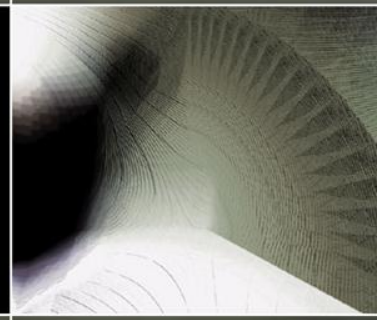
Analisi statistica della correlazione tra livello dell'acqua di invasi idrici e sismicita' indotta



Luciano Telesca
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National Research Council, Italy

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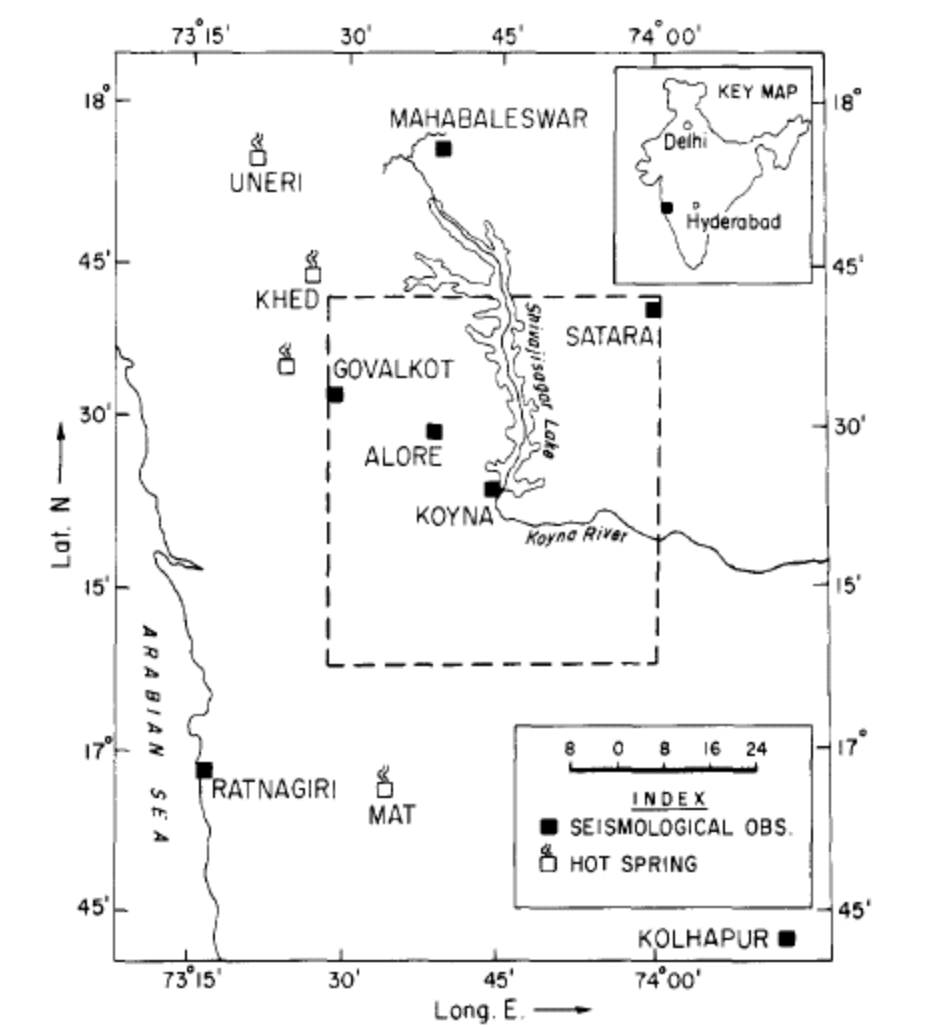
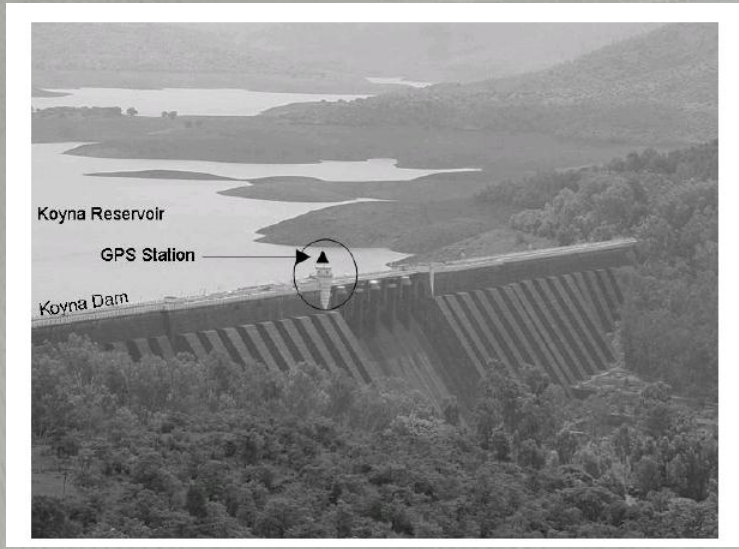
Case studies

1. **Koyna-Warna (India)**
2. **Açu (Brazil)**
3. **Aswan (Egypt)**
4. **Enguri (Georgia)**

1. Koyna-Warna (India)

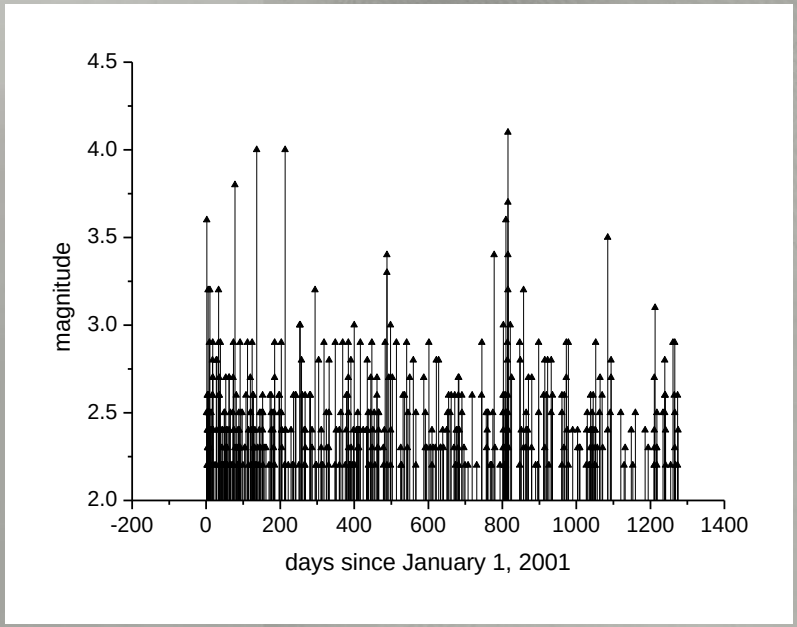


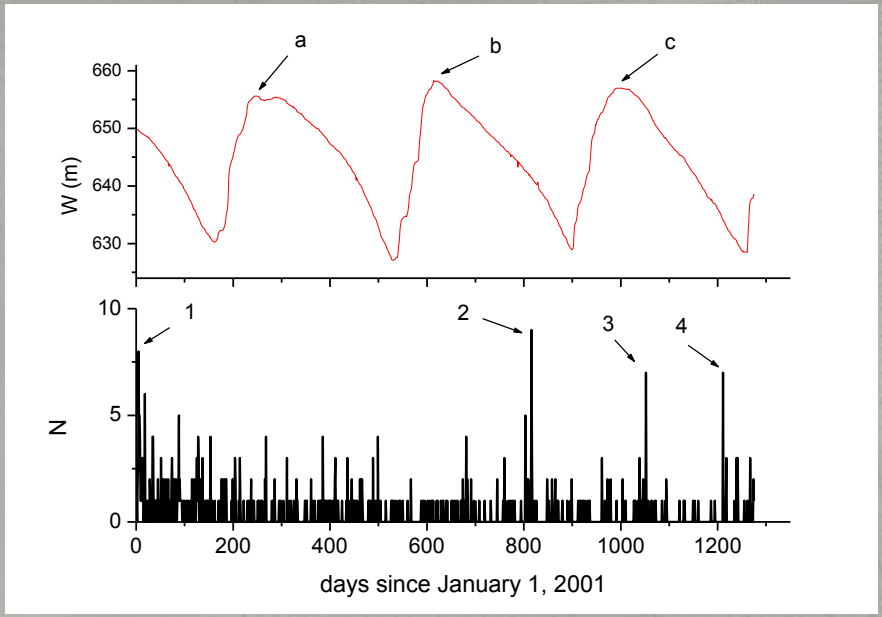


- Dam is 103 m high
- Previously a low-sesmicity area
- Impounding of water began in 1962
- Reports of local EQs increased dramatically
- Seismograms showed foci concentrated at shallow depths under Shivajisagar Lake
- M 6.5 EQ close to the Dam on Dec. 10, 1967

