Athens Journal of Sciences 2023, 10: 1-11
https://doi.org/10.30958/ajs.X-Y-Z

Heat Storage as Evidence of Hydrographic Cycles in the Southeastern Mediterranean Basin

By Ibrahim A. Maiyza[*], Tarek M. El-Geziry[±] & Shimaa I. Maiyza[°]

Numerous studies were conducted in the Southeastern Mediterranean Sea to determine whether variations in the hydrography and fisheries exhibit cyclic behaviour. This work investigated the long-term cyclic behaviour of physical properties in the Southeastern Mediterranean basin; taking heat storage as a parameter of interest. Heat storage is said to be a more accurate component to measure the probable thermal cyclic behaviour within a specific basin; it allows for the elimination of diurnal (full) and monthly effects on the examined thermal behaviour to a lesser extent. The work aims to: (1) provide the best fit model of heat storage anomaly changes; and (2) investigate any cyclic behaviour of change over a considerable span. The hydrographic data (temperature and salinity) were scattered over the period 1889-2021. However, because of the scarcity of data over the period 1892-1964, calculations of the mean annual heat storage and mean annual heat storage anomaly focused on the period 1965-2021 of continuous records. The minimum mean annual heat storage anomaly of the 300 m layer ranged from -9.0E9 Jm^{-2} (1992) to +0.84E9 Jm^{-2} (1994), with an overall mean of -0.016E9 Jm^{-2}. +0.43E9 Jm^{-2} was the standard deviation from the mean. The best fit model was produced for the variations in the mean annual heat storage anomaly. This was represented by a cubic equation with R^2 of 0.21. The minimum anomaly occurred in 1980 and the maximum in 2015. Therefore, the results confirmed the 70-year cycle of variation in the hydrographic conditions in the south-eastern Mediterranean region.

Keywords: *Southeastern Mediterranean Sea, heat storage, anomalies, cycles*

Introduction

A considerable body of scientific evidence reveals that the Earth's atmosphere has changed over time, indicating that the planet is warming (Masson et al. 2021, Thapa et al. 2021). This change is primarily caused by manmade activities that emit pollutants, with natural causes having a minor role (Jonathan and Raju 2017). Many signs of climate change can be found all around the world, e.g., higher air temperatures, drier locations, wilder weather, warmer seas, and faster rates of sea-level rise (Tonbol et al. 2018, El-Geziry 2021). According to the 5th Assessment

---

[*] Emeritus Professor, Laboratory of Physical Oceanography, Division of Marine Environment, National Institute of Oceanography and Fisheries (NIOF), Egypt.

[±] Professor and Head, Laboratory of Physical Oceanography, Division of Marine Environment, National Institute of Oceanography and Fisheries (NIOF), Egypt.

[°] Associate Professor, Laboratory of Fish Economy and Statistics, Division of Fisheries, National Institute of Oceanography and Fisheries (NIOF), Egypt.

Report of the Intergovernmental Panel on Climate Change (IPCC 2013), global surface temperature data calculated using linear trend showed a 0.85°C warming from 1880 to 2012. The spatiotemporal distribution of the increase in global air temperature is not uniform over Earth. The increase in air temperature varies by region, with the Northern Hemisphere having the greatest increase (Bačević et al. 2020). Rising air temperatures may have various repercussions on different parts of human life, including human settlements, agricultural goods, energy consumption, environmental and social processes, and so on (Piticar and Ristoiu 2014, Bonacci et al. 2021). However, in contrast to the considered continuous global warming concept, there is another sizeable group of researchers declared that the Earth, over ages, exhibits several recognized climatic cycles and teleconnections (Ilyes et al. 2022). By definition, cycles can have a recurring impact on the Earth's climate, whereas teleconnections can have a widespread impact on the weather (Ilyes et al. 2022). Typically, temperatures rise throughout the day and fall at night. Summer and winter have warmer and colder air, respectively. Climate also goes through cycles that last much longer than a human lifetime. Natural climate records, such as ice cores, fossilized pollen, ocean sediments, and tree growth rings, provide a large portion of the information we have on previous climatic conditions.

