II INTERNATIONAL CONFERENCE
TRANSPORT SYSTEMS TELEMATICS TST`02

ZESZYTY NAUKOWE
POLITECHNIKI ŚLĄSKIEJ 2002
TRANSPORT z.45, nr kol. 1570

marine transport system,
optimal ship route

Bernard WIŚNIEWSKI[1]

PROBLEMS OF WEATHER ROUTE NAVIGATION OF VESSEL IN THE OCEAN

Ocean route recommendations for some vessels of the Polish Steamship Company were prepared on the basis of digital hydrological and meteorological data and programs for determining time optimum routes. The isochrone method and the theory of graphs were used for route planning. As an example, a voyage of the m/v Pomorze Zachodnie is presented.

PROBLEMY NAWIGACJI NA TRASACH ZALEŻNYCH OD POGODY DLA STATKÓW OCEANICZNYCH

Zaprezentowano problematykę wyznaczania trasy minimalno – czasowej dla statku w podróży oceanicznej. Na przykładzie podróży m/v Pomorze Zachodnie przedstawiono rezultaty opracowania rekomendacji trasy przekazywanych z ośrodka lądowego armatora – Polska Żegluga Morska.

1. INTRODUCTION

There are two basic problems in marine navigation that might be formulated as questions:

- Where am I, i.e. what is my position and how accurate is it?
- How should the ship be steered to reach the destination in the most economical way?

The former problem has been solved satisfactorily by satellite systems of ship positioning (GPS, DGPS) for the purpose of steering a vessel along an ocean route. The latter question still constitutes a problem to be solved due to varying environmental conditions in which a ship sails, regarded as a control target. Obviously, sailors and ship navigators have always been interested in choosing the most advantageous sailing route. The British Admiralty issues seasonal maps for shipping known as Routing Charts. These are continually updated and used at present by ship captains for programming an ocean voyage and sailing.

Nowadays the preparation of an ocean voyage cannot be limited to the specifying of a seasonal route. As weather conditions change, a ship will be sailing along a route different from the planned one. To this end the ship will use computer programs for optimum route determination based on current weather forecasts and consult a route with an appropriate land-based centre, etc.

The sequence of voyage planning is as follows:

[1] Institute of Navigation, Maritime University of Szczecin, Wały Chrobrego 1-2, 70-500 Szczecin, Poland
bwis@wsm.szczecin.pl
Institute of Marine Science, University of Szczecin, Wąska 13, 71-434 Szczecin , Poland

- seasonal route
- route allowing for current weather forecasts – reception of facsimile maps, computer programs for route optimisation
- route recommended by specialised routing centres, e.g. Oceanroutes, Navitech, Metroute, PSC's Ship Routing Centre.

Several subjects are interrelated in the problems of ocean route optimisation:

- weather conditions (availability and quantity of information, its reliability)
- vessel as a control target (sea-keeping qualities, diversity of vessel types, different types of cargo)
- systems of communications, search and rescue, VTS surveillance, ...
- shipowners' requirements (voyage promptness, maximum loading states, navigation in difficult areas – ice conditions, icing, currents).

Weather routing aims at:

- objective navigational, hydrological and meteorological calculations as well as data processing
- satisfying the conditions for the safety of navigation, vessel and cargo
- allowing for voyage minimum-time, minimum fuel consumption indicator, avoidance of weather damage
- forecasting weather conditions and determining vessel movement conditions depending on its structural qualities and loading state.

Research methods used in solving the problems listed above are the following:

- solving non-deterministic and stochastic processes (weather) – spectrum of wave parameters, forecasting areas affected by wind, waves, icing, ...
- solutions offered by the control theory (characteristics of ship motion in high seas and wind, fuel consumption curves, ...)
- mathematical modelling, calculus of variations, and optimisation principles (dynamic programming using the isochrone method, graph theory, Bellman's optimisation principles, Pontryagin's maximum, ...).

