Satellite Laser Ranging Data Processing; HartRAO first results

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Outline

I. Introduction

II. Software algorithms

III. Processing configuration

IV. Testing influence of earth-tide on range bias

V. Results and conclusions

Introduction

- **Have been developing software during last 3 years > ”SLR Analysis Software”**
- **Why not use existing software ?**
  - Microcosm (cost), Geodyn (UNIX)
  - Own software development provides unique in-depth know-how
  - Can be enhanced, modified and tailored anytime, anywhere
- **Main objective is to develop ‘niche’ areas in SLR analysis**
- **SLR Analysis Centres have EOP parameters as product (ILRS EOP product)**
- **Other parameters can be solved for but as is (code cannot be optimised)**
- **Graphical user interface (click and play)**

Some basics

- SLR Data basically consist of time-of-flight of laser pulse at a certain epoch
- Data must be corrected for additional delay in atmosphere and relativity
- Satellite orbit is calculated via an orbit integrator with modelling of perturbing forces taken into account
- SLR station position variations are taken into account (plate tectonics, ocean loading, earth- tide, pole-tide, atmospheric loading)
- Two-way range is calculated and subtracted from range determined from SLR measured TOF
- Result is Observed – Computed (O-C) residual
- All is done in an inertial reference frame (J2000)

Software algorithms

Several forces need to be taken into account when determining the orbit of the satellite.

Gravitational forces perturbing the orbit of the satellite consist of

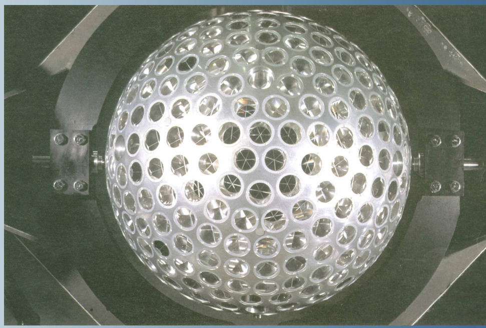
- Earth’s geopotential
- solid earth tides
- ocean tides
- planetary third-body perturbations (Sun , Moon and planets)
- relativistic accelerations atmospheric tide

The non-gravitational forces consist of

- atmospheric drag
- solar radiation pressure
- earth radiation pressure
- thermal radiation acceleration

Analysis strategy, conventions

Celestial reference frame	J2000
Terrestrial reference frame:	ITRF2000 epoch 1997.0
Solar, lunar and planetary ephemerides for 3rd body gravitational perturbation	JPL DE405 (Standish, 1998.)
Pole-tide correction (station position)	IERS 2003
Pole-tide acceleration of satellite	Not implemented
Relativity (space-time curvature)	IERS 2003
Earth–tide correction (station position)	Petrov 2005
Earth-tide acceleration of satellite	(Rizos and Stolz, 1985)
Ocean loading correction (station position)	Scherneck, 1991
Atmospheric loading	IERS 2003
Definition of origin	Geocentric
Gravity model	JGM-3 (20x20) (Tapley et al. 1996)
LAGEOS-2 model	Concentric annulus x 10
Reference epoch	1997.0
Tectonic plate model	ITRF2000 velocity field
Earth orientation	a-priori Earth orientation parameters and UTC-UT1 values as per IERS Bulletin B extrapolated to observation epoch
A priori precession model	IAU(1976) (Lieske, 1976)
A priori nutation model	IAU(1980) (Seidelmann, 1980) and dPsi and dEpsilon corrections (Herring et al. 1991) from IERS Bulletin B
O-C outlier rejection	> 1 sigma or 10 cm
Data rejection	<10 degrees elevation
Range bias	Enabled
Time bias	Disabled
Satellite centre-of-mass	251 mm, ILRS standard value (Otsubo and Appleby, 2003)



To evaluate our software

- processed a combined solution of LAGEOS 1 and 2
- evaluated the effect of including/excluding unmodelled forces (once per cycle once per revolution, solar radiation, earth albedo)
- 3 day arcs using Yarragadee (Australia)
- evaluated the effect on O-C residuals when Earth-tide modelling is included/excluded
- evaluated the effect on *range bias*