Long- and short-term cycles exist in the climate of the world (Millar et al. 2006). The former can be directly linked to variations in the amount of solar energy that the earth receives because of the geometry of the Earth's orbit and its passage around the sun. Scientists have also suggested that variations in the tilt of the Earth's axis could be a contributing cause. This angle influences both the annual temperature range and the long-term effects on the Earth's climate. Last but not least, tectonic motion and ocean circulation are two elements that impact the planet's long-term climate. On the other hand, seasonal fluctuations in natural parameters, e.g., temperature, and air-sea interaction processes, such as monsoons and ENSO, are the most prevalent ways to identify short-term cycles.

Schlesinger and Ramankutty (1994) revealed the oscillation of the global climate over 65-70 years. This was further determined by Minobe (1997) for the sea surface temperature (SST) variations over the North Pacific. According to several hydrometeorological patterns of the global-scaled climate cycles, SST and pressure anomalies (Renard and Lall 2014), precipitation (Bhatia et al. 2020) vary on annual to multidecadal time scales. A coherent pattern of rhythmic fluctuations of roughly 60–90 years in the North Atlantic multidecadal SST has been recognized by Kerr (2000). Knudsen et al. (2011) linked a persistent 50-70 year Atlantic multidecadal SST oscillation to internal ocean-atmosphere variability. Maiyza et al. (2015) modelled the long-term trends of Monthly SST and sea surface salinity anomalies (MSSTA & MSSSA), for 63 years (1948-2010) within the Northern Atlantic and Pacific Oceans. Their results revealed that the MSSTA exhibited cyclic behaviour within the two basins, whereas the MSSSA showed this behaviour only within the Atlantic Ocean. They concluded that the MSSSA within the Pacific might reflect the absence of cyclic variations or a very large cycle of variations, a tiny part of it, appeared throughout the period of investigation. Maiyza et al. (2021) extended their work to examine the behaviour of the mean annual surface temperature and salinity anomalies (MASTA & MASSA) within the South Atlantic and the South Pacific Oceans. They used long-term data sets over 103 years (1911-2013) within the former, and 155 years (1859-2013) within the latter ocean. They concluded that the two oceans in the Southern Hemisphere exhibited periodic (cyclic) trends in both MASTA and MASSA. Their conclusions are in agreement with those of Venegas et al. (1998) who showed that the SST anomalies in the Southern Atlantic Ocean exhibit interdecadal cyclic variations.

Not only the physical properties, but also the fishing resources (fish catch) have been proven to have cyclic behaviour of abundance, e.g., 60-year cycle of Pacific Sardine abundance (Baumgartner et al. 1992), the 60-70 year oscillation of Icelandic Cod (Jonsson 1994) and 50-70 year cycles in the stock dynamics of the main commercial species in the Atlantic and Pacific Oceans (Klyashtorin 1998).

Cyclic Behaviour in the Southeastern Mediterranean Sea

Numerous studies were conducted in the southeastern Mediterranean Sea to determine whether variations in the hydrography and fisheries exhibit cyclic behaviour. Maiyza and Kamel (2009) investigated the SST trend of variations in the southeastern Mediterranean Sea over the period (1948-2008) and their findings support the idea that SST fluctuates over time rather than continuously rising because of the so-called global warming. The results of Maiyza et al. (2010) showed that the sea surface temperature anomaly (SSTA) in the southeastern Mediterranean basin had both positive and negative fluctuations over the period 1948-2008. These cycles' lengths varied between 8 and 15 years. Nearly all of these cycles coincide with the 11-year cycle of sunspot activity. This was also confirmed for the sea surface salinity anomaly (SSSA) over the period 1948-2010 (Maiyza and Kamel 2010). Examining fluctuations in air temperature and hydrography as well as the River Nile drought phenomenon reveals that the 70-year cycle may be one of the most significant drivers of climate change (Maiyza et al. 2011). The drought extends approximately +/- 7 years each time it occurs, according to all the references given in Table 1, with droughts of duration of less than five years not considered. The River Nile droughts are revealed to be more tied to the droughts in the entire Nile valley (regional) and not only in the Egyptian territory (local). It appears from Table 1 that the River Nile drought has a 70-year cycle that can be regarded as a periodic cycle, affecting it from BC up until the 1980s. The verified Nile drought cycle has a difference of 70 years, even across very long epochs.

