ZBIGNIEW BURCIU, D.Sc.Eng.
Gdynia Maritime University

The influence of south baltic hydro- -meteorological conditions on determining the survivors search domain

SUMMARY

The paper presents a model of near surface currents in the South Baltic, developed on the basis of the recent field research. The application of the model and the comparison of the results obtained by using the methods usually applied today and the new method, are presented.

INTRODUCTION

Planning and organisation of a Search and Rescue (SAR) action are directly influenced by meteorological and hydrological conditions. However , for the South Baltic area, calculations of the Datum which is the most probable position of the search object, can be erroneous, especially when following the Iinternational Maritime Organization (IMO) Manual procedures with respect to the local currents. The effectiveness of the actions carried out in the Polish SAR responsibility area is highly dependent on the proper identification of the local external factors: e.g. wind and currents in South Baltic.

The comparison of the methods used at present to determine the search area with the method proposed by the author made it possible to state that only the knowledge of the influence of near surface currents [1] specific for a particular sea area on velocity and direction of a drifting object can significantly decrease time to search, what means the SAR action efficiency increasing.

DETERMINATION OF THE LEEWAY AND THE SEARCH DOMAIN AREA (A) AROUND THE DATUM (P)

A wind current vector is always inclined to the right from the wind direction, for the north hemisphere above 10° latitude, Fig.1, [5][6][7]. It is necessary to determine, according to the IMO diagram given in Fig.1, the wind current vector to estimate the object's drift for the life rafts and survivors.

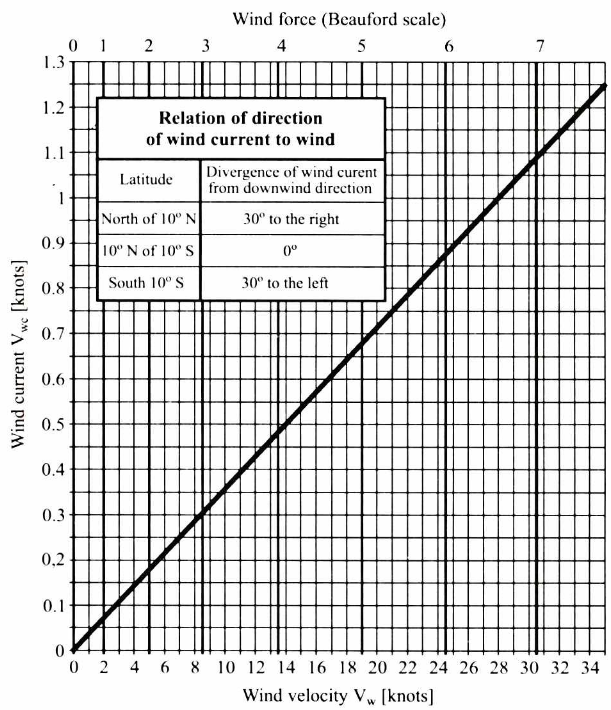

Fig.1. Relationship between the wind current direction and wind direction [5][6][7]

It is assumed that :

- the wind leeway vector is drawn downwind
- the direction of wind current vector should be diverged from the wind direction to the right by 30°.

The sum of these vectors is the drift vector of the search object, presented in Fig.2.

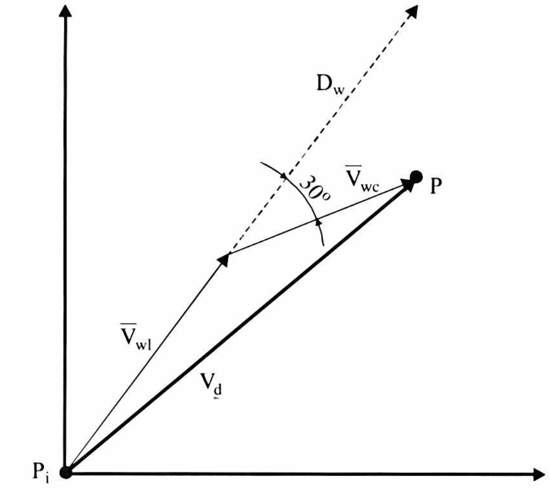

Fig.2. Determination of the leeway and Datum (P) of the search object [6]

where:

$\overline{V}_{wl}$ – wind leeway velocity vector
$\overline{V}_{wc}$ – wind current velocity vector
$\overline{V}_{d}$ – drift velocity vector
D_w – wind direction.

