TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Journées 2010, Paris
Session 4

Response of the Earth system to zonal tidal forcing examined by VLBI based dUT1 variations

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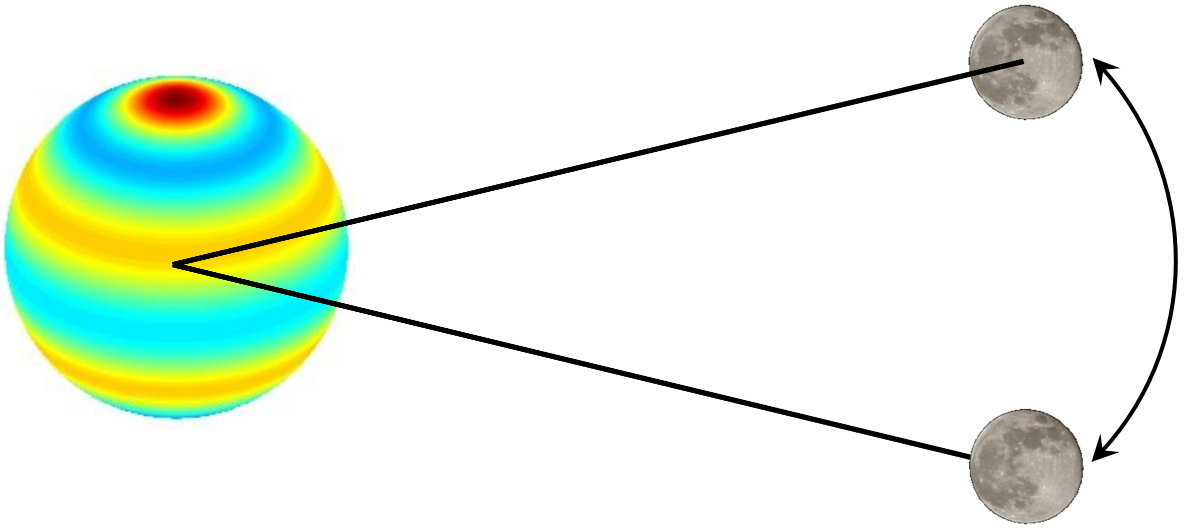
VieVS
Vienna VLBI Software

Outline

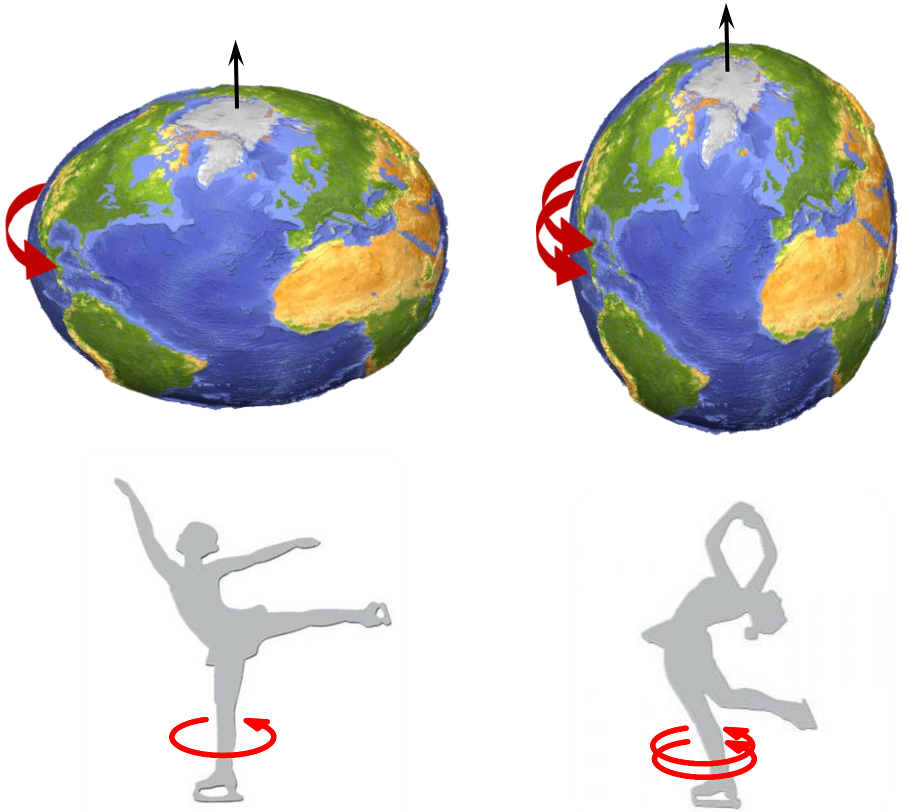
- The “zonal response coefficient” - basic concept
- Observed dUT1
  - The Vienna VLBI Software VieVS
  - Parameterization
- Estimation of the zonal response coefficient
  - Time series pre-processing
  - Functional model
- Preliminary results
- Summary and conclusions

