



Lab.1 Results - MATS mission analysis

Group 3: Buratti Diego, Patel Kirtan



Employed Tools

To retrieve TLEs over time:

The screenshot shows the Space-Track.org website interface. At the top, there is a header bar with the KTH logo, the text "SPACE-TRACK.ORG", a user email "diego.buratti@mail.polimi.it", and a timestamp "Current Time (UTC) 2024-05-14 07:10:39". Below the header is a navigation menu with links: HOME, HELP, Welcome, Box Score, SATCAT, Decay/Reentry, Query Builder, Favorites, ELSET Search (which is highlighted), Recent ELSETS, SSR, Conjunctions, Public Files, and Space Ops Tempo. The main content area is titled "HISTORICAL ELSET SEARCH". It contains a "Entries" input field with the value "MATS". Under "SORT BY", there are three options: "NORAD_CAT_ID" (radio button selected), "EPOCH" (radio button selected), and "Descending" (checkbox). Under "EPOCH", there are two options: "Latest" (radio button selected) and "Date Range". Below these are "From:" and "To:" date inputs, both set to "2024-05-10".

Employed Tools

To propagate TLEs (first part):

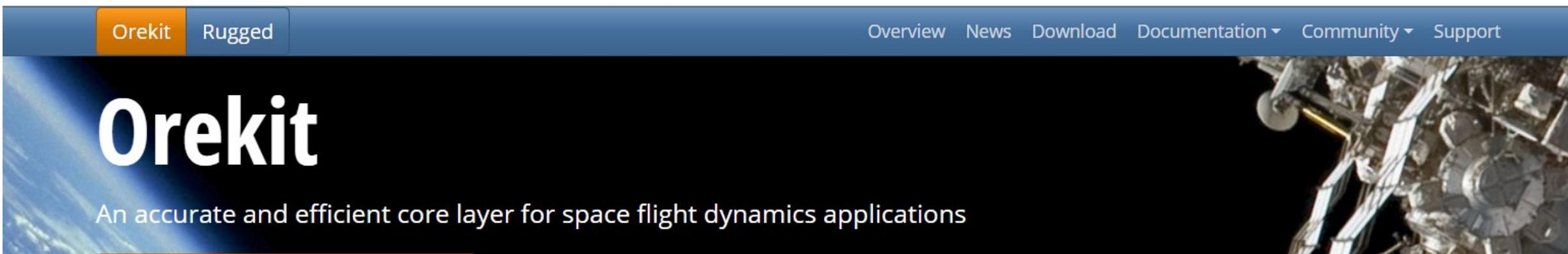


The screenshot shows the Horizons System interface. At the top left is the NASA/JPL logo. The main header reads "Jet Propulsion Laboratory California Institute of Technology". Below the header is a visualization of the solar system with various celestial bodies and their orbits. To the right of the visualization is a sidebar titled "Solar System Dynamics" containing mathematical equations for orbital mechanics, such as $M = E - e \sin(E)$ and $\frac{d^2x}{dt^2} = -\frac{\mu}{r^3} x$. The bottom navigation bar includes links for Home, About, Orbit & Ephemerides, Planets, Planetary Satellites, Small Bodies, Tools, and Extras.

Home / Tools / Horizons System

Horizons System

To propagate TLEs (second part):



The screenshot shows the Orekit website. The top navigation bar includes links for Orekit (highlighted in orange), Rugged, Overview, News, Download, Documentation, Community, and Support. The main title "Orekit" is displayed prominently in large white letters against a blue background. Below the title is the tagline "An accurate and efficient core layer for space flight dynamics applications". To the right of the text is a photograph of a satellite or space station module.

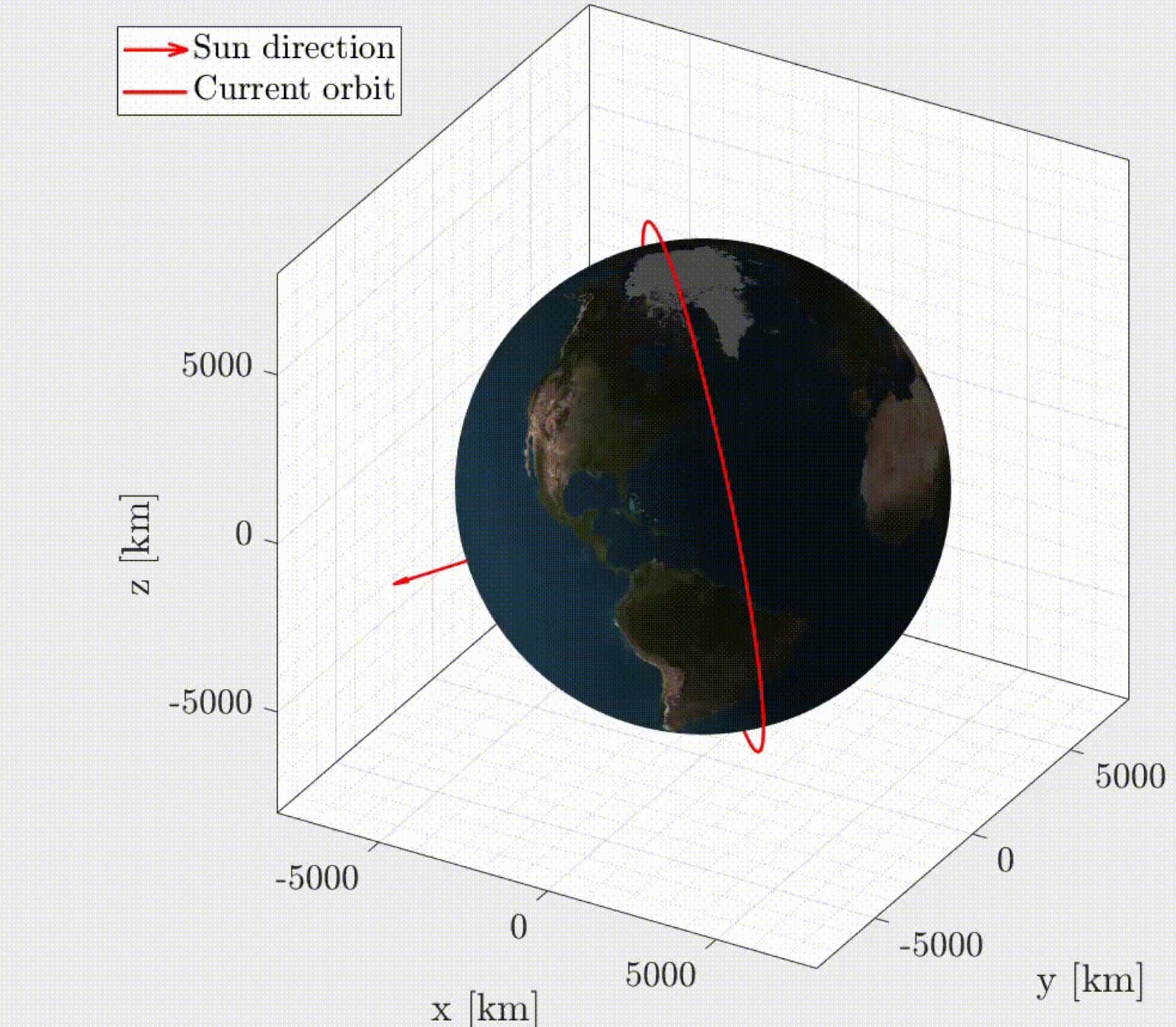
MATS orbit

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

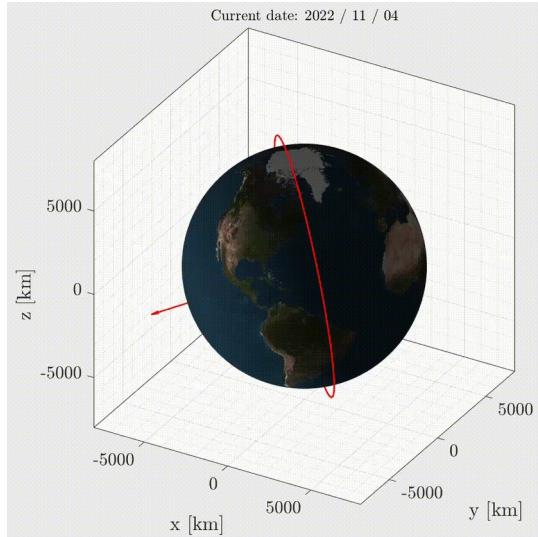
Nominal mission duration: 2 years.

Current date: 2022 / 11 / 04

→ Sun direction
— Current orbit

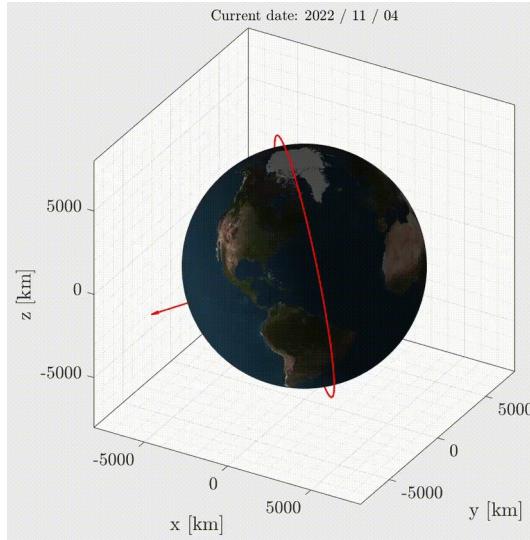


MATS orbit – Orbital Solar Zenith Angle

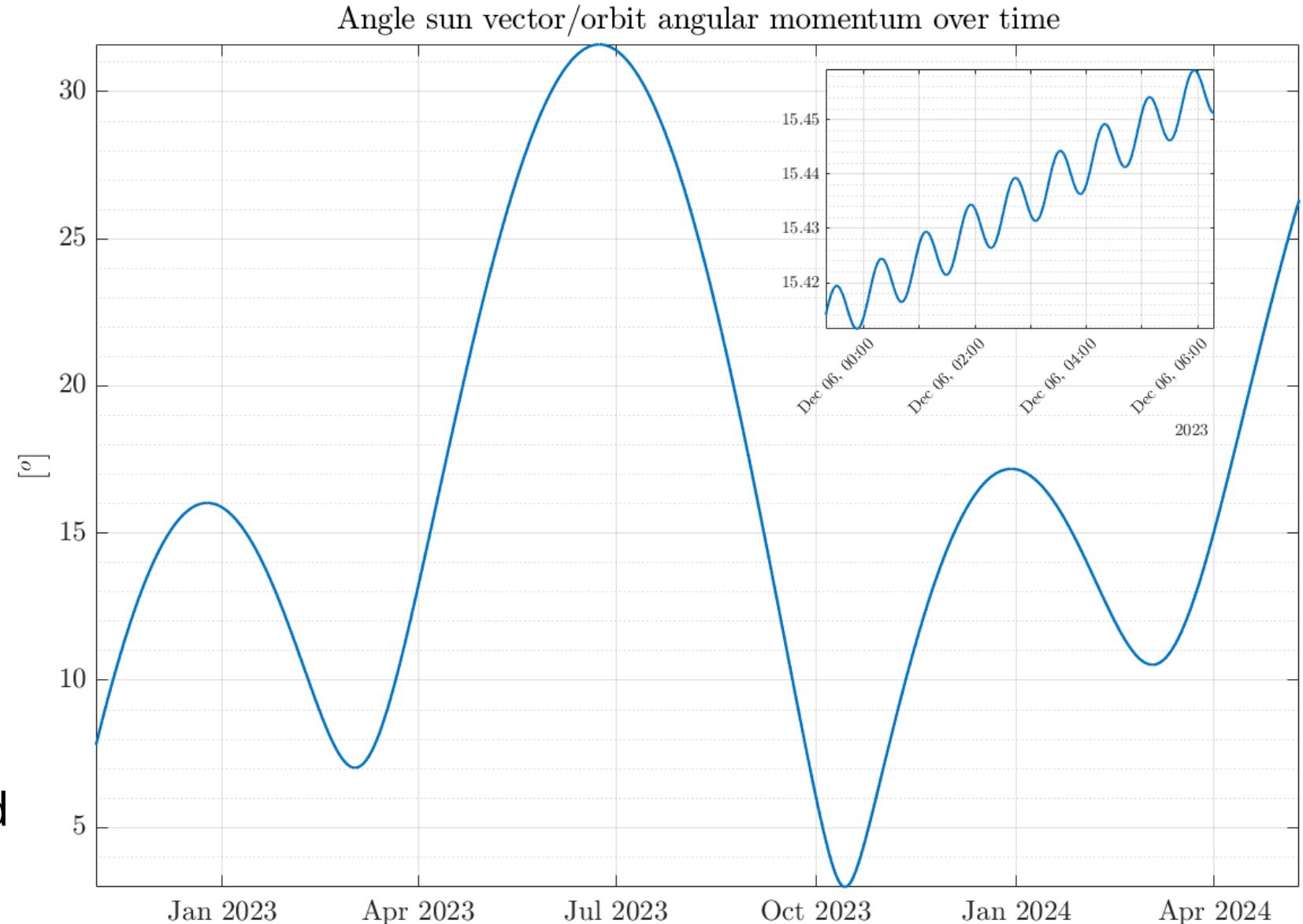


Solar zenith angle computed as the angle between the specific angular momentum of the orbit at each instant of time and the sun direction:

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**

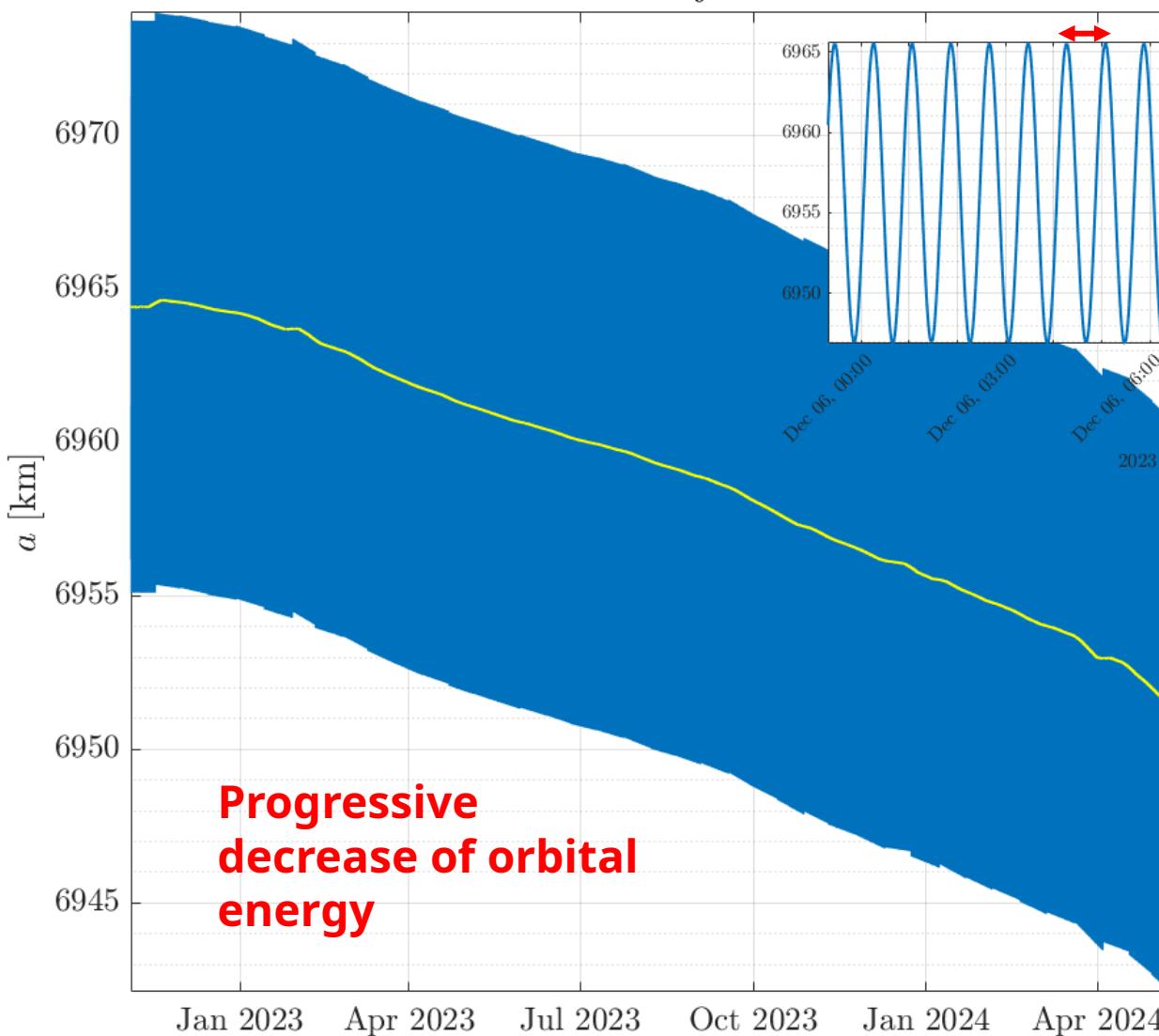


MATS orbit – Orbital Parameters (T~96 min.)

~96 min.

MATS orbit semi-maj axis over time

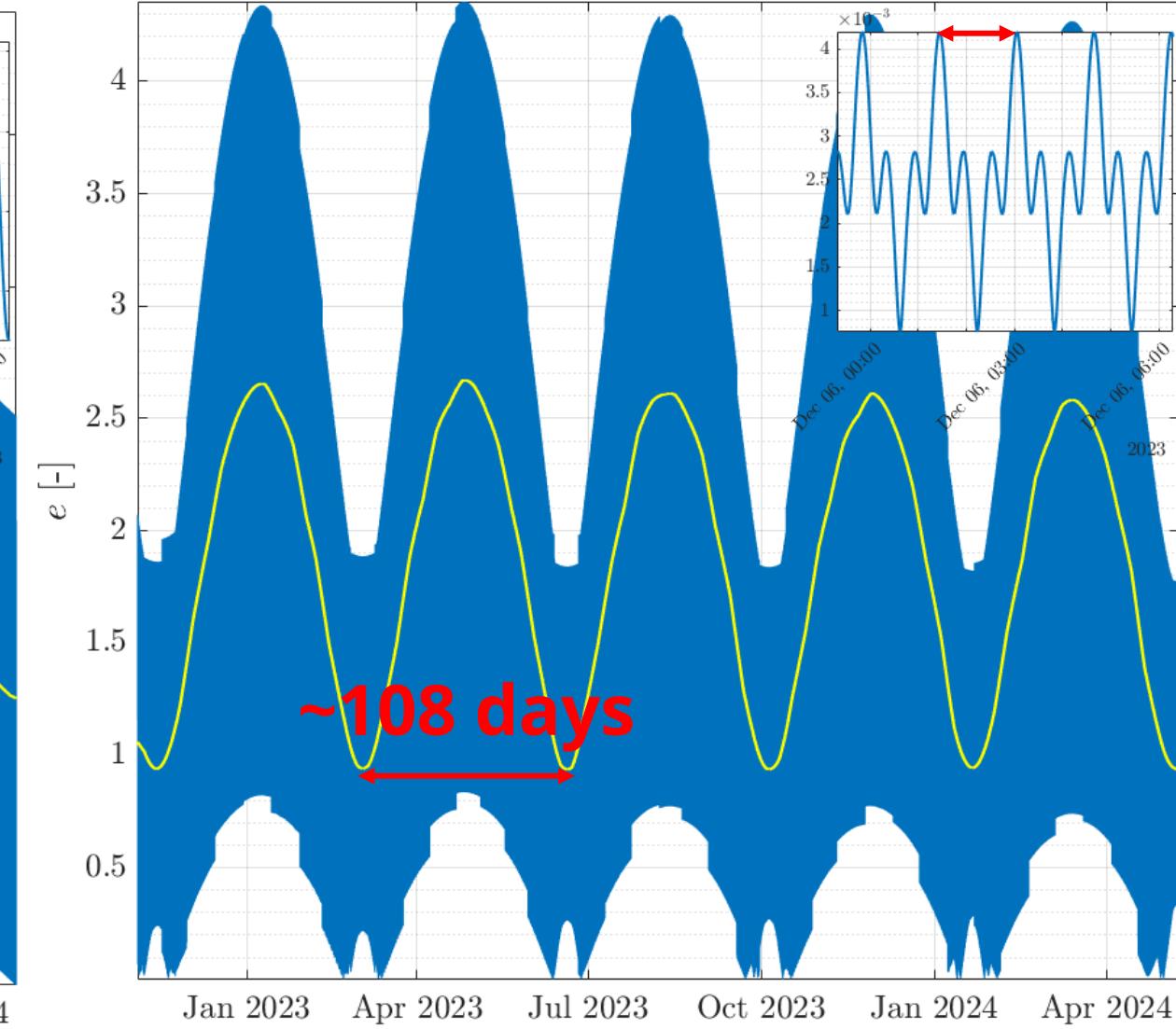
~50 min.