(Gupta et al., BSSA, 1980)

1. Koyna-Warna (India)

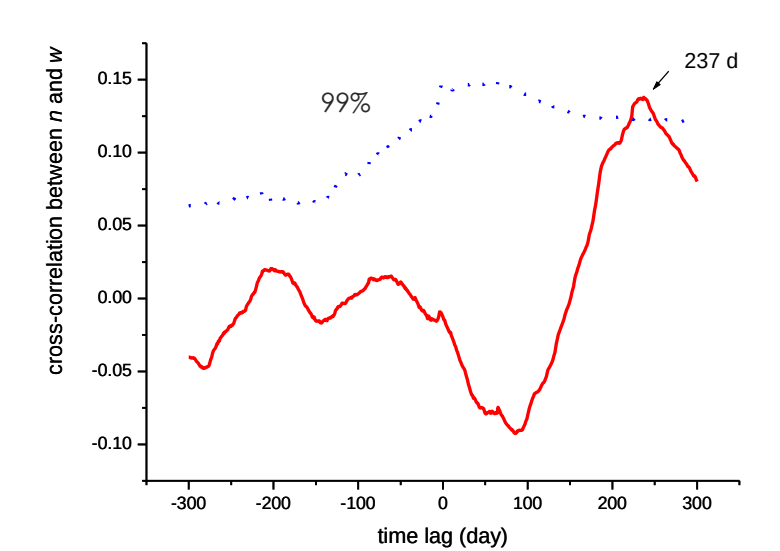




Observation period: 2001-2004
Mc =2.2
B-value=1.3

Telesca, BSSA, 2317-2312, 2010

1. Koyna-Warna (India)



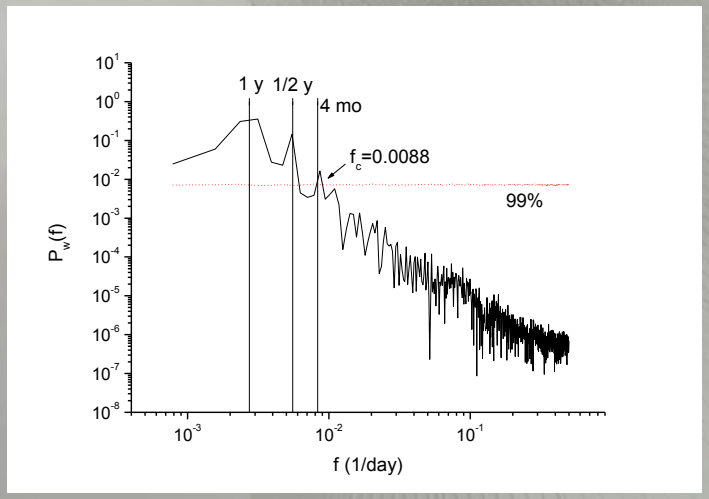
Confidence curve at 99%

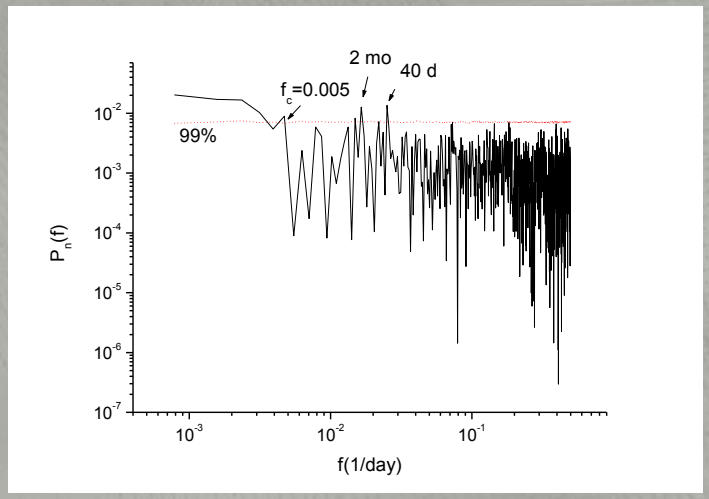
Saar and Manga, Earth Planet. Sci. Lett. 214, 605–618, 2003

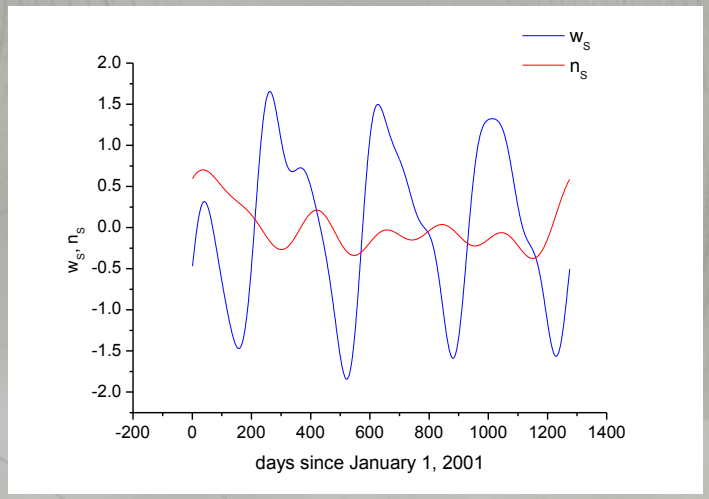
Little, et al., J. Acoust. Soc. Am., 119, 546–558, 2006

