VYBRANÉ PROBLÉMY ASTROFYZIKY ČASTÍC A ICH SPOJENIE S INFORMATIKOU

Pavol Bobík

Ústav experimentálnej fyziky SAV, v.v.i.

Oddelenie kozmickej fyziky

bobik@saske.sk

- Spolupráca s TUKE na mnohých diplomových prácach a kozmickom výskume.
  - Pre podrobnosti o témach diplomových prác kontaktujte mňa a doc. Jána Genčiho
  - O jednotlivých témach môžete diskutovať najmä s
    - Danielom Gecáškom, Janom Villímom (najmä COR system)
    - Martinom Nguyenom (najmä strojové učenie a astrofyzikálne problémy, ktoré ním riešime)
    - Michalom Solaníkom (CUDA)
    - a ďalšími (napríklad Martin Vaško, ... a zoznam je dlhší)

SPOLUPRÁCA S TUKE OD ROKU 2012
- DESIATKY DIPLOMOVÝCH PRÁC

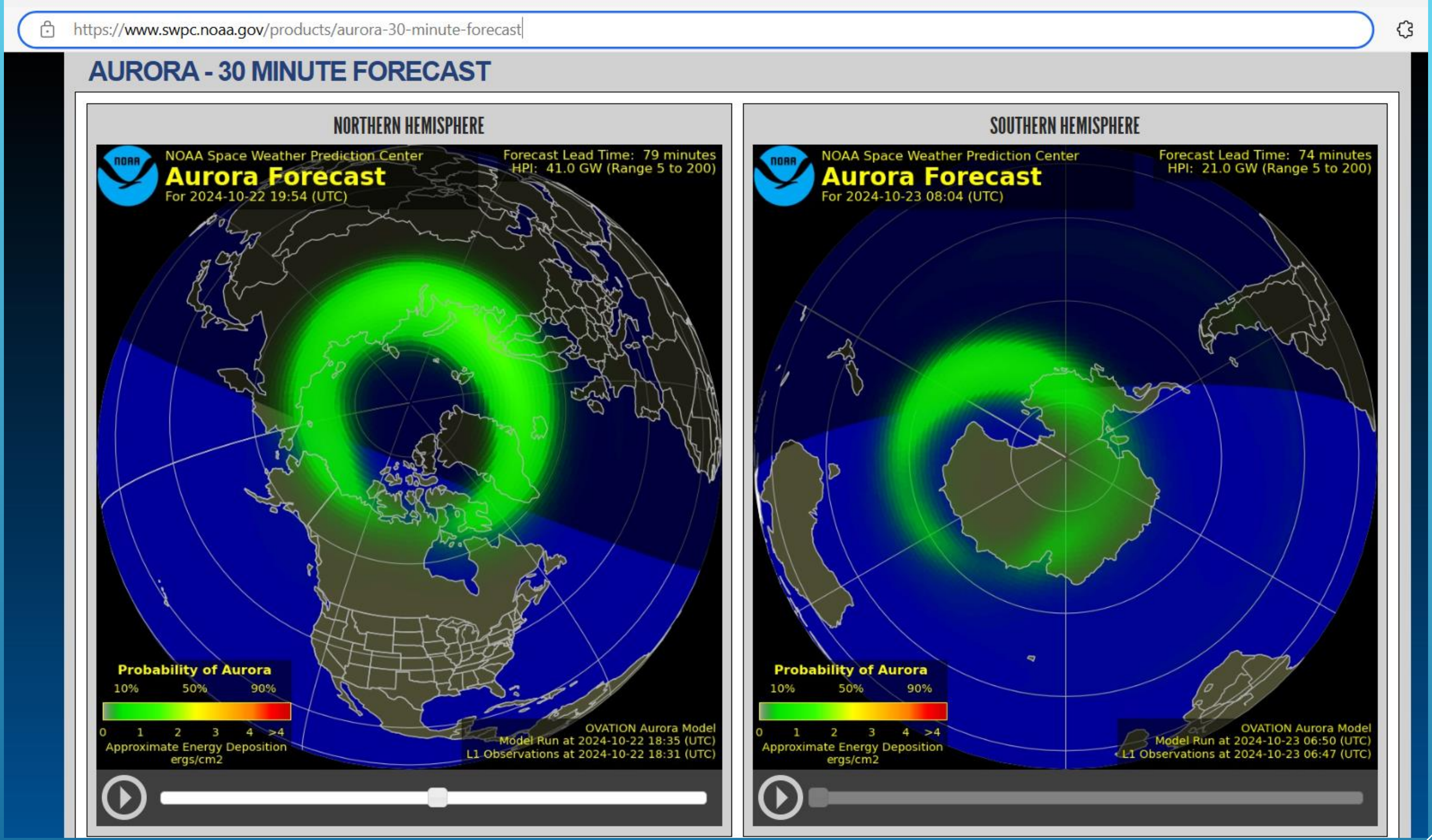
Abstrakt

V rámci prezentácie predstavíme astrofyzikálne témy riešené v spolupráci Ústavu experimentálnej fyziky SAV a Technickej univerzity v Košiciach. Povieme si o spresnení rádiouhlíkovej metódy datovania historických artefaktov, o odkrývaní vzťahu počasia a kozmického žiarenia, o použití metód strojového učenia pri opise radiačnej situácie na orbite Zeme a aj o tom ako môžete voľným okom vidieť subatomárnu časticu. A tiež, v rámci občianskej vedy vás zapojíme do riešenia záhady, ktorú práve riešime.

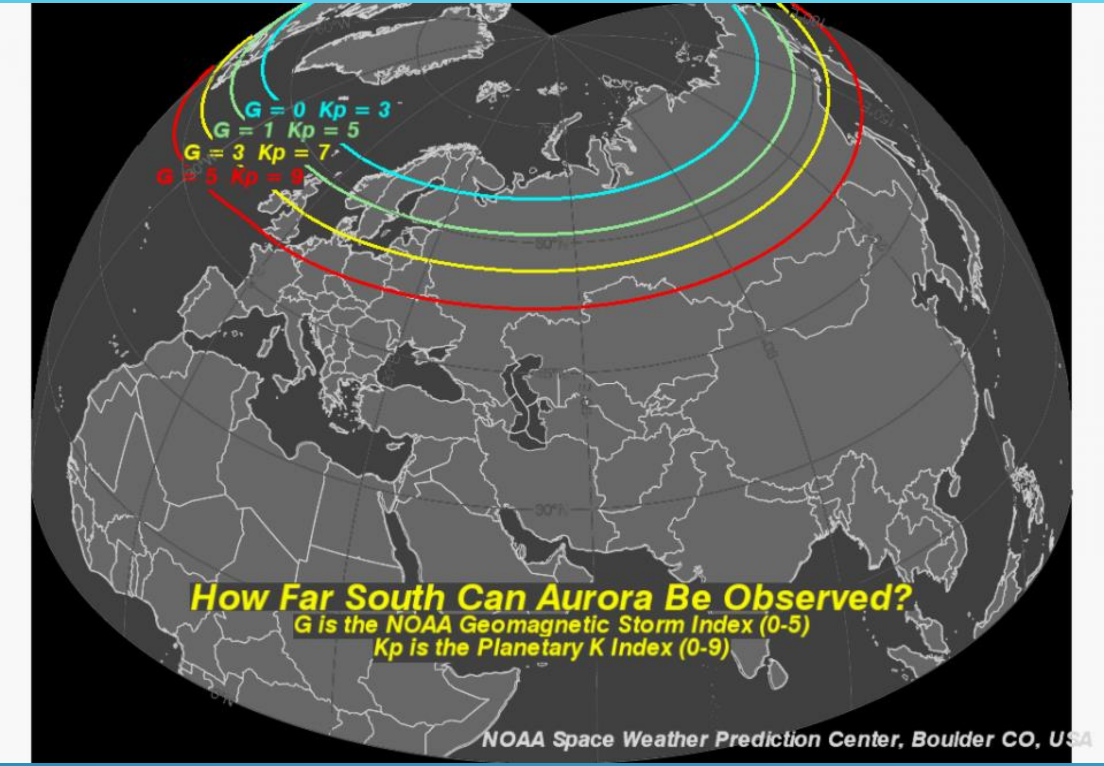
VYBRANÉ PROBLÉMY ASTROFYZIKY ČASTÍC A ICH SPOJENIE S INFORMATIKOU

Kto z vás videl polárnu žiaru?

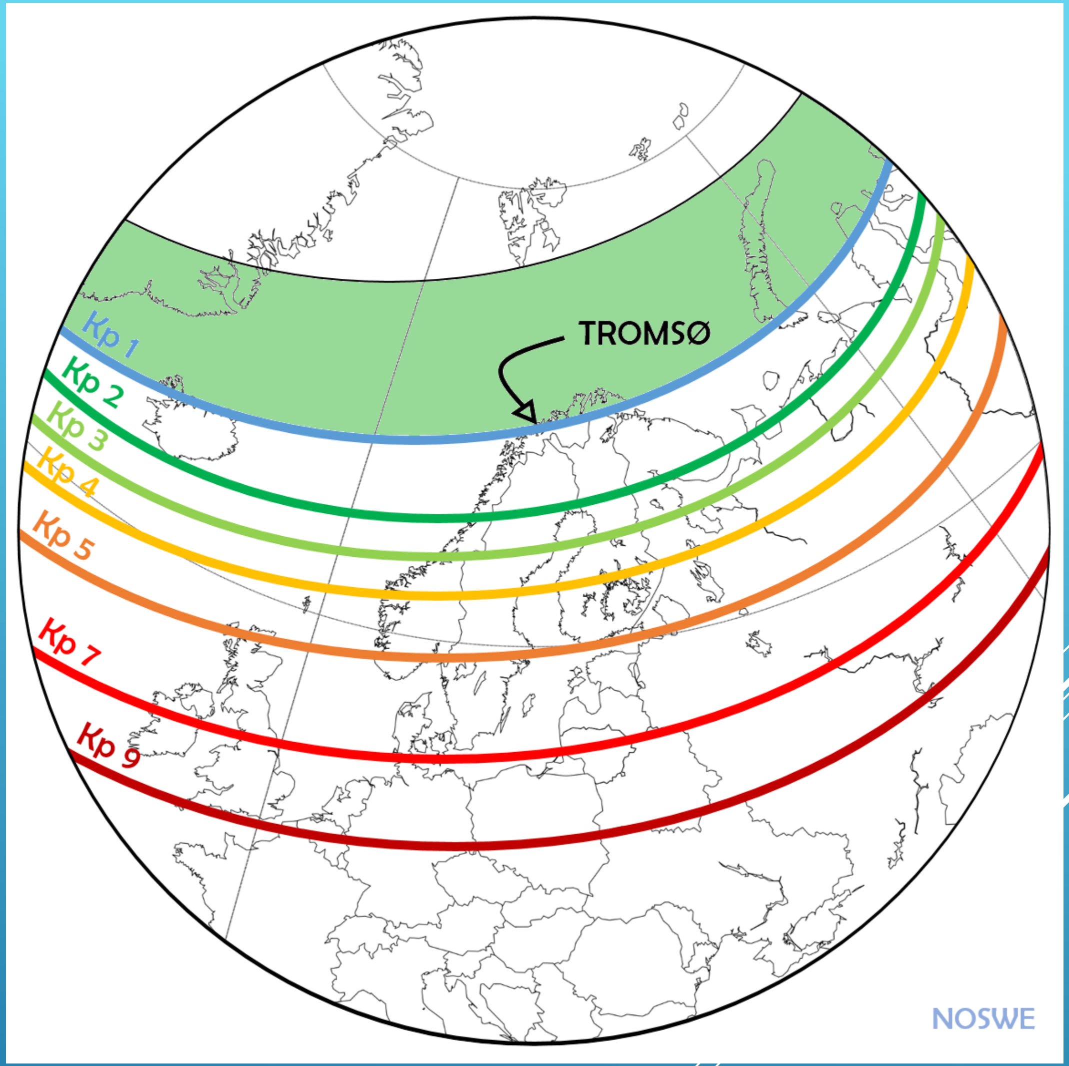
ZÁHADA ☺



[AURORA - 30 MINUTE FORECAST | NOAA / NWS SPACE WEATHER PREDICTION CENTER,](https://www.swpc.noaa.gov/products/aurora-30-minute-forecast)
https://www.swpc.noaa.gov/products/aurora-30-minute-forecast

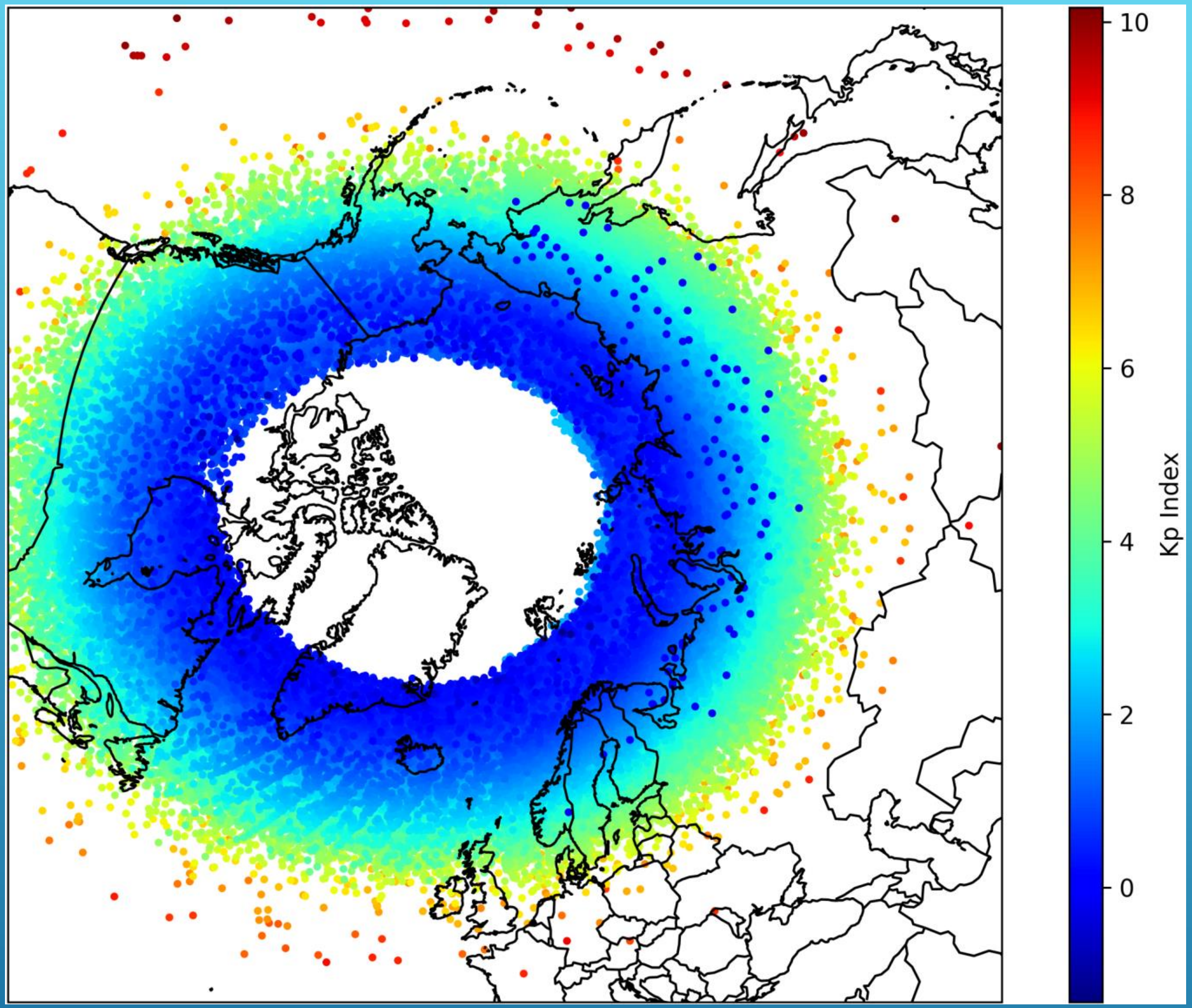


[Tips on Viewing the Aurora | NOAA / NWS Space Weather Prediction Center, https://www.swpc.noaa.gov/content/tips-viewing-aurora](https://www.swpc.noaa.gov/content/tips-viewing-aurora)

