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

Carlos Rodriguez-Solano(1)

Urs Hugentobler(1)

Peter Steigenberger(1)

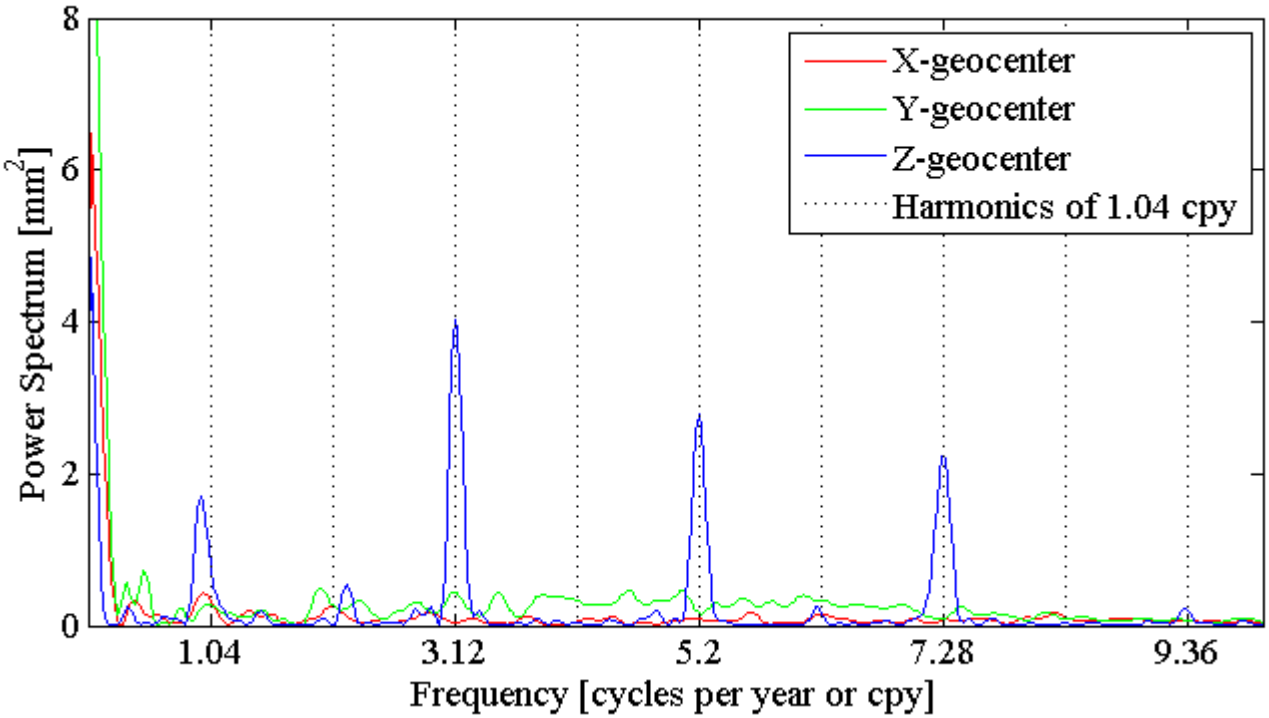
Mathias Fritsche(2)

