The United Kingdom Chemistry and Aerosol Community Model (UKCA)

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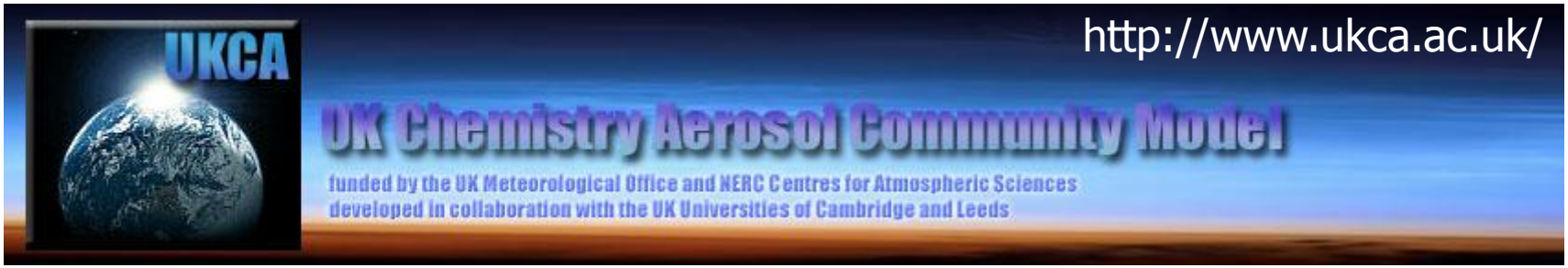
What is UKCA?

- UKCA is a community chemistry-climate model based on the Met Office's new dynamics Unified Model.



- It is a joint development between the Met Office, University of Cambridge (chemistry) and University of Leeds (aerosol), open to contributing partners, e.g. Universities of Reading (NCAS-CMS) and Oxford.
- UKCA will be part of the forthcoming Joint Climate Research Programme (JCRP).

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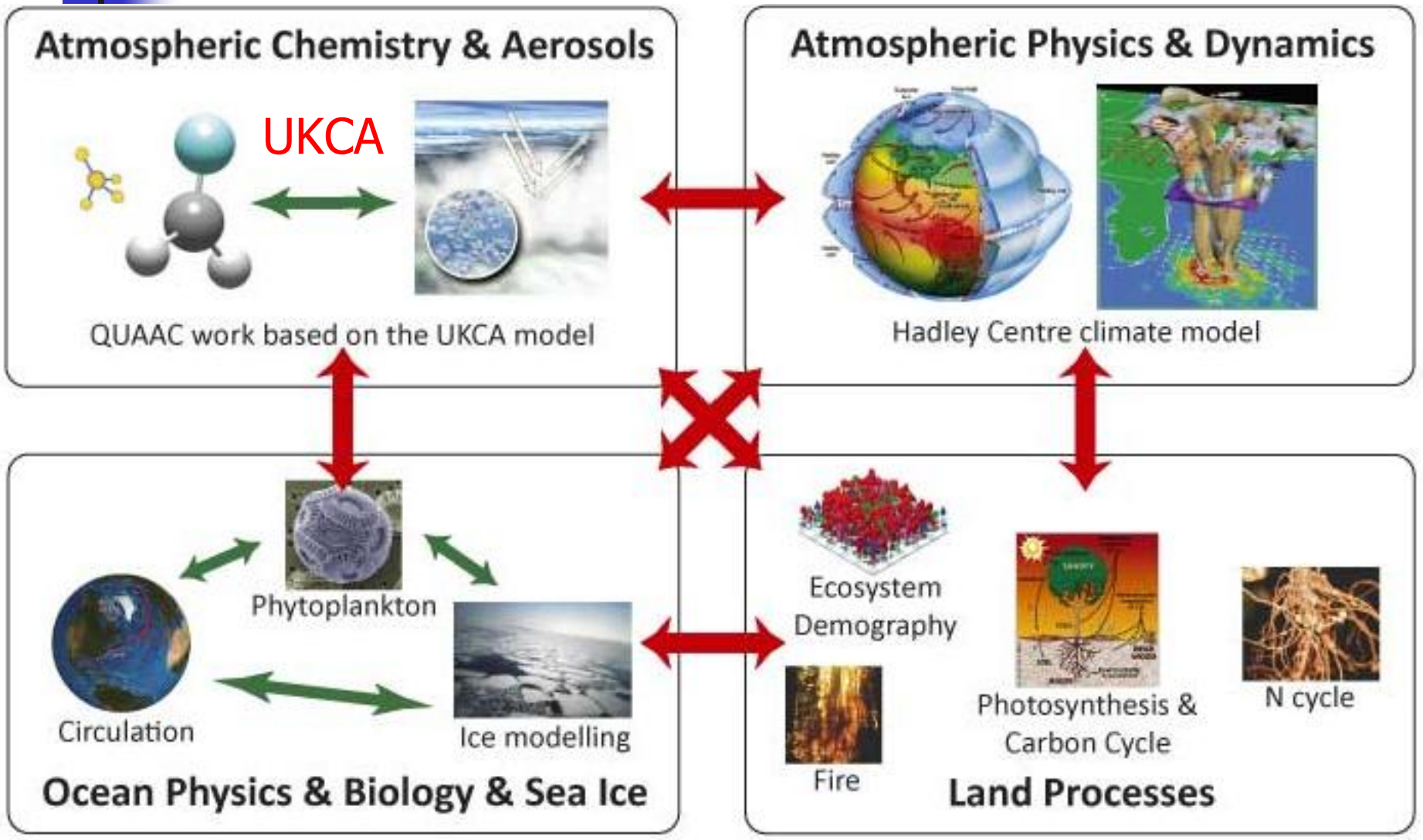
The bigger picture: ESMs



