The ESEAS-RI Sea Level Test Station: Reliability and Accuracy of Different Tide Gauges

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Abstract

In December 2002 a test station of six tide gauges using four different technologies (acoustic, pressure, pulse radar and FMCW radar) was established by Puertos del Estado at the port of Vilagarcía de Arousa (NW Spain), as part of the ESEAS-RI (European Sea Level Service- Research & Infrastructure) project. The aim was to compare the performance of the tide gauges in order to support the future decisions concerning the improving of the sea level observing systems. Although the comparison of the sea level time series showed that all the tide gauges met GLOSS (Global Sea Level Observing System) quality standards, the experiment also revealed some differences in the quality of the data for certain ranges of frequency.

Résumé

En décembre 2002, dans le cadre du projet européen ESEAS-RI (European Sea Level Service Research&Infrastructure), une station pilote de six marégraphes utilisant quatre technologies différentes (acoustique, à pression, radar par impulsions et radar à onde entretenue modulée en fréquence) a été installée par Puertos del Estado au port de Vilagarcía de Arousa (NO de l'Espagne). L'objectif était de comparer le fonctionnement des marégraphes afin de soutenir les futures décisions relatives à l'amélioration des systèmes d'observation du niveau de la mer. Bien que la comparaison des séries chronologiques du niveau de la mer ait montré que tous les marégraphes satisfont aux normes de qualité GLOSS (Système mondial d'observation du niveau de la mer), l'expérience a également mis en lumière certaines différences dans la qualité des données pour certaines gammes de fréquence.

Resumen

En diciembre de 2002, y como parte del proyecto europeo ESEAS-RI (European Sea Level Service Research&Infrastructure), Puertos del Estado instaló una estación piloto de seis mareógrafos de tecnologías diferentes (acústica, de presión, radar de pulso y radar de barrido de frecuencias) en el puerto de Vilagarcía de Arousa (NO España). El objetivo era comparar el funcionamiento de los mareógrafos con el fin de apoyar decisiones futuras concernientes a la mejora de las redes de medida del nivel del mar. A pesar de que las comparaciones realizadas con las series temporales de nivel del mar mostraron que todos los equipos satisfacen los requerimientos exigidos por GLOSS (Global Sea Level Observing System), el experimento también reveló algunas diferencias en la calidad de los datos para ciertos rangos de frecuencia.

Introduction

Apart from the most practical and immediate applications such as harbour operations or navigation, the monitoring of the sea level is crucial for understanding processes related with Global Climate Change. As recently stated in the Galway Declaration (EurOCEAN, 2004), one of the challenges of the European Union is "responding to the implications of global climate change and its impacts on marine and coastal environments and communities". Sea level monitoring requires a network of tide gauges, adequately located and managed, and this is one of the aims addressed in the ESEAS-RI project (ESEAS-RI, 2002). At present, there are several technologies available for measuring the sea level and it is not an obvious issue to determine which is the most reliable. In this study, and within the aforementioned project (EVR1-CT-2002-40025), some of the most relevant ones were examined: acoustic, pressure, pulse radar and Frequency Modulated Continuous Wave (FMCW) radar. With this aim, Puertos del Estado has maintained a test station of tide gauges in the port of Vilagarcía de Arousa (NW of Spain) for almost 2 years. It was the first time that so many tide gauges were tested simultaneously over such a long period and this provided an excellent opportunity to compare their advantages and disadvantages. For tide gauges employing acoustic or pressure sensors, there is already an important amount of experience accumulated (IOC, 2002). Radar systems, however, are a relatively new type of tide gauges, that is becoming popular due to its economical pricing and low maintenance (Barjenbruch et al., 2000).

The examination of the performance and adequacy of the equipment can be approached from different perspectives which, for our purposes, we will divide in two. The first perspective, comprises all that has to do with the operation of the equipment and is eventually related with the total cost of the data. The installation and maintenance expenses vary greatly and must be taken into account when purchasing a tide gauge. In addition to this, some tide gauges can be more robust than others and turn out to be more suitable for certain environments. Secondly, once the data are obtained, it is necessary to assess their quality. The quality of the data, considered in a broad sense, includes their accuracy, lack of spikes and gaps, stability of the measurements, etc. In this respect, GLOSS requirements for a GLOSS-quality tide gauge are the main reference. These requirements are described in the Implementation plan for GLOSS (IOC, 1997) and the IOC manuals (IOC, 2002), and in brief, they state that the equipment must measure to centimetre accuracy in all weather conditions for the temporal averaging indicated (typically hourly).

