Climate-chemistry-aerosol coupling for HadGEM2-ES

Climate Research seminar

Jamie Rae, 14th October 2008

Collaborators

- Colin Johnson

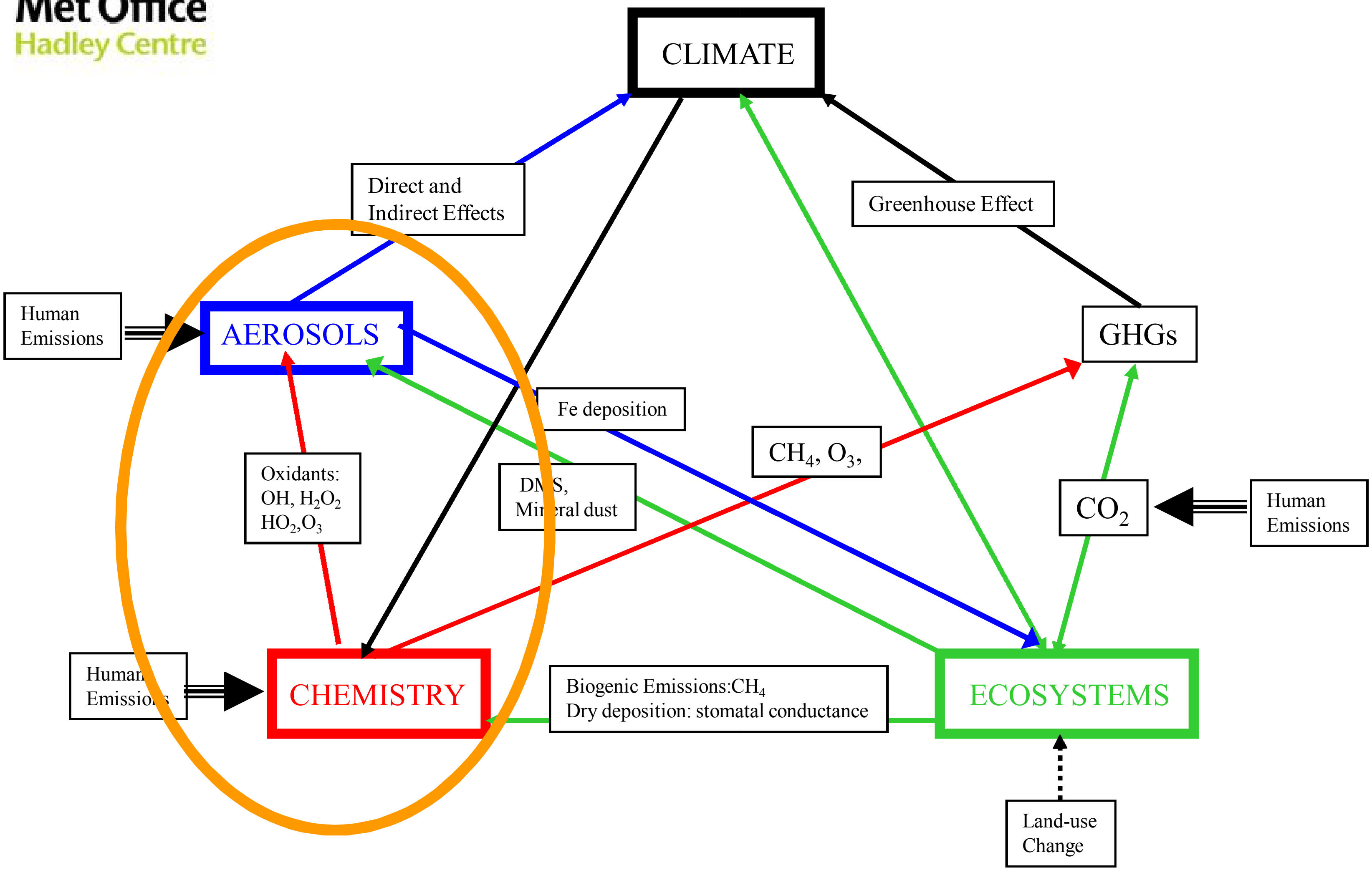
- Fiona O’Connor

Outline

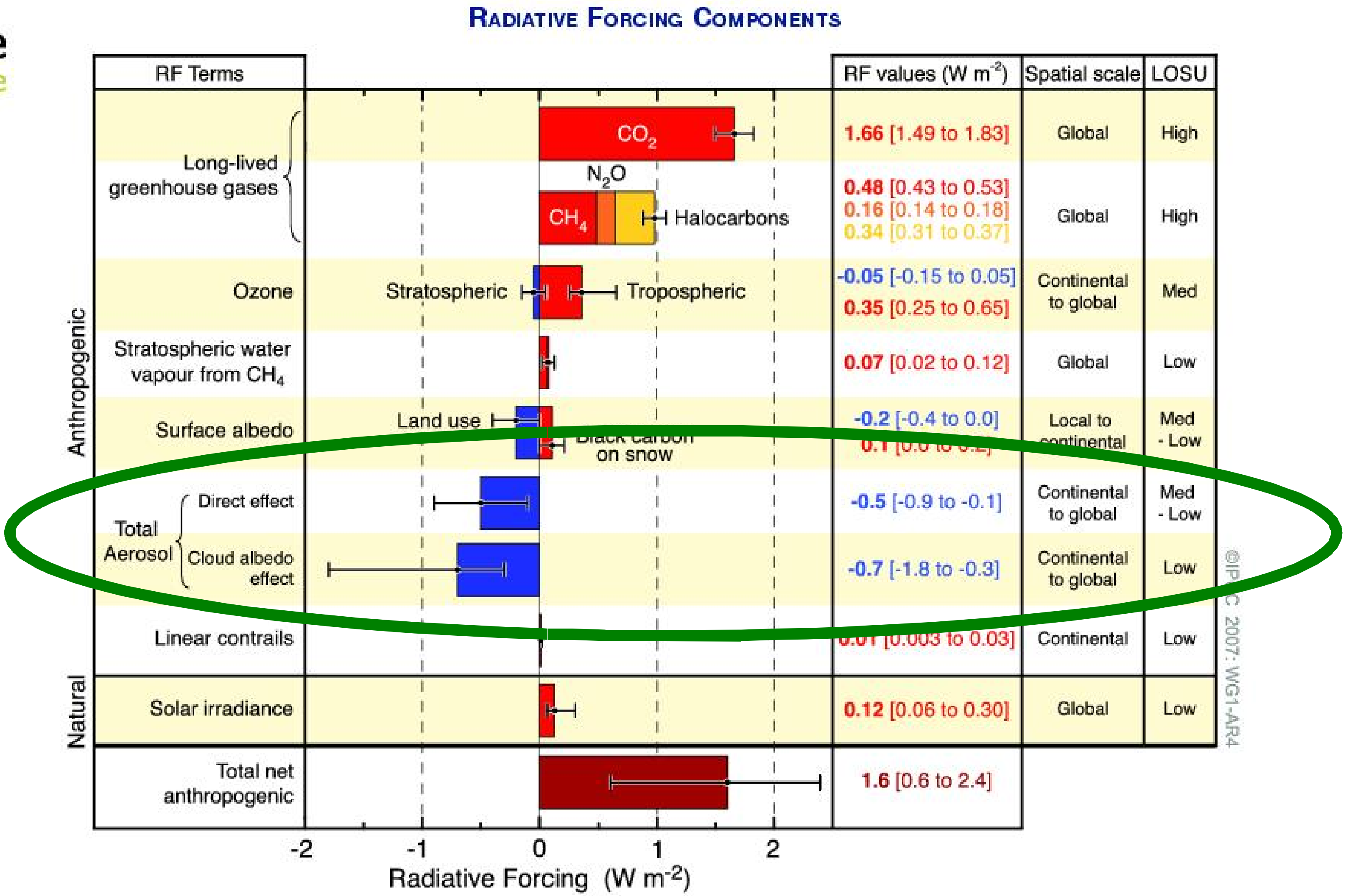
- Background and motivation
- Models and coupling
- Effect on model output
- Validation against observations
- Discussion
- Conclusions

