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prepared by

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1. Background & New context

The French tide gauges contributing to the GLOSS global network sums up to 15 (Table 1). This number of stations could be regarded as modest, if it was not for its global distribution on overseas French territories (Figure 1). Numerous difficulties have been raised due to this global distribution (technical, logistical, as well as administrative), that have prevented France from fulfilling adequately all the GLOSS station requirements (IOC 2006, pp. 52).

Today, the context is more favourable. The French hydrographic service SHOM has been designated as the official national liaison for in situ sea level observations, together with the management and publication of the resulting data (SGMer 2010; Pouvreau 2010). In parallel, SONEL (www.sonel.org) has been acknowledged as "Service d'observation" by the INSU (CNRS) in 2011, and similarly by AllEnvi (www.allenvi.fr), highlighting its utility for research on environmental issues.

One of the reasons for which SONEL was founded (founding members are SHOM, IGN, LIENSs and LEGOS) was to federate the tide gauge networks that exist in France, and ensure that emerging networks were properly incorporated. Due to practical difficulties, the tide gauge portal of SONEL was implemented at the University of La Rochelle in 2003 (first on-line observations) instead of at SHOM. But thanks to the new above-mentioned context, SHOM has now taken on the tide gauge data aspect, enabling the University of La Rochelle to focus its efforts on the GNSS aspect of the SONEL system.

To this end, the SHOM set up REFMAR (refmar.shom.fr) where users can find the data (raw in real time and quality checked in delayed mode) from tide gauges on French territory (Section 4). Moreover, it guarantees that tide gauge data is managed by recognized specialists in the field, heirs to an experience which goes back to the first French tide gauge designed by the hydrographic engineer R. Chazallon in 1843.

2. Overview of French Stations committed to GLOSS

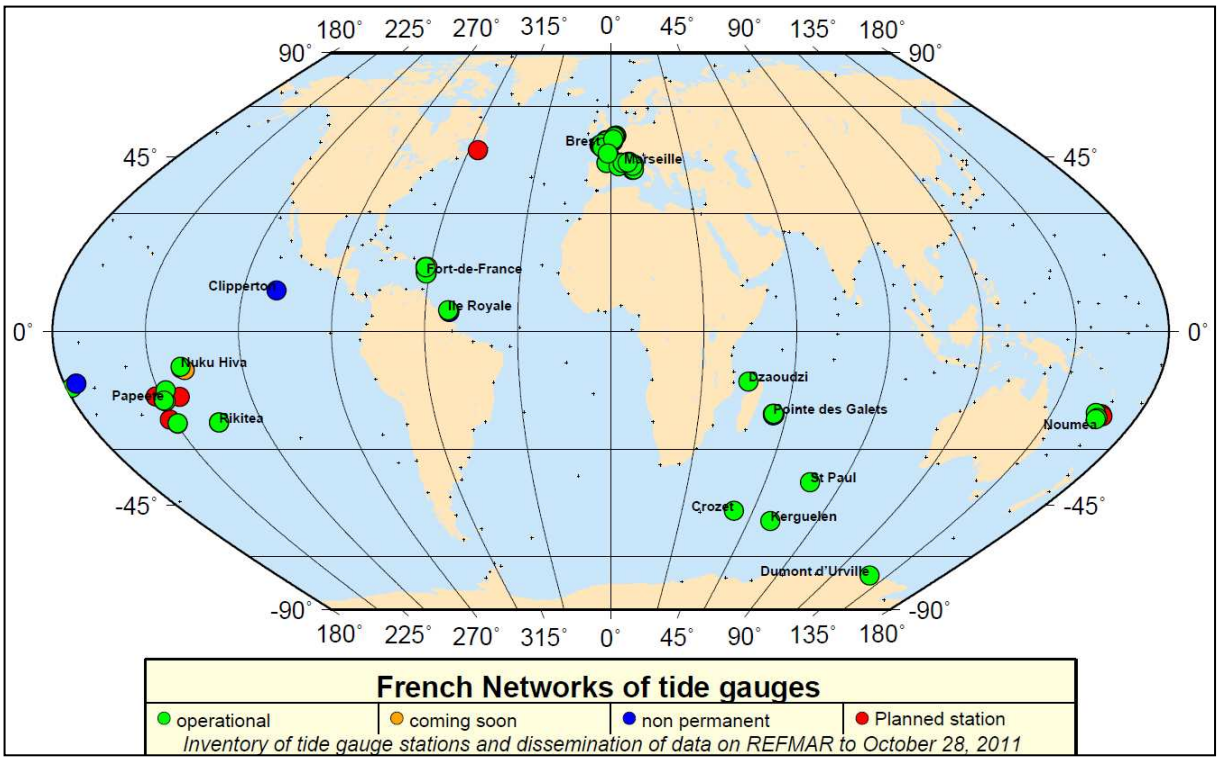

Figure 1: Geographical distribution of the French stations committed to GLOSS (black crosses represent the other GLOSS stations from the core network)

