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Long time SST and Chlorophyll-a Pigment concentration of Lake Van Using MODIS

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Abstract

Current work concentrated on long-time SST and Chlorophyll-a pigment concentration of Lake Van using Modis-Aqua acquired data. Investigating the relationship between sea surface temperature (SST) and chlorophyll-a (Chl-a) increases our understanding of marine ecosystem and also provide us to assess the effect on aquatic animals that may arise as a result of changes in the environment. Long term Sea Surface Temperature variability and its relationship with chlorophyll-a pigment of phytoplankton biomass were investigated by using MODIS-Aqua (Moderate Resolution Imaging Spectroradiometer) satellite imagery. SST and Chl-a acquired from MODIS-Aqua showed seasonal, annual and interannual variability of temperature. Monthly variability Chl-a from MODIS 2002 to 2020 also investigated, significant correlation between SST and Chl-a was not found $P<0.05$. First PCA of SST seems to show general average pattern of the lake, on the other hand PCA's of Chl-a could not be calculated due to lack of null pixels within images.

Keywords: Chlorophyll, SST, Lake Van, EOF, MODIS, Climate

Introduction

Lake Van is the largest lake in Turkey, located in the far east of the country in Van district. It is a saline soda lake, receiving water from numerous small streams that descend from the surrounding mountains. Lake Van is also one of the world's largest endorheic lakes (having no outlet). The original outlet from the basin was blocked by an ancient volcanic eruption. Although Lake Van is situated at an altitude of 1,640m with harsh winters, it does not freeze due to its high salinity except occasionally the shallow northern section, (Britannica, 2019).

Lake Van is located with GPS coordinates at 38° 38′ 27″ North and 42° 48′ 45″ East, 119 meters across at its widest point, averaging a depth of 171 meter with a maximum recorded depth of 451 meter. The lake surface lies 1,640 meter above sea level and the shore length is 430 kilometers. Lake Van has an area of 3,755km^2 and a volume of 607 km3 (E. Degens, Wong, Kempe, & Kurtman, 1984).

The western portion of the lake is deepest, with a large basin deeper than 400 m lying northeast of Tatvan and south of Ahlat. The eastern arms of the lake are shallower. The Van-Ahtamar portion shelves gradually, and the maximum depth at which it joins the rest of the lake on its northwest side is about 250 m. The Ercis arm is very shallow, it has a maximum depth of less than 50 m and a maximum of 150 m. (Wong & Degens, 1978) (Tomonaga, Brennwald, & Kipfer, 2011).

Climate change is considered to be one of the most severe threats to ecosystems around the globe (Adrian et al., 2009) (Hassol et al., 2004) (Rosenzweig et al., 2007). Monitoring and understanding the effects of climate change pose challenges because of the multitude of responses within an ecosystem and the spatial variation within the landscape. A substantial body of research demonstrates the sensitivity of lakes to climate and shows that physical, chemical, and biological lake properties respond rapidly to climate-related changes (Hassol et al., 2004) (Rosenzweig et al., 2007).

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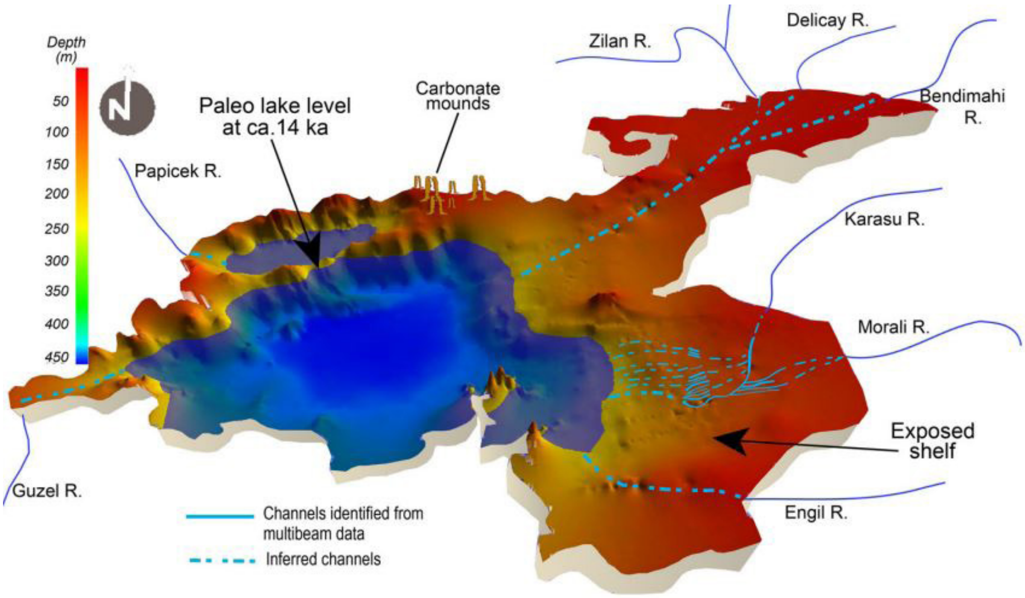

Figure 1. Bathymetry of Lake Van (Cukur et al., 2015).

Previous studies have suggested that lakes are good sentinels of global climate change because they are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere (Carpenter et al., 2007) (Pham, Leavitt, McGowan, Peres-Neto, & Oceanography, 2008; Williamson, Dodds, Kratz, Palmer, & Environment, 2008). One of the parameters, SST, which is important indicator of global warming first, was studied for Lake Van (Sari, Polat, & Saydam, 2000) from February 1998 to January 1999 to map SST with bathymetry and current using remote sensing techniques and by long-term SST (M. T. Kavak & S. Karadogan, 2012). Level change studied (Yıldız & Deniz, 2005). Environmental Geology of Lake Van Basin studied by (Çiftçi, Isık, Alkevli, & Yesilova, 2008). Affect by climate change studied by (Kadioğlu, Şen, & Batur, 1997). Geologically studied by E. T. Degens and Kurtman (1978).

