FIG Working Week 2023
FIG WORKING WEEK 2023
28 May - 1 June 2023 Orlando Florida USA
Protecting Our World, Conquering New Frontiers

Coordinates Trajectory Models

Basics and Implementation

Mohammed Aljafar

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Outline:

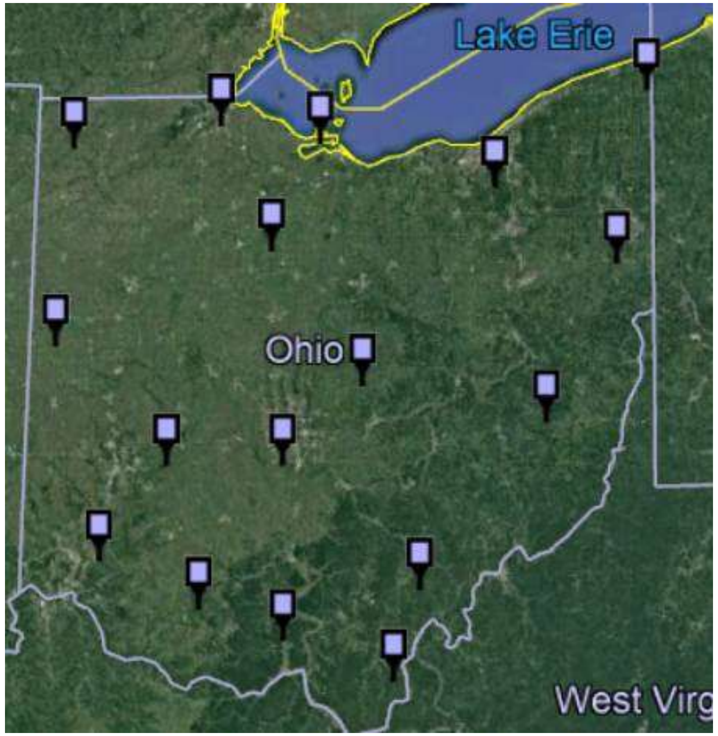
- Project Motive
- Area of Interest
- Trajectory Models
- Project Implementation
  - GNSS data gathering and processing
  - Application of the SLTM
- Investigation of Outcome

Project motive

- Create a geodetic hands-on experience using techniques such as least squares adjustment, GNSS data, and timeseries analysis
- Implement trajectory modeling on more CORS stations.

Area of Interest

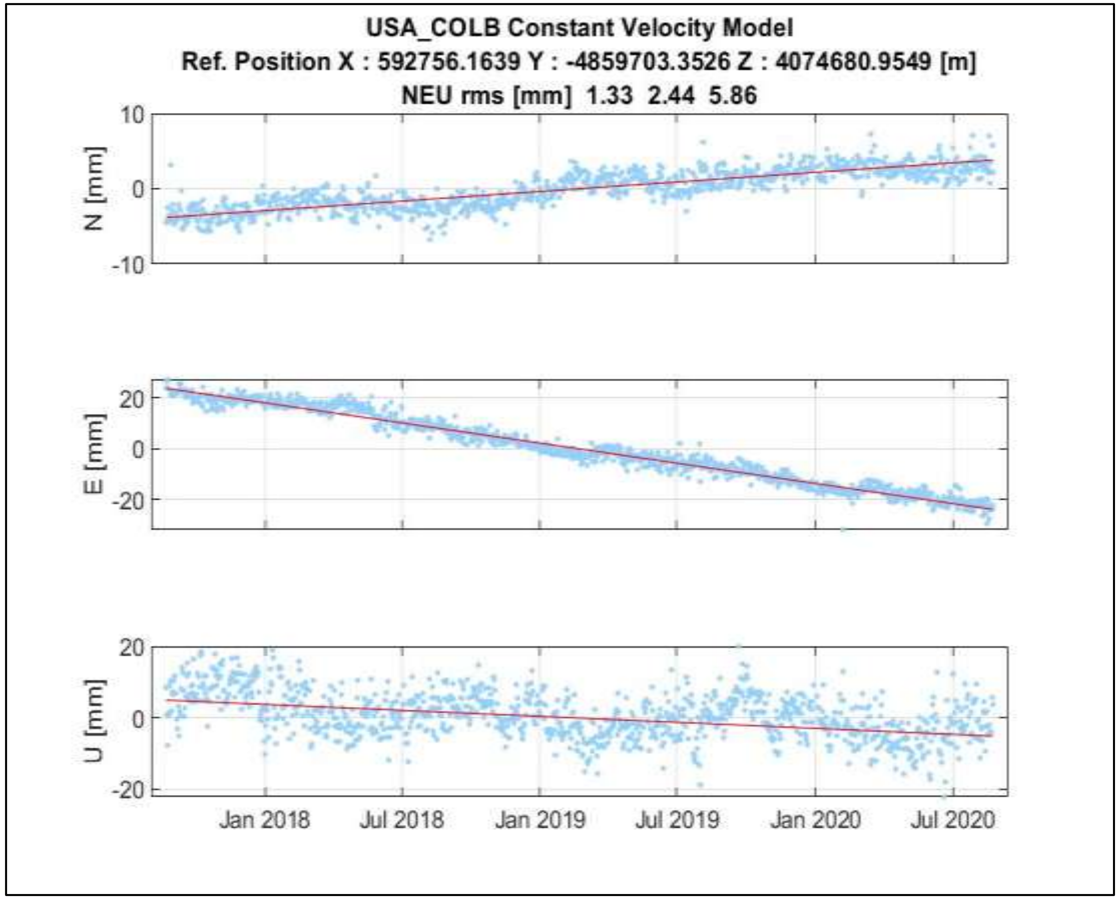
- 16 CORS stations from the state of Ohio.



