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An electron transport code independent of the planetary thermosphere

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Abstract

Transsolo is a code that describes the transport of the electrons from solar origin of from photoionisation in the upper atmosphere. Up to now, it has been adapted to the Earth, Venus, Jupiter, Uranus, Mars and Titan. However, these adaptations resulted in separate codes and improvements of one did not automatically follow in the others. In the frame of Europlanet, we re-wrote this code in a user-friendly manner to make it independent of the planet, so that it is easy to make measurements in many circumstances.

1. Introduction

Most of the observations of planetary upper atmospheres are their emissions. Some in-situ measurements also provide ion or electron densities, temperatures . . . To calculate these parameters requests to calculate the excitation, ionization and dissociation rates of the different species. In this aim, it is necessary to solve a Boltzmann kinetic transport equation for the electrons (i.e. [4] and references herein). These electrons have different origins: the can be precipitated from the solar wind (eventually after a journey within the magnetosphere) along the magnetic field lines. They can be due to the photoionisation by the solar energetic flux (EUV/XUV). They can also be secondary electrons due to the impact of the previous primary ones with the thermosphere. The Boltzmann equation accounts for all the sources and describes how a precipitated electron flux degrades its energy by collisions with the atmospheric neutral species. The main inputs are the electron impact cross sections, the neutral atmosphere density and temperature, the EUV solar flux, and the spectrum of the precipitated flux. The unknown of the Boltzmann equation is the electron stationary flux $[cm^{-2}eV^{-1}sr^{-1}s^{-1}]$ at all altitudes, energies and pitch angle. From this flux, different parameters can be deduced. The upward flux escaping the atmosphere is simply the upward stationary flux at the upper altitude. The different ions and excited states productions, and the emission rates are direct by-products of the equation.
The code solving this equation has been carried to different planets, such as the Earth [5], Titan [3] , Venus [2], Mars ([1] where it was used to asses the discovery of the Mars aurorae, and in [6] to predict the presence of intense blue auroras at Mars. In , [4], it allowed to model the Mars atmospheric escape). This series of codes written in FORTRAN is called “the Trans* family”.
This series of applications resulted in different codes that evolve independently. An improvement on one of them is not automatically carried to the others. However, Europlanet aims at building new tools to make comparative planetology easier. In this aim, we started building a new version of the code that is independent of the planet and with a user friendly interface.

2. Description

The physics has been described in different articles and will not be rewritten here (see for example [4]). The code starts with the making of two main files. NEUTRAL contains all the parameters describing the neutral atmosphere in which one will make the transport calculation. ELEC contains the parameters describing the electron precipitation characteristics and the ambient electron parameters, density and temperature. In particular, NEUTRAL indicates to the other codes which species have to be considered. These two files can be constructed by hand or using a pre-code called Stationo. The next step is to compute the photoelectron production. The previous versions of the code used the solar fluxes proposed by [9] or alternately the models from [7] or [8] (ref). These models had the great disadvantage of a truly bad discretization of the spectrum (37 or 39 lines). The new code uses the solar flux proposed by Woods et al., 2009 for a minimum solar activity (F10.7 = 68). For other activity levels, we use the same linear interpolation than between the min and max solar spectra proposed by [9]. The exact parameters will be published in a subsequent refereed

article.
The cross section files have been fully re-worked to allow the computation of any excited neutral or ionized state production (including doubly charged ions) of any gaseous species amongst $N_2, O_2, O, H, He, CH_4, H_2O, CO_2, CO$. Any other specie can be very easily added.
The next step is to compute the differential cross sections for the electron impact with the neutral gas. These electrons are either precipitated or photo produced. Here again, the code has been rewritten so that the code makes the computation only on the species indicated in the file NEUTRAL and on any excited neutral or ionized state.
Finally, the transport code itself solves the excitation, dissociation, ions and electron productions. It reads the results of the two preceding codes and solves the Boltzmann transport equation independently of the species.
This organization obliged us to add new modules to compute the emissions of the considered species independently. This is made through a new series of subroutine, one per species that gather all the codes developed for all the different planets studied before. The full new module is called Planetary-emissions.

3. Next steps

This is an ongoing work. In the case of the Earth, the magnetic mirroring makes it so that the electron transport code is sufficient to compute most of the emissions. This is hardly the case in many other configurations. A proton transport code has been developed but still need to be rewritten so that it too becomes independent of the planet. Only then will we be able to address most of the planetary configurations. The resulting code already results in several tens of thousands of Fortran lines. In order to make it useable for the Planetary research community, we need to work on a user friendly interface. These are the two next steps

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