

# Calibrating GNSS orbits with SLR tracking data

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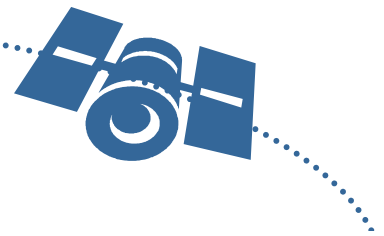
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## Contribution of SLR tracking data to GNSS orbit determination

- Completely independent validation of microwave-based GNSS orbits

Inter-technique biases?

→ SLR range residual analysis

- Combined analysis of microwave + SLR data for GNSS orbit determination

Orbit improvement?

→ A priori covariance analysis

# GNSS orbit validation

SLR range residuals =

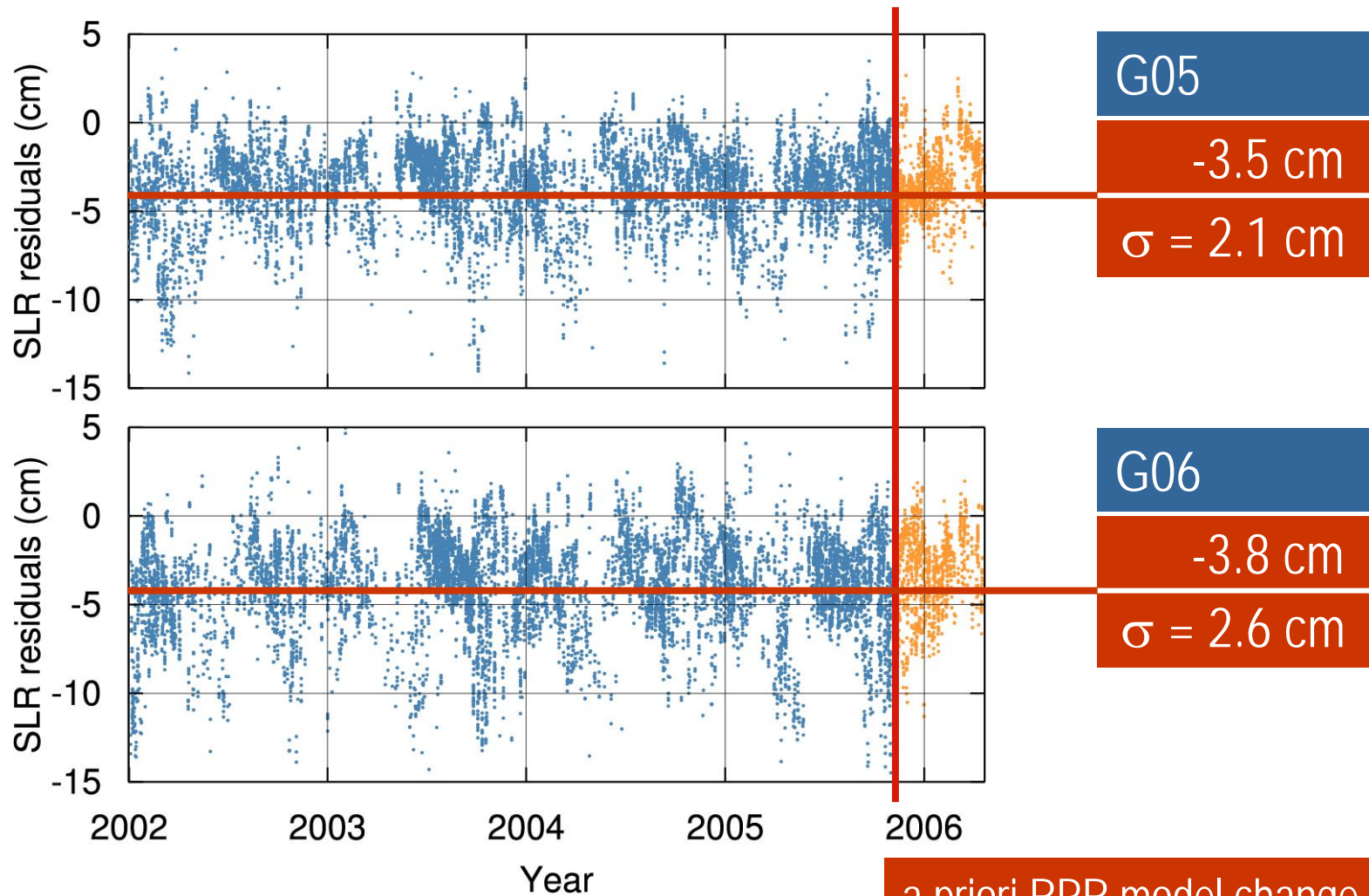
observed ranges (SLR) – computed ranges  
(relying on orbital information derived from  
microwave data)