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 (La Réunion)	SHOM / DMS-OC / MF	RONIM
021	Crozet	LEGOS / INSU	ROSAME
023	Kerguelen	LEGOS / INSU	ROSAME
024	Amsterdam St Paul	LEGOS / INSU	ROSAME
096	Dzaoudzi	SHOM / DMS-OC / 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	UHSLC	
165	Clipperton	SHOM	Not permanent
202	Ile Royale (Cayenne)	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	

Table 1: GLOSS stations under French responsibility

Given its isolated location, the new permanent tide gauge installed in Leava on the Futuna Island (Pacific Ocean) is suggested as new GLOSS station (Cf. Section 2.3.1).

3. Status of French stations committed to GLOSS

3.1. Atlantic Ocean & Mediterranean Sea

GLOSS 205: MARSEILLE
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 an ELTA tide gauge using a Khrone radar sensor. TGBMs are levelled yearly by IGN (Coulomb 2011). The results show a locally stable site at the millimetre level. The permanent GPS station is operational since July 1998 and is committed to TIGA. Historical data from IGN will be available after quality controls are finalized. Marseille station will contribute to the Mediterranean Tsunami Warning System.
Transmission: Real-time data are available for this gauge through both the IOC and the REFMAR websites thanks to an Internet connexion.

GLOSS 242: BREST
Since January 2004, a radar gauge Krohne BM100 records the "official" data for Brest station. Comparison with other systems (pressure gauge, GPS buoy) is planned in 2012. The distance between the GPS and the tide gauge is about 350 metres. Six levelling operations were carried out between 1999, 2004, 2006 and 2009 so that the station is linked to the GPS permanent station. The levelling results show that the whole site is stable at the millimetre level. This ensures that the GPS is actually monitoring the vertical motion that affects the tide gauge. The GPS station is operating continuously since October 1998 and is committed to IGS TIGA pilot project.
Transmission: Real-time data are available for this gauge through both the IOC and the REFMAR websites thanks to an Internet connexion.

GLOSS 204: FORT-DE-FRANCE, MARTINIQUE
A radar tide gauge was installed by SHOM in October 2005. The station is part of the RONIM network. The tide gauge is operated in collaboration with the local authorities of Meteo-France and the French Navy. Leveling operations carried out in 2006 and 2010 show a good stability of the benchmarks.
In December 2011, the University of La Rochelle will install a permanent GPS station on the same site as the tide gauge. Meanwhile, SHOM will install a Meteosat9 satellite transmitter and an Internet connexion in collaboration with Météo France. Thanks to these installations, Fort-de-France station should be submitted to the IGS/TIGA permanent service (GPS Tide gauge benchmark monitoring) and real-time data will be available through both the IOC and the REFMAR websites. Fort-de-France station will also contribute to the Caribbean Tsunami Warning System.

GLOSS 202: CAYENNE-ILE ROYALE-ILES DU SALUT, GUYANE FRANCAISE
There is no tide gauge in Cayenne anymore, so we suggest 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 tide gauge is part of the RONIM network and is operated with the collaboration of the local authority Direction de la Mer de la Guyane (DDE). Last levelling operations were carried out in 2002 and showed a good stability of the benchmarks.
In April 2012, SHOM will install a Meteosat9 satellite transmitter and an Internet connexion in collaboration with DDE Guyane. Thanks to these installations, the "Îles du Salut" real-time data will be available through both the IOC and the REFMAR websites. "Îles du Salut" station will contribute to the Caribbean Tsunami Warning System.

GLOSS 260: **SAO TOME**
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 IRD responsibility with the help on-site of the non-governmental organization "MARAPA". Data are transmitted in real-time via the Argos system and processed by the LEGOS. The data are available on the Hawaii Sea Level center, on the IOC website and on the ROSAME ftp site. The station is not operational since August 2010 and will be replaced in 2012.

