Luleå University of Technology
Division of Space Technology

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Computational Laboratory in
Space Physics

Laboratory Experiment with SPENVIS

version 1.0

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Contents

1 SPENVIS

You are going to do a laboratory experiment with SPENVIS.

SPENVIS is the abbreviation to the ESA's **SP**ace **ENV**ironment **I**nformation **S**ystem.

First of all, go to `https://www.spenvis.oma.be/intro.php`. If you come to the right site, you see the display shown in Figure 1.

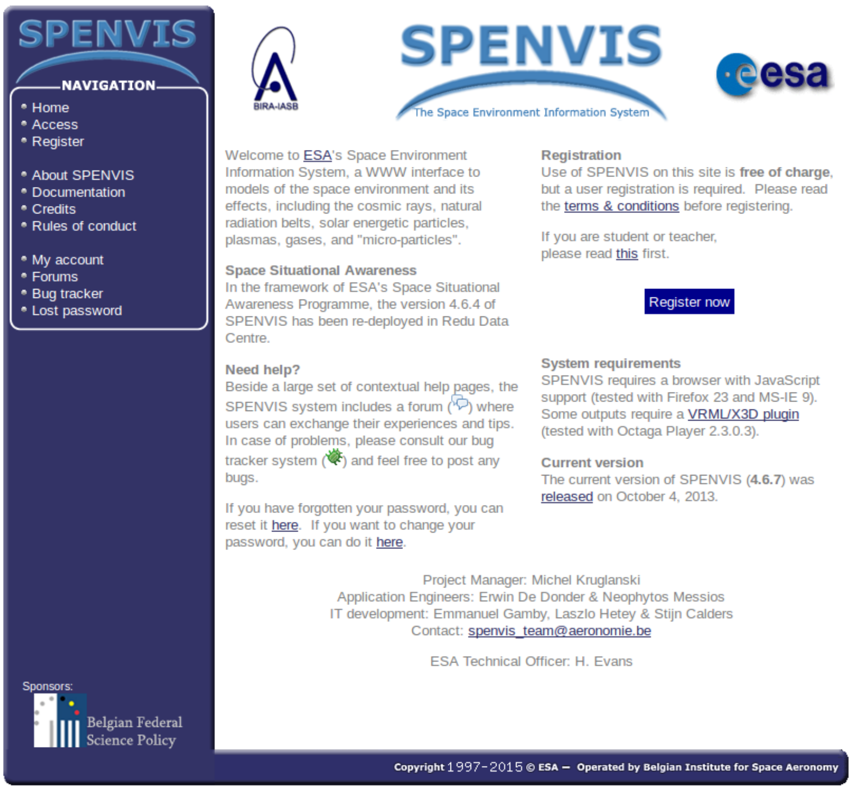

Figure 1: Homepage of SPENVIS

1.1 Log-in as a user

Click `Access` in the left column to log-in to the system. You will be assigned a user account (`username` and `password`) from your instructor. Type in your `username` and `password` in the pop-up window (Figure 2).

If you are succeeded in entering in the system, you will come to the **Project management** page. A "blank" Project management page seems like as shown in Figure 3.

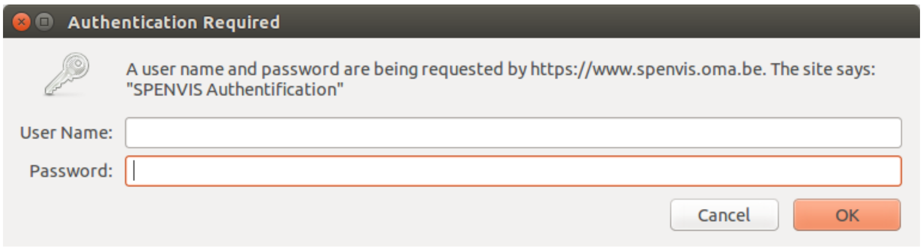

Figure 2: Log-in window to SPENVIS

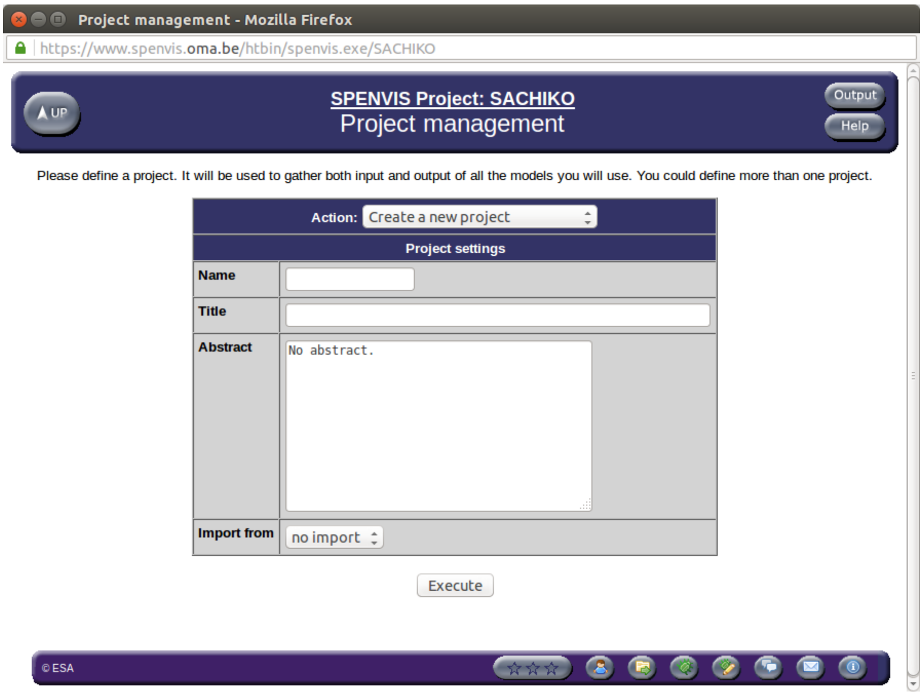

Figure 3: **Project management** page

1.2 Getting start with SPENVIS

In the Project management page, drag the pull-down menu of `Action` to select `Create a new project`.

