MANTLE CONDUCTIVITY MODELS AND GEOMAGNETIC JERKS

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ABSTRACT

Geomagnetic jerks correspond to abrupt temporal changes in the secular acceleration believed to be of internal origin. The most well know worldwide events occurred in 1969 and 1978 and they are characterized by a bimodal time behaviour which manifests as a later appearance in the south hemisphere of about two years. One way to explain this intriguing temporal pattern is considering the Earth's mantle as a conductor, so the geomagnetic field observed at the surface will correspond to a filtered version of the original field generated at the core-mantle-boundary (CMB). We consider a radial mantle conductivity model which is linear, causal and time-invariant filter. Conductivity values are based on information given by high pressure experiments simulating the conditions of the deep mantle. For each harmonic degree we calculated the impulse response function in the time domain, from where we estimated distinct time delays.

GEOMAGNETIC JERKS

Geomagnetic jerks are abrupt temporal variations of the magnetic field believed to be due to motions in the fluid core. At the Earth's surface jerks are manifest as changes in the slope of the first time derivative, dividing intervals of approximately linear secular variation (Fig. 1).

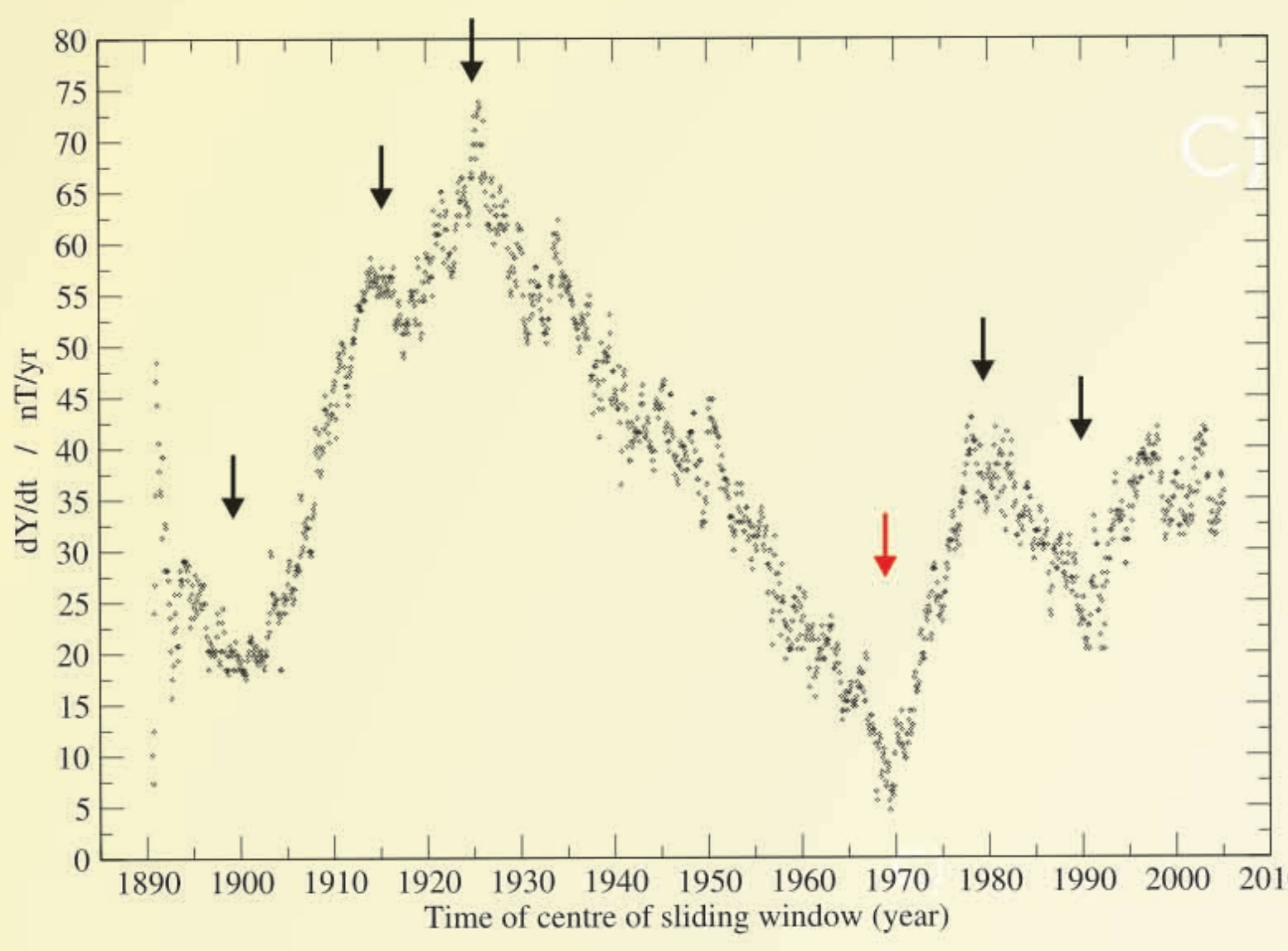


Figure 1. Secular variation of the Y component of Niemegk observatory in Germany, from 1890 to 2005. The arrows show the dates when the jerks occurred.

