Marine Forecasting Course - 2013

Introduction to

Ship Rout(e)ing

Outline

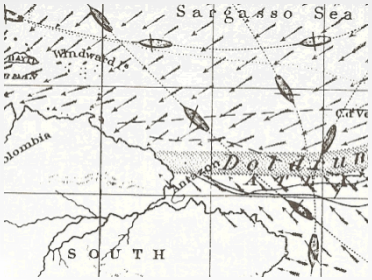
- A short History of Ship Routing
- Ocean Waves and other Hazards
- Climate & Weather Navigation
- Route Optimization
- Ship Performance
- Onboard & Shore-based Routing

Thomas.Bruns@dwd.de

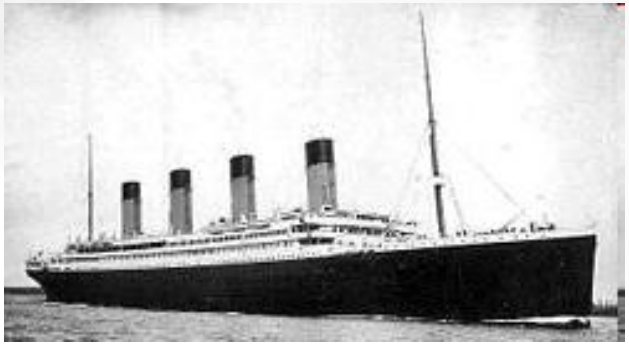

A Short History of Ship Routing

- **1855 Maury** published his **Sailing Directions**

Read More : http://www.britannica.com/EBchecked/topic/516637/Sailing-Directions



- **1912** RMS **Titanic** sank on April 15th



- **1914** "International Convention for the **S**afety **O**f **L**ife **A**t **S**ea" 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

The SOLAS‘74 - Convention

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.

Read More: http://en.wikipedia.org/wiki/SOLAS_Convention

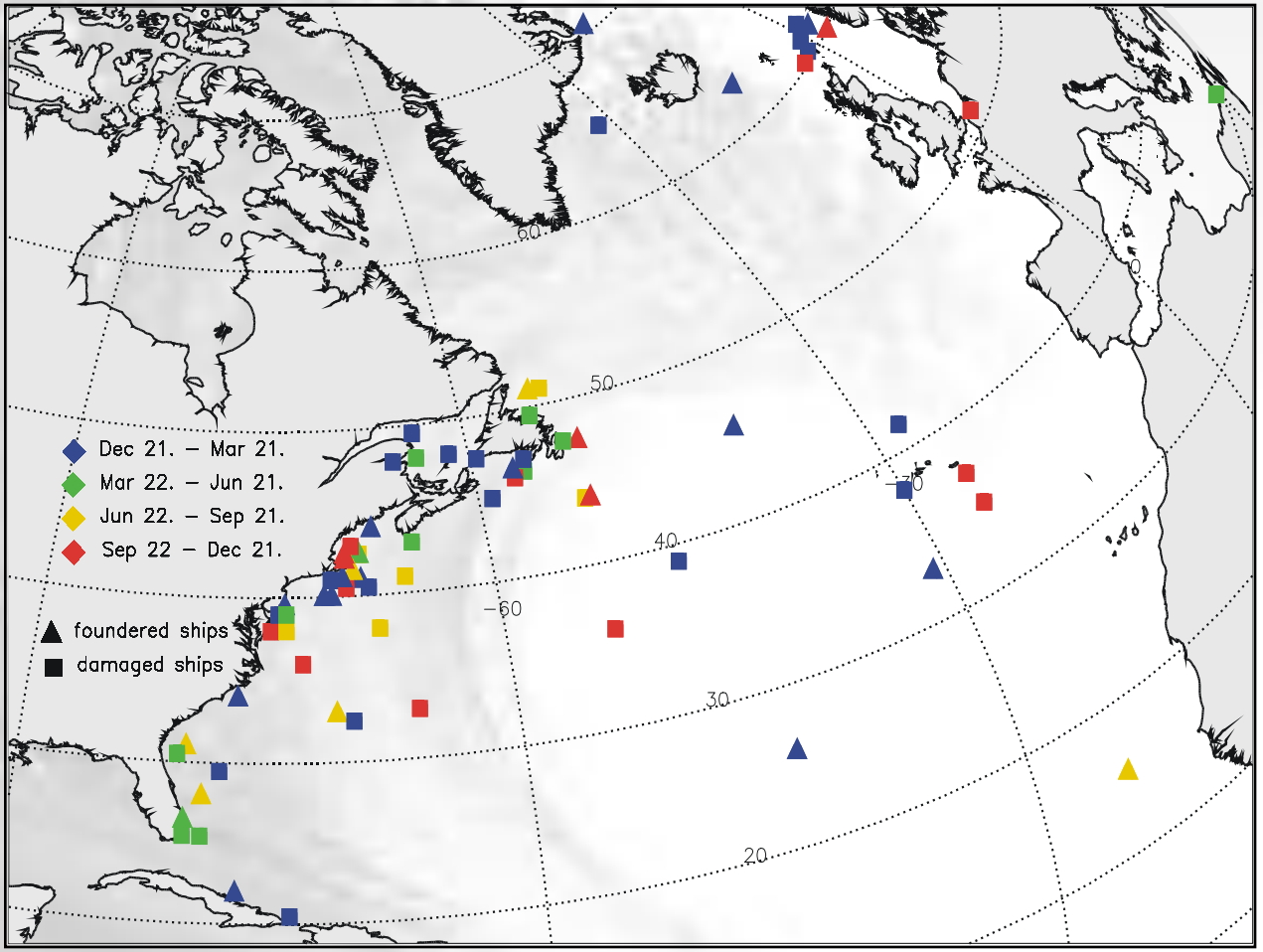
The Global Maritime Distress and Safety System

- 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)

Casualities 1995-1999



Casualities in 2008

Number of Casualties by Region and Type - 2008

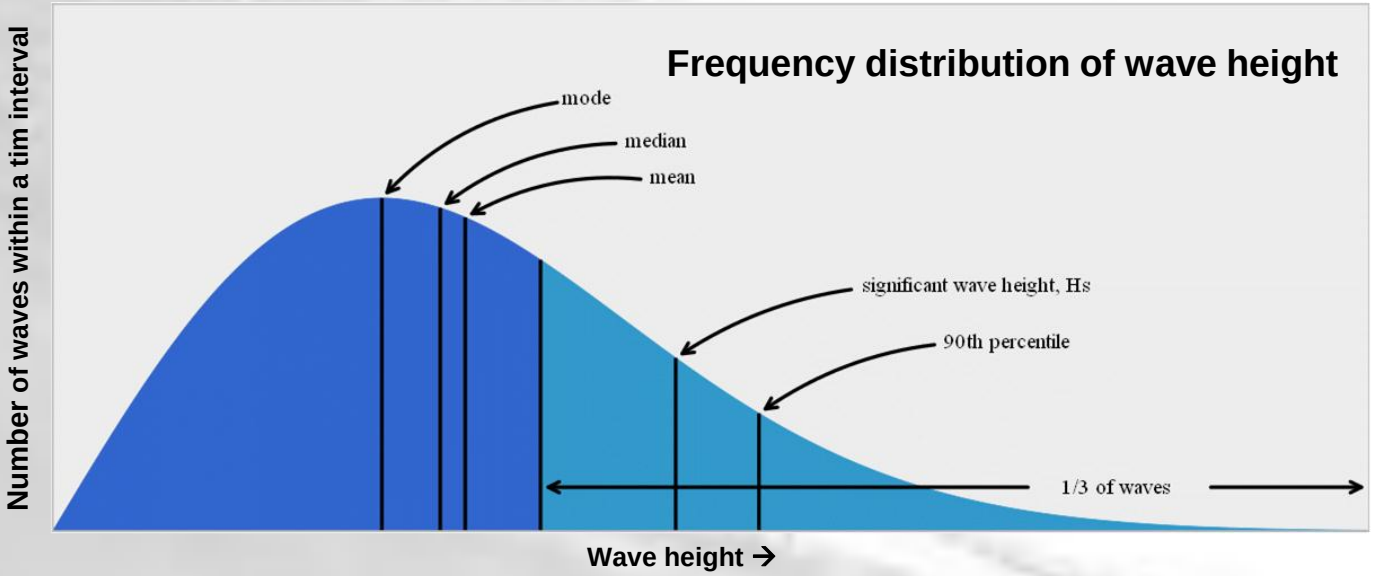
Cause	Africa	Asia	Austral-asia	Europe	Indian Sub-Continent	Middle East	North America	Other	South America	Total
Collision (vessels)	6	203	3	203	15	14	58	9	9	520
Contact (eg. Harbour wall)	2	26	4	171	2	3	77	7	3	295
Fire/explosion	7	34	6	105	5	5	46	18	6	232
Foundered (sunk, submerged)	7	44	4	44	3	3	31	8	3	147
Hull damage	3	5	2	28	2	4	39	3	6	92
Labour dispute	1			3			1			5
Machinery damage/failure	29	70	16	425	7	25	173	41	15	801
Miscellaneous	10	20	11	134	6	4	68	21	8	282
Missing/overdue		1								1
Piracy	33	8		1		42			1	85
War loss/damage					1					1
Wrecked/stranded	10	47	13	262	4	19	113	19	14	501
Total	108	458	59	1376	45	119	606	126	65	**2962**

