
Precise Orbit Determination of the GIOVE Satellites

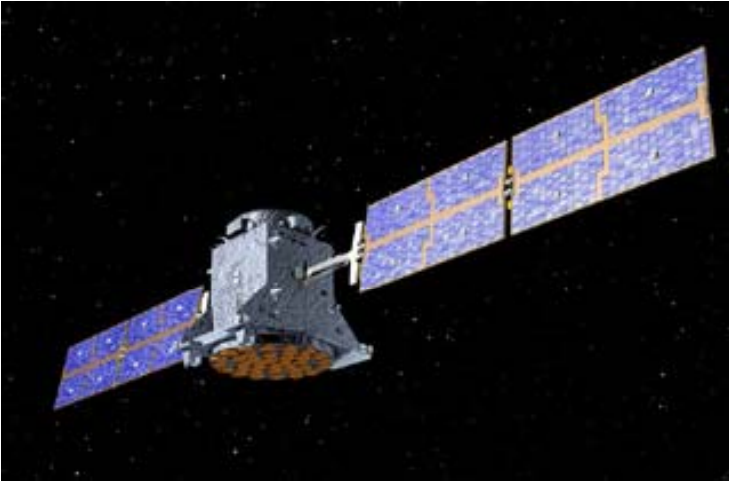


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Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen

Introduction



GIOVE-A, launch: 28 Dec. 2005



GIOVE-B, launch: 27 Apr. 2008

Galileo In Orbit Validation Element

Test satellites for the future
European GNSS Galileo

Outline

1. Orbit modeling
2. GIOVE POD at TUM
3. Precision and accuracy of orbits
4. Impact of clock modeling on orbits

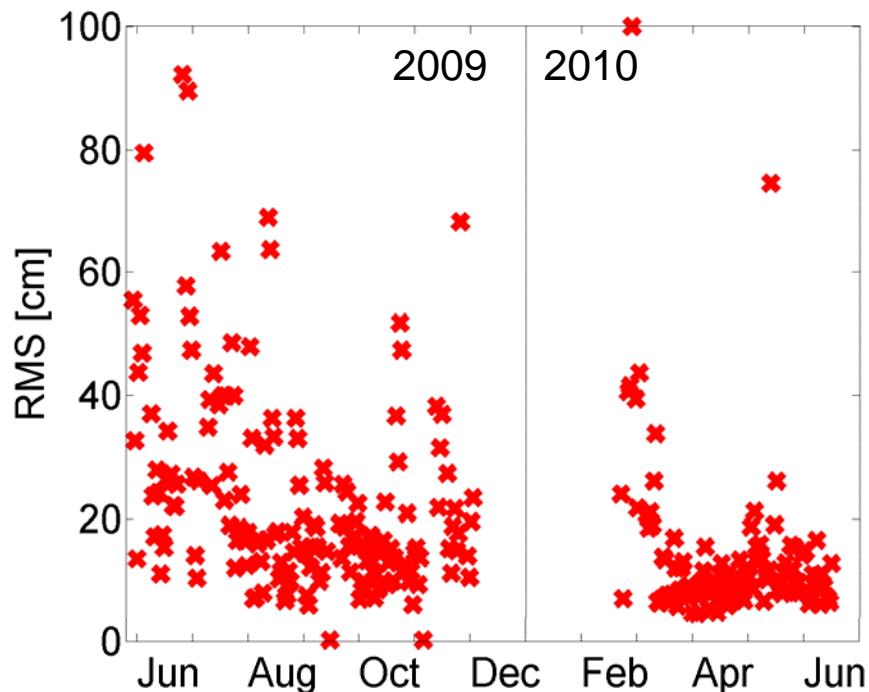
COoperative Network for GIOVE Observation



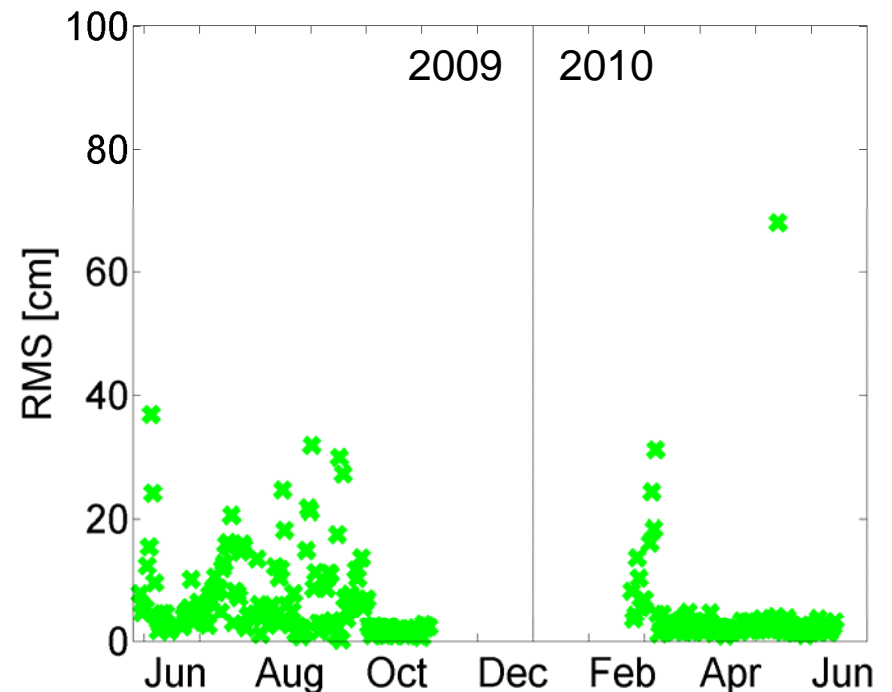
GIOVE Orbit Modeling

- 1-day orbit arcs unstable due to small number of tracking stations
- Long-arc solutions: 3 to 9 days
- Estimation of 5 or 9 radiation pressure parameters

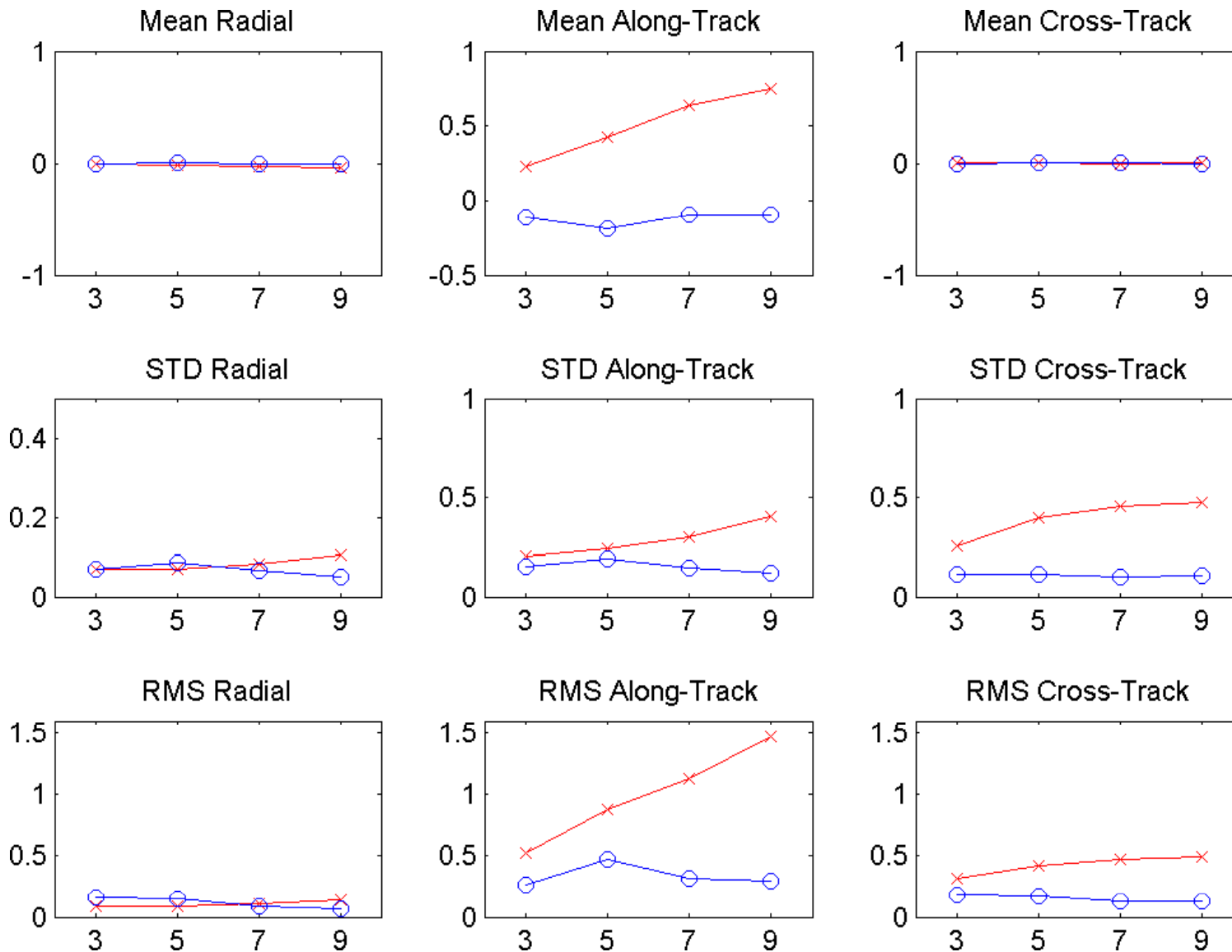
GIOVE-B orbit fits 1-day arcs



GIOVE-B orbit fits 5-day arcs



Orbit Differences Middle Day/Last Day



Mean/STD/RMS [m]

Orbit arc length

Number of RPR parameters:

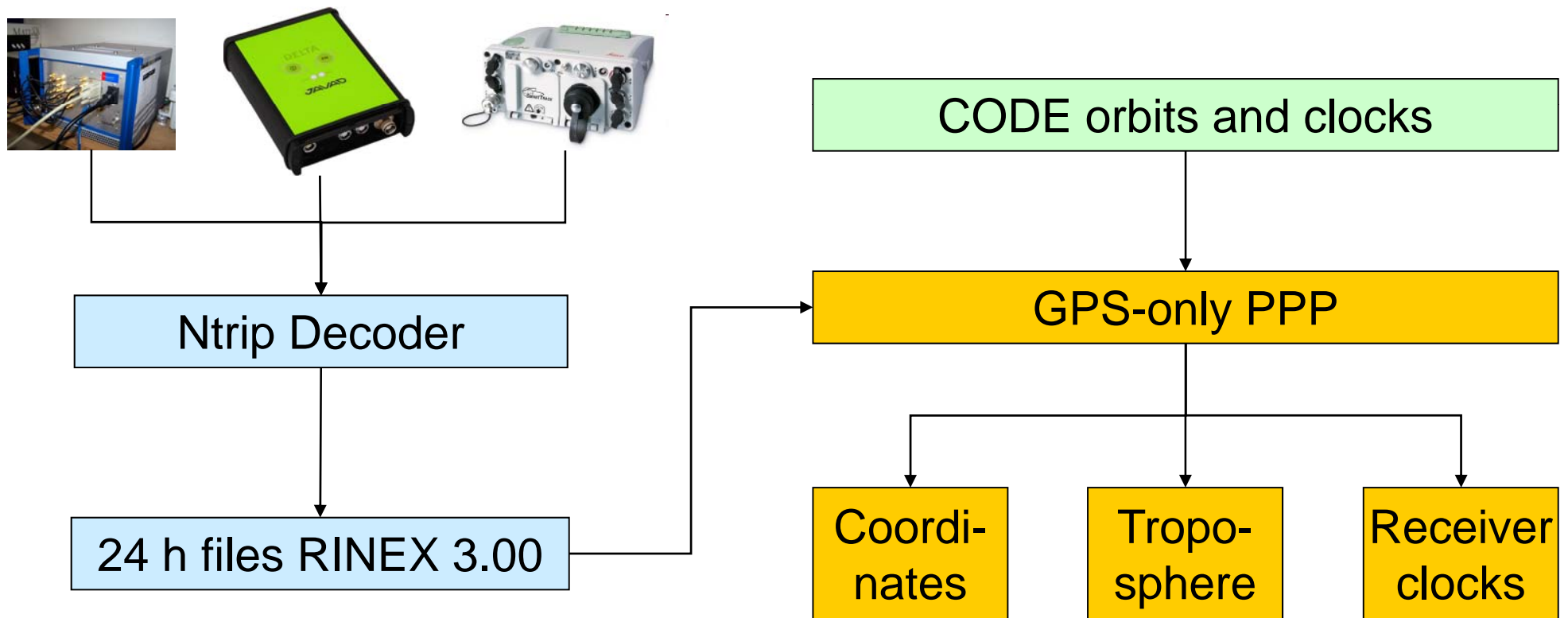
5 RPR

9 RPR

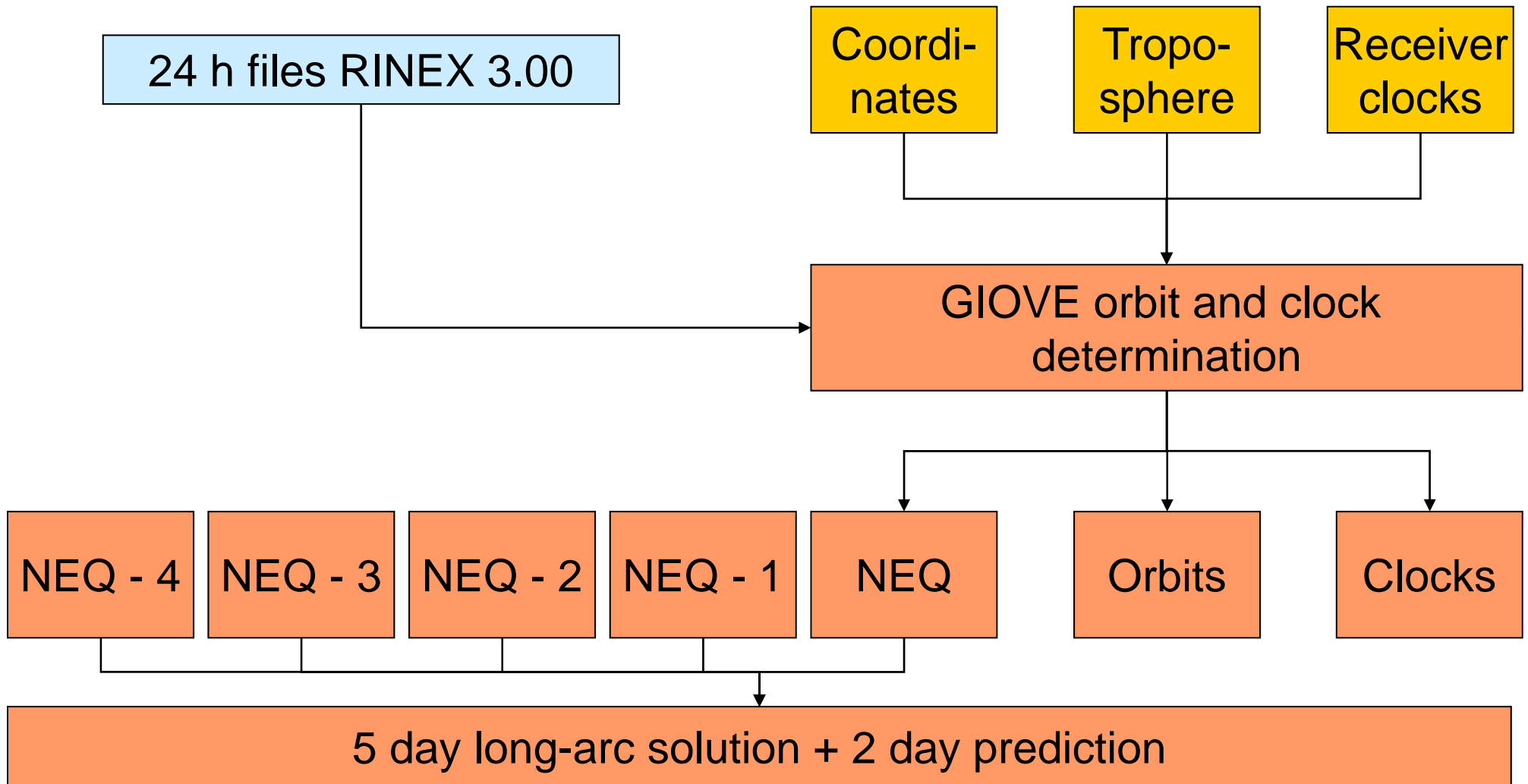
Operational Rapid Processing (1)

Modified Bernese GPS Software 5.0

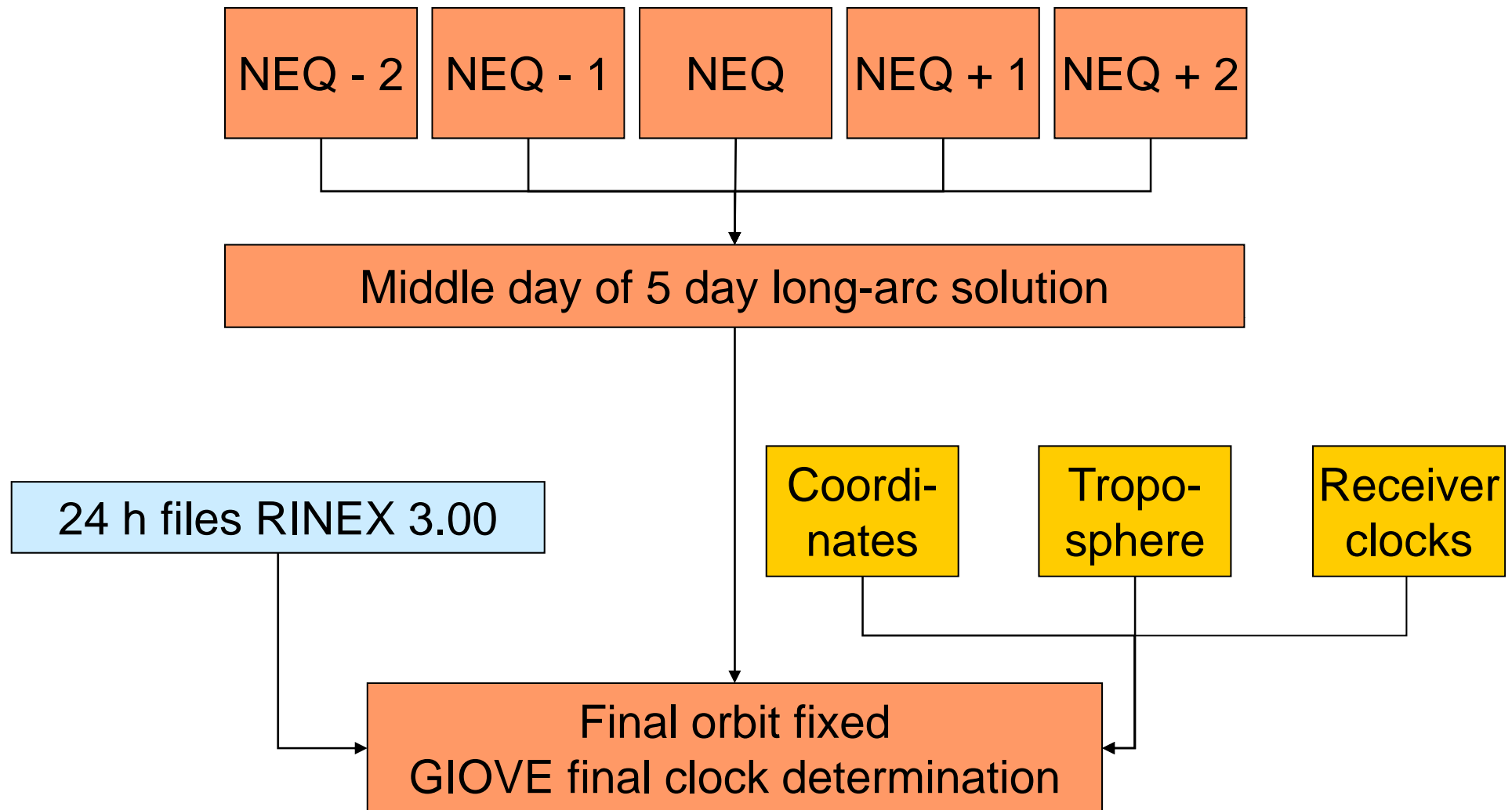
Ionosphere-free linear combination of L1/L2 (GPS) and E1/E5a (GIOVE)



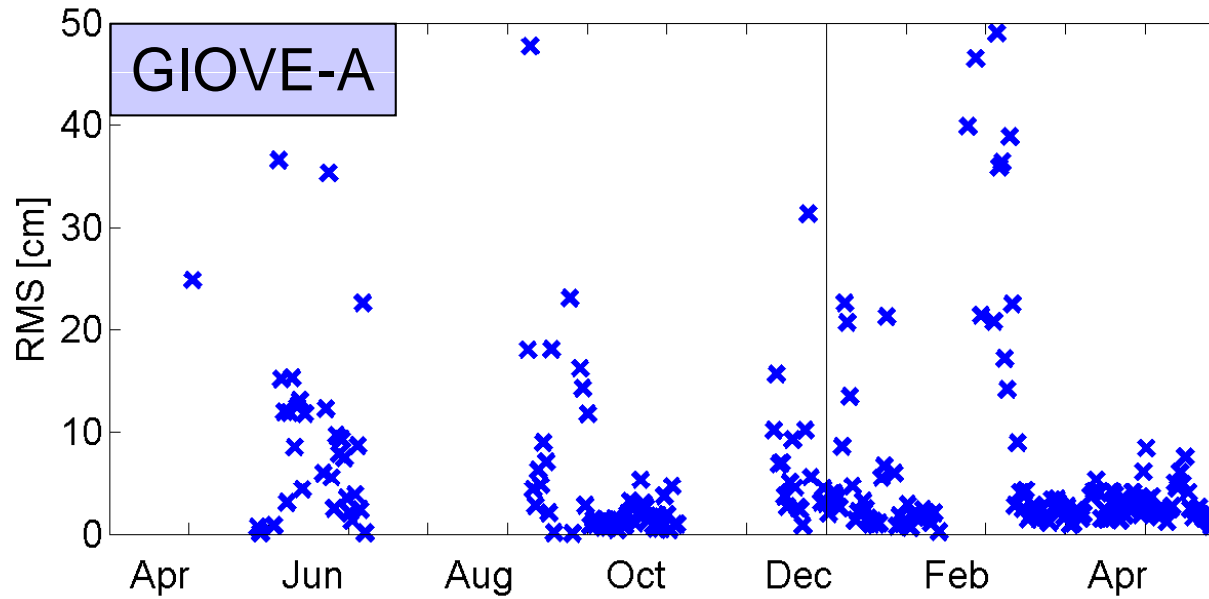
Operational Rapid Processing (2)



