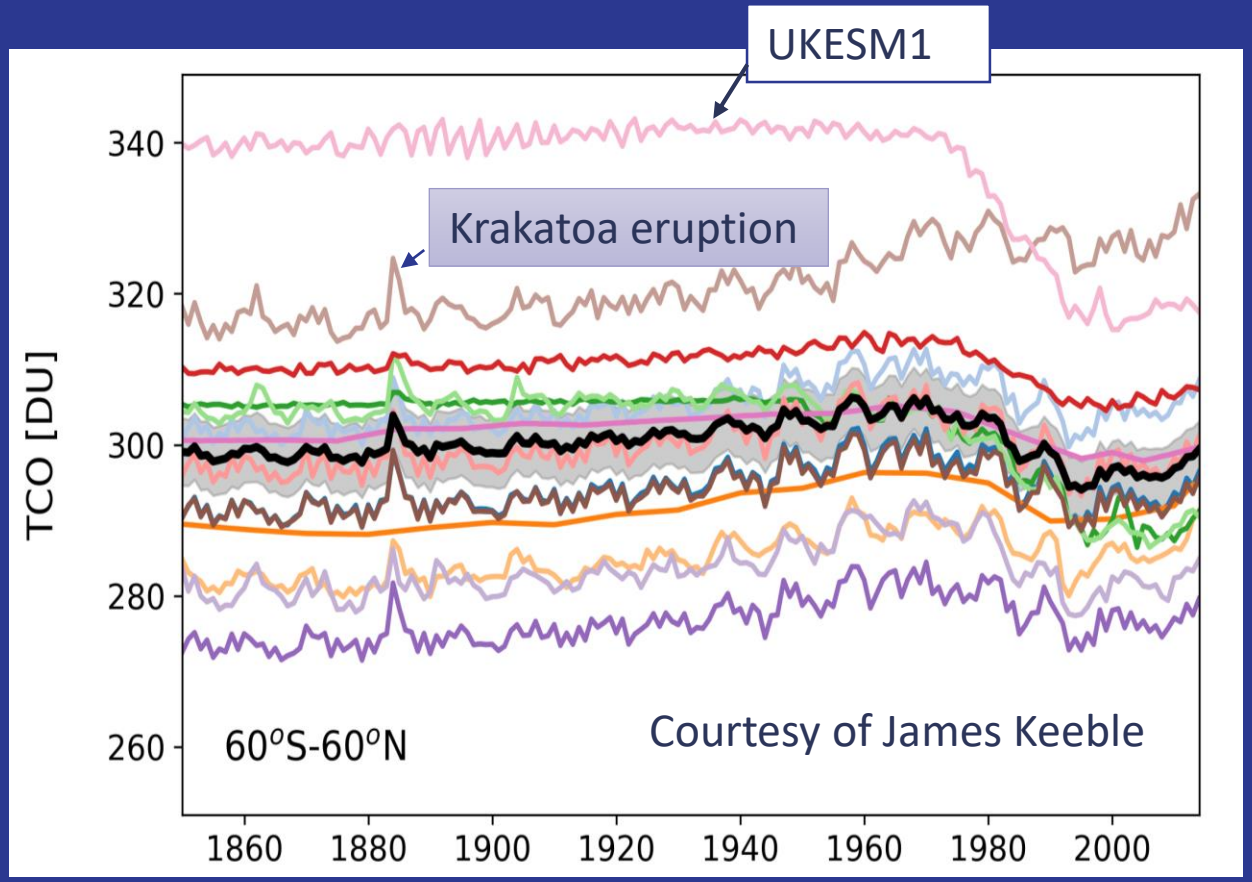
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Evaluating UKESM stratospheric composition using satellite datasets

Sandip Dhomse[1,2], Martyn Chipperfield[1,2], Wuhu Feng[1,3], Graham Mann[1], Luke Abraham[4,5], James Keeble[4,5], Alex Archibald[4,5], John Pyle[4]

1. University of Leeds
2. NCEO Leeds
3. NCAS Leeds
4. University of Cambridge
5. NCAS Cambridge



Outline

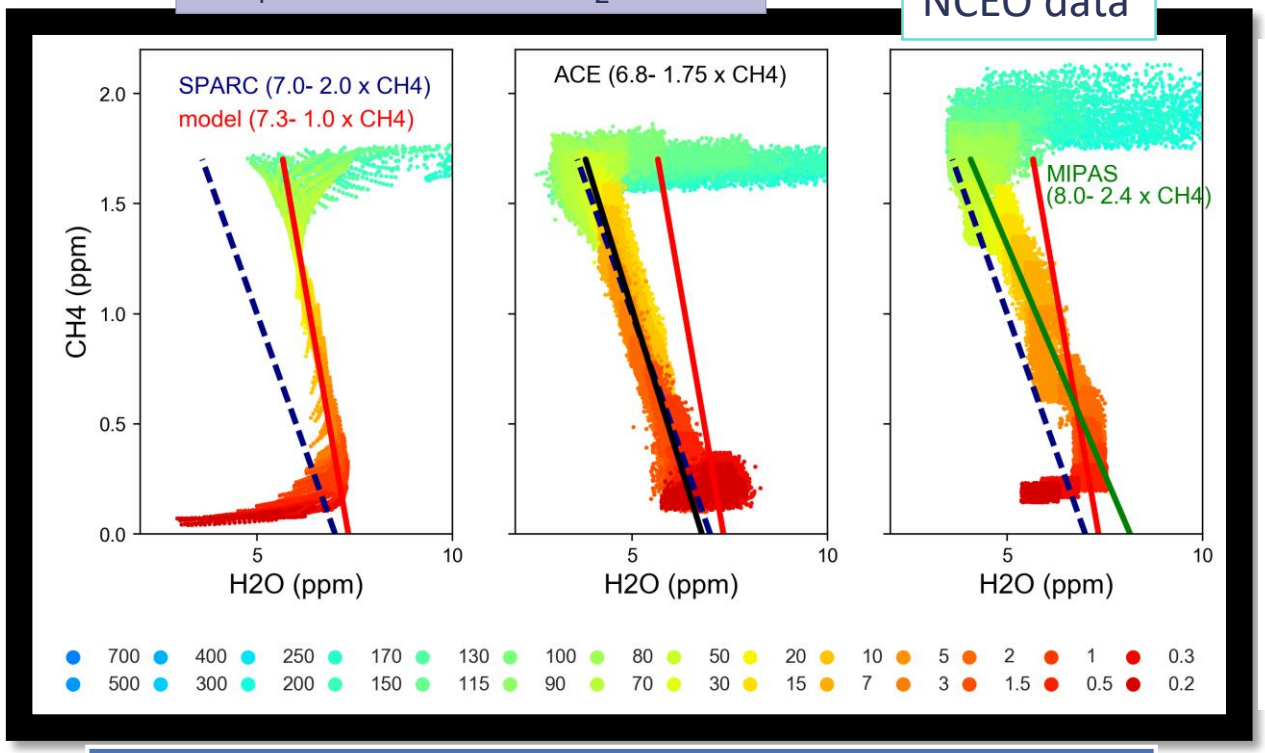
Using Satellite data to understand:

I. Low NOy bias, hence positive ozone bias
II. Volcanic aerosol forcing using interactive aerosol module

Tracer-tracer Correlation Analysis

CH_4 oxidation → $2H_2O$

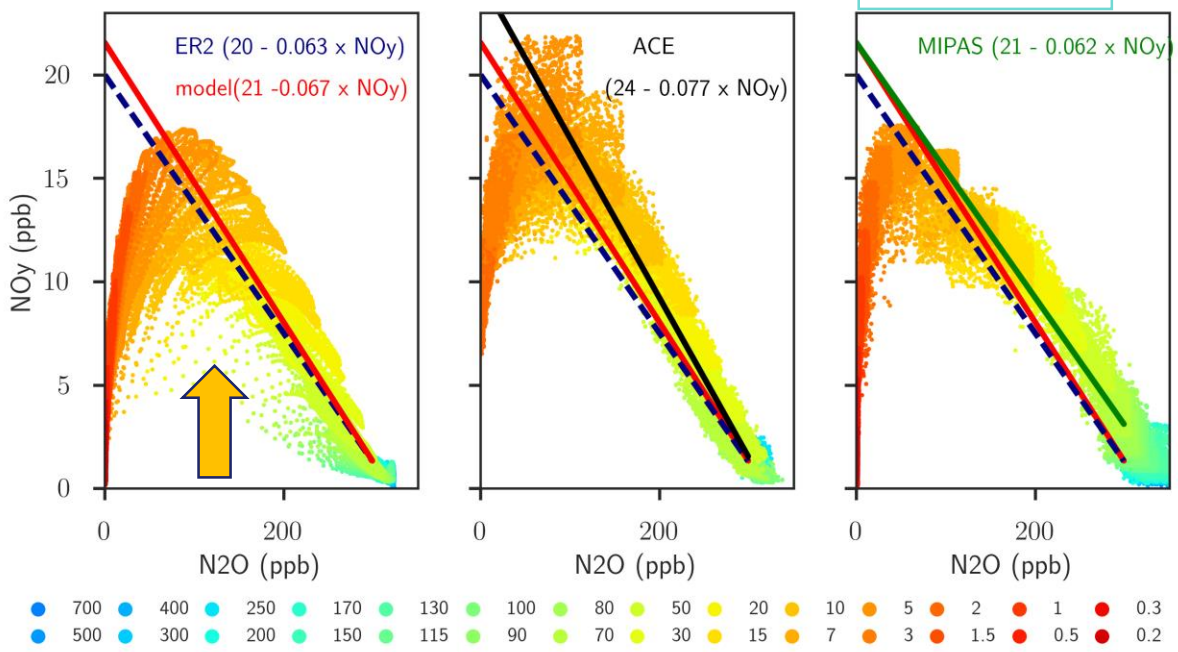
NCEO data



CH_4 loss correct but too humid stratosphere

N_2O loss → NOy

NCEO data



N_2O loss correct but NOy produced then lost too rapidly

Archibald et al., GMD (2020)

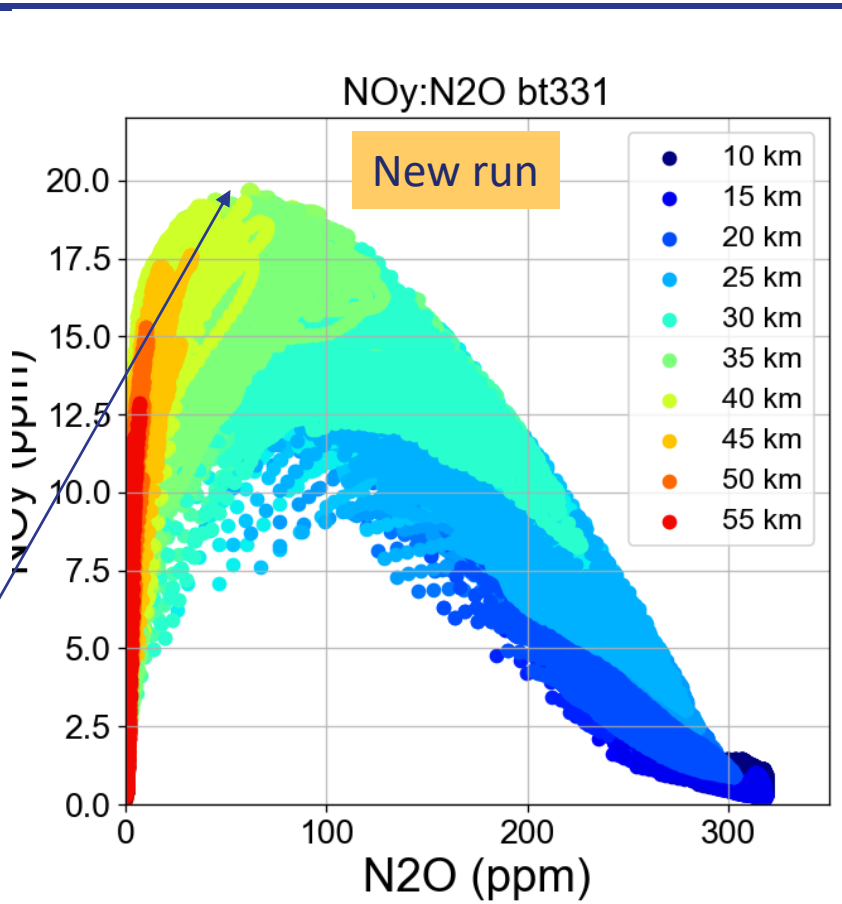
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

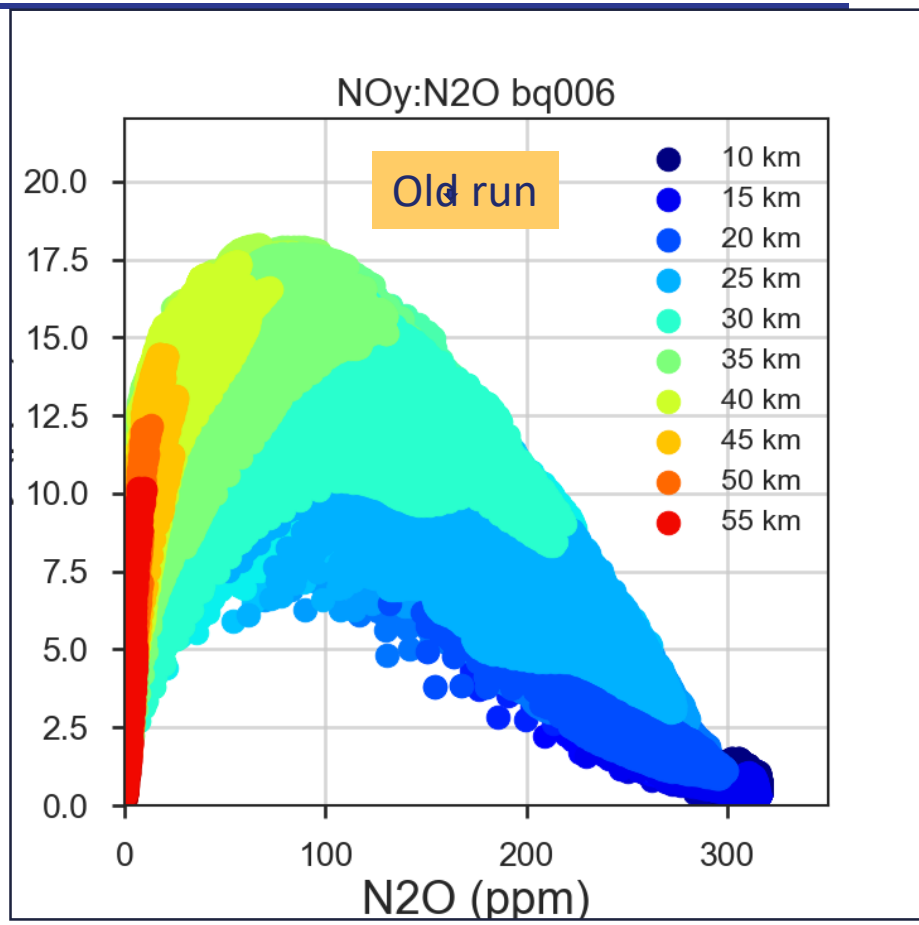
Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

