School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE

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Enhanced UK capability in global aerosol modeling

Graham Mann
(University of Leeds)

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

Acknowledgements

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Steve Arnold, Matt Woodhouse, Tom Brieder,
Martyn Chipperfield, Olivier Boucher.

Changes in aerosol strongly impact climate

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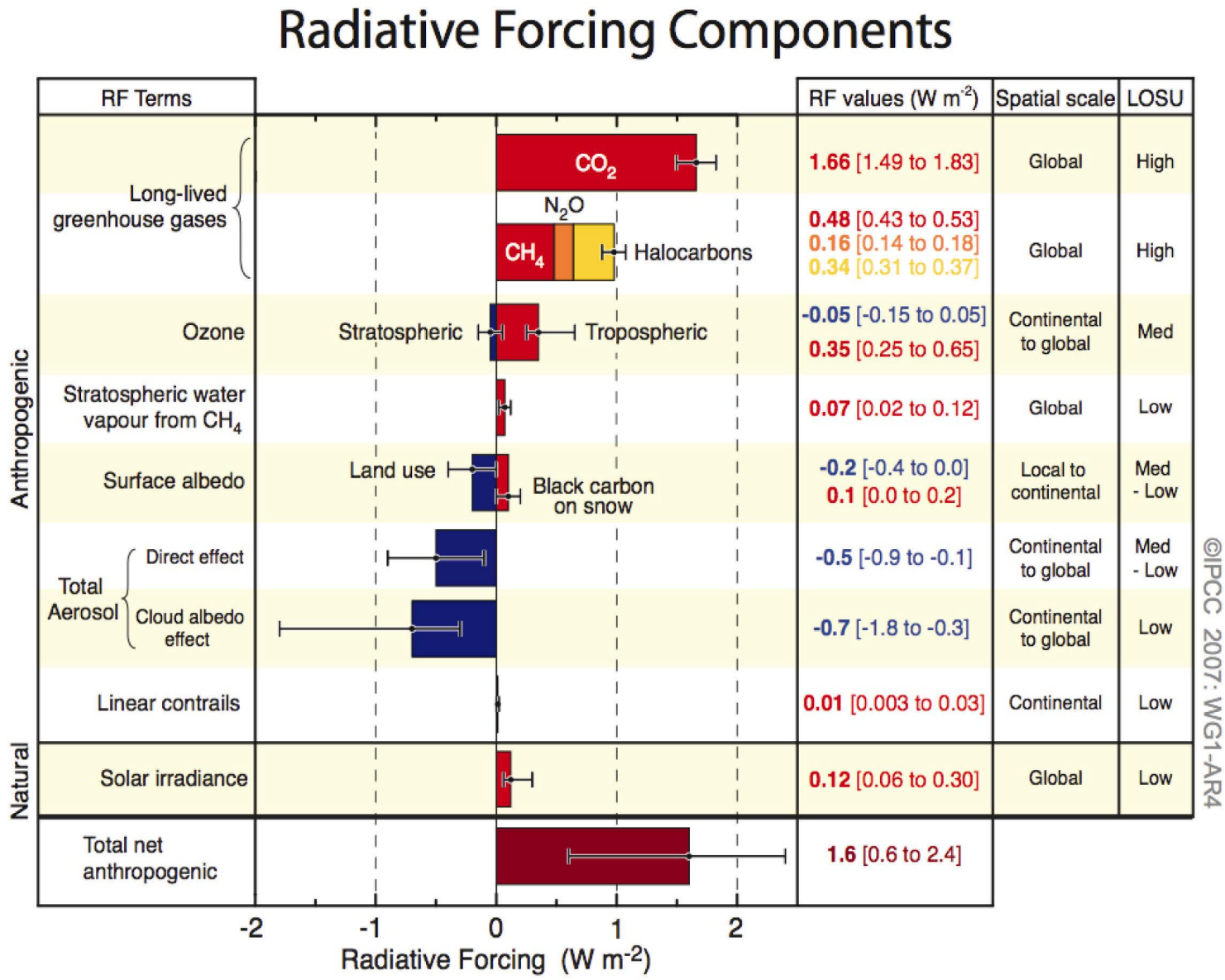

Aerosol representation in climate models

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IPCC models have hithero included only a simple representation of aerosols (CPU constraints).

Only mass of aerosol components is advected quantity:
(e.g., sulphate, black carbon, dust, sea-salt mass)

For size-dependent processes: An assumed size distribution

Direct aerosol forcing: Use composition-dependent mass scattering efficiency (or assume a fixed size distribution)

Indirect forcing: Use empirical cloud drop—aerosol relations,

New particle formation not included

Important aerosol types (e.g. organics, nitrate) omitted.