Operational Final Processing

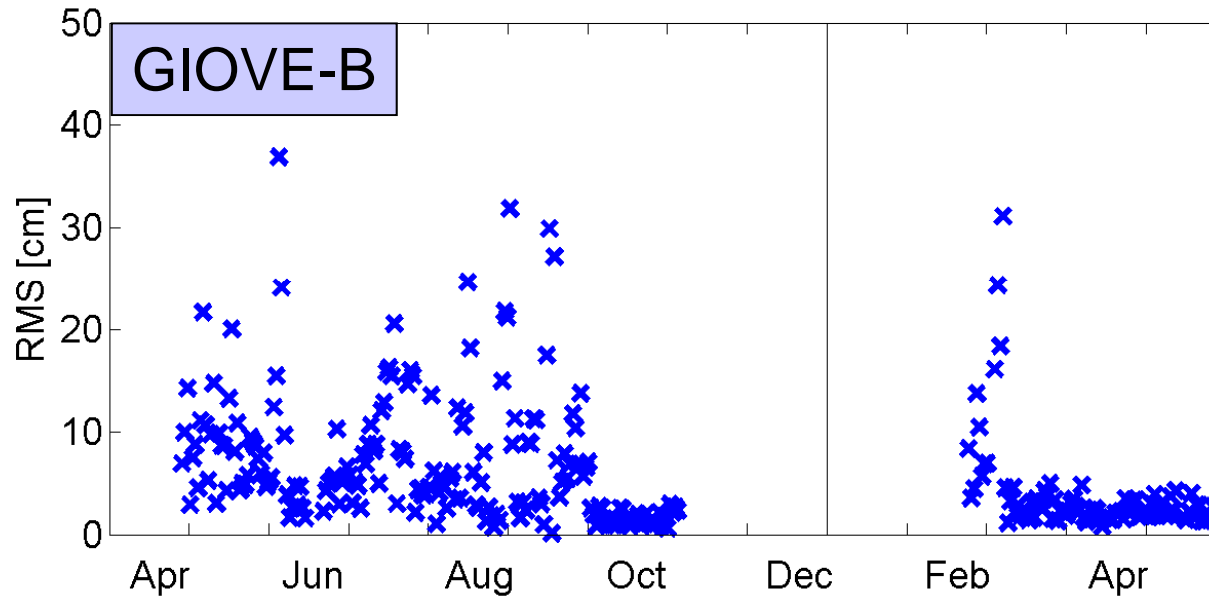


Internal Consistency: RMS of 2-day orbit fits



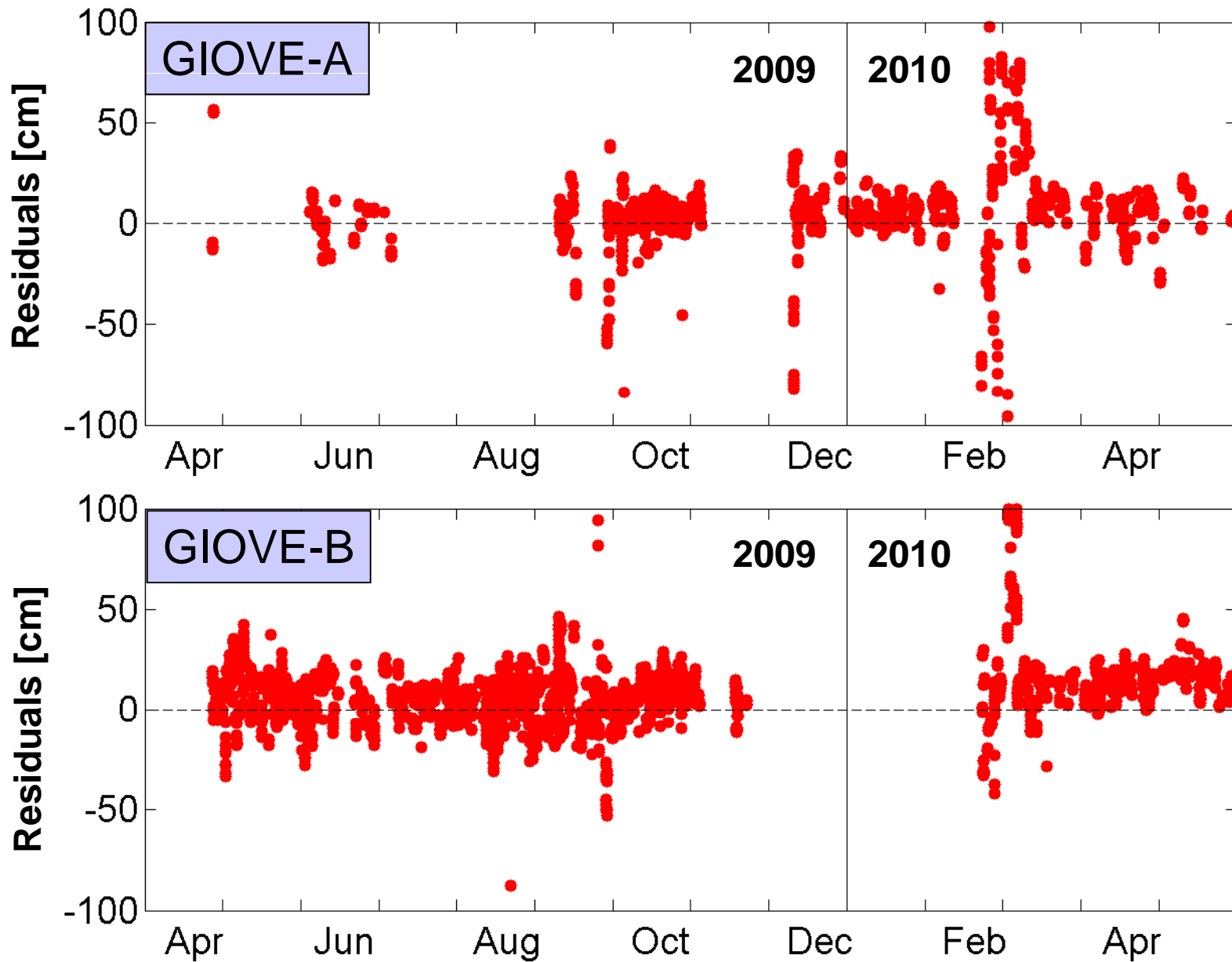
Median	2.8 cm
Mean	2.9 cm
April/May	2.9 cm

Middle days of 5-day arcs



Median	3.8 cm
Mean	2.3 cm
April/May	2.3 cm

SLR Orbit Residuals



Bias
4.3 cm

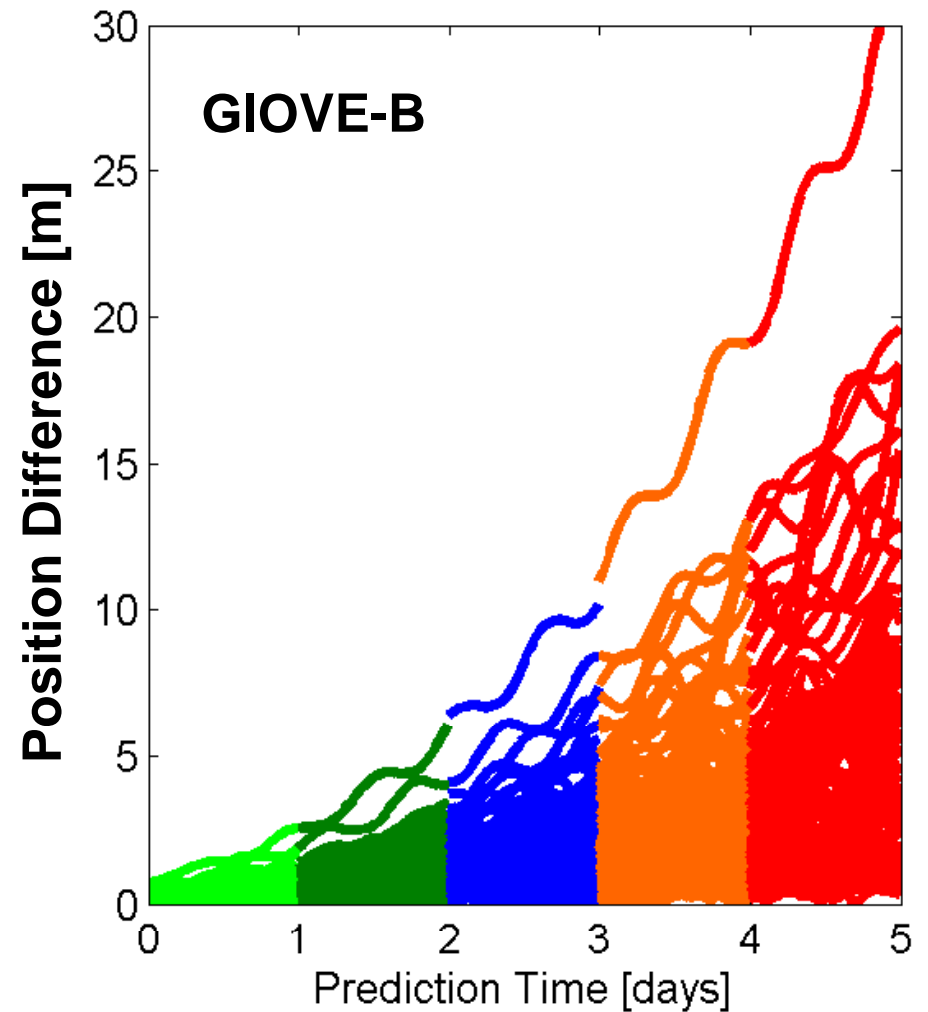
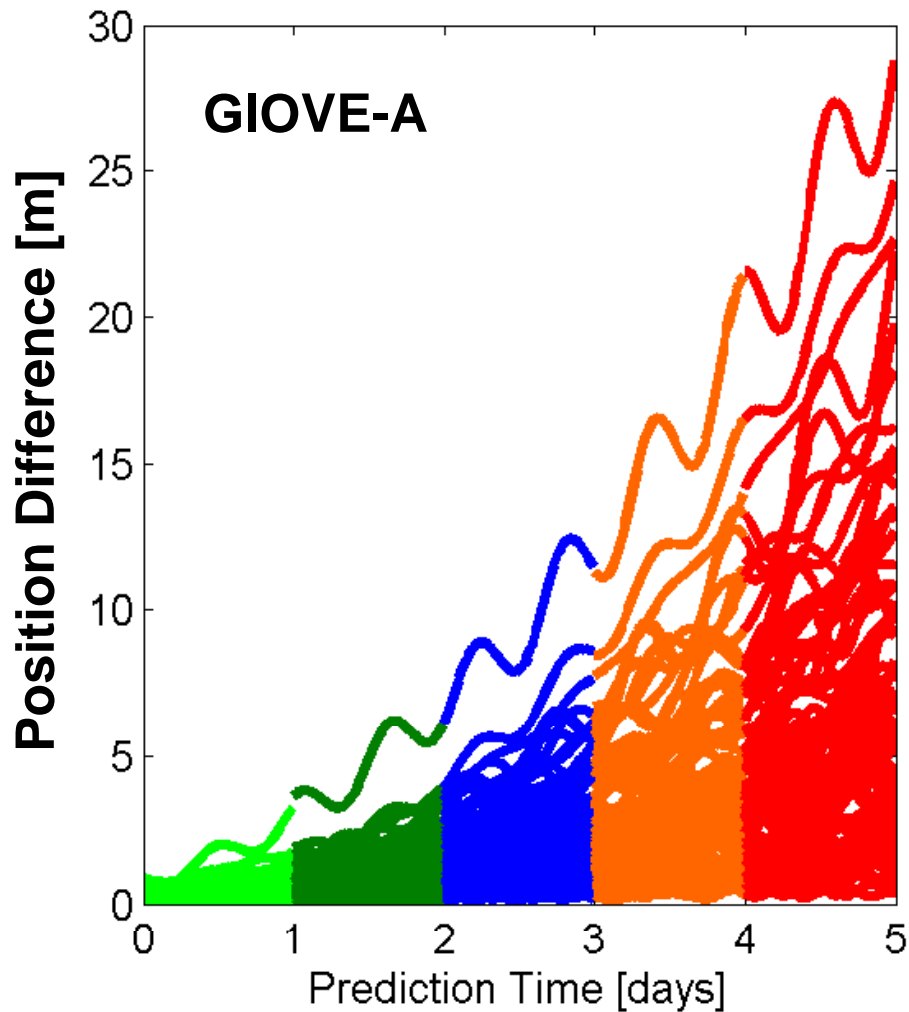
STD
11.4 cm

