ASPIS – PART I.

Data analysis and preprocessing

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Ústav experimentálnej fyziky SAV, v. v. i. 1969
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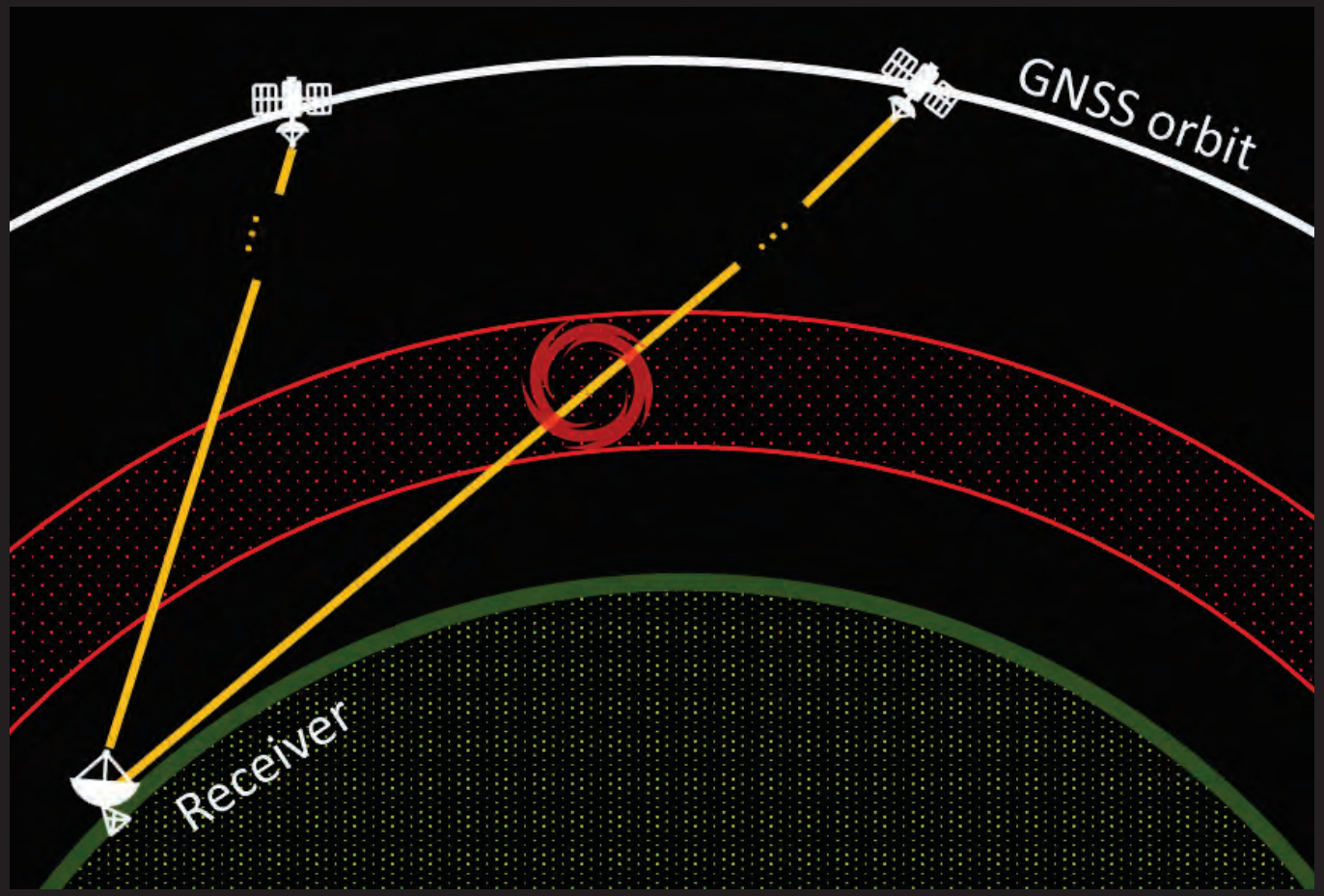
matfyz

What is ionospheric scintillation

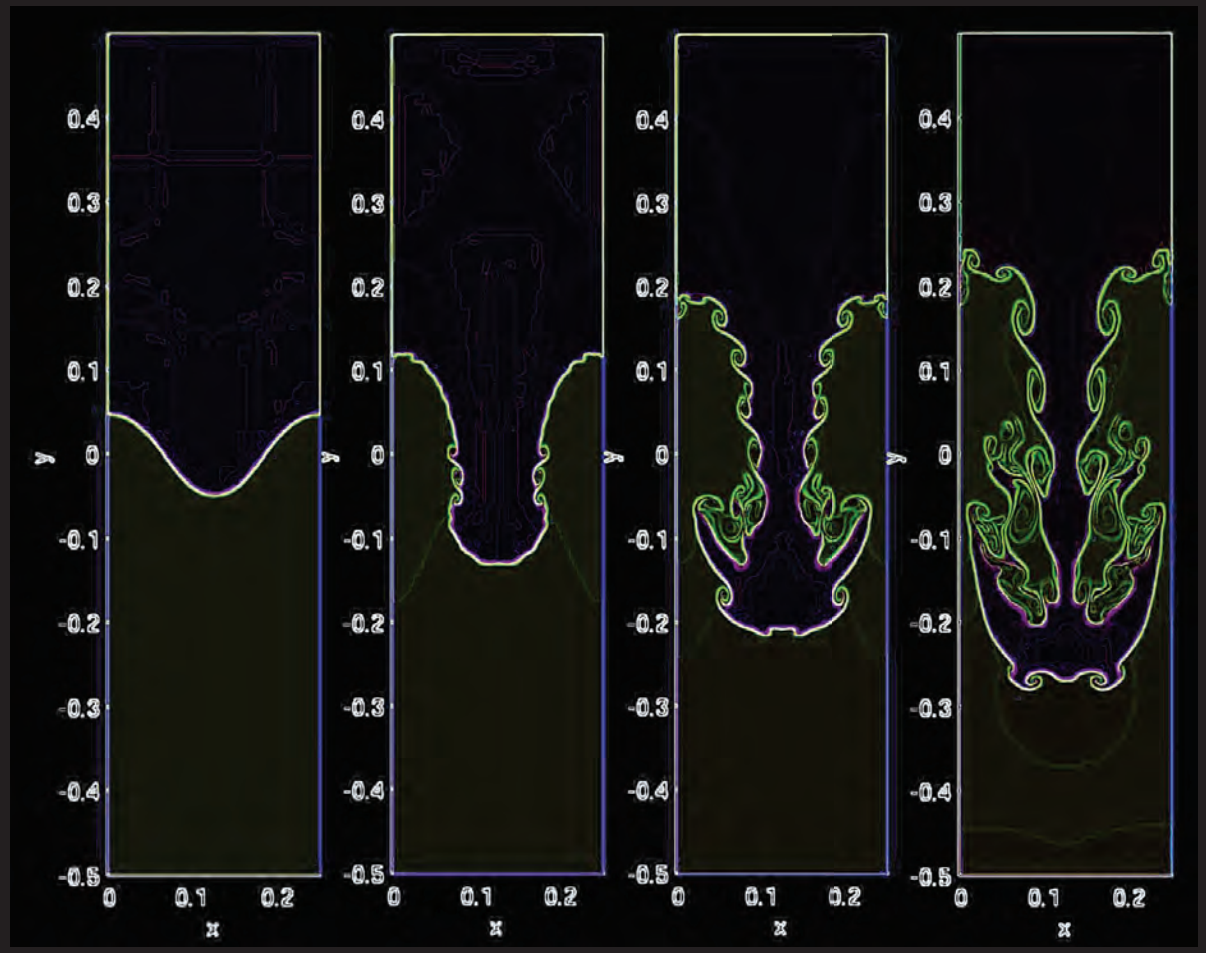
- Ionospheric scintillation is the rapid modification of radio waves.
- Propagating through ionosphere.
- Caused by small scale structures in the ionosphere.