In this report, after describing the test site and based on our experience during the two years of operation of the test station, some considerations are made regarding the functioning of the tide gauges. In a second step we will compare the data sets over a 6-month period (the longest period when all the tide gauges were working simultaneously) in order to assess their accuracy.

Description of the Experiment

In Table 1 are listed the tide gauges that we have evaluated in this study. Some of the tide gauges were loaned from public institutions such as the United States National Oceanic and Atmospheric Administration (NOAA) or the Proudman Oceanographic Laboratory (POL). In other cases, they were loaned by private companies (ENRAF). Finally, Puertos del Estado (PE) owned three of the sensors.

The test station was installed in the port of Vilagarcía de Arousa (Figure 1). The port of Vilagarcía is situated on the Northwest coast of Spain, in the sheltered waters of the inner Ría of Arousa (Longitude: 8° 46' W Latitude: 42° 36'N), a partially mixed estuary (Álvarez-Salgado et al., 1993). This location has several advantages: it has an adequate tidal range (mesotidal, up to 4.2m), it is

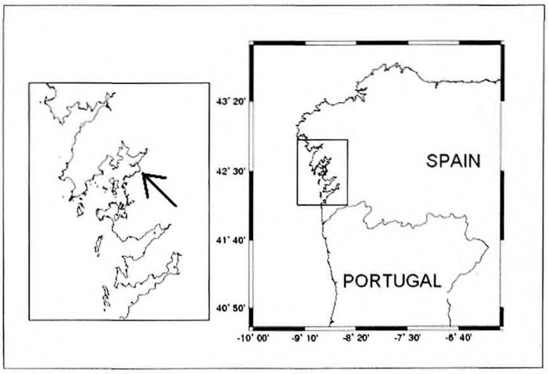

Figure 1: Location of the port of Vilagarcía de Arousa in the inner Ría of Arousa (NW of Spain), the test site.

Tide gauge (SHORT NAME)	Type of Sensor	Provider
Aquatrak (AQU)	Acoustic	NOAA
Geonica (GEO)	Pulse Radar	PE
Miros (MIR)	FMCW Radar	MIROS
Paroscientific (POL)	Bubbler Pressure	POL
Radac (RAD)	FMCW Radar	ENRAF
Seba (SEB)	Pulse Radar	PE
Sonar (SRD)	Acoustic	PE

Table 1: Tide gauges evaluated during the test: commercial name and short name used in the paper, type of sensor and provider of the equipment.

affected by varying meteorological conditions, and it has 24 hour surveillance. At this port, Puertos del Estado (PE) has operated an acoustic Sonar Research and Development (SRD) tide gauge station since 1997, which forms part of the REDMAR, the PE tide gauge network (Álvarez Fanjul et al., 2001; Pérez and López Maldonado, 2004). The sea level data obtained from this station undergo near-real time quality control (automatic detection of spikes, interpolation of short gaps and adjustment of the time of measurement) and are processed and analysed in more detail annually. Throughout the experiment the SRD permanent REDMAR station was used as a reference for the analysis of the data. The tide gauges that were part of the test station were placed on a different dock, approximately half a kilometre from the SRD permanent station. Computers and other electronic devices necessary for the operation of the tide gauge equipment: data loggers, the power supplies etc. were kept in a hut nearby (see Figure 2).

The operation of the test station spanned over almost two years since the first tide gauge installation till the start of dismantling. During that period, several tide gauges were progressively incorporated in the test (the last one, the bubbler gauge from POL in November 2003) while some others had to be repaired and for this reason were out of the test station during several months. For the purpose of evaluating the accuracy of data, in this report only the period from 11 December 2003 and 2 June 2004 was used. This is the longest period when the greatest number of tide gauges were working simultaneously and without interruptions.

