School of Earth and Environment
INSTITUTE FOR CLIMATE AND ATMOSPHERIC SCIENCE

UNIVERSITY OF LEEDS

Size distribution working group:

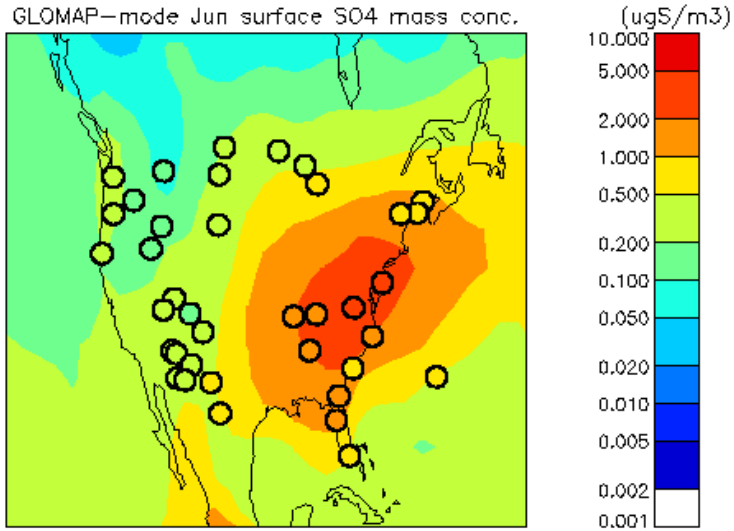
1. Observation datasets to constrain size distribution simulated by AEROCOM models.
2. Example model comparisons against observations
3. Proposed output to enable comparison

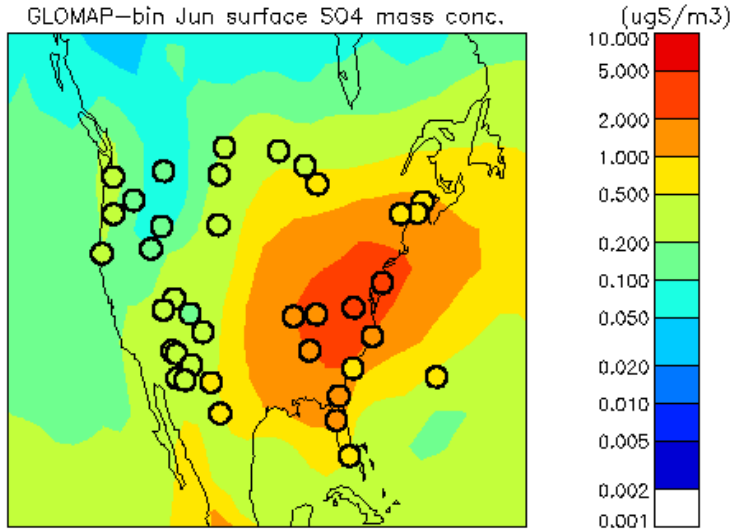
Graham Mann
(University of Leeds)

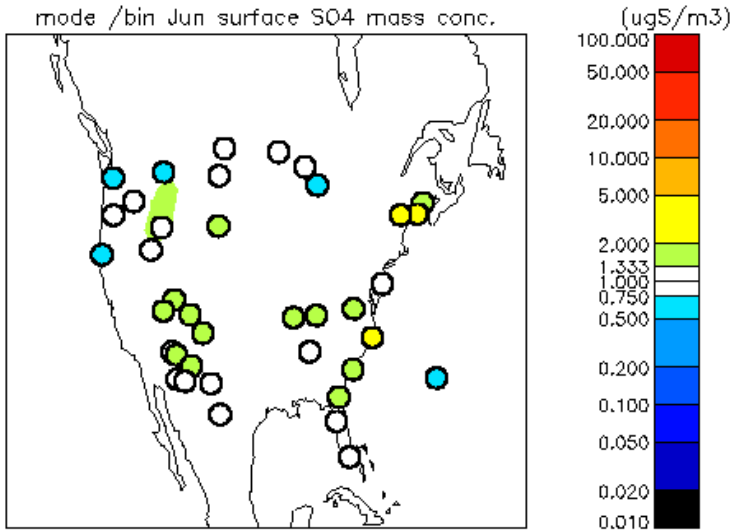
Please send suggestions to gmann@env.leeds.ac.uk

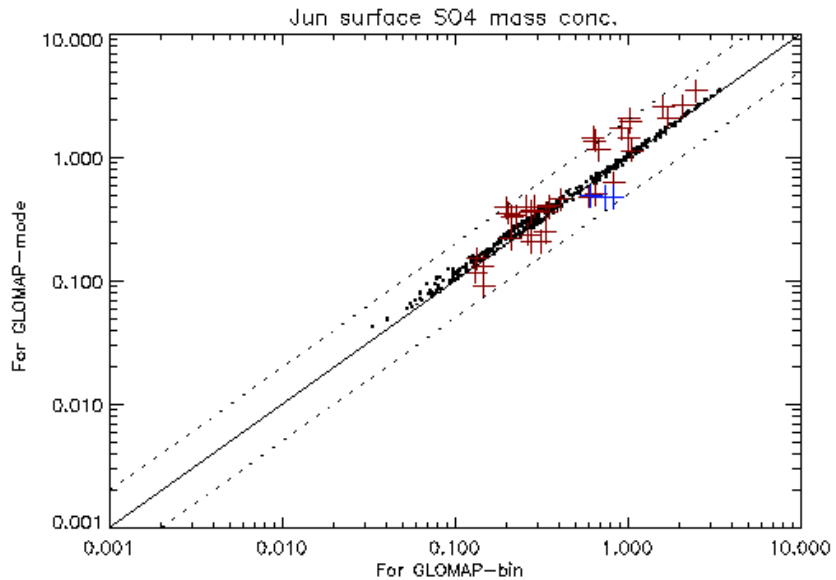
GLOMAP-mode/-bin SO4 mass concentration against IMPROVE (US), June mean

UNIVERSITY OF LEEDS



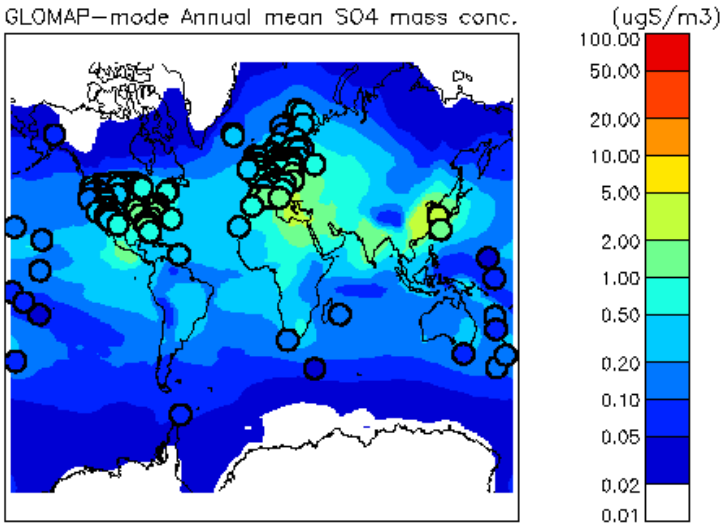


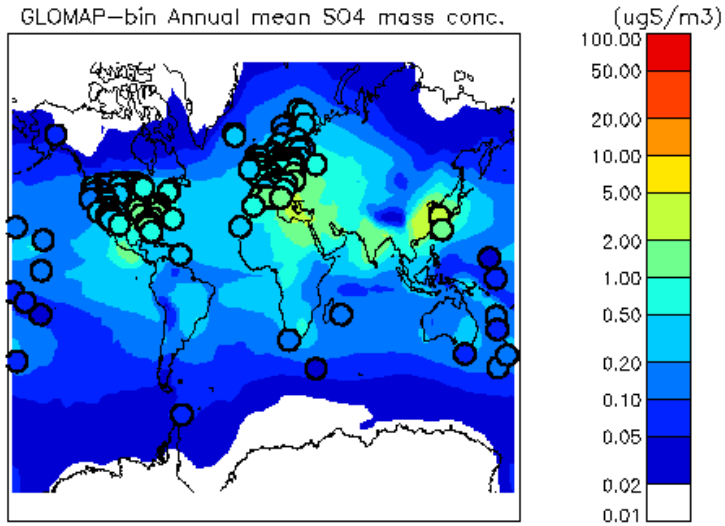


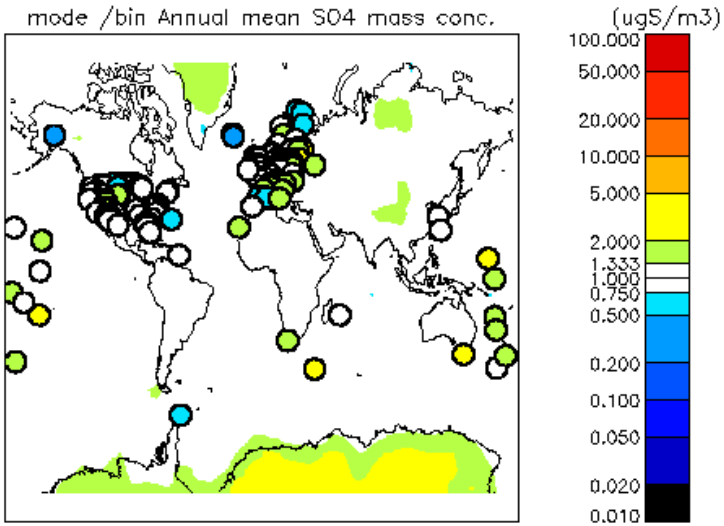


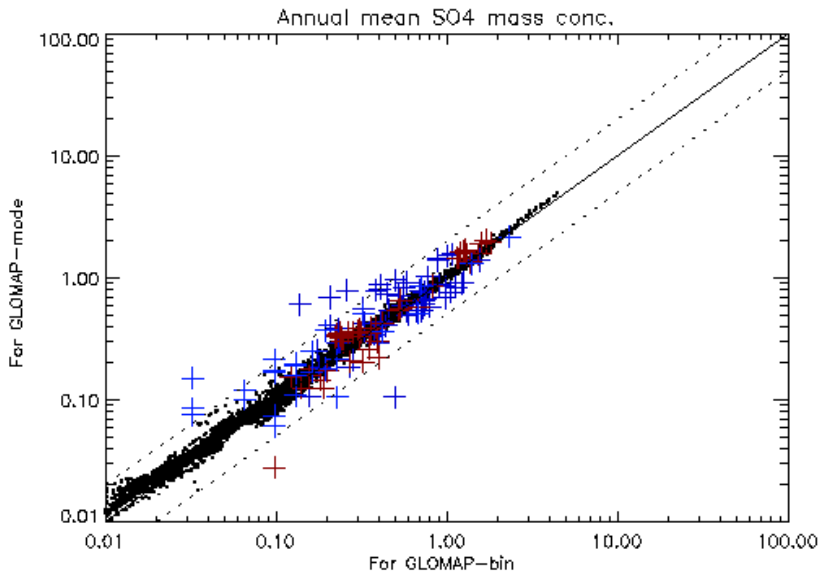
GLOMAP-mode/-bin SO4 mass concentration against U. Miami (Global), Annual mean

