Group 4 Experiment Type B: Regional Vector

Tate Colby, Jiahui Hu, Save Koontaweepunya, and Alexander Massoud

Motivation

- We ♡ the ionosphere
- Measuring ion velocity as a function of height and time
- Simultaneous measurements of electron density and LOS ion velocity
- Positional precision
- Mid-latitude summer nighttime anomalous ionospheric electron density enhancement (MSNA)

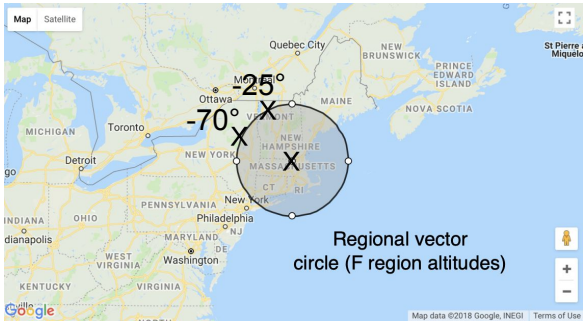


Figure 1. Panel obtained from Dr. Erickson's presentation. Top-down view of Experiment B.

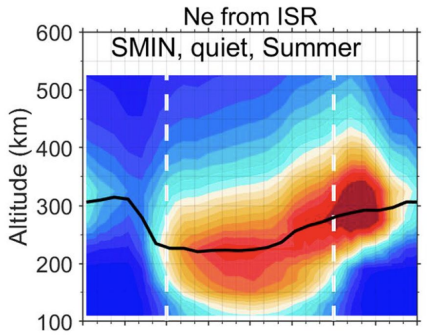
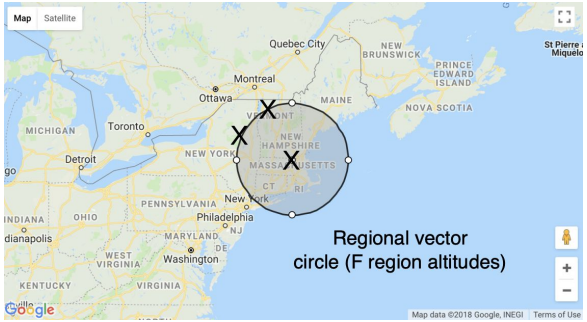


Figure 2. Panel obtained from Cai, Y. et al. (2022, *GRL*).

Review of Experiment B: Regional Vector



8-10pm LT (00-02 UT)

Constant data (~90 elevation) in Zenith

45 deg elevation at both MISA azimuths

Recorded data at two azimuths (-25°, -70°) (Currently MISA azimuth range is limited)

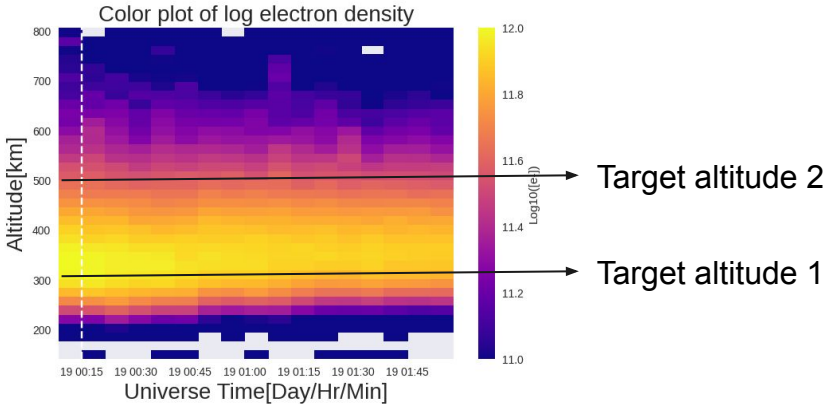
Zenith and MISA: 3 minutes

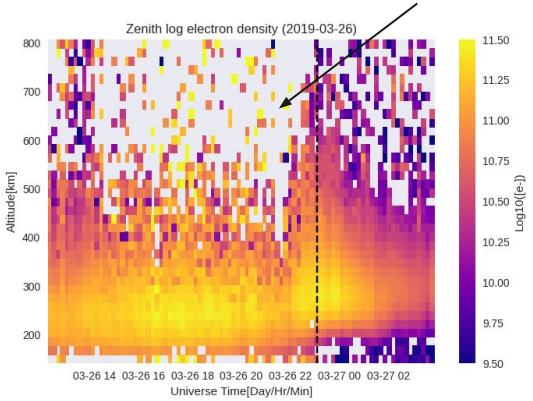
Comparison between two different seasons

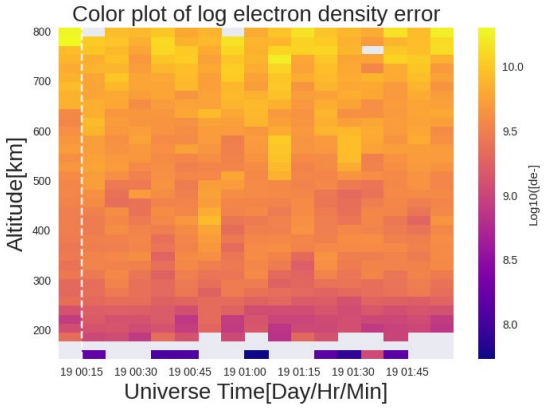
- Ionospheric behavior comparison for July-21-2022 v.s. March-26-2019
  - Electron Density
    - Enhancement at a range of altitude
  - Zenith Line of Sight velocity
  - Velocity components in magnetic field coordinates
- Different MISA azimuths between the two runs
  - July-21-2022: Azimuths = [-25, -70] deg. Difference = 45 deg.
  - March-26-2019: Azimuths = [-12, -40.5] deg. Difference = 28.5 deg.

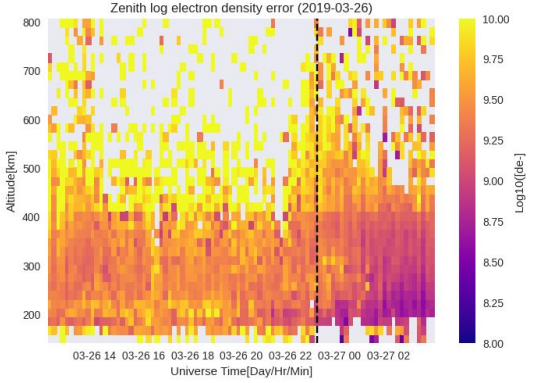
Electron Density and error (Zenith)

