School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE

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Global aerosol and climate: Why do we care about microphysics?

Ken Carslaw, Graham Mann, Dominick Spracklen, Kirsty Pringle, Joonas Merikanto, Paul Manktelow

www.ukca.ac.uk
http://researchpages.net/glomap

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Aerosol microphysics in large scale models

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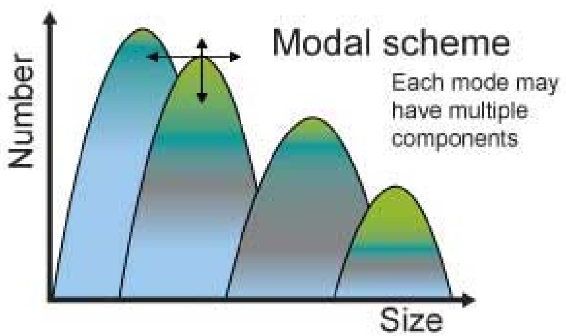
1990s – early 2000s

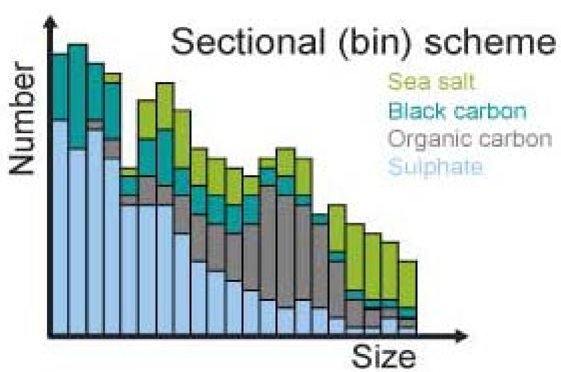
Aerosol mass only



Early 2000s to present in climate models

Some size information

12-60 tracers

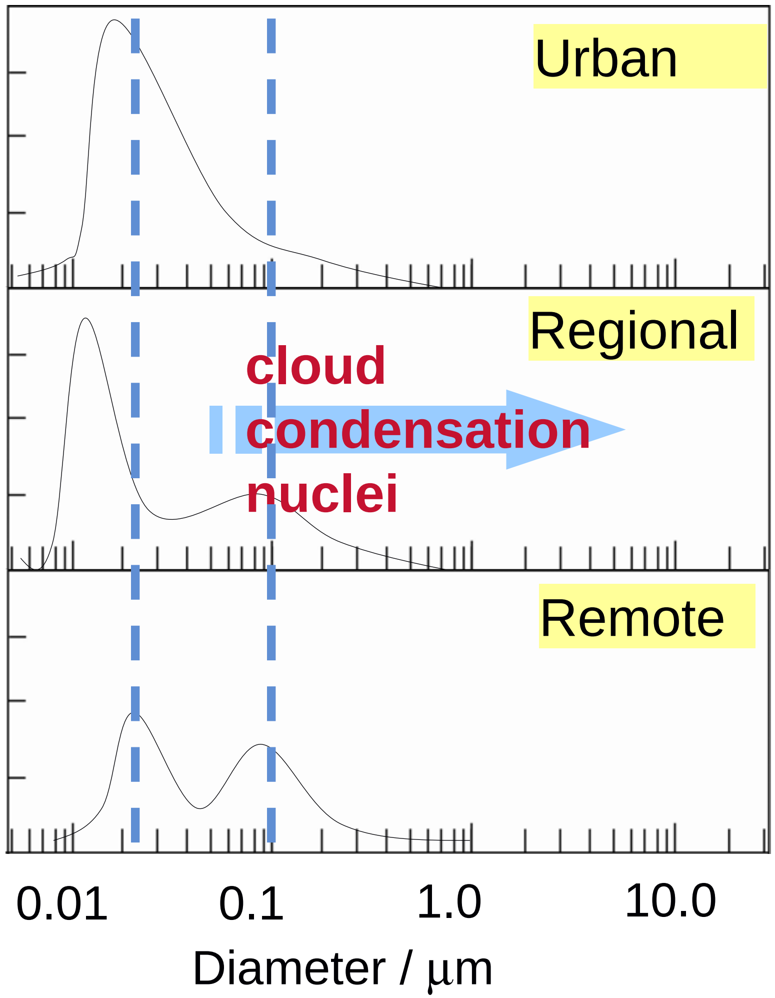


Early 2000s in "research models"

No compromise size information

60 to >300 tracers

Why is the size distribution important?