Processes control size & composition

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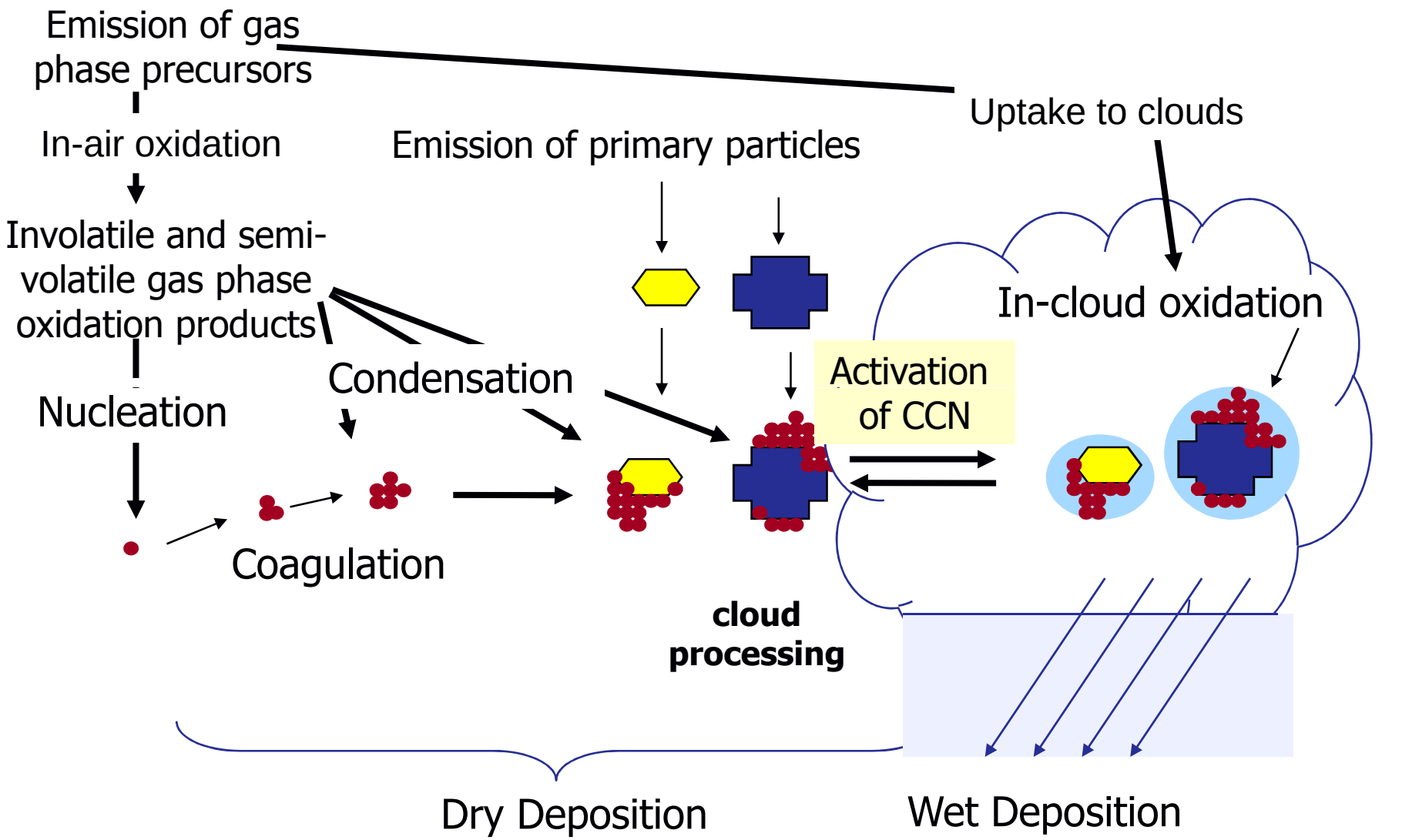

Global Model of Aerosol Processes (GLOMAP)

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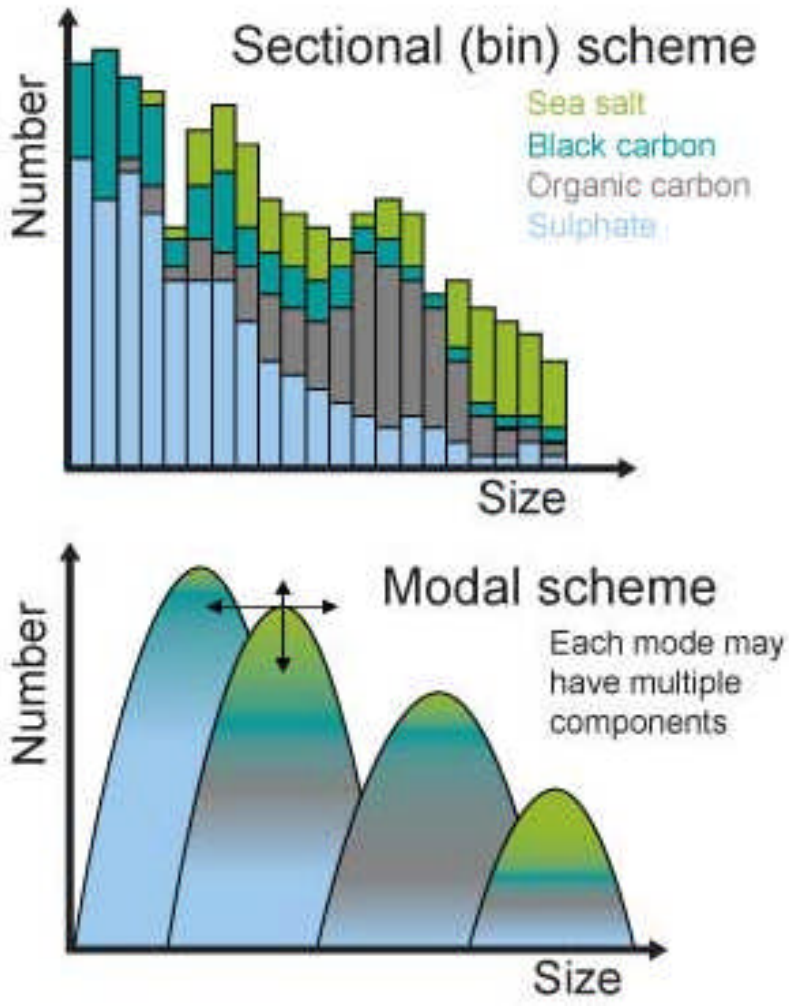
Developed in Leeds since 2003 to model global aerosol distribution with size-resolved representation of microphysics & chemistry.

Resolves processes that grow aerosol from nanometre sizes.