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

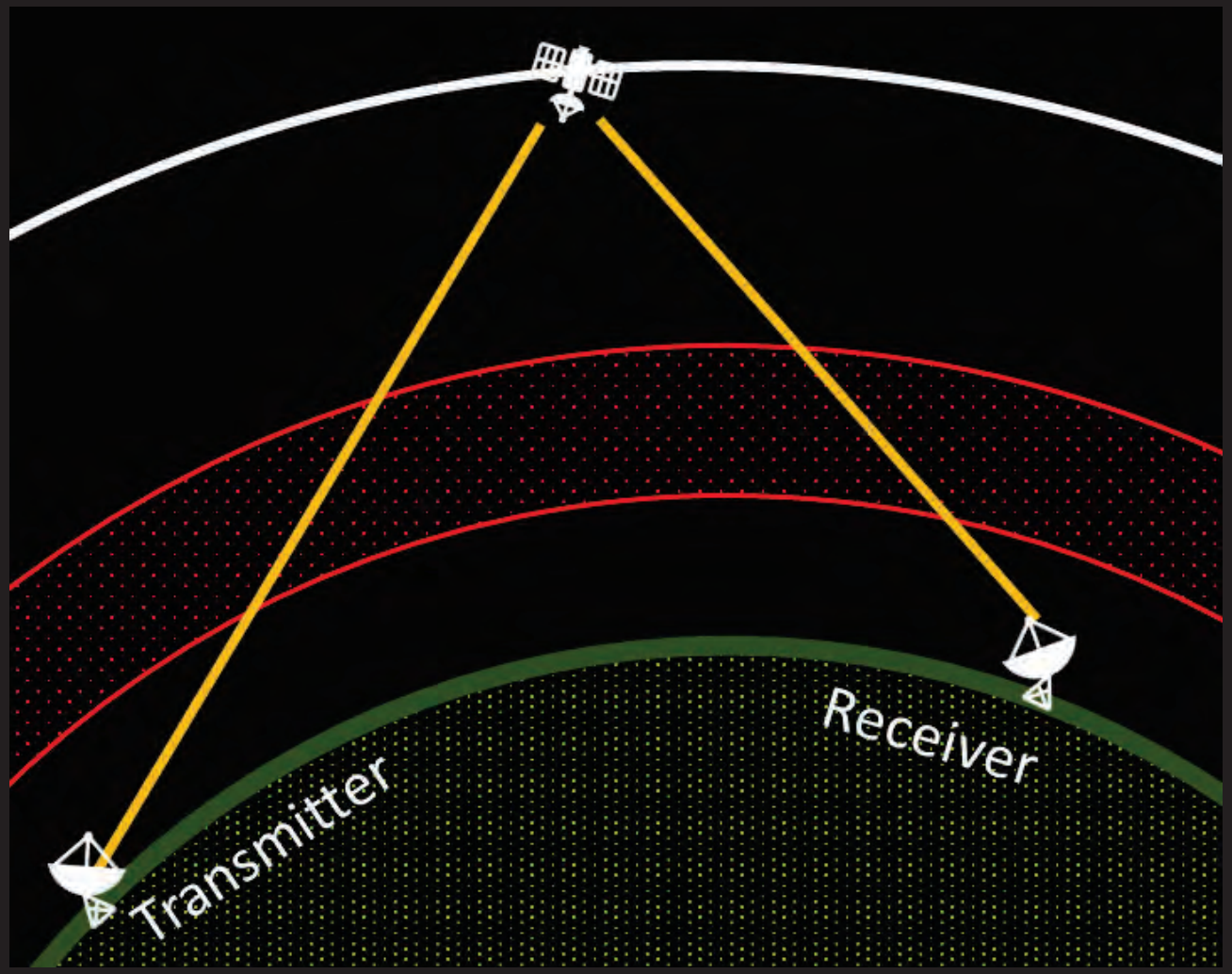


Coster, A.J. and Yizengaw, E. (2021). GNSS/GPS Degradation from Space Weather. In Space Weather Effects and Applications (eds A.J. Coster, P.J. Erickson, L.J. Lanzerotti, Y. Zhang and L.J. Paxton). https://doi.org/10.1002/9781119815570.ch8

Why should we bother

Satellite communication

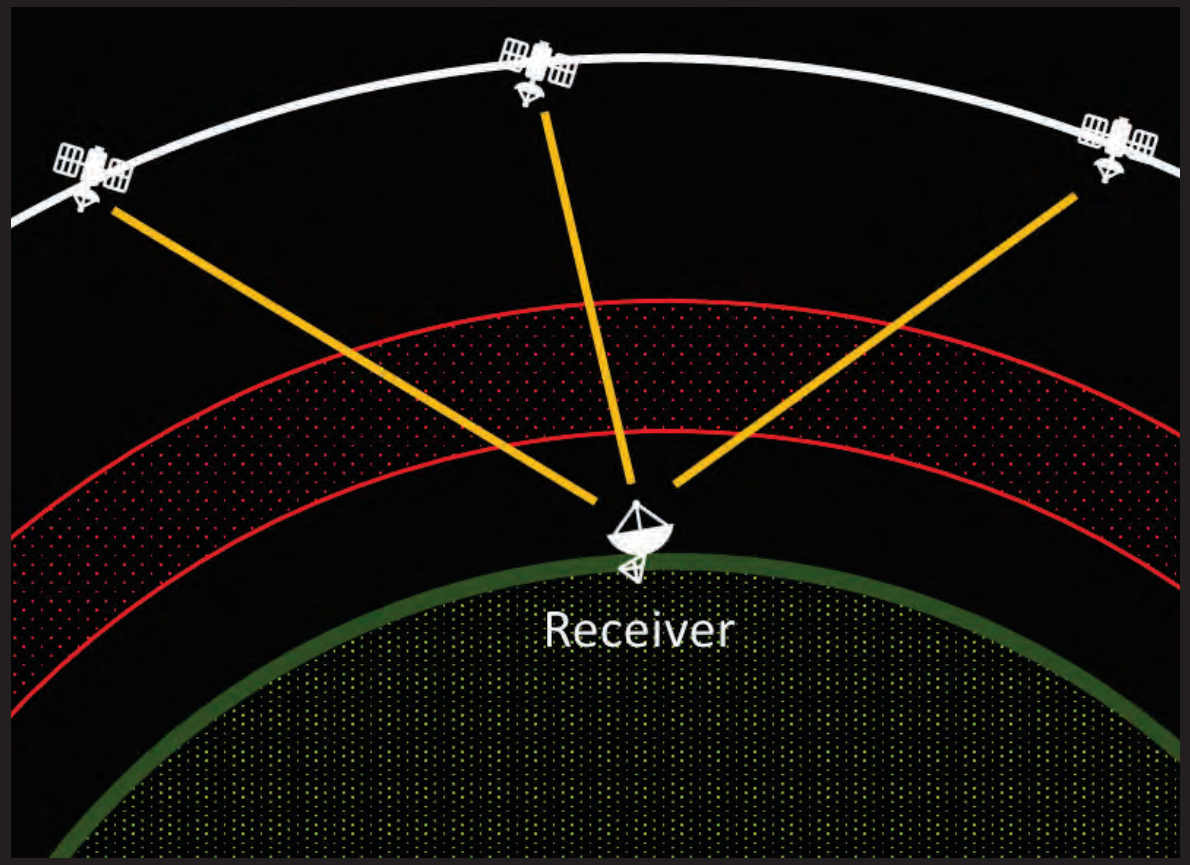
- Artificial satellites to provide communication links between various points on Earth.
- Scintillations may cause loss of communication capabilities.



Global satellite navigation (GNSS)

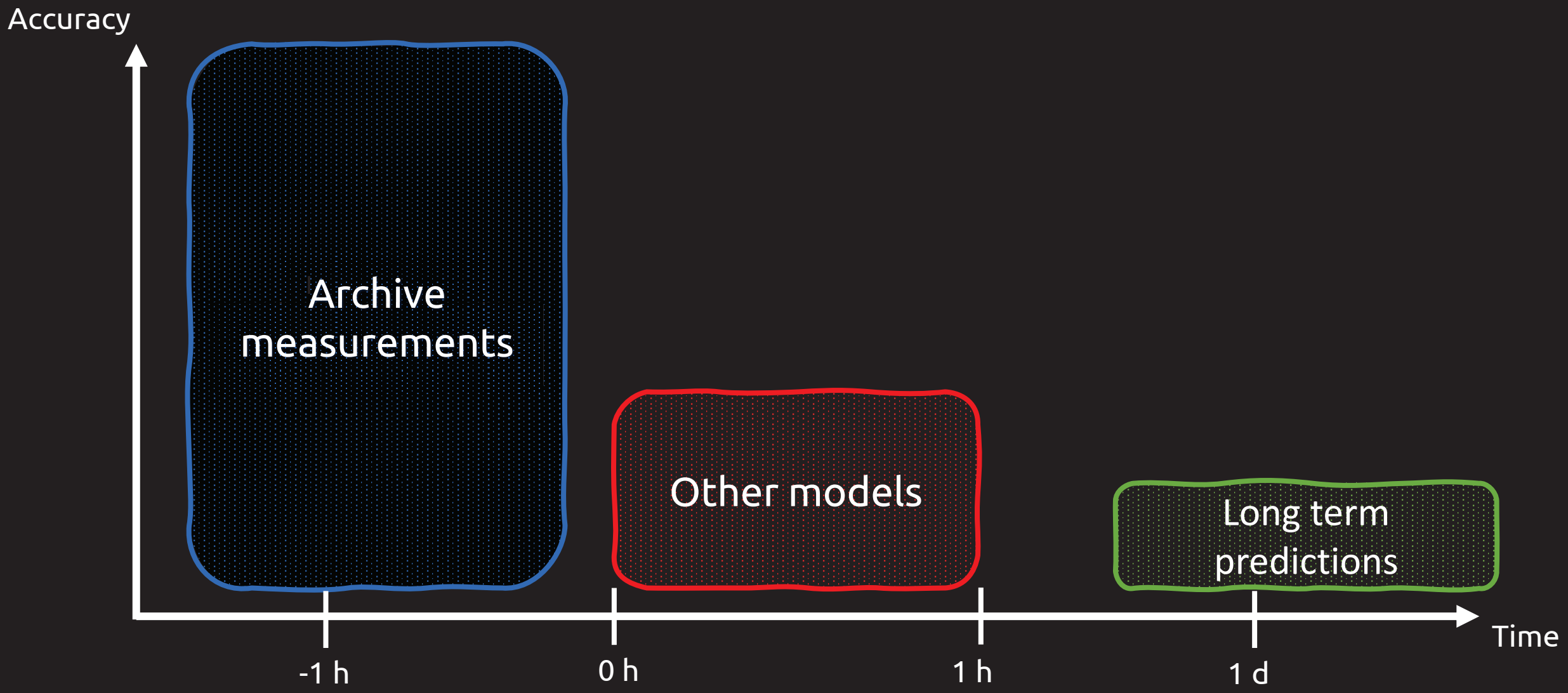
- Artificial satellites that autonomous geopositioning.
- Scintillations may cause loss of geopositioning capabilities.
- Affects all main systems:

GPS, GLONASS, Galileo.

