Tellus (1979), *31*, 558–564

On man-induced variations in the circulation of the Mediterranean Sea

By DORON NOF, *Cooperative Institute for Marine and Atmospheric Studies, University of Miami/NOAA, 4600 Rickenbacker Causeway, Miami, Florida 33149, U.S.A.*

(Manuscript received March 20, 1979)

ABSTRACT

The response of the Mediterranean Sea to a diversion of rivers, such as the Nile, for agricultural use, is investigated by a simplified dynamical model for the Mediterranean basin. Solutions are obtained by using the principle of "hydraulic control" at the Straits of Gibraltar, volume and salinity conservations, and perturbation techniques. It is found that such a diversion causes an increase of salinity in the basin and alters the exchange between the Mediterranean Sea and the Atlantic Ocean. The predicted result is an increase in the transport through the Straits of Gibraltar. This increase of both the transport into and from the Mediterranean is about eight times larger than the amount of water which is diverted and is expected to take place within 25–50 years after the diversion. For the Nile alone, which has been diverted in the mid-1960s, an increase of ~0.5% in the transport through the Gibraltar Straits will occur and, if all runoff flowing into the Mediterranean Sea was to be diverted, an increase of ~3.5% will take place.

1. Introduction

Recently, attention has been drawn to the changes of salinity that would occur if rivers flowing into the Arctic Ocean were diverted southward for agricultural purposes; the predicted result being a reduction in the Arctic sea-ice cover (Aagard and Coachman, 1975; Woods, 1978). In this paper the effects of a diversion of rivers flowing into the Mediterranean Sea (hereafter, referred to as MS) are investigated. Such a diversion has already been done in 1964, when the construction of the Aswan High Dam basin had been completed and the discharge of the Nile into the MS has been reduced to negligible amounts (Rzoska, 1976). As we shall see, the effects of diverting rivers flowing into the MS are less severe than those associated with a diversion of rivers flowing into the Arctic, but they are not entirely negligible.

The circulation in the MS is partly controlled by the exchange of water through the Straits of Gibraltar (Fig. 1). About 1.75 × 10^6 m^3/s of Atlantic water with a salinity of 36.25‰ flow into the MS from which ~70,000 m^3/s are lost by the

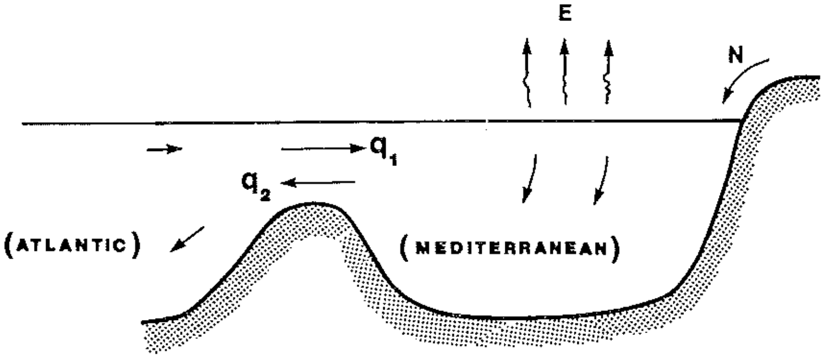

Fig. 1. Schematic diagram of the exchange of water between the Atlantic Ocean and the Mediterranean Sea.

0040-2826/79/060558-07$02.50/0

excess of evaporation over runoff and precipitation (Defant, 1961; Sverdrup et al., 1942). The Atlantic water circulates in the MS in a counterclockwise sense (Sverdrup, 1942) and returns to the Atlantic Ocean having a salinity of 37.75‰ (Defant, 1961, Sverdrup, 1942). Since the salinity of the return flow is determined by the excess of evaporation over runoff and precipitation, it is expected that a diversion of rivers may cause an increase in the salinity of the return flow. This study examines the possible increase of salinity and its effects on the exchange between the Atlantic Ocean and the MS.