Zonal tidal forcing

- V20 - latitude dependent part of the tide generating potential (TGP)
  - varies with the declination of the celestial body
  - causes long period tidal deformations (5 days – 18.6 years)



Conservation of angular momentum



- Deformation of the Earth gravity field / tensor of inertia is **proportional** to TGP
- Change in rotational velocity is also **proportional** to TGP

Proportionality factor

- Love number $\boldsymbol{k_2}$

$$\delta V_{20} = k_2 V_{20}$$

$$V_{20} = a_{20} P_{20}(\cos\theta)$$

- Induced change in δLOD in an elastic spherically symmetric Earth:

$$\frac{\delta LOD}{LOD_0} = -k_2 \frac{2}{3} \frac{R^3}{GC} a_{20}$$

C …	axial moment of inertia
G …	grav. Const.
R …	mean Earth radius
LOD_0	86400 s

Extension of the Love number concept

- Zonal response coefficient of the Earth-ocean system κ (Agnew & Farrell, 1978)
  - frequency dependent, complex-valued
  - Transfer function – also includes effects of the oceans, anelasticity of the mantle and fluid core

$$\frac{\delta LOD(\omega)}{LOD_0} = -\kappa(\omega)\frac{2}{3}\frac{R^3}{GC}a_{20}(\omega)$$

Extension of the Love number concept

- Zonal response coefficient of the Earth-ocean system κ (Agnew & Farrell, 1978)
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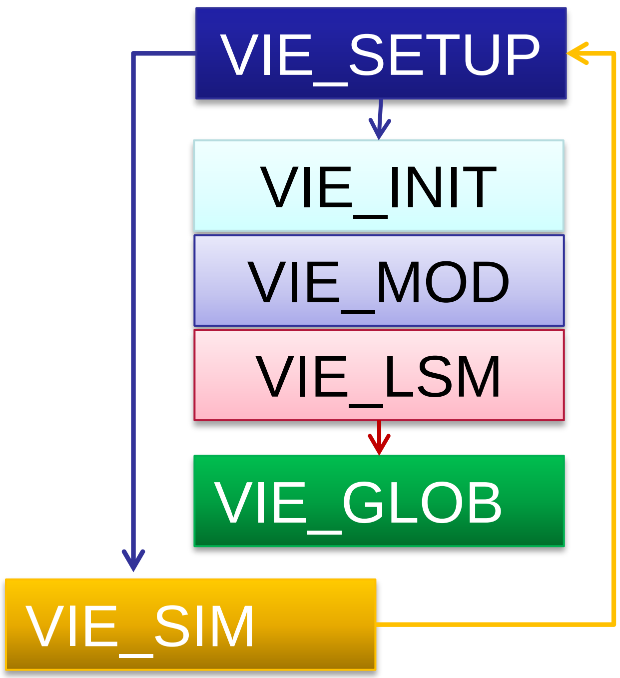
$$\delta UT1(\omega) = -\kappa(\omega)\frac{1}{i\omega}\frac{2}{3}\frac{R^3}{GC}a_{20}(\omega)$$

Vienna VLBI Software

- Developed at the Institute of Geodesy and Geophysics of the Vienna University of Technology
- Available for registered users: new users are welcome!



processing setup, graphical user interface

data reading

theoretical delay, partial derivatives

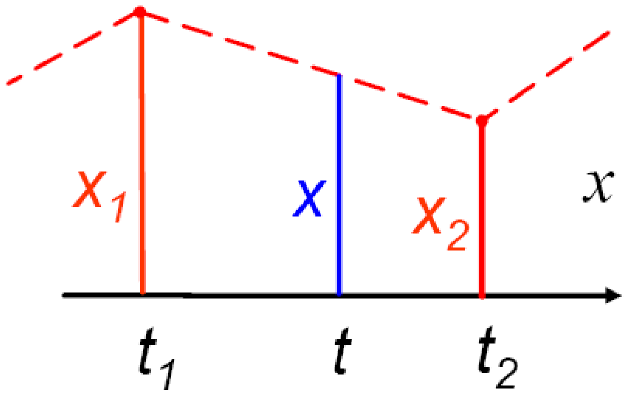
least squares adjustment

global solution

simulation tool

Estimation of dUT1 with VieVS

- Special parameterization: piecewise linear offsets at integer hours:

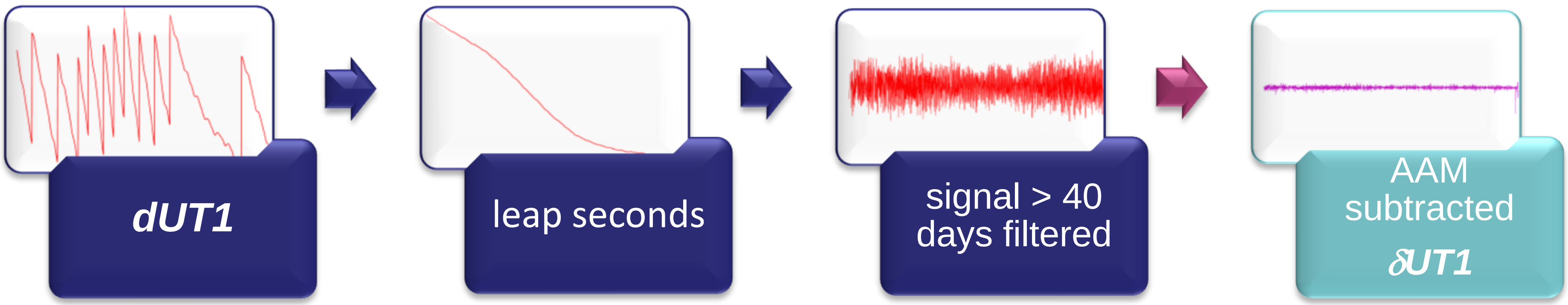


$$x = x_1 + \frac{(t - t_1)}{(t_2 - t_1)}(x_2 - x_1)$$

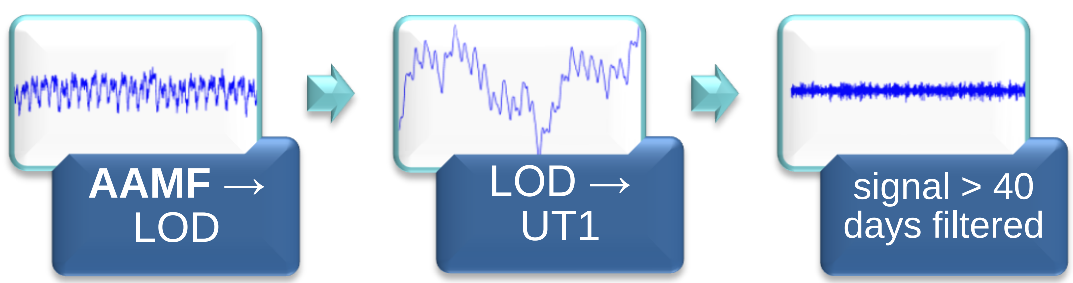
- dUT1
  - 6h interval
  - ~3600 sessions (1984-2010.5)

Estimation of κ

- dUT1 time series pre-processing → *δUT1*
  - "clean" time series from other than tidal signal
  - only tides with periods from 5-35 days are considered for the estimation of κ



Atmospheric excitation:
Effective Atmospheric Angular Momentum Functions from NCEP



Estimation of κ

- Functional model

Unknown parameters: magnitude and phase for each frequency

$$\delta UT1(\omega) = -\kappa(\omega)\frac{1}{i\omega}\frac{2}{3}\frac{R^3}{GC}a_{20}(\omega)$$

Pseudo-observations "measured" by VLBI

Amplitudes and frequencies from HW95 tidal potential catalogue

Theoretical values for κ

- For a spherically symmetric Earth without oceans:

$$\kappa = (\text{static})\, k_2 = 0.300$$

- + equilibrium ocean (+ 16%)

  + completely decoupled fluid core (-11%)

