DYASTIMA

Standalone application for the simulation of the showers produced in the atmosphere of a planet due to cosmic rays, based on the Geant4 simulation toolkit.

USER MANUAL

Powered by:

A.Ne.Mo.S

Athens Neutron Monitor Station (A.Ne.Mo.S.)

esa

Athens Cosmic Ray Group

National and Kapodistrian University of Athens

2019

DYASTIMA Software User Manual

Athens Cosmic Ray Group

Athens Neutron Monitor Station

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By:

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Anastasia Tezari

2019

DYASTIMA is a free software than can be used by the scientific community with only requirement the use of the following references:

- Paschalis P., Mavromichalaki H., Dorman L.I., Plainaki C., Tsirigkas D.: "Geant4 software application for the simulation of cosmic ray showers in the Earth's atmosphere", New Astronomy 33, 26-37, 2014.
- Agostinelli S., Allison J., Amako K., Apostolakis J. et al. (Geant4 collaboration): "Geant4-a simulation toolkit", Nucl. Inst. Meth. A 506, 250-303, 2003.
- Allison J., Amako K., Apostolakis J. et al. (Geant4 collaboration): "Geant4 developments and applications", IEEE Trans. Nuclear Sci. 53, 270-278, 2006.
- Allison J., Amako K., Apostolakis J. et al. (Geant4 collaboration): "Recent developments in Geant4", Nucl. Inst. & Meth. A 835, 186-225, 2016.
- Geant4, https://geant4.web.cern.ch/

This document provides all the necessary information to the user about the installation and operation of DYASTIMA software. It is issued by the Athens Cosmic Ray Group of the National and Kapodistrian University of Athens to ESA SWE SSA under contract (No 4000113187/15/D/MRP).

Change Log

30/11/2019	Initial Version

Table of Contents

1. Brief Description

1.1. What is DYASTIMA?

DYnamic Atmospheric Shower Tracking Interactive Model Application (DYASTIMA) is a standalone software application for the Monte Carlo simulation of the showers produced in the atmosphere of a planet due to the interaction of cosmic radiation particles with the atmospheric molecules [1].

The study of the atmospheric showers (Figure 1) during quiet or disturbed periods of solar activity and Space Weather phenomena is of great importance due to the multiple effects on technological and biological systems.

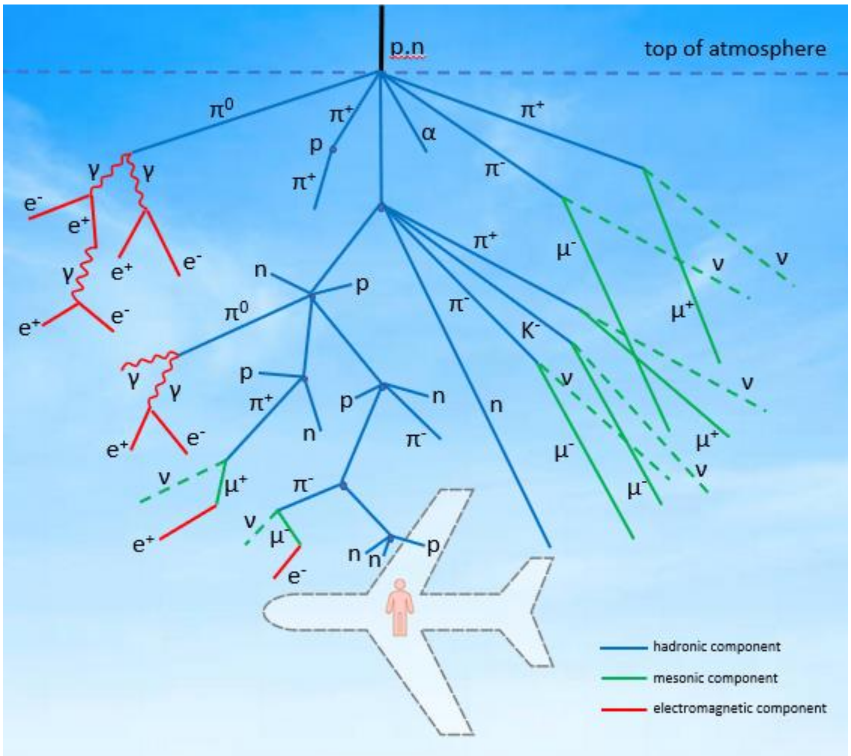


Figure 1: Graphical representation of the cascades of secondary particles produced in the Earth's atmosphere due to the interaction of primary cosmic rays with the atmospheric medium.

The software is implemented in C++ by Dr. Pavlos Paschalis and is based on the Geant4 simulation toolkit [2][3][4]. Geant4 can be used in various applications, such as space science, medical physics, nuclear physics and high energy physics, etc. and constitutes an excellent environment for the simulation of atmospheric showers. It covers high and lower energy ranges providing therefore a great variety of options and accuracy as well as good support and updates. More information about Geant4 are available at https://geant4.web.cern.ch/.

1.2. Previous versions

DYASTIMA is graphical user interface (GUI) – based application, which can be easily operated even by non – experienced users.

Nevertheless, the first version of DYASTIMA required input via .text files and atmosphere with constant composition (only Earth's atmosphere). The output was provided in .csv files and resume was not available.

The second version of DYASTIMA includs GUI parameterization and supports atmosphere with varying composition. The results are stored in a database, output is provided in .csv files and the option of resume is available. This version has already been used successfully for the study of the showers in the atmosphere of Earth and Venus [1][5][6]. It can be currently found at the portal of A.NE.MO.S. (http://cosray.phys.uoa.gr/index.php/dyastima).

1.3. Current version

The current version of DYASTIMA includes the functionality of the previous version, better visualization, many improvements concerning not only the graphical user interface but also the code itself, as well as the integration of the DYASTIMA-R component (see 1.4.). The implementation of the simulation is performed with the use of the version of GEANT4 10.4.

It supports extensive parameterization of several input parameters, allowing the simulation of any planet and any input spectra. The output provides all the necessary information about the atmospheric showers, such as number, direction, arrival time, energy and energy deposit of the secondary particles at different atmospheric altitudes allowing radiation dose calculations. A block diagram of DYASTIMA is given in Figure 2.

1.4. DYASTIMA-R

DYASTIMA current version is enhanced by a new feature that allows the calculation of radiation doses within the atmosphere of a planet, introducing the DYASTIMA-R extension.

DYASTIMA-R uses the output provided by DYASTIMA, in order to calculate the energy that is deposited on a cylindrical phantom (water, 1.75 m height, 0.25 m radius). The study of different flight scenarios is possible as DYASTIMA-R calculates the equivalent dose for various types of particles in different atmospheric altitudes and takes into account the phases of solar activity, as well as the geometry and shielding materials of the aircraft [1][7][8].