Earth system modelling within QUEST. Based on a diagram by M. Joshi

Barriers and opportunities

- Slightly different model versions on different platforms …
  - MO: NEC/IBM (latest version of the UM)
  - Universities: Cray XT4 (version chasing)
- Legacy data (including ancillary files)
- Transport requirements (mass versus atomic conservation)
- JCRP and a shared knowledge base will improve the situation

UKCA differences …

Met Office

- Chemical rates: Hardwiring required (assessment tool)
- Solver: Backward Euler (local, maximum numbers of iterations fixed)
- Integration into UMUI
- Easy access to new UM versions

Universities

- Chemical rates: Flexibility required (research tool)
- Solver: Newton-Raphson (regional, convergence depends on the patch)

UKCA in use

- MO: National IPCC contribution/forecast
  - Interactive wetland emissions (AR5?)
  - Towards air quality forecast
- Universities: In support for WMO and IPCC science
  - Past and (possible) future stratospheric ozone (WMO 2010?)
  - Improved estimates of aerosol radiative forcing

Current Model Setups

- Tropospheric UKCA
  - Resolutions: N48L38, N48L60, N96L38
  - Tropospheric chemistry
- Stratospheric and "Whole Atmosphere"
  - Resolutions: N48L60, (N96L60)
  - Stratospheric chemistry with tropospheric background
- Towards all resolutions, whole atmosphere chemistry, interactive aerosol …

Interactive CH_4 Ems Scheme

$$F^{w}_{CH4} = k_{CH4} * f_w * C_s * Q_{10}(T_{soil})^{(T_{soil}-T_0)/10}$$

F^{w}_{CH4} = methane flux from wetlands
k_{CH4} = scaling factor
f_w = wetland fraction
C_s = soil carbon content / weighted sum of carbon pools
Q_{10} = temperature sensitivity

