National Report of France to the XVth GLOSS Group of Experts Meeting, held in Columbia University, New-York, USA, 9-10 July 2017

prepared by

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1 Background and new context

In 2017, 15 French tide gauges are contributing to the GLOSS core network (Table 1), while 4 others in the Pacific area are in the process of being included: Leava (Futuna Island), Rangiroa, Makemo and Tubuaï (French Polynesia). This contribution relies mainly on the willingness of France to maintain instruments on its overseas Departments and collectivities that provide reliable and valuable data on sea level around the globe.

Since 2010, the French hydrographic service (Shom) has been designated as the official national coordinator for French in situ sea level observations (SGMer 2010; Pouvreau 2012a) and has developed a webportal (data.shom.fr) to access French high frequency sea level data. In parallel, the SONEL data center (www.sonel.org) has been acknowledged as "Service d'observation" by the INSU (CNRS) in 2011, and "Infrastructure de recherche" in 2016 by AllEnvi (www.allenvi.fr), highlighting its utility for research on environmental issues.

An outcome from the Xth GLOSS Group of Experts meeting and scientific workshop in 2009 was that the GLOSS program should designate a dedicated "GNSS at tide gauge" data assembly center. The proposal of the SONEL data center was retained and finally adopted at the XIth GLOSS Group of Experts meeting in 2011. The GLOSS Implementation Plan released in 2012 recognizes the SONEL data center as an associated infrastructure, along with the other dedicated data centers of the program such as the UHSLC or the PSMSL. The GNSS component of SONEL is hosted at the University of La Rochelle.

2 Overview of French Stations committed to GLOSS

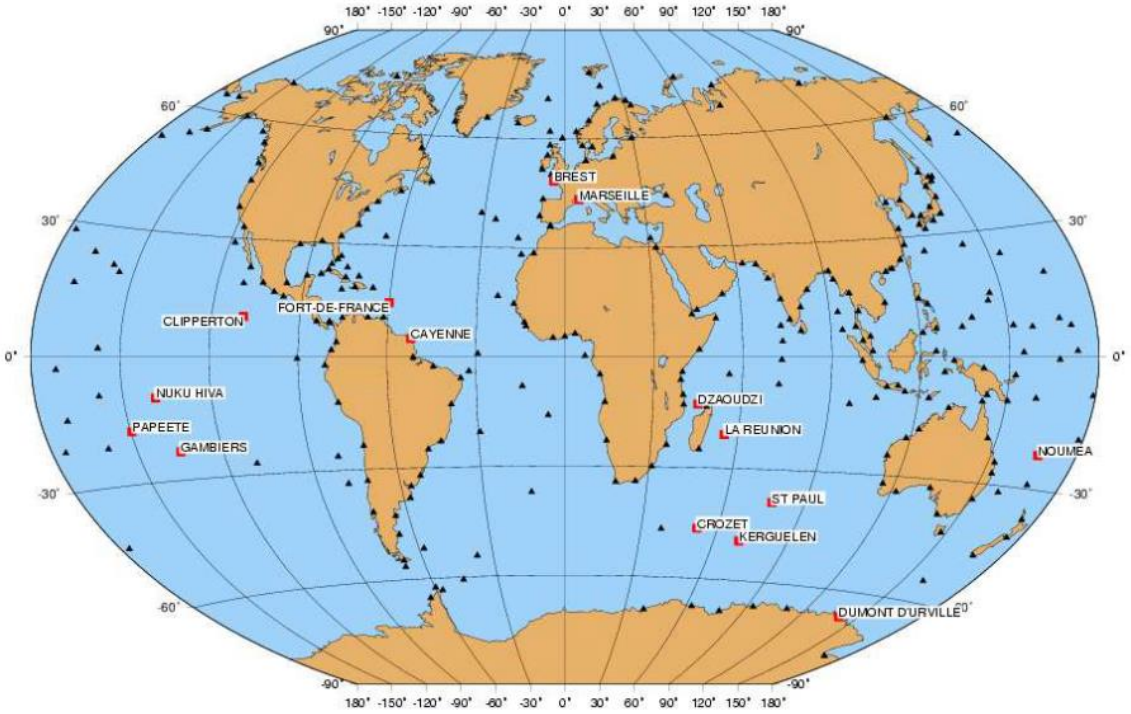


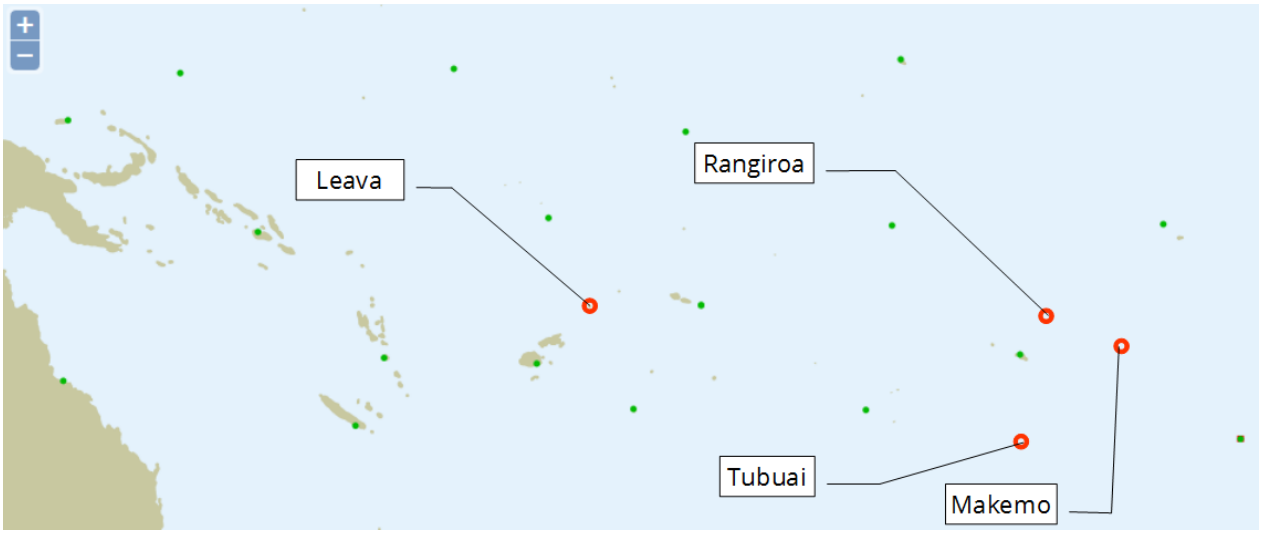
Figure 1: Geographical distribution of the French stations committed to GLOSS (black dots represents the other GLOSS stations of the core network)