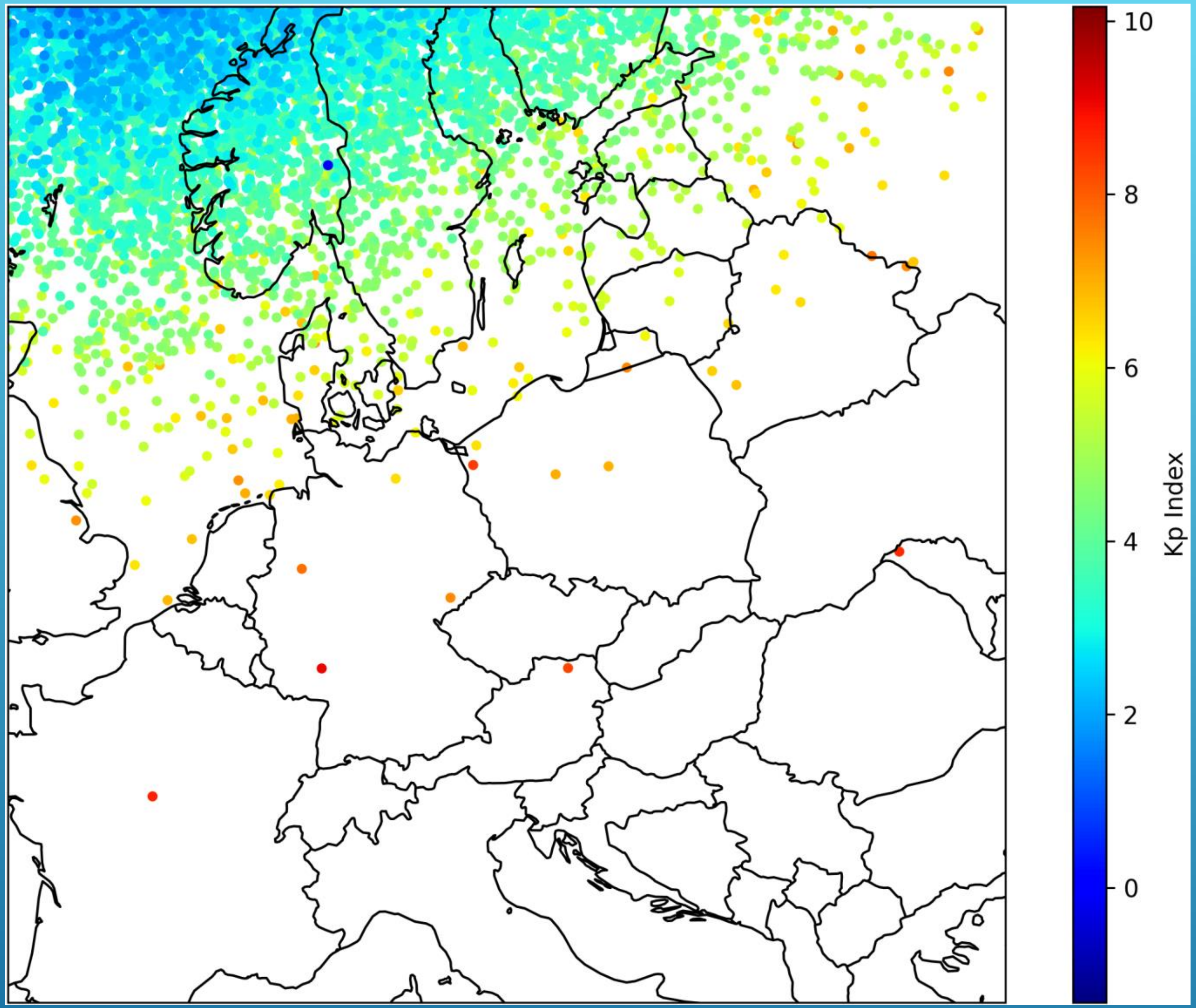


Aurora forecast on Yr – Yr help and information

VIDITEĽNOSŤ POLÁRNYCH ŽIAR



DMSP, meranie polôh aurorálneho oválu, 1983-2016
http://cedar.openmadrigal.org



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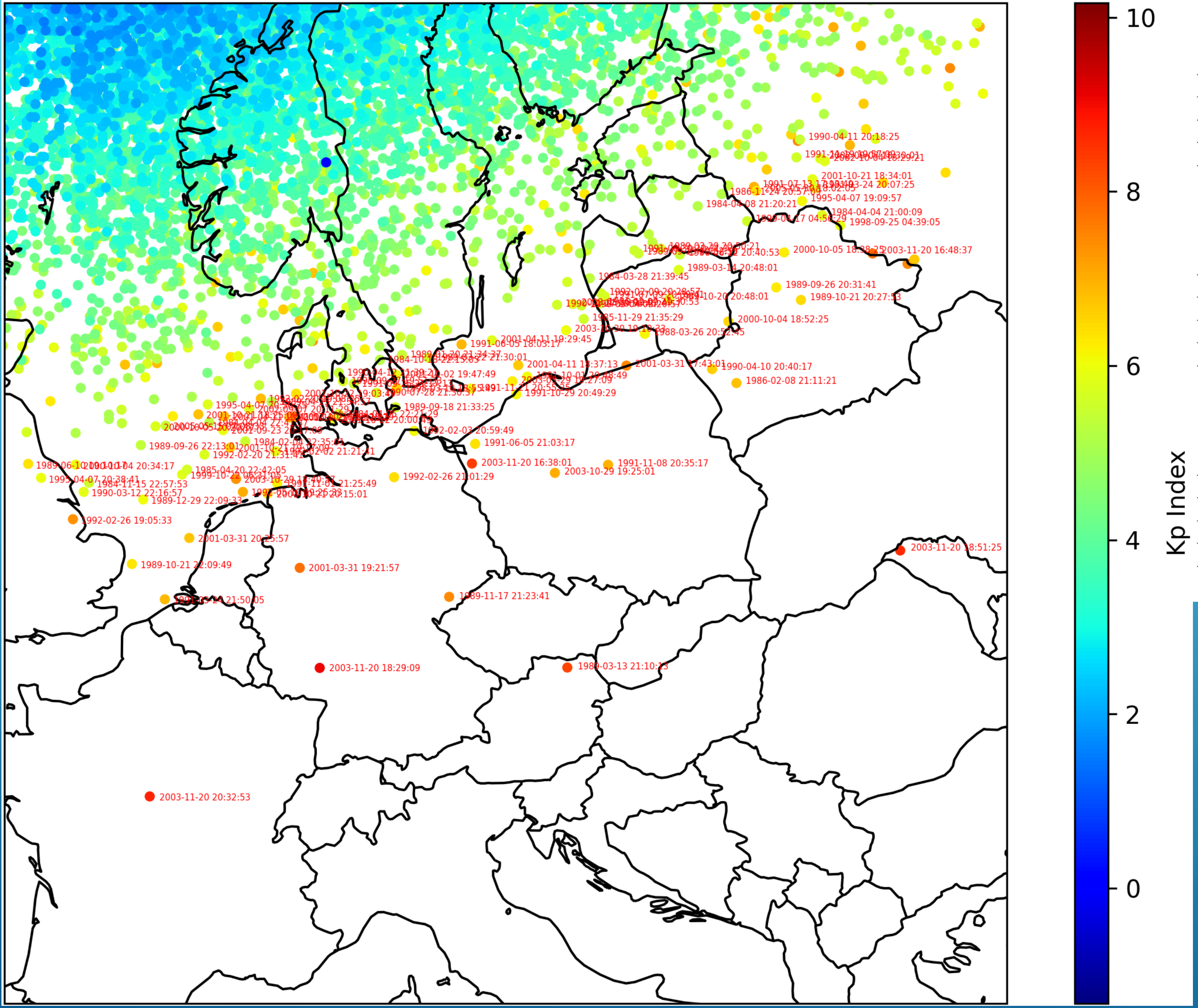
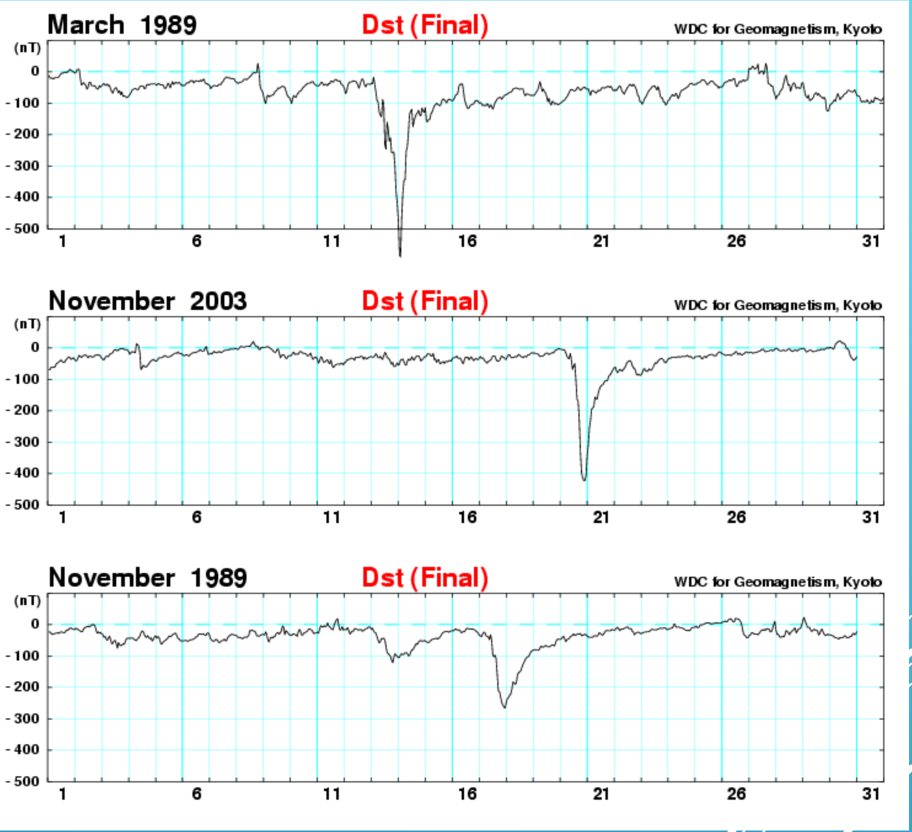
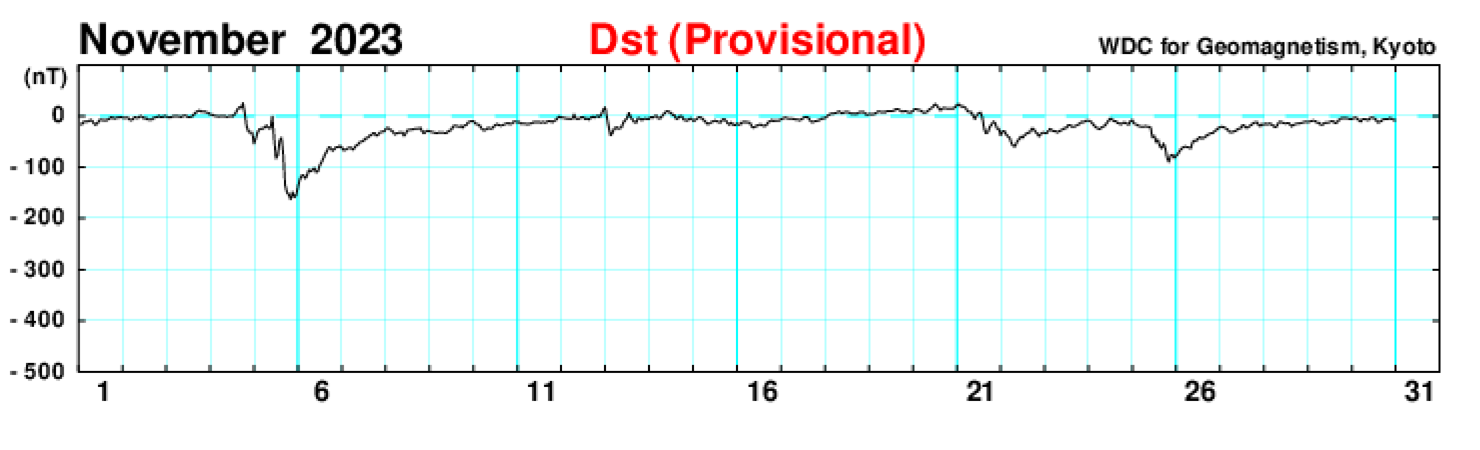
http://cedar.openmadrigal.org





[Geomagnetic Equatorial Dst index Home Page, https://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html](https://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html)

DMSP, meranie polôh aurorálneho oválu, 1983-2016



- 5.11.2023, [Fascinujúce svetelné divadlo: Nad Slovenskom sa objavila polárna žiara, https://www.teraz.sk/slovensko/shmu-na-slovensku-bolo-mozne-vidiet/752370-clanok.html]
  - [FOTO a VIDEO od čitateľov: Polárna žiara uchvátila Slovensko | TVNOVINY.sk, https://tvnoviny.sk/domace/clanok/865827-foto-a-video-od-citatelov-polarna-ziara-uchvatila-slovensko]
  - [Polárna žiara je PRÁVE viditeľná zo Slovenska voľným okom. Taká výrazná nebola už desaťročia. Pozrite si fotky | iMeteo.sk, https://www.imeteo.sk/spravy/polarna-ziara-je-prave-viditelna-zo-slovenska-volnym-okom-taka-vyrazna-nebola-uz-desatrocia-pozrite-si-fotky]
  - [Červená polárna žiara a zemetrasenie ako predzvesť KONCA SVETA? Odborníci reagujú - KOŠICE:DNES, https://kosicednes.sk/zaujimavosti/cervena-polarna-ziara-a-zemetrasenie-ako-predzvest-konca-sveta-odbornici-reaguju/]
- 25.11.2023, [FOTO a VIDEO: Polárna žiara nad východným Slovenskom. V najbližšej dobe budeme mať šancu pozorovať ďalšie | TVNOVINY.sk, https://tvnoviny.sk/domace/clanok/868990-foto-a-video-polarna-ziara-nad-vychodnym-slovenskom-v-najblizsej-dobe-budeme-mat-sancu-pozorovat-dalsie]
  - [Na východnom Slovensku bolo opäť vidieť polárnu žiaru. Pozrite si video - Korzár SME, https://presov.korzar.sme.sk/c/23249068/na-vychodnom-slovensku-bolo-opat-vidiet-polarnu-ziaru-pozrite-si-video.html]

Kp index, max. 7.3

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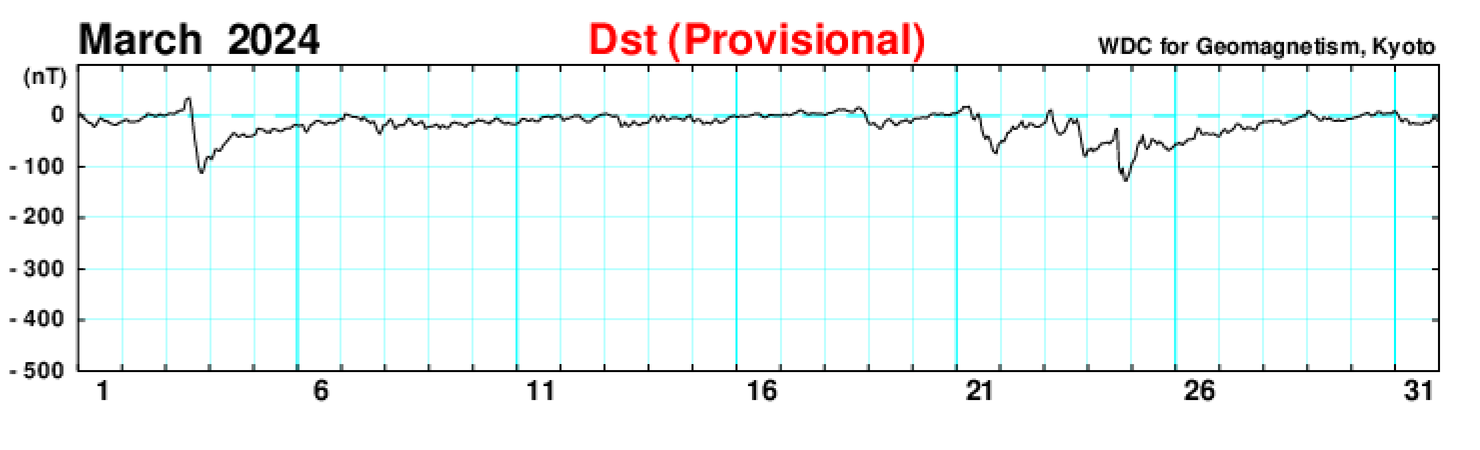

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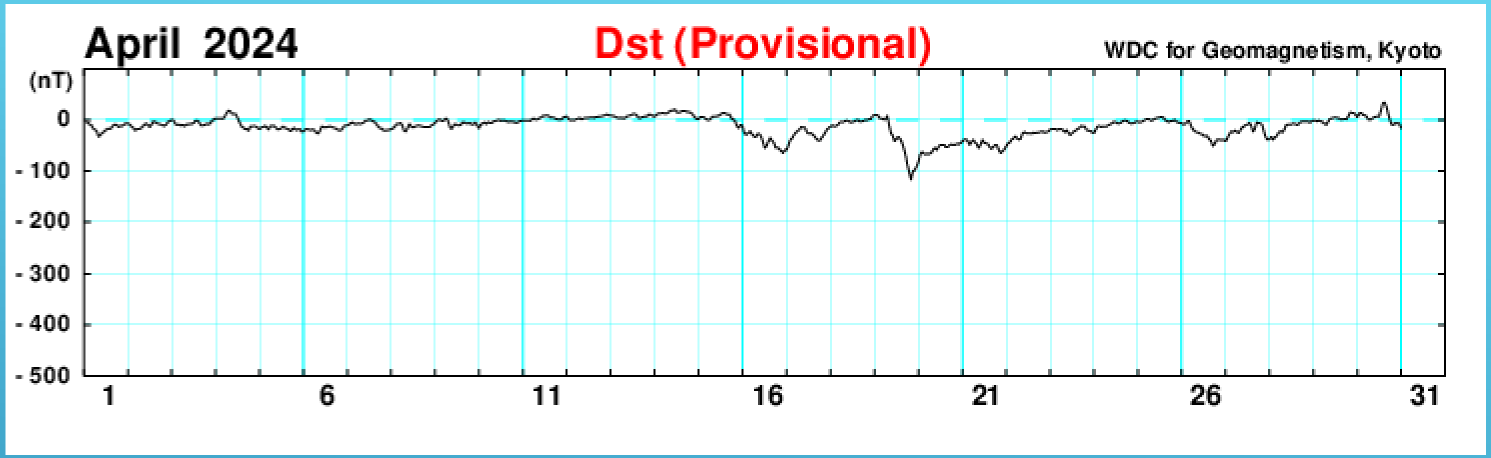
- 3.3.2024 - HNonline.sk - Nad Slovenskom sa objavila nečakaná polárna žiara, prekvapila aj meteorológov, https://hnonline.sk/slovensko/96134313-nad-slovenskom-sa-objavila-necakana-polarna-ziara-prekvapila-aj-meteorologov

MAREC 2024



- 19.4.2024, Prečo sme na Slovensku mohli opäť pozorovať polárnu žiaru? Poznáme odpoveď | iMeteo.sk, https://www.imeteo.sk/spravy/preco-sme-na-slovensku-mohli-opaet-pozorovat-polarnu-ziaru-pozname-odpoved
- Kp index max. 7

APRÍL 2024

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19-04-2024 22:00	3.7
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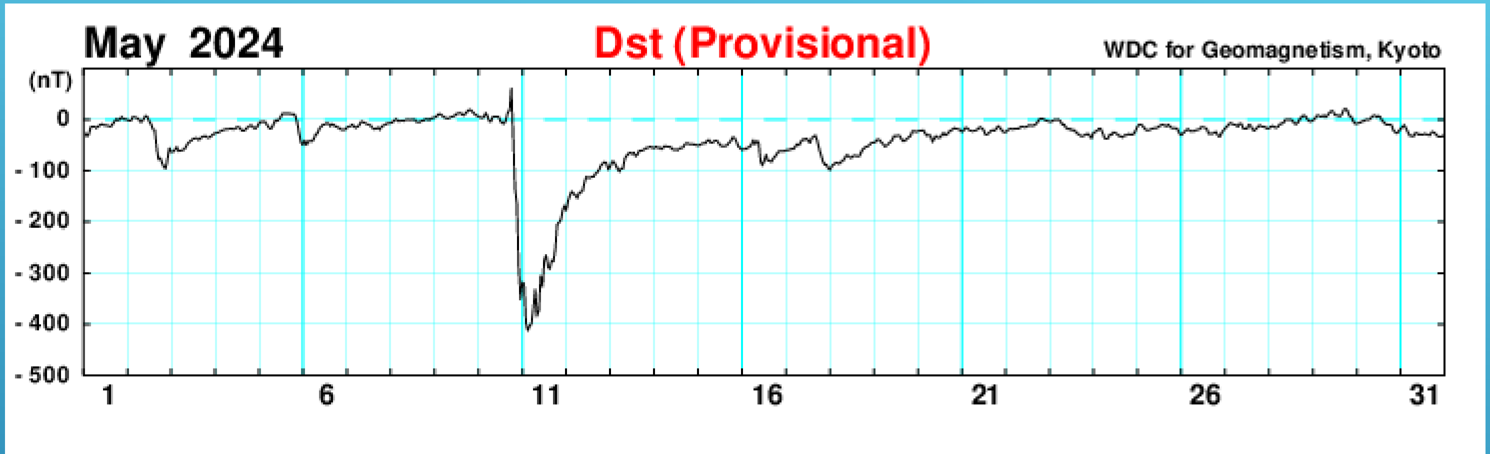
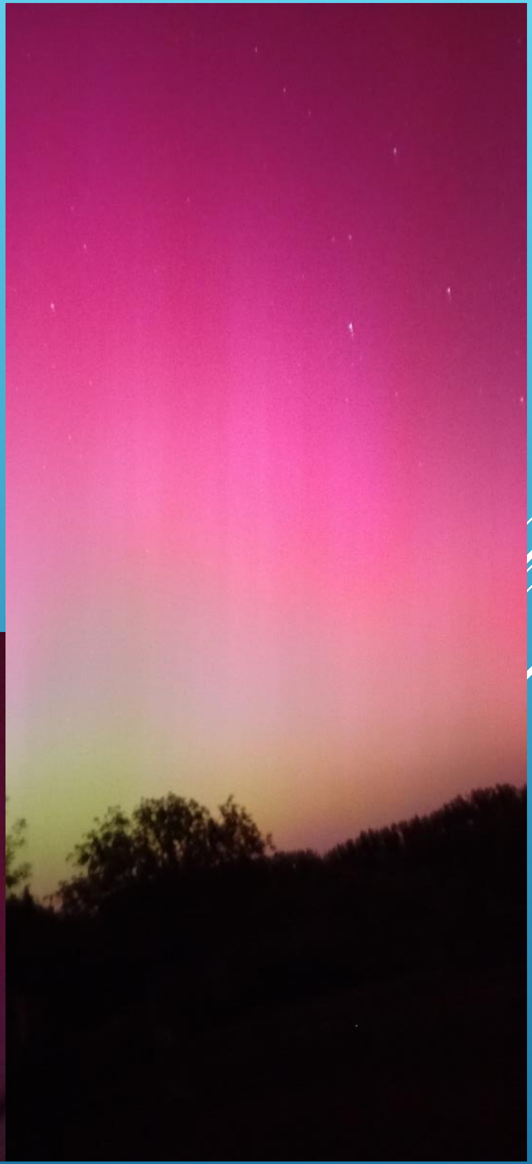
Malé Chyndice (okres Nitra) - noc z 10. Mája na 11. Mája 2024, 00:20, Kredit: Filip Jamrich





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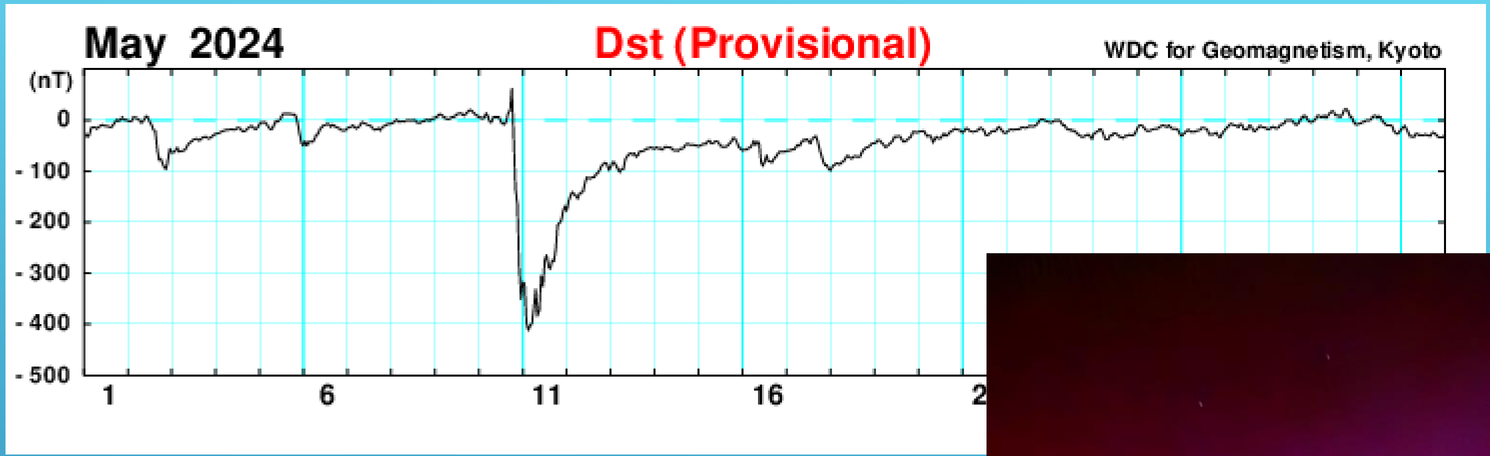

10.5.2024 Malacky, 22:26, Kredit: Katka

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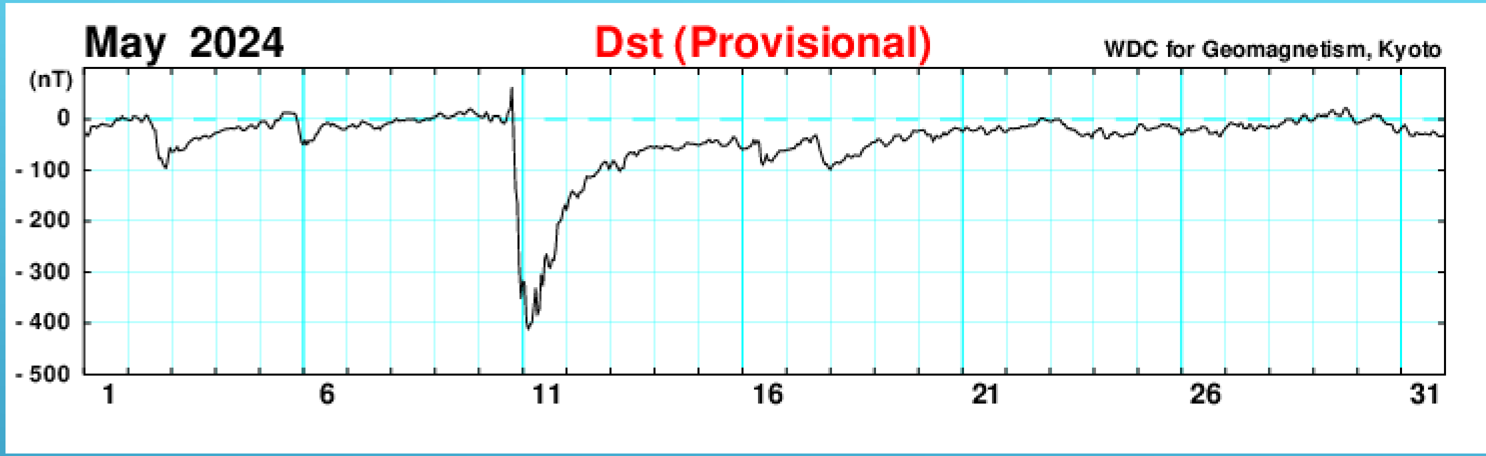
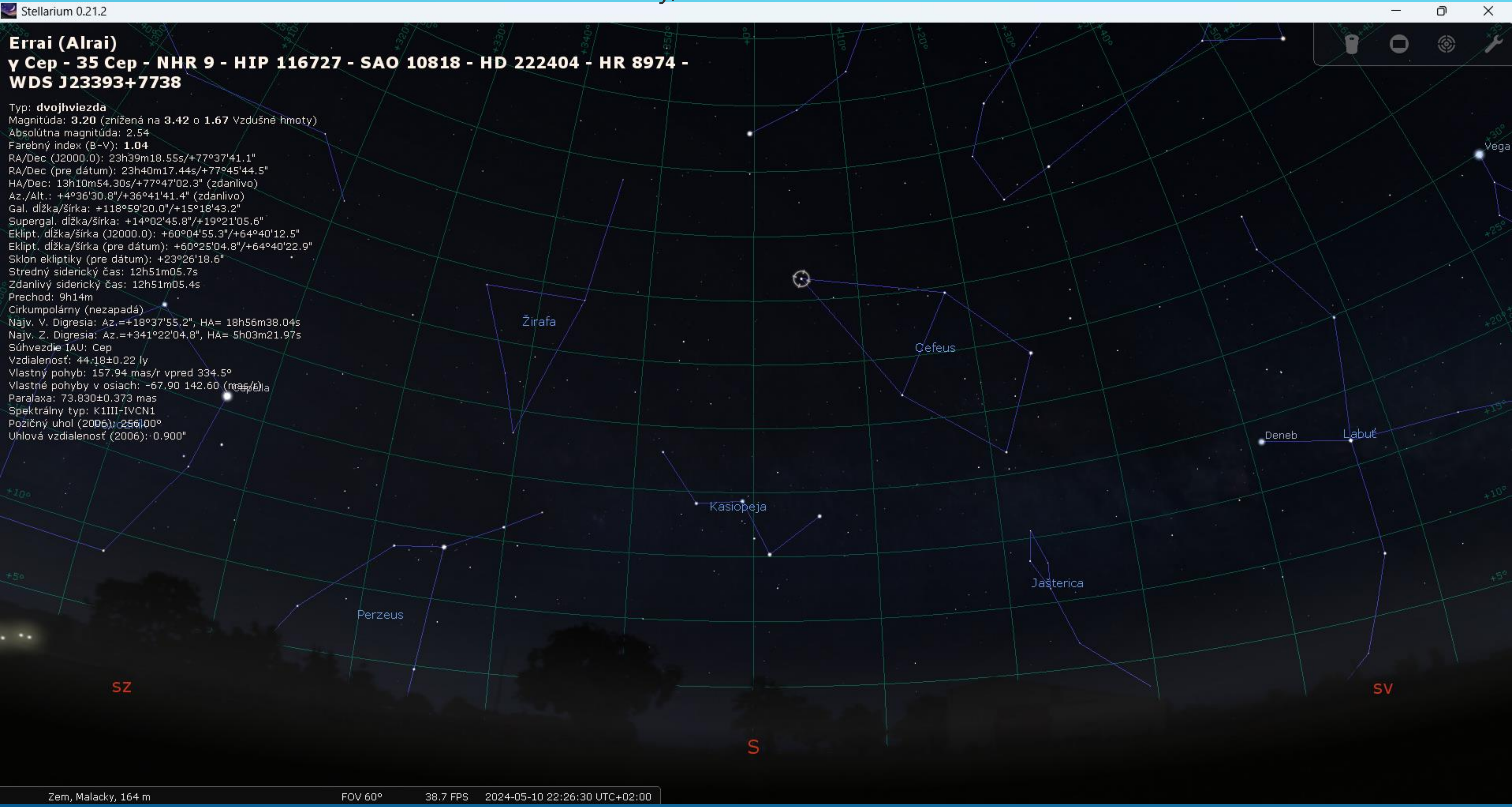
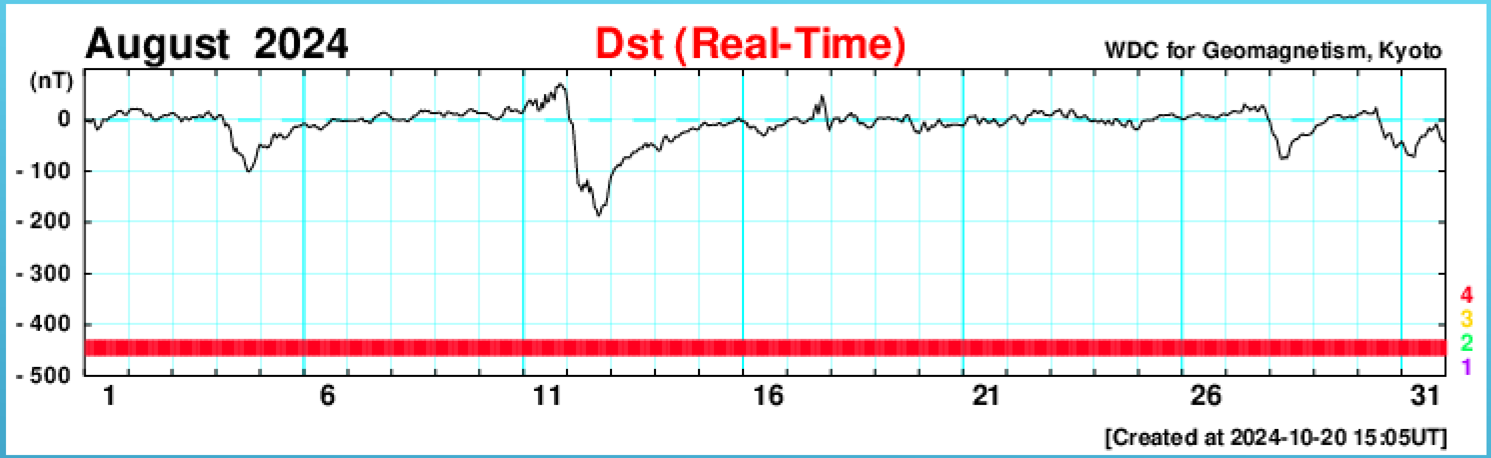


