Intergovernmental Oceanographic Commission
Workshop Report No. 176

MedGLOSS Workshop and Coordination Meeting for the Pilot Monitoring Network System of Systematic Sea Level Measurements in the Mediterranean and Black Seas

Co-sponsored by
International Commission for the Scientific Exploration of the Mediterranean Sea

Israel Oceanographic and Limnological Research,
Haifa, Israel,
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UNESCO 2002

IOC Workshop Report No. 176
Paris, 6 February 2002
English only

Abstract

This report provides a summary of the Joint IOC and CIESM Workshop and Coordination Meeting of the MedGLOSS Pilot Monitoring Network of Systematic Sea Level Measurements in the Mediterranean and Black Seas. The meeting included presentations by a number of experts as well as presentations of the sea-level monitoring activities in the participating countries, which are listed as submitted by the participants. Future MedGLOSS activities and implementation issues were discussed and a number of recommendations are presented.

(SC-2002/WS/21)

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ANNEXES

1. INTRODUCTION

1.1 GENERAL

The Workshop and Coordination Meeting of the MedGLOSS Pilot Monitoring Network of Systematic Sea Level Measurements in the Mediterranean and Black Seas, was held at the Israel Oceanographic & Limnological Research (IOLR) headquarters at the Tel Shikmona promontory hill in Haifa, 15-17 May 2000. The International Commission jointly sponsored it for the Scientific Exploration of the Mediterranean Sea (CIESM) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. This meeting was a further advancement of earlier initiatives taken by CIESM and IOC for the study of the sea level in this region.

The WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) has forecasted a worldwide eustatic sea-level rise due to the “greenhouse effect”. This is due to global warming, leading to water volume expansion as the major component and ice cap melting as the secondary one. However, it has been recognized that regional sea-level rise may differ significantly from the globally averaged sea-level rise forecasts, in particular due to tectonic movements, meaning that relative sea-level changes may be as important, or even more than those of the absolute sea-level.

Responding to these forecasts, a worldwide sea-level monitoring network named Global Sea-Level Observing System (GLOSS), itself a component of the Global Ocean Observing System (GOOS) was initiated by the Intergovernmental Oceanographic Commission (IOC) of UNESCO in 1985. The network emphasized its global character by selecting some 300 sites as major sea-level monitoring stations, most of them along the coasts of oceans and a few along those of marginal seas. The GLOSS network was readjusted in 1997, according to recommendations by the IOC Group of Experts on GLOSS, to form the core tide-gauge network for worldwide coverage, containing only some 250 stations which have been operational in the 1990s, ranked in four categories as follows: (a) GLOSS-LTT network subset for studies of long-term sea-level trends and accelerations; (b) GLOSS-ALT subset network for ongoing calibration of altimeters, based largely on islands; (c) GLOSS-OC subset network for monitoring issues related to the global ocean circulation; and (d) regional subsets of GLOSS-CN to be used as cores of regional densified subset networks, consisting of GLOSS-CN stations densified by additional regional stations which can provide GLOSS quality sea-level data, and which will strengthen data reliability, fill data gaps at neighbouring stations and add boundary conditions information for regional studies of regional sea-level changes, water circulation and air-sea interaction processes.

The Mediterranean/Black Sea basin has been represented in GLOSS by only a very small number of stations in spite of the fact that this region possesses a significant number of relatively low-lying coastal areas that may be significantly affected by sea-level rise. Although this basin is of relatively small size when comparing its water volume to those of the oceans, it represents for millenniums, a major centre of dense human habitat and activity. Hence, any sea-level changes in the Mediterranean or in its companion, the Black Sea, as well as the circulation and air-sea interaction processes taking place in this region are of utmost importance to the people living along the coasts of the Mediterranean and the Black Seas. Furthermore, the water balance and exchange between the Mediterranean and its companion with the Red Sea through the Suez Canal and in particular with the Atlantic Ocean and with the atmosphere, may be used as a model for world wide studies of water exchange processes. Aware of these facts, a preliminary expert workshop on monitoring sea level change in the Mediterranean basin was held at CIESM headquarters in Monaco in February 1996 as a joint initiative of CIESM and IOC. Following proposals presented there, it was decided by the two bodies to jointly co-operate in the study of sea-level change and plate tectonics in the Mediterranean basin, by establishing a long-term monitoring network system for systematic sea-level measurements in the Mediterranean and Black Seas.

In the summer of 1996 a Memorandum of Understanding was signed between CIESM and

IOC (by Dr. Frederic Briand - Director-General of CIESM and Dr. Gunnar Kullenberg – then Executive Secretary of IOC), establishing also a Joint Group of Experts on the MedGLOSS Programme, composed of Prof. Suzanna Zerbini (Italy), Mr. Pierre-Yves Le Traon (France), Cdr. M. Emin Ayhan (Turkey) and Mr. Dov S. Rosen (Israel). Later on, Dov Rosen was appointed Chairman of this group.

An initial meeting of the experts' group was held at UNESCO Headquarters, Paris, 20-21 January 1997. The Joint Group of Experts noted that the IOC Black Sea Regional Committee at its First Session (September 1996) had recommended initiating a Black Sea sea-level monitoring programme in association with GLOSS, with emphasis on coastal regions subject to flooding and sea level rise impact. As an outcome of the meeting, it was decided to launch the MedGLOSS (Mediterranean GLOSS subsystem) pilot network programme. This has been designed to meet the basic requirements and methodology of GLOSS developed by the IOC, aiming to provide high-quality standardized data, to be directly applied in regional, as well as worldwide studies, on sea level change and plate tectonics. The pilot network was planned to include some 27 stations in 13 countries, which expressed their interest in joining this international research network, with additional stations/countries to be considered if they would answer the requirements of the pilot stations.

Institutions joining the MedGLOSS pilot network, were required to commit themselves to long-term maintenance of the sea-level stations, to submit near-real time sea-level, atmospheric pressure data and sea-level benchmark GPS elevations to temporary MedGLOSS centres established at the Israel Oceanographic and Limnological Research, National Institute of Oceanography (sea-level verification and redistribution), at the 'Collecte Localisation Satellite' (CLS), Direction Océanographie Spatiale, Toulouse (satellite sea-level monitoring, atmospheric pressure) and at the University of Bologna (GPS Sea-Level Benchmark data) and then to the Permanent Service for Mean Sea Level.

1.2 OBJECTIVES OF THE WORKSHOP AND CO-ORDINATION MEETING

- The workshop was intended to bring together professionals involved and interested in the operation of the MedGLOSS pilot network for a discussion of the present state and future operation of the network. The workshop objectives were: to bring together professionals involved and interested in the operation of the MedGLOSS pilot network for a discussion of the present state and future active operation of the MedGLOSS sea-level pilot network;
- to exchange and update knowledge on sea level and sea level benchmark monitoring equipment and data analysis;
- to discuss the present state of the MedGLOSS pilot stations and their historic data availability and the needs for data rescue;
- to decide upon the active implementation and operation of the MedGLOSS pilot network;
- to nominate the permanent regional centre that will collect, check and disseminate data gathered by the pilot stations;
- to coordinate the data transfer and utilization among the MedGLOSS members as well as with other international projects and bodies such as the MFS, the MedGOOS and Black Sea GOOS;
- to identify (in addition to national sources) potential international sources for support for the full implementation and operation of the pilot network as well as for modernization of stations with inadequate equipment and to aid preparation of sea-level research proposal(s), which will be jointly submitted.

The meeting objectives presented above were defined on the basis of the initial MedGLOSS scope and tasks defined upon its initial kick-off meeting at IOC Headquarters in Paris, January 1997, namely:

(i) to detect regional long-term relative and absolute sea level changes trends and acceleration rates, as well as to determine plate tectonic movements in the domain affecting them by the creation of a densified regional long-term sea-level monitoring network in the Mediterranean and Black Seas. The high quality, standardized data gathered by the MedGLOSS network would facilitate the performance of regional studies regarding sea-level rise, water exchange and tectonic movements;

(ii) to create the MedGLOSS regional network from sea-level monitoring stations already active in GLOSS strengthened by additional operational sea-level stations in a number of countries along the coasts of the Mediterranean and Black Seas, and by new sea-level stations;

(iii) to monitor in addition to the hourly sea level and atmospheric pressure the sea level benchmark elevations. Data gathered by the MedGLOSS network should be transmitted for quality control, processing and further dissemination and publication to regional centres. To enable quick availability of the regional sea-level data, a quasi real-time monitoring network system will be adopted, using a software package of quasi real-time sea level monitoring and transmission system;

(iv) the regional centres will review the data received from the monitoring stations, process and analyze them, inform of suspicious malfunctioning to national coordinators and station operators, and disseminate the results to the national coordinators, to the Permanent Service for Mean Sea-Level (PSMSL), GLOSS and MFS centres. Space altimetry sea-level data regarding the Mediterranean and Black Seas will also be provided to the regional centres for combined analyses, the results of which will also be made available to the MedGLOSS members as well as to PSMSL and GLOSS;

(v) to conduct thorough continuous monitoring of tectonic movements of the land-based benchmarks of sea level monitoring stations and tie the elevations of the land-based benchmarks and the sea-level sensors. Regional centres will assist with the installation of constant Global Positioning System (GPS) stations at the Sea-Level Benchmarks (SLBM) and at selected station missions absolute gravity will be measured to determine rates and accelerations of land movements. The regional centres will also assist in rescue and compilation of historical data.

Under the joint IOC/UNESCO-CIESM managing board for MedGLOSS, the regional centres will be responsible for providing assistance, education and training in accordance with the GLOSS implementation plan, TEMA (Training, Education and Mutual Assistance), as follows: consultation in purchasing and possibly provision of gauge instruments and spare parts; assistance in site selection for new MedGLOSS stations and upgrading existing stations; assistance in the installation of gauges, in training technicians to maintain the gauges, and specialists to make maximum local use of the gauge data; training assistance to use and apply new sea level-related technologies (GPS, altimetry, etc.); promote/support attendance at relevant regional and international workshops, training courses, etc.; provision of training materials and other documents related to MedGLOSS, prepared with the assistance of IOC and CIESM; provision of sea-level data sets and a wide range of other suitable products.

2. WORKSHOP

2.1 REGISTRATION

The Workshop was held in the IOLR Auditorium at the National Oceanographic Institute in Haifa, on 15 May 2000. The MedGLOSS Workshop and Coordination Meeting programme is presented in Annex 1.

Prior to the workshop and coordination meeting, a half day visit to the Sea of Galilee was

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organized and sponsored by the IOLR on 14 May 2000 for the participants, explaining effects of routine major seasonal water level changes in the Sea of Galilee, which is used as Israel's major potable open water reservoir.

Dr. Yuval Cohen, Director-General of IOLR, who greeted the participants and expressed his best wishes for an active implementation of MedGLOSS pilot network, opened the Workshop.

Afterwards, Dr. Michael Beyth, Director-General of the Earth Sciences Research Administration, Israel Ministry of National Infrastructures, greeted the participants. He welcomed the participants on behalf of the Minister for National Infrastructures and added: *"I am very impressed by the representation at the meeting of 13 Mediterranean and Black Sea Countries. This is a good indication of the commitment of the countries of the region to the development and implementation of MedGLOSS. I can assure you that Israel is deeply committed to the programme. Our Ministry is in charge of the national institutions for geology, geophysics, marine and freshwater research including IOLR. These institutions are responsible for providing the Government with scientific advice on the management of Israel's natural resources now and in preparation for the future. In this context, we are well aware of the importance of accurate sea level monitoring. Sea level rise may have serious impact on our coastal zone and we must be warned in advance. MedGLOSS could provide that warning. We are also aware of the difficulties involved in the interpretation of sea level data. I am confident that you are in a good position to overcome these difficulties. I want to thank CIESM and the IOC for their support for MedGLOSS and for sponsoring this meeting. I also want to thank IOLR and especially Dov Rosen for taking the lead in developing MedGLOSS. I wish you a productive meeting and look forward to the implementation of the Pilot Phase of MedGLOSS and later on to the development of a full-scale programme. Thank you".*

Following the greetings Dr. Frederic Briand, Director-General of CIESM, welcomed the participants and wished them a fruitful and successful workshop. He thanked IOLR for hosting the meeting and expressed the continuing support commitment of CIESM to MedGLOSS programme, as an important scientific research programme for the countries bordering the Mediterranean and Black seas by stemming to provide long-term operational data and change trends regarding sea level rise and tectonic plate movements. He stressed the importance of this information as a basis for decision making in regards to mitigation of sea level rise and plate tectonic movement effects, and for serving as a good example to the worldwide community. Finally he announced that due to the successful installation of a modern MedGLOSS sea level station in Constantza port, Romania by an IOLR team led by Dov Rosen in December 1999 via a CIESM donation, CIESM decided to provide further funds for the purchase and installation of modern near real time sea-level monitoring stations in additional countries of the Mediterranean and Black seas, among them Croatia, Malta and Morocco.

Dr. Philip Woodworth, Chairman of GLOSS Group of Experts of IOC/UNESCO greeted the participants on behalf of IOC. He stressed the importance and difference between local relative sea-level rise and global average sea-level rise and expressed his hopes that the programme will bring a significant contribution in the sea level monitoring and long term trend assessment efforts.

Afterwards the meeting agenda and organization were updated by Dov Rosen. He mentioned that additional countries that expressed their interest in participating in MedGLOSS were invited (Tunisia, Egypt, Russia, Bulgaria, Cyprus), but due to various reasons were not able to come. The representative of Russia Dr. Oleg Zilberstein, member also of the GLOSS Group of Experts, submitted a written presentation. Dr. Mariana Popova from Bulgaria could not attend and her colleague Dr. George Mungov had submitted updated information on Bulgarian sea-level monitoring activities. In addition, Dr. George Zodiatis of Cyprus was at the time of the meeting on a research cruise but was expected to arrive at IOLR the week following the meeting and was updated with the outcomes of the meeting. Dr. Yves Le-Traon was represented by Dr. Gilles Larnicol who presented CLS activities.

2.2 STATE OF THE ART PRESENTATIONS BY INVITED EXPERTS

This workshop session was chaired by Dr. Aldo Drago and included a number of presentations by a number of experts in sea level measuring and analysis and in geodetic fixing of the sea level reference benchmarks (SLBM).

2.2.1 Brief GLOSS Overview with Emphasis on the Mediterranean Region - Philip Woodworth

The session was opened by Dr. Philip Woodworth, Chairman of the GLOSS Group of Experts who presented an overview on the GLOSS past, present and future activities. He gave special emphasis to the GLOSS activities relevant to the Mediterranean and Black Sea basins. Among these, he presented updated information on the sea-level data from these basins archived at the PSMSL, and a review of the various means of sea level measurement used in this region. Then he discussed the two major tasks of MedGLOSS namely (i) long-term studies of sea level change and plate tectonics; and (ii) near real time (NRT) data for assimilation in operational oceanography programs and models. He pointed out that for long-term trends there is not need for many stations, but that the selected stations must have long-term records. For operational oceanography, the most important stations are those transmitting NRT data and located in strategic locations such as in straits. Finally, he mentioned the European Sea Level Network, being developed under a COST project under the EU FP5. A more detailed description of his presentation is given in Annex IVl.

2.2.2 Sea Level Monitoring Equipment and Data Analysis - Philip Woodworth

Another review presented by Dr. Woodworth was on sea-level monitoring equipment and data analysis. He presented various sea level measuring methods and equipment and discussed software for sea level analysis and astronomic tide forecast. A more detailed description is also presented in Annex IVl.

2.2.3 MedGLOSS Pilot Status and Future - Dov S. Rosen

The following presentation was given by Dov Rosen who reviewed the present status and discussed the implementation of the MedGLOSS pilot network of monitoring sea level stations in the Mediterranean and Black seas. First, he expressed thanks to CIESM and IOC and in particular to Prof. Frederic Briand, to Dr. Thorkild Aarup and to Dr. Colin Summerhayes for their scientific, financial and administrative support to organize the workshop and coordination meeting on MedGLOSS.

He presented the history of MedGLOSS activities from its start until the more recent activities, which were the installation of modern digital and automatic sea-level stations in Constantza port, Romania and planned identical stations in Split port, Croatia as well as later in Nador port, Morocco, thanks to the full financial support of CIESM.

These new stations will provide links to historic sea-level measuring sites (Constantza, Split) or in an area with missing sea-level information (Nador, Morocco). He expressed appreciation for CIESM's commitment for additional sea-level stations upgrades and hoped that similar funding could be found by IOC, in addition to additional aid from research funds (EU, World Bank, etc.). Dov Rosen discussed the problems related to obtaining funding for conducting GPS missions and installation of fixed GPS stations at key sea level stations, in order to enable monitoring of the reference benchmarks.

Rosen suggested changing the common name of tide gauge benchmark (TGBM) to the more correct name of sea level benchmark (SLBM). Finally, he raised the issue of management modus of the MedGLOSS pilot network, i.e. the determination of the best *modus operandi* for the success of the network implementation, operation and integration with other international programmes.

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2.2.4 MedGLOSS Sea Level Benchmark Monitoring Requirements and Methods of Geodetic Height Fixing - Suzanna Zerbini

Professor Dr. Susanna Zerbini presented a state-of-the-art review on the methods and equipment requirements for monitoring sea level benchmarks and, in a separate session, the recommended methods of geodetic height fixing and data analysis. She explained the importance of the appropriate selection of SLBM from the point of view of land stability and distance from the referenced sea level gauge. She explained that over the last decades new technologies have become available for the set up of global height reference systems. These enable to detect and monitor, to the required level of accuracy, vertical movements of the Earth's crust and to tie tide gauge benchmarks on a global well-defined reference system. Space geodetic methods such as Satellite Laser Ranging (SLR), Very Long Baseline interferometry (VLBI) and Global Positioning System (GPS) measurements can be used to fix the TGBMs in a global reference system. However, GPS has been demonstrated to be the technique of choice for this application. Absolute gravimetry constitutes an independent means to observe and monitor vertical movements at TGBMs and reference stations.

Since sea level gauges measure local sea level with respect to a benchmark on land (SLBM), height measurements are important in order to decouple vertical crustal movements from true sea-level variations. Prof. Zerbini presented a series of examples of relative sea level changes obtained from tide gauge measurements at Stockholm (Sweden), Fort Phracula (near Bangkok, Thailand), Honolulu (Hawaii, USA) and Nezugaseki (Japan), which indicated clearly how sea level trends can be influenced by different geological settings.

By means of space geodetic methods SLBM positions can be defined on the same global geocentric reference system, this enables a direct comparison of the sea level gauge data series. Permanent GPS sites should be installed at sea-level stations in order to monitor continuously vertical crustal movements. One point of particular concern is the tie between the SLBM and the tide gauge contact point, which is the reference point for this instrument. At present, this measurement is still performed by means of high-precision levelling, though there are ideas to develop alternative methodologies, which would allow continuous monitoring of the height variations between these two points. In the following a few recommendations are listed:

- levelling should be performed frequently (at least once/year) and a small local network of 5 to 6 points is needed for long term monitoring;
- episodic GPS campaigns are not recommended, due to the occurrence of seasonal height fluctuations which were observed at permanent GPS recording stations and which can contribute up to a few mm/yr to a long-term trend. Continuous monitoring by means of GPS allows a higher temporal resolution compared to that achievable with data collected during episodic campaigns. Only such installations allow the correlation and modelling of observed seasonal fluctuations in the station heights with relevant environmental parameters;
- GPS receiver distance from the SLBM should be less than 500 m;
- it is important to look for proper location to allow geodetic levelling between the SLBM and the contact point to the required level of accuracy. It is important to consider the geologic setting of the site. Benchmark location on solid rock is preferable;
- permanent GPS stations shall be remotely controlled;
- it is required that GPS receivers are of the dual frequency type;
- the station height should be measured to the few mm level of accuracy on a daily basis and vertical crustal movements of the SLBM shall be determined to an accuracy of one mm/yr or better. GPS data processing should be carried out by means of well-known international standard software packages such as, for example, the Bernese software package.

As regards permanent GPS installations, they should be realized in such a way to secure maintenance of the distance between the antenna phase centre and ground benchmark to the sub millimetre level of accuracy. Collection of additional data such as atmospheric pressure, humidity, soil moisture, water table level, temperature and rainfall is recommended in order to allow modelling of the seasonal height fluctuations.

In addition to the GPS measurements, it is recommended that absolute gravity observations be performed on a regular basis to have an independent mean to crosscheck the vertical movements estimated by means of GPS.

Susanna Zerbini presented comparative results gathered at Porto Corsini/Ravenna showing sea level change rates derived from tide gauge records, GPS and satellite altimetry. These are reproduced in Table 1 below.

Table 1: Sea level rates at Porto Corsini from tide gauge, GPS and satellite altimetry

Source of data	**Rate (mm/yr)**	**Time scale (years)**
Tide Gauge data: 1990-1998	21.4±2.2	9.0
GPS vertical rate	7.8±0.2	3.5
Tide Gauge - GPS	13.6±2.2	
TOPEX, North Adriatic (Cazenave et al., 1999)	14.7±3.2	6.0

2.2.5 Satellite Altimetry Measurements of Sea Level - Gilles Larnicol

Dr. Gilles Larnicol described the method of sea-level measurement from satellite via synthetic aperture radar (SAR) altimetry measurement. He explained that present technological achievement enables to monitor the sea level over ocean basins to an accuracy of about 6 cm.

Satellite radar altimetry has already proved its great potential in oceanographic research on large-scale phenomena. With new technological developments and new satellite missions to be launched in the coming years, the application of satellite radar altimetry on smaller scales (such as the Mediterranean basin) seems very promising.

He explained that satellite altimetry in principle allows the integration with tide gauge stations across continental shelf. One of the major tasks to be done for the analysis of sea surface topography and seasonal and long term changes will be the combination of data from different satellite missions. While satellite altimetry is very accurate far from the coast, it needs further improvement near the coasts. For this purpose, the availability of ground truth data from existing tide gauges to tie together altimetry and ground truth data is necessary. Hence, atmospheric data gathered at MedGLOSS sea-level stations may serve this purpose well.

In addition, measurements of atmospheric pressure at sea-level stations are important for removing the inverse barometer atmospheric loading from the measurements. Finally, satellite altimetry enables long term monitoring of sea level changes over large areas, since the same ellipsoid reference is used. With the planned launch of a satellite for the absolute geoid gravimetry measurement, it will be possible to further improve the accuracy of the determined absolute sea level topography. Nevertheless, sea level gauges will continue to play an important role in calibration and validation of satellite altimeter data.

The sea level analyses gathered from satellite altimetry at CLS in Toulouse are provided to the scientific community as well as on the Internet. He presented graphic examples of seasonal averaged sea-level elevation maps over the Mediterranean and Black seas derived from satellite altimetry.

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2.2.6 GPS Permanent Network in Israel for Geophysical Applications - Elena Ostrowsky

Dr. Ostrowsky presented the new GPS permanent network recently established in Israel by the Survey of Israel (SOI), and its geophysical applications including oceanographic applications. The new GPS permanent network enable a high resolution and high accuracy-levelling network, which can serve for scientific research purposes, such as tying sea level benchmarks to the Israel New Land Survey Datum and for long term monitoring of tectonic plate movements in Israel. Some of the stations also report their data to the International GPS Service (IGS). SOI also cooperates with IOLR in the long term monitoring of vertical and horizontal movements of the sea level benchmark as well as for a few other related check points, for the Hadera GLOSS station no. 80.

2.3 HANDS-ON TRAINING

2.3.1 Presentation of ISRAMAR and New Sea-level Stations' Equipment

This session was dedicated to a presentation of the sea level equipment used in the new MedGLOSS automatic sea-level stations funded by CIESM and integrated by IOLR under the leadership of Dov Rosen. Furthermore, a demonstration of the ISRAMAR computer software package developed by IOLR was performed. A detailed presentation of the equipment is presented in Annex IVi.

2.3.2 Show of Sea-level Stations' Equipment

A set of the MedGLOSS station equipment was presented to the participants for a hands-on evaluation. It included the Paroscientific underwater intelligent digital pressure sensor, Setra atmospheric pressure sensor, RDI Workhorse wave and current meter as well as the other equipment utilities such as the Garmin GPS used for accurate timing.

2.3.3 Show of Benchmark Levelling Equipment

Levelling equipment including GPS was presented to the participants, and a hands-on demonstration and trial session was conducted by Mr. Yosi Melzer, Head of Research Department of SOI.

2.4 FIELD VISIT

2.4.1 Visit to Hadera GLOSS Station Number 80

The participants travelled to the Hadera GLOSS station no. 80, located at the offshore end of the Hadera offshore coal-unloading terminal. This site was selected on a platform which was loaded with 900 metric tons, reaching full consolidation, while its 6 legs (1.8 m diameter each) were driven to more than 30 m in the sea bottom, located about 27 m below MSL, about 2.2 km offshore. Furthermore, according to geologists, there are indications that the coast in this area has remained stable in the last 2000 years, as confirmed also by the nearby roman aqueduct still present in well-preserved condition since that time.

2.4.2 Visit to Caesaria Antique Port and Roman Aqueduct

Following the visit of the Hadera GLOSS station no. 80, the participants visited the site of the ancient harbour of King Herod at Caesarea and of the roman aqueduct mentioned above.

3. CO-ORDINATION MEETING

3.1 PRESENTATIONS BY PARTICIPANTS

Professor Zerbini chaired the first part of the coordination meeting. It included presentations of the sea level station reports by the participants. These are given in the order of their presentation below.

3.1.1 **Ukraine** - Leonid A. Koveshnikov

There are now three governmental organizations involved with observation of parameters related to the sea level. The first is the Hydromet Service that has a net of posts based on visual observations and uses very old equipment. There were a total of 30 meteorological and sea level observing posts along the coast. However, due to the lack of funds, some stations stopped operating. There are sea level data at Yalta since 1901. The second organization is the Ukraine Hydrographic Service that is five years old. In 1999, it started with the first organization of a project on the safety of navigation in the Black Sea, for which sea level data are collected. The third organization is the Marine Hydrophysical Institute (MHI) of the National Academy of Science of Ukraine, located in Katsively, Yalta. It maintains the Katsively sea level station, with a very long sea level record, starting in 1928. MHI is firmly committed to the participation in the MedGLOSS programme and is willing to provide old and new sea level data. However, the existing equipment is quite old and requires upgrading.

3.1.2 **Spain** - Maria Jesus Garcia

The Spanish Institute of Oceanography (IEO) has monitored sea level since 1943 when a tide gauge network was established covering the Spanish coast. That network had 23 stations. Now the network consists of 13 tide gauges with six on the Mediterranean Coast; three in the Iberian Peninsula, two in the Balearic Islands and one in the African coast. These are the stations: 3 in the Strait of Gibraltar (Tarifa, Ceuta, Algeciras), 2 in the Balearic Islands (Palma de Mallorca, Ciudadela), one on the south coast of Spain (Málaga) and one in the Gulf of Cádiz. (Cádiz). Two of these stations (Ceuta and Palma de Mallorca) were selected for the initial MedGLOSS Pilot Network. All the stations are ready to fulfil the MedGLOSS requirements. Only the station at Málaga does not have a telephone line or an atmospheric barometer installed, but a telephone line can be installed. The station of Ciudadela is not working now because of a problem with the station housing.

The IEO network has been renewed by furnishing the float tide gages with encoders and data loggers with digital output enabling data transmission by modem. The sea level measurements are relative to the Tide Gauge Zero (TGZ), normally the chart datum. In collaboration with the IGN, that is the national responsible of the National Levelling Network, the TGBM had been connected to the National Geodetic Network.

Monthly mean sea levels are regularly sent to the PSMSL. Recently an annual bulletin which includes: mean sea levels, extreme sea levels, tidal ranges and harmonic constants was published and distributed to public authorities. Up to now, there is no definite data policy at the IEO but, in any case, many scientists are using the sea level data provided by IEO in their research. A more detailed description of IEO activities related to sea level monitoring is given in Annex IVc.

3.1.3 **France** - Bernard Simon

The activities of sea level monitoring in the Mediterranean by the French Hydrographic Service relate to the operation of the sea-level station with a very long record at Marseille, holding data since February 1885. This station is one of the major GLOSS stations in the Mediterranean. The original tide gauge is based on a floating device coupled with a mechanical integrator, and its housing

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was built on a solid rock site in 1884. Since June 1998 an acoustic sea level gauge with digital recording and automatic data transmission has been operating at the same site. A permanent GPS station has also been in operation since July 1998. This GPS Station is based on a Trimble SSI receiver with Margolin dome antenna. The GPS antenna is located on the roof of the sea level gauge building, directly above the sea level gauge. Based on the data gathered at Marseille up to 1998, a long-term sea level rise trend of 1.22 + 0.08 mm/year has been determined. This is similar to the trend obtained at Brest, where another very long record of more than 100 years is available.

For the purpose of satellite altimetry calibration, a new station has been established at Aspretto in Corsica.

3.1.4 **Morocco -** Karim Hilmi

Sea level records in the Mediterranean have been gathered in Morocco by the Navy Hydrographic Service since 1986, using a floating gauge with chart recorder. In 1989, the ports authority added another recording station. The National Institute for Fisheries Research started monitoring sea levels at Nador port in 1995 using an Aandera pressure transducer with internal logging. Mr. Hilmi attended the sea level training workshop organized at POL by IOC and CIESM and his institution agreed to participate in the MedGLOSS pilot network. A MedGLOSS automatic sea level station provided by CIESM will be installed in the Nador Port. This installation is planned for the second half of 2000. The station will also require benchmark establishment, levelling, and tying it to the international reference frame.

3.1.5 **Malta -** Aldo Drago

A long historical data set of sea level chart records in the Grand Harbour is kept at the British Hydrographic Office and covers the period 1876-1926. The sea level gauge was held in the French Creek except for a period of five years starting from 1903 when the measurements were transferred to Ricasoli. Records after 1926 were lost due to the world war. Since 1988, the Malta Maritime Authority has operated a mechanical sea level gauge for intermittent periods in the Grand Harbour. Originally, the instrument was stationed at Pinto Wharf. Analyses of 13 months of data from May 1990 to May 1991 were used to obtain the tidal harmonic constants in the harbour. Measurements were interrupted in 1994 and resumed in 1996 at a position close to the mouth of French Creek. The instrument is currently positioned at Ras Hanzir, which is at an inner location along the main channel of the Grand Harbour.

The Physical Oceanography Unit of the University of Malta has also conducted sea level monitoring. It was established in the early 90s under the Malta Council for Science and Technology. It now constitutes the research arm of the IOI-Malta Operational Centre at the University of Malta. The unit collects densely sampled (2 min.) sea level, barometric pressure and wind vector recordings at two recently installed permanent stations on the northern coastal perimeter of Malta, as part of an ongoing research programme initiated by the PO-Unit in 1993. These measurements constitute the first digitised set of sea level recordings in the Maltese Islands and are to date the longest time series of simultaneous water level and meteorological parameters in the Central Mediterranean.

The permanent sea level installation is positioned at the head of Mellieha Bay, which is a small embayment on the northwestern coast of Malta. It consists of an ENDECO type 1029/1150 differential pressure tide gauge that is clamped inside a small stilling well connected to the sea. The instrument measures absolute pressure; atmospheric pressure is compensated by means of a vented tube which passes through the top case unit and terminates inside an environmental isolator in the form of a small exposed PVC tube with a bladder. The tide gauge datum is regularly checked for stability. Sea levels are given referred to the zero of the tide gauge that is 2.6507 m below BM No. 9541811 established by the Mapping Unit of the Malta Planning Directorate. The station was equipped with a new ENDECO 600XLM probe in May 2000. The system is operated by solar power and will be used as a secondary station to the MedGLOSS station that is planned to be installed at Porto Maso marina, near Valetta. Meteorological parameters are measured by Aanderaa sensors at a nearby automatic weather station in Ramla tal-Bir that is situated on the coastal strip overlooking the South Comino Channel. The sensors are positioned in an unobstructed location at a height of 20 m from mean sea level. The data set consists of wind speed and direction, air pressure and temperature, relative humidity and net atmospheric radiation each measured at one or two minute intervals. The station has been in operation since April 1994. Meteorological data from this station is missing in the period between mid-October 1994 and mid-March 1995 due to a sensor malfunction caused by the stray effect of a nearby lightning stroke. A more detailed description of Malta activities related to sea level monitoring is given in Annex IVb.

3.1.6 **Croatia -** Nenad Leder

The Hydrographic Office of the Austro – Hungarian Navy, installed tide-gauges at Rijeka, Lošinj, Zadar, Hvar and Krf on the Croatian coast at approximately the same time with the installation of the sea level station in Trieste (1859). It is interesting that the official Geodetic Datum for Croatia is defined as the mean sea level at Trieste in 1875. Since then more than 40 tide-gauge stations have been placed at the eastern part of the Adriatic Sea. Since 1859, various types of instruments have been installed and tide-gauge and stations changed their owners many times, according to the stirring history of the regions.

Tide-gauge stations maintained by the Hydrographic Institute are Rovinj (1955-1999), Zadar (1991-1999), Split-Luka (1929-1941, 1947-1999), Sućuraj (1986-1999), Dubrovnik (1954-1999).

Additional stations are operated by the Andrija Mohorovičić Geophysical Institute of Zagreb at BAKAR (1929-1939, 1949-1999) and by the Institute of Oceanography and Fisheries of Split at Split-RT Marjan (1952-1999). All tide gauges are of the float type, the majority of Ott manufacture.

Tide-gauge constants are checked twice a year at each station. Standard deviation of tide-gauge constants is not higher than ± 0.1 cm, indicating that there were no movements between the tide-gauge housing and the surrounding pier. The Hydrographic Institute has published the results of sea level measurements every year since 1955. A more detailed description of Croatia activities related to sea level monitoring is given in Annex IVe.

3.1.7 **Israel -** Boris Shirman

The Survey of Israel (SOI) has been monitoring sea level along the Mediterranean Sea coast over decades. The main aim of the monitoring was to derive mean sea level values in order to determine the mean sea level. Since 1996, SOI has conducted sea level measurements with digital instruments with a resolution of 1 cm and data recording every five minutes. These are carried out by identical instruments installed at Tel-Aviv marina, Ashdod port and Ashqelon marina. The aims of the work are to distinguish long time periods and to compare average tide level with the current datum. Combined monthly sea level average data from Ashdod, Jaffa, Tel-Aviv and Ashqelon for the period 1961-2000 were used in a long-term sea level trend study. Missing data were provided via the maximum entropy method. Comparisons between the Yaffa and Ashdod data from 1968 to 1982 indicated a difference between tide levels of about 5 cm. All the data were referred to the Jaffa datum. A more detailed description of SOI activities related to sea level monitoring is given in Annex IVk.

3.1.8 **Romania -** Viorel Malciu

Sea level recording in Romania dates back to 1859, when the European Commission of the Danube initiated the observation of the sea level by setting up a visual tide staff (VTS) where three readings were made daily. These values were afterwards used for the entire Danube levelling. In 1933, a float-type gauge was placed at Constantza and it is still operational in the same place. The Romanian Marine Research Institute of the Ministry of Waters, Forests and Environment Protection,

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was assigned to carry on this activity since 1970 up to present. After 1974, three other tide gauges were installed on the Romanian coast for better coverage. These operational sea level gauges are located at Constantza, Tomis, Sulina and Mangalia.

In December 1999 a MedGLOSS new digital automatic sea level gauge (pressure transducer type) and atmospheric pressure sensor were installed in Constantza port in cooperation with IOLR, and funded by CIESM. This new station provides NRT data using the ISRAMAR software package.

A general, preliminary approach of the sea level long-term trend indicates that a slight rise of the values is evident. Analysis of the data set between 1933 and 1998 reveals that annual means are positive, with only two exceptions: -2.44 cm in 1943, the lowest annual mean, and -1.22 cm in 1983; and that the highest annual mean (29.70 cm) occurred in 1970, when exceptional runoff was recorded. The analysis of the data measured at the Constantza sea level gauge during 1933-1998 period revealed the existence of a rising trend, in good agreement with the estimates made by other authors for different locations or for the entire Black Sea basin (consistent with the contemporary eustatic trend). Significant inter-annual and inter-decadal variations have also been observed and estimated through Spectral Analysis. They were correlated with the changes in the Danube discharge, the main contributor to the river input into the Black sea. However, the time series are not long enough to allow for the secular oscillations to be accurately assessed. A more detailed description of Romanian activities related to sea level monitoring is given in Annex IVf.

3.1.9 **Spain** - Begoña Perez Garcia

The Spanish Harbours tide gauge network (REDMAR), is particularly focused on the status of the Mediterranean stations operated by Puertos del Estado (Spanish Harbours). It consists of 14 acoustic gauges with radio or modem transmission of data to the harbour office, where data are automatically sent twice a day by ftp or mail to the central station in Madrid at the Clima Maritimo department. This department has also developed a storm surge prediction system, called Nivmar, based on the ocean circulation HAMSOM model (which performs the prediction of the meteorological residuals), and the tide gauge data, which are used both to obtain the astronomical prediction in the harbours and to validate the system.

The sea level equipment consists of the acoustic gauge of SONAR Research & Development Ltd., which enables real time data transmission to the harbour offices and their maintenance has been very easy. 13 harbours were selected in 1991 to establish the REDMAR network, and the stations were tested by the Centro de Estudios de Puertos y Costas until July 1992, when the network officially began to work continuously. Since then, data are stored, quality controlled and analysed in the Clima Maritimo department. The stations of the Mediterranean are: Barcelona, Valencia and Malaga. Since June 1999 a pressure sensor is also working in the island of Hierro (Canary Islands), a point that will belong soon to the REDMAR network, and a new station is being planned for the Ibiza Island, in the Balearic Islands, in collaboration with other institutions to get a permanent GPS monitored station for altimeter calibration.

The acoustic gauges require protection from sun heating which may affect the accuracy, but the problem of the temperature gradient is less important in the Mediterranean stations, because the tide range here is very small.

Most of the REDMAR stations measure sea level data with respect to the harbour-working datum, a reference provided by the harbour authorities. Besides, the Instituto Geografico National (IGN) has provided the Tide Gauge Benchmarks (TGBM) and their relation to the national levelling system for all the stations. The connection between the TGBM and the tide gauge zero is the responsibility of Puertos del Estado, and is checked twice a year by the maintenance staff. The tide gauge contact point for the SONAR gauges is the ring around the centre of the transducer, and is levelled to the TGBM with a few millimetres precision.

The Nivmar model (http://www.puertos.es/Nivmar) is run twice a day, forced by meteorological fields derived from the INM (Instituto Nacional de Meteorologia). Data from the REDMAR tide gauges are used to forecast the tidal elevations, to validate the system and to perform data assimilation, correcting systematic errors in the mean sea level due to physical processes that are not included in the ocean model. The forecast horizon is 48 hours. The automatic data transmission from the harbours to Clima Maritimo and their inclusion in the Nivmar system is under development. At the moment, this is working for two Mediterranean stations: Valencia and Barcelona. A more detailed description of the Puertos del Estado Spanish activities related to sea level monitoring is given in Annex IVg.

3.1.10 Greece - Theodoro Kardaras

The Hellenic Navy Hydrographic Service (HNHS) is responsible for the national marine operational observing system concerning the measurements of the sea level variations in the Aegean and Ionian seas. Up to the present time, a network of 19 sea level stations exists. The stations are installed in various ports of the mainland and in a number of major islands and their operation is under the control of the local port authorities.

In each station, a mechanical float type tide gauge is installed and the TGBM/datum of observations is connected to a local benchmark network. The chart recordings are collected, processed, digitised and stored as hourly values. The initial processing includes the calculation of the statistical variables of the sea level time series for each month. The procedure described above is taking place at the HNHS installations that have the overall maintenance, monitoring and responsibility of the network. Introduction of the computerized digitisation and storing of data on magnetic devices started around 1969 for all stations.