As the `Project settings`, you can freely write down `Name`, `Title`, and `Abstract`. The following is an example:

> **Name**: *your project name*
>
> **Title**: Laboratory experiment on Earth's atmosphere and ionosphere
>
> **Abstract**: Just short: Execute an ensemble of models to simulate physical properties of Earth's atmosphere and ionosphere. Later for details.

Figure 4 shows the example. You can change/modify/delete the project settings at any time. The way to do that (change/modify/delete) will be shown later.

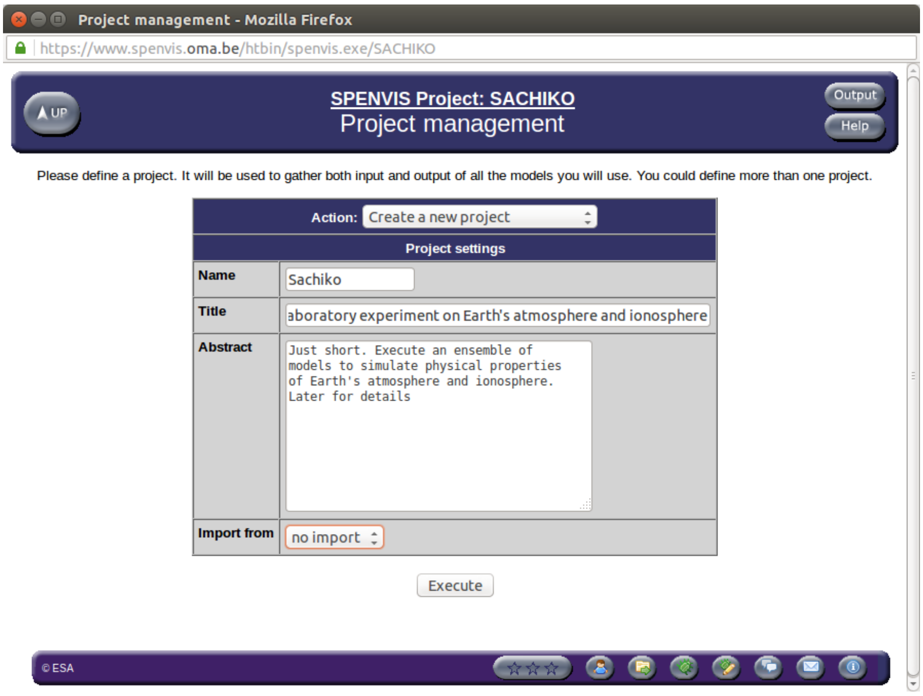

Figure 4: Example of a project description

When you complete to fill in the boxes of `Project settings`, click the `Execute` button at the bottom to proceed to the next step.

Now you proceed to **Model packages** (Figure 5). Hereinafter your project really starts.

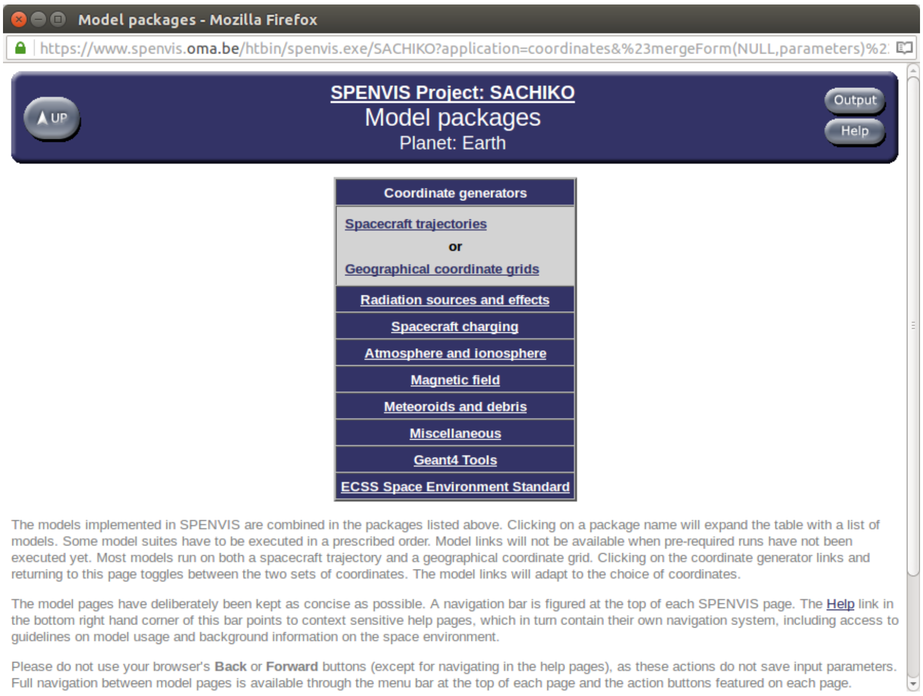

Figure 5: Start page of **Model packages**

2 Coordinate generators

When you click `Coordinate generators`, the sub-menu pops up (see Figure 5). From the sub-menu, select `Geographical coordinate grids`.