Operational Aspects of the Tide Gauges

As seen in Table 1, the sensors involved in the experiment basically belong to four types: acoustic, pressure, pulse radar and FMCW radar. In short, the first type of sensors measure the travel time of acoustic pulses reflected vertically from the air/sea interface. Pressure sensors use the changes in the pressure exerted by the water column as the tide progresses. Finally, radar sensors detect microwave pulses that are reflected by the air/sea interface, either by measuring the transit time of the signal (pulse radar) or the phase shift between the reflected and the emitted wave (optical phase ranging, Mai and Zimmerman, 2000). These different measuring techniques involve changes in the way the tide gauges were installed and operated. Acoustic sensors such as Aquatrak (AQU) or Sonar (SRD) must estimate the speed of sound, which depends on the air conditions. This requires their installation in a calibration tube where that process is performed continuously. In order to reduce the appearance of temperature gradients that might influence the estimation, the acoustic gauges had protective tubes painted white. Radar pulses, on the contrary, are not affected by air conditions, which implies that the radar sensors, i.e. Geonica (GEO), Miros (MIR), Radac (RAD) and Seba (SEB) could be placed directly above the surface of the sea without any further protective structure needed (see Figure 2). On the other hand, the POL bubbler pressure sensor had to be placed underwater, which required the hiring of divers and a more sophisticated installation process.

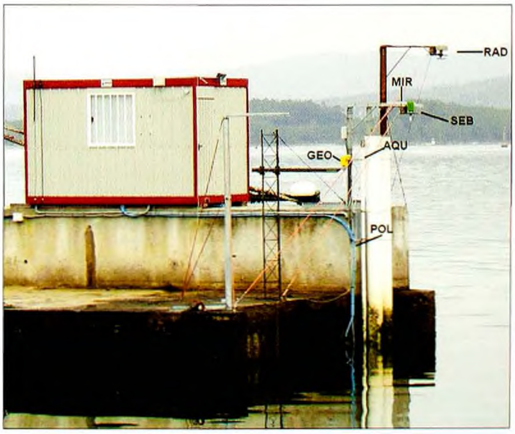

Figure 2: Test station with the tide gauges that formed part of the experiment and the hut where the electronic devices were kept. In the photograph we can see the horn-antenna of RAD, SEB and GEO radars, the plannar antenna of MIR radar, the protection tube of the AQU acoustic gauge, and the submerged POL gauge.

Another important difference concerns the storage of the raw data. Some of the systems allowed the storage of data each second (e.g. AQU, MIR, RAD) while some others only permitted storing one averaged value each 10s (POL), 1min (SEB, GEO) or 5 min (SRD). In addition to this, AQU, MIR, POL and RAD sent their data directly to the PC and the time assigned to the data was in fact the computer time. In other cases, the tide gauges recorded the data in a data logger which assigned the time (SEB, GEO). Finally in the case of the SRD acoustic gauge, the time and date were assigned by an internal EPROM inside the sensor. Only the GEO tide gauge had a GPS-controlled assignment of time, a type of control that we consider advisable for future stations. In the other tide gauges, as we shall see, the system clock can present shifts.

All the tide gauges required some basic maintenance operations to be carried out, namely, calibrating the sensor, levelling the transducer, downloading the data or controlling the power supply. The company that performed those operations (SIDMAR) made the maintenance visits each 4 months approximately. When the sensors were installed within protective tubes, these structures were revised and cleaned. Except for the GEO, which had its own method of adjusting the clock via GPS, the time assignment had to be checked and corrected if necessary. The bubbler pressure required draining of the compressor and checking the oil level and the air pressure.

As previously mentioned, the duration of the experiment was over two years. During that time, the AQU and SEB tide gauges experienced one severe breakdown each and had to be sent out for repairs. In both cases the malfunctions seemed to be related to the presence of moisture within the system. The RAD sensor had to be lifted 1m above the level of the rest of the radar sensors to ensure correct performance of the system. The tide gauges that presented a more robust behaviour, without breakdowns were GEO, MIR and POL. All data sets presented a very low percentage of peaks, particularly the radar sensors. It is also interesting to note that, despite the radar sensors being more exposed to wind and rain than those operating within a tube, they seemed to withstand storms (gusts up to 24m/s) without failing. In fact, the most important drawback of the open-air installation of the radar sensors, was the risk of vandalism. During the experiment, some attempts of robbery were detected; therefore, the use of radar sensors within protective structures would be advisable for permanent stations.

Data Comparison

Comparison of 5-min Time Series

The sea level is a sum of several signals that we can identify and relate to different processes: one is, obviously, the astronomical tide, whose energy concentrates mainly in the hourly-daily range. In the subtidal range some other processes such as the changes in the atmospheric pressure or the effect of wind can also leave their trace. In addition to this, higher frequency waves, with typical periods of several minutes can also appear (seiches, tsunamis...).

