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AIR QUALITY MODELLING IN SLOVENIA: STUDYING SENSITIVITY OF WRF/CHEM FORECAST

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Background

Air quality models:
• complete coverage of air quality (time&space)
• provide an improved understanding of the sources, causes and processes
• can be applied prognostically
• important tool for decisions about effective abatement strategies and for environmental assessments during planning stage
• ...

Challenges:
• require extensive input data (limited accuracy of inputs)
• many uncertainties in input data and model representation
• extensive validations and sensitivity analyses needed
• must be used together with measurements
AQ modelling at UL

Models:
• WRF/Chem model
• ALADIN/CAMx model
• statistical model for O$_3$ daily maximum forecasting

EuNetAir WG3: Environmental measurements and air-pollution modelling

Objectives:
• Report on chemical weather forecasting at global area and hot-spot case-studies;
• Assessment of air-quality modelling with data assimilation from integrated AQC gas sensors;
• …
Facilities: WRF/Chem model

On-line coupled

For past air pollution episode studies:
- model setup depends on purpose and area of interest

For participation in international initiatives, actions:
- AQMEII, COST action activities…

For operational AQ forecast in Slovenia:
- running since summer 2013
- available online:
  http://meteo.fmf.uni-lj.si/onesnazenje
- the basis for further scientific research
Facilities: Models running at SEA

ALADIN/CAMX:

- running operationally at Slovenian Environment Agency
- off-line coupled

**ALADIN/SI**
- meteorological fields

**SMOKE**
- biogenic emissions

**Anthropogenic emissions for EU**
- (TNO/MACC-II)

**Anthropogenic emissions for SI**
- (national database)

**Chemical boundaries**
- (MOZART model)

**Additional input fields**
- (landuse, TOMS...)

**CAMx**

**48 h AQ forecast**

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Statistical model for O₃ daily maximum forecast:

- Regression type model based on measured data, meteorological forecast and predicted trajectories
Anthropogenic emissions

For Slovenia:

a) Detailed database for year 2009 (currently used)
b) Detailed database for year 2011 (new, not yet implemented)

Outside Slovenia:

TNO/MACC-II for year 2009

NOx (tons/year), 100 m resolution

TNO/MACC II: PM2.5 (g/hour)
AQ measurements

National network: 17 AQ stations, most of them monitoring \( O_3 \), PM10; some of them: NOx, SO\(_2\), PM25, CO, heavy metals, benzene, benzo(a)pirene

Supplement network: 19 AQ stations monitoring SO\(_2\); some of them: \( O_3 \), NOx, PM10

17 AQ stations used in our analyses:

- KOP – urban
- NG – urban
- OTL – rural
- LJ – urban
- ISK – rural
- KRV – rural
- HRA – urban
- TRB – suburban
- CE – urban
- MS – rural
- ZAG – urban
- ZAD – rural
- VNA – rural
- KOV – rural
- ZAV – rural
- VEL – urban
- MOH – rural
Current activities

- **EuMetChem COST**: studying the importance of aerosol feedbacks with unified WRF/Chem model. Participated in international AQMEII exercise.

- **EuNetAir COST**: opportunity for exploring possibilities for combination of modeling with observational data to produce a most probable representation of the state of the variables (off-line data assimilation).

- Support to Slovenian Environment Agency (statistical model and ALADIN/CAMx modelling system)

- Studies on operational WRF/Chem forecasting system
  - to identify and estimate the impact of model uncertainties
  - focus on sources of uncertainties with highest impact
  - to improve model performance
Scientific questions

Coupled Chemistry Meteorology Model (CCMM) – WRF/Chem:

- Can an integrated model (considering many uncertainties) produce a good climatology of the most important chemical species?
- Is such model able to beat persistence or statistical forecast of these species?
- What is the impact of aerosol feedbacks on weather and AQ forecast?
- What is the added value of high resolution modelling (running forecast in 3.7 km resolution is computationally very demanding)?
- What is the sensitivity of WRF/Chem forecast to using detailed anthropogenic emission database for Slovenia (considering that Slovenia is a small country)?
Evaluation of O₃, NO₂ and PM10 WRF/Chem predictions
WRF/Chem, statistical forecast, persistence

