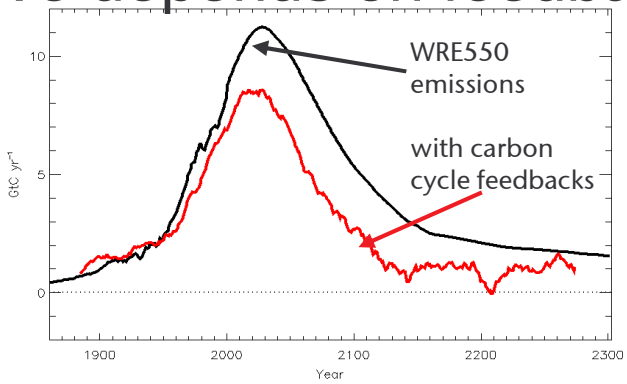
Introduction to HadGEM2-ES

Earth System Modelling

- How the climate will evolve depends on feedbacks
  - Ecosystems
  - Aerosols
  - Chemistry

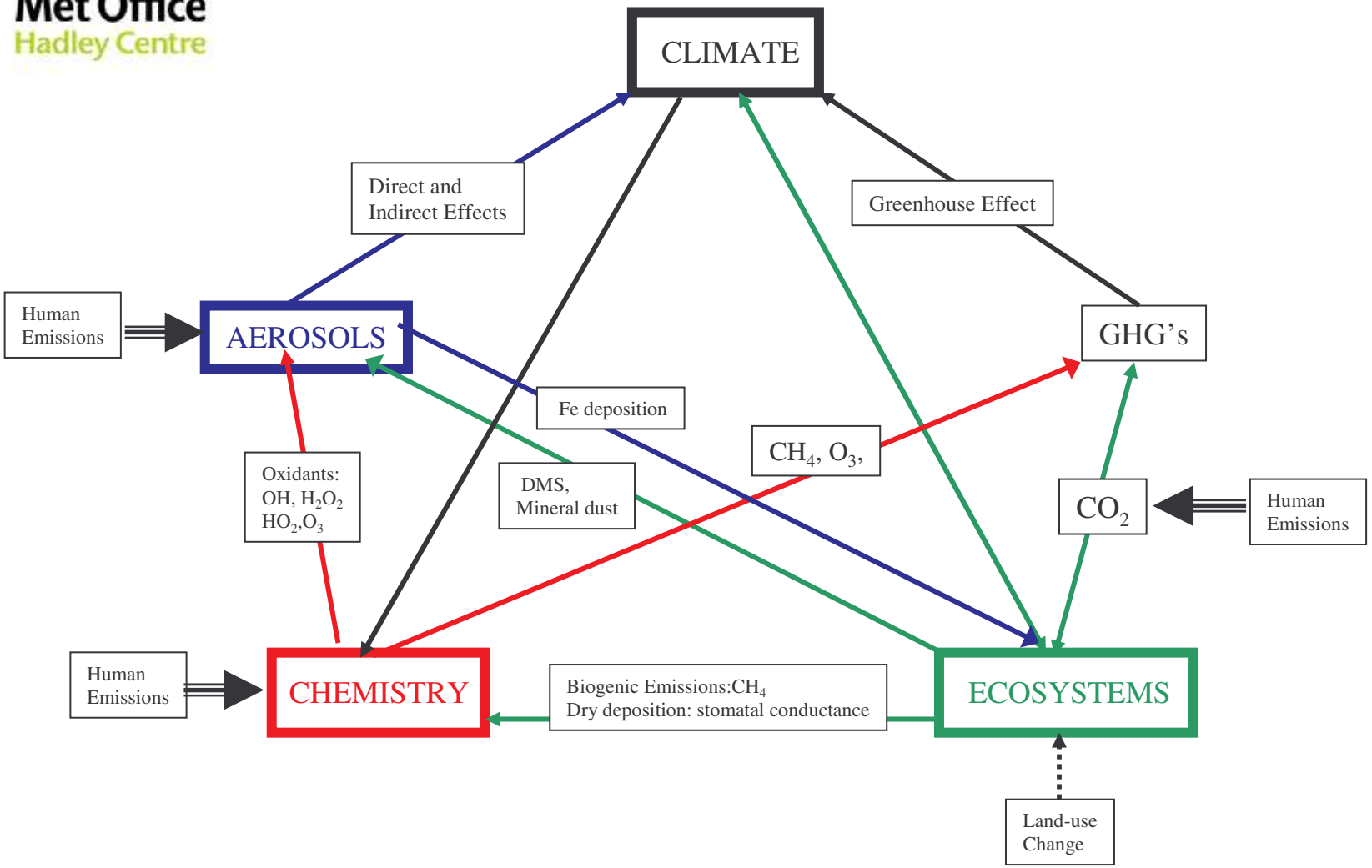


- Global-scale impacts require ES components
  - Surface temperature
  - Insolation
  - River run-off
  - Air quality
  - Food resources

