

Comparison of model-derived distribution of sensible heat flux over an urban area with radar-derived rainfall fields

M.G.D. Carraça^{1,2}, C.G. Collier¹

(1) University of Salford, UK; (2) University of Évora, Portugal
 Contacts: M.G.Carraça@pgr.salford.ac.uk and C.G.Collier@salford.ac.uk

14 June 04 Study days 21 June 04

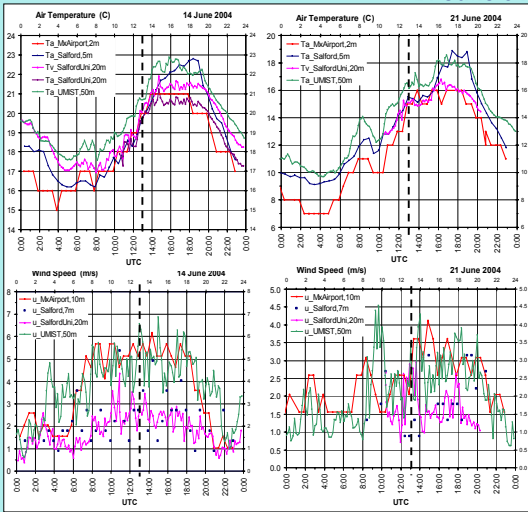


Fig. 2 - Air temperature, T (top), and wind, u (bottom) observations on the 14th (left) and 21st June (right) 2004 from different sources over Greater Manchester: _MxAirport MetOffice [www.metoffice.gov.uk,e.g.]; _UMIST University of Manchester Atmospheric Science Research Group, central Manchester; _SalfordUni field experiment at Salford University; _Salford AWS situated in Salford [www.wunderground.com].

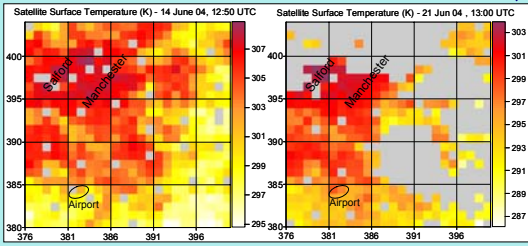
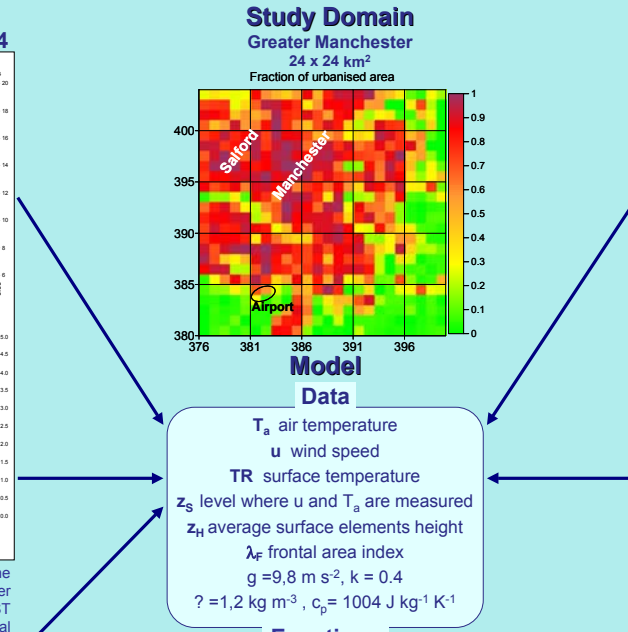


Fig. 3 - Radiometric surface temperature, T_R (K), over the Greater Manchester study area, from satellite imagery around 13 UTC, on the study days of (left) 14th and (right) 21st June 2004. Grey areas are cloud or missing data. (MODIS/Terra and MODIS/Aqua Land Surface Temperature [modisland.gsfc.nasa.gov])

Fig. 4 - Modelled surface sensible heat flux, Q_H (W/m^2), over the Greater Manchester study area, around 13 UTC, on the study days of 14th (left) and 21st (right) June 2004. Grey areas are cloud or missing data. The dotted lines delineate the 7 km wide swath through the city centre.



Surface Roughness

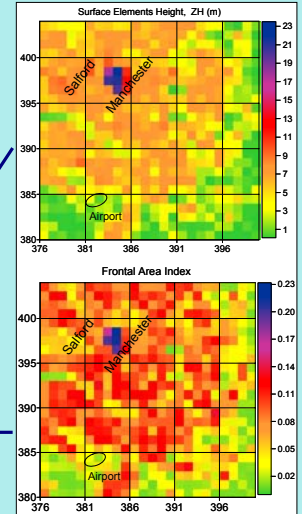


Fig. 1 - Top: Surface elements height z_H (m). Bottom: Frontal area index, λ_F . Note the large values of frontal area index in the city centre.