Trajectory models

- Early scientists considered coordinates as fixed.
- Multiple trajectory models have evolved throughout history with development of theories and technologies.
- Each new model tries to fit and better represent the data.

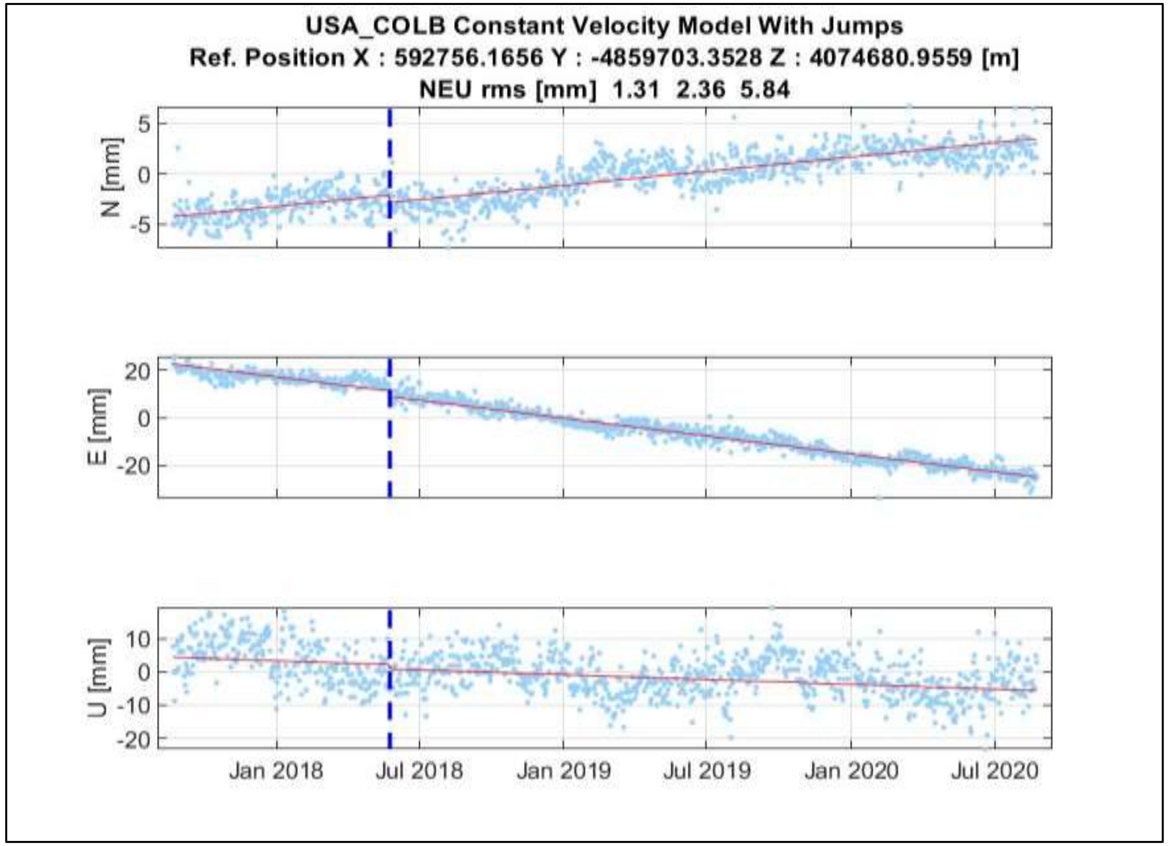
- **Constant Velocity Model (CVM)**
- $X(t) = X_R + V_x(t - t_R)$
- $Y(t) = Y_R + V_y(t - t_R)$
- $Z(t) = Z_R + V_z(t - t_R)$
- And in vector notation:
- $x(t) = x_R + v(t - t_R)$



