VIEVS DAYS 2026

SATELLITES IN VIEVS-VLBI

1 | DESCRIPTION

This exercise provides a brief introduction of analyzing VLBI observations to satellites using the VLBI module (VieVS-VLBI) of the Vienna VLBI and Satellite Software (VieVS). Using an arbitrary VLBI session containing observations to the **Genesis satellite** and **quasars**, it is explained how to process VLBI observations to satellites and how to estimate station coordinates, satellite positions, and orbital elements.

2 | DATA

The following exercise uses an example session containing both Genesis and quasar observations. The schedule for this session was generated using **VieSched++**.

Since satellite observations are not yet supported in the vgosDB format, an NGS file is used.

Download the following files from the TU Cloud (***VieVS Days 2026/HW/satellites_in_vievs***) and place them in the following directories:

- 25AUG03VS_N000 → *../VLBI/DATA/NGS/*
- G1_23776.sp3, G1_23780.sp3, G1_23781.sp3 → *../VLBI/ORBIT/SP3*
- LEVEL0/Genesis → *../VLBI/DATA/LEVEL0*
- LEVEL1/Genesis → *../VLBI/DATA/LEVEL1*

3 | BEFORE YOU START

- start Matlab
- browse to your VieVS-VLBI working directory VieVS/VLBI/WORK
- type ***vievs*** in the Matlab command window

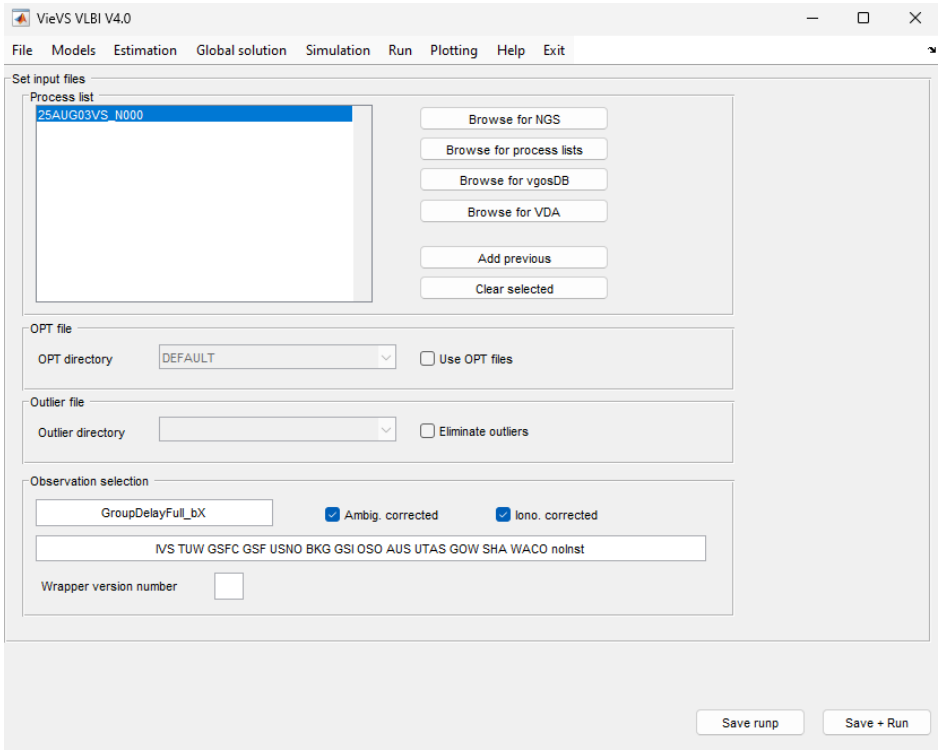
... now VieVS-VLBI should open.

3 | SESSION

We will analyze the session ***25AUG03VS_N000***. To load the session, follow these steps:

- Go to ***File → Set input files***.
- Press ***Browse for NGS*** to open a new window for file selection.
- **Select** session ***25AUG03VS_N000***.

Now the file should be listed in the “Process list”.