Cloud condensation nucleus (CCN) number is the number of particles in a (variable) size range

Similar arguments for radiative effects

Different processes and emissions affect different sized particles

Processes and emissions change with climate

…and location, time, etc

The Global Model of Aerosol Processes (GLOMAP)

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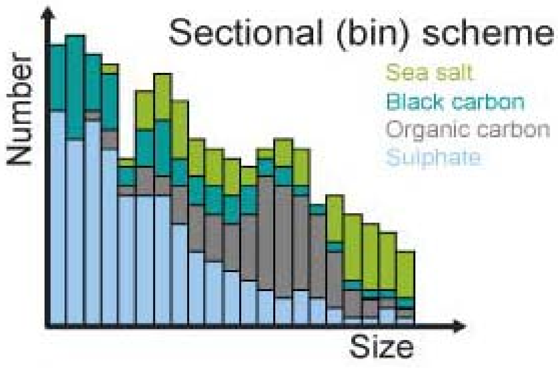

Microphysical Processes

Nucleation
Coagulation
Condensation growth
Cloud processing
Etc

The TOMCAT global CTM with a sectional aerosol microphysics module

ECMWF meteorology

2.8^{o} resolution, 31 levels

Spracklen et al. (2005, 2006, 2008)

Korhonen et al. (2008)

etc

Impact of regional SO_2 emissions on SO_4, CN and CCN

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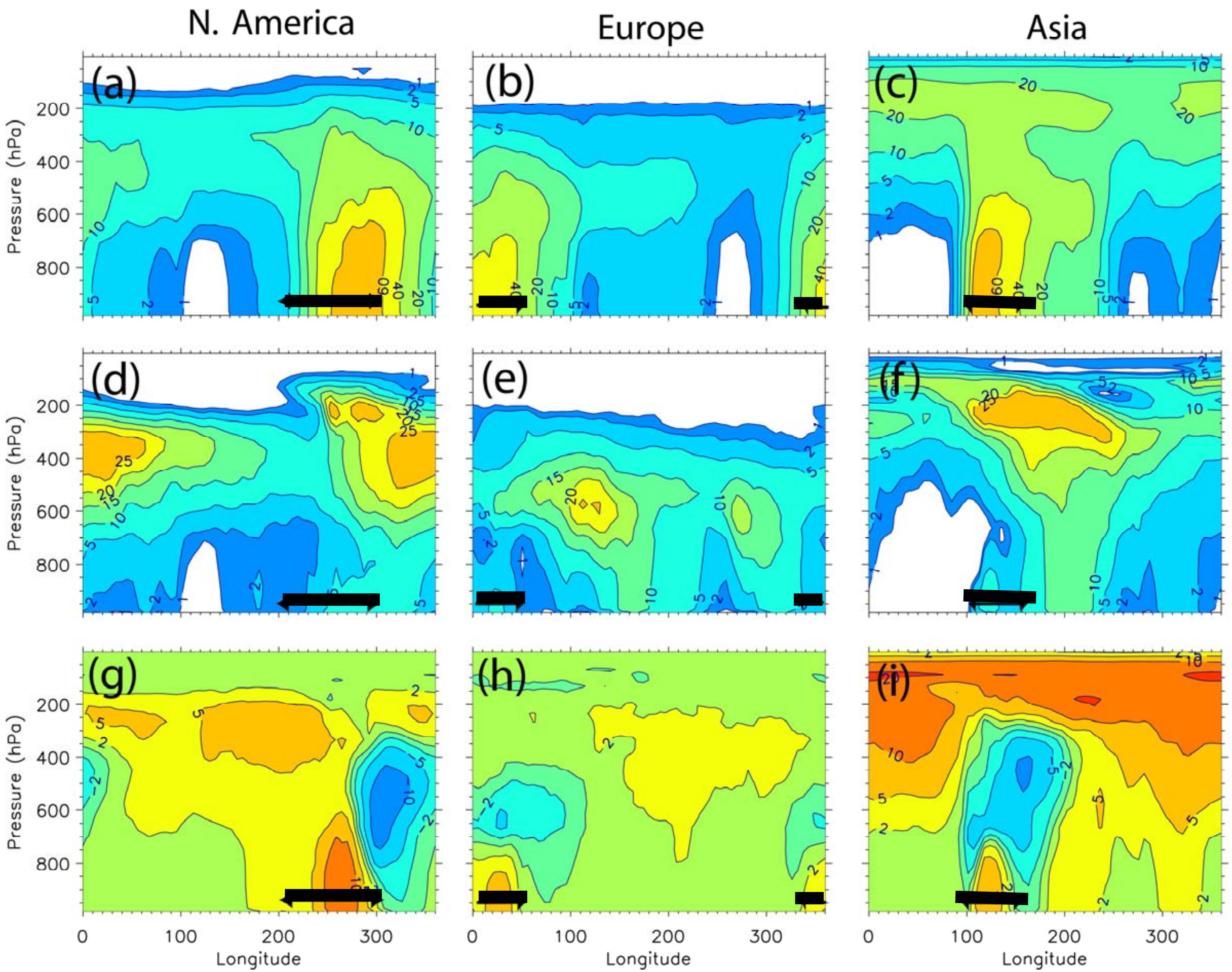
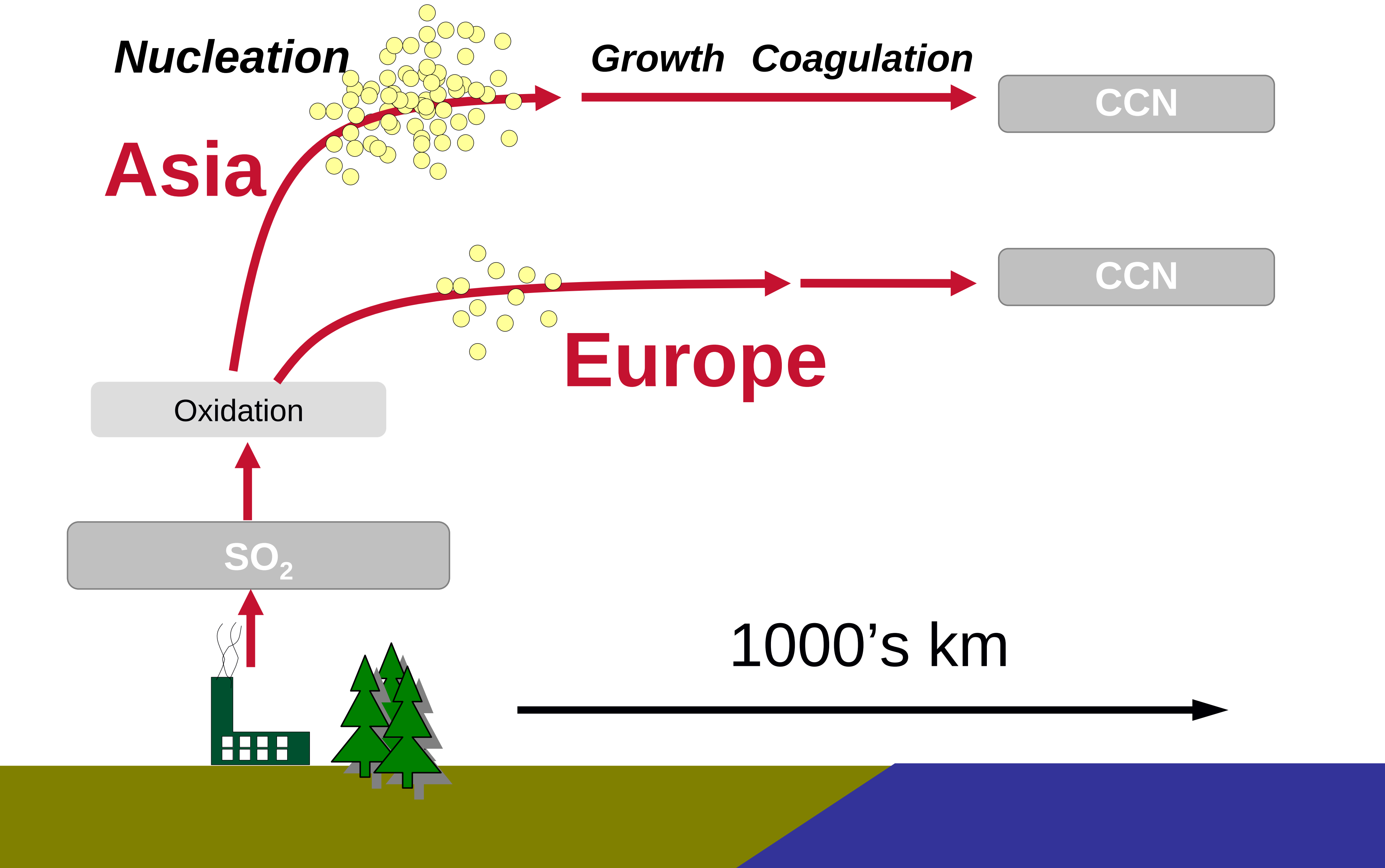


