Time series analysis of dose rate measurements from early warning systems network.

Fokion LEONTARIS, Alexandros CLOUVAS, Stelios XANTHOS*, Leontios HATJILEONTIADIS, Antonis MALTEZOS** and Costas POTIRIADIS**

Nuclear Technology Laboratory

Aristotle University of Thessaloniki

* Alexander Technological Education Institute ** Greek Atomic Energy Commission

ARISTOTLE UNIVERSITY OF THESSALONIKI

MetroERM radiological early warning

- The early warning stations, scattered all over Europe, is the best way against any radiological incident that may occur. The usefulness of the data they provide is not constrained to an early warning, but opens a wide range of data analysis. The amount of information gathered is enormous and more specific for our laboratory, the Nuclear Technology laboratory of Aristotle University of Thessaloniki, the database extends to 27 years (about 20000 measurements). The way of making the stations more secure and precise for any future incident is to understand and analyze the past, and that is exactly the purpose of the present work.

ARISTOTLE UNIVERSITY OF THESSALONIKI

MetroERM radiological early warning

Location of Measurements : 2 Locations in the Aristotle University Campus

1988-2015

Measurements were performed once per day for 27 years.

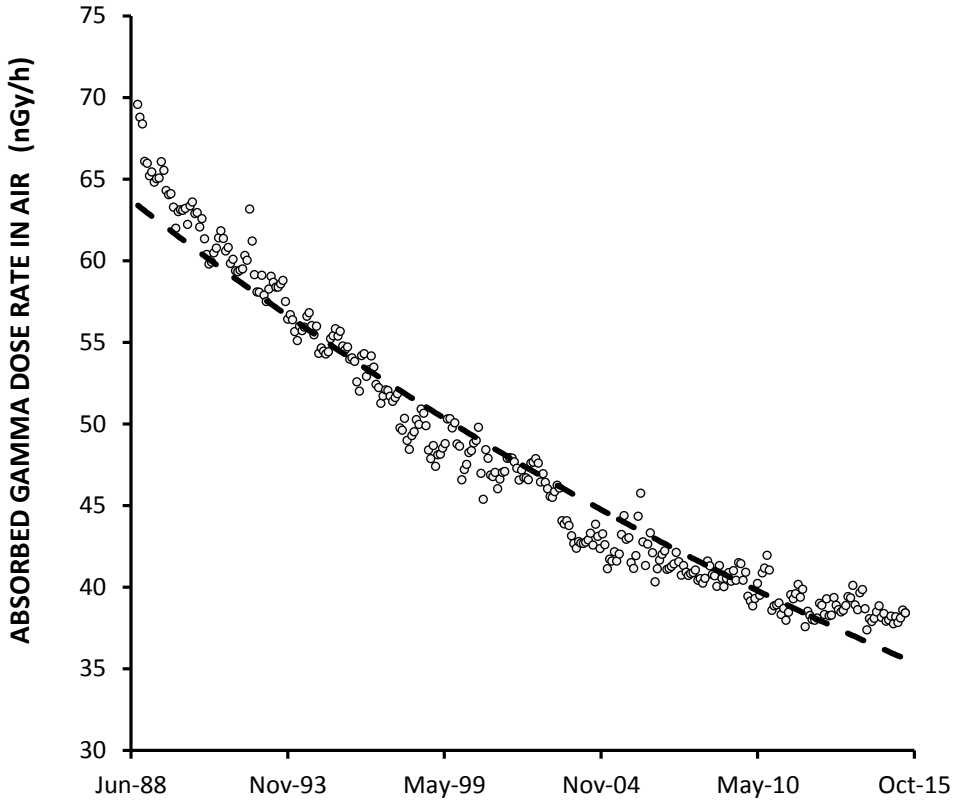
First Location

Mean monthly values of gamma radiation measurements

ARISTOTLE UNIVERSITY OF THESSALONIKI

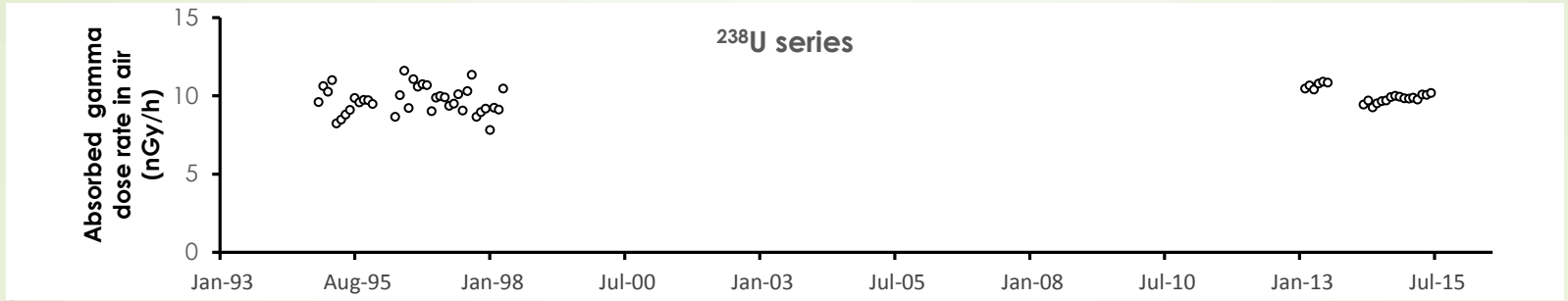
MetroERM radiological early warning

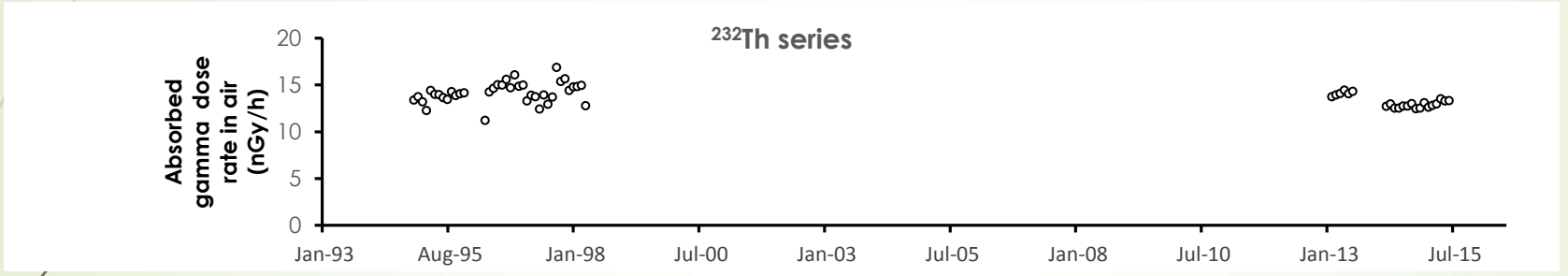
- The gamma dose rate decrease with an effective **Half-life** ($t_{½}$) of about 30 years
- The gamma dose rate is the sum of the gamma dose rates due to 1) Uranium series 2) Thorium series 3) K-40 4) Cs-137 (due to the Chernobyl accident).
- Taking into account that the decay **Half-life** ($t_{½}$) of Cs-137 is 30 years the effective **Half-life** ($t_{½}$) of the (total) gamma dose rate should be greater than 30 years (gamma dose rates due to Uranium series ,Thorium series and K-40 are in principle quite constant)