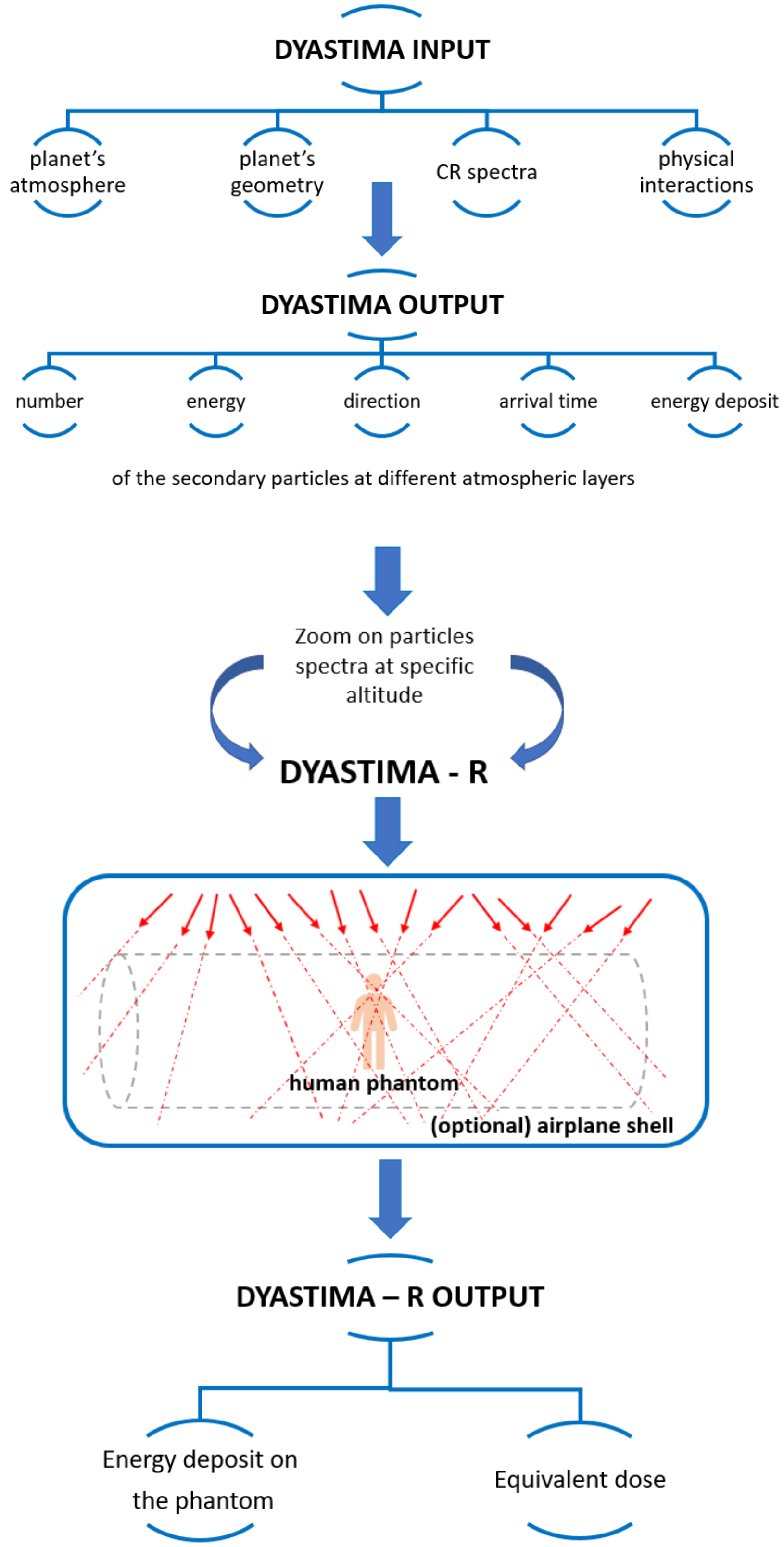


Figure 2: Block diagram of DYASTIMA and DYASTIMA-R applications.

2. DYASTIMA Federated Product

Dynamic Atmospheric Tracking Interactive Model Application (DYASTIMA) is a federated product of the European Space Agency of the Space Situational Awareness program of the Space Radiation Expert Service Centre (ESA SSA R-ESC). In order to access DYASTIMA, please visit the ESA SSA portal (http://swe.ssa.esa.int/) and sign in, through a simple Single Sign-On (SSO) procedure.

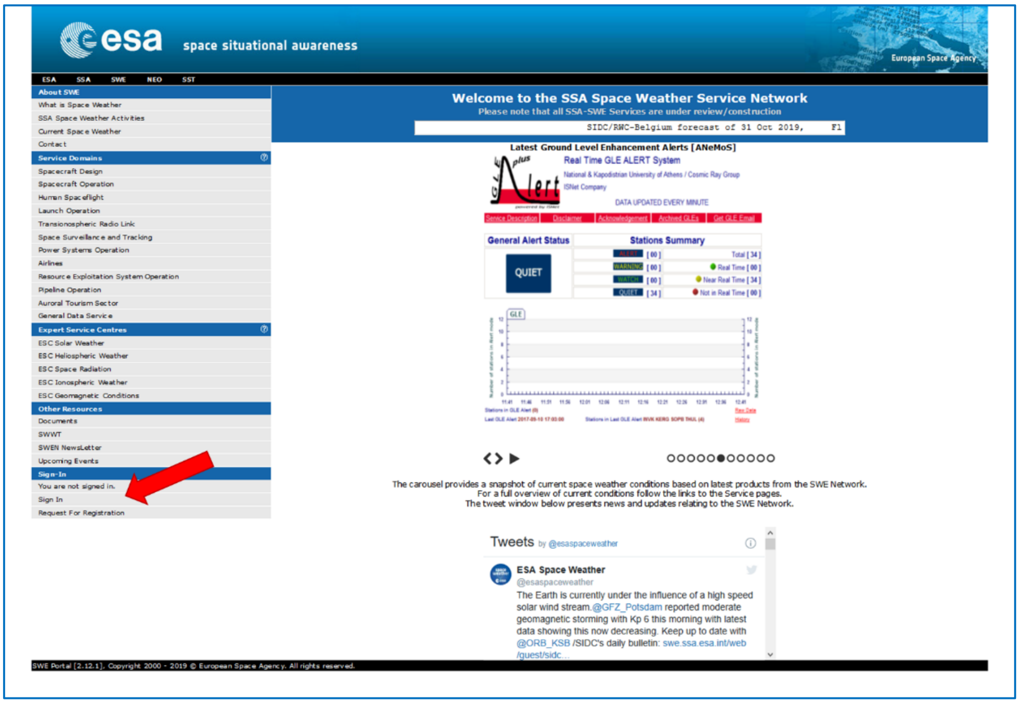


Figure 3: ESA SSA portal (http://swe.ssa.esa.int/).

Figure 4: ESA SSA SSO

After sign-in, click on the ESC Space Radiation Tab under the Expert Service Centres menu on the right side of the ESA SSA portal. Then, click on the Contribution Tabs and choose the services provided by Athens Neutron Monitor Station (UoA / ANEMOS). DYASTIMA is the Federated product R.137.

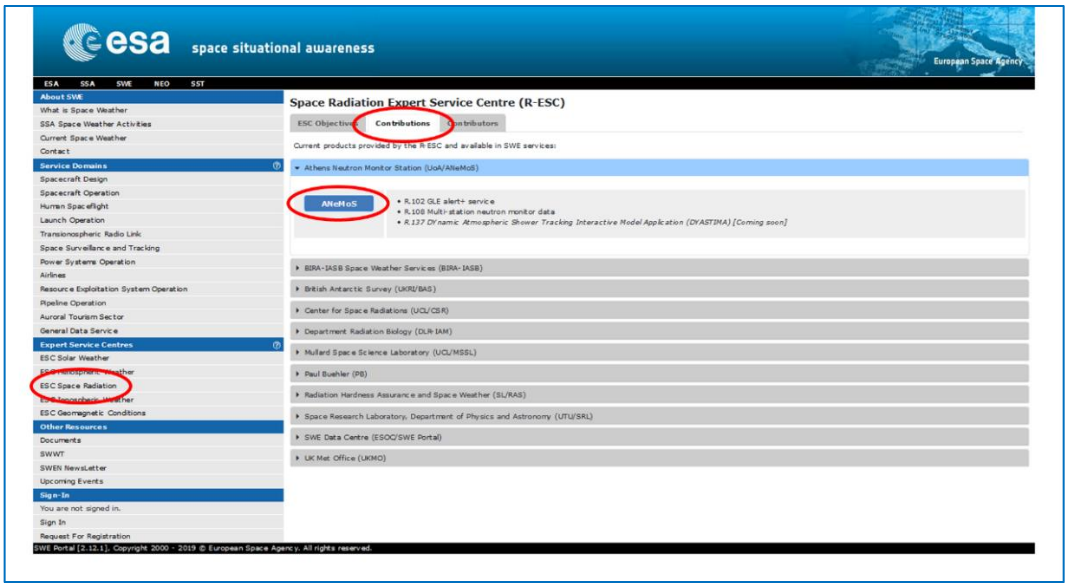


Figure 5: The Federated product DYASTIMA under the services of UoA / ANEMOS at the R-ESC.

On DYASTIMA homepage, the user can find the basic information about the DYASTIMA product. Through the navigation menu on the top of the page, by clicking on each tab, a new page is displayed, providing access to the corresponding material.

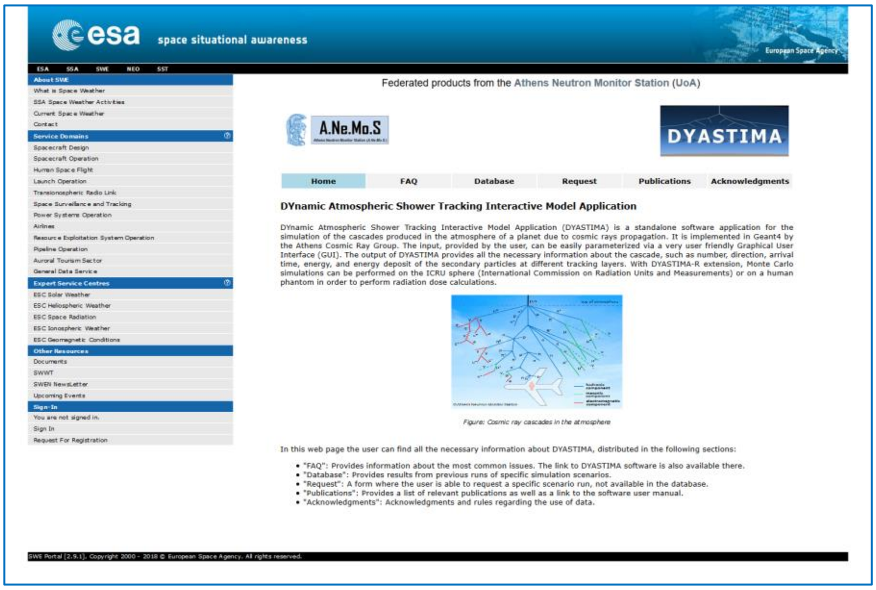


Figure 6: DYASTIMA Federated product homepage

On the Frequently Asked Questions (FAQ) tab, information about the most common issues is provided. Additionally, the link to DYASTIMA software is also available here (Question 2).

