Note DAPPLE - EnFlo 04
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Flow Visualisation Studies - I

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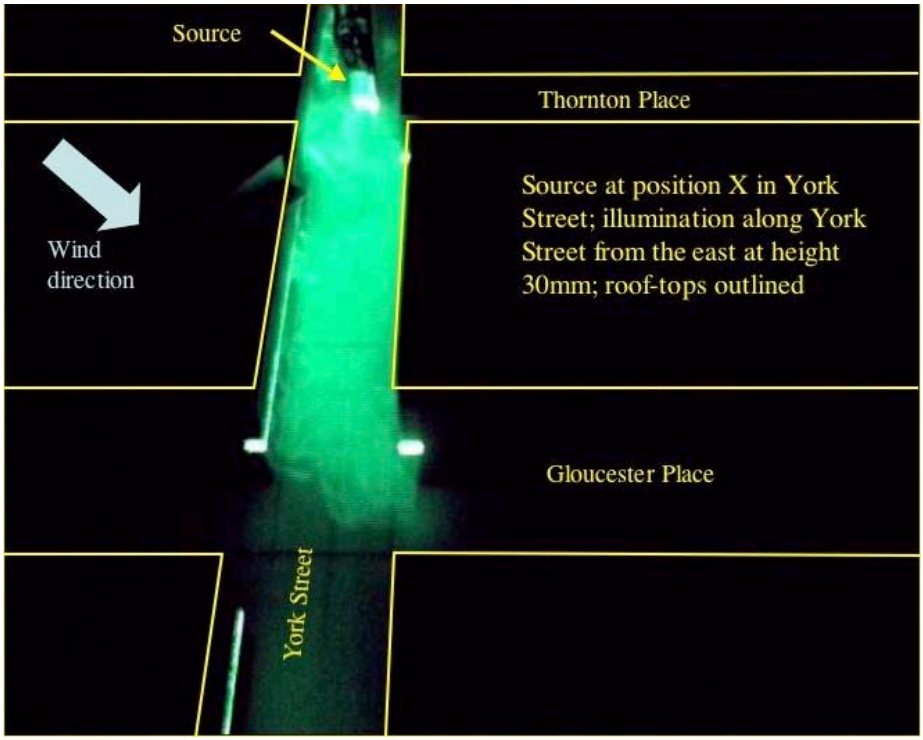
This note presents and discusses some preliminary flow visualisation studies for wind direction 51 degrees in model co-ordinates (i.e. approximately from the SW) over the 1:200 scale DAPPLE site model. The images shown were extracted from video recordings and it was these that actually provided much of the insight into flow behaviour.

1. York Street – Gloucester Place junction



The smoke source is at position X in York Street. The figure includes the approximate wind direction, source position and street names, with the tops of the building blocks approximately outlined in yellow. The laser light sheet is at a height of 30mm (i.e. 6m, full scale) in York Street (note that Gloucester Place is not illuminated). This is the most common flow state, with all the smoke at this level travelling along York Street to the junction and then along Gloucester Place. On occasions, but rarely, the smoke flow at 30mm continues along York Street, as illustrated below (all subsequent images show the same area, but without the outlines added), as well as turning into Gloucester Place.

This "branching" situation is not at all common. Much more frequent is a sequence in which a fraction of the flux in the smoke plume crosses the intersection and becomes detached from the main plume (at least at this height). The sequence on the next page illustrates this. However, the most common behaviour is that shown in the larger image above.

