Investigation of high frequency EOP variations

Recent results and future prospects of the SPEED project

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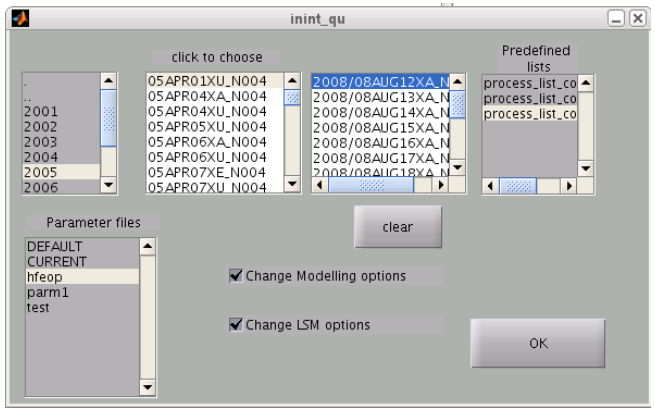
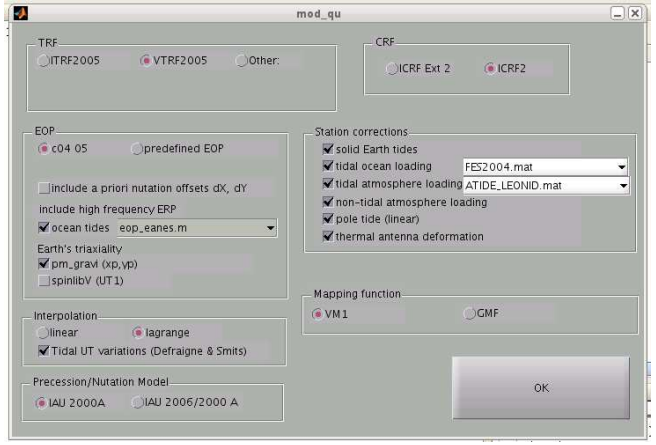
Introduction

- 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.

