

Glider – ship collision analysis

5th EGO Meeting, Las Palmas, 2011

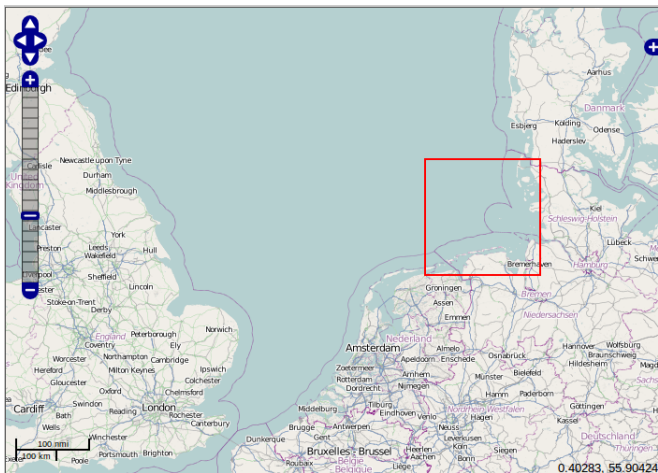
Lucas Merckelbach

Helmholtz Zentrum Geesthacht



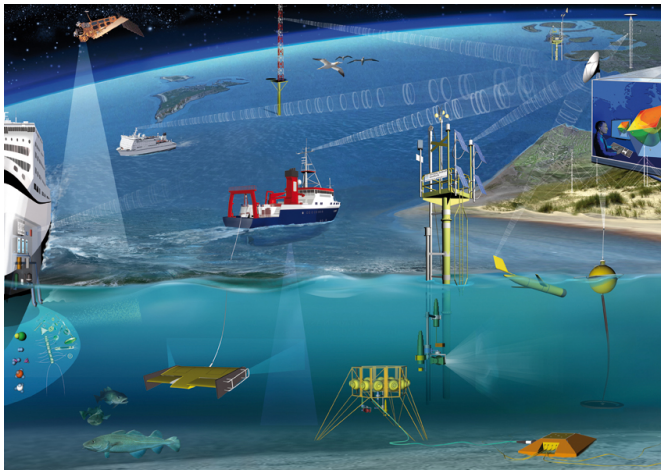
North Sea / German Bight

- Shallow (20-30 m waterdepth);
- Strong tidal currents (max. amplitude about 1 m/s).



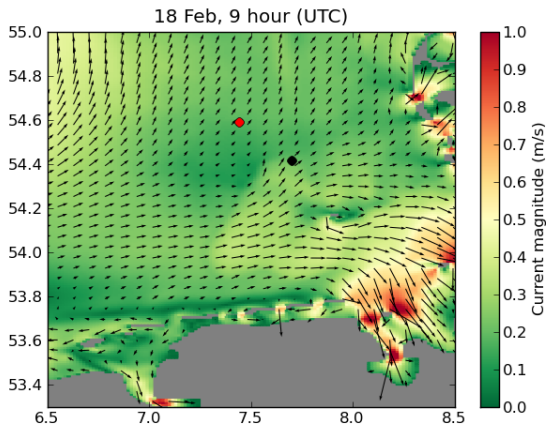
North Sea / German Bight

The COSYNA project: the construction of a long-term observatory for the German part of the North Sea.