%SO$_4$

%ΔCN

%ΔCCN

Impact of regional SO_2 emissions on CCN



Regional SO_4 and CCN budget

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	N. America	W. Europe	E. Asia
SO4 production efficiency	0.51	0.39	0.44
SO4 lifetime (days)	4.8	6.4	3.7
SO4 burden potential	0.89	0.93	0.59
Aerosol number potential	0.33	0.11	0.41
CCN potential	0.1	0.06	0.08

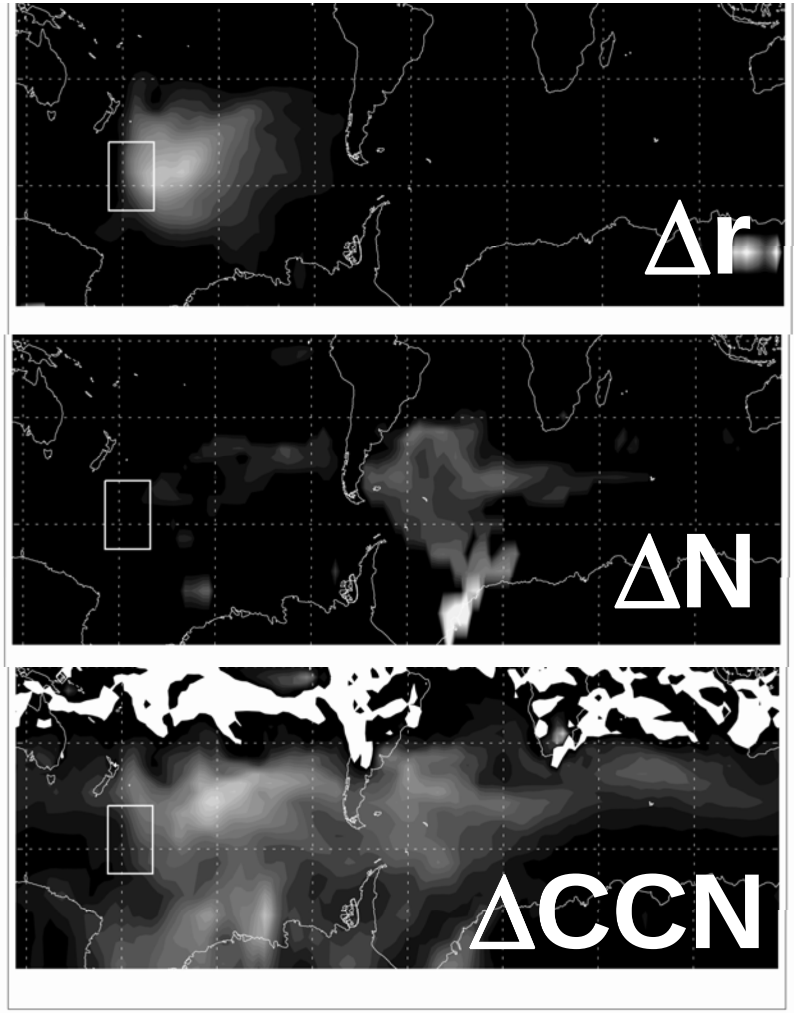
N America produces 3 times as many particles per unit SO_4 mass than Europe

N America produces 2 times more CCN per unit SO_4 mass

SO_4 mass is not a good predictor of CCN

Manktelow et al., ACP (submitted)

DMS and marine CCN



Downwind changes in aerosol size, number and CCN after perturbation to DMS in a patch

Woodhouse et al., Atmos. Env. (2008)

Modelling nucleation events

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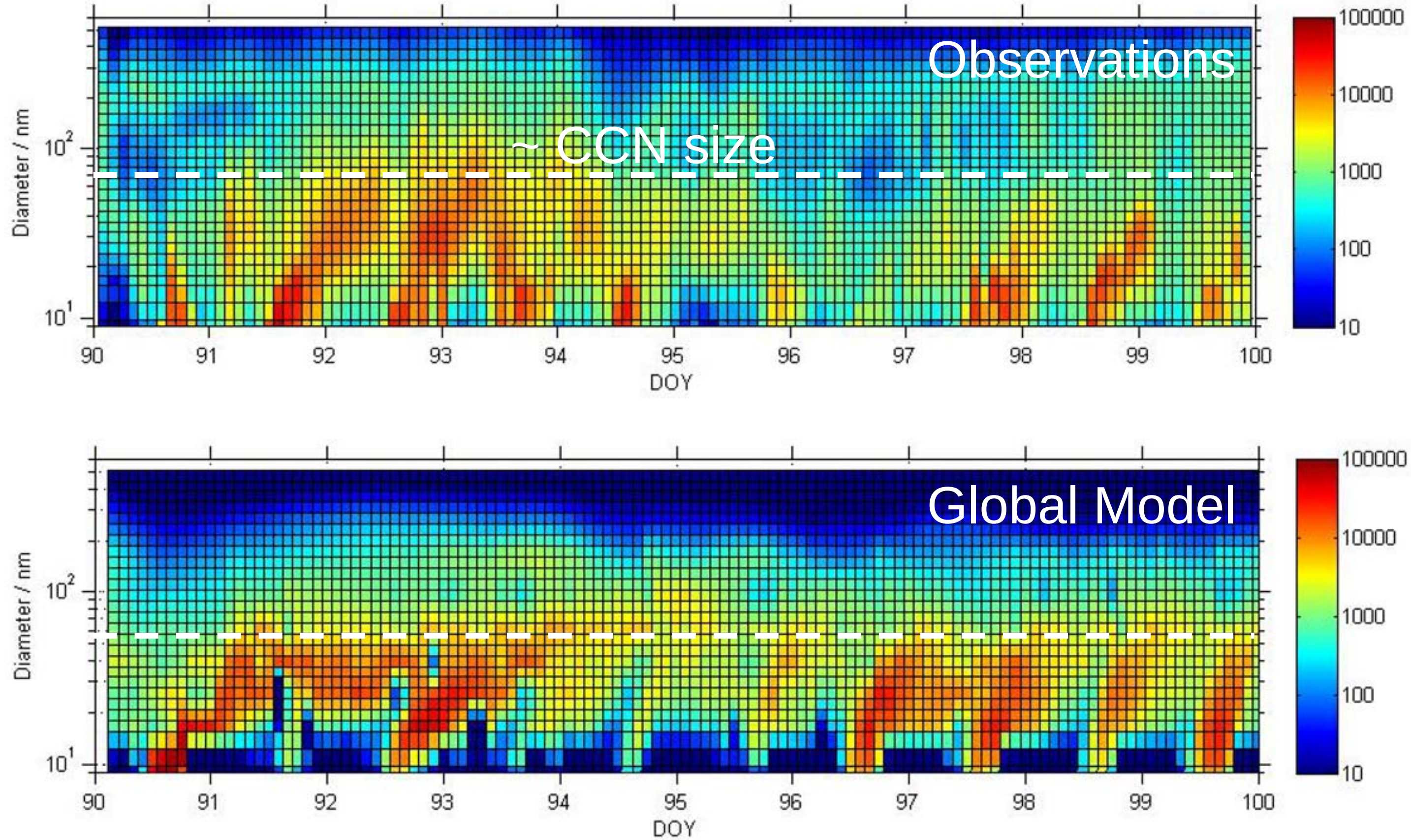
Observations from the Finnish forest observatory at Hyytiala

