TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

RESEARCH GROUP ADVANCED GEODESY
Institute of Geodesy and Geophysics

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Session 3:

Estimation of Geodetic and Geodynamical Parameters with VieVS

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Vienna VLBI Software (VieVS)

- VieVS: new geodetic VLBI data analysis software
  - written in Matlab

more details about the theoretical computed delay in:

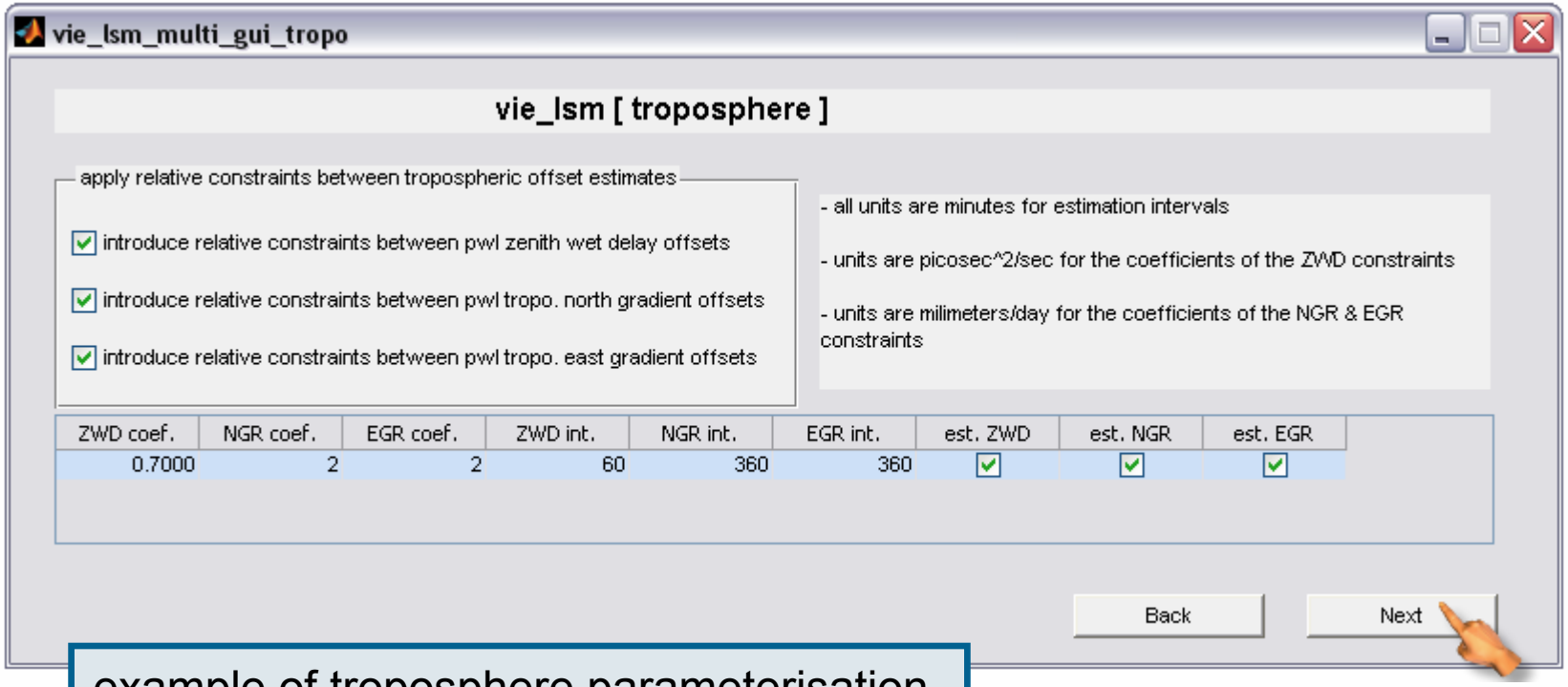
Session 3:

Comparison Campaign of VLBI Data Analysis Software – First Results

Lucia Plank

Vienna VLBI Software (VieVS)

- **single session solution** – classical least squares adjustment
  - time varying parameters are modelled by piecewise linear offsets at integer fractions of integer hours



example of troposphere parameterisation

Vienna VLBI Software (VieVS)

development of program unit for parameter estimation with so-called **global solution**

present state, common parameters: antenna coordinates and velocities, EOPs and Love & Shida numbers (reduction of clock parameters, zwd, troposphere gradients)

- Step 1: **reduction** of parameters

$$\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

estimated p.

reduced p.