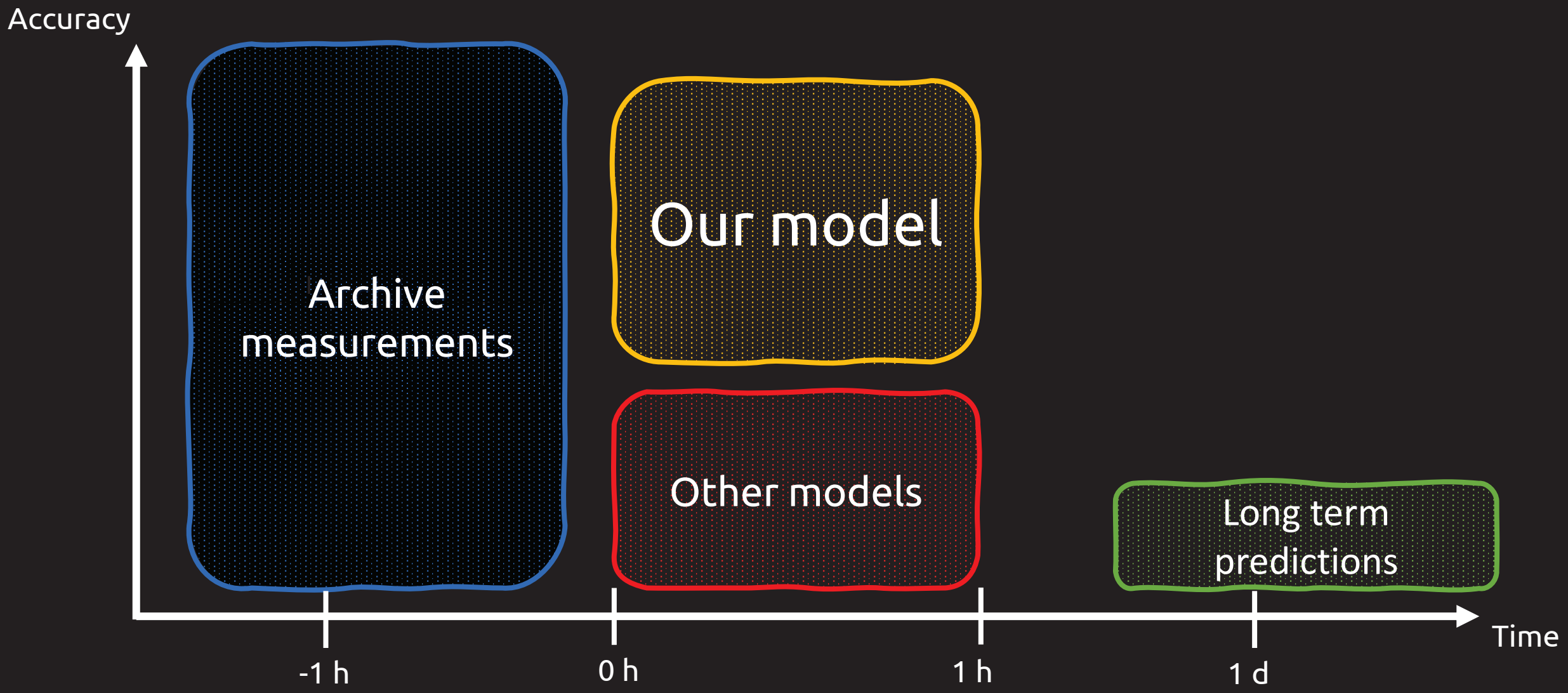


Previous work

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)

