Introduction to HadGEM2-ES
Earth System Modelling

- How the climate will evolve depends on feedbacks
  - Ecosystems
  - Aerosols
  - Chemistry
- Global-scale impacts require ES components
  - Surface temperature
  - Insolation
  - River run-off
  - Air quality
  - Food resources
HadGEM2-ES

- HadGEM2-ES is designed to run the major scenarios for IPCC 5AR
- Hadley Centre’s “standard” climate model.
- Not the last word on Earth System Modelling at the Met Office
- Not HadGEM2-ES+
  - More complex chemistry/aerosols? Nitrogen cycling
  - Research tool
- Not HadGEM3-ES
  - New ES components (probably QUESM-based)
The climate system – HadGEM2-ES

CLIMATE

AEROSOLS

GREENHOUSE EFFECT

Direct and Indirect Effects

Human Emissions

Human Emissions

CH4, O3,

DMS, Mineral dust

Oxidants: OH, H2O2, HO2, O3

Fe deposition

ECOSYSTEMS

Biogenic Emissions: CH4
Dry deposition: stomatal conductance

Land-use Change

CO2

Human Emissions

GHG’s

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HadGEM2-ES Components

Fully coupled Earth System Model

- Atmosphere, ocean, sea-ice, land surface
  - HadGEM2-AO + new hydrology scheme (wetland methane)
- Land ecosystems: dynamic vegetation, soil C
  - TRIFFID, RothC
- Ocean ecosystems: NPZD, diatoms, non-diatoms,
  - Diat-HadOCC
- Aerosols: Sulphate, BC, OC, dust, sea salt
  - Current aerosol scheme, with some improvements
- Troposphereric chemistry: ozone, methane, oxidants
  - UKCA
UKCA Tropospheric Chemistry

- CH4-CO-NOx-HOx-NMHCs chemistry scheme
- 24 Tracers and 46 Species
- Prescribed photolysis rates and upper boundary
- Emissions: Surface, aircraft, and lightning
- Wet and dry deposition
Various statistical measures of skill are also calculated (e.g. AAMB, RAMB, Model score, etc.)
UKCA Evaluation – O₃ Profiles
UKCA Evaluation – O₃ Profiles

Poor performance of prescribed ozone in the lower troposphere

Performance comparable in the UTLS region
UKCA Evaluation – O₃ Profiles

100 mb Climatology
UKCA agrcm
UM O3

200 mb Climatology
UKCA agrcm
UM O3

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Aerosols in HadGEM2-ES: Changes since HadGEM1

- **Sulphate**
- **Biomass-Burning Aerosols** *Improved*
- **Biogenic Aerosols**
- **Fossil Fuel Organic Carbon** *New*
- **Mineral Dust**
- **Sea Salt**
- **Black Carbon (soot)** *Same*
New Couplings

- Chemistry - Radiation (O₃, CH₄)
- Chemistry - Hydrology (Wetland CH₄ emissions)
- Chemistry - Sulphate (UKCA oxidants)
- Sulphate - Ocean Biology (DMS emissions)
- Dust - Ocean Biology (Fe fertilisation)
Impact of Chemistry on Climate

• Run A: HadGEM2-A
• Run B: Run A + TropMatch OFF
• Run C: Run B + O₃ Rad. Feedback ON
• Run D: Run C + CH₄ Rad. Feedback ON
Impact of Interactive Ozone (1)

Prescribed O3 (A)

Interactive O3 (C)

Abs. Difference (C–A)

Rel. Difference

Zonal Annual Mean Ozone
Impact of Interactive Ozone (2)

Very little impact on tropospheric temperatures
Impact of Interactive Ozone (3)

Warm tropical tropopause bias becomes larger
Impact of Tropopause Matching

Worsening of Warm Bias cannot be attributed to Tropopause Matching
Impact of Interactive Methane (1)

Prescribed CH4 (A/B/C) vs. Interactive CH4 (D)

Abs. Difference (D-C)

Rel. Difference

Zonal Annual Mean Methane
Impact of Interactive Methane (2)

DJF
Temp.

C - ECMWF

D - ECMWF

Reduction in cold bias in N.H. winter stratosphere
Conclusions

- HadGEM2-ES now built at UMvn6.1
- Evaluation of tropospheric chemistry
- Aerosol Improvements
- New aerosols: Biogenic, OCFF, and Dust
- Impact of chemistry on the mean climate
- Now building model at UMvn6.6
Updated from Jones *et al.* (2001) and Roberts and Jones (2004) by:

- **Improved partitioning** between Aitken and accumulation modes

- **Inclusion of aqueous oxidation** of dissolved SO$_2$ by O$_3$

**Winter time sulphate over Europe**
Biomass-Burning Aerosols

Updated from Davison et al. (2004) by:

• Altering size distribution of aged aerosol
• Reducing absorption
• Including hygroscopic growth
• Reducing ageing timescale
• Changing emissions
Biogenic Aerosols

Introduced into HadGEM2 as:

• Monthly climatology

• Fields derived from terpene oxidation scheme in STOCHEM

• Size distribution and optical properties from ground-based observations
Fossil Fuel Organic Carbon

- Similar to BB scheme
- Fresh, aged, and ‘in-cloud’ components
- Size distribution and optical properties similar to BB aerosols
- Emissions from AeroCom
Mineral Dust

Added in HadGEM2

- Scheme from Woodward (2001)
- Updated emissions scheme
Overall Aerosol Performance
New Couplings

- Chemistry - Radiation (O$_3$, CH$_4$)
- Chemistry - Hydrology (Wetland CH$_4$ ems)
- Chemistry - Sulphate (UKCA oxidants)
- Sulphate - Ocean Biology (DMS emissions)
- Dust - Ocean Biology (Fe fertilisation)
Conclusions

• Introduced tropospheric chemistry scheme
• Evaluation of tropospheric chemistry
• Sulphate and BB Aerosol Improvements
• New aerosols: Biogenic, OCFF, and Dust
• New couplings: Assess biogeochemical feedbacks in the climate system