

# Designing an n-pair satellite constellation for recovering daily Earth system mass change using a multi-objective genetic algorithm.

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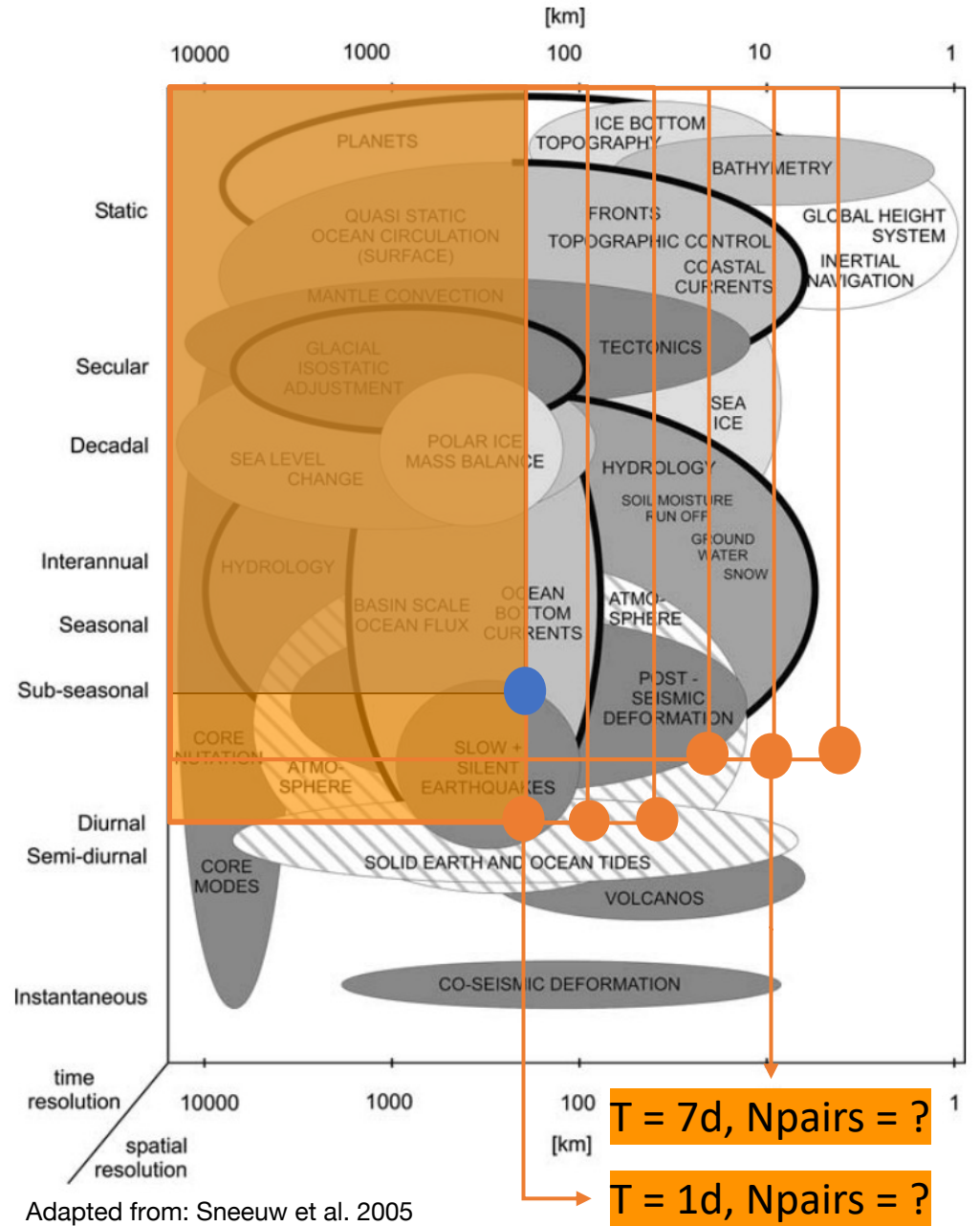
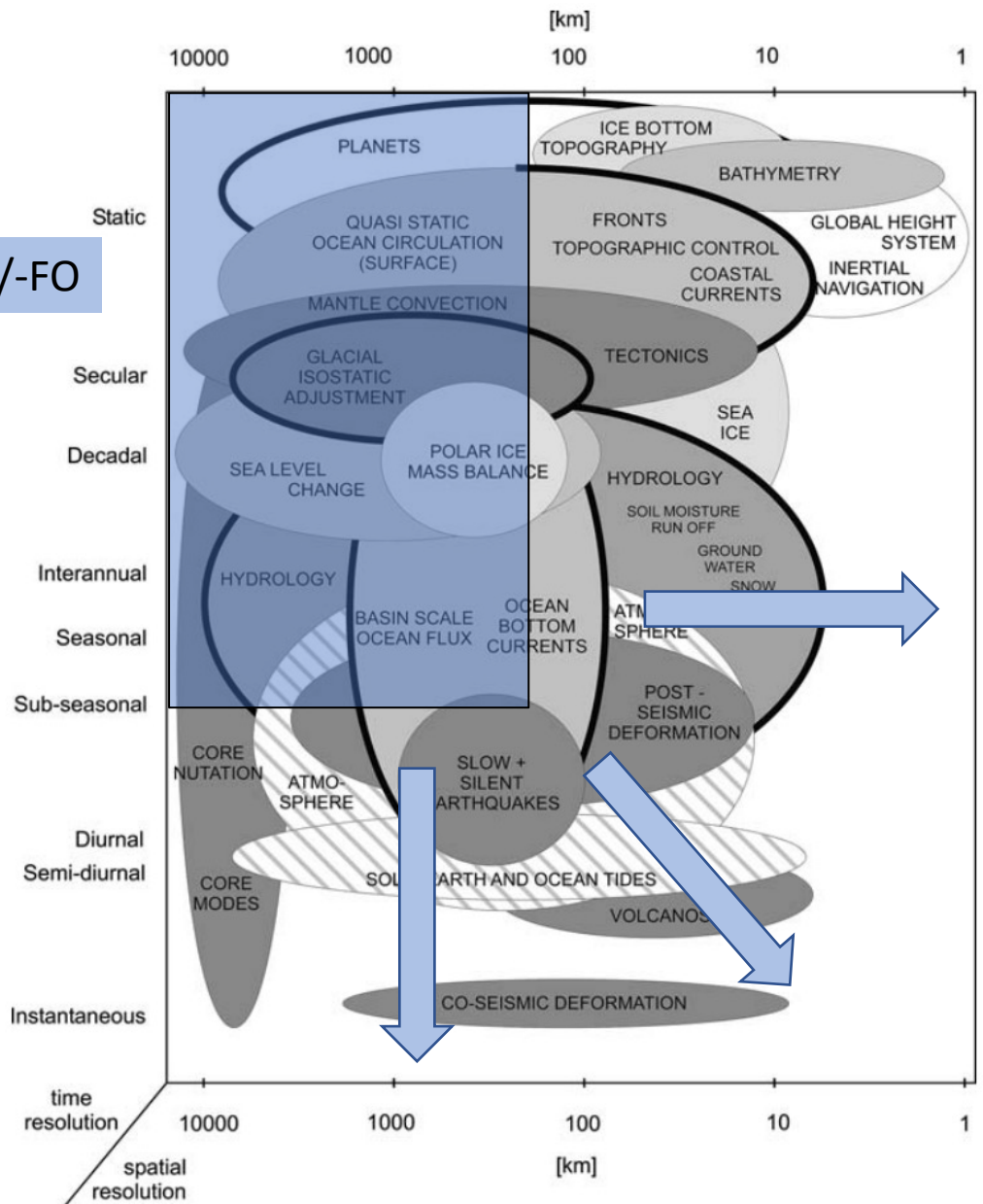
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GRACE-FO SCIENCE TEAM MEETING 2021, 12-20 October 2021