Table 1. *Different Years of the River Nile Drought Based on Historical Data*

Difference (in years)	Year	Reference
2800=40*70	1590 B.C.	http://www.aawsat.com/leader.asp?section=3&article=537284&issueno=11258
490=7*70	1210	El-Fandy et al. (1994)
210=3*70	1700	El-Fandy et al. (1994)
70=1*70	1910	Flohn (1975) and El-Fandy et al. (1994)
	1980	El-Baz (1986 and 1989), El-Fandy et al. (1994), Gad El-Rab (1994) and Flohn (1975)

Source: Maiyza et al. (2011).

Moreover, according to the estimates of Maiyza et al. (2011) using the quadratic trend-line approach, it has been possible to predict that the warm phase of the climate cycle during the research time (1948-2010) would finish by 2016 and be replaced by a new cold phase. Verification of the veracity of these results and conclusions has begun to be felt by people through the severely cold winters hitting the Egyptian territories. The cyclic behaviour of variations of the wind pattern over the southeastern Mediterranean basin was examined by El-Geziry et al. (2013a) throughout the period 1956-1990. The cycle in the catch of different species matches the cycle in the behaviour of anomalies in air temperature, salinity, and SST that have been previously studied in the vicinity of the southeastern Mediterranean Sea (El-Geziry et al. 2013b). Their results also proposed the 70-year cycle to dominate the cycles of catch as in other regions worldwide. The general behaviour of the mean annual salinity anomaly (1948-2012) for the Intermediate and Deep Levantine waters exhibits the same tendency of cyclic changes deduced for the surface layer, although with varying magnitude and occurrence patterns (El-Geziry et al. 2019). This is explained by the fact that these two water masses share a Mediterranean wintertime origin (Wüst 1961). For the deep Levantine water, the trend is only fully realized quite close to the area where this water mass was formed (Wüst 1961, Maiyza 1984, El-Geziry et al. 2019). In the southerneastern Mediterranean region, the general behaviour of the mean annual temperature anomaly at all levels—subsurface, intermediate, and deep—showed the same trend for the surface layer, although with varying intensities and recurrence times (El-Geziry et al. 2021). The late winter vertical convection on the extremely cold and saltier water column with transparency (30 m) in this area can be responsible for this. Throughout the water column, at all examine levels, and even near the location where the deep Levantine water mass was formed, the trend of "cyclic" parabolic behaviour is evident.

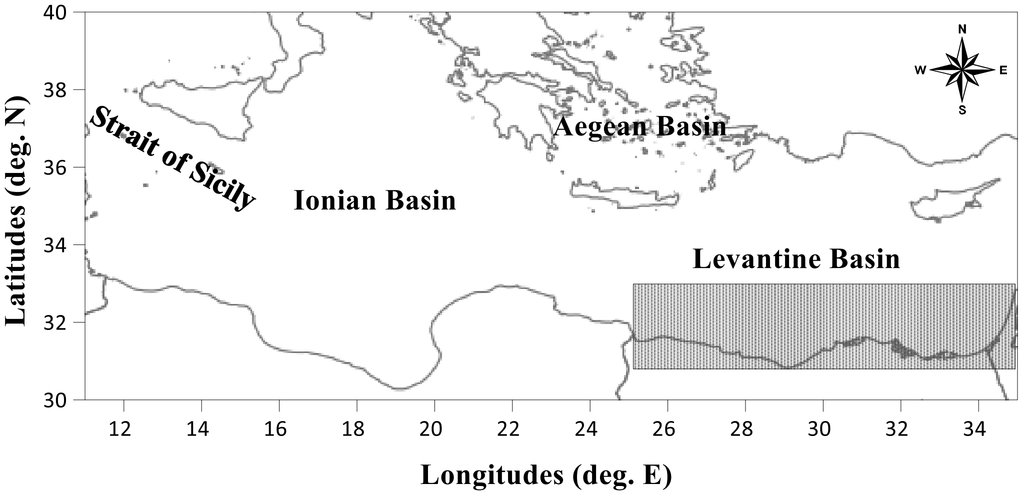
Ocean heat content is a crucial indicator of the shift in the Earth's radiative balance because 80% of the additional heat caused by anthropogenic warming now dwells in the ocean (Levitus et al. 2005). It also significantly contributes to the rise in sea level through thermal expansion (Domingues et al. 2008). Factually, Levitus et al. (2000) was the first to speak about the interannual-to-decadal variability of the ocean heat content. Since then, periodical updates and more investigations have been released. The observed temperature and salinity trends over the previous 30 years, as reported in Levitus et al. (2005), have substantially reversed since the mid-1990s in line with the North Atlantic Ocean (NAO) changing phase. This reflects a sign of a cyclic behaviour of variation. As it allows for the elimination of diurnal (full) and to a lesser extent monthly effects on the examined thermal behaviour, the heat content can be thought of as a more accurate component to measure the probable thermal cyclic behaviour within a specific basin.