The main producers that make food molecules (organic matter) in the water environment are phytoplankton. All phytoplankton includes at least one form of chlorophyll (chlorophyll-a) and thus can carry out energy photosynthesis, which means they have the ability to turn carbon dioxide and water into energy using sunlight. The role of phytoplankton in global climate change is important. It has been suggested that phytoplankton can reduce global warming by two different mechanisms. One of them is that this phytoplankton takes carbon dioxide from the atmosphere and converts it to organic carbon and send to the sea bottom with the dying organisms. Therefore, the amount of carbon dioxide in the atmosphere decreases and the greenhouse effect is reduced. Another mechanism is dimethyl sulfate gas, which comes out of some phytoplankton groups. This gas is oxidized to sulphate aerosols in the atmosphere and acts as cloud condensation core. It has been noted that this gas can lead to global cooling, as cloud formation will prevent the sun's rays from reaching the Earth. Phytoplankton also produces half of the earth's oxygen. Considering that phytoplankton, which is a direct or indirect food source of marine creatures, affects global warming, the importance of these organisms in the ecosystem is better understood (Develi, 2009).

On the other hand, the damages of phytoplankton should be taken into consideration as well as their benefits. While organic load and organic wastes, which are formed in the lighted layer and produced in connected productions, settle deeper in the water branch, cause the use of oxygen dissolved in water with bacterial breakdown and decrease the oxygen required for life. Chlorophyll-a concentration is considered as phytoplankton biomass and it increases along with eutrophication as a result of higher nutrient concentrations. Eutrophication, which occurs with increasing chlorophyll concentration, may decrease the amount of dissolved oxygen in the water and cause the death of the aquatic ecosystem in the long term, as well as damaging to the species by changing the habitat of aquatic animals like fish.

This study will lead to the assessment of the effect on aquatic animals by determining the chlorophyll concentration levels that are important for the aquatic ecosystem. It will also be a step towards the investigation of the effect of interpretable phytoplankton on global warming depending on the amount of Chl-a. In addition, it is possible to investigate the distribution of aquatic animals by examining the relationship between SST and Chl-a, and there are many articles about it.For example; by investigating the parameters of SST and Chl-a, the abundance of a fish species in a particular region was seasonally examined (Diankha, Sow, Thiaw, & Gaye, 2013). The relationship between sea surface temperature and chlorophyll-a concentration in fisheries aggregation area was investigated by using satellite images (Nurdin, Mustapha, & Lihan, 2013).

Present work concentrated on two parameters SST and Chlorophyll-a also their relationship using MODIS-AQUA data for 18 years which might be useful for scientists to study Lake Van for today and beyond with other parameters such as level change, eco-system, dissolved organic carbon (DOC), regional air temperature, aquatic animals' abundance and amounts in time an etc.

The aforementioned parameters, available from remote sensing observations, are commonly used to detect the presence of algal blooms: – Chlorophyll-a Concentration (Chl-a) – Chlorophyll-a Concentration Anomalies – Sea Surface Temperature (SST) – Optical Characteristics (absorption, backscattering).

Material and Method

To examine concentrations of chlorophyll-a pigment and SST; monthly average level 3 images of MODIS-AQUA were downloaded from the Ocean Color web site from August 2002 to April 2020 and used. 4μ nighttime SST was chosen as it is less affected from atmosphere during nighttime. 210 images for each parameter, 420 images in total were downloaded (The calendar month data value varies depending on the month; this will be 28, 29, 30, or 31 days.) and processed by using SNAP which was developed by ESA. (European Space Agency) (https://step.esa.int/main/download/snap-download/). Dominant pattern of SST and Chl-a was also studied using an Empirical Orthogonal Function (EOF) analysis, also known as Principal Components Analysis. This analysis has already been used for other regions by (Kelly, 1985); (Lagerloef & Bernstein, 1988; Paden, Abbott, & Winant, 1991); (Fang & Hsieh, 1993) (Gallaudet & Simpson, 1994); (Hernandez-Guerra & Nykjaer, 1997), (Kavak, 2012).

The main interest of EOF analysis is due to its capability of decomposing a data set onto orthogonal (i.e. independent) functions. The functions which contain high variance can generally be related to physical phenomena, while the functions which contain less variance are more difficult to interpret due to the orthogonality constraint and they can be considered as noise. This technique can represent the dominant patterns of residual variance found in large and complex datasets.

Figure 2 depicts the reflectance levels for set of pixels by plotting their positions in what is commonly called band space (in this case, for an image with two spectral bands). Each axis represents the reflectance in the indicated spectral band. Each image pixel can be plotted in this space by placing its location at the intersection of its reflectance level on each band. As can be noted, there is a significant amount of correlation between bands. Since the bands in Figure 2 are correlated, each does not carry independent information. Therefore, there is a good chance of being able to predict the reflectance of a pixel in one band from the reflectance in the other. Basically, principal components analysis creates new axes called band axes along the lines of maximum variance within the data. Therefore once the pixels have been located by their new co-ordinate system (see Figure 2) a band axis PC1 image would contain more information than any other band axis image (Parsons, 1985).

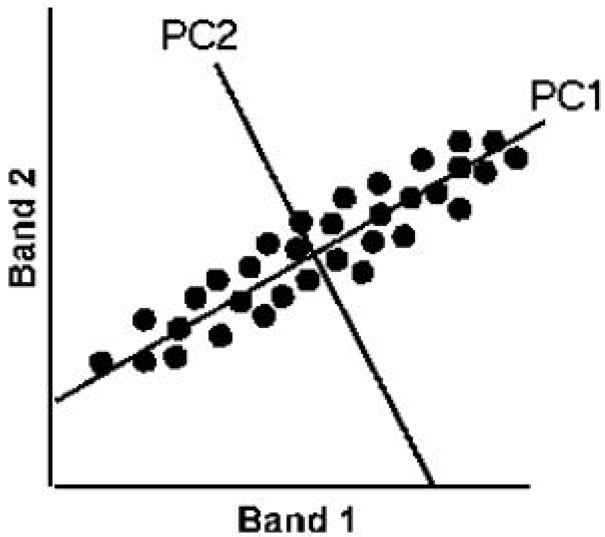

Figure 2. Principal component transforms.

