Tropospheric Chemistry Modelling

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UKCA Launch Meeting, Royal Society, 12 January 2009
Objective of UKCA

- To build and evaluate a new UK community atmospheric chemistry-aerosol model suitable for a range of topics in climate and environmental change research.
Outline of Presentation

• Description and Evaluation
• Scientific Highlights
• Conclusions
• Future work
Description and Evaluation
## Variety of Chemistry Schemes

<table>
<thead>
<tr>
<th></th>
<th>Trop</th>
<th>TropIsop = Trop+MIM</th>
<th>Aerchem = Trop + S</th>
<th>RAQ</th>
<th>ExtTC = TropIsop + VOCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracers</td>
<td>26</td>
<td>40</td>
<td>27</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Species</td>
<td>46</td>
<td>60</td>
<td>49</td>
<td>58</td>
<td>82</td>
</tr>
<tr>
<td>Ethane, Propane</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Isoprene</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Other non-CH(_4) VOCs</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Alkenes, Aromatics</td>
<td>Alkenes, Terpenes, Aromatics</td>
</tr>
<tr>
<td>Aerosol formation</td>
<td>No</td>
<td>No</td>
<td>Sulphate</td>
<td>No</td>
<td>SOA</td>
</tr>
</tbody>
</table>

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Other Features

• Uses UM ‘New Dynamics’ – SL advection
• Coupled to various UM configurations – climate and forecast models
• Surface and aircraft emissions
• Interactive CH$_4$ wetland, DMS, and lightning NO$_x$ emissions
• Offline or online photolysis
• Simple or multiple-resistance dry deposition
• Wet deposition
• Prescribed top boundary
Various statistical measures of skill are also calculated (e.g. AAMB, RAMB, Model score, etc..)
PAN from Trop and ExtTC

Trop

ExtTC

DJF

Gerd Folberth, Met Office Hadley Centre

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Pinatubo, ENSO & Isoprene Emissions

- Climate dependent C5H8 emissions in ’90s
- Effects of Pinatubo & ENSO
- Compare to background emissions
- Peak effect (1993) on both C5H8 & OH large

Paul Telford
Cambridge University
Chemistry-aerosol coupling

Rae et al., JGR, 2007:

- Effect of oxidant and climate changes on sulphate
- 21st-century oxidant changes important for sulphate

Added coupling between HadGEM2 sulphate and UKCA

Tested by performing 3 model experiments:

- CTRL (original prescribed oxidants)
- UKCA_OL (on-line oxidants)
- UKCA_PR (prescribed oxidants from UKCA_OL)
Comparison with Sulphate Obs

Sequoia National Park (118.83°W, 36.49°N)

Obs
Original prescribed oxidants
UKCA online oxidants
UKCA prescribed oxidants

5-year runs for 1990s conditions

Jamie Rae, Met Office Hadley Centre
Climate Model Biases

Fiona O’Connor, Met Office Hadley Centre
Effect of Biases on \( \text{O}_3 \) & OH

Impact of T bias

Impact of Q bias

GRL draft paper ready to be submitted
C21st Integration with Tropospheric Chemistry

• N96L38 HadGEM2-AO using A1B emissions scenario
• Full suite of aerosol species and UKCA “Trop”

New couplings:
• UKCA oxidants and sulphate
• UKCA and land surface (dry deposition)
• Interactive CH₄ wetland emissions
• O₃ and CH₄ Radiative Feedback

Integration has completed 85 years
C21st Integration: First Look

C. Johnson, F. O’Connor, and G. Folberth

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Future Land Use: Impact on C$_5$H$_8$ Emissions and O$_3$

Rachel Pike
Cambridge University

Letter to Nature
In Preparation
Main conclusions

• Tropospheric chemistry model fit for purpose
• Good comparisons with observations and other models
• Supports a variety of chemistry schemes
• Further development ongoing
• Will be included in QESM and HadGEM2-ES
• Various scientific work underway
Papers

• Telford et al., Effects of Climate Induced Changes in Isoprene Emissions After the Eruption of Pinatubo, In preparation.
Future Work
• Further evaluation incl. satellite data
• Interactive biogenic emissions
• Improve coupling: chemistry and aerosol aerosols and photolysis
• AR5 simulations (coupled vs uncoupled)
• CH$_4$ – wetlands, hydrates, mitigation
• Climate change and air quality
Thank you for your attention!
Additional Slides
The need for chemistry-aerosol coupling

- Current model:
  - Monthly-mean prescribed oxidant concentrations.
  - Seasonal variation but no annual variation.
    → No variation with emissions and climate.
- Rae et al. (2007, JGR):
  - Effect of oxidant and climate changes on sulphate.
  - 21st-century oxidant changes important for sulphate.
  → Accurate 21st-century sulphate prediction therefore requires fully-coupled runs.
Implementation of chemistry-aerosol coupling

• Coupling with UKCA introduced
  • Currently one-way: no feedback to UKCA
  • Two-way coupling is being introduced.
• Tested by performing 3 model experiments:
  • CTRL (original prescribed oxidants)
  • UKCA_OL (on-line oxidants)
  • UKCA_PR (prescribed oxidants from UKCA_OL)
• 5-year runs for 1990s conditions.
Sulphate concentration: annual cycle

Sequoia National Park (118.83°W, 36.49°N)

Obs
Original prescribed oxidants
UKCA online oxidants
UKCA prescribed oxidants

Sulphate (mg[S]/m³)

J F M A M J J A S O N D