The United Kingdom Chemistry and Aerosol Community Model (UKCA)

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What is UKCA?

- UKCA is a community chemistry-climate model based on the Met Office’s new dynamics Unified Model.

- It is a joint development between the Met Office, University of Cambridge (chemistry) and University of Leeds (aerosol), open to contributing partners, e.g. Universities of Reading (NCAS-CMS) and Oxford.

- UKCA will be part of the forthcoming Joint Climate Research Programme (JCRP).

http://www.ukca.ac.uk/
The bigger picture: ESMs

Earth system modelling within QUEST. Based on a diagram by M. Joshi
Barriers and opportunities

- Slightly different model versions on different platforms ...
  - MO: NEC/IBM (latest version of the UM)
  - Universities: Cray XT4 (version chasing)
- Legacy data (including ancillary files)
- Transport requirements (mass versus atomic conservation)
- JCRP and a shared knowledge base will improve the situation
## UKCA differences ...

<table>
<thead>
<tr>
<th>Met Office</th>
<th>Universities</th>
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<tbody>
<tr>
<td>Chemical rates: Hardwiring required (assessment tool)</td>
<td>Chemical rates: Flexibility required (research tool)</td>
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<tr>
<td>Solver: Backward Euler (local, maximum numbers of iterations fixed)</td>
<td>Solver: Newton-Raphson (regional, convergence depends on the patch)</td>
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<td>Integration into UMUI</td>
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<td>Easy access to new UM versions</td>
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UKCA in use

- MO: National IPCC contribution/forecast
  - Interactive wetland emissions (AR5?)
  - Towards air quality forecast
- Universities: In support for WMO and IPCC science
  - Past and (possible) future stratospheric ozone (WMO 2010?)
  - Improved estimates of aerosol radiative forcing
Current Model Setups

- **Tropospheric UKCA**
  - Resolutions: N48L38, N48L60, N96L38
  - Tropospheric chemistry

- **Stratospheric and “Whole Atmosphere”**
  - Resolutions: N48L60, (N96L60)
  - Stratospheric chemistry with tropospheric background

- Towards all resolutions, whole atmosphere chemistry, interactive aerosol ...
Interactive CH$_4$ Ems Scheme

\[ F_{w\,CH4} = k_{CH4} \times f_w \times C_s \times Q_{10}(T_{soil})^{(T_{soil}-T_0)/10} \]

- $F_{w\,CH4}$ = methane flux from wetlands
- $k_{CH4}$ = scaling factor
- $f_w$ = wetland fraction
- $C_s$ = soil carbon content / weighted sum of carbon pools
- $Q_{10}$ = temperature sensitivity

Interactive CH$_4$ emissions from wetlands coupled to UKCA
Interactive CH$_4$ Ems Scheme

Provided by Fiona O’Connor

Prescribed Vegetation

Interactive Vegetation

JAN

JUL
UKCA Validation

MIPAS data provided by Gabi Stiller, analysis PB

MIPAS N$_2$O: Yellow
UKCA N$_2$O: Red

Closer link to satellite community!

“2000” Climate versus 2002-2004 Observations

N$_2$O at 600K - DJF

N$_2$O at 600K - JJA
Pinatubo
June 12, 1991
Three days before major eruption of June 15, 1991
(Source: Alan Robock’s volcano lecture)
Quantifying Pinatubo

“Global Ozone” (60S-60N)

Ozone lost due to chemistry on aerosols (model only).
Residual (dynamical) ozone variation (observation and model).
QBO proxy (can account for most of the residual).

Paul Telford, Peter Braesicke and Olaf Morgenstern

“Tropical Ozone” (10S-10N)
The world avoided ...

What would have happened without the Montreal Protocol and its amendments?

Here:
We study the impact of the avoided ozone changes only!

(Additional GHG impacts are not considered!)
Surface temperature change “avoided” by the implementation of the Montreal Protocol and its amendments ...

Morgenstern et al., GRL, 2008
GLOMAP investigations: Radiative forcing potential of SO$_2$ emissions

ESMs & seamless predictions

UKCA Chemistry (Troposphere and Stratosphere)
Aerosols

Emissions: Biogenic and Anthropogenic (surface scheme)

MACC project
AQUM project (weather forecast?)

Aerosol forcing

NCAS-Climate-Chem.

UKCA-Troposphere
UKCA-Stratosphere

UKCA-WA +MODE (WA: whole atm.)

Climate projections AR5 - HadGEM2-ES

Climate projections Post-AR5 HadGEM2/3-ES

Short-term numerical weather prediction & Visibility forecasts
AQ forecasts
Seasonal forecasting
Decadal prediction

Adapted from Olivier Boucher, Met Office
Some technical detail ...

- Horizontal: N48 (3.75ºx2.5º), Arakawa-C
- Vertical: L60, hybrid height (non-hydrostatic), up to ~83km
- Transport: semi-Lagrangian scheme
  - Corrective conservative scheme, Priestly (1993)
  - A posteriori correction is applied to restore the desired quantity whilst minimizing changes to the original solution (mass conservation as controlled by underlying flux-form discretization for density; mass is globally conserved, but local elements abundance is not necessarily conserved)
- Parameterisations: comprehensive
- Here: SSTs and sea-ice are prescribed!
Model is constrained in zonal wind, meridional wind and potential temperature. The vertical velocity in the UM is a **prognostic** (and not a diagnostic) quantity!