УДК 656.62.004

DYNAMIC MODELS OF ENC IN THE ESTUARIES OF RIVERS

ДИНАМИЧЕСКОЕ МОДЕЛИРОВАНИЕ ЭНК НА УСТЬЕВЫХ УЧАСТКАХ РЕК

I.I. Gladkykh, *DSc, professor,* **A.P. Checha**,*senior lecturer*
И.И. Гладких, *д.т.н., профессор*, **А.П. Чеча**, *ст. преподаватель*

National University "Odessa Maritime Academy", Ukraine
Национальный университет «Одесская морская академия», Украина

ABSTRACT

The rapid development of modern information technology allows us to pose and solve the most complex tasks in the field skipper timely information on the occurrence of imminent danger and to choose ways to avoid it.One of these tasks is to create a dynamic ENC, an image which is changed and displayed in real time, depending on fluctuations in sea surface and bottom topography changes. In the article the algorithm for creating dynamic ENCs by mathematical modeling of the dynamics of the surface oscillations of the sea and sea bottom.

Keywords: dynamic of sea surface, sea bottom, pressure, density, temperature, fluid, fluctuation, motion, equation, dynamic modeling.

Problem setting in general and its connection with important scientific and practical tasks

The Maritime practice determined an established trend of increased accident vessels associated with the grounding in shallow water in the estuaries of rivers. In these areas, there are permanent dynamic processes associated with changes in the bottom relief, changes in water levels in rivers and seas, the excitement ebbs and surges etc. In these circumstances, as is often the areas of coastal vessels with a limited draft, it is important to take into account the dynamic processes occurring in the environment. For instance, in the close maritime area of the Danube estuary, nearest the outlet Bystroe high of the waves reaches up to 7m where depth average is about 8-12m. It is clear that for passing ships in this weather you need to know the depths dynamic components of the changes in real time.So, as practice shows, for safety navigation this dynamic should be taken into account in real time.

Analysis of recent achievements and publications, in which a solution of the problem and the selection of the unsolved aspects of the problem are being under studying

Solution of this problem is stipulation to the fact that the sea surface is in permanently motion, both in the vertical and horizontal planes. In confirmation of this fact we can show below the *figures 1,2* which eliminated changes in the sea level surface in time, received from the satellites. In fig.1 we can see how to change the ocean level surface which was measured by satellite altitude observations. Daily change of the Black sea level surface reaches in *fig.2*

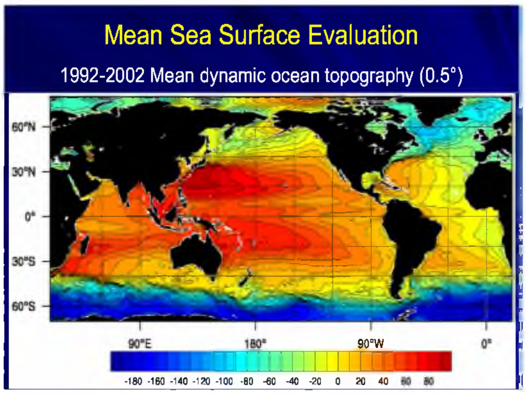


Fig.1. Ocean surface motion

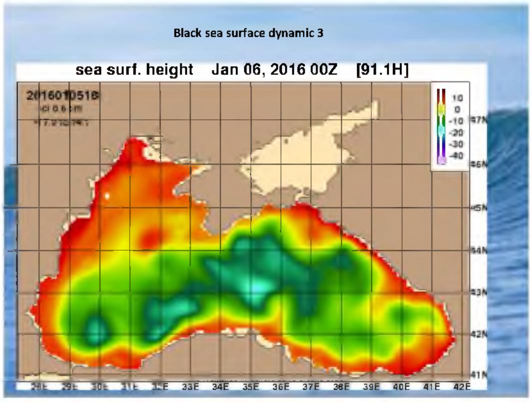


Fig.2. Black sea surface motion

The example of a research conducted by the Turkish, Ukrainian and Romanian scientists we can see that the Black Sea surface is in permanently motion as shown by the arrows in fig.3.