2.1 Grid parameters

In the `Coordinate grid generator/Grid parameters` window, you are going to set grid parameters by:

1. Drag the pull-down menu of `Grid type`, and select `profile`. **Profile** here means either, *vertical along height*, *latitudinal* or *longitudinal* (the latter is equivalent to time zone) profile.

2. Next, set the **start point** by 4 parameters:
   `Altitude [km]`: 50
   `Latitude [deg]`: 67.5
   `Longitude [deg]`: 20
   `Universal time [hr]`: 12
   Here we choose **Universal** time.

3. Drag the pull-down menu of `variable parameter`, and select `altitude` in order to simulate the **vertical profile along height** at the geographical coordinate (67.5°, 20°) and at 12 UT.

4. Then, set the **end point** in altitude [km] and `Step size` in [km] or `Nr of values` by:

`Last value`: 500
`Step size`: 10 (we choose `Step size`)

Figure 6 shows the completed settings by following the above proceeding.

When you confirm that your settings are completed, click the `Run` button at the bottom.

2.2 Run reporting

The run is successful, you will get a window as Figure 7. Before proceeding to the next step, you can check the reporting contents (`Run file` and `Coordinate grid`) and the contents of these files are shown in Figure 8 and 9, respectively.

In the window, shown by Figure 7, click the `Up` button at the upper-left corner in order to go back to the window of `Model packages`.

Note: Almost all the models of SPENVIS are depending on `Coordinate generators`. You should execute this model first in prior to executing other models.