We shall consider a dynamical model for the Mediterranean basin (Fig. 1) and examine the steady-state balances before and after the diversion. The equations for conservation of volume and salinity are applied and the principle of maximum transport through the Straits of Gibraltar is invoked. Since the equilibrium state after the diversion is expected to differ only slightly from the state prior to the diversion a perturbation technique is applied.

A complete renewal of all the water in the MS basin requires a period of about 75 years (Sverdrup, 1942) and it is therefore expected that any changes which are made along its shores will reach the Straits of Gibraltar in a period which is shorter than this time. Since most rivers enter the basin in the eastern and northern regions a period of 25–50 years will probably be sufficient to reach the new steady-state balance in the Straits of Gibraltar.

This paper is organized as follows: The formulation of the problem is discussed in Section 2, and Section 3 contains the mathematical solution. In Section 4 we discuss the results and validity of the approximations made in Sections 2 and 3. Section 5 summarizes this work.

2. Formulation

The model is formulated under the assumption that the diverted water is completely removed and does not enter the MS via evaporation from land and a subsequent precipitation over the sea nor via groundwater. It is further assumed that the excess of evaporation over runoff and precipitation, excluding the amount of water which is diverted, remains unaltered. That is, we assume that the diversion causes negligible variations in the actual evaporation rate and negligible changes in the exchange between the MS and the Black Sea, and in other sources of fresh water. Under such conditions the diversion causes an increase in the excess of evaporation over precipitation and runoff. While this approximation is plausible, it is not *a priori* obvious that it is a valid assumption since variations in the sea surface temperature which affect the evaporation rate may occur as a result of the diversion. It will be shown later, however, that the expected variations in the evaporation rate and in the exchange between the MS and the Black Sea are much smaller than the amount of water which is diverted and therefore can be neglected.

Under such conditions conservation of volume gives (see Fig. 2) for the steady states prior and after diversion:

$$q_1 = q_2 + \tilde{E} \qquad (1)$$

where q_1 and q_2 are the inflow and outflow through the Straits of Gibraltar and $\tilde{E}$ is the excess of evaporation over runoff, precipitation and the net inflow from the Black Sea.

Since there are no sources of salt in the MS, conservation of salt gives:

$$q_1 S_1 = q_2 S_2 \qquad (2)$$

where S_1 and S_2 are the salinities of the upper and lower layer (inflow and outflow) respectively.

Following Whitehead et al. (1974) we assume that the Straits of Gibraltar act as an "hydraulic control". That is, we assume that for a given amount of energy the transport will be maximized which implies that the internal Froude number will be unity (Officer, 1976):

$$q_1^2/n^3 + q_2^2/(1-n)^3 = g^* b^2 D^3 \qquad (3)$$

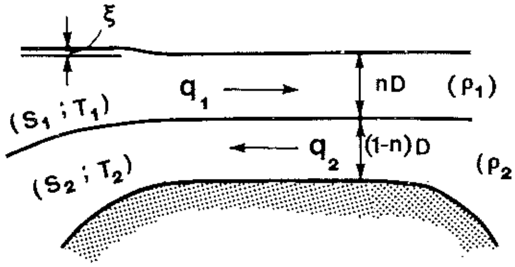

Fig. 2. Schematic diagram of the flow through the Straits of Gibraltar, q_1 and q_2 are the transports of the upper and lower layer respectively. ξ is the height difference between the free surface in the Atlantic Ocean and the free surface in the strait.

where nD is the depth of the upper layer, D the total depth, b the strait width and g^* is the "reduced gravity" given by:

$$g^* = \left(\frac{\rho_2 - \rho_1}{\rho_1}\right) g \approx \frac{(S_2 - S_1)\beta}{\rho_1} g \tag{4}$$

where ρ_1; ρ_2 are the densities of the upper and lower layer respectively, and β is the "expansion" coefficient for salinity.

