

# ICET

International Centre for Earth Tides

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B. Ducarme, Director Tel: + 32 2 373 02 48  
O. Francis, Vice-Director Fax: + 32 2 374 98 22  
Observatoire Royal de Belgique  
Avenue Circulaire, 3  
B-1180 Bruxelles  
Belgium  
[bernard@oma.be](mailto:bernard@oma.be)  
[francis@oma.be](mailto:francis@oma.be)  
<http://www.oma.be/KSB-ORB/ICET/>

## Introduction

The International Center for Earth Tides (ICET) is a service of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) and also a World Data Center C for Earth Tides of the International Council of Scientific Unions (ICSU).

The tasks ascribed to ICET have been until now: collection of tidal data (raw data from gravimeters, tiltmeters and extensometers), evaluation of data, comparison of data, calibration of data, filling gaps in data, discussion of the results collected in the Data Bank, diffusion of results and information.

## 1. Collection of Data (World Data Centre)

It was recommended by the Commission of Earth Tides (International Association of Geodesy) to store all recorded data at the International Centre for Earth Tides in Brussels which is recognized and acts as a World Data Centre C. All the data stored at ICET have now been transferred on diskettes and we are now in the procedure to store them on optical disks.

Today the ICET Data Bank contains results from 360 tidal gravity stations but not all stations provided the totality of their initial hourly readings and calibration data. The conservation of the data in the ICET World Data Centre C has the following advantages:

1) protection of the data against loss or damage. It has been our experience that when, for some reason, a scientist leaves his institution, geophysical data upon which he worked may be difficult to retrieve and even, sometimes, are simply lost. In several cases indeed, ICET has already provided

duplicates of data to institutions which originally acquired them;

2) automatic and safe introduction of the submitted data into the ICET Data Bank;

3) institutions providing tidal gravity data to the ICET Data Bank have access, free of charge, to all data included in the Data Bank (with the exception of course of those with requested restricted access).

A "Directory of Gravity meters in use for Earth tide measurements" published in June 1994 (BIM 118, 8777-8830) indicates that at least 938 records with a total of 5.179.074 Earth tidal hourly readings must exist at that time but that only 581 records with a total of 3.343.957 hourly readings have been received and stored in the ICET Data Bank. Thus the collection of data appears to be a difficult task. Despite the often renewed recommendations by the World Data Centre ICSU Panel and by the Scientific Unions and Associations some countries do not transmit any data measured on their territories. As a matter of fact many data have been lost.

## 2. Evaluation of Data

Since its foundation one of the main activities of ICET has been the development of appropriate computation methods. A great number of programs have been written and permanently improved to analyze and validate the quality of the submitted data. These programs have always been made freely available to interested institutions, a number of which used ICET procedures.

The method usually applied for the analysis of original hourly data was the least squares method

with Venedikov filters, but spectral analyses are also applied in some specific cases. With the present level of precision of the instruments commonly used (spring gravimeters, clinometers and extensometers), there is no significant difference with other proposed methods.

Recently, however, the appearance of long uninterrupted series of higher sensitivity, obtained with superconducting gravimeters and some exceptionally good classical spring gravimeters made absolutely necessary the development of a new generation of analysis methods like ETERNA which can be used with a simple Personal Computer and has been developed by H.-G. Wenzel.

New methods also benefit from a more rigorous and considerably extended development of the lunisolar potential as performed by Tamura, Xi Qin Wen, Hartmann-Wenzel and Roosbeek.

On the other hand, to evaluate the local loading and attraction effect of oceanic tides, ICET developed a program based upon Farrell's procedure and used the cotidal-corange oceanic maps of Schwiderski (nine tidal components) as a working standard. Today, ten new oceanic maps have been introduced in these computations.

The ultimate outputs of the usual computer programs are:

- a listing which gives all needed information: description of the concerned station with instrumental constants, methods of computation, epochs of measurements and, for each main group of tidal waves, the amplitude, the amplitude factor, the phase and the residuals (amplitude and phase) with respect to elastic Earth models and to oceanic contribution. Of course, internal errors are given.
- the automatic introduction of the information in the Data Bank.

