UNIVERSITY OF Southampton

Processing TLEs to facilitate re-entry prediction of spent rocket bodies from GTO

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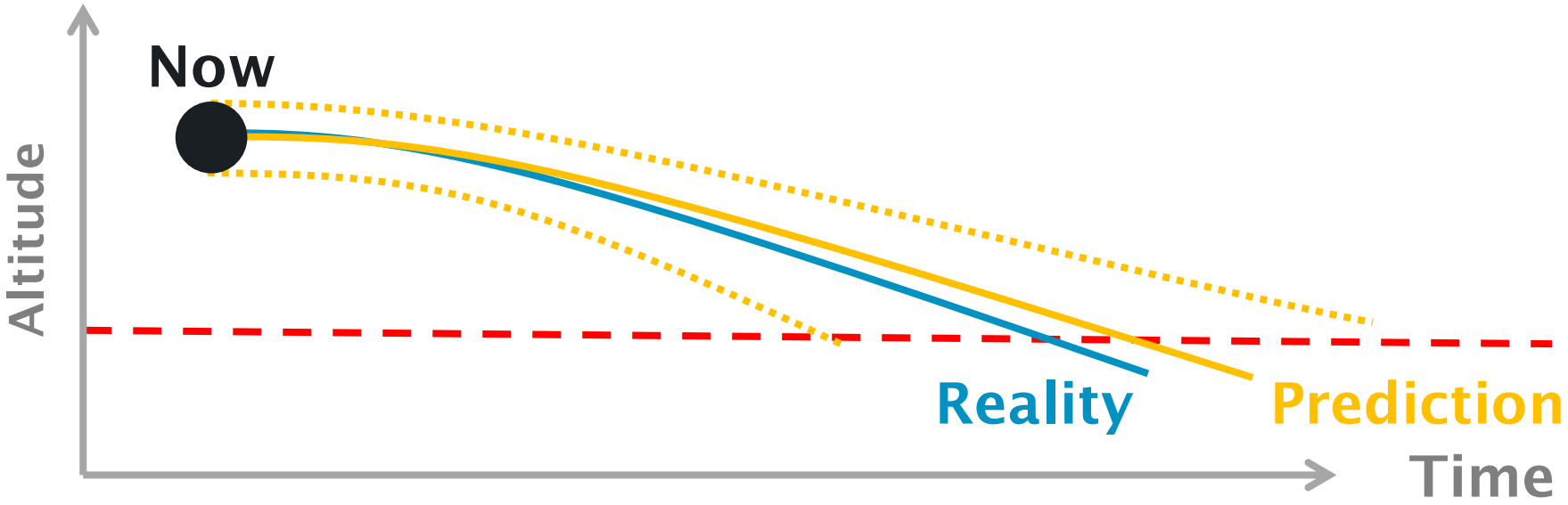
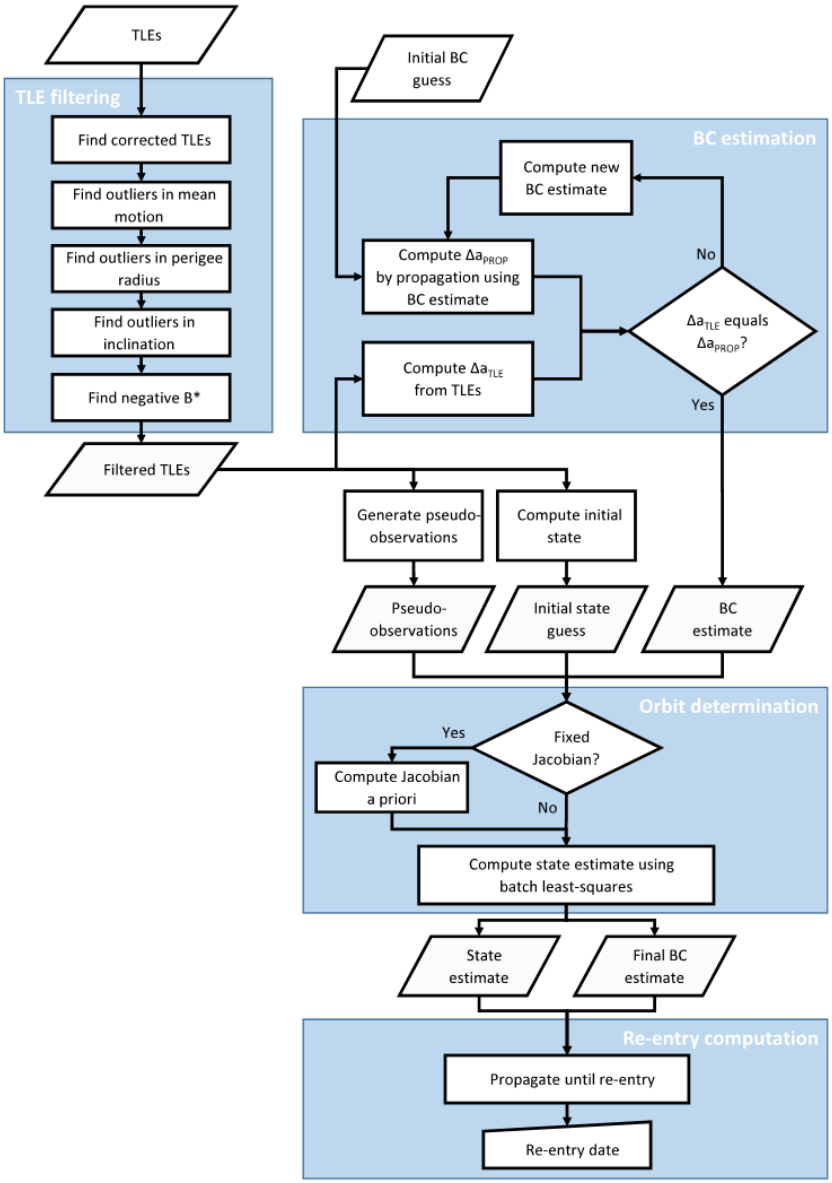
3 - European Space Operations Center