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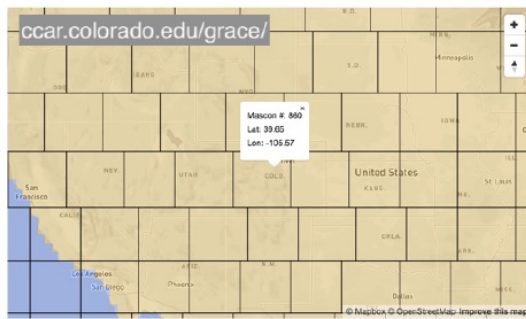
GRACE/-FO



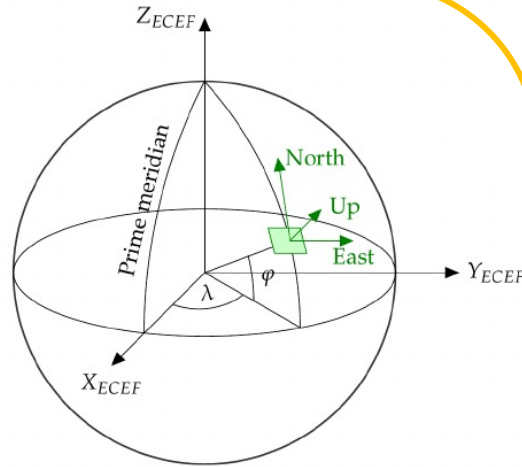
Adapted from: Sneeuw et al. 2005

# Objective function

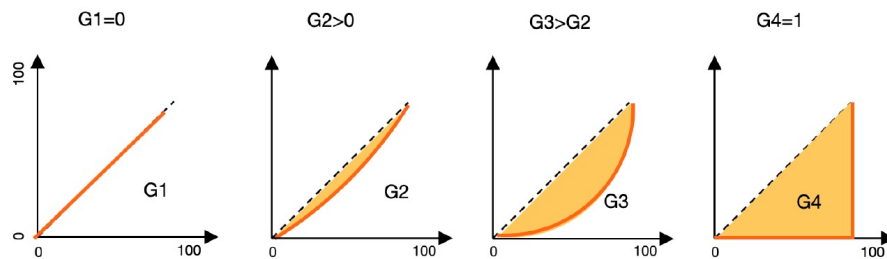
Spatial objective function ( $J_{sc}$ )



