



ASPIS – PART I.

Data analysis and preprocessing

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Fakulta elektrotechniky
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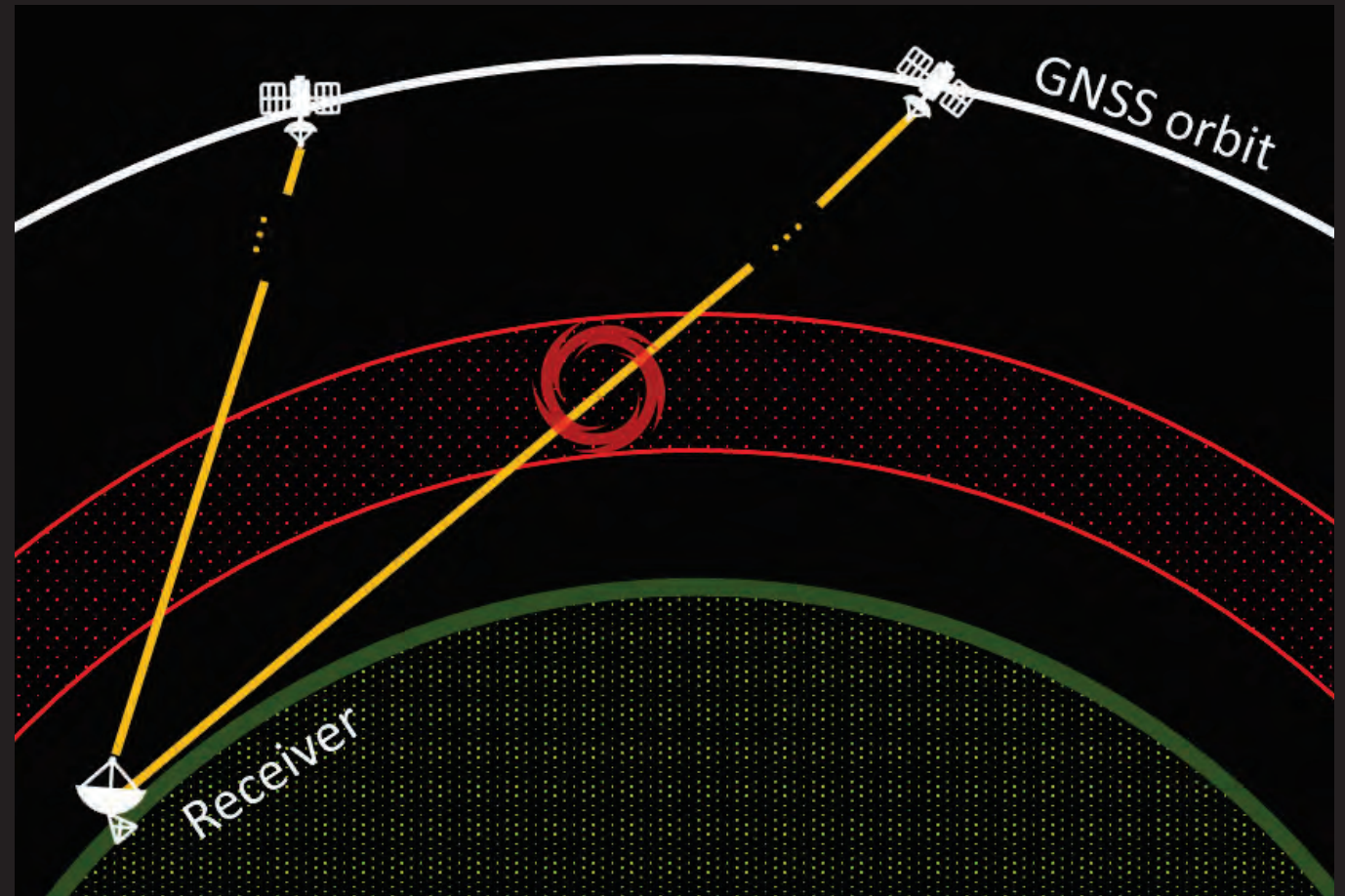


matfyz



What is ionospheric scintillation

- Ionospheric scintillation is the rapid modification of radio waves.
- Propagating through ionosphere.
- Caused by small scale structures in the ionosphere.

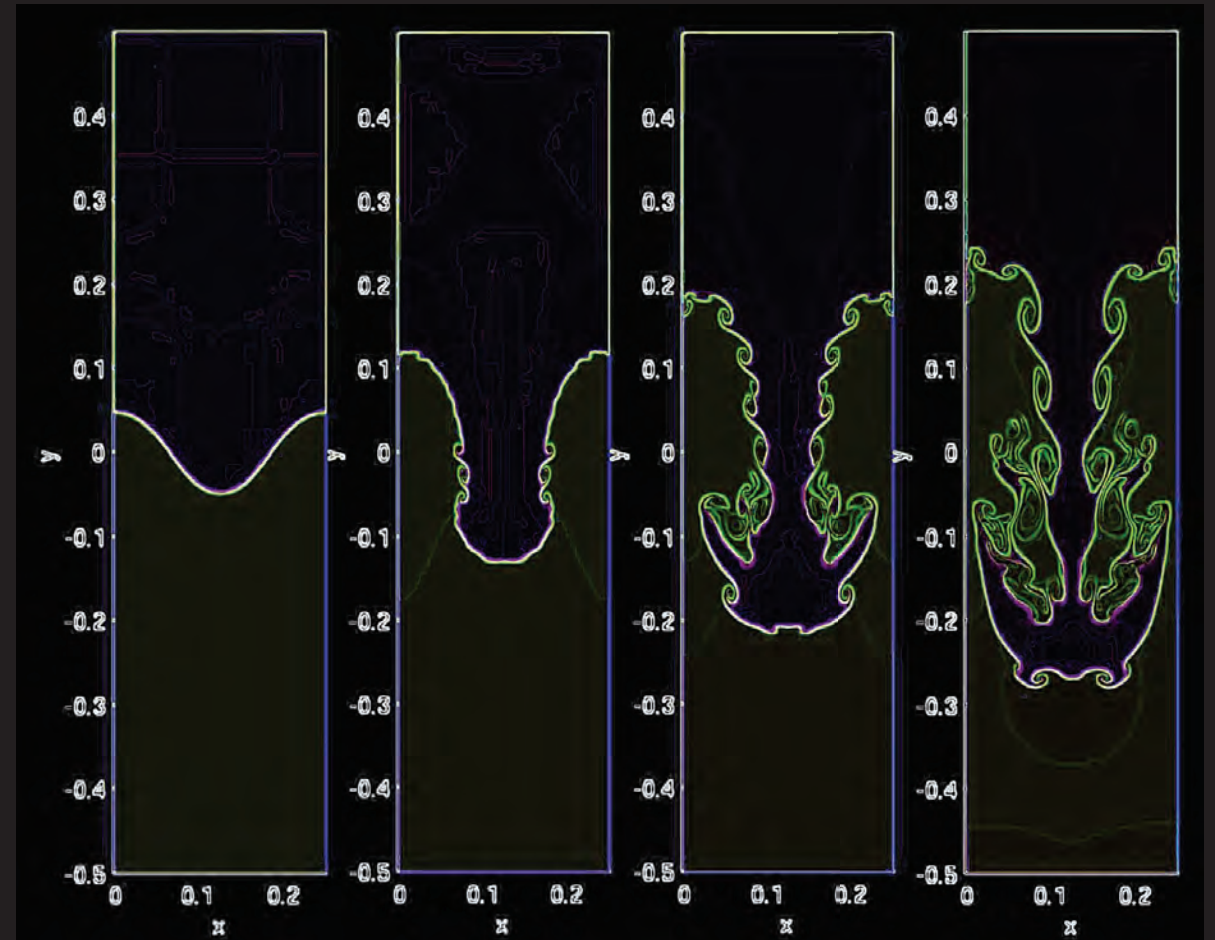


What is ionospheric scintillation

- Ionosphere is the ionized part of the upper atmosphere.
- Different layers have different densities.
- Because gr. field is present

