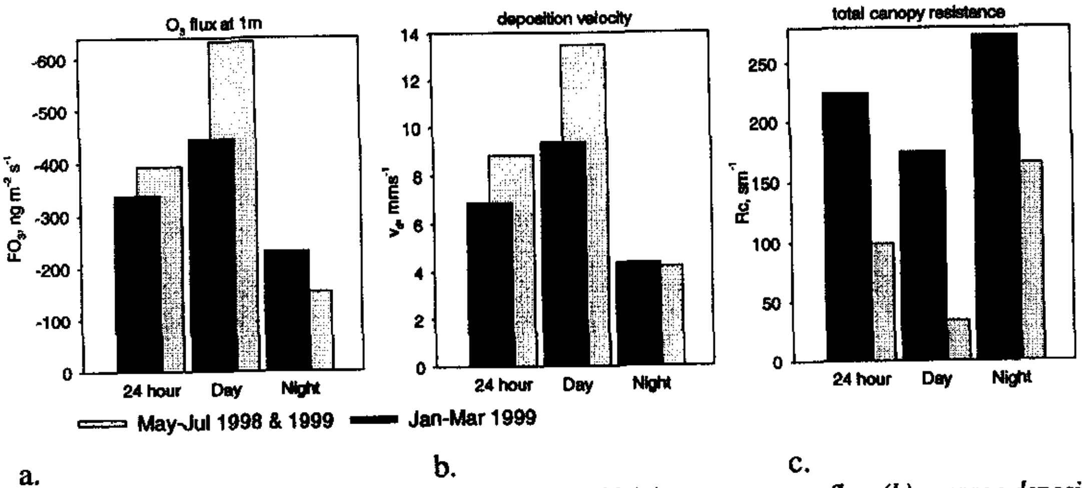


Figure 6. May to July 1998/1999 and January to March 1999 (a) average ozone flux, (b) average deposition velocity and (c) median canopy resistance. Daytime is taken to be when solar radiation ≥50 Wm^{-2}.

In conclusion, this initial analysis gives typical patterns of ozone deposition to arable crops, although the magnitude is slightly larger than has been reported from other field experiments. There are also indications that non-stomatal deposition makes up a significant fraction of the total throughout the year.

References

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