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



HadGEM2-ES Components

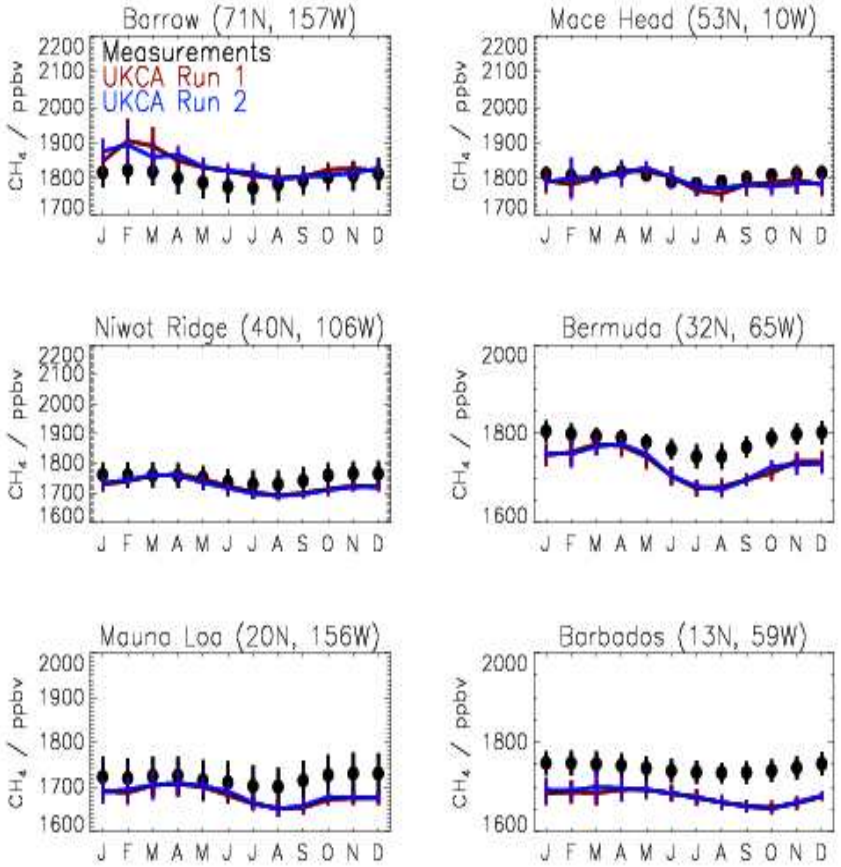
Fully coupled Earth System Model

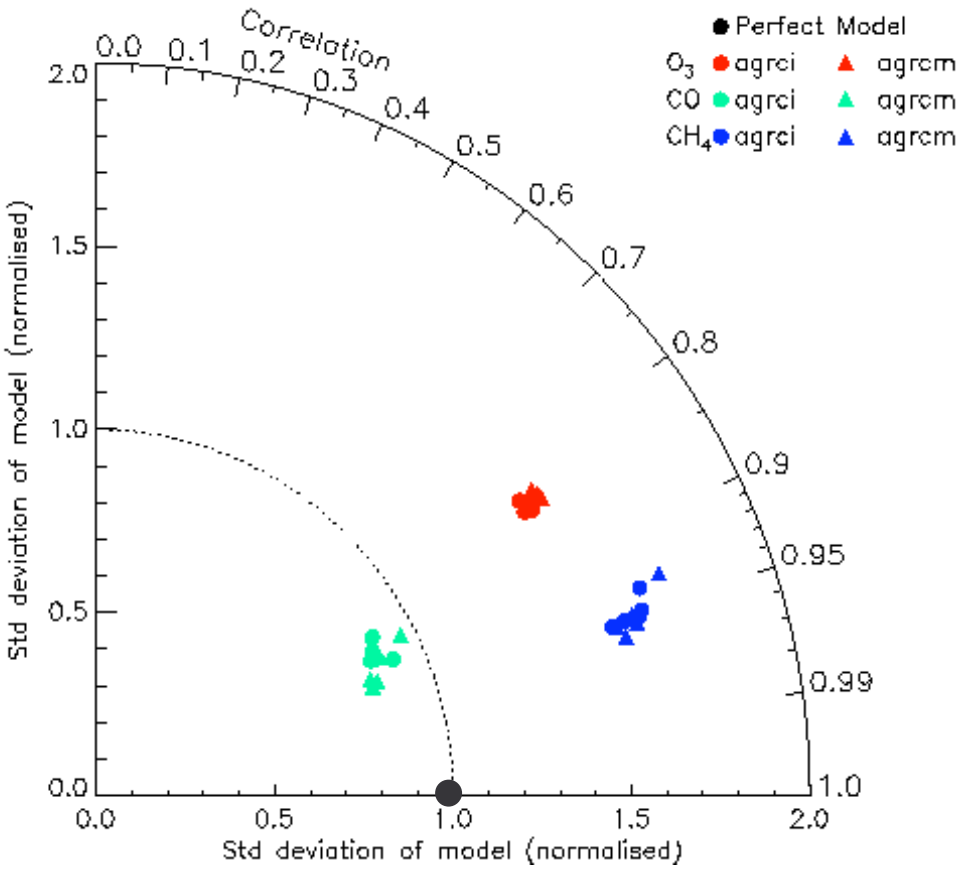
- Atmosphere, ocean, sea-ice, land surface
  - HadGEM2-AO + new hydrology scheme (wetland methane)
- Land ecosystems: dynamic vegetation, soil C
  - TRIFFID, RothC
- Ocean ecosystems: NPZD, diatoms, non-diatoms,
  - Diat-HadOCC
- Aerosols: Sulphate, BC, OC, dust, sea salt
  - Current aerosol scheme,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

UKCA Evaluation – Surface CH_4

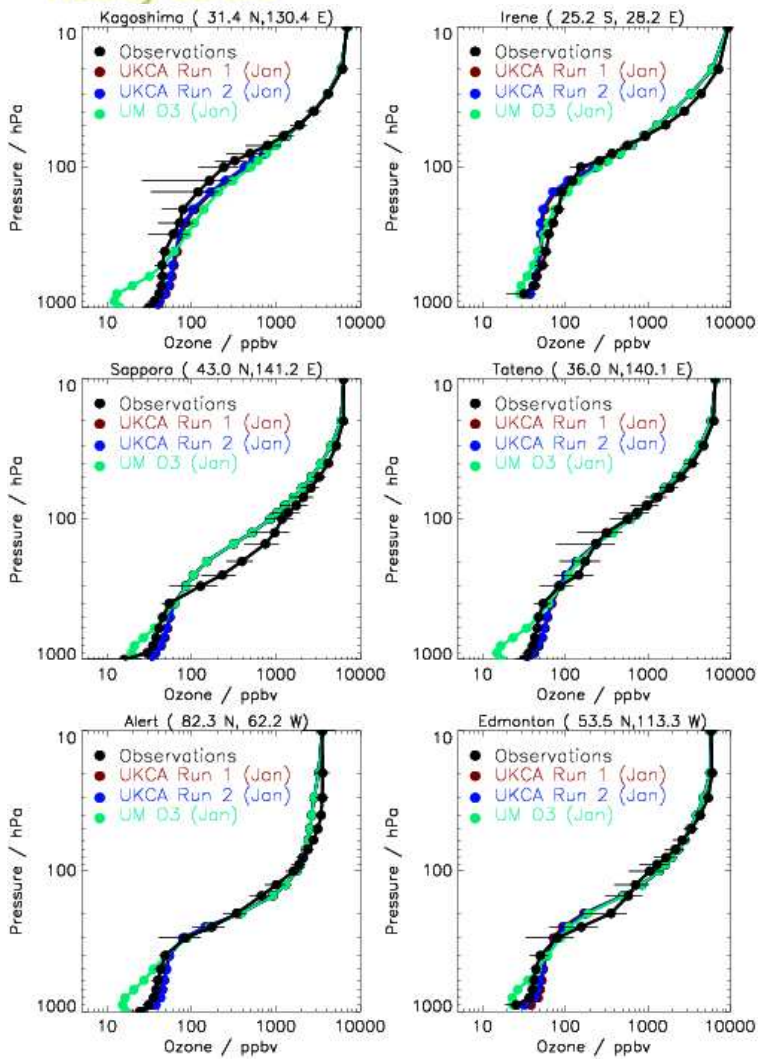


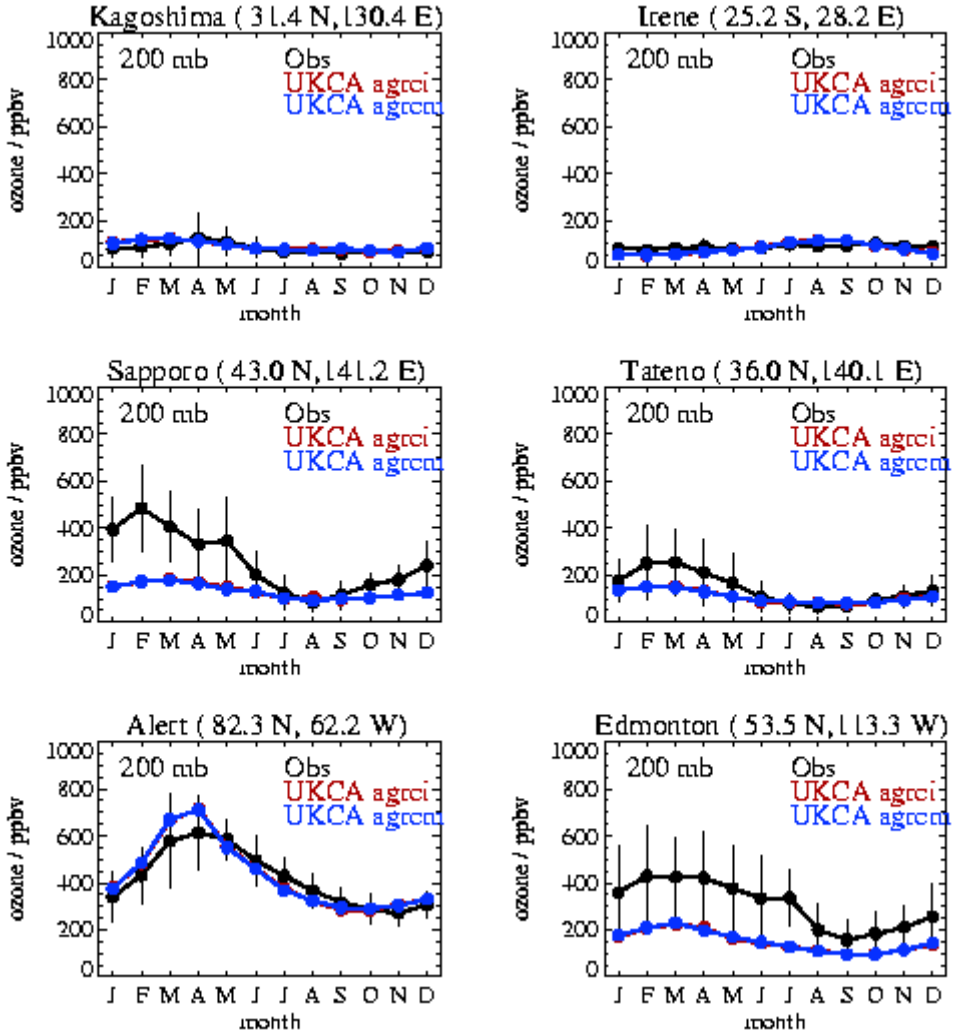


Various statistical measures of skill are also calculated (e.g. AAMB, RAMB, Model score, etc..)