Re-entry prediction

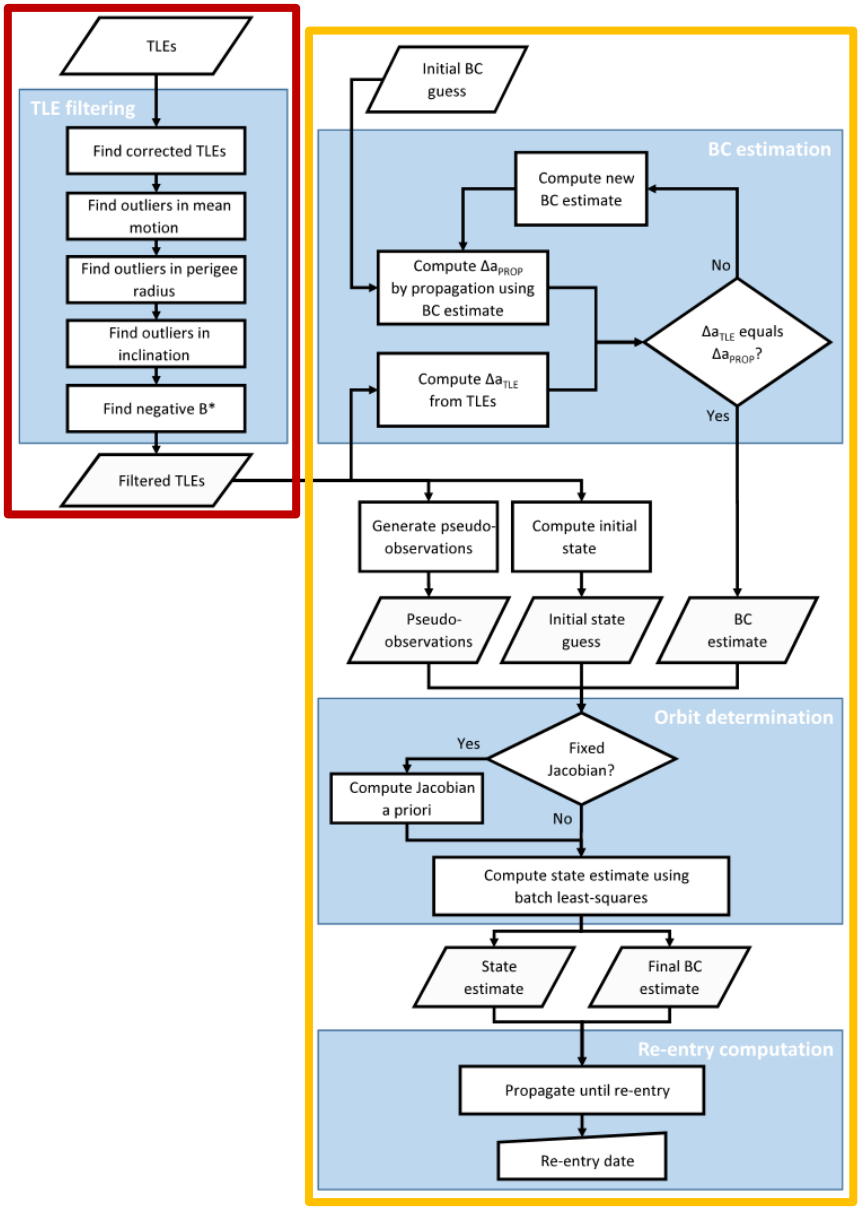


How to improve TLE-based predictions



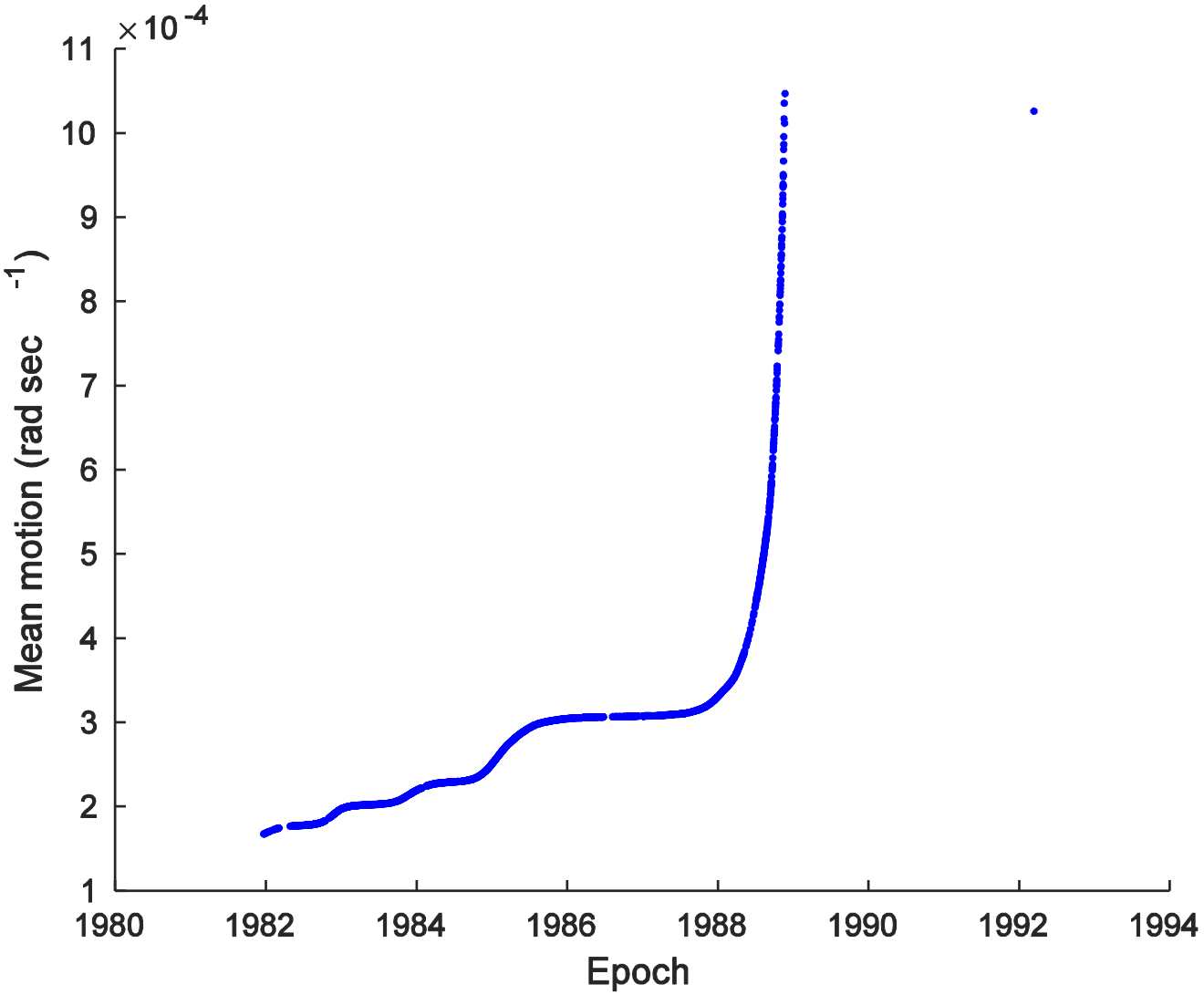
How to improve TLE-based predictions

Today

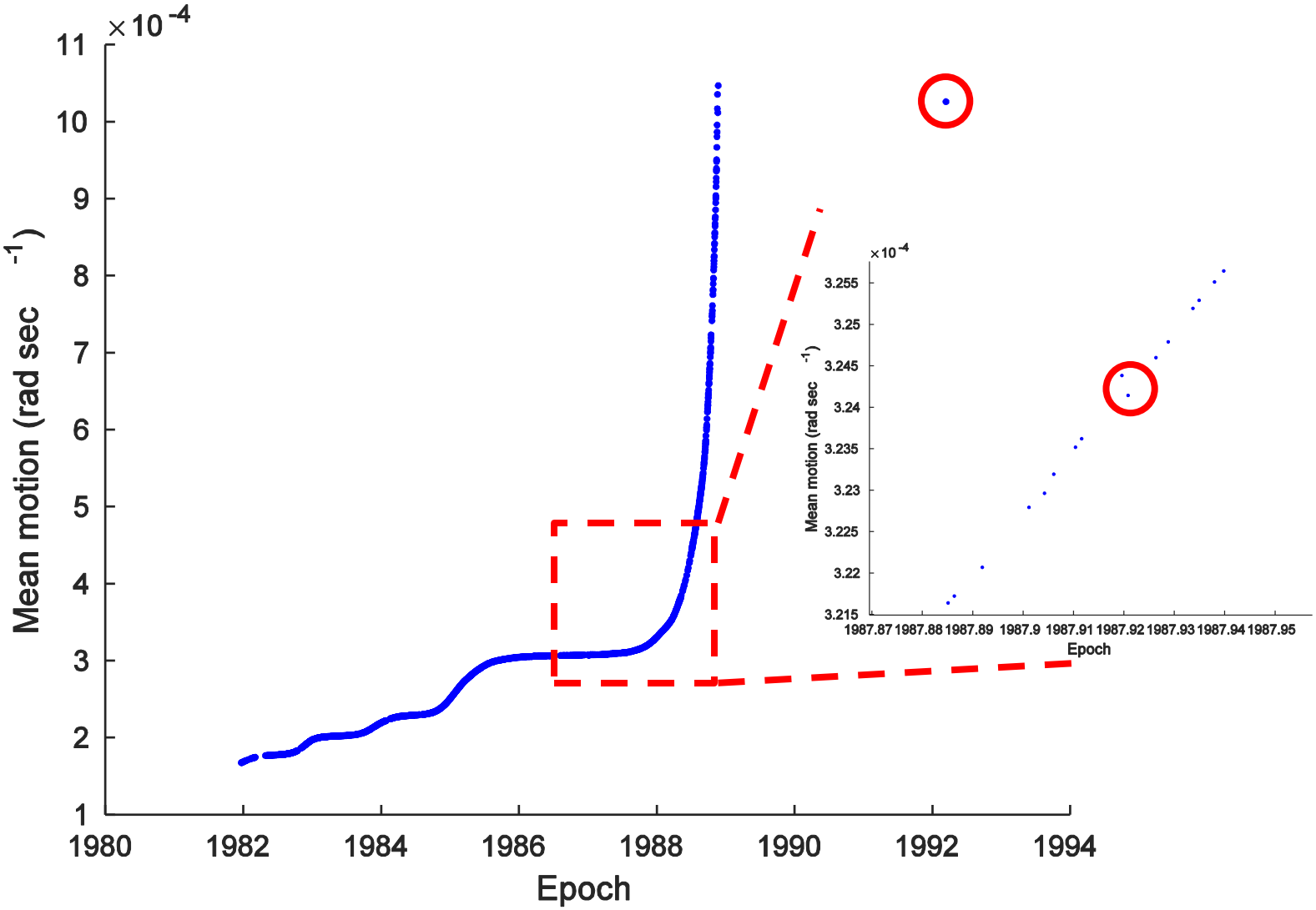


AAS 2016, Napa, CA

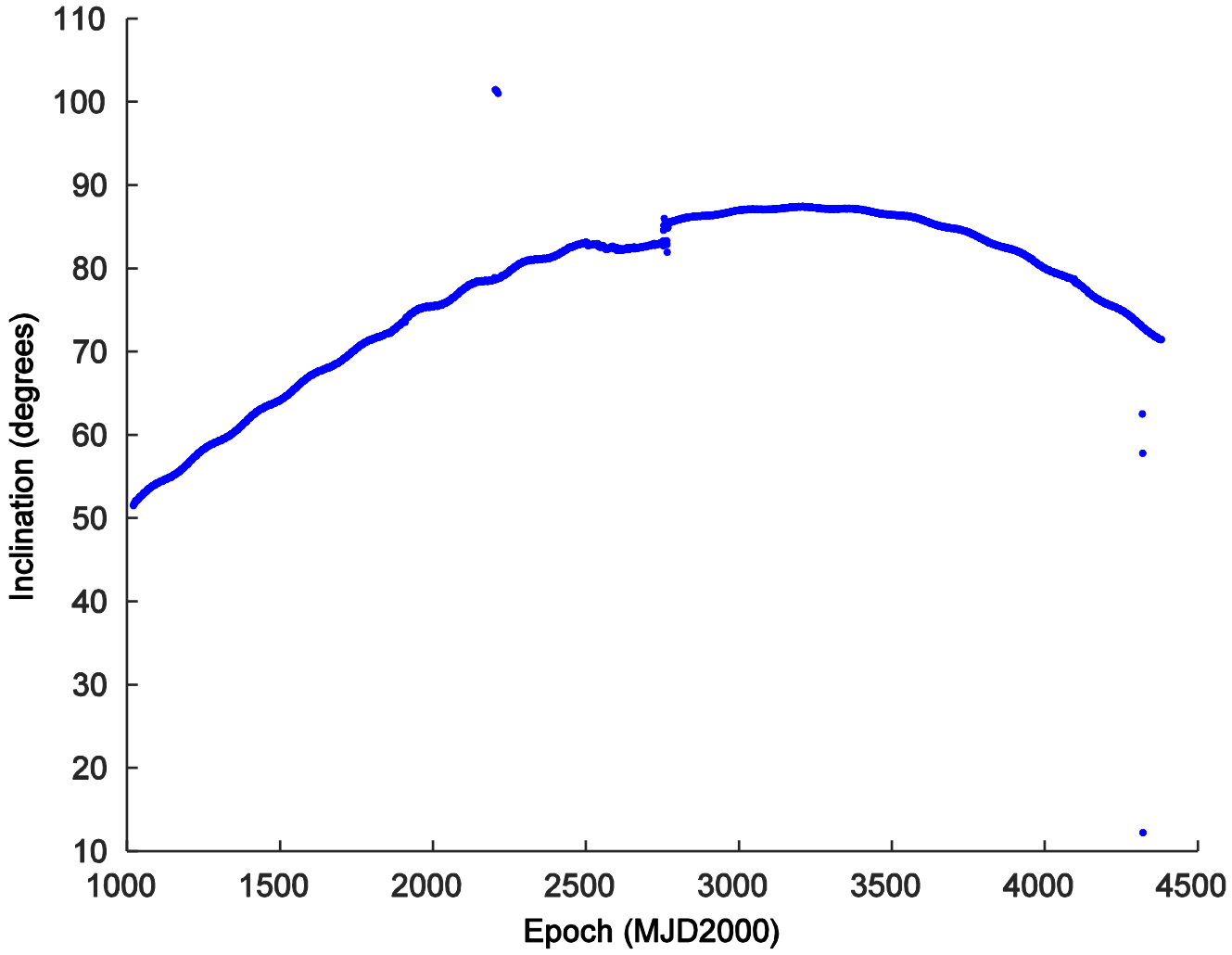
Problems with TLEs



Problems with TLEs

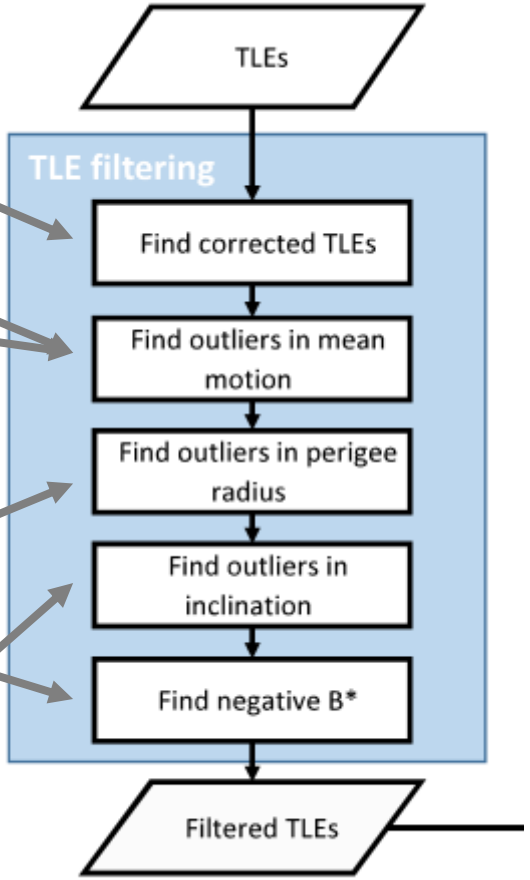


Problems - in life



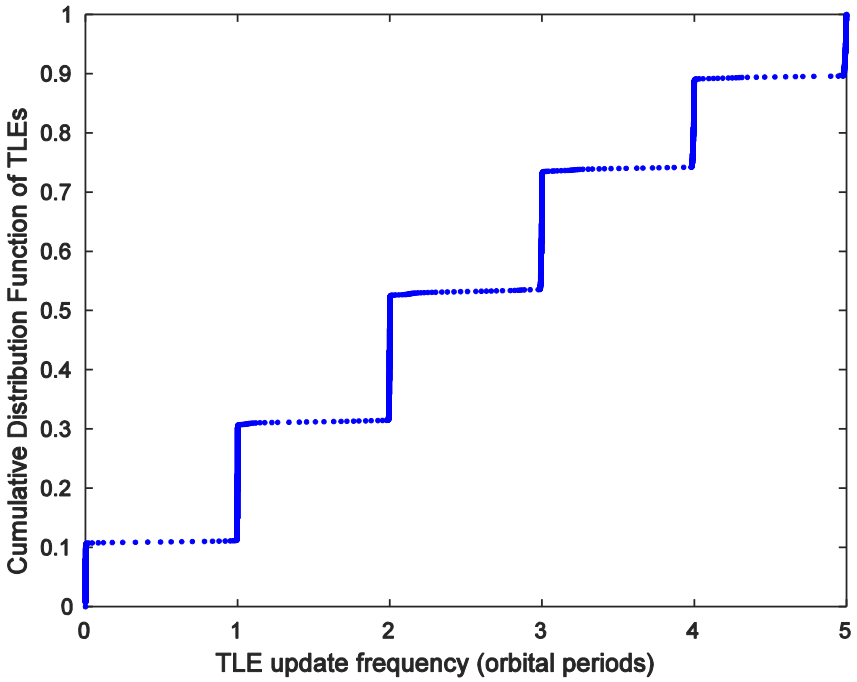
Addressing problems (with TLEs)

1. Corrected TLEs
2. Time gaps
3. Outliers in mean motion and events that physically change the object
4. Outliers in eccentricity and B^* – need to estimate the ballistic coefficient
5. Outliers in inclination – need orbit determination to converge