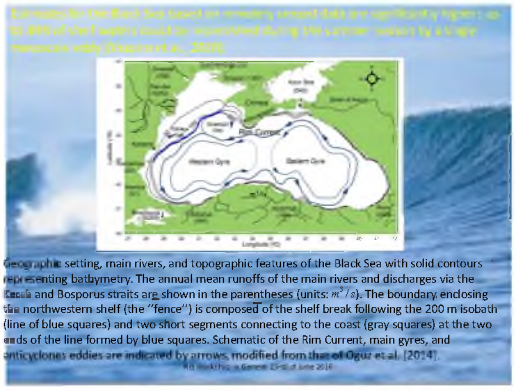


*Fig.3.*Black sea surface current

Purposes of the article (problem setting)

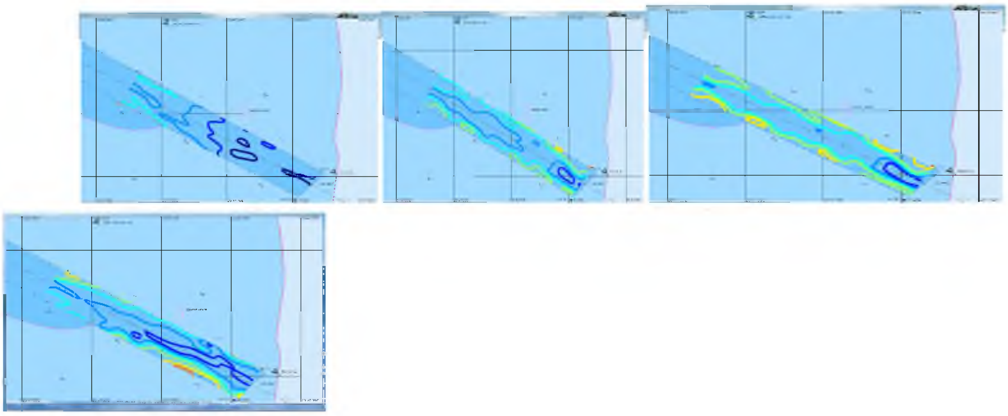
To create a mathematical model of the dynamics of the ENC in the mouth of the Danube carried out a number of studies, during which we installed hydro-meteorological buoy at theoutput of river (fig.4)

Fig.4.Hydrometeorological buoy

As a result of observation data obtained such that the parameters given below:

- Wind speed and direction; directional waves; visibility;
- Air temperature, air pressure and air humidity; buoy tracker;
- Current meter and sea temperature; current profiler; AIS unit.

At the same time hydro-meteorological observations performed repeated soundings by multibeamechosounder on the approaches to the Danube via the Bystroe Outlet, the results of which are shown in *fig.5 (a,b,c,d)*



a) *b) c) d)*

Fig.5.Soundings by multibeamechosounder

Main material research description with detailed analysis of the scientific results obtained

The results of repeated soundings indicate that in this area varies rather rapidly bottom relief over time. On the basis of field studies we developed an algorithm for constructing a dynamic model of the card shown in fig.6

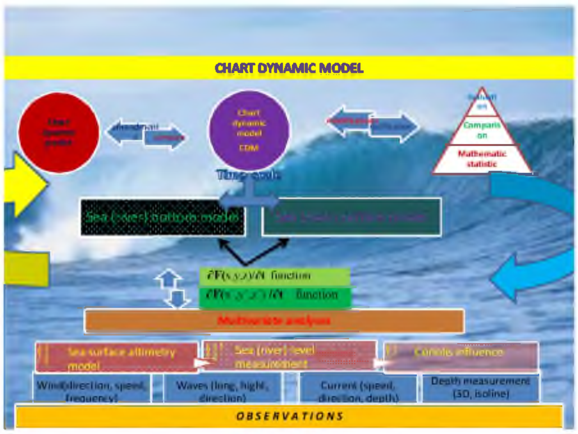


Fig.6. Chart dynamic modeling by algorithm

For modeling the dynamics of the sea level surface as a reference take Euler's equation to describe the motion of an inviscid fluid:

$$\frac{\partial U}{\partial t} + (U, \nabla) = -\frac{1}{\rho} gradP + F \quad (1)$$

with condition that div U = 0. (2)

Remark, that equation (1) we obtain from second Newton's law, where

U – fluid velocity; P – fluid pressure; ρ – fluid density; F – function of parameters

(x,y,z) and- t- time.