UKRI Natural Environment Research Council

UKESM Stratospheric Processes Working Group

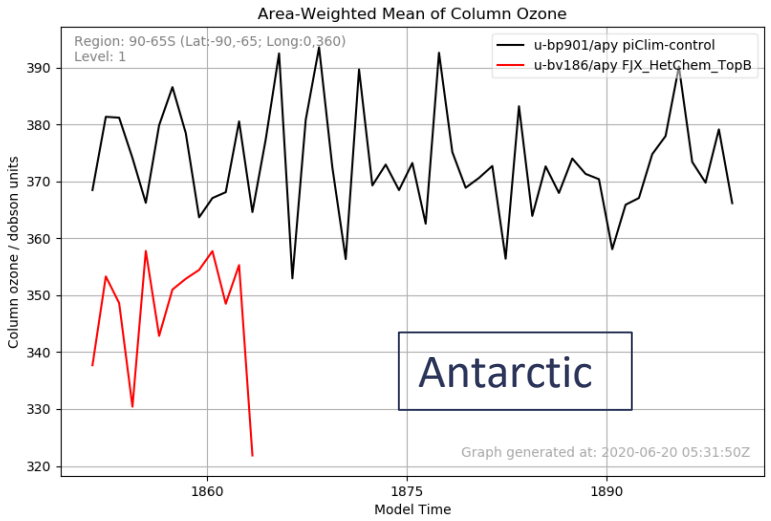
- Fast-Jx photolysis scheme- J_{NO} –scaled to 0.6
- Corrected $BrONO_2$ cross section
- Updated O_2, O_3, Cl_2O_2, BrCl, $ClONO_2$, SO_3 cross sections using JPL2015
- Some other minor corrections
- 4-year simulation for present day shows improvements in NOy

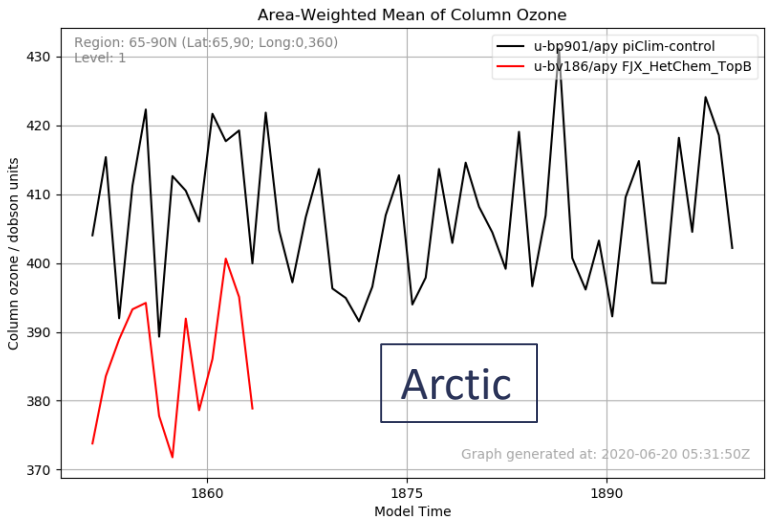


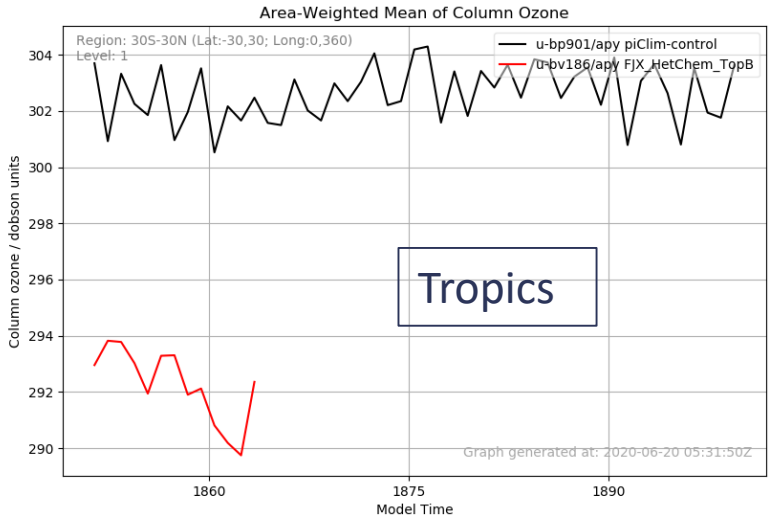


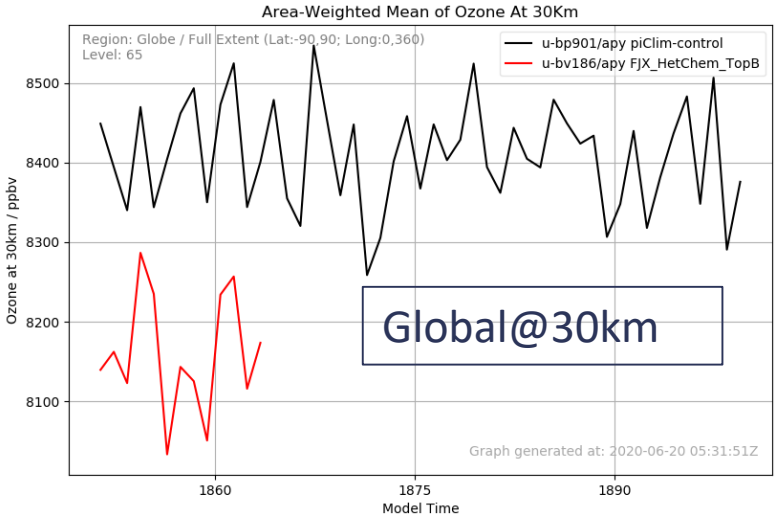
Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

