Numerical Model to Simulate Drift Trajectories of Large Vessels

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DHI
The expert in WATER ENVIRONMENTS

Australian Government
Australian Maritime Safety Authority

woodside

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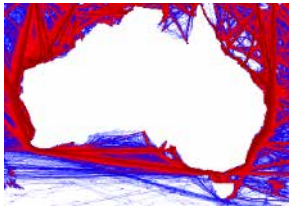
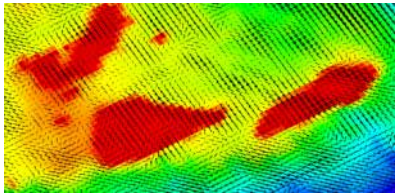
Conceptual framework - multi-layered risk estimation

Layer 1 (2011):
Ship specific risk (proxy for safety quality)



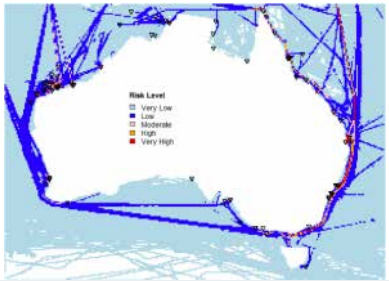
Layer 2 (2013/14/15):
Eg. Nm travelled, days in area, other metric (proxy for vessel traffic densities and/or exposure)



Layer 3 (2014/15): DHI Physical environmental layer (wind, waves, currents, bathymetry)

Layer 4 (2013):
Sensitivities (economic, cultural/social, ecological)

Total Risk Exposure:
Protect: property, life and marine environment



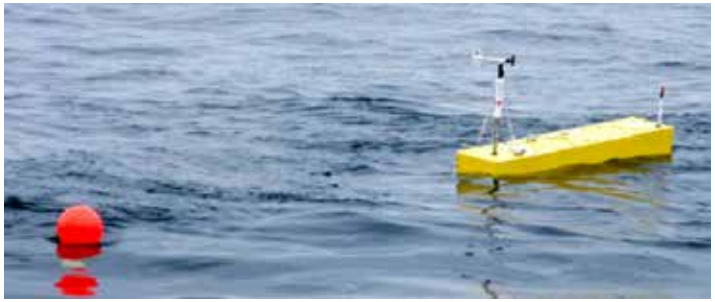
Expressed as:
- probabilities
- expected numbers
- monetary value at risk (proxy to consequences)
- oil on water
- oil on coast

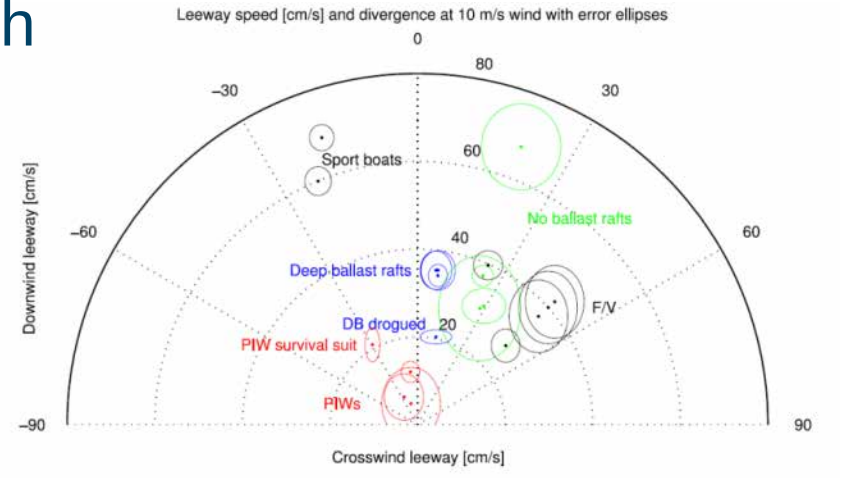
Risk Management (feedback loop)

Layer 5 (2014/15): Effects of risk control options (RCO):
- navigational aids
- aids to navigation
- vessel traffic services
- under keel clearance
- emergency response
- inspections and audits
- pollution preparedness
- general surveillance
- others as appropriate

(Acceptable) residual risk

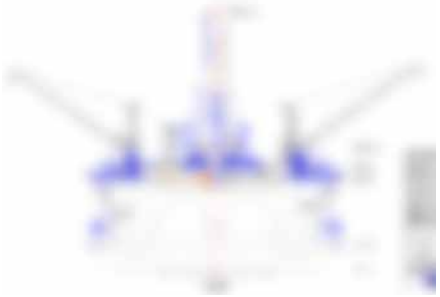
Limitations of Existing Approach

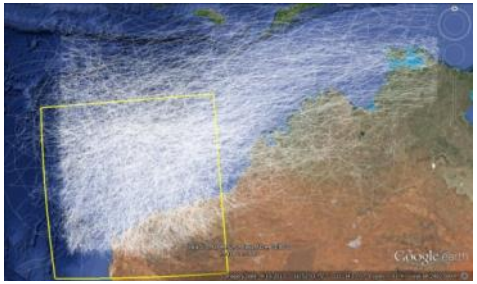




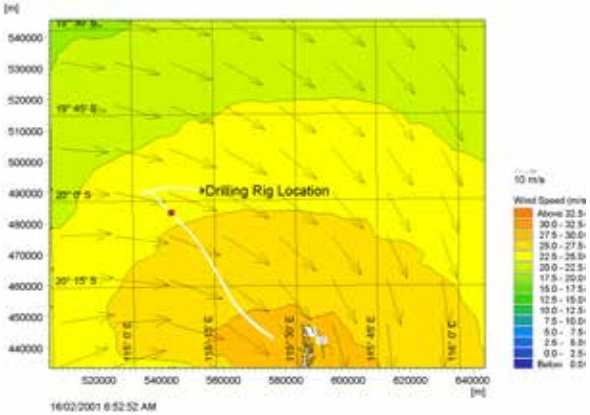
- Wind induced drift calculated stochastically based on a discrete number of controlled field drift experiments
- Derived model parameters only designed for small crafts and vessels
- No direct evaluation of vessel leeway drift
- Wave induced drift forces are either not included or simplified as function of the wind
- Full 3D hull representation is not included in response assessment

The Importance of Separate Treatment of Incident Forces

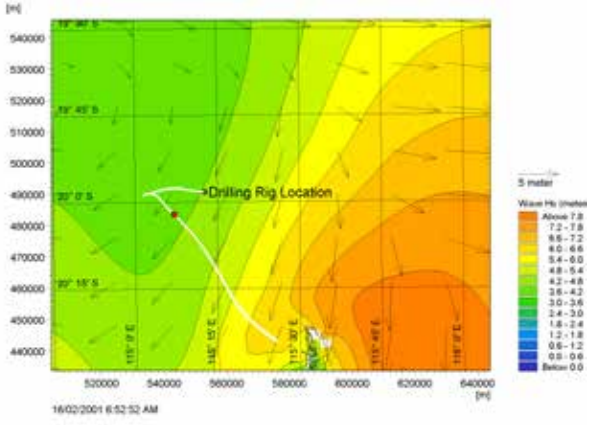




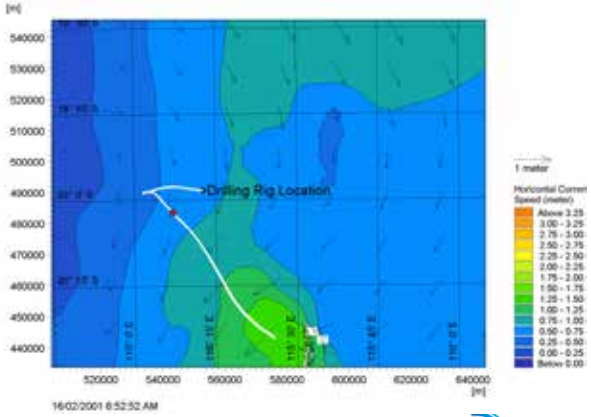
Wind Field



Wave Field



Current Field



Introducing DHIs Drifting Vessel Model (DVM)