The effect of the average temperature difference between the upper and the lower layer (1 °C according to Sverdrup, 1942) on the density difference has been neglected since the salinity difference (1.5‰) has a much larger contribution which is comparable to a contribution of ~8 °C temperature difference.

Equation (3) does not include effects of the earth's rotation which have been considered by Whitehead et al. (1974) nor frictional effects which have been studied by Assaf and Hecht (1974). However, since for the Straits of Gibraltar these effects do not alter the condition of "hydraulic control" substantially it is believed that our model will serve adequately to illustrate the fundamental points under discussion.

The height difference between the free surface in the Atlantic Ocean and the free surface at the strait (ξ) is found by applying the Bernoulli principle along the free surface. Assuming that the velocity in the Atlantic Ocean is very small compared to the velocity in the strait, one finds:

$$\xi = q_1^2/2gb^2 n^2 D^2 \tag{5}$$

Equations (1), (2), (3), and (5) hold for both equilibrium stages. For the basic state (i.e., the steady-state balance prior to the diversion) all quantities are known but for the state after diversion only S_1, b and $\tilde{E}$ are known since S_1 and b remain unaltered and $\tilde{E}$ can be found from the excess of evaporation over runoff, precipitation, and the amount of water which is diverted. In other words, for the state after diversion we have six unknowns [q_1, q_2, S_2, n, ξ and D] but only four equations [(1), (2), (3), and (5)]; two additional conditions are necessary in order to solve the problem. It will be shown in the next section, however, that a perturbation analysis and scaling indicate that the variations of n and D can be neglected and this enables us to solve the problem.

3. Analysis

In order to solve the set (1–5) the variables are split into two parts and a perturbation technique is applied. The basic state is taken to be the one corresponding to the state prior to the diversion and the perturbations are the deviations caused by the diversion, e.g.,

$$q_1 = \bar{q}_1 + q_1'; \quad n = \bar{n} + n' \tag{6}$$

where bars denote the basic state and primes denote perturbations. As mentioned earlier the salinity S_1 is taken to be unaltered since it corresponds to Atlantic water.

Equations (1) and (6) give for the basic and perturbed states:

$$\bar{q}_1 = \bar{q}_2 + \hat{E} - N \tag{7}$$

$$\bar{q}_1 + q_1' = \bar{q}_2 + q_2' + \hat{E} \tag{8}$$

where $\hat{E}$ is the excess of the evaporation over precipitation and runoff, excluding the amount of water which is diverted (N). Equations (7) and (8) give:

$$q_1' = q_2' + N \tag{9}$$

By substituting (6) into (2), (3), (4) and (5), neglecting products of the perturbations and subtracting the basic state the following equations are obtained:

$$q_1' \bar{S}_1 = \bar{q}_2 S_2' + q_2' \bar{S}_2 \tag{10}$$

$$\frac{2\bar{q}_1 q_1'}{(\bar{n})^3} + \frac{2\bar{q}_2 q_1'}{(1-\bar{n})^3} + 3n'\left[\frac{\bar{q}_2^2}{(1-\bar{n})^4} - \frac{\bar{q}_1^2}{(\bar{n})^4}\right] = g'b^2(\bar{D})^3 + 3\bar{g}(\bar{D})^2 b^2 D' \tag{11}$$

$$g' = \beta S_2' g/\rho_1 \tag{12}$$

$$D' = \bar{q}_1(\bar{q}_1 n'/\bar{n} - q_1')/g(\bar{n})^2(\bar{D})^2 b^2 \tag{13}$$

Equation (13) has been derived by considering the condition that the free surface height of the Atlantic Ocean is fixed (which requires $\xi' = -D'$) and noting that $|\xi| \ll \bar{D}$.