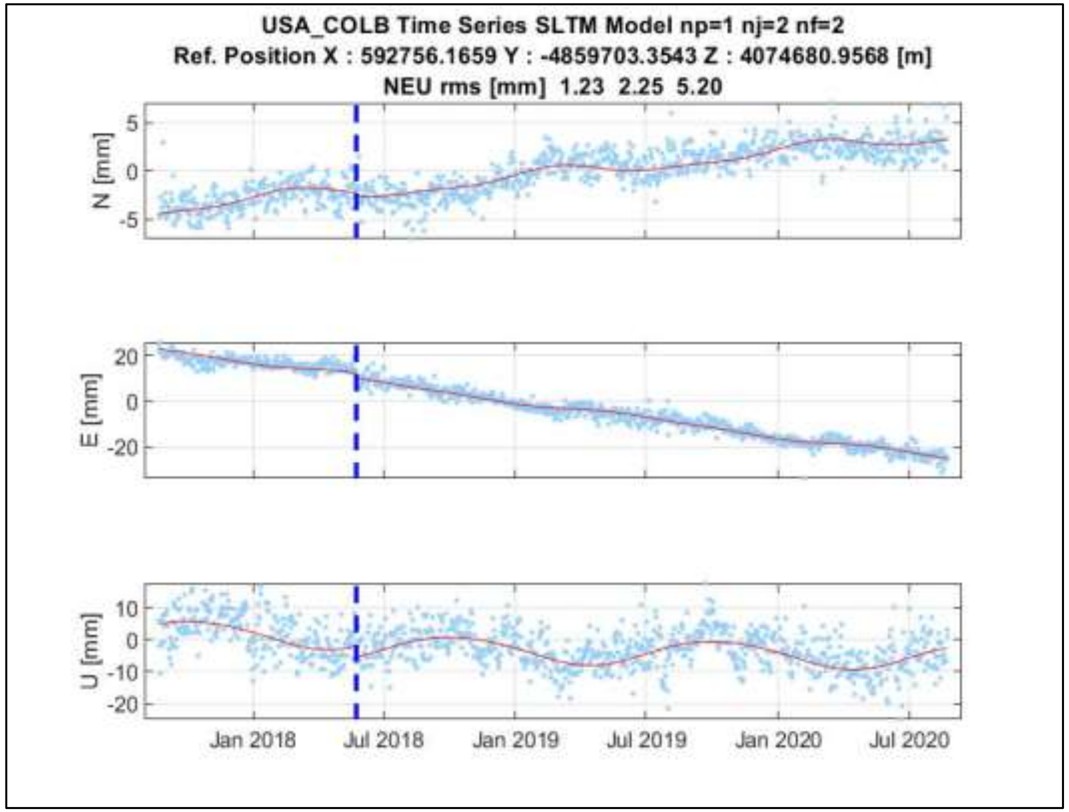
- Constant Velocity Model (CVM) with Jumps