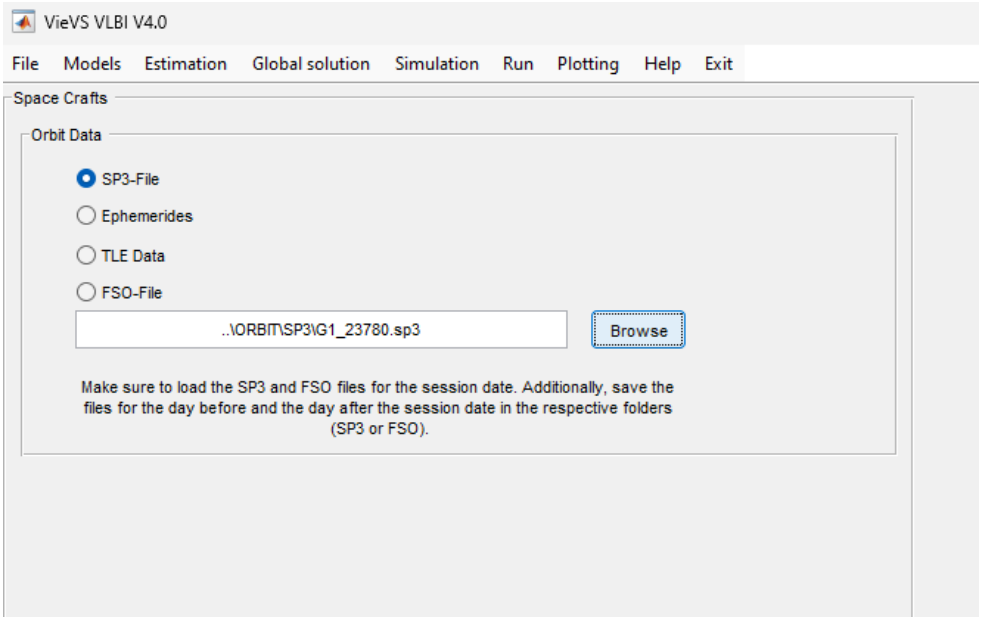
4 | ORBIT DATA

Satellite observations require orbit data. These can be either SP3, TLE, or FSO files. Orbit files must be stored in the following directory: *VieVS/VLBI/ORBIT/[SP3/TLE/FSO]/*
In the following, we use SP3 files.

> ⚠ **Important for SP3 and FSO files**
> To ensure accurate interpolation, you must include the SP3/FSO files for the **day of the session**, as well as the files for the **day before** and the **day after**. This is necessary because VieVS-VLBI uses 9th-degree Lagrange interpolation; files from adjacent days are required to calculate positions for observations near the beginning or the end of the day.

How to load the files:

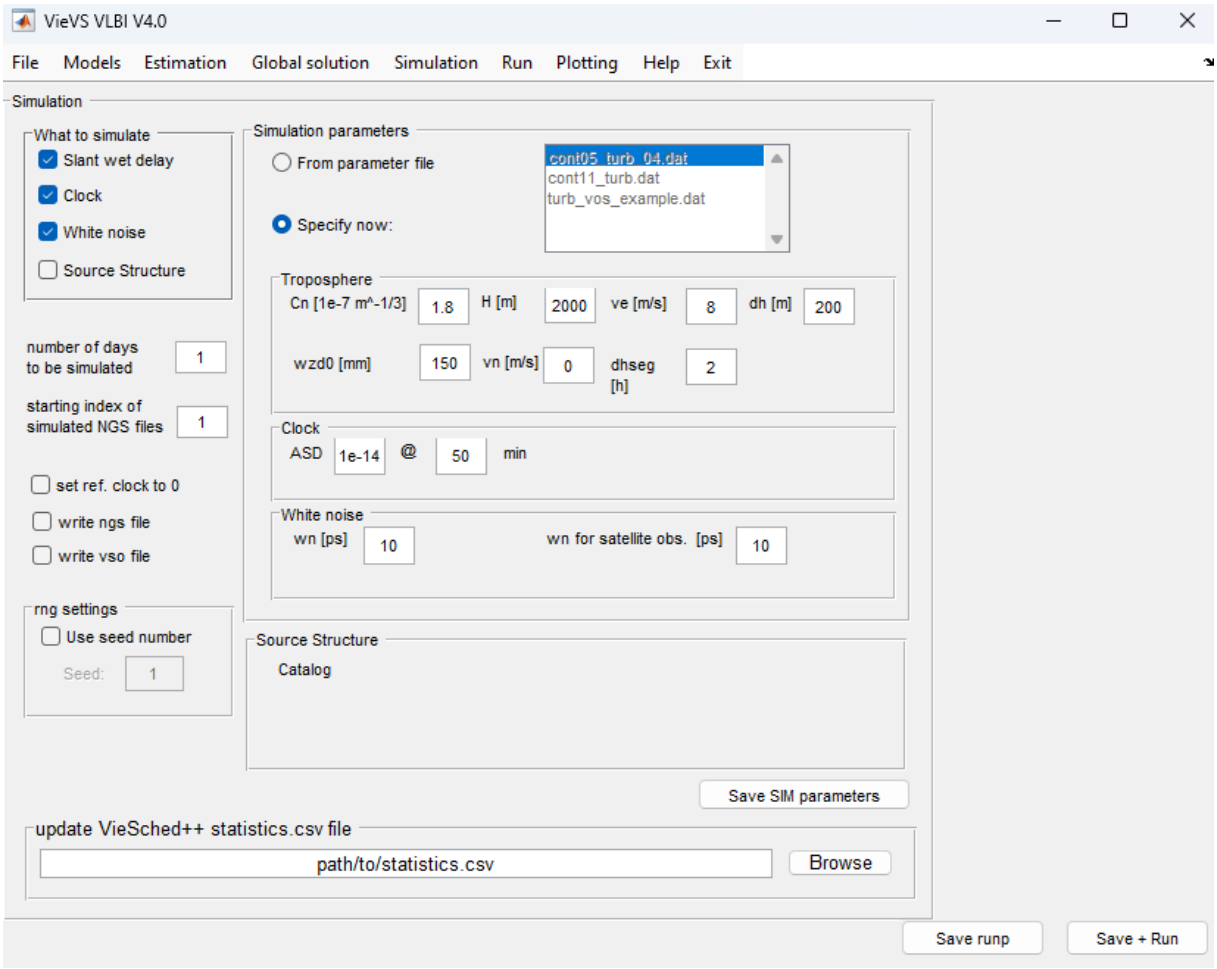
- Navigate to ***Models*** → ***Spacecrafts***.
- Select the ***SP3 file*** option and press ***Browse***.
- Navigate to the SP3 folder.
- Select the corresponding SP3 file for the session (e.g., *G1_23780.sp3*).
- Verification: Ensure that the files for the preceding and following days (e.g., *G1_23776.sp3* and *G1_23781.sp3*) are also present in the folder.



8 | SIMULATION

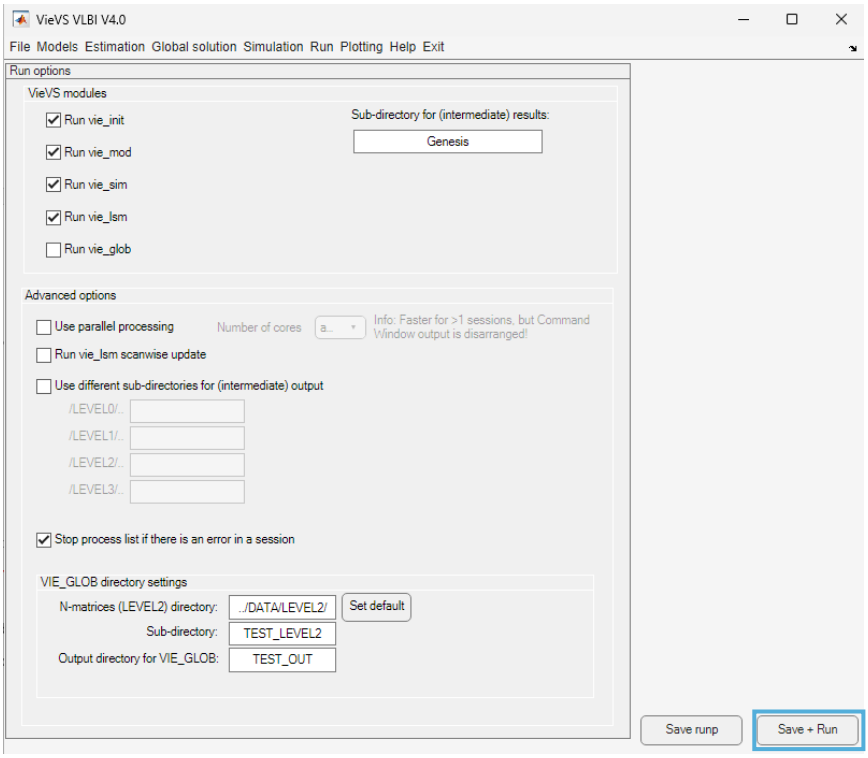
If a session was not observed and an empty NGS file is used, the observations need to be simulated to carry out a least-squares adjustment.