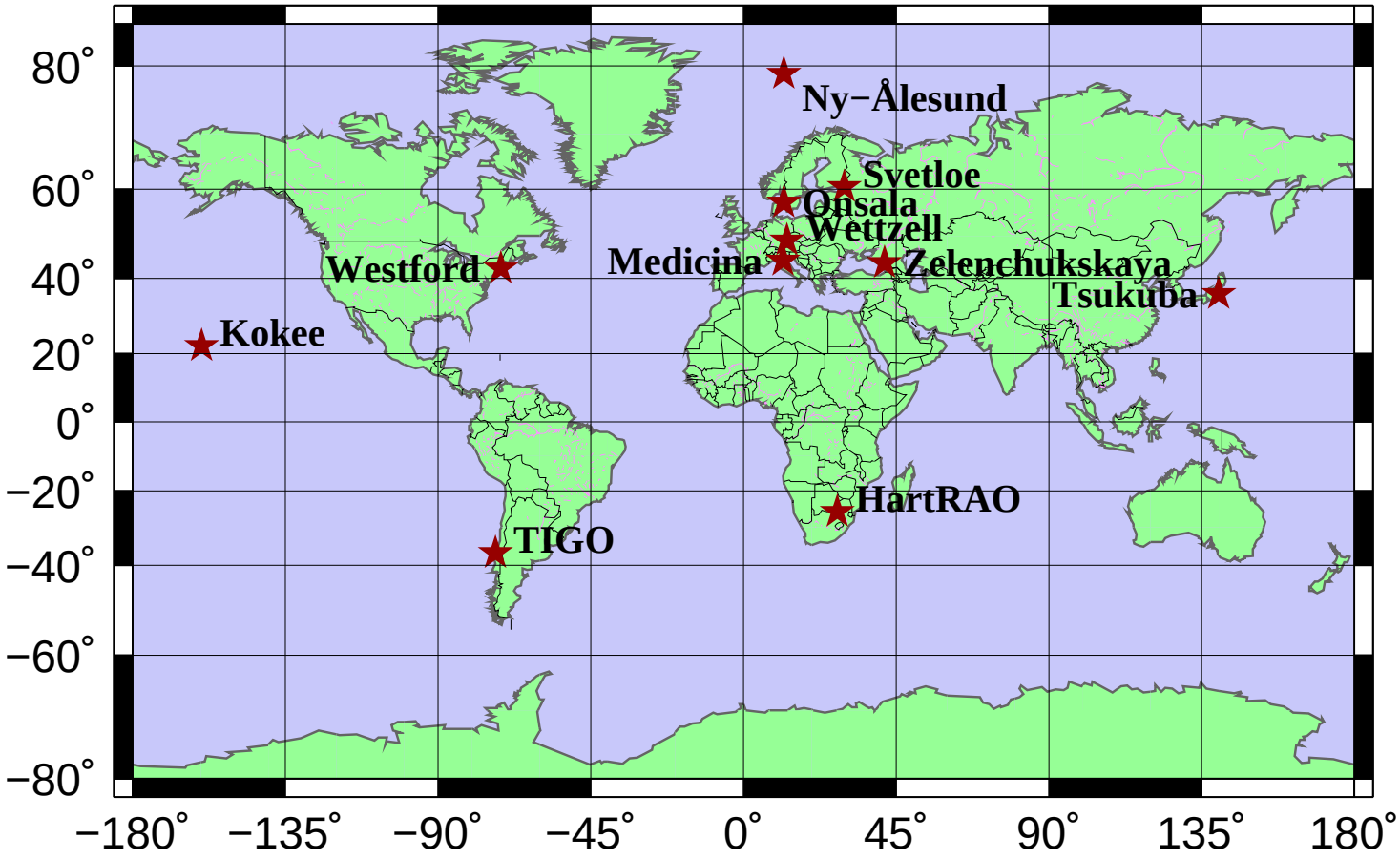




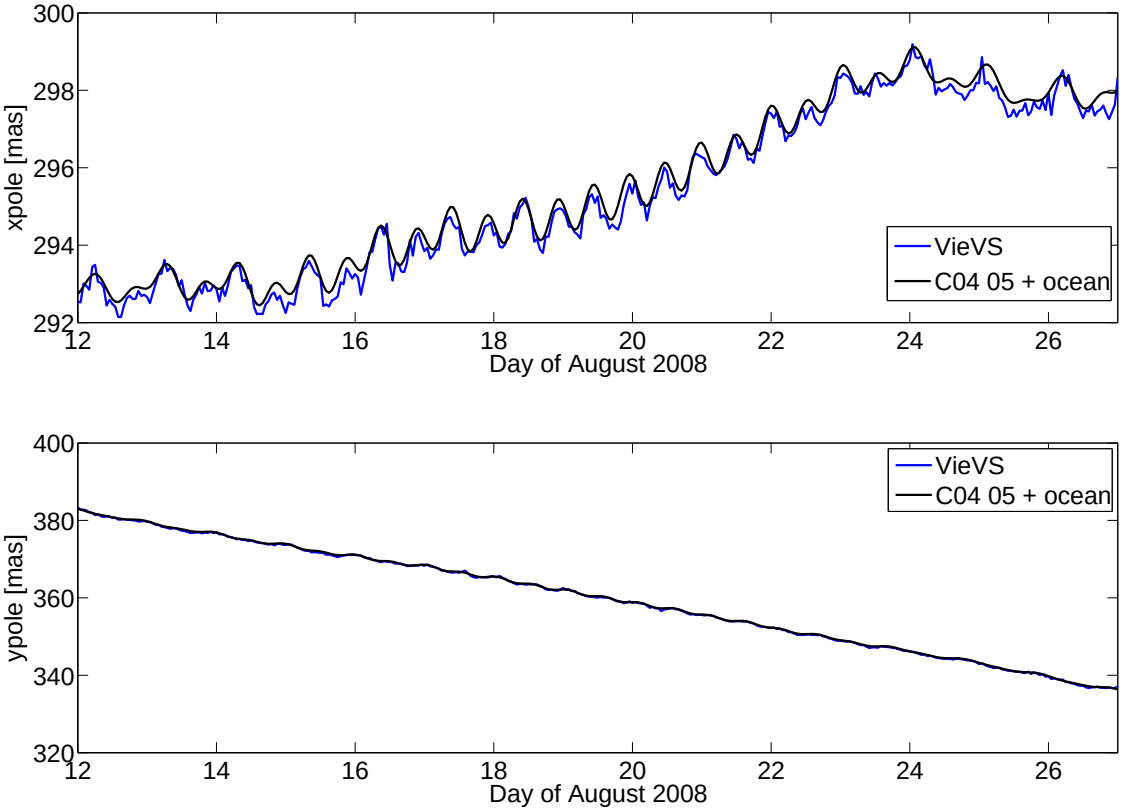
Data Processing

- 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: August 12–26, 2008

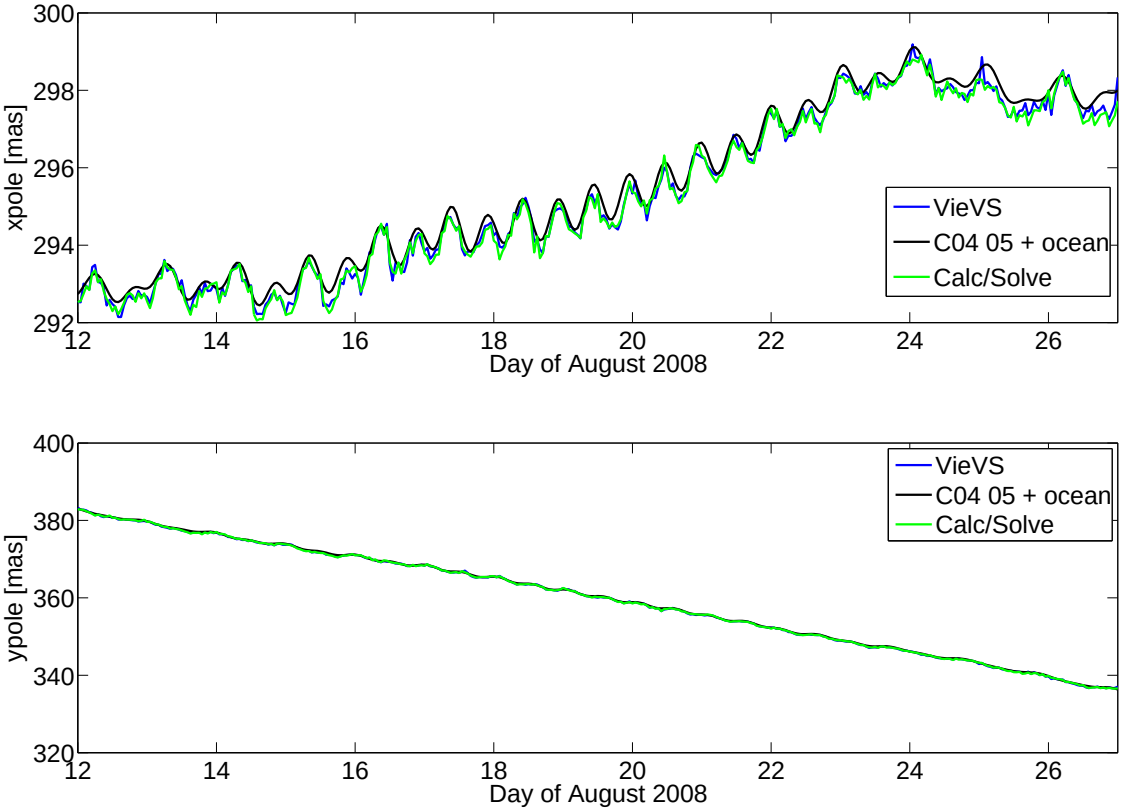


CONT08 Polar Motion Estimates



- Polar Motion estimates from **VieVS**
- **IERS 05 C04** series plus IERS recommended model for high frequency ERP variations.

CONT08 Polar Motion Estimates



- Polar Motion estimates from **VieVS**
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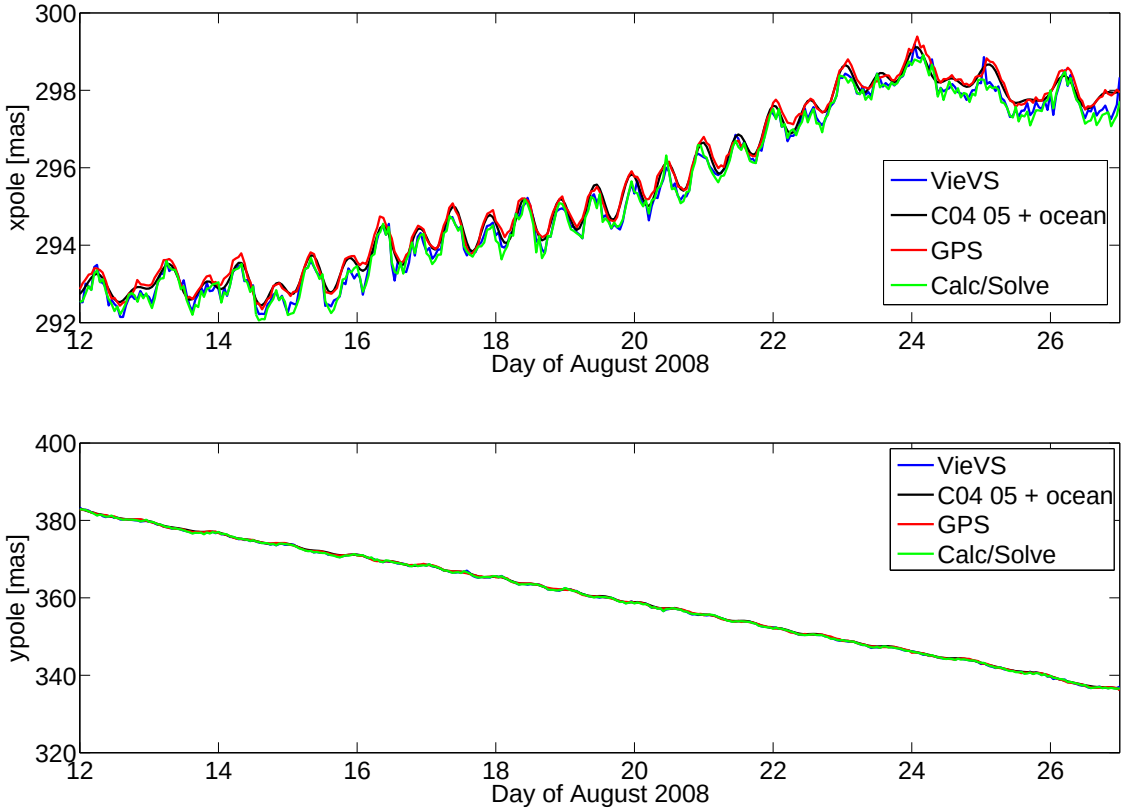
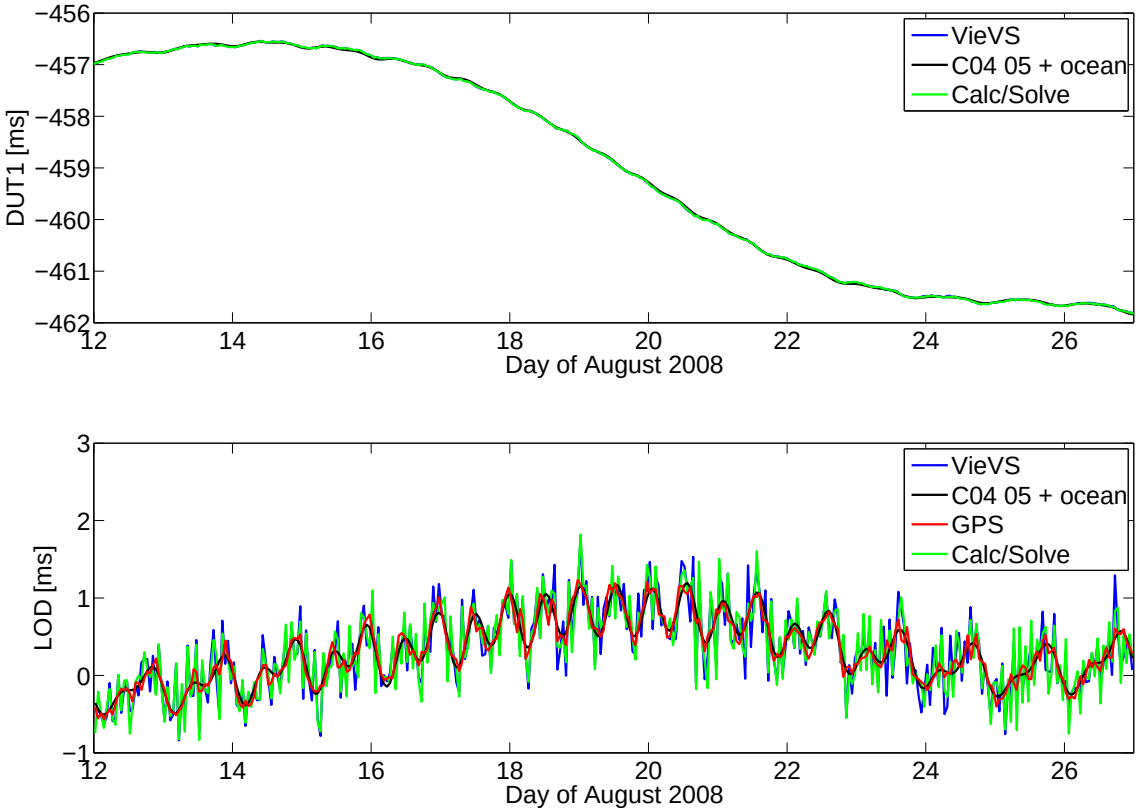
- VLBI solution **Calc/Solve** (from T. Artz, Uni. Bonn)

