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

esa

16TH EUROPEAN SPACE WEATHER WEEK
18 - 22 November 2019, Liège - Belgium
image by Anastasiia Kaufman

Validation of DYASTIMA and integration to ESA SSA R-ESC

Pavlos Paschalis[1], Anastasia Tezari[1][2], Helen Mavromichalaki[1], Norma Crosby[3], Marc Dierckxsens[3]

[1] Athens Cosmic Ray Group, Faculty of Physics, National and Kapodistrian University of Athens, Greece, [2] Medical Physics Laboratory, Medical School, National and Kapodistrian University of Athens, Greece, [3] Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Belgium

Abstract: Modelling the air showers created by the interaction of the primary cosmic ray particles with the atmosphere of a planet is of great importance for Space Weather studies. The DYnamic Atmospheric Shower Tracking Interactive Model Application (DYASTIMA) is a Monte Carlo simulation of the cascades produced in the atmosphere of a planet due to cosmic ray propagation, providing all the necessary information about the secondary particles. It is a standalone software application, based on a very friendly graphical user interface (GUI) and is implemented in Geant4 by the Athens Cosmic Ray Group. So far, DYASTIMA has been used successfully for the atmospheres of Earth and Venus. DYASTIMA-R, which is an additional simulation integrated into DYASTIMA software, performs radiation dosimetry calculations in the different atmospheric layers. More specifically, DYASTIMA-R provides the dose rate and the equivalent dose rate for various flight scenarios during different solar activity conditions and Space Weather phenomena. The validation of DYASTIMA-R is performed according to the recommendations set forth in ICRP 137 and ICRU 84 documents. DYASTIMA-R meets the ICRU/ICRP criteria satisfactorily and therefore can be used for a reliable determination of the exposure of aircrews and passengers to ionizing cosmic radiation. DYASTIMA is available at the European Space Agency Space Situational Awareness (ESA SSA) Space Radiation Expert Service Center portal (http://swe.ssa.esa.int/space-radiation) as a new federated product.

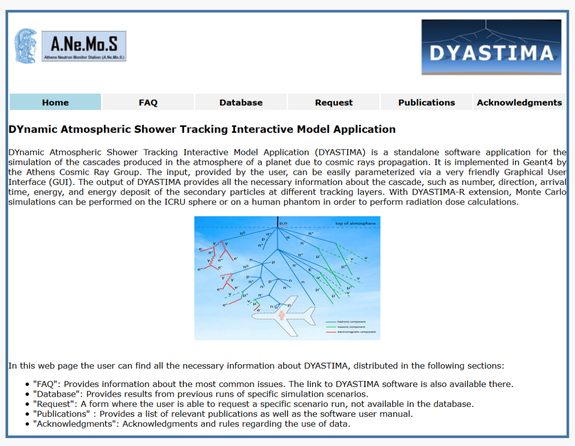
1. DYASTIMA / DYASTIMA-R

DYnamic Atmospheric Shower Tracking Interactive Model Application

- Monte Carlo simulation of the secondary particles cascades in the atmosphere of a planet.
- Developed with the GEANT4 simulation toolkit.
- Implemented by the Athens Cosmic Ray Group
- Provision of all the necessary information of the cascades at each atmospheric tracking layer.

DYASTIMA-R

Monte Carlo simulation for the calculation of radiobiological quantities (dose rate, equivalent dose rate, ambient dose equivalent) at each tracking layer.


A.Ne.Mo.S
DYASTIMA

Home | FAQ | Database | Request | Publications | Acknowledgments

DYnamic Atmospheric Shower Tracking Interactive Model Application

DYnamic Atmospheric Shower Tracking Interactive Model Application (DYASTIMA) is a standalone software application for the simulation of the cascades produced in the atmosphere of a planet due to cosmic rays propagation. It is implemented in Geant4 by the Athens Cosmic Ray Group. The input, provided by the user, can be easily parameterized via a very friendly Graphical User Interface (GUI). The output of DYASTIMA provides all the necessary information about the cascade, such as number, direction, arrival time, energy, and energy deposit of the secondary particles at different tracking layers. With DYASTIMA-R extension, Monte Carlo simulations can be performed on the ICRU sphere or on a human phantom in order to perform radiation dose calculations.

In this web page the user can find all the necessary information about DYASTIMA, distributed in the following sections:

- "FAQ": Provides information about the most common issues. The link to DYASTIMA software is also available there.
- "Database": Provides results from previous runs of specific simulation scenarios.
- "Request": A form where the user is able to request a specific scenario run, not available in the database.
- "Publications" : Provides a list of relevant publications as well as the software user manual.
- "Acknowledgments": Acknowledgments and rules regarding the use of data.

New Federated Product at the ESA – SSA R-ESC!