Pulse length = 9.6e-4

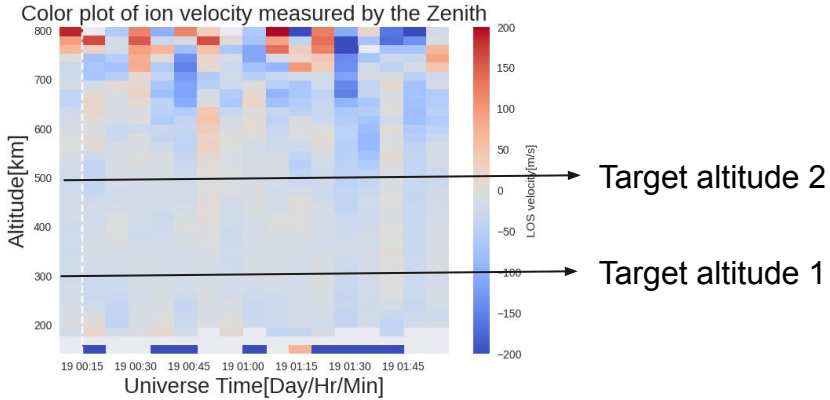


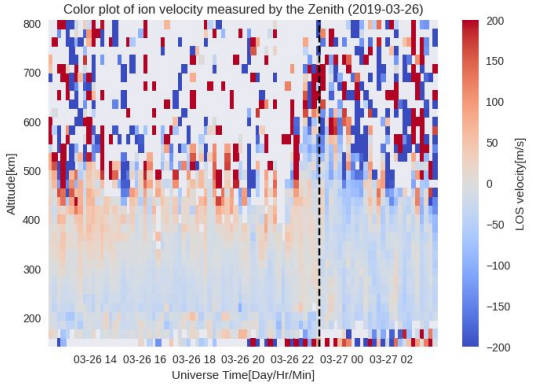


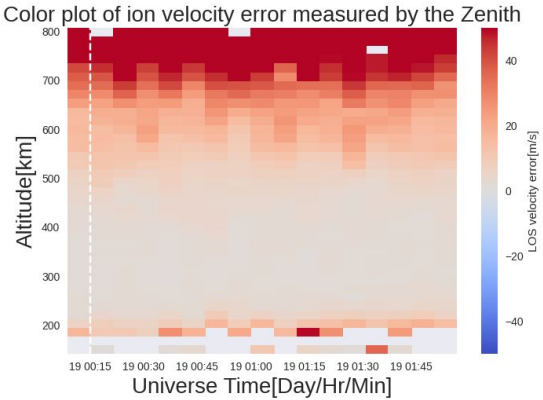


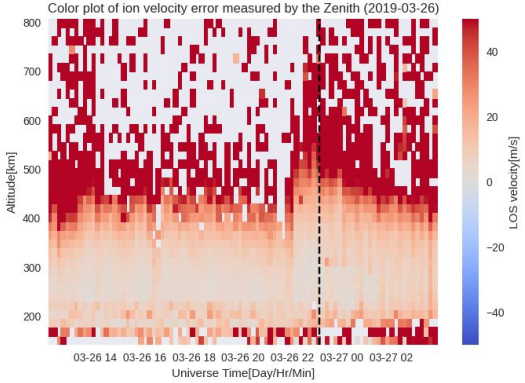


LOS ion velocity and error (Zenith)



