School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE

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The Aerosol Component of UKCA

Ken Carslaw and Graham Mann

Acknowledgements

Dominick Spracklen, Hannele Korhonen

Joonas Merikanto, Paul Manktelow, Kirsty Pringle, Dave Ridley

Martyn Chipperfield, Olivier Boucher, Colin Johnson

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

Content

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Background and motivation

Existing CLASSIC aerosol scheme versus UKCA

Description of model microphysics

Some results and evaluation

Model applications

Role of UKCA team

Aerosol representation in climate models

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IPCC climate models have mostly included only a simple representation of aerosols

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

Assumed size distribution

Chemical components not mixed

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

Indirect forcing: Use empirical cloud drop—aerosol relations

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

Processes control size & composition

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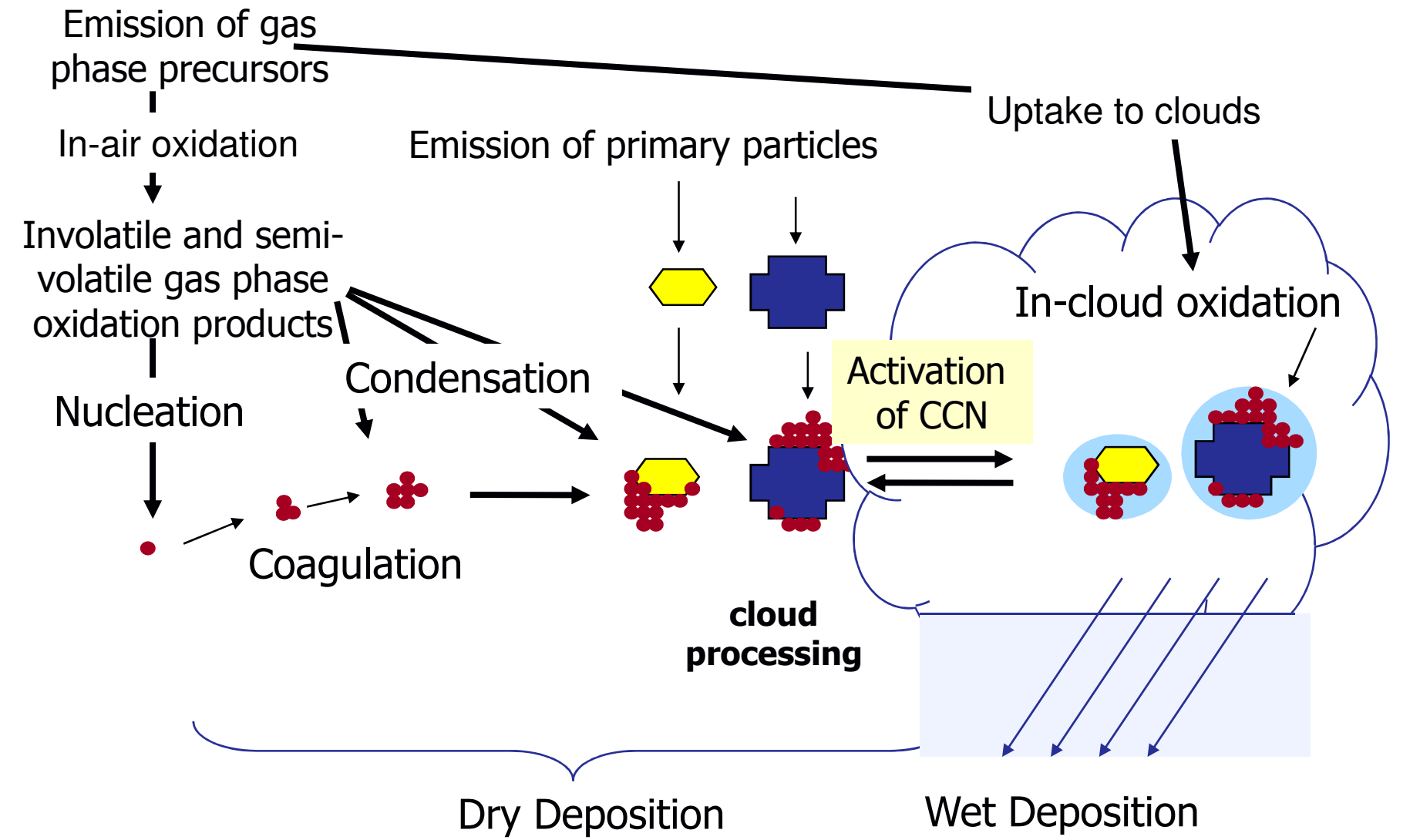

Observations show large variation in size

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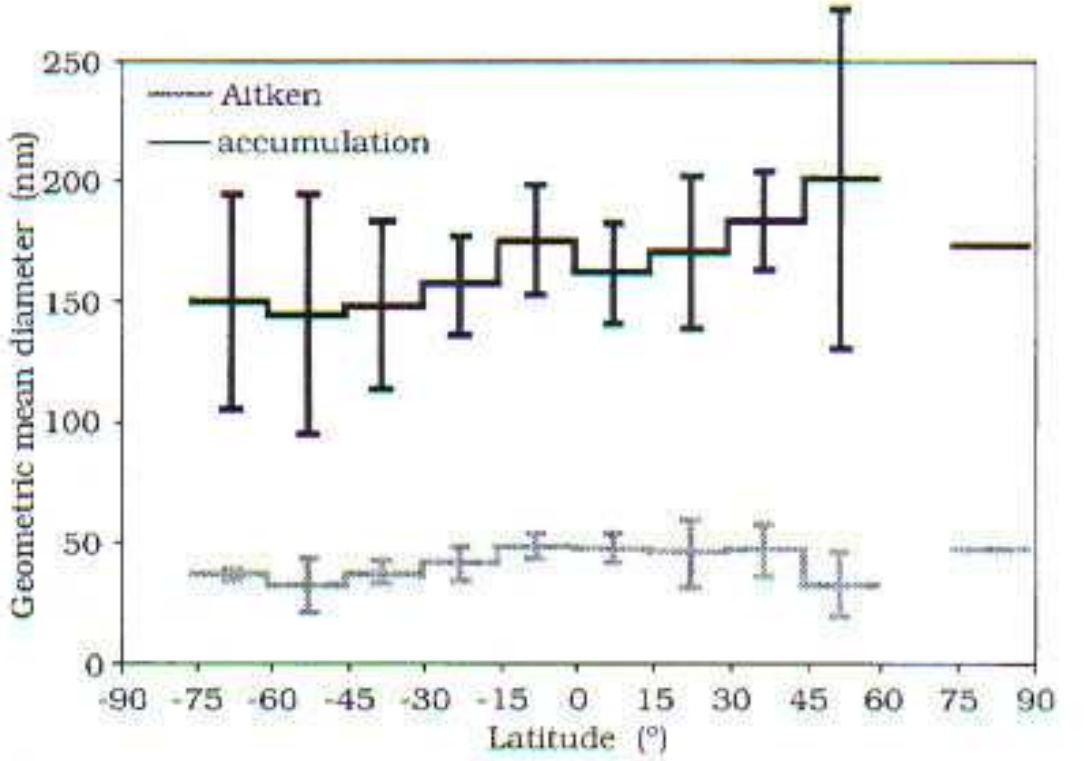

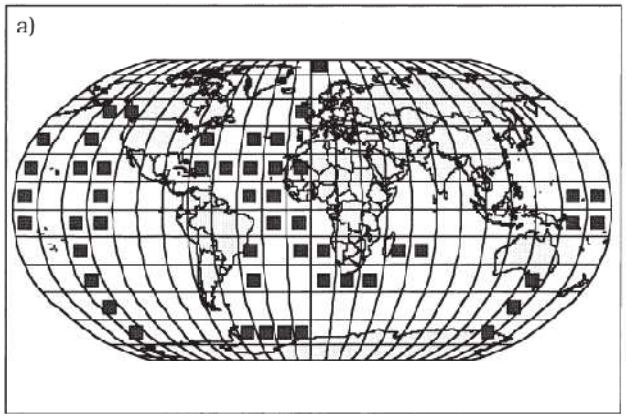

Heintzenberg et al (2000, Tellus B)

Table 1. *Sources of data on aerosol concentration and number-size distribution*

Source	Geographical area/ experiment
Bates et al., 1998b	Tasman Sea, Southern Ocean, ACE 1
Covert et al., 1996b	Arctic, IAOE91
Covert et al., 1996a	Central Pacific, MAGE
Covert et al. (unpublished data)	Equatorial Western Pacific, CSP
Davison et al., 1996a	Southern Ocean
Heintzenberg and Leck, 1994	Arctic
Jaenicke et al., 1992	Southern Ocean
Jensen et al., 1996	North E Atlantic, ASTEX
Leaitch et al., 1996	NW Atlantic
Quinn et al., 1990	Central N Pacific, MAGE
Quinn et al., 1993	Central Eastern Pacific, MAGE
Quinn et al., 1995	Central Pacific, MAGE
Quinn et al., 1996	Central Pacific, MAGE
Raes et al., 1997	Tenerife
Van Dingenen et al., 1995	North Atlantic
Van Dingenen et al. (unpublished data)	Tenerife, ACE 2
Wiedensohler et al. (unpublished data)	Tasman Sea, Southern Ocean, ACE 1
Nowak et al. (unpublished data	North and South Atlantic, Indic, AEROCRUISE 1999

