Investigation of high frequency EOP variations
Recent results and future prospects of the SPEED project

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Statusseminar DFG Forschergruppe FOR584
TU München, 29–30 October, 2009
Introduction

- Continuous VLBI campaigns – like CONT02, CONT05, and CONT08 – provide good data sets for studying high frequency variations in the Earth Rotation Parameters.
- A new VLBI processing software is being developed in Vienna: VieVS (Vienna VLBI Software).
- Goal of this work:
  - Evaluate the performance of VieVS for estimation of high frequency Earth rotation.
  - Investigate high frequency Earth rotation variations for the recent CONT08 campaign, as well as the previous campaigns CONT05 and CONT02.
VieVS – Vienna VLBI Software

- New geodetic VLBI processing software written in Matlab.
- Classical least squares adjustment.
- Parameters estimated as piecewise linear functions offsets at integer hours.
- Implement the latest IERS Conventions and models.
- OCCAM software used as a guideline.
Data Processing

- Polar motion, UT1-UTC, and nutation modelled as piecewise linear functions in one hour intervals.
- Stacking of parameters (EOPs, zenith wet delays and gradients) at session boundaries.
- Blocking of retrograde polar motion with periods between 16 and 48 hours, and of nutations with periods <2 days.
- One set of coordinates estimated for each CONT campaign. No Net Translation/Rotation w.r.t. VTRF2005 coordinates.
- Source coordinates fixed to ICRF2.
CONT08 Polar Motion Estimates

- Polar Motion estimates from VieVS
- IERS 05 C04 series plus IERS recommended model for high frequency ERP variations.
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- VLBI solution Calc/Solve (from T. Artz, Uni. Bonn)
**CONT08 Polar Motion Estimates**

- **Polar Motion estimates from VieVS**
- **IERS 05 C04** series plus IERS recommended model for high frequency ERP variations.
- **VLBI solution Calc/Solve** (from T. Artz, Uni. Bonn)
- **GPS solution** (*P. Steigenberger et al., JGR, (2006)*)
CONT08 DUT1 and Length Of Day Estimates

- UT1-UTC estimated from VLBI (VieVS and Calc/Solve).
- Length of Day estimated from VLBI (VieVS and Calc/Solve) and from GPS.
CONT08 Nutation Estimates

- Nutation estimated from VLBI (VieVS).
- Nutation from IERS 05 C04 series.
CONT08 Residual Polar Motion Estimates

- Polar Motion from VLBI (VieVS and Calc/Solve) and GPS minus IERS 05 C04 and high frequency ERP model.
CONT08 Residual Polar Motion Estimates

- Polar Motion from VLBI (VieVS and Calc/Solve) and GPS minus IERS 05 C04 and high frequency ERP model.
- X-pole offset between GPS and VLBI probably due to different datums.
- Offset decreases (by 140 \(\mu\)as) if ITRF2005 coordinates are used in VieVS solution instead of VTRF2005.
CONT08 Residual DUT1 and LOD Estimates

- Good agreement in DUT1 between the two VLBI solutions.
- LOD from VLBI is noisier than LOD from GPS. (VLBI LOD calculated from the time derivatives of the DUT1 estimates.)
CONT08 Polar Motion Spectrum

- Fourier spectrum of polar motion residuals.
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- peak at +24 h.
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- Peak at +24 h.
- Peak at +12 h for VLBI.
CONT08 Polar Motion Spectrum

- Fourier spectrum of polar motion residuals.
- Peak at $+24$ h.
- Peak at $+12$ h for VLBI.
- Peak at $-12$ h for GPS.
CONT08 Polar Motion Spectrum

- Fourier spectrum of polar motion residuals.
- Peak at +24 h.
- Peak at +12 h for VLBI.
- Peak at -12 h for GPS.
- Small peaks at +6 h (VLBI) and +8 h (GPS).
CONT08 DUT1 and LOD Spectra

- Fourier spectra of DUT1 and LOD residuals.
CONT08 DUT1 and LOD Spectra

- Fourier spectra of DUT1 and LOD residuals.
- Peaks at 12 h and 24 h.
# Unexplained Signals in the CONT Polar Motion

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<thead>
<tr>
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<th>Cont08 EOP</th>
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All solutions have a peak at 24 h prograde.
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Almost always 12 h retrograde signal.
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**CONT02:** 8 h retrograde signal.
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GPS: always a prograde 8 h signal.
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LOD: Peaks at 12 h and 24 h.
Atmospheric Angular Momentum

- There are peaks at $\pm 24$ h, $\pm 12$ h, and sometimes also at $\pm 8$ h in the Earth rotation spectra.

