

Simple Comparative Ionospheres Using the Chapman Layer Model

Introduction

This activity will allow you to explore ionospheric parameters that are accounted for in the Chapman Layer model. The application will allow you to adjust the model parameters and see how these effect the height and density of the ionospheric layer.

Goals:

Chapman Layers

Before you begin, consider the following

- *What parameters of the neutral atmosphere are important for modeling the ionosphere? How will these effect the altitude of the ionospheric layer and its peak density?*
- *What are the important parameters that change when a planet is further from the Sun? How will these effect the altitude of the ionospheric layer and its peak density?*
- *What are the layers in the Earth's ionosphere? How might these be accounted for in a simple model?*

Discuss these in your group and be prepared to talk about them with the other groups.

Getting Started

Go to this link and click on it [Insert Link Here]. The web page opens up and there are several links. The top most links are to pages that contain tables of parameters for different planets. The final link opens a page that allows you to explore a Chapman ionosphere model.

- Click on this link to open the simulation in a new browser window.

Two plots appear along with several sliders and input boxes.

- **Neutral Density Plot:** The top plot shows the neutral number density atmosphere as a function of altitude (plotted vertically) on a semi-Ln (Natural Log) scale.
- **Electron Number Density:** The second plot shows the electron number density, again on a semi-Ln scale.
- **Output:** The output panel shows the "Scale Height" for the neutral atmosphere, "Peak Alt." which is the altitude of the electron density maximum, and "Peak Den." - the maximum electron density.
- **Neutral Density Controls:** The first slider panel allows you to vary the temperature, acceleration due to gravity, and molecular mass of the atmosphere at 100 km altitude (reference altitude). You will also need to adjust the reference density at that altitude but changing the value in the box.

- **Solar Flux Controls:** The next slider panel allows you to vary the solar flux (at 1 AU) and then scale that depending on the distance from the Sun. This allows you to simulate the EUV flux conditions at different planets.
- **Plot Controls:** The bottom most panel has a two “Save” buttons and a “Reset” button. The reset button will clear the plots and reset the parameters to the initial values. The save buttons will allow you to save a particular results enabling you to compare results.

Exploring the Neutral Density

The neutral density altitude profile shows the results of a simple exponential atmosphere. (See Stan Solomon’s presentation, http://www.vsp.ucar.edu/Heliophysics/pdf/Solomon_Helio2009.pdf, and Fuller-Rowell and Solomn in section 12.3.2 of Vol. 2. In this model, the number density ($N(h)$) is given by

$$N(h) = N_0 \exp\left[-\frac{(h - h_0)}{H}\right]$$

Where H is the scale height given by

$$H = k_b T / mg$$

The plot is a horizontal plot on a semi-log scale.

- *What does the slope represent?*
- Explore the variations in the slope as you adjust temperature, acceleration due to gravity, and molecular composition. *Does the slope increase or decrease as you change these? Make a table. Why is the neutral atmosphere increase in density with higher temperature?*
- Using the tables showing parameters for each planet, find the slope in each situation. *Make a table of the slope (what should it be called) for each planet.*
- *What assumptions are used for this model? Are those assumptions valid?*
- *Where is LEO (Low Earth Orbit)? Why is the solar dependence of the atmosphere an issue during Solar Maximum?*

Exploring the Ionospheric Layer

The ionosphere model follows Chapman’s original calculation [Chapman, S.: 1931, Proc. Phys. Soc., 43, 26] which is outlined by Fuller-Rowell and Solomn in section 12.3.2 of Vol. 2.

The intensity of ionizing radiation ($I(z)$) is

$$I(z) = I_\infty \exp(-\tau(z))$$

$$\tau(z) = \frac{\sigma N(z)}{\mu}$$

and $\tau(z)$ is the optical depth.

The electron density plot is also on a semi-log scale.

Discuss and work on the following:

- *Describe the features of the ionosphere (Chapman) layer. Does it best describe an E-layer or an F-Layer.*
- *From the plot, identify the:*
 - *peak altitude*
 - *peak density*
 - *neutral density at peak altitude*
 - *top side slope*
- *From these, calculate the peak plasma frequency and the optical depth at the peak altitude?*
- *How does the plasma top side slope compare to the neutral scale height (slope of the neutral plot)?*
- *Explore how these features vary with some of the following quantities: neutral temperature, EUV flux (either with distance or through out the solar cycle), and reference neutral density.*
- *Make a table of summarizing your findings.*
- *Again consider the assumptions for this model and their effects on the result.*
- *Can you change between the E-layer and F-Layer profiles.*

“Comparative” Ionospheres

The tables on the web pages that accompany this simulation include some parameters for the atmosphere for Mars and Venus. Make a table of the values identified above for each of the rocky planets - Venus, Earth, and Mars - for both solar minimum and solar maximum (five times the default EUV flux at Earth). You will have to adjust all of the inputs.