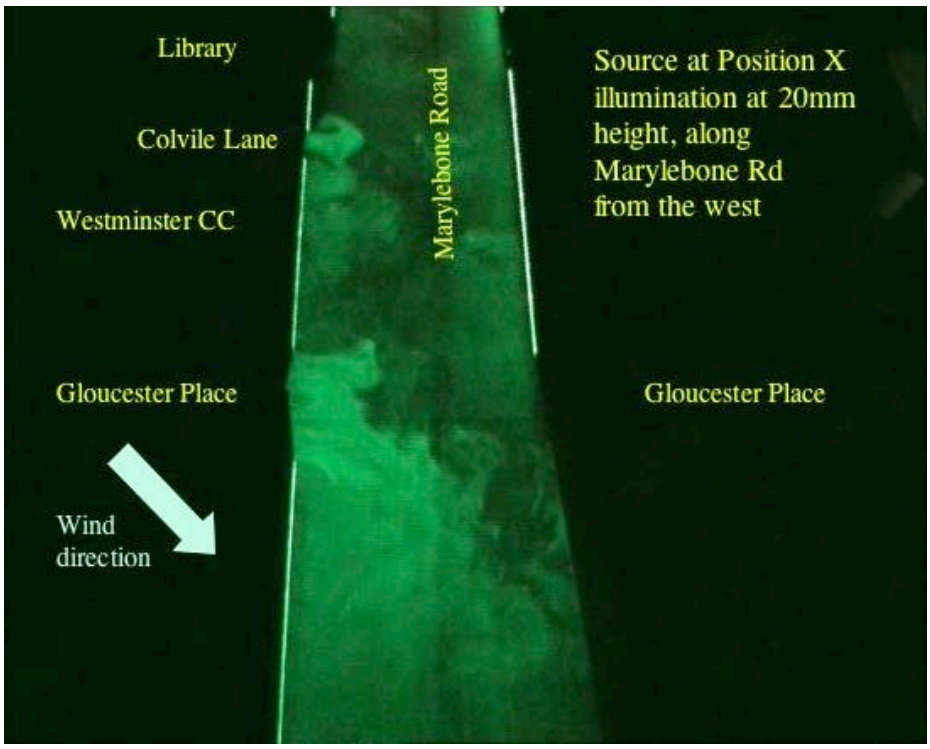
Care must be taken in interpreting these and other images as only one plane is illuminated and significant motion generally occurs perpendicular to that plane.





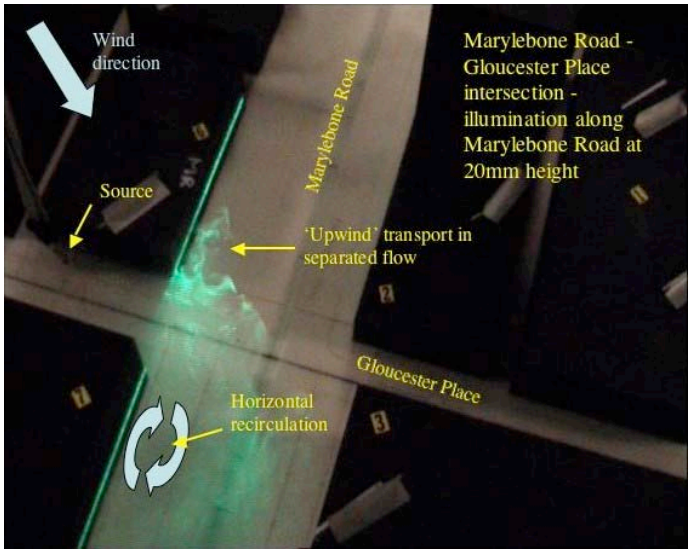
The sequence runs from left to right, top to bottom. A small smoke ‘cloud’ becomes detached from the main plume and continues along York Street. There is however vertical motion perpendicular to the plane of the light sheet, so the term ‘detached’ should not be taken too literally. For example, other observations, not included here, show some smoke escaping from the York Street canyon and travelling above roof level.

