Exam FYS-3003

Assignment 1

Task 1)

The first task ask’s us, to make functions that calculates the altitude variation of the atmospheric scale height.

Okey, so to start of we need to know what scale height is. Scale height tells us the vertical distance where the density and pressure fall by a factor of 1/e. We can obtain the scale height, we can imagen a slab of air, and use Newtons first law and the ideal gas law.

We see from the equation here, that the scale height is defined with the gravitational acceleration. Which we know, varies as we move away from Earth and we can define it as this.

And we obtain the following plot shown here, we can confirm that this looks correct, since if take a extra look at the equation for the scale height, we see that the scale height is smaller for heavier atoms and molecules.

Task 2)

Now we gone use the barometric equation as defined here, to calculate the atmospheric pressure variation.

This gives the following plot. Here we see that at lower altitudes, where the air is warmer the pressure is decreasing. When we get higher up the temperature is getting colder and the pressure will increase.

Task 3)

Now we gone compare the pressure profile with the ideal gas law.

In the ideal gas law, we use that the density is varying with altitude.

From the plot here we see that the ideal gas law is a pretty good approximation for the pressure variation in the atmosphere.

Task 4)

In the last task, we are asked to check the temperature-gradient for regions of instability to convective instability.

We execute this by checking if there’s any altitudes where the temperature is decreasing faster than the adiabatic laps-rate.

The adiabatic laps-rate tells us the rate at which the temperature of an air parcel changes in response to compression or expansion associated with altitude change, without any exchange of heat to the surroundings. And we have it defined as.

To calculate the temperature-gradient, we just divide the temperature and height difference. As shown here.

As we can see from the plot, the graph for the temperature gradient is not crossing over the adiabatic laps rate, which means that the atmosphere is stable.

Assignment 2

Task 1)

(Slide 1) The main task, in task 1. Is to calculate and plot the optical depth. But I also provide plots for the variation of the densities and plot the wave-length variation of the photo-absorption cross-section.

In the first plot here to the left, we have the absorption cross-section as function of the wavelength. We know that the absorption cross-section is strongly varying with the wavelength, which comes clear by look at the plot. This makes sense, since the absorption cross-section describes the probability for a photon be absorbed, when traveling through a molecule or a atom at a specific wavelength multiplied with the average cross-section of the molecules.

In the plot to the right here, we have the density with altitude variation. We see that for molecular nitrogen and molecular oxygen have higher density than atomic oxygen at lower heights and the density gets lower for molecular nitrogen and oxygen when the height increases, where we see that the atomic oxygen dominates. This makes sense since at lower altitudes (under 100km), we have less effects from the sun and also the pressure is lower. This leads to more collisions at lower altitudes. Also a lot of the heigh energy radiation form the sun is mostly absorbed down to this point, which means that the atoms can combine freely. That’s also the reason for atomic oxygen density, fully disappear at around 85km. At higher altitudes the radiation from the sun is higher, which keeps splitting recombing the molecules. Hence the radiation from the sun keeps atomic oxygen to recombine, making the atomic oxygen dominant.

(Slide 2) Now we go forward and plot the optical depth.

We have the optical depth defined as. This equation is only valid when, we have that the solar zenith angle is from zero to nineteen degrees, if we have bigger angles the equation becomes slightly more complicated.

The black line in the plot, shows the unit optical depth. And is where the optical depth equals one. This makes it easier for us, to see how the optical depth is varying.

From what the equation tells us, we should see that the optical depth is increasing, when the solar zenith angle is increasing. Which comes true by looking at the plots here. Which also makes sense if we think of the geometry for the solar zenith angle.

(Slide 3) If we increase our start altitude where we start out measurements (z\_0), the optical depth is lower. As we can see from the plot here, comes true. When the start altitude is set to 100km.

Task 2)

Now that we have calculated the optical depth we can go forward and calculate the photon-flux.

We have that the photon-flux is defined as. And as the name states, the photon-flux describes the number of photons fluxing through some given area.

In the plots here, we have also included the unit optical depth line. We see that by increasing the solar zenith angle from 0 to 90 degrees, we get a strong increase in the unit optical depth with is predicted. We also see that when increasing the solar zenith angle, the emission line stops higher up. As predicted, since the photons will go through more particles, hence more of the incident photons gets absorbed when the solar zenith angle is bigger than zero.

Assignment 3

Photo ionization (theory))

(Slide 1) So, before we gone look at the plots, I gone go through some theory.

Photoionization is main process that produces the ionosphere. The ions are produced when a heigh energetic photon, strikes a particle and has enough energy to rip-off an electron.

Here we have the photo ionization reaction equations, for the three major species which also includes the threshold wavelength. The threshold wavelength is the maximum wavelength that an incoming photon can have to cause photo ionization, at any higher frequency and the photon is not energetic enough to cause any photo ionization event.

If we have more energy that is necessary, to cause photo ionization. That energy will go into photo-electron. The energy of photo-electron is given by this equation. We are also interested in the production rate of the photo-electron as a function of their energy. Which we do by using the equation here. Where we have ignored the branching ratio, since it’s will be equal to one. Then we check the amount of energy that is left over after the photo-ionization, and we use the left over energy to calculate the production rate of photo-electron.

We have the number of photo ionization events defined as, which only yields for one single species. To get the total photo ionization rate, we just add up all the photo ionization events.

Task 1)

(Slide 1) In the first plots here, we can see that when we approach a higher altitude, the photo-electron production rate becomes increasingly similar, although having different solar zenith angles. This makes sense, since the photons will effect the same value of particles in the upper atmosphere when we have different solar zenith angles. But when the altitude becomes smaller, more of the photons with large solar zenith angles be absorbed more by particles on the way down.

