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Sea level rise along the Mediterranean coast of Egypt

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ABSTRACT

It is shown in the paper that the tide gauge of Alexandria, Egypt and the other tide gauges of the Mediterranean having enough quality and length all exhibit a low rate of rise without any sign of acceleration with oscillations about this trend. The misinterpretation of these oscillations is the only way to support non existing accelerating statements. The behaviour of the tide gauges of the Mediterranean is consistent with the behaviour of the other tide gauges of the world. The sea level result is in harmony with the trends for temperatures showing over the last century oscillations about a constant gradient.

SEA LEVELS ARE SLOWLY RISING WITH NO ACCELERATION IN THE MEDITERRANEAN AND ELSEWHERE

The mediterranean is a nearly closed water volume, separated from the Atlantic by the Gibraltar strait on the west. The narrow Strait of Gibraltar connects the Atlantic Ocean to the Mediterranean Sea and separates Europe from Africa by 14.3 km of ocean at the strait's narrowest point. The Strait's depth ranges between 300 and 900 metres. On the east, the Mediterranean sea is separated from the Marmara Sea by the Dardanelles, a narrow strait in northwestern Turkey connecting the Aegean Sea, part of the Mediterranean, to the Sea of Marmara. The Dardanelles is one of the Turkish Straits, along with its counterpart the Bosphorusm separating the Sea of Marmara from the Black Sea. The Dardanelles strait is only 1.2 to 6 kilometres wide, averaging 55 metres deep with a maximum depth of 103 metres.

Sea levelsdo certainly change as the climatein general does. However, the anthropogenic contribution through the changed composition of the atmosphere is much less strong that what is claimed, being any trace of global warming missed since the beginning of this century in any termometer measuring land or ocean temperatures in this case up to 2000 metres depth[8-10].

Sea levels oscillate with many periodicities, from hours to days, from months to years, and from decadal to multi-decadal periodicities since the era of the instrumental records[5-7], but with also centennial and millennial periodicities since ever. Sea levels have been generally relatively stable over the last 2,000 years, and this is particularly true for the Mediterranean, an internal sea, that even if not "*The Cradle of History*", it is certainly one of the most recognised historical cradles worldwide.Since the start of the civilization, sea levels have been much higher. Heracleion, a port near Alexandria, had a legend beginning the 12th century BC, andthe ruins are now located in Abu Qir Bay, 2.5 km off the coast. Heracleion was Egypt's main port during the late periods of the Pharaohs. Canopus was another port located in the Nile Delta first named in the 6th century BC and now in the eastern outskirts of Alexandria.

Simlarly, Ephesus was an ancient Greek port built in the 10th century BC on the coast of Ionia, now İzmir Province in Turkey, six kilimeters away from the Mediterranean.Ostia Antica was the harbour city of ancient Rome. Built in the 7th century BC, the town was developed during the first century AD but theplace now sits three kilometres from the Mediterranean.

Sea levels have been steadily rising in the Mediterranean and worldwide since the "*Little Ice Age*", a period of cooling that occurred after the Medieval Warm Period, conventionally defined as a period extending from about 1350 to about 1850. Very few tide gauges started their recording in the 1800s, and records of good quality and enough length to understand the multi-decadal oscillations and infer relative sea level rise trends within reasonable accuracy are unfortunately not too many worldwide and mostly concentrated in few geographical areas.

Since 1900, sea levels oscillate with multi-decadal periodicities up to a quasi-60 years fully detected in the instrumental records and very likely longer periodicities not fully cleared out because of the limited instrumental recordsabout a constant relative rate of rise[5-7]. Similarly the temperatures also oscillate with a quasi 60 years periodicity about a constant gradient that in the upwards biased GISS reconstruction is 0.7 degrees Celsius per century but very likely it is much less than this background warming[8-10]. Warming 1910 to 1940 was very

