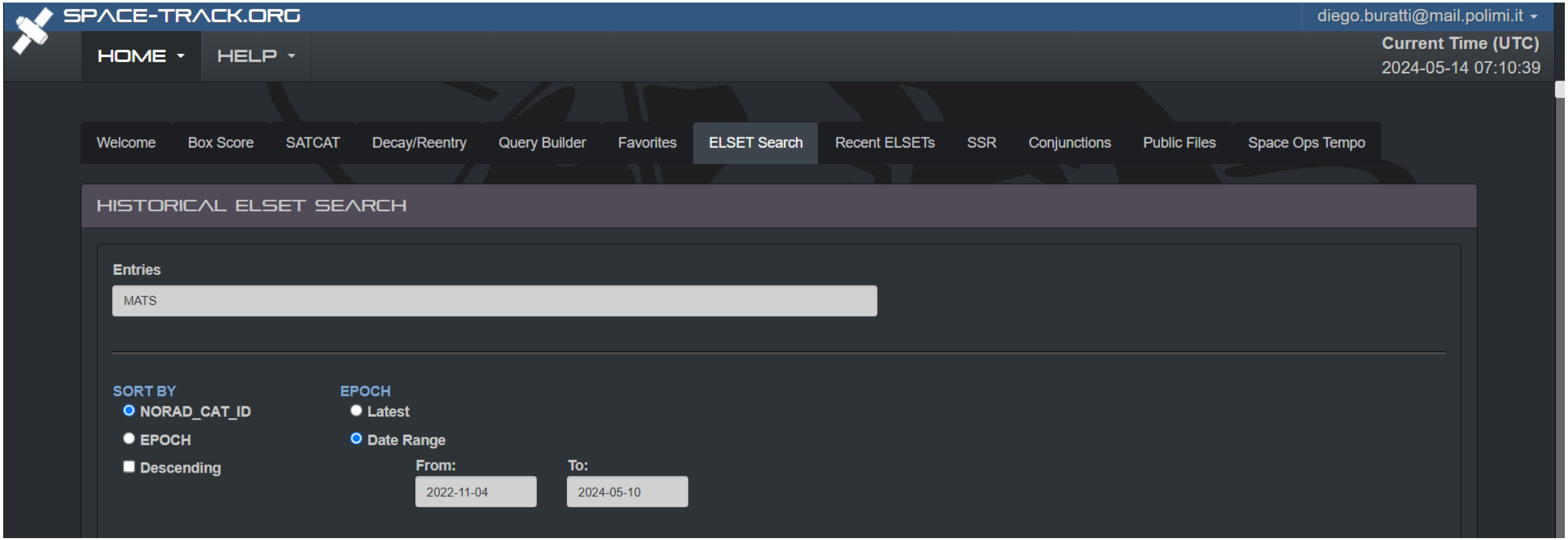
Lab.1 Results – MATS mission analysis

Group 3: Buratti Diego, Patel Kirtan

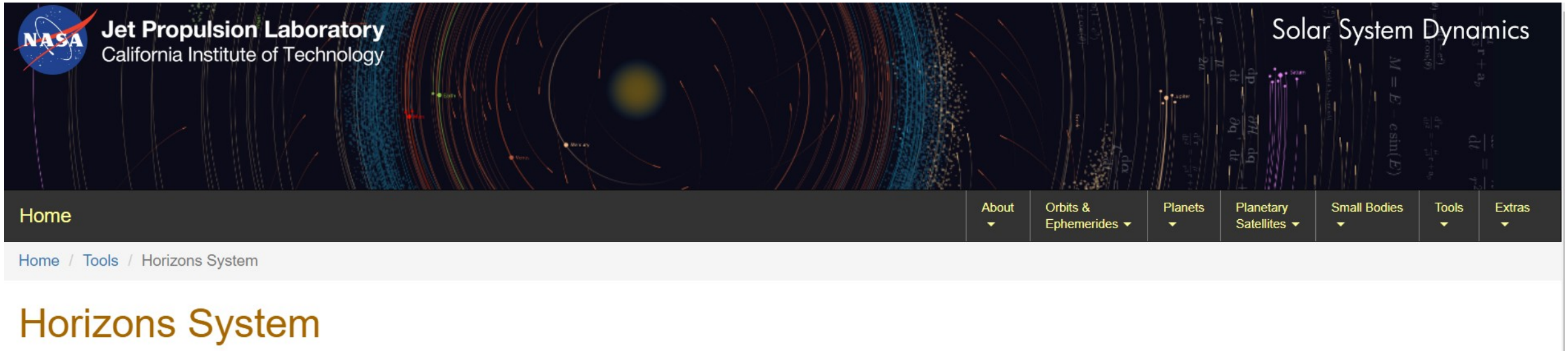
Employed Tools

To retrieve TLEs over time:

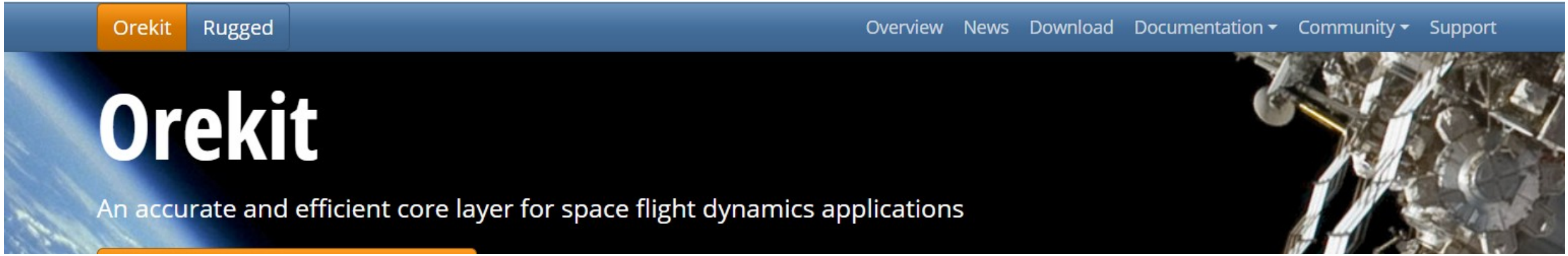


Employed Tools

To propagate TLEs (first part):



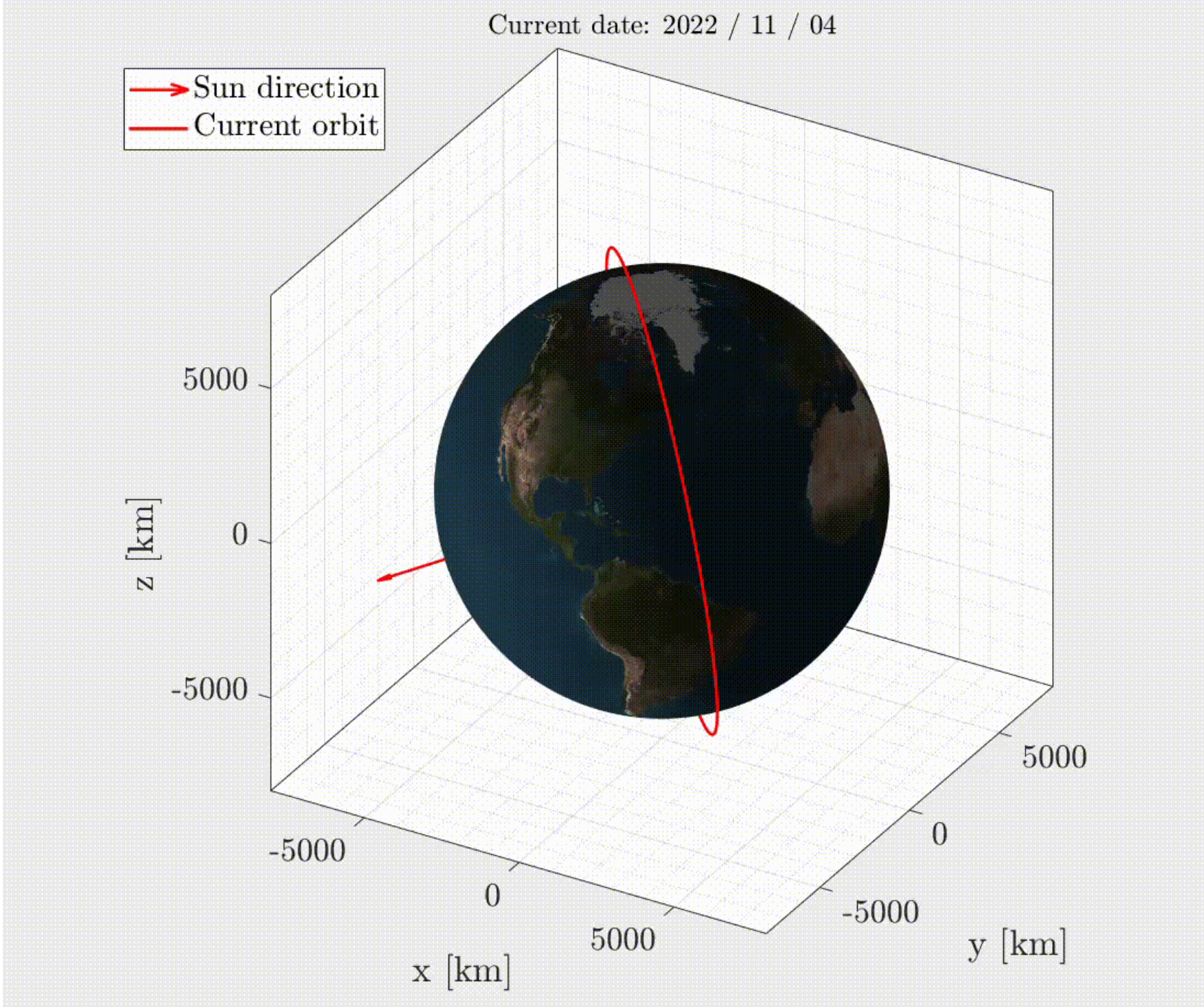
To propagate TLEs (second part):



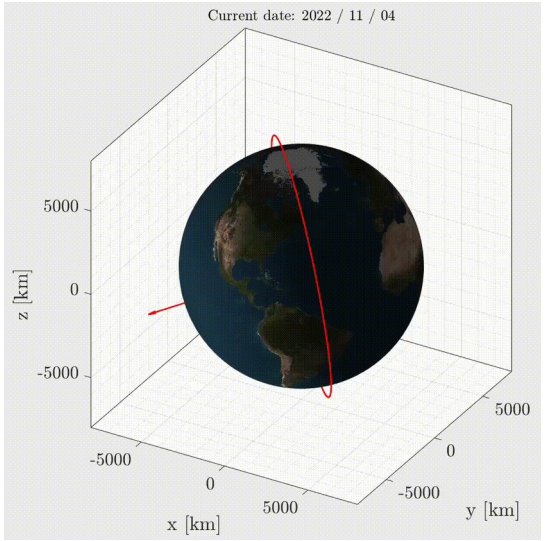
MATS orbit

The MATS microsatellite operates on a circular, sun-synchronous orbit at an altitude of about 585 km.

Nominal mission duration: 2 years.

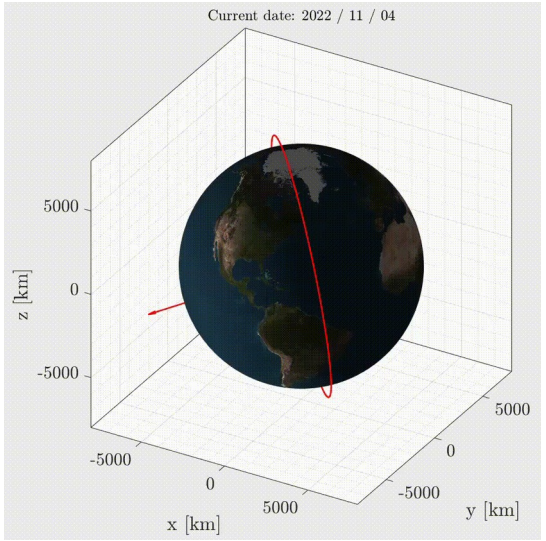


MATS orbit – Orbital Solar Zenith Angle



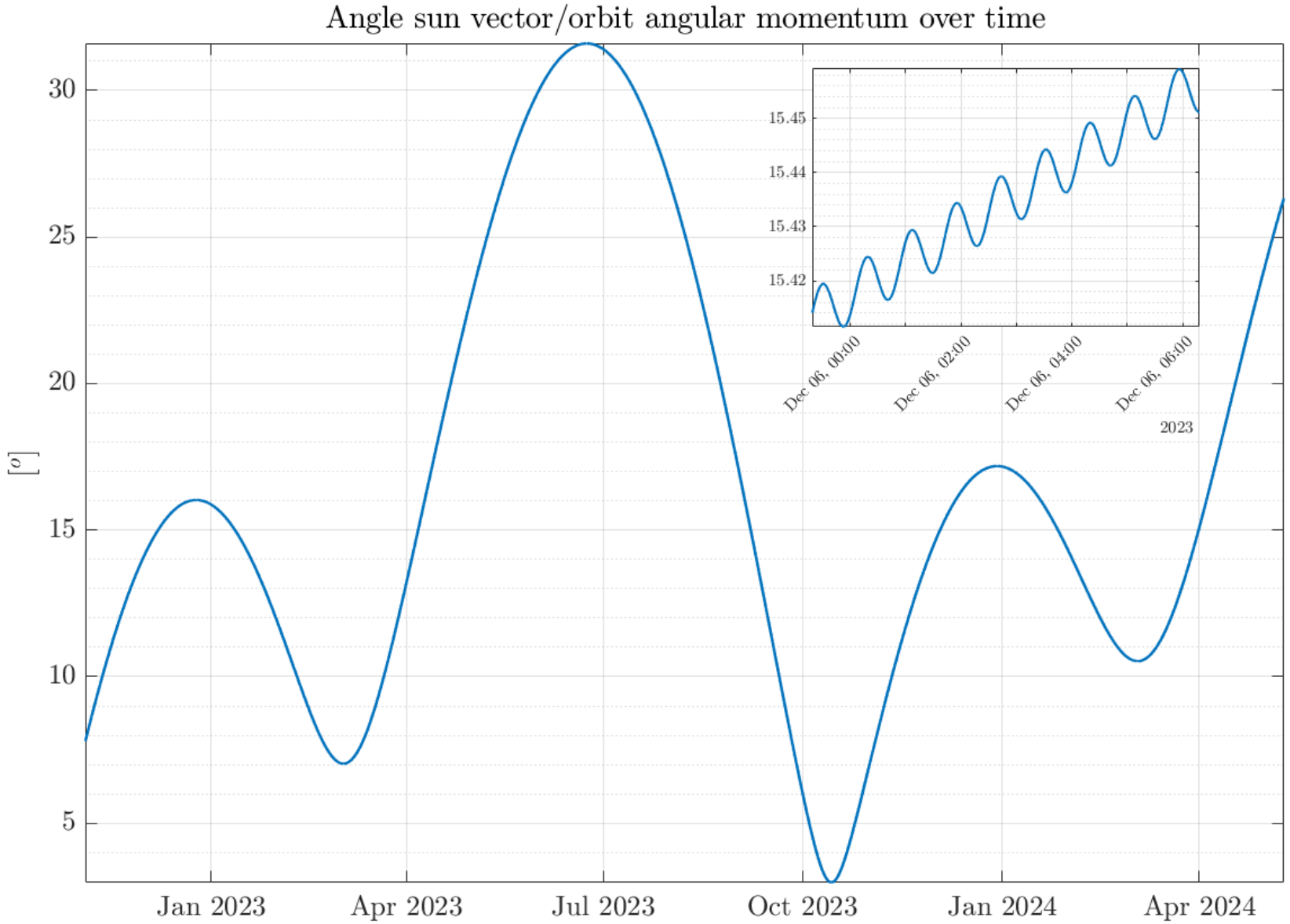
Solar zenith angle computed as the angle between the specific angular momentum of the orbit at each instant of time and the sun direction:

MATS orbit – Orbital Solar Zenith Angle



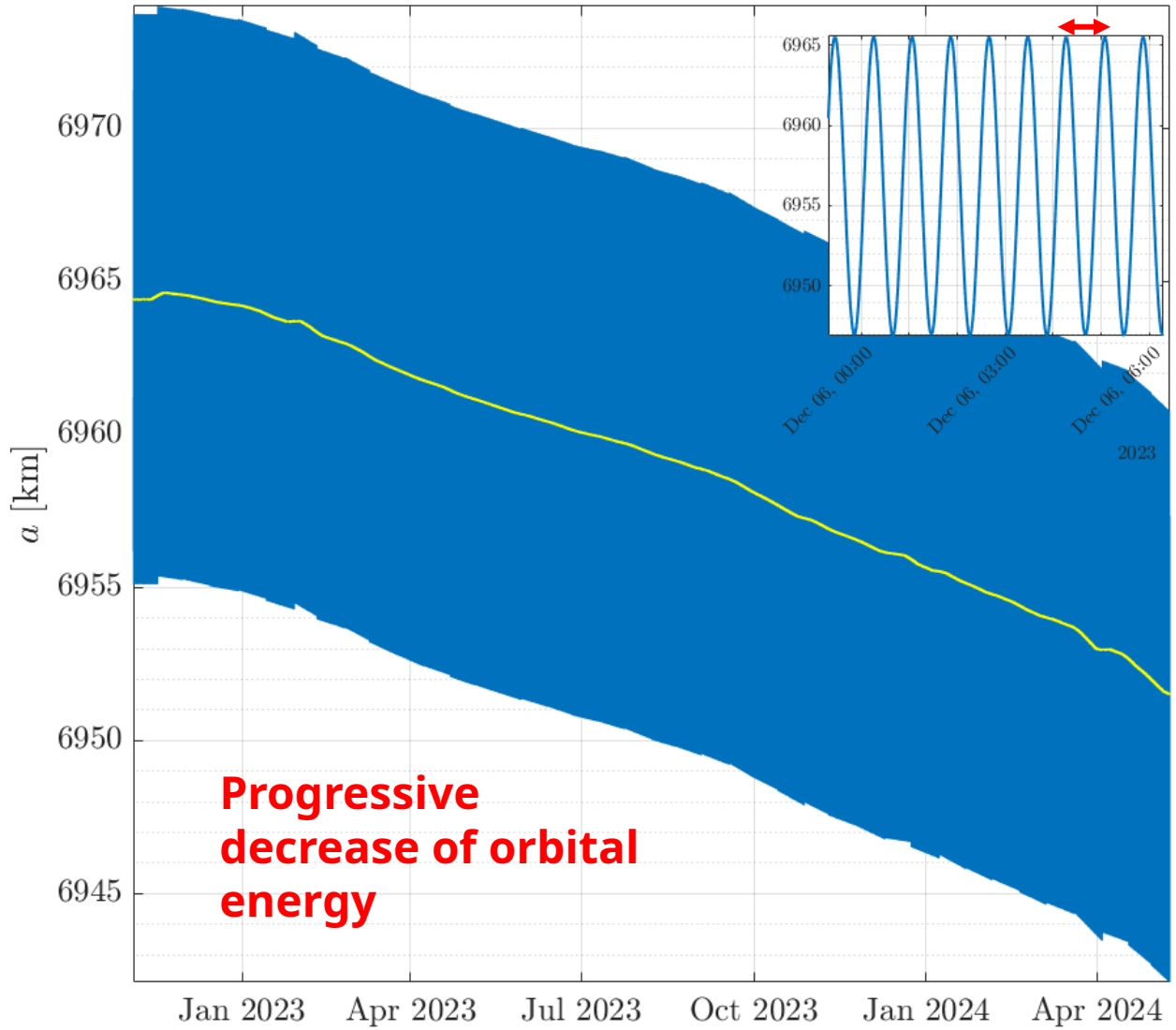
- Maximum solar zenith angle of ~31.61 reached on the **23-Jun-2023 08:10:00**

- Minimum solar zenith angle of ~2.9747 reached on the **14-Oct-2023 05:35:59**

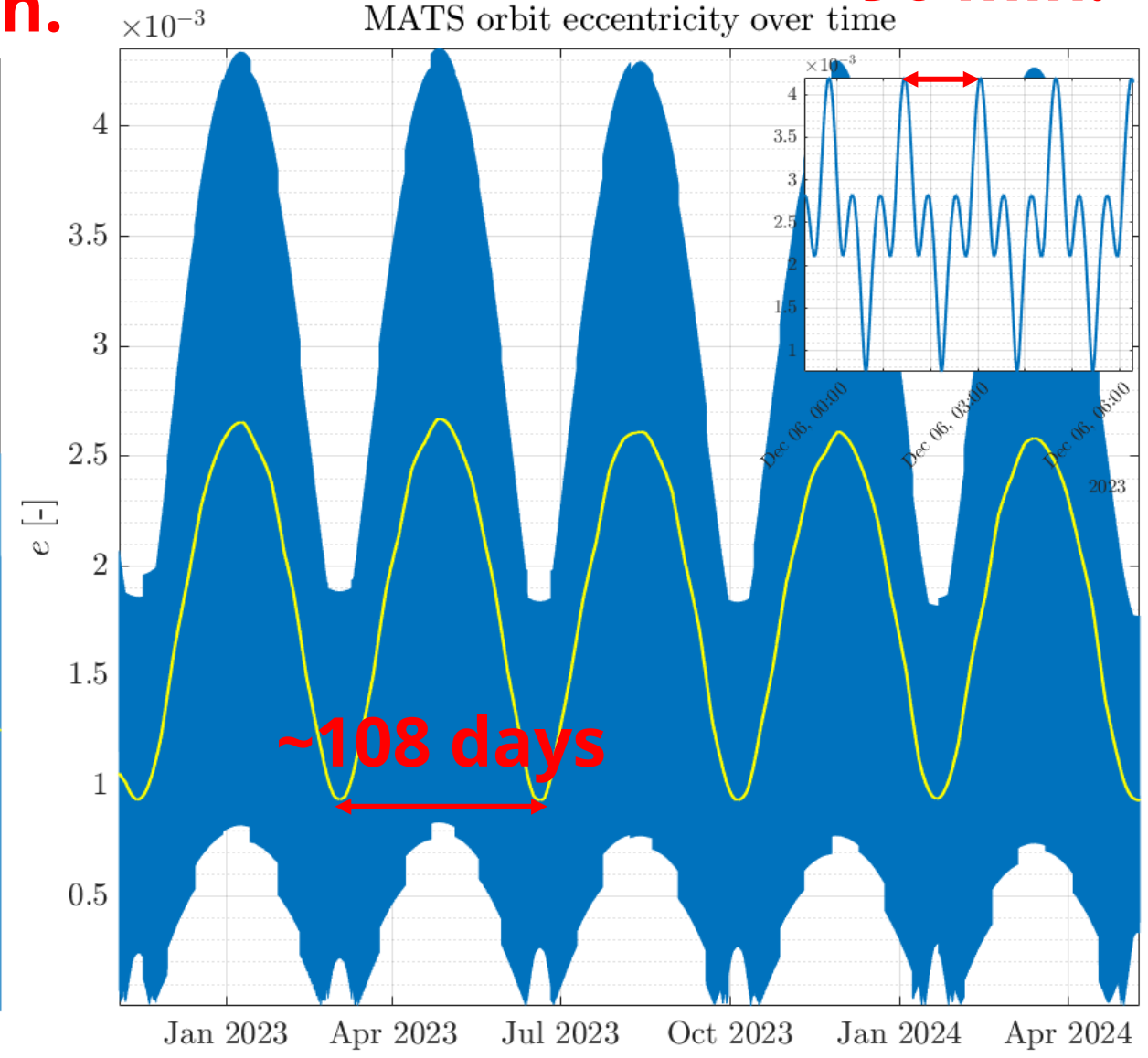


MATS orbit – Orbital Parameters (T~96 min.)

