In this section we will build up the single particle concentration calculation to use multiple particles, and we will keep increasing the particle number, until the simulation looks more realistic. If you are continuing from the previous section, your graphical user interface should already have been configured the way we need. But if not, retrieve the CONTROL file that you have saved, and the name list file. Once you've done that, open up the set up run menu and we're going to change the averaging time, mainly to reduce the number of output frames to make everything run a little bit faster, including the graphics. So go ahead and open up the grid menu and instead of putting out snapshots every hour, let's do it every three hours, so that we will have 4 output frames over the 12 hour simulation. Otherwise you can leave everything else the same. We will still look at this large layer, we will reduce that later on. Go ahead save, and save.

The next thing is we need to increase the particle number from one to 100, advanced, configuration, concentration, menu number four, so we change the 1 to 100. The maximum is just the number that you use to pre-allocate memory for the simulation. So we have sufficient memory to handle 10,000 particles. This number can be increased and the only limit to the number of particles in a simulation is how much memory you have in your computer. Save, and now run model, display, leave the defaults, and after three hours, we have a very small plume. The hundred particles are all in this domain, covering a few, just a few grid points, six hours later starting to spread it out, nine hours spread out even

further, but you can now start to see the individual particles, and finally at the end of the simulation, the hundred particles are almost individually visible. But you can't see the effect of what happens when the winds vary in height, transport particles in different directions.

Let’s go ahead and redo this, but now 1000 particles. Again menu number four, this becomes 1000, run model. After three hours it looks the same as the hundred particle simulation. Six hours, again it's very similar but it's starting to appear much smoother. Now at this point, at nine hours, you can only see the particles, individual particles at the edge, the central part of the plume is well-defined, and at 12 hours, again the central part is well defined, but the fringes, toward the end, individual particles are again evident. Now without saying, if we were to change the output from snapshot to three hour averages, much of this would be very smooth again. So there is a relationship between particle number, the grid cell size and the averaging time. The underlying issue is that you need to sample sufficient particles in your computational grid to get a realistic representation of the concentration patterns.

Let's go ahead and do this one more time, but this time we'll go to 10,000 particles. Notice it takes a little bit longer, because we're now following the trajectory of 10,000 particles rather than just 1000, 100, or one. And display, and you can see the first time, very smooth, second time the inner contours are very smooth, the third time period, again it's also very smooth, the edges are a

little rough, but still very it looks very good. And even at 12 hours, we get a very good pattern.

Now's as an experiment, let's go ahead and try one other thing. Let's reduce the size of the concentration grid. So go to set up run and grids. So instead of 5 km, let's make it a half a kilometer, .005° of latitude/longitude, and save.

Now this calculation, even though it is still using 10,000 particles, is much slower than the previous 10,000 particle calculation. The reason for this is that the time step, which you know is variable, and that depends upon the grid resolution. But is not just the grid resolution of the meteorological data, it is also the grid resolution of the concentration grid. So that a particle needs to intersect a concentration grid cell every time step as well as a meteorological grid cell. So by forcing a much smaller concentration grid, it forces the model to use a shorter time stamp to maintain the criteria that a particle cannot jump more than three quarters of a grid cell in one time step.

Let's exit and we're going to a display again. But this time before you click on execute, I would like you to unselect the contour drawing option. That is having this line around every grid cell, or every contour interval. By selecting none you will get much more distinct output here. Perhaps you should go ahead and leave to default and then you'll see why we want to select none, because all you would end up with is a lot of black.

Notice this also takes longer because there is more information to contour. So this is the first hour and everything still looks reasonable. And the second hour, now when we turned off the contour option, what we had previously, we would've had a black line for instance, drawn around this blue region to delineate that contour strength, as well as a black line drawn around the green region. But the problem when you get little cells here, is it would have black lines drawn around each one of these as well, and that can make the display, not only take longer, but it would then become a sea of black, in this particular configuration because the individual particles are again visible. So you can see how the concentration grid resolution can affect the quality of the product that you're getting. And this is quite evident at the end here where essentially these 10,000 particles are all distinctly visible. So this just reinforces the issue of grid resolution, time step, particle number, that is important to ensure that the model samples multiple particles per grid cell, per sampling interval. So a much larger sampling interval would've resulted in a smoother pattern. Remember this is a snapshot sample over one time step only.

So before we can close up this section, we should go ahead and save the configuration. So concentration, save as, let's keep it simple here, we'll call this cpart_control.txt, save, and in the advanced menu, for the name list, we will call this also cpart_setup.txt, save, save.

One last thing, let's go ahead and open the view message. I'd like to point out that we released 10,000 particles over

this first time step, and these 10,000 particles had a total mass of one, and that was maintained throughout the calculation. And you can see at the end of the simulation, the vertical mass distribution was such that most of the mass was below 3 km, and the bulk of it maybe below two kilometers.

So that concludes the multi particle simulation.