Free Core Resonance parameters from diurnal strain tides recorded by the Gran Sasso (Italy) and Canfranc (Spain) underground geodetic interferometers

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More details in a paper presently under revision.

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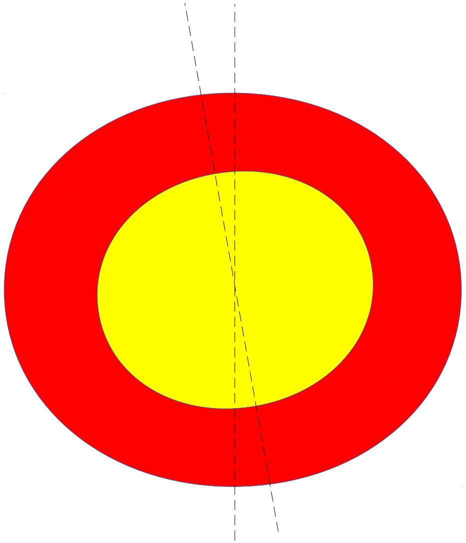
Motivations

Earth deformation at the diurnal tidal frequencies includes the resonant tidal-forcing response caused by the Free Core Nutation (FCN), a retrograde mode related to the slight misalignment of the rotation axes of the outer core and mantle.

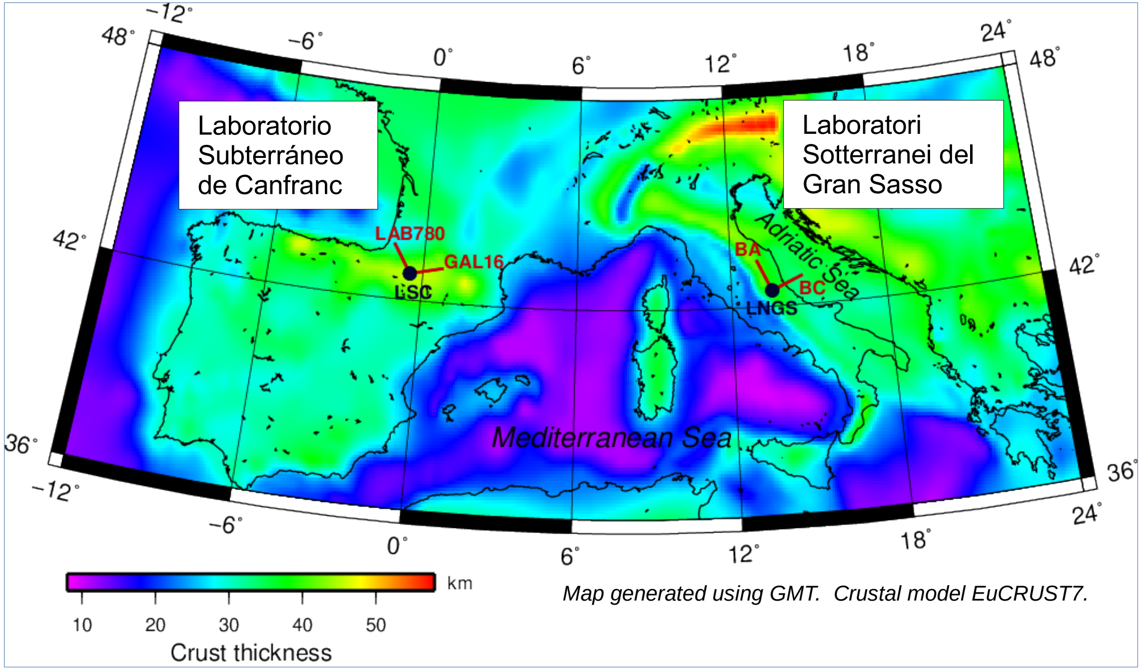


More generally, investigation of the resonant modifications of diurnal tides and forced nutations sheds light on the FCN, its related resonance parameters, the acting physical mechanisms, the relevant Earth geophysical properties, and ultimately the Earth interior. Many different research and application fields (e.g., the Earth's orientation in the space and global reference systems) would benefit of an accurate determination of the FCN parameters.

FCN effects on gravity tides (measured by gravimeters) and forced nutations (observed by VLBI) have been used since decades to estimate the FCN complex frequency.