In the „International Aeronautical and Maritime Search and Rescue Manual". Volume 3 – „Mobile Facilities" [7], for the first stage of the search it is recommended to define a search domain of the radius R = 10 NM, {the surface area is the square of 400 $(NM)^2$}, Fig.3.

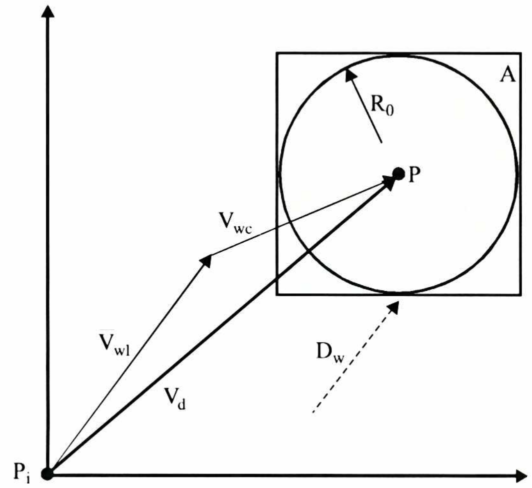

Fig.3. Determination of the search domain area (A) around the Datum (P), [6][7]

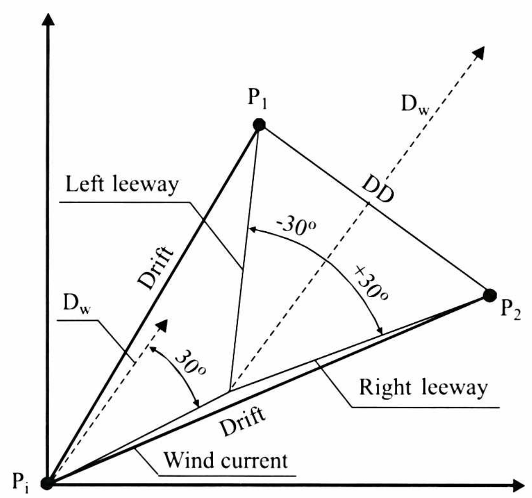

Fig.4.a. Graphically determined drifts of the search object, for Datums (P_1, P_2) and the distance between the Datums (DD)

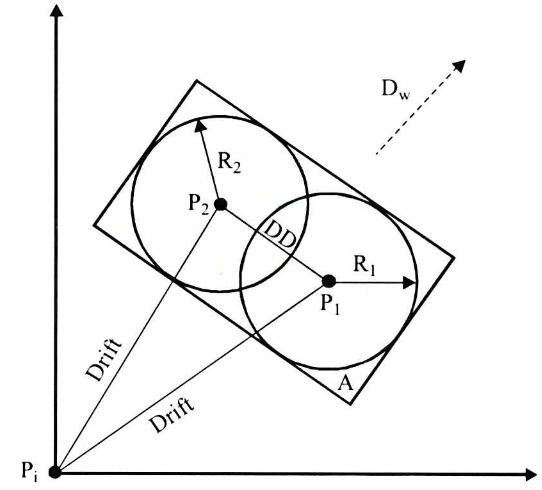

Fig.4.b. Graphically designated search domain with two Datums, [5]

The calculation model of the search domain for two Datums (P_1, P_2), *Leeway Divergence Datums*, is presented in Fig.4. The valid recommendations on the search domain determination take into account the drift error E_d in a different way [5].

COMPARISON OF THE MODELED NEAR SURFACE CURRENTS

The comparison of the modeled near surface currents area according to [1], [2], [3] with the IMO recommendations Fig.1 [5],[6],[7], shows that taking into consideration the influence of local conditions is necessary Fig.5., Fig.13.