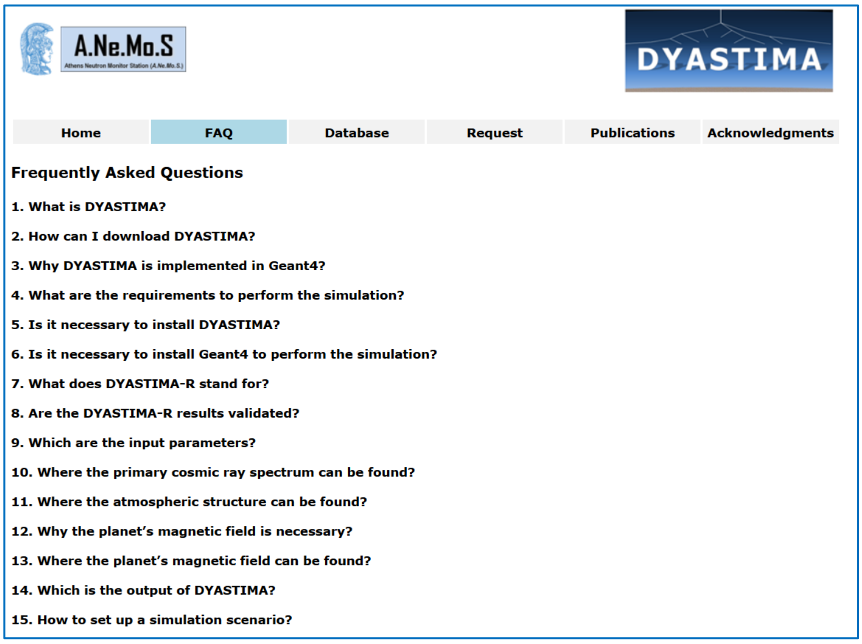


Figure 7: DYASTIMA Frequently Asked Questions (FAQ) Tab

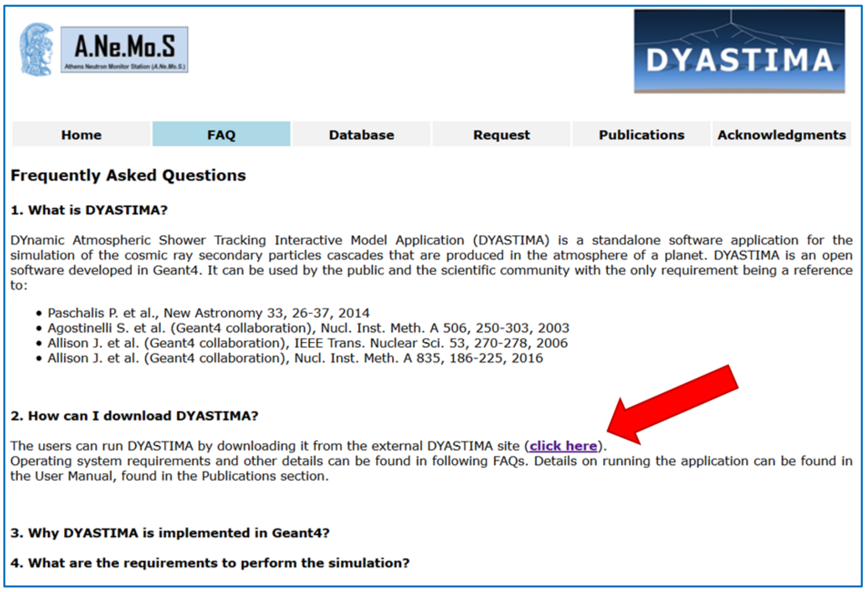


Figure 8: The link to download DYASTIMA software is available on the Question 2 of the FAQ.

In order to download DYASTIMA software click on the link provided here ("click here") and automatically you will be redirected to the webpage of A.Ne.Mo.S. (http://cosray.phys.uoa.gr/index.php/dyastima). After clicking on "here" in the middle of A.Ne.Mo.S. page, a pop-up window opens for the downloading of DYASTIMA software.

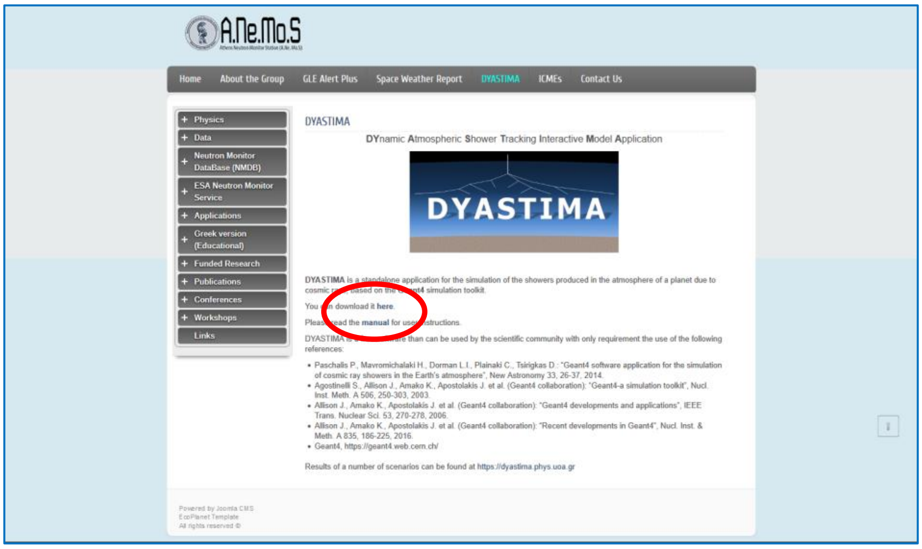


Figure 9: The A.Ne.Mo.S. portal (http://cosray.phys.uoa.gr/index.php/dyastima).

At the Database Tab, the user can find a table of results for different planets. In the initial phase, there are two scenarios available for Earth, one for solar minimum and one for solar maximum conditions. The Database will be enriched with more scenarios for Earth, as well as for other planets, such as Venus, Mars and Saturn.

Figure 10: DYASTIMA Database Tab

In order to access the results, click on the available scenarios. In the right panel, the followings appear:

- A description of the specific simulation scenario.
- An info text file regarding the input of the simulation as well as a list of .csv files corresponding to the specific simulation scenario. The files include the results for radiation dose, energy deposit, energy, and direction and arrival time at each altitude. Depending on the size of the results, the results of each case are splitted in .csv files of ~5MB.
- The references of the scenario settings.
  In order to download a specific file, just click on it.

