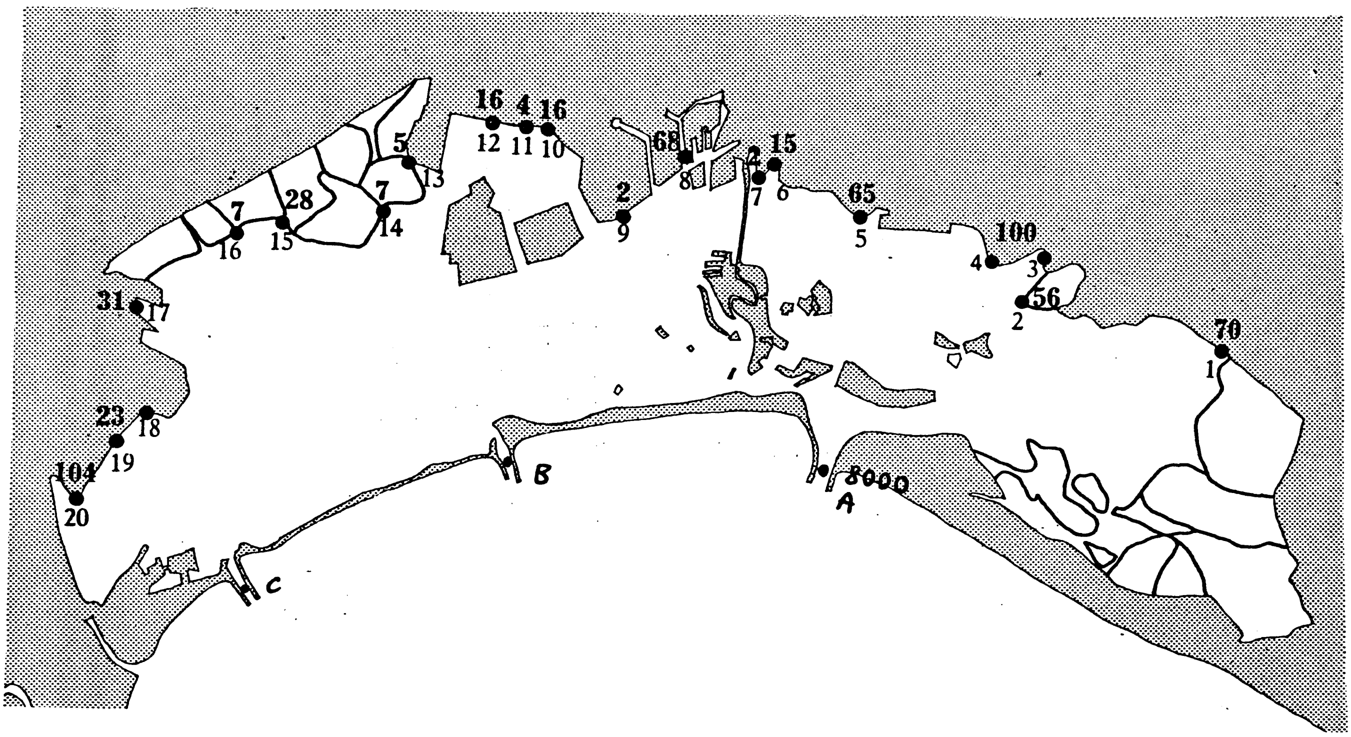
Title : TIDAL INDUCED EXCHANGES OF WATER PROPERTIES IN THE VENICE LAGOON

Authors : L.Battiston, A. Giommoni, L. Pilan, S. Vincenzi
Istituto per lo studio della dinamica delle grandi masse
1364 S.Polo VENEZIA

INTRODUCTION

Fresh water entering the lagoon,comes from various natural and artificial channels. It amounts to about 600 m^3/ sec at its maximum (ref.1),but it varies largely,depending on seasonal and meteorological conditions,down to about 200 m^3/ sec. Nevertheless,it maintains the salinity of the lagoon definitely at a lower level (about 5‰) with respect to the sea.
Recent and historical measurements of water currents through the three inlets,collecting the lagoon with the sea, (ref. 2), give some values of the water quantities inflowing or outflowing for each inlet,which on average are of the order of 10^8 m^3.
The fluxes reach the maximum value of about 8.ooo m^3/sec in correspondence of 120–150 cm/sec speeds.
This situation is described in fig. 1