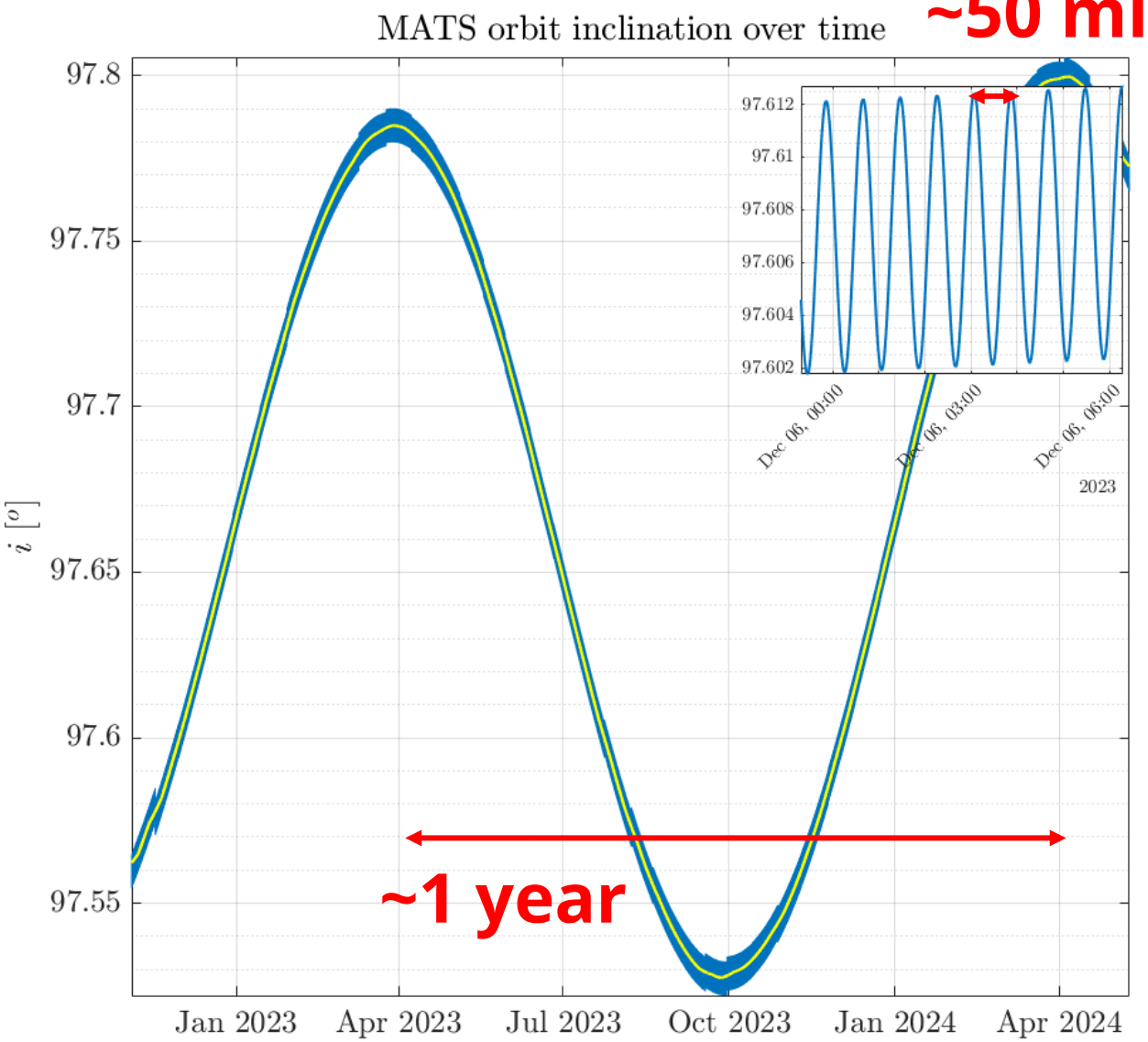
~50 min.

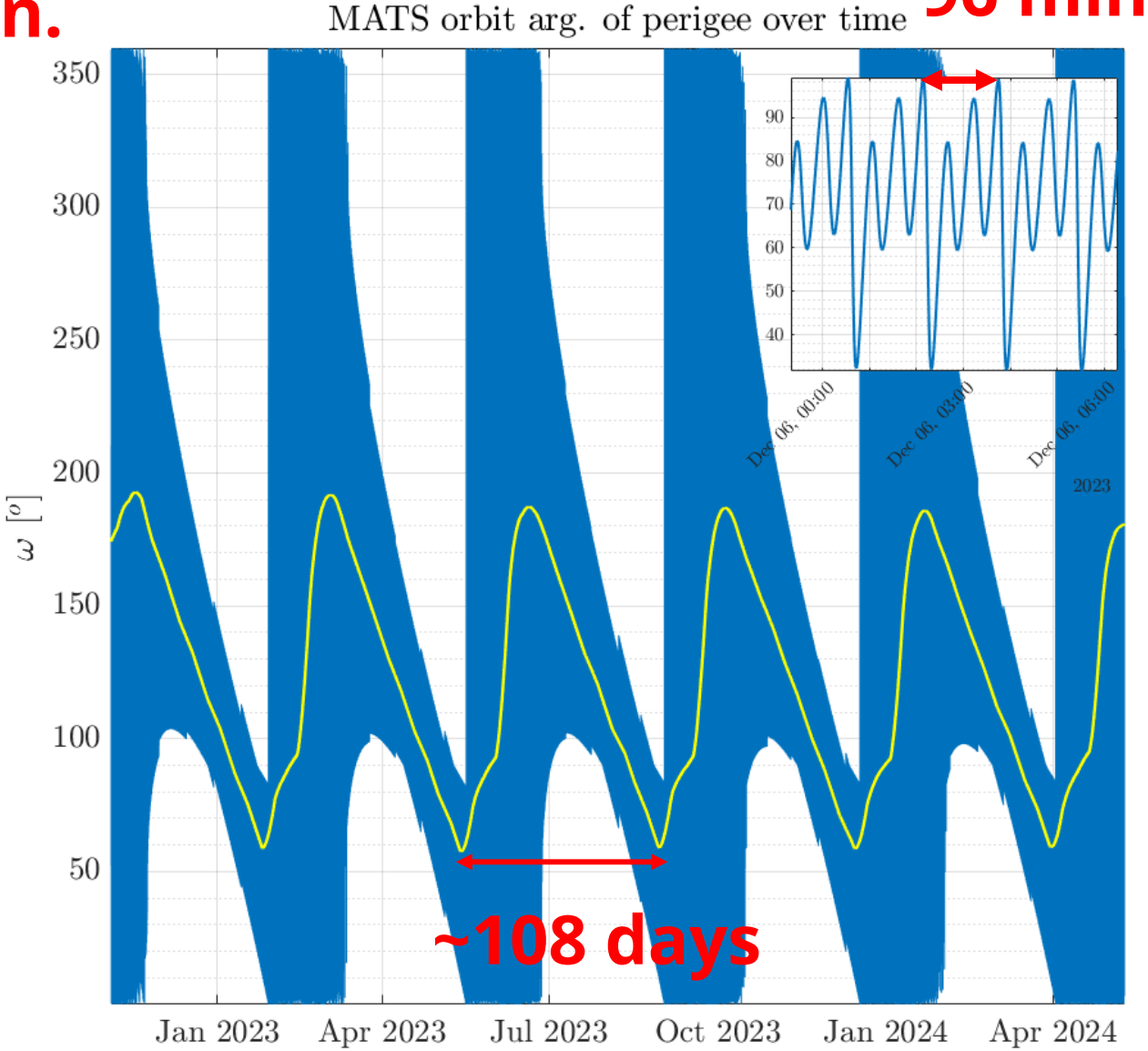


~96 min.



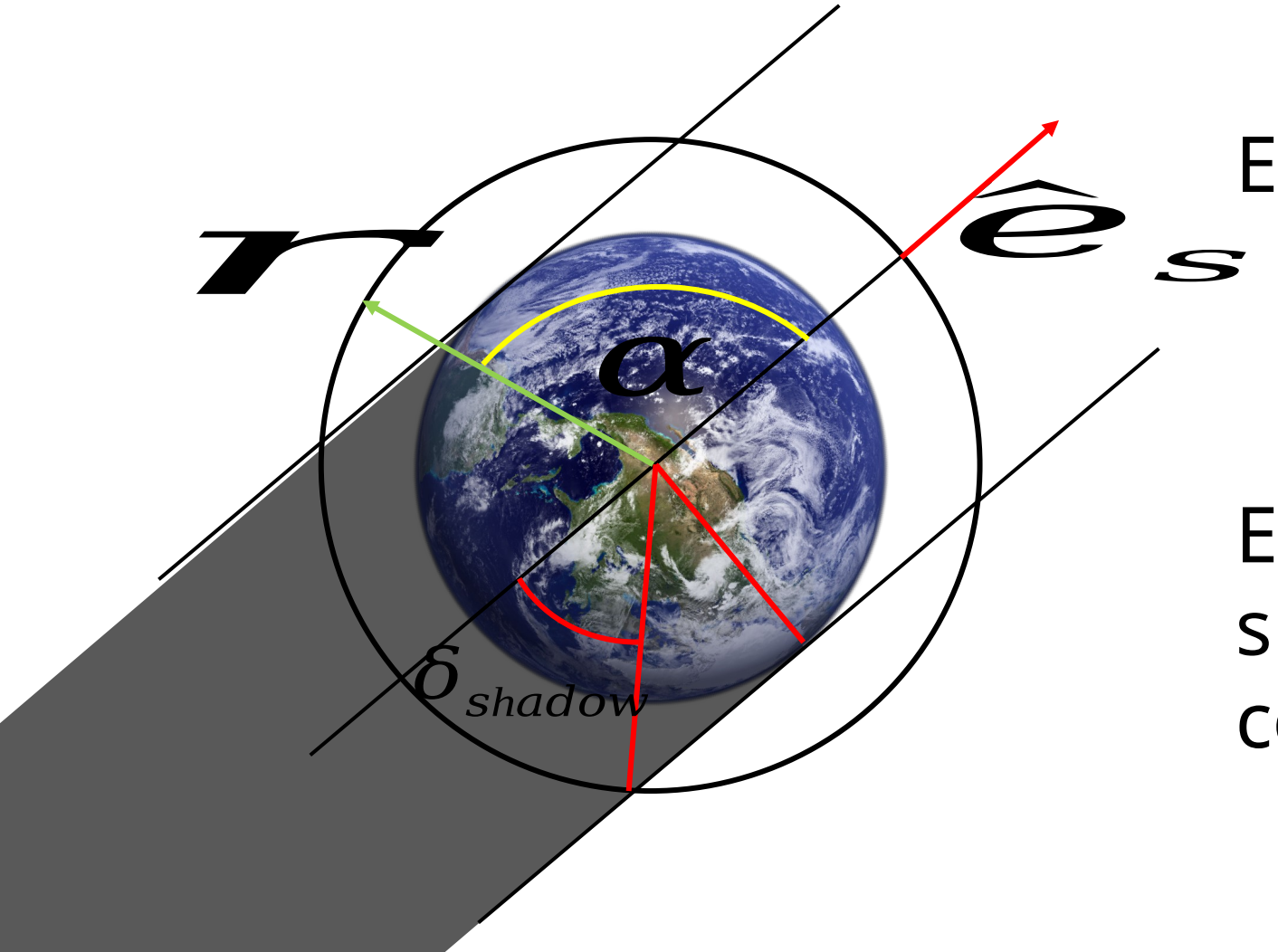
MATS orbit – Orbital Parameters (T~96 min.)





MATS orbit – Eclipses

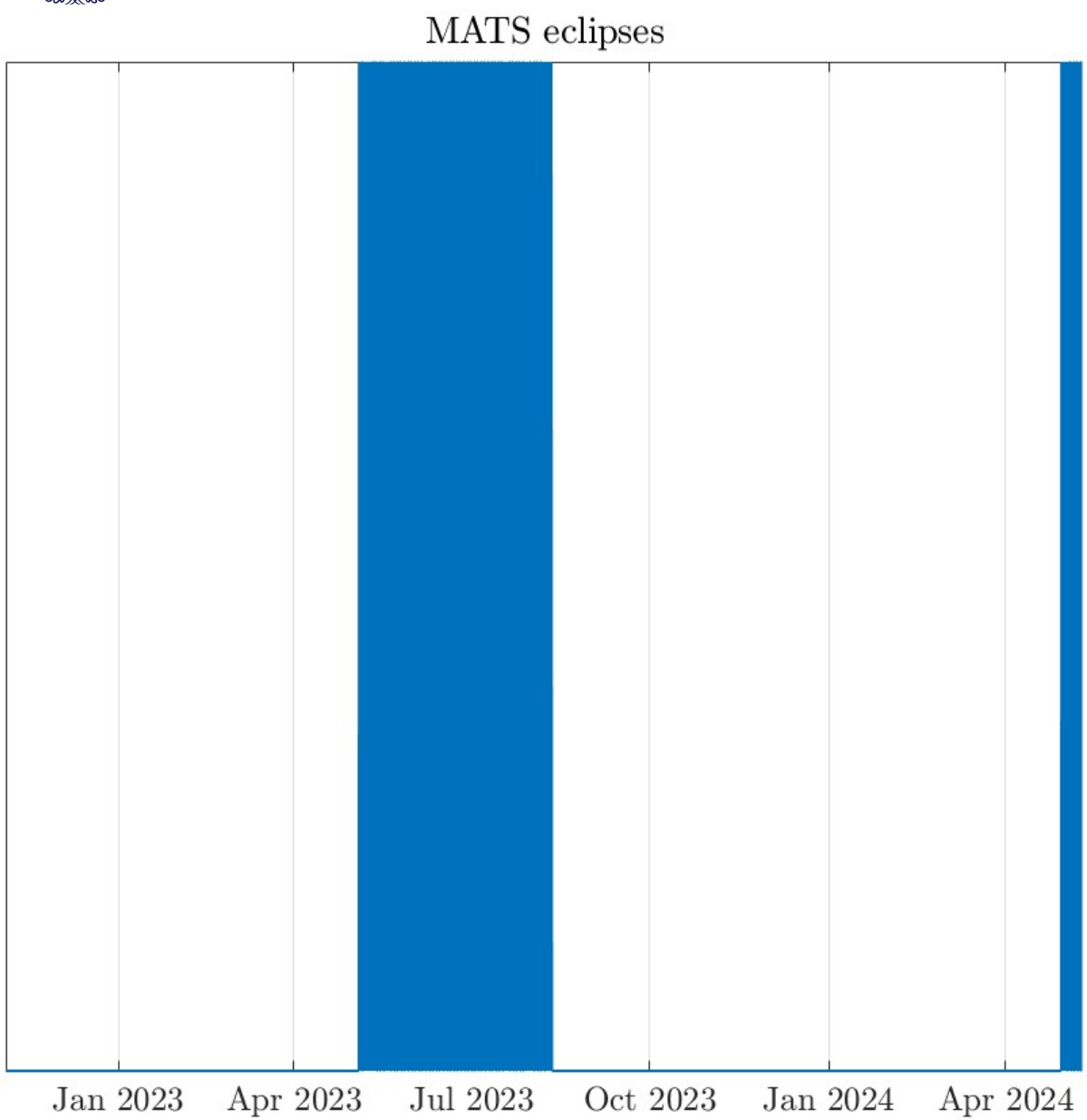
The following simplified model has been used to characterise MATS eclipses.

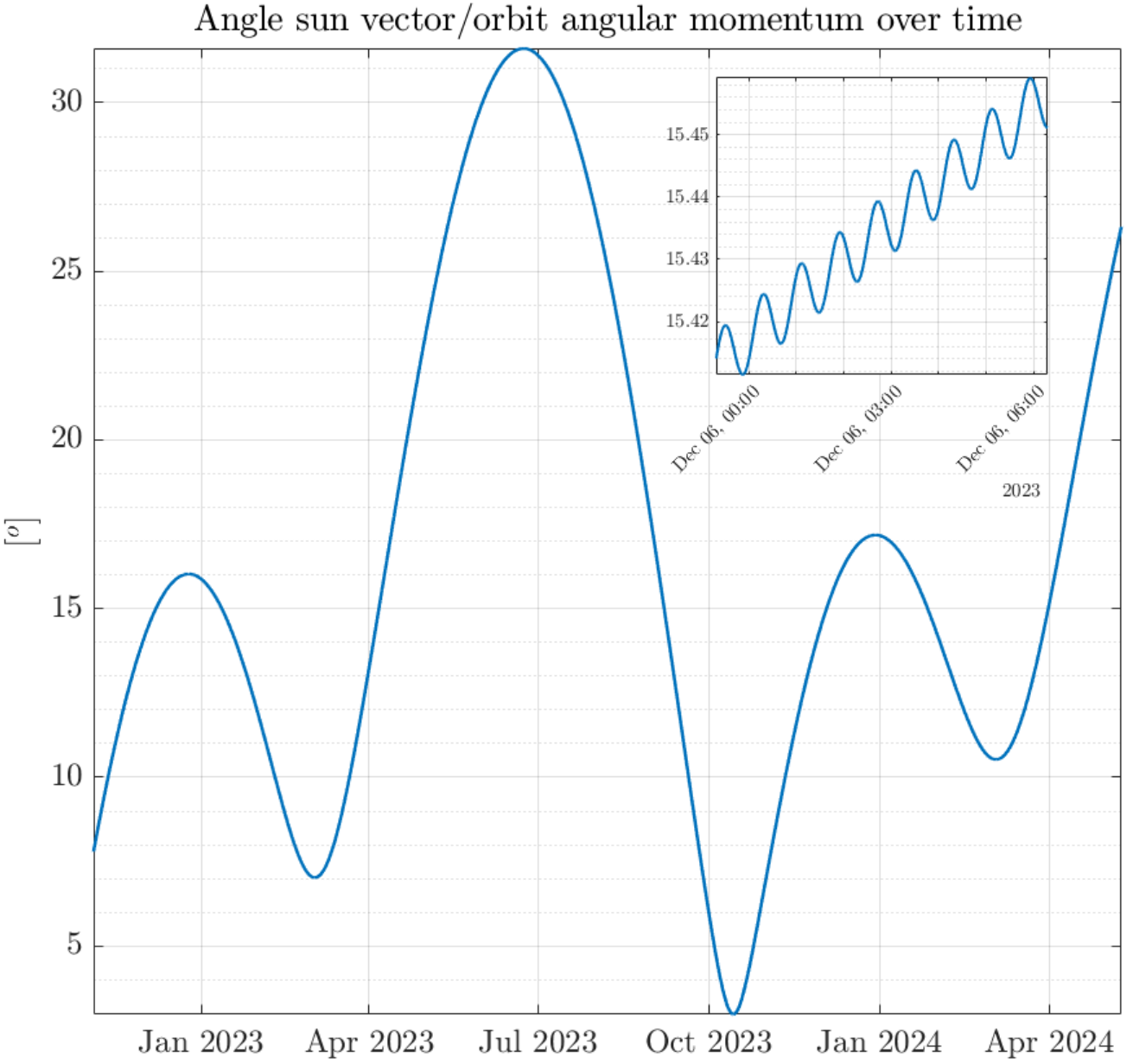


Eclipse present if:

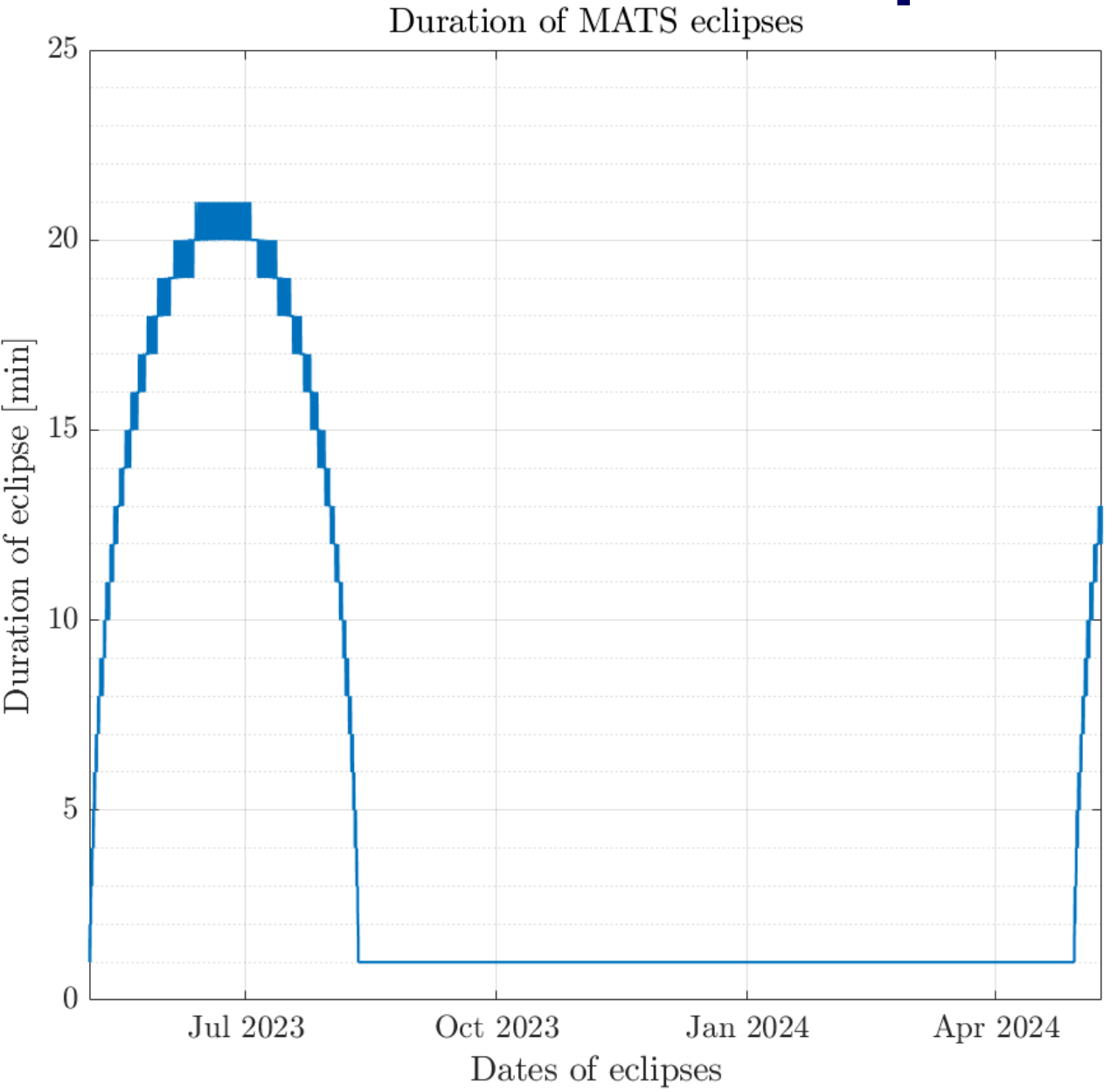
Earth assumed as a sphere, computed continuously.

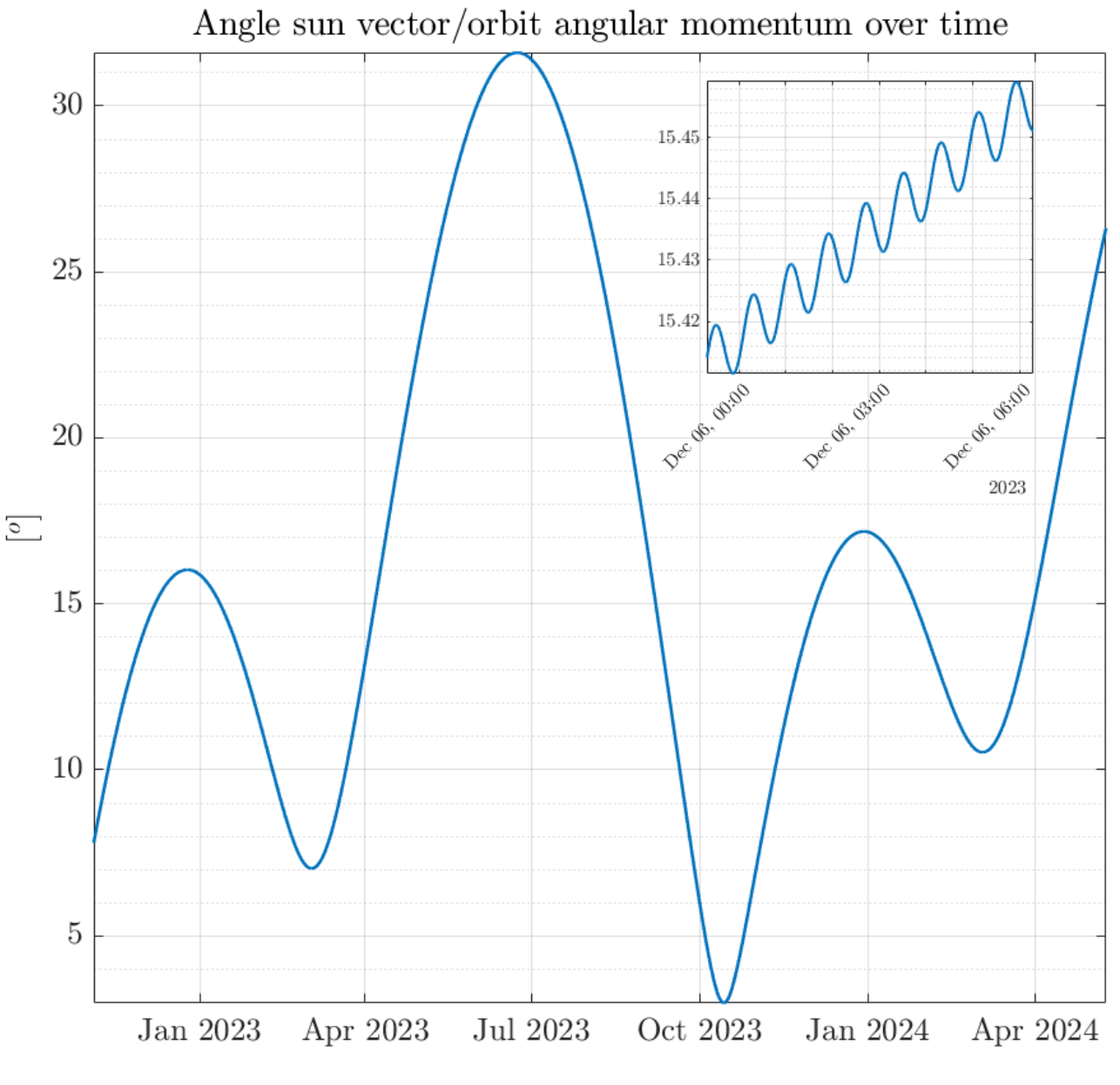
MATS orbit – Eclipses



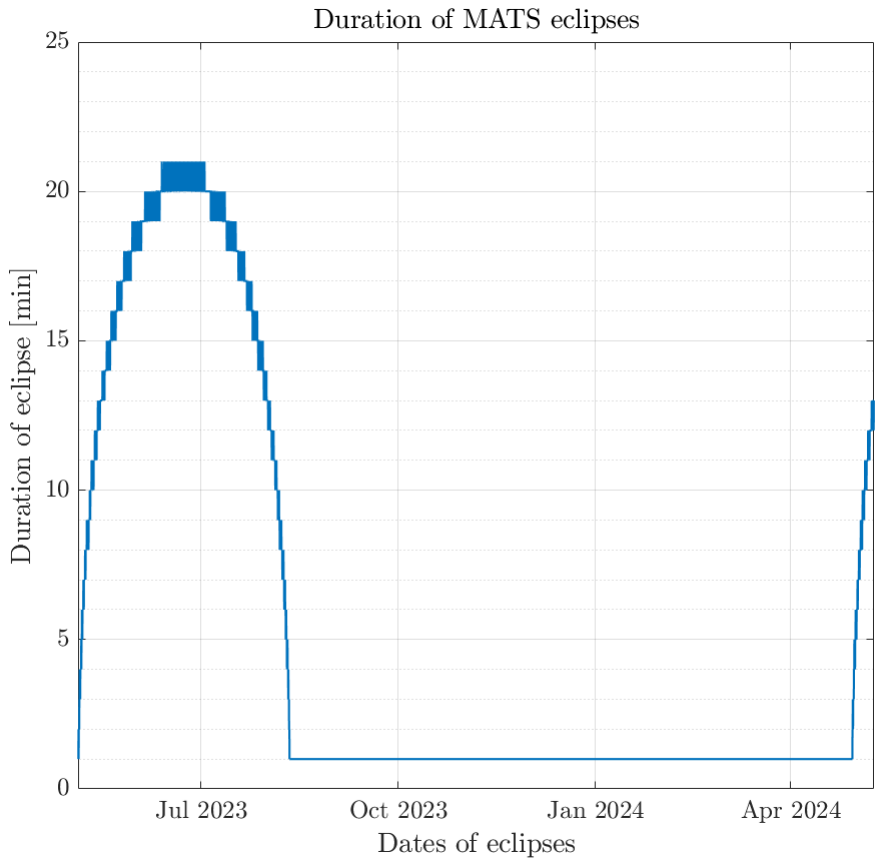


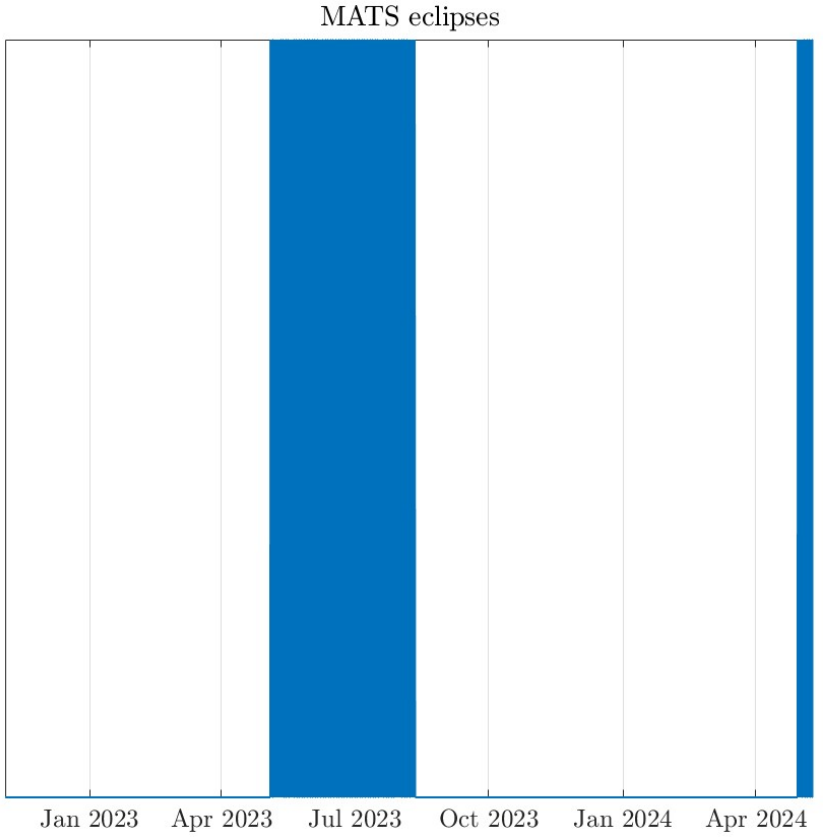
MATS orbit – Eclipses





MATS orbit – Eclipses





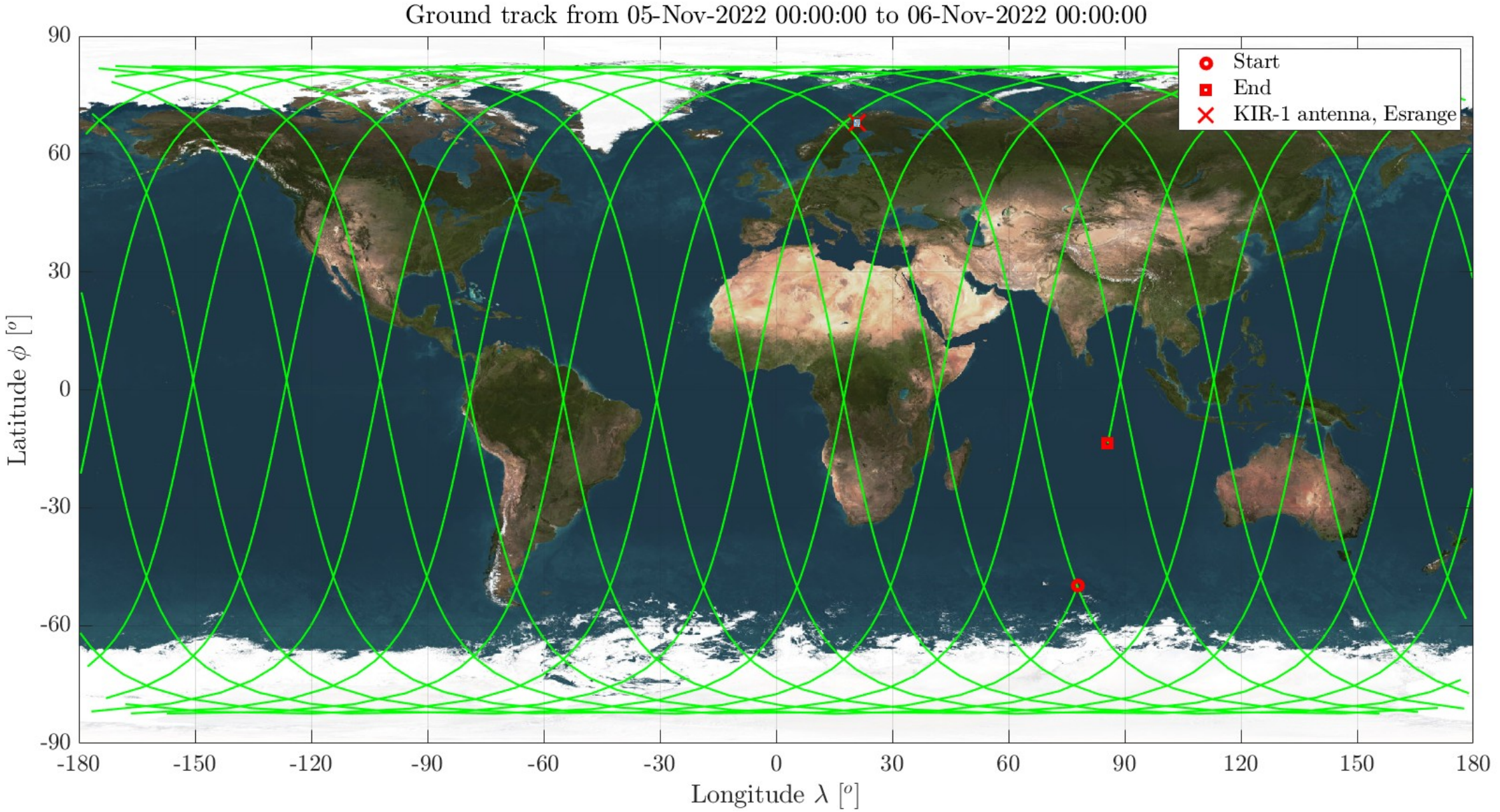
- Total number of eclipses experienced since launch: 1633
- Longest eclipse experienced by MATS: **21 minutes**, on the **12-Jun-2023 18:49:00**
- Average eclipse experienced by MATS: **15.50 minutes**

MATS orbit – Visibility Analysis from ESRANGE

Considered coordinates for KIR-1 antenna:

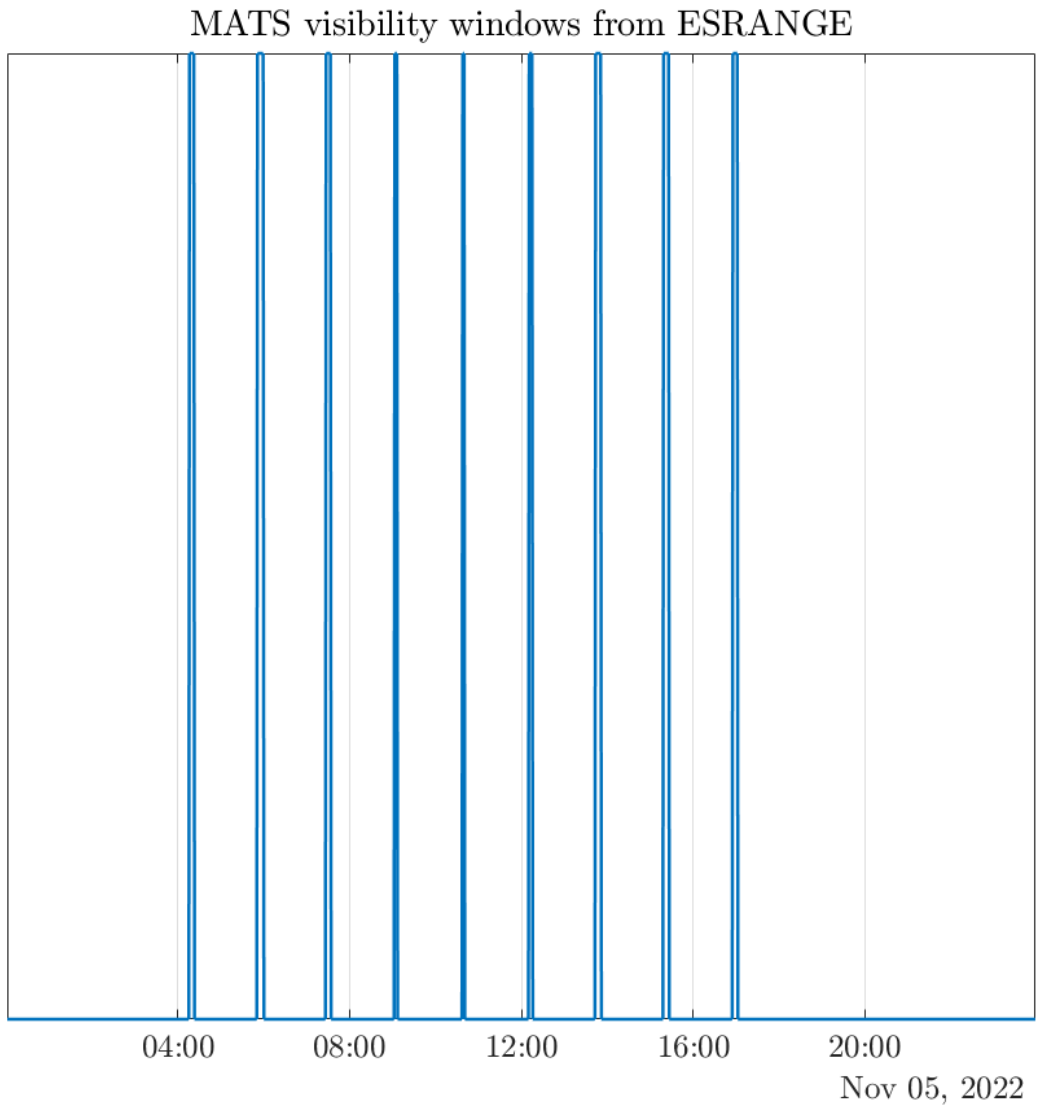
- +67° 51' 25.66”
- +20° 57' 51.57”
- 402.2 m (WGS-84)