### 3. Comparison of Data

Comparisons of stations and instruments have been made as an obvious result of the analysis of data. This gives guidelines for the improvement of installations or of instruments. With as much as 360 tidal gravity stations in the Data Bank, it has been found convenient to define, in an impersonal way, an "internal consistency factor" for each series of measurements, taking into account not only the internal errors but also the efficiency of the station related to interruptions and maintenance.

### 4. Calibration

The calibration of tidal instruments is not an elementary and easy task. At the time of IGY, when ICET was founded, calibration errors up to 10 percent were rather common as experience later demonstrated.

For what concerned gravimeters ICET proposed in 1975 to accept the results obtained with three Askania gravimeters operating at Brussels from 1958 to 1967. This defined the Brussels system and some 35 different instruments were installed there to be calibrated with respect to the local tidal amplitudes and phases. The system was kept without change until 1992 when it was clearly established by different methods that this system gave amplitudes in excess of 0.8 percent. In this respect ICET encouraged the development of an inertial oscillating platform at Brussels to experimentally calibrate the gravimeters.

The 0.8 percent correction was carefully made and the results published in a paper entitled "A new Data Bank for tidal gravity measurements (DB92)" by P. Melchior (1994).

For what concerns horizontal pendulums used as clinometers, J. Verbaanderd invented and developed a system called "crapaudine dilatable," a device interferometrically calibrated which ensures on site regularly repeated automatic calibrations of the pendulums with 1 percent accuracy or slightly better. ICET has calibrated some 150 crapaudines on its interferometer.

The interpretation of the observed results (amplitudes and phases for the main diurnal and semi-diurnal components at each station) thus rests with a comparison (1) to the corresponding parameters calculated on the basis of an ellipsoidal rotating Earth model with liquid core (Dehant-Defraigne-Wahr models), and (2) to the loading and attraction effects produced by the oceanic tides acting at exactly the same frequencies as the Earth tides.

The residues obtained by subtracting both effects from the observations are to be scrutinized to identify sources of anomalies, either instrumental, either geophysical. A correlation with large-scale regional tectonics through heat flow density and age of the continental crust is suggested and still a matter of contest and investigation.

### 5. Filling of Gaps in Data

Since the end of 1973, ICET has obtained support to develop in Africa, in Asia, the South Pacific, South and Central America, Trans-World Tidal Gravity Profiles which extend over 17,400 km, from Istanbul to Papeete and over some 7,200 km from Cape to Cairo as well as in South and Central America. These operations involved a total of 136 stations where measurements of a duration of four to eight months have been completed in 19 years, during the period 1973-1991. Eight different equipments of high quality were used for these measurements (Geodynamics and LaCoste Romberg gravimeters with quartz clocks, cassette and papers recorders).

Results are reported in a number of publications in international scientific journals.

Nowadays, ICET is promoting and supporting a project to establish a new gravity tidal profile along the Atlantic coast. The objective is to validate the new ocean tides models derived from the analysis of Topex/Poseidon altimeter data.

## 6. A New Data Bank for Tidal Gravity Measurements (DB92)

Tidal gravity parameters being available in 382 permanent or temporary stations all over the world, tentative interpretations of these data were made on the basis of a data bank created by ICET in 1980-1982 which contained all available results without any discrimination which could have appeared as arbitrary. These interpretations were criticized on the basis of the different qualities of instruments (null instruments or not), data, calibration and necessary corrections for ocean-continent interactions.

A careful reexamination of these basic data being needed before any geophysical discussion, we have built a new data bank which contains only those stations where rigid control of every step in the observations, calibrations and reduction could be made either because the original data are stored in the World Data Centre C, or because the published results give enough information to permit checks and revisions. 215 stations where oceanic effects are well controlled have been selected to determine the experimental values of the earth tide parameters with as a result, a scattering reduced by a factor of 2 with respect to the previous data while the mean values of the amplitude factors of the two main waves ( $O_1$  diurnal;  $M_2$  semi-diurnal) calculated continent by continent, agree with the best available earth model.