MATS orbit eccentricity over time

~96 min.

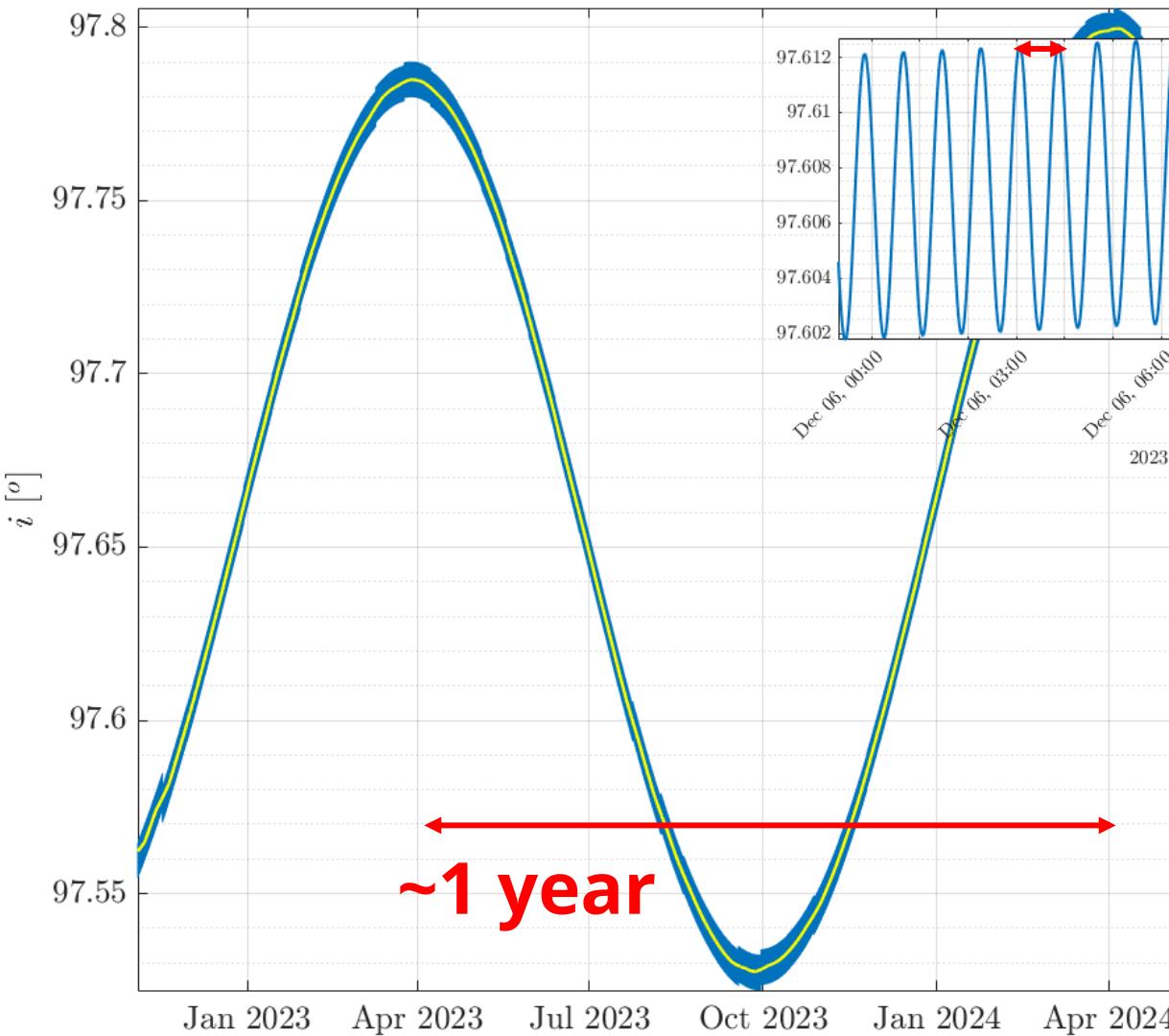
$\times 10^{-3}$



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

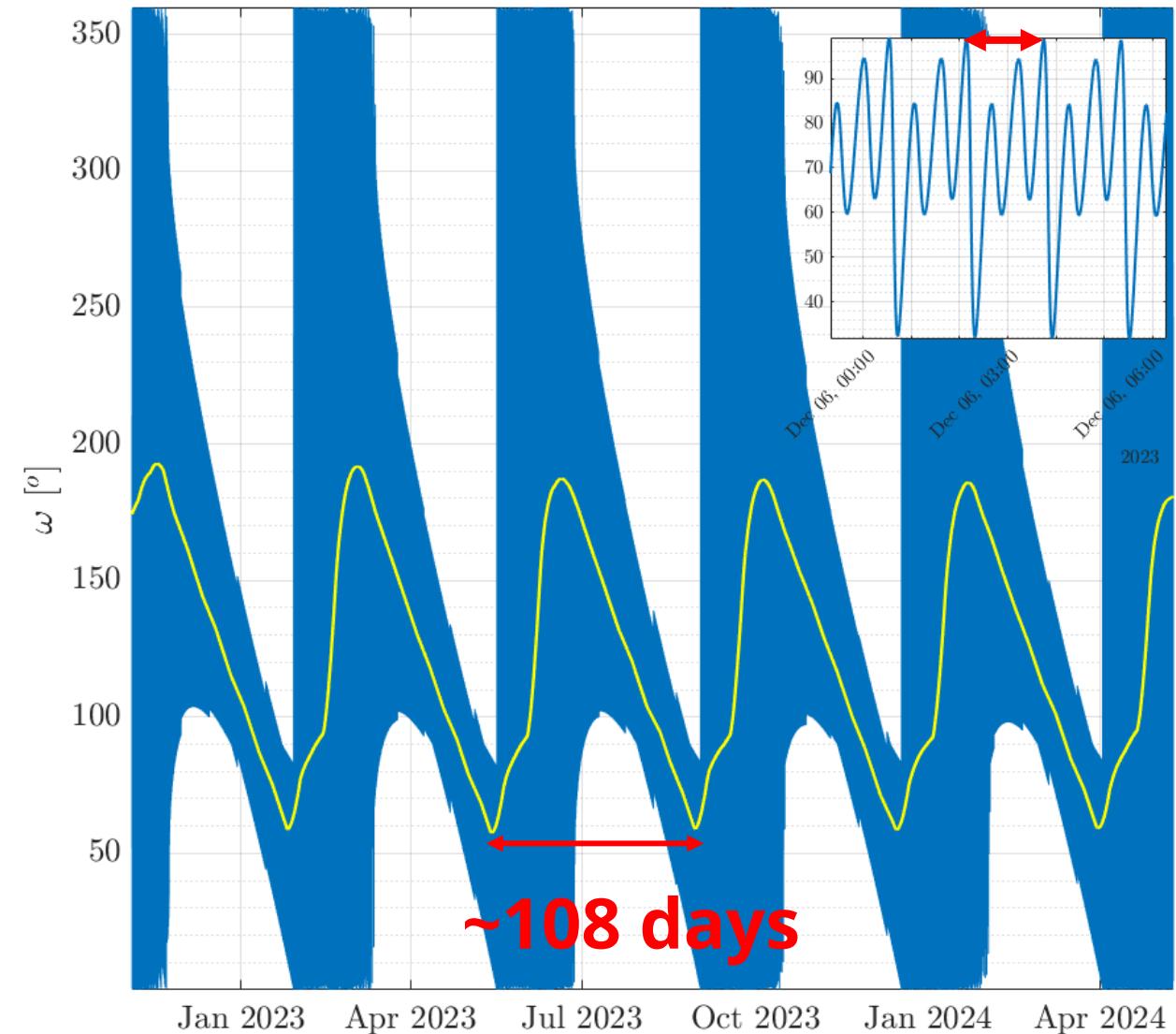
MATS orbit inclination over time

~50 min.



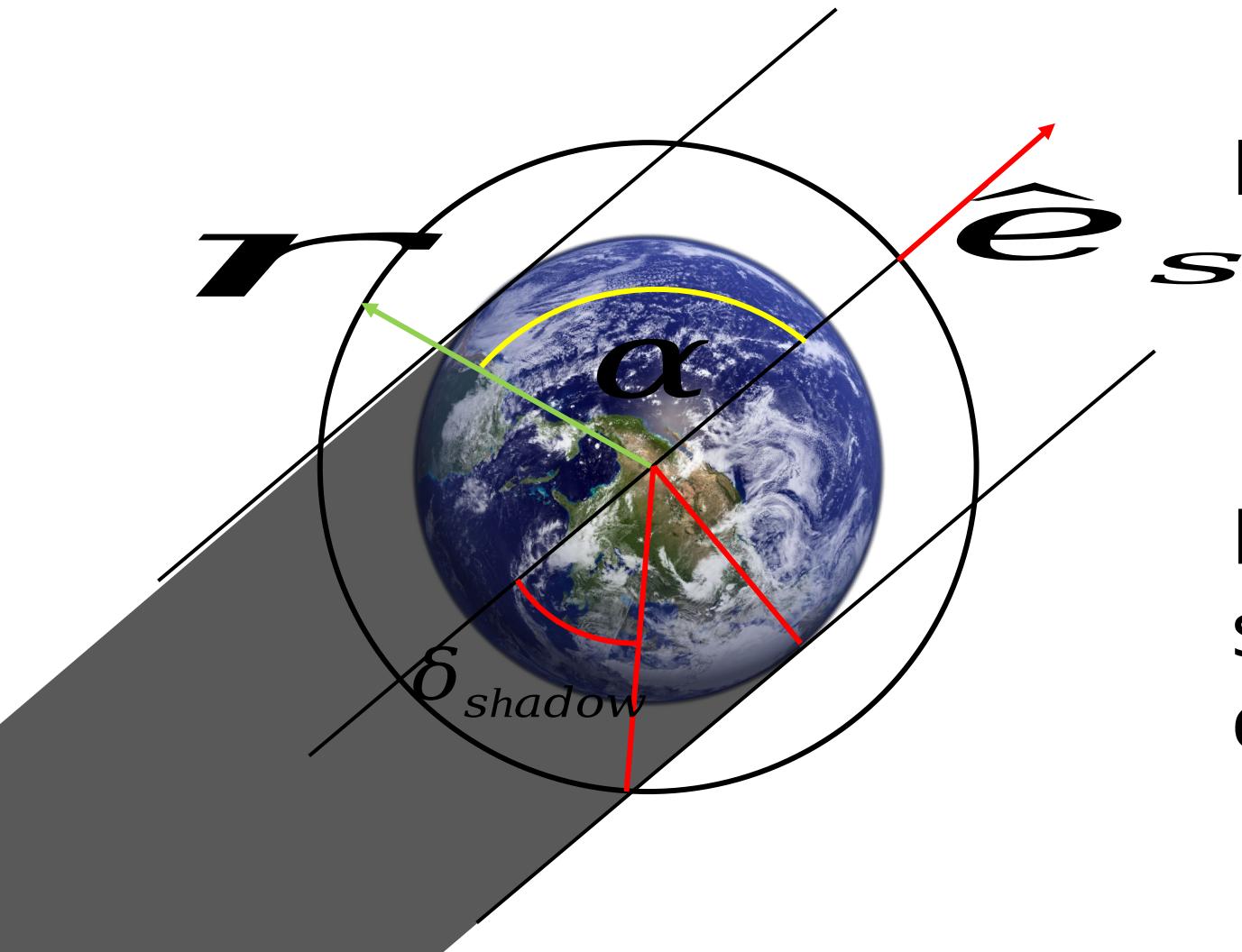
MATS orbit arg. of perigee over time

~96 min.



MATS orbit – Eclipses

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

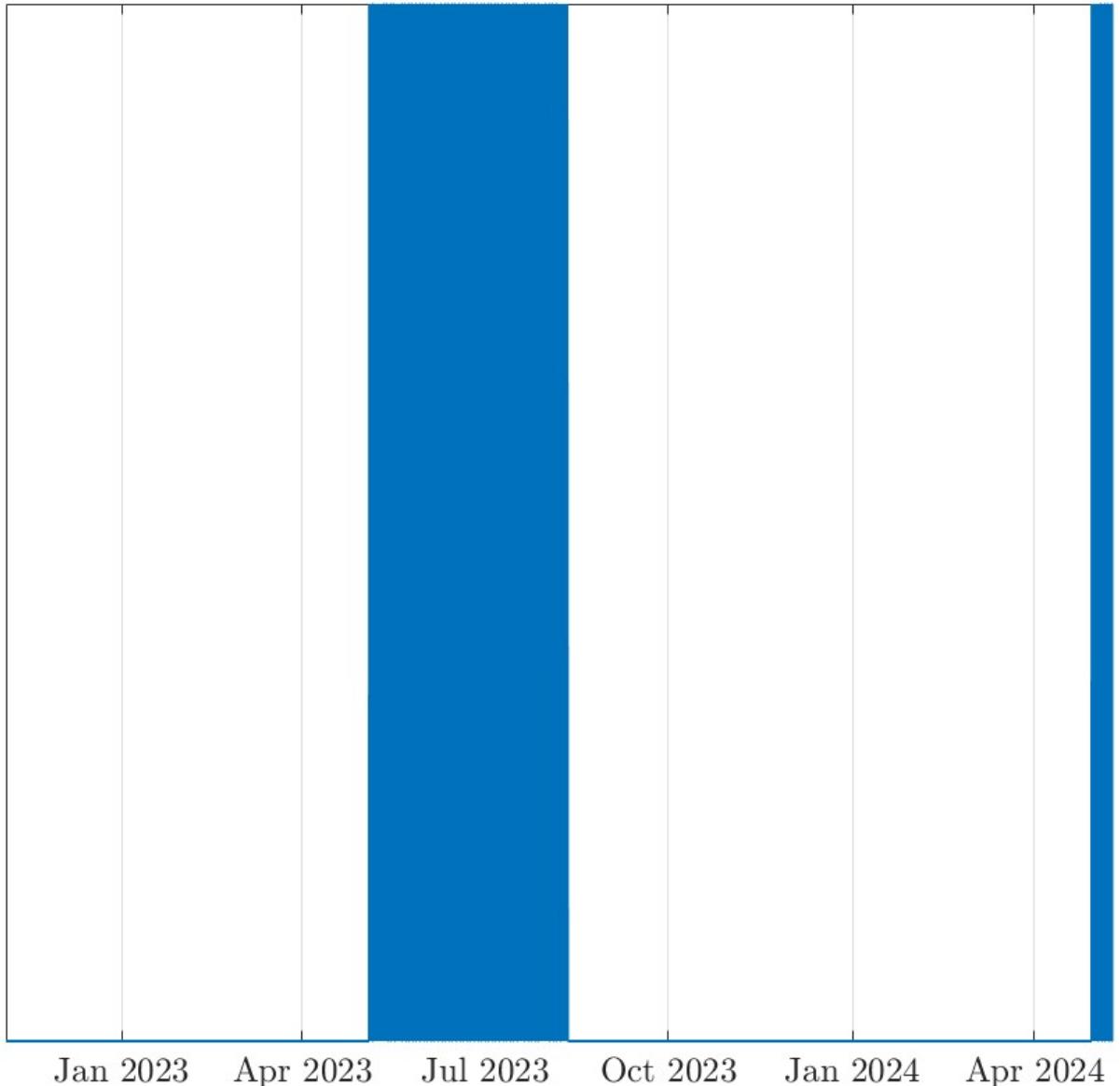


Eclipse present if:

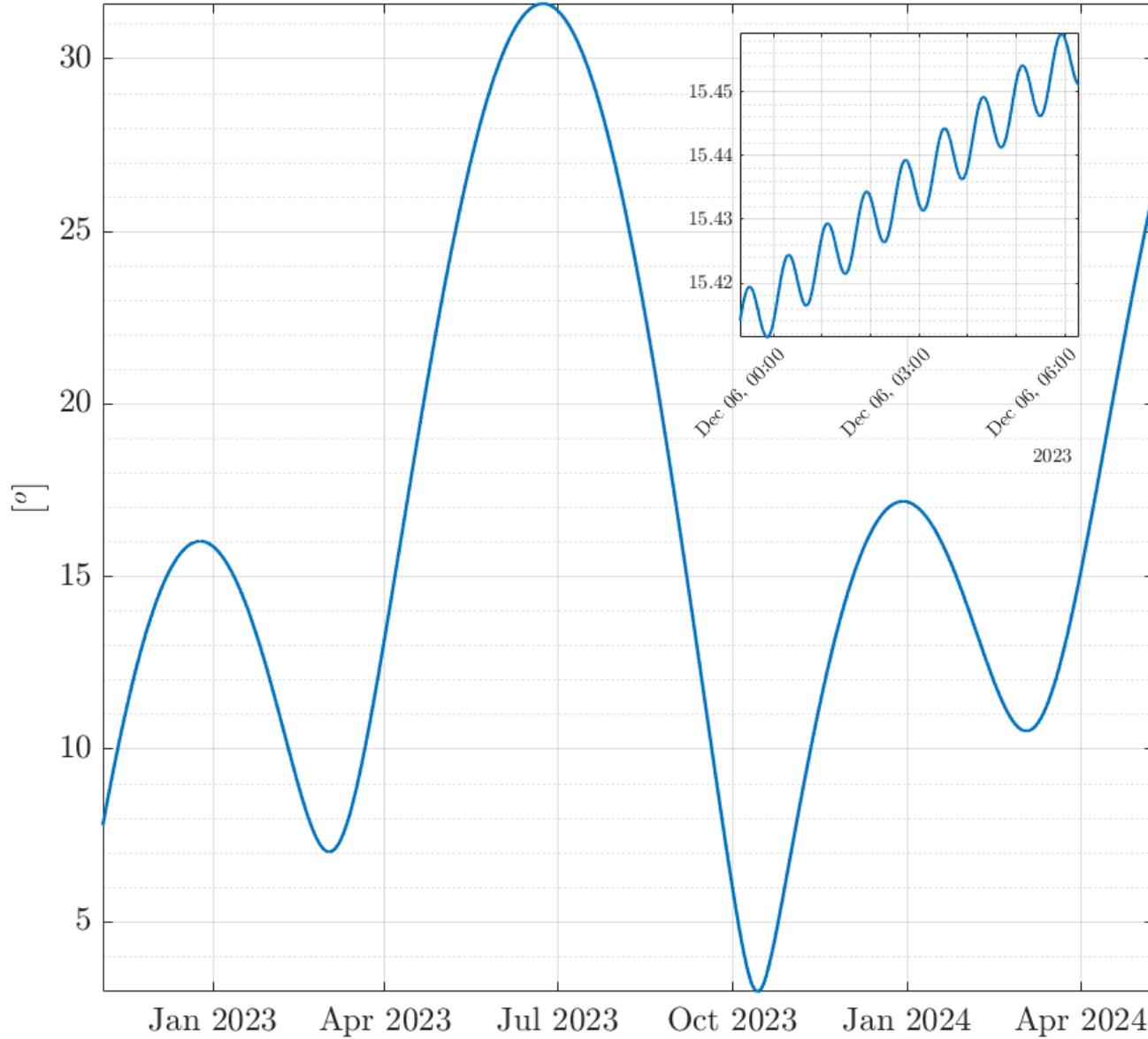
Earth assumed as a sphere, computed continuously.