Figure 1 highlights the geographical distribution of these stations around the world. We also report on an additional GLOSS station which is operated in collaboration with French organisms (Sao Tomé). The stations are namely:

GLOSS Id.	Station Name	Operator	Network
017	Pointe des Galets (Réunion Is.)	Shom / DMS-OC / MF	RONIM
021	Crozet	LEGOS/INSU	ROSAME (disabled)
023	Kerguelen	LEGOS/INSU	ROSAME
024	Amsterdam St Paul	LEGOS/INSU	ROSAME
096	Dzaoudzi	Shom/DMSOI/CG976/MF	RONIM
123	Nouméa	Shom / GNC / IRD	RONIM
131	Dumont d'Urville	LEGOS/INSU	ROSAME
138	Rikitea	UHSLC	
140	Papeete Fare Ute (Tahiti)	UHSLC	
142	Nuku Hiva (Marquesas Is.)	UHSLC	
165	Clipperton	Shom	Not permanent
202	Ile Royale (Fr. Guyana)	Shom / DM-Guyane	RONIM
204	Fort-de-France	Shom / MF / MN	RONIM
205	Marseille	Shom / IGN	RONIM
242	Brest	Shom	RONIM
260	Sao Tomé	LEGOS / IRD	Not permanent (disabled)

Table 1: GLOSS stations under French responsibility

During the XIIIth and XIVth GLOSS Group of Experts meetings, four new permanent tide gauges in the Pacific were suggested as new GLOSS stations (see sections 3.4 and 3.5): Leava (Futuna Island), Rangiroa, Makemo and Tubuaï (French Polynesia).



Map showing proposed French GLOSS stations in the Pacific (existing GLOSS stations are in green).

3 Status of French sea level stations committed to GLOSS

3.1 Atlantic Ocean & Mediterranean Sea

GLOSS 205: MARSEILLE

- Operated by IGN and Shom (RONIM TG Network).
- Contributing to the North-East Atlantic and Mediterranean Tsunami Warning System (IOC- ICG/NEAMTWS)
- **Sensor**: Although the original floating gauge is still operating in Marseille since February 1885, an acoustic tide gauge was installed in June 1998. It was replaced in April 2009 with a new tide gauge using a Khrone radar sensor.
Yearly, IGN in cooperation with Shom and LIENSs is performing controls and maintenance operations of the geodetic and sea-level infrastructure (Coulomb 2016). The results show a locally stable site at the millimetre level. Van de Casteele tests are regularly carried out. Absolute gravimetric observations have been carried out on some reference points and relative gravimetric observations close to the GNSS permanent station.
- **Data transmission**: Real-time data are available for this gauge through both the IOC and the Shom websites thanks to an Internet connection (http://data.shom.fr/#donnees/refmar/524).
- **GNSS**: The permanent GPS station is operational since July 1998 and is committed to the IGS/TIGA service (GPS Tide gauge benchmark monitoring).
- **Data**: Historical hourly data from IGN and dating back to 1885 are published as supplemental material in Wöppelmann et al. (2014). They will be available at the webportal data.shom.fr after quality controls are finalized.
- **Public communication:** Since 2013, the tidal observatory in Marseille is open to the public every year on the occasion of the European Heritage Days.

GLOSS 242: BREST

- Operated by Shom (RONIM TG Network)
- Contributing to the North-East Atlantic and Mediterranean Tsunami Warning System (IOC – ICG/NEAMTWS)
- **Sensor**: In April 2013, the radar sensor Krohne BM100 was replaced by a new KHRONE OPTIFLEX 1300C guided wave radar sensor.

- **Data transmission**: Real-time data are available for this gauge through both the IOC and the Shom websites thanks to an Internet connection (http://data.shom.fr/#donnees/refmar/3).
- **GNSS**: A GPS station is operating continuously since October 1998 and is committed to the IGS TIGA service. The distance between the GPS and the tide gauge is about 350 meters. Six levelling operations were carried out between 1999, 2004, 2006, 2009, 2010 and 2013 so that the station is tightly linked to the GPS permanent station. The levelling results show that the whole site is stable at the millimeter level. This ensures that the GPS is actually monitoring the vertical motion that affects the tide gauge.
- **Data**: Hourly data and associated mean sea levels from 1846 are available at the main GLOSS repositories UHSLC and PSMSL. Mean sea levels from 1711 have been calculated from daylight high water observations (Woodworth et al., 2010).
- **Public communication:** For the first time in 2016, the tidal observatory was opened to the public on the occasion of the International Maritime Festivals Brest 2016 (13-18 July). During 6 days, more than 10,000 visitors discovered how the sea level was measured and for what purposes.

GLOSS 204: FORT-DE-FRANCE, MARTINIQUE

- **Operated by Shom, Météo France, marine nationale (RONIM TG Network)**
- **Contributing to the Caribbean Tsunami Warning System (IOC – ICG/CARIBE-EWS)**
- **Sensor**: A radar tide gauge was installed by Shom in October 2005. In December 2011, the existing radar sensor Khrone BM70A has been replaced by a new Khrone Optiwave radar sensor. Levelling operations carried out in 2006, 2010, 2011 and 2015 show a good stability of the local benchmarks.
- **Data transmission**: In December 2011, Shom has installed a Meteosat satellite transmitter for GTS and an Internet connexion in collaboration with Météo France in order to meet the needs of the Caribbean tsunami warning system. Real-time data will be available through both the IOC and the SHOM websites (http://data.shom.fr/#donnees/refmar/126).
- **GNSS**: In December 2011, under SONEL program, the University of La Rochelle (LIENSs) and SHOM have installed a permanent GPS station on the same site as the tide gauge. Thanks to this installation, Fort-de-France station is committed to the IGS/TIGA service.

