Introduction to Ship Rout(e)ing

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Outline

- A short History of Ship Routing
- Ocean Waves and other Hazards
- Climate & Weather Navigation
- Route Optimization
- Ship Performance
- Onboard & Shore-based Routing
A Short History of Ship Routing

- **1855** Maury published his *Sailing Directions*
- **1912** RMS Titanic sank on April 15th
- **1914** "International Convention for the Safety Of Life At Sea" was initiated.
- **1955** First commercial Ship Routing Services in USA
- **1959** Foundation of the „International Maritime Organization“ (IMO)
- **1959** Ship Routing Service launched at German Weather Service (DWD)
- **1974** SOLAS 74: The convention was updated and amended
Chapter V - Safety of navigation

Chapter V identifies certain navigation safety services which should be provided by Contracting Governments and sets forth provisions of an operational nature applicable in general to all ships on all voyages. This is in contrast to the Convention as a whole, which only applies to certain classes of ship engaged on international voyages.

The subjects covered include the maintenance of meteorological services for ships; the ice patrol service; routing of ships; and the maintenance of search and rescue services.

The German vessel MS „München“ sank in a severe northatlantic storm in December 1978.

GMDSS was developed by IMO in 1979

Components of GMDSS (among others) are:

- EPIRB (Emergency position-indicating radio beacon)
- NAVTEX (system for instantly distributing maritime safety information)
- INMARSAT (telephone, telex and high-speed data services)
Casualties 1995-1999
### Casualties in 2008

#### Number of Casualties by Region and Type - 2008

<table>
<thead>
<tr>
<th>Cause</th>
<th>Africa</th>
<th>Asia</th>
<th>Austral-Asia</th>
<th>Europe</th>
<th>Indian Sub-Continent</th>
<th>Middle East</th>
<th>North America</th>
<th>Other</th>
<th>South America</th>
<th>Total</th>
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<tbody>
<tr>
<td>Collision (vessels)</td>
<td>6</td>
<td>203</td>
<td>3</td>
<td>203</td>
<td>15</td>
<td>14</td>
<td>58</td>
<td>9</td>
<td>9</td>
<td>520</td>
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<tr>
<td>Contact (eg. Harbour wall)</td>
<td>2</td>
<td>26</td>
<td>4</td>
<td>171</td>
<td>2</td>
<td>3</td>
<td>77</td>
<td>7</td>
<td>3</td>
<td>295</td>
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<tr>
<td>Fire/explosion</td>
<td>7</td>
<td>34</td>
<td>6</td>
<td>105</td>
<td>5</td>
<td>5</td>
<td>46</td>
<td>18</td>
<td>6</td>
<td>232</td>
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<tr>
<td>Founded (sunk, submerged)</td>
<td>7</td>
<td>44</td>
<td>4</td>
<td>44</td>
<td>3</td>
<td>3</td>
<td>31</td>
<td>8</td>
<td>3</td>
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<td>Hull damage</td>
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<td>5</td>
<td>2</td>
<td>28</td>
<td>2</td>
<td>4</td>
<td>39</td>
<td>3</td>
<td>6</td>
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<td></td>
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<td>5</td>
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<td>Machinery damage/failure</td>
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<td>70</td>
<td>16</td>
<td>425</td>
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<td>25</td>
<td>173</td>
<td>41</td>
<td>15</td>
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<td>Miscellaneous</td>
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<td>20</td>
<td>11</td>
<td>134</td>
<td>6</td>
<td>4</td>
<td>68</td>
<td>21</td>
<td>8</td>
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<td>Missing/overdue</td>
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<td></td>
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<td>Piracy</td>
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<td>War loss/damage</td>
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<td></td>
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<tr>
<td>Wrecked/stranded</td>
<td>10</td>
<td>47</td>
<td>13</td>
<td>262</td>
<td>4</td>
<td>19</td>
<td>113</td>
<td>19</td>
<td>14</td>
<td>501</td>
</tr>
<tr>
<td>Total</td>
<td>108</td>
<td>458</td>
<td>59</td>
<td>1376</td>
<td>45</td>
<td>119</td>
<td>606</td>
<td>126</td>
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</table>
Hazards in Stormy Weather

- Rough sea (storm intensity and duration)
- Cross sea (in the vicinity of tropical storms in particular)
- Extreme high (and steep) single waves („Rogue Waves“)
- Reduced visibility
Ocean Waves

- The Wave Spectrum
- Significant wave height \((H_s) =\)
  - the mean wave height (trough to crest) of the highest third of the waves
    \((H_{1/3}\) definition for “trained observers“)
  - four times the square root of the zeroth-order moment of the wave spectrum \((H_{mo})\)
- Rogue (freak) wave = higher than twice \(H_s\)
Other Hazards