- Navigate to ***Simulation → Parameters.***
- Select what you want to simulate, e.g. slant wet delay, clock and white noise.
- Set the parameters how you want to simulate these errors.
- Define the total number of days to be simulated.
- Choose whether to write the simulated observations to an NGS file.



9 | Run Session

- Navigate to ***Run → Run options***.
- In the module selection list, select the modules **vie_init, vie_mod, vie_sim** and **vie_lsm**.
- In the sub-directory field, enter a new name for your results (e.g., Genesis).
- Press ***Save + Run*** to start the process.



Theoretical delays are now being computed and stored. Please note that due to the high number of observations, this process may take some time.

Since the current NGS file is empty, a simulation must be performed to generate observations. This allows for the calculation of **observed minus computed (O-C)** residuals during the least-squares adjustment.

Note: The modules vie_init, vie_mod, and vie_sim only need to be executed **once** as the results are stored in the LEVEL0/Genesis and LEVEL1/Genesis folder. After the initial setup is complete, these modules can be **deselected** to improve computational performance.

> ⚠ **Using Pre-computed Data (Fast Track):**
> To accelerate the process, LEVEL0 and LEVEL1 data for this session have been pre-computed. To use this shortcut, **move** the prepared folders into the corresponding LEVEL0 and LEVEL1 directories within your VieVS folder. Ensure that the subfolder names within LEVEL0 and LEVEL1 exactly match the session name entered in the **Run Options** (e.g., Genesis).
> If the names match, you may **deselect vie_init**, **vie_mod**, and **vie_sim** and proceed directly to the least-squares analysis.

10 | Estimation

To configure the estimation process, navigate to the ***Estimation → Least Squares → **** menu and review the available parameters.

For the following analysis steps, you can deselect the estimation of radio sources in ***Estimation → Least Squares → Source coordinates.***

Troposphere & Clock & EOP

Tropospheric parameters, Earth Orientation Parameters, and Clock parameters are always estimated using the full set of available observations.

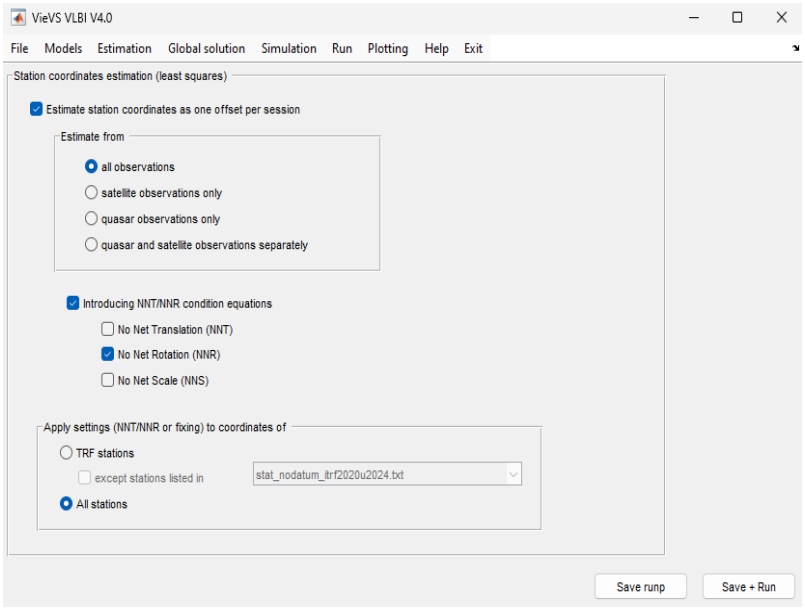
Station Coordinates

Navigate to ***Estimation → Least Squares → Station Coordinates***.

With the inclusion of VLBI observations to satellites, four distinct options are available for estimating station coordinates in VieVS-VLBI. The estimation can be based on

- **All observations** (combined quasar and satellite observations).
- **Satellite observations only.**
- **Quasar observations only.**
- **Separate estimation:** station coordinates are estimated separately based on quasar and satellite but within a single least-squares adjustment.

The resulting station coordinates from all four estimation options can be written to a SINEX file.



