15th International Laser Ranging Workshop
Extending the Range

GIOVE-A and GPS-35/36 satellite orbits: analysis of dynamical properties based on SLR-only tracking data

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Canberra, Australia

Overview

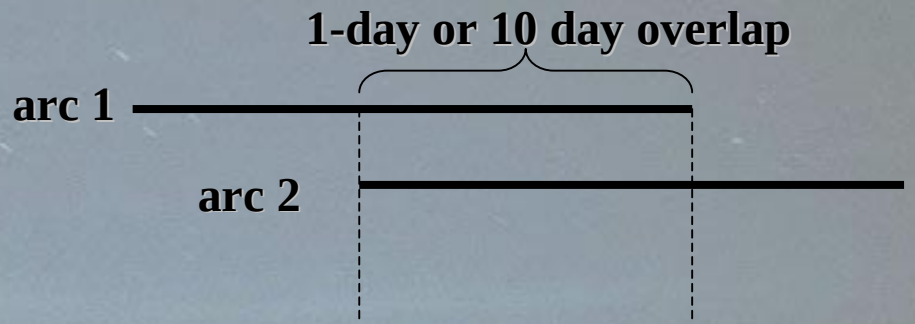
- GIOVE-A, GPS 35/36 SLR-orbit estimation strategy
- Data set
- Orbit analysis of GIOVE-A
- Orbit analysis of GPS 35/36
- Conclusions and perspectives

SLR-orbit estimation strategy

- **For the orbit fitting we are using GINS 6.1 GPS/SLR/DORIS/VLBI software**
- **The orbit analysis for GIOVE-A examines the overlap agreement of consecutive 2-day SLR only arcs.**
- **The orbit analysis for GPS 35/36 examines the overlap agreement between 10-day SLR only arcs and the IGS precise final orbits.**

$$rms_{overlap} = \sqrt{\frac{\left(\mathbf{x}^{GINS}_{GIOVE/GPS} - \mathbf{x}^{IGS/GINS}_{GPS/GIOVE}\right)}{n}}$$

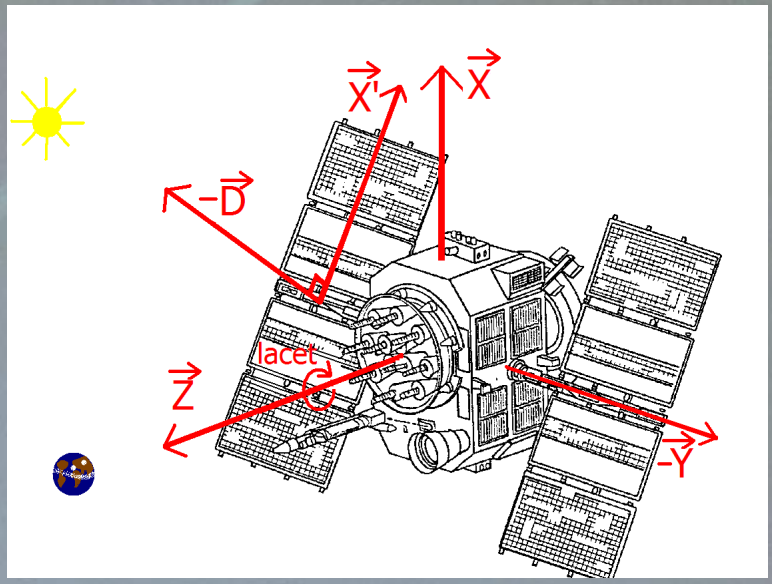
$$rms3D = \sqrt{rms^2_{Radial} + rms^2_{Along} + rms^2_{Cross}}$$



SLR-orbit estimation strategy

- For GIOVE-a, the solar radiation pressure modelling we are using is a new Box and Wing model. (Parameterisation for 8 surfaces and a-priori reflectivity and specularity coefficients).