UNIVERSITY OF LEEDS



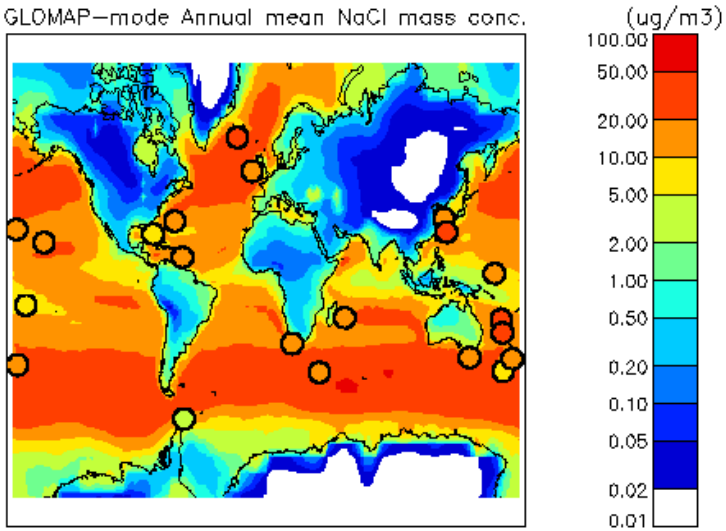


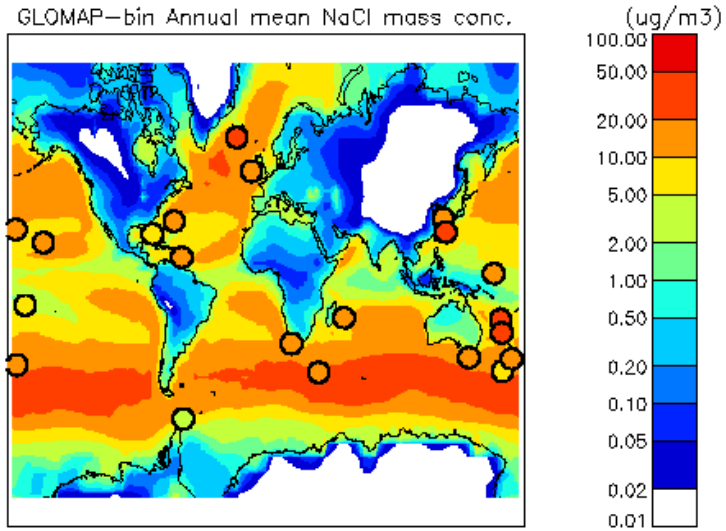


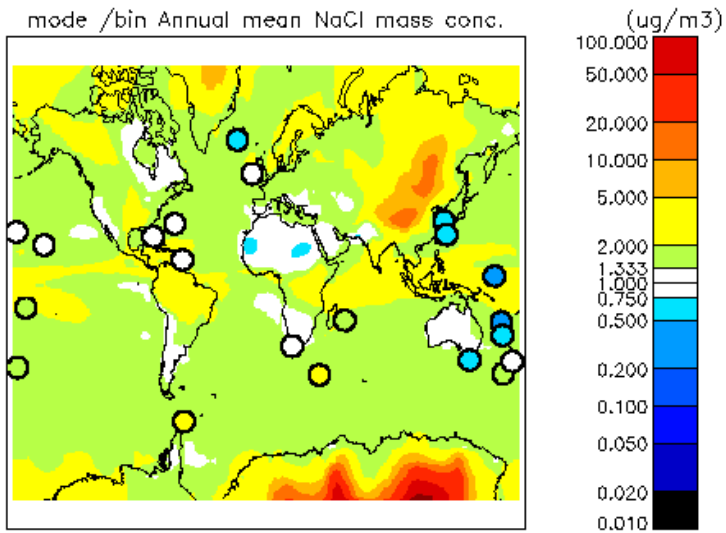


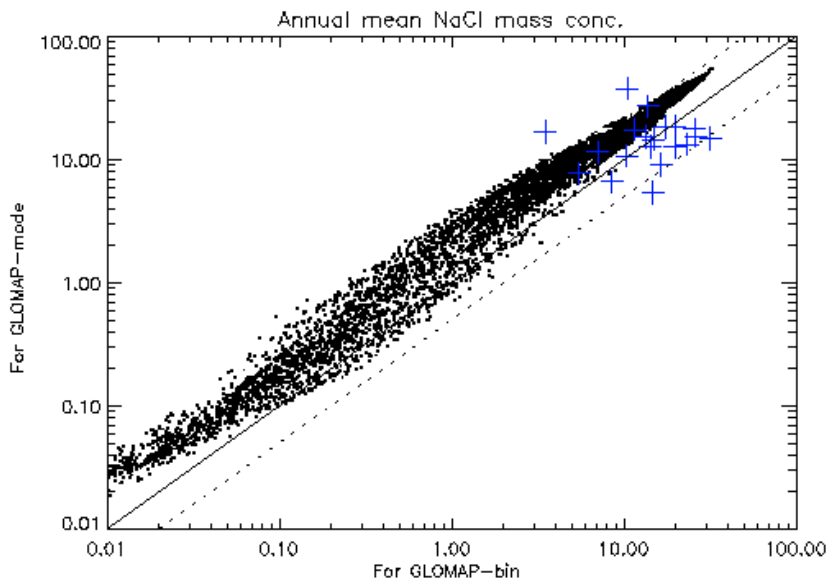
GLOMAP-mode/-bin NaCl mass concentration against U. Miami (Global), Annual mean

UNIVERSITY OF LEEDS



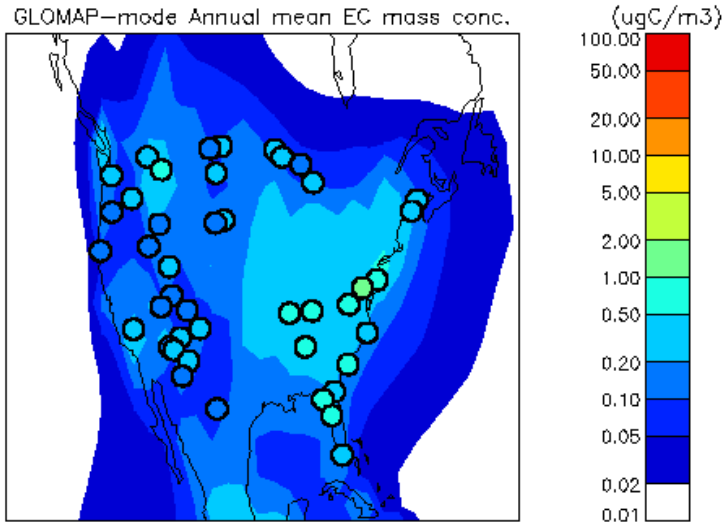


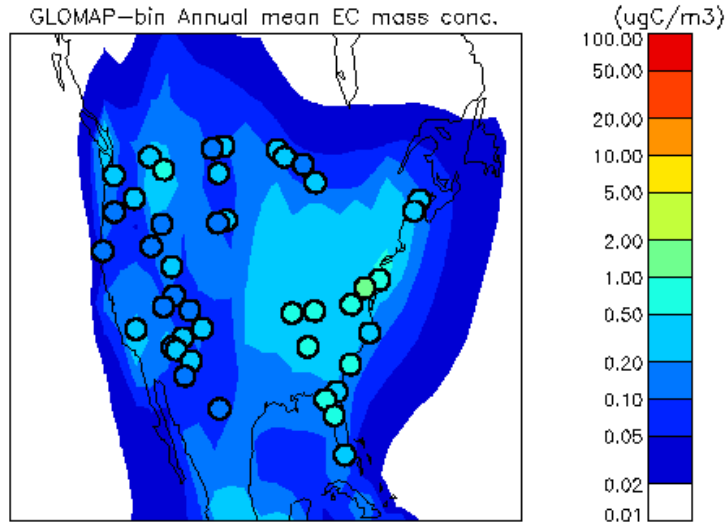


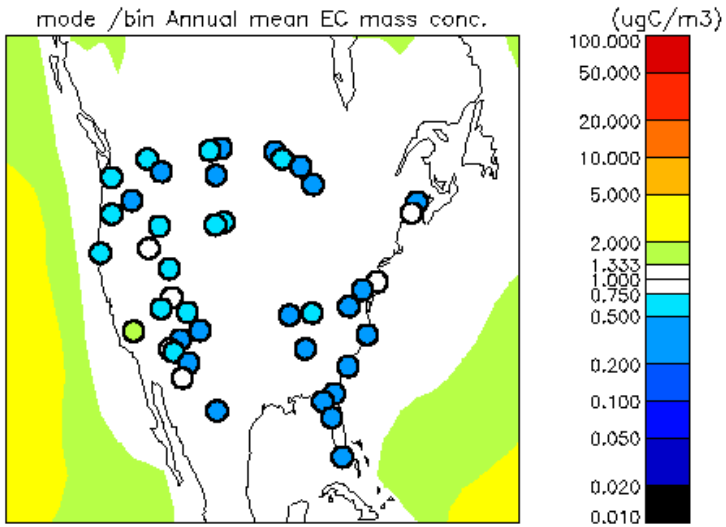


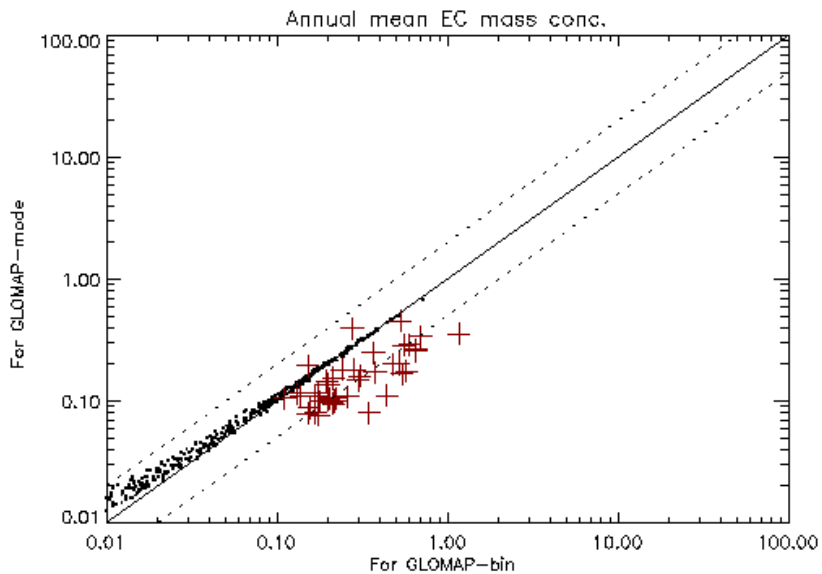
GLOMAP-mode/-bin EC mass concentration against IMPROVE (US), annual mean