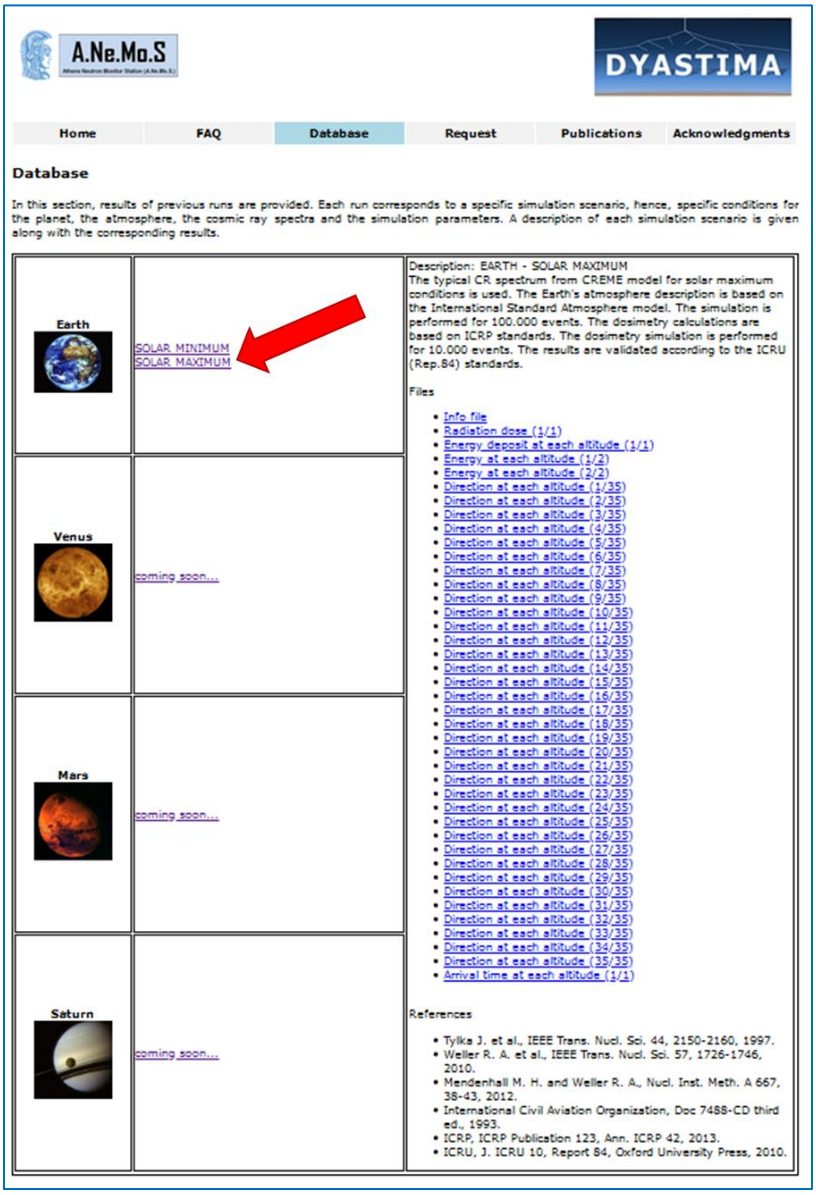
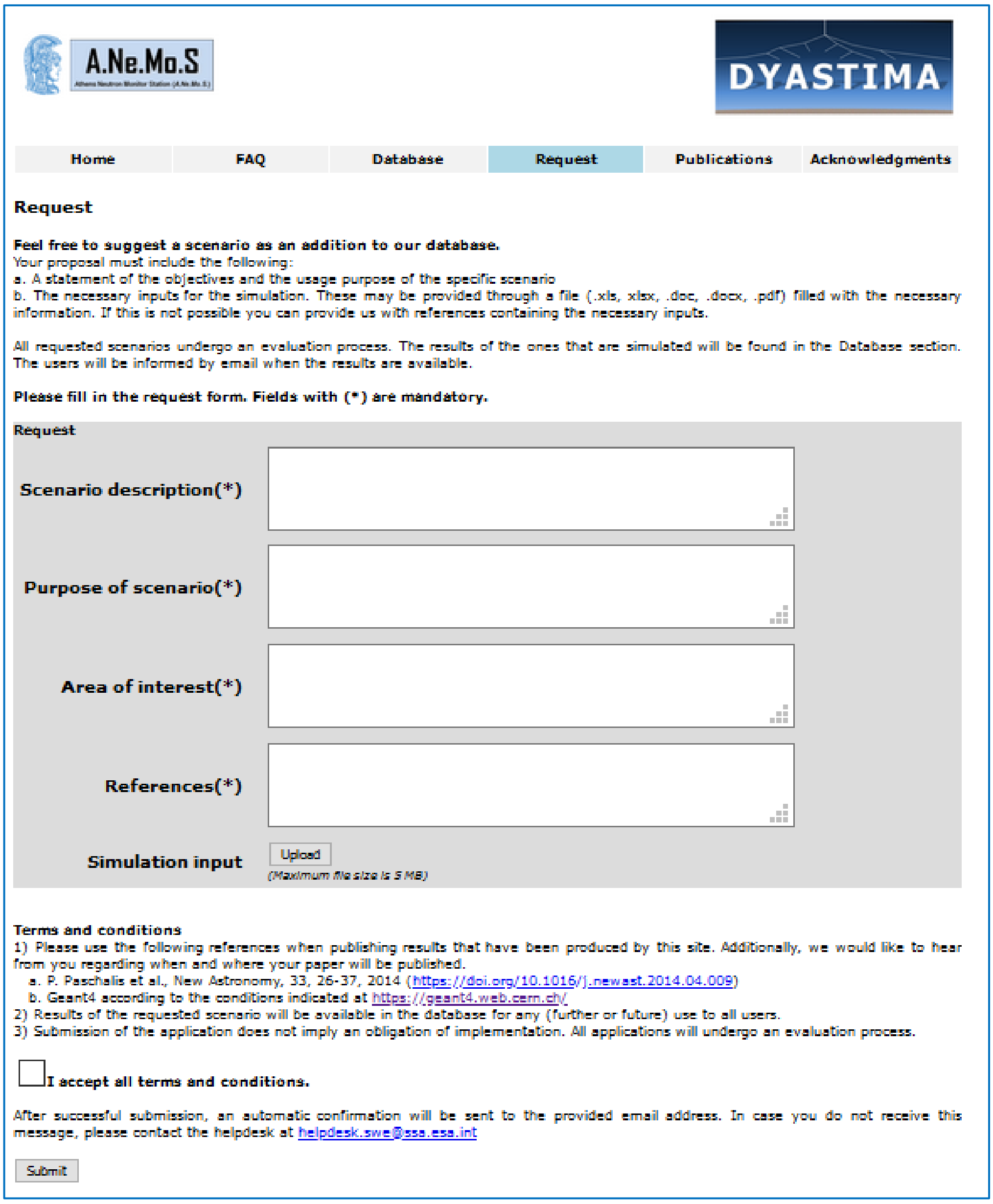


Figure 11: Results of a specific flight scenario at the DYASTIMA Database Tab.

At the Request Tab, the user can request a specific scenario run, through the available form. In order to submit the request, the user has to provide the scenario description, the purpose and the area of interest of the specific scenario, references as well as a simulation input file. This file should include basic information about the scenario, such as the cosmic ray spectra, the atmospheric profile etc. When all the input parameters are filled, check the "I accept all terms and conditions" box and click on "Submit".

Once the request is submitted successfully a confirmation email will be sent to the user.


A.Ne.Mo.S
DYASTIMA

Home | FAQ | Database | Request | Publications | Acknowledgments

Request

Feel free to suggest a scenario as an addition to our database.
Your proposal must include the following:
a. A statement of the objectives and the usage purpose of the specific scenario
b. The necessary inputs for the simulation. These may be provided through a file (.xls, xlsx, .doc, .docx, .pdf) filled with the necessary information. If this is not possible you can provide us with references containing the necessary inputs.

All requested scenarios undergo an evaluation process. The results of the ones that are simulated will be found in the Database section. The users will be informed by email when the results are available.

Please fill in the request form. Fields with (*) are mandatory.

Request

Scenario description(*)

Purpose of scenario(*)

Area of interest(*)

References(*)

Simulation input Upload
(Maximum file size is 5 MB)

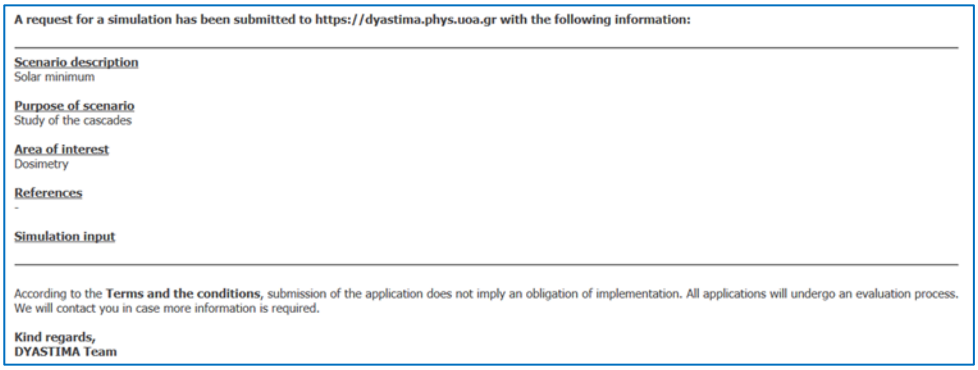
Terms and conditions
1) Please use the following references when publishing results that have been produced by this site. Additionally, we would like to hear from you regarding when and where your paper will be published.
a. P. Paschalis et al., New Astronomy, 33, 26-37, 2014 (https://doi.org/10.1016/j.newast.2014.04.009)
b. Geant4 according to the conditions indicated at https://geant4.web.cern.ch/
2) Results of the requested scenario will be available in the database for any (further or future) use to all users.
3) Submission of the application does not imply an obligation of implementation. All applications will undergo an evaluation process.

I accept all terms and conditions.

After successful submission, an automatic confirmation will be sent to the provided email address. In case you do not receive this message, please contact the helpdesk at helpdesk.swe@ssa.esa.int

Submit

Figure 12: The Request form available at the DYASTIMA Request Tab.



A request for a simulation has been submitted to https://dyastima.phys.uoa.gr with the following information:

Scenario description
Solar minimum

Purpose of scenario
Study of the cascades

Area of interest
Dosimetry

References
-

Simulation input

According to the **Terms and the conditions**, submission of the application does not imply an obligation of implementation. All applications will undergo an evaluation process. We will contact you in case more information is required.

Kind regards,
DYASTIMA Team

Figure 13: Example of the confirmation email after submitting a scenario request.

At the Publications Tab, a list of publications, conferences as well as related material are available. The link of the User Manual is also provided through this tab. The User Manual can also be accessed through the ANeMoS portal.

Finally, at the Acknowledgments Tab, the Acknowledgments and rules regarding the use of data are provided.

Figure 14: DYASTIMA Publications Tab.
The link for downloading the User Manual is also available here.

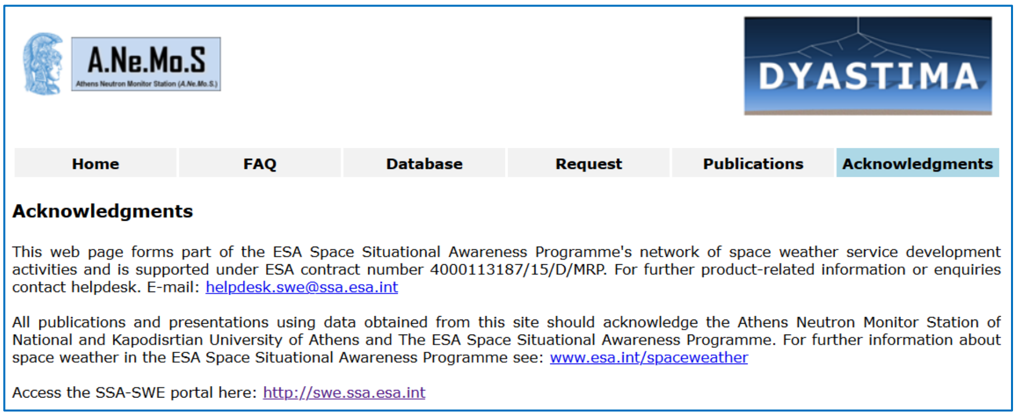


Figure 15: DYASTIMA Acknowledgments Tab.