Detailed information about principal component analysis may be found in some textbooks and published papers mentioned above, such as (Jensen, 2005) and (Gallaudet & Simpson, 1994).

Results and Discussions

Long time SST along with Chl-a of Lake Van. The red line represents SST, while the black represents Chl-a. As seen by the time both tend to increase over time (Figure 3).

Cross plot SST and Chl-a (Figure 4) show approximately -0.65% of correlation which were not statistically significant. Contrary to the Black Sea and Caspian Sea, which are two important water bodies close to Lake Van and studied by M.T. Kavak and S. Karadogan (2012) are showed statistically significant correlation. This situation can be attributed to the special conditions of Van Lake and the closed basin in which it is located. As a matter of fact, Van Lake is a closed basin and it is discharged only by karstic underground drainage. The surrounding of the basin is generally composed of volcanic units and has a feature of lake water soda. Perhaps the most important of the environmental conditions is the risk of increasing the pollution level with the city of Van on the lake and the surrounding agricultural elements.

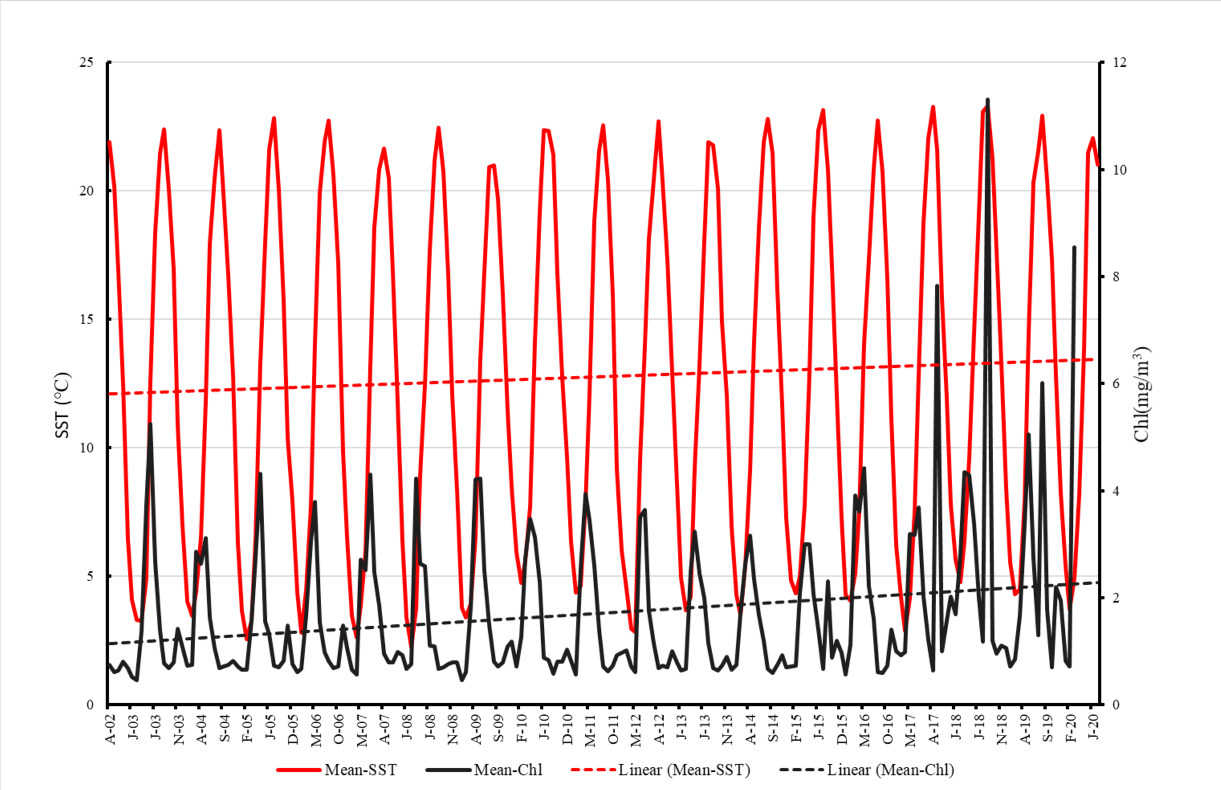

Figure 3. SST (and Clorophyll (mg/m³) variation of Lake Van from August 2002 to April 2020.