In parallel to the sea level measuring stations network, the Hellenic Meteorological Service has in operation a network of meteorological stations. Most of the seashore meteo stations are located in the neighbourhood of the sea level stations and close cooperation exists between the two Services for the exchange of data. The HNHS issues an update information manual where geographical and statistical information is presented for each station. Specifically, for each sea level station, the tide gauge zero reference datum is depicted with a detail sketch showing the local benchmarks network. The statistics (MWL, LLW, HWL, etc.) for the time series of the sea level data are also included, since the start of operation. Also available is a report concerning the harmonic analysis of the sea level data for all the stations belonging to the network, with an emphasis on the tidal field in the Aegean area. Upgrading of the network is one of the primary objectives of the HNHS. A first step is to evaluate the cost/effectiveness of the network automation by installing near real time transmission of the data from the various stations. It has been done already for one station and there are plans for two more stations. The data is converted from analogue plot to digital data and logged for data storing and transfer to a remote computer.

A joint proposal between HNHS and the Institute of Marine Biology at Crete was submitted to the European Union aiming to establish two climatic sea level stations at Rafina (East to Athens) and at Plomari (Lesvos island, Eastern Aegean). Each station would consist of a bubble pressure sea level sensor, a number of meteo sensors and a GPS receiver. Data collected would be transmitted in near real time to the HNHS installations for further analysis and dissemination. In addition, a joint project between HNHS and the Technical University of Crete is underway to install a complete new sea level measurement station at GAVDOS Island, south of Crete and upgrade the existing sea level station at Souda. The proposed station will be equipped with a state of the-art tide gauge sensor, a GPS receiver, transponder and meteo sensors. This project aims at providing satellite altimetry calibration. A more detailed description of HNHS activities related to sea level monitoring is given in Annex IVd.

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3.1.11 **Israel -** Dov Rosen

Sea level was monitored in Israel during the British mandate in Jaffa harbour, in Haifa port and in Eilat. The measurements were performed using a float-type mechanical mareograph (sea-level recorder as in fact it measures the total sea-level due to astronomic tide as well as other parameters (temperature, atmospheric pressure, wind surge, wave induced set-up, etc.). However, the records of sea-level data gathered during the period prior to the establishment of the State of Israel are not available and have probably been lost forever. Sea-level data were gathered since then in Israel by a number of authorities for certain periods and certain locations as follows: Ports and Railways Authority (Haifa, Ashdod and Eilat), Meteorological Service (Haifa, Eilat), Survey of Israel (Eilat, Jaffa shifted now to Tel-Aviv marina), Geological Survey Institute (Atlith), Israel Oceanographic and Limnological Research (Hadera, Haifa, Eilat). During the 50s and 60s (monthly averages) at Jaffa harbour (1955-1959, 1962-1967) were transmitted to PSMSL and thus are found in its archive. Also monthly average values of sea-level data gathered at Haifa port (1956-1959, 1965-1976) and from Ashdod port (1958-1980) are archived there. Yearly reports of measured hourly values of sea levels were published by the PRA during the period 1958-1984. However, only some of those of the 60s and 70s included sea levels gathered at the Port of Haifa, while all the reports included hourly sea levels gathered at the Port of Ashdod (and some also at the Port of Eilat). Goldsmith and Gilboa (1985), who uncovered some additional data from Jaffa at SOI and reported the monthly means, have conducted a survey of the Israeli sea-level data in the past.

Since April 1985, the Ports and Railways Authority (PRA) division responsible for the preparation of the yearly reports was dismantled, and the gathered data on paper chart remained unprocessed until 1989, when SOI collected and manually processed these data. However, the manual processing of the data included only daily highs and lows at Ashdod port, without recording of the actual time at which they occurred. Newer data from Ashdod and Haifa (1989-1995) are presently undergoing digitising by SOI, including recording of the times of the lows and highs. The Jaffa station, which was used originally as the benchmark for the establishment of the Israeli sea-level reference datum, was dismantled and a new station was installed in Tel-Aviv marina in 1996. The Ashdod, Tel-Aviv and Ashkelon stations are maintained by SOI.

In 1992, IOLR installed a next generation digital sea-level monitoring station at Hadera, which since 1994 has been in the Global Sea-Level Observing System (GLOSS) network (No. 80). In 1994, IOLR started digital gathering of long-wave data in the Port of Haifa that, as a by-product also enabled gathering of sea-level data there.

In 2000, a joint IOLR and SOI agreement enabled the installation of an automatic next generation NRT sea-level station at Eilat, on the western coast of Gulf of Aqaba. A more detailed description of Israel and IOLR activities related to sea level monitoring is given in Annex IVj.

3.1.12 **Italy -** Fabio Raicich

A few sea-level gauges were in operation in Italy already in the last decades of the 19th century, but a coordinated national network started to operate on a regular basis only recently. Long and almost uninterrupted time series of sea-level data are therefore available only for a few Italian stations. In Italy the following Organizations are involved in sea-level measurement:

- Dipartimento per i Servizi Tecnici Nazionali, Servizio Idrografico e Mareografico Nazionale (SIMN), Rome, with regional Department in Venice;
- Istituto Idrografico della Marina (IIM), Genoa;
- Comune di Venezia, Centro Segnalazioni e Previsioni Maree (CSPM), Venice;
- Istituto Sperimentale Talassografico (IST), Trieste.

SIMN is a section of the Dipartimento per i Servizi Tecnici Nazionali, a governmental Organization formally belonging to the Prime Minister Office. It is the official national service in charge of operating the National Sea-level Gauge Network. Its network has been in operation since June 1998. It is composed of 28 sea-level gauges located at the following sites: Imperia, Genoa, Livorno, Civitavecchia, Porto Torres, Carloforte, Cagliari, Naples, Salerno, Palinuro, Palermo, Lampedusa Island, Porto Empedocle, Catania, Messina, Reggio Calabria, Crotone, Taranto, Otranto, Bari, Vieste, Tremiti Islands, Ortona, Pescara, Marina di Ravenna, Ancona, Venice Lido and Trieste. At each station sea level is measured by means of one ultrasonic gauge with temperature compensation and one float gauge with analogue record on paper. The station benchmarks are levelled relative to the closest IGM (Istituto Geografico Militare, Army Geographic Institute) datum. Other parameters are observed, namely wind vector at 10 m height, atmospheric pressure, air temperature and sea temperature. All data are stored locally and transmitted in real time to SIMN headquarters in Rome.

One of the SIMN regional departments, based in Venice (SIMN-Venice) operates a regional sea-level gauge network in addition to the national one, for civil protection purposes connected with storm surge hazard along the Northern Adriatic coast. The SIMN-Venice network is composed of 49 sea-level gauges. Thirty-six gauges are located within Venice Lagoon, 3 within Marano Lagoon, 7 at the outlets and in front of Venice Lagoon, 2 at the outlets of Marano Lagoon and one on the coast South of Venice Lagoon. Almost half of the stations are provided with real-time data transmission to the central office in Venice.

IIM is a State Organization belonging to the Italian Navy. Its activity mainly deals with navigation, including chart production. It operates two sea-level gauges in the stations of Genoa and Brindisi, equipped with mechanical float gauges. Data is continuously recorded on paper and subsequently digitised.

CSPM is a public Organization belonging to the city administration of Venice. Its activity includes sea level monitoring at five sea-level gauges and sea-level prediction. It is also in charge of giving warnings to the population of Venice when particularly high sea-level events are predicted. CSPM operates 5 sea-level gauges (CSPM, 2000), one within Venice Lagoon, 3 at the lagoon outlets and one located at the CNR platform “Acqua Alta”, approximately 8 m offshore, where meteorological parameters are also measured. Data is transmitted to the central office at fixed intervals.

IST is a research institute belonging to Consiglio Nazionale delle Ricerche (CNR). It operates one sea-level station in Trieste for research purposes, which is equipped with two float gauges. Analogue records are made on paper, and digital records are stored in solid-state memory. Atmospheric pressure, wind vector, air temperature and sea temperature are measured at two stations within 500 m from the sea-level gauge. Sea-level related activity includes sea-level modelling and joint analysis of sea-level and atmospheric data time series on different time scales, namely from hourly/daily, as in the case of seiches and storm surges, to interannual/multidecadal, concerning mean sea level variability. IST also publishes astronomic tide predictions for Trieste.

GPS receivers, operated by University of Bologna, have been installed at the SIMN sea-level station at Marina di Ravenna (July 1996) and IST station at Trieste (March 2000). A more detailed description of Italy activities related to sea level monitoring is given in Annex IVh.

3.1.13 Turkey - Coskun Demyr

Turkish National Sea Level Monitoring Network presently consists of one data centre in Ankara and four tide gauges located on the Mediterranean, Aegean and Marmara Sea coasts and is planned to be expanded in future. The existing four tide gauges, operated by General Command of Mapping since 1985 with an analogous system, were upgraded to high standards enabling automatic data collection and real time data transfer. Monthly sea level values are obtained from hourly data

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between 1985-1999 after pre-analysis and mean sea levels and their changes are estimated by applying the harmonic analysis method. GPS measurements have been carried out at those tide gauges between 1992 and 1999. Sea level data, GPS and precise levelling observations connecting the tide gauges are combined to estimate relations between mean sea levels as well as vertical crustal movements at Turkish coasts.

Modern sea level monitoring activities in Turkey dates back to 1936 when the General Command of Mapping, established the first tide gauge at the Antalya harbour. A second one was installed at Karşıyaka/İZMİR in 1937. Soon after, this was passed to the operation of the General Directorate of Meteorological Affairs which subsequently installed nine additional tide gauges at different coasts of the country at different time intervals. Time series from those gauges varies from 5 to 40 years. At all tide gauges sea levels were recorded to daily or weekly charts with an analogous system by means of a float on a cable in a stilling well. In the late 1970s, it was not possible to operate those gauges properly anymore due to pollution and damage of the stilling wells.

Four new tide gauges namely Antalya II, Bodrum II, Menteş and Erdek were established and activated with the available analogous system in late 1985. At these stations sea level variations had been recorded to the weekly charts and ancillary data such as atmospheric pressure, air temperature, humidity, sea temperature had also been measured once a day. Graphical records together with the ancillary data were sent to the data centre. Monthly and hourly values were digitised manually and issued annually to the related national and international institutions.

As a first step towards establishing a modern sea level network in Turkey, the existing tide gauges were upgraded to GLOSS standards in 1999. Presently, all stations consist of a data collection unit with a self-calibrating acoustic ranging sensor and meteorological sensors such as atmospheric pressure, air temperature, air humidity, wind velocity and wind direction. Sampling rate is 10 seconds for the sea level data and 1 minute for the ancillary data. Measurement of sea level is based on a 10-minute average whereas meteorological parameters are based on an hour average. The data are downloaded to the data centre every three days using telephone lines and they are checked regularly for quality control.

To check the tide gauge datum and to monitor the local vertical movements at or near the gauges, the local levelling network consists of about three to five points that have been measured at 1- and 2-year intervals. Within the frame of other projects, periodic GPS measurements have been carried out since 1991. There are 3-4 year periodic GPS data that are most valuable in terms of tide gauge fixing. A first epoch of absolute gravity measurements were also carried out at tide gauge sites in 1997. The available monthly mean sea level values obtained from the newly digitised data were analysed and corrected for errors as far as possible. Mean sea level (MSL) and its change was calculated at four tide gauges. These values were incorporated with the national levelling data for the analysis of latitudinal changes of the mean sea levels. In addition to this, long-term changes of the MSLs and periodic GPS measurements were also combined to learn about vertical crustal movements.

The GCM spent much effort to re-process the historical sea level data using suitable methods as well as upgrading and expanding the existing sea level network. The data obtained by analogue systems are subject to many errors coming from both instrumental drift and the method of digitisation. In order to eliminate the errors as much as possible we started to re-digitise historical graphical records with a computer-aided digitiser in 1995 and this work is still going on.

GPS campaigns conducted between 1993-1999 at gauges in Turkey were processed with the BERNESE software version 4.0 using IGS products following the strategy proposed by EUREF subcommission. Analyses of available monthly sea level values and periodical GPS measurements provided important information on sea level trend and vertical crustal movements at the tide gauges and latitudinal sea surface gradient in Turkey. Yet, the results are considered preliminary, and need to be improved with additional GPS and sea level data. (See also Annex IVa).

3.1.14 Gibraltar - Philip Woodworth

The Gibraltar sea level station is maintained by the Queen's Harbour Master, H.M. Naval Base, Gibraltar. The sea level gauge is of the float gauge type. The Data was gathered between 1961-1990. From 1991 to 1993, there is a data gap, until a new gauge (Lea) was installed. Since 1993 to present, data is gathered but is archived only to 1996 in PSMSL, later data being awaited. The sea level gauge is still functioning well, (as updated in May 2000). The chart-recorded data are digitised by the Hydrographic Department, Taunton (Cmdr. John Page).

There is no direct contact between QHM and PSMSL, only via HD. The QHM, and not HD, controls the budget for gauge maintenance. Suggestions have been made by POL to upgrade the gauge for near real time which QHM will consider (May 2000).

GPS data has been collected for limited time periods in SELF and SELF II in mid-1990s, but there is no permanent GPS. For benchmark information, see GLOSS handbook and SELF-manual. The GLOSS Handbook web page contains hourly values from 1961-90. PSMSL web pages contain monthly data and plots. (See also Annex IVm).

3.1.15 Russia

As Dr. Zilberstein was unable to attend the meeting, a summarized description of the Russian stations in the Black Sea is given below, and a more detailed description is presented in Annex IVn.

Russia is forwarding mean monthly and annual sea level for its GLOSS stations, and one is located in the Black Sea at Tuapse, transmitting in NRT mode. Presently there are five sea level stations in operation on the Russian seashore of the Black Sea: Tuapse (1917-2000), Anapa (1917–2000), Gelendjik (1921–2000), Novorossisk (1923–2000) and Sochi (1916- 2000). Data for the period of 1977-1996 have been collected in digital form in ARRIHI-WDC (Obninsk). The Black Sea level network of the former USSR included the 36 sites. Duration of the observation series exceeds 50 years at the most part of the sea level sites, and exceeds 100 years at several sites of the former USSR (for example Odessa, Ochakov, Sevastopol, Batumi, Poti).

All sea level sites heights are determined relatively to major and auxiliary geodetic marks attached to a unified national geodetic reference system. At the majority of stations in Russia the sea level measurements accuracy meets GLOSS requirements. Unfortunately, the accuracy of regular routine observations is a little worse, and there are considerable shifts in the registration of the times of observations.

Some information on vertical plate tectonics in the Black Sea is found in literature. Mean velocity of the vertical movements of the Earth core does not exceed 1mm/year for the most part of the seashore sites.

For the majority of both Russian and the former USSR sites good correlation of annual oscillation with river flow exists.

At Tuapse a tendency of sea level rise was determined from the data gathered, while the opposite was obtained for Gelendjik, indicating that the latter data should be rechecked.

3.1.16 Mediterranean Forecasting System project - Steve Brenner

Dr. Brenner presented an overview of the Mediterranean Forecasting System international project supported by the European Commission. The first stage of this programme is the provision of weekly forecasts of the circulation and sea-levels in the Mediterranean basin, based on assimilation of NRT and long term data and operation of a Princeton 3D ocean circulation model version calibrated for the Mediterranean basin. He explained that ground truth data on sea level could improve the model

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calibration and validation.

3.2 DISCUSSIONS ON MedGLOSS PILOT IMPLEMENTATION

After presentation of the status of the MedGLOSS and other sea-level stations, the meeting participants conducted a one and a half day session of round table discussions on the objectives of MedGLOSS and its pilot network structure and active implementation. Dov Rosen chaired this session. In his opening remarks, he expressed the hope that the participants had updated their knowledge on the situation of the sea level stations in the states participating in MedGLOSS and would use this knowledge in their suggestions and decisions. Dov Rosen further reminded the participants that among the meeting tasks were the formulation of an agreement for data sharing and near real time data transmission, selection of regional centres for data gathering, processing, quality assurance and for assimilation, utilization and dissemination to the public of the outcomes, as well as for the provision of technical and training support to neighbouring MedGLOSS members in need and finally the identification of sources for raising additional funding for MedGLOSS stations upgrading and for submission of joint research proposals for research. Dov Rosen asked the participants to present their views on the objectives presented and any other suggestions, questions and/or remarks, as they felt appropriate. Afterwards the roundtable discussions started, and below are the minutes of the main remarks of the participants, in the order they were made (based on notes taken by Rosen). The participants are identified by their last name.

Purini: *The participants should focus in the discussions on the major tasks, namely NRT data for operational oceanography, preparation of joint proposals to the European Commission research funds and international support on obtaining matching funds on national level to those received from international bodies.*

Zerbini: *Propose to start this session by preparing an inventory of all suitable and available stations, mark all proposed MedGLOSS stations on a map and then have decisions of priorities and standards for the stations.*

Leder: *Agrees with Prof. Zerbini, wants to know who are the proposed regional centres for MedGLOSS suggested in the MedGLOSS pilot network set-up document.*

Drago: *Suggests to define the strategy and data utilization and transfer policy within MedGLOSS members and with external bodies such as MFS. He expressed his opinion that for the pilot network it would be better to have one focal Mediterranean sea level centre, while other regional centres would be related to future expansion of MedGLOSS and be involved with the operational parts. Since IOLR has already taken this duty so far he suggests it continues to be the focal sea level data centre.*

Raicich: *Agreed with Prof. Zerbini suggestions. Also, for the long-term operation of MedGLOSS network stations there is need of financial support for both manpower and equipment.*

Malciu: *Mentioned that the MedGLOSS pilot network start up has already been agreed to by the IOC and CIESM, meaning that this gives strong international support of MedGLOSS importance to all national authorities. He remarked that beyond the initial costs of equipment and installations, the long term operation and data transmission also impose needs for financial funding, even though the maintenance costs are reduced in comparison with the initial expenses. Supports that IOLR will be the focal point sea level centre for the pilot stage.*

Koveshnikov: *Regarding start up of the operational pilot network he thinks that each station can start its MedGLOSS activity just by sending the existing data. However, he would like to have better definition of the needs from the data providers.*

Simon*:* *Agreed with Prof. Zerbini as for the first discussion step. In regards to data transmission in near real time, SHOM is not ready yet to transmit NRT to MedGLOSS but he will check the issue when he returns home and will update on the situation.*

Rosen*:* *Reminded that the Marseille station is a major GLOSS station, supposed to provide NRT data to GLOSS so he hopes that these data will be made available to MedGLOSS as well. He mentioned that the NRT transmission rate from the MedGLOSS stations is supposed to be 1 hour. Such rate is already reported from Hadera GLOSS station 80 and at Constantza station. He also accepted Prof. Zerbini's proposal. In regards to the regional data centres, he reminded that the initial set-up until the decision on the regional centres is taken, was that IOLR takes care of the sea level data (to be passed also to PSMSL), CLS takes care of satellite altimetry and will receive the atmospheric data measured at MedGLOSS stations and that Prof. Zerbini's Department at the University of Bolognia will get the benchmark data (GPS, absolute gravity, etc.).*

Larnicol*:* *Would like to have the definition of the MedGLOSS strategy. In regards to the atmospheric pressure data, CLS does not want to collect the data directly from each station separately, but rather receive it via the international meteorological bodies (WMO). Thus, he'd rather have the atmospheric data gathered by the same body which will collect the sea level data.*

Purini*:* *He would like to understand better why the real time data is needed, namely for what purposes and needs. In his opinion, it could be difficult to have near real time transmission systems as these involve increased costs. To cut down costs perhaps the NRT update rate should be twice per day, as this most probably are sufficient for most purposes.*

Simon*:* *He does not have any estimate on the costs involved with NRT data transmission so first needs to have an estimate of the expected costs. However, the most important issue is to save the measured data. In regards to the data from Marseille, he will check next week in Paris.*

Rosen*:* *Asks to have suggestions for a Memorandum of Understanding (MOU) on the provision of data. Mentioned that the policy for the sea level data from Hadera station is to provide it free to the scientific community. We would prefer to have a number of regional centres in order to spread the load of work, but would agree to be one of the regional sea level data centres.*

Koveshnikov*:* *Can provide both old and new data but only from Katcively, but the problem, as mentioned before is that equipment used is old and needs upgrading.*

Malciu*:* *The Romanian MedGLOSS sea level station in Constantza port already transmits NRT data, however the telephone and Internet service costs are rising, making the data transmission difficult due to the financial situation.*

Raicich*:* *The transmission of NRT data for us is a problem, we lack manpower for this purpose, perhaps one person per station. Our data is gathered off line since1939, but there are sea level records since 1917.*

Drago*:* *A strategy document is needed including free sharing of the data by the MedGLOSS pilot network. Historical data is not given priority but should be saved by digitising. The sharing of data to others could be via placing data and/or products on the web. Funding of station operation and maintenance is necessary to ensure routine long-term operation.*

Leder*:* *Agreed with Raicich on the NRT sea level data transmission. Being in bad financial condition, the phone and Internet transmission needs funding (cost estimated to $100/month) which is unavailable at present. Without additional funds, data may be*

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transmitted only once/week. Their stations need a GPS campaign for benchmarks fixing.

Zerbini*:* *Cannot talk about tide gauge data. For plate tectonics, the products may be delayed tide gauge data. Regarding GPS data we have to look at it in a different way since there is no real time solution of the GPS network derived vertical movements but it takes some 10 days to get solutions. Regarding standards, one should take the resolutions recommended by Mike Bevis' commission namely cm resolution for oceanographic purposes and mm resolution for issues related to climate change. Suggests to look at climate related effects, which imply certain standards. Some will be to the cm agenda, others on the mm agenda. It is necessary to identify those stations that have already or will have soon permanent GPS receiver stations and have to agree to the set standards. In regards to funding based on research proposals, they can help only on a temporary basis, not for long-term operation commitments. Regarding engineering or commercial use of the data, a policy should also be decided.*

Raichich*:* *Reminds that most customers are interested in relative sea level data and not eustatic sea level data.*

Zerbini*:* *Within MedGLOSS objectives it is necessary to define the NRT data provision necessity.*

Rosen*:* *Suggested to prioritise the sea level stations according to their objectives of operation, namely: climate related sea level data, operational oceanography related sea level data and according to these categories choose the stations needed to provide NRT data. Also remarked that the NRT data allow for a better quality control.*

Drago*:* *Operational oceanography needs NRT data, but please remember that there is a delay of 1 week in sea level data via satellite altimetry, due to the processing time involved.*

Woodworth*:* *The operation of the Mediterranean barotropic model needs updating of sea levels and atmospheric pressure every day.*

Hilmi*:* *There should be standardization of the data processing. So far, our data is not NRT but we agreed to receive and operate a MedGLOSS NRT sea level station donated by CIESM, to be installed in Nador port.*

Jesus Garcia: *For improving budgeting to the MedGLOSS participating institutions, one must influence their governments via IOC and CIESM. There is need for a written document from IOC and CIESM recommending such support.*

Perez*:* *Agrees with Jesus Garcia completely. Permanent GPS receivers cannot be installed and maintained without appropriate funding with long-term commitment. For example, only Alicante has permanent GPS receiver station.*

Turker*:* *Agreed that real time data are necessary, but the Hydrographic Service cannot provide such data as it does not have digital data. It would be willing to provide if they had. However, it has historical sea level data which can be provided.*

Kardaras*:* *Our data are readily available as 1 month delayed sea level data. We will have three digital stations by the end of 2000. Also two climatic stations. Transfer of the NRT sea level data will be discussed with our authorities. The problem with GPS permanent stations must be discussed too. We would be willing to take responsibility in regards to a regional MedGLOSS centre.*

Demyr*:* *Our organization is operating now four NRT sea level stations. There is need for an agreement on GPS data provision. We are digitising the historical sea level data and we would be interested to be one of the regional MedGLOSS centres.*

Woodworth: *Is not optimistic about the future of NRT data. Past data must be available. It is necessary to have a GPS committee and adopt for MedGLOSS the standards proposed to be accepted internationally for GLOSS. MedGLOSS should provide its data also to the international sea level centre in Hawaii after full quality analysis of the data is performed. It is nice to have standards for the data analysis but this is not very important. In addition, it is important that MedGLOSS will have a data transfer policy and publish it to the public knowledge.*

Larnicol: *Has no comments on tide gauges; CLS is involved in MFSPP; CLS prefers to have the atmospheric data sent to meteorological centres or to the sea level centre of MedGLOSS.*

Woodworth: *Recommends that MedGLOSS adopt a 2-mode data gathering approach: a NRT mode for certain stations and a delayed mode for the other stations. He is interested in the subject of data archaeology since there is a lot of old data that may form a most important set. The straits should be equipped with NRT sea level gauges. Also, after an initial GPS mission at all stations, installation of permanent GPS receivers should be done at the delayed mode stations with long sea level records and to all GLOSS primary sea level stations. Recommends preparing a one-page summary of the meeting for the forthcoming IOC Executive Council Session.*

Demyr: *Would like to clarify which of the proposed sea level stations meet which requirements.*

Kardaras: *It is necessary to receive information on the adopted standards. In regards to funding, suggested that bilateral agreements of Hydrographic Services may become an additional source of financial funding.*

Perez: *The proposed 2-mode approach of data transfer is much more realistic. The division of the sea level activities to a number of regional centres will be cumbersome. In the pilot phase, only one focal point should gather the sea level data from the MedGLOSS participants. Standards for data quality assurance and dissemination must be applied. Suggests also that IOLR will be the focal sea level centre.*

Jesus Garcia: *Each national data centre should be ready to submit its data at the time of the start of data operation of the MedGLOSS pilot network. Supports Perez concerning one focal sea level data centre for the pilot network.*

Hilmi: *Agrees fully with Zerbini. His institute will need assistance with the benchmark fixing to the international reference system.*

Rosen: *Should discuss the MOU main items. Suggests it will include a description of the objectives, the data processing commitments, and the data sharing/exchange policy. It should also include policy meetings and conferences, list of regional centres and their duties. It should also include a technical annex concerning agreements on GPS campaigns and permanent GPS operation, and on historic sea level data digitising and archiving. Furthermore, the national members should include not only sea level measuring bodies but also geodetic bodies. It should also address the need for national funds to support GPS/Absolute Gravity missions and for long-term maintenance and operation of permanent GPS stations and sea-level stations. Supports the request to IOC and CIESM to prepare a joint document asking national authorities to financial support of MedGLOSS participating national organizations.*

Following the discussions, an updated survey of the duties and the suitability of various sea level stations were conducted among the participants. The results of the survey were summarized and discussed until a consensus layout configuration of the updated pilot network of sea level stations was achieved. It is presented in table 2 (in 3 parts due to lack of space) and map in the Mediterranean and Black seas.

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Based on the integration of the data of the various stations proposed to be included in MedGLOSS pilot network, it was decided for each station what should be its modus of operation (NRT transmission twice a day or in delayed mode).

The delayed mode was defined as provision of hourly sea level data with a delay of up to 6 months from the date of measurement. The chosen status is shown in Table 2 part b on the SLG (sea level gauge) column and the station primary objectives are described in the Main Objectives column there.

A photo of the co-ordination meeting participants is shown below (clockwise from left side):
Ahmet Turker, Theodoros Kardaras, Coşkun Demyr, Philip L. Woodworth, Dov S. Rosen, Gilles Larnicol, Maria Jesus Garcia, Nenad Leder, Bernard Simon, Begoña Perez Gomez, Roberto Purini, Suzanna Zerbini, Lazar Raskin, Karim Hilmi, Fabio Raicich, Viorel Malciu, Aldo Drago, Leonid A. Koveshnikov (deceased).

Furthermore, at the request of additional participants, IOLR accepted to become the focal centre for sea-level data and atmospheric data for the pilot network. As a result, Dov Rosen announced that upon further discussion with IOLR Director-General Dr. Yuval Cohen, IOLR accepted this duty and thanked all participants for their trust and hoped to prove to be worth of this honour by making MedGLOSS pilot network into an all Mediterranean and Black seas common network.

The legend of abbreviations in Table 2 is given below:

OP- operational;
NO - not operational;
P - pressure;
t - temperature;
SLG - sea level gauge;
SF - strait fluxes;
LT - long term;
NRT - near real time data transmission;
DLY - delayed mode data transmission;
ABS - absolute gravity;
Wind - wind parameters;
Waves - waves parameters;
Current - current parameters;
Salin - salinity

Table 2a – Status of updated MedGLOSS selected stations, part a (legend)

No.	**NRT MedGLOSS station #**	**Station Name**	**Latitude** (deg.)	**Longitude** (deg.)
1	1	Ceuta	35.900	-5.317
2	2	Gibraltar	36.117	-5.350
3		Malaga	36.900	4.433
4		Alicante	38.210	-0.290
5	3	Barcelona	41.385	2.177
6	4	Palma	39.583	2.633
7	5	Marseille	43.300	5.350
8	6	Aspretto	41.933	8.817
9		Genova	44.400	8.900
10		Napoli	40.833	14.250
11		Otranto	40.133	18.500
12		Brindisi	40.633	17.933
13		Ravenna	44.500	12.283
14		Medicina	44.478	11.632
15	7	Trieste	45.650	13.750
16	8	Split	43.507	16.442
17		Dubrovnik	42.667	18.067
18		Porto Empedocle	37.283	13.533
19		Cagliari	39.200	9.167
20	9	Porto Maso	35.909	14.519
21		Alexandropoulis	40.850	25.883
22		Thessaloniki	40.617	23.033
23		Skopelos	39.132	23.723
24	10	Chios	38.376	26.140
25	11	Piraieus	37.940	23.639
26	12	Rhodos	36.433	28.233
27	13	Souda	35.500	24.050
28	14	Kalamata	37.017	22.133
29	15	Preveza	38.950	20.767
30	16	Antalya	36.833	30.617
31		Bodrum	37.036	27.429
32		Mentes	38.414	26.732
33		Erdek	40.383	27.850
34		Istanbul	41.004	28.976
35	17	Burgas	42.501	27.487
36	18	Constantza	44.167	28.667
37	19	Katcively	44.416	34.050
38	20	Tuapse	44.100	39.067
39	21	Paphos	34.783	32.401
40	22	Hadera	32.467	34.917
41		Ashdod	31.811	34.635
42	23	Alexandria	31.217	29.917
43	24	Nador	35.167	2.950

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Table 2b – Status of updated MedGLOSS selected stations, part b (legend on previous page)

NRT station #	Station Name	Main Objective	Operation Mode NRT / DLY	GPS type C / E	Gravity ABS /REL
1	Ceuta	SF	NRT	C	ABS (done)
2	Gibraltar	SF, LT	DLY (NRT)	E	?
	Malaga	LT	DLY	E	
	Alicante	LT	DLY	C	ABS (done)
3	Barcelona	Storm Surges	NRT	E (EUVM)	?
4	Palma	seiches	NRT	C? E (av.)	?
5	Marseille	LT	DLY (NRT)	C	ABS (done)
6	Aspretto	Altimeter Calibr.	DLY (NRT)	C	?
	Genova	LT	DLY	C (rogue)	ABS (done)
	Napoli	LT	DLY	C (Leica) ?	ABS (done)
	Otranto	SF	DLY	-	-
	Brindisi				
	Ravenna	LT	DLY	C (Leica)	ABS (done)
	Medicina	LT	-	C (Leica)	ABS regular+g continuous
7	Trieste	LT, Extreme events, prediction	DLY (NRT)	C (Leica)	ABS (done)
8	Split	LT,Extreme events	NRT	E	-
	Dubrovnik	LT	DLY	E	-
	Porto Empedocle	Sicily channel flux	DLY	-	-
	Cagliari	LT	DLY	C (Rogue) ?	-
9	Porto Maso	SF, seiches, LT	NRT	E	-
	Alexandropoulis	LT	DLY	E (au.)	ABS (done)
	Thessaloniki	LT	DLY	E	-
	Skopelos	LT	DLY	E	-
10	Chios	modelling, prediction	NRT	E	
11	Piraieus	modelling, prediction	NRT	E (au.)	ABS (done)
12	Rhodos	modelling, prediction	NRT	E (au.)	ABS (done)
13	Souda	modelling, prediction	NRT	E (au.)	ABS (done)
14	Kalamata	modelling, prediction	NRT	E (au.)	ABS (done)
15	Preveza	modelling, prediction	NRT	E (au.)	ABS (done)
16	Antalya	modelling, prediction	NRT	E (au.)	ABS (done)
	Bodrum	LT	DLY	E (au.)	ABS (done)
	Mentes	LT	DLY	E (au.)	ABS (done)
	Erdek	LT	DLY	E (au.)	ABS (done)
	Istanbul	SF	DLY	E	
17	Burgas	LT	NRT	E	
18	Constantza	modeling, prediction	NRT	E	-
19	Katcively	modeling, prediction	DLY (NRT)	E	-
20	Tuapse	LT	DLY	E	
21	Paphos	LT, modelling	NRT		
22	Hadera	LT, modelling	NRT	Trimble	-
	Ashdod	LT	DLY	E	-
23	Alexandria	LT	DLY (NRT)	E	
24	Nador	modelling, prediction	NRT	E	-

Table 2c – Status of updated MedGLOSS selected stations, part c (legend above)

NRT station	Station Name	Other Parameters	Status SLG	Status GPS	Remarks
1	Ceuta	P, t	OP	to be installed	GLOSS-episodic GPS - carried out
2	Gibraltar	P, t	OP	?	SLG requires upgrade; GLOSS station, Meteo. from Gibrltr. Airport
	Malaga		OP		
	Alicante	P	OP	OP	Zero Spain Levelling Network
3	Barcelona	P, t, wind	OP	?	>1cm accuracy for inst. measurements
4	Palma	P, t	OP	to be installed	SLG requires upgrade, GPS Rel. for EU network;? dist. of GPS to SLG
5	Marseille	P, t	OP	OP	Zero - France Levelling Network
6	Aspretto	P, t	OP	GPS scheduled in 2000	JASON Satellite Altim. Mission Calibr. Site
	Genova	P	OP	move GPS closer to SLG	Discuss agreement with Italian Navy; Zero of Italy Levl. Network
	Napoli	P	OP	if available	GPS to be discussed
	Otranto	P, t, H, wind	OP	-	
	Brindisi				
	Ravenna	P, t, H, WT, RF	OP	OP (since 1996)	
	Medicina	P, t, H, WT, RF, BRS	NO	OP (since 1996)	GPS reference site, no SLG
7	Trieste	P, t, H, SR, WI, WTE	OP	OP	RT achievable
8	Split	P, t, wind	OP	-	
	Dubrovnik	P, t, wind	OP	-	
	Porto Empedocle	-	OP	-	
	Cagliari	P, t, H	OP	OP few km to SLG	GPS ASI
9	Porto Maso	P, t, wind	OP	-	Meteo data to be acquired from a station 15 km far from SLG in 1 yr
	Alexandropoulis	P	OP	?	
	Thessaloniki	P	OP		
	Skopelos	P	OP		
10	Chios	P	OP		
11	Piraieus	P	OP		
12	Rhodos	P	OP		
13	Souda	P	OP		
14	Kalamata	P	OP		
15	Preveza	P	OP		
16	Antalya	P, t, H, wind	OP		4 - 5 GPS Epoch campains available
	Bodrum	P, t, H, wind	OP		1 Epoch Abs. Gravity
	Mentes	P, t, H, wind	OP		1 - 2 year interval, high prec. levelling
	Erdek	P, t, H, wind	OP		
	Istanbul	P, t, H	OP		Suggested new station
17	Burgas	?	?		Requires upgrading
18	Constantza	P, t, wind	OP	GPS visit done	GPS visit (EUREF, 1997); Abs. Gravimetry-1995
19	Katcively	P, t, waves	OP		Zero Baltic Levelling Network
20	Tuapse	P,	OP		Needs upgrading
21	Paphos	P, t, H, wind	NO		To be installed in 2001
22	Hadera	P, t H, wind, salin; currents, waves	OP	Yearly visits	New permanent GPS station to be installed in year 2001
	Ashdod	P, wind	OP	Yearly visits	
23	Alexandria		?		
24	Nador	P, t, wind	NO		New station, to be installed in Fall 2000, GPS and Meteo needed

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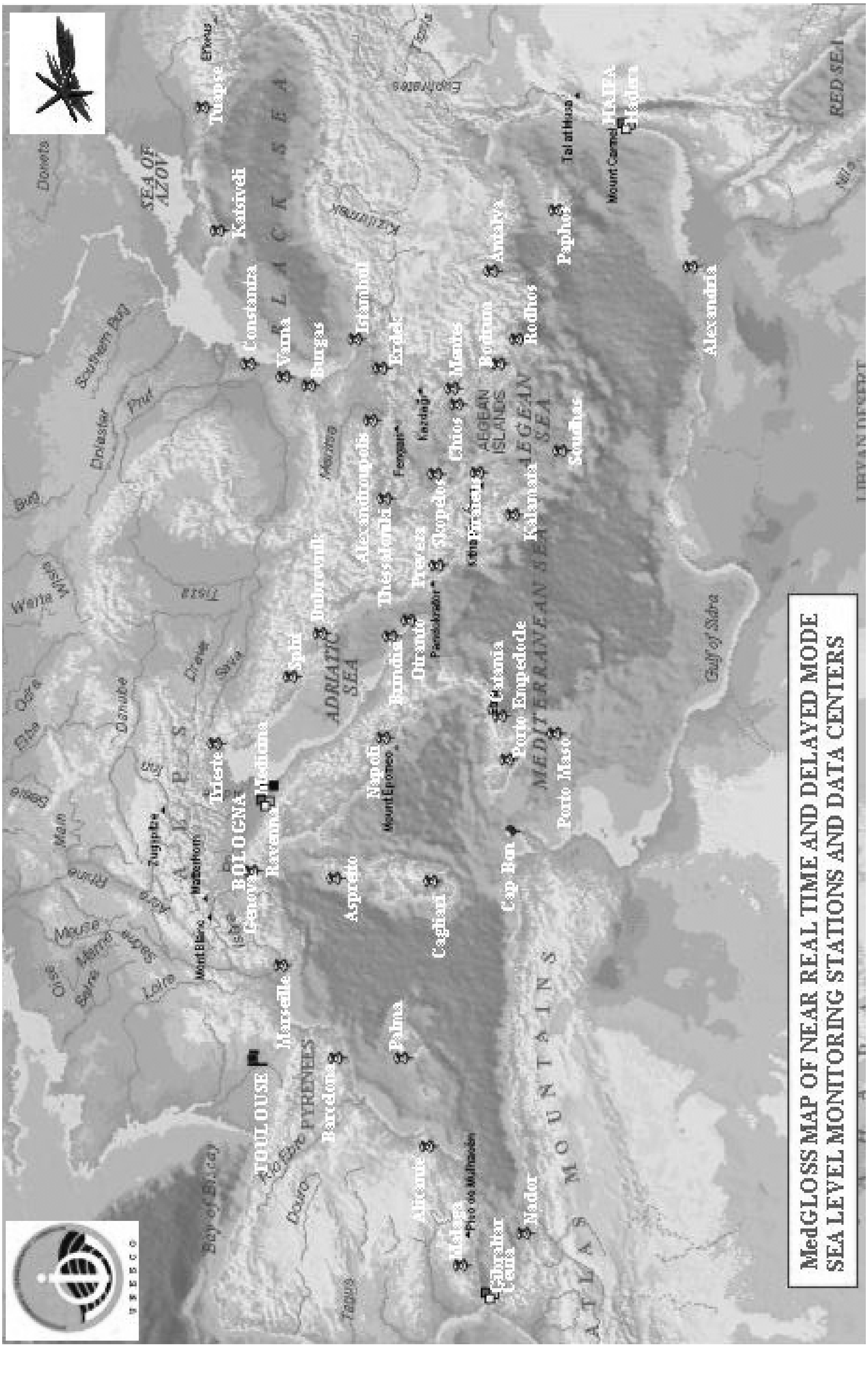
MedGLOSS MAP OF NEAR REAL TIME AND DELAYED MODE
SEA LEVEL MONITORING STATIONS AND DATA CENTERS
BLACK SEA
SEA OF AZOV
ADRIATIC SEA
AEGEAN SEA
AEGEAN ISLANDS
MEDITERRANEAN SEA
RED SEA
ALPS
PYRENEES
ATLAS MOUNTAINS
Bay of Biscay
Gulf of Sidra
LIBYAN DESERT
TOULOUSE
BOLOGNA
HAIFA
Gibraltar
Ceuta
Malaga
Nador
Almeria
Alicante
Barcelona
Palma
Marseille
Genova
Aspretto
Cagliari
Cap Bon
Ravenna
Trieste
Napoli
Porto Maso
Porto Empedocle
Catania
Split
Dubrovnik
Brindisi
Otranto
Preveza
Thessaloniki
Alexandroupolis
Erdek
Istanbul
Burgas
Varna
Constantza
Katsiveli
Tuapse
Chios
Mentes
Bodrum
Rodhos
Antalya
Paphos
Soudhas
Kalamata
Alexandria
Hadera
Tal at Musa
Mount Carmel
Zugspitze
Mont Blanc
Loire
Seine
Rhine
Danube
Elbe
Oder
Tisza
Drava
Sava
Dniester
Southern Bug
Prut
Donets
Euphrates
Tigris
Nile
Douro
Tagus
Rio Ebro

3.3 DECISIONS

Based on the discussions held, proposals for meeting decisions were raised. The following items constitute the major decisions unanimously agreed to by the participants:

The MedGLOSS programme initiated by IOC and CIESM is considered very important to the national and international society for monitoring of sea-level rise due to forecasted climate change, for monitoring of long term plate tectonic movements and for providing boundary conditions and ground-true data to operational oceanography modelling and now casting in the Mediterranean and Black Seas.

