HIGH STANDARD TIDE GAUGE NETWORK FOR SCIENTIFIC STUDIES

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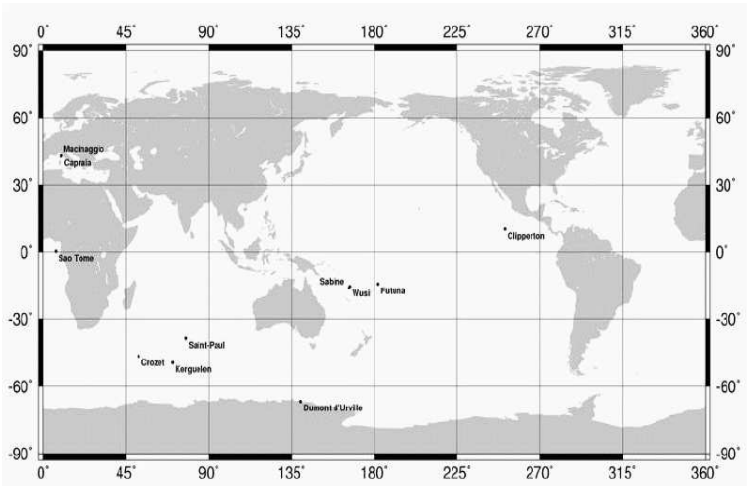
INTRODUCTION:

The comparison between sea level derived from satellite altimetry and sea level derived from tide gauges has proved to be of major technical and scientific interest. From the beginning of the altimetric mission tide gauges have been used to estimate the reliability and accuracy of the satellite altimeter. Tide gauge is presently the reference instrument used for absolute calibration of altimetric mission (Ménard et al, 1994). Moreover, the use of the global distribution of the tide gauges provided by the GLOSS data bank permit to monitor the stability of the satellite altimeter (Mitchum, 1998). On the other hand the accuracy of the T/P and Jason mission is now able to identify some of the particular bias of tide gauges such as sensor drift or appreciable land movement (Cazenave, 1999). The comparison of both instruments was also very fruitful for sea level rise studies. The existence in some countries of long sea level time series that cover for some of them the whole 20th century was at the origin of the first reliable estimation of recent sea level rise. These estimates of the global sea level rise are based on historical tide gauge data maintained by the Permanent Service for Mean Sea Level (PSMSL) (Spencer et Woodworth, 1993). Now, the coverage allowed by satellite combined with the accuracy of altimetric sea level has greatly improved our knowledge of the response of the ocean to the climate change in the past ten years, especially in the open ocean where *in situ* sea level measurements were inexistent. As an example, the quasi global sea level rise given by the analysis of the trend of more than ten years of T/P data has shown that previous estimate given by tide gauges can be biased because of the non homogenous geographical distribution of tide gauges (Cabannes, 2001). But maps of altimetric derived sea level trend also shows strong regional differences that are probably influenced by the decadal variability of the ocean. The principal inconvenient of establishing dedicated absolute calibration site is the heaviness of structure to be deployed and the cost it leads. This can be done only on few particular site easy to access and maintained on short time scale. On the contrary the global approach does not allow to look individual or regional relation between coastal and open ocean sea level variability or to make regional experiments. Our approach is then to use already existent sites relatively well distributed around the world ocean. We will then have a relatively representative situation and propose to maintained or update these sites on a long term base in order to make a network of highly controlled sea level gauges able to be useful for altimeter calibration and for scientific applications. One of the underlying objective of this proposal is also to put the foundations of a permanent sea level network able to produce in the future a highly reliable estimate of the sea level trend on the different part of the ocean. Indeed a great care will be taken to the monitoring of the sensor drift, of the vertical motion and on the representativeness of each site in term of sea level variability. One of the scientific objective we will pursue within this network is to better understand the link between the open ocean sea level variability measured by satellite altimeter and the coastal sea level variability measured by sea level gauges.



The tide gauges core network. All theses sites are operational (*except Clipperton and Futuna that are scheduled*)

South Indian and Austral Ocean

The LEGOS is in charge for many years now of the ROSAME tide gauges network. This network is composed of four permanent tide gauges located on islands in the southern part of the Indian Ocean and in Dumont d'Urville in Antarctica.

Kerguelen Island is equipped with a real time pressure gauge station since 1993. It has an IGS permanent GPS at 3 km away from the tide gauge at the CNES station and a DORIS beacon. First GPS measurements near the tide gauge and levelling were made during the maintenance campaign in January 2003. A GPS is now installed 50m away from the tide gauge and monthly tide pole lectures are done. A radar tide gauge station is scheduled for December 2005.

Saint-Paul Island is equipped with a real time pressure gauge station since 1994. Due to mask problem GPS is problematic on this Island. Amsterdam Island 80 km away from Saint-Paul have a DORIS beacon.

Crozet Island is equipped with a real time pressure gauge station since 1995. This island has been equipped with a DORIS beacon in November 2003. In the next 2 years a GPS station is scheduled at Crozet

Dumont d'Urville is equipped with a real time pressure gauge station since 1997. This site is equipped with DORIS and permanent GPS.