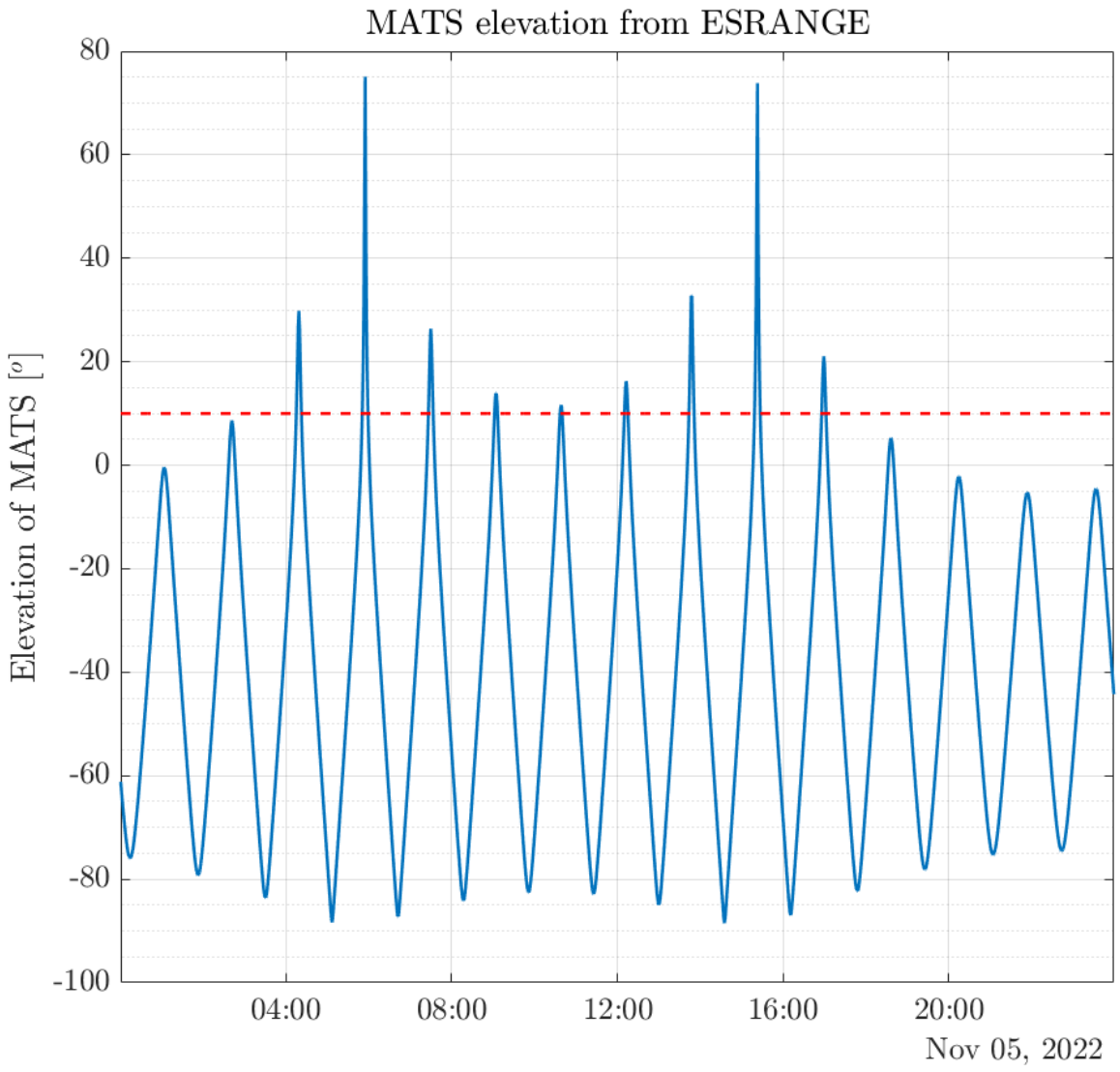
MATS orbit – Visibility Analysis from ESRANGE



MATS orbit – Visibility Analysis from ESRANGE

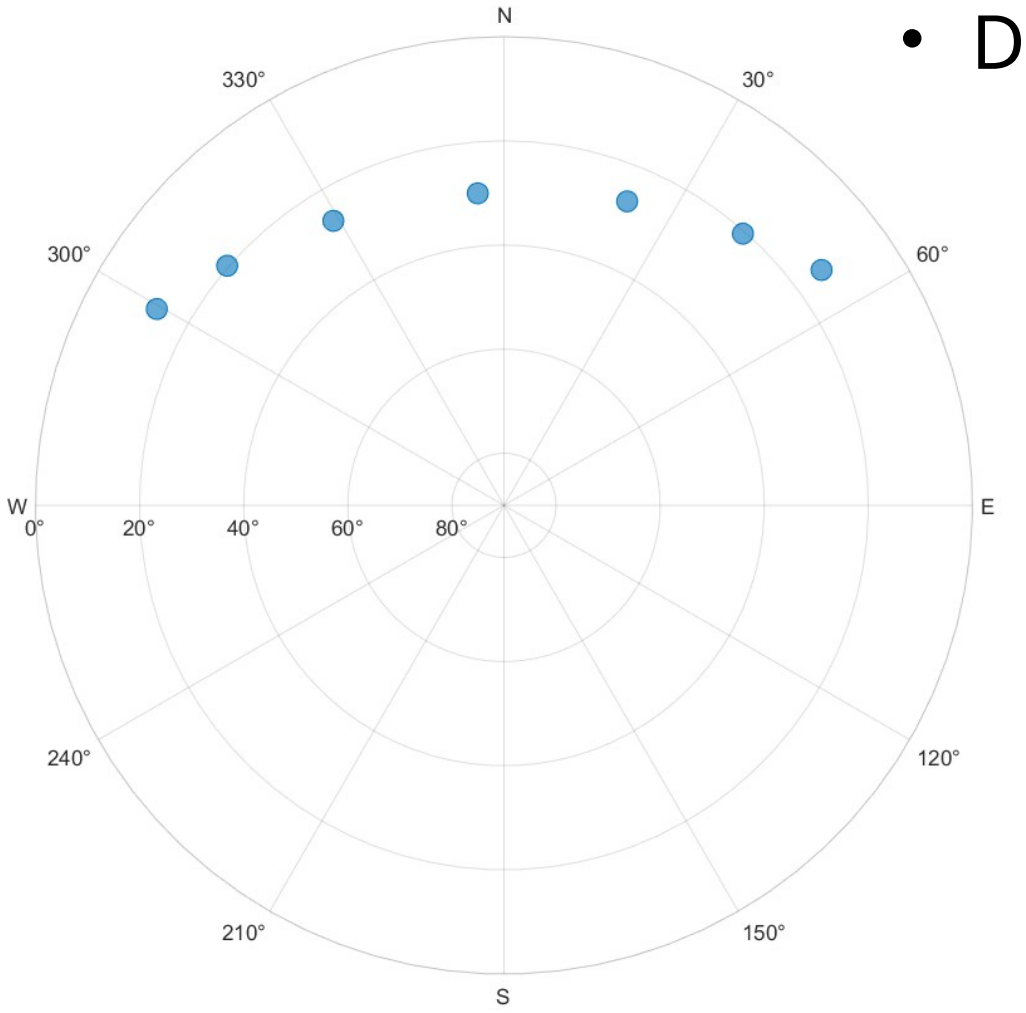
Signal elevation mask for MATS signals assumed to be 10°





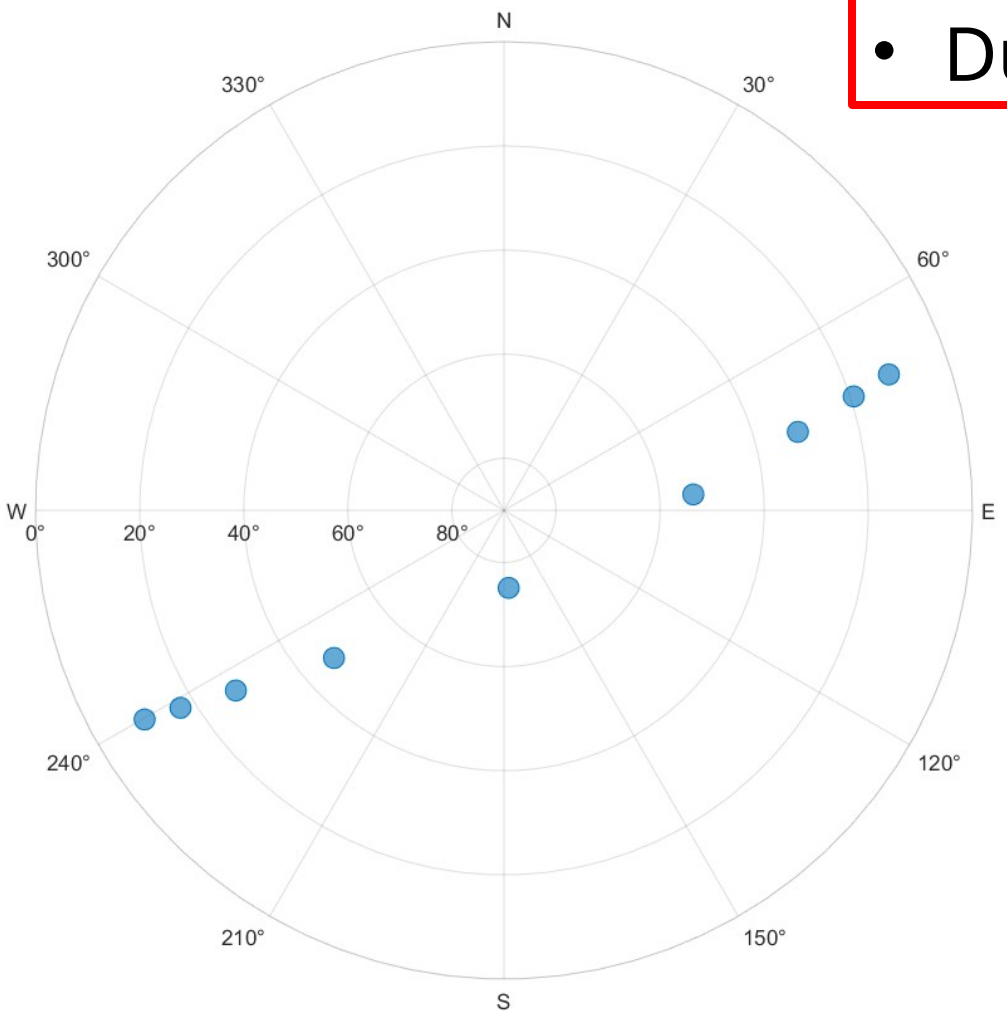
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 04:16:00
- Duration: 6 minutes



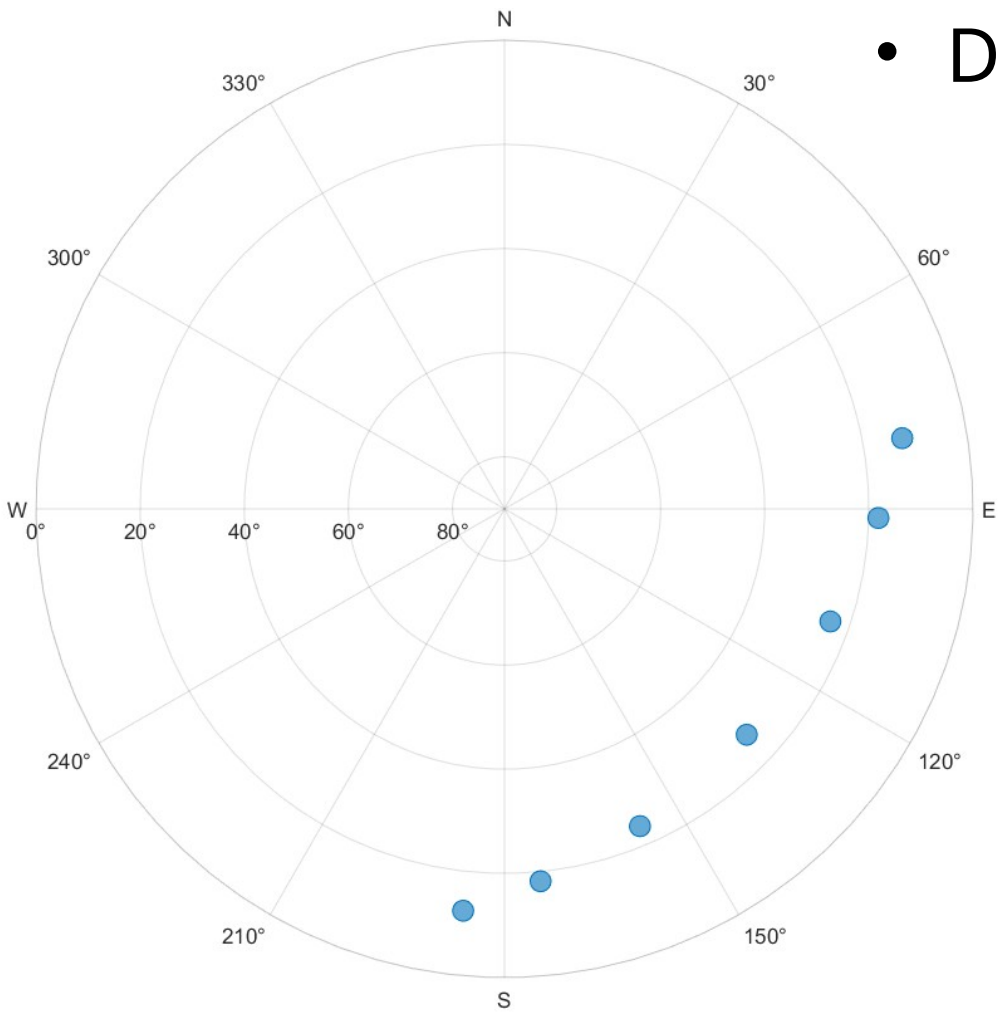
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 05:50:59
- Duration: 8 minutes



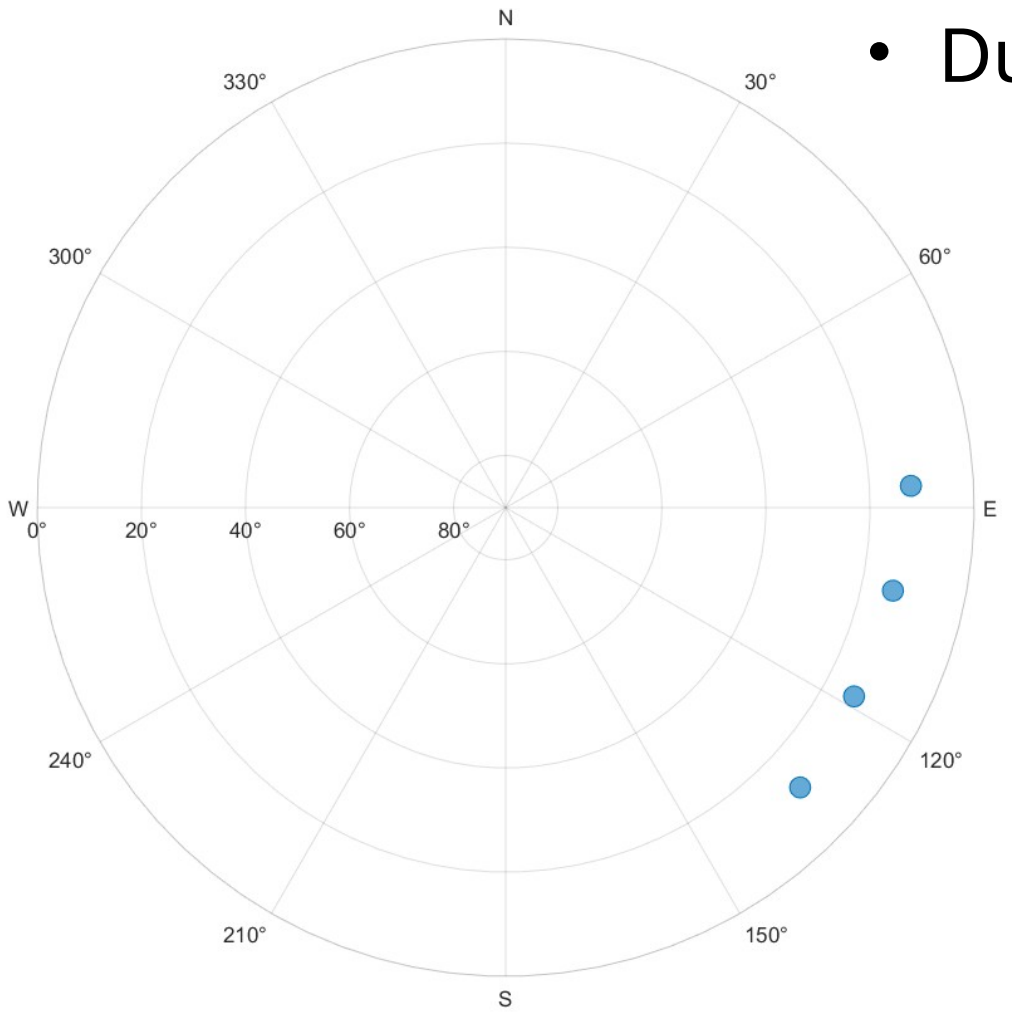
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 07:27:00
- Duration: 6 minutes



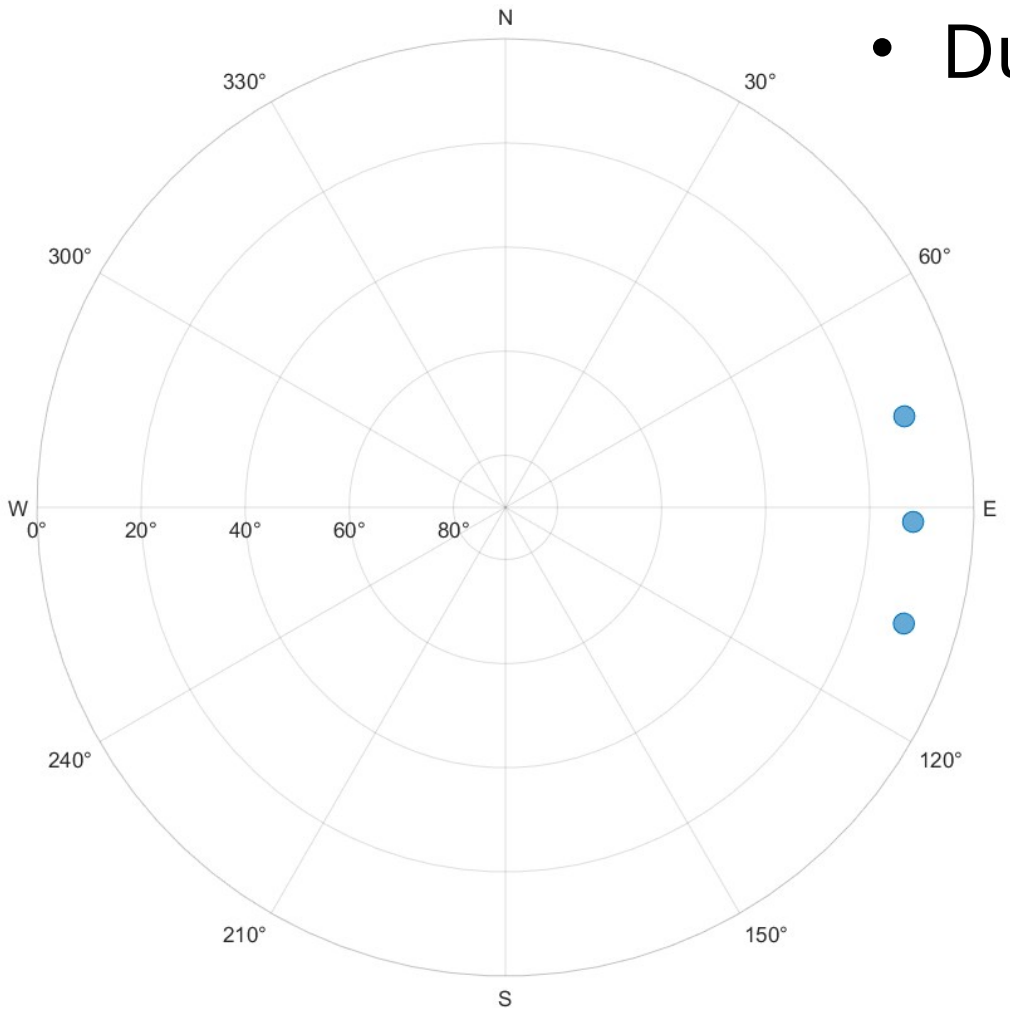
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 09:02:59
- Duration: 3 minutes



