

Potential Climate Change Threats to underwater cultural heritage

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Abstract

Climate change is our greatest challenge. The paper is looking for the impact on underwater cultural heritage (UCH), deep oceans, and coastal zone through literature reference and case studies. It will discuss the causes of climate change, the results, with a focus on the sea surface temperature (SST) changes in the Mediterranean Basin and the Pacific. SST will be calculated using Landsat 8 which is equipped by two bands of thermal infrared sensor (TIRS). It is suitable for coastal zone monitoring due to its high resolution. The study depends on the use of Landsat 7 which carried the Enhanced Thematic Mapper Plus (ETM+) sensor. Both images are interpreted and analyzed on the QGIS to calculate the radiance and reflectance of each image to conclude the value of SST. The paper will finish by presenting the cycle factors which threaten the UCH and summarize the relationship between the change of climate and the UCH and how they help researchers understand climate in the past and the adaptation by humans in past.

Keywords: climate change, SST, UCH, satellites imagery

List of Abbreviations

Carbone dioxide CO₂
Normal Difference Vegetation Index NDVI
Operational Land Imager OLI
Sea surface temperature SST
Sea surface salinity SSS
Thermal Infrared Sensor TIRS
Thematic Mapper TM
U.S. Geological Survey USGS
Underwater cultural heritage UCH

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INTRODUCTION

The topic of this paper fits best within this Session “Major Threats to Underwater Cultural Heritage and its environment,” because it will discuss the main disturbances and problems facing the maritime archeological sites and underwater cultural heritage (UCH) due to climate change. This paper defines the relation between climate and seas and oceans health, where the relationship is strong and interdependent.

Climate can be defined into two levels: local climate, which is related to a specific area, city or country; and global climate of Earth. The global climate is the connected system of sun, land and oceans, wind, rain and snow, forests, deserts and savannas, and human activity (Lange 2020). All these local factors are connected and responsible for the balance of ecosystems; any change in one ecosystem leads to change in global climate. For example, global warming which is increasing of heat or energy in the atmosphere of the Earth led to climate change (Rockman and Hritz 2019). Rising temperature of the atmosphere led to melting of the ice in the poles which led to sea level change, this event was recognized at the beginning of 19th century (Kennedy et al. 2002).

Anthropogenic factors are the main factor of climate change at a population of 7.8 billion people (World Bank 2023). This is well defined and explained by the assessment reports of the Intergovernmental

Panel on Climate Change which describe the influence of human activities that lead to warmer atmosphere. Urbanization, development, and lots of industrial businesses accelerate the deterioration of seas and oceans due to illegal infringement on the coast, increased illegal fishing, and toxic gas emissions, all those led to change the main property of climate. One of results of climate change is the increasing of the sea surface temperature, which led to change the chemical property of salt water (Splading 2011). The paper presents the changes of sea surface temperature (SST) in Chekka, Lebanon with satellites imagery on QGIS.

CASE STUDIES

The case studies under consideration are the following regions: the Mediterranean and the Pacific basins. This paper detects the changes in sea surface temperature in the Mediterranean basin through focusing in one example taking from Lebanon: Chekka area- North Lebanon (Figure 1). The aim of taking this example is to prove how the human activity next to the sea, lead to change and increase in the SST and land surface temperature in general. Chekka is a coastal area located in the Lebanese northern provenance facing the Mediterranean Sea (Figure 2). Chekka provides two potential locations for harbours, one to the north and one to the south of the headland of Chekka and its harbour is mentioned when it was occupied by the Arwad's fleet¹ (Safadi 2014). The town was covered by olive trees and salt marshes on the coast. These conditions of the town have been changed after the construction of the first cement factory in the area dated back to 1931 CE followed by another company after two decades. The coastline changed becoming heavily populated and many agricultural areas vanished.

The main reason of this paper is to detect and monitor the changes of SST in the Chekka area as a typical example for human activity effect on the seas and oceans health. The study is going to compare the SST during summer and winter seasons during the last 20 years. This will be using satellites imagery of Landsat program is the longest-running enterprise for acquisition of satellite imagery of Earth. It is a joint NASA / USGS² program and launched on 23 July 1972.