GNSS satellites with Laser retroreflectors

- 2 GPS
- all GLONASS

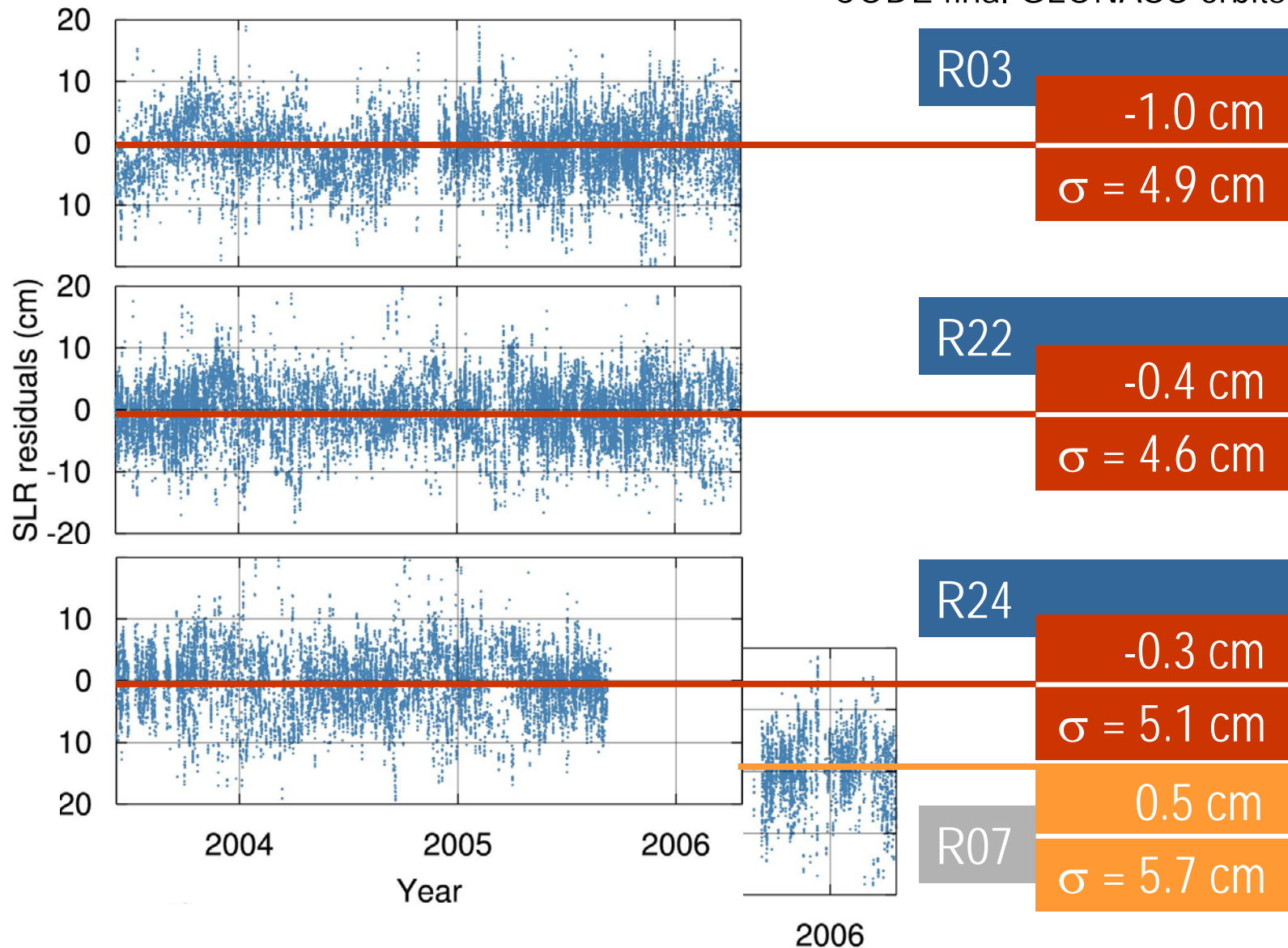
# SLR range residuals

CODE final GPS orbits



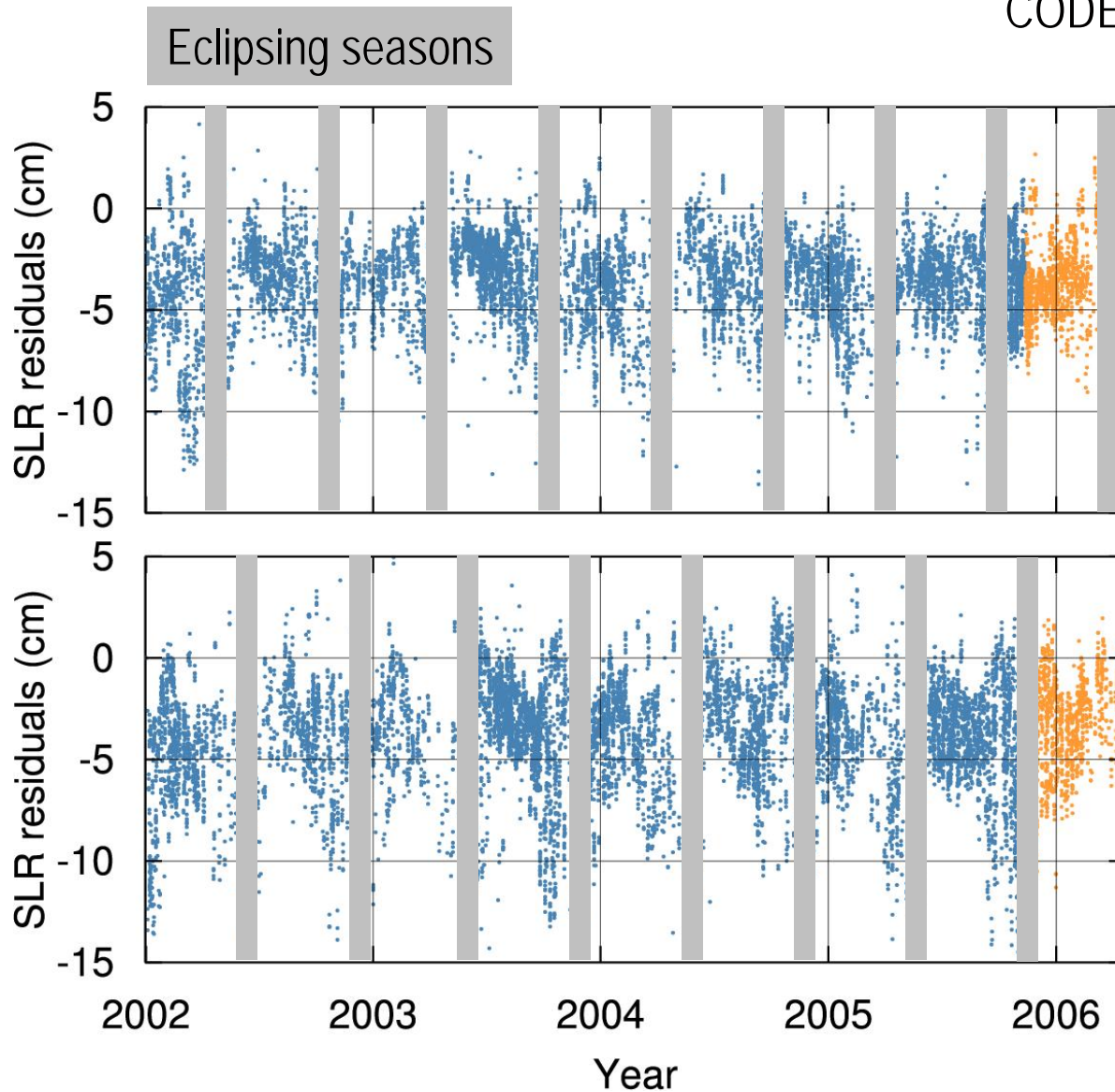
# SLR range residuals

CODE final GLONASS orbits



