RETRIEVING DIURNAL AND SEMIDIURNAL SIGNALS IN POLAR MOTION AND UT1 FROM ANALYSIS OF THE ROUTINE VLBI OBSERVATIONS

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Joint Discussion 16

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Overview

1. Introduction

2. Parametrization of polar motion and UT1

3. Analysis of VLBI observations

4. Results

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Introduction

Diurnal and subdiurnal signals in polar motion (PM) and UT1:

- Tidal effects: regular and predictable, harmonic models provided by the IERS Conventions (2003), Tables 5.1, 8.2a,b and 8.3a,b
  - Influence of the gravitationally forced ocean tides with diurnal and semi-diurnal periods; amplitudes up to 300 μas
  - Direct influence of the tidal gravitation on the triaxial structure of the Earth, diurnal in PM, semidiurnal in UT1; amplitudes up to 30 μas
- Geophysical signals: irregular or quasi-harmonic, adequate representation by time series; expected total amplitude between 10 and 30 μas
  - Atmospheric and nontidal oceanic influences: S_1/S_2 components with periods $24/12$ hrs and their side lobes generated by seasonal modulations
  - Atmospheric normal modes ψ_1^1, ξ_2^1 with central periods of 1.2, 0.6 days, respectively

Introduction (cont.)

Modeling efforts and observational evidence

- Concern mostly the purely harmonic ocean tide influence which is dominant effect in diurnal and semidiurnal bands
  - Ocean tide model: hydrodynamic model constrained by T/P altimetry observations (Chao et al., 1996), recommended by IERS Conventions (2003)
  - VLBI solutions: (Sovers et al., 1993; Herring & Dong, 1994; Gipson, 1996)
  - SLR solution: (Watkins & Eanes, 1994) with later updates by R. Eanes
  - GPS solution: (Rothacher et al., 2001)
- Geophysical signals
  - Estimated in most of the space-geodetic solutions cited above, but deeper analysis done only in case of GPS
  - Continuous observation campaigns, like CONT94, CONT02, CONT05
  - Estimation from high-resolution atmospheric/oceanic excitation data

Introduction (cont.)

Our purpose:

- To extract from the routine VLBI observations the high-frequency (diurnal, semidiurnal, . . .) signals in polar motion and UT1, which can be used for constraining the tidal models and for time domain comparisons with the available geophysical excitation data.

The method:

- Proposed originally by Herring and Dong (1994) and further developed by Mathews and Herring (2000), Brzeziński (1994; 2000), relies upon the so-called complex demodulation technique.

Parametrization of polar motion and UT1

Polar motion

$$p(t) = x(t) - iy(t) = \sum_{\substack{\ell=-N \\ \ell\neq-1}}^{N} \left[x_\ell(t) - iy_\ell(t)\right] e^{i\ell\phi}$$

or, equivalently

$$\begin{bmatrix} x(t) \\ y(t) \end{bmatrix} = \sum_{\substack{\ell=-N \\ \ell\neq-1}}^{N} \left\{ \begin{bmatrix} x_\ell(t) \\ y_\ell(t) \end{bmatrix} \cos(\ell\phi) + \begin{bmatrix} y_\ell(t) \\ -x_\ell(t) \end{bmatrix} \sin(\ell\phi) \right\}$$

Universal time

$$\mathrm{UT1}(t) = \sum_{\ell=0}^{N} \left[u_\ell^s(t)\sin(\ell\phi) + u_\ell^c(t)\cos(\ell\phi)\right]$$

where $i = \sqrt{-1}$ denotes imaginary unit, t – time, and $\phi =$ GMST$+\pi$

Parametrization of polar motion and UT1 (cont.)