In this figure (ref.1) the superior numbers give the maximum fluxes in m^3/sec.
Inferior numbers indicate the position and the progressive number of the fresh water sources
A,B,C, are respectively Lido ,Malamocco,Chioggia inlets;

1 – THE SALINITY BEHAVIOUR

The water inflowing and outflowing through the inlets has a varying salinity due to the tidal cycle. We have measured the salinity at some cross–sections of the inlets and the main feature of the salinity behaviour (fig.2,3)is its slowly decreasing during outflowing and sudden increasing with incoming tide,and then reaching a constant value for the last part of the cycle.

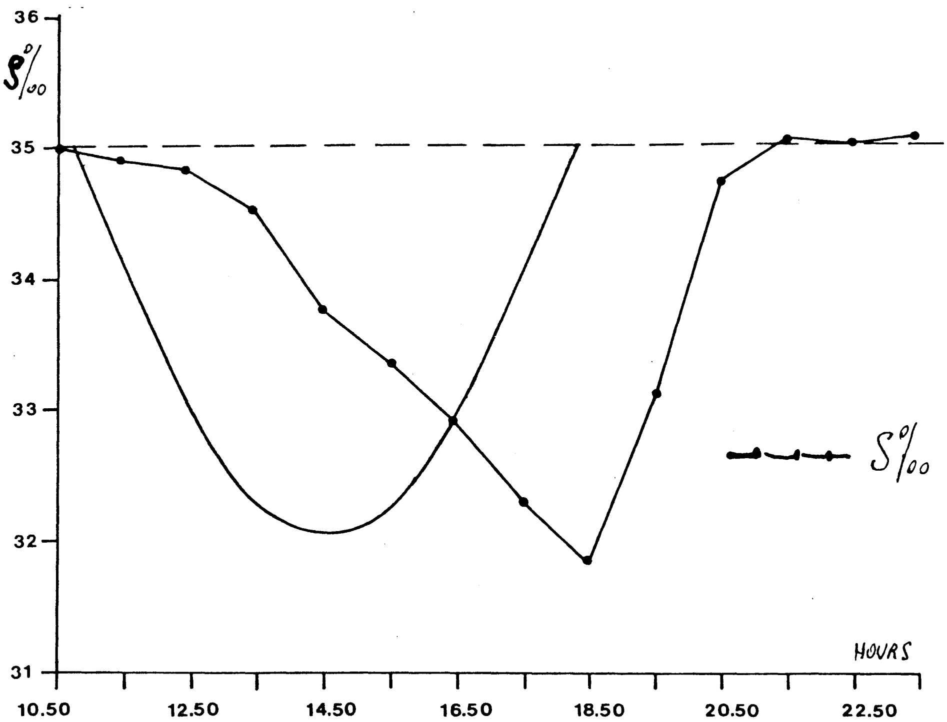


fig.2 (Lido '75) – Salinity and water flux behaviour.Water flux in arb. units

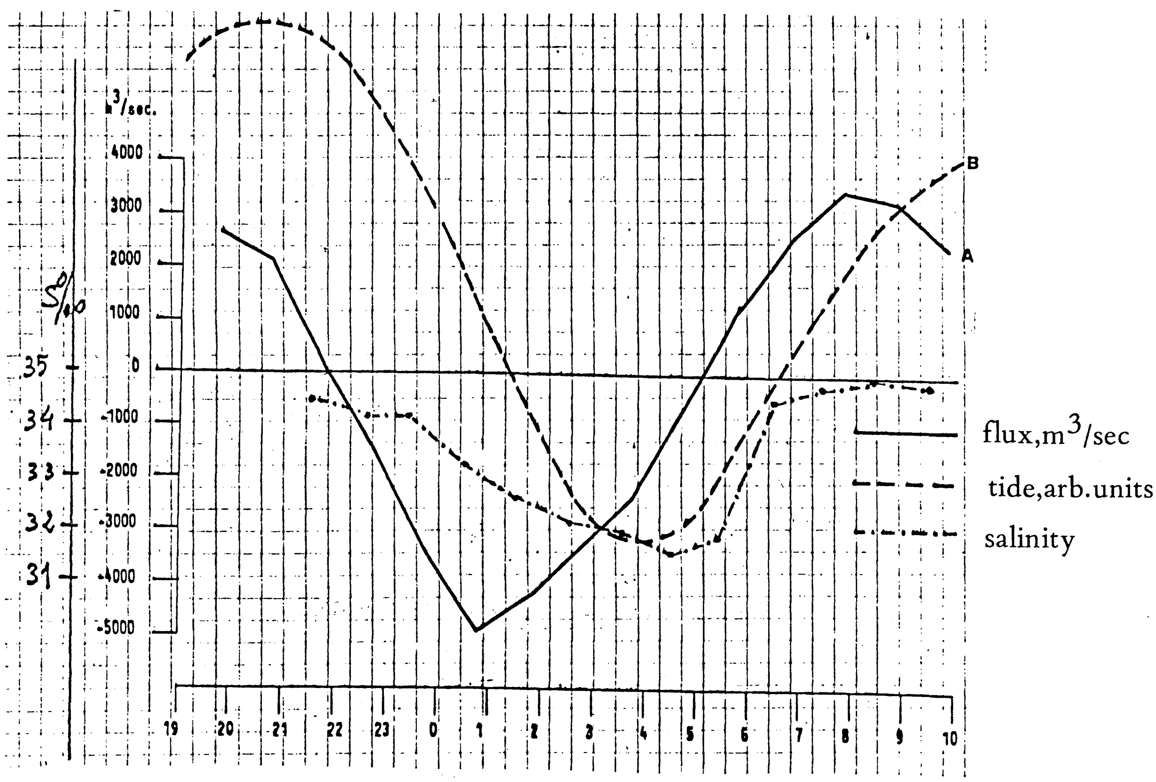


fig.3 (Malamocco '77) – Salinity,water flux and tide behaviour

It is evident from fig.2 and fig.3,that the sudden increasing of the salinity is due to the mixing of the sea water with some part of the lagoon water outflowed. If the maximum value of the salinity is roughly constant for several cycles,we assume this value as a characteristic one for the salinity of the sea.

2 – THE CHARACTERISTIC TIME OF RENEWAL OF WATER

Starting from the characteristics of water and salt fluxes at the inlets,we have investigated the problem of the renewal of the polluted water in the Venice lagoon,using frsh water as a tracer, and we propose a method for the determination of a characteristic time of renewal of the fresh water,which behaves more or less like a pollutant,as far as concentration is concerned.
Let us introduce the quantity:

(1) $$\rho \frac{S_m - S(t)}{S_m} P(t)$$ where

ρ – water density
S_m – sea salinity
$P(t)$ – water flux trough one inlet