Bias
7.3 cm

STD
11.9 cm

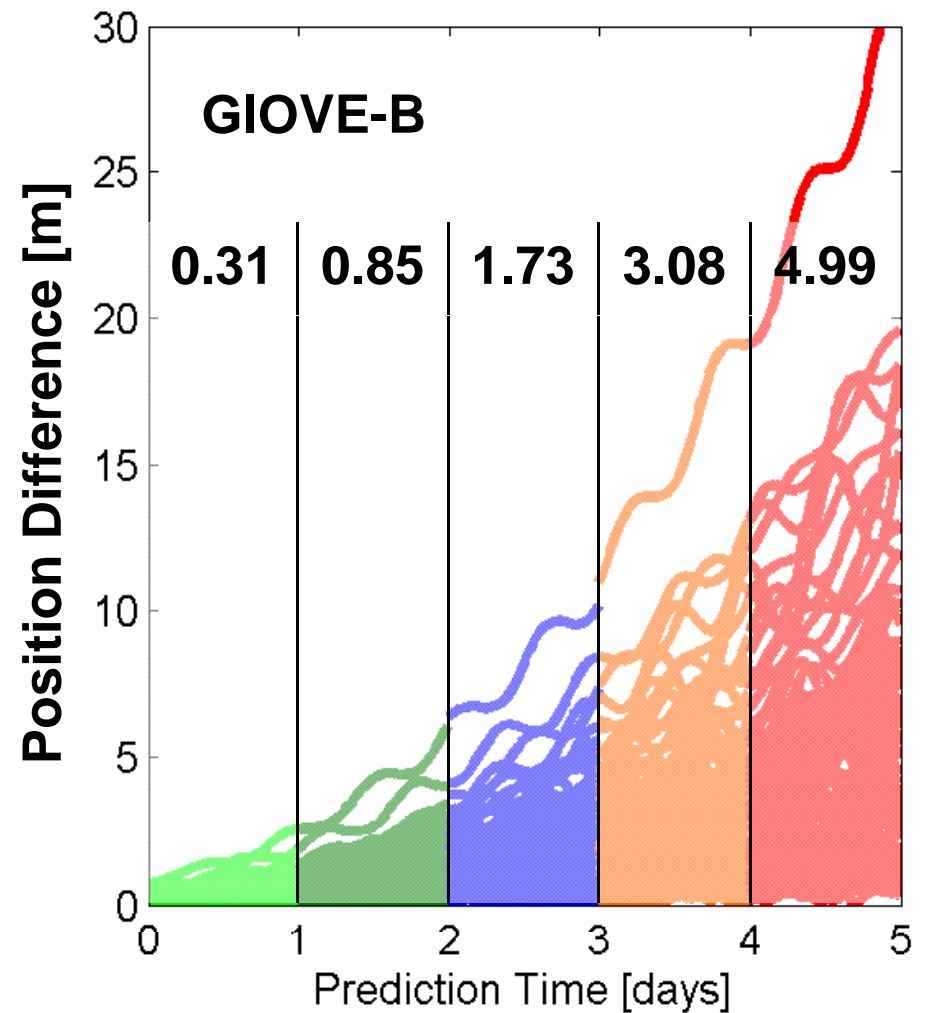
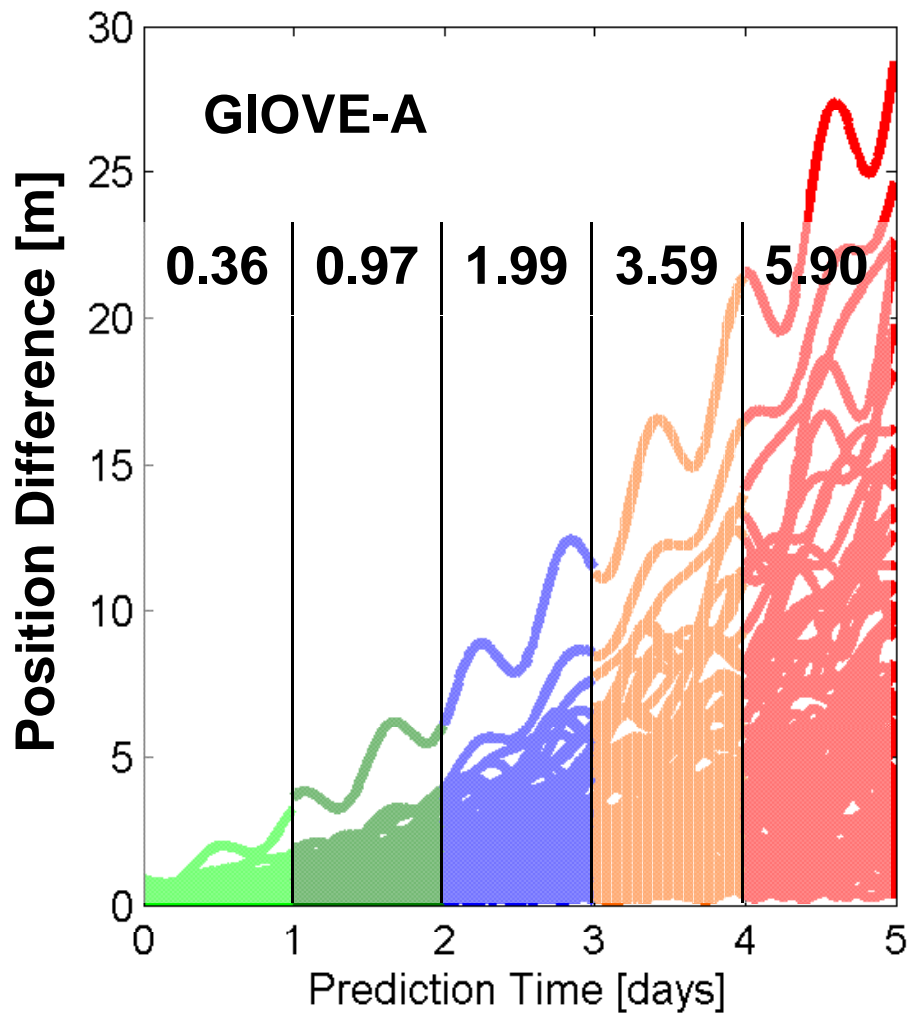
Orbit Predictions