A statistic elaboration of the results obtained from the research at sea, enabled to work out the surface currents area in function of the wind velocity and to estimate the level of wind velocities for the disappearing reverse current, on the left and right side of the wind direction.

For the winds of the velocity less than 18 knots, Fig.13, the influence of earlier existed hydrometeorological components is crucial, and it is impossible to construct, for the winds of the velocity less than 18 knots, a credible regression model describing the relationship between V_c and V_w. Therefore, it is assumed, taking into consideration measurement errors, that for such winds in the model V_c does not exceed 0.35 knots, Fig.13.

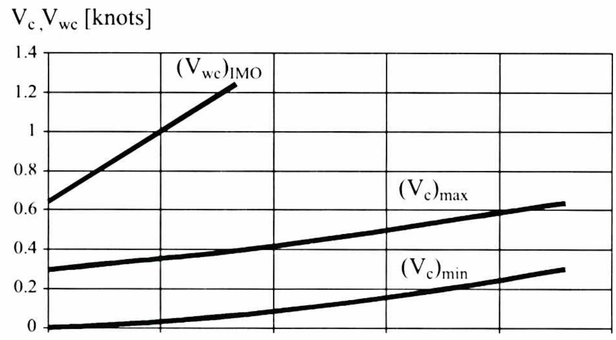

Fig.5. Model of the near surface current velocity (V_c) in function of the wind velocity (V_w) [1],[2] in relation to the model of the wind current (V_{wc}) according to IMO [6][7]

The analysis of the influence the South Baltic hydro-meteorological conditions carried out on the basis of the author's own measurements taken in the South Baltic area made it possible to develop the regression models of near surface current velocities and directions, which are presented in the tables below.

Tab.1. Model of the near surface current velocity

Wind velocity V_w [knots]	Near surface current velocity V_c [knots]
≤ 18	0 ÷ 0.35 (always greater than zero)
> 18	$(0.230446 + 0.0070957 \cdot V_w)^2 \pm 0.17$

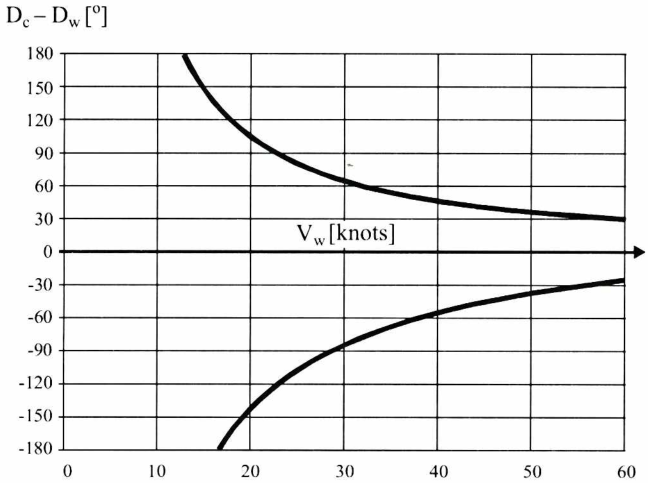

***Fig.6.** Left and right envelopes of the wind direction (D_c, D_w) in function of the wind velocity V_w*

***Tab.2.** Model of the sector of directions of near surface current, ($D_c - D_w$)*

V_w [knots]	To the left from the wind direction	To the right from the wind direction
≤ 18	Sector from –180° to 0°	Sector from 0° to 180°
> 18	$D_c - D_w =$ $= 1 / (0.00165675 +$ $- 0.000559348 \cdot V_w)$	$D_c - D_w =$ $= - 35.338 +$ $+ 3587.98 / V_w$