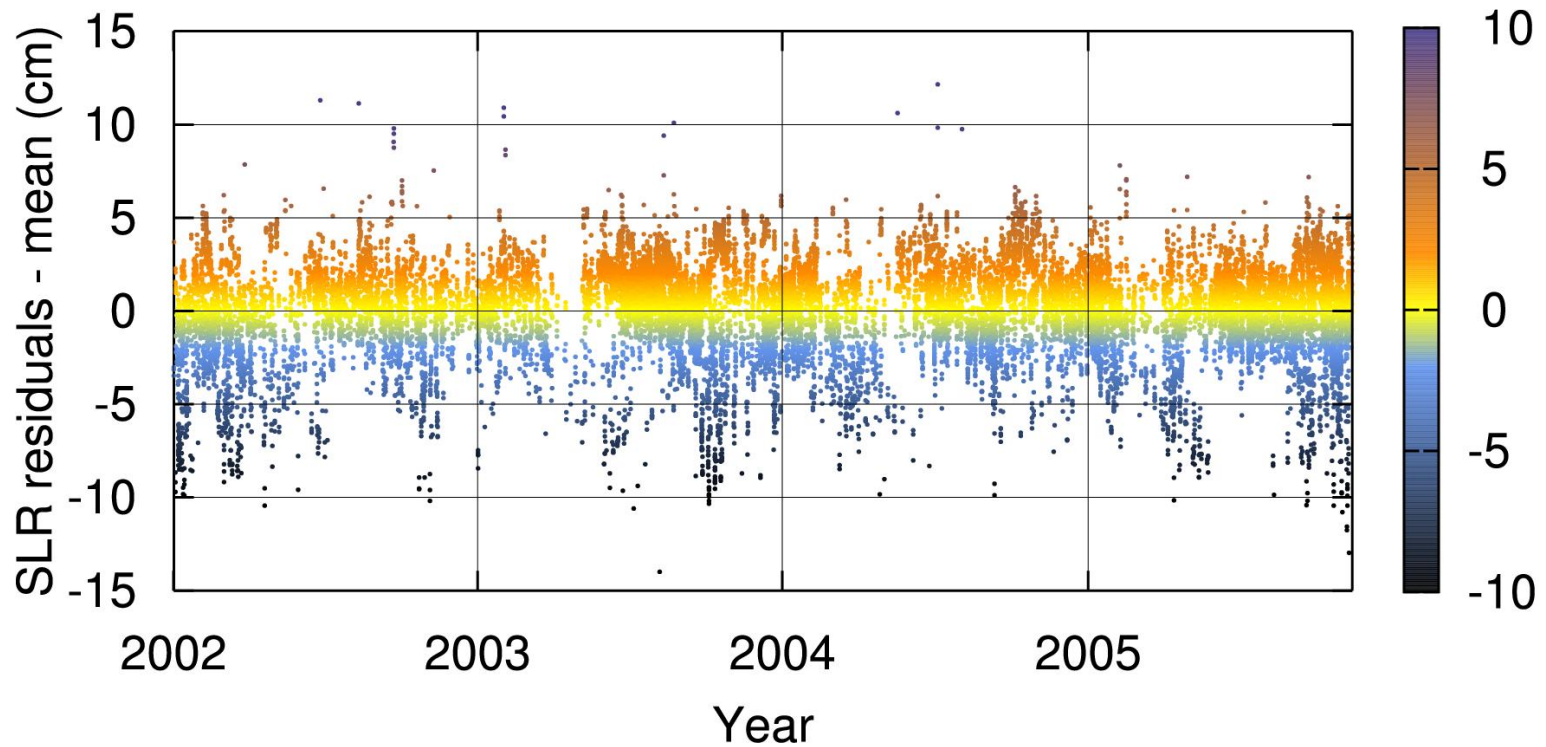
# SLR range residuals

CODE final GPS orbits



# Investigation of periodic signature

CODE final GPS orbits

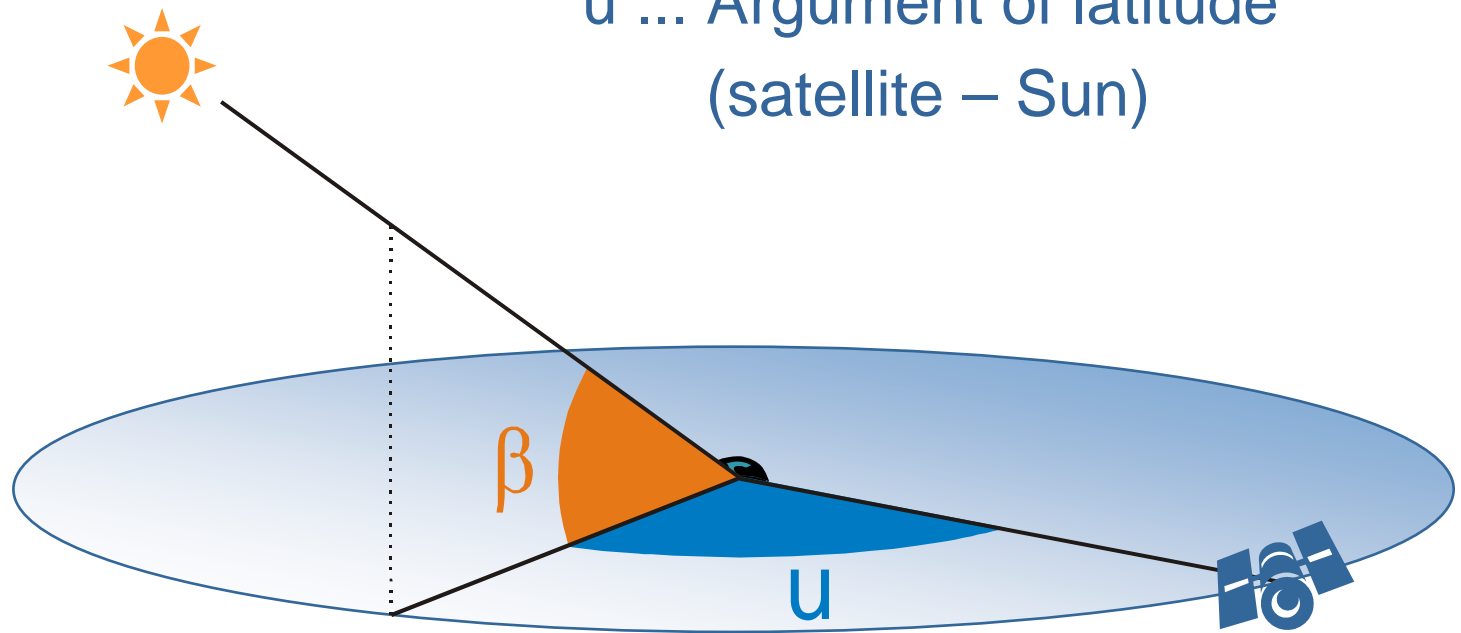


