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# ESTIMATING THE EVAPORATION OVER NASSER LAKE IN THE UPPER EGYPT FROM METEOSAT OBSERVATIONS

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## ABSTRACT

The water loss from Nasser Lake in the South of Egypt is one of the national problems, because the lake is the water bank of Egypt and the evaporated water range between 10 to 16 billion cubic meter every year, which represent 20 to 30% of the Egyptian income from Nile water. Correlation analysis between tile cloudiness observed by Meteosat in the infra-red band (10.25 - 12.5 µm) and ground station measurements for atmospheric infra-red, temperature and water vapour content has performed at the northern head of the lake near Aswan High Dam. Models and empirical relations for estimating the evaporation over the lake are deduced and tested. Using Meteosat infra-red window (10.5 - 12.5 µm) observations and the empirical models, we can estimate the evaporated water every day. The yearly water loss can be determined from the integration of the daily values. 

## INTRODUCTION

Nasser Lake is the second largest man-made lake in the world, extending from the southern part of Egypt to the northern part of Sudan, about 500 km length, and 7000 km circumference. The level of water oscillates between 147 to 182 meter above the sea level during a year, and from year to year.

Nasser Lake, the water bank of Egypt, contains about 135 billion cubic meter from fresh and renewable water. The lake is surrounded by empty flat desert, where the nominal annual insolation is more than 2500 kWh/m$^2$. The water loss from the lake is one of the national problems. The evaporated water loss ranges between 10 to 16 billion cubic meter every year, which is equivalent to 20 to 30% of the Egyptian income from Nile water (Figure 1). Net Radiation is an essential parameter for estimating evaporation from large water surfaces by energy balance method (Omar and Mosalam Shaltout, 1988a,b). Net radiation has been measured for the first time over the Nasser Lake for 132 days including warm and cold seasons (El-Bakry, 1994). Solar energy distribution and moisture estimation over Egypt has been performed for the first time from Meteosat Satellite observations during 1990's (Mosalam Shaltout, 1990, 1996). The purpose of this study is to derive an empirical relation applicable over the lake to estimate the evaporation using the measured data at ground for atmosphere infrared radiation, air temperature, and cloudiness measured in infrared spectral band by artificial satellite Meteosat.

## DATA

### Satellite Data

'The Meteosat satellite is stationed in a geostationary orbit at nearly 36,000 km above the equator and the Greenwich meridian (0°E). The principle payload of the satellite is a multi-spectral radiometer (Morgan, 1978). This provides the basic data of the Meteosat system. The three channel radiometer includes

- Two identical adjacent visible channel in the 0.4 - 1.1 μm spectral band..
- A thermal infra-red (window) channel in the 10.5 - 12.5 μm spectral band.
- An infra-red (water vapour) channel in the water vapour absorption band (5.7 - 7.1 μm), which can be operated in place of one of the two visible channels.

The set of images in any one half hour period are the 2.5 km resolution visible, and the 5 km for water vapour absorption band (5.7 - 7.1 μm) that is the thermal near infra-red band.

Every day at L.M.T $11^h$, the Meteorological Authority of Egypt Cairo, receives images from the satellite Meteosat to analyze cloudiness over Egypt and the surrounding countries. One image is in the visible spectral band (0.14 - 1.1 μm), and the other who are in the thermal infra-red window (10.5 - 12.5 μm), and the water -vapour absorption band (5.7 - 7.1 μm). The brightness of each pixel as seen by the satellite is interpreted as an index of atmospheric opacity. We classified the brightness within five bins (very dark areas are zero, while very bright areas are four), and measured the daily brightness of the cloudiness in the spectral band (10.5 - 12.5 μm) for Aswan for the period (1990 - 1992). Such that 0 means very clear sky as in Oktas scale, and value 1 correspond to value 2 in Oktas scale and so on, where 4 is correspondant to 8 in Oktas scale.

### Ground Data:

Aswan is located on the north end of Nasser Lake at coordinates (23° 58'N, 32° 48'E). There is a meteorological ground station for measuring different components of solar radiation and the other meteorological elements. The atmospheric infra-red radiation is measured at Aswan by Epply precision infra-red radiometers.