(1)Institute for Astronomical and Physical Geodesy, TU München

(2)Institute for Planetary Geodesy, TU Dresden

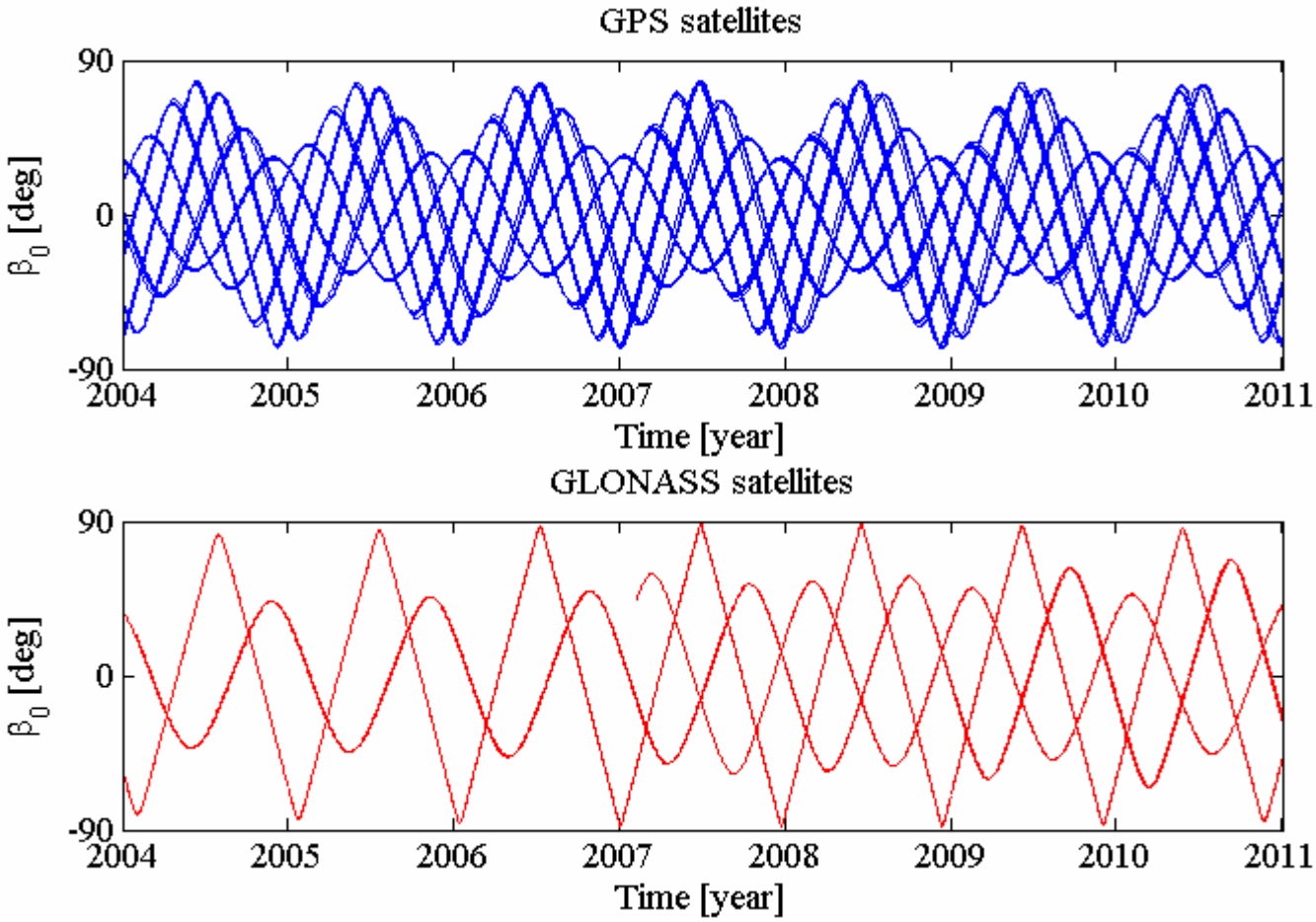
Motivation

- **Z-component of GNSS-derived geocenter:**
  - ➔ Orbit-related frequencies
  - ➔ GPS draconitic year ~ 351 days or 1.04 cpy
  - ➔ GLONASS draconitic year ~ 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: β_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:

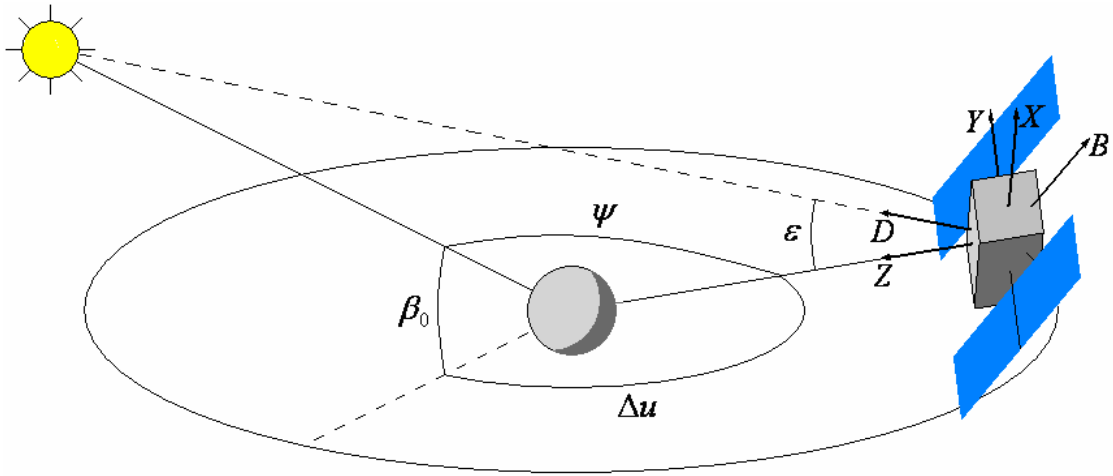
  ➔ **CODE radiation pressure model** (widely used within the IGS)
  Beutler et al., 1994

  ➔ **Adjustable BOX-WING model**

  Rodriguez-Solano CJ, Hugentobler U, Steigenberger P (2012)
  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 [m/s^2] per day
  - constant in **DYB** directions and 1-per-rev periodic in **B** direction



- 3 pseudo-stochastic pulses per day
  - radial
  - along-track
  - cross-track

$$\mathbf{a} = \mathbf{a}_{apri} + a_D \cdot \mathbf{e}_D + a_Y \cdot \mathbf{e}_Y + a_B \cdot \mathbf{e}_B$$

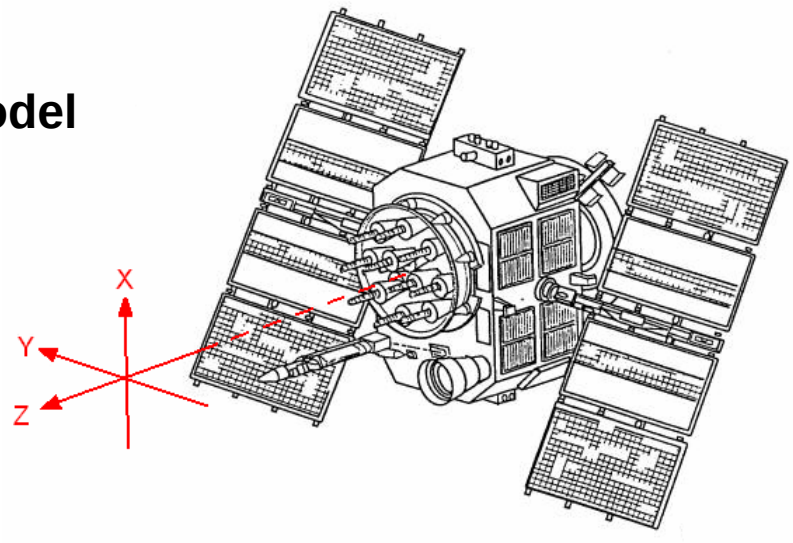
$$a_D = D_0$$
$$a_Y = Y_0$$
$$a_B = B_0 + B_c \cos(u) + B_s \sin(u)$$

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



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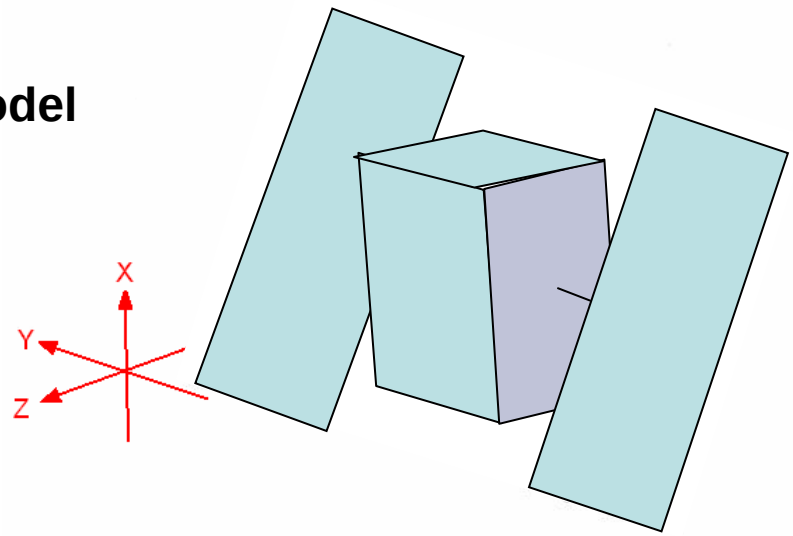