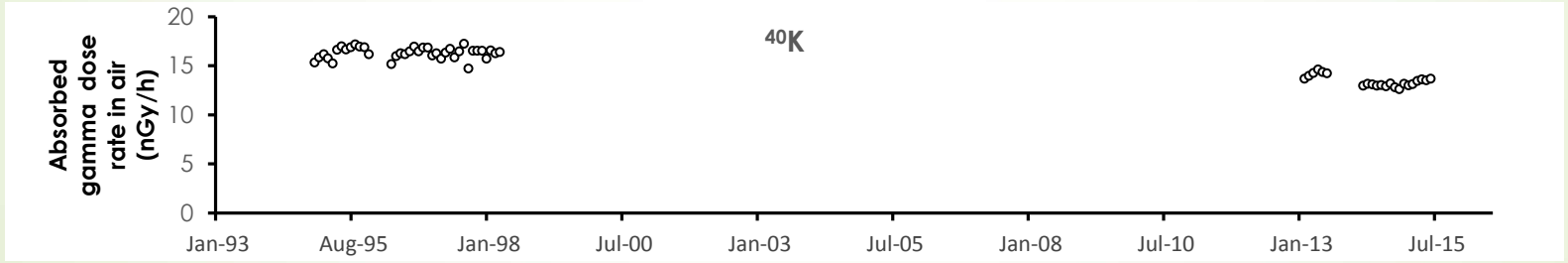


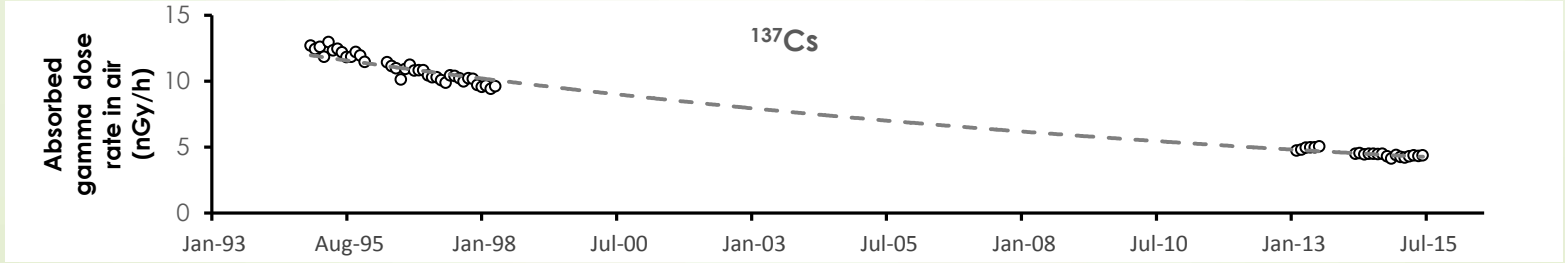
Measurements with HPGe detectors

- The Xetex 501 A monitoring system cannot distinguish between the different contributions (Uranium series , Thorium series , K-40 ,Cs-137)
- About 700 measurements were also performed during 1995-1998 , 2013 and 2014-2016 with three HPGe detectors .

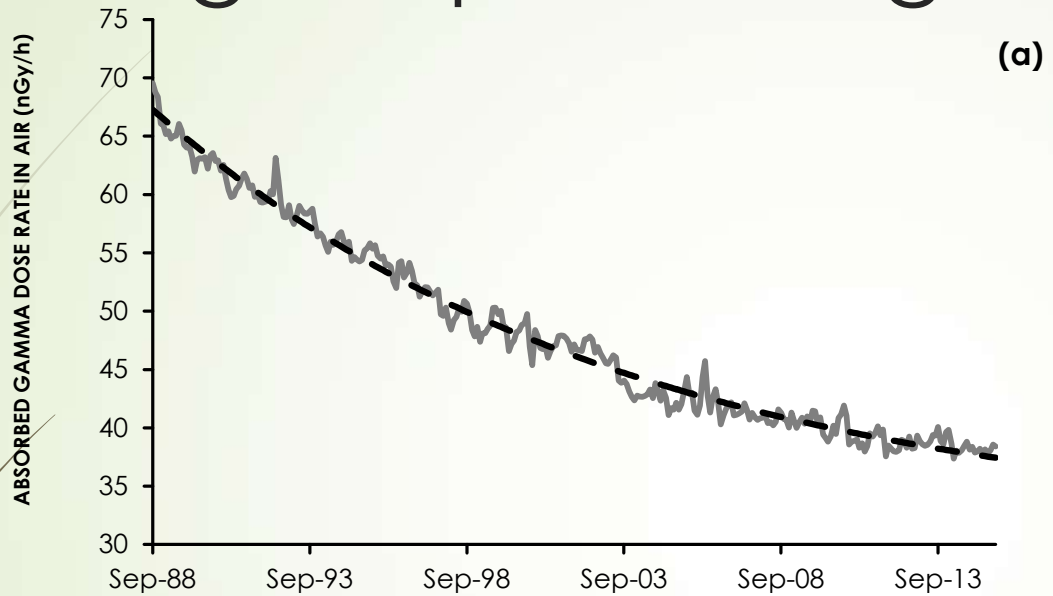

238U series
Absorbed gamma dose rate in air (nGy/h)
0
5
10
15
Jan-93
Aug-95
Jan-98
Jul-00
Jan-03
Jul-05
Jan-08
Jul-10
Jan-13
Jul-15