MATS orbit – Eclipses

MATS eclipses

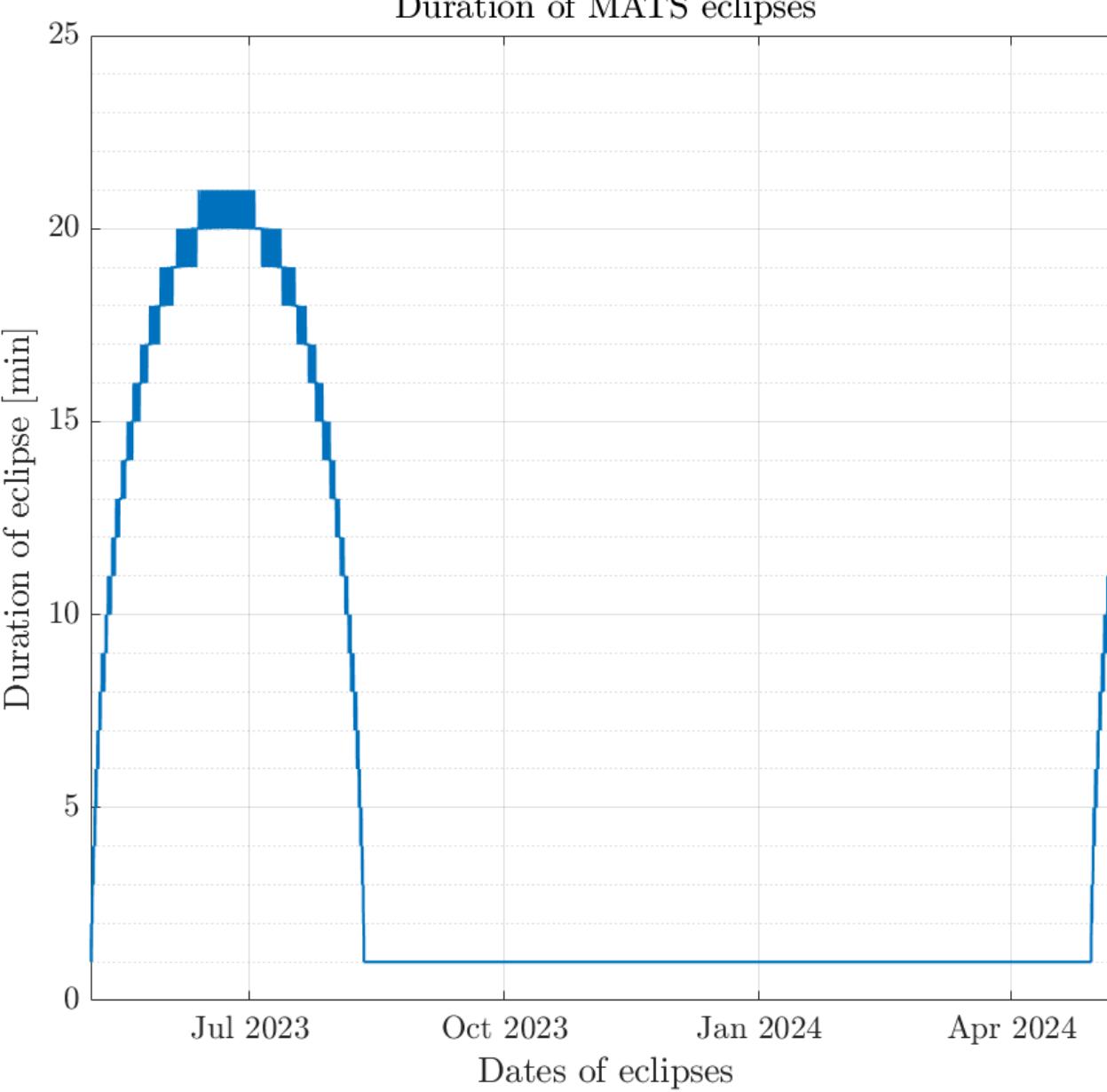


Angle sun vector/orbit angular momentum over time

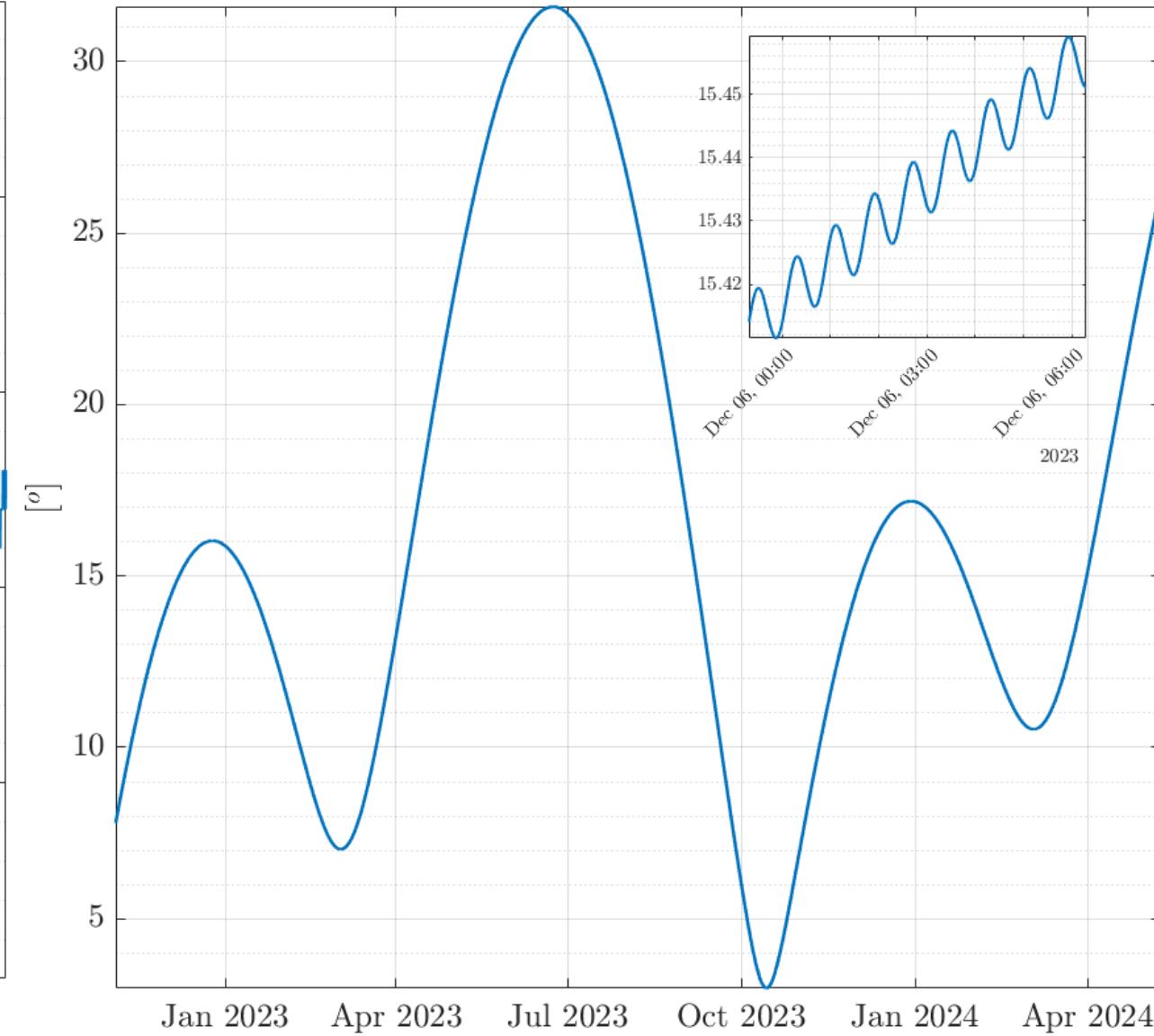


MATS orbit – Eclipses

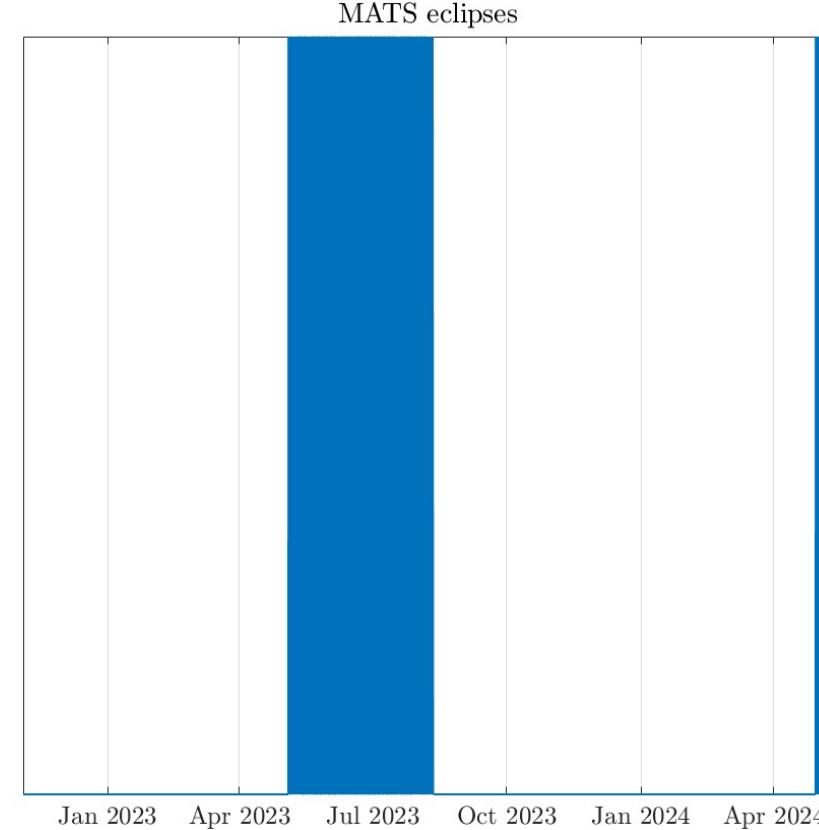
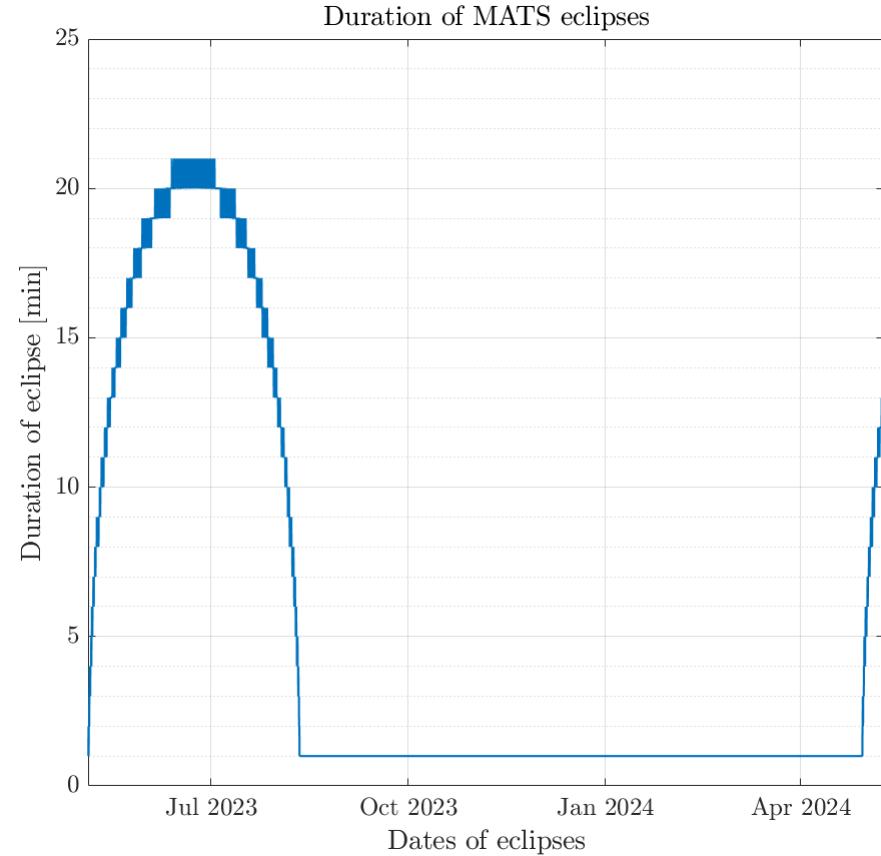
Duration of MATS eclipses



Angle sun vector/orbit angular momentum over time



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**

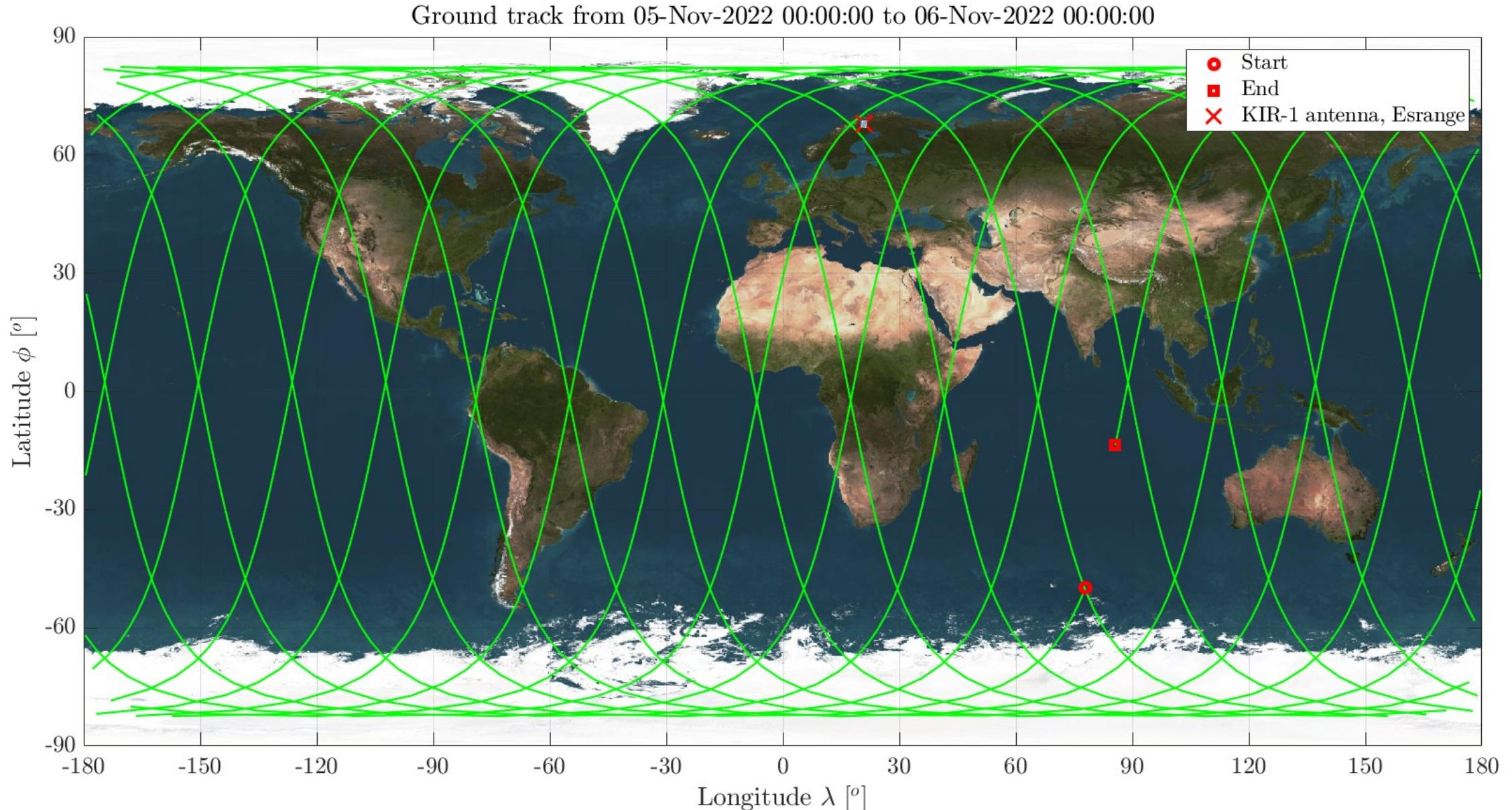
MATS orbit – Visibility Analysis from ESRANGE

Considered coordinates
for KIR-1 antenna:

- $+67^{\circ} 51' 25.66''$
- $+20^{\circ} 57' 51.57''$
- 402.2 m (WGS-84)



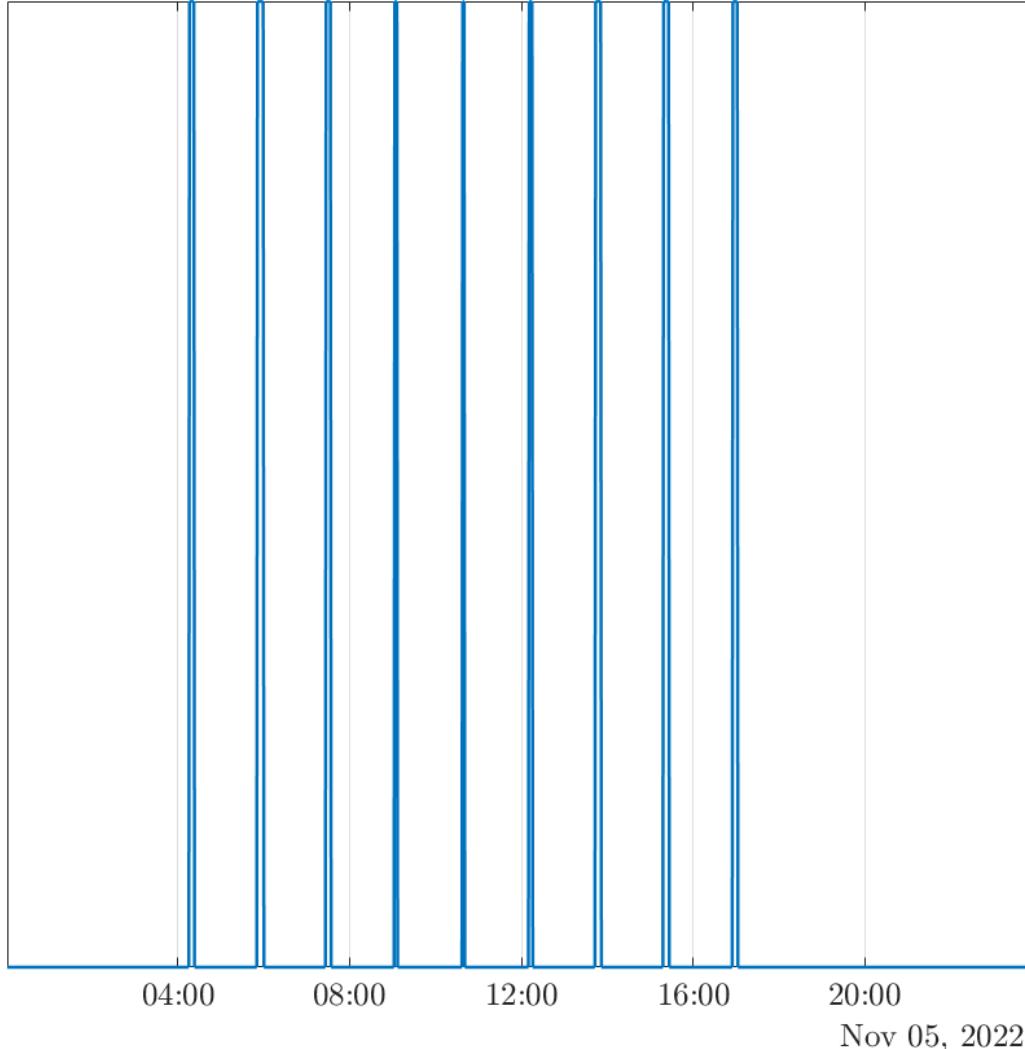
MATS orbit – Visibility Analysis from ESRANGE



MATS orbit – Visibility Analysis from ESRANGE

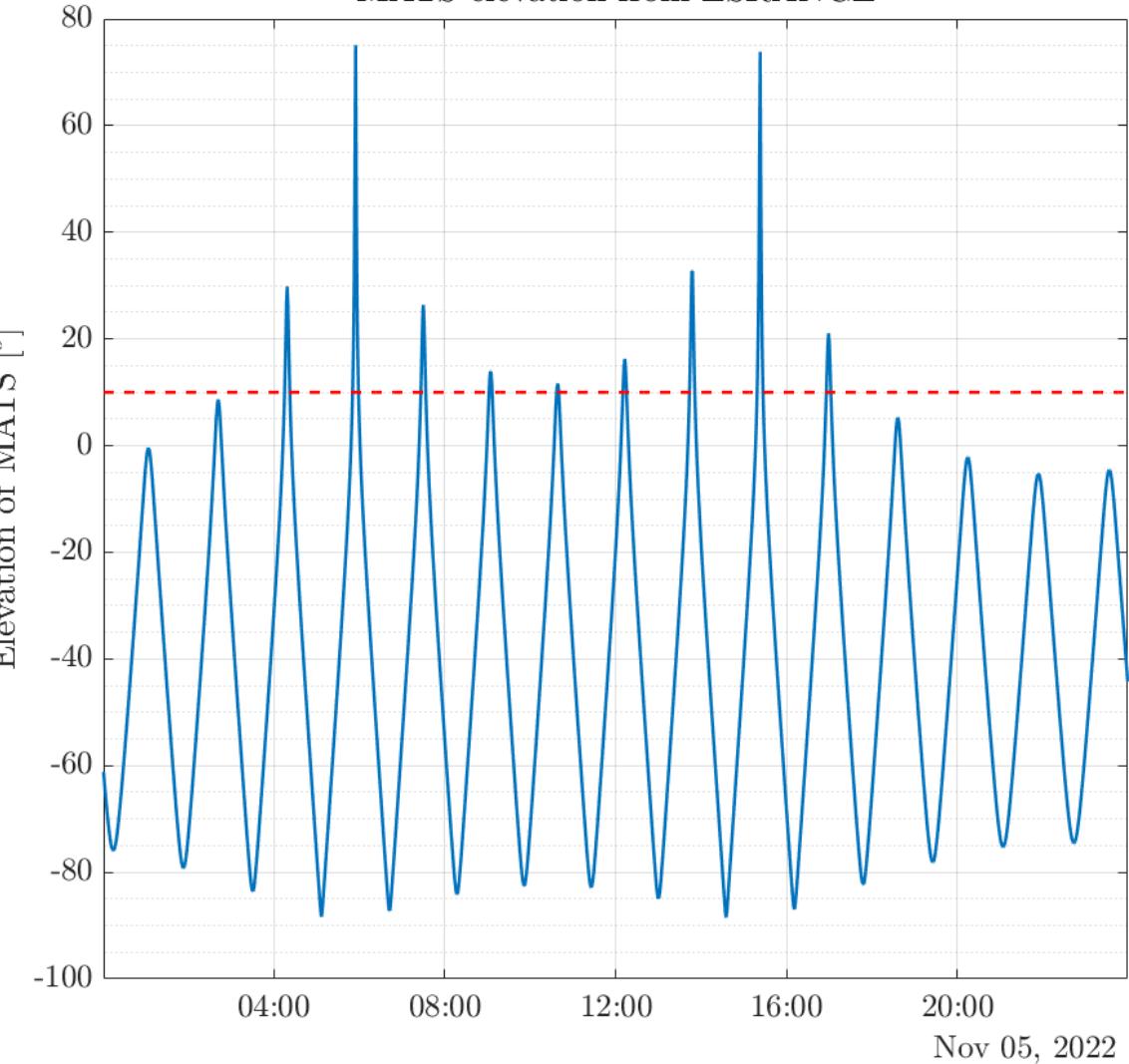
Signal elevation mask for MATS signals assumed to be

