In the next few sections we will learn how to configure HYSPLIT to do the dry deposition or wet deposition of gases and particles.   Starting with gases, the term dry deposition refers to the depletion of pollutant mass from gases and particles when they interact with the ground surface in the absence of rainfall.   Gases or particles within the surface layer, that layer closest to the ground, will lose mass at a rate proportional to the deposition velocity.   Particles but not gases, will also gravitationally settle toward the surface, where they then can be subject to dry deposition.   And as I mentioned before, all the calculations in this section are examples, because the tracer does not deposit.

We should start by rerunning the base case.   We're going to do the same thing as we did previous section for transformations. So perhaps let's do a reset so that we can all be on the same page, and then retrieve the captex_control and captex_setup files.   In this case I'm going to go to the tutorial files directory, where I know they exist. And as you recall we did the run for a shorter duration, therefore not as many particles are needed.   So we've reduced that number to 20,000.   And we did the simulation, we did the simulation for 25 hours, rather than 68.   So go ahead and do the run just to make sure we have a base simulation that we can compare the results to.

Let’s ensure that we get the right answer by doing a display, and as you recall, we convert to pico-grams. We will let it do it’s own contouring and execute.   We should have 8 frames with the last frame showing in maximum concentration of 9000 pg. The last thing I would recommend is let’s save the MESSAGE file and give it a unique name. Open the hysplit4/working directory and let's call this, rename this MESSAGE file to base, or maybe even nodep for no deposition, that would be better. And just to make sure, let’s take a look at it, and you can see that the end of the simulation, we still had 20,000 particles and 201 kg of mass, and within the lowest four layers, the surface layer, we had about 14, 15% of the mass in this region here.

So the next step is to configure the model for dry deposition of a gas, and as I mentioned, the deposition is parameterized through a deposition velocity. And this deposition velocity is defined as the deposition flux, this parameter, mass over area over time divided by the air concentration, mass over volume. So what that means is from the standpoint of the model calculation, the model predicted concentration is multiplied by the deposition velocity to obtain a mass flux, a deposition mass flux. And the deposition is only computed when the computational particle is within the surface layer. In terms of HYSPLIT, it's usually defined as the top of the second meteorological data level.

Now there are other removal processes that might be occurring, besides dry deposition, we will cover these in sequential order in the subsequent sections. But when we have multiple processes occurring, then we use this beta term, which is the velocity, the deposition velocity divided by the depth of the surface layer, to give us a time constant, inverse time constant, and we use that in conjunction with the exponential decay term to reduce the mass of the particle. If of course, similar to what we have done with transformations, if Beta is very small then you can just approximate it, you don't need to do the exponential. But when we add together multiple removal mechanisms at the same time, then really, it's pretty prudent to use this expression to compute the total deposition flux, which is then removed from the particle. And this brings up an interesting point, that it is not possible to separate out the dry deposition, the wet deposition, the different removal processes, as independent processes. They are all occurring at the same time. So if you were to do a simulation with only dry deposition and then do another simulation with only wet deposition, because you're interested in the partition between the two for various reasons. That result, it would not be accurate, if you were to add those two together after the computations have completed. That calculation needs to be done during the transport and dispersion phase.

Okay to configure the model for deposition, open up the concentration menu, in the deposition bar, and the first thing we need to do is actually tell the model, or defining another grid, so that the deposition results can be saved. So right now the only output is the air concentration grid that covers the one layer from the ground to 100 m. We need to define an additional vertical level, if you will, at 0 m. And this becomes the deposition output level. It has no depth, no vertical depth. And that’s where the deposition will be accumulated into that array element. And then the second array element would be the air concentration from zero to 100 m, from the ground to 100 m. That’s important. If you do not specify the zero level, the model will still compute deposition correctly, but it will not give you any deposition output. So the air concentrations would be reduced by the deposition, but you would just not be able to see it.

And the second thing is we need to define the deposition. But before we do that, let's save this deposition configuration, this two level case, because we will use it then to define other variations for deposition. So let’s do a save as here and let’s call this deposit_control.txt, we can do the same for the name list, although it's really not, really much different, call it deposit_setup.txt.