Forces:

$$F'_{cur} = 0.5 \cdot Lpp \cdot T \cdot \rho_w \cdot C_{cur} \cdot u'^{2}_{cur}$$

$$F'_{wi} = 0.5 \cdot A \cdot T \cdot \rho_{air} \cdot C_{wi} \cdot u'^{2}_{wind}$$

$$F'_{wa} = 0.5 \cdot Lpp \cdot T \cdot \rho_w \cdot \int_{f=0}^{f=\infty} C_{wa}(f,\theta)\, E(f,\theta) df - Damp$$

Moments

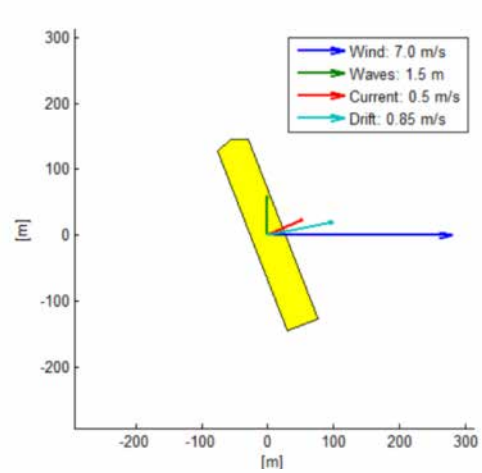
$$M'_{cur} = 0.5 \cdot Lpp^2 \cdot T \cdot \rho_w \cdot CN_{cur} \cdot u'^{2}_{cur}$$

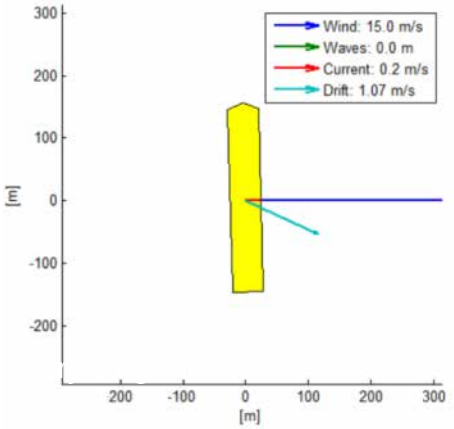
$$M'_{wi} = 0.5 \cdot A_T \cdot T \cdot \rho_{air} \cdot CN_{wi} \cdot u'^{2}_{wind}$$

$$M'_{wa} = 0.5 \cdot Lpp^2 \cdot T \cdot \rho_w \cdot \int_{f=0}^{f=\infty} CN_{wa}(f,\theta)\, E(f,\theta) df$$

$$F'_{cur} + F'_{wi} + F'_{wa} = 0$$

$$M'_{cur} + M'_{wi} = 0$$

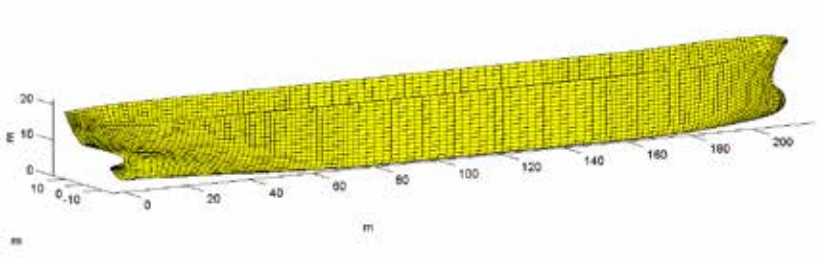


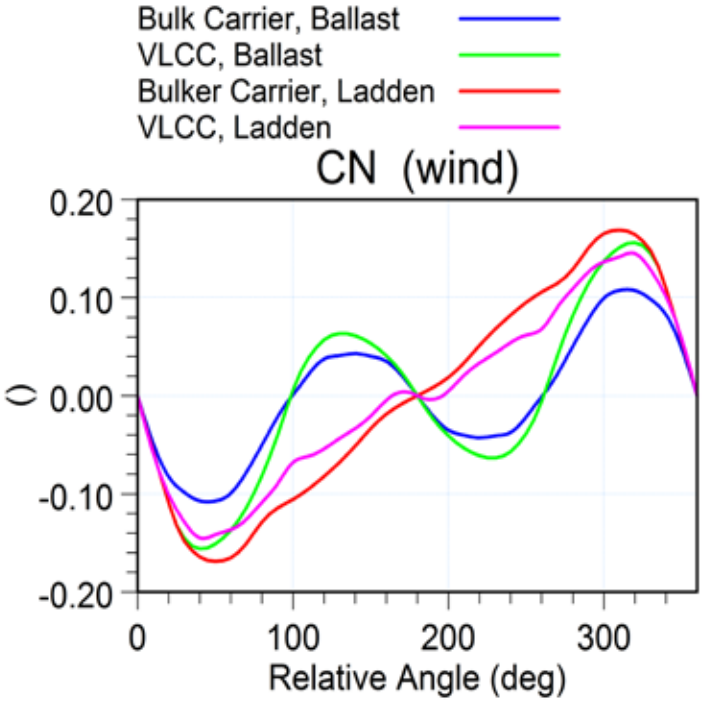


Incorporating Physical Response of Real Vessels

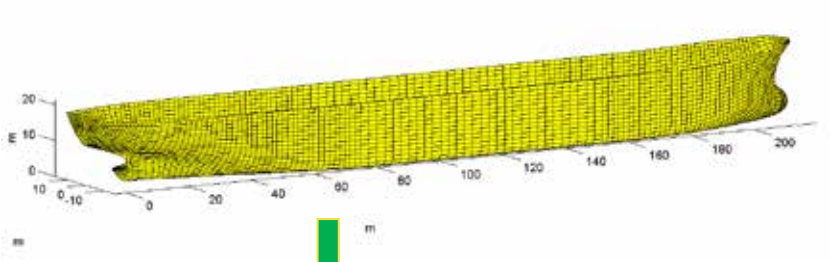
Vessel F_x, F_y and M_z depends on the following:

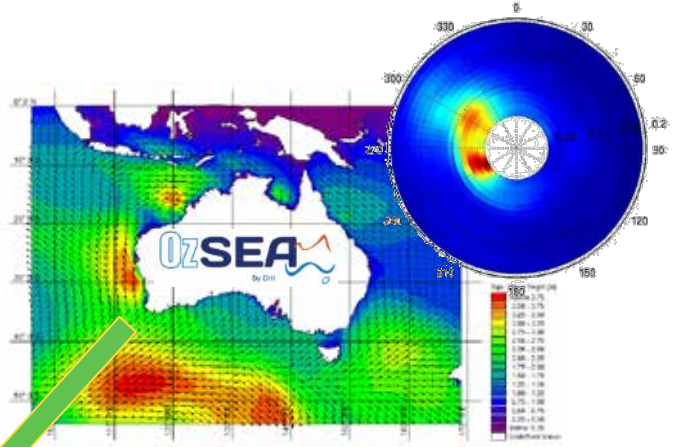
- Vessel Class
- Vessel Dimension
- Vessel Draft
- Loading Condition
- Water Depth
- Incident Wave Spectrum
- Relative Vessel Orientation
- Vessel Speed