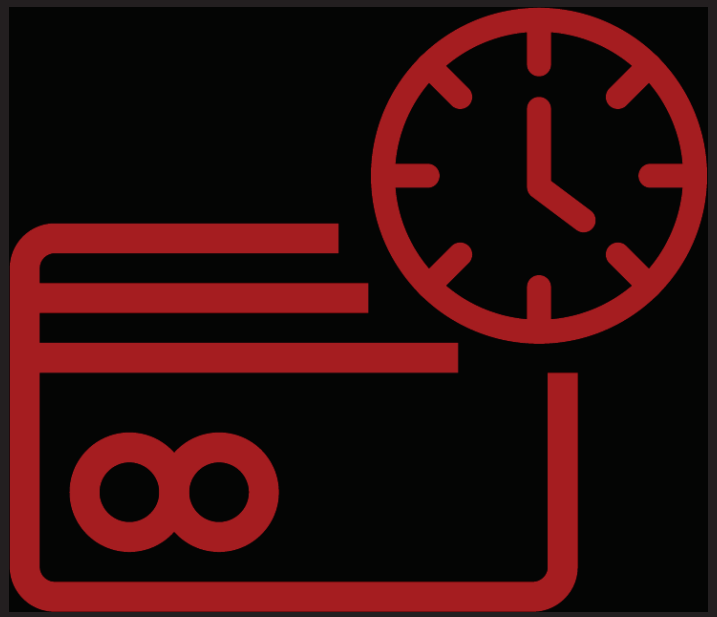
Prediction using data mining techniques

Main problems

Current problems

Low accuracy and precision

Short time of prediction

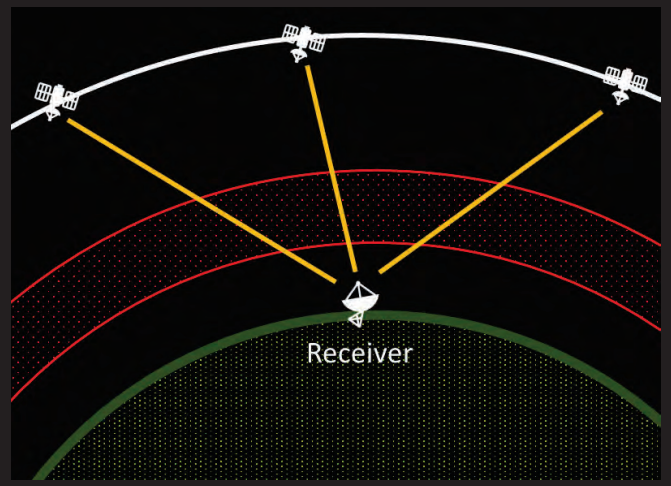


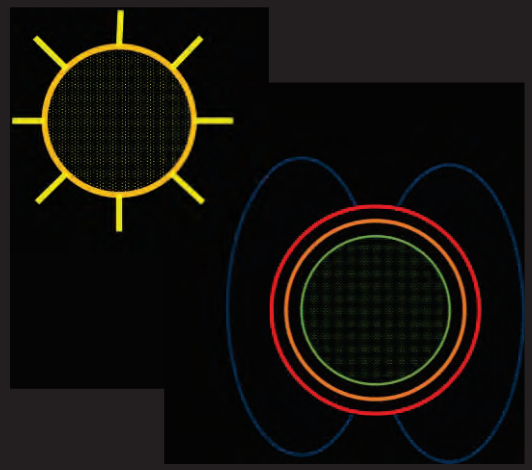
Our approach

- Data driven method

  Years of measurements, with an emphasis on physics

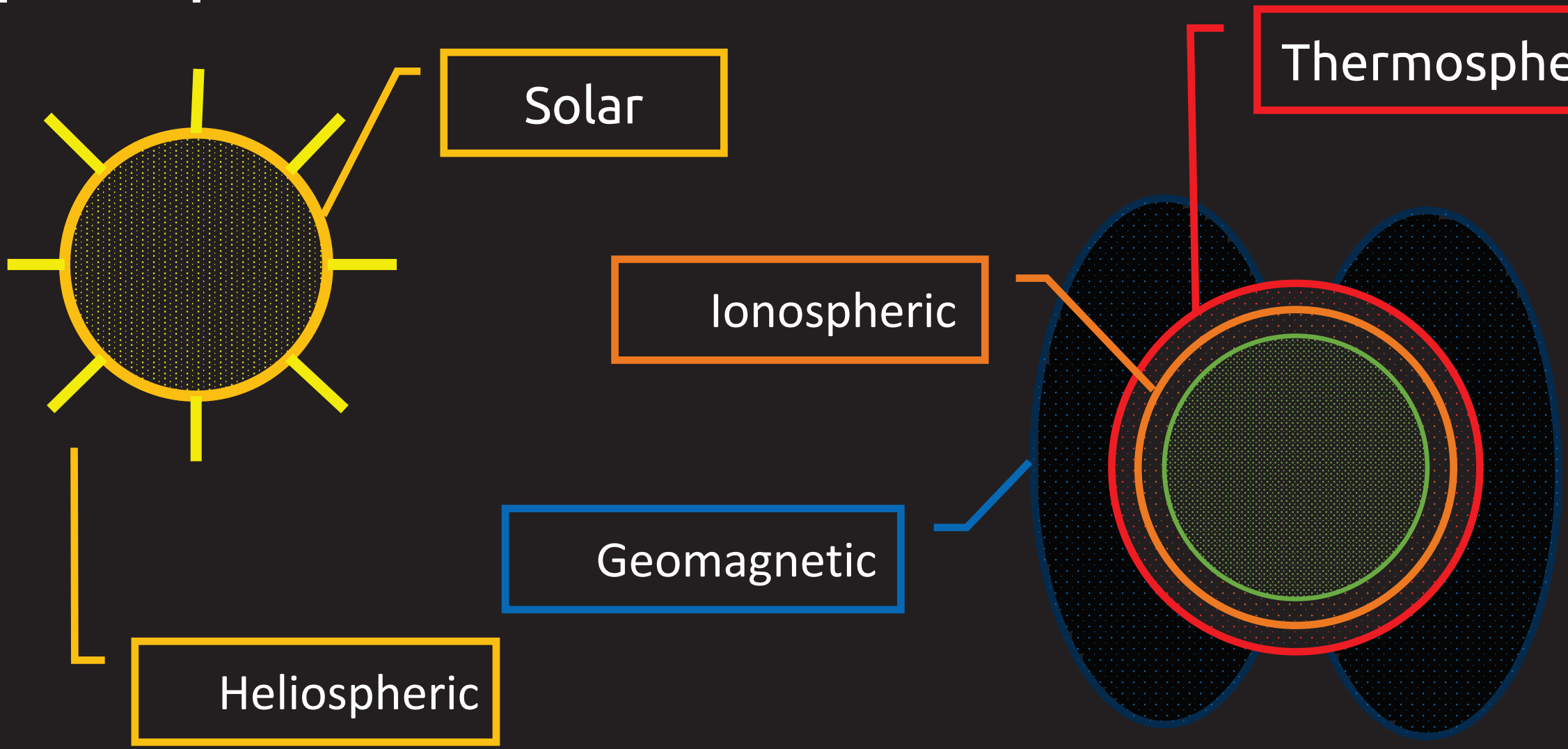
- Using of deep neural network





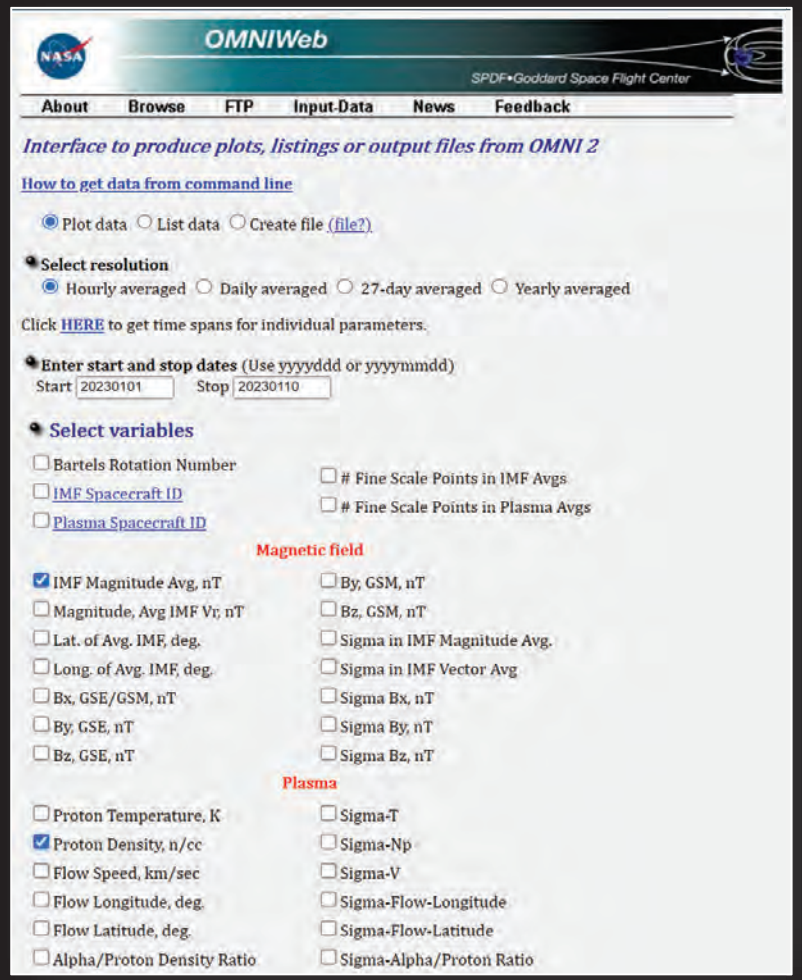