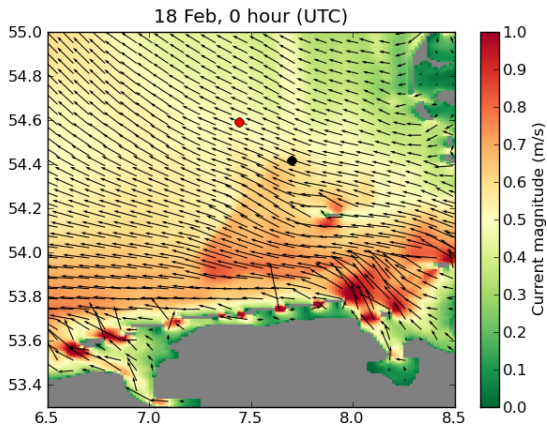
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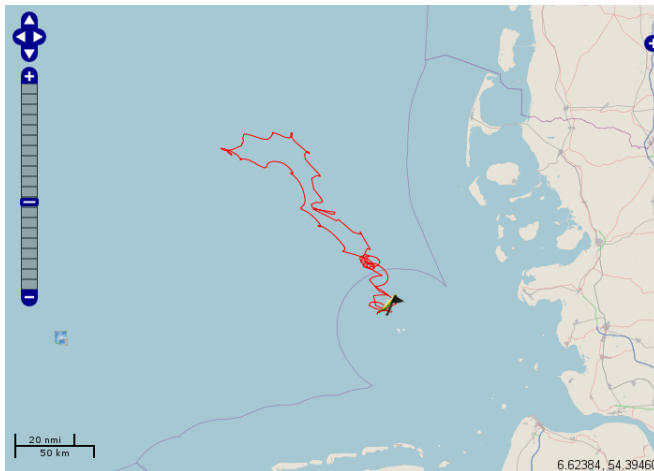
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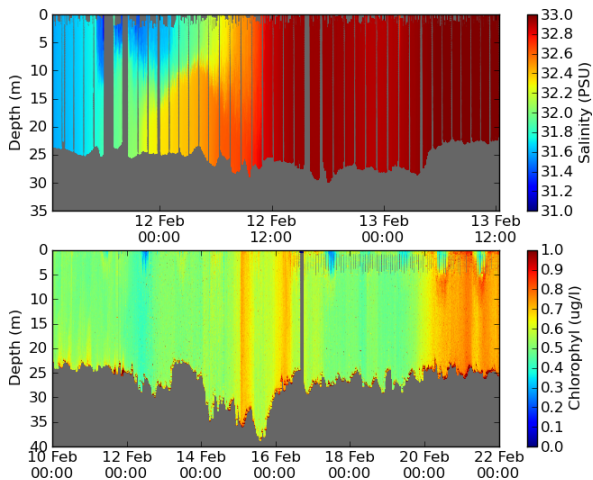
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Ships...

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Vessels in Range: 21983. Vessels Displayed: 463.

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Outline

- 1 Introduction
- 2 AIS
- 3 Probability of collision: simple model
- 4 Probability of collision: Monte Carlo simulation
- 5 Summary

AIS

AIS = Automatic Identification System

Contains:

- Vessel ID;
- Location;
- Heading;
- Speed;

and is communicated between ships and Vessel Tracking Services, aiding to prevent ship-ship collisions. Compulsory for larger ships and passenger vessels.

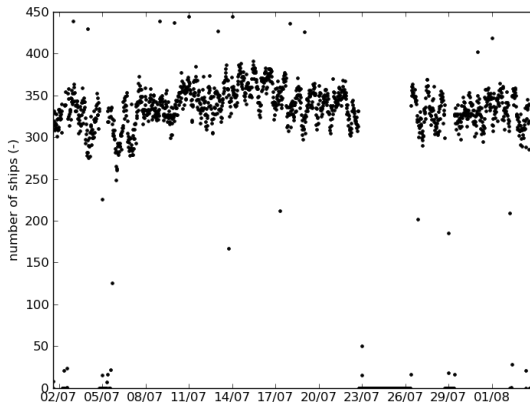
Historic data can be bought from specialised companies. For this work, data were collected from <http://www.marinetraffic.com>.

Dataset

- Collected data for July 2010;
- AIS data download from <http://www.marinetraffic.com> each 5 minutes;
- Building data base with ship dimensions (also from <http://www.marinetraffic.com>);
- Gridding data onto $1 \times 1 \text{ km}^2$ grid at 30 minute time resolution.

