Brief MCMA Plume Analysis

Benjamin de Foy, MIT, 4 November 2004.

Background:

MM5 simulations were run for 3 nested domain with resolutions of 27, 9 and 3km based on the AVN global model. Particle trajectories were then calculated using Flexpart for multiple particles, taking into account vertical diffusion in the simulated boundary layer. Particle paths were converted to concentration fields by mapping the hourly trajectories to a grid (this is called residence time analysis). Conceptually, this is like overlaying hourly snapshots of a release of multiple particles and counting the particles in each grid cell. In order to highlight preferred impact areas (or source areas for back-trajectories), the concentration fields were then normalised with the concentration field that would result from uniform dispersion of a point source in all directions. The net result are plots identifying the areas that are more impacted by a plume but where the units are non-dimensional and the numbers meaningful in a relative sense.

MCMA Forward Plume:

100 particles are released every 6 hours over a 1 hour period with random starting locations within a rectangle roughly covering Mexico City for the duration of the MCMA-2003 Field Campaign (31 March – 5 May 2003). Figures 1 & 2 show the impact areas of this plume segregated by height above ground. Figure 1 shows the impact area in the surface layer (below 500m) and Figure 2 shows the impact above 2000m.

From Figure 1, it can be seen that the impact areas are:

- To the North, looping around the West of Sierra de Guadalupe
- To the South, passing through the Amecameca pass in the South-East and into the Cuautla valley to the South.

In the vertical, the situation is similar although the plume to the South passes more directly into the Ajusco mountain, and the plume to the North goes towards the North-East.

Figure 3 shows the same residence time analysis on the regional scale. From this, there is a clear component of transport to the SW and even stronger to the NE. Notice how particle trajectories are trapped on the side of the Sierra Madre Oriental by the sea breeze winds of the Gulf of Mexico. Looking at the individual particle tracks show that initially they are all vented from the Mexico City Basin at high altitude. The ones that remain high leave the domain very rapidly towards the ENE (by the predominant Westerlies), but some are brought down to the surface and leave much more slowly towards the North.

Back-trajectories for 2 possible downwind sites:

10 particles are released every 6 hours over a 1 hour period for 15-28 March 2004 for 2 sites:

San Miguel Topilejo (483.8 E, 2124.3 N, UTM Zone 14)

Cerro Gordo (518.25 E, 2184 N, UTM Zone 14)

Figures 4 & 5 show the residence time analysis for each site, for all vertical heights. Figure 4 shows that the air mass at Topilejo follows a path from the North along the West side of the basin before reaching the site. The air masses at Cerro Gordo on the other hand originate in the South and move up the East of the basin.

Discussion:

For high pollution days during MCMA-2003, there were two types of days: ones with the Ozone peak in the NW and ones with the Ozone peak in the South. The wind patterns in the basin are actually remarkably similar for these 2 types of episodes. The crucial difference is the timing of the wind shift from northerly to southerly (winds from the North to winds from the South). When this occurs in the mid-afternoon, the ozone peak is in the NW (these are the most severe days). When the shift is in the early evening the peak is in the South. In terms of the downflow site, the South is therefore a good place to see slightly aged particles in the early evening on days with a late wind shift. On the other days however, this will sample clean air from the SW. The NE would seem to be a good place to measure the more aged plume as it leaves the basin. One issue here however is that very strong vertical mixing leads to rather dilute plumes, and Cerro Gordo may be too low (altitude-wise) to see the plume. This can be seen by comparing Figures 1 and 2. With regard to Figure 3, episodes with early wind shifts have a clear movement of the airmass to the NE. The episodes with the later wind shift correspond to anticyclonic conditions on the synoptic scale with weak winds aloft. The air mass moves to the SW initially before being turned clockwise and back towards the NE.

There is substantial experience at CCA-UNAM (Dr. Telma Castro) on measurements at boundary sites. We should bear in mind that the analysis in this paper is entirely model based and should be ground-truthed with the existing field experience. In particular, there have not been any measurements at Cerro Gordo. Previous measurements at Teotihuacan nearby and at La Reforma, in the vicinity of Pachuca, have failed to detect high ozone levels and have seemed to be measuring air masses dominated by local sources.