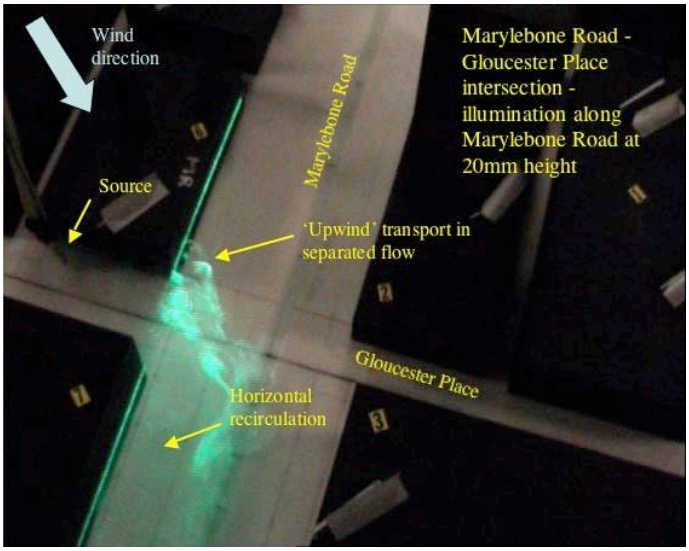
2. Marylebone Road



The image shows smoke laden flows emerging from Gloucester Place and "Colvile Lane" into Marylebone Road and then being advected in the general flow along Marylebone Road. The source is at position X in York Street, so this picture is a continuation of the previous case, where the York Street – Gloucester Place intersection was shown. Details of the flow structure in Marylebone Road are illustrated later.

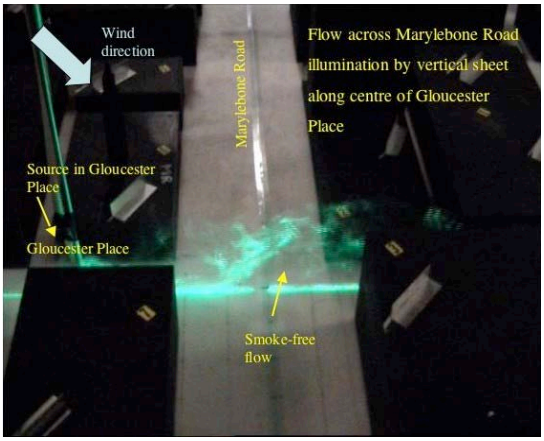
3. Marylebone Road – Gloucester Place junction

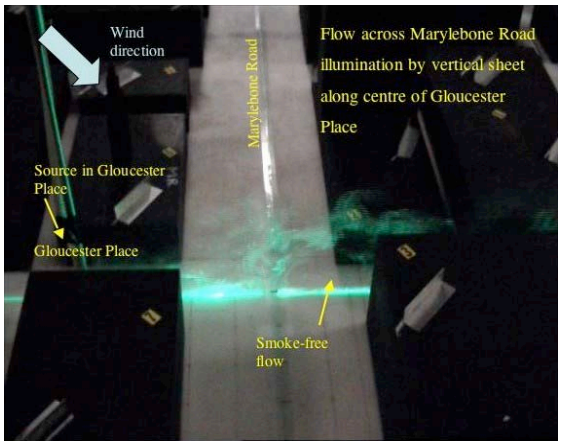




The figures illustrate the horizontal component of the flow at the intersection. The source is placed in Gloucester Place alongside Westminster CC Hall to inject smoke into the flow region of interest. At the height of illumination, 20mm, smoke in the region shown is confined mainly to the south side of Marylebone Road. An extensive, horizontal recirculation region is labelled in the upper picture, downstream from the junction on the south side of the road. Smoke can be seen 'upstream' from the junction on the south side of Marylebone Road, in the recirculation region in the wake of WCC Hall. Intermittent 'shear layer' vortices (see later) are apparent in the video of this flow and are associated with this 'upwind' transport.

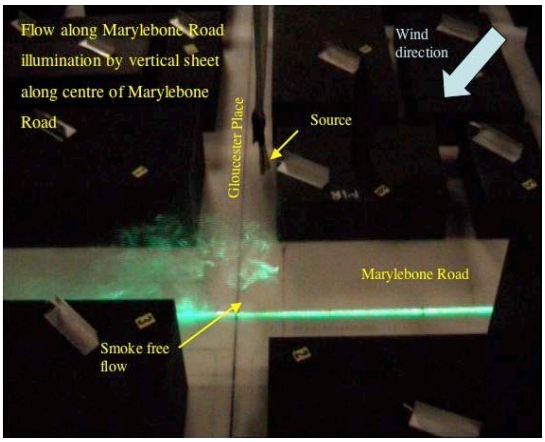
The following pictures show that significant vertical motions occur at the intersection on the north side of Marylebone Road. Vertical motion is also likely in the recirculation region and shear layer vortices mentioned above.