3. Installation

3.1. How to install DYASTIMA

To have access to DYASTIMA software, it is necessary to subscribe as a user at the ESA SWE ESC Space Radiation (http://swe.ssa.esa.int/space-radiation), following the SSO (single sign-on) procedure. Then, sign in and click on the DYASTIMA product (as it is hown in Chapter 2), in order to visit the dedicated DYASTIMA webpage.

Once you are at the dedicated DYASTIMA webpage, you will be able to download the DYASTIMA software by clicking on the link that you will find at the homepage. You will be re-directed to the Athens Neutron Monitor Station (A.Ne.Mo.S.) portal for DYASTIMA. There you can download DYASTIMA. DYASTIMA is a free software with the only requirement to use the references provided in Page 2 of this document. The User Manual can easily be downloaded at the homepage, too.

3.2. Requirements

DYASTIMA is a GUI-based application, developed in Microsoft Visual Studio. As a result, a Microsoft Windows operating system and the .NET library are required. The Geant4 library and Geant4 datasets are also required. DYASTIMA can automatically download all the required files of Geant4 and set the necessary environmental variables. The current version of DYASTIMA uses the version 10.4 of Geant4 and the corresponding datasets. The graphical user interface is presented in Figure 16.

For the execution of DYASTIMA, it is optimal to use an over mid-range computer. Commonly, the results of a simulation run require about 100 MB of disk space, depending strongly on the desired collected output. The required disk space may be increased in case of several tracking layers and/or in case the horizontal position of the particles is recorded, as well as in the case of radiation dosimetry calculations.

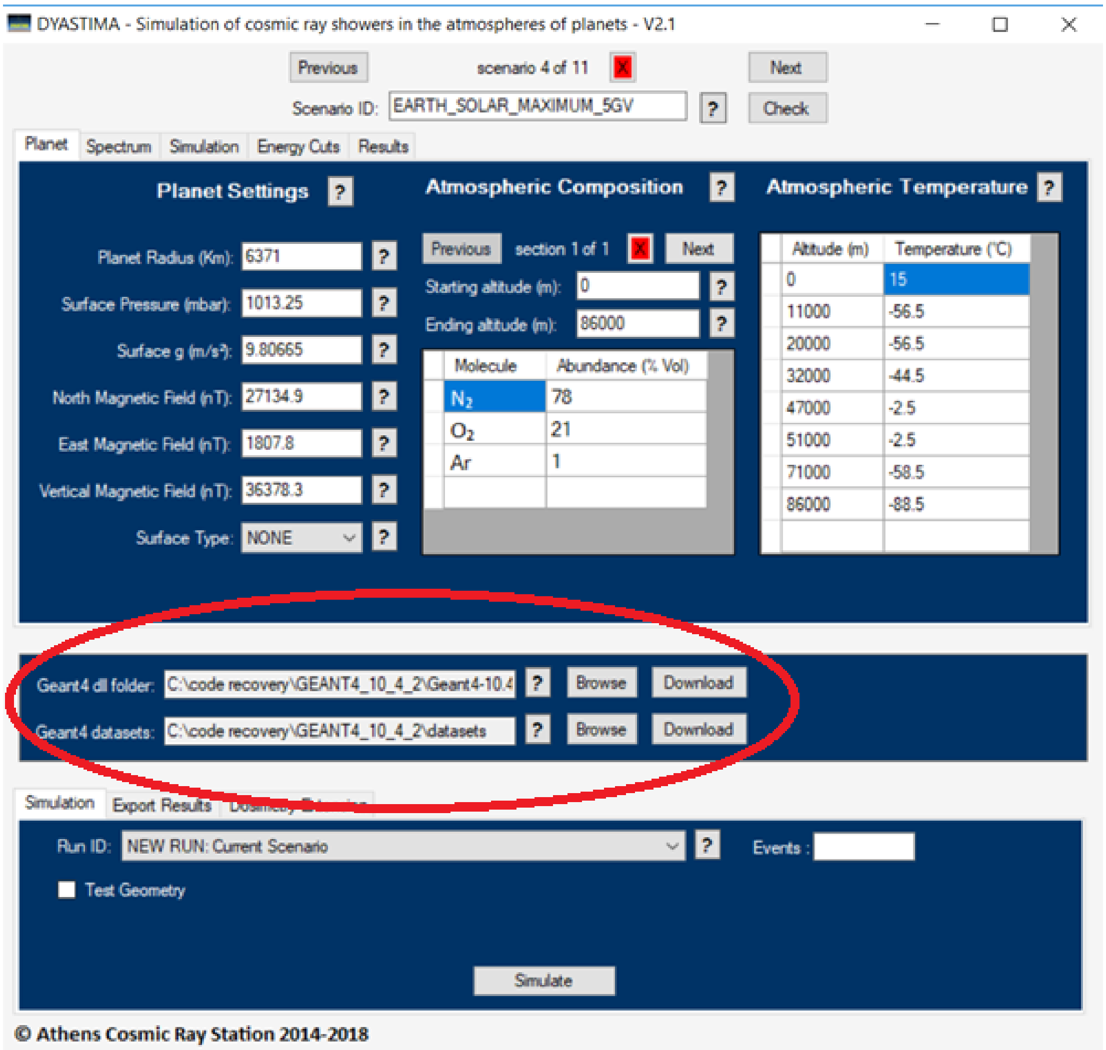


Figure 16: A snapshot of the DYASTIMA GUI.

4. Execution

4.1. General information

4.1.1. Input

The simulation requires several input parameters, categorized as following:

- general characteristics of the planet (radius, surface type, surface magnetic field, surface pressure and surface gravitational acceleration) structure of the atmosphere (composition, temperature profile)
- spectra (particle types, flux, zenith and azimuth range)
- settings regarding Geant4 and the simulation geometry (simulation area width, geometry model, division of the atmosphere, physics list, production range cut, beam altitude)
- altitudes in which the tracking of particles is performed
- optional energy cuts for the production, simulation or tracking of particles.

If the user also wishes to perform radiation dosimetry calculations some more input parameters are required, such as the phantom's dimensions and material.

As already mentioned, the simulation scenario is described by a user-friendly GUI. Help buttons provide ? the necessary information at every step and guide the user for the correct input of the parameters through the simulation process.

4.1.2. Output

Regarding the output, DYASTIMA executes the simulation of a specific scenario for a number of primary cosmic ray particles (events) defined by the user, providing all the necessary information about the air showers (Figure 17). Resume of a finished or a stopped run is also supported. For radiation dosimetry calculations, a second simulation is performed with the DYASTIMA-R extension (Figure1 8).

Finally, the user can test the simulation scenario and geometry by simulating one event for a specific particle, energy and incoming direction. The geometry test creates a .heprep file that can be viewed by the HepRApp browser (http://www.slac.stanford.edu/~perl/HepRApp/).

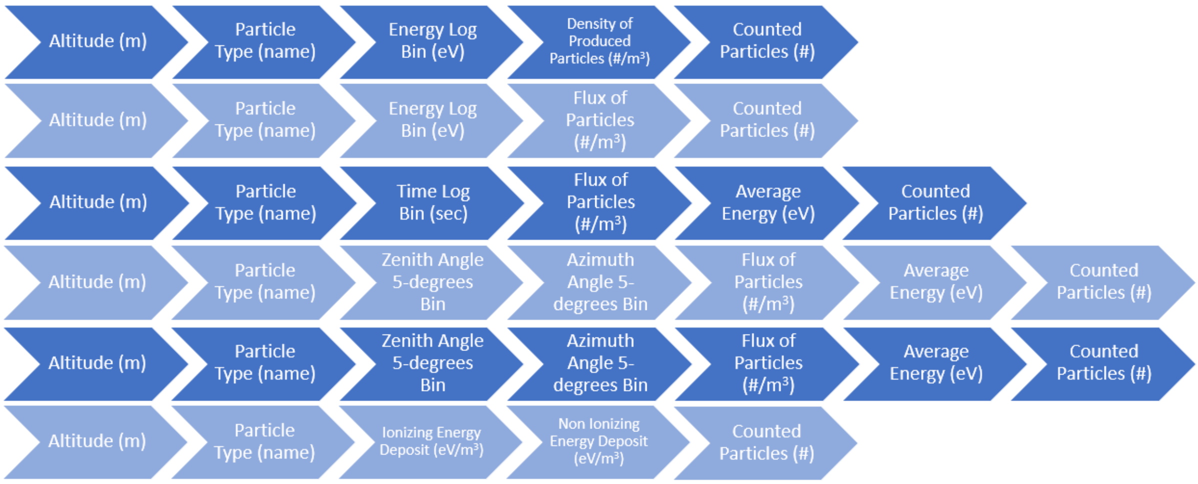


Figure 17: DYASTIMA output

Figure 18: DYASTIMA-R output

4.2. Description of the simulation scenario

After the installation of DYASTIMA, run the DYASTIMA.exe in order to access the GUI. For better description of the usage, the following figures show a testing simulation scenario. For a simulation scenario the user should define the required parameters that are distributed in the tabs of the GUI.