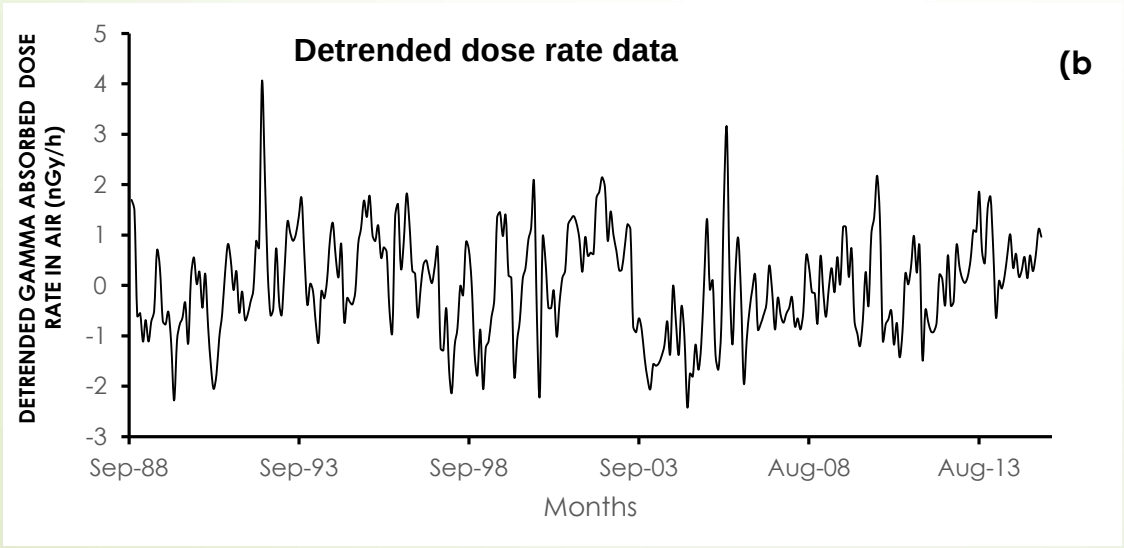

232Th series
Absorbed gamma dose rate in air (nGy/h)
0
5
10
15
20
Jan-93
Aug-95
Jan-98
Jul-00
Jan-03
Jul-05
Jan-08
Jul-10
Jan-13
Jul-15


40K
Absorbed gamma dose rate in air (nGy/h)
0
5
10
15
20
Jan-93
Aug-95
Jan-98
Jul-00
Jan-03
Jul-05
Jan-08
Jul-10
Jan-13
Jul-15


137Cs
Absorbed gamma dose rate in air (nGy/h)
0
5
10
15
Jan-93
Aug-95
Jan-98
Jul-00
Jan-03
Jul-05
Jan-08
Jul-10
Jan-13
Jul-15