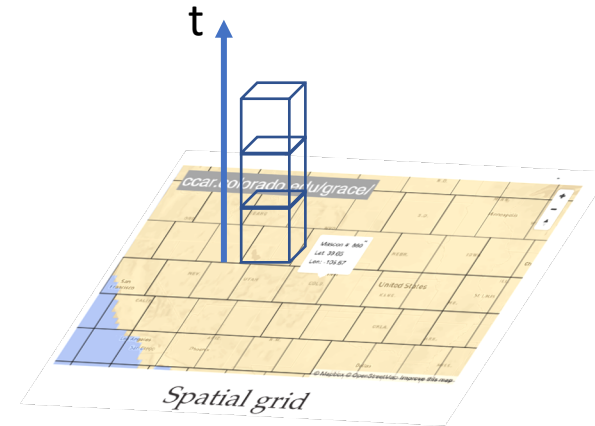
Spatial grid



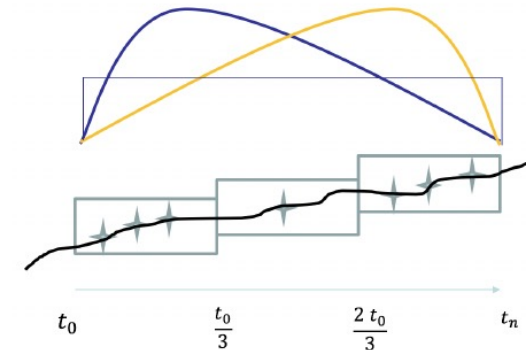
N-S vs E-W information



Uniformity



Spatial grid

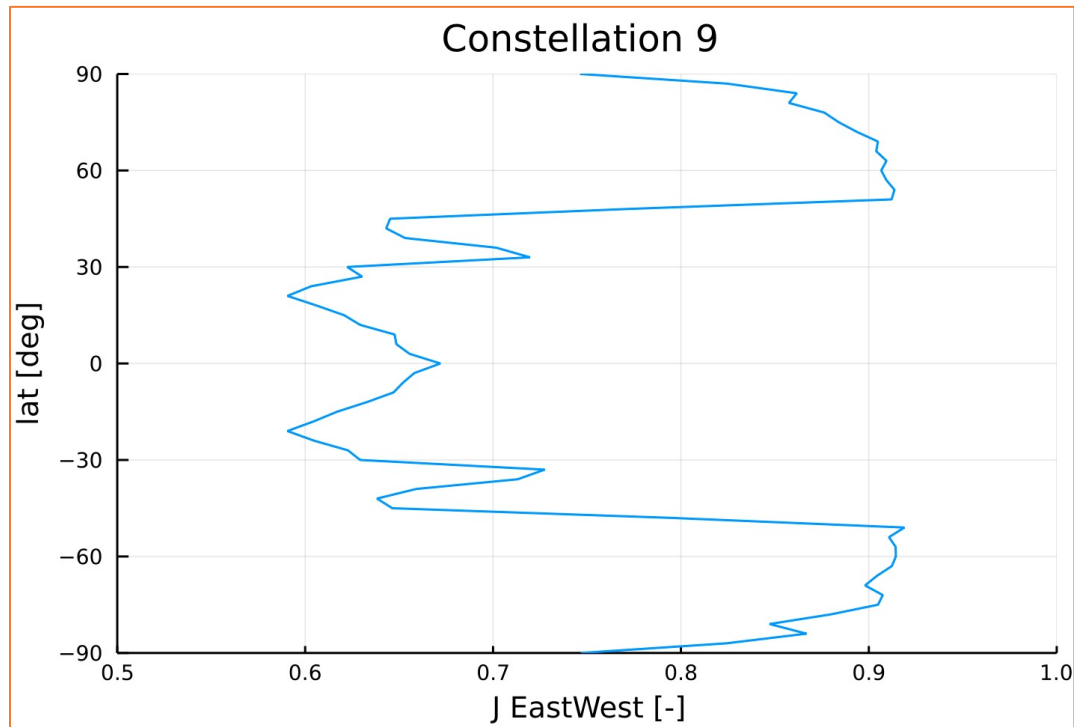


Temporal grid

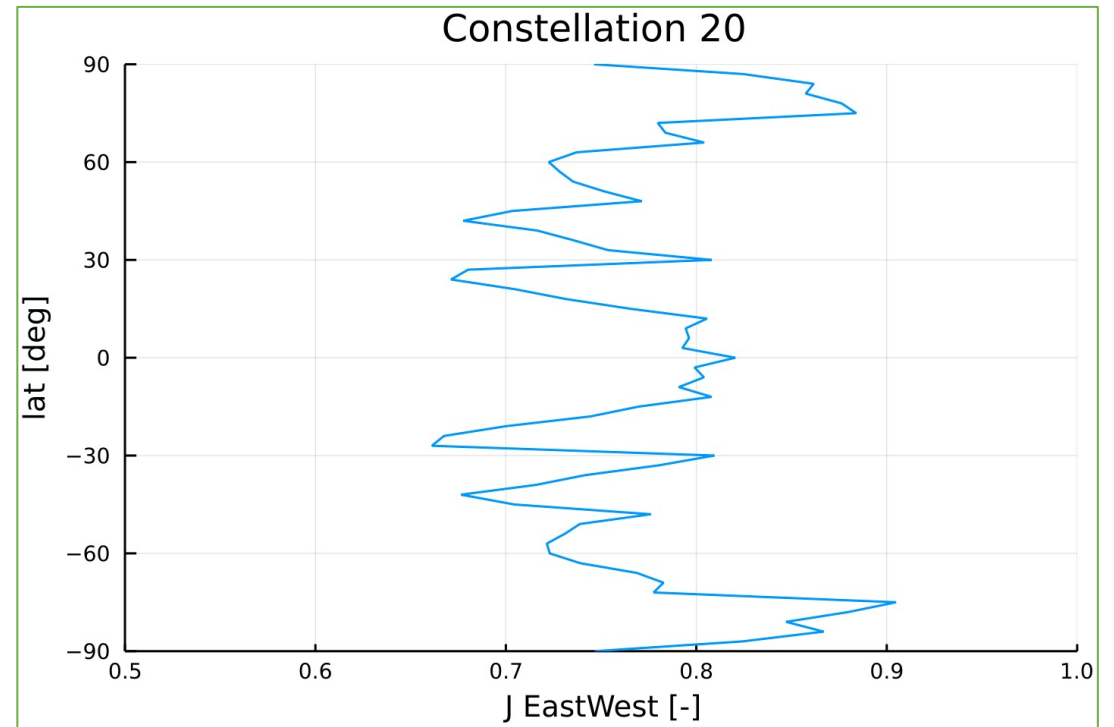
Temporal objective function ( $J_{TC}$ )

# EW information by latitude

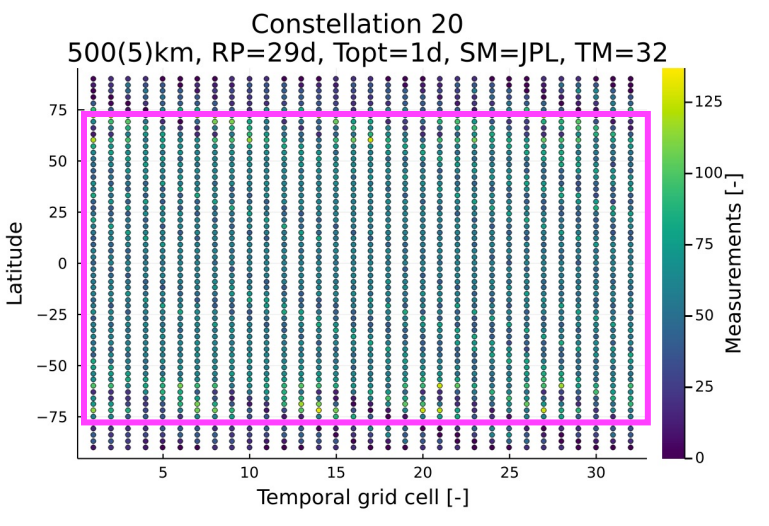
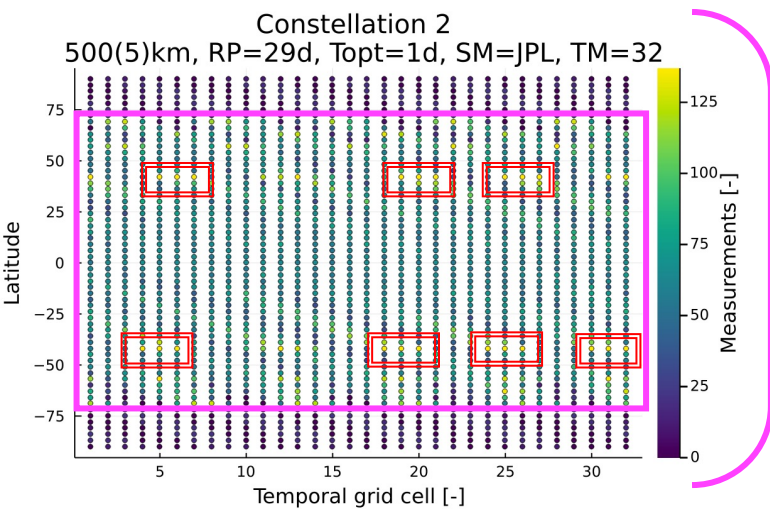
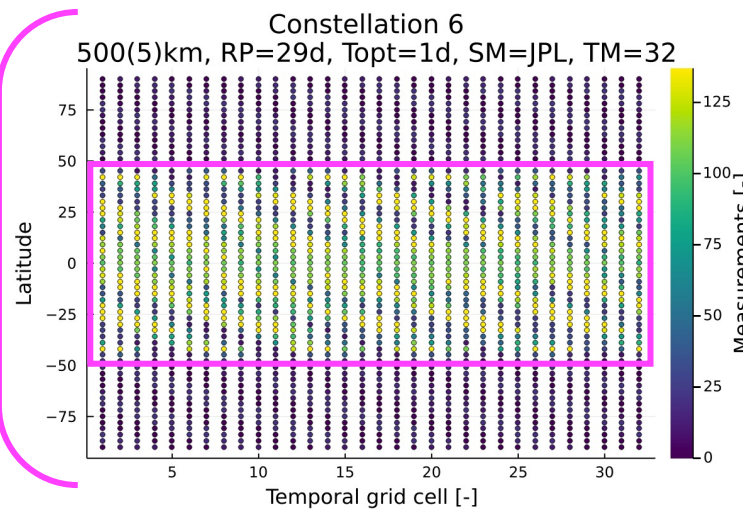
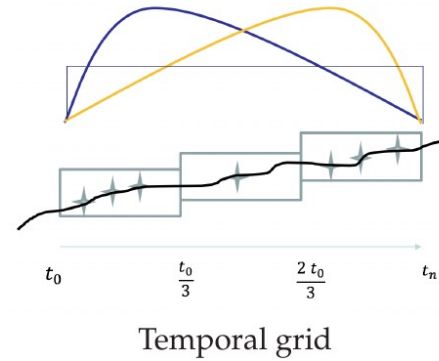
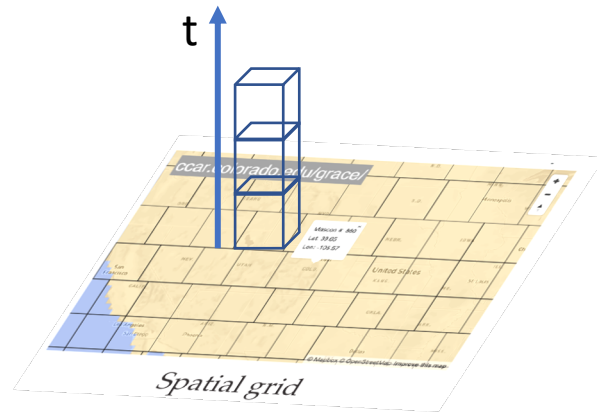
C09 has on average better EW information, but not uniformity.