CONT08 Polar Motion Estimates



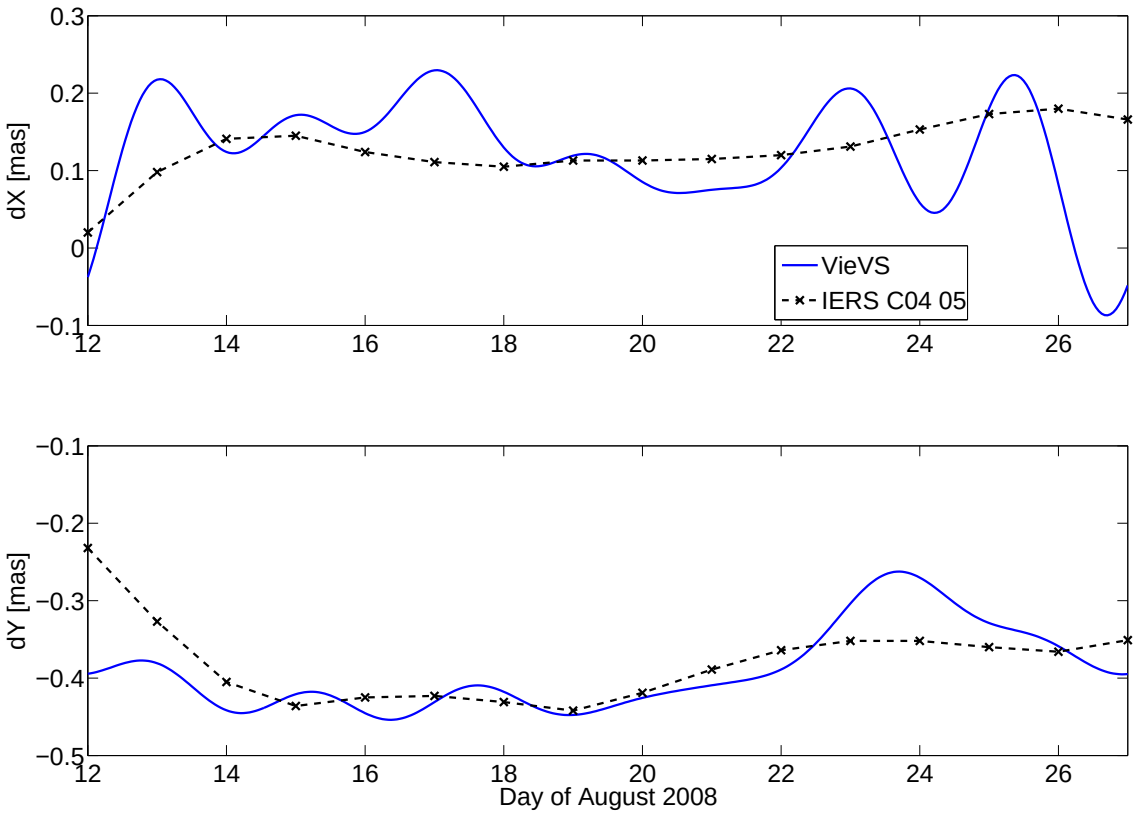
- Polar Motion estimates from **VieVS**
- **IERS 05 C04** series plus IERS recommended model for high frequency ERP variations.
- VLBI solution **Calc/Solve** (from T. Artz, Uni. Bonn)
- **GPS** solution (*P. Steigenberger et al., JGR, (2006)*)

CONT08 DUT1 and Length Of Day Estimates



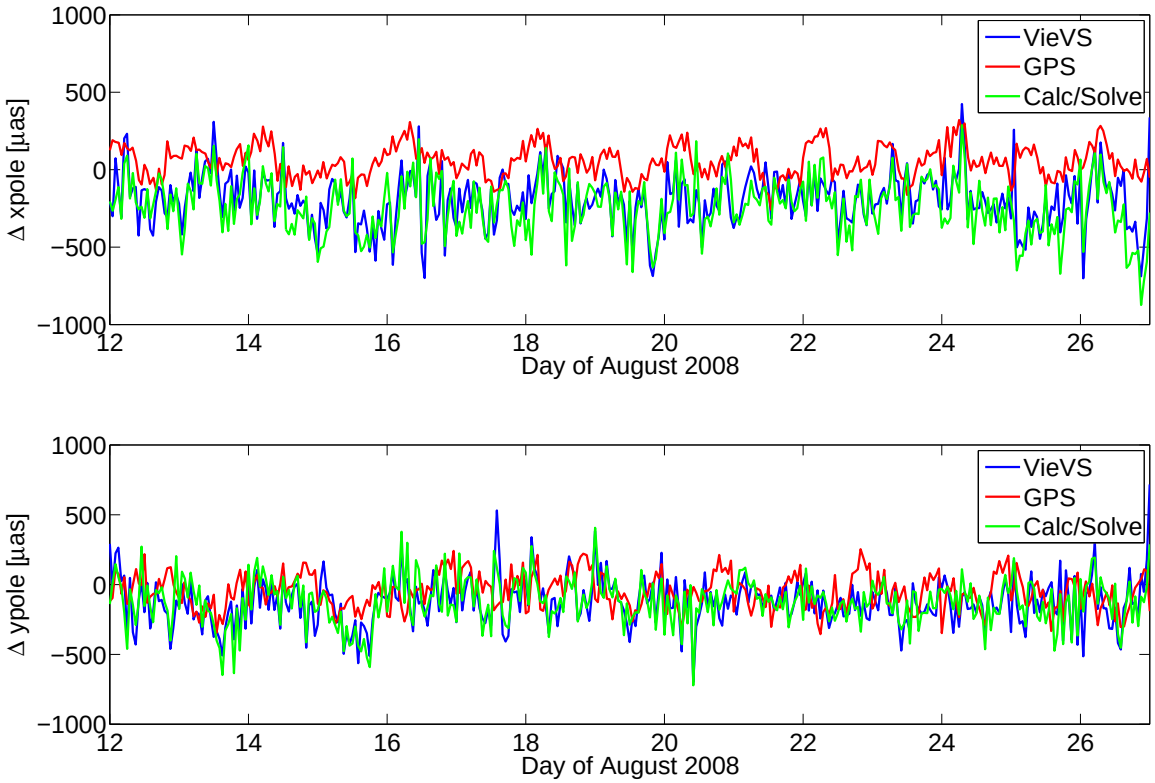
- UT1-UTC estimated from VLBI (VieVS and Calc/Solve).
- Length of Day estimated from VLBI (VieVS and Calc/Solve) and from GPS.

CONT08 Nutation Estimates



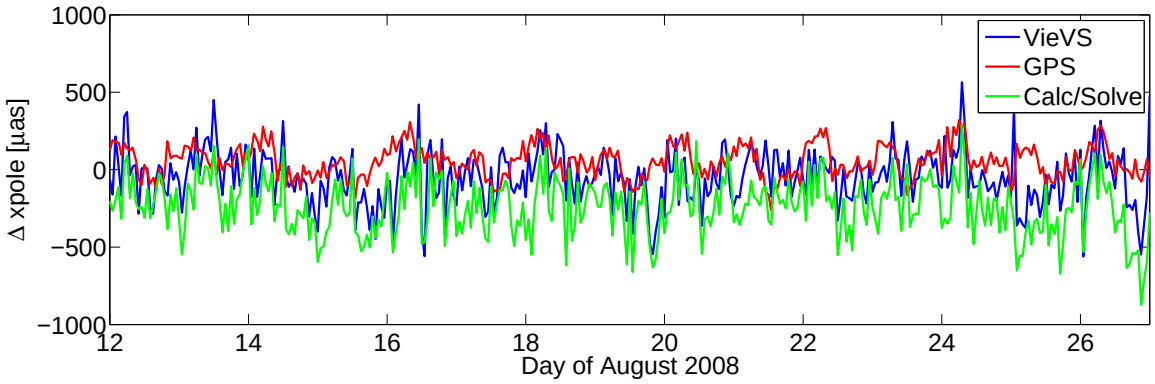
- Nutation estimated from VLBI (VieVS).
- Nutation from IERS 05 C04 series.