The occurrence of jerks is not uniformly distributed at the Earth's surface; in some observatories they are not detected while in others they occur only locally. However, the most well known jerk, in 1969 is worldwide and shows an intriguing temporal-spatial pattern: a first arrival in the Northern hemisphere followed by a delayed arrival in the Southern hemisphere by about 2 years. This intriguing spatial and temporal behaviour is still not well understood. One way to explain it is by considering a conducting mantle, consequently the magnetic field observed at the Earth's surface (output) will be a filtered version of the original field at the CMB (input) (Fig.3).

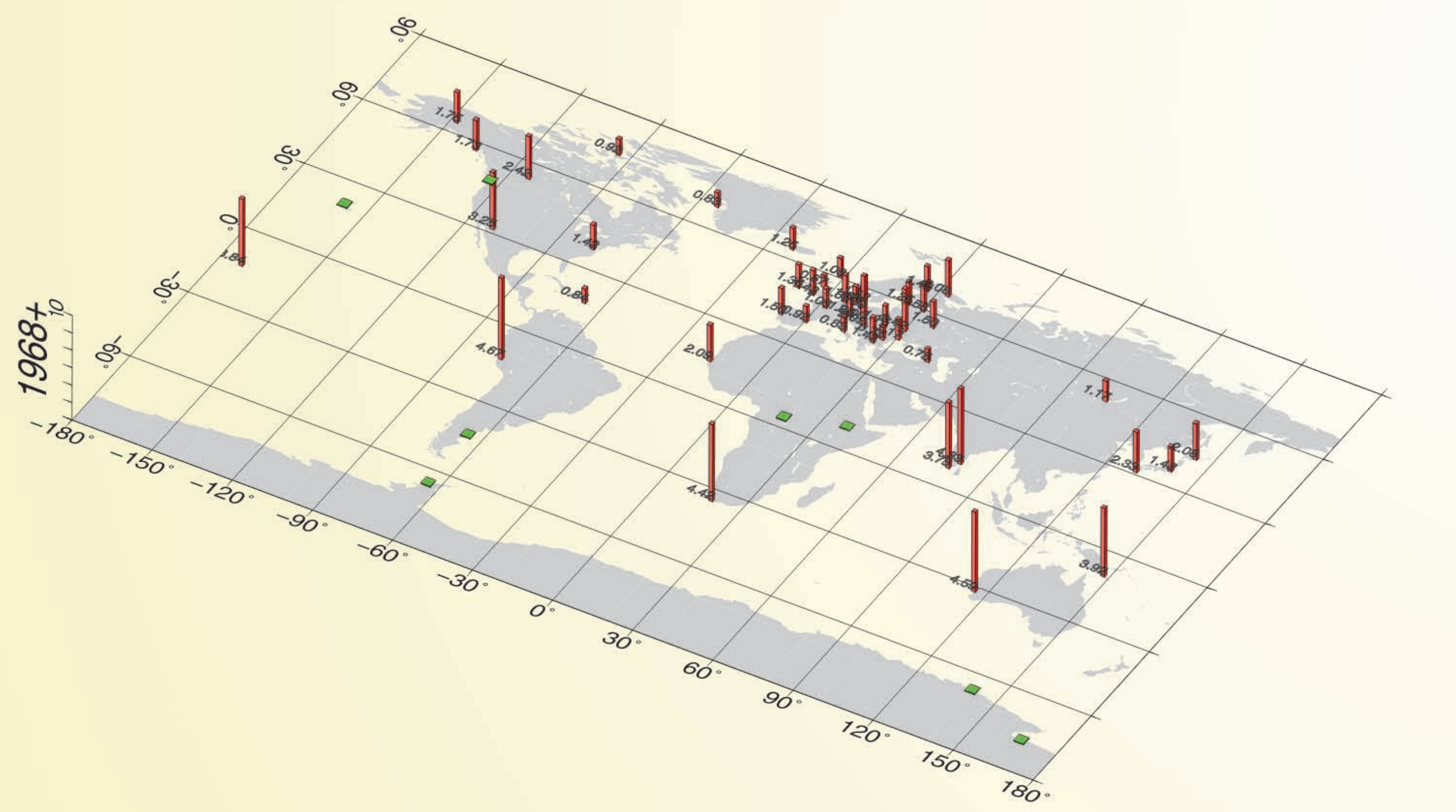
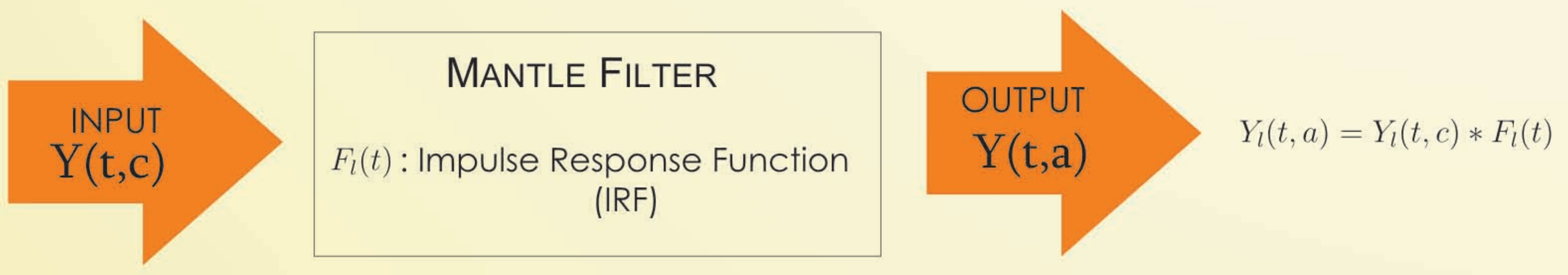