X, Y, D attitude model



X : completes the system

Y : points along the solar panels

D : points towards the sun

SLR-orbit estimation strategy

GINS software	GPS 36/35	GIOVE-A
Gravity field	GRIM5_c1 (20x20)	EIGEN_GL04S (20x20)
Solar Radiation Pressure	Box and Wing	Box and Wing
Datum definition	ITRF2000, EOPC04	ITRF2000, EOPC04
Tidal displacements	IERS 2003	IERS 2003
Atm. + Ocean loading , Troposphere	ECMWF,FES2004, Marinni-Murray	ECMWF, FES2004, Marinni-Murray
Satellite retro-reflector offsets	x=-0.863, y=0.524, z=-0.658	x=0.828, y=0.655, z=-0.701
Attitude model	X, Y, D	X, Y, D
Albedo and infrarouge model	Analytical model (10dx10d)	Analytical model (10dx10d)
Numerical integration	Cowell 8th order, step=180s	Cowell 8th order step=180s
Adjustement	Weighted LSQ (1cm SLR) 6 orbital param., 1 SRP coeff. , 1 Yb, 1 X,D per-rev/2-days	Weighted LSQ (1cm SLR) 6 orbital param., 1 SRP coeff., 1 Yb, 1 X,D per-rev/2-days
Orbital param.	Init. cond. from broadcasted ephemerides	Init. cond. from analytic integration based on SLR measurements

Data set

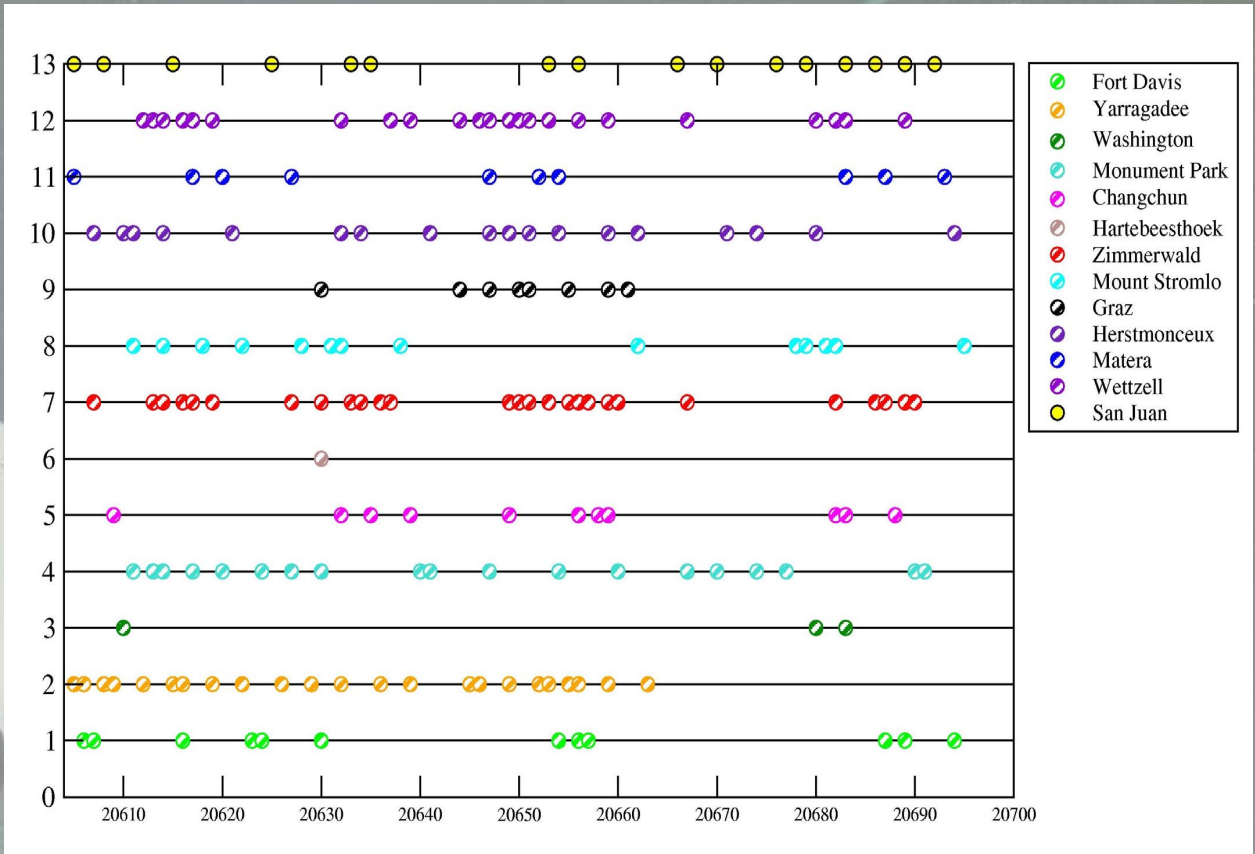
GPS 35/36 :