Cloud drop number-aerosol relations

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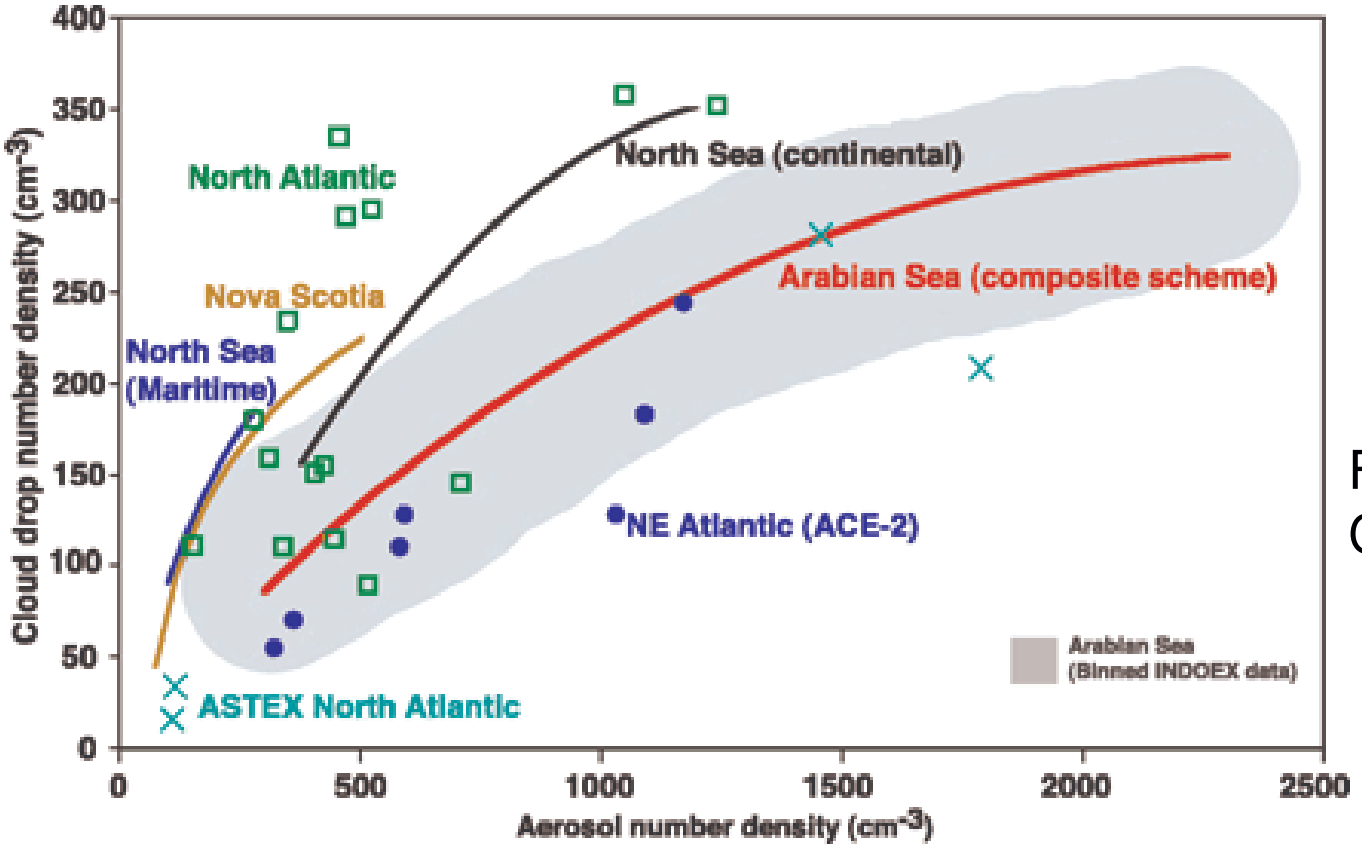

From Ramanathan, Crutzen et al (2001)

- No single relationship fits observed CDN vs aerosol number.
- Different regions have different particle types, size distbtn, etc.

Importance of driving processes

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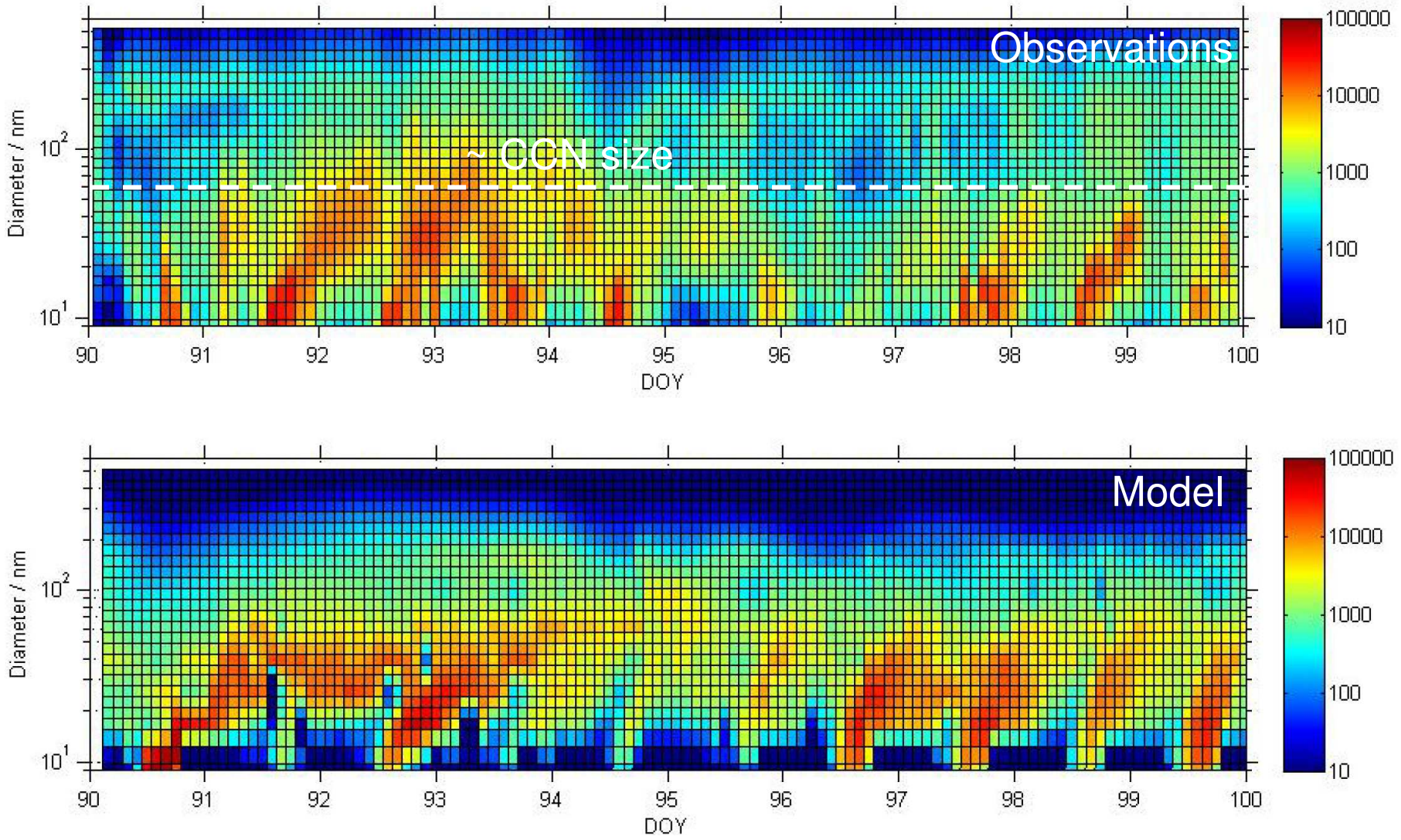
Growth of new particles to cloud condensation nuclei



Priority UKCA aerosol developments

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Dynamic aerosol size distribution (particle size distribution)

Internal mixing of particles

Missing components (NH_4, NO_3, SOA, etc)

Coupled aerosol-chemistry

Dedicated UM sub-model

Existing UM aerosol scheme (CLASSIC)

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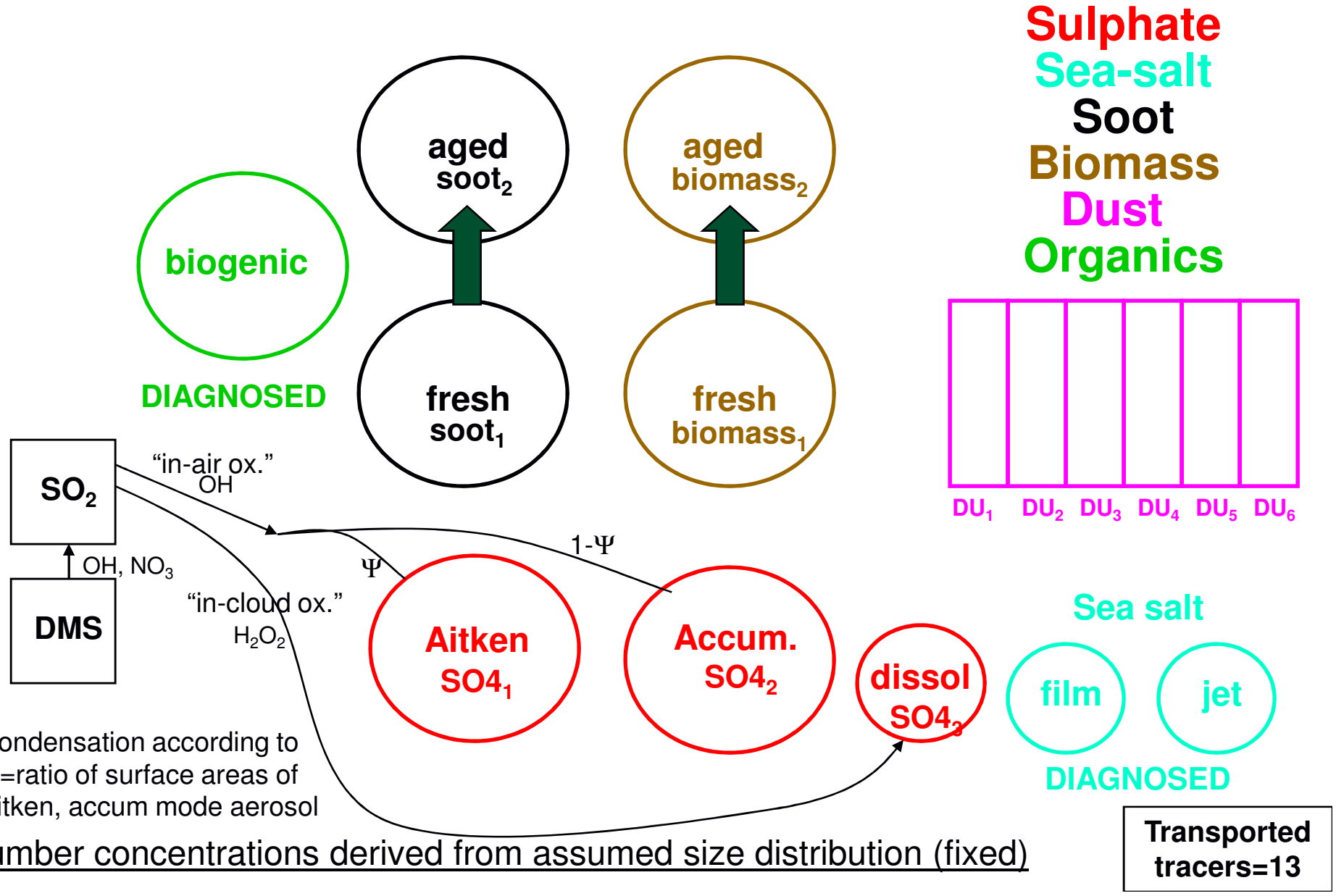