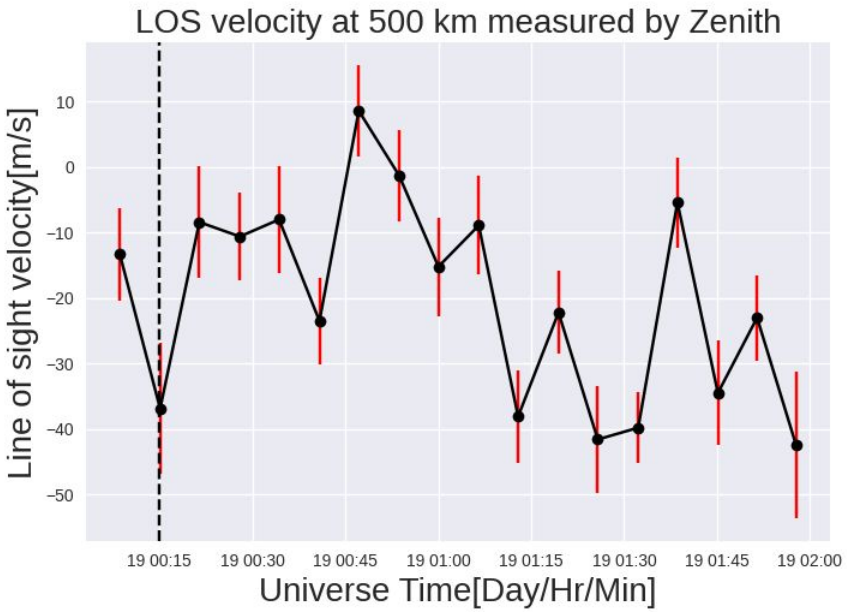




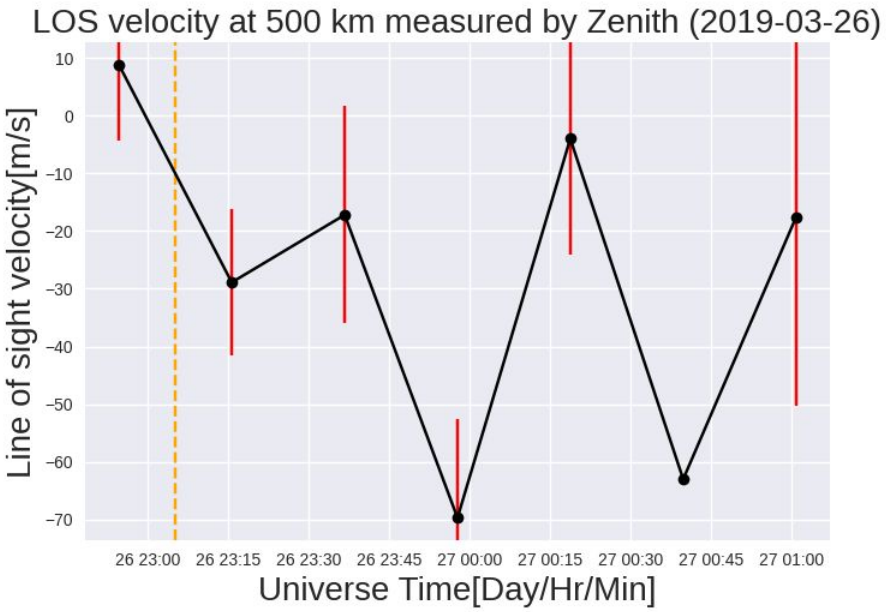


LOS ion velocity at 500 km

July-21-2022

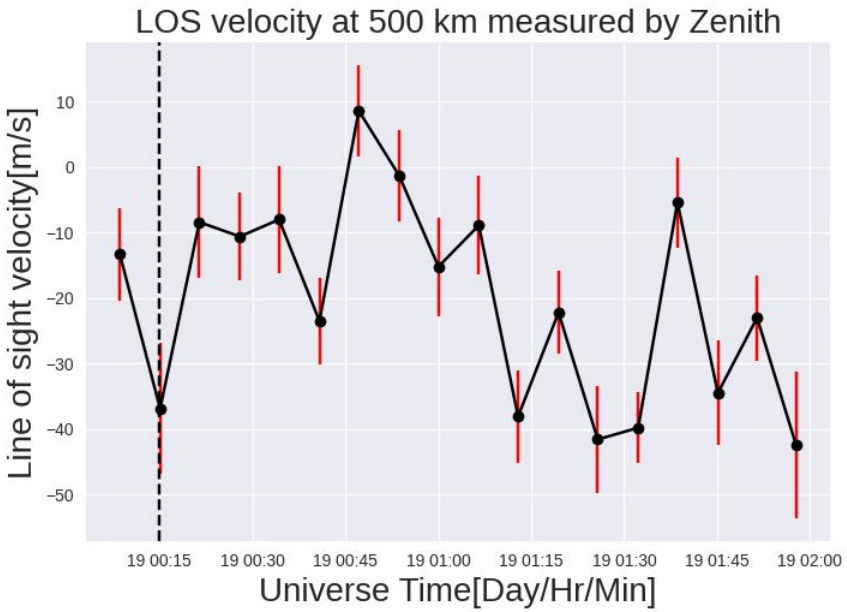


March-26-2019



Error bars at 500 km

July-21-2022



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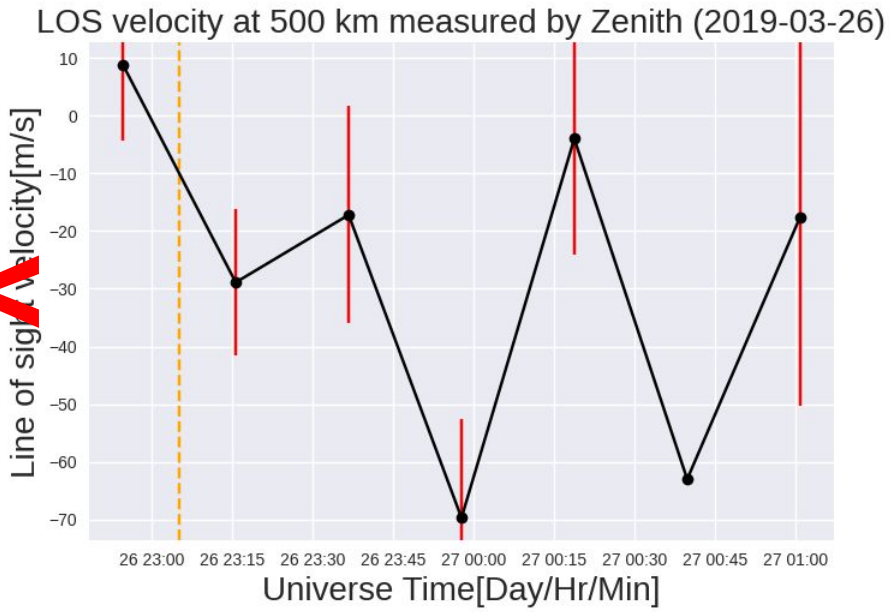
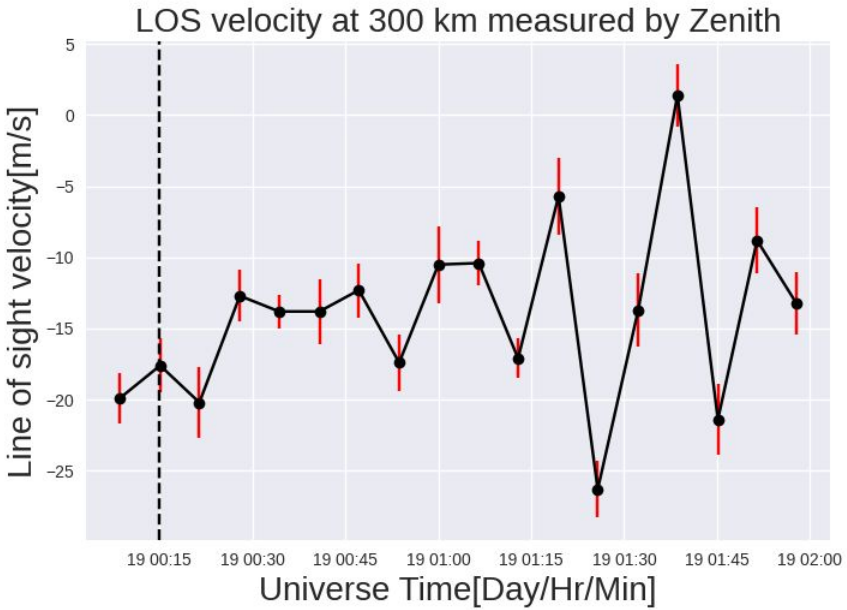
March-26-2019

