The Environmental Data Acquisition System (EDAS) developed at the Royal Observatory of Belgium

Michel van Ruymbeke (1)*, François Beauducel (2) and André Somerhausen (1)

(1) Royal Observatory of Belgium, Avenue Circulaire,3 B-1180 Bruxelles, Belgium
(2) Institut de Physique du Globe, Place Jussieu, F-75252 Paris Cedex 05 France

Abstract

Multi-parameters approach is required for the monitoring of complex interactions induced by tectonic activities (volcanic, geothermal and seismic areas, land-slide zones...).The diversity of sensors becomes so broad that the use of existing technology provides a difficult barrier for scientists not familiar with metrology. To address this problem, the Royal Observatory of Belgium develops the Environmental Data Acquisition System EDAS. The core base of this standardised system are the DAS, µDas and nanoDAS monitoring devices. They produce data files which follow a standard sequence containing date, time and the recorded values in ASCII columns.

Different type of electronic for instruments with resistive and capacitive transducers were designed. They operate using standard supplies. Their output signals are compatible with the data acquisition system. In complement to the EDAS system, a set of applications has been written for the data analysis, known as EDAT, like HiCum software which is tool useful to analyse signatures on special periodicity's from graphics obtained with stacking method. The EDAS concept complete tidal probes by improvement of access to various signals susceptible to influence tidal records.

1. Introduction

With the improvement of accuracy in tidal instrumentation, devices like gravimeters, tilt meters and strain meters, now exhibit various effects from environmental origins in the residues of signals. During three meetings organized in Walferdange – Grand Duchy of Luxemburg (1993), Aussoie - France (1994) and Lanzarote - Spain (1995), a group of European geophysicists selected the requirements to meet in priority for a monitoring system adapted to the environment's parameters. The answer consists of a concept named EDAS for Environmental Data Acquisition System that obeys to a series of standards rules. After a period dedicated to the introduction of electronics in existing instruments installed in the Underground Laboratory of Walferdange (Gr. Duchy of Luxembourg) (Flick,J. & al.,1991), prototype systems were developed in collaboration with the State Seismological Bureau of China (Cai Weixin & al.,1991) mainly dedicated to the monitoring of ground deformation.

Instrumentation was designed and installed in the three main laboratories on the island of Lanzarote (Canarian archipelago, Spain) (Vieira,R. & al., 1995) (van Ruymbeke & al, 2000a.); difficults conditions due to thermal waves were met. Similar equipment (EDAS) was also experimented on during the solar eclipses that took place in the south of Brazil in November 1994 and throughout Europe in August 1999 (van Ruymbeke & al, 2000b).

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* Fax:++32-2373-0286, E-mail: labvruy@oma.be

2. Methodology of EDAS concept

The probes designed at the Royal Observatory of Belgium are adapted to the monitoring of various geophysical parameters. It is necessary to consider the environment where the instruments will be installed, as it is an intrinsic part of the transducer. In order to increase the precision of the sensor, evaluated by the signal to noise ratio, we systematically select passive transducers that need a minimum of energy transfer from the surrounding medium. The effect of the sensor on the medium is thus minimised. Only resistive and capacitive sensors are considered. Optical sensors based on on/off detection are adaptable to EDAS electronics, but this topic is not addressed in this paper. The transducer's qualification is carried out in a laboratory where the admittance of various parameters that could influence the output signal is established. For on-site operation, a procedure allows to ensure that each sensor is working properly within its range and further quick testing confirms that the instruments will provide the same transfer function as in laboratory conditions.

The EDAS family of sensors and interfaces are designed to work in relatively stable temperature environments, if this is not the case, an EDAS temperature sensor should be added to the installation in order to demodulate temperature effects from real measurements and eventually to apply theoretical corrections.