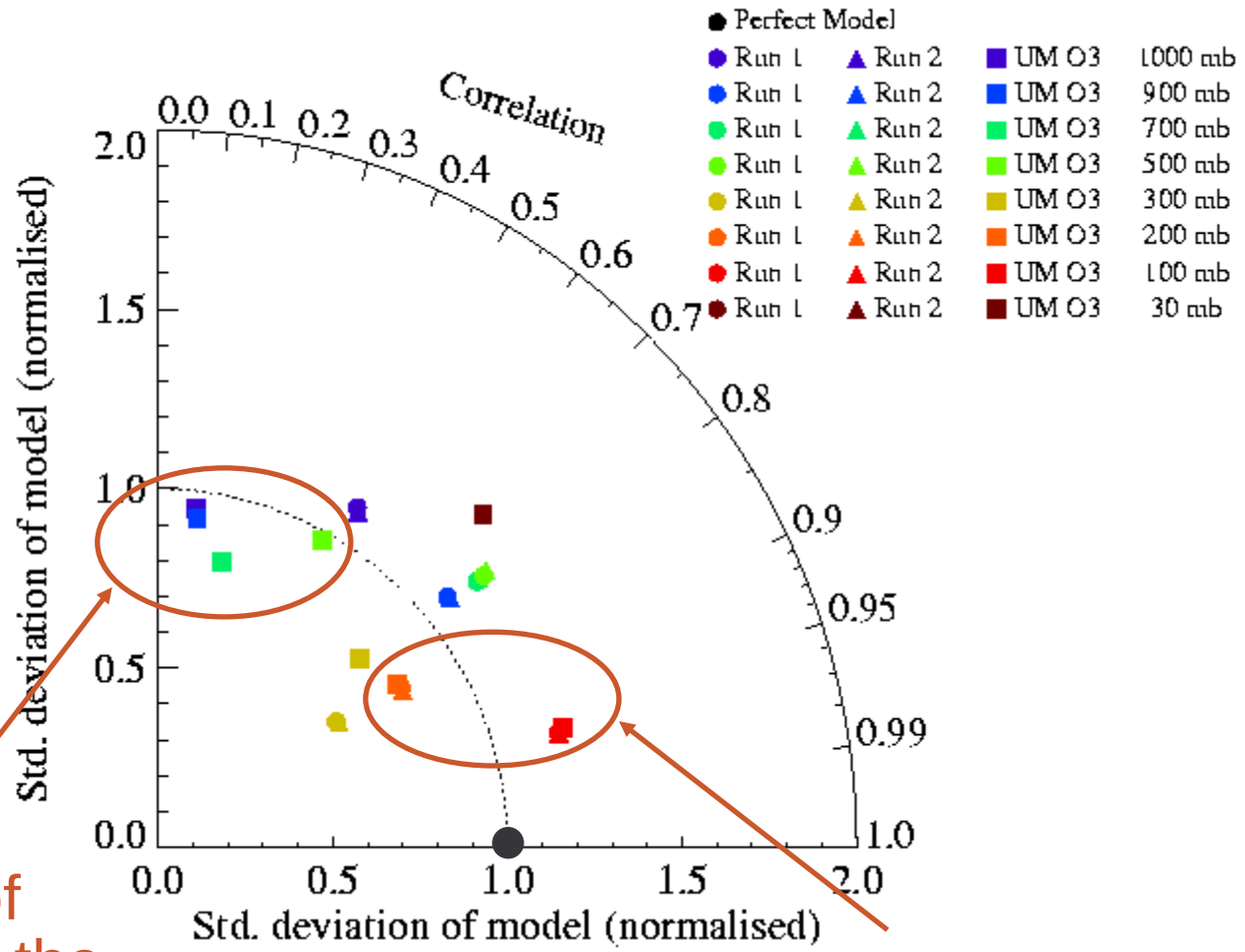
UKCA Evaluation – O_3 Profiles

Met Office
Hadley Centre





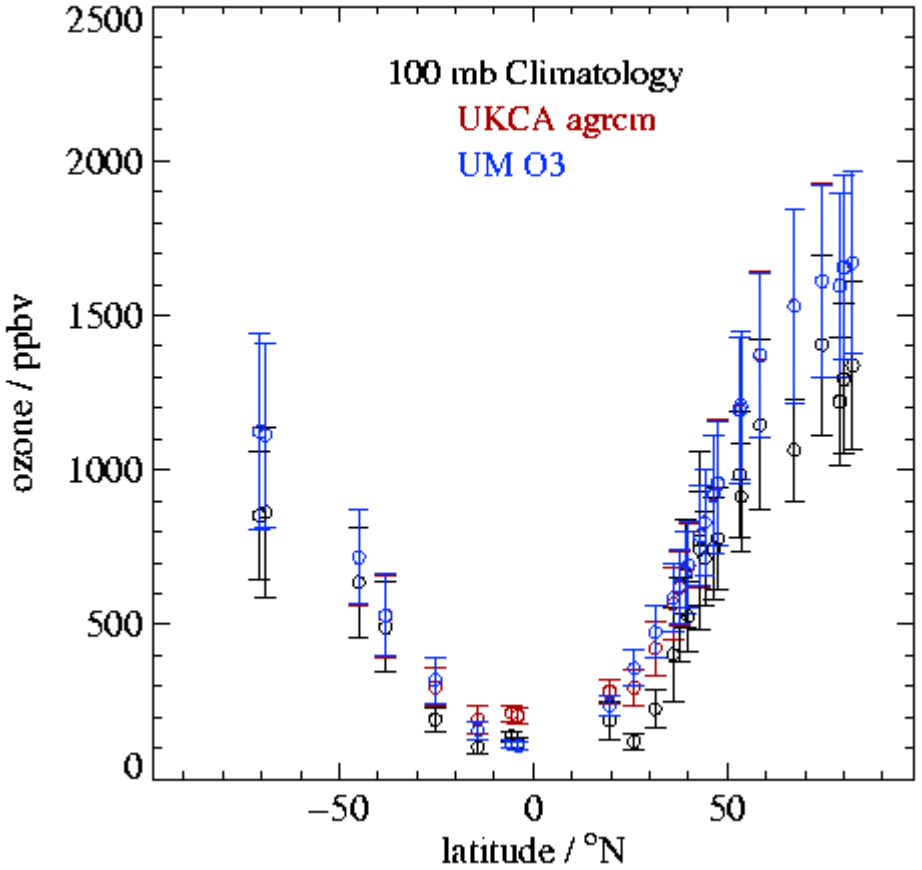
UKCA Evaluation – O_3 Profiles

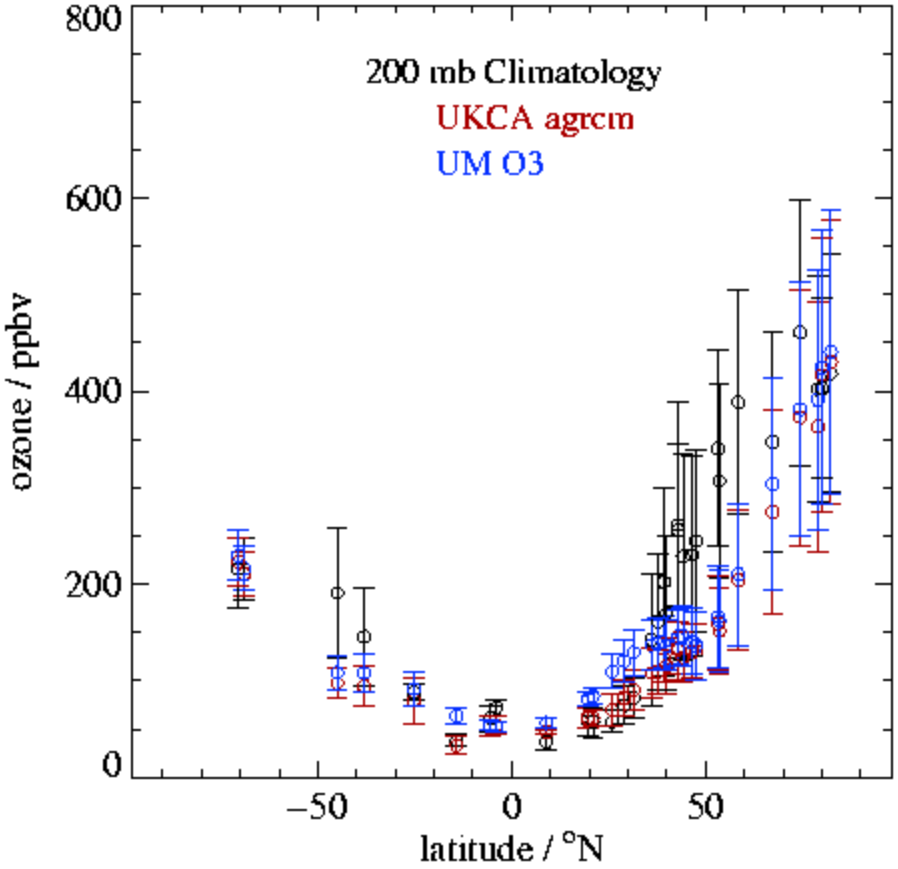


Poor performance of prescribed ozone in the lower troposphere

Performance comparable in the UTLS region

UKCA Evaluation – O_3 Profiles





Aerosols in HadGEM2-ES: Changes since HadGEM1

- Sulphate
- Biomass-Burning Aerosols

Improved

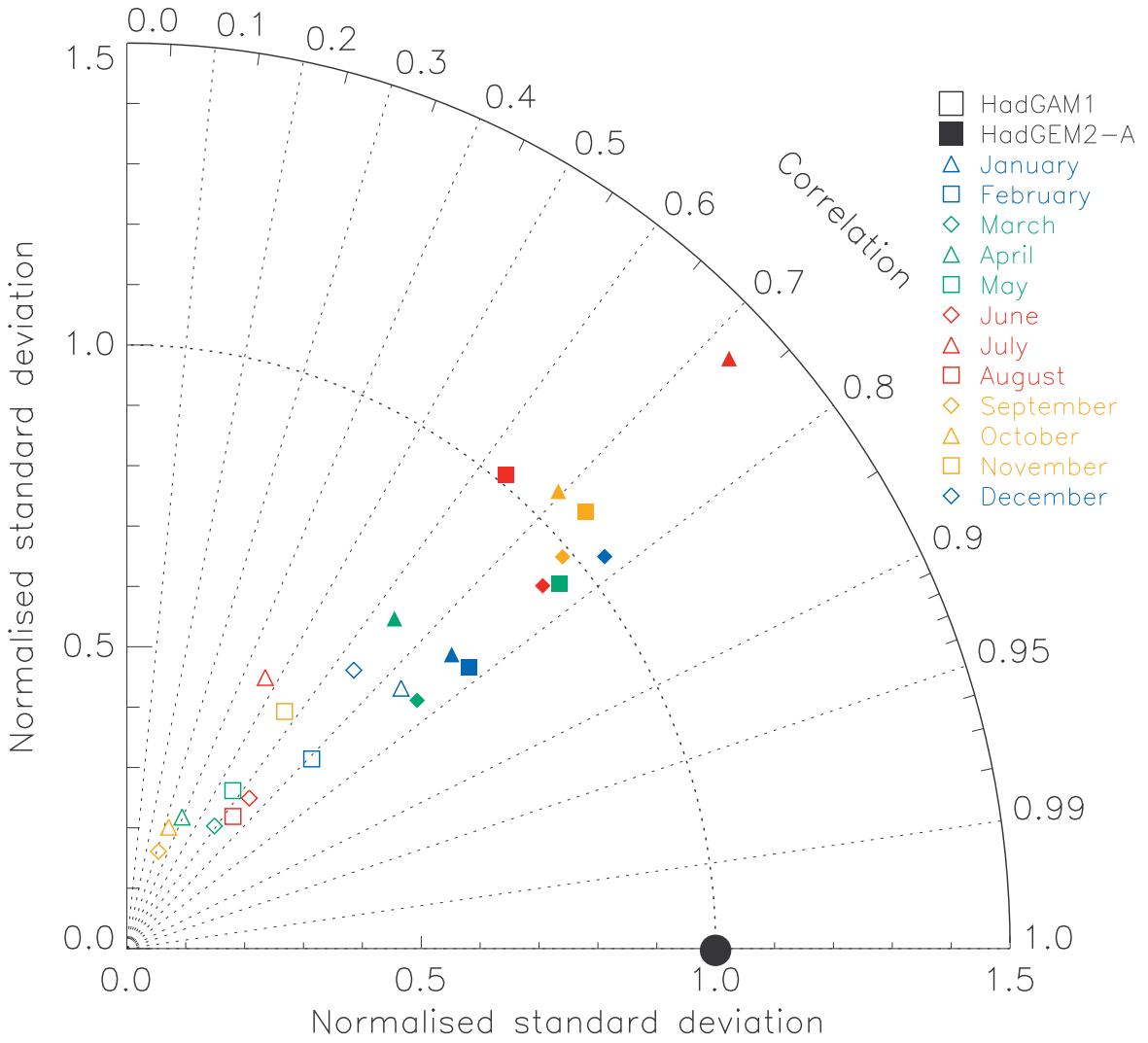
- Biogenic Aerosols
- Fossil Fuel Organic Carbon
- Mineral Dust

New

- Sea Salt
- Black Carbon (soot)

Same

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)