Improvements in Pre-industrial Ozone in UKESM







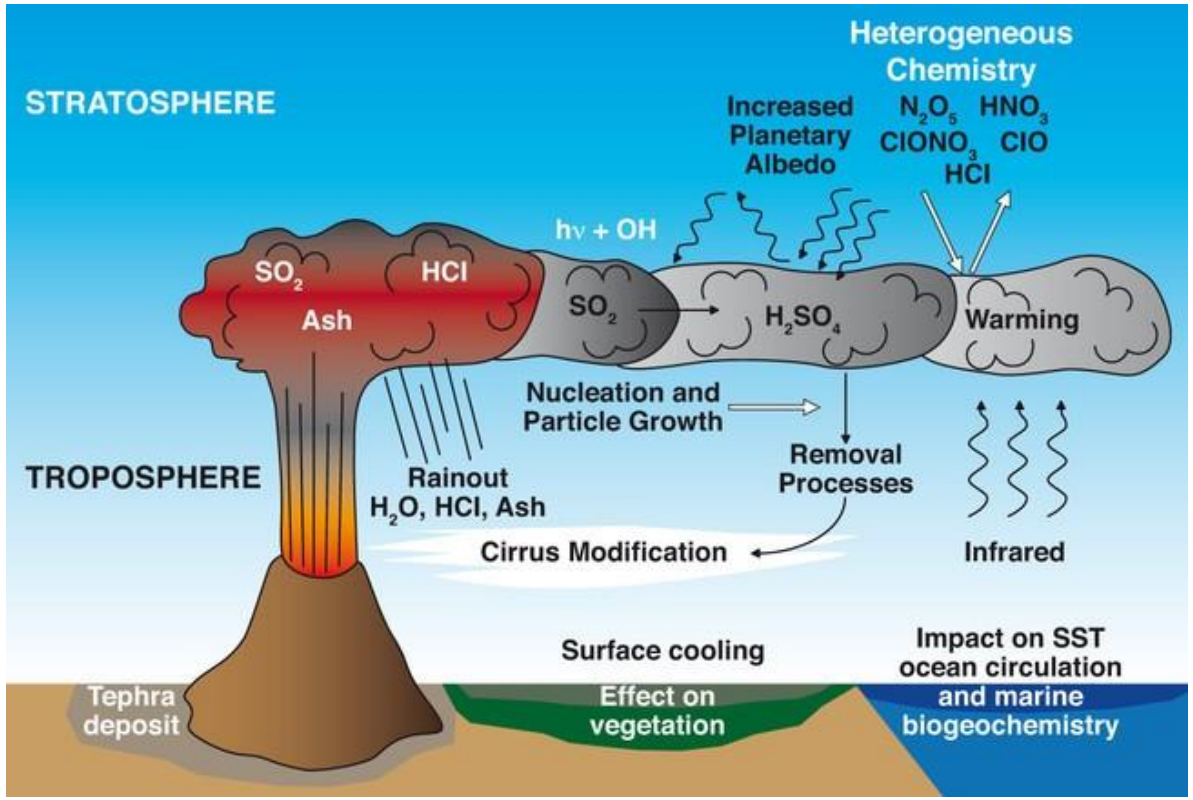


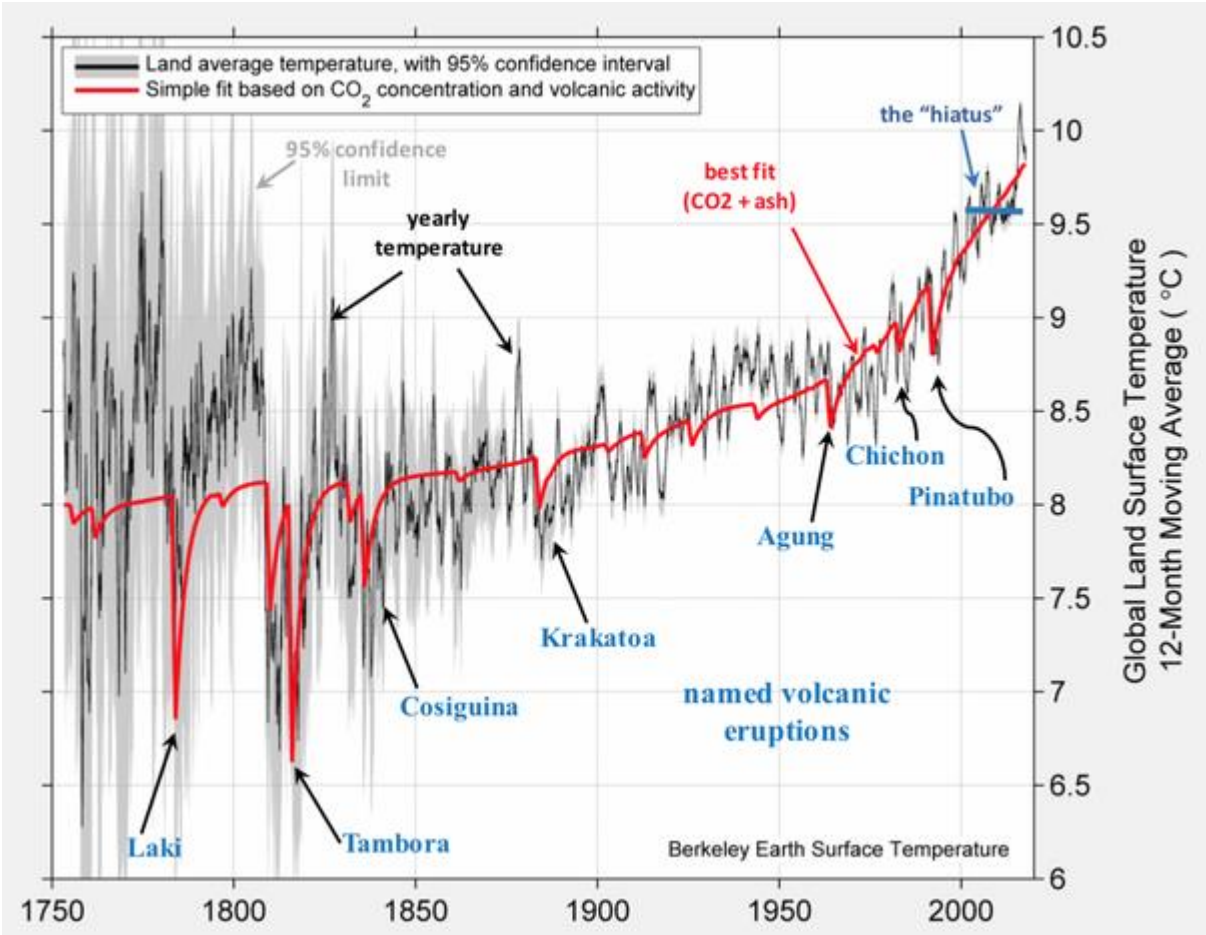
→ New simulation with photolysis rate correction (Luke Abraham)
→ Significant improvements in total column and ozone profile
→ Pre-industrial ozone is largely controlled by NOx and HOx cycles
→ Model still shows high bias against other models

Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

Natural Environment Research Council

Stratospheric Aerosol Scheme in the UKESM



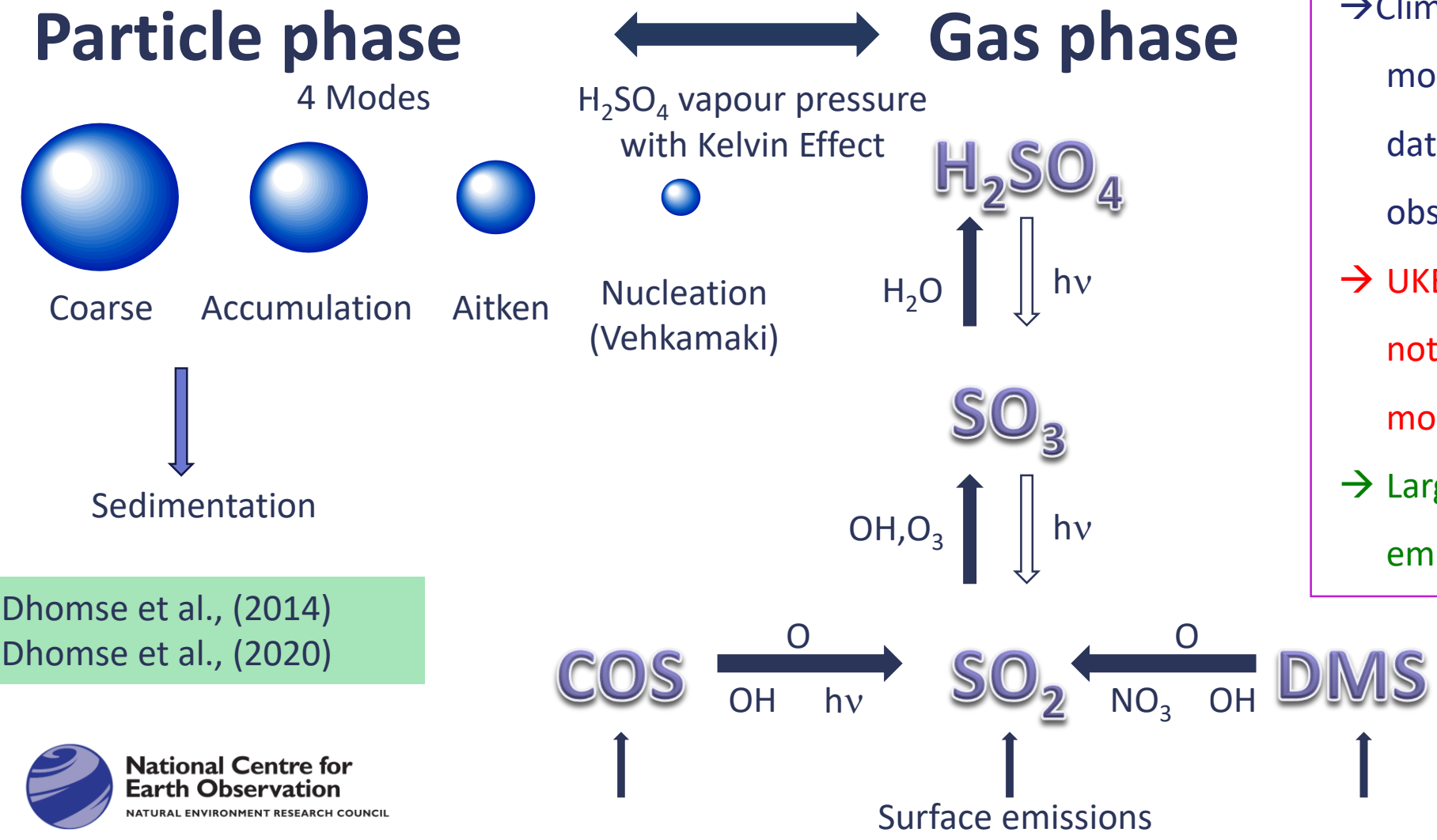


National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

UKRI Natural Environment Research Council

Stratospheric Aerosol Module in the UKESM



→Climate models without aerosol module use external forcing datasets that are constructed with observations and models

→ UKESM simulation for CMIP6 does not include interactive aerosol model for volcanos

→ Large uncertainties about SO_2 emitted during each eruption

Dhomse et al., (2014)
Dhomse et al., (2020)

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

UKRI Natural Environment Research Council

Set-Up for Mt. Pinatubo Simulation

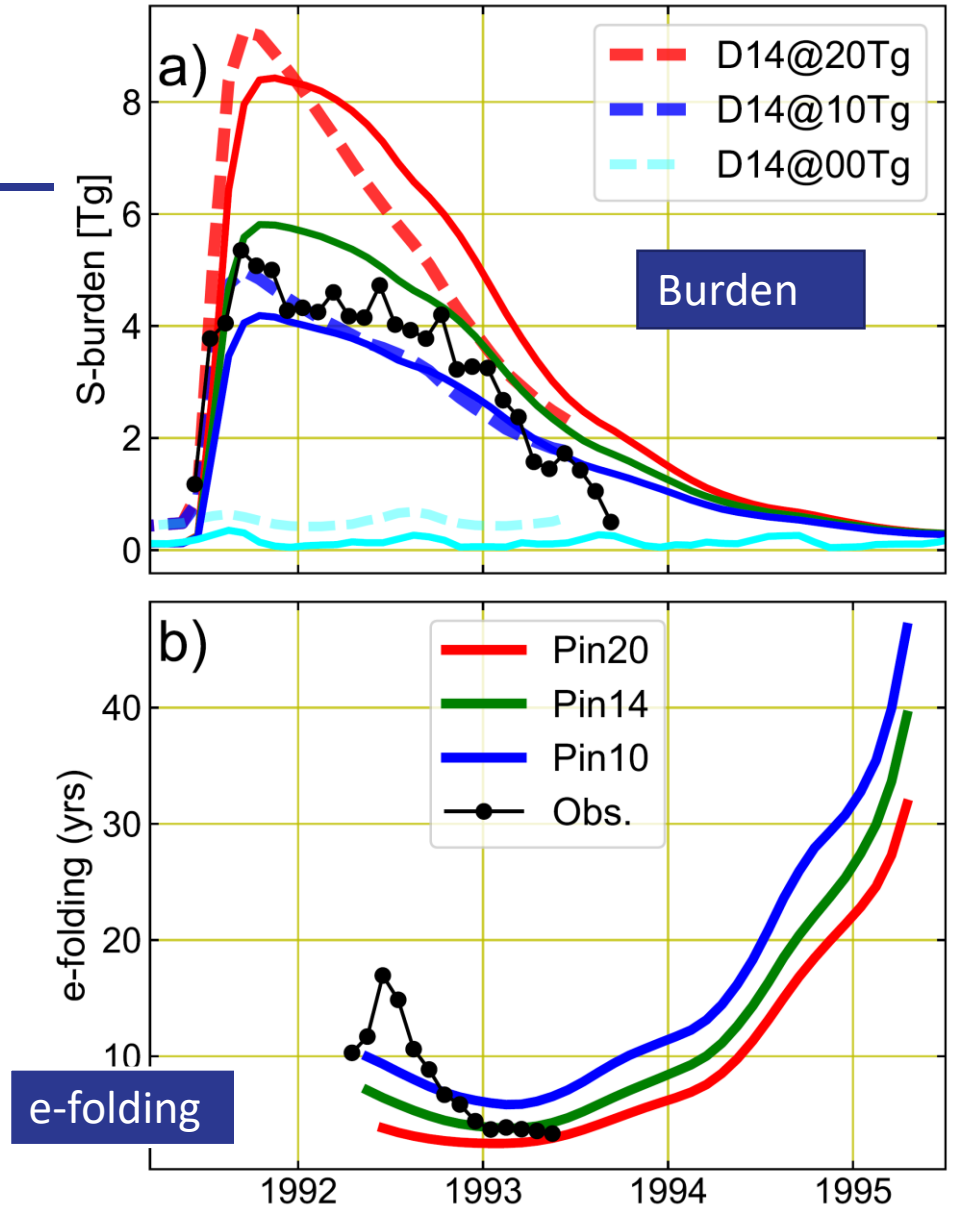
- Interactive strat-trop aerosol configuration of UM-UKCA for aerosol properties across stratosphere & troposphere (nb H_2SO_4 (aq) particles evaporate to gas phase z>30km).