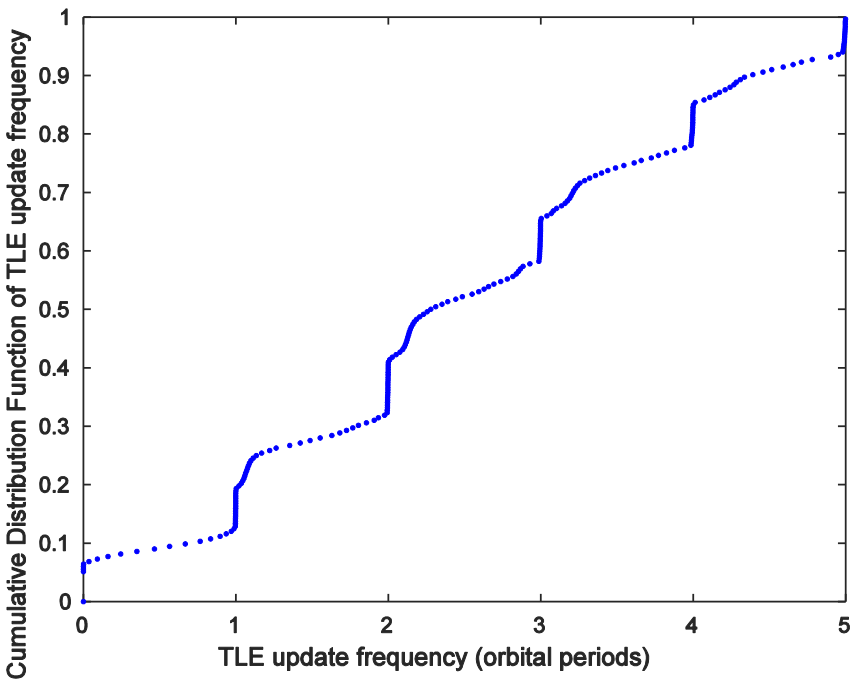


Corrections

Before 2011

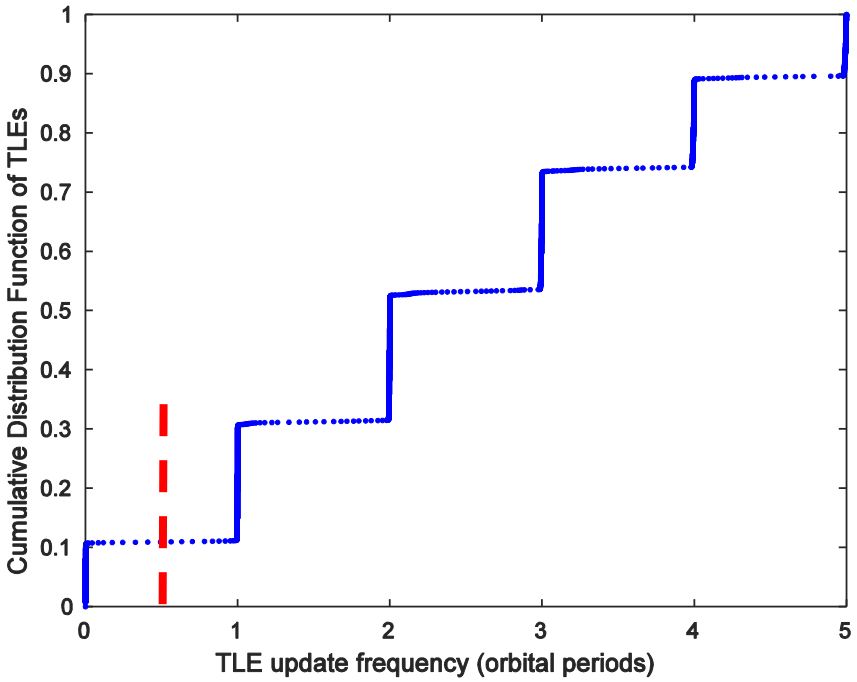


After 2011

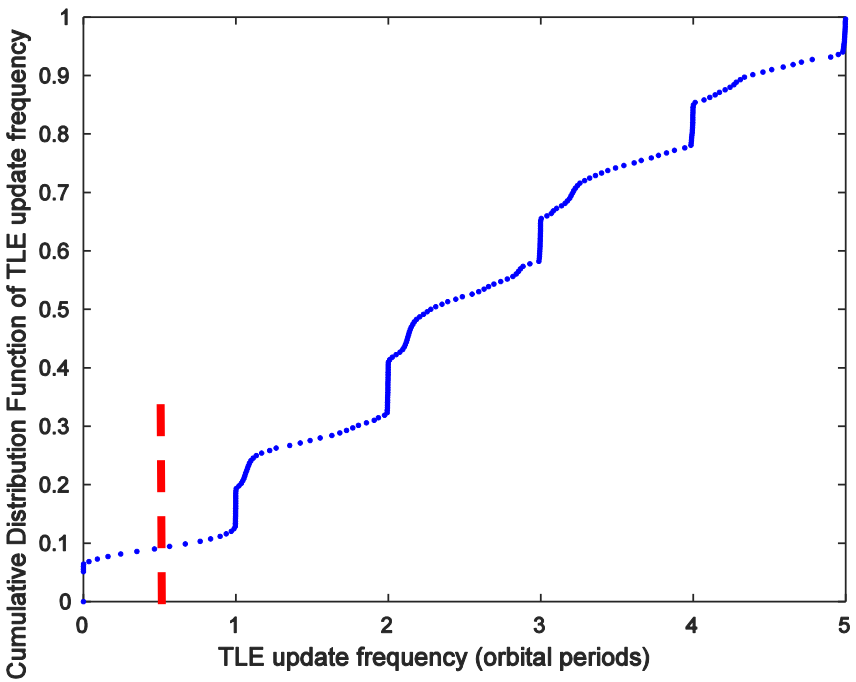


Corrections

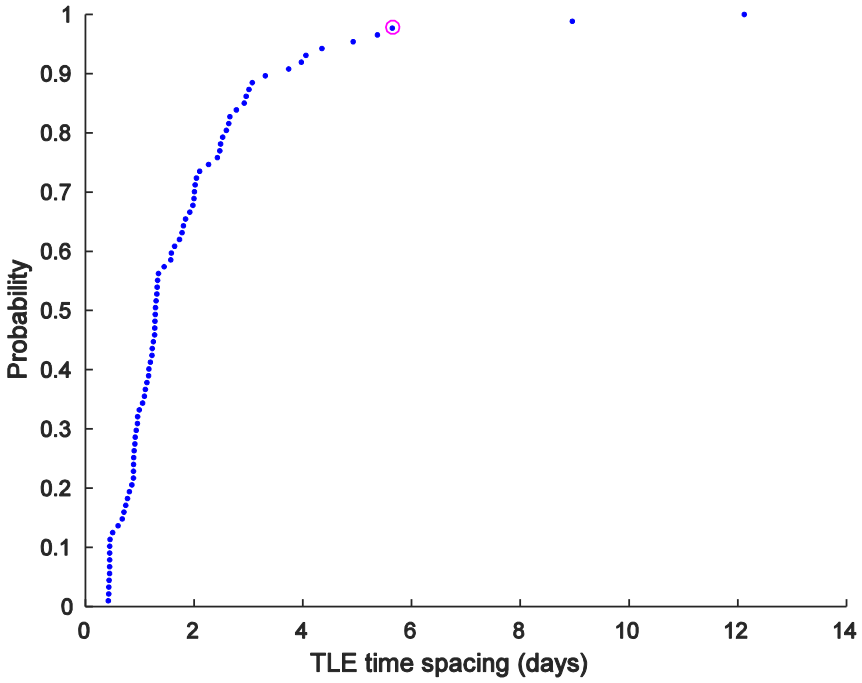
Before 2011

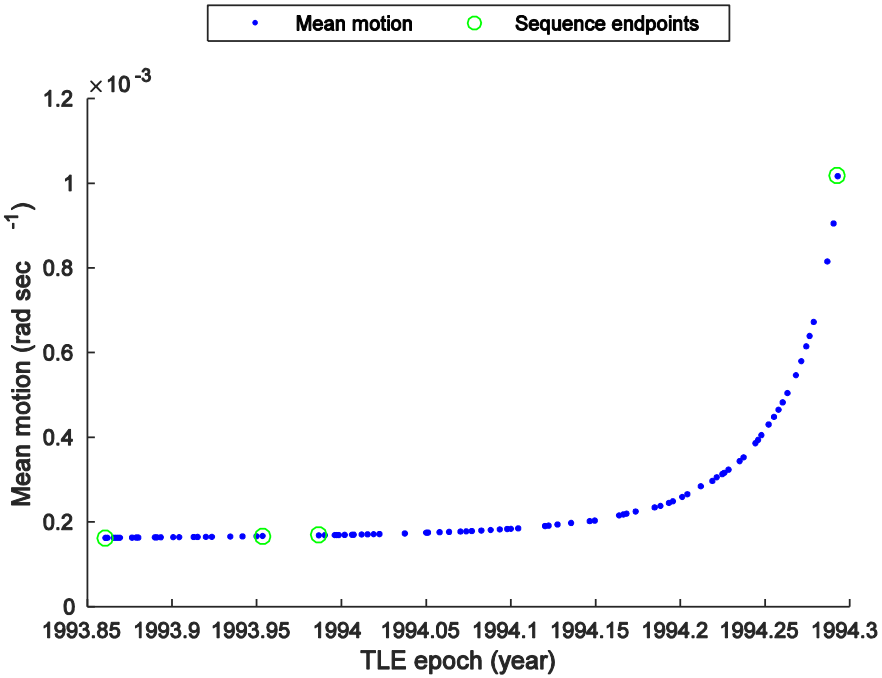


After 2011

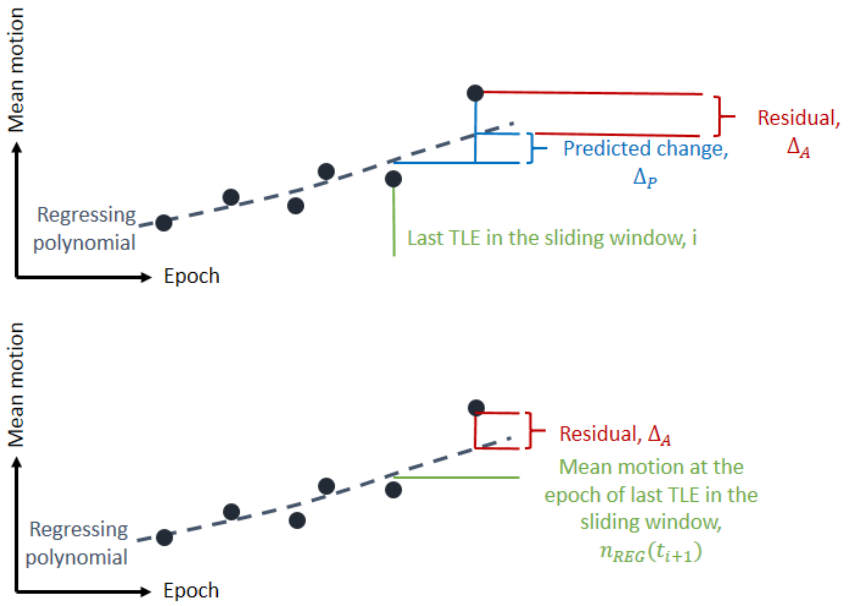


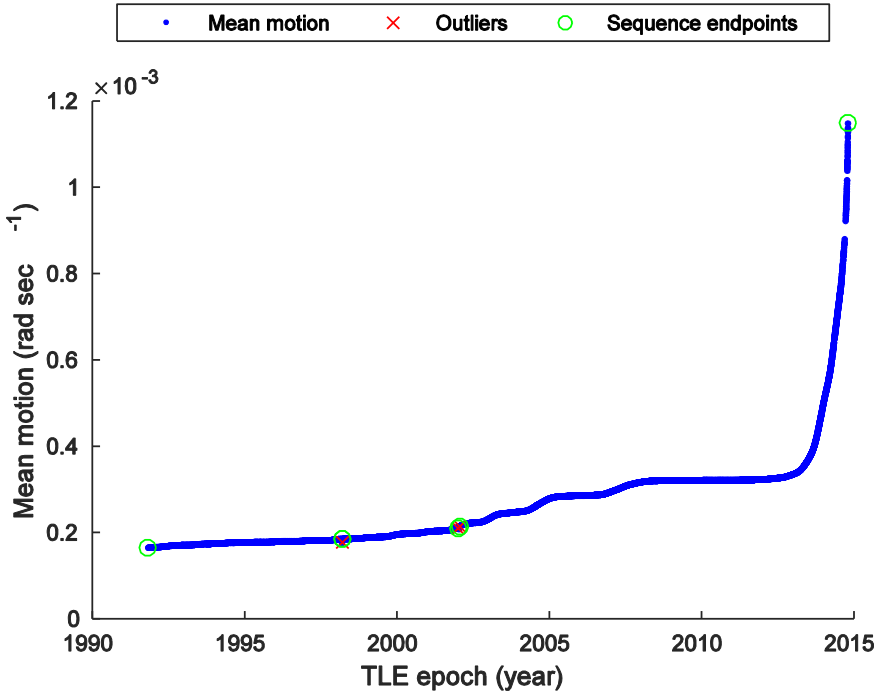
Time gaps


Probability
TLE time spacing (days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14

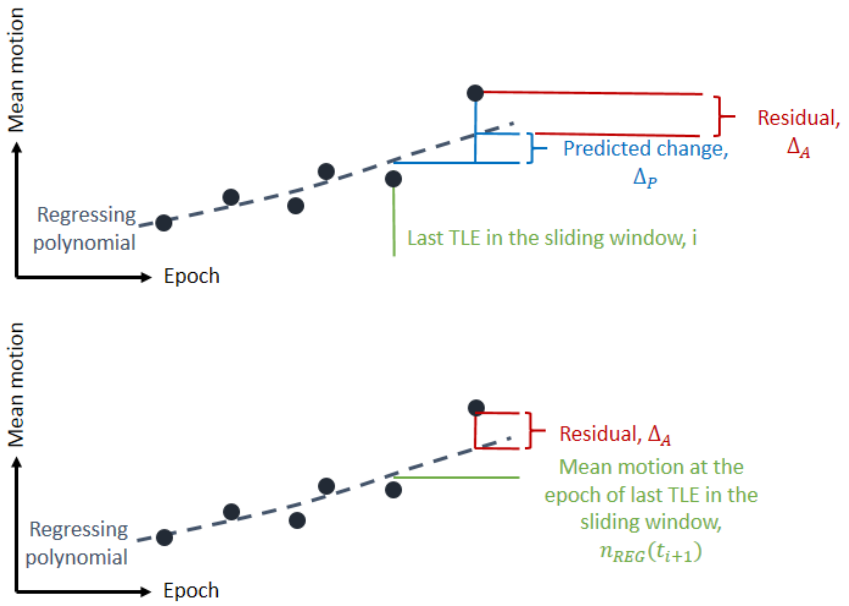

Mean motion
Sequence endpoints
×10^-3
Mean motion (rad sec^-1)
TLE epoch (year)
0
0.2
0.4
0.6
0.8
1
1.2
1993.85
1993.9
1993.95
1994
1994.05
1994.1
1994.15
1994.2
1994.25
1994.3