- $x(t) = x_R + v(t - t_R)$

- $+ \sum_{j=1}^{nj} b_j H(t - t_j)$



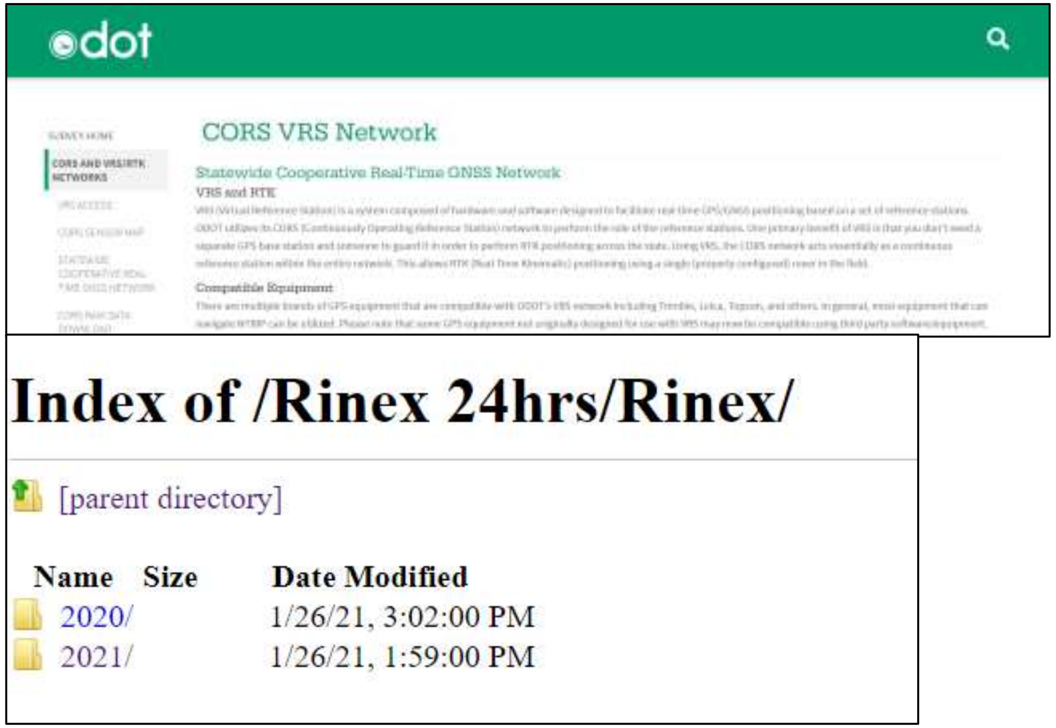
- **Standard Linear Trajectory Model (SLTM)**
- $x(t) = \sum_{i=1}^{np+1} p_i (t - t_R)^{i-1}$
- $+\sum_{j=1}^{nj} b_j H(t - t_j)$
- $+\sum_{k=1}^{nf} [s_k sin(\omega_k t) + c_k cos(\omega_k t)]$



- **Extended Linear Trajectory Model (ELTM)**
- $x(t) = \sum_{i=1}^{np+1} p_i (t - t_R)^{i-1} +$
- $\sum_{j=1}^{nj} b_j H(t - t_j) +$
- $\sum_{k=1}^{nf} [s_k sin(\omega_k t) + c_k cos(\omega_k t)] +$
- $\sum_{i=1}^{nT} a_i log(1 + \Delta t_i / T_i)$
- * We usually use two values for T where T1=1 and T2=0.0523