4.2.1. Scenario ID

The user can describe several simulation scenarios by using the buttons at the top of the form, as shown in figure 19. Each simulation scenario should have an ID. There is a button for checking the validity of the parameters that describe the scenario.

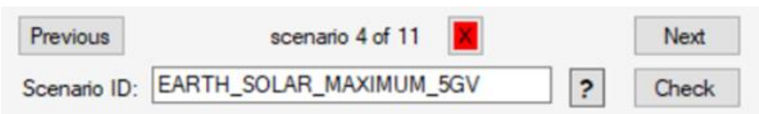


Figure 19: Buttons for navigation among the different simulation scenarios

4.2.2. Planet tab

In this tab, the user can define the characteristics and the atmosphere of the planet, as shown in Figure 20.

Planet Settings:

- Planet Radius: the radius of the planet in kilometres
- Surface Pressure: Surface pressure of the planet in mbar.
- Gravitational Acceleration: Surface Gravitational acceleration in m/s^2.
- North Magnetic Field: North-South component of the magnetic field at the planet's surface in nT. Positive values are towards the North direction.
- East Magnetic Field: East-West component of the magnetic field at the planet's surface in nT. Positive values are towards the East direction.
- Vertical Magnetic Field: Downward-Upward component of the magnetic field at the planet's surface in nT. Positive values are towards the downward direction.
- Surface Type: The surface type of the planet beneath the atmosphere. Selection among NONE - GROUND – SEA.

Information about the characteristics of a planet can be easily found online or in reference books. Some indicative examples are the following:

- Earth (https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html)
- Venus (https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html)
- Mars (https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html).

The values of the north, east and vertical Earth's magnetic field are available by NOAA (http://www.ngdc.noaa.gov/geomag/).

Atmospheric Composition:

The user should define sequential sections from the bottom to the top of the atmosphere. For each section the user should define:

- the starting and the ending altitude of the section in meters.
- the composition of the section in Molecule type - Abundance(%Vol) pairs. Abundances in each layer should sum to 100%.

<u>Atmospheric temperature</u>:

The user should define Altitude(m) - Temperature(°C) pairs from the bottom to the top of the atmosphere.

A good approximation of the Earth's atmosphere is provided by:

- The US Standard Atmosphere [9]
- the International Standard Atmosphere [10].

Both models are identical up to 32 km from the Earth's surface. It should be noted that these models are based on average conditions at middle geographic latitudes.

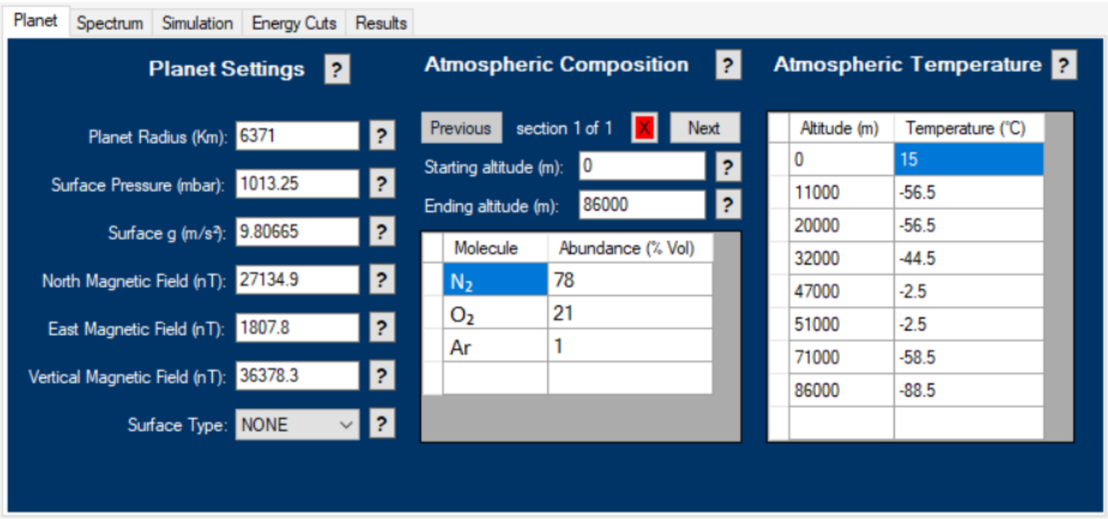


Figure 20: Example of the Planet Tab

4.2.3. Spectrum tab

The spectrum of several particles of the cascade can be defined as shown in Figure 21. For each spectrum the user should define:

- the particle name according to Geant4 notation
- the minimum and maximum zenith angles of the incoming particles in degrees
- the minimum and maximum azimuth angles of the incoming particles in degrees
- the differential spectrum in Energy/nucleon - Flux pairs. Units are MeV/n - Particles/(m^2·Sr·s·MeV/n) respectively.

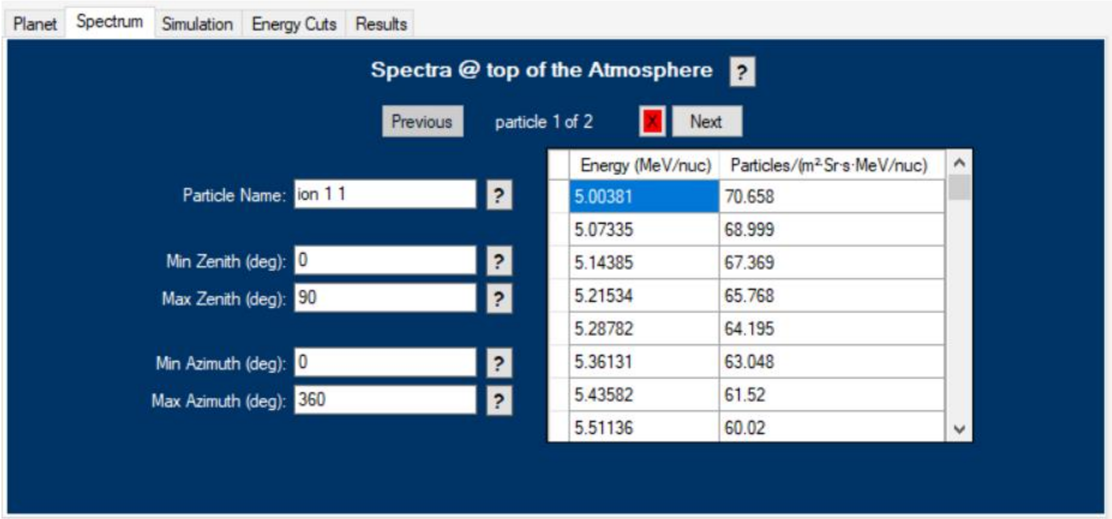


Figure 21: Example of the Spectrum Tab

It is noted that the differential spectrum is integrated numerically to calculate the total flux that is used in the normalization of the results. Linear interpolation is considered during the integration. Therefore, the user should define the points of the spectrum densely for accurate results. According to the General Particle Source documentation, used in Geant4 simulations, the maximum number of the defined points is 1024.

The fluxes of the galactic cosmic ray particles (Z=1 to Z=26), therefore the differential primary cosmic ray spectrum, can be calculated by the user with several models. Indicative examples are the ISO-15390 model [11], the CRÈME96 model [12][13][14] and the Nymmik et al. model [15]. These models are available by various online tools, such as:

- SPENVIS, https://www.spenvis.oma.be/ by BIRA-IASB and ESA, where the user can find all the models mentioned above
- CRÈME (https://creme.isde.vanderbilt.edu/) by Vanderbilt University, where one can find the CRÈME96 and the Nymmik et al. model
- OMERE, (http://www.trad.fr/en/space/omere-software/) by TRAD, where one can find the ISO-15390 and the CRÈME96 model.

4.2.4. Simulation Tab

In this tab, the user is able to define several simulation parameters, concerning the geometry of the simulation as well as the atmospheric tracking layer where the simulation is performed.

Simulation Settings

- Simulation Area Width: the horizontal dimension of the simulation area in Km. Representative value is 500-800 Km.
- Geometry Model: Selection between FLAT - SPHERE for the shape of the atmosphere.
- Air Density Change: Percentage decrease (%) of the density within the layers, used for the division of the atmosphere in slices. Representative value is 5%.
- Physics: Reference physics list of Geant4 that is used in the simulation. Optimal physics lists are predefined (FTFP_BERT_HP, QGSP_BERT_HP, QGSP_BIC_HP). The user can declare another reference physics list than the predefined ones.
- Range Cut: Production range cut of the particles in meters. Particles of a range smaller than the range cut are not produced. Optimal value is 1m. Small values increase accuracy with a trade-off to performance.
- Spectrum Altitude: Altitude of the particle source in meters.