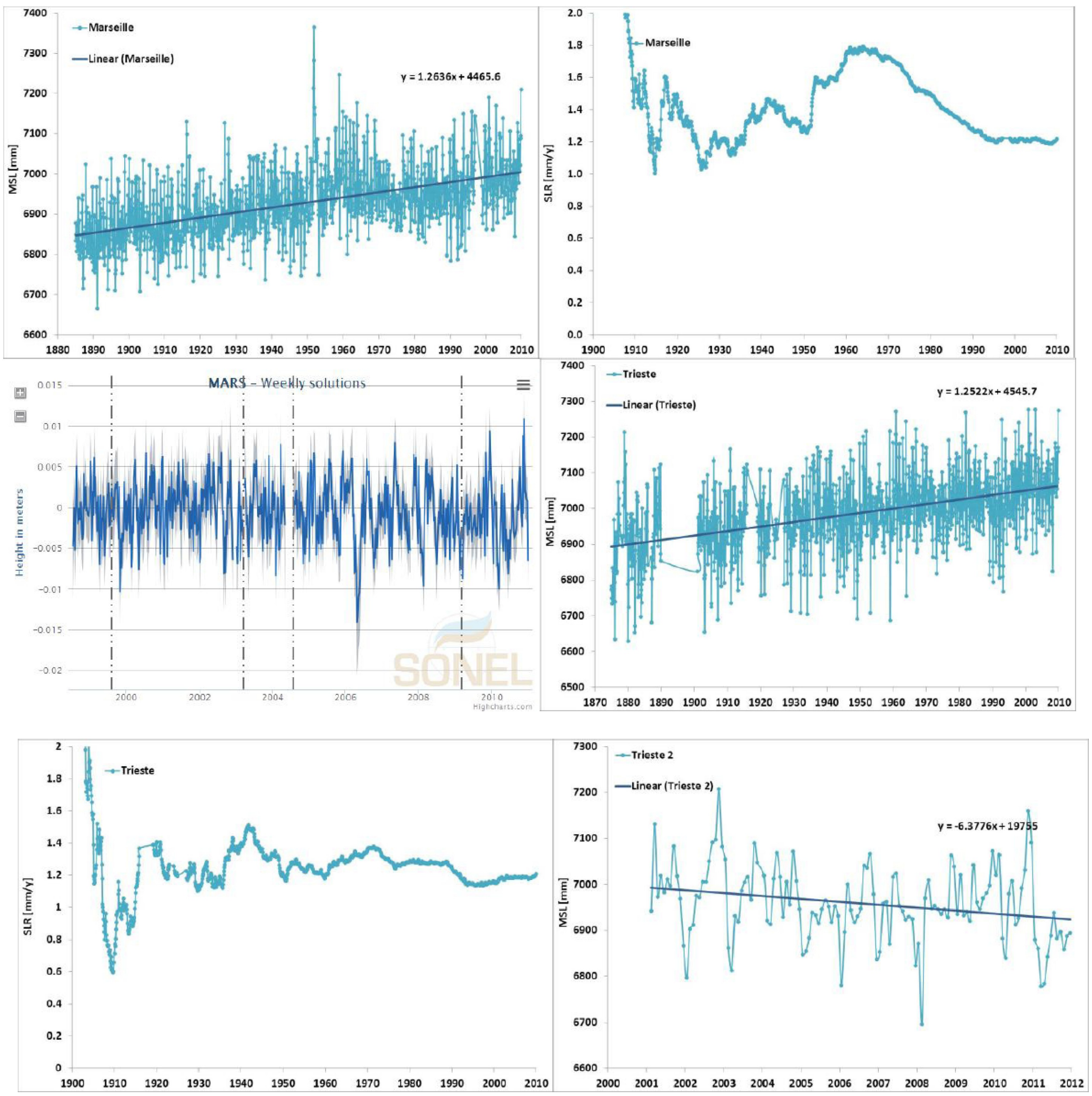

Figure 1 : Monthly average relative mean sea level, relative rate of rise of sea levels (data from[1]) and vertical land motion in nearby GPS stations (from[2]) for Marseille and Trieste

TABLE 1 : Measured sea level rise (mm/year) in Mediterranean locations (from[3])