## ANALYSIS AND RESULTS

As a first step we carried out a simple linear regression for the data at Aswan for the period (1990-1992), between the incoming long wave radiation-for clear skies (R) and $\sigma T^4$, where $\sigma T^4$ ($mW/cm^2$) represent the total infra-red emission by a black-body in all wavelengths at temperature T °K (Stefan's law). The correlation coefficient (cc) between R and $\sigma T^4$ is 0.97, the standard error (se) of estimate is 1.14, and the relative error (re) is 2.9. The regression equations is :

$$R = -22.32 + 1.386\,\sigma T^4 \qquad (1)$$

As a second step, we introduce the effect of the water vapour pressure (e) with temperature to get a preferable result for estimating R in the humid regions.

Elsasser (1947) shows that, since the spectrum of water vapour is not continuos (i.e. in the water vapour bands, the lines are so far apart from each other that each absorbs or emits independently of the others) but a line spectrum does not obey an exponential but a square root law of absorption and emission. Hence, we selected $\sqrt{e}$ as a second variable in Eq. 2.

$$R = -25.312 + 1.550\,\sigma T^4 - 1.093\,\sqrt{e} \qquad (2)$$

where the multiple correlation coefficient (mcc) is 0.975, the se is 1.059, and re is 2.7.

As a third step, we introduced the effect of the cloud amount (C) beside the effects of the temperature and water vapour pressure to get a preferable result for estimating R in the cloudy condition. This is because cloud cover increases the atmospheric emission and most clouds radiate as black-bodies at their surface temperature. We have two types of cloudiness, $C_g$ is the mean daily cloud amount observed from ground, and $C_{st}$ is the mean daily cloud amount observed by Meteosat Satellite in infra-red band (10.5 - 12.5 µm). The clouds are measured in tenths (i.e. $O \leq C \leq 1$), and we took only the amount of cloud for simplicity, ignoring the type and height information.

It is found that the cc between R and $C_g$ is -0.56, the standard deviation is 0.185, and the regression equation is:

$$R = -21.64 + 1.482\,\sigma T^4 - 1.156\,\sqrt{e} - 6.18 C_g \qquad (3)$$

The cc between $C_g$ and $C_{st}$ for this period (1990-1992) is about 0.90. When we use this regression to estimate R value in cloudy days, we find that the accuracy is poor. Hence to clear the effect of cloud in Eq. 3, we isolate the days which have amount of clouds equal or greater than 4 Octs. From this period there are about 100 values and the cc's between R and $C_g$ and $C_{st}$ are -0.59 and -0.55, respectively. For the cloudy days the regression is

$$R = 15.82 + 1.388\,\sigma T^4 - 1.291\,\sqrt{e} - 6.21\,C_g \qquad (4)$$

where the mcc is 0.986, the se is 0.78, and the re is 2.03.

For the case of clouds measured by Meteosat Satellite $C_{st}$, the regression is

$$R = 16.6 + 1.3828\,\sigma T^4 - 1.66\,\sqrt{e} - 2.026\,C_{st} \qquad (5)$$

where the mcc is 0.978, the sc is 0.83, and the re is 2.8.

## CONCLUSION

We conclude from Eq. 2 for the clear sky days, and from Eq. 5 for the cloudy days, we can estimate the water vapour pressure e, and the evaporation over Nasser Lake from the knowledge of incoming long wave radiation for skies, and screen temperature T measured at ground stations, and cloudiness $C_{st}$ from Meteosat observations in infra-red band (10.5 - 12.5 µm).

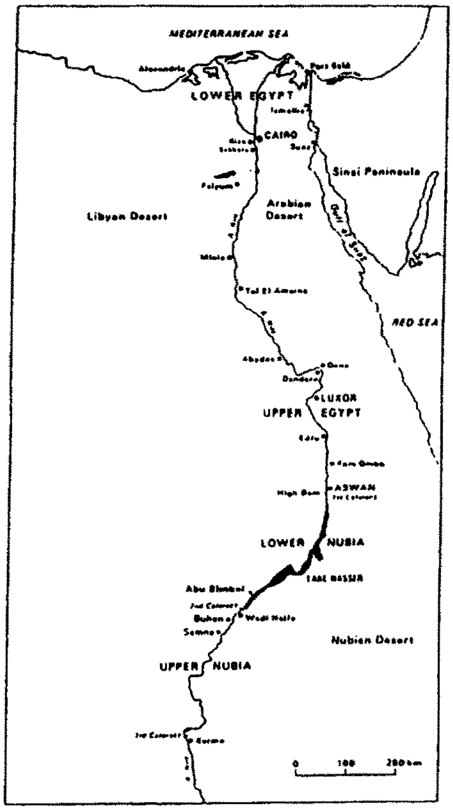


Fig. 1. Location of Lake Nasser in Upper Egypt

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