Interactive CH_4 emissions from wetlands coupled to UKCA

Interactive CH_4 Ems Scheme

Provided by Fiona O'Connor

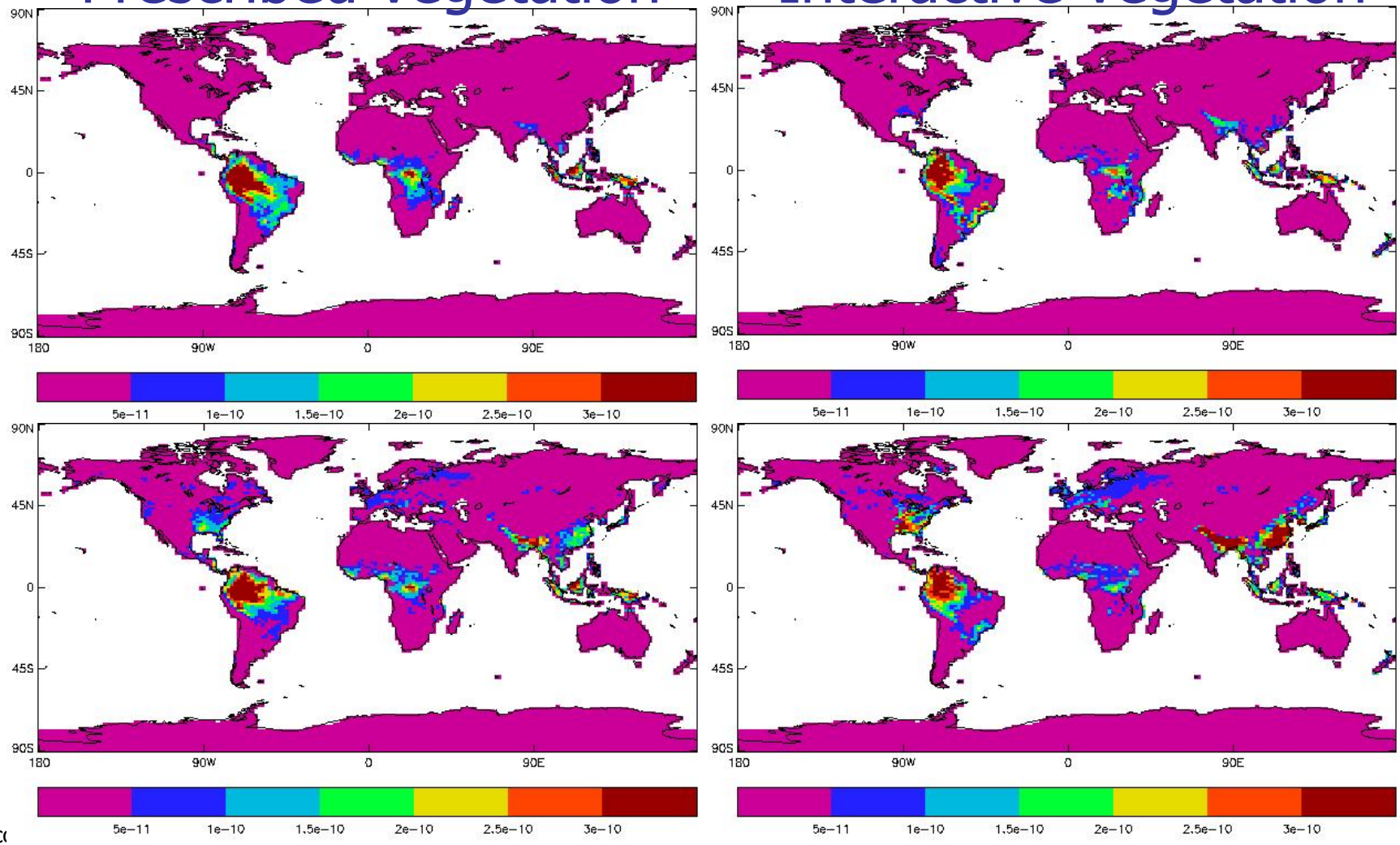
Met Office Hadley Centre

Prescribed Vegetation

Interactive Vegetation

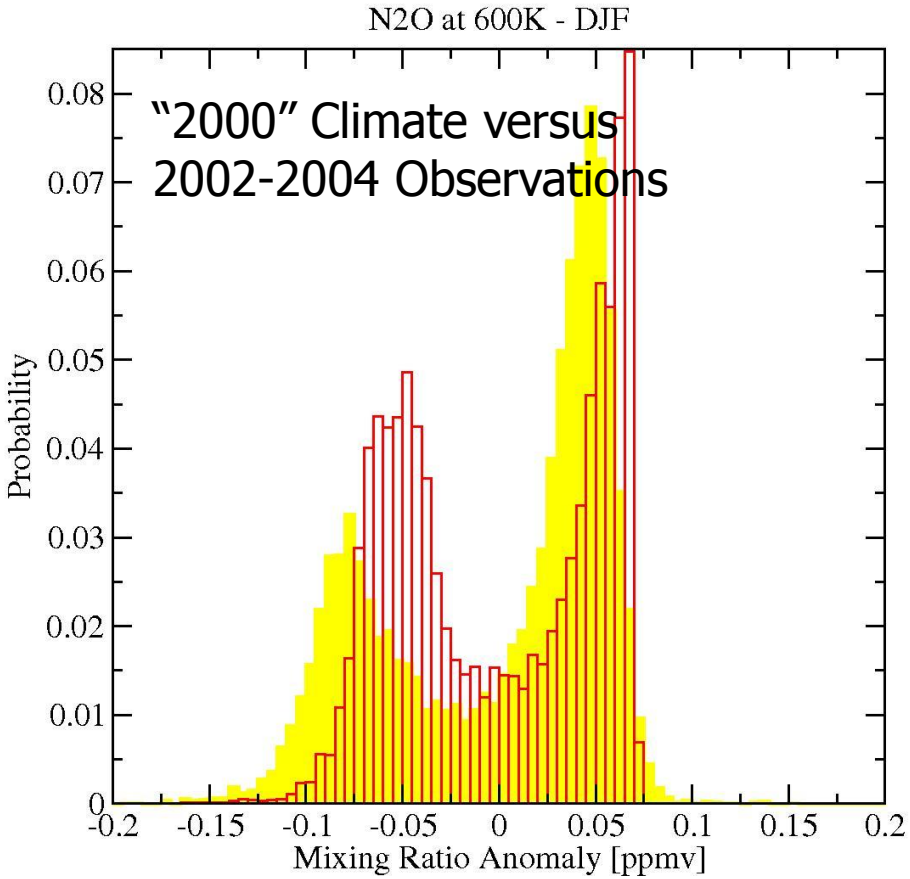
JAN

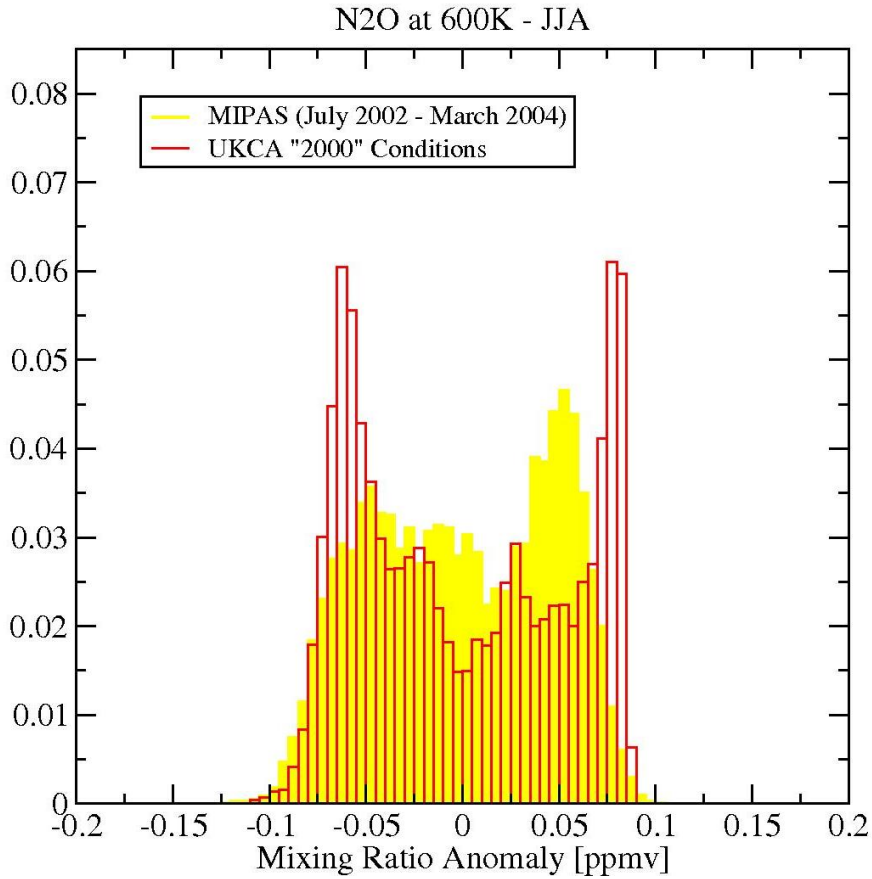
JUL



UKCA Validation

MIPAS data provided by Gabi Stiller, analysis PB