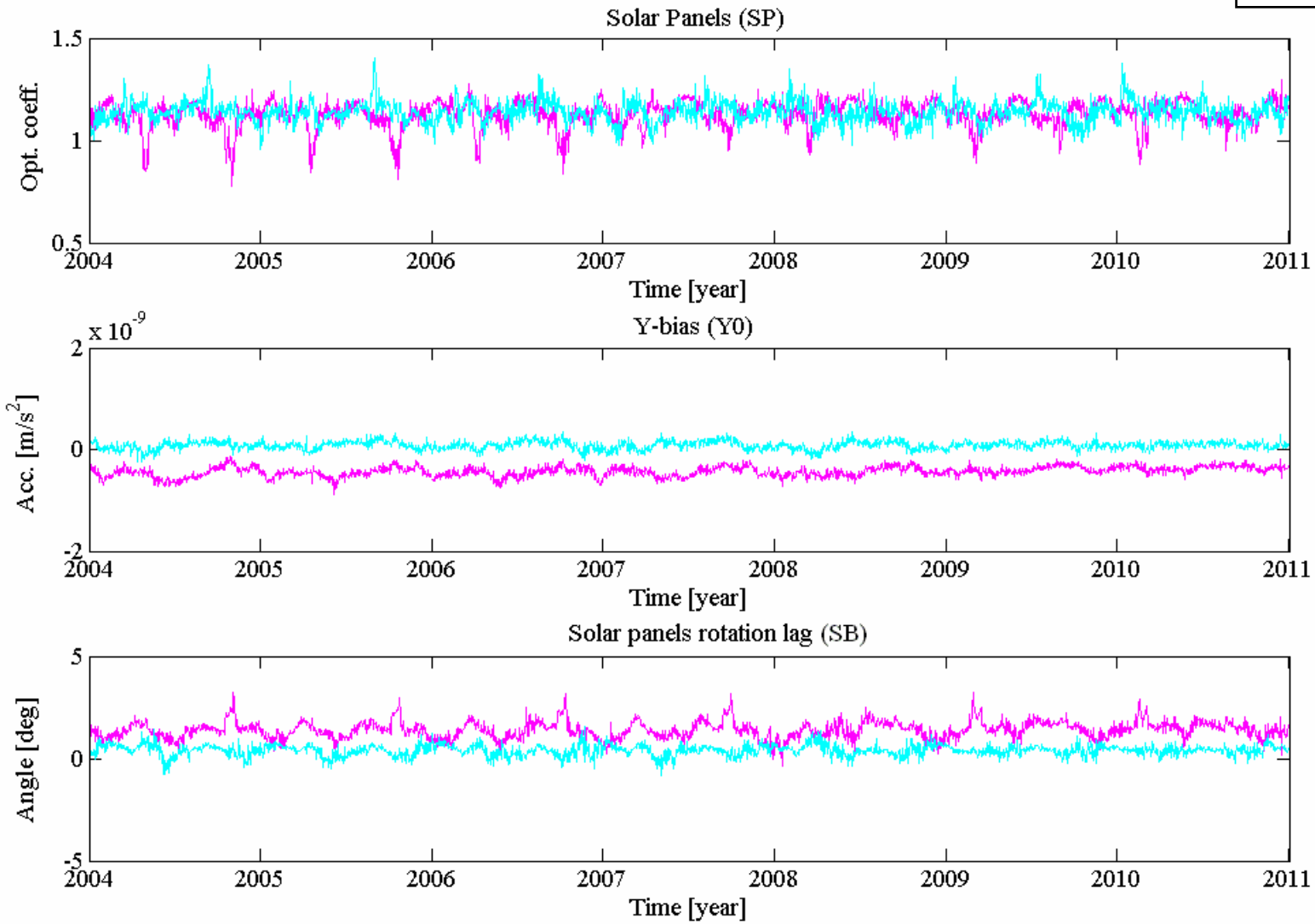
- Model capable of fitting the GNSS tracking data