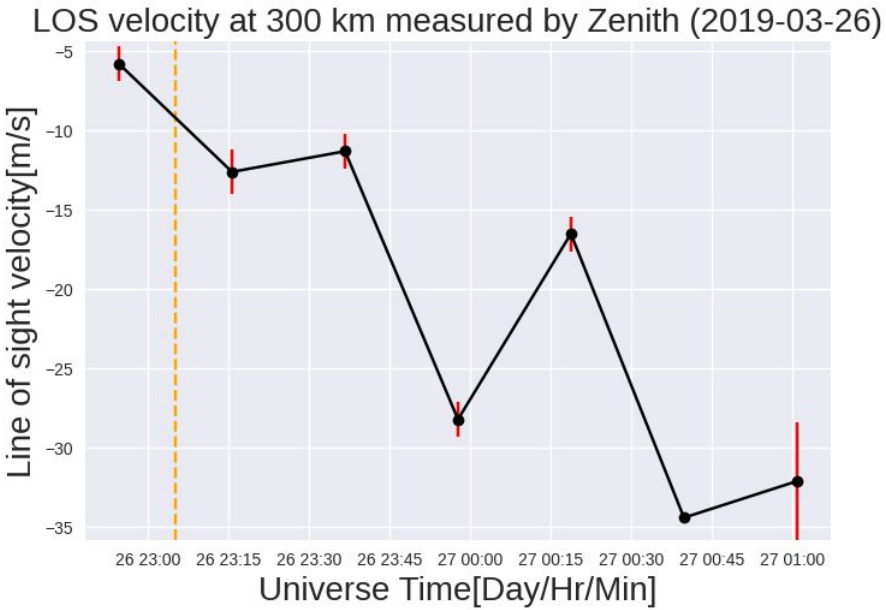


LOS ion velocity at 300 km

July-21-2022

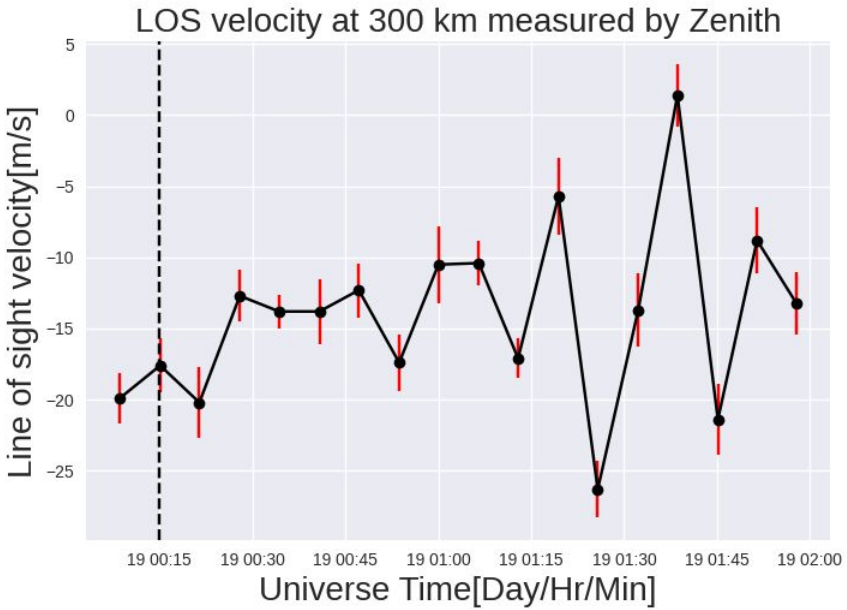


March-26-2019



Error bars at 300 km

July-21-2022



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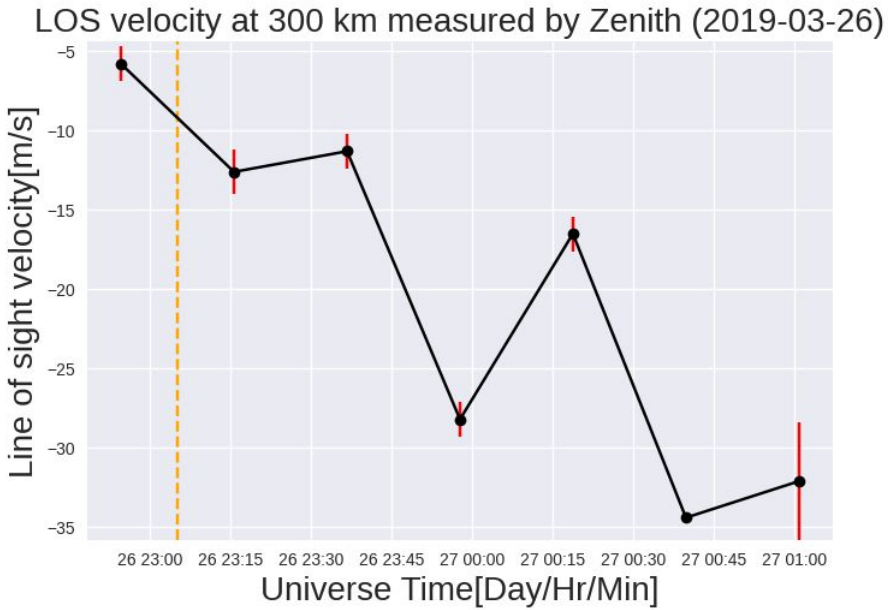
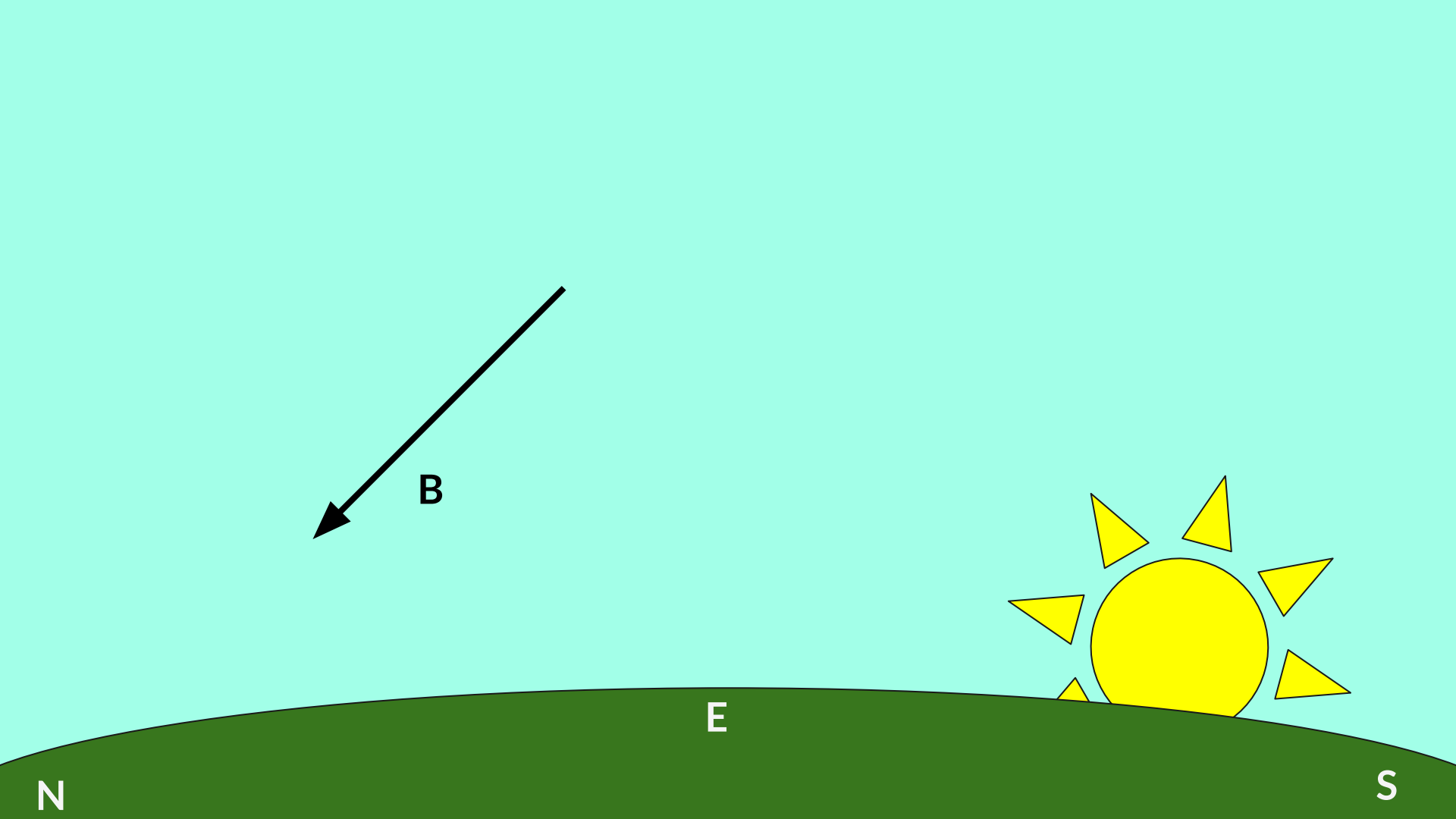
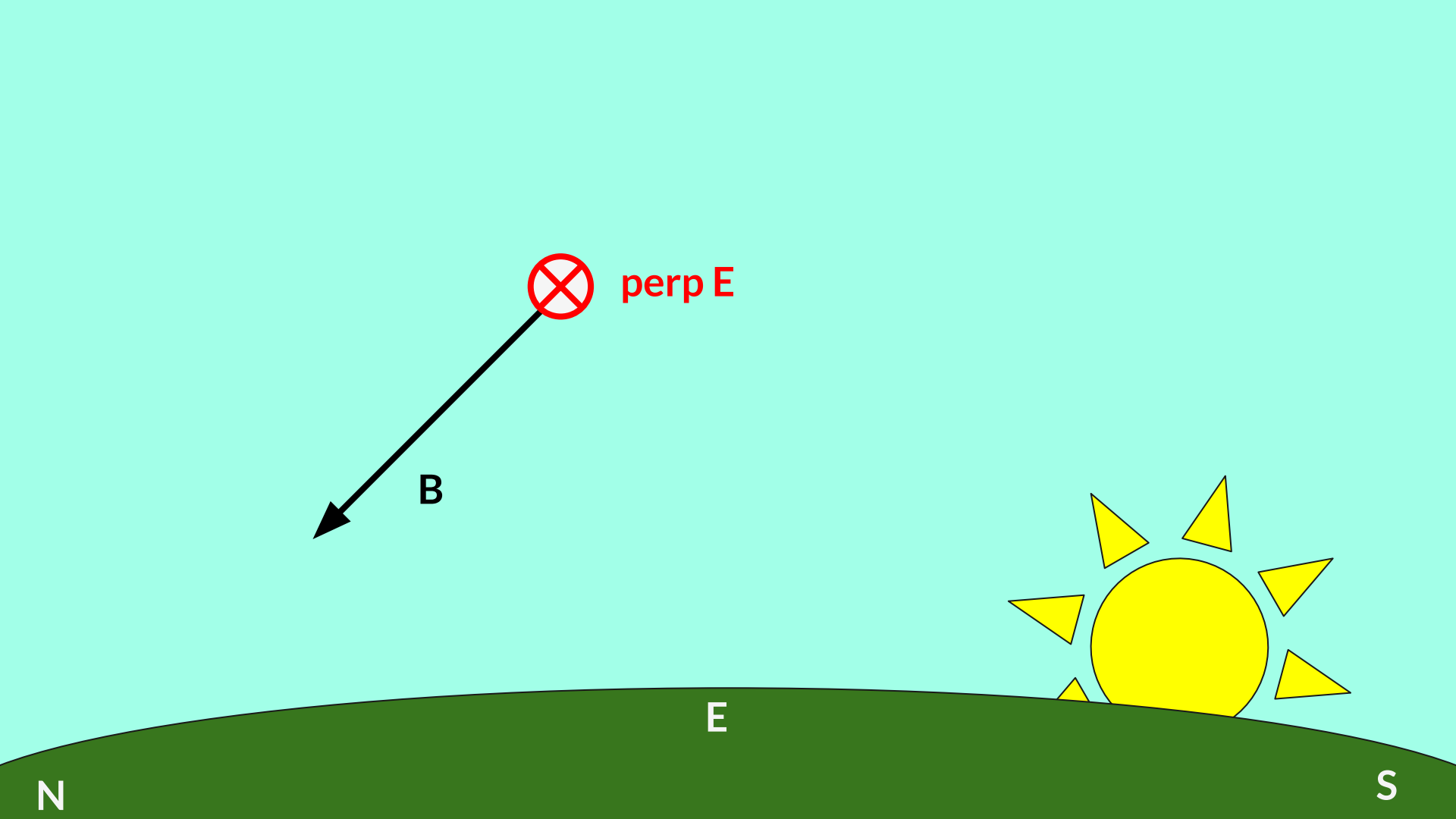
March-26-2019




