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IMPLICATIONS OF EXPECTED CLIMATIC CHANGES ON THE ISLAND OF RHODES

MARINE PHYSICAL PROCESSES OF THE ISLAND OF RHODES

by

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F I R S T D R A F T

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2.4. MARINE PHYSICAL PROCESSES OF THE ISLAND OF RHODES

INTRODUCTION

The island of Rhodes together with the islands of Karpathos and Kassos form what is usually termed as the Eastern Straits of the Cretan Sea. Those straits separate the Cretan Sea (and in fact the whole Aegean Sea) from the Levantine Sea. A 16 Km narrow passage separates the northern edge of Rhodes from the mainland of Asia Minor. The maximum depth of this passage (also named Strait of Rhodes) is approximately 350 m. To the southwest, the strait of Karpathos lies, which is 40 km wide and has depths going down to more than 700 m. The western coasts of Rhodes are not very steep and face the northeastern part of the Cretan sea while the eastern coasts are very steep and as one moves to the southeast the water depths reach a trough 4000 meters deep. This is the area where the so-called Rhodes Gyre is situated, one of the major features of Eastern Mediterranean. It is a sub-basin cyclonic feature and a permanent characteristic of the northwestern Levantine. The hydrology and general circulation properties of the Levantine and of the Eastern Mediterranean have been the object of a number of papers during the last few decades. A major step towards the understanding of the phenomenology and the dynamics of the area has been achieved through the international program POEM and its coordinated basin scale cruises that started in 1986. General reviews of the Eastern Mediterranean can be found among others in Hopkins 1978, Malanotte-Rizzoli and Hecht 1988, and Ozsoy et al 1989.

The area southeast of Rhodes is believed to be the formation zone of one of the most important water masses of the Mediterranean-the Levantine Intermediate Water (LIW)-is formed (Ovchinnikov 1984). The other two important water masses of the Eastern Mediterranean are the North Atlantic Waters and the Eastern Mediterranean Deep Waters. During winter, northerly dry and cold winds (the so-called Poyraz winds) blow from the Asia Minor continent to the northern Levantine basin. These winds are strengthened as they pass through the Taurus mountain along the turkish coast. Since they are cold and dry they are very effective both in cooling and evaporating of the surface waters in the Rhodes gyre. Thus the density of the surface waters in the centre of the dome of the gyre is increased and the newly formed waters sink at the periphery of the gyre and are subsequently arrested at intermediate depths. After their formation the LIW waters spread at intermediate depths inside the Eastern Mediterranean, pass through the straits of Sicily to the Western Mediterranean and eventually go through the Gibraltar straits. They then sink into the Northern Atlantic and travel westwards as far as the eastern coasts of the American continent.

2.4.1. <u>Currents</u>

The Rhodes gyre is permanent but undergoes changes in intensity, shape and extension on a seasonal and probably interannual basis. Its maximum intensity is found over the deep trough mentioned earlier but it is sometimes extended eastward up to the western coasts of Cyprus. Its southward extent is usually limited by the so-called Marsa-Matruh anticyclonic gyre wich dominates the area northwest of Egypt. Between the Rhodes gyre and the Turkish coast lies the Asia Minor Current which moves westward along the south coast of Asia Minor. This strong current transports large amounts of heat and salt westward and it eventually reaches the northern part of Rhodes (The POEM Group 1992).

In summer, the Asia Minor Current enters the Aegean through the Rhodes strait and continues its course towards the north, along the eastern Aegean. This passage through the Rhodes strait results in a very strong westward moving current inside the strait, with mean velocities which can go up to 40 cm/sec.

In winter, the current through the Rhodes strait is weakened because only part of the Asia Minor current passes through the strait. In fact the major part of the Asia Minor current after reaching Rhodes turns to the southwest, moves along the eastern coasts of Rhodes, passes east of Karpathos island and then enters the Aegean through the strait of Kassos island. It then moves northward but when it reaches again Karpathos it is divided into two parts: one continues its path to the north along the eastern Aegean while the other bifurcates to the west and forms a sort of belt around the Cretan sea.

In any case, as far as the currents around the Rhodes island is concerned, we can say that the strongest currents are found in the Rhodes strait during summer with typical westward velocities up to 40 cm/sec. In the eastern coast the currents are directed toward the southwest with typical velocities of the order of 10 cm/sec. Finally along the western coasts, the currents are quite weaker especially during summer.

2.4.2. <u>Temperature/Salinity</u>

Based on its Temperature-Salinity characteristics the water column can be subdivided during summer in the following layers (Hecht et al. 1988).