Simulate potential climate impacts with maximum degree of realism.

Analysed meteorology used to drive model.

Detailed & simple version of model.



Growth of particles from nanometres to cloud nucleii

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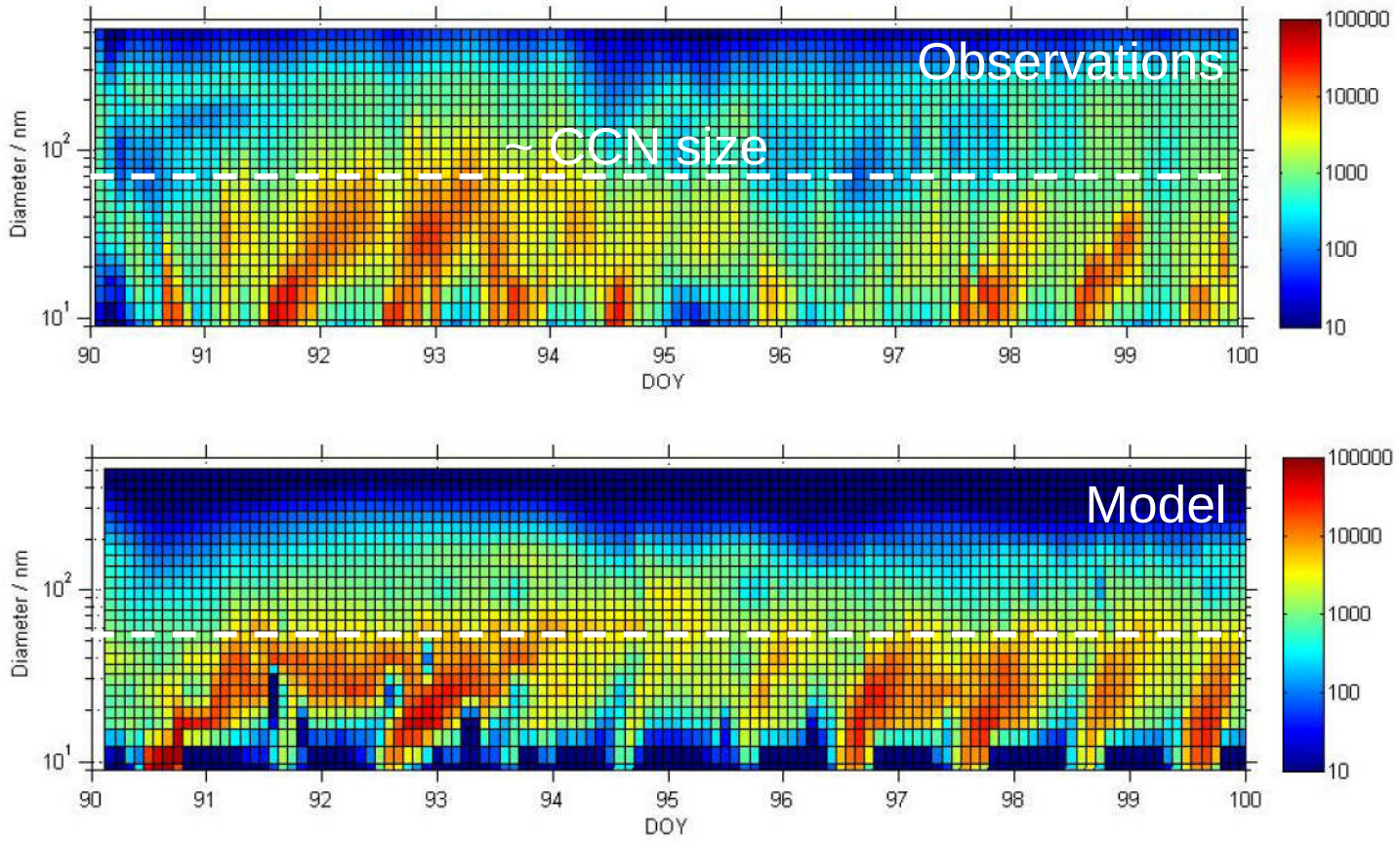
Observations at many sites show new particle formation at nanometre sizes and growth to cloud condensation nucleii (CCN) during long-range transport



UK Chemistry & Aerosols project (UKCA)

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- Collaboration between NCAS & UK Met Office Hadley Centre since 2005.
  Universities of Leeds & Cambridge main NCAS partners (Oxford & Reading)

- Aerosol-chemistry model in Met Office Unified Model environment
  for a range of applications (climate, Air Quality, Earth System science etc.)
  Developed simplified version of GLOMAP scheme for use in long timescale runs within General Circulation Model.

- Improves representation of aerosol in UK climate model
  -- resolves growth by simulating particle number as well as mass.

- Ongoing NERC projects using GLOMAP have elucidated controlling processes for aerosol impacts on climate (e.g. new particle formation, secondary organic aerosol, mechanistic activation, ultra-fine sea-spray).

- Ensures these and other new developments from other NCAS projects are pulled-through through to UK climate model aerosol.

- Enhances UK capability in aerosol-climate-earth system modeling and provides integration for NERC and Met Office initiatives.