MIPAS N_2O: Yellow

UKCA N_2O: Red

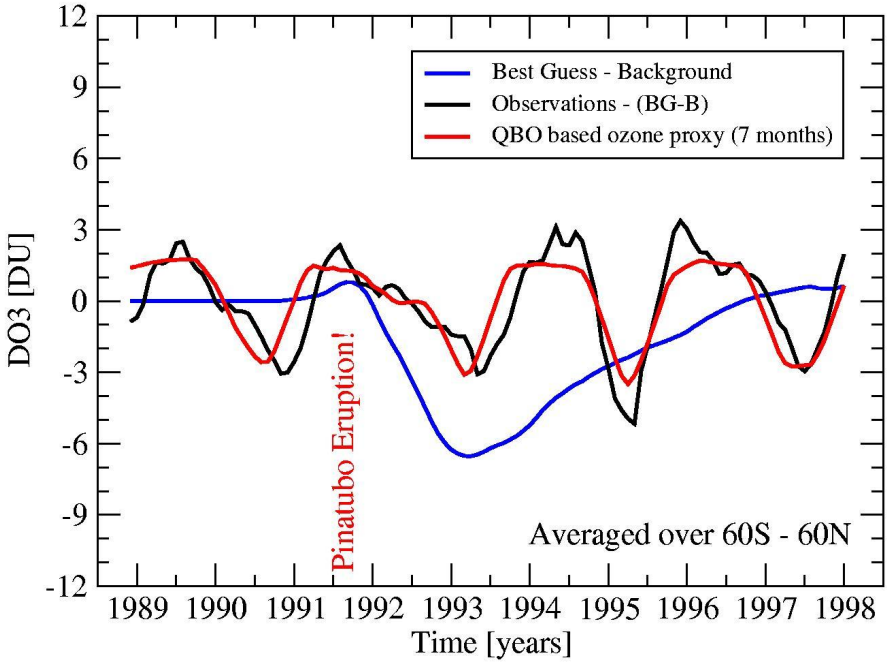
Closer link to satellite community!

Pinatubo
June 12, 1991
Three days before major eruption of
June 15, 1991

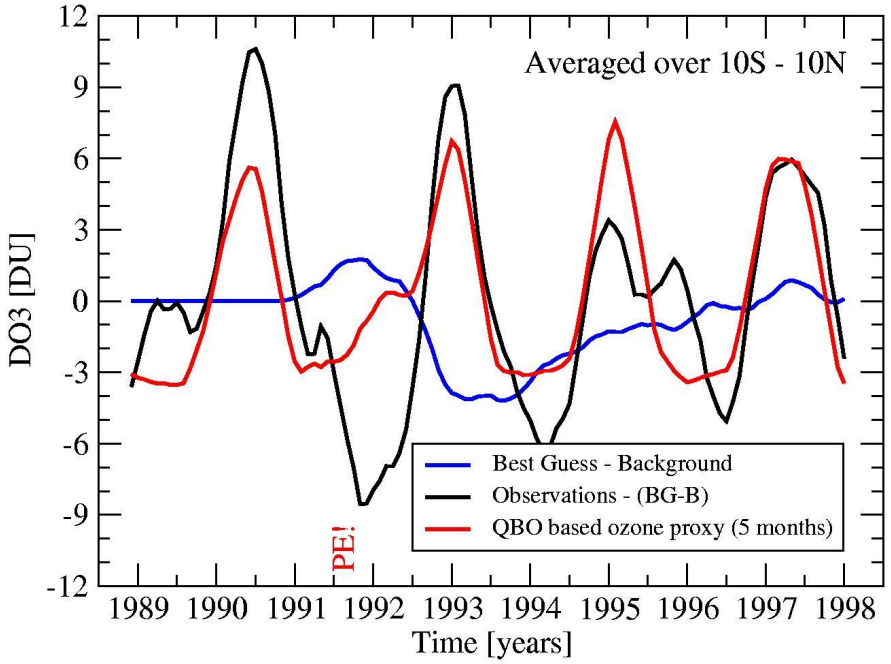
(Source: Alan Robock's volcano lecture)

Quantifying Pinatubo

"Global Ozone" (60S-60N)



"Tropical Ozone" (10S-10N)



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).