Differences of predicted GIOVE orbits w.r.t. last observed day

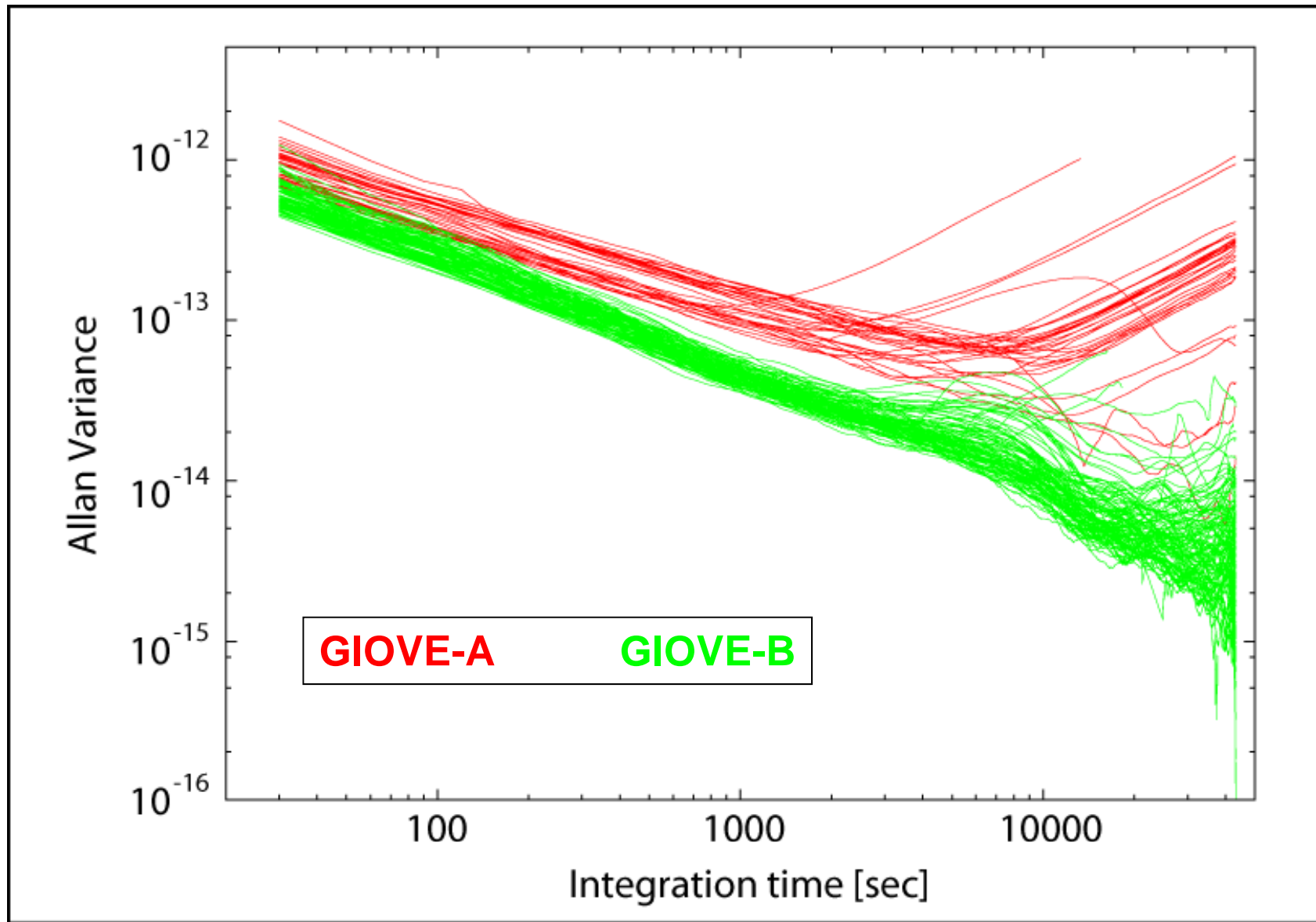


Orbit Predictions

Differences of predicted GIOVE orbits w.r.t. last observed day

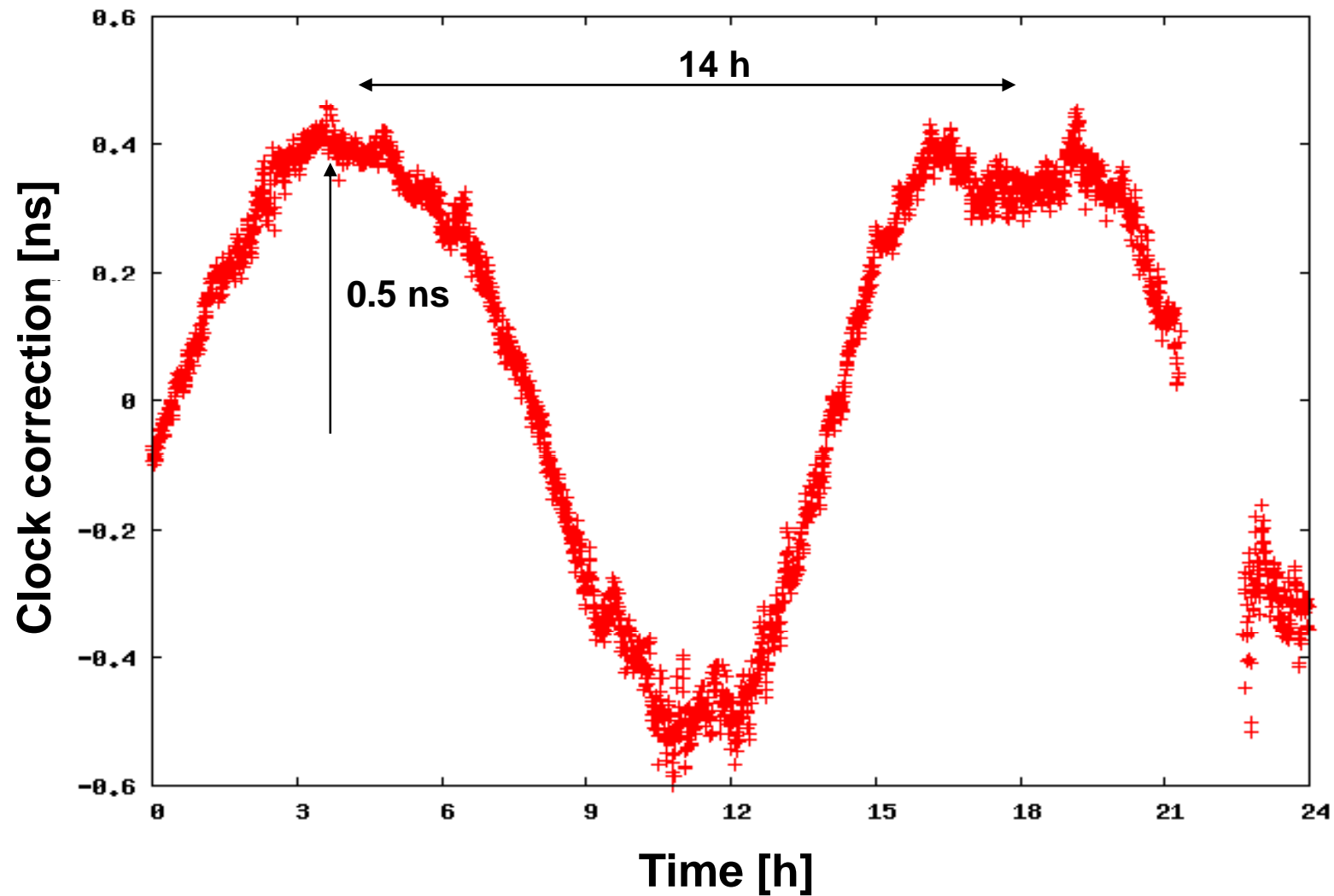


GIOVE-B Hydrogen Maser



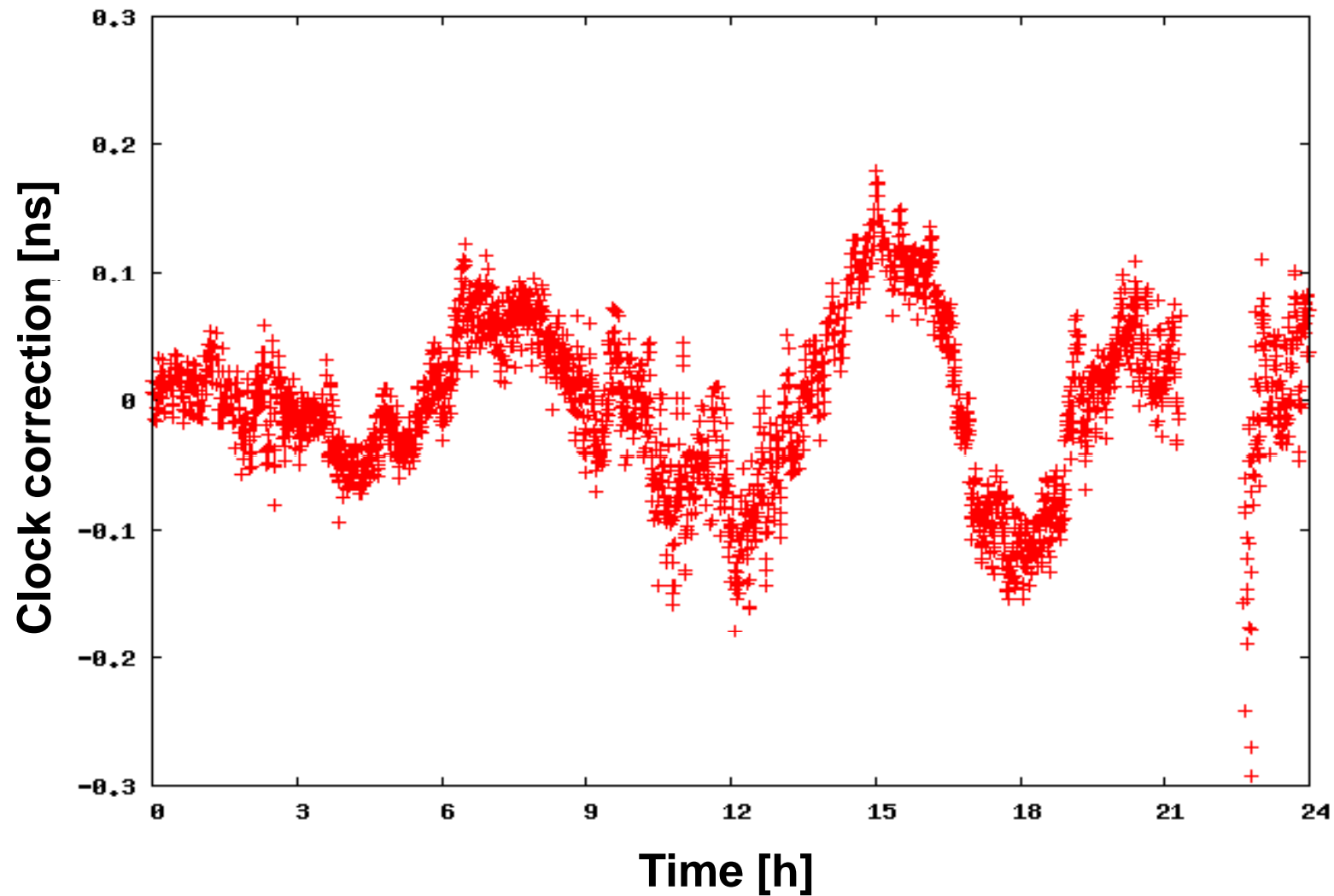
GIOVE-B Clock Estimates

Quadratic term and jumps removed



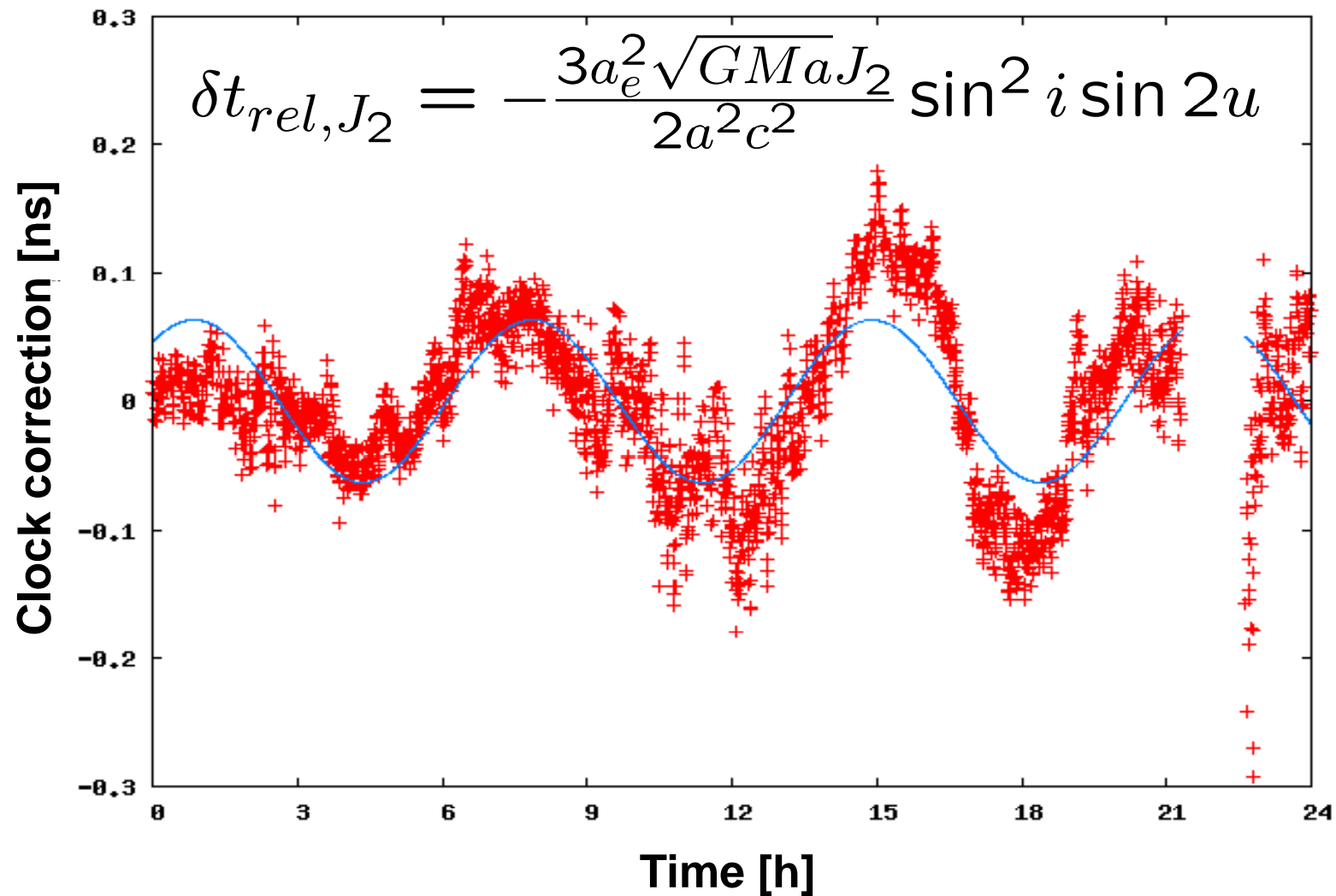
GIOVE-B Clock Estimation

Quadratic term, jumps und 1-per-rev removed



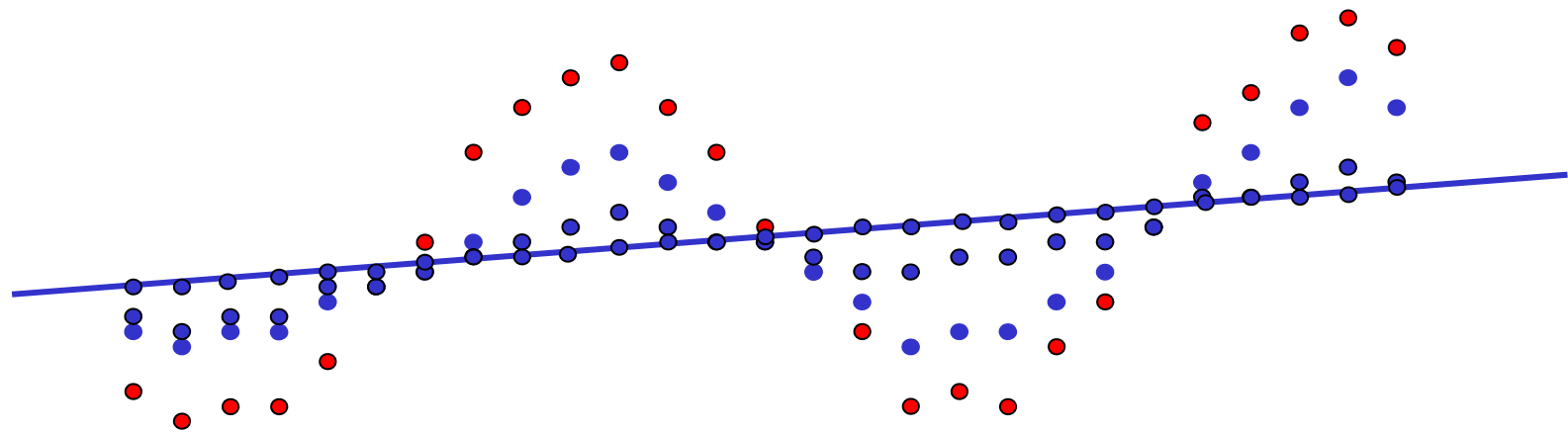
GIOVE-B Clock Estimation

Quadratic term, jumps und 1-per-rev removed