In this section we will make a general comparison of the tide gauges based on the analysis of the 5-min time series and thus consider the response of the systems at frequencies lower than 0.1 cycles/minute. The comparison of the performance of the tide gauges for higher frequencies may be approached by using the raw data provided by AQU, MIR, POL and RAD but it is beyond the scope of this report.

In an ideal situation, all tide gauges should have been measuring exactly the same signal, but the fact is that several factors resulted in differences in the input signal. For example, AQU, SRD and POL were installed within protective structures, which can partially eliminate the effect of high-frequency oscillations. These oscillations are in general of no interest when we are measuring sea level and, in the case of radar sensors, they can be eliminated by averaging. It is also important to note that SRD permanent station was not located on the same dock as the test station.

Another factor to bear in mind is the different sampling strategy followed by the tide gauges. In order to obtain homogeneous time series we performed the data were reduced until one value at 5 minute intervals was obtained, precisely the sampling period of the SRD reference tide gauge. The actual number of raw data employed to obtain the final average value during that reduction process was different.

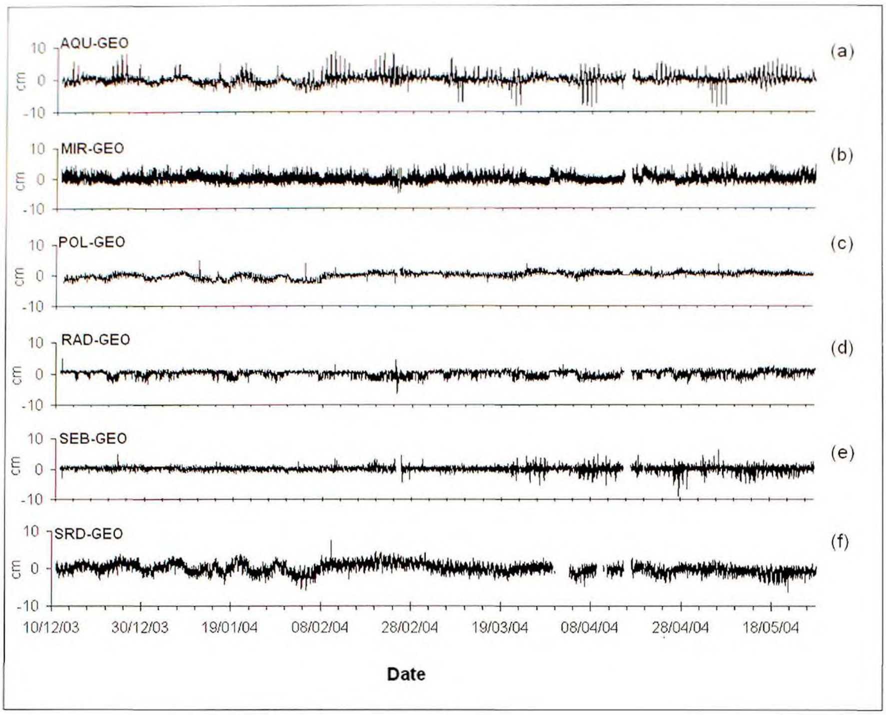

Figure 3: Time series of the differences between each tide gauge and GEO tide gauge. Vertical scale ±10cm.

Finally, the analysis of two sea level time series must ensure that the data compared correspond to the same time as accurately as possible. In this respect, slight shifts of the system clock can alter the final results. Clock shifts can be avoided by controlling the time of the measurement via GPS, but this has not been the rule until recently, and, in our case, only the GEO system had this capability. For the rest of the systems, the clock was adjusted during the maintenance visits to the test station when differences of several min (< 6 min) between the PC clock (where data from AQU, MIR, POL and RAD were stored) and the UTC time were detected. We verified that these shifts could cause a mean difference of 5cm when comparing the time series. To avoid this effect and minimise the influence of the clock on the experiment results, we obtained 1-min time series via linear interpolation between the 5-min data and made the comparisons between the original time series when theoretically simultaneous and when shifted up to 6 min with respect to GEO. We then searched for the shift that provided the best results, in other words, the shift that corresponded to the greatest correlation between the GEO time series and the others. This optimal shift varied between sensors and during the course of the experiment so, we decided to divide the time series into shorter intervals of 3 days. For each interval we calculated the optimal delay and this allowed us to correct the time assigned to each level value and to reconstruct the time series.