$S(t)$ – mean salinity in the inlet at time t

Now (1) represents the quantity of fresh water which outflows trough one inletin the unit time (if $P>0$) or which incomes (if $P<0$).Consequently the integrals:

(2) $$\int_0^{t_1} \rho \frac{S_m - S(t)}{S_m} P(t)\,dt$$

(3) $$\int_{t_1}^{T} \rho \frac{S_m - S(t)}{S_m} P(t)\,dt$$

represent respectively the quantity of fresh water which outflows in the interval $(0-t_1)$ and which comes into again inthe next phase in the interval $(t_1 - T.)$
The sum of (2) and (3) represents the net of fresh water which leaves the lagoon per tidal cycle.
Let us define the parameters :

(4) $$r = \int_0^{t_1} \rho \frac{S_m - S(t)}{S_m} P(t)\,dt \Big/ \int_0^{t_1} \rho\, P(t)\,dt$$

(5) $$p = \int_{t_1}^{T} \rho \frac{S_m - S(t)}{S_m} P(t)\,dt \Big/ \int_0^{t_1} \rho \frac{S_m - S(t)}{S_m} P(t)\,dt$$

r is the ratio between the quantity of fresh water which outflows and the quantity of the total water which outflows in the same phase.
p is the ratio between the quantity of fresh water which comes into again and the quantity of fresh water outflowed during the preceding phase.
We have calculated the values of r and p for two different situations : at Lido inlet in decem ber 1975 and Malamocco inlet in june 1977. The figures 2 and 3 give the description of the behaviour of the water flux and of salinity in function of time for the two cases. In the first case it has not been possible to evaluate the water flux in the phase of incoming tide; for this reason we are not able to calculate p directly,but assuming that the flux is consistent with one half sine with the same amplitude of the preceding phase,it possible to give an indicative value of p also for the Lido inlet.