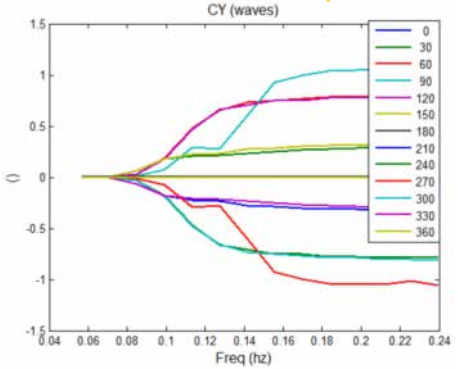


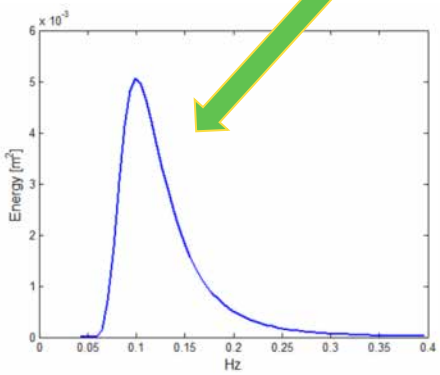


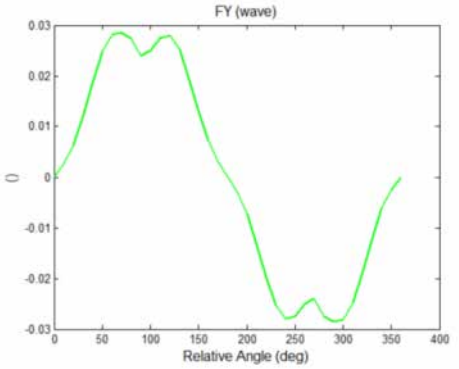
Wave Induced Drift Forces











MIKE by DHI Integration

Drifting Vessel Model Configuration

- Stochastic Framework for Treatment of all variables and vessel modes
- Config of Vessel Modes (cruising, drifting, evading, leaking, ect)
- Interaction with other Vessels (collision)
- Interaction with domain (spilling oil, propeller wash, underwater noise)

driftingVessel.dll

INPUT → **ECOLAB Template (Open Source)**

Waves, Winds, Currents, Bathymetry

INPUT → MIKE ABM Lab → OUTPUT

- Vessel Trajectories
- Position Likelihood
- Grounding Risk
- *Customized Output*

INPUT

Core Multiple Vessel Input(s)

- Class, Dimension
- Condition, Draft
- Initial Positon and Heading
- Vessel Traffic Patterns
- Receptor Maps (e.g coral reefs)
- *Custom input Specified in Template*

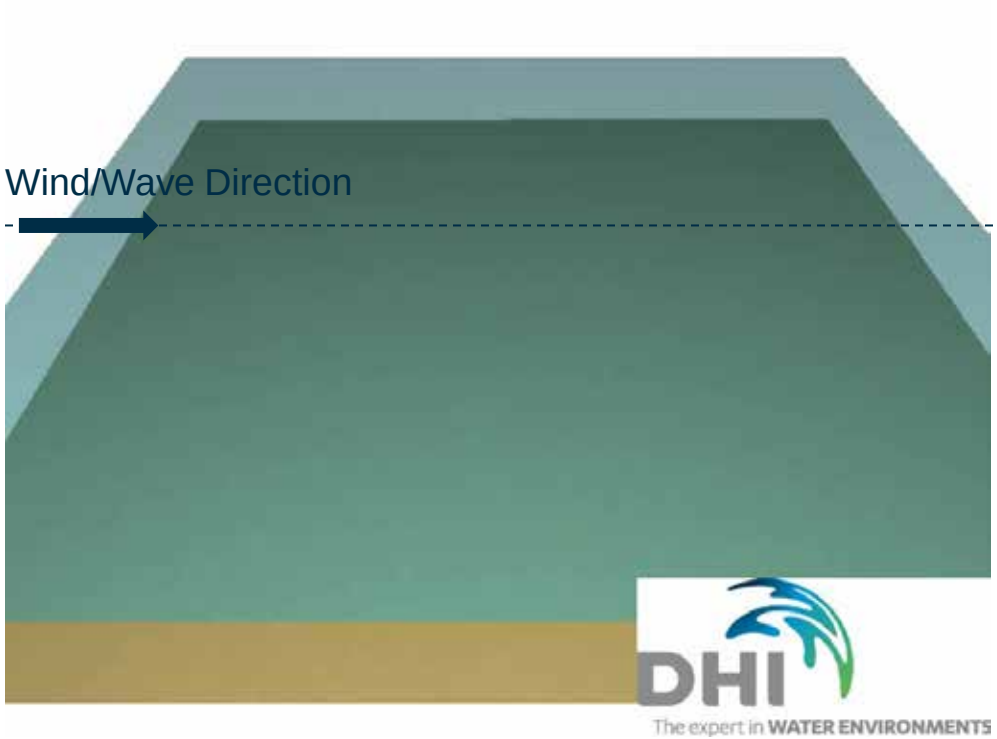
3rd Party Provider
e.g. eReef, BOM, HYCOM

Through NetCDF = DFS Conversion (Matlab,Python)

Introducing The Hockey Puck Test

Initial Vessel Heading:

0° North



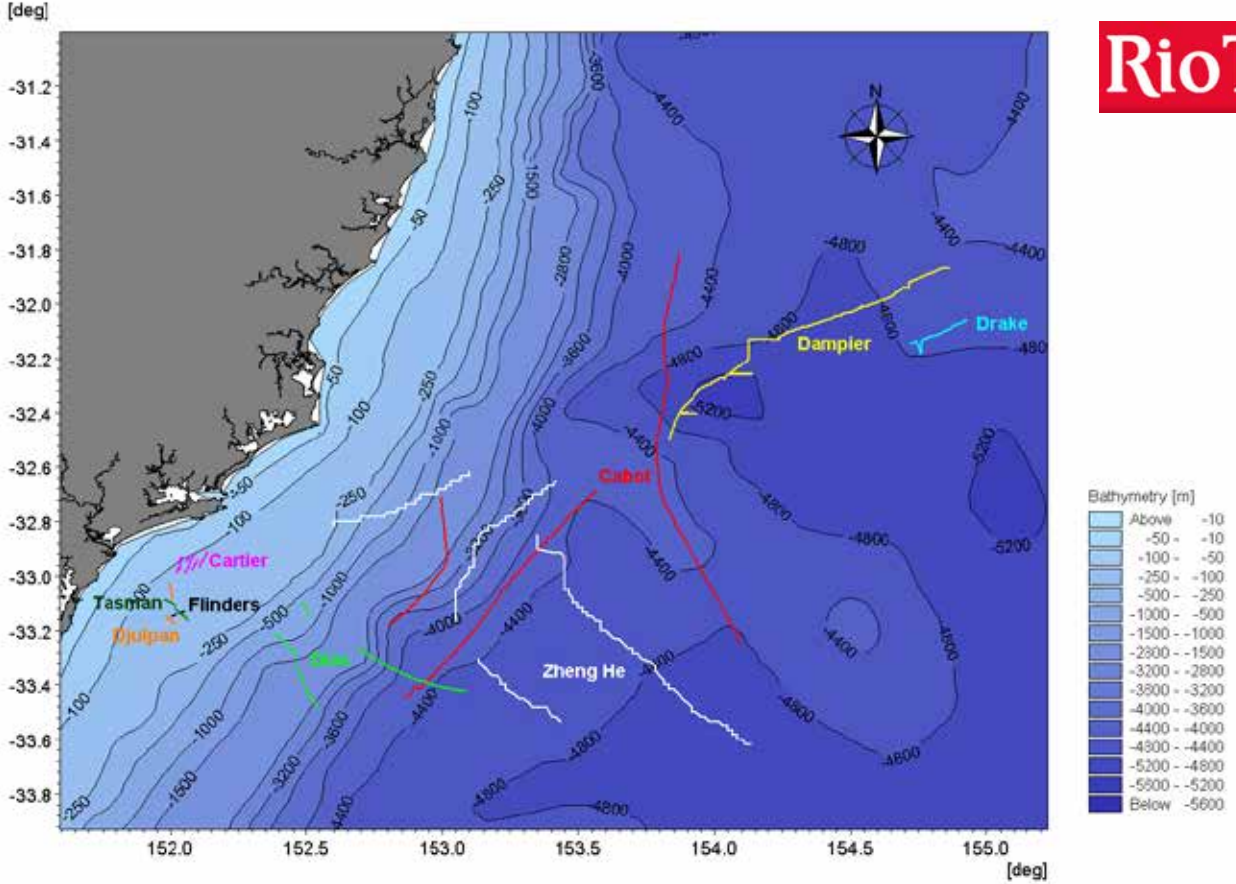
Bulk Carrier, Ballast

- No Wind, Hs: 2m, Tp: 6s, West
- No Wind, Hs: 2m, Tp: 10s, West
- No Wind, Hs: 5m, Tp: 10s, West
- 10 m/s West, no Waves
- 20 m/s West, no Waves

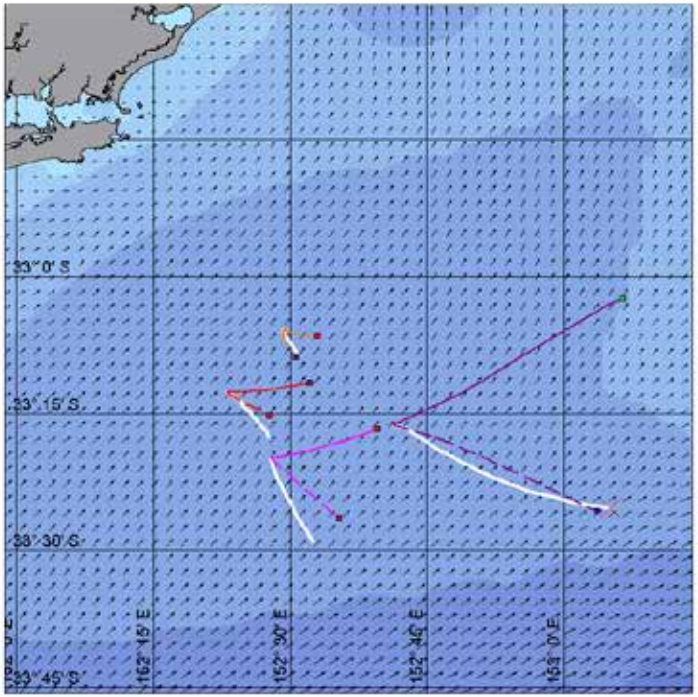
VLCC

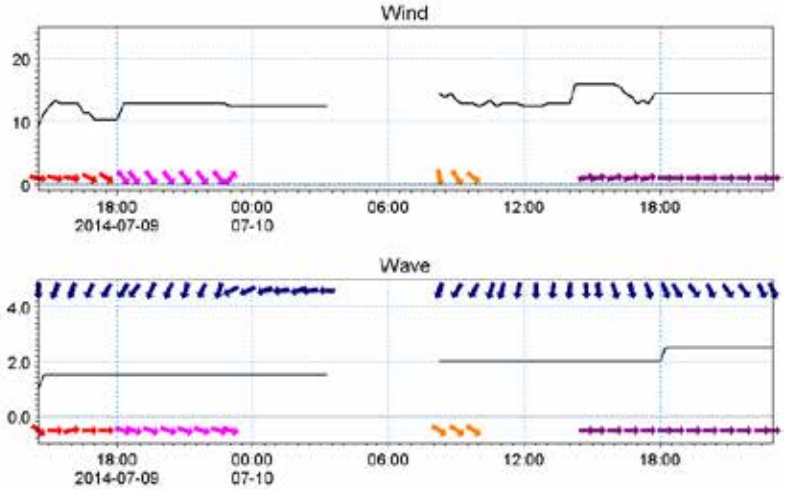
- 10 m/s West, no Waves, ballast

Overview of validated tracks (9 vessels)



Vessel: RTM Dias





Wind speed (m/s)

Wind direction, going to (°N)

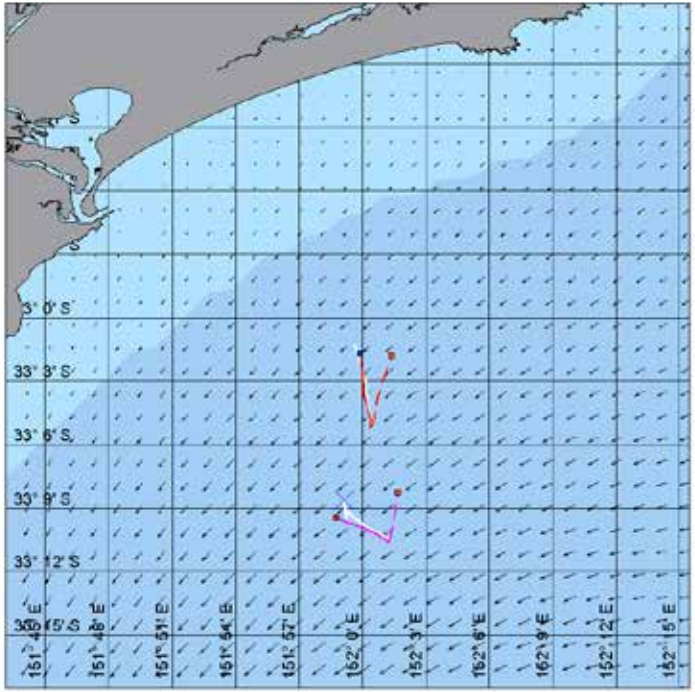
Ship bow is pointing to

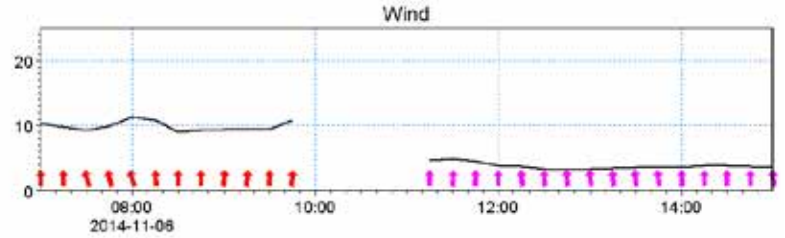
Wave height (m)

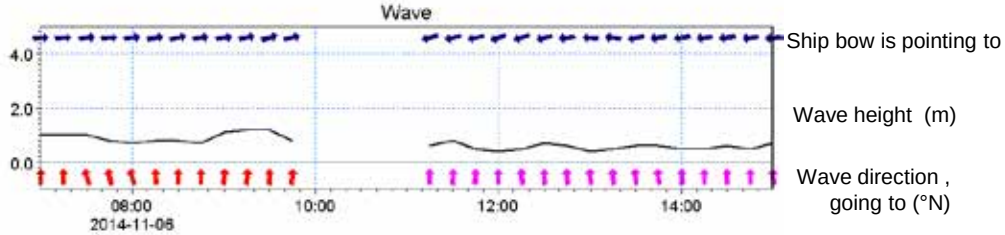
Wave direction , going to (°N)