The present work is on the same track of investigating the long-term cyclic behaviour of physical properties in the southeastern Mediterranean basin; considering the heat storage as a parameter of interest. The work aims to: (1) provide the best fit model of heat storage anomaly changes; and (2) investigate any cyclic behaviour of change over a considerable span.

Data and Methods of Analysis

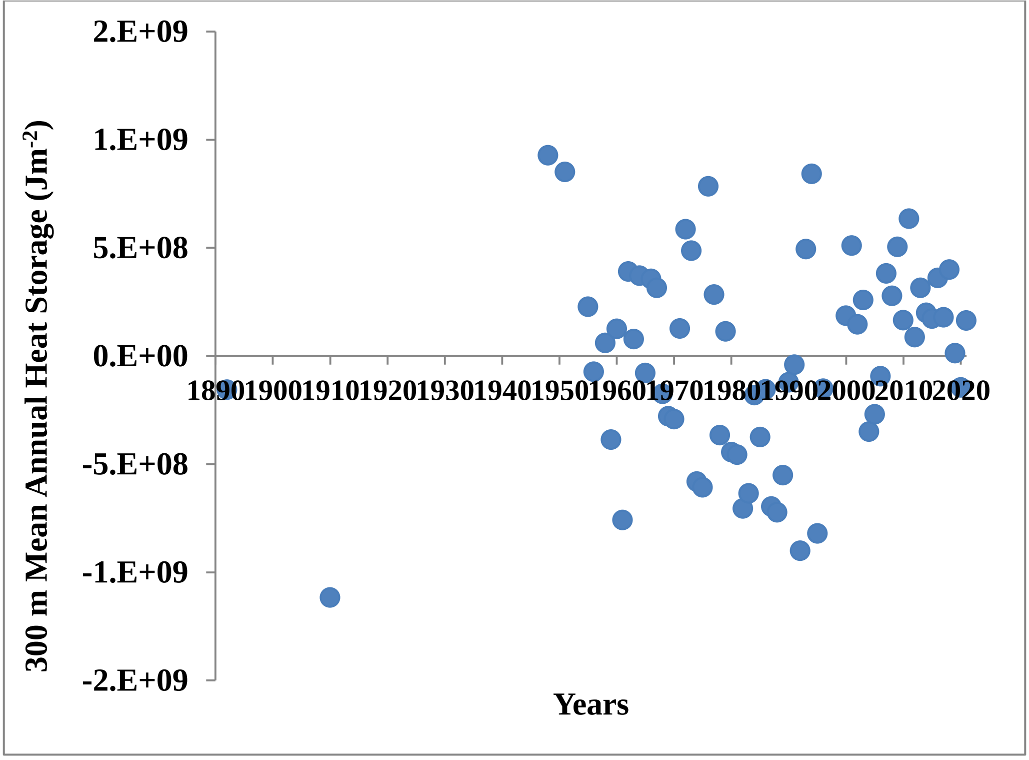
The current area of investigation is located in the southeasterrn Mediterranean Sea, southern Levantine border, off the coast of Egypt (Figure 1). Latitudinally, this region stretches from the Mediterranean coast of Egypt to 33° N, while longitudinally, it stretches from 25° E to the Asian shore.