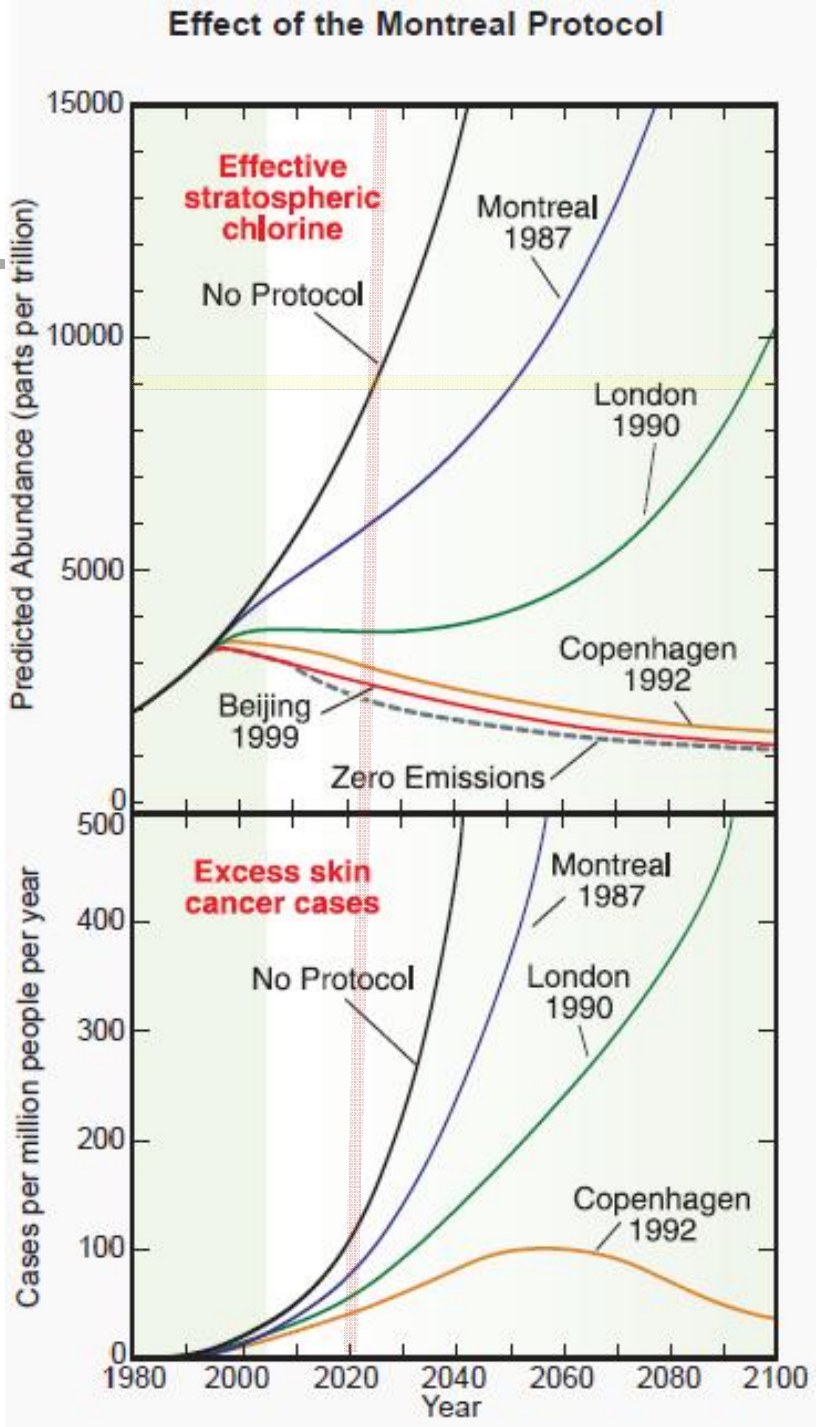
Paul Telford, Peter Braesicke and Olaf Morgenstern

The world avoided …

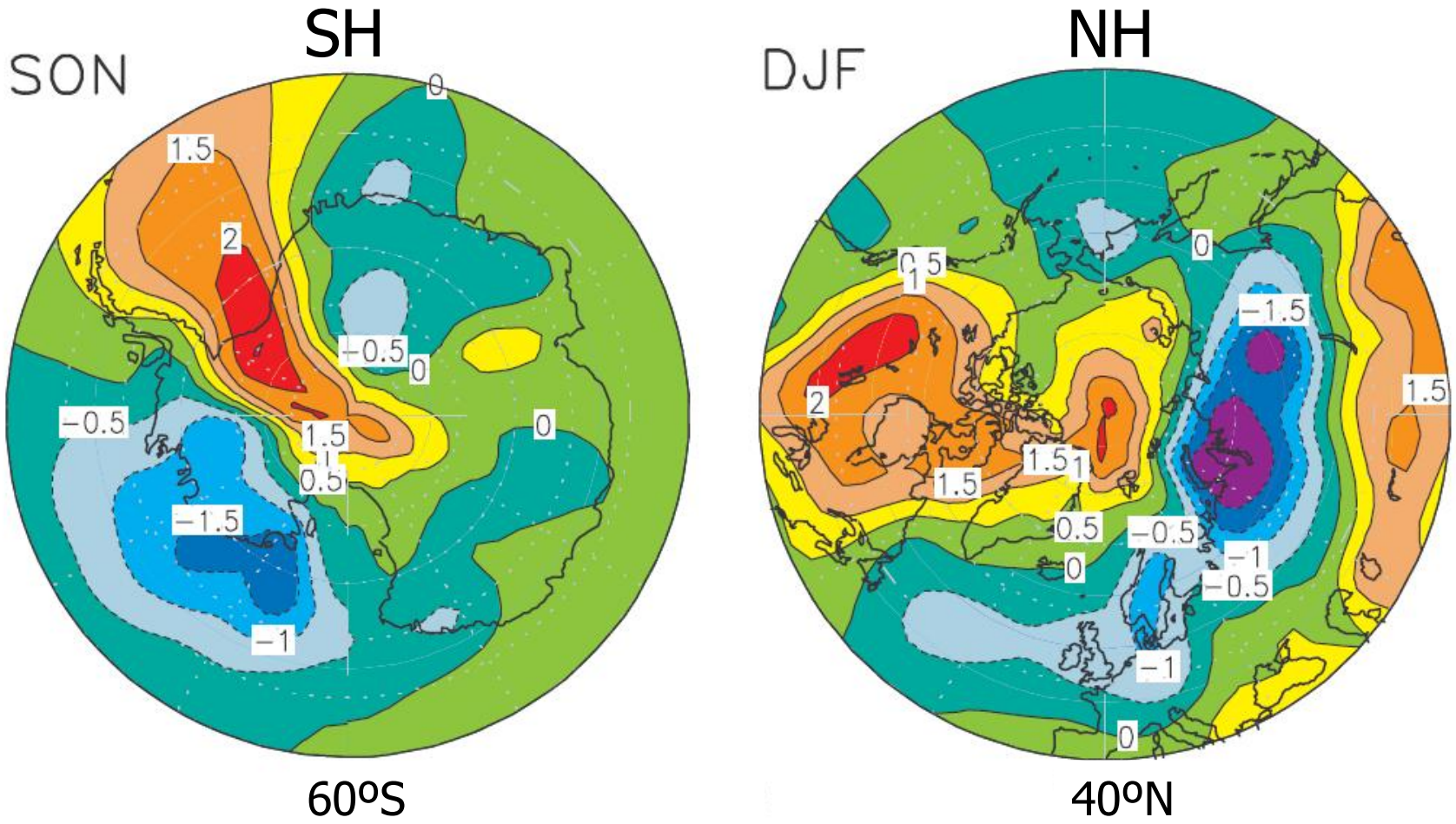
What would have happened without the Montreal Protocol and its amendments?