$$N_{reduc} = N_{11} - N_{12} \cdot N_{22}^{-1} \cdot N_{21}$$

$$b_{reduc} = b_1 - N_{12} \cdot N_{22}^{-1} \cdot b_2$$

- Step 2: **stacking** of the reduced normal equation systems

$$N = N_{reduc\_1} + N_{reduc\_2} + \ldots + N_{reduc\_nse}$$

$$b = b_{reduc\_1} + b_{reduc\_2} + \ldots + b_{reduc\_nse}$$

$$x = N^{-1} \cdot b$$

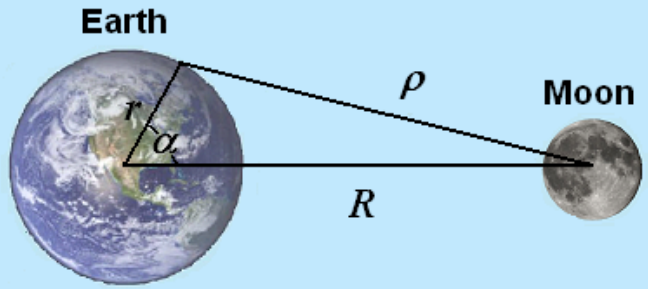
Love & Shida numbers

- **Solid Earth tidal deformation** arises from the variations in the Earth's gravitational field caused by the **Moon/Sun** relative to its strength at the geocentre

$$V_{Grav} = \frac{GM_M}{R}\sum_{n=0}^{\infty}\left(\frac{r}{R}\right)^n P_n(\cos\alpha) = V_0 + V_1 + V_2 + \ldots$$

→ tidal potential V^{tid}

- **Love and Shida** numbers *h*, *l* are dimensionless **parameters**, which characterize how strong is the **effect** of the potentional component **on the displacement**



tidal displacement in REN system →

basic Earth model:

spherical, non-rotating, elastic, isotropic

h and ***l*** **depend only on the degree** of the tidal potential

$$u_R = \sum_{n=2}^{\infty} h_n \cdot \frac{1}{g} \cdot V_n^{tid}$$

$$u_N = \sum_{n=2}^{\infty} l_n \cdot \frac{1}{g} \cdot \frac{\partial V_n^{tid}}{\partial \varphi}$$

$$u_E = \sum_{n=2}^{\infty} l_n \cdot \frac{1}{g \cdot \cos\varphi} \cdot \frac{\partial V_n^{tid}}{\partial \lambda}$$

Love & Shida numbers

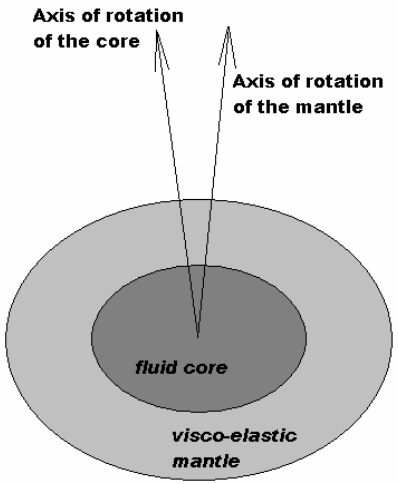
More precise **Earth model with fluid core and elastic mantle**

- the tidal response of the Earth becomes frequency dependent in the diurnal band

$$\delta u^{(21)}_{\mathrm{R}(f)} = -\frac{3}{2}\sqrt{\frac{5}{24\pi}} H_f \delta h_{21(f)} \sin(2\varphi)\sin(\theta_f + \lambda)$$

the corrections to radial displacement coming from the harmonic terms of the second degree tidal potential in the diurnal band

H_f	Cartwright-Tayler amplitude of the tidal term
$\delta h_{21(f)}$	difference of $h_{21}(f)$ from the nominal value h_2
θ_f	tidal harmonic argument



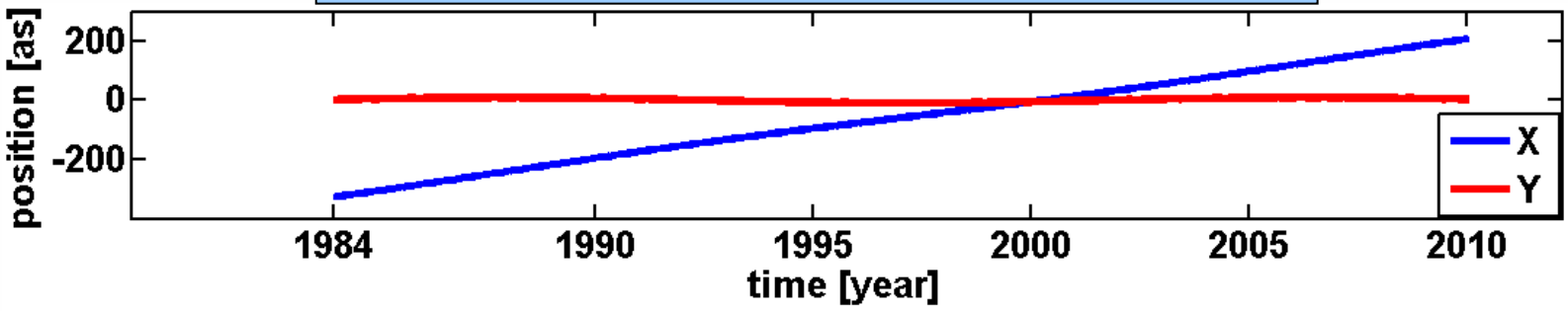
- **Resonance** of the tidal force with the forces at the elliptical core-mantle boundary at the Free Core Nutation period