The study is also looking at the changes in SST of Pacific region and identifying the main reason for these changes. The North Pacific has a temperature higher than the South, and that is because of the ratio of land to sea areas is larger in the Northern Hemisphere and because Antarctica and the Southern Ocean also influence water temperature (Cotter et. al. 2023). From the studying of those two regions, the paper is identifying the results and consequences of changes in SST and the effect on the ocean, and therefore to determine the effects on the maritime sites in seas and deep oceans. Radiance and reflectance of images captured by the thematic sensor of Landsat are essential to calculate the value of temperature. This will be explained in detail in the methodology.

¹ It developed into a trading city in the Bronze Age, as did most of the Phoenician cities on this coast. It had a powerful navy, and its ships are mentioned in the monuments of Egypt and Assyria (Safadi 2014).

² The U.S. Geological Survey is the nation's largest water, earth, and biological science and civilian mapping agency (USGS website)



Figure 1. Lebanese land map



Figure 2. Chekka area with the cements factory's location (Landsat8 2022)

METHODOLOGY / RESOURCES

The use of remote sensing and geographic information system as the QGIS free and open source, becomes a new technique used in studying many marine (Ramdani et al. 2021).

The paper studies the changes in SST through satellites imagery, calculate and measure the temperatures on QGIS tools, in reason the detect the increasing of temperature during the last 20 years taking into consideration the seasons: winter and summer. The study is based on literature and previous study on the effect of climate change on the maritime sites, and how the maritime resource becomes a factor to understand the climate change.

The algorithm created on ERDAS imagery 2014 for calculating the land surface temperature (LST), it's the same concept for SST (Advan and Jovanovska 2016). The layers used in the project are raster and vector interpret and analyzed on QGIS version 3.6. The main coordinate system used is the WGS84 UTM zone 36N, ESPG: 32636.

The Landsat 8 which is working on infrared radiometer band 10 and 11 provides huge data covered the Lebanese land. The sensors deployed on satellites imagery Landsat8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments allow to assess water parameter efficiently. Through TIRS we can measure the land temperature in two thermal bands with a new technology that applies quantum physics to detect heat. The process worked by measuring the amount of infrared light emitted from the earth and the radiant temperature of water bodies (Bourouhou and Salmoun 2021). Both sensors are covered the landmass with 30m of resolution (visible, NIR, SWIR); 100 meters (thermal); and 15 meters (panchromatic). The primary features on Landsat 7 include a panchromatic band with 15-meter spatial resolution, an onboard full aperture solar calibrator, five percent absolute

radiometric calibration, and a thermal infrared channel with a four-fold improvement in spatial resolution over Thematic Mapper (TM) (NASA, 2021).

Steps of calculating SST

1. Calculating the Top of Atmosphere radiance which is the raw images captured by sensor of satellites, the radiance is the amount of radiation coming from the area, surface and cloud.
2. Calculating top of atmosphere reflectance which provides the ratio of radiation reflected to the incident solar radiation on a given surface, and also from the cloud and atmospheric aerosols and gases.
3. The brightness temperature is the measurement of radiance of the microwave radiation traveling upward from the top of atmosphere to the satellites.

The process continues in progression to find the emissivity ϵ of each pixel to convert the brightness temperature into land surface temperature or in the other hand the sea surface temperature. The emissivity is originated from the value of Normal Difference Vegetation Index NDVI which is provided by the visible red and near infrared bands. The result returns the maximum and minimum values of NDVI which are used in finding the proportion of vegetation in reason to rescale the NDVI between values representing bare soil and total vegetation.

The operation is going to show the difference of temperature during the last 20 years with taking into consideration the same seasons, where the result section interprets the analysis value through literature resources of the impact of SST changes on UCH.

RESULTS

The results observed after calculating the SST through the Landsat images present an increasing of temperature by almost 1 °C during the last 20 years. Extracting results from maps shows the increasing of temperature on the coastline near the cement factory, where the SST in the middle of sea become more less. Figure 3 present clearly these changes, where the temperature on the coastline during summer in 1999 was 24°C -25 °C, and it was almost 23 °C far from the coast, but today the temperature on the coastline in 28 °C-29 °C, and it's almost 27 °C far from the coast.