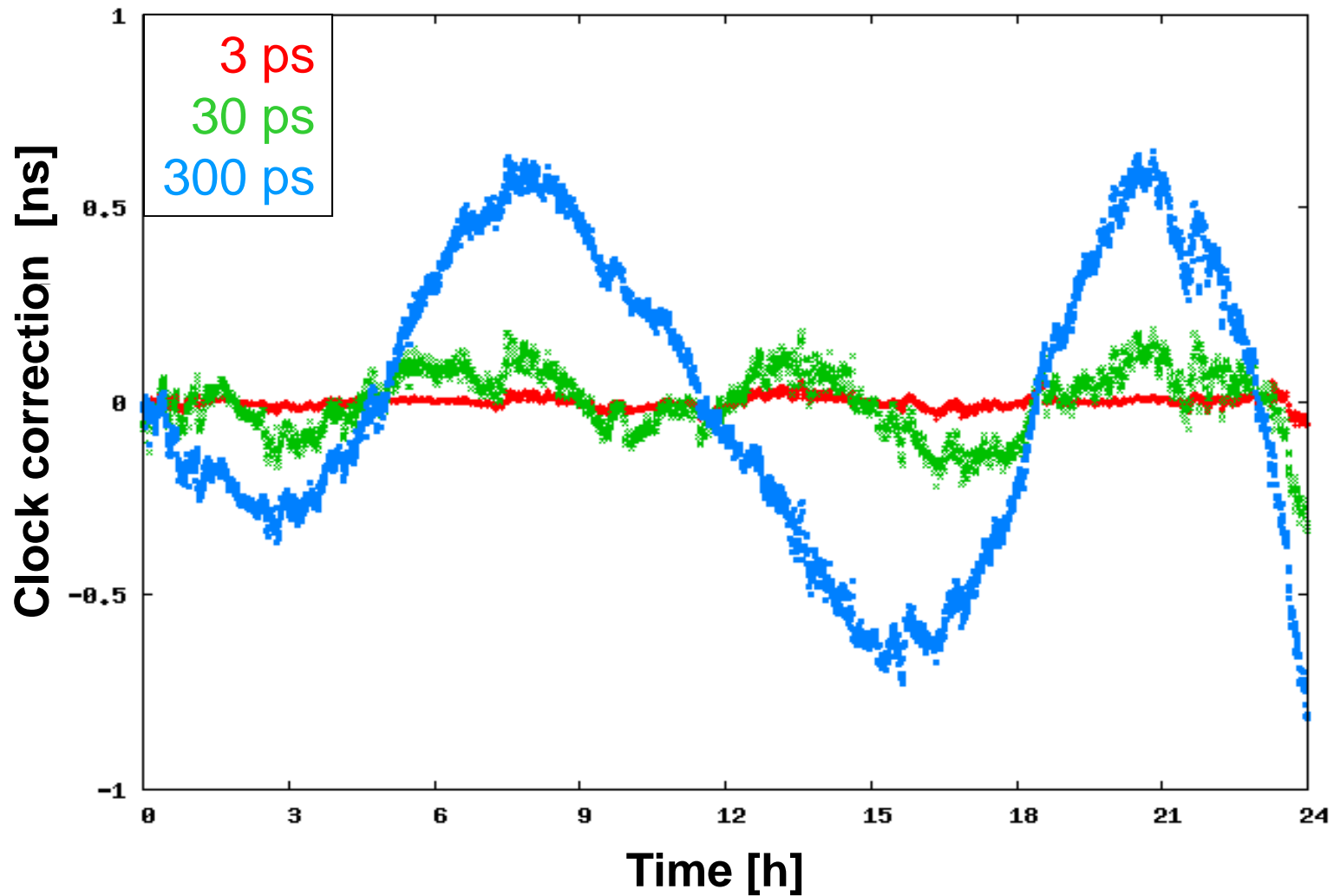
GIOVE-B Clock Modeling

- Estimated clock parameters:
 - offset and drift of a linear clock model for entire day
 - relativistic J2-correction modeled
 - epoch-wise clock corrections, constrained



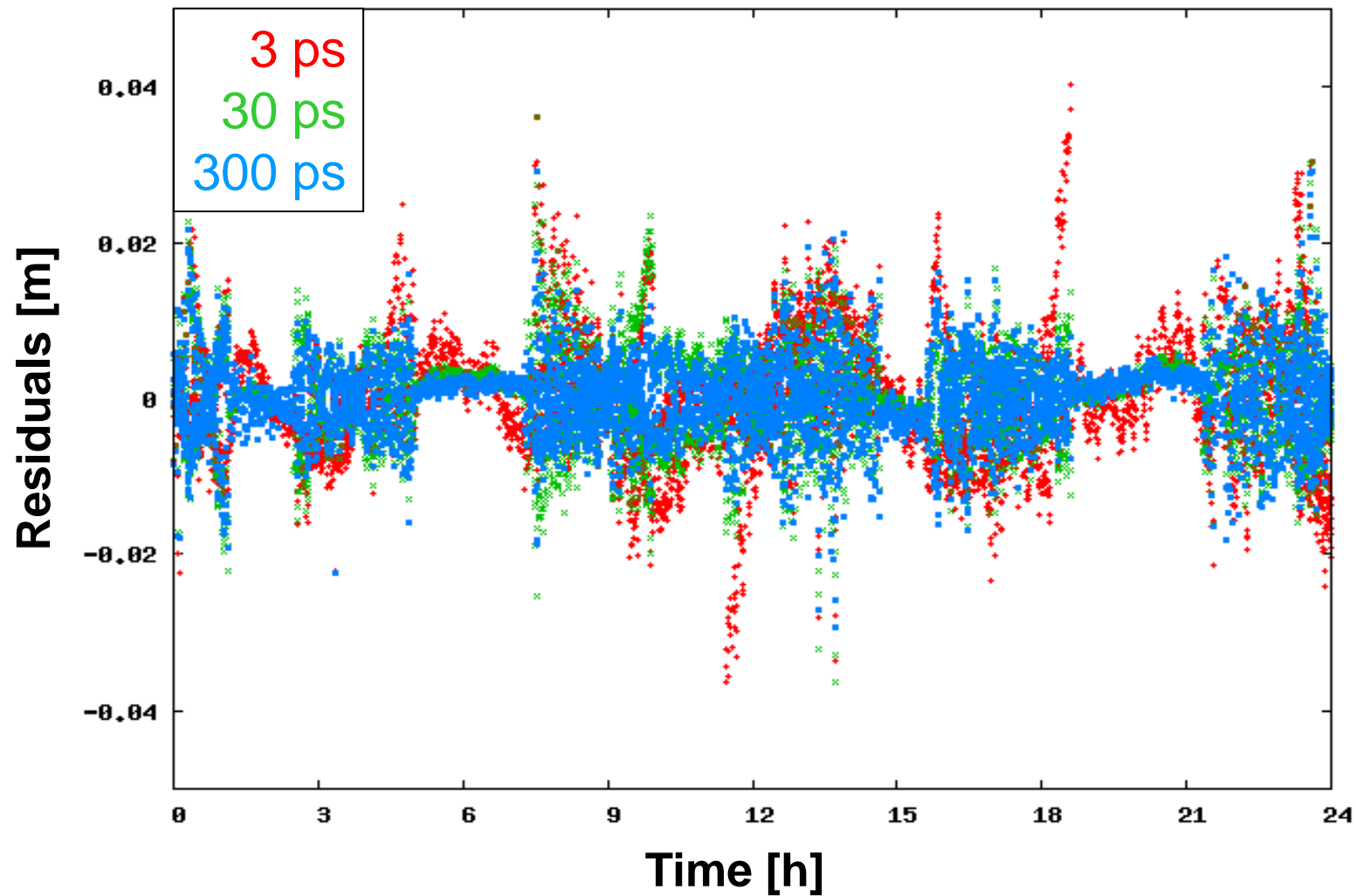
GIOVE-B Clock Modeling

Clock corrections for different clock constraints



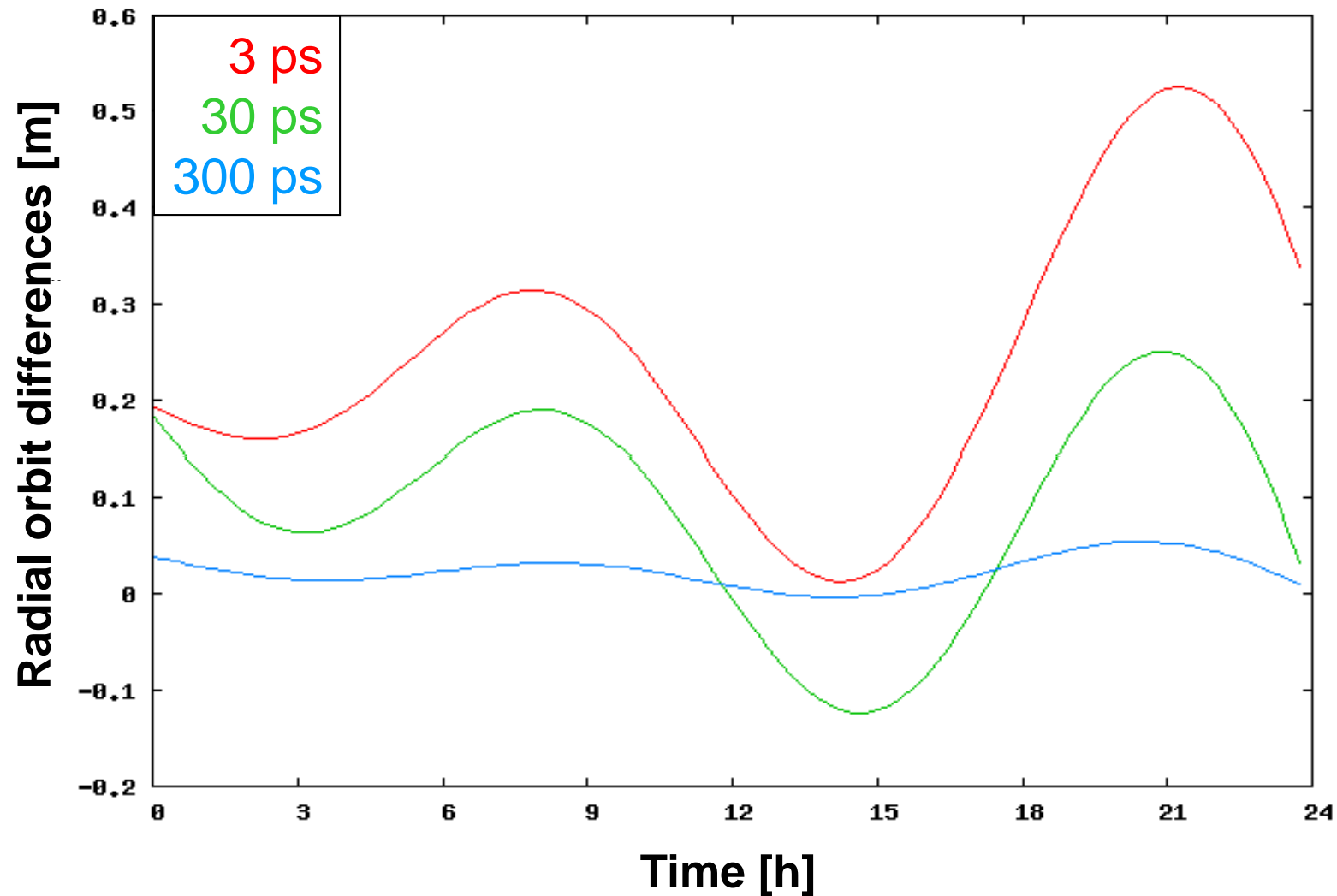
GIOVE-B Clock Modeling: Residuals

Phase residuals for different clock constraints



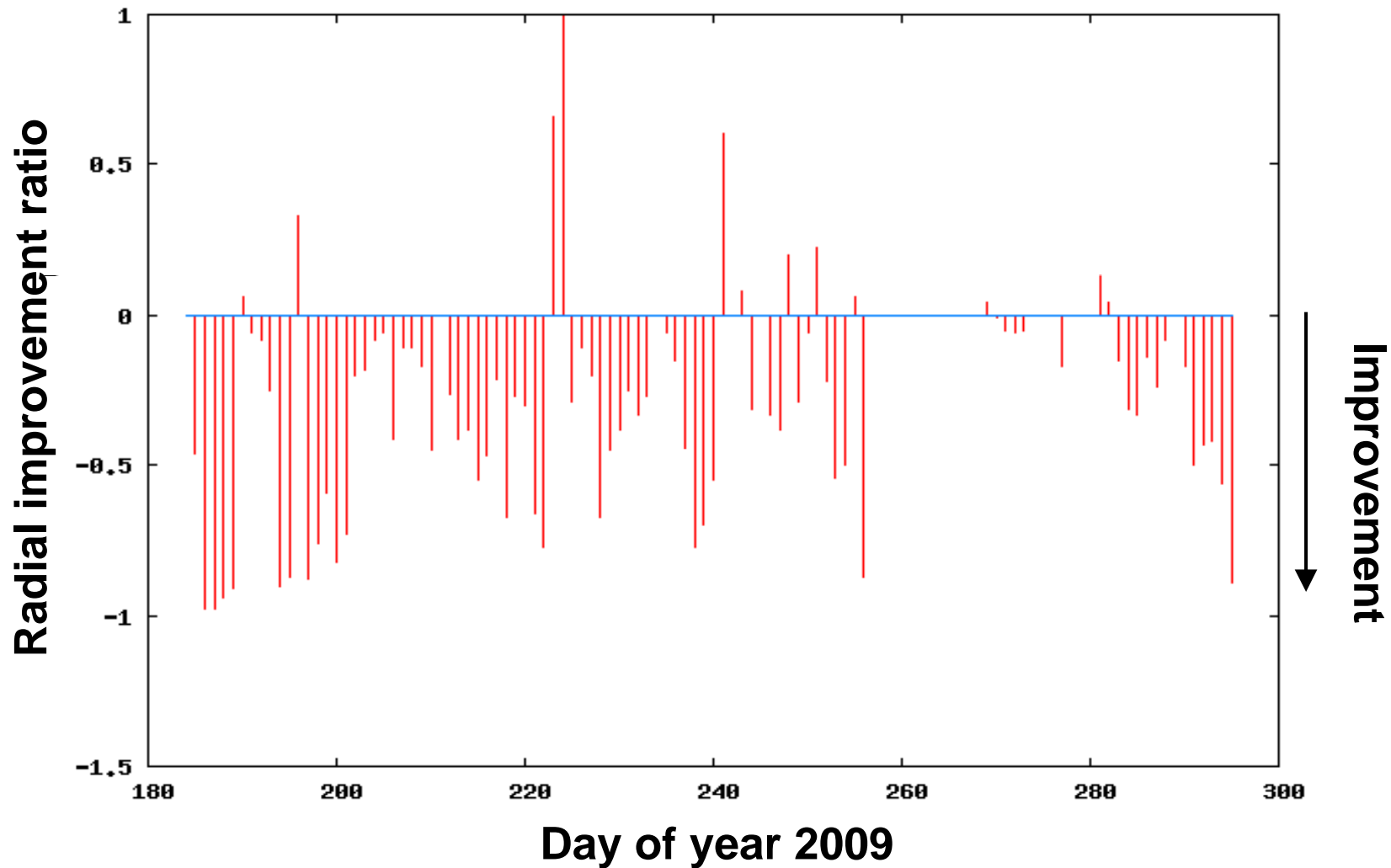
GIOVE-B Clock Modeling: Orbit Differences