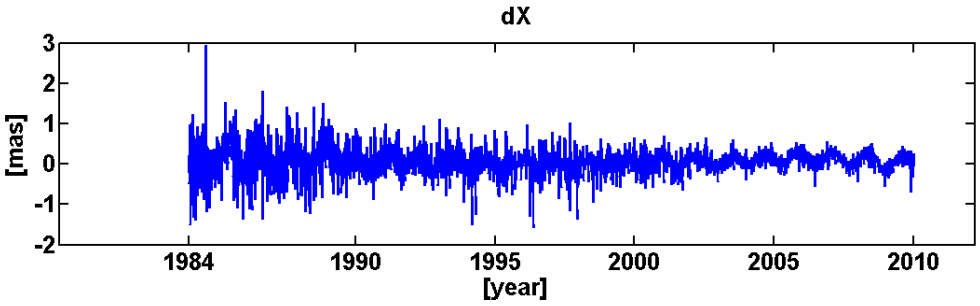
- **FCN**: the fluid core rotates around an axis which is slightly inclined w.r.t. the axis of rotation of the mantle → **small periodic motion of the Earth's axis of rotation** (Wahr, 1981)

Free Core Nutation (FCN)

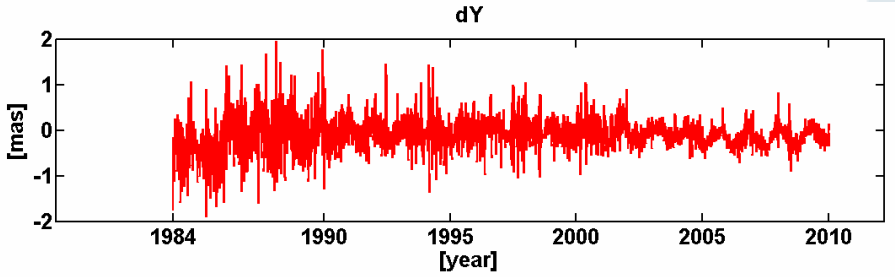
Motion of the Earth‘s rotational axis in the celestial system

Position of the **Celestial Intermediate Pole** in the **Geocentric Celestial Reference System**