Figure 2. The bars show the times of occurrence of the 1969 jerk and the squares represent the places where the jerks were not detected. The results were taken from Alexandrescu *et al.* (1996), where jerks were detected by wavelet analysis.

GEOMAGNETIC JERKS AND THE SCREENING BY THE MANTLE

We consider a radial mantle conductivity model acting as a linear, causal and time-invariant filter.



INPUT
Y(t,c)

MANTLE FILTER

$F_l(t)$: Impulse Response Function (IRF)

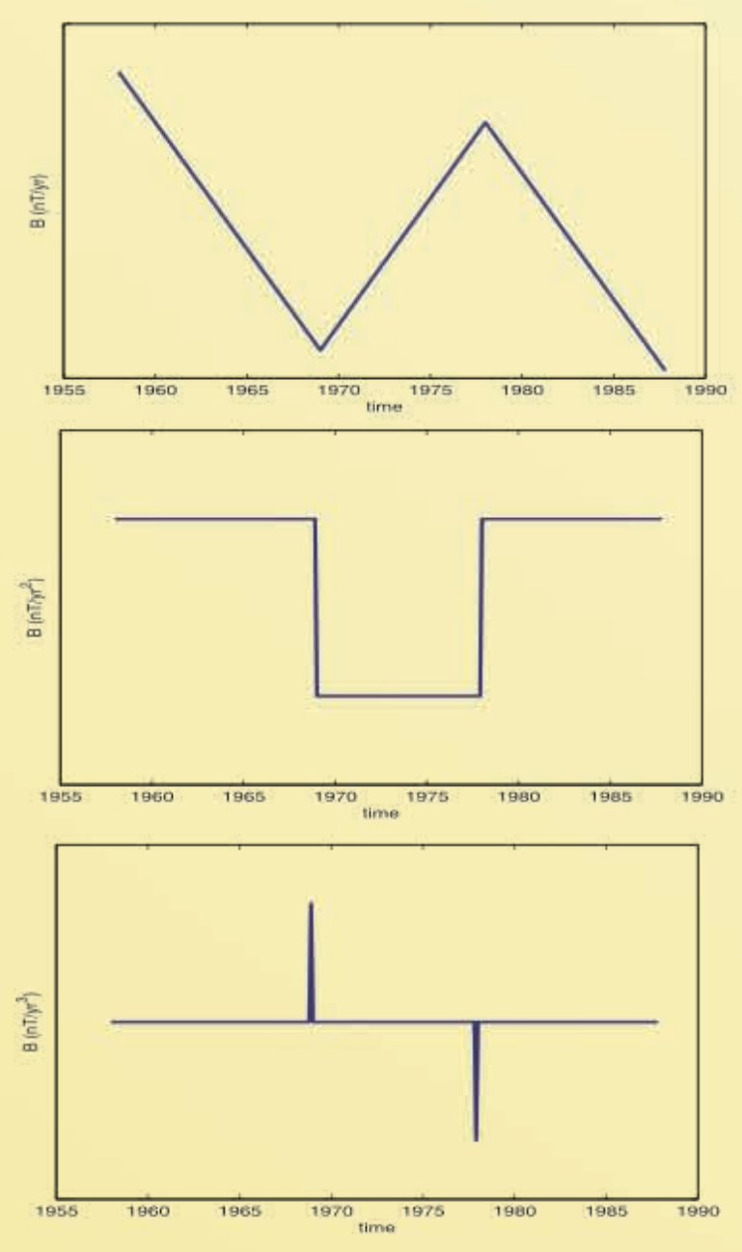
OUTPUT
Y(t,a)

$$Y_l(t,a) = Y_l(t,c) * F_l(t)$$

Figure 3. Schematic of the effect of the mantle filter on the input (e.g Y component at the CMB). The correspondent output (Y component at the Earth's surface) will be the convolution of the input with the filter (conducting mantle).

INPUT

The jerk is simulated as an impulse in time at the CMB (Fig.4) and the core magnetic field morphology approximated by using the Le Huy *et al.* (1998) spherical harmonic model of the 1969 jerk for the Y component. Equation 1 shows the jerk coefficients, eq. 2 the gradient of the potential (V) and in eqs. 3 and 4 the evaluation of the Y component.



$$\delta\ddot{g}_l^m(post) - \ddot{g}_l^m(pre) = \ddot{g}_l^m(jerk) \tag{1}$$

$$\delta\ddot{V} = a\sum_{l=1}^{\infty}\sum_{m=0}^{l}\left[\left(\frac{a}{r}\right)^{l+1}(\delta\ddot{g}_l^m\cos m\phi + \delta\ddot{h}_l^m\sin m\phi)\right]P_l^m(\cos\theta) \tag{2}$$

$$\delta\ddot{Y} = -\frac{1}{r\sin\theta}\frac{\partial(\delta\ddot{V})}{\partial\phi} \tag{3}$$

$$\delta\ddot{Y} = \frac{1}{\sin\theta}\sum_{l=1}^{\infty}\sum_{m=0}^{l}\left[\left(\frac{a}{r}\right)^{l+2}m(\delta\ddot{g}_l^m\sin m\phi - \delta\ddot{h}_l^m\cos m\phi\Big)\right]P_l^m(\cos\theta) \tag{4}$$

Figure 4. Simple schematic of secular variation in component of B. The second and third graphs show sketched the secular acceleration and the third derivative, respectively.

MANTLE CONDUCTIVITY MODEL

The diffusion equation was solved for a radial mantle conductivity model showed by eq.5 (Gubbins and Roberts, 1987) and Fig.5A. Conductivity values are based on information given by high pressure experiments simulating the conditions of the deep mantle (Xu et al., 2000). The IRF was evaluated for each harmonic degree (l) as it is shown in Fig.5B. The time delay of each harmonic degree is given by the first moment (eq.6).