After achieving homogeneous, in principle simultaneous 5-min time series, we made the comparisons between each pair of sensors. With this aim, we obtained the mean absolute deviation of each couple of sea level time series, that is to say, the root mean square error (RMS) between them. To illustrate this process, refer to Figure 3, which corresponds to the time series of the differences between GEO and the rest of the tide gauges. In the time series of the differences we can first observe high-frequency oscillations, which are more important when comparing GEO with AQU (Figure 3(a)), MIR (Figure 3(b)) and SRD (Figure 3(f)). In addition to this, we can clearly distinguish long term variations (several days long, with differences up to 3cm). These are more relevant when comparing GEO with the non-radar systems, particularly during the first two months of the experiment. Those long term variations might be related to meteorological processes that take place typically in the low-frequency scale. It might happen, for example, that radar measurements were biased during high wave conditions if reflection took place

RMS (cm)

	AQU	GEO	MIR	POL	RAD	SEB	SRD
AQU	0.0	1.4	1.9	1.4	1.7	1.6	1.5
GEO	1.4	0.0	1.2	1.0	0.9	0.7	1.3
MIR	1.9	1.2	0.0	1.6	1.1	1.3	1.8
POL	1.4	1.0	1.6	0.0	1.4	1.2	1.4
RAD	1.7	0.9	1.1	1.4	0.0	1.0	1.6
SEB	1.6	0.7	1.3	1.2	1.0	0.0	1.4
SRD	1.5	1.3	1.8	1.4	1.6	1.4	0.0

Table 2: Root Mean Square Error (RMS, in cm) for the record of differences between the 5-min time series provided by each couple of tide gauges.

to a proportionately greater extent from wave troughs than crests (as was mentioned in Woodworth and Smith, 2003). In order to investigate this possibility we used the time series of significant wave height calculated at the entrance of the Ría de Arousa and the atmospheric pressure recorded at a nearby meteorological station. Up to now no clear relationship between those variables and the time series depicted in Figure 3 has been found. Nevertheless, for certain applications of the tide gauges such as altimeter calibration or the validation of circulation models, such differences can be of great relevance. Consequently, further studies focused on particular storm events and with a better control of the environmental variables would be required.

If we calculate the standard deviation of each of the time series depicted in Figure 3, we will obtain the RMS between the GEO and each corresponding tide gauge (these values are presented in the second column of Table 2). The RMS for all the possible comparisons between pairs of tide gauges are presented in Table 2. As we see in Table 2, the RMS between the pairs of time series oscillated between 0.7 and 1.9cm. After smoothing the time series to obtain hourly sea levels, the RMS values were reduced by approximately 10% (20% for MIR). Following Woodworth and Smith (2003), RMS values below 1.4cm would yield a precision better than 1cm, which is consistent with Global Sea Level Observing System (GLOSS) standards (IOC, 2002). Consequently, most of the tide gauges would meet these standards when measuring at a 5-min rate, and all of them would if only hourly values were used. This is the main conclusion derived from the RMS analysis; however, there are some other features worth mentioning. For example, it is remarkable that the highest RMS were obtained between the acoustic tide gauges (AQU and SRD) and the rest of sensors. There are several explanations for this. On the one hand, as already mentioned, the speed of sound is affected by the temperature, and temperature gradients can occur within the tube, which might alter the evaluation of the speed. This may likely be the case for AQU, as already described in previous works (Vassie et al., 1992). To compensate for these effects, the temperature gradients within the tube are usually controlled by installing two thermistors, but the AQU in Vilagarcía did not have the thermistors in use. As we see in Figure 3(a), the differences between AQU-GEO present some periods of peaks with diurnal variability (e.g. around 10 February). This is consistent with the appearance of temperature gradients, which we might expect to be greater during the day than at night. Figure 3(f) suggests that SRD system was not as sensitive to the temperature effects as AQU and relatively high RMS might be more related with its location on a different dock, for some local phenomena can be affecting the level value. In addition to this, the data for the SRD were the product of averaging up to 128 signals within a window 37-50 s each 5 min, whereas the other equipment performed a continuous integration of data along the 5-min interval.