UKCA standard aerosol structure

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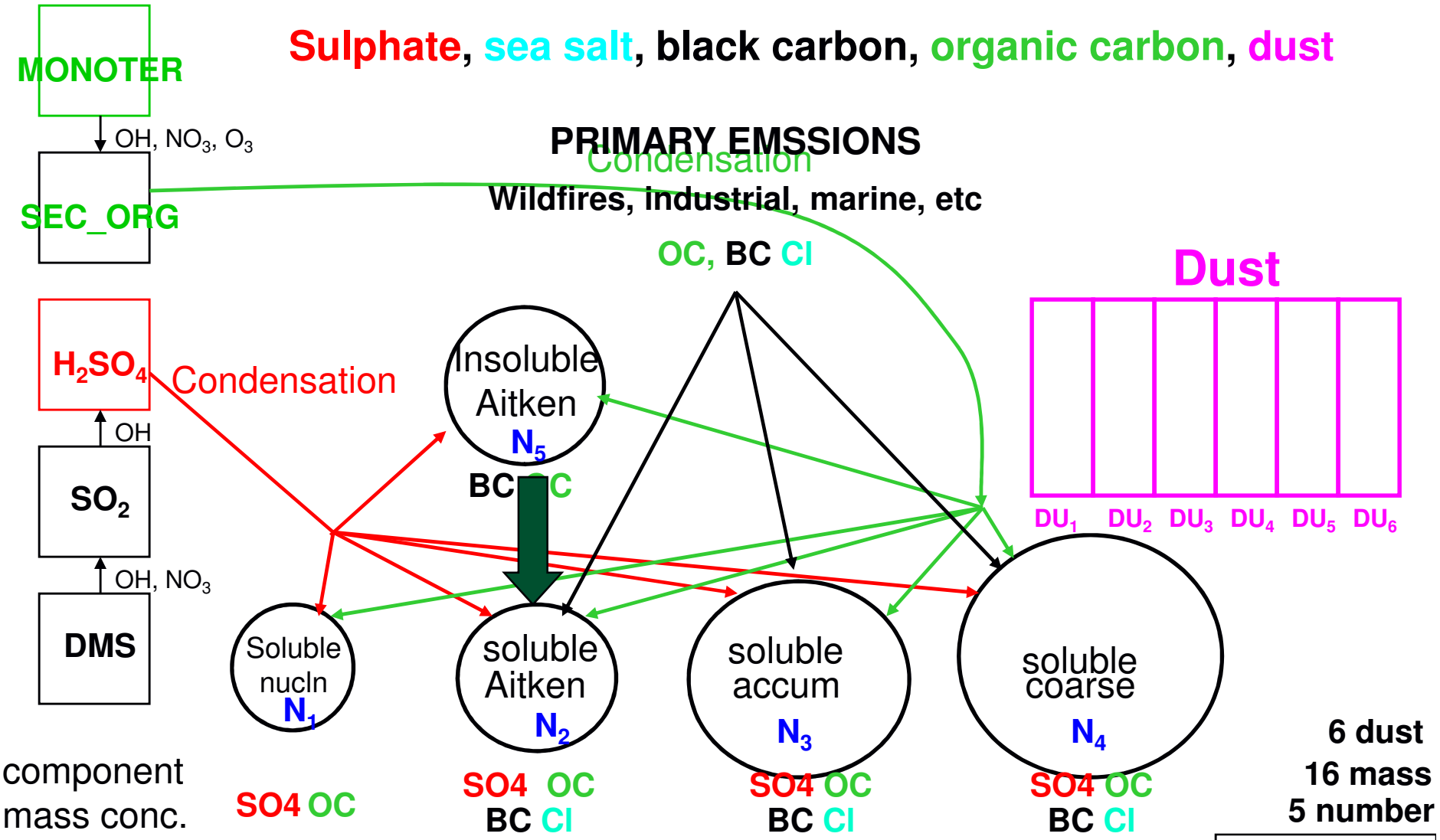

no. conc'ns controlled by NPF, primary emissions, coagulation, removal.

CLASSIC and UKCA compared

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	CLASSIC	UKCA
Transported particle types	Associated with emissions (sulphate, biomass, etc)	Defined by microphysics (Aitken, accumulation, etc)
Size distribution	Prognostic m Fixed size N derived from m and size	Prognostic N, m Variable size Log-normal modes
Mixed composition	No	Yes
Chemistry	Offline oxidants	Coupled chemistry
Cloud drop number	From mass	From size, N, mixed composition
Particulate tracers	13	27 (min 24)

UKCA collaboration

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Leeds: aerosol dynamics, composition, evaluation

Inorganic mixed aerosol composition was supported by Manchester's DIAC work

Secondary organic aerosol development as part of the QUEST-QUAAC project

Met Office: Precursor chemistry (Rae, Johnson), cloud chemistry (Rae), radiation coupling (Bellouin), UM sub-model coding (Johnson)

Cambridge: Trop and strat chemistry, nudging

UKCA aerosol strategy

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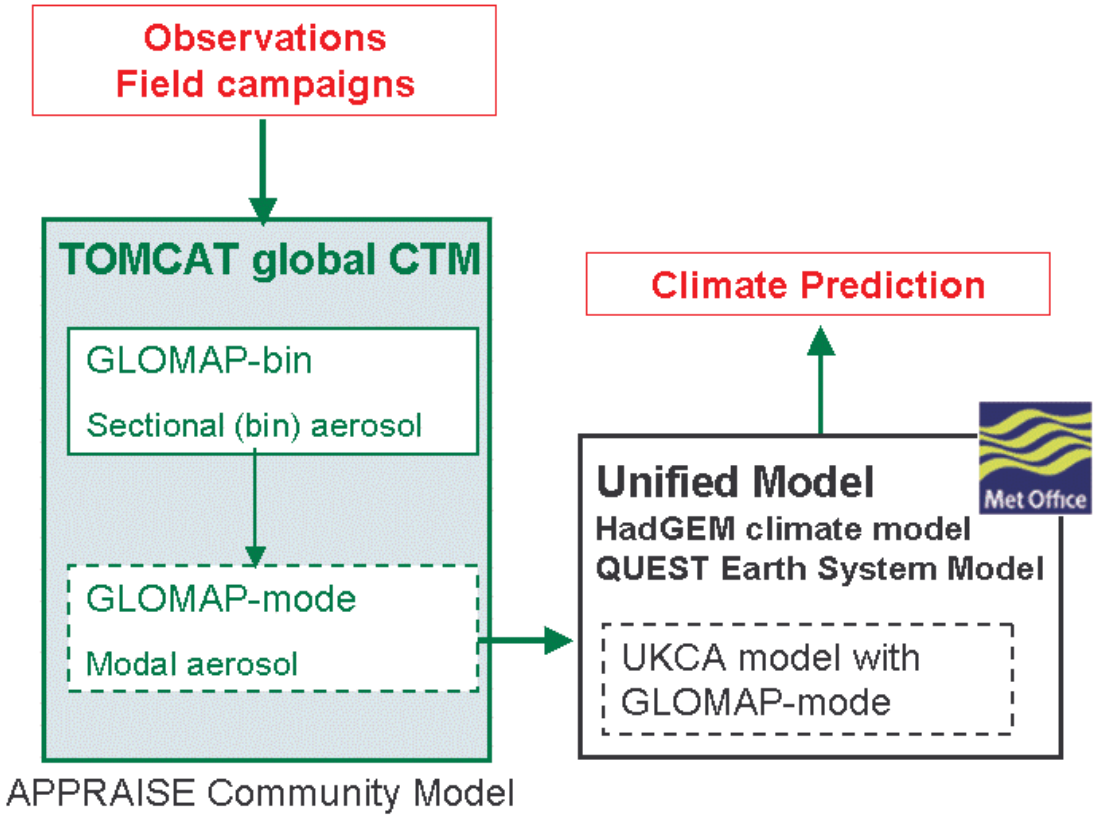
UKCA is part of a wider development of global aerosol models

GLOMAP-mode: As in UKCA (also in TOMCAT CTM)

GLOMAP-bin: a bin-resolved version in TOMCAT



Strong connection between the future development of UKCA and new observations and process knowledge

Example UKCA results (UMv6.6) – October mean

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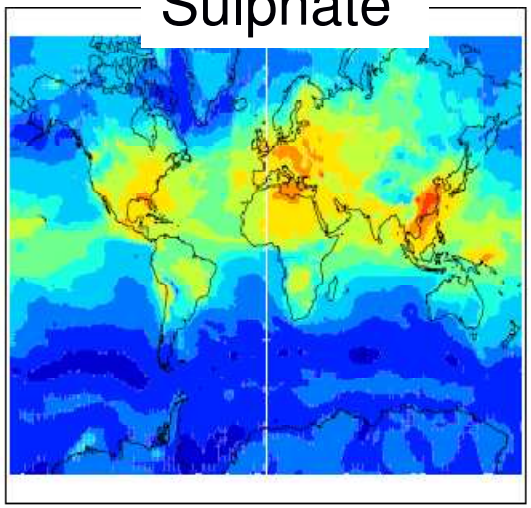
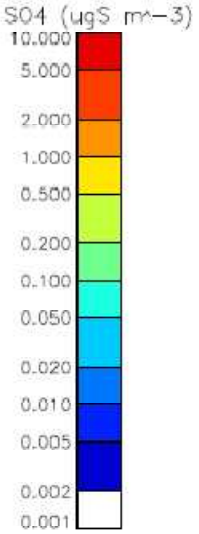
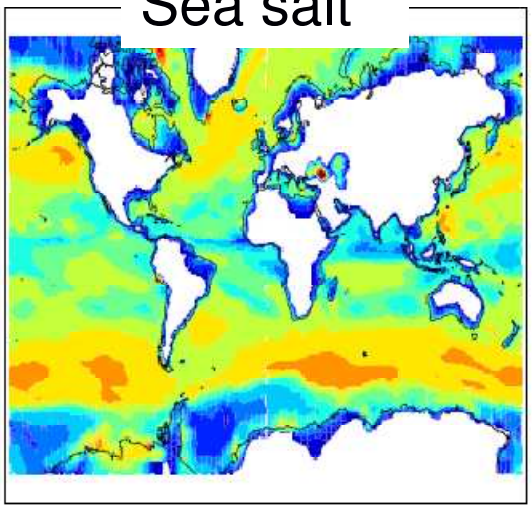
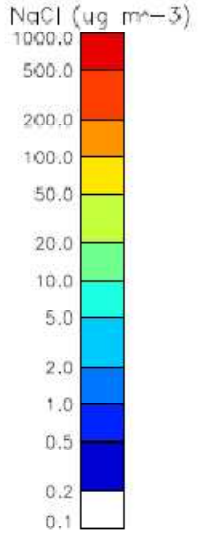
Sulphate