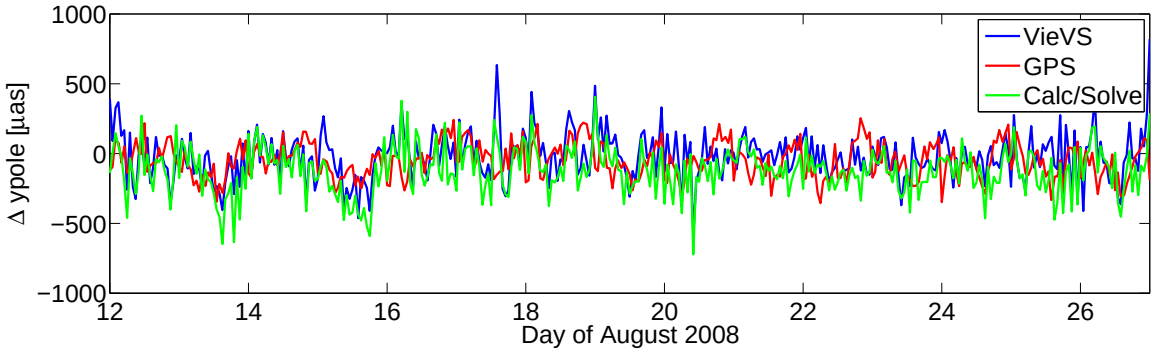
CONT08 Residual Polar Motion Estimates



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

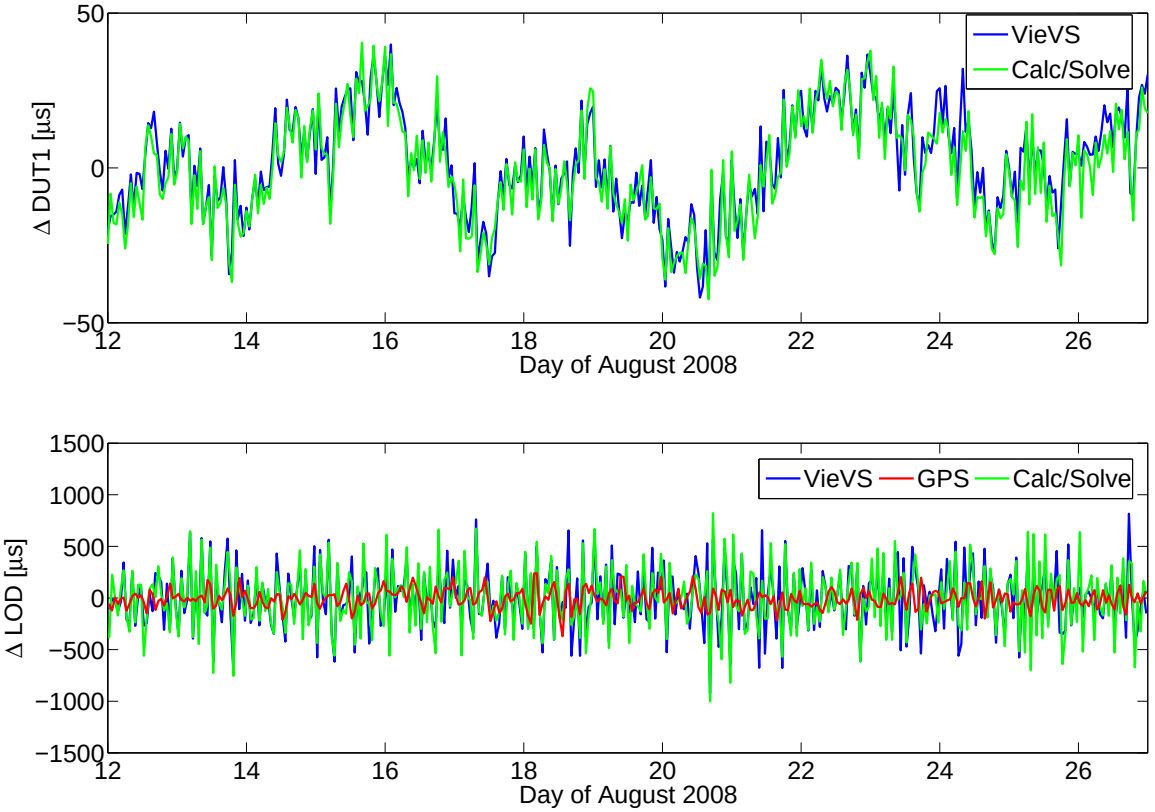
CONT08 Residual Polar Motion Estimates





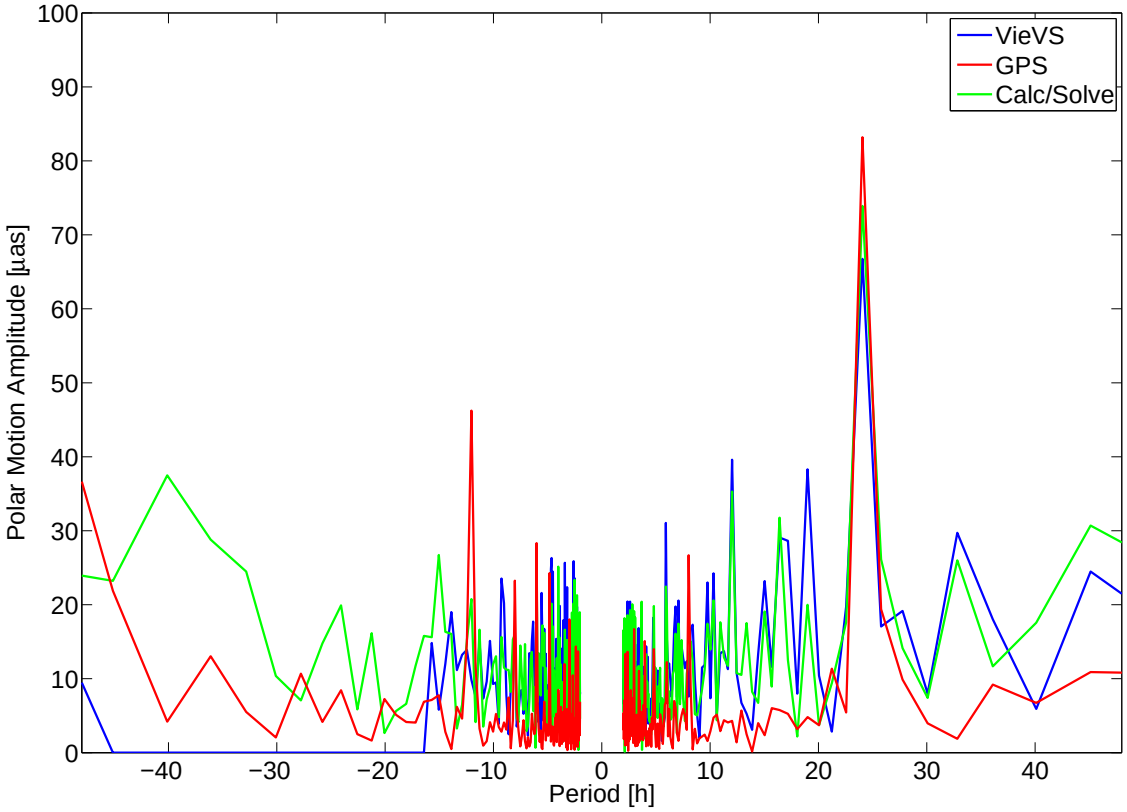
- Polar Motion from VLBI (VieVS and Calc/Solve) and GPS minus IERS 05 C04 and high frequency ERP model.
- X-pole offset between GPS and VLBI probably due to different datums.
- Offset decreases (by 140 μas) if ITRF2005 coordinates are used in VieVS solution instead of VTRF2005.

CONT08 Residual DUT1 and LOD Estimates



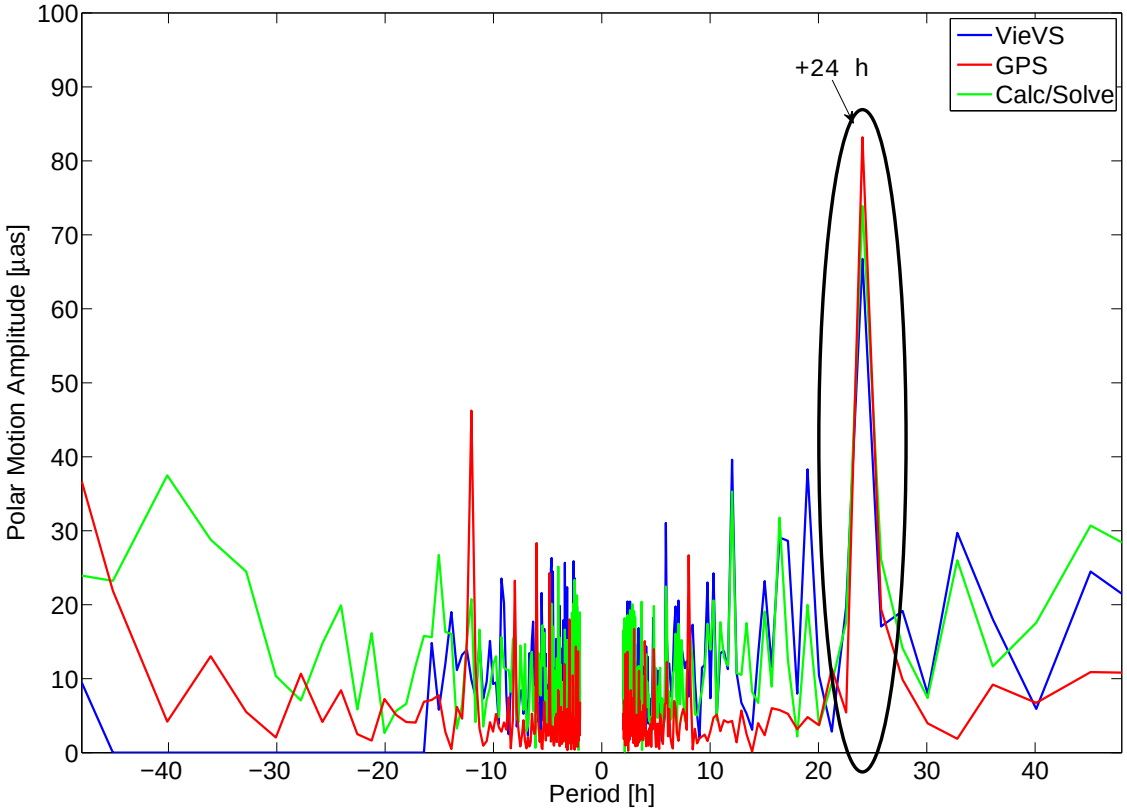
- Good agreement in DUT1 between the two VLBI solutions.
- LOD from VLBI is noisier than LOD from GPS. (VLBI LOD calculated from the time derivatives of the DUT1 estimates.)