The participants agreed that the MedGLOSS pilot network will consist of 40 selected monitoring stations (2 additional stations to be installed in Morocco and in Cyprus). Of these 21 will operate in near real time mode providing at least twice a day data for operational oceanography (strait fluxes, surges, satellite altimetry calibration, etc.), while 32 of them (with long historic records) will act in delayed mode, providing data at least every 6 months for long term monitoring and prediction.

All MedGLOSS stations have to measure and provide data according to the international standards defined for GLOSS stations. Minimum data will include hourly averaged values of sea level and atmospheric pressure.

All near real-time stations need to have their reference benchmarks measured by GPS missions at 1-2 year intervals, while those selected also or only for long term monitoring, need installation of permanent GPS monitoring stations at or near the benchmarks.

Rescue of existing historic sea-level data (digitisation) at the pilot stations should be given assistance and considered of high priority.

The participants expressed their appreciation to IOC and CIESM for supporting the meeting and to CIESM also for providing funds to upgrade sea-level stations in a number of countries. In view of the relatively modest funding needs for upgrading of equipment, maintenance and operation of the monitoring stations and historic data rescue, the national research financing bodies should be contacted by IOC and CIESM, to assist their national organizations participating in MedGLOSS in the long term performance of these tasks, for the benefit of the national and international communities. However, additional funding would be seeked via international research programmes and from the MedGLOSS programme sponsors, IOC and CIESM.

MedGLOSS pilot network will operate from one focal point, agreed to be at the Israel Oceanographic & Limnological Research, Haifa, which will gather the sea-level data from the MedGLOSS sea-level stations, quality control, include them in a basin wide data base and disseminate the data to the participating organizations and to other international organizations and programmes such as the PSMSL, WMO, MFS, etc. Upon full implementation of MedGLOSS in all Mediterranean and Black Seas countries, additional support centres will be selected to aid the focal centre with quality-controlled data.

A Memorandum of Understanding draft will be circulated by Dov Rosen - MedGLOSS coordinator, to the MedGLOSS participating organizations, to be signed upon approval, which will coordinate the MedGLOSS pilot network operation and the data rights and transfer to third parties outside MedGLOSS, according to the purpose of data use (commercial, scientific).

The formal active operation of MedGLOSS pilot network will start on 1st October 2001.

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3.4 RECOMMENDATIONS

The MedGLOSS Workshop and coordination meeting participants, upon consideration of the scope and objectives of MedGLOSS pilot sea level monitoring network recommended the countries bordering the Mediterranean and Black Seas which have not yet joined the pilot programme to join MedGLOSS by equipping and operating their national sea level monitoring station according to the standards agreed by the MedGLOSS network and by sharing their data with the MedGLOSS international member community.

The participants recommended IOC and CIESM to assist and support the national MedGLOSS institutions not only from international sources, but also by addressing the National Authorities of all MedGLOSS member countries to better understand the importance to the community of each country of the MedGLOSS programme and provide national, financial and moral support, which shall make possible the long term operation of the MedGLOSS network for the common benefit of the national as well as international public interests.

4. ACKNOWLEDGEMENTS

The participants expressed their acknowledgments to IOC and CIESM for their continuing support of MedGLOSS and, in particular, for providing funds for the meeting.

Thanks were also expressed to IOLR for hosting the meeting and for its additional financial contribution in bringing additional participants.

The participants also acknowledged the logistical assistance received during the meeting from Mr. Lazar Raskin and to Ms. Einat Ben-Hanan of Ofir Tours Travel Agency, Haifa who handled the travel arrangements.

ANNEX I

MedGLOSS Workshop and Coordination Meeting Programme 15 -17 May 2000

1. MedGLOSS Workshop - Monday 15 May 2000

Time	Activity	Speaker Name
8:15	Departure from hotel to IOLR	
8:15-8:45	Arrival at IOLR,	
8:45-9:15	Registration, coffee	
9:15-10:00	**Opening Session**	**CHAIR: Yuval Cohen**
	Welcome greetings	Frederic Briand - CIESM
	Welcome greetings	Michael Beyth - E.S.R.A. Min. Natl. Infrastructures
	Welcome greetings	Philip Woodworth-IOC/UNESCO
	Agenda & organization	Dov Rosen
10:00-13:15	**Session 2-State of art of sea level and bench mark monitoring**	**CHAIR: Aldo Drago**
10:00-10:20	Brief GLOSS overview with emphasis on the Mediterranean region	Philip Woodworth
10:20-10:40	MedGLOSS pilot status & future	Dov Rosen
10:40-11:00	MedGLOSS Sea Level Benchmark monitoring requirements	Suzanna Zerbini
11:00-11:20	Coffee break	
11:20-11:45	Satellite altimetry of sea-level	Gilles Larnicol
11:45-12:15	Sea-level monitoring equipment and data analysis	Philip Woodworth
12:15-12:40	Methods of geodetic height fixing	Suzanna Zerbini
12:40-13:05	GPS permanent network in Israel for geophysical applications	Elena Ostrowsky
13:05-14:00	Lunch break	
14:00-18:00	**Session 3-Training & field visit**	**CHAIR: Philip Woodworth**
14:00-14:20	Presentation of ISRAMAR & new sea-level stations' equipment	Dov Rosen
14:20-14:40	Show of sea-level equipment	Dov Rosen
14:00-15:00	Show of survey equipment	Josef Melzer
15:00-15:30	Travel to Hadera GLOSS station #80	
15:30-16:00	Visit site of station 80	
16:00-16:20	Travel to Caesaria antique port	
16:20-17:30	Visit antique Caesaria roman aquaduct	
17:30-18:00	Transfer to hotel	
	Free evening, dinner at hotel	

2. MedGLOSS Pilot Network Coordination Meeting - Tuesday 16 May 2000

Time	Activity	
8:15	Departure from hotel to IOLR	
8:15- 8:45	Transfer to IOLR	
9:00-13:00	**Session 4 Sea-level station reports**	**CHAIR: Suzanna Zerbini**
9:00 - 9:15	Ukraine	Leonid Koveshnikov
9:15 - 9:30	Spain	Maria Jesus Garcia
9:30 - 9:45	France	Bernard Simon
9:45 -10:00	Morocco	Karim Hilmi
10:15-10:30	Malta	Aldo Drago
10:30-10:45	Croatia	Nenad Leder
10:45-10:30	Israel	Boris Shirman
11:00-11:30	*Coffee break*	
11:30-11:45	Romania	Viorel Malciu
11:45-12:00	Spain	Begona Perez Gomez
12:00-12:15	Greece	Theodoro Kardara
12:15-12:25	Israel	Dov Rosen
12:25-12:30	Russia	D. Rosen for Oleg Zilberstein
12:30-12:45	Italy	Fabio Raicich
12:45-13:00	Turkey	Coskun Demyr
13:00-14:00	*Lunch break*	
14:00-14: 30	Gibraltar and comments	Philip Woodworth
14:30-15:00	Mediterranean Forecasting System project	Steve Brenner
15:00-15:30	*Coffee break*	
15:30-18:00	**Session 5 - Round table on future coordination & active implementation**	**CHAIR: Dov Rosen**
15:30-18:00	Discussions on sea level stations selection, MedGLOSS coordination and pilot network active implementation	
18:00-18:30	Transfer to hotel	
18:30-19:30	Pause	
19:30-20:00	Transfer to Restaurant "Dolphin"	
20:00-22:30	Dinner hosted by IOLR	
22:30-23:00	Transfer to hotel	

2. MedGLOSS Pilot Network Coordination Meeting - Thursday 17 May 2000

Time	Activity	
8:15	Departure from hotel to IOLR	
8:15- 8:45	Transfer to IOLR	
9:00-18:00	**Session 5 - Round table on future coordination & active implementation -continued**	**CHAIR: Suzanna Zerbini**
09:00-11:00	Discussions on sea level stations selection, MedGLOSS coordination and pilot network active implementation	
11:00-11:30	*Coffee break*	
11:30-13:00	Discussions on sea level stations selection, MedGLOSS coordination and pilot network active implementation	
13:00-14:00	*Lunch break*	
14:00-16:00	Discussions on sea level stations selection, MedGLOSS coordination and pilot network active implementation	
16:00-16:30	*Coffee break*	
16:30-18:00	Concluding session, voting, closure	

ANNEX II

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ANNEX III

LIST OF ACRONYMS

CIESM	International Commission for the Scientific Exploration of the Mediterranean Sea
CLS	Collecte Localisation Satellite
CNR	Consiglio Nazionale delle Ricerche (Italy)
GLOSS	Global Sea Level Observing System (IOC-WMO-UNEP-ICSU)
GOOS	Global Ocean Observing System (IOC-WMO-UNEP-ICSU)
GPS	Global Positioning System
HNHS	Hellenic Navy Hydrographic Service
IEO	Instituto Espanol de Oceanografia (Spain)
IGN	Instituto Geografico National (Spain)
INM	Instituto Nacional de Meteorologia (Spain)
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IOLR	Israel Oceanographic & Limnological Research (Israel)
IPCC	Intergovernmental Panel on Climate Change
MedGLOSS	Mediterranean GLOSS Subsystem of Systematic Sea Level Monitoring Stations Network
MFSPP	Mediterranean Forecasting System Pilot Project
MHI	Marine Hydrophysical Institute
MOU	Memorandum of Understanding
MSL	Mean Sea Level
NRT	Near Real Time
PRA	Ports and Railways Authority (Israel)
PSMSL	Permanent Service for Mean Sea Level
POL	Proudman Oceanographic Laboratory (UK)
SELF	Sea-Level Fluctuations Geophysical Interpretation and Environmental Impact
SLBM	Sea-Level Benchmarks
SLR	Satellite Laser Ranging
SOI	Survey of Israel
TEMA	Training, Education and Mutual Assistance (COI-UNESCO)
TGBM	Tide Gauge Benchmark
TGZ	Tide Gauge Zero
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VLBI	Very Long Baseline Interferometry
VTS	Visual Tide Staff
WMO	World Meteorological Organization

ANNEX IV

PAPERS AND MATERIAL PRESENTED AT THE MEETING

	Annex
Demir C., M. A. Gürdal, *Sea level monitoring activities in Turkey*, General Command of Mapping, Ankara, Turkey.	IVa
Drago A., *Sea Level Measurements in Malta*, Physical Oceanography Unit, University of Malta, Valetta, Malta.	IVb
Jesús García M., *IEO Mediterranean Tide Gauge Stations*, Instituto Español de Oceanografía, Madrid, Spain.	IVc
Kardaras T., *The national network of sea level measurements*, Hellenic Navy Hydrographic Service, Athens, Greece.	IVd
Leder N., *Status of tide gauge stations in Croatia*, Hydrographic Institute of the Republic of Croatia, Split, Croatia.	IVe
Malciu V., V. Diaconu, *Long-term trend of the sea level at the Romanian Littoral*, Romanian Marine Research Institute, Constantza, Romania.	IVf
Perez B., E. Alvarez, J. D. Lopez, I. Rodriguez, *Sea level monitoring and forecasting activities of Puertos del Estado*, Departamento de Clima Maritimo Ente Publico, Puertos del Estado, Madrid, Spain	IVg
Raicich F., *Sea-level gauge networks in Italy*, CNR, Istituto Sperimentale Talassografico, Trieste, Italy.	IVh
Rosen D. S., *Description of new MedGLOSS sea-level stations funded by CIESM,* Israel Oceanographic & Limnological Research, National Institute of Oceanography, Haifa, Israel.	IVi
Rosen D. S., *A review of sea level monitoring status in Israel*, Israel Oceanographic & Limnological Research, Haifa, Israel.	IVj
Shirman B., Y. Melzer, *Sea level measurements along the Israeli coast between 1961-2000*, Survey of Israel, Tel-Aviv, Israel.	IVk
Woodworth P. L., *A Brief Overview of the IOC GLOSS Programme with Some Comments Relevant to the Mediterranean and Black Seas and a Review of Tide Gauge Technologies*, Permanent Service for Mean Sea Level, CCMS Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside, United Kingdom.	IVl
Woodworth P. L., *Summary of Gibraltar Sea Level Station 36 deg 7 min N, 5 deg 21 min W, GLOSS Number 248 PSMSL Code 215/001*, Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside, United Kingdom.	IVm
Zilberstein O. I., O.V. Tikhonova, *Current status of Russian Black Sea sea level network*, ROSHYDROMET, Moscow, Russia.	IVn

IVa -SEA LEVEL MONITORING ACTIVITIES IN TURKEY

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ABSTRACT

Turkish National Sea Level Monitoring Network presently consists of one data center in Ankara and four tide gauges located along the Mediterranean, Aegean and Marmara Sea coasts and is planned to be expanded to also cover the Black Sea and the East Mediterranean. The existing four tide gauges, operated by General Command of Mapping since 1985 with an analogous system, were upgraded to high standards enabling automatic data collection and real time data transfer. Monthly sea level values are obtained from hourly data between 1985-1999 after pre-analysis and mean sea levels and their changes are estimated by applying harmonic analysis. GPS measurements carried out at those tide gauges between 1992 to 1999 are also processed and evaluated. Sea level data, GPS and precise leveling observation connecting tide gauges are combined to estimate relations between mean sea levels as well as vertical crustal movements at Turkish coasts.

1. INTRODUCTION

Sea level monitoring activities in Turkey dates back to the 1930s. The General Command of Mapping (GCM), having responsibility of the basic geodetic control networks in Turkey, established the first tide gauge at the Antalya harbor in 1936 in order to define zero level surface for heights. Right after the establishment of the second one at Karşıyaka/İZMİR in 1937, they were transferred to General Directorate of Meteorological Affairs. By this institution, nine more tide gauges had been set up subsequently and operated at different coasts of the country at different time intervals. Time series from those gauges varies from five to 40 years. At all tide gauges sea level variations were recorded to daily or weekly charts with an analogous system by means of a float on a cable in a stilling well. In the late 1970s, it was not possible to operate those gauge properly and to obtain correct values due to increase in pollution and plunging of the wells caused by urbanizations surrounding the gauges (HGK, 1991; Gürdal, 1997; 1998).

During the 1980s, taking into consideration the importance of the absolute sea level variations and its outcomes, GCM, with the intention of removing deficiencies in sea level activities, took over the responsibility of operating permanent tide gauges countrywide. Afterwards, all tide gauges were scrutinized and discontinued. Instead, four new tide gauges namely Antalya II, Bodrum II, Menteş and Erdek were established and activated with the available analogous system in late 1985. At these stations sea level variations had been recorded to the weekly charts and ancillary data such as atmospheric pressure, air temperature, humidity, sea temperature had also been measured once a day. Graphical records together with the ancillary data were sent to the data center, and monthly periods and hourly values were digitized manually and issued annually to the related national and international institutions.

Due to the difficulties encountered in obtaining spare parts and in order to eliminate errors subjected to the analogous system, it was decided to modernize the existing tide gauges and to establish a state of the art sea level monitoring network and expand it with new tide gauges where necessary. Furthermore, it was also decided to re-digitize the historical sea level records with a computer-aided system to obtain more accurate time series. Due to this much effort has been made since 1995 and first step towards establishing modern sea level network in Turkey was accomplished by upgrading the existing tide gauges to GLOSS standards in 1999 (IOC, 1997).

Presently, all stations consist of a data collection unit with a self-calibrating acoustic ranging sensor and meteorological sensors such as atmospheric pressure, air temperature, air humidity, wind velocity and wind direction. Sampling rate is 10 seconds for the sea level data and 1 minute for the ancillary data. Measurement of sea level is based on a 10-minute average whereas meteorological parameters are based on one-hour average. The data are downloaded to the data center every three days using telephone lines and quality controlled regularly.

To check the tide gauge datum and to monitor the local vertical movements at or near tide gauges, local leveling network consisting of about three to five points have been measured at one and two year intervals. Within the framework of different projects, periodic GPS measurements have also been carried out since 1991. We have three-four year periodic GPS data, which are of most value in terms of tide gauge fixing (Carter et al., 1989). First epoch of absolute gravity measurements were also fulfilled at tide gauge sites in 1997.

The available monthly mean sea level values obtained from the newly digitized data were analyzed and corrected for errors as much as possible, and mean sea level (MSL) and its changes at four tide gauges was computed. These values were incorporated with the national levelling data for the analysis of latitudinal changes of the mean sea level. In addition to this, long-term changes of the MSLs and periodic GPS measurements were also combined to study vertical crustal movements.

2. ANALYSIS OF MONTHLY MEAN SEA LEVEL DATA

The water level measured at a tide gauge is affected by a number of oceanographic and meteorological phenomena. In addition vertical crustal movements are of particular importance in determining the secular mean sea level changes. Accurate prediction of secular sea level changes (rise or fall) requires long-term data and is only possible if those effects are modelled properly. Therefore, historical sea level data provides valuable data for the studies of both crustal motion and eustatic sea level trends.

The GCM spent much effort to re-process the historical sea level data using suitable methods as well as upgrading and expanding the existing sea level network. The data obtained by analogous system is subject to many errors coming from both the instrumental drift and the method of digitization (IOC, 1985; 1994). In order to eliminate the errors as much as possible we started to re-digitize historical graphical records with a computer-aided digitizer in 1995 and this work is still on going.

Hourly sea level values are predicted from digitized values by linear interpolation and evaluated with the software of TOGA Sea Level Center (Caldwell, 1991) in order to eliminate time and datum errors. Daily and monthly mean sea levels are then obtained by simple arithmetic mean. Table-1 summarizes the re-processed data so far.

Table-1: Re- digitized and processed sea level data

Tide-gauge	Available data	Re-digitized	Processed	Remarks
Antalya I	1936-1977	1936-1977		Not operational
Antalya II	1985-1999	1985-1999	1985-1999	
Bodrum II	1985-1999	1985-1999	1985-1999	
Menteş	1985-1999	1985-1999	1995-1999	
Erdek	1985-1999	1985-1999	1995-1999	

We determined the mean sea levels and its changes by analyzing the monthly mean sea level data from four tide gauges listed in Table-1 using the well-known equation (Bath, 1974; Pugh, 1987),

$$h_i = Z_o + a\ t_i + \sum_{j=1}^{N} A_j \cos(\omega_j t_i - \theta_j)$$

Where, t_i is the number of months from reference epoch t_o, Z_o mean sea level, a secular trend (cm/month), A_j, ω_j and θ_i, amplitude, angular velocity and phase of the i^{th} harmonic constituent respectively. Meteorological parameters are not included in the model since they are not yet completely arranged before the analysis. In Figure-1, the measurements and model values are depicted. It can be seen from the figure that the data has many gaps due to frequent failures in the analogous system. From this analysis, mean sea level changes are found to be 7.3 ± 1.1 mm/y for Antalya, 2.1 ± 2.1 mm/y for Bodrum, 15.5 ± 6.0 mm/y for Menteş and 22.5± 4.8 for Erdek tide gauge. The computed values of the mean sea level changes at Bodrum and Erdek tide gauge are suspicious due to that their time series have many gaps. But at Antalya tide gauge having 14-year data, rising in the mean sea level is clearly identified and is compatible with the results given by Hekimoğlu et al. (1996). Although the length of data at Erdek tide gauge is 5 years, which can be considered as too small for such an analysis, it gave us clear evidence for the mean sea level rise.

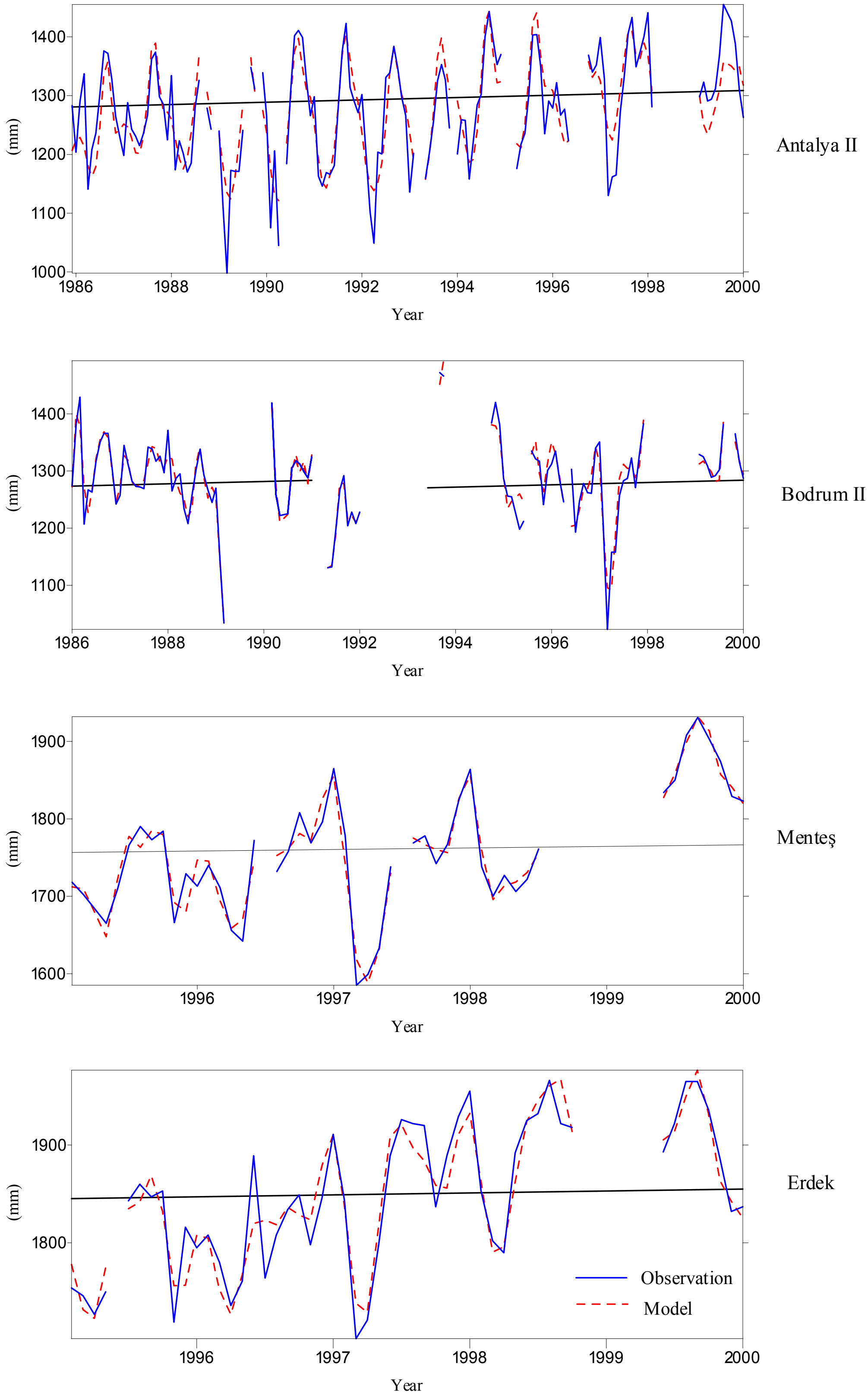

Figure-1: Observed and predicted monthly mean sea levels and mean sea level trends.

Moreover, mean sea levels were incorporated with the first or second order leveling observations between tide gauges and the latitudinal slope of mean sea level is computed as 8.9 ± 0.2 cm per degree of latitude (Fig.-2.). Mean sea level at Samsun tide gauge is based on old sea level measurements. It can be seen from the figure that the mean sea level difference between the Black Sea and the Mediterranean Sea due to sea surface topography is about to be 40 cm.

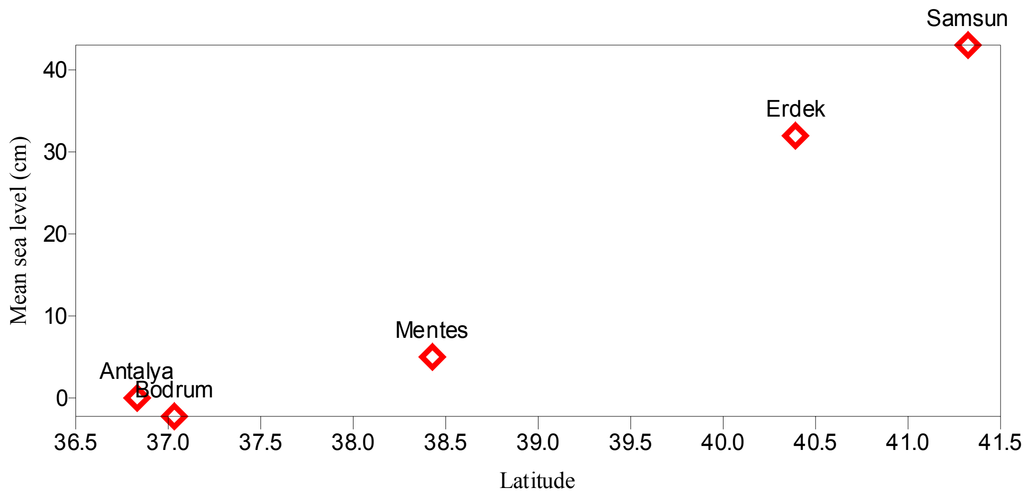

Figure-3: Latitudinal slope of the mean sea levels

3. VERTICAL CRUSTAL MOVEMENTS

Turkey is situated in a tectonically very active region where major tectonic plates interact. Although the horizontal velocity field of Turkey is more or less modeled using periodic GPS measurements conducted for ten years, we have still many questions for the vertical crustal movements. GPS measurement campaigns, carried out so far at existing four tide gauges, are given in Table-2.

Table-2: GPS measurements at tide gauges

Gauge/year	93	94	95	96	97	98
Antalya II		x	x	x	x	x
Bodrum II		x	x	x	x	x
Erdek	x	x (2)		x (2)		x
Menteş	x	x	x	x		x

(x) Observed in two different campaigns

GPS campaigns conducted between 1993-1999 at gauges in Turkey are processed with BERNESE software version 4.0 (Rothacher and Mervart, 1996) using IGS products following the strategy proposed by EUREF sub commission. Loosely constrained solutions of SINEX format are combined with the last GLOBK software (Herring, 1997) in ITRF96. In the combination, we applied 1 mm constrains for both velocity and coordinates of some selected IGS sites for reference frame fixing. These results are given with the mean sea level rises in Table-3.

Table-3: Rate for the up component and mean sea level trends at gauges.

Tide gauge	Vu (GPS) (mm/y)	MSL trend (mm/y)
Antalya II	1.4 ± 2.7	7.3 ± 1.1
Bodrum II	3.4 ± 1.3	2.1 ± 2.1
Erdek	-8.5 ± 5.6	22.5 ± 4.8
Menteş	1.2 ± 1.8	15.5 ± 6.0

Table-3 shows that velocities at Antalya and Menteş tide gauge are insignificant due that MSL rise at Menteş and Bodrum are seem to be unreliable due to many gaps. Besides, mean sea level trend and GPS measurements at Erdek tide-gauge are somehow confirming the vertical crustal movements here, although the sea level data period is fairly short. It is anticipated that more GPS surveys and long series of sea level data will yield better results for the understanding of vertical motion at tide gauges.

CONCLUSION

In this paper, the present practices of the General Command of Mapping relevant to sea level activities were explained. We intended to give a general status of the work done rather than focus on a comprehensive investigation. Modernization of the Turkish tide gauge network, efforts for re-digitization of historical sea level records and periodical GPS measurements are also emphasized. Analyses of available monthly sea level values and periodical GPS measurements gave us interesting information about sea level trend and vertical crustal movements at tide gauges and, latitudinal sea slope in Turkey. But these results should be considered preliminary, and need to be improved with GPS and additional sea level data using more complex evaluation of the data.

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IVb - SEA LEVEL MEASUREMENTS IN MALTA

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Mission of the PO-Unit

The Physical Oceanography Unit was established in the early 90's under the Malta Council for Science and Technology. It now constitutes the research arm of the IOI-Malta Operational Centre at the University of Malta.

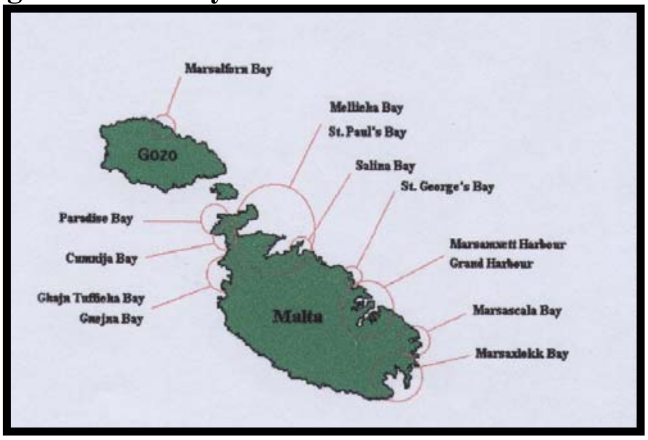
The PO-Unit undertakes fundamental research in coastal meteorology, hydrography and physical oceanography with a main emphasis on the experimental study of the hydrodynamics of the sea in the vicinity of the Maltese Islands. It offers facilities for the gathering, processing, analysis and management of high quality physical oceanographic observations both for long term and baseline studies as well as for general applications in marine environmental research and assessments. The Unit endeavours to enhance its activity on an operational scale by the installation and maintenance of permanent monitoring systems that provide data for ocean forecasting, and by applying numerical modelling techniques in the study of physical marine systems. It operates in collaboration with international organizations with which it has expanded its activities through a number of funded research projects. The Unit provides services and technical support to local entities including government departments and private agencies. It organizes conferences, seminars, workshops and specialized training programs in order to promote oceanography in Malta and in the Mediterranean.

Sea level measurements by the PO-Unit

A main activity of the PO-Unit consists in the collection of densely sampled (2min) sea level, barometric pressure and wind vector recordings at two recently installed permanent stations on the northern coastal perimeter of Malta. This forms part of an ongoing research programme that was initiated by the PO-Unit in 1993. These measurements constitute the first digitized set of sea level recordings in the Maltese Islands and are to date the longest time series of simultaneous water level and meteorological parameters in the Central Mediterranean.

The permanent sea level installation is positioned at the head of Mellieha Bay, which is a small embayment on the northwestern coast of Malta (Fig. 1). It consists of an Endeco Type 1029/1150 differential pressure tide gauge that is clamped inside a small stilling well connected to the sea. The sensor is a highly accurate strain gauge with slight non-linearity, but ultra-high repeatability and with practically no long-term drift. The pressure transducer is located in a subsurface case and at each recording it samples for a total of 49s in order to filter surface waves; records are logged onto a removable solid-state EEPROM cartridge situated in a top case recording unit. A thermistor bead bonded to the strain gauge is used to measure temperature and allows compensation for temperature effects on the transducer. The instrument measures absolute pressure; atmospheric pressure is compensated by means of a vented tube which passes through the top case unit and terminates inside an environmental isolator in the form of a small exposed PVC tube with a bladder. The tide gauge datum is regularly checked for stability. Sea levels are given from the zero of the tide gauge that is 2.6507 m below BM No. 9541811 established by the Mapping Unit of the Malta Planning Directorate.

Fig.1 Main embayment in the Maltese Islands



The station was equipped with a new ENDECO 600XLM probe in May 2000. The system is operated by solar energy and will be used as a secondary station to the MedGLOSS station that is to be installed at Porto Maso.

Meteorological parameters are measured by Aanderaa sensors at a nearby automatic weather station in Ramla tal-Bir, which is situated on the coastal strip overlooking the South Comino Channel. The sensors are positioned in an unobstructed location at a height of 20 m from mean sea level. The data set consists of wind speed and direction, air pressure and temperature, relative humidity and net atmospheric radiation each measured at one or two minute intervals. The station has been in operation since April 1994. Meteorological data from this station is missing for the period between mid-October 1994 and mid-March 1995 due to a sensor malfunction caused by the stray effect of a nearby lightning stroke.

In addition to the data from the permanent stations, short-term deployments have also been undertaken, both along the coast and in the open sea. This includes simultaneous recordings by an array of land-based barographs and a set of simultaneous bottom pressure recordings across the Malta Channel.

On the merit of the position of the island within the Strait of Sicily, these data sets are particularly important for understanding the role of the Strait in controlling the exchange between the two major basins of the Mediterranean Sea. With an internal Rossby radius of just a few tens of kilometres on the shelf areas, mesoscale phenomena in the Strait of Sicily are impossible to detect and follow unless a detailed observation set is available in both time and space. Under such circumstances, sea level measurements become of great relevance as an indicator of the general dynamics of the sea (Wunsch, 1972) especially when measured, as in the case of Malta, at a location away from the continental mainland.

These data sets are used for studies on climate change and sea level rise, for assessing salt intrusions in the natural ground water acquifer, the effect on the dispersion and flushing of pollution in the coastal areas, the calculation of extreme sea levels in connection with coastal structures, and others. With sufficiently long time series of the relevant sea and atmospheric parameters it will be possible to model the effect of the wind and atmospheric pressure on the mean sea level, and hence permit a more precise prediction of sea levels including the prediction of surges.

An exhaustive and detailed analysis of the sea level data collected in the period June 1993 - December1996 is given in DRAGO, 1999. This work gives a broad and updated study of sea level variations in Malta particularly with reference to long period waves.

Other sea level measurements

A long historical data set of sea level chart records in the Grand Harbour is kept at the British Hydrographic Office and cover the period 1876-1926. The sea level gauge was held in the French Creek except for a period of five years starting from 1903 when the measurements were transferred to Ricasoli. Unfortunately no records have been found after 1926.

Since 1988 the Malta Maritime Authority has also operated a mechanical sea level gauge for intermittent periods in the Grand Harbour. Originally the instrument was stationed at Pinto Wharf. Analysis of 13 months of data from May 1990 to May 1991 was used to obtain the tidal harmonic constants in the harbour (Drago, 1992). Measurements were interrupted in 1994 and resumed in 1996 at a position close to the mouth of French Creek. The instrument is currently positioned at Ras Hanzir, which is at an inner location along the main channel of the Grand Harbour.

The 'milghuba' phenomenon

A most remarkable feature in the sea level signals observed in Malta consists of a band of high frequency signals with periods ranging from several hours to as low as a few minutes. These non-tidal short period sea level fluctuations are an expression of a coastal seiche, known by local fishermen as the '*milghuba*'[1]. This phenomenon has now been observed to occur all along the northern coast of the Maltese archipelago and manifests itself with very short resonating periods of the order of 20 minutes in the adjacent coastal embayments. The phenomenology, generation and impact of the '*milghuba*' on the coastal dynamics constitute the major focus of the study by Drago, 1999.

Analysis shows that weak seiching is present uninterrupted and appears as a background 'noise' on the tidal records. During random sporadic events the seiche oscillations can however become greatly enhanced and mask completely the astronomical signal. These large-amplitude sea level oscillations are accompanied by remarkable currents that are triggered by the sloshing water masses. While these seiche induced currents can be an important means for the flushing of coastal inlets and harbours, they can on the other hand be dangerous to navigation. Similar seiche oscillations have been reported in other parts of the world ocean, with the most recent studies being those conducted in Puerto Rico and the Philippines (Giese et al., 1982), in Nagasaki on the southern coast of Japan (Hibiya & Kajiura, 1982), at Capetown in South Africa (Shillington, 1984), at the Balearic Islands (Monserrat et al., 1991), and in the South Kuril Islands (Djumagaliev & Rabinovich, 1993). They are reported to cause severe damage to coastal areas, boats and port constructions. Due to their close relation with the behaviour of tsunami, research on seiches is considered to be important in disaster mitigation studies (Taku et al., 1992).

Reference to similar sea level variations (known as the '*Marrubbio*') on the southern coast of Sicily is found in the Italian 'Portolano' for ship navigation. Their occurrence is reported to be most frequent in May or June in association to southeasterly winds, and their crest-to-trough amplitudes reach as high as 1.5 m. Literature on the '*Marrubbio*' is however very scarce and the only relevant publication is by Colucci & Michelato (1976). It is interesting to note that one of the first scientific studies on seiches by Sir George Airy (1878) refers precisely to the Grand Harbour in Malta. Since then the seiche phenomenon in Malta remained unstudied until the work conducted recently by the PO-Unit, which indeed constitutes the first study dealing with these high frequency sea level oscillations in the Central Mediterranean.

The large amplitude seiches in the Maltese Islands are mainly of an atmospheric origin. The simultaneous measurements of sea level and atmospheric pressure reveal the presence of pressure fluctuations of the order of a few millibars in coincidence with the occurrence of seiche events. These pressure signals are believed to be the surface expression of atmospheric wave disturbances that propagate in the lower troposphere as internal gravity waves. Their interaction with the open sea surface triggers the long period waves that subsequently force the seiches in the coastal areas.

[1]The term '*milghuba*' comes from the Maltese verb '*laghab*' which means 'play'. The terminology refers to the 'play of the sea'.

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IVc - IEO MEDITERRANEAN TIDE GAUGE STATION

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INTRODUCTION

Sea level has been monitored in the IEO from 1943 when a tide gauge network of 23 stations covering the Spanish coast. Presently the network consists of 13 tide gauges, six on the Mediterranean Coast; three in the Iberian Peninsula, two in the Balearic Island and one on the African coast. Some of these stations (Ceuta and Palma de Mallorca) were selected for the MedGLOSS Pilot Network.

The sea level measurements are relative to the Tide Gauge Zero (TGZ), normally the chart datum. In collaboration with the IGN, which is the national responsible of the National Levelling Network, the TGBM had been connected to the National Geodetic Network.

The IEO network has been renewed by connecting the float tide gauge with an encoder and a data logger in order to have a digital output with data transmission through a telephone line.

During 1996-1998, in the frame of the project: Integration of Spanish Tide Gauge Network, financed by CYCIT, through the National Programme of Marine Science and Technology, a big effort was made by the partners (IEO, PE/CM), IGN, IHM) in order to harmonize the different Spanish tide gauge networks.