Equations

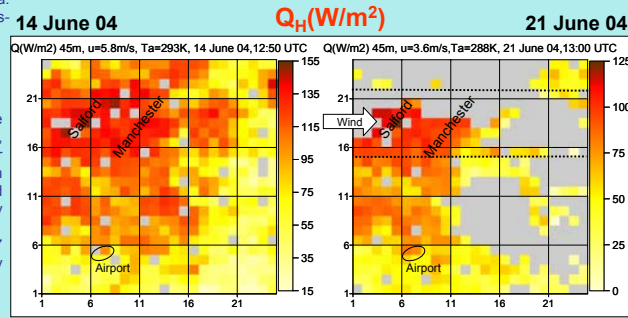
$$Q_H = \rho c_p \frac{(T_R - T_a)}{r_h} \quad z_d(z_H, \lambda_F) \text{ and } z_{0m}(z_H, \lambda_F, z_d), \text{ Raupach(1994)}$$

$$r_h = \frac{1}{k u_*} \left[\ln \left(\frac{z_s - z_d}{z_{0m}} \right) - \Psi_H \right] + \frac{1}{k u_*} \ln \left(\frac{z_{0m}}{z_{0HR,T}} \right) \quad z_{0HR,T}(z_{0m}, Re), \text{ Brutsaert (1982)}$$

$$L = \frac{-u_*^3 \rho c_p T_a}{kg Q_H} \quad u_* = k u \left[\ln \left(\frac{z_s - z_d}{z_{0m}} \right) - \Psi_M \right]^{-1} \quad \Psi_{M,H}(z_s - z_d/L), \text{ Paulson(1970):}$$

$\Psi_M, L < 0$, and Ψ_H , Hogstrom(1988)-
 Dyer(1974)
 $\Psi_M, L > 0$, Ulden & Holtslag (1985)

Surface sensible heat flux Q_H (W/m^2)



Conclusions

-The large surface roughness values lead to large values of Q_H , indicating thermal forcing leading to convective cell generation in a moist unstable atmosphere.

- In our case study the rainfall appears to be initiated from the high surface sensible heat flux in the city centre region as shown in the Hovmoller diagrams.

Radar-derived rainfall fields - 21 June 04

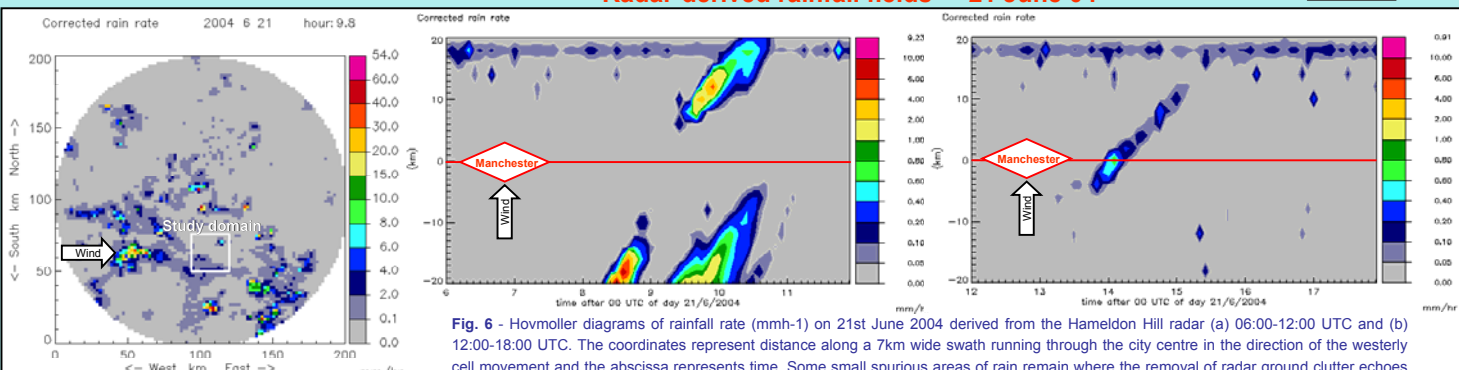


Fig. 5 - Rainfall rate (mmh^{-1}) on 21st June 2004, around 10 UTC, given by the Hameldon Hill C-band radar located some 24km north of the centre of Manchester, North West England. This image is an example of the radar product used in this work (10 min image, with $2 \times 2 \text{ km}^2$ resolution).

Fig. 6 - Hovmoller diagrams of rainfall rate (mmh^{-1}) on 21st June 2004 derived from the Hameldon Hill radar (a) 06:00-12:00 UTC and (b) 12:00-18:00 UTC. The coordinates represent distance along a 7km wide swath running through the city centre in the direction of the westerly cell movement and the abscissa represents time. Some small spurious areas of rain remain where the removal of radar ground clutter echoes has been incomplete. Note that in the morning a cell forms about 5 km downwind of the city centre. This is consistent with the time it takes for the thermal forcing associated with the large buildings in the city centre of Manchester. In the afternoon a cell is generated about the same distance upwind of the city centre over Salford consistent with the large values of Q_H here.

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