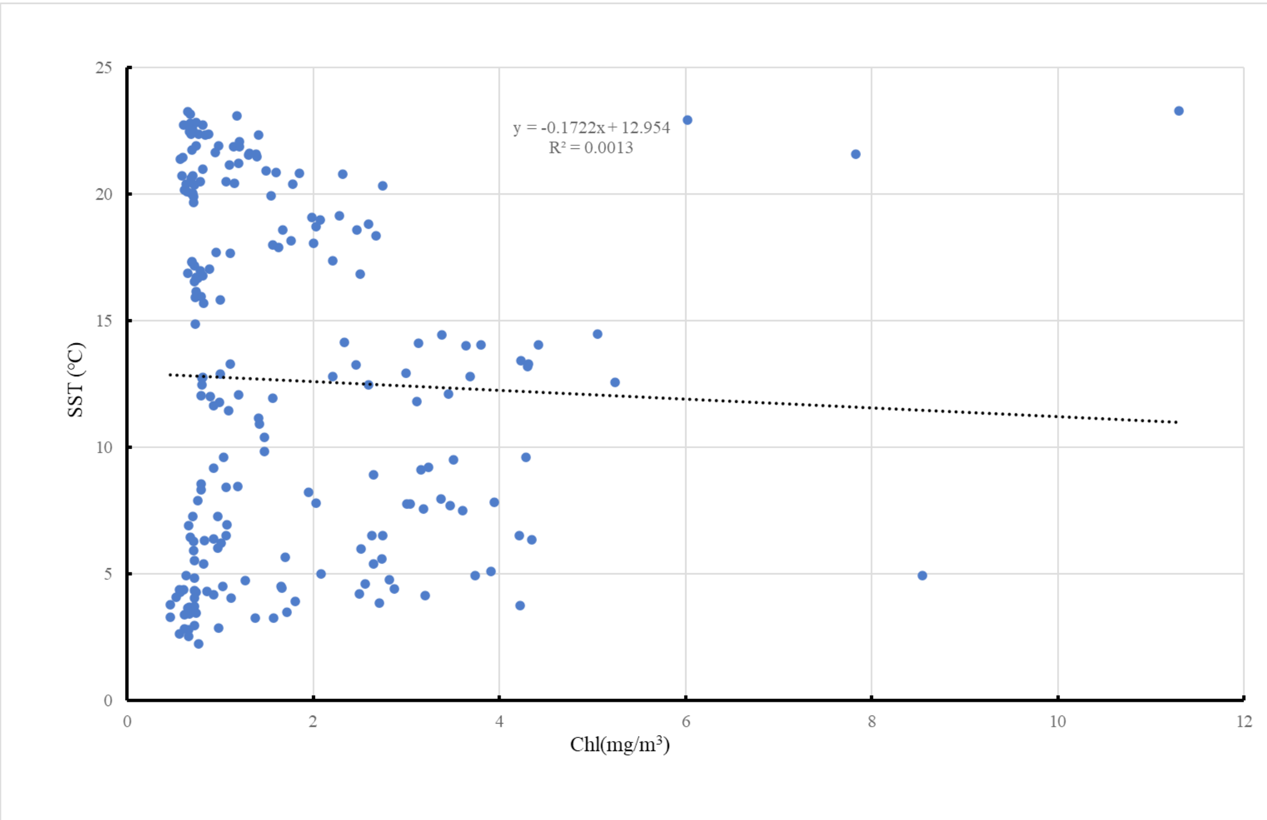

Figure 4. Relationship between SST and Chl-a values from August 2002 to April 2020.

Looking at the seasonal chlorophyll-a variation of Lake Van (Figure 5), it could be seen that March 2003 and 2012 were below average, and September 2017, August 2018-2019 March 2020 was above the average. Highly remarkable values that were well above the average should be related to urban coastal landscaping and landscape studies.

Likewise, anomalies draw attention in the temperature graph (Figure 6). However, the deviations from the average seen on the temperature graph depend on the meteorological conditions and were in line with the temperature values at the same date.

Figure 6 shows 18 years of monthly distribution of SST values which shows that October, November 2002 and May, June 2003 are slightly off the average.

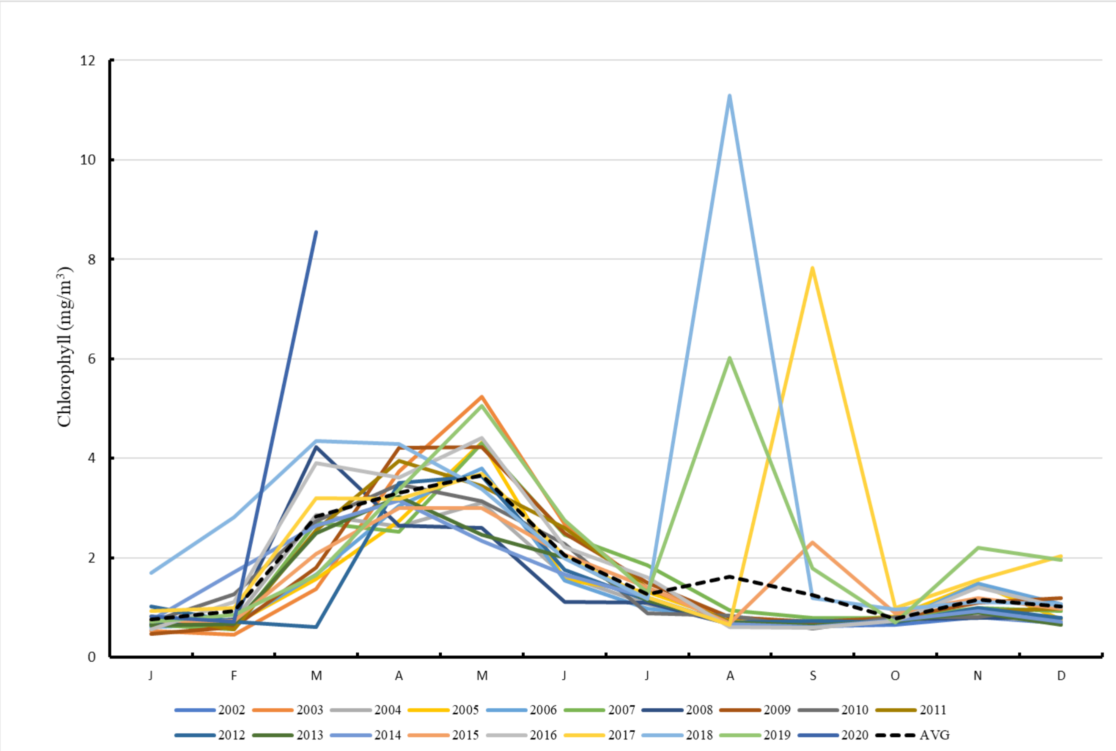

Figure 5. Monthly distribution of chlorophyll-a pigment concentration of lake Van