UNIVERSITY OF LEEDS



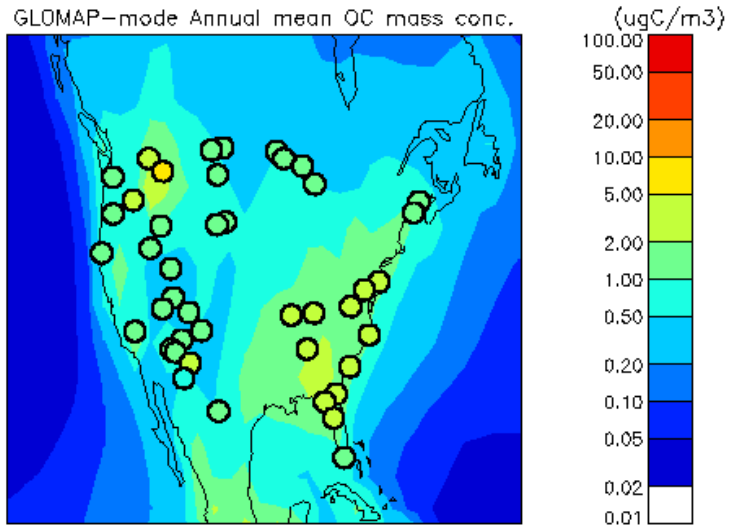


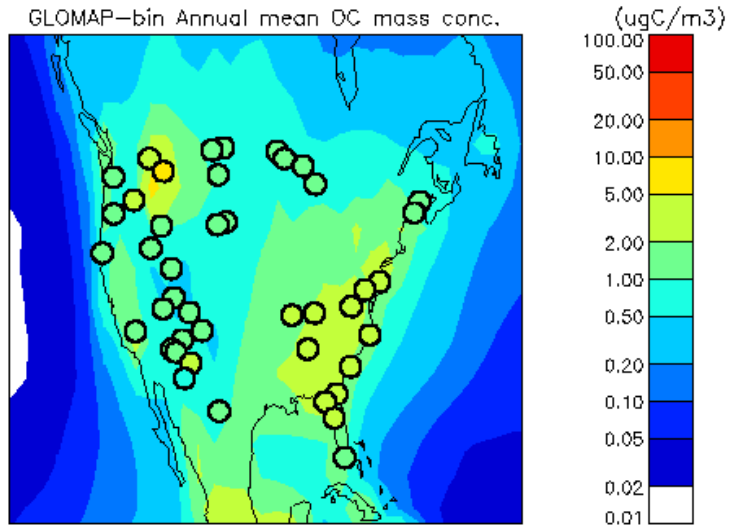


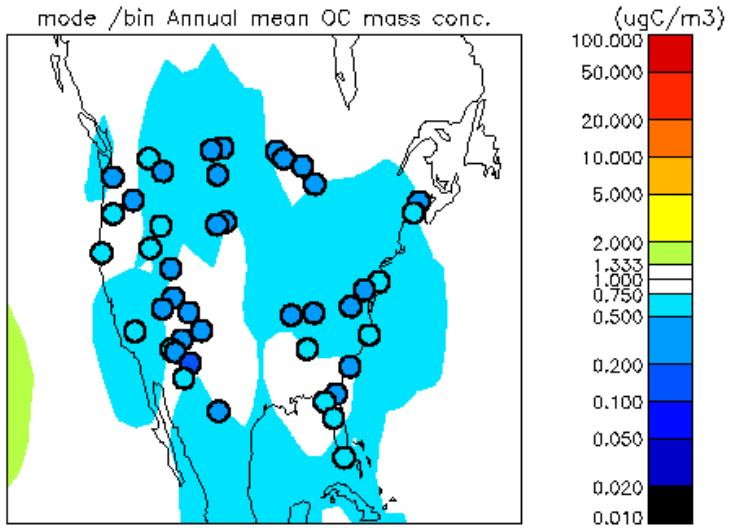


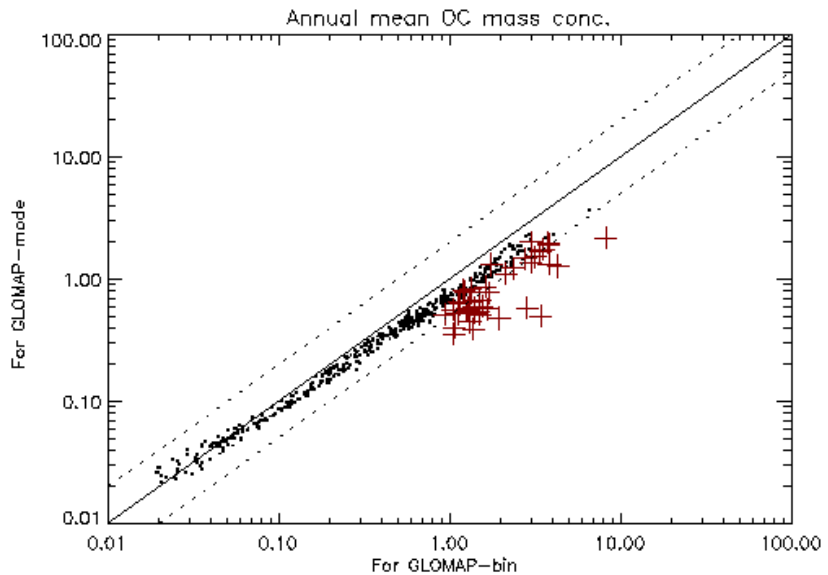
GLOMAP-mode/-bin OC mass concentration against IMPROVE (US), annual mean

UNIVERSITY OF LEEDS

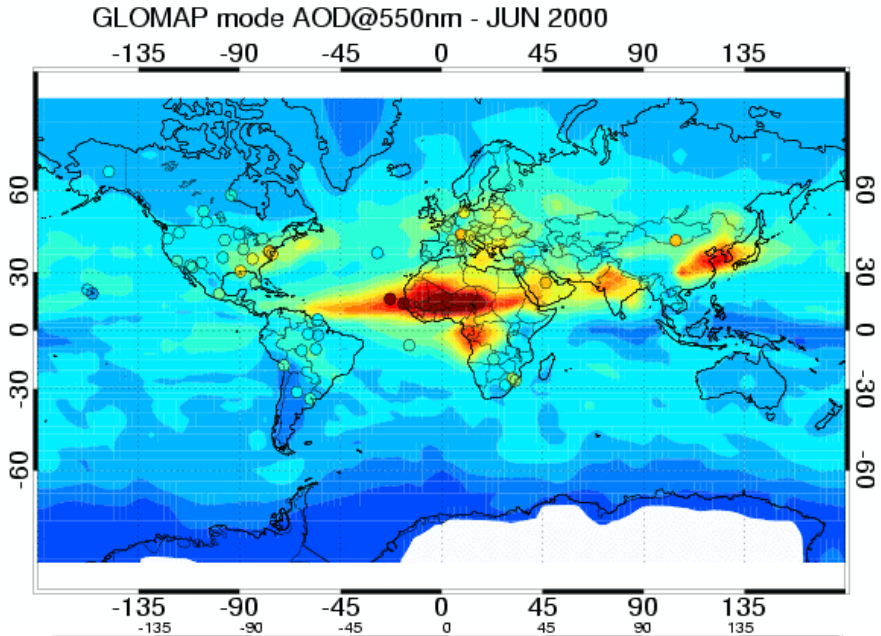


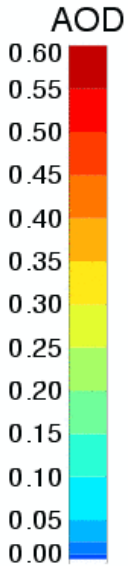






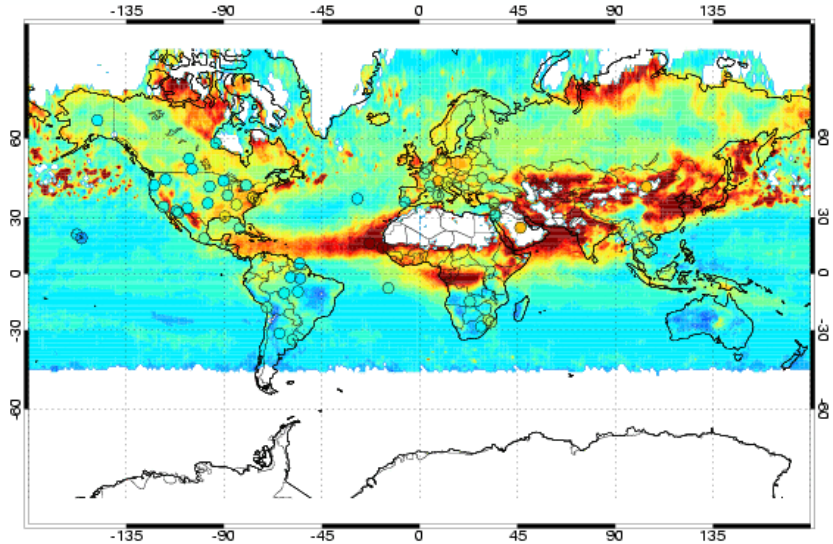
Aerosol Optical Depth model vs observed

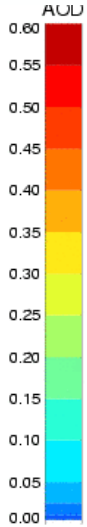




Jun00 GLOMAP-mode Aerosol Optical Depth (550nm)

AERONET AOD observations overplotted with coloured circles.





Jun00 MODIS Aerosol Optical Depth (550nm)

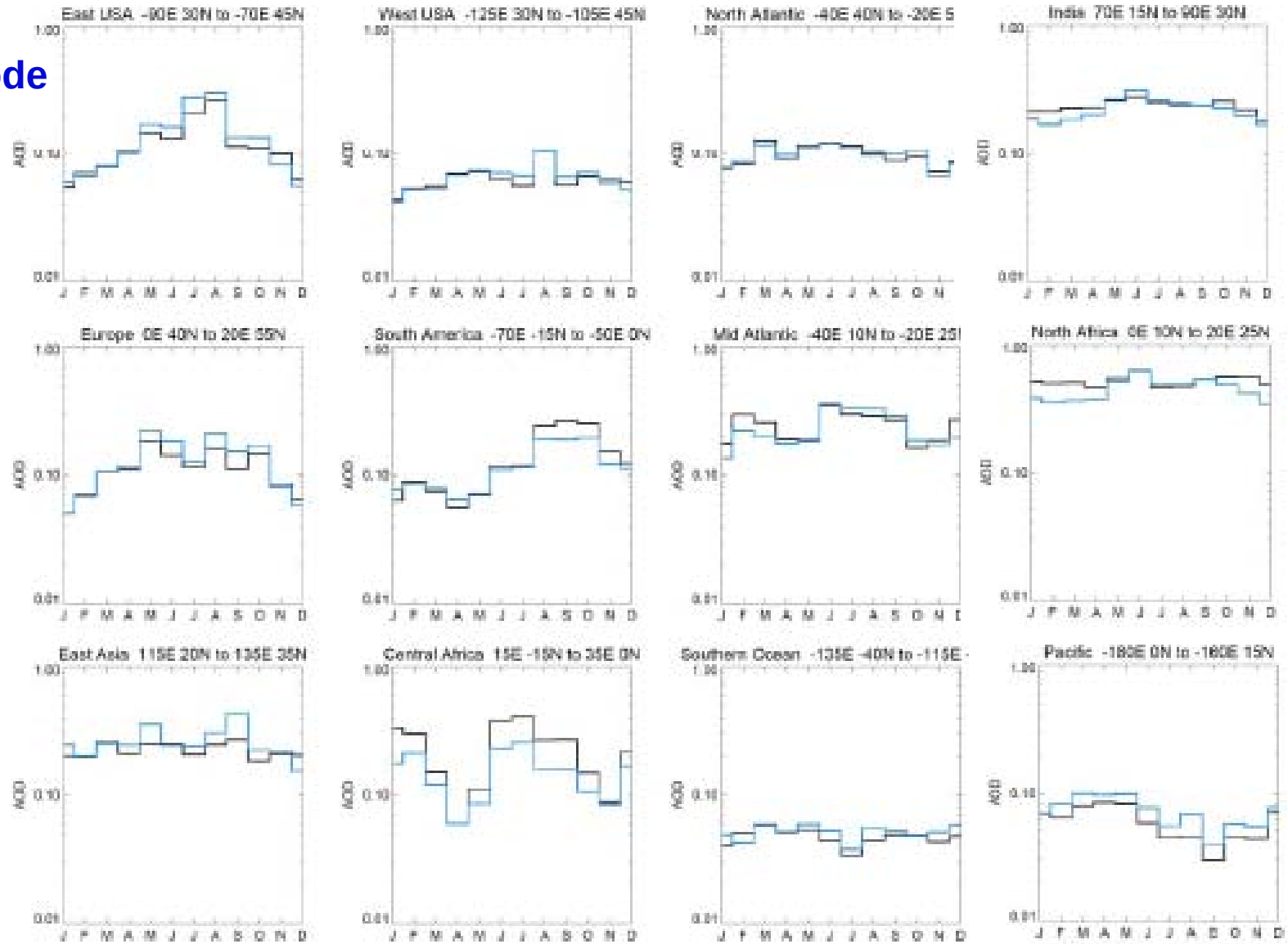
AERONET AOD observations overplotted with coloured circles.

Dave Ridley (Leeds)

Aerosol Optical Depth annual cycle in bin/mode

UNIVERSITY OF LEEDS

GLOMAP-bin
GLOMAP-mode

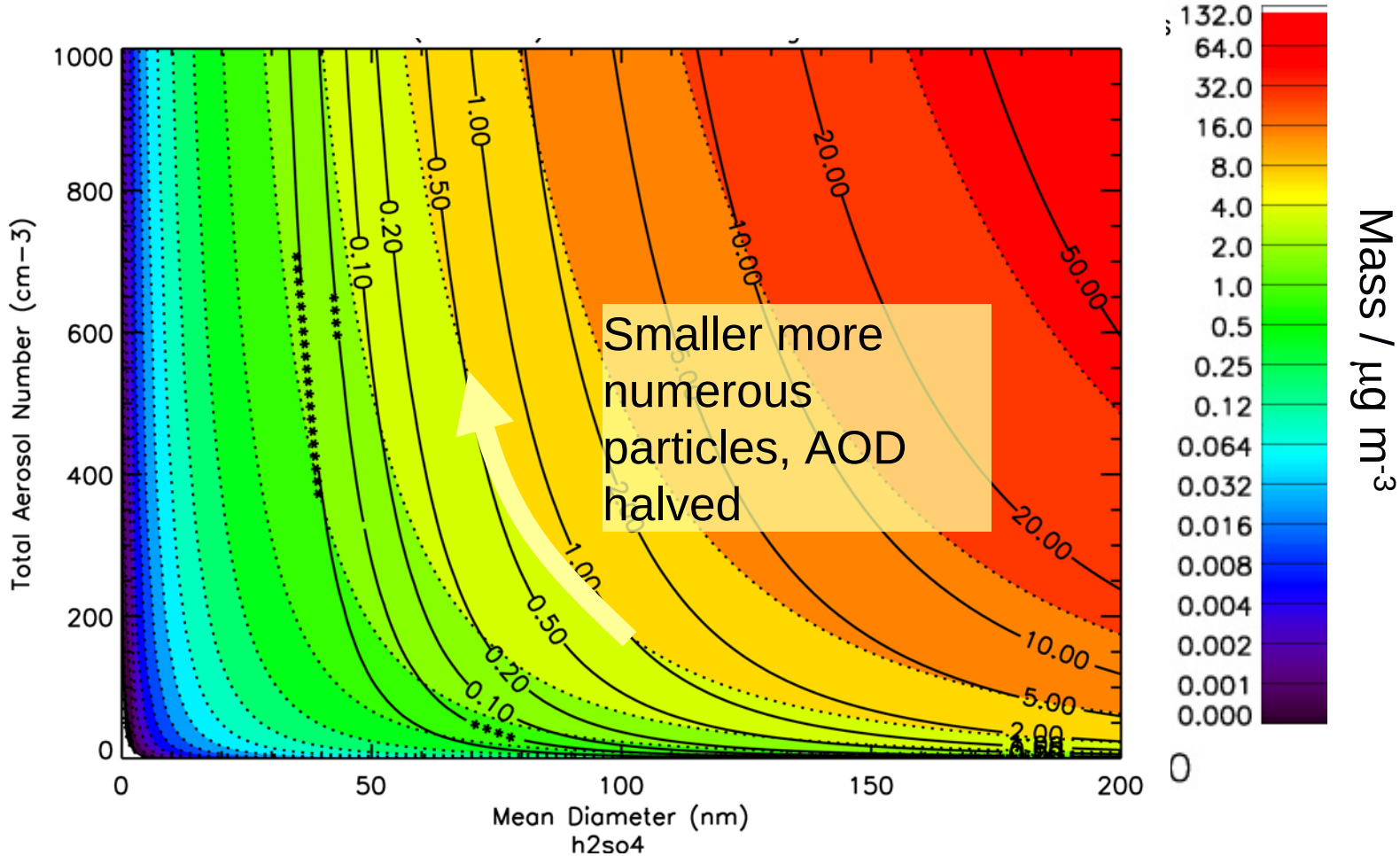


Dave Ridley
(Leeds)

