

# International Geodynamics and Earth Tide Service (IGETS)

<http://igets.u-strasbg.fr/>

*Chair of the Directing Board: Hartmut Wziontek (Germany)*

*Director of the Central Bureau: Jean-Paul Boy (France)*

## Structure

- Directing Board: H. Wziontek, J.-P. Boy, V. Palinkas, J.-P. Barriot, C. Foerste, H.-P. Sun, B. Meurers, D. Crossley, J. Hinderer, S. Pagiatakis, S. Bonvalot, N. Sneeuw
- Central Bureau: J.-P. Boy
- Data Center: C. Förste, C. Voigt

## Overview

The primary objective of the International Geodynamics and Earth Tide Service (IGETS), established at the 2015 IUGG General Assembly in Prague (Czech Republic), is to provide a service to monitor temporal variations of the Earth gravity field through long-term records from ground gravimeters, tiltmeters, strainmeters and other geodynamic sensors. IGETS continues the activities of the Global Geodynamic Project to provide support to geodetic and geophysical research activities using superconducting gravimeter data within the context of an international network. IGETS also continues the activities of the International Center for Earth Tides, in particular, in collecting, archiving and distributing Earth tide records from long series of gravimeters, tiltmeters, strainmeters and other geodynamic sensors.

Superconducting Gravimeter data are still the major source of data available at IGETS, and different product levels are derived from gravity and pressure data:

- Raw gravity and local air pressure records sampled at 1 or 2 seconds, in addition to the same records decimated at 1-minute samples (Level 1 products).
- Gravity and air pressure data corrected for instrumental perturbations, ready for tidal analysis (Level 2 products).
- Gravity residuals after geophysical corrections (Level 3 products).

## Status of the Analysis Centers

The two IGETS Analysis Centers, located at the University of French Polynesia (Tahiti) and at EOST (Strasbourg, France) provide the different Level-2 and Level-3 products. The two centers have been processing the Level 2 data from the raw Level 1 data, i.e. gravity and pressure data corrected for all major disturbances. The EOST center has produced the Level 3 data, i.e. gravity residuals after correction of all major geophysical signals.

### *IGETS preprocessing Centre at University of French Polynesia (UPF), Tahiti*

Raw minute data (IGETS-SG-MIN) are preprocessed and validated at IGETS preprocessing Centre Tahiti. In total, 776 months of data have been processed. Hourly data are also generated as one-year blocks (IGETS-SG-HOUR, code h2) for these sites. Table 1 summarizes the status, where data processed in 2018 are highlighted in red.

New stations (shaded in Table 1) have been preprocessed for the first time: Djougou, La Plata, Lhasa and Lijiang. For these new stations a report was sent to the data owners providing a comparison between the observed tidal gravity factors and those modelled from a theoretical body tide model (Dehant et al., 1999) and ocean tide loading, which allows to assess an upper limit of the calibration error of the instrument.

Table 1: Status of IGETS data preprocessed and analyzed by UPF on April 1<sup>st</sup> 2019  
n: number of preprocessed months in 2018 N: number of days analyzed  
STD: standard deviation of the tidal analysis (ETERNA)