Figure 1. *The Eastern Mediterranean Basin with Area of Investigation Shaded*



Source: Authors by using Surfer16® Software.

Figure 2. *The 300 m Mean Annual Heat Storage Anomaly Calculated Based on the Hydrographic Data Availability over the Period 1892-2021*



Source: Authors.

The hydrographic data (temperature and salinity) were scattered over the period 1889-2021 (Figure 2). The data files came from the Egyptian National Oceanographic Data Centre (ENODC), the World Data Centers (WDC) A and B (Washington and Moscow, respectively), and the Russian cruises through the Physical Oceanography of Eastern Mediterranean (POEM) project. However, because of the scarcity of data over the period 1892-1964, calculations of the mean annual heat storage anomaly in the present work were mainly based on the period 1965-2021 of continuous records.

The monthly heat storage was considered for the upper 300 m depth, known to comprise the surface, subsurface and upper level of the intermediate water masses in the eastern Mediterranean Basin (Maiyza 1993). The integrated monthly heat storage was calculated using the following equation:

$$h = \int_0^z \rho \, C_p \, T dZ \tag{1}$$

Where,

h is the monthly heat storage (Jm^{-2})
ρ is the mean seawater density (kgm^{-3})
C_p is the mean specific heat capacity ($Jkg^{-1}C^{-1}$)
T is the mean seawater temperature (°C)

The specific heat capacity was calculated using the following equation (Korne 1972):

$$C_p = 4186\,[1.0049 - 0.001621\,S + (3.5261 \times 10^{-6}\,S^2) - \{(3.2506 - 0.1479\,S + 7.7765 \times 10^{-4} S^2)10^{-4} T\} + \{(3.8103 - 0.12084\,S + 6.121 \times 10^{-4} S^2)10^{-6} T^2\}] \tag{2}$$

The integrated monthly heat storage anomaly was calculated as:

$$\Delta h = h - h_m \tag{3}$$

Where,

Δh is the mean monthly heat storage anomaly (Jm^{-2})
h is the calculated monthly heat storage using Eq. (1)
h_m is the climatologic heat storage over a specific month (Jm^{-2}).

Using the entire set of available monthly event in every year over the period 1965-2021, the mean annual heat storage anomaly (ΔH; Jm^{-2}), which is the mean monthly heat storage over a specific year, was calculated, using the following equation:

$$\Delta H = \sum \frac{\Delta h_m}{n} \tag{4}$$

Where n is the number of events

The best fitted representational models of the mean annual heat storage anomaly have been investigated using time series analysis using the ordinary least squares approach. Based on the highest determination coefficient (R^2) value and the lowest standard error of its estimation for the model, the represented models have been chosen. Using the SPSS® software, the significance of regression coefficients and the entire model were evaluated in accordance with the results of the t- and the F- tests. The models represent mean annual heat storage anomalies as dependent variables (Y_{300}) and the time (t) as an independent variable.