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



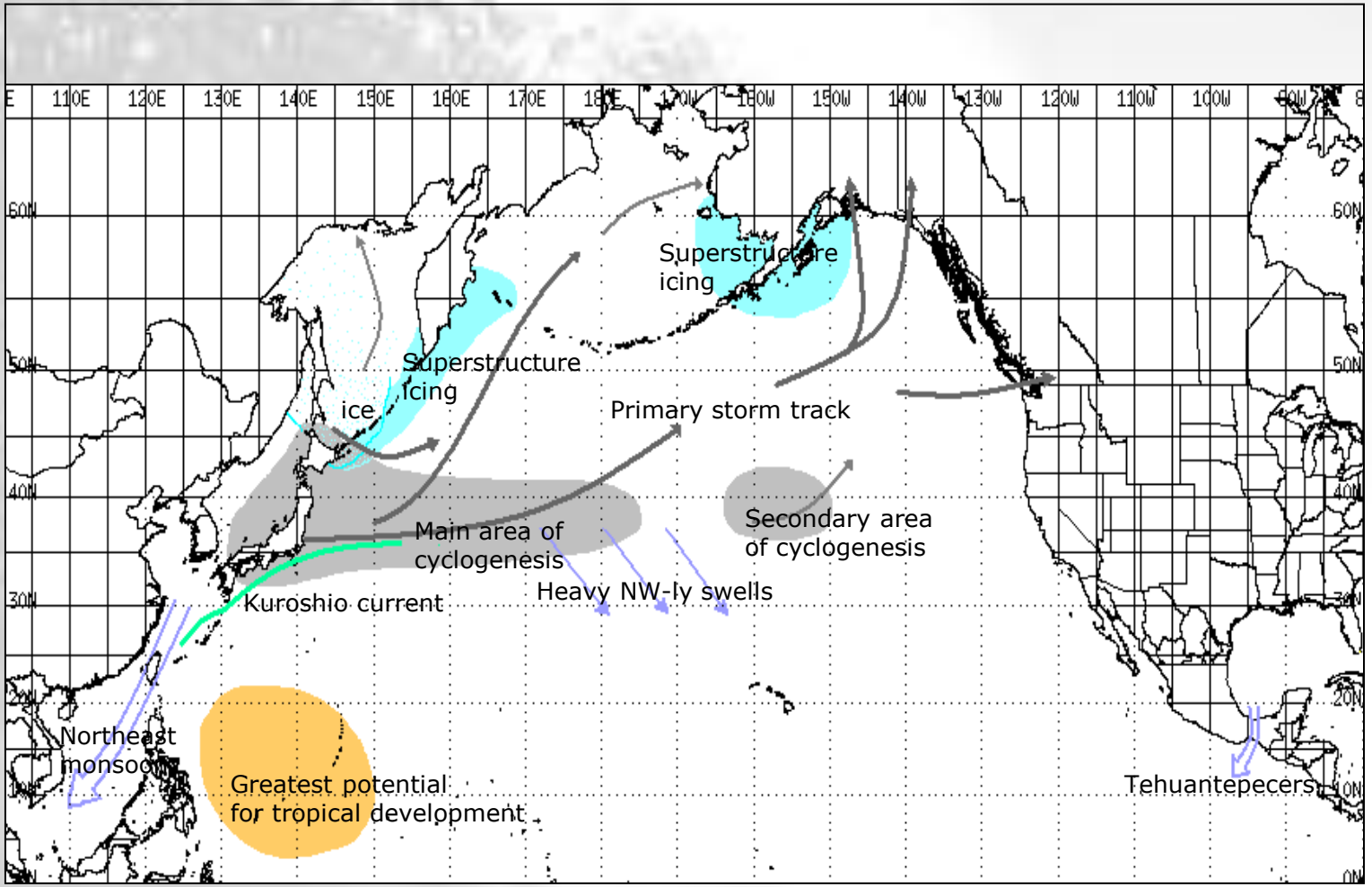
Other Hazards

- 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

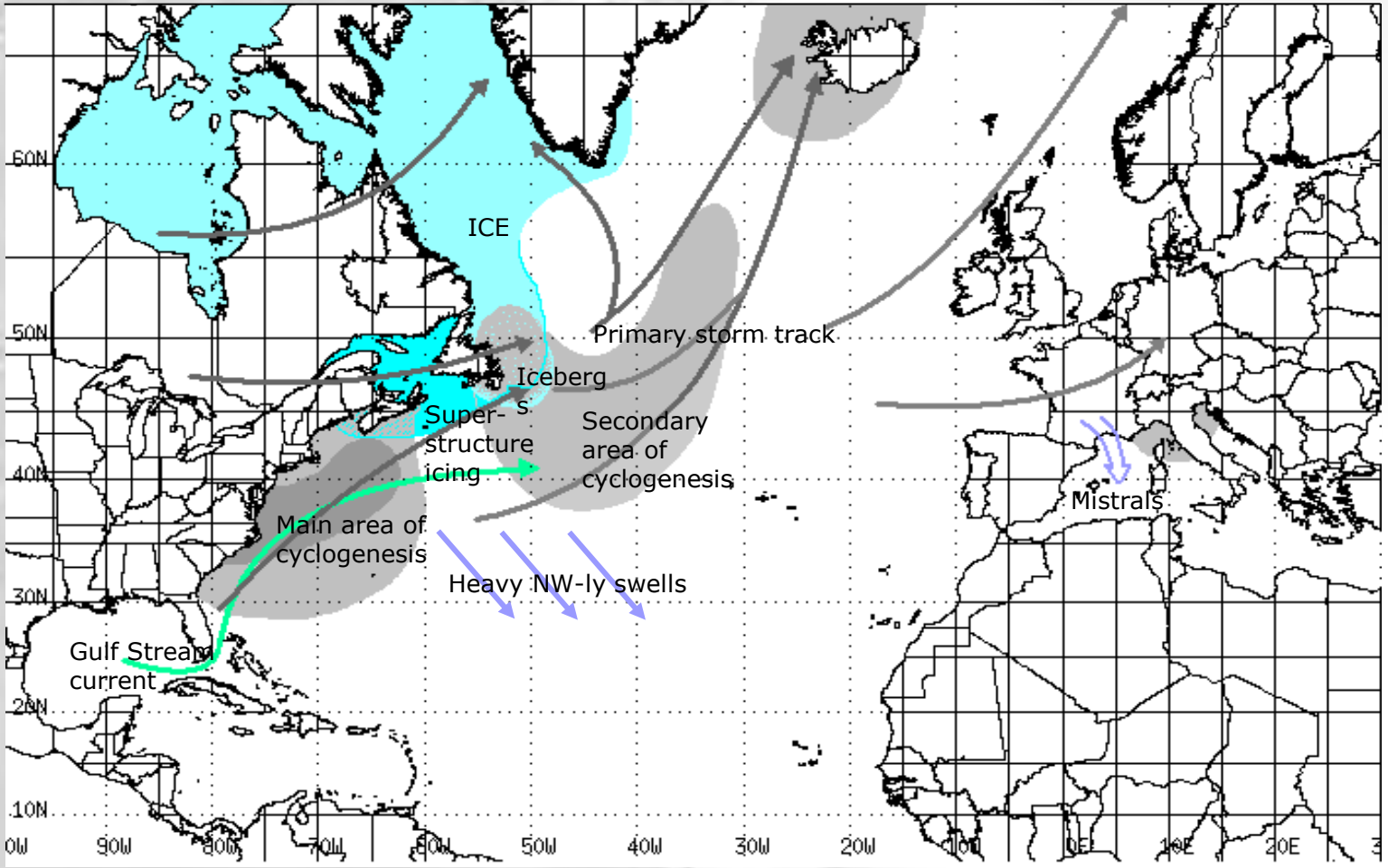
Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg



Courtesy of Weather News International

Hazards in the North Atlantic Winter

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg

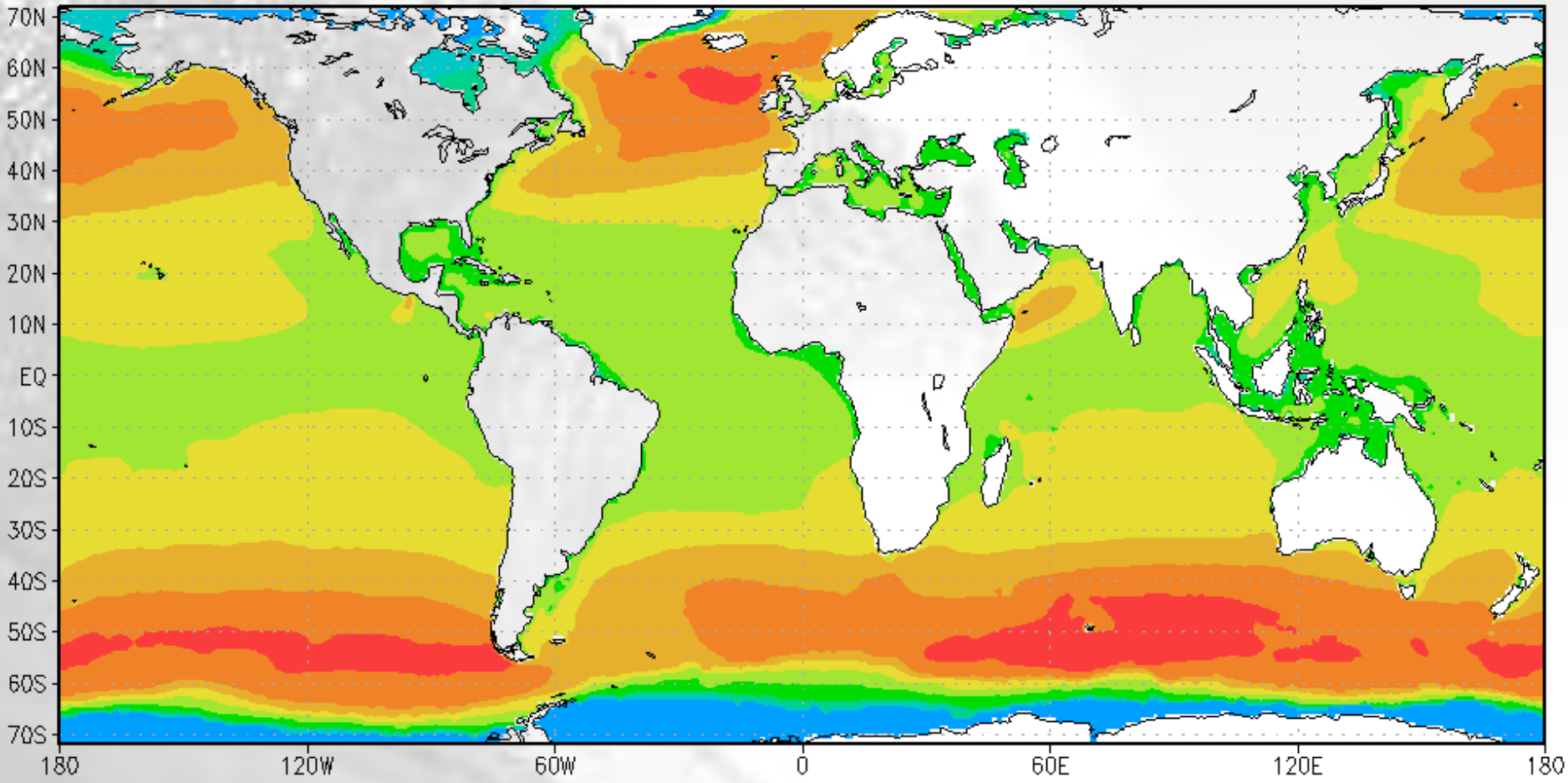


Courtesy of Weather News International

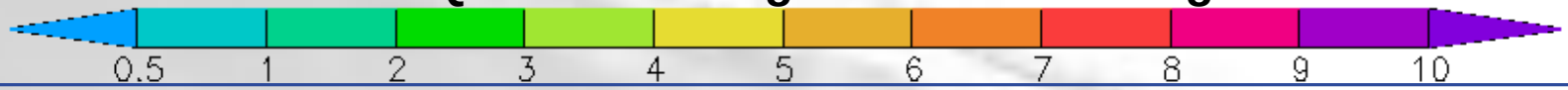
Thomas.Bruns@dwd.de

Wave Height Percentiles

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg



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

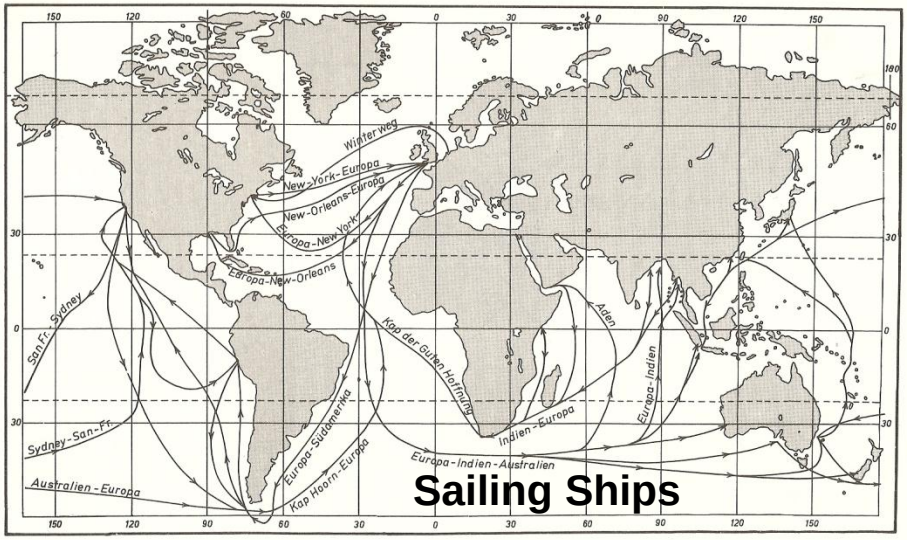
Environment
- Climatology
- Short Term Weather Variability