Solid line: Netwater.
Dash line: HYCOM

Vessel: RTM Djulpan

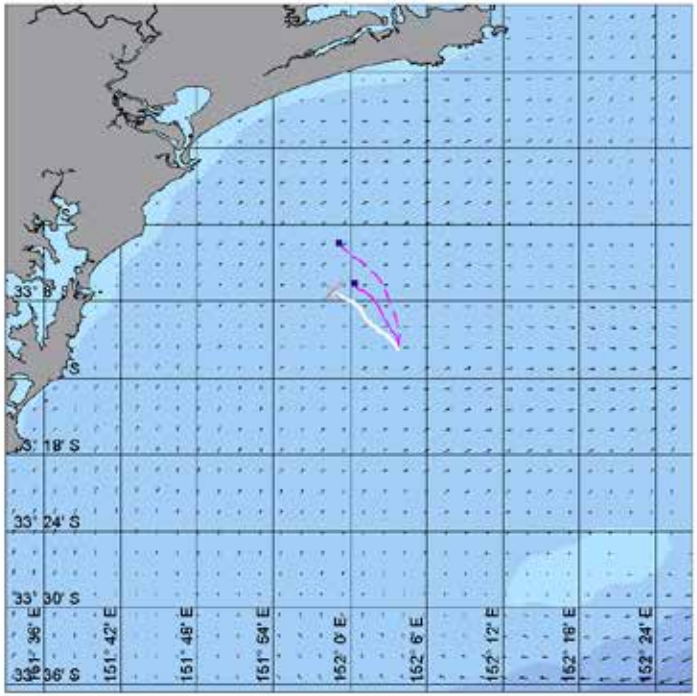


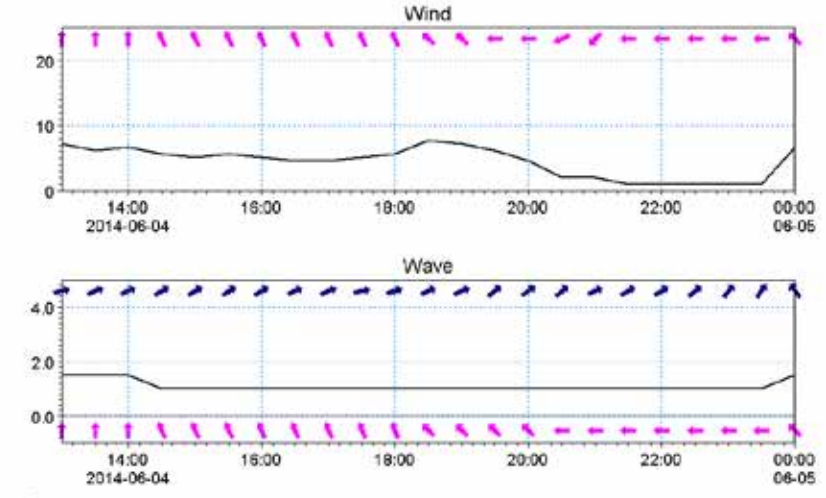




Solid line: Netwater.
Dash line: HYCOM

Vessel: RTM Tasman





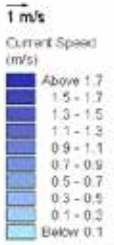
Wind direction, going to (°N)

Wind speed (m/s)

Ship bow is pointing to

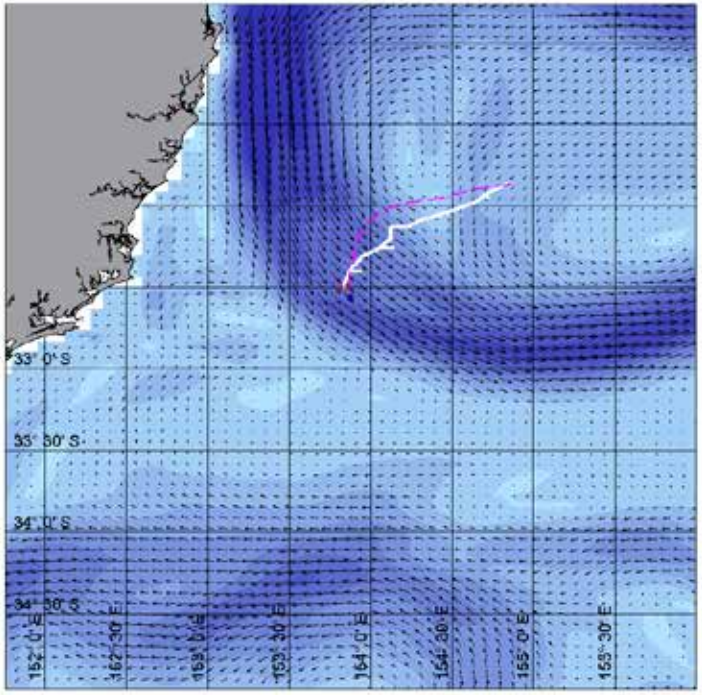
Wave height (m)

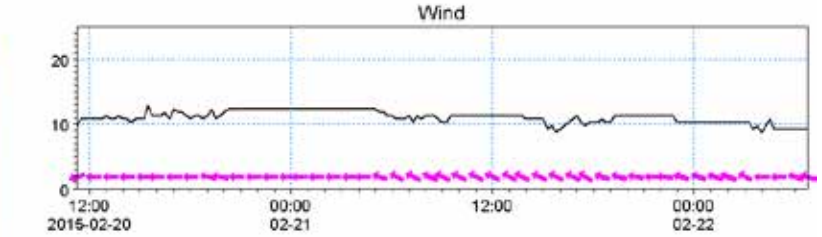
Wave direction , going to (°N)



Solid line: Netwater.
Dash line: HYCOM

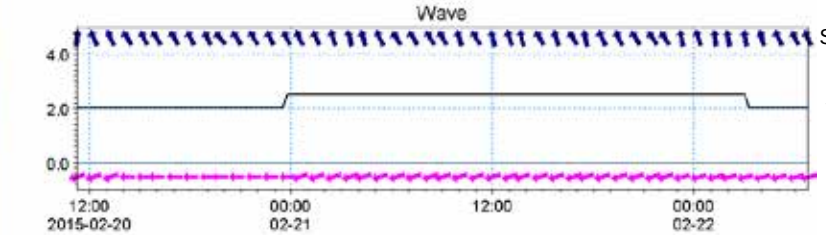
Vessel: RTM Dampier





Wind speed (m/s)

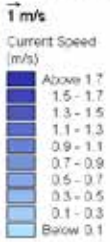
Wind direction, going to (°N)



Ship bow is pointing to

Wave height (m)

Wave direction , going to (°N)