B
E
N
S


perp E
B
E
N
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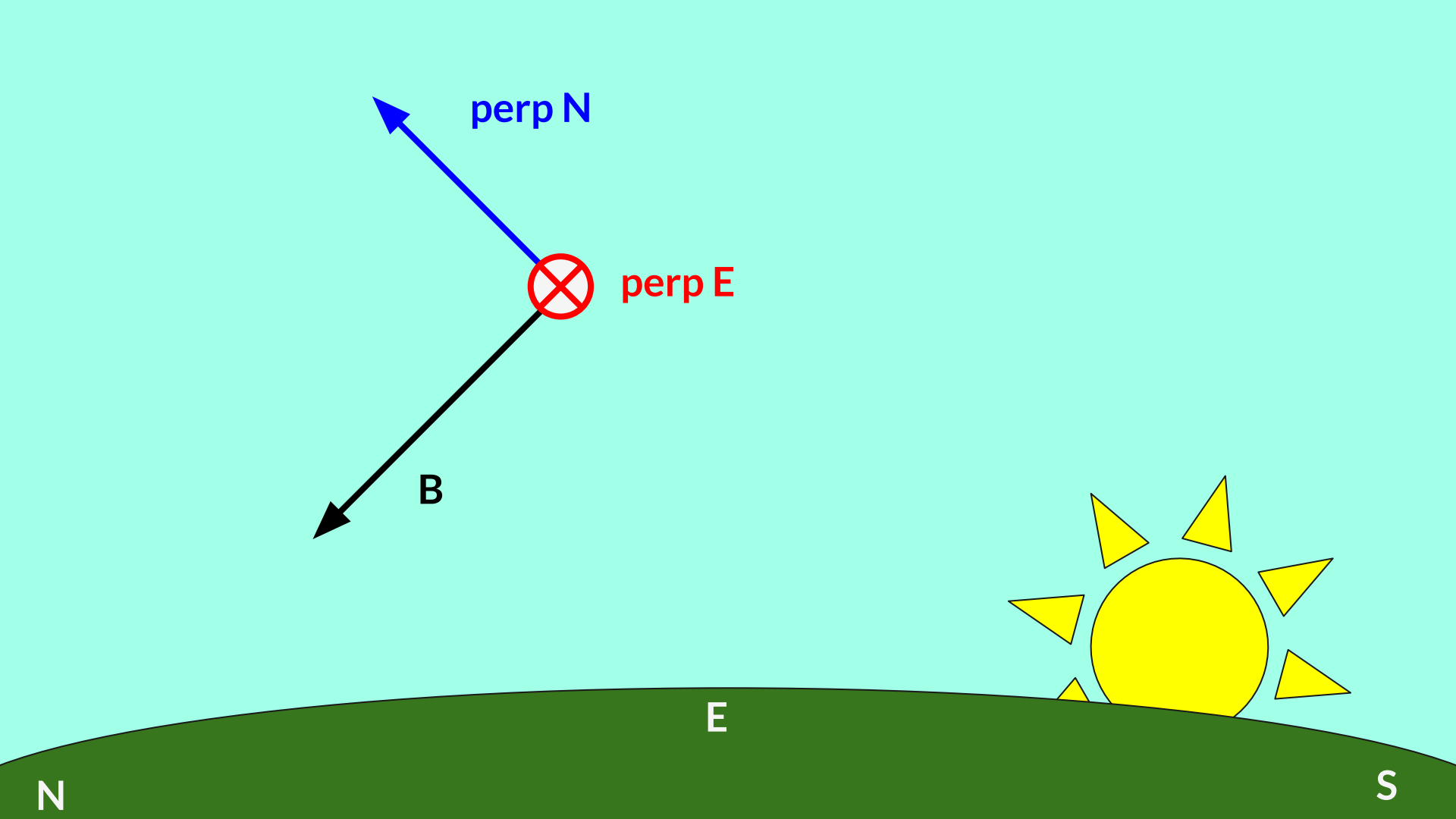
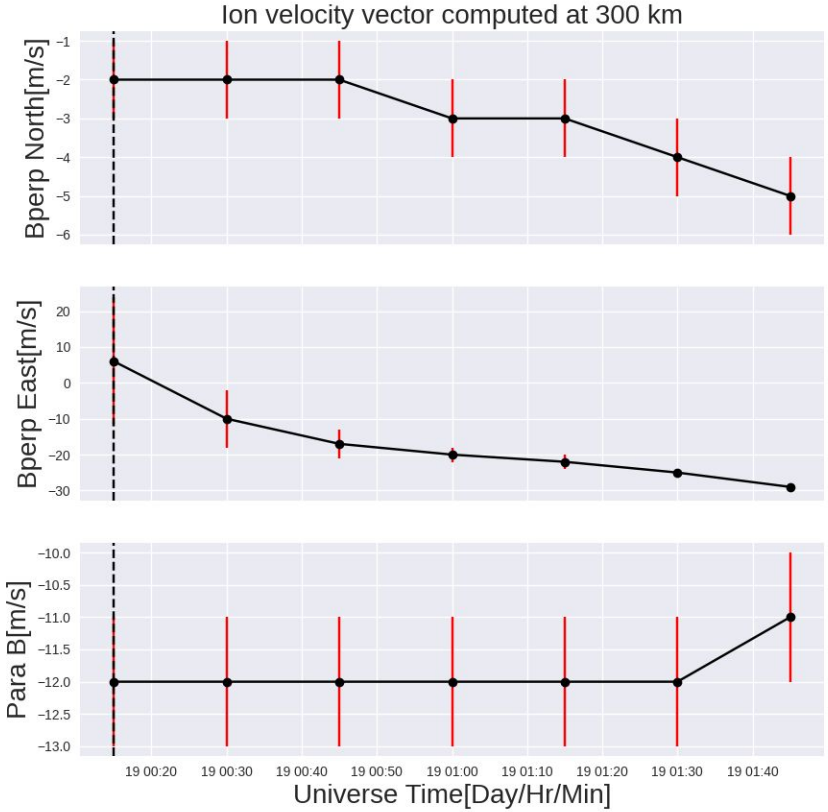
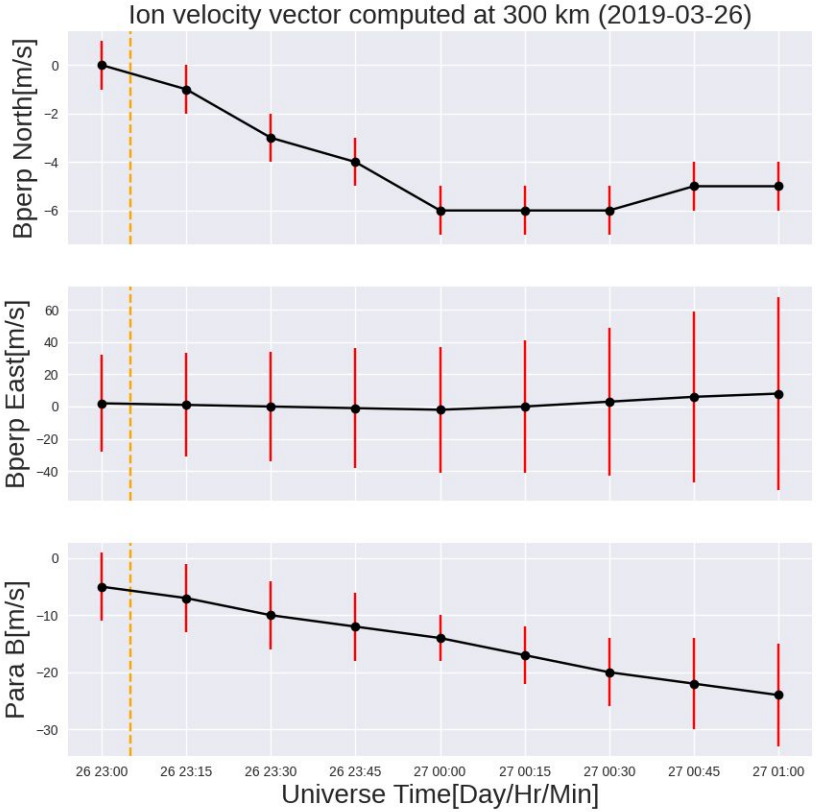

perp N
perp E
B
E
N
S

Error bars for velocity components (300 km)

Azimuth difference = 45°



Azimuth difference = 28.5°



Error bars for velocity components (300 km)

