A multi-model case study on aerosol-meteorology interactions with regional online coupled chemistry-meteorology models

Objective

Integrated or online coupled meteorology-chemistry models permit the simulation of

- aerosol radiative effects (direct aerosol effect)
- aerosol cloud interactions and resulting effects on radiation (indirect aerosol effect)
- feedback effects to meteorology

Different online coupled meteorology-chemistry models may respond differently to the same aerosol emissions
COST ES1004 (EuMetChem) Case Studies

Simulations for prescribed episodes with identical emissions and boundary conditions

- Base case: no interactions with simulated aerosol
- Only direct aerosol effect based on sim. aerosol
- Direct and indirect aerosol based on simulated aerosol effect

Two episodes in the year 2010

- The July/Aug. Russian heat and wildfires episode
- A period in October 2010 (rainy, later a dust event)
COST ES1004 Case Studies: Setup

General setup (following AQMEII model intercomparison)
• 1-day meteo-only spin-up + 2-days simulations with chemistry
• Chemistry restarted from previous 2-day run
Long enough to allow feedback ↔ short enough for suppressing semi-direct effects?

• Most modelling domains cover entire Europe + North Atlantic
• Smaller domain for DE3 and CS2
# Contributions to the case Studies

<table>
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<tr>
<th>Lead Institution</th>
<th>Model</th>
<th>Episode</th>
<th>Runs</th>
<th>Resolution</th>
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<tr>
<td>CS1</td>
<td>Univ. Lubljana, KIT/IMK-IFU *</td>
<td>WRF-Chem (a)</td>
<td>Fire, dust</td>
<td>Base, direct, dir&amp;indir</td>
</tr>
<tr>
<td>CS2</td>
<td>Univ. Lubljana, KIT/IMK-IFU *</td>
<td>WRF-Chem (b)</td>
<td>Fire</td>
<td>Base, direct, dir&amp;indir</td>
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<tr>
<td>ES1</td>
<td>Univ. Murcia</td>
<td>WRF-Chem (c)</td>
<td>Fire, dust</td>
<td>Base, direct, dir&amp;indir</td>
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<tr>
<td>ES3</td>
<td>UPM-ESMG</td>
<td>WRF-Chem (d)</td>
<td>Fire, dust</td>
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<td>DE3</td>
<td>IFT Leipzig</td>
<td>COSMO-MUSCAT</td>
<td>Fire, dust</td>
<td>Base, direct</td>
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<tr>
<td>CH1</td>
<td>EMPA</td>
<td>COSMO-ART</td>
<td>Fire (3 days missing)</td>
<td>Base, direct</td>
</tr>
</tbody>
</table>

(a) RADM2/MADE-SORGAM  
(b) same as (c), but with higher resolution  
(c) RADM2/MADE-SORGAM, Lin microphysics  
(d) CBMZ/MOSAIC  

*: Joint effort, also including ZAMG, RSE, UPM-ESMG
Russian heat wave and fire episode

Concentrate on
- CS1 (WRF-Chem with RADM2-MADE)
- DE3 (COSMO-MUSCAT with MADE-Soot)
- CS2 (WRF-Chem with better resolution)
- ES3 (WRF-Chem with CBMZ-MOSAIC)

ES1 (like CS1, but with different cloud microphysics)
Quite similar to CS1 contribution. See talks by Rocío Baró (this afternoon) and Palacios Peña Laura (tomorrow)

CH1: (COSMO-ART with MADE-Soot [not complete])

Comparison with observations near Moscow courtesy of Dr. Natalia Chubarova, Moscow State University. Surface measurement data from Mosecomonitoring, Meteorological Observatory of Moscow
Baseline PM10

Episode mean PM10 (μg m⁻³)