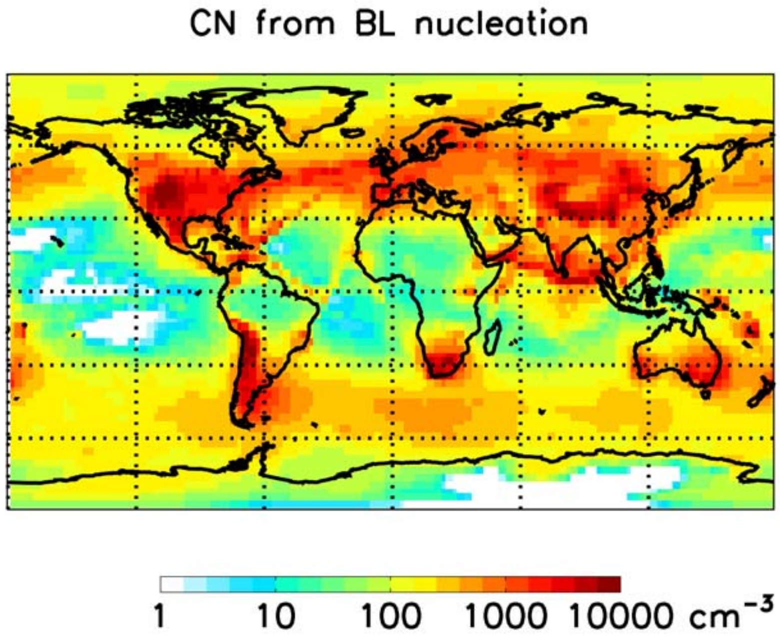


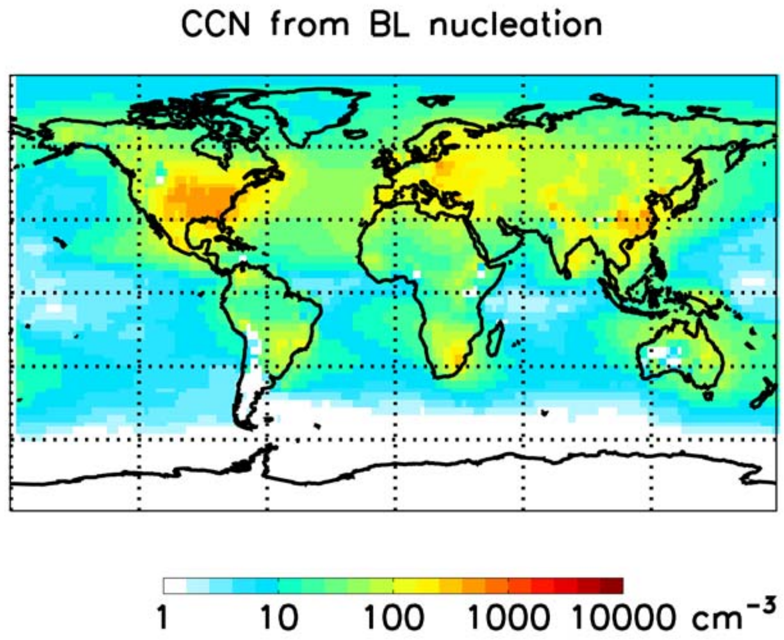
Spracklen et al., ACP, 2006

Global impact of boundary layer nucleation

CCN enhancements:

Global mean 3-20%, regional mean up to 50%, short term factor 3-4





Predicting cloud drop number

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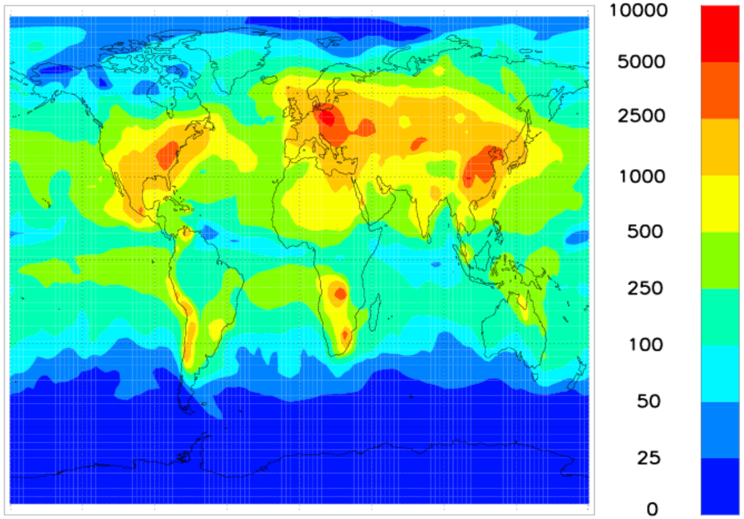
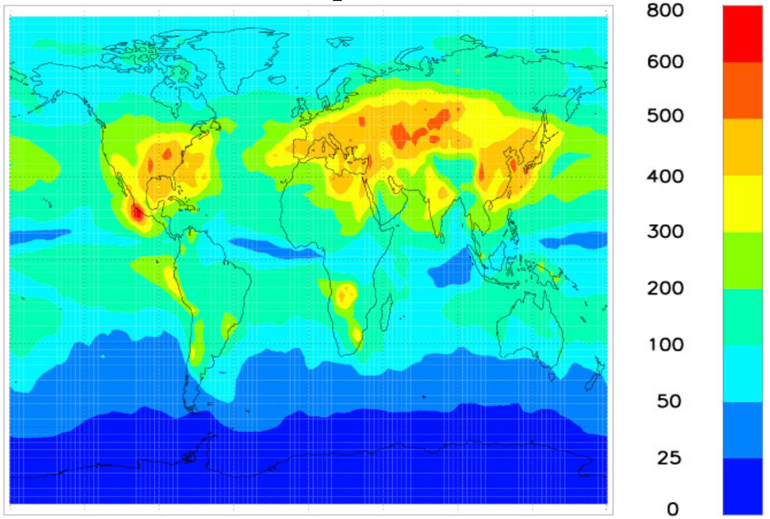
Aerosol