In the presentation of works in progress (bibliography [1-6]), it is worth emphasising that author's theoretical solutions have proved useful in operational recommendations of ocean routes for Polish Steamship Company vessels (PSC). As a result of many years of experience gained by the Polish merchant fleet, the Polish Steamship Company and Szczecin Maritime University have established a ship routing centre. In its operational system the centre recommended routes to vessels in the North Atlantic and North Pacific Oceans. The author's route selection programs were used, making use of digital hydro-meteorological data of the GTS network. The isochrone method and route selection based on the graph theory were used in the programs. For daily communications with the ships recommendations and calculation results were prepared.

2. METHODS AND AN EXAMPLE

One good example of ideal co-operation between the PSC's ship routing centre and vessels was the daily elaboration of recommendations for a voyage of the m/v Pomorze Zachodnie from Ventspils to Montreal, on which the vessel saved 37.3 hours as compared to a

traditional seasonal route in particular weather conditions that prevailed in the North Sea and North Atlantic (between 24.04. and 03.05. 1998).

The motor vessel Pomorze Zachodnie left the port of Ventspils on 20 April with a cargo of steel heading for Montreal. Due to the cargo, the vessel, shipowner's operating department and chief navigator's office were asked consulted. The vessel was recommended, if possible during the voyage route planning, to avoid seas higher than 5 m coming from abeam; it was said that the vessel could reduce speed when the characteristic wave* h_c>3m coming from ahead; that the vessel should not proceed by itself through ice covering more than 50% of the area, etc.

In April 1998 on several occasions before the voyage of the m/v Pomorze Zachodnie, waves in the North Atlantic exceeded 10 m (data from wave analyses and forecasts) and for this and other reasons the vessel and centre exchanged in great detail weather and operating data. The vessel encountered in the Baltic Sea conditions average in that season of the year, whilst in the North Sea the conditions were worse than average (-5° to 6°B). The most important decision in the first leg of the voyage was taken on 21/22. April before the Skagen light vessel was passed. The decision was based on wind and waves forecasts for the North Atlantic up to 120 hours in advance. The forecasts indicated that high seas (to 9m) would develop mainly in latitudes of approx. 50° North. The route recommended then went through Pentland Strait across the Atlantic along approx. 60°N latitudes, where the expected winds were to blow from astern. It was also known that practically the route by Belle Isle to St Lawrence Bay would be closed and that vessels would have to avoid the limit of pack ice and spreading icebergs in way of Newfoundland. Other essential information was sent to the vessel when detailed forecasts were confirmed and the vessel was about to go through Pentland Strait on 24 April. Following an alternative seasonal route, it would still have been in the North Sea before entering routes in the English Channel. Spreading iceberg limits before Newfoundland up to 48°N 043°W made it necessary to test routes to 46°N 046°W (Fig.1).

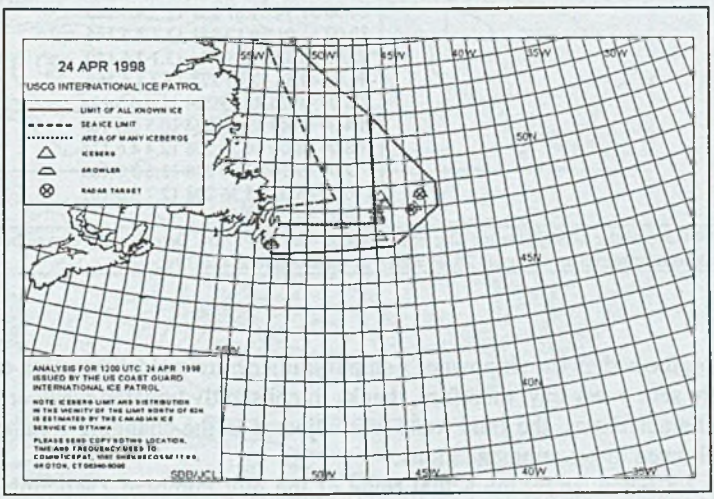


Fig.1. A chart of ice conditions in the area of Newfoundland on 24 April 1998. Source: Ice Patrol

* Characteristic wave is observed by lookouts onboard a vessel. Its height is similar to the significant wave ($h_{1/3}$) and statistically, the probability of its occurrence in the wave area is equal to 9%.