TWO DIMENSIONAL MODEL

The assumed shape of the search area [4], is presented in Fig.7. The axis of ellipse (l_1) depends on the V_c, V_w, E_{wV} and on the error of the leeway vector of the life rafts $(E_{wl})_r$, which depends on the life rafts loads:

$$l_1(t) = [Vc + (E_{wl})_r] \cdot t + E_{wV}$$

The axis of ellipse (l_2) depends on the V_c, V_w, E_{wD} and on the angle ($D_c - D_w$) of the drift vector :

$$l_2(t) = [\sin(D_c - D_w)V_c]\, t + E_{wD}$$

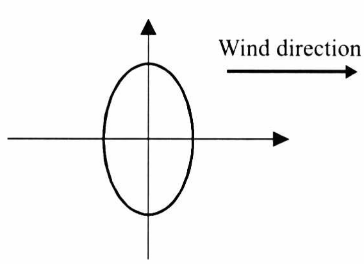

***Fig.7.** The assumed shape of the search area*

The search area [1], [4], is an ellipse of the surface area given by the formula:

$$S = \pi\, l_1\, l_2$$

The changes of the axis lengths $l_1(t)$, $l_2(t)$ are continuous functions of time (t).

Hence the surface area S = S(t) is also a function of time (t). It means that the probability of large changes of the surface area (S) during short periods of time approaches zero. Therefore, it is possible to present the changes of the surface search area (S) by using the equation of diffusion :

$$\frac{\partial Pr}{\partial t} = -\frac{\partial A_s P}{\partial S} + \frac{\partial^2 G_S Pr}{\partial S^2}$$

where :

- Pr – probability
- t – time
- A_S – average velocity of changes of the surface area (S)
- G_S – mean square of changes of the surface area in function of time.

The G_S parameter describes random changes of the search area.

By using the formula obtained by this author [1],[4], the following Fokker – Planck equation may be introduced :

$$\frac{\partial U(l_1,l_2,t)}{\partial t} = -\lambda \frac{\partial U(l_1,l_2,t)}{\partial l_1} \Delta l_1 (Pr_1 + Pr_3) +$$
$$-\lambda \frac{\partial U(l_1,l_2,t)}{\partial l_2} \Delta l_2 (Pr_2 + Pr_3) +$$
$$+\frac{\lambda}{2} \frac{\partial^2 U(l_1,l_2,t)}{\partial l_1^{\,2}} (\Delta l_1)^2 (Pr_1 + Pr_3) +$$
$$+\frac{\lambda}{2} \frac{\partial^2 U(l_1,l_2,t)}{\partial l_2^{\,2}} (\Delta l_2)^2 (Pr_2 + Pr_3) +$$
$$+\frac{\partial^2 U(l_1,l_2,t)}{\partial l_1 \partial l_2} (\Delta l_1 \Delta l_2) Pr_3$$

where:

- U – density function
- Δl_1, Δl_2 – l_1 and l_2 axes of the search area increments, respectively
- Pr_0 – the probability that growth of the search area does not occur
- Pr_1 – the probability that growth of the search area occurs in the l_1 axis direction complying with the wind direction
- Pr_2 – the probability that growth of the search area occurs in the l_2 axis direction perpendicularly to the wind direction
- Pr_3 – the probability that growth of the search area occurs in both the axis directions.

The probabilities Pr_0, Pr_1, Pr_2, Pr_3 satisfy the equation :

$$Pr_0 + Pr_1 + Pr_2 + Pr_3 = 1$$

The following function is the solution of the equation :

$$U(l_1,l_2,t) = \frac{1}{2\pi\sqrt{s_1(t)s_2(t)}\sqrt{1-r^2}} \cdot$$
$$\cdot \exp\left\{-\frac{2}{2(1-r^2)}\left[\frac{(l_1 - m_1(t))^2}{s_1(t)} + \right.\right.$$
$$-2r\frac{(l_1 - m_1(t))\,(l_2 - m_2(t))}{\sqrt{s_1(t)s_2(t)}} +$$
$$\left.\left. + \frac{(l_2 - m_2(t))^2}{s_2(t)}\right]\right\}$$

$$s_1(t) = \int_0^t \lambda(Pr_1 + Pr_3)\Delta l_1^2(x)\,dx$$

$$s_2(t) = \int_0^t \lambda(Pr_2 + Pr_3)\Delta l_2^2(x)\,dx$$

$$m_1(t) = \int_0^t \lambda(Pr_1 + Pr_3)\Delta l_1(x)\,dx$$

$$m_2(t) = \int_0^t \lambda(Pr_2 + Pr_3)\Delta l_2(x)\,dx$$

$$r = \frac{\int_0^t \lambda Pr_3 \Delta l_1(x)\,\Delta l_2(x)\,dx}{\sqrt{s_1(t)s_2(t)}}$$

