Glider – ship collision analysis
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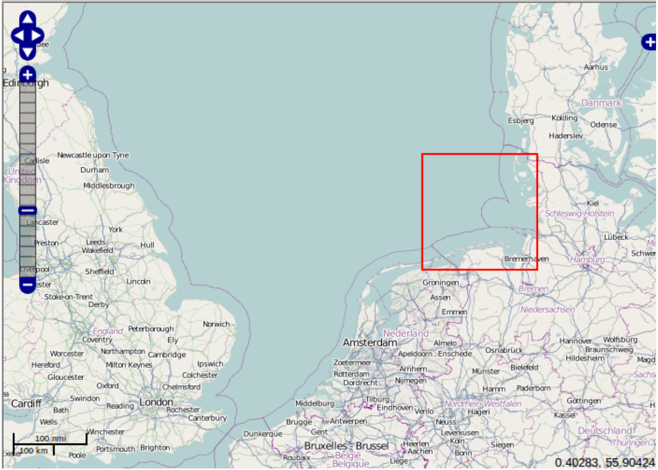
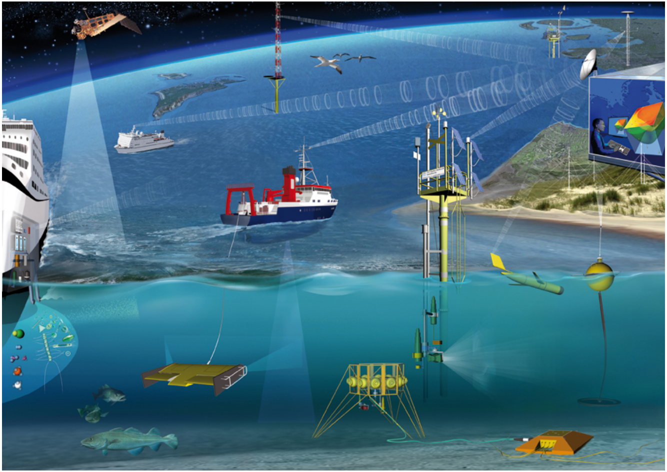
North Sea / German Bight

- 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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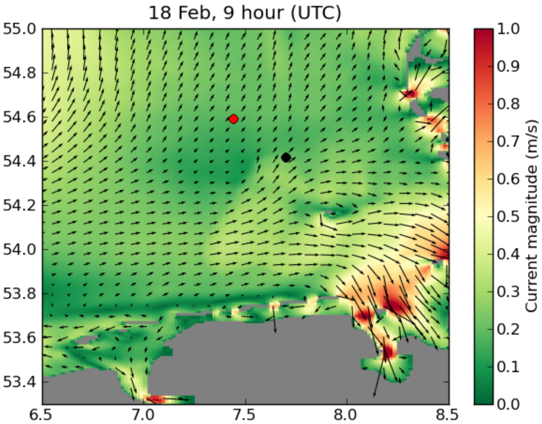

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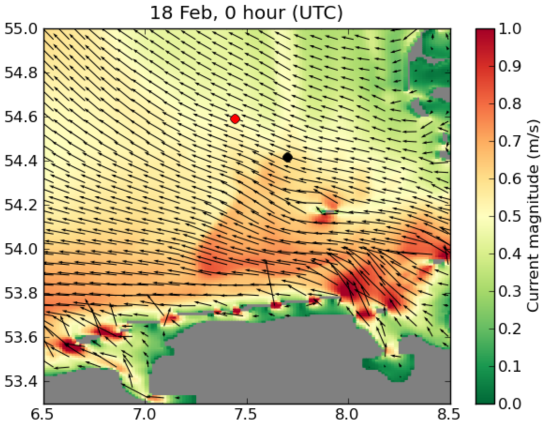

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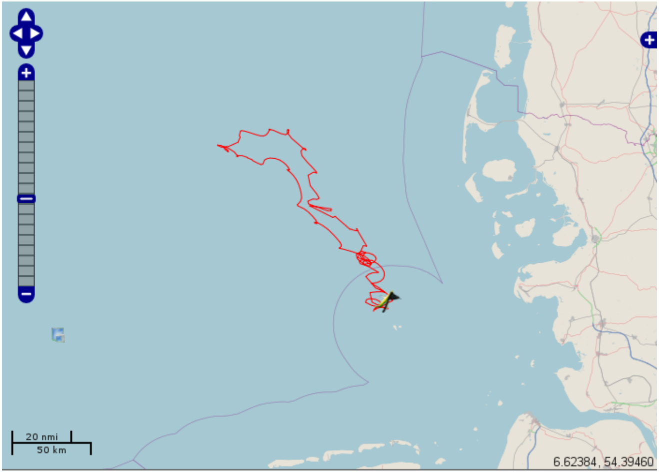

