

Before continuing on with the air concentration calculation examples, we will take a look at the equations used for these calculations. The air concentration calculation is composed of particle trajectories. Each particle trajectory is then adjusted according to the turbulence. Remember when we talked about trajectories, simple trajectories, when we computed the advection term, we used the mean wind velocity that came from the meteorological data and multiplied that by the time step to obtain the position each time, over each time step. Well that position in reference to dispersion, we're going to refer to that here as the mean position vector. And in a manner similar to the mean trajectory calculation, we will add to that position, an offset, a turbulent offset in the position, which is composed of a turbulent velocity times a time step and that will give us the final turbulent adjusted position for that particle, for that particle trajectory. So instead of the trajectories following the mean wind, as they do in the pure trajectory calculation, the air concentration calculation, the trajectories, the particle trajectories have a random turbulent component that is added to the position each time step.

So the next step is how to compute this turbulent velocity. Well that turbulent velocity is composed of a, the terminal velocity at the next time step, which is what we're defining here, is composed of the turbulent velocity at the previous time step, times an auto-correlation function, that is R . What the auto-correlation says is, you know, if we have a certain turbulent velocity now, if we look a short time later, we would have very much the same turbulent velocity, so

that the auto-correlation is high. But if we were to look at a time much longer after the measurement time, then the correlation drops, and the turbulent velocities are no longer correlated.

And in addition to the auto-correlation component, we also add a random component, this U'' , to the turbulent velocity, this random component also is associated with the same auto-correlation function. And the auto-correlation function is computed from the time step and a turbulent velocity timescale, a Lagrangian timescale, which tells us over what time the auto-correlation is lost.

An example of that might be, you might be, you might be watching, for instance, the smoke coming out of a smoke stack, and if you can sort of picture this meandering smoke plume going downwind from this stack, you know at times it might be moving upward and then it might be moving downward. So when the turbulent velocity changes direction we're starting to lose the correlation. And the faster it changes direction, the shorter the Lagrangian times scale is here.

Now the, this component, the double prime component, which is a turbulent component generated, a random number generator turbulent component, comes from the random number generator in the computer. Where λ here is the random number, a Gaussian random number, generated by the computer. And that random number is multiplied by the statistical parameter, the standard

deviation of the turbulent velocity, in that component direction. These calculations are done individually for each of the three components, U, V, and W. This form of this equation is such that, for example, if you were to look at the fluctuations of an anemometer, let's say, and you were to compute the standard deviation of those fluctuations, that number would be what goes in into this. So that the standard deviation of the fluctuation is related to the standard deviation in that component direction, divided by the wind speed. If you were to create a time series of turbulent velocities, using the random number generator, multiplied by sigma U, that statistic, and you take that string of randomly generated turbulent velocities and then compute standard deviation, you would get that sigma U.

So the question is where we get the statistic, the standard deviation of the velocity component. Well that, it'll be some other sections later on, we will discuss how that is generated. But generally that statistic is determined from the mean gradients from the meteorological data. So for instance in the vertical direction you might be looking at the gradient of wind speed and temperature and there are equations that would parameterize those mean gradients and determine a stability or a mixing strength. And these equations we will review later on. The meteorological model may also generate the standard deviation or some kind of turbulent statistic directly as well and if it does we can use it.

Now there are two approaches to computing dispersion within HYSPLIT. One is the top hat approach and the

other is the particle approach, or, but there's a puff approach and then there's a particle approach. And the puff approach has two different methodologies. First, the difference in the terms of the particle approach, the default when you run HYSPLIT is to run the model as a 3-D particle model, so that means we are computing the turbulent offset to the particle trajectories, and we're just following particle trajectories, and the dispersal of those trajectory end points is a measure of the dispersion. So if you were to compute the horizontal standard deviation of the position of those particles, you will get the statistic, sigma H for the horizontal distribution. Of course again, this could be done in the component directions. The other approach is instead of modeling the individual particles and their dispersal, we can just model the standard deviation, we can model the statistic of the particle distribution - how does the particle distribution change with time? And this, for instance, is a very simple relationship, the change in the particle distribution, as it increases with time, is just related to the standard deviation of the turbulent velocity. And so, in this case, we modeled the change in the distribution, we modeled the change in the particle distribution as a function of time, rather than directly modeling the change in the particle positions. Which means that we can follow fewer particles in this approach.

And as I mentioned, there are two puff approaches. We call this the puff approach, when you model the particle distribution. We can model the distribution as a Gaussian or we can model it as a top hat. Top hat just means that if

we have a sampling point within our sampling grid, within this domain, the average concentration would be related to this number and it will always be the same, but outside of this domain, it would be zero. And in the Gaussian, of course, the concentration distribution follows the Gaussian form. The relationship between these two is such that the area below this redline, so this area underneath the Gaussian equals the area of that Gaussian above the red line.

So depending upon which approach is used, if we're computing 3-D particle dispersion, then the change in concentration over each let's say time step is going to be equal to the mass that's associated with each of the particles divided by the volume of the grid cell. In the top hat approach for a puff, it's something similar, that the change in concentration is the mass divided by the volume. But in this case it is not the volume of the grid cell, but it is the volume of the puff, so the area of the puff, πR^2 , times its depth, ΔZ . In this case it is the ΔZ of the puff not the ΔZ of the of the grid cell. And in the Gaussian approach, it is again very similar, except that this time we have the Gaussian exponential term that is added to this. Now these equations are simplified and if you want a more complete explanation of the calculations, that can be found in the HYSPLIT technical memo ARL- 224, which can be found in your hysplit4 directory under documents.

And this concludes the review of the air concentration calculation equations. In the next few sections I will go

step-by-step in building up the calculation.