- SLR normal points for june 2006: 306 for GPS35, 402 for GPS36
- Fitted arcs of 2, 10 and 30 days

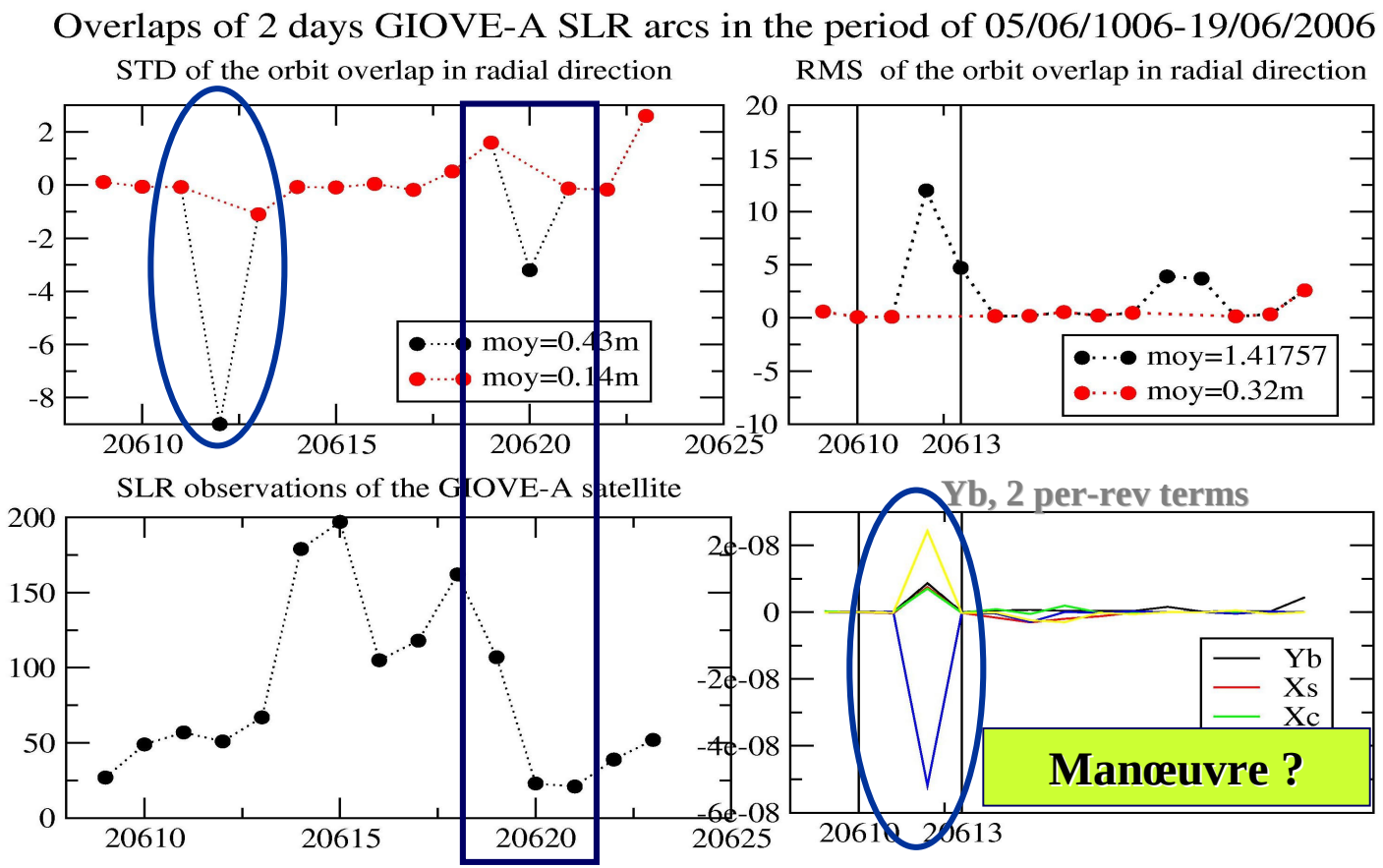
GIOVE-A :

