According to GHHD project proposal for 2023: Development of new methods of analysis of strains/seismicity in the area of large dams, using machine learning tools, GHHD planned to perform the following activities:

a. Continuation of measurements of tilts in the main sections of the dam as well as of deformation (extension/compaction) of the fault in the foundation of the dam.

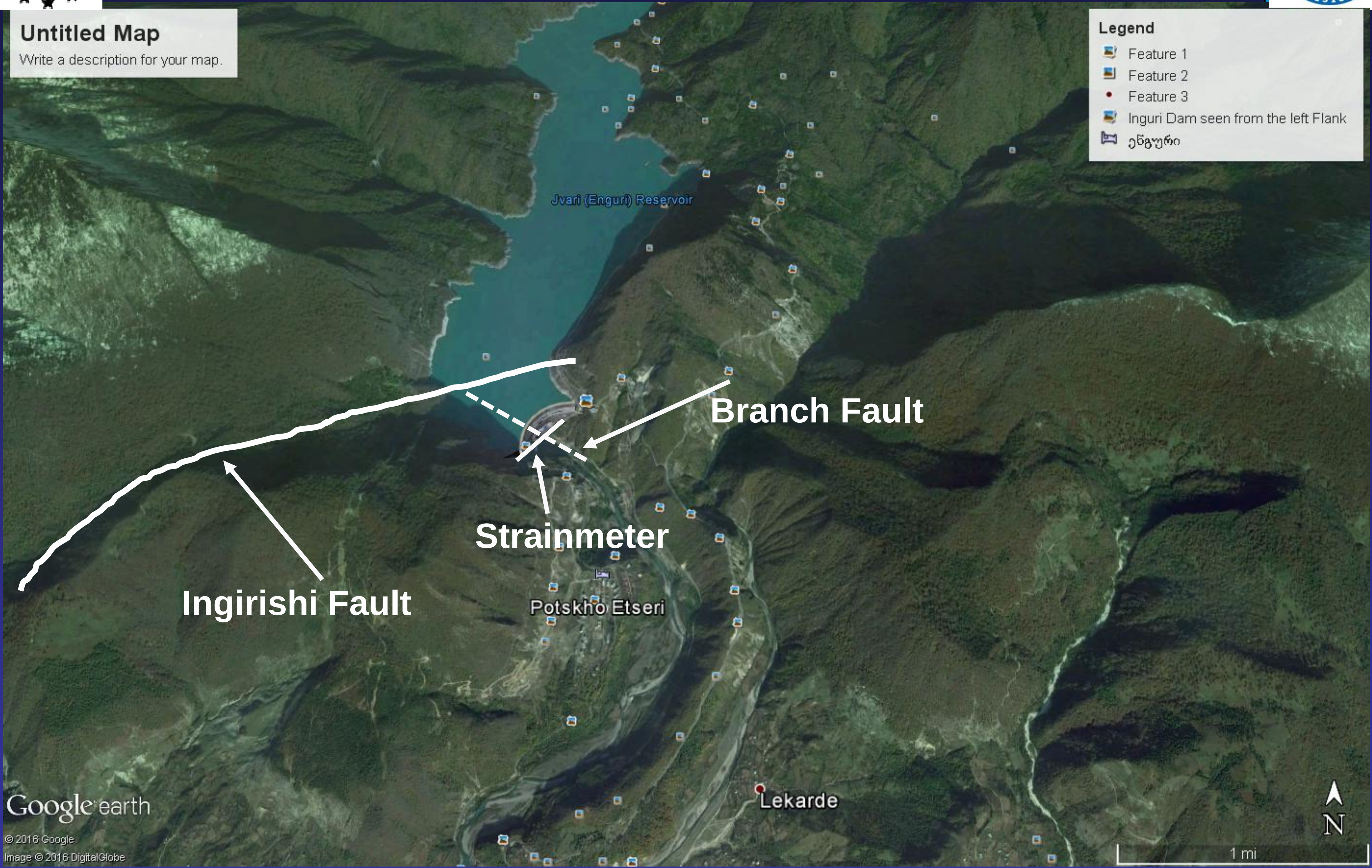
b. Application of new measures of high dams stability using nonlinear dynamics tools. In the present report a new approach, namely, analysis of Tsallis entropy variation in dam strain time series was performed