Velocity U (x,y,z,t) consist from components : u (x,y,z,t) ; v (x,y,z,t) ; ω (x,y,z,t) defined any point of surface (x,y,z,t) and t time.

Formulas (1) and (2) related to time t∊ (t_0; t_1).

We can take four restricted conditions, which is below [1]

$\partial D_1 - coastline;$

$\partial D_2 - seasurface;$

$\partial D_3 - floatingvessel;$

$\partial D_4 - simply/coastalsurface.$

For each condition we can define velocity vector properties – U.

For $\partial D_1; U_n = 0 or (U,n) = 0$.

For $\partial D_2 \to z = \xi(x,y,t)$ we following to the next conditions $\frac{\partial \xi}{\partial t} + (U, grad\xi) = \omega$;

P = P_a,where P_a – atmosphere pressure.

For $\partial D_3 \to G(x,y,z,t) = 0$ we following to the next conditions

$\frac{\partial G}{\partial t} + (U, gradG) = 0$.

For ∂D_4 we need certain velocity vector of explicit function. Whereas Euler's equations (1) and (2) closed to hyperbola, considering fluid in the field of action of potential forces:

F = grad A, where A – fluid flow potential in gravity field which action on the plumb line direction – z axis. A = gz.

For potential of movement velocity vector Γ along an arbitrary closed fluid circuit l is defined as

$$\frac{\partial \Gamma}{\partial t} = \frac{d}{dt}\int_l (U, d_x) = 0 . \qquad (3)$$

Using the Stokes theorem, we can write

$$\int_\ell (U, d_x) = \int_z (rotU, U) d\Sigma , \qquad (4)$$

where - ∑ is surface with circuit l. Whereas ∑ is arbitrary surface, it's mean that for all the time

$$\text{rot } U = 0 \ , \qquad (5)$$

and called vorticity. In (5) there is no rotation, in this reason we can use scalar function φ(x,t) – velocity potential

$$U = \text{grad } \varphi, \qquad (6)$$

here φ is harmonious function of Laplace

$$\Delta\varphi = \frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2} = 0 \ , \qquad (7)$$

taking into account of inertia equation can be written

$$grad(\frac{\partial \varphi}{\partial t} + \frac{u^2 + \upsilon^2 + \omega^2}{2} + \frac{P}{\rho} - A) = 0, \qquad (8)$$

and equation Koshi LaGrange

$$\left(\frac{\partial\varphi}{\partial t}+\frac{u^2+\upsilon^2+\omega^2}{2}+\frac{P}{\rho}-A\right)=\Phi, \tag{9}$$

where Φ = Φ(t) – arbitrary function at time t.

Assuming that

$$\Delta\varphi=0; U=grad\varphi$$
$$\frac{u^2+\upsilon^2+\omega^2}{2}+\frac{P}{\rho}-A=const. \tag{10}$$

Equation of inviscid compressed fluid motion are shown below

$$\frac{\partial U}{\partial t}+(U,\nabla)U=-\frac{1}{\rho}gradP+F \ ; \tag{11}$$

$$\frac{\partial\rho}{\partial t}+div(\rho U)=0 \ ; \tag{12}$$

$$\frac{ds}{dt}=\frac{\partial s}{\partial t}+(U,\nabla)_s=0 \ ; \tag{13}$$

$$P=P(\rho,s) \ , \tag{14}$$

where - s is entropy for water flow = const.

