

Summer School Lab Activities

Lab #9: Exploring the structure of the Ionosphere

Introduction

In this lab we will compare the global structure of the ionosphere by looking at a solar minimum case, a solar maximum case and a storm case.

The goals for this lab are:

- understand the structure of the ionosphere over the surface of the globe.
- understand how the ionosphere evolves during the day
- understand how the ionosphere is disturbed during a storm

Getting Started

This lab uses the IDL visualization package to explore the results of an ionospheric model called the Thermosphere- Ionosphere-Electrodynamics General Circulation Model (TIEGCM). To start the lab change into the lab9 directory.

- To start IDL type “**idl**” at the prompt. You should get an IDL prompt that looks like “IDL>”.
- In IDL, modules can be written and compiled to run in IDL. Such a module has been created for this lab and is run by entering the command “**tgcmproc**”.
- A small window with that name should appear with three menus at the top.
- In the **File** menu, select **Open...** and then select the *min_pyr02178.nc* file and click **OK** (ignore any error message that is generated).
- Now from the **Plot** menu, select **Maps...** A Maps window will open.
- In the Maps window, click on the **PlotOptions** menu and select the **Continents -> Black** option. This will display a black outline of the continents on the map as a reference.

Exploring the Image

The map you see is a density map with the position defined by latitude and local time relative to Greenwich Mean Time. The colors displayed depend on the value of the field chosen. Keep in mind that what is displayed is a slice through a simulation volume. The slice viewed is set by choosing the relative pressure or scale height. To see how this corresponds to altitude select the “**Z**” option from the **Field** menu at the top of the window. This shows the height of a constant pressure surface on the map. The relative pressure is selected using the right hand slider near the top of the window. Move that slider so that *log pressure levels* is set to 2. The altitude for this constant pressure surface should be between 269 and 285 KM (see the color bar at the bottom of the window). This is roughly the height of the F2 peak.

Exploring the Electron Density at Solar Min and Solar Max

From the Field menu, choose the NE (the number of electrons per cubic centimeter). The image is displayed on a log scale. To better resolve the structure change to a linear scale by going to the **PlotOptions** menu, selecting the “**Plot log10 of field**” pull down and selecting the “**Plot linear**” option. Examine the structure of the electron density.

1. **What is the maximum electron density?**

2. **At about what local time does this occur?**
3. **What is the minimum electron density?**
4. **At about what local time does this occur?**

5. **Why do the maxima and minima occur at these local times?**

Now open a new terminal window, switch to the lab 9 directory, start idl again and type “tgcproc” to start another instance of the program. This time load the max_pyr02178.nc data file and open the map. Use the same options as used for the solar minimum case and compare the two images. Be sure to look at the color scale on the bottom! You can use the “*Custom Contour*” feature on **PlotOptions** menu to set your own maximum and minimum color values. Some suggested values are:

for the solar minimum case: min -> 5.e4, max ->1.e6, and interval -> 1e5

for the solar maximum case: min -> 1.e5, max ->3.e6, and interval -> 2.e5

N.B. Notice that the two scales are not the same so the color map on each map is different.

The structure of the ionosphere as a function of position on the Earth.

Now use the ModelTime menu to explore how the electron density changes as the earth rotates. In this menu you will find a list of simulation results at hour intervals in Universal Time (UT). Look at 4 snap shots at 6 hour intervals In your notebook, make a table and record the value and location of the maximum and minimum electron densities for both the solar minimum and solar maximum case.

1. **Do you see a pattern how the electron density evolves? Use the other snapshots the help describe the changes you see.**
2. **What is the difference between the solar minimum and solar maximum case?**
3. **Can you explain the changes you see? How would you verify your explanation?**

Exploring the Electron Density During a Geomagnetic Storm

Open file from the solar maximum case: in the original window goto **File -> Open...** and choose *max_pyr_storm_02178.nc*. (If you replace the solar minimum case you can compare the solar max to the storm time case). Follow the instructions at the beginning to adjust the plot settings. Now observe the changes in the position of the maximum and minimum electron density. The storm last 10 hours from 1000 UT to 2000 UT. Start by looking at 1800 UT on day 178.