# Coordinate system $\beta$ - $u$

Satellite's position w.r.t. the Sun

$\beta$  ... Elevation of the Sun  
above the orbital plane

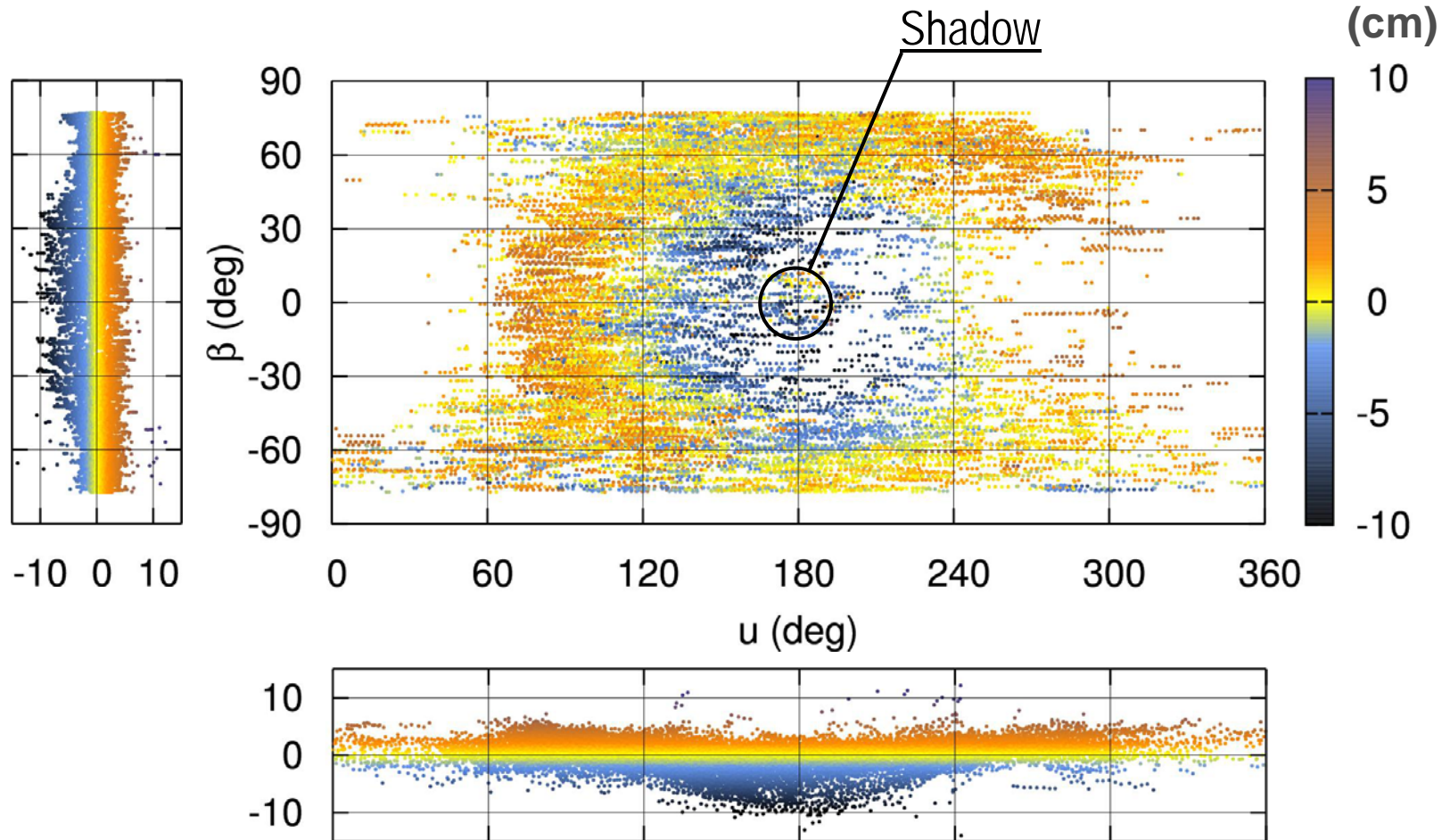
$u$  ... Argument of latitude  
(satellite – Sun)