It is easy to show that if $\bar{q}_1 \approx \bar{q}_2$ and $\bar{n} \approx 0.5$ the quantity in the square brackets in (11) is very small and the third term on the left-hand side can be neglected. By using the actual values for $\bar{q}_1$, $\bar{q}_2$, $\bar{n}$ and n' it will be shown later (in Section 4) that the neglect of this term is justified. Equation (11) can be further simplified by noting that substitution of (13) into (11) indicates that the second term on the right-hand side of (11) is of the order of the terms on the left-hand side times $\Delta\rho/\rho$ and therefore can be neglected. Hence, (11) reduces to:

$$\frac{2\bar{q}_1 q'_1}{(\bar{n})^3} + \frac{2\bar{q}_2 q'_2}{(1-\bar{n})^3} = g' b^2 (\bar{D})^3 \tag{14}$$

It is now clear that the perturbation analysis and the neglect of the third term on the left-hand side of (11) reduced the number of unknowns and enables us to solve the set. Equations (9), (10), (14), and (12) contain only four unknowns q'_1, q'_2, S'_2 and g' and it is now possible to obtain an expression for each of them. By eliminating q'_2, S'_2, and g' from (9), (10), (14), and (12) one obtains:

$$q'_1 = N\left[\gamma\beta\bar{S}_2 + \frac{2\bar{q}_2}{(1-\bar{n})^3}\right]\left[\frac{2\bar{q}_1}{(\bar{n})^3} + \frac{2\bar{q}_2}{(1-\bar{n})^3} + \gamma\beta(\bar{S}_2 - \bar{S}_1)\right]^{-1} \tag{15}$$

where

$$\gamma \equiv b^2 (\bar{D})^3 g/\bar{q}_2 \rho_1 \tag{16}$$

Equation (15) gives the increase of transport into the MS as a function of the variables corresponding to the state prior to the diversion and the amount of water which is diverted (N). With the aid of (15) the increase of the outflow transport and salinity (q'_2 and S'_2) can be calculated from (9) and (10).

We shall now estimate the expected variation in the temperature field. The Atlantic water enters the MS with an average temperature of 14 °C and is cooled to 13 °C during its residence time (Sverdrup, 1942). The equation for conservation of heat flow for a mass flux M_1 with a temperature T_1 which is cooled to T_2 is:

$$C_p M_1 T_1 - H = C_p M_1 T_2 \tag{17}$$

where C_p is the heat capacity at constant pressure and H is the heat loss. The latter is given by:

$$H = Q_e + Q_s + LW - SW \tag{18}$$

where Q_e is the heat loss due to evaporation, Q_s the sensible heat loss, LW the net heat loss by long wave and SW is the net short wave heat gain.

To find the relationship between the state after diversion to that prior to the diversion we use, as previously, a perturbation technique. Noting that T_1 remains unaltered, due to its association with Atlantic water, we take:

$$M_1 = \bar{M}_1 + M'_1; \quad T_2 = \bar{T}_2 + T'_2;$$
$$H = \bar{H} + H'; \quad T_1 = \bar{T}_1.$$

By substituting these new quantities into (17) one obtains:

$$C_p M'_1 (\bar{T}_1 - \bar{T}_2) = H' + C_p \bar{M}_1 T'_2 \tag{19}$$

where H', the change in the heat loss, is given by:

$$H' = Q_e' + Q_s' + (LW)' - (SW)' \tag{20}$$

Assuming that the conditions in the air above the MS are not affected by the diversion one finds that the only possible change in the heat loss is due to variation of the sea surface temperature (hereafter, referred to as SST). Since the lower layer is formed by evaporation and sinking (see Fig. 1) it is not entirely clear that the diversion will cause any changes in the SST. However, it is clear that if there will be a change in the SST it will not be larger than T'_2. In order to estimate the maximum temperature change we shall assume that T'_2 corresponds also to a change in the SST but it will become clear later that this assumption is not essential. By inspecting the dependence of Q_e, Q_s, LW and SW on the SST (see e.g., Bunker, 1976) one finds that if $T'_2 > 0$ then $H' > 0$ and if $T'_2 < 0$ then $H' < 0$. That is, an increase of SST causes an increase of the heat loss and vice versa. Since the left-hand side of (19) is positive ($M'_1 > 0$; $\bar{T}_1 > \bar{T}_2$) it follows that $T'_2 < 0$ is impossible and one concludes that the temperature must increase after the diversion ($T'_2 > 0$). Therefore, the upper bound for T'_2 is found simply by setting $H' = 0$ in (19):