=> Rayleigh–Taylor instability

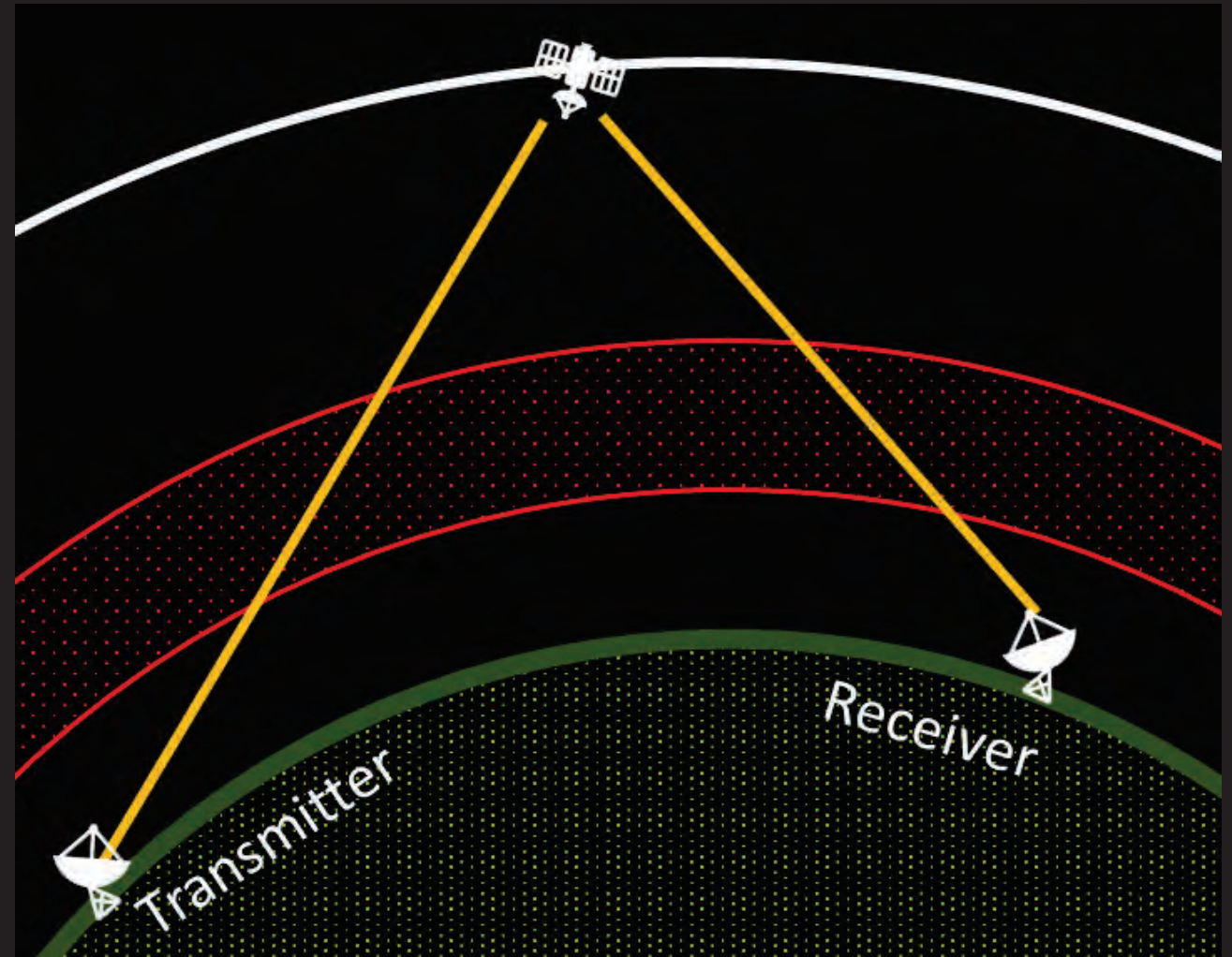
Coster, A.J. and Yizengaw, E. (2021). GNSS/GPS Degradation from Space Weather. In Space Weather Effects and Applications (eds A.J. Coster, P.J. Erickson, L.J. Lanzerotti, Y. Zhang and L.J. Paxton). <https://doi.org/10.1002/9781119815570.ch8>



Why should we bother

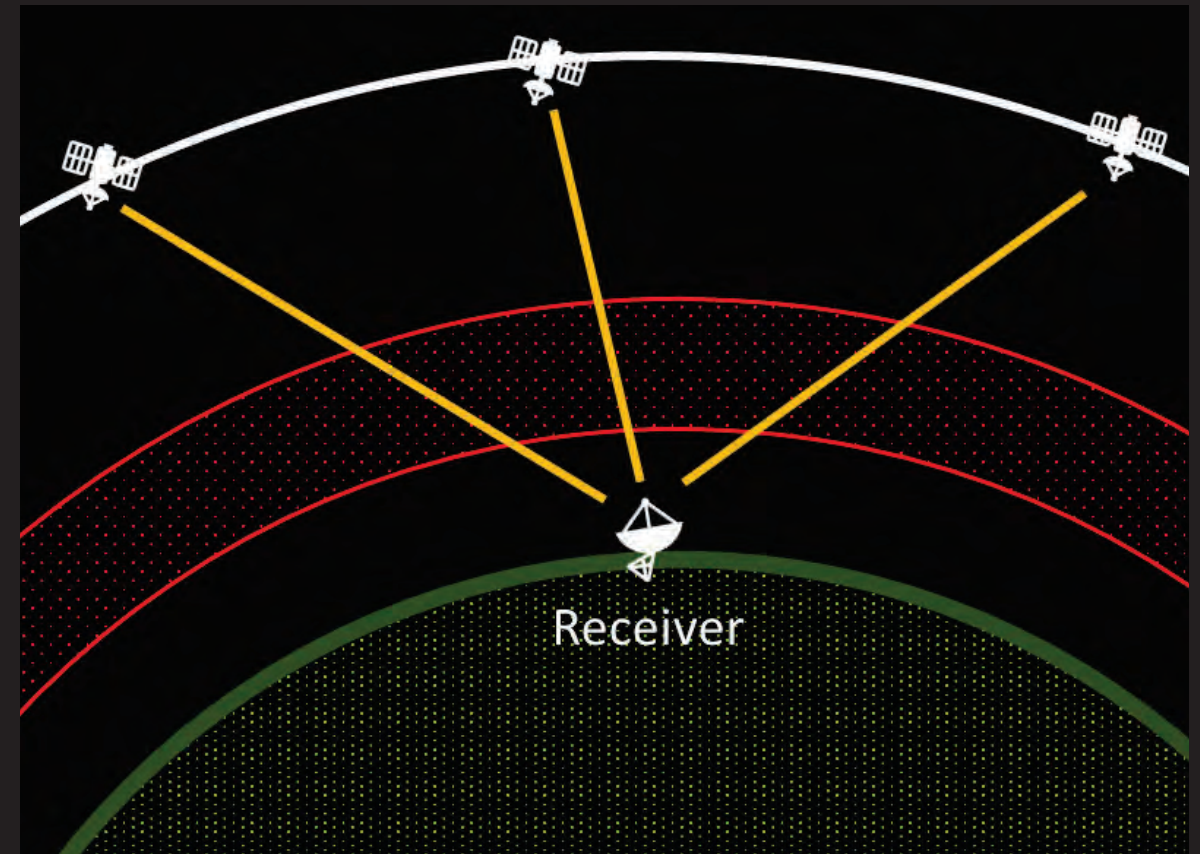
Satellite communication

- Artificial satellites to provide communication links between various points on Earth.
- Scintillations may cause **loss of communication capabilities**.



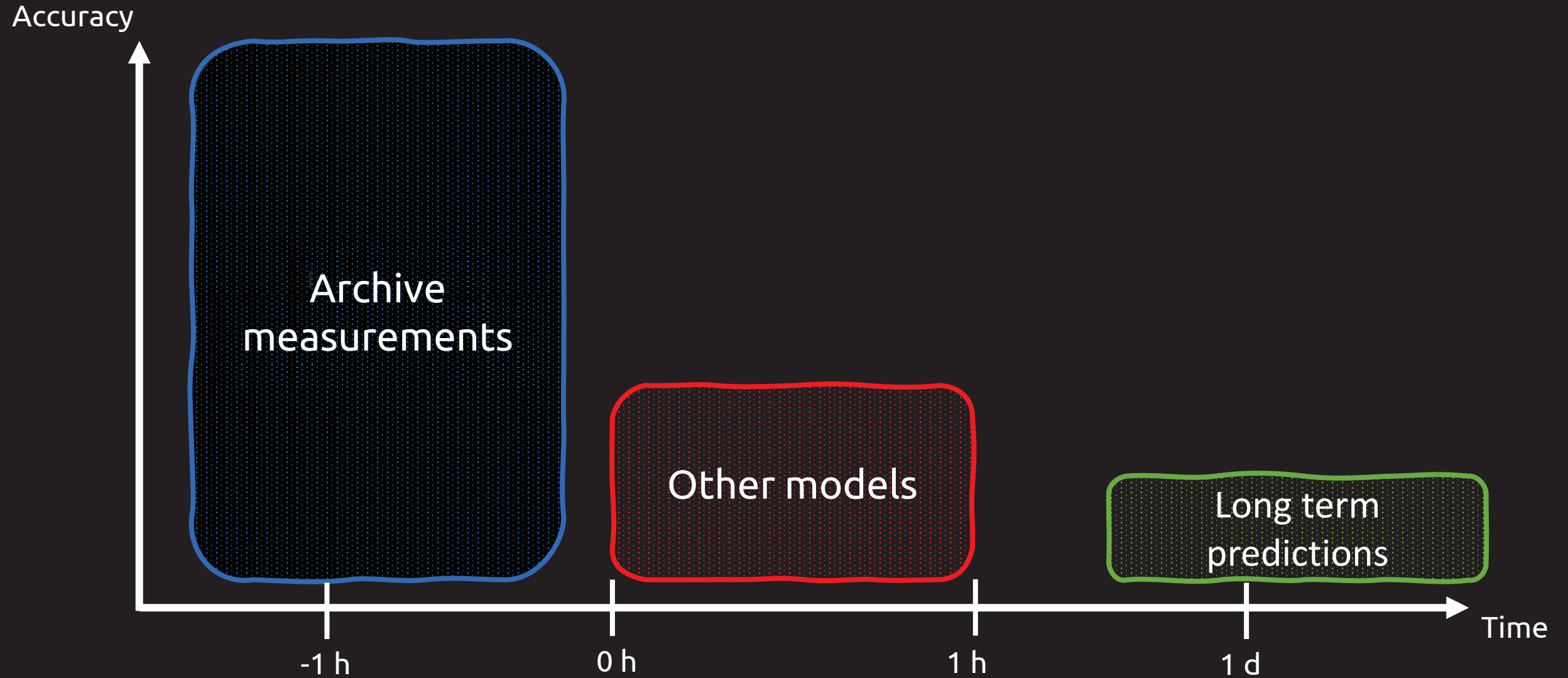
Global satellite navigation (GNSS)

- Artificial satellites that autonomous geopositioning.
- Scintillations may cause **loss of geopositioning capabilities**.
- Affects all main systems: GPS, GLONASS, Galileo.