c. Preparation of the review paper on new methods of analysis of Dam Stability

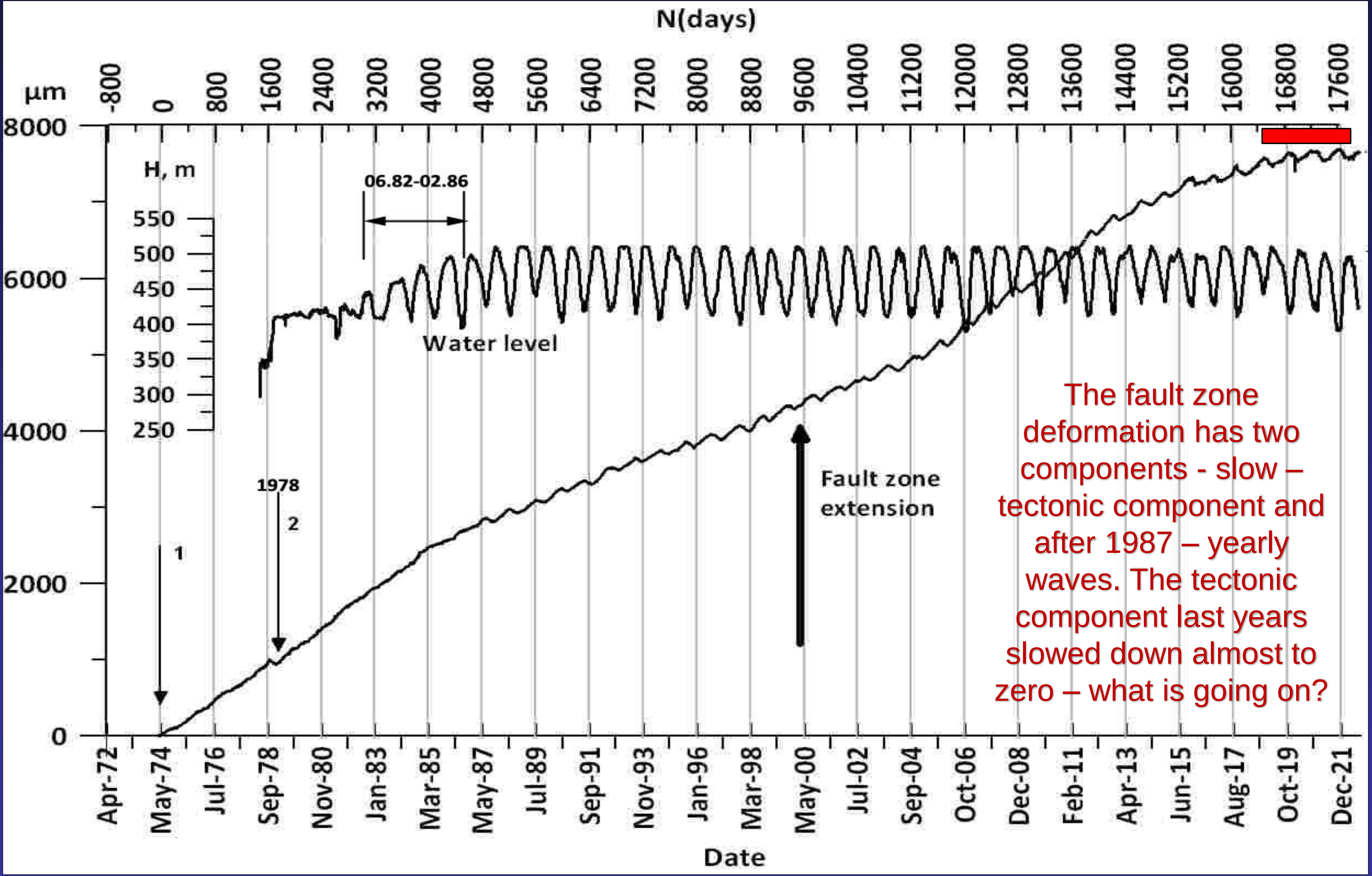
d. To develop a new strain/acceleration continuous recording for the Enguri dam y, the special monitoring system was composed of Analog dual-axis, Jewell Instruments AMI Series Inclinometers 02550316-0211-ATP, the triaxial Jewell Instruments AMA series accelerometer: AMA-3-02-G-V1 as well as Arduino Duo and Internet shield was assembled. The system was tested in laboratory conditions

In addition, the GHHD take part in the International project DAMAST. "Monitoring for High Dam Lifetime: Reliable Supply of Water and Electricity in times of Decarbonization" is projected for 2022-2024. It aims on sharing the knowledge gained within DAMAST to help the freshwater management and to supply the public with clean, reliable and affordable power. This project is the first step towards a Scientific Centre of Competence in the Caucasus. Such a centre would be ideal to combine the goals of climate change and energy security.