- 2311 SLR normal points for june, july, august 2006.
- Fitted arcs of 2, 10, 30, 90 days

3 months GIOVE-A SLR campaign

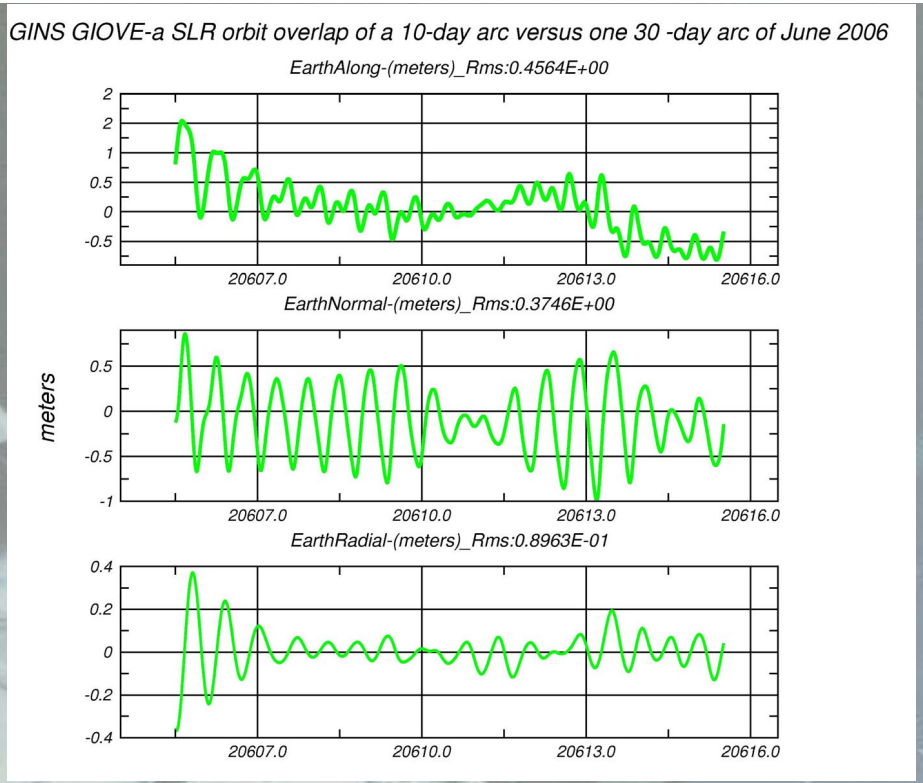


Orbit analysis of GIOVE-A

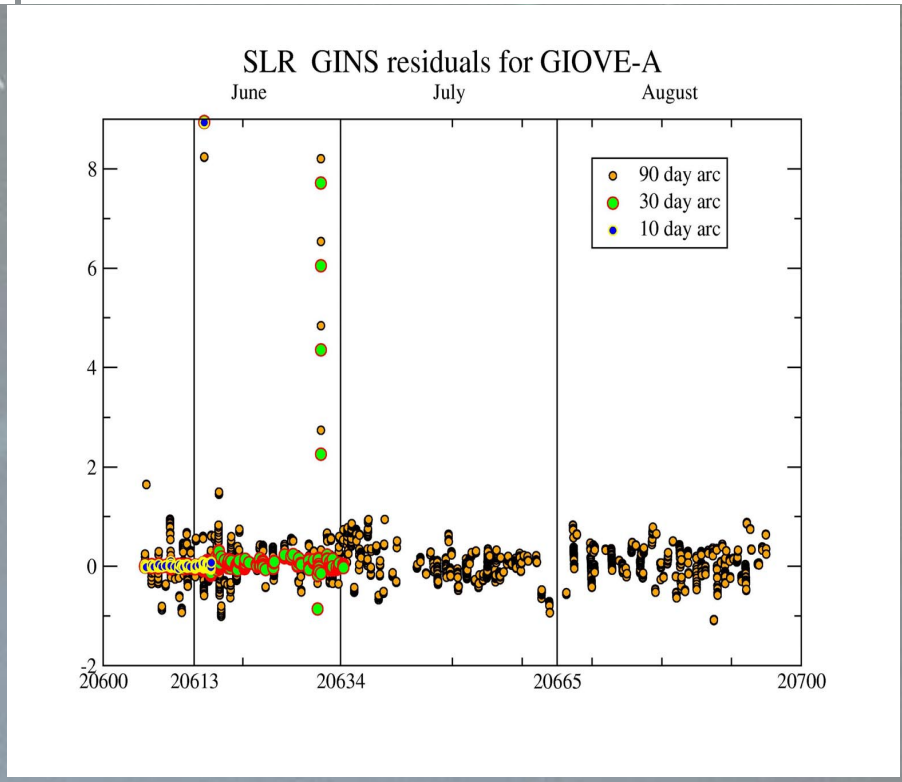


Orbit analysis of GIOVE-A

10-day overlap of a GIOVE 30-day arc versus a 10 –day arc in the beginning of June 2006