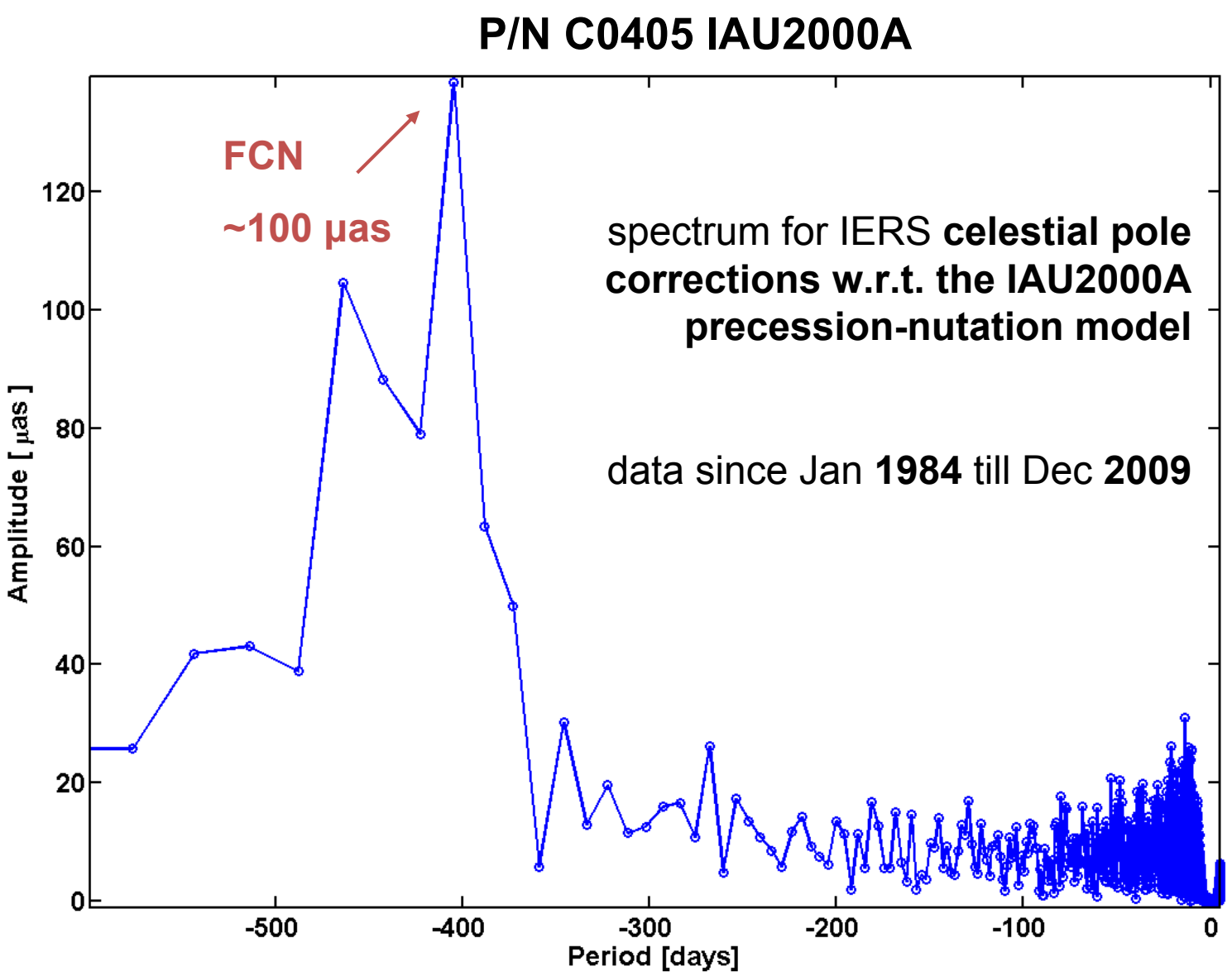


Celestial pole offsets w.r.t. the IAU 2000A precession-nutation model



FCN is a rotational free mode of the Earth, which **cannot be predicted** rigorously. It is not considered as a part of the a-priori precession-nutation model

Free Core Nutation (FCN)

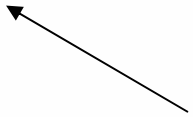


Free Core Nutation (FCN)

- Three options for determining the FCN-period

1. analysis of **celestial pole offsets**
   - e.g. Herring et al.,1986; Vondrak and Ron, 2006
2. analysis of tidal **gravity data**
   - e.g. Defraigne, 1994; Florsch and Hinderer, 2000; Ducarme et al., 2007
3. analysis of observed solid Earth **tidal displacements**, e.g., of the VLBI antennas
   - Haas and Schuh, 1996 – 10 years data

   (Determination of frequency dependent Love and Shida numbers from VLBI data. Geophysical Research Letters. Vol. 23 No. 12/1996. p.1509-1512)