Signal processing…



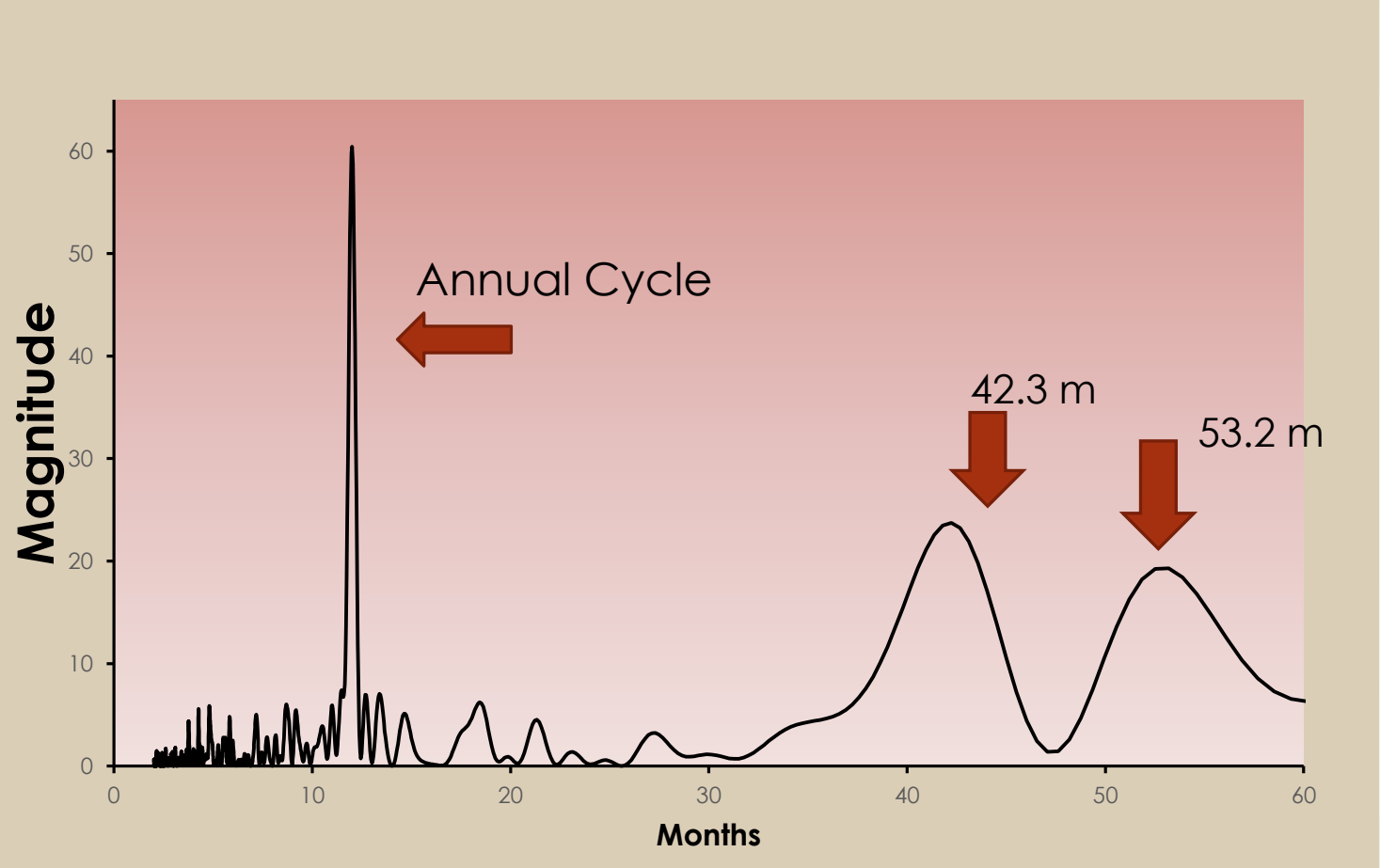


The signal we are analyzing (time dependence of the total absorbed gamma dose rate D(t) in air) has some valuable components. From mathematical point of view the trend T(t) of the signal, is described by equation $T(t) = A + Be^{-bt}$ Parameter A is related to