Assumption

- $x_\ell(t)$, $y_\ell(t)$, $u^s_\ell(t)$, $u^c_\ell(t)$ do not vary significantly during the observing session (in computations we estimate them as constant during one 24-hour session)

Remarks

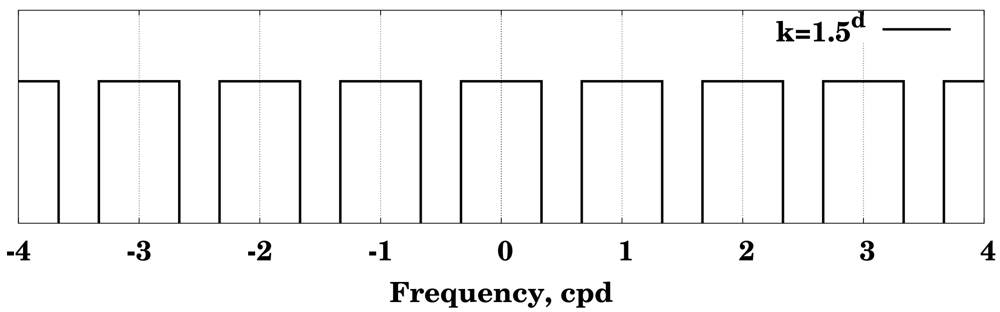
$\Rightarrow$ in standard estimation of EOPs from VLBI observations $N = 0$ that is the summation for both PM and UT1 reduces to one term only (with $\ell = 0$)

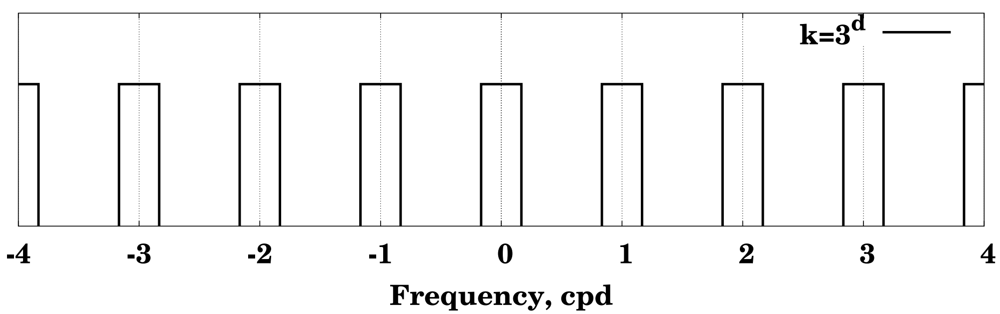
$\Rightarrow$ $\ell = 0$: $p_o(t) = x_o(t) - iy_o(t)$ and $u^c_o(t)$ are the long periodic components of polar motion and UT1

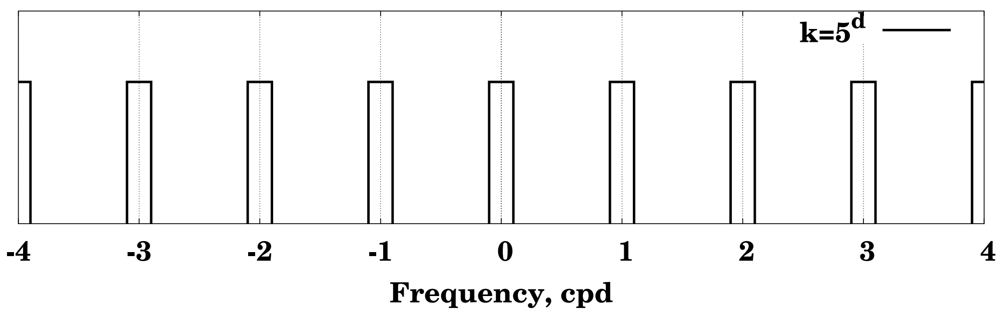
$\Rightarrow$ $\ell = 1, 2, \ldots$: the ℓ-th term expresses quasi diurnal, semidiurnal, ... variations in polar motion (retrograde/prograde for $-/+$) and in UT1

$\Rightarrow$ $\ell = -1$: this term of polar motion is not included in the expansion because it is parameterized as nutation (the celestial pole offsets)

Parametrization of polar motion and UT1 (cont.)