Telesca, BSSA, 2317-2312, 2010

1. Koyna-Warna (India)

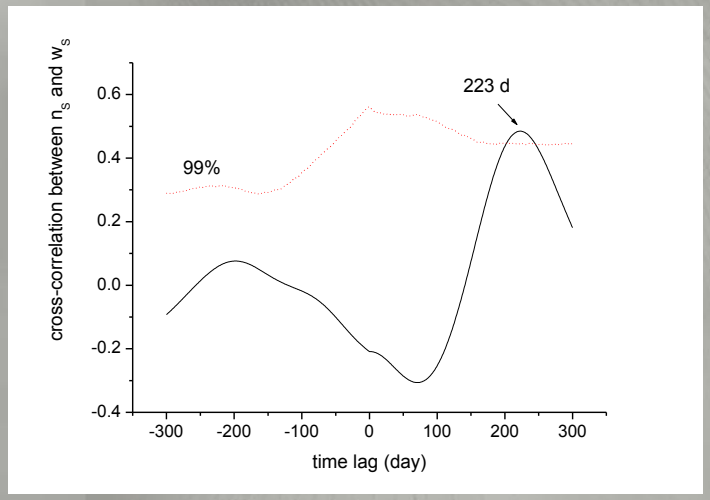


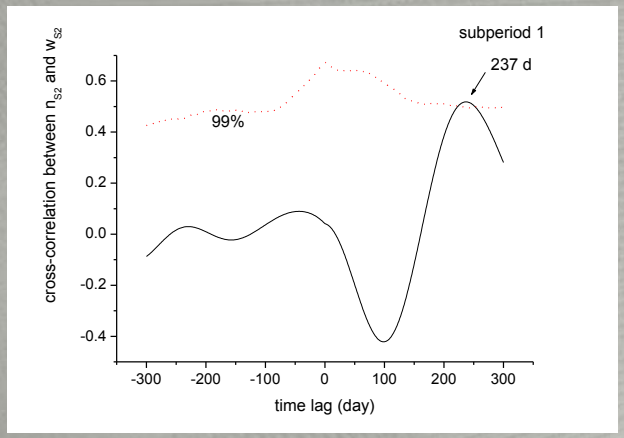


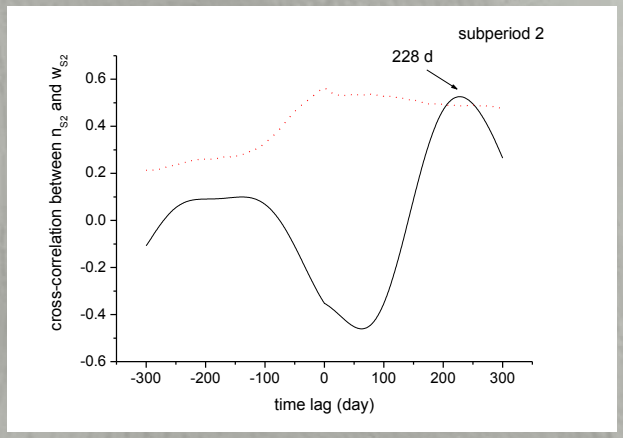


Telesca, BSSA, 2317-2312, 2010

1. Koyna-Warna (India)







Telesca, BSSA, 2317-2312, 2010

1. Koyna-Warna (India)

Hydrological model

Diffusion equation and boundary conditions

$$D\frac{\partial^2 P}{\partial h^2} = \frac{\partial P}{\partial t}, \qquad P(t, h=0) = P_0 e^{i\omega t}$$

D: Hydraulic diffusivity
P: Pore pressure
H: depth

Solution

$$\frac{P}{P_0} = e^{-h\sqrt{\frac{\omega}{2D}}} e^{i\omega\left(t - \frac{h}{\sqrt{2\omega D}}\right)}$$

Plane wave:

1. attenuation coefficient $\sqrt{\frac{\omega}{2D}}$

2. velocity $\sqrt{2\omega D}$

Decrease of the pore-pressure amplitude with depth *h*

Periodic behavior of the pressure as a function of depth *h* and time *t*

Telesca, BSSA, 2317-2312, 2010

1. Koyna-Warna (India)

Hydrological model

Diffusivity $D = \frac{h^2}{2\omega t^2}$

ω=2π(year)$^{-1}$

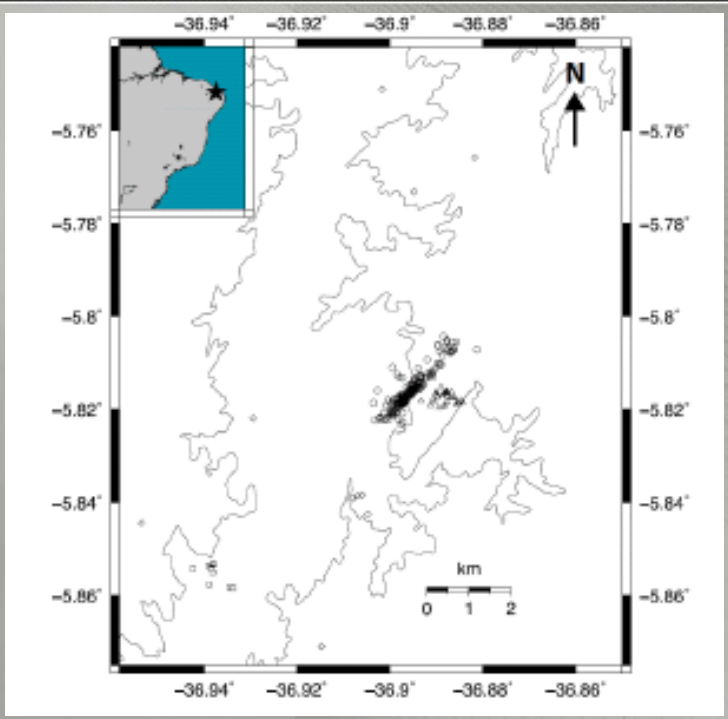
t=223 days

h= mean depth μ_h of the seismic events

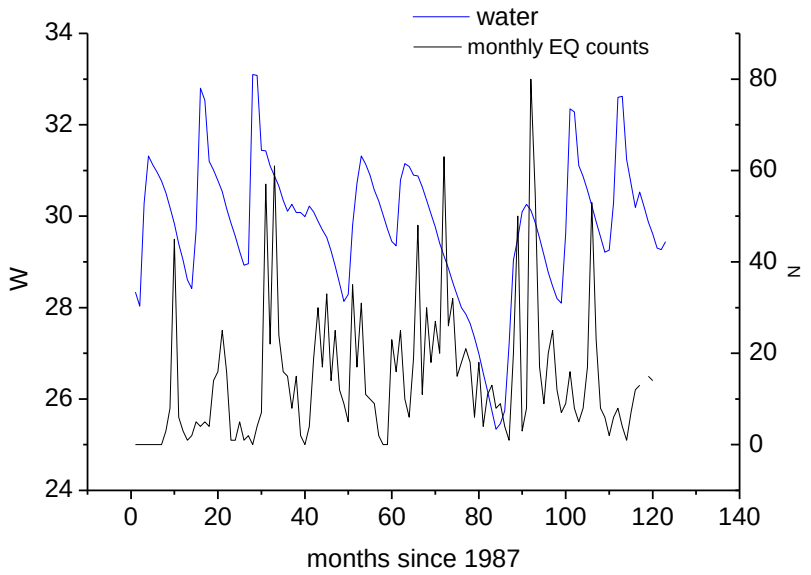
D=0.20±0.18 m^2/s

Telesca, BSSA, 2317-2312, 2010

2. Açu (Brazil)



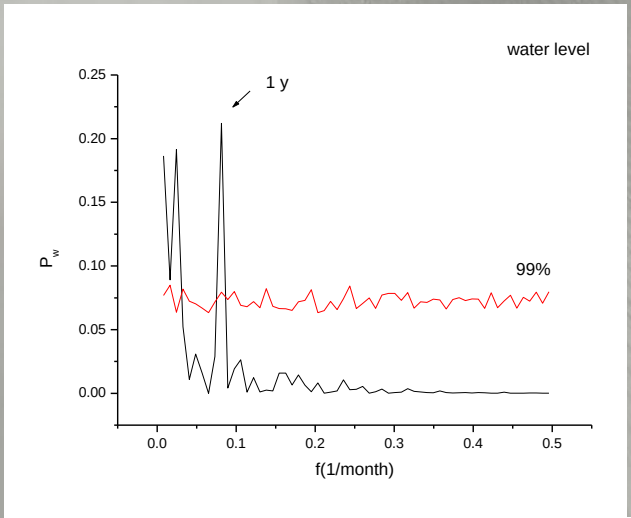
Period: Jan 1987-Mar 1997



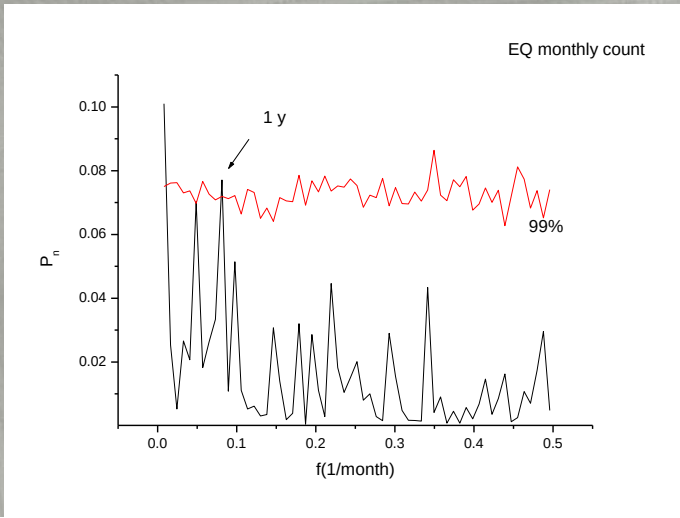
Telesca, do Nascimento, Bezerra, Ferreira, NHESS, 12, 805, 2012

