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Global warming and decadal trends of sea surface temperature in Hurghada, Red Sea, Egypt

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ABSTRACT

The Red Sea is a semi-enclosed sea basin that is extremely warm, and it is experiencing rapidly rising temperatures. Sea Surface Temperature (SST) is influenced by weather factors as well as oceanographic factors. The relationship between SST and air temperature (AT) was studied using data from 2010 to 2019 for both air and sea temperatures, and a comparison between these data and those in Luksch's tables. A strong relationship was found between the temperature in the air and the surface temperature of the sea, where the air and sea temperatures reach maximum values in the summer season. The temperature tends to increase at an annual rate of 0.109 while the sea temperature tends to increase at an annual rate of 0.036 °C. It was found that the air temperature increased in the period 2010-2019 by about 4.57°C, while the difference between them in the SST was about 2.21°C.

INTRODUCTION

Hydrographic investigations in the Red Sea area were first undertaken by the Pola Expedition in 1895 **(Natterer, 1898; Luksch, 1901).** Early studies were also made with the Magnaghi **(Vercelli, 1927).** The John Murray Expedition of 1933-1934 **(Thompson, 1939)** occupied numerous stations, and this was followed by an Egyptian Survey of the northern Red Sea **(Mohammed, 1939)**.

Global warming results as changing the radiative balance in the atmosphere and produces many negative effects, among the most important of these negative effects is the rise in sea surface temperature, the temperature of permafrost to rise, and the infiltration of salinity due to anthropogenic influences on the sea and overland **(IPCC, 2019)**. Accordingly, the sea level has risen, causing surges in rafts and extreme rainfall severe heavy weather on the north shore of Egypt. The sea level, according to an IPCC survey, is by 2100; a rise of approximately 60 CM is expected **(Ali and El-Magd, 2016).**

A warming of the Earth's surface is likely to have vital ecological, economic and political consequences, not only because of its effect on terrestrial environments and ecosystems, agriculture and forestry e.g. **(Strzepek and Smith, 1995),** and also very important, due to its effect on aquatic environments and ecosystems, water supplies and fisheries **(Watson *et al*., 1996)**.

The Red Sea is a semi-enclosed, extremely warm sea basin, experiencing rapid warming **(Belkin, 2009 ; Raitsos, 2011& 2013).** Between 1982 and 2006, the average annual temperature of the Red Sea increased by 0.74 °C **(Belkin, 2009)**, comparable to the global average of 0.85 °C **(Rhein *et al*., 2013).** An intense warming event occurred in 1994 leading to a 0.7°C increase in mean annual sea surface temperature **(Raitsos, 2011).** Currently, the average temperatures in the Red Sea already exceed those of other tropical regions **(Cantin, 2010).** Yet, the Red Sea hosts one of the largest reef systems in the world, where organisms may be already close to their thermal limits.

SST is one of the most important physical properties of aqueous systems; any change in SST can alter marine ecosystems, affect in plant, animal species and microbes in the ocean, also, have an impact on migration and reproduction patterns, threaten sensitive ocean life such as coral reefs and exert influence on the frequency and intensity of harmful algal blooms such as “Red Tide” **(Ostrander *et al*., 2000)**, in addition to, marine organisms tolerate a specific range of temperatures **(Dunham *et al*., 2003)**.

The Red Sea can be divided into five sub-basins as: the Gulf of Aden Basin, southern Bab Al-Mandab Strait, southern Red Sea, central Red Sea and northern Red Sea **(Al-Horani *et al*., 2006).** The latter basin was considered to be in an arid climate zone with little rainfall and runoff. Also, **Langodan *et al*. (2017)** showed that the northern region of the Red Sea is affected by the Mediterranean climate and therefore it is always exposed to the northern winds, but the high mountains surrounding it prevent these winds from some areas and thence, the weather varies from one region to another.

Generally, several studies consider that meteorological parameters as well as hydrological parameters are the main factors affecting SST changes **(Lima *et al*., 2012 and Chaidez *et al*., 2017).**

This paper deals with data of air and sea surface temperatures collected during the "Pola" Expeditions in 1895 - 1898 by **(Luksch, 1901)** of the Red Sea, and compare with air and sea surface temperature values of the period from 2010 to 2019 of north Hurghada on the Red Sea coast. Also, to understand the changed in sea surface temperature and air temperature for long time.

