Confronting Climate Models with Earth Observation Data

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Structure

• The ozone layer: past and future
• Interaction between composition and climate
• Model and reality
• Examples of confrontations:
  – Brewer-Dobson Circulation (BDC)
  – Tropical Tropopause (TT)
• Summary and outlook
THE OZONE LAYER: PAST AND FUTURE

Introduction
Schematic of chemistry–climate interactions.
“There is now new and stronger evidence of the effect of stratospheric ozone changes on Earth’s surface climate, and of the effects of climate change on stratospheric ozone. These results are an important part of the new assessment of the depletion of the ozone layer presented here.”
INTERACTION BETWEEN COMPOSITION AND CLIMATE
Surface Temperature and Ozone

Morgenstern, Braesicke et al., GRL, 2008

60 deg. S

DJFMAM trend; Thompson and Solomon, 2002
Confrontation 2

MODEL AND REALITY
Schematic of chemistry–climate interactions.
Model Components

Sub-Models: Ocean, sea-ice, biosphere, ...

Boundary conditions and/or scenarios

Observations Other models

Coupled partial differential equations describing:
1. Atmospheric dynamics and thermodynamics
2. Composition (water vapour, ozone, aerosol, etc.)
3. Microphysics (clouds)
4. Radiation and photolysis (other sub-models)

Model

Simulated climate: Prognostic and diagnostic variables

Numerical methods
High Perf. Computer

How to propagate an error through the model?
Sensitivity studies/parameter sweep experiments ...
Ensemble simulations...
UMUKCA Chemistry-Climate Model

UMUKCA is

• based on the Met Offices Unified Model (UM)
  – grid point model (N48,96,216,320; L60,85), non-hydrostatic, hybrid sigma-height vertical coordinate, includes physical parameterisations for weather forecasts and climate projections (was v6.1 for CCMVal; now v7.3)

• the UK’s community chemistry-climate model

• Chemistry: Stratospheric, Tropospheric, CHEST
  – ASAD with Newton-Raphson solver & boundary conditions

• Aerosol: modal scheme (not included for CCMVal)

• UKCA is part of the UM ESM setup (Ocean, Biosphere (Vegetation), Cryosphere, etc.)
Assimilation und Klimamodell (T)

\[ \Theta = 390 \text{K} \]
Assimilation und Klimamodell ($O_3$)

O$_3$=150 ppbv
BREWER-DOBSON CIRCULATION

Process 1
Brewer-Dobson Circulation

The world is fuzzy: Probability density functions of PDFs

BDC!

STE!  \( \text{N}_2\text{O} \) (ppbv)

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Transport Evaluation: N$_2$O PDFs

CheS Timeslice

SPARC CCMVal Report, Chapter 5: Transport, 2010
Process 2

TROPICAL TROPOPAUSE
UKCA vs SHADOZ Ozone

Alajuela (2007-present):
Lon=-84.21
Lat=9.98
Costa Rica

The world is seasonal:
Means and standard deviations

Including a comprehensive
tropospheric chemistry...
UKCA vs SHADOZ Ozone

Alajuela (2007-present):
Lon=-84.21
Lat=9.98
Costa Rica

Including a comprehensive tropospheric chemistry ...
Summary and Outlook

• Observations and models complement each other!
• A confrontation of models and observations helps to improve models ...
• ... and supports the subsequent assessment of model forecasts and projections (expert knowledge)!
• Current assessment of errors is at best heuristic (trial-and-error)!
• Hierarchy of errors:
  – Measurement errors (systematic, random) at **level 1**
  – Retrieval error (propagated from level 1 and including errors due to the retrieval process) at **level 2**
  – **Level 3 or 4** product error (propagated from level 2 and including errors due to the assimilation process)

• End user (for example me):
  – Level $\frac{3}{4}$ with confidence interval (preferably with bias removed)
  – For climate application: **representativeness!**
Thank you!

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Pillars of our work

Knowledge and understanding of the natural world ... (policy)

Model validation & intercomparison (Climatologies, “sanity checks”)

Confrontation of model & observations (Process and case studies, “simulators”)

Projections for assessments (WMO/UNEP ozone assessment)

“What if ...” scenarios (“World avoided”, Geoengineering)

A model fit for purpose (UMUKCA) ...
(c) Antarctic October total column ozone
Lifetime Assessment Model Version

Best guess using T bias correction

Ozone change due to T bias correction
CheS Chemistry and Fast-Jx

SHADOZ Data and UMUKCA CheS
Attribution of O3 changes

“Global Ozone” (60°S-60°N)

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).

Application of nudged UKCA

Telford et al., ACP, 2009
Recently: Impact of the Pinatubo Eruption on Isoprene;
Sarychev eruption (Jim Haywood, Met Office)