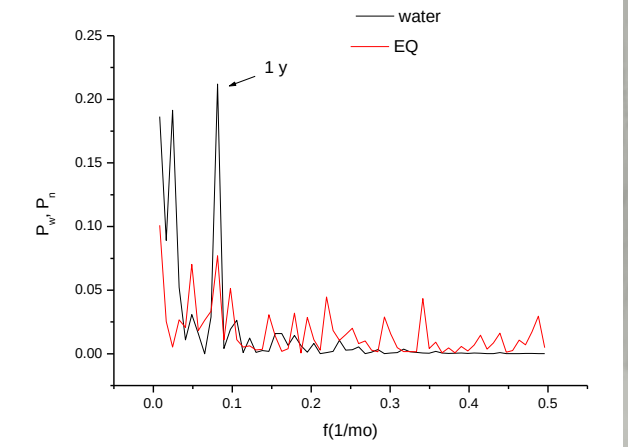
Telesca, do Nascimento, Bezerra, Ferreira, in preparation, 2013

2. Açu (Brazil)



Power spectrum analysis



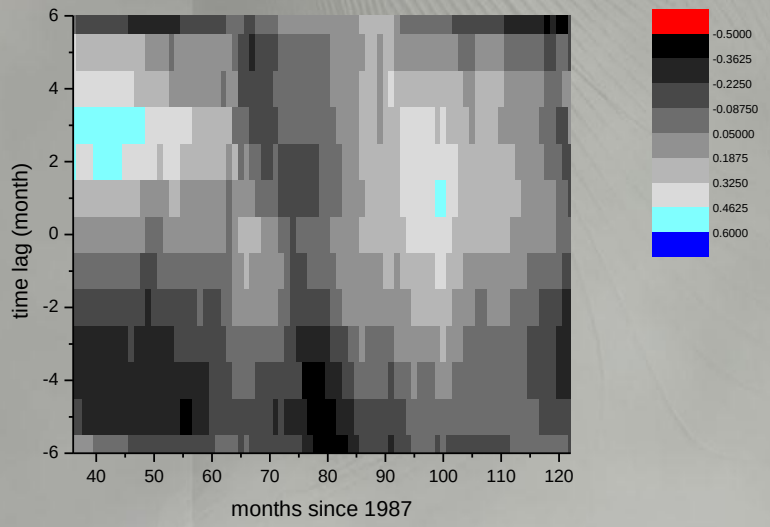


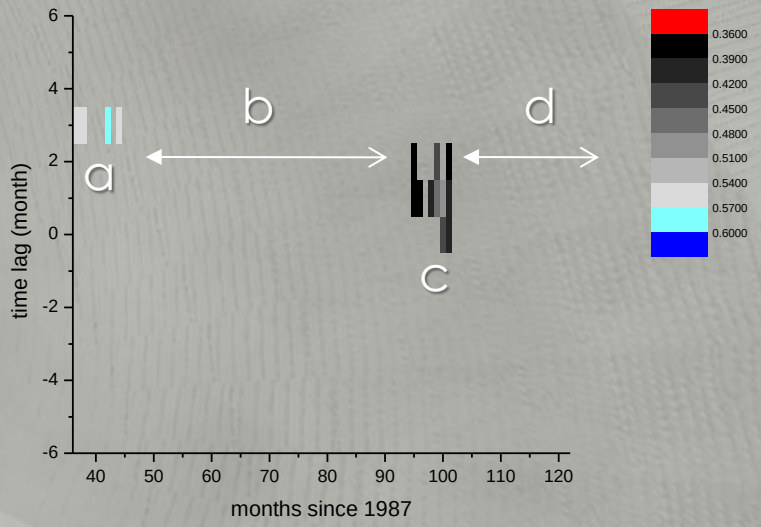
Telesca, do Nascimento, Bezerra, Ferreira, in preparation, 2013

2. Açu (Brazil)

Cross-correlation analysis

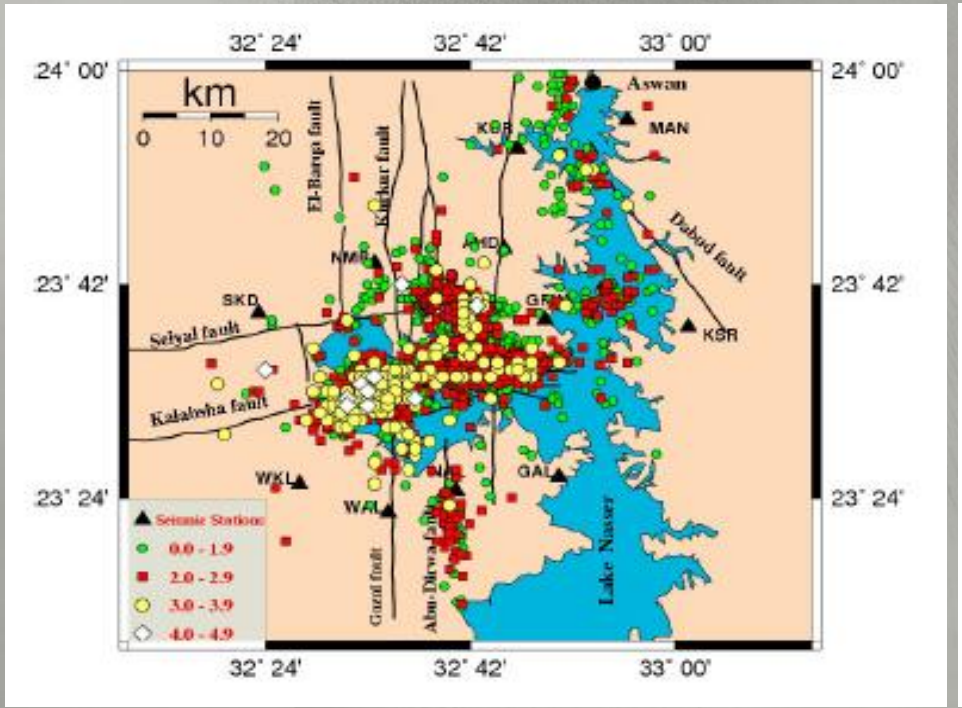
time variation of the cross-correlation: time window of 36 months shifting by 1 month through the overall record; the data included within such time window were cross-correlated and the results associated to the time of the last datum in the window





Telesca, do Nascimento, Bezerra, Ferreira, in preparation, 2013

3. Aswan (Egypt)



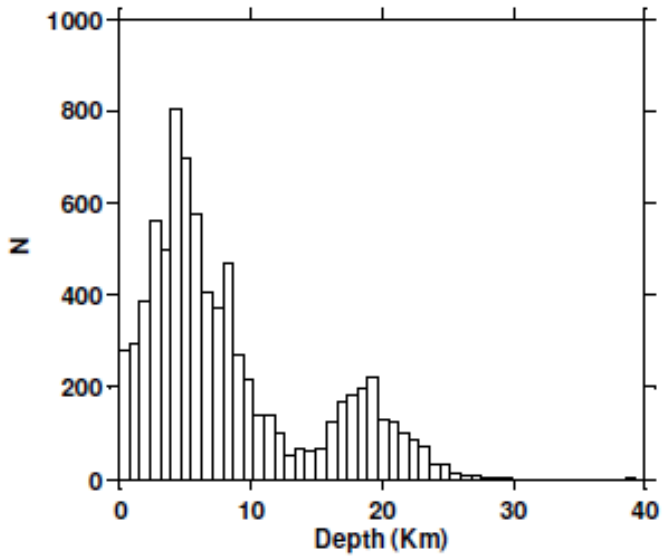


Fig. 2. Depth distribution of the whole seismicity.