The best results (i.e. the lowest RMS) are found when comparing GEO, RAD and SEB (all radar sensors). It is expected that pairs of tide gauges that use similar technologies, present lower RMS. This is particularly the case with GEO and SEB (RMS = 0.7cm), both pulse radar sensors that in fact employ the same transducer (Vegapuls). Figure 3(e) also illustrates the similarities between both data sets. The time series of the differences between GEO and SEB does not show the fluctuations that we find when comparing the other tide gauges. Greater RMS are found with the other radar tide gauge (MIR, see Figure 3(f)) that we shall investigate by means of the spectral analysis.

slope

	AQU	GEO	MIR	POL	RAD	SEB	SRD
AQU	1.000	0.999	1.001	0.995	1.000	1.000	1.001
GEO	1.000	1.000	1.002	0.996	1.001	1.001	1.002
MIR	0.999	0.998	1.000	0.994	0.999	0.999	1.000
POL	1.005	1.004	1.006	1.000	1.005	1.005	1.006
RAD	1.000	0.999	1.001	0.995	1.000	1.000	1.001
SEB	1.000	0.999	1.001	0.995	1.000	1.000	1.001
SRD	0.999	0.998	1.000	0.994	0.999	0.999	1.000

Table 3: Slope of the linear regression analysis between the 5-min time series provided by each couple of tide gauges.

Pressure systems such as POL require the estimation of the density of the seawater prior to the calculation of the sea level, thus, their measurements can be affected by the changes in the seawater salinity. This can be more clearly seen after studying the slope of the linear regression trend between the time series (Table 3). This slope expresses the distinct sensitivities of the sensors to the tidal range. Taking a look at the POL results (4th column), we can appreciate that the slope between the POL time series and the rest of the systems oscillates around 0.995±0.001. Consequently, the POL tide gauge is recording lower tidal ranges (approximately 5‰) than the other sensors. Since POL system assumes a constant salinity of 35 psu, some bias might have been introduced for not taking into account the likely decreases of this variable in the Ria due to the run-off. As far as the other systems are concerned, the slope falls within 1.000±0.001, thus, their sensitivity is more similar, with SRD and MIR being the two gauges that measure the highest tidal ranges.

Spectral Analysis

We have already presented some factors that help to explain the differences in the data obtained by each tide gauge. To obtain more information we can also study the power spectra of the time series by means of the Fast Fourier Transform to find out whether those differences are more relevant in certain ranges of frequency. We have selected a one-month period just after the installation of POL gauge. The results are presented in Figure 4.

Beginning from the low frequency ranges, we first distinguish the most important diurnal and semidiurnal tidal peaks, which present almost identical values for all the time series. As the frequency increases, differences arise: in the range 0.01<F(cycles/minute)<0.03 (i.e., for periods between 30 and 100 min), MIR data clearly present more energy (darkest, thicker line). The differences were found to be due to small inaccuracies in an interpolation algorithm used internally in the sensor. This problem has seldom any effect in the results for the tidal range, but might be of importance when considering supratidal oscillations such as seiches. The company has undertaken to solve it by upgrading the software. This explains the relatively high RMS values found for the MIR and clarifies why the reduction of the RMS when using hourly values was greater in that case than for the other tide gauges.

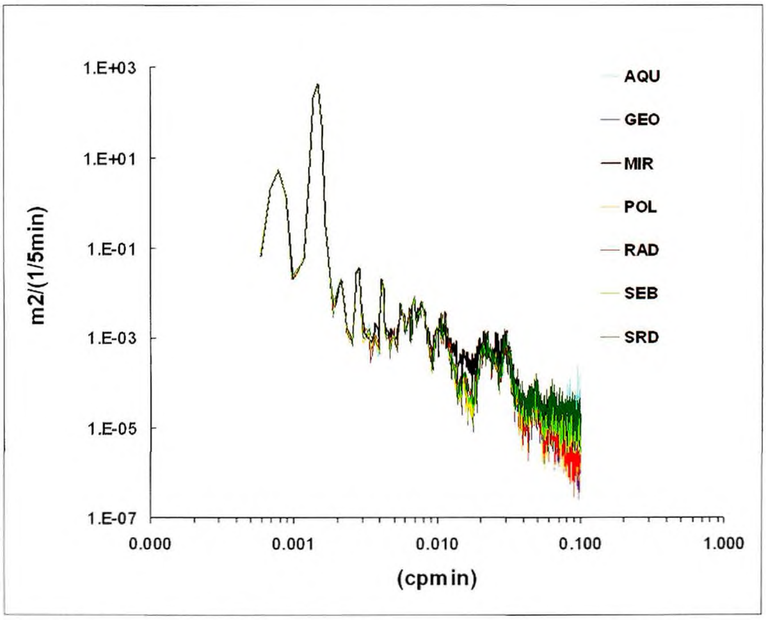

Figure 4: Power spectral density for the 5-min time series provided by all the tide gauges during the period December 2003-January 2004.