# SLR range residuals

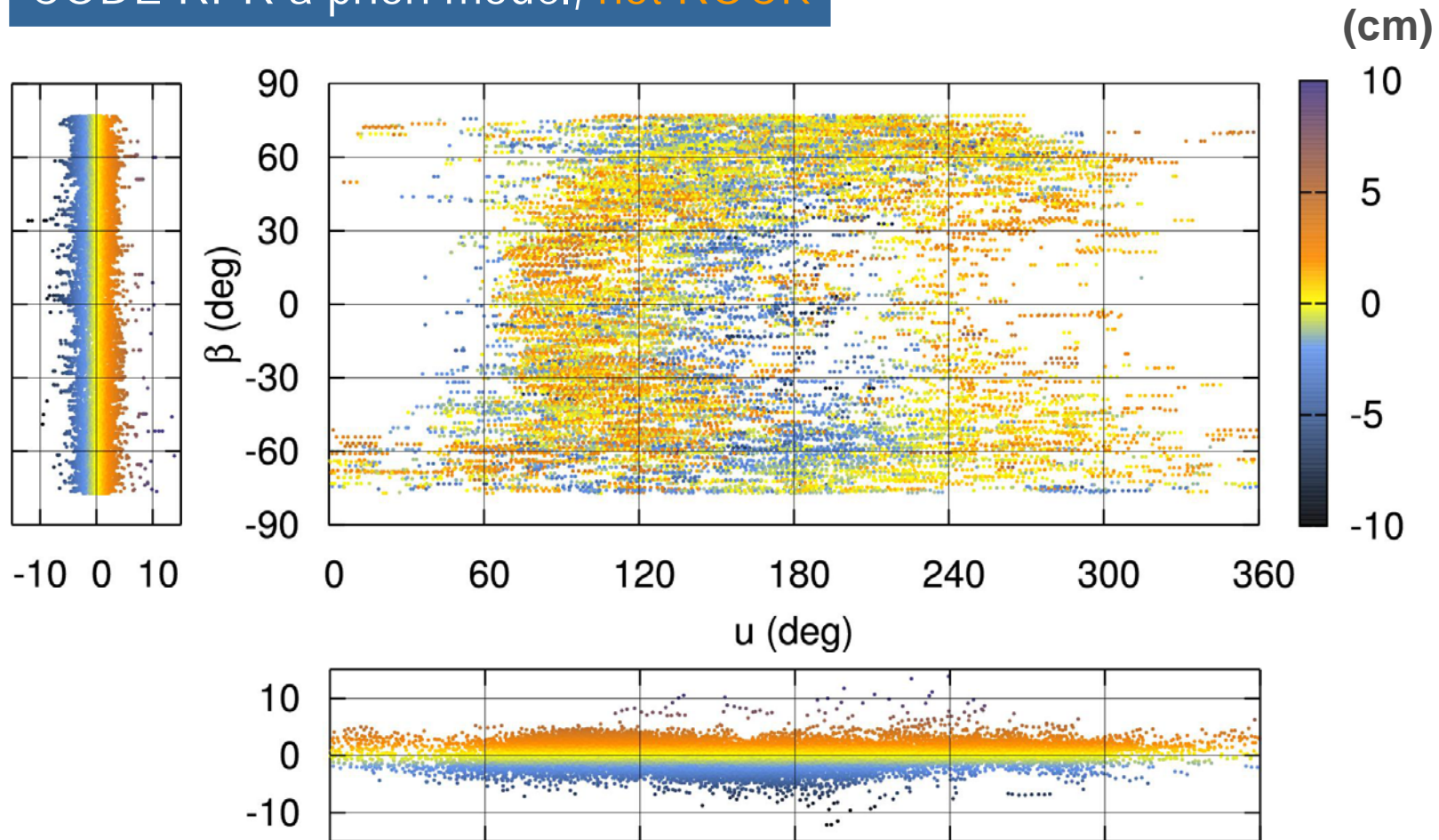
CODE final GPS orbits



# SLR range residuals

CODE rapid GPS orbits

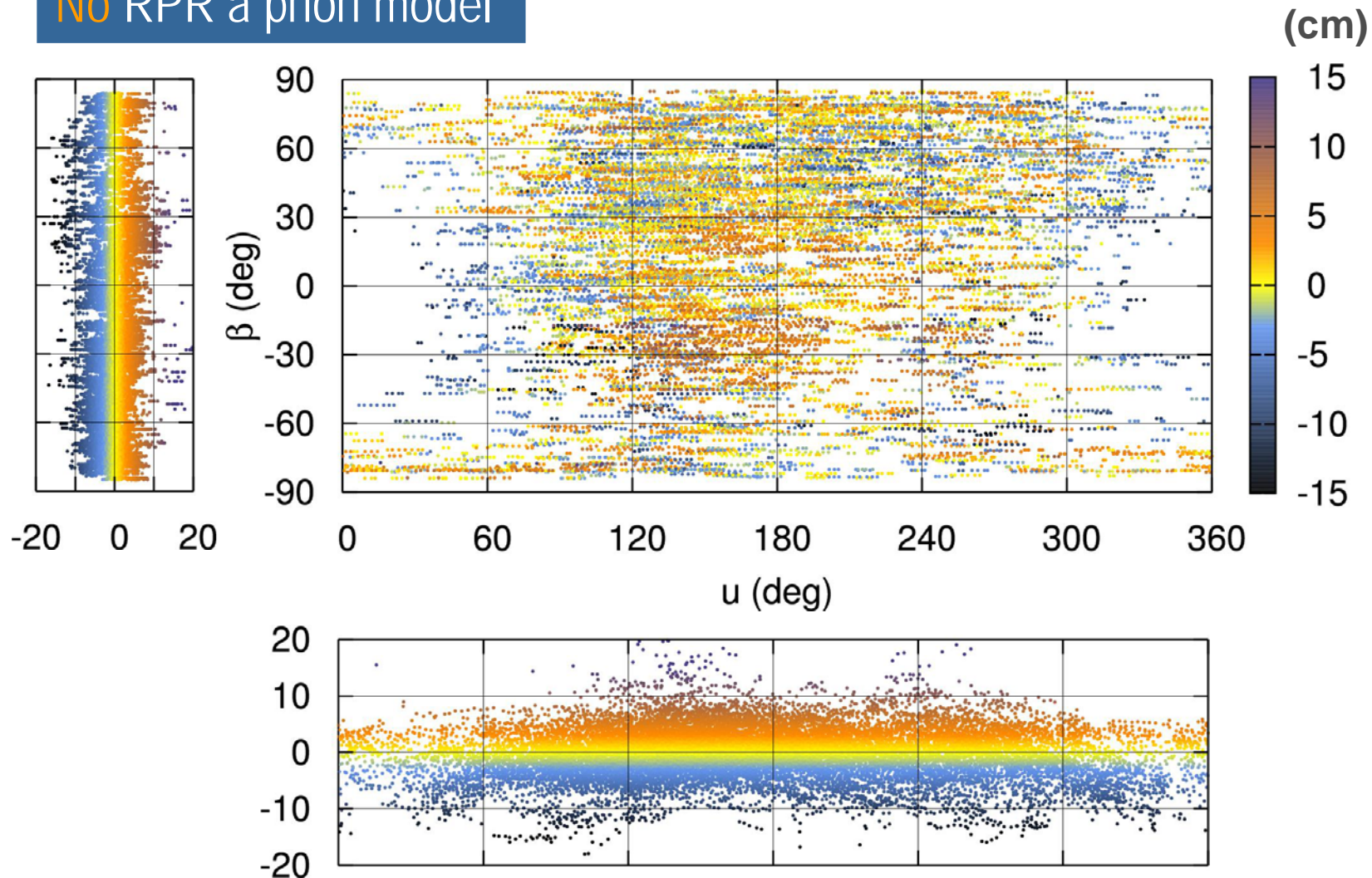
CODE RPR a priori model, not ROCK



# SLR range residuals

CODE final GLONASS orbits

No RPR a priori model



# Validation results

**Periodic signature** in the range residuals of the GPS satellites reveals orbit modeling problems.



Attitude

Solar radiation pressure

Earth albedo

**Range biases** of 3-4 cm for GPS satellites are unexplained.



Laser retroreflector offsets

Does it make sense to perform GNSS orbit determination on the basis of the two observation techniques