Figure 6: Setting window of `Grid parameters`

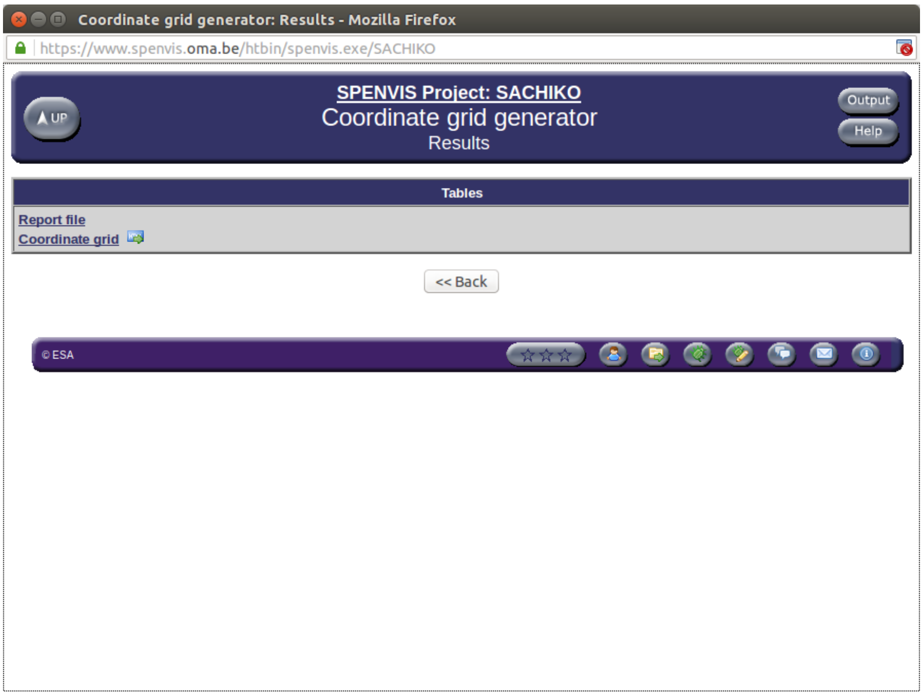

Figure 7: Reporting window after **Run**

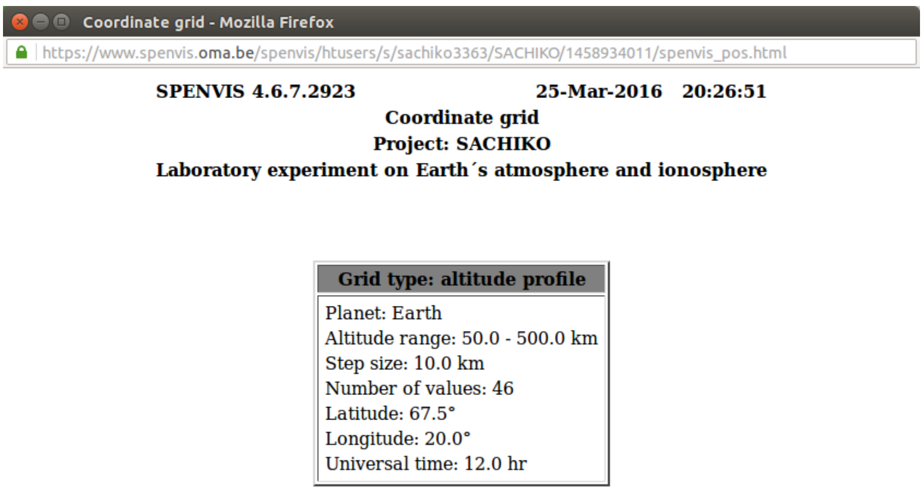

Figure 8: Content of `Run file`, by new window

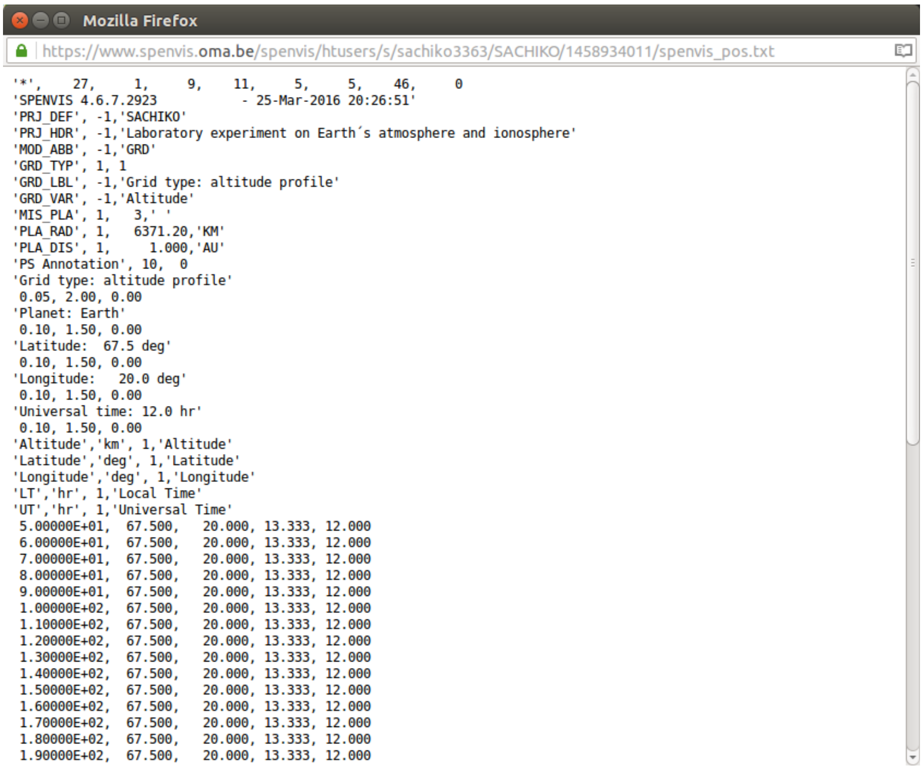

Figure 9: Content of `Coordinate grid`, by new window

3 Atmosphere and Ionosphere

When you click `Atmosphere and Ionosphere` in the `Model packages` window, a unique sub-menu (`Density and temperature maps and profiles`) pops up as shown in Figure 10. Select the sub-menu.

Hereinafter, you are going to simulate some physical properties of the Earth's ionosphere by using **several** models. Each model has **advantage(s)** and **disadvantage(s)** depending on **what you focus on**. We first practice by using the ready-made coordinate grid and the model **IRI2001**.

3.1 Ionospheric model, IRI2001

IRI is the abbreviation of the **I**nternational **R**eference **I**onosphere. This model had been developed in the late sixties to produce an empirical standard model of the ionosphere, based on all available data sources. For given location, time and date, IRI describes the electron density, electron temperature, ion temperature, and ion composition in the altitude range from about 50 km to about 2000 km. It provides monthly averages in the non-auroral ionosphere for magnetically quiet conditions.

There is a free access site to the article: *"International Reference Ionosphere 2000" (Bilitza, 2001)*, and `http://ccmc.gsfc.nasa.gov/modelweb/ionos/iri/iri_2000_rs.pdf`.

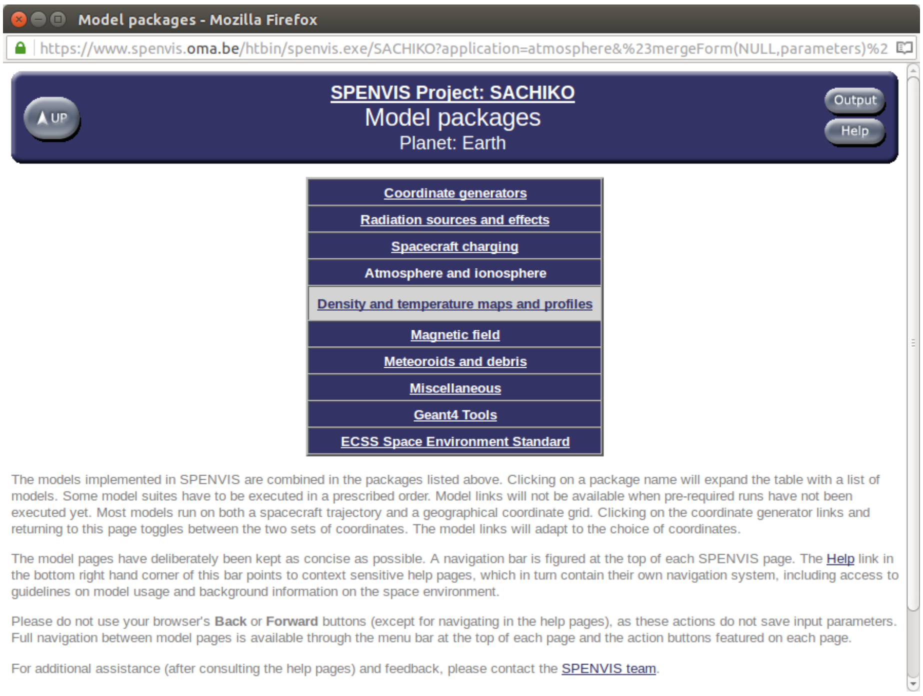

Figure 10: Start page of **Model packages**, highlighted by `Atmosphere and Ionosphere/Density and temperature maps and profiles`