Tracking Layers

Tracking Layers are the altitudes in which the tracking of particles is performed. The layers can be defined either in altitude (m) or in atmospheric depth (g/cm^2).

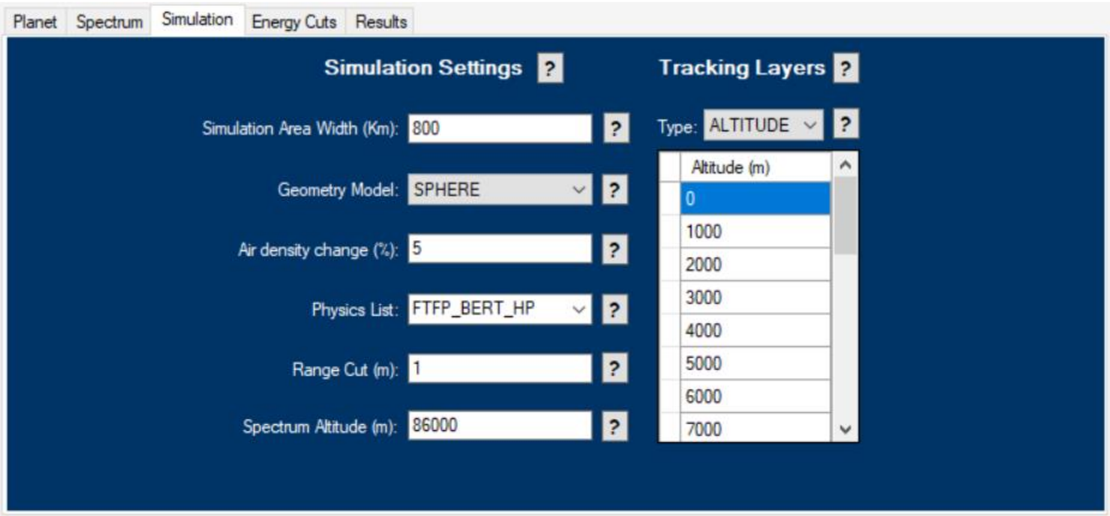


Figure 22: Example of the Simulation Tab

4.2.5. Energy Cuts Tab

In this tab, optional energy cuts for the production, simulation and/or tracking of particles can be defined. Particles with energy smaller than the defined one are excluded from the production, simulation and/or tracking respectively. The user should define pairs of Particle name (Geant4 notation) - Energy (MeV). A negative energy value excludes the particles completely.

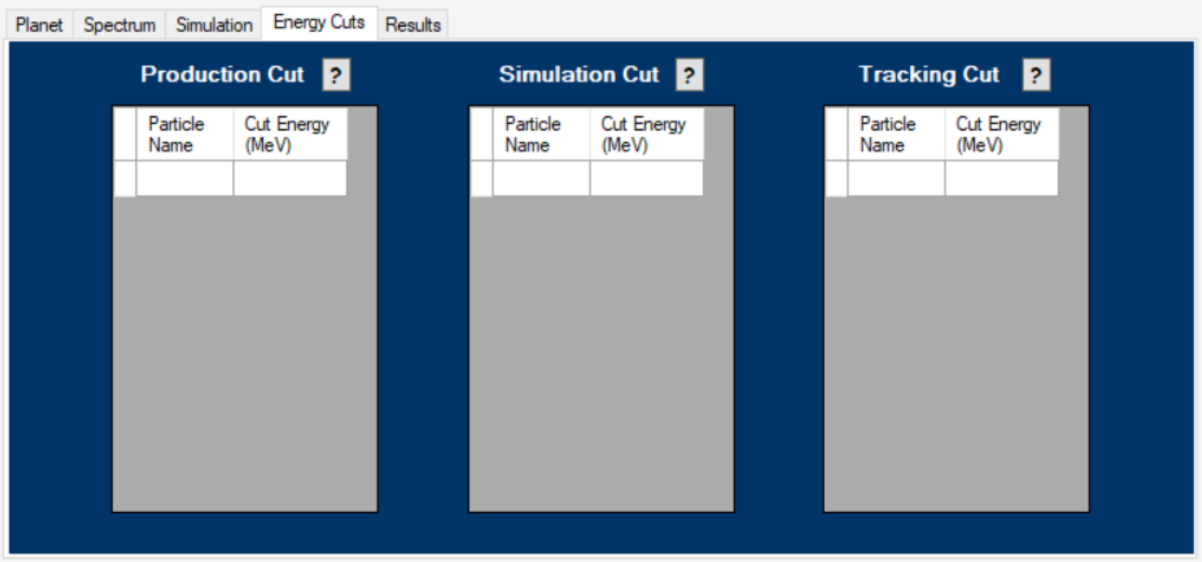


Figure 23: Example of the Energy Cuts Tab

4.2.6. Results Tab

In this tab, the user can define the histogram's bin range at the tracking layers of the simulation. Specifically, the parameters are:

- <u>Energy</u>, which is the energy range bin of particles at each tracking layer. The option <u>Log Energy Bin</u> provides the opportunity of categorizing the particles in bins in logarithmic scale.
- <u>Zenith angle</u> and <u>azimuth angle</u>, which corresponds to the zenith angle and azimuth angle range bins respectively of particles at each tracking layer.
- <u>Time</u>, which is the arrival time range bins of particles at each tracking layer. The option <u>Log Time Bin</u> provides the opportunity of categorizing the particles in bins in logarithmic scale.

- Energy of new particles at production time, which corresponds to the energy range bins of particles at production time and altitude. The option of categorizing the particles in bins in logarithmic scale is available by clicking on Log Energy Bin.
- Track spatial distribution, corresponding to the tracking of the horizontal position of particles. This option is useful for directional beams in order to study the horizontal dimension of the shower. It is noted that tracking may increase the required disc space significantly.
- Longitude and latitude direction distance, which are the longitudinal and latitudinal range bins respectively of particles at each atmospheric layer.

Finally, if the user desires to perform radiation dosimetry calculations with the second simulation by DYASTIMA-R, the data can be stored by ticking the check box.

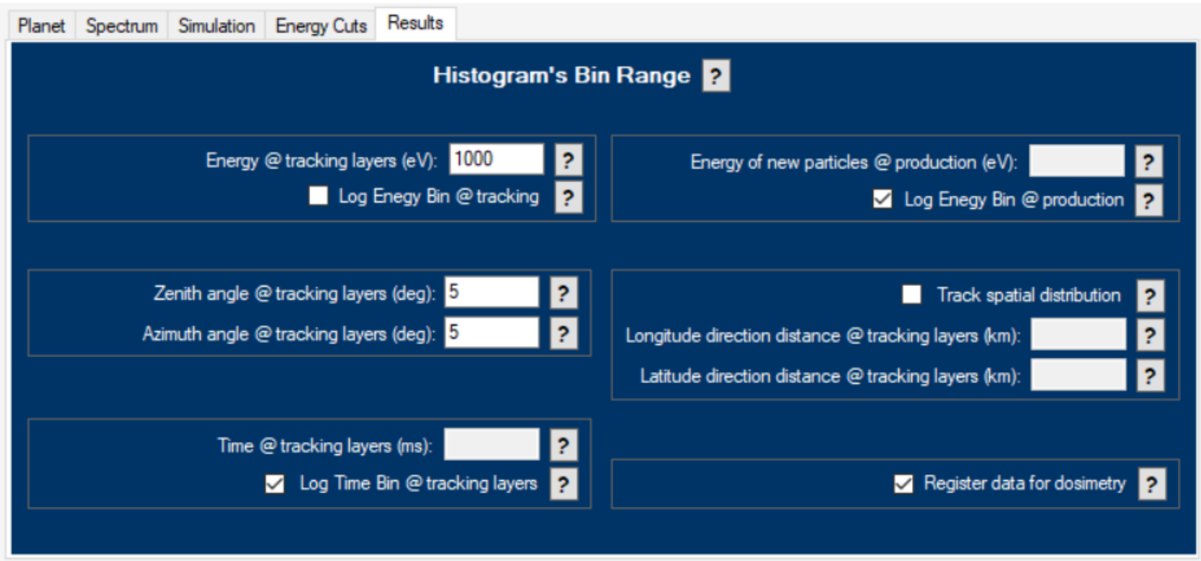


Figure 24: Example of the Results Tab

4.2.7. Geant4 Required Files

The current version of DYASTIMA uses the version 10.4 of Geant4 and the corresponding datasets. The user can download the necessary files from Geant4's webpage or download them by using the form. There is no need to download the entire Geant4 toolkit since DYASTIMA can automatically download all the required files of Geant4 and set the necessary environmental variables. The user should declare the folders in which the Geant4 dlls (bin folder) and Geant4 datasets are located.

