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Thermal Stratification in Lake Nasser, Egypt Using Field Measurements

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Abstract: This study describes and discusses the water temperature gradient of Lake Nasser. The Lake (23°N and 32°E) is the second largest man-made lake in the world. The results of the study showed that its water column mixes to bottom in February, with a weakly difference of only less than three degrees. Winds blowing across the lake's surface cause the water to pile up on the downwind layers. The lake becomes thermally stratified in July, when the inflow at the southern region of the Lake and air temperature reaches ultimate. The epilimnion extends to a depth of 12 m below the lake surface, with average temperature of 29.7°C. The thermocline thickness in the lake changes from region to another. Its thickness is 5 m at the southern region, with a difference of five degrees. The northern and the middle regions of the lake have the thickness of 13 m, with a nine degrees difference. The hypolimnion of the northern and middle regions of lake Nasser is below approximately 25 m, while in the southern region , it is below about 17 m depth. The average temperature of the hypolimnion in the lake is about 18.5°C. The thermal stratification is influenced by the weather condition and the water inflow to the lake.

Key words: Lake Nasser · Temperature and thermal stratification.

INTRODUCTION

The temperature and consequently thermal stratification is one of important features, which have great impact on the ecological environment in a lake [1-2]. Water temperature is a major regulator of physical, chemical and biological processes occurring in lakes. The unique temperature related properties of water, including its high specific heat, high latent heat of vaporization and particular density temperature relationships govern all life processes. Most organisms have an optimum temperature range above and below which they become stressed and at extreme temperatures, die [3]. Therefore, the knowledge of the thermal structure for a lake has become a key problem for the lakes development and management.

Numerous studies performed at different latitudes [4-8], discussed the thermal stratification at different lakes. They concluded that, the thermal stratification in each lake are influenced by various factors including; latitude, altitude and inflow from tributaries. The response of a water body to these stratified mechanisms depends on a number of factors such as lake morphometric characteristics and meteorological factors. The formation and thickness of the stratification trend is dependent on internal hydrodynamic mechanisms [9].

Lake Nasser (Fig. 1), together with Lake Nubia, is the second largest man-made lake in the world. The Lake represents the national freshwater bank of Egypt. The only source of water is the River Nile with its inflow in the south and one outflow in the north. The flood season is always takes place from July to November. The Lake lies between Latitudes 22°00′ -23°58′ N and Longitudes 30°35′ -33°15′ E. The reservoir is about 300 km long [10]. The aim of this study is was to describe and discusses the water temperature gradient in three regions of Lake Nasser during two periods.

MATERIALS AND METHODS

The relationship between temperature stratification of the water column and meteorological forcing and inflow was examined for Lake Nasser by using the field measurements. Measuring data were collected from three regions during two months; February and July 2007, with lowest and highest water temperature. Measurements were made at 1m intervals until the bottom was reached. The vertical temperature structure was recorded (applied Microsystems DBT; Depth-Bottom and Temperature).

RESULTS

Figure 2 shows the water temperature structure in the three regions of Lake Nasser. The Lake showed a much smaller temperature difference between the surface and

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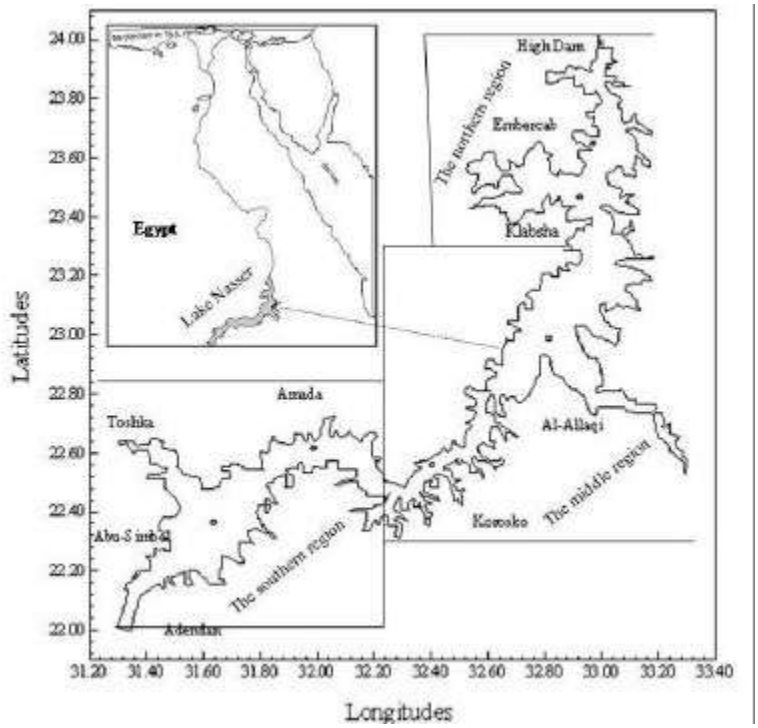