- V noci z 2. na 3. mája 2024,
  - Slovenskú oblohu rozžiarila polárna žiara: Výnimočné snímky, https://www.startitup.sk/nad-slovenskom-sa-objavila-unikatna-polarna-ziara-internet-zaplavili-snimky-uchvatneho-vesmirneho-divadla/
  - GALÉRIA: Slováci mohli pozorovať nádherné vesmírne divadlo. Takto polárna žiara rozžiarila Slovensko | iStream.sk, https://www.istream.sk/galeria-slovaci-mohli-pozorovat-nadherne-vesmirne-divadlo-takto-polarna-ziara-rozziarila-slovensko/

MÁJ 2024

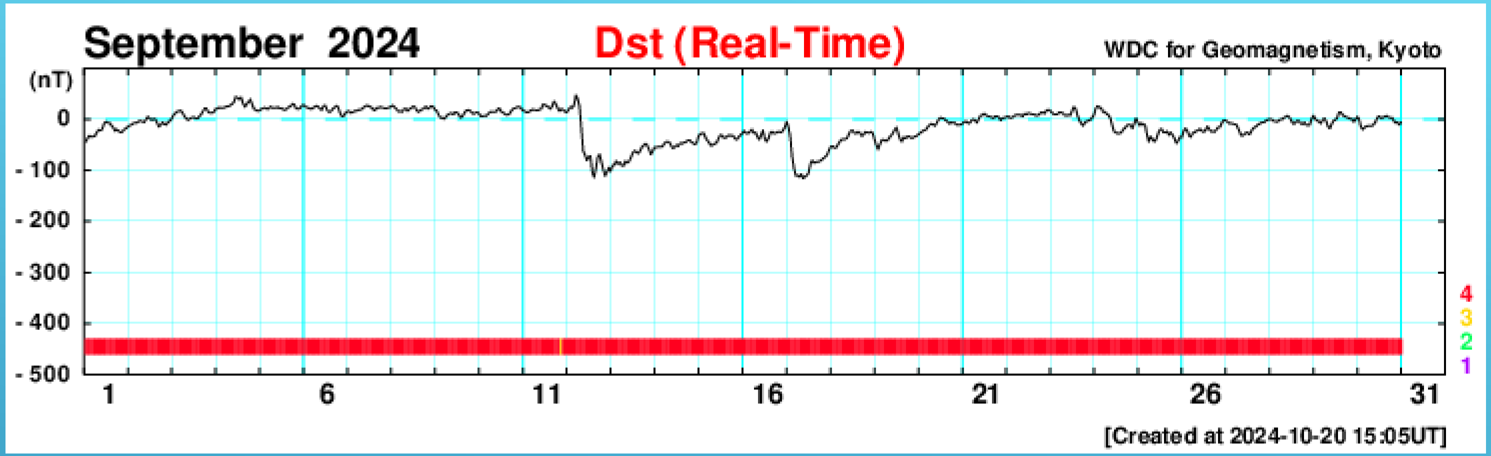
Malacky, 10.5.2024 22:26





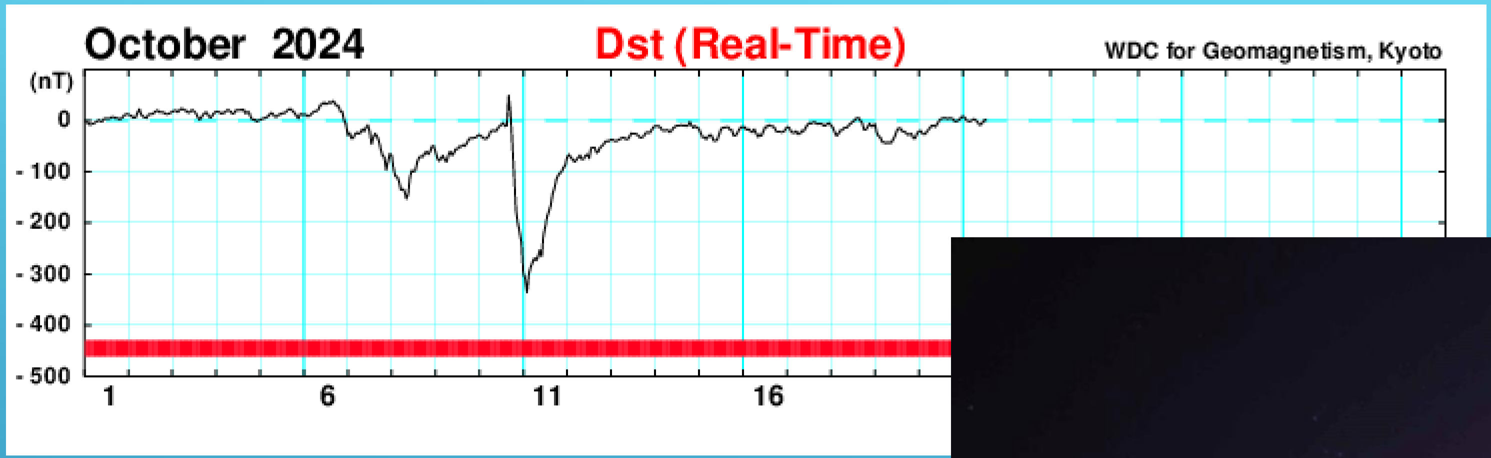
- 12. augusta 2024, FOTO: V noci sa nad Slovenskom ukázala POLÁRNA ŽIARA, oblohu skrášľovali aj PERZEIDY | iMeteo.sk, https://www.imeteo.sk/spravy/foto-v-noci-sa-nad-slovenskom-ukazala-polarna-ziara-oblohu-skraslovali-aj-perzeidy,

AUGUST 2024



- 12.9.2024, [FOTO: Nad Slovenskom sa ukázala polárna žiara. Pre nepriaznivé počasie ju nevideli všetci | iMeteo.sk, https://www.imeteo.sk/spravy/foto-nad-slovenskom-sa-ukazala-polarna-ziara-pre-nepriaznive-pocasie-ju-nevideli-vsetci](https://www.imeteo.sk/spravy/foto-nad-slovenskom-sa-ukazala-polarna-ziara-pre-nepriaznive-pocasie-ju-nevideli-vsetci)

SEPTEMBER 2024



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OKTÓBER 2024

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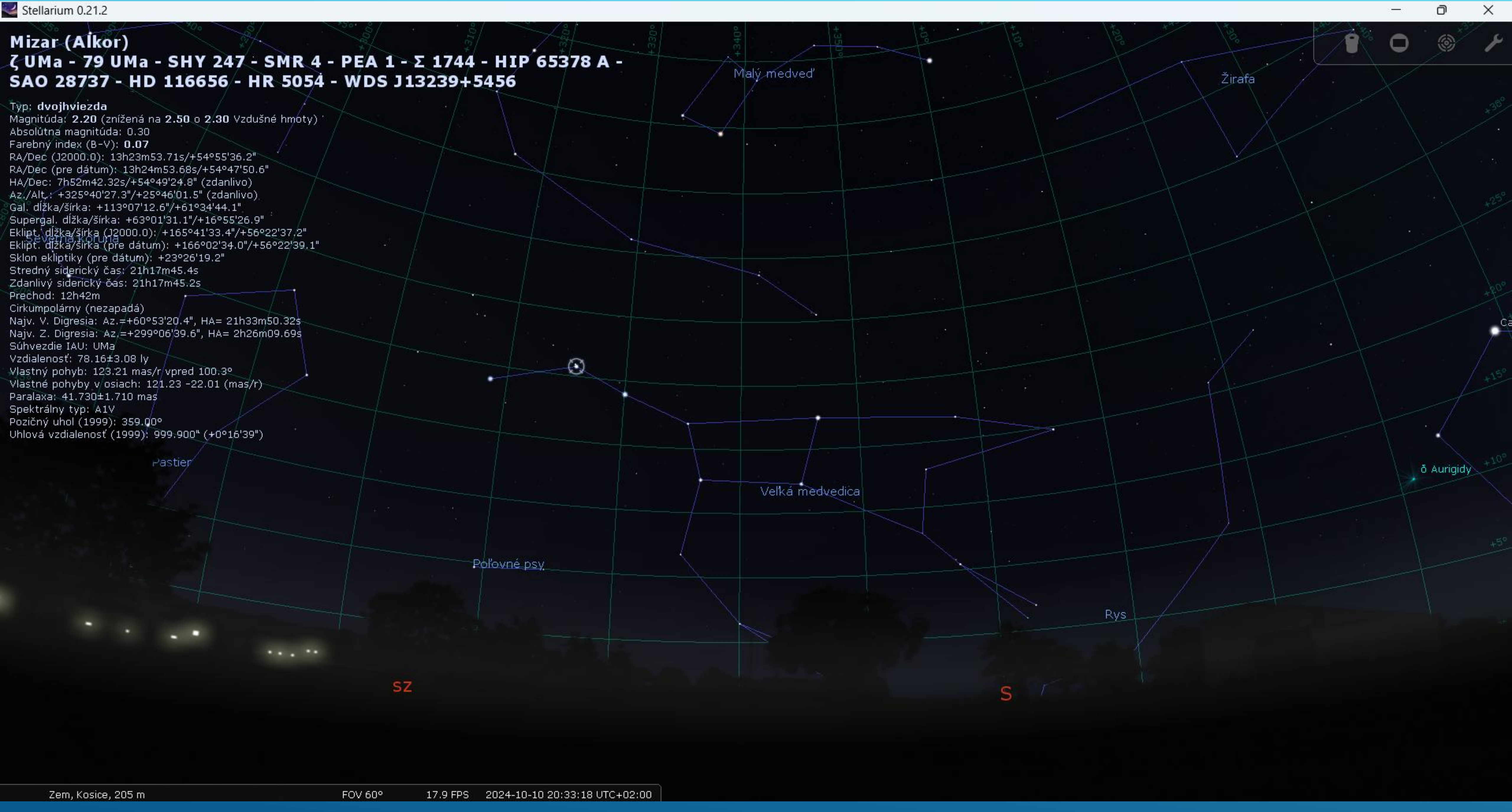
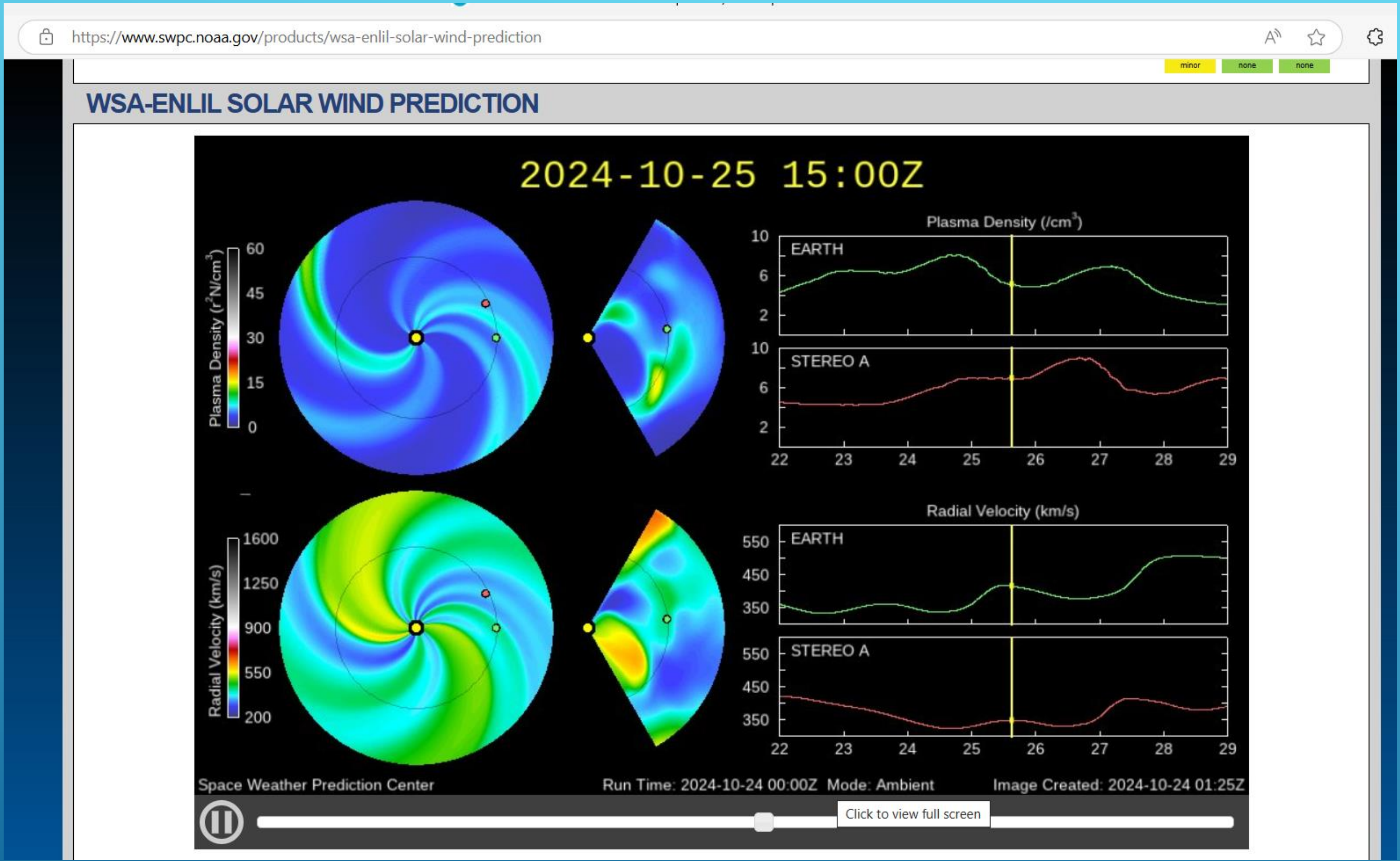


PREDPOVEĎ NA DNES/ZAJTRA



- WSA-ENLIL Solar Wind Prediction | NOAA / NWS Space Weather Prediction Center, https://www.swpc.noaa.gov/products/wsa-enlil-solar-wind-prediction

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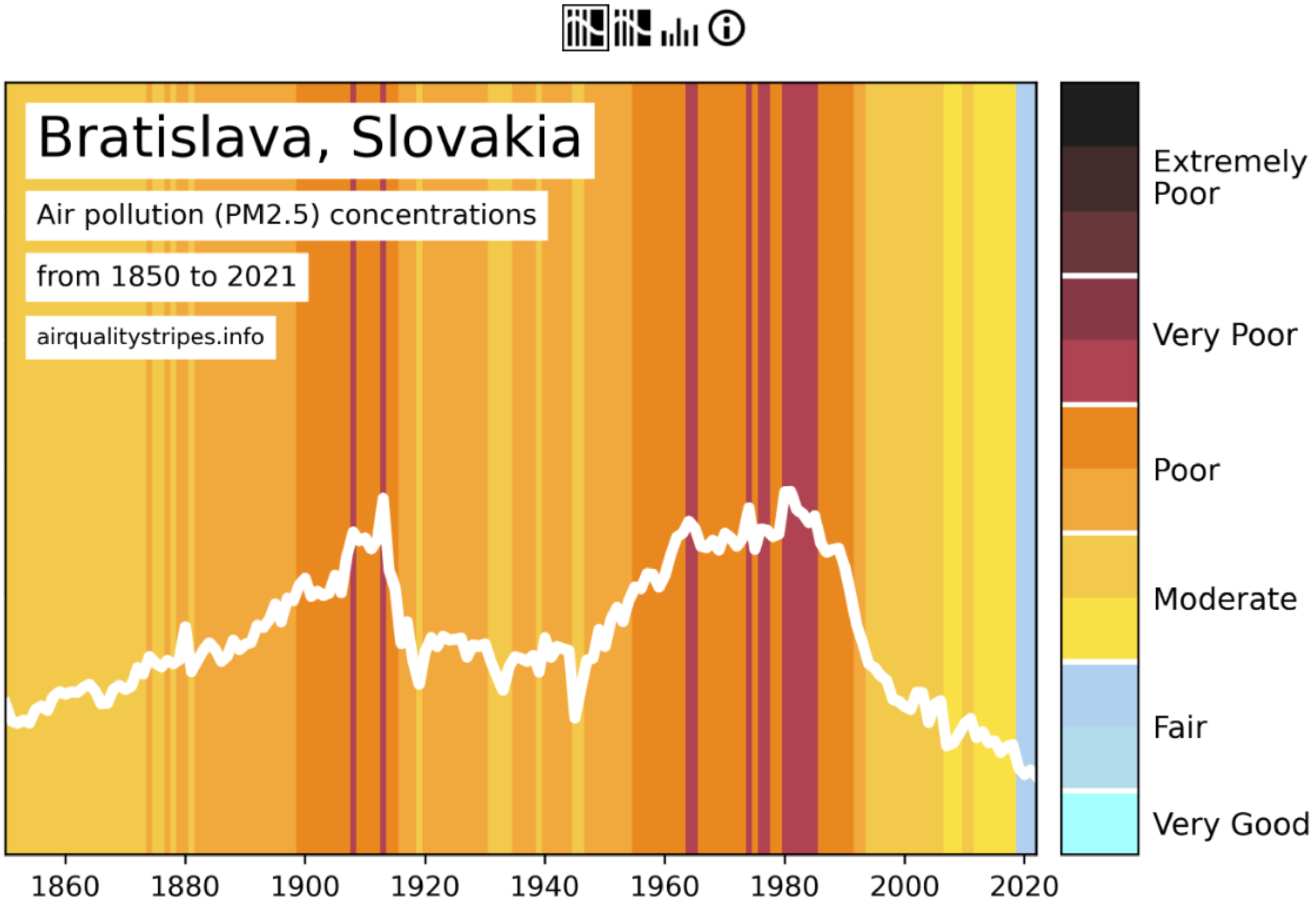

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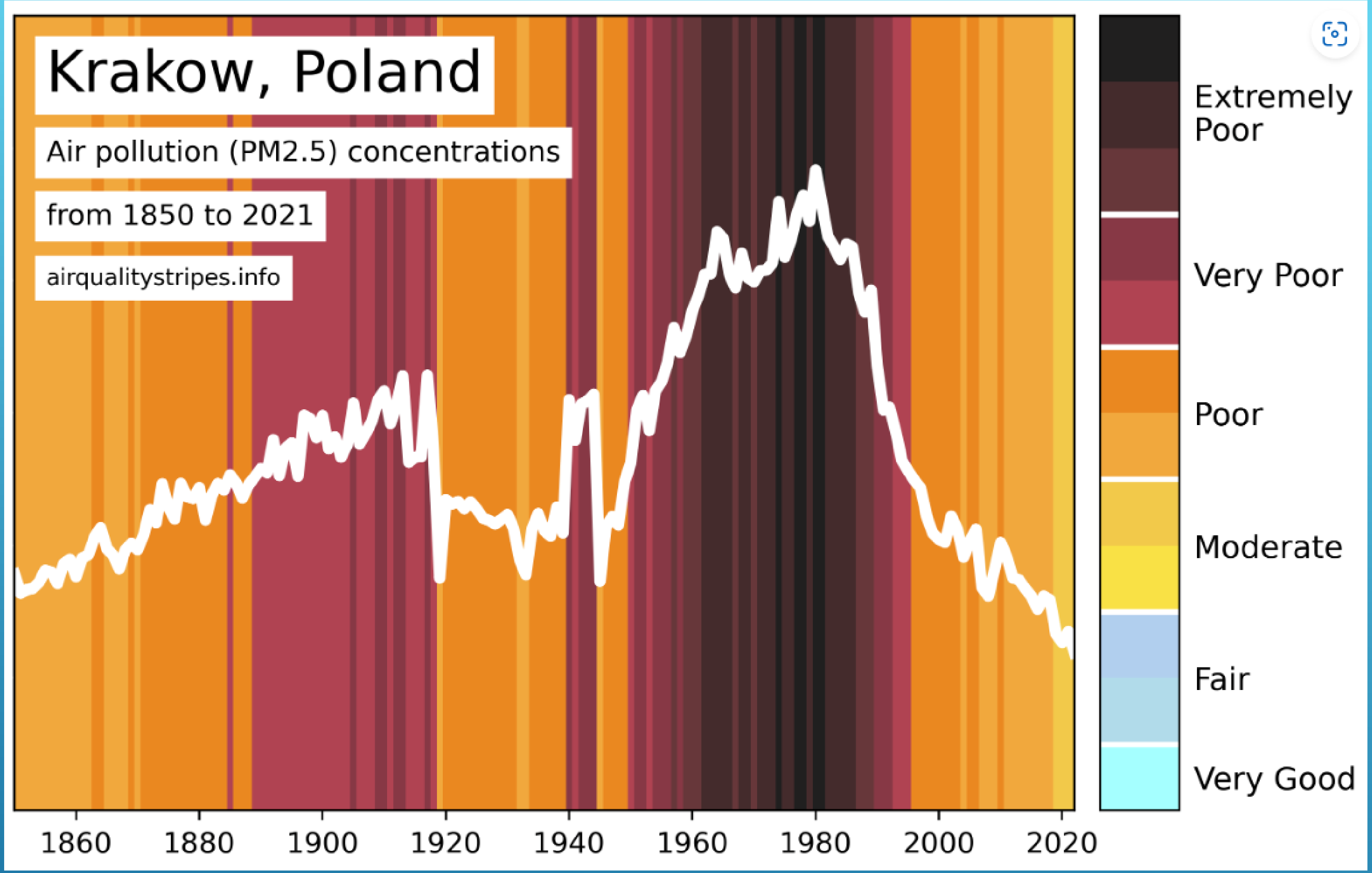

- Air Quality Stripes, https://airqualitystripes.info/

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COR system: A tool to evaluate cosmic ray trajectories in the Earth's magnetosphere

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Received 5 December 2021; received in revised form 28 May 2022; accepted 1 June 2022

Abstract

We present a tool for simulations of cosmic ray trajectories in the magnetosphere called COR (Cut-Off Rigidity). The COR tool provides a framework offering a wide range of functionalities and the possibility to realize extensive simulations at scalable multicore/multinode systems. COR is available at https://cor.crmodels.org.

Code used by COR for simulations of cosmic ray trajectories was validated by simulations and results published in a series of articles in the last three decades. In the article, we additionally validated the results of the code by comparison with other available codes. The code for simulations of trajectories is published at GitHub from https://github.com/COR-Cut-off-rigidity/Trajectories_IGRF_T04_C.