$$T'_2 \leq \frac{M'_1}{\bar{M}_2}(\bar{T}_1 - \bar{T}_2) \tag{21}$$

Equation (21) gives the maximum temperature change in the lower layer and allows us to estimate the possible changes in the evaporation rate over the basin as will be shown in the next section.

4. Results and discussion

In this section we shall evaluate the corresponding changes (q'_1; q'_2; S'_2; T'_2) and examine the validity of the assumptions made in Sections 2 and 3, in particular the assumption regarding the unaltered evaporation rate.

We shall first determine the numerical values of the variables corresponding to the basic state. As mentioned in Section 1, for the Straits of Gibraltar, $\bar{q}_1 = 1.75 \times 10^6$ m^3/s; $\bar{q}_2 = 1.6805 \times 10^6$ m^3/s; $S_1 =$ 36.25‰ and $\bar{S}_2 =$ 37.75‰. The depth above the sill is about 300 m and the strait average width (corresponding to the 100 m depth contours) is ~12.1 km. These values were determined from a cross section along the sill given by Frassetto (1960). By taking into account an average temperature of 13.5 °C one finds that the unperturbed densities of the upper and lower layers are $1.02710 \cdot 10^3$ kg/m^3 and $1.02835 \cdot 10^3$ kg/m^3 respectively. Using these values and application of (3) to the basic state [i.e., $\bar{q}_1^2/(\bar{n})^3 + \bar{q}_2^2/(1 - \bar{n})^3 = \bar{g}b^2 (\bar{D})^3$] one finds two positive roots for $\bar{n}$:

$$\bar{n}_1 = 0.514 \quad \text{and} \quad \bar{n}_2 = 0.496$$

These two roots differ only slightly from each other which shows that the unperturbed basic flow is close to the state of "overmixing" as defined by Stommel and Farmer (1953) for estuaries. We chose to work with the first root ($\bar{n}_1 = 0.514$) since a cross section along the strait given by Defant (1961) shows that above the eastern sill [where the depth is ~300 m according to Frassetto (1960)] the limit between currents of different direction lies somewhat below mid-depth (150 m). It should be pointed out, however, that the results discussed below are not very sensitive to this choice. If the second root had been chosen, similar values would have been obtained.

Substitution of the known quantities into (15) and (9) gives:

$$q_1' \approx 8N; \quad q_2' \approx 7N$$

We see that the increase of transport through the Straits of Gibraltar is substantially larger than the amount of water which is diverted (N). This results from the flow in the straits being controlled by the salinity difference between the upper and lower layer which is sensitive to the freshwater discharge into the MS.

For the diversion of the Nile, whose discharge to the MS was ~1060 m^3/s (Rzoska, 1976), one finds that the transport into the MS will increase by ~8500 m^3/s which is ~0.5% of the transport prior to the diversion. If all the runoff which enters the MS (7300 m^3/s according to Sverdrup, 1942) was to be diverted an increase of ~3.5% will occur.

The increase in salinity of the flow into the Atlantic Ocean, associated with the diversion of the Nile alone, is ~1.6×10^{-2}‰ which corresponds to a lower layer new salinity of 37.77‰ and an increase of ~1% in the salinity difference. Using these new values it is now possible to estimate the change in the interface depth and to find whether the neglect of the third term on the left-hand side of (11), which was made earlier, is justified. To do so one substitutes the new values into (3) to find that the new root (corresponding to $\bar{n} = 0.514$) is $n = 0.517$. This gives $n' = 0.003$, for which the neglected term in (11) is ~10% of the other terms which indicates that its neglect is adequate. Note that the new value of n shows that the interface will deepen by ~90 cm as a result of the diversion.