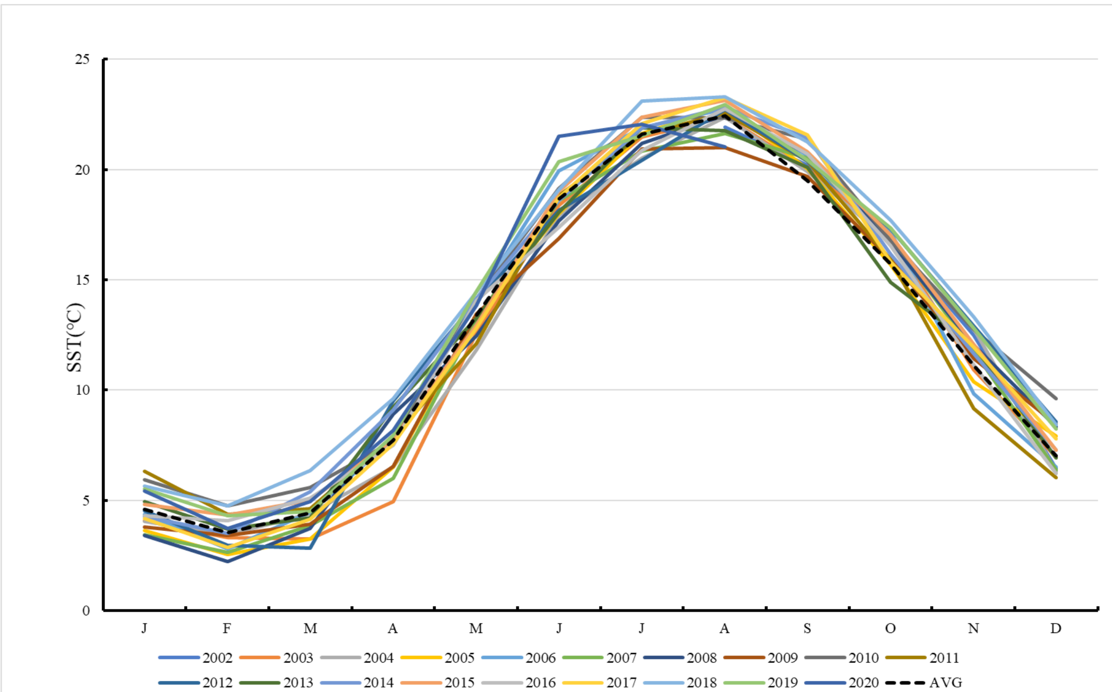

Figure 6. Monthly distribution of SST October, November 2002 and May, June 2003 are off the average.