Importance of the size distribution: Aerosol optical depth

UNIVERSITY OF LEEDS

Extinction coefficient calculations based on log-normal SO_4 aerosol



Kirsty Pringle (PhD thesis)

Models can be tuned to get AOD & mass well vs observations but since AOD is column & size-integrated, not good constraint on size or CCN concentration.

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

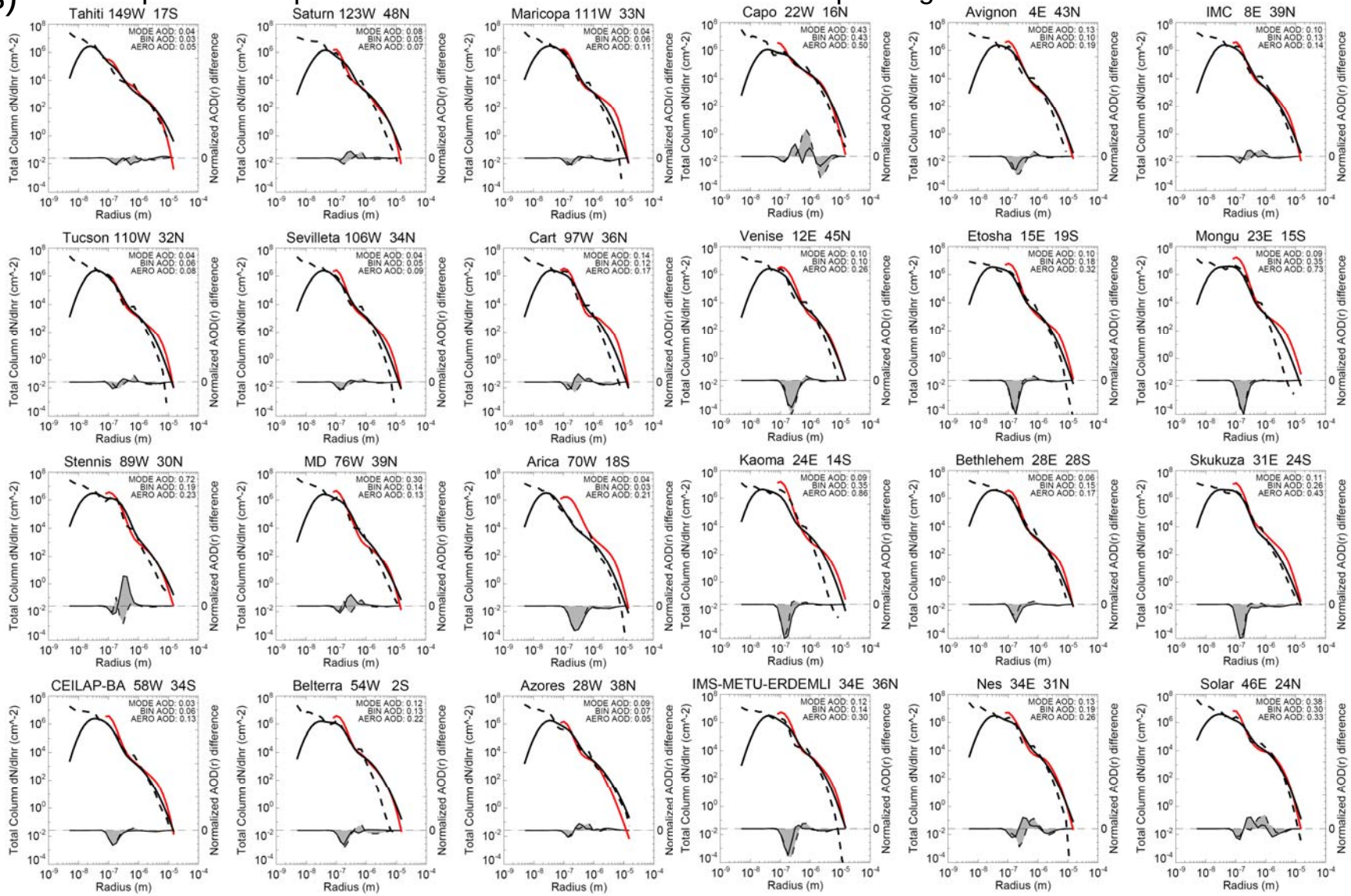
1) AERONET size distributions.

AERONET size distributions vs model

UNIVERSITY OF LEEDS

Dave Ridley (Leeds)

But still column integrated product and retrieval technique includes implicit assumptions above size distbn? --- better to compare against in-situ?



Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

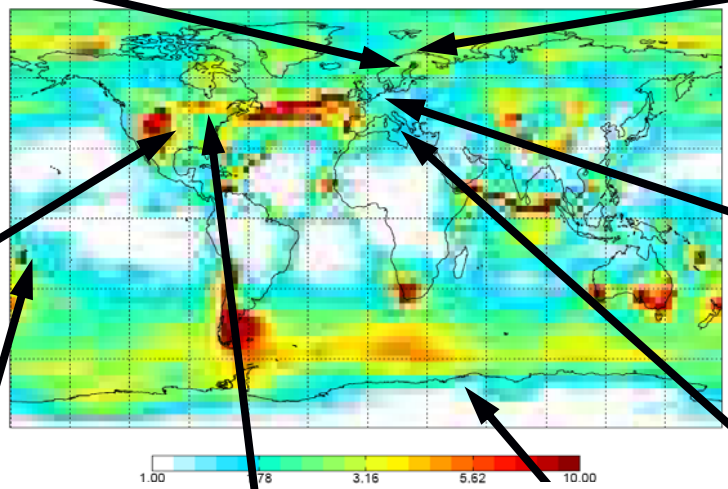
But column & size integrated product --- better to compare to in-situ observations

2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements over last 5+ years

GLOMAP CN being evaluated against observations at GAW and ARM sites

UNIVERSITY OF LEEDS

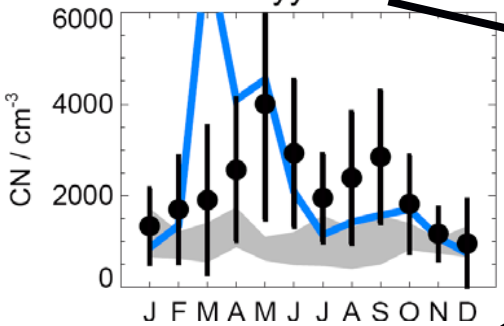
Ratio of simulated annual mean CN concentation with BL new particle formation: without

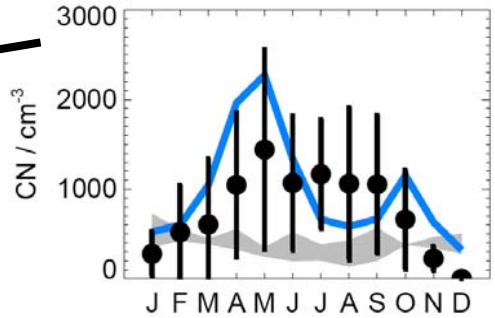


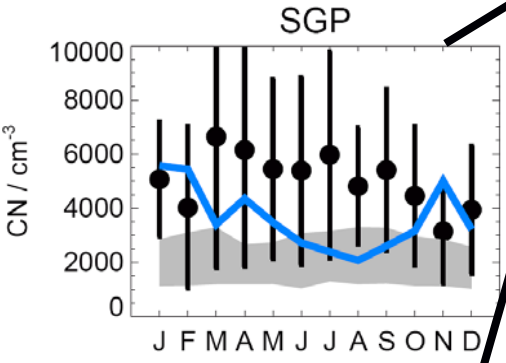
1 10

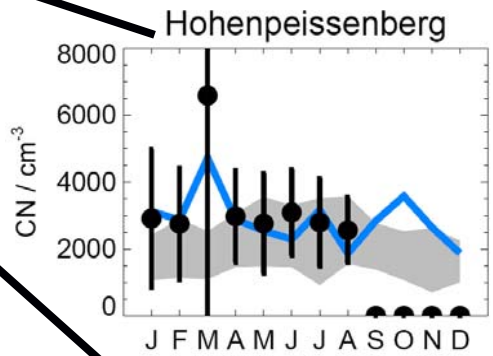
Model: Binary Homogeneous nucleation. Shading shows primary particle number emission varied by a factor 8

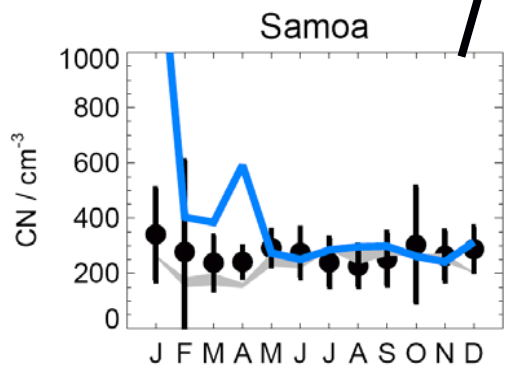
Model: BL New Particle Formation ($A = 2 \times 10^{-6}\ s^{-1}$, M=1) + primary particles

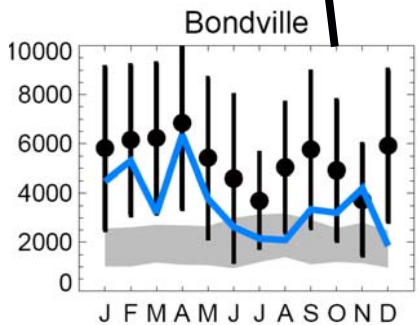


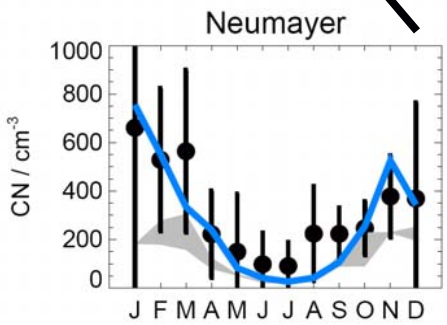


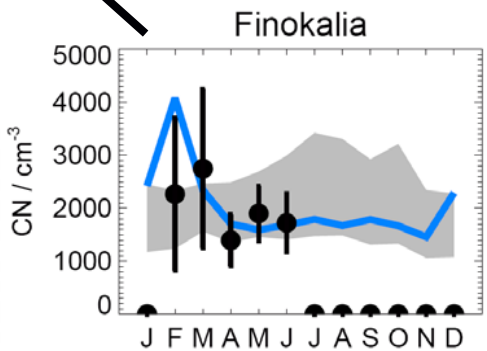












Spracklen et al (in preparation)