For what concerns the distribution of oceanic loading and attraction effects, islands and coastal stations are added and an amount of 289 stations have been used in a recent investigation (1995) about 10 new corange-cotidal maps.

It is expected that this new data bank will be used for renewed discussions of the results.

## 7. Diffusion of Data and Information

ICET also acts as an information and supporting agency in the field of Earth tides through:

- (a) the publication of the 127 issues of the "Bulletin d'Informations des Marées Terrestres" covering 9,855 pages from 1956 to 1997. In particular, the Proceedings of the Earth Tides Commission Working Groups meetings have been published in the Bulletin. This Bulletin is distributed to some 350 scientists and scientific institutions.
- (b) numerous translations of Russian scientific papers amongst which 373 translated papers have been

published in the Bulletin d'Informations des Marées Terrestres, covering 3,843 pages, occasionally Chinese papers (too few, unfortunately) and even an important Portuguese paper.

- (c) the maintenance of a General Bibliography of scientific papers related to Earth tides, with numerical code (7,000 titles), available on diskette.
- (d) three to four visitors per year, sometimes more.
- (e) participation in the organization of the International Symposia on Earth Tides: thirteen symposia have been held from 1957 to 1997.
- (f) ICET has often had a role of scientific counselor for the benefit of different organizations faced with the Earth tides problem. As examples are:
  - the calculation of horizontal areolar deformations acting upon the CERN particles accelerator LEP at Genève (Switzerland),
  - initiation of several Chinese groups (Beijing, Wuhan, Lanzhou, Kunming, etc.) at the time of the opening of IUGG cooperation with China,
  - instructions about the calculation of oceanic effects for the southern hemisphere,
  - long time cooperation, principally with Argentina, Australia, Brazil, China, Finland, Indonesia, New Zealand, Russia, Spain and Ukraine,
  - tidal predictions for field gravimetric measurements.
- (g) ICET is the Data Center of the ongoing Global Geodynamics Project (GGP) which is a proposal to monitor changes in the Earth's gravity field at periods of seconds and longer using a network of superconducting gravimeters. The GGP goals are:
  - to detect inertial gravity waves in the Earth's liquid core,
  - to investigate the gravity effect of atmospheric loading and mass redistribution on the solid Earth,
  - to refine estimations of the nearly diurnal free wobble of the Earth and models of oceanic loading on the solid Earth,
  - to observe gravity variations associated with slow and silent earthquakes, tectonic motions, sea-level changes,
  - to monitor the location of the rotation pole of the Earth.

## 8. Provided Services

The Centre provides assistance for the setup of new stations, calibrations of instruments, data processing as well as for tidal analysis. The assistance is accomplished either by a stay at the Centre or by providing software developed at the ROB. The ICET makes also available tidal predictions for any place

and time, which are absolutely needed for field gravimetry, absolute gravity measurements and for tilt measurements. These predictions can be computed either on the basis of elastic Earth models and oceanic cotidal maps, or on the basis of results of direct measurements.

Each year, about five scientists visit ICET, sometimes for a long stay.

#### 9. Recent Publications

P. Melchior, A new data bank for tidal gravity measurements (DB92), *Physics of the Earth and Planetary Interiors*, **82**, 125-155, 1994.