SLR + microwave

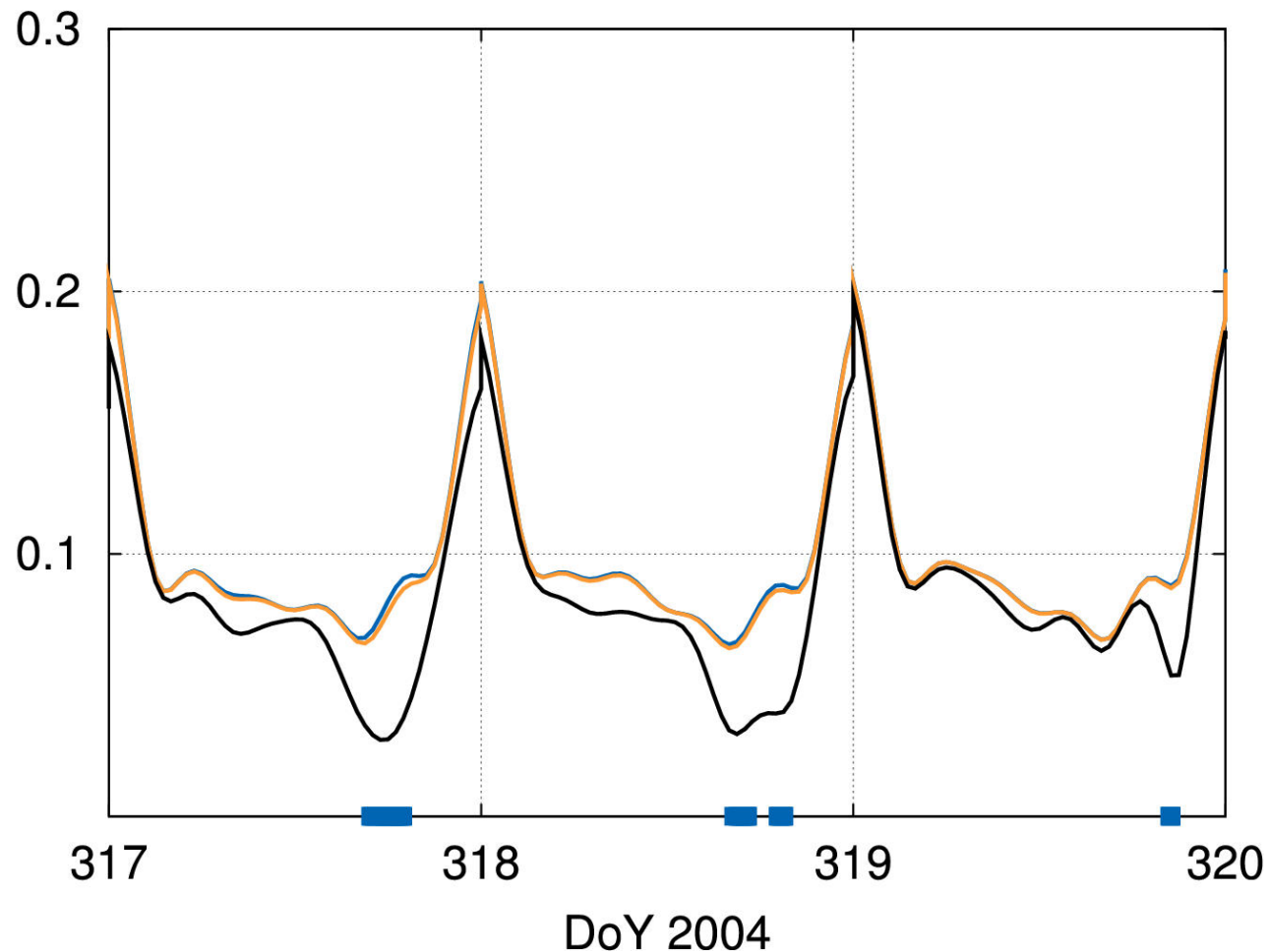


A priori covariance analysis

# A priori formal orbit error (radial)

microwave + SLR data of a GPS satellite

(mm)