Here:
We study the impact of the avoided ozone changes only!

(Additional GHG impacts are not considered!)



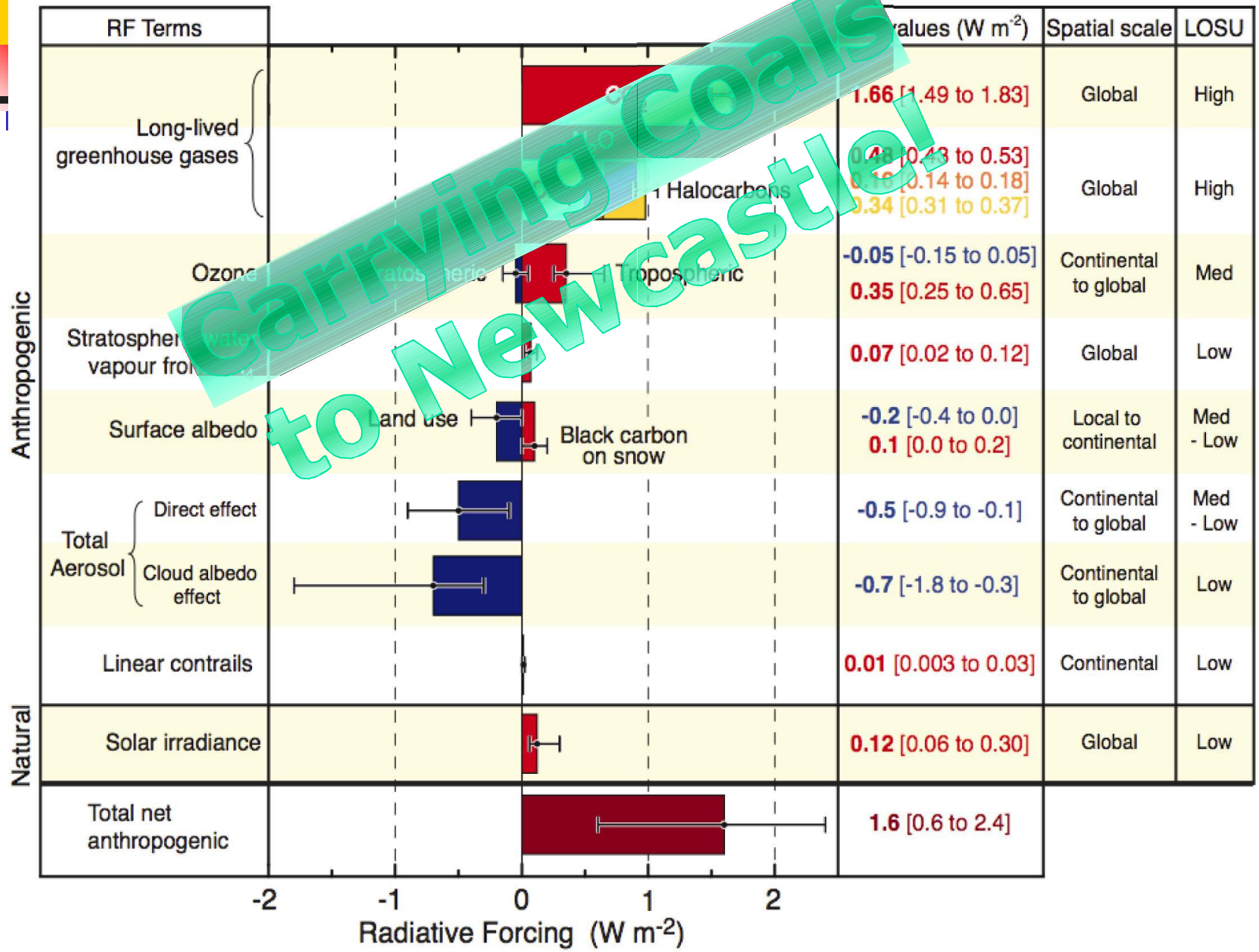
Temperature change avoided



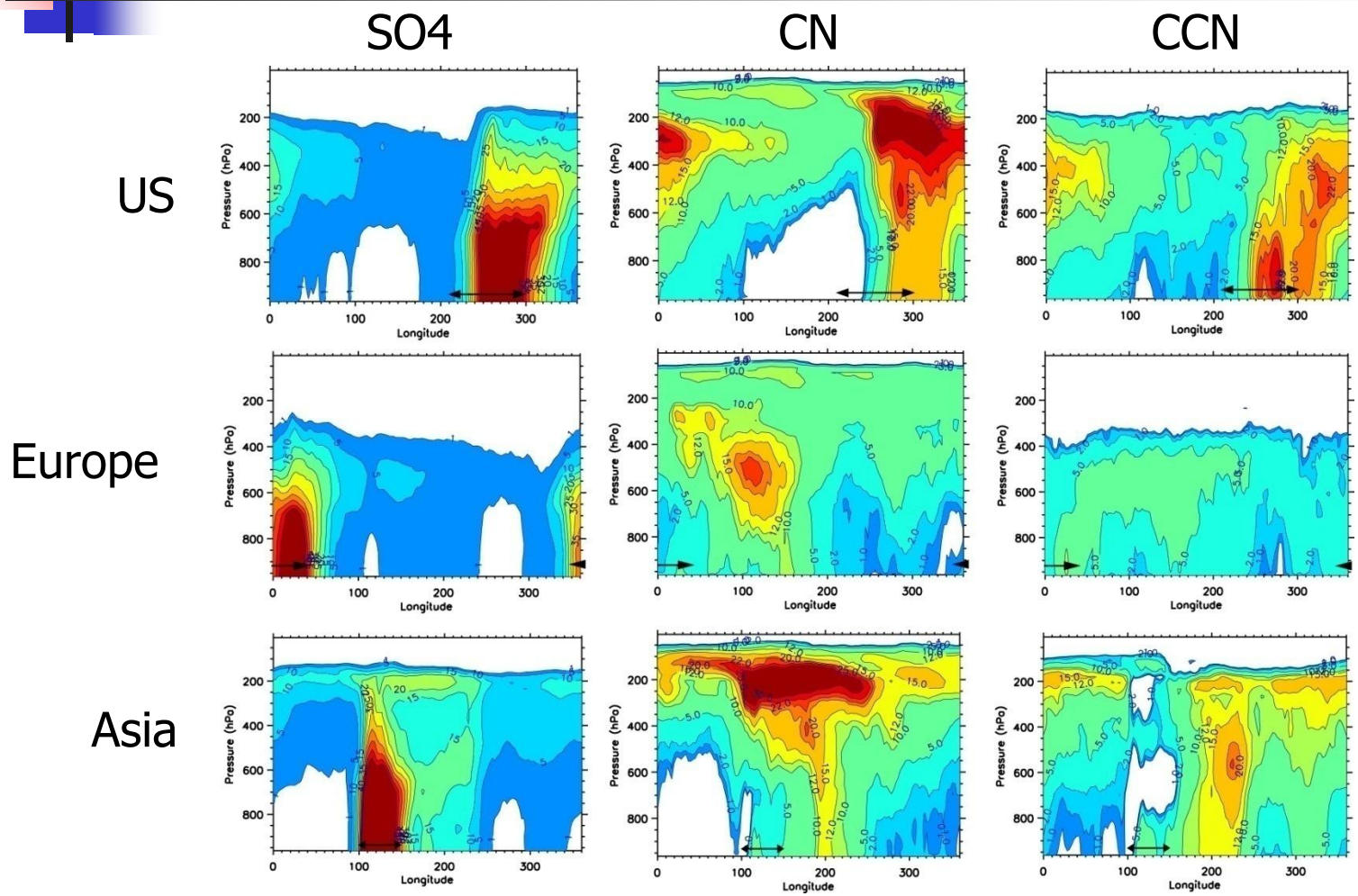
Morgenstern et al., GRL, 2008

Surface temperature change "avoided" by the implementation of the Montreal Protocol and its amendments …