Space parameters

Space parameters

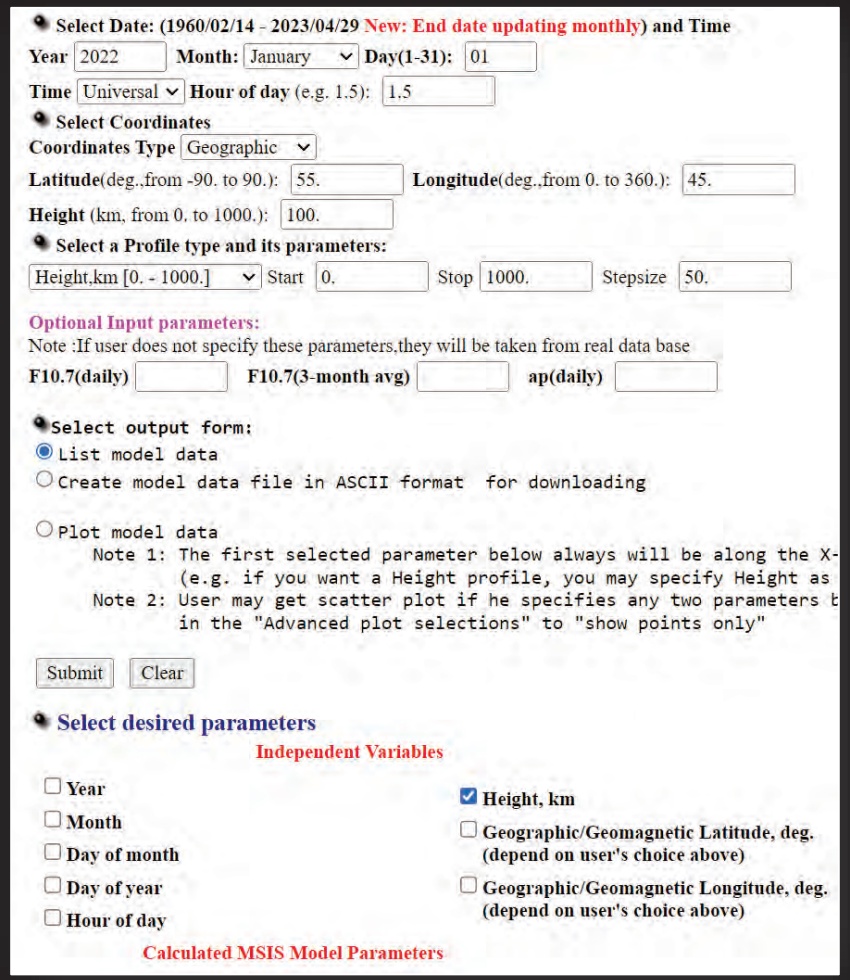


Sources of data

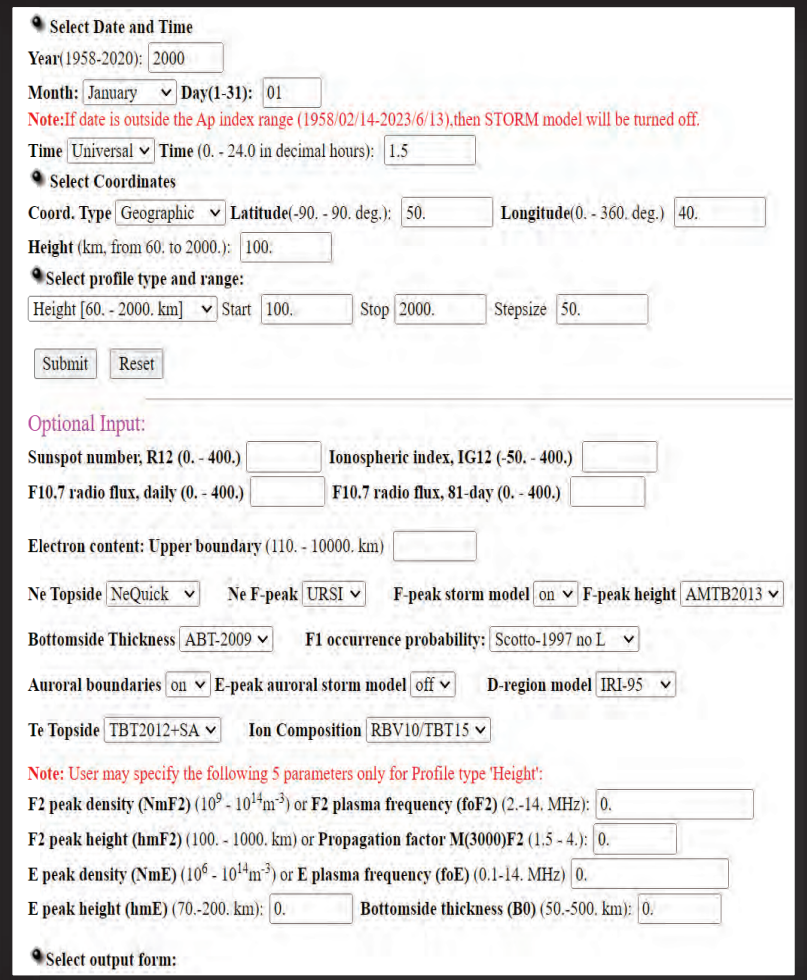
OMNIWeb



NRLMSISE-0

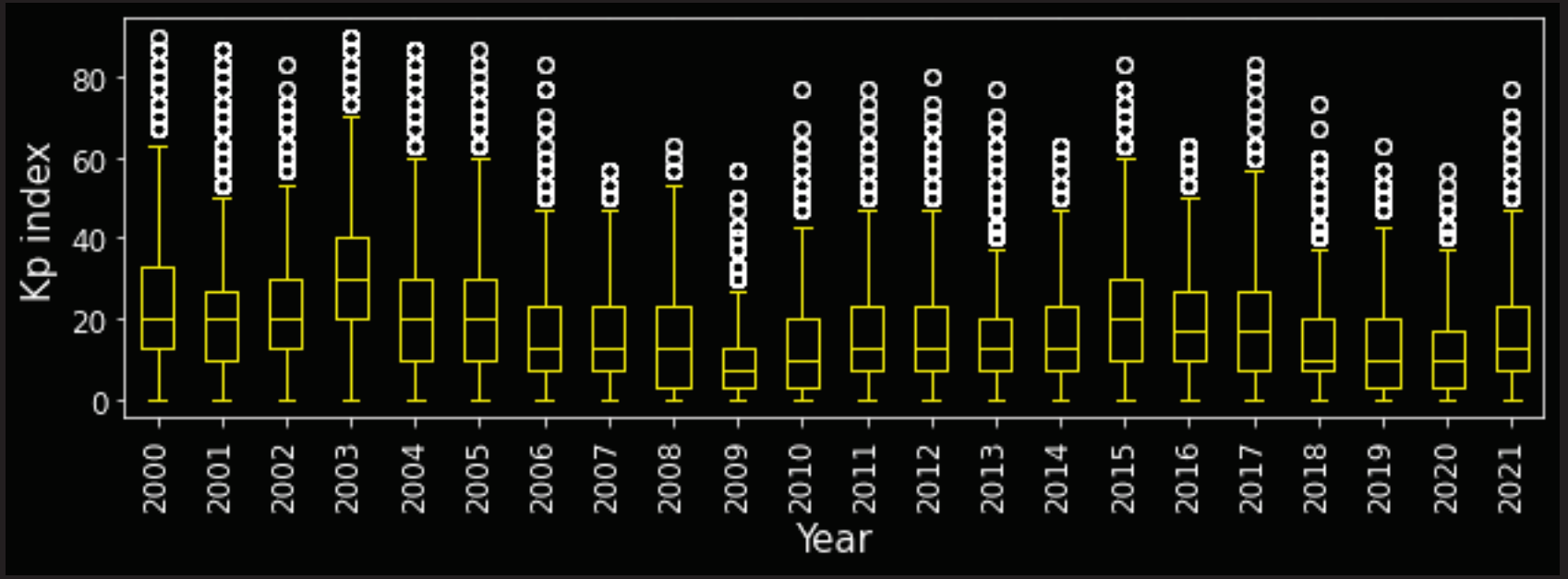


IRI-2016



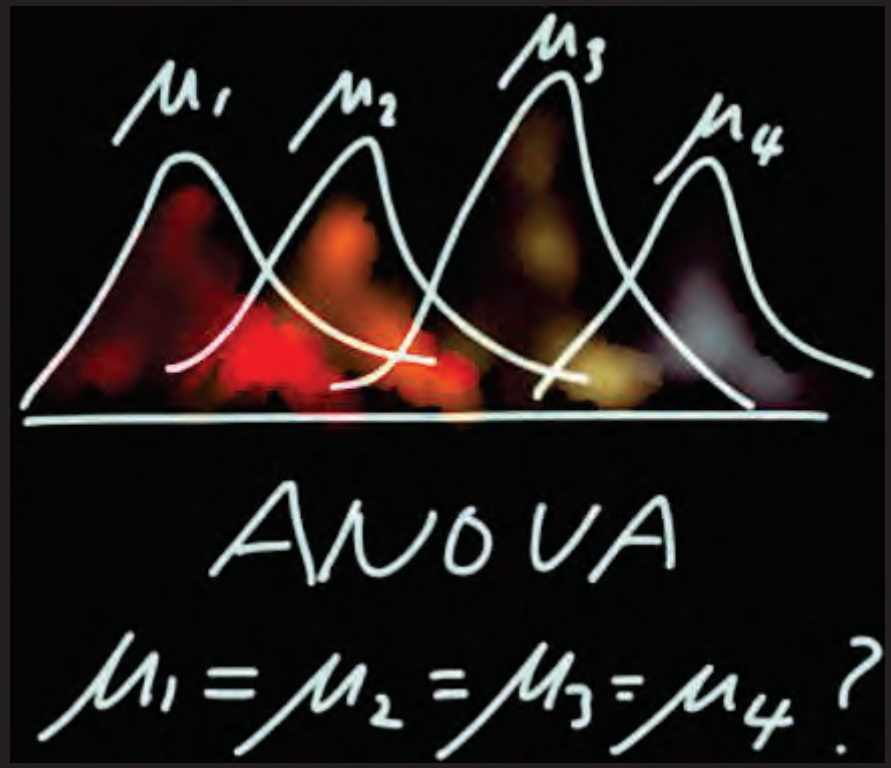
Statistical analyses

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



What is ANOVA?

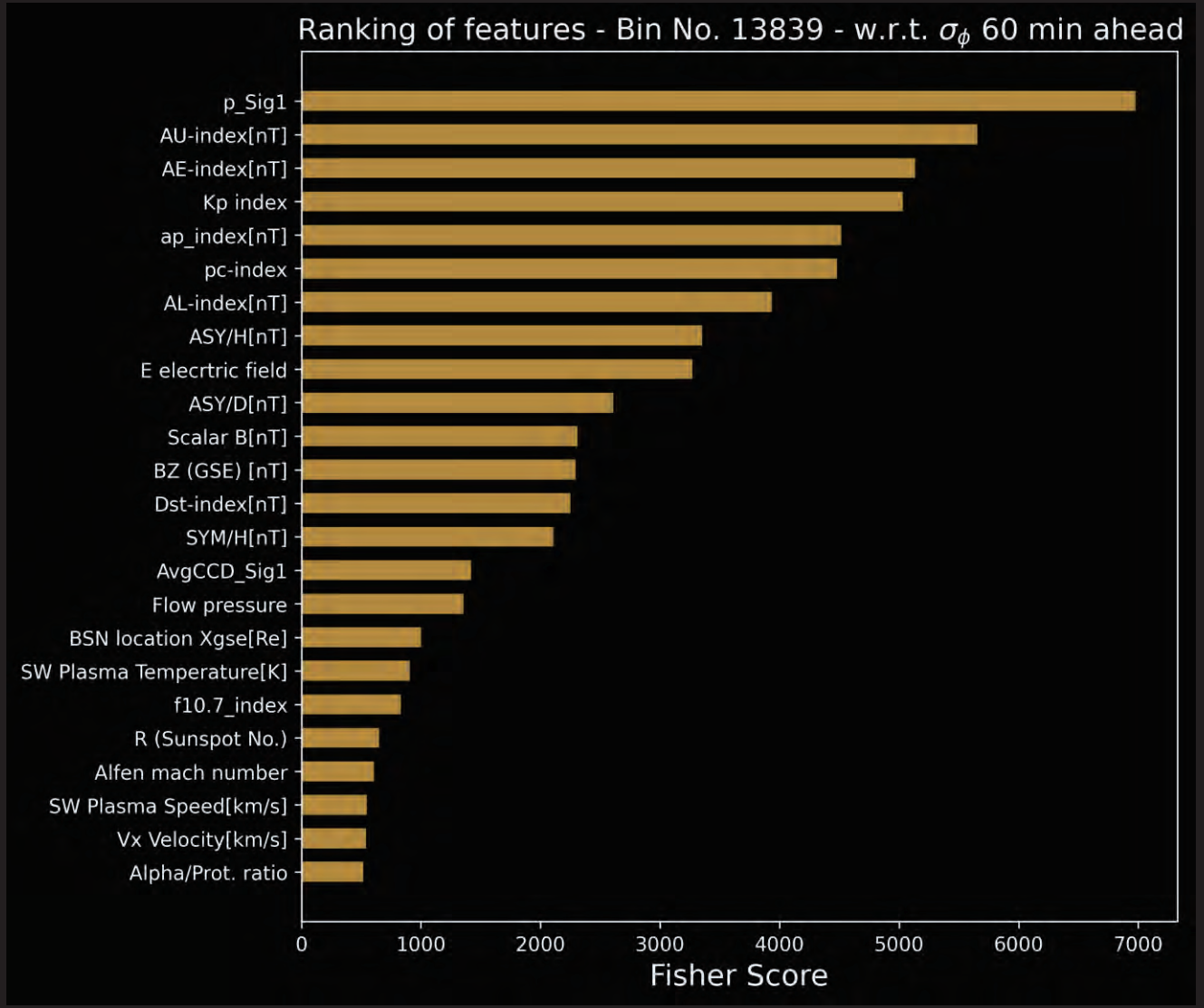
- Analysis of variance (ANOVA).
- Used to analyze the differences among mean.