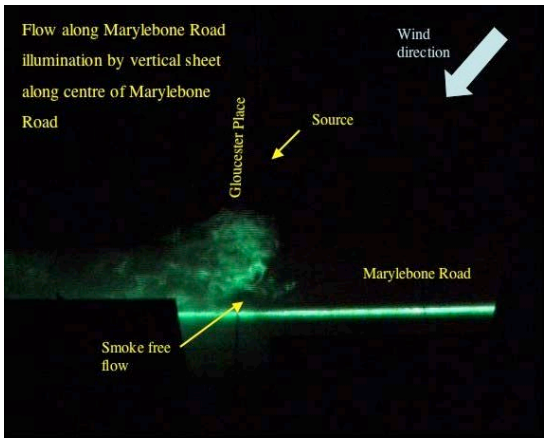




The smoke source is as before and a vertical light sheet is directed along the centre of Gloucester Place, from the south. Plume 'lift-off', illustrated here at about the centre of Marylebone Road, is frequently observed in the video recording from which these stills have been taken. There is a continuous flow of smoke into Gloucester Place north.

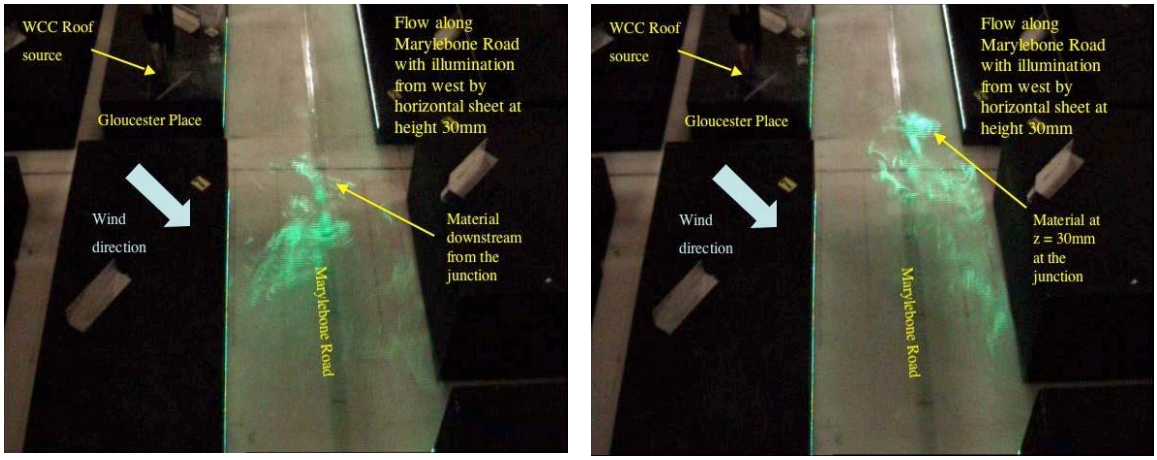
The images below were obtained with the vertical light sheet redirected along the centre of Marylebone Road, from the west. An elevated plume is again seen at the intersection, though its height appears to decrease as it is carried further 'downstream' along Marylebone Road. Again, the flow of smoke into Marylebone Road east is continuous.





Taken together, the three sets of images show smoke flow from Gloucester Place South into both Marylebone Road and Gloucester Place North, the exchange being associated with significant three dimensionality in the flow at the intersection.

A final piece of evidence comes from visualisation of dispersion from a source on the roof of WCC Hall and is illustrated in the following images.