$$\sigma(r) = \sigma_c(\frac{r_c}{r})^{2\gamma+2} \tag{5}$$

$$\tau_l = \frac{1}{\tilde{F}(0)}\int_{-\infty}^{\infty} F_l(t)tdt \tag{6}$$

area under the IRF curve

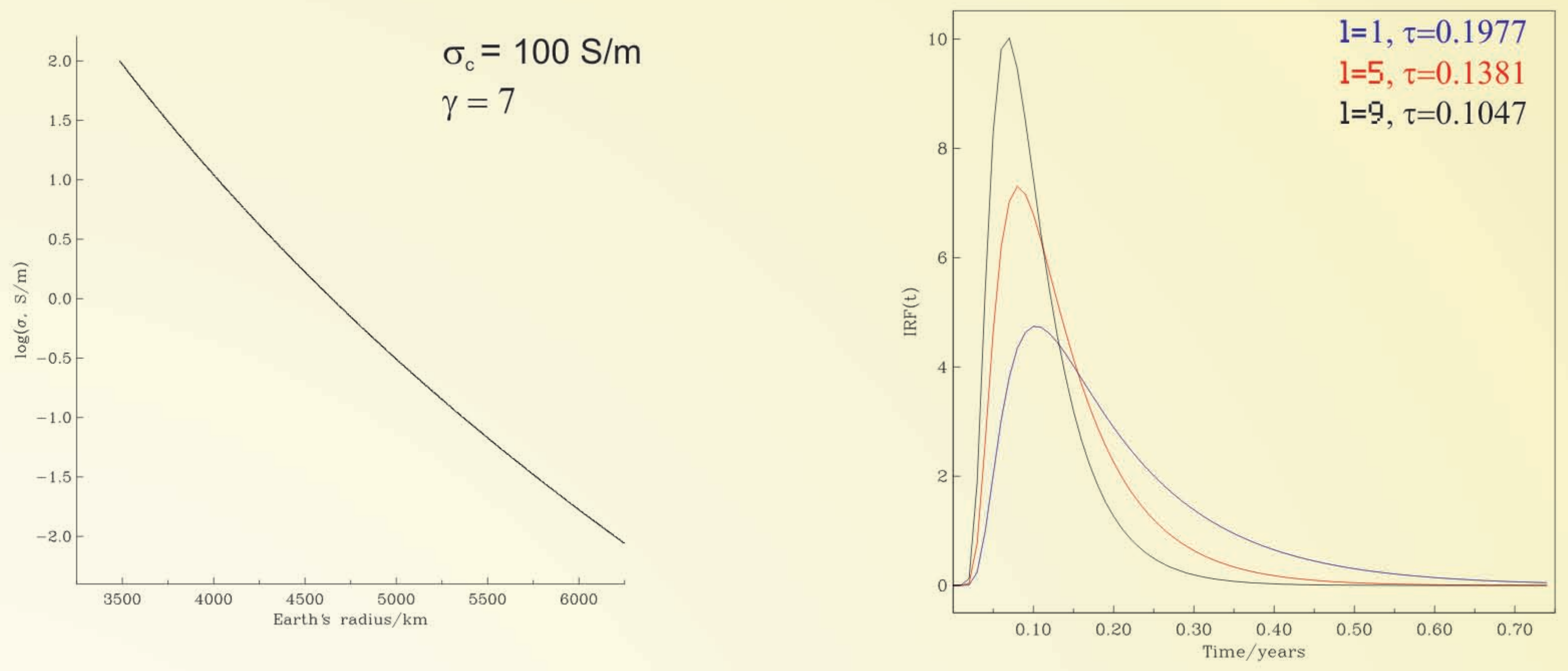


Figure 5. In A it is shown the mantle conductivity radial model and in B the impulse response function evaluated for each harmonic degree.

OUTPUT

The IRF is different for each harmonic degree and location, as it is shown in Fig.6 (eq.7). The output will correspond to a linear combination of the different filters at each point at the Earth's surface (eq.8), consequently, the time delays for each observatory will be different.