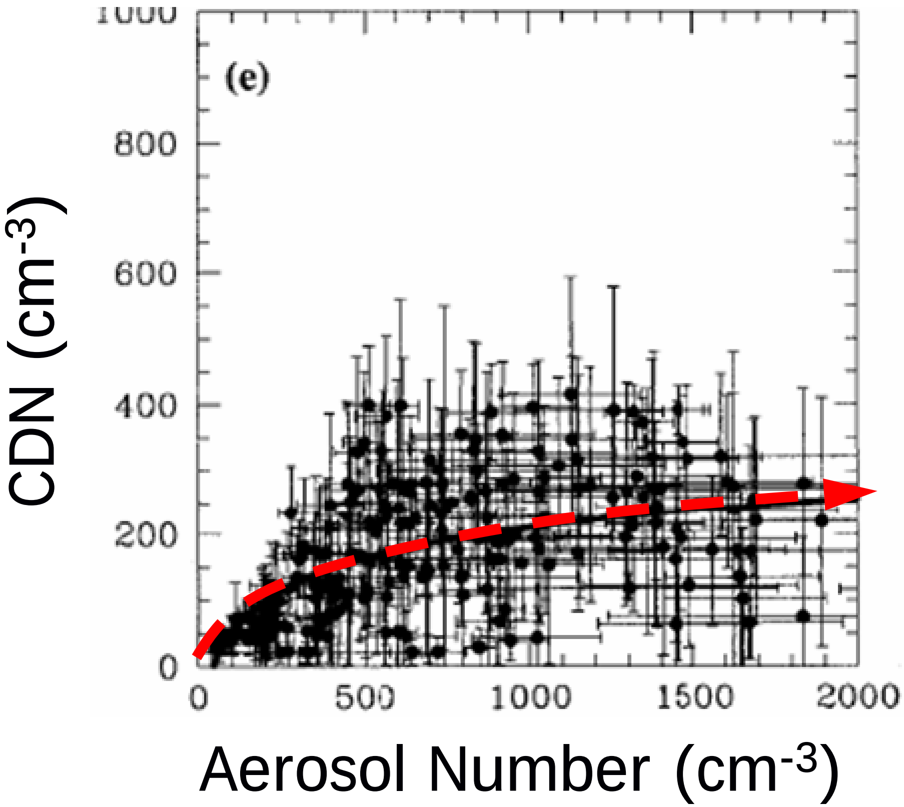


Cloud parcel model

Cloud drop number



Cloud drop number in a climate model

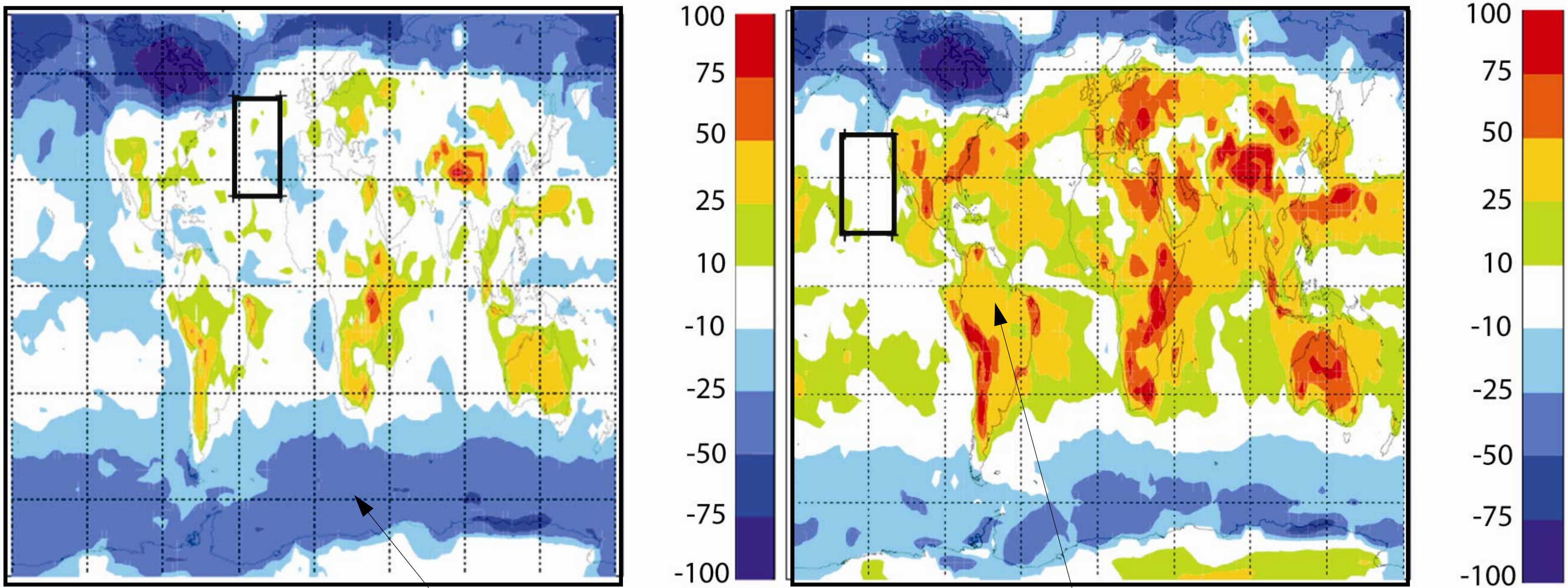


Simple fit of CDN to aerosol mass or number

Gultepe and Isaac (1999)

Error in predicted cloud drop number

Percent difference between simple fit equation and full mechanistic calculation



CDN underpredicted by ~50%

CDN overpredicted by ~50%

Pringle et al., ACP (submitted)