3. EDAS Interfaces

Based on the Voltage to Frequency (V-F) converter geometry, a series of interfaces have been developed:
- The Floating Bridge Interface (Fl Br) designed in order to interface the signal coming from a capacitors or resistors bridge whose central element is floating.
- The Grounded Bridge Interface (Gr Br) developed for measurements using capacitor bridges with the central element connected to the ground (i.e.: recording the displacement of the mass of tiltmeters or seismometers, moving between two floating plates).
- The oscillator interfaces which are relaxation oscillators using voltage comparators to send a frequency modulated signal proportional to the value of capacitors or resistors.
- The 556-Oscillator circuit which consists of two parts. The first is an oscillator delivering a signal at a frequency given by the inverse of the values of R and C components attached to it. This signal is used to trigger a mono-stable circuit with a pulse length determined by two other components R' and C' . So the final signal is a Pulse-Width-Modulation with a ratio depending of the four components R,R',C and C'.
-The Maximum Voltage Retroaction which is a feedback system used for instruments equipped with a capacitive transducer bridge like LaCoste & Romberg gravimeters. Its principle is based on the application of an electrostatic force on the plates of a capacitive sensor in order to keep a moving mass at a fixed position.

4. EDAS Data loggers

The microDAS data acquisition system is the result of an evolution within the EDAS standards. It is a Data Acquisition System (DAS) based on a Microprocessor, hence its name, for environmental parameters monitoring. A new version of the microDAS which is named nanoDAS, takes advantage of the latest technology. It is adapted for long term measurements, with an increased stability in time keeping device, and much larger static memory for data safe keeping. The system provides more than six months of autonomy for four channels with 24 bits recording data every minute. The EDAS family loggers can be used in any combination in RS-485 networks. A single computer can easily manage several EDAS logger networks. Providing automatic data collection and alarm systems, the networks are ideal for monitoring purposes in real time. The satellite microDAS casing contains the main microDAS acquisition board, the RS-232 to RS-485 interface, an AC and low power battery charger, and a back-up battery. The system is equipped with standard DIN connectors for the channel input and power supply, and one standard connector for the microDAS network.

5. EDAS Software - MDASNet

The MDASNet software developed at the Royal Observatory of Belgium is a management tool for the EDAS family of data loggers. It is compatible with both microDAS and nanoDAS systems. It provides an interactive visual user interface as well as an automated mode. The system is programmable and may be interfaced with the mailing and website programs of the EDAS software family. The file output is directly compatible with most data analysis programs. A RS-485 network of both nanoDAS and microDAS may be used simultaneously by the program. Several networks may be used on the same host by means of several serial ports. Internet UDP links are used to communicate with other programs in the EDAS family, therefore requiring TCP/IP protocol to be installed in order to use these links. The software is designed for use with Microsoft's Windows 32 bit systems. The output files of the MDASNet application are directly compatible with the µDAS grapher-MGR data treatment program.

6. EDAT Software - µDAS Grapher

µDAS Grapher was developed for data processing of data collected by the µDAS, but it can be used with almost all types of ASCII data file(s) for basic processing and displays of data as time referenced graphics. The graphic mode is interactive and intuitive. You can select channels to view, zoom, adjust scales, apply basic formula or export data files in any other format very simply with the keyboard or mouse. Many functions such as numerical filtering, curve smoothing, and derivatives have been implemented. Numerous plotting options are also available as well as graphical file outputs. µDAS Grapher is a small DOS program running with standard EGA, VGA or SVGA display and processor 80286 or higher. Memory requirements are independent from the size of the data file, and can handle up to 30 channels of data and manipulate up

to 200 files together. All options can be specified on a single line at the DOS prompt or into alias script files. µDAS Grapher can be used in different ways. First, to process data, change date, time and data formats of almost any ASCII data file(s), with a set of options on the DOS line command. Second, to visualize these data file(s) as full time referenced graphics in interactive mode, with keyboard or mouse functions.

One of the newest features of the µDAS Grapher application is the integration of the HiCum analysis method.

7. EDAT Software – HiCum Method

The **Hi**stograms **Cum**ulation method originally developed at the Royal Observatory of Belgium is now integrated in the µDAS Grapher application.