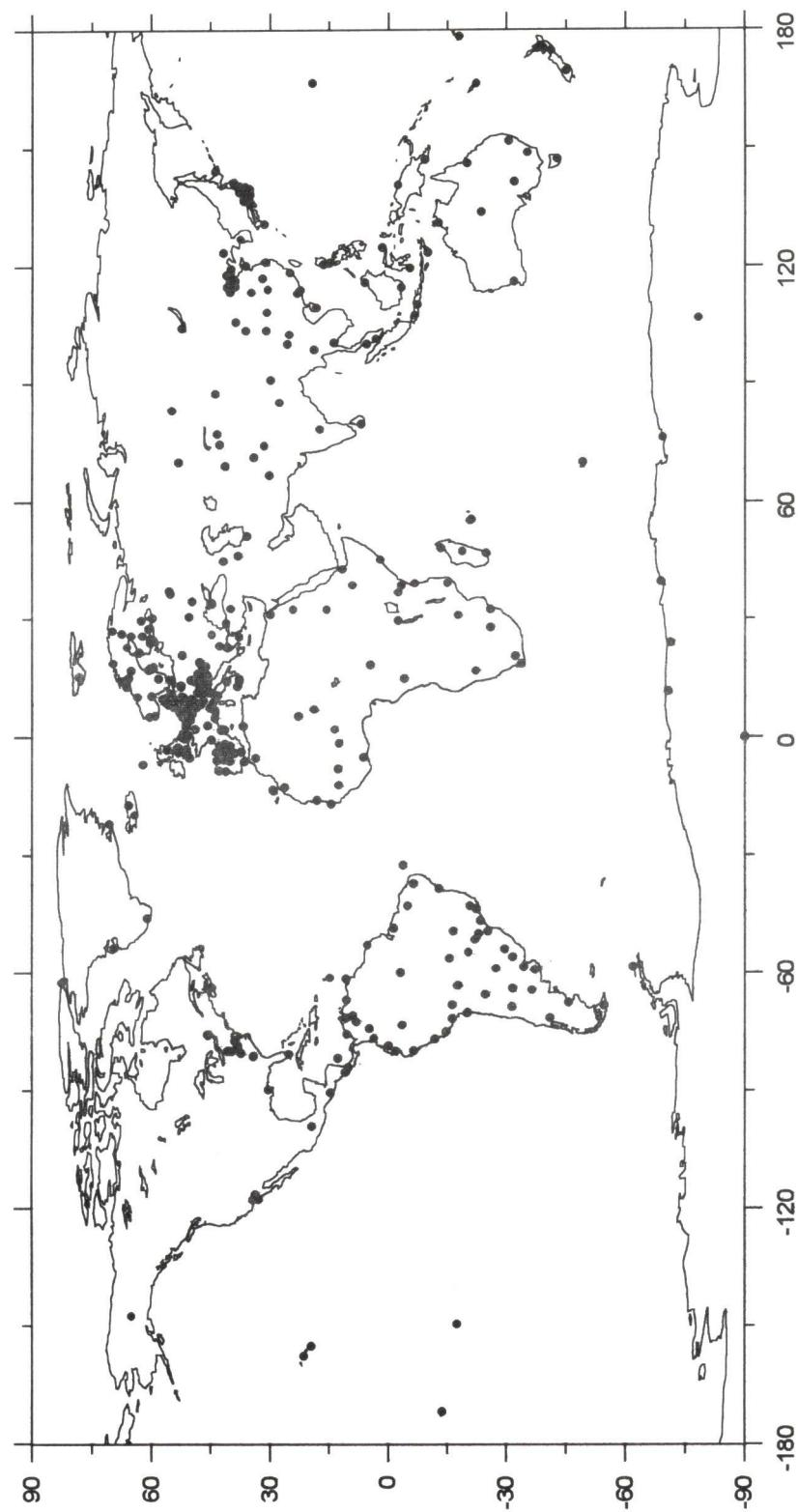
P. Melchior, A continuing discussion about the correlation of tidal gravity anomalies and heat flow densities, *Physics of the Earth and Planetary Interiors*, **88**, 223-256, 1995.

P. Melchior and O. Francis, Comparison of recent oceanic corange-cotidal maps with ground based tidal gravity measurements through the gravitational attraction and elastic loading due to the moving water masses, *Marine Geodesy*, **19**:291-330, 1996.

O. Francis and P. Melchior, Tidal loading in south western Europe: A test area, *Geophysical Research Letters*, **23**, 17, 2251-2254, 1996.

P. Melchior and O. Francis, Proper Usage of the ICET Data Bank, *Du bon usage de la Banque de Données ICET, Comparison with theoretical applications on Earth Models*, Proceedings of the XIIIth Symposium in Earth Tides, Bruxelles, Belgium, 1997.

## World distribution of the tidal gravity stations



## Network of the GGP stations