The size distribution matters

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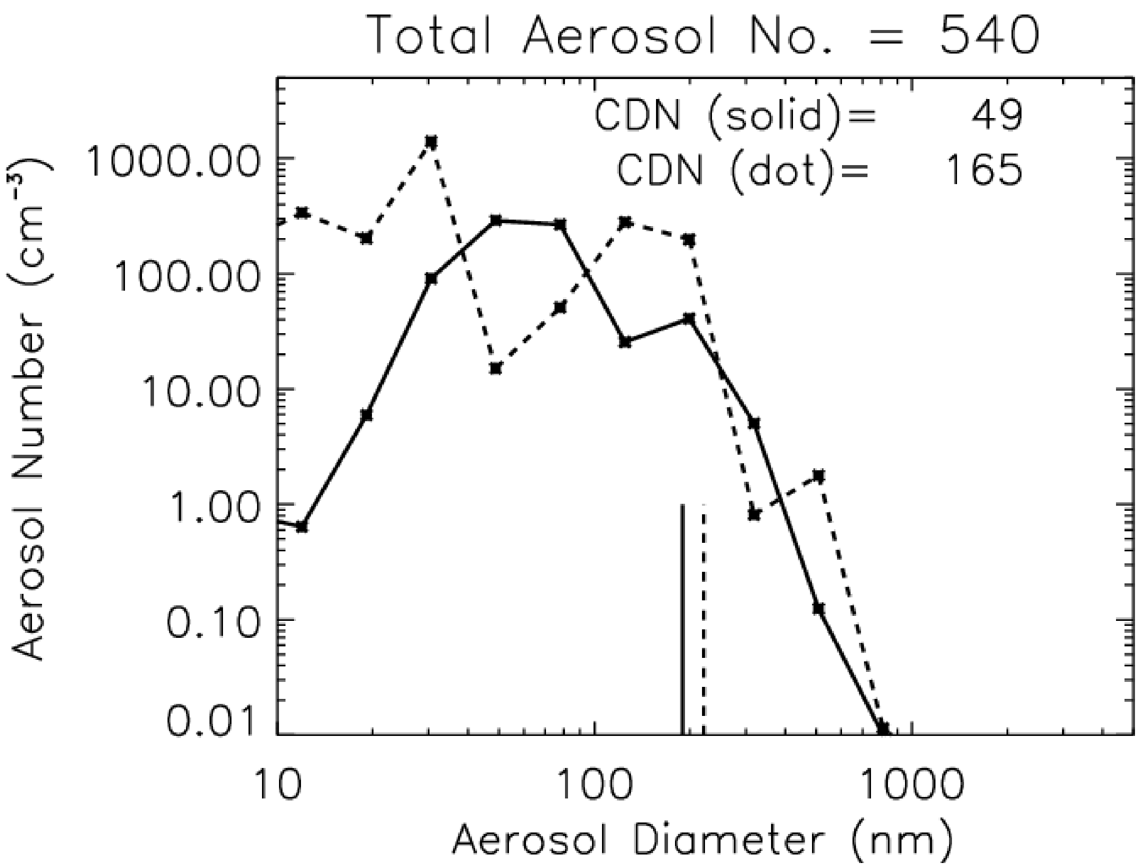
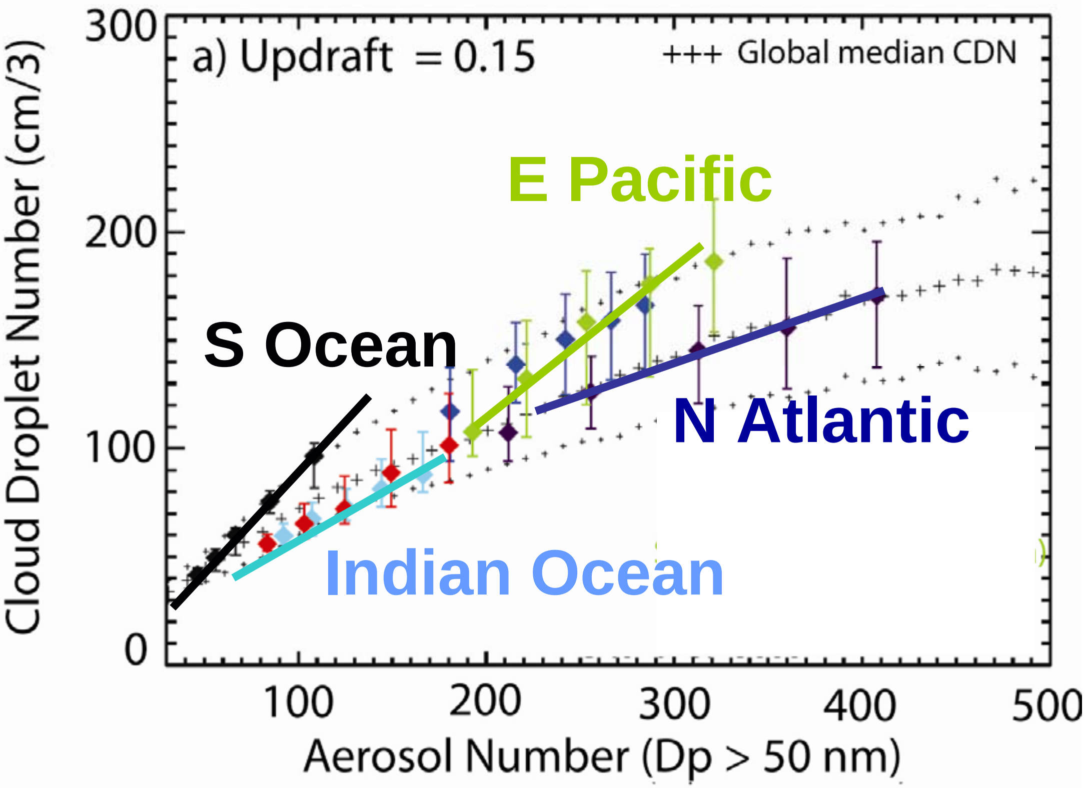


Two aerosol distributions

Same particle number, different sizes

Factor 3 difference in CDN

Sensitivity of cloud drop number to aerosol



Factor 4 regional variation in $\partial CDN / \partial N_a$

Pringle et al., ACP (submitted)

Conclusions

Aerosol microphysics matters

1. Factor 2 difference in CCN per SO_4 mass from different continents because of nucleation
2. Nucleation generates a large fraction of global surface-level CCN
3. Change of cloud drop number with aerosol varies regionally by a factor 4 because of differences in particle size distribution
4. Many more examples…

Conclusions

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1. More expensive aerosol codes like UKCA will bring benefits
2. The challenge is to optimise the cost-benefit and demonstrate improvement