Differences with and without clock modeling



GIOVE-B Clock Modeling: Orbit Quality

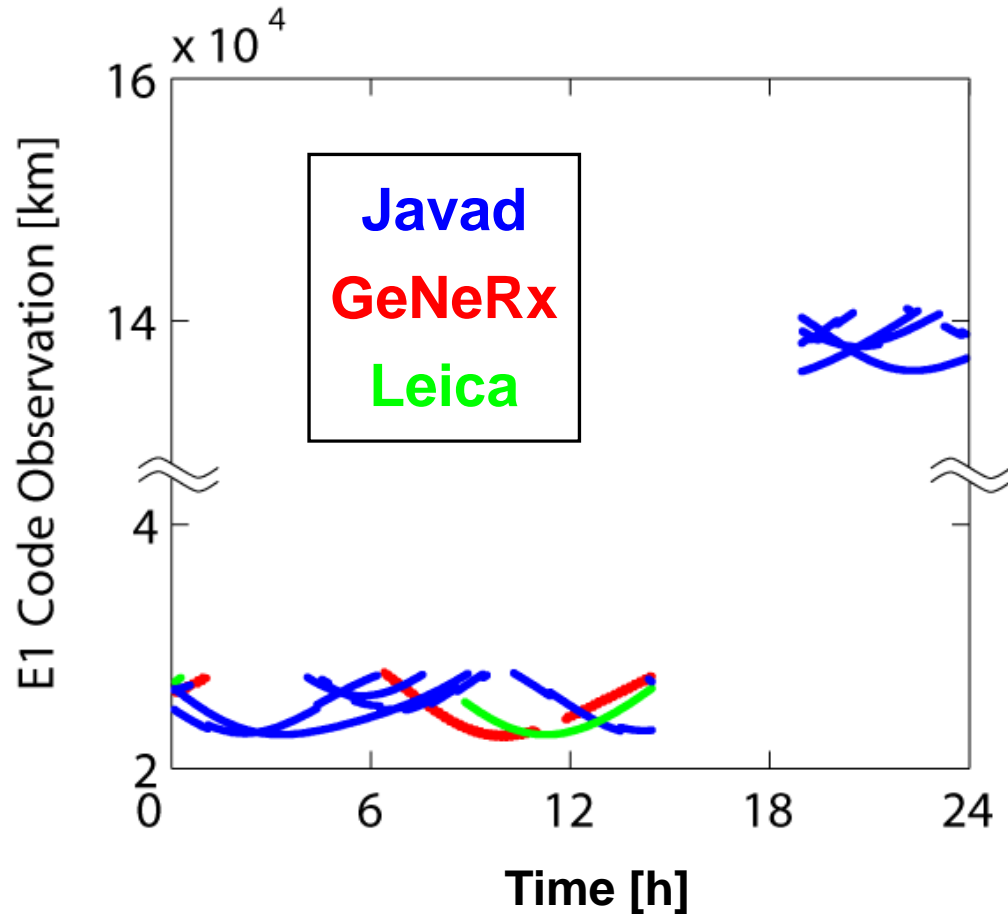
Improvement ratio orbit fits with and without clock modeling



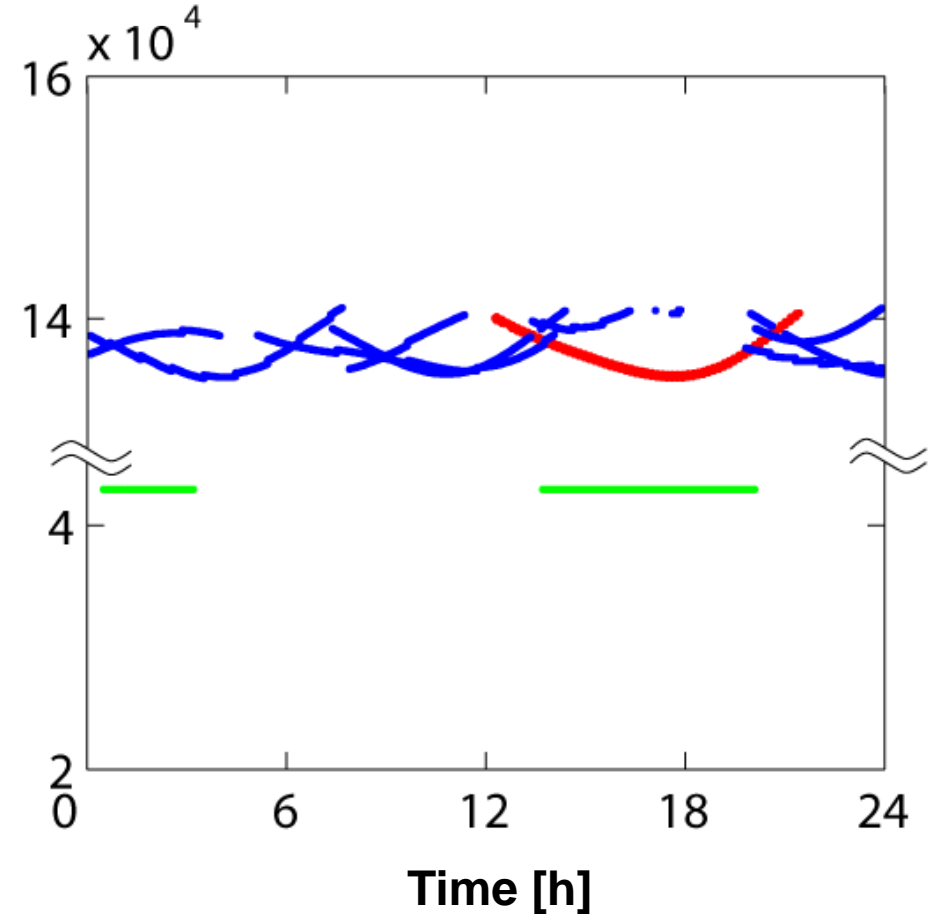
GIOVE-A Maneuver 23 June 2010

Interrupted transmission during maneuver, clock synchronization

23 June



24 June



Summary and Conclusions

- The **CONGO network** allows for **GIOVE orbit determination** with **decimeter accuracy** and **meter level predictions**
- Orbit accuracy is limited by the **small number of stations**
- **Clock modeling** can improve the orbit quality

- **RINEX 3.00** is **mandatory** for processing GIOVE/Galileo data
- Installation of **Galileo-capable** antennas and receivers **next to IGS stations** before launch of the IOV satellites desirable
- **Parallel operation** for reasonable time span (reference frame stability)
- Satellite antenna offsets and phase center variations for different ionosphere-free linear combinations (E1/E5a, E1/E5b, E1/E5, E1/E6)

Estimated Radiation Pressure Parameters

$$\mathbf{a}_{RPR} = D(u) \cdot \mathbf{e}_D + Y(u) \cdot \mathbf{e}_Y + X(u) \cdot \mathbf{e}_X$$

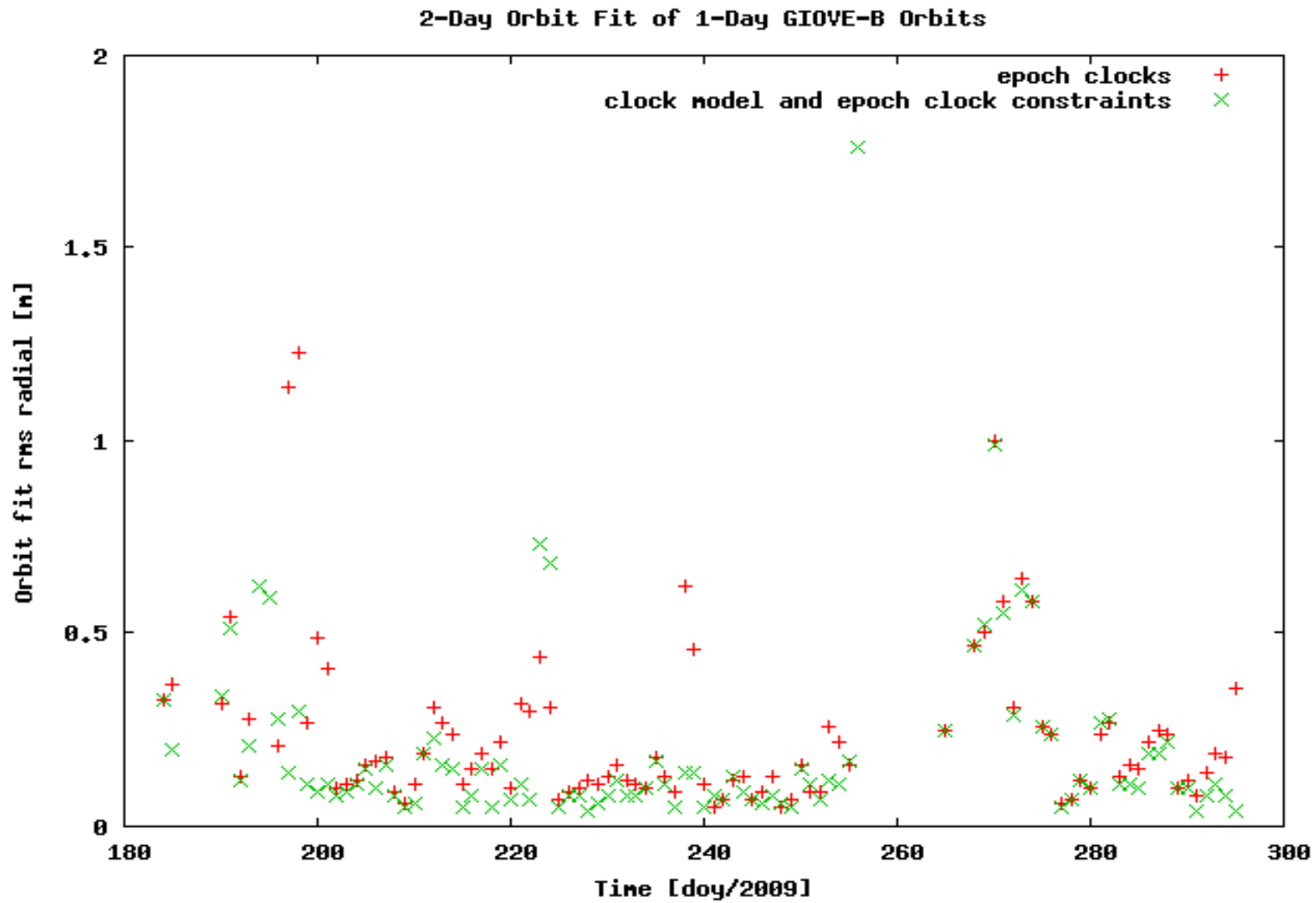
$$D(u) = D_0 + D_C \cdot \cos u + D_S \cdot \sin u$$