A surface mixed layer 30 m to 50 m thick is usually called the Levantine Surface Waters (LSW). During summer these waters are produced locally, by excess heating and evaporation and they overtop the lower salinity North Atlantic Waters (NAW) layer (see below). The temperature of this layer can reach 24-25^{o} C in the open sea in August and possibly higher values in shallow coastal areas, while its salinity reaches a maximum in September, obtaining values up to 39.3 p.s.u. The exact value of this maximum seems to depend strongly on the interannual variability of the atmospheric parameters. In fact, recent measurements in the Cretan Sea (September, 1990) carried out by the University of Athens and the Institute of Marine Biology of Crete indicated surface salinity values as high as 39.55 p.s.u., which is quite higher than the expected climatological mean for the area. This is probably an indication of sea response to the particularly dry weather that prevailed in the area during the period 1987-1990.

Below the LSW layer a sharp salinity minimum indicates the existence of North Atlantic Waters. These waters enter the Mediterranean through the Gibraltar straits, and are transported eastward by the North African Current. After entering the Eastern Mediterranean this current leaves the north African coast and travels eastward as a mid ocean current or jet (the so-called Mid-Mediterranean jet). Due to mixing, the salinity of the NAW layer increases as it propagates to the east. In the northern Levantine typical values range from 38.7 to 38.9 psu. The bottom of this layer is usually found at 80 to 100 m.

Immediately below the NAW layer we find the Levantine Intermediate Water layer which is characterized by a salinity maximum. The core value of this maximum is 39.1 psu while the temperature at the core lies between 14.7 and 15.5^{o}C. The extend of the LIW depends on the area but it usually goes down to 350 m., while it occasionally reaches the 500m depth.

Finally, below 1500 m we find the Eastern Mediterranean Deep Waters (EMDW) with characteristic values S=38.6 psu and T=13.3 ^{o}C. In between the LIW and the EMDW a transition layer lies, with intermediate characteristics.

In winter, convection mixes the surface waters to a depth which ranges from 150 m to 400 m, depending on the area. The NAW layer cannot be distinguished any more in most of this sector (with the exception perhaps of the Mersa Matruh gyre). Surface salinities are lower than in summer and have typical values from 38.8 - 39.1 psu. Surface temperatures range from 14.5 to 16 ^{o}C.

2.4.3. Waves

The surface wave regime depends mainly on the winds that prevail in each area. The most frequent winds are (data from Greek Meteorological Office) from the West (40.24%), the NW (12.40%) and the SW (7.84%) while of minor occurrence are winds from the SE (7.61%), from the S and N (3.26 and 2.55% respectively) and finally from the E and NE (2.24 and 0.75% respectively). Winds with strength less than 1 in Beaufort scale account for 23.09%.

The W and NW winds have an important fetch and thus can generate waves at the western coasts of the island. By applying empirical formulas for the computation of the significant wave height, we calculated that winds of these two directions with a force of 7 in the Beaufort scale, can generate waves having significant height of 2.5-3 m if their duration is 10 hours, and 4 m if their duration exceeds 36 hours. We should note at this point that the W and NW winds prevail during the summer period and rarely attain strengths larger than 7 B. Their maximum strength observed is 8 B, with a frequency of occurrence 0.03% and 0.06% respectively, which amounts to a total of 3 and 6 hours approximately.

On the contrary winds from the E and especially from SE although less frequent are much stronger and as a result they are more effective in wave generation. These winds occur during the winter and are related with the passage of the cyclonic disturbances through the area. At 7 B they have an annual frequency of occurrence 0.59%, at 8 B 0.22% at 9 B 0.06% and at 10 B 0.01% (52, 20, 5 and 1 hr respectively). This means that once or twice per year, SE winds blow under severe storm conditions and can generate waves with a significant wave height of 5 to 6 meters. What should be noted at this point is that those winds are related with low atmospheric pressures which (because of the inverse barometric effect) increase the mean sea level. Thus the destructiveness of these events can be very important both because of the significant wave height and because the increased mean sea level causes the wave breaking to occur closer to the coast.

2.4.4. Sea level

The mean tidal range in the port of Rhodes (for the period 1956-1978) is only 13 cm, while the maximum tidal range observed during this period is 45 cm (data from Greek Hydrographic Service) . This very well agrees with results of tidal models for the Aegean which, for the semidiurnal tides, show the existence of a nodal point somewhere in the Cyclades (Papaioannou, 1990). In this area tidal ranges are of course close to zero and increase as one moves to the south and to the north. They reach their maximum values in northern Greece.