  ➔ 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

GPS-IIA
GPS-IIR



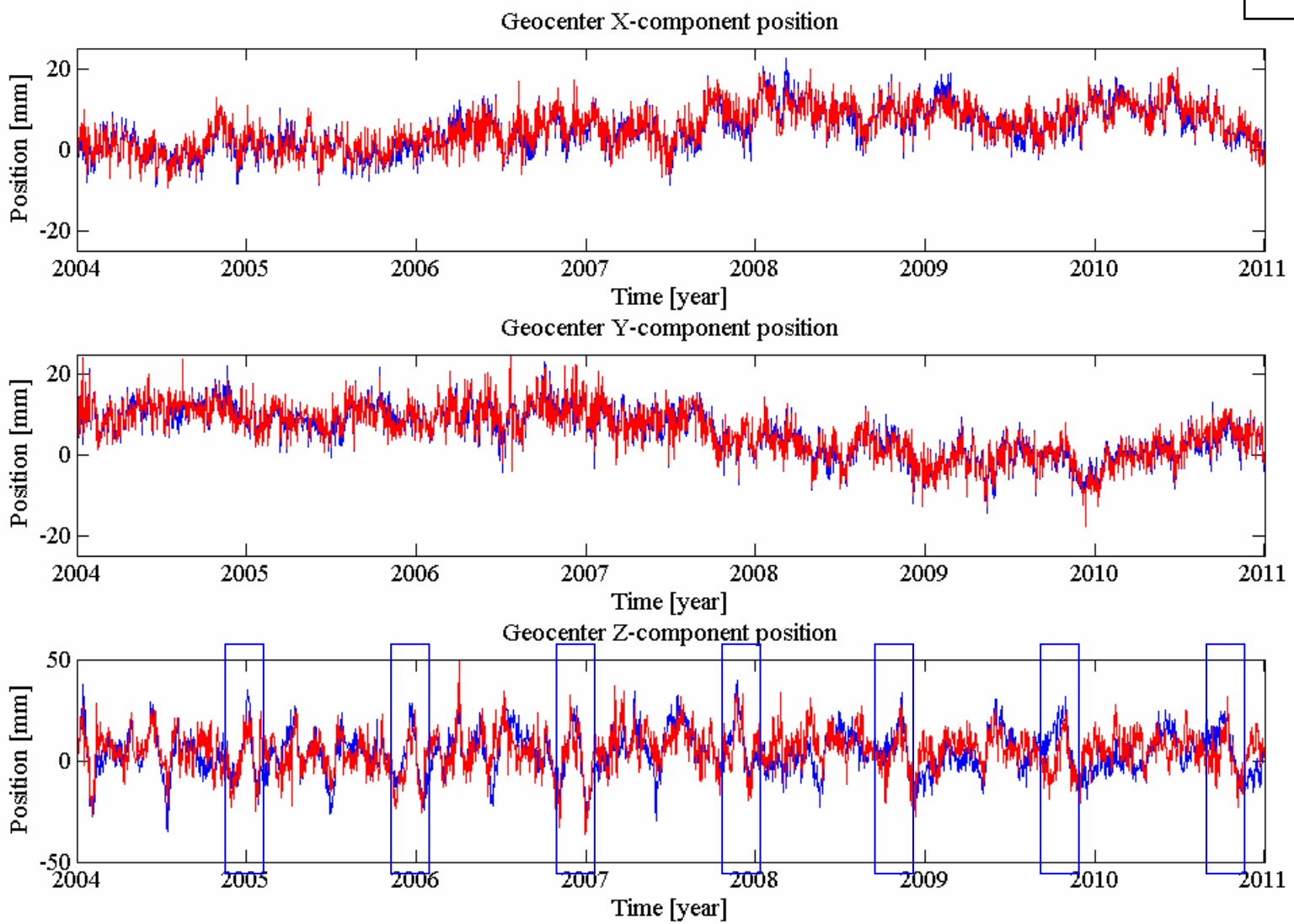
Solar Panels

Y-bias

Solar Panels Lag

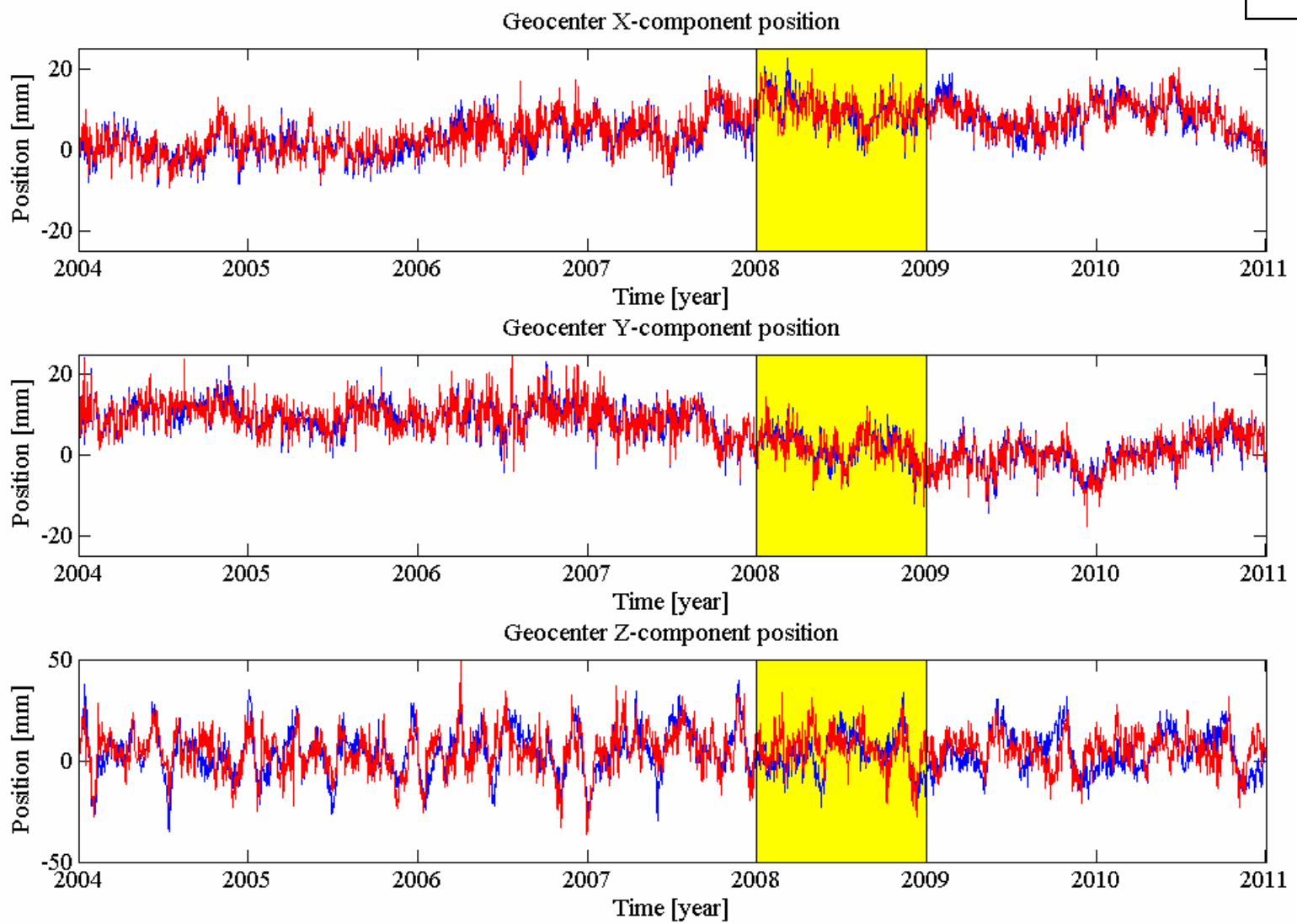