Background and motivation

HadGEM2-ES

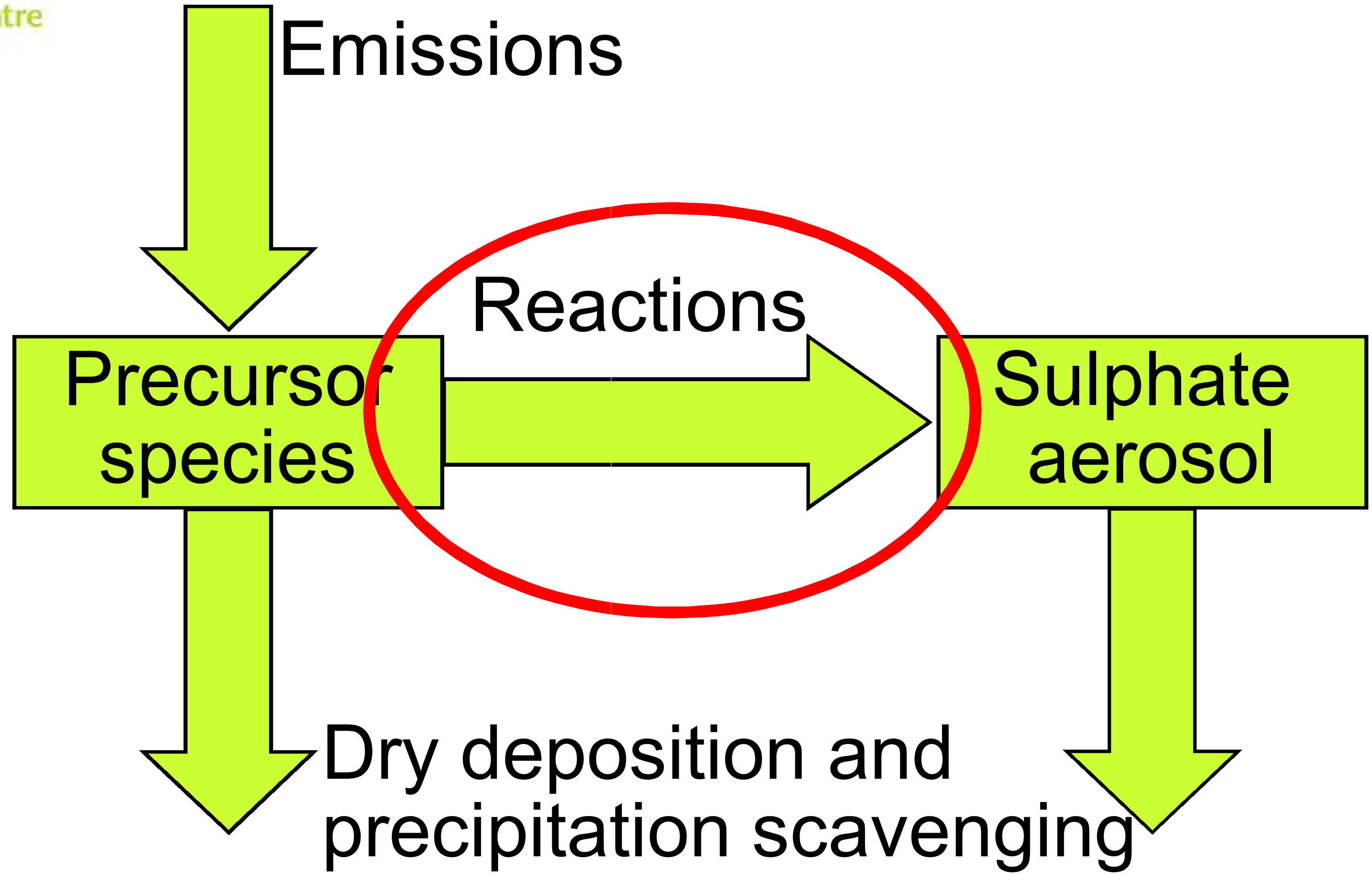

CLIMATE
Direct and
Indirect Effects
Greenhouse Effect
Human
Emissions
AEROSOLS
GHGs
Fe deposition
CH_4, O_3,
Oxidants:
OH, H_2O_2
HO_2,O_3
DMS,
Mineral dust
CO_2
Human
Emissions
Human
Emissions
CHEMISTRY
Biogenic Emissions:CH_4
Dry deposition: stomatal conductance
ECOSYSTEMS
Land-use
Change

Motivation

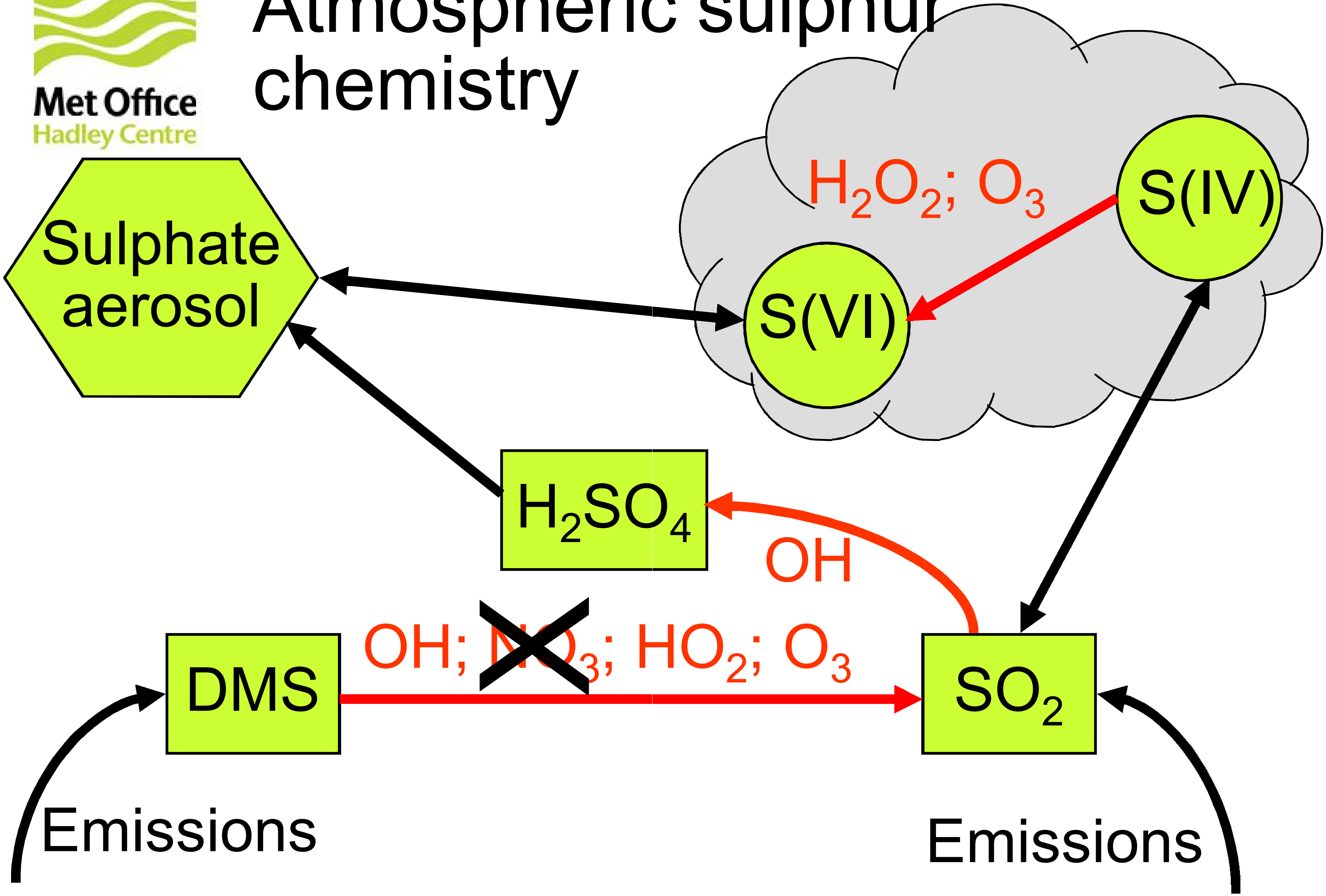


Source: IPCC AR4

The sulphur cycle



Atmospheric sulphur chemistry



The need for chemistry-aerosol coupling –1

- Current model:
  - Monthly-mean prescribed oxidant concentrations.
    - OH, H_2O_2, HO_2, O_3.
  - Seasonal variation but no annual variation.