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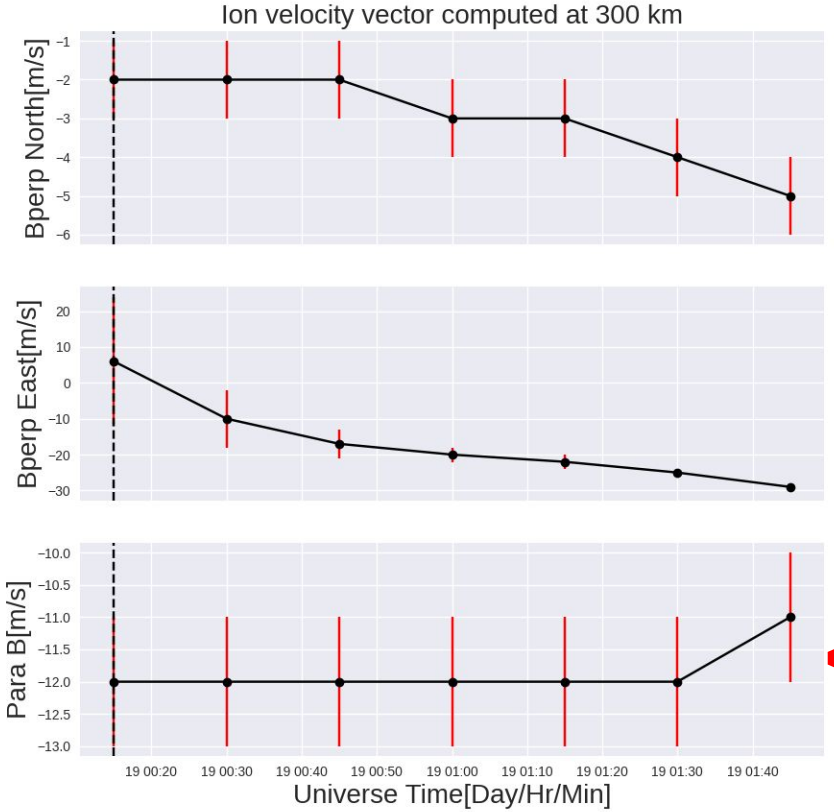
Azimuth difference = 45°



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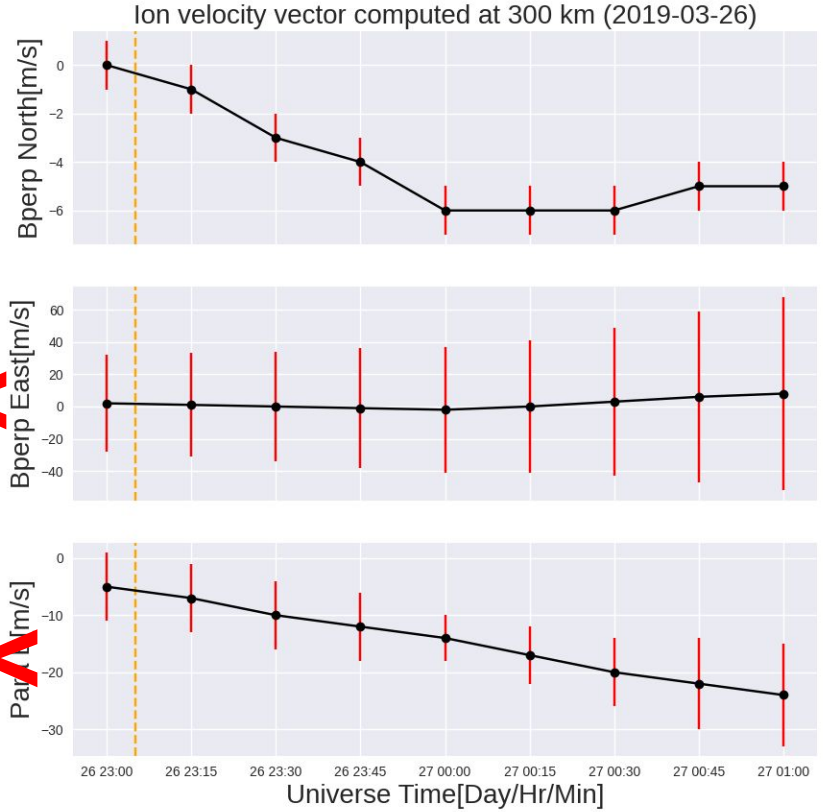
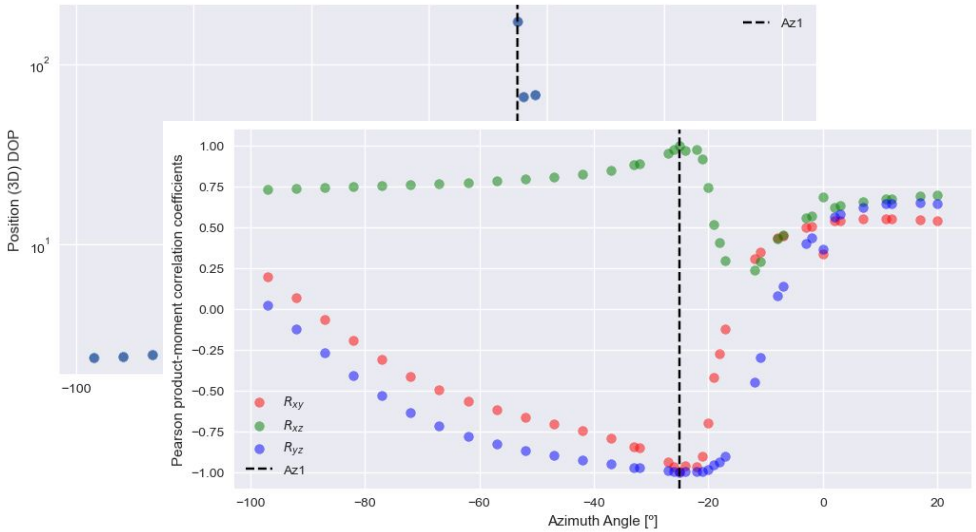
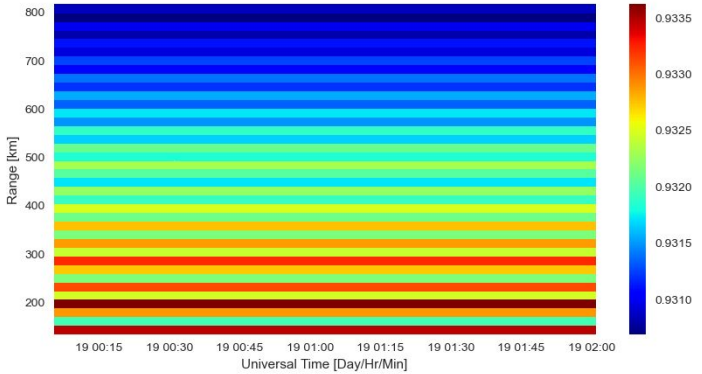