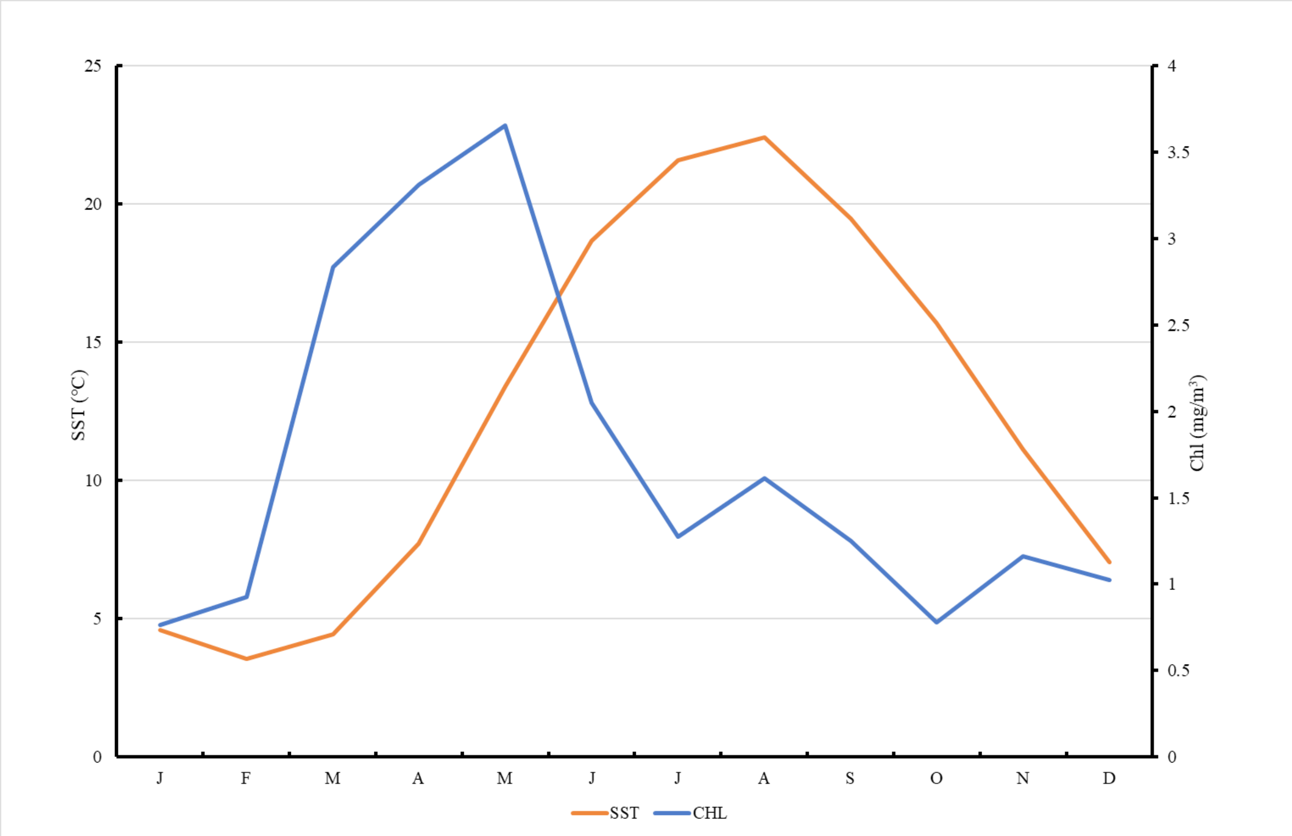

Figure 7. Monthly distribution SST and Chl-a average of Lake Van

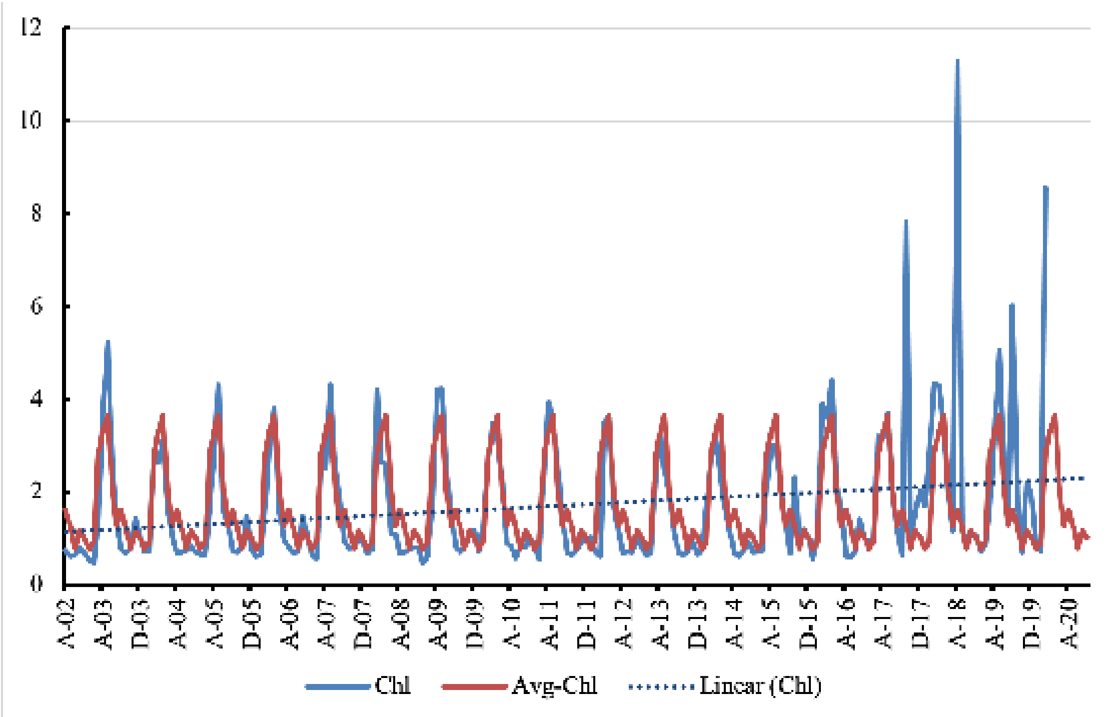

Figure 8. Long term chlorophyll-a pigment concentration along with the average variation of the Lake Van from August 2002 to April 2020.

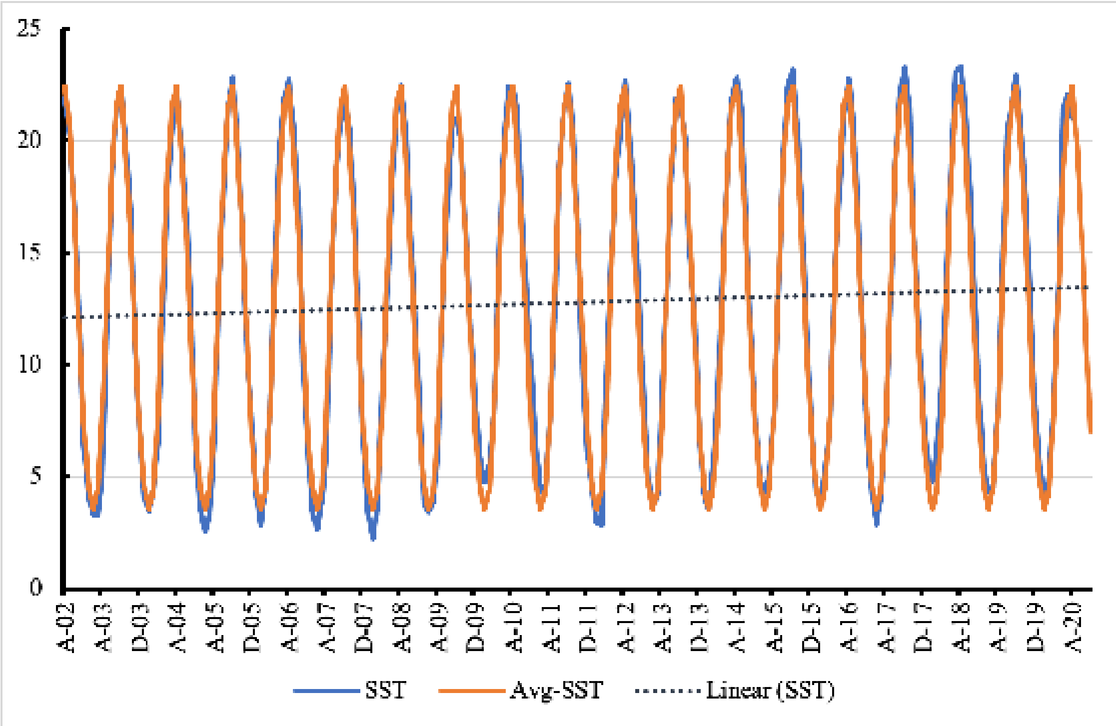

Figure 9. Long-term SST distribution with average and trendline

Although the correlation was not significant, both with a lag behaving similarly, increasing or decreasing (Figure 7).

August 2003, September 2017, March April and August 2018, and May August 2019 were off the average, general trend also showed an increase on Chlorophyll-a pigment concentration.

Long term SST in general behaved normally since it followed a sine curve however, October November 2002 and May June 2003 were off the average (Figure 8).

Long term SST (Figure 9) in general behaved normally since it followed a sine curve however, October November 2002 and May June 2003 were off the average. Increase in trendline may be due to global warming and tectonic activities present at the region.