Impact on geocenter

CODE
BOXW



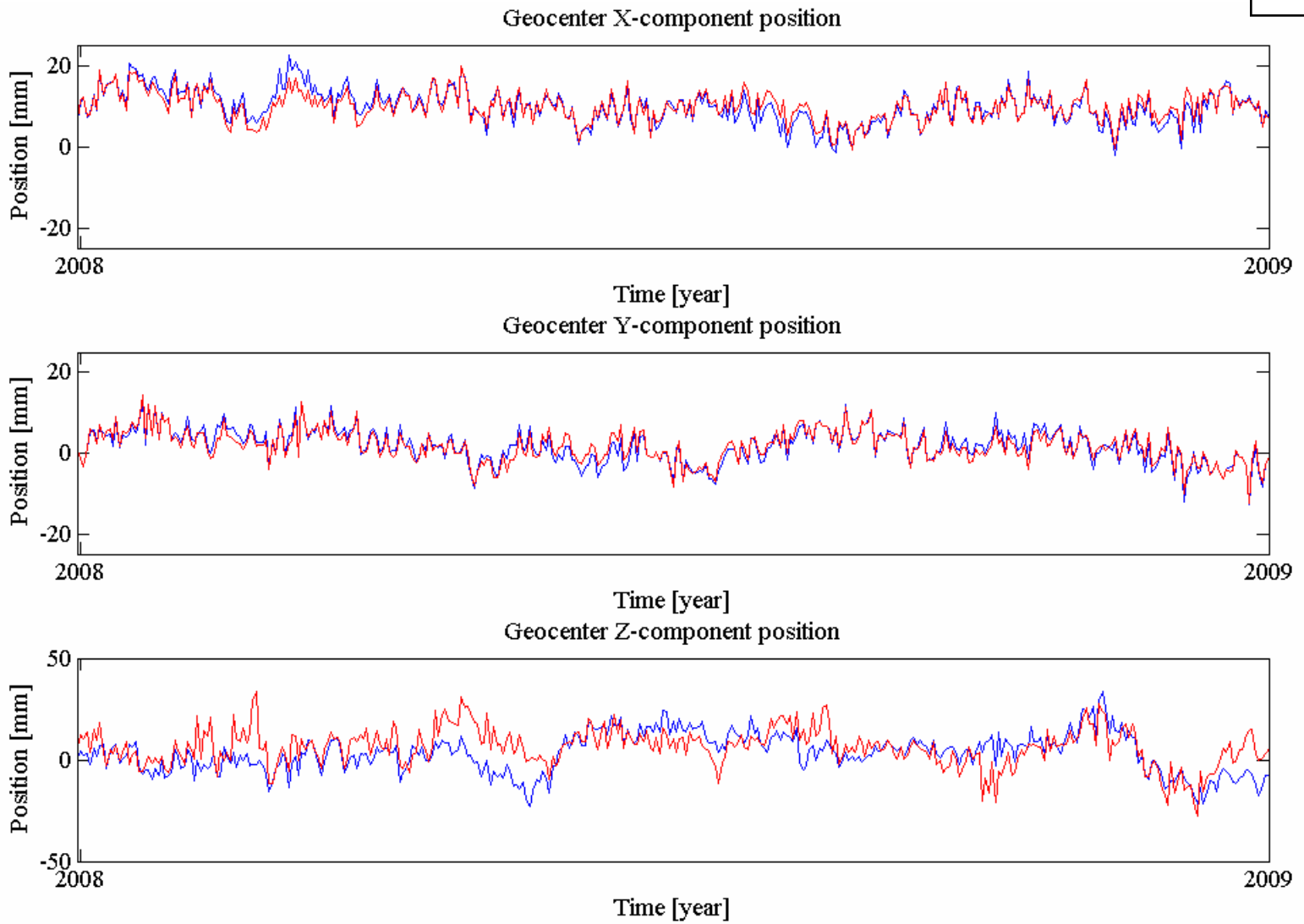
Impact on geocenter

CODE
BOXW



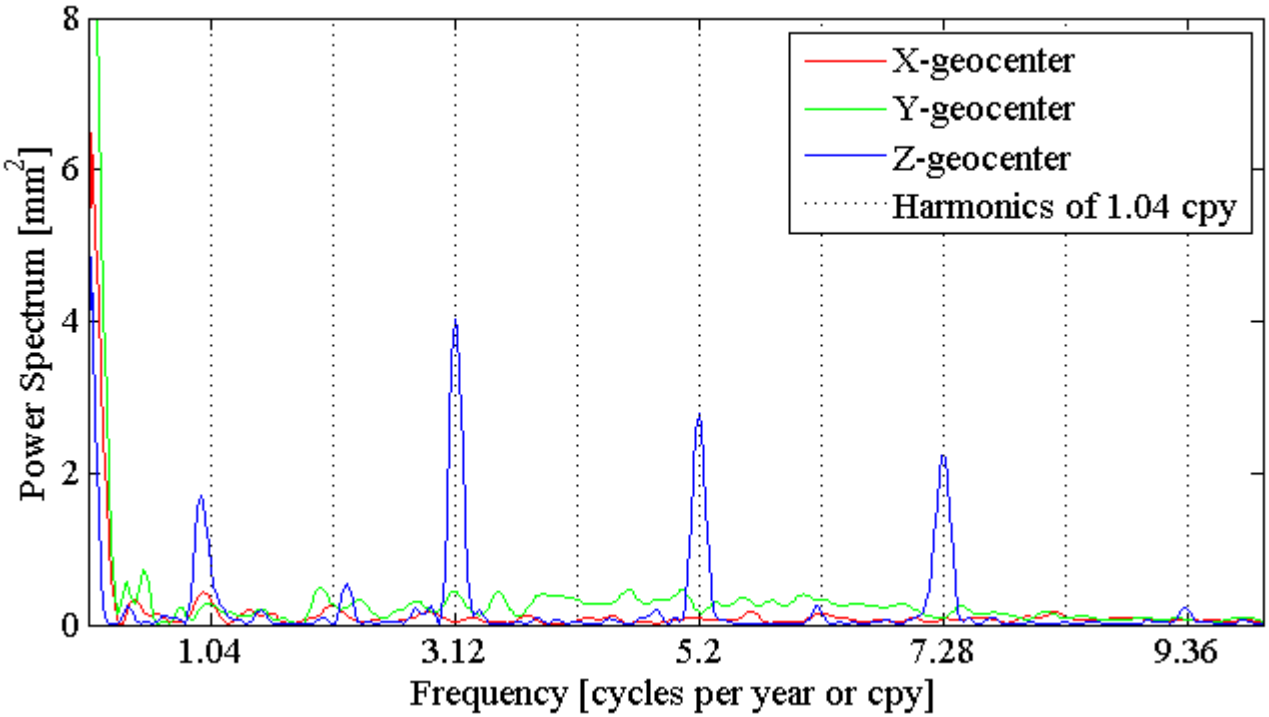
Impact on geocenter

CODE
BOXW