Code	Location	SG Instr.	Code	RAW	Corrected	n (months)	N (days)	STD (nm/s <sup>2</sup> )
AP	Apache Point, USA	SG046	00466090	180800	180822	17	2873	1.142
BA*	Bandung, Indonesia	T008	00084100	030600	030622		1104	2.938
BE*	Brussels, Belgium	T003	07790200	000900	000901		¶6692	1.641
BF	Black Forest, Germany	CD056_L CD056_H	01560716 02560716	190100 190100	180122 180122	21	2651 2698	0.576 0.629
BG	Borowa Gora, Poland	iGRAV027	00270908	170100	170212 ●●			
BH	Bad Homburg, Germany	(T001) CD030_L CD030_U SG044	01300734 02300734 00440734	070400 070400 170300	070422 * 070422 * 170322 *		¶1005 2222 2218 3619	0.950 0.783 0.835 0.521
BO*	Boulder, USA	C024	00246085	031000	031022		1850	1.109
BR*	Brasimone, Italy	T015	00150515	991200	991222		1428	2.954
CA	Cantley, Canada	T012	00126824	190200	170422		6084 ¶7755	1.539 1.613
CB	Canberra, Australia	C031	00314204	161200	161222	12	6809	0.778
CI	Cibinong	CT022	00224102	120500	120522		872	1.970
CO	Conrad, Austria	C025	00250699	170300	170322	25	2880	0.609
DJ	Djougou, Bénin	C060	00603335	190100	180222	90	2522	0.769
ES*	Esashi, Japan	T007	00072849	081200	081222	→20040225	2274	1.491
HS	Hsinchu, Taiwan	T048	00482695	120800	090622 ●●		898	2.249
KA*	Kamioka, Japan	T016	00162828	130700	130722		3006	1.229
KY*	Kyoto, Japan	T009	00092823	030600	030622	→20020731	1533	3.691
LP	La Plata, Arg..	RT038	00387800	180200	171222	24	729	1.277
LH	Lhasa	OSG057	00572650	170600	170622	91	2391	0.503
LI	Lijiang	OSG066	00662651	130400	170622	51	1378	0.811
MA*	Matsushiro, Japan	T011	00112834	080600	080622		3954	1.008
MB	Membach, Belgium	C021	00210243	120900	120922 ●●		5907	0.705
MC	Medicina, Italy	C023	00230506	180300	170622		6990	0.891
ME	Metsahovi, Finland	T020	00200892	160900	150422 *		5409 ¶5935	1.167 1.159
		iGRAV013 iOSG022 OSG073_N6 OSG073_N7	00130892 00220892 01730892 02730892	180300 180300 150100 150400	150122 150422		356 381	0.683 0.608
MO	Moxa, Germany	CD034_L CD034_U	01340770 02340770	181200 181200	181222 181222	35 35	6600 6672	0.535 0.548
NY*	Ny Alesund, Norway	C039	00390005	120100	120122		3776	2.687
OS	Onsala, Sweden	OSG54	00540875	181200	180122	22	3113	1.217
PE	Pecny, CZ	OSG050	00500930	181000	181022	27	4065	0.628
PO*	Potsdam, Germany	T018	00180765	980900	980912		2250	0.856
ST	Strasbourg, France	(T005) C026	00260306	181000	161122	19	3272 6775	2.265 0.630
SU	Sutherland, South Africa	CD037_L CD037_U SG052	01373806 02373806 00523806	181200 181200 170900	181222 181222 170922	32 32 17	5850 5373 2845	0.802 0.769 0.721
SY	Syowa, Antarctic	T016	00169960	030100	030122 *	→20001231	1279	1.387
TC	Tigo, Concepcion, Chile	RT038	00387621	150400	150422 *		3544	1.071
VI*	Vienna, Austria	C025	00250698	061200	061222		3402 ¶4278	0.525 0.463
WE	Wetzell, Germany	(SG103) CD029_L CD029_U CD030_L CD030_U iGRAV006	01030731 01290731 02290731 01300731 02300731 00060731	980900 1803001 80300 180300 180300 170300	980921 * 180322 180322 180322 180322 170322	68 68 16 16 24	¶726 6294 6260 2776 2791 672	2.639 0.583 0.584 0.604 0.576 1.004
WU	Wuhan, China	T004 C065	00322647 00652647	120700 170600	120712 * 170600 ●●		3844	0.937
YS	Yebes, Spain	OSG64	00640435	190200	180222	24	2228	0.723
				TOTAL		776		

Legend: \* instrument or station stopped

( ) not included in IGETS

●●preprocessed only by data owner

¶ with data before 1997/07

→ end of analysis

### ***IGETS processing at EOST, University of Strasbourg, France***

EOST has produced Level 2 and 3 data from 37 records, from 31 instruments located at 27 different sites, with its own processing strategy.