The monthly mean sea levels are regularly sent to the PSMSL. Recently an annual bulletin has been published which includes: mean sea levels, extreme sea levels, tidal ranges and harmonic constants.

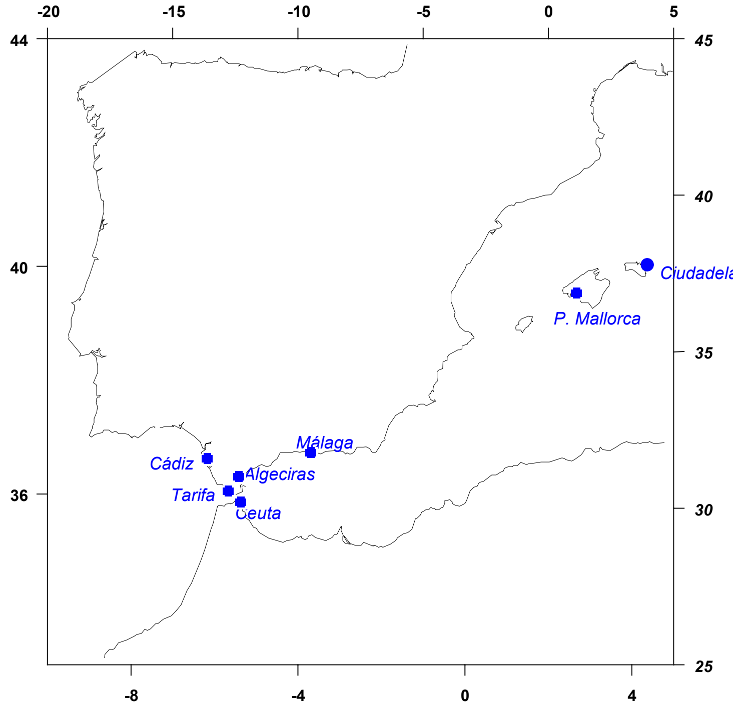
Up to now, there is not any clear data policy at the IEO but, in any case, many scientists are using these data in their researches.

In this paper we present the state-of the-art of the IEO Mediterranean Tide Gauge Stations: Installations and equipment, reference system, time series data and some activities related to the sea level in the Mediterranean.

STATIONS

The IEO stations do not cover the Mediterranean coast very well. Three are located in the Strait of Gibraltar, two in the Balearic Island, one in the south coast of Spain and there is one in the Gulf of Cadiz. (Figure 1).

The station in Cádiz may be of interest for monitoring the flow through the Strait of Gibraltar.



IEO Mediterranean Tide Gauge Stations			
Code	**Name Station**	Latitude	Longitude
008	Cádiz	36º 32' N	06º 17' W
009	Tarifa	36º 00' N	05º 36' W
019	Ceuta	35º 54' N	05º 19' W
010	Algeciras	36º 07' N	05º 26' W
011	Málaga	36º 43' N	04º 25' W
014	Palma de Mallorca	39º 33' N	02º 38' E
027	Ciudadela	40º 00' N	03º 51' E

Figure 1: Geographical Distribution of the IEO stations.

Installations and Equipment

All the stations are ready to fulfill the MedGLOSS requirements. Only at the station of Málaga there are no telephone lines and no atmospheric barometer is installed. However, a phone line can be installed. Currently the station of Ciudadela is not working because of the building station problem.

Station	Type	Res.	Acc.	Parameter	GPS	BM	Inst.
Cádiz	Float / digital output	1mm	± 3mm	atm. pres	SELF SELF II (1)	yes	elect. tele-line
Tarifa	Float / digital output	1mm	± 3mm	atm. pres	MAGIES 93 SELF SELF II	yes	elect. tele-line
Algeciras	Float / digital output	1mm	± 3mm	atm. pres	MAGIES 93 SELF SELF II	yes	elect. tele-line
Ceuta	Float / digital output	1mm	± 3mm	atm. pres air temp	MAGIES 93 SELF SELF II (2)	yes	elect. tele-line
Málaga	Float / digital output	1mm	± 3mm		(2)	yes	elect.
P. Mallorca	Float / digital output	1cm	± 3mm	atm. pres sea-temp	(2)	yes	tele-line
Ciudadela	Float / digital output	1mm	± 3mm			yes	

Note: (1) The ROA has installed an Antenna in the City of Cádiz
(2) The IGN is going to install Antenna on those places.

The GPS received are not being connected directly to the benchmark and some campaign has to be done every one or two years.

Reference Systems

The sea level measurements are relative to the TGZ but from the beginning the TGZ were related to TGBM. Normally more than one BM is close to the gauges and all are connected to the national levelling network. The origin of this network is the Mean Sea Level in Alicante (NMMA) obtained for the period 1870-1880.

Station	TGBM	Altitude over NMMA	Auxiliary Benchmarks
Cádiz	NAPG-479	3.595 meters	
Tarifa	Cruz	2.345 meters	NGM353, SS/NGK-92
Algeciras	NGR-15	1.691 meters	NGR-16, NAPG486
Ceuta	NGR-101		SSC-1, SSC-7
Málaga	SS2NGK-236	0.829 meters	NAPA-548, NGS-406
P. Mallorca	MFO	2.537 meters (over local NM)	ClAVO AYTO
Ciudadela			

Note: these altitudes are obtained in 1998 and they are very different to those in the earlier reports.

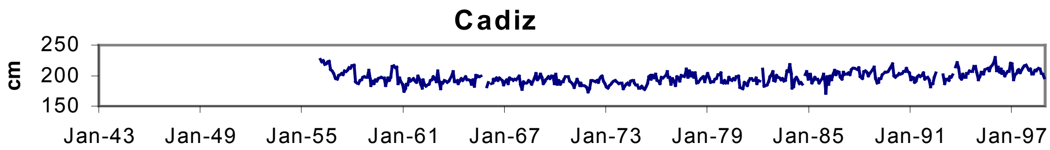
During these last years, some GPS campaign has been performed in Palma de Mallorca and in the Strait of Gibraltar but up to now there is no information about the crustal movements.

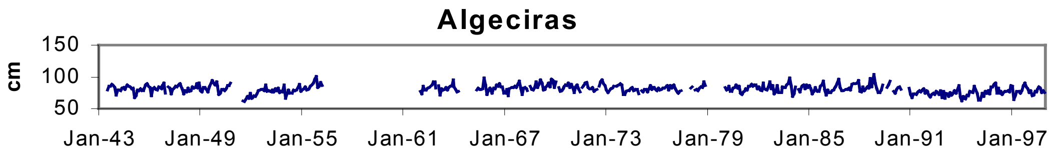
The information of TGZ related to the reference system WGS-84 has been performed by the ROA (Jorge Garata & J. Martín Davila) during the SELF II campaigns:

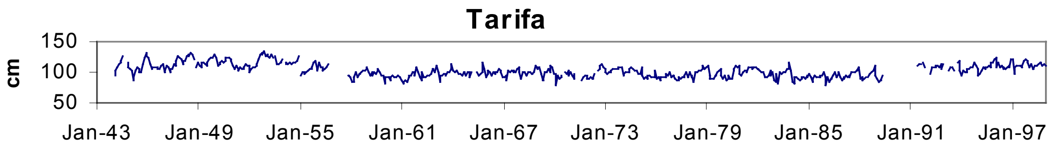
Station	Altitude: TGZ over WGS-84	Distance: TGZ under TGBM	TGBM
Cádiz	43.197 meters	5.423 meters	NAPG-479
Tarifa	40.492 meters	3.300 meters	Cruz
Algeciras	41.713 meters	2.300 metros	NGR-15
Ceuta	41.314 meters	4.195 meters	NGR-101

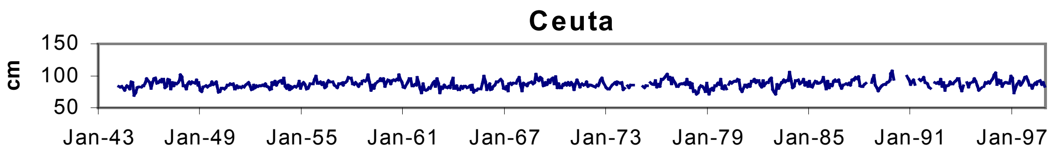
Time series

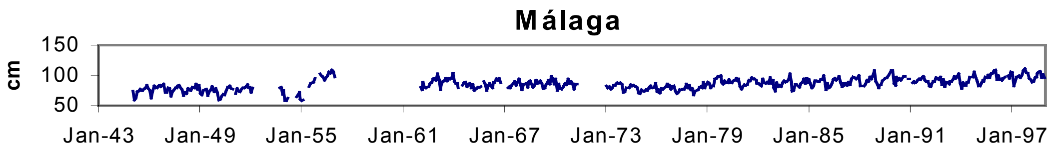
Sea level has been monitored since 1943, but there are some gaps in the time series. The data is already digitized but in some stations the quality control is not finished. The monthly mean sea levels are presented in the graph where the different TGZ references can be seen.











A general inventory is presented in this table.

Stations	Years
Cadiz	1945-1999
Tarifa	1943-1961 1963-1989 1991-1999
Algeciras	1943-1955 1961-1999
Malaga	1943-1959 1961-1999
Ceuta	1943-1999
P. Mallorca	1963-1982 1989-1993 1996-1999
Ciudadela	1990-1991

Routine Processing:

- data is registered at 10 minutes interval.
- data is transmitted to the Data Center by Modem. (except Málaga).
- quality control of the raw data (date, picks, obvious errors).
- filtering to obtain hourly data.
- conversion to USLC format.
- quality control, mean sea level and harmonic constants. USLC software.
- extremes and tide ranges.
- Annual bulletin with the above information

Quality Control Review

In addition to the time series the information about the TGZ is needed to determine the sea level trends. Detailed information as sent to PSMSL is presented:

Country: Spain
Station: Málaga
Latitude: 34º 43' N Longitude: 04º 25' W
Period: (1944-1951):
Unit Used: centimeters
Datum of observation: TGZ
TGBM: Clavo Nº 3
Description of the TGBM: Clavo located in the mouth of the well of the tide gauge, with a geometrical altitude over the Mean Sea Level of Alicante of 1.216 meters.
Levelling: from NAPA 546 located in the lighthouse

Vertical distance between Datum of observations and the TGBM: 2.134 meters.

Period (1962:1997): NEW INSTALATION
Unit used: centimeters.
Datum of observations: TGZ
Reference Bench Mark: SSK 236
Description of the TGBM: SSK-236 located in front of the door of the tide gauge building, with a geometrical altitude over Alicante mean sea level of 0.644 meters. Levelling Motril-Málaga line.
Vertical distance between Datum of observations and the TGBM: 1.64 meters

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OBSERVATIONS:

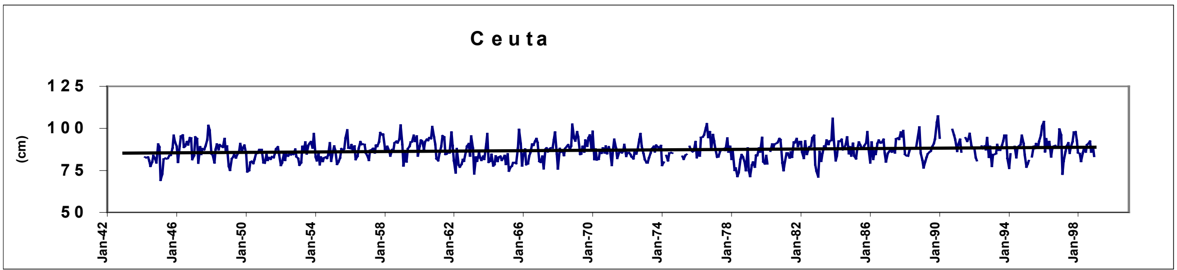
During the period from January 1973 to May 1979 probably the datum has been changed about 5 cm but there is no information in the documentation.

Mean Sea Level

An example of Ceuta sea level trend and the monthly variability is presented:

- Country Spain
- Station Ceuta (GLOSS Number 249)
- Datum of observations: TGZ TGBM: NGR-101
- Description of TGBM: NGR-101. Located in the stilling well mouth.
- Geometrical altitude 3.401 meters. Levelling: Ceuta-Tetuan line (1929)
- Vertical distance between Datum of observations and the TGBM: 4.195 meters
- Type of gauge: Mechanical Float with digital output.

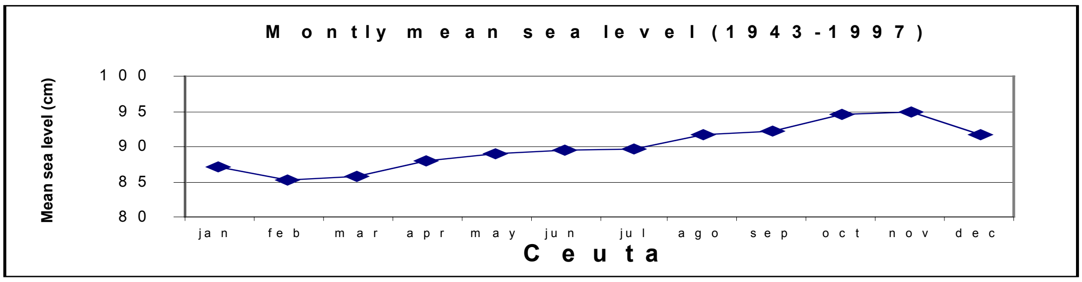
a) Trends:



The slope of the linear fit y= ax+b is 0.61 mm/year.

This is the trend found with the all data but it can be analysed in more detail to find some cycles.

b) Monthly Variability



The sea level increase from February to October is in a range of 10 cm. This is a very representative monthly variability in the Strait of Gibraltar. The atmospheric pressure and the wind are the main factors that contribute to this variability.

IVd -THE NATIONAL NETWORK OF SEA LEVEL MEASUREMENTS

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GENERAL

The Hellenic Navy Hydrographic Service (HNHS) is responsible for the national marine operational observing system concerning the measurements of the sea level variations in the Aegean and Ionian seas.

NETWORK AND STATION DESCRIPTION

Up to the present time a network of 19 sea level stations exists as shown in figure 1. The stations are installed in various ports of the mainland and in a number of major islands and their operation is under the control of the local port authorities.

In each station, a mechanical float type tide gauge is installed and the TGBM/datum of observations is connected to a local benchmark network. The chart recordings are collected, processed, digitized and stored as hourly values. The initial processing includes the calculation of the statistical variables of the sea level time series for each month. The procedure described above is taking place at the HNHS installations, which has the overall maintenance, monitoring and responsibility of the network.

Although the starting year of operation for each station is different, the introduction of the computerized digitization and storing of data on magnetic devices started at about 1969 for all stations.

In parallel to the sea level measuring station network, the Hellenic Meteorological Service has in operation a network of meteorological stations. Most of the seashore meteo stations are located in the neighbourhood of the sea level stations and a very close cooperation exists between the two Services for the exchange of data. In Figure 2 selected meteo stations are depicted which could be used to correlate meteo and sea level data.

The HNHS issues an update information manual where geographical and statistical information is presented for each station. Specifically, for each sea level station, the tide gauge zero reference datum is depicted with a detailed sketch showing the local benchmarks network. The statistics (MWL, LLW, HWL, etc.) for the time series of the sea level data are also included, since the starting year of operation. There is also available a report concerning the harmonic analysis of the sea level data for all the stations belonging of the network, with an attempt to describe the tidal field in the Aegean area.

DATA EXPLOITATION

Based on the processed sea level data, a great number of scientific presentations and publications have been produced and a number of EEC and national funded research projects made use of them. The following is an indicative list:

1. Variagin M.A., 1974. Contribution to the analysis and prediction of Hellenic ports tides. Oceanographic study no 9, Hellenic Navy Hydrographic Service (in Greek).

2. Kardaras T. and A. Zoi-Moroy, 1987. Low frequency sea level fluctuations in the Aegean Sea. Procedures of the 2nd Panellenic Symposium of Oceanography and Fisheries, Athens, 1987, 174-179 (in Greek).

3. Lascaratos A. and M. Gacic, 1990. Low frequency sea level variability in the Northeastern Mediterranean, Journal of Physical Oceanography, Vol 20, No 4, 522-533.

4. Nittis K., 1993. A study of the Aegean and Ionian seas variability in the synoptic and seasonal scale. Ph.D. dissertation, University of Athens, 1993.

5. Tsimplis M. and G. Vlachakis, 1994. Meteorological forcing and sea level variability in the Aegean Sea. Journal of Geophysical Research, V.99, No C5, 9879-9890.

THE FUTURE

1. Upgrading of the network is one of the primary objectives of the HNHS. A first step is to evaluate the cost/effectiveness of the network automation by installing a near real time transmission of data from the various stations. The procedure has already been started by connecting the appropriate equipment to a specific station (there are plans for two more stations), which converts the analog plot to digital format data and provides the means for data storing and transferring to a remote computer. The outcome is going to assist with the further steps of development.

2. A joint proposal between HNHS and the Institute of Marine Biology at Crete was submitted to the 3rd Framework Programme of the European Union. The proposal aims to establish two climatic sea level stations at Rafina (East to Athens) and at Plomari (Lesvos island, Eastern Aegean). Each station will consist of a bubble pressure sea level sensor, a number of meteo sensors and a GPS receiver. Data collected will be transmitted in near real time to the HNHS installations for further analysis and dissemination.

3. A joint project between HNHS and the Technical University of Crete is underway in order to install a complete new sea level measurement station at GAVDOS Island, south of Crete. The upgrading of the existing sea level station at Souda area is also included in the project. The proposed station will be equipped with state of the art tide gauge sensor, a GPS receiver, transponder and meteo sensors. The project aims to provide satellite altimetry calibration.

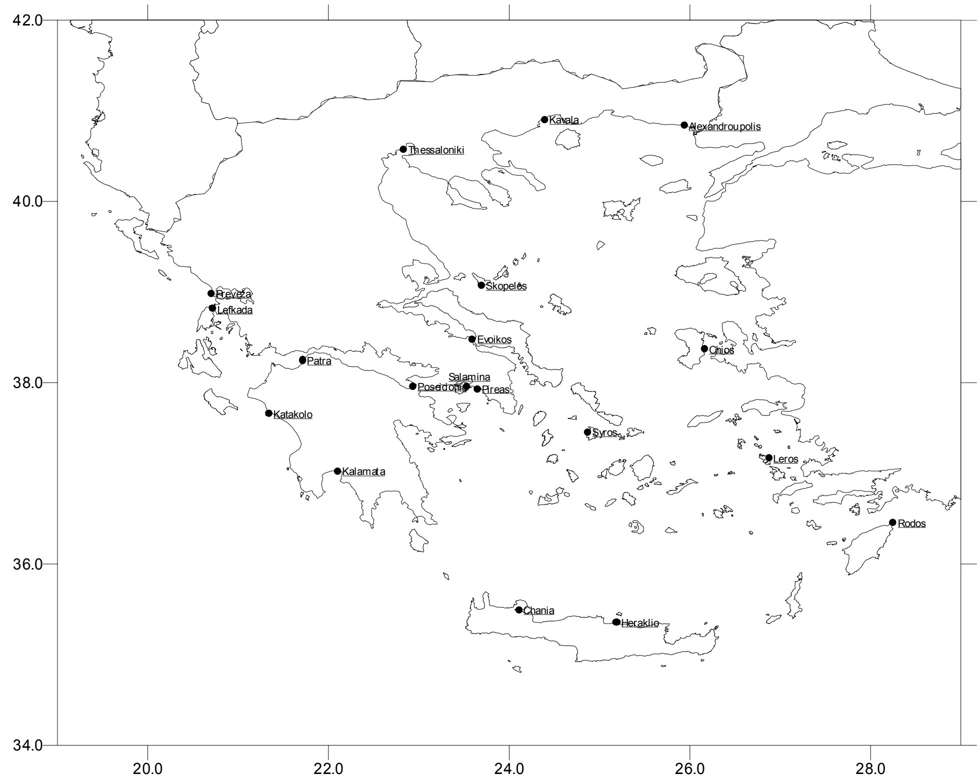

Figure 1. Map showing the sea level stations

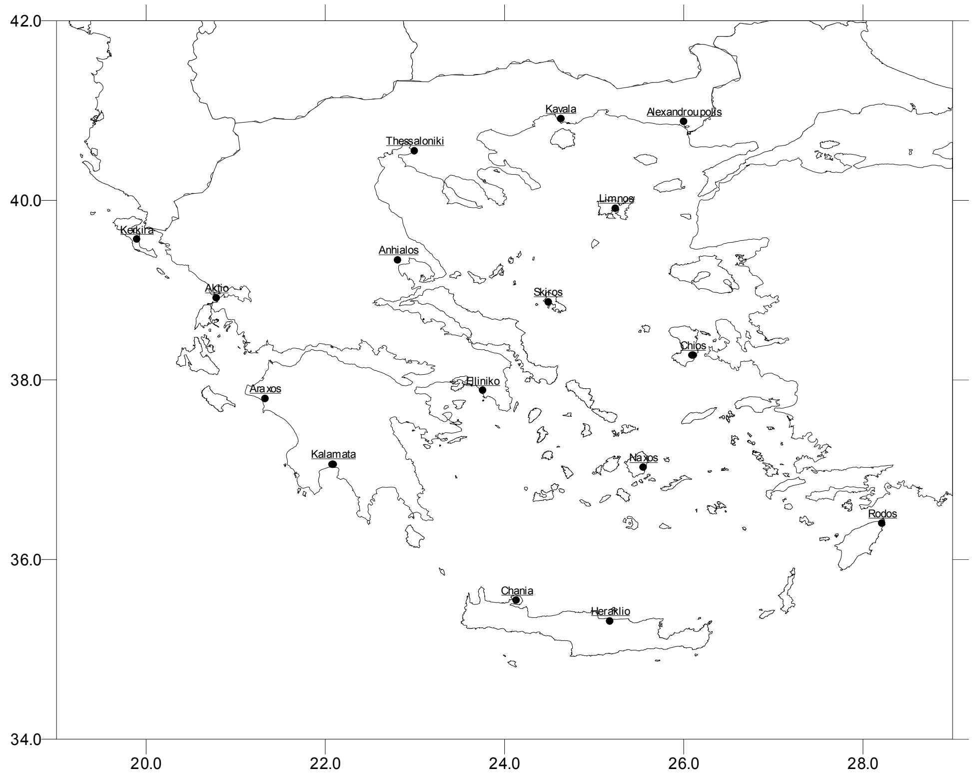

Figure 2. Map showing the selected meteo stations

IVe - STATUS OF TIDE-GAUGE STATIONS IN CROATIA

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Systematic measurements of sea level in the Adriatic Sea began in 1859 in Trieste. A tide-gauge was housed at the end of Molo Sartorio. Tidal observations and measurements were carried out under administration of Academic Nautica and later the Osservatorio Marittimo (Godin and Trotti, 1975). It is interesting that the official Geodetic Datum for Croatia is defined as the mean sea level at Trieste in 1875.

Approximately at the same time Hydrographic Office of the Austro – Hungarian Navy installed tide-gauges at Rijeka, Lošinj, Zadar, Hvar and Krf (Tešić, 1955).

These efforts had two purposes: first, a scientific research of tide, and second, to fulfill experimental demands of the hydrographic survey (safety of navigation).

Since these first steps more than 40 tide-gauge stations have been placed at the eastern part of the Adriatic Sea. It should be pointed out that since 1859 various types of instruments have been installed and tide-gauge stations have changed owners many times, to stirring history in these regions.

The aim of this short review is to describe the present network of tide-gauge stations under the jurisdiction of the Republic of Croatia (Fig. 1). A special attention will be devoted to the stations with more than 50 years of permanent work and respectable historical time series of data.

Fig. 1 shows a map of tide-gauge network stations in the Republic of Croatia. All types of tide-gauges are mechanical (Fig. 2). Types of tide-gauge, registration ratios, intervals of registration and owners are presented in Table 1.

Tide-gauge stations at Rovinj, Split and Dubrovnik have been maintained by the Hydrographic Institute. Tide-gauge constant is checked twice a year at each station. Standard deviation of tide-gauge constants is not higher than ± 0.1 cm, indicating that there were no movements between the tide-gauge housing and the surrounding pier.

Sea level data were processed as follows:

1. Registrations of sea level height (marigrams) were analog, giving weekly registrations. Marigrams were conserved in the archives of the Hydrographic Institute. This is particularly important for the era before computers;
2. Sea level analogue records were smoothed manually to eliminate short-period seiches (periods lower than 2 hours);
3. Hourly and extreme sea level heights, times and heights of high and low water were obtained from marigrams by using computer, digitizer and software developed at the Hydrographic Institute;
4. A Database containing sea level data was created for each tide-gauge station on the basis of monthly time series.

Fig. 1 Tide-gauge stations operating along the east Adriatic coast.

Fig. 2 Mechanical tide-gauge A. Ott – Kempten at Split.

The results of sea level measurements have been published every year since 1955 in the publication “Report on tide-gauge measurements along the east Adriatic coast”, issued by Hydrographic Institute.

The first results of harmonic analysis of tides along the east coast of the Adriatic Sea were published by W. Kesslitz (1919). In Croatia, harmonic constants were first determined for Bakar by Kasumović (1952), on the basis of hourly sea level heights measured in 1950. According to the instructions of Kasumović, Šigud (1973) calculated harmonic constants for 6 stations along the east Adriatic coast.

Harmonic constants for Rovinj, Split and Dubrovnik are shown in Table 2.

On the basis of harmonic constants determined by Kasumović and Šigud, Hydrographic Institute has been performing harmonic synthesis of tides since 1974. Predicted sea level data have been published in publication "Tide tables, Adriatic Sea – east coast", issued by Hydrographic Institute.

Table 1. Types of tide gauges, registration ratios, intervals of registration and owners for the Croatian tide-gauge network.

STATION	TYPE OF TIDE-GAUGE	REGISTRATION RATIO	INTERVAL OF REGISTRATION	OWNER
ROVINJ	A.OTT Kempten	1:5	1955-1999	Hydrographic Institute-Split
BAKAR	A.OTT Kempten	1:5	1929-1939 1949-1999	Andrija Mohorovičić Geophysical Institute-Zagreb
ZADAR	A.OTT Kempten	1:5	1991-1999	Hydrographic Institute-Split
SPLIT-LUKA	A.OTT Kempten	1:5	1929-1941 1947-1999	Hydrographic Institute-Split
SPLIT-RT MARJAN	A.OTT Kempten	1:5	1952-1999	Institute of Oceanography and Fisheries-Split
SUĆURAJ	Fuess	1:10	1986-1999	Hydrographic Institute-Split
DUBROVNIK	A.OTT Kempten	1:5	1954-1999	Hydrographic Institute-Split

Table 2. General data and harmonic constants for Rovinj, Split and Dubrovnik.

Standard Port	Geographical coordinates	Z_0	Harmonic constants							
			const	M_2	S_2	N_2	K_2	K_1	O_1	P_1
Rovinj	$\varphi = 45^o 05'N$ $\lambda = 13^o 38'E$	48	H g	19.30 271.5	10.78 280.1	2.99 263.8	3.08 269.9	16.35 71.8	5.04 57.9	5.25 68.4
Split	$\varphi = 43^o 30'N$ $\lambda = 16^o 26'E$	20	H g	7.95 129.0	5.58 130.8	1.38 125.6	1.64 124.1	8.82 55.9	2.69 47.5	2.90 51.8
Dubrovnik	$\varphi = 42^o 40'N$ $\lambda = 18^o 04'E$	18	H g	9.28 115.1	5.76 120.4	1.68 110.6	1.65 115.7	5.19 62.4	1.90 47.3	1.69 60.2

Parameters presented in Table 2 are as follows:

Z_0 - Mean water level above Chart Datum
H - Mean amplitude of a tidal constituent
g - Modified epoch of a tidal constituent
M_2 - Principal lunar semidiurnal constituent
S_2 - Principal solar semidiurnal constituent
N_2 - Larger lunar elliptic semidiurnal constituent
K_2 - Lunisolar semidiurnal constituent
K_1 - Lunisolar diurnal constituent
O_1 - Lunar diurnal constituent
P_1 - Solar diurnal constituent

An impressive database of sea level data measured along the east coast of the Adriatic Sea was elements of scientific research. Many professional and scientific papers were published in Croatian and international journals, by Croatian and foreign scientists. The list of scientific papers published in international journals by the scientists from Hydrographic Institute of the Republic of Croatia, in the last five years is as follows:

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IVf - LONG-TERM TREND OF THE SEA LEVEL AT THE ROMANIAN LITTORAL

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ABSTRACT

The analysis of the longest sea level record at Constantza reveals a significant rising trend. Also, the interdecadal changes, as related to the variations of the river discharge, are investigated.

INTRODUCTION

Sea level recording in Romania dates back to 1859, when European Commission of the Danube, in order to improve the navigation conditions at the Danube mouths, initiated the observation of the sea level by setting up a visual tide staff (VTS) where three readings were made daily. These values were afterwards used for the entire Danube leveling.

In 1933 a float-type gauge was placed at Constantza and it is still operational in the same place. Different institutions were in charge with the exploitation of this tide gauge such as Maritime Harbour Service or Military Hydrographic Service. Romanian Marine Research Institute as being subordinated to the Ministry of Waters, Forests and Environment Protection, was assigned to carry on this activity since 1970, the year of its foundation, and this work is ongoing. After 1974, three other tide gauges were put into function for a better coverage of the entire Romanian littoral.

Tide gauge network at the Romanian littoral

RMRI tide gauges that are operational are located in the following points: Constantza, Tomis, Sulina and Mangalia (Fig. 1).

Description of the tide gauges:

Constantza: (Fig. 1, Fig. 2, Picture 1, Fig 3a, Fig 3b);
Geographical position: 44°10'21. 0" N, 28°39'34.0" E. Float operating tide gauge, OTT type, functional in Constantza Port since 1933, recordings on paper chart, changed once a week. Two VTS are used; one of them for control, and three readings are made daily.

Tomis: (Fig. 1, Picture 2), situated in a small marina, about 1.5 km north from Constantza Port. Float operating and VTS. Three VTS readings are made daily.

Sulina: (Fig. 1, Picture 3), situated at the northern limit of the Romanian littoral. Geographical position: 45°09'45. 6" N, 29°43'37.2" E. Float operating tide gauge, type SUM, functional since 1977, daily charts. It is placed near the meteorological station 6 km downstream Sulina locality, on the southern side of the jetty. A horizontal pipe connects the stilling well with the open sea. Violent storms damaged the VTS and a new one is to be installed this year.

Mangalia: (Fig. 1, Picture 4) Situated in the southern area of the Romanian littoral in Mangalia harbour. Geographical coordinates are 43°48'30"N, 28°35'30"E. Float operating, SUM type, daily chart, VTS readings three times a day. Due to sand accumulation that obstructed the stilling well, it was relocated in Dec. 1998 to a new position on the opposite quay of the same port.

Characteristics of the hydrological and meteorological regime of the area

Situated at mid latitudes, the northwestern part of the Black Sea experiences the general conditions imposed by a temperate continental climate, with cold winters and warm summers. Siberian anticyclone influence alternates with the southern Mediterranean circulation. Consequently the rivers which debauch in this area will have an annual high in spring season when the precipitation in their hydrographic basins are in excess, and a minimum in warm seasons when evaporation processes become dominant.

The main components of the water balance in the area of our littoral (Altman, 1990; Bondar et al. 1991) is continental runoff via the Danube discharge, which is 60% of the total fresh water discharged into the sea, and precipitation and evaporation. The high sea levels in the first part of the year occur in the condition of a considerable increase of the river volume and important precipitation quantities (53% in May - August) and a reduced evaporation (37% in the first six months of the year. (Selariu, 1971). Analysis of our data regarding Danube's annual regime indicates a maximum mean discharge in May of 23.74 km^3. Maximum discharge of 38.89 km^3 occurred in May 1970. The lowest mean discharge, 11.82 km^3, was recorded in October, with a minimum of 5.89 km^3 in October 1946.

The wind regime at the Romanian littoral is variable, but in certain seasons prevalent frequencies may occur (Climate of Romania). Long-term averages of the wind (1941 - 1997) indicate high frequencies from northern and western directions, 14.9% north and 15% west, where the highest mean speed was recorded as well (north 6.0 m/s). South and southeast winds present a notable frequency, 11.9% and 9.3%, respectively. Due to the coastline orientation, onshore winds produce a sea level rise (northerly and easterly), while offshore wind have an opposite effect (Fig. 4). A significant change of the sea level is induced by strong winds blowing from the same direction for more than 48 hours. Also, short-term changes in the sea level are due to the sub-basin seiches (Blatov et al., 1984).

Sea level annual characteristics

As previously mentioned, sea level evolution presents high values in the first part of the year and low ones in the second (Fig. 5). Mean monthly values, which are positive all over the year, range between 6.84 cm in October and 21.24 cm in May. The maximum mean value, 46.40 cm occurred in March 1970, and the Danube discharge reached its maximum mean monthly value in May of the same year, 38.89 km^3. The low values in the autumn, -13.20 cm in October and -14.20 cm in November, are exceeded in February 1949, when the volume of the Danube is low (7.16 km^3), and severe winter conditions were recorded.

The highest amplitudes, 54.90 cm and 54.40 cm, occurred in February and March, respectively, while lowest amplitude, 35.20 cm, occurred in September and corresponded with the Danube volume's lowest amplitude of 16.27 km^3 in September as well.

Sea level long term evolution

A general, preliminary approach of the sea level long-term evolution indicates that a slight rise of the values is evident. Soviet scientist Altman (1990), considering the entire Black Sea basin, indicated a rising tendency between 1875 and 1985, especially in the last 50 years. His estimate is 1.5-2.0 mm/year. Romanian scientists (Banu, 1961; Bondar & Filip, 1963; Selariu, 1971) analyzed the sea level evolution in different periods and they all identified a rising tendency. Using data between 1933 and 1956, Banu (1961) indicated a mean value 12.7 cm and a tendency of 0.425 cm/year. Selariu (1971), for the period 1933 - 1969, found 13.02 cm as mean value and a tendency of 0.256 cm/year. Later on, studies of the Romanian Marine Research Institute (RMRI) found 13.5 cm for 1933 - 1978 and 14.3 cm for the period 1933 – 1983.

Analysis of the data set between 1933 and 1998 reveals the following aspects:

- annual means are positive, with only two exceptions: -2.44 cm in 1943, the lowest annual mean, and -1.22 cm in 1983;
- the highest annual mean (29.70cm) occurred in 1970, when exceptional runoff was recorded;
- negative values in the entire period represent only 9.7% of the data and these occurred between September and February;
- the mean sea level value, 14.2 cm, is positive relative to the initial reference zero;
- for the entire period, the linear rising trend (Fig. 6) has a value of 0.128 cm/year;
- the Danube's mean water flow at the outlet into the Black Sea during 1858-1988, with an average value of about 191 km^3/year, also has an increase trend in time (Bondar);
- the interannual and interdecadal variations have large amplitudes, and a long period oscillation could be detected;
- the averages computed for the 1946-1955 decade is 10.8 cm, while that of the 1966-1975 reaches 18.6 cm;
- spectral analysis reveals strong oscillations with periods of 2.5 years and 4 years, similar to those of the river discharge;
- the correlation of the variables in the time domain (monthly averages) is significant;
- the wind regime has only a temporary influence and does not affect the long-term evolution of the sea level.

Conclusions

The analysis of the data measured at the Constantza sea level gauge during 1933-1998 period revealed the existence of a rising trend, in good agreement with the estimates made by other authors for different locations (Gorjachkhin, 1995) or for the entire Black Sea basin (Altman et al., 1990). This is also consistent with the contemporary eustatic trend.

Also, significant interannual and interdecadal variations have been observed and estimated through spectral analysis. They are correlated with the changes in the Danube discharge, the main contributor to the river input into the sea. However, the time series are not long enough to allow for the secular oscillations to be accurately assessed.

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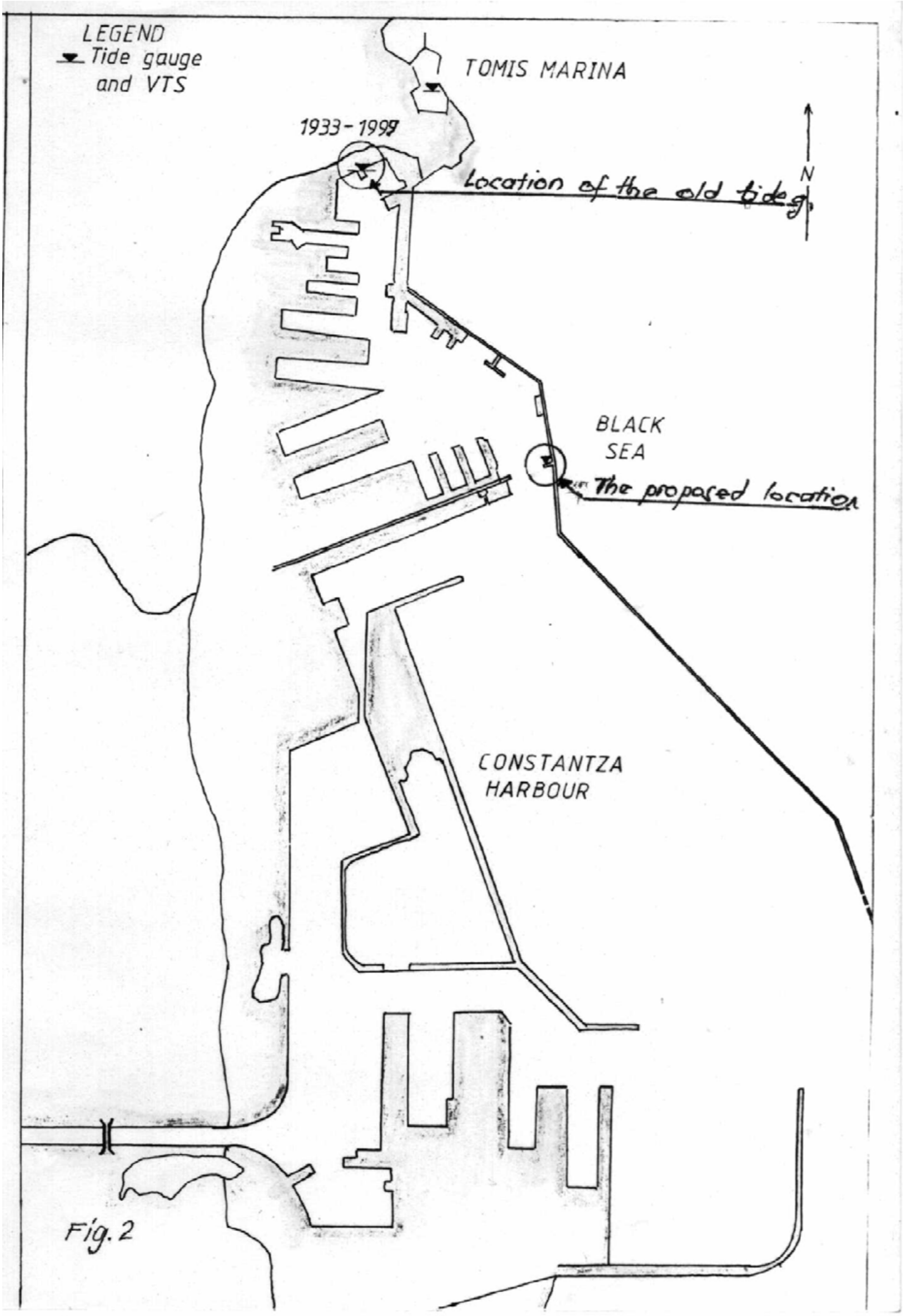

Figure 1. Map of the Constantza area.