Now let's go back to the deposition menu. So now to configure the model for dry deposition, what we're going to do is explicitly define a deposition velocity. And this is the second line here in the CONTROL file, the deposition section of the CONTROL file. They are fast switches here to give you a quick configuration. For instance, define a particle or a gas, and let’s review that right now. So a gas is when the particle characteristics are all zero. And the particle characteristics are the diameter in micro-meters, the density in grams per cc, and the shape factor, which is how spherical a particle is. So these are just some default values, gasses are zero, so we are going to be doing a gas. Dry deposition, the second line, this line here is dry deposition. So it’s yes or no. There are two types of dry deposition. There’s a forced dry deposition where we tell the model explicitly what the dry deposition velocity is in meters per second, or we can let the model compute the dry deposition, by defining some different characteristics, that is the pollutants molecular weight, activity ratio, diffusivity ratio, and Henry's constant. Going into this is a little bit beyond the scope of the tutorial. If you go into the literature there are references to these parameters for different pollutants. If you look in the help file, that is discussed in a little more detail, in an addition to references are given. And you can read about what these different parameters do. But what happens is, once they're defined, HYSPLIT will look at the meteorological conditions at that point in space and time, and the land use, and using the equations as noted in the Technical Memorandum, it will compute a dry deposition velocity. But we're not going to go to that complexity, and we're just going to define a dry deposition velocity of 1 cm/s for this calculation.

The next line is for wet deposition, which we'll do in a subsequent session. This line defines a radioactive decay, and this line defines any pollutant resuspension, that is once a pollutant has deposited, what is the rate of resuspension into the atmosphere. We will discuss this in a subsequent section, when we talk about dust storms. So for now this is all that you need to do, we are not going to preconfigure anything. I should point out that this pre-configuration, if you would select particle, this particle definition gives you the same dry deposition velocity if you were to pre-define this as a gas as 0.6 cm per second. Like I said, for this case let’s assume 1 cm/s, which is actually a relatively large deposition velocity. Save, save, save, and then run model.

Let's take a look at the result, and now you can see there are two levels here, 0 and a 1000, 100, and we’re going to look at both. And we want to see the deposition layer and we want to see the air concentration. Also let's give the plot a different name, let’s just call it plot for dry deposition here. And we also need to define the multiplier for deposition, for the deposition flux field to get picograms.

Now we have some options with regard to this plotting here. Do we want a deposition plot? Do we want a deposition plot each time period, that is for every three hour sample we could get a total deposition of the three hours, or we could sum the deposition every three hours, or we can just get a total deposition, that is a sum but at the end of the simulation, and that's what we're going to do. Internally each time the model outputs air concentration, it also outputs the deposition, every three hours, we have no option to change them independently of each other. And then the deposition array gets zeroed out for accumulation in the next output period. However for many deposition applications, the interest is in the total deposition, not the change in deposition as a function of time, so this accumulation is done in the post processing. So either as a sum so that each three hour period would show the accumulation of that three hour period and all the previous three hour periods, or just the total at the end.

I think at this point we can click on display and you can see here the first is air concentration, for each three hours until we get to the end, and then the last frame is the total deposition. So let's go back just one frame, and if you recall with no deposition, the maximum concentration at the end of the simulation was 9000, it is now approximately 3000 picograms, and this results in the deposition pattern. So this essentially shows the track of the particles, the computational particles. And the total deposition appears to be quite large, but these are not per cubic meter, these are per square meter, so it's actually not that big a number: 15,000,000 pg/m^2. You can turn that into grams and you realize that it's not that large a number, 10^{12} pg per gram, which means that there's 10^{-5} g/m^2 being deposited for every square meter that was covered. So if you were to integrate the deposition over this entire domain, you will get some number, that if you look at the MESSAGE file for this simulation, would show you that at the end, we have 130,000 grams left, or it's about a little more than half was deposited, so about 70,000 grams was deposited over the area that the plume past. And if you do some arithmetic, you'll probably find that's consistent with the deposition patterns that were shown.

The other point if you look at the last four layers here, we're seeing 9, 11, maybe around 12% of the mass is now in the lowest four layers, whereas in the no deposition calculation about 15% of the mass was in the lower layers. So before we terminate this discussion, let’s rename the

MESSAGE file, so we can go back and look at that later on, and we'll just call it MESSAGE_dry.

And that terminates the discussion on gaseous dry deposition.