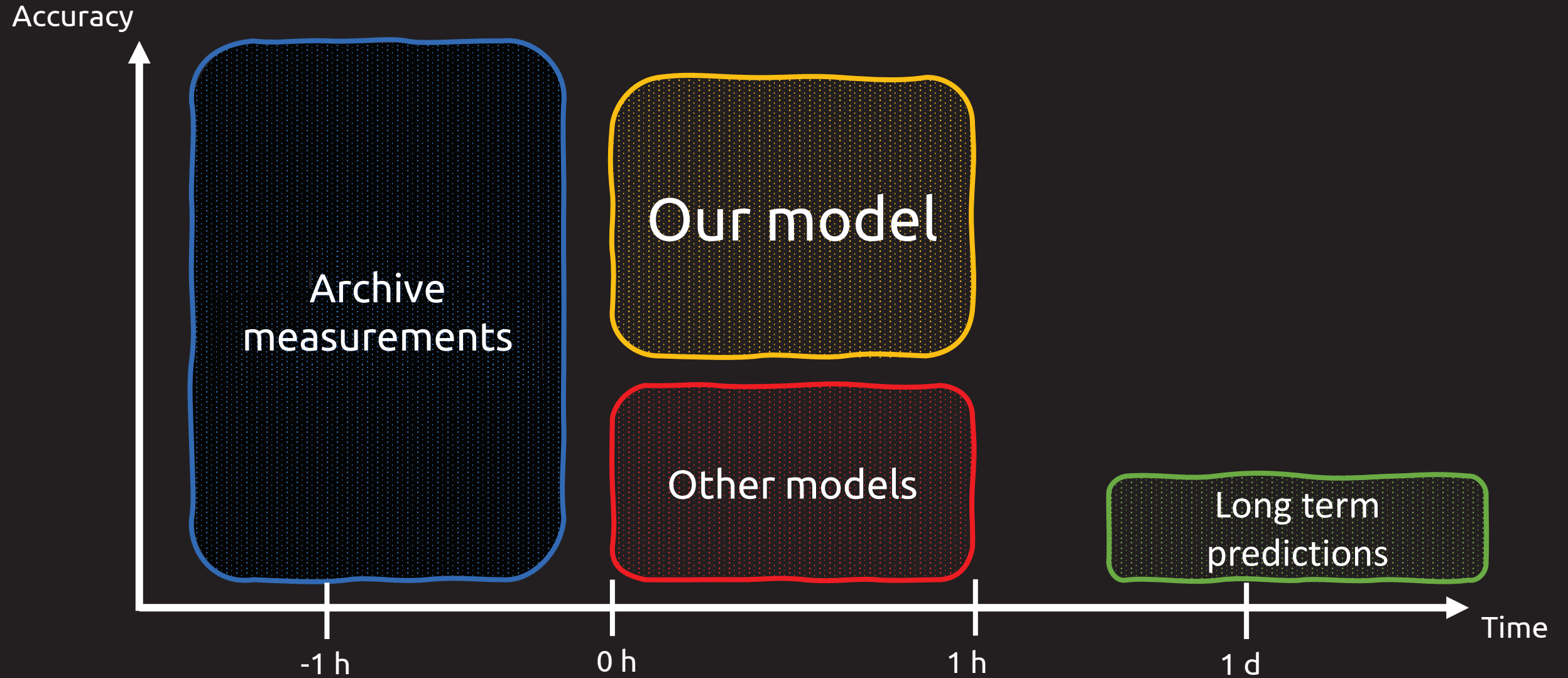


Previous work

Other models - Family photo



Other models - Family photo



Other works in field

Fremouw and Rino (1973)

S 4 on VHF/UHF, under weak-scatter conditions

GISM (1999)

Global ionospheric scintillation model

WBMOD (1985)

15-min peak-to-peak scintillation indices

L. F. C. Rezende (2010)

Prediction using data mining techniques

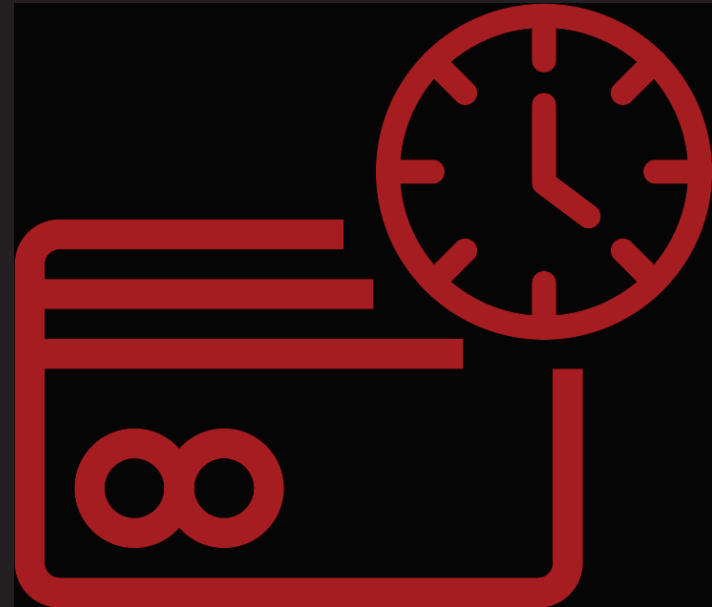
Main problems

Current problems

Low accuracy
and precision

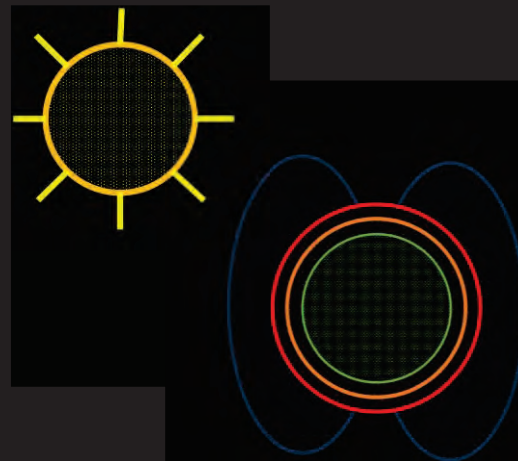
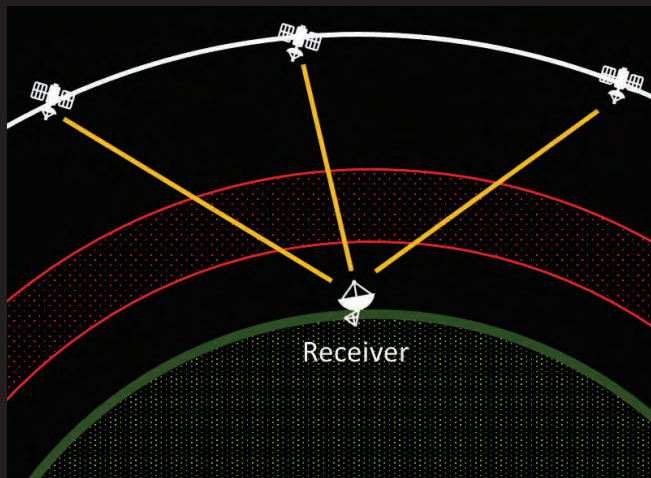


Short time of
prediction



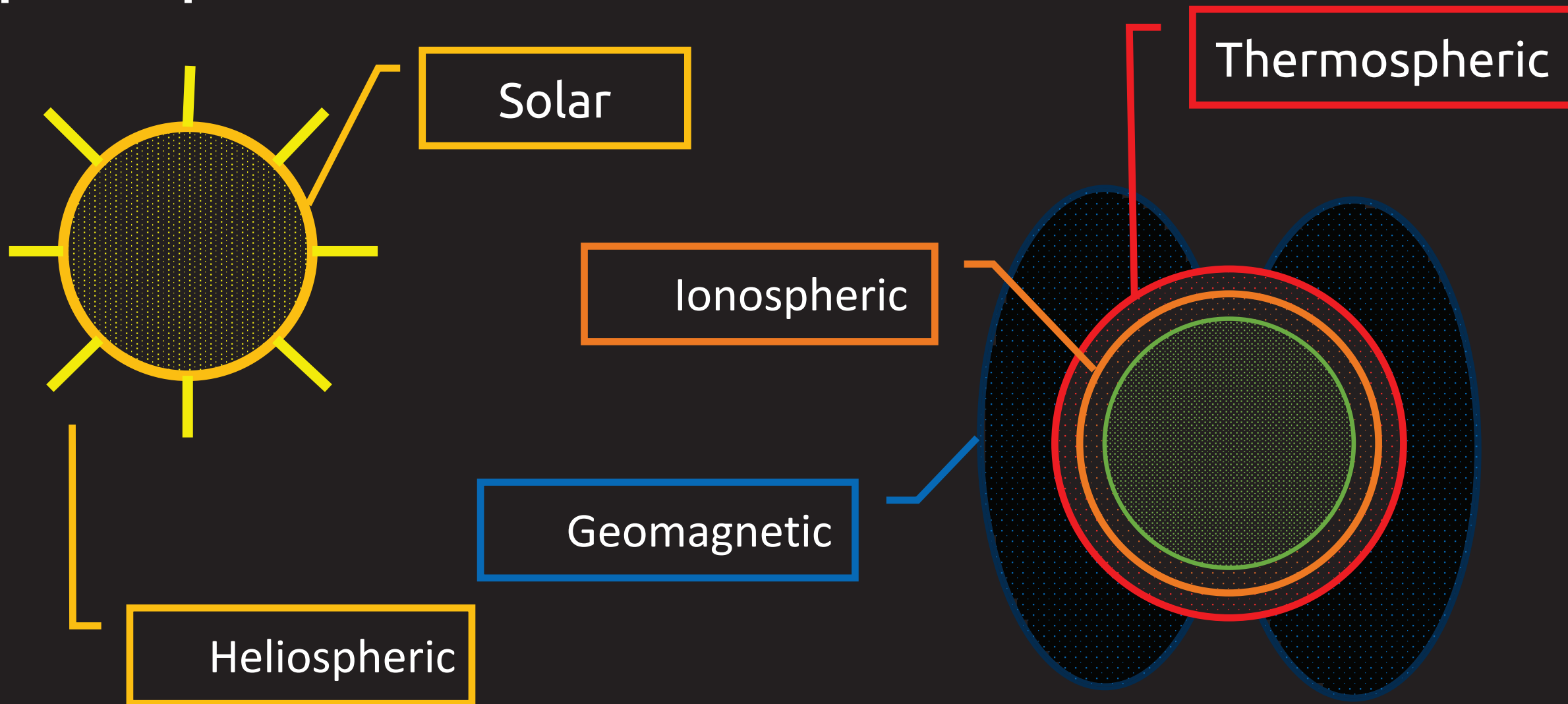
Our approach

- Data driven method
Years of measurements, with an emphasis on physics
- Using of deep neural network



Space parameters

Space parameters



Sources of data

OMNIWeb

OMNIWeb
SPDF•Goddard Space Flight Center

Interface to produce plots, listings or output files from OMNI 2

How to get data from command line

Plot data List data Create file (file?)