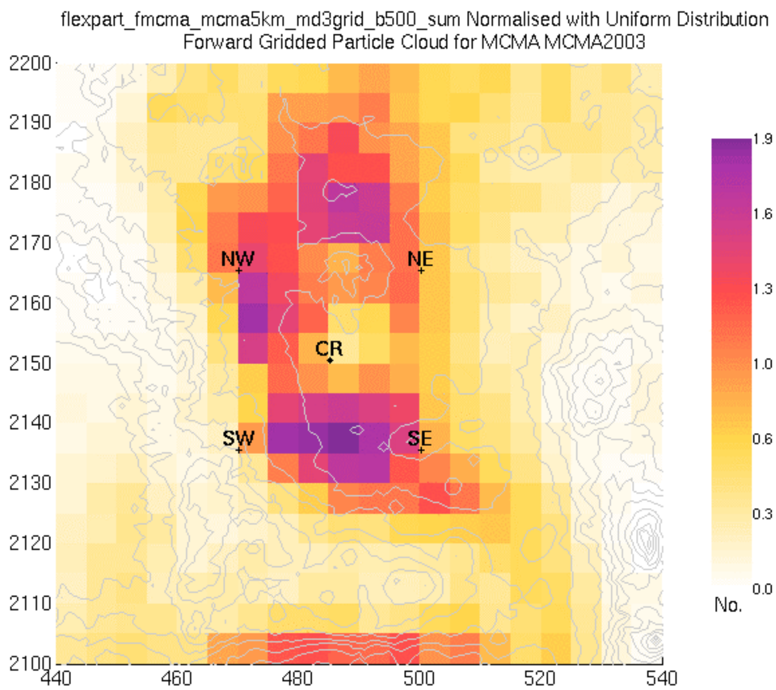

Figure 1. Residence time analysis for Forward Particle Trajectories for particles below 500m agl, showing venting to the North around the Sierra de Guadalupe and to the South through the pass at Amecameca.

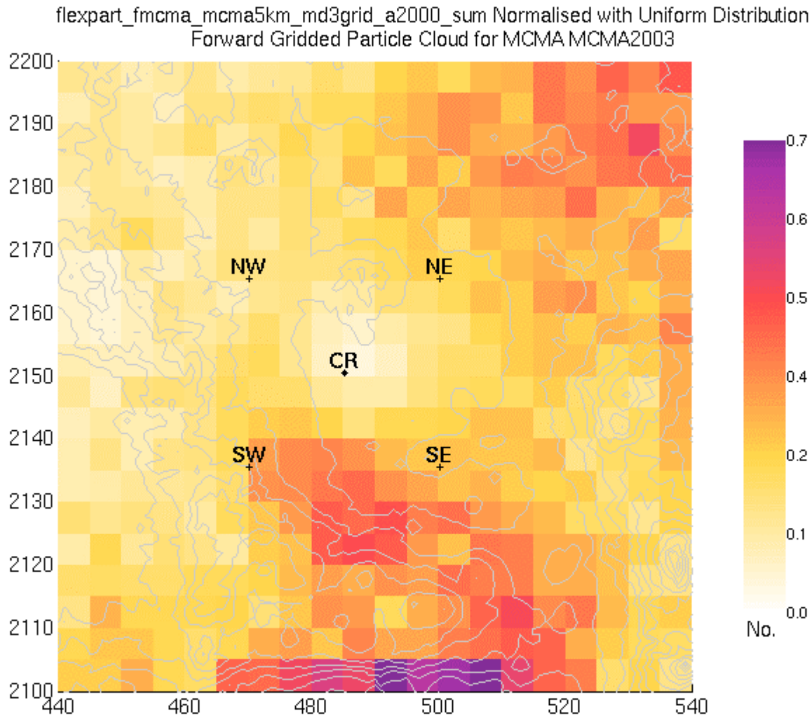

Figure 2. As for Figure 1, but only for particles above 2000m agl, showing venting to the South and to the North-East.

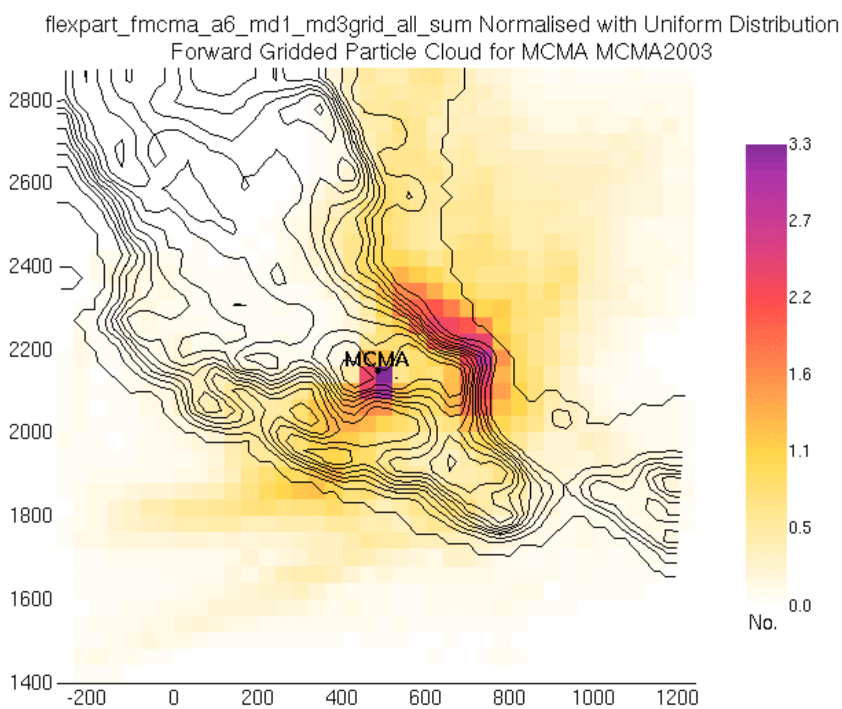

Figure 3. As for Figure 1, but on a larger scale and for all vertical positions. Shows some venting to the SW but mainly to the NE. Strong particle capture in the sea breeze of the Gulf of Mexico can be seen on the side of the Sierra Madre Oriental.