Fig. 1: Egypt and Lake Nasser map

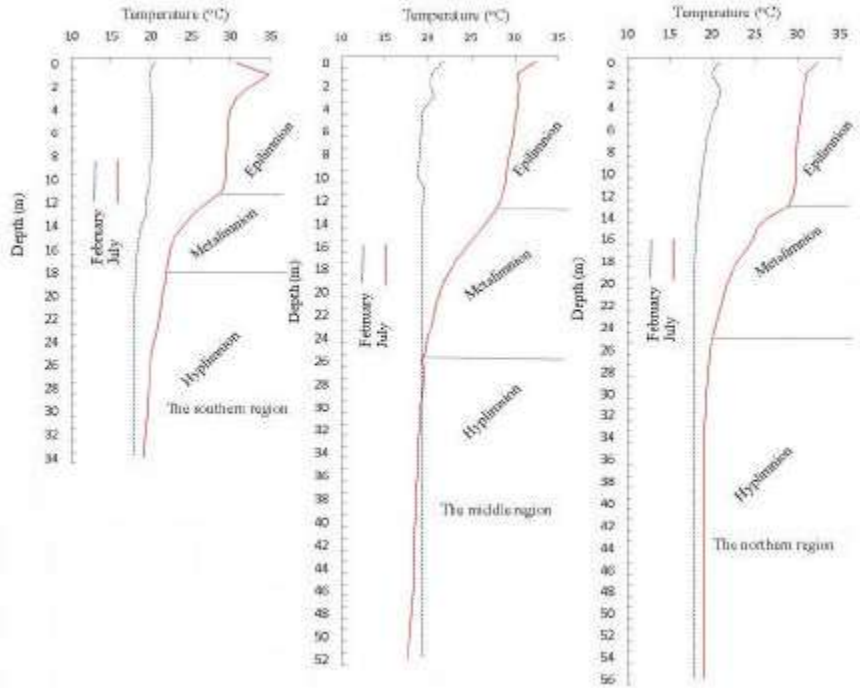

Fig. 2: The thermal stratification and temperature profiles of Lake Nasser in February and July 2007

the bottom in February. The water temperatures averaged 20.9-17.9°C at the northern region, 21.7-19.2°C at the middle region and 20.6-17.9°C at the southern region. In July, the temperature difference between the upper layer and the bottom layer increased. The temperatures averaged 32.3-18.9°C at the northern region, 32.5-17.7°C at the middle region and 30.8-19.2°C at the southern region.

DISCUSSION

The complete homogeneity of the water temperature in Lake Nasser develops during February; whereas, the temperature difference between surface water and near bottom was under unstratified conditions. The temperature tends to be uniform with the largest difference about less than three degrees in vertical gradient. The mixing occurs through a number of mechanisms, including wind-induced turbulence, convective mixing [12]. Winds blowing across the Lake's surface cause the water to pile up on the downwind layers and the water moves downward, across the lake bottom. The entire Lake begins to circulate from top to bottom, maintaining a uniform temperature [11]. The extent and frequency of mixing is a balance between the turbulent kinetic energy inputs to the lake relative to the resistance to mixing of the water column. Resistance to mixing arises due to buoyant forces in place as a result of thermal stratification [13-14].

In July, the temperature differential between the warm and the colder layers is obvious, with a fourteen degree difference. In July the inflow at the southern region of the lake and air temperature reaches ultimate [10]. Weather (wind) conditions cannot cause the two layers to mix and the lake will remain stratified until fall [14]. Heating rate within the water column depends on energy input by solar radiation and on heat exchange across the surface as controlled by convection [15]. With warm water gets heavier and goes up, the thermocline near surface appears. At the same time, the inflow gets warm and goes up along the surface, which makes the water near the surface warmed up. The surface water is slowly warm and a thermocline layer exists between the warm layer and the cold layer [16, 17].

The sunshine heats the lake surface makes a warm layer of water with a low density. Then a layer with higher density and lower temperature will stay under this condition [18]. In this way the lake is stratified to epilimnion, metalimnion and hypomnion layers. These three layers are not completely separated from each other, water fluctuations; different hydrological and meteorological factors affect each layer [19].

Temperature profiles in July showed that thin layer is up to one meter below the surface, due to the effect of directly wind in the water surface [20]. The epilimnion (warm water) is up to 12 m below the lake surface, with average temperature of 29.7°C. The hypolimnion (cold water) of the northern and the middle region of Lake Nasser was below approximately 25 m, while the southern region was below about 17 m. The average temperature of the hypolimnion in the Lake regions is about 18.5°C. Between the epilimnion and hypolimnin is water called (thermocline), is characterized by a rapid decrease in temperature [21-22]. The depth of the thermocline (metalimnion) was considered as the mid-point of the depth interval at which the greatest change in temperature occurred in the water column profile. The average thickness of the thermocline at the northern and the middle regions is 13 m, with a nine degree difference. At the southern region the thermocline is a relatively thin layer of water about 5m, with a five degree difference. Generally, the thermal stratification is one of the most important physiochemical phenomenons [23]. Thermocline is a very significant layer, which is formed between epilimnion and hypolimnion and prevents the vertical mixing of upper and lower layers [24].

It was concluded that the thermal stratification is one of important features, which has great impact on the ecological environment in the lakes. The temperature stratification of the water column was examined for lake Nasser by using the field measurements. The lake temperature profiles varied in the two months (February and July), with cool isothermal conditions in the February and warm thermally stratified condition in July.

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