During all the subsequent days the vessel was sending to the Centre current data on its position, weather, conditions, possibly its speed-down table, whereas the Centre delivered recommendations in the form displayed below in Table 1.

Table 1

A recommendation sent to the vessel

fm: polsteam-oceantramp, szczecin
to: master m/v pomorze zachodnie

recommended route for Vo=13.7 w.:

Lat [n]	Long [w]	time [h]	distance [Mm]
58.42	8.50	0.00	0.00
58.42	9.50	2.38	31.17
58.42	11.50	7.24	93.51
58.42	12.50	9.59	124.68
58.42	13.50	11.98	155.86
57.42	19.50	26.93	354.82
56.42	24.50	39.52	528.06
54.42	31.50	59.36	793.42
52.42	36.50	75.25	1007.76
51.42	38.50	82.94	1102.68
50.42	40.50	90.76	1198.88
48.42	43.50	104.15	1366.07
46.00	46.00	118.22	1550.47

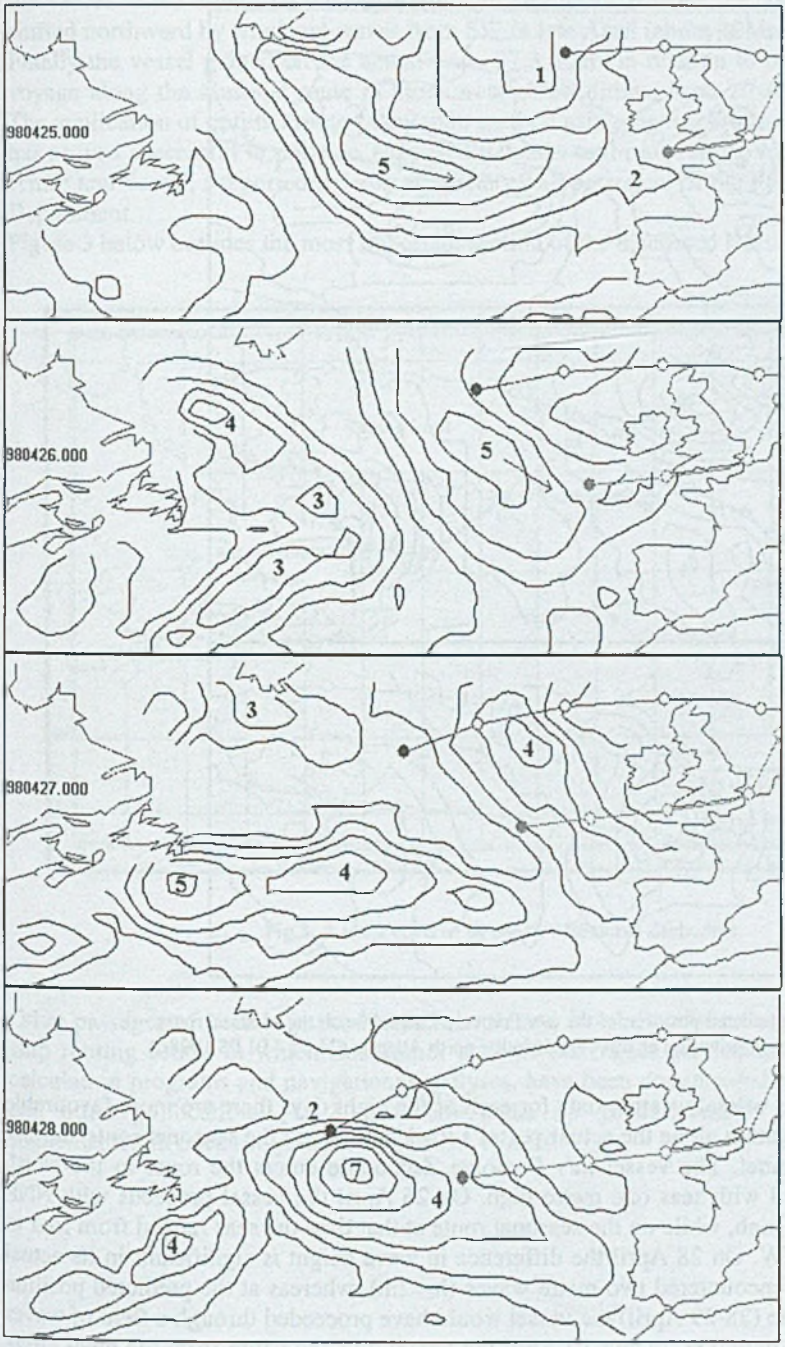
Expected conditions in route:

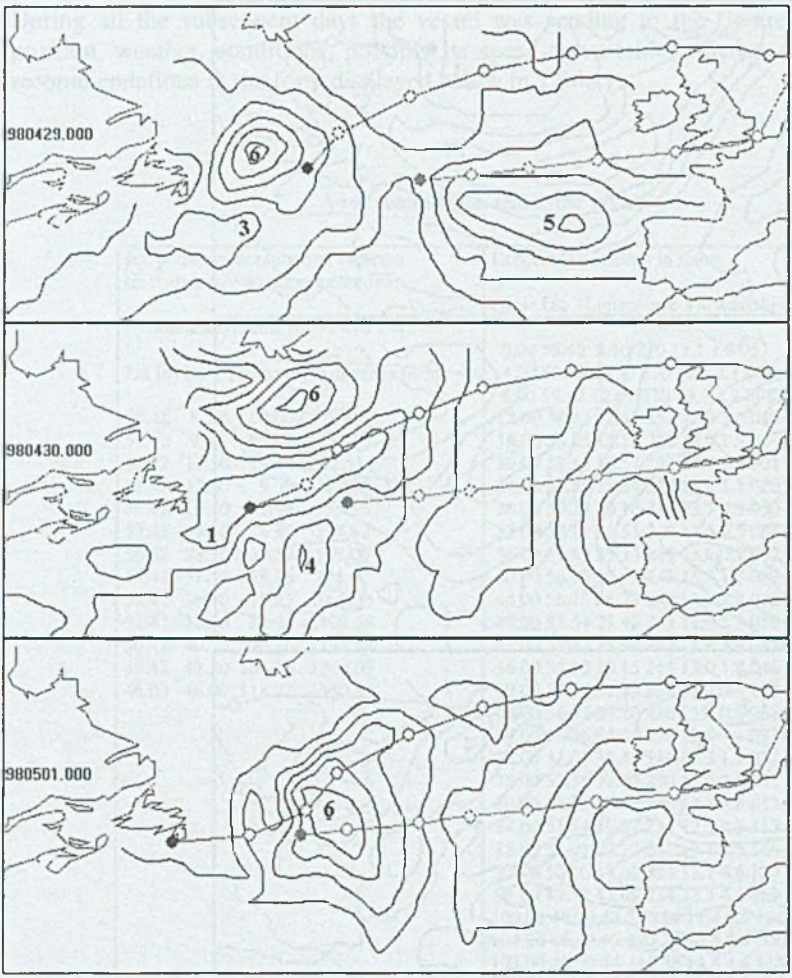
time	Lat	Long	course	Vs	wave height	angle
0.00	58.42	8.50	270	13.1	1.8	053
4.00	58.42	10.30	270	12.8	2.1	048
8.00	58.42	12.09	270	13.3	2.2	098
12.00	58.42	13.50	252	13.2	1.6	049
16.00	58.26	15.25	252	12.9	1.9	024
20.00	58.11	16.57	252	12.7	2.1	001
24.00	57.55	18.34	252	13.4	1.1	020
28.00	57.37	20.16	249	13.7	0.3	050
32.00	57.18	21.51	249	13.6	0.5	054
36.00	56.59	23.25	249	13.6	0.7	082
40.00	56.39	25.00	243	13.3	1.7	082
44.00	56.16	26.24	243	13.0	2.2	072
48.00	55.54	27.40	243	11.9	3.3	059
52.00	55.33	28.54	243	11.6	3.9	067
56.00	55.10	30.15	243	13.0	1.8	046
60.00	54.37	32.03	236	13.7	0.4	032
64.00	54.07	33.20	236	13.6	0.8	058
68.00	53.36	34.36	236	13.5	1.3	091
72.00	53.07	35.49	236	13.2	1.9	074
76.00	52.36	37.02	230	12.6	2.3	041
80.00	52.05	38.05	230	12.4	2.8	057
84.00	51.34	39.07	231	12.5	4.3	113
88.00	51.01	40.12	231	13.1	4.5	146
92.00	50.30	41.08	224	13.1	3.6	120
96.00	49.52	42.05	224	13.3	4.5	169
100.00	49.20	42.55	224	11.4	6.5	124
104.00	48.49	43.39	224	10.5	6.8	106
108.00	48.00	44.24	208	12.4	4.6	115
112.00	47.16	45.00	208	12.6	3.8	103
116.00	46.31	45.36	208	12.7	3.5	101
118.22	46.00	46.00				