Summer 2013, ozone daily maximum:

- **BIAS**: 
  - μg/m³

- **RMSE**: 
  - μg/m³

- **CORR**
  - ME

- **F 1day**
- **F 2day**
- **P 1day**
- **P 2day**
- **SF 1day**
- **SF 2day**

**SF, SF:** statistical forecast

**P, P:** persistence

**F, F:** WRF/Chem forecast

**M:** measurements
Sensitivity experiments

5 model predictions for summer 2013:

1. **OPER** – operational forecast
   - 1\textsuperscript{st} day and 2\textsuperscript{nd} day forecast for June-August 2013
   - WRF-Chem model, selected parameterization schemes
   - 2 nested domains, the resolution of the inner domain (D2) 3.7 km
   - detailed anthropogenic emissions for Slovenia, TNO/MACC-II for EU
   - aerosol effects on radiation processes taken into account (but not impacts on microphysical processes)

2. **RES** – lower horizontal resolution
   - Predictions on the outer domain (D1) with 11 km resolution
Sensitivity experiments

3. NOE – no aerosol effects on radiation processes
   • Zero aerosol concentrations considered in radiation schemes -> reduced scattering of solar radiation or absorption (e.g. black carbon) ...
   • subsequent changes in temperature, boundary layer height, relative humidity, clouds,…

4. EMIS – different anthr. emissions for Slovenia
   • TNO/MACC-II emissions everywhere
   • Resolution: 1/8° × 1/16°, top-down approach

5. PER – persistence (pollutant level today and tomorrow the same as yesterday)
Impact of model resolution

Mean for summer 2013

DIFF in $O_3$ daily max

DIFF in PM10

DIFF in $O_3$

DIFF in NO$_2$
Impact of no aerosol direct effects

Mean for summer 2013

DIFF in O$_3$ daily max

DIFF in O$_3$

DIFF in PM10

DIFF in NO$_2$
Impact of TNO/MACC emissions for Slovenia

Mean for summer 2013

DIFF in $O_3$ daily max

DIFF in $O_3$

DIFF in PM10

DIFF in $NO_2$
WRF/Chem, statistical forecast, persistence

Summer 2013, ozone daily maximum:

BIAS

RMSE

CORR

OPER - operational forecast
RES - 11 km resolution
NOE - no aerosol effects
EMIS - TNO/MACC-II for Slovenia
PER - persistence
Impact of model parameterization schemes

- WRF-Chem model sensitivity study
- August 2003 episode, 51 ensemble simulations
- Compared impacts on simulated ozone concentrations for varying:

  - PBL, LSM, SL - model physics parameterization options
  - RAD - radiation schemes
  - ICC - chemical initial conditions
  - BCC - chemical boundary conditions
  - +NOx, +VOC - anthropogenic emissions (+30%)
  - BIO - biogenic emissions
  - RES - model domain setup and resolution

![Graph showing ozone concentration changes](image)
Data assimilation

Models:
- WRF/Chem model (online)
- ALADIN/CAMx model (offline)
- statistical model for $O_3$ daily maximum forecasting

Challenges related to chemical data assimilation (Bocuet et al., 2014):
- major limitation for chemical data assimilation in models is likely to be the limited availability of data, particularly in near-real-time
- On-line chemical data assimilation in coupled chemistry meteorology models is still in its infancy
- ...

Off-line data assimilation techniques (data fusion)

National and supplement network of AQ monitoring stations in Slovenia
Conclusions

• Depending on station and statistical measure applied, WRF/Chem model can beat persistence or statistical model predictions (for ozone daily maximum).

• Further improvements of WRF-Chem forecasting skill could be obtained by applying one of the bias-correction methods in order to account for unresolved topographical effects and emission patterns.

• Data assimilation in on-line coupled models still in its infancy: only a few applications of data assimilation in coupled meteorology-chemistry models, many potential difficulties.

• Can EuNetAir Cost action help to make steps towards data fusion to produce a most probable representation of the state of the variables by combining model outputs and measurements.
Thank you!

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