Assume for simplicity the regular time distribution of VLBI sessions, with a separation of k days. The frequency domain of $x_\ell(t)$, $y_\ell(t)$, $u^s_\ell(t)$, $u^c_\ell(t)$ is limited to the Nyquist interval

$$(-1/2\text{k}, +1/2\text{k}) \text{ cpd.}$$

The frequency domain of the total expansion and for

k=1.5 days,

k=3 days,

k=5 days,

is shown in the figures.

VLBI data analysis

VLBI data:

- From 1984.0 till February 2006
- 2,790 VLBI sessions, 4,698,363 dual frequency delays
- 2078 radio sources, 109 stations

Models:

- IERS Conventions (2003)
- Ocean and atmospheric pressure loading (Petrov and Boy, 2003)

Software:

- SteelBreeze

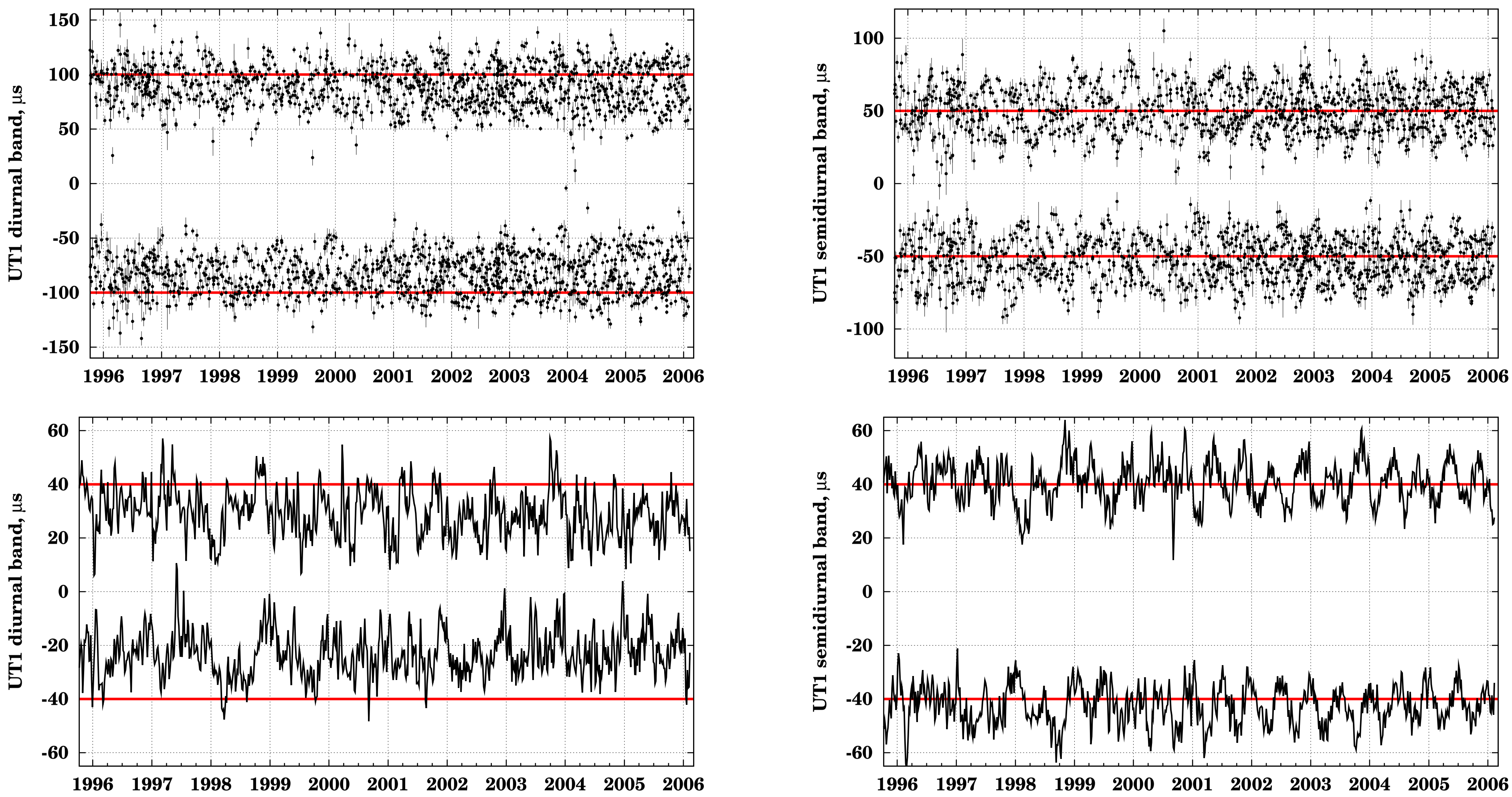
Estimated parameters:

- global parameters: coordinates of radio sources, positions and velocities of VLBI stations
- local parameters: CIP offset $[dX, dY]$, $[x_\ell(t), y_\ell(t)]$ and $[u^c_\ell(t), u^s_\ell(t)]$, for $|\ell| \leq 10$
- stochastic parameters: station clock function, wet zenith delay and its gradients

For consistency check two runs were performed:

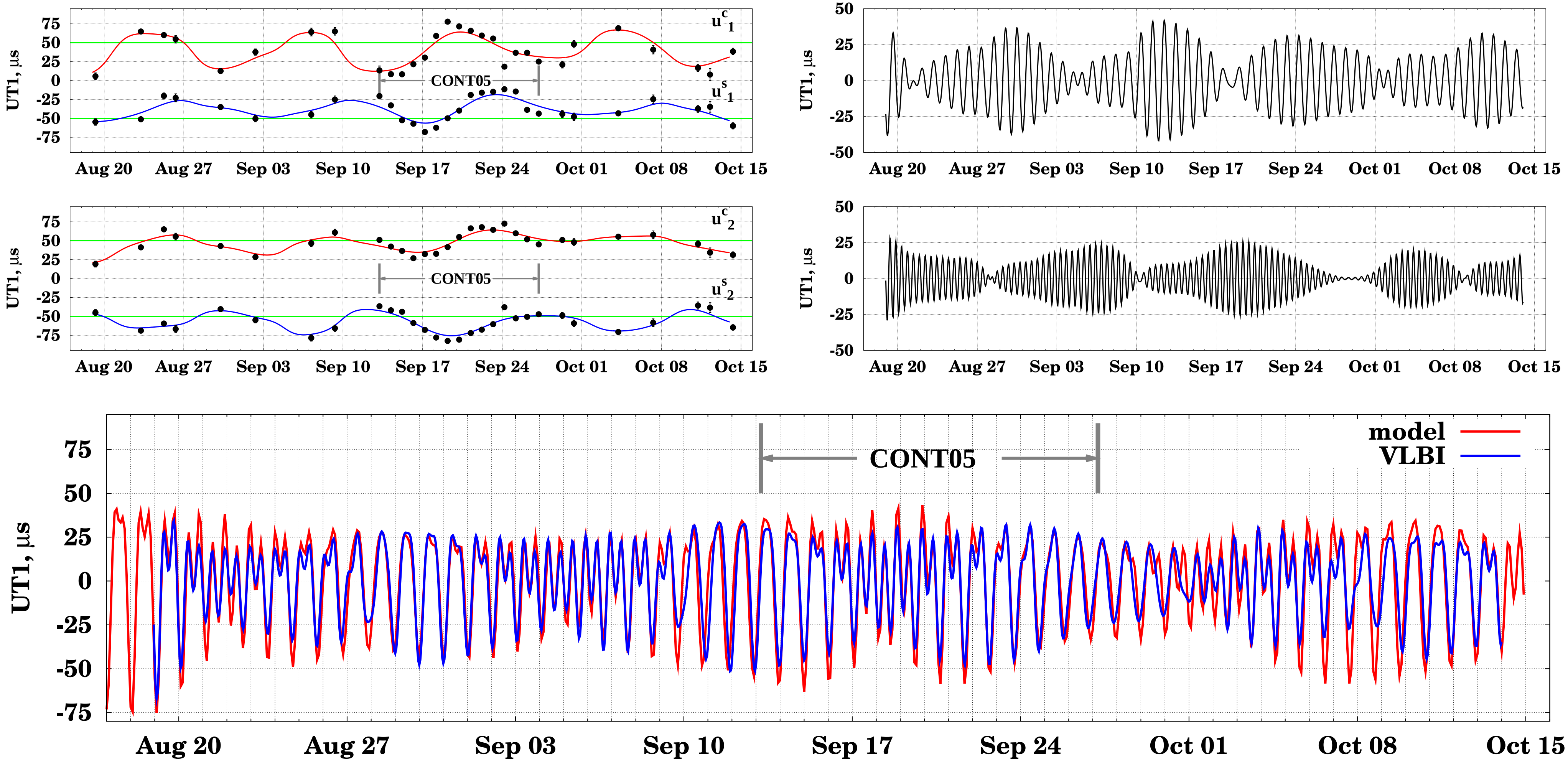
- with a priori model of diurnal/semidiurnal ocean tide variations
- without a priori model