GINS SLR global residuals for a 90-day, 30-day, and 10-day GIOVE arc



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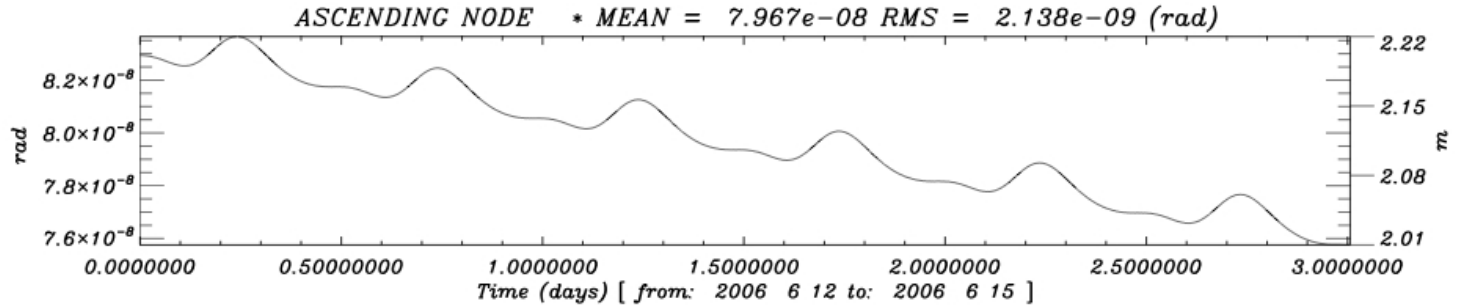
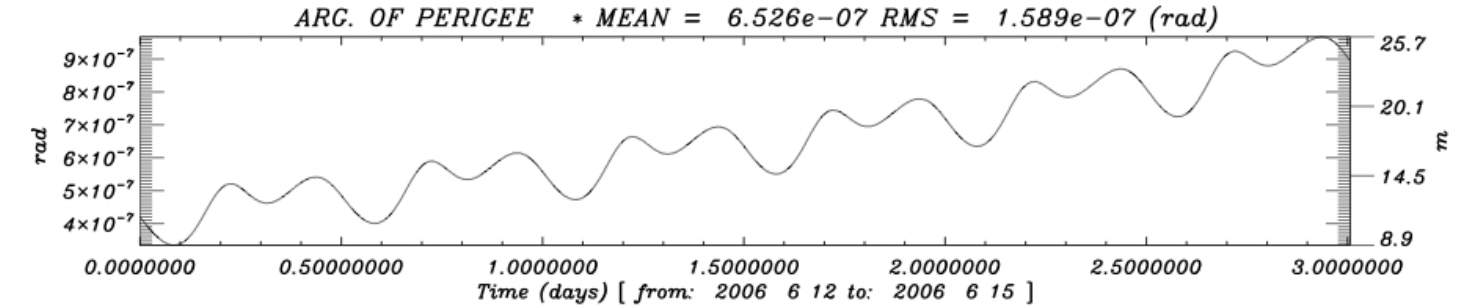
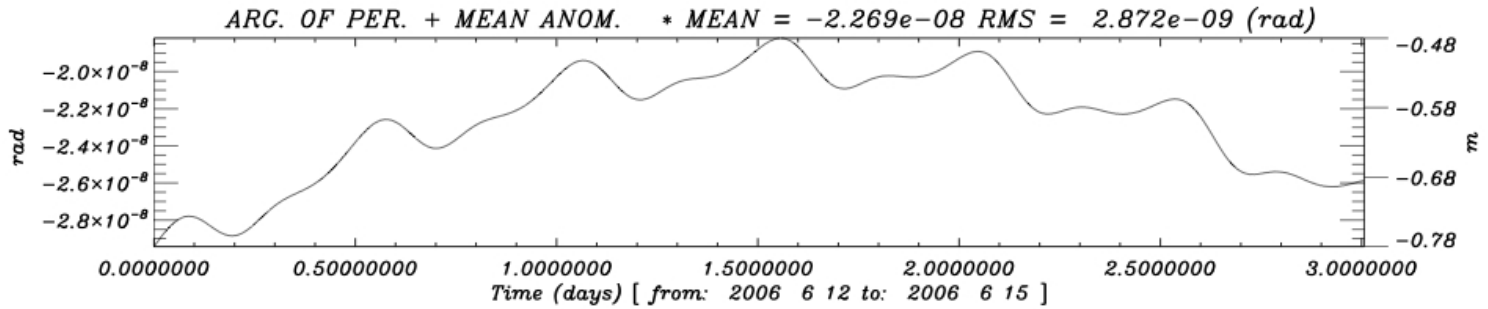
Orbit analysis of GPS35/36