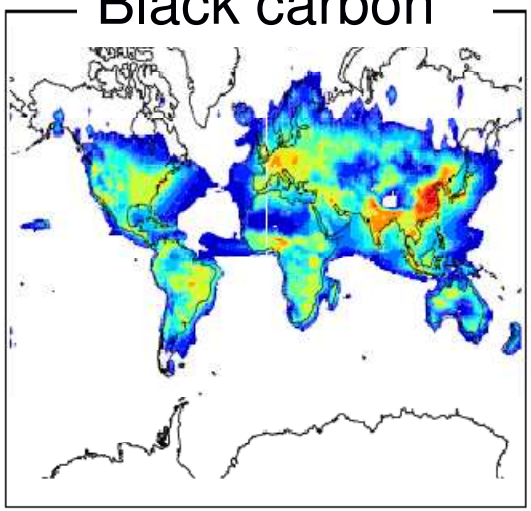


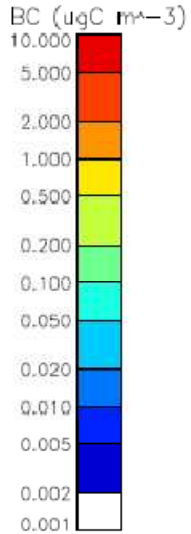
Sea salt



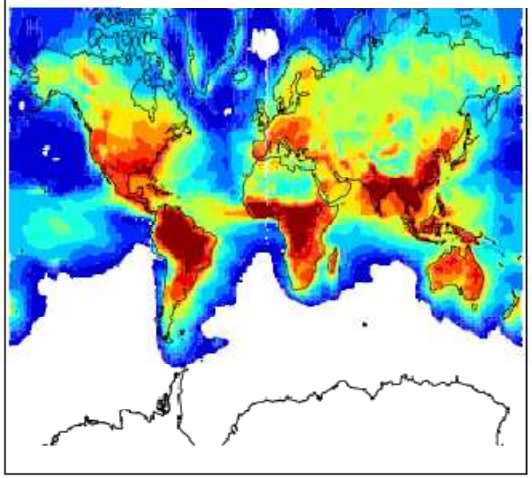


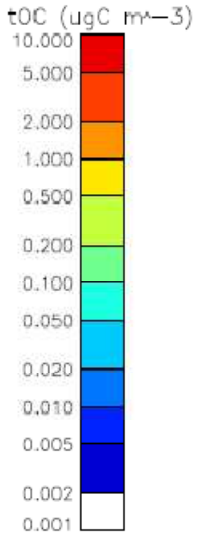
Black carbon





Organics





Example UKCA results (UMv6.6) – October mean

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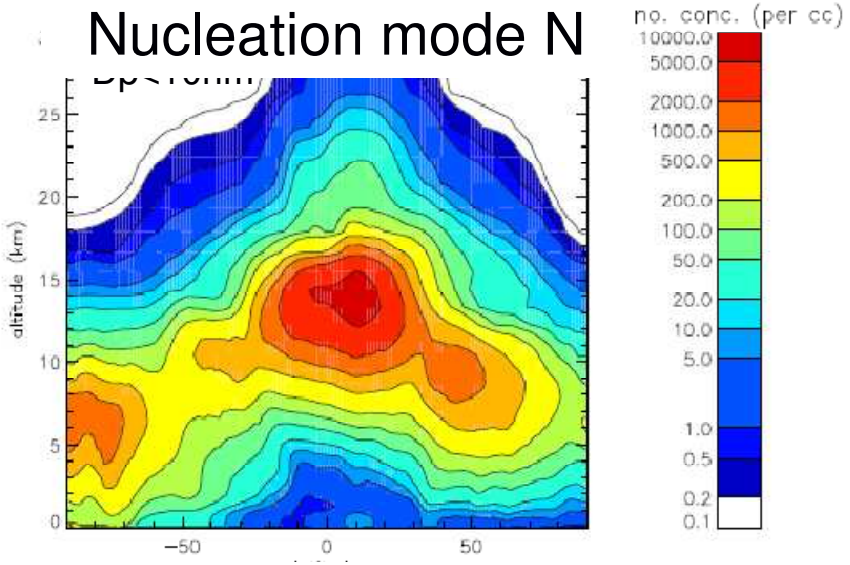
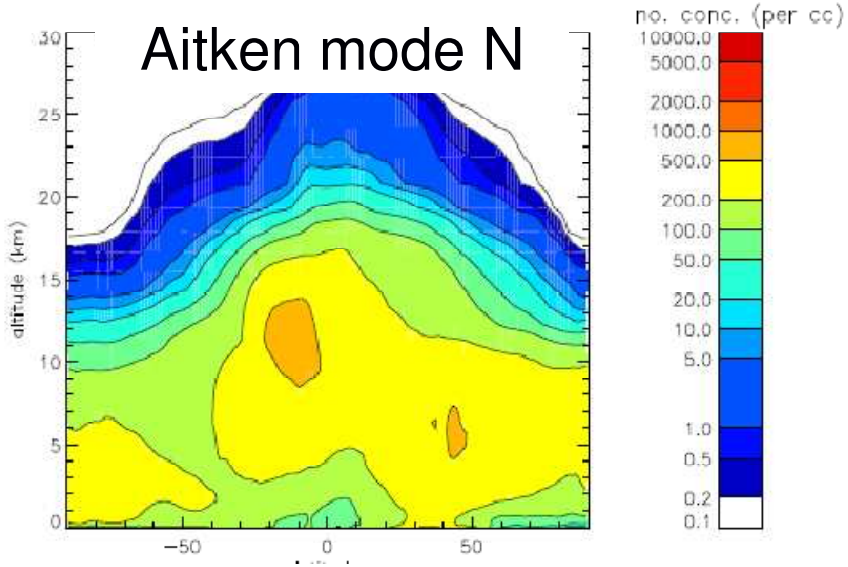
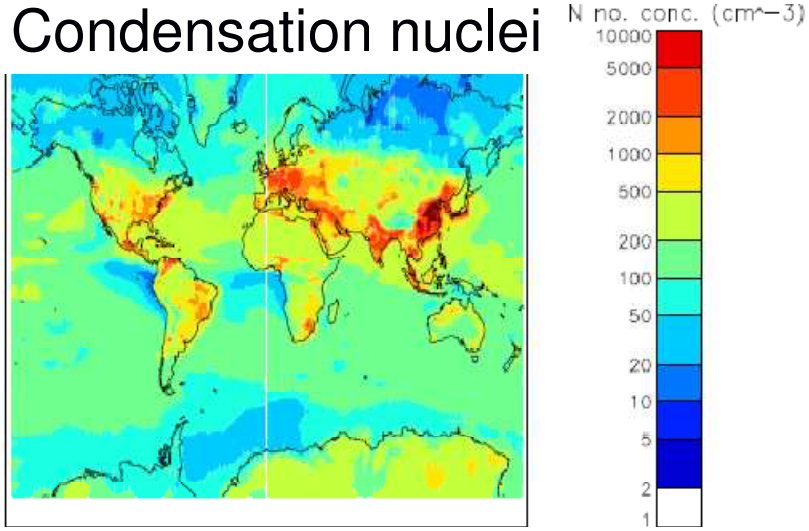
Nucleation mode N



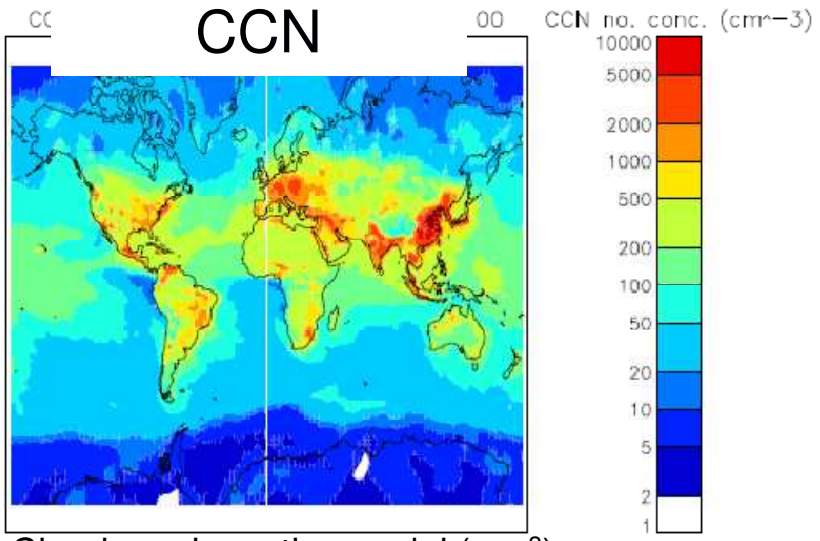
Aitken mode N



Condensation nuclei



CCN



Cloud condensation nuclei (cm^{-3})
(Dp>50nm -- S~0.3%)

UKCA in UMv6.6 (agrvo, SUSSBCOC_5mode)

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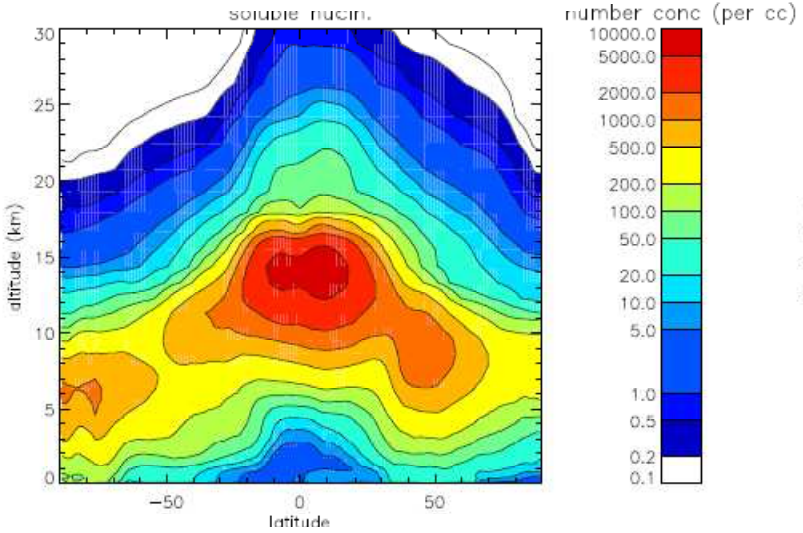
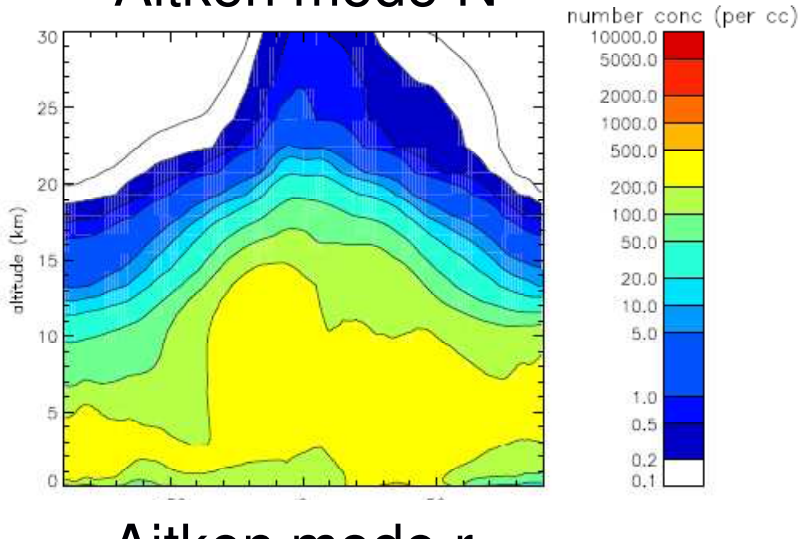
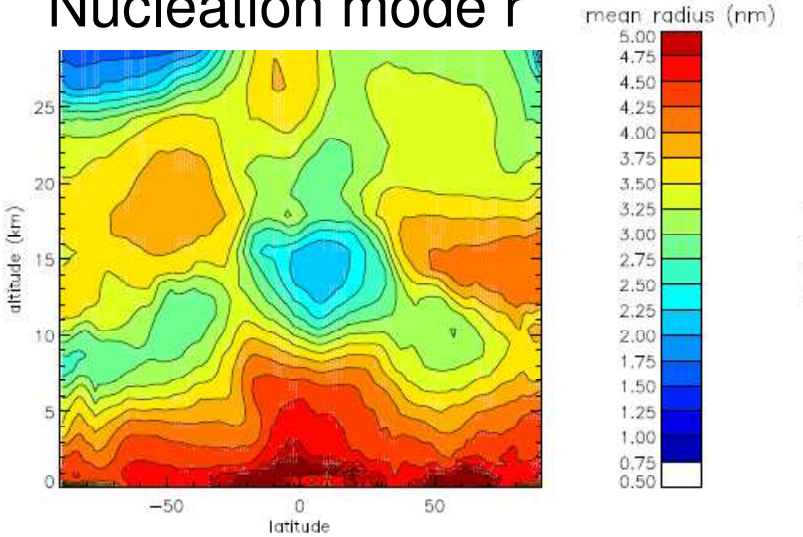
Nucleation mode N