MATS visibility windows from ESRANGE



10

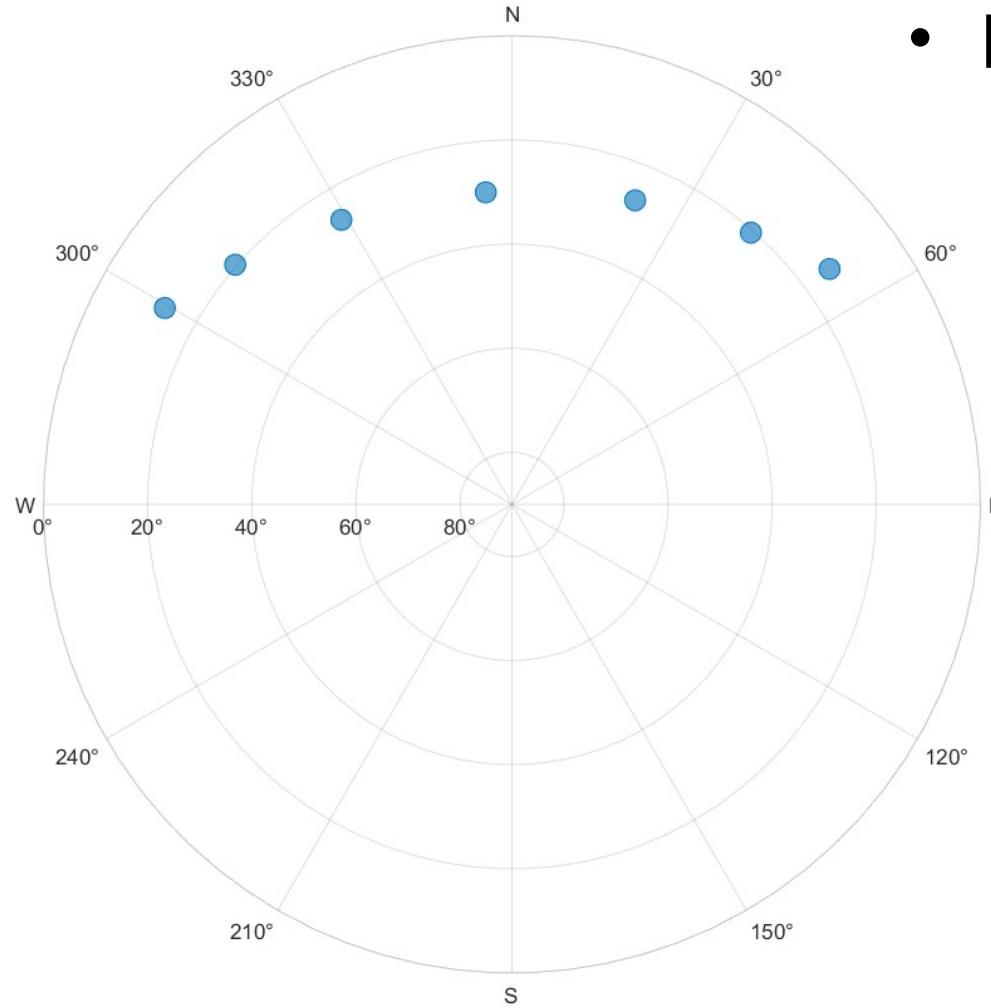
MATS elevation from ESRANGE



Nov 05, 2022

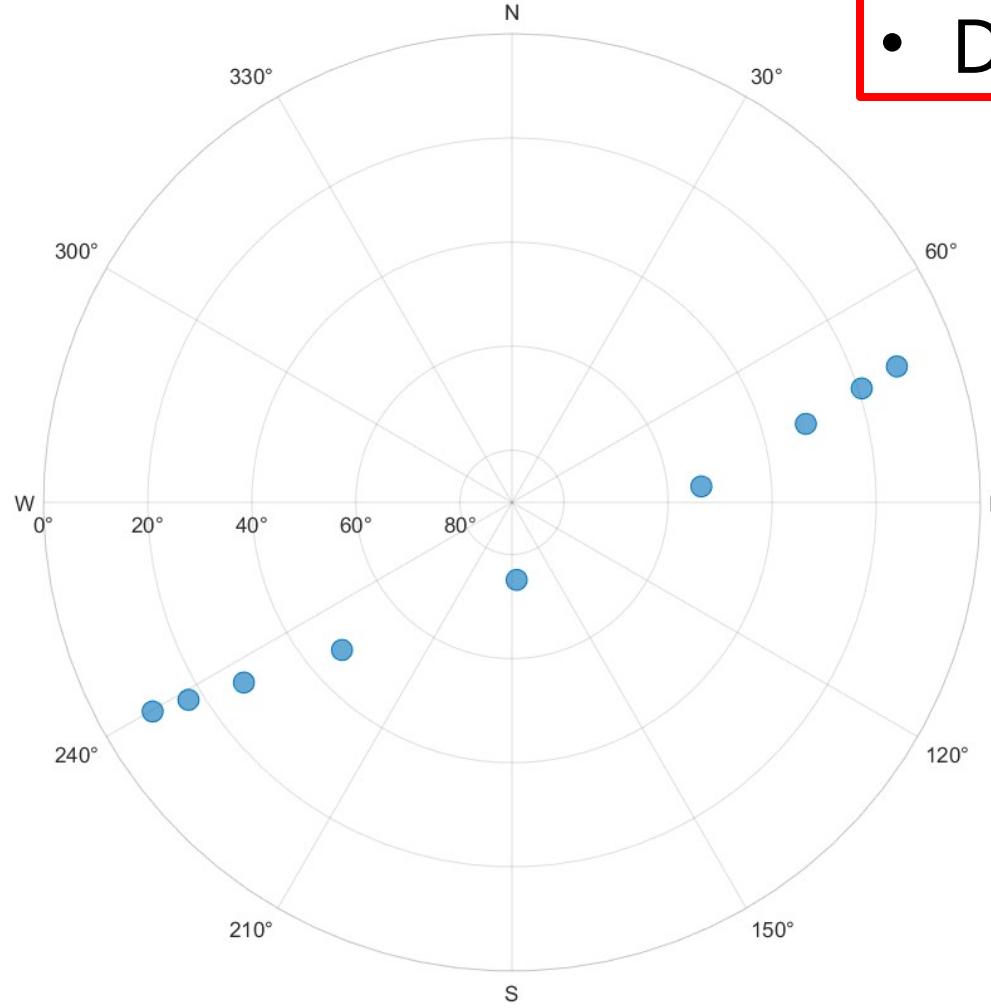
MATS orbit – Visibility Analysis from ESRANGE

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



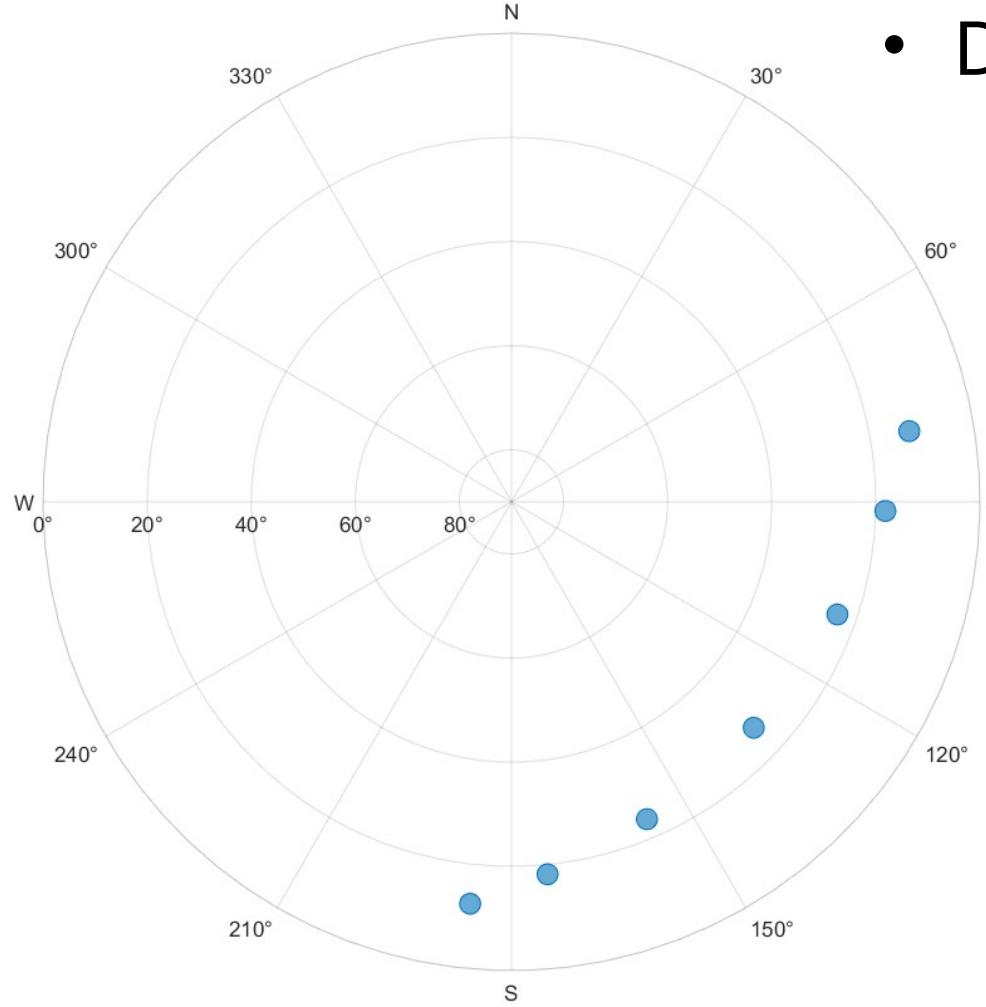
MATS orbit – Visibility Analysis from ESRANGE

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



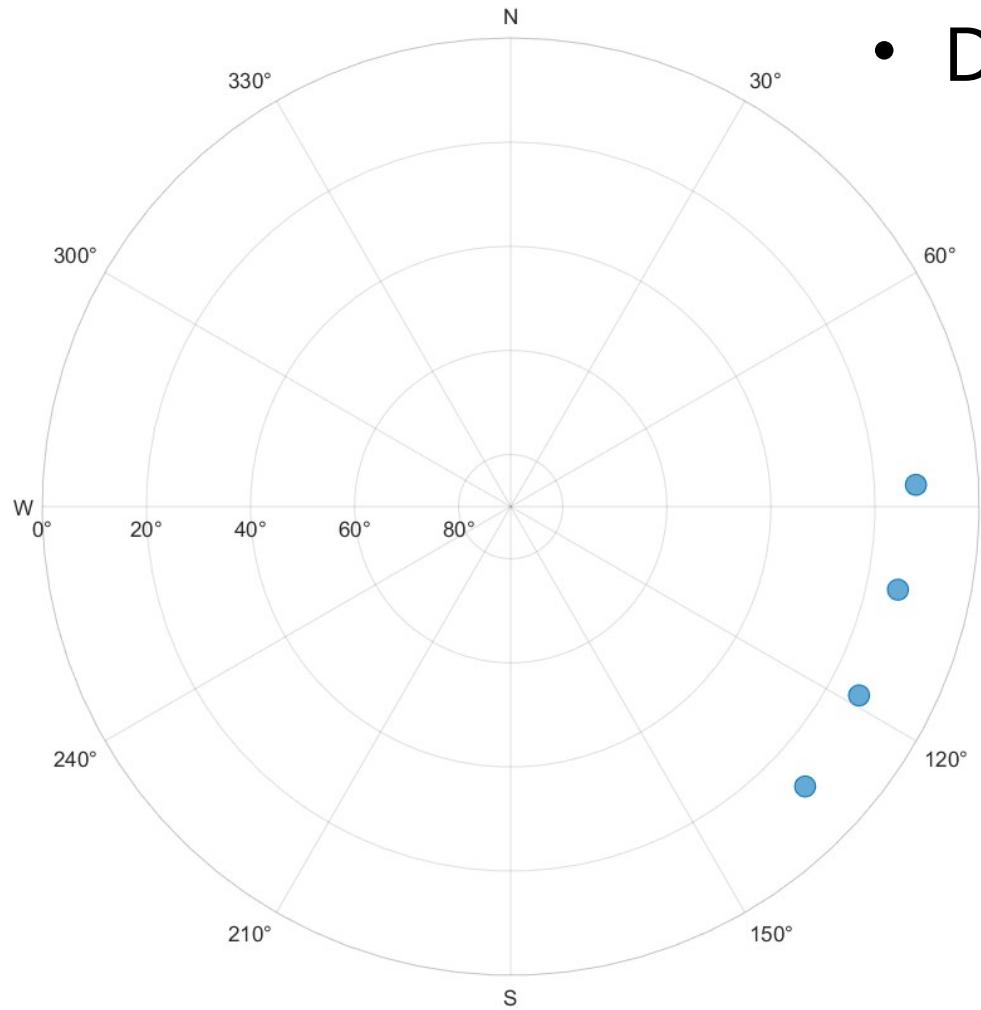
MATS orbit – Visibility Analysis from ESRANGE

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



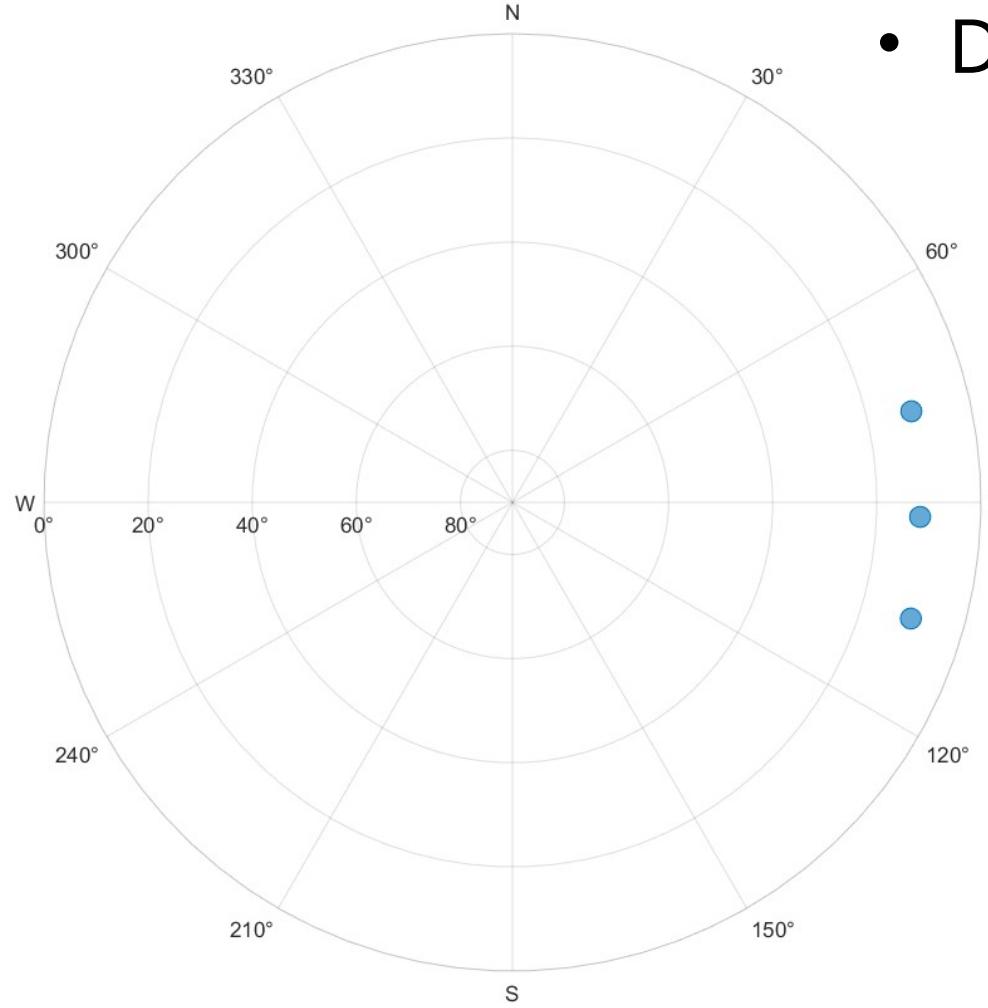
MATS orbit – Visibility Analysis from ESRANGE

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



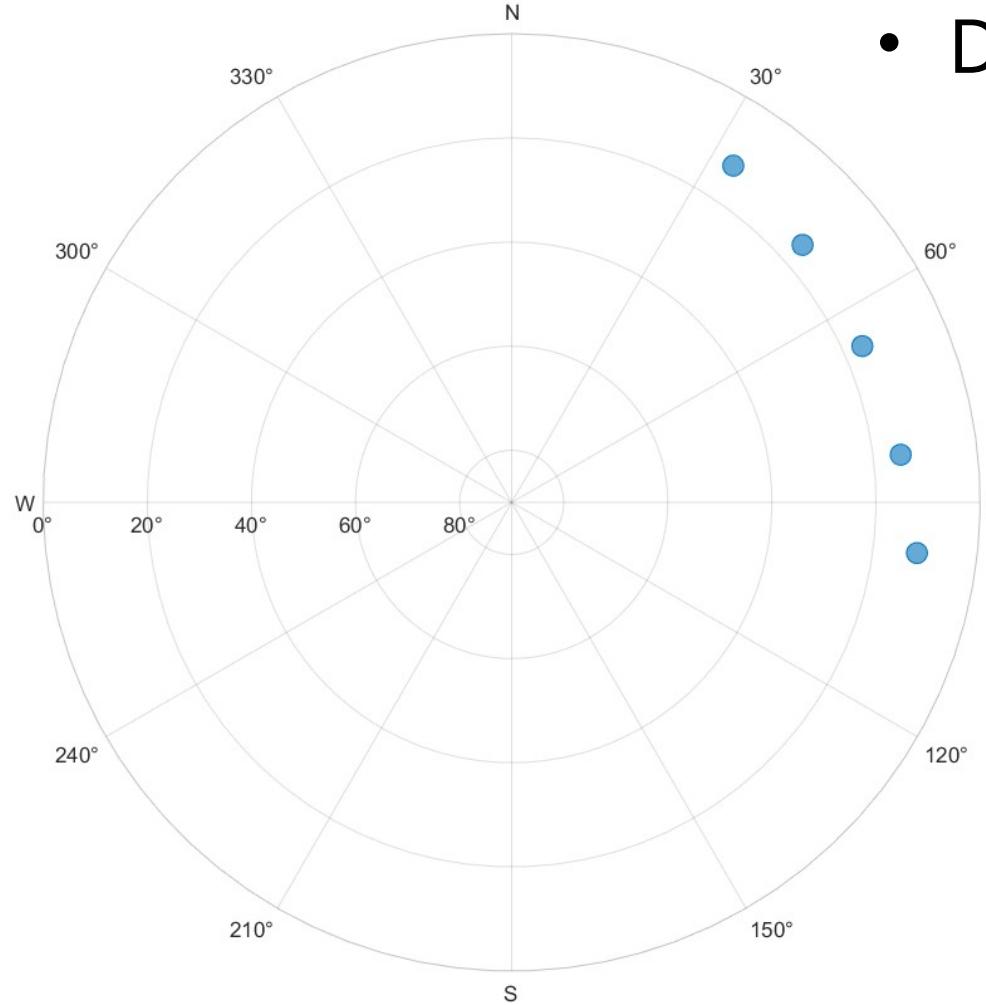
MATS orbit – Visibility Analysis from ESRANGE