CONT08 Polar Motion Spectrum



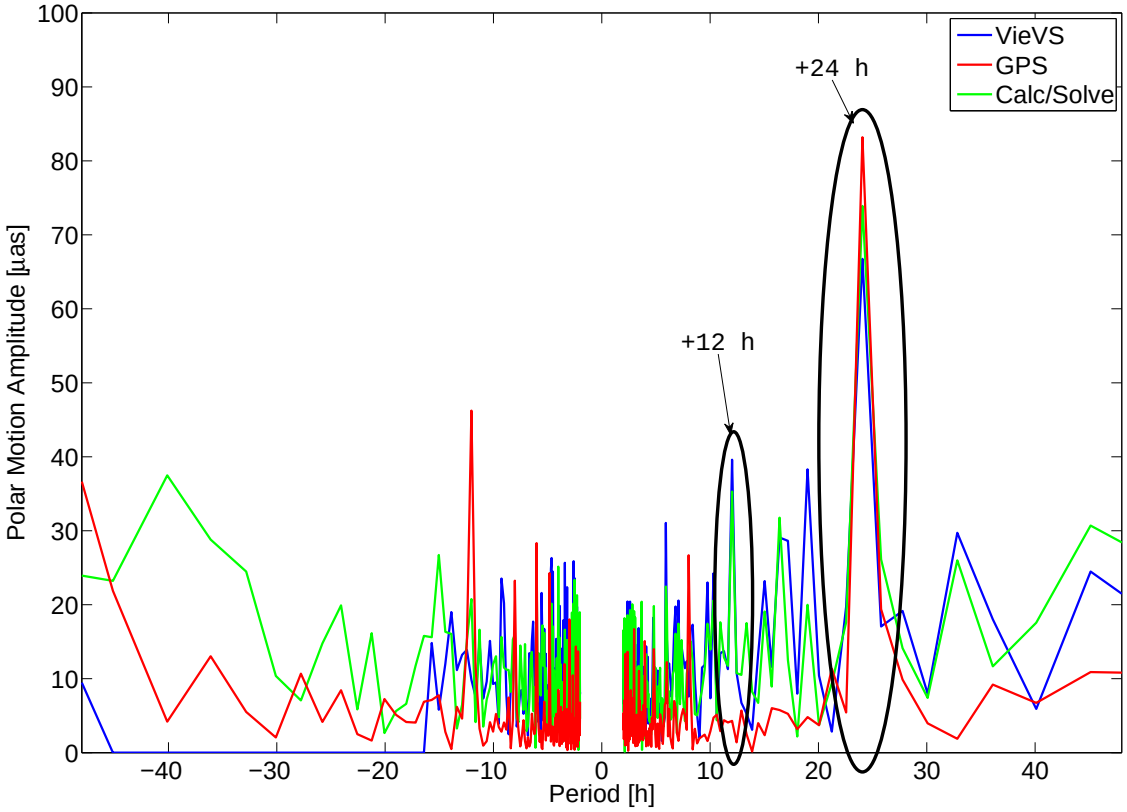
- Fourier spectrum of polar motion residuals.

CONT08 Polar Motion Spectrum



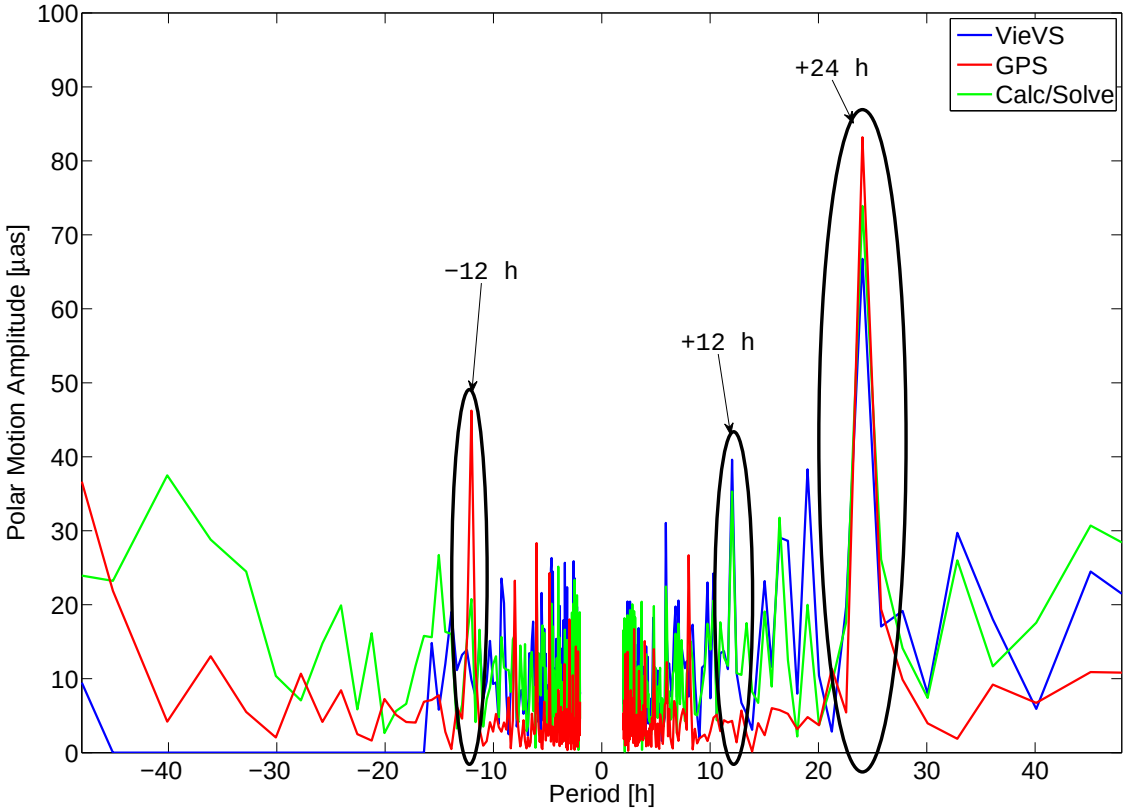
- Fourier spectrum of polar motion residuals.
- peak at +24 h.

CONT08 Polar Motion Spectrum



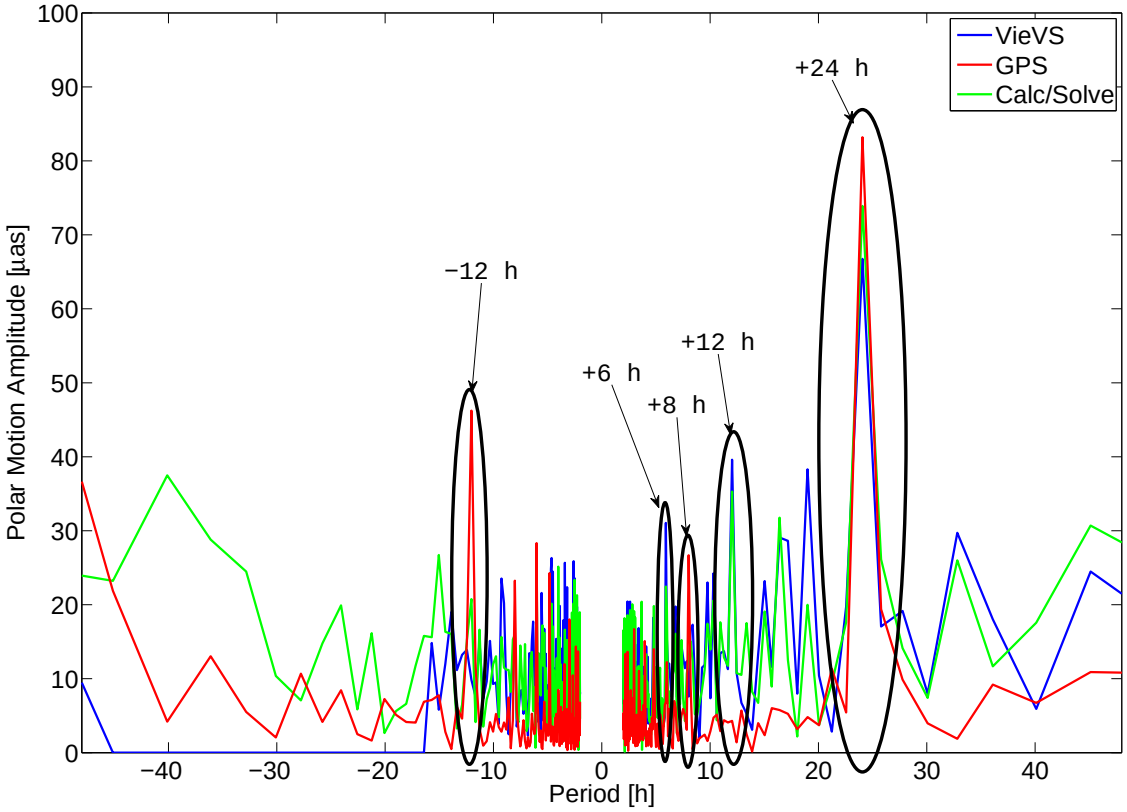
- Fourier spectrum of polar motion residuals.
- peak at +24 h.
- Peak at +12 h for VLBI.

CONT08 Polar Motion Spectrum



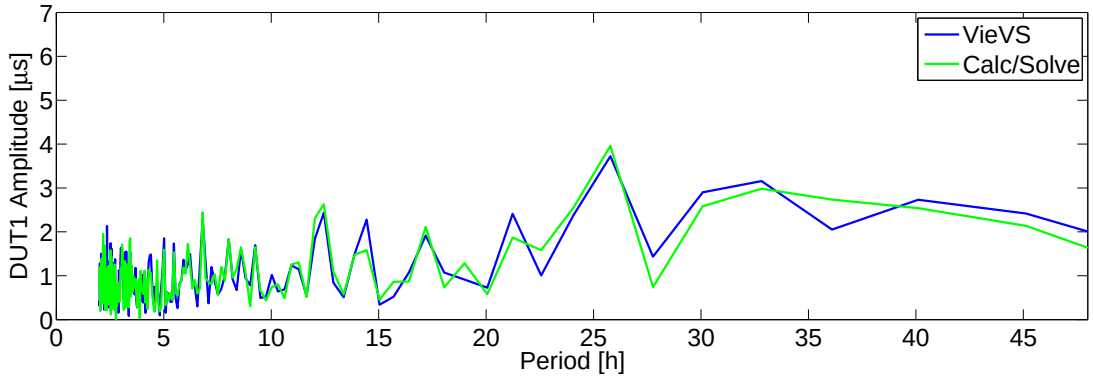
- Fourier spectrum of polar motion residuals.
- peak at +24 h.
- Peak at +12 h for VLBI.
- Peak at -12 h for GPS.