Enguri Dam area

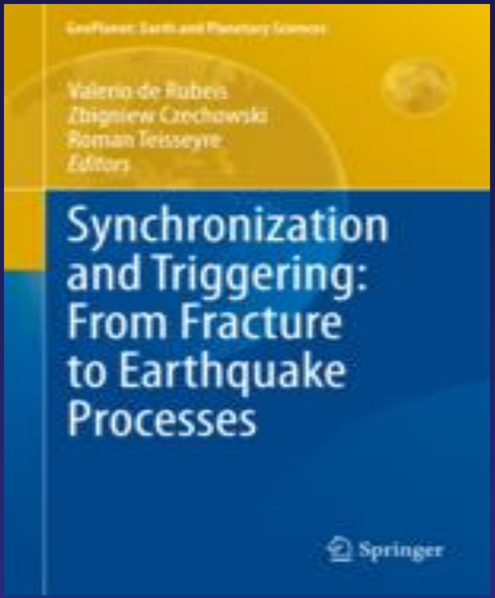


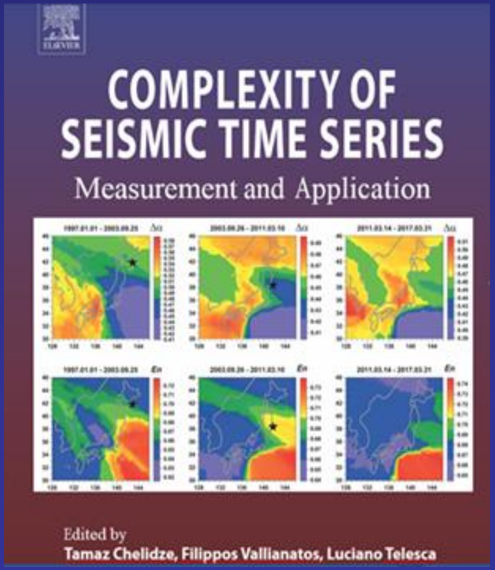
Monitoring results –
Dynamics of the Fault in foundation



The fault zone deformation has two components - slow – tectonic component and after 1987 – yearly waves. The tectonic component last years slowed down almost to zero – what is going on?