    → No variation with emissions and climate.

The need for chemistry-aerosol coupling – 2

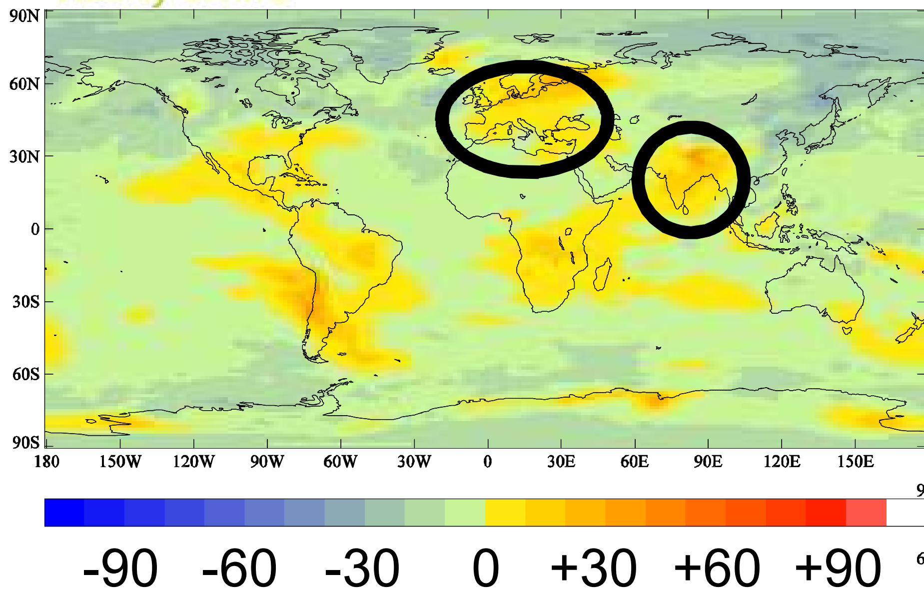
- Oxidant concentrations likely to depend on:
  - Precursor emissions
  - Temperature
  - Humidity
  - Cloud fraction
  - Cloud liquid water content
  - Precipitation
  - Stratosphere-troposphere exchange

The need for chemistry-aerosol coupling – 3

- Rae et al. (2007, JGR):
  - Effect of oxidant and climate changes on sulphate.

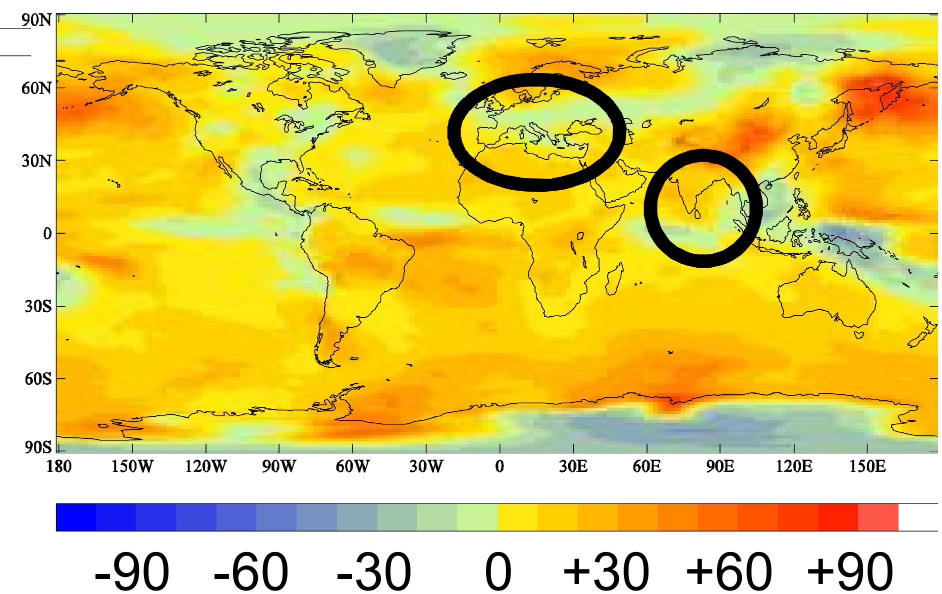
Percentage changes in sulphate column density (1990—2100) (Rae et al. 2007)

Met Office
Hadley Centre



Oxidants change only

Climate change only



The need for chemistry-aerosol coupling – 3

- Rae et al. (2007, JGR):
  - Effect of oxidant and climate changes on sulphate.
  - 21st-century oxidant changes important for sulphate.

→ Accurate 21st-century sulphate prediction therefore requires fully-coupled runs.

Models and coupling

UKCA Tropospheric Chemistry

- Simplified tropospheric chemistry scheme
- 24 tracers and 46 species
- Prescribed photolysis rates and upper BCs
- Emissions: Surface, aircraft, and lightning
- Wet and dry deposition

Implementation of chemistry-aerosol coupling

- Coupling with UKCA introduced
  - Currently one-way: no feedback to UKCA
  - Two-way coupling will be introduced.
- Tested by performing 3 model experiments:
  - CTRL (original prescribed oxidants)
  - UKCA_OL (on-line oxidants)
  - UKCA_PR (prescribed oxidants from UKCA_OL)
- 5-year runs for 1990s conditions.