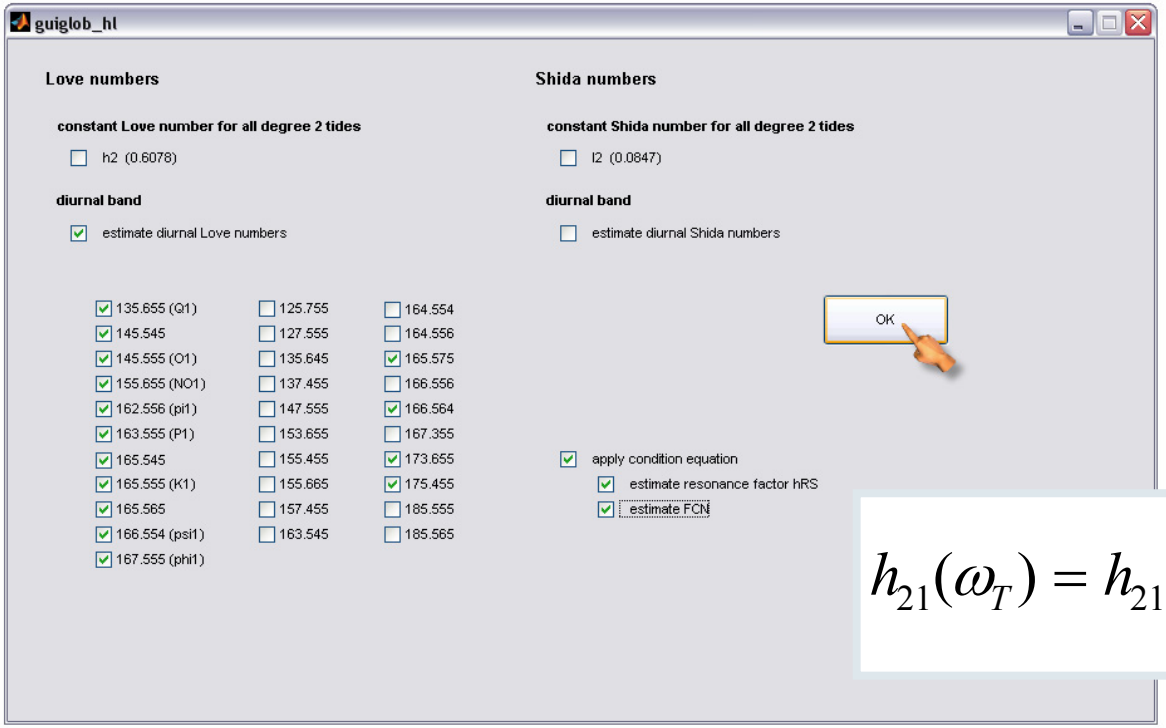


motivation for our work

Vienna VLBI Software (VieVS)

Present state in VieVS

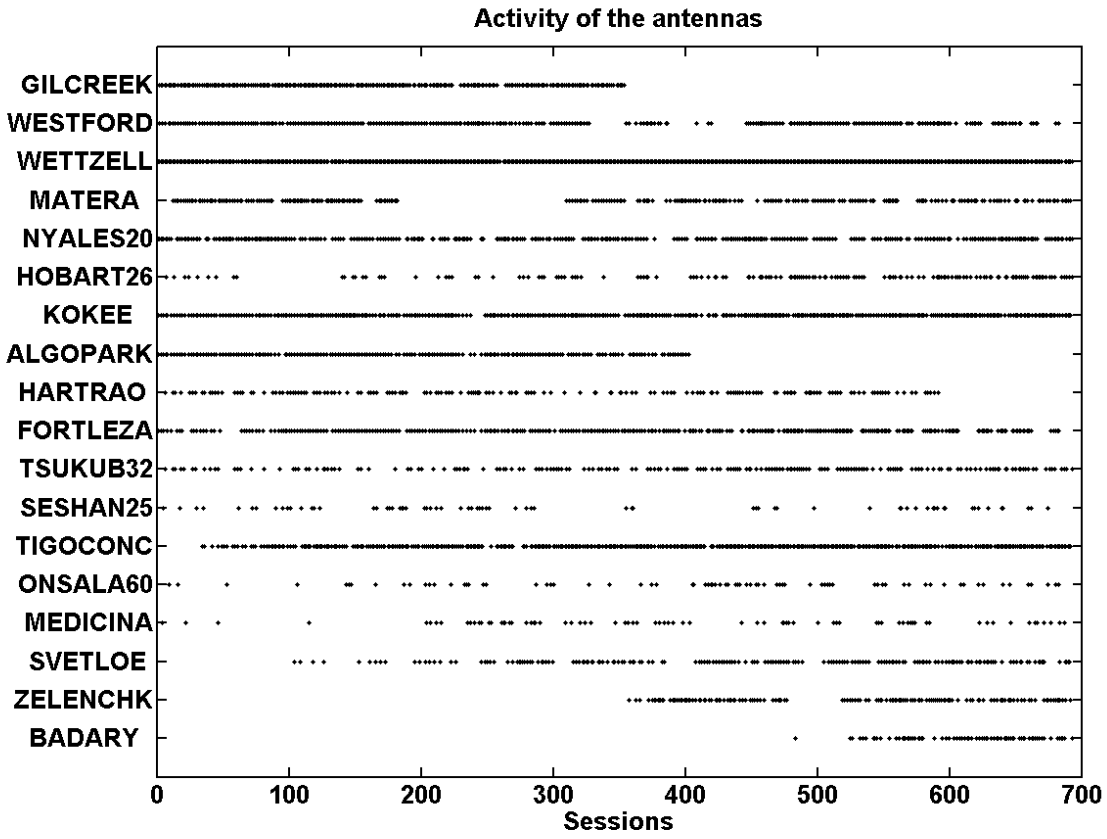
- degree 2 Love & Shida numbers: **h2, l2**
- **frequency dependent** Love & Shida numbers in the diurnal band
  - 31 diurnal tidal waves (also in dehanttideinel.f (=subroutine provided by V.Dehant))
  - estimate Love & Shida numbers separately or
  - apply condition equation with **FCN-period** and **resonance strength** factor



$$h_{21}(\omega_T) = h_{21}(\omega_{O1}) + h_{RS} \cdot \frac{\omega_T - \omega_{O1}}{\omega_{FCN} - \omega_T}$$