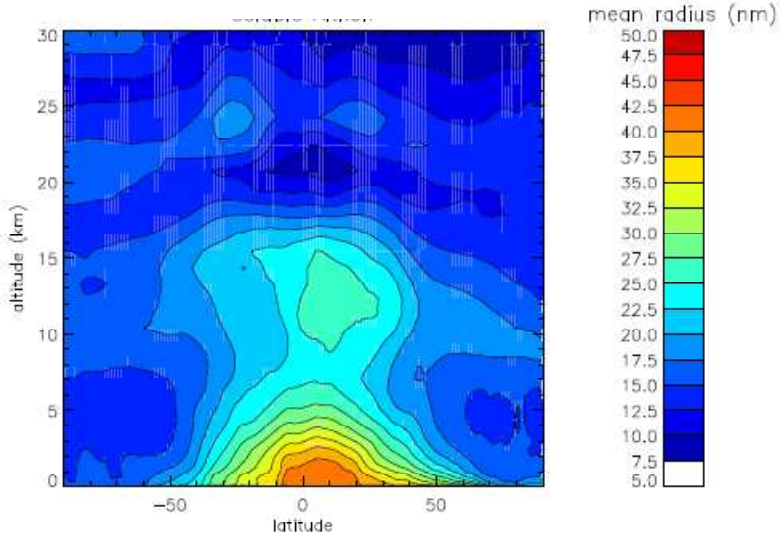
Aitken mode N



Nucleation mode r



Aitken mode r



Model evaluation

An ongoing task

Much bigger task than for CLASSIC

Using AOD, component masses, CN, CCN, particle number, size, vertical profiles, seasonal cycles

Field campaigns

European SO4 in December and June

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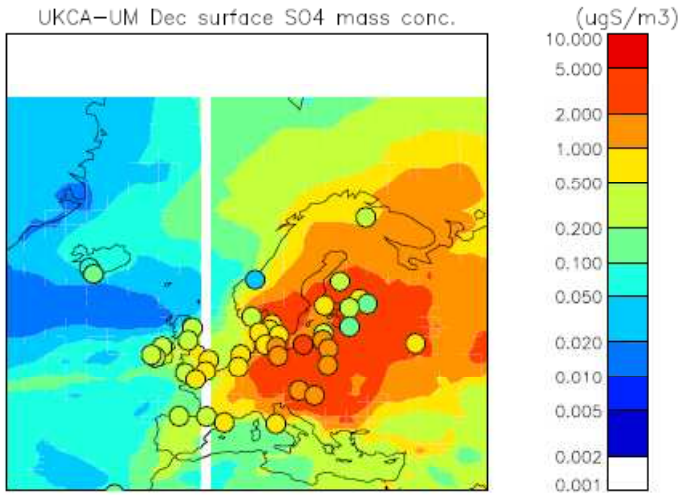
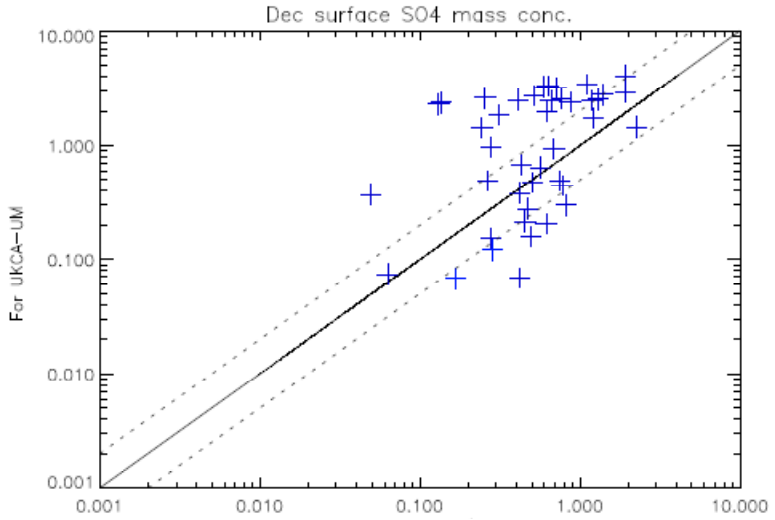
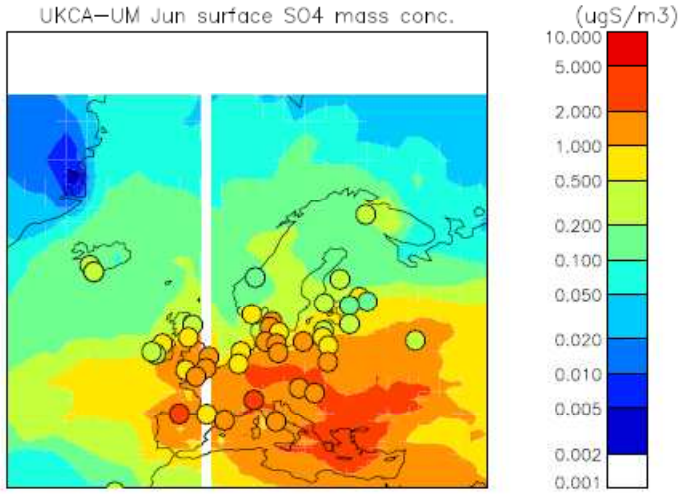
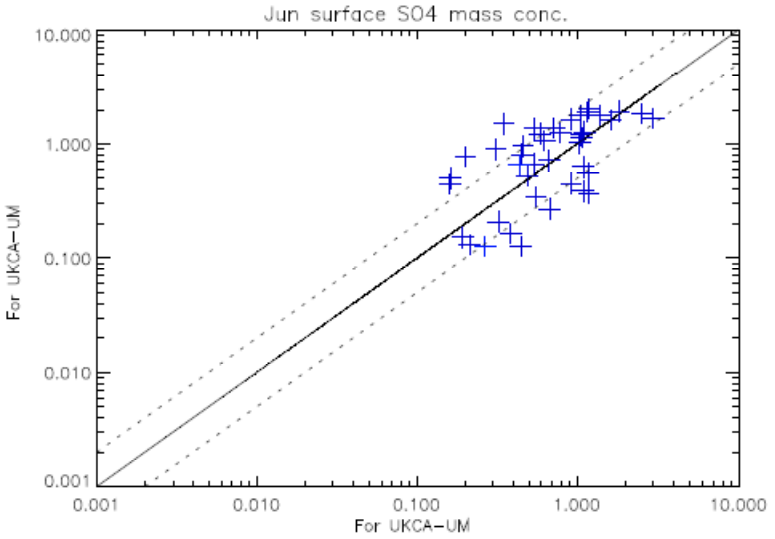
Dec





June





US SO4 in December and June

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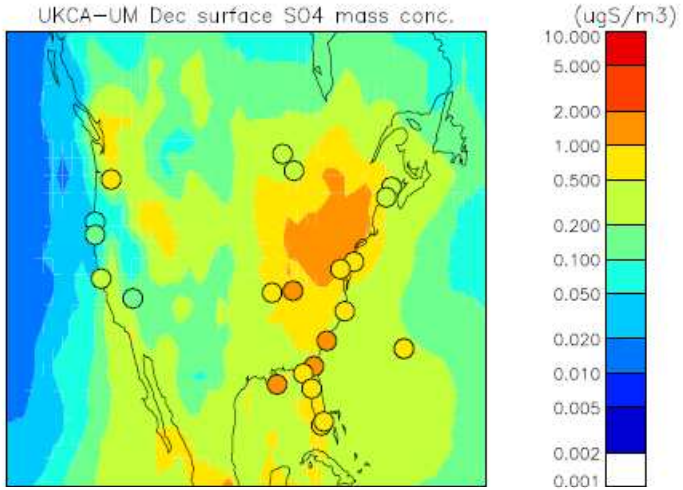
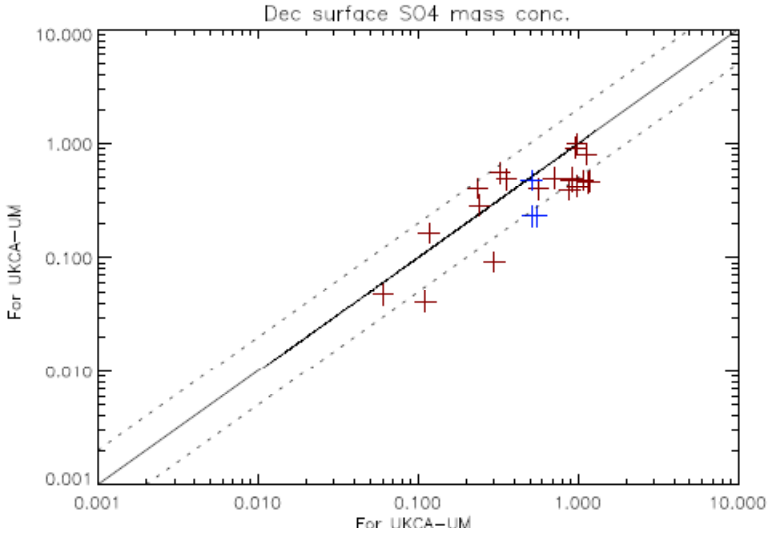
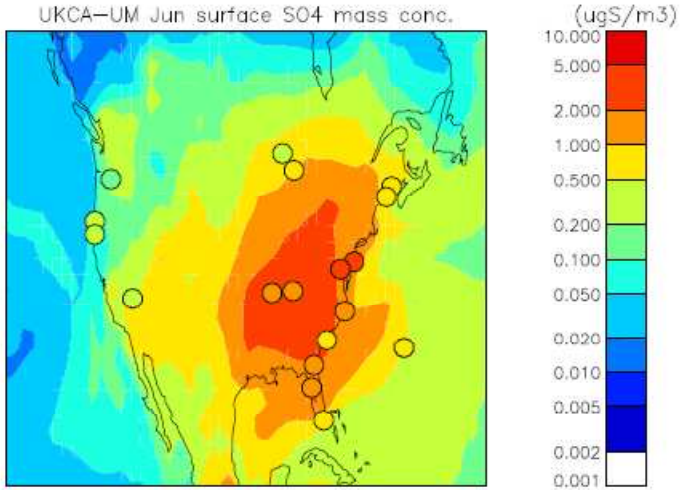
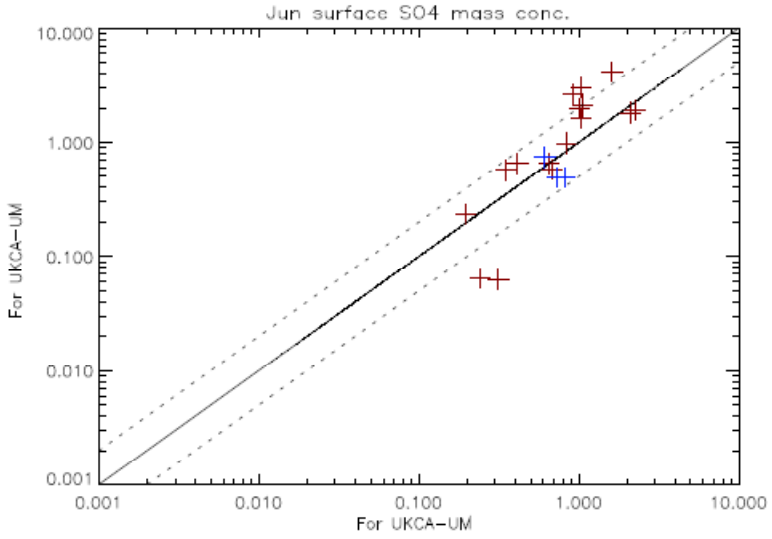
Dec