GLOSS 202: CAYENNE-ILE ROYALE-ILES DU SALUT, GUYANE FRANCAISE

- **Operated by Shom and DM Guyane (RONIM TG Network)**
- **Contributing to the Caribbean Tsunami Warning System (IOC – ICG/CARIBE-EWS)**

There is no permanent tide gauge in Cayenne anymore, ***it has been suggested replacing it with the nearby "Îles du Salut" tide gauge, which is operating since 2006, and subsequently becoming the GLOSS station Nr. 202 in replacement of Cayenne***. The oldest data measured at this island date back to 1896, which makes this station more interesting for GLOSS scientific objectives than Cayenne.
- **Sensor**: Last levelling operations were carried out in 2002 and 2013 and show a good stability of the benchmarks. In April 2017, the existing Khrone OPTIFLEX radar sensor was replaced by a new one.
- **Data transmission**: In December 2012, Shom has installed a Meteosat satellite transmitter for GTS and an Internet connection in collaboration with DM Guyane. Thanks to these installations, real-time data is now available through both the IOC and the Shom websites (http://data.shom.fr/#donnees/refmar/749).
- **GNSS**: In December 2012, under SONEL and REGINA programs, IGN and Shom have installed a permanent GNSS station on the same site as the tide gauge. The antenna has been moved to its final position in October 2013 by IGN. A precise levelling survey between the tide gauge local markers and the local levelling network was performed. Some local geodetic points have also been tied by GPS observations. Thanks to this installation, Île Royale station can be submitted to the IGS/TIGA service (GPS Tide gauge benchmark monitoring).

GLOSS 260: SAO TOME

- **Operated by LEGOS, IRD and MARAPA (PIRATA Network)**
- **/!\ due to financial issue this site has been (temporarily) uninstalled on 21 November 2016.**
- **Sensor:** Sao Tomé was installed in 1989 by IRD and is part of the global observing network in the Tropical Atlantic and part of the PIRATA network since 1997. The tide gauge maintenance is performed under the technical responsibility of IRD with the help on-site of the non-governmental organization "MARAPA". The station is not operational since August 2010 and has been replaced in October 2013.
- **Data transmission**: Since its uninstallation the data were transmitted in real-time via the Argos system and processed by the LEGOS and were available on the Hawaii Sea Level center, on the IOC website and on the ROSAME ftp site.
- **GNSS**: Episodic GNSS campaigns and associated levelling were carried out regularly.

3.2 Indian Ocean & Antartica

GLOSS 017: POINTE DES GALETS, LA REUNION

- **Operated by Shom, DEAL La Réunion, Météo France (RONIM TG Network)**
- **Contributing to the Indian Ocean Tsunami Warning System (IOC – ICG/IOTWS)**
- **Sensor:** A Khrone OPTIFLEX radar tide gauge was installed in October 2007 by SHOM. Levelling operations carried out in 2007, 2010 and 2016 show a good local stability of the benchmarks.
- **Data transmission**: The real-time data are available on both the IOC and Shom websites thanks to an Internet connection and a Meteosat satellite transmitter (http://data.shom.fr/#donnees/refmar/110).
- **GNSS**: Under SONEL program, a GNSS antenna may be installed in the near future depending on the resolution of onsite technical difficulties and masks.

GLOSS 096: DZAOUDZI, MAYOTTE

- **Operated by Shom, CG976, DMSOI, Météo-France (RONIM TG Network)**
- **Contributing to the Indian Ocean Tsunami Warning System (IOC – ICG/IOTWS)**
- **Sensor:** A radar tide gauge was installed in November 2008 by SHOM. Levelling operations carried out in 2006, 2008, 2010 and 2014 show a good stability of the benchmarks.
- **Data transmission**: The data are transmitted in real-time both through an Internet connection and a Meteosat satellite transmitter. They are available on both the IOC and Shom websites (http://data.shom.fr/#donnees/refmar/30).
- **GNSS:** Under SONEL and REGINA programs, in cooperation with the local authorities (the DREAL and the General Council of Mayotte), a GNSS permanent station was installed in November 2013 and was tied with precise leveling to all the local markers and leveling network benchmarks.

GLOSS 015: NOSY-BE, MADAGASCAR

-**Non permanent station**. Shom and IH.SM have historical analogic observations in Nosy-Bé between 1958 and 2000 which were digitized in cooperation with IH.SM.
-In 2014, French Oceanographic ship Beautemps-Beaupré moored a Shom pressure gauge in Hellville harbor between June 21st and October 5th. Dipping, GPS and levelling measurements were carried out. After post-processing work by Shom, the dataset was made available to UHSLC in March 2015.

GLOSS 021, 023, 024, 131, 260

The four stations of the South Indian Ocean are part of the ROSAME network operated by LEGOS, INSU Technical Division and IGN.
- **Sensor:** They are basically equipped with pressure and radar sensors.
- **Data transmission**: All the stations transmit their data in real time through ARGOS. The raw data are processed at LEGOS and then, after validation, are collected by National and International Institutions and Data Centers (REFMAR, GLOSS...).

GLOSS-023: KERGUELEN

- Operated by LEGOS (ROSAME TG Network)
- Contributing to the Indian Ocean Tsunami Warning System (IOC – ICG/IOTWS)
- Sensor:
The station is operational since April 1993, with only a short gap of a few days in January 2000. Monthly tide gauge calibrations were performed until 2003 in order to monitor the sensor drift (Martin Miguez et al., 2012). A new station was installed in 2006 in the frame of the Indian Ocean Tsunami Warning System (IOTWS). This new station is equipped with radar and pressure gauges. Due to the replacement of the wharf in 2015 the tide gauge station has been removed and replaced later by a set of two operational stations KER2 (starting from 9 January 2016) and a new station KER3 (radar-only sensor starting from 27 March 2016).
- **Data transmission**: Real time 1-minute data are available on IOC website through GTS message. KER3 high frequency data 1-minute is sent via internet to LEGOS
- **GNSS**: The TGBMs were connected in December 2003 using precise levelling and differential GNSS to the IGS permanent station (KERG). This IGS station is located at a distance of about 3 km. It is operational since November 1994, close to a DORIS station, which is operational since January 1998. In December 2009, a new GNSS station (KETG) has been installed close to the tide gauge. In April 2014, this station was upgraded with a new receiver and a real time connection and receive the GALILEO constellation. In April 2012, during a GNSS station installation (KRGG) close to the DORIS and existing IGS station, some local tide gauge markers have been tied by GNSS to the permanent GNSS stations. GNSS buoy sessions are made few times a year in order to tie the instrumental references of all sensors. Thanks to these installations, the data from the GNSS stations (KERG, KRGG) are submitted to the IGS/TIGA data center (SONEL) and KRGG is also included in the REGINA network