For shallow water we can write [2]:

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+\upsilon\frac{\partial U}{\partial y}=g\frac{\partial\xi}{\partial x} \ ; \tag{15}$$

$$\frac{\partial\upsilon}{\partial t}+U\frac{\partial\upsilon}{\partial x}+\upsilon\frac{\partial\upsilon}{\partial y}=g\frac{\partial\xi}{\partial y} \ ; \tag{16}$$

as a result of the dynamics of the sea surface equation can be written in the form of a medium-sized changes in the turbulent field:

$$\frac{\partial U}{\partial t}-[1-m\left(\frac{n}{m}\right)^{`}U]\upsilon+\frac{m}{\rho_0}\frac{\partial P}{\partial x}=\frac{\partial}{\partial z}\nu_u\frac{\partial U}{\partial z}+F^u \ ; \tag{17}$$

$$\frac{\partial\upsilon}{\partial t}+[1-m\left(\frac{n}{m}\right)^{`}\upsilon]U+\frac{n}{\rho_0}\frac{\partial P}{\partial y}=\frac{\partial}{\partial z}\nu_\upsilon\frac{\partial\upsilon}{\partial z}+F^\upsilon \ ; \tag{18}$$

$$\frac{\partial P}{\partial z}-g\rho=0 \ ; \tag{19}$$

$$m[\frac{\partial U}{\partial x}+n\frac{\partial}{\partial y}(\frac{\upsilon}{m})]+\frac{\partial\omega}{\partial z}=0; \tag{20}$$

$$\frac{dT}{dt}=\frac{\partial}{\partial z}\nu_T\frac{\partial T}{\partial z}+F^T; \tag{21}$$

$$\frac{dS}{dt}=\frac{\partial}{\partial z}\nu_S\frac{\partial S}{\partial z}+F^S; \tag{22}$$

$$\rho=\rho(T,S,P) \text{ in space D (x,y,z)} \tag{23}$$

Equations (17 – 23) making of solution our task in left side coordinate system(x,y,z),

where x – axis in along the latitude direction on east;

y - axis in along the longitude direction jn north;

z - axis in along plumb line direction in the center of earth.

D space is limited of ∂D for the undisturbed sea surface , i.e. Z= 0, coastline $\sum$ and bottom relief H(x,y) along the normal n_H . U, ϑ, ω – components of the velocity vector; T – potential of the temperature; S – salinity; P – pressure; ρ – density; ν_u; ν_ϑ; ν_T; ν_s - coefficients of vertical turbulent velocity and diffusion; μ_u; μ_ϑ; μ_T; μ_s – coefficients of horizontal turbulent velocity and diffusion; l – Carioles parameter.

CONCLUSION

Studies on the mouths of the Danube show us sufficiently intense dynamic processes as the water level of the surface and the bottom relief. On this basis, we propose in these areas to develop dynamic ENC that reflect the current situation isobaths in real time. An algorithm for constructing such ENCs proposed in this article.

REFERENCES

1. K. E.Trenberth. Progress during TOGA in understanding and modeling global teleconnections associated with tropical sea surface temperatures / K. E.Trenberth, G. W.Branstator, D.Karoly// Journal of Geophysical research, 1998.- p. 210-265. - Wiley Online Library.
2. A. J. Kettle. A global database of sea surface dimethylsulfide (DMS) measurements and a procedure to predict sea surface DMS as a function of latitude, longitude, and month / A. J. Kettle, M. O. Andreae, D. Amouroux, T. W. Andreae, T. S. Bates // Global biogeochemical Cycles, Volume 13, Issue 2,- June 1999 , Pages 399–444.
3. S.H. Yueh. Polarimetric measurements of sea surface brightness temperatures using an aircraft K-band radiometer / S.H. Yueh, W.J. Wilson , F.K. Li //IEEE Transactions on Geoscience and Remote Sensing, Vol.33, issue 1.- 1995, pages 85-92.
4. T. Hengl.Mathematical and Digital Models of the Land Surface / T.Hengl, I.S. Evans// - Developments in Soil Science. -Volume 33, 2009, Pages 31–63. Geomorphometry — Concepts, Software, Applications
5. Аббасов И. Б. Моделирование нелинейных волновых явлений на поверхности мелководья - М.: Физматлит, 2010. - 128 с.
6. Емельянов, С.В. Труды ИСА РАН: Алгоритмы. Решения. Математическое моделирование. Управление рисками и безопасностью - М.: Ленанд, 2014. - 102 с.