The application of NNT and NNR conditions depends on the observation type and the Earth Rotation Parameters (ERP) estimation:

- **NNT (No Net Translation):** Not required when using satellite observations.
- **NNR (No Net Rotation):** Required if ERP are estimated; not required if ERP are fixed.

The output files of the analysis are stored in the folder: ../VLBI/DATA/LEVEL3/Genesis/

Case 1: All Observations (Combined satellite & quasar)

In this mode, a single set of station coordinates is estimated using both satellite and quasar observations in the least-squares adjustment.

- **NNT:** required if there are only quasar obs.; not required if there are satellite obs.
- **NNR:** required if ERP are estimated
- **Output:** *x_25AUG03VS_N000.mat → coorx, coory, coorz*

Case 2: Satellite Only

In this mode, station coordinates are estimated using only satellite observations within the least-squares adjustment.

- **NNT:** not required
- **NNR:** required if ERP are estimated
- **Output:** x_25AUG03VS_N000.mat → *coorx_sat, coory_sat, coorz_sat*

Case 3: Quasar Only

In this mode, station coordinates are estimated using only quasar observations within the least-squares adjustment.

- **NNT:** required
- **NNR:** required if ERP are estimated
- **Output:** x_25AUG03VS_N000.mat → *coorx_qu, coory_qu, coorz_qu*

Case 4: Separate Estimation (in one adjustment)

In this mode, two distinct sets of station coordinates are estimated within a single least-squares adjustment: one based on satellite observations, and one based on quasar observations.

- **NNT:** required (applied to quasar-based estimates only)
- **NNR:** required if ERP are estimated (applied to both satellite-based and quasar-based estimates separately)
- **Output:** x_25AUG03VS_N000.mat → Satellite: coorx_sat, coory_sat, coorz_sat
  Quasar: coorx_qu, coory_qu, coorz_qu

> ⓘ **NOTE**
> *Applying a condition that is not required by the current configuration (e.g., applying NNR while ERP are fixed) will over-constrain the solution. In such cases, a warning will be displayed, allowing you to either adjust the settings or proceed.*

SATELLITE POSITIONS

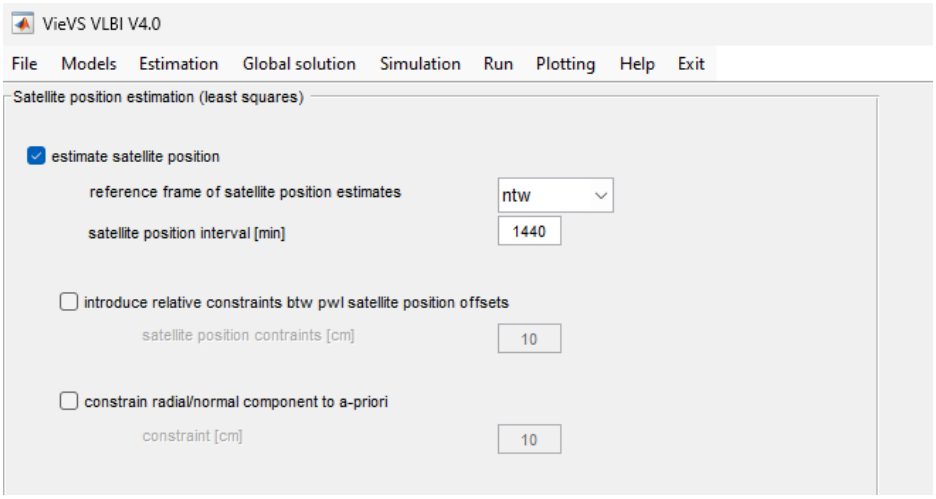
- Navigate to ***Estimation → Least Squares → Satellite Position***.
- Select ***estimate satellite position*** to enable the following options.
- Select a **reference frame** for estimating the satellite position and a **time interval**.

This section configures the estimation of satellite positions within different frames. Users can select the coordinate system for estimating offsets, including:

- NTW system: Normal, Tangential, and Cross-track.
- RSW system: Radial, Along-track, and Cross-track.
- Geocentric Celestial Reference Frame (GCRF)
- Terrestrial Reference Frame (TRF)

Offsets are estimated as piecewise-linear offsets. Additionally, the system allows the introduction of relative constraints between these piecewise-linear offsets.