June





Particle size versus latitude

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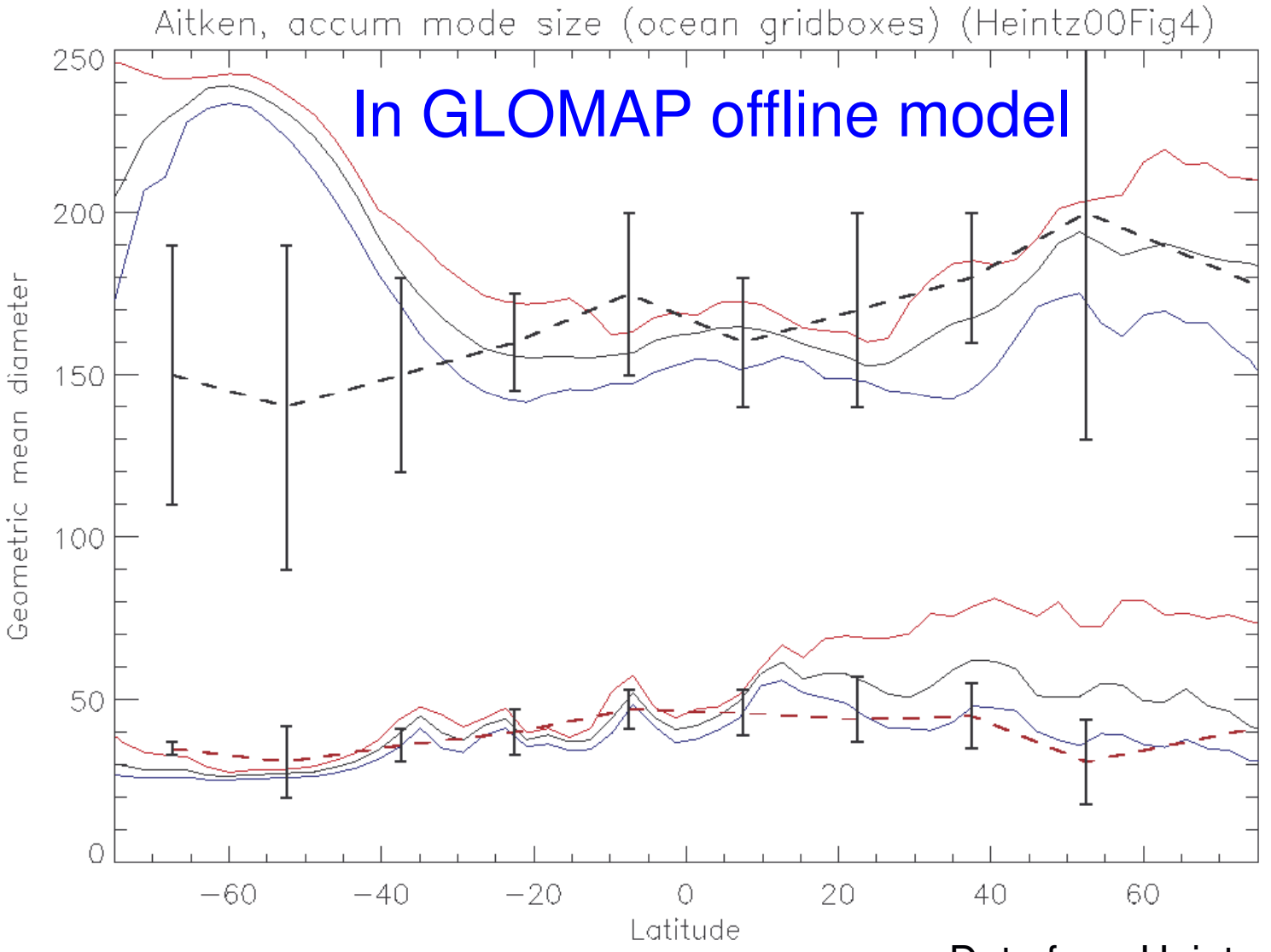

Data from Heintzenberg, 2000

CN vertical profiles

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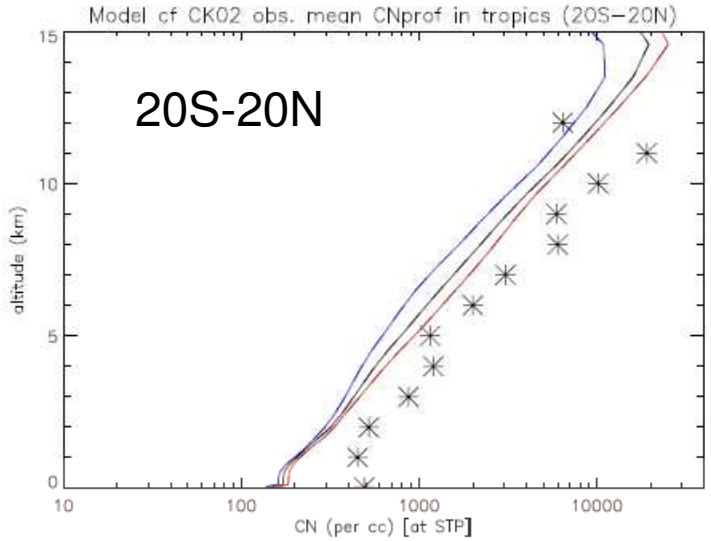