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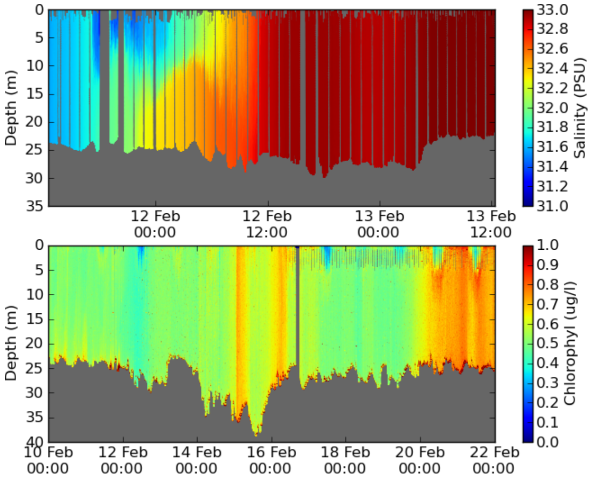
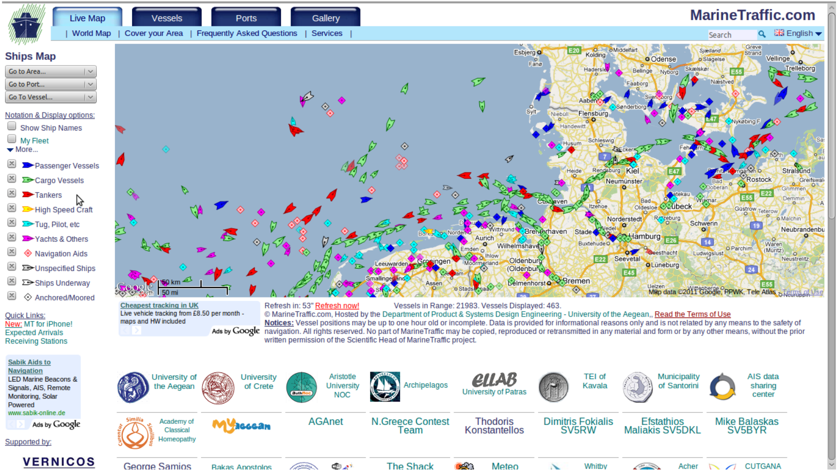


Ships...

Live ship positions on the web (http://www.marinetraffic.com)



Outline

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.

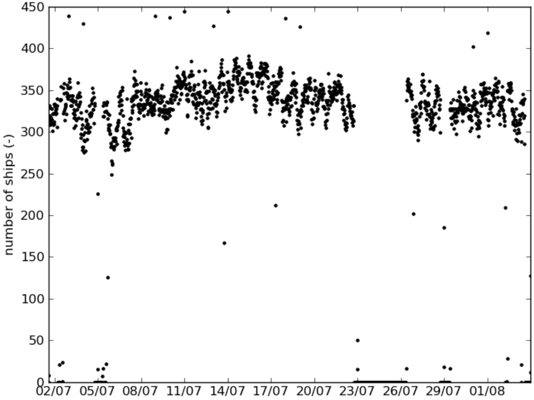
Historic data can be bought from specialised companies. For this work, data were collected from http://www.marinetraffic.com.

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 1x1 km^2 grid at 30 minute time resolution.

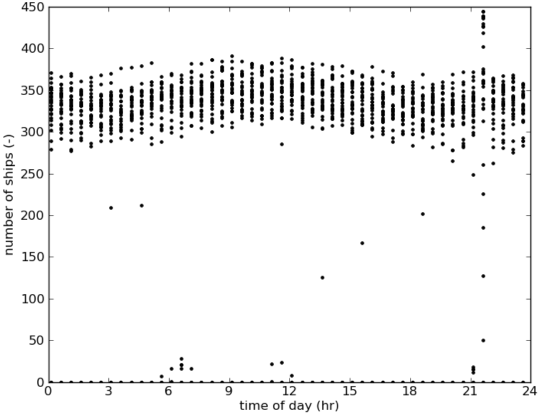
Dataset

Number of ships per day:



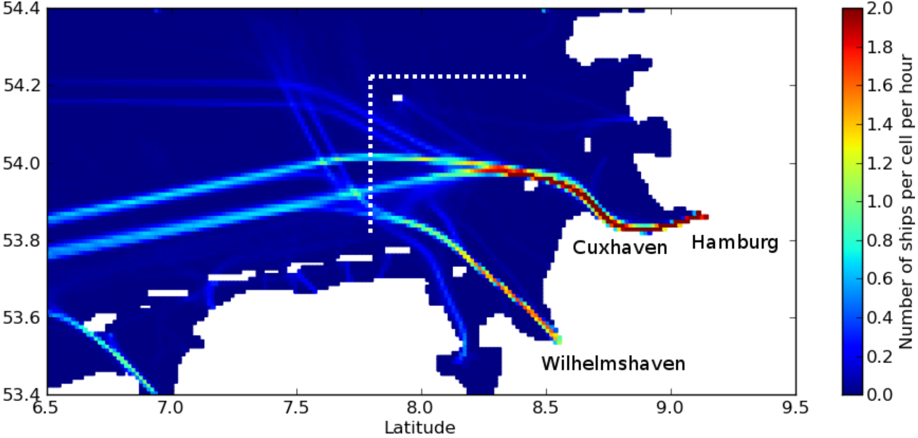
Dataset

Number of ships as function of time of day:



Dataset

Ship density map



Simple collision model

$$p_c = \rho T_t \times \frac{B}{L_t} \times \psi, \tag{1}$$

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):

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

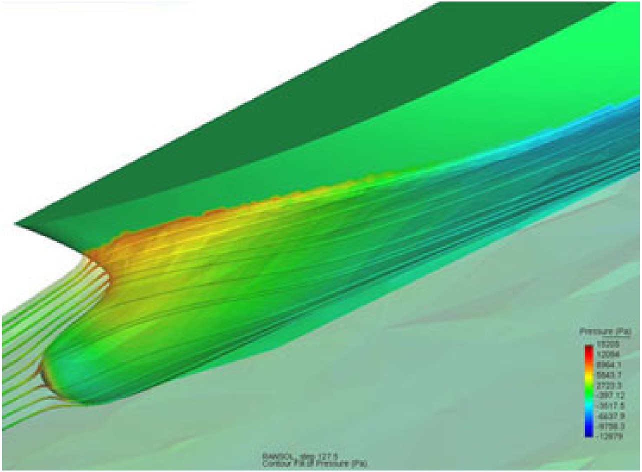
Probability of surviving a mission:

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

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

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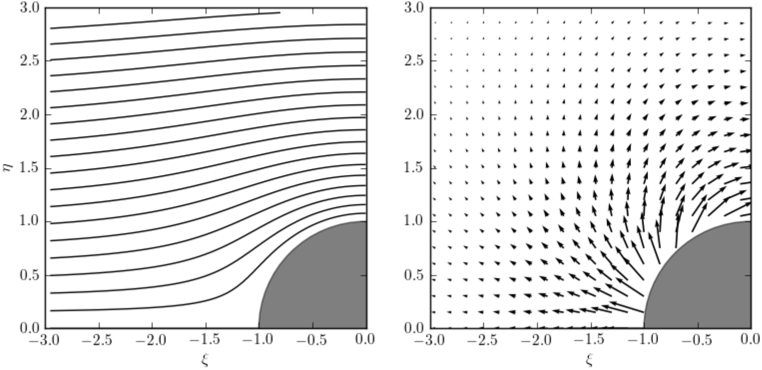


Streamlines around a hull

Flow field:

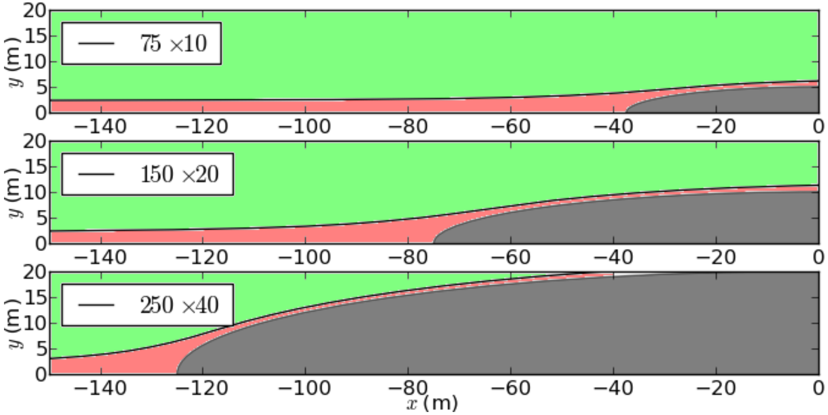
$$u_x = f_x(u_s, x, y, L, B)$$
$$u_y = f_y(u_s, x, y, L, B)$$