Sea level oscillations in the range of a few days (storm surges) are also not very important in the area under study. The results of a research conducted by the University of Athens (Nittis et al. 1990) showed that storm surge maxima occur in northern Aegean, while in the Rhodes area they rarely exceed 20 cm. This fact is related both to the track of the cyclones during the winter season in the greater area and to the small "pilling up" effect in the straits, compared to the greater effect caused by the continuous coastline of northern Greece.

2.4.5. Discussion of the climate changes implications

In figures 1 to 4 we present variations of atmospheric pressure, air temperature, rainfall and sea level for the period 1953-1989. Unfortunately the available sea level data is for a much shorter period. Following are a few comments regarding these figures:

- All these parameters show an important interannual variability during the last few decades.

- The sea level undergoes similar oscillations with those of other stations in Greece (not shown here). In fact the sea level seems to be the parameter with the best spatial coherence in the greater area.

- A decrease in air temperature is observed from the early sixties to the early seventies (quite common in most Aegean stations), followed by an important increase thereafter. This increase is the greatest observed in the Aegean.

- The increase in air temperature after 1973, is well correlated with an increase in atmospheric pressure.

- Finally, the rainfall continuously decreases from the early seventies until today.

If we try to relate the variability of these parameters, we could say that an increase in atmospheric pressure is accosiated with an increase in the frequency of occurrence of dry north winds, and this in turn could explain the observed decrease of rainfall. However an increase of the north winds should also be followed by a decrease, and not an increase, in air temperature as observed in fig. This point elucidates the complexity of the climatic regime of the area. Obviously, a very important parameter of the climate of the region is the so called "climate of the ocean". Indeed, as mentioned earlier, Rhodes lies in the path of the Asia Minor current which transports large amounts of heat from the northeastern Levantine. This means that the local air temperature is significantly influenced by changes in the heat content of the Asia Minor current.

From the above brief discussion it is concluded that the present and the future climate of Rhodes, depends substantially on the advected "oceanic climate" of the North Levantine Basin which must also be studied if one desires to have any degree of confidence in his predictions.

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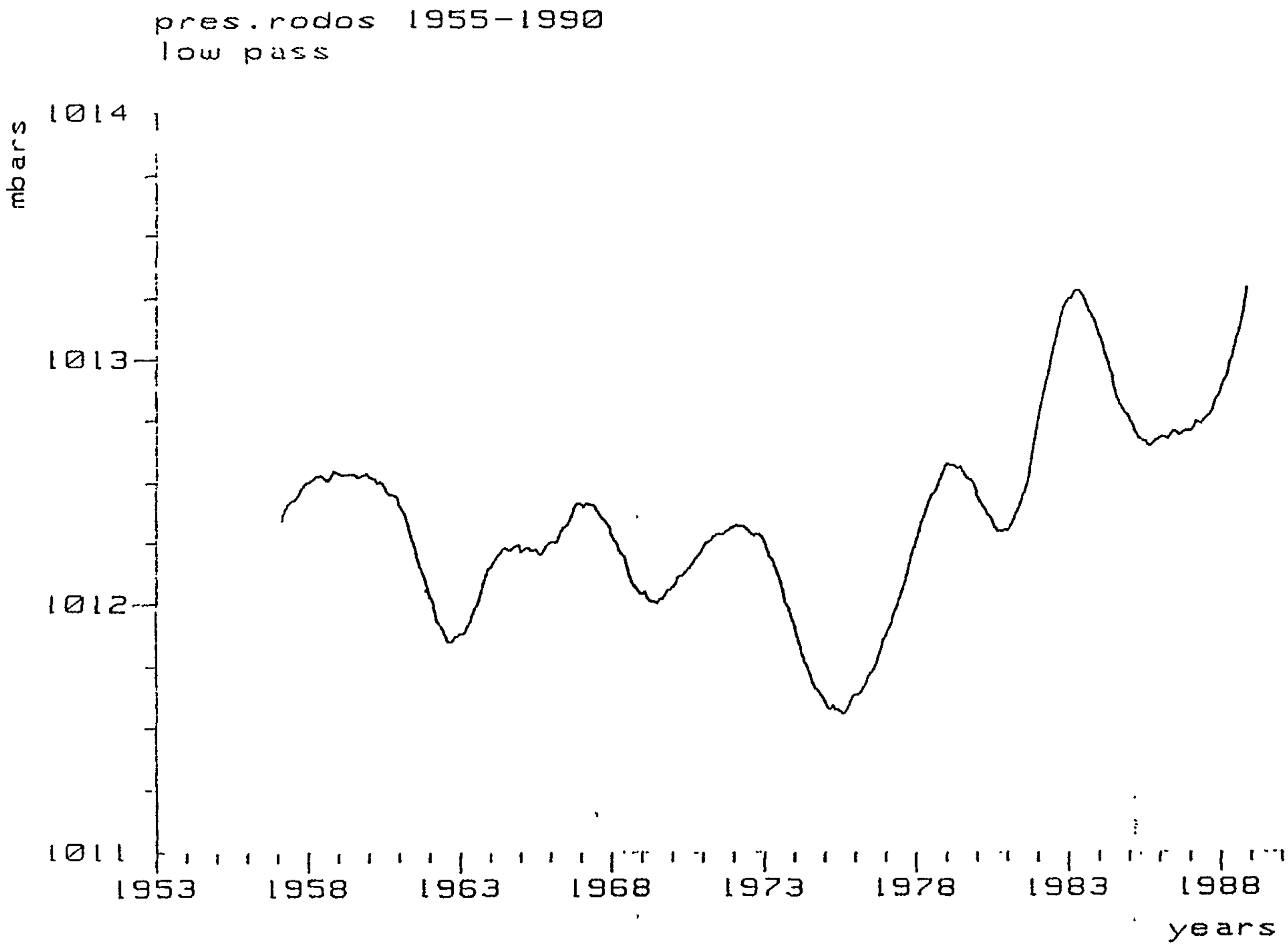

