Insight from other regions: Development of air quality forecasts for winter-time PM2.5 episodes occurring on multiple cities in south-central Chile

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Trivia: What city is this and how big is it?

City: Osorno. Population: ~150k inhabitants
Severe PM2.5 episodes in south-central Chile

- Produced by a combination of:
  - Complex topography
  - Episodic meteorological conditions
  - Emissions due to anthropogenic activities

- Episodes are declared to warn the public and to try to reduce the impact by invoking temporary measures
Forecasting system

- WRF-Chem model at high spatial resolution to resolve met conditions, topography and emissions
PM2.5 modeling

- CO and PM are highly correlated during episodes
- Use CO tagged tracers ("traffic" and "wood burning stoves") and an empirically calibration for 2014
- The conversion factors are chosen to match observed episode statistics.
- Factors are introduced to include physical processes including % contribution of stoves by city, weekend effect, and temperature dependence

Saide et al., Atmos Env 2011
Saide et al., JGR 2016
Episode’s Temperature dependence

- Episodes associated to colder temperatures (statistically significant)
- This is due to emissions from wood burning stoves for heating
- Including temperature correction helps reproduce histograms
WRF-Chem configuration was tuned to resolve episodes

- No vertical diffusion thresholds for Chem
- No horizontal diffusion on the inner domain
- Sensitivity analysis was done for selecting vertical resolution (first two layers 10m thick, 6 levels below 100m), PBLH scheme (MYNN) and Meteorological Boundary conditions (GFS)

Saide et al., Atmos Env 2011
Episode evolution (Osorno)

a) 4 pm

b) 8 pm

c) 1 am

d) 5 am

e) 9 am

f) 1 pm
Results

- Large variability within forecasts due to different meteorological initialization. Ensemble forecasting should be explored in the future.
- Overall skill of 53–72% of episodes accurately forecasted which is generally better than persistence.

Saide et al., JGR 2016
Emission influence on different days

- Episodes are declared to reduce emissions to avoid bad air quality
- 48 forecasts needed to declare episodes in advance

Saide et al., Atmos Env 2011
Forecasting for 2015

- System in place since 2015 pollution season
- Provided good guidance with similar skill as the 2014 calibration

Emergency in Santiago

Emergency in Osorno
How would a forecasting system for AQUARIUS could look like?

• Two (or more?) nested domains to capture each sampling region
• Similar configuration as Chilean system to predict episode occurrence
• Ensemble forecasts to get a probabilistic forecast of episode occurrence
• Post-campaign simulations would be performed with full chemistry for analysis
Science questions

• Can a forecasting system developed for other regions predict winter-time air quality episodes in the western US?
• Does an ensemble system improve predictability?
• Once the accumulation of pollutants is properly modeled, can air quality models predict the chemical evolution during episodes?
• Can data assimilation of atmospheric constituents (AOD, CO, NO₂) help in the predictability of these events? Does the addition of geostationary satellites data play a role?

Previous work on data assimilation/inverse modeling: Saide et al., PNAS 2012; Saide et al., GRL 2014; Saide et al., GRL 2015a,b; Saide et al., JGR 2016; Saide et al., ES&T 2018;
Questions or comments?

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Supplemental slides
PM2.5 modeling

- CO and PM are highly correlated during episodes
- Use CO tagged tracers ("traffic" and "wood burning stoves") and an empirically calibration for 2014
- The conversion factors are chosen to match observed episode statistics.
- Factors are introduced to include physical processes

\[
PM2.5_{t,s} = Tr\_to\_PM_s \times A\_weekend_{t,s} \times \ldots
\]

\[
[ F\_WB_s \times A\_WB(T\_mean_{t,s}) \times \max_{i \in s \cup N_s} Tr\_WB_{t,i} ] + (1 - F\_WB_s) \times \max_{i \in s \cup N_s} Tr\_T_{t,i} \]

24 hour mean PM2.5 vs CO

Temuco (Las Encinas)  
Santiago (Cerro Navia)
Weekend effect

• There were 137%, 34% and 38% more episodes on average for weekend days than for weeks-days in Santiago, Rancagua and Talca, respectively.

• Activity increases in Friday and Saturday nights, which generates episodes on Saturday and Sundays

• Inflation factors:
  – 1.4 for Santiago
  – 1.2 for Rancagua
  – 1.3 for Talca and Chillán

• Improvement in model performance:
  – 67% to 72% in Santiago
  – 64% to 69% in Rancagua
  – 57% to 63% in Talca
  – 63% to 67% in Chillan
Results

- Large variability within forecasts due to different meteorological initialization

- Variability in PM2.5 much larger than T and wind speed

- Ensemble forecasting should be explored in the future

- Overall skill of 53–72% of episodes accurately forecasted (61–76% for the best initialization) which is generally better than persistence.
Wind evaluation

Santiago (Cerro Navia)

Talca (Universidad de Talca)

Temuco (Padre de las Casas II)

Rancagua (Rancagua I)

Chillán (Purén)

Valdivia (Valdivia)

Curicó (Curicó)

Los Ángeles (21 de Mayo)

Osorno (Osorno)

OBS

MODEL

OBS

MODEL

OBS

MODEL
Precipitation

Temuco Centro
Forecast skill

- Forecasts one, two and three days in advance all have skill in forecasting
- Latest forecast no necessarily the best
- Forecast generally beat persistence

<table>
<thead>
<tr>
<th>City</th>
<th>Station</th>
<th>Episode days (%)</th>
<th>% correct Episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santiago</td>
<td>Pudahuel</td>
<td>21%</td>
<td>63% 72% 69% 68%</td>
</tr>
<tr>
<td></td>
<td>Cerro Navia</td>
<td>30%</td>
<td>71% 69% 76% 72%</td>
</tr>
<tr>
<td>Rancagua</td>
<td>Rancagua II</td>
<td>35%</td>
<td>68% 72% 68% 69%</td>
</tr>
<tr>
<td>Curico</td>
<td>Curico</td>
<td>21%</td>
<td>61% 48% 48% 53%</td>
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<tr>
<td>Talca</td>
<td>La Florida</td>
<td>38%</td>
<td>66% 64% 59% 63%</td>
</tr>
<tr>
<td>Chillan</td>
<td>Puren</td>
<td>40%</td>
<td>65% 67% 62% 64%</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>21 de Mayo</td>
<td>33%</td>
<td>67% 67% 65% 67%</td>
</tr>
<tr>
<td>Temuco</td>
<td>Museo Ferroviario</td>
<td>33%</td>
<td>73% 69% 71% 71%</td>
</tr>
<tr>
<td></td>
<td>Las Encinas</td>
<td>33%</td>
<td>68% 62% 68% 66%</td>
</tr>
<tr>
<td></td>
<td>Padre Las Casas II</td>
<td>38%</td>
<td>73% 71% 68% 71%</td>
</tr>
<tr>
<td>Valdivia</td>
<td>Valdivia</td>
<td>31%</td>
<td>59% 61% 61% 60%</td>
</tr>
<tr>
<td>Osorno</td>
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<td>38%</td>
<td>71% 64% 63% 66%</td>
</tr>
</tbody>
</table>

Pers: Percentage of correct forecasts
Episode evolution (Temuco)

Saide et al., JGR 2016

a) 4 pm LT

b) 9 pm LT

c) 1 am LT

Saide et al., JGR 2016