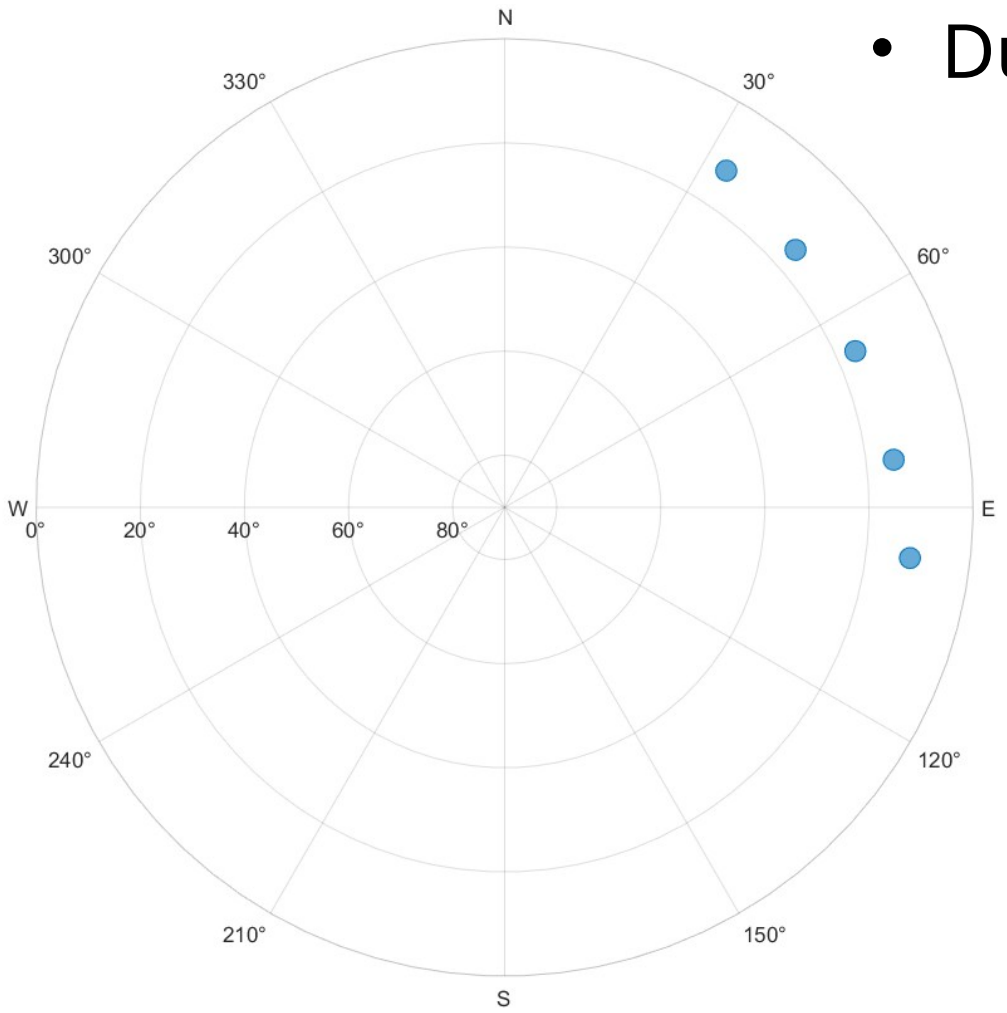
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 10:38:00
- Duration: 2 minutes



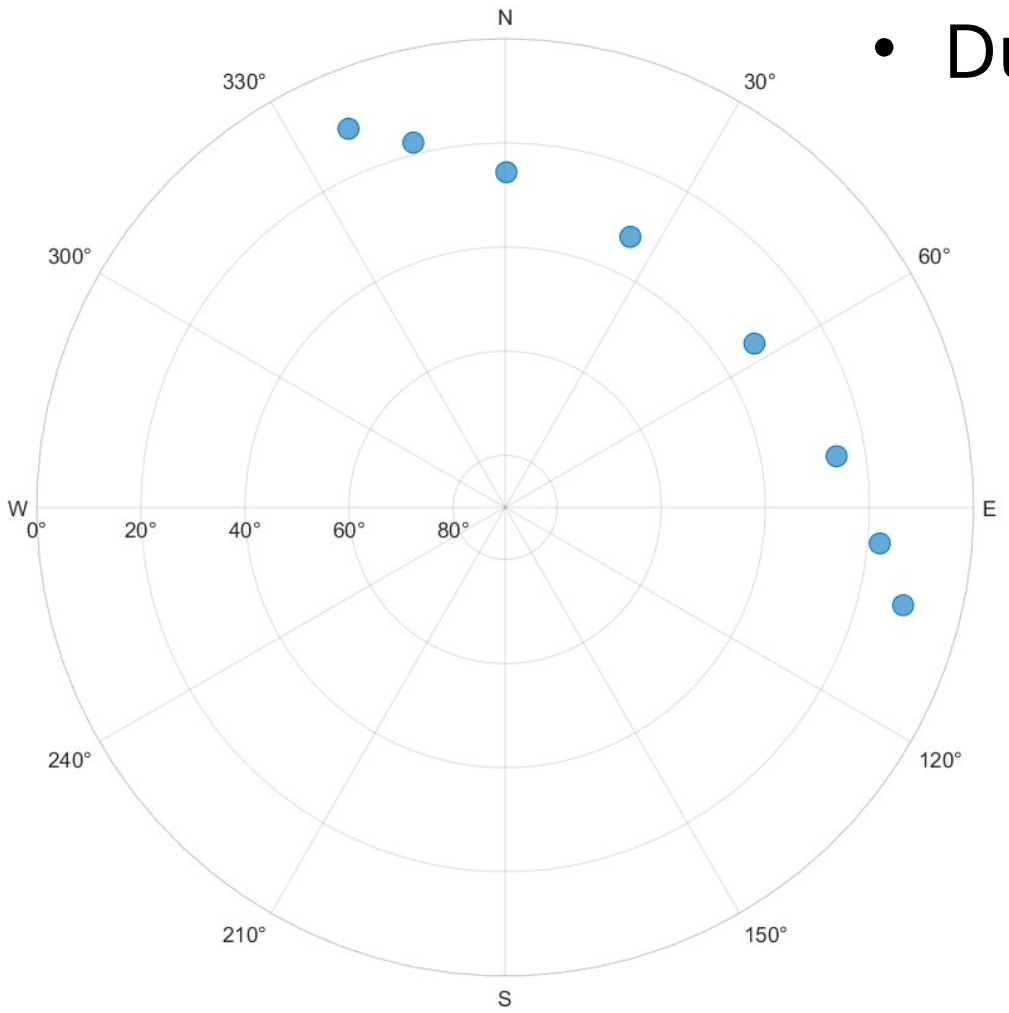
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 12:11:00
- Duration: 4 minutes



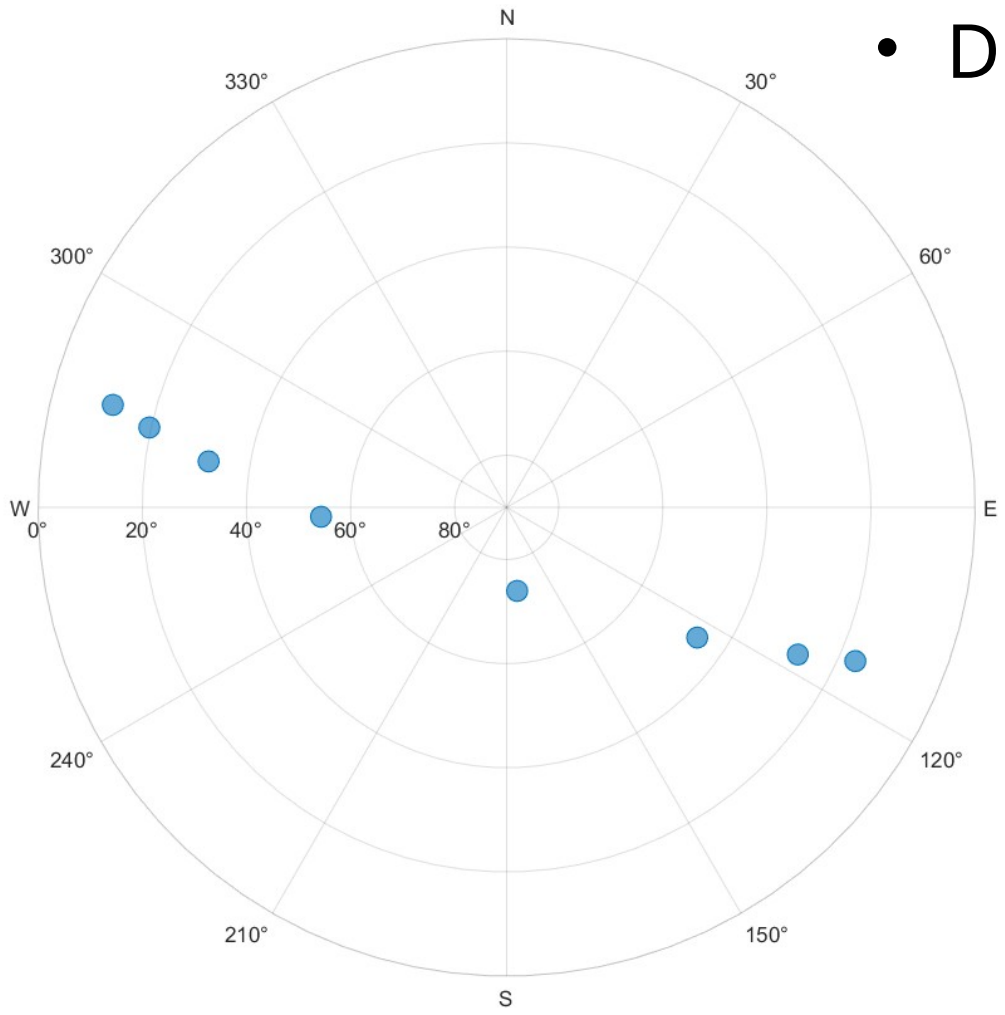
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 13:43:59
- Duration: 7 minutes



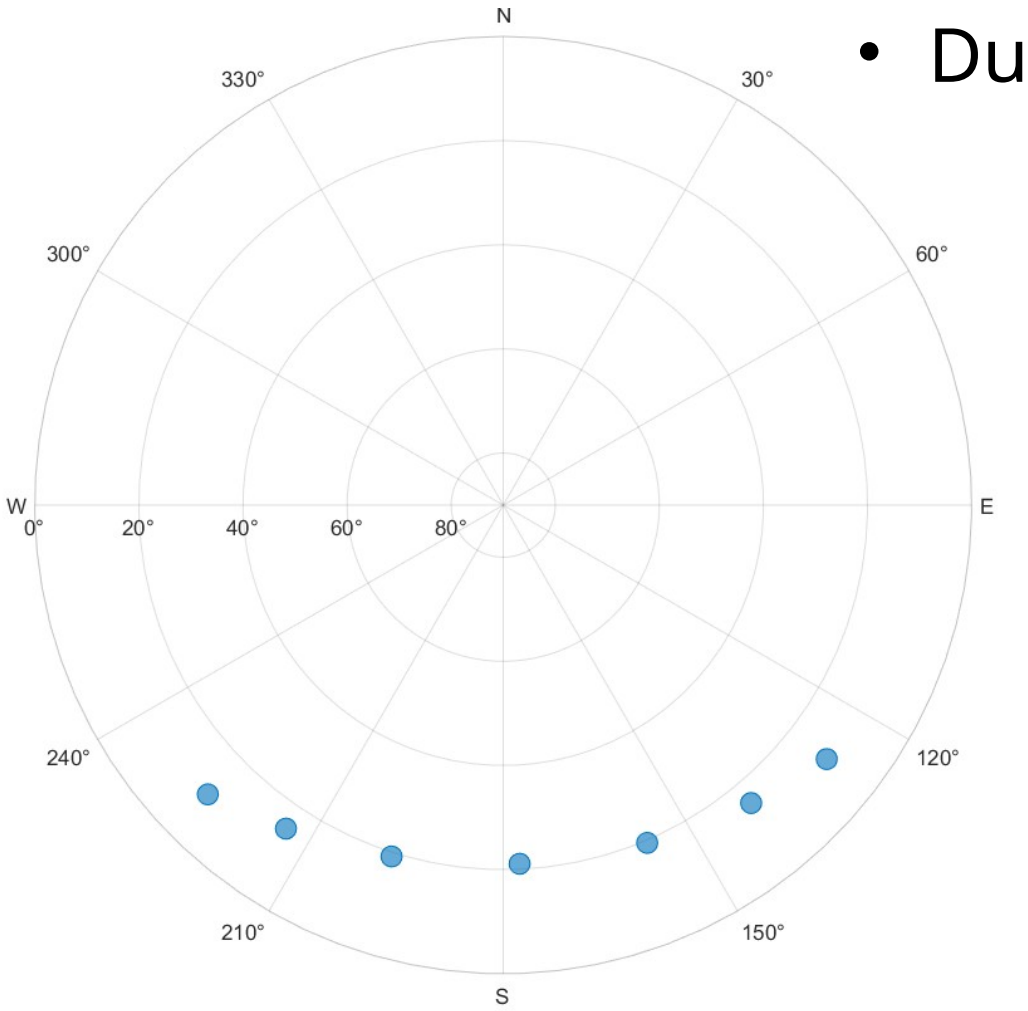
MATS orbit – Visibility Analysis from ESRANGE

- 05-Nov-2022 15:19:00
- Duration: 7 minutes

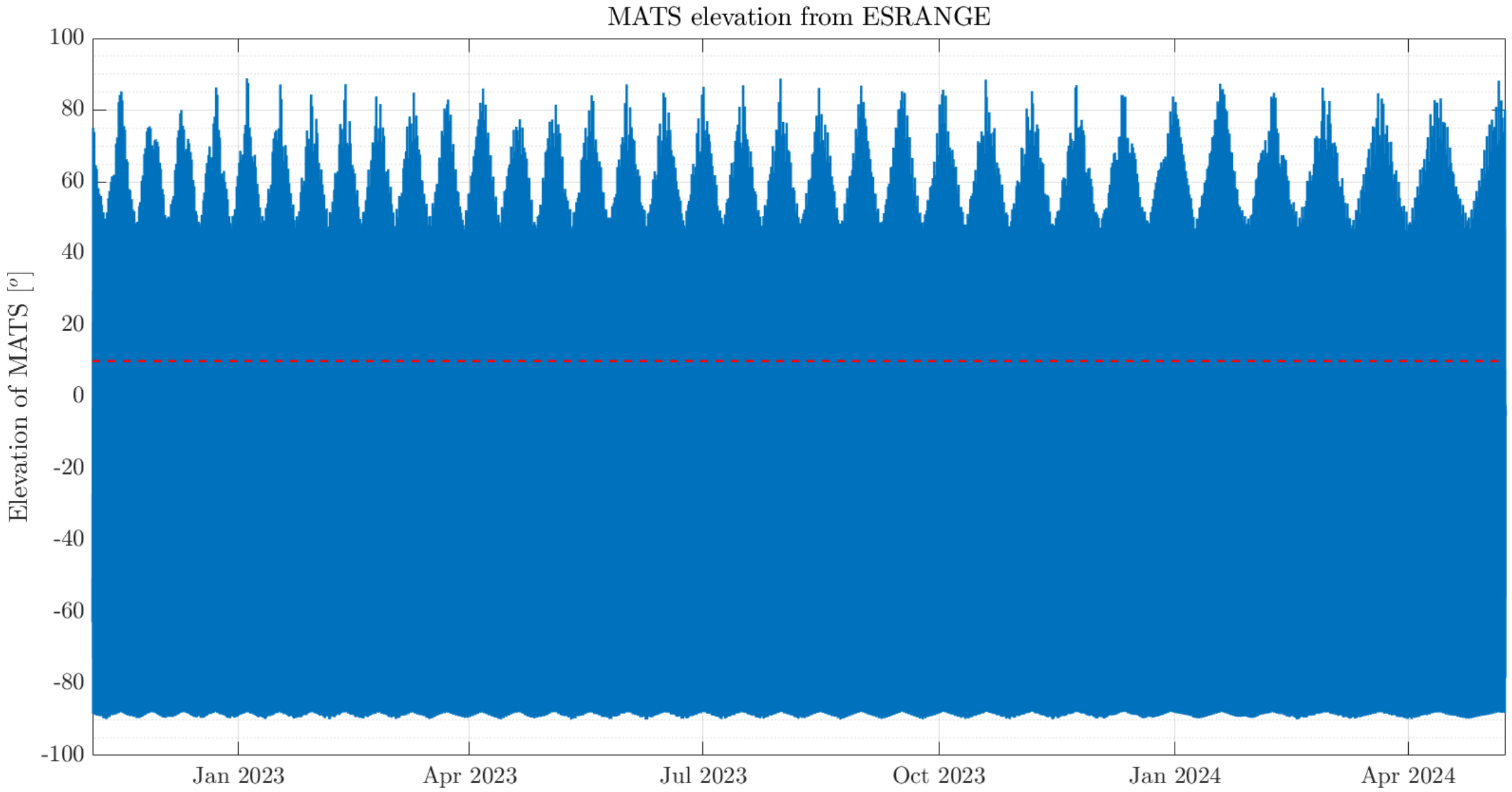


MATS orbit – Visibility Analysis from ESRANGE

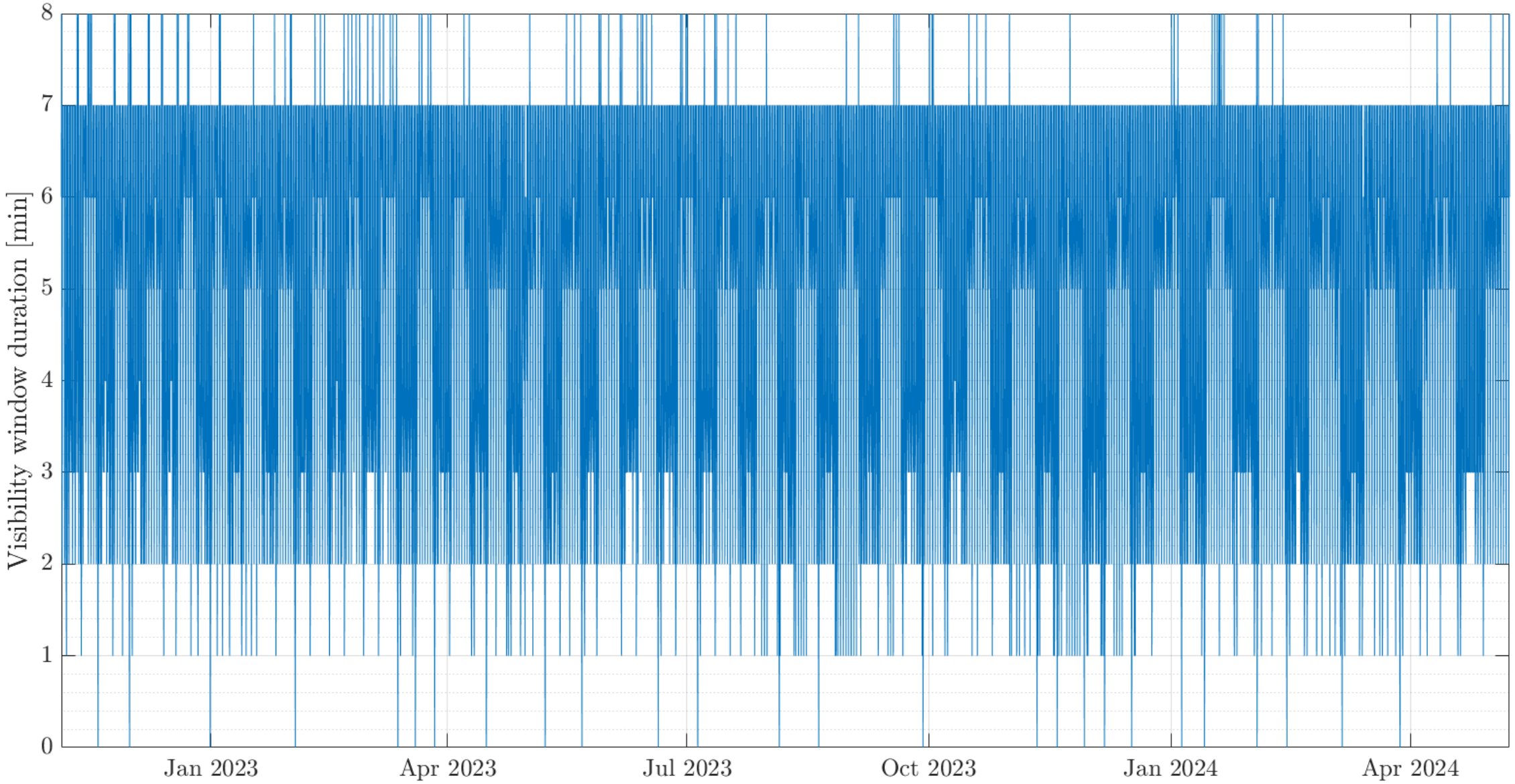
- 05-Nov-2022 16:55:59
- Duration: 6 minutes