The results are also extracted from the SST map during the winter season for 2000 and 2021, where the average temperature in Chekka area increased 2 °C during the last 20 years (Figure 4).

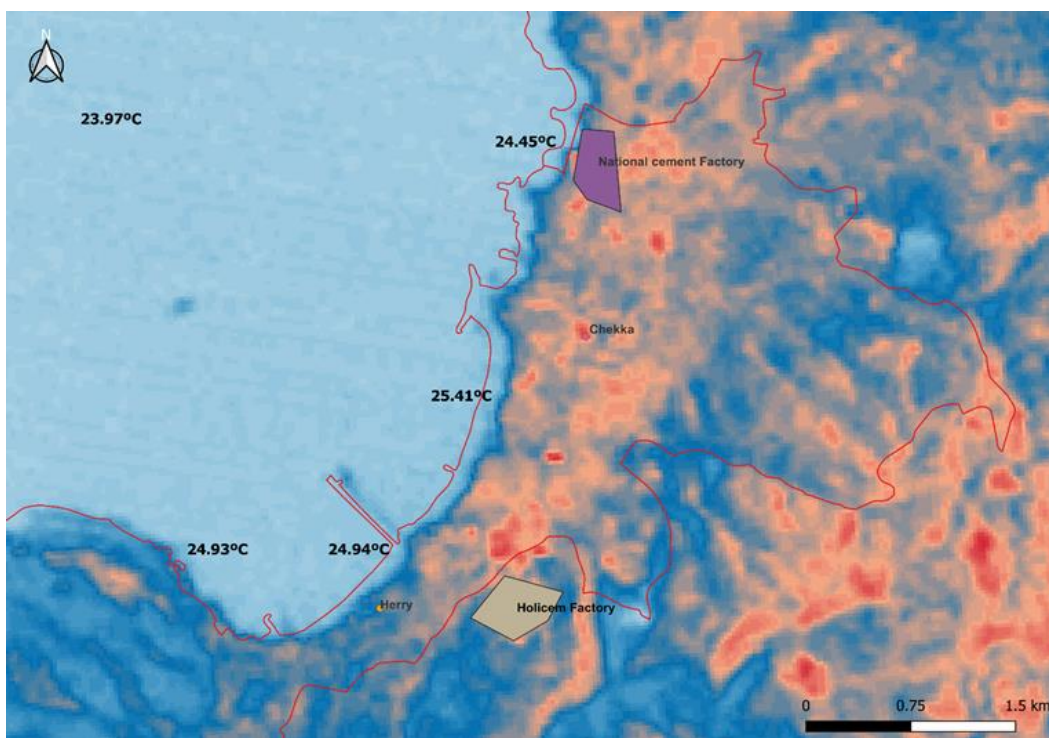
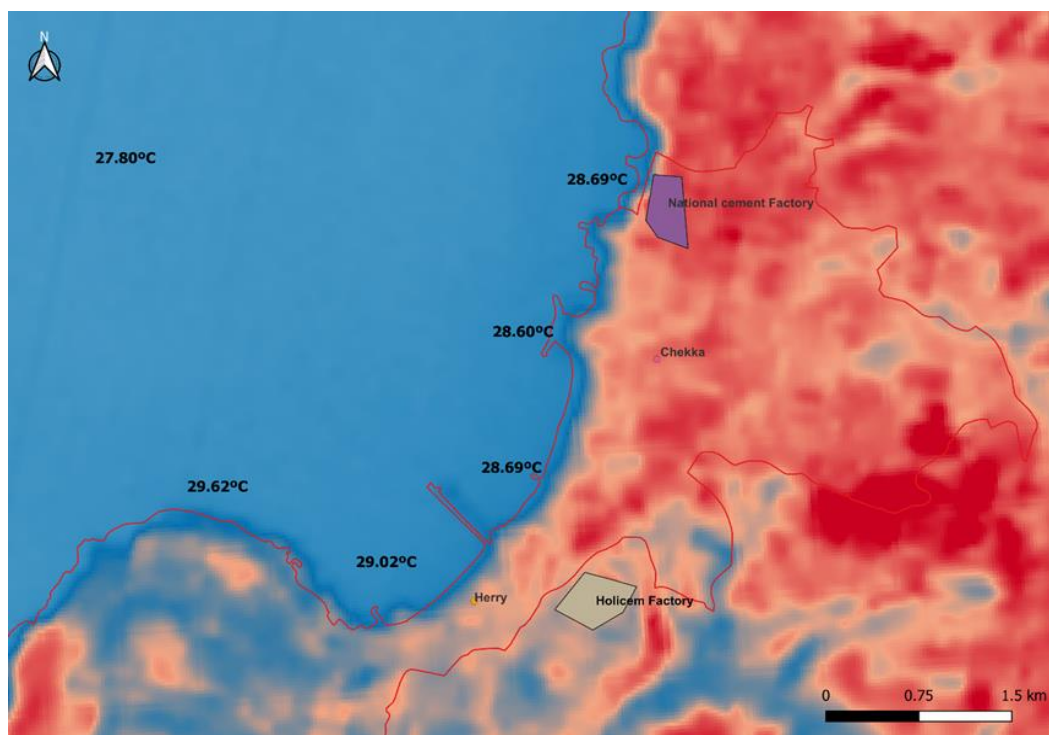