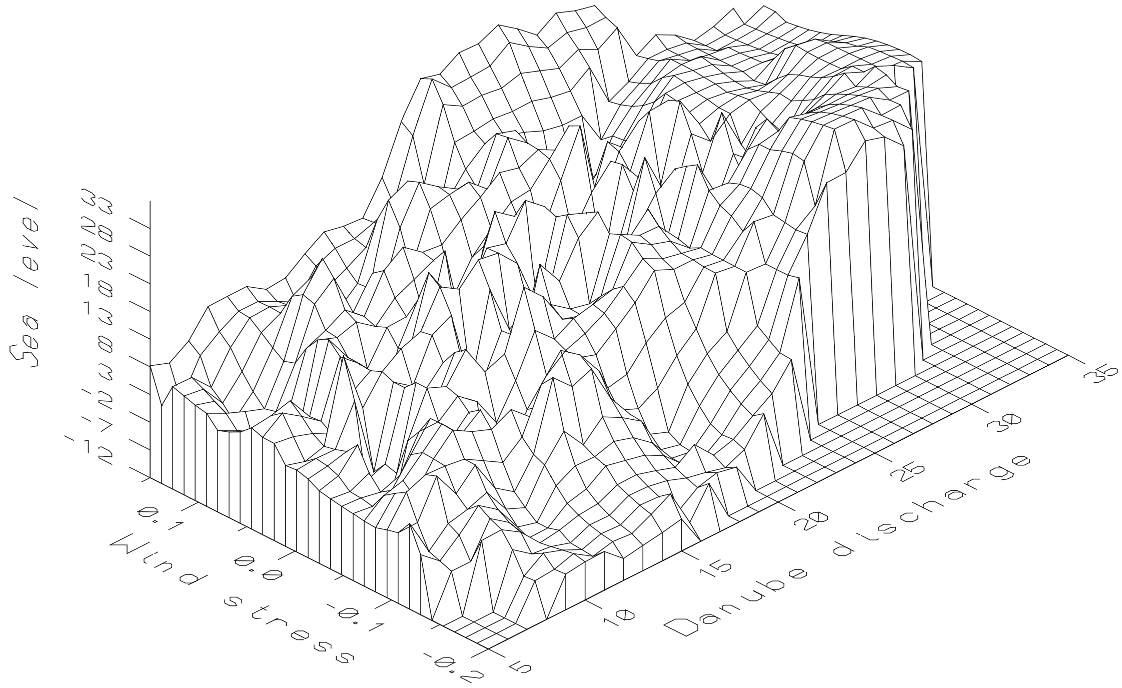

Fig. 2 Correlation between sea level and hydro-meteorological parameters

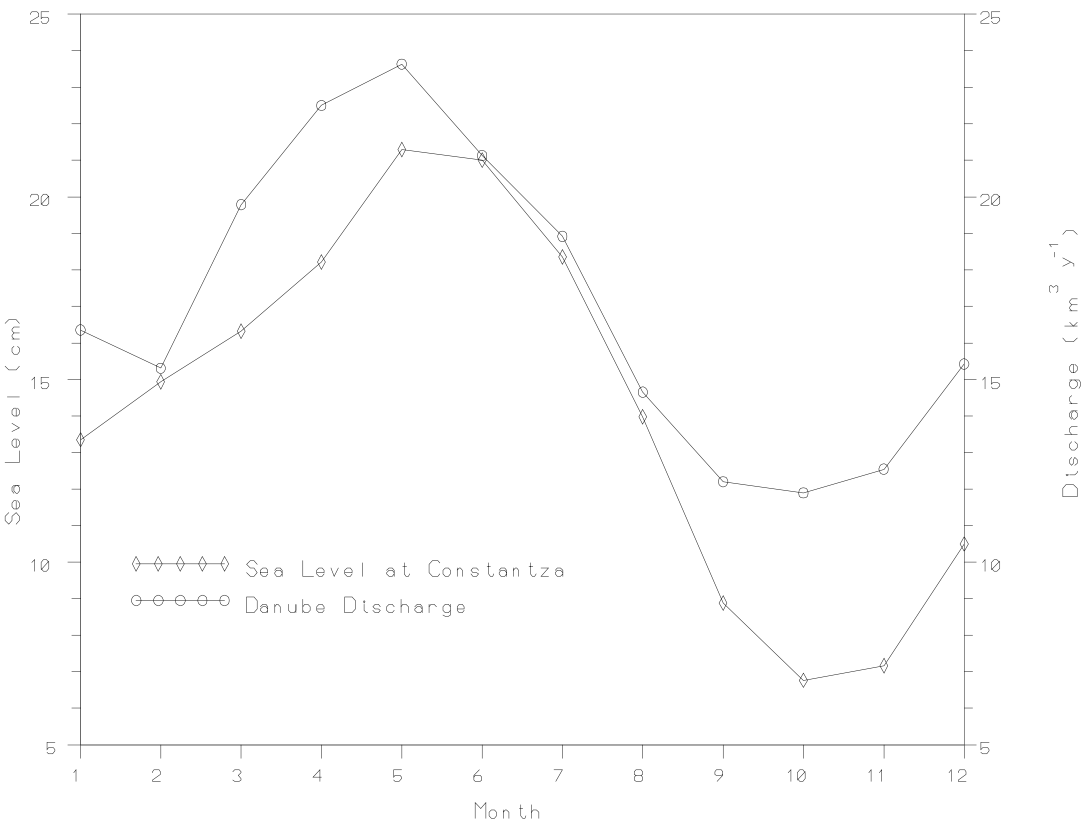

Fig. 3 Annual evolution of the sea level at Constantza and Danube Discharge (1933 - 1998)

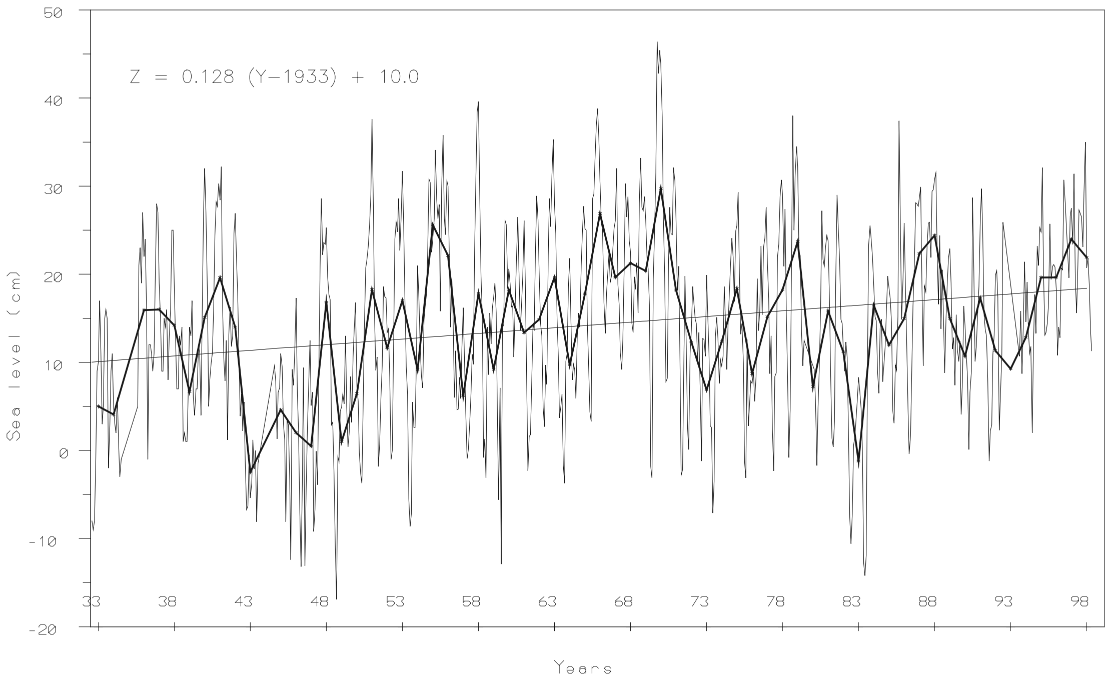

Fig.4 Evolution of the monthly and annual means of the sea level at Constantza and their trend

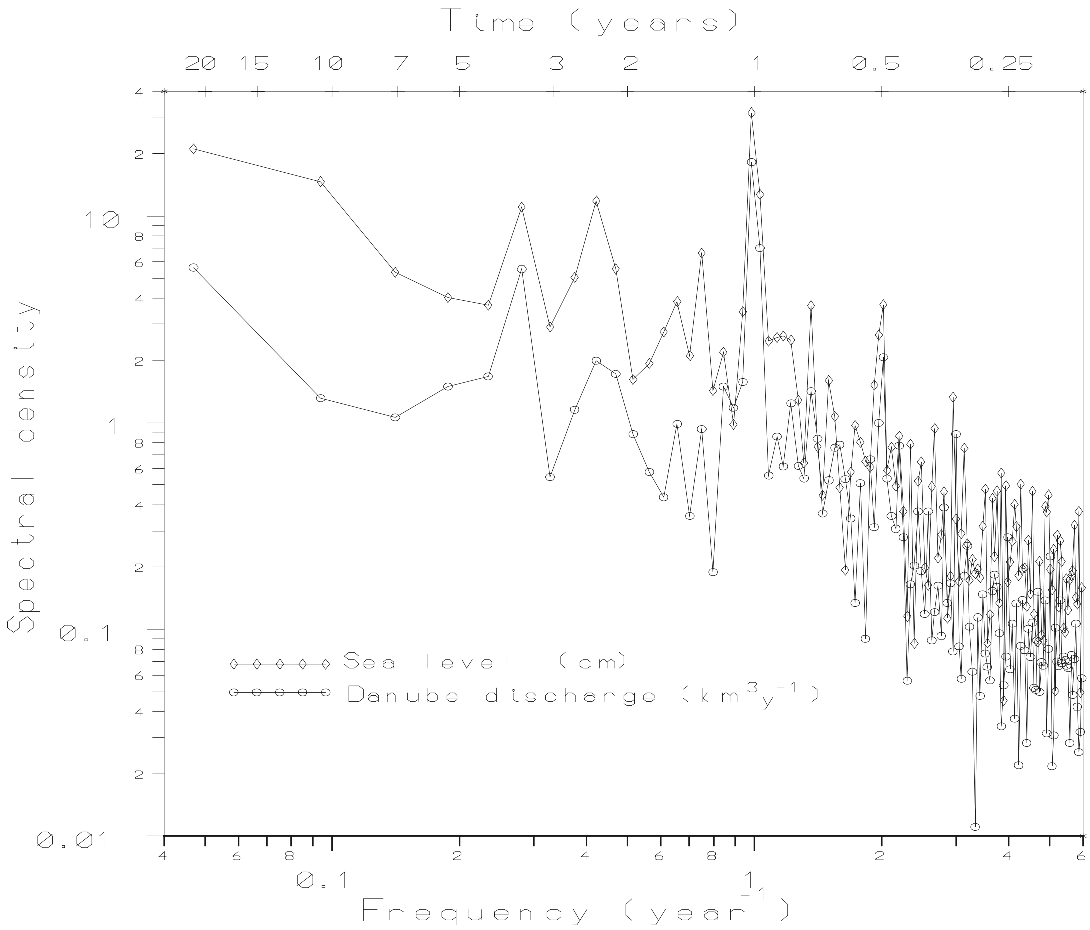

Fig. 5 Spectral density of the sea level at Constantza and Danube discharge

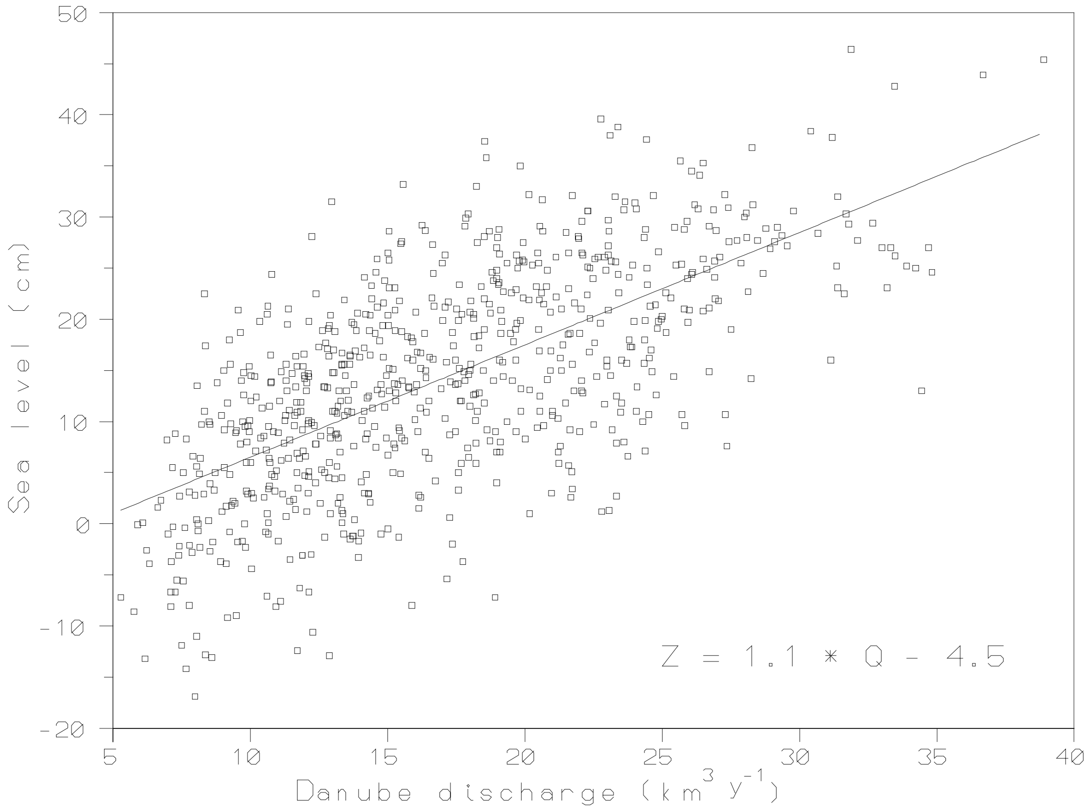

Fig. 6 Correlation between sea level monthly means and Danube discharge

IVg - SEA LEVEL MONITORING AND FORECASTING ACTIVITIES OF PUERTOS DEL ESTADO

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A description is made of the Spanish Harbours tide gauge network (REDMAR), especially focused on the status of the Mediterranean stations. This network consists of 14 acoustic gauges with radio or modem transmission of data to the harbour office, where data is automatically sent twice a day by ftp or mail to the central station in Madrid (Clima Maritimo). This department has also developed an storm surge prediction system, called Nivmar, based in the ocean circulation HAMSOM model (which performs the prediction of the meteorological residuals), and the tide gauge data, which is used both to obtain the astronomical prediction in the harbour and to validate the system.

1. INTRODUCTION

In 1989 the old Spanish State Harbours Office (Direccion General de Puertos) decided to create a permanent sea level monitoring system which included the possibility of consulting the data in real time by the harbour users apart from generating historical series to be included in the Clima Maritimo Data Bank, linked to this Office. The design of the network was supervised and executed by the Centro de Estudios de Puertos y Costas (CEDEX, Ministry of Public Works), under the direction of the mentioned Clima Maritimo Department.

The equipment selected was the acoustic gauge of SONAR Research & Development (Ltd.), because it included real time data transmission to the harbour office and their maintenance was very easy. In 1991 13 harbours were selected to establish the REDMAR network, and the stations were tested by the Centro de Estudios de Puertos y Costas until July 1992, when the network officially began to work continuously. Since then, data is stored, quality controlled and analysed in the Clima Maritimo department of the Puertos del Estado (Spanish Harbours). The stations of the Mediterranean are: Barcelona, Valencia and Malaga. A new station is being planned for Ibiza (Balearic Islands).

A storm surge prediction system (Nivmar) has been working since 1998 for the Spanish Atlantic coast and since 1999 for the Mediterranean coast (http://www.puertos.es/Nivmar). Nivmar is based on the ocean circulation HAMSOM model and on the harmonical prediction of tides computed from data measured by REDMAR. The model is executed twice a day, forced by meteorological fields derived from the INM (Instituto Nacional de Meteorologia) operational application of the HIRLAM atmospheric model. Data from the REDMAR tide gauges are used to forecast the tidal elevations, to validate the system and to perform data assimilation, correcting systematic errors in the mean sea level due to physical processes that are not included in the ocean model. The forecast horizon is 48 hours.

The automatic data transmission from the harbours to Clima Maritimo and their inclusion in the Nivmar system is under development. At the moment, this is working for four stations: Bilbao, Villagarcia, Valencia and Barcelona.

2. REDMAR NETWORK

A map is presented in Figure 1 with the 14 stations that currently constitute the REDMAR network. Since June 1999 a pressure sensor has also been working in the island of Hierro (Canary

Islands), a point that will soon belong to the REDMAR network. A new station is also being planned for the Ibiza Island, in the Balearic Islands, in collaboration with other institutions to get a permanent GPS monitored station for altimeter calibration.

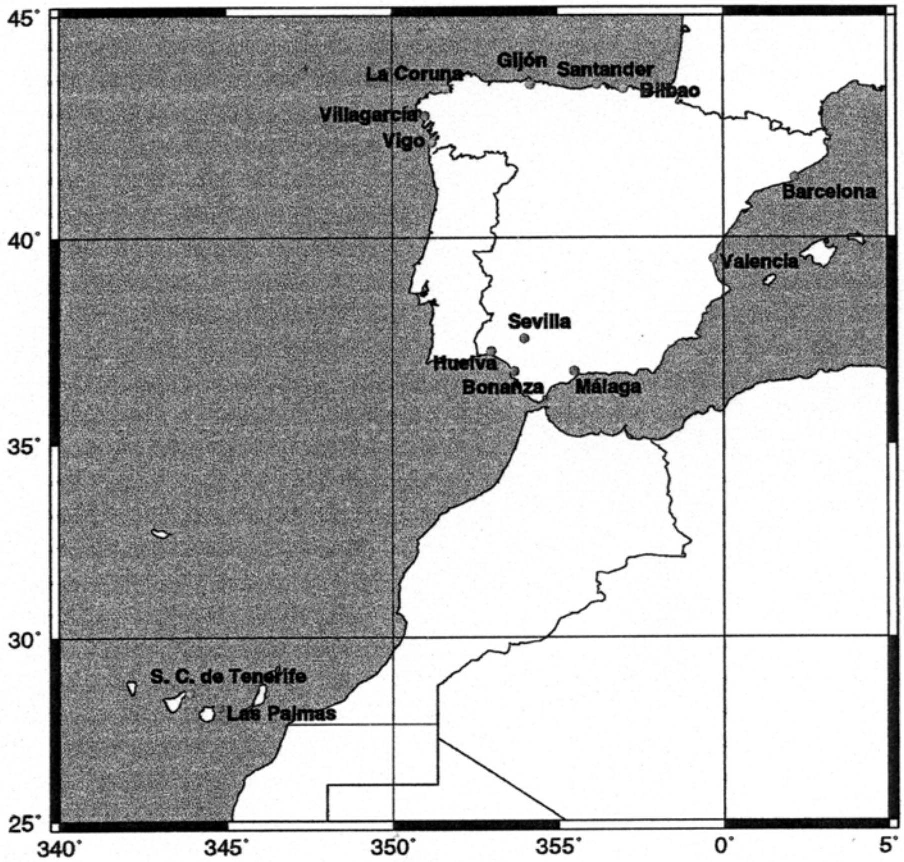

Figure 1: stations of the REDMAR tide gauges network

2.1 Description of the SONAR gauge

The selected equipment was the SONAR Research & Development acoustic tide gauge with real time radio transmission to the harbour office. The technical specifications are:

- height measurement range: 10 meters height measurement resolution: 1 cm
- height measurement accuracy: 0.05 % (better than 1 cm for instantaneous levels) time measurement resolution: 1 s
- time measurement drift lower than 1 minute per month acoustic frequency: 50 KHz
- telemetry output: RS 232 every minute
- sampling period: 1,2,3,4,5,6,10,15,20 and 30 minutes
- averaging period: number of measurements used to provide averaged tide height can be: 1,2,4,8,16,32,64.

The transducer is located above the sea surface, at a distance not less than 2 meters during high tide and not more than 9 meters during low tide (the highest tide range in Spain is about 5 meters). The transducer has to be mounted within 2 degrees of horizontal to achieve optimum results. The view of the transducer should be unobstructed within a 10-degree conical angle to avoid interfering targets. For permanent installations it is strongly recommended that the system operate down a plastic tube.

The distance to the water (air distance) is obtained from the sound velocity and the time the ultrasonic ray needs to reach the water surface and go back to the transducer again. The distance from the sensor to the reference level or zero is called the *datum;* sea level is then calculated as the difference between the datum and the obtained air distance.

As sound velocity depends on environmental conditions, especially on the temperature, it is calculated before each measurement by sending ultrasonic pulses to a fixed target located at 0.75 m from the sensor (this distance is factory set). In this way, each measurement lasts around 36 seconds: the first 10 seconds are used to determine the sound velocity by sending 128 valid echoes to the target; then another 128 valid echoes are sent to the water surface and a mean value is calculated to filter the high frequency waves.

For most of the REDMAR stations the transducer measures inside a 0.30 m diameter plastic tube, with its lower extreme at a point below the lower low water and a small hole of 3 cm. The role of the tube is of course not only to filter the waves but also to protect the ultrasonic rays path. In some places, like Santander, it was possible to install it in an existing stilling well, inside a small building.

Although the reference target is employed to take into account variations in temperature and other parameters, this is done in the first 1-meter distance of the tube, so it is still possible that strong temperature gradients along the tube affect the signal. This has happened especially in our southern harbours where the summer is very hot. Our recommendations for the harbours are the same than for other acoustic sensors: to employ white painted tubes, to avoid different ambients along the tube, to do small holes above the higher high water to facilitate ventilation and even to construct a protection from the sun. This has proven to be a very good solution. From our experience, the above-mentioned requirements of the installation are critical to get the accuracy claimed by the manufacturer. It has also been noted that the system works perfectly inside a building above a stilling well, like the stations in Santander and Malaga harbours. Even without a stilling well, as is the case for Villagarcia, the careful design of the installation to protect the tube from the sun has provided data with accuracy better than 2 cm for instantaneous measurements. The principal disadvantage of this type of acoustic sensor is that is very dependent on these conditions of the installation.

The problem of the temperature gradient is less important in the Mediterranean stations, because the tide range here is very small.

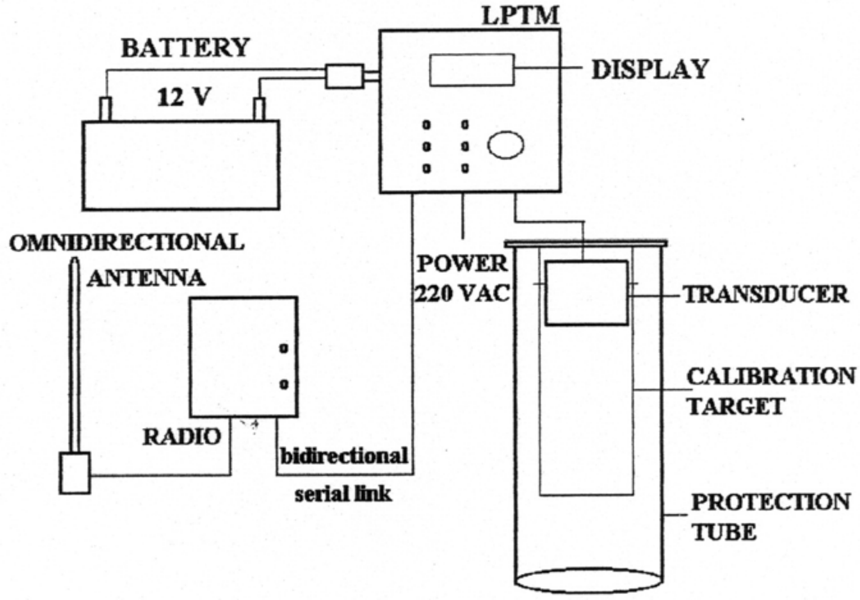

Figure 2: Elements of a normal station of the REDMAR network

2.2 Data storage and transmission

The ultrasonic transducer is connected to an intelligent unit (LPTM: Low Power Telemetry Unit), which allows to select the sampling interval (5 minutes at this moment for all the REDMAR stations), the averaging period (1 measurement), the station number and to establish the tide gauge datum, as well as to adjust the clock time, display the data and store them. It provides also the power supply (Figure 2).

The LPTM may be connected to a personal computer and transmit data by modem to the harbour and to the central station in Madrid or, as is the case for most of the stations of REDMAR, it may transmit the data by radio to the harbour office, where data are stored in a PC and transmitted by mail or ftp to the central station. The sensor has an internal cyclic memory that permits to store up to 28 days of 5-min data.

2.3 Datums and levelling status of the REDMAR stations

Most of the REDMAR stations measure sea level data with respect to the harbour-working datum, a reference provided by the harbour authorities. Besides, the Instituto Geografico National (IGN) has provided the Tide Gauge Bench Marks (TGBM) and their relation to the national levelling system for all the stations. The connection between the TGBM and the tide gauge zero is responsibility of Puertos del Estado, and is checked twice a year by the maintenance staff. The tide gauge contact point is for the SONAR gauges the ring around the centre of the transducer. This is leveled to the TGBM with a few millimeters precision, by the tide gauge maintenance responsible. Anyway, and as it is recommended by the supplier, the datum is initially adjusted to give the expected tide height as indicated on a local tide staff, or by measuring manually (e.g. an electric tape) the distance to the water surface; this allows any small anomalies between the reference measurement and the tide measurement to be assessed. Our experience is that this calibration is needed the first time the gauge is installed, and is checked twice a year, together with the levelling of the Tide Gauge Contact Point to the TGBM. However, due to the resolution of the datum value (1 cm), the reference level for this equipment is fixed at best with 1 cm accuracy.

Also the conditions to make the manual measurement or the reading of the tide staff influence very much the accuracy of the first establishment of the reference. It is very easy when the gauge is measuring in a stilling well, because here the water is quiet (for example our station in Santander), but when a tube is used, it is not possible to open it and measure inside without affecting the sensor, so we have suggested to the harbours to install a parallel calibration tube that filters the waves, in order to check the reference with more reliability.

The national datum for the Iberian Peninsula has been for the last 100 years the Alicante Mean Sea Level (NMMA) during the period 1870-1880. In 1998 the IGN redefined the levelling network and, as it has occurred in other countries in the past, the heights of the TGBM with respect to NMMA have changed up to 30 cm in the harbours of the North coast. Nowadays the IGN is beginning to establish GPS permanent stations all around the country, although only two are at this moment completely operational: Alicante and Coruna, in both cases located exactly in the place of the corresponding IGN tide gauge. Puertos del Estado and IGN are about to sign an agreement to connect the IGN GPS permanent stations close to the REDMAR tide gauges with the corresponding TGBM and to install a sufficient number of auxiliary marks in the proximity of the tide gauge, to be checked periodically (this has not been done up to now).

2.4 Data processing

The gauges measure sea levels at five-minute intervals. Once the raw data is received in Clima Maritimo a quality control procedure is initially applied to detect the most obvious errors: clear spikes, gaps, sudden change of reference-etc. So a clean 5 min-sampling series is obtained before calculating the hourly means.

The hourly means are obtained by means of a 54 points symmetrical filter (Pugh, 1987) in order to average the seiches, especially important in the Mediterranean stations.

The software developed by the University of Hawaii Sea Level Center (Caldwell, 1998), based on the harmonic analysis and prediction programmes developed by Foreman (1977), is used to obtain the harmonic constants, residuals, and mean sea levels, although an adapted version for Unix systems is being developed in the department. Also tide ranges and extremes are calculated on an annual basis and published in form of technical reports for the harbour authorities. All these data are stored in the Clima Maritimo Data Base and will be in the near future accessible for the users on the web page.

2.5 Mediterranean stations

There are three stations of the REDMAR network in the Mediterranean coast: Malaga (Alboran Sea), Valencia (in front of the Balearic Islands) and Barcelona (Cataluna). As it was mentioned another one is being planned for Ibiza (Balearic Islands).

As for the rest of the REDMAR stations, the recording interval is 5 minutes. This seems to be especially important in the Mediterranean gauges, due to the existence of sub-hourly higher frequency noise due to seiches that may occasionally reach amplitudes of nearly 0.5 meters. It is interesting for the harbour authorities to have this phenomenon registered.

In Figure 3 the daily and monthly means for the three stations are presented since the beginning of the operation in 1992. The tide range is much smaller than in the Atlantic coast, especially in Valencia, very close to the M2 amphidromic point that is located close to Alicante. In Table 1 the principal harmonic constants are shown for the three harbours. From South to North the semidiurnal constants are dominant in Malaga (semidiurnal tide, Form Factor=0.20), are less important than the diurnal ones in Valencia (mixed tide, mainly diurnal, Form Factor=2.67), and are again just a little bit higher in Barcelona (mixed tide, mainly semidiurnal, Form Factor=0.96).

	Malaga - .		Valencia		Barcelona	
	Amp (cm)	Phase (g.)	Amp (cm)	Phase (g.)	Amp (cm)	Phase (g.)
01	1.79	124.20	2.51	107.47	2.54	102.30
Kl	3.42	152.60	3.73	162.60	3.68	170.72
M2	19.06	49.43	1.79	196.22	4.71	212.87
S2	7.21	74.07	0.54	146.76	1.74	232.60

Table 1: principal harmonic constituents *derived from 1999 hourly values*

In Table 2 also the extremes for the period July 1992 to December 1998 are presented for the three stations, obtained from the hourly and 5-min data, as well as an estimation of the maximum and minimum residual value. The tide range is only included for Malaga because the tide is really small in Barcelona and Valencia. The standard deviations of the residuals in 1999 are 6.6 cm (Malaga), 7.0 cm (Valencia) and 7.0 cm (Barcelona). The hourly data standard deviations for 1999 are 18.7 cm (Malaga), 14.4 cm (Valencia) and 11.8 cm (Barcelona).

Harbour	Hourly level		5 min	level	Surge		tide range	
	Max	Min	Max	Min	Max	Min	Max	Min
Malaga	122	-8	133	-10	48	-35	84	12
Valencia	145	56	158	41	42	-35		
Barcelona	72	-25	76	-26	45	-35		

Table 2: *Extremes for the* period *July 1992-December 1998*

Malaga: (36°42'50" N, 004° 24'52" W)

The tide gauge is located beside the Instituto Espanol de Oceanografia (IEO) float gauge. They measure in the same stilling well, although in two different tubes inside it. The TGBM is SS2NGK-236, and is located in the outside of the stall, next to the door. Another stable benchmark is the NAP-548 located in the wall of the lighthouse La Farola a few hundred meters from the gauge.

The LPTM is directly connected to a PC inside the stall, which transmits automatically by modem the data to another PC in the harbour office. This second PC is connected to the local informatic network and receives data not only from the tide gauge but also from other type of sensors in buoys close to the harbour. From this PC data are sent automatically via mail or ftp to the central station (Clima Maritimo). This is cheaper than the tide gauge PC sending direct by modem the data to Madrid.

Name:	*NMMA:*	*Harbour zero:*	*IEO zero:*
SS2NGK-236	0.829	1.244	1.640
NAP-548	5.393	5.808	6.204

Table 3: altitudes (meters) *of the principal* bench marks above *the NMMA,* harbour *zero* and *TEO* zero *for Malaga station*

The IGN has recently installed a permanent GPS station at about 5 km of the tide gauges station that has not been connected yet to the TGBM.

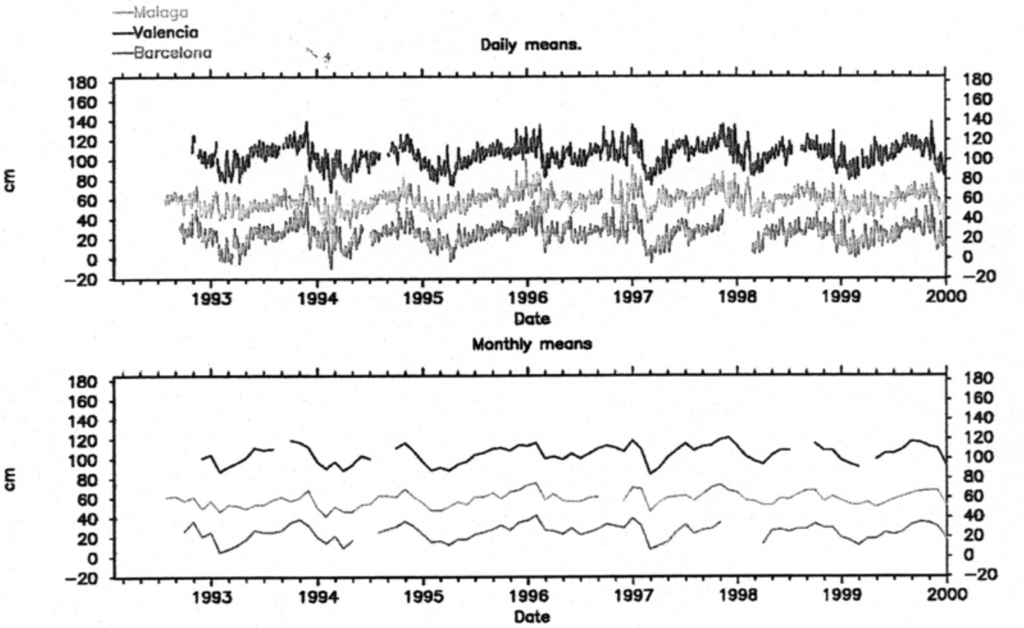

Figure 3: daily and monthly means *for the* three *Mediterranean stations since the* beginning of the operation

Valencia: (39°2T42" N.000° 19'33" W)

The tide gauge measures inside a 300 mm tube, with an outer protection for the sun and the ships. The TGBM (NGU 66) is located close to the tube on the pavement of the pier. The LPTM and the antenna are inside a nearby workroom. Another stable benchmark is the SS, located in a corner of the fish market building.

NCU- 66

Name: NMMA: T.G. Zero: 1.808 2.786	
SS 1:355 2.333 B	

Table 4: *altitudes* (in meters) *of the principal* benchmarks in Valencia above *the NMMA and* the Tide Gauge *Zero*

In this case, the tide gauge zero is not the harbour zero but a reference situated 1 meter below it. The IGN has established a permanent GPS station in December 1999 at about 4 km from the tide gauge, not yet connected to the TG.

Real time data are sent by radio to the harbour office and collected by a PC that, as it is connected to the local informatic network, sends the data automatically twice a day to Clima Maritimo by mail or ftp.
Barcelona: (41°21'01"N,002°09'41"E)

This gauge measures also inside a 300 mm tube and transmits the data like the Valencia station to the harbour (real time radio transmission) and to the Madrid central station (twice a day). The TGBM (NGP 791) is on the pavement in front of the South side of the stall. Another stable benchmark is NGP 792, between the CAMPSA tanks and the "Can Tunis" Institute walls.

Name:	*NMMA:*	*Harbour zero:*	*UELN:*
NGP-792	4.148	4.174	3.663
NGP-791	2.412	2.438	1.927

Table 5: Altitudes in meters of the *principal* benchmarks in *Barcelona,* station

A GPS campaign (EUVN97) was made in May 1997 by the IGN. The antenna was collocated at a near TIR building inside the harbour, in such a way that the distance between the NGP 791 and the EUVN point was 580 m. The IGN also connected by high precision levelling the two points, giving the altitude of the bench mark above the UELN (Unified European Levelling Network).

3. NIVMAR SYSTEM

As mentioned in the introduction, in 1998 a storm surge prediction system was first established by the Clima Maritimo department, based on the ocean circulation HAMSOM model and on the harmonically prediction of tides derived from the REDMAR network. The HAMSOM is a three-dimensional and finite difference ocean circulation model developed by the IFM (Institute fur Meereskunde, Hamburg) and by Clima Maritimo. (Backhaus, 1983; Backhaus, 1985; Backhaus and Hainbucher, 1987; Rodriguez and Alvarez, 1991; Rodriguez et *al,* 1991; Stronach *et al, 1993;* Alvarez *et al,* 1997). It is based on the set of primitive equations (Reynolds equations) and uses hydrostatic and Boussinesq approximations. It is formulated on an Arakawa-C grid and based on a semi-implicit scheme. The model can take into account the tides, wind, atmospheric pressure, heat fluxes and baroclinic gradients inside the ocean. It has been applied to a large variety of scales and phenomena, from studies of tides in the Eastern North Atlantic to estuarine circulation in the Ria of Vigo (Galicia).

The Nivmar system consists of a set of different applications and programmes that make use of the barotropic and vertically integrated version of the HAMSOM model. The model domain covers an area extending from 20°N to 48°N in latitude and from 34°W to 30°E in longitude. The bathymetry employed, based on the DTM5 data set (GETECH, 1995), was built by using a variable grid size scheme in order to reduce the number of computational points. The region from 25ºN to 48ºN and from 20ºW to WE keeps a constant resolution of 10'x15'. The grid size in the rest of the domain is increased progressively to the boundaries.

The HAMSOM is executed twice a day using the output from the INM (Instituto Nacional de Meteorologia) application of HIRLAM (Kallen, 1996) to give the meteorological sea levels with a forecast horizon of 48 hours. The meteorological data consist of six hourly fields of winds at 10 m and pressures, with 0.5°x0.5° resolution. These are interpolated to the HAMSOM grid in an initial stage.

IVh- SEA-LEVEL GAUGE NETWORKS IN ITALY

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INTRODUCTION

A few sea-level gauges were in operation in Italy already in the last decades of the 19th century, but a coordinated national network started to operate on a regular basis only recently. Long and almost uninterrupted time series of sea-level data are therefore available only for few Italian stations (Spencer and Woodworth, 1993).

In Italy the following Organizations are involved in sea-level measurement:

i) Dipartimento per i Servizi Tecnici Nazionali, Servizio Idrografico e Mareografico Nazionale (SIMN), Rome, with regional Department in Venice;
ii) Istituto Idrografico della Marina (IIM), Genoa;
iii) Comune di Venezia, Centro Segnalazioni e Previsioni Maree (CSPM), Venice;
iv) Istituto Sperimentale Talassografico (IST), Trieste.

This paper gives a short summary of the present situation of Italian sea-level gauge stations according to the information from the above Organizations.

The networks

SIMN is a section of the Dipartimento per i Servizi Tecnici Nazionali, a governmental Organization formally belonging to the Prime Minister's Office. It is the official national service in charge of operating the National Sea-level Gauge Network. Its network (Gasparri et al., 1996) has been in operation since June 1998. It is composed of 28 sea-level gauges located at the following sites: Imperia, Genoa, Livorno, Civitavecchia, Porto Torres, Carloforte, Cagliari, Naples, Salerno, Palinuro, Palermo, Lampedusa Island, Porto Empedocle, Catania, Messina, Reggio Calabria, Crotone, Taranto, Otranto, Bari, Vieste, Tremiti Islands, Ortona, Pescara, Marina di Ravenna, Ancona, Venice Lido and Trieste. At each station the sea level is measured by means of one ultrasonic gauge with temperature compensation and one float gauge with analog record on paper. The station benchmarks are levelled relative to the closest IGM (Istituto Geografico Militare, Army Geographic Institute) datum. Other parameters are observed, namely wind vector at 10 m height, atmospheric pressure, air temperature and sea temperature. All data are stored locally and transmitted in real time to SIMN headquarters in Rome.

SIMN includes regional Departments, one of which is based in Venice (SIMN-Venice) and operates a regional sea-level gauge network in addition to the national one for civil protection purposes connected with storm surge hazard along the Northern Adriatic coast. The SIMN-Venice network is composed of 49 sea-level gauges. 36 gauges are located within Venice Lagoon, three within Marano Lagoon, seven at the outlets and in front of Venice Lagoon, two at the outlets of Marano Lagoon and one on the coast South of Venice Lagoon. Almost half of the stations are provided with real-time data transmission to the central office in Venice.

