Modelling and implementation of fugitive dust emissions caused by wind erosion and agricultural activities

Marc Guevara¹, Albert Soret¹, Francesc Martínez¹, José M. Baldasano¹.²

¹Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Barcelona, Spain
²Environmental Modeling Laboratory. Technical University of Catalonia (UPC), Barcelona, Spain

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Motivation and Objective

• The Spanish CALIOPE air quality system (http://www.bsc.es/caliope/es) (WRF-ARW/HERMESv2.0/CMAQ/BSC-DREAM8b) has a clear tendency to underestimate PM$_{10}$ concentrations (Baldasano et al., 2010; Pay et al., 2011)

• Spain is a Mediterranean country characterized by:
  1. Large semiarid regions and low amounts of precipitation (Gomes et al., 2003)
  2. Large shares of total land area dedicated to cultivate crops (MAGRAMA, 2013)

• Wind erosion and agricultural management dust emissions are implemented within CALIOPE in order to improve PM$_{10}$ modelled concentrations

Gomes et al. (2003)  
EEA (2012)
Methodology

Wind erosion
Methodology based on:
Korcz et al. (2009) (NatAir project)

\[ E(\text{g/unit area}) = \{\text{land area, m}^2\} \times \left\{ \text{[spike emission rate, g m}^{-2}\right\} \]
\[ + \left( \text{duration of erosion event, h} \right) \times \left( \text{emission factor, g m}^{-2} \text{ h}^{-1} \right) \]

Land Use → CORINE (EEA, 2012)

Soil texture → European soil data center
Panagos et al. (2012)

\[ W_{\text{threshold_velocity}} \rightarrow 8.9 \text{ m} \cdot \text{s}^{-1} \] (Friedrich, 2007)

\[ \frac{\text{PM}_{2.5}}{\text{PM}_{10}} \rightarrow 0.2 \]

Vertical emission (g/unit area) = \( E \times \text{ALFA} \)

ALFA \( \rightarrow 5.5 \cdot 10^{-4} \) (Curci et al., 2007)

Agricultural activities

Methodology based on:
Schaap et al. (2009)

\[ F_{\text{ars}} = \sum_{\text{operation}} C_{\text{operation}} EF_{\text{operation}} A \]

Agricultural calendar → FEGA (2014)

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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</thead>
<tbody>
<tr>
<td>Fertilization &amp; Growing season</td>
<td>Harvest</td>
<td>Land Preparation &amp; Seeding</td>
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<tr>
<td></td>
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<td>Harrowing</td>
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<tr>
<td></td>
<td>Discing</td>
<td>Ploughing (dry)</td>
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</tr>
<tr>
<td></td>
<td>Cultivating</td>
<td></td>
<td></td>
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<td></td>
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<table>
<thead>
<tr>
<th>Operation type</th>
<th>( \text{EF (mg} \cdot \text{m}^{-2} )</th>
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<tbody>
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<tr>
<td>Harrowing</td>
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<tr>
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<tr>
<td>Discing</td>
<td>137</td>
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<tr>
<td>Ploughing (dry)</td>
<td><strong>1050</strong></td>
</tr>
</tbody>
</table>
PM$_{10}$ emission results

Wind erosion

PM$_{10}$ [t·year$^{-1}$]

\[ 23,920 \]

\[ 137,427 \]

\[ 215,593 \]

HERMESv2.0  AgriAct  WBDust

Agricultural activities

Wind erosion + Agricultural activities PM$_{10}$ emissions Spain (2009)
PM$_{10}$ Air quality results – Agricultural activities
(1th – 15th Aug)

$\Delta$ Emissions [kg·h$^{-1}$]

$\Delta$ Concentrations [µg·m$^{-3}$]

$\Delta$ Dry deposition [kg·ha$^{-1}$]

PM$_{10}$ average concentrations [µg·m$^{-3}$] (1$^{\text{th}}$ – 15$^{\text{th}}$ Aug)

<table>
<thead>
<tr>
<th>Station</th>
<th>SinAgr</th>
<th>ConAgr</th>
<th>SinAgr</th>
<th>ConAgr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-19.9</td>
<td>-16.6</td>
<td>0.22</td>
<td>0.22</td>
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<td>2</td>
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<td>-10.4</td>
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<td>0.55</td>
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<td>-5.1</td>
<td>0.25</td>
<td>0.20</td>
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<tr>
<td>4</td>
<td>-22.9</td>
<td>-20.6</td>
<td>0.11</td>
<td>0.18</td>
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<tr>
<td>5</td>
<td>-7.1</td>
<td>-4.7</td>
<td>0.10</td>
<td>0.16</td>
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<tr>
<td>6</td>
<td>-8.3</td>
<td>-6.0</td>
<td>0.23</td>
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<td>8</td>
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<td>-11.2</td>
<td>0.32</td>
<td>0.45</td>
</tr>
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<td>9</td>
<td>-26.3</td>
<td>-23.1</td>
<td>0.20</td>
<td>0.21</td>
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<td>10</td>
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<td>-15.2</td>
<td>0.60</td>
<td>0.54</td>
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<td>TOTAL</td>
<td>-15.2</td>
<td>-12.3</td>
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EEA (2013)
Effect of dry deposition

Station ES1636 - PM$_{10}$ Emissions vs Dry deposition

Station ES1636 - PM$_{10}$ Concentrations vs Dry deposition

$\Delta$ Emissions [kg] $\rightarrow$ 1250.2

$\Delta$ Dry deposition [kg] $\rightarrow$ 866.9

Dry deposition amounts 70% of total extra PM$_{10}$ emitted
Conclusions

- **PM$_{10}$ emissions:**
  - Wind erosion (24kt·year$^{-1}$) and arable land management (216kt·year$^{-1}$) sources implies an increment of ~240kt·year$^{-1}$ PM$_{10}$ Spanish emissions
  - Agricultural emissions are 40% higher than the rest of anthropogenic emissions (137kt·year$^{-1}$), with an average contribution up to ~1 kg·h$^{-1}$·km$^{-2}$
  - More than 90% of these emissions occur during Summer and Autumn

- **PM$_{10}$ concentrations:**
  - Local strong effects of agricultural activities near arable areas (up to 6 µg·m$^{-3}$)
  - Deposition mechanism was found to be a significant sink for agricultural emissions in CMAQ (up to 70% of total extra PM$_{10}$)
  - Low air quality impacts are expected from windblown dust emissions
• Friedrich, 2007. Improving and applying methods for the calculation of natural and biogenic emissions and assessment of impacts to the air quality. SIXTH FRAMEWORK PROGRAMME. FP6-2003-SSP-3 – Policy Oriented Research