- Icebergs (growlers)
- Sea Ice
- Freezing spray (superstructure icing)

- High swell waves (resonance effects)
- Fog
- Cold upwelling (may affect cargo)
- Currents (may affect speed and heading, interaction with waves)
- Piracy
Hazards in the North Pacific Winter

Greatest potential for tropical development

Main area of cyclogenesis

Secondary area of cyclogenesis

Primary storm track

Kuroshio current

Northeast monsoon

Heavy NW-ly swells

Superstructure icing

Tehuantepecers

Courtesy of Weather News International
Hazards in the North Atlantic Winter

- **Main area of cyclogenesis**
- **Primary storm track**
- **Secondary area of cyclogenesis**
- **Mistrals**
- **ICE**
- **Iceberg**
- **Superstructure icing**
- **Gulf Stream current**
- **Heavy NW-ly swells**

Courtesy of Weather News International
Wave Height Percentiles

95% - Quantiles of Significant Wave Height
Planning a Route

Mission
Take cargo from A to B

Strategy
Choose / modify the route

Operation
Choose Speed and Course

Ship Performance

Requirements
Navigability
Safety
Rentability
Habitability (Comfort)

Environment
Climatology
Short Term Weather Variability

Strategy
Choose / modify the route
Climate Navigation

Climate routes reflect the seasonal variation of:

- Tropical and extra-tropical storm tracks
- Monsoon regimes
- Areas of high swell
- Sea ice cover
- Prevailing ocean currents
Weather Navigation

Two basic strategies:

- First follow the climate route and deviate if the weather becomes better or worse.

- First follow the shortest track and deviate if the weather becomes worse.
The Climate Route

From Florida to the English Channel via Abaco and Azores

4082 nm

Rhumblines
Shortest Track: The Great Circle

From Florida to the English Channel via Florida Strait

3778 nm
Weather Navigation

Start on great circle, fall back to climate route

4072nm
Regional Features

Making use of Gulf stream in the Florida Strait

Traffic Separation in the Singapore Strait
Tactical Weather Routing
(Meteorological Navigation)
The Marine Meteorological Office in Hamburg

- Ocean Wave Forecast
- **Ship Routing**
- Consultancy for the Offshore Industry
- Advisory onboard German Research Vessels
- Antarctic Flight Weather Guidance
- Analyses of Maritime Accidents
- Regatta Guidance
- Online Weather Information Systems
- Research Projects
Classical Shore-based Routing

Environment
(Model Data + Observations)
Wind, Waves, Currents, Sea Ice, Icebergs, Tropical Storms

Routing Software
(Dead Reckoning)

Meteorologist

Weather Maps
(Synoptic Overview)

Navigational Maps
(Route Monitoring)

Initial Recommendation
Frequent Updates
Routing for Coastal Shipping

From Emden to Brunsbüttel

Sign. Wave Height

Swell Height

Ship speed + course
## Contents of a Route recommendation

**Text**
- Weather situation and development
- Waypoints of the recommended route
- Alternate route(s)
- Forecast weather enroute
- Additional notes on hydrographical hazards

**Graphics**
- On request: maps of surface pressure, wind, waves

**Media**
- E-Mail
- Fax
- SMS
- Phone
- Telex

## Monitoring and updated recommendations

Ships will be monitored enroute by their consultant with regard to
- Unexpected weather changes
- Changing weather forecasts
- Deviations from the recommended route

Recommendations will be updated if necessary, however, at least every 3 days.

Ships are requested to send their position and observed weather every day.

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### Synoptic situation and development:
Low 29.00UTC 998 central Japan moving east but slowly, weakening, 01.00UTC 1004 37N145E, then filling. Large high 29.00UTC 1034 45N160E moving east, 01.00UTC 1035 45N180E, moving south furtheron, 03.00UTC 1032 40N180E.
Low 3.00UTC 1002 45N155W moving south. No tropical storms reported.

We therefore recommend great circle to waypoint 4630N164E, then rhumbline to Cape Flattery. Estimated average speed 24.6kt

### Forecast:
29.09.: East to southeast abt. 4, sea near 2 m
30.09.: veering south increasing up to 7,
sea 2 to 3 m, incoming southerly swell 3 to 4 m
01.10.: South to southwest 7, sea 3 to 4 m
02.10.: southwest decreasing 6, sea 2 to 3 m
03.10.: veering northwest 5, decreasing 3, sea still 2 to 3 m
04.10.: becoming southeast 4 to 5, sea 2 m

### NOTE:
In case of significant change of weather, you will receive further recommendation enroute. Please send your daily noon-observation to dwd in standard weather observation code (WMO-code) or at least in the following form under code "Routing":

- **A:** Date and Time (local time and UTC)
- **B:** Position (e.g.: Pos. 55.03n 11.30w)
- **C:** Wind in BFT (e.g.: Wind NW 5)
- **D:** Sea and Swell in m (e.g.: Sea 3m, Swell SW 4m)
- **E:** Significant weather (e.g.: sign.Wx Thunderstorms).