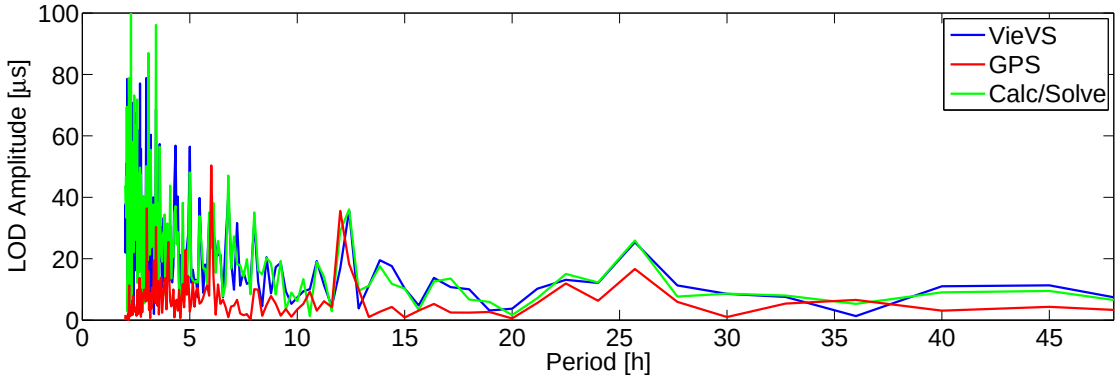
CONT08 Polar Motion Spectrum



- 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).

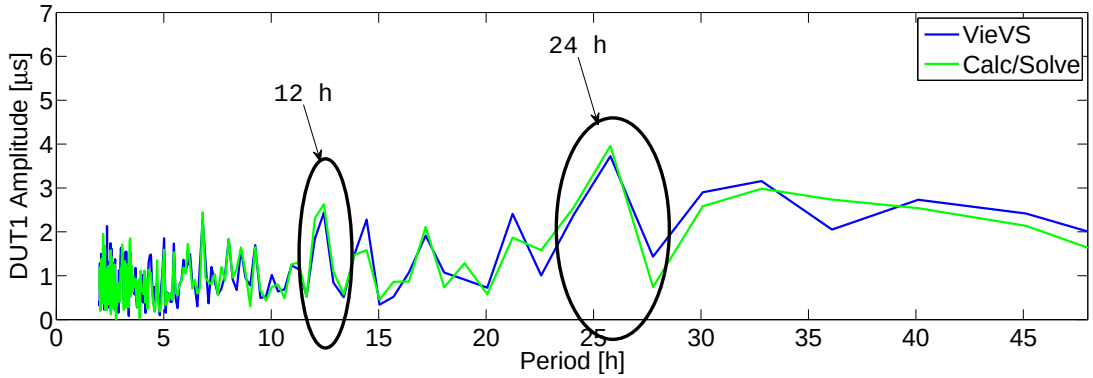
CONT08 DUT1 and LOD Spectra

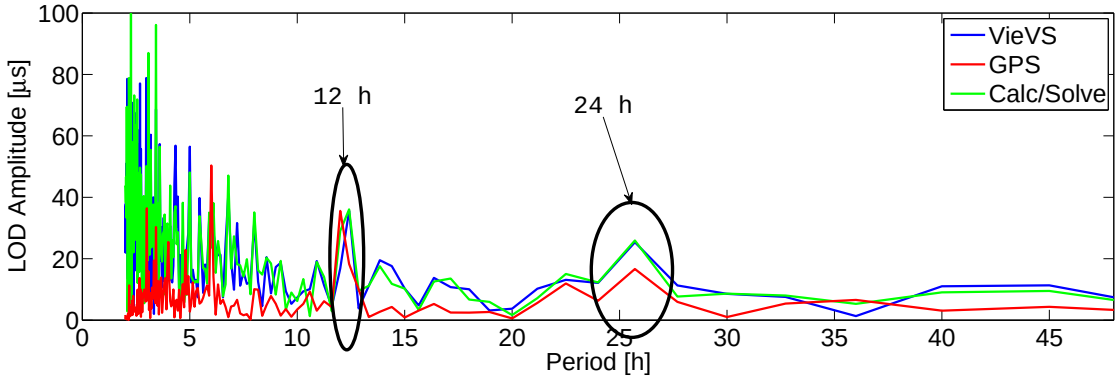




- Fourier spectra of DUT1 and LOD residuals.

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

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

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	C/S			X		X	X	X	X
	GPS	X			X		X	X	X
C05	VieVS	X				X	X	X	X
	GPS	X			X		X	X	X
C02	VieVS	X	X				X	X	X
	GPS	X	X		X		X	X	

All solutions have a peak at 24 h prograde.

Unexplained Signals in the CONT Polar Motion

		Polar Motion						LOD	
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C08	VieVS			X		X	X	X	X
	C/S			X		X	X	X	X
	GPS	X			X		X	X	X
C05	VieVS	X				X	X	X	X
	GPS	X			X		X	X	X
C02	VieVS	X	X				X	X	X
	GPS	X	X		X		X	X	

Almost always 12 h retrograde signal.

Unexplained Signals in the CONT Polar Motion

		Polar Motion						LOD	
	Sol.	-12 h	-8 h	+6 h	+8 h	+12 h	+24 h	12 h	24 h
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	C/S			X		X	X	X	X
	GPS	X			X		X	X	X
C05	VieVS	X				X	X	X	X
	GPS	X			X		X	X	X
C02	VieVS	X	X				X	X	X
	GPS	X	X		X		X	X	

CONT02: 8 h retrograde signal.

Unexplained Signals in the CONT Polar Motion

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

GPS: always a prograde 8 h signal.

Unexplained Signals in the CONT Polar Motion

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

LOD: Peaks at 12 h and 24 h.

Atmospheric Angular Momentum

- There are peaks at +24 h, ±12 h, and sometimes also at ±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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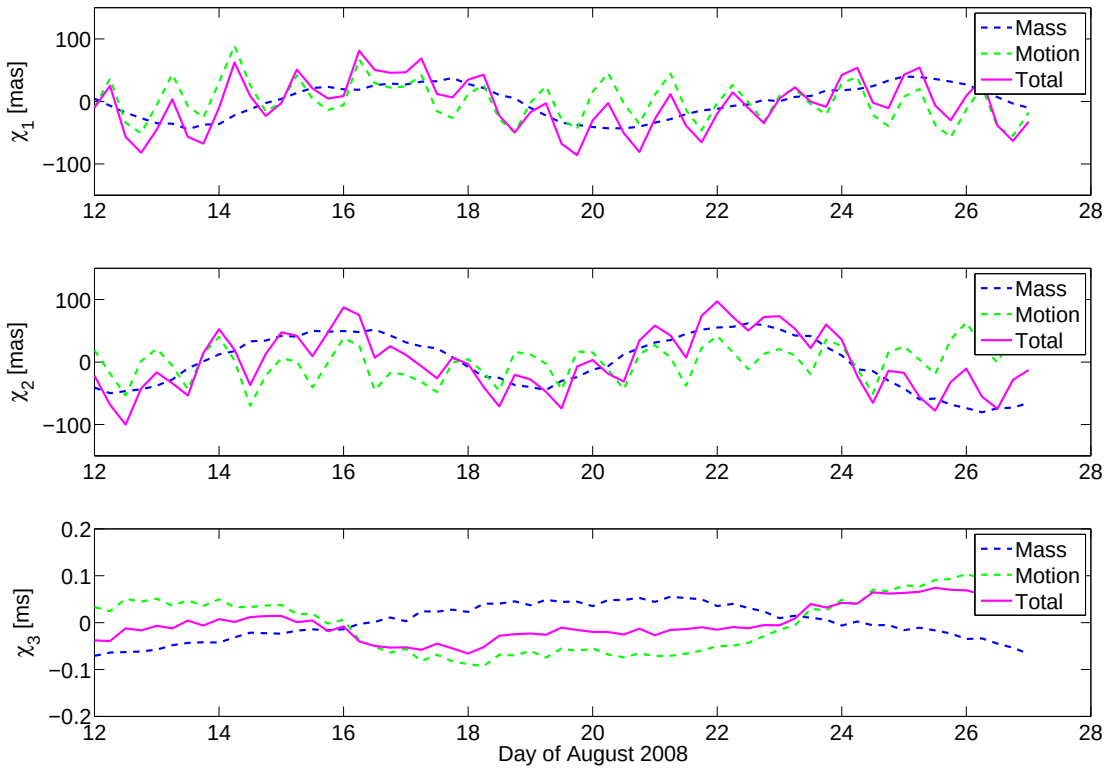
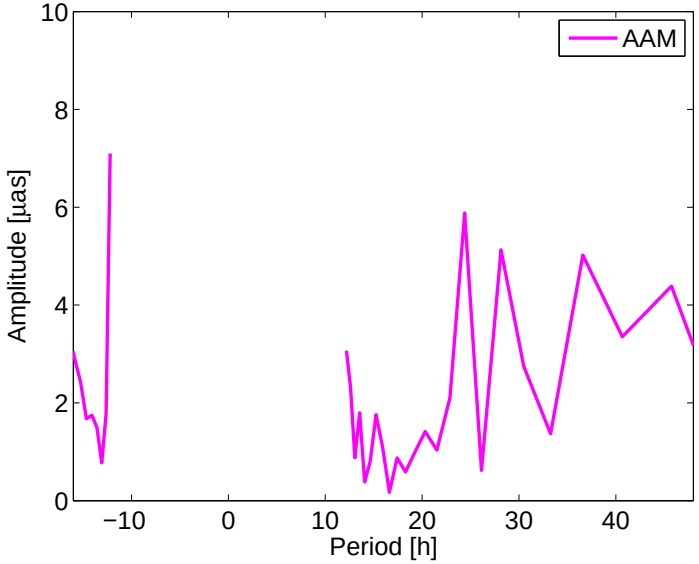
Atmospheric Angular Momentum for CONT08