1981 Aswan Eq occurred 17 years after the starting of reservoir filling

- **Temporal variations of shallow seismicity associated with a high rate of water level fluctuation, while no clear correlation with the deeper seismicity (Awad and Mizoue, 1995)**
- **Maximum correlation at timelag of 2 months during 1982–1985 (depth h< 40 km, M> 2.0) (Selim et al. 2002)**
- **Seismicity rate correlates with the seasonal fluctuations of the lake level, indicating positive evidence for the Aswan seismicity to be reservoir-triggered in the 1982–2001 (Mekkawi et al., 2004)**

3. Aswan (Egypt)

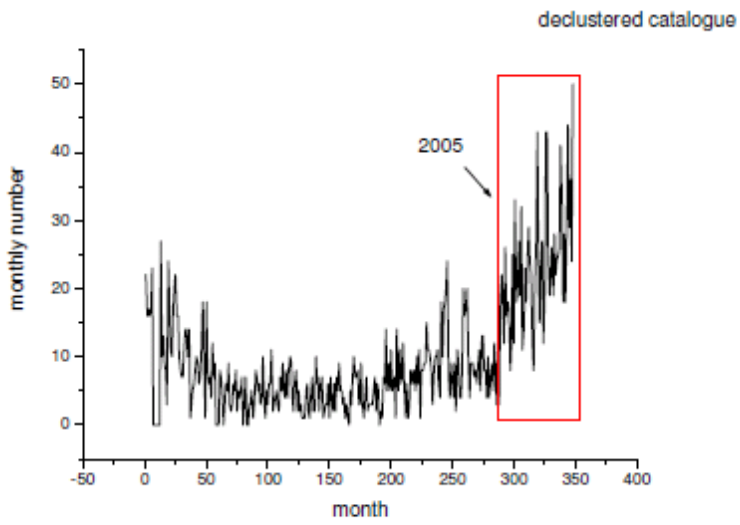


Fig. 3. Monthly seismic activity of the declustered catalogue (all the magnitudes).

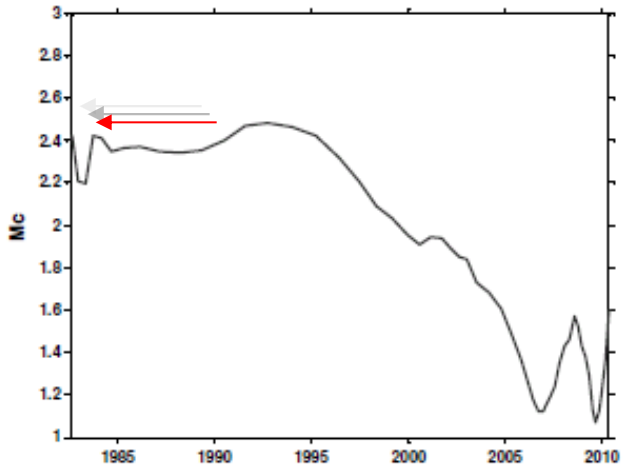


Fig. 4. Time variation of the completeness magnitude for the declustered catalogue.

Analysed period: 1 Jan 1982 to 31 Dec 2010
Data Source: Bulletins of the Aswan Earthquake Regional Research Center
Size of the whole catalogue: 7901
Size of the catalogue after declusterization (Reasenberg (1985)): 3545
Mc=2.5

Telesca, Mohamed, ElGabry, El-Hady , Elenean, Chaos Solitons & Fractals, 45, 47, 2012

Telesca, Lovallo, Mohamed, ElGabry, El-Hady, Elenean, ElBary, Physica A, 391, 2889, 2012

Telesca, Lovallo, Mohamed, ElGabry, El-Hady, Elenean, ElBary, NHESS, 12, 1267, 2012

Telesca, ElBary, Mohamed, ElGabry, NHESS, 12, 2203, 2012

3. Aswan (Egypt)

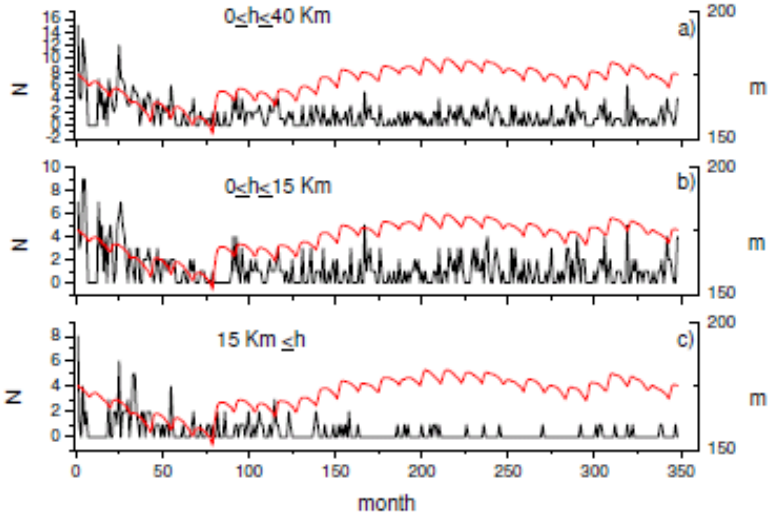


Fig. 5. Monthly maximum water level and number of earthquakes with $M \geq 2.5$ for the whole **(a)**, shallow **(b)** and deep **(c)** seismicity.

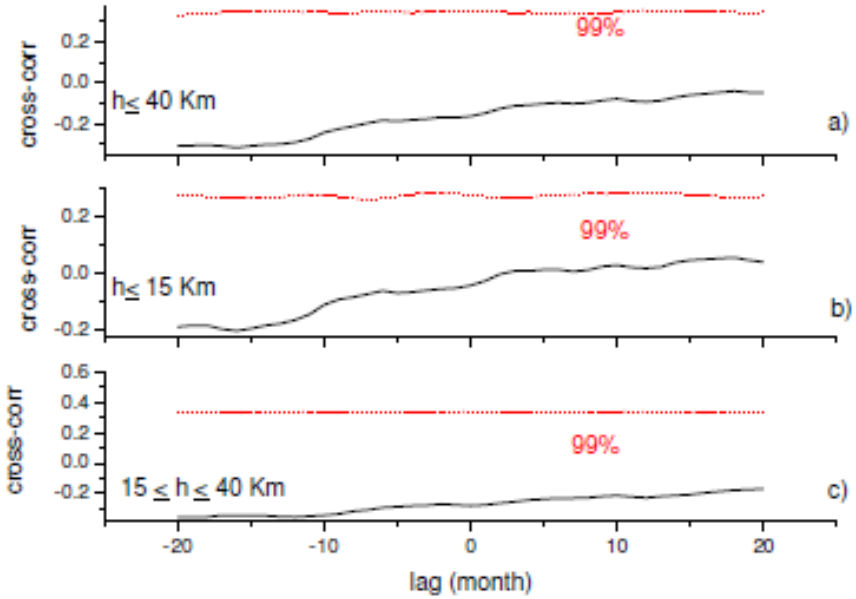


Fig. 6. Cross-correlation between water level and number of earthquakes for the whole **(a)**, shallow **(b)** and deep **(c)** seismicity. The red dotted lines are the 99 % confidence curves.