MATERIALS AND METHODS

Air temperature (AT) values were recorded each hour of the period from 2010 to 2019 from https://www.worldweatheronline.com/h Hurghada-weather-history/al-bahr-al-red./, while and sea surface temperature (SST) measurements were recorded from https:// sea temperature.info/march/el-gouna-water-temperature.html. The study area is located north of Hurghada on the Red Sea coast at Lat. 27° 23' 18.01" N & Long. 33° 40' 44.55" E. on the other hand, AT and SST data were taken from Luksch's table according to (**Sherif, 1953**) to carry out a comparison with the new results of the period from 2010 to

2019. The newly data was processed in Excel and SPSS programs, while the location map was drawn up using Golden Software Surfer 15 (Fig. 1).

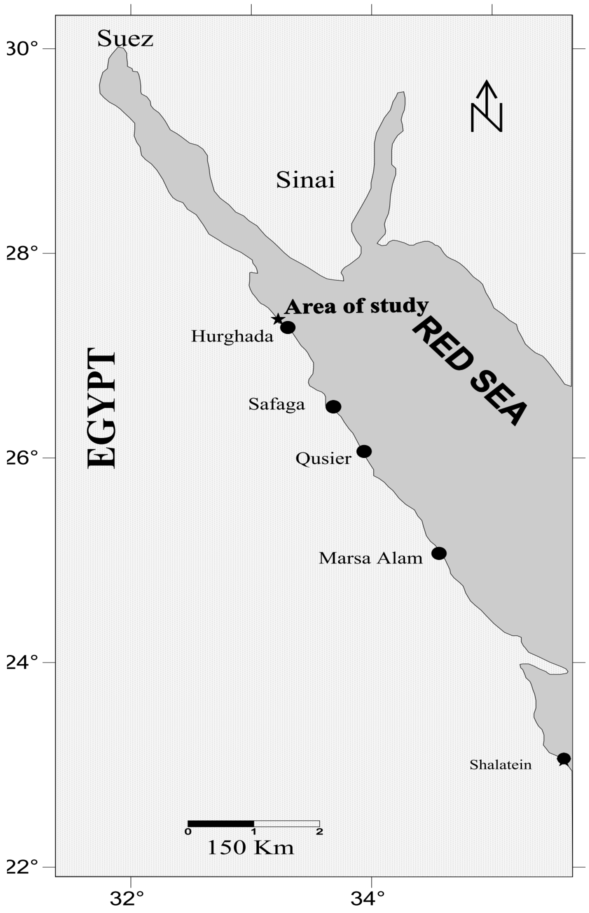

Fig.1. Location map of the study area.

RESULTS AND DISCUSSION

The heat balance of the sea is determined primarily by three radiative and two non-radiative heat exchange processes; the absorption of direct and diffuse short-wave radiation from the sun and the atmosphere, respectively; the absorption of long-wave radiation from the atmosphere; the emission of long-wave radiation from the sea surface; the exchange of latent heat between sea surface and atmosphere due to evaporation and condensation; and the convective exchange of sensible heat between sea surface and atmosphere **(e.g. Sweers, 1976).**

1- The air temperature (AT)

Insolation of sea water surface varies across the world depending on latitude and season. The net radiation at a certain location is positive during the day, as the surface gains heat from the sun's rays, while at night, the flow of short wave radiation stops, but the earth continues to radiate long wave radiation, therefore, the net radiation becomes negative. Daily cycles of **AT** northern Hurghada during period 2010-2019 are shown in (Fig. 2). The height of the **AT** curve varies with the seasons, in the summer; temperatures are warm and the daily curve is high, while in the winter; the temperatures are cold. The September equinox is considerably warmer than the March equinox even though net radiation is the same, this is due to the temperature lag behind net radiation, reflecting earlier conditions.

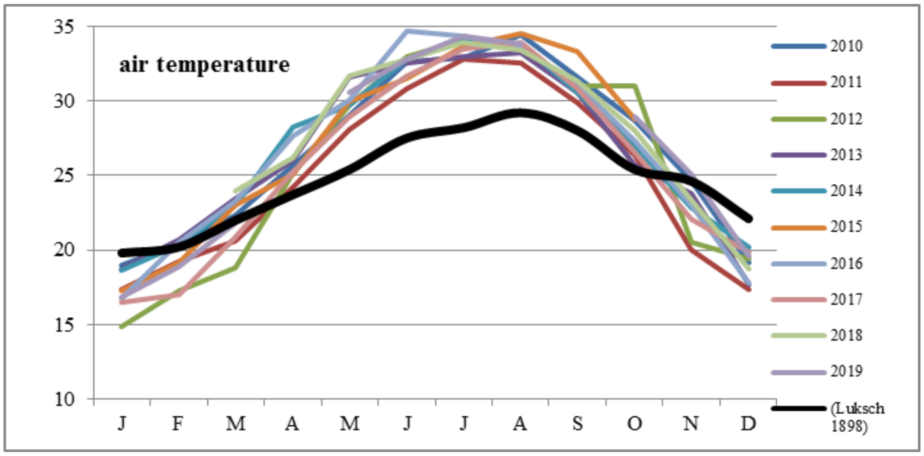

Fig. 2.The annual variation of **AT** from north Hurghada during the period 2010-2019 corresponding data recoded by Luksch's table (1898).