Requirements
Navigability
Safety
Rentability
Habitability (Comfort)

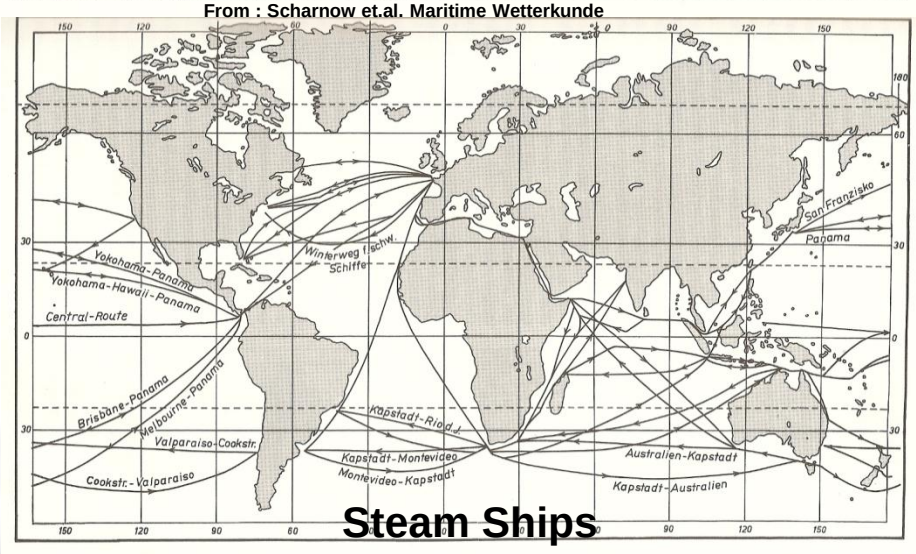
Climate Navigation

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



From : Scharnow et.al. Maritime Wetterkunde

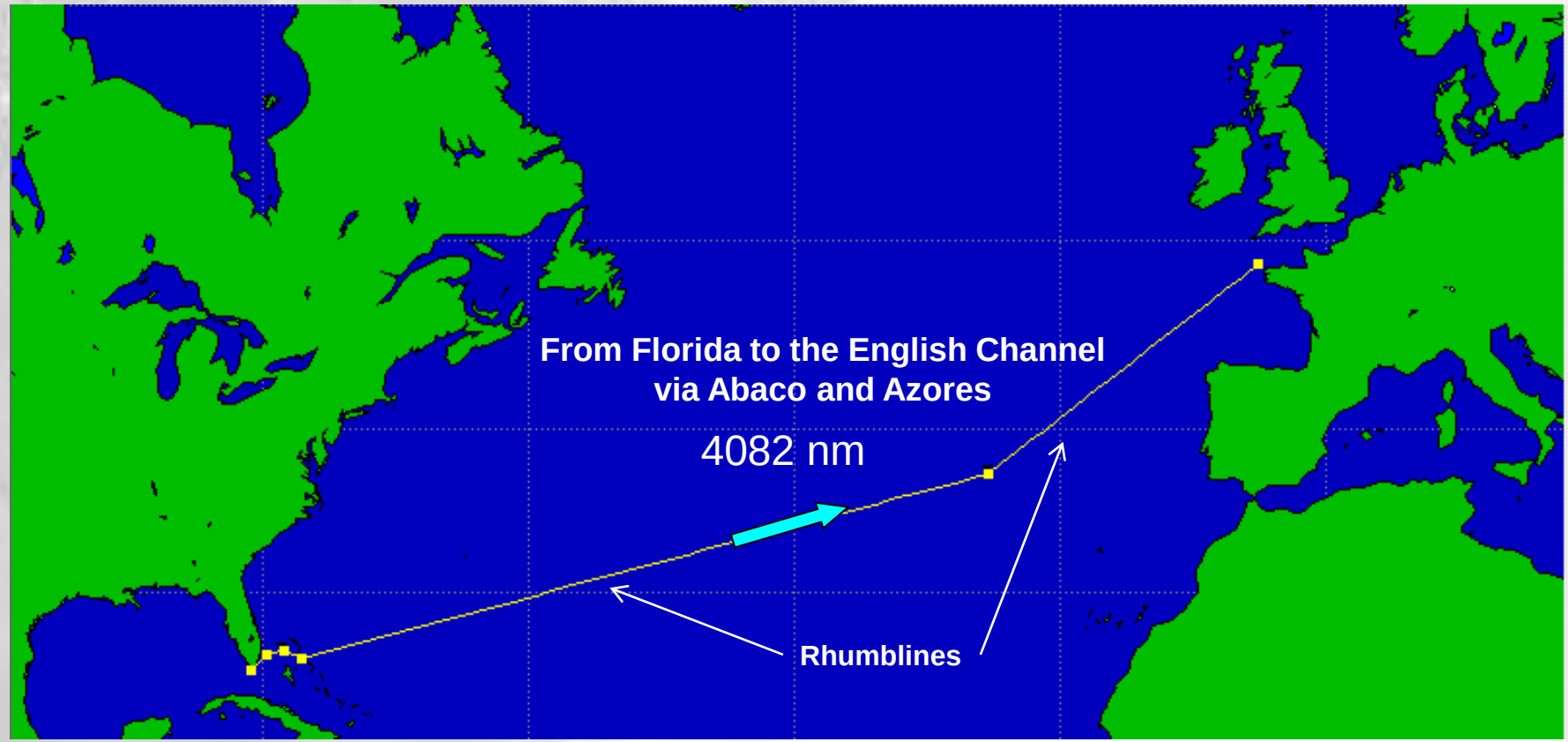


Weather Navigation

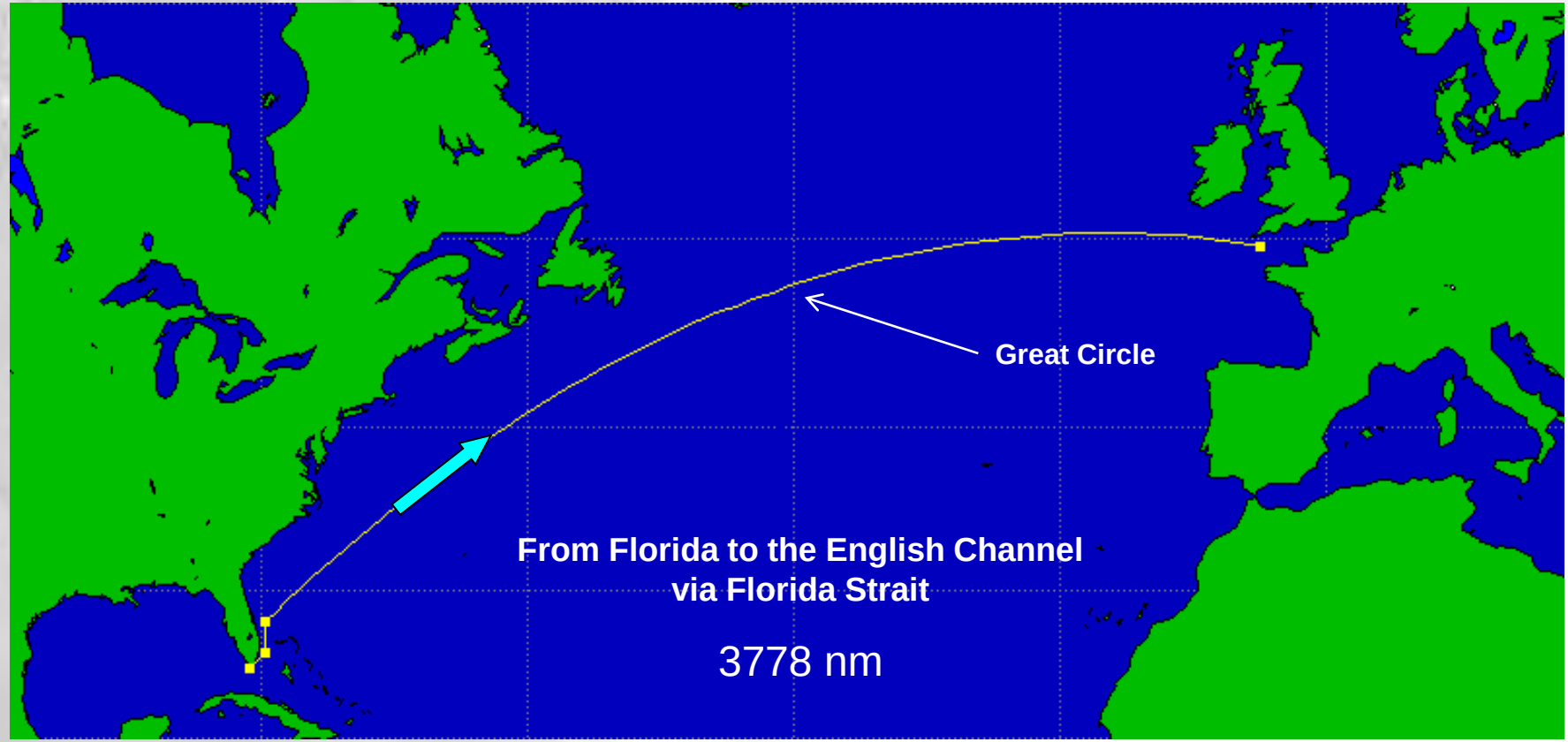
Two basic strategies :