UKCA in QUEST & HadGEM Earth System models

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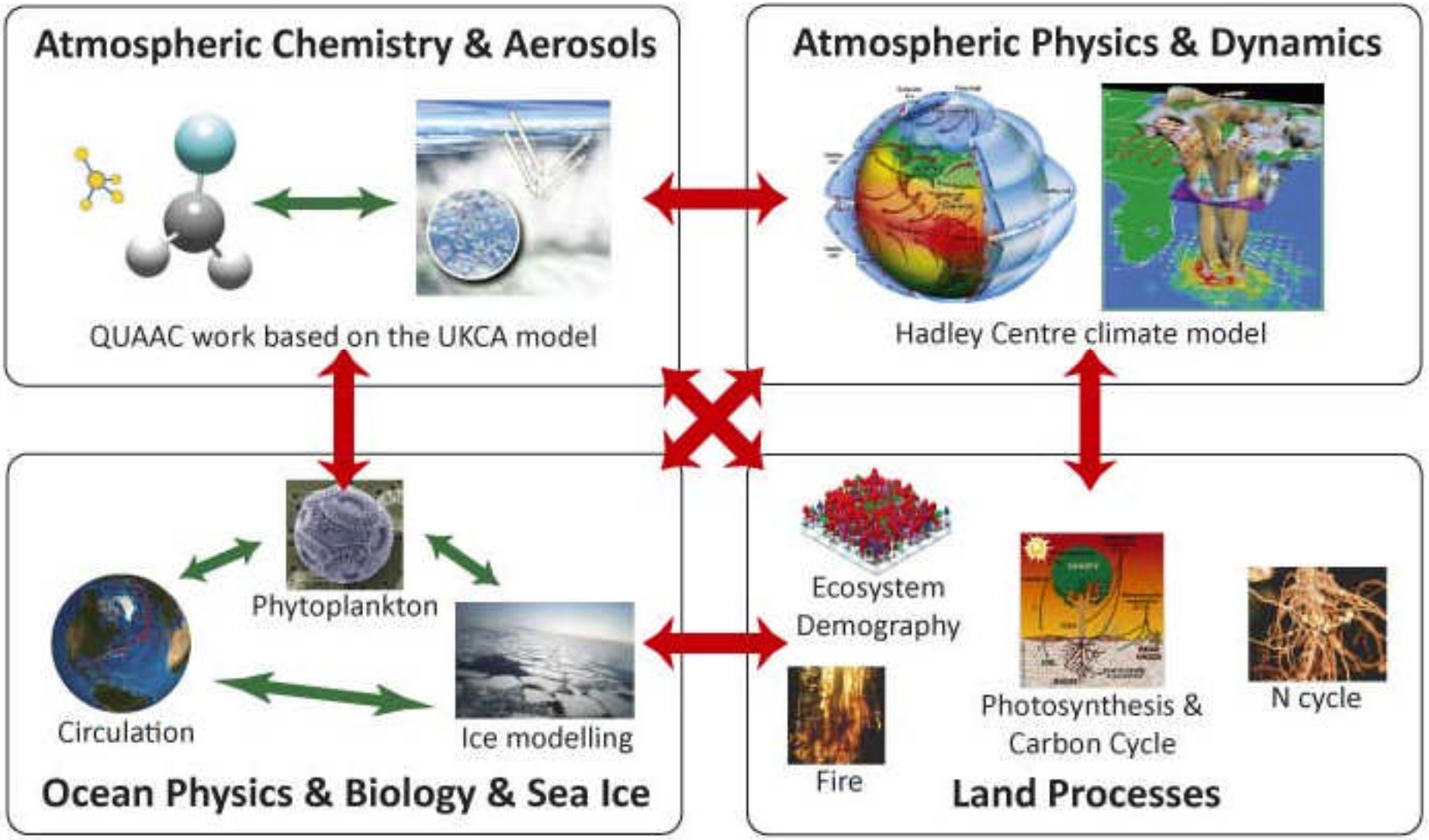

Earth system modelling within QUEST. Based on a diagram by M. Joshi

UKCA : Ensures NERC-MO knowledge exchange

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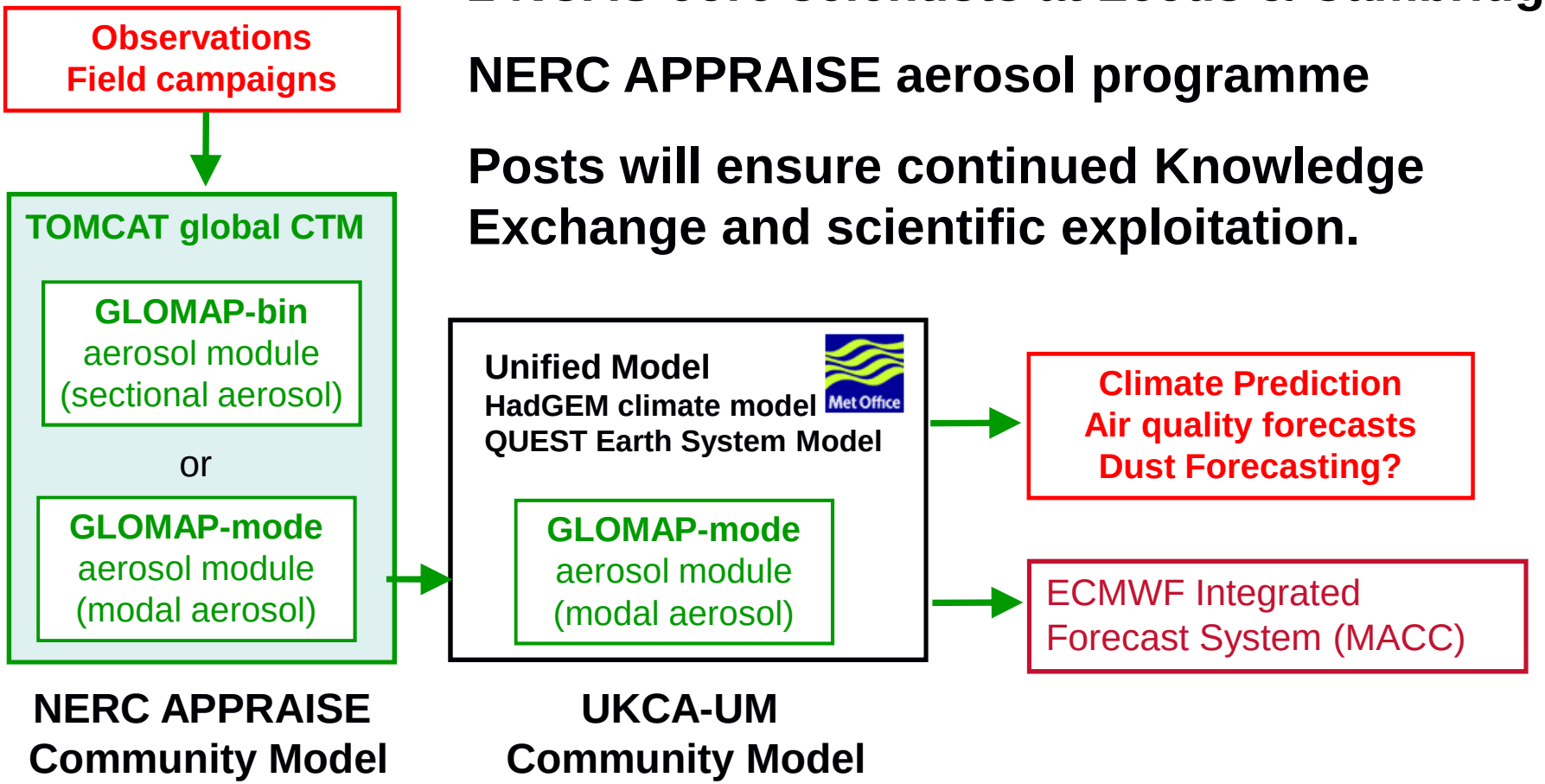
JCRP & NERC posts to support UKCA.