Keywords: Cosmic rays; Magnetosphere; Rigidity

https://cor.crmodels.org

COR | Home | Publications | Simulations | New Trajectory | Trajectories | Login

Cut-off rigidity model

Cut-Off Rigidity model (COR model) is a model for simulation of cosmic rays propagation in the Earth's magnetosphere. The model provides an evaluation of cut-off rigidities for stations at Earth surface or detectors measuring on orbits inside the magnetosphere.

Cut-off rigidities are evaluated for multiple incoming directions. A registered user could run simulations to evaluate cut-off rigidities for 577 incoming directions including the vertical one. To use the model, register here.

Complete simulation for one selected point with a 0.01GV step takes several hours. After submitting a request for simulation, your request will be processed and published when it will be done.

The catalogue of all to date realized simulations is in the part Simulations.

COR model uses a combined internal (IGRF) and external (Tsyganenko 96, Tsyganenko 05) geomagnetic fields. COR with Tsyganenko 96 model is available for years 1968 - 2016. COR with Tsyganenko 05 model is available for years 1995 - 2016. For more information about the model, results visit the section Publications.

COR model is also available for period 0 - 1968. Used geomagnetic models are described in article [Kudela K., Bobik P., 2004].

For educational purpose COR provides visualization of single cosmic ray trajectory in section New Trajectory.

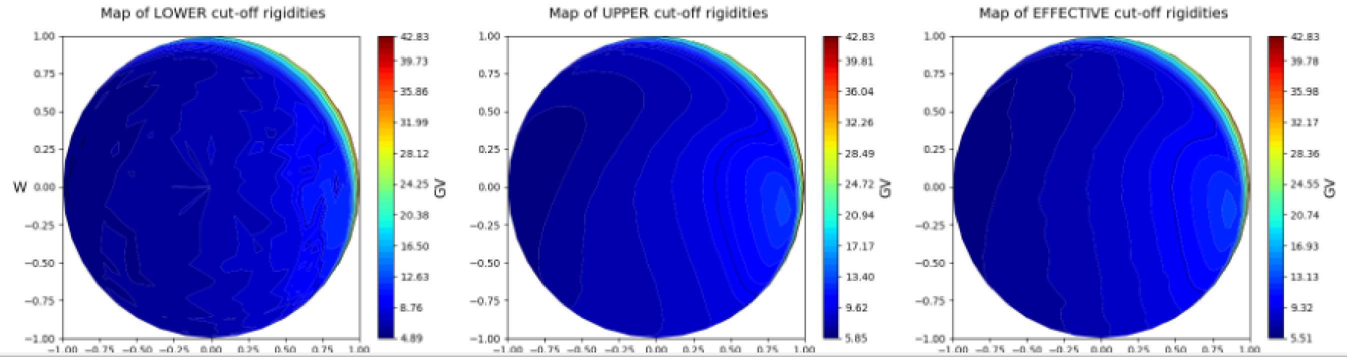
For a collection of significant results, see this link. For updates, see this link.

COR model code

Code to solve Lorentz force equation by Runge-Kutta scheme of 6th order in Tsyganenko 04 model for simulating Earth's external magnetic field and IGRF (gen. 9 - 13) for simulating Earth's internal magnetic field is publicly available at Github repository Trajectories_IGRF_T04_C.

Example of model results

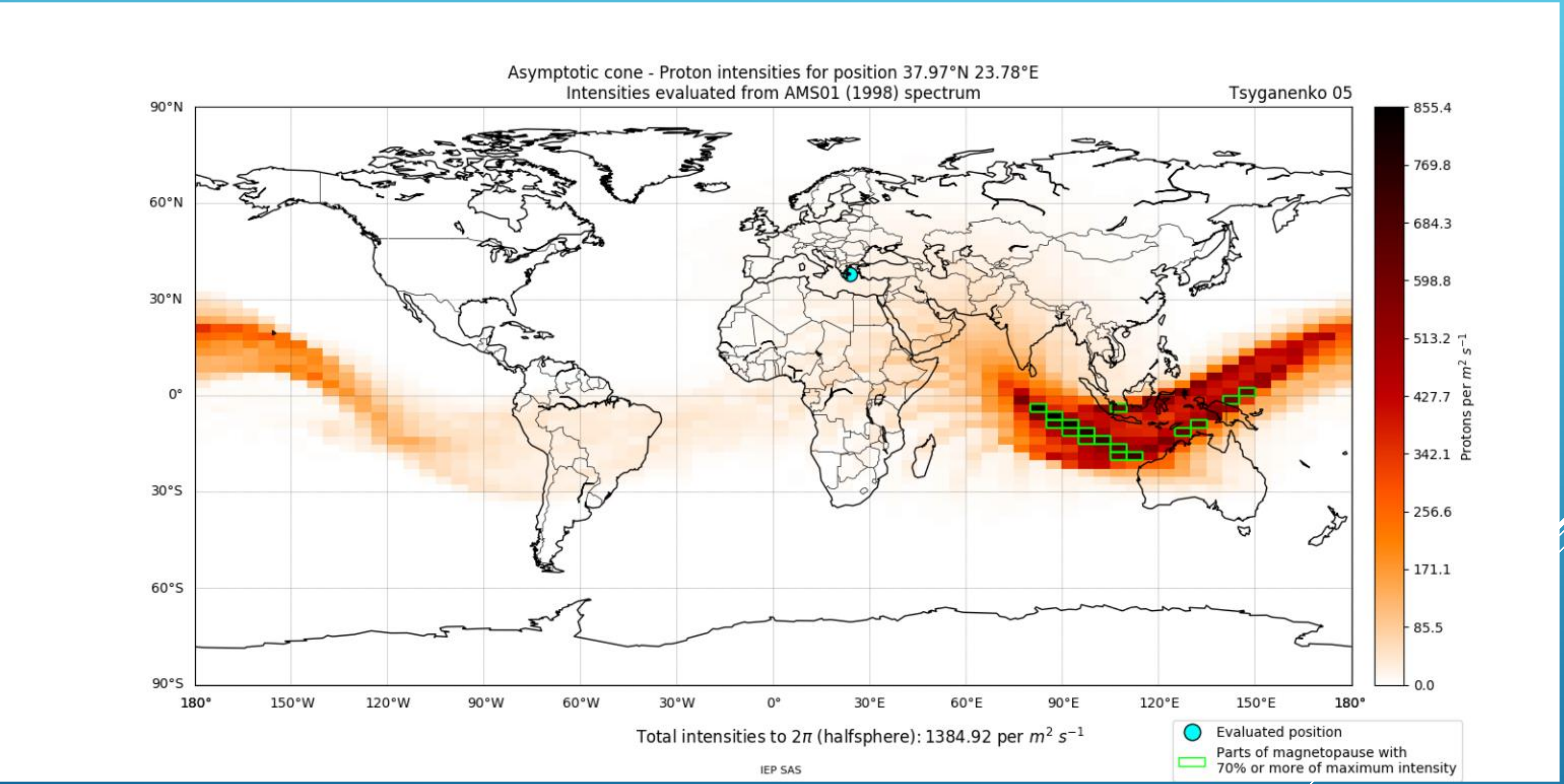
Effective cutoff rigidity sky map for Athens neutron monitor station with latitude 37.97 deg. N and longitude 23.78 deg E. The cutoff rigidity sky map was evaluated for 7. June 1998, with the Tsyganenko 05 model of the external geomagnetic field.



https://cor.crmodels.org/

COR MODEL

- Cut-Off Rigidity model (COR model) - model for simulations of the motion of cosmic rays through the Earth's magnetosphere

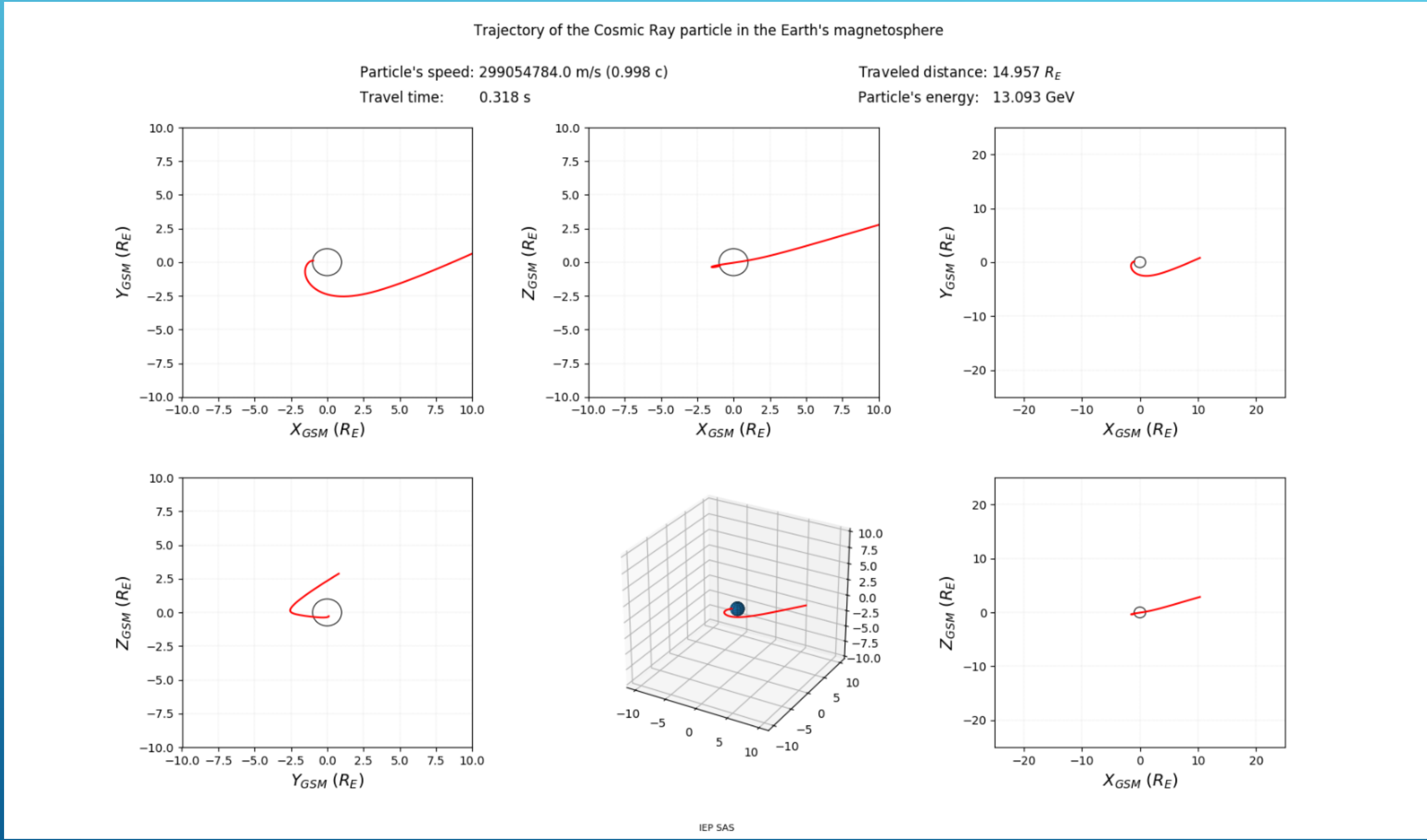


COR model:
Pavol Bobik
Institute of Experimental Physics, SAS

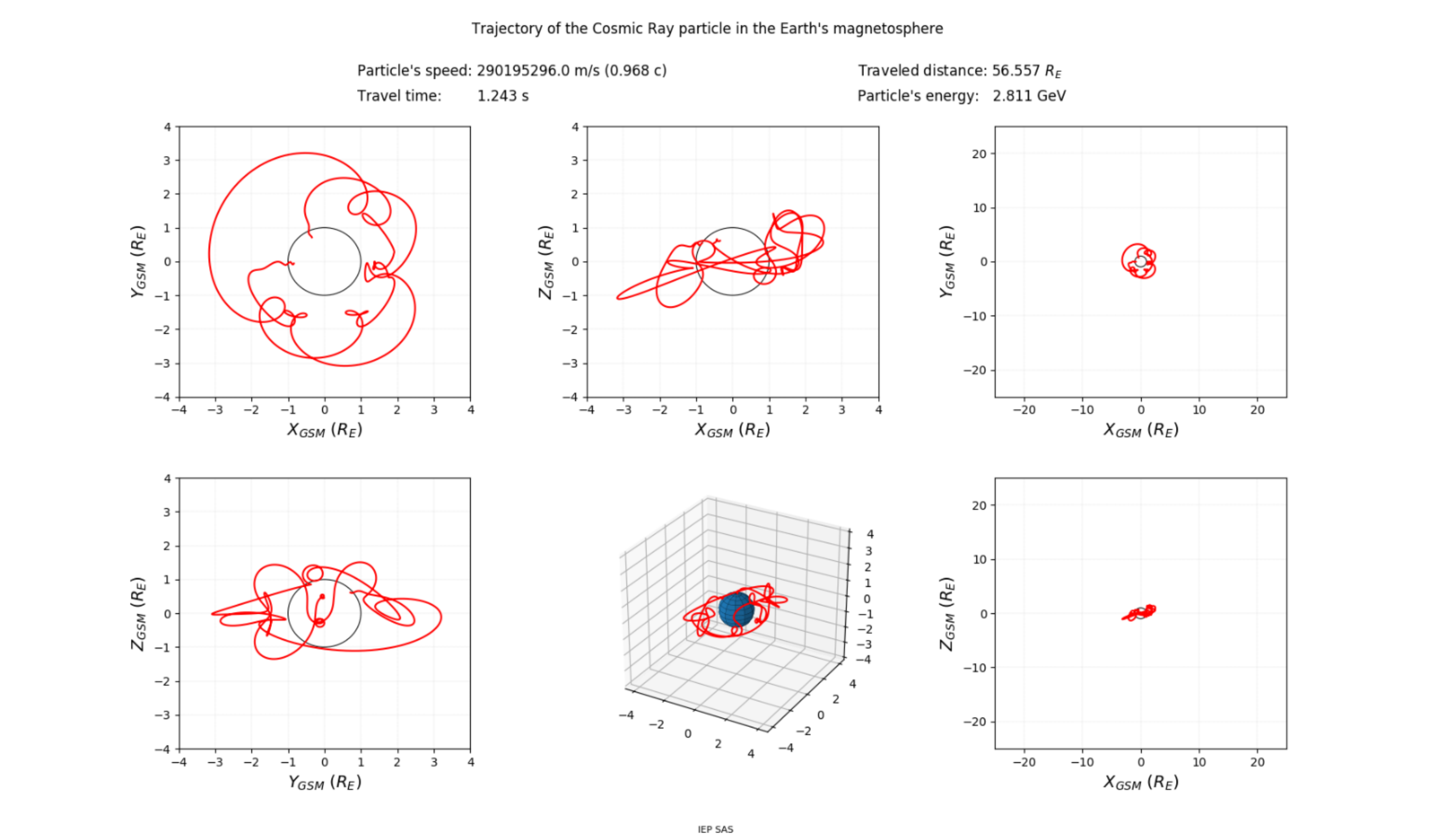
Simulations management system and web framework:
Daniel Gecasek, Michal Vrabel and Jan Genci
Technical University of Kosice

Patricipation on visualisation module:
Martin Vasko and Ivan Bernat
Technical University of Kosice

COR MODEL


Trajectory of the Cosmic Ray particle in the Earth's magnetosphere
Particle's speed: 299054784.0 m/s (0.998 c)
Travel time: 0.318 s
Traveled distance: 14.957 R_E
Particle's energy: 13.093 GeV
Y_{GSM} (R_E)
X_{GSM} (R_E)
Z_{GSM} (R_E)
IEP SAS

COR MODEL


Trajectory of the Cosmic Ray particle in the Earth's magnetosphere
Particle's speed: 290195296.0 m/s (0.968 c)
Travel time: 1.243 s
Traveled distance: 56.557 R_E
Particle's energy: 2.811 GeV
Y_{GSM} (R_E)
X_{GSM} (R_E)
Z_{GSM} (R_E)
X_{GSM} (R_E)
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Y_{GSM} (R_E)
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X_{GSM} (R_E)
IEP SAS

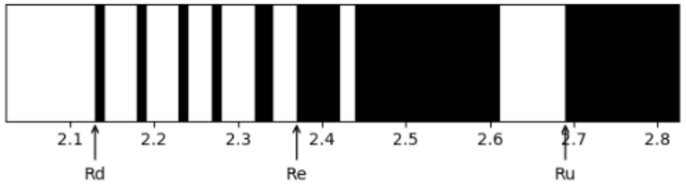
COR MODEL

Geological position: 40.21°N 287.79°E

2010/01/10 00:00:00

YYYY/MM/DD HH:MM:SS

Direction ID: 000



$\Delta R = 0.01$

Rd = 2.13 GV

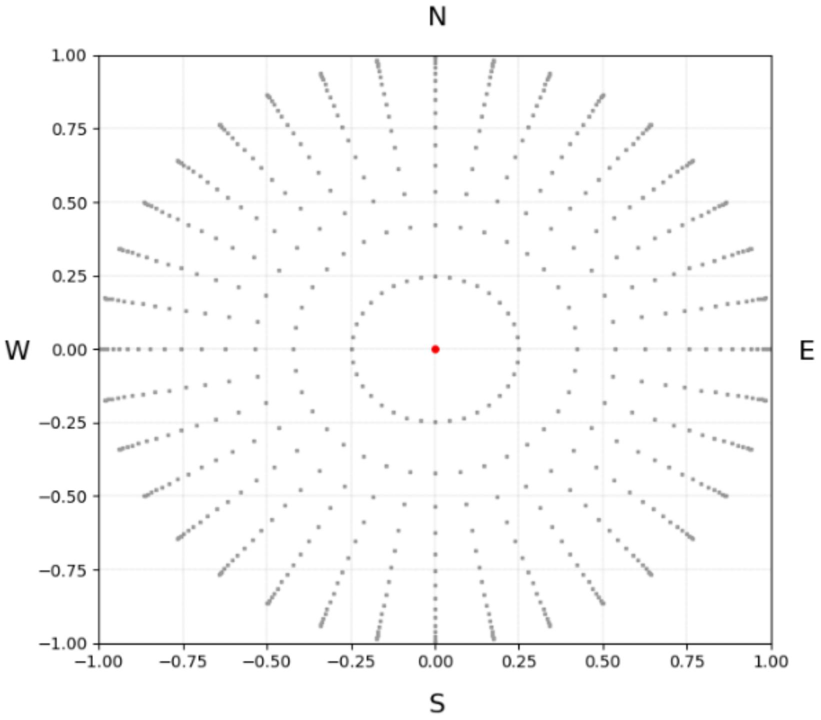
Re = 2.37 GV

Ru = 2.69 GV

Model: Tsyganenko 05

$\theta = 0.0°$

$\varphi = 0.0°$



The spectrum of allowed and forbidden rigidities (left panel)

The incoming direction is signed by the red point (rigth panel)

IEP SAS

0 /576 > »

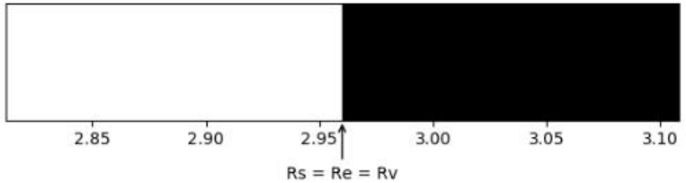
COR MODEL

Geological position: 40.21°N 287.79°E

2010/01/10 00:00:00

YYYY/MM/DD HH:MM:SS

Direction ID: 576



ΔR = 0.01

Rd = 2.96 GV

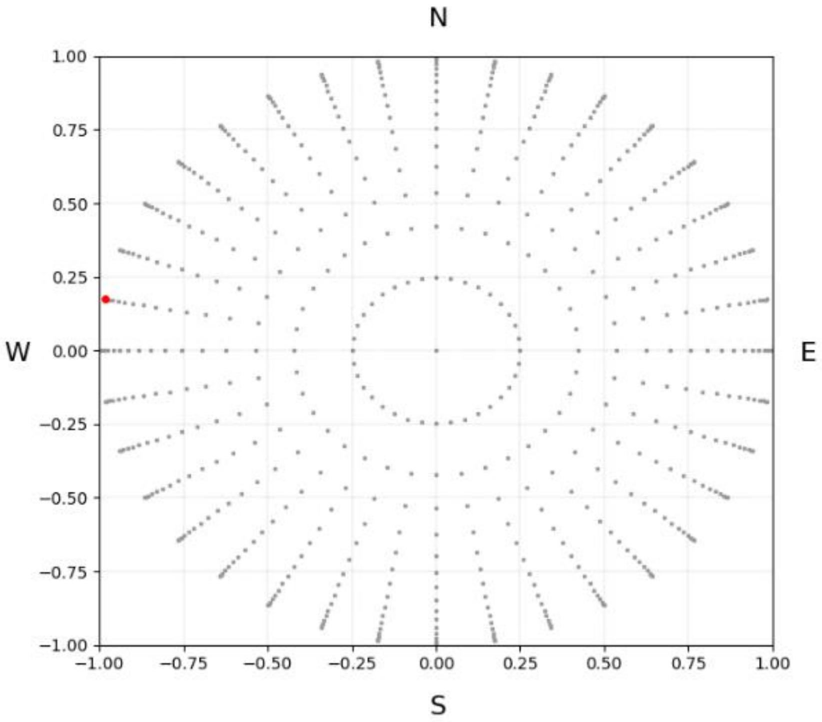
Re = 2.96 GV

Ru = 2.96 GV

Model: Tsyganenko 05

θ = 88.21°

φ = 350.0°



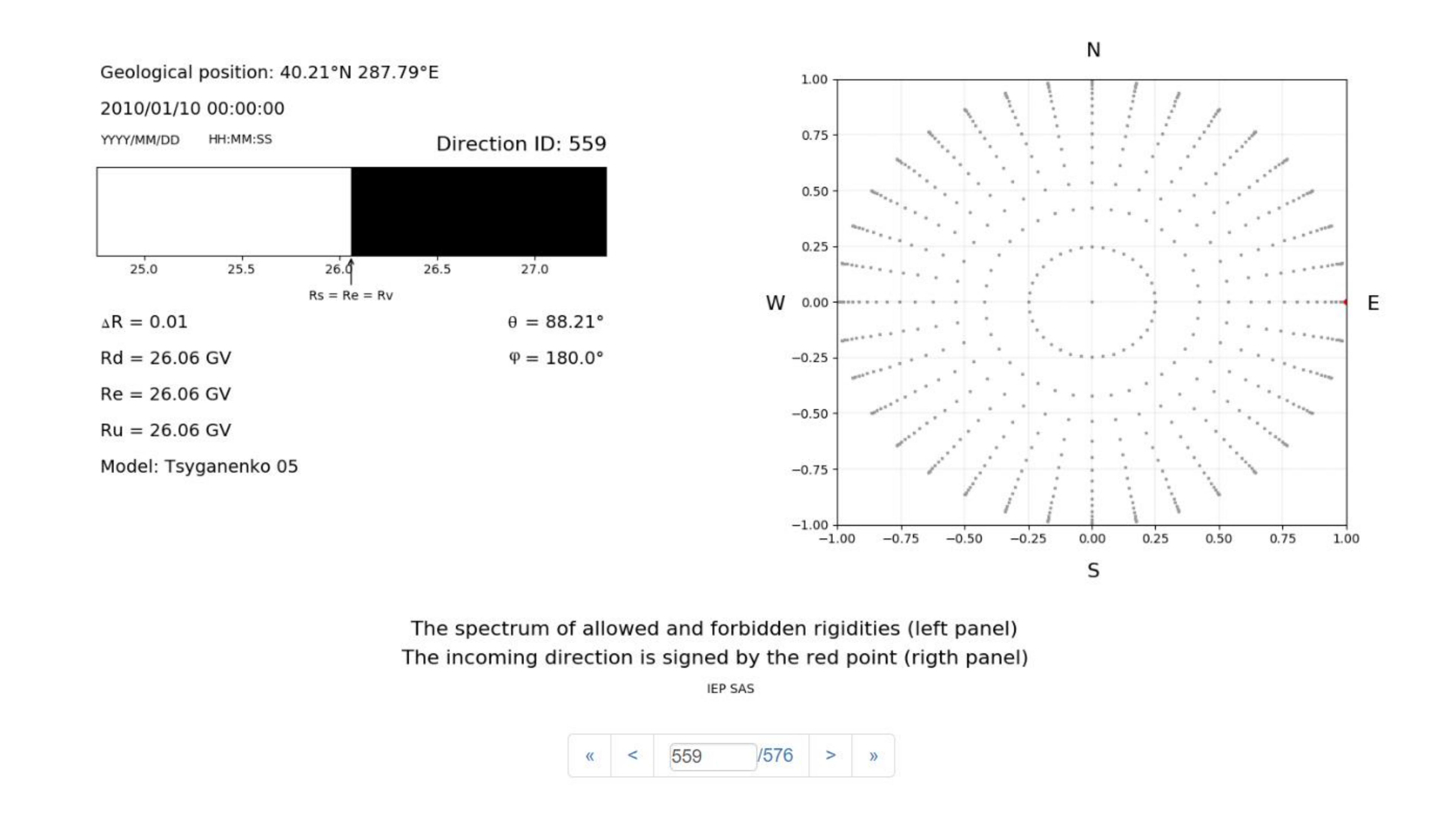
The spectrum of allowed and forbidden rigidities (left panel)

