A general methodology for beached oil spill hazard mapping and its application to the Atlantic basin coasts

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1. Understand uncertainties in oil spill model simulations and use ensemble method
2. The nexus of a general hazard mapping methodology
3. A general Beached oil distribution for the hazard: The Weibull distribution
4. Conclusions and outlook
The Challenges of Sustainable development

• The first target for SDG 14 is:
14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

• So we need to establish replicable and reproducible estimates of pollution hazard. We started with oil pollution
Why oil pollution?

- Millions of tonnes of oil transported by vessels
- Over 600,000 tonnes end up in the marine environment
- Almost 50% are due to operational spills and we ignore their impacts on the our coasts
What are the uncertainties connected to oil spill hazard modelling?


[Map showing release points with various icons representing Stokes drift, Oil API, Spill duration, and Current and wind fields.]
The nexus of oil hazard mapping

- How do we synthetize the oil spill information considering the uncertainties?
- Can we construct a probability distribution of the beached oil on the coasts that will be equal for all the coasts so that we can compare distribution parameters?
- Do other examples of such methodology exists? Yes, for example in earthquake hazard mapping.

Earthquakes, Woessner and Wiemer 2005
Need to construct the probability distribution for many different coastal areas.

<table>
<thead>
<tr>
<th>Changing currents</th>
<th>Use ensemble simulations to map beached oil due to changing ocean and atmosphere conditions and different release points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realistic oil model</td>
<td>Use a realistic model for fate and transport of oil and oil beaching processes</td>
</tr>
<tr>
<td>Different coasts</td>
<td>Compare areas with very different coastal segments and in particular ocean current regimes</td>
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<tr>
<td>Beached oil distributions</td>
<td>Study the statistical distribution of concentration at the coasts and extract a general relationship</td>
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First let’s do a gedanchen-experiment (thought-experiment)

Only one release point for variable ocean currents

Analysis of the oil concentration crossing the red line

The oil concentration distribution along the red line: A Weibull (1950) distribution!

Now let's do realistic coastlines and many release points

The distribution is the same but with different distribution parameters.

The Weibull distribution is:

\[ W(x; \beta, \eta) = \frac{\beta}{\eta} \left( \frac{x}{\eta} \right)^{\beta-1} \exp \left( -\frac{x}{\eta} \right)^\beta \]

\( \beta \)  Shape parameter
\( \eta \)  Scale parameter
What do we do now with the distribution: the beached Oil Hazard Index

- The Weibull distribution is a fat-tail distribution and it informs us that all coastal areas have the possibility of large concentration of oil deposited after operational releases.
- We can define the Weibull tail distribution $H$ to assess the hazard and intercompare the different areas

$$H = 1 - F(x_{cut}) = e^{-\left(\frac{x_{cut}}{\eta}\right)^\beta}$$

- Where $x_{cut}$ is a threshold oil concentration here chosen to be 25 tons/km

$H$ is the beached Oil Hazard Index that is reproducible and replicable
The hazard is larger in the Western Atlantic Island

<table>
<thead>
<tr>
<th>Area</th>
<th>Beached oil Hazard Index</th>
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<tbody>
<tr>
<td>East Atlantic Archipelago</td>
<td>0.16 ± 0.01</td>
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<tr>
<td>Western Atlantic island</td>
<td>0.18 ± 0.01</td>
</tr>
<tr>
<td>Bahia (Brazil)</td>
<td>0.14 ± 0.01</td>
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</table>

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<tr>
<th>Weibull Parameters</th>
<th>Eastern Atlantic Archipelago</th>
<th>Western Atlantic Island</th>
<th>Bahia (Brazil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>scale ($\eta$)</td>
<td>5.1 ± 0.6 tons/km</td>
<td>5.86 ± 0.75 tons/km</td>
<td>4.2 ± 0.5 tons/km</td>
</tr>
<tr>
<td>shape ($\beta$)</td>
<td>0.362 ± 0.008</td>
<td>0.377 ± 0.009</td>
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</tr>
<tr>
<td>mean ($\mu$)</td>
<td>23 tons/km</td>
<td>23 tons/km</td>
<td>17 tons/km</td>
</tr>
<tr>
<td>standard deviation ($\sigma$)</td>
<td>85 tons/km</td>
<td>80 tons/km</td>
<td>58 tons/km</td>
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</table>
Conclusions and outlook

• We have demonstrated a straightforward and objective method to quantify the coastal oil spill hazard based on ensemble oil spill experiments which sample the uncertainties associated with oil spill accidental releases.

• Both oil in the open ocean and beached oil concentrations are successfully described by the Weibull distribution. The large beach oil concentrations are contained in a “fat tail” which characterizes this distribution.

• We propose a new hazard index for beached oil which allows to intercompare different world ocean areas and their different hazards.

• Future work will consider an in-depth study of the ocean flow field parameters and how they modulate the coastal oil spill hazard.
Visit us at the whole Atlantic Oil Hazard Index site!

https://glamor.sincem.unibo.it/