**Figure 3. Summer temperature today (TOP, Landsat8 2021).
Summer temperature 20 years ago (BOTTOM Landsat7 1999)**

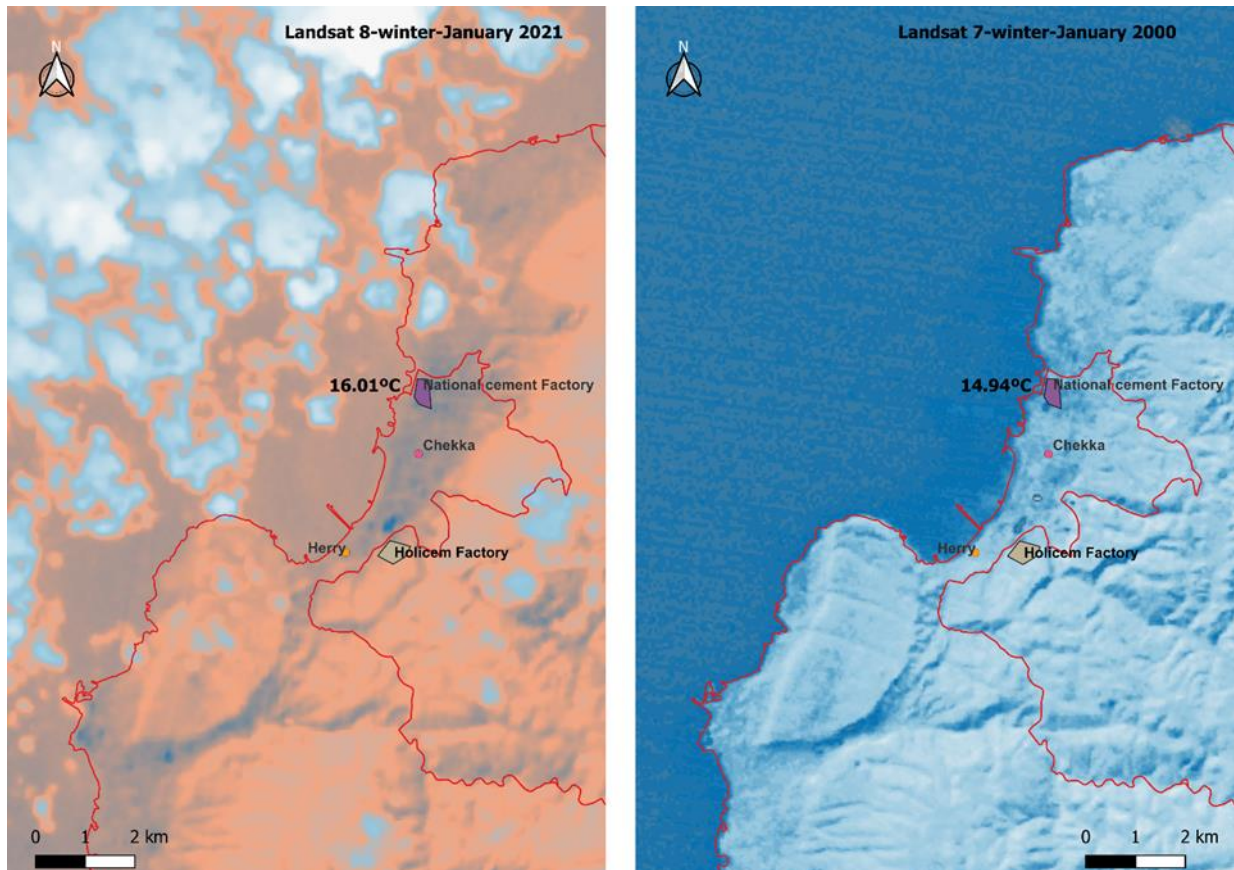


Figure 4. Winter SST today (left) and 20 years ago (right) (Landsat8 2021; Landsat7 1999).

This example describes the changes in SST due to the rising of toxic gases from the cement factories next to the coastline. The main issue is to understand how the increasing of SST effect on the seas and oceans health, thus on the maritime and coastal sites. There are an estimated three million shipwrecks on the floors of the world's oceans (Gregory et al. 2022), and more than 1000 coastal sites are under threat and damage because of sea level rise (Reiman et al. 2018)

Increasing of CO₂ in the atmosphere due to pollution and toxic gases, it leads to increase the temperature of air, thus, to melt the ice of poles where this lead to rise the sea level. Research confirms the rise of sea level by 1m by the end of 21st century, together with an increase in ocean surface temperatures (i.e., water to a depth of approximately 100m) of between 0.2 and 0.5°C (Gregory et al. 2022). In summary, rising of sea level led to many unprecedented weather events which impact directly on the coastal sites and erosion of coastline due to high tides. (Sesana et al. 2020). The effect of sea-level rise led to flooding and storms especially during the heavy rainfall, where the coastal sites become underwater sites with time. The effect of sea level not only on culture heritage but also on the marine boundary higher level will result in legal maritime boundaries become less well defined (Perez-Alvaro 2016).

In addition, the submerged sites will be affected by the sea level rise because adding more water led to put the UCH under more depth, and more mass of water quantity on the shipwreck lying on the seabed which may be more than they can withstand (Sesana et al. 2020). Furthermore, the most recent IPCC report indicates not only an impact on surface ocean, temperatures but also on the deep ocean, with increases of 0.6–2.0°C chemical reaction rates double for every 10°C increase in temperature (Kennedy et al. 2002). This would reduce the amount of time a diver can remain underwater.