- 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

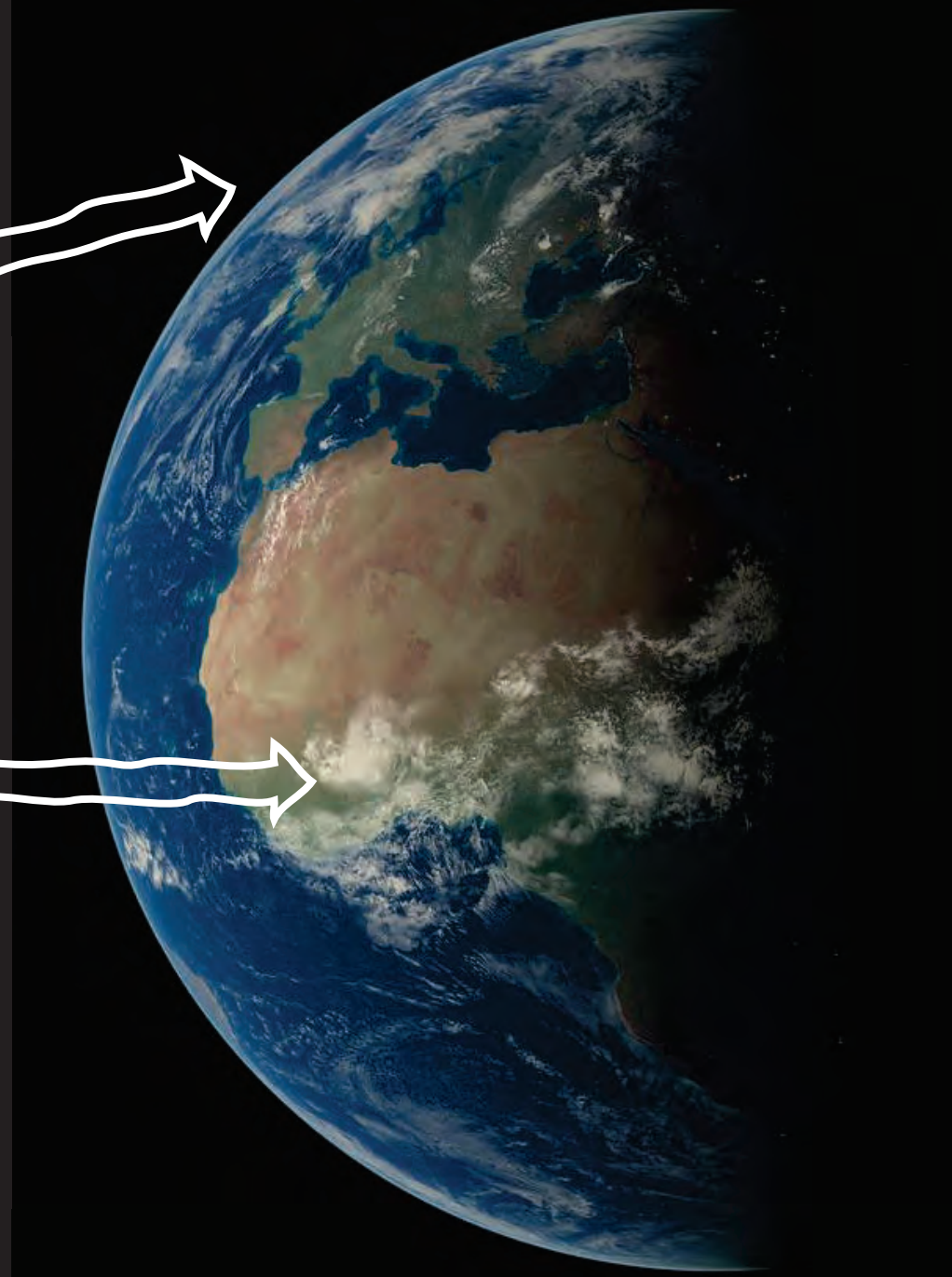
Scintillation parameters

- Phase scintillation

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

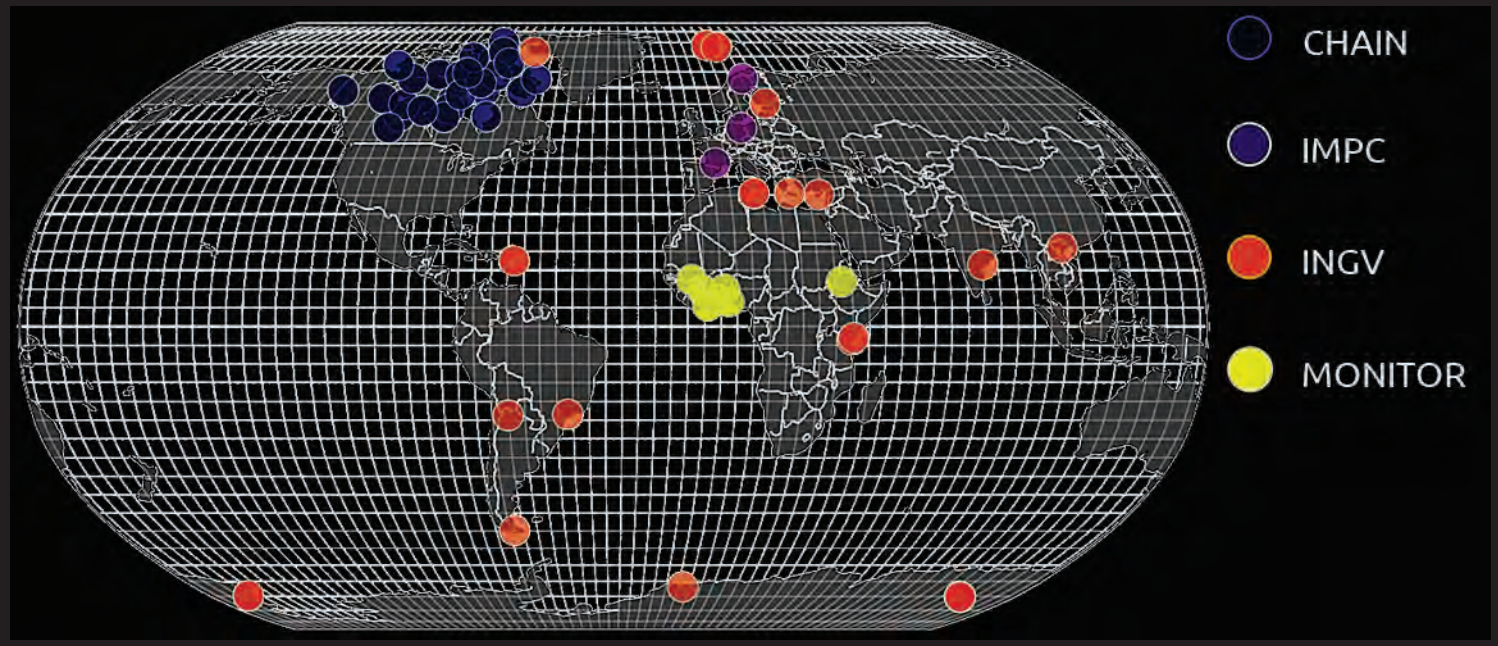
- Amplitude scintillation

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



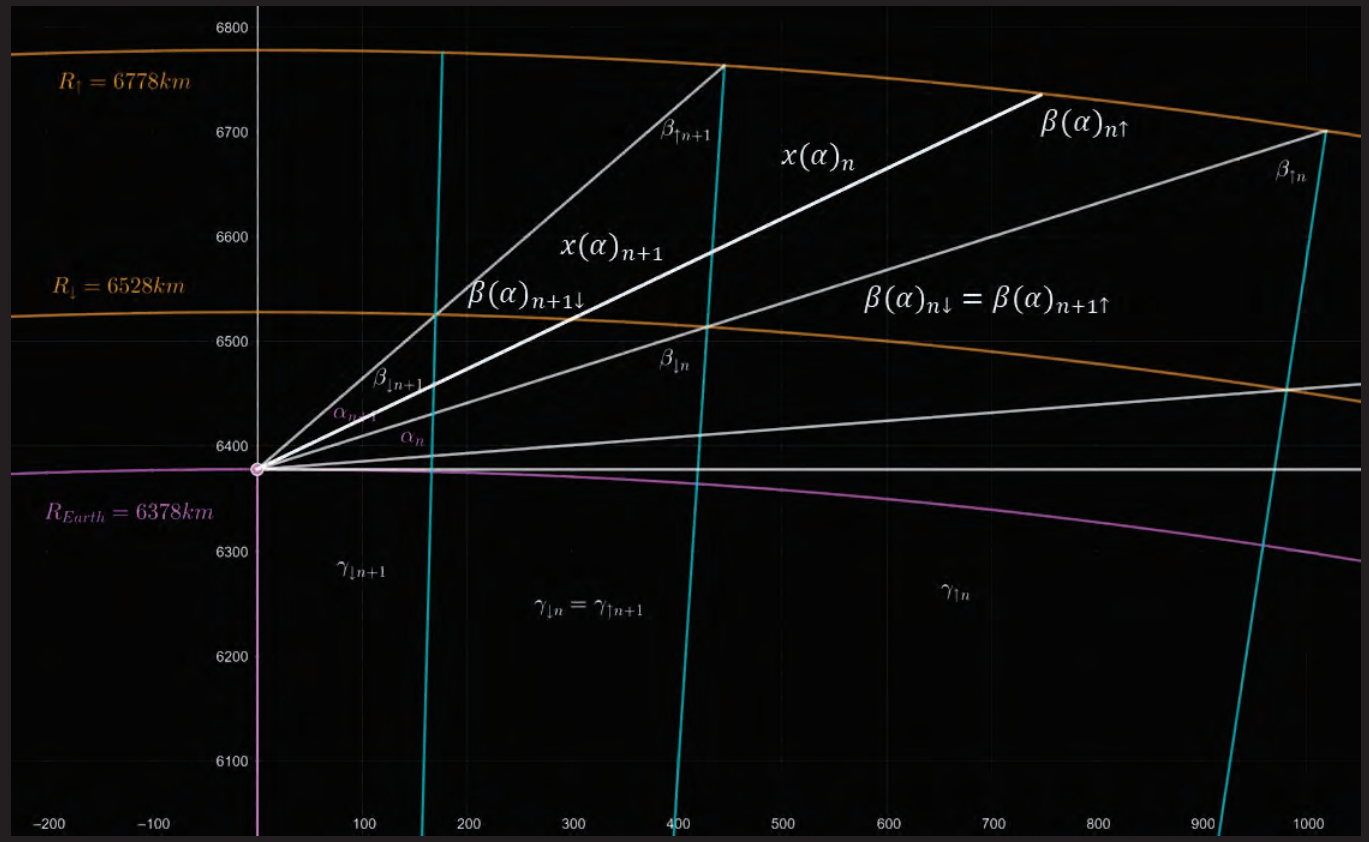
Sources of data

- 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

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

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

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

- For binning

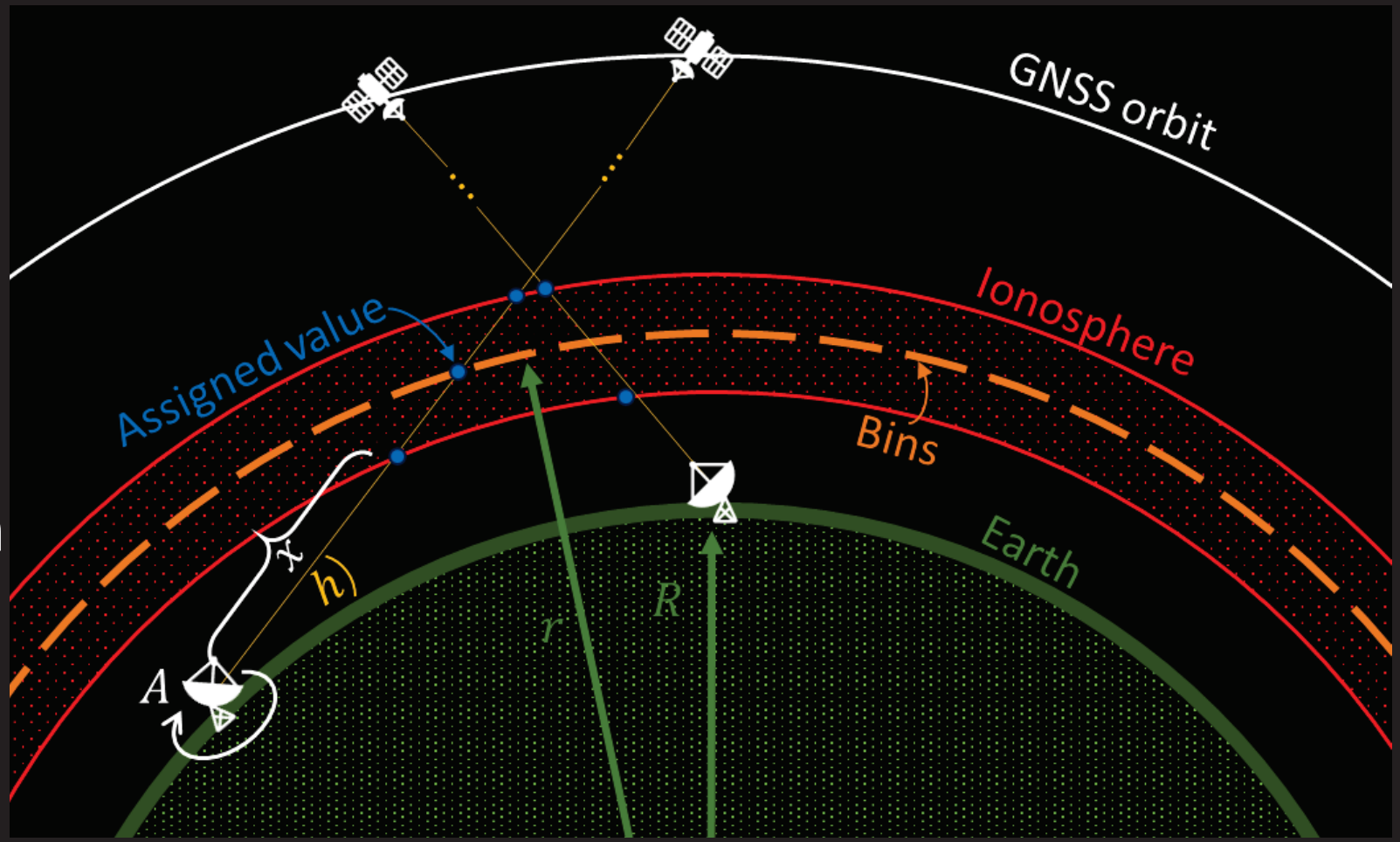
$$a = \sin\left(\frac{\Delta l}{2}\right) + \cos(l_1)\cdot\cos(l_2)\sin^2\left(\frac{\Delta\varphi}{2}\right)$$

