TIDE AMPLITUDE AND WATER FLUXES RELATIONSHIP IN THE HYDRAULICALLY CONTROLLED SOUTH LAKE OF TUNIS

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Abstract
We study the hydrodynamic process that controls the water renewal of the Tunis South Lake at semi-diurnal time scales. In order to shed light on the relation between tide amplitude and renewal time, we combine current and surface level observations at the lake locks with a 2-D analytical model that takes inTO account both the M_2 tide forcing and the locks hydraulic effect. Then a numerical model, forced by the surface level observations and based on the analytical model, allows us to simulate the filling, the slack and the emptying phases.
Keywords : Lagoons, Tides, Coastal Models, Analytical Methods.

Introduction
The South Lake (Fig. 1) is located southeast the city of Tunis (10°30'E, 36°47' N). After dredging works [1], its area was reduced to 7 km^2 and its depth becomes uniform (H=2.2 meters). Two groups of locks allow a water exchange between the Bay of Tunis and the lake: the "Radès locks", which allow water inflow from the Bay of Tunis and the "Tunis locks", from which the water outflows, via the "Tunis Channel". Thanks to this hydraulic design, the lake water volume increases, when the sea surface level is higher than the lake surface level, and decreases in the opposite situation. In the Bay of Tunis, the surface level variations are mainly forced by the semi-diurnal tide wave M_2 [2]. Our goal is to verify and establish analytically the relation between surface level variations and currents observed at the locks, and then to numerically simulate the filling, the slack and the emptying phases, by taking advantage from the observed parameters.

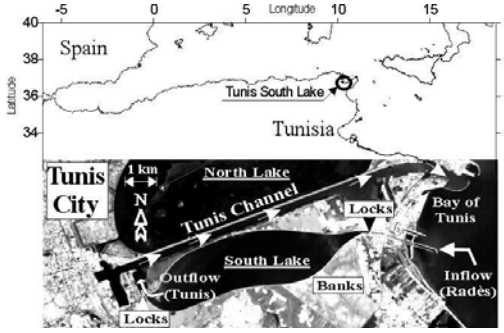

Fig. 1. Location of the Tunis South Lake (top) and sketch of the water exchange between the lake and the Bay of Tunis (bottom).

Data and methods
First, a simultaneous monitoring of the incoming (Radès) and outgoing (Tunis) currents across the 2 groups of locks and the surface level variation was carried out during several semi-diurnal tidal cycles. Fig. 2 shows the typical shapes of the surface level and currents time series. Then, we developed a simplified analytical model to understand the relation between surface level variations and currents observed at the lock gates. The model takes into account the alternate opening and closing of the locks that permits only inflow at Radès and outflow at Tunis.

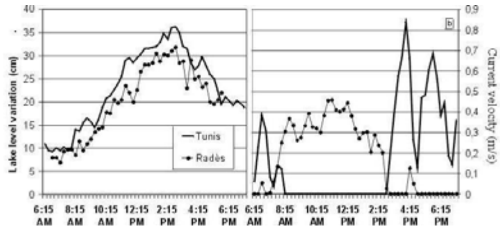

Fig. 2. Water level variation (left) and velocity (right) recorded at the locks during one tide cycle.

We assume that the time interval $[0, TM_2/2[$ corresponds to the tide flood, so the Radès gates are opened, while the Tunis gates are closed. At reverse, during the time interval $[TM_2/2, TM_2[$ corresponding to the ebb, the Tunis gates are opened, while the Radès gates are closed. On the basis of mass and momentum conservation and vertically integrated Saint-Venant equations, one can show, after some calculus, that:

$u_{in} = \frac{S}{He.Le.Lg} \frac{\partial}{\partial t} \int_0^{Lg} h(x,t)dx$ and $u_{out} = 0$ during the tide flood (E.1)

$u_{in} = 0$ and $u_{out} = - \frac{S}{He.Le.Lg} \frac{\partial}{\partial t} \int_0^{Lg} h(x,t)dx$ during the tide ebb (E.2)

u_{in} and u_{out} are the inflow and outflow currents respectively at the filling (Radès) and the emptying (Tunis) locks,
S: Lake's area, *He*: Water depth at the locks, *Le*: Locks width, *Lg*: Lake length, h(x,t): surface level elevation along the longitudinal axis of the lake, TM_2: Period of the semi-diurnal M_2 tide wave (12h24min).
Furthermore, it is possible to show that the residence time is:

$TR = TM2.H.Lg / [\int_0^{Lg} h(x,t)dx]_0^{TM2}$ (E.3)

The numerical model is forced by equation (E.1) and (E.2), where h(0,t) and h(Lg,t) are respectively the surface level at the Radès and Tunis locks. For this purpose, we satisfy a Dirichlet type condition at the two groups of locks and a Neumann type along the banks of the lake.

Main results
- The monitoring of the surface level and velocities (inflow at Radès and outflow at Tunis locks) allows us to verify experimentally the relation: $u_{in} - u_{out} = f(\delta h/\delta t)$ (E.4), as it clearly appears from the two curves of Fig. 2. The relation E.4 is in fact a combination of relation E.1 and E.2. The correlation between $(u_{in}-u_{out})$ and $\delta h/\delta t$ is about 0.75. This results means that the magnitude of the emptying or flushing fluxes, i.e. the renewal time, is a function of the speed by which the surface level varies with time.
- The renewal times deduced from current observations ranges from 6.9 to 9.3 days. Thanks to the mathematical model, that allows us to understand the overall mechanisms that is governing the lake hydrodynamic, by taking in account both the M2 tide forcing and the hydraulic control processes due to the locks (E.3), we estimate that the water time renewal varies between 6.7 and 8.2 days, depending on tide forcing condition. These values are in a good agreement with the values calculated with current observations.
- Thanks to the modelling of the hydraulic design that controls the incoming and outgoing fluxes, the model has the ability to reproduce the transient state corresponding to the slack phase. During this phase, the model shows a quick reversion of the 2D currents, which occurs during 20 minutes (not shown). It is the time needed, by the gravity wave, to cross the lake along its longitudinal axis, from the Tunis lock gates to the Radès lock gates. We have verified this phenomenon in site.

References

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