$$Y(u) = Y_0 + Y_C \cdot \cos u + Y_S \cdot \sin u$$

$$X(u) = X_0 + X_C \cdot \cos u + X_S \cdot \sin u$$

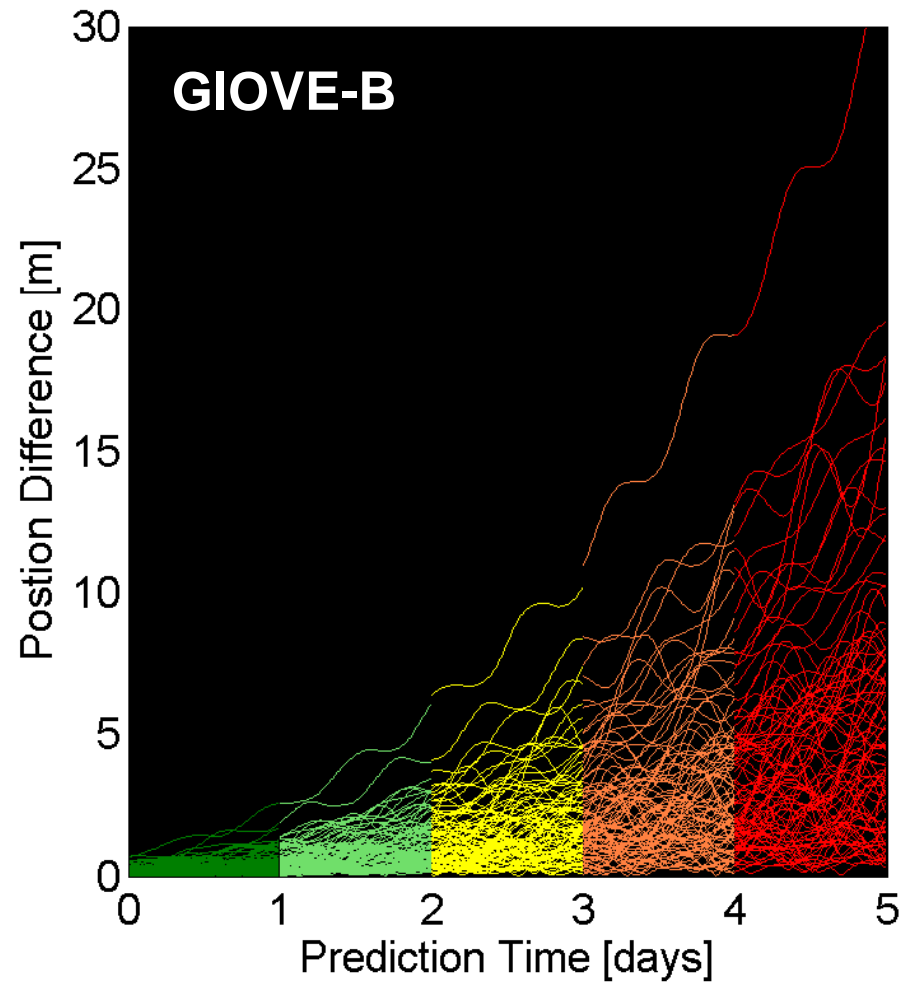
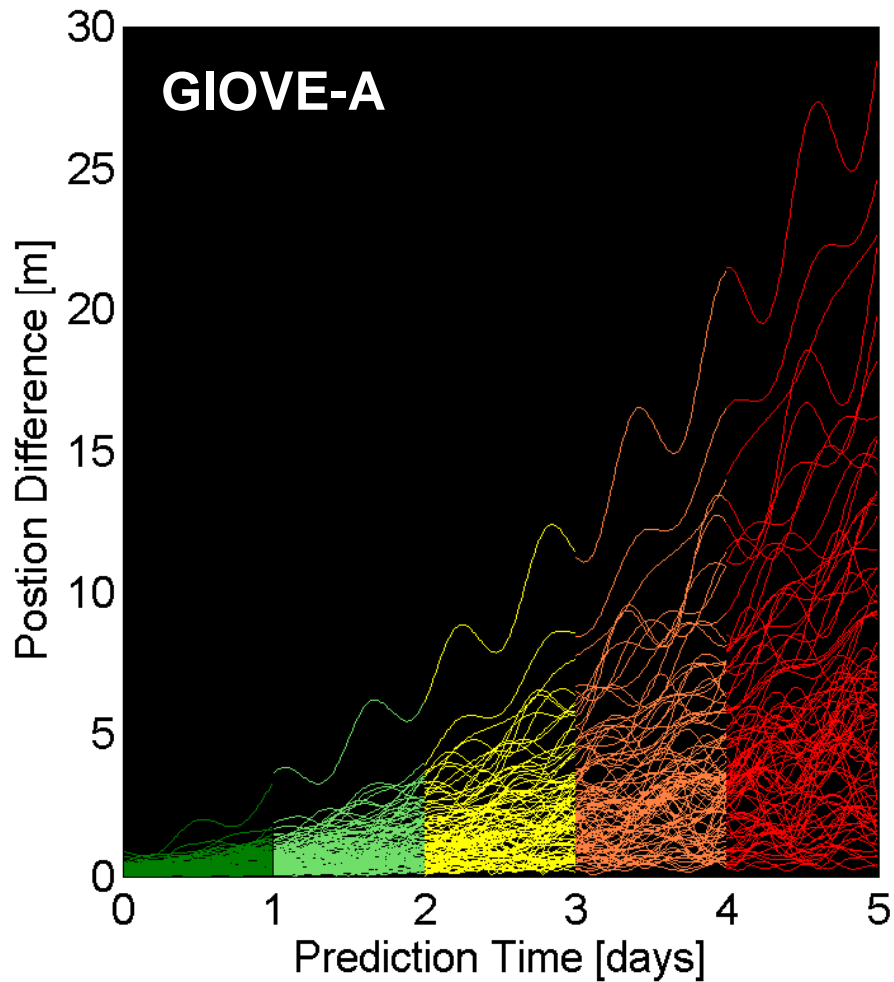
u	Argument of latitude
e_D	Unit vector Sun-satellite
e_Y	Unit vector along the solar panel axis
e_X	$e_Y \times e_D$
$D(u), Y(u), X(u)$	Accelerations due to radiation pressure in the directions e_D, e_Y und e_X

GIOVE-B Clock Modeling: Orbit Quality



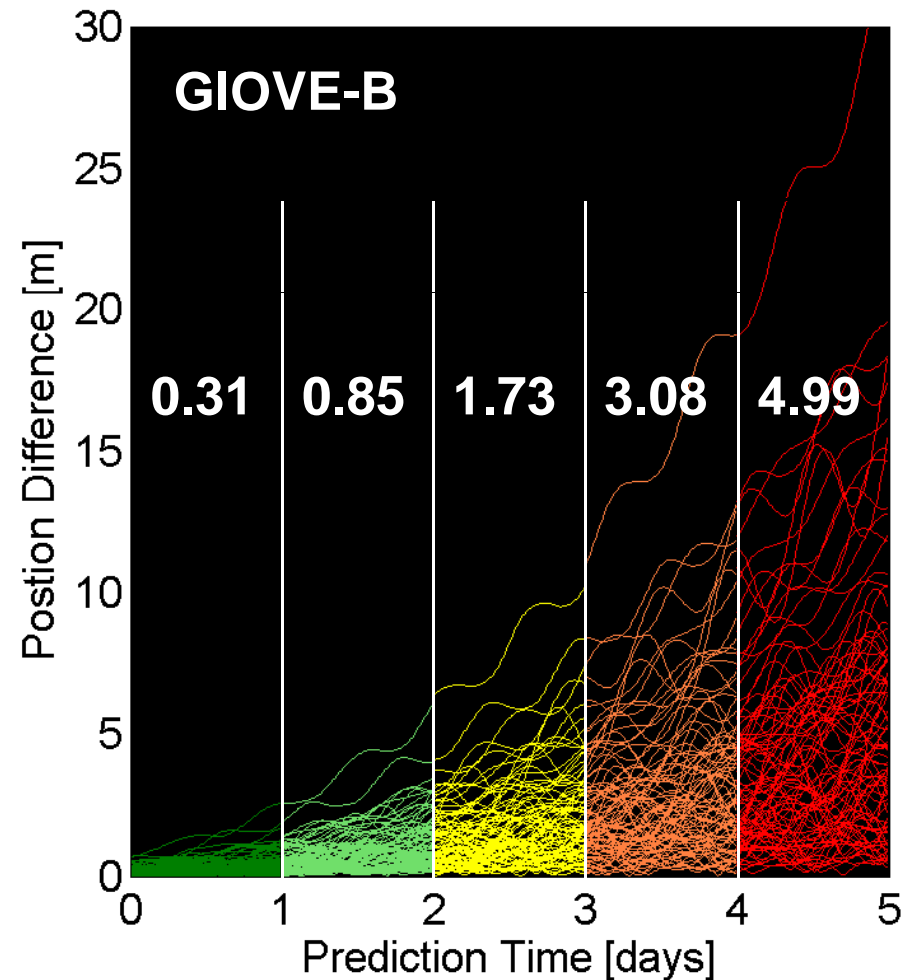
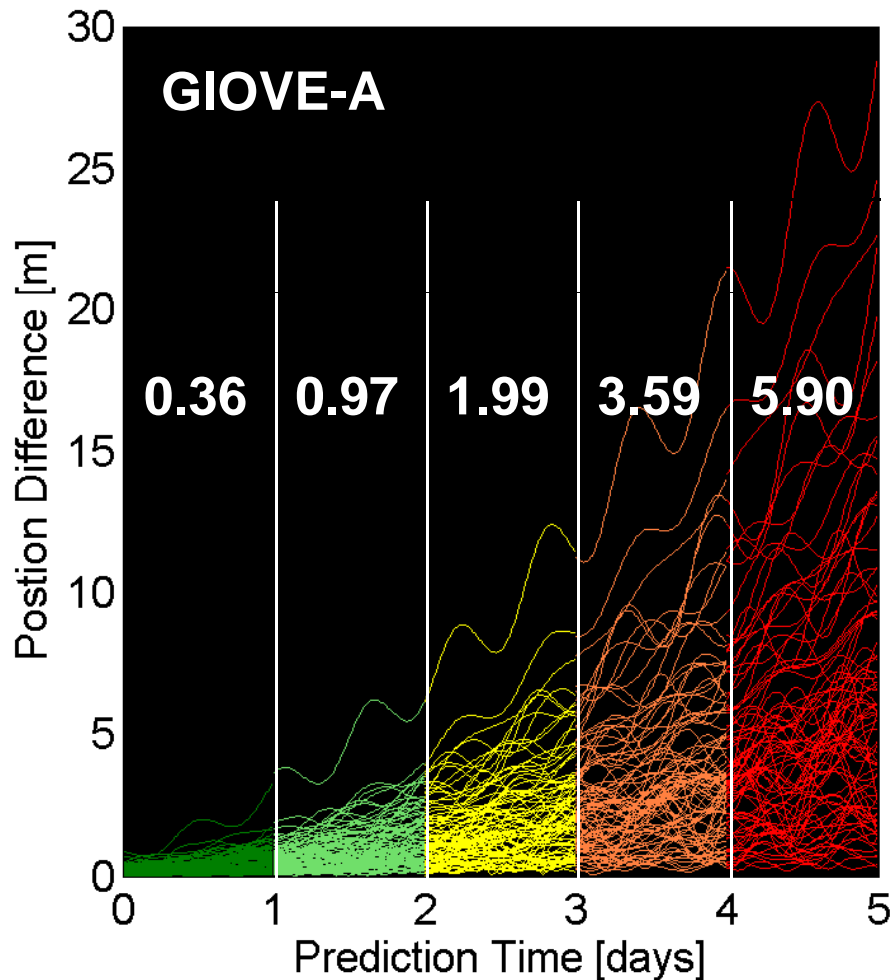
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