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

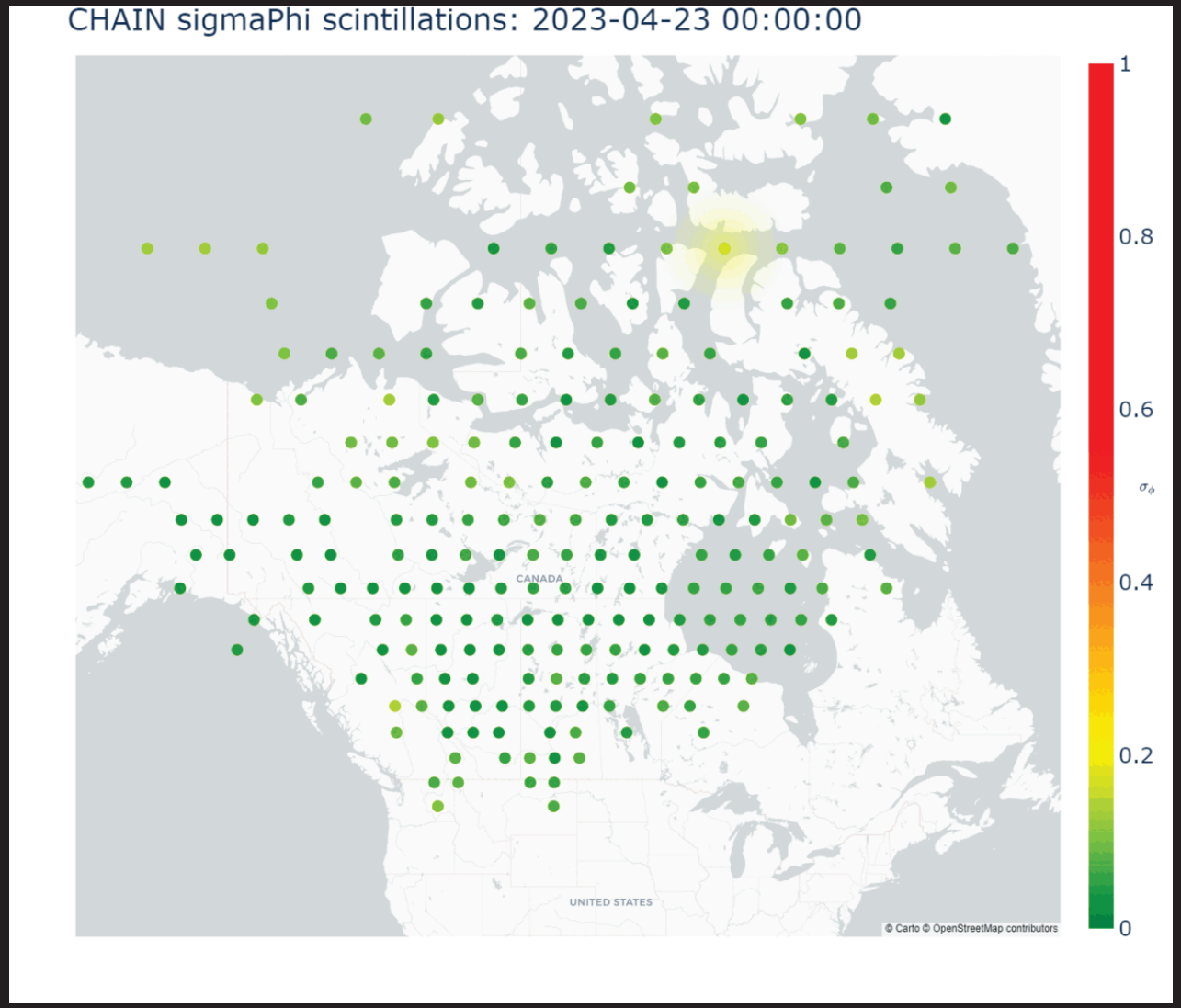
$$= 2\cdot\arctan\left(\frac{\sqrt{a}}{\sqrt{a-1}}\right)$$

Binning

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

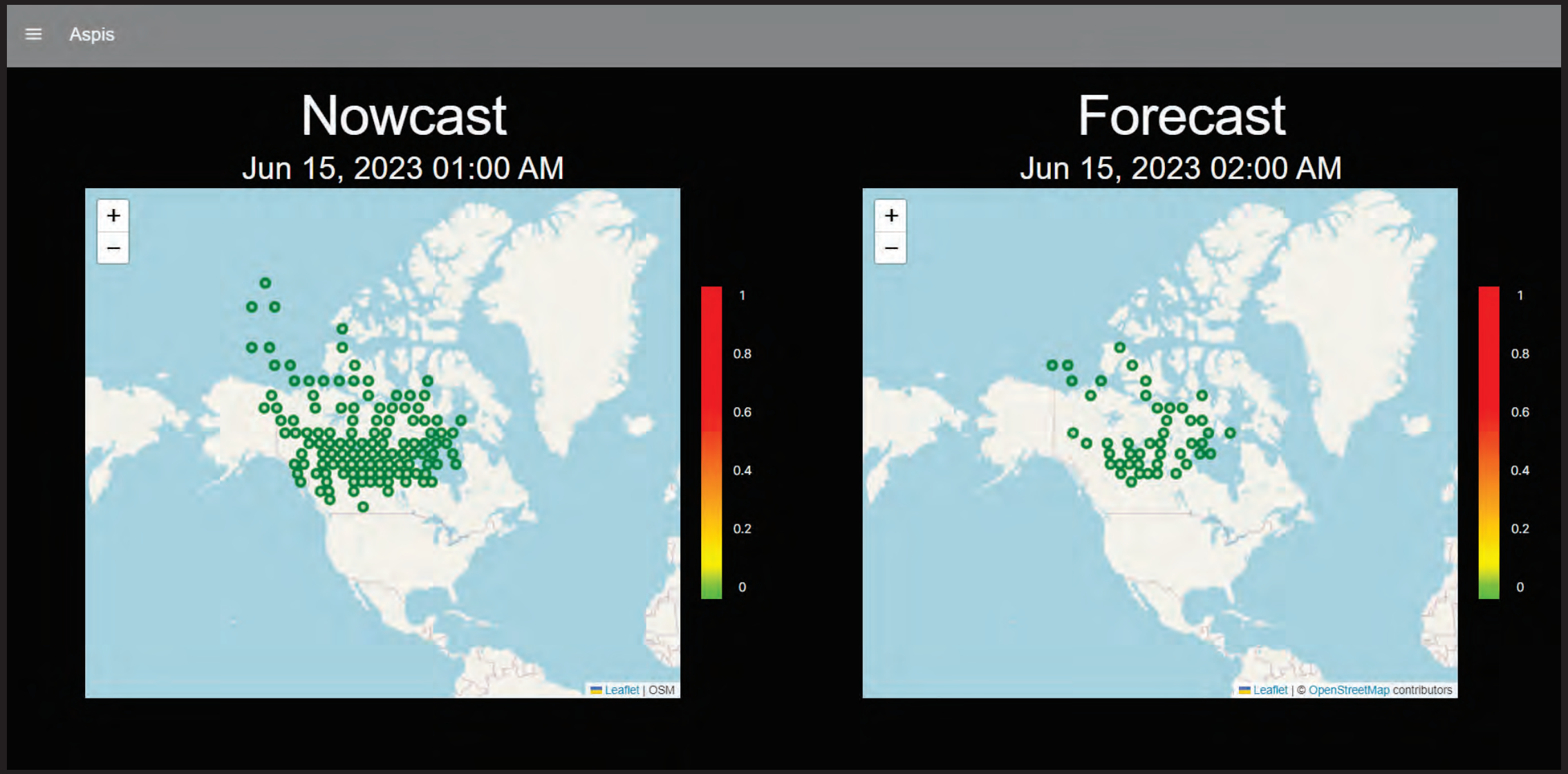


Example of event observation



Summary

Results


Aspis
Nowcast
Jun 15, 2023 01:00 AM
Forecast
Jun 15, 2023 02:00 AM
1
0.8
0.6
0.4
0.2
0
Leaflet | OSM
Leaflet | © OpenStreetMap contributors