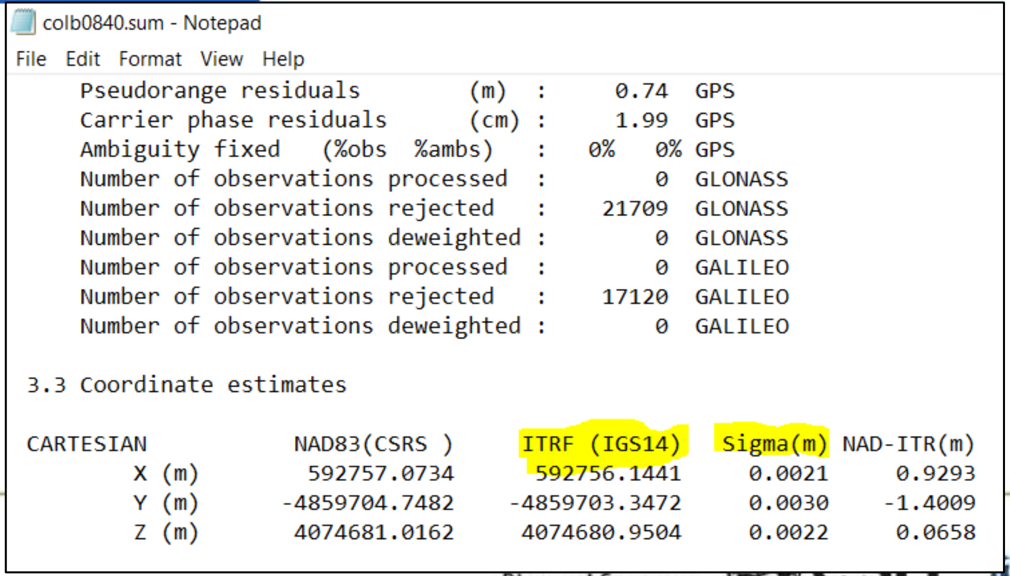
- **GNSS data processing**

- Needed data is 3 years of data.
- Out of the stations available in the OSU archive,16 spread stations are selected
- Obtained all RINEX files from for processing.



- **GNSS data processing**

- Downloaded the GPSACE software along with required files such as precise ephemeris, clock correction, and earth rotation parameters files from NASA website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Pseudorange residuals          (m)  :    0.74  GPS
Carrier phase residuals        (cm) :    1.99  GPS
Ambiguity fixed    (%obs  %ambs)    :  0%    0% GPS
Number of observations processed    :       0  GLONASS
Number of observations rejected     :   21709  GLONASS
Number of observations deweighted   :       0  GLONASS
Number of observations processed    :       0  GALILEO
Number of observations rejected     :   17120  GALILEO
Number of observations deweighted   :       0  GALILEO