$\sigma_{SLR} =$

$\infty$

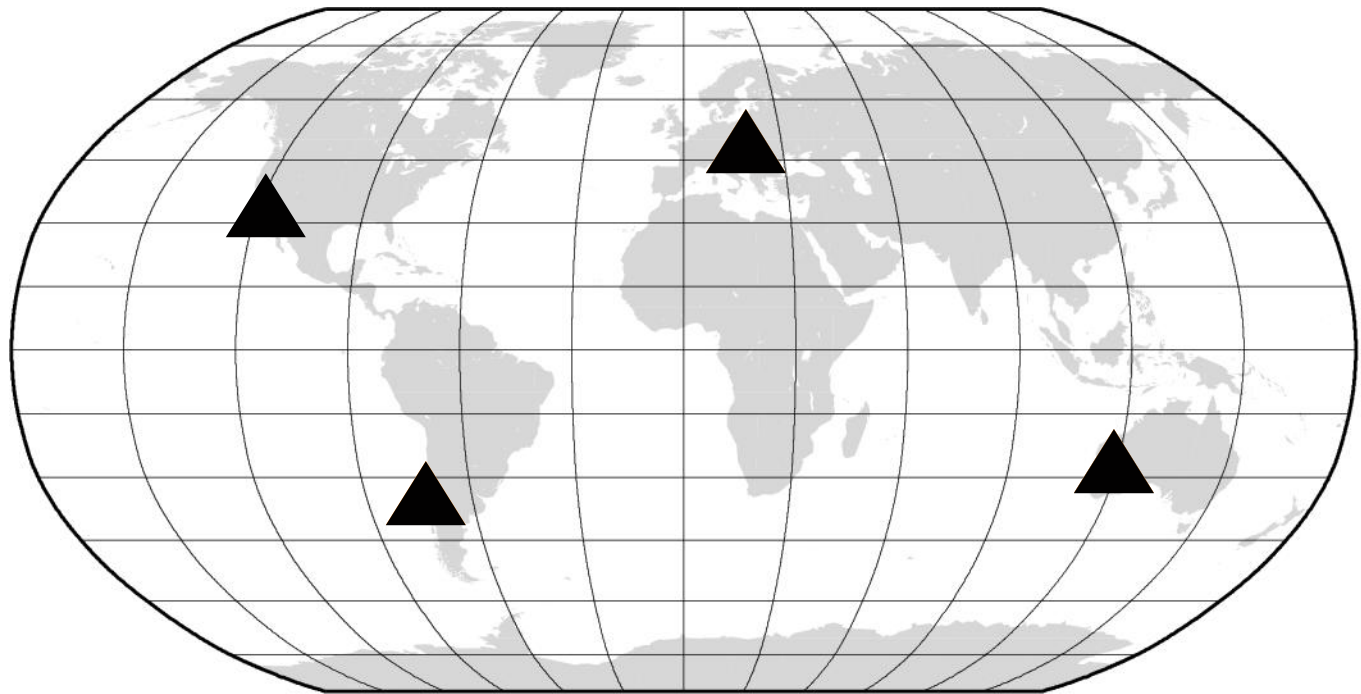
1 cm

1 mm

SLR data

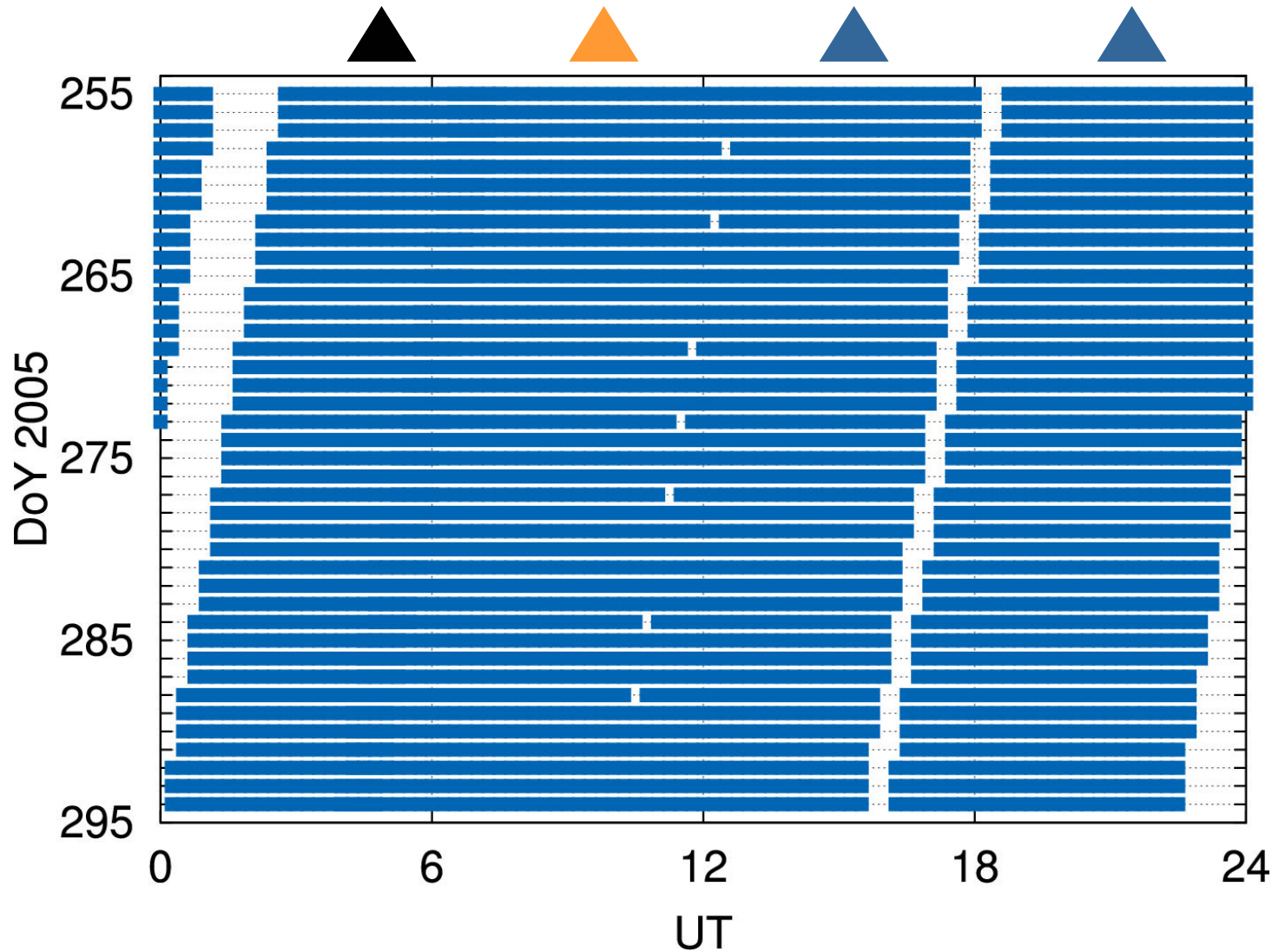
# Simulation of SLR observations

SLR stations: 15 min sampling,  $\sigma = 5$  mm



# Simulated SLR observations

for a GPS satellite

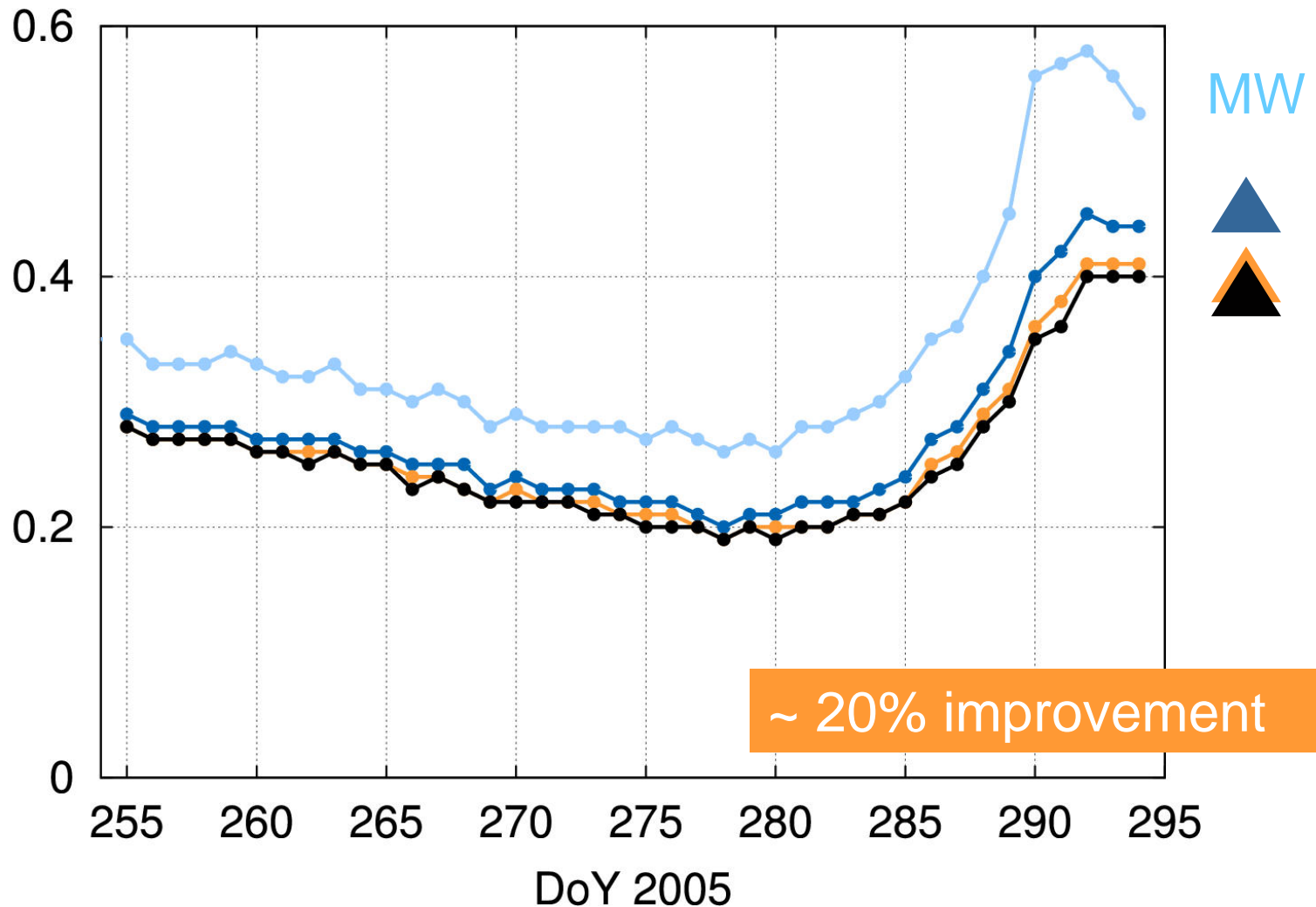




# A priori formal error of semi-major axis

microwave + simulated SLR data for a GPS satellite

(mm)

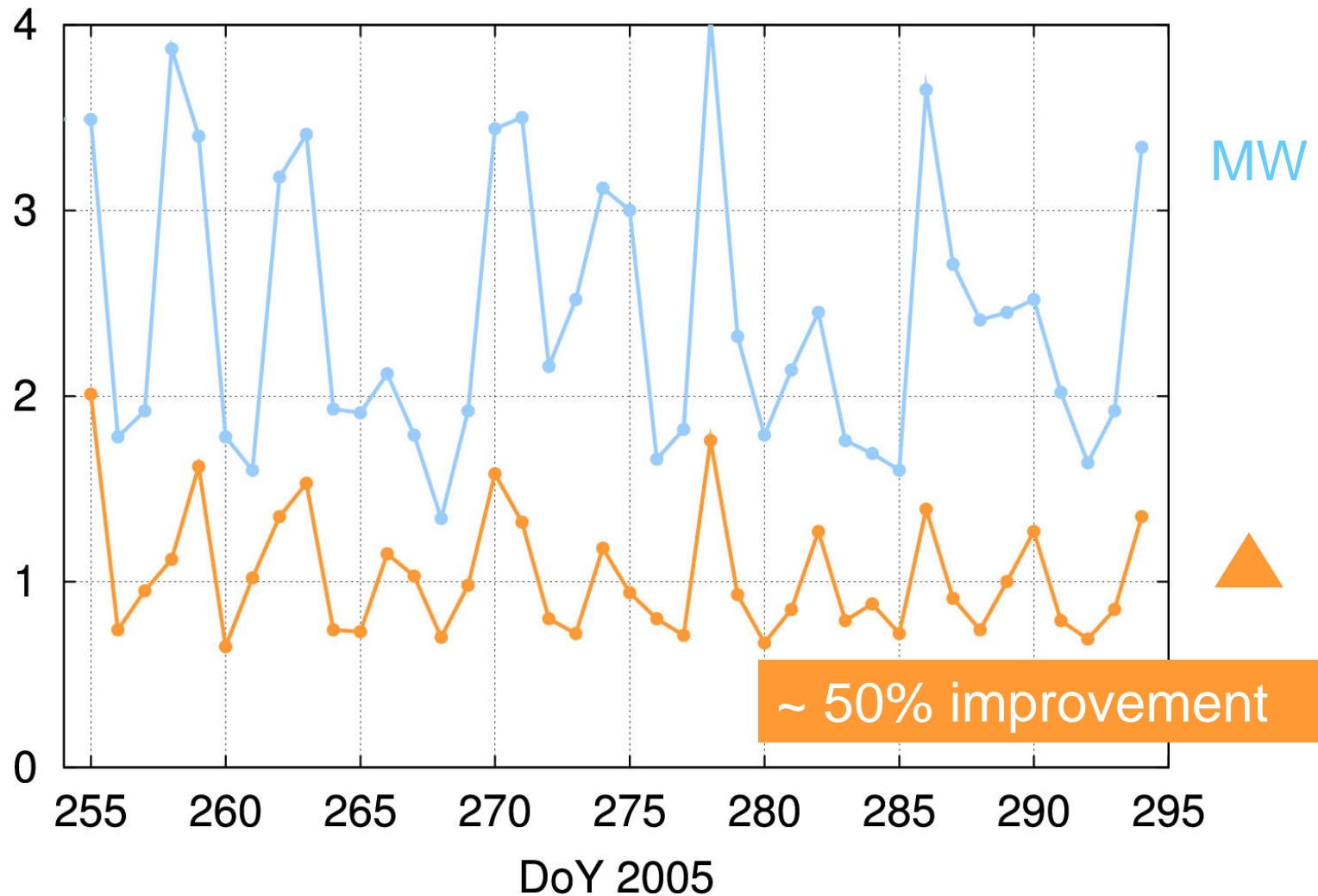


~ 20% improvement

# A priori formal error of semi-major axis

microwave + simulated SLR data for a GLONASS satellite

(mm)



~ 50% improvement

# Conclusions

- SLR observations are very useful for **independent validation** of microwave orbits.
- The validation reveals **orbit** (or attitude) **modeling deficiencies**.
- A **combined analysis** of microwave and SLR observations for GNSS orbit determination is useful provided that:
  - ✓ Orbit modeling + bias problems are solved.
  - ✓ Good temporal coverage of SLR data is available (at least 3 globally distributed SLR sites tracking GNSS satellites continuously).
  - ✓ Microwave tracking network is very sparse.

→ GIOVE-A