We shall now show that the neglect of the change in the evaporation rate is justified. It is recalled that the evaporation enters the problem through its excess over precipitation and runoff as it appears in eqs. (7) and (8). Assuming that the precipitation and all runoff except the Nile remain unaltered it is sufficient to show that the expected change in the evaporation rate is much smaller than the amount of water which is diverted (N). The evaporation rate in mm/day has been given by Jacobs (1942) in the form:

$$E = 0.143(e_w - e_a)\, U$$

where e_w is the vapor pressure over the water in millibars, e_a the vapor pressure in the air (at anemometer level) and U is the air velocity in m/s at the same height. Assuming that the conditions in the air, at anemometer level, remain unaltered we obtain that the change in the evaporation rate (ΔE) is given by:

$$\Delta E = 0.143 \Delta e_w\, U \tag{22}$$

where Δe_w depends both on the changes in temperature and salinity. The maximum change in the SST due to the diversion is given by (21), which for the diversion of the Nile gives $T_2' \leq 0.005$ °C. Using this value one finds that a typical increase in the vapor pressure is ~0.005 mb (List, 1971). Similarly, for a salinity increase of ~0.016‰ one finds that the vapor pressure will decrease by ~10^{-5} mb (List, 1971). By considering these quantities, a typical air velocity of 5 m/s (at anemometer level) and a total evaporation rate of 145 cm a year, corresponding to 115,000 m^3/s (Sverdrup, 1942), one finds that due to temperature change the evaporation rate may increase by

100 m^3/s. Due to the salinity increase the evaporation will decrease by less than 1 m^3/s. Both quantities are much smaller than the amount of water which is diverted (1060 m^3/s) which shows that the neglect of the change in the evaporation rate is adequate.

We shall now examine the validity of the assumption regarding the exchange between the MS and the Black Sea. The neglect of the variation in this exchange is justified by the following reasoning. The principle of maximum transport for the strait connecting the MS and the Black Sea gives in view of (3):

$$q^2 = 0[\tilde{g}B^2 d^3] \tag{23}$$

where q is the transport, $\tilde{g}$ the "reduced gravity", B the width and d is the total depth. The relative change in the transport is:

$$\Delta q/q = 0[\Delta\tilde{g}/2\tilde{g}] = 0[S_2'/2(S_2 - S_3)] \tag{24}$$

where S_2 is the salinity of the lower layer (Mediterranean water), S_3 the salinity of the upper layer (Black Sea water) and S_2' is the increase of salinity in the MS which was found earlier to be 0.016‰. The salinity difference between the Black Sea and the MS is ~17‰ and the inflow into the MS is ~17,000 m^3/s (Sverdrup, 1942). For these quantities one finds by (24) that the expected change in the exchange between the MS and the Black Sea is 0 (10 m^3/s) which is two orders of magnitude smaller than the amount of water which is diverted. Hence, the neglect of the change in the interaction between the MS and the Black Sea is adequate.

Before concluding the discussion it should be emphasized that since our model is a box model it predicts the mean changes, in temperature and salinity, over the whole basin. These predictions are not necessarily equal to the actual changes that will occur in various locations.

5. Summary

Before listing our conclusions it is perhaps appropriate to stress once more the limitations of this study. The model is formulated under the assumption that the diversion is complete in the sense that no diverted water reaches the MS via evaporation over the land and a subsequent precipitation over the sea nor via groundwater. In reality, some diverted water may eventually reach the sea and this may alter the results. Other processes which may affect the results are the minor changes in the evaporation rate, and the influence of the complex geometry of the Straits of Gibraltar which have been neglected.

The model predicts that a diversion of rivers will cause an increase in both the salinity and temperature of the water flowing from the MS into the Atlantic Ocean. This increase is accompanied by an increase in the transport to and from the MS (through the Straits of Gibraltar). It is found that the transport increase is substantially larger than the amount of water which is diverted and amounts to about eight times the diverted discharge.