- Free-running transient atmos-only simulations in high-top (80 km) version of v8.4 UM-UKCA (GA4) GCM with time-varying prescribed SSTs & sea ice as AMIP2.

- UKCA stratospheric-troposphere chemistry scheme (Abraham et al., 2016) extended with sulphur chemistry.

- For each eruption, control-run spun-up to GHG, ODSs, then 3-member ensemble from different initial fields with common specified QBO-transition for SO_2 emission at
a) mid-pt, b) upper bound, c) lower bound.

Pinatubo: a) 14, b) 20, c) 10 Tg SO_2 at 21-23 km 1990 GHGs & ODSs, June eruption with easterly QBO

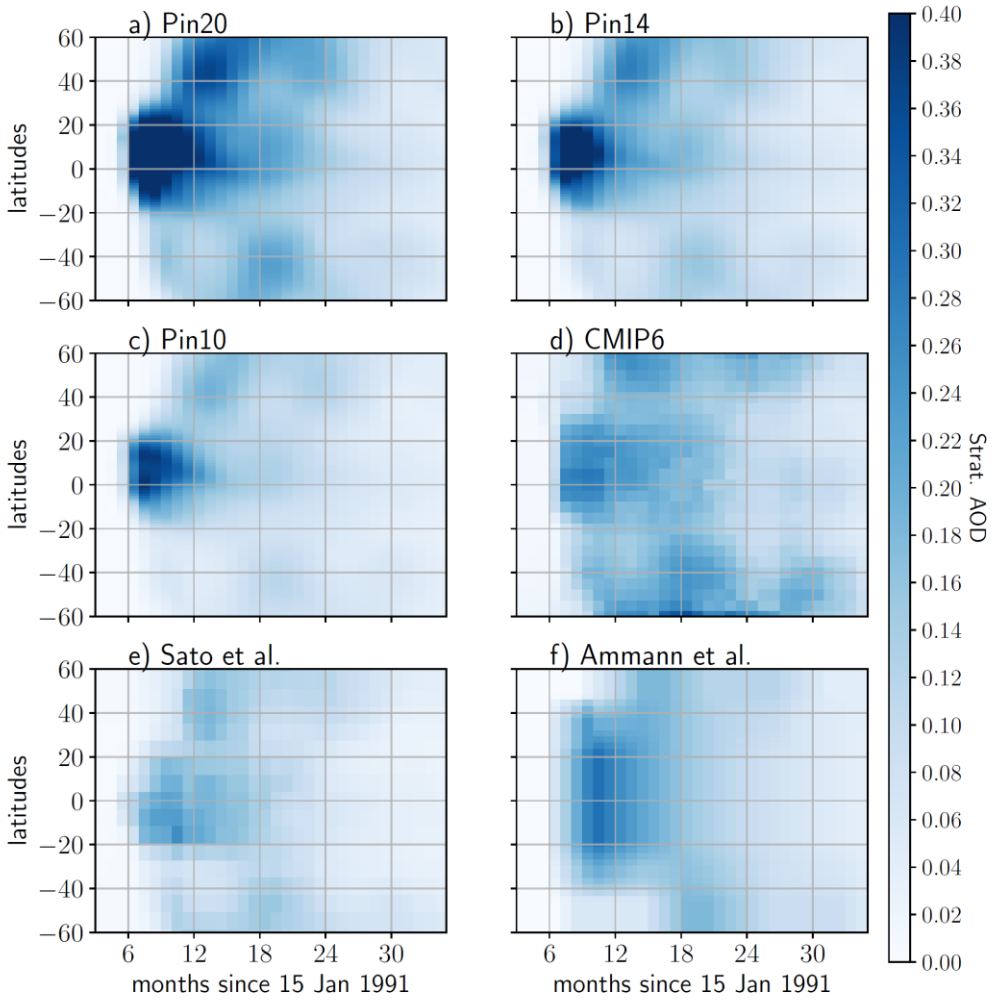


National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

UKRI Natural Environment Research Council

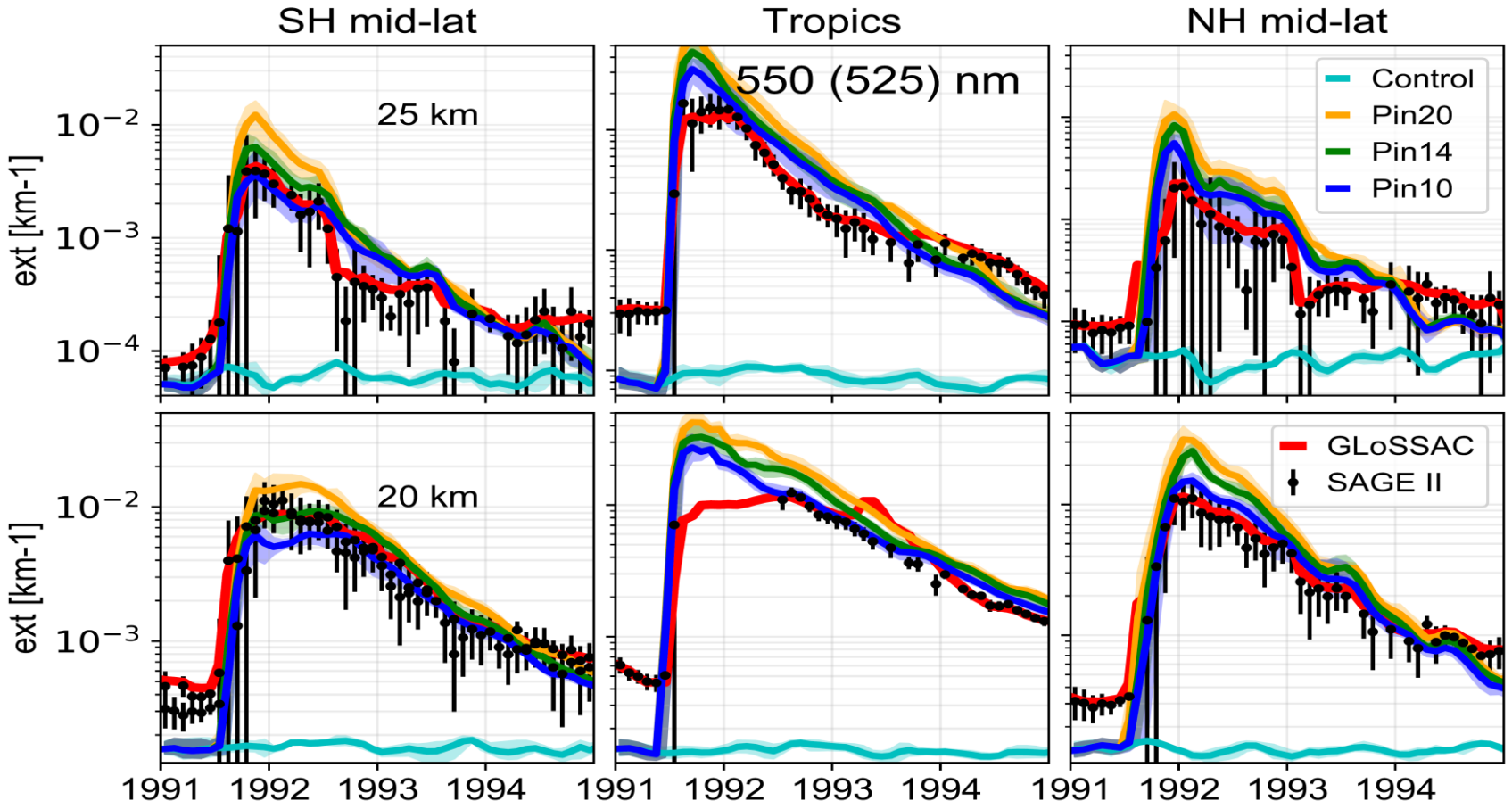
Pinatubo Evaluation (Stratospheric AOD)