If the vector N = (X,Y) has the character of the two-dimensional normal distribution of the density function $U(l_1, l_2, t)$ the probability of the event that it takes the values from the search area confined by the ellipse (S) of the following equation :

$$\frac{(x-m_1)^2}{l_1^2} + \frac{(y-m_2)^2}{l_2^2} = 1$$

where :

$$l_1 = \kappa \cdot \sqrt{s_1} \qquad l_2 = \kappa \cdot \sqrt{s_2}$$

can be obtained by using the formula:

$$P(N \in S) = 1 - e^{-\frac{\kappa^2}{2}}$$

This function is the Rayleigh's cumulative distribution function.

The analysis of the areas of near surface current enables to introduce three categories of the search areas [1], [2], [3] :

Category I :

when the search area grows equally in both the directions, (for the wind velocity V_w<18 knots).

An example of such search area is given in Tab.3, and the appropriate parameters of the probability density function $U(l_1, l_2, t)$ in Tab. 4.

Tab.3. *Data of the example search area of Category I*

Hydro-meteorological conditions			**Parameters of the search area**		
Wind direction	270	[°]	Length	5.24	[NM]
Wind velocity	15	[knots]	Breadth	4.79	[NM]
Drift time of 6 hours			Surface	25.20	[NM ^{2}]

Tab.4. *Parameters of the probability density function $U(l_1, l_2, t)$, for the drift time of 6 hours*

s_1	2.74868617
s_2	3.06936
m_1	2.043038152
m_2	0.190643478
r	0.939103185

The shape of the example search area of Category I is shown in Fig.8.

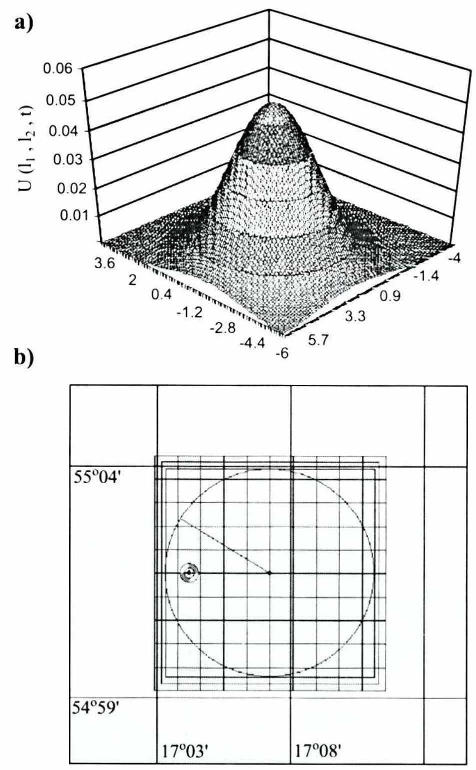

Fig.8. *The shape of the example search area of Category I [1]*
a) *Probability density function* ***b)*** *Search domain*

Category II :

when there is a dominating direction of the search area growth perpendicular to the wind direction (for the wind velocity: 18 < V_w < 30 knots), [1].

Category III :

when there is a dominating direction of the search area growth parallel to the wind direction (for the wind velocity V_w > 30 knots), [1].

AN EXAMPLE OF DETERMINATION OF SEARCH AREAS FOR A SURVIVOR IN THE WATER

The example parameters assumed to determine the search area for a survivor in the water are given below :

- Wind velocity V_w = 15 knots, (Category I)
- Wind direction (downwind) D_w = 090°
- Wind leeway velocity V_{wl} = 0.15 knots, Fig.9, [5]
- Divergence angles : +/-20°, Fig.9, [5]
- Probable leeway : 0.25 knots. Fig.9, [5]
- Wind currents : 0.54 knots, Fig.1, [5],[6],[7]