2 NCAS core scientists at Leeds & Cambridge

NERC APPRAISE aerosol programme

Posts will ensure continued Knowledge Exchange and scientific exploitation.



UKCA to be used at Met Office on range of scales

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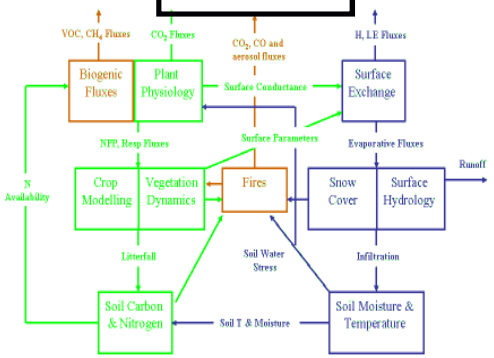
UM

Seamless prediction

UKCA Troposphere & Stratosphere & Aerosols

Biogenic emissions

JULES



Land surface

MACC project

AQUM project

Aerosol forcing

UKCA-trop
UKCA-strat

UKCA-whole atm
UKCA-MODE

Short-term numerical weather prediction & Visibility forecasts

AQ forecasts

Seasonal forecasting

Decadal prediction

Climate projections AR5 - HadGEM2-ES

Climate projections Post-AR5 HadGEM2/3-ES

Slide from O. Boucher, Met Office

GLOMAP investigations:
New particle formation & climate effects

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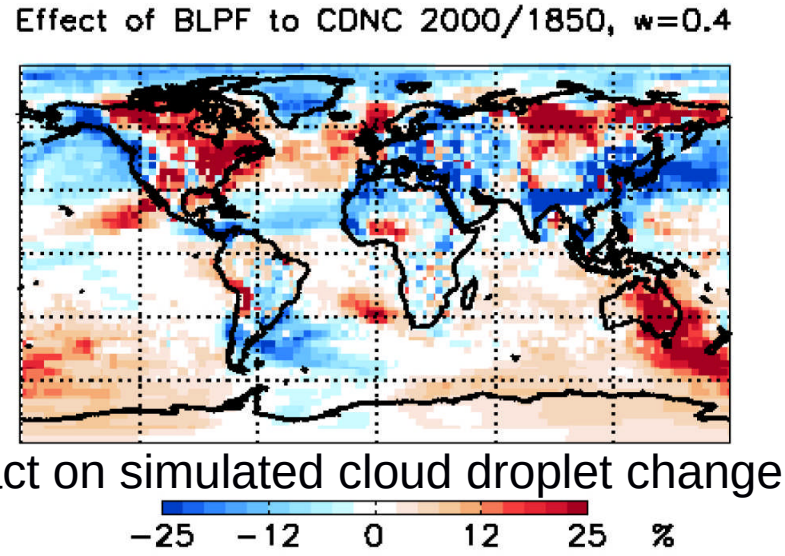
Including new particle formation substantially alters the simulated magnitude of indirect forcing
(+-50% change regionally)

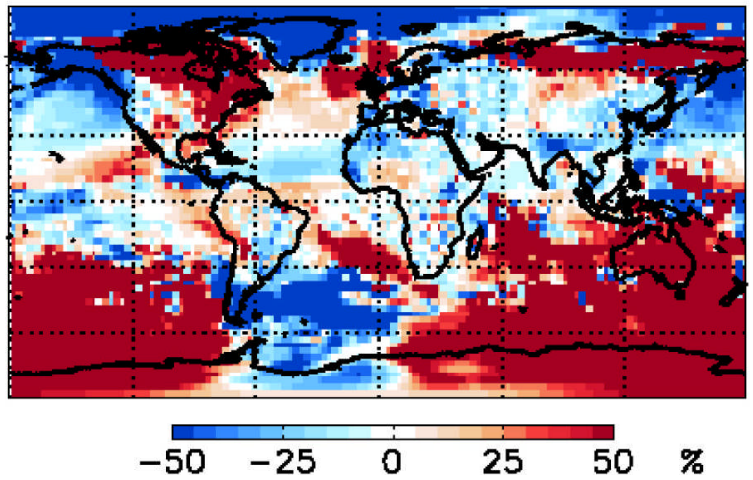
A neglected process in existing climate models

UKCA will ensure this is included in aerosol-climate simulations.