Uniformity is a key measure of a constellation's performance.



# Temporal objective function

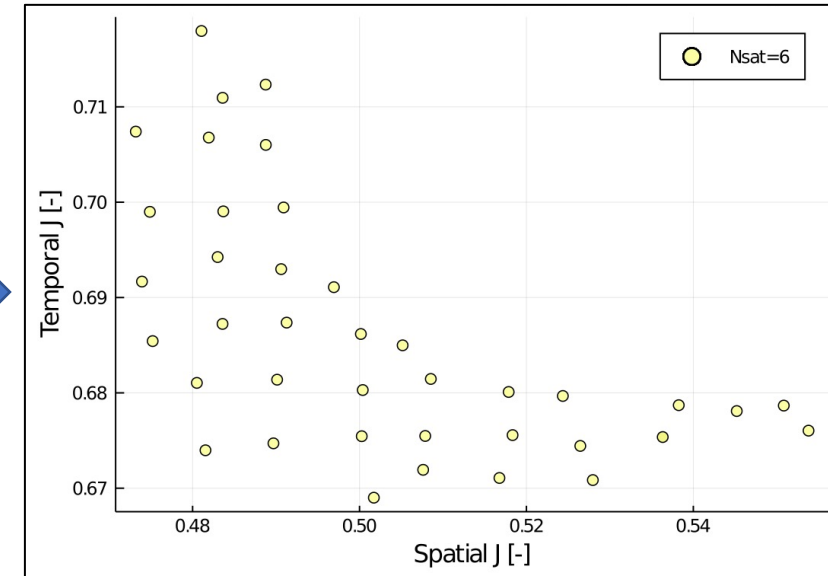


# GA variables

- Solution period
  - Each day of 13 days
- First satellite pair
  - $i_1=90$
  - $M_1=5$
  - $\Omega_1=5$
- Altitude
  - $h \approx 500(5)$  km

Fixed parameters

- Search space
  - $n_{\text{pairs}} = 6$
  - $i_{n>1} = [40 - 89, 91 - 140]$ 
    - intervals of 3.26 deg
    - $2 \cdot 2^4$  options
  - $M_{n>1} = [5 - 360]$ 
    - intervals of 50 deg
    - $2^3$  options
  - $\Omega_{n>1} = [5 - 360]$ 
    - intervals of 50 deg
    - $2^3$  options