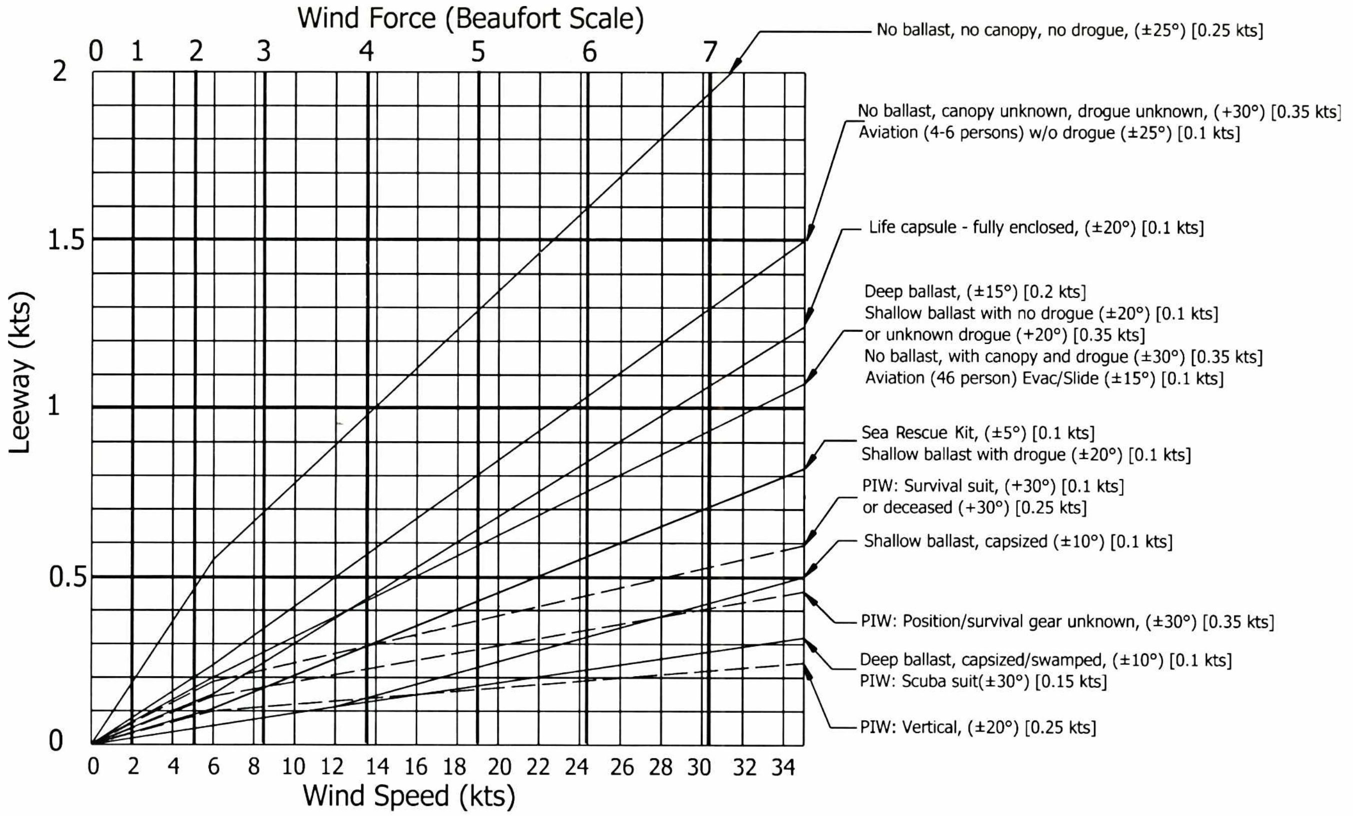

Fig.9 *Diagram according to [5]*

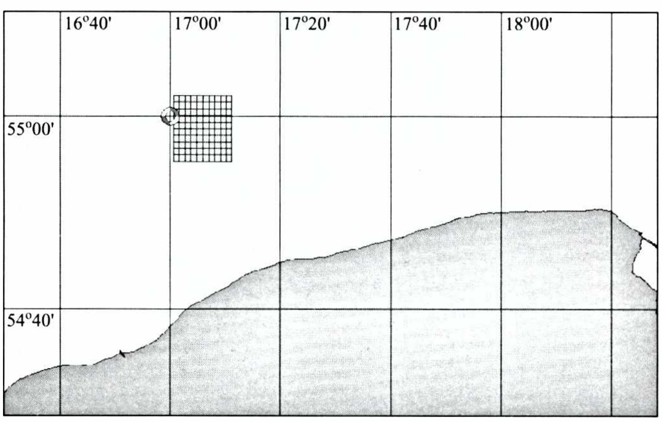

Fig.10. *Survivors search area modeled for 57% probability of survivors location in SAR area, according to the IMO model [5],[6].*
SAR area =38 (NM)^2

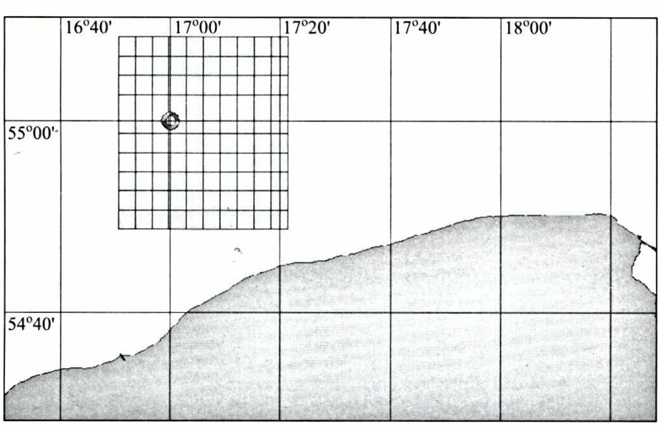

Fig.11. *Survivors search area modeled for 95% probability of survivors location in SAR area, equal to, according to the IMO model [5],[6].*