ID	Station Name	First Year	Last Year	Year Range	% Completeness	MSL Trend	+/- 95 % CI
220-003	Cadiz III, Spain	1961	2010	50	97	4.02	0.74
220-011	Algeciras, Spain	1943	2002	60	81	0.43	0.30
220-031	Malaga, Spain	1944	2010	67	82	0.65	0.50
230-051	Marseille, France	1885	2011	127	97	1.25	0.14
250-011	Genova, Italy	1884	1997	114	78	1.20	0.14
270-061	Trieste, Italy	1905	2011	107	94	1.27	0.20
280-006	Rovinj, Croatia	1955	2009	55	99	0.58	0.46
280-011	Bakar, Croatia	1930	2009	80	86	0.97	0.36
280-021	Split Rt Marjana, Croatia	1952	2009	58	99	0.28	0.48
280-031	Split Harbour-Gradska Luka, Croatia	1954	2009	56	100	0.62	0.48
280-081	Dubrovnik, Croatia	1956	2009	54	99	1.02	0.45
290-017	Katakolon, Greece	1969	2011	43	89	1.81	0.66
290-021	Kalamai, Greece	1969	2011	43	78	4.37	0.58
290-034	Khalkis North, Greece	1969	2011	43	88	0.35	1.02
290-051	Thessaloniki, Greece	1969	2011	43	90	3.73	0.80
290-065	Alexandroupolis, Greece	1969	2011	43	88	1.78	0.81
290-071	Khios, Greece	1969	2011	43	88	3.58	0.87
290-091	Leros, Greece	1969	2011	43	79	1.06	0.71
290-110	Rodhos, Greece	1969	2011	43	69	0.91	1.19
340-001	Ceuta, Spain	1944	2009	66	96	0.52	0.29

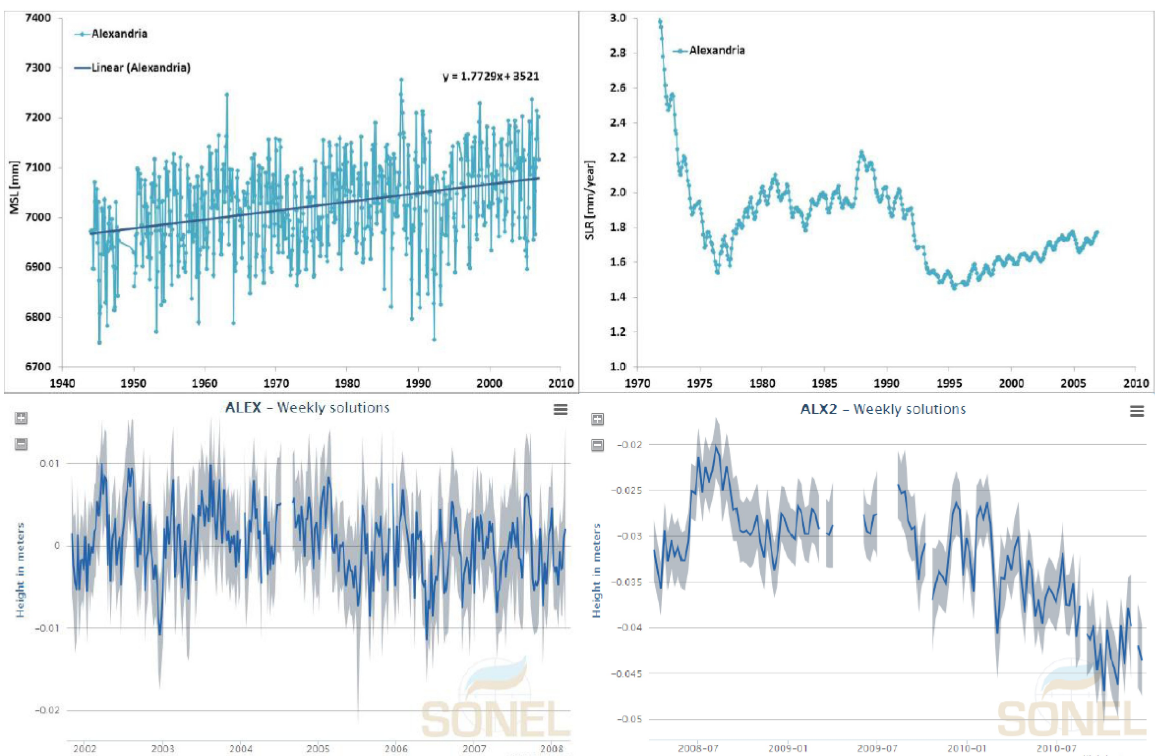

Figure 2 : Monthly average relative mean sea level, relative rate of rise of sea levels (data from[1]) and vertical land motion in nearby GPS stations (from[2]) for Alexandria