Raw 1-minute gravity and pressure (Level 1 data) are first calibrated using the available calibration files. We start processing the air pressure data, removing interpolated hourly surface pressure from MERRA2 (Gelaro et al., 2017) reanalysis model. We correct manually these residuals for eventual offsets, and fill any gaps with a linear interpolation. The de-gapped series is then corrected for the remaining perturbations (spikes) using a threshold on its derivative, following Crossley et al. (1993) procedure. The full air pressure is then restored by adding back the MERRA2 pressure. For gravity, the methodology is similar: calibrated gravity is corrected for a local tidal model, including polar motion, and local air pressure effects. Offsets are manually corrected, gaps are filled with a linear interpolation, and remaining perturbations (spikes, earthquakes) are corrected using a threshold on the derivative of the gravity residuals. The full gravity is then restored by adding back the modeled tidal signal and air pressure effects.

1-min. gravity residuals are computed after subtracting to the Level 2 data: Solid Earth tides and ocean tide loading, atmospheric loading, polar motion and length-of-day induced gravity changes, and an instrumental drift.

Tidal gravity variations are computed differently for the long-period tides and for the diurnal and sub-diurnal bands:

- At high frequency, a local tidal model, adjusted by least-squares, is used.
- At frequencies below diurnal tides, we model the tidal signal using the DDW99 gravimetric factor (Dehant et al., 1999) and HW95 tidal potential (Hartmann and Wenzel, 1995) for the Solid Earth tides, and FES2014b (Carrère et al., 2016) for the ocean tidal loading.

This hybrid methodology allows us to remove most of the short-period tides, and to keep all other long-period variations, including, for example, the seasonal hydrological contributions (Boy and Hinderer, 2006).

Atmospheric loading is computed according to Boy et al. (2002), using MERRA2 (Gelaro et al., 2017) hourly surface pressure, and assuming an inverted barometer ocean response to pressure. MERRA2 pressure is replaced by the 1-minute local pressure record for angular distance less than  $0.10^\circ$  to the station.

The polar motion and length-of-day induced gravity variations are modelled using the IERS EOPC04 daily series (<http://hpiers.obspm.fr/iers/eop/eopc04/>) (Wahr, 1985), and assuming a  $\delta_2$  factor of 1.16. We also model ocean pole tide as a self-consistent equilibrium response (Agnew and Farrell, 1978; Chen et al., 2008).

Depending on the sensor, the instrumental drift is generally modelled as a polynomial or an exponential function (Van Camp and Francis, 2007). When available, we use time series from absolute gravimeters for the adjustment.

#### References:

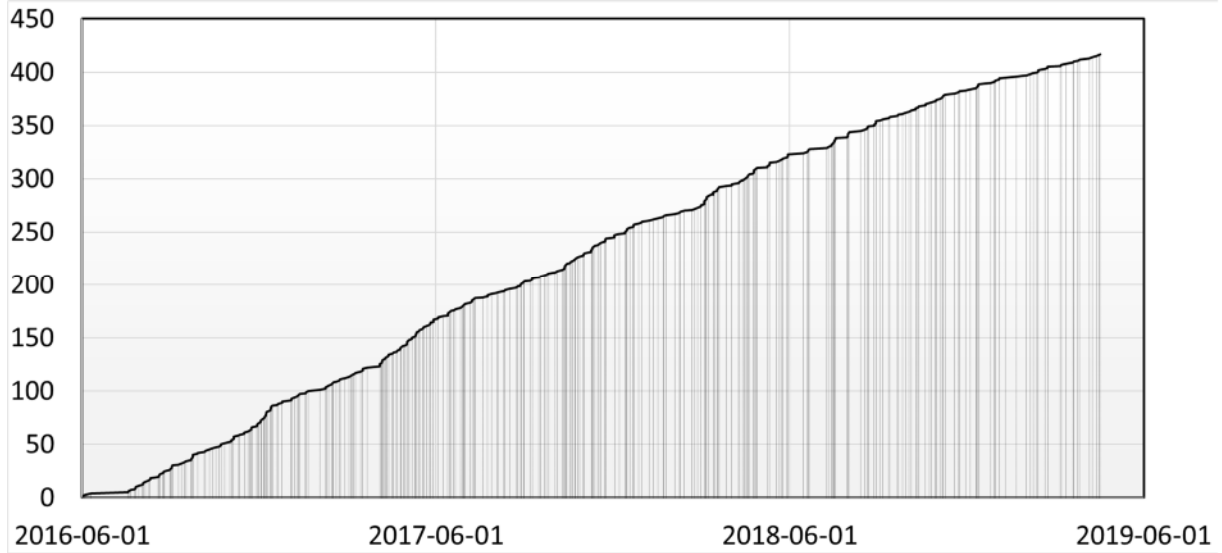
- Agnew, D. C., and W. E. Farrell, 1978. Self-consistent equilibrium ocean tides, *Geophys. J. R. astr. Soc.*, 55, 171-181.
- Boy, J.-P., P. Gegout and J. Hinderer, 2002. Reduction of surface gravity data from global atmospheric pressure loading, *Geophys. J. Int.*, 149, 534-545.
- Boy, J.-P., and J. Hinderer, 2006. Study of the seasonal gravity signal in superconducting gravimeter data, *J. Geodyn.*, 41, 227-233.