- 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

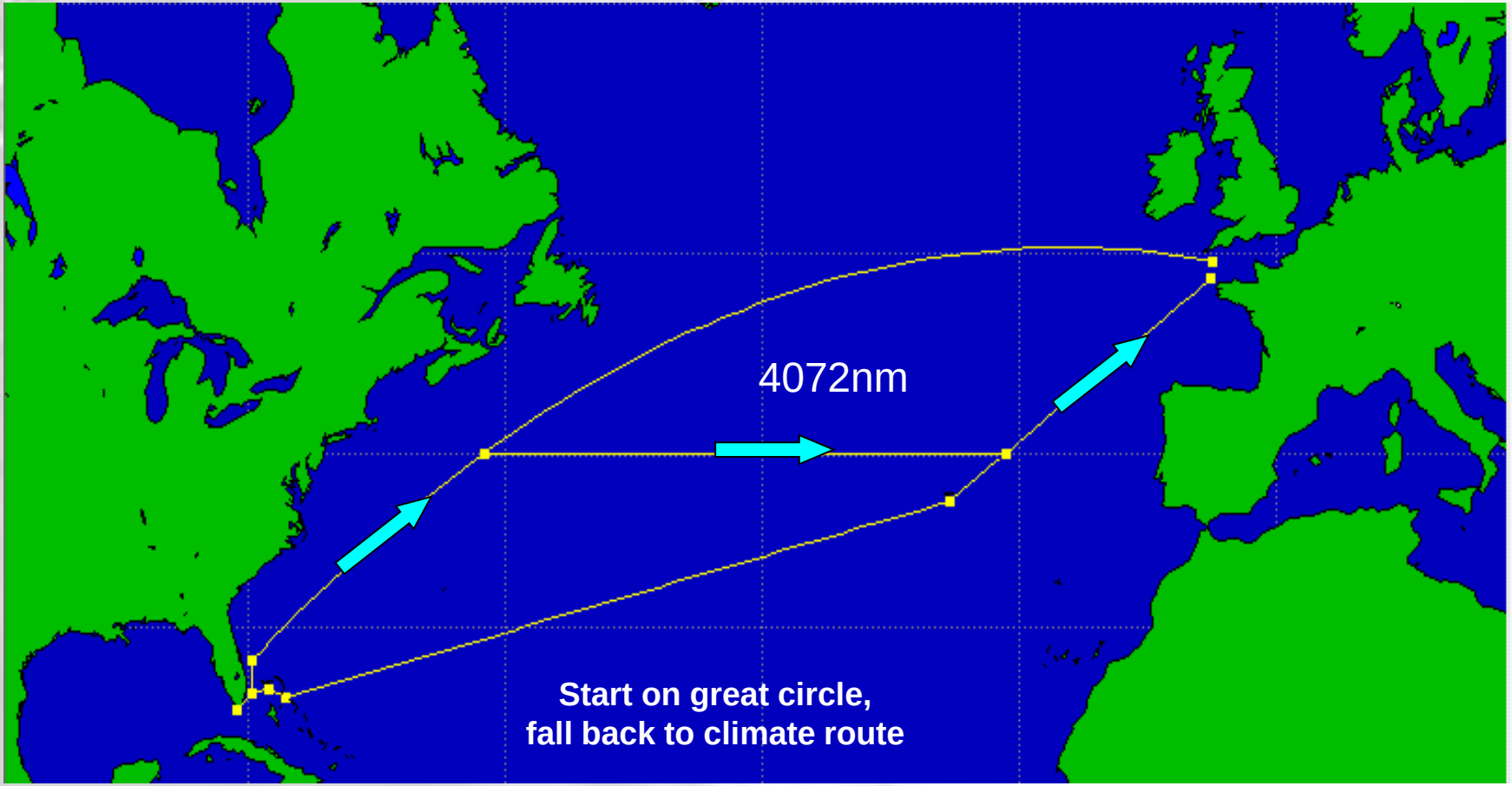
The Climate Route



Shortest Track : The Great Circle



Weather Navigation



Regional Features

Making use of Gulf stream in the Florida Strait

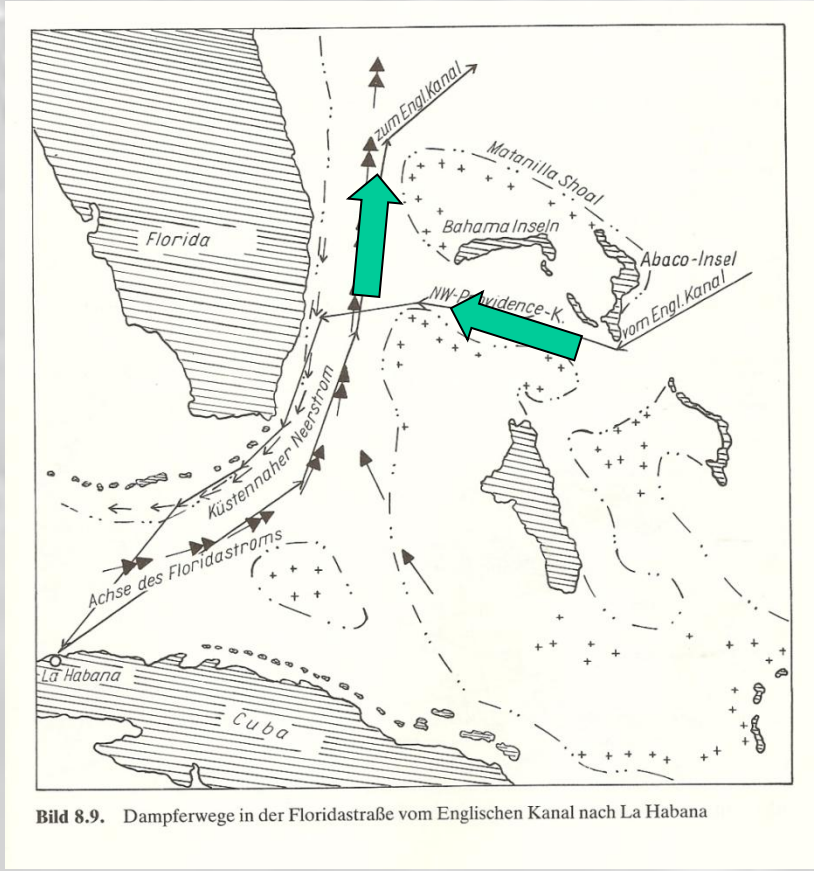
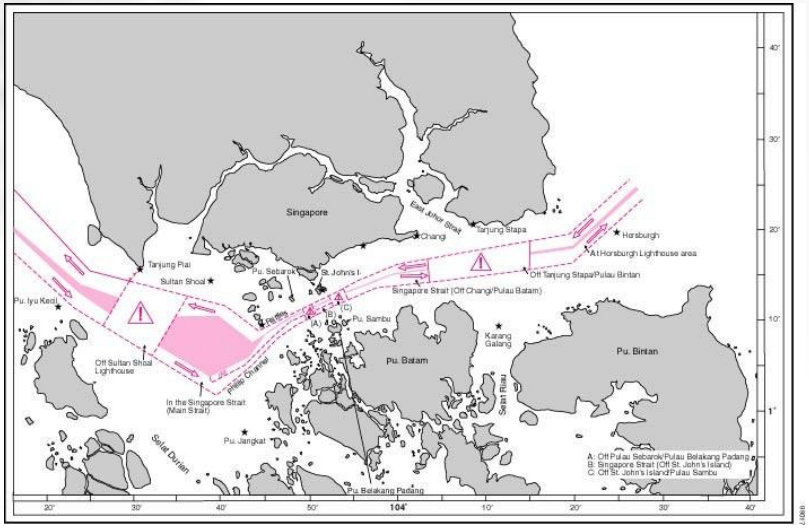


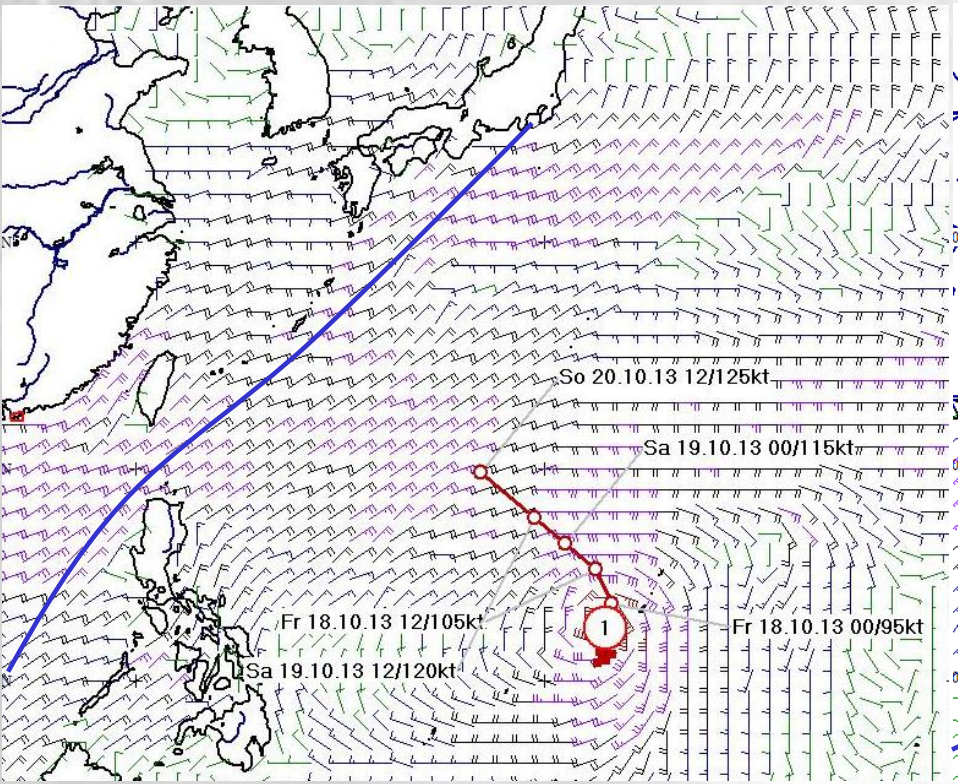
Bild 8.9. Dampferwege in der Floridastraße vom Englischen Kanal nach La Habana

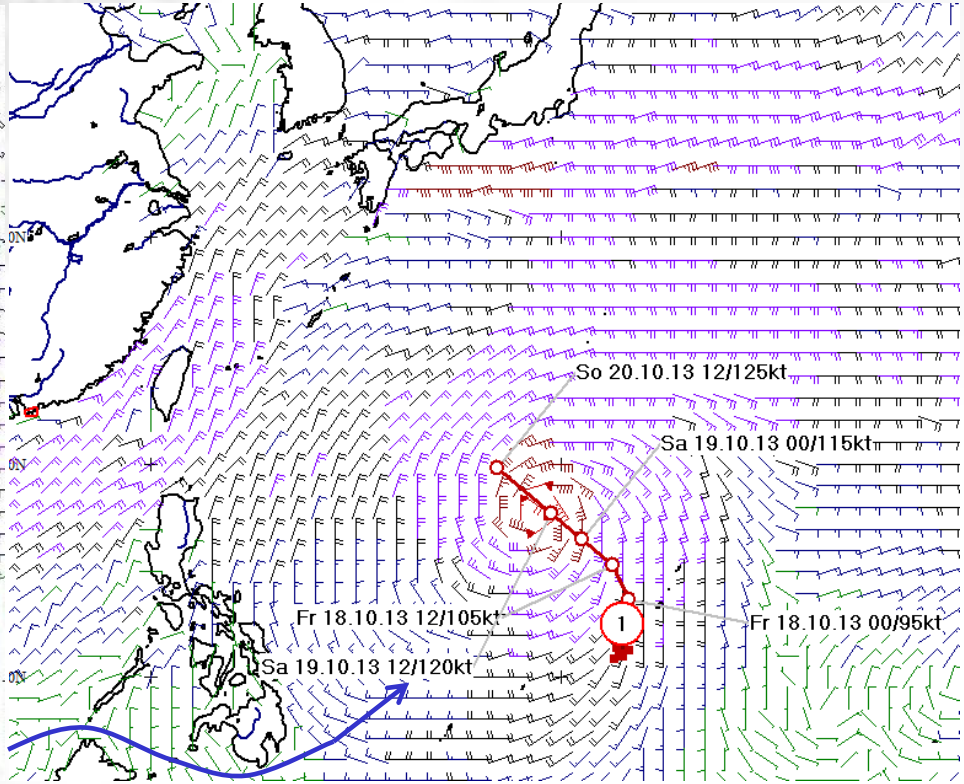


Traffic Separation in the Singapore Strait

Tactical Weather Routing
(Meteorological Navigation)