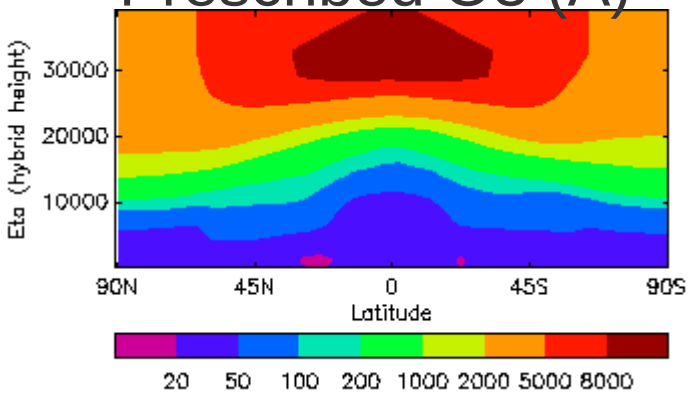
Impact of Chemistry on Climate

- Run A: HadGEM2-A
- Run B: Run A + TropMatch OFF
- Run C: Run B + O_3 Rad. Feedback ON
- Run D: Run C + CH_4 Rad. Feedback ON

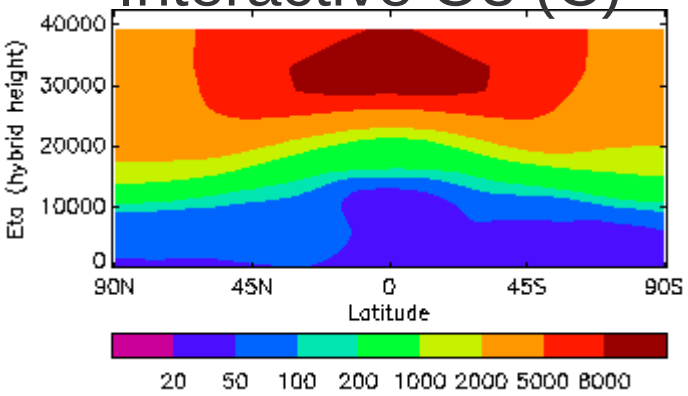
Impact of Interactive Ozone (1)

Met Office
Hadley Centre

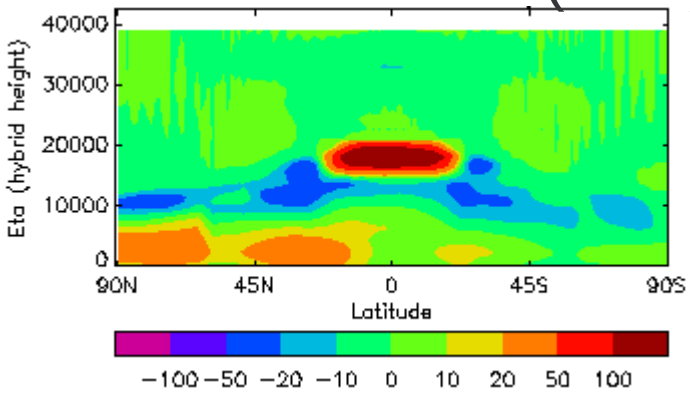
Prescribed O3 (A)



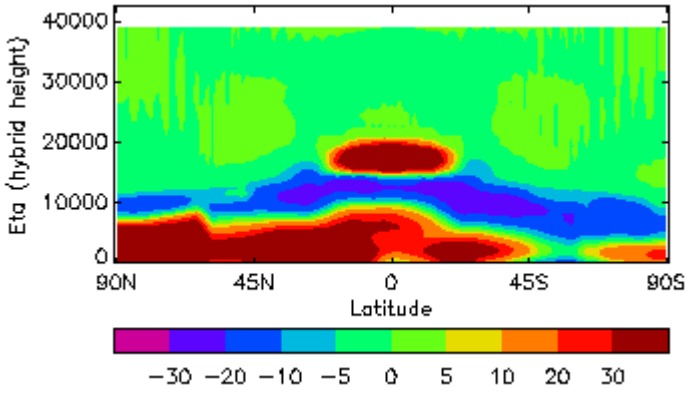
Interactive O3 (C)



Abs. Difference (C–A)



Rel. Difference

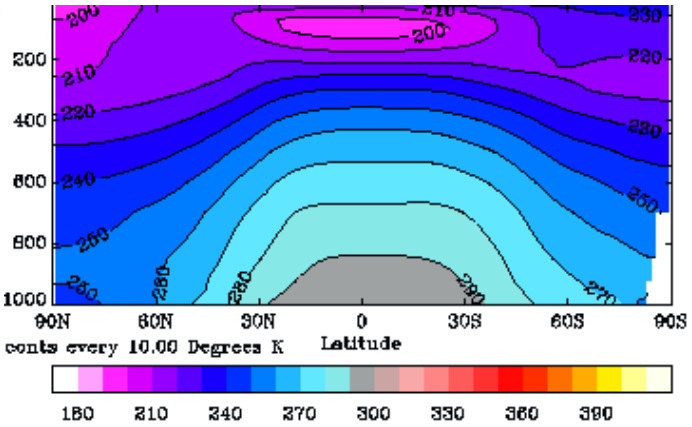


Zonal Annual Mean Ozone

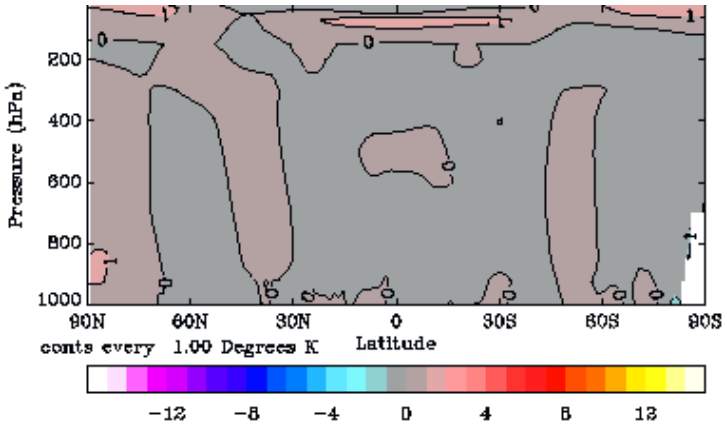
Impact of Interactive Ozone (2)

DJF Temp.