VLBI data

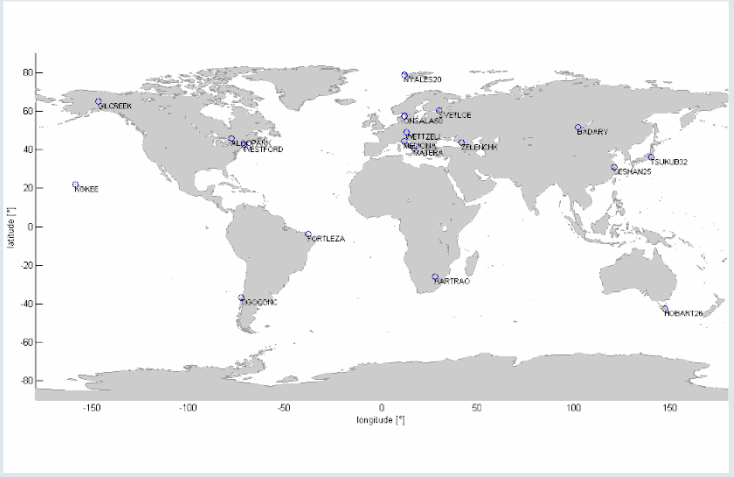
- R1 and R4 IVS sessions
  - 24-hour sessions
  - since Jan 2002 – Nov 2009 (7 years)



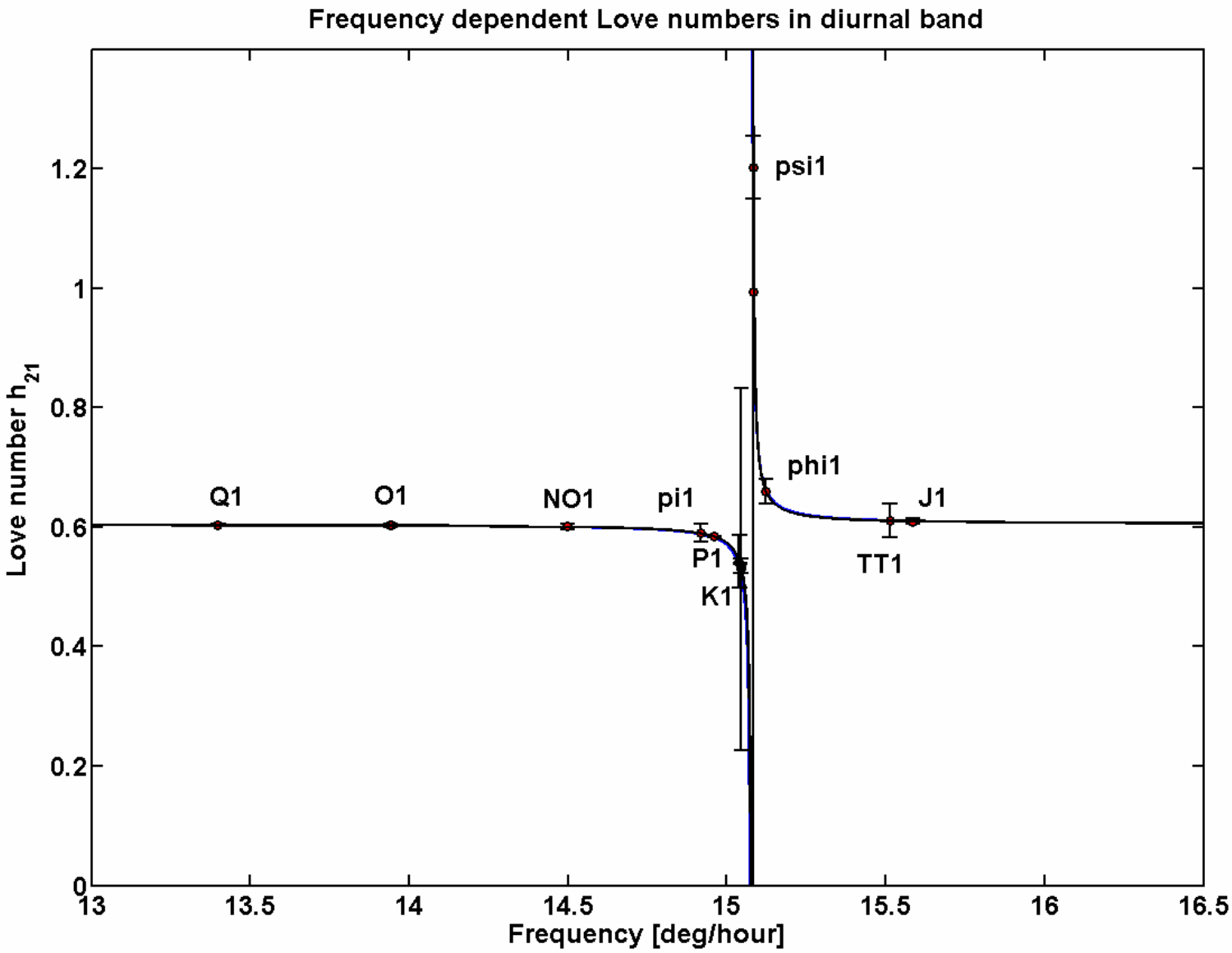
- outliers in observations removed
- only sessions with a posteriori variance of unit weight < 1.5