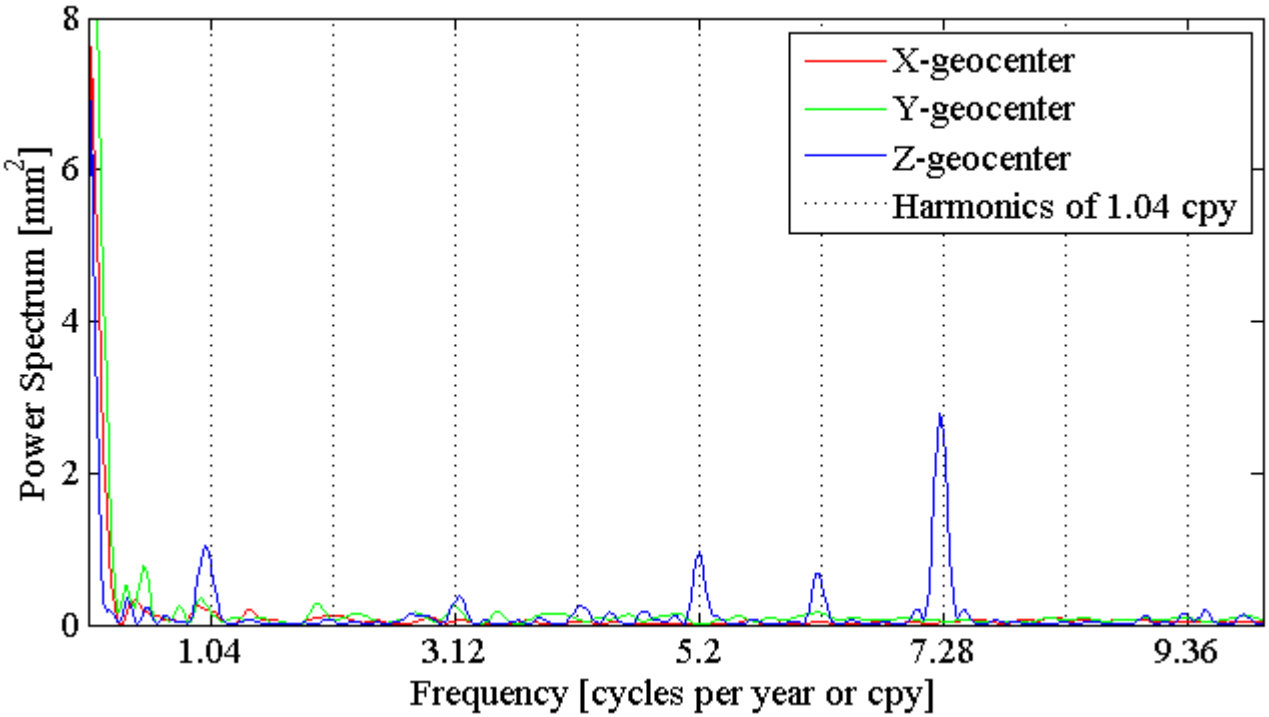
Impact on geocenter

- Power spectrum of geocenter: **CODE**



Impact on geocenter

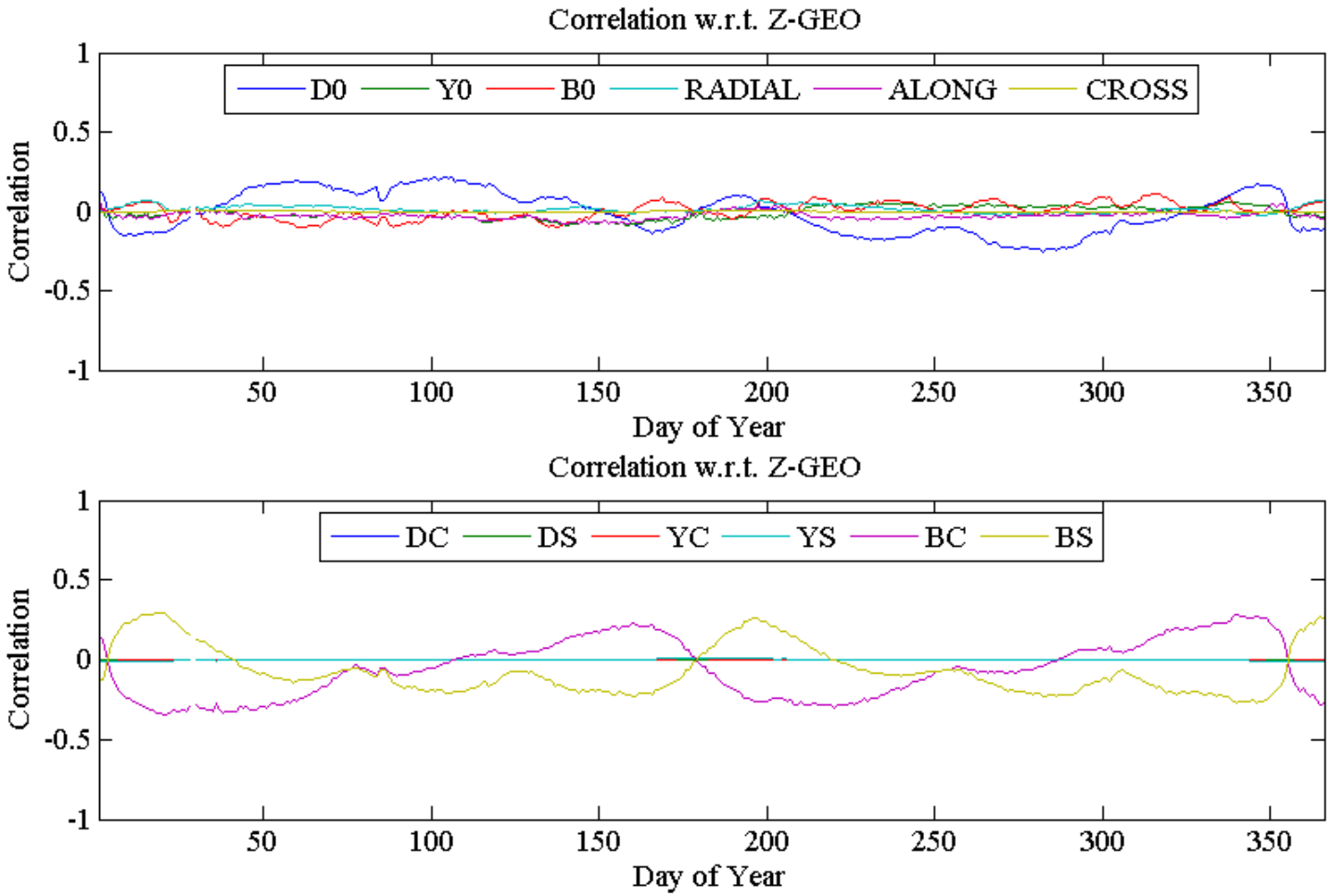
- Power spectrum of geocenter: **BOX-WING**