Effect on model output

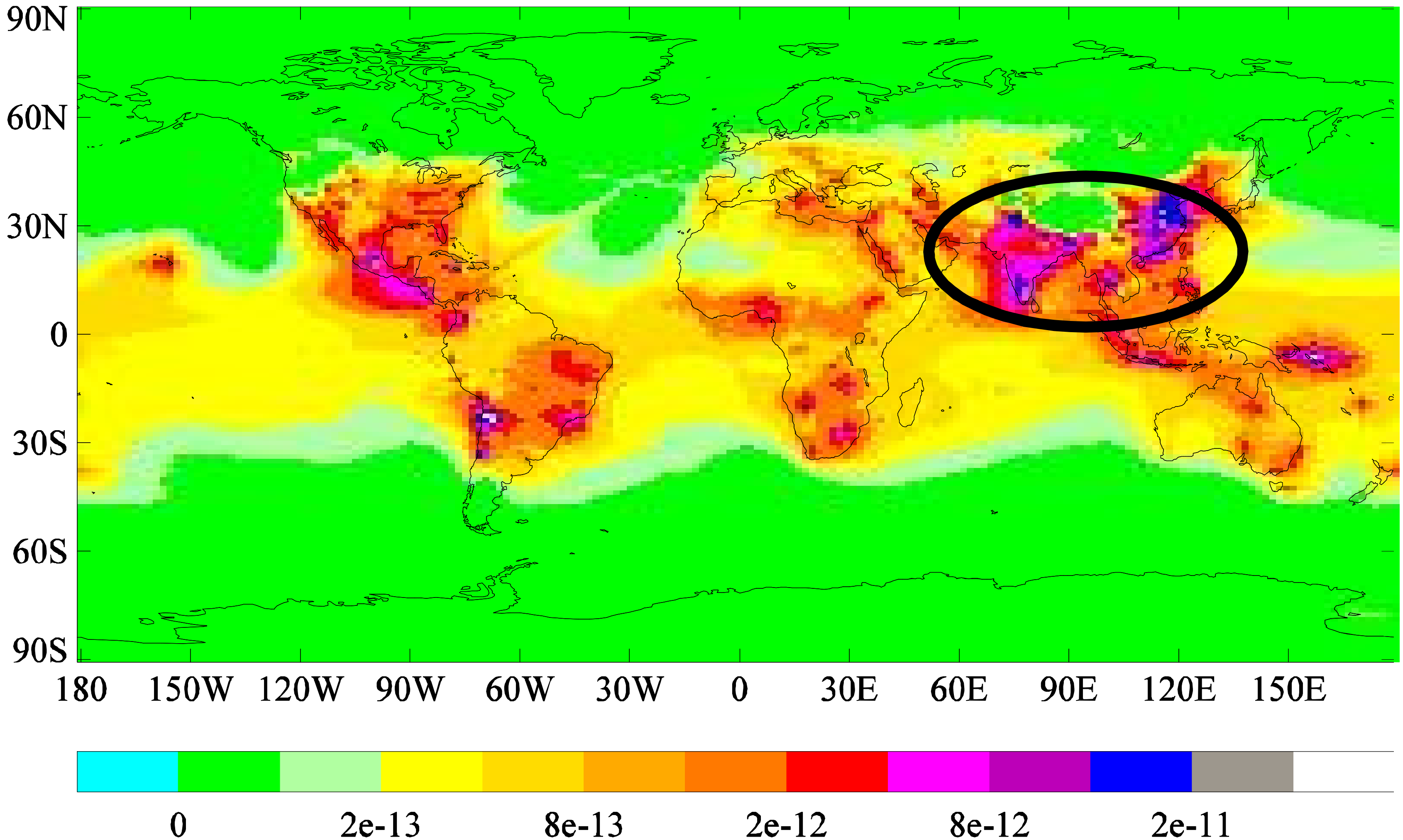
Impact on HadGEM sulphur cycle

Differences in 5-year mean global totals

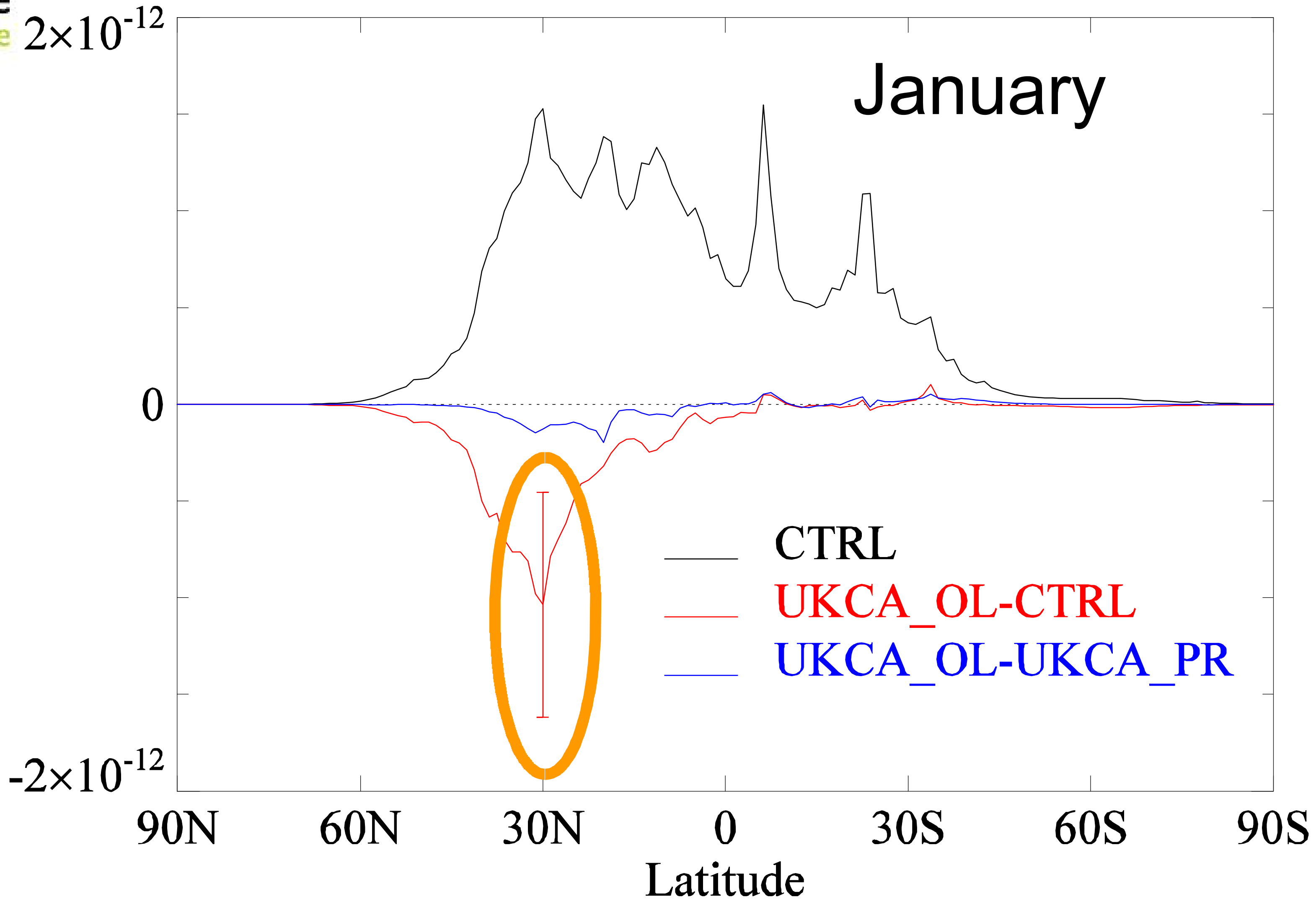
		UKCA_OL–UKCA_PR
SO_2+OH		–0.1 %
S(IV)+H_2O_2		+12.2 % (*)
S(IV)+O_3		–7.4 % (*)
SO_2		+5.1 % (*)
Total sulphate		–0.5 %
Sulphate optical depth		–0.5 %
Total aerosol optical depth		–0.7 %

