Numerical Model to Simulate Drift Trajectories of Large Vessels

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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)

- navigational aids
- aids to navigation
- vessel traffic services
- under keel clearance
- emergency response
- inspections and audits
- pollution preparedness
- general surveillance
- others as appropriate

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

(Acceptable) residual risk

Risk Management (feedback loop)
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:
\[ F'_{\text{cur}} = 0.5 \cdot L_{pp} \cdot T \cdot \rho_w \cdot C_{\text{cur}} \cdot u'_{\text{cur}}^2 \]
\[ F'_{\text{wi}} = 0.5 \cdot A \cdot T \cdot \rho_{\text{air}} \cdot C_{\text{wi}} \cdot u'_{\text{wind}}^2 \]
\[ F'_{\text{wa}} = 0.5 \cdot L_{pp} \cdot T \cdot \rho_w \int_{f=0}^{f=\infty} C_{\text{wa}}(f, \theta) E(f, \theta) df - \text{Damp} \]

Moments
\[ M'_{\text{cur}} = 0.5 \cdot L_{pp}^2 \cdot T \cdot \rho_w \cdot C_{\text{Ncur}} \cdot u'_{\text{cur}}^2 \]
\[ M'_{\text{wi}} = 0.5 \cdot A_T \cdot T \cdot \rho_{\text{air}} \cdot C_{\text{Nwi}} \cdot u'_{\text{wind}}^2 \]
\[ M'_{\text{wa}} = 0.5 \cdot L_{pp}^2 \cdot T \cdot \rho_w \int_{f=0}^{f=\infty} C_{\text{Nwa}}(f, \theta) E(f, \theta) df \]

\[ F'_{\text{cur}} + F'_{\text{wi}} + F'_{\text{wa}} = 0 \]
\[ M'_{\text{cur}} + M'_{\text{wi}} = 0 \]
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)

**Waves, Winds, Currents, Bathymetry**

**3rd Party Provider**
e.g. eReef, BOM, HYCOM
Through NetCDF = DFS Conversion (Matlab, Python)

**driftingVessel.dll**

**ECOLAB Template (Open Source)**

**MIKE ABM Lab**

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

**INPUT**

**OUTPUT**

- Vessel Trajectories
- Position Likelihood
- Grounding Risk
- Customized Output
Introducing The Hockey Puck Test

- Wind/Wave Direction
- 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)
Wave height (m)
Wave direction, going to (°N)

Solid line: Netwater.
Dash line: HYCOM
Vessel: RTM Djulpan

Wind speed (m/s)
Wind direction, going to (°N)
Wave height (m)
Wave direction, going to (°N)

Solid line: Netwater.
Dash line: HYCOM
Vessel: RTM Tasman

Wind speed (m/s)

Wave height (m)

Wind direction, going to °N

Wave direction, going to °N

Ship bow is pointing to

Solid line: Netwater.
Dash line: HYCOM

© DHI
Vessel: RTM Dampier

- Wind speed (m/s)
- Wind direction, going to (°N)
- Wave height (m)
- Wave direction, going to (°N)

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
Diamond Passage – Strategic Grounding Risk – 3 year dataset
Diamond Passage – Strategic Grounding Risk – 3 year dataset
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