- Z-component power spectrum:
  - ➔Reduction of 1st, 3rd and 5th peaks
  - ➔Increase of 7th peak

Correlation w.r.t. SRP parameters

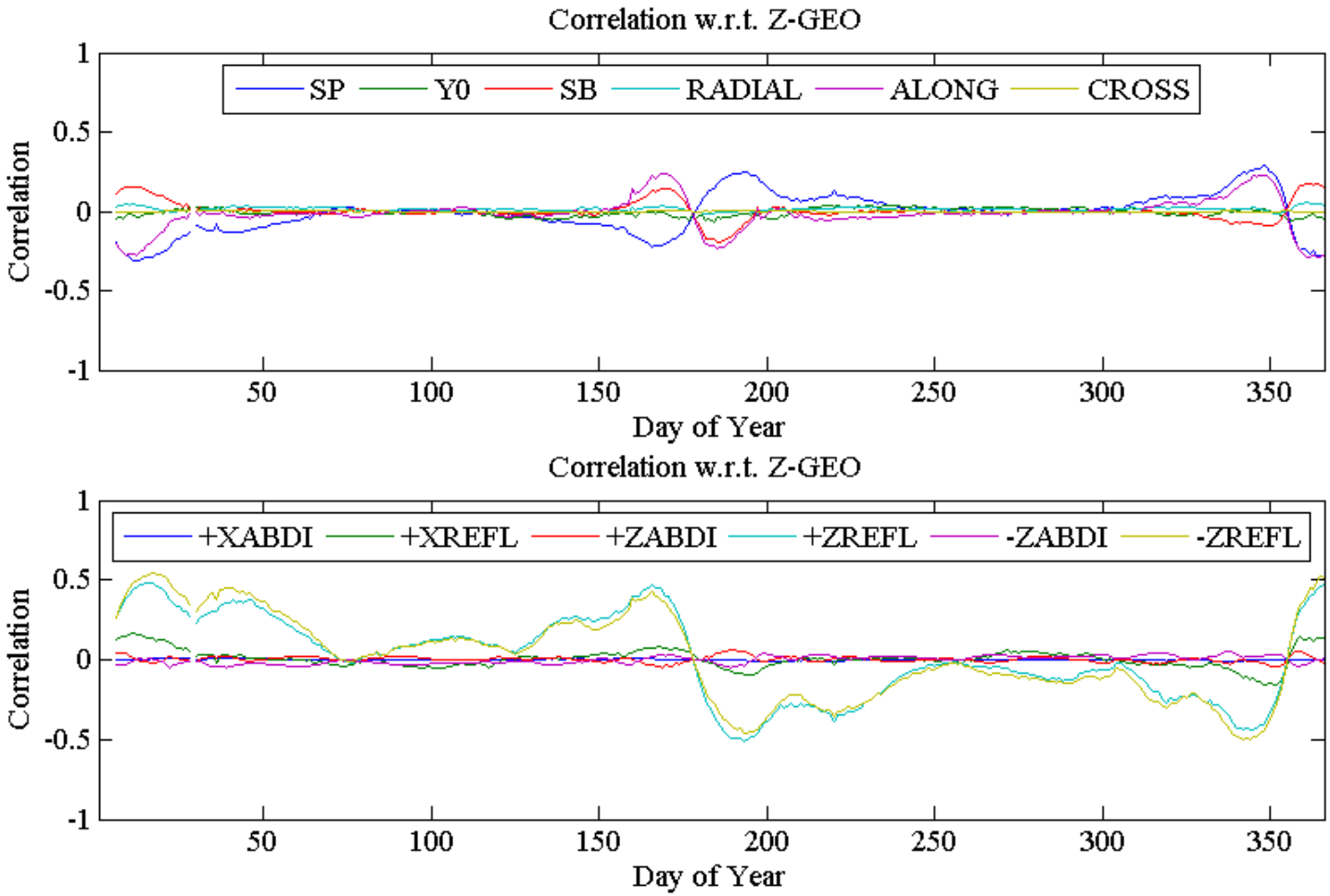
- Correlation between geocenter Z-component and **CODE** model parameters **(GPS)**