3.2 Default run of IRI2001

Now you come to `Model parameters` window. Here you drag the pull-down menu `Atmosphere/ionosphere model` to select `IRI2001` among the several other models. Figure 11 shows the switched display with the default setting.

You hold the default values:

`Day of year`: 1

`Daily` $F_{10.7}$ `[`10^{-22}`W m`$^{-2}$ `Hz`$^{-1}$`]`: 70.0

`Sunspot number (12 month average)`: 60.0

`Year`: 2003

and click the `Run` button at the bottom. If the run is successful, you will get the run report as shown in Figure 12.

Now you are going to plot your result of the IRI2001 run with default values. In the `New plots` panel, you will set as following (and as shown in Figure 13):

`Inverse altitude profile of` of `e-number density` (`logarithmic` scale) with `linear` altitude scale

`Plot as` `Portable Network Graphics (PNG)`

Then, click the `Plot as` button to generate a plot.

When a plot is generated, a statement `Two-dimensional plot of atmospheric parameters(PNG)` is displayed in the panel `Plots` in the `Positional version: Results` window, as shown in Figure 14.

A plot on **electron(e)-number density** vs. **inverse altitude** by executing **IRI2001** model with the settings (**Day of year**=**1**, **Daily** $F_{10.7}$=**70.0**, **Sunspot number (12 month average)**=**60.0** and **Year**=**2002**) is shown in Figure 15.