Solution (Earth-tide variation of gravity field enabled, unmodelled accelerations constrained)	O-C (mean of RMS)	Mean range bias
LAGEOS-1 plus LAGEOS-2 (Earth-tide on)	0.040 ± 0.0062	-0.004 ± 0.0053
LAGEOS-1 plus LAGEOS-2 (Earth-tide off)	0.040 ± 0.0053	-0.010 ± 0.0089
LAGEOS-1 (Earth-tide on)	0.035 ± 0.0081	-0.005 ± 0.0056
LAGEOS-1 (Earth-tide off)	0.035 ± 0.0081	-0.003 ± 0.0062
LAGEOS-2 (Earth-tide on)	0.048 ± 0.0178	0.002 ± 0.0187
LAGEOS-2 (Earth-tide off)	0.041 ± 0.0139	0.0005 ± 0.011

Summary of results listing the mean of the RMS values of the O-C residuals of 3-day arcs and the mean of the range biases.

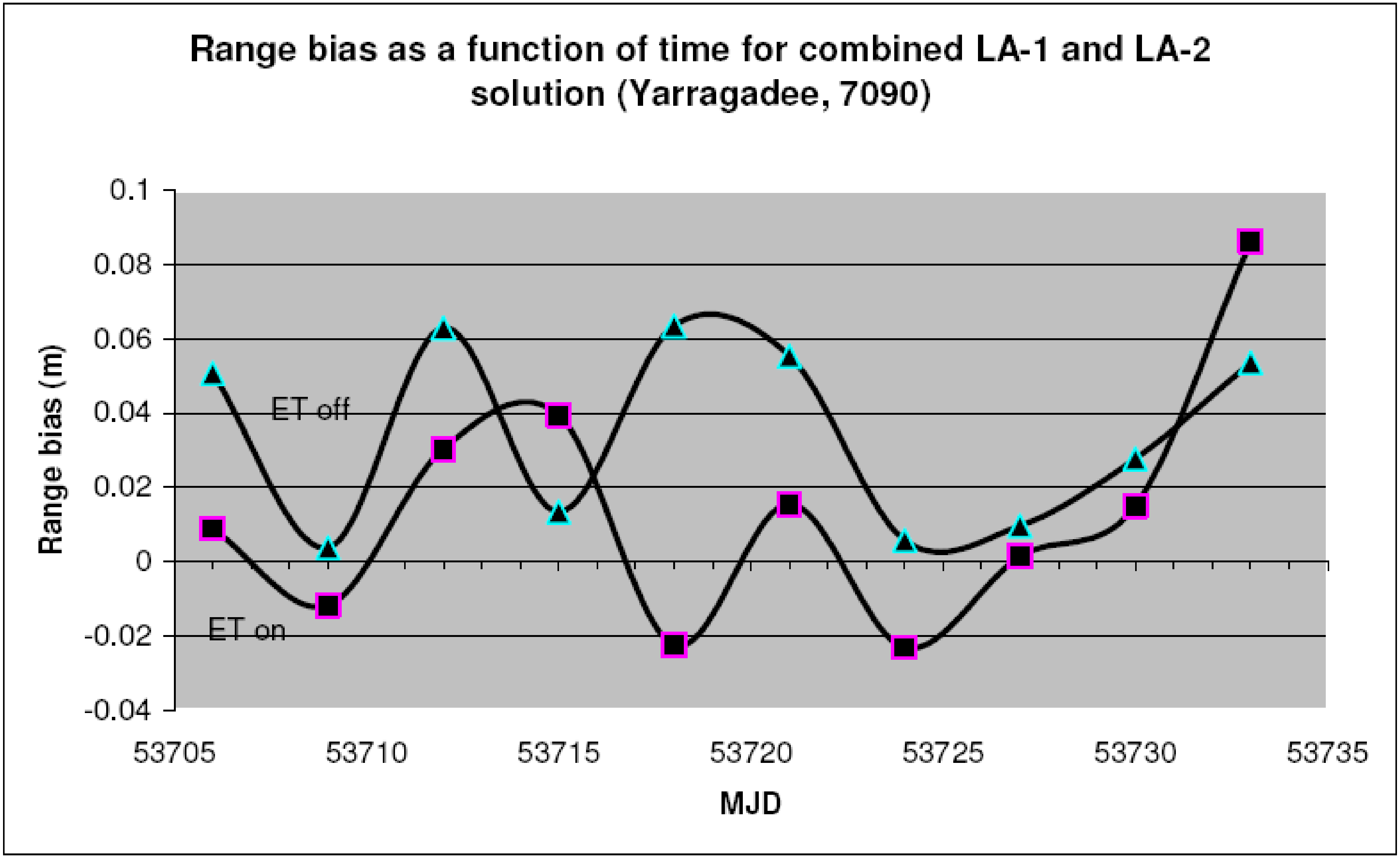


Figure 1. Range bias for the combined solution of LAGEOS-1 and LAGEOS-2 indicating a reduction in range bias as a result of including Earth-tide modelling. Perturbations due to Earth-tide effects on the static gravity field was disabled.