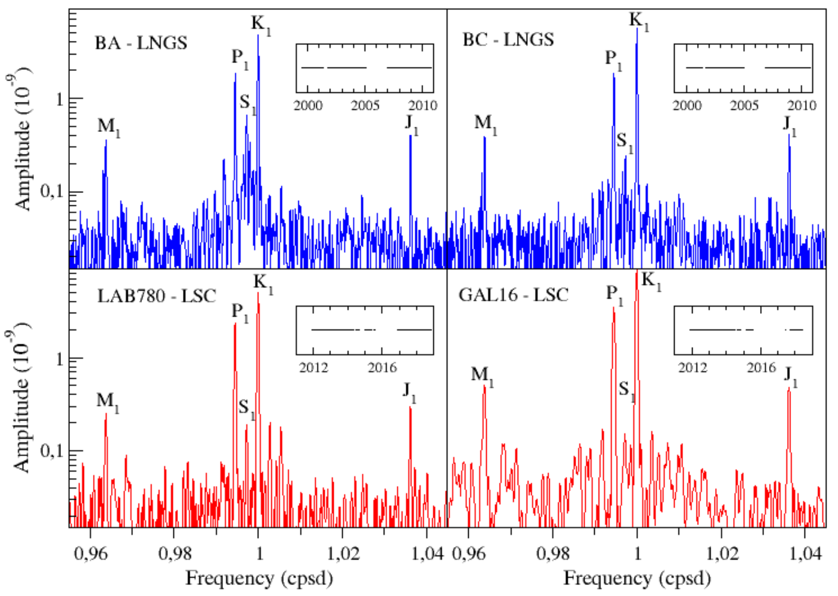
We analyse data from four underground high-sensitivity laser extensometers, whose signal-to-noise ratio in the diurnal tidal band is particularly high, and provide an alternative independent estimate of the FCN complex frequency with respect to more usual approaches (VLBI and gravimeters).

Data: extension ΔL/L, recorded by four underground laser extensometers (strainmeters)



Map generated using GMT. Crustal model EuCRUST7.

Amplitude spectrum and analysed time intervals.



Extension at the tidal frequencies includes the response of the solid Earth to the forcing tidal potential (**solid tides**) and to the water load oscillations caused by ocean tides (**ocean loading**), their sum giving **strain tides**.

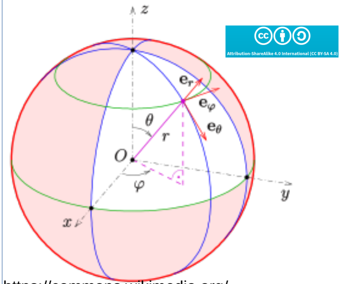
We compute **ocean loading** using two ocean models (FES2014 and TPXO9) and three Earth models (Gutenberg-Bullen, PREM, IASP91).

The interferometers measure local strain directly, but local strain is biased by siting effects. Coupling between local extension ε (measured by the interferometers) and regional deformation ε_{ij} can be effectively described by three coefficients α, β , and γ per interferometer:

$$\varepsilon = \alpha\,\varepsilon_{xx} + \beta\,\varepsilon_{yy} + \gamma\,\varepsilon_{xy}$$

where the *x*-axis is parallel to the interferometer.

Degree-2 diurnal solid strain tides (spherical coordinates) in terms of latitude- and frequency-dependent Love (*h*) and Shida (*l*) numbers



https://commons.wikimedia.org/wiki/File:Kugelkoord-lokale-Basis-s.svg

Extension along the azimuthal direction η

$$\varepsilon(\eta) = \frac{\varepsilon_{\theta\theta} + \varepsilon_{\phi\phi}}{2} + \frac{\varepsilon_{\theta\theta} - \varepsilon_{\phi\phi}}{2}\cos(2\eta) - \varepsilon_{\theta\phi}\sin(2\eta)$$

$$\frac{\varepsilon_{\theta\theta} + \varepsilon_{\phi\phi}}{2} = 3\sqrt{\frac{5}{24\pi}}\frac{|H_f|}{a} A \sin\theta\cos\theta$$

$$\frac{\varepsilon_{\theta\theta} - \varepsilon_{\phi\phi}}{2} = -3\sqrt{\frac{5}{24\pi}}\frac{|H_f|}{a}(S+C)\sin\theta\cos\theta$$

$$\varepsilon_{\theta\phi} = -3i\sqrt{\frac{5}{24\pi}}\frac{|H_f|}{a}(S-C)\sin\theta,$$

H_f = amplitude (m) of the tidal term of frequency f,

θ = geocentric colatitude of station,

ϕ = east longitude of station,

Parameters *A, S, C* are complex and can be expressed in terms of latitude- and frequency-dependent Love (*h*) and Shida (*l*) numbers.