Orbit analysis of GPS35/36

Helmert transformation wrt. the IGS microwave orbits for GPS35 doy 157-167

-.786898E-02 +/- 0.997E-02	1 : translation in x - (m)
-.485564E-03 +/- 0.997E-02	2 : translation in y - (m)
0.598395E-01 +/- 0.997E-02	**3 : translation in z - (m)**
0.620124E-09 +/- 0.375E-09	**4 : scale factor (ppb)**
-.336947E-03 +/- 0.947E-04	5 : rotation in x (arcsec)
0.135668E-04 +/- 0.956E-04	6 : rotation in y (arcsec)
-.242881E-02 +/- 0.942E-04	**7 : rotation in z (arcsec)**
0.165406E-01 +/- 0.100E-01	**4 : scale factor (m)**

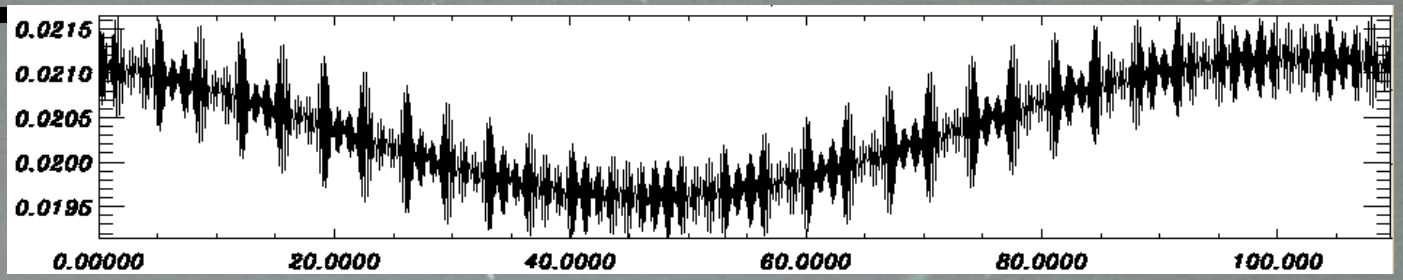
Helmert transformation wrt. the IGS microwave orbits for GPS36 doy 157-167

0.222380E-02 +/- 0.531E-02	1 : translation in x - (m)
0.836202E-03 +/- 0.531E-02	2 : translation in y - (m)
0.453187E-01 +/- 0.531E-02	**3 : translation in z - (m)**
0.712820E-10 +/- 0.200E-09	**4 : scale factor (ppb)**
-.303654E-03 +/- 0.508E-04	5 : rotation in x (arcsec)
0.446041E-04 +/- 0.505E-04	6 : rotation in y (arcsec)
-.145764E-02 +/- 0.501E-04	**7 : rotation in z (arcsec)**
0.190437E-02 +/- 0.534E-02	**4 : scale factor (m)**