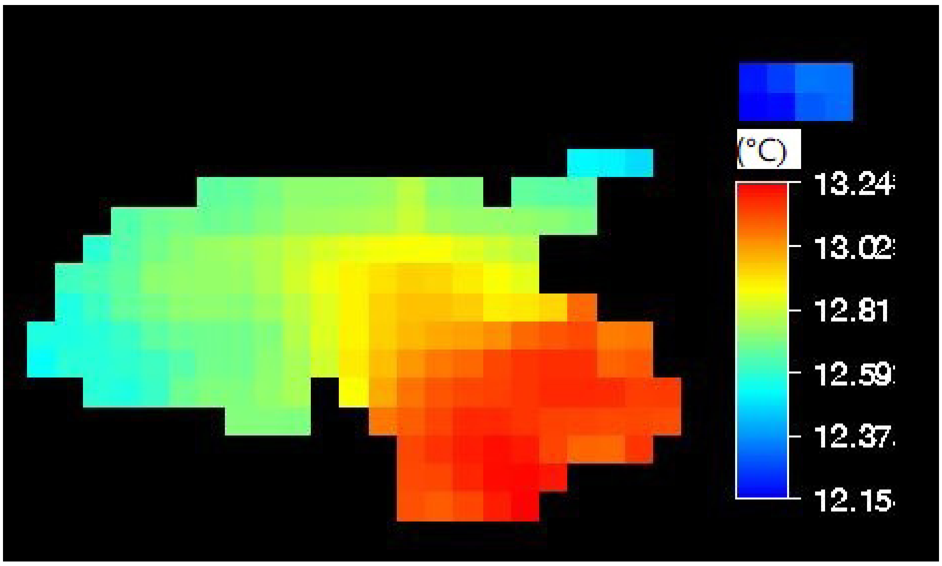

Figure 10. General average of SST of 210 images.

Average of 210 images shows that southeastern side of the lake has higher temperature than the other parts of the lake may be due to stratification caused by lack of wind. North of the lake has lower temperature caused by cold water input and bathymetry.

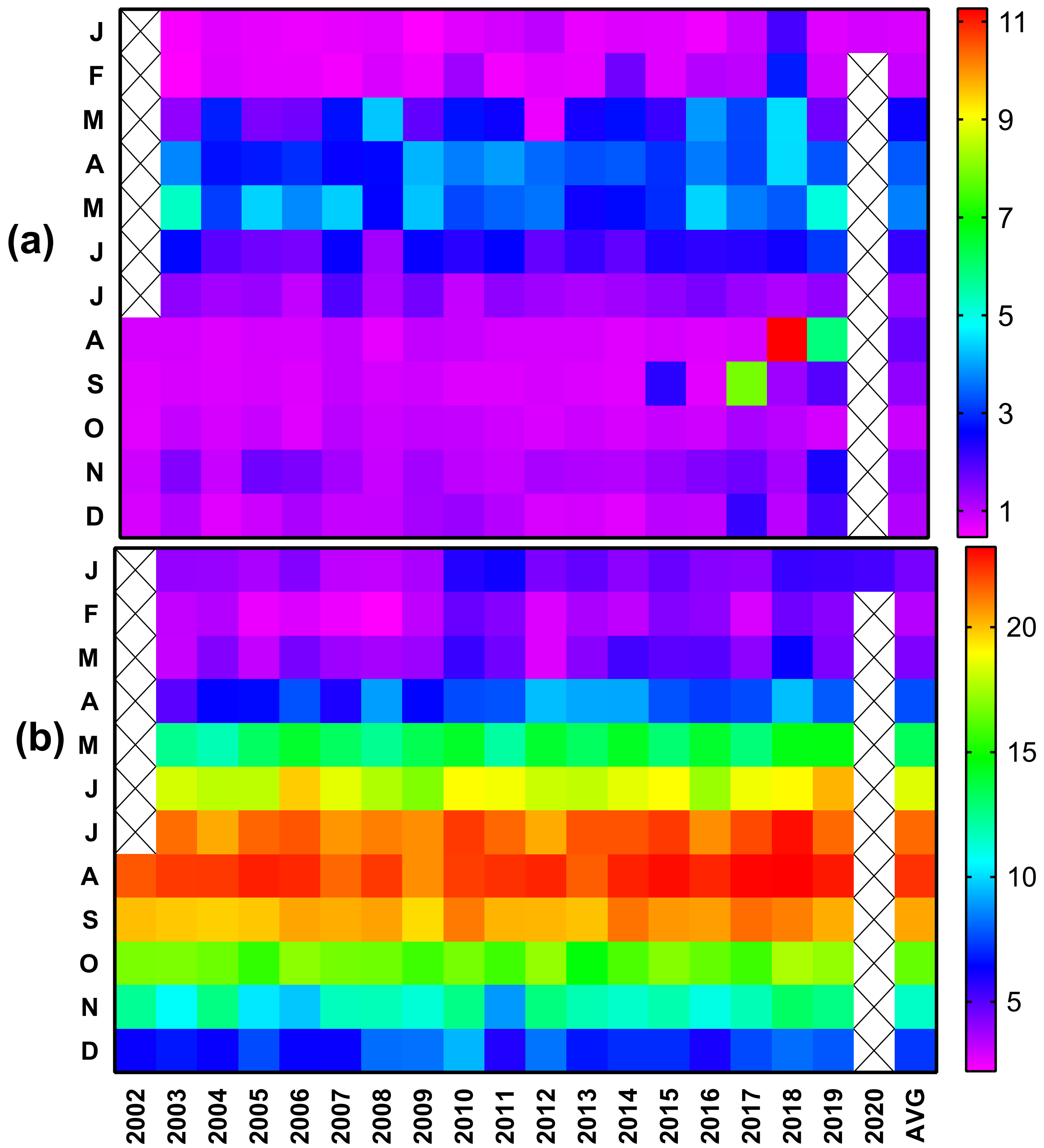

Figure 11. Monthly heatmap of Chlorophyll-a pigment concentration (mg/m^3) (a) and SST (°C) (b).

Apart from 3 extreme values, high pigment concentration generally could easily be seen (Figure 10a) on March, April, May, and June, these may be results of seasonal activities on coastal zone. According to heat map (Figure 10b) August is the warmest month of the year due to less cloud cover which blokes sun light reaching the lake surface.