A, S, C follow the resonance formula:

$$L(\sigma) = L_0 + \sum_{j=1}^{3}\frac{L_j}{(\sigma - \sigma_j)}$$

j=1, Chandler wobble; ***j*=2, FCN**; *j*=3, free inner core nutation

$$\sigma_2 = \left(1 + \frac{1}{T_{FCN}}\right)\left(1 + \frac{i}{2Q_{FCN}}\right)$$

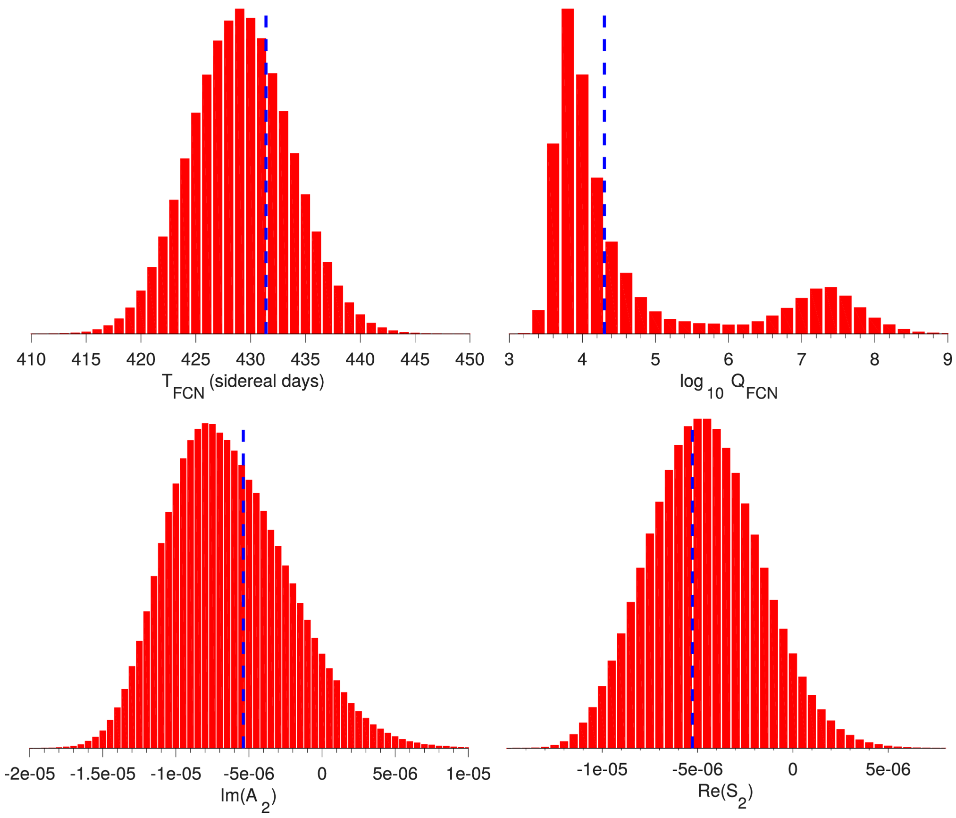
The inversion technique produces reliable estimates of T_{FCN} , Q_{FCN} (actually, $\log_{10} Q_{FCN}$), Re(A_2), Im(A_2), Re(S_2), and, for each interferometer, α, β , and γ.

There is a strong trade-off (linear correlation) between Re(A_2) and T_{FCN} , with a T_{FCN} increase by about 10 sidereal days when Re(A_2) decreases by about 5%. Thus, we fix Re(A_2) to its IERS value in the inversions.

Probability distributions of T_{FCN}, $\log_{10} Q_{FCN}$, Im(A_2), Re(S_2)

We estimate probability distributions and possible correlations of inverted parameters following a frequentist approach based on the L^1-norm inversion of thousands of synthetic data sets, which we obtain from the experimental one by adding a gaussian random noise whose standard deviation is given by the tidal analysis of the first-difference strain sequences.

Blue dashed lines give "reference values" computed by using reference IERS Love and Shida numbers at 42.6° latitude, i. e. between LNGS and LSC.



Discussion

Some (currently) unavoidable inconsistencies in our approach.

1) Theoretical solid tides are computed using Love and Shida numbers based on a Spherical Non Rotating Elastic Isotropic (SNREI) Earth model (PREM) and modified to account for ellipticity and rotation. Computations of solid tides using a full 3D Earth model with mantle heterogeneities evidence differences < 0.1% in gravity and vertical displacement with respect to a radially symmetric Earth model (Métivier & Conrad 2008): these differences are small and eventually counterbalanced by siting effect corrections, which are estimated during the inversion procedure.

2) Because of the trade-off between Re(A_2) and T_{FCN} , Re(A_2) is fixed to its reference value from parameters in IERS Conventions 2010, which were obtained from VLBI data using geophysical models available at the end of the 20th century. Any change in Re(A_2) would imply a change in T_{FCN}.

3) Strain Green functions from SNREI Earth models (GB, PREM, IASP91) are used for ocean loading. A more correct approach would involve computing deformation using a full 3D Earth model, which should be particularly accurate at short distances from the stations.

Thanks for your attention

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