- Simulations with 10 Tg and 14 Tg SO_2 injection show reasonable agreement with most of the observational data sets.
- Low biases in the SH (Hudson eruption in Oct. 1991).
- Large difference in volcanic forcing data set.
- Created and tested microphysically consistent off-line (easy aerosol) forcing data set for three largest volcanic eruptions (Mt Pinatubo (1991), El Chichon (1982) and Mt Agung (1983)) over last century.
- Model simulations suggest much lower SO_2 amount is needed to simulate past volcanic eruption possibly indicating missing removal mechanism (e.g. co-emitted volcanic ash).

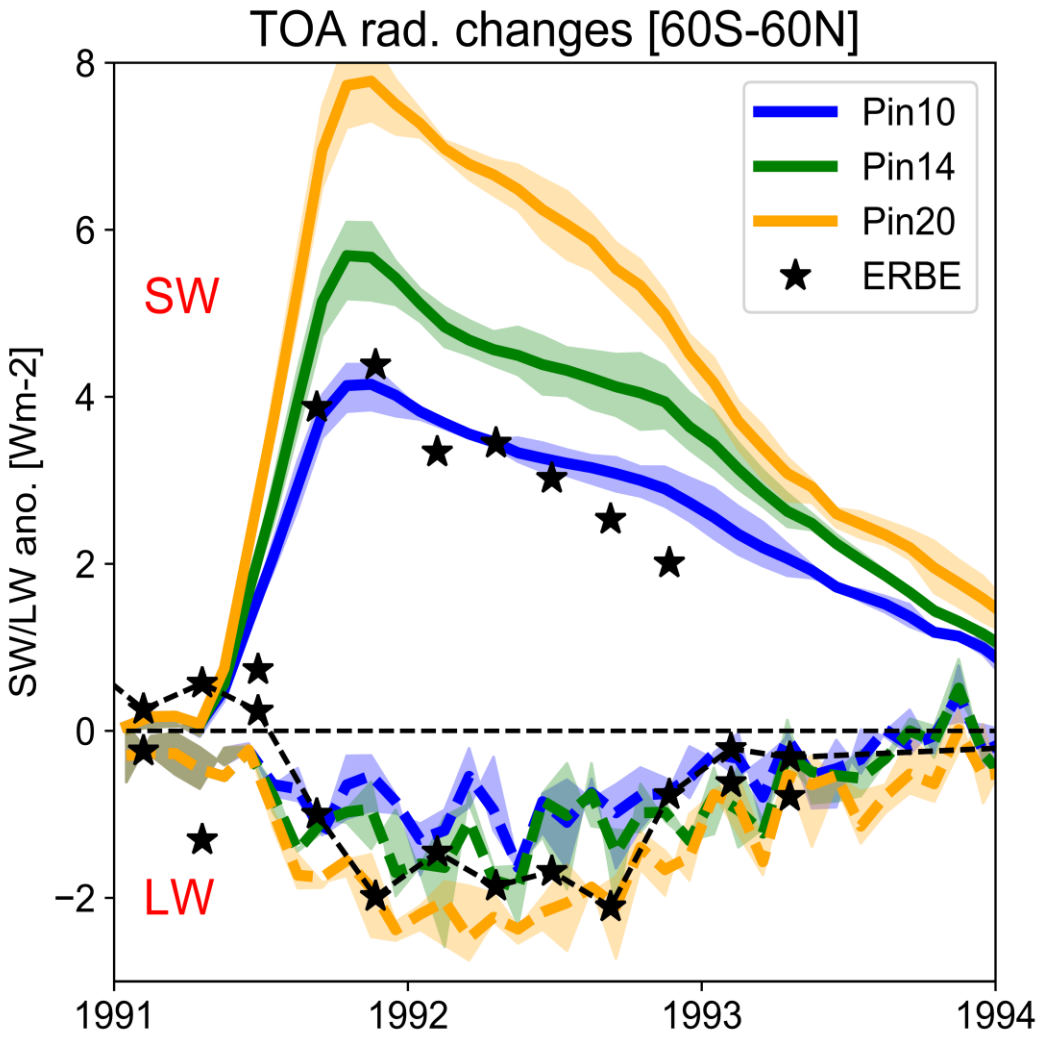
Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