Select resolution
 Hourly averaged Daily averaged 27-day averaged Yearly averaged

Click [HERE](#) to get time spans for individual parameters.

Enter start and stop dates (Use yyyyddd or yyyyymmdd)
 Start 20230101 Stop 20230110

Select variables

Bartels Rotation Number # Fine Scale Points in IMF Avgs
 IMF Spacecraft ID # Fine Scale Points in Plasma Avgs
 Plasma Spacecraft ID

Magnetic field

IMF Magnitude Avg, nT By, GSM, nT
 Magnitude, Avg IMF Vr, nT Bz, GSM, nT
 Lat. of Avg. IMF, deg. Sigma in IMF Magnitude Avg.
 Long. of Avg. IMF, deg. Sigma in IMF Vector Avg
 Bx, GSE/GSM, nT Sigma Bx, nT
 By, GSE, nT Sigma By, nT
 Bz, GSE, nT Sigma Bz, nT

Plasma

Proton Temperature, K Sigma-T
 Proton Density, n/cc Sigma-Np
 Flow Speed, km/sec Sigma-V
 Flow Longitude, deg. Sigma-Flow-Longitude
 Flow Latitude, deg. Sigma-Flow-Latitude
 Alpha/Proton Density Ratio Sigma-Alpha/Proton Ratio

NRLMSISE-0

Select Date: (1960/02/14 - 2023/04/29 **New: End date updating monthly**) and Time
 Year 2022 Month: January Day(1-31): 01
 Time Universal Hour of day (e.g. 1.5): 1.5

Select Coordinates
 Coordinates Type Geographic
 Latitude(deg.,from -90. to 90.): 55. Longitude(deg.,from 0. to 360.): 45.
 Height (km, from 0. to 1000.): 100.

Select a Profile type and its parameters:
 Height,km [0. - 1000.] Start 0. Stop 1000. Stepsize 50.

Optional Input parameters:
 Note :If user does not specify these parameters,they will be taken from real data base
 F10.7(daily) F10.7(3-month avg) ap(daily)

Select output form:
 List model data
 Create model data file in ASCII format for downloading
 Plot model data
 Note 1: The first selected parameter below always will be along the X- (e.g. if you want a Height profile, you may specify Height as
 Note 2: User may get scatter plot if he specifies any two parameters t in the "Advanced plot selections" to "show points only"

Submit Clear

Select desired parameters

Independent Variables

Year Height, km
 Month Geographic/Geomagnetic Latitude, deg. (depend on user's choice above)
 Day of month Geographic/Geomagnetic Longitude, deg. (depend on user's choice above)
 Day of year
 Hour of day

Calculated MSIS Model Parameters

IRI-2016

Select Date and Time
 Year(1958-2020): 2000
 Month: January Day(1-31): 01
 Note:If date is outside the Ap index range (1958/02/14-2023/6/13),then STORM model will be turned off.
 Time Universal Time (0. - 24.0 in decimal hours): 1.5

Select Coordinates
 Coord. Type Geographic Latitude(-90. - 90. deg.): 50. Longitude(0. - 360. deg.) 40.
 Height (km, from 60. to 2000.): 100.

Select profile type and range:
 Height [60. - 2000. km] Start 100. Stop 2000. Stepsize 50.

Submit Reset

Optional Input:

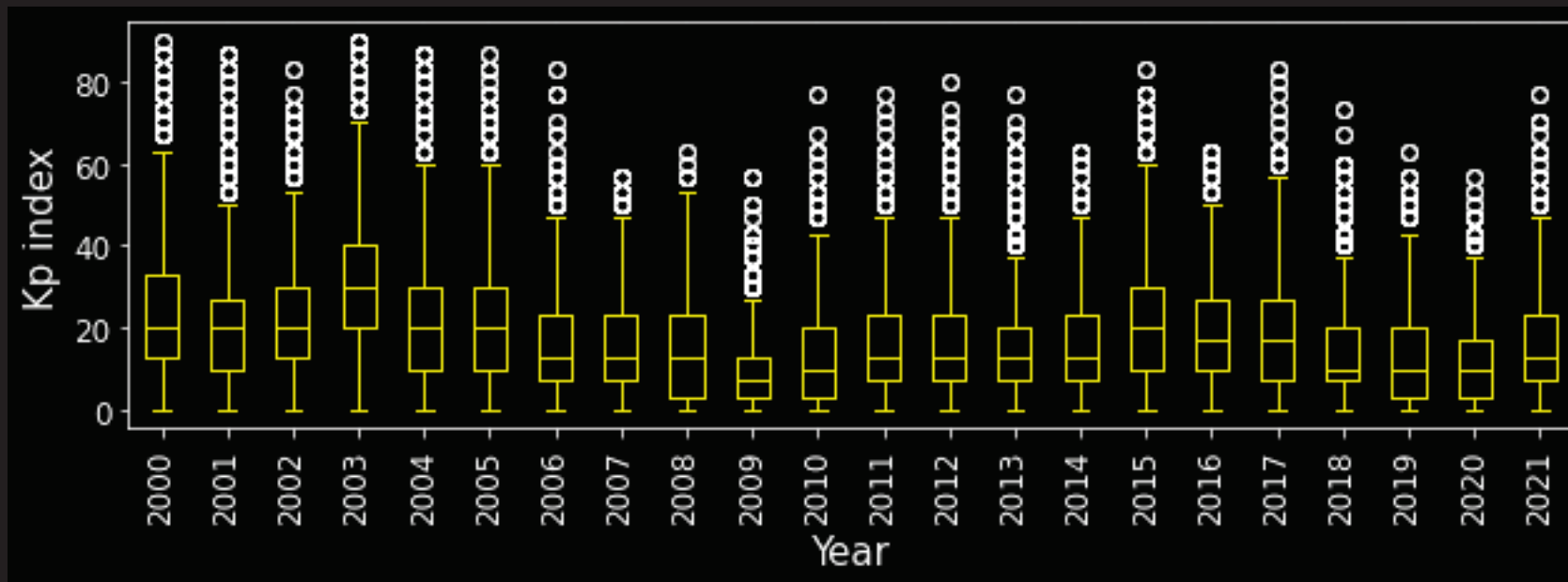
Sunspot number, R12 (0. - 400.) Ionospheric index, IG12 (-50. - 400.)
 F10.7 radio flux, daily (0. - 400.) F10.7 radio flux, 81-day (0. - 400.)
 Electron content: Upper boundary (110. - 10000. km)
 Ne Topside NeQuick Ne F-peak URSI F-peak storm model on F-peak height AMTB2013
 Bottomside Thickness ABT-2009 F1 occurrence probability: Scotto-1997 no L
 Auroral boundaries on E-peak auroral storm model off D-region model IRI-95
 Te Topside TBT2012+SA Ion Composition RBV10/TBT15

Note: User may specify the following 5 parameters only for Profile type 'Height':
 F2 peak density (NmF2) ($10^9 - 10^{14}m^{-3}$) or F2 plasma frequency (foF2) (2.-14. MHz): 0.
 F2 peak height (hmF2) (100. - 1000. km) or Propagation factor M(3000)F2 (1.5 - 4.): 0.
 E peak density (NmE) ($10^6 - 10^{14}m^{-3}$) or E plasma frequency (foE) (0.1-14. MHz) 0.
 E peak height (hmE) (70.-200. km): 0. Bottomside thickness (B0) (50.-500. km): 0.

Select output form:

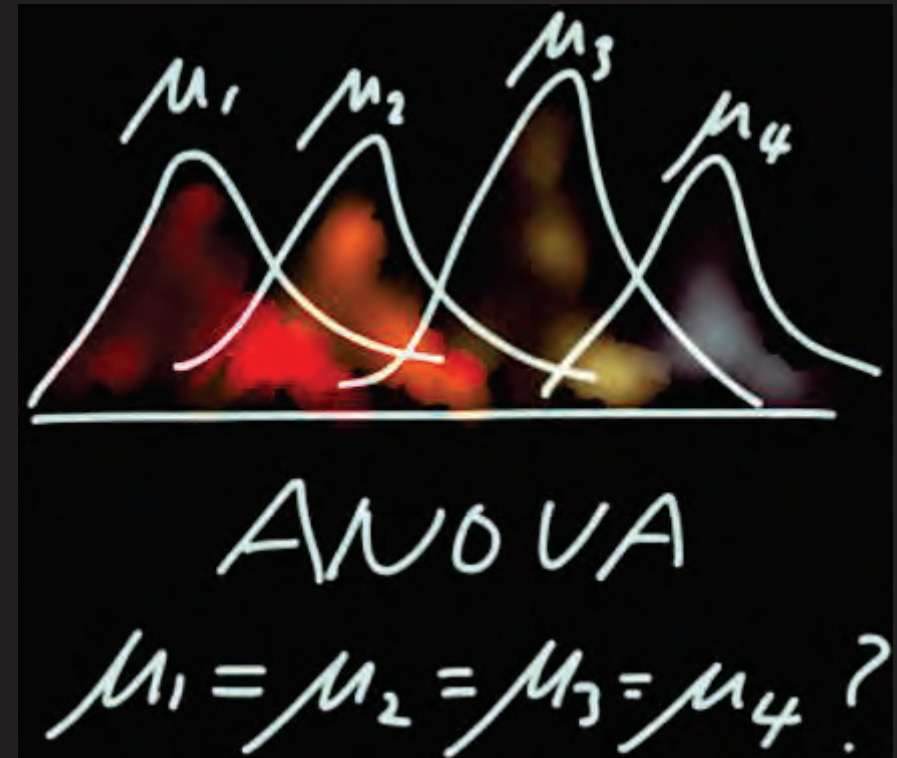
Statistical analyses

- 55 parameters
- 1 hour resolution
- Box plots
- Observing of long-term changes



What is ANOVA?