Atlantic ocean

Sao Tomé Island is equipped with a real time pressure gauge station since 1999 but have record since 1988. A levelling program was done in February 2004.

Abidjan in Ivory Coast and ***Pointe Noire*** in Congo will probably be reinstalled in collaboration with the LEGOS in the next few years.

Pacific Ocean

Futuna will be set to complete the geodetic network surveyed on this island to monitor the co-seismic and inter-seismic crustal motions. Real time tide gauge station and GPS are scheduled in the next years.

Clipperton has been included in the GLOSS installation plan for many years, but due to strong logistic difficulties haven't been installed yet. A first experience will be done between January 2004 and March 2005 with a couple of pressure gauge and GPS and the possibility of installing a real time station will be studied at this time.

Sabine and ***Wusi*** pairs of bottom pressure gauges are on both rims of the New Hebrides subduction zone, where Sabine is stable and Wusi experiences crustal motions, although they are only a few tens of km apart.

A tide gauge in ***Marquesas Island*** have been installed by the Tsunamy Warming System. An agreement is foreseen with this organization for collecting these data.

Mediterranean Sea

Macinaggio Pressure gauge is installed and maintained by LEGOS since June 2003. This site was levelled and a GPS buoy levelling between Capraia and Macinaggio has been done in Septembre 2004.

Capraia Pressure gauge is already installed by ENEA (Italy) and University of Bologne and Pise.

Ibiza Pressure gauge maintained by Spain (University of Majorque & University de Barcelone and Puertos del Estado) since June 2003 through a Franco-Spanish collaboration.

Senetosa 3 Pressure gauges installed and maintained by CNES-CERGA-NOVELTIS since 1998 for absolute calibration purposes.

Sète and ***Banyuls*** are scheduled by LEGOS.

Technical objectives

Technical requirements for each site:

- ✓ High quality pressure gauge sensor (+ temperature and conductivity) or radar (in test)
- ✓ Installed auto-calibration system on each site in order to follow the sensor drifts
- ✓ Reliable atmospheric pressure data
- ✓ Real time access to data (via satellite or modem transmission)
- ✓ Permanent GPS or frequent GPS campaign in the vicinity of the gauge
- ✓ Yearly maintenance of site in particular with levelling.
- ✓ GPS buoy levelling between the TG and the satellite track

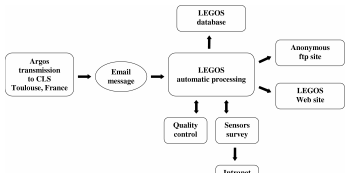
Quality control and data distribution

An automatic acquisition/quality control/fast delivery software for real time follow up of the data coming from a tide gauge network is presently developed in the LEGOS laboratory, a version of this software is at the moment in test on the ROSAME tide gauges. This software detect:

- Initialisation messages send by tide gauges station when maintenance operation is in hand.
- If same Argos message is always received
- If there no message received
- If an error arises during the automatic processing steps (date, threshold, gaps)

Future developments will concern the scientific validation of the data:

- Harmonic analyses and tidal prediction
- Data filtering and comparison with tidal model
- Etc…



Schema of the automatic software presently developed at LEGOS

In 2005 ROSAME and Sao Tomé database will be weekly updated an anonymous ftp site. All the future data treated and controlled at LEGOS by this software will be available on weekly base for national (SONEL), european (ESEAS) and international (GLOSS) database. In the future we expect to deliver our data on daily bases when all steps of the software will be optimised.

N°	Station Name	Operational	Real Time	Meteorological Stati	Permanent GPS	DORIS	Moorings	Levelled	Gps Buoy Levelling	Local Assistance	Sensor Calibration	Update site	Meteorological Stati	GPS buoy Levelling	Install GPS	Real - Time
1	**Kerguelen**	Y	Y	Y	Y	Y	Y	Y	-	Y	●	●		●		
2	**Saint-Paul**	Y	Y	-	-	-	Y	-	-	-	●	●	●	●		
3	**Crozet**	Y	Y	Y	Y	Y	Y	S	-	Y	●					
4	**D. d'Urville**	Y	Y	Y	Y	Y	-	-	-	Y	●	●				
5	**Sao Tome**	Y	Y	Y	-	-	-	Y	S	Y	●				●	
6	**Sabine bank**	Y	-	-	-	-	-	-	Y	-	●					
7	**Wusi bank**	Y	-	Y	Y	S	-	-	Y	-	●					
8	**Futuna**	Y	-	Y	Y	Y	-	Y	-	Y	●					●
9	**Macinagio**	Y	-	-	-	-	-	Y	Y	Y	●		●	●	●	●
10	**Capraia**	Y	-	-	-	-	-	Y	Y	Y	●					●
11	***Clipperton***	-	-	-	-	-	-	-	-	-	●	●	●	●	●	●
12	***Sète***	-	-	-	-	-	-	-	-	Y	-					
13	***Banyuls***	-	-	-	-	-	-	-	-	Y	-					
14	Nouméa	Y	Y	Y	-	Y	Y	Y	-	Y						
15	Marquises	S	S	Y	-	-	-	S	-	Y						
16	Ibiza	Y	Y	Y	Y	-	-	Y	Y	Y						
17	Senetosa	Y	-	Y	Y	-	-	Y	Y	Y						
18	Abidjan	S	S	-	-	-	-	S	-	Y			●			
19	Pointe Noire	S	S	-	-	-	-	S	-	Y			●			