The average values of **AT** from the north Hurghada oscillates between the months of June and August, whereas the highest value (34.68 °C) was recorded only during June (2016), while in Luksch's table (1898) it is 29.20 °C (Table 1). Also, the lowest value (14.88 °C) was recorded during January 2012, while it was 19.80 °C in Luksch's table (1898). A cloud-like curve shows the temperature values over the period from 2010 - 2019 (Fig. 2). The width of this cloud is the least possible in the summer season, especially in July (1.60 °C) and widened in the winter and autumn seasons to about 5.2 °C. The change in the values of the incident radiation and the rate of evaporation in the winter season may be led to a change in the **AT** within ten years causing its wide range in the winter. However, the **AT** in the cloud curve is much higher than they were since nearly a hundred years. Line′s Luksch divided **AT** line to worm and cold parts (Fig. 3), where worm part extends from April to September and cold one extends from October to March.

Table 1.The average values of AT during the period 2010 – 2019 of north Hurghada and corresponding data recoded by Luksch's table.

year month	Jan.	Feb.	Mar.	Apr.	May	Ju.	Jul.	AU.	Sep.	Oct.	Nov.	Dec.
2010	18.93	20.45	22.32	25.65	29.02	32.64	32.85	34.45	31.58	28.67	24.64	19.12
2011	17.30	19.20	20.64	24.18	28.04	30.86	32.77	32.53	29.89	26.36	20.05	17.35
2012	14.88	17.28	18.84	25.11	29.68	32.95	34.11	33.44	30.98	30.98	20.55	19.39
2013	18.72	20.69	23.41	25.99	31.60	32.56	33.00	33.20	30.52	25.66	23.79	17.73
2014	18.59	20.35	23.03	28.23	29.72	32.79	33.98	33.79	30.59	26.95	22.82	20.16
2015	17.23	19.16	23.04	25.05	29.94	31.52	33.66	34.47	33.26	28.77	32.56	28.78
2016	16.72	20.54	23.24	27.68	30.03	34.68	34.30	33.52	31.10	27.26	22.99	17.75
2017	16.48	17.04	20.84	25.27	28.97	31.63	33.52	33.94	30.80	26.55	22.03	19.83
2018	17.88	*	23.97	26.17	31.69	32.83	33.91	33.35	31.37	28.01	23.35	18.72
2019	16.86	18.90	21.81	*	30.54	32.83	34.36	33.84	*	28.90	25.03	19.60
Luksch' table	19.80	20.20	22.00	23.70	25.40	27.50	28.20	29.20	28.00	25.40	24.60	22.10

* not detected

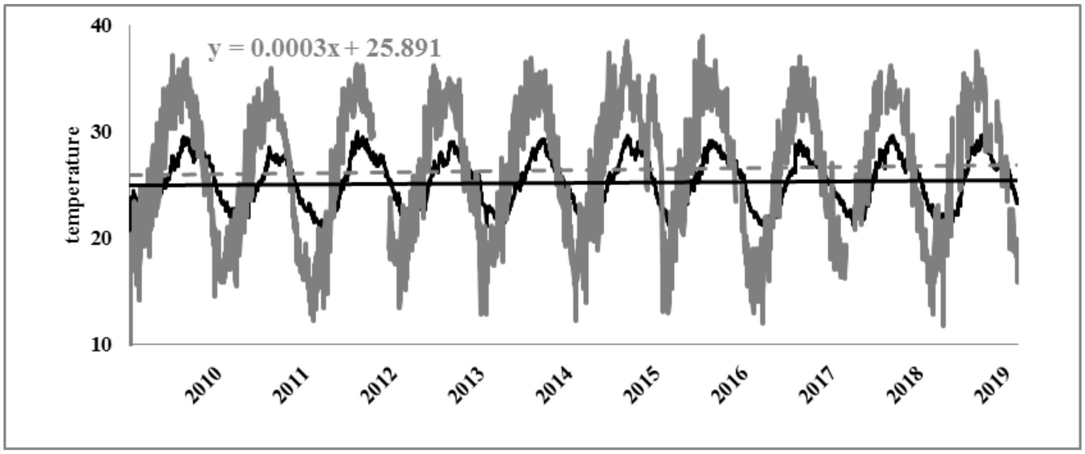

Fig. 3.The annual variation of AT (pale line), SST (dark line), trend line of AT (pale dotted line) and trend line of SST (dark sold line) during the period 2010 – 2019.