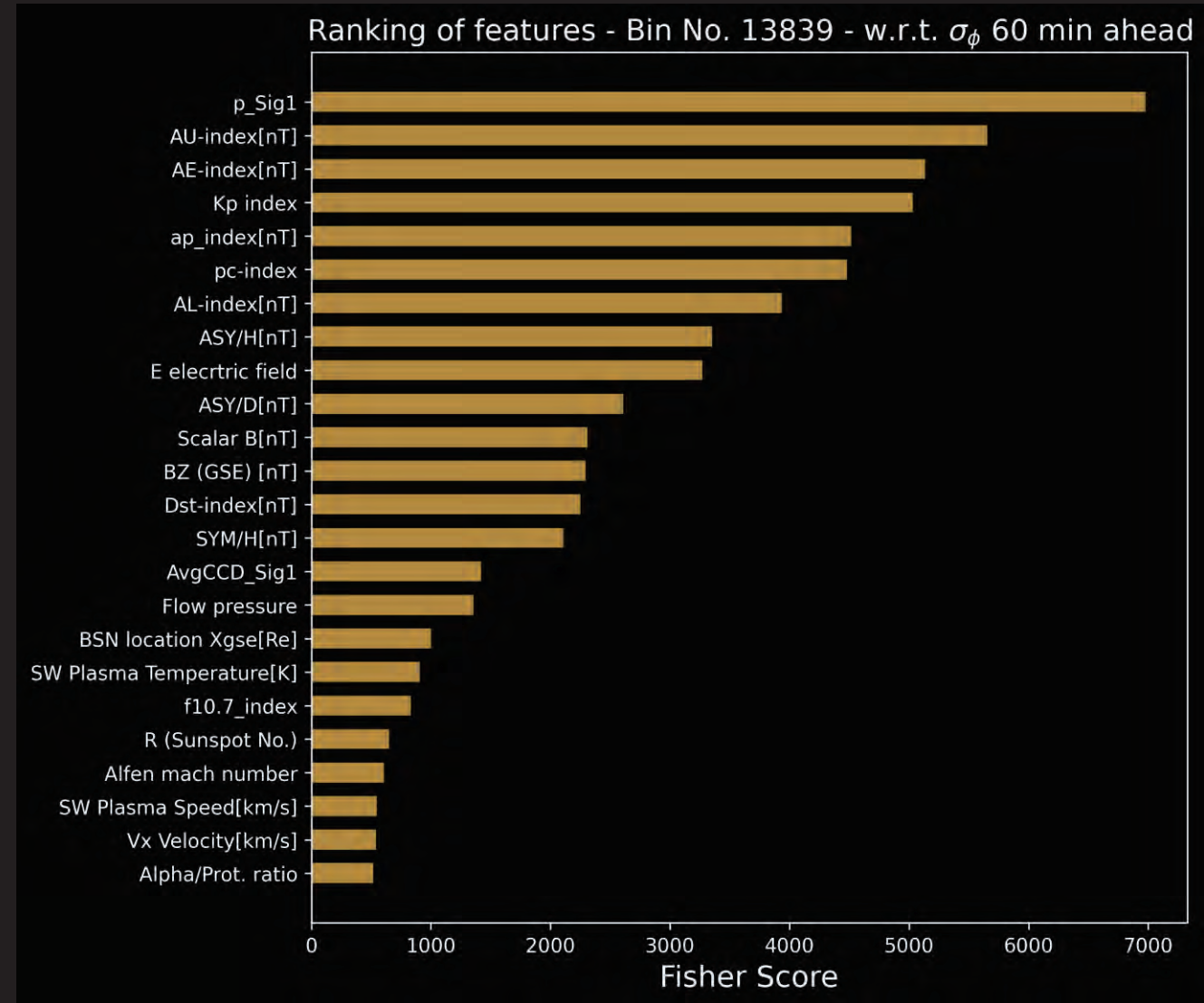
- Analysis of variance (ANOVA).
- Used to analyze the differences among mean.



- If the average variation between groups is bigger compared to the average variation within groups, then groups mean is not equal to the others.

ANOVA analyses of data

- Important parameters to consider.
- Possible use in models.
- **Kp index**
- **Bz GSE**
- **AE index**
- **PC(N)**
- **Electric field**