Results



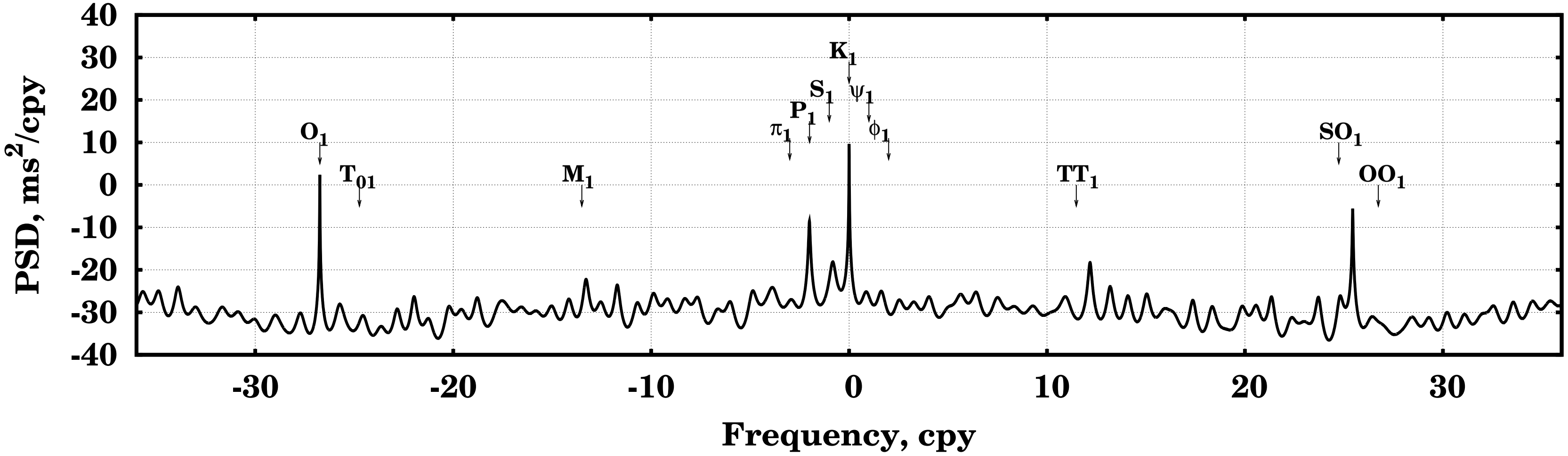
UT1 diurnal (left) and semidiurnal (right) components demodulated from VLBI data, row estimates (top) and smoothed values (bottom)