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

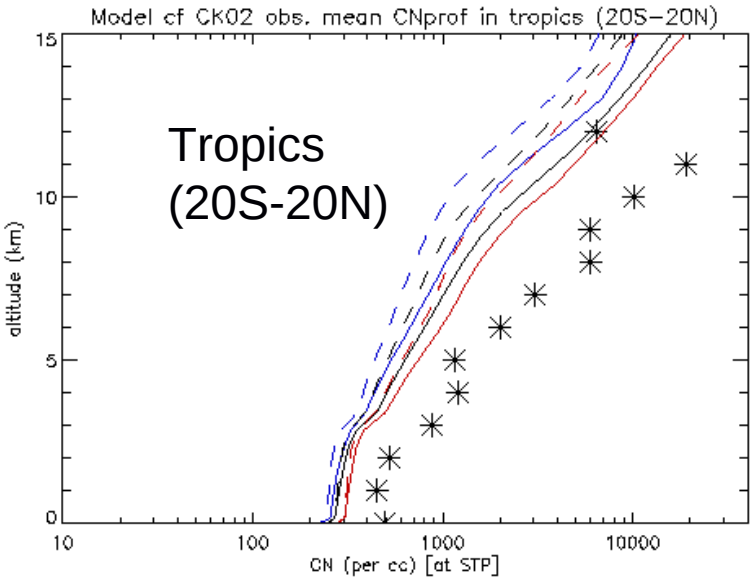
2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

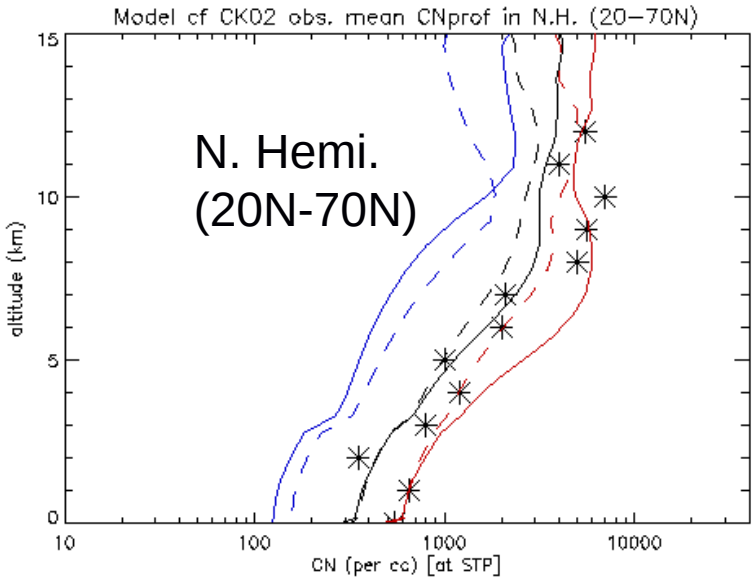
Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

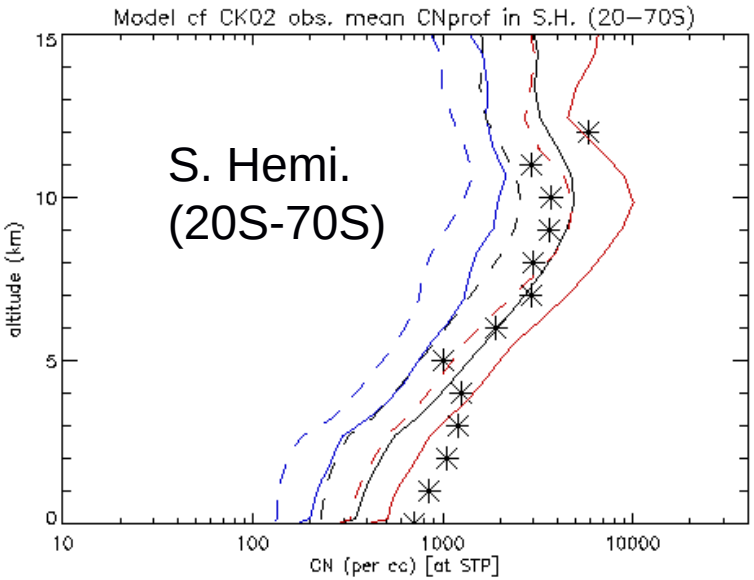
3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])

CN profiles vs Clarke & Kapustin (2002) profiles

UNIVERSITY OF LEEDS







—— GLOMAP-mode
------ GLOMAP-bin
* aircraft CN obs

Max. month value
Annual mean
Min. month value

Both model versions underestimate tropical FT CN (~2) over Pacific.

NH & SH Pacific compare better but BL concentrations too low
(remedied when BL nucleation included).

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

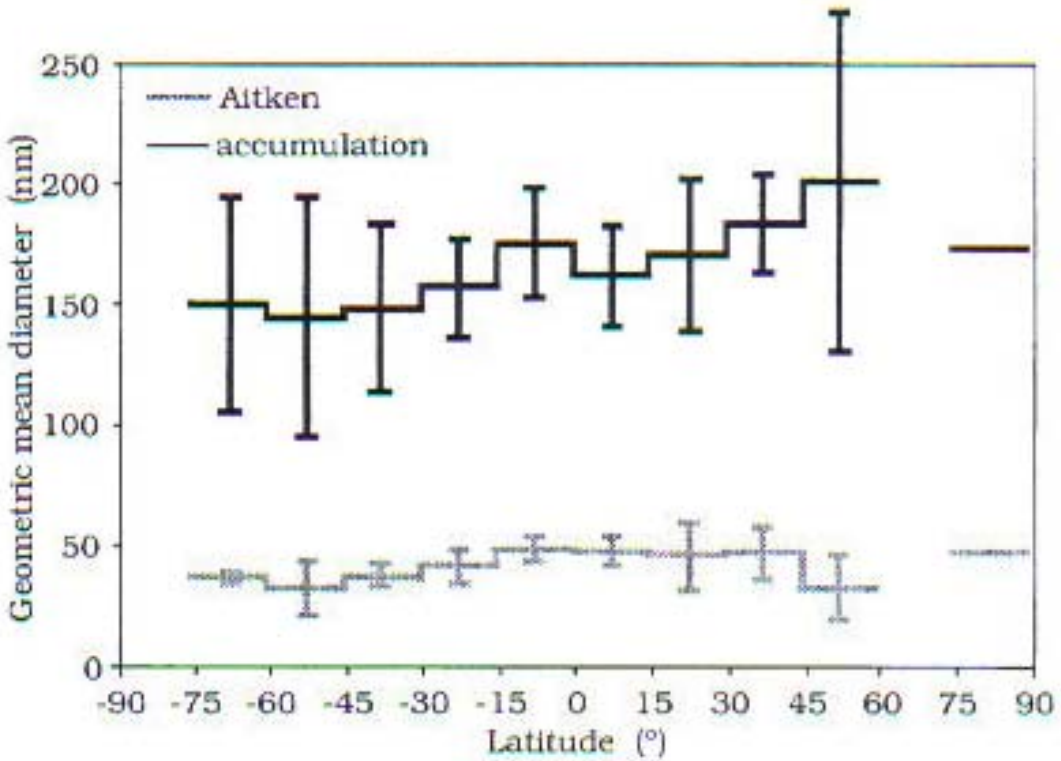
But still column integrated product --- better to compare to in-situ observations

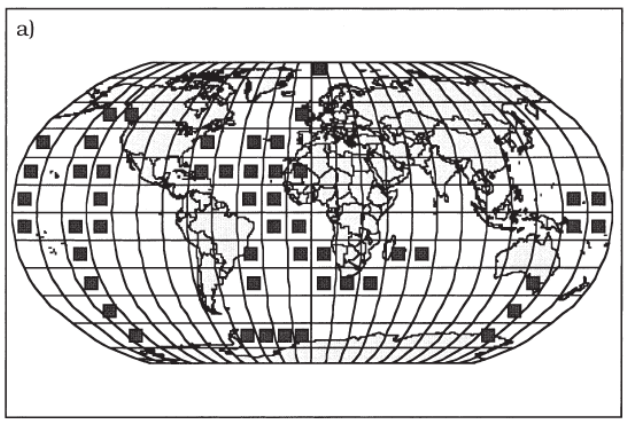
2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])
-- MBL climatology of size distribution, number (Heintzenberg et al, 2000)

Compilation of MBL aerosol observations





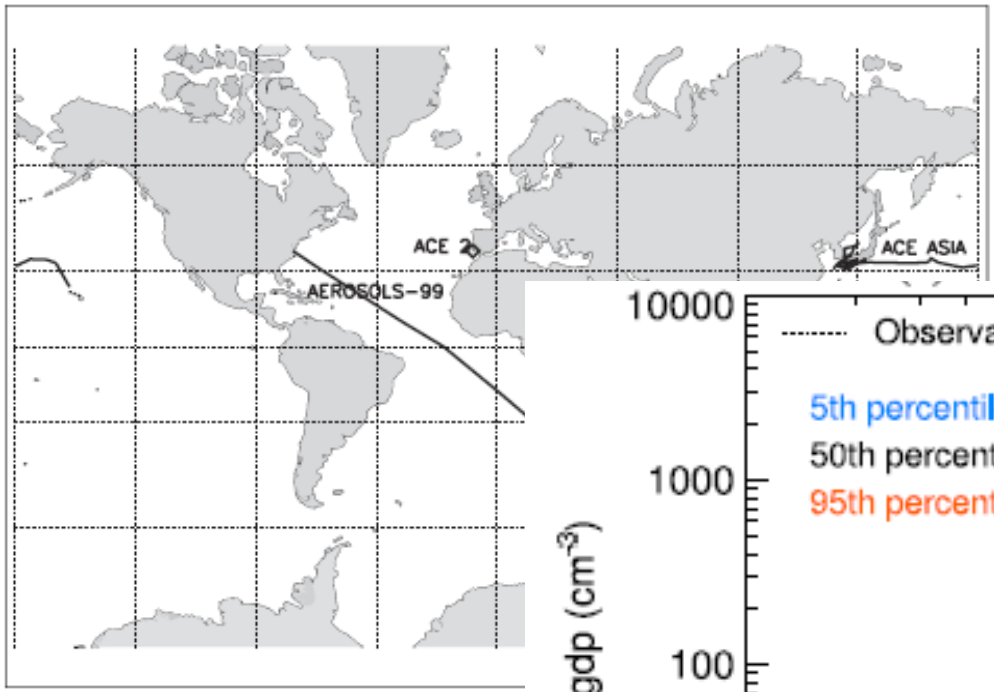
Heintzenberg et al (2000, Tellus B)

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

GLOMAP-bin size distributions vs observations

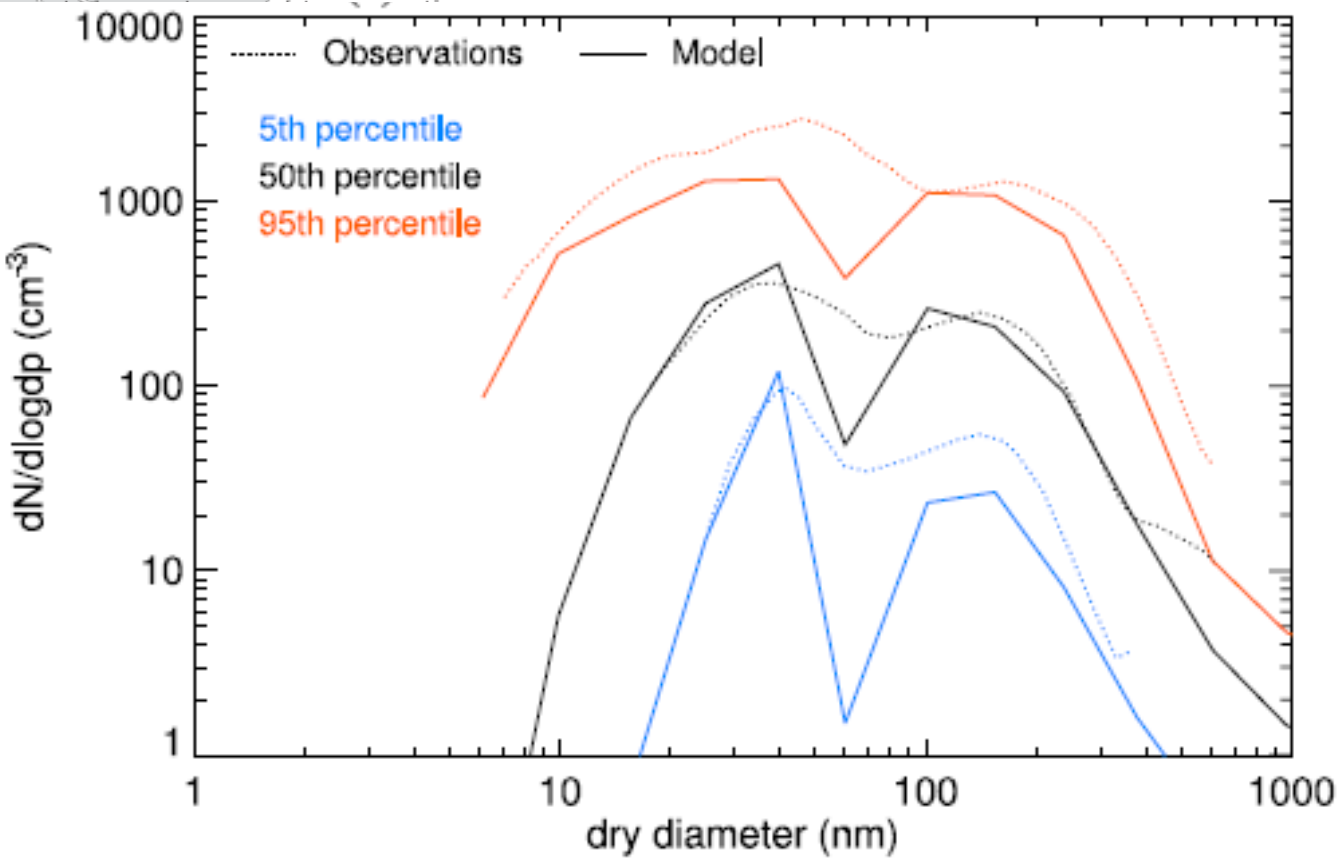
UNIVERSITY OF LEEDS



Experiment	Locatic
ACE-1	Cape Grim, Sout 40.8° S, 14
ACE-2	Sagres, NE A 37° N, 9°
Aerosols99/ INDOEX	Atlanti Indian Oc
ACE-Asia	Pacific Oc