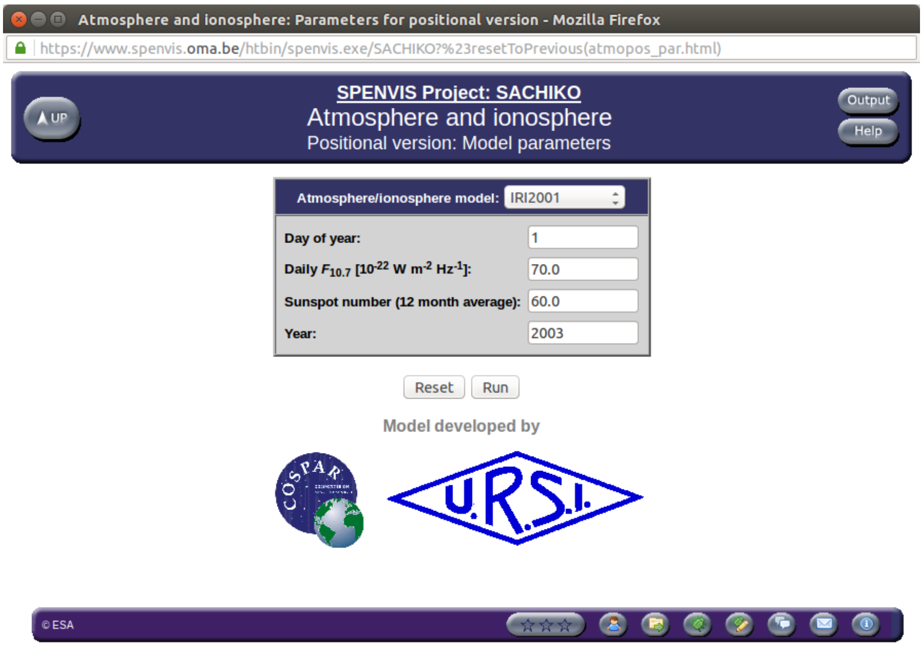

Figure 11: Default setting of IRI2001

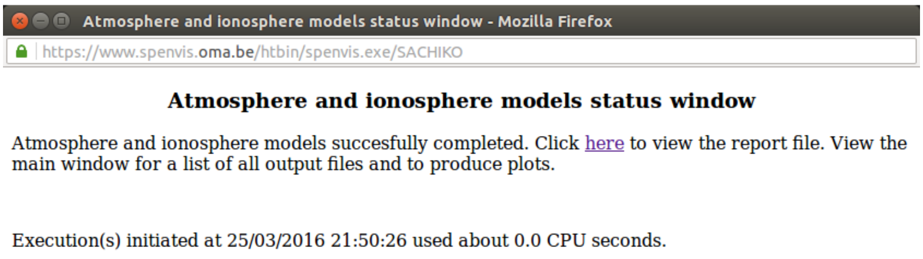

Figure 12: Run report of executing IRI2001, by new window

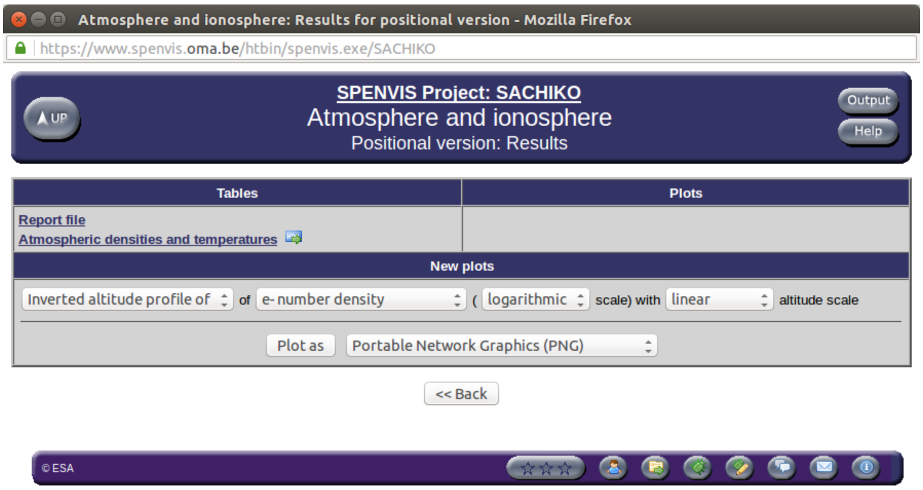

Figure 13: Plot setting window on the IRI2001 run

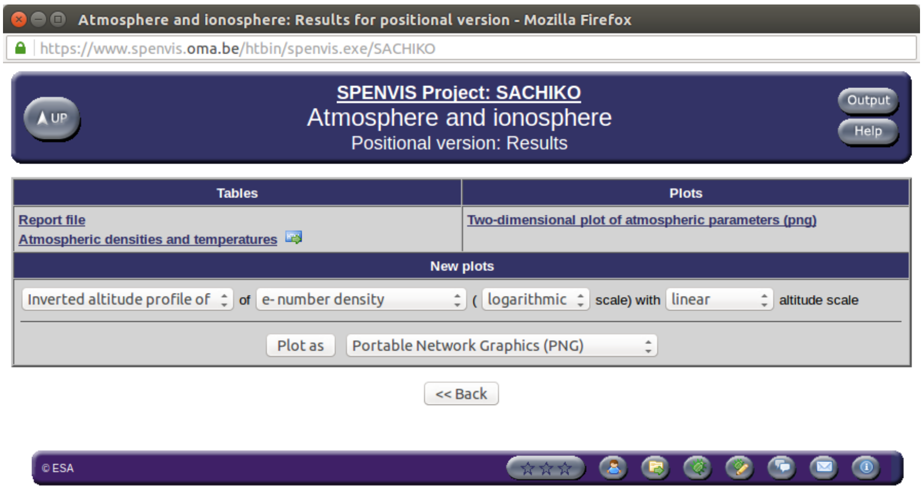

Figure 14: Plot generating report

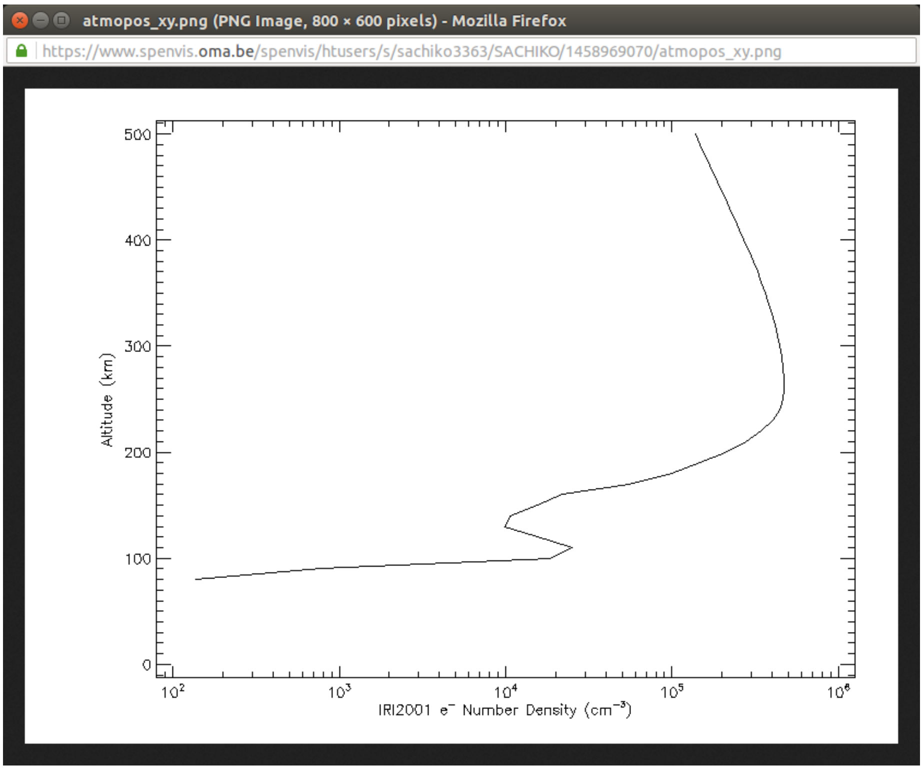

Figure 15: A plot example

3.3 Assignments

Click the `Back` button (as shown in Figure 14) to go back to the **model selection & associated parameters setting** window (as shown in Figure 11).

Assignment 1 You should go to the sites below to fetch data on **Daily** $F_{10.7}$ and **Yearly mean total sunspot number**, and pre-process the data.