IIM is a State Organization belonging to the Italian Navy. Its activity mainly deals with navigation, including chart production. It operates two sea-level gauges (IIM, 2000) at the stations of Genoa and Brindisi, equipped with mechanical float gauges. Data is continuously recorded on paper and subsequently digitized.

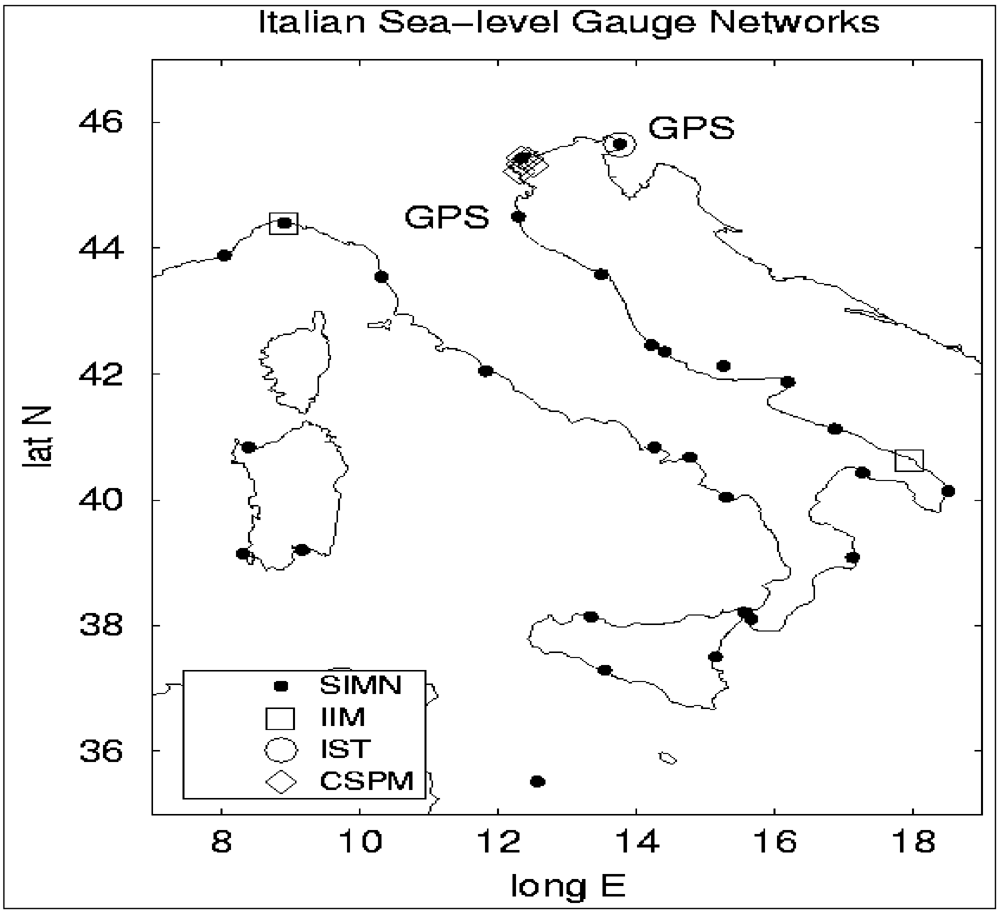
CSPM is a public Organization belonging to the city administration of Venice. Its activity includes sea level monitoring at five sea-level gauges and sea-level prediction. It is also in charge of issuing warnings to the Venice population when particularly high sea-level events are predicted. CSPM operates 5 sea-level gauges (CSPM, 2000), one within Venice Lagoon, 3 at the lagoon outlets and one located at the CNR platform “Acqua Alta”, approximately 8 nm offshore, where meteorological parameters also are measured. Data is transmitted to the central office at fixed intervals.

IST is a research institute belonging to Consiglio Nazionale delle Ricerche (CNR). It operates one sea-level station in Trieste for research purposes, which is equipped with two float gauges. Analog records are made on paper, and digital records are stored on solid-state memory. Atmospheric pressure, wind vector, air temperature and sea temperature are measured at two stations within 500 m from the sea-level gauge. Ferraro (1972) reports the details on the sea-level gauge, including the different zeroes adopted during the secular history of the station. Sea-level related activity includes sea-level modelling (Raicich et al., 1999b) and joint analysis of sea-level and atmospheric data time series on different time scales, namely from hourly/daily, as in the case of seiches and storm surges (Raicich et al., 1999a), to interannual/multidecadal, concerning mean sea level variability (Crisciani et al., 1994; Raicich and Crisciani, 1999). IST also publishes astronomic tide predictions for Trieste (Maselli and Raicich, 1999).

Figure 1 displays the sea-level gauge locations along the Italian coast. All stations are shown except for the 49 SIMN-Venice stations, mostly located in the Northern Adriatic lagoons.

GPS receivers, operated by University of Bologna, have been installed at the SIMN sea-level station at Marina di Ravenna (July 1996) and IST station at Trieste (March 2000).

Fig.1 – Sea-level gauge locations along the Italian coast. (49 SIMN-Venice stations mostly in the Northern Adriatic lagoons are not shown. The two stations with GPS are labelled accordingly).



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IVi - DESCRIPTION OF NEW MEDGLOSS SEA-LEVEL STATIONS FUNDED BY CIESM

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1. General

The description presented below gives details of the new MedGLOSS sea-level stations funded by CIESM within the CIESM/IOC MedGLOSS pilot network programme. The equipment was selected based on the long-term experience gathered at the Hadera GLOSS station no. 80 as well as at other stations installed in Israel by IOLR. The stand of the sea level was designed by Impac Engineering Ltd., of Haifa according to guidelines provided by the author, in order to enable simple, easy and long lifetime of the equipment and its maintenance.

2. Equipment description

The equipment of the new stations includes an underwater pressure sensor of Paroscientific Inc. manufacture, type Digiquartz Intelligent sensor, model 8DP060-1 with an RS-232 communication cable; Setra atmospheric pressure sensor, type 470, Garmin GPS II Plus Personal Navigator unit with serial output and remote antenna for accurate time recording, computer (Pentium II 350MHz computer with Windows 98 and 6 MB disk and US Robotics 32,000 baud rate modem), connections and power supply unit (designed and built at IOLR).

The underwater sensor is attached to a stand which can be dismantled for maintenance (cleaning needed from time to time) but which when reinstalled brings the sensor to its original elevation within less than 0.2 mm accuracy. The underwater stand has to be attached a wharf/pier.

The underwater Paroscientific sensor dimensions are about 10cm diameter, about 25cm long (details at http://www.paroscientific.com). As shown in Figure 1 below, it is housed in a stainless steel (type 316-L) protective open housing, attached to a sea-level stand, about 6m long. The stand is attached to the wharf/pier via two special screws initially cast in the wall of the wharf. Furthermore, underwater, at the end of the stand is attached a special rod. This rod is inserted underwater into a vertical stainless steel tube, welded to a horizontal stainless rod, which is attached to a steel plate (40cm x 40cm x 2cm) which must be attached (cast using special epoxy glue) to the wharf or pier *in situ* (in case of concrete it can be done by drilling holes in the concrete and then inserting screws with expanding nuts, in case of steel structure it is necessary to perform underwater welding). In the stand there are special arrangements for enabling one-time setting of the two leading plates with a notch. After the lower end of the stand is inserted in the tube and its top plate rests on the tube end, the leading plates at the top of the stand are adjusted such that the upper screw touches the upper end of the notch. Then, to take the stand with the sensor out of water for cleaning or maintenance, the stand is pulled upwards to extract the bottom rod from the tube, and than the nuts attached to the two screws are removed.

[1] Programme coordinator and chairman, IOC/CIESM Joint Group of Experts on MedGLOSS

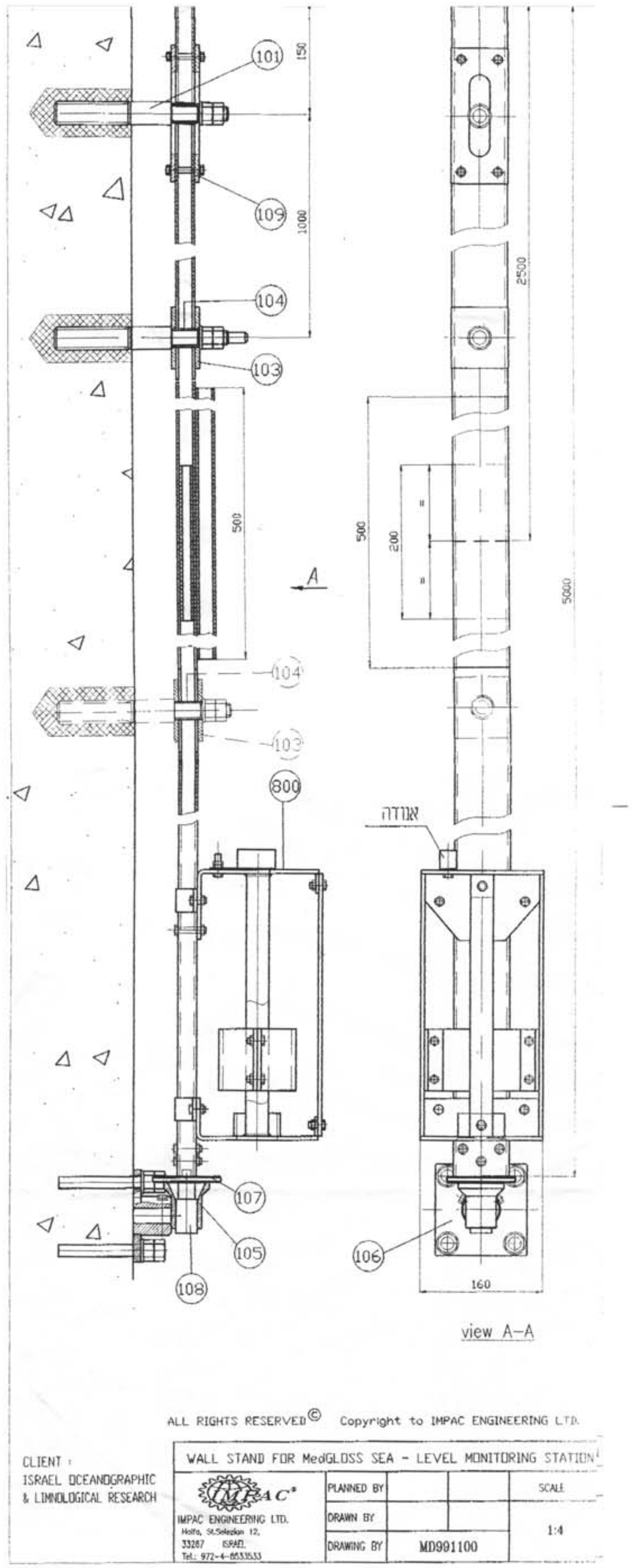

Figure 1 - New MedGLOSS sea-level stand with Paroscientific sensor housing

In regards to maintenance of the equipment, depending on the local conditions, it is necessary to clean the underwater sensor once per week. The cleaning and maintenance takes 10 minutes at the most, including cleaning of the underwater pressure sensor and its orifice, and its underwater cable and once every few months also cleaning of dust of the atmospheric pressure sensor. About once per month it is necessary to download data from the computer hard disk for archiving at your institute. Again it is an operation, which needs a few minutes. A telephone line is available at the location of the logging computer (near the sea-level station, preferably less than about 150m), so that the data gathered and processed by it can be transmitted by modem and telephone line to a computer with modem and telephone line at the institute in charge with the station operation. From there it may be sent via Internet to the other centers. Otherwise it may be sent by telephone, say once per day to save costs also to the regional centers and to PSMSL.

Prospects of the equipment are available via Internet from the following addresses:

- For Paroscientific underwater pressure Intelligent Digi quartz sensor:
  http://www.paroscientific.com/Ds.htm
- For Setra atmospheric pressure sensor:
- http://www.setra.com/tra/ins/pdfs/m470.pdf

IVj - A REVIEW OF SEA LEVEL MONITORING STATUS IN ISRAEL

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Introduction

Sea levels have been measured since the early 1920s at Jaffa fishing port, but these data are not available, except for some data found at the PSMSL in UK during the 1950s.

New sea levels were gathered at Ashdod and Haifa ports, and since 1992 at Hadera. Recently sea level is being recorded also in Tel-Aviv, inside the Gordon Marina, and at Ashkelon Marina.

The information presented in this report was derived using historic sea-level data gathered originally by PRA and archived at the Permanent Service for Mean Sea-Level (PSMSL) in UK. Additional sea-level data were gathered in the recent years by IOLR for PRA in Haifa. Correlation between simultaneous data gathered at Haifa and Ashdod in the past, and between Haifa and Hadera in the recent years allowed determining the relationship between long-term elevations at Haifa, Hadera and Ashdod.

Recent History of Sea-Level Monitoring on the Mediterranean Coast of Israel

Sea level has been monitored in Israel during the British mandate in Jaffa harbour, in Haifa port and in Eilat. The measurements were performed using a float-type mechanical mareograph (sea-level recorder as in fact it measures the total sea-level due to astronomic tide as well as other parameters (temperature, atmospheric pressure, wind surge, wave induced set-up, etc.). However, the records of sea-level data gathered during the period prior to the establishment of the State of Israel are not available and have probably been lost forever.

Sea-level data were gathered since then in Israel by a number of authorities for certain periods and certain locations as follows: Ports and Railways Authority (Haifa, Ashdod and Eilat), Meteorological Service (Haifa, Eilat), Survey of Israel (Eilat, Jaffa shifted now to Tel-Aviv), Geological Survey Institute (Atlith), Israel Oceanographic and Limnological Research (Hadera, Haifa, Eilat). During the 50s and 60s (monthly averages) at Jaffa harbour (1955-1959, 1962-1967) were transmitted to PSMSL and thus are found in its archive. Also monthly average values of sea-level data gathered at Haifa port (1956-1959, 1965-1976) and from Ashdod port (1958-1980) were found archived there. Yearly reports of measured hourly values of sea levels were published by the PRA during the period 1958-1984. However, only some of those of the 60s and 70s included sea levels gathered at Haifa port, while all the reports included hourly sea levels gathered at Ashdod port (and some also at Eilat port). A survey of the Israeli sea-level data has been conducted in the past by Goldsmith and Gilboa (1985), who uncovered some additional data from Jaffa at the Survey of Israel and reported the monthly means.

Since April 1985, the Ports and Railways Authority (PRA) division responsible for the preparation of the yearly reports was dismantled, and the gathered data on paper chart remained unprocessed, until 1989, when the Survey of Israel (SOI) started gathering and manual processing these data. However, the manual processing of the data included only the daily highs and lows at Ashdod port, without recording of the time at which they occurred. The data between 1989 and 1992 were provided to the author by the SOI. The newer data from Ashdod and Haifa (1989-1995) are presently undergoing digitization by SOI, including recording of the times of the lows and highs, following the author’s remark on the importance of time recording. The Jaffa station, which used originally as the benchmark for the establishment of the sea-level reference, was dismantled and since 1996 a new station was installed in Marina Gordon at Tel-Aviv, site that however is not best suited for long-term sea level monitoring, being located in shallow water and consequently affected by wave set-up. The Ashdod, Tel-Aviv and Ashkelon stations are maintained by SOI.

In 1992 IOLR installed a next generation digital sea-level monitoring station at Hadera, which became since 1994 one of the primary stations (No. 80) of the Global Sea-Level Observing System (GLOSS) network of the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Sea levels gathered at Hadera are considered to be of superior quality due to the equipment used and due to the location of the station, 2.1km offshore, far beyond influence of wave induced sea-level set-up occurring in the surf zone. Since 1994, IOLR started digital gathering of long-wave data in Haifa port, which, as a by-product enabled also gathering of sea-level data there.

Previous analyses of sea levels in Israel were performed by Gilboa and Goldsmith (1986), by Vajda (1989), and by Inman and Aubrey (1990). However, all these authors used for their analyses monthly average values, and could thus not determine the nominal values of mean lower low water (MLLW), mean sea-level (MSL), or mean higher high water (MHHW). These according to their definitions must be determined over a datum Epoch period (averaging period of 19 years to cover for the sun periodicity of 18.6 years). Hence, until recently their relative positions from the Israel Land Survey Datum (ILSD) were unknown and only roughly estimated to be some few centimeters to few tens of centimeters away from the ILSD.

A few years ago, within the framework of a High-School final thesis in Physics by Blank (1988) under author's supervision, Blank digitized 19 years of hourly data from Ashdod (1966-1984), which, after verification for errors in digitizing or of data recording with the aid of the TASK software package developed by the Proudman Oceanographic Institution in UK (maintaining the PSMSL and its archives), were used to determine corrected hourly values for the above mentioned period as well as the respective contributions of the astronomic tide and those of the meteorological induced residuals. Blank and Rosen (1998) determined the relative values of the MSL, MHHW and MLLW from the ILSD for Ashdod for the period 1966-1984. Assuming that the ILSD is the constant along the Israeli coast (which unfortunately are known to differ in the old ILSD system, now being reestablished by the SOI in a new unified ILSD datum) one may provide only a rough estimate. This estimate, is due to the fact that the location of the Ashdod benchmark and monitoring site was moved twice at least between 1958 and 1984. Once by moving from Eshkol cooling basin (Ashdod coast) to Ashdod port in January 1968 (+6 cm thereafter according to Goldsmith and Gilboa-1985), and once again within the port from the inner part to the entrance sector of the port at an unknown date (record lost). Using the available data, the sea level monthly average values were plotted in Figure 6a,b, and c. A very good coincidence appears among Haifa, Jaffa and Ashdod in many occasions, leading to the conclusion that the differences between the stations benchmarks are no more than about 10 cm, probably less.

The analysis of the old hourly records (available only as printed hard copy data), included digitizing of the printed hourly data, followed by a corrective process to remove random or systematic errors. Due to this cause, it may be said that the Ashdod data published in the past could not provide a reliable estimate of the tidal datum's as they did not passed such error correction.

The investigation covered more than a full Epoch (a 18.6 year cycle, representing the largest astronomic solar cycle relevant to human life-time changes) period (1966-1984), for which all the hourly data were digitized, analyzed, corrected and processed to obtain the MSL, MHHW and MLLW.

According to the results of Blank and Rosen (1998), the MLLW is 12 cm (11.92) below the ILSD at Ashdod (1958-1984 period), while the MSL is 2.73 cm above ILSD and MHHW is 18 cm (17.77) above ILSD. Assuming that no changes in the position of the benchmark at Ashdod occurred since 1984, the above data may be used also for the present sea level state, until a new ILSD is finalized as mentioned before. Yearly values of average and extremes of astronomic tide and meteorological residuals of the sea level determined at Ashdod are presented in Table-2.

As explained in the next section, attempts to assess long-term sea-level change based on the Ashdod data until 1985 led us to the conclusion that due to the shifting of the Ashdod sea-level gauge station and reference bench mark location a number of times and due to the large seasonal sea-level change (up to 20 cm), does not enable to reliably determine if any long term sea-level change has occurred at the Israeli coast. It is expected that with the new accurate and continuous sea level data gathered at the Hadera GLOSS station no. 80, combined with the simultaneous *in situ* systematic gathering of atmospheric pressure, waves, currents, wind, sea water temperature and reference bench mark elevation, it will be possible in the forthcoming years, after a sufficient amount of accurate data have been collected, to reliably determine the extent of the forecasted global warming induced sea-level rise on the Mediterranean coast of Israel.

Characterization of the Sea-Level Climate at the Mediterranean Coast of Israel

The tidal (astronomic) range on the Mediterranean coast of Israel is characteristic of the low-tide range of the Eastern-Mediterranean basin, being induced by the combined effect of the attraction forces of the moon and of the sun, and by the location of this coastal sector on the globe. Analyses of the local constituent contributions conducted by the author have shown however that the latter are only of very minor importance, and thus the sea-levels are in general very similar along the Mediterranean coast of Israel (see Figures 1, 2 and 3). The tide usually varies between 0.4 m during spring tides (occurring in spring and autumn), and 0.15m during neap tides (occurring in winter and summer). The tide contribution exhibits semi-diurnal periodicity (twice a day highs and lows) as well as fortnight (14 days) periodicity. An example of daily variations is presented in Figure 5.

Extreme sea levels may occur in combination with extreme meteorological conditions. However these may differ from site to site along the coast of Israel. An example is shown in Figure 4 for December 22-23, 1967, whereas the sea levels at Ashdod located on the open coast reached a very high elevation, but not so at Haifa Port. During spring and particularly in November – December months, easterly winds occurring at Haifa reduce sea levels in Haifa port and bay area, while that effect is not detected at other locations further south along the coast.

Low sea levels occur in winter during February-March months, while high sea levels occur in August-September, with a second maximum in December. Although the high levels are coincident to the warm and cold seasons (steric effect of water volume change due to temperature) it was found that the major contribution is due to the astronomic tide and that the steric contribution is minor in this respect. Thus, the main reason for the seasonal sea levels is the relative position of the sun versus earth in winter and in summer (see Figure. 5).

Assessment of extreme sea-levels was based on two methods: (a) using values of yearly maxima and minima from Ashdod, (2) using astronomic tide and extreme yearly residuals (maxima or minima) from the 19 years of hourly data analyzed for Ashdod (See Figure 7).

In Table 1 below are presented the sea levels for average return periods of 1, 50 and 100 years.

Table 1 – Extreme Sea-Levels at the Israeli coast

Average Return Period [Years]	Low Sea Level [m]	High Sea Level [m]
1	-0.38	0.64
50	-0.74	1.04
100	-0.87	1.10

The above values do not include the expected sea-level rise due to the "greenhouse effect". According to Warrick and Oerlemans (1990) the most probable assessed average global sea-level rise for 2030 is 18 cm and 70 cm for year 2100. However, it is agreed by the professional bodies involved with this assessment that the sea-level rise can differ from the above depending to the location on the globe. A regional change may significantly differ from the above assessment because of local plate tectonic movements, land rebound due to groundwater withdrawal, etc. As the warming is expected to accelerate only in the next century, the signs of sea-level rise are difficult to detect presently, being masked by other factors like seasonal warming and cooling of the sea-water (steric effect), wind induced sea-level rise during storms (wind surge), wave induced sea-level set-up in the surf zone, atmospheric loading by passing high and low atmospheric.

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Table 2 – Ashdod Yearly Values of Average and Extremes of Astronomic Tide and Meteorological Residuals of the Sea Level

year	Residual			Tide			Sea-level		
	max	Average	min	max	average	min	max	average	min
	cm	cm	cm	cm	cm	cm	cm	cm	cm
1966	52.9	0.0	-34.9	32.3	-1.1	-42.4	71.0	-1.1	-58.0
1967	75.0	0.0	-27.3	32.4	-3.2	-37.5	93.0	-3.2	-55.0
1968	44.3	0.0	-17.1	41.1	9.0	-29.5	69.0	9.0	-39.0
1969	38.7	0.0	-22.8	41.9	9.0	-20.9	66.0	9.0	-34.0
1970	29.3	0.0	-24.3	39.0	6.8	-25.6	56.0	6.8	-35.0
1971	39.4	0.0	-36.9	41.5	5.4	-25.5	44.0	5.4	-38.0
1972	37.4	0.0	-19.8	33.0	3.3	-28.3	44.0	3.3	-42.0
1973	32.0	0.0	-34.0	45.0	6.8	-30.4	46.0	6.8	-46.0
1974	30.5	0.0	-18.7	35.7	7.5	-24.0	45.0	7.5	-37.0
1975	34.5	0.0	-11.8	40.1	5.1	-27.7	46.0	5.1	-33.0
1976	39.9	0.0	-16.1	33.2	5.7	-25.7	44.0	5.7	-40.0
1977	45.9	0.0	-31.2	35.6	2.4	-30.3	52.0	2.4	-47.0
1978	25.7	0.0	-22.6	44.4	11.9	-15.2	51.0	11.9	-31.0
1979	33.5	0.0	-15.4	45.9	15.0	-19.8	59.0	15.0	-32.0
1980	36.5	0.0	-27.3	48.3	15.3	-14.7	61.0	15.3	-37.0
1981	30.3	0.0	-15.8	38.3	7.5	-24.8	46.0	7.5	-33.0
1982	28.3	0.0	-14.3	36.1	5.5	-26.7	49.0	5.5	-36.0
1983	35.3	0.0	-15.9	36.7	8.3	-24.8	48.0	8.3	-33.0
1984	32.7	0.0	-15.8	40.4	9.6	-20.2	50.0	9.6	-33.0

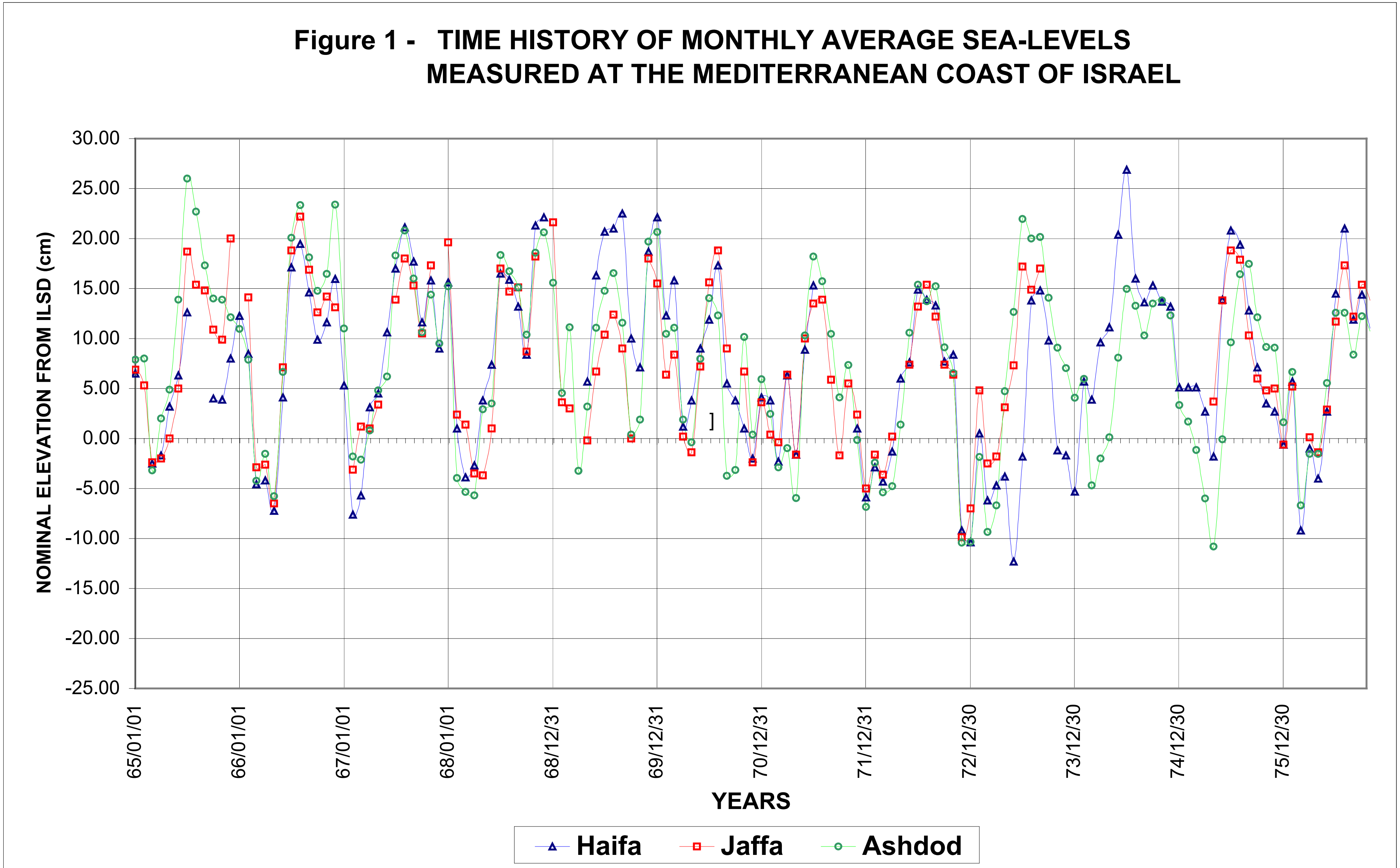
Figure 1 - TIME HISTORY OF MONTHLY AVERAGE SEA-LEVELS MEASURED AT THE MEDITERRANEAN COAST OF ISRAEL
NOMINAL ELEVATION FROM ILSD (cm)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
65/01/01
66/01/01
67/01/01
68/01/01
68/12/31
69/12/31
70/12/31
71/12/31
72/12/30
73/12/30
74/12/30
75/12/30
YEARS
Haifa
Jaffa
Ashdod

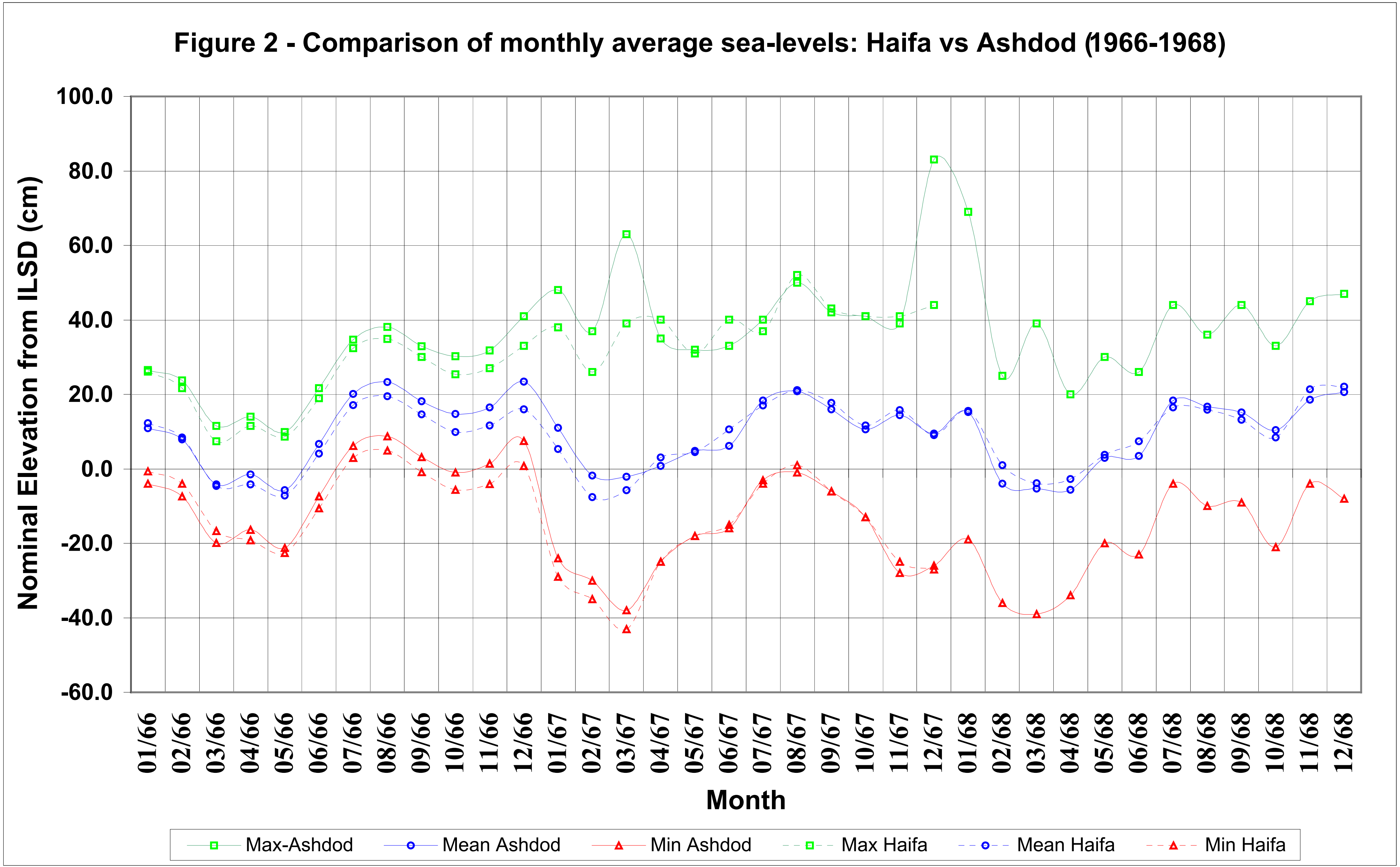
Figure 2 - Comparison of monthly average sea-levels: Haifa vs Ashdod (1966-1968)
Nominal Elevation from ILSD (cm)
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
01/66 02/66 03/66 04/66 05/66 06/66 07/66 08/66 09/66 10/66 11/66 12/66 01/67 02/67 03/67 04/67 05/67 06/67 07/67 08/67 09/67 10/67 11/67 12/67 01/68 02/68 03/68 04/68 05/68 06/68 07/68 08/68 09/68 10/68 11/68 12/68
Month
Max-Ashdod
Mean Ashdod
Min Ashdod
Max Haifa
Mean Haifa
Min Haifa

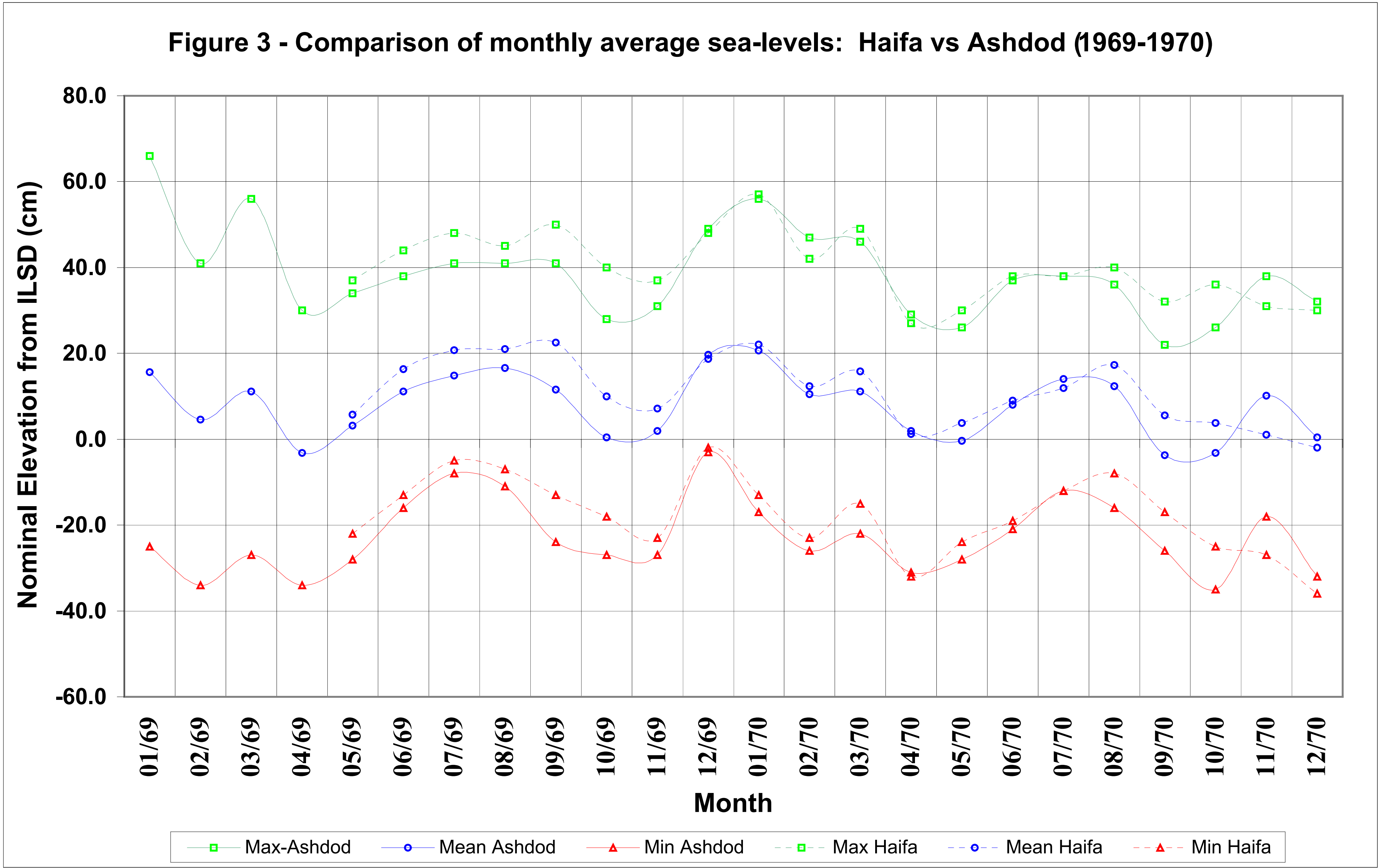
Figure 3 - Comparison of monthly average sea-levels: Haifa vs Ashdod (1969-1970)
Nominal Elevation from ILSD (cm)
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
01/69
02/69
03/69
04/69
05/69
06/69
07/69
08/69
09/69
10/69
11/69
12/69
01/70
02/70
03/70
04/70
05/70
06/70
07/70
08/70
09/70
10/70
11/70
12/70
Month
Max-Ashdod
Mean Ashdod
Min Ashdod
Max Haifa
Mean Haifa
Min Haifa

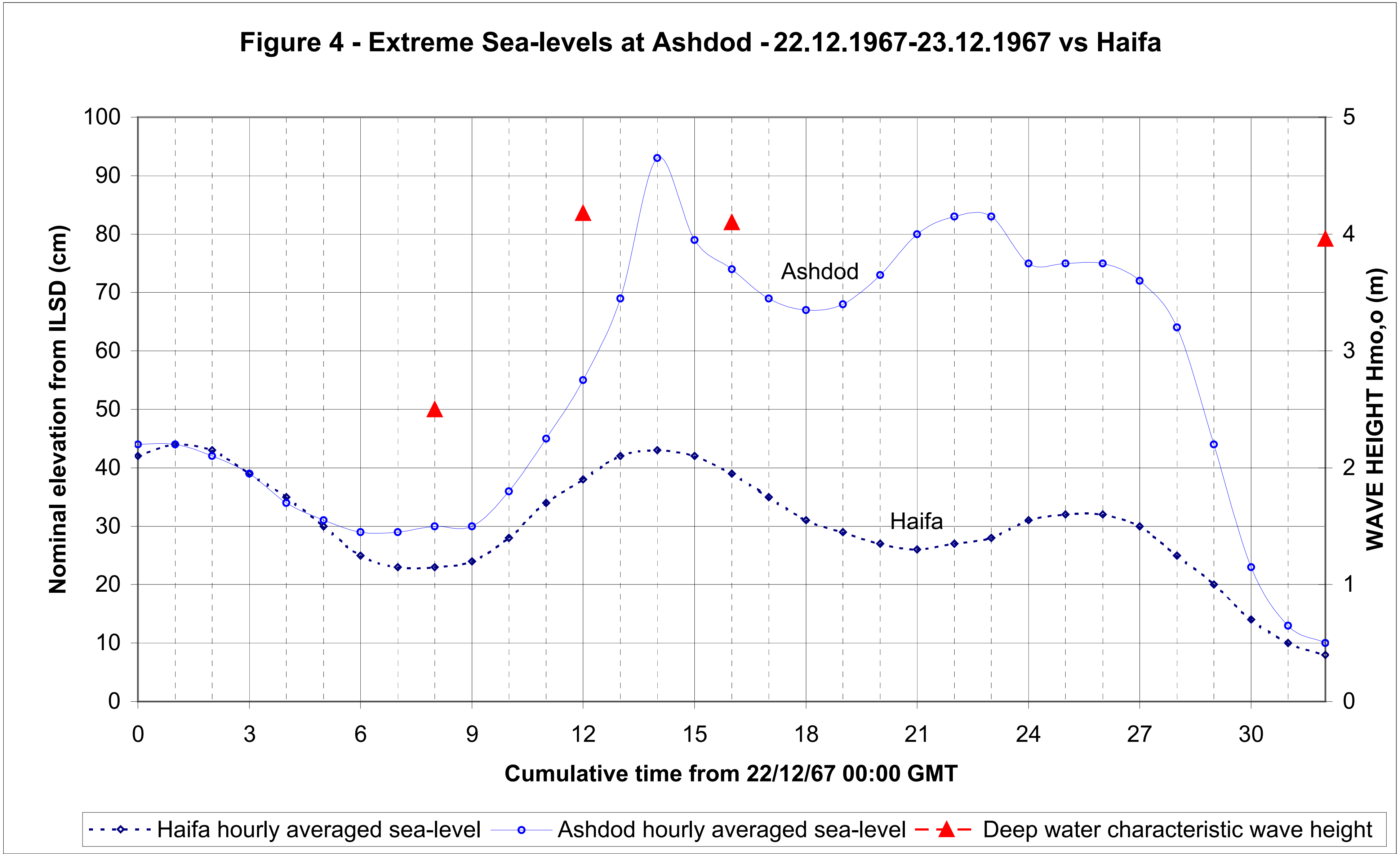
Figure 4 - Extreme Sea-levels at Ashdod - 22.12.1967-23.12.1967 vs Haifa
Nominal elevation from ILSD (cm)
WAVE HEIGHT Hmo,o (m)
Cumulative time from 22/12/67 00:00 GMT
Ashdod
Haifa
Haifa hourly averaged sea-level
Ashdod hourly averaged sea-level
Deep water characteristic wave height