(*): statistically significant at 95% level

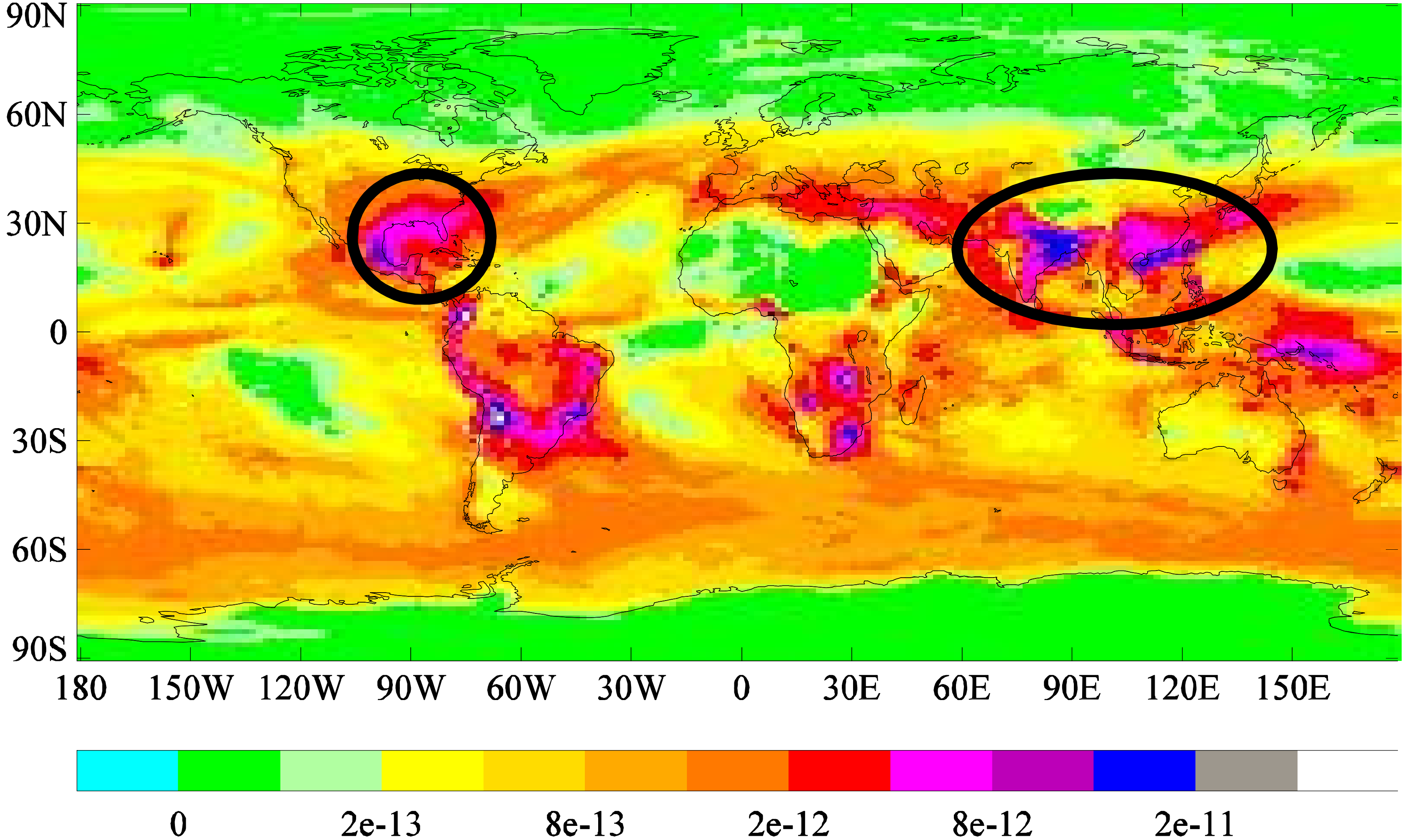
Column-integrated SO_2+OH reaction rate (kg m^{-2} s^{-1}) – January



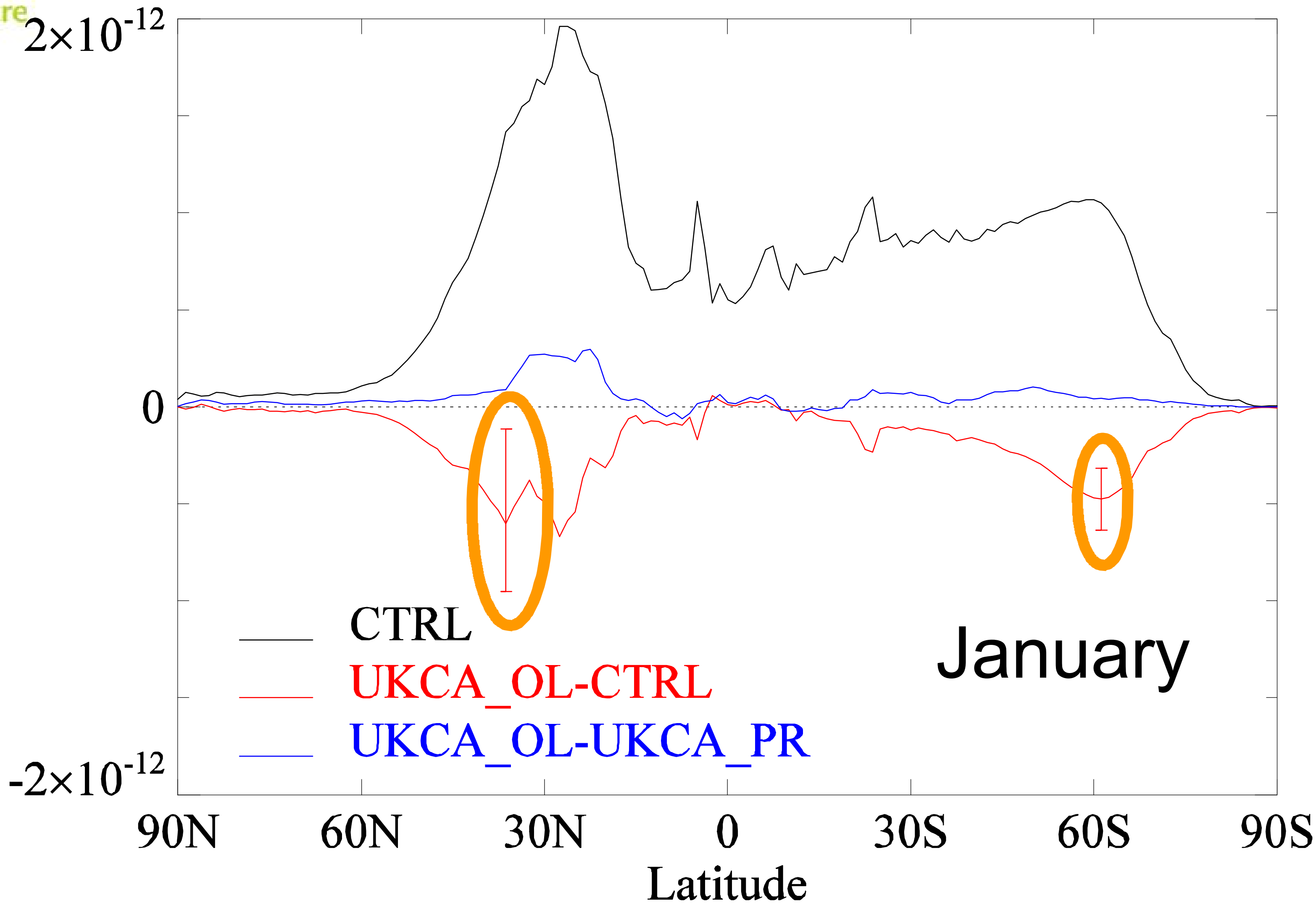
SO_2+OH reaction rate (zonal mean, column integrated) (kg m^{-2} s^{-1})