H
(cm)

Tide	AQU	GEO	MIR	POL	RAD	SEB	SRD
O1	6.3	6.4	6.3	6.3	6.4	6.3	6.3
K1	6.6	7.3	7.3	7.2	7.4	7.3	7.4
N2	23.4	23.3	23.4	23.2	23.5	23.6	23.7
M2	114.3	114.2	114.4	113.8	114.2	114.2	114.6
S2	40.9	40.9	41.1	40.8	41.0	41.0	40.7

G
(deg)

Tide	AQU	GEO	MIR	POL	RAD	SEB	SRD
O1	71.8	73.5	71.1	70.5	71.3	71.0	71.7
K1	48.0	53.1	54.0	51.8	51.3	52.7	60.0
N2	66.9	68.1	66.9	67.0	67.9	66.9	64.5
M2	80.0	80.5	79.9	80.0	80.5	79.9	79.3
S2	104.9	105.1	105.2	105.3	105.8	105.2	104.9

Table 4: Main tidal constituents determined from the time series provided by the tide gauges. Amplitude (H, cm) and Greenwich phase lag (G, deg). Period December 2003-June 2004.

In the high-frequency range (F>0.05 cycles/minutes), even greater differences are found. As explained in the previous section, the measuring technique is diverse (e.g. pressure, time of flight, phase shift...) and the tide gauges were actually measuring physically different oscillations; in particular, radar sensors measure directly the sea level 'seen' by the transducer above the water surface whereas acoustic sensors were located inside tubes and the pressure sensor was submerged. Another possible reason is the data reduction process performed to obtain the 5-min time series (i.e. the actual raw data evaluated and averaged), which differed for each tide gauge. However, it must be noticed that the plot is using a logarithmic scale, thus, the differences relate to an almost non-energetic part of the spectra and they are exaggerated.

Comparison of Hourly and Daily Values

A harmonic analysis of the time series provided by each tide gauge was performed using a set of procedures and programs employed in Puertos del Estado for the treatment of the data of the REDMAR network. This was based on Foreman's Tidal Analysis programs (Foreman, 1977). The results for the most important tidal constituents are presented in Table 4. The amplitudes for the main diurnal and semidiurnal constituents are very similar, and the same applies for the phase lag values. Slightly lower amplitude values are found for the POL gauge pressure gauge, which is consistent with the results described in Table 3 and the considerations about the changes in salinity.

The quality of the data depends not only in how accurately the tide gauge measures the level variations, but also in the precision of the timing and the stability of the mean sea level. Both aspects can affect the results of the comparison. In the first case, as we have already mentioned, we faced the problem using the GPS-referenced GEO system to correct the time assignment of the rest of the tide gauges. The second parameter should be ensured by an accurate levelling of the sensors, which in our case consisted of periodically checking the distance between the sensors and the Tide Gauge Bench Mark (the datum). The error in the measurements was ±1cm. Ideally, the datum of the sensors should have remained the same throughout the experiment, but some slight changes were found during the maintenance visits. Since the installation of the sensors took place at different times and some of the systems had to be reinstalled, these changes are not surprising, yet it is clear that the operation of a permanent station would require of a better control of the datum. Another way of examining the stability of the datum is studying the evolution of the daily mean values and their trends during the test period. In spite of the limitations, we found those trends to be comparable for all the tide gauges and thus, no clear drift in the datum of the systems (that should result in a differential trend) was evident.

Conclusions

In this study we have undertaken the intercomparison of seven tide gauges employing different technologies for the monitoring of the sea level, namely two acoustic sensors (AQU and SRD), two pulse radar (GEO, SEB), two FMCW radar (MIR, RAD) and one bubbler pressure (POL). The experiment provided an excellent opportunity for evaluating their performance, both in terms of their operational properties and the accuracy of their data.

Radar sensors presented clear advantages with respect to their installation and maintenance, which was easier. Despite being installed without any protective structure, they did not present any failure associated to bad weather conditions. However, their greater exposure had another drawback, namely vandalism.

