

Sea Level Measurements in Malta

by Dr. A. Drago, Head of the Physical Oceanography Unit, University of Malta

- 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 which provide data for ocean forecasting, and by applying numerical modelling techniques in the study of physical marine systems. It operates in collaboration with international organisations 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 organises conferences, seminars, workshops and specialised 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 which was 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 Mellicha 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 which 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 topcase 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 topcase 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 which is

2.6507m below BM No. 9541811 established by the Mapping Unit of the Malta Planning Directorate.

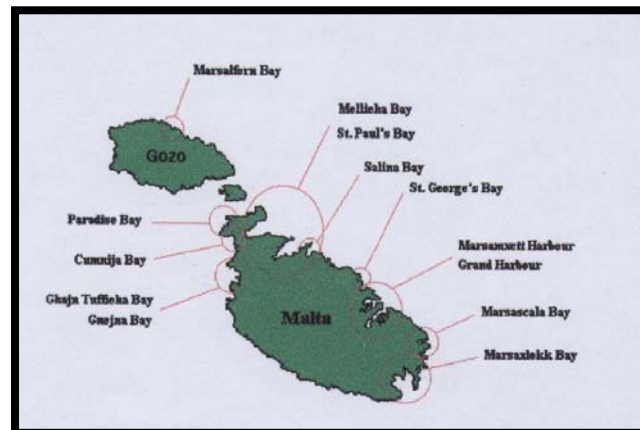


Fig.1 Main embayments in the Maltese Islands

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 20m 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 is 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.

In addition to the data from the permanent stations, short term deployments have been also 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 aquifer, 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 - December 1996 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 are 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 were 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 tsunamis, 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

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

1.5m. Literature on the 'Marrubio' 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.

REFERENCES

- Airy G.B., 1878, On the tides in Malta, *Phil. Trans. R. Soc. London*, 169, 123-138.
- Colucci P. and A. Michelato, 1976, An approach to the study of the 'Marrubio' phenomenon, *Bollettino di Geofisica Teorica ed Applicata*, V13(69), p3-10.
- Djumagaliev V.A., Rabinovich A.B. and Fine I.V., 1995, Theoretical and experimental estimation of transfer peculiarities of the Malokurilsk Bay coast, the Island of Shikotan, *Atm. Oc. Phys.*, Vol. 30, No. 5, 680-686.
- Drago A., 1992, TIDE TABLES 1993, Grand Harbour, Malta, *MRN Technical report Series*.
- Drago A., 1999, A study on the sea level variations and the 'Milghuba' phenomenon in the coastal waters of the Maltese Islands, *Ph.D thesis, School of Ocean and Earth Science, University of Southampton, UK*.
- Giese G.S., R.B. Hollander, J.E. Fancher and B.S. Giese, 1982, Evidence of coastal seiche excitation by tide-generated internal solitary waves, *Geophys. Res. Lett.*, 9, 1305-1308.
- Hibiya T. and K. Kajiura, 1982, Origin of 'Abiki' phenomenon (a kind of seiches) in Nagasaki Bay, *J. Oceanogr. Soc. Japan*, 38, 172-182.
- Monserrat S., Ramis C., Thorpe A. J., 1991, Large amplitude pressure oscillations in the Western Mediterranean, *Geophys. Res. Lett.*, 18, 183-186.
- Monserrat S and A.J. Thorpe, 1992, Gravity wave observations using an array of microbarographs in the Balearic Islands, *Q. J. Roy. Meteor. Soc.*, 117, 553-570.
- Shillington F.A., 1984, Long period edge waves off southern Africa, *Continental Shelf Res.*, Vol.3, No.4, 343-357.
- Taku T., Yoshinobu T., Masahito T., Yoshikazu U., Masayuki K., Takashi E., Yasuhiro Y, 1992, Comparison of Observed and Theoretically Calculated Seiches of Heda Bay, *Pageoph*. Vol.138, No.2.
- Wunsch C., 1972, Bermuda sea level in relation to tides, weather, and baroclinic variations, *Rev. Geophys. Space Phys.*, Vol. 10, No.1, 1-49.