the absorbed gamma dose rates due to natural emitters (Uranium series, Thorium series, ^{40}K), which are quite constant and parameter B is related to absorbed gamma dose rate in air due to ^{137}Cs from the Chernobyl accident.

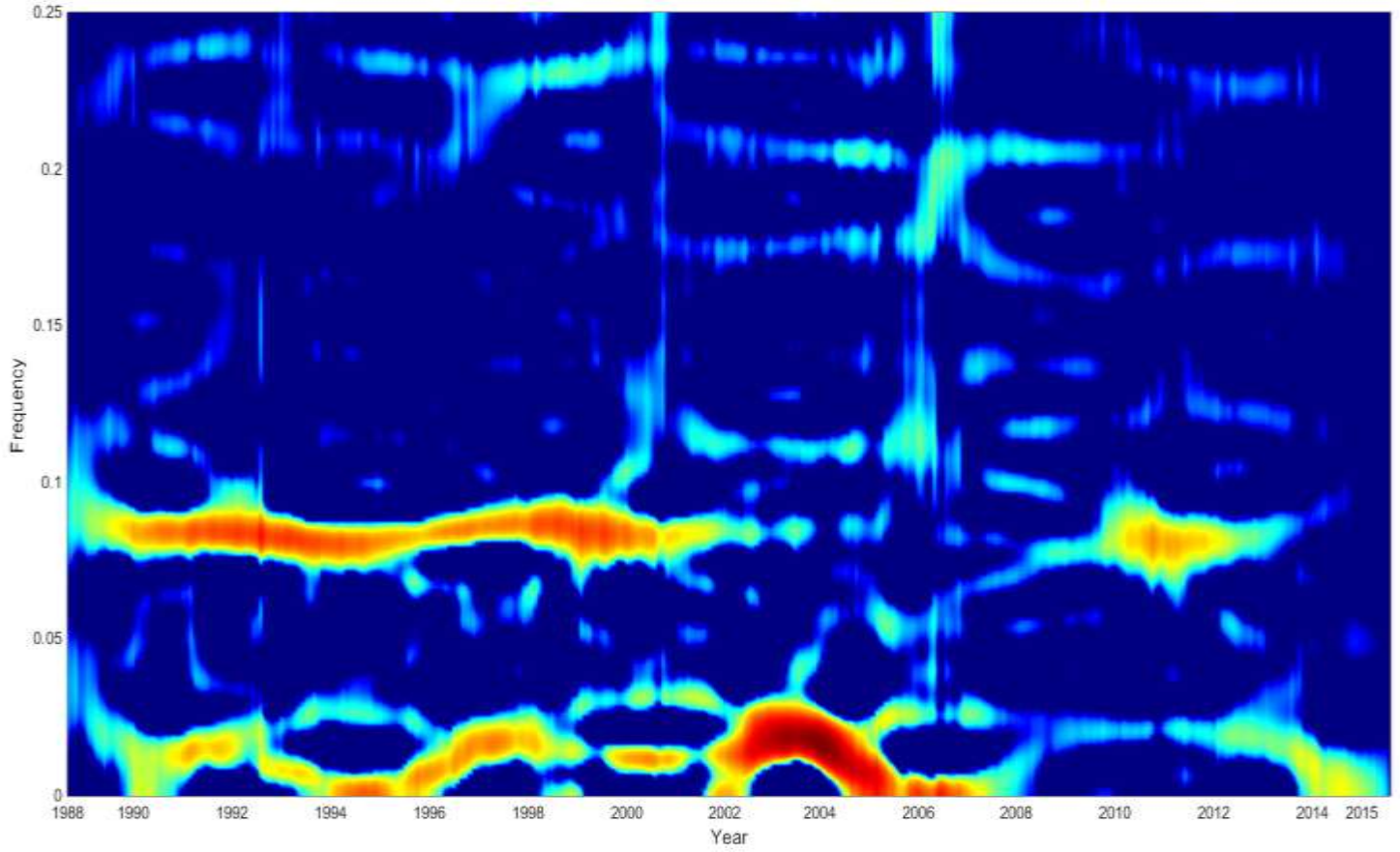
Periodicity Analysis of the Detrended dose rate data