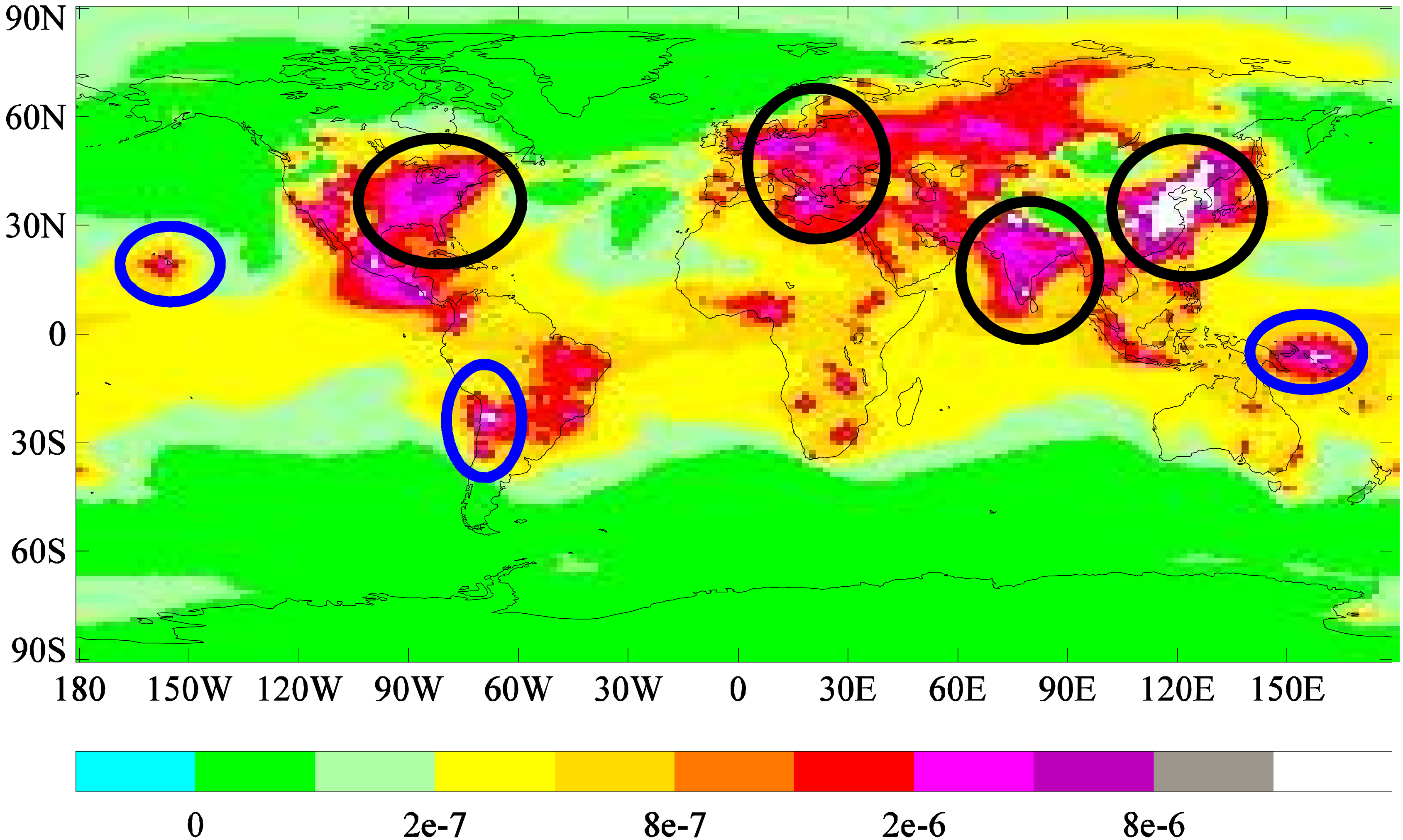
Column-integrated S(IV)+H_2O_2 reaction rate (kg m^{-2} s^{-1}) – January



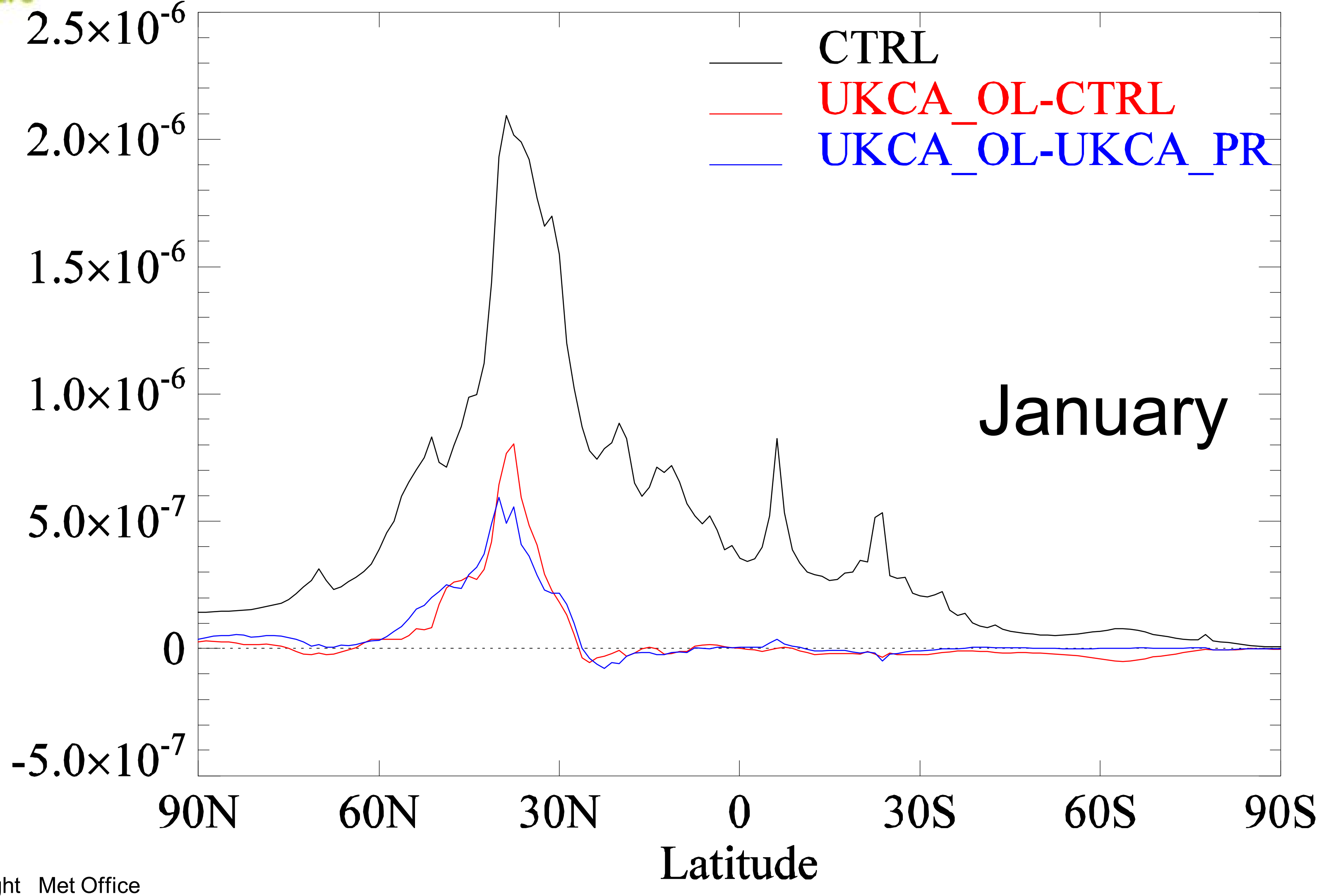
S(IV)+H_2O_2 reaction rate (zonal mean, column integrated) (kg m^{-2} s^{-1})