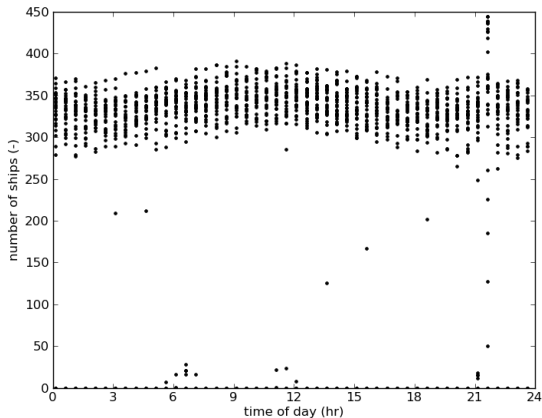
Dataset

Number of ships per day:



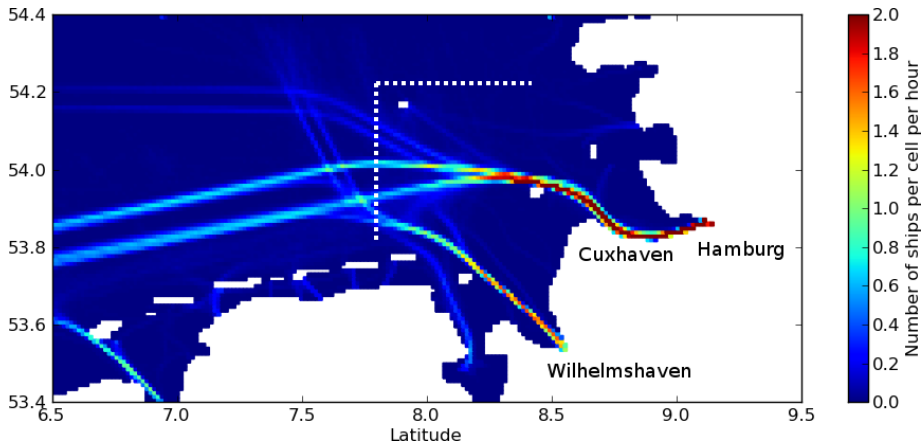
Dataset

Number of ships as function of time of day:



Dataset

Ship density map



Simple collision model

$$p_c = \rho T_t \times \frac{B}{L_t} \times \psi, \quad (1)$$

p_c probability of collision

ρT_t probability of being in same cell as a ship

ρ ship density

T_t glider transit time of cell

$\frac{B}{L_t}$ probability of being in the wrong place

B ship's width

L_t cell size

ψ probability of being too shallow to avoid collision

Simple collision model

Probability of collision for crossing one cell (1 km):

$$p_c = \rho T_t \times \frac{B}{L_t} \times \psi \quad (2)$$

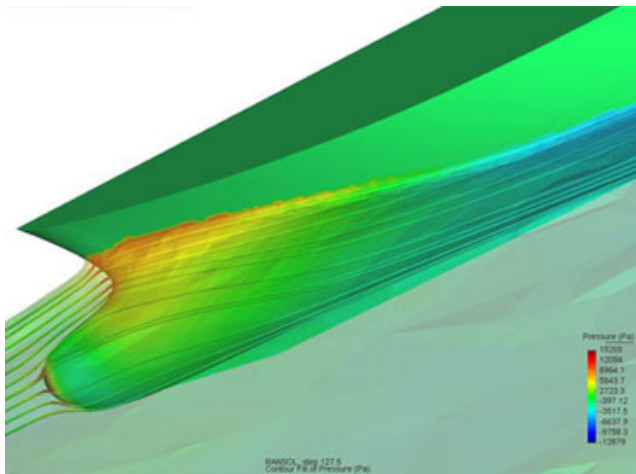
Probability of surviving a mission:

$$p_m = (1 - p_c)^m. \quad (3)$$

m mission length in cell sizes.

Streamlines around a hull

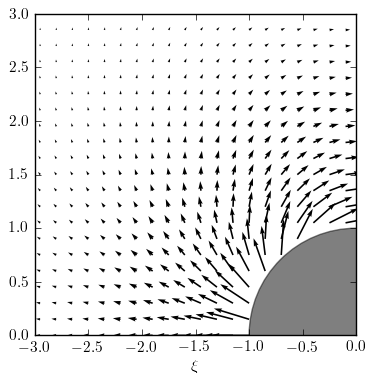
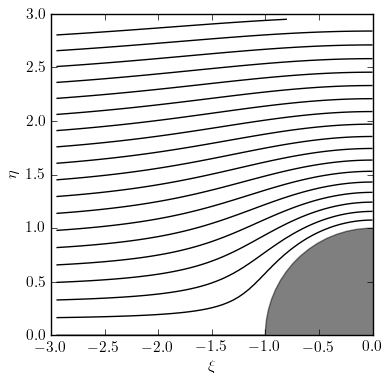
Assumption: ship's hull planview is linearly transformed circle.