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



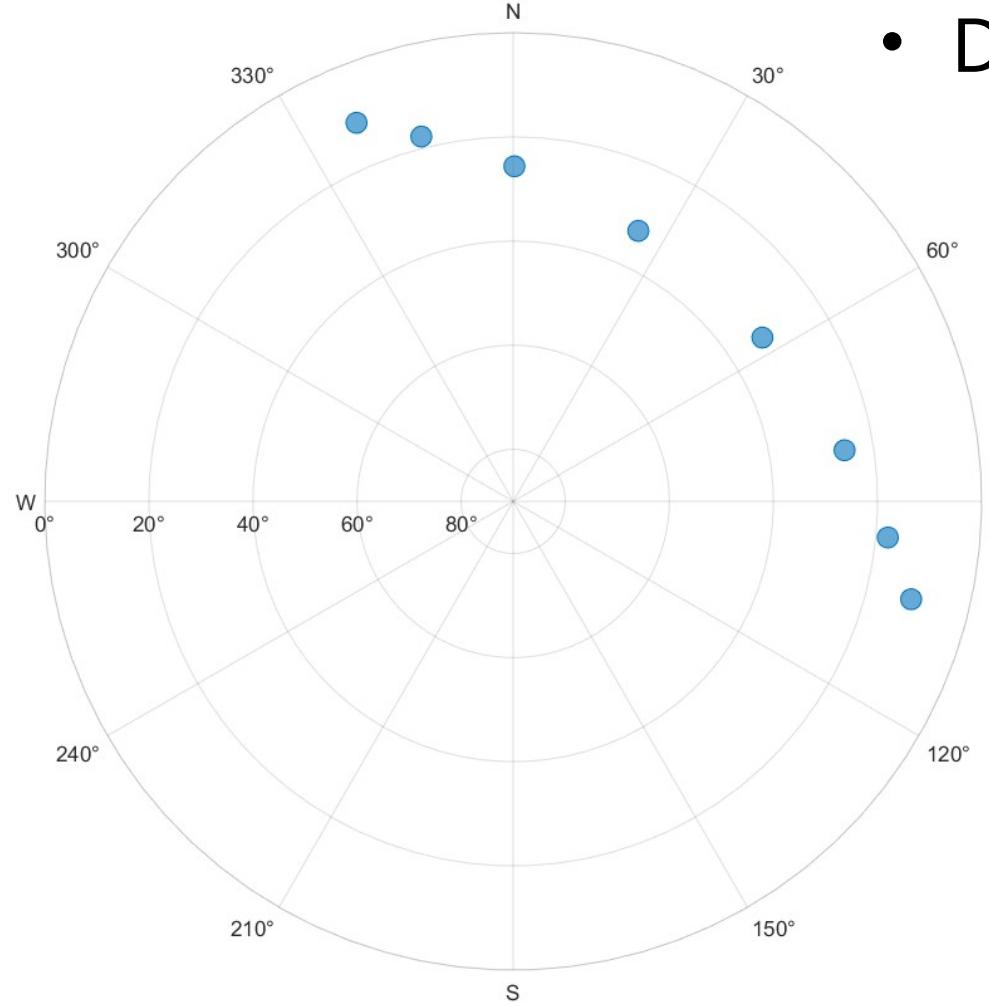
MATS orbit – Visibility Analysis from ESRANGE

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



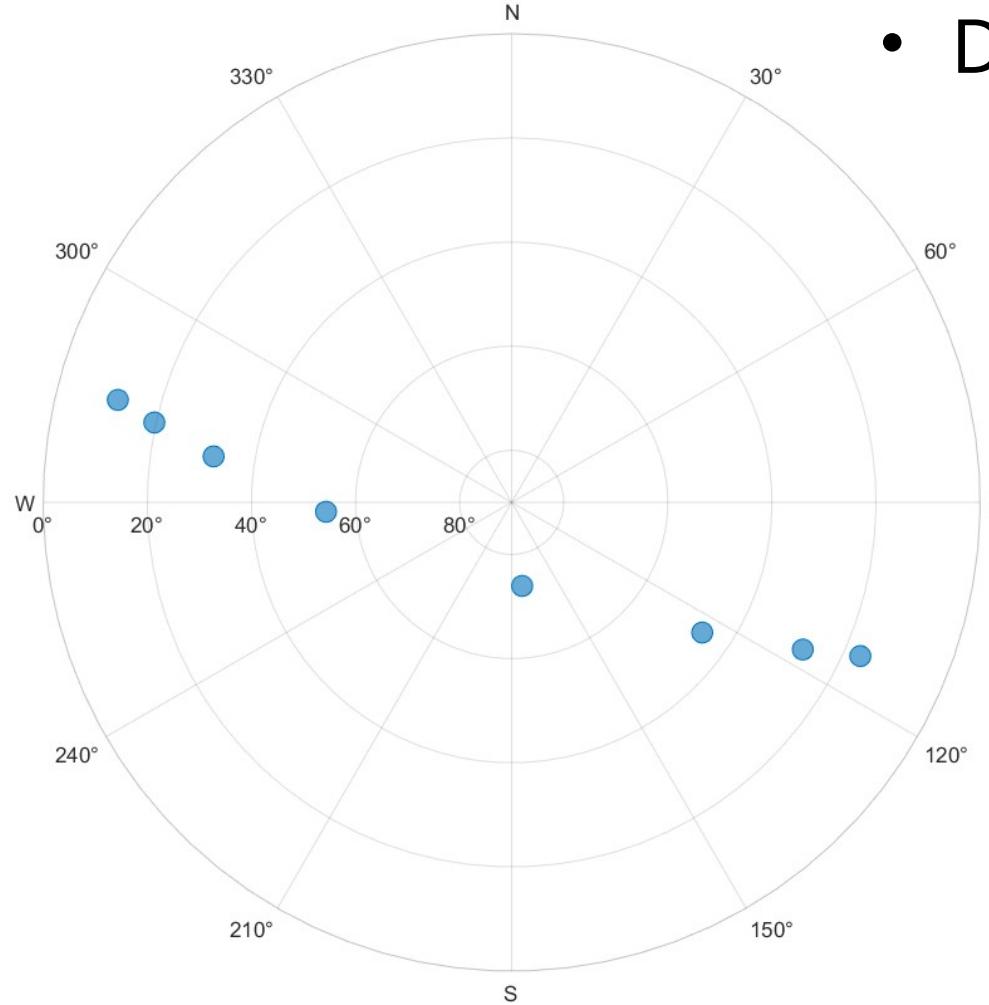
MATS orbit – Visibility Analysis from ESRANGE

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



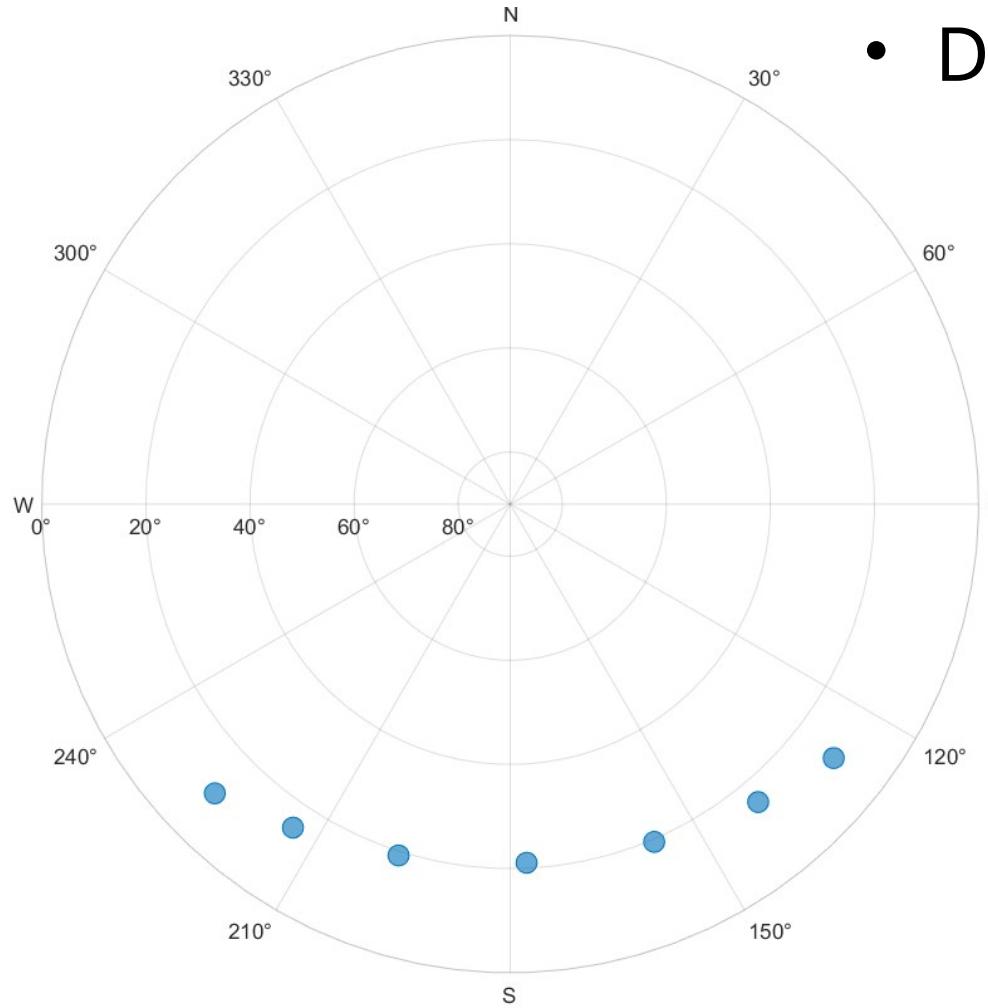
MATS orbit – Visibility Analysis from ESRANGE

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



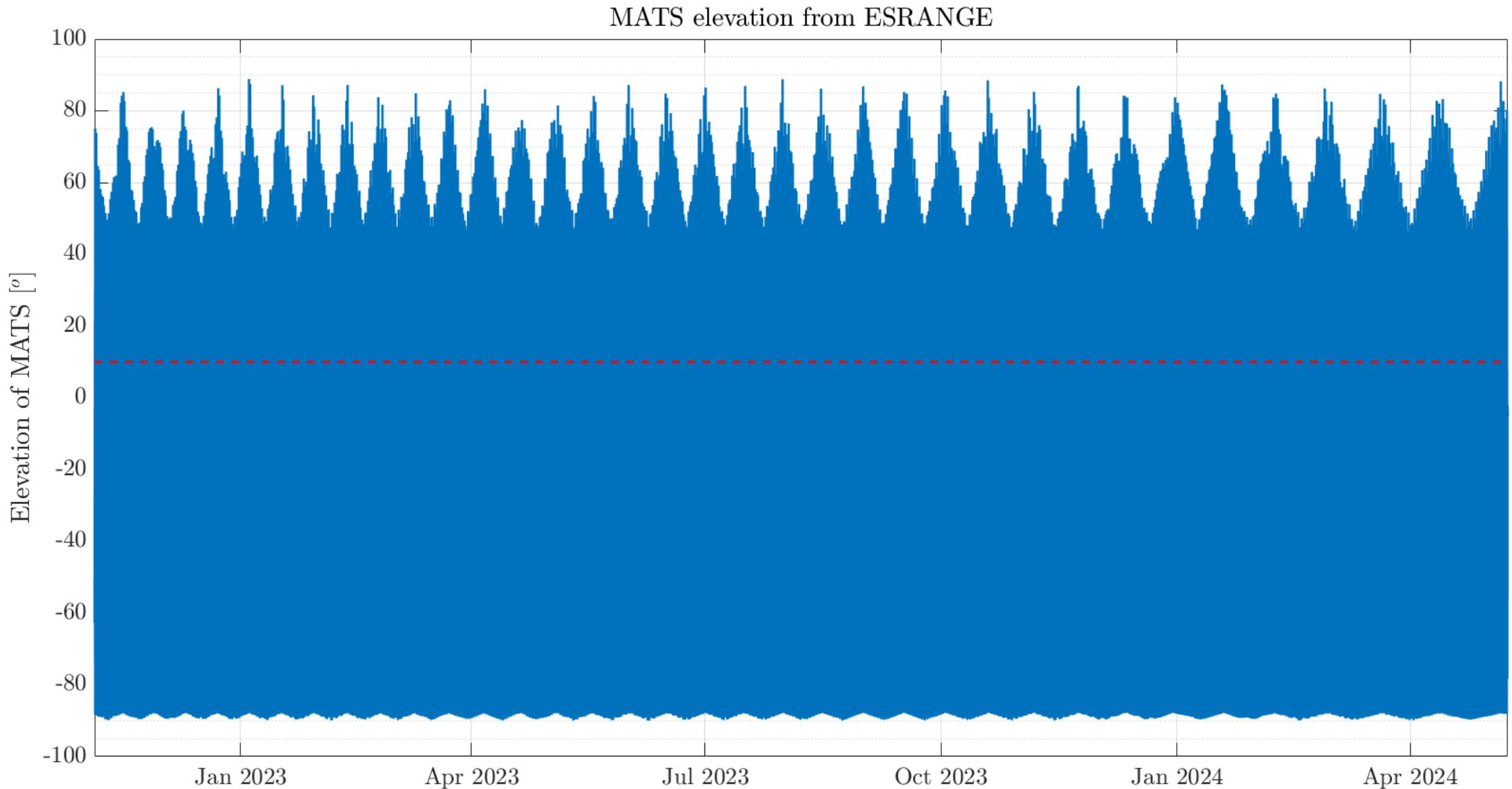
MATS orbit – Visibility Analysis from ESRANGE