Preprocessing of archive Data

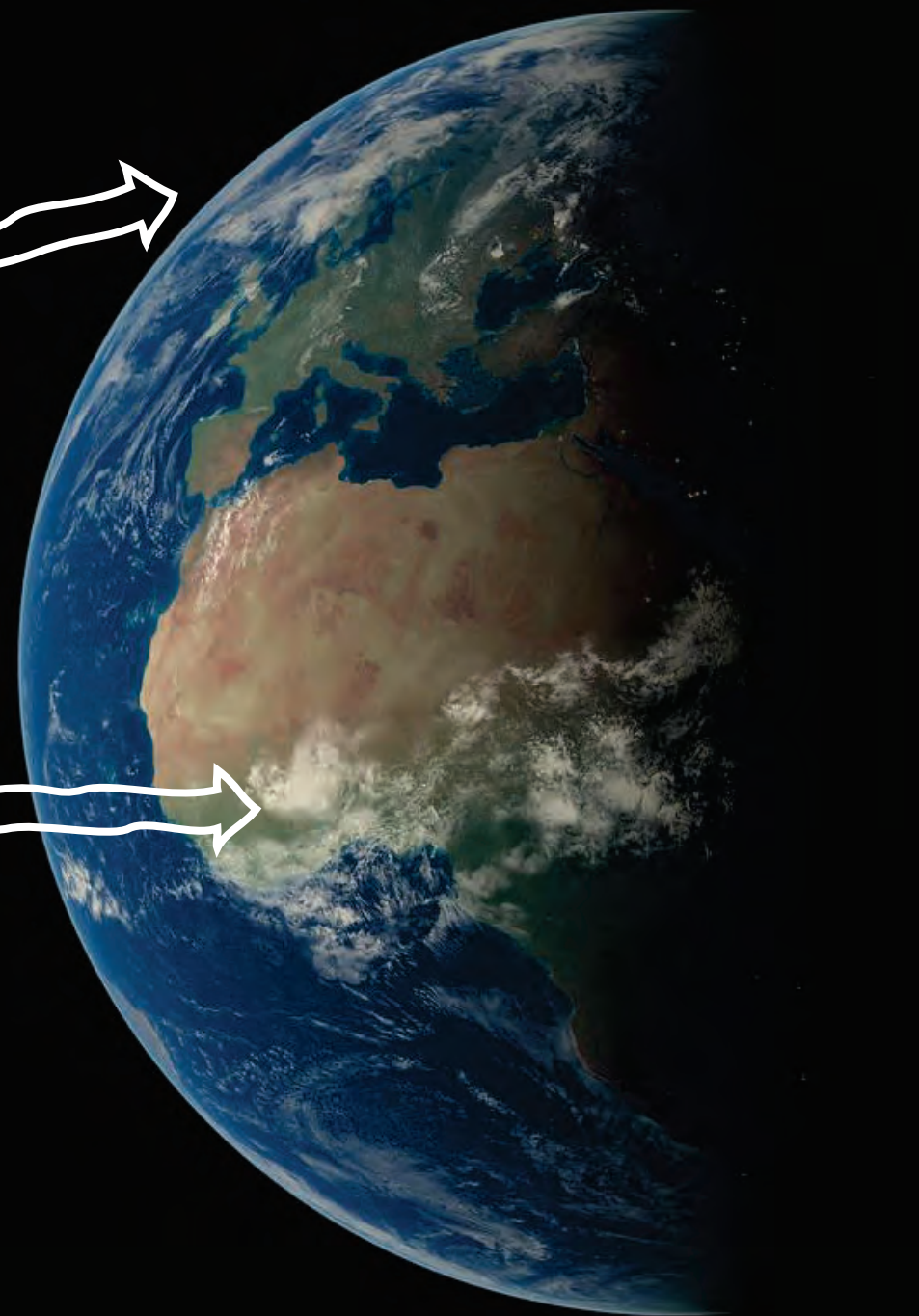
Scintillation parameters

- Phase scintillation

$$\sigma_{\varphi} = \langle \varphi^2 \rangle - \langle \varphi \rangle^2$$

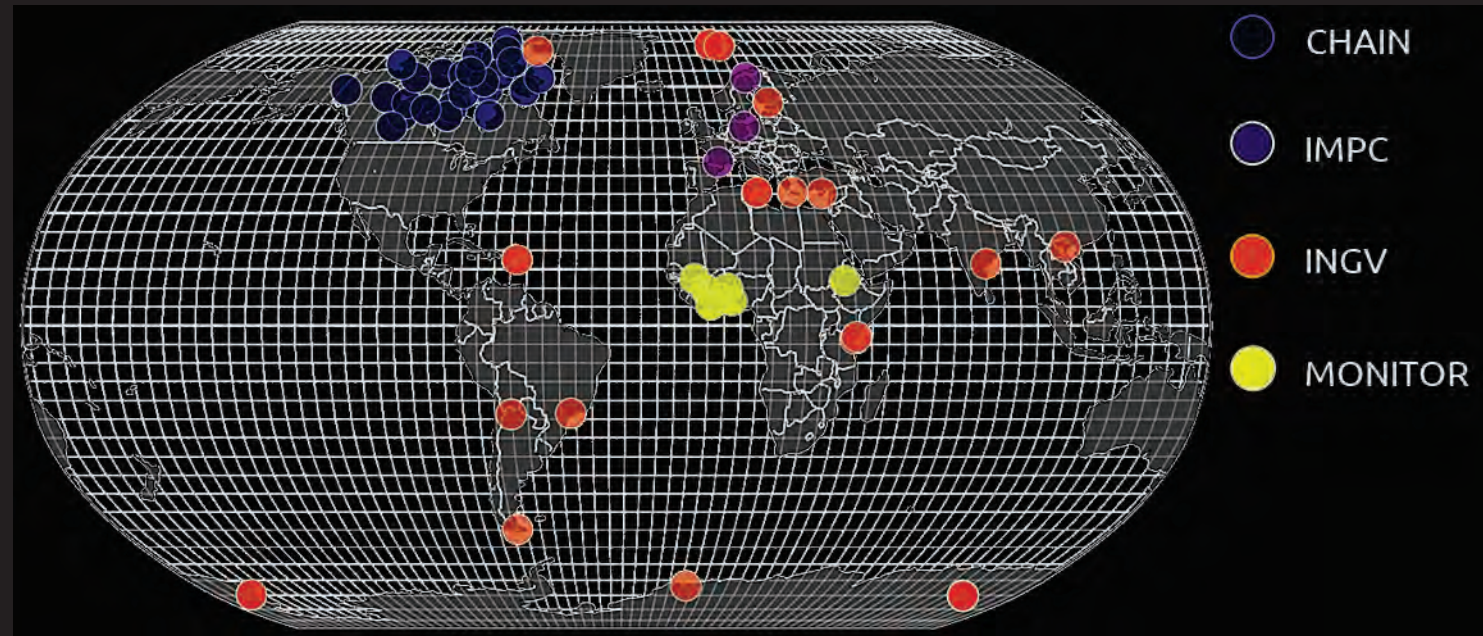
- Amplitude scintillation

$$S_4^2 = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}$$



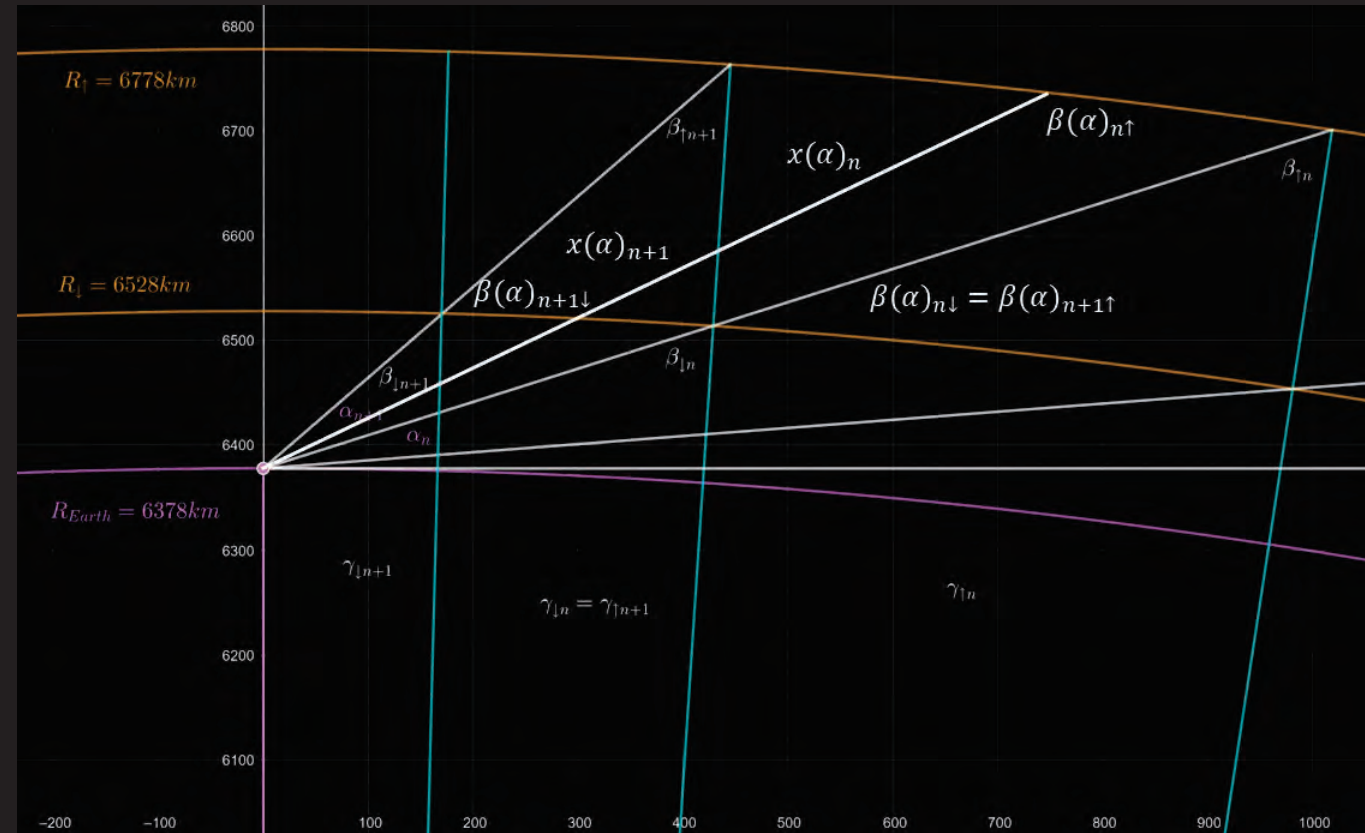
Sources of data

- Canadian high arctic ionospheric network (CHAIN).
- **Every hour published measurements.**
- 2008-> present
- 26 stations



Problem of sphere

- How to interpret measurement.
- Measurement create ruled surface.
- Ionosphere is between sphere.



Transformation to Sphere

- Nontrivial task of transforming

ruled surface -> sphere

$$|\vec{x}| = \sqrt{R_{Earth}^2 + r^2 + 2R_{Earth}r\sin(\alpha)}$$

$$\varphi_x = \arcsin\left(\frac{(R_{Earth} + r\sin(\alpha))\sin(\varphi) + r\cos(\alpha)\cos(A)\cos(\varphi)}{|\vec{x}|}\right)$$

$$l_x = \arctg\left(\frac{(R_{Earth} + r\sin(\alpha))\cos(\varphi)\sin(l) - r\cos(\alpha)(\cos(A)\sin(\varphi)\sin(l) - \sin(A)\cos(l))}{(R_{Earth} + r\sin(\alpha))\cos(\varphi)\cos(l) - r\cos(\alpha)(\cos(A)\sin(\varphi)\cos(l) + \sin(A)\sin(l))}\right)$$

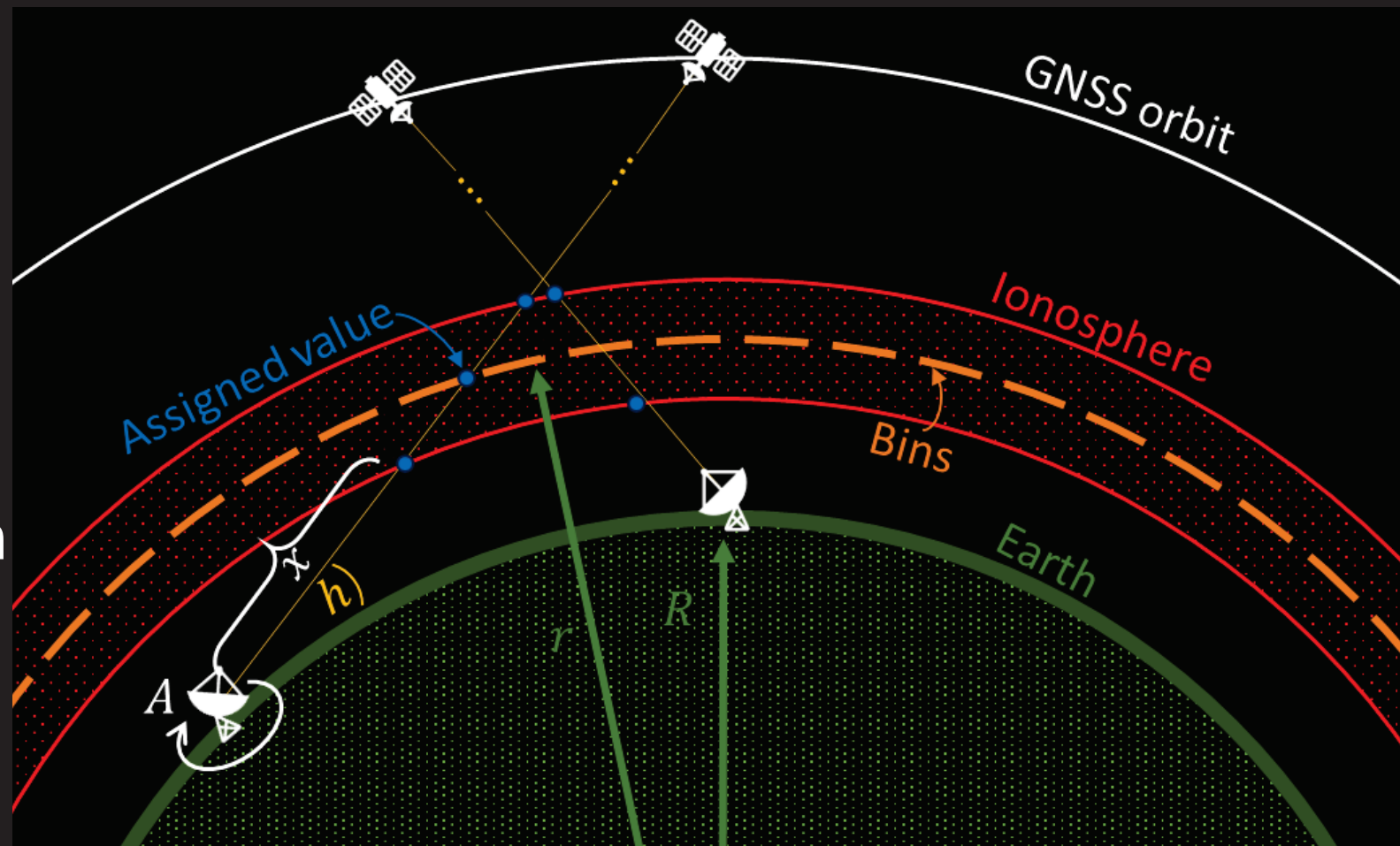
- For binning

$$a = \sin\left(\frac{\Delta l}{2}\right) + \cos(l_1) \cdot \cos(l_2) \sin^2\left(\frac{\Delta\varphi}{2}\right)$$