Results and Discussion

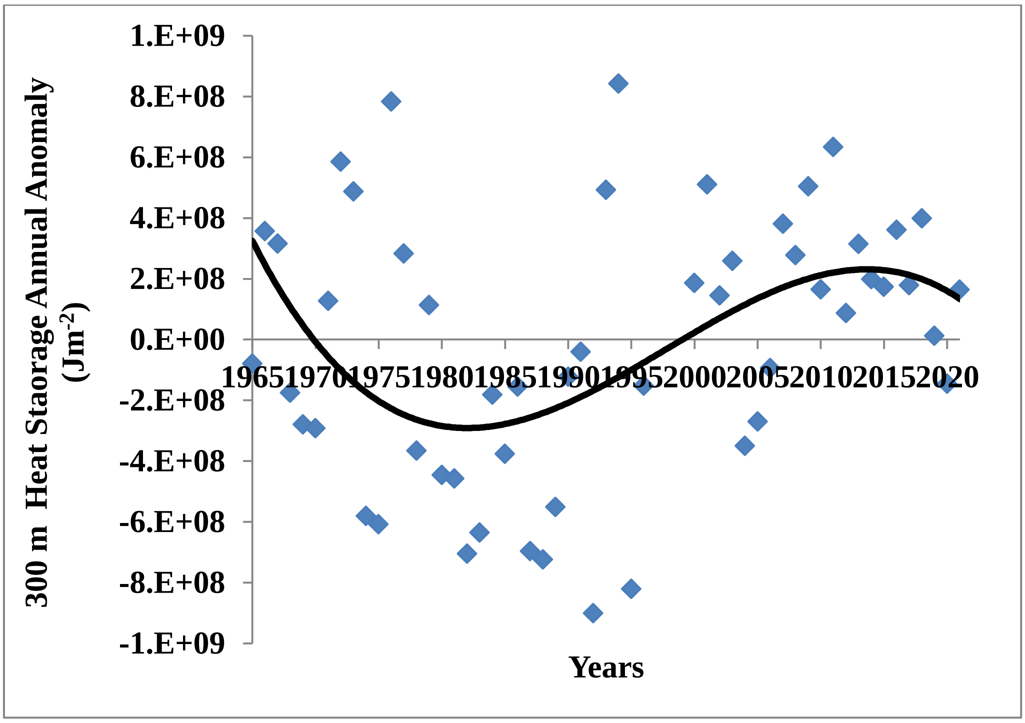
The minimum mean annual heat storage anomaly of the 300 m layer ranged from -9.0E9 Jm^{-2} (1992) to +0.84E9 Jm^{-2} (1994), with an overall mean of -0.016E9 Jm^{-2} during the period (1965-2021). +0.43E9 Jm^{-2} was the standard deviation from the mean. Figure 3 depicts the mean annual heat storage anomaly during the specified period (1965-2021). The following cubic equation provides the best fit model to represent variability in the present mean annual heat storage anomaly dataset:

$$Y_{300} = -\,38205.47\, t^3 + 3707343\, t^2 - 9E7\, t + 4.3E8$$

The R^2 coefficient of the model was 0.21, with a standard error of the estimates of +0.4E9 Jm^{-2}.

According to this best-fit model, the minimum mean annual heat storage anomaly occurred in 1980 and the maximum was in 2015. This reveals a 70-year cycle of variation in the heat storage of the upper 300 m in the southeastern Mediterranean basin. This result confirms the conclusion of Maiyza et al. (2011) that the anticipated warm part of climate cycle in the southeastern Mediterranean region would end by the 2016 to start a cold cycle part. It also coincides with the 70-year cycle in the southeastern Mediterranean catch concluded by El-Geziry et al. (2013b), which, itself, was in agreement with the cyclic behaviour concluded for the hydrographical (Maiyza and Kamel 2009, 2010, Maiyza et al. 2010) and air-temperature conditions (Maiyza et al. 2011) affecting the area of investigation. The present result comes also in agreement with the conclusion of Levitus et al. (2005) that the observed temperature and salinity trends have substantially reversed since the mid-1990s in line with the North Atlantic Ocean (NAO) changing phase. Iona et al. (2018) concluded a 40-year cycle of fluctuation in the heat content of the whole Mediterranean basin during the period 1950-2015; following the Atlantic Multidecadal Oscillation climate cycle. They distinguished three intervals of change in the Mediterranean heat content: a decrease from 1960 to 1980, followed by a stable content from 1980 to 1990, followed by an increase from 1990 to 2015.

Figure 3. *The 300 m Mean Annual Heat Storage Anomaly for the Specified Period 1965-2021 with the Best Fit Model Shown in Black Line*



Source: Authors.

Based on the present results, the perspective of future work is highly recommended to involve the examination of the relationship between the values of the inversion periods and the occurrence of extreme events of floods and heat waves, forest fires, drought and flooding of lakes and rivers.

Conclusion

To conclude, the 70-year cycle of variation in the hydrographic conditions in the southeastern Mediterranean region is confirmed in the present work, taking the heat storage parameter as examined parameter. Heat storage is said to be a more accurate component to measure the probable thermal cyclic behaviour within a specific basin; as it allows for the elimination of diurnal (full) and to a lesser extent monthly effects on the examined thermal behaviour.