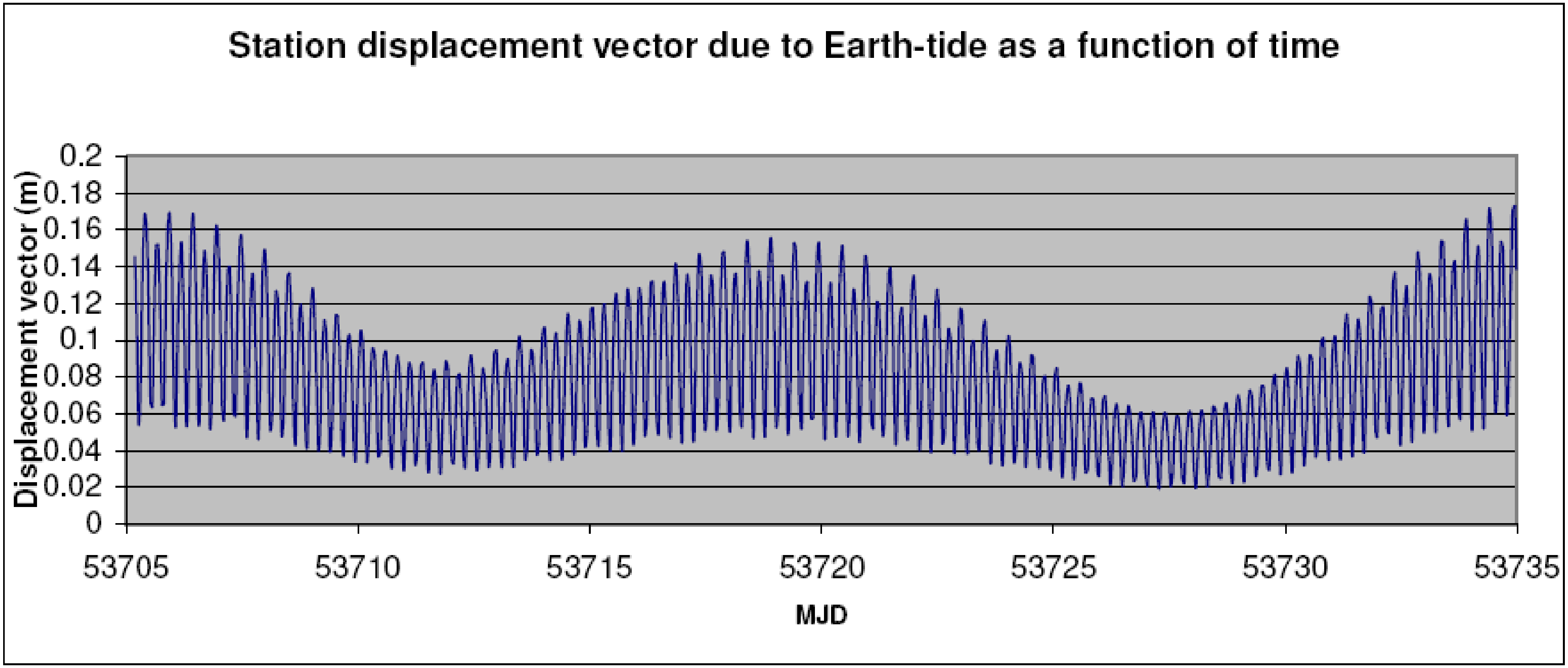


Figure 2. Position displacement of the SLR station Yarragadee (Australia) due to Earth-tide indicating sub-diurnal and longer periods due to the gravitational potential of the Sun and Moon.