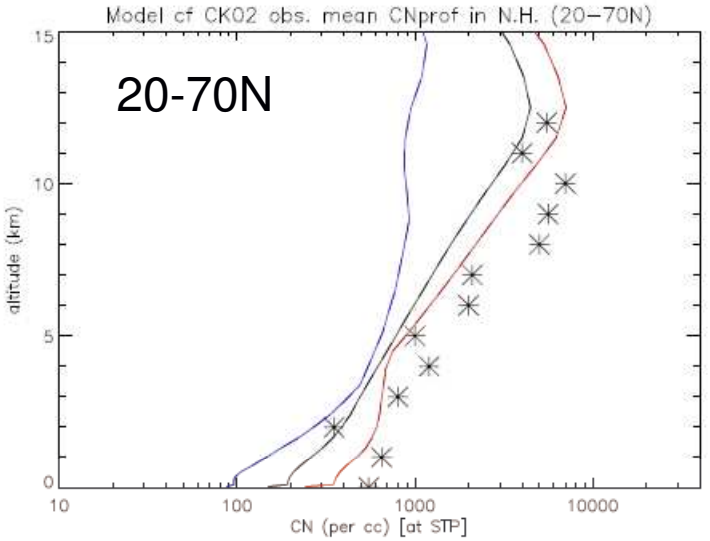

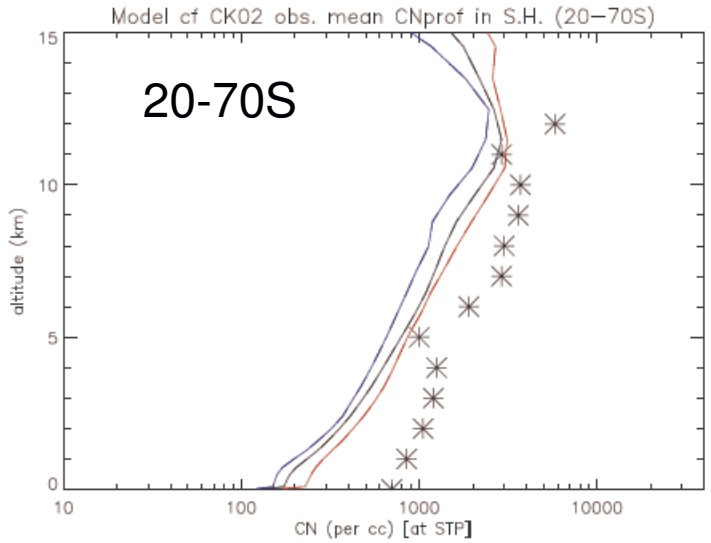

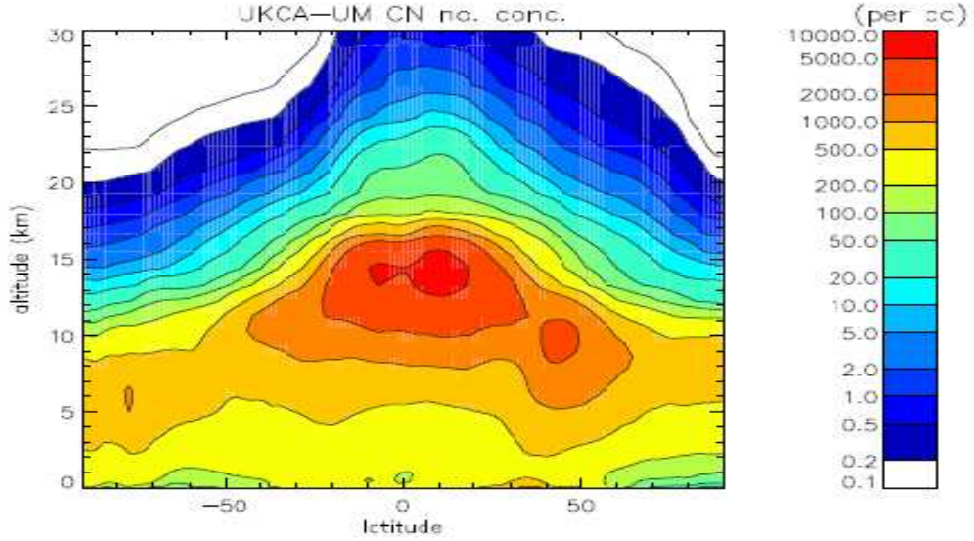

CCN

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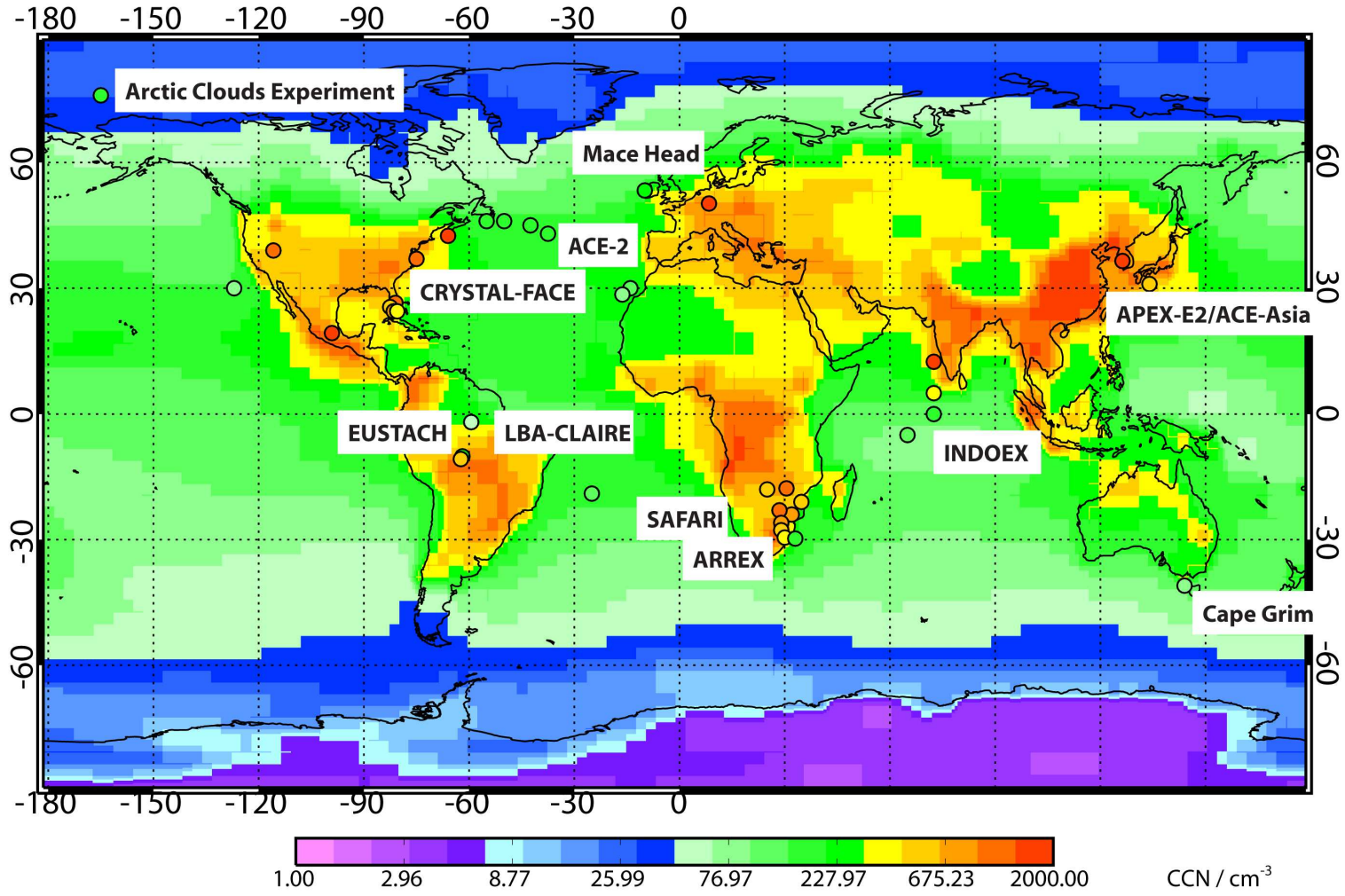

CCN comparison

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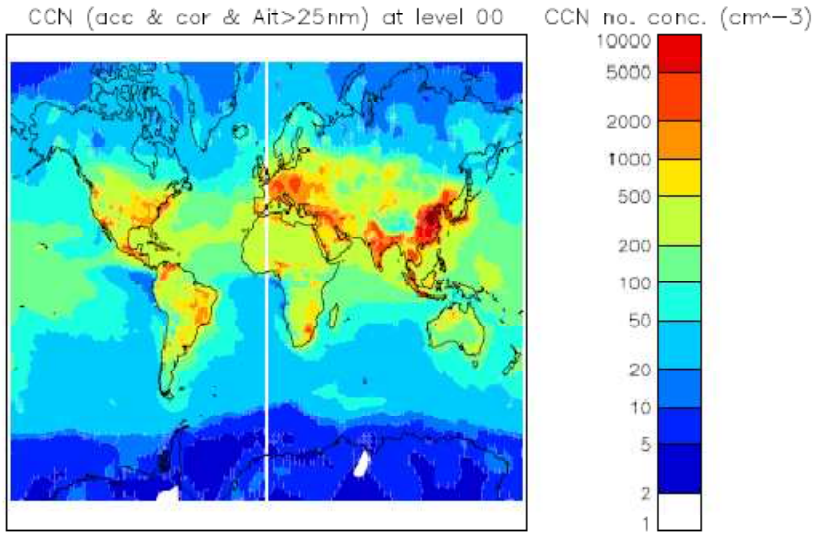
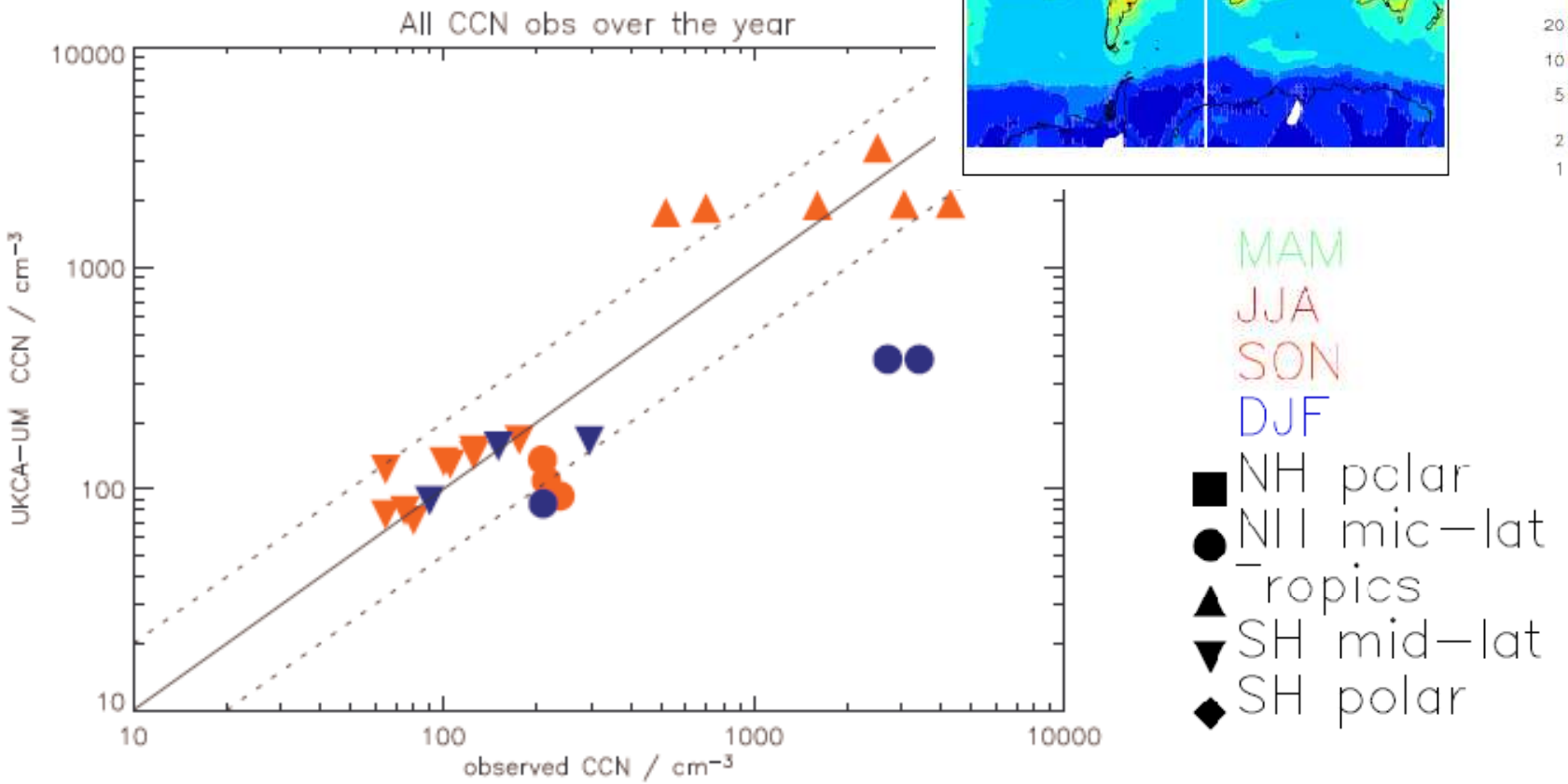
Run not complete yet…





Remote CCN annual cycle

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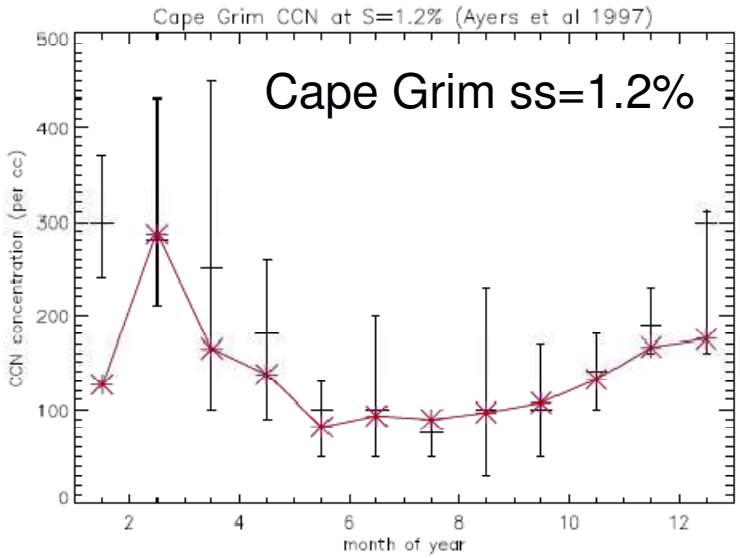

