In section 15, we will examine how to configure HYSPLIT for radioactive pollutants. We will start with a hypothetical example to view the basic configuration and then we will examine a realistic simulation.

The computation of radioactive decay is handled very similar to the deposition approach, in that we define an inverse time constant that we apply in the exponential equation to reduce the mass of a particle. And for radioactive decay, this inverse time constant, has units of one over t, is simply the natural log of two divided by the half-life, the radioactive element half-life. Now the decay process from the perspective of the model, starts at the time the particle is released. This has several implications, the first being that you need to know the source term with respect to how that particular material decays. So in the way HYSPLIT is configured, if the decay starts when the particle is released, that means that the total fission inventory that you use for the emission has to be valid at that time. If it is an instantaneous release, that's not a problem. However, if it is a continuous release, your inventory, or the release rate if you will, will decline as a function of time as the material decays. So either the release rate needs to change was time to account for the decay, or the computation needs to be handled in a different way. The more complicated approach will be discussed in the next two sections. However in this section we will just use this simple approach, where the decay starts at the time of the particle release. The issue of decay with respect to the emission inventory is not going to be so much of an issue for radioactive pollutants that have a very long half-life. For those pollutants that have a very short half-life this could be quite a significant issue.

The other computational point that I need to make is that the decay process within the model occurs for the particle during transport and it also occurs for the particles that have been deposited. That is, the mass in the deposition array as it accumulates as a function of time will also be decayed. However this decay process stops as soon as the output file is written and the output file gets updated as the model runs, as each sampling time period is completed the output is updated. And then the decay for what has been written into the file, of course, also terminates. So this is another complication that is not dealt with in the approach that we're looking at here, this hypothetical approach to radioactive decay. Again in the next section we will address these issues. So for now we just want to take a look at how could we set up a simple hypothetical computation using radioactive decay.

So start by pressing the reset button, we’re not sure where we came from here. And we will go back and redo this CAPTEX case that we used for the other deposition examples, so that you have a reference point. So go ahead and retrieve the CAPTEX CONTROL and name list files. And since we cleaned up, it's not in that working directory, so we need to find it in the tutorial directory under captex.

And what we’re going to do is we're going to assume that we’re going make some numbers up that are sort of realistic, and we’re going to assume that we have a 3000 MW reactor that's been running for year which created about 10^{17} Bq of Cesium-137, and naturally many other fission products, and we’re going to assume that 10% of that cesium is going to be released in the accident over a one hour period.   So keeping with the limitations of doing a radiological calculation using this methodology, we're using a very long half-life product, and we're looking at just a short-term release.

So open up the menu and as you recall we, the other deposition cases were only run for 25 hours, to give us 8 three hour samples and then open up the source menu of the pollutant menu and let's define the pollutant as C137 and we're going to release 10% of 1×10^{17} or one E+16 and we're only going to release it for one hour.

Let's take a look at the concentration grid and let's give it a unique name like C137 and we should define a deposition layer, so we can see the deposition output.   And then lastly we should open up the deposition menu, and we can use the switch, the button to pre-populate the menu for cesium, and its defining a particle, we're not giving it any particular particle characteristics, but we can override that by defining a dry deposition and settling velocity of a tenth of a cm/s. So it is relatively small and we do define this wet deposition for particles, same value we were using before, and in this case we define the radioactive half-life as for Cesium-137 as 10,960 days.   So the half-life is defined in days.   Now those are really all the changes that are needed and we can go ahead and now run the model.

Now while that is running, let me point out that the next step is we want to convert air concentration to health effects, that is dose. And to determine how the radioactive dose relates to health effects, there are publications available from government agencies, most of them from the Nuclear Regulatory Commission, that describes different health effects that can, that will occur with different doses. So I would point you to that for more information. But more important, we also have a website, in this case related to the EPA, where we can get dose conversion factors, that is we want to convert air concentration to dose.