$$\sigma_0^2 = \frac{\boldsymbol{v}^T \boldsymbol{P} \boldsymbol{v}}{n_{obs} - u_{par}}$$

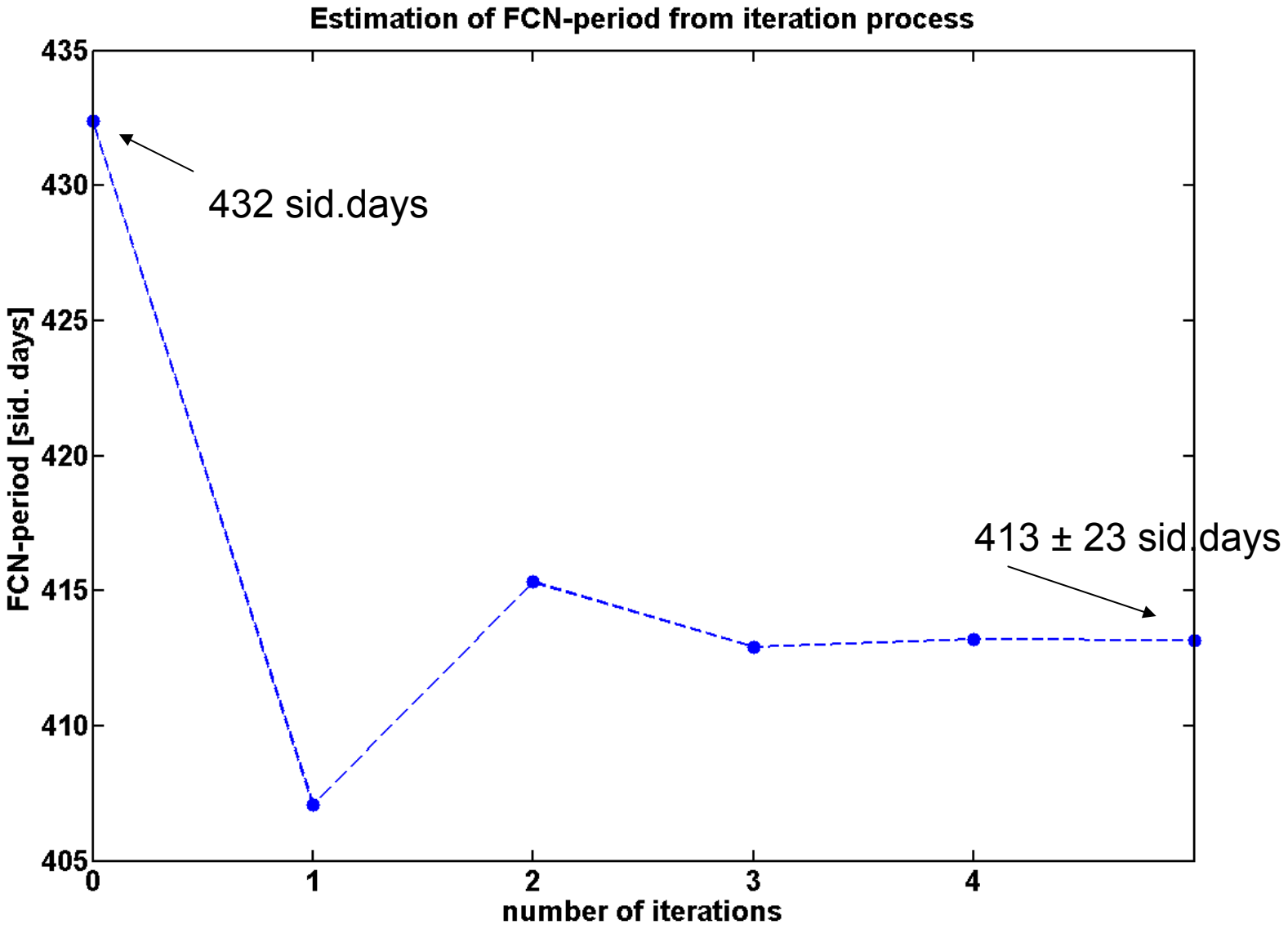
- 692 sessions at total



First results

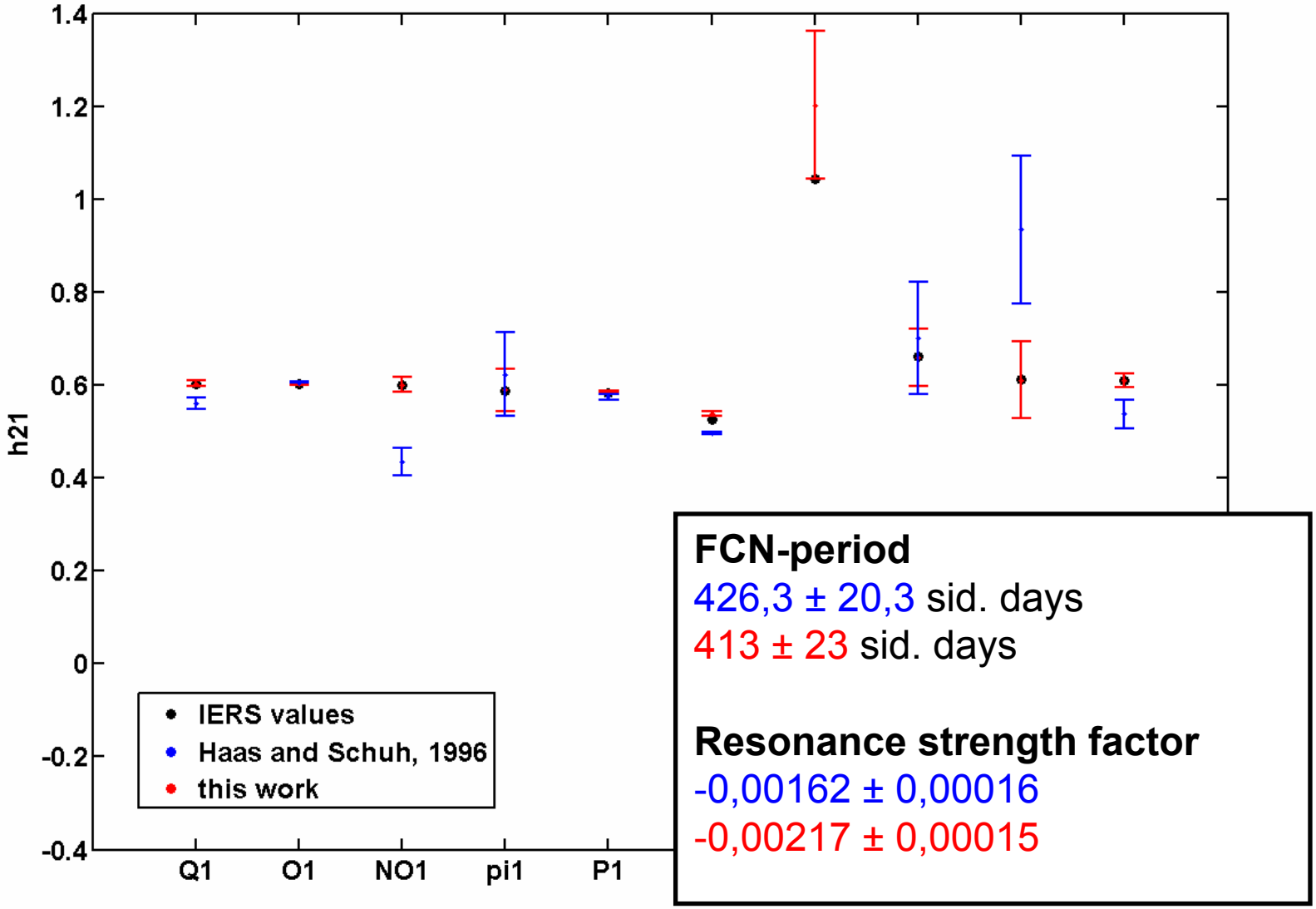


First results



First results

Estimates of frequency dependent Love numbers h21



FCN-period

426,3 ± 20,3 sid. days

413 ± 23 sid. days

Resonance strength factor

-0,00162 ± 0,00016

-0,00217 ± 0,00015

Summary

- VLBI group at TU Vienna is developing a new data analysis software, called VieVS (Vienna VLBI Software) http://mars.hg.tuwien.ac.at/~vievs/
- a new modul for global adjustment of more sessions is being implemented into the software
- aside from estimation of a new TRF/CRF or EOPs the global modul allows to determine geophysical parameters such as frequency dependent Love and Shida numbers and the Free Core Nutation period from solid Earth tidal deformations

Thank you for your attention!

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