Exploring Ionosphere Structures

Before you Begin

Discuss in your group:
- **What drivers or inputs are needed for an ionosphere/thermosphere model?**
    - **What regions of the ionosphere or thermosphere will be affected?**
    - **What kind of long term variation do you need to consider?**
- **What features should you look for in a full ionosphere/thermosphere model?**
- **What output would you expect from the model?**

Part 1: Global Structure of the Ionosphere

Choose one of the published results from the "Solar Cycle" series on this page:
http://ccmc.gsfc.nasa.gov/support/HSS_2015/cycles_iono.php
- Click "View 3D Ionosphere/Thermosphere (low altitude: 80-500 km)".
   Choose "N_e" in Q1 (scroll about ⅓ of the way down the page)
  and then click "Update Plot".
- The parameter plotted, "N_e", is the electron number density at a particular pressure
  level (roughly equivalent to constant altitude).
- **Orient yourself to the image.**
- **Based on these simulation results, what season is this?**
- **Where is the center of the map geographically located?**
    - Just below the "Update" button, click the checkbox for "Show Continents" and
      click "Update" again.
- **What features do you see in these results?**
  What are the external "drivers" that generate those features?
      Keep this plot open and open the same run in a new window or screen.

Vertical Structure of the ionosphere
- Open the same simulation results in a new window.

To plot the vertical structure of the ionosphere above a particular latitude and longitude, choose
the following settings on the page:
- Plot Mode - > "Vertical Line (1D)"
- Again Choose "N_e" in Q1.
- Scroll to "Choose Plot Area", about ⅔ of the way down the page.
- Choose Plot Area -> lon1 and lon2 -> 180 [Why 180? What is the local time?]

- Choose Plot Area -> lat1 and lat2 -> 0
- Choose Plot Area -> click the radio button next to "H1"
- Update Plot
- **Can you identify different layers of the ionosphere?**

Ion Species contributing to the layers of the ionosphere

Find which species of ions contribute to the various layers of the ionosphere.
- From "Choose quantities", choose various ions number densities
  [N_O+, N_O2+, N_NO+, etc.] and compare these results to the electron number density. Use "Q2" and "Q3" to plot different ion densities on the same axis but pay attention to the scale.
- **Which ions contribute to which layers?**
- To see this better, you may want to fix range.
    - Scroll to "Plot Options for selected Plot Modes".
    - Select "Log scale" and click "Update Plot".
    - Note that the scales for the different species are different.

Complete this table for the layers you can identify.
Solar Phase (Based on F 10.7 flux) _____

Layer / Solar Phase	Density / Indicator Ion Species	Altitude
E Layer, Noon		
F Layer, Noon		
E Layer, Midnight		
F Layer, Midnight		

- Use the "lon1" and "lon2" settings to adjust the time of day.

