SIMULATION OF SO$_2$ EPISODES EXCEEDING EU REGULATIONS IN THE INDUSTRIAL AREA OF LE HAVRE WITH THE MM5, SWIFT AND SPRAY MODELS

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Summary

- Context and Goal
- Input Data
  - Topography
  - Meteorological data
  - Emission data
- Modelisation scheme
- Model validation
- Validation of the emission mitigation measures
- Conclusion
European regulations for SO₂:
- Daily concentration averages:
  - \( C_m < 125 \ \mu g/m^3 \)
  - Maximum number of exceedance / year : 3
- Hourly concentration averages:
  - \( C_h < 350 \ \mu g/m^3 \)
  - Maximum number of exceedance / year : 24

2007 measurements: Number of exceedance per industrial zone

<table>
<thead>
<tr>
<th>Industrial Zone</th>
<th>( C_m )</th>
<th>( C_h )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Le Havre</td>
<td>18</td>
<td>37</td>
</tr>
<tr>
<td>Port Jérôme</td>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>
European commission ask French Government to respect the european regulations

- The local industry manager DREAL had to validate emission mitigation measures asked to the industrial plants

- Choice of air dispersion modeling has been made for this validation in a two step study:
  - The model validation over the 2007 peak episodes for 5 sensors
  - The modeling of the mitigation reductions over these episodes and comparisons with the EU regulations
SO2 Peaks Study – Le Havre area

Site description

- Sea shore site: Wide Estuary extended by the Seine river
- High cliff: 100 m along the northern border of the estuary

Land Cover map
- Purple ➔ Industrial zones
- Red ➔ towns

Données topographiques : IGN – 100m
SO2 Peaks Study – Le Havre area
Concentration sensors

EDF power plant

TOTAL petrochemical plant

EXXON petrochemical plant
SO2 Peaks Study – Le Havre area
Meteorological data

- Octeville: WS, WD 10m
- Cap de la Hève: WS, WD 10m
- CAU: WS, WD at 119m, T profile: 3 → 119m
- RNO: WS, WD 10m
- TDF: WS, WD 40m, T profile: 6-40 m
- PJZ: WS, WD 10m
SO2 Peaks Study – Le Havre area

Stacks

- **Plant:**
  - EDF: 3 stacks – H: 240m each
  - TOTAL: 18 stacks – H: 25 to 110m
  - EXXON MOBIL: 16 stacks – H: 38 to 140m
  - Takes into account 90% of SO2 releases for Le Havre area and 95% for Port Jérôme area

- **SO2 emission rates:** Given by the Industrials on an hourly basis
Two different approaches

- Using only local meteorological data:
  - SWIFT model using all local meteorological stations: 100m resolution

- A classical nested approach from continental scale to regional scale:
  - MM5+ SWIFT
    - MM5:
      - 3D pour prévision ou analyse à échelle régionale
      - Imbrication de plusieurs domaines → résolution finale 3km
      - Initialisation à partir des données NCEP (ex GFS)
    - Adaptation à l’échelle du site: SWIFT
      - Assimilation des verticales mM5 à des mesures virtuelles
      - Assimilations de toutes les mesures du site
      - Utilisation des données du site à petite échelle
SO2 Peaks Study – Le Havre area

Wind Modeling: nesting approach

<table>
<thead>
<tr>
<th>Domain</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM5 - D1</td>
<td>27 Km</td>
</tr>
<tr>
<td>MM5 - D2</td>
<td>9 Km</td>
</tr>
<tr>
<td>MM5 - D3</td>
<td>3 Km</td>
</tr>
<tr>
<td>SWIFT 1</td>
<td>400 m</td>
</tr>
<tr>
<td>SWIFT 2</td>
<td>100 m</td>
</tr>
</tbody>
</table>

Local data

Virtual wind and temperature profiles
SO2 Peaks Study – Le Havre area

Local scale domains

- To improve simulation time ➔ 3 simulation domains have been considered

<table>
<thead>
<tr>
<th>Domain</th>
<th>SW point</th>
<th>Number of points</th>
<th>Size in Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Le Havre</td>
<td>(433,2495)</td>
<td>201x141</td>
<td>20.1x14.1</td>
</tr>
<tr>
<td>Port Jérôme</td>
<td>(461,2497)</td>
<td>151x121</td>
<td>15.1x12.1</td>
</tr>
<tr>
<td>Le Havre+Port Jérôme</td>
<td>(432,2495)</td>
<td>451x151</td>
<td>45.1x15.1</td>
</tr>
</tbody>
</table>