At north Hurghada; trend line of air temperature during the period 2010 – 2019 tend to increase (Fig. 3), this increasing was calculated according to the equation;

$$T_a = 0.0003\ t + 25.927$$

Where:

T_a is air temperature , t is the time

From the (figure 3) we can deduce the temporal change of air temperature which tends to increase with rate of 0.109 °C annually, this value corresponds to the global average of the oceans 0.85 °C, **(Rhein, *et al*., 2013)**, and lower than the average values 0.74 °C which calculated between 1982 and 2006 detected by **(Belkin, 2009)** and also lower than the global average 0.7 °C which recorded by **(Raitsos, 2011).**

2- The Sea Surface Temperature (SST)

The northern Red Sea experiences maximum annual temperature (T_m) throughout July while T_m is reached between late July and mid– August in the southern Red Sea **(Chaidez *et al*., 2017). Eladawy *et al*., (2017)** illustrate that SST is affected by many weather factors; they considered that wind is one of the most influential factors. **Raitsos *et al.*, (2011)** showed that SST appears to track air temperatures, this opinion was confirmed by **(Shaltout and Omstedt, 2014)**. Sea level pressure, precipitation and total cloud cover, surface wind stress, and air & sea heat flow affect SST **(Sartimbul *et al*., 2018).**

The highest and lowest SST values depend on the change from season to another one and the air temperature above surface water to a large extent, where the change in the SST follows the change in the AT **(Livingstone and Lotter, 1998).** As it is showed in Figure (4); SST distribution produces a curve similar to AT distribution, also the values of peak SST are fluctuate between 28.98 and 29.27 °C which recorded during August, and it is less than the average temperature (27.9 °C), recorded by (Luksch's table) and the bottoms of SST curves were observed during March 2012 as 21.28 °C (Table 2), which were lower than the average value of SST (21.40 °C) which detected by (Luksch's table).

Also, as shown in figure (3); the trend line of the SST curves increases according to the following equation:

$$T_w = 0.0001\, t + 25.022$$

Where: T_w is SST and t is the time.

This equation exhibits that the average value of SST tends to increase with a rate of 0.036 °C annually, this trend is lower than these occurred in 1994 with rate (0.7 °C), **(Raitsos, 2011),** while in the present study (from 2010 to 2019) mean SST is higher than those in the Lucksh's table.

3- The relation between AT and SST

In general, the essential similarity in the physical processes which determine AT and SST can result in a high degree of correlation between them, allowing at least some inferences on the one to be drawn from the other, **(Webb, 1974)**.

Based on the scheme of the relationship between SST distribution and corresponding values of AT (Fig .5) annually from 2010 to 2019. In general, increases in AT are mirrored well on SST than are equivalent decreases. This is due to increasing temperature increase is associated with an increase in thermal stability among the upper layer of water in a stratified sea. This separates the upper layer of water from the lower layer to a certain extent, essentially reducing the thickness of the mixed layer and causing it to react more sensitively to fluctuations in the net heat flux through the sea surface. In contrast, a decrease in SST is associated with a decrease in thermal stability among the upper layer of water in a stratified sea, and consequently with an increase in turbulent mixing and a deepening of the mixed layer, reducing the sensitivity of its response to fluctuations in the net heat flux.

Table 2.The average of SST during the period 2010-2019 and those recorded in Luksch’s table.

year month	Jan.	Feb	Mar.	Ap.	May	Jun.	Jul.	Au.	Sep.	Oct.	Nov.	Dec.
2010	23.82	23.33	23.04	23.20	24.81	26.46	27.48	29.06	27.83	28.09	27.24	25.24
2011	23.43	22.57	22.27	22.61	23.85	25.14	26.94	27.51	27.59	26.72	24.59	22.98
2012	22.36	21.44	21.28	22.75	24.63	26.65	28.68	28.93	27.86	27.56	26.31	24.40
2013	23.50	21.95	22.46	22.93	25.38	26.95	27.23	28.61	27.61	26.35	25.79	23.83
2014	22.60	22.24	22.21	23.42	25.14	26.28	27.99	28.98	27.70	26.55	25.16	24.19
2015	22.67	22.09	22.09	22.70	24.58	25.88	27.68	28.87	28.27	28.00	26.08	23.65
2016	22.20	21.89	22.60	24.01	25.30	27.14	28.66	28.46	27.43	26.95	25.99	23.87
2017	22.18	21.41	21.72	22.65	24.63	26.15	28.43	27.83	26.99	26.08	25.18	24.11
2018	22.93	22.10	22.71	22.91	26.05	27.51	28.55	28.83	27.14	27.12	25.99	23.95
2019	22.31	21.95	21.45	22.14	24.76	27.38	28.43	29.27	*	26.75	26.18	24.33
Luksch’ table	22.10	21.40	22.10	22.90	24.20	25.30	26.60	27.90	26.90	27.00	25.10	23.50