- For the data analysis two methods were applied. The first one is **the Fourier Transform** which can extract from the signal the average periodicities that are present during the whole or partial duration of the signal **but cannot provide any information about the presence of those frequencies over time.** An alternative approach that addresses this problem refers to the use of the second method, i.e., **Zhao Atlas Marks Transform** that falls within the category of Time-Frequency signal analysis, which is defined as the analysis of a signal in both the time and frequency domains simultaneously. The result is a **two dimensional signal that contains the dynamic (in time) frequency distribution.**

Fourier Transform



Periodogram of the data (Detrended gamma dose rate). There are three main discernible periodicities: 12±0.2 m, 42.3±2.9 m and 53.2±3.2 m.

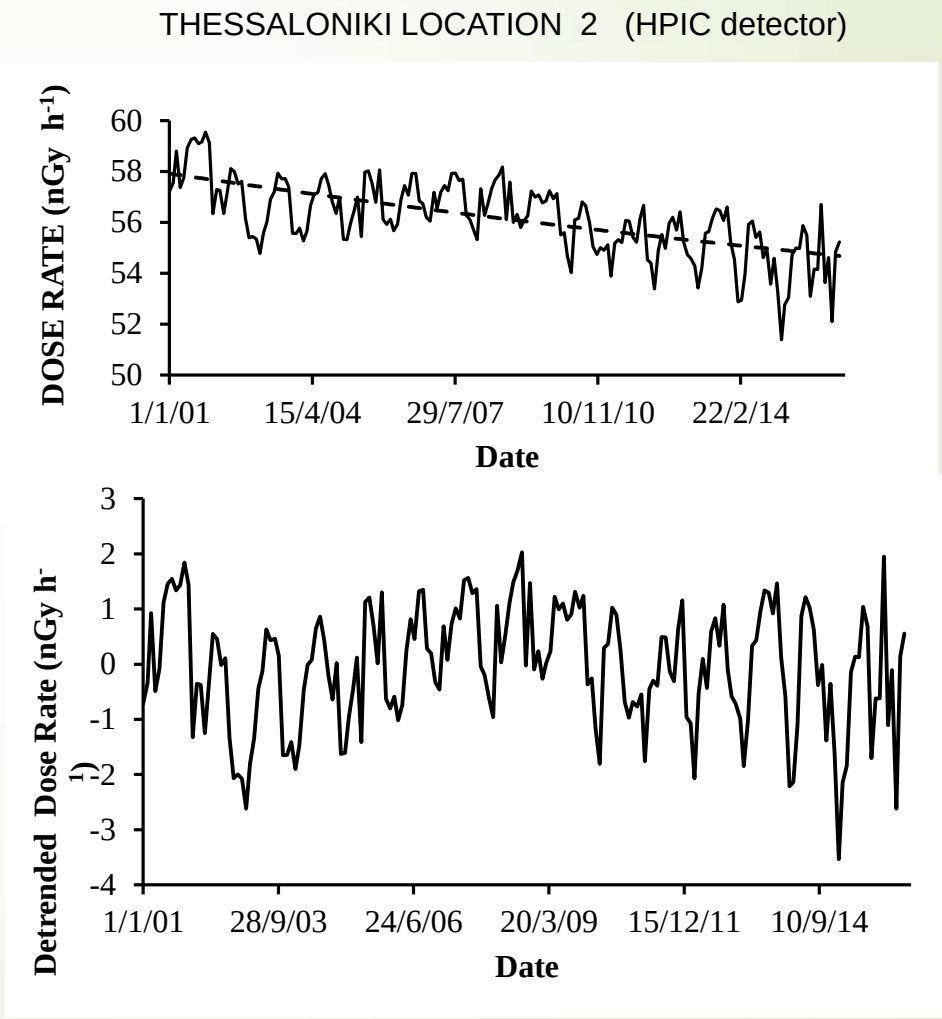


Zhao Atlas Marks Transform of the detrended gamma dose rate data. The Frequency is given in months^{-1}.The annual periodicity (frequency 0.083 months^{-1}) is not visible in the whole period (1988-2015). It is mainly visible from 1998-2002 and 2008-2014. On the contrary the 42 and 53 months periodicities (frequency about 0.02 months^{-1}) were very intense during the years 2002-2004 when the annual periodicity was weak.