Source: <http://www.vicusdt.com>

Streamlines around a hull

Assumption: ship's hull planview is linearly transformed circle.



Streamlines around a hull

Flow field:

$$u_x = f_x(u_s, x, y, L, B)$$

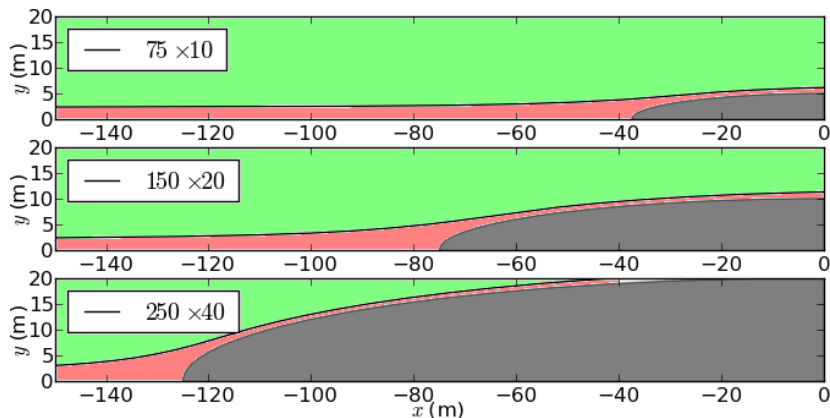
$$u_y = f_y(u_s, x, y, L, B)$$

Simple glider model:

$$(m + m_a)\dot{v} = \frac{1}{2}\rho C_d A V^2 e_v, \quad (4)$$

Streamlines around a hull

$$\frac{B'}{B} = C_0 \exp\left(-\frac{L}{L_0}\right), \quad L_0 = 100 \text{ m, and } C_0 \approx 0.48. \quad (5)$$



Streamlines around a hull

Recall: probability of surviving a mission ($B \rightarrow B'$):

$$p_c = \rho T_t \times \frac{B'}{L_t} \times \psi, \quad (6)$$

and

$$B' \approx 0.1B \quad (7)$$

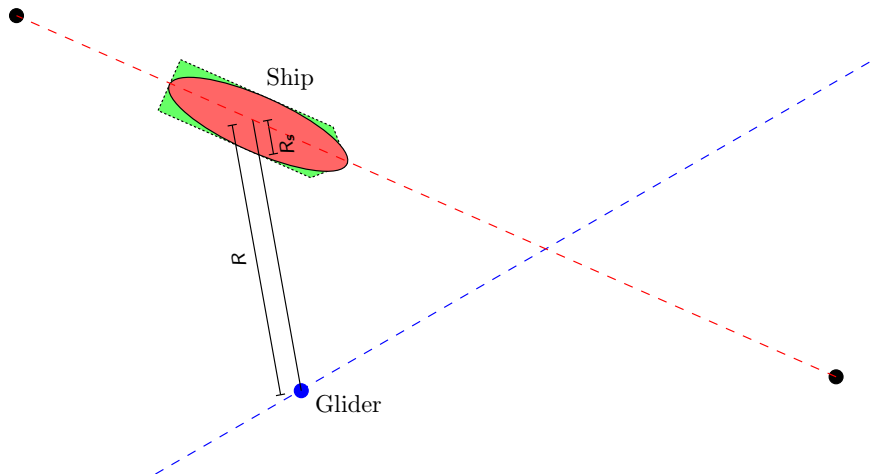
Monte Carlo Simulation

Algorithm:

- Construct ship tracks from positional data in database. Successive locations with a time difference more than 2 hours is new track.
- Deploy a large fleet of gliders randomly along a transect and let them move back and forth at constant speed.
- Time step through data and check for collisions. If a collision occurs, remove glider from fleet.