SO_2 column density (kg m^{-2}) – January

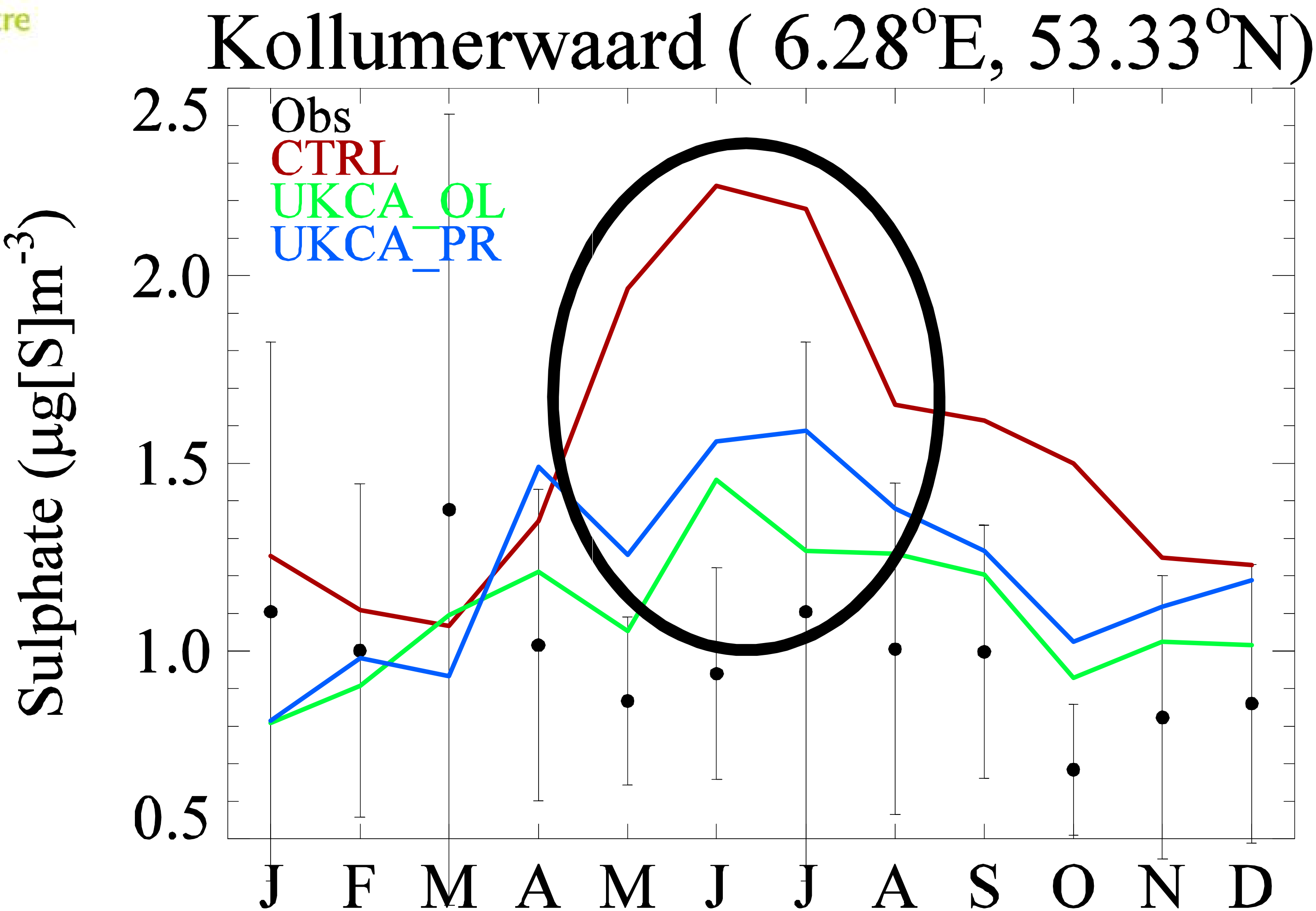


Zonal mean SO_2 column density ($kg\ m^{-2}$)