25.04 wave centre at 50n/38w moving ESE, towards 40n 20w 27.04. Deterioration of weather conditions expected on our route 28.04 with 6 m wave centre at 48n/38w.

Calculations performed at the shipowner's ship routing centre and information exchange with the vessel were sent every day, therefore, thanks to constantly updated weather forecasts and ship motion characteristics, the final route was adjusted to the changing weather conditions, and Master followed the recommendations.

Figures 2.1 – 2.8 below show the actual route of the m/v Pomorze Zachodnie in particular days.


980425.000
1
2
5
980426.000
4
3
3
5
980427.000
3
4
5
4
980428.000
2
7
4
4



Figs.2.1.-2.8. Real and predicted positions of the m/v Pomorze Zachodnie on the seasonal route against the distribution of wave fields in the north Atlantic (24.04 – 01.05 1998r.)

In the above records of real weather data for each of the eight days there are more favourable conditions for navigation alone the actual vessel's track than along the seasonal route starting at the English Channel. The vessel m/v Pomorze Zachodnie enters the route in the North Atlantic on 24 April with seas one metre high. On 26 April the vessel proceeds with NNE waves three metres high, while on the seasonal route at that time the seas ranged from four to five metres from NW. On 28 April the difference in wave height is significant; in its actual position the vessel encountered two-metre waves (h_c=2m), whereas at the predicted position on the seasonal route (28-29 April) the vessel would have proceeded through a field of waves up to seven metres high. On 29 and 30 April the vessel diverted south from the great circle „giving way" to waves 6 metres high that was moving from the vicinity of Newfoundland to NNE. That diversion southward was also necessitated by ice fields that had to be avoided, particularly concentrations of icebergs in the area of 48°N 045°W. On 30 April by daytime

the vessel sailed along the iceberg limit, (initially to 47°N, then 46°N) which was slightly shifted northward by wind and waves from SW in late April (about 40Mm).
Finally the vessel gained on the actual route 37.3 hours in relation to the simulated time of voyage along the seasonal route in those weather conditions from 20 April to 1 May 1998. The application of optimal route calculation method using the isochrone and digraph methods has proved successful in practice, supposedly thanks to the smooth co-operation between the centre and vessel, supported the vessel operator and personnel of the PSC's Chief Navigator Department.
Figure 3 below outlines the most important section of the discussed North Atlantic route.