Telesca, ElBary, Mohamed, ElGabry, NHESS, 12, 2203, 2012

3. Aswan (Egypt)

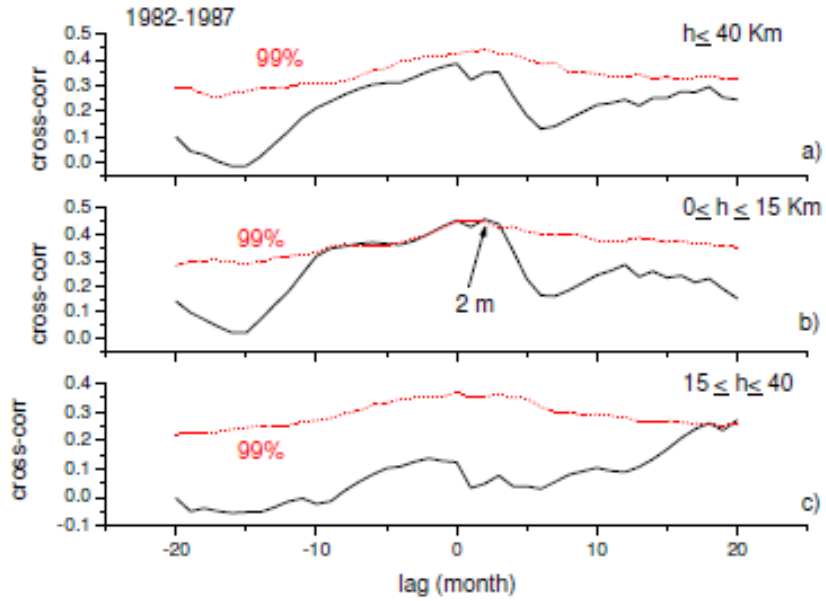


Fig. 7. Cross-correlation between water level and number of earthquakes for the whole (**a**), shallow (**b**) and deep (**c**) seismicity in the period 1982-1987. The red dotted lines are the 99 % confidence curves.

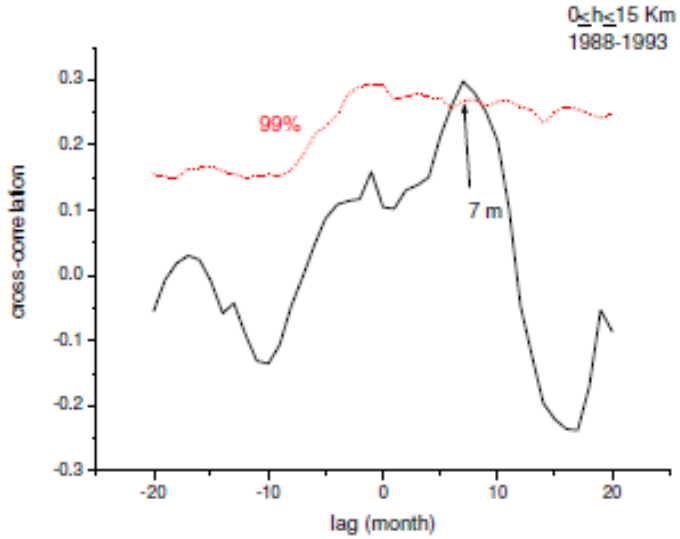
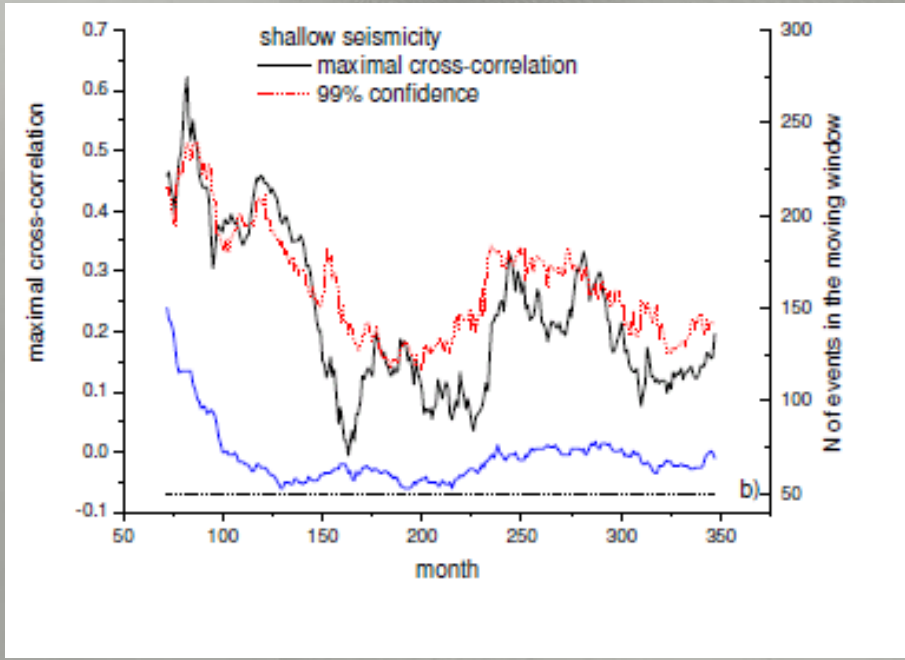


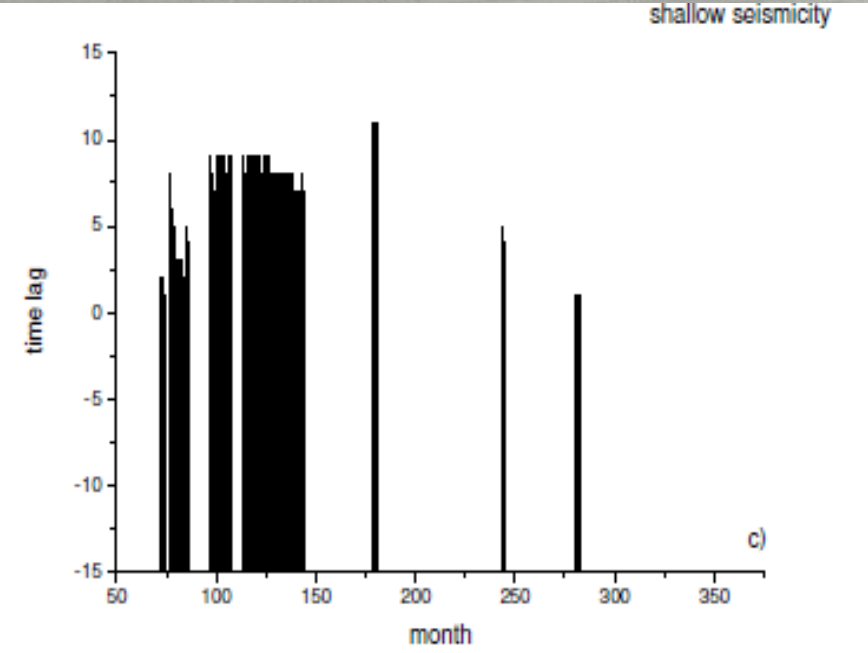
Fig. 8. Cross-correlation between water level and number of earthquakes for the shallow seismicity in the period 1988–1993. The red dotted lines are the 99 % confidence curves.