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



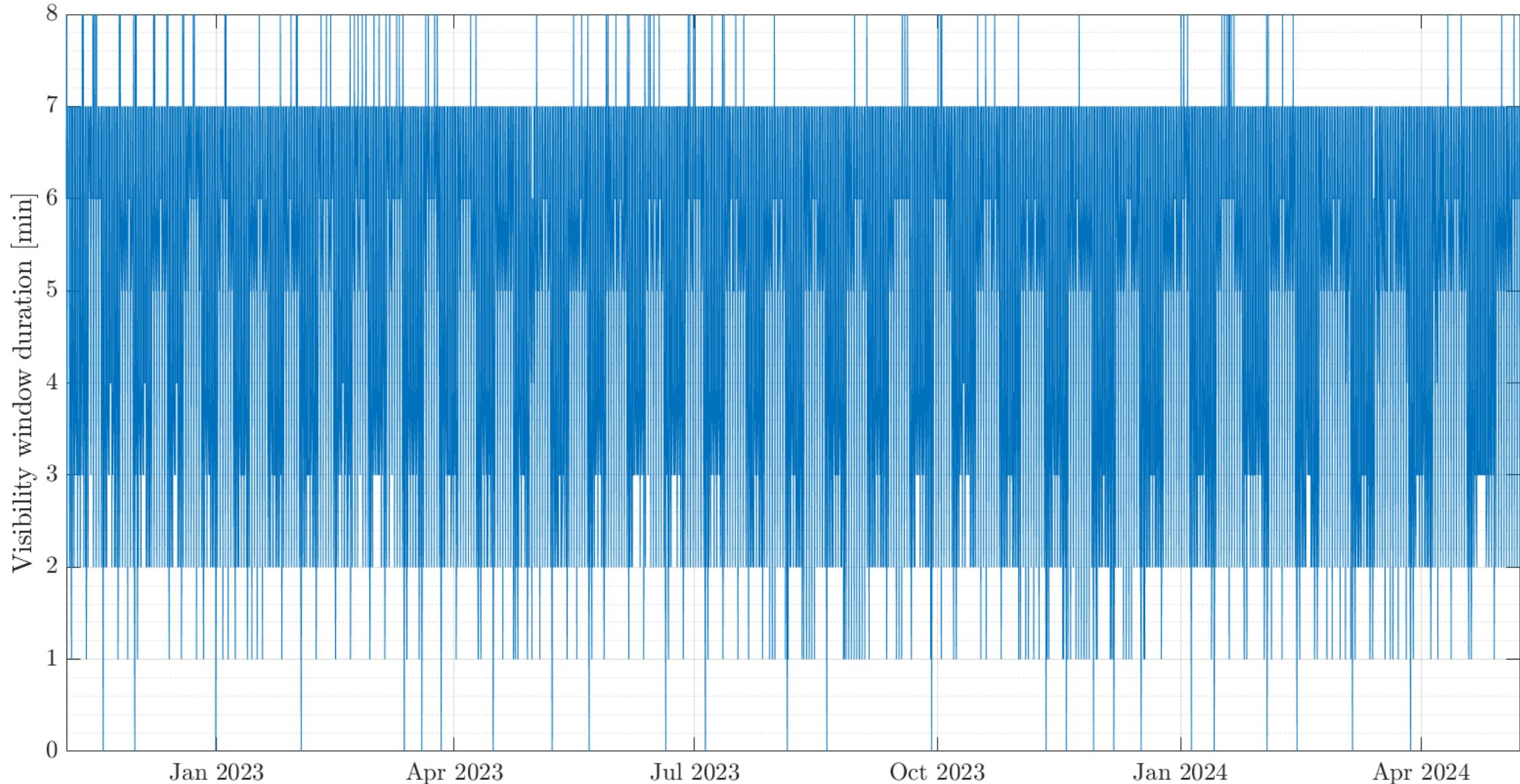


MATS orbit – Visibility Analysis from ESRANGE

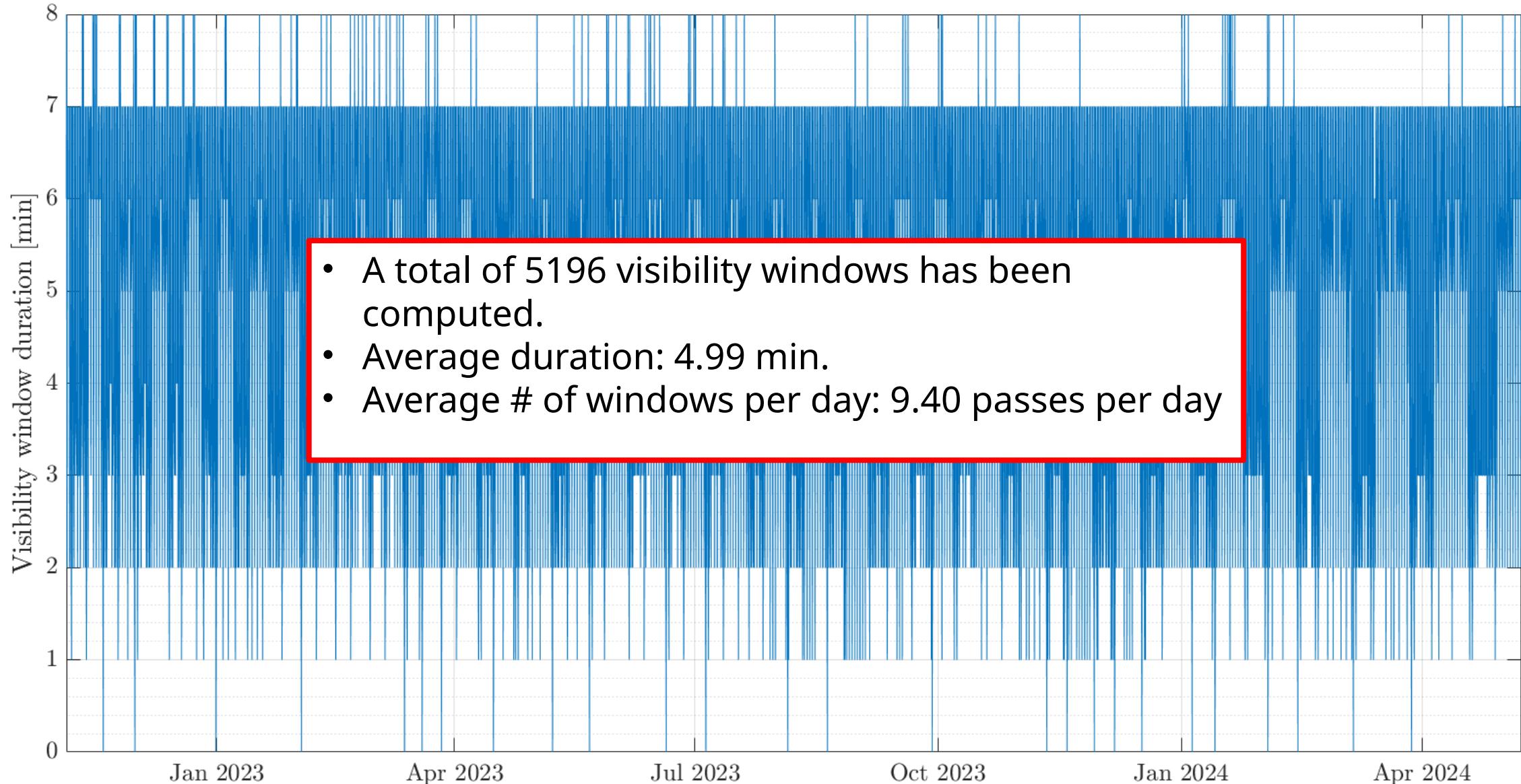




MATS orbit – Visibility Analysis from ESRANGE

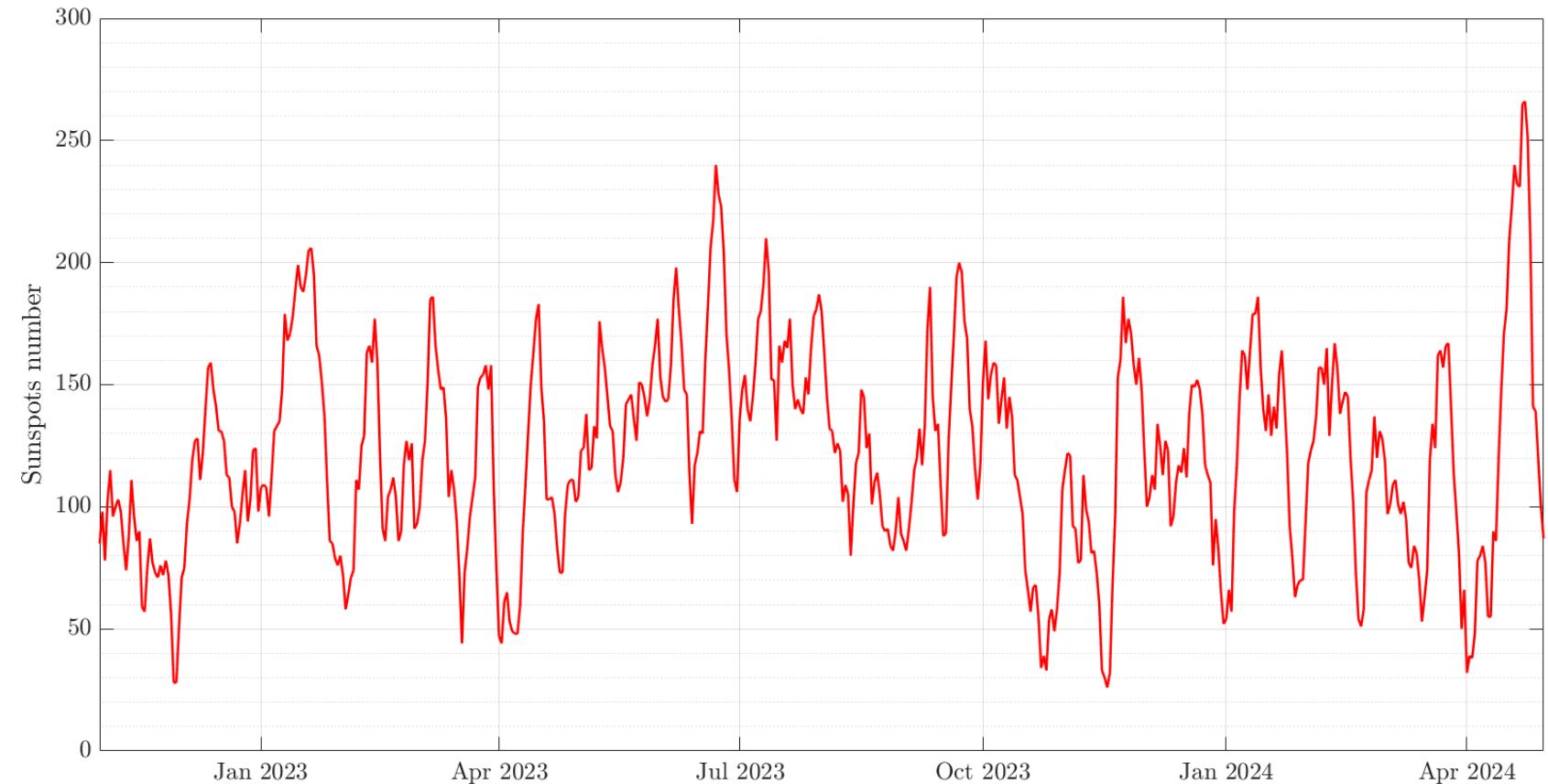
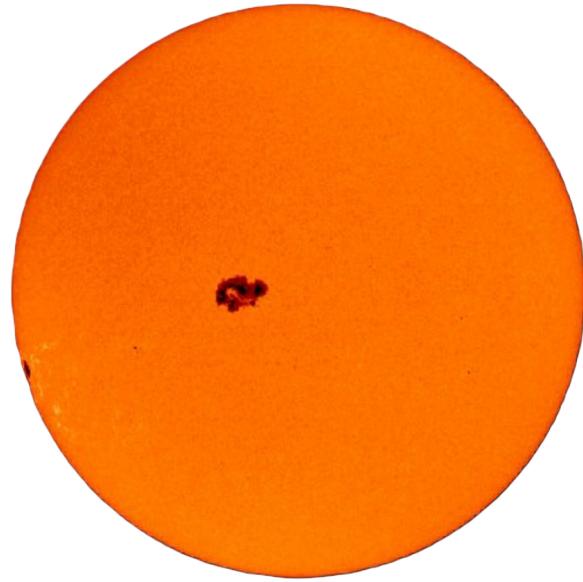


MATS orbit – Visibility Analysis from ESRANGE



MATS orbit – Solar Activity

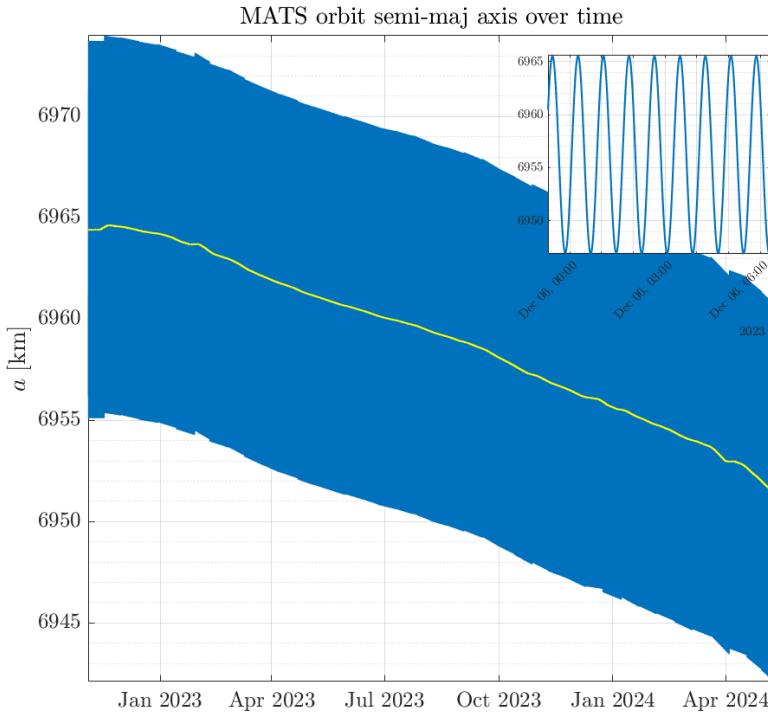
For the scope of the current work, solar activity has been assessed using sunspots number as main indicator.



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

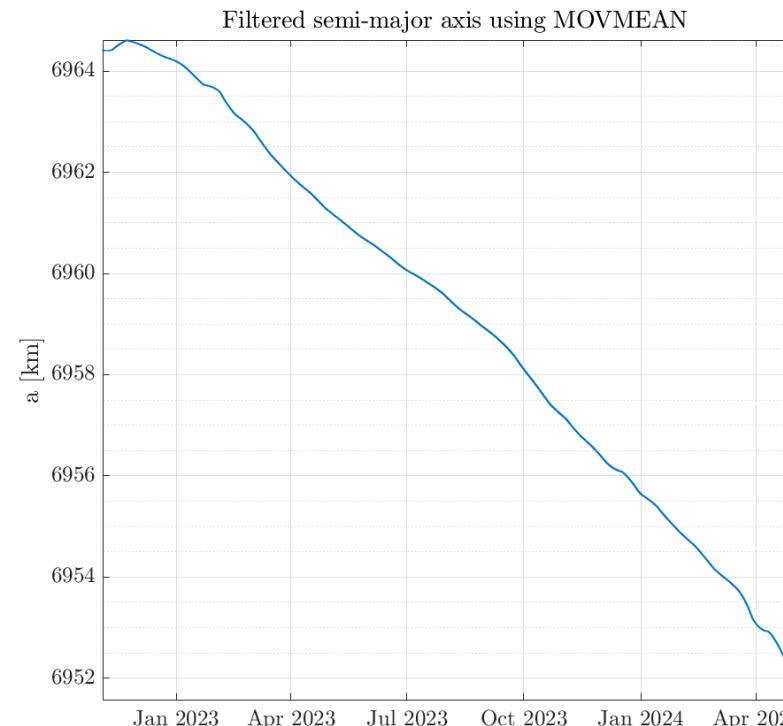
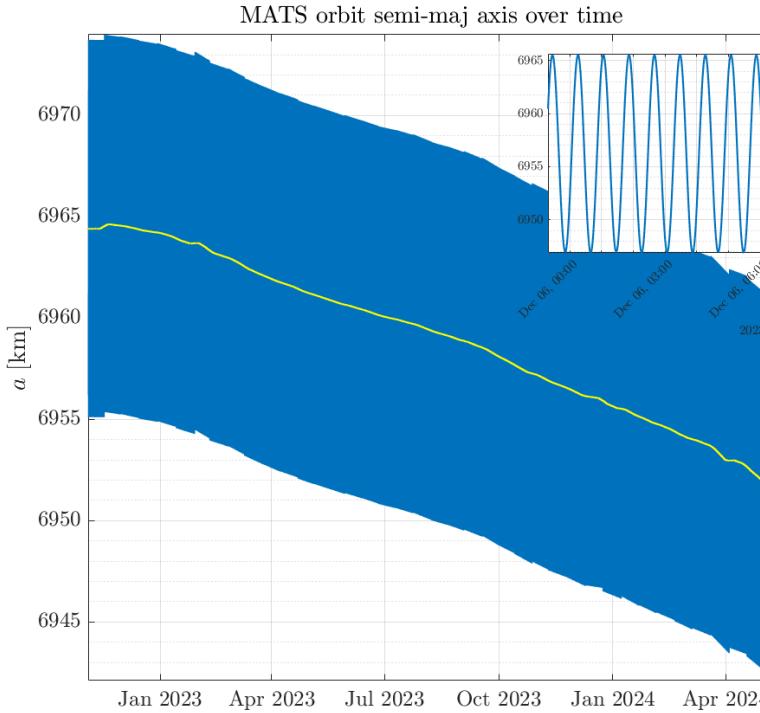
MATS orbit – Solar Activity

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 .



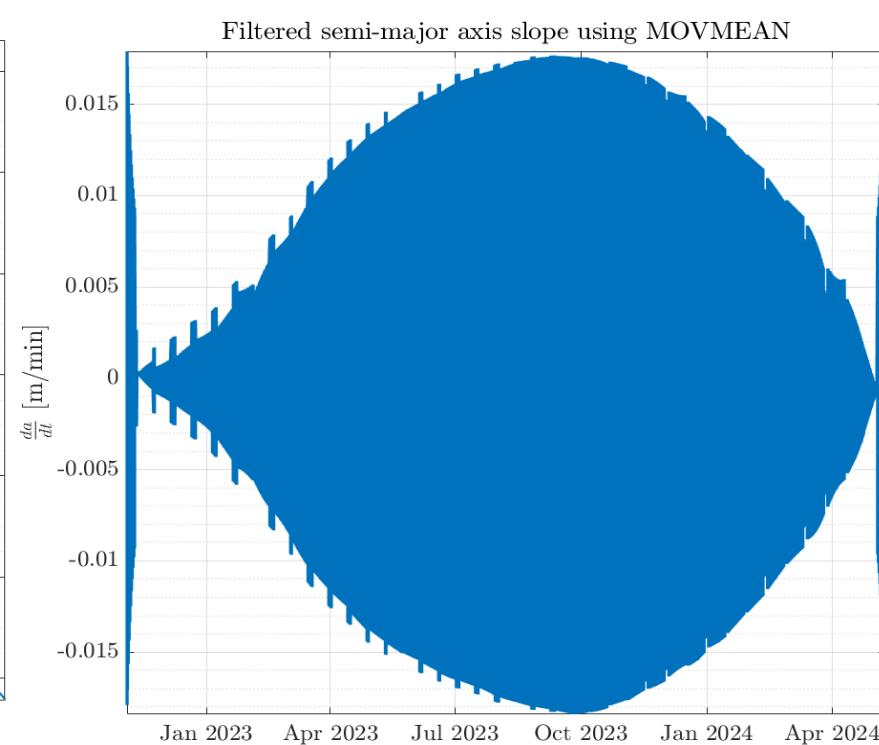
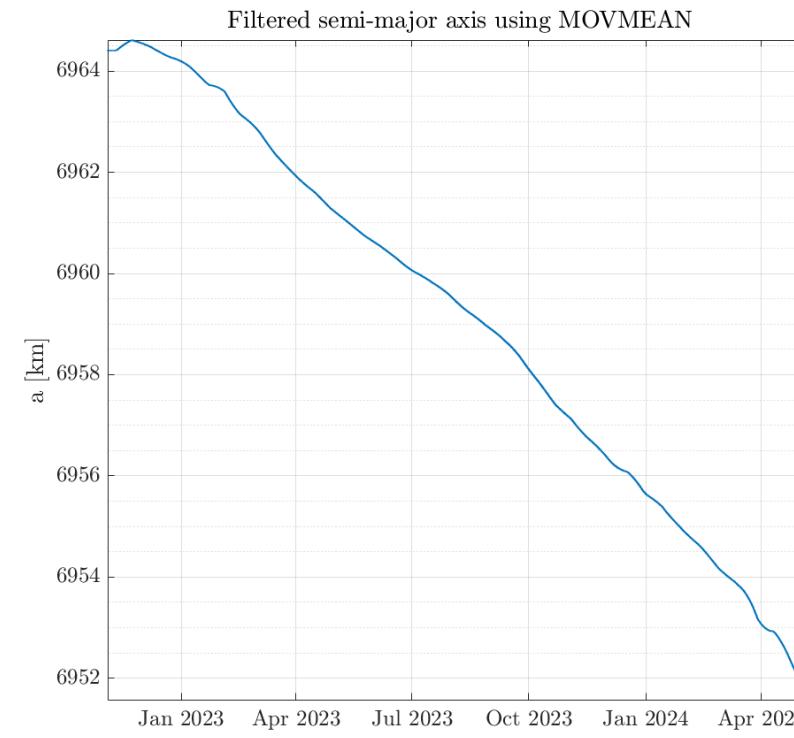
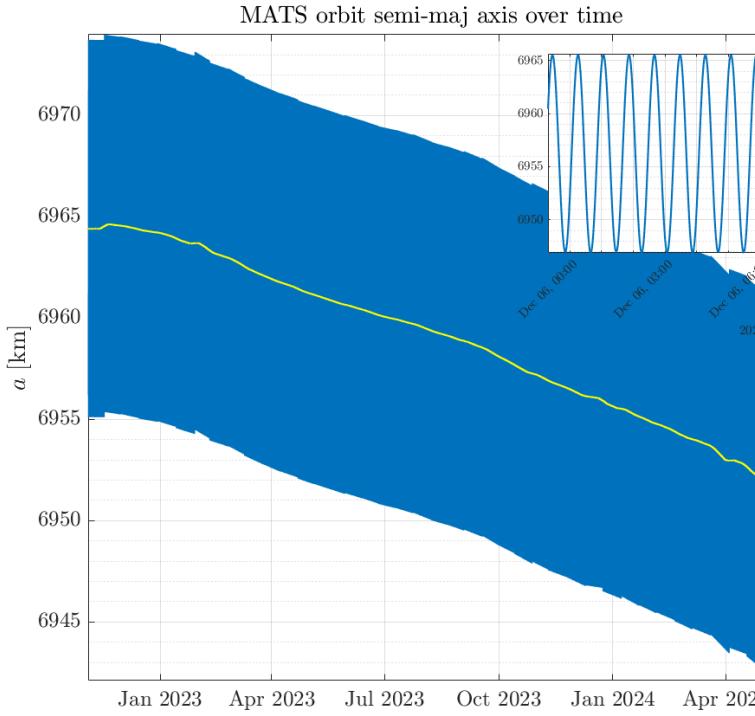
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MATS orbit – Solar Activity

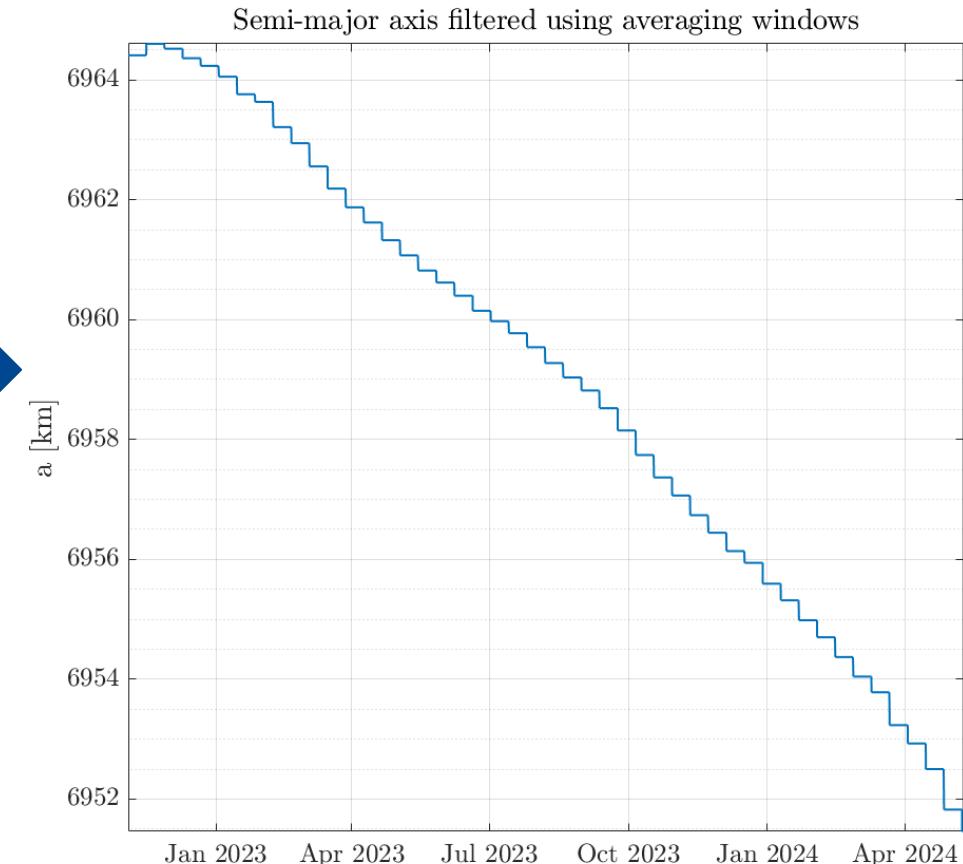
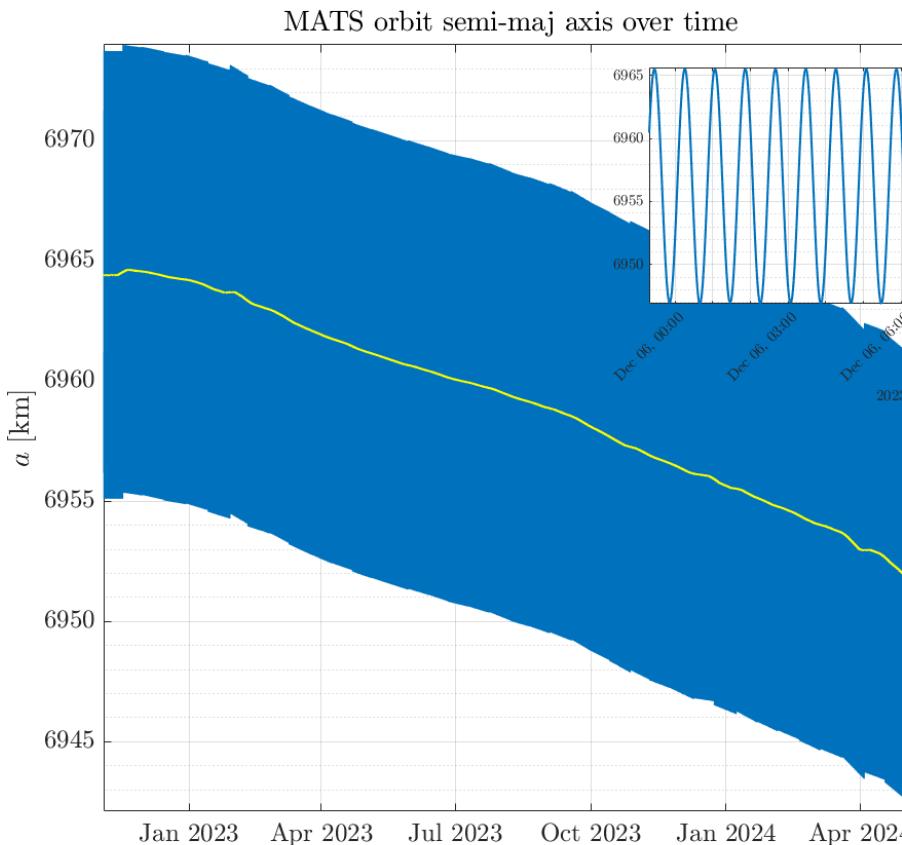
Because one of the main effects of high solar activity is the increase of density of the upper atmosphere, a stronger decrease in orbital energy is searched for when the sunspot number grows .