GLOSS-021: CROZET

- Operated by LEGOS (ROSAME TG Network)
- /!\ due to financial/technical and logistical issues the tide gauge has been (temporarily ?) uninstalled on 21 November 2015. The GNSS station is still fully operational

- **Sensor**: The station was installed in December 1994. Then, it was destroyed at the end of July 2001. A new infrastructure was built in December 2003. It was destroyed again in February 2007. A new installation was installed in late 2009 and was operational until April 2013 when a station breakdown stopped data acquisition. The station has been reinstalled in April 2014 but it experiences software problem since then. In September 2015 the station has been destroyed by a storm. This site is particularly difficult to maintain and a solution of relocation of the station is envisaged.
- **GNSS**: A GNSS permanent station was installed in April 2014 close to the DORIS station at a distance of about 1 km from the tide gauge. This station is also included in REGINA network and receive the GALILEO constellation. Since 2016 the receiver has been upgraded to receive the BEIDOU constellation.

GLOSS-024: SAINT-PAUL

- Operated by LEGOS (ROSAME TG Network)

- **Sensor:** The station is operational since October 1994, with a gap from April to June 1999. The station was rebuilt in 2007 and operated with radar and pressure gauges since November 2008. This station faced strong software and hardware difficulties in 2009 and later on. This station is partially active and still faces energy and software problem, a mission is scheduled in April 2018 to fix them..
- **GNSS**: In December 2011, a permanent GNSS station was installed but faced power supply issues. A new GNSS receiver has been installed in April 2014. Data have been collected up to April 2016.

GLOSS-131 : DUMONT D'URVILLE

- Operated by LEGOS (ROSAME TG Network)
- **Sensor**: Dumont d'Urville station was installed in February 1997. It has been operational from February 1997 to August 1997, from February 1998 to May 1998, and since February 1999, with a short gap in January and February 2000. It was reinstalled in January 2006 with high data acquisition sampling (2 minutes) but the data link was broken beginning of 2007 by an iceberg. The station was reinstalled completely in January 2008. In 2010 the cable was damaged. The station was fully reinstalled in January 2012 including new sensors (Oxygen, PAR and Fluo), but a new cable problem stopped the data acquisition. The station has been reinstalled in January 2014. The argos antenna has been destroyed in August 2015 discarding the real time transmission. The aerial part of the station has been re-located in 2017. The full system is now operational.
- **GNSS**: Close to a DORIS station, the DUM1 GPS station is committed to IGS/TIGA. A second GNSS station (DUMG) has been installed close by the DORIS station in the frame of the SONEL Observing System in January 2017 and receive GALILEO constellation. DUMG is included in the REGINA network and DUM1 is part of the IGS network.

3.3 Pacific Ocean

GLOSS 165: CLIPPERTON

- **Non permanent station**. It is not easy to install and maintain a permanent real time station at Clipperton, partly for technical reasons (large shore and breaking waves) and partly because of security problems.
- January to March 2005: LEGOS moored two pressure gauges at Clipperton: one in the open sea and the other in the lagoon (Testut et al. 2008).
- November 2006 to May 2008: The French Navy moored a Shom pressure tide gauge at Clipperton.
- In August 2011, the French Navy ship Arago has moored a Shom pressure gauge (OT660). Dipping, GPS and levelling measurements were carried out. The tide gauge was only recovered in May 2013 by the French Navy. After more than one year of data acquisition the tide gauge stopped out of memory in November 2012. After post-processing work by Shom, the dataset was made available to UHSLC in March 2015.
Leveling was carried in April 2015, showing good site stability.

3.4 New Caledonian and Wallis & Futuna Islands

GLOSS 123: NOUMEA-NUMBO

- Operated by Shom (RONIM TG Network)
- Contributing to the Pacific Tsunami Warning System (IOC – ICG/PTWS)
- **Sensor**: A modern radar tide gauge was installed at Numbo by Shom in January 2005 to replace the floating and the acoustic gauges in Nouméa (Chaleix) that were getting older. The Numbo station is about 6 km away from the older one. The old and new tide gauges were operated simultaneously for 5

months and comparisons showed little difference between the two records (<4cm). Levelling operations are regularly carried out (last in 2014) and show a good local stability of the benchmarks
- **Data transmission**: The data are transmitted in real-time both through an Internet connection and GTS. They are thus available at both the IOC and Shom websites (http://data.shom.fr/#donnees/refmar/659).
- **GNSS**: Under SONEL program, in cooperation with the local authorities (DITTT), a GNSS permanent station was installed in April 2015 and was tied with precise leveling to all the local markers and leveling network benchmarks. Another GNSS station, part of REGINA network and close to the DORIS station, is installed at a distance of about 7 km from the tide gauge.

PROPOSAL: LEAVA, FUTUNA ISLAND

- Operated by DéGéOM (General Delegation of the French Overseas Territories), SPP (Permanent Secretariat for the Pacific), Shom,
- Contributing to the Pacific Tsunami Warning System (IOC – ICG/PTWS)
- **Sensor**: Since October 2011, a KELLER PR-36XW pressure gauge has been installed at Leava on Futuna Island. It transmits real time data through GTS MTSAT-1 of the Japan Meteorological Agency (JMA). First, the pressure sensor showed an important drift and, moreover, the cable was destroyed by a great storm at the end of 2011. In April 2013, the pressure sensor was replaced and a radar sensor QHR 104-1 has been installed.
- **Data transmission**: Real time data are sent to the PTWC through GTS and are available on the IOC and Shom websites (http://data.shom.fr/#donnees/refmar/501).
- **GNSS**: A permanent GPS station is installed on the roof of the gauge, providing accurate land level monitoring and provides data to the IGS/TIGA data center (SONEL). At 4 km from the tide gauge, IGN has installed, in May 2012, a REGINA GNSS station co-located with the DORIS antenna.
- **Data**: The oldest sea level data date back 1986.