(Slide 2) Here we have plotted the data as a color mesh image. We see that the production-rate stops at approximately 130km, this is because most of the high energy photons, are mostly absorbed to this point. Also by looking at the plots, we see that we have the biggest production rate where the atmosphere starts to get denser. We also see that the production-rate becomes lower as the solar zenith angle grows bigger. Which comes from what we stated, in the previous slide.

Task 2)

(Slide 1) Here we can see that, we have the biggest photo ionization production rate, when the solar zenith angle is zero. Which as stated in previous slide, comes from geometry of the propagation of the photons in the atmosphere and how they get absorbed.

(Slide 2) To get more accurate prediction of the ionization rate and how it varies with the solar zenith angle. We can use the Chapman profile. The Chapman profile is the theoretical result we get from deriving an equation for the photo ionization profiles.

By comparing out ionization rate with the theoretical Chapman profile, we see that they are pretty similar, beside that we have some deviation between the plots for when the solar-zenith angle is 75 degrees.

Assignment 4

Theory)

First, we gone look at the table shown here.

The dissociative recombination is one of the most important chemical reactions that takes place in the D, E and F-region. The process involves that a molecular ion recombines with an electron. This forms a highly energetic and unstable neutral molecule. As a result of this the neutral molecule dissociates.

Then we have the rearrangement process, which is that ions and neutral species react to form a new product, or there is charge transfer.

And at last we have the radiative recombination, is where we have a recombination process which release energy as electromagnetic radiation.

Task 1)

(Slide 1)

We have that our continuity equation for an ion species formed, defined as. As we can see, I also neglect the transport term.

From the task we are given the production of molecular nitrogen ion, which we redefine to obtain the production for molecular oxygen and atomic oxygen ion.

Now we can move to loss term in the equation. We calculate this part, by using the table form the previous slide and see where the different species is lost in the reaction. Here I show how we do this, for molecular nitrogen ion.

Than we can put in what we found for the production and the loss term into the continuity equation. And we end up with the following coupled ODEs.

(Slide 2) Now we can go forward and solve our coupled ODEs, by using a excellent package from SciPy which gone solve the equations for us.

And we end up with the plots shown here, for the ion densities at different altitudes. We see that in the plot with lowest altitude, is where the different species have the highest density. This makes sense since that’s where we have the biggest ion production.

We also see in the first plot that the molecular oxygen and molecular nitrogen oxygen ion, is the dominant species at low altitude. And as the altitude increases, atomic oxygen ion is getting dominant.

(Slide 3) I have also included a plot for the charge conservation, to show that the charge is approximately zero. The deviation here, may occur from some rounding’s in the calculations.

The plot here shows the reaction rates, at different altitude. To show which reaction rates, that will dominate as the altitude increases.

Task 2)

We see in the plots here, as the ion pulse is switched of, all the density for the individual species falls rapidly. This comes from that as the ion pulse is switched of we can’t continue to have a production of ions maintaining the ion density. From this it’s follows that the ions species will undergo the processes of rearrangement and recombination.

For example, we see that at the lowest altitude molecular nitrogen ion falls rapidly in density, as the ion-pulse is switched off and can maintain the density. So the molecular ion will exchange charge with molecular oxygen to form an molecular oxygen ion by the reaction (9) in the table shown below here.

Task 3)

And we obtain the following plots. Here we can see that the reactions is effect by this temperature change, specially the ions containing reactions where the temperature is defined.

As the temperature increases at first by 1000k the loos of density with time becomes little bit less, and as the temperature is even more increased the density loos over time becomes even more slow. This means that the reaction rates become slower as the temperature is increasing.

Task 4)

(Slide 1) By using the beta-model, the decay of electron density follows a exponential pattern. This model suggest that the loss rate of electrons is proportional to the electrons density itself. Here we have the beta-decay and the decay parameter

The alphadevay on the other hand, says that the loss rate is proportional to the square of the electron density.

(Slide 2) From the previous plots we saw that in the E-region the species was more effected by recombination, and here we see that the electron loss rate is proportional to the square of the electron density.

In the F-region however, we saw that charge rearrangement reactions was dominant, and the loss rate of the electrons as we can see here is proportional to the electron density itself.

So beta-decay is a better model in the F-region and the alpha-decay is a batter model in the E-region.

Task 5)

As we can see from the plots here. If the ionization source is sinusoidal or periodic, then the atmospheric densities also vary periodically. However, once the ionization source is switched off, there is no periodicity in the decay of the atmospheric densities. This is interesting since, the periodic variation of the ions and electrons can affect the behavior of plasma in the ionosphere.

EISCAT Experiment:

UHF)

In the electron density plot, we have the highest electron density in the F2-region. Also the F2 peaks occurs often around 250-300km, which is pretty evident here.

In the electron temperature plot, we see that where the high electron density was in the F2-region, is where the temperature is at is lowest. Which is predicted, since a increase in electron density often leads to a decrease in electron temperature.

In the ion temperature plot, we have that the temperature is somewhat lower than the electron temperature.

And if we look at the ion velocity plot, the ions do not have any heigh velocities. Which is predicted when they have low temperature.

VHF)

In the electron density plot, we can see that we have some abnormalities in the E-region, with some high peaks for the electron density.

As mentioned in the previous slide, when we have high electron density this often leads to lower temperature in that region. We see that for the abnormalities, we had in the electron density plot. We have some lower peaks of electron temperature at around 200km.

In the plot for the ion temperature, we can see that we have ion with high temperature, in both the F1- and F2-region. That have so and say the same location as the high electron temperature peaks.

In the ion velocity plot, we see that where the high temperature peaks were. We have low velocity, but we also have some ions with great velocity.