

**Centre International des Marées Terrestres
International Centre for Earth Tides**



**SCIENTIFIC ACTIVITY REPORT
for the period 2003-2007**

by
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The staff of ICET, which is completely supported by the Royal Observatory of Belgium, our host Institution, is composed as follows:

Prof. B.Ducarme, Director(part time)

Mrs. L.Vandercoilden, technician(full time)

The Royal Observatory of Belgium is hosting ICET since 1958 and continues to provide numerous administrative and scientific facilities especially for the publication of the “ Bulletin d’Information des Marées Terrestres” (BIM), for the tidal data processing and for the maintenance of the ICET WEB site.

The ICET directing board met in Ottawa (2004) and in Perugia (2007). The ICET director took part to several Federation of Astronomical and Geophysical data Services (FAGS) meetings in Paris and to the general assembly of the International Association of Geodesy (IAG) in Cairns (2005) and Perugia (2007). He attended all the meetings organised in the framework of the Earth Tides sub-commission: “15th International Symposium on Earth Tides”, Ottawa (2004), workshop on “Analysis of Data from Superconducting Gravimeters and of Deformation Observations regarding Geodynamic Signals and Environmental Influences”, Jena (2006) and “First Asia Workshop on Superconducting Gravimetry”, Hsinchu, Taiwan (2007).

1. Terms of reference

The terms of reference of the International Centre for Earth Tides (ICET) can be summarised as follows:

- *to collect all available measurements on Earth tides as World Data Centre;*
- *to evaluate these data by convenient methods of analysis in order to reduce the very large amount of measurements to a limited number of parameters which should contain all the desired and needed geophysical information;*
- *to compare the data from different instruments and different stations distributed all over the world, evaluate their precision and accuracy from the point of view of internal errors as well as external errors;*
- *to help solving the basic problem of calibration by organizing reference stations or realizing calibration devices;*
- *to fill gaps in information and data;*
- *to build a data bank allowing immediate and easy comparison of earth tides parameters with different Earth models and other geodetic and geophysical parameters ;*

-to ensure a broad diffusion of the results and information to all interested laboratories and individual scientists.

These goals are achieved essentially by the diffusion of information and software, the data processing, the training of young scientists and the welcome of visiting scientists.

2. Main Commitments

It appears first that most geodetic measurements are affected by earth tides, as at the centimetre level the tidal displacement of the station is no more negligible. It will thus remain an important task for ICET to provide algorithms for tidal computation or analysis. For example the geophysicists, such as seismologists or volcanologists, who are measuring crustal deformations for natural hazards monitoring, are now conscious of the necessity of dealing properly with the tidal signals. In a similar way absolute gravity measurements require accurate tidal corrections that should take into account the local tidal parameters. These parameters have to be computed including oceanic tidal loading effects or even require in situ tidal gravity observations.

On the other hand the earth tidal scientific community is limited. The last International Symposium on Earth Tides, held in Ottawa, Canada from August 2 to 6, 2004, brought together only a bit more than seventy participants. The groups are always very small and often marginally involved in tidal research. The papers dealing specifically with tidal studies are not fitting so well to international journals. It is thus very important to keep a specialized diffusion and information medium. It is the vocation of the "Bulletin d'Information des Marées Terrestres"(BIM). ICET is publishing one or two issues per year. Which is the scientific challenge for global Earth tide studies now?

The mathematical modeling of the astronomical tidal forces as well as the elastic response of the Earth made decisive progress. It is now possible to model the astronomical tidal forces to within 0.05 nm.s^{-2} in the time domain. The different mathematical techniques for the evaluation of the tidal response of the Earth do agree now to better than 0.1%. The most recent models include inelasticity in the mantle.

The last problems to be solved are linked to the fluid elements of our planet: liquid core resonance, oceanic loading, meteorological effects, underground water.