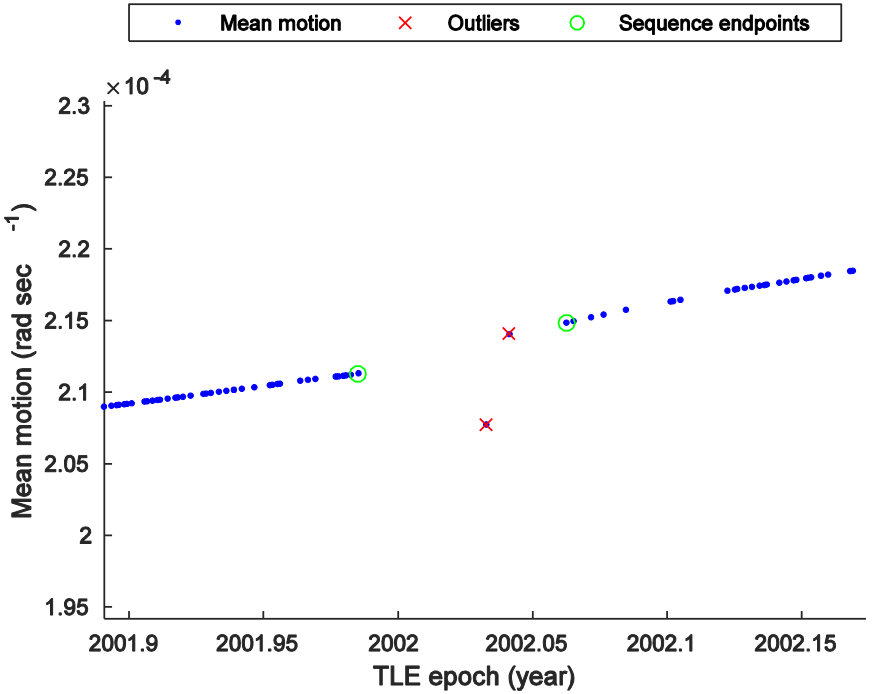
Mean motion outliers



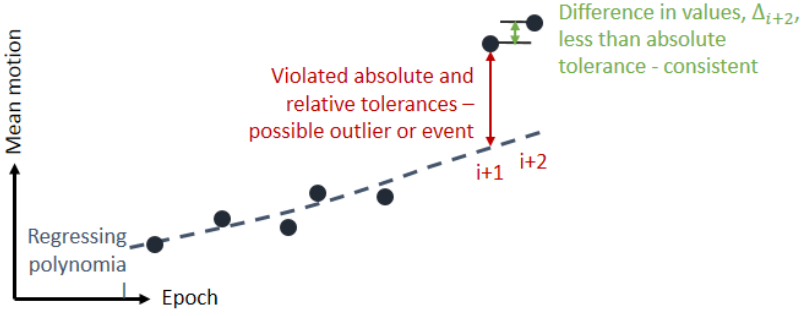


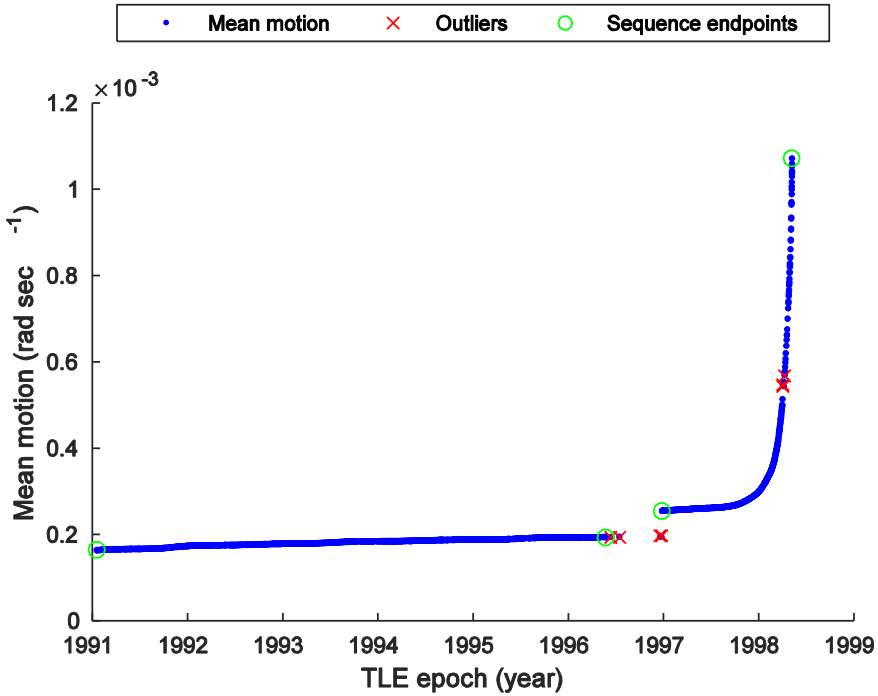
Mean motion outliers



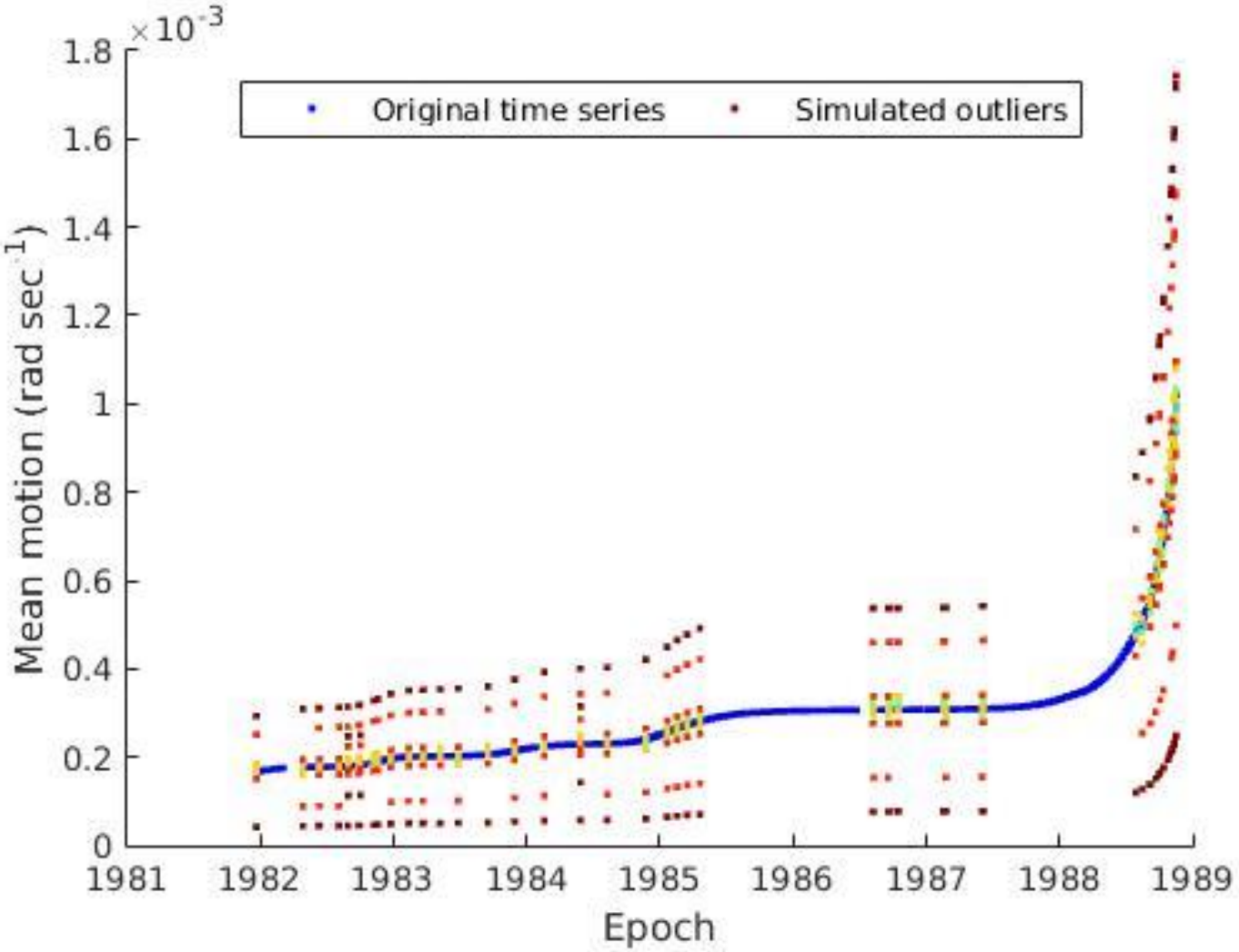


Events – change BC and SRPC

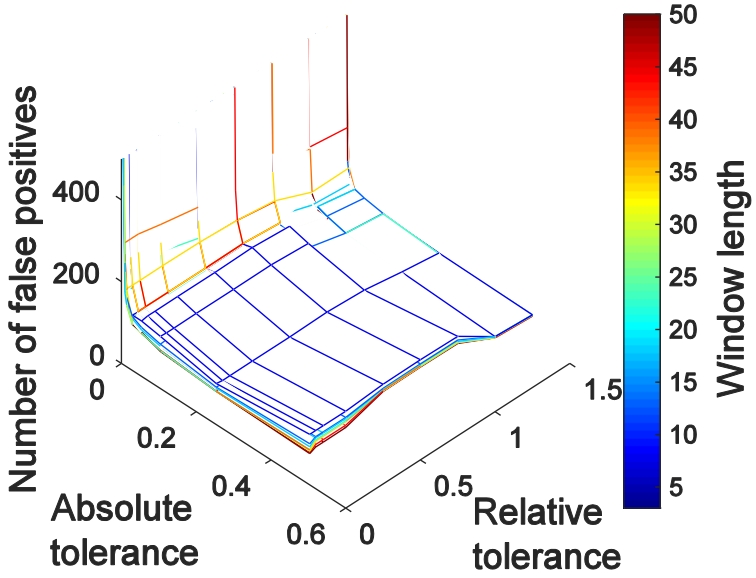


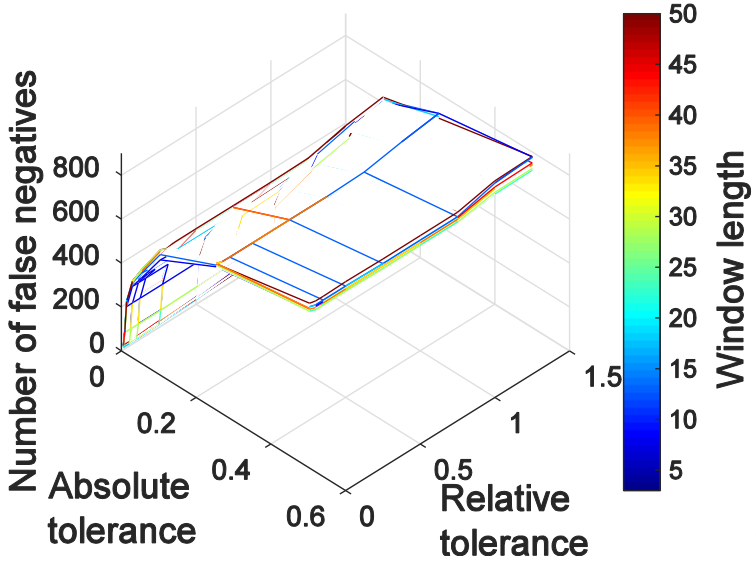


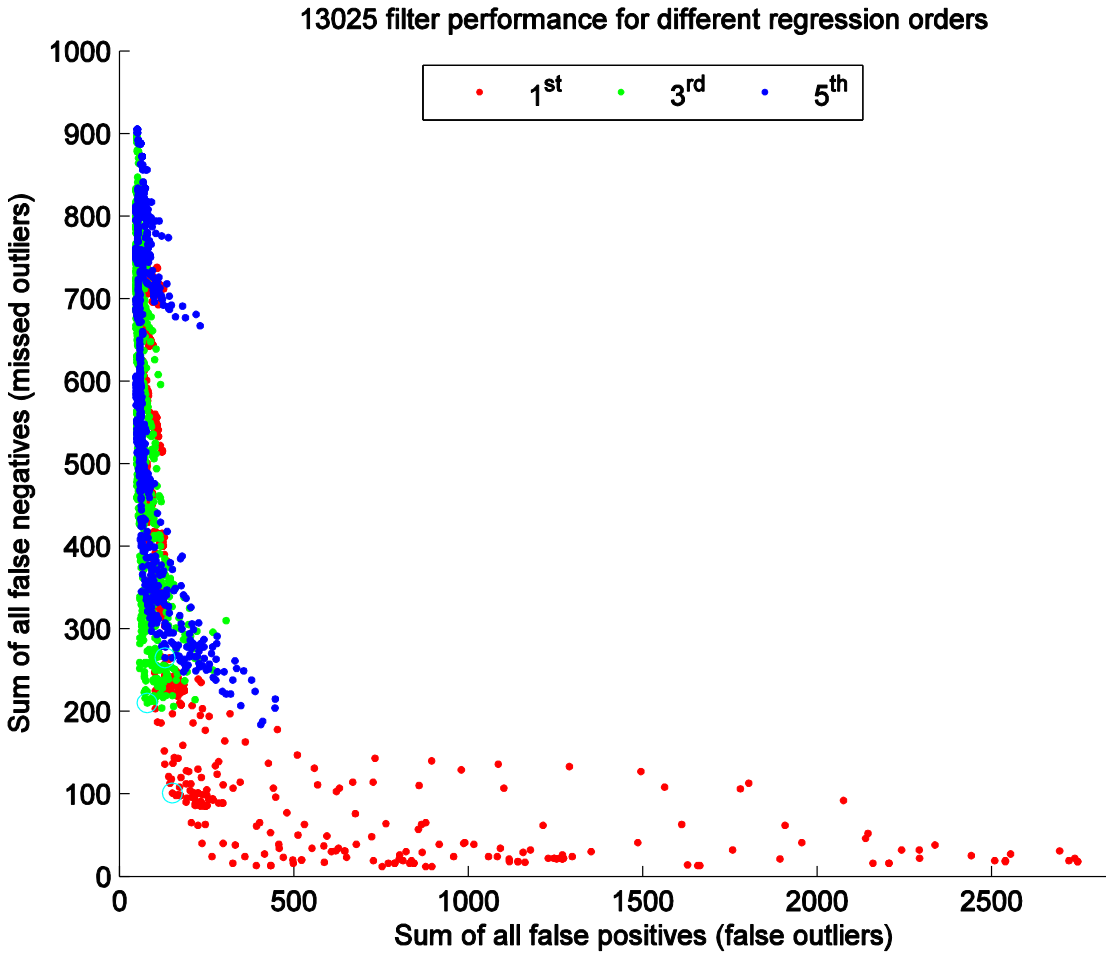
Mean motion filter tuning



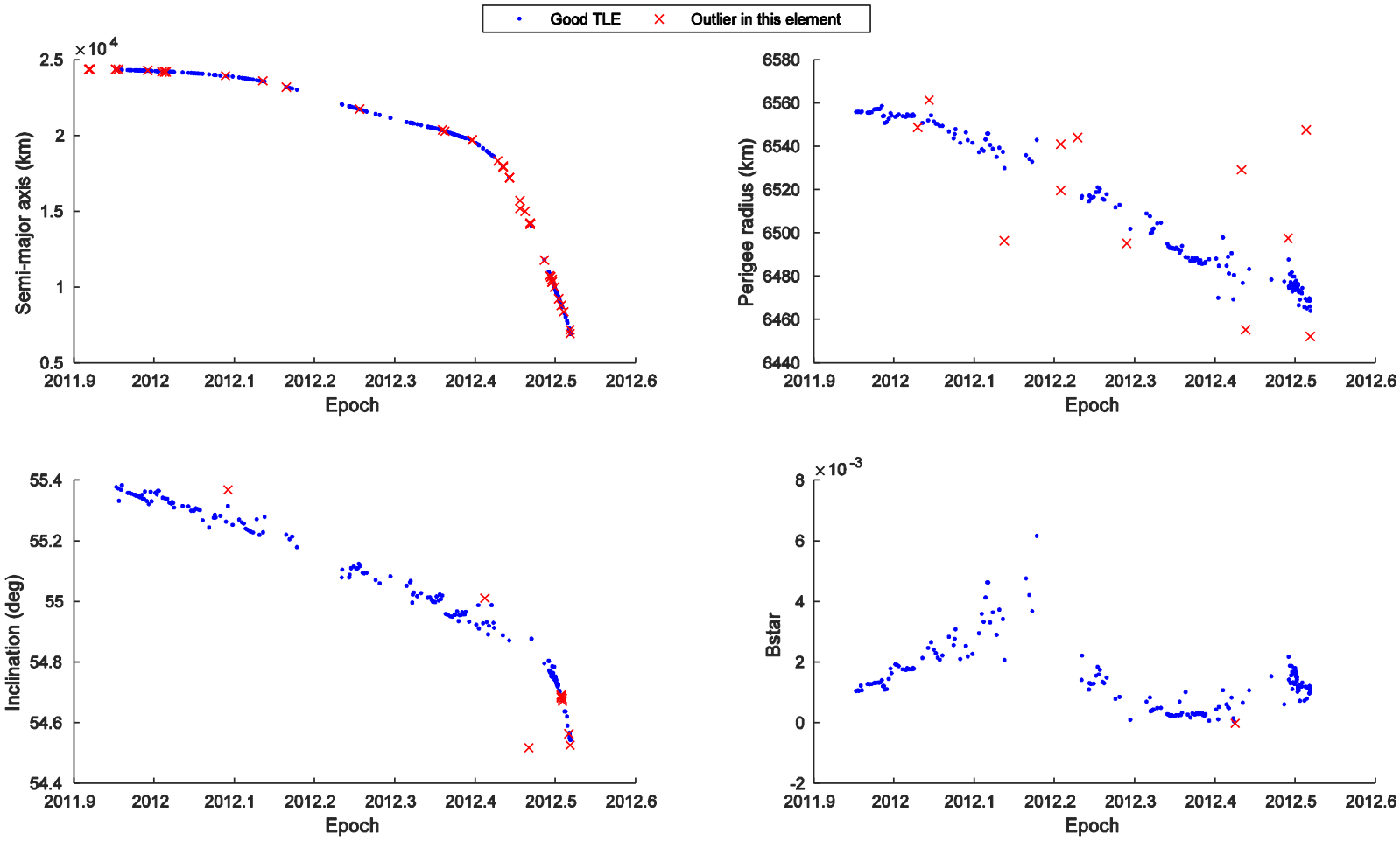