Radiative Forcing Components

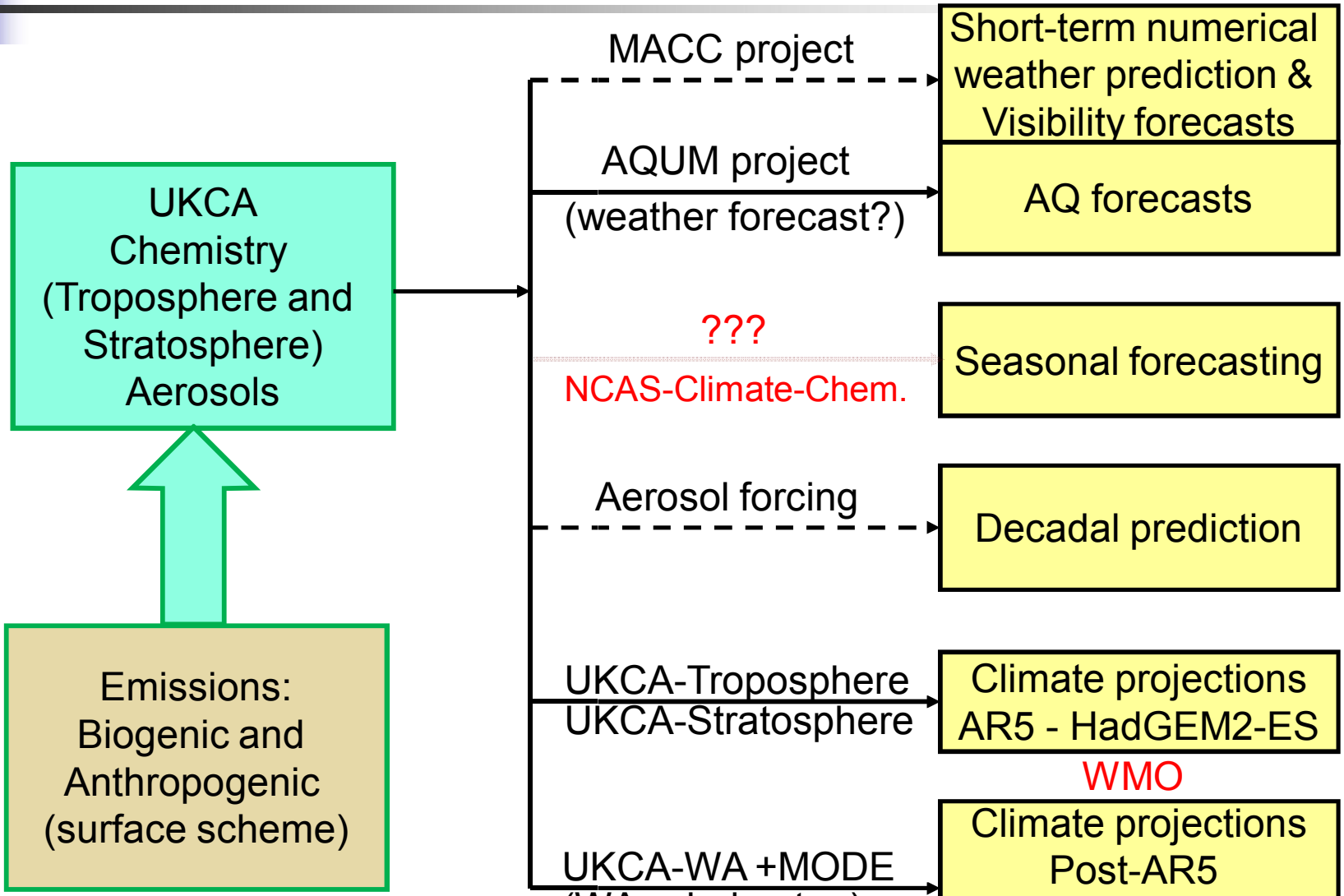


GLOMAP investigations: Radiative forcing potential of SO_2 emissions



New particle formation in Upper Troposphere.
Potential aerosol-cloud climate impacts of exported pollution varies by a factor 3 between Asia, US and Europe, (Manktelow, 2008, NCAS student)

ESMs & seamless predictions



Adapted from Olivier Boucher, Met Office

Met Office

Thank You!

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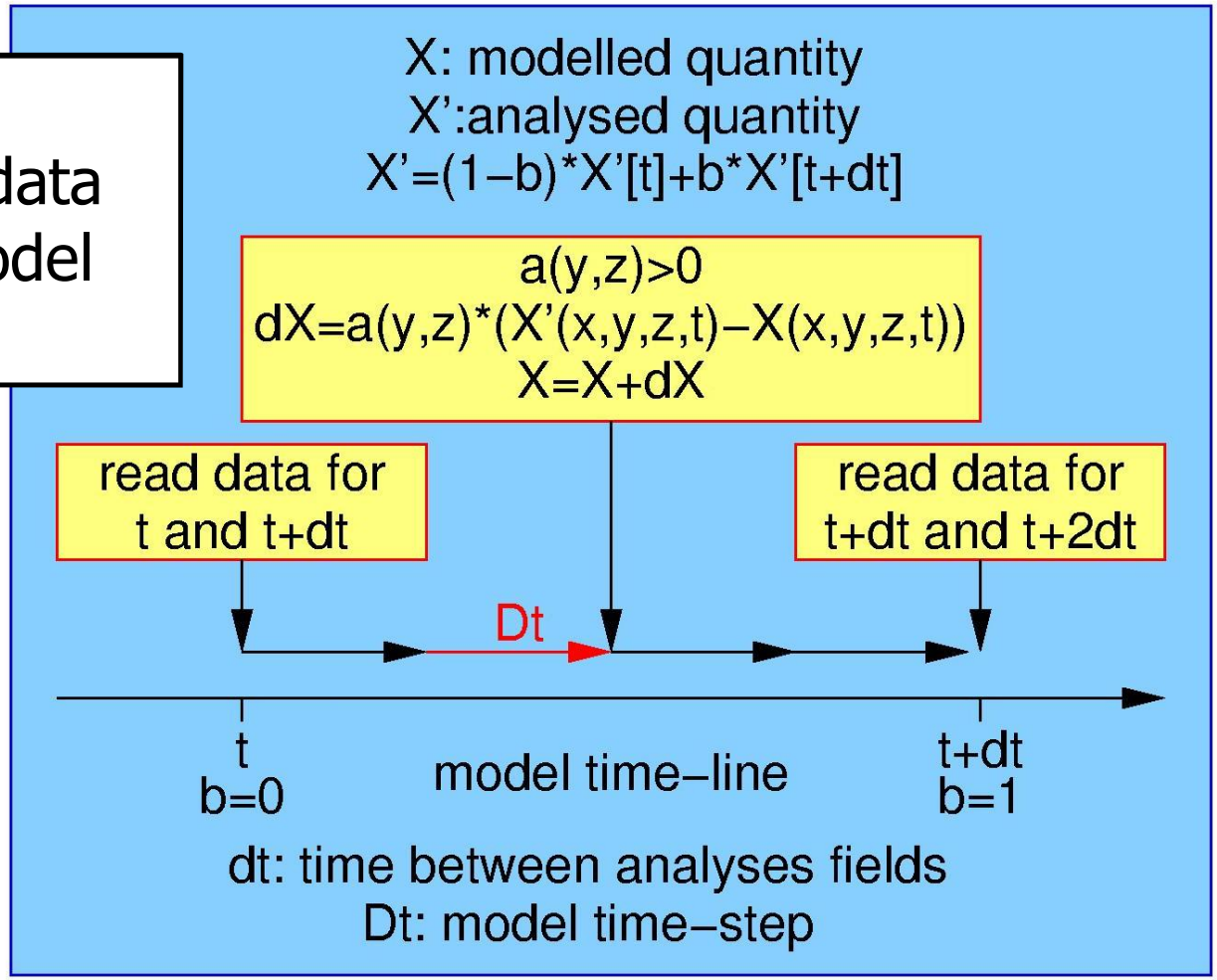
Some technical detail …

- Horizontal: N48 (3.75ºx2.5º), Arakawa-C
- Vertical: L60, hybrid height (non-hydrostatic), up to ~83km
- Transport: semi-Lagrangian scheme
  - Corrective conservative scheme, Priestly (1993)
  - A posteriori correction is applied to restore the desired quantity whilst minimizing changes to the original solution (mass conservation as controlled by underlying flux-form discretization for density; mass is globally conserved, but local elements abundance is not necessarily conserved)
- Parameterisations: comprehensive
- Here: SSTs and sea-ice are prescribed!

Nudged UKCA

Timescales:
6 hourly ECMWF data
15-30 minutes model time step

Telford et al., ACP, 2008



Model is constrained in zonal wind, meridional wind and potential temperature. The vertical velocity in the UM is a prognostic (and not a diagnostic) quantity!