Impact of solar radiation pressure modeling on GNSS-derived geocenter motion

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EGU 2012, Vienna, Austria
Motivation

- **Z-component of GNSS-derived geocenter:**
  - Orbit-related frequencies
  - GPS draconitic year $\sim 351$ days or 1.04 cpy
  - GLONASS draconitic year $\sim 353$ days or 1.03 cpy
Motivation

- **GPS/GLONASS draconitic year:**
  - The repeat period of the Sun w.r.t the GPS/GLONASS constellation
  - Period of the Sun elevation angle above the orbital plane: $\beta_0$
Experiment

- Reprocessing of two multi-year GPS/GLONASS solutions
  DFG project “Geodätische und geodynamische Nutzung reprozessierter GPS-, GLONASS- und SLR-Daten”

- 7 years of GNSS data (GPS+GLONASS) reprocessed: 2004-2010
  ➔ Long time series are needed to identify anomalous frequencies

- Two different solar radiation pressure models:
  
  ➔ **CODE radiation pressure model** (widely used within the IGS)
    Beutler et al., 1994

  ➔ **Adjustable BOX-WING model**
    Adjustable box-wing model for solar radiation pressure impacting GPS satellites
    Advances in Space Research 49(7): 1113-1128
Solar radiation pressure models

- **CODE empirical model:**
  - 5 empirical acceleration parameters \([\text{m/s}^2]\) per day
  - constant in \(\text{DYB}\) directions and 1-per-rev periodic in \(\text{B}\) direction

\[
a = a_{\text{apri}} + a_D \cdot e_D + a_Y \cdot e_Y + a_B \cdot e_B
\]

\[
a_D = D_0
\]

\[
a_Y = Y_0
\]

\[
a_B = B_0 + B_c \cos(u) + B_s \sin(u)
\]

- 3 pseudo-stochastic pulses per day
  - radial
  - along-track
  - cross-track
Adjustable box-wing model

- Physical interaction between:
  Sun radiation + simple box-wing model

- Four main surfaces:
  - Solar panels front
  - Bus +X side
  - Bus +Z side
  - Bus –Z side
Adjustable box-wing model

- Physical interaction between:
  Sun radiation + simple box-wing model

- Four main surfaces:
  - Solar panels front
  - Bus +X side
  - Bus +Z side
  - Bus –Z side

- Model capable of fitting the GNSS tracking data
  → adjusting the optical properties of the satellite’s surfaces

- Additional parameters:
  - Solar panels rotation lag angle
  - Y-bias and pseudo-stochastic pulses (as CODE model)
Adjustable box-wing model - parameters

Solar Panels

Y-bias

Solar Panels Lag
Impact on geocenter

Geocenter X-component position

Position [mm]

Time [year]

2004 2005 2006 2007 2008 2009 2010 2011

X

Geocenter Y-component position

Position [mm]

Time [year]

2004 2005 2006 2007 2008 2009 2010 2011

Y

Geocenter Z-component position

Position [mm]

Time [year]

2004 2005 2006 2007 2008 2009 2010 2011

Z
Impact on geocenter

Geocenter X-component position

Position [mm]

2004 2005 2006 2007 2008 2009 2010 2011

X

Time [year]

Geocenter Y-component position

Position [mm]

2004 2005 2006 2007 2008 2009 2010 2011

Y

Time [year]

Geocenter Z-component position

Position [mm]

2004 2005 2006 2007 2008 2009 2010 2011

Z

Time [year]
Impact on geocenter

Geocenter X-component position

Position [mm]

Time [year]

2008

2009

Geocenter Y-component position

Position [mm]

Time [year]

2008

2009

Geocenter Z-component position

Position [mm]

Time [year]

2008

2009

CODE
BOXW

Institute for Astronomical and Physical Geodesy
Vienna, 26.04.2012

Institute for Planetary Geodesy
Impact on geocenter

- Power spectrum of geocenter: CODE
Impact on geocenter

- Power spectrum of geocenter: **BOX-WING**

![Graph showing power spectrum of geocenter](image)

- **Z-component power spectrum:**
  - Reduction of 1\textsuperscript{st}, 3\textsuperscript{rd} and 5\textsuperscript{th} peaks
  - Increase of 7\textsuperscript{th} peak
Correlation w.r.t. SRP parameters

- Correlation between geocenter Z-component and **CODE** model parameters (GPS)

![Graph](image)

2008
Correlation w.r.t. SRP parameters

- Correlation between geocenter Z-component and BOXW model parameters (GPS)
Geocenter formal errors

Geocenter X-component formal error

Geocenter Y-component formal error

Geocenter Z-component formal error

CODE BOXW
Impact on station coordinates

- GNSS daily position estimates, 266 ground stations (2004-2010)
  - UP-component
- Average power spectrum
- Negative sign of differences
  - reduction
- Difference of standard deviation
  - (between BOX-WING and CODE)
Conclusions

- Solar radiation pressure parameters are correlated with geocenter Z-component
  - CODE model: BS and BC parameters (once-per-rev in B direction)
  - BOX-WING model: reflection coefficients of +Z and –Z surfaces

- A more physical modeling of solar radiation pressure (BOX-WING)
  - can not only improve the GNSS orbits
  - but can also partially mitigate systematic errors in geodetic time series
    - in particular errors related to draconitic frequencies

- Most lines in the spectrum of draconitic harmonics in geocenter Z-component are reduced for the BOX-WING model with respect to the CODE model.