- Possible reasons:
  - Inaccurate ocean tidal model for high frequency Earth rotation variations.
  - Atmospheric excitation of Earth rotation.
  - Excitation of Earth rotation by other sources.
  - Artefacts from the processing of the VLBI/GPS data.
Atmospheric Angular Momentum

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Atmospheric Angular Momentum for CONT08

- Excitation functions for the CONT08 period calculated from ECMWF data.
- Resolution 6 hours.
- For \( \chi_3 \), the mass and motion terms seems to counteract each other (see also Diploma Thesis by M. Schindeleggger, TU Wien, 2009).
Spectra of the expected ERP variations due to atmospheric angular momentum variations.
• Spectra of the expected ERP variations due to atmospheric angular momentum variations.
• Amplitudes small compared to those observed with VLBI.
Combination of EOP time-series

- Several different techniques exist to measure high frequency Earth rotation (VLBI, GPS, ringlasers etc.). All have their advantages and disadvantages.
- To obtain the highest accuracy, the results from different techniques should be combined.
- Kalman filtering has proven to be a useful technique for combining daily estimates of ERPs.
- One goal of the second phase of the SPEED project is to develop a Kalman filter for combining high frequency EOPs from different techniques.
Combination of ERPs for CONT08

- Combination of VLBI and GPS results using a Kalman filter (following Morabito et al. (1988), with some modifications).
- Kalman filter polar motion estimate close to GPS since the GPS formal errors are smaller than those from VLBI.
• Potential interesting source of high frequency Earth rotation data: Ring laser gyroscopes.
• Sensitive to the Instantaneous Earth Rotation Pole (IRP). I.e. sensitive to a combination of the polar motion and nutation rate of the Celestial Intermediate Pole (CIP).
• Left: Example of ringlaser measurements from Wettzell, compared to the expected high frequency IRP effects.
Future work

- Attempt to include ringlaser data in Kalman filter.
- Include estimation of nutation in the Kalman filter (ringlasers are sensitive to the nutation of the CIP as well as polar motion).
- Investigate the effect of systematic errors in the input data, and how to mitigate them.
- Improve the filter by e.g. using more realistic stochastic processes for the polar motion excitation functions.
Conclusions

- The Earth Rotation Parameters estimated from VieVS agree well with those estimated by Calc/Solve.
- Signals in the spectra of polar motion residuals with periods of $+24\,\text{h}$, $\pm 12\,\text{h}$, $+8\,\text{h}$ (GPS), and $-8\,\text{h}$ (in CONT02).
- Signals in LOD (and DUT1) at $24\,\text{h}$ and $12\,\text{h}$.
- The contribution from the atmosphere to the sub-diurnal Earth rotation variations is a magnitude lower than the observed variations.
- Diurnal and semi-diurnal signals probably due to incorrect ocean tidal models.
- More accurate time-series of Earth rotation can be obtained by combing results from several techniques using a Kalman filter. Further work is needed in order to optimize the Kalman filter for retrieval of high frequency EOP.
Danke für Ihre Aufmerksamkeit!
Ringlaser data

- Spectrum of the ringlaser measurements (after tilt correction).
- Compared to what is expected from Earth rotation variations.
Ringlaser data

- Spectrum of the ringlaser measurements (after tilt correction and removing Oppolzer terms (effects of nutation of CIP)).
- Compared to what is expected from high frequency polar motion (due to ocean tides).
Ringlaser data

- Spectrum of the ringlaser measurements (after correction for tilt and Earth rotation).