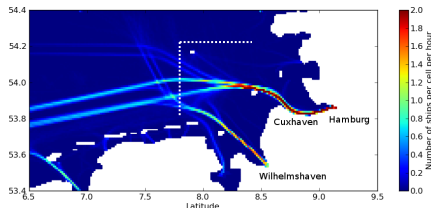
Monte Carlo Simulation

Collision algorithm:



Monte Carlo Simulation

Scenario's:



	Reduced ship Width (B or B')	Safe passaging under ship ($\psi = 1$ or $\psi = 0.5$)
a)	No	No
b)	Yes	No
c)	No	Yes
d)	Yes	Yes

Monte Carlo Simulation

Expected population size of gliders, assuming constant probability of collision per transect p_t :

$$N/N_0 = 1 - (1 - p_t)^{\frac{v_g t}{L_t}}. \quad (8)$$

N number of gliders out of initial fleet N_0

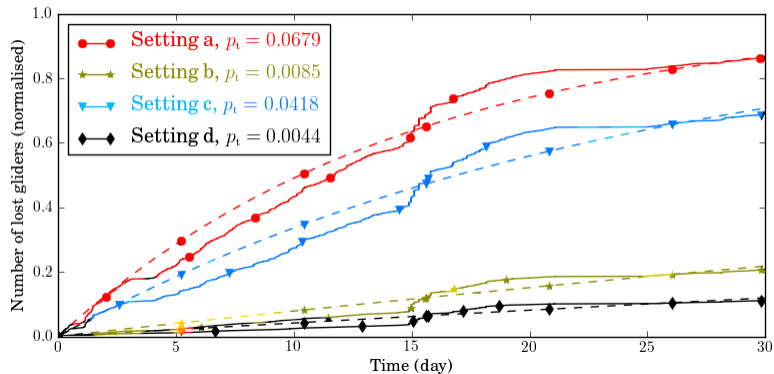
v_g glider speed

L_t length of transect (40 km)

t time

Monte Carlo Simulation

Results:

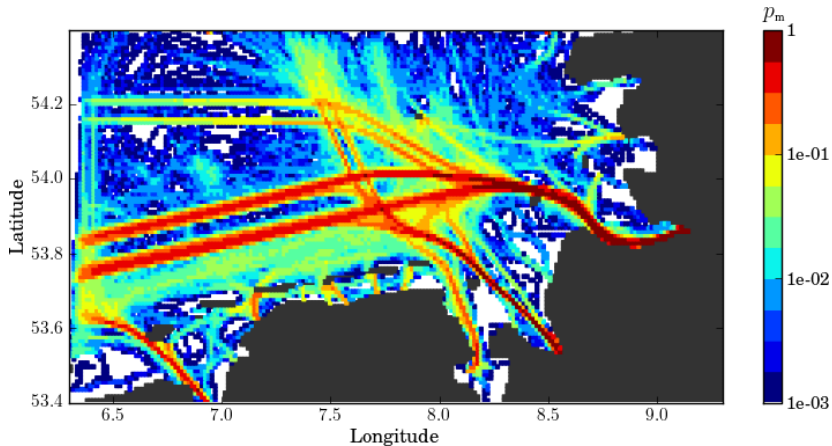


Comparison Simple model and Monte Carlo Simulation

	setting a $\psi = 1$ $B = 20 \text{ m}$	setting b $\psi = 1$ $B = 2.6 \text{ m}$	setting c $\psi = 0.55$ $B = 20 \text{ m}$	setting d $\psi = 0.55$ $B = 2.6 \text{ m}$
Simple model	7.3×10^{-2}	9.6×10^{-3}	4.0×10^{-2}	5.2×10^{-3}
Monte-Carlo	6.8×10^{-2}	8.5×10^{-3}	4.2×10^{-2}	4.4×10^{-3}

Risk map

Probability of collision map for a 30 day mission.



Summary

- Use of AIS data to graph ship density, which varies from 0.8-2 ships per hour per km^2 in shipping lanes.
- Set up a simple collision model to translate ship density to collision probability and verified by Monte Carlo simulation.
- Estimated apparent ship width at about 0.1 of the real ship width.
- Results:
 - risk map to be used in transect planning.
 - expected (long term cost) of a given transect.
- Method can be applied easily to other areas.

Thanks to D. Lekkas, Department of Product and Systems Design Engineering University of the Aegean, Greece, for allowing the AIS data to be used.