➤ **Discrete** analysis of the search space

# Verification with GEODYN

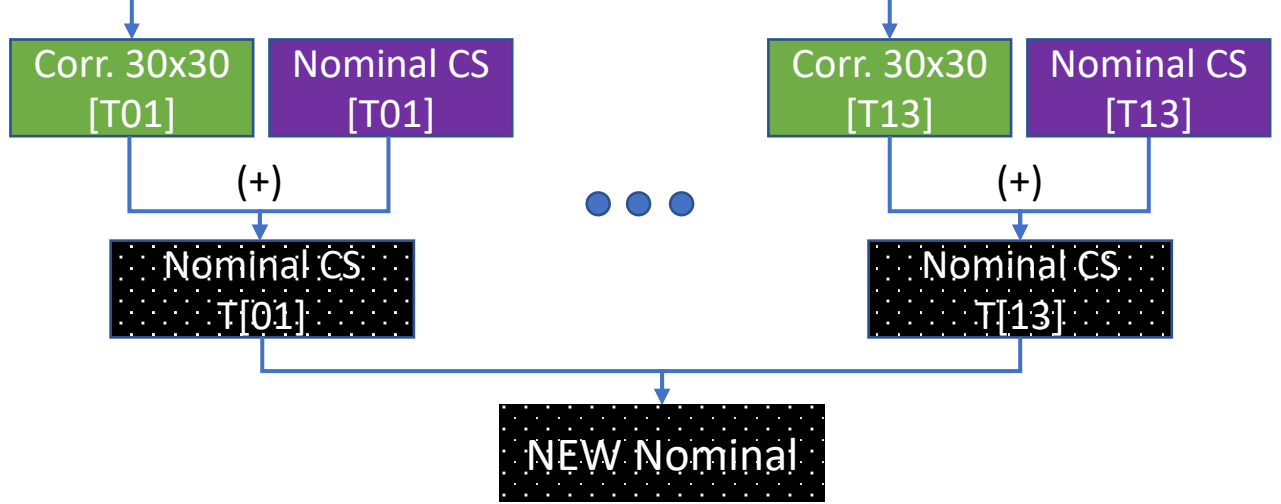
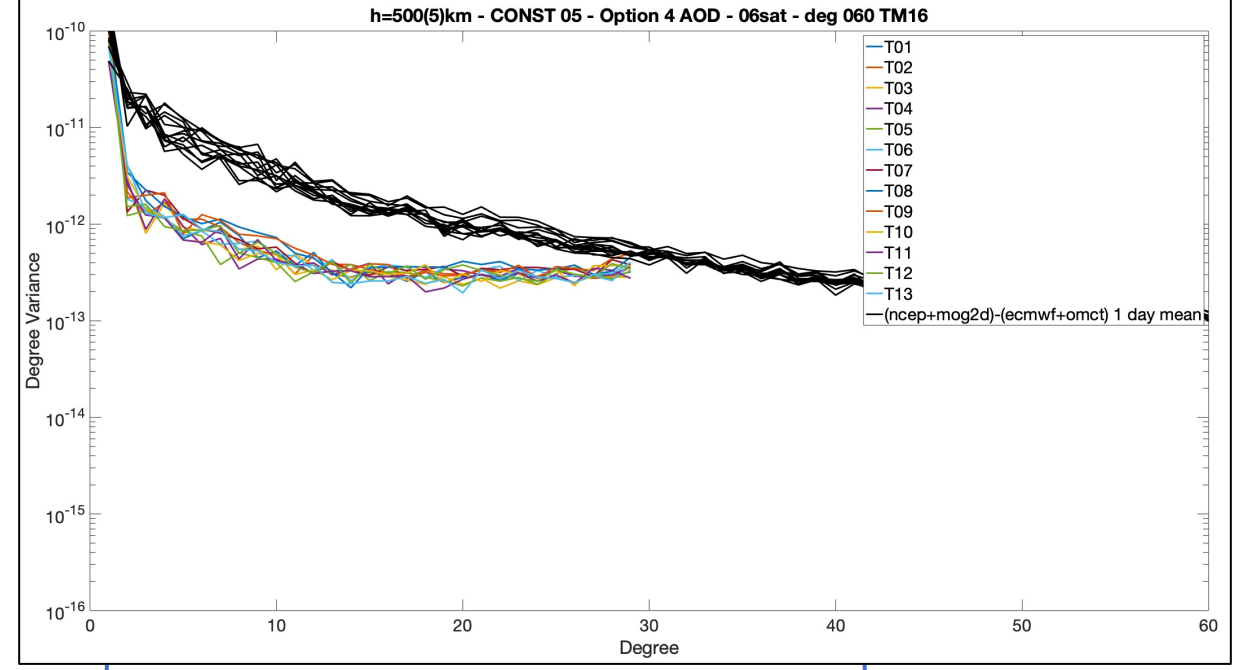
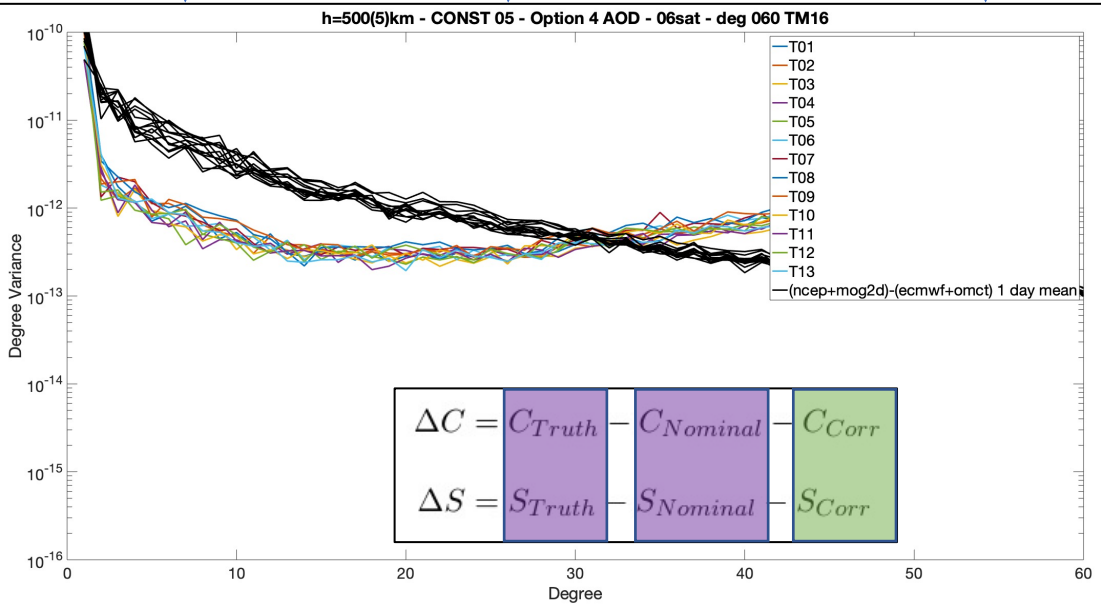
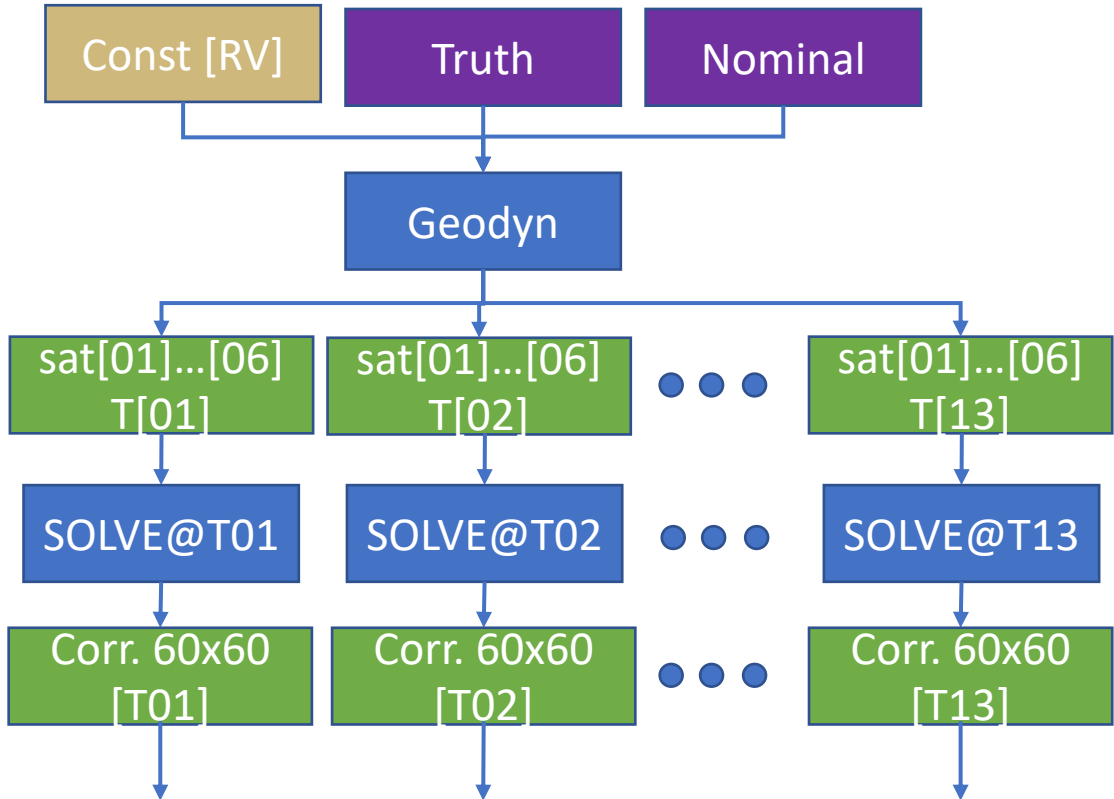
- Truth: EIGEN-GL04C + EMCWF + OMCT
- Nominal: EIGEN-GL04C + NCEP + MOG2D