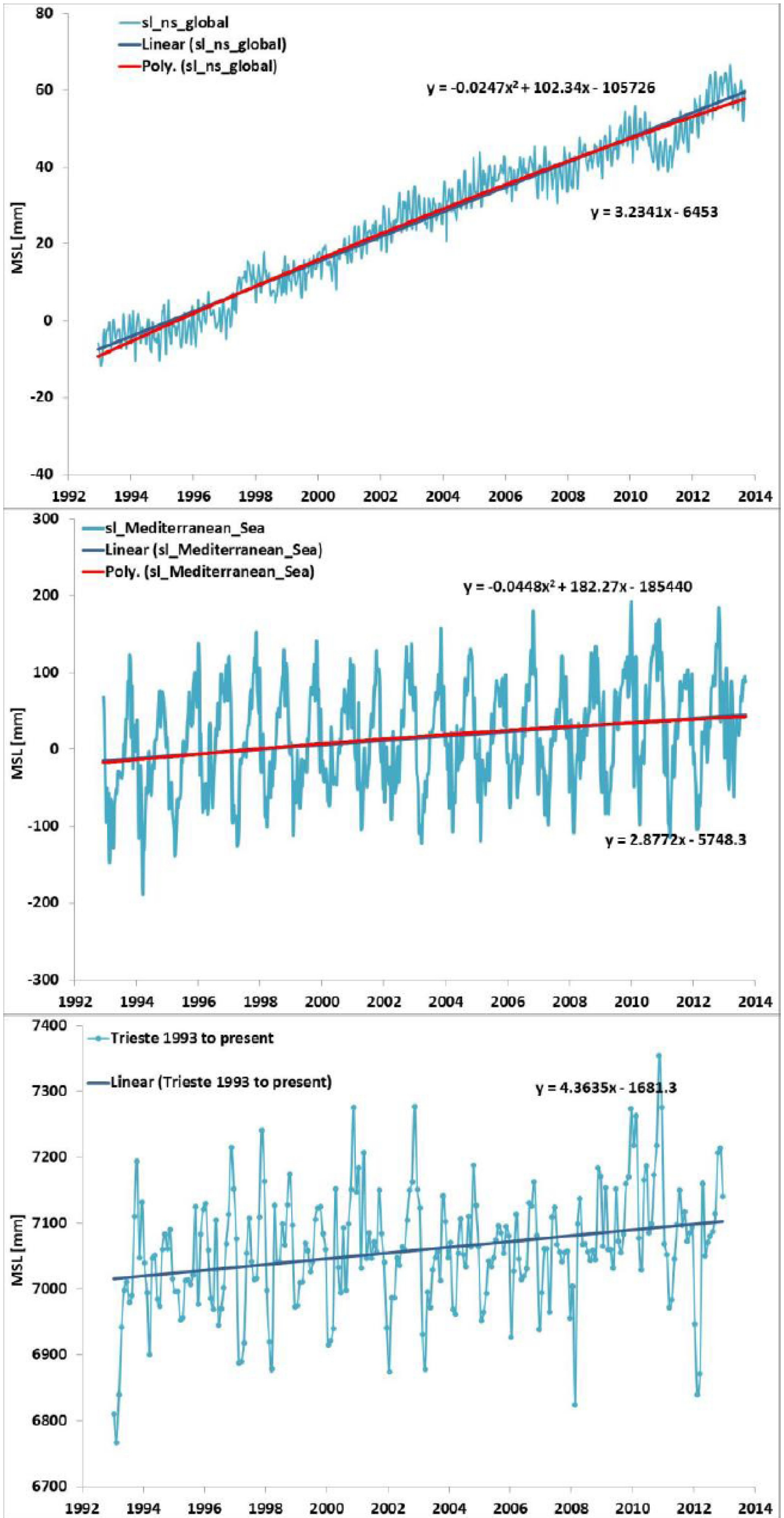

Figure 3 : Mediterranean and global mean sea levels from the satellite reconstruction (from[4]) and tide gauge record of Trieste over the same time window

close to warming 1970 to 2000, and the lack of warming up to 1910 and 1940 to 1970 is also occurring since the beginning of this century.