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

MATS orbit – Solar Activity

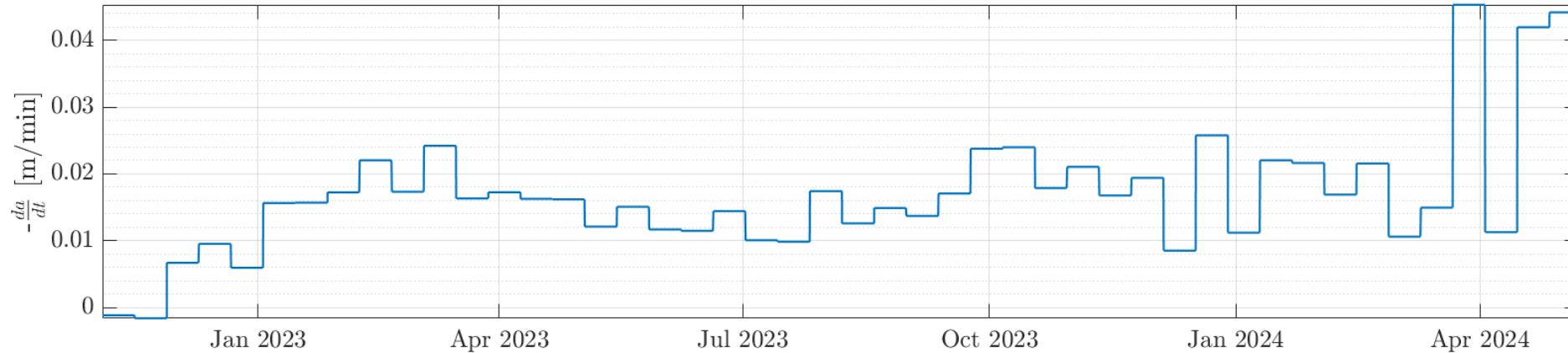
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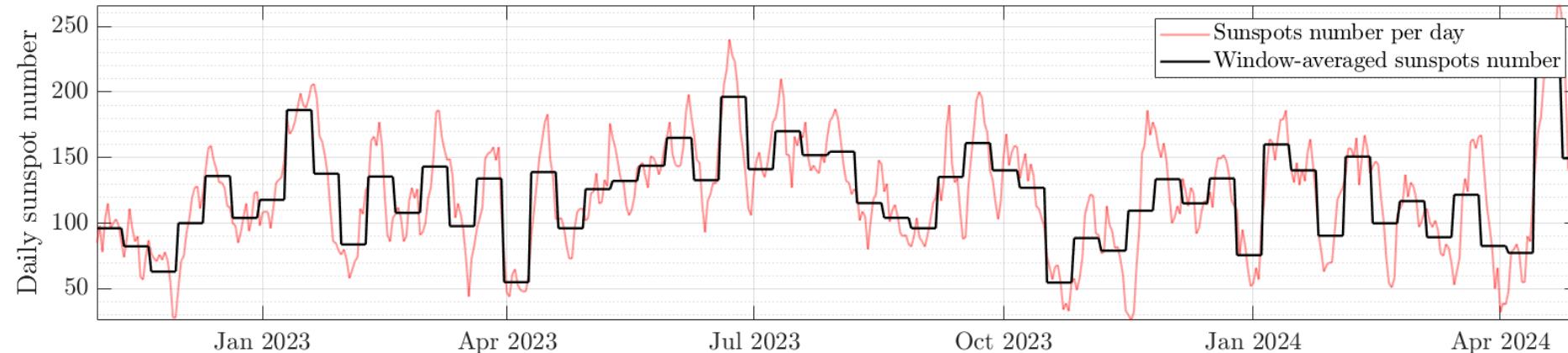
MATS orbit – Solar Activity

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Semi-major axis slope filtered using averaging windows

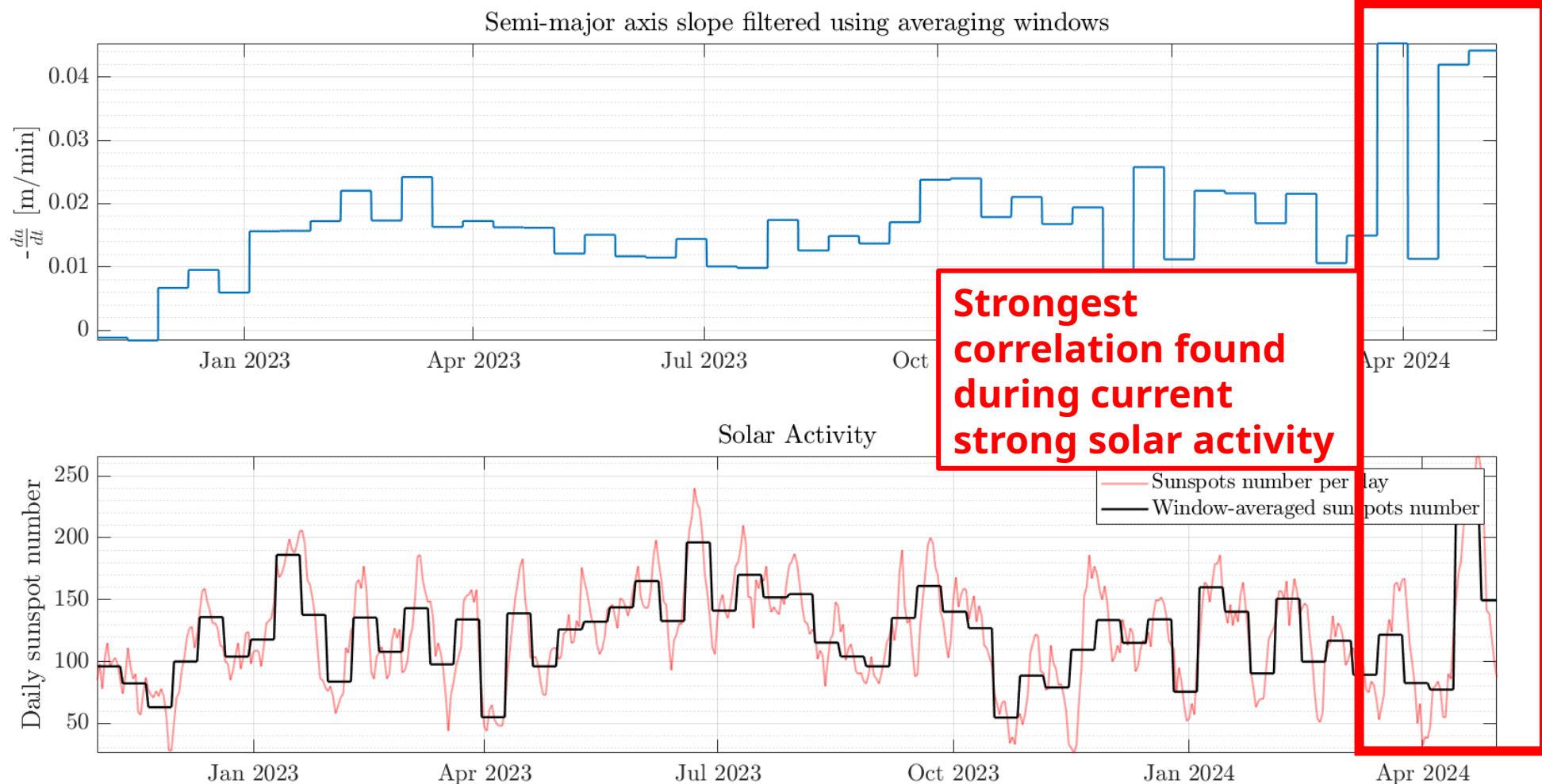


Solar Activity



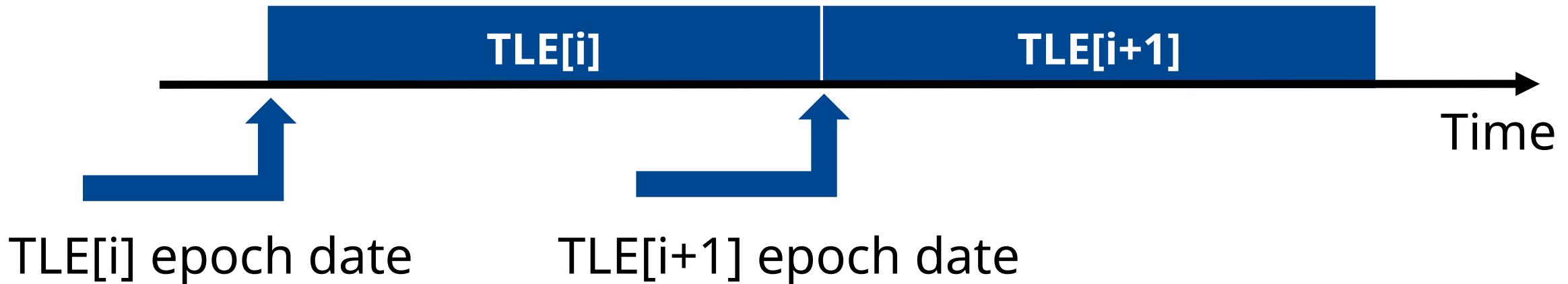
MATS orbit – Solar Activity

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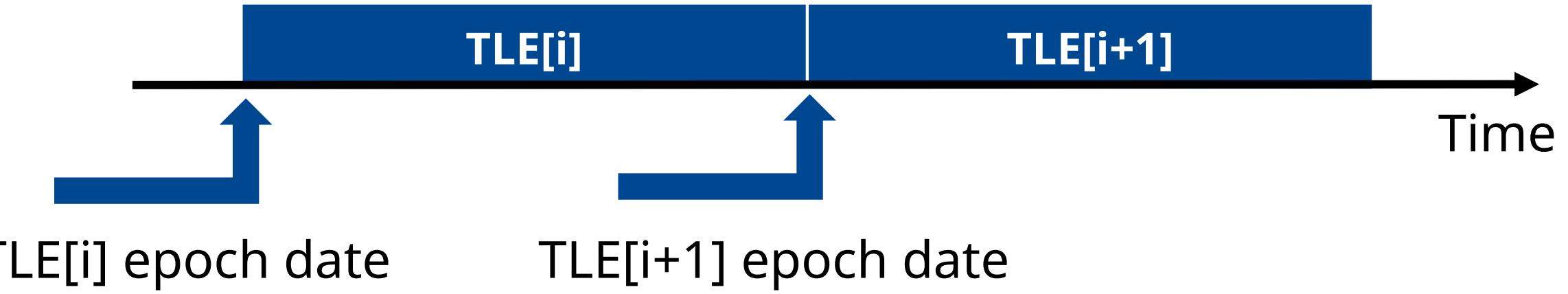
Line-Of-Sight Visibility Analysis - STARLINK

TLE Propagation Methodology



Line-Of-Sight Visibility Analysis - STARLINK

TLE Propagation Methodology



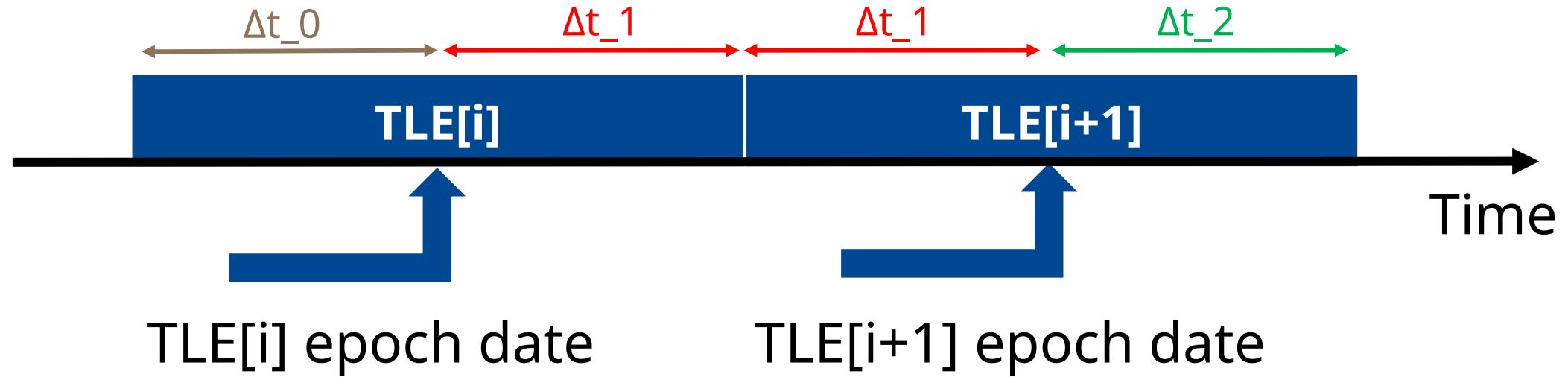
Why?

"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 :