- Carrère, L., F. Lyard, M. Cancet, A. Guillot and N. Picot, 2016. FES 2014, a new tidal model - Validation results and perspectives for improvements, ESA Living Planet Conference, Prague, Czech Republic, 9-13 May 2016.
- Chen, X., B. Ducarme, H.-P. Sun and J. Xu, 2008. Loading effect of a self-consistent equilibrium ocean pole tide on the gravimetric parameters of the gravity pole tides at superconducting gravimeter stations, *J. Geodyn.*, 45 (4-5), 201-207, doi: 10.1016/j.jog.2007.11.003.
- Crossley, D. J., J. Hinderer, O. Jensen and H. Xu, H., 1993. A slewrate detection criterion applied to SG data processing, *Bull. d'Inf. Marées Terr.*, 117, 8675-8704.
- Dehant, V., P. Defraigne and J. Wahr, 1999. Tides for a convective Earth, *J. Geophys. Res.*, 104 (B1), 1035-1058, doi: 10.1029/1998JB900051.
- Gelaro, R., et al., 2017. The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2). *J. Climate*, 30, 5419–5454, doi: 10.1175/JCLI-D-16-0758.1
- Hartmann, T., and H. G Wenzel, 1995. The HW95 tidal potential catalogue, *Geophysical Research Letters*, 22 (24), 3553-3556, doi: 10.1029/95GL03324.
- Van Camp, M. and O. Francis, 2007. Is the instrumental drift of superconducting gravimeters a linear or exponential function of time?, *J. Geod.*, 81 (5), 337-344, doi: 10.1007/s00190-006-0110-4.
- Wahr, J. M., 1985. Deformation induced by polar motion, *J. Geophys. Res.*, 90 (B11), 9363-9368, doi: 10.1029/JB090iB11p09363.