Similarly to all the other long term tide gauges of the world of enough quality and length, also the long term tide gauges of the Mediterranean are acceleration-free over the period of recording.

Figure 1 presents the monthly averaged mean sea levels (MSL) for Trieste and Marseille, plus the rates of rise of sea levels (SLR) computed by linear fitting of all the MSL data up to a certain time, while Figure 2 presents same results for Alexandria. The nearby GPS signal is also included to indicate a likely occurrence of subsidy to bias upwards the SLR results. The tide gauge results are from[1], the GPS data is from[2].

Marseille has time span of data 1885 – 2012 and completeness (%) 97. Trieste has time span of data 1875 – 2012 and completeness (%) 86. Nearby Trieste 2 has time span of data 2001–2011 complete-ness (%) 98. Alexandria has time span of data 1944 – 2006 and completeness (%) 96. With 60 years of data, Alexandria permits to compute a meaningful sea level rate of rise that however is much less reliable than the one in Trieste and Marseille spanning many more data. Trieste 2 is definitively too short to infer any trend but it is useful to show that short records may provide false impressions of rates of rise much larger or in this case also much smaller than the legitimate value. With only 10-20 years of data, the SLRs computed by linear fitting are macroscopic overestimation or underestimation of the true long term trend because of the multi–decadal oscillations. Subsidy should not account for too much of the SLR result for Marseille and Trieste, while Alexandria may have a larger SLR because of subsidy.

TABLE 1 presents the sea level rise computed by linear fitting of all the data in locations of the Mediterranean of[3]. The records of TABLE 1 have variable length. Those records satisfyingthe 60 years minimum length are in bold. The average rate of rise of sea levels is 1.52 mm/year. Considering only stations with more than 60 years of data, the average rate of rise of sea levels drops to 0.90 mm/year. This is a measure of the relative motion of the sea vs. the land. This result is only the average value of the compilation of tide gauges.

Figure 3 presents the satellite Mediterranean and global mean sea levels (from[4]). The figure also presents the analysis of the tide gauge record of Trieste over the same time window. This result is not a measurement but a simulation. The satellite measurement only returns within a not negligeable measurement error a Z sea level of a latitude X and a longitude Y but also of a time t. Being the sea levels continuously oscillating over many different scales from very high to very low frequencies, the reconstruction of the GMSL from the raw satellite signal is everything but trivial. Raw satellite signals are mostly noise without a specific trend, and pivoting this trend from only few carefully selected short tide gauges (the GMSL satellite simulation started in 1993), the GMSL may become a high rise curve. The 2.88 mm/year of the satellite Mediterranean mean sea level is similarly to the 3.24 mm/year of the satellite GMSL a number completely scorrelated from the tide gauge behaviour along the coast in the past and in the present. Being the early 1990s a valley of the multi-decadal oscillations, the apparent rate of rise of Trieste from the short record 1993 to present is 4.37 mm/year to compare with the legitimate 1.25 mm/year.

It is claimed in[4] that while "*we do calibrate the altimeter sea level measurements against a network tide gauges to discover and monitor drift in the satellite (and sometimes tide gauge) measurements*", "*The global mean sea level (GMSL) we estimate … cannot be used to predict relative sea level changes along the coasts*", that does not make too much sense. For sure, it is wrong to compare the SLR of Figure 3 with the average SLR of previous tide gauge compilations to claim the sea level are rising faster and they are accelerating.

The compilation of tide gauges of TABLE 1 is made of long term tide gauges all not accelerating. Despite of doubtful significance, the GMSL and Mediterranean reconstructions of Figure 3 are also acceleration free.

The lack of acceleration in the sea level records is discussed in many other papers, as for example[11-15], as the climate and sea level quasi 60 years oscillations is also discussed in[16-19].

CONCLUSIONS

Focusing on what is actually measured by thermometers and tide gauges, it is very unlikely that the sea level by 2100 will rise more than 7.8 cm on average along the Mediterranean coastline, and more than 15.4 cm in front of Alexandria, Egypt.

The sea level rise on the Mediterranean coastal areas in Egypt, particularly the Nile River Delta, has no reason to be an issue of major concern to Egypt's population and the government and the true risks associated with the modest sea level rise do not request immediate and significant adaptation measures.

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