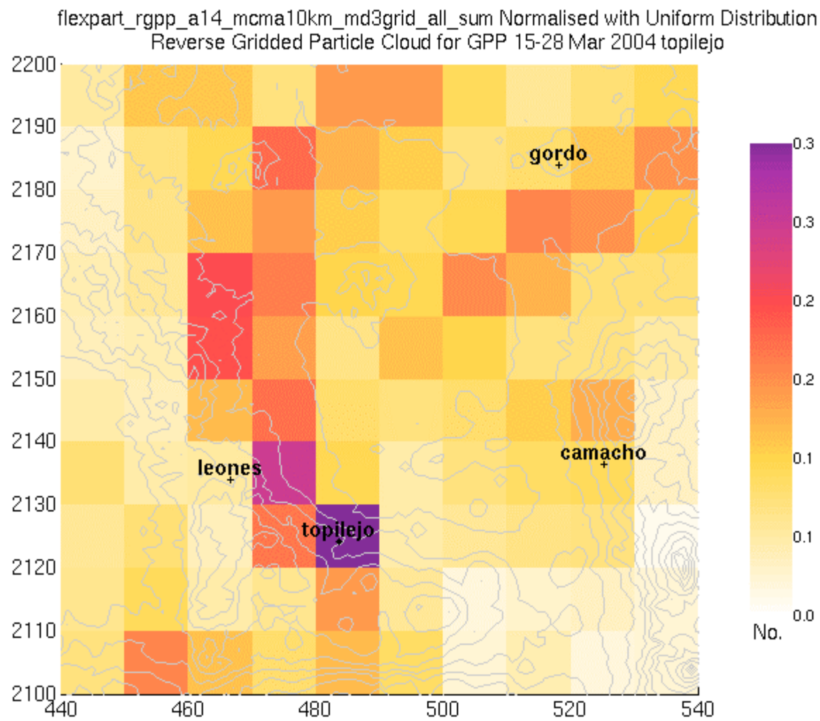

Figure 4. Residence Time Analysis for BackTrajectories from Topilejo. Shows influence from the NW with some urban plume.

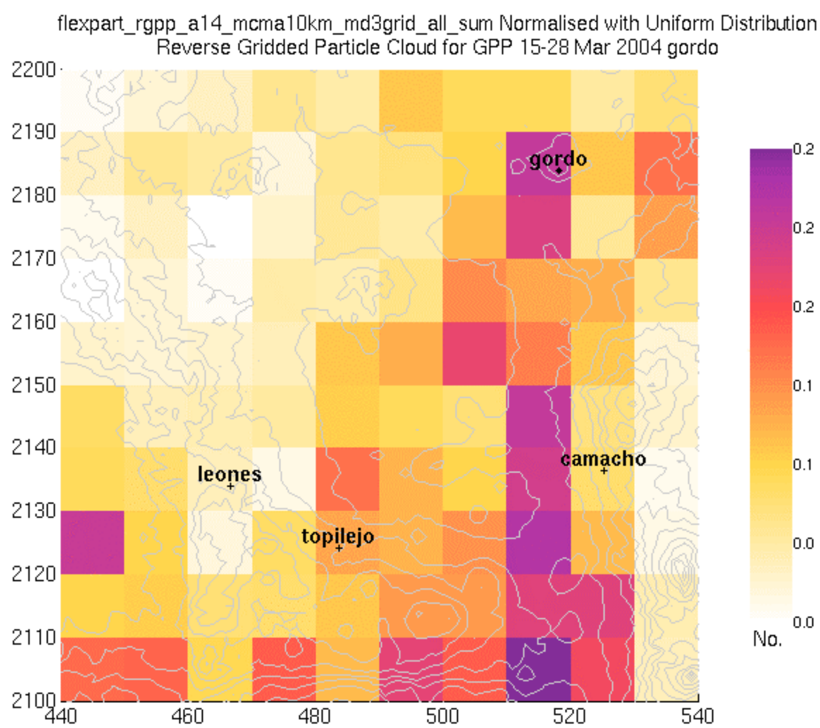

Figure 5. Residence Time Analysis for BackTrajectories from Cerro Gordo. Shows influence from the SE, with some urban plume.