Among the ground based observations only gravity tides are able to give information valid at the regional level. The other components (tilt, strain, volume change) are heavily depending of the local parameters of the crust, including cavity or topography effects. These observations should be mostly used to monitor tectonic deformations and to study local tidal influence and correlations.

Tidal gravity observations are able to provide constrains on the liquid core resonance by means of very precise observations in selected sites. The same is valid also for the selection of the most realistic model for the elastic or inelastic response of the Earth. For that purpose it is essential to improve the calibration methods in order to achieve a 0.1% accuracy in amplitude and a 0.01° accuracy in the phase determination. It is also necessary to use up to date oceanic tides models for tidal loading corrections. The determination of the amplitude factor of the polar motion effect on gravity will constrain the Earth viscosity at low frequency.

3. The Global Geodynamics Project (GGP)

These objectives are now directly addressed by the "Global Geodynamic Project" (GGP). A network of 25 stations equipped with cryogenic gravimeters is in operation since July 1997, using a similar hardware and the same procedures for data acquisition.

Besides tidal research, an important objective of GGP is to study the residues after elimination of the tidal contribution in order to detect inertial accelerations such as free oscillations of the Earth core and mantle with periods larger than 50 minutes, which are difficult to observe by means of conventional seismometers. In fact the cryogenic gravimeters are extra-large band instruments covering phenomena with period ranging from one second to more than one year.

It was a unique opportunity to obtain high quality well calibrated tidal observations. It is a reason why ICET has been interested to support this project since its beginning. ICET is responsible of the "Global Geodynamics Project-Information System and Data Centre" (GGP-ISDC, (<http://ggp.gfz-potsdam.de>)) and firmed an agreement with the GeoForschungZentrum (GFZ) Potsdam which is physically hosting the data base. The data owners can upload themselves the original minute sampled data. The data are carefully preprocessed at ICET using a standard procedure, to correct for tares and spikes. The data are then decimated to one hour and analysed. The analysis results are directly communicated to the data owners. This follow up is required to detect as soon as possible the anomalies that could affect the data. Each year CD-ROM's are edited with the raw and corrected minute data as well as the log files and the auxiliary data, when available.

The archiving of the data is rather complex as the data are only released according to a strict time table. The constrain has been relaxed for the second GGP term beginning in 2003. The data are sent to ICET six months after their production. During one additional six months period the data are only available to the GGP members and can be freely accessed only after one full year. The software provided for the management of GGP-ISDC by the GFZ Potsdam is continuously updated.

With the collaboration of guest scientists ICET pushed forward researches using the GGP data sets and concerning for example the liquid core resonance, the determination of the pole tide and the detection of the inner core oscillations known as Slichter's mode (see bibliography). We have now more than 20 high quality data sets with a minimum length of six years and we can provide on request not only tidal parameters, oceanic loading corrections according to different models but also tidal residues to study non tidal effects such as core modes. These series, if they are well constrained by absolute measurements, will be also useful in the interpretation of satellite gravity data. To improve the tidal loading corrections ICET gathered the most recent ocean tides models.

4. Ongoing Activities

The "Bulletin d'Information des Marées Terrestres"(BIM) is printed in 300 copies. Some 275 copies are sent to libraries and individual scientists all over the world. It is devoted essentially to scientific papers concerning tidal research. From December 2003 until September 2006, six issues n° 138 to 142 have been published with a total number of 500 pages. In 2006 we had the opportunity to publish the proceedings of the workshop on "Analysis of Data from Superconducting Gravimeters and of Deformation Observations regarding Geodynamic Signals and Environmental Influences, Jena, March 27-31 2006". All the published papers are immediately available on the ICET WEB site.

ICET is authorised to distribute freely the ETERNA tidal analysis and prediction software among the scientific community for non commercial purposes. Some forty CD-ROMS with ETERNA software are requested from ICET each year.