> ⓘ **NOTE**
> *Because the radial/normal component typically has higher uncertainty, it can be constrained to improve estimation stability.*



The results are stored in x_25AUG03VS_N000.mat using the following variable sets:

- **NTW:** sat_posN, sat_posT, sat_posW
- **RSW:** sat_posR, sat_posS, sat_posW
- **GCRF / TRF:** sat_posX, sat_posY, sat_posZ

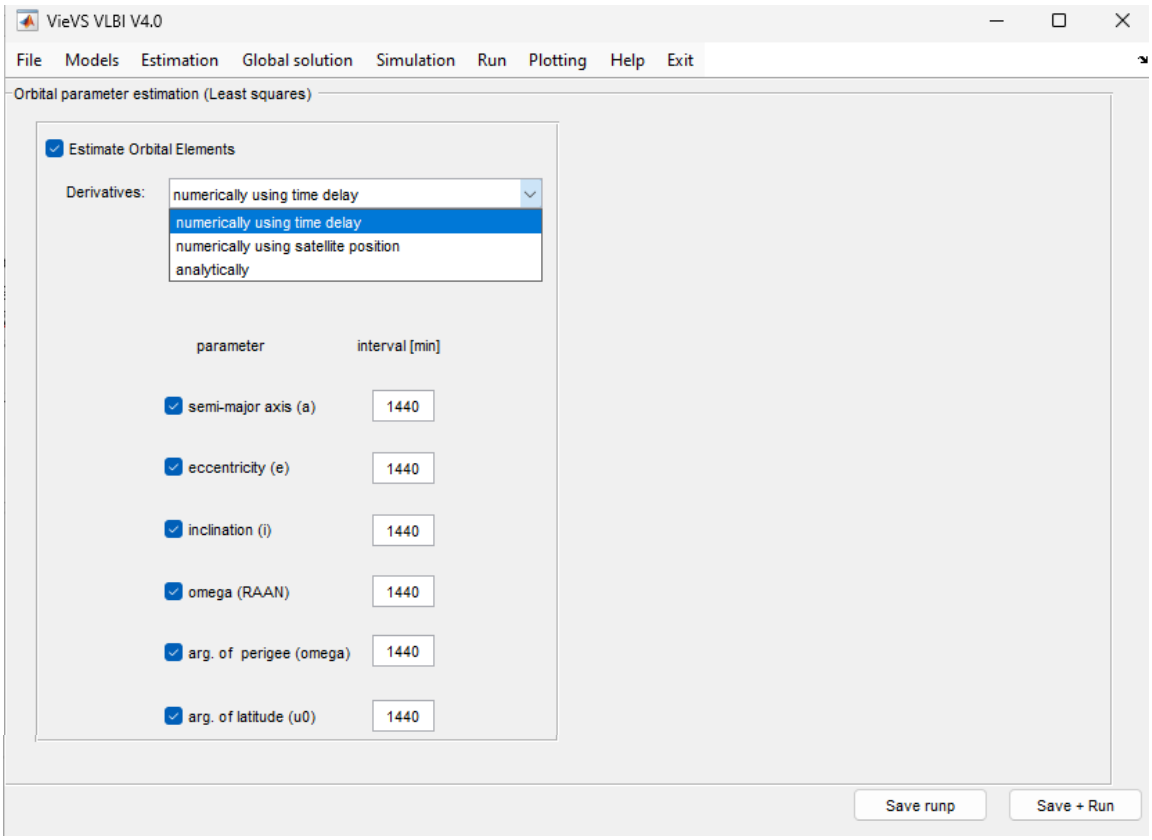
ORBITAL ELEMENTS

- Navigate to ***Estimation → Least Squares → Orbital Elements***.
- Select a method for building partial derivatives.
- Select orbital elements you would like to estimate with the respective interval.

The orbital elements are estimated as piecewise-linear offsets. All orbital elements can be estimated independently using custom time intervals.

The partial derivatives of the time delay w.r.t. the orbital elements can be built based on different methods:

- **Numerical (Time Delay):** Building partials numerically based on the time delay τ.
- **Numerical (Satellite Position):** Building partials numerically based on satellite position.
- **Analytical:** Building partials analytically.



The results are stored in x_25AUG03VS_N000.mat within the variable ORB ***(x_.ORB.*)***

- sma – semi-major axis
- ecc - eccentricity
- inc - inclination
- raan – right ascension of ascending node
- argp – argument of perigee
- argl – argument of latitude