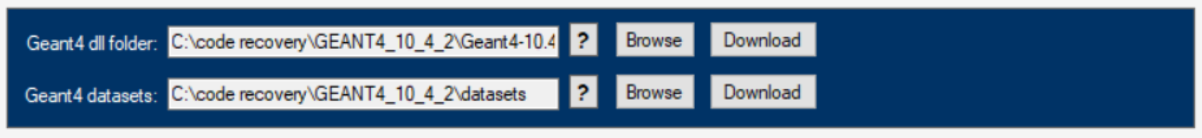


Figure 25: Required Geant4 datasets directly available for downloading by DYASTIMA.

4.3. Execution of the simulation scenario

4.3.1. Simulation Tab

The user selects from the “Run ID” drop-down menu the scenario that will be simulated. The “NEW RUN: Current Scenario” choice as well as previous simulations that may exist are shown in the drop-down menu, providing the possibility of resume. The user can start a new run of the current scenario or continue a previous one. The number of events for the simulation is also defined. Finally, the geometry of the scenario for a specific particle, energy and direction can be tested.

Figure 26: Starting / resuming a simulation scenario.

If a new run is selected, the scenario is checked by pressing the simulation button. Possible errors or invalid parameters are indicated to the user. If the scenario is valid, the scenario ID is associated with the current date and time and a new folder with this name is created in the results folder of DYASTIMA. This folder contains three files:

- the sqlite database file
- a .txt file containing the parameters of the scenario
- a .txt file containing the output of Geant4

If the user proceeds with DYASTIMA-R, two more files will be added to the folder:

- the sqlite database file for dosimetry calculations
- a .txt file containing the output of Geant4 for dosimetry calculations.

Name	Date modified	Type	Size
EARTH_SOLAR_MINIMUM_0GV__12-11-2018__12-18-23	12/11/2018 12:21	Data Base File	8,408 KB
EARTH_SOLAR_MINIMUM_0GV__12-11-2018__12-18-23_DOSIMETRY	12/11/2018 12:40	Data Base File	16,328 KB
EARTH_SOLAR_MINIMUM_0GV__12-11-2018__12-18-23_DOSIMETRY_output	12/11/2018 12:40	Text Document	37 KB
EARTH_SOLAR_MINIMUM_0GV__12-11-2018__12-18-23_output	12/11/2018 12:18	Text Document	38 KB
INFO_EARTH_SOLAR_MINIMUM_0GV__12-11-2018__12-18-23	12/11/2018 12:18	Text Document	148 KB

Figure 27: The files created for the simulation.

The simulation procedure is performed via a console application (Figure 18). For each event the application indicates the particle that enters the atmosphere, the energy, the time spent for the processing of the event and the estimated remaining time. The results of the simulation are flushed every 3 minutes in .db file while any message from Geant4 is written in the output .txt file. In case of testing the geometry, the simulation is performed for the one particle and a .heprep file is generated in the folder of the run.

```
Select C:\Users\anastasia\Desktop\DYASTIMA\DYASTIMA_RELEASE\DYASTIMA_files\DYASTIMA_SIMULATION.exe
/////////////////////////////////////////////////////////////////////////////////
//  DYASTIMA: COSMIC RAY SIMULATION IN ATMOSPHERE BY USING GEANT4              //
//  University of Athens - Physics Department - Cosmic Ray Station             //
//                                                                             //
//  Reference:                                                                 //
//  1) P. Paschalis et al., "Geant4 software application for the               //
//     simulationof cosmic ray showers in the EarthÆs atmosphere",             //
//     New Astronomy, Volume 33, 26-37, 2014                                   //
//                                                                             //
//  Based on Geant4 toolkit:                                                   //
//  1) Geant4 collaboration, "Geant4 - a simulation toolkit",                  //
//     NIM A, Volume 506, Issue 3, 250-303, 2003                               //
//  2) Geant4 collaboration, "Geant4 developments and applications",           //
//     IEEE Transactions on Nuclear Science, Volume 53, No.1, 270-278, 2006    //
/////////////////////////////////////////////////////////////////////////////////

Geant4 is being initializing. This may take a few seconds

Processing Event 1/10000 ------- Particle: proton , Energy: 0.341869 GeV
Event took 0.01 seconds ------- Estimating remaining time 99.99 seconds

Processing Event 2/10000 ------- Particle: proton , Energy: 2.35741 GeV
Event took 0.476 seconds ------- Estimating remaining time 2429.51 seconds

Processing Event 3/10000 ------- Particle: proton , Energy: 10.5118 GeV
Event took 1.912 seconds ------- Estimating remaining time 7990.94 seconds

Processing Event 4/10000 ------- Particle: proton , Energy: 0.238892 GeV
Event took 0.003 seconds ------- Estimating remaining time 6000.1 seconds
```

Figure 28: DYASTIMA console application.

4.3.2. Export Results Tab

The results of a simulation run are collected in the corresponding file of the sqlite database. There are VIEWS defined in the database that transform the collected raw results according to the format of Figures 27 and 28. An experienced user can use any sqlite browser and access the results by sending simple SQL queries.

However, DYASTIMA provides functionality for exporting the results to .csv files. The user selects the ID of the simulation, the category of the results, the altitude and the type of particle. The category of results includes the following:

- Energy of new particles at production
- Energy at tracking layers
- Time at tracking layers
- Direction at tracking layers
- Position at tracking layers
- Energy deposition at tracking layers.

Since several records may be available and in order to avoid creating huge .csv files that are not functional, the user has to define the line limit after which the .csv file will be split. The .csv files are stored in folder /CSVs of the simulation folder.

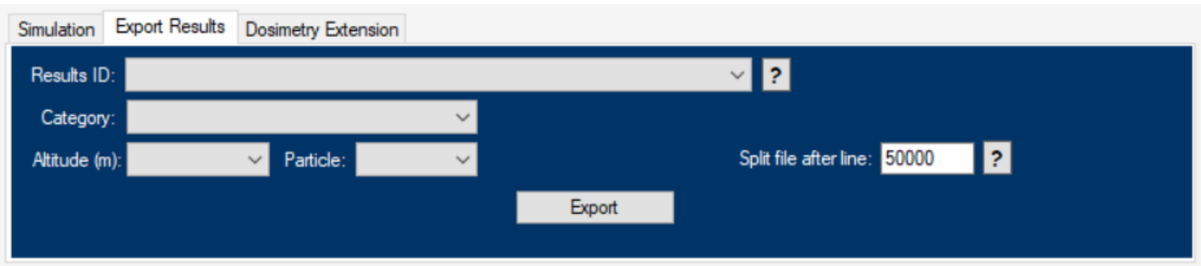


Figure 29: Example of the Export Results Tab.

4.3.3. Dosimetry Extension Tab

To perform radiation dosimetry calculation, a second simulation with the DYASTIMA-R extension will be performed. The quantities calculated are the dose rate (Gy/sec) and equivalent dose rate (Sv/sec) at each atmospheric layer, based on the ICRP [16][17] and ICRU [18] standards.

First of all, the user has to register data for dosimetry (See 3.2.6.). Then the ID scenario has to be selected. The simulation settings concern:

- Number of iterations, which corresponds to the number of interactions of the collected particles at each tracking layer with the phantom
- Reference physics list of Geant4 that is used in the simulation. Optimal physics lists are predefined (FTFP_BERT_HP, QGSP_BERT_HP, QGSP_BIC_HP).
- Phantom, where the user is able to define the phantom dimensions (height and width) as well as the phantom material. The option of a reference phantom (ICRU sphere) is also available.

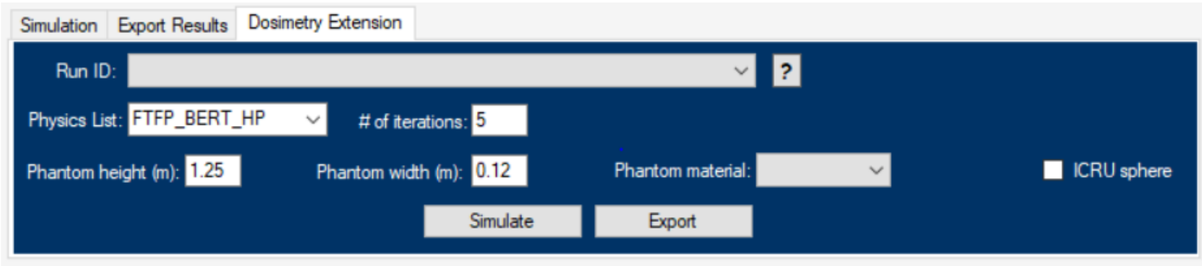


Figure 30: Example of the Dosimetry Extension Tab.

5. References

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[17] ICRP: "Assessment of Radiation Exposure of Astronauts in Space", ICRP Publication 123, Ann. ICRP 42, 2013.
[18] ICRU: "Reference Data for the Validation of Doses from Cosmic-Radiation Exposure of Aircraft Crew", Journal of the ICRU 10, Report 84, Oxford University Press, 2010.

Useful links:

- Athens Cosmic Ray Group, http://cosray.phys.uoa.gr/
- ESA SWE SSA R-ESC portal, http://swe.ssa.esa.int/space-radiation
- Geant4, https://geant4.web.cern.ch/
- SPENVIS, https://www.spenvis.oma.be/
- OMERE, http://www.trad.fr/en/space/omere-software/
- CRÈME, https://creme.isde.vanderbilt.edu/