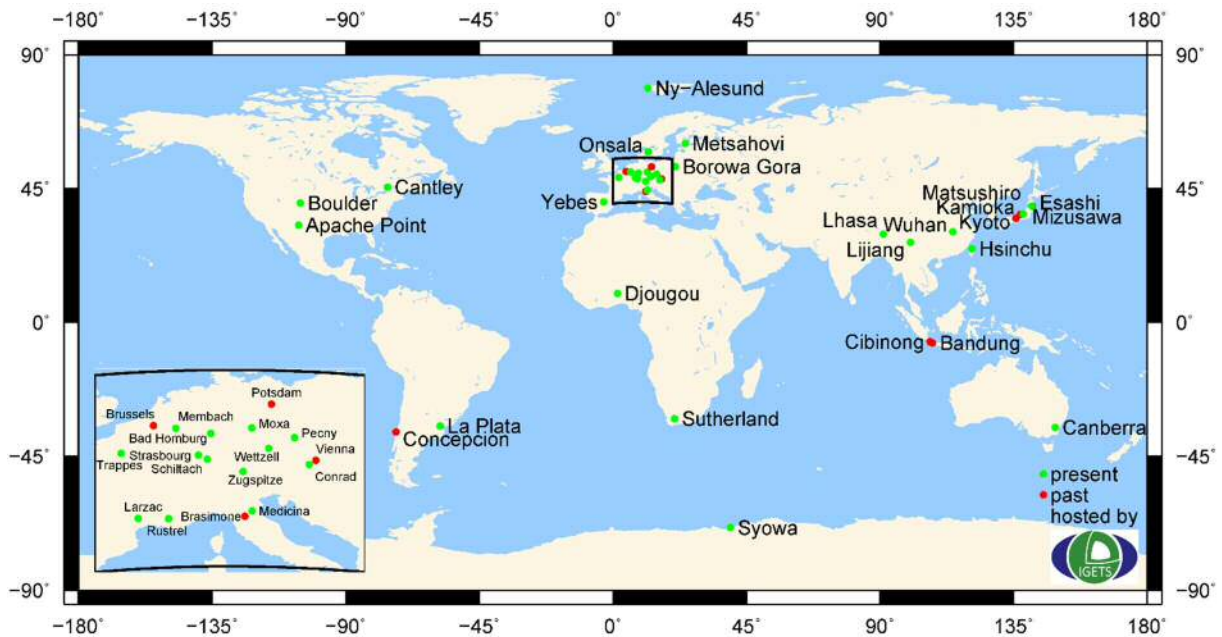
### **Status of the Data Center**

The IGETS data sets are stored on a FTP server and are freely available after user registration. The number of IGETS users has been rapidly increasing since the launch in summer 2016 (see Fig. 1) and reached the number of 400 in Feb 2019. The data base server is hosted by GFZ Potsdam (Germany) and is accessible via <http://igets.gfz-potsdam.de>.

Currently Level 1 data from 42 stations and 60 sensors are available, globally distributed (see Fig. 2), provided by 28 producers covering a time span of up to 30 years (see Fig. 3). Records from superconducting gravimeters made by GWR of compact (CT) and observatory (OSG) type are predominant. However, data from four transportable GWR iGrav superconducting gravimeters and one LaCoste & Romberg spring gravimeter were added. The Level 2 data are processed on a regular basis by the University of French Polynesia (see Table 2). These cover all stations and sensors with Level 1 data with the exception of the very recently added sensors. Level 3 data are provided by EOST since Mar 2019 for 27 stations and 37 sensors (see Fig. 4). All relevant information on the IGETS data base were compiled in the scientific technical report Voigt et.al. (2016), comprising station and sensor information, available data sets, directory structure, file name convention, repair codes and file formats. Data descriptions originating in large part from the Global Geodynamics Project (GGP) were updated and extended for IGETS.



**Fig. 1** Number of IGETS data base users since the launch in summer 2016 (status from 18 Apr 2019)



**Fig. 2** Present and past stations included in the IGETS data base



Station	Sensor	1989	90	91	92	93	94	95	96	97	98	99	2000	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18							
Apache Point	ap046																																					
Bad Homburg	bh030-1																																					
Bad Homburg	bh030-2																																					
Bad Homburg	bh044																																					
Bandung	ba009																																					
Borowa Gora	bg027																																					
Borowa Gora	bg1036																																					
Boulder	bo024																																					
Brasimone	br015																																					
Brussels	be003																																					
Canberra	cb031																																					
Cantlev	ca012																																					
Cibinong	ci022																																					
Concepcion	tc038																																					
Conrad	co025																																					
Djougou	dj060																																					
Esashi	es007																																					
Hsinchu	hs048																																					
Kamioka	ka016																																					
Kvoto	kv009																																					
Larzac	la002																																					
La Plata	lp038																																					
Lhasa	lh057																																					
Lijiang	li066																																					
Matsushiro	ma011																																					
Medicina	mc023																																					
Membach	mb021																																					
Metsahovi	me013																																					
Metsahovi	me020																																					
Metsahovi	me022																																					
Metsahovi	me073-1																																					
Metsahovi	me073-2																																					
Mizusawa	mi007																																					
Moxa	mo034-1																																					
Moxa	mo034-2																																					
Nv-Alesund	nv039																																					
Onsala	os054																																					
Pecny	pe050																																					
Potsdam	po018																																					
Rustrel	ru024																																					
Schiltach	bf056-1																																					
Schiltach	bf056-2																																					
Strasbourg	st023																																					
Strasbourg	st026																																					
Sutherland	su037-1																																					
Sutherland	su037-2																																					
Sutherland	su052																																					
Syowa	sy016																																					
Trappes	tr005																																					
Vienna	vi025																																					
Wetzell	we006																																					
Wetzell	we029-1																																					
Wetzell	we029-2																																					
Wetzell	we030-1																																					
Wetzell	we030-2																																					
Wetzell	we103																																					
Wuhan	wu004																																					
Wuhan	wu065																																					
Yebes	ys064																																					
Zugspitze	zu052																																					