Due to its isolated location (800 km from GLOSS stations of Fidji and Tonga), this station can substantially improve the data coverage of the Pacific Ocean, making it worth for GLOSS objectives. During the XIIIth GLOSS GE it was thus suggested to be included to the GLOSS core network. This suggestion was endorsed by the committee and is expected to be finalized soon.

3.5 French Polynesia

The University of Hawaii maintains the three stations of Rikitea, Papeete Fare Ute, and Nuku Hiva. Three new additional stations from UPF and Shom are proposed.

GLOSS 138: RIKITEA

- Operated by UHSLC
- Contributing to the Pacific Tsunami Warning System (IOC – ICG/PTWS)
- **Sensor**: In May 2012, the Geodetic observatory of Tahiti from the University of French Polynesia and SHOM have installed a radar (Vegapulse) and a pressure tide gauge close to the UHSLC facility. The new tide gauge will be dedicated to tsunami and storm surge warning. Indeed, it appears that UHSLC tide gauge is located near a fish-tank that could possibly disturb the measurements. In the future, the Shom/UPF station may take over the UHSLC station. Maintenance and control works were made by Shom in July 2016.
- **Data transmission**: The two stations provide real time data to PTWC and IOC website through GTS. Hourly heights are collected in delayed mode on SHOM website (http://data.shom.fr/#donnees/refmar/43).

- **GNSS**: As part of the REGINA program and in cooperation with Meteo France, a GNSS permanent station was installed in June 2011, very close to the DORIS station and using the former Japanese GSI reference point and monument (GAMB). Marker of the tide gauge run by the University of Hawaii Sea Level Center was tied by GPS observations with the DORIS and GNSS reference point by IGN in 2007 and 2009 using GNSS observations. In May 2012, a permanent GNSS antenna has been installed by SHOM on the roof of the Shom/UPF tide gauge station. The GNSS data at the GLOSS station should be submitted to the IGS/TIGA data center (SONEL).

GLOSS 140: PAPEETE FARE UTE

- Operated by UHSLC
- Contributing to the Pacific Tsunami Warning System (IOC – ICG/PTWS)
- **Sensor**: UHSLC station has been maintained by UHSLC in September 2013. Levelling operations carried out in 2006, 2007, 2008 and 2010 show a good stability of the benchmarks.
- **Data transmission**: Real time data are provided to PTWC, IOC and Shom websites through GTS (http://data.shom.fr/#donnees/refmar/383).
- **GNSS**: A CNES permanent GPS station is installed on the top of the tide gauge. It is operating since August 2003 and is providing data to the IGS/TIGA data center (SONEL). A DORIS station is also operating about 7 km from the tide gauge since July 1995, alongside with an IGS station.

3.5.1 GLOSS 142: NUKU HIVA

- Operated by UHSLC
- Contributing to Pacific Tsunami Warning System (IOC – ICG/PTWS)
- **Sensor**: The station operates a Druck pressure sensor and a Vegapuls radar sensor for measuring water level. Levelling operations carried out in 2007 and 2009 show a good stability of the benchmarks.
- **Data transmission**: Real-time data are transmitted to PTWC, IOC and Shom websites through GOES satellite transmitter (http://data.shom.fr/#donnees/refmar/795).
- **GNSS**: In June 2011, the University of French Polynesia and Shom have installed a new tide pole and a permanent GPS station that should participate to the IGS/TIGA service.

PROPOSAL: RANGIROA

-Operated by Shom and UPF
-Contributing to Pacific Tsunami Warning System (IOC – ICG/PTWS)
-Sensor: Since 2009, the station operates a Druck pressure sensor and a Vegapuls radar sensor for measuring water level. Control and levelling operations are regularly carried out by SHOM (last in June 2015).
- **Data transmission**: Real-time data are transmitted to PTWC, IOC and Shom websites through GOES satellite transmitter (http://data.shom.fr/#donnees/refmar/78).
-GNSS: When created, the station was equipped with a permanent GNSS that should participate to the IGS/TIGA service.
Its location 350 km away from Tahiti GLOSS station and on the western bound of the Tuamotu Archipelago makes it a proper candidate for GLOSS core network. The idea was endorsed during the XIIIth GLOSS GE and needs to be formally confirmed.

PROPOSAL: MAKEMO

-Operated by Shom and UPF
-Contributing to Pacific Tsunami Warning System (IOC – ICG/PTWS)

-Sensor: Since 2013, the station operates a Druck pressure sensor and a Vegapuls radar sensor for measuring water level. Control and levelling operations are regularly carried out by Shom (last in February 2016).
- Data transmission: Real-time data are transmitted to PTWC, IOC and Shom websites through GOES satellite transmitter.
-GNSS: When created, the station was equipped with a permanent GNSS that should participate to the IGS/TIGA service.
Its remote location more than 600 km away from Tahiti GLOSS station makes it an interesting candidate for GLOSS core network. The idea was endorsed during the XIIIth GLOSS GE and needs to be formally confirmed.

PROPOSAL: TUBUAI

-Operated by Shom and UPF
-Contributing to Pacific Tsunami Warning System (IOC – ICG/PTWS)
-Sensor: Since 2008, the station operates a Keller pressure sensor and a Vegapuls radar sensor for measuring water level. Control and levelling operations are regularly carried out by Shom (last in October 2016).
- Data transmission: Real-time data are transmitted to PTWC, IOC and Shom websites through GOES satellite transmitter (http://data.shom.fr/#donnees/refmar/113).
-GNSS: When created, the station was equipped with a permanent GNSS that should participate to the IGS/TIGA service.
Its remote location more than 650 km away from Tahiti GLOSS station and southernmost within French Polynesia makes it a candidate for GLOSS core network. The idea was endorsed during the XIIIth GLOSS GE and needs to be formally confirmed.

4 GLOSS requirements & the French stations

The table below provides a synthetic overview of the station status regarding the GLOSS requirement (IOC 2012).