3.2. Indian Ocean & Antarctica

GLOSS 017: POINTE DES GALETS, LA REUNION
A radar tide gauge was installed in October 2007 by SHOM. The station is part of the RONIM network. The tide gauge is operated with the collaboration of the local authority DDE La Réunion. Levelling operations carried out in 2007 and 2010 show a good local stability of the benchmarks.
The real-time data are available on both the IOC and REFMAR websites thanks to an Internet connexion and a meteosat9 satellite transmitter. This station contributes to Indian Ocean Tsunami Warning System.

GLOSS 096: DZAOUDZI, MAYOTTE
A radar tide gauge was installed in November 2008 by SHOM. The station is part of the RONIM network. The tide gauge is operated with the collaboration of the local authority DE Mayotte. Levelling operations carried out in 2006, 2008 and 2010 show a good stability of the benchmarks.
The data are transmitted in real-time both through an Internet connexion and a Meteosat9 satellite transmitter. They are thus available on both the IOC and REFMAR websites. This station contributes to Indian Ocean Tsunami Warning System.

GLOSS 021, 023, 024, 131, 260
The four stations of the South Indian Ocean are part of the ROSAME network. They are basically equipped with pressure sensor. 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...).

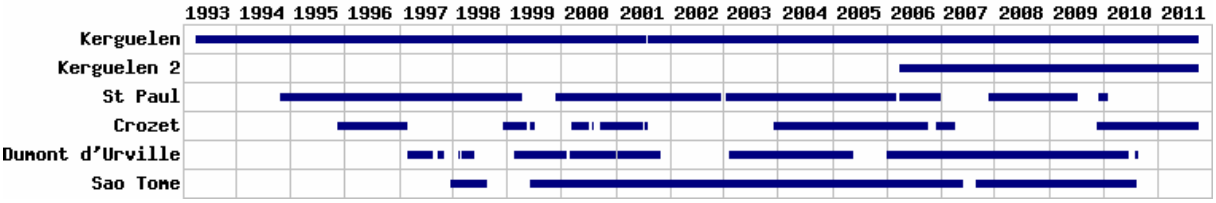

Fig. 2: Timeline of the available data for the ROSAME tide gauge network.

- **GLOSS-023**: **Kerguelen** is operational since April 1993, with only a short gap of a few days in January 2000 (Figure 2). Monthly tide gauge calibrations were performed until 2003 in order to monitor the sensor drift (Martin Miguez *et al.*, in press). 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. For this station high frequency data are available at 2 minutes sampling. The TGBMs were connected in December 2003 by precise levelling and differential GPS 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. GPS buoy sessions are made few times a year in order to tie the instrumental references of all sensors. Real time 2-minute data are available on IOC website through GTS message.

- **GLOSS-021**: **Crozet** was installed in December 1994. It was destroyed 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 is operational until then (Guillerm et al. 2009). This site is particularly difficult to maintain.

- **GLOSS-024**: **Saint-Paul** 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 will be replaced in December 2011, together with a permanent GPS station being installed. An archaeological exercise allowed estimating the sea level change at Saint-Paul for the last 135 years (Testut *et al.* 2010).

- **GLOSS-131**: Dumont d'Urville was installed in February 1997. It has been operational from February 1997 to August 1997, from February 1998 to May 1998, and from February 1999, with a short gap in January and February 2000. It was reinstalled in January 2006 with high data acquisition frequency (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 will fully be reinstalled in January 2012 including new sensors (Oxygen, PAR and Fluo).

3.3. Pacific Ocean

GLOSS 165: CLIPPERTON

LEGOS moored two pressure gauges at Clipperton from January to March 2005: one in the open sea and the other in the lagoon (Testut *et al.* 2008). The French Navy moored a SHOM pressure tide gauge at Clipperton from November 2006 to May 2008.

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 will be recovered in February 2012 by the French survey ship Atalante.

It is not easy to install and maintain a permanent real time station at Clipperton, partly for technical reason (large shore and breaking waves) and partly because of security problems.