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg





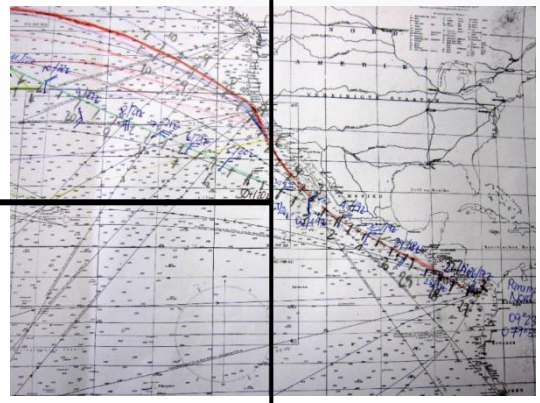
The Marine Meteorological Office in Hamburg

- 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

Weather Maps
(Synoptic Overview)



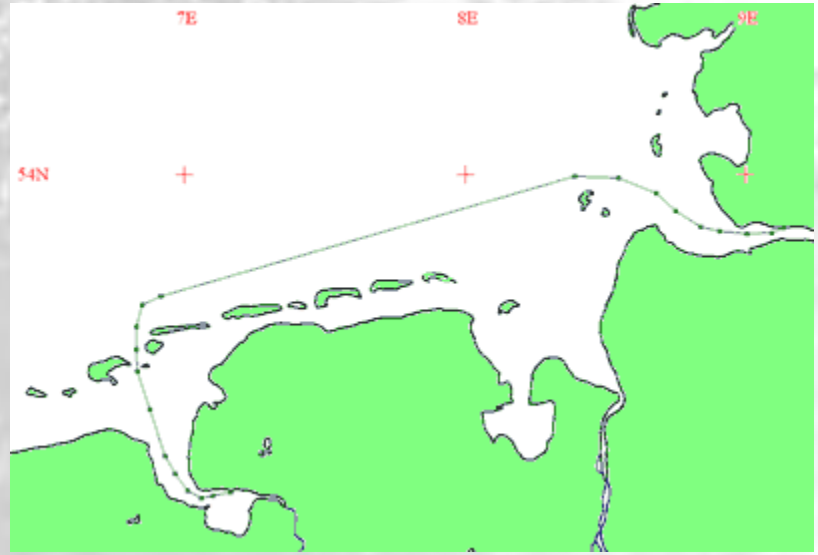
Routing Software
(Dead Reckoning)

Initial Recommendation
Frequent Updates

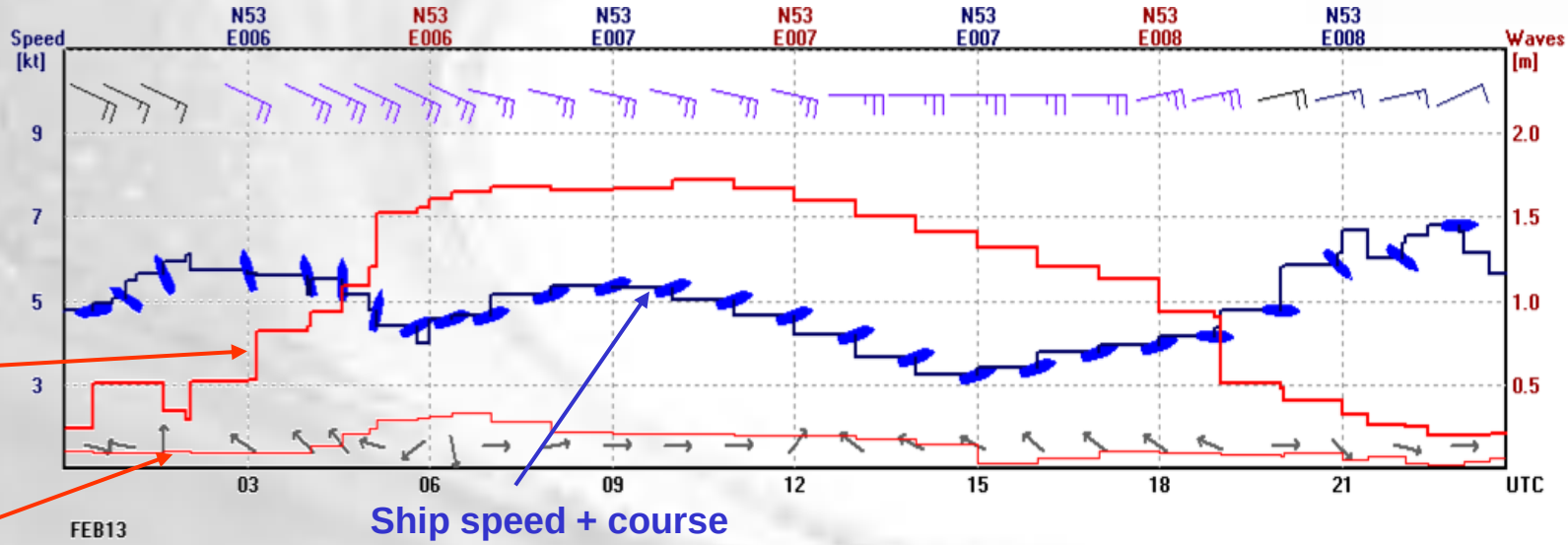
Navigational Maps
(Route Monitoring)

Routing for Coastal Shipping

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg



From Emden to Brunsbüttel



Sign. Wave Height

Swell Height

Ship speed + course

Text Messages

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg

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

Grafics

- 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.

From: German Meteorological Service (DWD), Marine Met Office
Weather Ship Routing WV 13, phone/fax ++69 69 8062 6187/6184
issued: 29.09.04 11 UTC
To
1. MV Example
   0582 999777888
2. Shipping Company

Ref.: Routing/track weather forecast

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://www.oceansltd.com/route.html
- http://www.wriwx.com/cargo/home.php
- 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

$$t_z = f(X_0 .. X_z, h_0 .. h_z, n_0 .. n_z)$$

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**

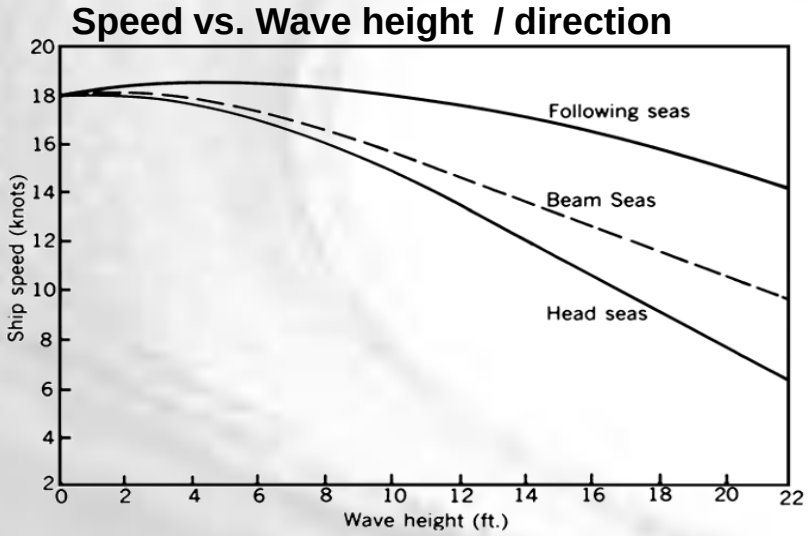
The most simple Solution

Time Optimization :

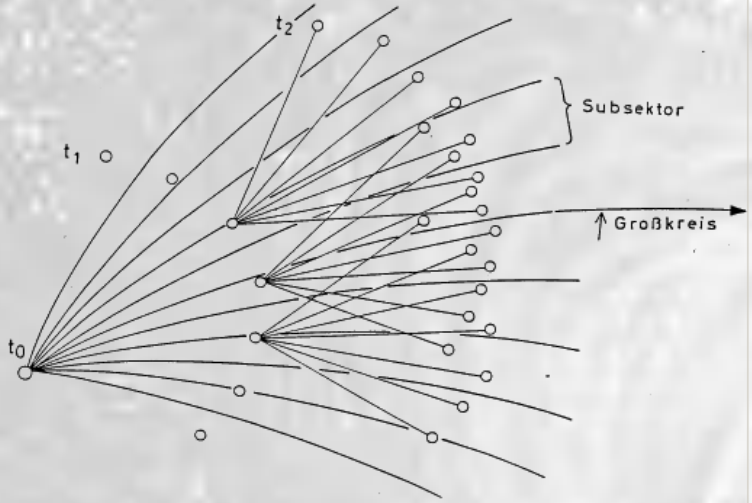
Minimize the cost function

$$J = \int_{t0}^{tz} A(X,h,n,t)dt + B(t_z, t_s)$$

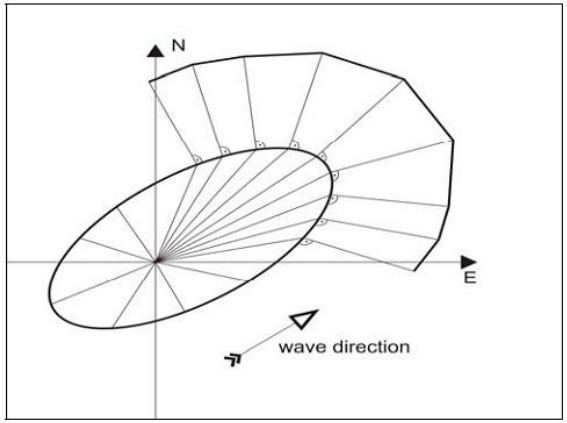
A = 1 **B = 0**



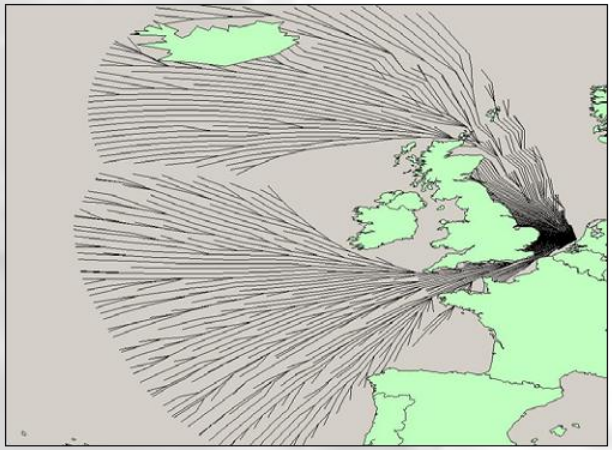
Time Optimization using the Isochrone Method



