Investigation of draconitic errors in IGS second reprocessed products at WHU

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Outline

- Background
- Data processing strategy
- Effect of ambiguity fixing
- Draconitic errors in subdaily solution
- Latitude-dependent characteristic
- Summary
GPS draconitic year errors
- Systematic errors at harmonics of the GPS draconitic year (351.2 days/k, k=1, 2......n., Ray et al, 2008), pervasive in all GPS products

Magnitude and effect
- Velocity: 0.2mm/yr (Santamarí-Gómez et al., 2011)
- Position: 3, 3.2 and 6.5 mm for NEU (Amiri-Simkooei, 2003)
- Difficult to be precisely separated from seasonal variations

Two possible mechanisms
- Long-period GPS satellite orbit modeling errors
e.g. Solar radiation pressure
- Aliasing of subdaily errors with standard 24h data processing e.g. Multipath errors, subdaily EOP tide model, S1-S2 etc.
Subdaily aliasing: \( f_a = |f - Nf_s|, f_s < 2f \)

- **Aliasing Signal** \( T_a = 96.0 \text{ h} \)
- **Sampling** \( T_s = 24.0 \text{ h} \)
- **Origin Signal** \( T_0 = 19.2 \text{ h} \)

Subdaily solution adopted:
- 8h: **diurnal signals** aliasing prevented
- 4h: **diurnal and semidiurnal signals** aliasing prevented
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Data processing strategy

- Raw observation processing
  - Network & data: 143 IGS14 RF stations, 2001~2015
  - Processing mode: PPP by PANDA software
  - Processing sessions: 24 hours, 8 hours, 4 hours
  - Precise orbit & clock products: ES2
  - Ocean tide: FES2004 in CF frame
  - EOP: IERS C04

- Time series analysis
  - Aligned to IGS14 frame
  - Remove linear velocity, offset and seasonal signals
  - Power spectra analysis by stacking all stations residuals

Fig 1. Distribution of stations
Fig 2. Stacked spectra of coordinate residuals time series
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Drac harmonics (N\times1.04 cpy)
Fig 2. Stacked spectra of coordinate residuals time series
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7.8 day periods (GLONASS-related)
Fig 2. Stacked spectra of coordinate residuals time series

Diurnal and semi-diurnal signals
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Spectra of amb-free solution

### Tab 1. Power reduction compared to 24 hour solution

<table>
<thead>
<tr>
<th>Freq /cpy</th>
<th>8hour North</th>
<th>8hour East</th>
<th>8hour Up</th>
<th>4hour North</th>
<th>4hour East</th>
<th>4hour Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.04</td>
<td>26.4%</td>
<td>31.5%</td>
<td>15.3%</td>
<td>25.1%</td>
<td>47.1%</td>
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<tr>
<td>2.08</td>
<td>26.1%</td>
<td>29.9%</td>
<td>18.5%</td>
<td>26.6%</td>
<td>-2.6%</td>
<td>28.4%</td>
</tr>
<tr>
<td>3.12</td>
<td>-4.4%</td>
<td>18.5%</td>
<td>9.5%</td>
<td>11.9%</td>
<td>43.4%</td>
<td>21.4%</td>
</tr>
<tr>
<td>4.16</td>
<td>5.7%</td>
<td>33.7%</td>
<td>21.1%</td>
<td>7.3%</td>
<td>34.1%</td>
<td>11.5%</td>
</tr>
<tr>
<td>5.20</td>
<td>21.3%</td>
<td>31.1%</td>
<td>18.9%</td>
<td>27.9%</td>
<td>23.2%</td>
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</tr>
<tr>
<td>6.24</td>
<td>43.3%</td>
<td>32.9%</td>
<td>37.1%</td>
<td>53.3%</td>
<td>-21.7%</td>
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</tr>
<tr>
<td>7.28</td>
<td>30.1%</td>
<td>37.9%</td>
<td>35.5%</td>
<td>40.4%</td>
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<td>9.36</td>
<td>3.7%</td>
<td>10.1%</td>
<td>20.7%</td>
<td>21.3%</td>
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<tr>
<td>average</td>
<td>18.9%</td>
<td>27.5%</td>
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- **Power reduction (8h/4h vs 24h):** 20%~30% in NEU