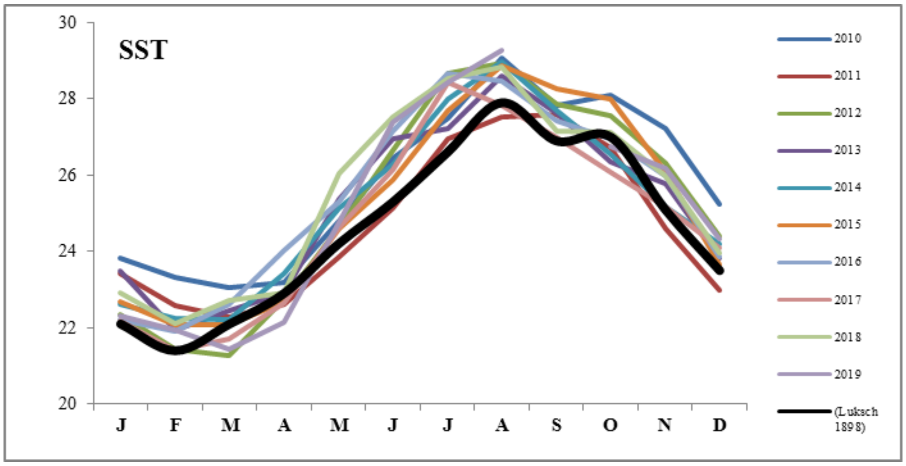

Fig. 4.The annual variation of SST during the period 2010-2019 and the corresponding data in Luksch’s table .

The SST corresponds to AT throughout each year can be divided into two parts:

The first part (worm part): ATs rise to their highest levels during the year lasts for about 8 months, usually starts from March and ends in October. This period is repeated in most years, while it was shorten for 6 months as happened in 2011. This result agrees with past statements calculated from table of Luksch.

Average differences of AT is higher than SST in the worm part, whereas it varies from -7.54°C and -1.57°C (Tab. 3). The worth noting that; the difference between the At values and their equivalents in SST during 10 years (2010-2019) is considered high compared to the Luksch's table which ranges from -2.2 to -0.8 °C.

The second part (cold part): It is noticeable that; the cold part fluctuates between 4 and 6 months during the period from 2010 to 2019, while it occupies 6 months in table of Luksch. In recent data; SST values were higher than AT ones in the cold part. The differences average between both AT and SST values ranges between 2.61°C and -0.60 °C, therefore, this difference in temperature is considered high.

Table 3. Average differences between AT and SST during the period 2010- 2019 and corresponding to data recorded in Luksch's table.

year **month**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
2010	4.89	2.88	0.72	-2.45	-4.21	-6.18	-5.37	-5.39	-3.75	-0.58	2.60	6.13
2011	6.12	3.37	1.63	-1.57	-4.19	-5.72	-5.83	-5.02	-2.30	0.36	4.54	5.63
2012	7.48	4.16	2.44	-2.36	-5.05	-6.29	-5.43	-4.51	-3.12	-3.41	5.76	5.00
2013	4.78	1.26	-0.95	-3.07	-6.22	-5.61	-5.78	-4.59	-2.91	0.69	2.00	6.10
2014	4.01	1.88	-0.82	-4.81	-4.58	-6.51	-5.99	-4.80	-2.89	-0.39	2.34	4.03
2015	5.44	2.93	-0.95	-2.35	-5.36	-5.64	-5.98	-5.60	-4.99	-0.77	6.48	5.13
2016	5.48	1.36	-0.64	-3.66	-4.73	-7.54	-5.63	-5.07	-3.66	-0.31	3.01	6.13
2017	5.70	4.38	0.88	-2.62	-4.34	-5.49	-5.08	-6.11	-3.81	-0.47	3.15	4.27
2018	5.04	*	-1.26	-3.26	-5.64	-5.32	-5.36	-4.52	-4.23	-0.88	2.64	5.23
2019	5.45	3.05	-0.37	*	-5.78	-5.45	-5.93	-4.57	*	-2.16	1.15	4.72
Luksch' table	2.3	1.2	0.1	-0.8	-1.2	-1.9	-1.6	-1.3	-1.1	0.6	0.3	1.4

* Not detect

The simplest model for the relationship between AT and SST is a purely linear relationship according to the following equation:

$$T_w=a_o+a_1 \, X \, T_a+ \varepsilon$$

Where:

T_w is SST, Ta is air temperature, a_0 and a_1 are the regression coefficients, ε is an error term.