Impact on simulated cloud droplet change

Change in indirect forcing when NPF included.



GLOMAP investigations: Radiative forcing potential of SO_2 emissions

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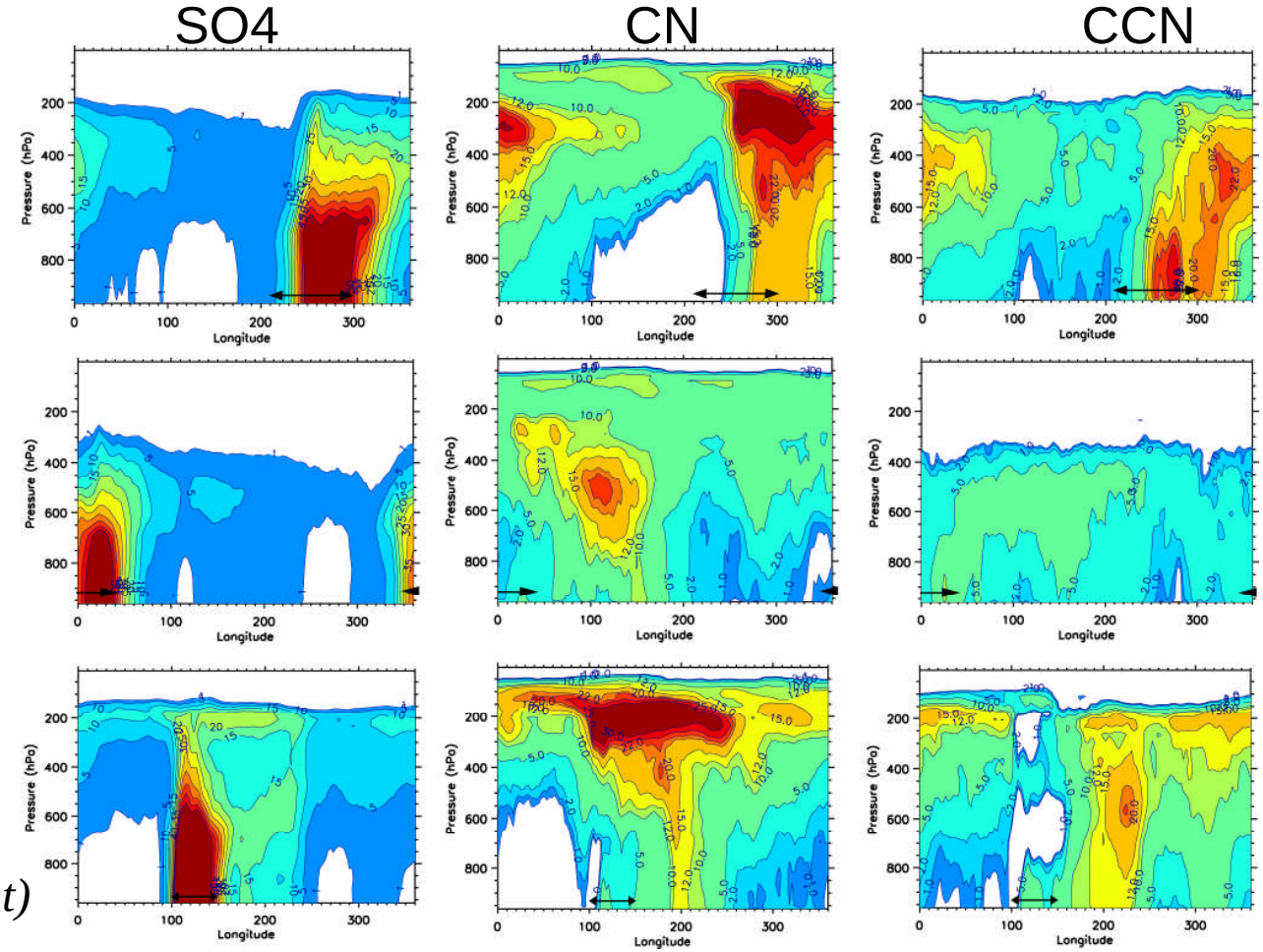
New particle formation in Upper Troposphere.
Potential aerosol-cloud climate impacts of exported pollution varies by a factor 3 between Asia, US and Europe



Manktelow 2008 (NCAS student)