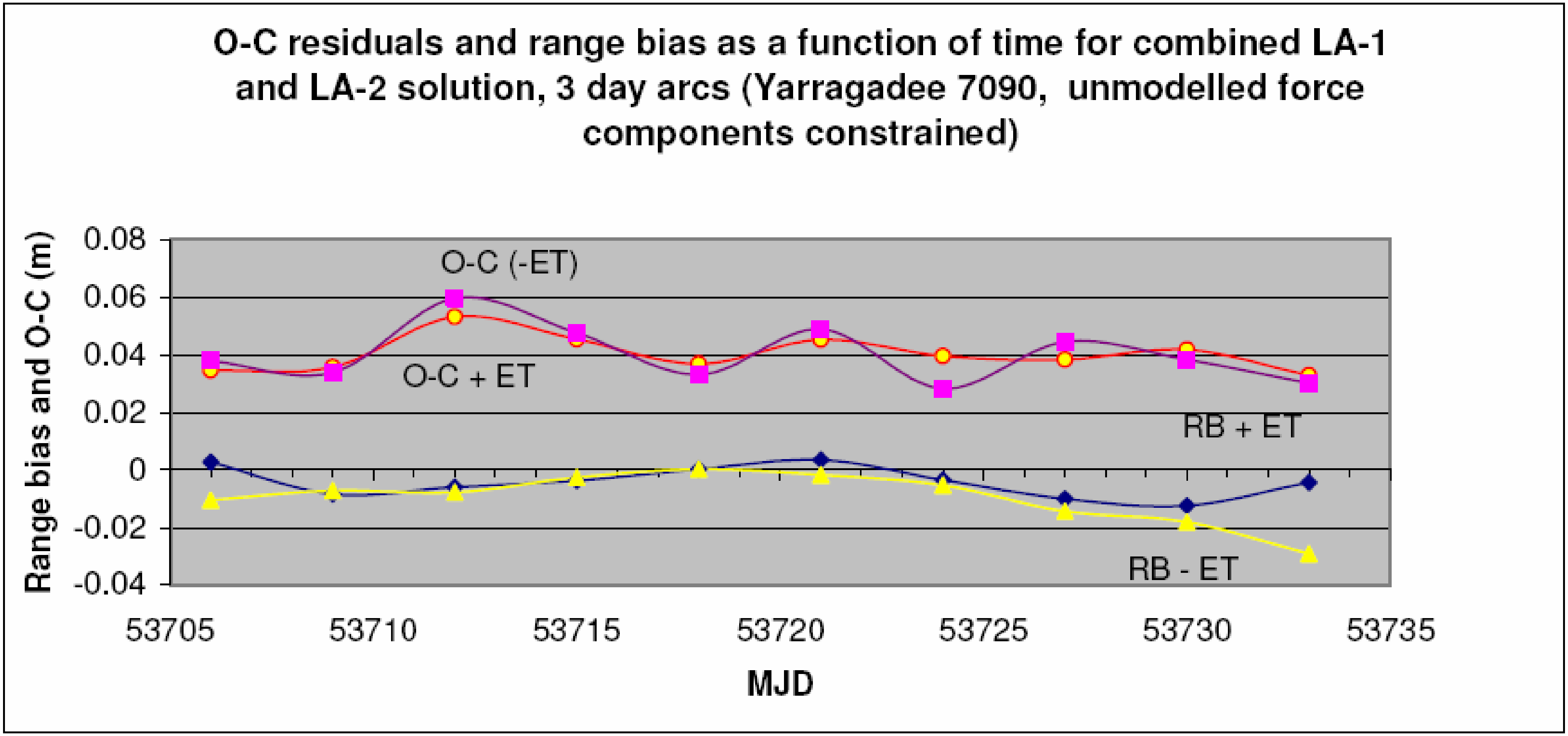


Figure 3. Range bias for the combined solution of LAGEOS-1 and LAGEOS-2 indicating a reduction in range bias as a result of including Earth-tide modelling. The unmodelled acceleration component was constrained and perturbations due to Earth-tide effects on the static gravity field were enabled.

Conclusions

- The SLR analysis software performs very well considering its homebrew origin
- Additional modelling and functionality will provide a useful analysis tool
- Niche areas in SLR analysis will be exploited

Main result of combined LAGEOS 1 and 2 solution tests

- **Comparison between the Yarragadee station position perturbation vector resulting from solid Earth- tide and calculated SLR range bias indicates a correlation**

- **This probably results from an overestimate of the Earth-tide vector**

- **This sensitivity of the SLR technique indicates that it would be possible to test different models and assess them (or improve them) in terms of accuracy**

- **This will lead to *tuned* station displacement or Earth-tide models**

Thank You!