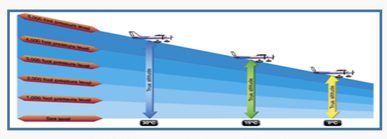
http://swe.ssa.esa.int/web/guest/dyastima-federated

https://dyastima.phys.uoa.gr

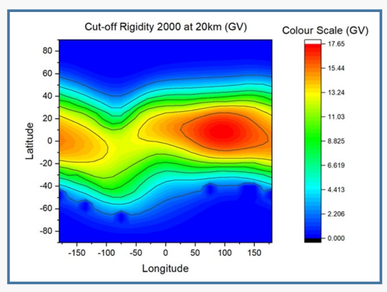
http://cosray.phys.uoa.gr/index.php/dyastima

2. DYASTIMA-R Validation

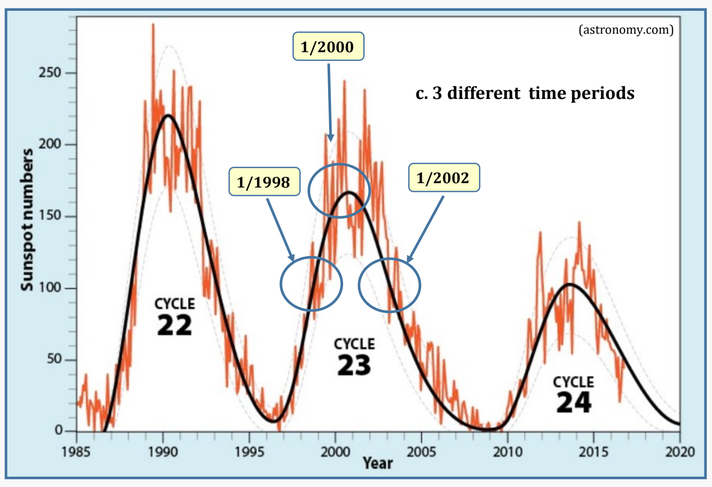
- Calculation of ambient dose equivalent H*(10).
- Comparison of the obtained values with ICRU Reference Data.
- Recommended acceptable uncertainty limit of ±30%.



a. 3 different flying altitudes (FL310, FL350, FL390)



b. 18 different vertical cut-off rigidities (Rc=0-17 GV)



c. 3 different time periods

More than 50 different flying scenarios simulated!

DYASTIMA Input Parameters

Earth's atmosphere
International Standard Atmosphere

CR Spectra @ top of the atmosphere
ISO Model
Extracted with OMERE by TRAD

3. DYASTIMA-R Validation Results

Ambient dose equivalent H*(10) as a function of the geomagnetic cut-off rigidity (DYASTIMA-R / ICRU Ref. Data / Percentage diff.)for 3 different flying altitudes, for January 1998.

Ambient dose equivalent H*(10) as a function of the geomagnetic cut-off rigidity (DYASTIMA-R / ICRU Ref. Data / Percentage diff.)for 3 different flying altitudes, for January 2000.

Ambient dose equivalent H*(10) as a function of the geomagnetic cut-off rigidity (DYASTIMA-R / ICRU Ref. Data / Percentage diff.)for 3 different flying altitudes, for January 2000.

4. Conclusions

- In high and middle geographic latitudes (0 GV to 10 GV), DYASTIMA-R calculated values of ambient dose equivalent are in good agreement with the reference data, without exceeding the 30% uncertainty proposed by ICRU.
- Above 10 GV (equatorial regions) a greater deviation seems to be observed, with a maximum uncertainty of about 41%, probably due to the more complicated geomagnetic field near the equatorial places.
- DYASTIMA-R tends to underestimate the ambient dose equivalent.
- The results are in good accordance with other models.
- The deviation observed in all flying scenarios may also be attributed to the input parameters of the used simulation, as the atmospheric profile and the primary cosmic ray spectra are based on different models. Therefore, DYASTIMA is being constantly improved in order to provide more precise results.

In conclusion, DYASTIMA/DYASTIMA-R meets the ICRU/ICRP criteria and can be used for the reliable determination of the exposure of aircrews and passengers to ionizing cosmic radiation.

References

1. S. Agostinelli et al. (Geant4 collaboration), Nucl. Inst. Meth. A 506 (2003), 250-303.
2. J. Allison et al. (Geant4 collaboration), IEEE Trans. Nuclear Sci. 53 (2006), 270-278.
3. J. Allison et al. (Geant4 collaboration), Nucl. Inst. & Meth. A 835 (2016), 186-225.
4. P. Paschalis et al., New Astronomy 33 (2014), 26-37.
5. P. Paschalis, et al., XXV ECRS 2016 Proceedings -eConf TBA, arXiv:1612.08937 [physics.space-ph] (2016).
6. ICRP, Ann. ICRP 45, ICRP Publication 123 (2016).
7. ICRU, Journal of the ICRU 10, Report 84, Oxford University Press (2010).
8. ICAO, Doc 7488-CD third ed. (1993).
9. ISO 2533:1975 (2007).
10. ISO 15390:2004 (2004).
11. OMERE, http://www.trad.fr/en/space/omere-software/
12. D.F. Smart, M.A. Shea, 30th ICRC, Mexico 2007.
13. M. Gerontidou, et al. , NMDB MEETING (2019).
14. ICRP, Ann. ICRP 42, ICRP Publication 123 (2013).
15. M. Pelliccioni, Rad. Prot. Dos. 88, 4 (2000), 279–297.

Acknowledgements: This work is supported by ESA SSA P3-SWE-III Space Radiation Expert Service Centre (70/3/12707). The European Neutron Monitor Services research is funded by ESA SSA Tender: RFQ/3-13556/12/D/MRP. A.Ne.Mo.S is supported by the Special Research Account of Athens University (70/4/5803). Many thanks to BIRA-IASB for the excellent cooperation and assistance to make DYASTIMA a federated product under the ESA SSA R-ESC.
A.T. thanks the Hellenic State Scholarship Foundation (IKY) for supporting her with a doctoral scholarship through the Operational Programme «Human Resources Development, Education and Lifelong learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), co-financed by Greece and the European Union (European Social Fund- ESF).

DYASTIMA

ppaschalis@phys.uoa.gr
anatez@med.uoa.gr