Are your results consistent (though not necessarily identical) with another model output represented below? (Be sure to check the units).
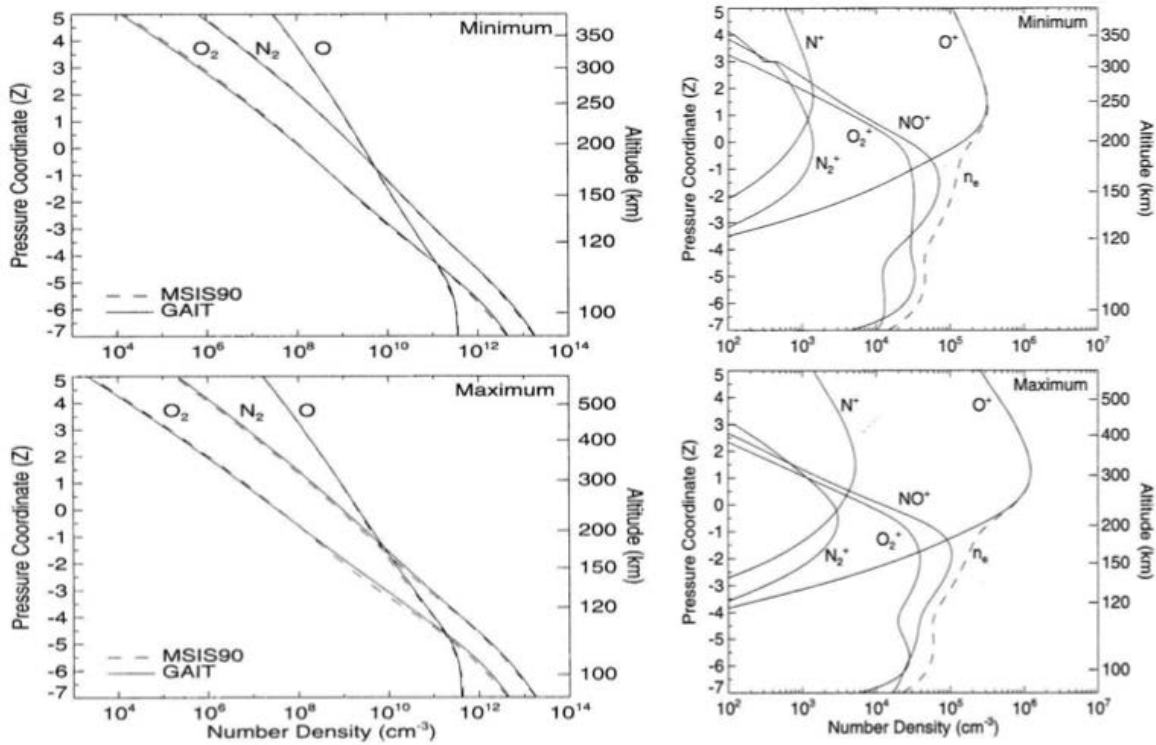
The caption for this image can be found in "Principles of Heliophysics", Fig. 13.2

Part 2: Group Explorations (For Synchronous Groups)

Each group will start by exploring one of these questions below.

1. Variations in the ionosphere with latitude

Goal: Explore the variation of the structure of the ionosphere with latitude.
Before you start:
  ● ***How do you think the ionosphere structure varies at different latitudes?***
    Discuss in your group and make some predictions.

Choose one of the published results from the "Solar Cycle" series on this page:
http://ccmc.gsfc.nasa.gov/support/HSS_2015/cycles_iono.php
  ● Click "View 3D Ionosphere/Thermosphere (low altitude: 80-500 km)".
  ● Go to the "Map" view (ColorCountour(2D)) of the ionosphere.
  ● From the Quantity —> Q1 Menu choose "TEC" to look at the "Total Electron Content".
    (TEC is the integrated electron content over the column of the
    thermosphere/ionosphere)
  ● "Update" the plot.
  ● **For a specific longitude, how does the structure vary with latitude?**
  ● Look at the vertical plots for specific attitudes.
    How does the structure of the layers change at various latitudes?
  ● From the "Seasonal Variation" list, choose a result either the winter or summer (Northern
    Hemisphere) solstice. Look at the TEC map and the structure of the layers for different
    latitudes
  ● **How does the latitudinal variation different for different seasons?**

2. Daily Variations and Variation with Time of Day

Goal: Explore the variation of the structure of the ionosphere with the time of day.
Before you start:
  ● ***How do you think the ionosphere structure varies at different times of day? Is this***
    different from the variation in longitude?
    Discuss in your group and make some predictions.

Choose one of the published results from the "Solar Cycle" series on this page:
http://ccmc.gsfc.nasa.gov/support/HSS_2015/cycles_iono.php
  ● Click "View 3D Ionosphere/Thermosphere (low altitude: 80-500 km)".
  ● Go to the "Map" view (ColorCountour(2D)) of the ionosphere.
  ● From the Quantity —> Q1 Menu choose "TEC" to look at the "Total Electron Content".
    (TEC is the integrated electron content over the column of the
    thermosphere/ionosphere)
  ● ***What variations do you see in longitude?***

- Open another window and plot vertical plots for various longitudes for the electron density [N_e].
- ***How does the vertical structure of the ionosphere change for different longitudes (times of day)? What happens to the height and density of specific layers at different times of day?***

You can also change the simulation time for a fixed longitude.