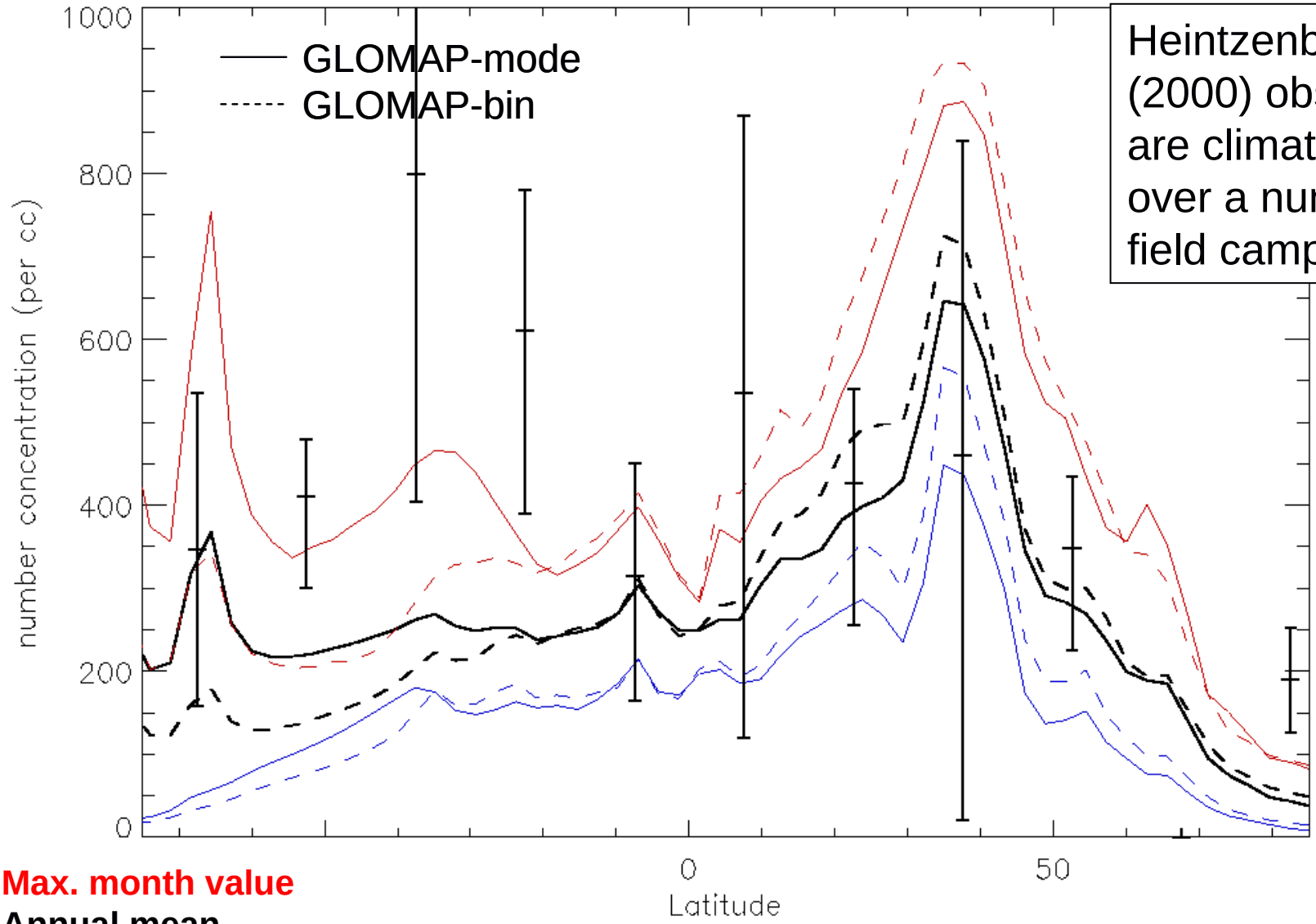
Spracklen et al. (2007)

Here sample model daily-means and compare median & 5/95 pctile to observational climatology.



Zonal mean surface MBL CN concentrations, GLOMAP-mode vs –bin vs observations

UNIVERSITY OF LEEDS



Heintzenberg et al (2000) observations are climatology over a number of field campaigns

Max. month value
Annual mean
Min. month value

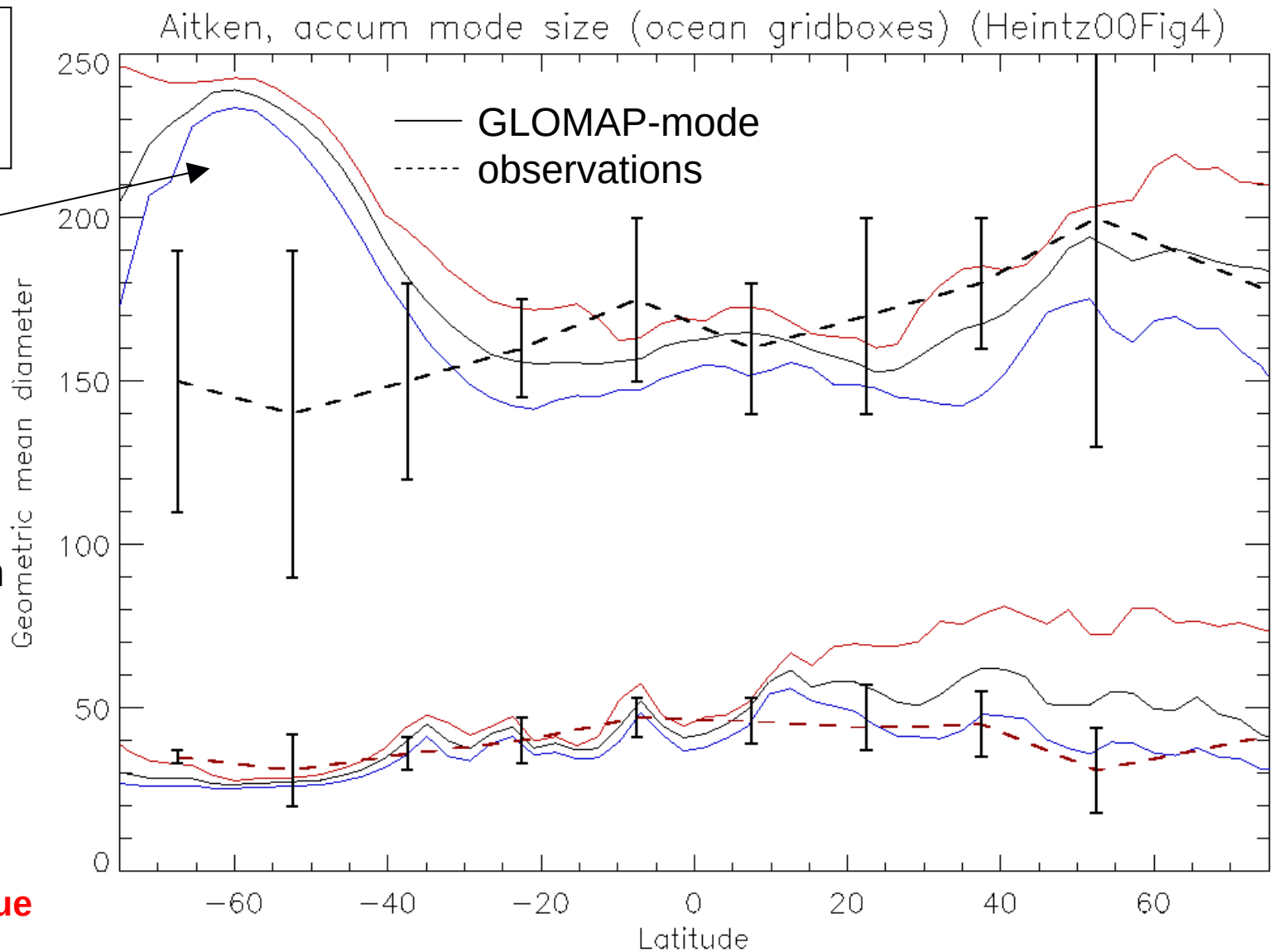
Zonal mean surface MBL mean mode radius, GLOMAP-mode vs observations

UNIVERSITY OF LEEDS

Heintzenberg et al (2000) observations

S. Ocean discrepancy in particle size (also number).

This run uses Gong sea-spray source function (not include UF sea-spray)



Max. month value
Annual mean
Min. month value

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

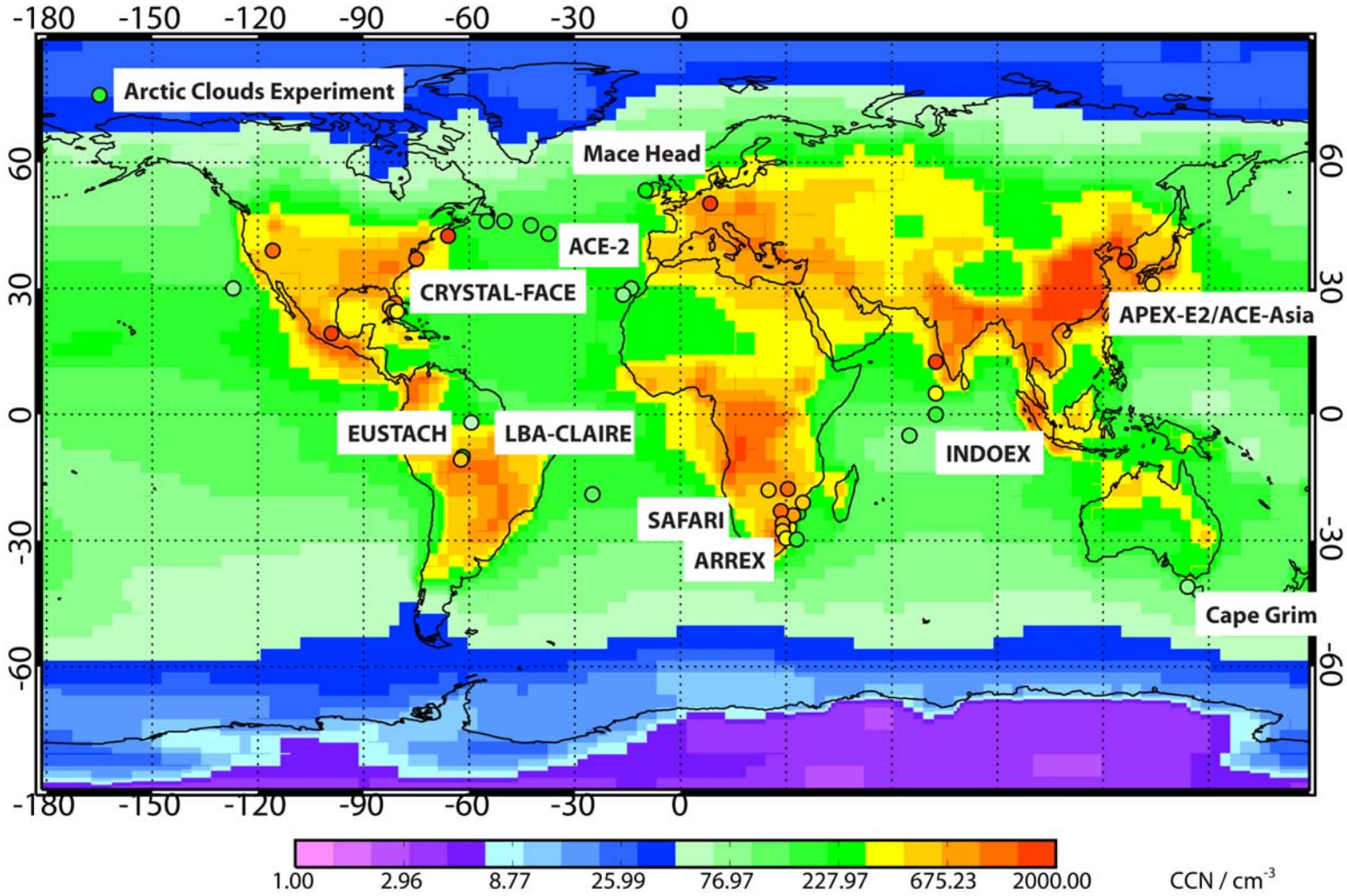
2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])
-- MBL climatology of size distribution, number (Heintzenberg et al, 2000)
-- surface CCN from many field campaigns measured @ many supersaturations