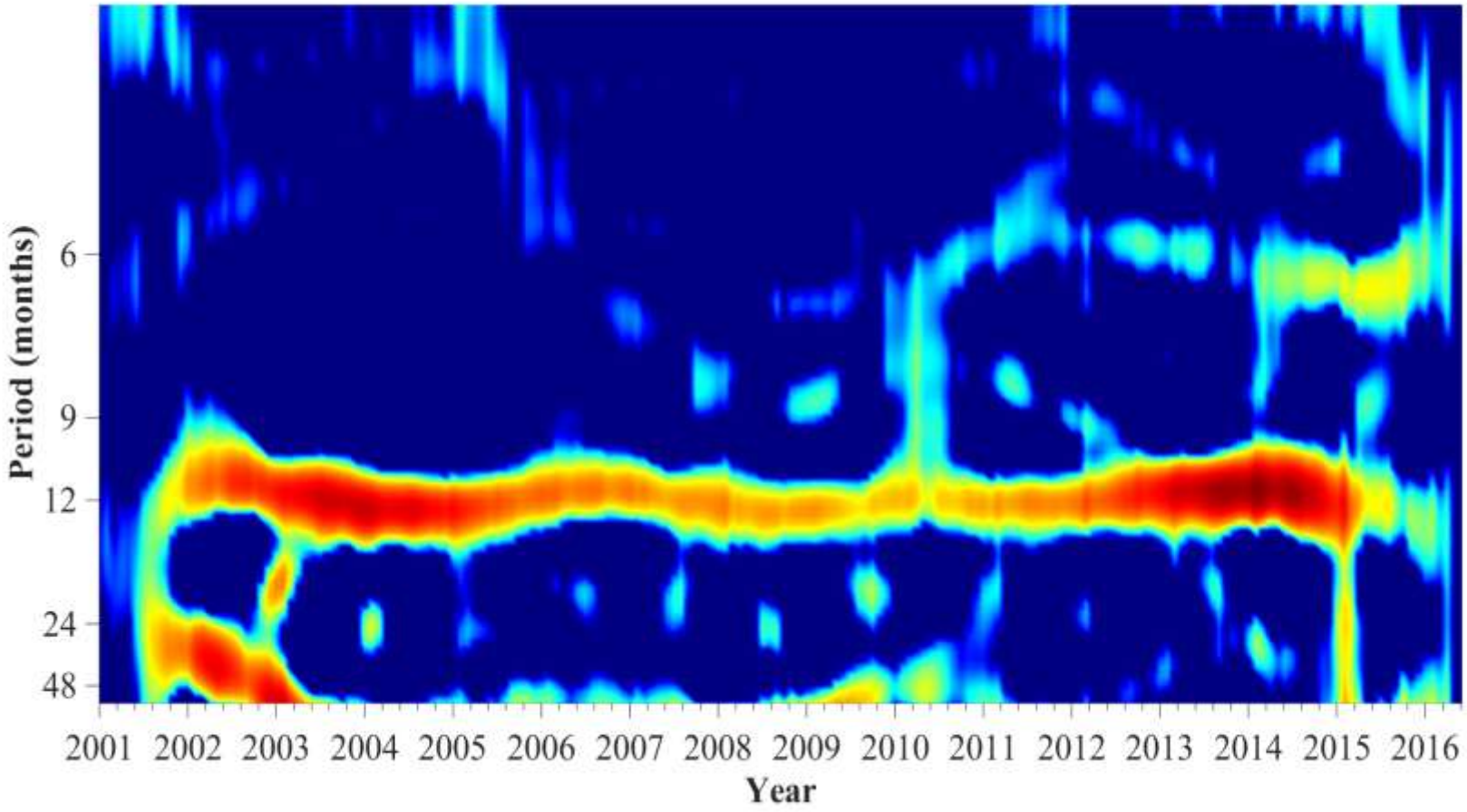
…..Possible explanations

- A 44 months periodicity identified by periodicity analysis of satellite global lower troposphere temperature data, 1979-2013, is in agreement with our 42.3±2.9 m periodicity. Troposphere is the most important for operational meteorology, as this layer contains almost all the water vapor, and by far the greatest part of the mass of the atmosphere.
- Researchers of the Department of Meteorology and Climatology of the Aristotle University of Thessaloniki in Greece, performed spectral analysis of monthly surface temperature values from stations in Central and Eastern Mediterranean region for the 1950-1988 period. They found periodicities of 18, 36, 48, 54, 60 and 96 months. **Out of these only the 48 and 54 months periodicities appear in the spectra of most stations**