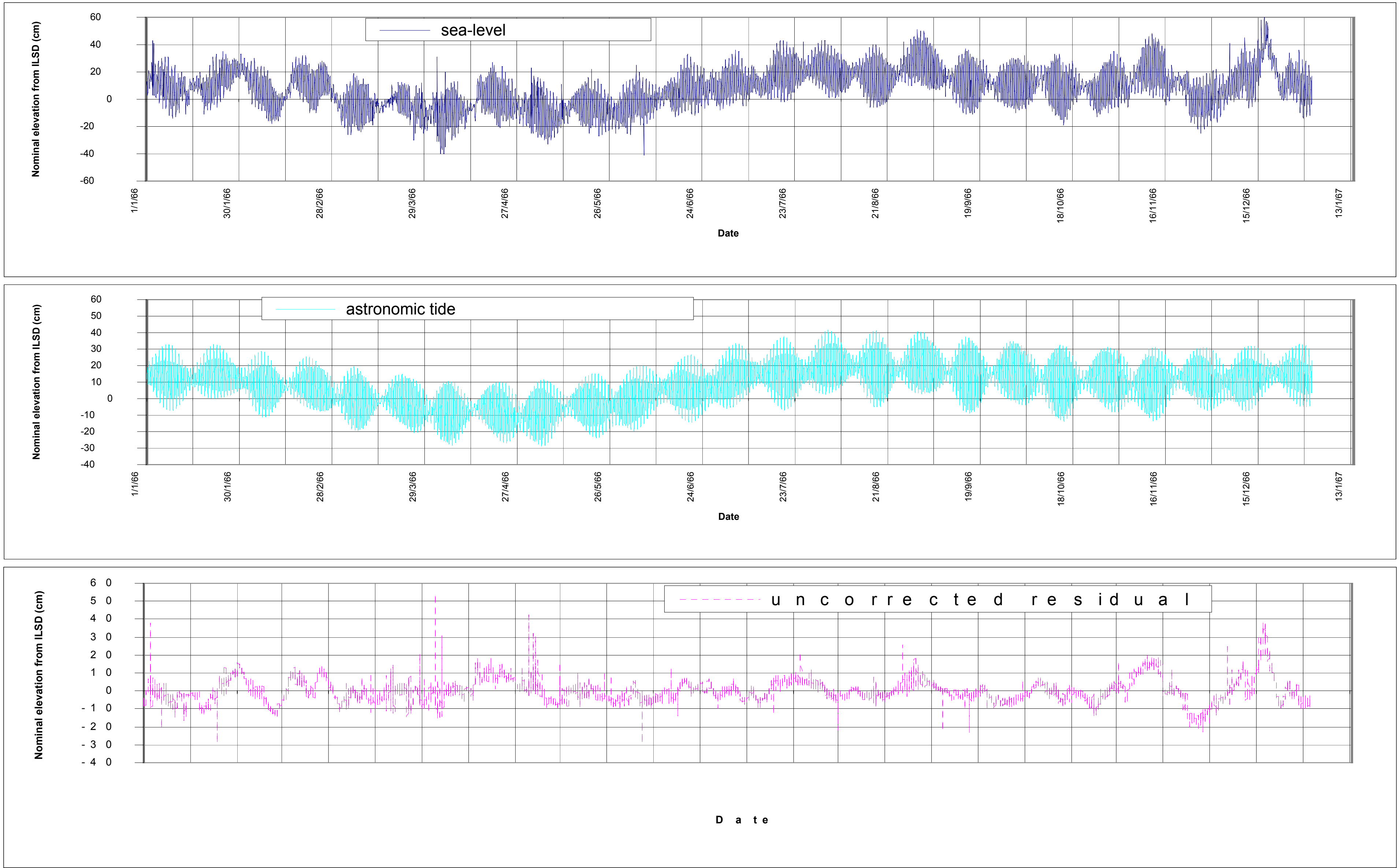

Figure 5 - Example of 1 year of hourly sea levels - Haifa 1966

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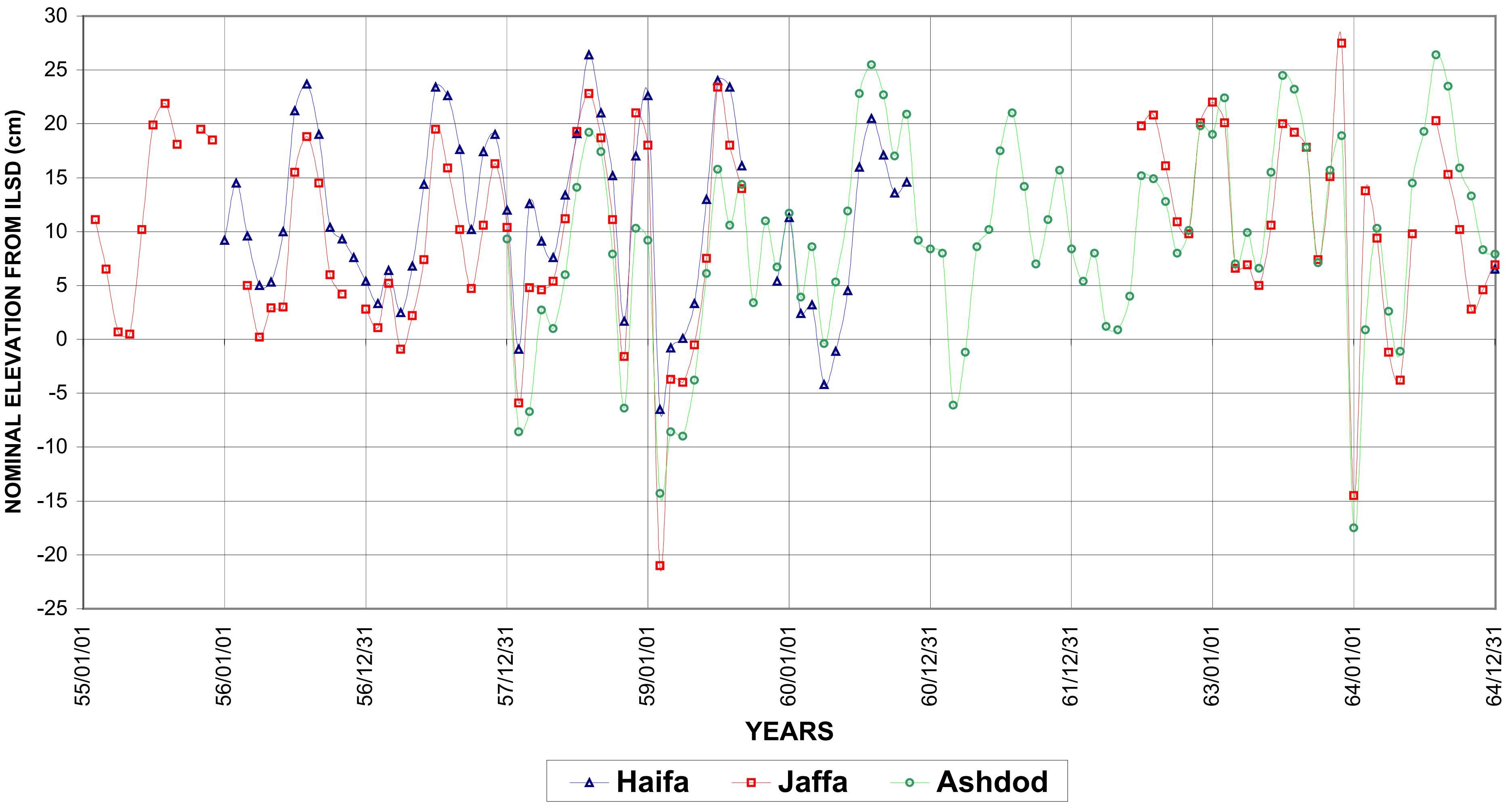
Figure 6a - TIME HISTORY OF MONTHLY AVERAGE SEA-LEVELS MEASURED AT THE MEDITERRANEAN COAST OF ISRAEL



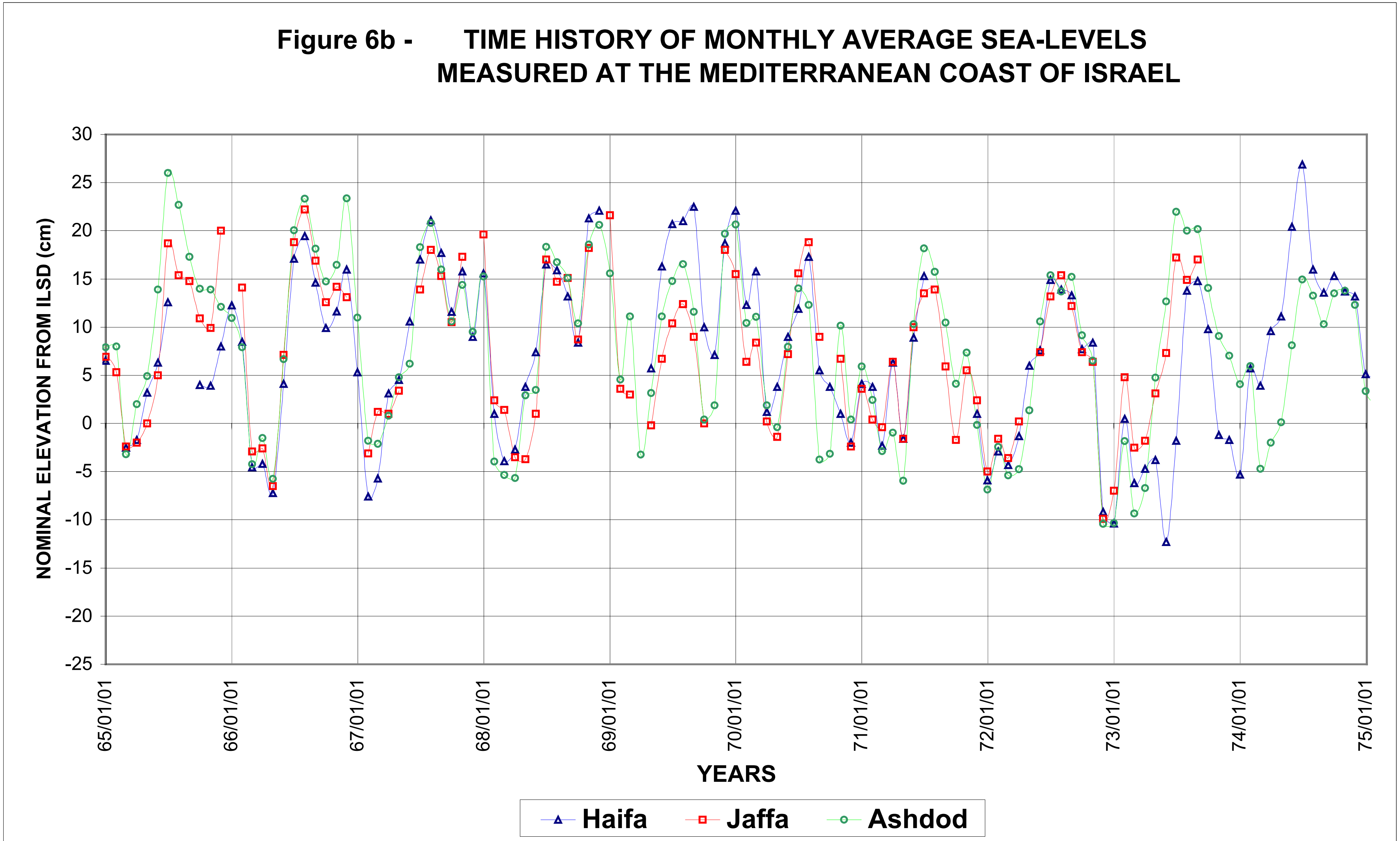


Figure 6b - TIME HISTORY OF MONTHLY AVERAGE SEA-LEVELS
MEASURED AT THE MEDITERRANEAN COAST OF ISRAEL
NOMINAL ELEVATION FROM ILSD (cm)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
65/01/01
66/01/01
67/01/01
68/01/01
69/01/01
70/01/01
71/01/01
72/01/01
73/01/01
74/01/01
75/01/01
YEARS
Haifa
Jaffa
Ashdod

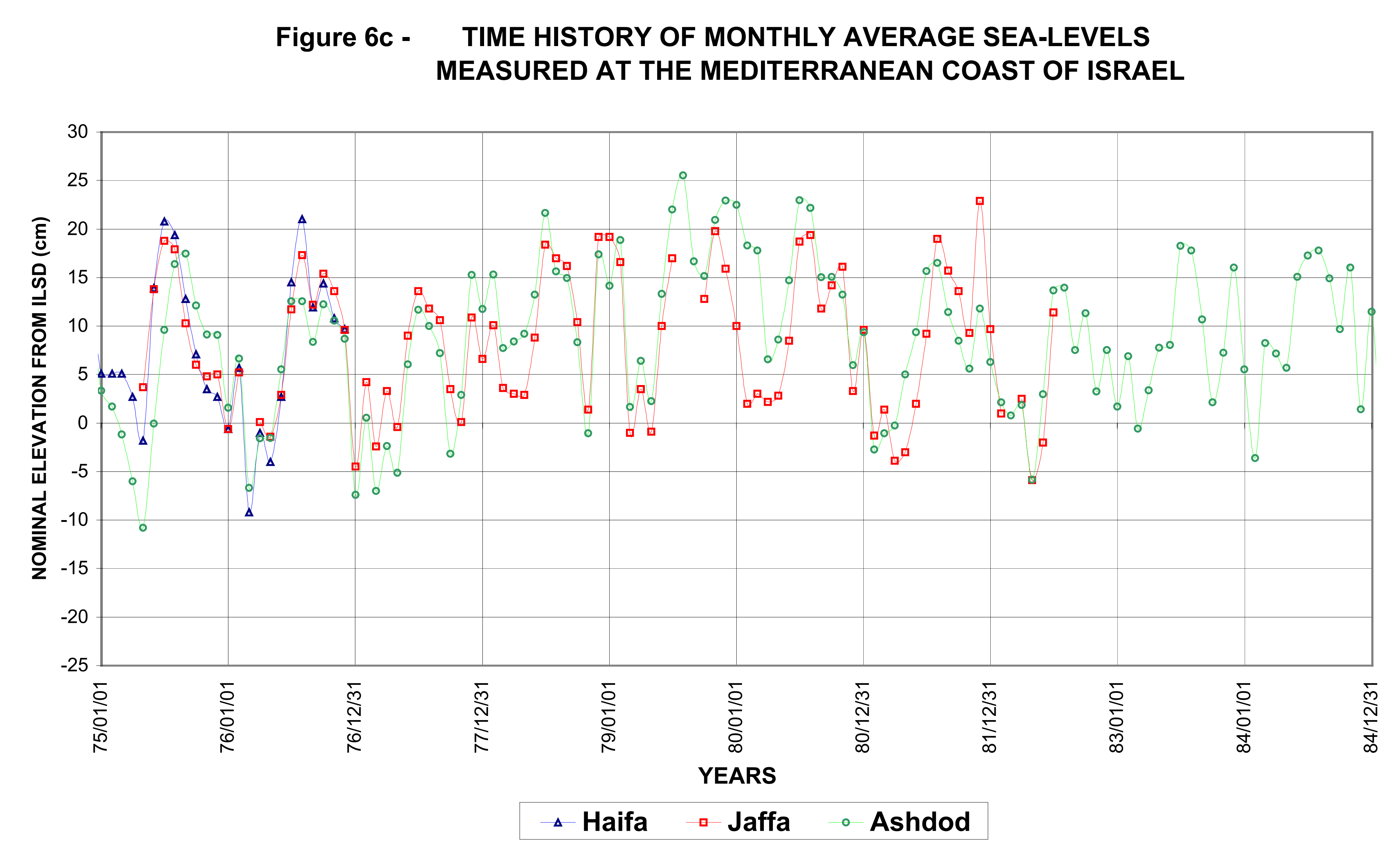
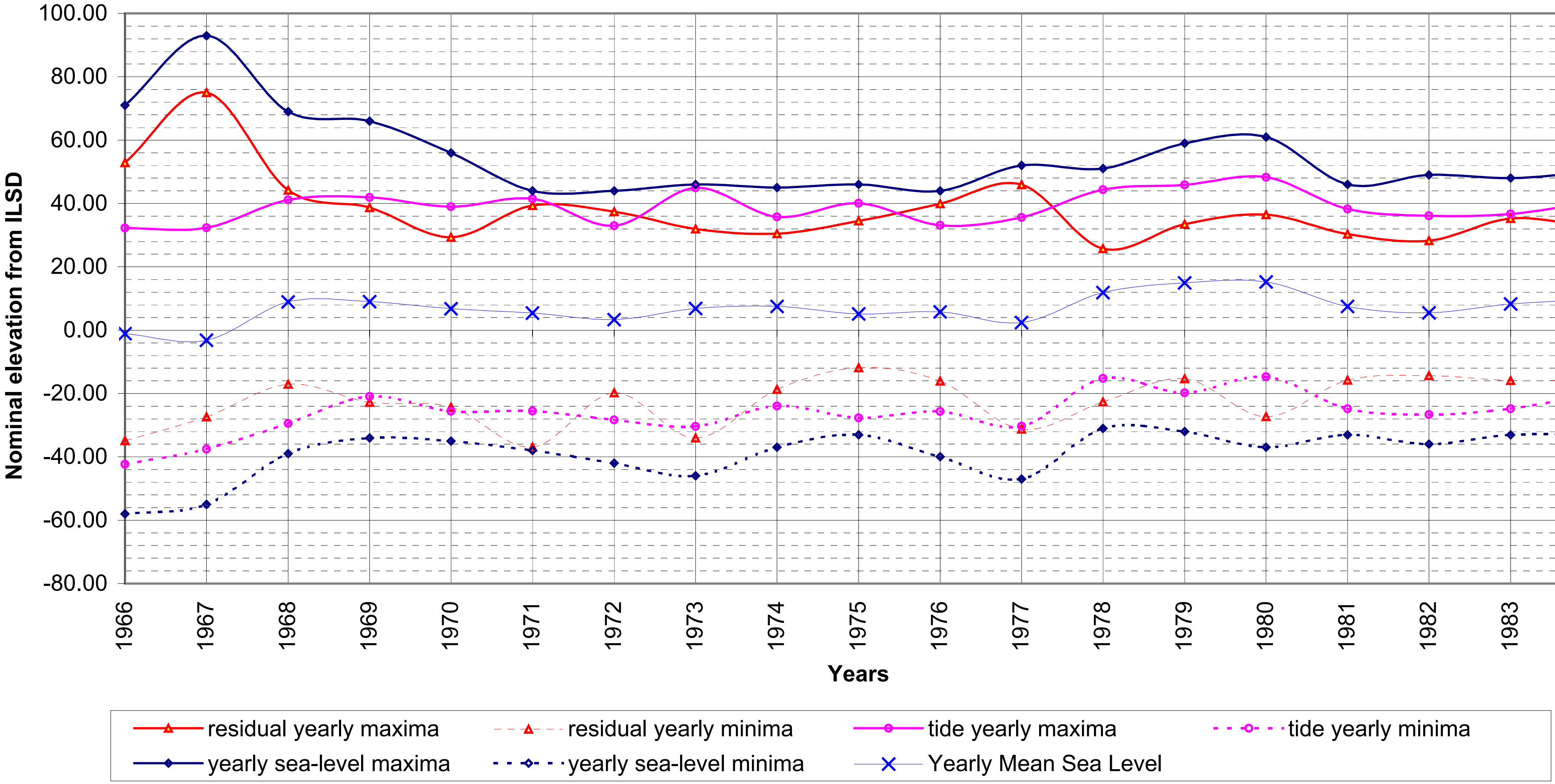


Figure 6c - TIME HISTORY OF MONTHLY AVERAGE SEA-LEVELS MEASURED AT THE MEDITERRANEAN COAST OF ISRAEL
NOMINAL ELEVATION FROM ILSD (cm)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
75/01/01
76/01/01
76/12/31
77/12/31
79/01/01
80/01/01
80/12/31
81/12/31
83/01/01
84/01/01
84/12/31
YEARS
Haifa
Jaffa
Ashdod

Figure 7 - Extreme values of astronomic & meteorologic contributions at Ashdod for a solar cycle of 19 years (1967 - 1984)



IVk - SEA LEVEL MEASUREMENTS ALONG THE ISRAELI COAST BETWEEN 1961-2000

B. Shirman,Y. Melzer

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boris@soi.gov.il/Fax: 972-3-6231806

The Survey of Israel (SOI) has been monitoring sea level along the Mediterranean Sea coast over decades. The main aim of monitoring is to derive mean sea level value in order to determine height zero level. Since 1996 SOI has conducted the measurements by digital instruments with a resolution of 1 cm and data recording every five minutes.

Identical instruments were installed at the Tel-Aviv, Ashdod and Ashqelon stations. The aims of the work are to distinguish tide long time periods and to compare average tide level with the current datum. The data from Ashdod, Yaffa, Tel-Aviv and Ashqelon for the period 1961 2000 were used. Missing data were provided by the maximum entropy method. Comparisons between the Yaffa and Ashdod data from 1968-1982 indicate a difference between tide levels of about 5 cm. All the data were referred to the Yaffa datum.

The following results were obtained:

a) Tide level changes caused by influences from the Moon and the Sun are in the same phase and amplitude along the coast between Tel-Aviv and Ashqelon. This justifies linking together data from different stations into a continuous time series of 40 years.
b) Spectral analyses of the tide level changes revealed periods of about 19 years, one year and about half year.
c) The average tide level relative to the Yaffa datum is about 0.5 cm.
d) Time series averages during a period of 19 years indicate a gradual rise in the tide level by 5 cm over the last fifteen years.

IVl - A BRIEF OVERVIEW OF THE IOC GLOSS PROGRAMME WITH SOME COMMENTS RELEVANT TO THE MEDITERRANEAN AND BLACK SEAS AND A REVIEW OF TIDE GAUGE TECHNOLOGIES

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This short report summarizes presentations made at the MedGLOSS Pilot Network Workshop and Coordination Meeting in Haifa, Israel 15-17 May 2000. In order to simplify the report, reference is given to a number of web addresses that allow access to considerably more information than is possible here.

PSMSL, GLOSS AND GOOS

The Permanent Service for Mean Sea Level (PSMSL) is the global data bank for long-term sea level change information from tide gauges. It was established in 1933 and operates at Bidston Observatory under the auspices of the International Council for Science (ICSU). Almost all tide gauge authorities contribute values of monthly mean sea level to the PSMSL on an *ad hoc* basis, and the data bank now consists of approximately 45,000 station-years of information from about 1,800 sites. In other words, records are typically 20 years long with the oldest data from 1806. For more information on the PSMSL, including maps of its data coverage and access to all its data sets and ancillary information, see: -

http://www.pol.ac.uk/psmsl/psmsl.html

The Global Sea Level Observing System (GLOSS) was established in the mid-1980s by the Intergovernmental Oceanographic Commission (IOC) with the aim, amongst other things, of improving the regularity of data delivery to the PSMSL, and of ensuring the uniformity of quality of data. For information, see: -

http://www.pol.ac.uk/psmsl/gloss.info.html

Prior to 1997, GLOSS could be characterized as a global network of about 300 gauges distributed worldwide, together with regional densifications, and with associated programmes of training and workshops for standards and for special situations (e.g. operations in polar areas). In 1997, a new Implementation Plan for GLOSS was published by IOC, which recognized the several important changes in the field since GLOSS was first proposed. In particular, these were concerned with the development of satellite altimetry and of advanced geodetic techniques for measuring land movements (GPS, DORIS, absolute gravity etc.). In this new document, the former 'GLOSS network' was referred to as the 'GLOSS Core Network' (GCN), while sub-networks were defined to serve the purposes of ongoing altimeter calibration from tide gauges (GLOSS-ALT), of ocean circulation monitoring (GLOSS-OC) and of the measurement of long term sea level trends (GLOSS-LTT). For more details, see: -

http://www.pol.ac.uk/psmsl/gip97/README

The GCN can be considered to be over two-thirds complete, with most sites in the remaining third being in difficult areas such as Polar Regions. GLOSS-ALT is essentially complete. GLOSS-OC and -LTT are also under development by the community, with the need for circulation monitoring in future by gauges being re-assessed (i.e. as CLIVAR takes over from WOCE) and as the number of sites for long term sea/land level monitoring (which implies GPS etc. measurements) increases. The status of the GLOSS programme can be inspected from the above web page.

The 1997 Implementation Plan also differed from the original Plan (published finally in 1990) for the GLOSS programme in the importance it attached to preservation of original data (i.e. typically hourly values). In the first GLOSS Plan, the only requirement of an authority participating in the programme was that they should send their monthly and annual mean values (and ancillary information) to the PSMSL, which was a requirement that most authorities were already fulfilling. In the new 1997 Plan, authorities were also required to send monthly and annual means as before to the PSMSL, but they were also required to make the original (e.g. hourly) data available to the community in one of several possible ways (see the Plan for details). Most recently (1999), GLOSS has established a 'Fast Delivery Centre' (FDC) at the University of Hawaii which will receive and redistribute data from a subset of gauges in quasi-real time (typically one or two weeks) without final quality control, primarily for the benefit of altimeter specialists; this GLOSS FDC will continue the functions of the WOCE FDC which has operated during the 1990s.

Note that the GCN, and the earlier 'GLOSS Network', contains relatively few stations from the Mediterranean and Black Seas, and also from the Baltic, North Sea and other marginal seas, as the emphasis for the network was on open ocean sites. This choice is frequently misunderstood. The intention was not to imply that data from the Mediterranean etc. were relatively unimportant, and both GLOSS Plans (1990 and 1997) stressed that the GCN would have to overlap and be complemented by regional networks, such as that of MedGLOSS under discussion.

In many ways GLOSS was in advance of other IOC monitoring programmes and experience with GLOSS was very valuable to IOC in the development of planning for the Global Ocean Observing System (GOOS). GLOSS can be considered now as a component of GOOS. However, GOOS will require sea level measurements in a number of its modules (e.g. Monitoring of the Coastal Environment and its Changes), which are additional to those, considered by GLOSS so far. There will, therefore, be a major requirement in coming years in many regions for sea level related hardware and for training in its use.

Since 1983, at least one GLOSS-related training course has been held somewhere in the world. In the early years, most courses were held at Bidston at the PSMSL and in English. However, in the 1990's efforts have been made to hold courses on all continents and in as many languages as possible, consistent with the requirement to complete the network. In 1997 a course co-funded by IOC and CIESM was held at Bidston for eight participants from Mediterranean and Black Sea countries, and it is gratifying that attendees at that course were present also in Haifa. More recently, a Mediterranean participant from Egypt attended a course in Saudi Arabia in April 2000, held in Arabic and co-funded by PERSA and IOC. It is to be discussed whether these courses will continue in future at the same frequency, given the reduction in IOC's overall funding and the perceived need to use scarce resources in 'demonstration projects' around the world (e.g. in West Africa), and given the exciting developments in web-based training methods. A start on such web materials can be found via:-

http://www.pol.ac.uk/psmsl/training/training.html

THE MEDITERRANEAN SEA PSMSL DATA SET

The most successful components of GLOSS can be claimed to be some of its regional activities. If scientists, engineers and others can collaborate in a region, and especially if there is a clear purpose to their efforts, then the best results can be obtained. Examples include the development of the Pacific and Caribbean networks (with obvious relevance to El Nino etc. for the former, and with application to monitoring currents between islands, some with economically-important sandy beaches, for the latter).

There is also the general point to make that sea level data gain in value enormously if it can be acquired in a network. A single long sea level time series might be very nice to have, but if there are two or more nearby then data quality can be verified much more rigorously than for a single station, and sea level gradients can be computed in addition to sea level time series, for application to oceanographic studies. Collaboration between countries in the Mediterranean and Black Seas is therefore to welcome very much as, in effect, providing a regional component of GLOSS with the potential for excellent data quality control within a network.

The historical PSMSL data set for the Mediterranean and Black Seas includes a large number of measurements from the northern Mediterranean coastline and Black Sea but virtually none from the African coast between Ceuta in the west and Alexandria in the east, see:-

http://www.pol.ac.uk/psmsl/medgloss.haifa/med_psmsl.ps

(See also Tsimplis and Spencer, Journal of Coastal Research, 13, 534,544, 1997 for a more complete description of the PSMSL Mediterranean data set.) This north-south polarisation is even more apparent if one inspects the availability of station records with more than 40 years of data, that length of record being a typical amount for the calculation of a ‘good’ secular trend (i.e. a standard error on a trend of less than 0.5 mm/year), see:-

http://www.pol.ac.uk/psmsl/medgloss.haifa/med_psmsl40.ps

It is immediately clear that much work will have to be done to convince African countries of the value of making measurements for MedGLOSS. One convincing argument is to point to the amount of good research, which has already been made with the sparse data set. An oceanographic example is the observation of a possible linkage of sea level trends with regional hydrography with a change in trend around 1960, see: -

http://www.pol.ac.uk/psmsl/medgloss.haifa/tsimplis.eps

which is taken from a recent paper by Tsimplis and Baker (Geophysical Research Letters, in press). A practical example relevant to local coastal planners can be taken from the time series from the historic city of Venice, which shows until the 1970’s a much greater rate of rise of sea level than from Trieste nearby, due primarily it is believed to anthropogenic effects (ground water pumping). Since the pumping stopped, the two time series have been very similar, see: -

http://www.pol.ac.uk/psmsl/medgloss.haifa/venice.trieste.ps

These are not by any means the only examples that could be given. A quick search of papers from my own institute which discuss Mediterranean sea levels in some way showed that at least a dozen were published in the last decade, covering themes such as tides, storm surges and long term trends. It is clear that the institutes based in the region should be even better placed to make use of the combined information as the MedGLOSS data set expands.

Now, it is clear that no-one will be convinced of the need for new stations in MedGLOSS if it is implied that 100 (or even 40) years of data are needed before useful results flow. The fact is that the establishment of gauges will provide a range of local products (tide tables, statistics of high and low extremes etc.) which can be acquired from a very short record, gradually building into those long time series of most interest to the scientific community.

COMMENT ON GAUGE TECHNOLOGIES IN USE IN THE MEDITERRANEAN

While the north coast of the Mediterranean contains a relatively large number of gauges, the simple distribution hides the fact that many of them are older chart-recording float gauges, which require digitization of the charts, and therefore provide slow data delivery to data centres. Even for the north coast, there is, therefore, a requirement for modernization and, perhaps eventually, for standardization of technologies. Table 1 summaries the types of gauge used in each country (please forgive omissions).

Table 1

Gibraltar – float gauge, chart recorder.

Spain - floats (IEO and IGN), new investments Clima Maritimo acoustics (SRD)
France - floats collocated with acoustics (MORS). Tests with radar gauges.

Italy – new network with float gauges and acoustic backups. Separate data supply from Navy (Genova, Brindisi) and from Trieste and Venice.

Croatia/Slovenia - float (chart). MedGLOSS Croatia one gauge planned (June 2000)

Greece - float (chart), plans for several bubblers

Black Sea - floats + poles not automatic. MedGLOSS Romania gauge installed (Oct 99)

Turkey – Geodetic Dept 4 acoustic (NGWLMS) gauges

Israel - Hadera pressure gauge

Egypt - Alexandria float + 3 planned new gauges. MedGLOSS gauge planned (?)

Cyprus – plans for a gauge (type unknown)

Turkish Rep. North Cyprus – plans for acoustic gauge

Malta - MedGLOSS gauge planned (late 2000)

Tunisia - plans for own gauges. Morocco - MedGLOSS gauge planned (late 2000)

MEDGLOSS EXPANSION BEYOND THE PILOT PROJECT

The emphasis in the planning for MedGLOSS is on the need for gauges for long term studies (climate change, oceanography, geodesy), which can take place with ‘delayed mode’ data delivery, and for operational purposes (MedGOOS, Mediterranean Forecasting System, storm surges), which require ‘real time’ data.

Several authors have speculated on the eventual gauge network requirements for the Mediterranean from the points of view of climate, oceanography and geodesy (e.g. see Baker et al., Journal of Marine Systems, 13, 163-171, 1997). At the Workshop, the real time requirements of MFS for sea level data were also stressed and modellers performing assimilation studies will need as much data as they can get.

Some speculations can perhaps be made on how the MedGLOSS might look in future to get some discussion going:

(i) For long-term trends studies one does not need a large number of stations in the Mediterranean and Black Seas. The requirement should be on long, high quality records with permanent GPS etc. measurements of land movements (see also below). Perhaps a maximum of 10 stations in the Mediterranean and 4 in the Black Sea would be sufficient. Beware that for long-term climate studies the Mediterranean may not be typical of the world ocean (cf. the Tsimplis and Baker paper mentioned above).

(ii) For regional oceanography such as flow through straits (Turkish, Sicily, Gibraltar), for storm surge monitoring and for MFS, one needs real time data with, at the present time at least, no obvious need for permanent GPS as the ocean timescales under study are so different to those of land movements.

(iii) For surveying purposes a number of sites with delayed mode data delivery and campaign GPS will be required.

(iv) Finally, national organizations need to be convinced of the utility of measurements in the short term as well as for long term (e.g. climate) studies. They need tidal data and statistics on extremes. MedGLOSS will have to play a role, therefore, in helping each country develop its own densified national network for a range of applications.

COMMENT ON GEODETIC (GPS) MEASUREMENTS

Many aspects of GPS measurements in the Mediterranean were covered in detail by Susanna Zerbini at the Workshop. See in particular her comments on the 'Mike Bevis millimeter or centimeter agendas'. However, I would like to make the following points from a tide gauge operator's point of view.

The main reasons for operating GPS at a gauge appear to be:

- The need to determine rates of vertical land movement at a site in order to combine with rates of relative sea level obtained from the gauge in order to determine 'real' sea level trends.

This is definitely part of the Bevis 'millimeter agenda'.

In locations that are relatively quiet from the point of view of tectonics (i.e. earthquakes), the GPS vertical trends, which might be acquired over say the next 15 years, might be applicable with caution in 'hind cast mode' to the historical relative trends determined from the long gauge records over say 50-100 years. It is clear, therefore, that the priority for receiver installations should be at tide gauge sites with long records (Marseille, Genova, Trieste etc.) and which are 'geologically stable' (so far as one can make that statement).

The second priority for installation should be at sites, which have short gauge records so far, or at new sites, both in the 'stable' areas. It is clear that if a new gauge and GPS start measuring sea and land levels respectively at the same time, that the GPS will have an accurate trend in a shorter period than the gauge as land levels tend to be (thankfully) free of typically-decimetric variability as in the ocean.

A lower priority should be at locations, which experience significant tectonic activity. In these places, it will be very difficult to apply any GPS trends to historic gauge records in hind cast mode, even if the gauge records are long. It is clear that the Mediterranean contains a great range of different geology from the French coast, which so far as one can tell has been 'stable' for the last 10,000 years, to Greece and Turkey, which experience frequent tectonic events.

- The need for satellite altimeter calibration.

The Mediterranean contains a number of sites that are being, or could be, used for altimeter calibration. These include sites in Corsica (Aspretto), Ibiza, Crete and possibly Malta. This activity is part of the 'Bevis centimeter agenda' because 1 cm (typically) is adequate for the purpose, other parts of altimeter error budget being larger. It has in common with the previous application, however, that the GPS deployments must be permanent.

- The need for collocated sea level and GPS measurements for surveying.

In this application, which is presumably also ‘centimetric’, one suggests that there is no need (at present, given the present cost of receivers) for permanent receivers and that ‘episodic’ (or ‘campaign’) measurements are adequate.

For a review of the present state of the art of GPS measurements at gauges, see the report of Neilan et al. available via:

http://www.pol.ac.uk/psmsl/training/training.html

A REVIEW OF TIDE GAUGE TECHNOLOGIES

In a second presentation at the Haifa Workshop, a review was given of the different types of tide gauge technology available and also of software tools (tidal packages). The different technologies include:-

- Traditional float gauges (but with electronic data loggers, datum probes etc.) These have been the main technology by which the historical tide gauge data set for the last two centuries has been collected.

- Acoustic gauges in sounding tubes or open air.

- Pressure gauges (bubblers, single and multiple transducer systems).

- Radar gauges.

- Hybrid systems (e.g. a pressure gauge in a stilling well).

These systems are reviewed in the 3rd Volume of the IOC Manual on Sea Level Measurement and Interpretation, a draft of which can be inspected via: -

http://www.pol.ac.uk/psmsl/manual3.doc

in Word 97 format. Any suggestions for additions, changes etc., to the draft will be very welcome and the final version will be made towards the end of the summer. Also note that there are some sections that will be added on data analysis etc.

Table 2.1 of this manual attempts to summarize the merits and demerits of each technology and makes recommendations for the main technologies to be used for GLOSS. It is clear that if an operator has an existing technology that he is happy with and which is well maintained, then it does not make much sense to swap equipment for new technologies without considerable thought. The recommendations have, therefore, always had to be taken into consideration within the local context.

IVm - SUMMARY OF GIBRALTAR SEA LEVEL STATION

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36 DEG 7 MIN N, 5 DEG 21 MIN W, GLOSS NUMBER 248 PSMSL CODE 215/001

Operated by: Queen's Harbour Master, H.M. Naval Base, Gibraltar

Float gauge: 1961-90, 91-93 data gap, new gauge (Lea) 1993-present (only to 1996 in PSMSL, later data awaited). Gauge functioning okay still as of May 2000.

Data processed (charts digitized) by: Hydrographic Department, Taunton (Cmdr. John Page). Page will contact QHM immediately to ascertain present status.

There is no direct contact between QHM and PSMSL, only via HD. The QHM, and not HD, controls the budget for gauge maintenance. Suggestions have been made by POL to upgrade gauge for near real time, which QHM will consider (May 2000).

Campaign GPS only so far (in SELF and SELF II in mid-1990's), no permanent GPS (there may be GPS for navigation, we are checking). For BM information, see GLOSS handbook and SELF-manual.