Le Havre domain

Port Jérôme domain

All domains together
SO2 Peaks Study – Le Havre area
Dispersion Modeling : Spray

- Non steady state lagrangian dispersion model
- Wind and turbulence fields coming for SWIFT
- Well adapted to complex topography
- High number of particle release
  ➔ accuracy : 1µg/m³
Choice of the validation point

- Wind speed sensor precision: +/-0.5 m/s
  - At 2km, possible delay of 15mn on the plume transport
- Wind direction sensor precision: +/-5°
  - At 2km, possible error of 180m for the plume center line

We choose to take the Best 4 calculated values at t-dt, t+dt with dt=1/4h
SO2 Peaks Study – Le Havre area
Model Validation Results

Caractéristiques des pointes :

- 58 simulations :
  - 14 dealing with hourly concentration averages
  - 36 dealing with daily concentration averages
  - 8 dealing with both hourly and daily concentration averages

Results:

- 32 good simulations :
  - ex : Port Jérôme, Le Havre

- 26 not so good simulations :
  - ex : Port Jérôme, Le Havre
Well correlated wind speeds and directions

Good results!
SO2 Peaks Study – Le Havre area
Simulation n°24 – Port Jérôme

Low and uncorrelated winds—Fluctuant wind directions

Poor results!
SO2 Peaks Study – Le Havre area
Simulation n°24 – Le Havre

Well correlated wind speeds and directions

Good results!
SO2 Peaks Study – Le Havre area
Simulation n°11 – Le Havre

Meteorological data

ROM Sensor

GOR Sensor
SO2 Peaks Study – Le Havre area
Statistical results

- **Port Jérôme**: Good results

<table>
<thead>
<tr>
<th>ND2 sensor</th>
<th>Correlation</th>
<th>Fractional Biais</th>
<th>Mean geometric Biais</th>
<th>FAC2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.56</td>
<td>-0.12</td>
<td>0.9</td>
<td>0.91</td>
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</table>

- **Le Havre**: Ok for the GOR and ROG sensors – Not ok for CAU

<table>
<thead>
<tr>
<th></th>
<th>GOR</th>
<th>ROM</th>
<th>CAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>0.59</td>
<td>0.52</td>
<td>0.27</td>
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<tr>
<td>Fractional Biais</td>
<td>0.05</td>
<td>0.05</td>
<td>-1.11</td>
</tr>
<tr>
<td>Mean geometric Biais</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>FAC2</td>
<td>0.86</td>
<td>0.68</td>
<td>0.31</td>
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</tbody>
</table>

- **Both sites at the same time**: OK for moderate to high wind speeds, not OK for low wind speeds → most of the situations

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<thead>
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<th>GOR</th>
<th>ROM</th>
<th>CAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>-0.24</td>
<td>0.34</td>
<td>-0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Fractional Biais</td>
<td>-0.71</td>
<td>-0.15</td>
<td>-0.68</td>
<td>-1.5</td>
</tr>
<tr>
<td>Mean geometric Biais</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>FAC2</td>
<td>70%</td>
<td>58%</td>
<td>48%</td>
<td>13%</td>
</tr>
</tbody>
</table>
Two categories of meteorological situations:

- Moderate to high wind speeds with good correlation between the ground stations and profiles ➔ good or acceptable results
- Low and fluctuant winds ➔ poor results

An exceptional meteorological situation: Christmas 2007 with a very stable situation, very low wind speeds during 4 days ➔ poor results

Further work on models to improve this low wind situations:

- Enhance turbulence scheme
- Try to use ECMWF results instead of GFS
- Have a real vertical profile in the estuary to measure vertical gradients at stack heights
SO2 Peaks Study – Le Havre area
Validation of the mitigation measures

- The well represented peaks have been kept to validate the mitigation measures
- A new sets of simulation have been performed taking into account emission mitigations
- In each case, results have been presented taking into account the modeling errors from the model validation

Simulation 1 – Hourly concentration averages

Simulation 1 – Daily concentration

→ Only one situation still shows SO2 concentration exceeding EU regulations
SO2 Peaks Study – Le Havre area
Validation of the mitigation measures

Thank You for your attention