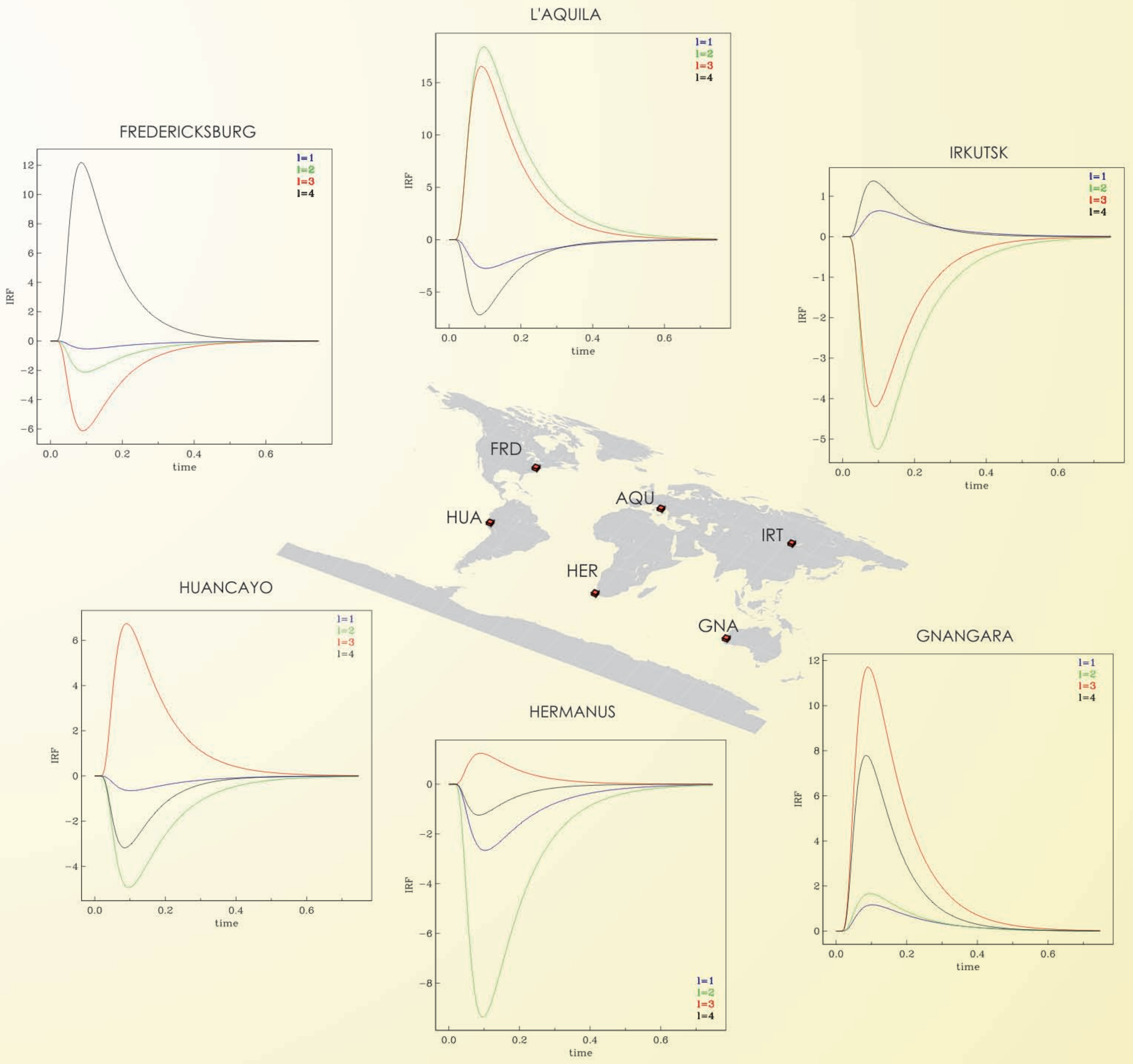


Figure 6. Impulse response functions of 6 observatories for each harmonic degree.