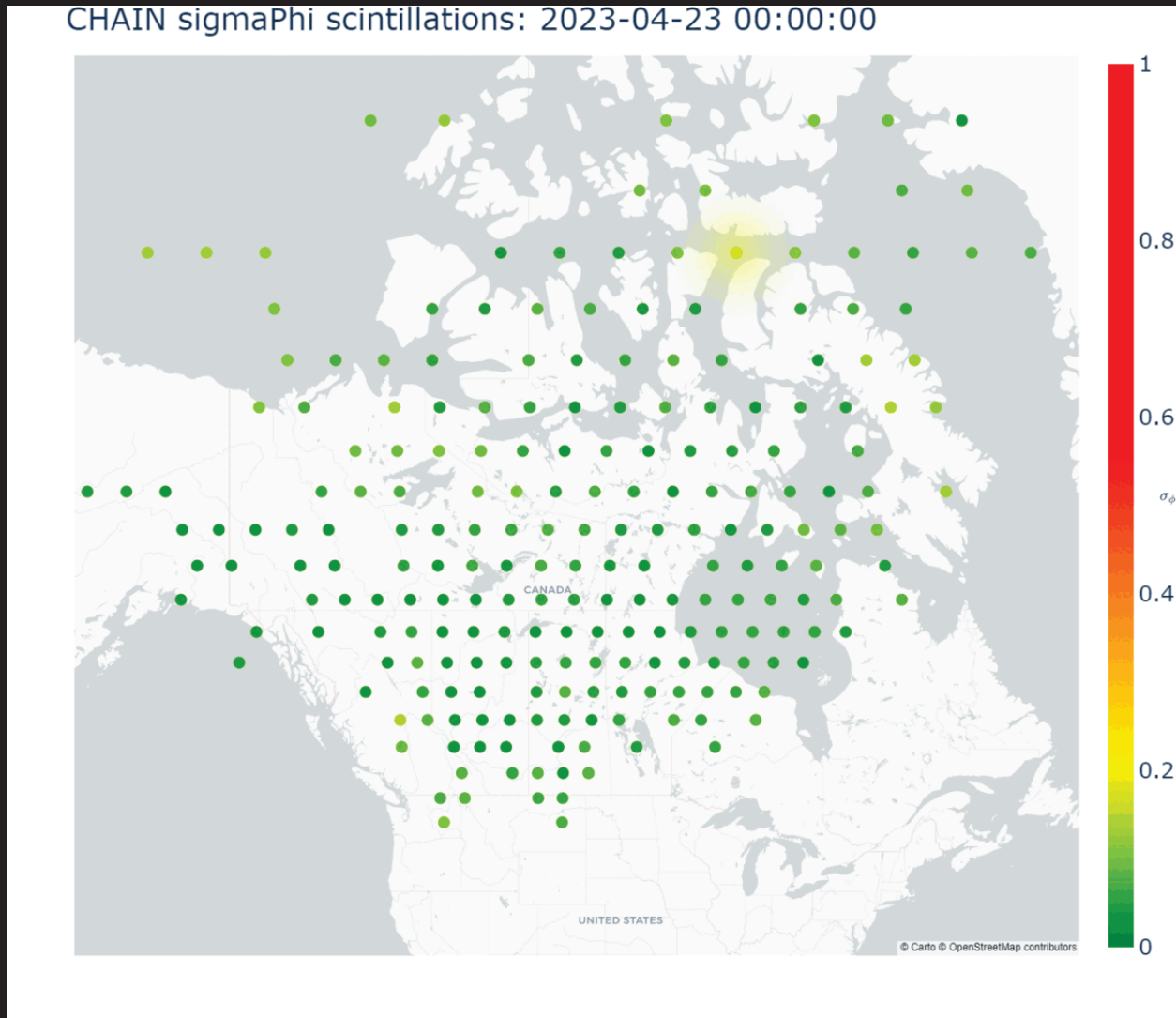
$$c = 2 \cdot \arctan2[\sqrt{a}; \sqrt{a-1}]$$
$$= 2 \cdot \arctan\left(\frac{\sqrt{a}}{\sqrt{a-1}}\right)$$

Binning

- Uniform binning of ionosphere
- Central of mass
- Nearest bin centrum for intersection of ionosphere and measurement

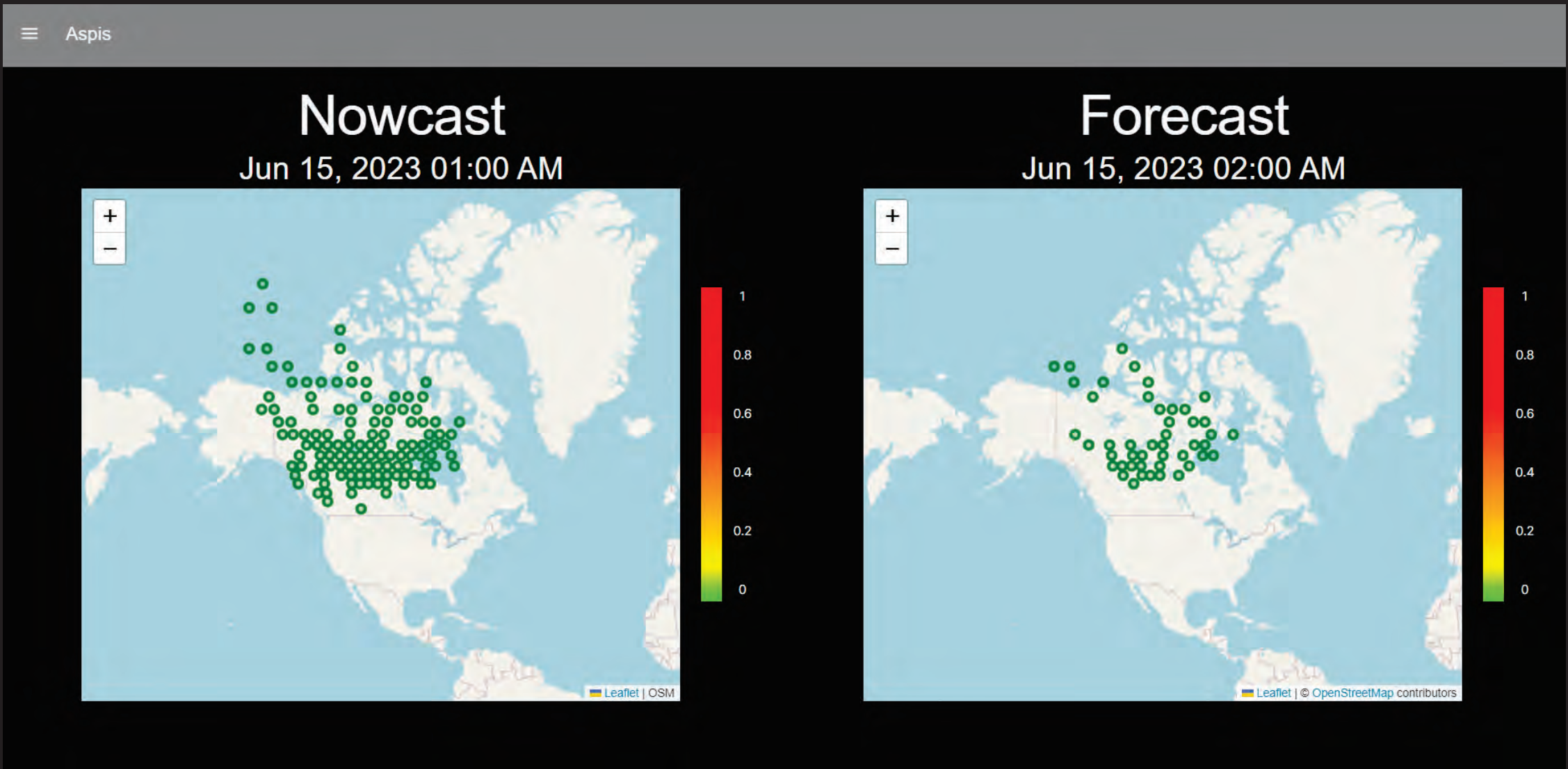


Example of event observation



Summary

Results



Summary

Space parameters

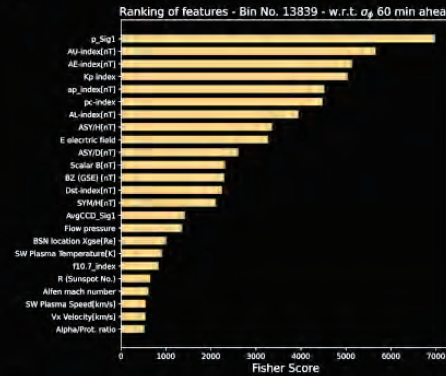
Data interpretation

Results

Machine learning

ANOVA analyses of data

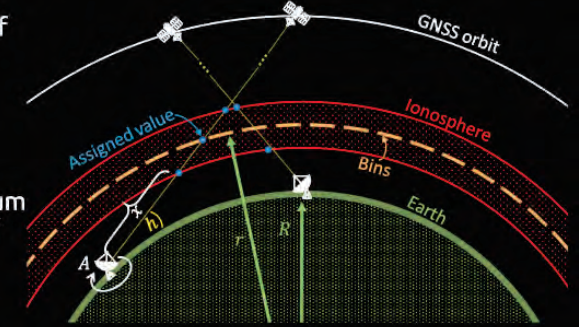
- Important parameters to consider.
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13. 6. 2023 The Autonomous Service for Prediction of Ionospheric Scintillations (ASPIS) - Data analysis and preprocessing Bezevec 2023 Conference of Young Astronomers 20