Fig. 4 Temporal coverage of the Level 3 data provided by EOST to the IGETS data base (status of 18 April 2019)



**References:**

Voigt, C., Förste, C., Wziontek, H., Crossley, D., Meurers, B., Pálinkáš, V., Hinderer, J., Boy, J.-P., Barriot, J.-P., Sun, H. (2016): Report on the Data Base of the International Geodynamics and Earth Tide Service (IGETS), (Scientific Technical Report STR - Data ; 16/08), Potsdam: GFZ German Research Centre for Geosciences

**Data Publication and Citation – DOI**

IGETS established the provision of digital object identifiers (DOI) for the data sets of every station. DOIs are unique and persistent identifiers used to reference and link the individual data sets. The advantages are a clear reference to data sets, to link scientific results with associated publications, an improvement of the access to scientific data and an enhancement of the visibility of research data, encouraging new research to be conducted, and foster scientific cooperation.

For Level 1 data, the DOI is assigned for each station, i.e. one for all sensors of a station referencing the station operators. The DOIs of the Level 1 data sets resolve to DOI landing pages with an overview of the station and the data. For data of Level 2 and Level 3, the DOI are assigned for all IGETS stations in total. For level 2 data contributed by station operators, a DOI can be assigned individually for each station.

**Meetings**

A first meeting was held in Trieste during the 18<sup>th</sup> International Symposium on Geodynamics and Earth Tides. An introduction to the database updates was given by C. Voigt and aspects of the documentation of instrumental parameters by the calibration file were discussed. At the symposium, the progress during the first year was presented by J.-P. Boy and a status update of the Analysis Centre Tahiti (former ICET) was given by J.-P. Barriot.

A second meeting was held in April 2017 during the EGU General Assembly in Vienna with station reports, a report about the IGETS database and a discussion about the current status of the different product levels. The IGETS database was presented with a poster.

A third meeting was held in August 2017 at the IAG-IASPEI Joint Scientific Assembly in Kobe, Japan. The status report for Japan given by Y. Tamura was of special interest. Further details on Level 2 and 3 data processing were discussed.

The last meeting was held in April 2019 during the EGU General Assembly in Vienna with station reports, a report about the IGETS database and a presentation of Level 3 products, including a discussion about the current status of the different product levels, analysis software and data formats.

Meeting reports are provided at the IGETS homepage <http://igets.u-strasbg.fr/stations.php>

A first IGETS Workshop with 35 participants from 12 countries was organized in Potsdam (Germany) from the 16<sup>th</sup> to the 18<sup>th</sup> of June 2018, covering various topics: Station reports, data products and scientific applications. The program and the presentations can be found on <http://igets.u-strasbg.fr/workshop.php>.

**References:**

- Barriot, J.-P., Ducarme, B. Verschelle, Y (2016): IGETS Analysis Centre Tahiti (ICET): Status of GGP data processing, Poster presentation, 18th International Symposium on Geodynamics and Earth Tides, Trieste.
- Boy, J.-P., Barriot, J.-P., Crossley, D., Foerste, C., Hinderer, J., Meurers, B., Palinkas, V., Pagiatakis, S., Sun H.-P., Wziontek, H. (2016): Report of the first year of the International Geodynamics and Earth Tide Service (IGETS), Presentation, 18th International Symposium on Geodynamics and Earth Tides, Trieste.
- Voigt, C., Förste, C., Wziontek, H., Crossley, D., Meurers, B., Pálinská, V., Hinderer, J., Boy, J.-P., Barriot, J.-P., Sun, H. (2017): The Data Base of the International Geodynamics and Earth Tide Service (IGETS), Geophysical Research Abstracts, Vol. 19, EGU2017-4947, EGU General Assembly 2017.

**Publications**

A list of publications related to IGETS can be found at: <http://igets.u-strasbg.fr/biblio.php>