Telesca, ElBary, Mohamed, ElGabry, NHESS, 12, 2203, 2012

3. Aswan (Egypt)

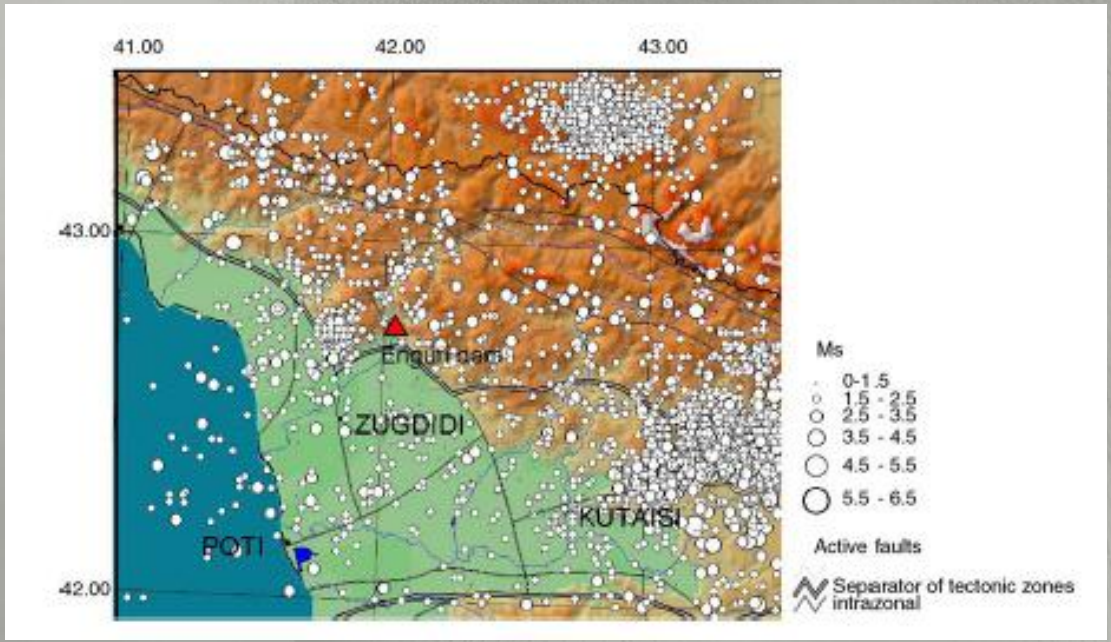
Time-variant cross-correlation:
time window of 6 years, moving through the data, with a shift of 1 month

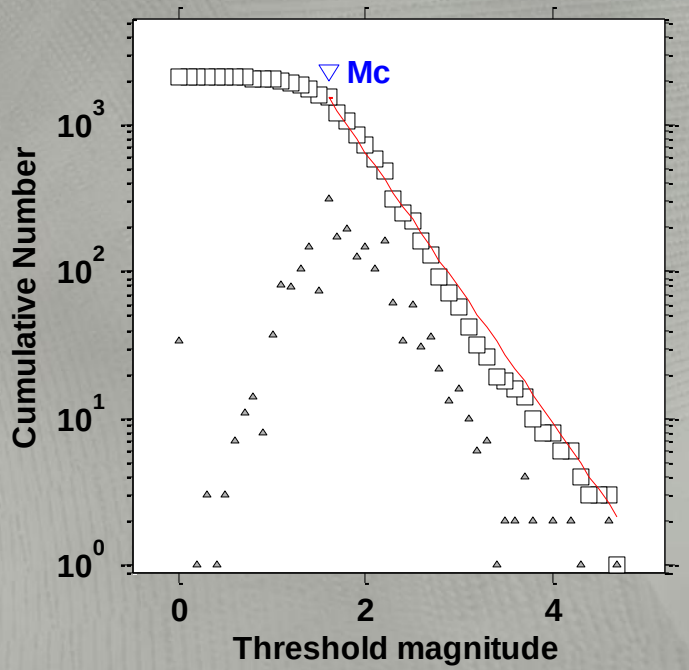




Telesca, ElBary, Mohamed, ElGabry, NHESS, 12, 2203, 2012

4. Enguri (Georgia)



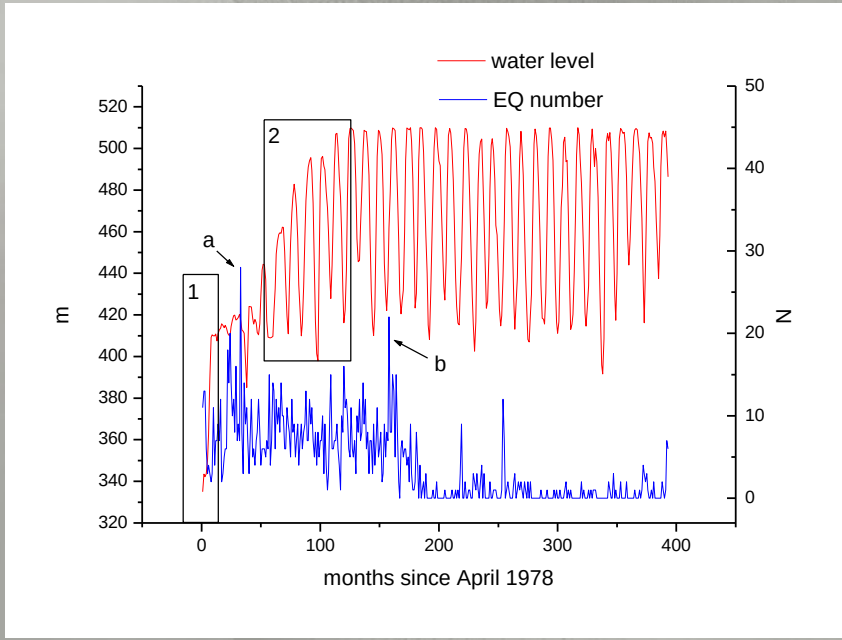


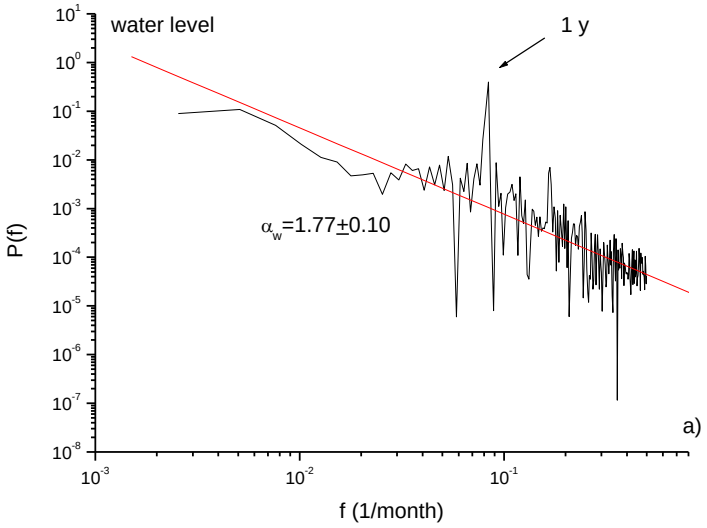
- Heigth: 272 m
- Building period: 1971-1983
- Preliminary flooding of the territory started at the end of December 1977

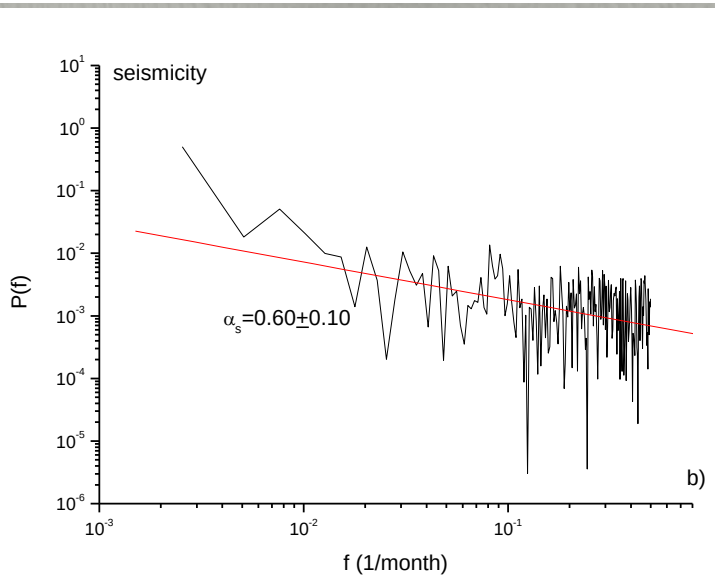
- Period of analysis: 1978-2010
- Size of declustered catalogue: 2131
- Max mag: 4.7
- Depth max: 32 km
- Mc: 1.6
- b-value: 0.92 (whole Caucasus 0.72)