Time to look at geometry, matrices, and error propagation

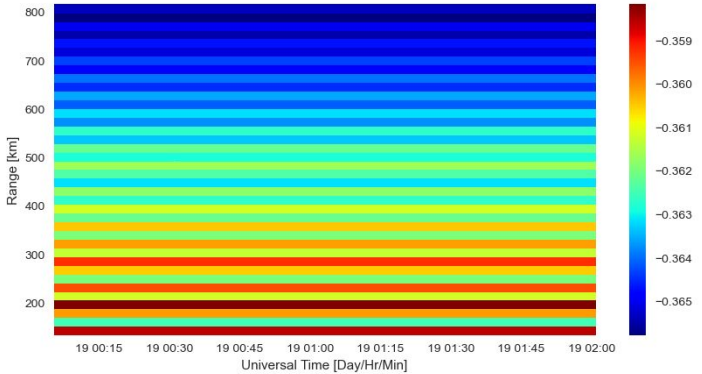


Zenith Single-Pulse

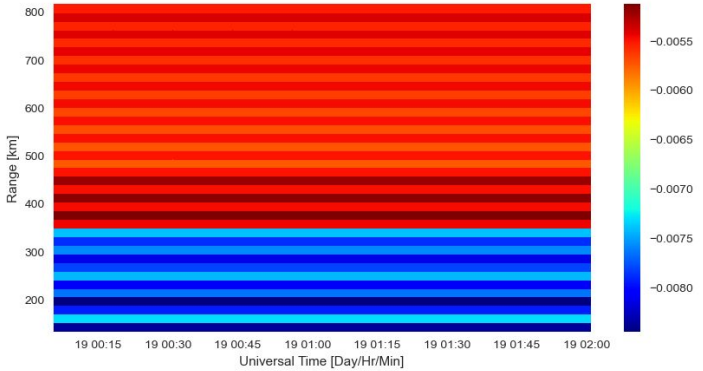
CZR



CXR

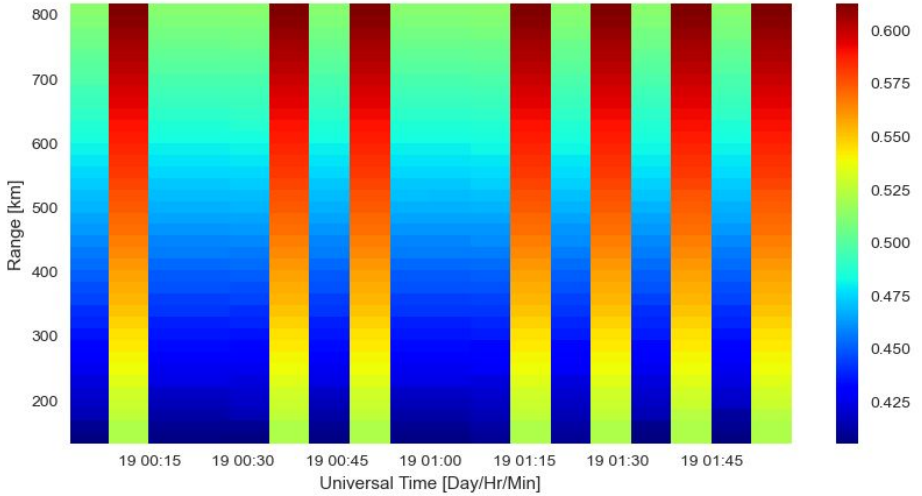


CYR

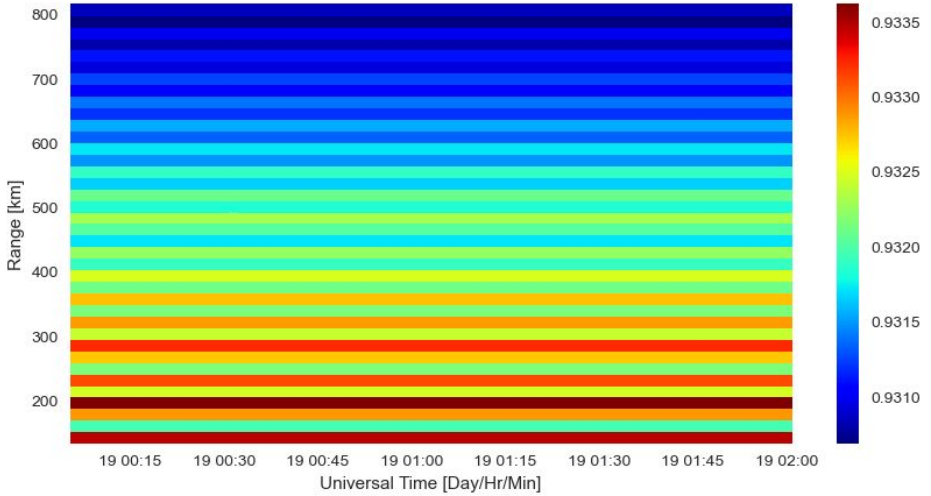


What about MISA single-pulse? Let's compare

CZR (MISA)



CZR (Zenith)



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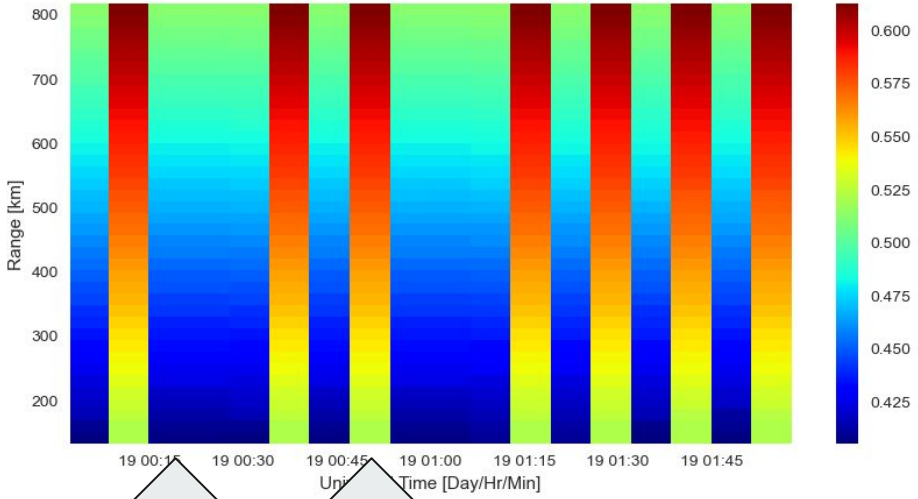
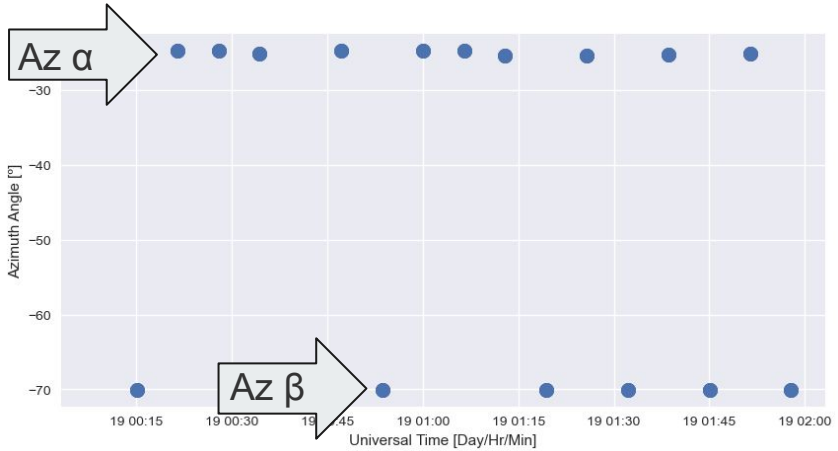


Az α

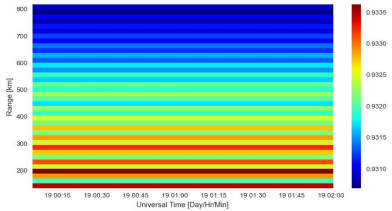
Az β

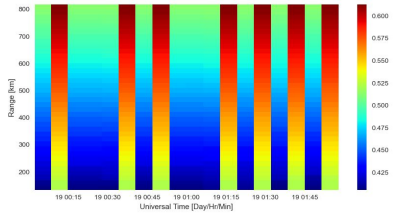


The matrix we construct and why

Each coefficient is the “x/y/z-cosine of the radar line-of-sight with respect to apex coords.”

$$M = \begin{bmatrix} \mathrm{czr}^{Z} & \mathrm{cyr}^{Z} & \mathrm{cxr}^{Z} \\ \mathrm{czr}^{M1} & \mathrm{cyr}^{M1} & \mathrm{cxr}^{M1} \\ \mathrm{czr}^{M2} & \mathrm{cyr}^{M2} & \mathrm{cxr}^{M2} \end{bmatrix}$$





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M = $\begin{bmatrix} \mathrm{czr}^{Z} & \mathrm{cyr}^{Z} & \mathrm{cxr}^{Z} \\ \mathrm{czr}^{M1} & \mathrm{cyr}^{M1} & \mathrm{cxr}^{M1} \\ \mathrm{czr}^{M2} & \mathrm{cyr}^{M2} & \mathrm{cxr}^{M2} \end{bmatrix}$

$Q = AA^{T}$, where $A = M^{-1}$ and $Q = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xz} \\ \sigma_{xy} & \sigma_y^2 & \sigma_{yz} \\ \sigma_{xz} & \sigma_{yz} & \sigma_z^2 \end{bmatrix}$