Its objective is to put forward in a graphical display the behavior of certain non-linearity recorded by instruments. It is based on a stacking method well applied to earth-tides (Fig.1).
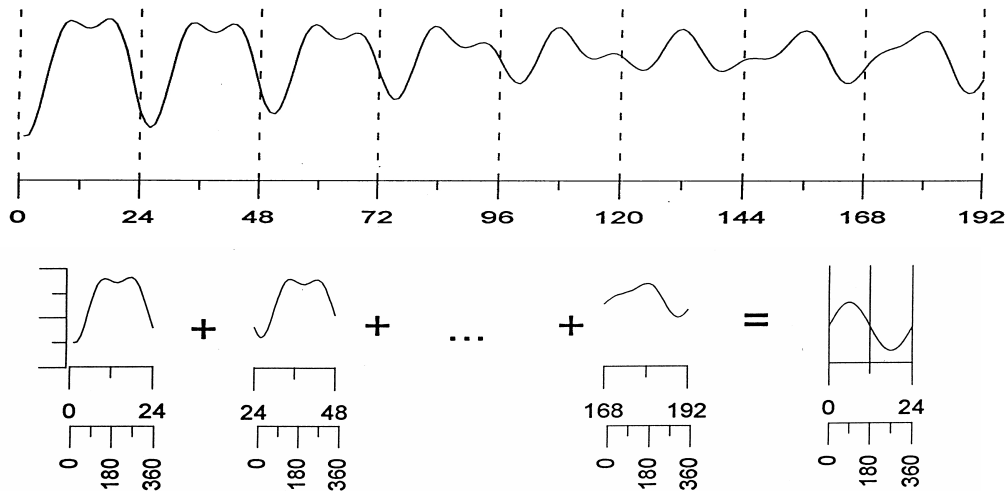
Fig. 1. Principle of HiCum Stacking applied to a height days gravimeter signal (hourly scale).
The series is cut in constant length time interval corresponding to the period selected by a Doodson argument (i.e. 360° for 24 hours S1 period). The obtained histograms are simply added to averaged the concerned component.

We select one component of the tide. Then for each raw data recorded in the file, we compute the phase with respect to the selected wave. We create a series of 360 sectors of 1°, histogram's synchronized with the wave selected and normalized by the number of events in each sector. The averaging of the series gives the shape of the tidal component. Once we have this histogram, we can compute the barycentral parameters (i.e. Phase and Amplitude). We can remove from the histogram the calculated fundamental sine wave and check the residuals for any non-linearity or harmonics present.