- Setup deck and initiation script includes:
  - AOD errors (EMCWF + NCEP) – (OMCT + MOG2D)
  - Range rate errors (GRACE-FO levels)
  - Accelerometer errors (GRACE-FO levels)
  - Tidal aliasing (FES2004 - GOT.00)
  - Satellite position errors (10 cm)

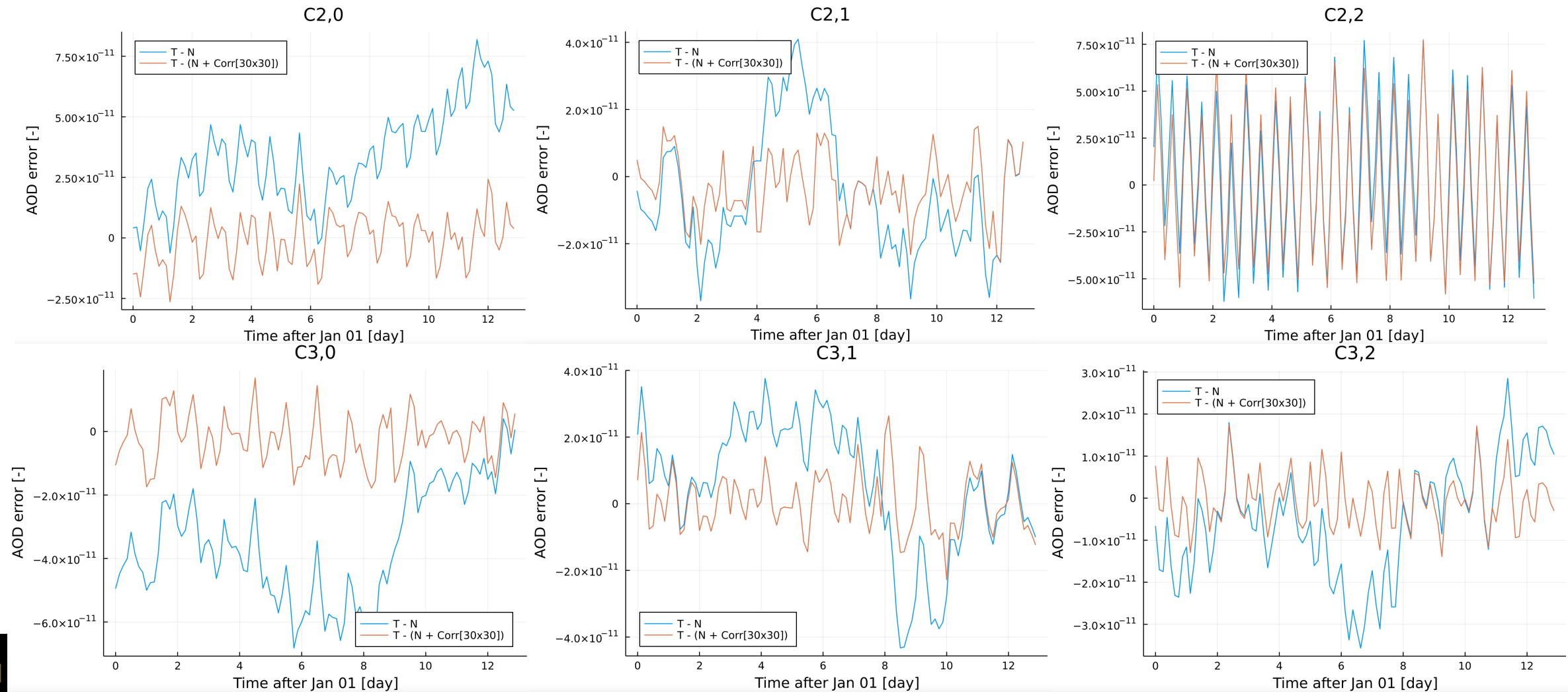
➤ Recovered CS error due to Range rate, Accelerometer and AOD error