Some useful parameters we can now obtain

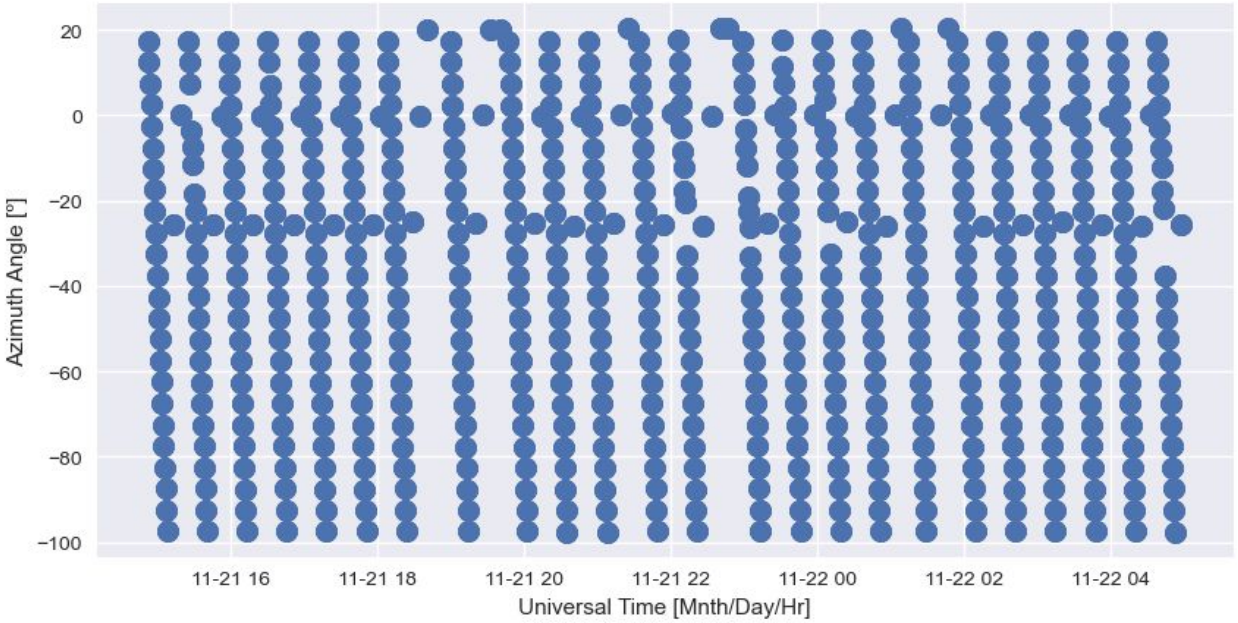
$$PDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2}$$ = Trace(Q)

$$R_{ij} = \frac{\sigma_{ij}}{\sqrt{\sigma_i^2 \sigma_j^2}}$$

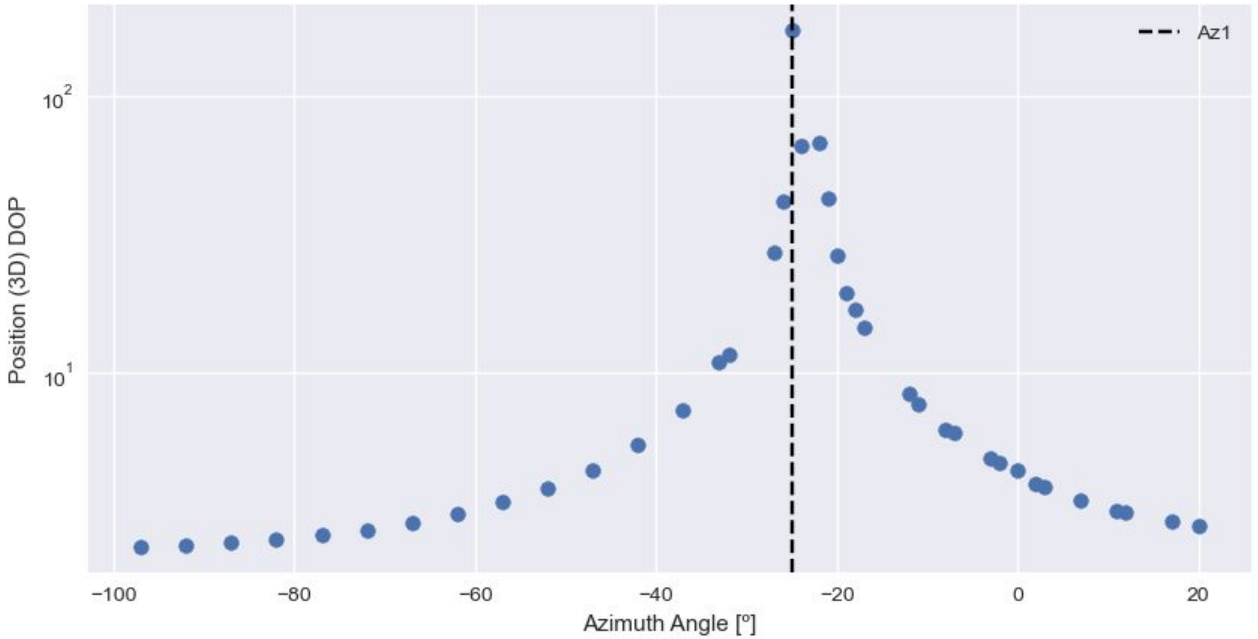
Wide Coverage Azimuth Scan Experiment (2019-11-21)

Disclosure:
6º of elevation,
not 45º

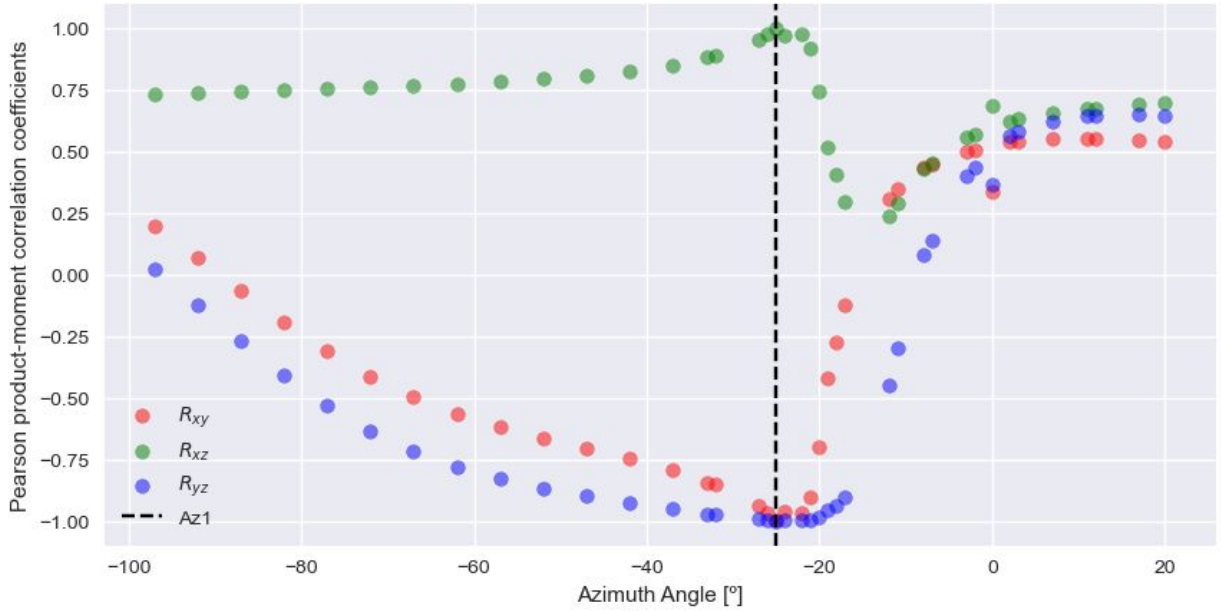
$$\begin{bmatrix} \mathrm{czr}^{Z} & \mathrm{cyr}^{Z} & \mathrm{cxr}^{Z} \\ \mathrm{czr}^{M1} & \mathrm{cyr}^{M1} & \mathrm{cxr}^{M1} \\ \mathrm{czr}^{M2} & \mathrm{cyr}^{M2} & \mathrm{cxr}^{M2} \end{bmatrix}$$



Positional (3D) Dilution of Performance



Pearson Correlation Coefficient



Conclusion

Enhanced electron densities at altitude range approximately 250-550[km]

Rapid changes and increased downward ion velocities after sunset.

Smaller MISA azimuth difference = bigger error bars in magnetic coordinates

The PDOP and Pearson correlation coefficient are powerful diagnostic quantities

An interactive lecture supplement for next year's summer school?