GLOMAP investigations: CLAW hypothesis

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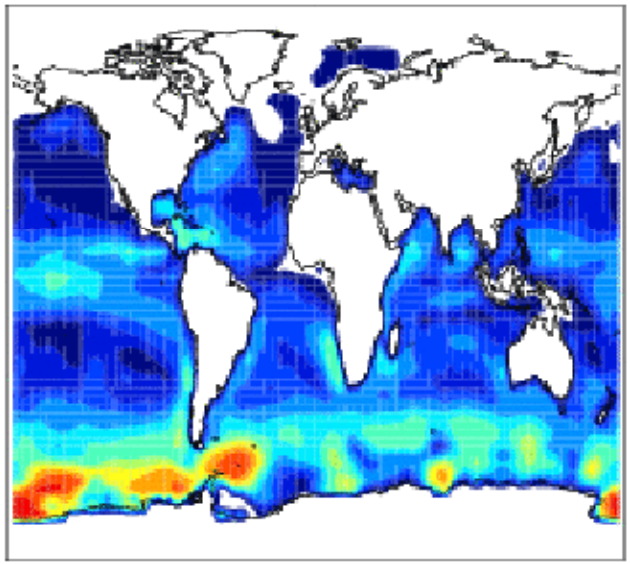
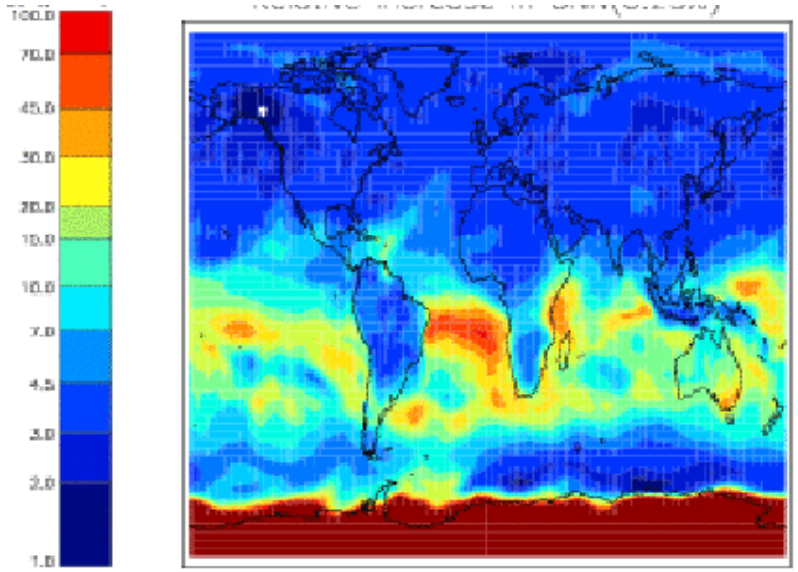
Suggested biogenic climate feedback via DMS-aerosol-cloud.
Climate impact of marine biota not well understood 20 years later.
Sensitivity studies in GLOMAP reveal role of DMS in climate.



Oceanic DMS emissions



% change in cloud nucleii when DMS included

Korhonen et al (2008, JGR)

Find effect of DMS on cloud very spatially inhomogeneous.

Low increase in CCN in 50-65S despite highest DMS emissions
Highest increase in CCN in 30-50S (>+50 cm-3, +70-100%)

GLOMAP investigations:
Sensitivity tests reveal controlling processes.

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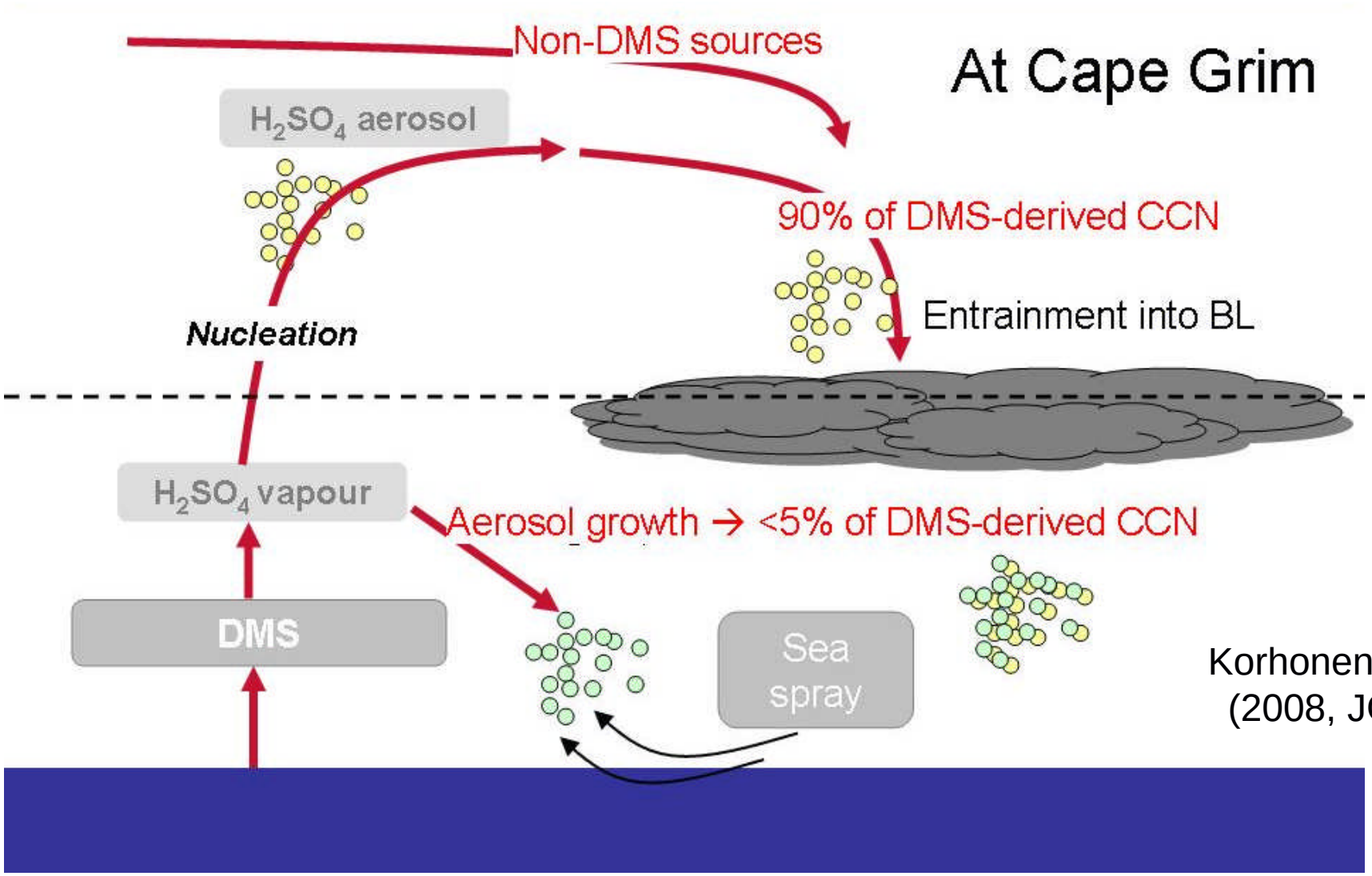