The accuracy of the data was evaluated by comparing the 5-min averaged time series. The analysis showed that all the tide gauges evaluated provided data that were suitable for the study of the sea level for most typical applications. In particular, GEO, RAD and SEB data sets were the most alike, with mean deviations lower than 1cm. However, a closer look at the time series revealed some other aspects worth highlighting. The records of the AQU acoustic gauge and the POL pressure gauge appear to be affected by changes in the air temperature and salinity, respectively. In addition to this, deviations between the radar and non radar sensors presented a subtidal variation whose range of frequency suggests some relation with meteorological forcing, yet to be elucidated. The spectral analysis revealed that MIR data presented more energy in the range of frequency $0.01 < F < 0.03$ cycles/minutes, this being related with a small inaccuracy in the interpolation algorithm used by the sensor. Finally, several possible explanations for the difference in response of the systems for $F > 0.05$ cycles/minute have been mentioned. Further studies focusing on the analysis of the high-frequency time series will certainly shed light in that direction.

Acknowledgements

We are grateful to the companies (MIROS and ENRAF-RADAC) and the public institutions (NOAA, POL) that have loaned their tide gauges for the experiment. Our special thanks to the authorities of the Harbour of Vilagarcía, and especially Felipe Pérez for his support during the study. The authors also wish to thank the members of SIDMAR for their fieldwork and their constant input. Finally, we wish to express our gratitude to Philip Woodworth for his help throughout the study.

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Belén Martín Míguez received her MsC in Environmental Sciences and her PhD in Physical Oceanography in 2003. Since then she has worked as a research scientist for the Spanish Harbours Authority (Puertos del Estado), within the Department of Marine Environment. Her current field of expertise is the comparison of technologies for the monitoring of the sea level.

Begoña Pérez Gómez has been responsible since 1992 for the Spanish Harbours' Tide Gauges Network (REDMAR) and since 2000 also of the operation of the Nivmar storm surge forecasting system. She specialises in time series quality control and sea level data processing, operation and instrumentation of tide stations and numerical circulation models. Since 2005 she has been the chairperson of the Technical Subgroup of GLOSS (Global Sea Level Observing System).

Enrique Alvarez Fanjul leads the Department of Marine Environment of Puertos del Estado. He is responsible for the oceanographic networks (buoys, tide gauges, current meters) that allow the surveying, monitoring and modelling of the coastal areas in order to give service to the Spanish harbours. He is the co-ordinator of the project ESEOO (Implementation Spanish Operational Oceanography System).

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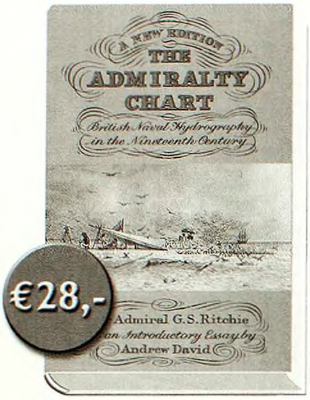
Fourth Biennial Conference of the IAG/IHO/IOC Advisory Board on the Law Of the Sea (ABLOS)

The IAG/IHO/IOC Advisory Board on Scientific and Technical Aspects of the Law of the Sea (ABLOS) is pleased to announce its Fourth Biennial Scientific Conference, which will take place in Monaco from 10-12 October.

This year's Conference will consist of two consecutive events: a one-day Tutorial Session on the fundamentals of implementing Article 76 of the UN Convention on the Law of the Sea, followed by a two-day Symposium that will explore various topics within the Theme Marine Scientific Research and the Law of the Sea: the Balance between Coastal State and International Rights.

Conference organisers invite prospective speakers to submit abstracts that address various aspects of the Symposium theme. These will be accepted until 31 May. There will be separate registrations for the Tutorial Session and the Symposium, with discounts available if paid before 31 August.

Visit the ABLOS website at www.gmat.unsw.edu.au/ablos/ for more information concerning the Conference, the submission of abstracts and applications for registration.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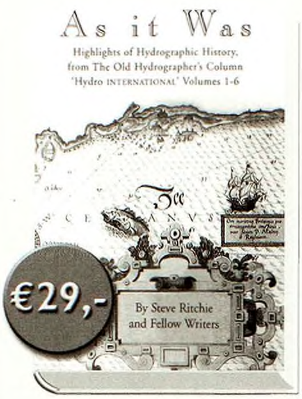
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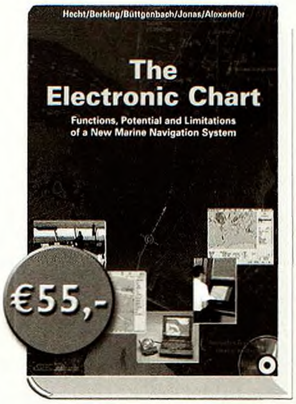
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