Simple glider model:

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

Streamlines around a hull

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



Streamlines around a hull

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

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

and

$$B' \approx 0.1B \tag{7}$$

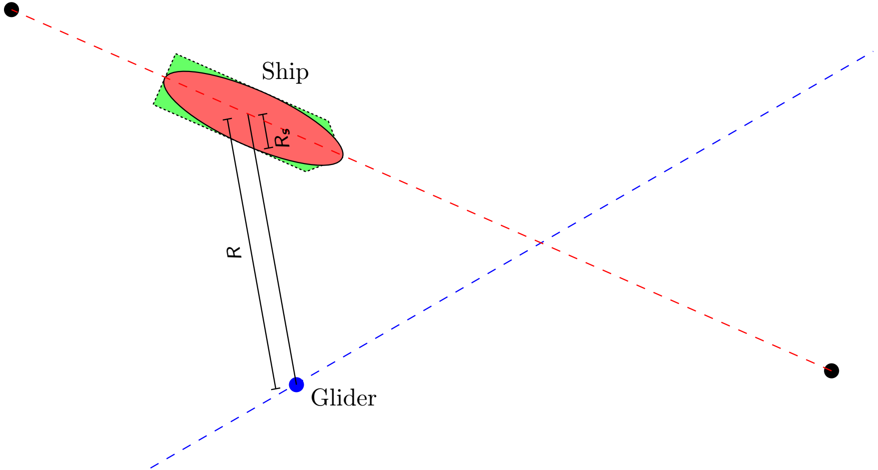
Monte Carlo Simulation

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.

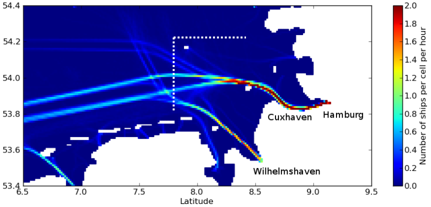
Monte Carlo Simulation

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

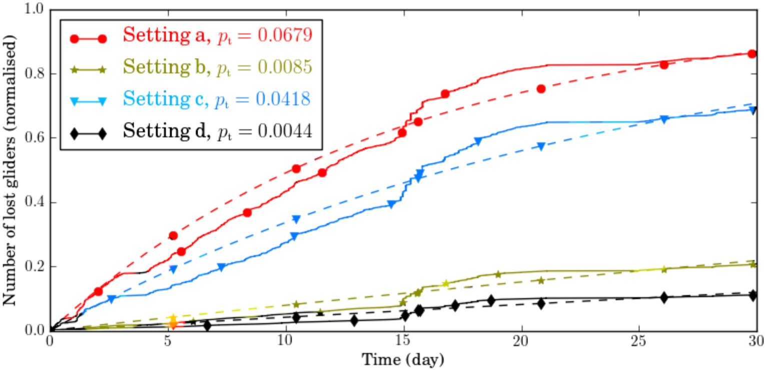
Expected population size of gliders, assuming constant probability of collision per transect p_t:

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

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:

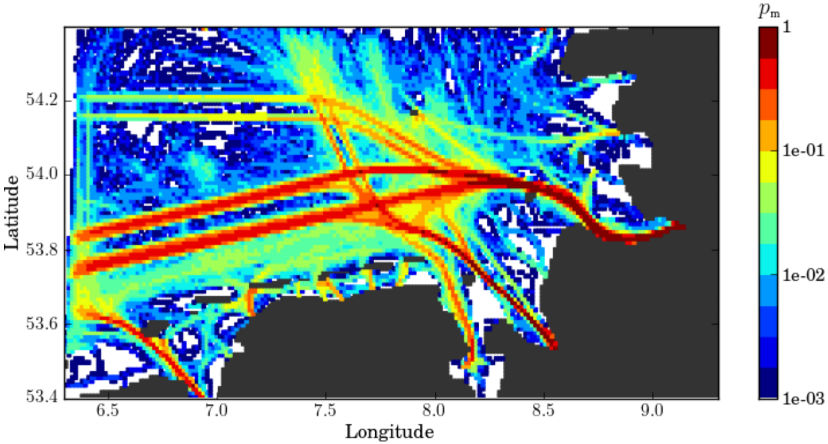


Comparison Simple model and Monte Carlo Simulation

	setting a $\psi = 1$ $B = 20$ m	setting b $\psi = 1$ $B = 2.6$ m	setting c $\psi = 0.55$ $B = 20$ m	setting d $\psi = 0.55$ $B = 2.6$ 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.

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