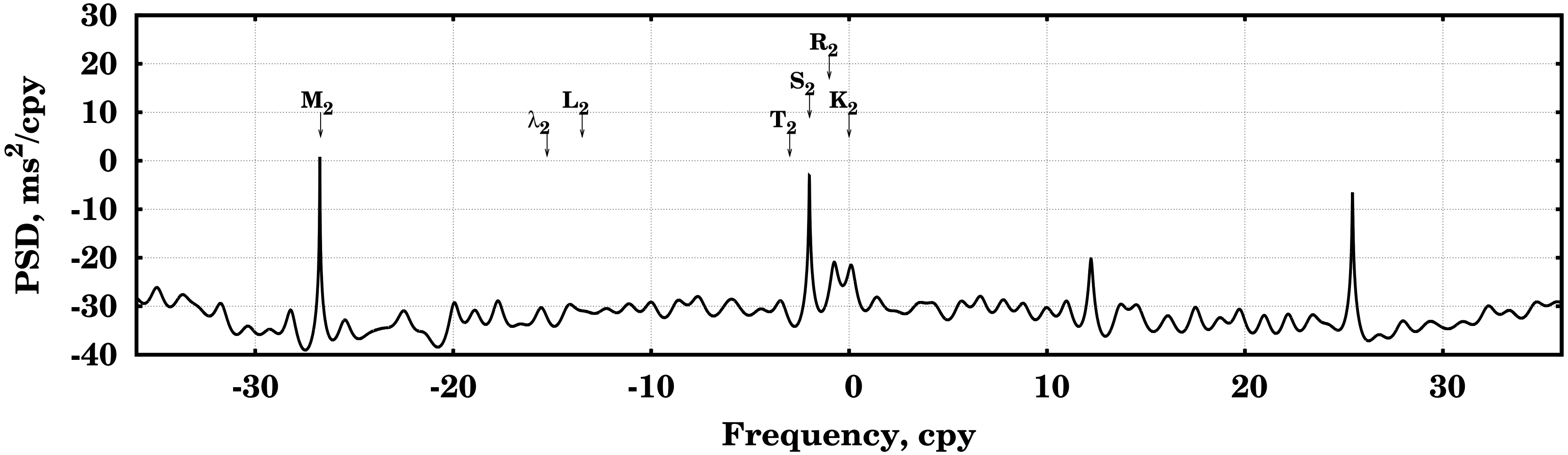
Results (cont.)



UT1 diurnal and semidiurnal components, estimation from VLBI observations (upper plots) and comparison with the modeled ocean tide effect (lower plot)