GLOSS Handbook web page contains hourly values 61-90. PSMSL web pages contain monthly data and plots.

IVn - CURRENT STATUS OF RUSSIAN BLACK SEA LEVEL NETWORK

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GLOSS in Russia is based upon the observational network of ROSHYDROMET, the Federal Service for Hydrometeorology and Environental Monitoring. Observations collected by regional bodies of the Roshydromet are sent to All-Russian Research Institute for Hydrometeorological Information - World Data Centre (ARRIHI-WDC) in Obninsk for cataloguing and archiving. Via that institute monthly mean and annual mean sea levels form Russian GLOSS stations are forwarded to PSMSL in Beadstone and to Specialized IGOSS Sea Level Centre in Pacific (Honolulu).

In compliance with international obligations Russia is forwarding mean monthly and annual sea level for the eight stations. Four of them are only working in real time. In the Black Sea only one Russian GLOSS-site Tuapse is located.

There are five sea level stations in operation on the Russian seashore of the Black Sea (Table-1).

Table 1. Russian sea level sites in operation

GLOSS number	Site name	Period of observation, years
98	Tuapse	1917-2000
-	Anapa	1917 – 2000
-	Gelendjik	1921 – 2000
-	Novorossisk	1923 – 2000
	Sochi	1916 - 2000

Data for the period of 1977-1996 have been collected in digital form in ARRIHI-WDC (Obninsk).

The Black Sea level network of the former USSR included the 36 sites (fig.1).

Duration of the observation series exceeds 50 years at the most part of the sea level sites, and exceeds 100 years at several sites of the former USSR (for example Odessa, Ochakov, Sevastopol, Batumi, Poty).

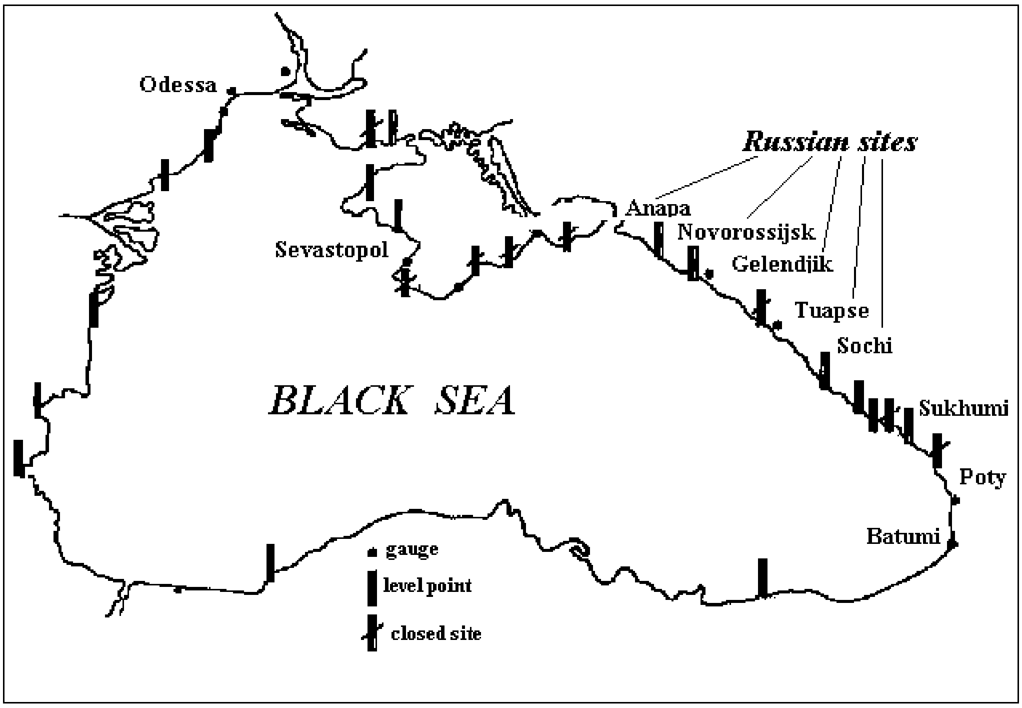

Fig. 1. Black Sea network and location of the Russian sites

Quality of Observations

All sea level sites heights are determined relatively major and auxiliary geodetic marks. All these marks are attached to unified national geodetic reference system (Main basic height-1977 of the former USSR with its basic landmark - zero datum of point in Kronstadt in the Baltic Sea).

At the majority of stations in Russia level measurements accuracy meets GLOSS requirements. Sea level error does not exceed 1-2 cm, and error in time of observation is less than one minute. Unfortunately, accuracy of regular routine observations is a little worse, and there are considerable shifts in times of observations.

There is some information on vertical movements of the Earth core in the Black Sea region from literature. Mean velocity of the vertical movement of the Earth core does not exceed 0.1 cm/year for the most part of the seashore sites. Only for Odessa (Ukraine) and Poty (Georgia) these velocities have been evaluated as -0.5 ÷ -0.6 cm/year.

1.2 Long-term variability of sea level variation

For the majority of both Russian and the former USSR sites good correlation of annual oscillation with river flow exists.

There is a well-marked cyclic character of oscillations in observational series with the periods of 2-3, 4-5, 9-17 and 25-30 years. A period with some falling of sea level (the 70 years XIX century – 30 years of the XX century) and period with sea level rising (up to present time) have been observed against the background of the global sea level rising for the whole observation period (linear trends in fig. 2-10).

According to the most widespread point of view – the rising of World Ocean level is assumed to be the main reason of the Black Sea level rising. Inter-annual variations of the Black Sea level are equal to 6 cm (as average value) and 15 cm as maximal ones.

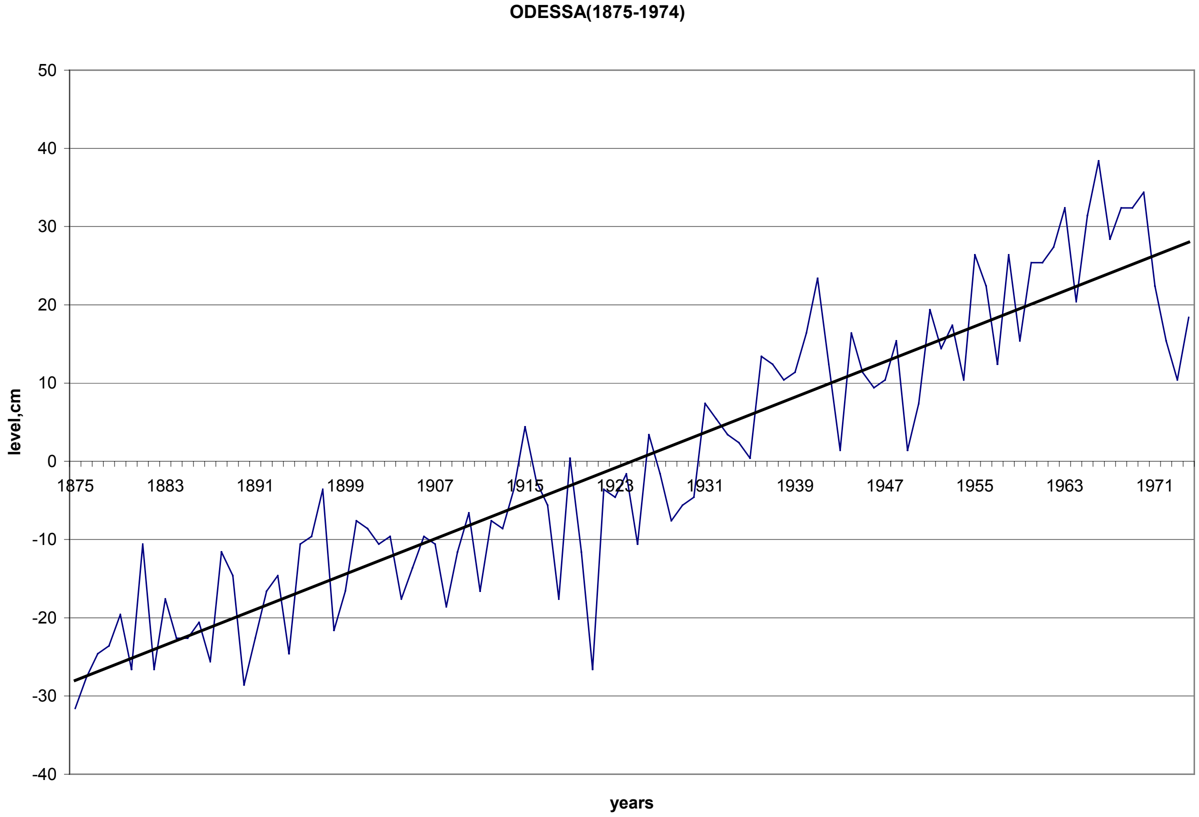

Figure 2. Temporal annual mean sea level variations and linear trend in Odessa (Ukraine)

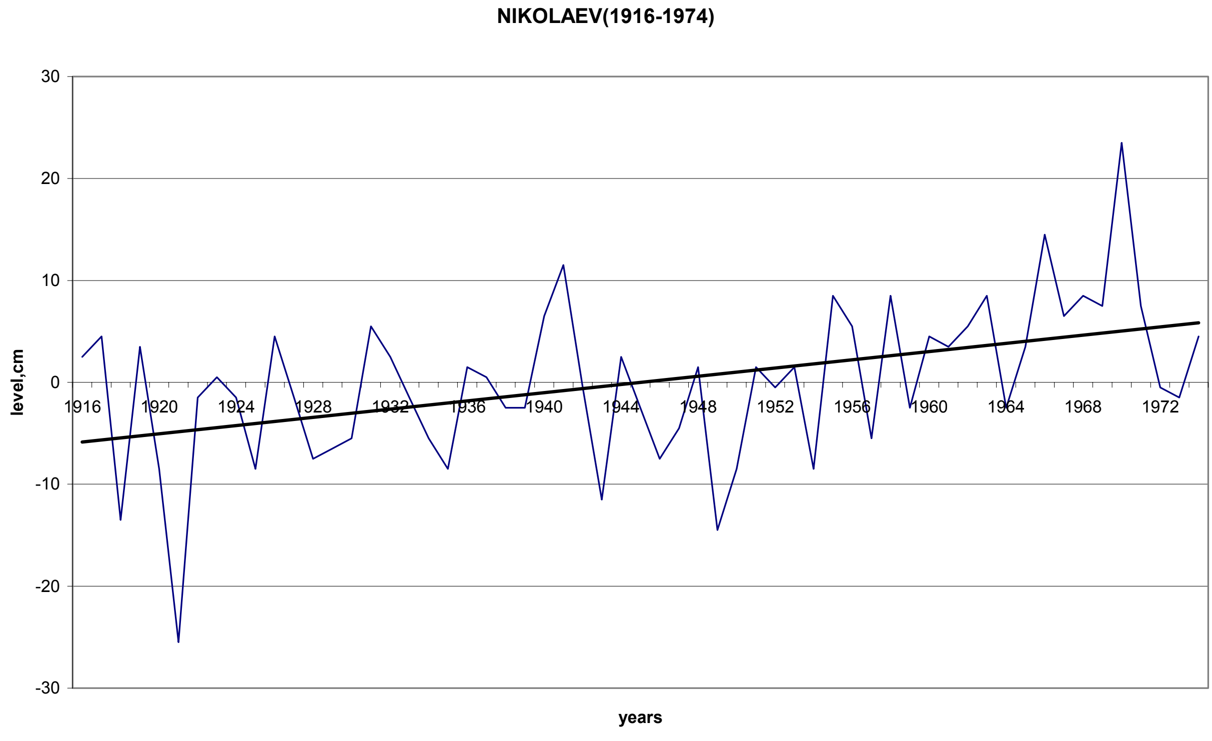

Figure 3. Temporal annual mean sea level variations and linear trend in Nikolaev (Ukraine)

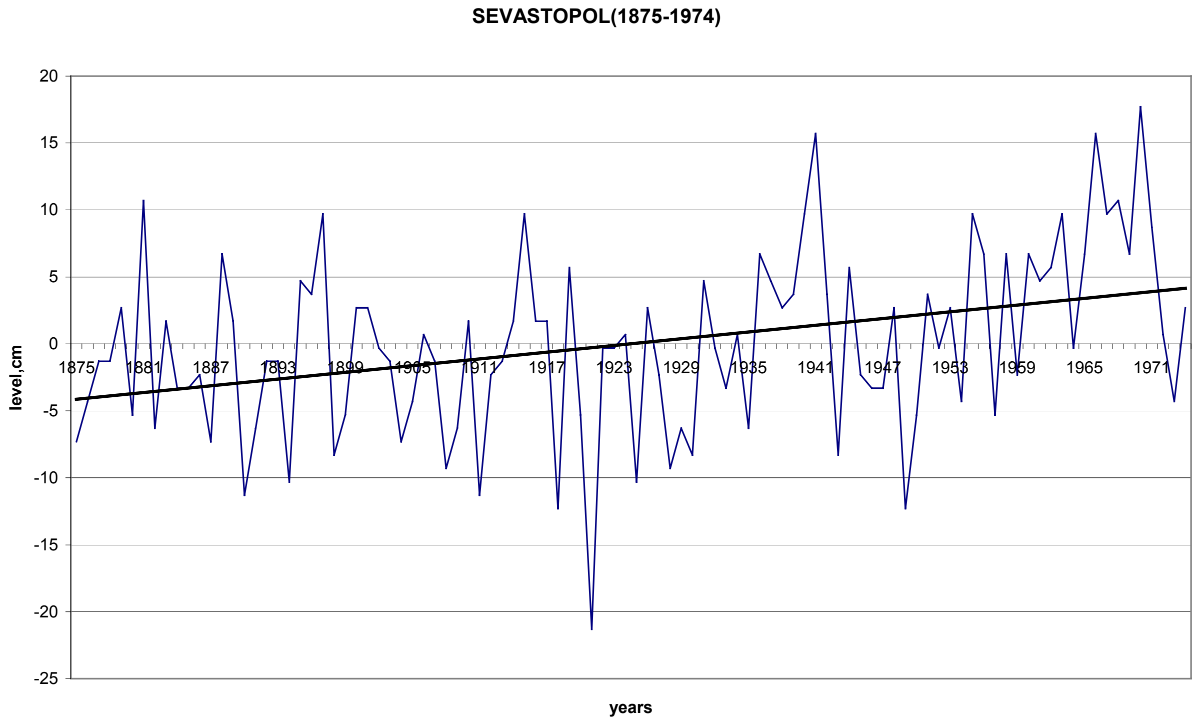

Figure 4. Temporal annual mean sea level variations and linear trend in Sevastopol (Ukraine)

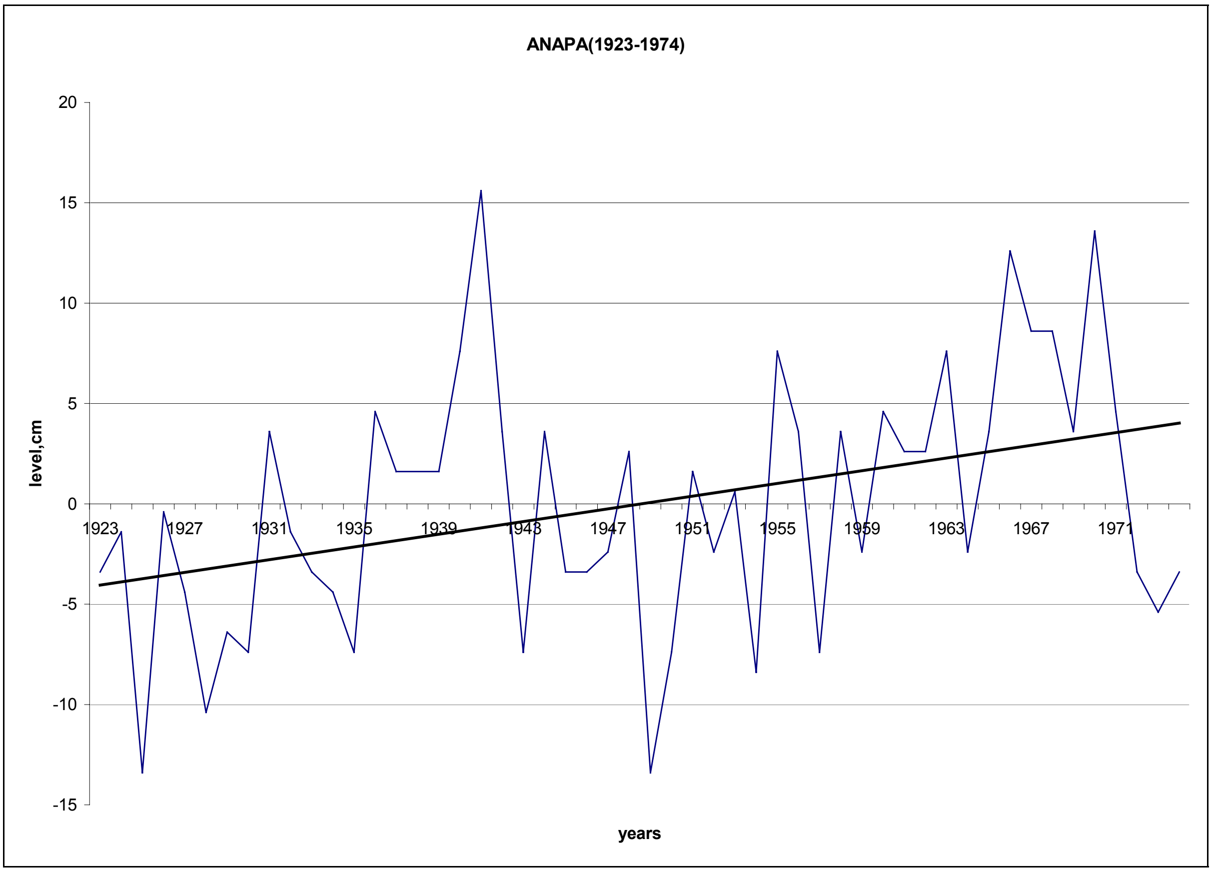

Figure 5. Temporal annual mean sea level variations and linear trend in Anapa (Russia)

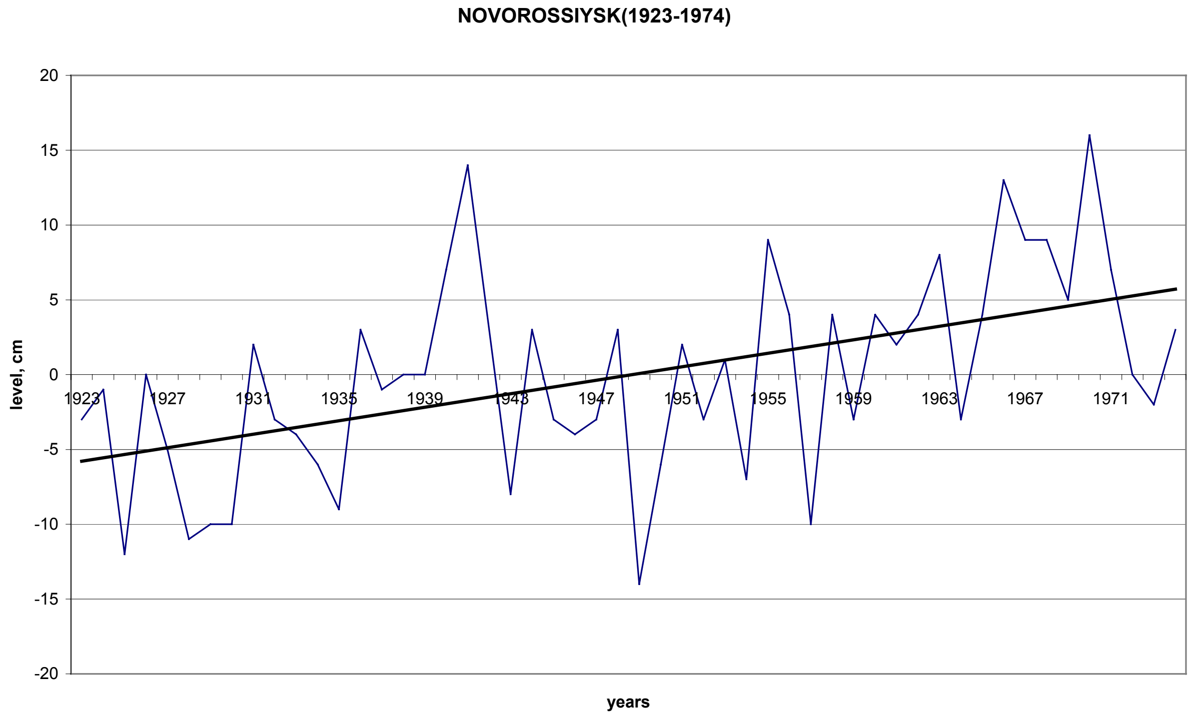

Figure 6. Temporal annual mean sea level variations and linear trend in Novorossiysk (Russia).

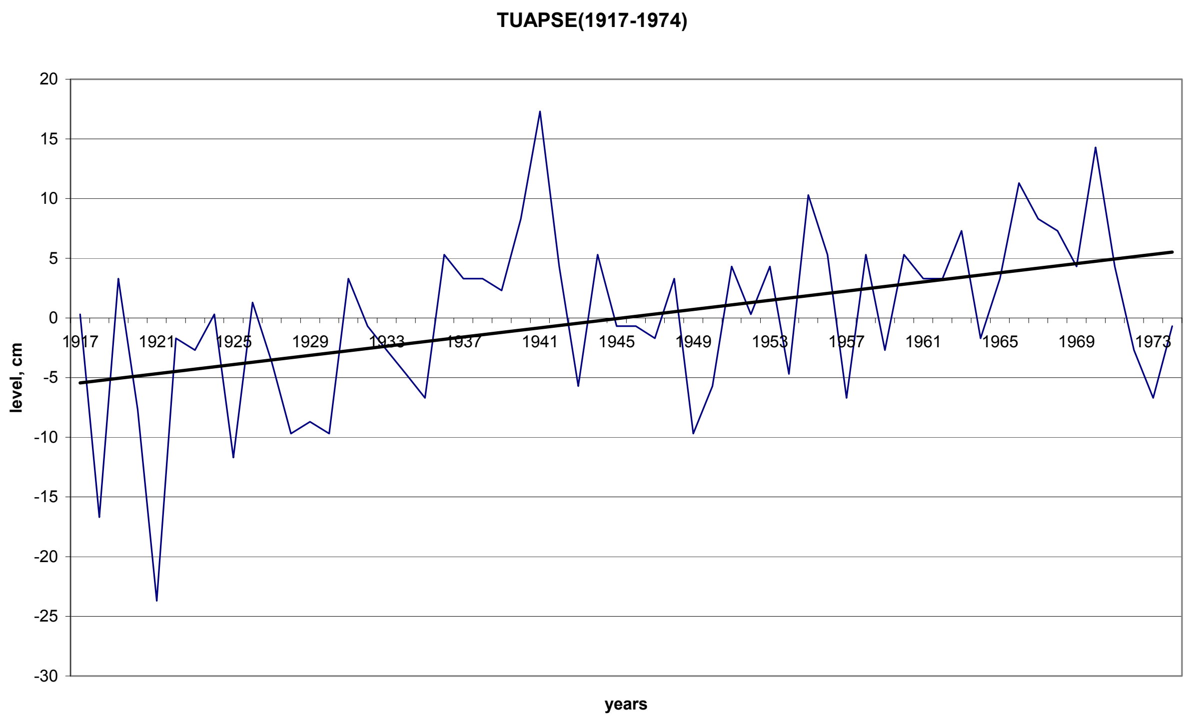

Figure 7. Temporal annual mean sea level variations and linear trend in Tuapse (Russia). GLOSS number of site –98

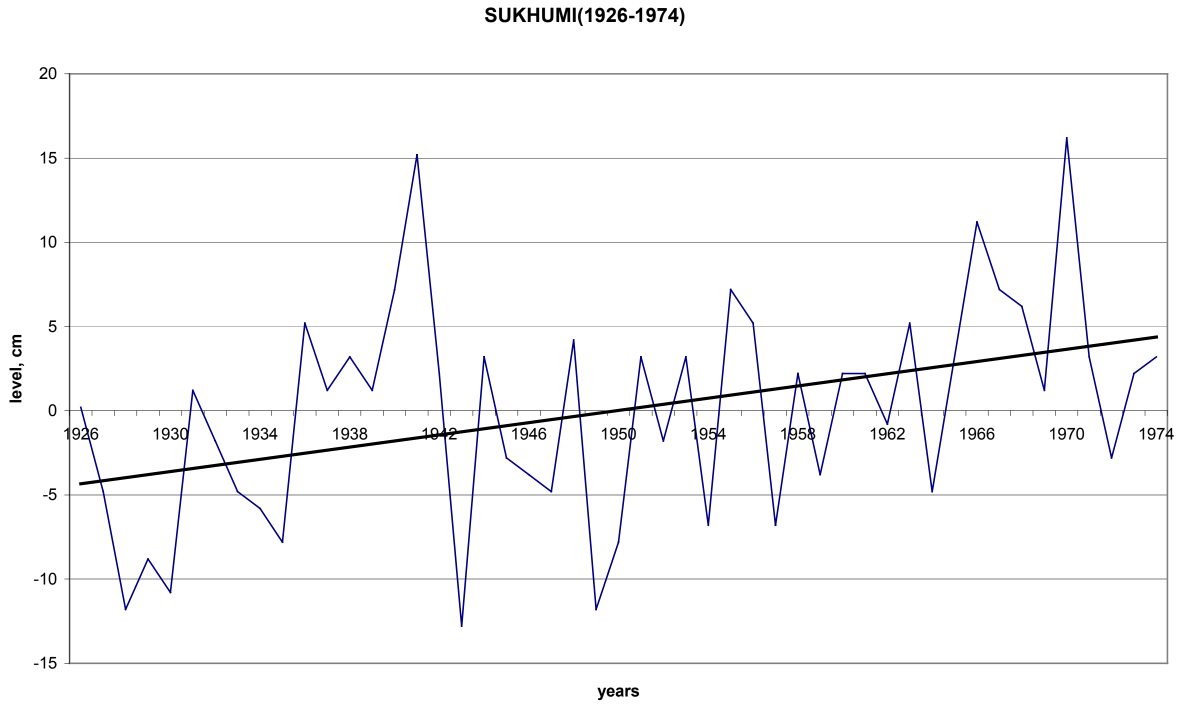

Figure 8. Temporal annual mean sea level variations and linear trend in Sukhumi (Georgia)

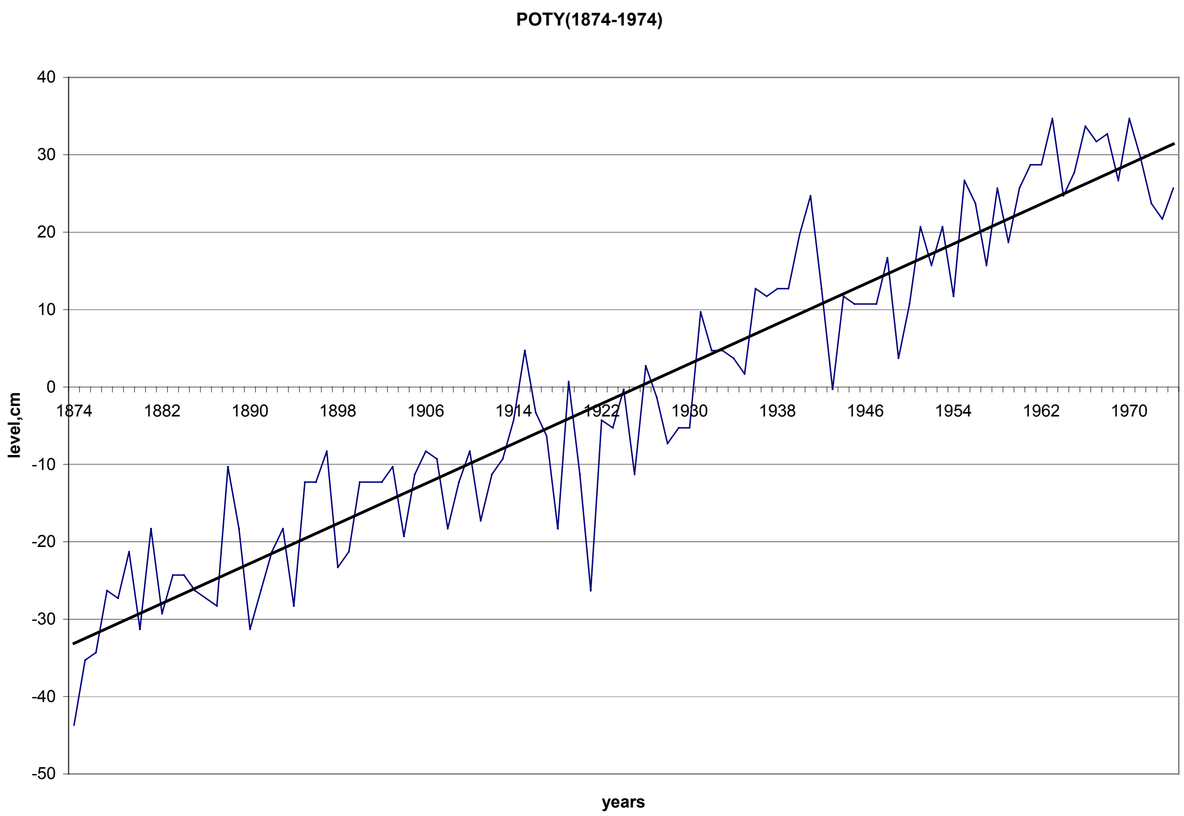

Figure 9. Temporal annual mean sea level variations and linear trend in Poty (Georgia)

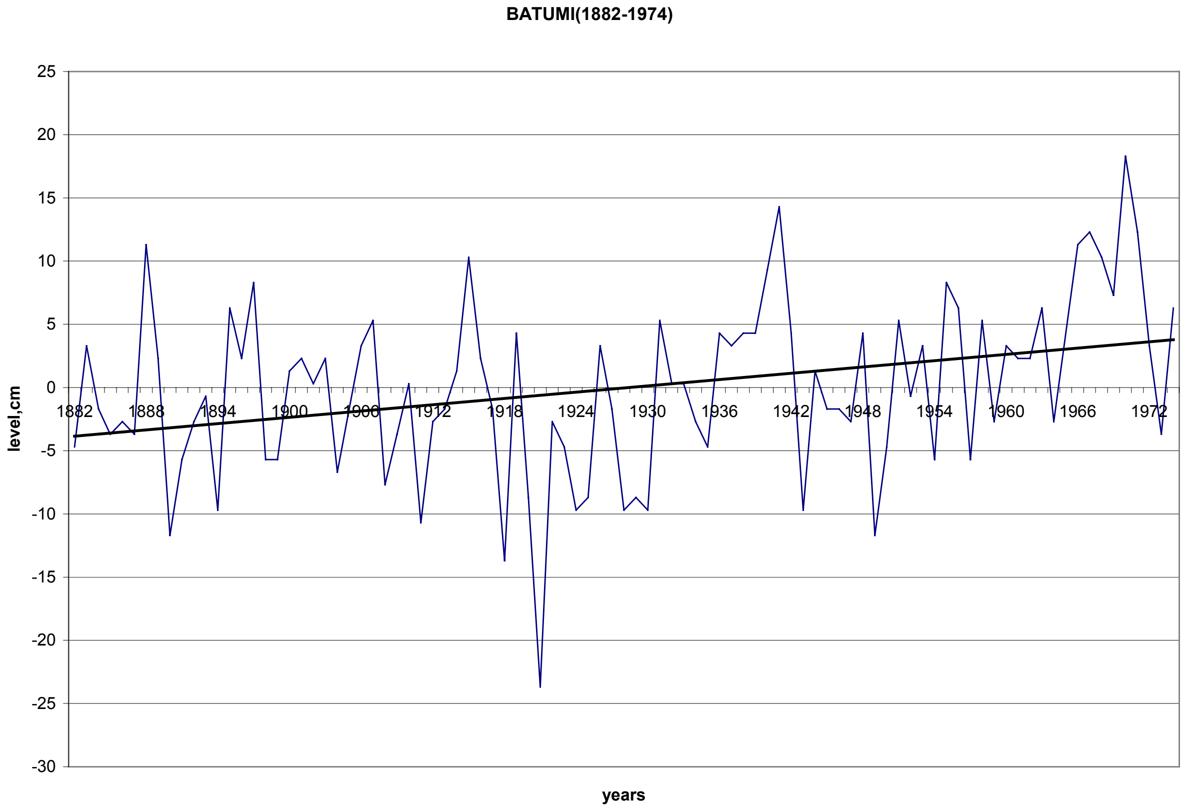

Figure 10. Temporal annual mean sea level variations and linear trend in Batumi (Georgia)

The results of analysis of more modern data (20-years period from 1977 to 1996) from two Russian sites Tuapse and Gelendjik, produced by AARIHI-WDC of Roshydromet. At the site of Tuapse a tendency of sea level rising is conserved (fig.11) when a sea level lowering is observed at Gelendjik (fig.12). Data from this site may require additional checking.

Numerical values of linear trends are shown in Table 2 for the sites, which observation series are presented at the figures (2-12).

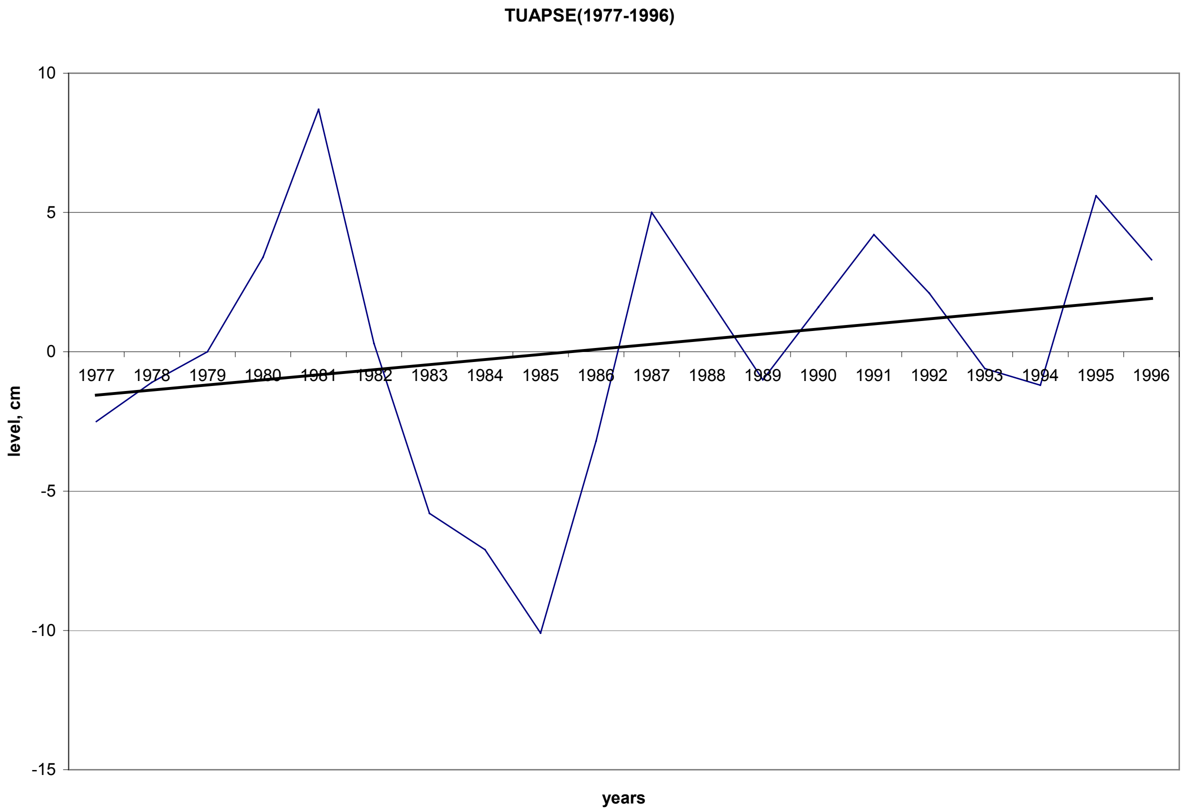

Figure 11. Temporal annual mean sea level variations and linear trend in Tuapse (Russia) for period 1977-1996. GLOSS number of site –98.

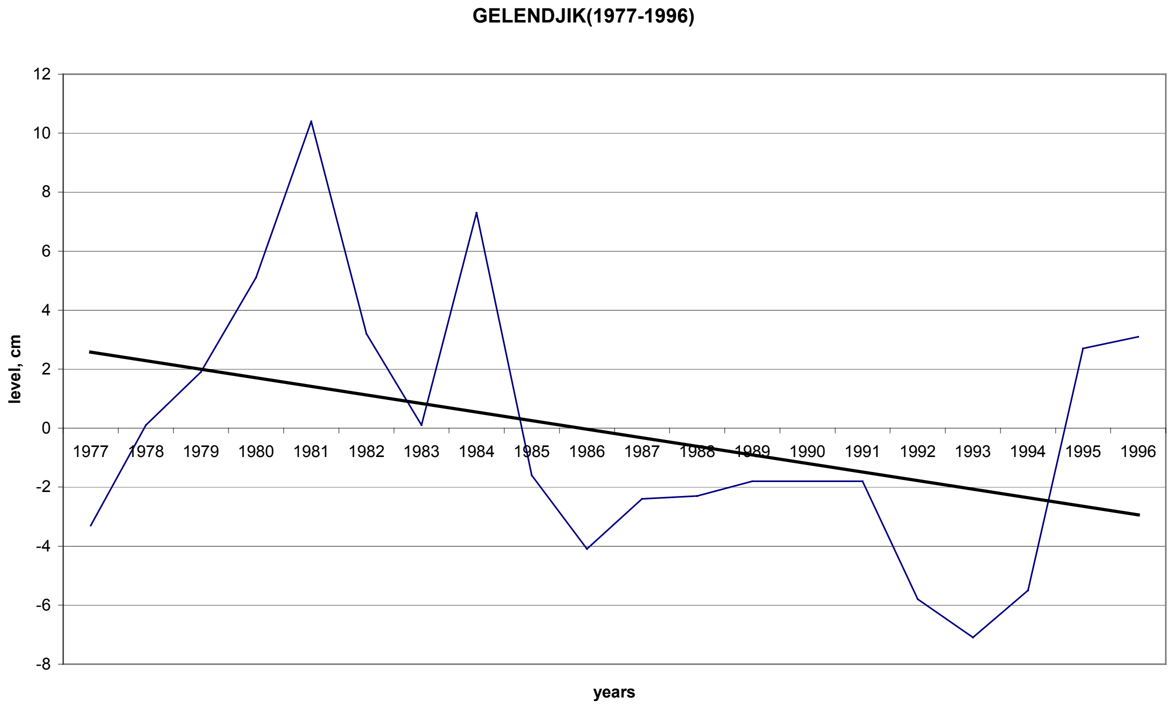

Figure 12. Temporal annual mean sea level variations and linear trend in Gelendjik (Russia) for period 1977-1996.

TABLE 2 LINEAR TREND VALUES FOR DIFFERENT BLACK SEA SITES.

GLOSS number	Site name	Linear trend value sm/year
	Odessa	0.566 (1875-1974)
	Nikolaev	0.202 (1916-1974)
	Sevastopol	0.084 (1875-1974)
	Anapa	0.158 (1923-1974)
	Novorossijsk	0,225 (1923-1974)
	Gelendjik	-0.290 (1977-1996)
	Tuapse	0.192 (1917-1974) 0.183 (1977-1996)
	Sukhumi	0.182 (1926-1974)
	Poty	0.646 (1874-1974)
	Batumi	0.083 (1882-1974)