Mean motion filter tuning



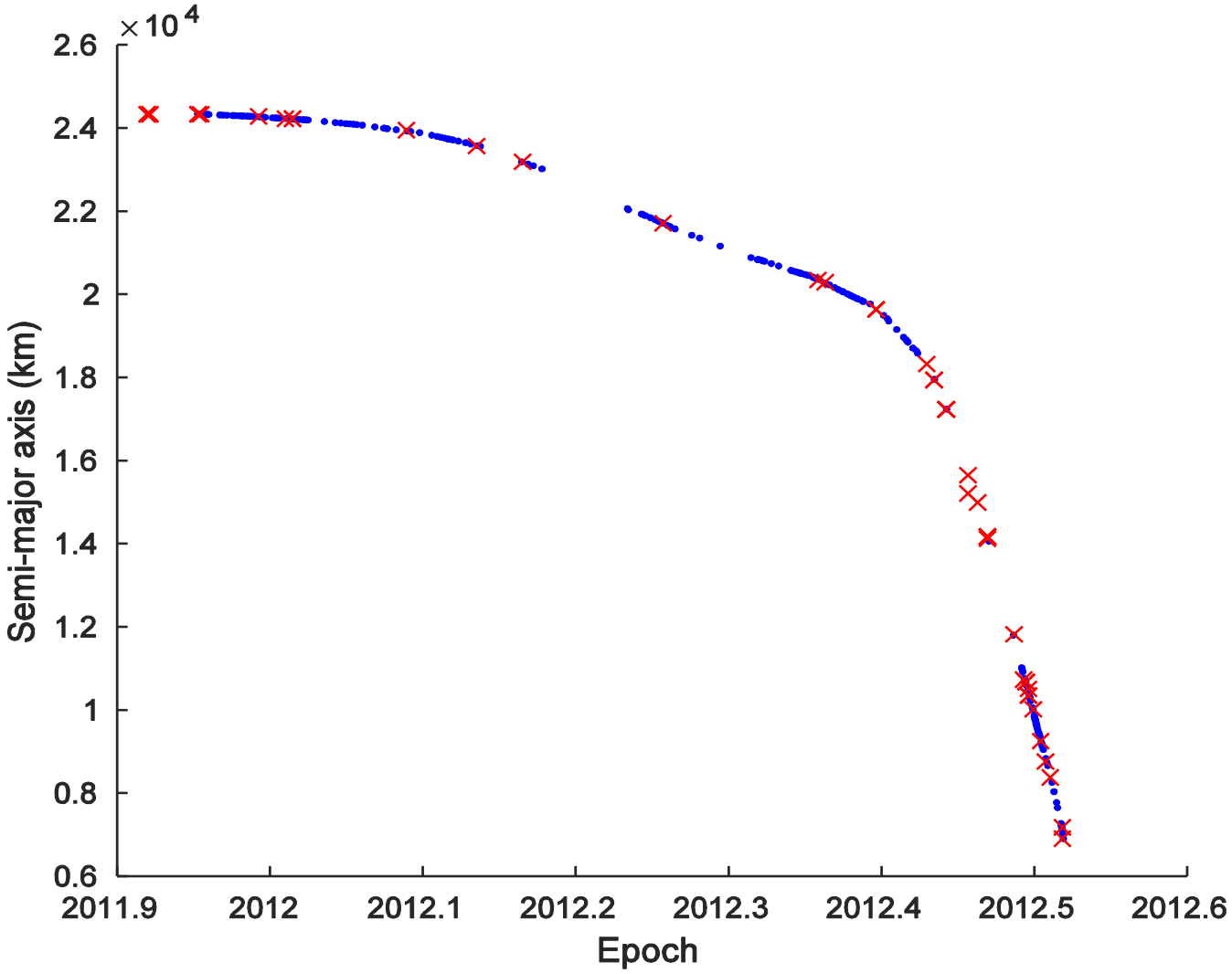




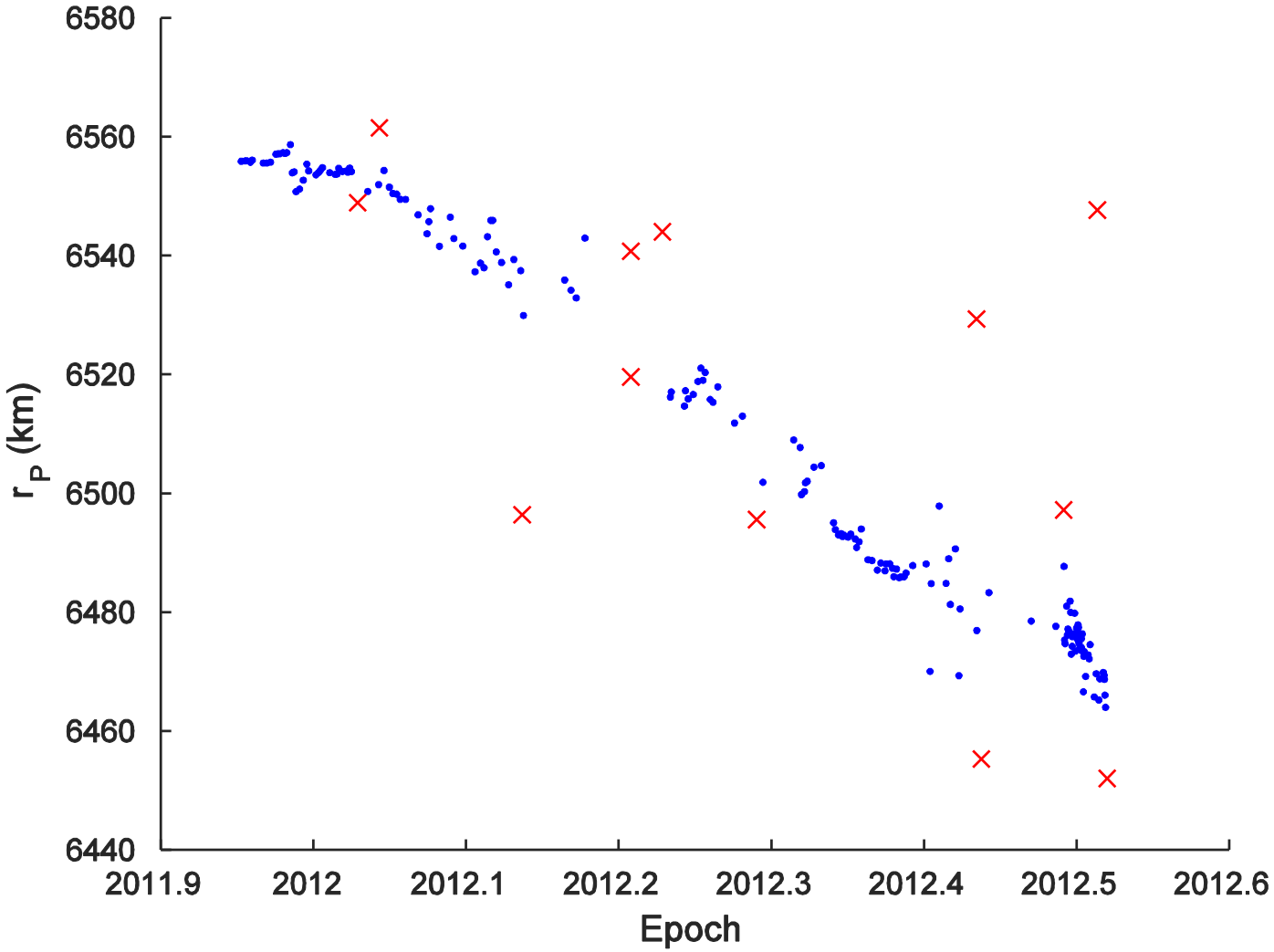
Outliers in n, e, *i*, and *B**



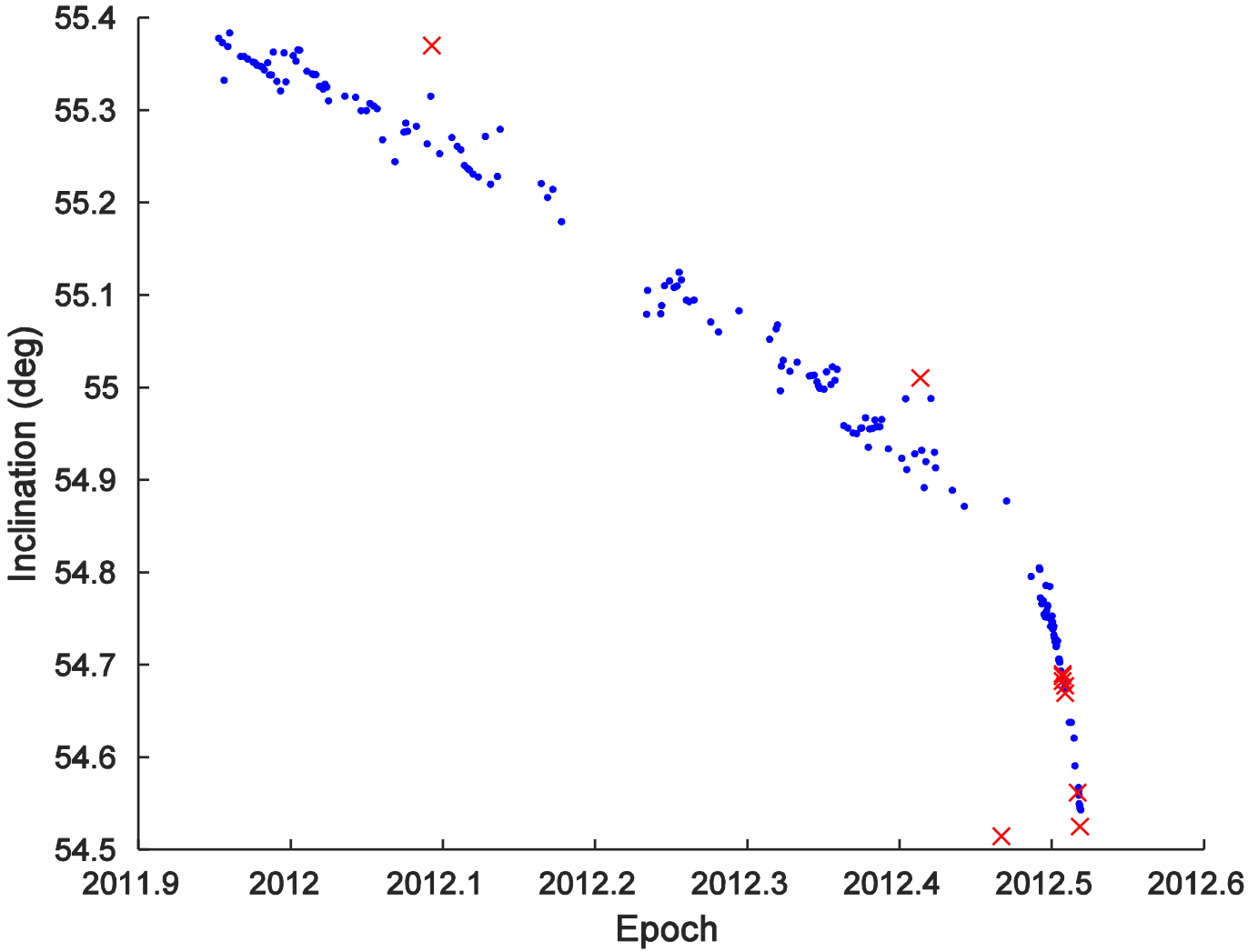
Outliers in n



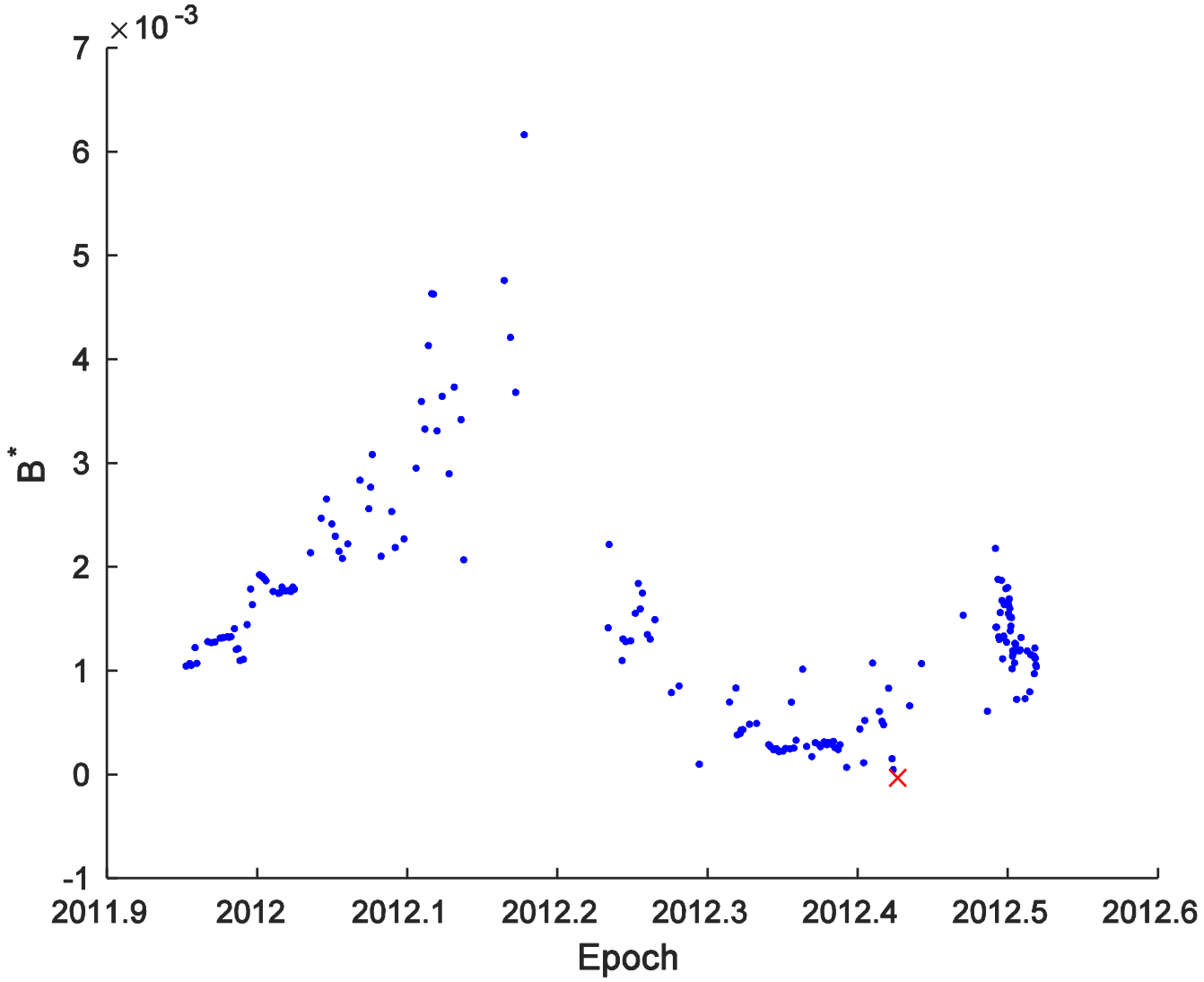
Outliers in *e*



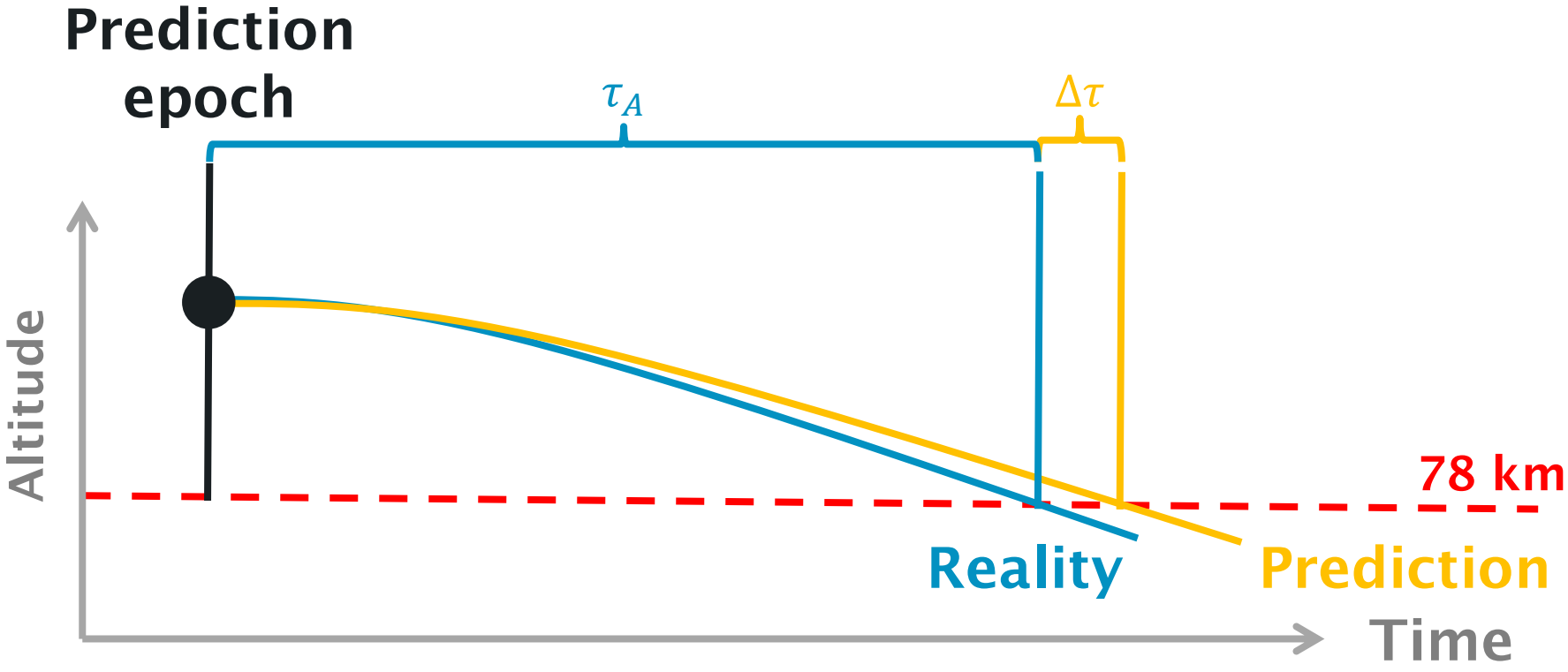
Outliers in *i*



Outliers in B^*

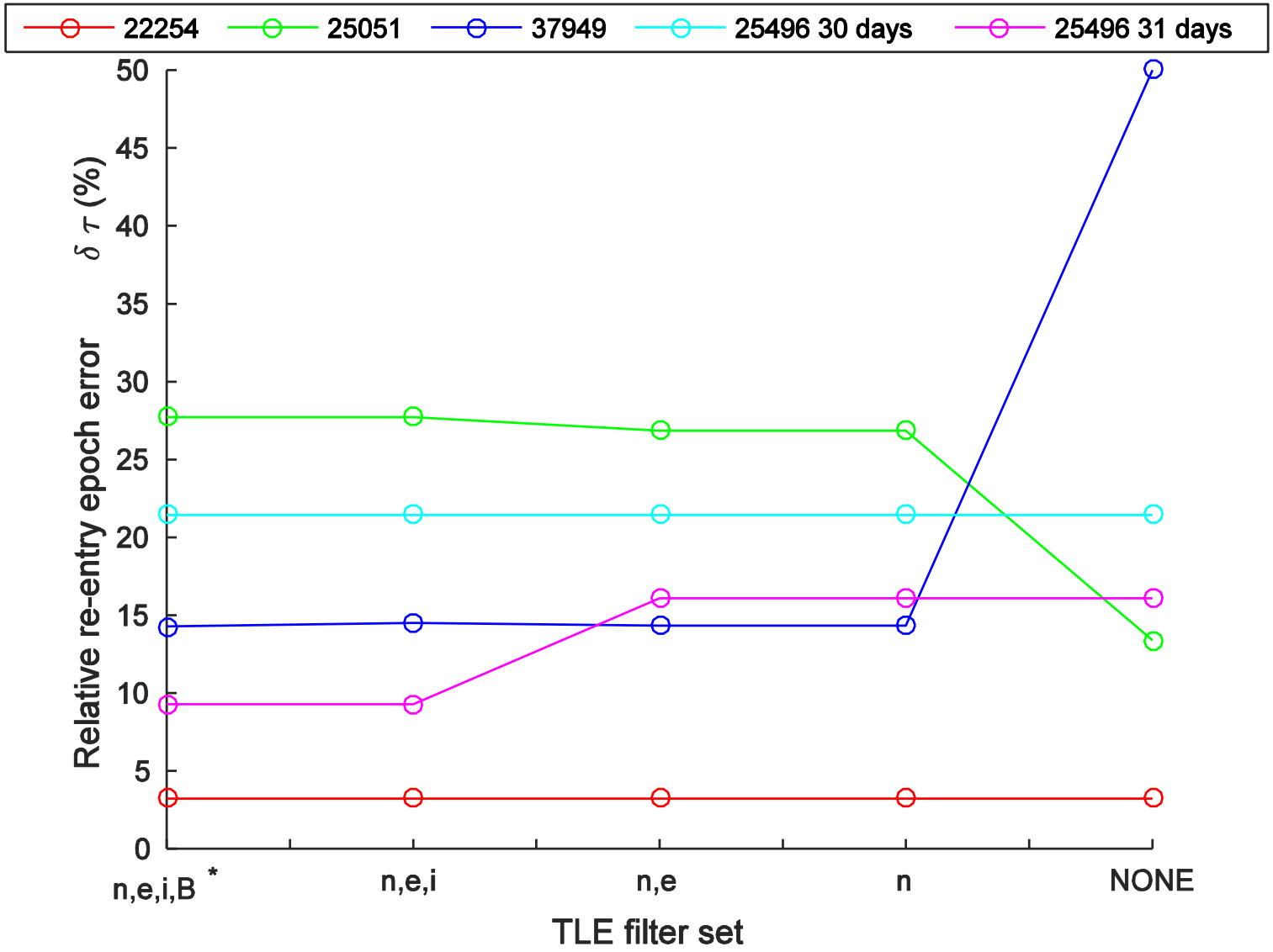


Re-entry prediction error

