Regional climate change impacts on air quality in high resolution

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Goals

• To establish and validate a RCM/CTM modeling system for investigating the climate-chemistry interactions using models RegCM3 and CAMx.

• To assess the climate change impact on air quality in high resolution

• Attribute AQ changes to change of individual meteorological parameters and processes
Models involved

**RegCM**

- Regional Climate Model: Giorgi et al. (1993a,b), Giorgi et al. (1999), and Pal et al. (2005).
- Being developed in ICTP, [http://users.ictp.it/~pubregcm/RegCM3](http://users.ictp.it/~pubregcm/RegCM3)
- MM5 dynamical core
- 23 vertical $\sigma$-levels reaching up to 70hPa, with time step of 30 s,
- **10 km resolution.**

**CAMx**

- Eulerian chemical transport model (ENVIRO Corp.)
- [http://www.camx.com](http://www.camx.com)
- Meteorology from RegCM
- Chemistry schemes: SAPRC99 and CB-IV+Aerosols
- IC – clean conditions

- BC – provided by 50km x 50km runs carried out by Aristoteles University of Thesaloniki
- Emissions – EMEP (Europe, 50km) and POP (CE, 5km) emissions for y2000, biogenic emissions of Isoprene and Monoterpenes following Guenther’s approach.

**RegCM2CAMx**

- **Coupling interface** – converts RegCM meteorology to CAMx input fields.
- Developed by Charles University
Model’s grid

182 x 162, 10 km resolution

Boundary conditions from 50 km domain covering most of the Europe - CTM runs by Aristoteles University of Thessaloniki.
• Four decadal CTM runs: 2 for present situation and 2 for near and far future conditions (3 decades involved).

Meteorology – dynamically downscaled from ERA40/ECHAM via RegCM 25 km x 25 km and RegCM 10 km x 10 km runs

ERA40

ECHAM

PRESENT

CONTROL

Emissions (EMEP+POP)

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

DEK2

“near future”

DEK3

“far future”
Model validation

- The 1991-2000 CAMx run driven by downscaled ERA40 meteorology served for model validation.
Model validation

- The 1991-2000 CAMx run driven by downscaled ERA40 meteorology served for model validation.
Climate change impact on air quality

Present (reference) SO2 exceedances

Future SO2 exceedances
MEASURE\text{future} - MEASURE\text{present}

- **Measures:**
  - Annual/Seasonal Averages (ozone)
  - AOTs (Accumulated concentration Over a Threshold) for ozone
  - Exceedances according to EC Directives (hourly/daily averages, see below)

### EU air quality thresholds for different averaging intervals

<table>
<thead>
<tr>
<th>Averaging interval</th>
<th>O\textsubscript{3} Threshold (µg/m\textsuperscript{3})</th>
<th>NO\textsubscript{2} Percentile Threshold (µg/m\textsuperscript{3})</th>
<th>PM\textsubscript{10} Percentile Threshold (µg/m\textsuperscript{3})</th>
<th>SO\textsubscript{2} Percentile Threshold (µg/m\textsuperscript{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly</td>
<td>--</td>
<td>--</td>
<td>99.79</td>
<td>350</td>
</tr>
<tr>
<td>Daily</td>
<td>93.15</td>
<td>200</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Annual</td>
<td>--</td>
<td>40</td>
<td>50</td>
<td>125</td>
</tr>
</tbody>
</table>

Left: threshold value in µg/m\textsuperscript{3}, right: percentile value corresponding to the number of allowed exceedances of the AQ limit value.
Impact on future concentrations
Average ozone

2041-2050

2091-2100

Winter

Summer

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Impact on future concentrations
AOT40 for crops/forests (absolute change)

2041-2050

Crops

Forests

2091-2100

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Impact on future concentrations
AOT40 for crops/forests (relative change)

Crops

Forests

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Impact on future concentrations
Ozone exceedances/maximum values

Number of days 8-hour O3 > 120 microg/m³ DEK2–CONTROL

Maximum O3 DEK2–CONTROL [ppbv]

Number of days 8-hour O3 > 120 microg/m³ DEK3–CONTROL

Maximum O3 DEK3–CONTROL [ppbv]
Impact on future concentrations
Particulate matter

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Impact on future concentrations
Sulfur dioxide hourly/daily exceedances

**2041-2050**

Num. hours $\text{SO}_2 > 350 \text{ ug/m}^3$ DEK2-CONTROL

**2091-2100**

Num. hours $\text{SO}_2 > 350 \text{ ug/m}^3$ DEK3-CONTROL

$N_{1h>350}$

$N_{1d>125}$

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HARMO13 – Paris - France 1-4 June 2010
Impact on future concentrations
PM10 daily exceedances

2041-2050

2091-2100

N_{1d>50}
The future air quality shift can be attributed to change of which meteorological parameters?

Expectations:

**Ozone change**: temperature, solar radiation (cloud optical depth)

**Sulfur dioxide exceedances**: change in horizontal/vertical mixing, wind speed/direction, PBL height

**Particle matter exceedances**: change in horizontal/vertical mixing, windspeed, PBL height
Climate change impact on AQ
Temperature at 2 m “future”-”present”

Winter

Summer
Climate change impact on AQ
Incident solar radiation [W/m²] “future”–”present”

Winter

Summer

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Climate change impact on AQ
Total precipitation [mm/day] “future”-“present”

Winter

Summer

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Climate change impact on AQ
Ventilation coefficient [m²/s] “future”-”present”

Winter

Autumn

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Climate change impact on AQ
Wind speed [m/s] “future”-”present”

Winter

2041-2050

2091-2100

Autumn
Climate change impact on AQ
Wind components [m/s] “future”-”present”

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Conclusions

- Offline couple of RCM and CTM well captured the climatology of selected gases in the troposphere in the terms of average values. Simulation of extremes is weaker.

- Yearly averages: ozone shows small reduction both in the near and far future decades in CE. During summer, far future, ozone increases in some areas: southern Germany, northern Italy

- AOT for crops increases by the factor of up to 30% in the far future in selected regions, for forests, increase occurs on smaller areas but with the same magnitude

- Future ozone exceedances show to be more frequent (up to 50%) and higher ozone maxima are expected, at some areas, by up to 15 ppbv
Conclusions cont’d

- SO$_2$ - shift of the high polluted spots. Increase of exceedances at some areas in Central Europe.

- PM10/2.5 – average levels decrease in the future, num. days of with exceedance decrease. Not significant increase occurs at many areas.

- Average ozone reductions attributed to lower solar radiation “defeating” temperature increase. Temperature rise is important only in summer far future. AOTs, exceedances and maxima increase due to temperature increase.

- SO$_2$: shift of polluted spots partially due to change of wind pattern, areas of pure increase occur where ventilation(wind speed) is reduced

- PM10: decrease in Romania due to increased ventilation(wind speed), decrease of average values and exceedances around Benelux unexplained so far.
Thank you for your attention
Any question?

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