1. **Is the pattern different from the way that it is during quiet geomagnetic times? If it is different, characterize the changes.**
2. **Has the pattern revert to its quiet time state at the end of the main phase of the geomagnetic storm?**
3. **Is it similar to its quiet state 12 hours after the end of the storm (day 179 0600 UT)? After 24 hours (day 179 1800 UT)?**
4. **If it has not returned to its quiet state immediately after the storm has ended, why not?**
5. **Do you expect the results to be similar in the northern and southern hemisphere? Are they? Explain?**

Other Thermospheric Fields

The term “ionosphere” refers to the only the plasma components (ions and electrons) in the

Earth's upper atmosphere while the term "thermosphere" refers to the neutral species. As you can see from the fields menu, many other variables are included in the model including all of the relevant neutral atoms and ion species and their associated temperatures. Let's start by looking at the neutral temperature both the solar max and solar max storm case. Use the "Field" menu on each map to choose the TN field (for "temperature of neutrals"). You may want to use the "Costume Contour" option on the PlotOptions menu to set the maximum and minimum values of the color map (set: **min->800, max-> 1800, interval -> 150**).

- 1. Start with 0000 UT on either map (they should be the same before the storm) and describe the neutral temperature pattern.**
- 2. Now select 18 UT for both maps and compare. Reset scales to**
- 3. Have the temperatures changed?**
- 4. Is the shape of the pattern different?**
- 5. What do you think has happened?**

Now let's look at the amount of atomic (neutral) oxygen in this layer of the thermosphere during a storm (max_pyr02178_storm.nc). From the "Field" menu choose O1. This field represents the Mass Mixing Ratio (MMR), which is the ratio of the mass density of atomic oxygen to the total mass density. Choose a linear plot [**PlotOptions -> Plot linear**] and set the scales (**min -> 0.0, max -> 1, interval -> 0.05**)

- 1. Compare O1 at 0 UT on day 178 with O1 at 18 UT on this date. How has it changed? Why has it changed?**

We can also look at the vertical component of the wind velocity ("W" from the Field Menu).

- 2. Again, compare quiet time to storm time. (Be sure the check the scales when you do that!)**

Vertical Structure of the Ionosphere

Let's now look at the layer structure of the ionosphere during a quiet time for solar max. We will mainly be exploring the F region at about 400 km and the E region from 100- 130 km.

- In the original (small) window that has a file menu upper right hand corner, use the file menu to choose the max_pyr02178.nc file if it has not been chosen already.
 - Under the "Plot" menu, choose "Lon Slice..." which will display a longitudinal slice through the atmosphere. A window will open with scale height (log of pressure) on the vertical axis and latitude on the horizontal axis. Thus, this plot shows a slice vertical slice through the atmosphere from one pole to the other pole. Notice that the right side of the plot has the average height for the associated scale height.
 - Again, choose "NE" from the "Field" menu to look at the electron density variations with height and latitude.
 - Check the right slider at the top of the window to make sure it is set to 12.00 Local Time.
- 1. Identify the approximate altitude of the F2 region. Also identify regions of auroral precipitation.**
 - 2. Is it summer or winter in the Northern Hemisphere? What is your evidence? (What features of the electron density tell you this?)**

Fix the Custom Contour [**PlotOptions->Custom Contour**] so the minimum is 4.0, the maximum is 6.0, and the interval is 0.25.

Use the slider to vary the “Local Time” in two hour increments to explore changes in electron density with local time. (Note that changing “Local Time” is changing the longitude of the slice and those changing. To change the actual universal time for a fixed longitude, you can use the Model Time, though global pattern is the same.)

- 3. Does the F region persist during the night?**
- 4. Does the E region persist during the night?**
- 5. Can you identify sunset? Does it occur at the same time at all latitudes?**