What about …. In Location 2



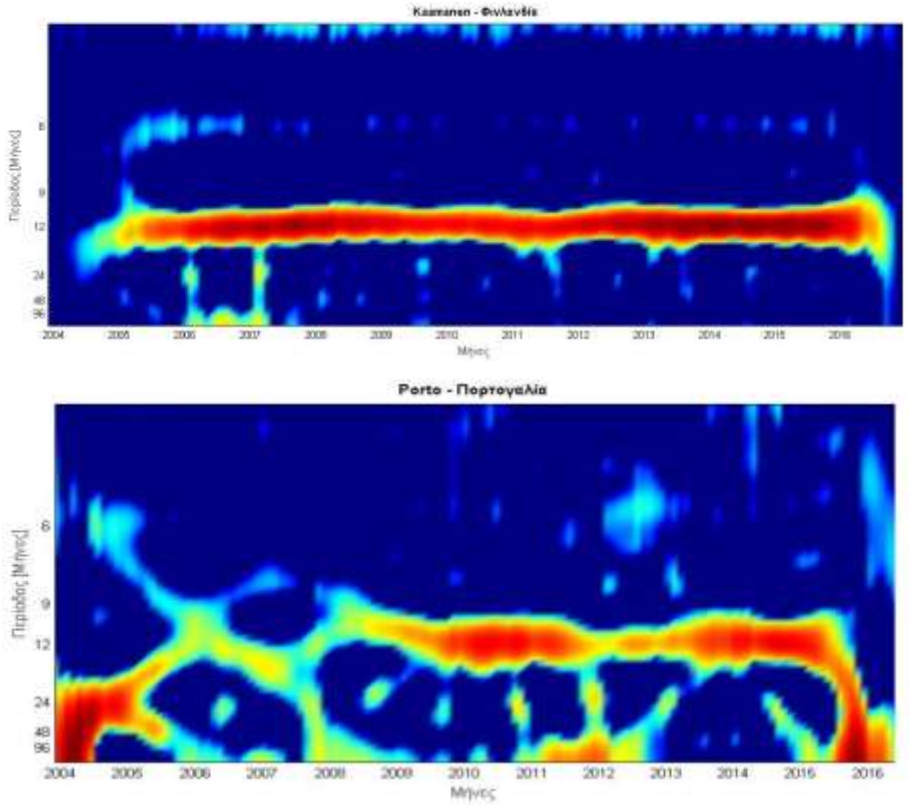
Location 2 : HPIC Reuter Stokes Detector
(ZAM Transform of the detrended mean monthly dose rate values)



…….As a conclusion

- It is interesting to apply these methods (FFT, ZAM) to dose rate time series measurements in other locations and other type of detectors.
- **What is needed : Long term (at least since 2000 , more than 17 years) mean monthly dose rate measurements**

- If you are interested please contact me : Alexander Clouvas clouvas@eng.auth.gr



This work was financed under contract ENV57-REG1 (EMRP Organization Researcher Grant) in the framework of the ENV57 MetroERM Project. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

This work is part of the ongoing PhD thesis of Mr. Fokion Leontaris (fleontar@ece.auth.gr)