SOSeas: An assessment tool for predicting the dynamic risk of drowning on beaches

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OS4.7 – The Copernicus Marine Environment Monitoring Service (CMEMS)

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The problem in numbers

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→ 360,000 annual deaths from drowning all around the world (WHO, 2018)

The cost impact of drowning (WHO, 2018; SOBRASA, 2018)

- US: US$ 273 million
- Australia: US$ 85.5 million
- Canada: US$ 173 million
- Brazil: US$ 228 million (only drownings on beaches)

→ 1 drowning every 91 minutes in Brazilian beaches (SOBRASA, 2018)

- 2nd cause of death in children aged 1-4 years
- 4th cause of death in children aged 5-9 years
- 3rd cause of death in children aged 10-14 years
- 4th cause of death in teenagers aged 15-24 years

→ Teenagers has the largest risk of death (SOBRASA, 2018)
Numerical forecasting background

Classical projects to obtain electronic flag ➔

Process based models:
- High computational resources
- Not easy scalable to cover new areas
- Not valid to give a quick response

“ensuring healthy lives and promoting the well-being at all ages”

SOSeas? ➔ Dynamic risk on beaches using CMEMS data and Artificial Neural Networks (ANN)
General overview

The problem...

Historical Data
(CMEMS Product + drowning events)

Artificial Neural Network
(ANN)

CMEMS Products
(Nowcast & Forecast)

Tailored information
for end users
(Beach users and lifeguards)

the Solution...
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Study site

Santa Catarina: 139 coastal beaches

Source: Google maps

Source: Nomadsurfers.com
Drowning and Flags events

Brazilian Life Saving Society (SOBRASA)
http://sobrasa.org

**Historical data**

- **Drowning database contains 52,712 records from January 2001 to May 2019**

- **Flags database contains 79,487 records from November 2016 to July 2019**

**Metoecean conditions**

- **ERA 5 – C3S** ➔ **Wind**

- **GLOBAL_REANALYSIS_PHY_001_030 (CMEMS)** ➔ **Currents**

- **TPXO** ➔ **Water Level**

- **GLOBAL_REANALYSIS_WAV_001_032** ➔ **Waves**
Beach characterization

\[ \Omega = \frac{H_b}{W_s \cdot T} \quad RTR = \frac{M}{H_b} \]

<table>
<thead>
<tr>
<th>Modal state</th>
<th>Percentage of Santa Catarina’s beaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissipative</td>
<td>17.05 %</td>
</tr>
<tr>
<td>Longshore bar &amp; trough</td>
<td>4.66 %</td>
</tr>
<tr>
<td>Rhythmic bar &amp; beach</td>
<td>5.43 %</td>
</tr>
<tr>
<td>Transverse bar &amp; rip</td>
<td>34.1 %</td>
</tr>
<tr>
<td>Low tide terrace</td>
<td>18.6 %</td>
</tr>
<tr>
<td>Reflective</td>
<td>20.16 %</td>
</tr>
</tbody>
</table>

Cross analysis:
Beach type-Forcings-Flags

Non-linear correlation higher than linear correlation between variables

\[ \chi = \frac{H_s}{T_m} \]

- Hs
- Tm
- Incidence wave angle
- Wind
- Marine Current
- Beach modal state

ANN
Categorical input variables

- Incidence angle
- Modal state
- Wind
- Hs
- Tm
- Marine currents

3 Hidden layers (48, 24, 24)

ANN development

The problem...

The solution...

Historical Data (wind, wave conditions)

Marine currents

Categorical input variables

ODF (Motor Power)

ANN (Artificial Neural Network)

Tailored intervention for any event

The problem...

The solution...

Historical Data (wind, wave conditions)

Marine currents

Categorical input variables

ODF (Motor Power)

ANN (Artificial Neural Network)

Tailored intervention for any event

TensorFlow

pandas

NumPy

SciPy.org
Input training data
- Hs
- Tm
- Incidence angle
- Beach modal state
- Wind
- Marine currents

**ANN (deep learning)**

**Results**

**ANN results**

- **Hit rate:** 0.87
- **Success index:** 0.81
- **BIAS score:** 1.03

**Error metrics**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Formula</th>
<th>Range of values</th>
<th>Ideal value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias score (frequency bias)</td>
<td>( \frac{\text{Hits} + \text{False alarms}}{\text{Hits} + \text{Misses}} )</td>
<td>0-( \infty )</td>
<td>1</td>
<td>Indicates if the model tends to under- (&lt;1) or over- (&gt;1) estimate.</td>
</tr>
<tr>
<td>Hit rate (Probability of detection)</td>
<td>( \frac{\text{Hits}}{\text{Hits} + \text{Misses}} )</td>
<td>0-1</td>
<td>1</td>
<td>Sensitive to hits but ignores false alarms. Good for rare events.</td>
</tr>
<tr>
<td>Success index</td>
<td>( \frac{\frac{\text{Hits}}{\text{Hits} + \text{Misses}} + \frac{\text{Correct negatives}}{\text{Total}}}{2} )</td>
<td>0-1</td>
<td>1</td>
<td>Weights equally the ability of the model to correctly detect occurrences and non-occurrences of events.</td>
</tr>
</tbody>
</table>
# Nowcast and forecast

<table>
<thead>
<tr>
<th>Type</th>
<th>Variables</th>
<th>Product – Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waves</td>
<td>Significant total weight Hs</td>
<td>GLOBAL_ANALYSIS_FORECAST_WAV_001_027 – CMEMS</td>
</tr>
<tr>
<td></td>
<td>Mean wave period Tm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direction of waves</td>
<td></td>
</tr>
<tr>
<td>Water level</td>
<td>Water level variation</td>
<td>GLOBAL_ANALYSIS_FORECAST_PHY_001_024 – CMEMS</td>
</tr>
<tr>
<td>Currents</td>
<td>Magnitude of marine currents</td>
<td></td>
</tr>
</tbody>
</table>

**And also...**

<table>
<thead>
<tr>
<th>Type</th>
<th>Variables</th>
<th>Product – Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Magnitude of wind velocity</td>
<td>Global Forecast System (GFS) – NOAA</td>
</tr>
<tr>
<td></td>
<td>Direction of winds</td>
<td></td>
</tr>
</tbody>
</table>
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SOSeas Architecture
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Conclusions

→ A cross-reference analysis between historical flag events and metocean conditions (CMES Products) finding a non-linear relationship ➔ Starting point of ANN application

→ An ANN has been developed based on deep learning to predict electronic flag using CMES products.

→ Operational system SOSseas has been released integrating the developed ANN and the metocean conditions (real time and forecasting CMEMS products) to provided tailored information about the dynamic risk on beaches based on electronic flag criteria.

→ SOSseas tool is available at Santa Catarina beaches (Brazil) and fully scalable to any worldwide beach.
SOSeas: An assessment tool for predicting the dynamic risk of drowning on beaches

Thank you for your attention

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