Examples of the method is shown in the Figures 2, 3, 4 and 5 where we show various HiCum graphs obtained for the M2-wave, on a three years data files of Brussels superconducting T-03 gravimeter and atmospheric pressure.
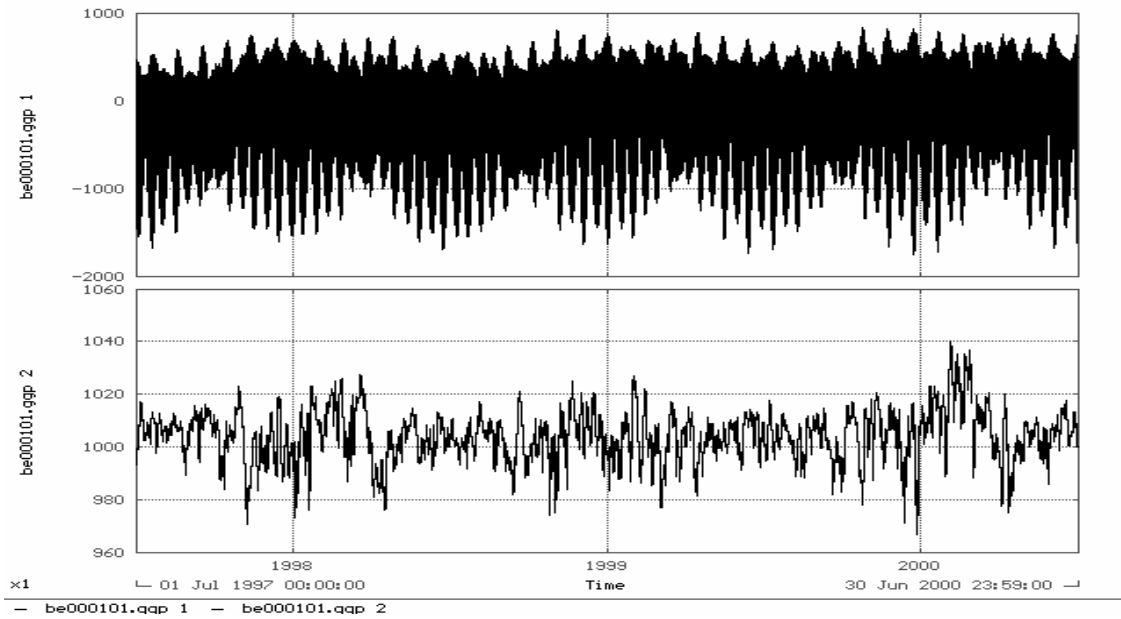
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Fig 2.   To illustrate the HiCum method we have chosen to use data from the Brussels T-03 super conducting gravimeter. Three years of one-minute recording of gravity and atmospheric pressure have been considered. The First graphs show the raw data from these two instruments.
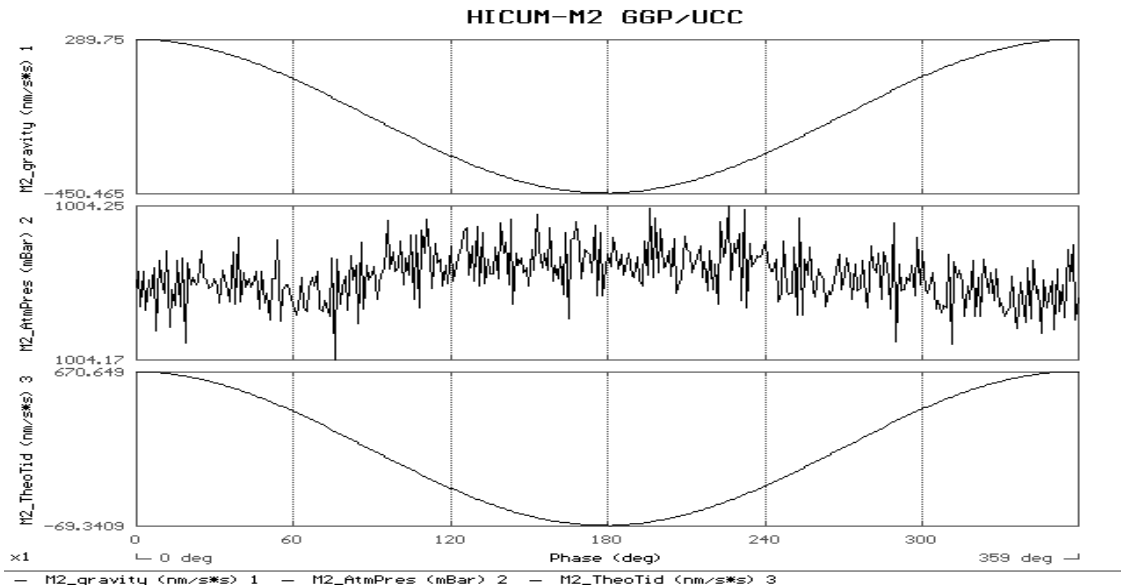

Fig 3.   The semi diurnal lunar component M2 of the tide was selected as reference wave for this example. We see in this graph, the HiCum-M2 for gravity (top), for atmospheric pressure (centre) and finally for a theoretical tide (bottom) calculated for Brussels station. Of course, we can clearly see that the M2 component is present in the gravity meter and in the theoretical tide. The atmospheric M2 is in opposition of phase and noisy with an peak to peak amplitude of 0,04 mBar.