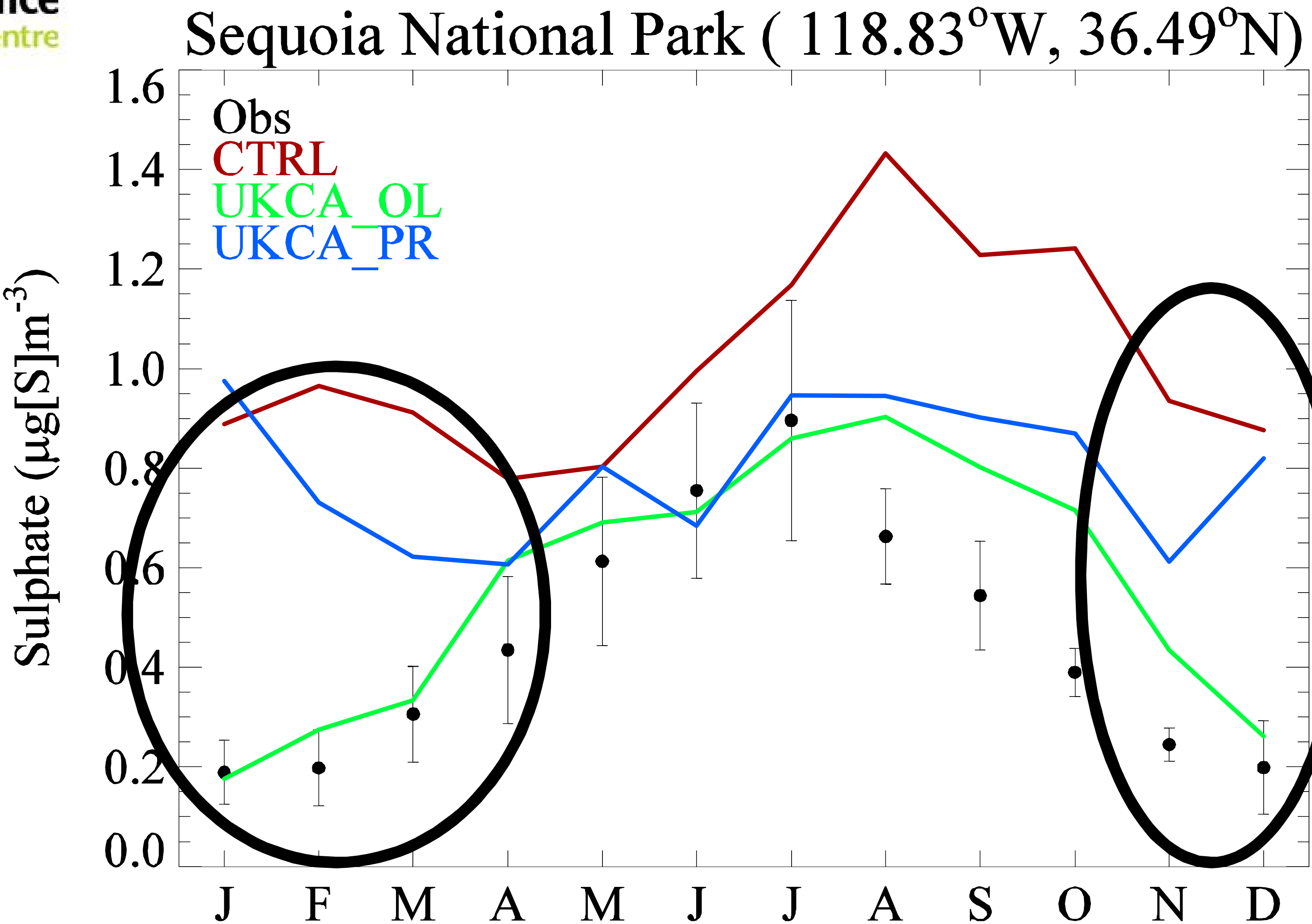


Validation against observations

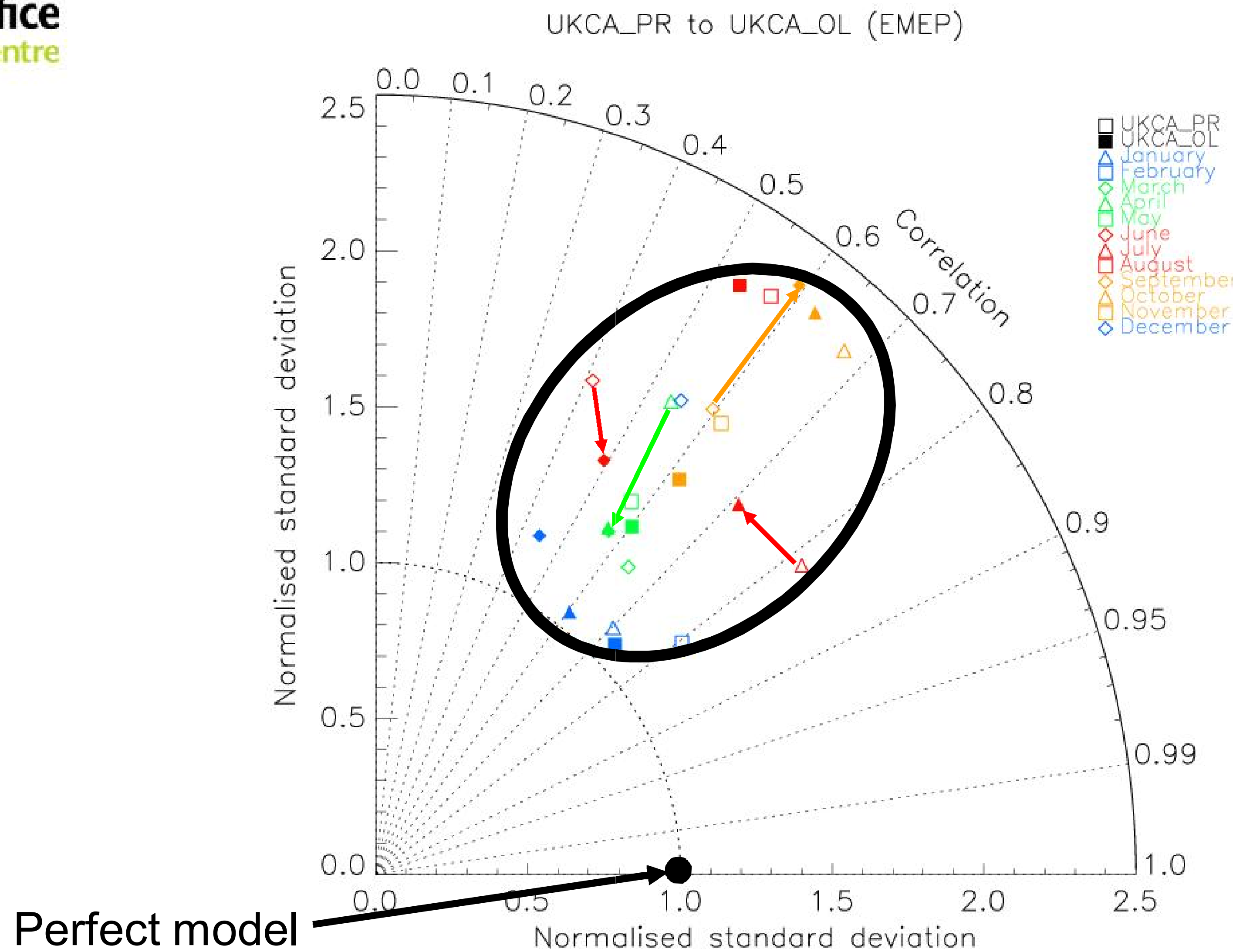
Sulphate concentration: annual cycle



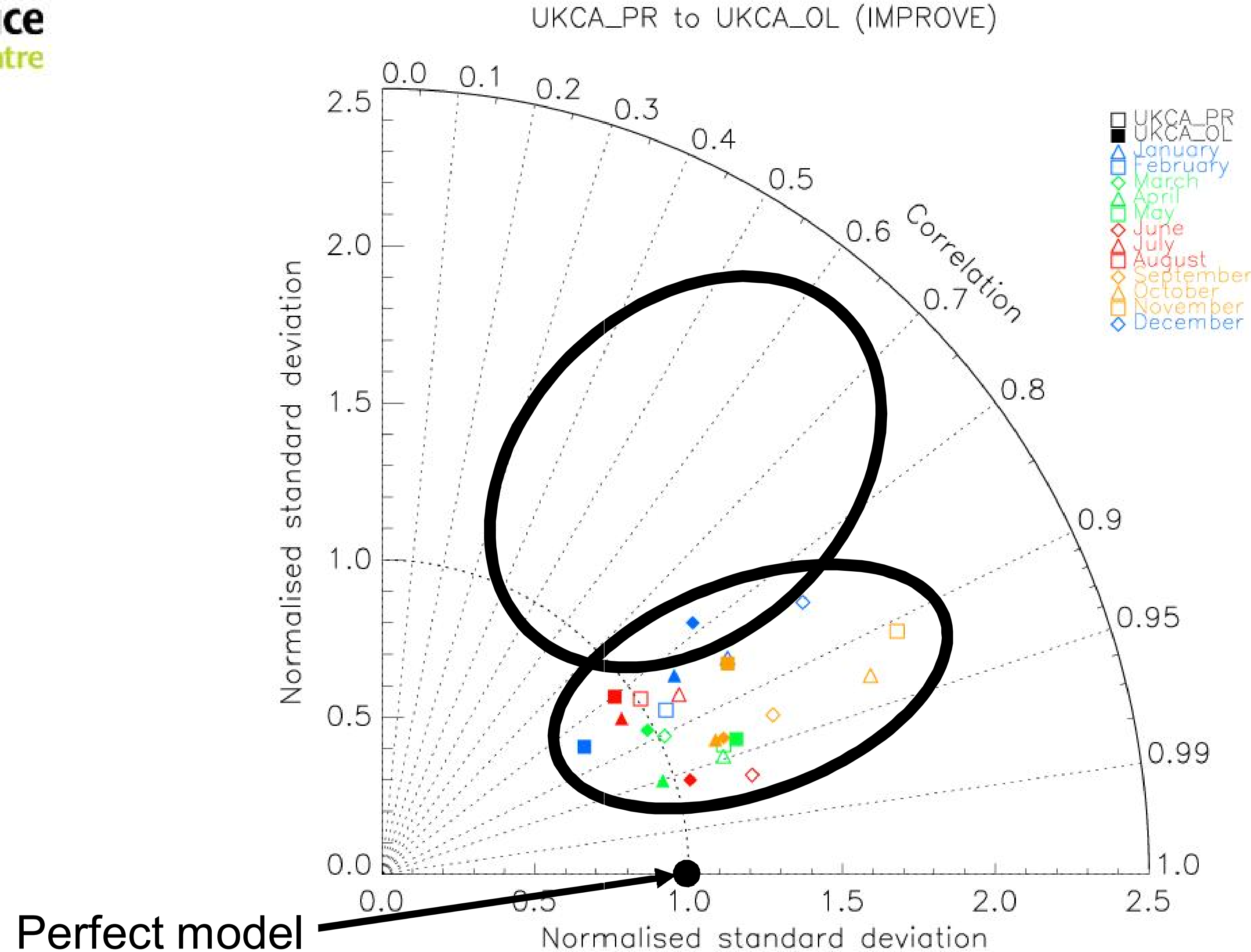
Sulphate concentration: annual cycle



Validation against observed surface concentrations: Europe



Validation against observed surface concentrations: N. America



Discussion and conclusions

Discussion – 1

- Improvement in present-day output is small.
- However, we want to perform full 21st-century runs.
- Prescribed oxidants not available for these runs.
- Can now use on-line oxidants in this case.

Discussion – 2

- Air quality forecasts:
  - Higher spatial and temporal resolution.
    - → Feedbacks from meteorology may be important.
    - → On-line oxidants useful here.
- Can now investigate climate-chemistry-aerosol feedbacks.
- Additional aerosol schemes possible (e.g. nitrate).

Discussion – 3

Additional functionality without negative impact on model output.

Conclusions – 1

- Model currently uses off-line oxidant concentrations
- No climate-chemistry-aerosol feedbacks represented.
- Such feedbacks are important for future scenarios.
- Modification introduced to use on-line oxidants from UKCA.
- Difficult to draw conclusion about significance of changes.

  → Need longer runs / runs without aerosol-climate feedbacks.

- Comparison with observations neither better nor worse overall.

Conclusions – 2

- **Additional functionality introduced without negative impact.**

  → A positive development.

Questions and answers