1. Introduction to UKCA sub-model

- Major collaboration since 2005 to develop composition-climate model.
- Main partners are: Univ. Leeds, Univ. Cambridge, and the UK Met Office.

- Aerosol-chemistry sub-model in UK Met Office Unified Model environment for a range of applications (climate, Air Quality, Earth System science).
- Troospheric and stratospheric chemistry available.

- Aerosol precursor extension to UKCA chemistry so that the climate model simulated aerosol is coupled to atmospheric chemistry.

- Improved representation of aerosol in UK climate model simulations.

- New particle formation & growth using GLOMAP aerosol microphysics.

- Enhances UKCA interactive ozone, methane and aerosol (direct/indirect).

2. GLOMAP aerosol microphysics module

Global Model of Aerosol Processes (GLOMAP)

Developed in Leeds since 2003 to simulate global aerosol with size-resolved number and composition.

- It resolves processes that grow aerosol from nm to CCN sizes.

- Aerosol Optical Depth comparison with satellite data sets.

- Includes only 4 soluble modes used here.

- UKCA includes comprehensive stratospheric chemistry scheme (Cheb) (Morgenstern et al., 2009).

- Five running simulations in high-40km version of HadGEM-A-GLOMAP simulation.

- Extended Cheb with stratospheric sulphur chemistry coupled to GLOMAP-mode (Megen et al. 2010).

- Simulations here use double-cell forcing configuration (no aerosol feedback on model dynamics).

3. Impacts of Pinatubo eruption

- Mount Pinatubo eruption in June 1991 injected ~15-20 Tg of SO2 into the tropical stratosphere thickening Jule layer ~21-28km altitude.

- Sulphur dioxide is converted to sulphuric acid and readsily taken up into the stratospheric aerosol phase.

- Thicker stratospheric aerosol layer caused heating of tropical stratosphere and cooling of troposphere and Earth surface.

- Warming of tropical stratosphere caused enhanced upwelling with effects on meridional transport & dynamical ozone & H2O changes.

- Global veiw of enhanced stratospheric sulphuric acid aerosol formed over 3.6 months with surface area density factor-100 higher initially, and still factor-10 higher at all latitudes 2 years after the eruption.

- Enhanced surface area-density increased heterogeneous chemical conversion of N2O5 into less reactive HNO3.

- Pinatubo aerosol effects may also have enhanced PSCs causing increased ice particle formation and growth to climate phase precursors.

- Stronger tropical upwelling also transported more low-ozone air into lower stratosphere causing dynamical decrease in stratospheric ozone.

- The stratospheric heating may have caused anomalous positive Arctic Oscillation causing Europe to be much warmer in subsequent winter.

- Entrainment of enhanced stratospheric aerosol into troposphere may also have caused changes to cirrus & tropospheric aerosol properties.

4. GLOMAP-mode simulates stratospheric aerosol evolution in whole-atmosphere UKCA composition-climate model

- Aerosol Optical Depth evolution is well captured by model simulations, but have slightly higher bias compared to the observations.

- Timing of AOD peaks well captured – in tropics at Aug-Sep 1991 in NH mid-latitudes Jan-Feb AODs generally well captured by model with slight high bias.

- But transport to Southern Hemisphere not well captured in these simulations (i.e., no feedback on dynamics here).

5. Comparison of simulated stratospheric aerosol surface area density (SAD) vs satellite derived dataset used by Climate-Chemistry Models (e.g. as used in SPARC CCMV2).

- High-top HadGEM-UKCA model simulates evolution of the stratospheric aerosol size distribution with new particle formation and growth coupled to stratospheric chemistry.

- Simulated compositional aerosol properties through Pinatubo perturbed period (1991-95) compare well with a range of observations but have general moderate high bias.

- Observed timing of tropical (~20km) & NH mid-latitude (~40km) peaks in AOD/extinction well captured by the model.

- Aerosol extinction evolution also well captured but lower than observed (indicating model has too many small particles).

6. Stratospheric Dynamics in UKCA

- Zonal mean U850 (m/s) (125°-120°

- Figure 3 - a) Model has realistic QBO downward propagation speed & phase change.

- b) Model has slightly too young age of air at mid-high latitude stratosphere.

7. Aerosol Optical Depth comparison

- Figure 4 - Comparison of simulated aerosol optical depth (AOD) with satellite data sets.

- (c) and (d) are total & stratospheric only AODs from model simulations

- (a) and (b) are total & stratospheric only AODs from satellite measurements.

- Temporal AOD evolution is well captured by model simulations, but have slightly higher bias compared to the observations.

- Significant biases in 1020 ext. may be due to model treatment of growth & subsequent sedimentation.

- Many other uncertainties (injection height, primary aerosol, etc.)

- Pinatubo Ensemble Study using simulations to investigate this.

8. Evolution of particle effective radius

- Figure 5 - Temporal evolution of extinctions in the tropics (25S-25N).

- Shows extinction at 55km (left panels) & 100km (right panels)

- Orange and blue coloured lines are model simulations with 20Mm & 5Mm SAD30 injected (2127) June 1991 & GLEAM II extinction simulations with black circles.

- Overall good agreement between model & observed extinctions.

- But in lower stratosphere (~20km) extinction biases in 1020 may be due to model treatment of growth & subsequent sedimentation.

- Many other uncertainties (injection height, primary aerosol, etc.)

- Pinatubo Ensemble Study using simulations to investigate this.

9. Extinction comparison (tropics)

- Figure 6 - Extinction comparison in the tropics (25S-25N).

- Shows extinction at 55km (left panels) & 100km (right panels)

- Orange and blue coloured lines are model simulations with 20Mm & 5Mm SAD30 injected (2127) June 1991 & GLEAM II extinction simulations with black circles.

- Overall good agreement between model & observed extinctions.

- But in lower stratosphere (~20km) extinction biases in 1020 may be due to model treatment of growth & subsequent sedimentation.

- Many other uncertainties (injection height, primary aerosol, etc.)

- Pinatubo Ensemble Study using simulations to investigate this.

10. Summary and Conclusions

- High-top HadGEM-UKCA model simulates evolution of the stratospheric aerosol size distribution with new particle formation and growth coupled to stratospheric chemistry.

- Aerosol evolution is well captured by model simulations.

- Observed timing of tropical (~20km) & NH mid-latitude (~40km) peaks in AOD/extinction well captured by the model.

- Model effective radius evolution also well captured but lower than observed (indicating model has too many small particles).

11. References