We have assumed for S_m the roughly constant value which S(t) reaches after the sudden increasing during incoming tide. see fig.2,3. In both cases S_m is very near to 35‰ .
From these considerations we have the following result :

	Lido inlet	Malamocco inlet
r	~ 3%	~ 6%
p	~ 28%	~ 16%

The values of r and p are quite sensible to the value assumed for S_m and this value is too critic if the salinity differences along the cross section are not negligible with respect to the total escursion of the salinity of outflowing water and the method would not be applicable any longer. But this is not the case for the situatios we have studied.(ref. 3).
We wish to point out that,as in the case of Malamocco inlet,the behaviour of S seems to show a "maximum" ;then S_m could coincide with this maximum or have an higher value.
If,for instance,we assume for this case $S_m = 36/_{oo}$,we have $r \simeq 9\%$ and $p \simeq 25\%$
It is probably more convenient to adopt for the Malamocco inlet some intermediate values for r and p,say $r \sim 7-8\%$ and $p \sim 20\%$
In the Lido case $r \sim 3\%$ is much reliable (because of the stability of S_m),but p is affected by the incertainties already pointed out.

Let us suppose now that S_m is roughly constant for several tidal cycles and introduce the quantity :

(6) $$Q = \rho \frac{S_m - \langle S \rangle}{S_m} V$$ where

$\langle S \rangle$ is a temporal and spatial average of the salinity of the lagoon for several tidal cycles
V is the average volume of water in the lagoon.

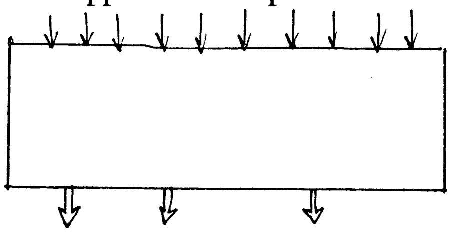
Then Q is the quantity of fresh water which is present on average in the lagoon.
Let us define the last quantity :

(7) $$\tau = \frac{Q}{\sum_{i=1}^{3} \int_0^T \rho \frac{S_m - S_i(t)}{S_m} P_i(t)\, dt}$$

where the sum is extended to the three inlets.
This quantity has the dimension of a time (espressed in tidal cycles) and which can be assumed as a renewal time for the fresh water considered as a tracer.
Up to this moment ,because of the fact that the long series data have not yet been processed, we can only argue that this time is of the order of 100 cycles,if $S \sim 28‰$ for instance is assumed.
An interesting approach to the the phisical meaning of the renewal time τ ,is offered by a very simple scheme of the lagoon.Let us suppose to idealize the lagoon with a rectangular basin of constant depth.In this picture (to be compared with the real situation in fig.1),all the sources of fresh water are along one major side (fig.4) and the three inlets in the opposite one.
The distribution of salinity is taken linearly increasing from side a to side b.

If one considers an exchange mechanism of diffusive type,from very simple calculations,one can deduce that after the time τ the value of concentration of fresh water is reduced to 1/3 of the initial value when one supposes to stop the sources of fresh water.

fig.4



This value of 1/3 should represent the maximum value of concentration of fresh water which remains after the time τ '.

REFERENCES

(1) – S.Cavazzoni : Acque dolci nella laguna di Venezia – T.R. n.64 – 1973
Ist.per lo studio della dinamica delle grandi masse – Venezia S.Polo 1364

(2) – Comune di Venezia –Assessorato ai LL.PP. – Ricerche sull'idrodinamica dei porti della laguna e del nodo del porto di Lido. – 1970

(3) – T.R.91 – T.R98 – 1978
Ist.per lo studio della dinamica delle grandi masse – Venezia S.Polo 1364