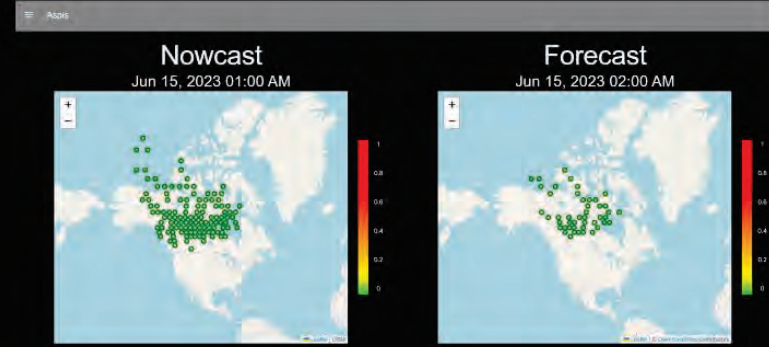
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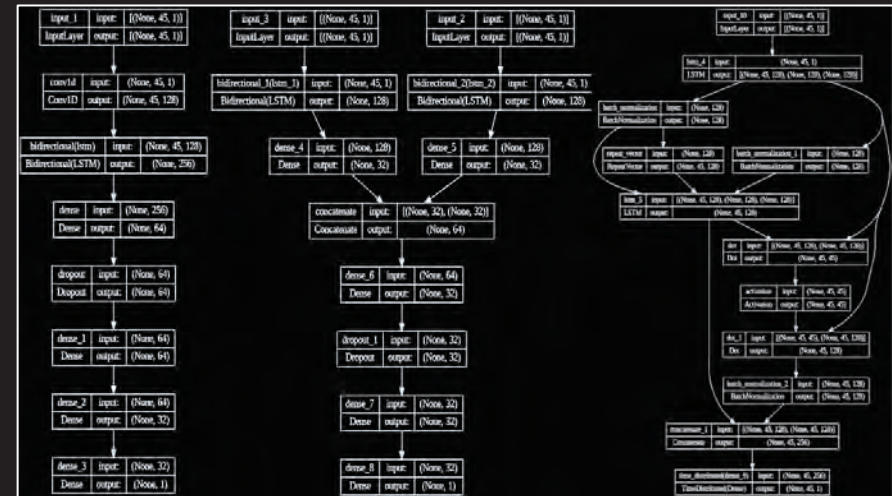


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Results

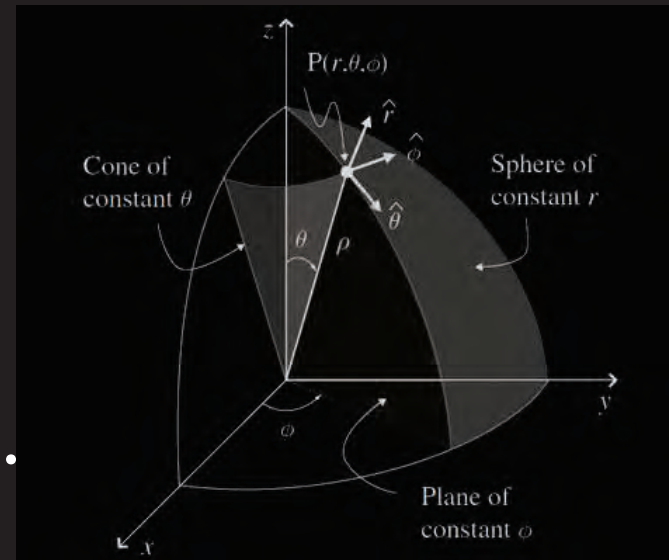


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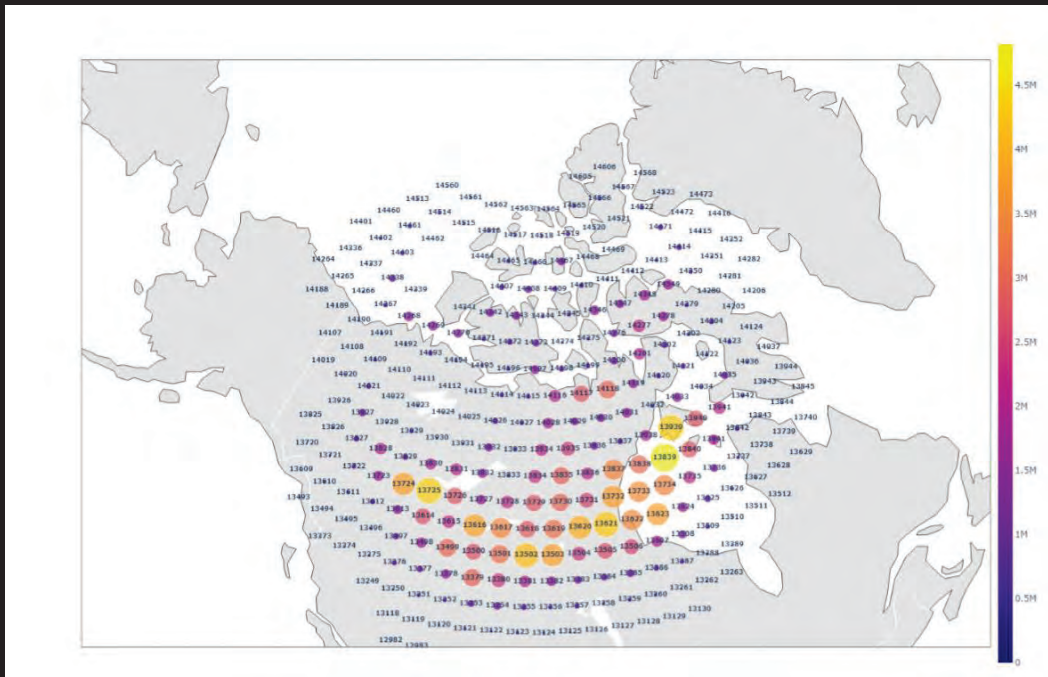
Future work

- Examination of possibilities of better measurement interpretation.
- Tracking of changes in ionosphere.
- Best way for backward transformation visualization.

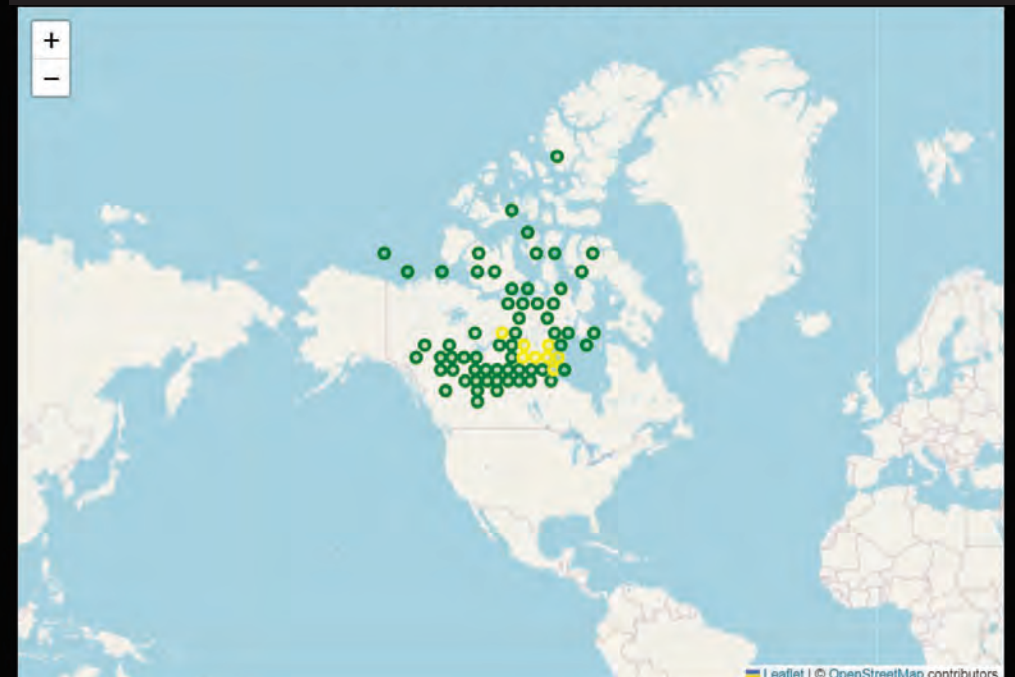


Before | After

Archive data and experiences



Working forecast



Thanks for your attention

Wait for part II.

Disclaimer



ASPIS is supported by the government of Slovakia through ESA contracts under the PECS (Plan for European Cooperating States).

ESA disclaimer: The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency.

Apendix