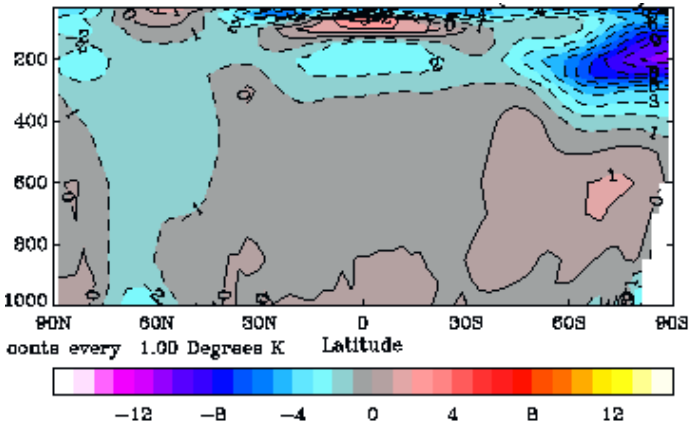
A



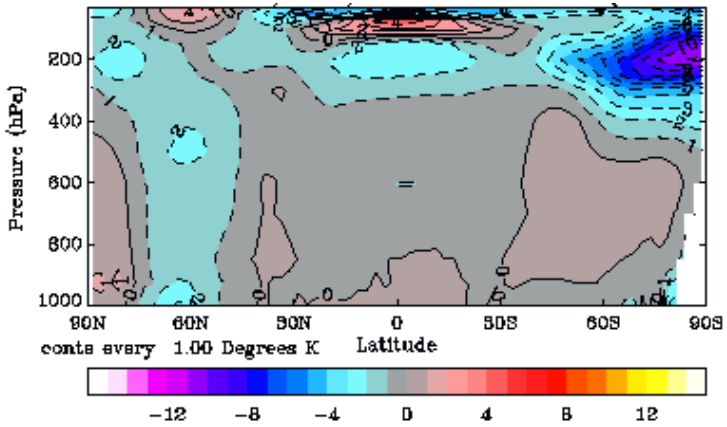
C-A



A - ECMWF



C - ECMWF

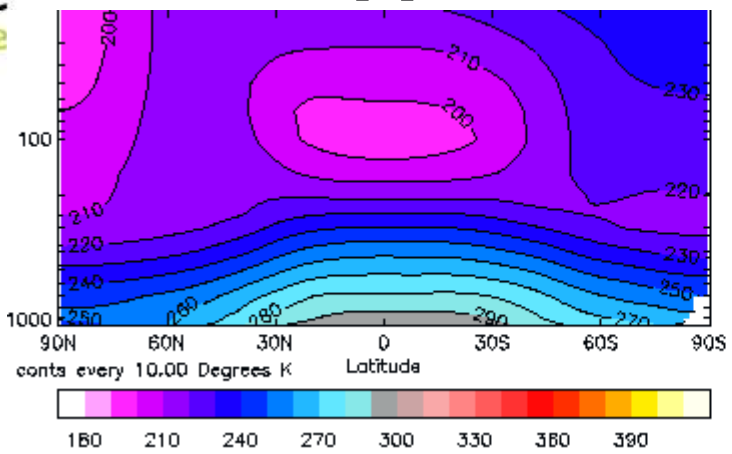


Very little impact on tropospheric temperatures

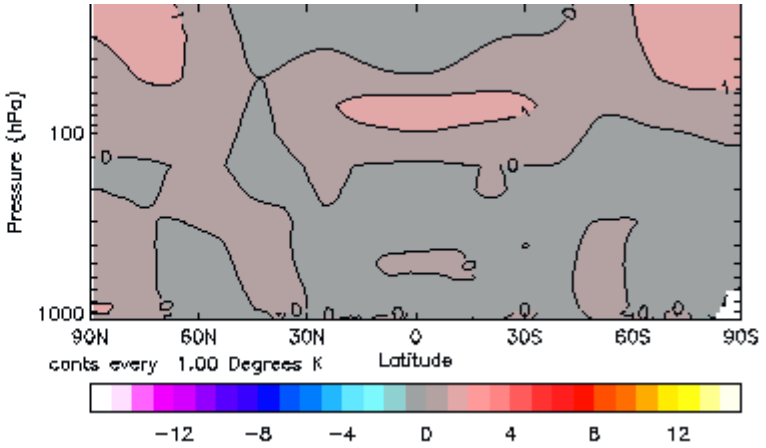
Impact of Interactive Ozone (3)

DJF Temp.

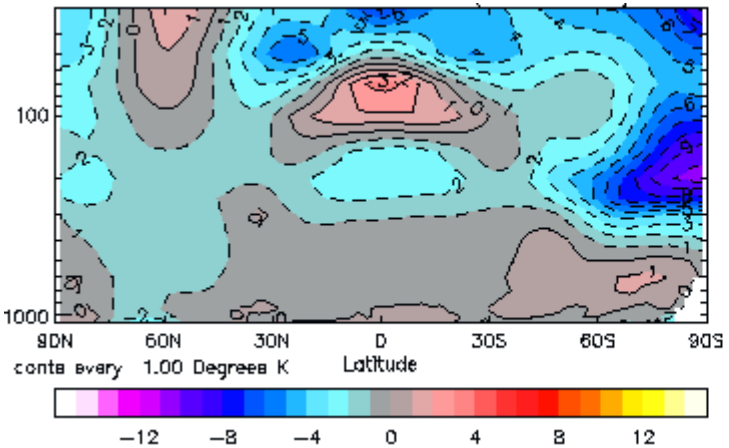
A



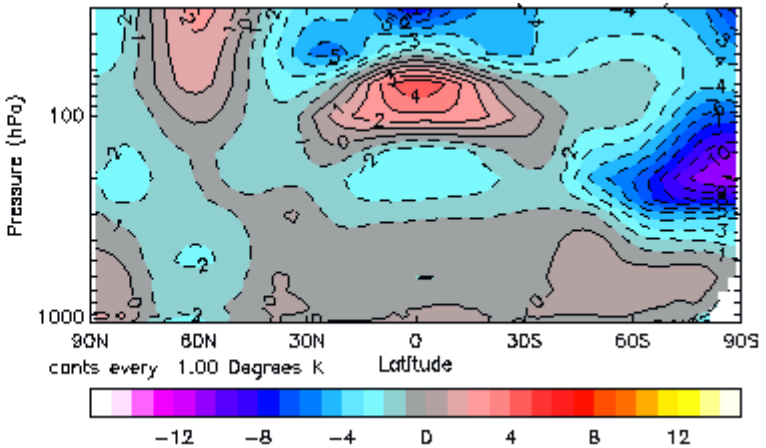
C - A



A - ECMWF



C - ECMWF

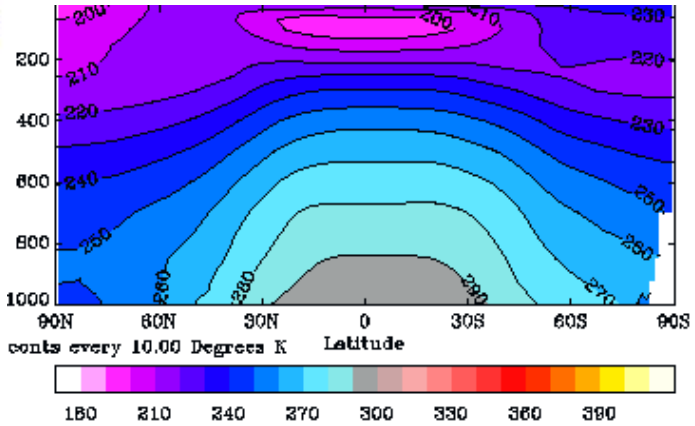


Warm tropical tropopause bias becomes larger

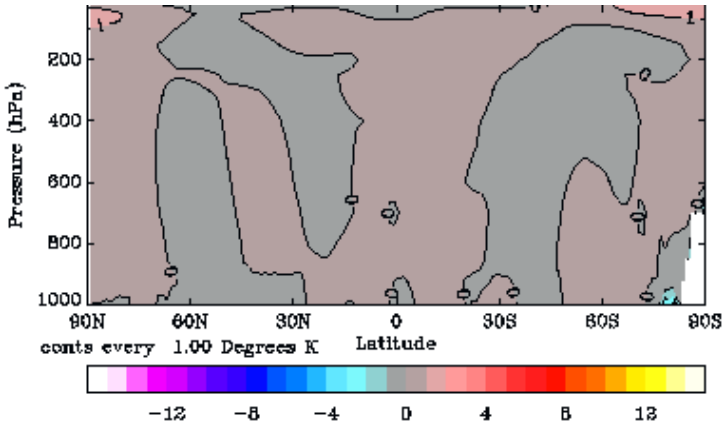
Impact of Tropopause Matching

DJF Temp.