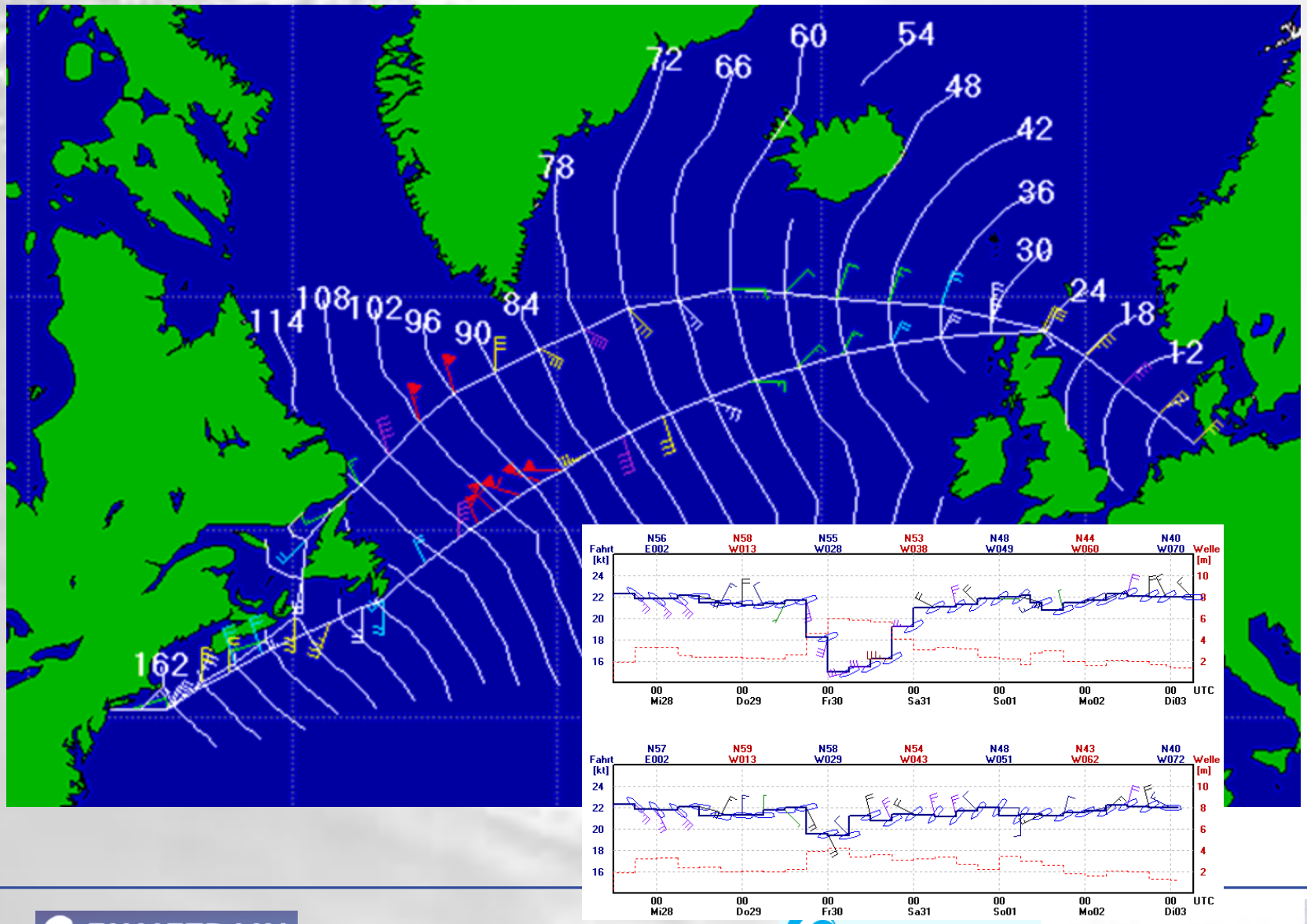
Isochrones are lines of equal arrival time



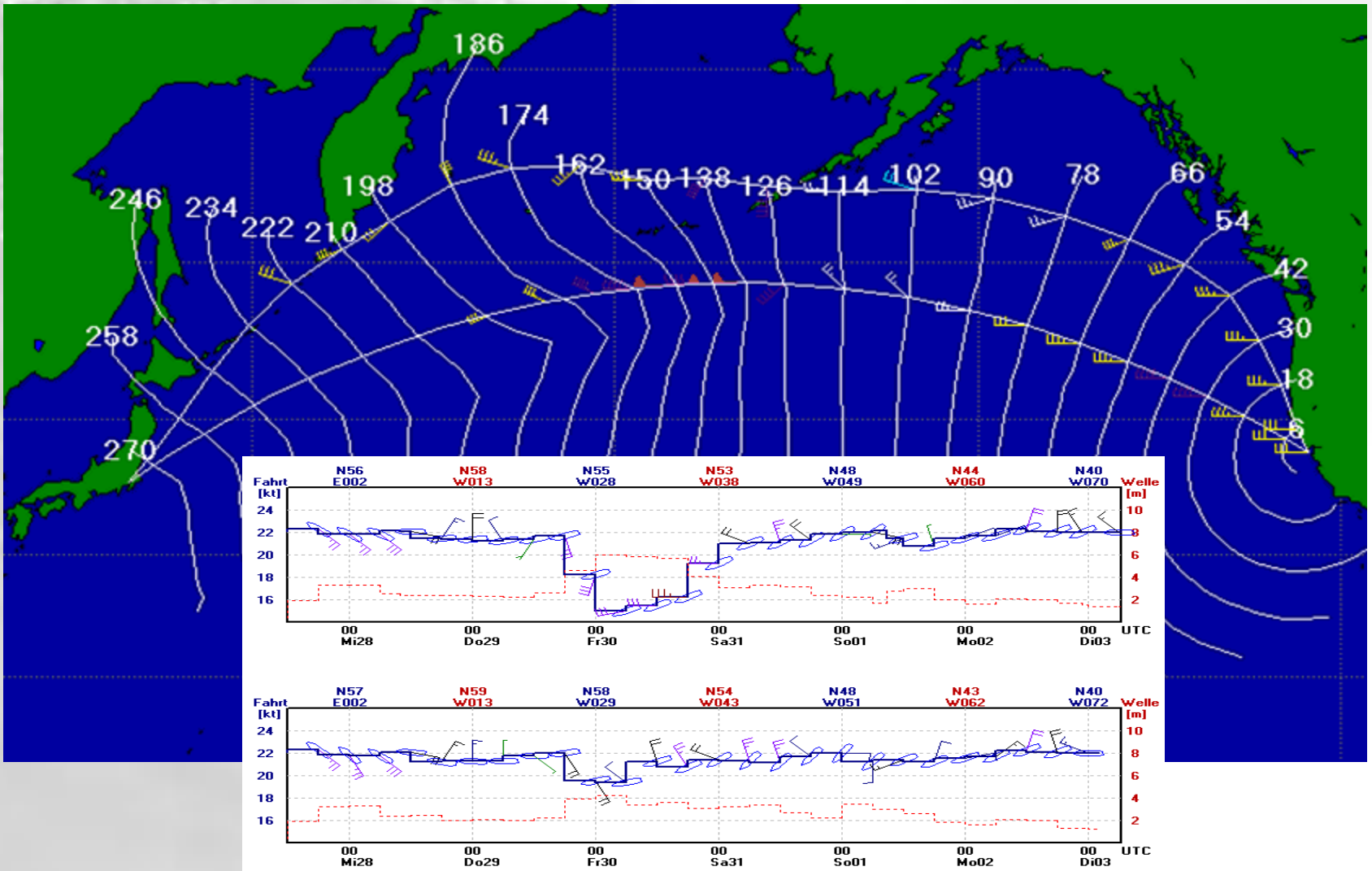
Construction of the first and second isochrone