> Daily $F_{10.7}$:
> `ftp://ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP/`
>
> Yearly mean total sunspot number:
> `http://www.sidc.be/silso/datafiles`

Once you fetch the data, then you need **pre-processing** of the data.

The data structure for **Daily** $F_{10.7}$ is:

> Column: **66-70** in each line
>
> Format: **f5.1** which means one digit below the decimal point and three digits at max as integer part, e.g. 123.4.
>
> **Flux qualifier** in the column **71** with the format **i1** (one integer digit) should be taken into account for the usage.

0: flux required no adjustment.
1: flux required adjustment for burst in progress at time of measurement.
2: a flux approximated by either interpolation or extrapolation.
3: no observation.

Basic information such as **year**, **month** and **day** are given in
Year: column=1-2, format=i2, so that "2003" is shortened as "03" by two integer digits.
Month: column=3-4, format=i2.
Day: column=5-6, format=i2.

The data of **Yearly mean total sunspot number** is already processed, so that nothing is necessary except for checking the data format.

Assignment 2 If you are succeeded in processing the data, you may realize that the default settings for the model IRI2001 (see Figure 11) are not really correct.

Set the values from the processed data and re-run the IRI2001 model.

Compare the new result with the old one. Describe the differences between them **quantitatively**. For example, if you can handle MATLAB, you can produce a figure, as shown in Figure 16, using the text files from the run report.

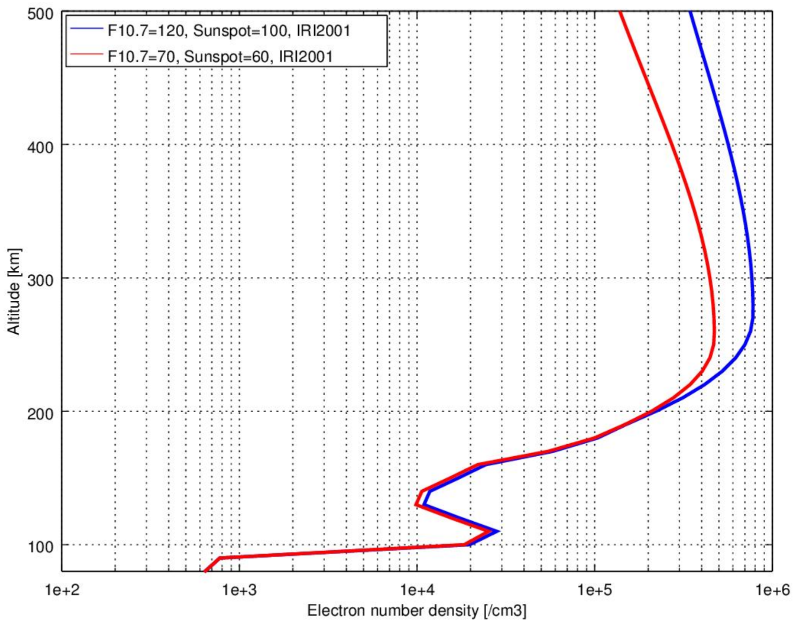

Figure 16: Comparison of two cases in one figure. The figure is produced by using GNU Octave/MATLAB.

Assignment 3 As you can see in Figure 16, the vertical profiles of the electron number density are different for different values of the parameters, i.e. **Daily** $F_{10.7}$ and **Sunspot number (12 month average)** for the model IRI2001.

Continue to use the model IRI2001 for the year 2003, but change to the other values for the parameters (**Day of year**, **Daily** $F_{10.7}$, and **Sunspot number (12 month average)**) on the basis of the Assignment 1 above.

It's up to you to choose the values of the three parameters, but keep in mind that

1. How does one parameter affect the physical properties (e.g. electron number density) in the Earth's ionosphere? In the case of **Sunspot number (12 month average)** (to be investigated), you can test the following **three** cases:
   `Case 1 = Sunspot number (12 month average) + SD,`
   `Case 2 = Sunspot number (12 month average),`
   `Case 3 = Sunspot number (12 month average) - SD,`
   where SD is the standard deviation.
2. Is there any diurnal variation in the physical properties in the Earth's ionosphere?
3. Is there any seasonal (annual) variation in the physical properties in the Earth's ionosphere?

For this assignment, to read **2. External Drivers/2.1 Solar Indices and Ionospheric Indices** (of the article linked to `http://ccmc.gsfc.nasa.gov/modelweb/ionos/iri/iri_2000_rs.pdf`) will help you.

Assignment 4 As given in the description on the model IRI2001, "*... It provides monthly averages in the non-auroral ionosphere for magnetically quiet conditions.*", the coordinate grid and the year 2003 are not suitable for this model.

Can you motivate the reason for that?

You are going to regenerate coordinate grid (go back to Section 2) and to choose another year for the model IRI2001.

Assignment 5 Read carefully **7.5 An Example: The Earth's Ionosphere** (p196-) in the textbook. Then you will run the model IRI2001 and determine the ionospheric layers (i.e. D, E, F_1 and F_2) from your results. It's up to you to choose the coordinate grid and the year (and thus inclusive of Day of year, Daily $F_{10.7}$ and Sunspot number).

In this assignment, you also need other plots on other physical properties for analysis and the subsequent comprehensive discussion.

Figure 17 shows Chapman layers for different scale heights. Compare the IRI model results with the Chapman layer, and discuss how those are different and why those are different.