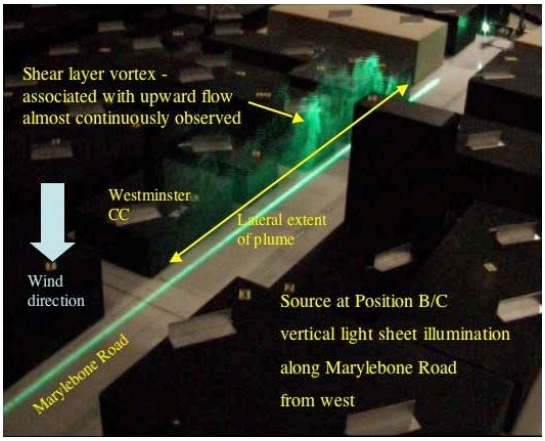


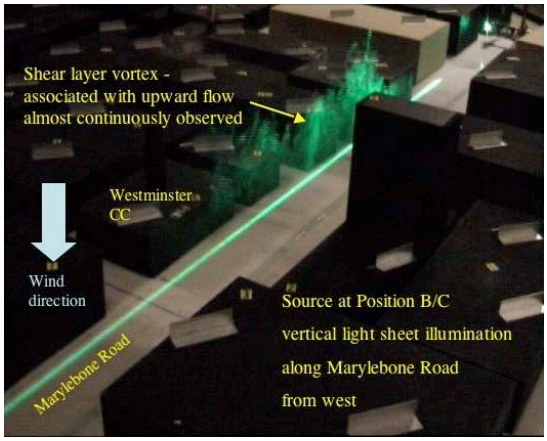
The roof-top source is located half-way along the Gloucester Place side of the building, half-way between the roof edge and the central tower. The light sheet is directed along Marylebone Road at a height of 30mm. At this level the distribution of smoke in the region shown above is highly variable. Overall, it is most likely to be seen in the central or northern part of the Road and not in the large recirculation region on the south side.

3.1 Discussion

Behaviour in the vicinity of the intersection is clearly very unsteady and involves flow from Gloucester Place displacing the (stronger) flow in Marylebone Road to the north side of the road. Typically, some of the flow leaving Gloucester Place is deflected directly into Marylebone Road (south side) and some appears to rise over the displaced flow on the north side of the road before in part entering Gloucester Place North and in part being deflected along Marylebone Road. Upstream of the intersection, in both Marylebone Road and Gloucester Place, the mean flows probably contain canyon vortex circulations, though of opposite senses and different strengths, and these circulations are likely to be quite quickly re-established downwind from the junction. This is probably the mechanism by which the roof level emission is brought to low levels in Marylebone Road.

The interaction of two unequal flows containing canyon vortices of opposite senses and different strengths is likely to lead to very complex, three dimensional conditions at the intersection. Additionally, vortices with approximately vertical axes can form in the shear layers separating from the building walls. Significant vertical transfer is likely to result, taking polluted air out of the street network (e.g. in the shear layer vortices) and entraining external air elsewhere. Good examples of ‘tight’ vertical vortices were not often seen in the visualisation around the Marylebone Road – Gloucester Place junction, though they were found elsewhere as the following images show. The vortex shown was more often than not observed at the intersection of Upper Montagu Street and Marylebone Road and was clearly associated with strong up-flow. That such vortices were not commonly observed at the main intersection might simply reflect the lighting arrangement used there, since in the case shown below the vertical light sheet was positioned along the south side of Marylebone Road.





Unsteadiness appears to be chiefly manifest as variations in the relative strength and extent of the features described, rather than changes between one pattern of flow and another. At any fixed location this might appear as flow direction 'switching', leading to a bimodal wind direction pdf, whereas another location might simply record a broad distribution of directions around a long-term mean.

In general, flow behaviour at an intersection will be sensitive to the relative strengths of the flow and circulation in the two streams approaching the intersection. These will reflect the geometry of, and the wind direction relative to the street network.

These deductions are based on the video records rather than the images included here that simply characterise them. Even so, considerable speculation is involved that needs to be reviewed and (most likely) revised as additional evidence becomes available. The aim of further work will be to use flow visualisation and anemometry to investigate the details of the flow in the vicinity of the intersection.