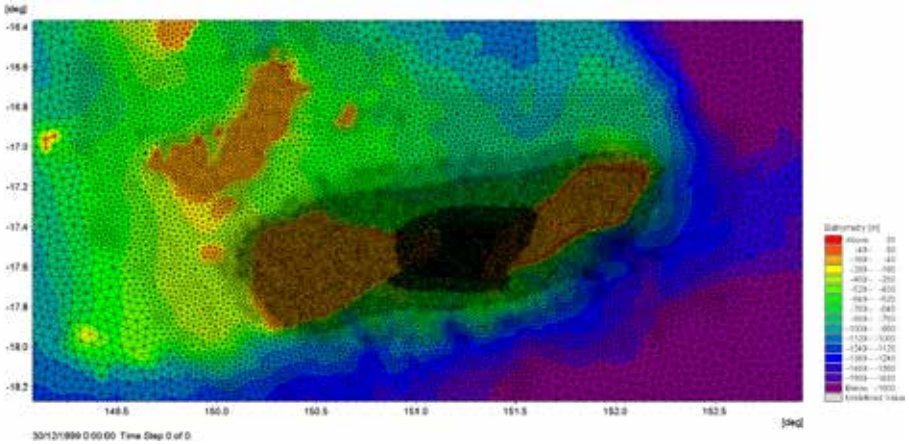
22/02/2015 00:00:00

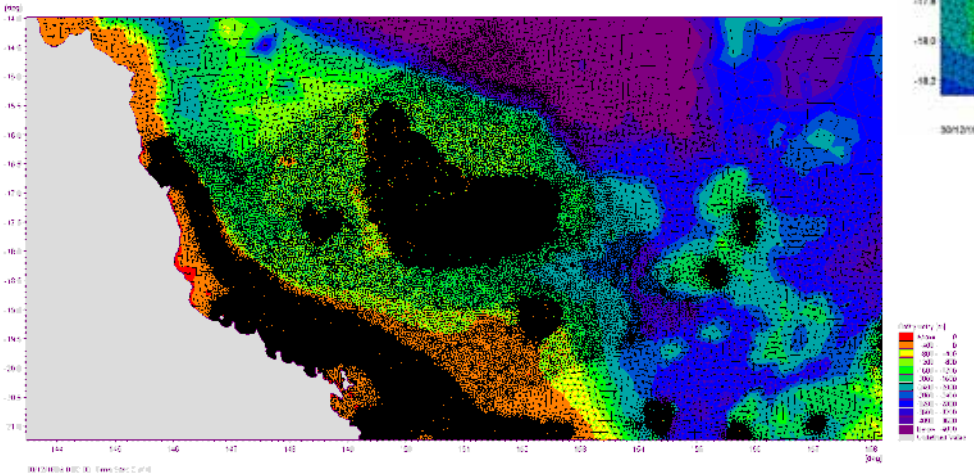
Netwater data not available.
Dash line: HYCOM

Diamond Passage – Strategic Grounding Risk – 3 year dataset

Wave Forecast/Hindcast

- **Flexible Mesh Approach**
- Detailed resolution of complex areas
- Maximum CPU efficiency





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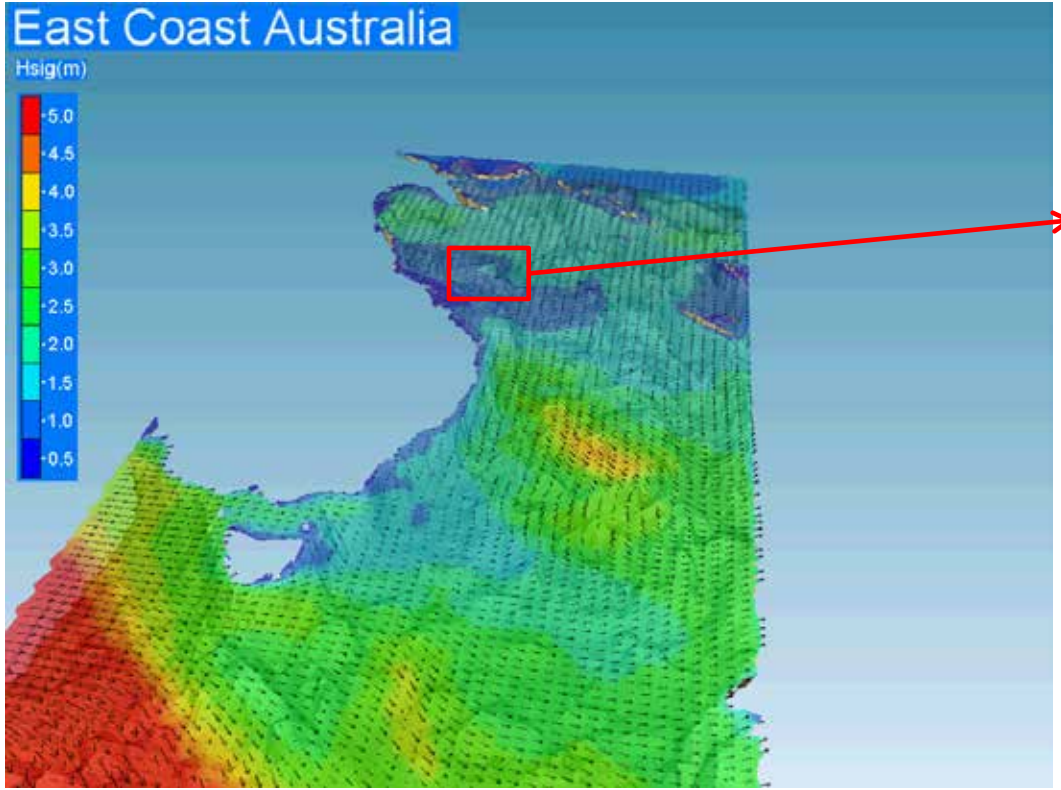
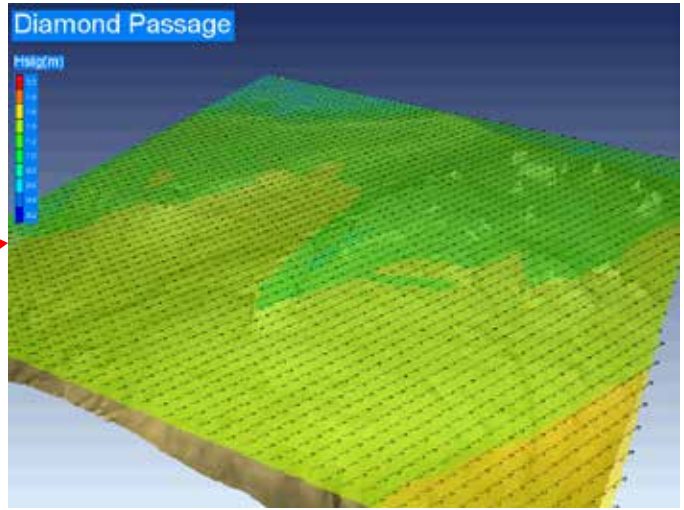
Diamond Passage – Strategic Grounding Risk – 3 year dataset





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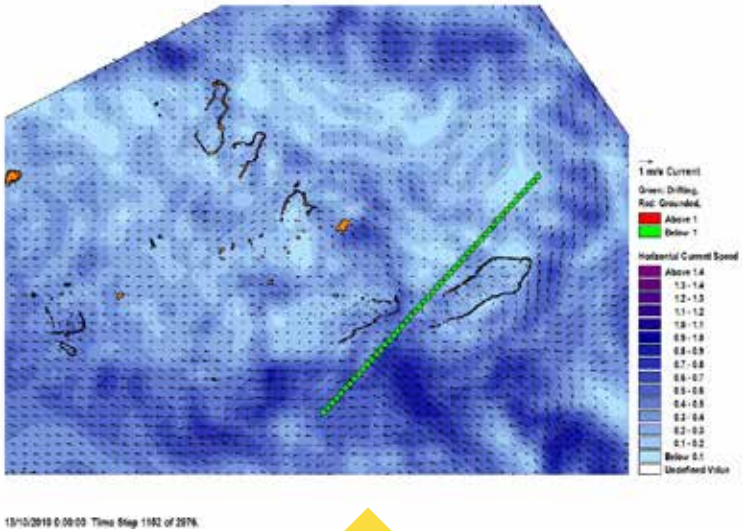
Diamond Passage – Strategic Grounding Risk – 3 year dataset