The incoming direction is signed by the red point (rigth panel)

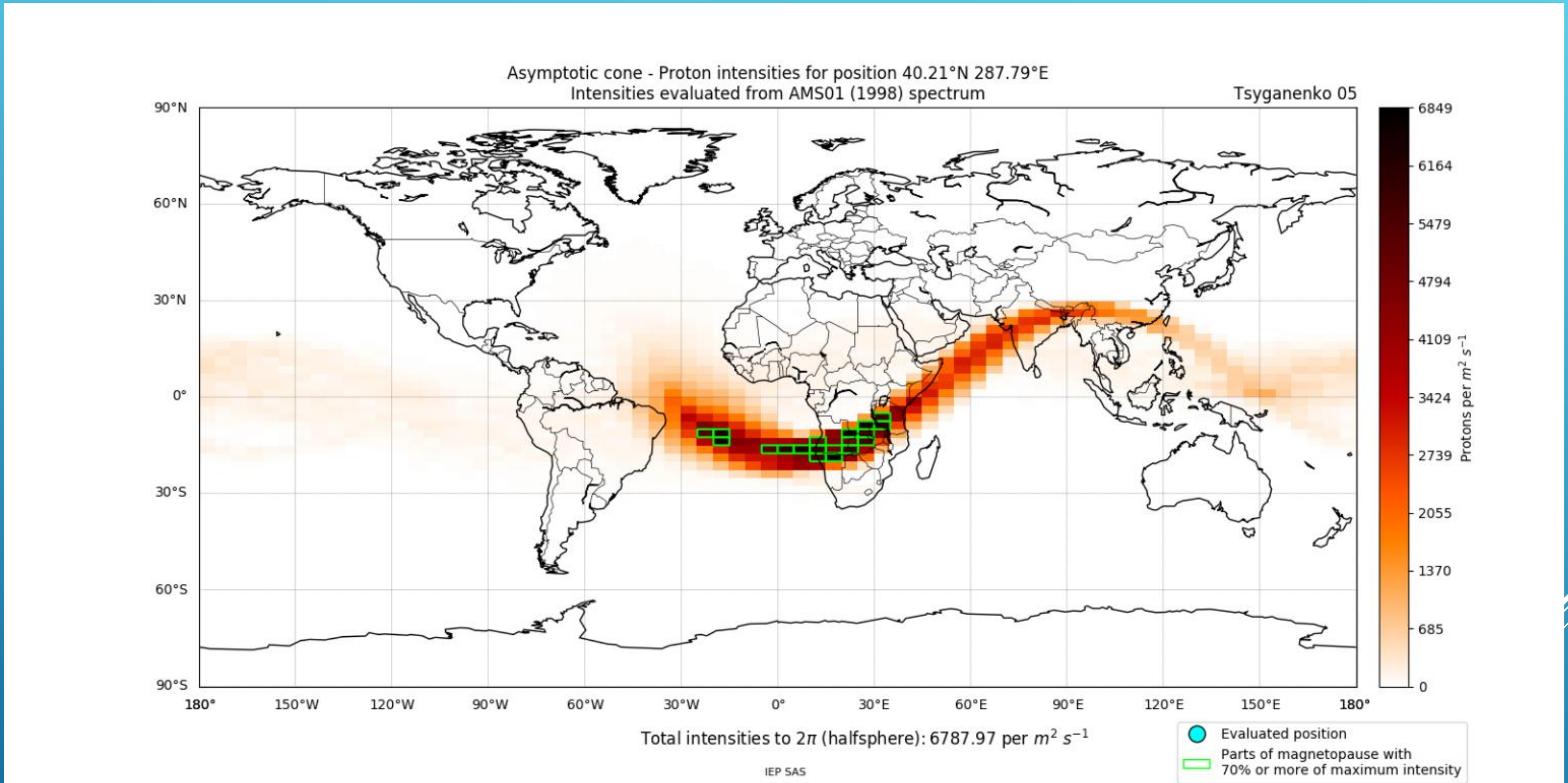
IEP SAS

« < 576 /576

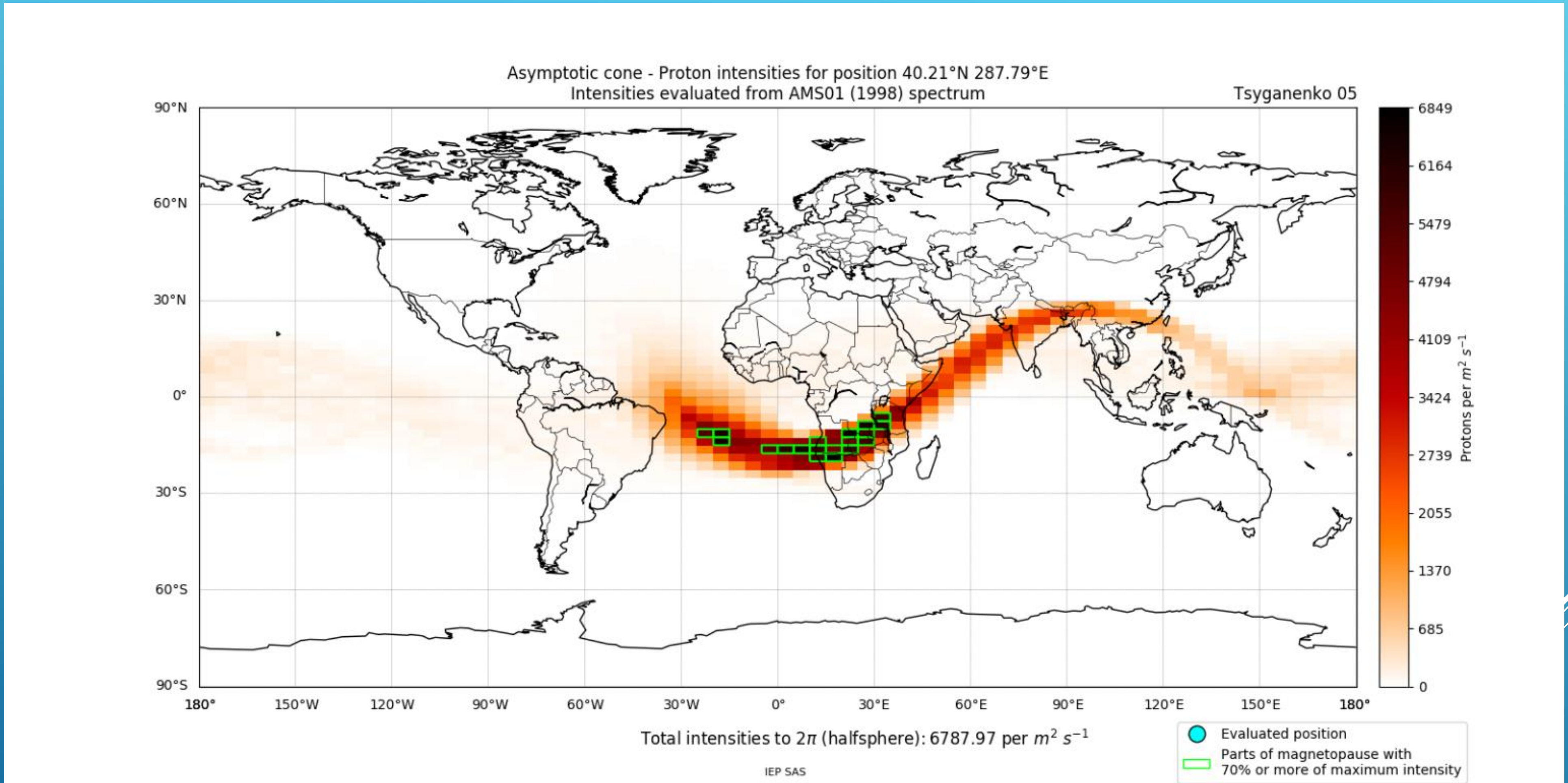
COR MODEL


Geological position: 40.21°N 287.79°E
2010/01/10 00:00:00
YYYY/MM/DD HH:MM:SS
Direction ID: 559
25.0 25.5 26.0 26.5 27.0
Rs = Re = Rv
ΔR = 0.01
Rd = 26.06 GV
Re = 26.06 GV
Ru = 26.06 GV
Model: Tsyganenko 05
θ = 88.21°
φ = 180.0°
N
S
W
E
1.00 0.75 0.50 0.25 0.00 −0.25 −0.50 −0.75 −1.00
−1.00 −0.75 −0.50 −0.25 0.00 0.25 0.50 0.75 1.00
The spectrum of allowed and forbidden rigidities (left panel)
The incoming direction is signed by the red point (rigth panel)
IEP SAS
« < 559 /576 > »

COR MODEL

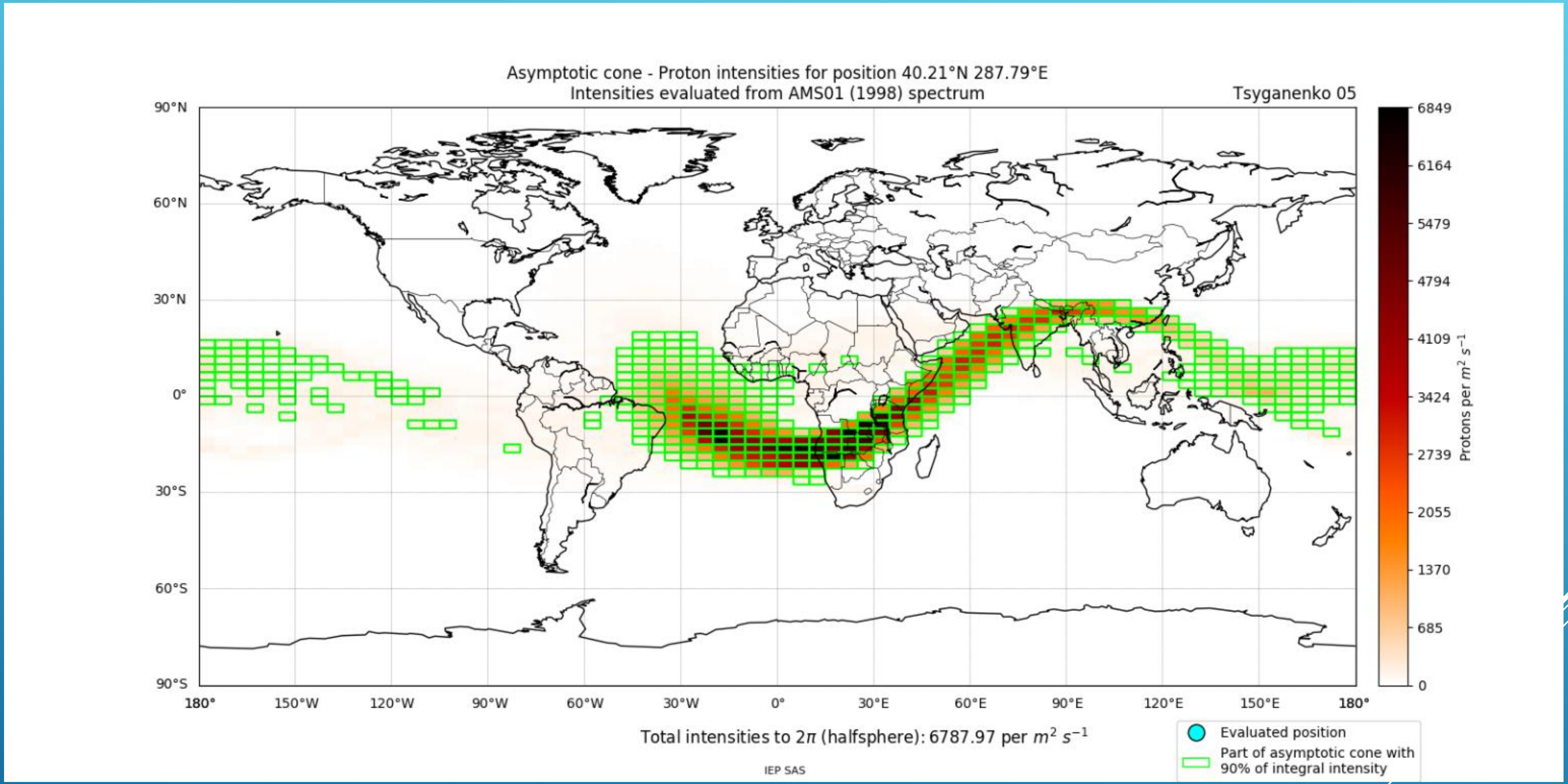

Asymptotic cone - Proton intensities for position 40.21°N 287.79°E
Intensities evaluated from AMS01 (1998) spectrum
Tsyganenko 05
90°N
60°N
30°N
0°
30°S
60°S
90°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
6849
6164
5479
4794
4109
3424
2739
2055
1370
685
0
Protons per m^2 s^{-1}
Total intensities to 2π (halfsphere): 6787.97 per m^2 s^{-1}
IEP SAS
Evaluated position
Parts of magnetopause with
70% or more of maximum intensity

COR MODEL



Asymptotic cone - Proton intensities for position 40.21°N 287.79°E
Intensities evaluated from AMS01 (1998) spectrum
Tsyganenko 05
90°N
60°N
30°N
0°
30°S
60°S
90°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
6849
6164
5479
4794
4109
3424
2739
2055
1370
685
0
Protons per m^2 s^{-1}
Total intensities to 2π (halfsphere): 6787.97 per m^2 s^{-1}
Evaluated position
Parts of magnetopause with
70% or more of maximum intensity
IEP SAS

COR MODEL



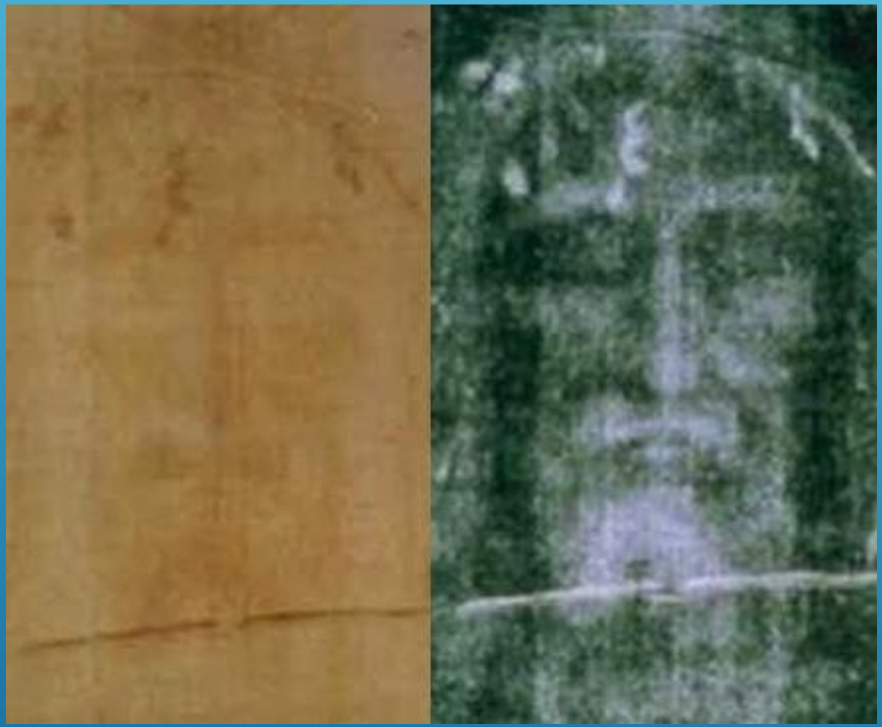
Asymptotic cone - Proton intensities for position 40.21°N 287.79°E
Intensities evaluated from AMS01 (1998) spectrum
Tsyganenko 05
90°N
60°N
30°N
0°
30°S
60°S
90°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
6849
6164
5479
4794
4109
3424
2739
2055
1370
685
0
Protons per m^2 s^{-1}
Total intensities to 2π (halfsphere): 6787.97 per m^2 s^{-1}
IEP SAS
Evaluated position
Part of asymptotic cone with 90% of integral intensity

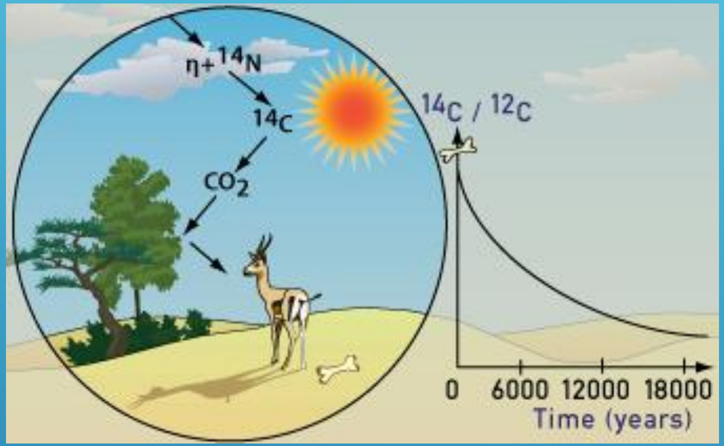
SHROUD OF TURIN

INTERESTING NOTES ABOUT COSMIC RAYS

The Shroud of Turin, also called the Turin Shroud (Italian: Sindone di Torino, Sacra Sindone [ˈsaːkra ˈsindone] or Santa Sindone), is a length of linen cloth bearing the negative image of a man. Some claim the image depicts Jesus of Nazareth and the fabric is the burial shroud in which he was wrapped after crucifixion.

Source: https://en.wikipedia.org/wiki/Shroud_of_Turin





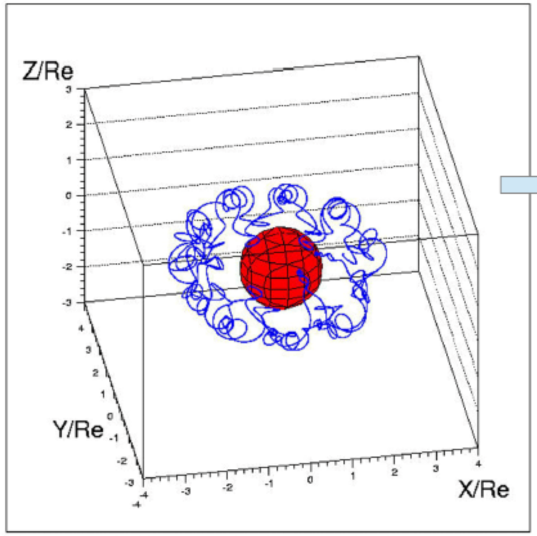
Source: http://www.webexhibits.org/pigments/intro/dating.html

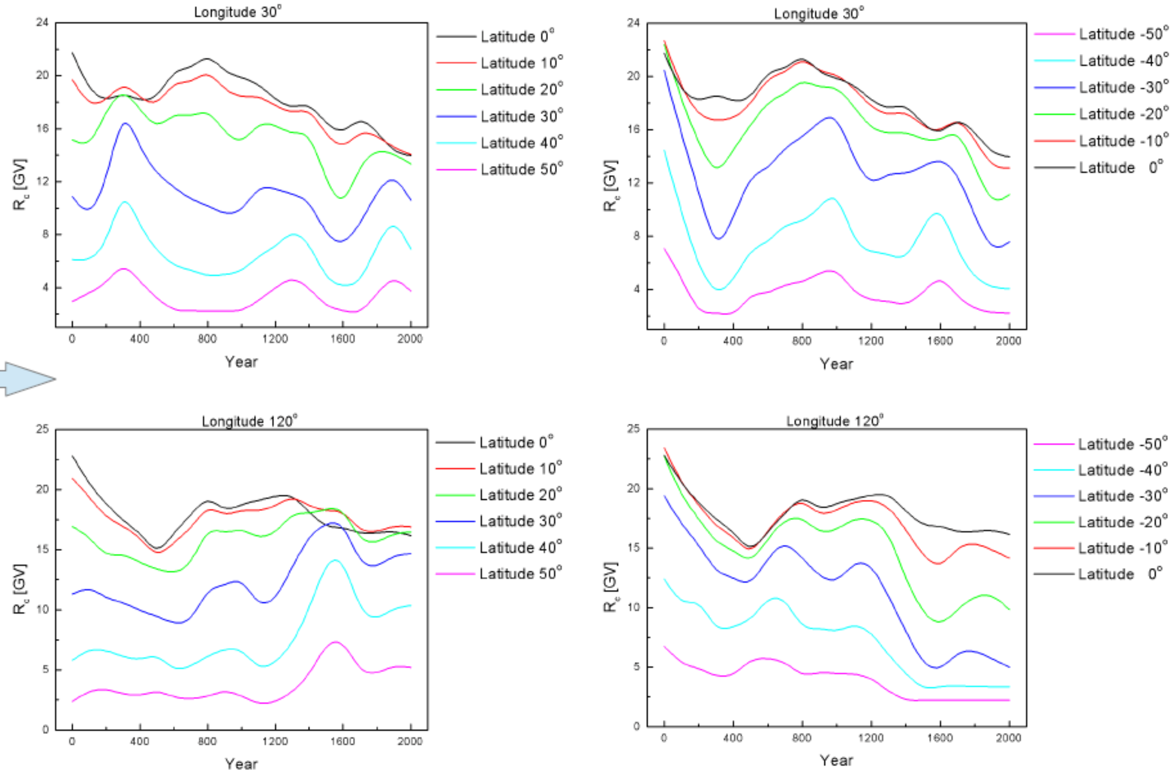
But

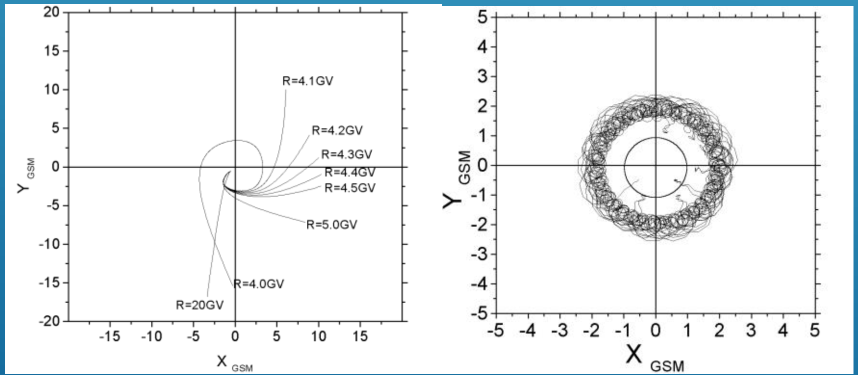
Cosmic ray intensity around the Earth and the transparency of the magnetosphere varies

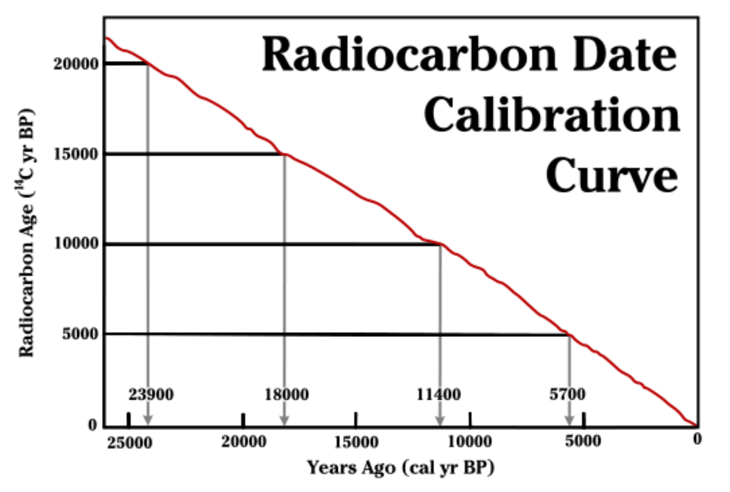
Shroud of Turin

Interesting notes about cosmic rays









Kudela, K.; Bobik, P., Long-Term Variations of Geomagnetic Rigidity Cutoffs, Solar Physics, Volume 224, Issue 1-2, pp. 423-431, 2004