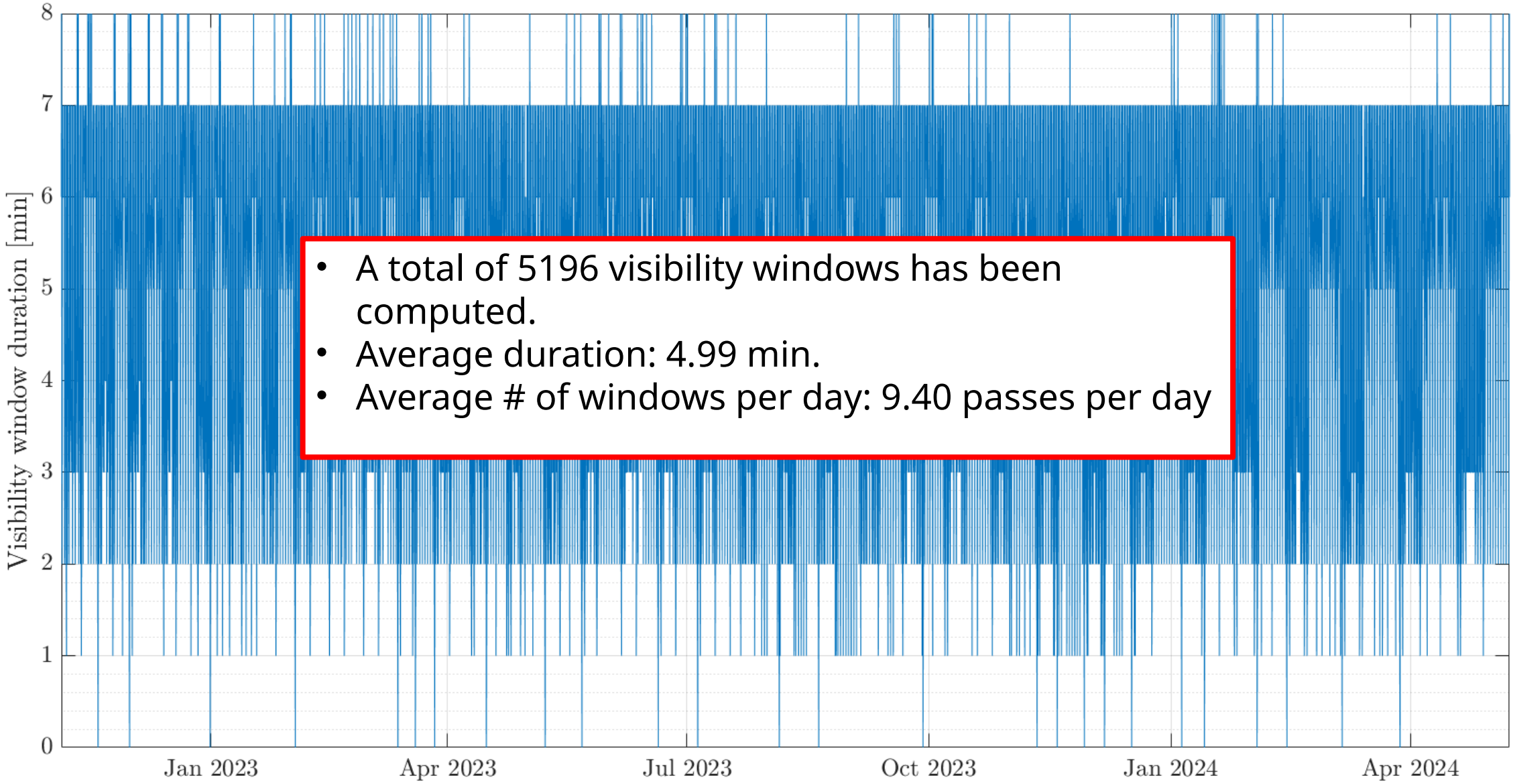
MATS orbit – Visibility Analysis from ESRANGE



MATS orbit – Visibility Analysis from ESRANGE



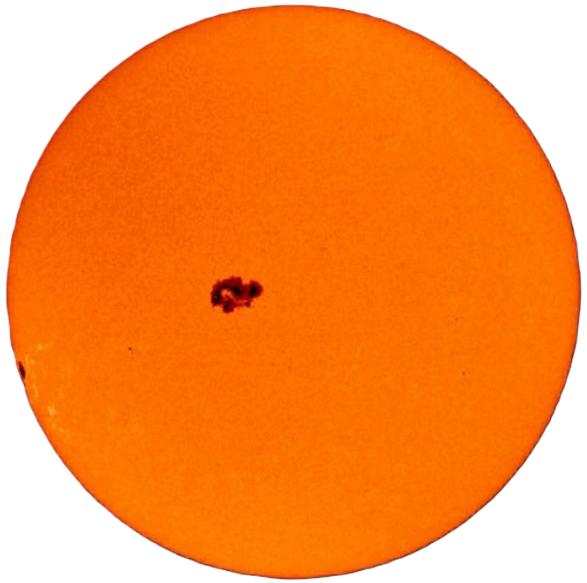
MATS orbit – Visibility Analysis from ESRANGE

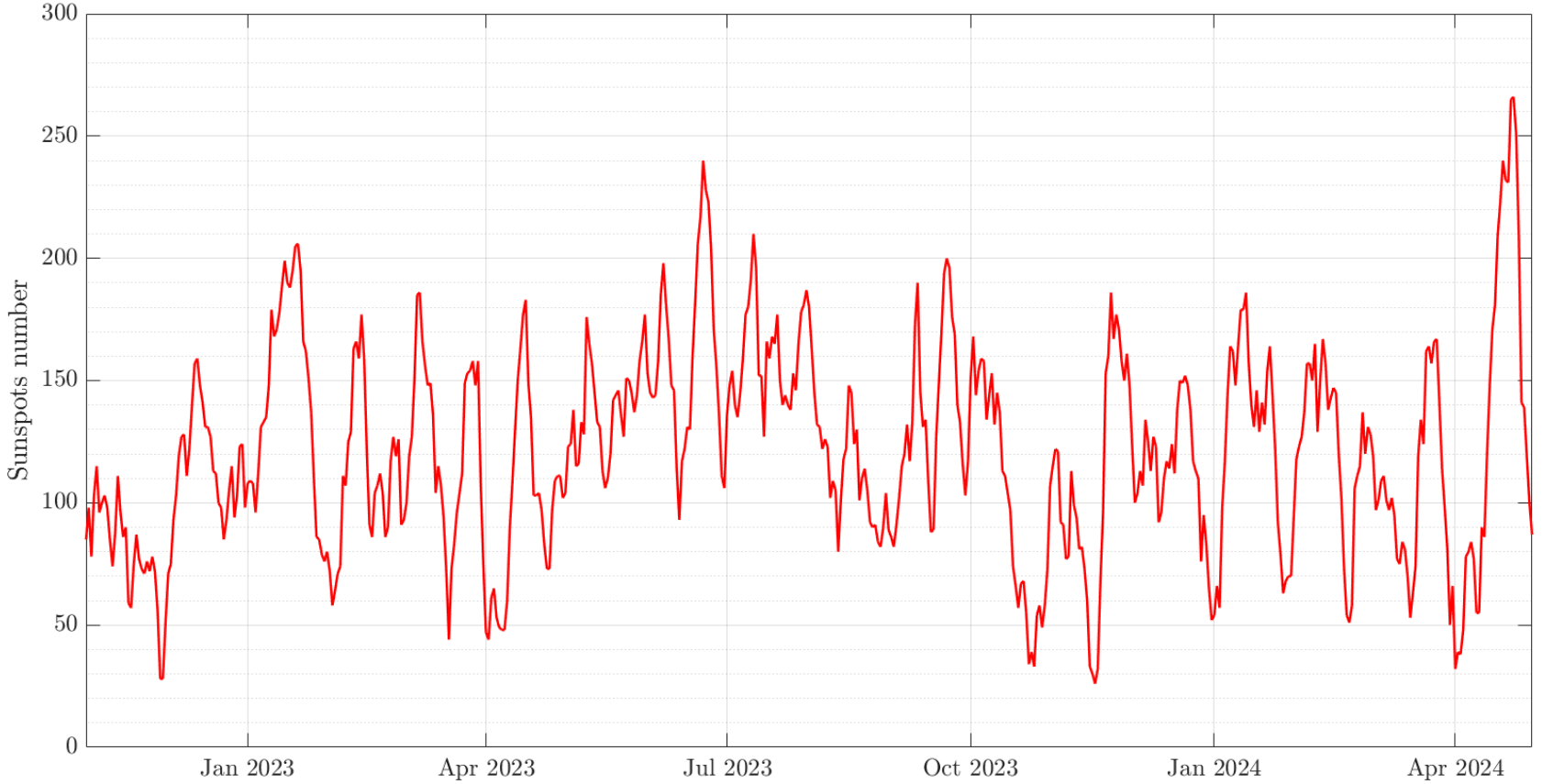


- A total of 5196 visibility windows has been computed.
- Average duration: 4.99 min.
- Average # of windows per day: 9.40 passes per day

MATS orbit – Solar Activity

For the scope of the current work, solar activity has been assessed using sunspots number as main indicator.

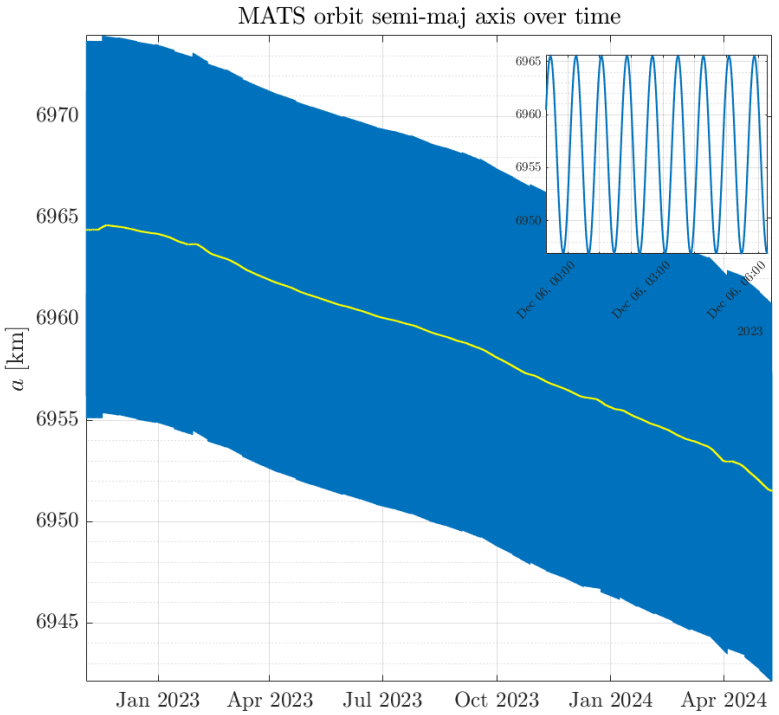




Sunspots data from: https://www.sidc.be/SILSO/datafiles

MATS orbit – Solar Activity

Because one of the main effects of high solar activity is the increase of density of the upper atmosphere, a stronger decrease in orbital energy is searched for when the sunspot number grows .



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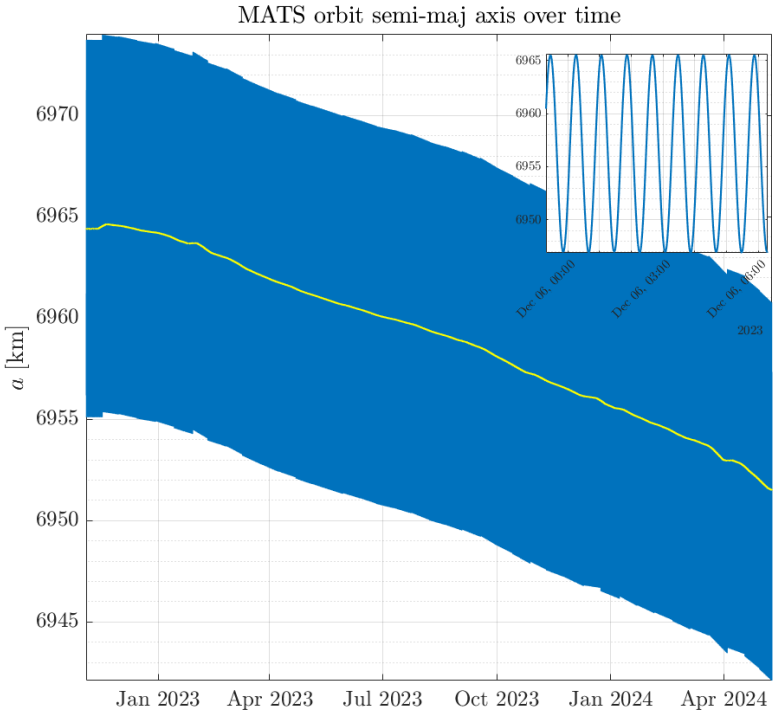

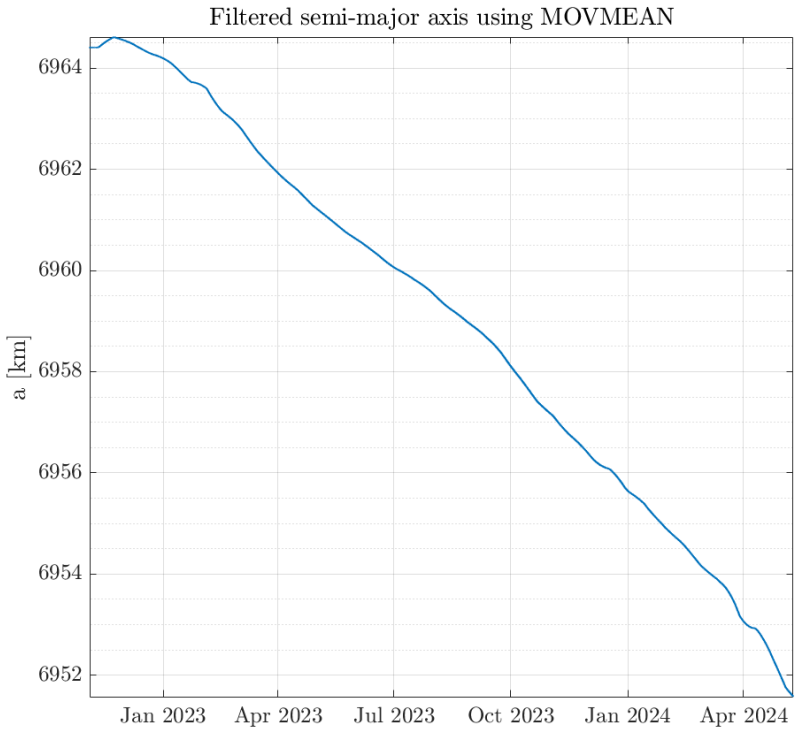

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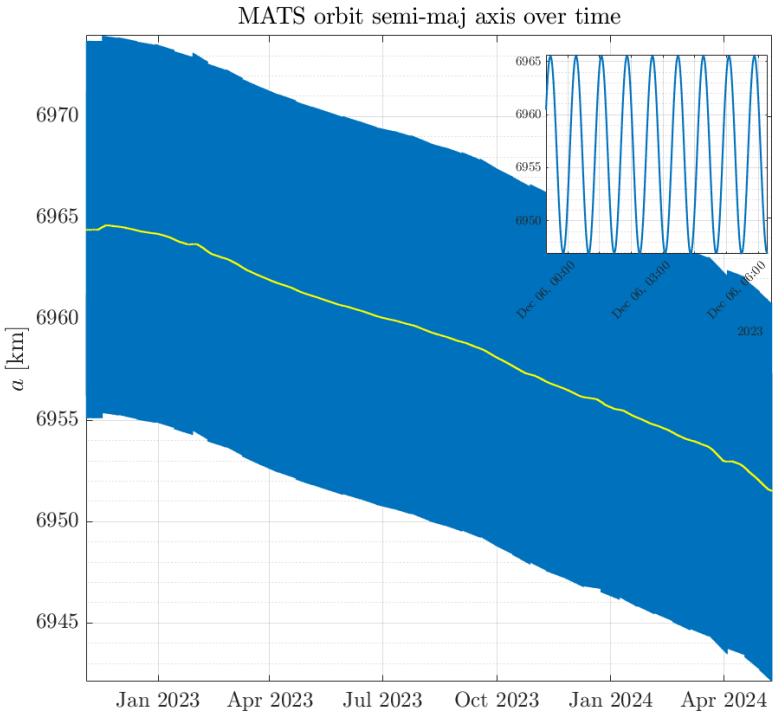

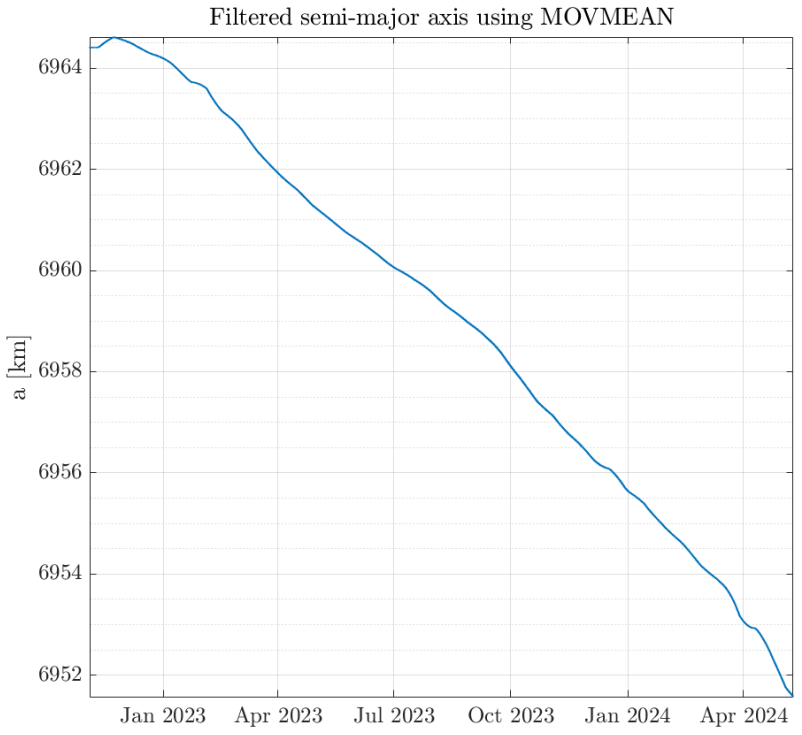

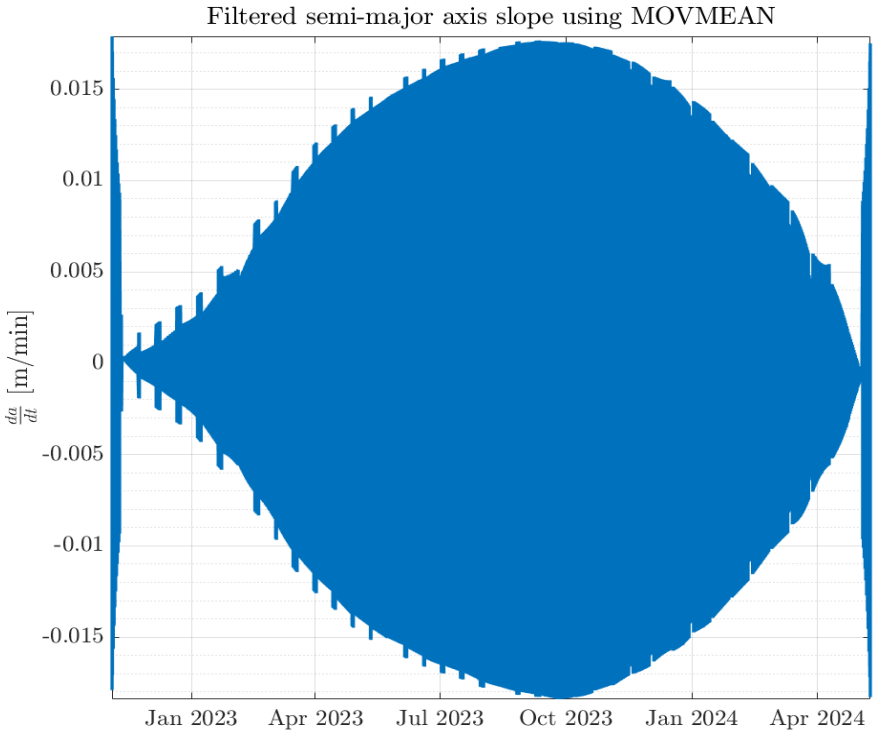

Using a moving averaging window resulted in noisy slopes, which cannot be used for further analysis

MATS orbit – Solar Activity

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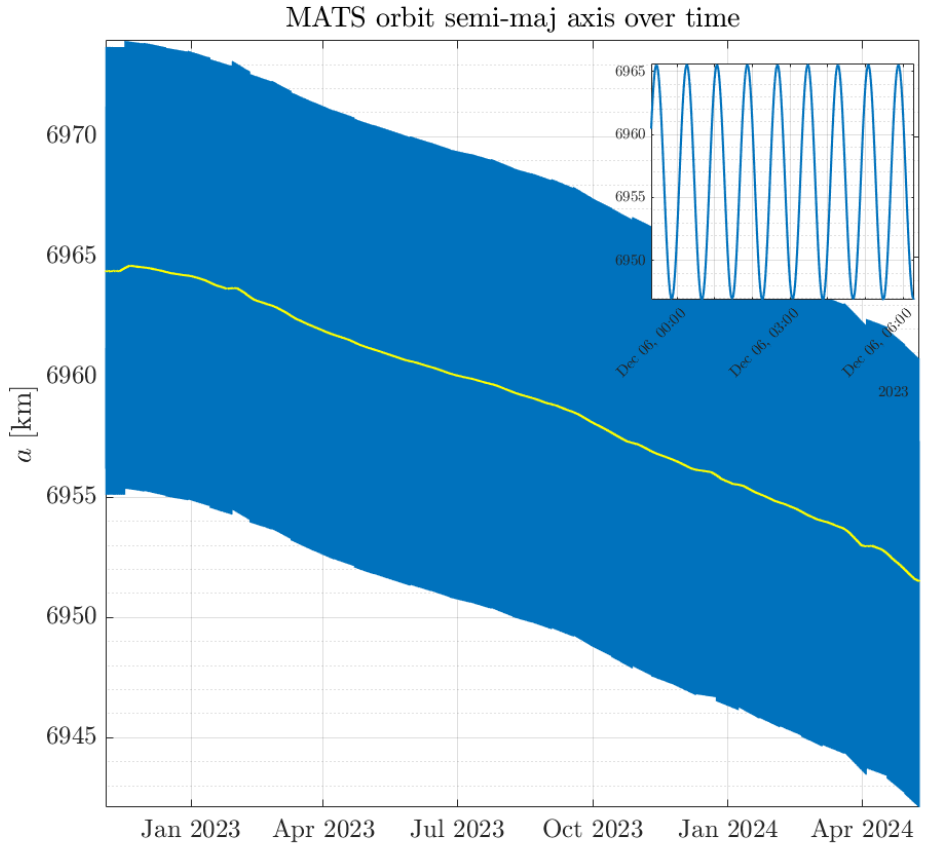