References

Bačević N, Valjarević A, Kićović D, Milentijević N, Ivanović M, Mujević M (2020) Analysis of air temperature trends: city of Podgorica (Montenegro). *The University Thought - Publication in Natural Sciences* 10(1): 31–36.

Baumgartner TR, Soutar A, Ferreira-Bartrina V (1992) Reconstruction of the history of Pacific sardine and Northern Pacific anchovy populations over the past two millennia from sediments of the Santa Barbara basin, California. *California Cooperative Ocean Fisheries Investigations Report* 33: 24-40.

Bhatia N, Singh VP, Lee K (2020) Sensitivity of extreme precipitation in Texas to climatic cycles. *Theoretical and Applied Climatology* 140(3): 905–914.

Bonacci O, Bonacci D, Patekar M, Pola M (2021) Increasing trends in air and sea surface temperature in the Central Adriatic Sea (Croatia). *Journal of Marine Science and Engineering* 9(4): 358.

Domingues CM, Church JA, White NJ, Gleckler PJ, Wijffels SE, Barker PM, et al. (2008) Improved estimates of upper-ocean warming and multi-decadal sea-level rise. *Nature* 453(7198): 1090–1093.

El-Baz F (1986) Space photographs of drought in Africa. In *Lunar and Planetary Science XVII*, 200–201. Houston, Texas: Lunar and Planetary Institute.

El-Baz F (1989) Monitoring Lake Nasser by space photography. Remote Sensing and Large-Scale Global Processes. In *Proceedings of the IAHS 3rd International Assembly*, 177–181.

El-Fandy MG, Ashour ZH, Taiel SMM (1994) Time series models adoptable for forecasting Nile floods and Ethiopian rainfalls. *Bulletin of the American Meteorological Society* 75(1): 83–94.

El-Geziry TM (2021) Analysis of long-term rainfall and air temperature patterns in Alexandria (Egypt). *Arabian Journal of Geoscience*s 14(13): 1199.

El-Geziry T, Maiyza I, Maiyza H (2013a) General trend of wind anomalies in the South Eastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 24(2): 85–97.

El-Geziry T, Maiyza I, Abdel-Hafez S, Maiyza Sh, Kamel M (2013b) Interannual variability of the South-eastern Mediterranean catch and its relation to hydrographical and air-temperature anomalies. *Journal of King Abdulaziz University: Marine Sciences* 24(1): 43–54.

El-Geziry TM, Maiyza IA, Kamel MS (2019) Salinification in the Southeastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 29(2): 1–12.

El-Geziry TM, Maiyza IA, Kamel MS (2021). Behaviour of temperature variations in subsurface layers in the South-Eastern Mediterranean Sea. *Athens Journal of Sciences* 8(1): 9–22.

Flohn H (1975) History and intransitivity of climate. In *World Climate Data Programme, WMO, Geneva, WMO/GARP Publications Series* 16: 106–117.

Gad El-Rab R (1994) *Heat, salt and water budget of Lake Nasser*. MSc Thesis. Faculty of Science, Assuit University.

Ilyes C, Szűcs P, Turai E (2022) Appearance of climatic cycles and oscillations in Carpathian Basin precipitation data. *Hungarian Geographical Bulletin* 71(1): 21–37.

Iona A, Theodorou A, Sofianos S, Watelet S, Troupin C, Beckers J-M (2018) Mediterranean Sea climatic indices: monitoring long-term variability and climate changes. *Earth System Science Data* 10(4): 1829–1842.

IPCC (2013) *Climate change 2013: the physical science basis*. Cambridge, UK: Cambridge University Press.

Jonathan KH, Raju PS (2017) Analysis of rainfall pattern and temperature variations in three regions of Sultanate of Oman. *International Journal of Civil Engineering and Technology* 8(2): 173–181.

Jonsson J (1994) Fisheries off Iceland, 1600-1900. In *ICES Marine Science Symposium* 198: 3–16.