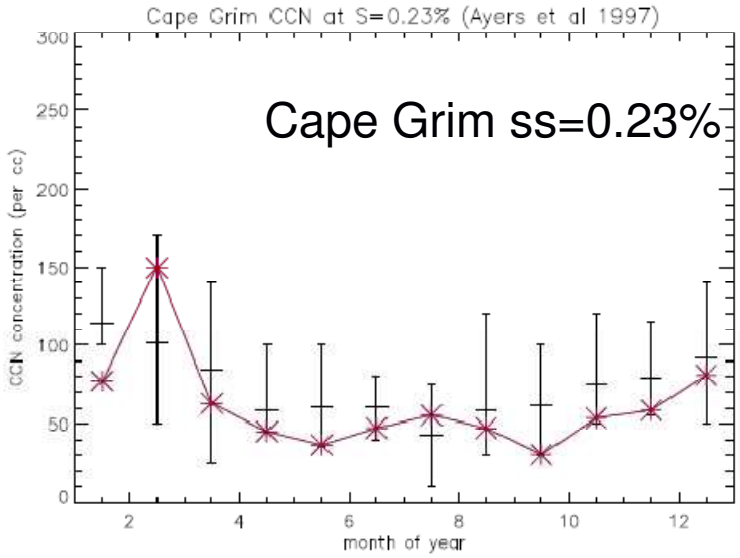

CCN cycle driven by DMS and sea spray

AERONET size distributions vs model

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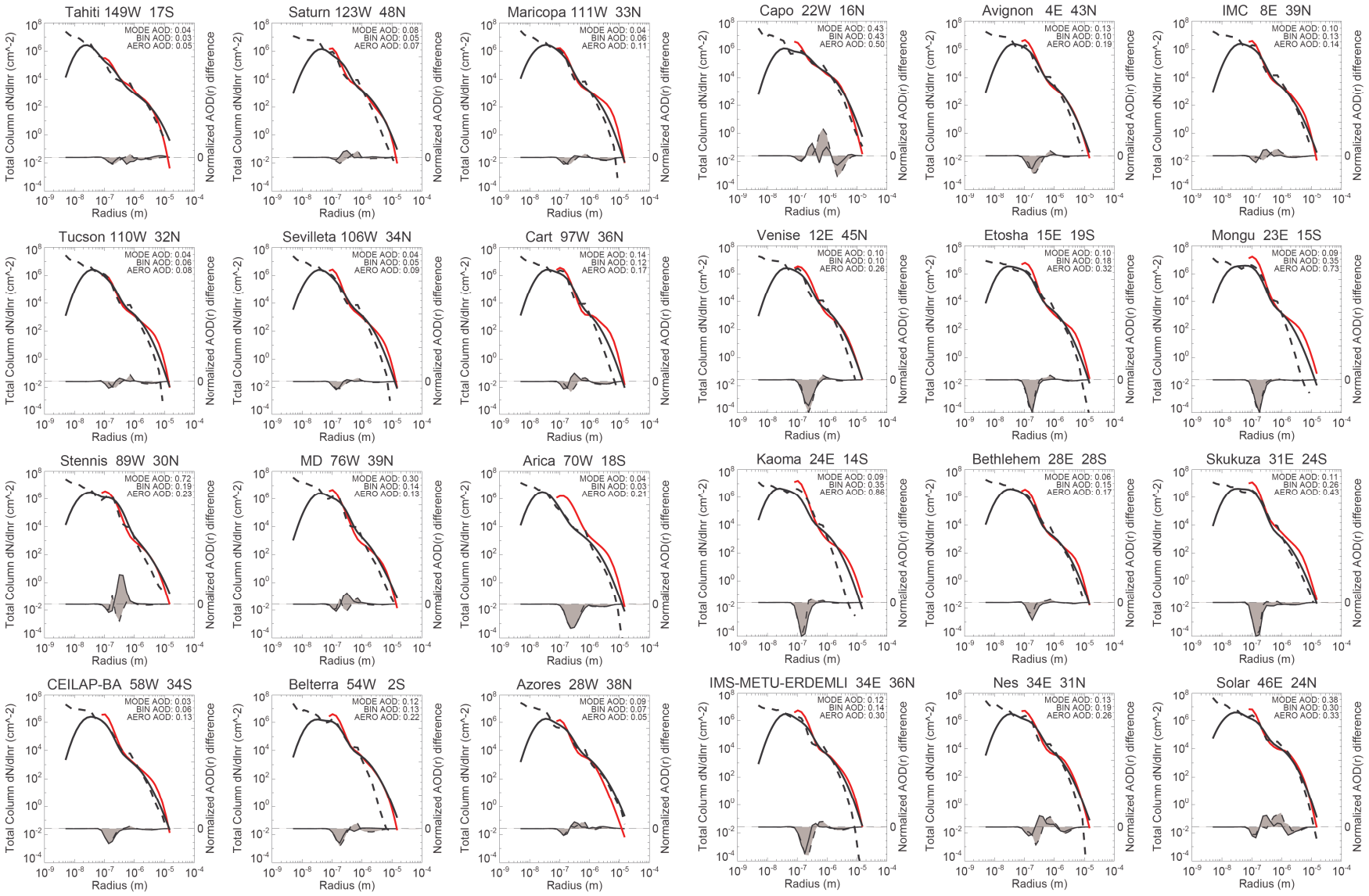

— **AERONET-retrieval** — **GLOMAP-mode** - - **GLOMAP-bin**

Dave Ridley (Leeds)

Model applications

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UKCA aerosol microphysics/chemistry is universal and flexible

It's a case of tailoring

CLIMATE

Re-evaluation of global dimming/brightening, IPCC

AIR QUALITY

Climate/air quality interactions

Basis of GEMS-2 in ECMWF Integrated Forecasting System

PROCESSES

Natural cycles: DMS, CLAW, interaction with sea spray

Geoengineering: sea-spray/cloud interaction, stratosphere, ocean fertilisation

EARTH SYSTEM RESEARCH…

UKCA is integral to NERC QUEST-ESM

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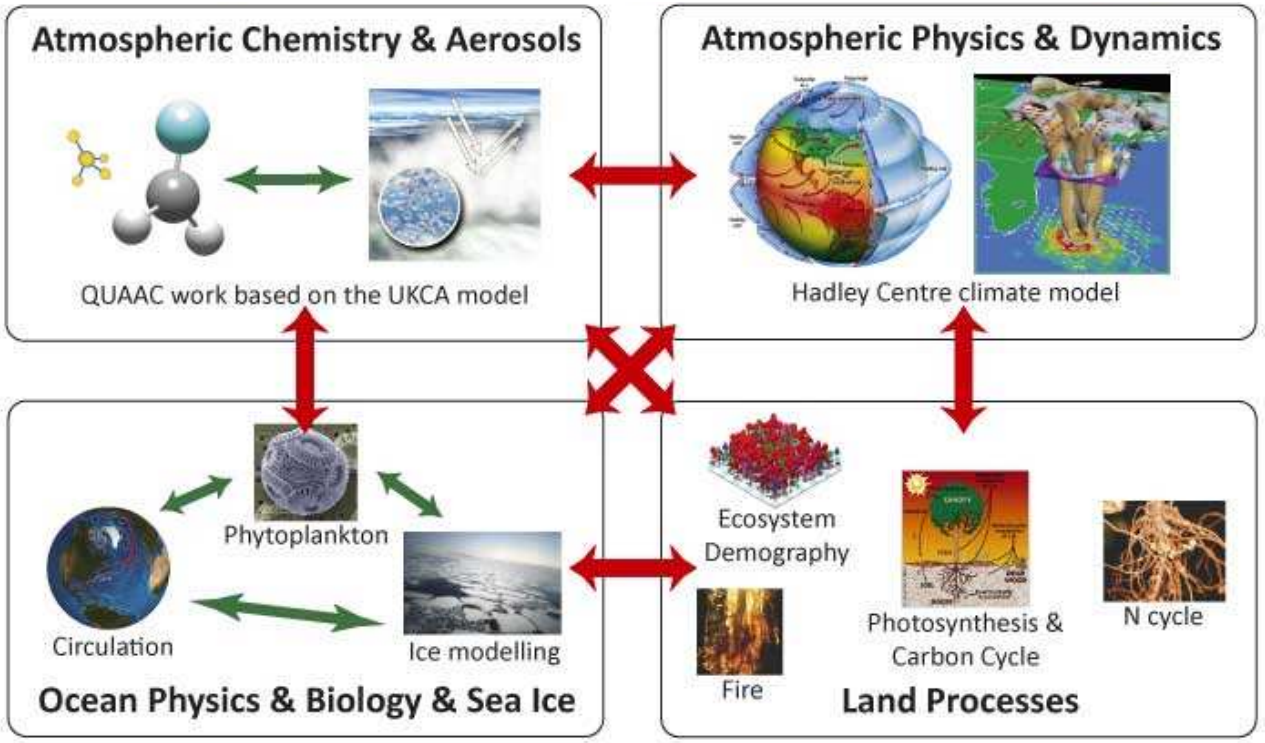
- 1-yr QUEST funding to progress UKCA modal dust & sandblasting schemes



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

EARTH SYSTEM
Ecosystem-climate interactions (SOA, CCN…)

Dust-ocean-atmosphere coupling

Volcanic aerosol-biosphere feedbacks

Palaeo-aerosol

Diagram from Paul Young.

UKCA to be used at Met Office on range of scales

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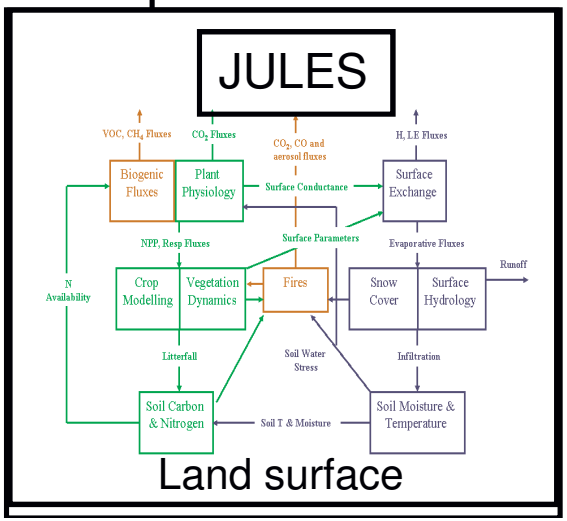
UM

Seamless prediction

UKCA Troposphere & Stratosphere & Aerosols

Biogenic emissions



MACC project → Short-term numerical weather prediction & Visibility forecasts

AQUM project → AQ forecasts

Seasonal forecasting

Aerosol forcing → Decadal prediction

UKCA-trop
UKCA-strat → Climate projections AR5 - HadGEM2-ES

UKCA-whole atm
UKCA-MODE → Climate projections Post-AR5 HadGEM2/3-ES

Slide from O. Boucher, Met Office

Projects exploiting UKCA

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European Integrated Project (EUCAARI) using UKCA as part of the Earth System modeling work package

Direct effect (BC ageing/absorption) in APPRAISE-ADIENT

Marine aerosol (SOLAS) project on coupled halogen/sulphur cycle

Stratospheric aerosol & geoengineering (Cambridge/Leeds NERC project)

Palaeo aerosol from flood basalt eruptions

Ion-induced nucleation and cosmic rays (EU Marie Curie)

QUEST Earth System Model …

Met Office CASE projects: Heterogeneous chemistry (M. Evans, Leeds);
Dust and DMS in the Earth System (G. Mann);
Arctic aerosol/climate (K. Carslaw, Leeds);
Ozone indirect effects (S. Arnold, Leeds);
CDN & aerosol indirect effect (P. Stier, Oxford)

Will be implemented in the ECMWF-IFS via EU MACC project (GEMS2)

Ongoing role of the UKCA team

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To maintain and further develop an evaluated and documented state-of-the-science global aerosol-chemistry model

Evaluation, inter-comparison, benchmarking

AEROCOM (new initiatives in microphysics, OA, etc)

NERC-AEROS (Uncertainty importance analysis, necessary level of complexity)

Improvement and extension

SOA, nitrate, nucleation, dust, marine OC, etc

Coupling

Radiation, clouds, Earth system sub-models

Collaboration and coordination… and support (NCAS, JCRP)