Table 1. Eigen values along with accumulated variances

Bands	PC1	PC2	PC3	PC4
Cov. Eigenvalues	26.115	12.714	3.558	1.814
% Variance	0.487	0.237	0.66	003
Accumulated Variance	0.48	0,72	0.79	0.82

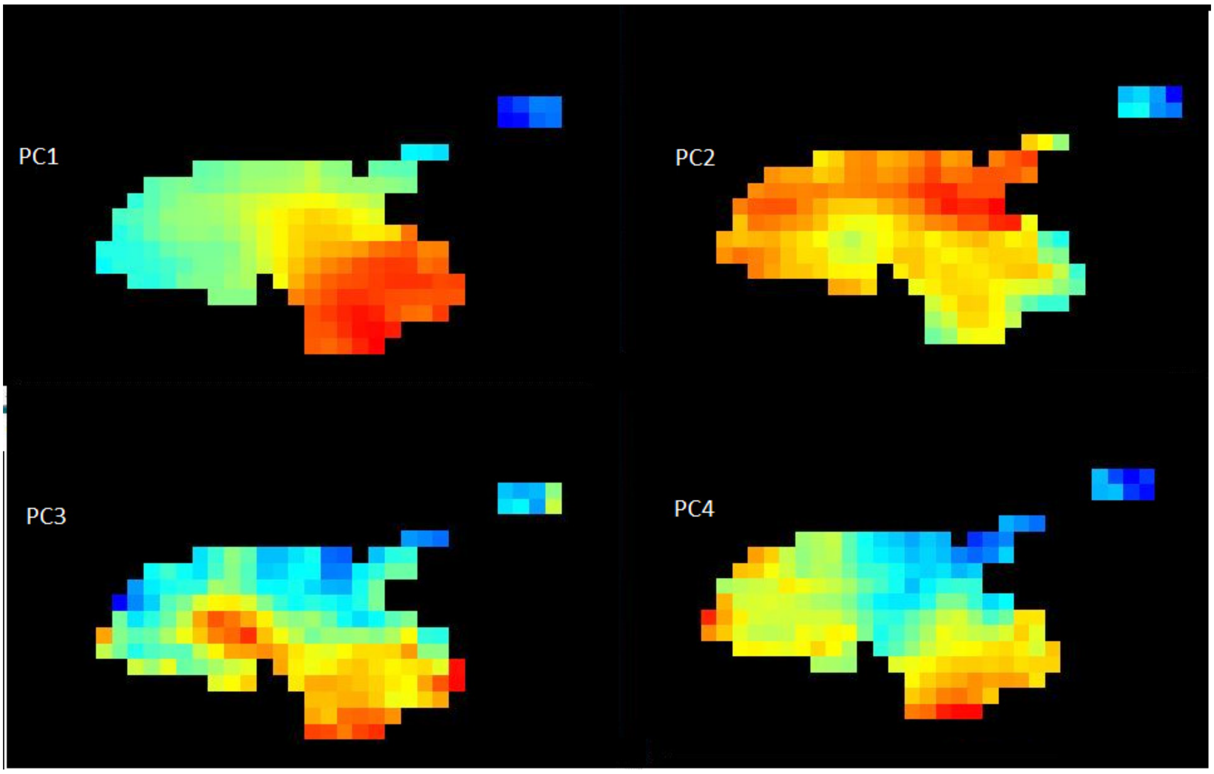

Figure 12. PC1, PC2, PC3 and PC4 all contain 82% of variances.

General Average of 210 images (Figure 11) shows that southeastern side of the lake has higher temperature than the other parts of the lake may be due to stratification caused by lack of wind. North of the lake has lower temperature caused by cold water input and bathymetry.

PC1 value in Table 1 which contains 48% of variance, almost identical to the pattern of general average SST and seems to represent bathymetry of the lake. On the other hand, PC's for Chl-a could not be calculated due do null values within the images. Generated pattern of the components PC1, PC2, PC3 and PC4 can be seen in Figure 12.

PC1 which contains 26.11% of variance, almost identical to the pattern of general average SST and seems to represent bathymetry of the lake. On the other hand, PC's for Chl-a could not be calculated due do null values within the images.

According to the findings obtained:

Contrary to the surrounding water bodies no significant correlation was found between SST and chlorophyll-a concentration. This could be because of the special geographical conditions of Lake Van and the basin in which it is located should be sought. Both in a long time tend to increase but not proportionally to each other. Both lake surface water temperature and Chlorophyll-a concentration show quite different deviations from the average in some periods. The anomalies seen in the chlorophyll-a concentration could be related to the periodic effects caused by the dense urban settlement in the environment.

While chlorophyll-a pigment concentration tended to decrease until 2011, it has been in a marked upward trend in recent years. The results also showed best time to study chlorophyll-a is March, April, May, and June. The amount of Chl-a in 2017 and 2018 deviated from the average and showed a significant upward trend, which may indicate that the habitat of aquatic animals in that area has deteriorated these years. This study can help to reach necessary parameters to investigate the reasons for the reduction of aquatic animals in water and the investigation of phytoplankton effects on global warming, which is the biggest problem of the century. In addition, it is possible to examine the abundance and distribution of aquatic animals using SST and Chl-a parameters.

In addition, it is possible to examine the effect of SST and Chl-a parameters (climate change effect) on fisheries, population parameters (e.g. growth, mortality and reproduction) the abundance and distribution of aquatic animals and fish species (Van fish, Alburnus tarichi) in the Van Lake.

Lake Van is very important in terms of recreation, tourism, and aquaculture for residential areas in the eastern regions as well as for neighboring countries. In addition, the investigation of the properties and habitat of lake water is of great importance for scientific research. For this reason, many studies are carried out by many different disciplines. In this study, lake surface temperature and chlorophyll-a concentration were investigated using satellite data for a long time. This study may be a guide for future research on local discharged water.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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