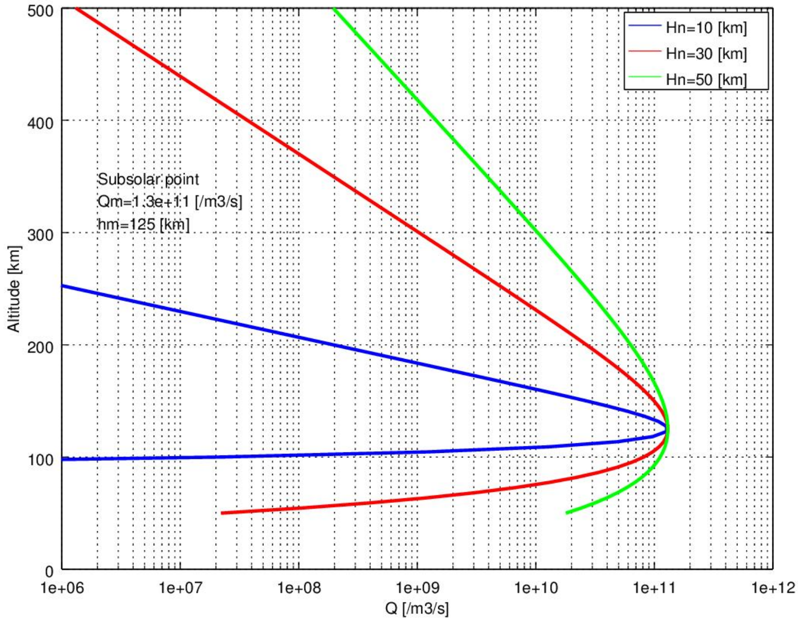

Figure 17: Chapman layer model, for three different scale heights (H_n) but fixed (1) zenith angle (χ=0, subsolar point), (2) peak production rate (Q_m [/(m^{3}s)]) and (3) peak production height (h_m [km]).

$\boxed{\textbf{Assignment 6, but optional}}$ The original and the latest versions of the model IRI are provided by the International Reference Ionosphere Work Group `http://iri.gsfc.nasa.gov/`. By using the model IRI2012 (`http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html`), a model ionosphere is produced and plotted in Figure 18. Even though two cases share the same parameters, the two cases are slightly different on the basis of different models (IRI2001 and IRI2012).

Survey the IRI's HP to find the update/revision information on the models.

Otherwise, you can refer the site: `ftp://hanna.ccmc.gsfc.nasa.gov/pub/modelweb/ionospheric/iri/`. Here you will find the source codes in Fortran90. You can survey the difference (or in other word, model-dependency) to differ the corresponding two source codes.

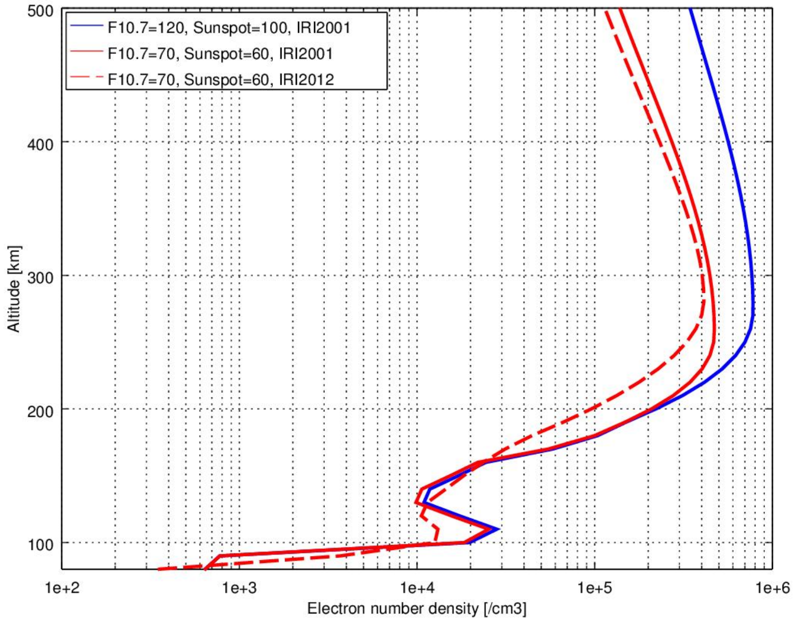

Figure 18: Two cases by the model IRI2001 and one case by the model IRI2012.

4 Appendix

The following is a GNU Octave/MATLAB "m"-file with which you can do data pre-processing (Assignment 1).

```
% ============================================================
% Read the file on Kp/Ap and F10.7
%
% File being fetched from:
%   ftp://ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP/
%
% Usage of this M-file:
%   octave:xxx> F107
%   octave:xxx> val(doy)
% where "doy" is the day of year.
%
% Written by Sachiko Arvelius, 2016-03-27
% ============================================================

clear all;

val = zeros(365,1);

fid = fopen ("2003_kpap_df10.7.txt","r");
for i=1:365
  [tmp,count,err] = fscanf(fid,"%65c",1); % skip the first 65 characters
  [tmp,count,err] = fscanf(fid,"%5c",1); % read the characters in column 66-70
```

```
  val(i) = sscanf(tmp,"%f",1); % convert the above characters into float
  [tmp,count,err] = fscanf(fid,"%2c",1); % read the line to the end
end
fclose (fid);
```