This table lists the tide gauges where LEGOS appears as principal administrato or as collaborator (n°14→20). It summarizes some of the present characteristics of the network and points out the future needs (black dots ●) [S=Scheduled, Y=Yes]. The Sensor Calibration item corresponds to the need of a reliable on site calibration method (mainly to control offsets and drifts in the data). When a black dot appears in the Update site item, that is to say the station is old and need to be updated or replaced by a new one. Meteorological Station points out the need of reliable atmospheric pressure data near the tide gauge, it is often the case when no airport or METEO Stations are in the vicinity of the tide gauge. Install GPS points out the need to install a permanent GPS station and GPS buoy levelling the needs to related the sea surface height at the tide gauge to the sea surface height under the satellite track. Real Time point out the need of satellite transmission of the data in near real time. Some of the site nearly fulfil the technical requirements cited above (ex: Kerguelen, Noumea, Futuna). *Italic sites are scheduled sites.*

Scientific Objectives

Validation of dedicated coastal altimetry products

Errors due to land points contamination on the geophysical corrections affecting the sea surface height (SSH) computing are not well quantified. Nonetheless, the impact of wet troposphere correction can reach 2 cm on the SSH final bias. It is the case of the radiometer visible field in coastal zone, contaminated by existing terrestrial surfaces. Bias introduced by these surfaces in antenna temperature records and brightness temperatures (Tb) estimation prevent to reproduce precisely wet troposphere correction, then the altimetric range over ocean. If we search a precision of the order of one centimetre on SSH bias, it is necessary to make a pre-treatment to be able to use altimetric data close to the coasts. A method will be developed trough a collaboration between Noveltis and the CTOH in LEGOS. This algorithm will be validated using the results obtained from the method and will be compared to the LEGOS tide gauges in tests sites which have different land configuration relative to the ground track.

Contribution to regional multi-mission calibration

In-situ calibration of altimeter sea surface height is usually done at the vertical of a dedicated CALVAL site, by directly comparing altimetric data with in-situ sea level data. Recently, Noveltis and CNES altimetry team have extend the calibration opportunities by using, not only over-flying passes, but also satellite passes located far away from the calval site. In such a case, two main effects interfere in the SSH bias determination, the geoid slope and the ocean dynamics. In order to correct from the geoid slope, distant SSH altimetric data are propagated along a succession of known 11 years of Topex-Poseidon and Jason altimetric mean sea level profiles up to the in-situ reference site. Ocean dynamics differential effect which is becoming larger as the distance from the site is increasing, is corrected by using ocean numerical MOG2D model. This method was first tested at the Senetosa site (Corsica) with a Jason-1 data set then, applied to Topex-Poseidon on its new orbit and to GFO, using NOAA-GDR. Such a method is applicable to any altimetric satellite, assuming that there is an accurate mean altimetric profile available over the CalVal site to connect off-shore altimetric data with in-situ data. This method will be applied to some of the LEGOS tides gauges (mainly in Pacific and Mediterranean Sea where GPS buoys will be deployed).

Monitoring of variable and absolute transport of currents

The barotropic transport intensity (or variability) of a current can be calculated from the sea level across slope following the quasi-geostrophic balance. Then comparing referenced tide gauges measurement on either side of a current would permit in theory to reconstitute the transport variability time series. Two currents will be concerned by this study at two different scale:

- The **Antarctic Circumpolar Current** (ACC) is the most important current of the ocean in term of transport. Its role is crucial from a climatic point of view. Then variation of its transport are fundamental to understand and/or to model the future climate variation. During its travel around Antarctica ACC flow in between Kerguelen and Saint-Paul Islands where two long time series of sea level are available (from 1995 up to now). This two site are "joined" by the T/P and Jason satellite track n°103.

- The **Ligurian Current** (LC) flow through the Corsica Channel. This transport is of high scientific and environmental interest as it represents most of the northern current transport, circulating from the Italian Rivera to the Spanish waters. The central jet is located between the Macinaggio and Capraia island tide gauge sites.

Use of numerical models to link coastal and off-shore sea level

This study aimed to analyse the high frequency response of the ocean at small scale and at larger scale on the plateau of Kerguelen and in the South Indian ocean. The regional MOG2D model will be forced at its boundary by the global MOG2D model. This study will help to understand the transfer function between the signal in the open ocean measured by T/P and Jason and the signal measured by the tide gauge at Kerguelen, this will be made in connection with the Proposal made by H.Y. Park of French National Museum in Paris. We will also expect in this comparison to point out weakness in the geophysical corrections of the alimeter and expect to discriminate between these weakness and the dynamical difference. A better understanding of this transfer function will permit *a posteriori* to reanalyse the 11 year of comparison of both signals and then improve the significance of the variability.

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