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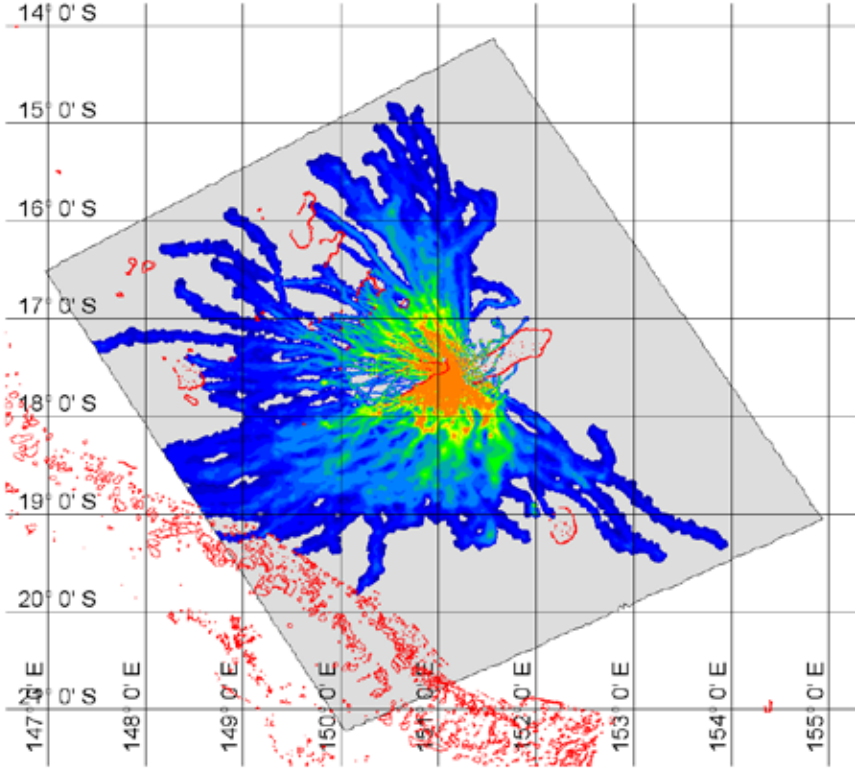
eReefs

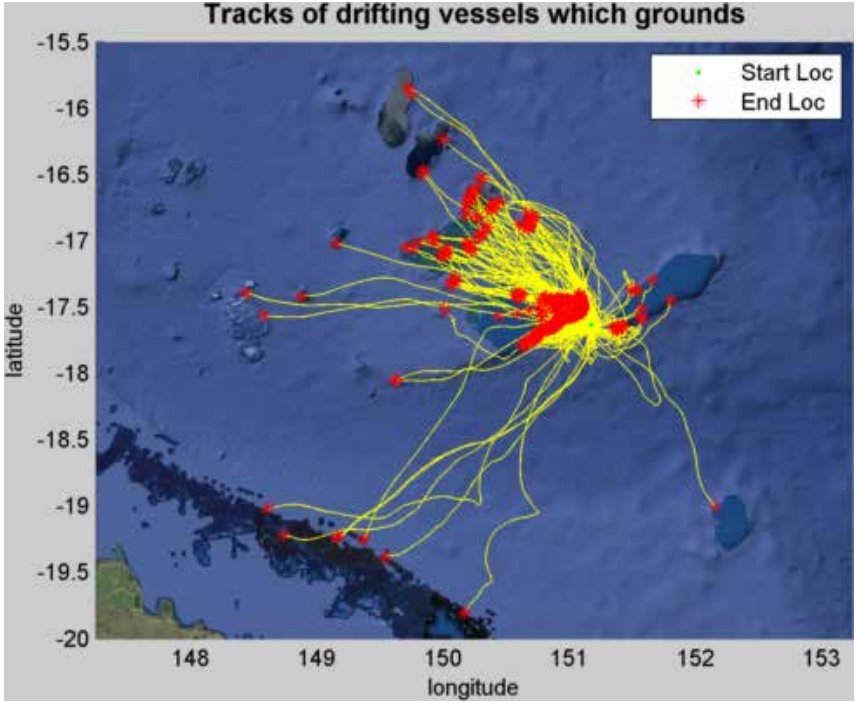
DHI

Diamond Passage – Probability Density Map

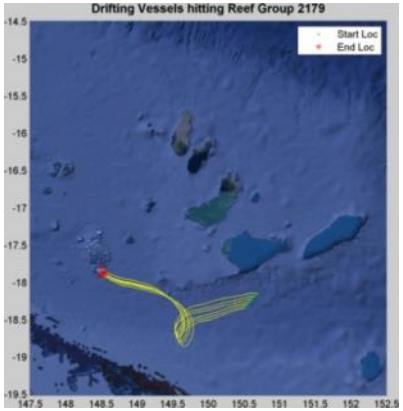
- 3 Years of historic wind, waves and currents 2011-2013
- 1019 Drifting Bulk Carriers events
- Contour plot illustrates likelihood of drifting vessel fate
- CPU time = ~6 days on a 12 core workstation