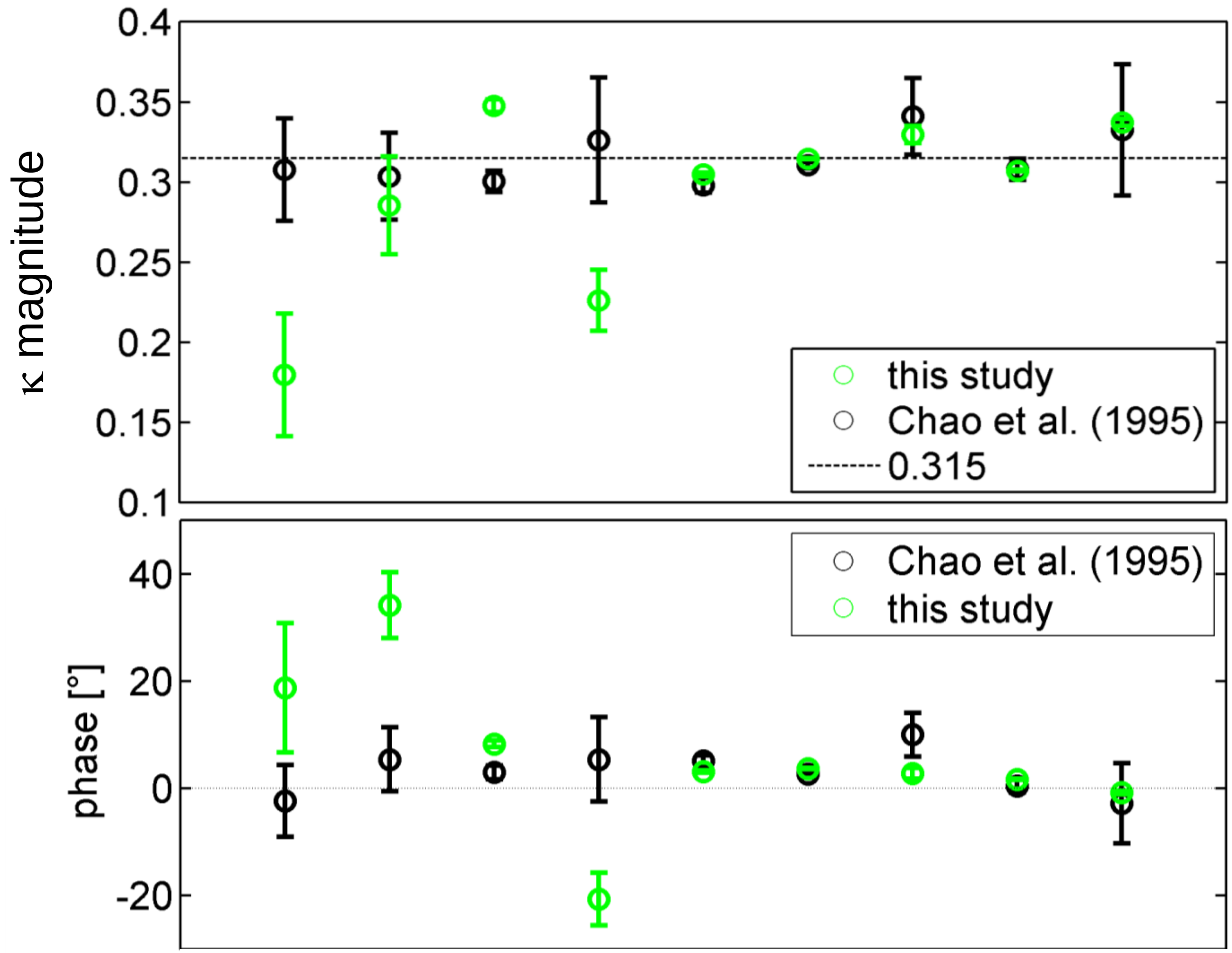
$$\kappa = 0.315$$

- Dynamic oceans, time dependent core-mantle coupling and mantle anelasticity introduce **frequency dependence** and **phase lag**:

$$\kappa(\omega \pm \varphi)$$

Values from Chao et al. (1995)

Preliminary results



Mqm	*Msqm*	*Mtm*	*Mstm*	*Mf'*	*Mf*	*Mtm*	*Mm*	*Msm*	**Tidal wave**
6.86	7.10	9.13	9.56	13.63	13.66	14.77	27.56	31.81	Period(d)

Summary and conclusions

- We re-processed VLBI sessions from 1984-2010.5 using the Vienna VLBI Software VieVS to generate a long dUT1 time series.
- dUT1 variations from 5-35 days were used to derive the zonal response coefficient κ for various tidal frequencies.
- First results for the longer periods (> 14d) agree well with the findings of older studies, e.g. Chao et al. (1995). Most of the κ of terms with periods <10 days seem to have smaller magnitudes with bigger phase lags, but this has to be confirmed by further investigations (because these terms also show larger formal errors).
- More detailed examination is needed, e.g. in terms of pre-processing and reliability of AAM data at short periods, before real statements about the geophysical meaning of the κ magnitudes and phases can be made.

Thank you!

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Preliminary results

- Main tidal periods

Tide	Period [d]	κ(magn.) ± σ		κ(phase) ± σ [°]	
Mqm	6.86	0.1798	±0.0382	18.77	±12.06
Msqm	7.10	0.2857	±0.0305	34.21	±6.16
Mtm	9.13	0.3476	±0.0039	8.31	±0.63
Mstm	9.56	0.2264	±0.0190	-20.65	±4.95
Mfp	13.63	0.3049	±0.0013	3.13	±0.24
Mf	13.66	0.3147	±0.0005	3.71	±0.09
Msf	14.77	0.3297	±0.0055	2.78	±0.99
Mm	27.56	0.3073	±0.0005	1.68	±0.09
Msm	31.81	0.3373	±0.0022	-0.78	±0.38