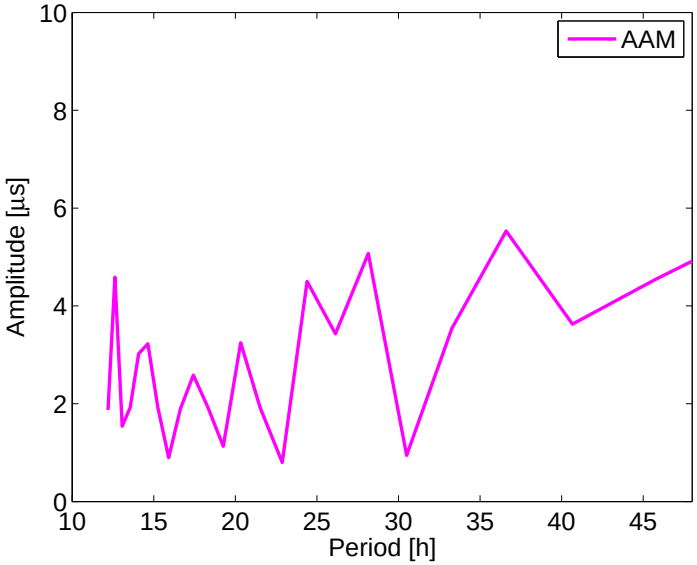
- Excitation functions for the CONT08 period calculated from ECMWF data.
- Resolution 6 hours.
- For χ_3, the mass and motion terms seems to counteract each other (see also Diploma Thesis by *M. Schindeleggger, TU Wien, 2009)*.

CONT08

Polar motion



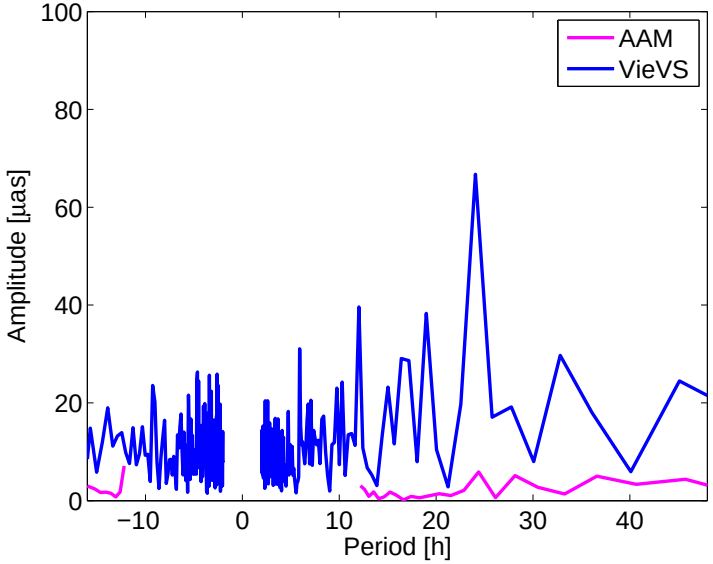
Length of Day



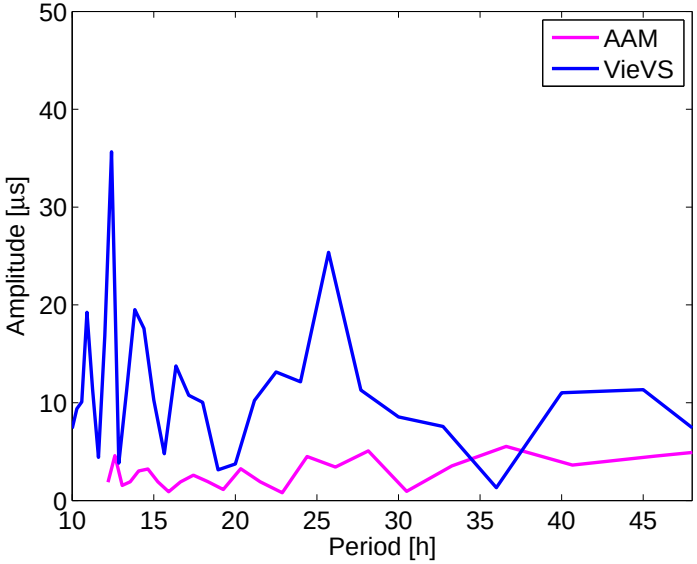
- Spectra of the expected ERP variations due to atmospheric angular momentum variations.

CONT08

Polar motion



Length of Day

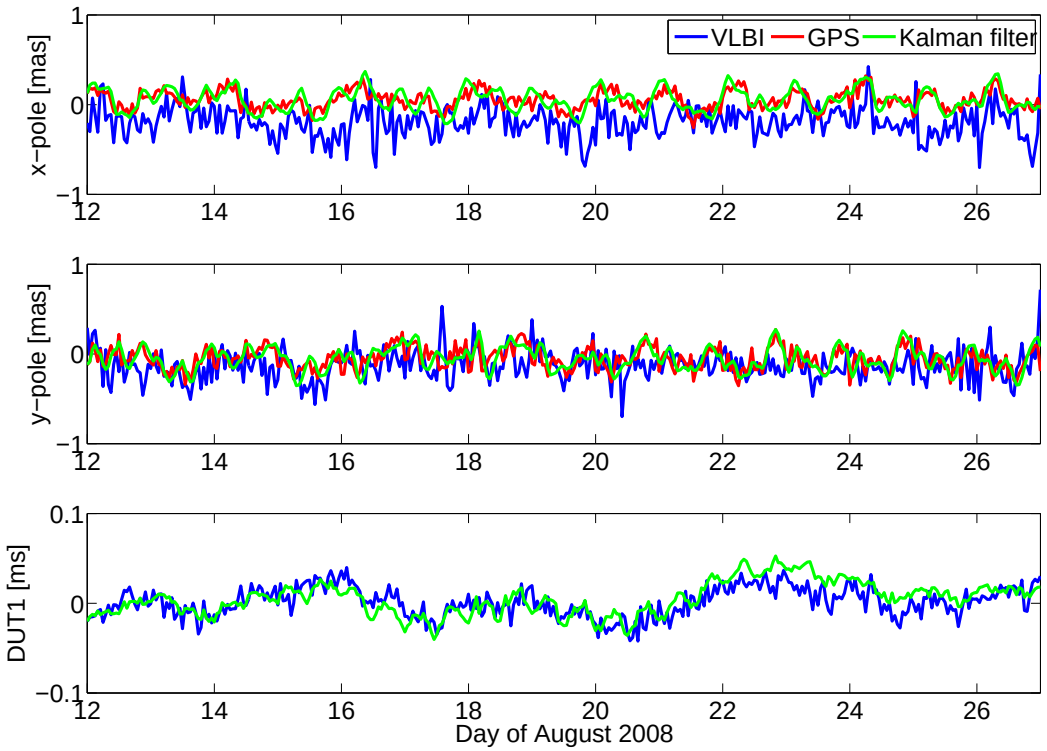


- Spectra of the expected ERP variations due to atmospheric angular momentum variations.
- Amplitudes small compared to those observed with VLBI.

Combination of EOP time-series

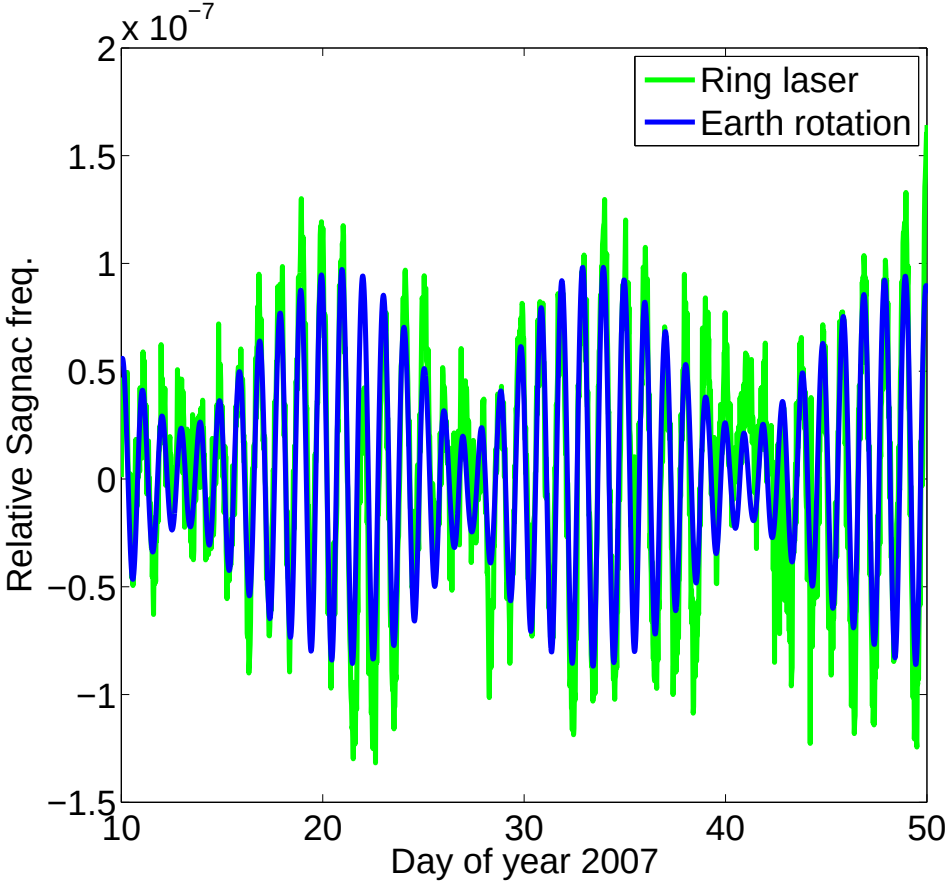
- Several different techniques exist to measure high frequency Earth rotation (VLBI, GPS, ringlasers etc.). All have their advantages and disadvantages.
- To obtain the highest accuracy, the results from different techniques should be combined.
- Kalman filtering has proven to be a useful technique for 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.