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**Fig 3. Draconitic harmonics without ambiguity fixing**
Amb-flee vs. amb-fixed

- Ambiguity fixing could reduce drac errors in 24h/8h/4h solutions, especially for East (50%~60%)

Tab 2. Reduction of RMS and power of amb-fixed solutions compared with amb-free solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>RMS/mm (Free/Fixed)</th>
<th>RMS reduction</th>
<th>Power reduction</th>
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<tbody>
<tr>
<td></td>
<td>North</td>
<td>East</td>
<td>Up</td>
</tr>
<tr>
<td>24h</td>
<td>2.7/2.5</td>
<td>3.9/2.7</td>
<td>6.7/6.4</td>
</tr>
<tr>
<td>08h</td>
<td>4.0/3.7</td>
<td>6.3/4.5</td>
<td>9.9/9.3</td>
</tr>
<tr>
<td>04h</td>
<td>5.1/4.5</td>
<td>8.8/6.3</td>
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<td>24.4%</td>
<td>31.3%</td>
<td>4.3%</td>
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- **Power reduction (4h vs 24h):** 31%, 4%, 30% in N, E, U
- **Power reduction (8h vs 24h):** 18%, 0%, 24% in N, E, U

Fig 5. Draconitic harmonics with amb-fixed
Combined daily solution

- Combined 24h sol. compared with 24h sol.:
  - WRMS is at the same level
  - Drac. errors are reduced by 19%, -25%, 16% in N,E,U
  - Amb-fixing strategy for 4h solution need to be improved for better East

Fig 7. WRMS of 24h, combined 24h and 4h solution
Combined 24h VS standard 24h sol.

Fig 7. CEDU station@Australia

Fig 8. DRAO station@Canada
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Latitude-dependent characteristic

Station partition

<table>
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<tr>
<th>Latitude range</th>
<th>Station number</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30~30</td>
<td>29</td>
</tr>
<tr>
<td>-38<del>30, 30</del>38</td>
<td>30</td>
</tr>
<tr>
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<td>27</td>
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<tr>
<td>-60<del>45, 45</del>60</td>
<td>34</td>
</tr>
<tr>
<td>-90<del>60, 60</del>90</td>
<td>23</td>
</tr>
</tbody>
</table>

- Stations located in low latitudes show more powerful drac signals
  (Tregoning and Watson 2009, 2011)

Fig 9. Stacked spectra of 24h amb-fixed solution for stations located in different latitude ranges
Lat-dependent characteristic (Up)

- Power reduction show lat-dependence characteristic
- Multipath is excluded

Fig 10. Power of draconitic signals in the Up component of amb-fixed solutions
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Summary

- Subdaily solution can reduce drac errors: by 20~30% for NU components of 4h-solution compared to standard 24h-solution
- Amb-fixing can reduce drac errors, but the reduction degraded with shorter the processing session, especially for East
- Except for East, the new 24h-solution combined by 4h-solution show reduced drac errors, and the precision is at the same level of standard 24h solution
- Lat-dependent subdaily errors may be one potential origin of drac error, so multipath errors is excluded
Thanks for your attention!
Orbit spectra

[Graph showing power spectra for different coordinates (Along, Cross, Radial) with various data points and frequency ranges.]
GFZ spectra

GPS draconitic harmonics

North

East

Up

Power Spectrum [mm²]

Frequency [cpy]

GFZ 24h  GFZ 8h  GFZ 4h
Lat-dependent characteristic — North

**Fig 10.** Power of draconitic signals in the North component of amb-fixed solution

- **Power reduction (4h vs 24h):** show lat-dependent characteristic
Lat-dependent characteristic — East

Fig 11. Power of draconitic signals in the East component of amb-fixed solution

- Power reduction (4h vs 24h): show lat-dependent characteristic
- Multipath error is excluded (station-related error)