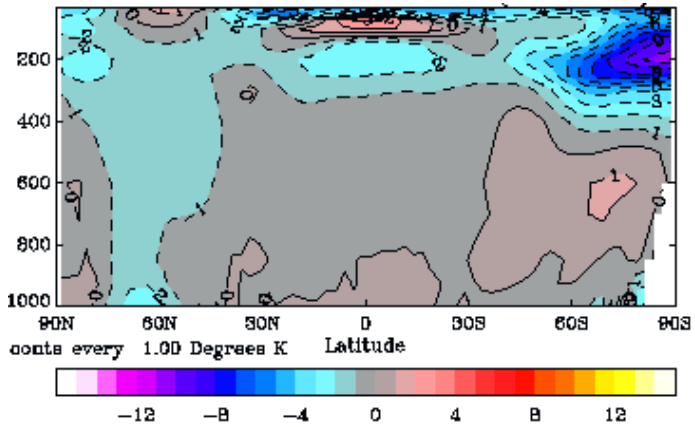
A



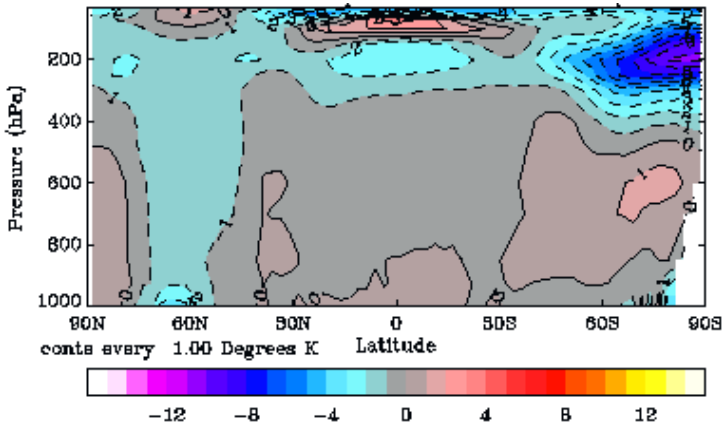
B - A



A - ECMWF



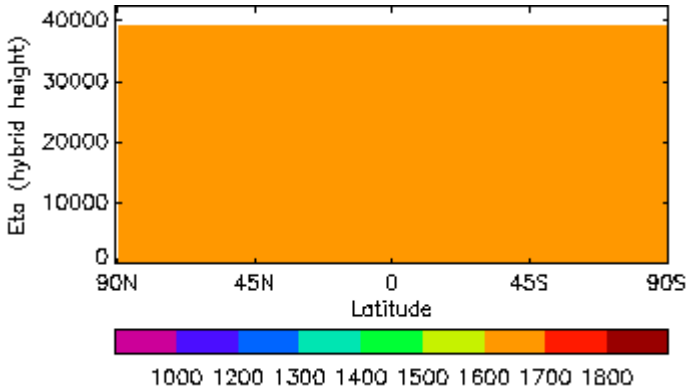
B - ECMWF



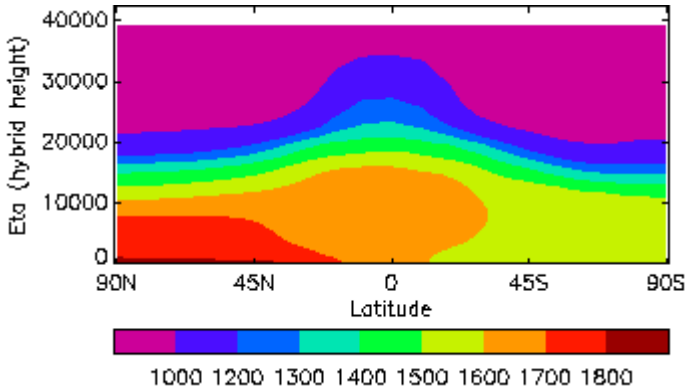
Worsening of Warm Bias cannot be attributed to Tropopause Matching

Impact of Interactive Methane (1)

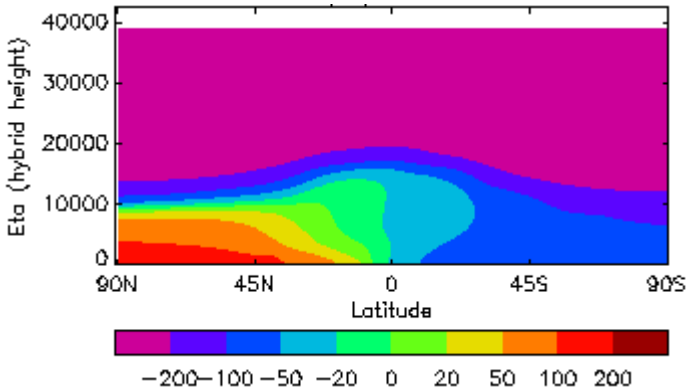
Prescribed CH4 (A/B/C)



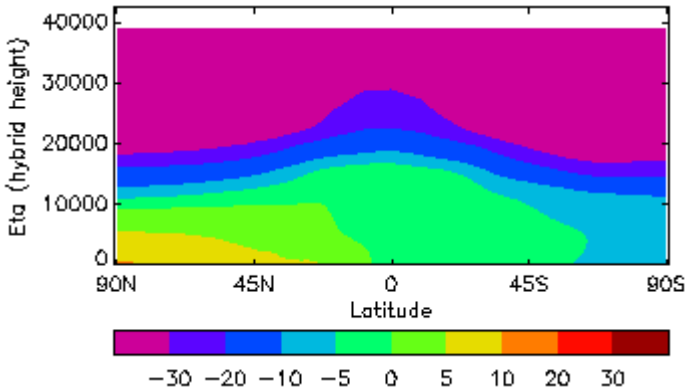
Interactive CH4 (D)



Abs. Difference (D-C)



Rel. Difference

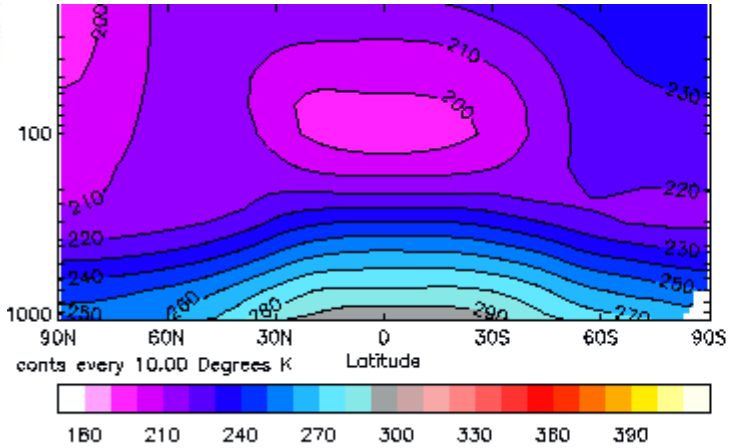


Zonal Annual Mean Methane

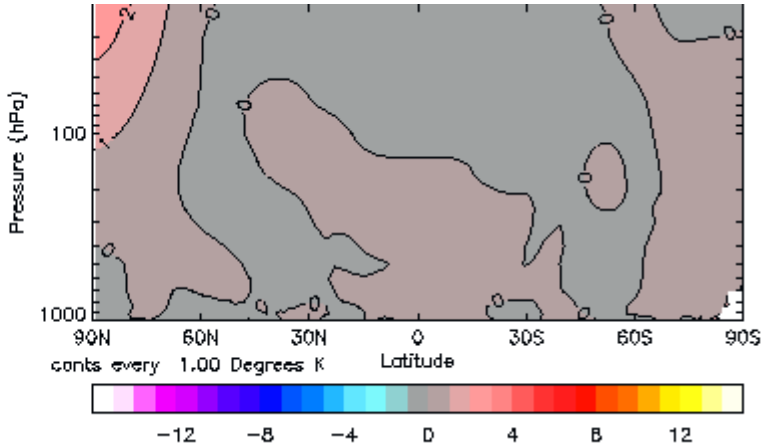
Impact of Interactive Methane (2)

DJF Temp.