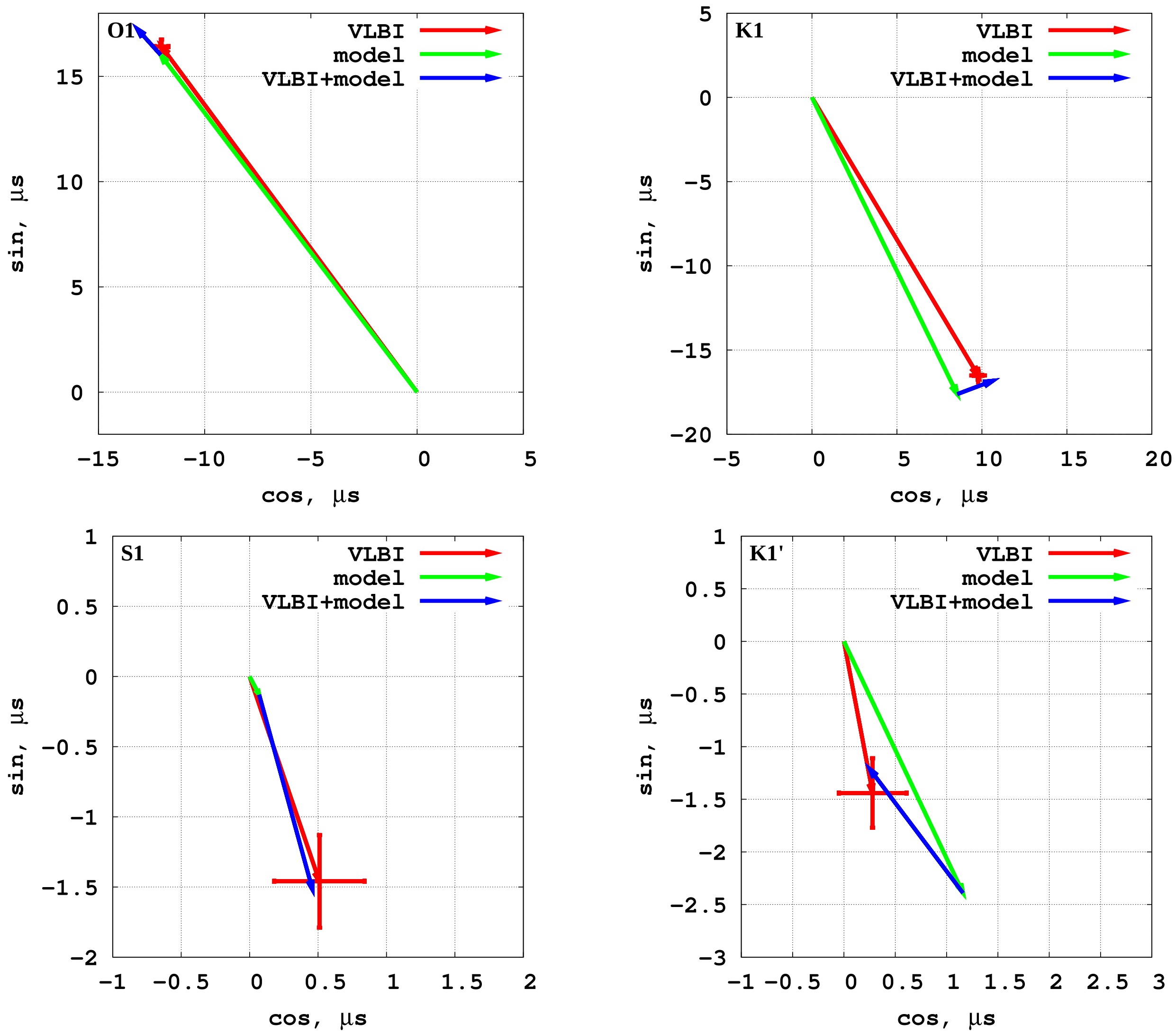
Results (cont.)