Kerr RA (2000) A North Atlantic climate pacemaker for the centuries. *Science* 288(5473): 1984–1985.

Klyashtorin LB (1998) Long-term climate change and main commercial fish production in the Atlantic and Pacific. *Fisheries Research* 37(1–3): 115–125.

Knudsen MF, Seidenkrantz M-S, Jacobsen BH, Kuijpers A (2011) Tracking the Atlantic multidecadal oscillation through the last 8,000 years. *Nature Communications* 2(1): 178.

Korne RA (1972) *Marine chemistry (water composition and chemistry of hydrosphere).* Moscow: USSR (in Russian).

Levitus S, Antonov J, Boyer T (2005) Warming of the world ocean, 1955–2003. *Geophysical Research Letters* 32(2): L02604.

Levitus S, Antonov JI, Boyer TP, Stephens C (2000) Warming of the world ocean. *Science* 287(Mar): 2225–2229.

Maiyza IM (1984) *Long term variation of water temperature in the eastern part of the Mediterranean Sea*. PhD Thesis. Moscow University (in Russian).

Maiyza IM (1993) Heat storage in the Eastern Mediterranean. *Journal of Physical Oceanography* 23(6): 1259–1263.

Maiyza I, Kamel M (2009) Climatological trend of sea surface temperature anomalies in the South Eastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 20(1): 59–66.

Maiyza I, Kamel MS (2010) Climatological trend of sea surface salinity anomalies in the South Eastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 21(2): 63–72.

Maiyza IA, El-Geziry TM, Maiyza HI (2021) Trends of variations in the mean annual surface temperature and salinity anomalies in the Southern Hemisphere. *Indian Journal of Geo-Marine Science* 50(4): 271–276.

Maiyza I, Said M, Kamel M (2010) Sea surface temperature anomalies in the South Eastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 21: 151–159.

Maiyza I, El-Geziry T, Maiyza H, Kamel M (2011) Climatological trend of air temperature anomalies in the South Eastern Mediterranean Sea. *Journal of King Abdulaziz University: Marine Sciences* 22(2): 55–65.

Maiyza IA, El-Geziry TM, Maiyza HI, Kamel MS (2015) On the long-term variations of the surface hydrographic anomalies in the Northern Hemisphere. In *Proceedings of the 1st International Conference of Science, Engineering and Environment (SEE),* 457–461.

Masson V, Zhai P, Pirani A, Connors SL, Pean C, Berger S, Caud N, et al. (2021) *IPCC, 2021: summary for policymakers, in: Climate Change 2021: The Physical Science Basis*. UK: Cambridge University Press.

Millar C, Neilson R, Bachelet D, Drapek R, Lenihan J (2006) *Climate change at multiple scales, in: forests, carbon and climate change*. USA: Oregon Forests Institute.

Minobe S (1997) A 50–70 year climatic oscillation over the North Pacific and North America. *Geophysical Research Letters* 24(6): 683–686.

Piticar A, Ristoiu D (2014) The influence of changes in teleconnection pattern trends on temperature and precipitation trends in northeastern Romania. *Riscuri Si Catastrofe* XIII: 109–122.

Renard B, Lall U (2014) Regional frequency analysis conditioned on large-scale atmospheric or oceanic fields. *Water Resource Research* 50(12): 9536–9554.

Schlesinger ME, Ramankutty N (1994) An oscillation in the global climate system of period 65–70 years. *Nature* 367(Feb): 723–726.

Thapa A, Silwal A, Gautam SP, Nepal CK, Bhattarai S, Timsina D (2021) Surface air temperature trends in Kathmandu Valley for 2011-2017. *BIBECHANA* 18(2): 95–104.

Tonbol KM, El-Geziry TM, ElBessa M (2018) Evaluation of changes and trends in air temperature within the Southern Levantine basin. *Weather* 73(2): 60–66.

Wüst G (1961) On the vertical circulation of the Mediterranean Sea. *Journal of Geophysical Research* 66(10): 3261–3271.

Venegas SA, Mysak LA, Straub DN (1998) An interdecadal climate cycle in the South Atlantic and its links to other ocean basins. *Journal of Geophysical Research* 103(C11): 24723–24736.