Korhonen et al (2008, JGR)

GLOMAP investigations:
Test geo-engineering ideas – e.g. fertilization on CCN

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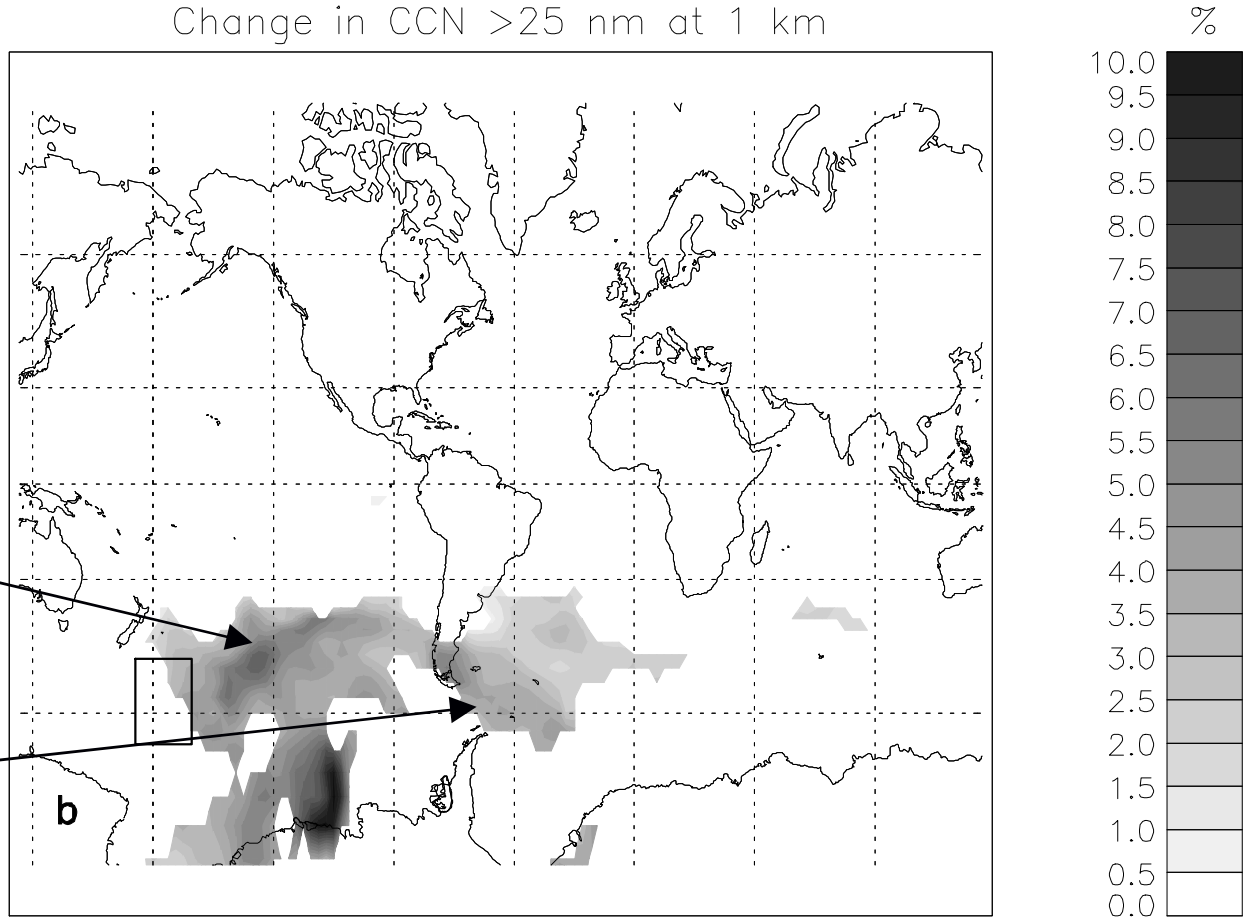
5 x DMS in seawater patch experiment

Matches SOFEX observed change in DMS following fertilization

Growth of existing particles near patch

Entrainment of new particles into BL far from patch due to nucleation, growth



(Woodhouse et al, Atmos. Env. 2008)
CASE studentsthip with Met Office

Find effect on cloud nucleii concentrations smaller than suggested, but potential cloud effects non-local to patch and widespread.

UKCA : future perspectives

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UKCA is a community model that will improve rapidly as it is applied and evaluated in many other projects. Current examples include:

The European Integrated Project (EUCAARI) using UKCA/UM as part of the Earth System modeling work package and campaign analysis

NERC APPRAISE Aerosol Programme (ADIENT direct effect and ACES organic aerosol consortia)

Stratospheric aerosol and geoengineering in a NERC Cambridge/Leeds collaboration

Met Office CASE projects: Heterogeneous chemistry; Dust and DMS in the Earth System; Arctic aerosol/climate; Ozone indirect effects; Cloud drop number and indirect effect

UKCA is the basis for NERC's new QUEST Earth System Model

Will be implemented in the ECMWF-IFS in the EU MACC project

Already ensuring maximum Knowledge Exchange & integration between Met Office and NERC NCAS projects.