Figure 1 - Atmospheric pressure

Figure 2 - Air temperature

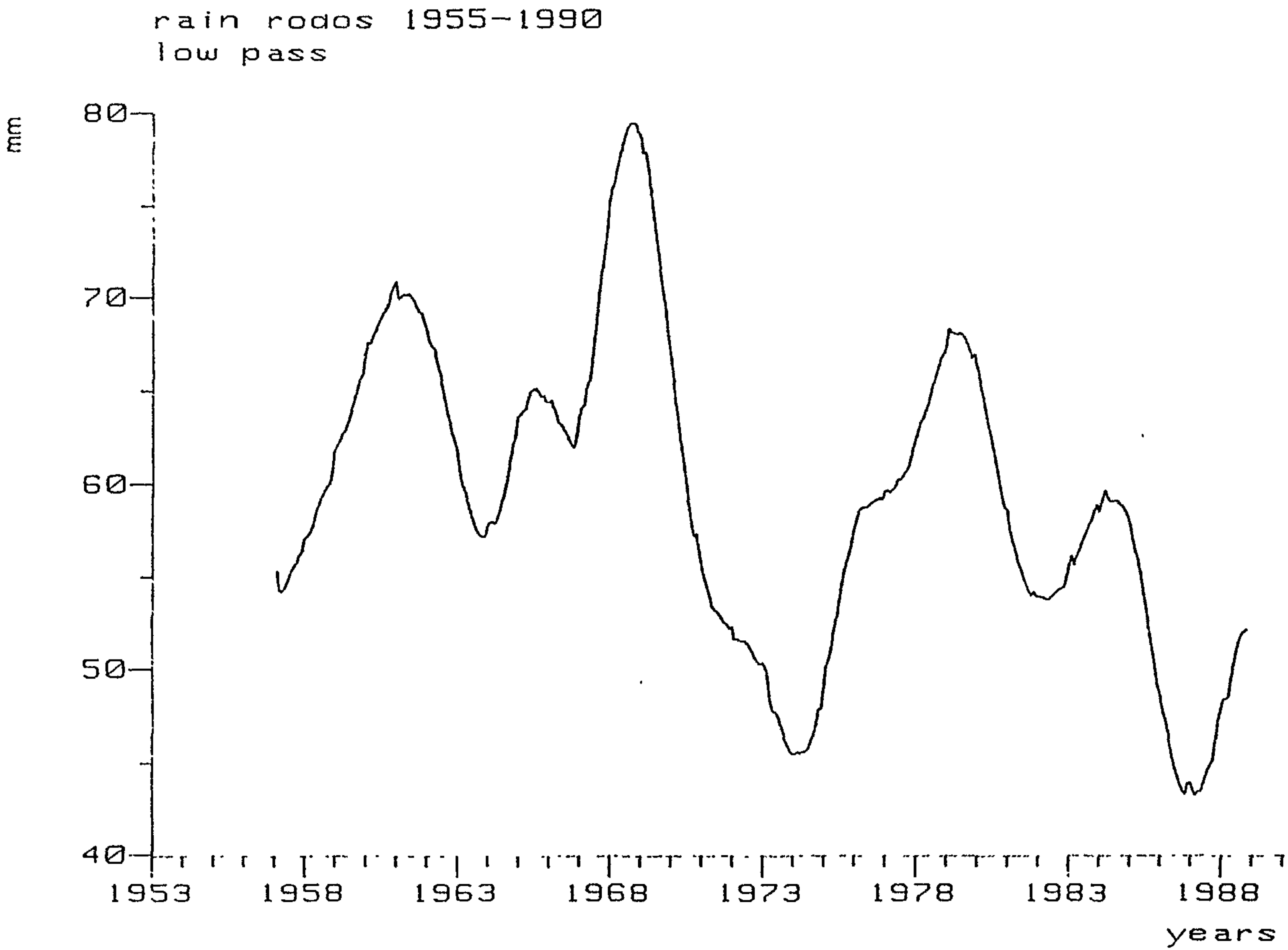