Station	Type	Digital	Precision	Control	Meteo	Last Levelling	CGPS	Real-time
La Réunion	Radar	Yes	1cm	Semestrial	Pressure	2016	No	ADSL + GTS
Crozet	Pressure	Yes	1cm	<Annual	Pressure	2010	Yes	ARGOS (disabled)
Kerguelen	Pressure Radar	Yes	<1cm	Monthly	Pressure	Yes	Yes	ARGOS ADSL GTS
Amsterdam St Paul	Pressure Radar	Yes	<1cm	Annual	Pressure	Yes	Yes	ARGOS
Dzaoudzi	Radar	Yes	1cm	Semestrial	Pressure	2014	**Yes**	GPRS + GTS
Nouméa - Numbo	Radar	Yes	1cm	Semestrial	Pressure	2014	**Yes**	ADSL
Dumont D'Urville	Pressure	Yes	1cm	Annual	Pressure	2008	Yes	ARGOS ADSL
Rikitea	Radar Pressure Float	Yes	1cm	UHSLC		2012	Yes	GTS
Papeete	Radar Pressure	Yes	1cm	UHSLC		2010	Yes	GTS
Nuku Hiva	Radar	Yes	1cm	UHSLC		2009	Yes	GTS
Clipperton	Pressure 2005, 2006-2008, 2011-2012	Yes	5cm	Annual	model	2015	No	No
Ile Royale	Radar	Yes	1cm	Semestrial	Pressure	2013	**Yes**	GPRS + GTS

Fort-de-France	Radar	Yes	1cm	Semestrial	Pressure	2015	Yes	ADSL + GTS
Marseille	Radar Float	Yes	1cm	Semestrial	Pressure	2015	Yes	ADSL
Brest	Radar	Yes	1cm	Semestrial	Pressure	2013	Yes	ADSL
Sao Tomé	Pressure	Yes	1cm	<Annual	Pressure	2010	No	ARGOS (disabled)
Leava, Futuna Island	Radar Pressure	Yes	1cm	Annual	Pressure	2016	Yes	GTS
Rangiroa	Radar Pressure	Yes	1cm	Annual	Pressure	2015	Yes	GTS
Makemo	Radar Pressure	Yes	1cm	Annual	Pressure	2016	Yes	GTS
Tubuai	Radar Pressure	Yes	1cm	Annual	Pressure	2016	Yes	GTS

5 Sea level data distribution

5.1 Access to data

Since 2010, SHOM has been charged by a French Prime Ministerial instruction to gather and coordinate tide gauge observations in French territories (SGMer 2010). The Shom website (data.shom.fr), hosted at Shom, provides a portal that would take inventory and distribute tide gauge high frequency data from the various French producers.
Depending on the quality controls, raw data or validated data are available on the portal. Real time data is also available.

For GLOSS applications, hourly sea level data from the French stations committed to GLOSS are provided directly to the University of Hawaii Sea Level Centre (UHSLC) which acts as GLOSS data centre.

Mean sea levels and GPS data at the tide gauges are available at SONEL (www.sonel.org) which also acts as IGS/TIGA data centre and as GLOSS data assembly centre for GNSS at tide gauges. Through SONEL webportal, mean sea levels are also provided to the PSMSL (www.psmsl.org).

In parallel, SHOM, UHSLC and LEGOS real-time sea level data are available on the IOC sea level monitoring facility (www.ioc-sealevelmonitoring.org/)

5.2 REFMAR coordination of French sea level observations

Since 2010, REFMAR has begun contacting French sea level data producers to draw an inventory of all the French sea level stations that could be operated by Port Authorities, Research institutes, universities, flood warning systems, local authorities, and so on. REFMAR pays particular attention to general data access and data policy conditions. The origin of each data set is acknowledged, so that REFMAR will ensure the visibility of the producers and trace the applications of the tide gauge observations in research and commercial fields.

Through REFMAR website and meetings, Shom also aims at providing advice and recommendations to producers and will promote state-of-the-art measurement practices: For example, REFMAR has created teaching sheets to describe how to install a tide staff, what is a sea level observatory, etc. http://refmar.shom.fr/documentation/recommandations/fiches-techniques

In 2015 and 2016, REFMAR has provided support to French collectivities in the Caribbean (Saint-Martin and Saint-Barthelemy) to install new sea-level observation facilities mainly aiming at tsunami and storm warning. Thanks to REFMAR actions, these new stations will also be capable of long-term sea-level observations.

In the meantime, Shom has been ramping up its own tide gauge network RONIM. Two new stations were installed in 2015 (Dielette, Normandy) and 2016 (Ouistream, North of France). These stations are equipped with GTS transmission.

In order to meet the organizations producing observations of sea level and users of tide gauge data, the second edition of "Journées REFMAR", an international conference on the observation of the sea level, mainly aiming at French-speaking countries, was held from 2 to 4 February 2016 in UNESCO Paris. This symposium, funded in part by the French Ministry of the Environment was organized in collaboration with IOC / GLOSS.
Three themes were developed during the 3-day event:

- The sea level observations for the benefit of research
- The sea surges
- Understanding sea level changes

http://refmar.shom.fr/journees-refmar-2016

The event was widely acclaimed for the quality of presentations and the opportunities it gave for multilateral exchanges. Many African representatives expressed their interest in sea-level issues and their will to accelerate their own national capacities in this area. Actions have been undertaken in order to establish a strategy toward these countries. The next edition of "Journées REFMAR", scheduled in March 2019, will show the first results of these actions.

6 French cooperation on foreign GLOSS stations

As part of the DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) and REGINA (Réseau GNSS pour l'IGS et la navigation) programs in partnership with CNES, IGN is mainly in charge of the installation and maintenance of the geodetic infrastructures (DORIS and GNSS stations). In this framework, provided tide gauge locations are close to the geodetic stations, they are considered as co-located instruments and, as far as possible, are integrated in the local survey operations. In any case, GNSS data of REGINA stations are freely and publicly available at the IGS data centers, and when it offers an interesting co-location, provided to the SONEL GNSS at tide gauges data center.

In most of the cases, reports including the field operations, markers descriptions and the results (three dimensional as well as height differences) are available upon request.