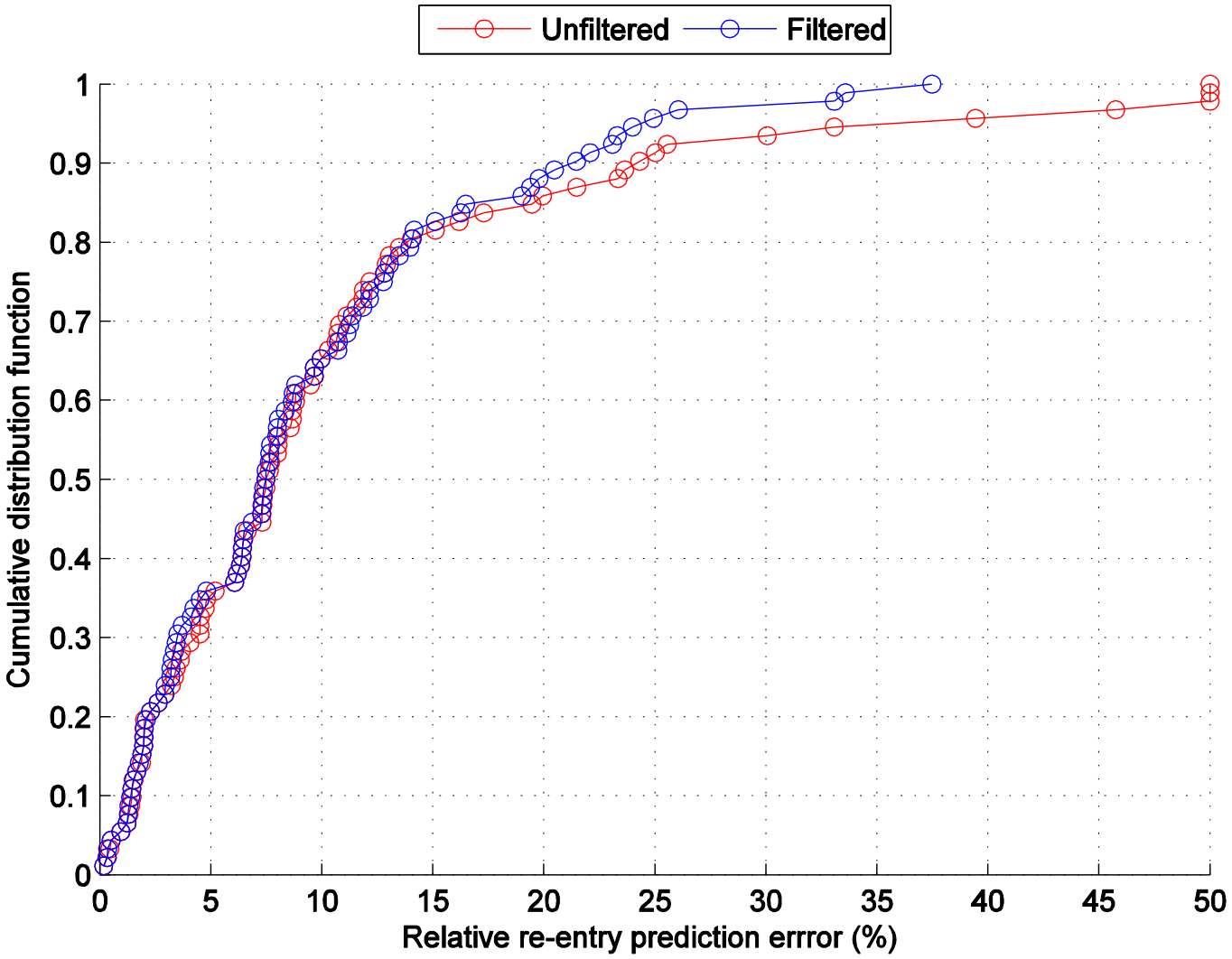


Relative error: $\delta\tau = \frac{\Delta\tau}{\tau_A}$

Effects of filtering on prediction accuracy



Importance of filtering



Conclusions and recommendations

- Filtering of the TLEs is key to get good predictions, however it isn't always necessary
- Filter in all orbital elements you're using
- Be wary that the TLEs change with time (2011, 2013…)
- Outliers => robust statistics