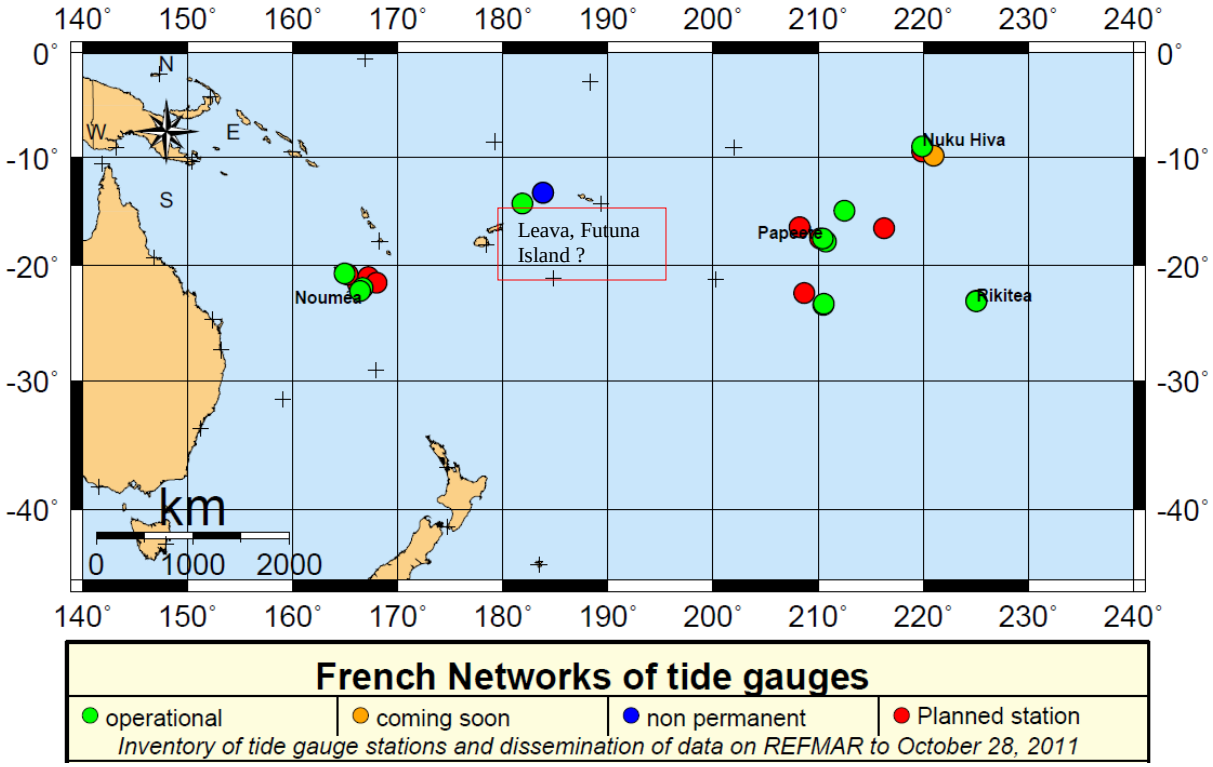

Fig. 3: Geographical distribution of the French stations in the Pacific Ocean (except Clipperton) committed to GLOSS (black crosses are other GLOSS stations)

3.3.1. New Caledonia and Wallis & Futuna Islands

GLOSS 123: NOUMEA-NUMBO

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. Unfortunately, the plan to operate both French old and new tide gauges simultaneously for at least a year was not carried out. Furthermore, the IGS station is now about 10 km distance, and it is set up on a different ground. Levelling operations carried out in 2006, 2007 and 2008 show a good local stability of the benchmarks.

PROPOSAL: LEAVA, FUTUNA ISLAND

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) and a permanent GPS station is installed on the exact same site, providing accurate sea level monitoring and intending to commit to the IGS/TIGA. Oldest data date back 1986.

Its isolated location (800km from GLOSS stations of Fidji and Tonga) makes it interesting for GLOSS objectives. We therefore suggest it included to the GLOSS core network.

3.3.2. French Polynesia

GLOSS 138: RIKITEA

The University of Hawaii maintains these three stations (Rikitea, Papeete Fare Ute, Nuku Hiva).

In 2012, the University of French Polynesia and SHOM will install a radar (Vegapulse) and a pressure tide gauge close to the UHSLC installations. 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.

GLOSS 140: PAPEETE FARE UTE

A CNES permanent GPS station is installed on the top of the tide gauge. It is operating since August 2003 and is intended to be submitted to the IGS/TIGA. A DORIS station is also operating about 7 km from the tide gauge since July 1995, alongside with an IGS station. Levelling operations carried out in 2006, 2007, 2008 and 2010 show a good stability of the benchmarks.