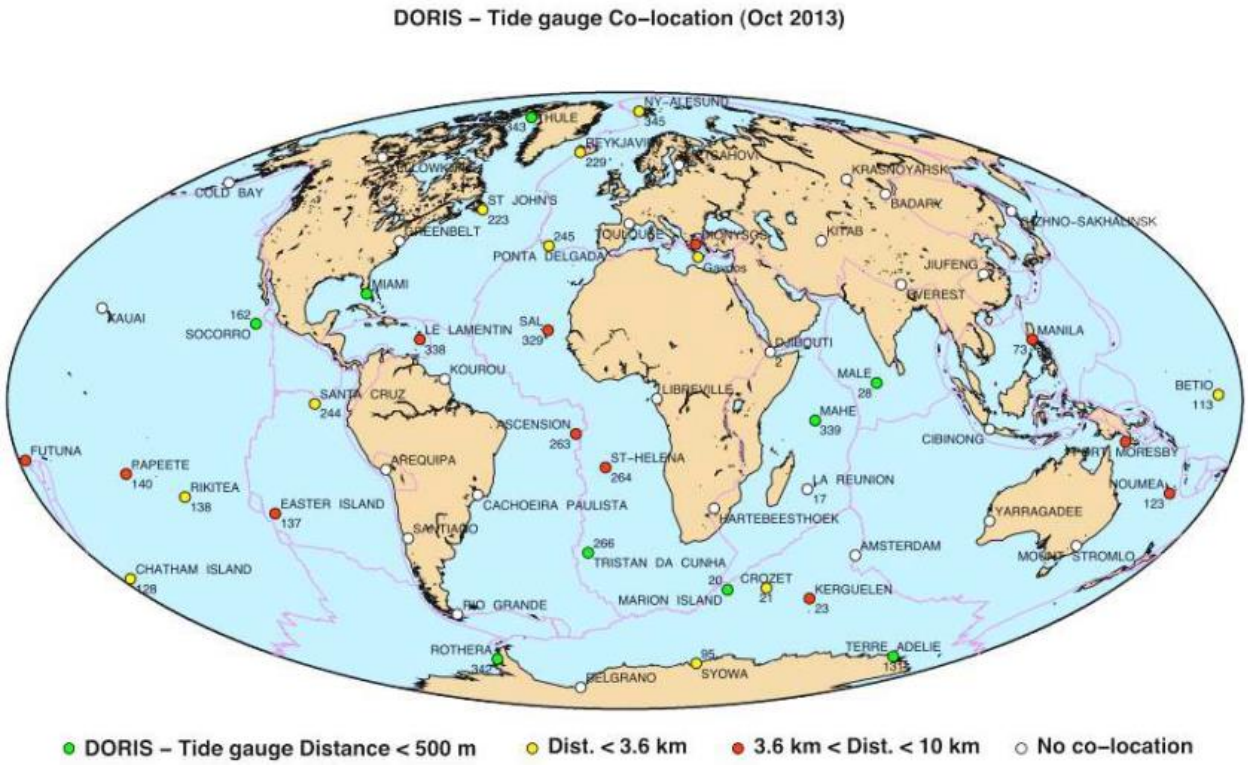


Fig. 4 Map of DORIS co-location with Tide Gauges (source : JC. Poyard, IGN)

Fig. 5 Map of REGINA stations co-location with Tide Gauges (source : T.Donal, IGN, December 2016)

GLOSS 266: Tristan Da Cunha, United Kingdom

In 1986, the first station of the DORIS network was installed on behalf of CNES at Tristan da Cunha by Bob Spencer from National Oceanography Centre (NOC).
As part of a station renovation in June 2012, the GNSS station belonging to NOC in the immediate vicinity of the DORIS station was included in the tie operation. A precise leveling survey was carried out between all the markers, including the tide gauge reference benchmark.

GLOSS 253: Dakar, Senegal

In the frame of a local project, IGN performed in the first half of October 2011 a precise levelling between the markers close to the tide gauge, the local levelling network and the new IGS DAKR station. A new point, very close to the tide gauge has also been included in the survey and tied using GPS observations to the IGS station. During this work, the technical possibility for a future GNSS permanent station at very close proximity of the tide gauge was also explored (Poyard J-C. 2011). With the support of DTGC (Direction des Travaux géographiques et cartographiques), an installation is planned at the end of the year 2017.

GLOSS 339: Pointe la Rue, Seychelles

As part of the REGINA program and in cooperation with the Seychelles national meteorological services, a GNSS permanent station was installed in June 2012, about 300m from the tide gauge and close to the DORIS station. Markers around the tide gauge were visited and tied using GPS. For logistics reasons, no precise leveling was performed.

GLOSS 002: Djibouti.

At the end of the year 2013, during a joint REGINA station installation in cooperation with the CERD, conditions in terms of long term maintenance, GNSS observations and data communications, was explored for a GNSS station installation at the immediate vicinity of the tide gauge.

GLOSS 342: Rothera, Antarctica.

The DORIS station was renovated in February 2011. Markers around the tide gauge were visited and tied using precise leveling.

GLOSS 245: Ponta delgada, Portugal.

The DORIS station was renovated in September 2014. Markers around the tide gauge were visited and tied using GPS. For logistics reasons, no precise leveling was performed.

GLOSS 162: Socorro Island, Mexico.

The DORIS station was renovated in April 2014. Markers around the tide gauge were visited and tied using precise leveling.

GLOSS 393: St John's, Canada.

As part of the REGINA program and in cooperation with the Natural Resources Canada (NRCan), a GNSS permanent station was installed in July 2013, close to the DORIS station at a distance of about 3,5 km from the tide gauge. Markers around the tide gauge were visited and tied using GPS. For logistics reasons, no precise leveling has been performed.

GLOSS 128: Chatham Island, New Zealand.

As part of the REGINA program and in cooperation with the Land Information New Zealand (Linz), a GNSS permanent station was installed in November 2014, close to the DORIS station and close to a tsunami monitoring tide gauge managed by Linz, at a distance of about 17 km from the GLOSS site. Markers around the tide gauges were visited and tied using GPS for GLOSS site and precise local survey for Linz site. For logistics reasons, no precise leveling was performed.

GLOSS 263: Ascension Island, United Kingdom.

As part of the REGINA program and in cooperation with the European Space Agency (ESA), a GNSS permanent station was installed in July 2015, close to the DORIS station and at a distance of about 5,5 km from the tide gauge. Markers around the tide gauge were visited and tied using GPS. For logistics reasons, no precise leveling was performed.

