Modelling the impact of climate variability and change on air pollution over Europe using MATCH linked to regional climate scenarios and ERA40

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Main messages

1) It is important to study long time periods (decades) due to substantial natural variability in climate

2) Large changes in near-surface ozone (and SIA) expected in Europe due to changes in regional climate

3) Uncertainties in climate projections are substantial - an ensemble approach is necessary
Climate change has the potential to change the concentration of air pollutants through:

- Changed transport pathways
- Changed mixing/turbulence
- Changed chemical and physical conversion rates
- Changed background field of precursors and oxidants
- Changed emissions (natural as well as anthropogenic)
- Changed surface/vegetation may affect deposition and emission processes
Some policy related questions regarding air quality and climate on regional scale

- Will natural variability dominate over climate change feedback on air quality in the coming decades?
- Are changes in air quality arising from emission control measures larger than or less than the changes in air quality that may arise from climate change?
- Will regional emission changes affect regional climate?
- Will air quality emission reduction policies lead to emission changes that counteract climate change policies?
Setup to investigate the impact of climate variability and change on air pollution in Europe

- Run a state-of-the-art regional off-line chemical transport model under different climates – past and future
- Keep anthropogenic emissions and boundary values at their present values
- Study “traditional” air-pollutants, i.e.:
  - acidifying and eutrophying deposition (SOX, NOY, NHX)
  - Secondary Inorganic Aerosols (SIA)
  - Near-surface ozone (O3)
MATCH offline regional CTM

- Flexible to use different met forcing, chemistry, and domains
- Resolutions ranging from 500 m to typically 50 km
- Used in GEMS regional part (model running on ECMWF systems since 2004)
- One of six regional models in MACC
- Involved in EURODELTATA and several other activities supporting the evaluation and development of EMEP models
Fractional bias (percent) of summer mean ozone concentrations compared to the 46-year summer mean (1958–2003)

Andersson and Langner, 2007 WASP.
Trends - concentration change per decade (%)
1979-2001

For more results visit the poster!

Andersson and Langner, 2007 Tellus
Impact of climate change on regional air pollution over Europe

Global climate change

Regional climate change

Impact on e.g. NOx-dep (%)
**The Rossby Centre regional climate model (RCA3.0)**

**RCA3.0:**
- **Atmosphere, land surface, lakes**
- **Resolution:** ca 12.5, 25, 50 km
- **Time step:** 15-30 min.
- **Domains:** Europe, Arctic, S. Africa, North and South America

Builds on RCA2 (Jones et al., Ambio 2004)
Tiled approach for the LSS (Samuelsson et al., 2006)
Model description and evaluation (Kjellström et al., 2005)
The Rossby Centre ensemble: a way of dealing with uncertainties in regional CC

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Transient regional climate change scenario for Europe 1961-2100 using RCA3 with boundaries from ECHAM4 SRES A2

Temperature change (°C)
2071-2100 vs. 1961-1990

Precipitation change (%)
2071-2100 vs. 1961-1990

Source: SMHI, Rossby Centre
Early attempts to look at impacts of climate change used too short time slices, 10 years – no significance

Relative change in NOx deposition (%)

Significance

Langner et al. (2005), Atmos. Env.
Climate change and natural variability - Simulated change in annual mean temperature for Sweden
RCA3 provides 140-year transient regional climate change downscaling on 50 km resolution

Drive MATCH with data from three 30-year time windows (reference, scenario1, scenario2). N.B. Need complete model states (at all model layers) at regular time intervals (every 6 h)

All non-biogenic emissions (SOX/NOX/VOC/CO/NH3) kept constant at 2000 year level (from EMEP)

No variation in tracer boundary conditions (thus omitting change in hemispheric background)

No change (either in RCA3 or MATCH) in lower boundary (i.e. albedo, surface roughness, vegetation type, …)
Results…

- Secondary Inorganic Aerosols (SIA)
- Deposition (sulphur- and nitrogen compounds)
- Ozone
Current and future near-surface O$_3$ concentration, apr-sep daily mean

Present climate

1111 Seasonally averaged diurnal-mean ozone (amjjas)

1961-1990

2211 Change, diurnal-mean ozone (amjjas)

2021-2050

3311 Change, diurnal-mean ozone (amjjas)

2071-2100

Change
Number of days with daily-maximum 8 hour O$_3$ concentration >120µg m$^{-3}$ (60 ppb(v))

1961-1990

2021-2050

2071-2100
Importance of changes in dry deposition and isoprene emissions

- Contribution, change in isoprene (%)
- Contribution, change in dry dep. (%)

Isoprene emissions (10-30%)
Dry deposition dependency on soil moisture (30-80%)

Andersson and Engardt submitted to JGR
Summary

- Large changes in near-surface ozone (and SIA) expected in Europe due to changes in regional climate

- Changes are particularly pronounced in S.W. Europe during summer

- Parts of S. Europe may experience decreased deposition of sulphur- and nitrogen containing species

- Changed atmospheric lifetime of many species may affect source receptor relationships in Europe (EMEP’s blame-matrix)
Challenges and future directions

- Assess uncertainty in climate simulations (use output from a number of models/scenarios; high demand on computer resources)
- Quantify the relative effect of climate change, changing background concentrations and European emission changes
- Include feedback between chemistry and climate models
- Include effects of vegetation change etc.
- Perform source-receptor calculations during future climate