« Mean observed elements »

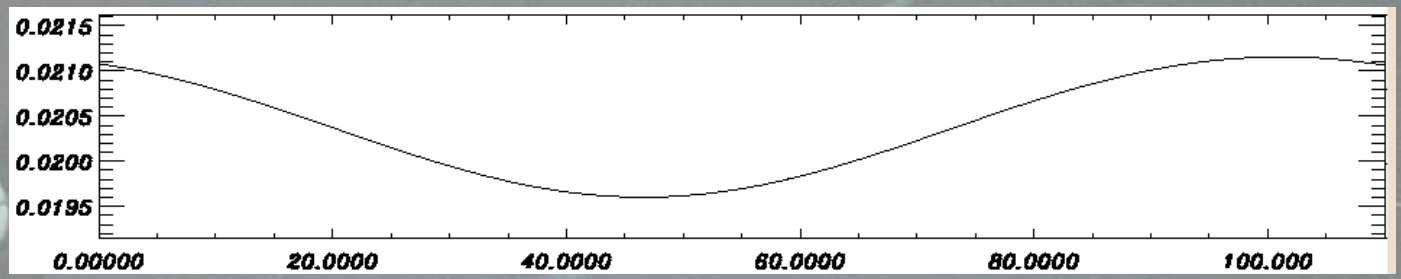
Osculating motion

$$\frac{d\mathbf{E}}{dt} = SM(\mathbf{E}, \Sigma)$$
$$\mathbf{E}(t_0) =$$



Long Period terms

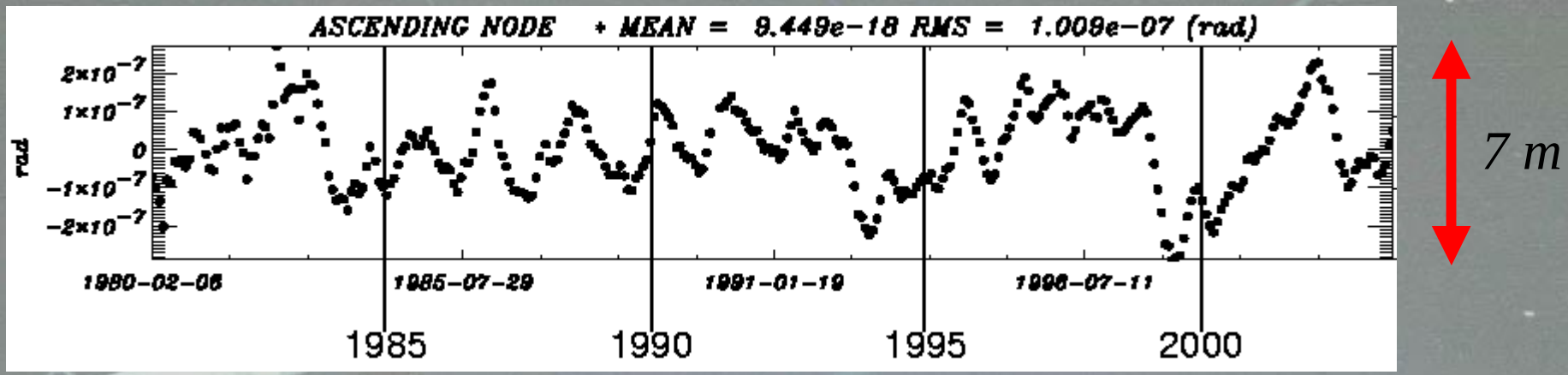
$$\frac{d\mathbf{E}'}{dt} = SM'(\mathbf{E}', \Sigma)$$



- Mean equations of motion obtained with an analytical averaging (5th order in J_2), based on Lie transformations, which are integrated in a numerical way
  - Earth gravity field (coupling effects J_2J_n up to *n=40), Moon & Sun effects*
  - Radiation pressure, …
- Short periodic terms (with great amplitude) filtered from osculating orbits thanks to a filtering approach
- One single arc fitted on « *mean observed elements* » in view of:
  - Gravitational parameters: GM, post-glacial rebound, …
  - Non gravitational effects: dynamical modelling, error budget
  - Mission analysis