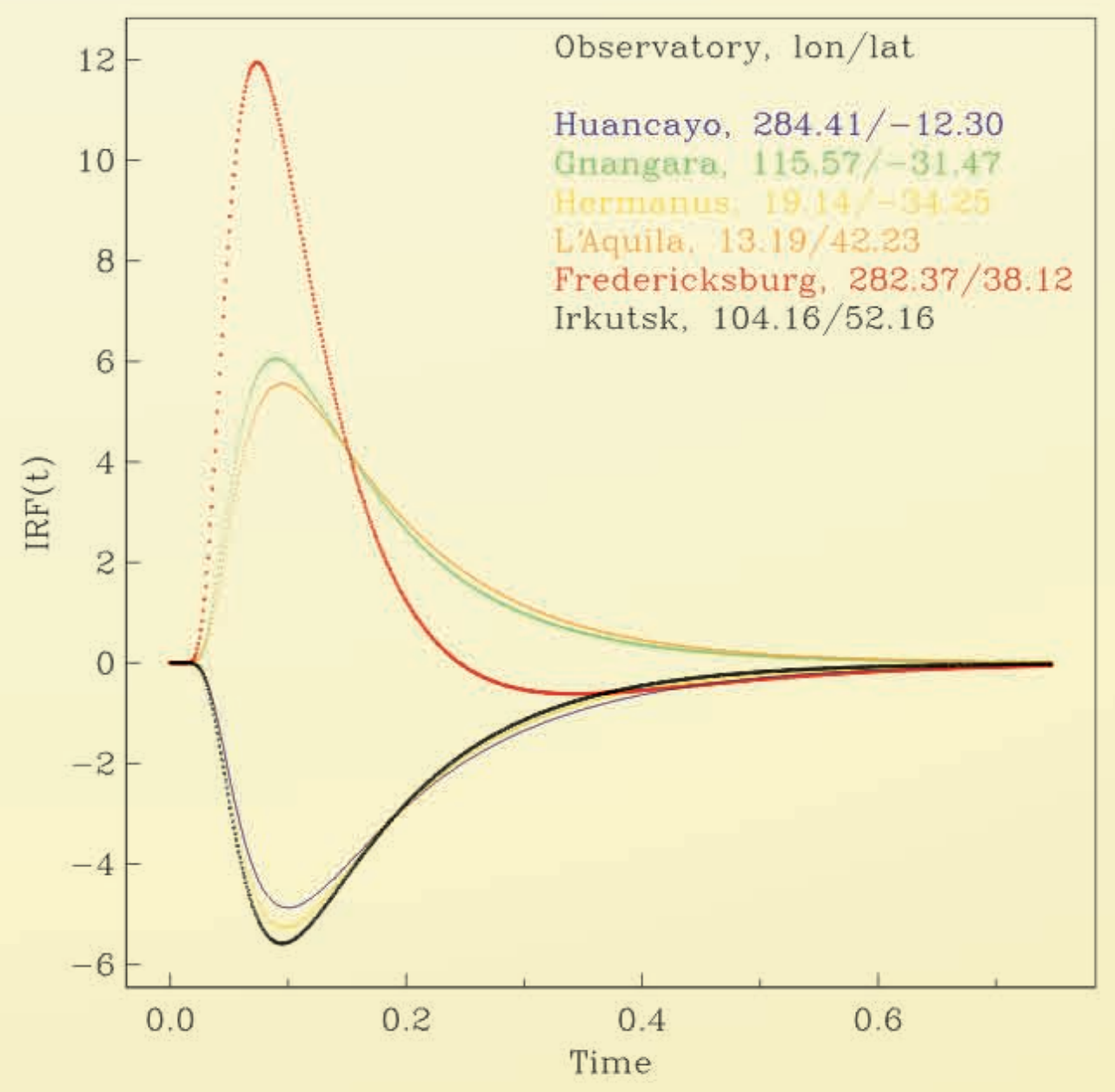


Figure 7. Linear combination of IRFs for each observatory.

$$Y(t,a) = \sum_{l=1}^{4} Y_l(t,a) \tag{7}$$

$$Y_l(t,a) = Y_l(t,c)F_l(t) \tag{8}$$

FUTURE WORK

* EVALUATE TIME DELAYS IN DIFFERENT OBSERVATORIES AND COMPARE WITH REAL DATA, FOR:
  * 1969, 1978 AND 1991 JERKS
  * DIFFERENT COMPONENTS (X, Y AND Z)

* CHANGE INPUT MODEL AND EVALUATE TIME DELAYS

SATELLITES AND JERKS

One of the general limitations when studying jerks is the non-uniform distribution of observatories, especially when one compares differential time delays at different locations. Geomagnetic data obtained by satellites can contribute with a better data coverage and consequent improvement of the resolution of the field morphology, mainly in places where there are few observatories. Satellite measurements can also provide a better distinction between magnetic sources and contribute to answer the fundamental question of whether jerks are entirely of internal origin or whether they have some external influence.