Time Optimization using Isochrones

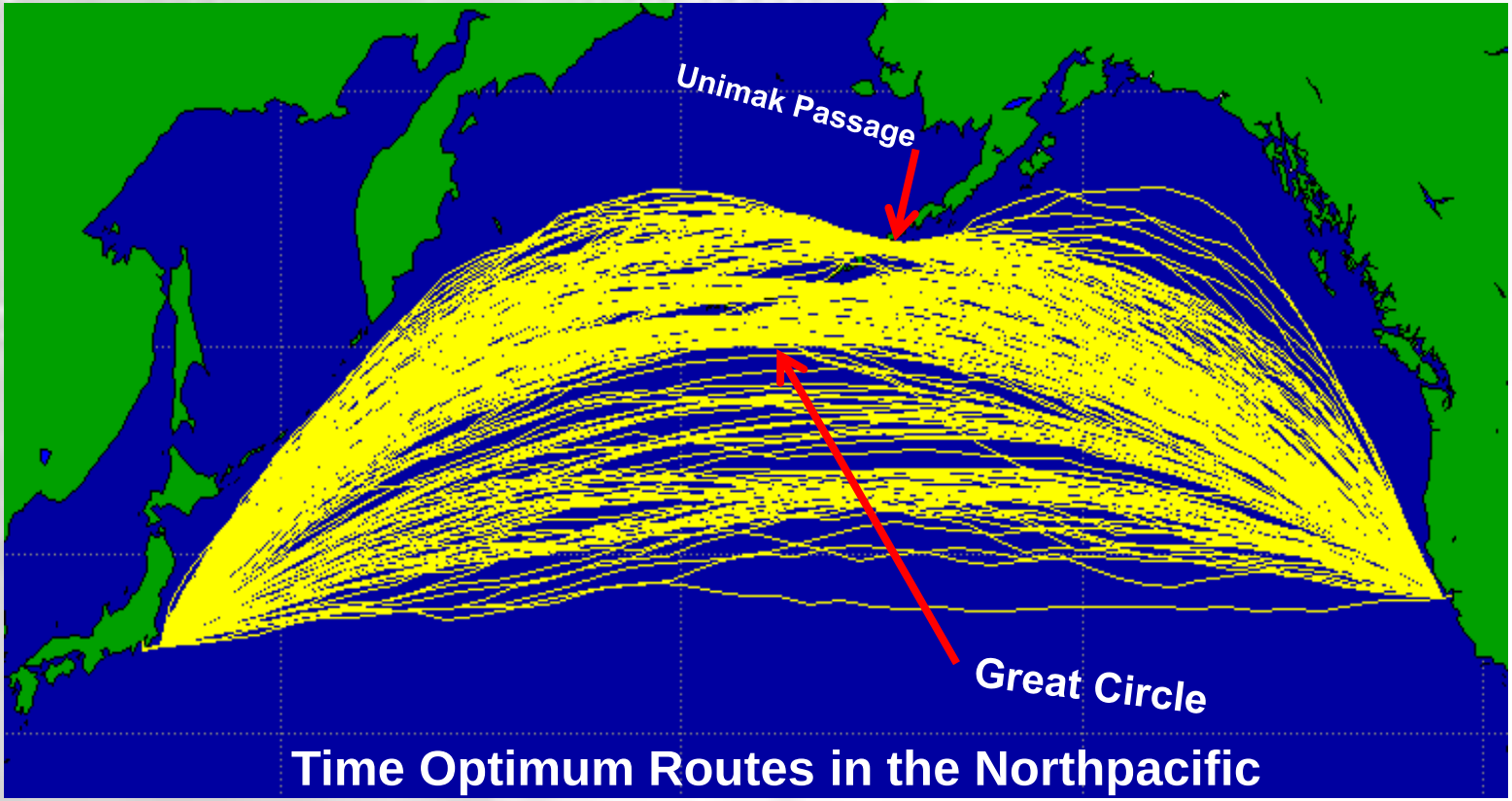


Time Optimization using Isochrones



Hindcast of Time Optimum Routes

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg

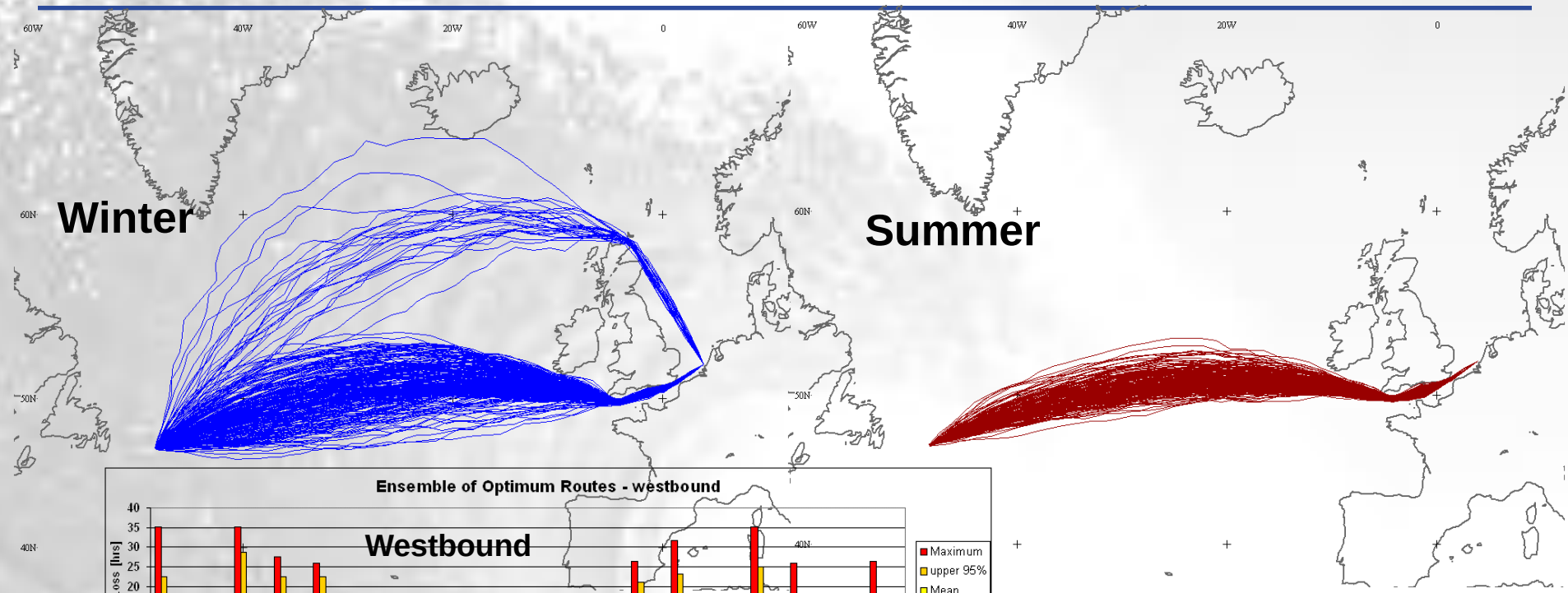


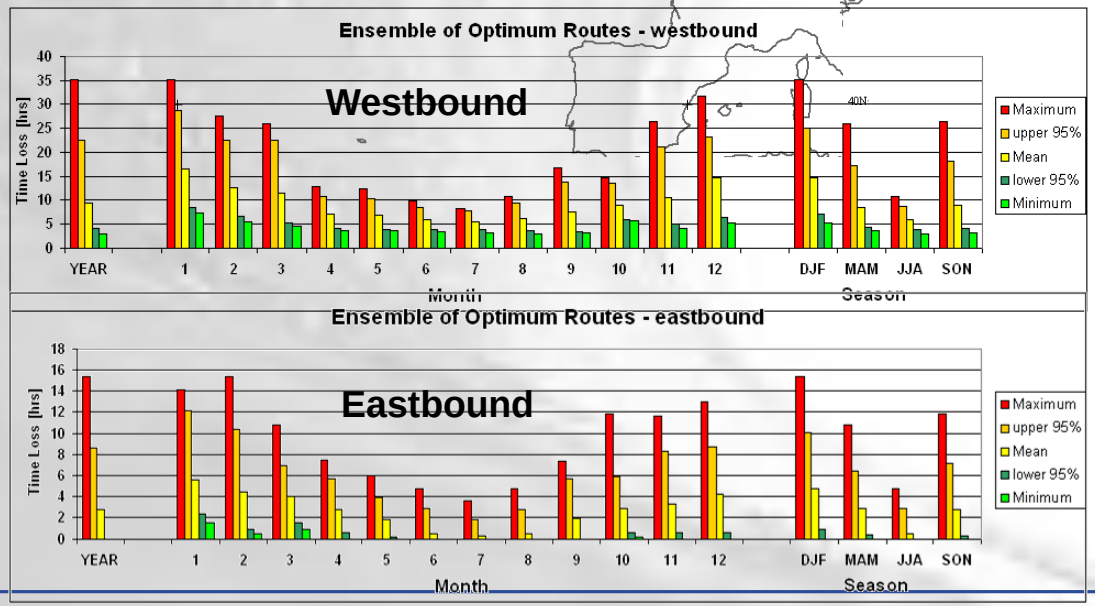
Time Optimum Routes in the Northpacific

Wintertime

Westbound Route Climatology for a Gas Tanker

Deutscher Wetterdienst
Seeschifffahrtsberatung Hamburg





Time loss
(relating to calm conditions)

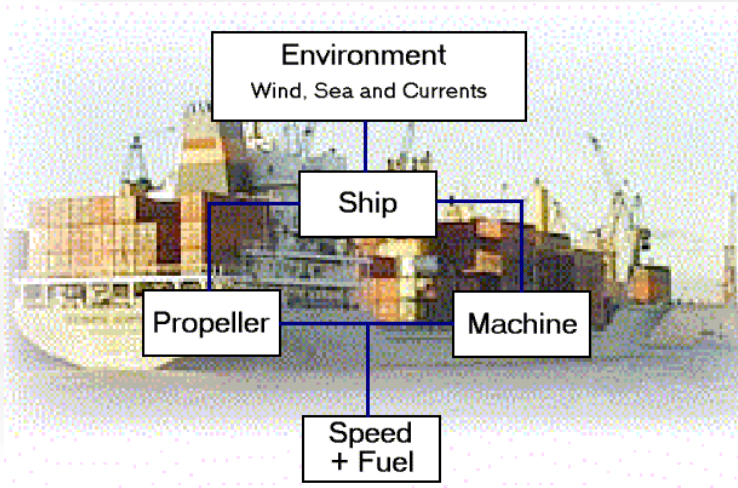
Thomas.Bruns@dwd.de

Ship Performance : Propulsion

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

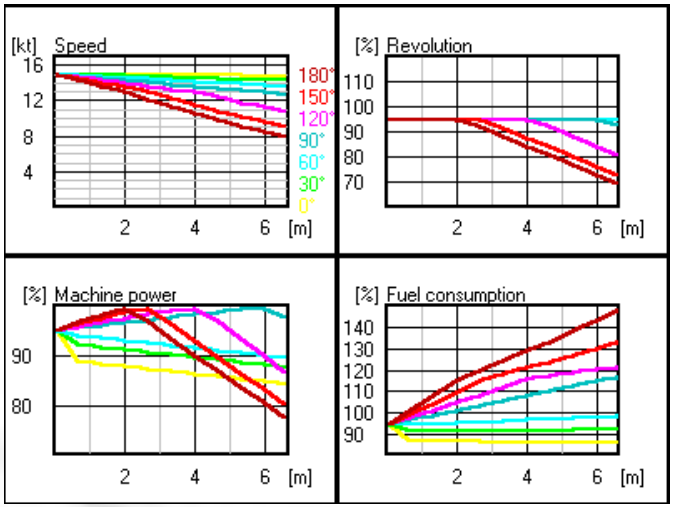
- **Total resistance**

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



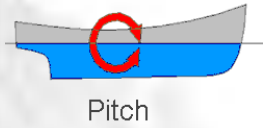
- A large number of ship, propeller and machine characteristics have to be considered to calculate the speed.