GLOSS 142: NUKU HIVA

Station 142 (Nuku Hiva, Marquises) operates a Druck pressure sensor and a Vegapuls radar sensor for measuring water level. Real-time data are transmitted through GOES satellite transmitter. Levelling operations carried out in 2007 and 2009 show a good stability of the benchmarks. In June 2011, the University of French Polynesia and SHOM has installed a new tide pole and a permanent GPS station that would participate to the IGS/TIGA.

4. GLOSS requirements & the French stations

The table below provides a synthetic overview of the station status regarding the GLOSS requirements (IOC 2006, pp. 52).

Station	Type	Digital	Precision	Control	Meteo	Last Levelling	CGPS	Real-time
La Réunion	Radar	Yes	1cm	Semestrial	Pressure	2010	No	ADSL + GTS
Crozet	Pressure	Yes	1cm	<Annual	Pressure	2010	No	ARGOS
Kerguelen	Pressure Radar	Yes	<1cm	Monthly	Pressure	Yes	Yes	ARGOS ADSL GTS
Amsterdam St Paul	Pressure Radar	Yes	<1cm	Annual	Pressure	Yes	No	ARGOS
Dzaoudzi	Radar	Yes	1cm	Semestrial	Pressure	2008	No	GPRS + GTS
Nouméa - Numbo	Radar	Yes	1cm	Semestrial	Pressure	2008	No	ADSL
Dumont D'Urville	Pressure	Yes	1cm	Annual	Pressure	2008	Yes	ARGOS ADSL
Rikitea	Radar Pressure Float	Yes	1cm	UHSLC		1997?	No	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?	Yes	5cm	Annual	model	2006	No	No
Ile Royale	Radar	Yes	1cm	Semestrial	Pressure	2006	No	ADSL + GTS

								in 2012
Fort-de-France	Radar	Yes	1cm	Semestrial	Pressure	2010	Yes	ADSL + GTS in 2012
Marseille	Radar Float	Yes	1cm	Semestrial	Pressure	2009	Yes	ADSL
Brest	Radar	Yes	1cm	Semestrial	Pressure	2009	Yes	ADSL
Sao Tomé	Pressure	Yes	1cm	<Annual	Pressure	2010	No	ARGOS
Leava, Futuna Island	Pressure	Yes	1cm	Annual	Pressure	2011	Yes	GTS

5. Sea level data distribution

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 REFMAR website (refmar.shom.fr), hosted at SHOM, provides a portal that would take inventory and distribute tide gauge data from the various French producers. This way, SHOM will also provide advice and recommendations and will spread state-of-the-art measurement practices.

REFMAR will pay particular attention to general data access and data policy conditions. The origin of each data set will be acknowledged, so that REFMAR will esnure the visibility of the producers and trace the applications of the tide gauge observations in research and commercial fields.

The role of coordination covers all areas under national jurisdiction, that is to say in metropolitan France and overseas. SHOM, LEGOS, IPGP, UPF, UHSLC or local port authority observations are about to be available soon through REFMAR.

Depending on the quality controls, raw data or validated data will be available on the portal. Real time data will be also available every 2 hours thanks to the web collecting system. Of course, real-time data of RONIM stations are already available on the portal. In addition to the raw data, hourly data are provided after a quality control procedure. The latency of the latter data is about 2-3 months.

It should be pointed out that a free data policy is applied for years at SHOM for scientific applications under conditions that the user has to accept before accessing the data:
- to register as user of REFMAR;
- to briefly describe the objectives of the study;
- to provide a copy of any result, either partial or final;
- to acknowledge REFMAR and its relevant contributors as source of data;
- to inform REFMAR contacts about any data problem;
- to agree not to transfer REFMAR data to third parties.

Hourly sea level data from the French stations committed to GLOSS are provided 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. Mean sea levels are also provided to the PSMSL (www.psmsl.org).

The data from the ROSAME network (LEGOS) can be retrieved at the anonymous FTP server ftp.legos.obs-mip.fr/pub/soa/niveau_mer/rosame.

Of course, as already mentioned, SHOM, UHSLC and LEGOS real-time sea level data are displayed at the IOC sea level monitoring facility (www.ioc-sealevelmonitoring.org/)

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