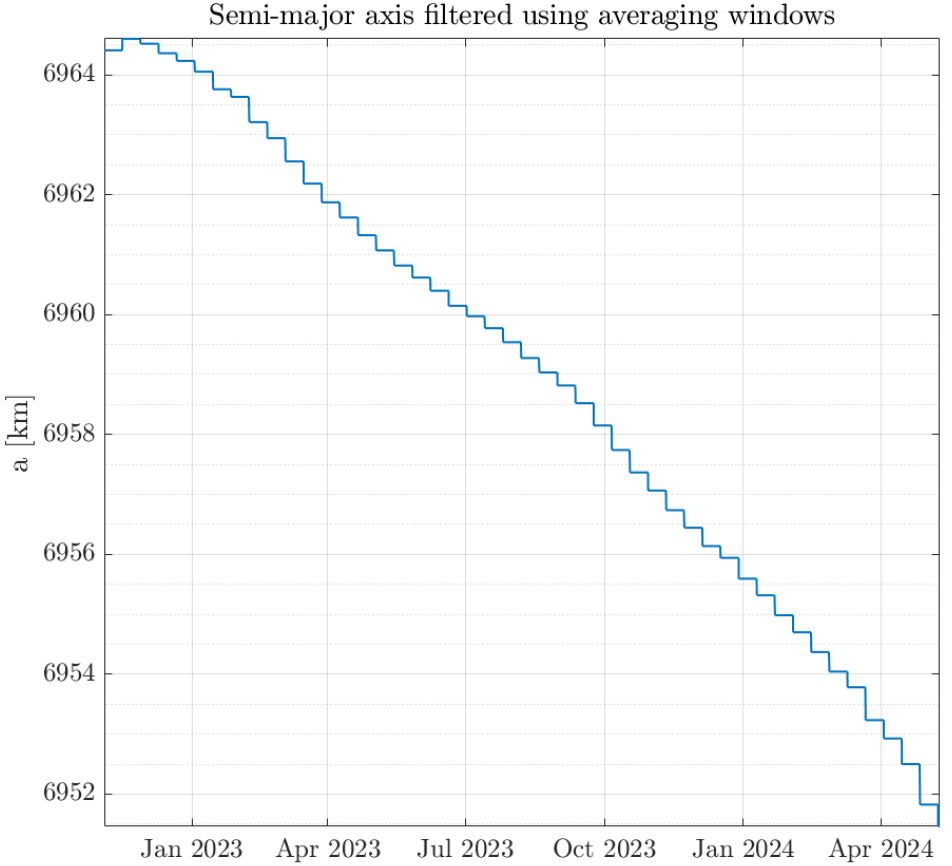

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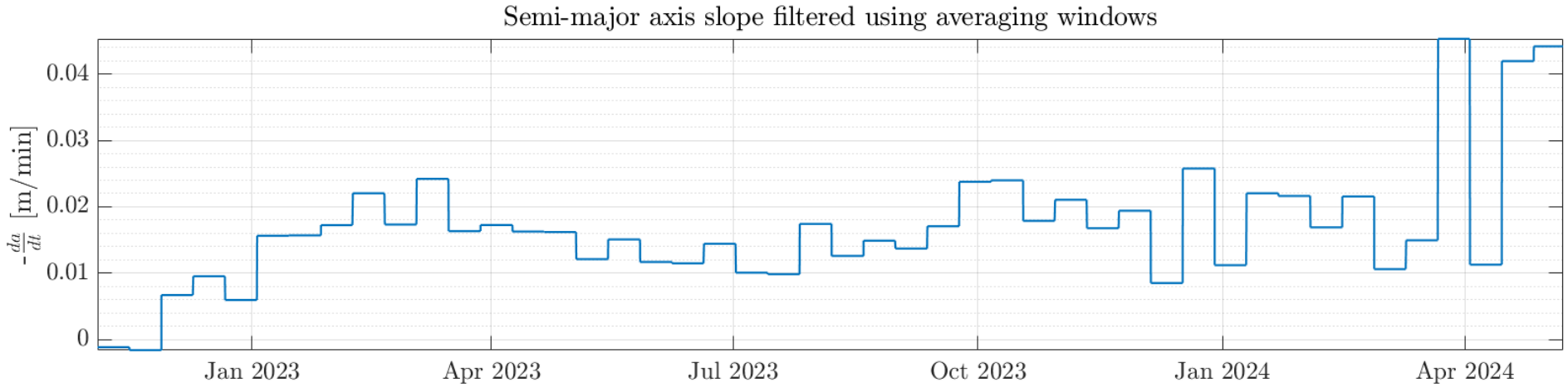

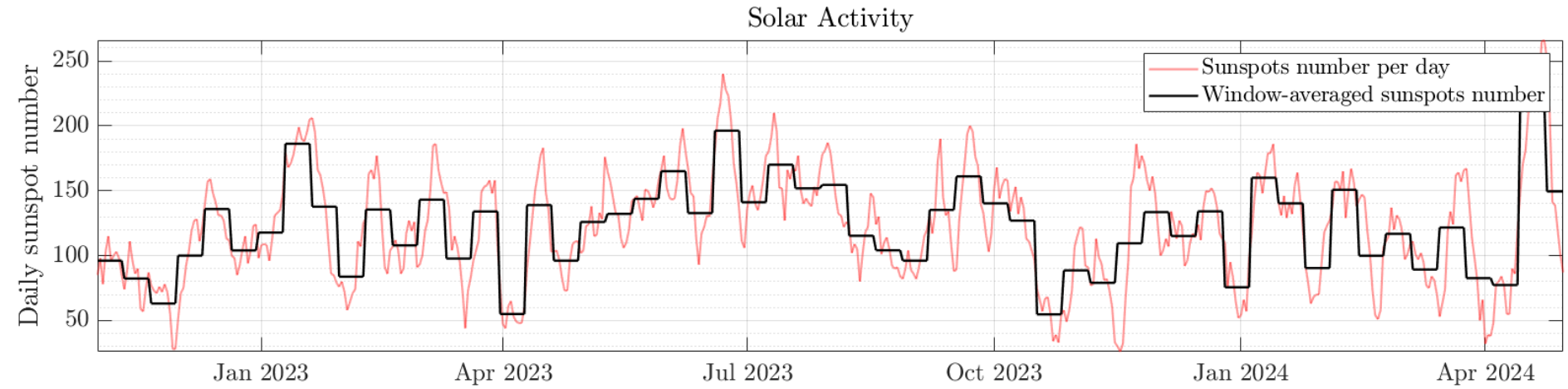

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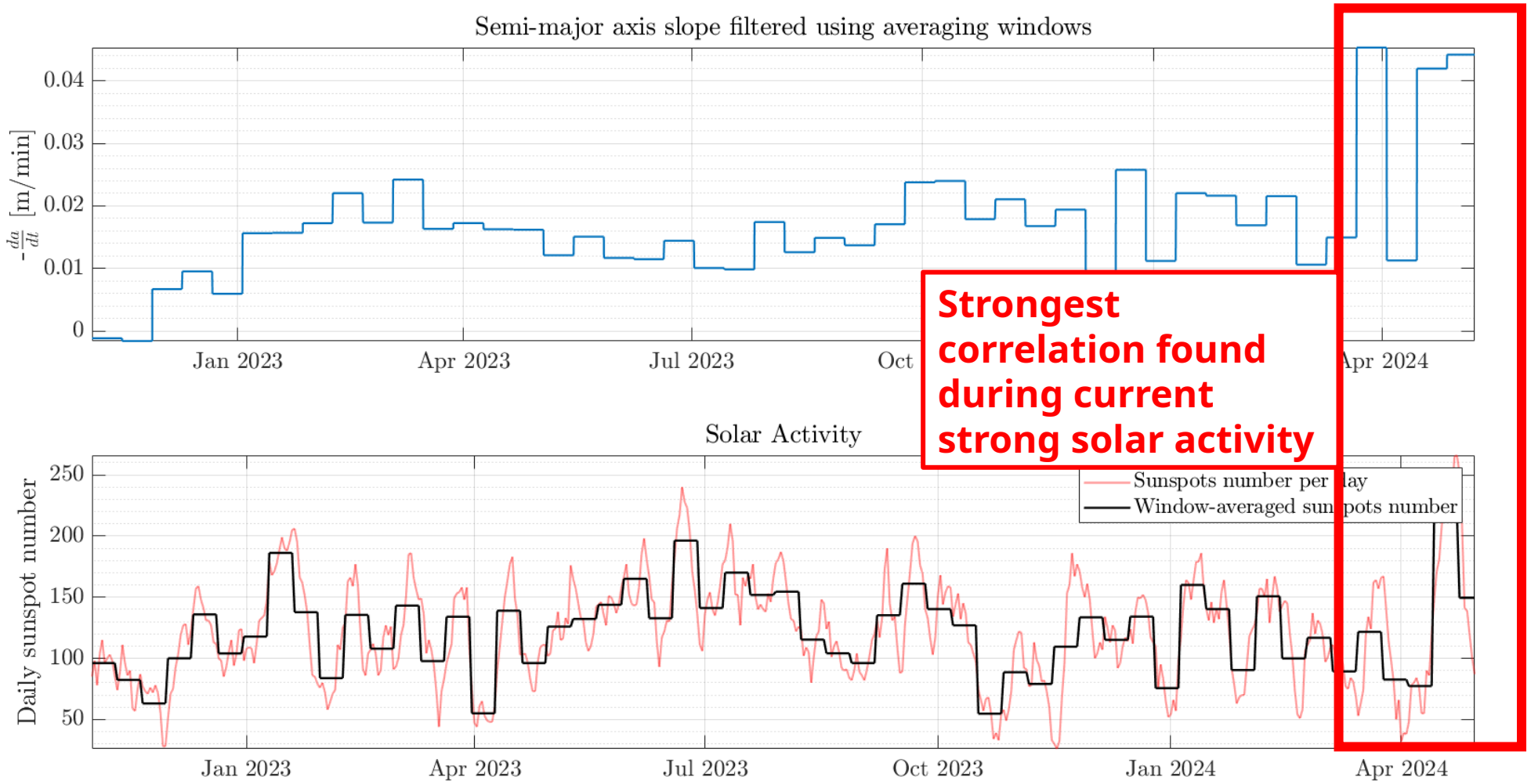
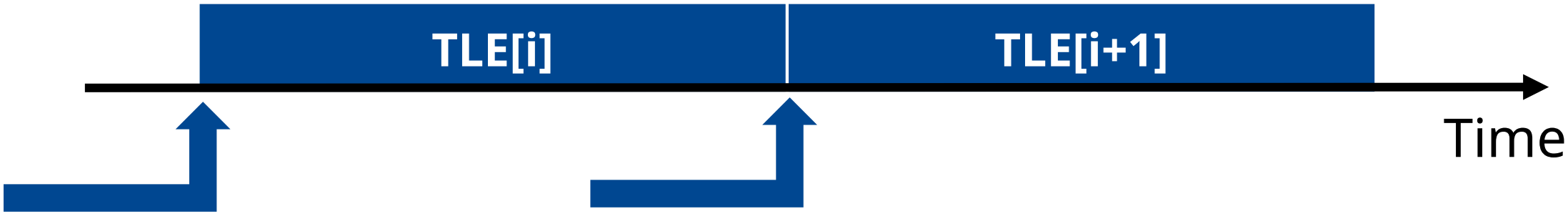


Line-Of-Sight Visibility Analysis - STARLINK

TLE Propagation Methodology

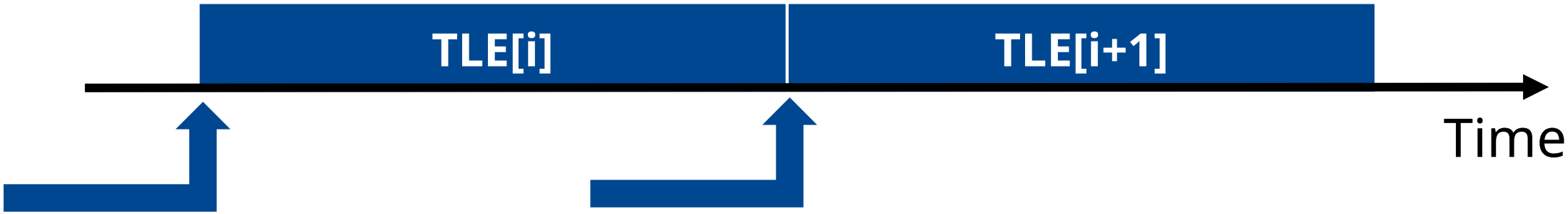


TLE[i] epoch date

TLE[i+1] epoch date

Line-Of-Sight Visibility Analysis - STARLINK

TLE Propagation Methodology



TLE[i] epoch date TLE[i+1] epoch date

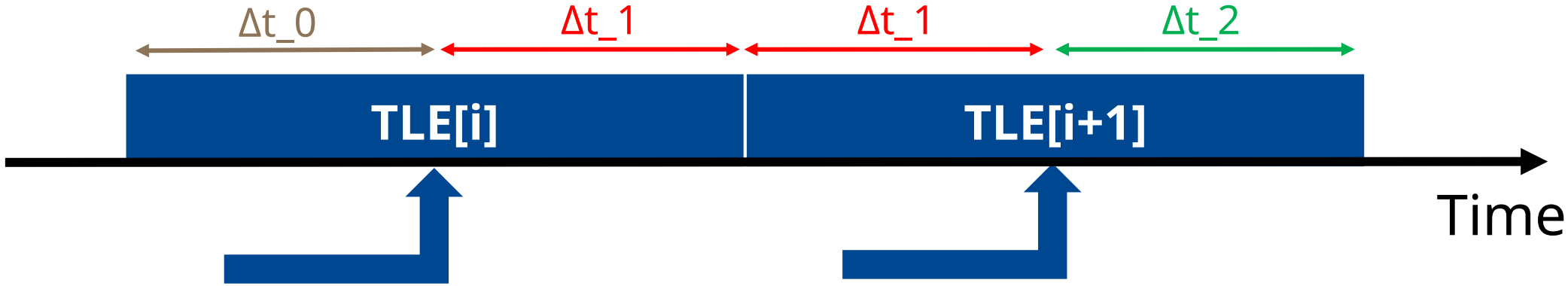
Why?

“The maximum accuracy for a TLE is limited by the number of decimal places in each field. In general, TLE data is accurate to about a kilometer or so at epoch and it quickly degrades.”

- Revisiting Spacetrack Report #3

Line-Of-Sight Visibility Analysis - STARLINK

TLE Propagation Methodology : Improvement Suggestion



Satellite elements go rapidly out of date. Thus, you will want to pay attention to the "epoch" — the date on which an element set is most accurate — of every TLE element set you use. Elements are only useful for a week or two on either side of the epoch date.

Line-Of-Sight Visibility Analysis - STARLINK

Mathematical Formulation

Line-Of-Sight Visibility if :

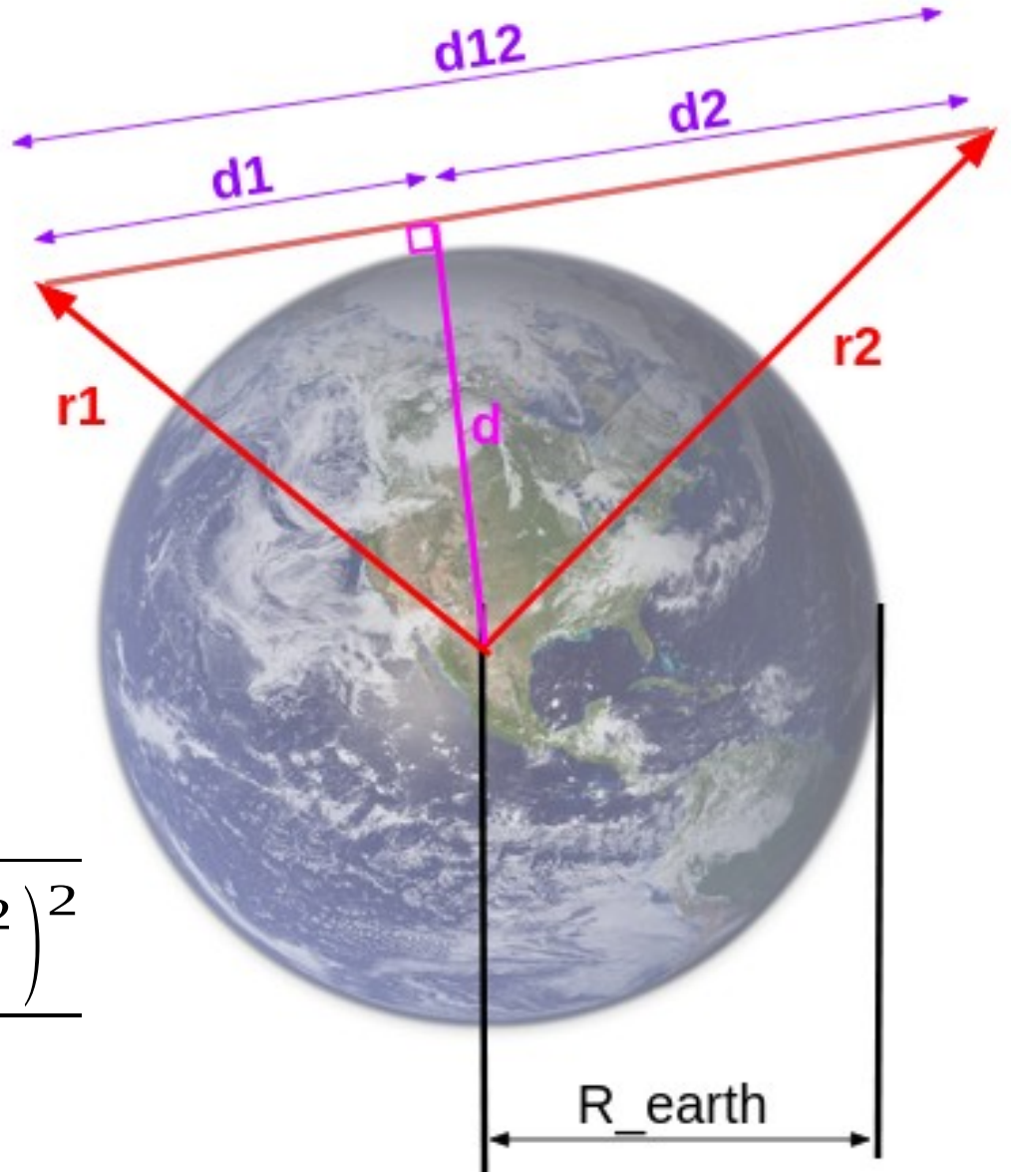
d > R_earth = 6378 km

Obstructions : Clouds
Highest (Noctilucent) = 80km

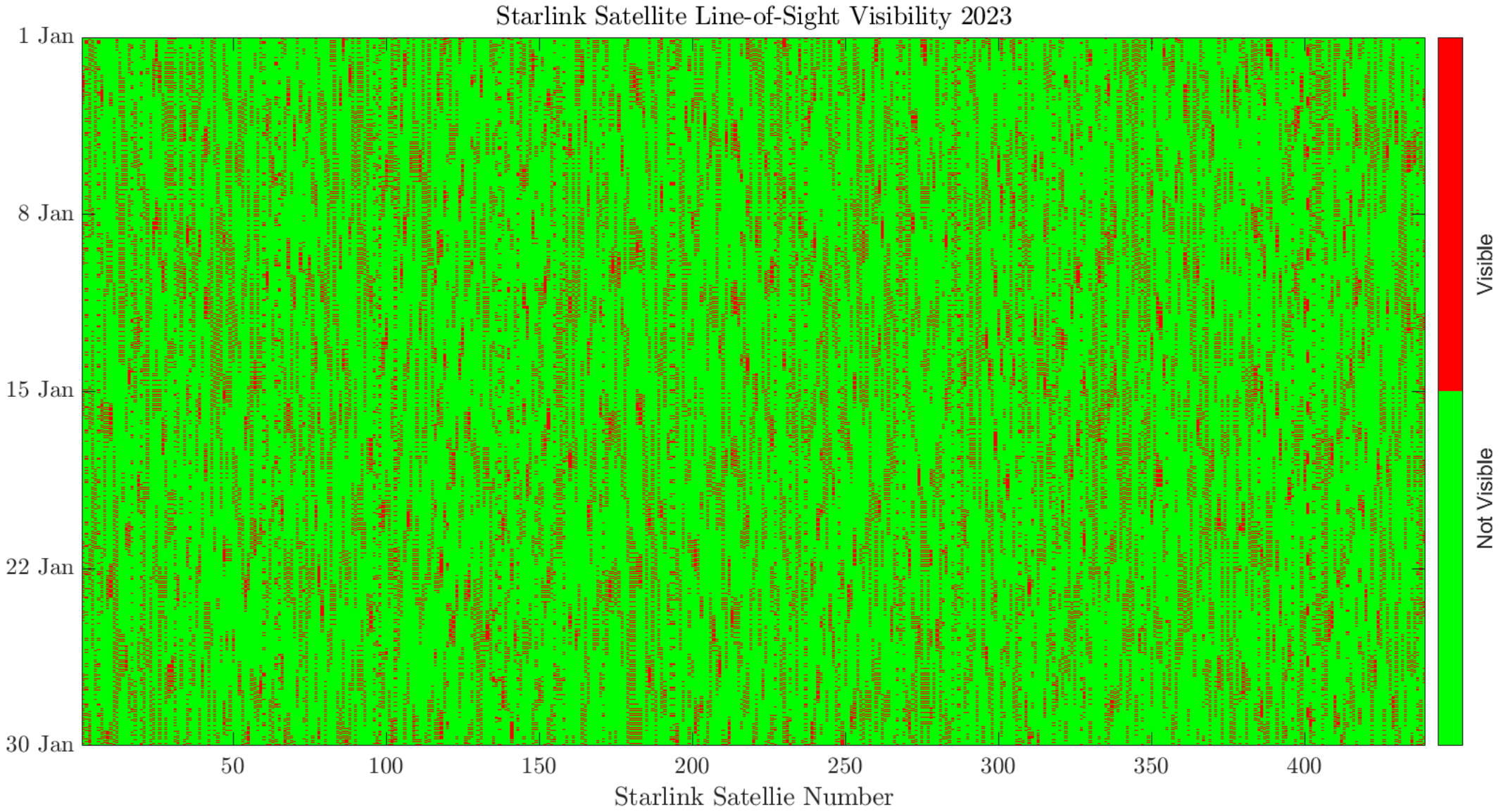
Adjusted Line-Of-Sight Visibility

d > R_adjusted = 6,460 km.