Now dose is a measure of the impact of the decay products on human tissue and it varies according to the radionuclide, some radionuclides are more dangerous than others, and it accounts for different, different radionuclides have different decay modes, it could be alpha, beta, or gamma decay. Each would have different effects on health and of course how they're ingested, or whether you're sitting in this cloud of radioactive gas or particles. So these things are accounted for and you can look up, there are tables, and if you go to these websites, and download the information, you would find that for cesium 137, for the airborne particle of plume, the dose conversion factor is 3.4×10^{-11} REM per becquerel per cubic meter. They are different radiological units that are used. For instance the source we described in terms of becquerel, the HYSPLIT output will be in terms of becquerel per cubic meter. Source terms may also be described in terms of Curies. The dose is described in terms of REM, but international units and some organizations will describe dose in Sieverts. This is all beyond the scope of the discussion here, but the point is you can, there are conversion factors to go between these different units. And the other conversion factor you need is for the dose, I'm sorry for the deposited material. And the deposited material again will give you REMS per hour per, in this case becquerel per square meter. So we have really two different conversion factors that we need to account for.

So in this simplified HYSPLIT simulation, now that is completed, we can go to the menu, the display menu, and we will select both the deposition level and the zero to hundred meter level, and we will look at, the multiplier now is going to become the, is going to become the dose, the dose conversion factor. So for instance, for this number. I'm sorry for what we're doing here is taking the 1.1 for the deposited material, so this is REM per hour and we want to look at a dose over the full 24 hour simulation, because the material like it's deposited doesn't go away, it just stays on the ground. So if each, if you're occupying a grid cell that has deposition, that deposition continues as long as you, that dose continues as long as you occupy that grid cell. So the 1.1×10^{-12} REM per hour times 24 hours, would give us a dose conversion factor for a 24 hour dose of 2.6E-11. And for the air concentration, well the plume just moves by, and so your concentration will only, or the dose is only going to be for a three hour period. This is three hour output and as you recall, the number was 3.4×10^{11} REM per hour per Bq per cubic meter. So we take that number and multiply by three to get us a three-hour dose, so that would be approximately 1 E-10.

And we can execute this but I'm not going to, well let's do this now. So let's fix the contours, so do not do dynamic, it means that the colors are fixed from frame to frame. So we can see the color not changing, but the values will change. And take a look at the just for a moment, but we need to fix up the labels. So let's fix the labels and we can do that by going back here, and file edit, border labels, and we can turn this into cesium, and call this, say dose equivalent, and let's get rid of the average, and mass units will be REM, and there is no volume involved, and do other information either. Now save, and now let's go ahead and execute display.

So let's go ahead and look at these numbers here, so the peak as we go away from the source, you can see it's really a micro REM, if you will. It's almost like the peak value when we started out was a micro REM and it just gets lower, and the last frame shows two micrograms as the peak here near the source, obviously the closer you are to the source, the higher the values. To put that in perspective, typically humans are exposed to cosmic radiation on the order of a 10th to one REM per year. So that the one REM is a kind of a number that's used as the maximum annual exposure that the population, may, should be, exposed to. So if you are numbers above one REM then it starts to get serious. I think for radiation workers the limit is a little higher.

So this one micro REM is really a small number and of course from the standpoint of dose the air concentration went away, blows away, and the only thing you would have to worry about is that if you were staying in this location here. So if you were to be exposed to 1 micro REM per day, you would have to be there for 1 million days to get a REM. And you could do that calculation, by changing the, multiplying by 8760 rather than 24, okay, we multiply by the dose conversion factor by 24 and that number would be the 9.6, right, so it would be 365 time larger. So this number, here, would be changed to $9.6x10^{-9}$. And now we would get, we would get the dose in, for a year. This is now the annual dose and you can see the high-value near the source is on the order of 1 milli-REM. So again you would have to be here 1000 years, but of course the half-life is 10,000 days. So it's not, so this whole calculation is not quite as accurate as it could be, but it gives you order of magnitude sense of the problem involved.

So before we close this you should go ahead and save the configuration because we will use it later on and go ahead and setup and save as and I would suggest you call it conc_decay_control and I don’t think we actually changed anything here from the CAPTEX case but you might as well save it anyway.

And so that is how you would configure HYSPLIT in a very simple radiological decay case. And as I said this is not that realistic, because of the issues with short half-life products, and the assumptions that need to be made when running the model, and how the output is treated, with respect to the deposition values that are not decayed after they're written to the output file. So we will review these issues and show you how to configure HYSPLIT in very, much more realistic manner for radiological simulations in the next two sections.

This concludes the basic radioactive decay and dose section.