This equation has been used in many studies linking between two AT and SST, where **Johnson** (1971) used it to describe the average monthly SST recorded in six streams in New Zealand and also used by **Song *et al.*** (1973) to describe temperatures in the Minnesota streams (China), in addition to, this equation has been mentioned in many papers such as (**Erickson and Stefan, 2000**). To make a comparison between the SST and its analogues in the AT, a scatter plot has been plotted (Fig. 6) which exhibits that AT and SST is closely related annually in the period 2010 - 2019, and presence a linear relationship between AT and SST governed by the equation:

$$T_w = a_0 + a_1 X T_a$$

Where: T_w is Sea surface temperature, T_a is air temperature, a_0 & a_1 are the regression coefficients

CONCLUSION

Rising temperatures around the world resulting due to climate change have led to global warming. Whereas, global warming is the long-term warming of the Earth's climate system observed since the pre-industrial period due to human activities. Such studies require information on weather fluctuations over longer time scales. Sea surface Temperature (SST) is influenced by many weather and oceanographic factors; in additional some studies have indicated that SST tracks air temperatures (AT) in their changes.

The change in AT and SST were similar and they change at the same frequency, and the difference between them lies in the maximum values of the temperatures that range between 32.77 and 34.68 °C in the air temperature and between 27.59 and 29.27 °C in the water temperature, also in the lower values varies between 14.88 and 18.93 °C in the air temperature and range between 21.28 and 23.04 °C in the water temperature. By comparing these results with that was recorded by Luksch (1898) since more than one hundred years ago, it is found that the monthly data recorded in the old years are less than the newly recorded ones.

The difference in modern data of AT may reach about 4.57 °C (during summer season from April to October), this indicates an increase in temperature than it used to be, and this reinforces the tendency of the AT to increase about 0.109 °C. Also, SST behaves in the same way as the AT, as well as it rose higher than those temperature recorded by **Luksch (1898)** since more than one hundred years ago with difference degree fluctuate between 1.28 °C and 2.65 °C.