GLOMAP CCN being evaluated against a range of worldwide observations

UNIVERSITY OF LEEDS

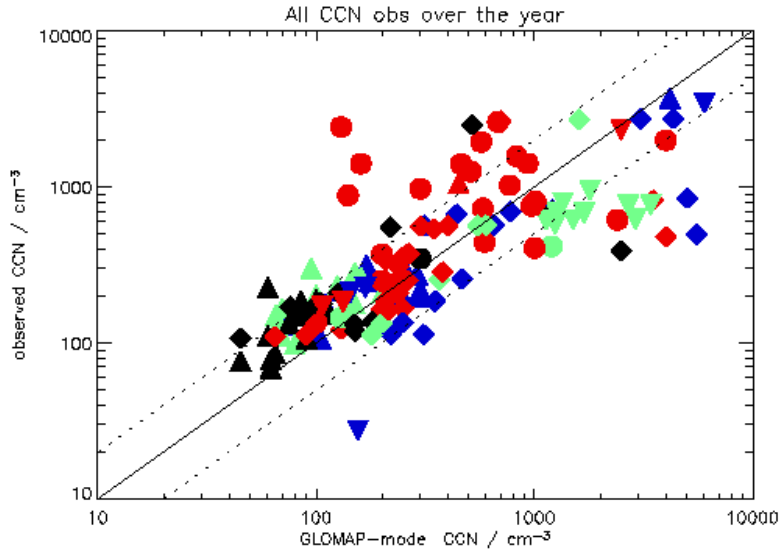


Note: map shows CCN at 0.2% supersaturations.
Coloured circles show observations at range of supersaturations

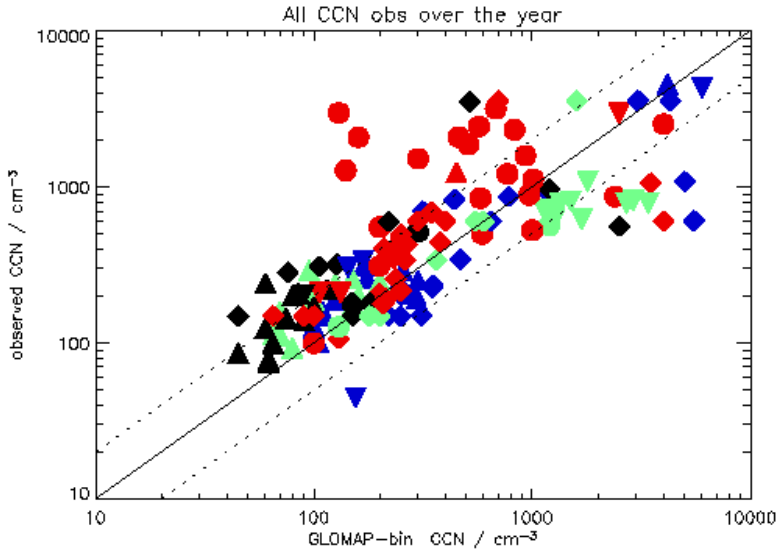
GLOMAP CCN being evaluated against a range of worldwide observations

UNIVERSITY OF LEEDS

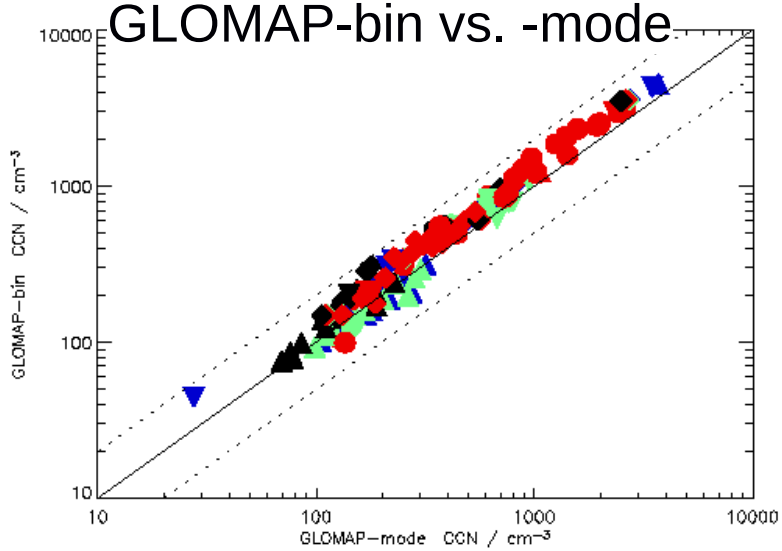
GLOMAP-mode vs. observations

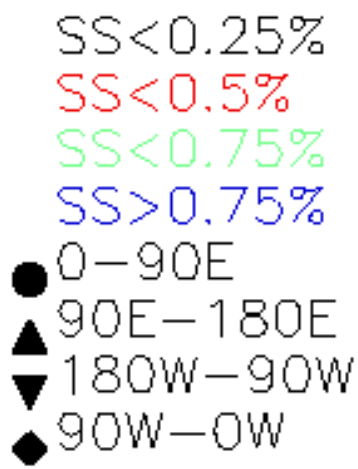


GLOMAP-bin vs. observations



GLOMAP-bin vs. -mode





Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

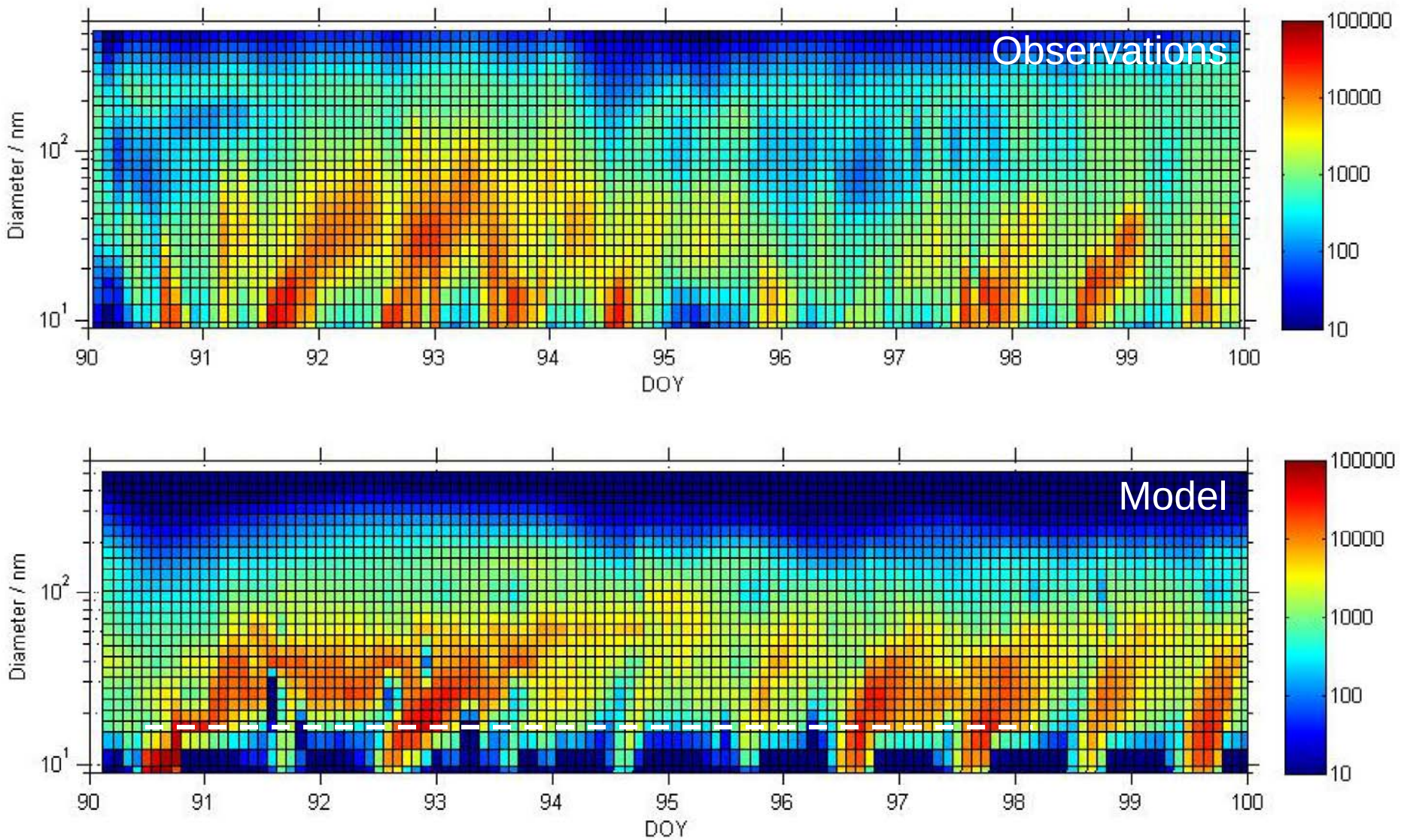
Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])
-- MBL climatology of size distribution, number (Heintzenberg et al, 2000)
-- surface CCN from many field campaigns measured @ many supersaturations

4) EUSAAR supersites with DMPS & AMS for EMEP intensive years 2006 & 2008

GLOMAP-bin vs DMPS at Hyytiala (hourly means)

UNIVERSITY OF LEEDS

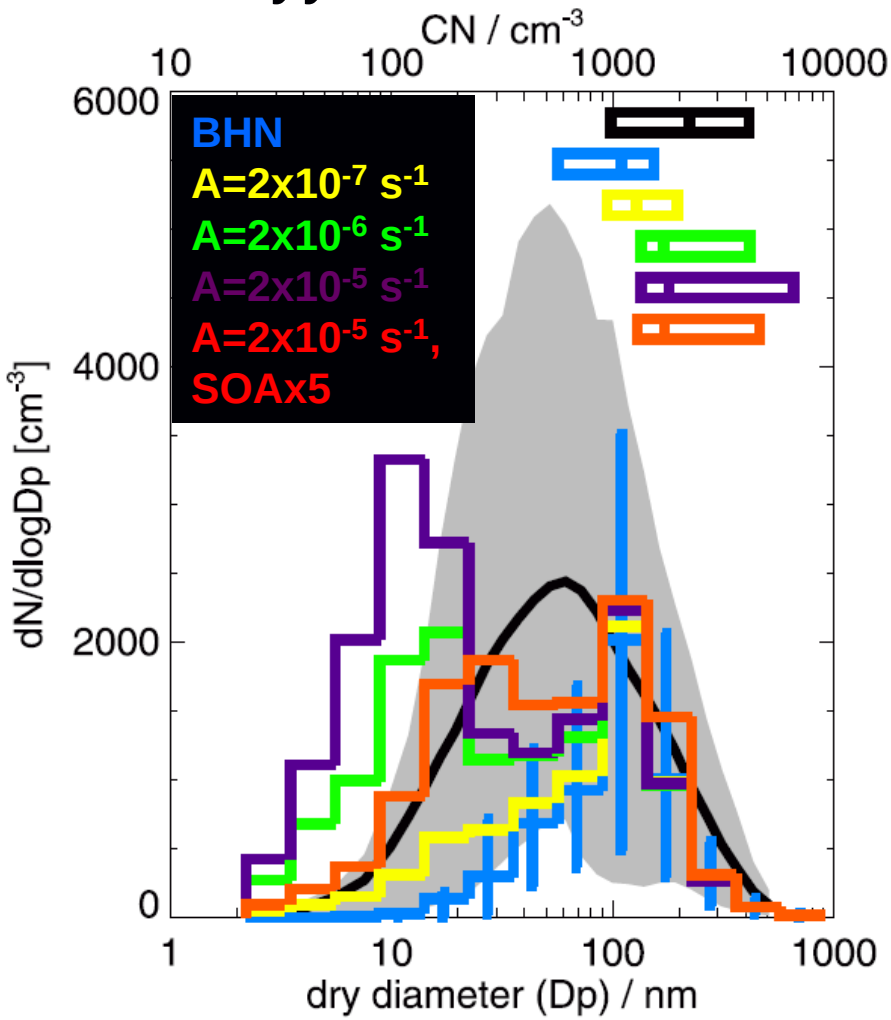


Spracklen et al (2006, ACP)