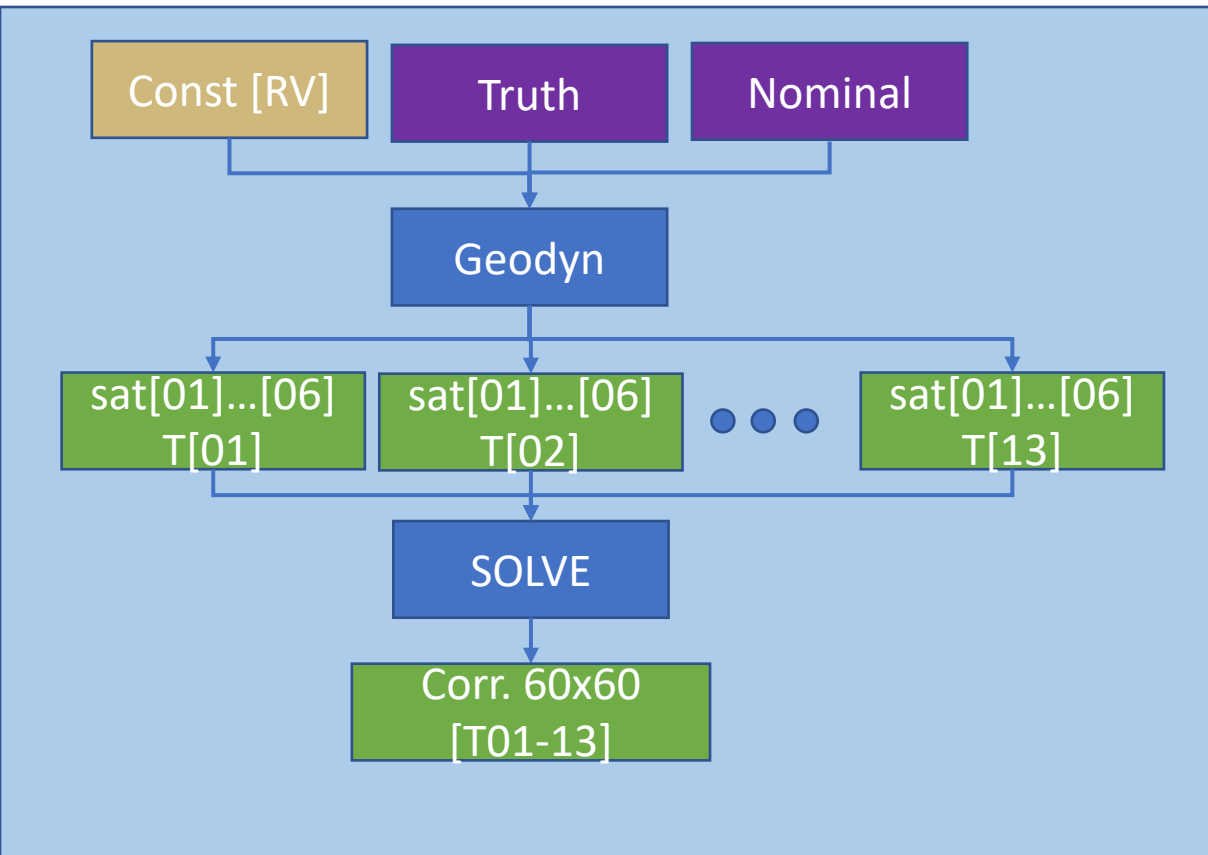






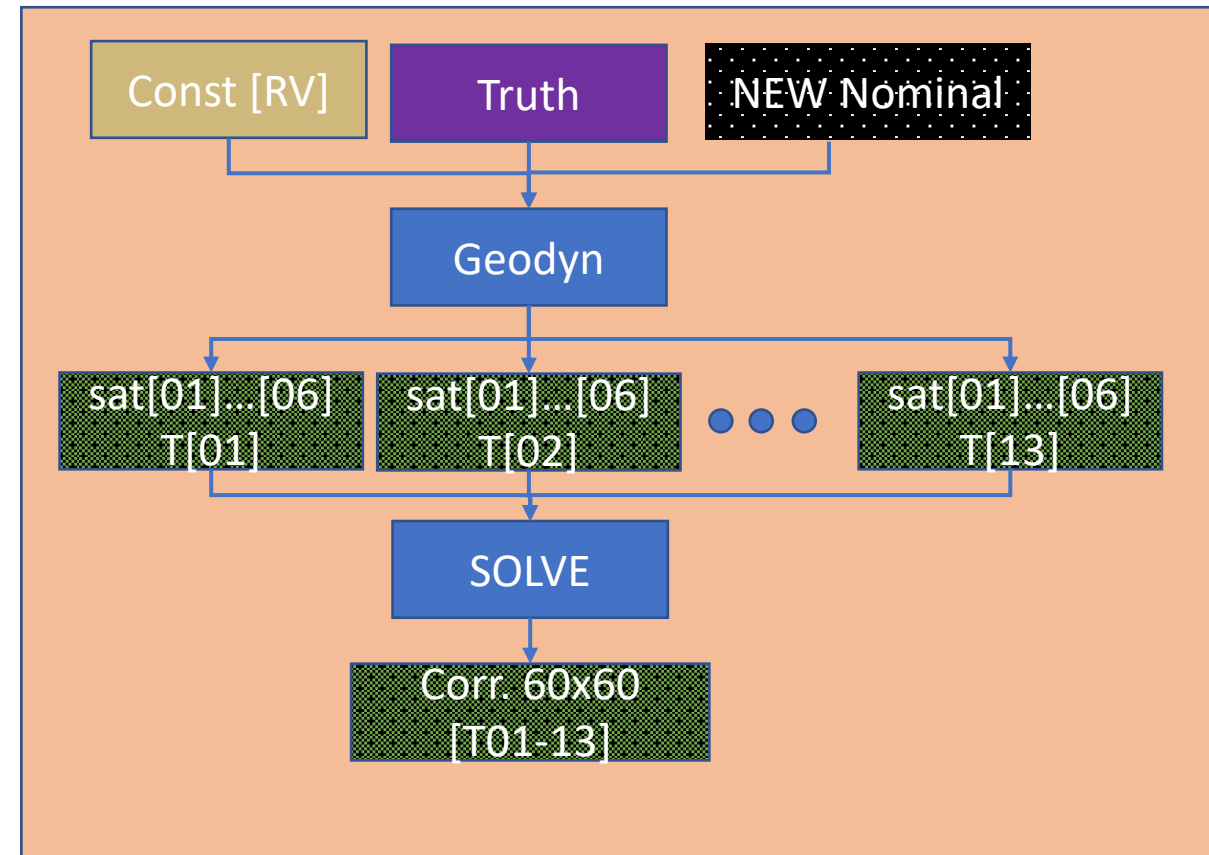
# Daily AOD error





$$\Delta C = C_{Truth} - C_{Nominal} - C_{Corr}$$

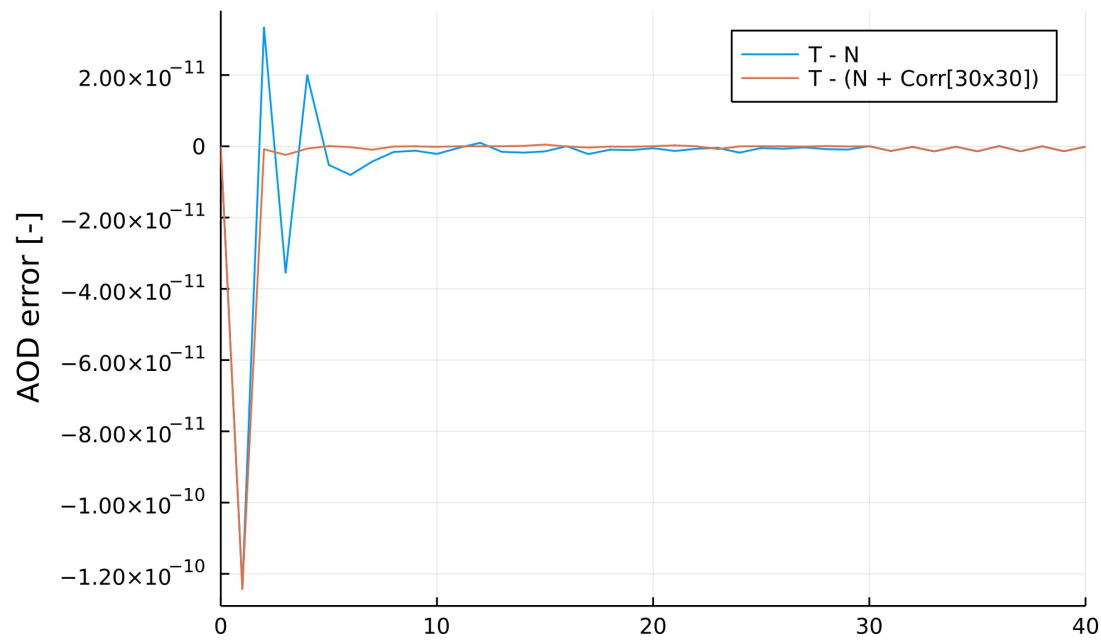
$$\Delta S = S_{Truth} - S_{Nominal} - S_{Corr}$$



