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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





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- 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.

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- 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.

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000 Ge CO4 05predeteed EDF include a priori instation officies dC, dT include high frequency 600 © ocean tides exp.eares m	Station corrections Windla Danth rides Windla Danth rides Windla Careta Isolang PES2004 eva: Windla unrespherer Salatig Xingeneral Isolang Windla Unrespherer Salatig Windla Unresphere Salatig Windla Unresphere Salatig
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- 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.

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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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- Polar Motion estimates from VieVS
 - IERS 05 C04 series plus IERS recommended model for high frequency ERP variations.
 - VLBI solution
 Calc/Solve (from
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 Bonn)

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- Polar Motion
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- IERS 05 C04
 series plus IERS
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 model for high
 frequency ERP
 variations.
- VLBI solution
 Calc/Solve (from
 T. Artz, Uni.
 Bonn)
- **GPS** solution (*P.* Steigenberger et al., JGR, (2006))

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-456 VieVS -C04 05 + ocea -457 Calc/Solve [se -458 1 -459 1 -460 -461 -462 12 22 26 14 16 18 20 Day of August 2008 24 VieVS -C04 05 + ocear GPS LOD [ms] Calc/Solve 14 16 18 20 Day of August 2008 22 24 26

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.

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CONT08 Nutation Estimates



estimated from VLBI (VieVS).

Nutation from IERS 05 C04

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

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- 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 μas) if
 ITRF2005
 coordinates are
 used in VieVS
 solution instead of
 VTRF2005.

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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.)

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CONT08 Polar Motion Spectrum



• Fourier spectrum of polar motion residuals.

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CONT08 DUT1 and LOD Spectra



 Fourier spectra of DUT1 and LOD residuals.

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CONT08 DUT1 and LOD Spectra



- Fourier spectra of DUT1 and LOD residuals.
- Peaks at 12 h and 24 h.

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Unexplained Signals in the CONT Polar Motion

-					LOD					
		Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	12 h	24 h
	C08	VieVS			Х		Х	Х	X	Х
		C/S			Х		Х	Х	X	X
		GPS	х			х		х	X	Х
	C05	VieVS	Х				Х	Х	X	X
		GPS	Х			Х		х	X	Х
	C02	VieVS	X	X		v		X	X	X
		GFD	~	^		~				

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Conclusions

Unexplained Signals in the CONT Polar Motion

					LOD				
	Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	424 h	12 h	24 h
C08	VieVS			Х		Х	Х	Х	Х
	C/S			Х		Х	Х	X	X
	GPS	Х			Х		X	X	Х
C05	VieVS	х				х	х	x	х
	GPS	Х			Х		Х	X	Х
C02	VieVS	х	Х				х	x	х
	GPS	Х	Х		Х		X	X	

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All solutions have a peak at 24 h prograde.

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Unexplained Signals in the CONT Polar Motion

		(Polar Motion							
	Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	12 h	24 h	
C08	VieVS			Х		Х	Х	Х	Х	
	C/S			Х		Х	Х	X	X	
	GPS	Х			Х		Х	X	X	
C05	VieVS	х				x	х	x	х	
	GPS	Х			Х		Х	X	X	
C02	VieVS	х	x				х	x	х	
	GPS	Х	Х		Х		Х	X		

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Almost always 12 h retrograde signal.

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Unexplained Signals in the CONT Polar Motion

				LOD					
	Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	12 h	24 h
C08	VieVS			Х		Х	Х	X	X
	C/S			Х		Х	Х	X	X
	GPS	X			Х		X	X	X
C05	VieVS	x				Х	x	x	X
	GPS	X			х		Х	X	X
C02	VieVS	x	(x)				х	x	X
	GPS	X			Х		Х	X	

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CONT02: 8 h retrograde signal.

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Unexplained Signals in the CONT Polar Motion

				Polar Motion								
_		Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	12 h	24 h		
_	C08	VieVS			Х		Х	Х	Х	Х		
		C/S			Х		Х	Х	X	X		
		GPS	х			Х		Х	X	Х		
(C05	VieVS	х				X	х	x	Х		
		GPS	Х			Х		Х	X	Х		
(C02	VieVS	х	Х				х	x	Х		
		GPS	Х	Х		X		X	X			

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GPS: always a prograde 8 h signal.

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Unexplained Signals in the CONT Polar Motion

			Polar Motion							
	Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	<u>1</u> 2 h	24 h	
C08	VieVS			Х		Х	Х	X	X	
	C/S			Х		Х	Х	X	X	
	GPS	X			Х		Х	X	X	
C05	VieVS	x				х	х	x	х	
	GPS	X			Х		Х	X	Х	
C02	VieVS	x	Х				х	x	х	
	GPS	Х	Х		Х		Х	\ X		

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LOD: Peaks at 12 h and 24 h.

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Conclusions

Atmospheric Angular Momentum

- There are peaks at +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.

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Atmospheric Angular Momentum

- There are peaks at +24 h, \pm 12 h, and sometimes also at \pm 8 h in the Earth rotation spectra.
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Atmospheric Angular Momentum for CONT08



- Excitation functions for the CONT08 period calculated from ECMWF data.
- Resolution
 6 hours.

For χ_3 , the mass and motion terms seems to counteract each other (see also Diploma Thesis by *M*. *Schindeleggger*, *TU Wien*, 2009).

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 Spectra of the expected ERP variations due to atmospheric angular momentum variations.

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- Spectra of the expected ERP variations due to atmospheric angular momentum variations.
- Amplitudes small compared to those observed with VLBI.

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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.

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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.

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Ringlaser data

- 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

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- 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

High frequency EOP Varitaions

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- 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 h, ± 12 h, +8 h (GPS), and -8 h (in CONT02).
- Signals in LOD (and DUT1) at 24 h and 12 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.

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Ringlaser data

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Ringlaser data

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- 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

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