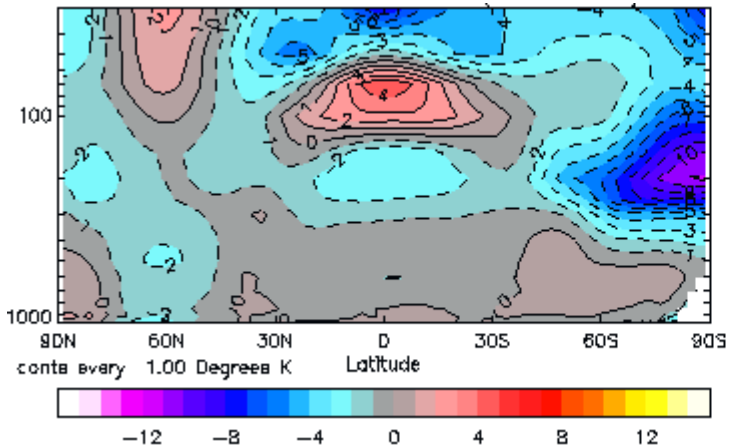
C



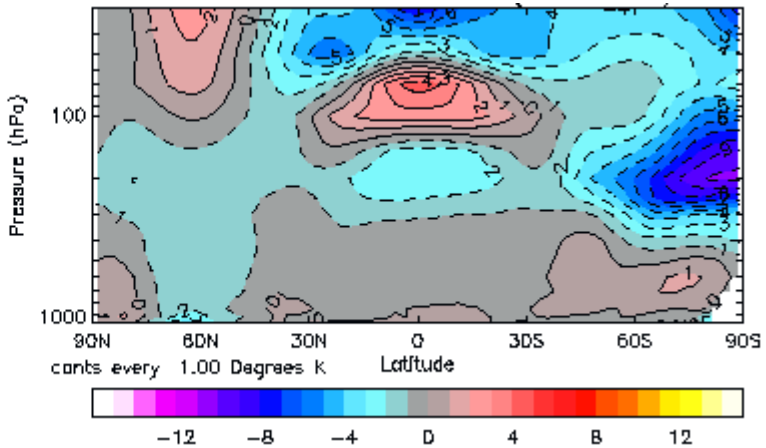
D - C



C - ECMWF



D - ECMWF



Reduction in cold bias in N.H. winter stratosphere

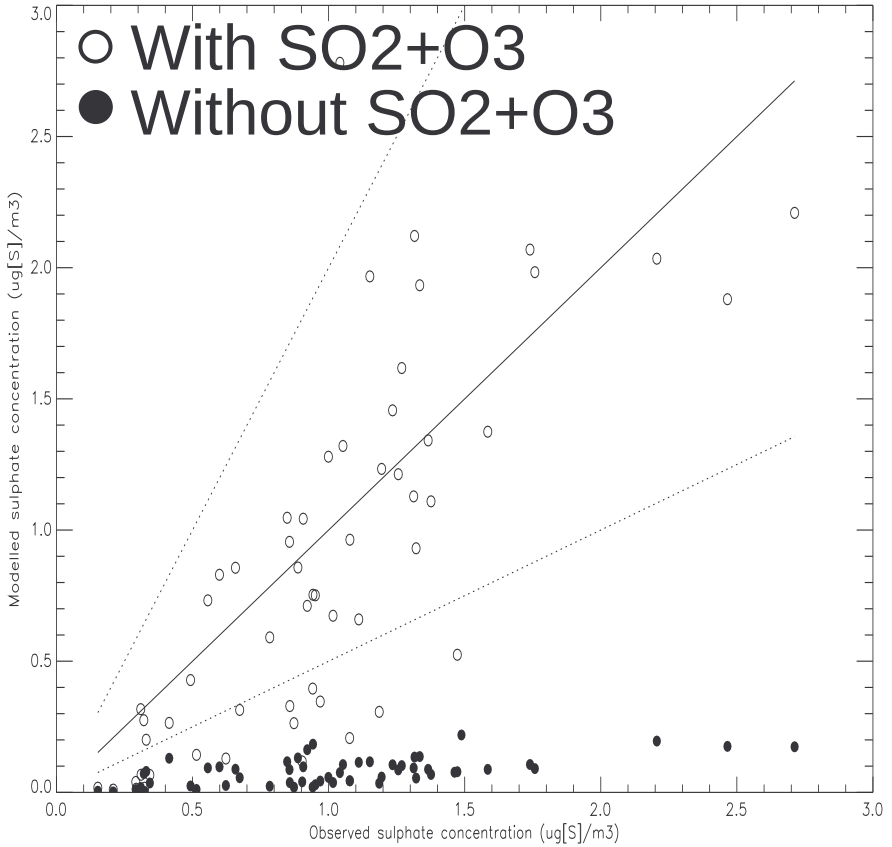
Conclusions

- 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

Sulphate Scheme

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

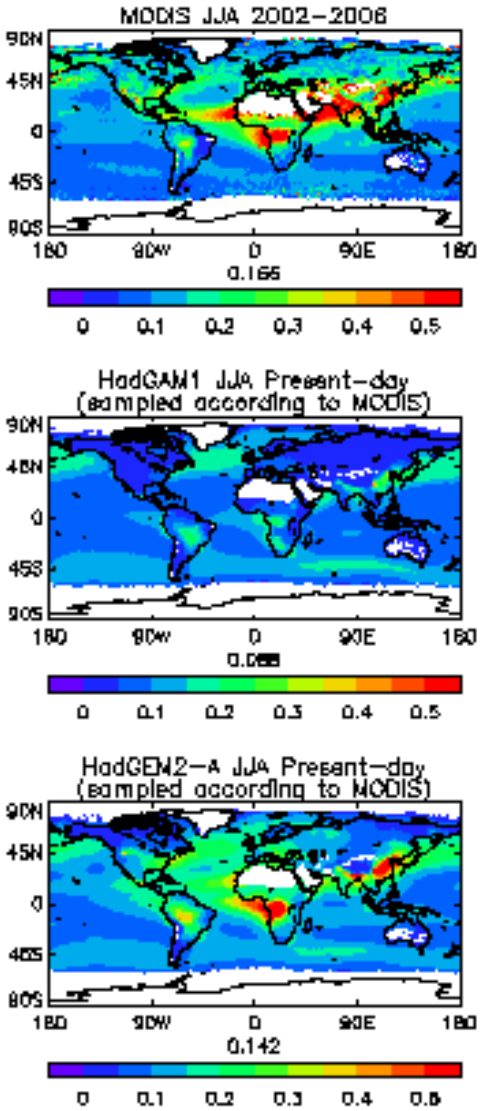


Winter time sulphate over Europe

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



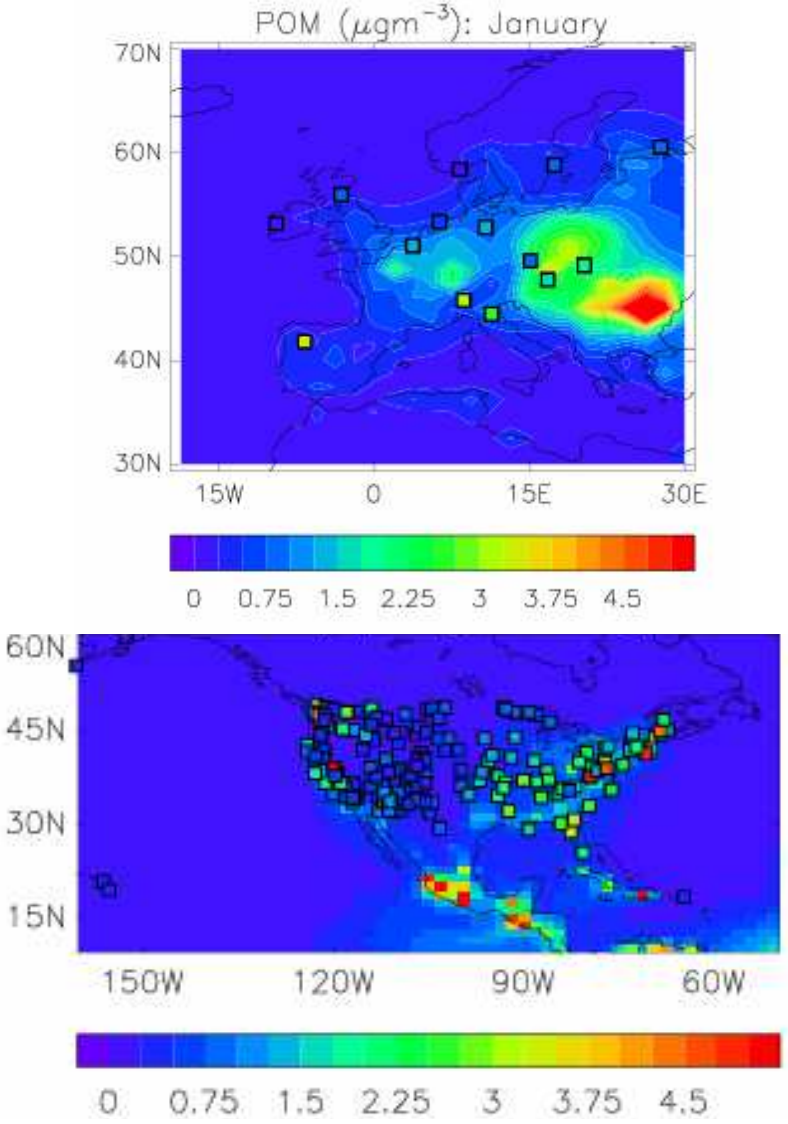
Biogenic Aerosols

Introduced into HadGEM2 as:

- Monthly climatology
- Fields derived from terpene oxidation scheme in STOCHEM
- Size distribution and optical properties from ground-based observations

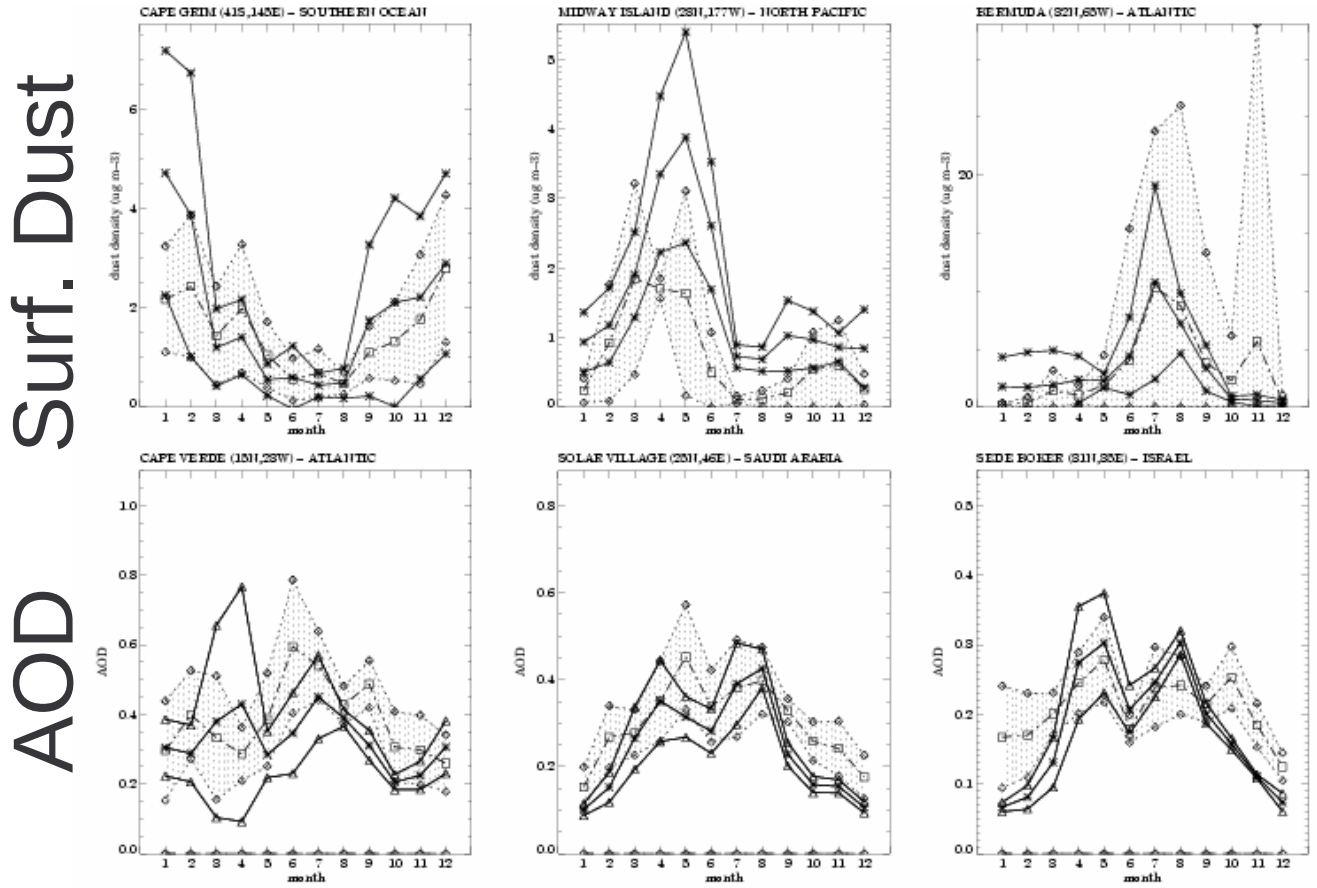
Fossil Fuel Organic Carbon

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



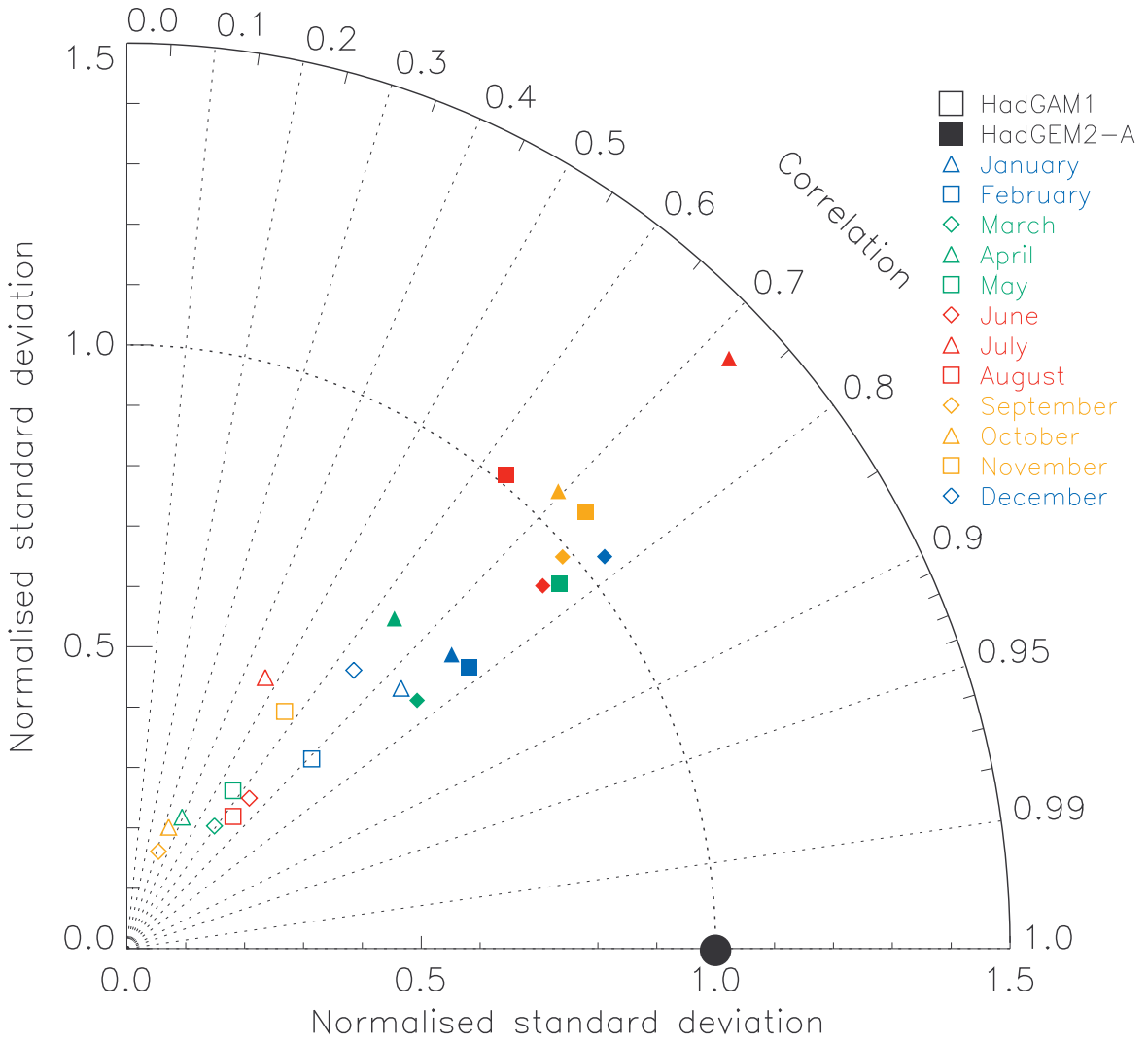
Mineral Dust

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