- *What general conclusions can you draw?*
- *What conclusions can you draw about the peak altitude plasma frequency?*
- *...optical depth?*
- *Can you recreate any of the layers measured at Mars and Venus, recreated below.*
- *How would this inform the design of an instrument for a mission to these planets?*

Final Note

The GPS geoposition system is plagued by the variability of the ionosphere TEC (Total Electron Content). Why do you think TEC is important and how would this be obtained from the results you have been looking at?

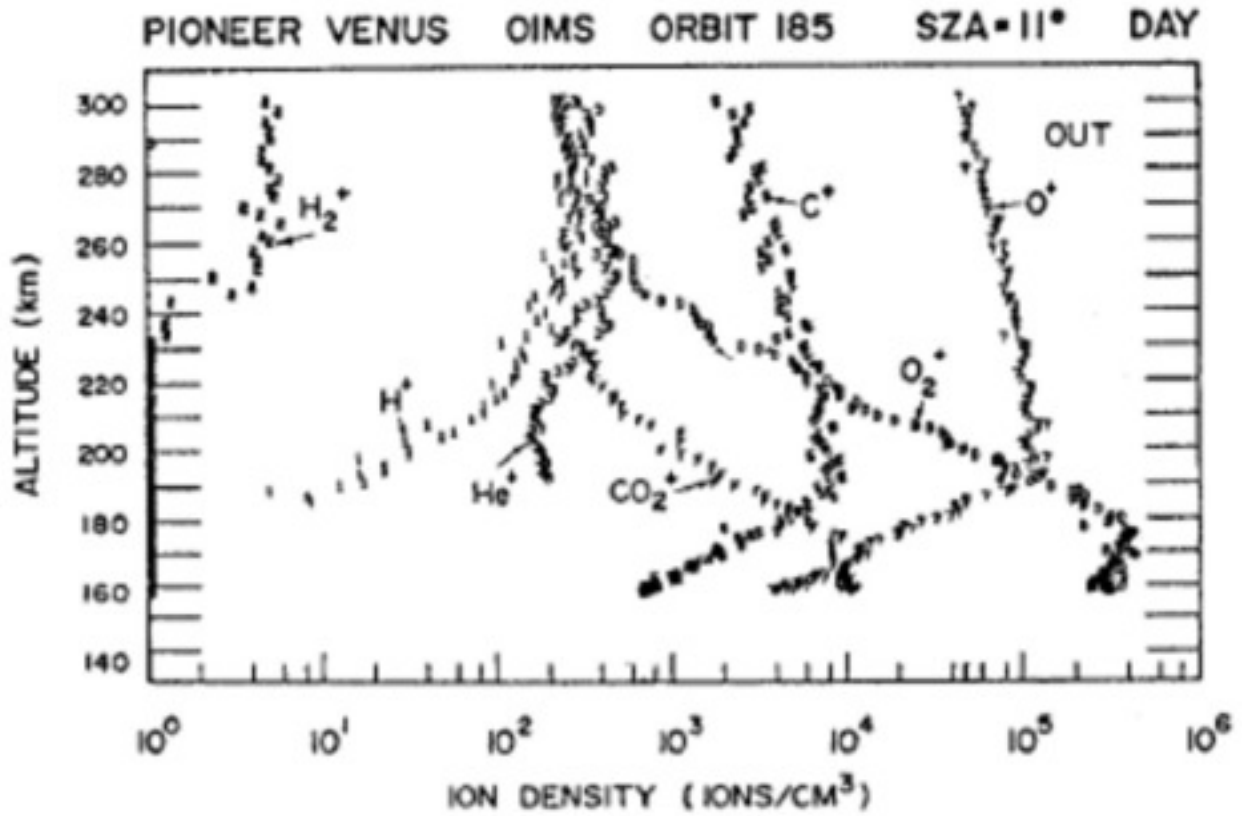


Fig. 13.5. Measurements of the ionosphere of Venus from the ion mass spectrometer on the Pioneer Venus spacecraft.

Fig. 13.6. Measurements of the ionosphere of Mars from the ion mass spectrometer on the Viking-1 spacecraft (symbols), and a model ionosphere calculation (lines) for comparison.