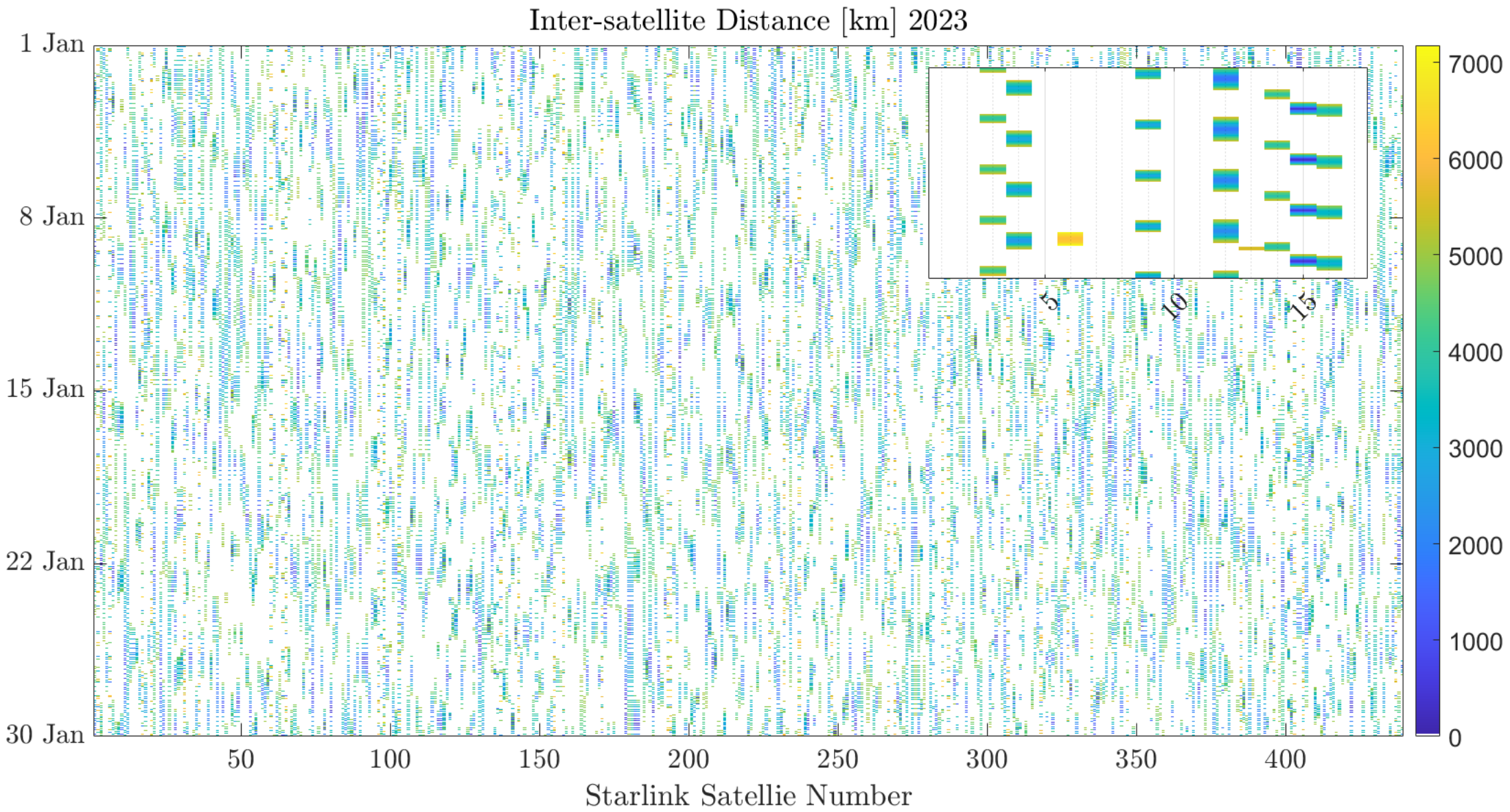
$$|d| = \sqrt{|r_1|^2 - \frac{\left(|d_{12}|^2 + |r_1|^2 - |r_2|^2\right)^2}{4|d_{12}|^2}}$$

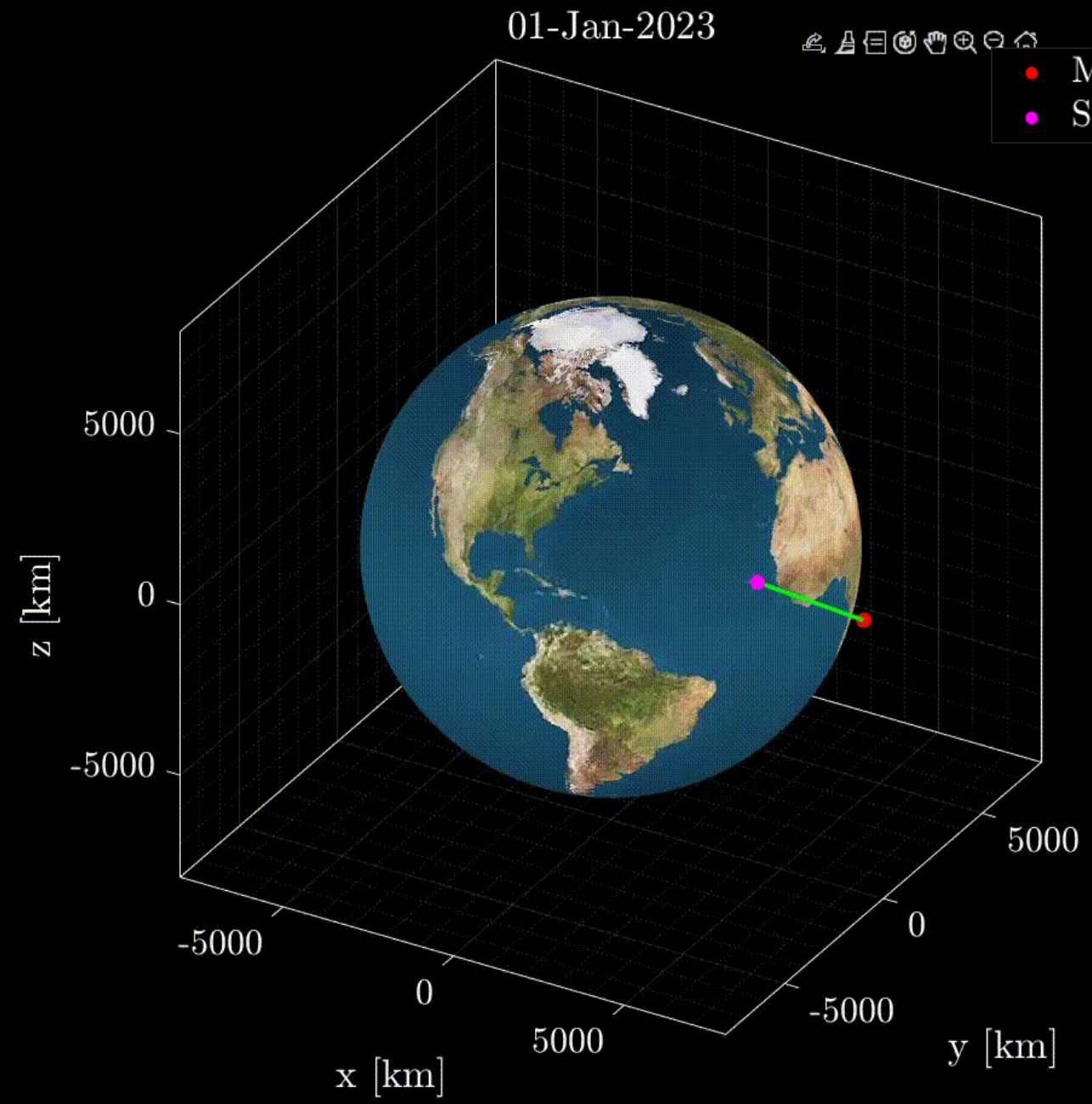


Results : Visible or Not?

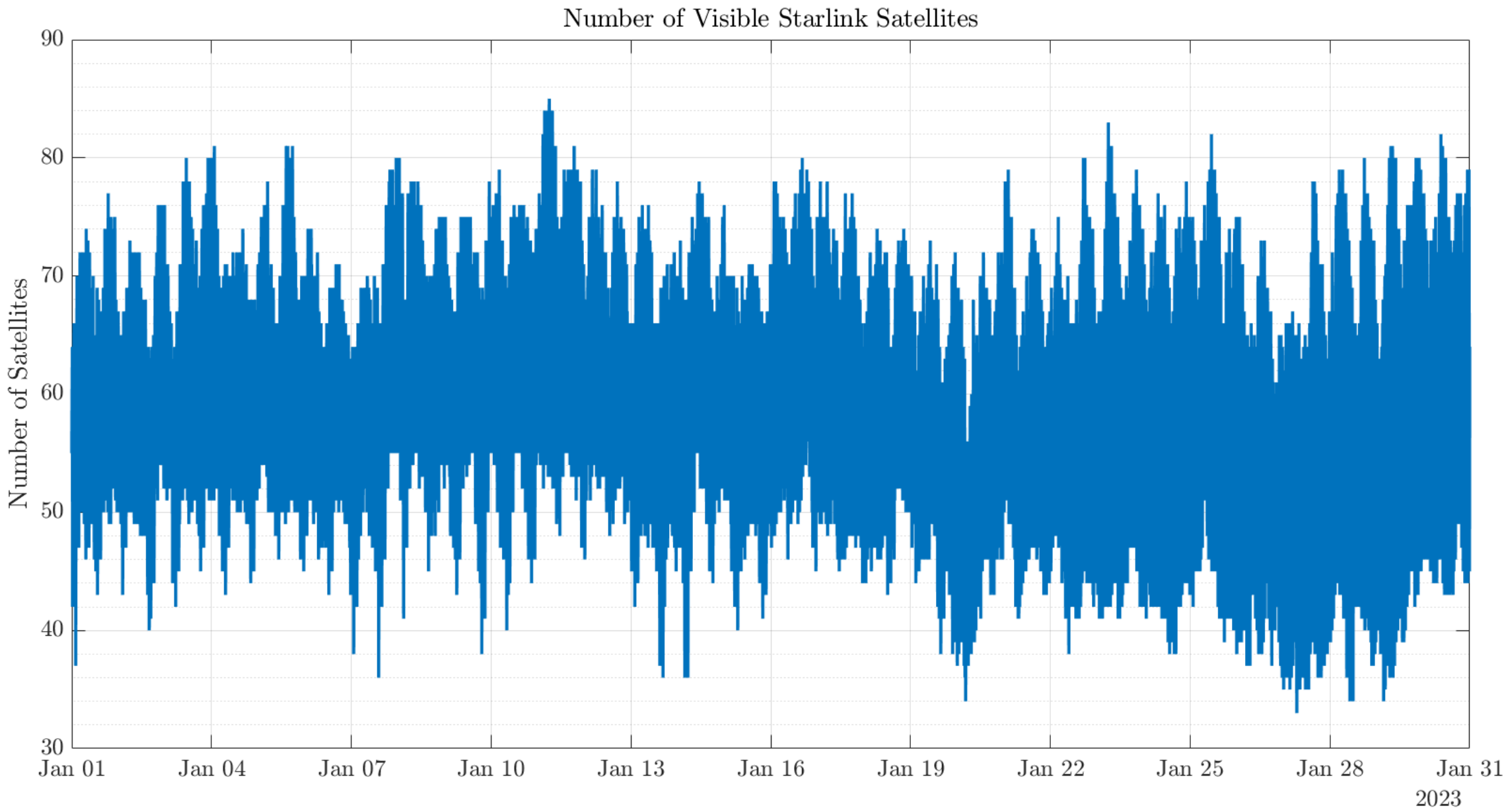


Results : Inter-satellite Distance for all?

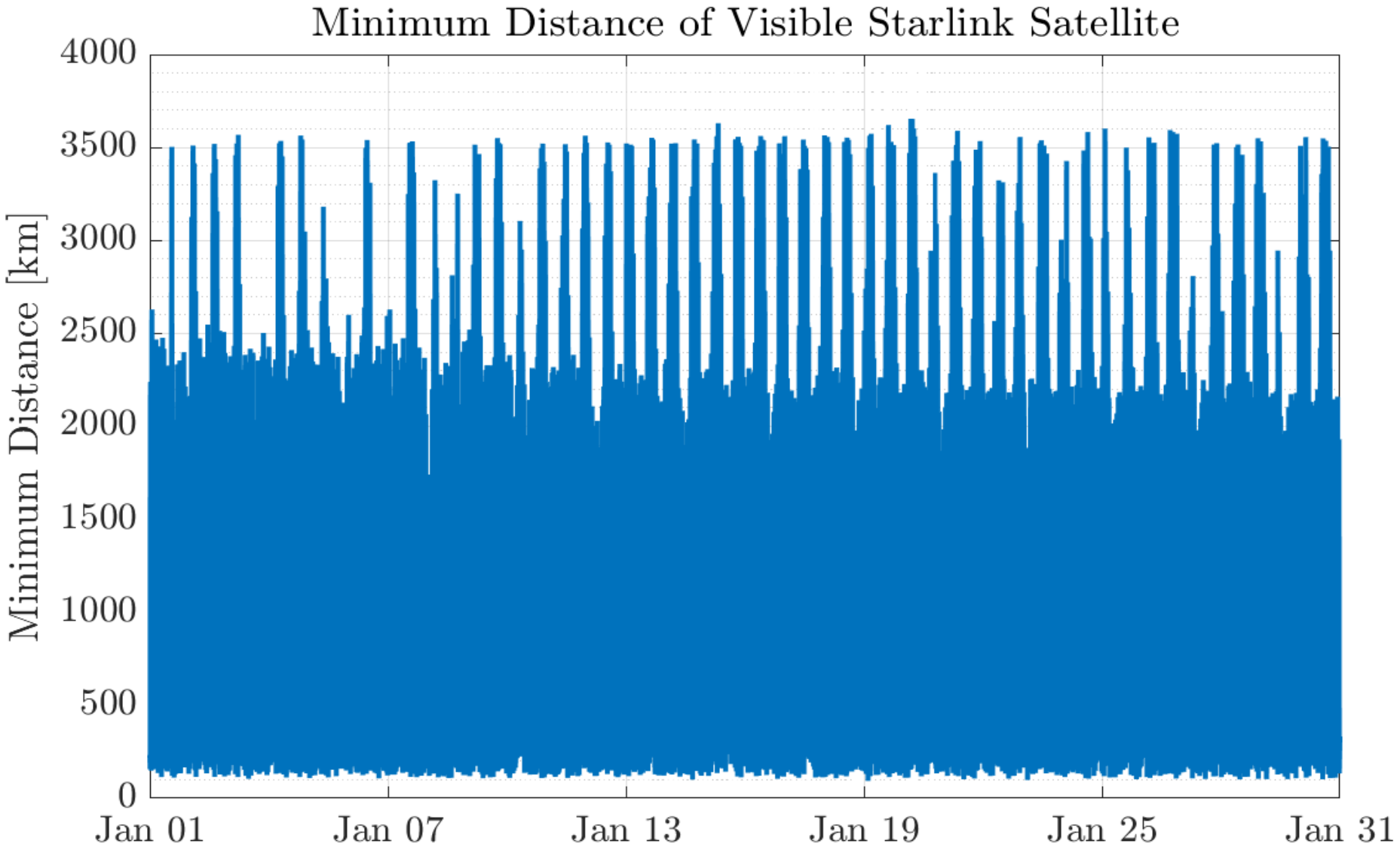



01-Jan-2023
MATS
Starlink Satellite 12
5000
0
-5000
z [km]
-5000
0
5000
x [km]
5000
0
-5000
y [km]

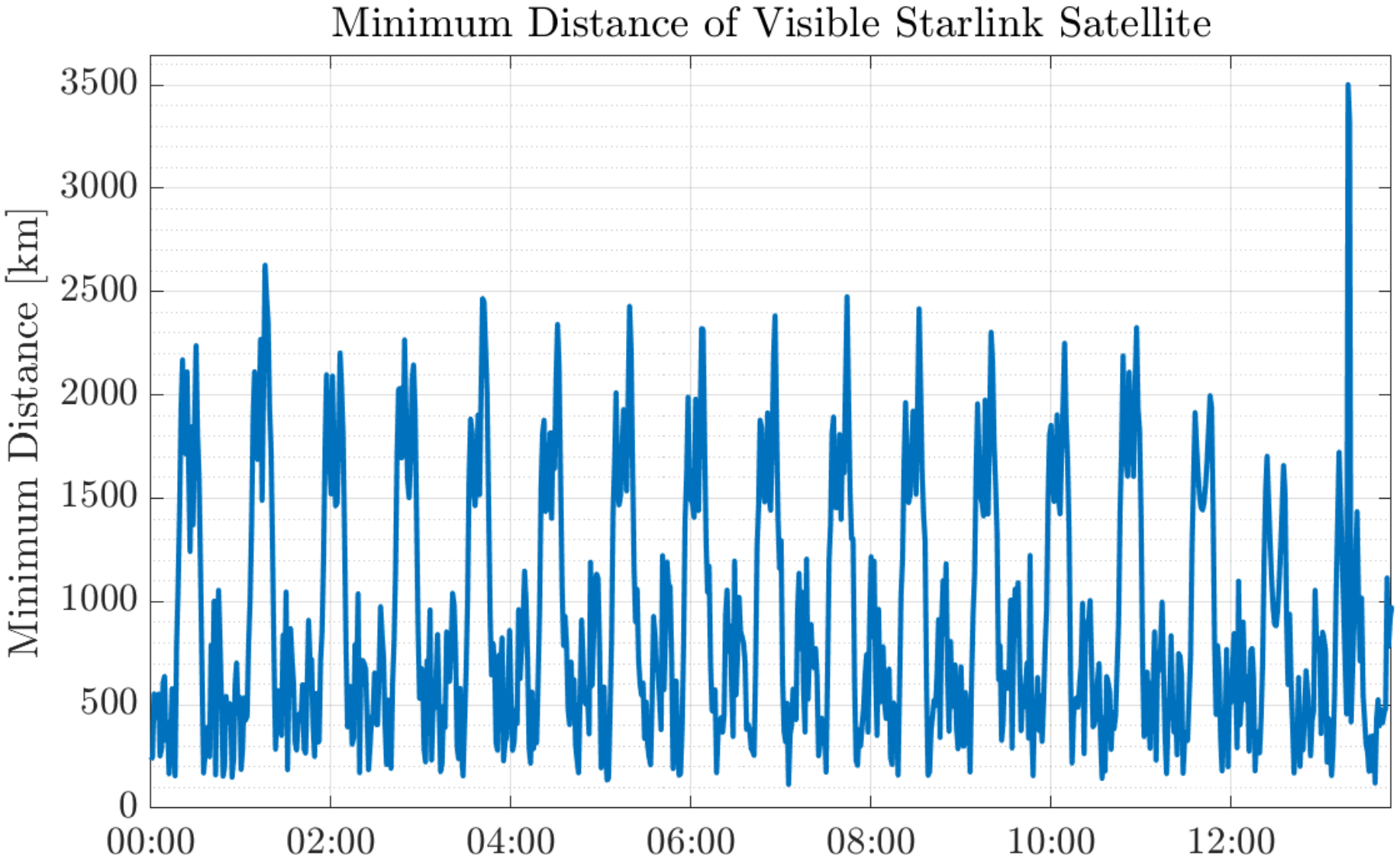
Results : How Many Visible?



Results : Minimum Distance?



Results : Minimum Distance?



Thank you

Group 3: Buratti Diego, Patel Kirtan