Analysis effects in IGS station motion time series

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Background: expected signals

• IGS station position time series mainly consist of:
  
  – Trends + discontinuities

  ![Graph showing time series data]

  Ex: YAR2 (Australia) height time series

  – Seasonal variations, including:
    • Displacements due to mass transfers at the Earth’s surface (loading)
    • Thermal expansion of ground and monuments
    • Other local deformations
    • Artificial variations due to, e.g.,
      – Mis-modeling (orbits, troposphere...)
      – Observation data & data quality variations
      – Local multipath variations
Background: GPS draconitic year

• Period at which the GPS/sun orientation repeats

\[
\dot{\Omega} = -3\pi \frac{J_2}{T} \left( \frac{R_e}{a} \right)^2 \cdot \cos i = -14.1^\circ/\text{year}
\]

\[
T_R = \frac{2\pi}{2\pi - \dot{\Omega}_{\text{GPS}} \cdot 1 \text{ year}} \cdot 365.25 \text{ days} \approx 351.5 \text{ days}
\]

– Detected by Ray (2006) in IGS position time series
– Visible in nearly all IGS products

– Possible origins:
  • Aliasing of local site effects (multipath, antenna mis-calibration...)
  • Orbit errors (e.g. due to errors in IERS subdaily ERP tide model, Griffiths & Ray, 2011)
Goal: Investigate systematic errors in IGS station positions

1) Load-corrected IGS combined station positions
   - What is the contribution of draconitic errors?

2) Inter-AC discrepancies
   - Are there systematic AC-specific analysis artifacts?
   - How large are they compared to the IGS-load residuals?
IGS positions & loading model: Data

• **GPS position time series:**
  – (Special) combination of AC repro1/operational weekly SINEX solutions
  – Time series segmentation
  – Corrections for offsets, velocities & apparent geocenter motion

• **Non-tidal loading model:**
  – Green’s function approach
  – Earth model: Gutenberg-Bullen
  – Reference Frame: Center of Figure (CF) of the Earth (*Blewitt, 2003*)
IGS positions & loading model: Comparison

- Conclusions from Collilieux et al., 2011 and Ray et al., 2011:
  - Load corrections reduce WRMS for most stations, even in horizontal.
    (Mostly due to reduction of annual signals.)

- But most residual signal remains, especially in horizontal.
  - Inaccuracy of loading models
  - Thermal + local deformations
  - GPS errors

- Draconitic errors must contribute to remaining annual signals, but magnitude is unknown.
Load-corrected IGS positions: annual or draconitic?

- **Simultaneous estimation of annual & draconitic:**
  - Possible with long enough time series (beat period ≈ 25 years)
    cf. *Watson et al., UGGI 2011 & Haines et al., AGU 2011*
  - But hypothesis of time-variable annual signal plausible as well.

**Draconitic amplitudes: load-corrected GPS series vs. raw GPS series**
(records longer than 3 years)

- Estimated draconitic signals seem reliable.
Load-corrected IGS positions: annual or draconitic?

- **Annual estimated alone:**

  ![Annual amplitudes in raw and load-corrected GPS](image)

  **Amplitudes (mm):**
  - Red: Annual in raw GPS
  - Black: Annual in load-corrected GPS

- **Annual & draconitic estimated simultaneously:**

  ![Annual and draconitic amplitudes in load-corrected GPS](image)

  **Amplitudes (mm):**
  - Pink: Annual in load-corrected GPS
  - Blue: Draconitic in load-corrected GPS

→ Simultaneous estimation of annual & draconitic does not significantly improve the agreement between GPS and loading models at the annual frequency.

→ Residual annual & draconitic signals have similar magnitudes.
Load-corrected IGS positions: annual/draconitic

Annual – East

Annual – North

Annual – Up

Draconitic – East

Draconitic – North

Draconitic – Up
Load-corrected IGS positions: semi-annual/2\textsuperscript{nd} draconitic

Semi-annual – East

Semi-annual – North

Semi-annual – Up

2\textsuperscript{nd} draconitic – East

2\textsuperscript{nd} draconitic – North

2\textsuperscript{nd} draconitic – Up
Inter-AC discrepancies

- Are there systematic AC-specific analysis artifacts?
- How large are they compared to the IGS-load residuals?