Figure 3 - Rainfall

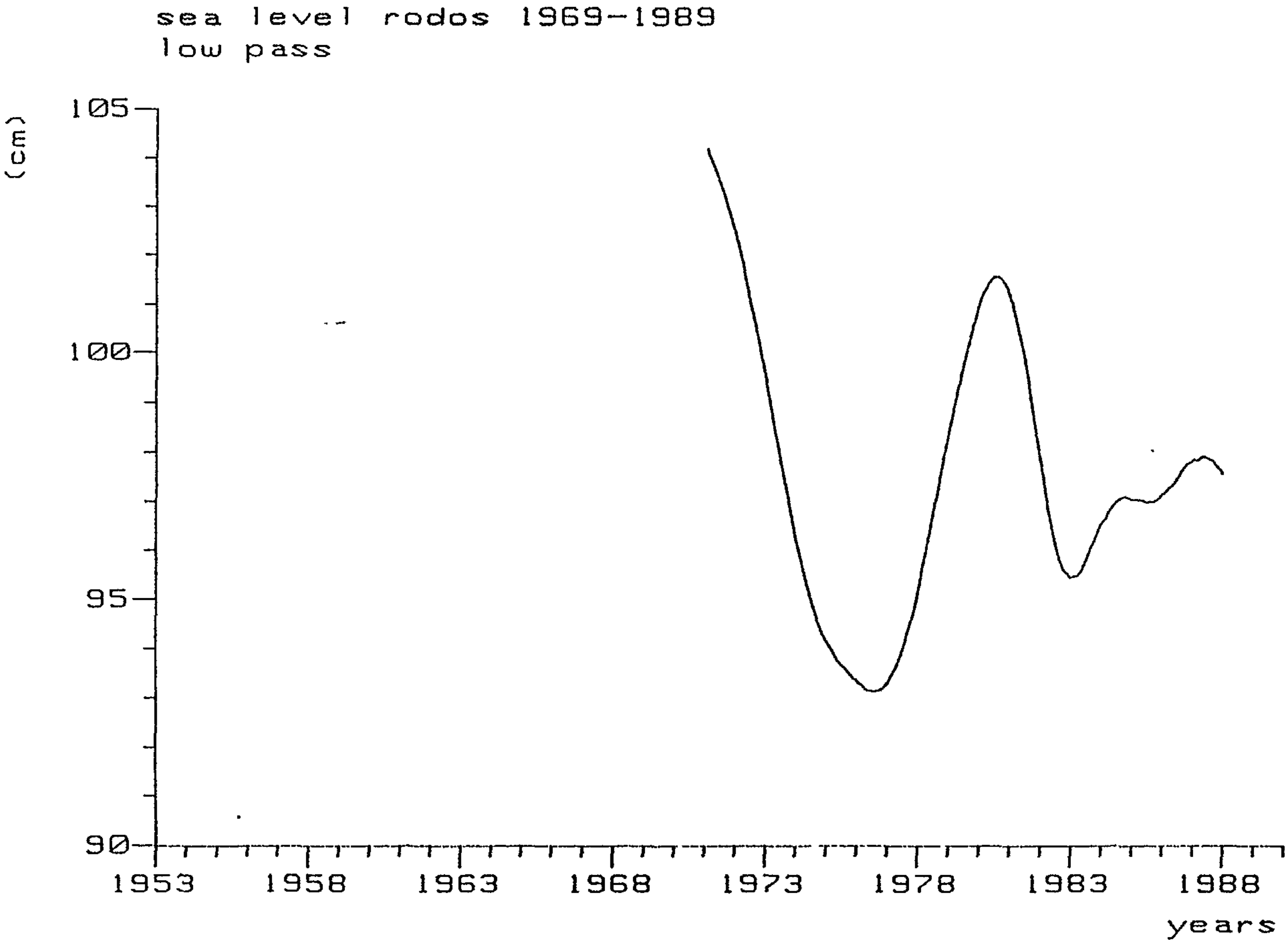

Figure 4 - Sea level