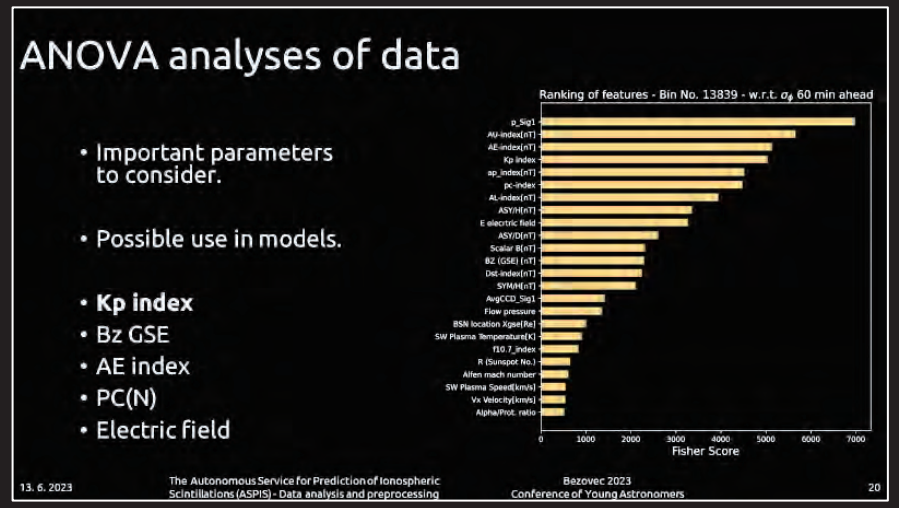
Summary

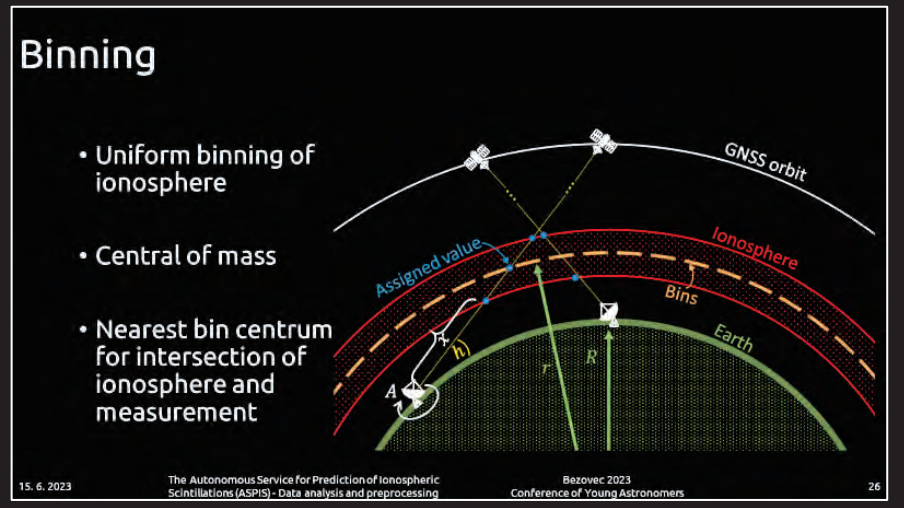
Space parameters

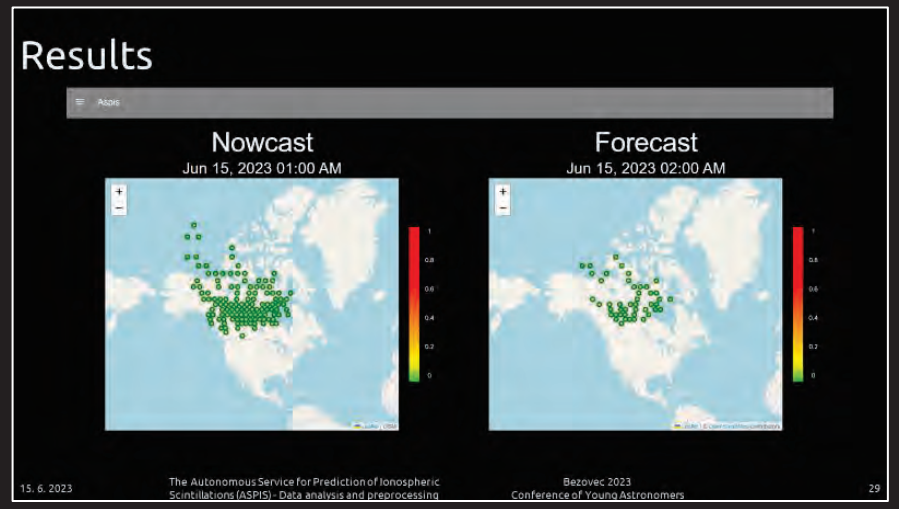
Data interpretation

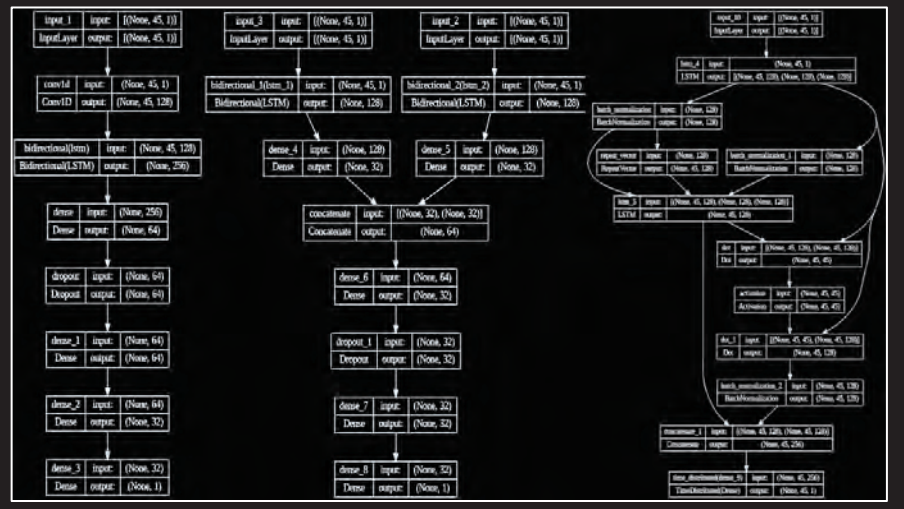
Results

Machine learning



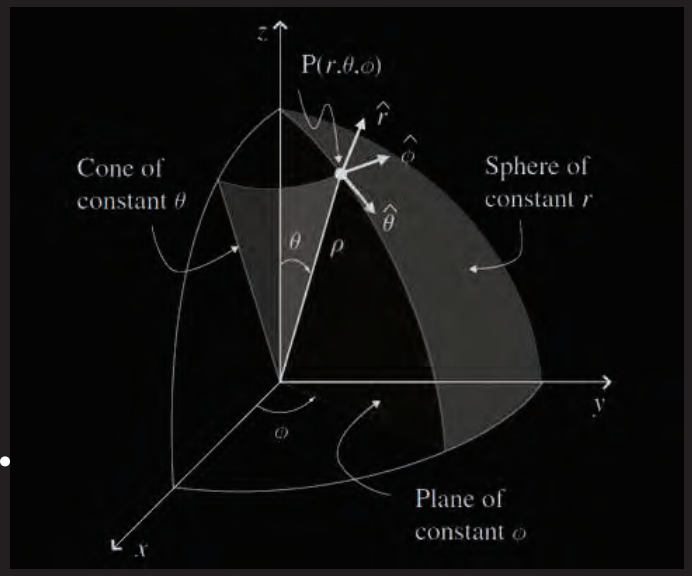






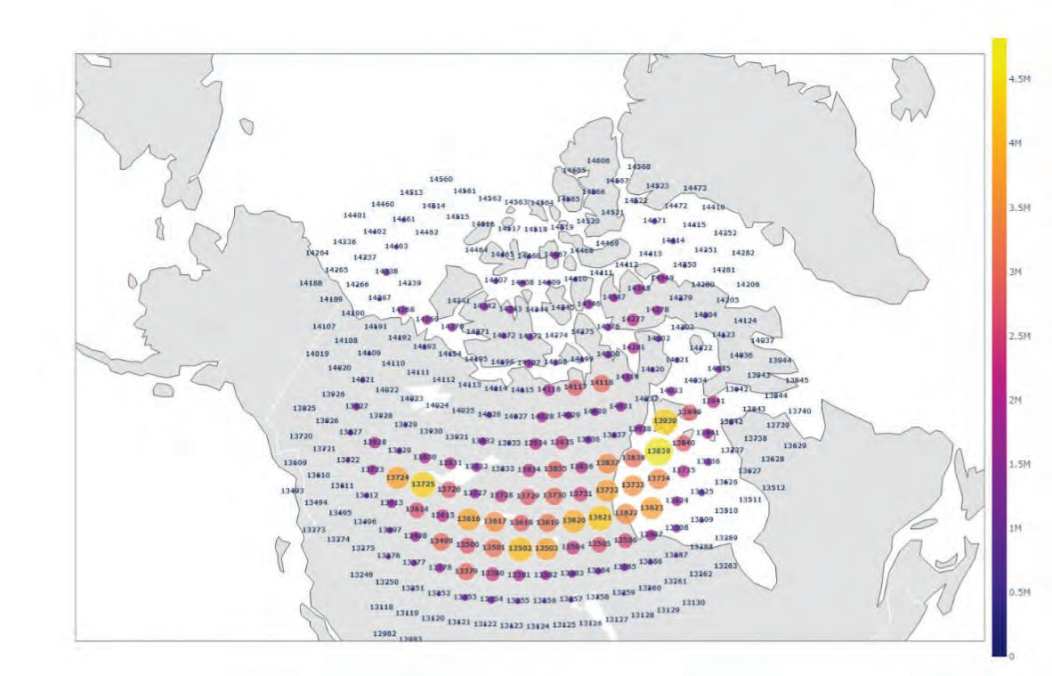
Future work

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

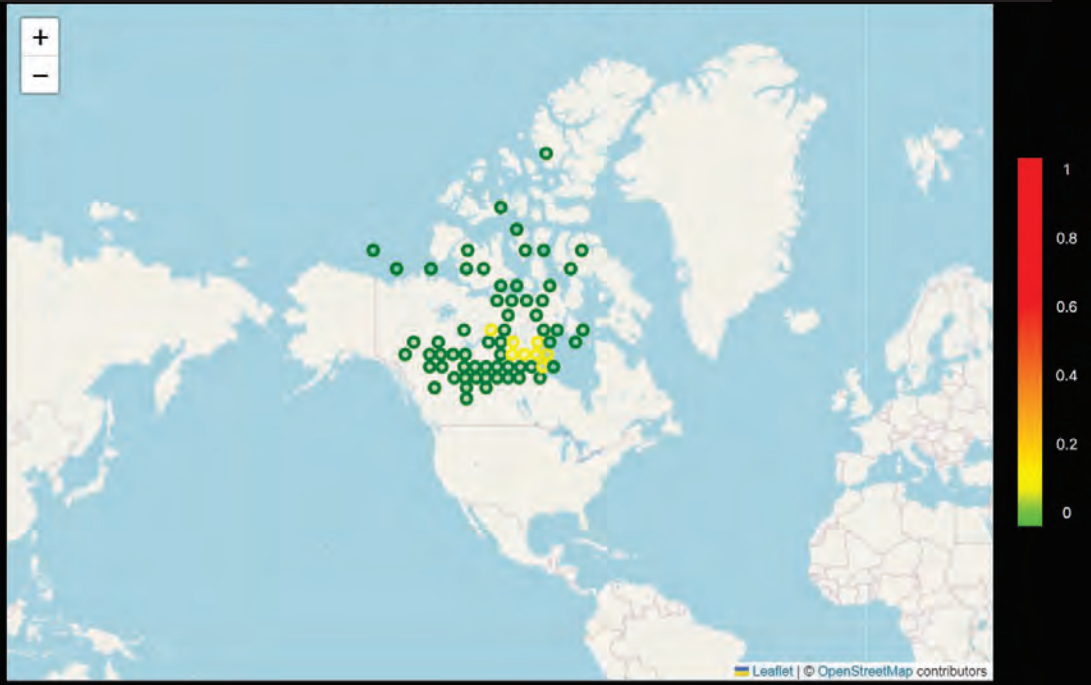


Before | After

Archive data and experiences



Working forecast



Thanks for your attention

Wait for part II.

Disclaimer

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Apendix