→ Investigate residuals of the weekly SINEX combinations
  = differences between AC and IGS weekly station positions

Geophysical signals should cancel out, leaving analysis related effects:

- Differences in data modeling/selection/weighting
- Metadata errors
- Different impacts of common modeling errors (e.g. antenna mis-calibrations, sub-daily EOPs)
Inter-AC discrepancies: VENE

Seasonal signals

Large offsets before ant+rec change
Inter-AC discrepancies: MCM4

Offsets due to analysis changes

Non constant seasonal amplitude

Offsets
Inter-AC discrepancies: MALI

East

North

Up


cod
emr
esa
gfz
gt1
jpl
mit
ngs
pd1
sio
ul1

cod
emr
esa
gfz
gt1
jpl
mit
ngs
pd1
sio
ul1

2nd draconitic harmonic

Apparent drifts (or offsets?)
Inter-AC discrepancies: SANT (co-located)

≈ constant AC-specific biases
Inter-AC discrepancies: Earthquakes

Are there differences between AC co-seismic offset estimates?

CONZ: IGS weekly combined positions

CONZ: weekly combination residuals (AC – igs)

See poster by Lercier et al.
Inter-AC discrepancies: Spectra

Stacked periodograms (stations present more than 75% over 2000.0 – 2012.5)

Unexpected peaks at 27.55d & 14.4d

Bump near 14d
Inter-AC discrepancies: Ocean tidal loading

- Peaks at 27.55d & 14.4d probably explained by an error in the version of hardisp.f distributed in 2006 (Agnew, 2008)

- Corrected version used at CODE since week 1529:

- Stacked periodograms of CODE Up residuals:
  - before week 1529
  - after week 1529

- Older version still in use at ESA?
Inter-AC discrepancies: Annual - Up
Inter-AC discrepancies: 1\(^{st}\) draconitic - Up
Inter-AC discrepancies: Semi-annual - Up
Inter-AC discrepancies: 2\textsuperscript{nd} draconitic - Up

COD  EMR  ESA  GFZ  IGS

GFZ  IGS-load  JPL

MIT  NGS  SIO
Conclusions (1/2)

• **Load-corrected IGS positions:**
  - Simultaneous estimation of annual & draconitic does not significantly improve the agreement between GPS and loading model at the annual frequency.
  - Residual annual & draconitic signals have similar magnitudes.
  - Spatial coherence of draconitic errors suggests major orbit-related source. (e.g., due to errors in IERS subdaily ERP tide model)

• **Inter-AC discrepancies:**
  - A lot can be learnt from the weekly combination residual time series.
  - Deeper investigation needed to understand biases and offsets, especially at co-location sites!
  - Two-step combination planned for repro2:
    1. Combination
    2. Investigation of residual time series; Exclusion of aberrant AC positions; 2nd combination
Conclusions (2/2)

• Inter-AC discrepancies (continued):

  – Spectral analysis reveals AC specificities:
    • hardisp.f problem
    • Large 2\textsuperscript{nd} draconitic signals in NGS residuals, with strong spatial coherence (?)
    • JPL residuals often the largest at other frequencies, with less spatial coherence.
      (modeling difference at the station level?)

  – Inter-AC discrepancies globally smaller than IGS-load residuals, at all frequencies.

→ Common modeling errors (and/or loading model errors) predominant over AC specificities.
Additional slides
Inter-AC discrepancies: Annual - Up

COD                    EMR                    ESA
GFZ                   IGS

JPL

IGS workshop 2012, Olsztyn, Poland 26

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MIT                    NGS                    SIO
Inter-AC discrepancies: $1^{st}$ draconitic - Up
Inter-AC discrepancies: Annual - North
Inter-AC discrepancies: 1\textsuperscript{st} draconitic - North
Inter-AC discrepancies: Annual - East
Inter-AC discrepancies: 1st draconitic - East
Inter-AC discrepancies: Semi-annual - Up
Inter-AC discrepancies: 2\textsuperscript{nd} draconitic - Up
Inter-AC discrepancies: Semi-annual - North
Inter-AC discrepancies: 2nd draconitic - North
Inter-AC discrepancies: 2\textsuperscript{nd} draconitic - East