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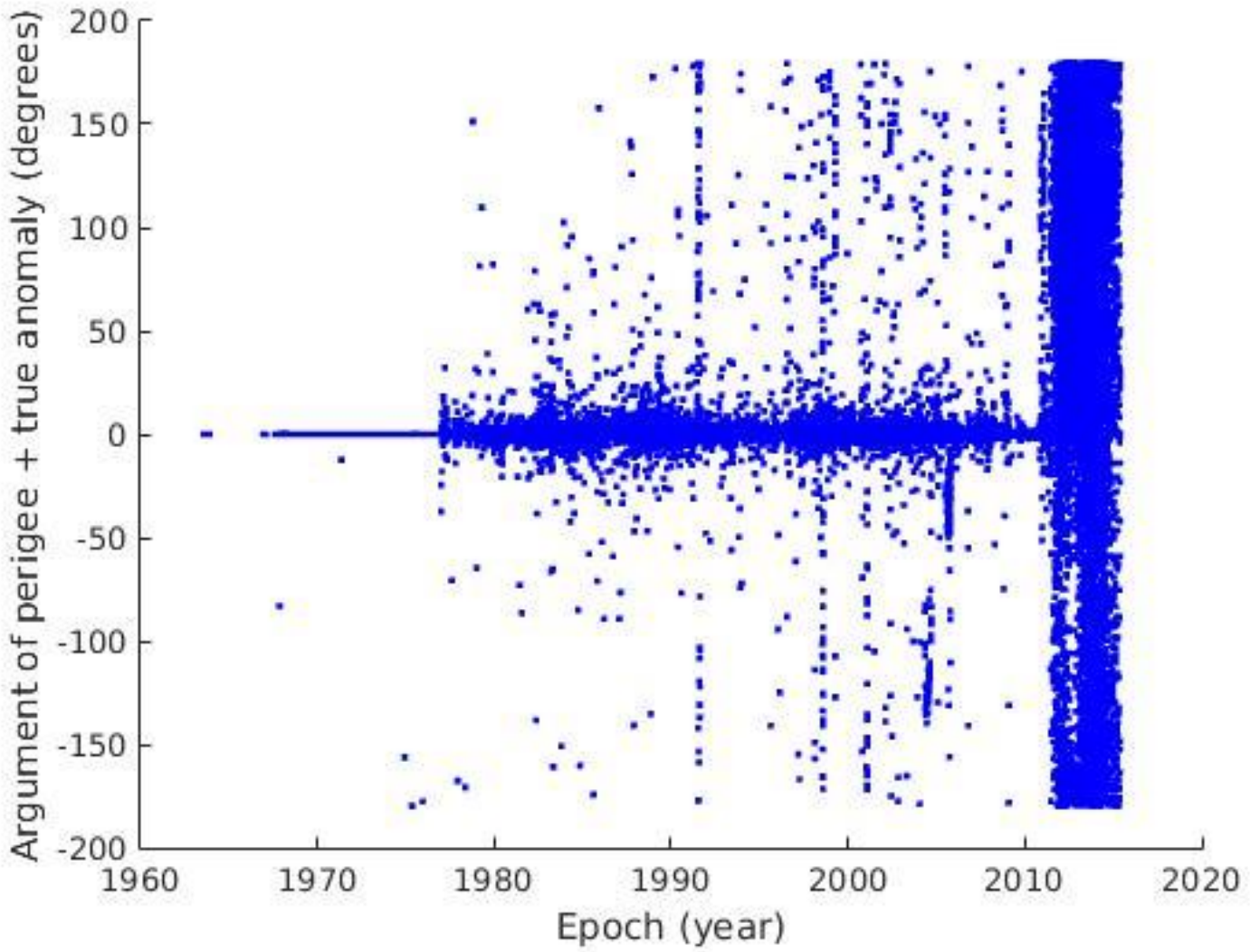
Changes in TLE generation process



Why do we care

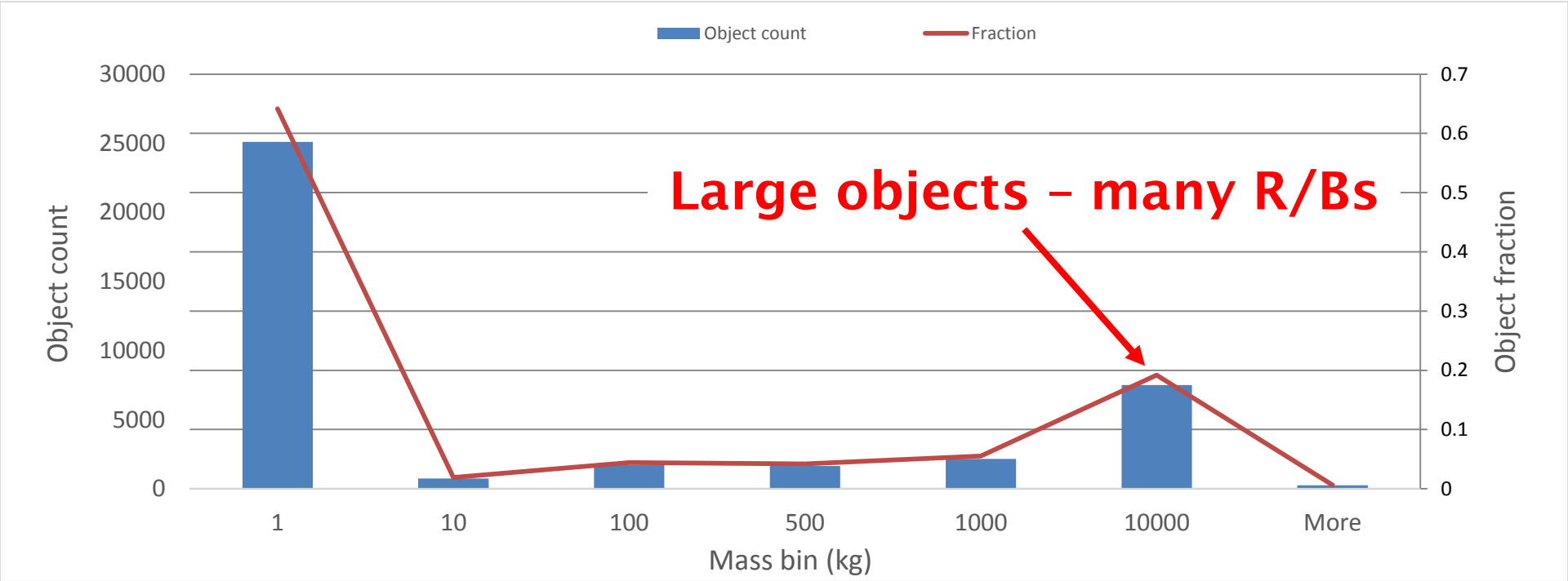
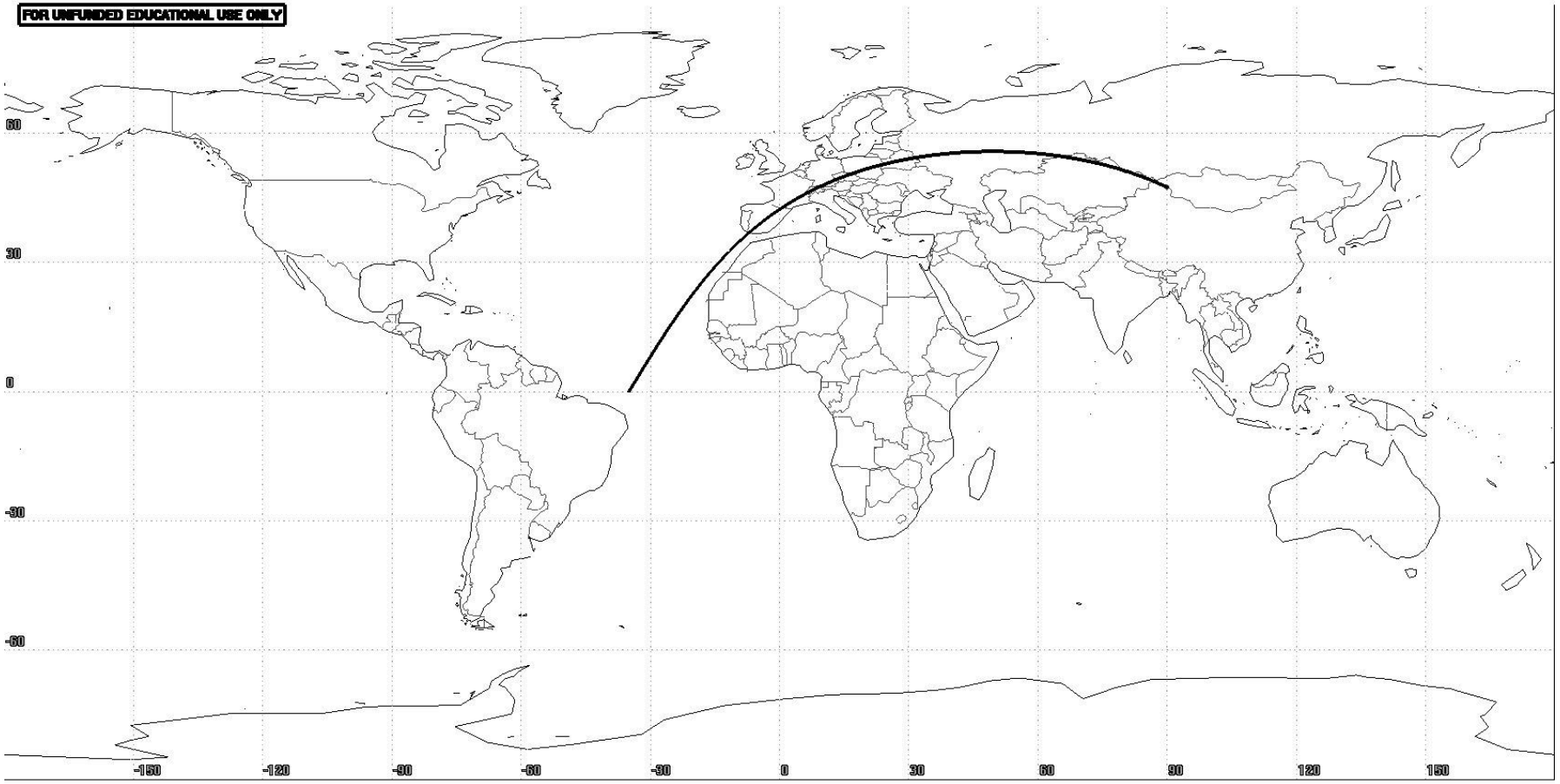