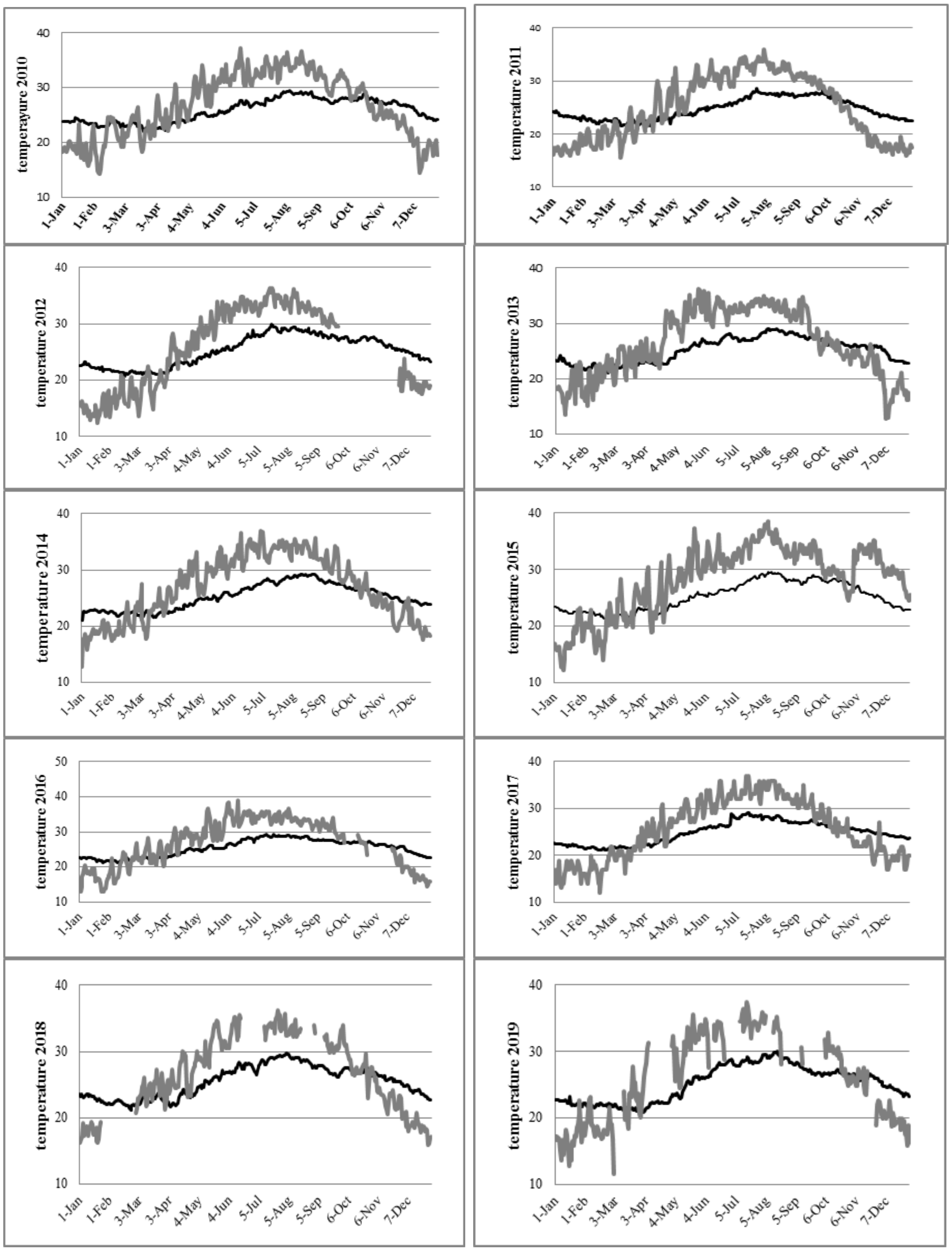

Fig. 5.Comparison between annual AT data (dark lines) with composite SST data (pale lines) during period 2010 – 2019 .

REFERENCES

Ali, E. M. and El-Magd, I. A. (2016). Impact of human interventions and coastal processes along the Nile Delta coast, Egypt during the past twenty-five years. Egyptian Journal of Aquatic Research, 42 (1): 1–10. https://doi.org/10.1016/j.ejar.2016.01.002.

Al-Horani, F. A.; Al-Rousan, S. A.; Al-Zibdeh, M.; Khalaf, M. A. (2006). The status of coral reefs on the Jordanian coast of the Gulf of Aqaba, Red Sea. Zool. Middle East, 38 :99-110. http://dx.doi. org/10.1080/09397140.2006.10638171.

Belkin, I. M. (2009). Rapid warming of large marine ecosystems. Progress in Oceanography **81**, : 207–213.

Cantin,N.E.; Cohen, A. L.;Karnauskas, K. B.; Tarrant, A. M. and McCorkle, D.C. (2010). Ocean warming slows coral growth in the central Red Sea. Science, 329: 322–325.

Chaidez, V.; Dreano, D.; Agusti, S.; Duarte, C. M. and Hoteit, I. (2017). Decadal trends in Red Sea maximum surface temperature. Scientific Reports, 7: 8144 DOI:10.1038/s41598-017-08146-z.

Dunham, J.; Schroeter, R. and Rieman, B. (2003). Influence of maximum water temperature on occurrence of Lahontan cutthroat trout ithin streams. North Am. J. Fisheries Manage., 23: 1042-1049.

Eladawy, A.; Nadaoka, K.; Negm, A.; Abdel-Fattah, S.; Hanafy, M. and Shaltout, M. (2017). Characterization of the northern Red Sea's oceanic features with remote sensing data and outputs from a global circulation model Oceanologia., 61: 484—504.

Erickson,T.R.& Stefan H.G.,(2000). Linear air-water temperature correlations for streams during open water periods. ASCE Journal of Hydrologic Engineering,5(3):317-321.

https://seatemperature.info/el-gouna-water-temperature.html

https://www.worldweatheronline.com/h Hurghada-weather-history/al-bahr-al-red

IPCC. (2019). Special Report: The Ocean and Cryosphere in a Changing Climate, (September), in preparation. https://doi.org/https://www.ipcc.ch/report/srocc/

Johnson, F.(1971).Stream temperatures in an alpine area. Journal of Hydrology 14:322-336.

Langodan, S.; Cavaleri L; Vishwanadhapalli Y.; Pomaro A.; Bertottib L. and Hoteit I., (2017). The climatology of the Red Sea –part 1: the wind. Int. J. Climatol. **37**: 4509–4517.