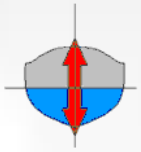
Google : Ship resistance and propulsion

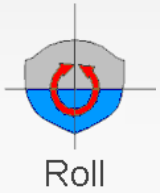


Hazardous Events

- Slamming







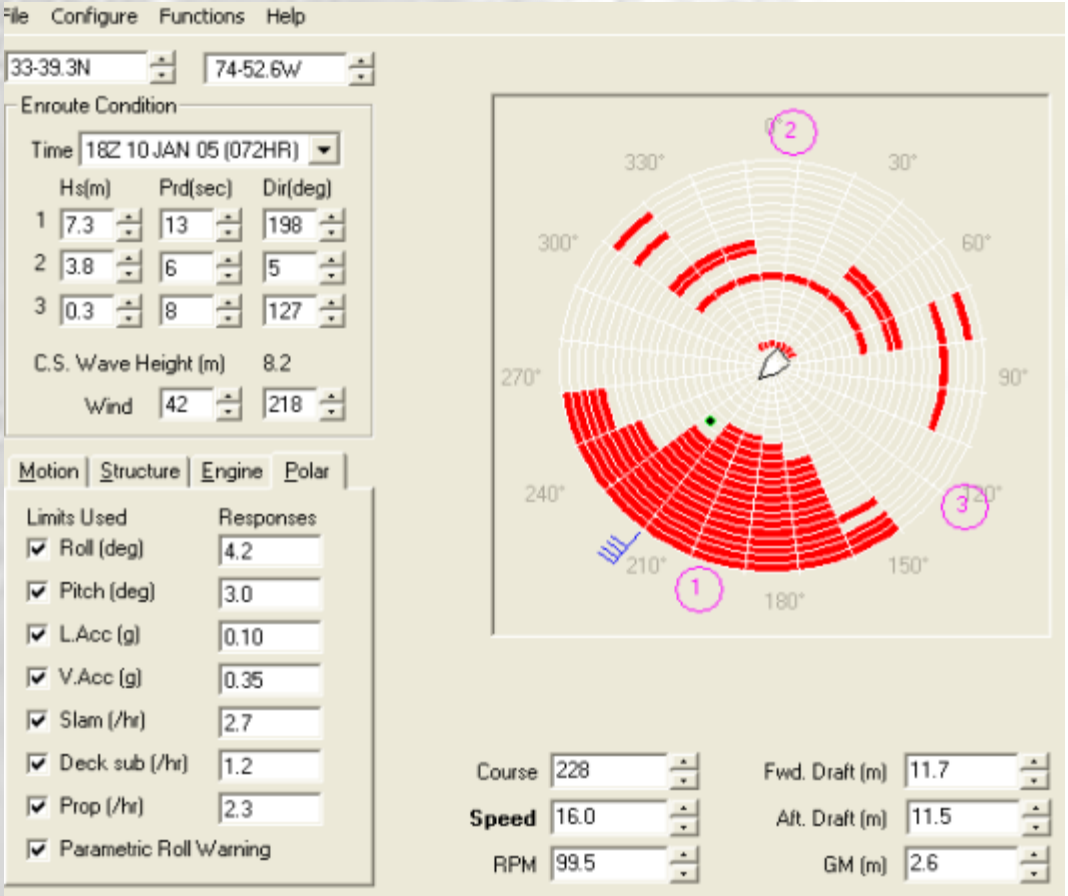
- Parametric rolling

  (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

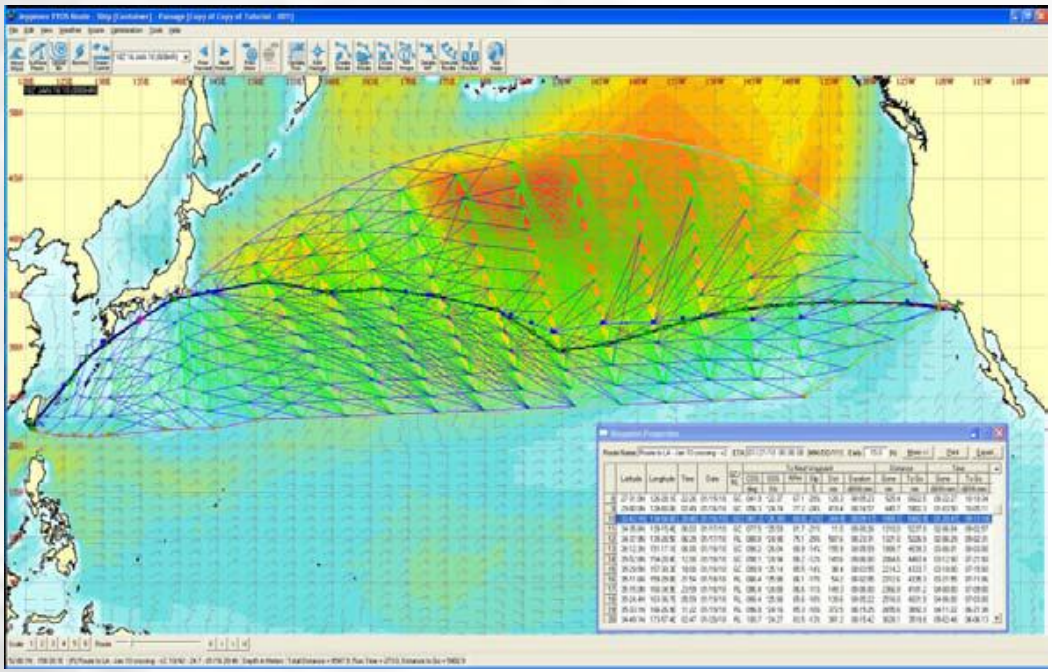


http://www.jeppesenmarine.com/files/whitepapers/VoyageOptimizationversusWeatherRouting1.pdf

Sophisticated Optimization Techniques

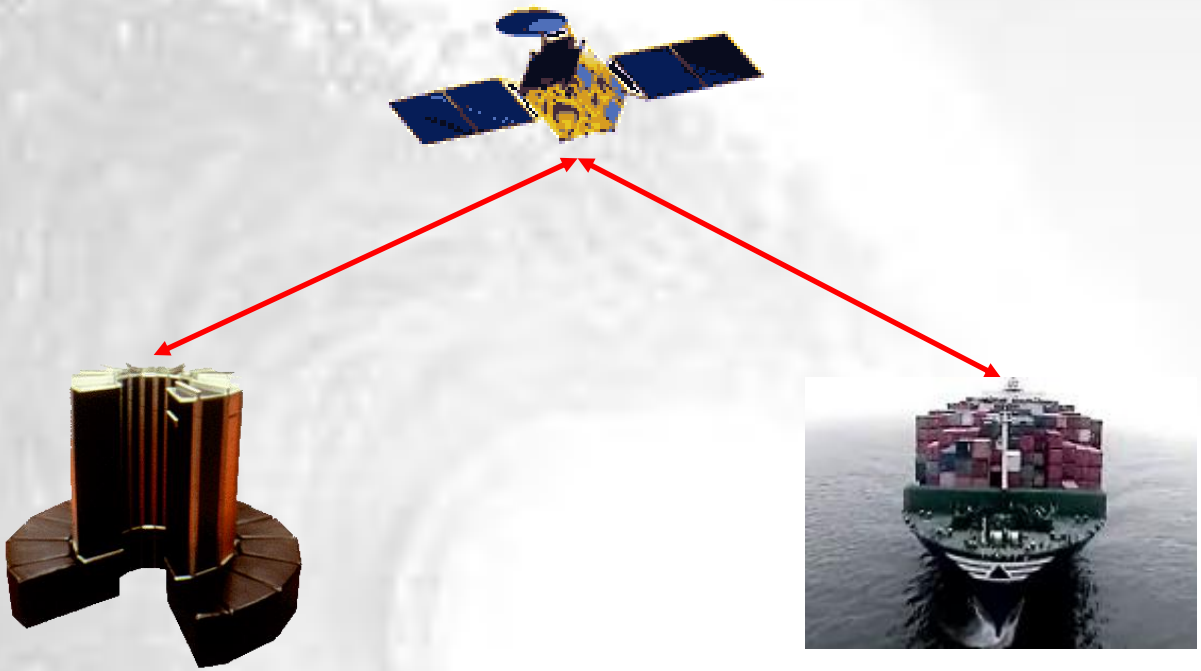
- Linear Programming (Kantorovich, 1939)
- Dynamic Programming (Bellman, 1957)
- Branch & Bound (Land & Doig, 1960)

Optimization using Dynamic Programming



http://www.jeppesenmarine.com/files/whitepapers/VoyageOptimizationversusWeatherRouting1.pdf

Onboard Routing Software

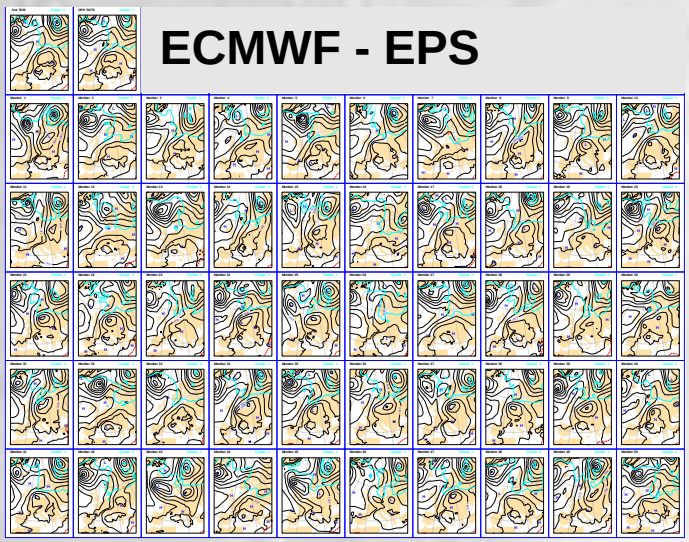


- http://www.awtworldwide.com/products/
- http://ww1.jeppesen.com/marine/commercial/vvos/commercial-marine-product.jsp
- http://www.ocean-systems.com/VOSS.htm

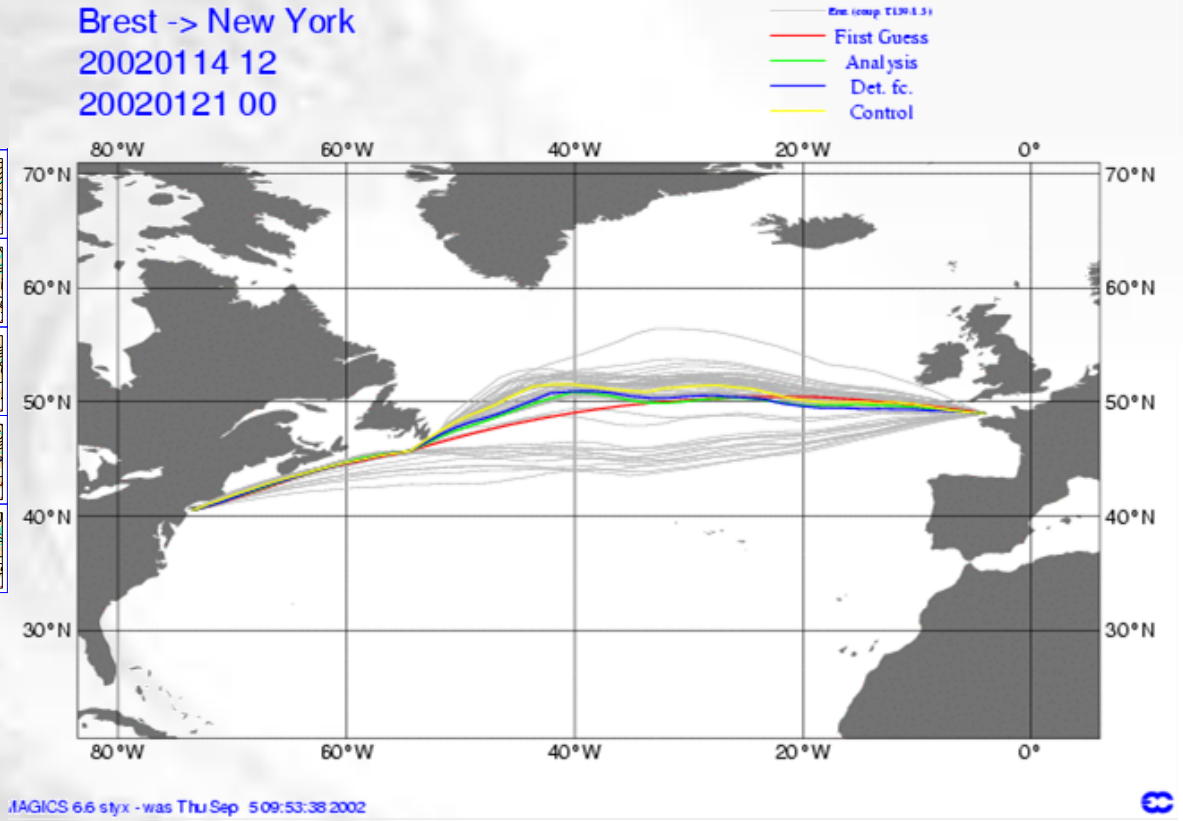
These are just a few examples!
Google for more!

Ensembles of Optimum Routes

Considering the uncertainties of the medium range weather forecast (>3 days) by using an **E**nsemble **P**rediction **S**ystem.



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



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 insufficent (chartered ships)
  - access to a variety of forecast models
  - MetOcean experts give short and clear advice


Thanks for your attention !