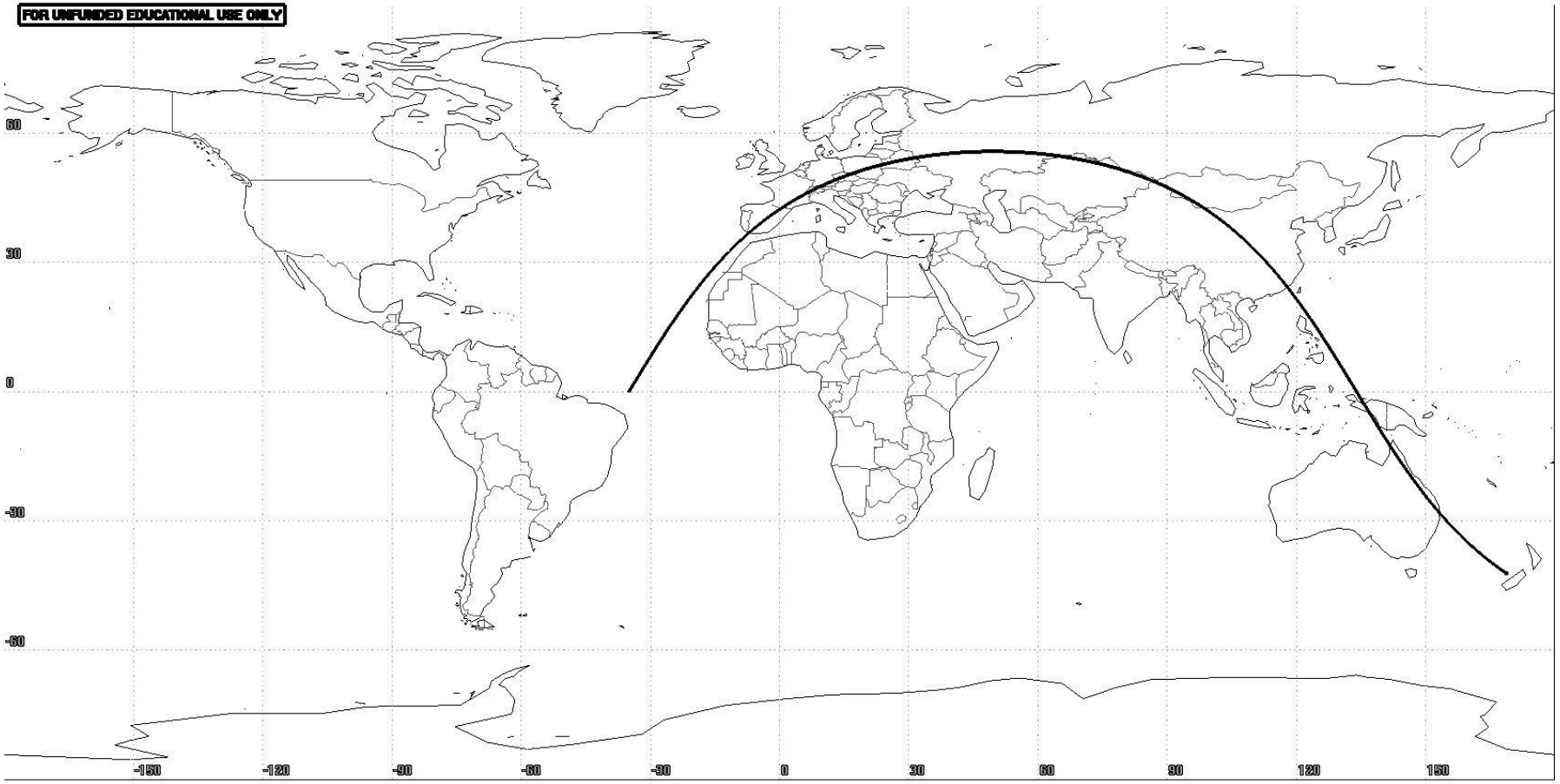
Image credit: NASA

We don’t know the re-entry epoch too well



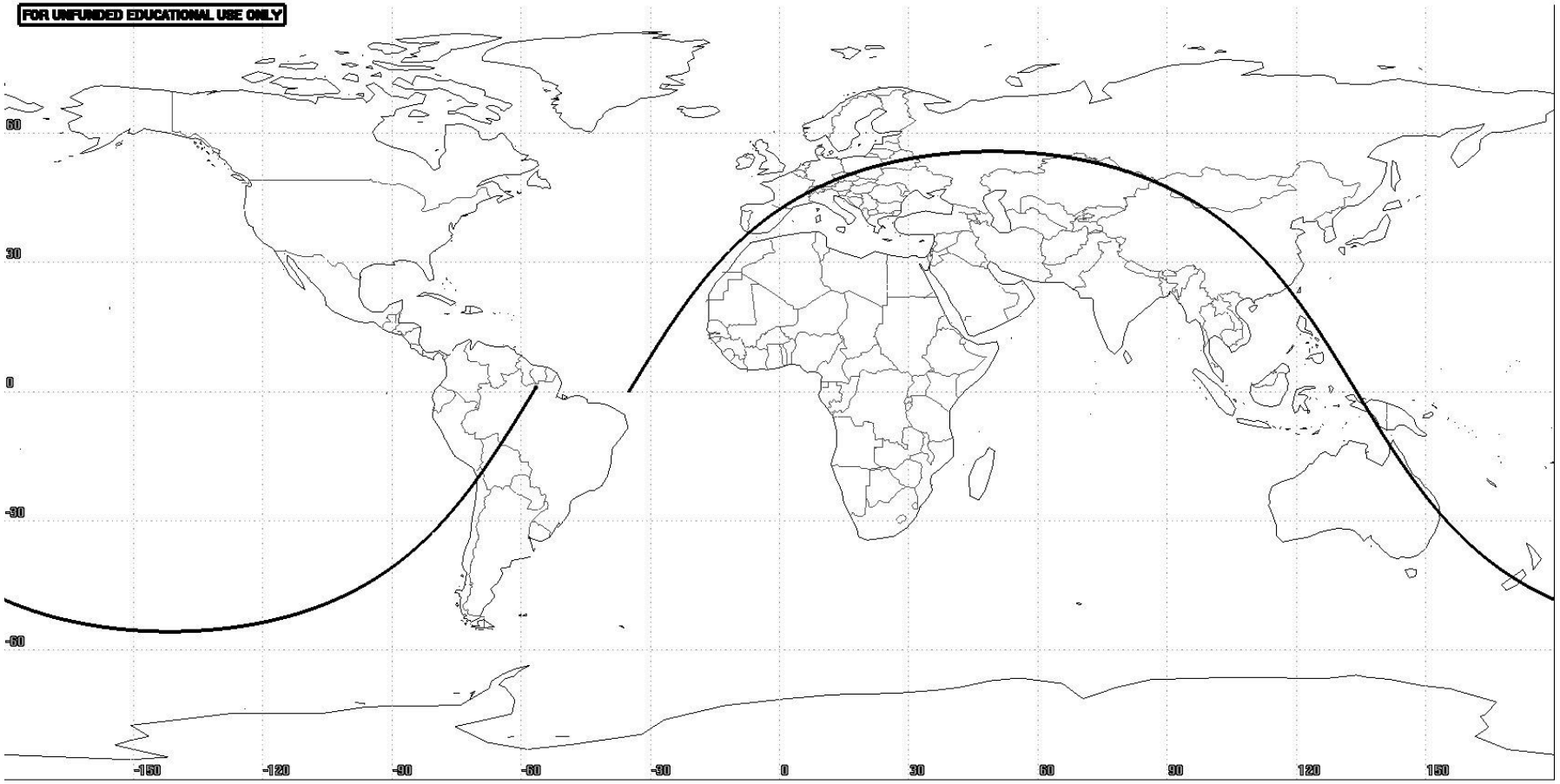
24 hours lead time.

We don’t know the re-entry epoch too well



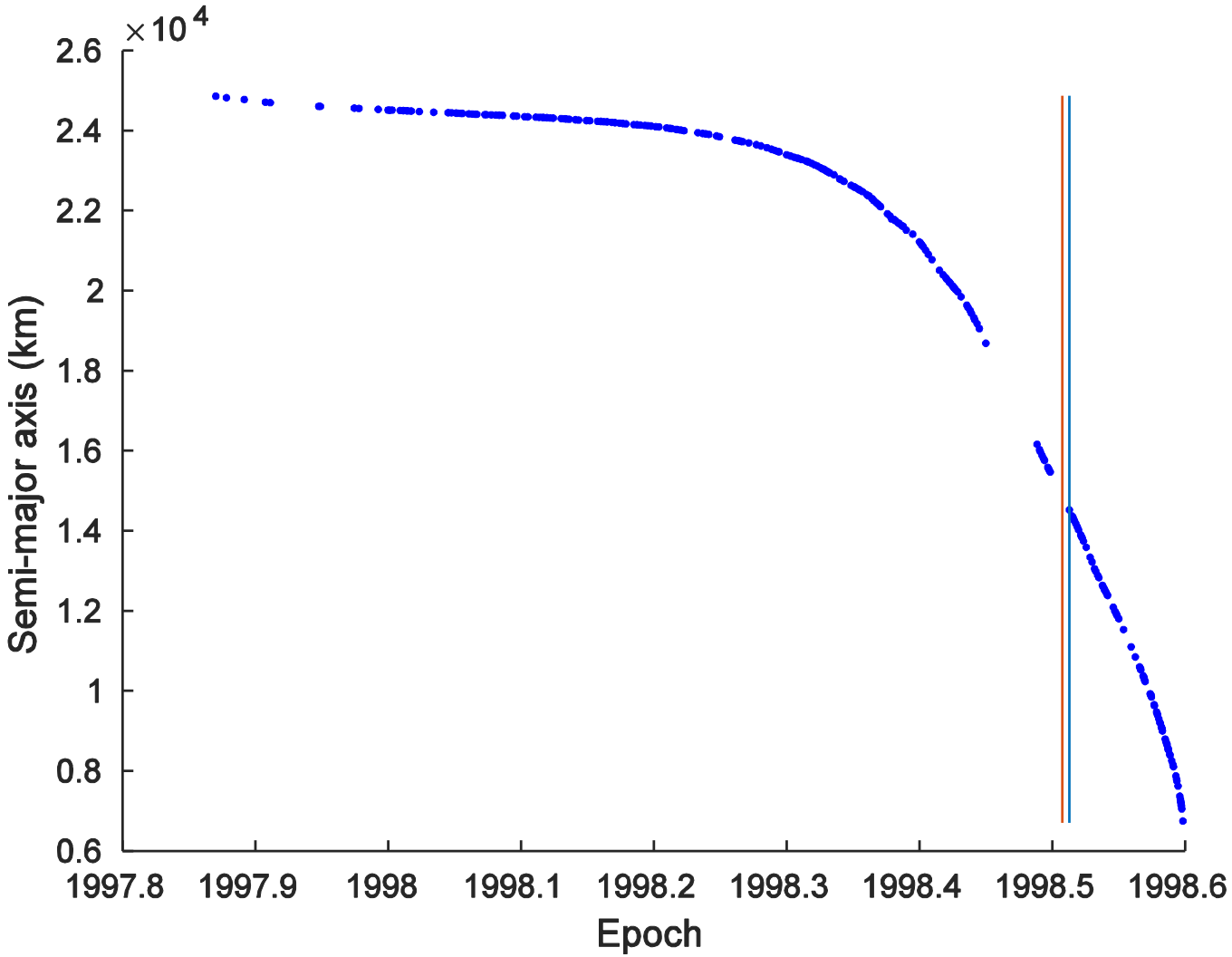
48 hours lead time.

We don’t know the re-entry epoch too well



74 hours lead time.

When we filter too many TLEs



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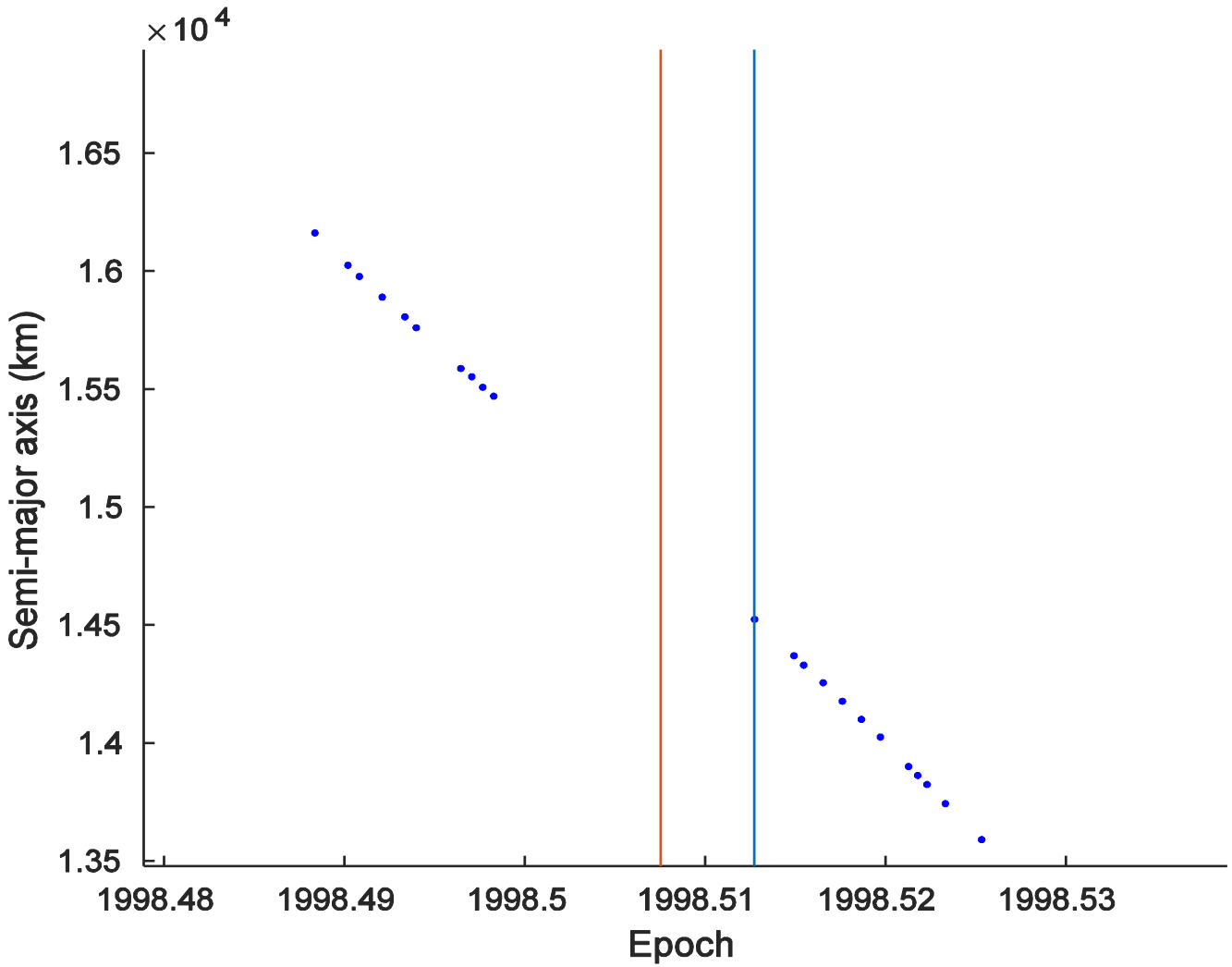

When we DO NOT filter TLEs