Increased CO₂ in the atmosphere, which is absorbed by the oceans, leads to increase in the acidification of seas and oceans where the PH of water decrease and influences the iron and steel of shipwrecks by

increasing the rate of corrosion (Perez-Alvaro 2016; Wright 2016). With more evaporation and precipitation and formation of sea ice lead all together to increase the salinity in water and change the chemical and physical property of sea and ocean, that will create new bacteria and new organisms, which affect and threaten the archeological features especially the shipworms, causing damage to underwater wooden structures (Sesana et al. 2020).

This study shows the high impact of climate change and the relation with the UCH, which became a main part of marine environment, the changes of sites help to understand the changes in climate.

CONCLUSION / DISCUSSION

We conclude that climate change will directly affect coastal and underwater sites, including the deterioration of our UCH. The relation between climate change and maritime archeological sites is very connected because shipwrecks become part of the marine environment such as artificial reefs.

Today, maritime archeology help researchers to understand the past climate and the human past adaptation with climate change, where maritime and coastal sites illustrate the environmental changes. Several projects provide the opportunity for maritime archaeology research on climate in the past and then educate humanity to better understand the climate crisis. For example, several studies that focus on the human-environment interaction such as migration in ancient periods, and human uses of aquatic environment may inform what may happen in the future. It is important to involve cultural heritage in climate action because heritage includes the identity of people that they want to pass to future generations, and which may be at risk due to climate change.

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