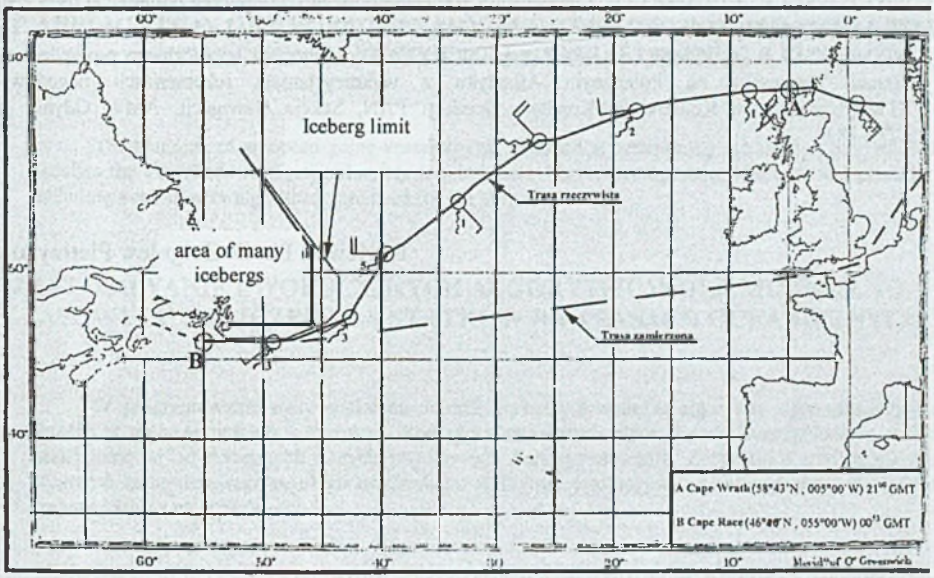


Fig.3. A track covered by the m/v Pomorze Zachodnie

Other passages of vessels in the North Atlantic and North Pacific recommended by the PSC ship routing centre in which this author and his colleagues participated, that made use of calculation programs and navigational analyses, have been documented in research materials and other publications [1, 2, 6]. They make up good examples of weather routing implemented in ocean shipping of merchant vessels.

BIBLIOGRAPHY

[1] WIŚNIEWSKI B., CHOMSKI J., DROZD A., „Rekomendacje tras statków na Atlantyku opracowane w ośrodku armatora PŻM", III Sympozjum Nawigacyjne Gdynia WSM 1999, s. 161-170.
[2] WIŚNIEWSKI B., CHOMSKI J., DROZD A., P. MEDYNA P., „Rezultaty operacyjnego prowadzenia statków PŻM na trasach oceanicznych z wykorzystaniem rekomendacji pogodowych", V Konferencja „Okrętownictwo, Oceanotechnika, Maszyny i Systemy Transportowe. Międzyzdroje 2000, s. 333-340.
[3] WIŚNIEWSKI B., „Optymalizacja drogi morskiej statku z uwzględnieniem warunków pogodowych", WSM Szczecin 1986.
[4] WIŚNIEWSKI B., „Problemy wyboru drogi morskiej statku", Wyd. Morskie, Gdańsk, 1991.
[5] WIŚNIEWSKI B., CHOMSKI J., „Zastosowanie grafu skierowanego do obliczeń optymalnej trasy statku", Zeszyt Naukowy WSM Szczecin nr 37, Szczecin 1990, s. 181-197.
[6] WIŚNIEWSKI B., CHOMSKI J., DROZD A., MEDYNA P., „Rezultaty operacyjnego prowadzenia m/v Ziemia Tarnowska na Północnym Atlantyku z wykorzystaniem rekomendacji pogodowych", XI Międzynarodowa Konferencja Komitetu Geodezji PAN, Sekcja Nawigacji. AMW Gdynia 1998, s.276-284

Reviewer: Ph. D. Zbigniew Pietrzykowski