WRF-Chem modal

PM10_C11_CS1

Moscow

WRF-Chem modal

PM10_C11_CS2

COSMO-MUSCAT

PM10_C11_DE3

WRF-Chem sectional

PM10_C11_ES3

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Baseline AOD at Moscow

AOD at Moscow

- AOD 555 CH1_C12
- AOD 555 CS2_C11
- AOD 555 ES1_C11
- AOD 555 ES3_C11
- AOD 555 DE3_C11
- AOD 555 CS1_C11
- AOD 555 MODIS_AOD
- AOD 440
- MODIS_AOD 550
Baseline AOD at 555nm

WRF-Chem modal

COSMO-MUSCAT

WRF-Chem sectional

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Baseline AOD at 555nm
Comparison with MODIS (overpass time: morning)
Effect on solar radiation

Episode mean global radiation difference between 'direct effect' and base (W m\(^{-2}\))

- **WRF-Chem modal**
  - SWGD C12-C11 CS1

- **COSMO-MUSCAT**
  - SWGD C12-C11 DE3

- **WRF-Chem sectional**
  - SWGD C12-C11 ES3

**COSMO-MUSCAT:**
Smaller reduction in spite of higher AOD than Wrf-CHem!
Aerosol effect masked by clouds & different baseline assumptions
Solar radiation at Moscow

Global radiation: CS1 (WRF-Chem, green), DE3 (COSMO-MUSCAT, red)

C11: Base, C12: Direct aerosol effect based on simulated aerosol
Effect on Temperature

Episode mean temperature difference between 'direct effect' (C12) and baseline (C11)
Local effect on Temperature: CS1 vs. obs

WRF-Chem baseline (CS1 C11) and „direct aerosol effect“ (CS1 C12) compared to T at Moscow station (T obs)

Improvement with direct effect from prognostic aerosol

Improvement for single days with high AOD
Local effect on Temperature: DE3 vs. obs

**COSMO MUSCAT** baseline (DE3 C11) and „direct aerosol effect“ (DE3 C12) compared to T at Moscow station (T obs).

- Improvement with direct effect from prognostic aerosol
- Improvement for single days with high AOD
Effect on Temperature = Improvement?

Difference to EOBS

WRF-Chem modal  \( T_{max \ CS1 \_C11 \ - \ EOBS} \)

„Improvement“ (red=yes, blue=no)

"Improvement" of Tmax against EOBS

COSMO-MUSCAT  \( T_{max \ DE3 \_C11 \ - \ EOBS} \)

WRF-Chem (CS1)

COSMO-MUSCAT (DE3)
Wet and ‘Dust’ October episode

Pronounced PM10 variability among models for direct effect

Baseline PM10

PM10 difference direct effect - base
Wet and ’Dust‘ October episode

Direct effect: Response of WRF-Chem and COSMO-MUSCAT

Difference in cloud liquid water path

WRF-Chem modal CS1 C22-C21 Cloud liquid water path

COSMO-MUSCAT DE3 C22-C21 Cloud liquid water path

Difference in T

Note: mean dT< 0.2 K for this episode
Wet and 'Dust' October episode

Indirect & dir. effect: WRF-Chem modal and sectional aerosol

Difference in cloud LWP for modal and sectional aerosol

Note: positive dT up to 0.5 K
Summary and conclusions

- Generally similar response to direct aerosol effect for different WRF-Chem and the COSMO-MUSCAT simulations for high aerosol concentrations.
- Aerosol effect on temperature is only significant for fire hotspot areas with very high AOD during a short episode (and only for $a=0.1$).
- Different baseline assumptions can strongly affect the model response to aerosol.
- Inter-model differences in simulated chemical and meteo variables are often larger than aerosol direct and indirect effects.
Acknowledgments:

- All groups for doing simulations and contributing their results
- UL and BSC for the space on their FTP server
- TNO (anthropogenic emissions database): Hugo Denier van der Gon
- ECMWF/MACC project & Météo-France/CNRM-GAME (chemical boundary conditions)
- FMI (fire emissions)
- Dr. Natalia Chubarova, Moscow State University and AERONET
- Members of the Cost action ES1004 EuMetChem

Thanks to everyone who contributed!

Thank you for your attention