Source: IntCal04 Terrestrial radiocarbon age calibration". Radiocarbon 46: 1029-58, 2004

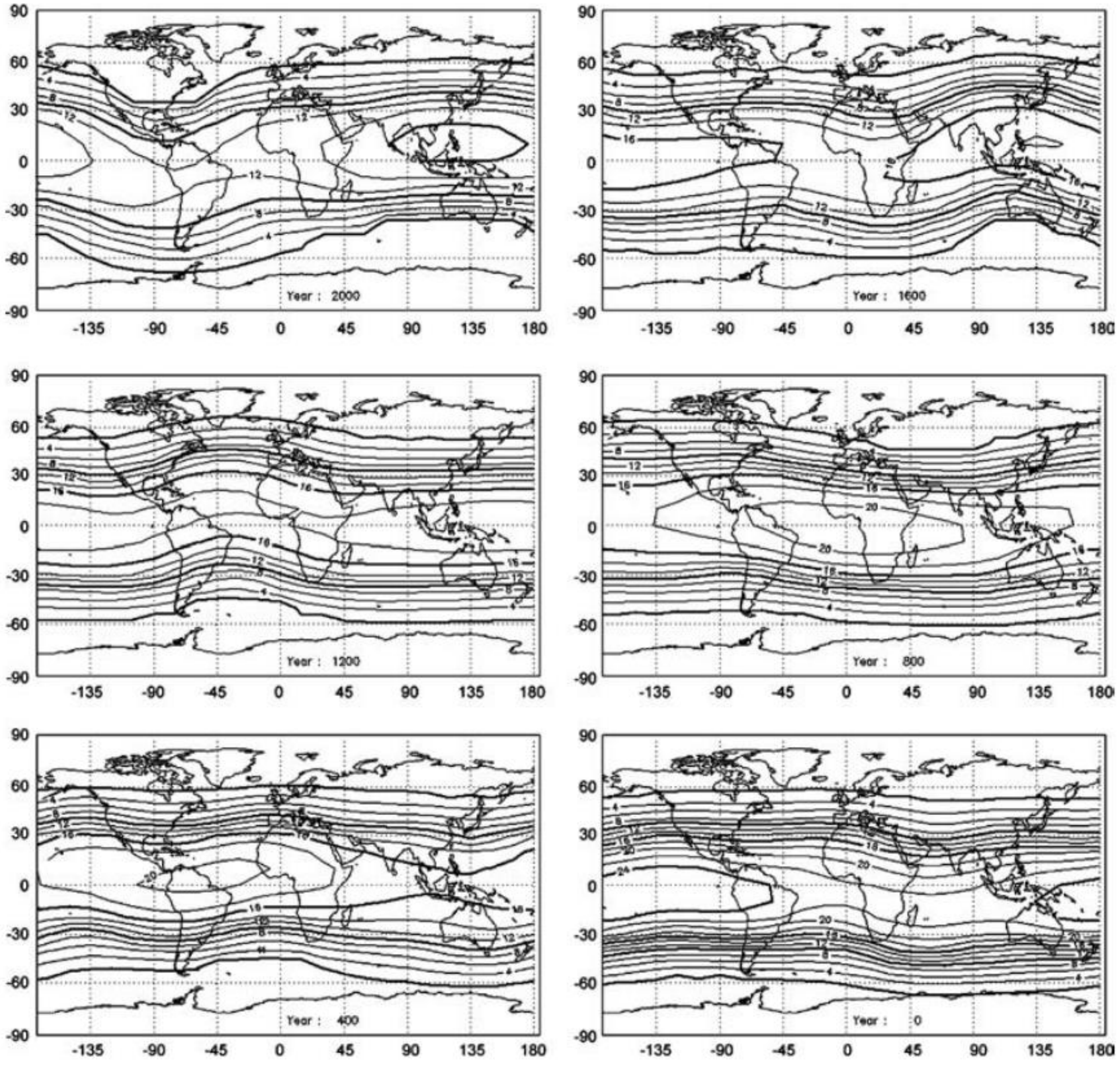
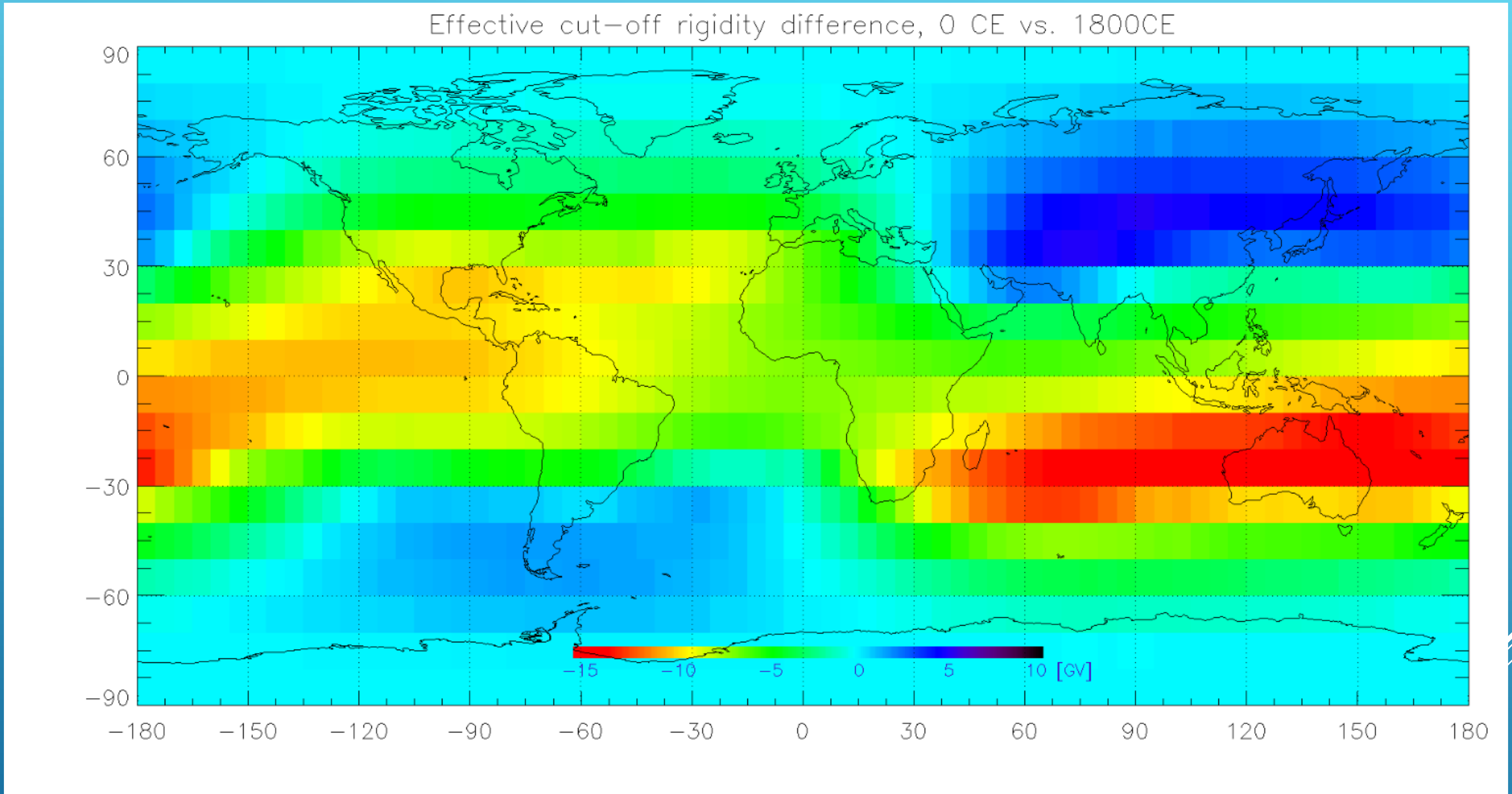
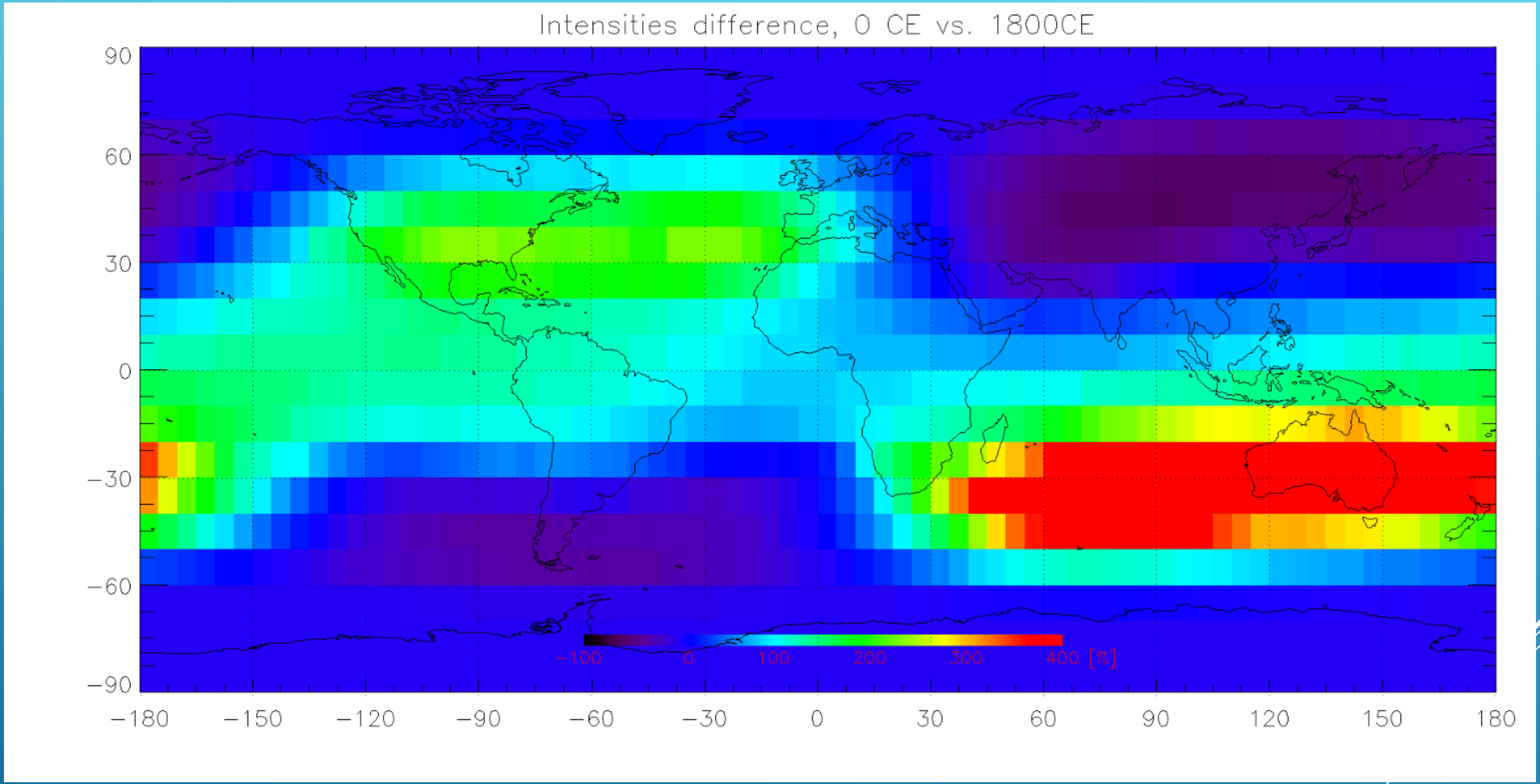


Figure 3. Contour maps of vertical cutoff rigidities estimated from the computations using the approximation $n = 2+$ in years 0, 400, 800, 1200, 1600 (coefficients from Hongre, Hulot, and Khokhlov, 1998) and for year 2000 using $n = 2+$ selection from IGRF model.

Kudela, K.; Bobik, P., Long-Term Variations of Geomagnetic Rigidity Cutoffs, Solar Physics, Volume 224, Issue 1-2, pp. 423-431, 2004


Effective cut-off rigidity difference, 0 CE vs. 1800CE
90
60
30
0
−30
−60
−90
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
−15
−10
−5
0
5
10 [GV]



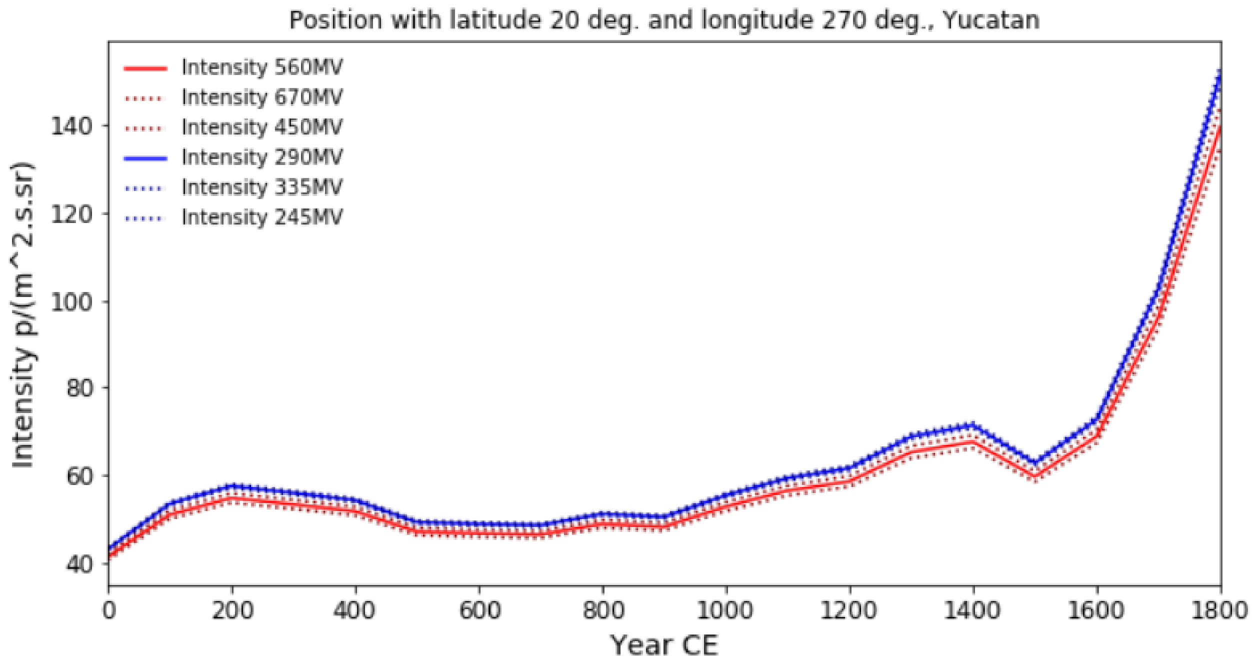
Gecášek D., Bobik P., Genci J., Transparency of magnetosphere for cosmic rays in last two millennia, 37th International Cosmic Ray Conference. 12-23 July 2021. Berlin, Germany - Online, published March 18, 2022. Online at https://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=395, id.133, 2022 DOI: 10.22323/1.395.01335

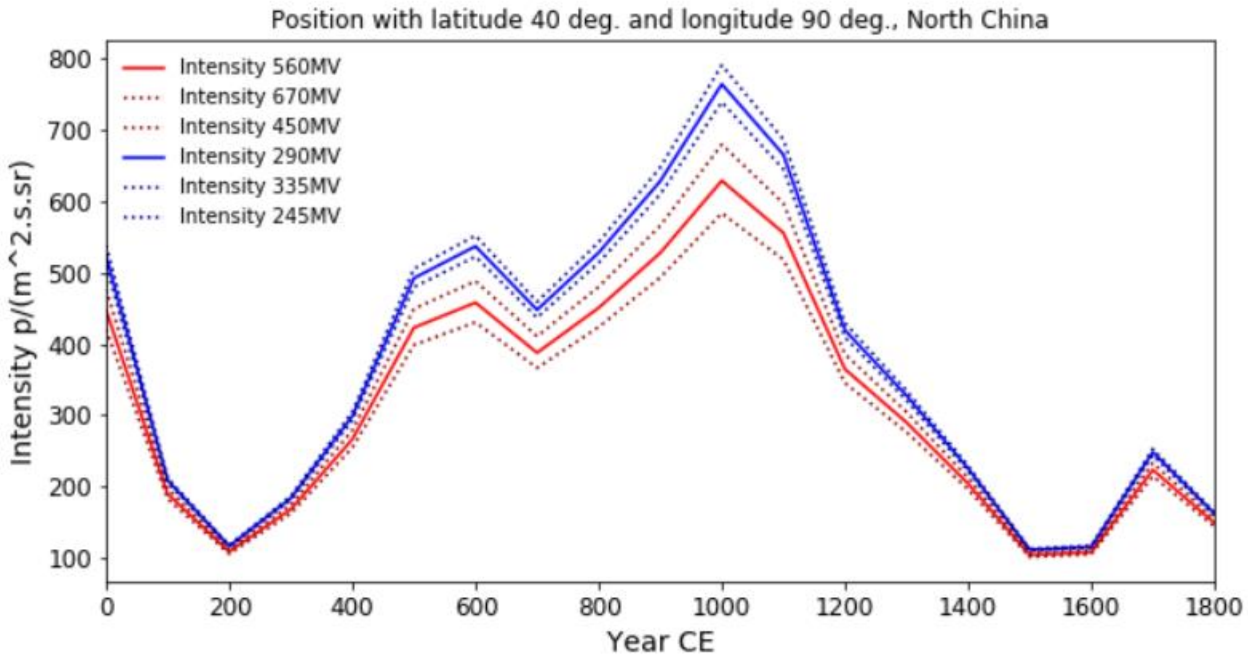
Table 2: Selected regions with significant changes in CR intensities between years 0 and 1800CE for minimum and maximum limit spectra.

Latitude	Longitude	I in 0 $[p/(m^2.s.sr)]$ 560 MV / 290MV	I in 1800CE $[p/(m^2.s.sr)]$ 560MV / 290MV	Relative difference in [%] 560MV / 290MV	Region name
-30^o	145^o	39 / 41	328 / 374	738 / 817	Southern Australia
30^o	270^o	80 / 84	322 / 367	354 / 384	New Orleans area
20^o	270^o	41 / 43	139 / 151	238 / 251	Yucatán
40^o	355^o	200 / 220	575 / 691	188 / 214	Spain
30^o	30^o	127 / 137	145 / 157	14 / 15	Egypt, Cairo area
40^o	90^o	447 / 524	149 / 162	-67 / -69	North China
-50^o	290^o	589 / 710	364 / 418	-38 /-41	South Argentina

Table 3: Selected regions with significant changes in CR intensities between years 0 and 1800CE for extreme minimum intensity spectrum.

Latitude	Longitude	I in 0 $[p/(m^2.s.sr)]$	I in 1800CE $[p/(m^2.s.sr)]$	Relative difference 1360 MV [%]	Region name
-30^o	145^o	35	231	564	Southern Australia
30^o	270^o	67	228	284	New Orleans area
20^o	270^o	37	111	204	Yucatán
40^o	355^o	152	357	134	Spain
30^o	30^o	102	115	12	Egypt, Cairo area
40^o	90^o	294	118	-60	North China
-50^o	290^o	364	251	-31	South Argentina


Position with latitude 20 deg. and longitude 270 deg., Yucatan
Intensity 560MV
Intensity 670MV
Intensity 450MV
Intensity 290MV
Intensity 335MV
Intensity 245MV
Intensity p/(m^2.s.sr)
Year CE
40
60
80
100
120
140
0
200
400
600
800
1000
1200
1400
1600
1800


Position with latitude 40 deg. and longitude 90 deg., North China
Intensity 560MV
Intensity 670MV
Intensity 450MV
Intensity 290MV
Intensity 335MV
Intensity 245MV
Intensity p/(m^2.s.sr)
Year CE
100
200
300
400
500
600
700
800
0
200
400
600
800
1000
1200
1400
1600
1800

The preliminary results show that changes in CR intensities from magnetosphere field evolution in the last two thousand years were remarkably stronger than changes from the Sun's activity.

Results hints to a possible need for calibration curve of carbon dating method modification, that take the geographic dependence of ^{14}C production into account.

KOZMICKÉ ŽIARENIE A OBLAČNOSŤ

Where on the Earth's surface, are the biggest changes, in the cosmic ray intensity during geomagnetic storms?

Conference: 38th International Cosmic Ray Conference, 2023

Daniel Gecášek, Viacheslav Mykhailenko, Pavol Bobík, Ján Villim and Ján Genči

DOI: 10.22323/1.444.0101

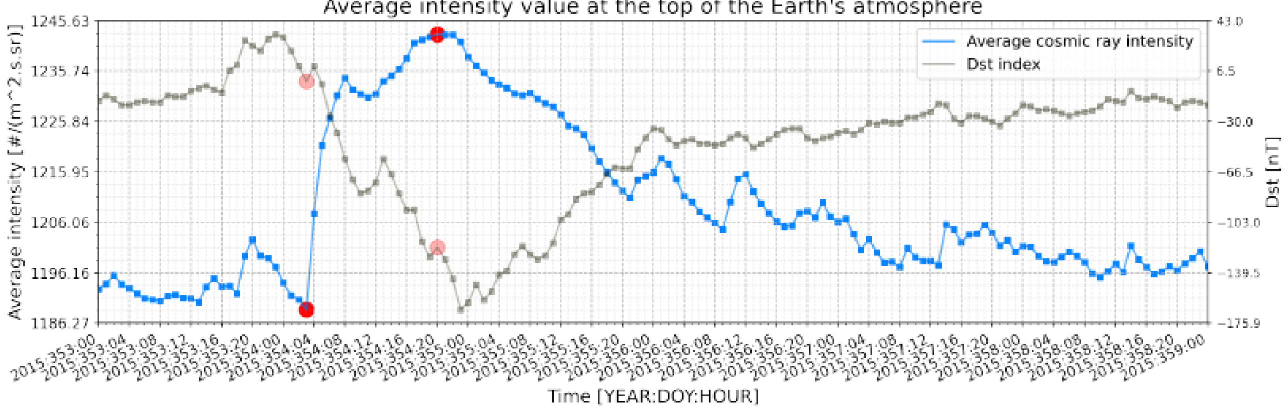


Figure 6: Average global CR intensity at the top of the Earth's atmosphere, and Dst index for December 2015 storm. The red points signify minimum and maximum values of average global CR intensity.