Complexity Analysis of monitoring time series



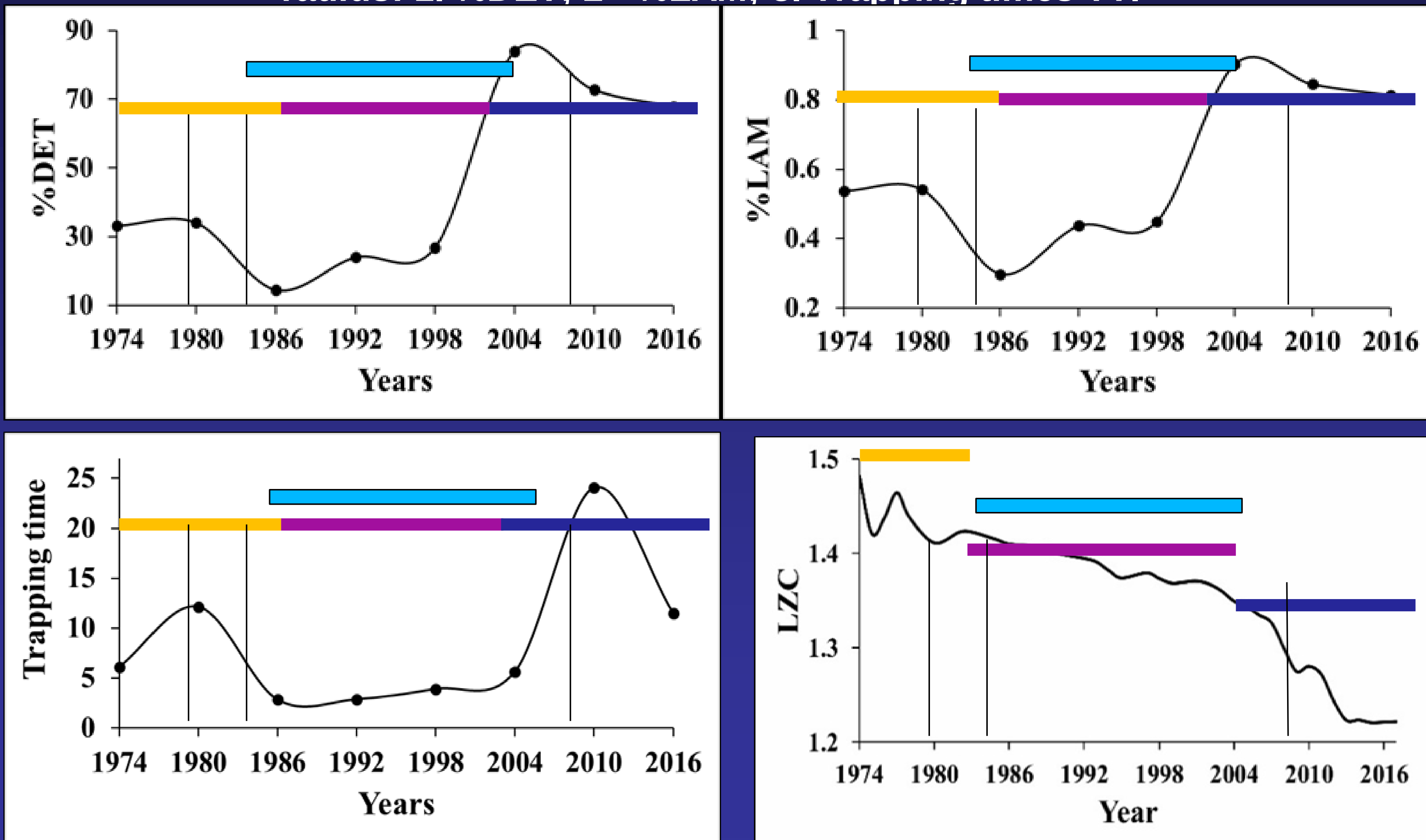


In order to ensure correct statistical and dynamical investigation of dam stability problem, modern methods of linear and nonlinear analysis of strain and tilt time series are used, namely: detrended fluctuation analysis (DFA), multifractal correlation and information dimension calculation (LZC); recurrence plots (RP) and recurrence quantitative analysis (RQA) (Press et al. 1996, Strogatz 2000, Marwan 2003, Matcharashvili&Chelidze 2000).

Nonlinear analysis allows revealing hidden structures (regularities) in seeming random time series!!

The phenomenon of Reservoir-Induced Seismicity Synchronization - RISS.

RQA characteristics of earthquake waiting (interevent) times in 1974-2017 in the original seismic catalog in the Enguri dam area within 100 km radius: 1. %DET; 2 - %LAM; 3. Trapping times TT.



Development of new technological tools for monitoring dam performance, namely, creation of cost-effective telemetric acceleration/tilt unit for the dam monitoring on the basis of new technologies

In the frame of project GHHD assembled and tested the systems for multi-channel monitoring both tilts and accelerations using the GSM platform for data transmitting from Enguri HPS. We used the modern MEMS type three-channel accelerometer AMA-3-02-G-V1 and two-channel tiltmeter AMI-2-10-V1 with MEMS sensors

```
+-----------------------------------+
|   Arduino Device (Data Source)    |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      Arduino Code                 |
|      - Collects data              |
|      - Sends data via WebSocket   |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      Communication Protocol       |
|      - Wired (Ethernet) or        |
|        Wireless (GSM, Wi-Fi)      |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      WebSocket Server (PHP)      |
|      - Listens for data from      |
|        Arduino via WebSocket     |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      Data Storage Process         |
|      - Circular buffer logic      |
|      - Manages data on SD Card    |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      SD Card (Flash)              |
|      - Physical storage medium   |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      Monitoring/Display           |
|      - Web interface or app for   |
|        viewing stored data        |
+-------+---------------------------+
        |
        | Data
+-------+v---------------------------+
|      User Interaction             |
|      - Configuration settings,   |
|        data viewing, etc.         |
+-----------------------------------+
```

Arduino images of acceleration values in the micro-impact experiment