- For both the map and the vertical plots change the simulation time using "Choose data time" near the top of the page.
- ***How does the structure of the ionosphere change with varying time of day?***

3. Seasonal Variations in the Ionosphere
Goal: Explore the variation of the structure of the ionosphere with different seasons.

Before you start:
- ***How do you think the ionosphere structure (density and height) varies throughout the year? Is it different from the variation in latitudes? Do the hemispheres respond differently?***
- ***At mid latitudes at noon, what time of year do you think has the largest TEC.***
  Discuss in your group and make some predictions.

Choose one of the published results from the "Seasonal Study" series on this page:
http://ccmc.gsfc.nasa.gov/support/HSS_2015/cycles_iono.php
Be sure to note which season the run is from.
- Click "View 3D Ionosphere/Thermosphere (low altitude: 80-500 km)".
- From the original run list, choose a run from the seasonal variation study.
- From the Quantity —> Q1 Menu choose "TEC" to look at the "Total Electron Content".
  (TEC is the integrated electron content over the column of the thermosphere/ionosphere)
- **From the TEC, can you tell what time of year it is (or what season is it in the Northern Hemisphere)?**

In a new window, choose a latitude to plot a line plot for varying longitude.

- From "Plot Mode" select "Line (1D)"
- Set Q1 -> TEC, Q2 -> NmF2 *(the maximum density of the F layer)*,
  and Q3 -> HmF2 *(height of the F layer)*
  [Note: all of these quantities are independent of height]
- In "Choose Plot Area" set lon1 -> 0 and lon2 -> 360, lat1 = lat2 -> [your choice]
- **What time of day does the F layer have its highest density?**
  What time of day is the F layer at the highest altitude?
- **Note the peak values for each quantity.**
- **Record the maximum values in the chart below for various times of the year.**

Date/Day						
TEC						
NmF2						
HmF2						

- ***Revisit the questions you started with given the results tabulated.***
- ***Based on global TEC values, how does the structure change in latitude and longitude throughout the year?***

4. Variations throughout the Solar Cycle

Throughout the solar cycle (http://solarscience.msfc.nasa.gov/SunspotCycle.shtml) the solar F10.7 radio wave emissions flux varies in the same way as the average sunspot number (http://www.swpc.noaa.gov/phenomena/f107-cm-radio-emissions). F10.7 flux is a very good proxy for the EUV flux which affects the ionosphere.
Goal:
Explore the variation in the ionosphere due to changes in EUV flux throughout the solar cycle
Before you start:
- ***Using the links above identify the typical values of the F10.7 flux during solar minimum and solar maximum. Why is F10.7 used as a proxy for EUV flux?***
- ***Throughout the course of the solar cycle, what changes will you see in the structure of the ionosphere?***
    - ○ ***What will happen to the density and altitude of the ionospheric layers?***
    - ○ ***What will happen to the TEC?***
- ***What latitudes will most likely be affected by this change? Why?***
Discuss in your group and make some predictions.

Choose a couple of the published results from the "Solar Cycle Study" series on this page: http://ccmc.gsfc.nasa.gov/support/HSS_2015/cycles_iono.php
Start with one from the "solar minimum" and one from "solar maximum".

- From the Quantity —> Q1 Menu choose "TEC" to look at the "Total Electron Content". (TEC is the integrated electron content over the column of the thermosphere/ionosphere)

In a new window, choose a latitude to plot a line plot for varying longitude.

- From "Plot Mode" select "Line (1D)
- Set Q1 -> TEC, Q2 -> NmF2 (the maximum density of the F layer), and Q3 -> HmF2 (height of the F layer) [Note: all of these quantities are independent of height]
- In "Choose Plot Area" set lon1 -> 0 and lon2 -> 360, lat1 = lat2 -> [your choice]
- For a specific longitude, read the values for the three quantities plotted
- Complete the chart below for various times of the year.

Solar Cycle Phase	Solar Min	Rising Phase	Solar Max	Declining Phase
TEC				
NmF2				
HmF2				