The ICET WEB site (<http://www.astro.oma.be/ICET/>) is continuously updated and developed. Besides general information including historical aspect and previous ICET reports, it proposes to the visitors an access to:

- the general bibliography on Earth Tides from 1870-1997 either by alphabetical order of the first author or following the decimal classification introduced by Prof. P.Melchior;
- the table of content of all the previous BIM, n° 1-142, and starting from BIM 133 an electronic version of the papers;
- tidal analysis and preprocessing software available from different WEB sites or on request from ICET.
- ocean tides loading computations and the predicted tidal gravity parameters for all the tidal gravity stations, more than 1,000 stations.

Most information requests (one per week minimum) concerned software. According to the internal GGP rules ICET is preparing annually CD-ROM's, with the raw and processed minute data. We already edited CD-ROM's for the 9 first years, 1997/07 to 2006/06, of the project.

5. Visitors

ICET welcomed more than 10 visitors. Besides visitors coming only for a short stay we must consider also guest scientists and trainees.

Prof. S. de Freitas ("Universidade Federal de Parana", Curitiba, Brazil) and Dr. Filippo Greco ("Istituto Nazionale di Geofisica y Vulcanologia, Sezione di Catania") visited ICET to discuss future cooperation.

The guest scientists bring their own know how or data to work at ICET during several weeks or even months. Prof. A.P.Venedikov (Institute of Geophysics, Bulgarian Academy of Sciences, Sofia) came in 2004, 2006 and 2007 to finalize its tidal analysis software VAV and extend its application to ocean tides. Some guest scientists worked on the ICET and GGP data banks, as Prof. H.P. Sun and his assistants X. D. Chen and J. C. Zhou (Institute of Geodesy and Geophysics, CAS, Wuhan, China). Others brought their own data sets to perform tidal analyses using the ICET software and computing facilities, as Prof. L.Brimich (Geophysical Institute, Slovak Academy of Sciences, Bratislava) and Dr. M. Benavent ("Instituto di Astronomia y Geodesia, CSIC-UCM", Madrid).

Mr. Daniel S. Costa ("Escola. Politécnica, Universidade de São Paulo, Brasil") and Mr. Stefano Panepinto ("Dipartimento di Chimica e Fisica della Terra, Università di Palermo") stayed during several months to receive intensive training on earth tide data processing and analysis.

As a follow up, many communications have been presented at International conferences and several papers have been published in international journals (see bibliography below).

ICET has been contacted by the Department of Technical support (Topographic Service) of the European Nuclear Research Center (CERN) in connection with the installation the Large Hadron Collider (LHD). The persons in charge have to monitor on line the tilt of the ground. As a first step our expertise is required to determine the most appropriate tidal parameters from theoretical models as well as from clinometric measurements. In a second step we should provide software for the real time prediction of the tidal tilts.

6. Summer School

In the framework of the International Gravity Field Service (IGFS), an International School on "Micro-gravimetric techniques: static and dynamics aspects", has been organised jointly by the "Bureau Gravimétrique International" (BGI) and ICET. It took place at Lanzarote (Canarias, Spain) from October 24 to 28, 2005.

7. Future of ICET

As the ICET Director is retiring at the beginning of 2008, it was necessary to prepare the transfer of the Service. As early as in 2004, the ICET director contacted all Scientific Institutes with a tradition in Earth Tides research. The requirements to host ICET were clearly explained in a document "Requirements to host the International Centre for Earth Tides (IAG Service and World Data Center)". The GGP group discussed this matter and sent an official letter with his view of the future of ICET. Finally IAG issued an announcement of opportunity which has been widely circulated.

Two institutions presented an official candidature:

- the "European Center for Geodynamics and Seismology", Luxembourg, Grand Duchy of Luxembourg;
- the University of French Polynesia at Papeete.

The ICET Directing board evaluated the candidatures on scientific grounds and selected the University of French Polynesia. This choice was accepted by the Earth Tide sub-commission and the IAG executive bureau during the XXIVth General Assembly of the IUGG.

The main task of the new Director will be to convert the ICET WEB site into a real "Virtual Observatory" on Earth Tides and to provide an interactive "portal" to answer specific questions.

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