$$d > R_{\text{earth}} = 6378 \text{ km}$$

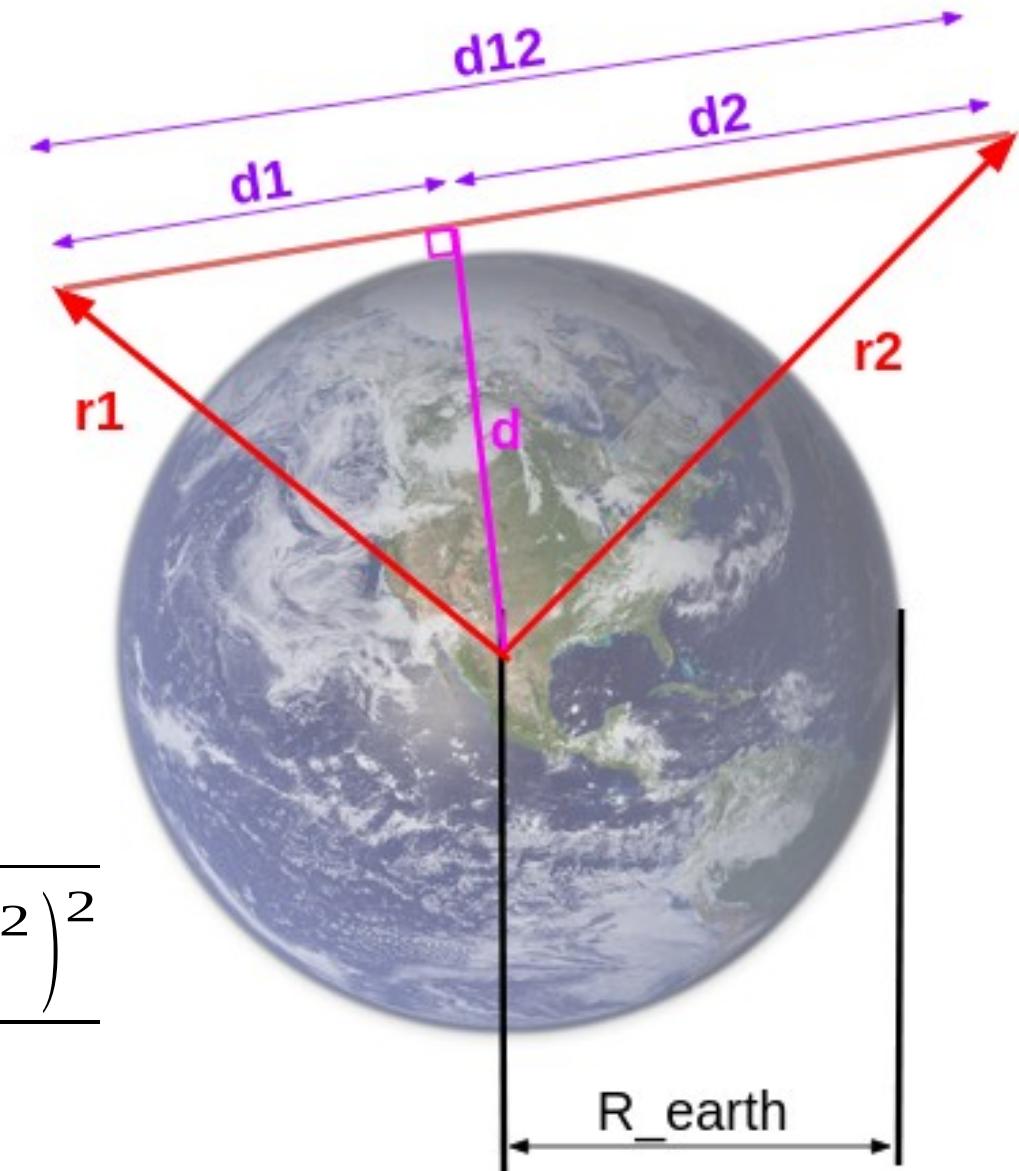
Obstructions : Clouds

Highest (Noctilucent) = 80km

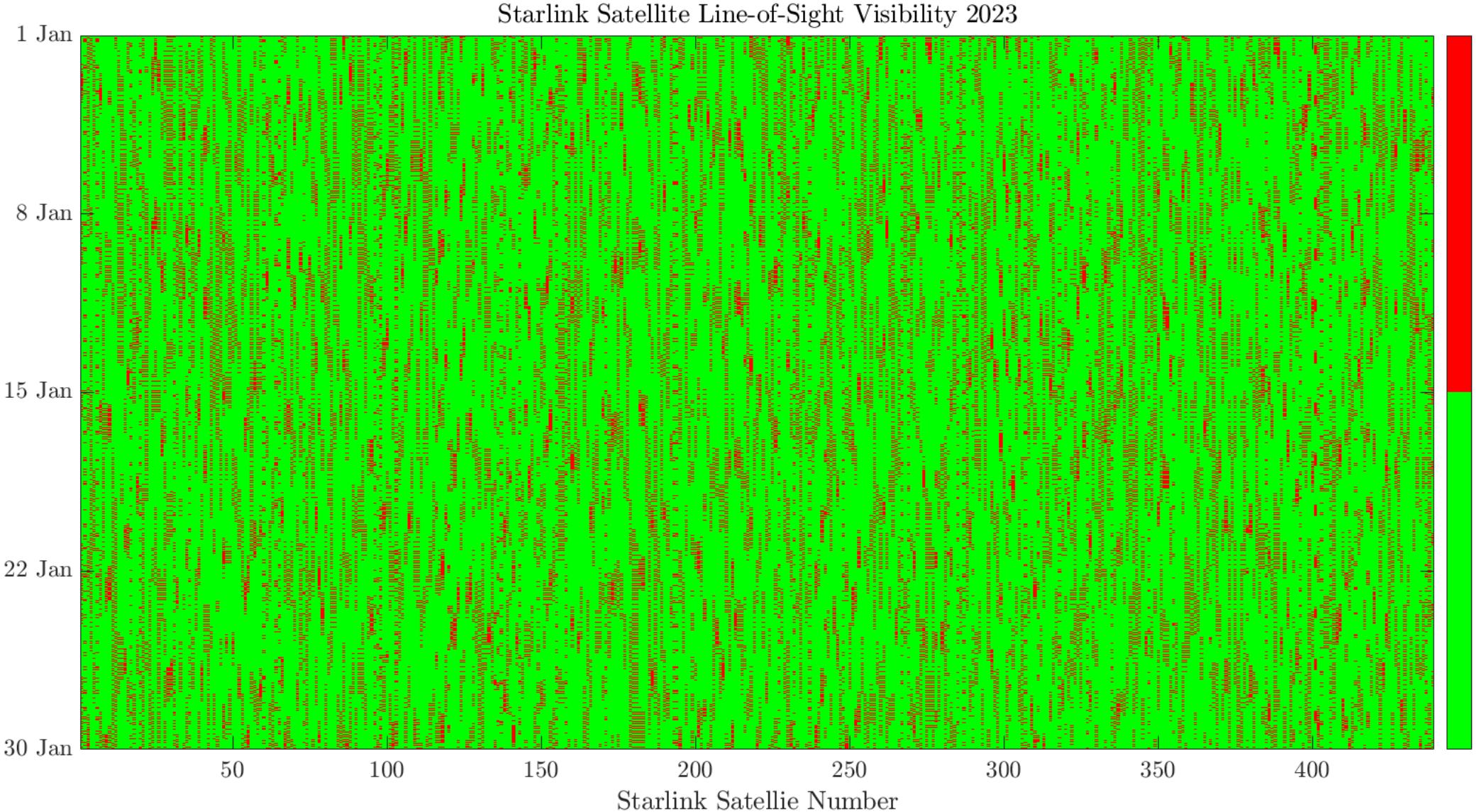
Adjusted Line-Of-Sight Visibility

$$d > R_{\text{adjusted}} = 6,460 \text{ km.}$$

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



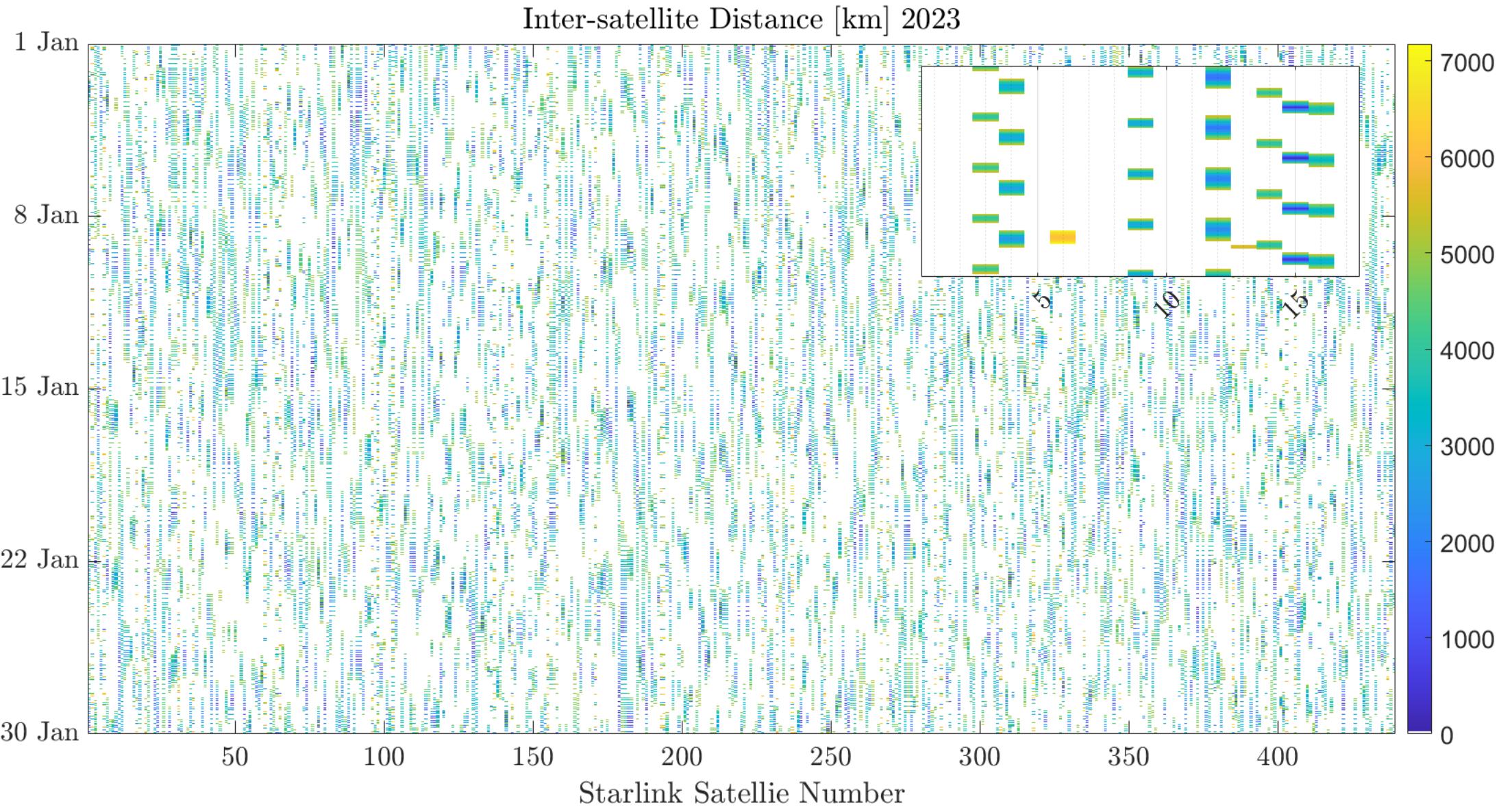
Results : Visible or Not?



Visible

Not Visible

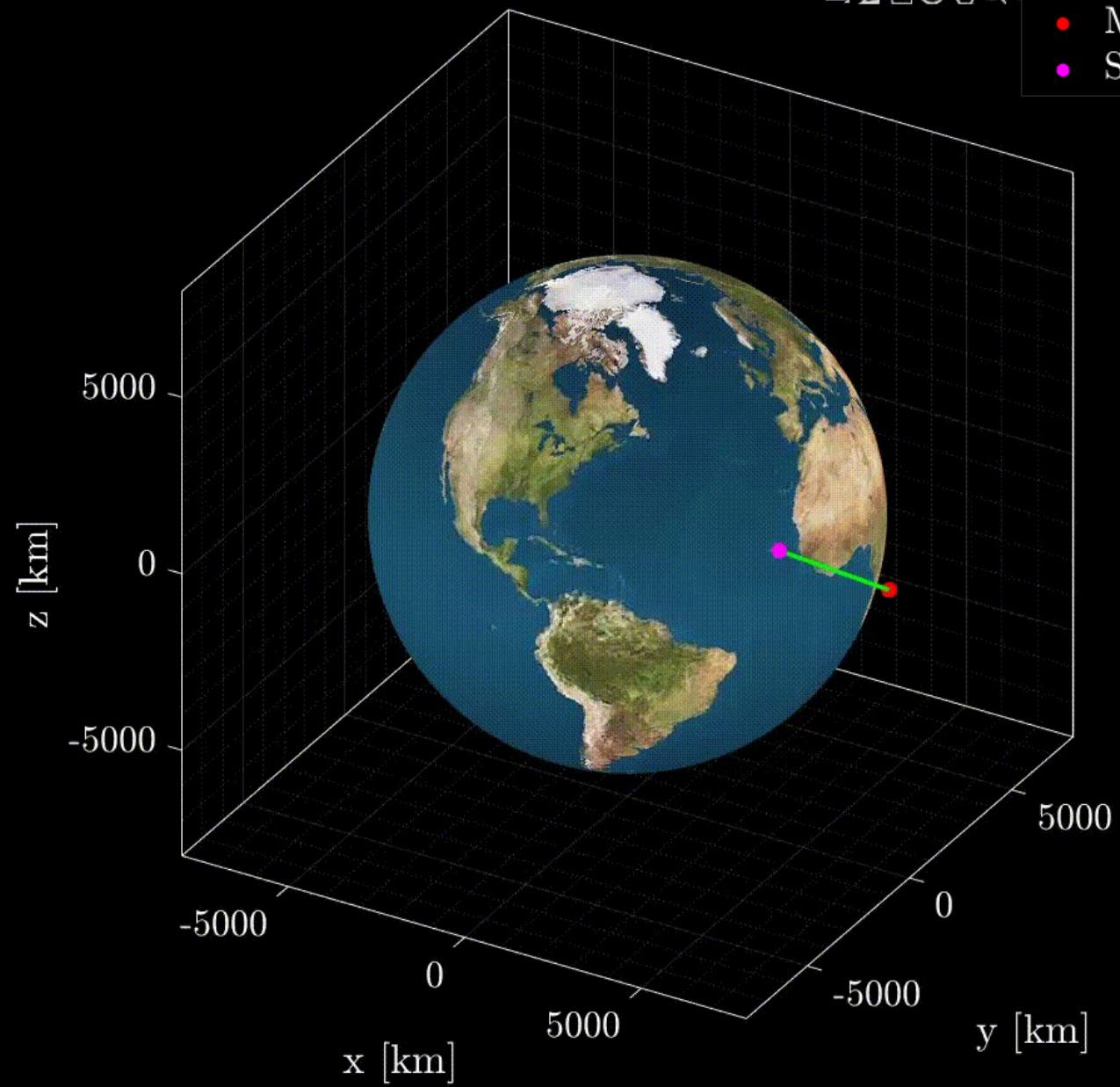
Results : Inter-satellite Distance for all?



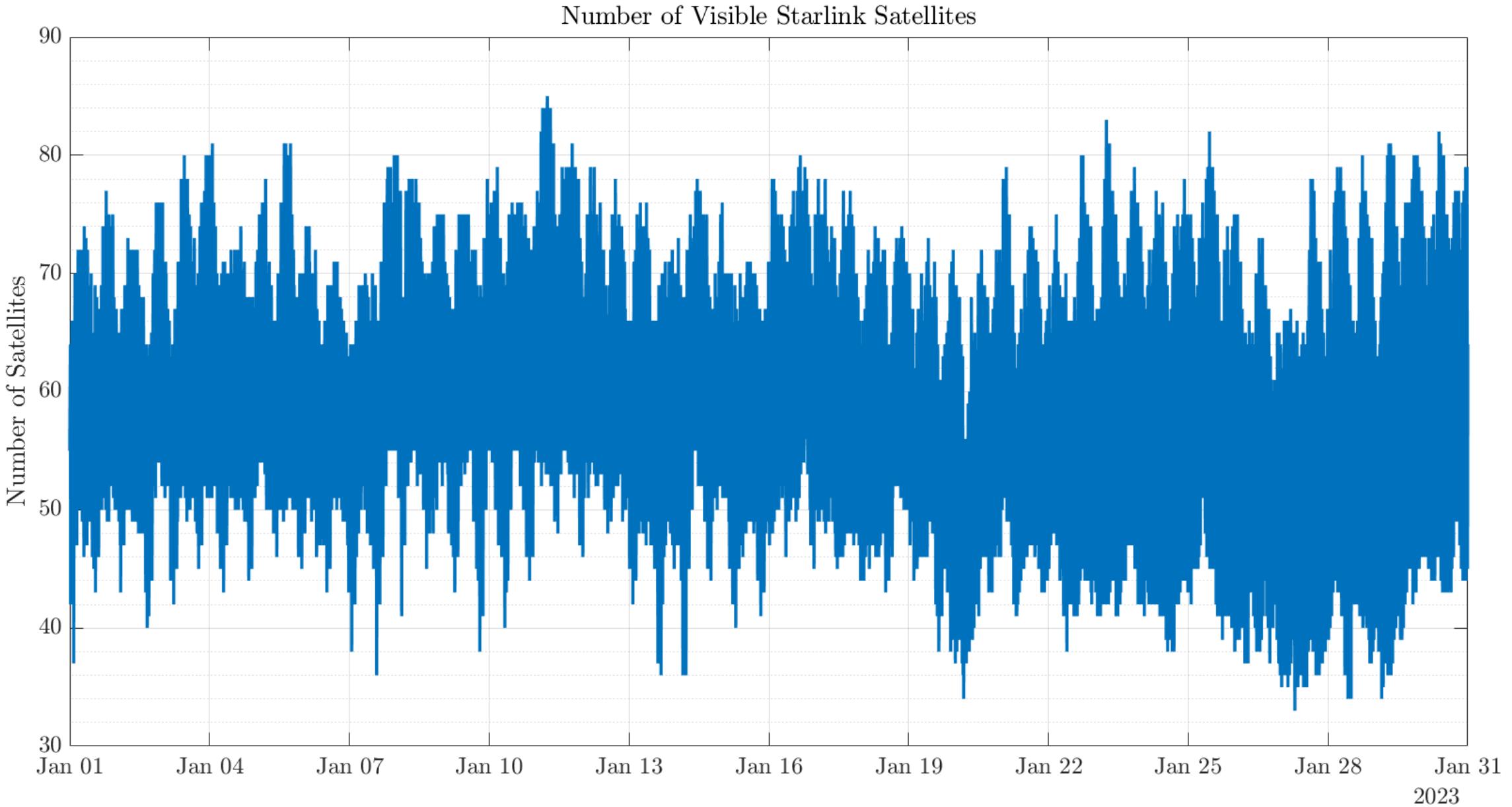
01-Jan-2023

☰ ☰ 🔍

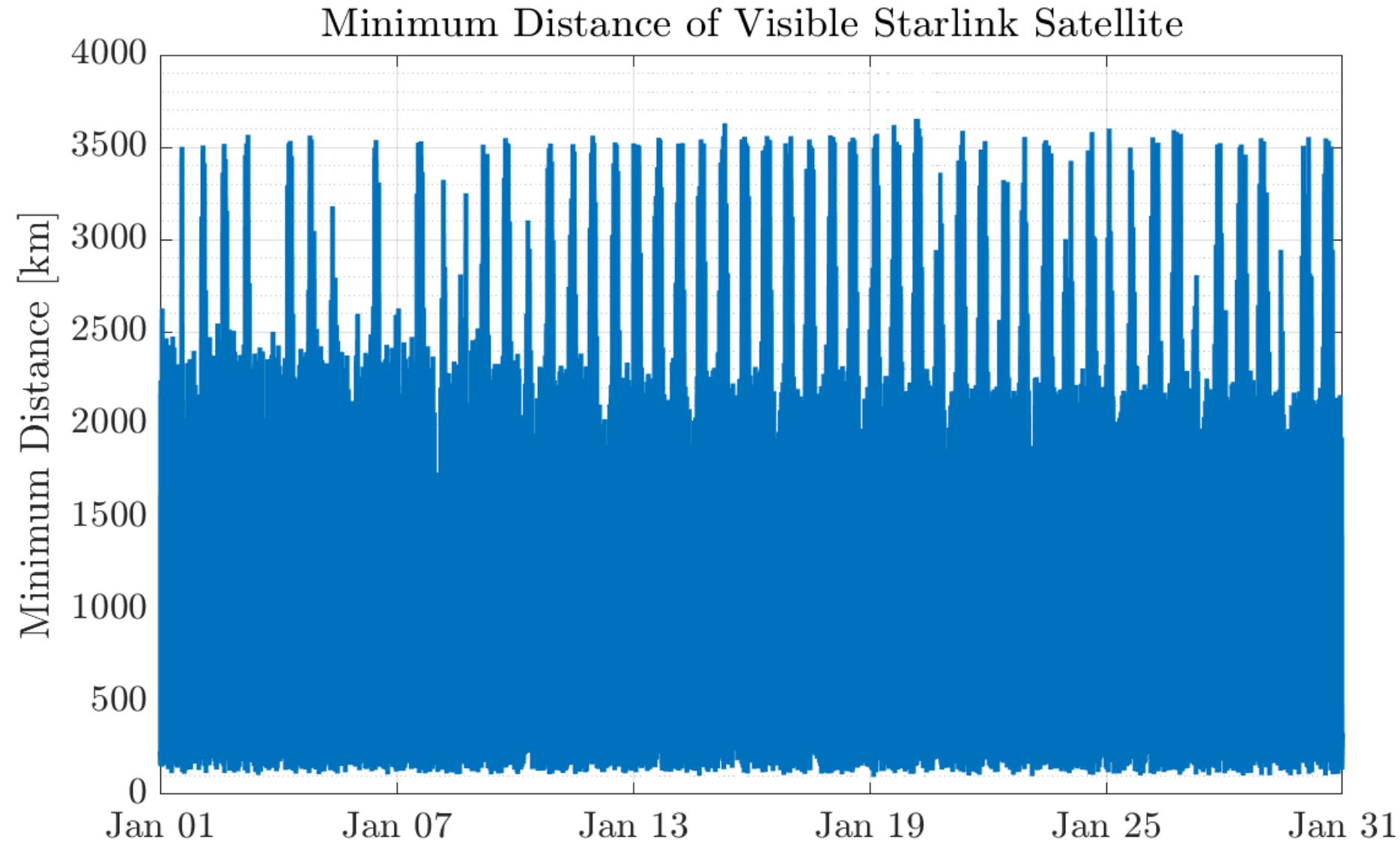
- MATS
- Starlink Satellite 12



Results : How Many Visible?

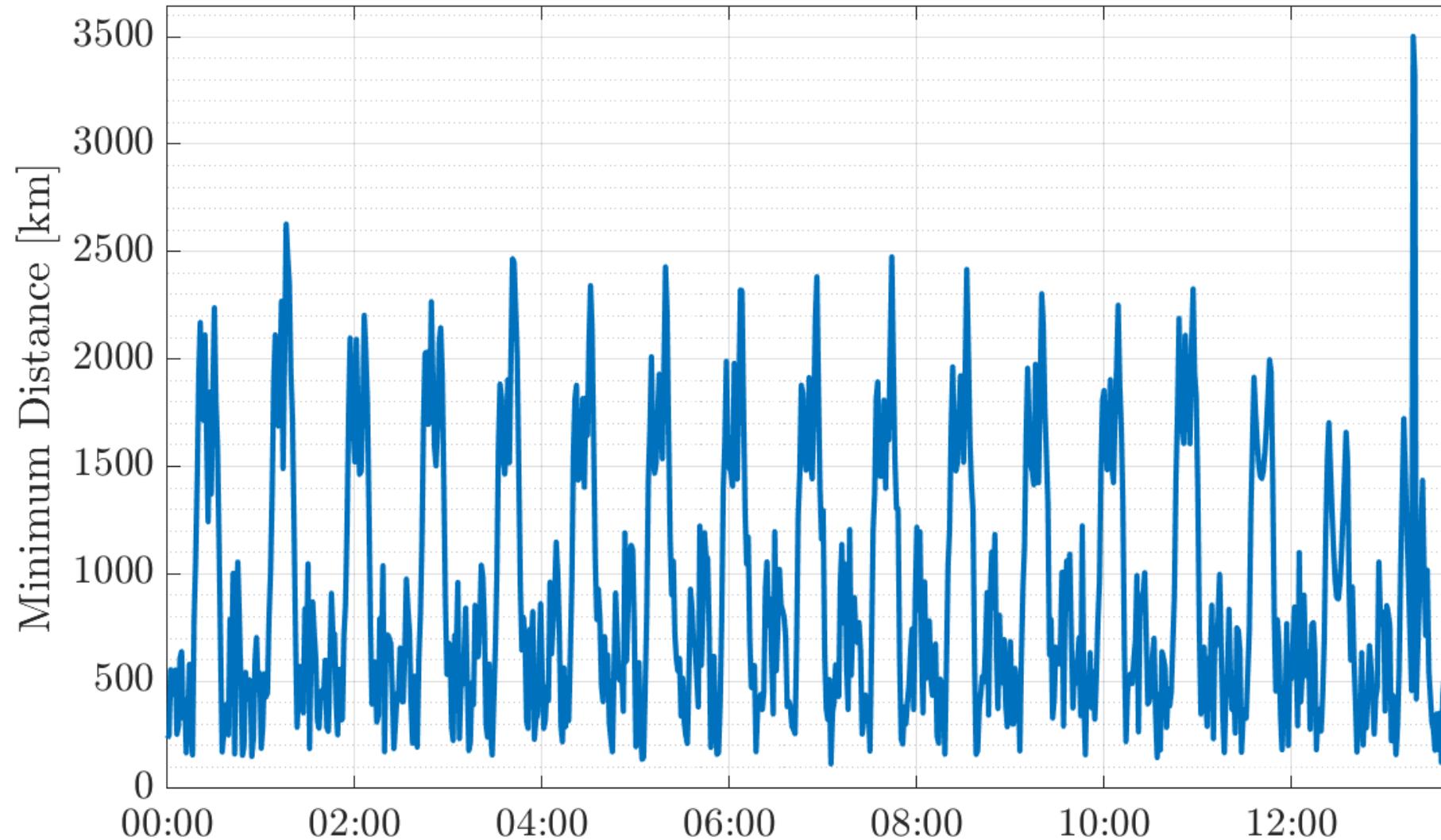


Results : Minimum Distance?



Results : Minimum Distance?

Minimum Distance of Visible Starlink Satellite





Thank you

Group 3: Buratti Diego, Patel Kirtan