3.3 Coordinate estimates

CARTESIAN             NAD83(CSRS )     ITRF (IGS14)   Sigma(m)  NAD-ITR(m)
        X (m)         592757.0734      592756.1441     0.0021      0.9293
        Y (m)       -4859704.7482    -4859703.3472     0.0030     -1.4009
        Z (m)        4074681.0162     4074680.9504     0.0022      0.0658
```

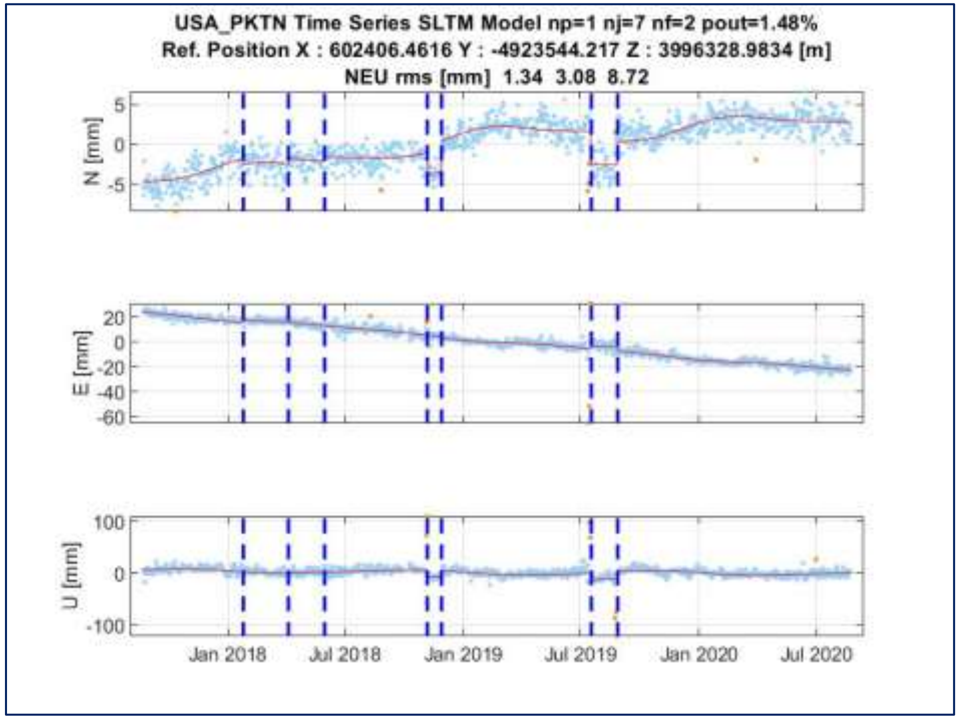
- Standard Linear Trajectory Model (SLTM)
- $x(t) = \sum_{i=1}^{np+1} \boldsymbol{p_i}(t - t_R)^{i-1}$
- $+\sum_{j=1}^{nj} \boldsymbol{b_j} H(t - t_j)$
- $+\sum_{k=1}^{nf} \begin{matrix} [\boldsymbol{s_k} sin(\omega_k t) \\ +\boldsymbol{c_k} cos(\omega_k t)] \end{matrix}$

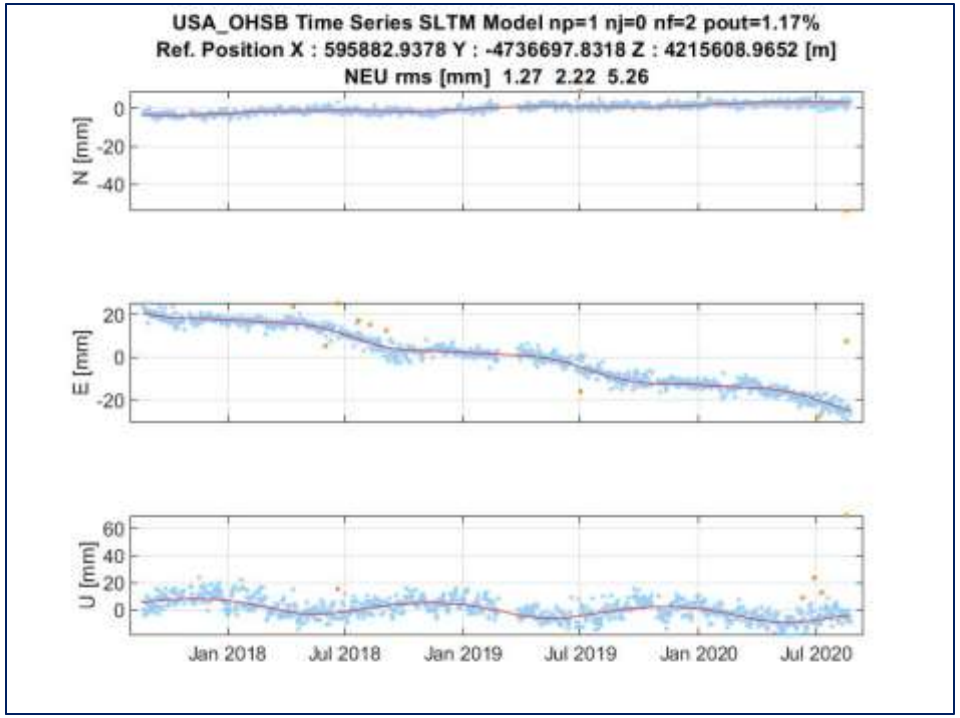
- **Weighted Least Squares Adjustment**
- $\hat{x} = B^{-1}\left(A^T C_b^{-1} b\right)$
- $B = A^T C_b^{-1} A$
- $C_x = B^{-1}$
- A is the design or coefficient matrix