SAR area = 357 (NM)^2

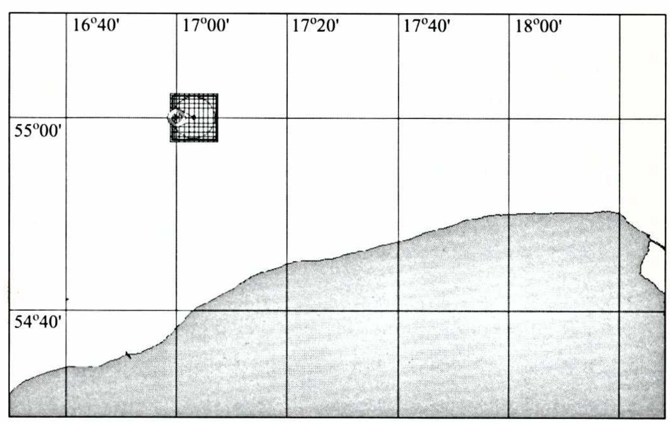

Fig.12. *Survivors search area modeled for 95% probability of survivors location in SAR area, according to the author's model [1][2][3].*
SAR area = 25 (NM)^2

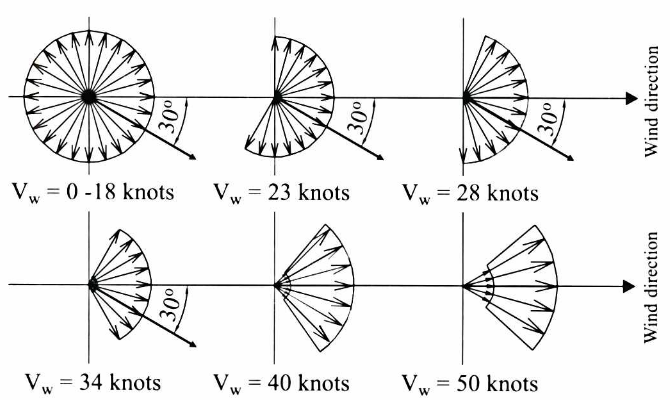

Fig.13. *Modelled areas of vectors of near surface currents [1][2][3] in comparison to the wind-current vectors (⟶), according to IMO recommendation, [5][6][7].*