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

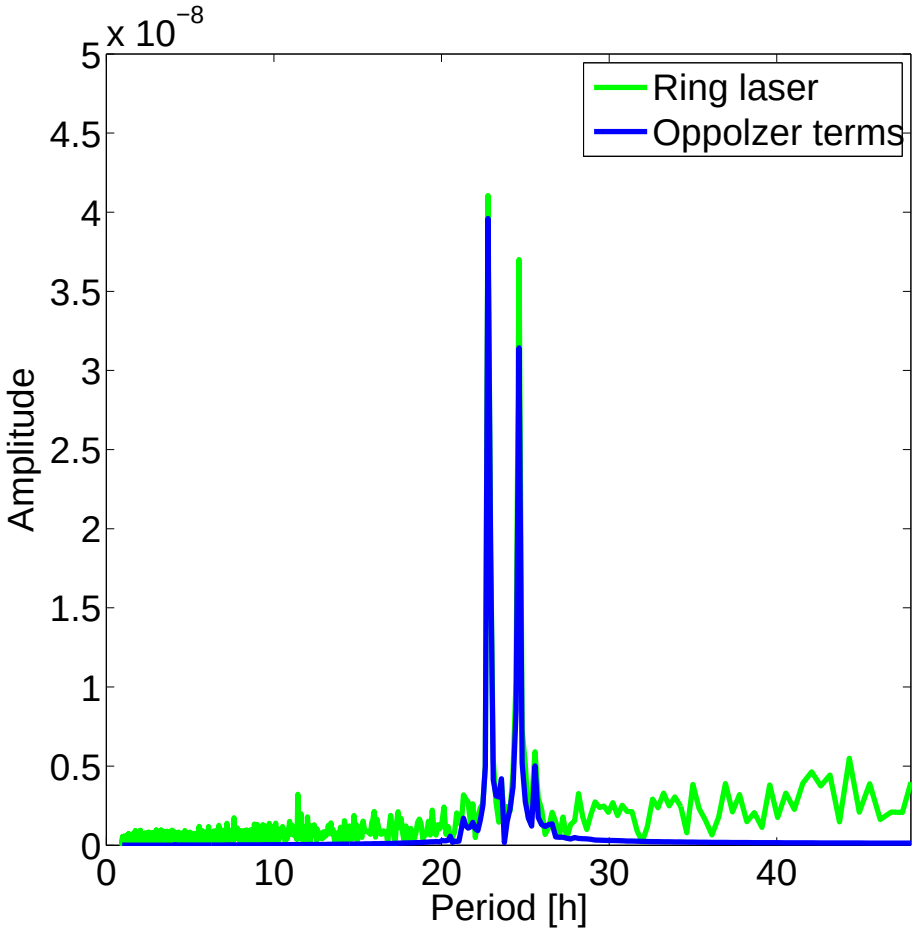
- Attempt to include ringlaser data in Kalman filter.
- Include estimation of nutation in the Kalman filter (ringlasers are sensitive to the nutation of the CIP as well as polar motion).
- Investigate the effect of systematic errors in the input data, and how to mitigate them.
- Improve the filter by 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 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.

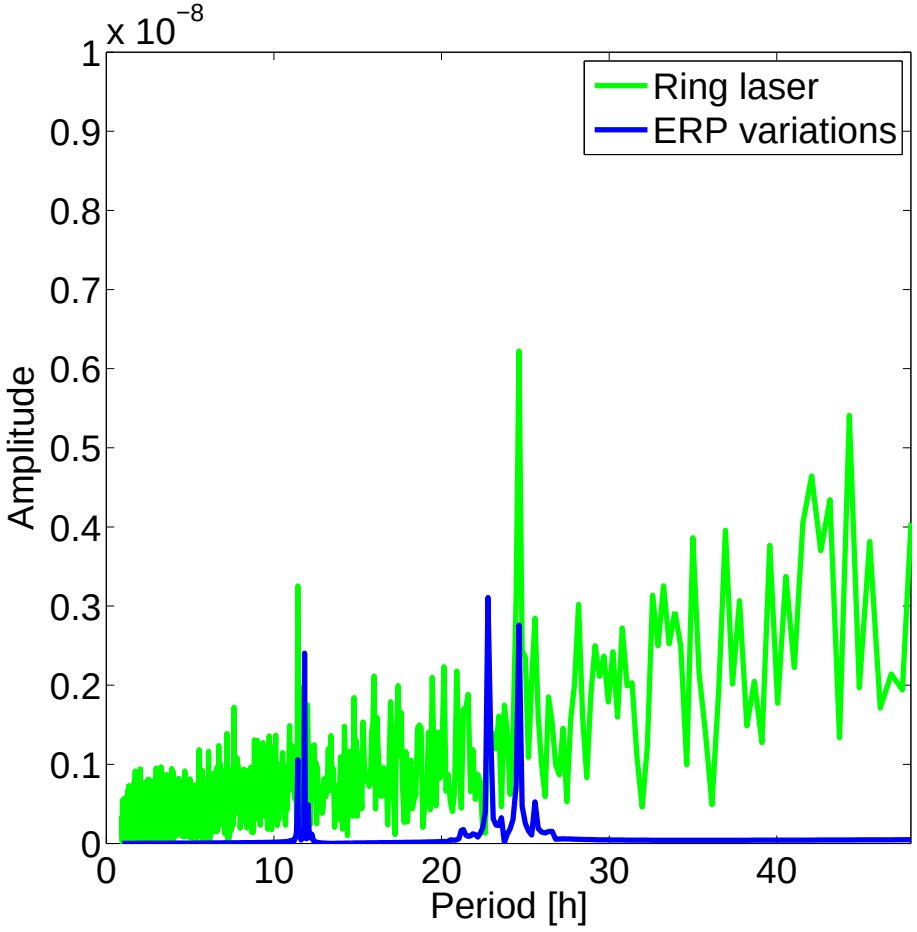
Danke für Ihre Aufmerksamkeit!

Ringlaser data



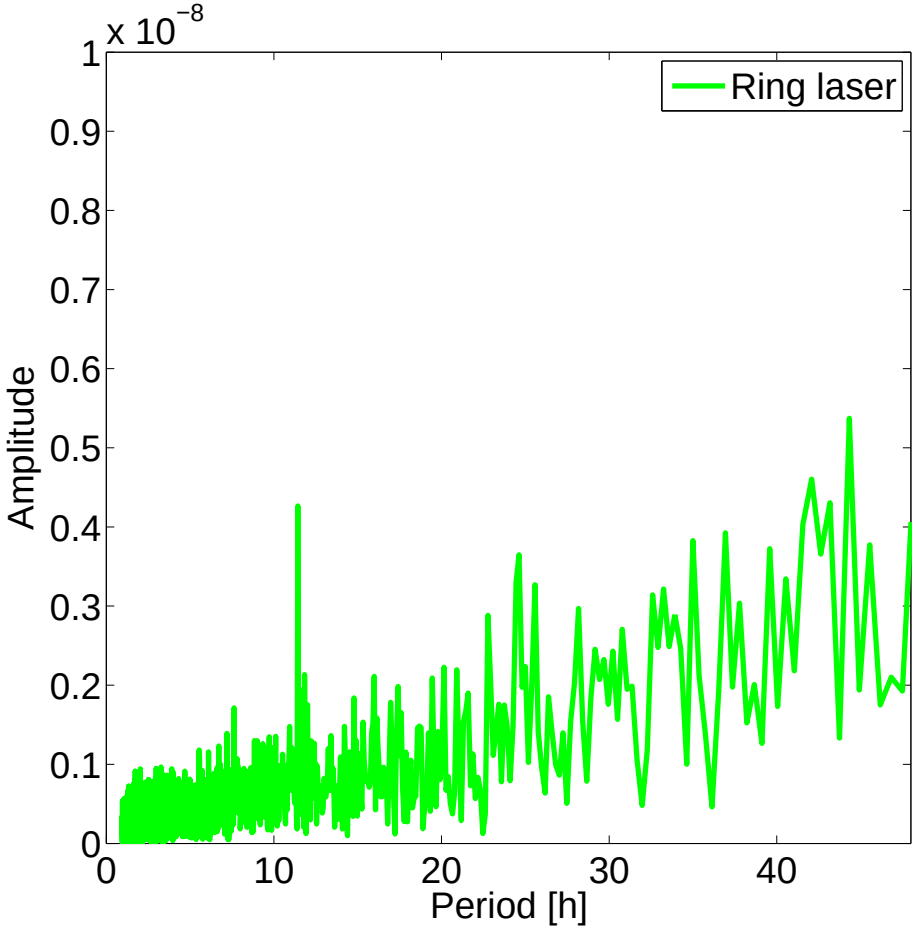
- Spectrum of the ringlaser measurements (after tilt correction).
- Compared to what is expected from Earth rotation variations.

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).