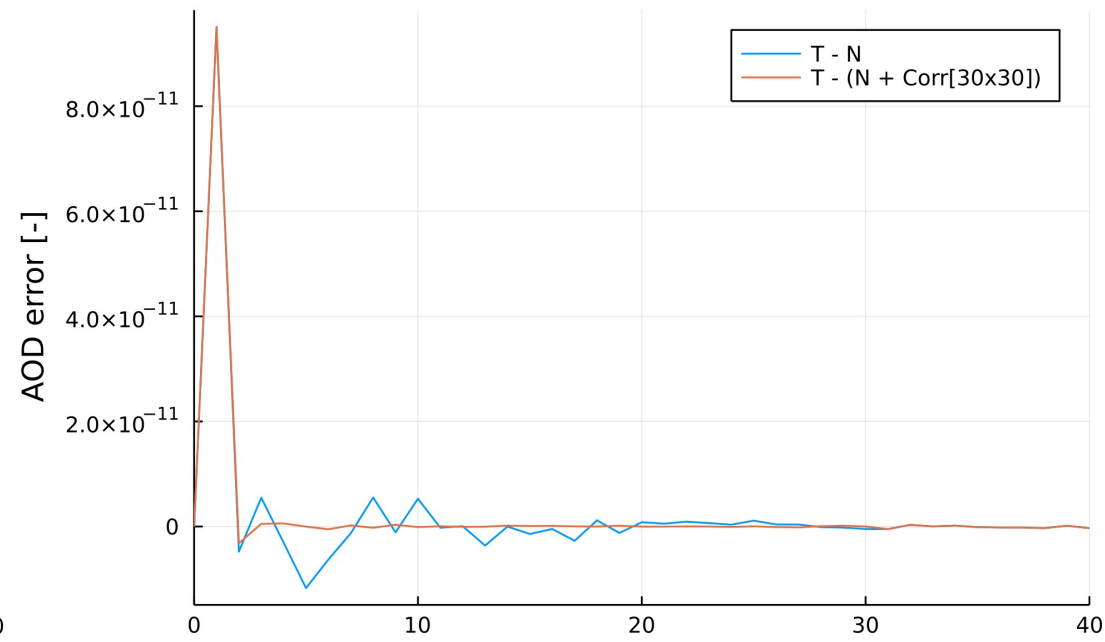
$$\Delta C = C_{Truth} - C_{Nominal} - C_{Corr}$$

$$\Delta S = S_{Truth} - S_{Nominal} - S_{Corr}$$

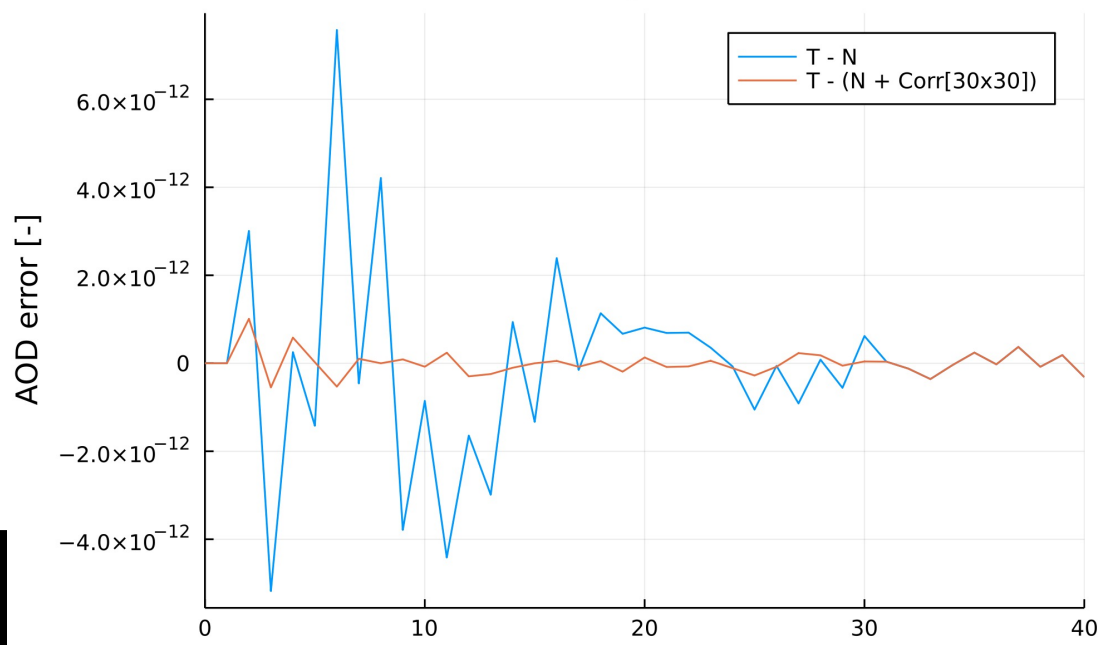
13 day mean



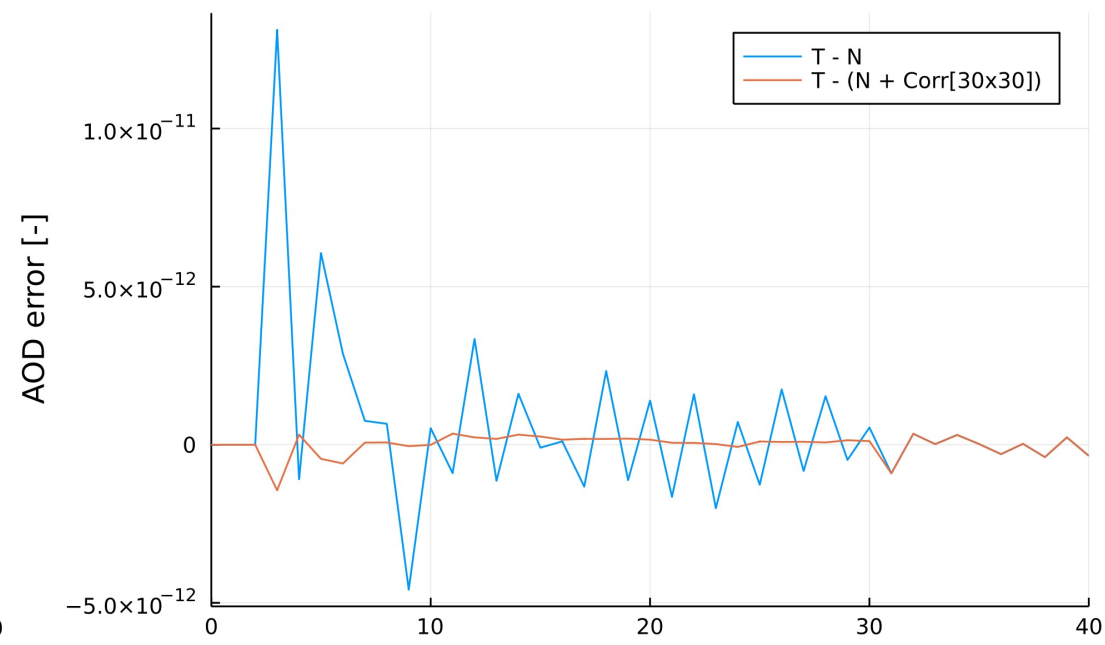
13 day mean



13 day mean



13 day mean



# Conclusions

- This objective function for a GA based search algorithm provides a very fast analysis of the search space.
- The resulting constellations are optimized for uniform spatial and temporal coverage.
- 6 satellite pairs are needed to estimate 1-day gravity models of d/o 30.
- Including daily corrections significantly improves the gravity retrieval performance for longer periods of time.
- Further details will be available in an upcoming journal publication.
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