Our office is on duty around the clock:
telex: 211 291 hadwd Fax: +49-69-8062-6184 E-mail: routing(AT)dwd.de

good voyage
Erdmann/DWD Marine Meteorological Service
Other Providers of Shore-based Routing

- http://www.metworksltd.com/services/fwr.htm
- http://oceanweatherservices.com/

These are just a few examples! Google for more!
Route Optimization

- Minimum cost (all ships)
- Minimum fuel (freight liner).
- Minimum time (tramp shipping)

- Best weather (cruise ships)
  - Safety and comfort of personnel and passengers
  - Need to take a chance for maintenance work at sea
The Costs of a Shipping Mission

- Fuel consumption, variable fuel prices
- Employees (salaries, flights, hotels etc)
- Insurance rates
- Charges for pilots, water gates etc.
- Demurrage (in case of early arrival)
- Unpredictable events (damages, traffic jam, strike at destination etc)

The true costs are quite difficult to estimate!
Route Optimization

Minimize the cost function

\[ J = \int_{t_0}^{t_z} A(X, h, n, t) dt + B(t_z, t_s) \]

\( A \) cost per time
\( X \) ship position
\( h \) heading
\( n \) propeller rotation
\( B \) late/early arrival penalty

Arrival time

\[ t_z = f(X_0 \ldots X_z, h_0 \ldots h_z, n_0 \ldots n_z) \]

Side Conditions:

- Ship must not hit land, sea ice, icebergs, shoals
- Traffic separation zones must be considered
- The propeller rotation must not exceed certain upper and lower limits
- Ship motions must not exceed acceptable limits
The most simple Solution

Time Optimization:

Minimize the cost function

\[ J = \int_{t_0}^{t_z} A(Xh,n,t)dt + B(t_z,t_s) \]

\[ A = 1 \quad B = 0 \]

Speed vs. Wave height / direction
Time Optimization using the Isochrone Method

Isochrones are lines of equal arrival time

Construction of the first and second isochrone
Time Optimization using Isochrones
Time Optimization using Isochrones
Hindcast of Time Optimum Routes in the North Pacific Wintertime
Westbound Route Climatology for a Gas Tanker

Winter

Summer

Time loss (relating to calm conditions)
Ship Performance: Propulsion

- In order to gain a certain speed, machine and propeller have to work against the ship’s resistance.

- Total resistance
  - Frictional resistance ~ shipspeed$^2$
  - Wave making resistance
  - Wind resistance ~ windspeed$^2$
  - Wave resistance = f (wave spectrum)

- A large number of ship, propeller and machine characteristics have to be considered to calculate the speed.

Google: Ship resistance and propulsion
Hazardous Events

- Slamming
- Parametric rolling (may occur in following or heading seas)
- Supercritical accelerations / bending stresses
- Green water on deck
- Propeller emerging
- Psychological constraints

→ Voluntary speed reduction
Safe operating speed and heading

Sophisticated Optimization Techniques

- Linear Programming (Kantorovich, 1939)
- Dynamic Programming (Bellman, 1957)
- Branch & Bound (Land & Doig, 1960)

Optimization using Dynamic Programming

Onboard Routing Software

- http://www.awtworldwide.com/products/
- http://www.ocean-systems.com/VOSS.htm

These are just a few examples! Google for more!
Ensembles of Optimum Routes

Considering the uncertainties of the medium range weather forecast (>3 days) by using an Ensemble Prediction System.

- 1 Deterministic run
- 1 Control run
- 50 ensemble members

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ECMWF - EPS

Brest -> New York
20020114 12
20020121 00

Envelope range

Ensemble members

First Guess
Analysis
Det. fc.
Control

MAGICS 6.6 styx - was Thu Sep 5 09:53:38 2002

Courtesy of ECMWF
Conclusions

- **Onboard Route Optimization**
  - considering specific ship performance
  - large data sets increase communication costs
  - optimum route may strongly depend on selection of options

- **Shore-Based Routing**
  - information on ship properties often insufficient (chartered ships)
  - access to a variety of forecast models
  - MetOcean experts give short and clear advice
Thanks for your attention !