GLOSS 329: Palmeira, Cap Vert.

As part of the REGINA program and in cooperation with the Instituto Nacional de Meteorologia e Geofisica (INMG), a GNSS permanent station was installed in October 2013, close to the DORIS station and at a distance of about 6,5 km from the tide gauge. Markers around the tide gauge were visited. Markers and TGCV GNSS antenna were tied by precise leveling in October 2015 .

GLOSS 137: Easter Island, Chile.

A recognition was done in February 2014 to prepare the relocation of DORIS station. GLOSS site was visited and local tie will be measured during the mission of installation (planned 2018).

GLOSS 245: Ny-Alesund, Norway.

A recognition visit was done in August 2015 to prepare the relocation of DORIS station. GLOSS site was visited and local tie will be measured during the mission of installation (planned 2018).

GLOSS 149: Apra Harbour, GUAM.

A recognition visit was done in May 2016 to prepare an installation of DORIS station. GLOSS site was visited and local tie will be measured during the mission of installation (planned 2018).

7 SONEL data center: GNSS data co-located to TG

All mean sea levels and GNSS data from the above-mentioned French stations are made available on SONEL website (www.sonel.org).

Since 2011, SONEL has been designated to act as the data assembly centre for GLOSS concerning observations from GNSS stations co-located with tide gauges. This GNSS activity is described in a dedicated report to the GLOSS Group of Experts.

8 Data rescue / Data archeology / Inventory

- In December 2011, under the auspices of the IOC/GLOSS and supported by IHO launched an update of the inventory of all historic data remaining in paper form that could be rescued.

After his first work published in his thesis published in 2008 (Pouvreau, 2008), M. Nicolas Pouvreau has consolidated his inventory of French historic sea level data in non-electronic form and has made it available on REFMAR website:
http://refmar.shom.fr/mesures-maregraphiques/french-historic-tide-gauges-data-in-non-digital-form

The webpage gives information on the period of measurement, the owner of the data, the place where it is archived, the form of the data (charts, tables,..) and even the time step of the acquisition.

Around 2 200 years of non-electronic sea level data have already been identified.

Nevertheless, this inventory is obviously not exhaustive and further searching needs to be funded and carried out.

- In July 2013, M. Thomas Gouriou et al. have published a paper on "the reconstruction of the two-century long sea-level record for the Pertuis d'Antioche (France)". (Gouriou 2013)
- Jérôme Aucan (IRD) continued its work on the reconstruction of tidal observations in Noumea (New Caledonia). Paper data from the early twentieth century were scanned by SHOM and made available to the IRD. A scientific article is being written.
- In September 2014, M. Guy Wöppelmann et al. have published a paper on the "rescue of the historical sea level record of Marseille (France) from 1885 to 1988 and its extension back to 1849–1851" (Wöppelmann 2014).
- In September 2013, M. Yann Ferret begun a 3-year study at SHOM on the recovery and the digitization of the sea level measurements performed on historical time period in Saint-Nazaire, France. Since the beginning of the project, all identified data in paper-form (tables, marigrams, mainly from SHOM and Nantes Port authorities) have been digitized. The covered period is up to 190-year-long (dating back to 1821), including 125 years of relatively continuous sea level measurements at Saint-Nazaire. An important work was done to make these data consistent over time in terms of vertical reference and time systems in order to be able to work with and to estimate sea level trend in this region (Ferret 2016).
http://refmar.shom.fr/en/applications_maregraphiques/programmes-projets/construction-analyse-series-coherentes-niveau-mer/port-de-saint-nazaire

During the last two years, the importance of this activity was acknowledged and an effort is going to be made in order to intensify data rescue operations.
Following his work on Saint-Nazaire, and thanks to a dedicated funding from Ministry of Environment, Yann Ferret has been recruited at Shom as Data Rescue Expert. He will be able to coordinate several recovery and digitization works in parallel. At least two new sites have been identified as candidates for data rescue operation: Saint-Malo and Bourcefrand-le-Chapus. Works on these data series are expected to start in 2018.
Shom is also co-tutoring with University of Dunkirk a PHD student (Alexa Latapy) who started working in 2017 on reconstruction of sea level variations in the area of Dunkirk.

Following the REFMAR 2016 wokshop, Shom is also involved in other data rescue operations currently being developed with Senegal, Cameroon and Côte d'Ivoire in the form of scientific projects or as part of a thesis.

This growing activity around data rescue is made possible thanks to funding support from SONEL:
9 640 paper document were scanned in 2016 on SONEL budget.
In 2017, it is estimated that 20 000 out of 40 000 sea-level related paper documents have been properly identified and 18 000 have been rasterized.

9 New developments

In order to improve sea-level observation capacities, Shom has developed a prototype of mobile radar tide gauge. This system is to be installed at locations where permanent systems are not required or authorized (in touristic areas for instance).

Using an autonomous, solar-powered, radar-equipped tide gauge, it is capable of several month continuous operations much like its permanent counterpart. It only lacks data transmission which would require too much electrical power.

Installation of the mobile tide gauge is a one-hour process and requires one or two technicians. The structure has adaptable feet and arms in order to insure steadiness and adaptability to many situations

(large tidal amplitude, sloppy ground, non-vertical wharf). Stability can be achieved by bolts attaching the feet to the ground, or by the use of lead blocks mounted to the feet in order to ballast the structure. The complete tide gauge weighs less than 25kg and can be easily transported in a car.

Mobile Tide Gauge being installed (credit: Shom)

Mobile Tide Gauge in Saint-Jean-de-Luz (credit: Shom)

The sensor is a Vegapuls64, chosen for its narrow beam angle (3°), reduced size and robustness. Electrical power is supplied by a pyramid mounted with 4 solar panels (8W each) and supplemented by a 12V-battery. The data logger is equivalent to those in use within Shom's RONIM Tide gauge network. The system is also supplemented with wind and atmospheric pressure sensor.

The mobile tide gauge was put under one month trial between March and April 2017. Comparison with nearby permanent tide gauge (with stilling well) has proven encouraging with less than 2cm mean difference between the two systems. Longer deployments are planned in order to validate the prototype.

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