CONCLUSIONS

- The near surface currents at the South Baltic may move in different directions, and their velocity does not exceed 0.35 knots Fig.13, [1], [2], at the wind velocity up to 18 knots. According to IMO, [5][6] the wind current vector amounts to 0.65 knots for wind velocity V_w = 18 knots, Fig.1.
- The performed comparison of the wind currents [5][6][7], (Fig.1), with the modelled surface current [1],[2], and Fig.13., confirms that the influence of hydro - meteorological features of the South Baltic on estimating the search area, is crucial (see Fig.10, Fig.11, Fig.12).
- The comparison of the modelled areas for which the wind currents acc. IMO [5][6][7], were taken into account when modelling the near surface current, confirms that the influence of the peculiar hydro - meteorological features of the South Baltic on determining the Datum and search areas, is considerable Fig.10, Fig.11, Fig.12.

Appraised by Jerzy Girtler, Prof.,D.Sc.

NOMENCLATURE

A	-	determined area of the search domain acc. IMO
A_S	-	average change rate of the surface area (S)
DD	-	Divergence Datum, distance between, P_1 and P_2
Dc	-	near surface current direction
D_w	-	wind direction
E_d	-	total probable drift error
E_{wD}	-	wind direction error
$(E_{wl})_r$	-	error of leeway determination
E_{wV}	-	wind velocity error
G_S	-	mean square of changes of the surface area in function of time
IAMSAR	-	International Aeronautical and Maritime Search and Rescue
IMO	-	International Maritime Organization
P	-	Datum acc. IMO
P_i	-	initial position
Pr	-	probability
R	-	optimum search radius acc. IMO
S	-	surface area
SAR	-	Search and Rescue
$U(l_1, l_2, t)$	-	probability density function of search area in two perpendicular directions at instant t
V_c	-	near surface current velocity
V_{wc}	-	wind current velocity acc. IMO
$\Delta l_1, \Delta l_2$	-	increase of search area in direction of semi-axes l_1 and l_2 , respectively

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Miscellanea

International cooperation

Since 1998 the Faculty of Ocean Engineering and Ship Technology, Gdansk University of Technology and Hochschule Bremen have continued mutual cooperation.

Generally the coopoeration has been focussed on the following areas :

- ⇨ Ship stability
- ⇨ Hydromechanical safety of ships and ocean objects
- ⇨ Developing *the International program of studies on Ocean Engineering and Shipbuilding* commenced in Bremen in 1997.

The topics have been so far realized in the following ways :

- ➢ seminars and lectures carried out reciprocally by parcitipants of the cooperation during yearly visits
- ➢ elaboration of the book titled : *Stability of sea-going ships* of the authorship of Prof. L. Kobyliński, Gdańsk and Prof. S. Kastner, Bremen

The main participants of the cooperation from the side of Hochschule Bremen are : Prof. S. Kastner and Prof. A. Kraus, and of Gdańsk University of Technology – Prof. L. Kobylński and Dr J. Stasiak.

This cooperation valuable for both sides is financed by the DAAD, a German foundation.

FOREIGN conference

IMDC 2003

On 5÷8 May 2003 in Athens held was :

8th International Marine Design Conference

organized by the School of Naval Architecture and Marine Engineering, National Technical University of Athens. A great interest was paid to it which was manifested by that scientific research centres of as much as 14 European countries as well as Japan, China, Korea and USA took part in preparation of the conference's papers.

Also Polish scientific workers were among the authors, who prepared 3 papers :

For the session II on : **Design for Safety :**
A general framework of new subdivision regulations
by Z. Karaszewski (JACER Corp. USA)
and M. Pawłowski (Gdańsk University of Technology)

For the session I on : **Simulation of Design :**
The modelling of information flow during early design stage of ship system
by W. Chądzyński (Technical University of Szczecin)

For the session on : **Design for Reliability :**
Development of expert system for designing safe ship power plants
by L. Hempel and W. Tarełko (Gdynia Maritime University)

Besides, Prof. M. Pawłowski of Gdańsk University of Technology was in the chair of the session IV on Design for Safety.