For the diversion of the Nile alone, the predicted increase in the salinity and temperature differences between the upper and lower layer in the Straits of Gibraltar are ~1% and ~0.5% respectively and the predicted increase in the transports is ~0.5%. If all runoff flowing into the MS was to be diverted a transport increase of ~3.5% will take place; the associated relative increases in the salinity and temperature difference between the upper and lower layer are ~7% and ~3.5% respectively.

The main purpose of this study is to point out that the Mediterranean Sea, being an enclosed basin connected to the Atlantic Ocean by a narrow strait, is a sensitive physical system. Consequently, the effects of a diversion of rivers for agricultural purposes are not confined to the immediate vicinity of the outflow but extend to the entire basin and to the Atlantic Ocean.

6. Acknowledgements

This research was supported by NSF under Grant ATM-77-28126 and Grant ATM-75-22940.

REFERENCES

Aagård, K. and Coachman, L. K. 1975. Toward an ice-free Arctic Ocean. *Trans. Amer. Geophys. Union 56*, 484–486.

Assaf, G. and Hecht, A. 1974. Sea straits—a dynamical model. *Deep-Sea Res. 21*, 947–958.

Bunker, A. F. 1976. Computations of surface energy flux and annual air-sea interaction cycles of the North Atlantic Ocean. *Mon. Weather Rev. 104*, 1122–1140.

Defant, A. 1961. *Physical oceanography*, Vol. 1. Pergamon, 729 pp.

Frassetto, R. 1960. A preliminary survey of thermal microstructure in the Straits of Gibraltar. *Deep-Sea Res. 7*, 152–162.

Jacobs, W. C. 1942. On the energy exchange between sea and atmosphere. *J. Mar. Res. 5*, 37–66.

List, R. J. 1971. *Smithsonian meteorological tables.* Smithsonian Institution Press, 527 pp.

Officer, C. B. 1976. *Physical oceanography of estuaries (and associated coastal waters).* Wiley, 465 pp.

Rzoska, J. 1976. A controversy reviewed: The arguments over the Aswan High Dam on the river Nile continue. *Nature 261*, 444–445.

Stommel, J. and Farmer, H. G. 1953. Control of salinity in an estuary by a transition. *J. Mar. Res. 12*, 13–20.

Sverdrup, H. V., Johnson, M. W. and Fleming, R. H. 1942. *The oceans.* Prentice-Hall, 1087 pp.

Whitehead, J. A., Leetmaa, A. and Knox, R. A. 1974. Rotating hydraulics of strait and sill flows. *Geophys. Fluid Dyn. 6*, 101–125.

Woods, J. D. 1979. Modelling oceanic transport in studies of climate response to pollution. *Proceedings of the international conference on man's impact on climate* (ed. W. Bach). Elsevier. In press.

О ВЫЗВАННЫХ ЧЕЛОВЕКОМ ИЗМЕНЕНИЯХ ЦИРКУЛЯЦИИ В СРЕДИЗЕМНОМ МОРЕ

С помощью упрощенной динамической модели для бассейна Средиземного моря исследовалась его реакция на забор воды из рек, таких как Нил, для сельскохозяйственных нужд. Решения получены при использовании принципа “гидравлического контроля” в Гибралтарском проливе, сохранения объема и солености и метода возмущений. Найдено, что такой забор вызывает увеличение солености в бассейне и изменяет обмен между Средиземным морем и Атлантическим океаном. Предсказывается увеличение переноса через Гибралтарский пролив. Это увеличение переноса как в Средиземное море, так и из него, примерно в восемь раз больше количества забираемой воды и ожидается, что оно произойдет в течение 25–50 лет после забора. Если учитывать только Нил, заборы из которого начались в середине 1960-х годов, то перенос через Гибралтарский пролив увеличится примерно на 0,5%, а если весь сток в Средиземное море будет задерживаться, то увеличение переноса будет примерно на 3,5%.