Determination of the Temporal Variations of the Earth’s Centre of Mass from Multi-Year SLR Data

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Overview

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Introduction

- Geodetic parameters used to monitor global change are generally estimates of station coordinates, gravity field coefficients and their time variation.
- These are referred to a TRF defined by its origin (geocentre), orientation and scale which is also time varying.
- Need to know how the parameters defining the TRF also change with time.
- How does the CoM (Geocentre) deviate from the defined origin?
Introduction

• Temporal variation of the CoM and orientation is a measure/symptom of mass transport -- what can be learned from this?
• What are the dynamics that cause the geocentre, orientation and scale to vary?
Gravity SH and Geocentre Definition

- MacCullagh’s formula established the relationship between the lower degree harmonics of the Earth’s gravity field and its physical representation [geocentre (=0), orientation, etc]
- Evaluation of the degree one harmonics give direct access to the Earth’s CoM

\[
\begin{align*}
X_{\text{com}} &= C_{11} R_\oplus; \\
Y_{\text{com}} &= S_{11} R_\oplus; \\
Z_{\text{com}} &= C_{10} R_\oplus
\end{align*}
\]

\(C_{10}, C_{11}, S_{11}\) are unnormalised SH coefficients

\(R_\oplus = \text{Earth radius}\)
SLR Data Processed

• Lageos-1 and Lageos-2 from January 1993 to end September 2006

• Stella and Starlette from beginning 1996 to end 2005
Computation Standard
Geodyn / Solve

Weekly Arcs

– ITRF2000 + Earth and Ocean tide loading
– GGM01S + Earth and Ocean tides + time varying gravity
– EOP – C04 apriori
Computation Standard

Estimated Arc Parameters
- State Vector
- SRP – once per arc
- General Acceleration – once per arc – constant (along track) and 1/rev (along & cross track)
- Range bias – some stations (ILRS AWG Rules)

Estimated Global Parameters
- Station Coordinates
- X,Y Pole, LOD
- Gravity Coefficients to (2,2)
Lageos: COM Results

**Dominant Periods**

- ≈ 1200 days (39 months) – 3 cm
- ≈ 720 days (2 years) – 3.5 cm
- ≈ 18 months
Lageos: COM Results

Dominant Periods

- \( \approx 1200 \text{ days (39 months)} - 2 \text{ cm} \)
- \( \approx 900 \text{ days (30 months)} - 3 \text{ cm} \)
- \( \approx 18 \text{ months} - 3 \text{ cm} \)
Lageos: COM Results

Dominant Periods

- $\approx 1200$ days (39 months) – 3 cm
- $\approx 900$ days (30 months) – 2 cm
- $\approx 310$ days – 1.5 cm
Stella/Starlette: COM Results

X-COM OFFSET (S/S) (métres)
Stella/Starlette: COM Results

Y-COM OFFSET (S/S) (metres)

MDJ Weekly Arcs
Stella/Starlette: COM Results

Z-COM OFFSET (S/S) (metres)
Summary from Lageos Results

– All the CoM components vary with periods of approximately 40, 30 and 18 months as their dominant periods
– X-component has an additional period of 24 month period
– A 10 year period registers but not conclusive in a 14-year data set.
Conclusion

• 14 years of Lageos-1,-2 data and 10 years of Stella/Starlette data was processed and weekly CoM determined.

• Periodic motion of the CoM established.

• Next Steps:
  – Visualise the motion of the geocentre on the equatorial plane (XY or Azimuth) and elevation (z) so that some directional relationship can be established.
Conclusion

• Next Steps
  – Compute changes in moments of inertia $\Delta I_{xx}$, $\Delta I_{yy}$, $\Delta I_{zz}$ using the changes in the estimated gravity coefficients
  – Improve the Stella/Starlette solutions to see if there are any definitive “messages” in the data set
  – Torque