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HICUM-M2 GGP/UCC
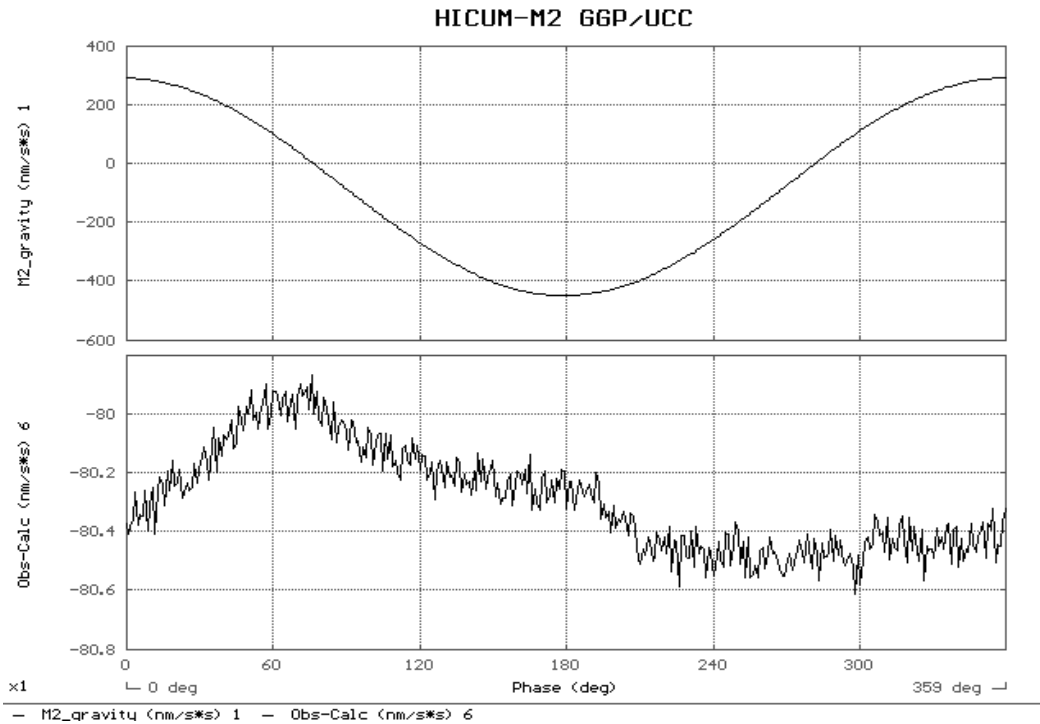
Fig 4.   The top graph here shows the HiCum-M2component of the gravity signal. As soon as we remove the M2-HiCum of the theoretical tide, we can see some anomalous behaviour in the residuals. Note that the vertical axis divisions of the bottom graph represent 0,2 nm/s².
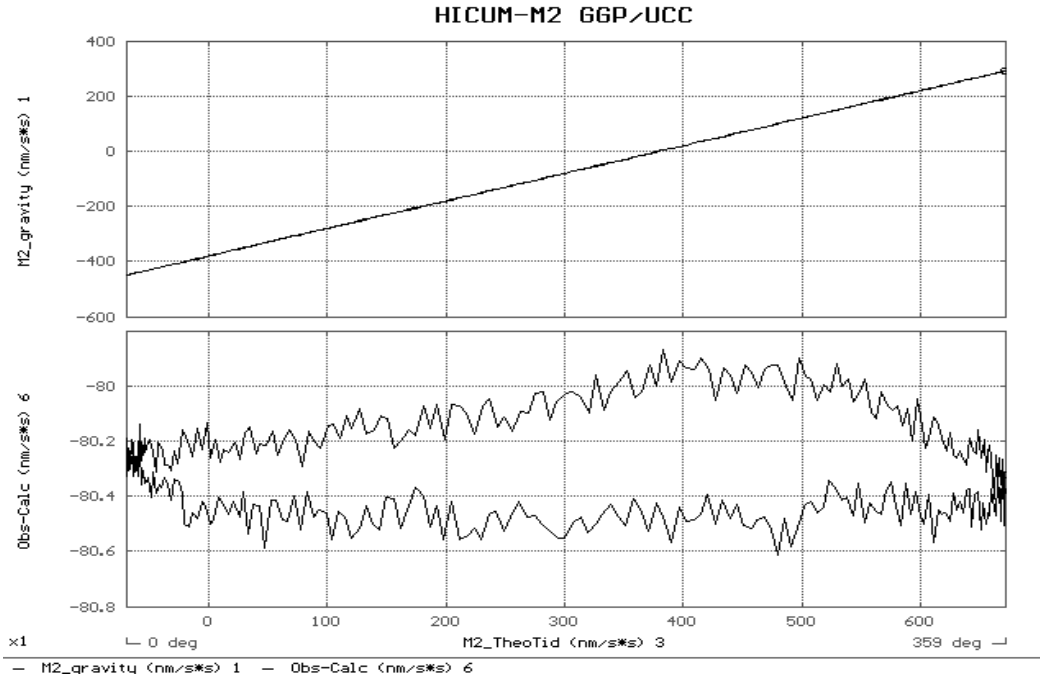

HICUM-M2 GGP/UCC

Fig.5.   An X-Y plot of the HiCum-M2 for the gravity versus the HiCum-M2 for the theoretical earth tide show a perfect linear correlation in the top graph. Once we remove the linear trend, we can see the non-linear behaviour of M2 component in the super conducting gravimeter. We see a small lag between the two signals, and a non-linear hysteresis behaviour with an amplitude of about 0,5 nm/s².

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Acknowledgements:

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