Telesca, Matcharashvili, Chelidze, NHESS, 12, 1905, 2012

4. Enguri (Georgia)

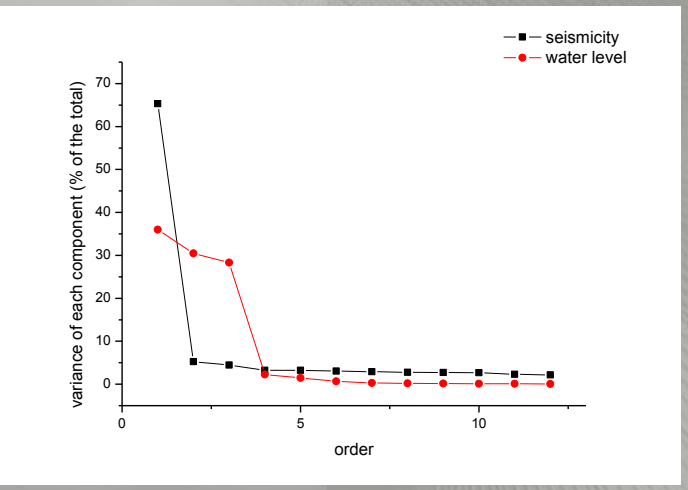




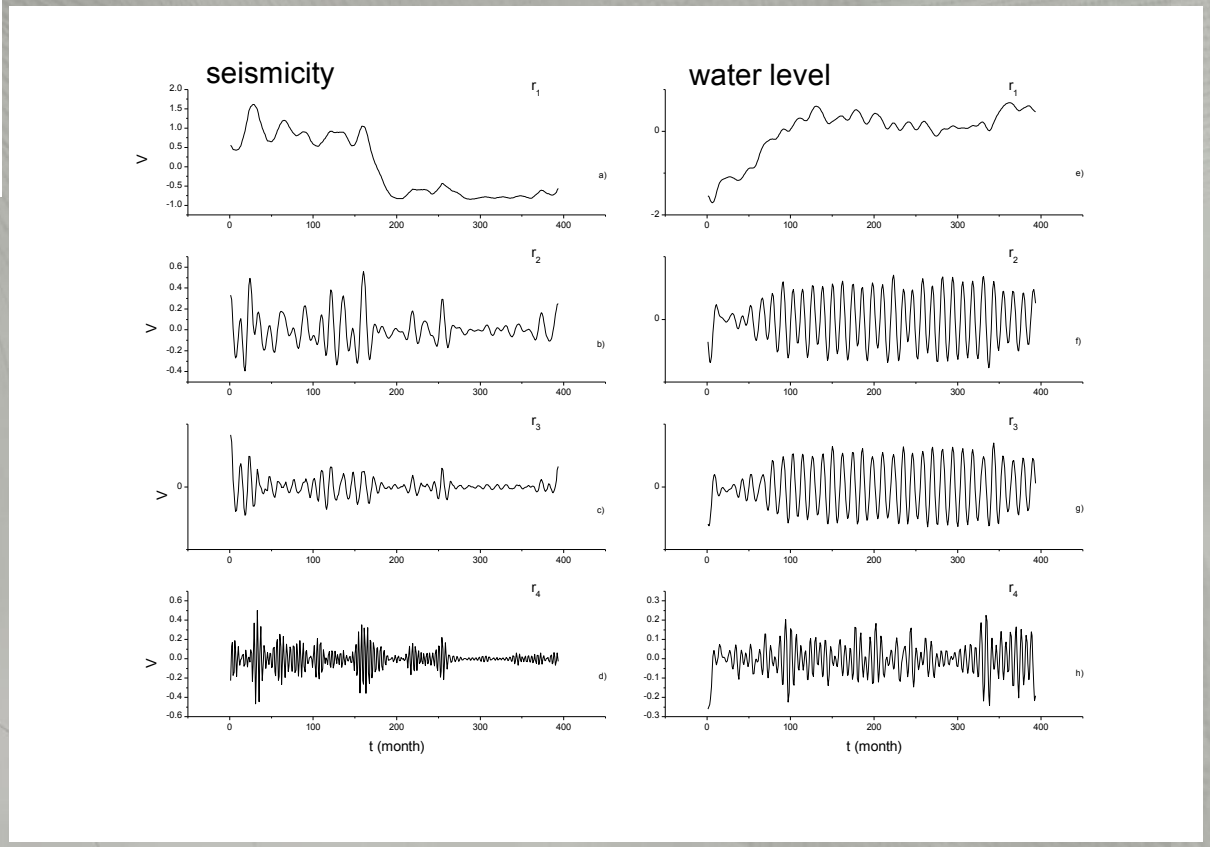


Telesca, Matcharashvili, Chelidze, Zhukova, NHESS, 12, 2479, 2012

4. Enguri (Georgia)

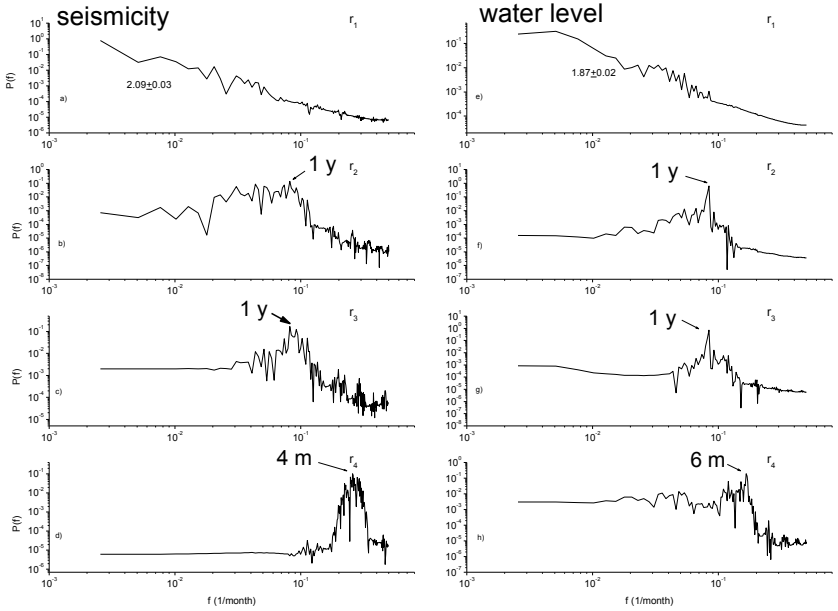


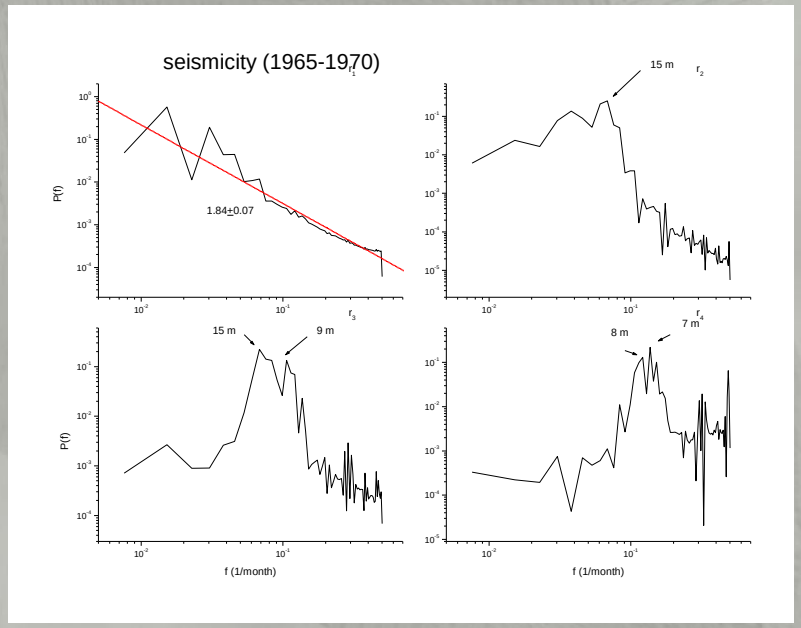
Singular spectrum analysis



Telesca, Matcharashvili, Chelidze, Zhukova, NHESS, 12, 2479, 2012

4. Enguri (Georgia)





Telesca, Matcharashvili, Chelidze, Zhukova, NHESS, 12, 2479, 2012