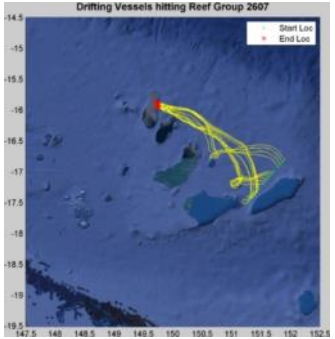


Diamond Passage – Grounding Risk

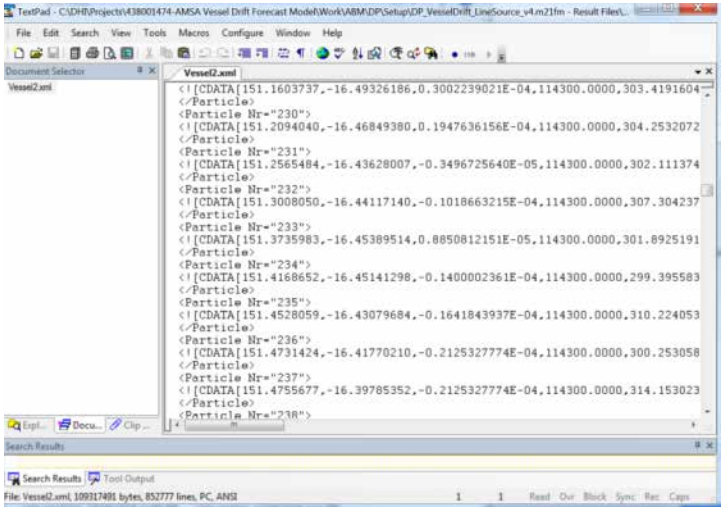


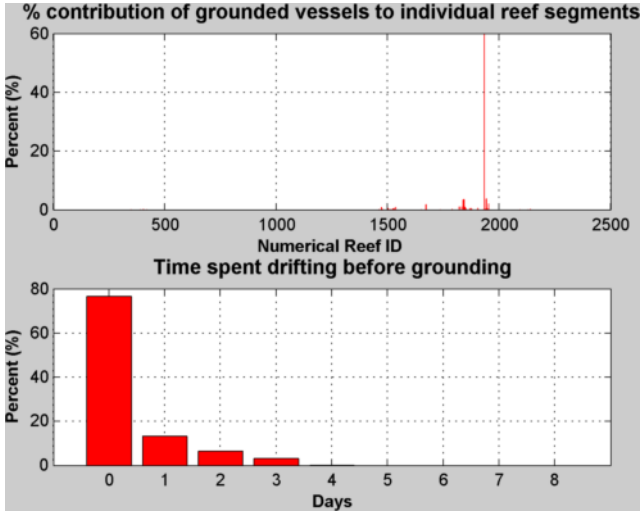
Grounding Risk Backcasting





Diamond Passage – Grounding Risk





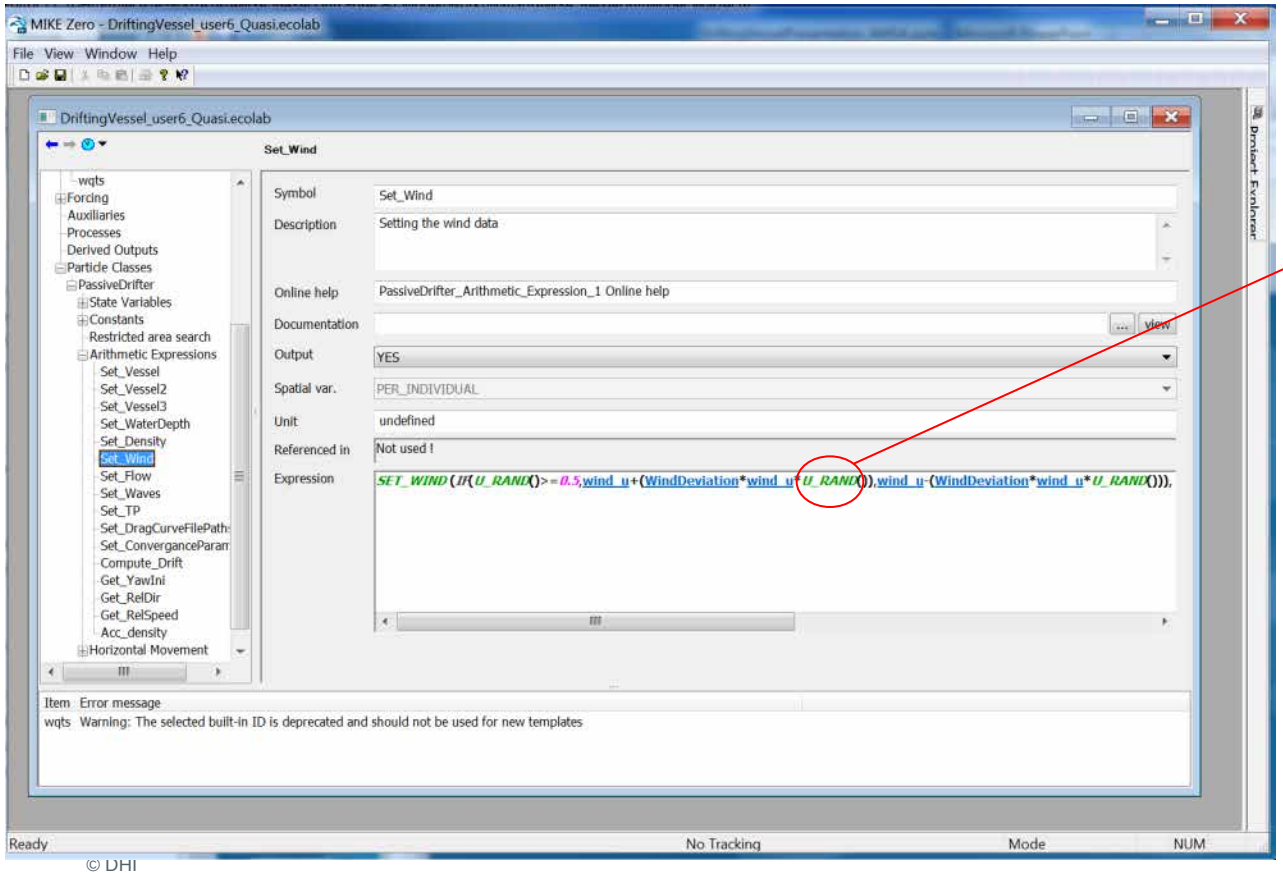
Total number of vessels grounding: 784 (out of 1019 vessels)

Number of unique reef segments hit: 76 (out of 2139 reefs in the domain)

59.8% of all grounding vessels hit Reef Segment 1933

46.9% of all vessels hitting Reef Segment 1933 grounds within 24 hours

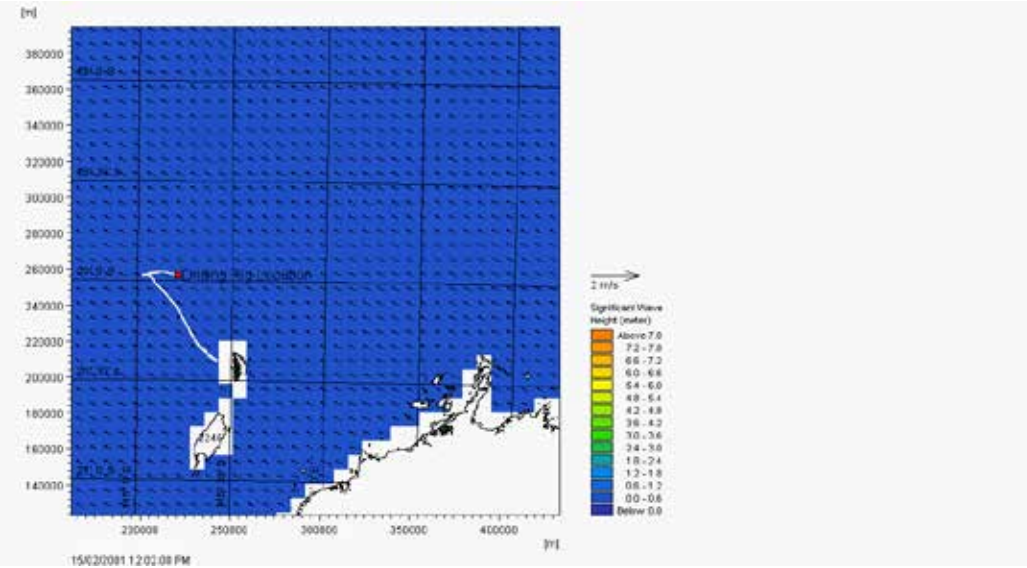
Handling of uncertainty of forcings or vessel config

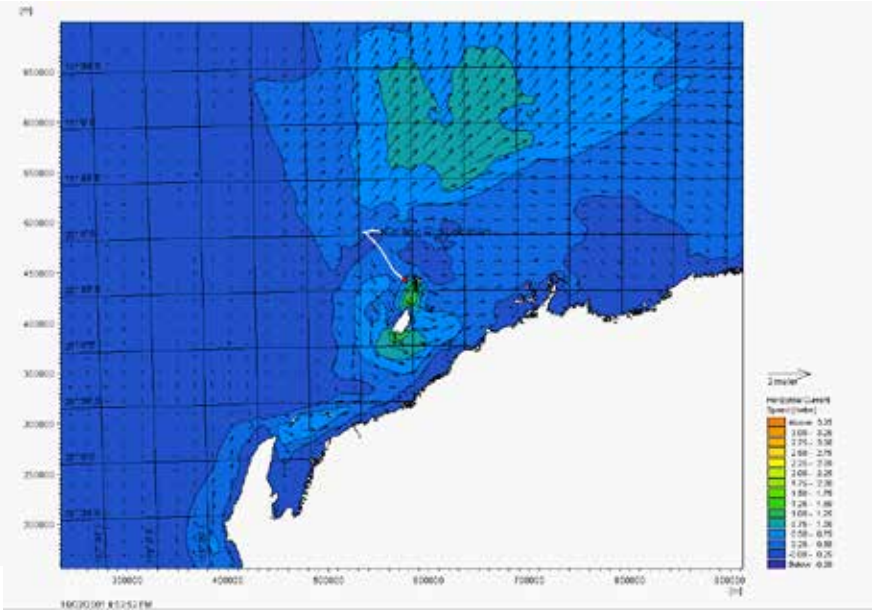


Inbuilt Probability Functions

- Uniform
- Normal
- Exponential
- Possion
- Gamma
- Binomial

Conditional Onset of Moored Vessel Drift – Tropical Cyclones





Conditional Onset of Moored Vessel Drift – Loss of Propulsion