2008

Correlation w.r.t. SRP parameters

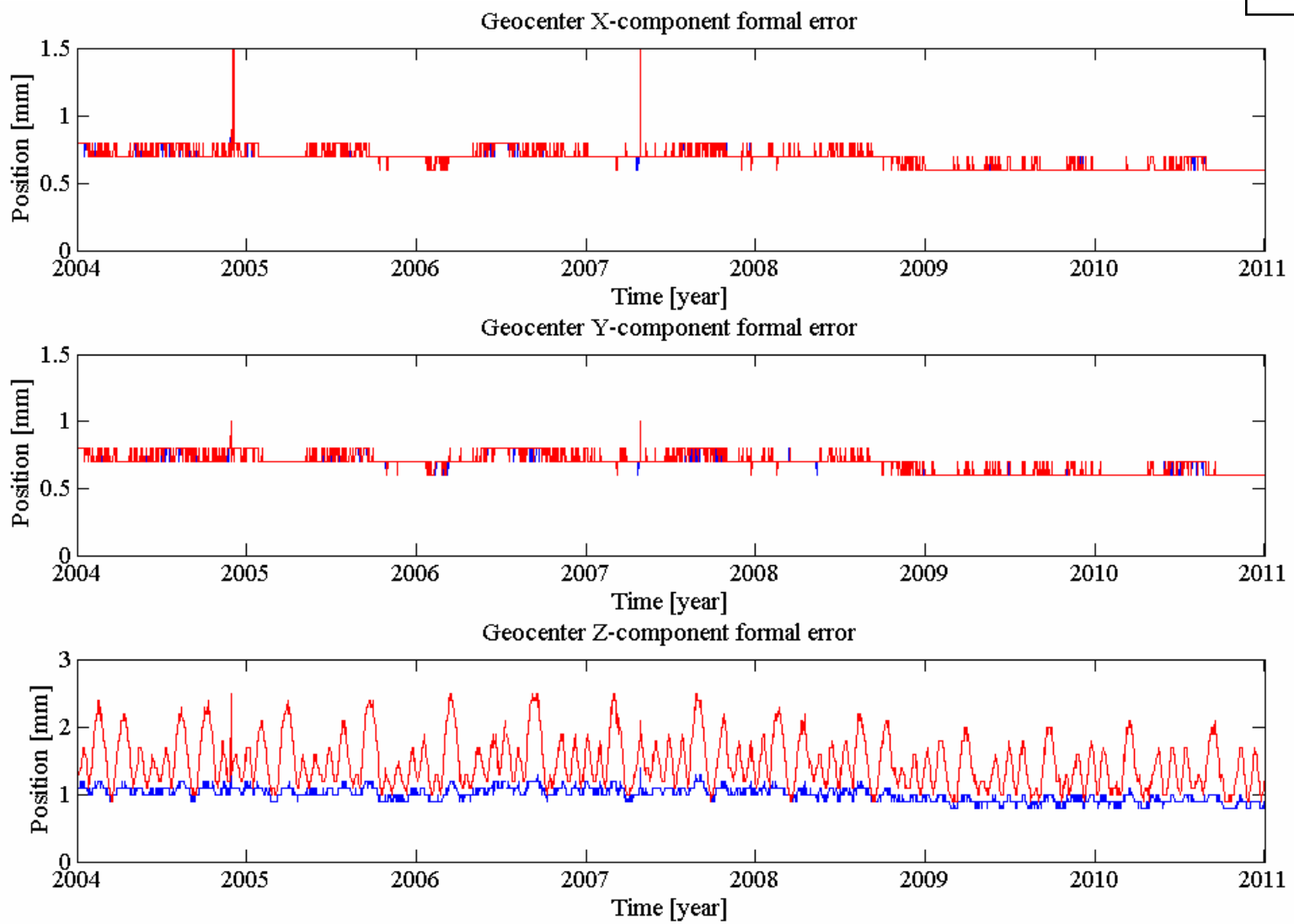
- Correlation between geocenter Z-component and **BOXW** model parameters **(GPS)**



2008

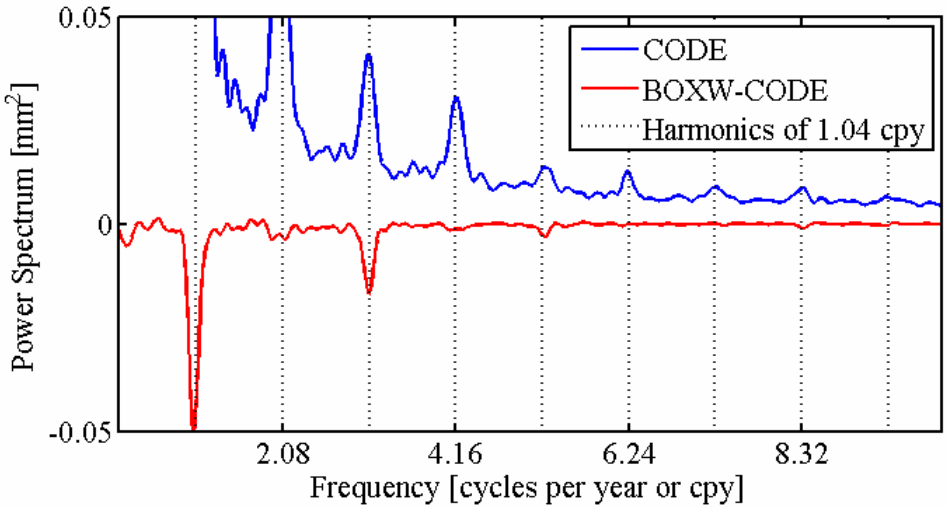
Geocenter formal errors

CODE
BOXW

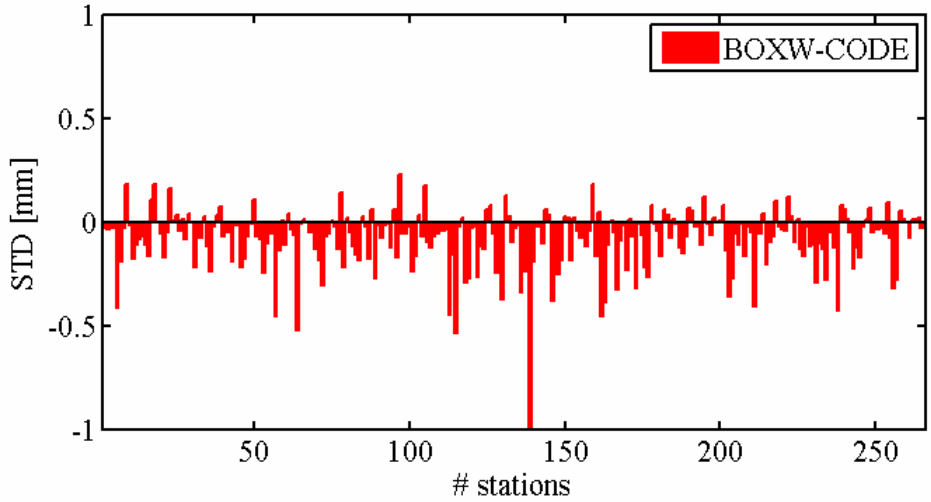


Impact on station coordinates

- 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.