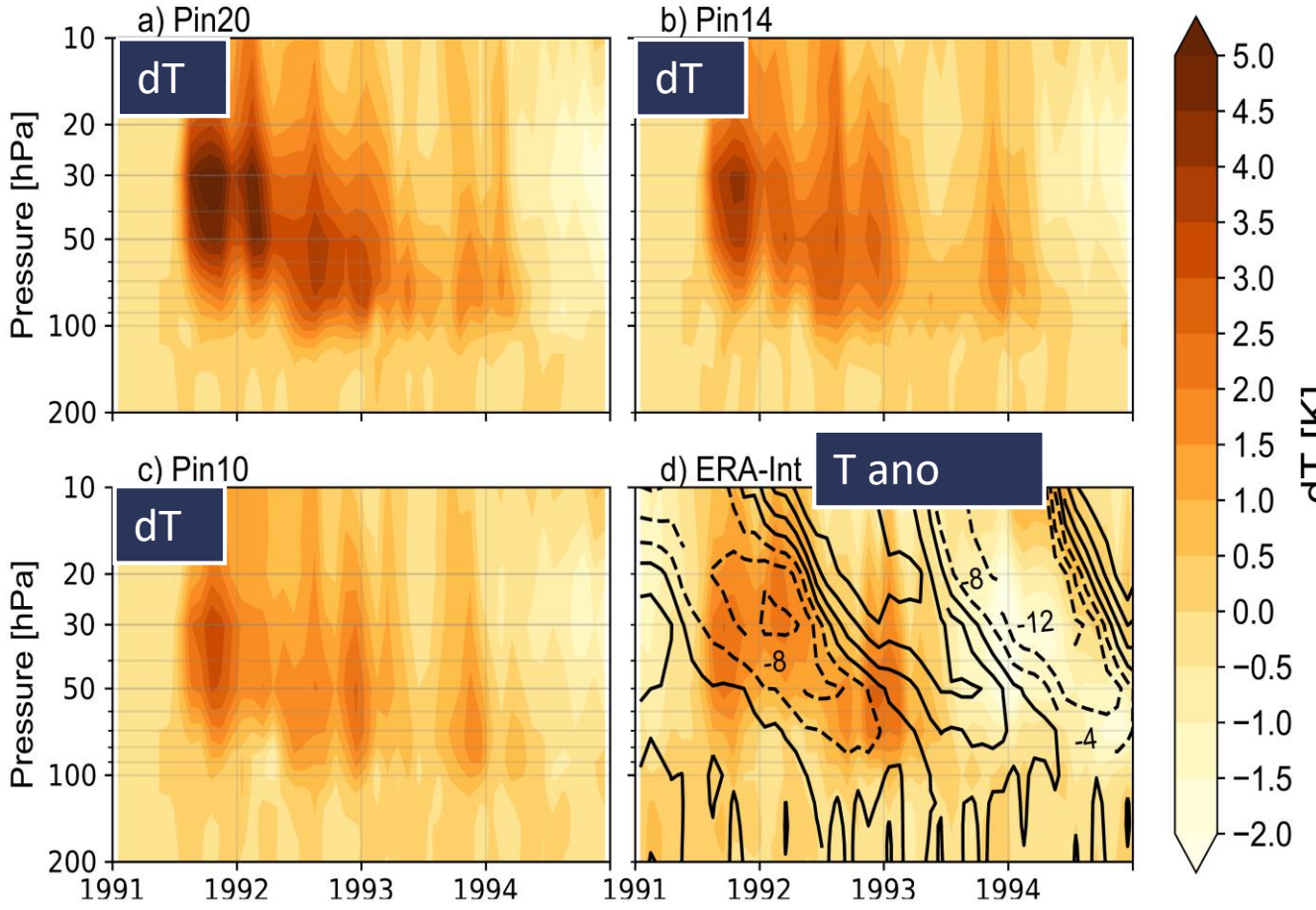
Pinatubo - Extinction at 550nm (SAGE II)



- 10 to 14 Tg seems to show better agreement
- CMIP6 data show plateau in tropical extinction

Radiative Forcing and Lower Stratospheric Heating





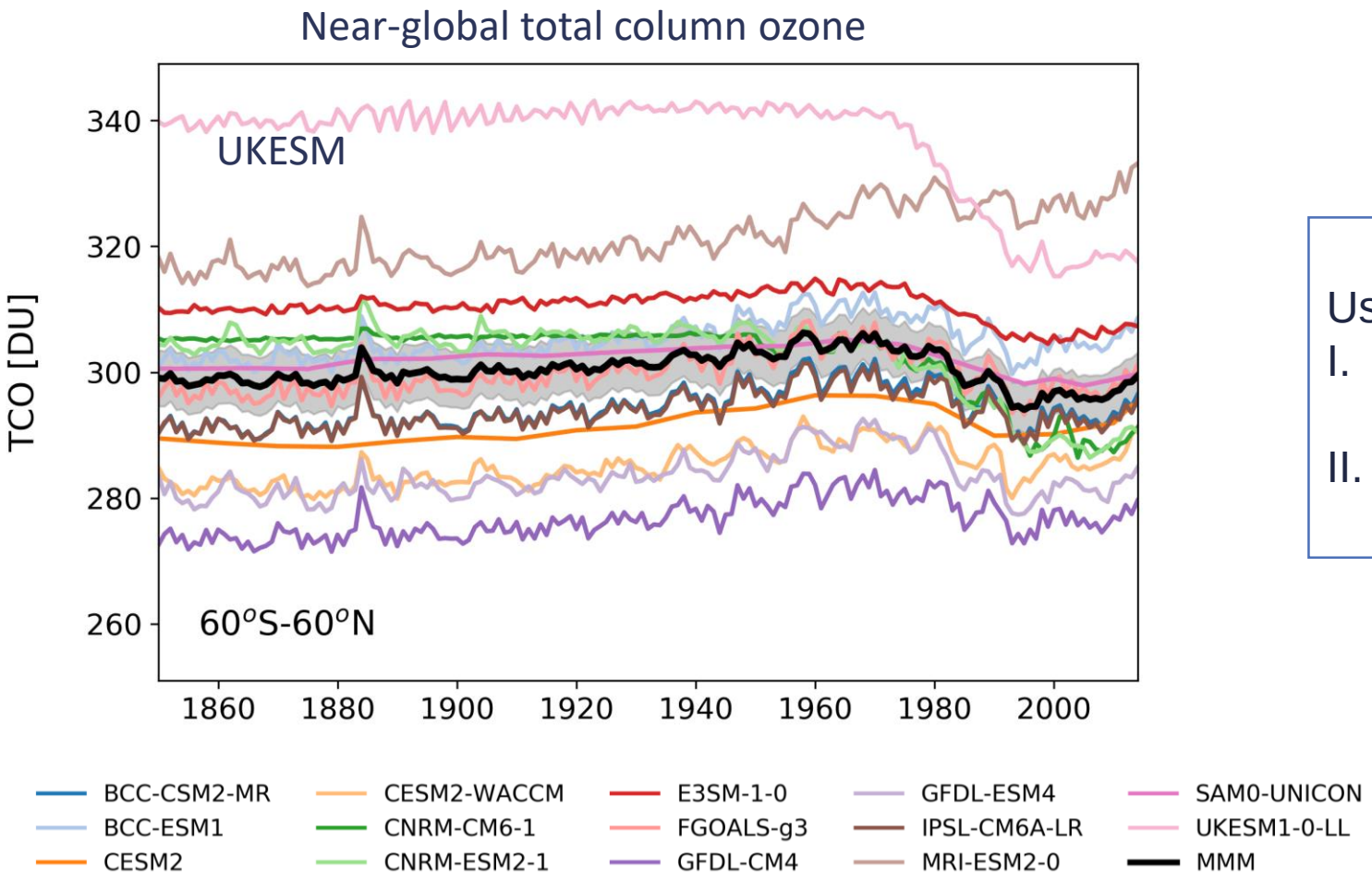
Sandip Dhomse | s.s.dhomse@leeds.ac.uk | University of Leeds

Natural Environment Research Council

Summary

- Updated photolysis data in the UKESM. Updated simulation shows increase in stratospheric NOy, but model still shows more ozone and less NOy than observations.
- Simulated stratospheric aerosol properties following Mt. Pinatubo eruption have been evaluated against a range of observational data sets.
- Smaller amount of SO_2 injection is needed to simulate changes in stratospheric aerosol following past eruptions suggesting (probable) missing mechanism.
- Microphysically consistent volcanic forcing data has been created for Mt Pinatubo, El Chichon and Mt Agung eruptions.

Extra Slides



Outline

Using Satellite data to understand:

I. Low NOy bias, hence positive column ozone bias

II. Volcanic aerosol forcing using interactive aerosol module

Courtesy of James Keeble