« Mean observed elements »

- Example: residuals obtained on the ascending node of LAGEOS-1



- « Mean observed elements » for GIOVE-A:

	GIOVE-A Day 20620 (12h)
Semi-major axis (km)	0.29634097232910E+08
Eccentricity	0.83825404091530E-03
Inclination (rad)	0.97770690917969E+00
Ascending Node (rad)	0.32480748016896E+01
Argument of perigee (rad)	0.57041260521250E+01
Mean anomaly (rad)	0.31670464980501E+01

Dynamical properties (1/2)

Metric elements

- Resonance effects on semi-major axis (GPS orbit)

QuickTime™ et un
décompresseur TIFF (LZW)
sont requis pour visionner cette image.

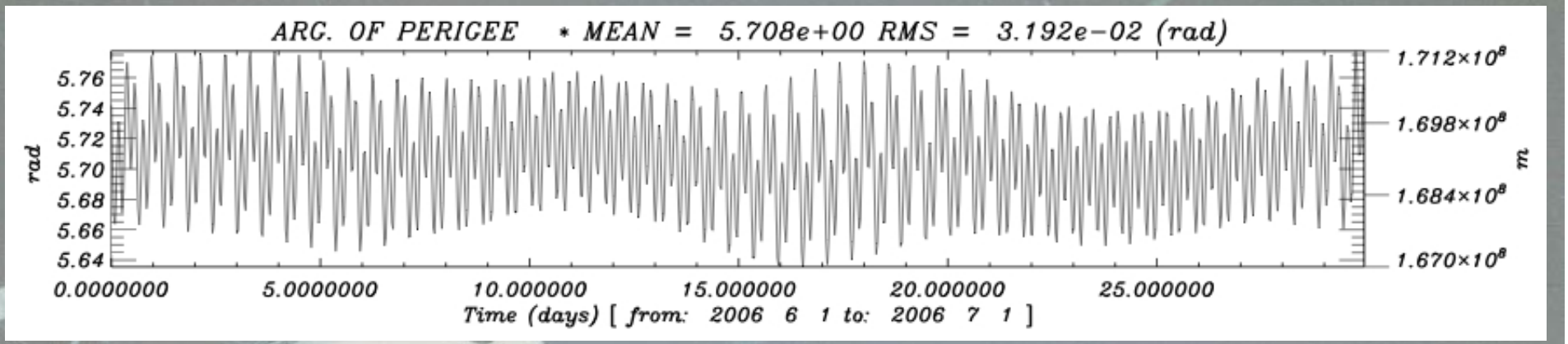
- Si

Time (days) [from: 2006 1 1 to: 2025 12 27]

Dynamical properties (2/2)

Angular elements

- GIOVE-A argument of perigee



- GIOVE-A / GPS36:

	GIOVE-A	GPS36
PerigeeÕsperiod (day)	27843	13825
Ascending node period (day)	13979	8948

Conclusions and perspectives

GIOVE - A

- **We have calculated 2, 10, 30-day GIOVE-A SLR only orbits with an internal accuracy of 5-10 cm in radial direction**
- **For 90, 30 and 10 -day arcs the orbit dynamics is a stronger constraint than for 2 – day arcs.**
- **Our SRP modelling is still under investigation. An adjustment procedure of the specularity and reflectivity coefficients of the satellite is on the way together with a new empirical SRP modelling.**
- **The residual level for the 10 and 2 days arcs are below the level of 10cm**
- **Further investigation would be to know the exact date of a change in the orbit as clearly seen in the 2-days arcs, and introduce a new set of accelerations.**

GPS 35/36

- **The overall agreement of the SLR orbits compared wrt. the IGS final orbits is of the order of 1-3 cm in Radial, 5-10 cm in Along and 25-40 cm in Cross-track.**
- **The internal precision stays itself in the level of 30-40 cm 3DRMS**
- **Offset values for the translation coefficients in Z verify once again the effect of the non-homogeneity of SLR tracking stations. A similar explanation can be given for the lack of consistency between the relative scales of SLR and microwave orbits.**