Lima, F. P. and Wethey D. S., (2012). Three decades of high-resolution coastal sea surface temperatures reveal more than warming. Nature Communications 3.

Livingstone, D. M. and Lotter A. F., (1998). The relationship between air and water temperatures in lakes of the Swiss Plateau: a case study with palæolimnological implications. Journal of Paleolimnology **19:** 181–198.

Luksch, J. (1901). Expedition S. M. *Pola* in das Rathe Meer. Denksch. Akad. Wiss. XVIII. Physical. Unterschungen. LXIX, :pp.337-398.

Luksch, J. (1898). Physikalische untersuchungen, Exp. S. M. S.”pola” in das Rothe Meer. Ber. Comm, Oceanogr., Forsch., (6): 351-422.

Mohammed, A. F. (1939). The Egyptian exploration of the Red Sea. Proc. Royal Sac. London, Ser. B 128: 306-316.

Natterer, K. (1898). Chemische Untersuchungen Exped. S.M. *Pola* in das Rathe Meer, nordliche halfte (1895-1896). Ber. Komm. Oceanogr. Forsch. Denksch. D. K. Akad. D. Vfiss., Wien. Math-naturw. CI. LV, pp.445-572.

Ostrander, G. K.; Armstrong, K. M.; Knobbe, E. T.; Gerace, D. and Scully, E. P. (2000). Rapid transition in the structure of a coral reef community: The effects of coral bleaching and physical disturbance. P. Natl. Acad. Sci. USA. 97(10):5297–5302.

Raitsos, D. E.; Pradhan, Y.; Brewin, R. J. W.; Stenchikov, G. and Hoteit, I. (2013). Remote sensing the phytoplankton seasonal succession of the Red Sea. PloS one 8 .

Raitsos, D. E.; Hoteit, I.; Prihartato, P. K.; Chronis, T.; Triantafyllou, G.; Abualnaja, Y.; Release, E.O.; Hole, W.; Sciences, A. and Carolina, N.; (2011). Abrupt warming of the Red Sea. Geophys. Res. Lett. 38 (14): 1410-1425.

Rhein, M.; Thomas, F.; Dahe, Q.; Gian-Kasper, P.; Melinda, M.; Simon, K.; Judith. B., Alexander, N.; Yu, X.; Vincent, B. and Pauline, M. (2013). Observations: ocean. In: Climate Change 2013: the physical science basis. Contribution of Working Group I to the Fifh Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Sartimbul, A.; Nakata, H.; Rohadi, E.; Sari, S. H. J.; Najib, M.; Salisafira, S.; Ikhsani, N. and Listiyaningsih, D. (2018). Water temperature variation of Segara nakan, Sempu Island, South Malang, Indonesia in relation to the climate variation. Earth and Environmental Science 162 (2018) 012017 doi :10.1088/1755-1315/162/1/012017

Shaltout, M. and Omstedt, A. (2014). Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. Oceanologia., 56 (3): 411-443, http://dx.doi.org/10.5697/oc.56- 3.411.

Sherif, F. G. (1953). Hydrography of the Red Sea. Egypt. PhD. thesis, Science Fuc . Alexandria University, 153pp.

Song, C.; Pabst, A. and Bowers, C. (1973). Stochastic Analysis of Air and Water Temperatures, Journalof Environment Engineering 99: 785-800.

Strzepek, K.; Oneyji, C.; Saleh, M. and Yates, D. (1995). 'An Assessment of Integrated Climate Change Impacts on Egypt', in Strzepek, K. and Smith, J. (eds.), *As Climate Changes: International Impacts and Implications*, Cambridge University Press, Cambridge, 180pp.

Sweers, H. E. (1976). A nomogram to estimate the heat-exchange coefficient at the air-water interface as a function of wind speed and temperature; a critical survey of some literature. J. Hydrol. 30: 375–401.

Thompson, E. F. 1939. Chemical and physical investigations. *The exchange of water between the Red Sea and Gulf of Aden over the " sill". Sci. Rep. John Murray Exped.* 1933 – 1934, 2: 105 –19.

Watson, R. T.; Zinyowera, M. C.; Moss, R. H. and Dokken, D. J. (1996). Climate change 1995 – impacts, adaptations and mitigation of climate change: scientific-technical analyses. Contribution of ship between diatoms and water temperature in 30 subarctic Fennoscandian lakes. Arctic Alpine Res.

Webb, M. S. (1974). Surface temperatures of Lake Erie. Wat. Resour. Res. 10: 199–210

Vercelli, F. (1927). The Hydrographic Survey of the R. N. Amrairaglio Magnaghi in the Red Sea. Annual Hydrographic, 2: 1-290.