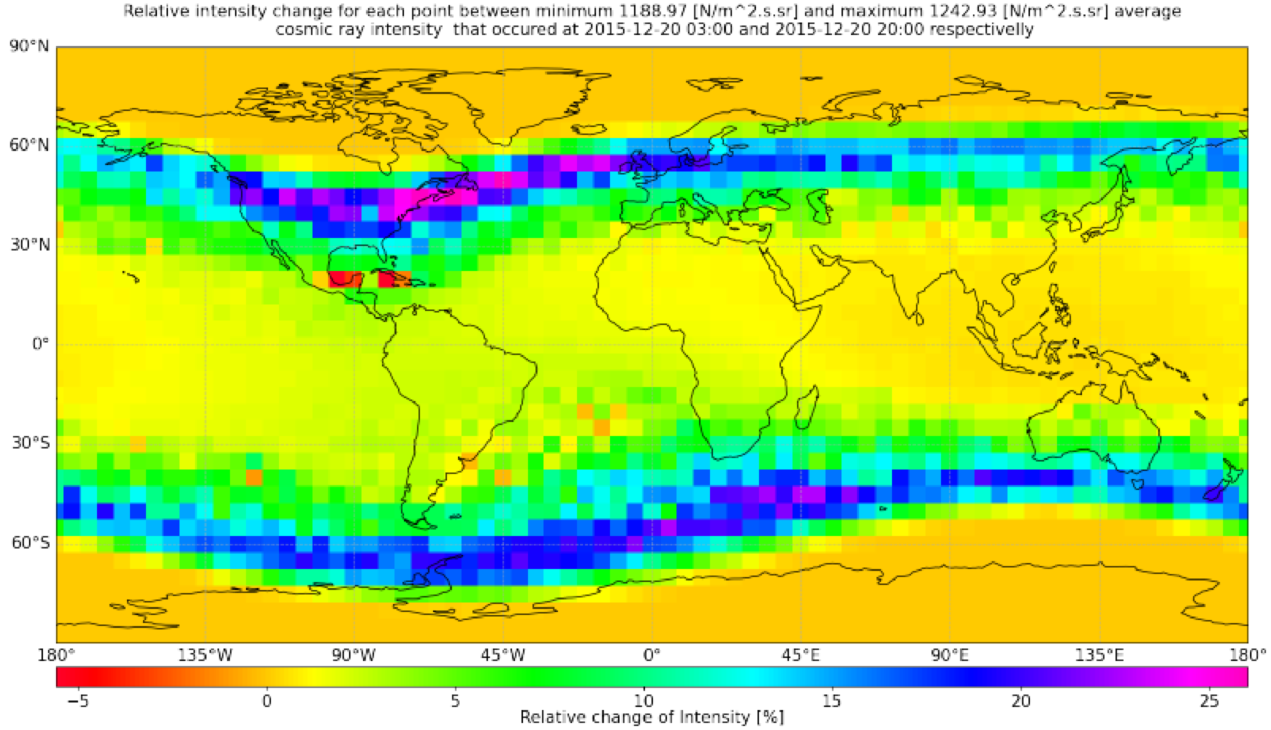


Figure 7: Relative CR intensity at the top of the Earth's atmosphere for each evaluated point between time-points with minimum and maximum average intensity signified by red dots in the figure 6.

https://www.kaggle.com/code/adminpretaktovaniesk/cosmic-rays-spectra-ams-02-daily-fluxes-prl-2021

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13 Edit

Cosmic rays spectra, AMS-02 daily fluxes, PRL 2021

Python · Cosmic rays, AMS-02 daily fluxes dataset, PAMELA 08 2013, test version, PAMELA, bin 0.46-0.50GeV 2006-2013 +2

Notebook Input Output Logs Comments (6) Settings

Run
90.5s

Version 16 of 16

Add Tags

Work in progress, published in the current state mainly for students/colleagues.

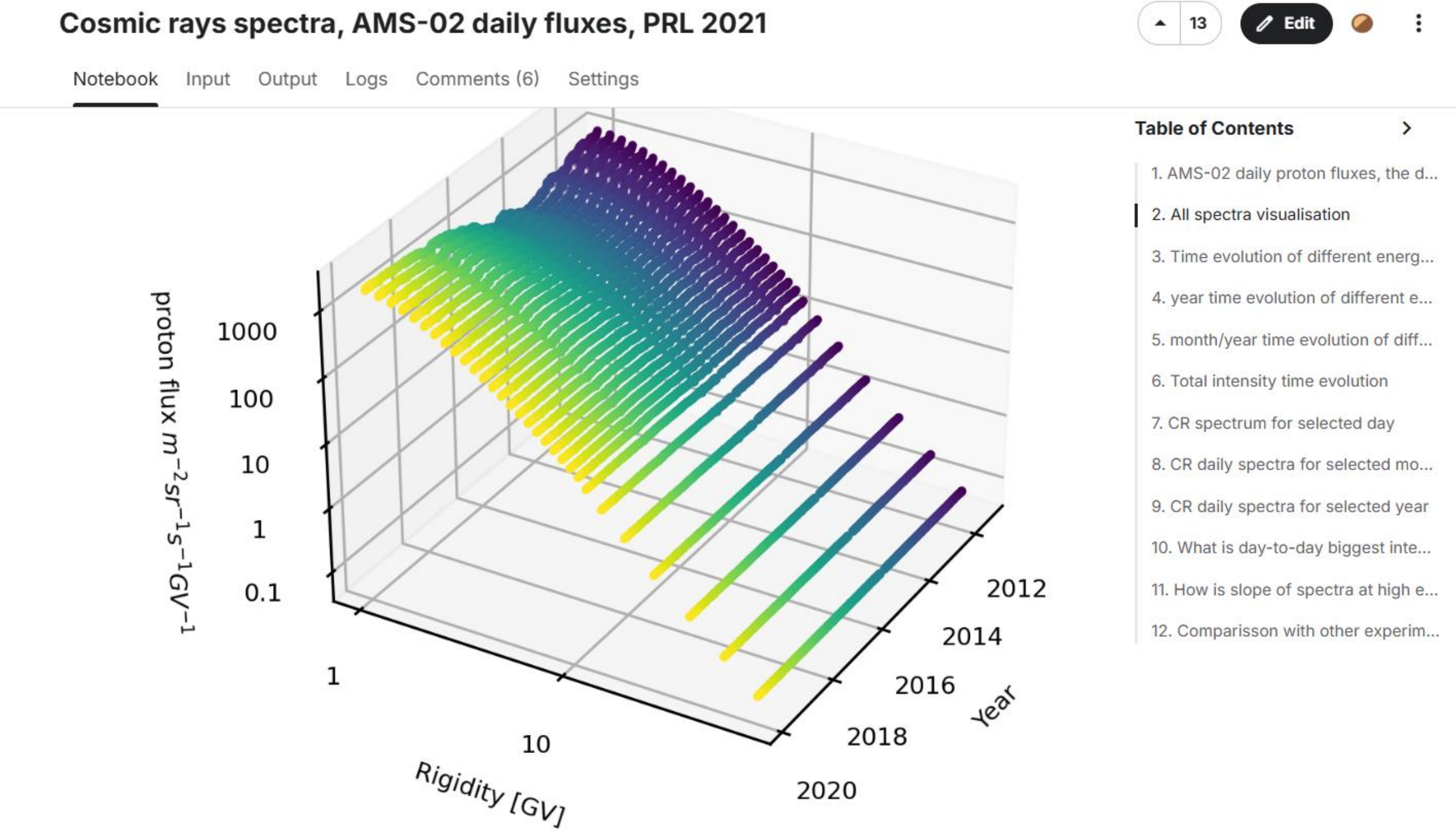
1. AMS-02 daily proton fluxes, the data set

The published AMS-02 cosmic ray daily spectra in PRL 2021 [1] (proton component) and data set [2] give a unique opportunity to see the time evolution of radiation at 1AU, i.e. at Earth's orbit around the Sun in the interplanetary space.

The spectra were measured at low Earth's orbit aboard the International Space Station, i.e. inside of Earth's magnetosphere, but the effect of the magnetosphere is "cleaned out" in those data. From all measured events, those included in the data set [2], were not affected by the geomagnetic field. The process is called event selection and details could be found in the article by M. Aguilar et al.

Table of Contents

Cosmic rays spectra, AMS-02 daily fluxes, PRL 2021, https://www.kaggle.com/code/adminpretaktovaniesk/cosmic-rays-spectra-ams-02-daily-fluxes-prl-2021



[Cosmic rays spectra, AMS-02 daily fluxes, PRL 2021, https://www.kaggle.com/code/adminpretaktovaniesk/cosmic-rays-spectra-ams-02-daily-fluxes-prl-2021](https://www.kaggle.com/code/adminpretaktovaniesk/cosmic-rays-spectra-ams-02-daily-fluxes-prl-2021)

ASTROFYZIKA A SPOJENIE S INFORMATIKOU

Martin Nguyen

Doktorand (3. ročník)

Katedra Počítačov a Informatiky (KPI TUKE)

martin.nguyen@student.tuke.sk

ÚEF SAV

ATvl 2019

- C++: Paralelizácia výpočtových simulácií na GPU
- Desktop developer: CUDA HelioCommander nástroj (C#)
- Web developer: Weather aplikácia www.whdproject.com
    - Frontend: Angular, TypeScript
    - Backend API : FastAPI Python, microservices
- Machine learning:
    - Korelácia kozmického počasia s vplyvmi na zemi (Štatistika)
    - Predikcia denných AMS-02 spektier (Neurónky, random-forest, XGBoost...)

NA ČOM SA DÁ U NÁS PRACOVAŤ?

1. PARALELIZÁCIA VÝPOČTOVÝCH SIMULÁCIÍ NA GPU

- Cieľom je zrýchliť výpočet simulácie zložitých rovníc na čo najkratší čas
- Napr. pri miliardách simulovaných častíc
  - CPU kód, synchrónny, runtime = 2 týždne
  - CPU kód, na viacerých jadrách, runtime = 6 dní
  - GPU verzia kódu, na miliónoch vlákien, runtime = 2 hodiny
- CPU jadrá => Nvidia GPU a ich CUDA jadrá

https://github.com/msolanik/Geliosphere/

1. PARALELIZÁCIA VÝPOČTOVÝCH SIMULÁCIÍ NA GPU

3. Stochastic Approach

Historically, the FPE was developed during the investigation of Brownian motion in a radiation field [*Fokker*, 1914; *Planck*, 1917]. However, the rigorous mathematical basis was developed later by *Kolmogorov* [1931]. In the most general case, the transition density function $Q(s,y;t,x)$ from a phase-space point y at time s to a new time and position (t,x), associated to an advective and a diffusive process described by moderately smooth functions, satisfies the following partial differential equations [see *Klöden and Platen*, 1999, equation (1.7.14); *Zhang*, 1999, equation (8); *Pei et al.*, 2010, equation (7); *Kopp et al.*, 2012, equation (13)]:

$$\frac{\partial Q}{\partial t} = -\sum_i \frac{\partial}{\partial x_i}[A_{F,i}(t,x)Q] + \frac{1}{2}\sum_{i,j}\frac{\partial^2}{\partial x_i \partial x_j}[C_{F,ij}(t,x)Q] - L_F(t,x)Q + S \qquad (5)$$

where $A_{F,i}$ is the advective term for ith coordinate (e.g., convection due to solar wind and magnetic drift), $C_{F,ij}$ is the diffusion tensor, L_F describes (catastrophic) "losses" [*Strauss et al.*, 2011] (e.g., used to describe radioactive decay by *Trotta et al.* [2011]), and finally, S describes "source" of particles (e.g., Jovian electrons) [see *Strauss et al.*, 2011]. This equation gives the *forward-in-time* evolution with respect to the final state (t,x).

In term of differential operators, formally the *backward-in-time* evolution is described by the adjoint operator of the time forward [*Kopp et al.*, 2012]. In this approach the *Kolmogorov backward equation* [*Klöden and Platen*, 1999, equation (1.7.15)] gives the backward evolution of the associated transition density function with respect to the initial state (s,y) [see, e.g., *Zhang*, 1999, equation (13); *Strauss et al.*, 2011, equation (A2); *Kopp et al.*, 2012, equation (14)]:

$$\frac{\partial Q}{\partial s} = \sum_i A_{B,i}(s,y)\frac{\partial Q}{\partial y_i} + \frac{1}{2}\sum_{i,j} C_{B,ij}(s,y)\frac{\partial^2 Q}{\partial y_i \partial y_j} - L_B Q + S \qquad (6)$$

where $A_{B,i}$ is the advective term for ith coordinate (e.g., convection due to solar wind and magnetic drift), $C_{B,ij}$ is the diffusion tensor, L_B describes (catastrophic) losses and finally S describes source of particles. We underline that $\partial s > 0$ represents a propagation backward-in-time.

The Stochastic approach allows to reevaluate the diffusion process by mean of a set of SDEs than can be generally expressed for the forward-in-time evolution as

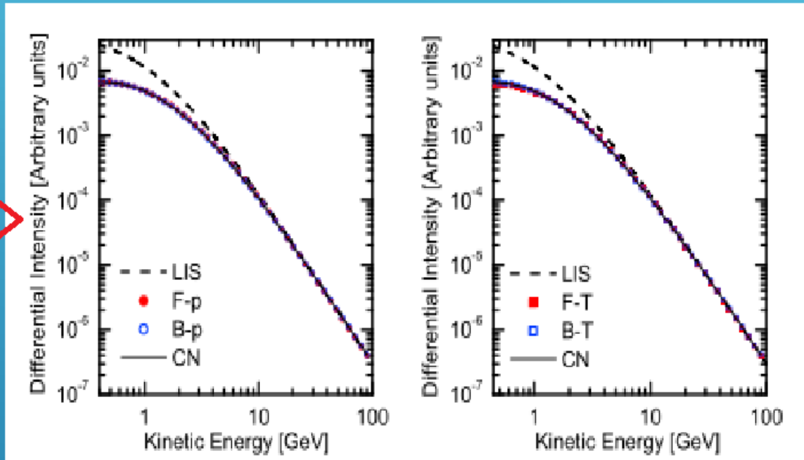
$$\mathrm{d}x_i(t) = A_{F,i}\mathrm{d}t + B_{F,i,j}\mathrm{d}W_j(t) \qquad (7)$$

and for the backward-in-time evolution as

$$dy_i(s) = A_{B,i}ds + B_{B,i,j}dW_j(s), \qquad (8)$$

where $\tilde{C} = \tilde{B}\tilde{B}^T$, $\mathrm{d}\vec{W}$ represents the increments of a *standard Wiener process* that can be depicted as an independent random variable of the form $\sqrt{\mathrm{d}t}N(0,1)$ (or $\sqrt{\mathrm{d}s}N(0,1)$), and finally, $N(0,1)$ denotes a normally

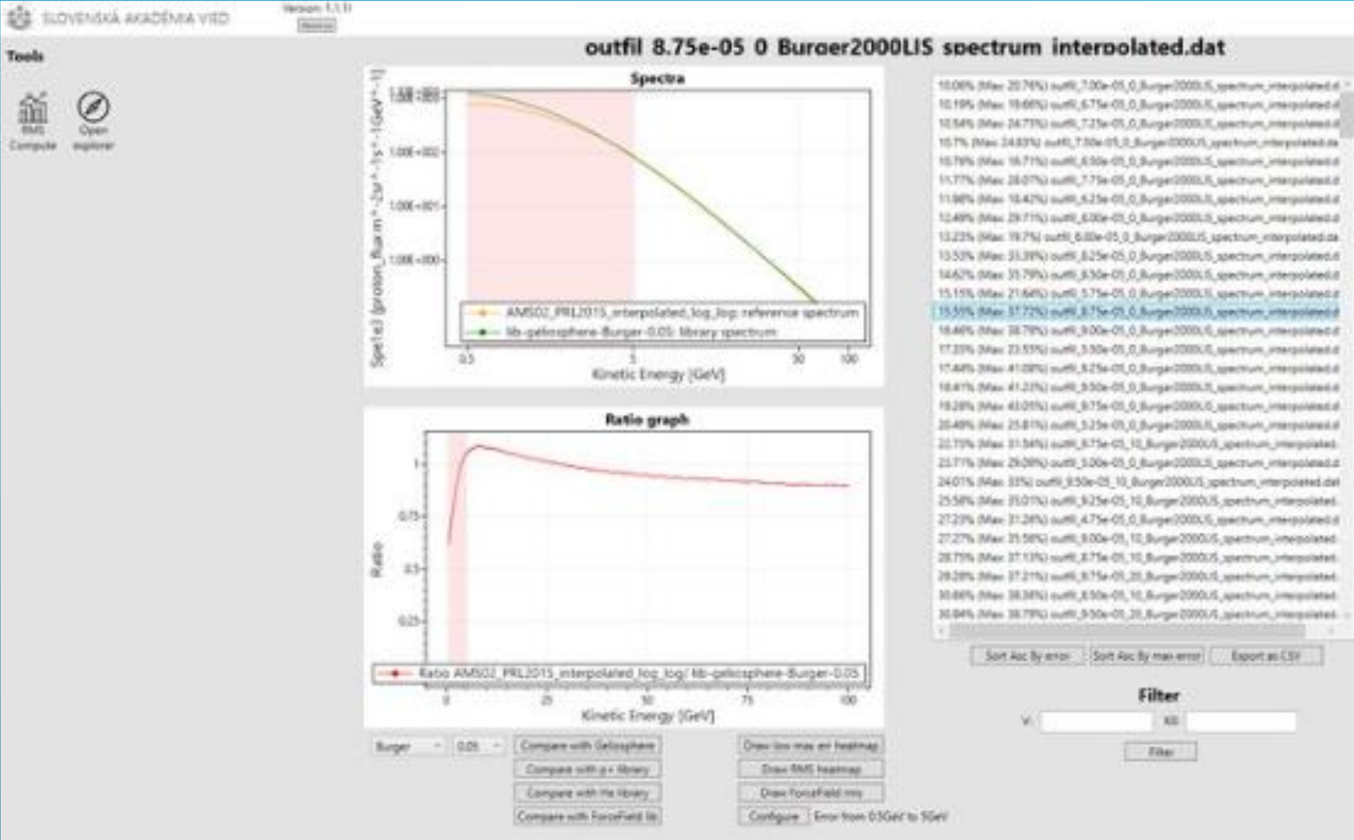
```
while (r < 100.0002) {
  beta = sqrt(Tkin * (Tkin + T0 + T0)) / (Tkin + T0);
  Rig = sqrt(Tkin * (Tkin + (2.0 * T0)));
  Kdiff = K0 * beta * Rig;
  arnum = distribution(generator);
  dr = (V + (2.0 * Kdiff / r)) * dt;
  dr = dr + (arnum * sqrt(2.0 * Kdiff * dt));
  dp = 2.0 * V * p * dt / (3.0 * r);
  cfactor = 4.0 * V / (3.0 * r);
  sumac = sumac + (cfactor * dt);
  rp = r;
  pp = p;
  r = r + dr;
  p = p - dp;
  Rig = p * c / q;
  Tkin = sqrt((T0 * T0 * q * q * 1e9 * 1e9) + (q * q * Rig * Rig)) -
        (T0 * q * 1e9);
  Tkin = Tkin / (q * 1e9);

  if (beta > 0.01 & Tkin < 100.0) {
    if ((r - 1.0) / ((r - dr) - 1.0) < 0.0) {
      outputMutex.lock();
      outputQueue.push({pinj, p, r, w, sumac});
      outputMutex.unlock();
    }
  }
```



https://github.com/msolanik/Geliosphere/

2. CUDA HELIOCOMMANDER NÁSTROJ

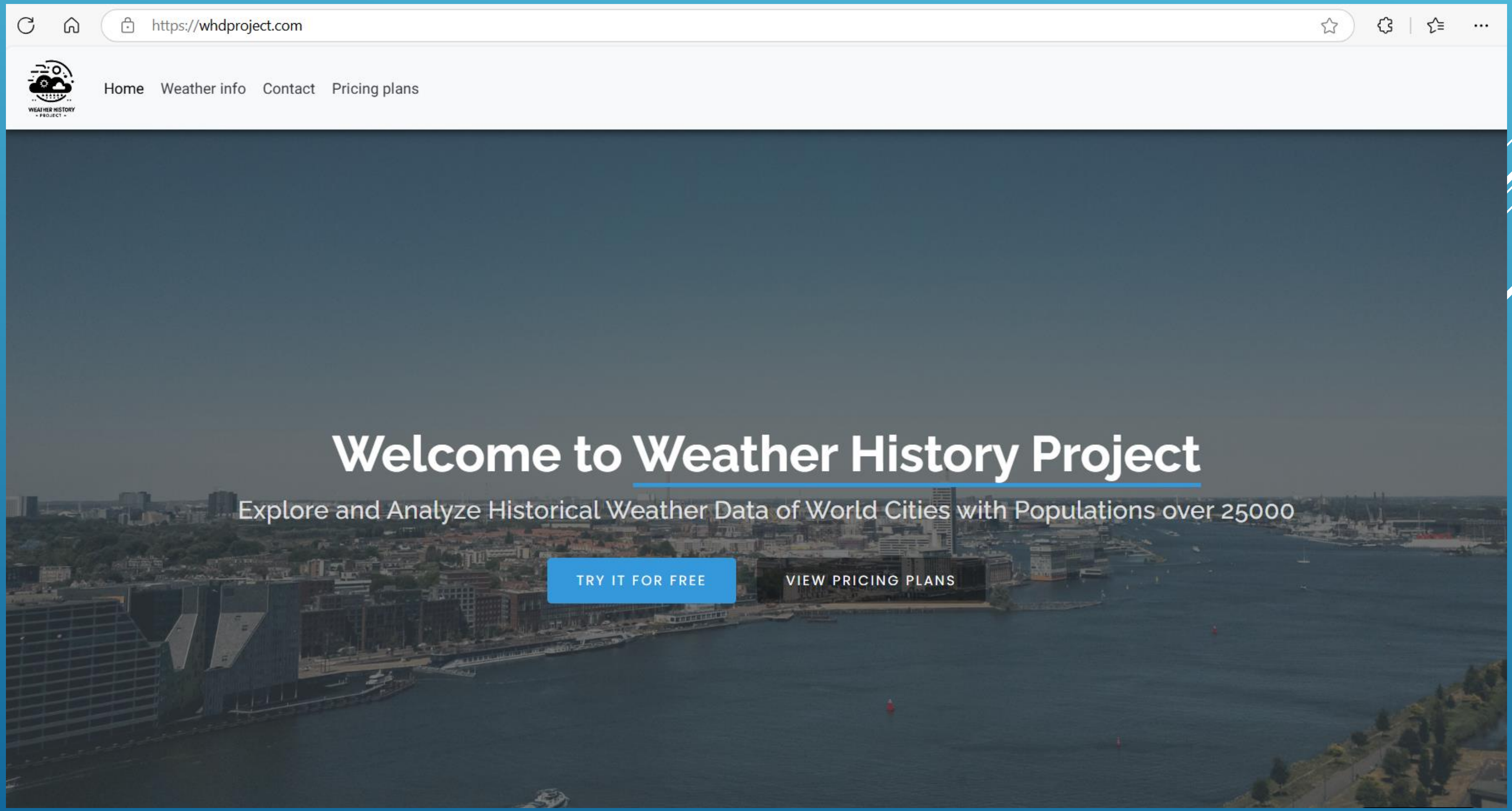
- Slúži na vizualizáciu/export dát, ktoré produkuje simulačný nástroj
- Desktopová aplikácia (C#, WPF)