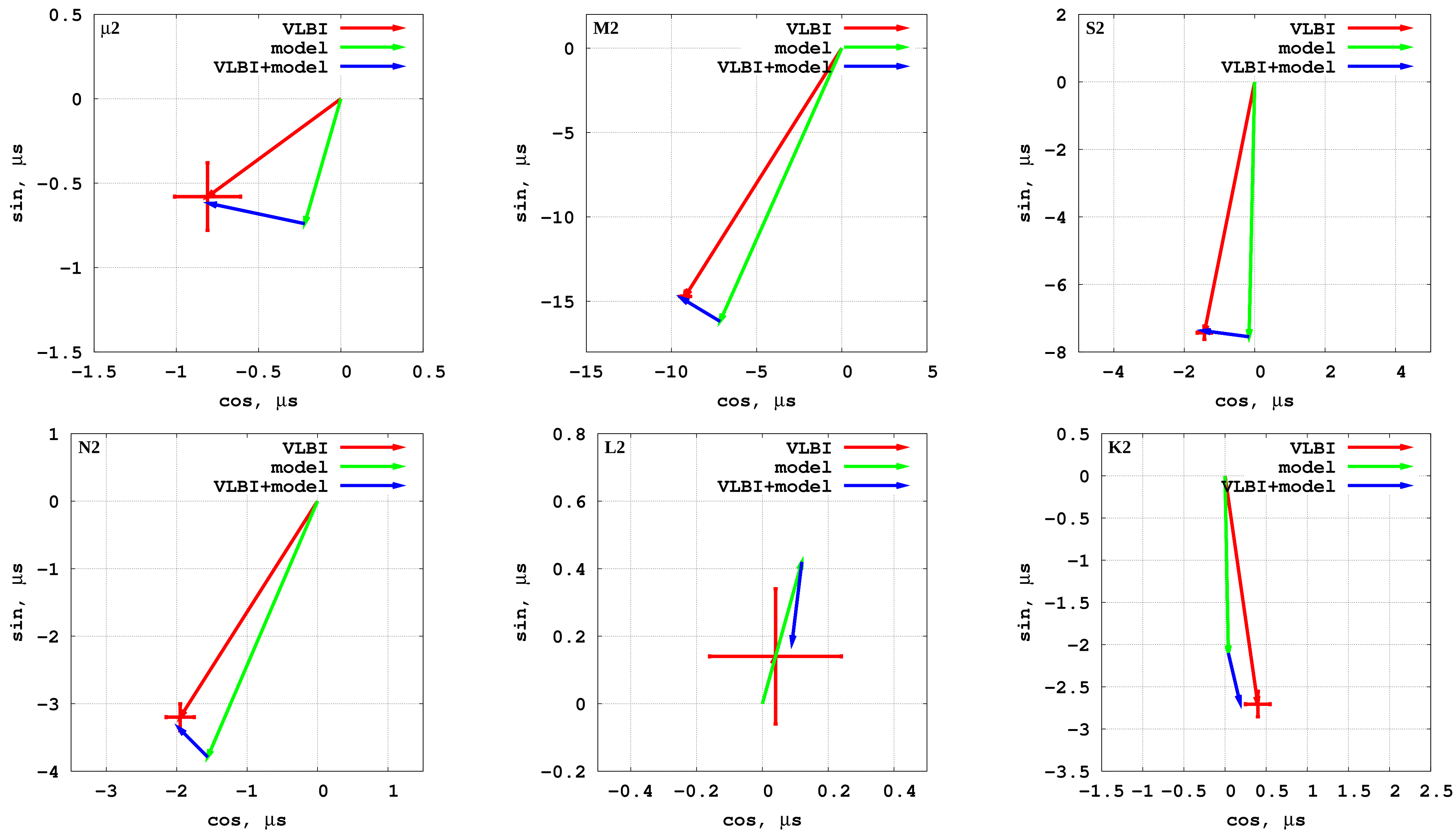
Power spectrum of UT1 variations: diurnal (top) and semidiurnal (bottom). Model of the ocean tide variations has been not removed in the estimation.

Results (cont.)



Diurnal UT1 variations: VLBI estimates vs. modeled ocean tide influence.

Results (cont.)



Semidiurnal UT1 variations: VLBI estimates vs. modeled ocean tide influence.

Conclusions

- Parametrization implemented in this work enables derivation of the high frequency signals in PM and UT1 from the routine VLBI observations.

- Spectral analysis showed that the estimated time series expressing diurnal and semidiurnal variations describe adequately real physical signals, however

  $\Rightarrow$ we discovered significant differences with the model of ocean tide effects.

- At higher frequencies (3, 4, . . . , cpd) the estimated series do not show any nontrivial spectral features therefore can be neglected in the parametrization.

- This research needs continuation:

  $\Rightarrow$ comparison with alternative solutions based on different VLBI software or derived from observations by other space geodetic techniques;

  $\Rightarrow$ comparison with diurnal and semidiurnal signals extracted from the high resolution atmospheric and oceanic angular momentum data.

Conclusions

- We recommend that the analysis centers which estimate the EOP and EOP rates with at least daily averaging

  $\Rightarrow$ will add diurnal and semidiurnal amplitudes of PM and UT1 to the set of the estimated parameters.

  $\Rightarrow$ will perform reanalysis of the archived sets of observations using this extended model, in order to recover past behavior of diurnal and semidiurnal signals.

- Conventional model of the ocean tide influences on PM an UT1 should be improved using new data sets from satellite altimetry and from space geodesy.