- $\hat{x}$ vector of unknown parameters

- **MATLAB Code Structure**
  - Import coordinate time series with sigmas
  - Import metadata such as jumps times.
  - Generate the design matrix A
  - Perform 1st lest squares to generate reference position
  - Convert coordinates from xyz to enu.
  - Perform 2nd least squares to estimate parameters of the model.

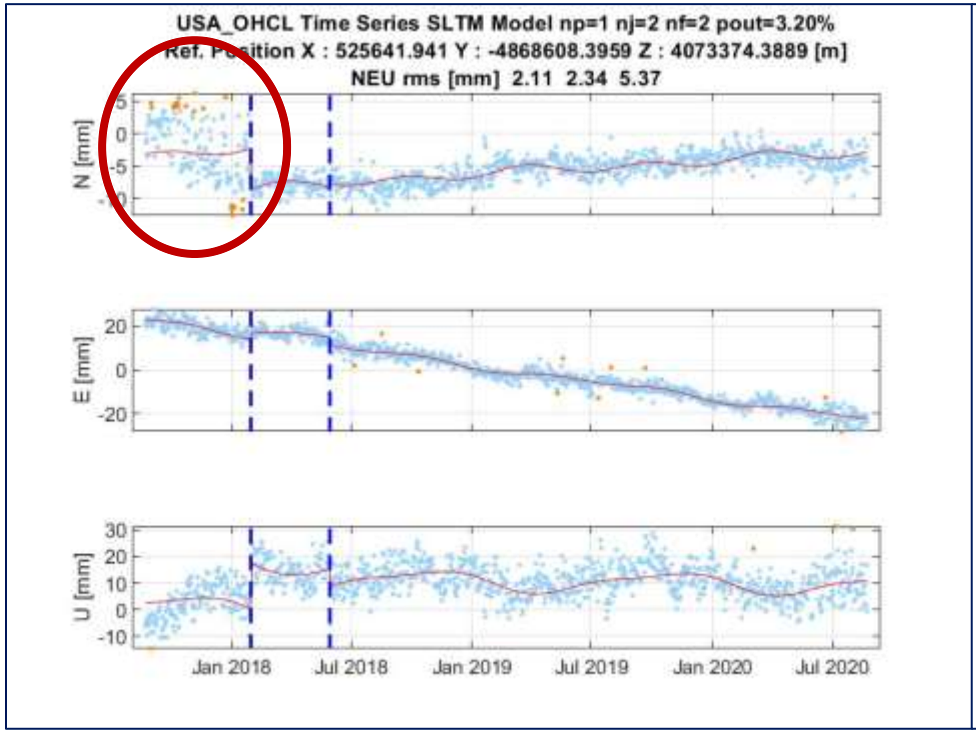
- **MATLAB Code Structure**
  - Outlier detection and removal
  - Perform 3rd least squares to estimate final parameters of the model.
  - Use the design_sltm to generate uniform time series.
  - Plot the data.

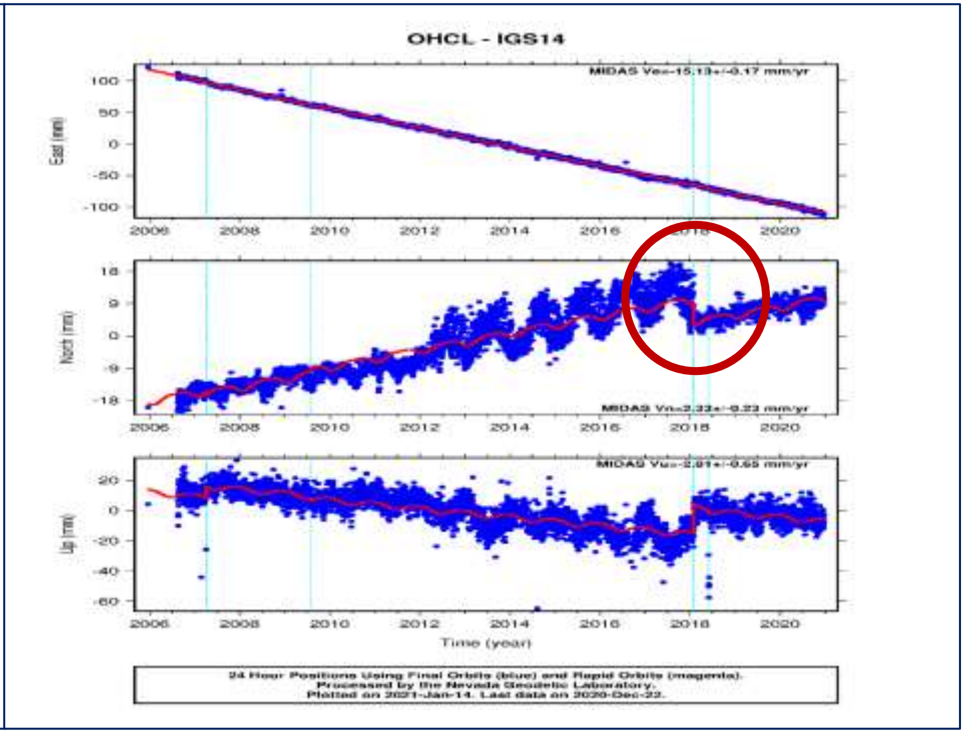
- **Investigation of outcome**





- **Investigation of outcome**





*Nevada Geodetic Laboratory Plot of OHCL

Thank you

This is a Peer Reviewed Paper
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Mohammed ALJAFAR, Saudi Arabia