https://github.com/gladiatus55/CudaHelioCommanderLight

3. WEATHER APLIKÁCIA WHDPROJECT.COM

- Získavanie historických dát o počasí pre mestá na celom svete



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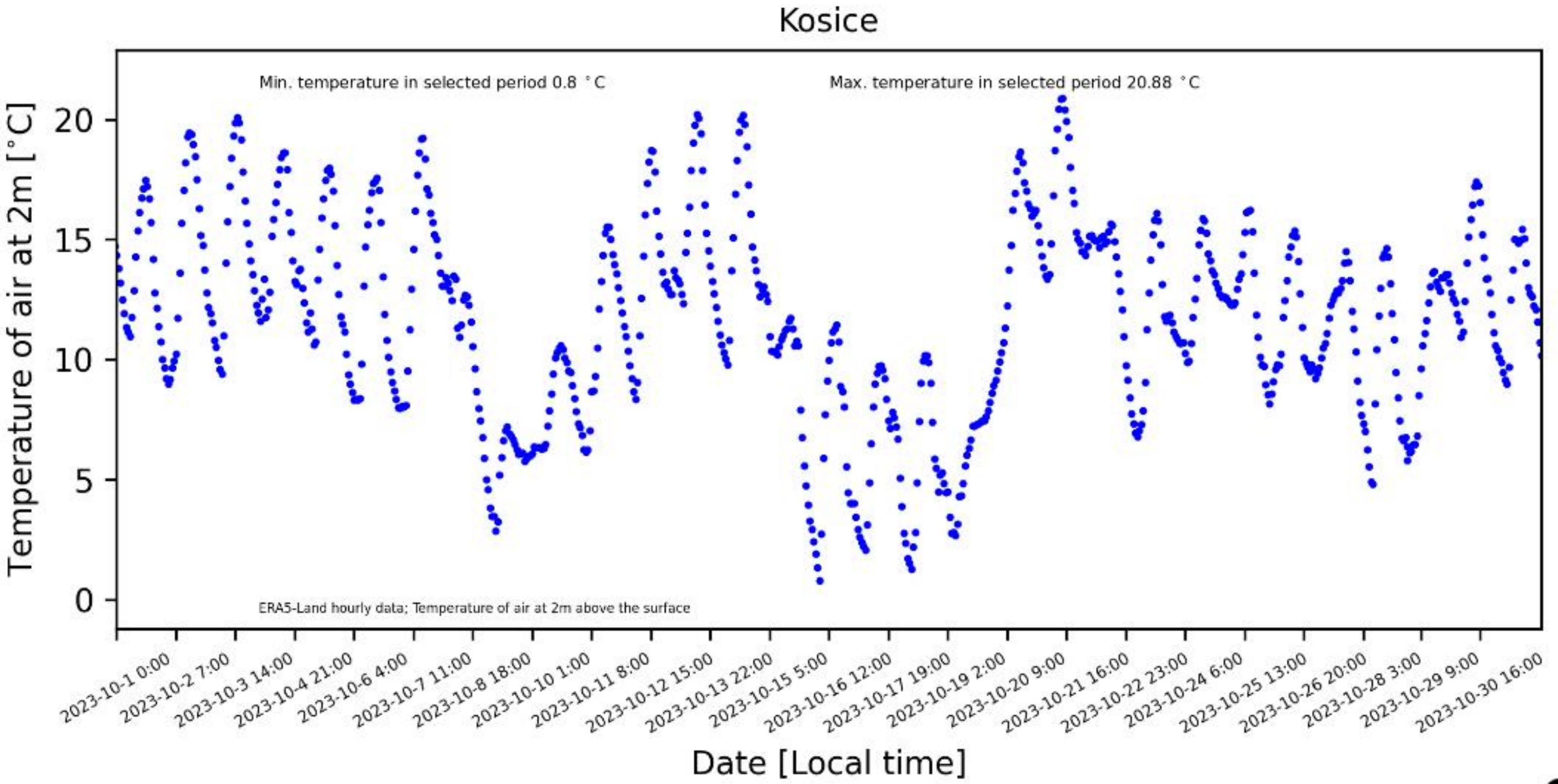
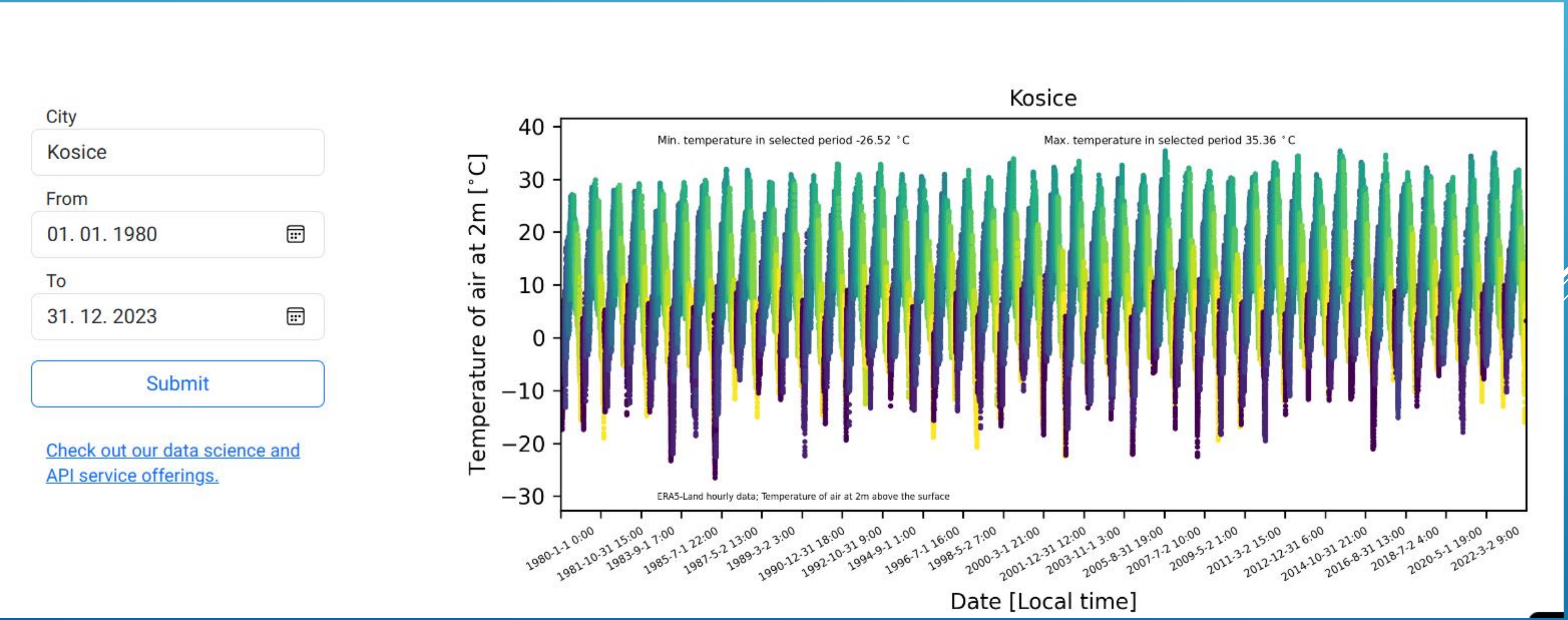


3. WEATHER APLIKÁCIA WHDPROJECT.COM

- 15 tisíc najväčších miest na svete, roky 1950-2023
- 200GB csv súborov, spracovaných z 10TB hdf5 súborov



https://cds.climate.copernicus.eu

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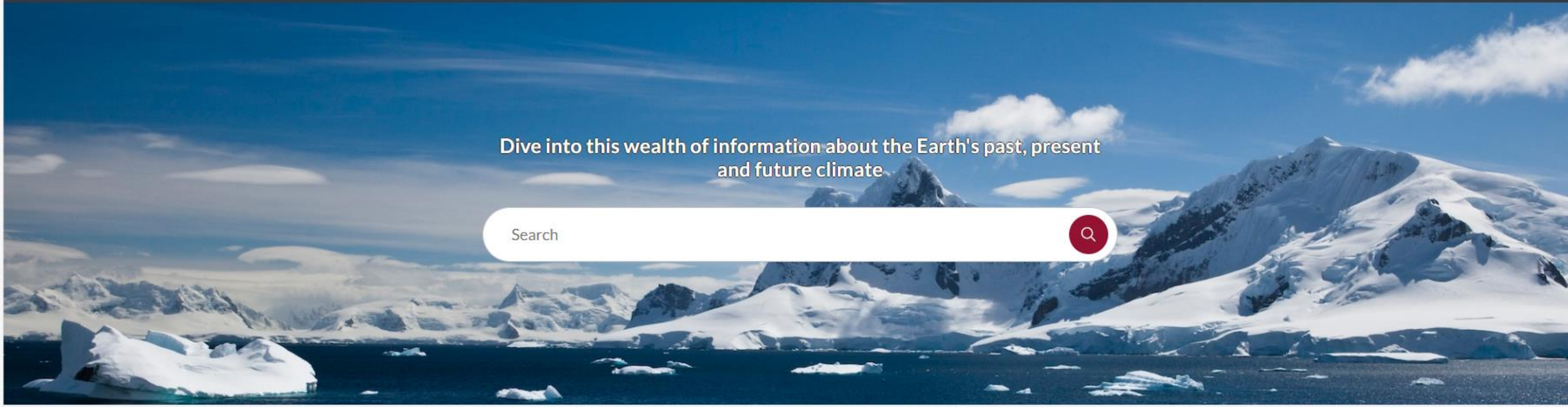
Climate Data Store

Datasets | Applications | User guide | Live | Background

Info 28 Sep 2024 **Welcome to the New Climate Data Store (CDS)! This new system is in its early days of full operations and still undergoing enhancements and fine tuning. Some disruptions are to be expected. Your feedback is key to improve the user experience on the new CDS for the benefit of everyone. Thank you.** 1/5



API

store catalogue, with search and

Training

Copernicus Climate Change Service (C3S) data tutorials

earthkit

Open-source Python tools simplifying data access

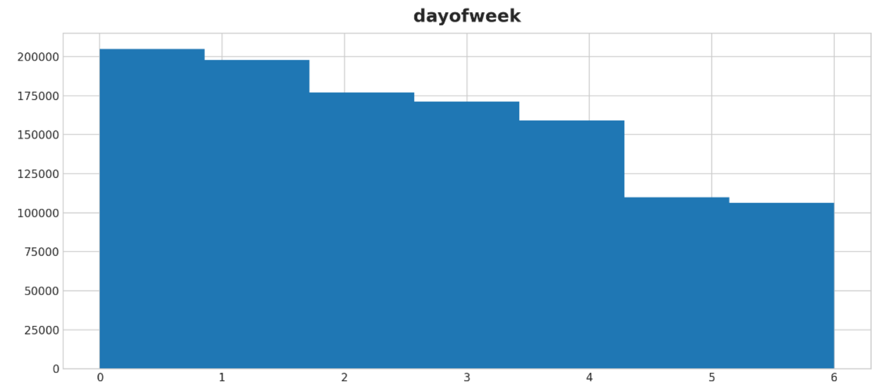
https://cds.climate.copernicus.eu/training

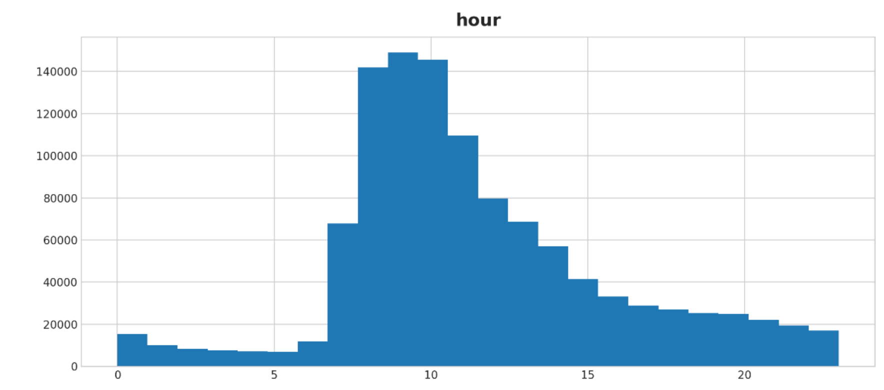
4. MACHINE LEARNING

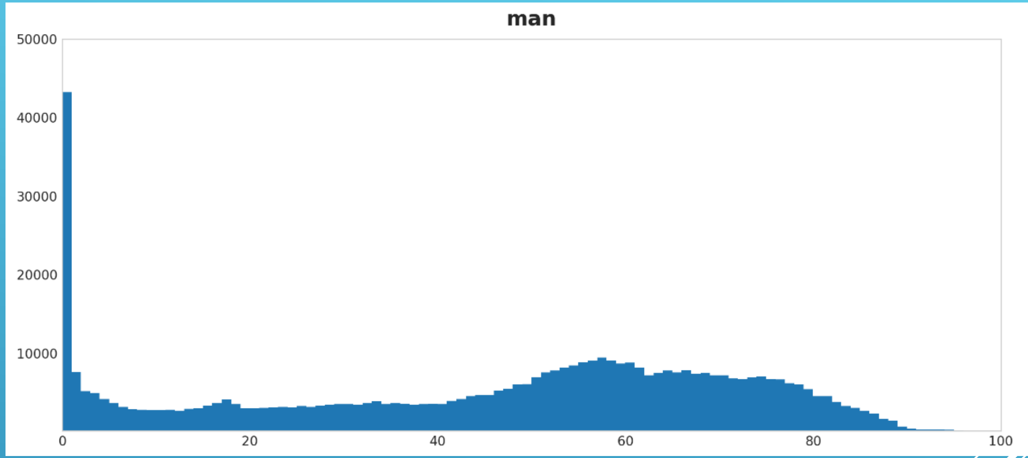
- Korelácia kozmického počasia s vplyvmi na zemi
  - Zdravie človeka
  - Elektrické rozvodné siete, elektrické zariadenia a pod.
- Predikcia denných AMS-02 spektier
  - Aplikácia ML algoritmov na aproximáciu spektier kozmického žiarenia
  - Koľko protónov na rôznych energetických úrovniach dosiahne Zem ak nás chráni Slnko?
- Zapájanie sa do rôznych súťaží na Kaggle
  - Napr. Exploratívna analýza dát pri dostihových pretekoch

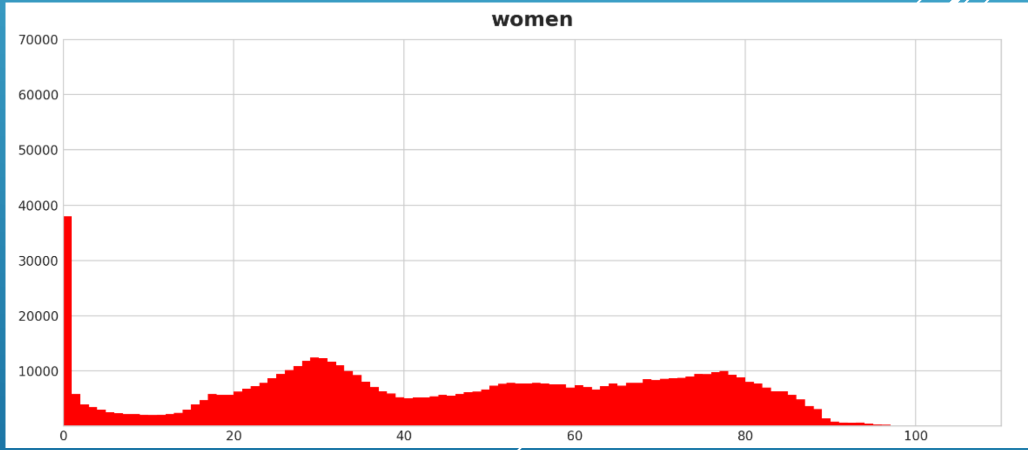
4A. MACHINE LEARNING – KORELÁCIE

- Dátový set hospitalizácií pre roky 2007-2014
- Napr. hospitalizácie za r. 2008 = 1126069









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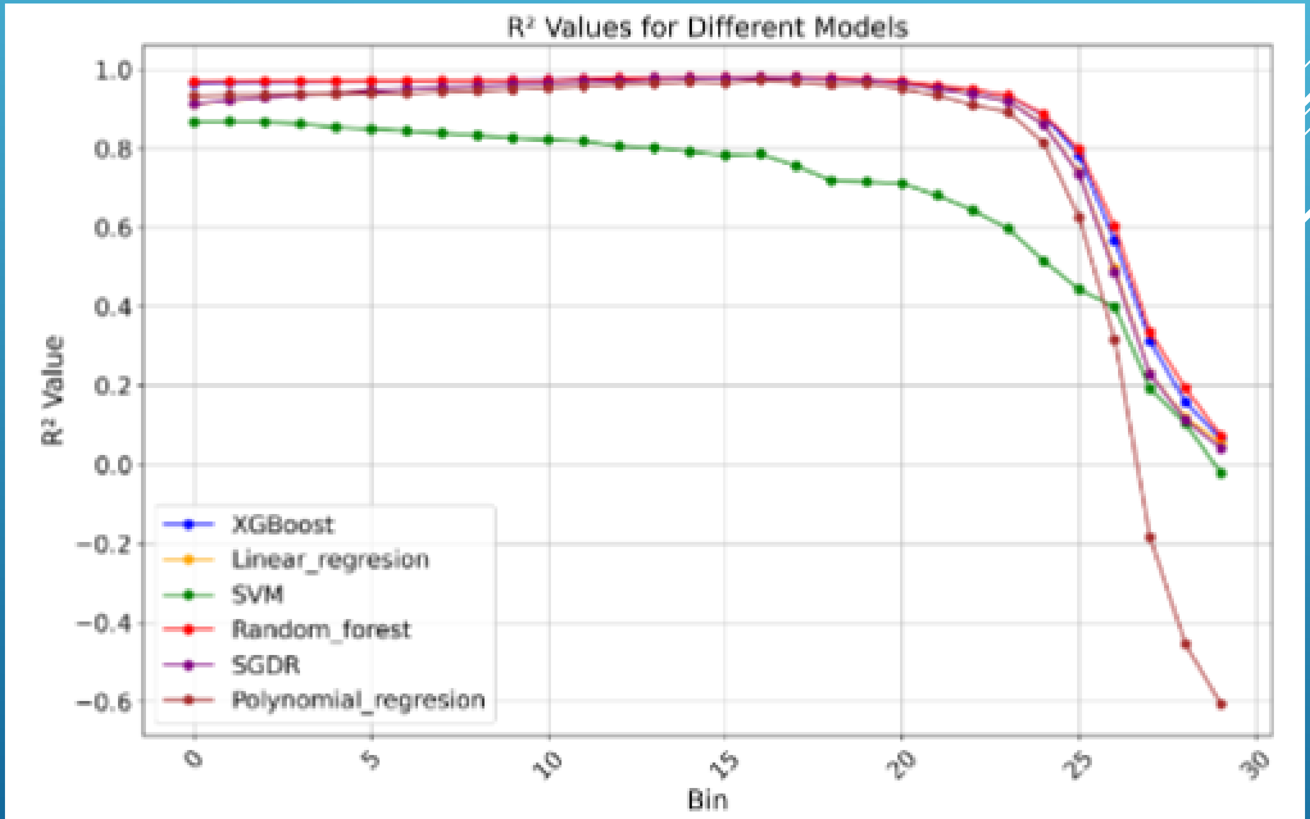
[1]:

	rok_sprac	dat_prij	diag_hosp_od_3	diag_hosp_od_3_popis	diag_hosp_od_kap	diag_hosp_od_kap_pop	pacobec_okres	pacobec_okres_kod_st	pacobec_okres_popis	pacvek	pacpohlavie
0	2008	2007-04-10 09:00:00	C18	Zhubny nador hrubeho creva	2	II. k a p i t o l a - Nadory (C00 - D48)	704	SK0414	Okres Levoca	85	1
1	2008	2007-09-24 11:00:00	I64	Porazka (apoplexia- iktus) blizsie neurcena ak...	9	IX. k a p i t o l a - Choroby obehovej sustavy...	710	SK041A	Okres Stara lubovna	76	1
2	2008	2007-09-10 09:00:00	I70	Ateroskleroza	9	IX. k a p i t o l a - Choroby obehovej sustavy...	706	SK0416	Okres Poprad	88	2
3	2008	2007-12-18 11:00:00	S72	Zlomenina stehnovej kosti	19	XIX. k a p i t o l a - Poranenia- otravy a dak...	703	SK0413	Okres Kezmarok	90	1
4	2008	2007-12-19 10:00:00	I69	Neskore nasledky cievnych mozgovych chorob	9	IX. k a p i t o l a - Choroby obehovej sustavy...	706	SK0416	Okres Poprad	83	2
5	2008	2008-11-01 11:00:00	I64	Porazka (apoplexia- iktus) blizsie neurcena ak...	9	IX. k a p i t o l a - Choroby obehovej sustavy...	703	SK0413	Okres Kezmarok	90	2
6	2008	2008-11-01 12:00:00	C33	Zhubny nador priedusnice	2	II. k a p i t o l a - Nadory (C00 - D48)	706	SK0416	Okres Poprad	72	1
7	2008	2007-12-10 10:00:00	G93	Ine poruchy mozgu	6	VI. k a p i t o l a - Choroby nervoveho system...	706	SK0416	Okres Poprad	56	1
8	2008	2008-01-18 11:00:00	I46	Zastavenie srdca	9	IX. k a p i t o l a - Choroby obehovej sustavy...	706	SK0416	Okres Poprad	73	1
9	2008	2007-11-27 10:00:00	R40	Somnolencia- stupor a koma	18	XVIII. k a p i t o l a - Subjektivne a objekti...	706	SK0416	Okres Poprad	91	2
10	2008	2008-01-21 09:00:00	I60	Subarachnoidalne krvacanie	9	IX. k a p i t o l a - Choroby obehovej sustavy...	706	SK0416	Okres Poprad	59	1
11	2008	2008-01-28 11:00:00	C71	Zhubny nador mozgu	2	II. k a p i t o l a - Nadory (C00 - D48)	810	SK042A	Okres Spisska Nova Ves	53	2
12	2008	2007-10-24 11:00:00	N19	Zlyhavanie obliciek- blizsie neurcene	14	XIV. k a p i t o l a - Choroby mocovej a pohla...	703	SK0413	Okres Kezmarok	81	2
13	2008	2008-01-02 11:00:00	I70	Ateroskleroza	9	IX. k a p i t o l a - Choroby obehovej sustavy...	706	SK0416	Okres Poprad	77	1

4B. MACHINE LEARNING – APROXIMÁCIA

- Veľký dátový set spektier kozmického žiarenia
- Trénovanie ML algoritmov a vyhodnocovanie ich úspešnosti



4C. MACHINE LEARNING – KAGGLE

https://www.kaggle.com/code/adminpretaktovaniesk/big-data-derby-2022-statistical-model

kaggle

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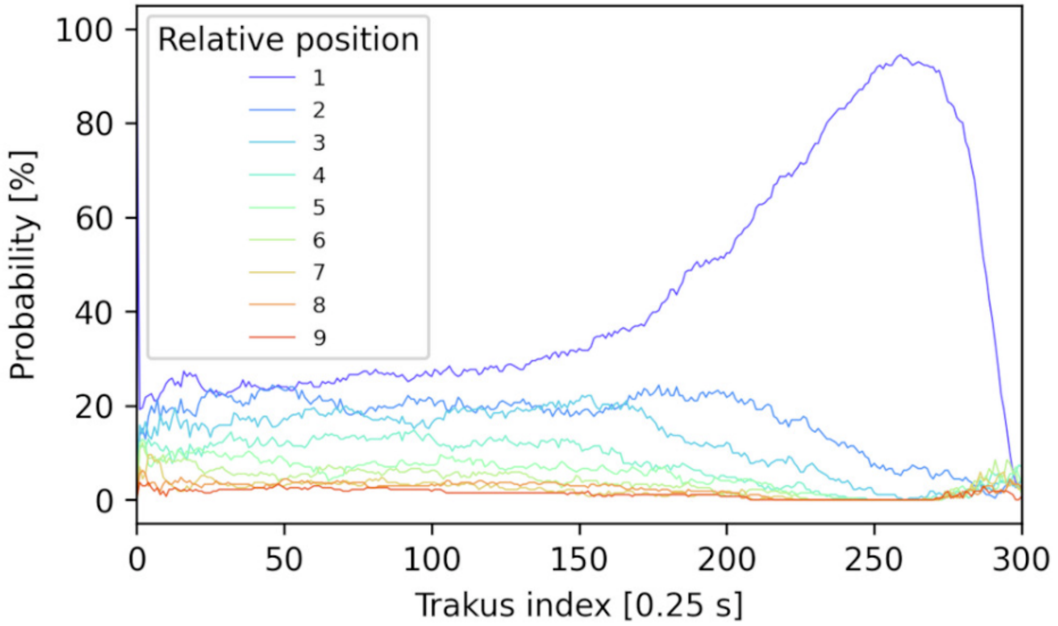
Big Data Derby 2022: Statistical model

14 Edit

Notebook Input Output Logs Comments (5) Settings

presentened in the next figure.



One could notice that the biggest chance to win a race, has horse in first position, and this is valid statement for the whole race. The relative chances to win are relatively stable in first two thirds of race, and then they start to spread, when horses reach the finishing straight (here, for 6 furlong races at Aqueduct, around trakus index 170).

However at the start of the finishing straight (around trakus index 170) summary chances to win from second and third positions are

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Pavol Bobik · Daniel Gecášek · Martin Nguyen · Michal Solanik · Jan Genci

14 Edit

Big Data Derby 2022: Statistical model

Python · Aqueduct_stadium_model, Saratoga stadium model, Aqueaduct stadium model - approximated v.2 +1

Competition Notebook
Big Data Derby 2022

Run
3635.8s

Version 16 of 16

Add Tags

Big Data Derby 2022: Statistical model, model of horses positions in course of race, finish line model

Abstract

We present a statistical evaluation of probabilities to win the race from different relative positions during the race. Probabilities show a chance to win a race at different moments of a race from different relative positions, i.e.for example, a chance to win the race for the first horse in the n-th trakus index. The condition of the course the race was run on influence to results is discussed.

Additionally, from a model of the stadium and a model of the finish line, we identified, that the tracking table's last trakus index is

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CESTA PHD. – ŠTÚDIUM, VÝSKUM A CESTOVANIE

- Spoznávanie nových ľudí
- Stáže v zahraničí
- Účasť na konferenciách
- Šanca zmeniť svet k lepšiemu

ĎAKUJEME ZA POZORNOSŤ ☺