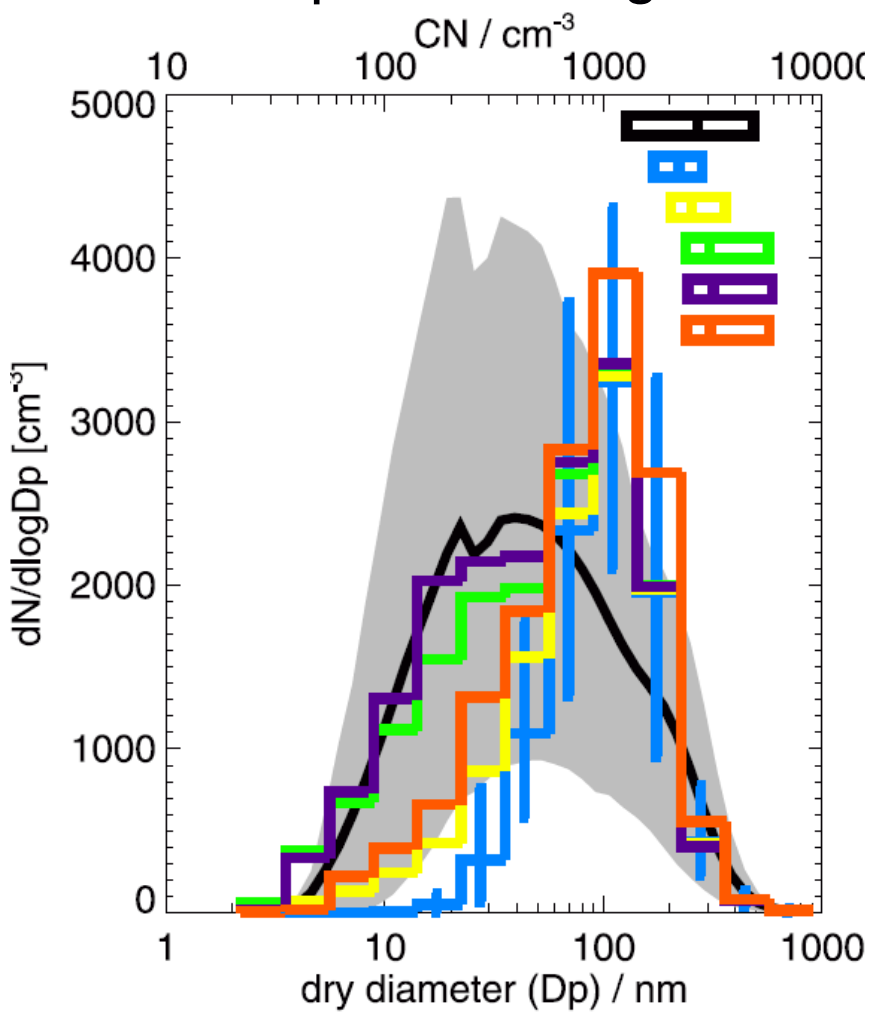
GLOMAP size distributions being evaluated against European DMPS observations

UNIVERSITY OF LEEDS

Hyytiala, Finland

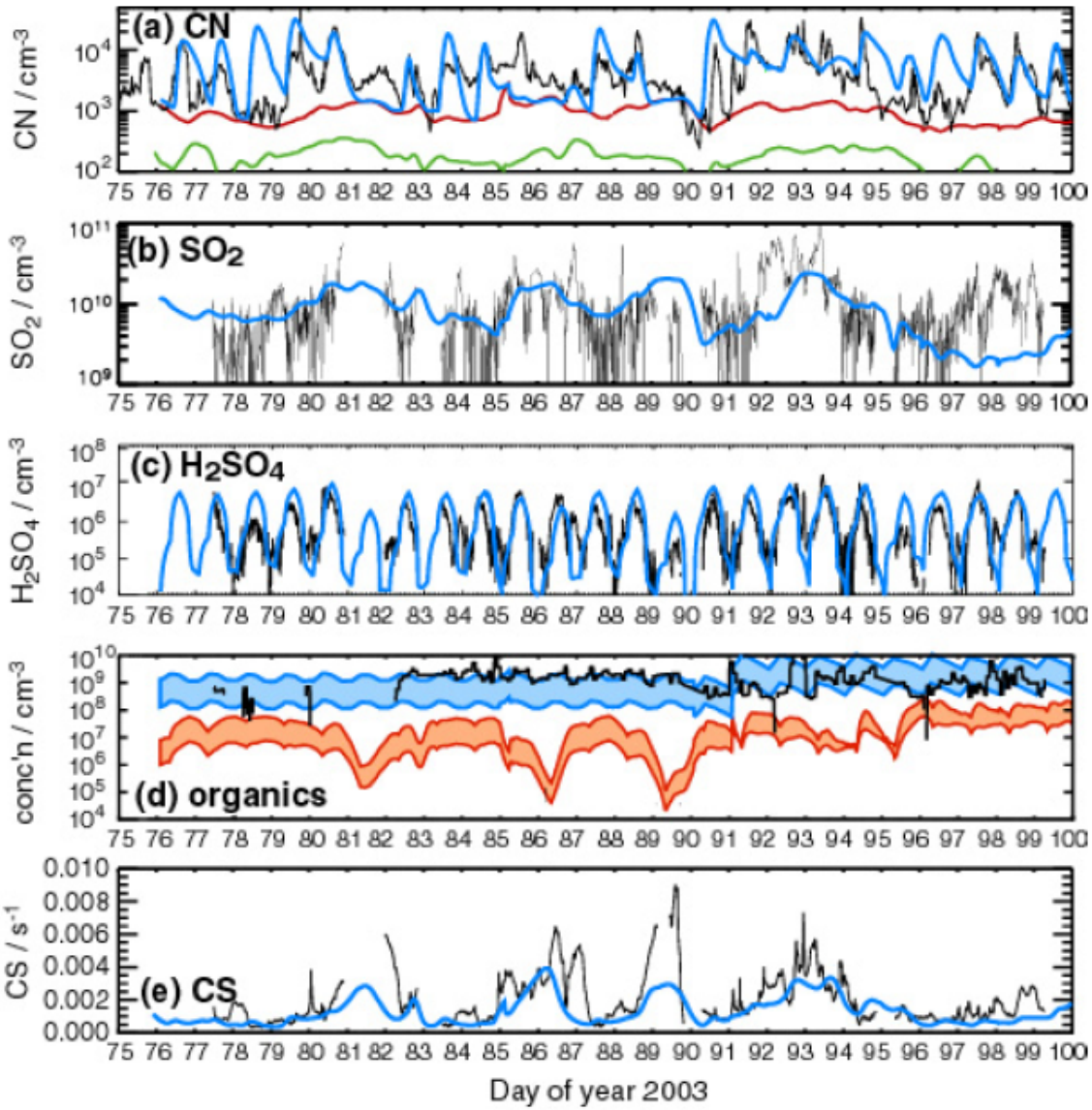


Hohenpeissenberg, Germany



Spracklen et al (2008, GRL)

Can compare CS among models



New particle formation rate at 3nm part-controlled by condensation sink CS

Potential to compare CS among models even among those with no BL nucleation to investigate potential differences in BL nucleation behaviour among models.

Spracklen et al (2006, ACP)

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

Cape Grim has 20+ years record of CN & CCN showing trend of increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

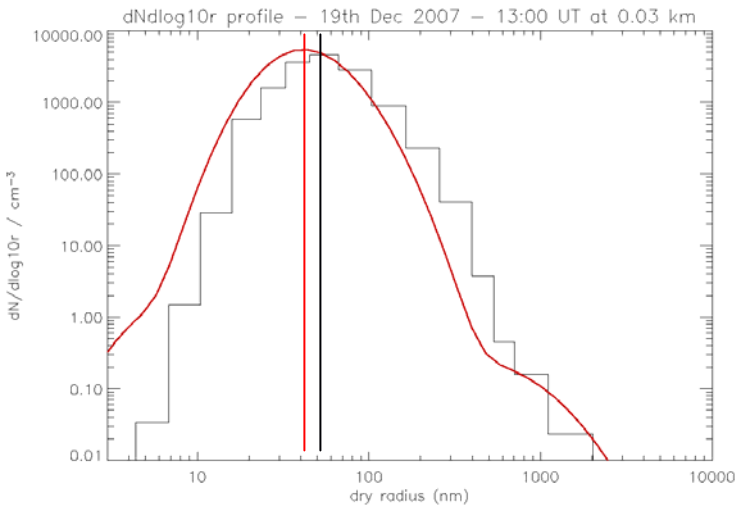
3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])
-- MBL climatology of size distribution, number (Heintzenberg et al, 2000)
-- surface CCN from many field campaigns measured @ many supersaturations

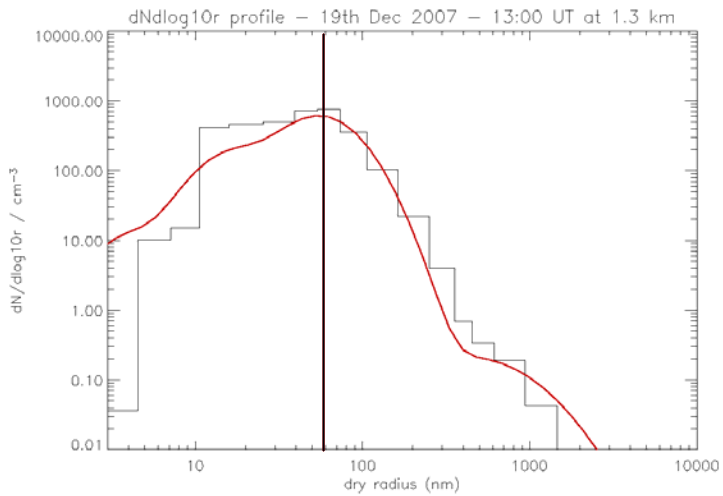
4) EUSAAR supersites with DMPS & AMS for EMEP intensive years 2006 & 2008

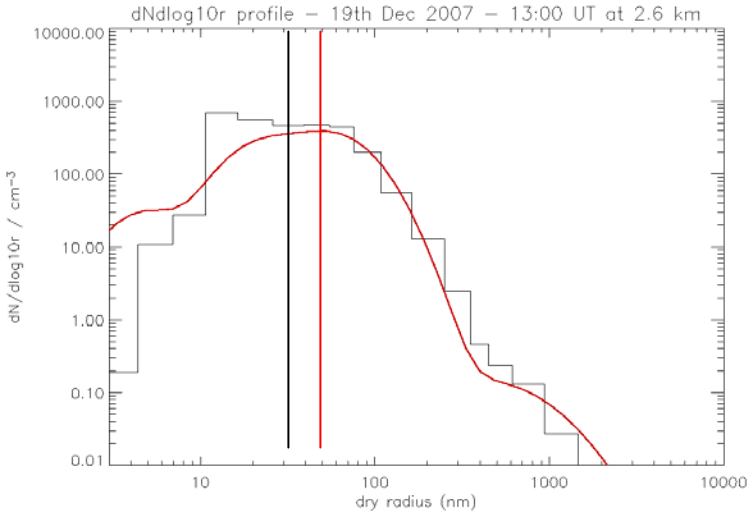
5) EUCAARI & ADIENT aircraft observations from May-June 2008

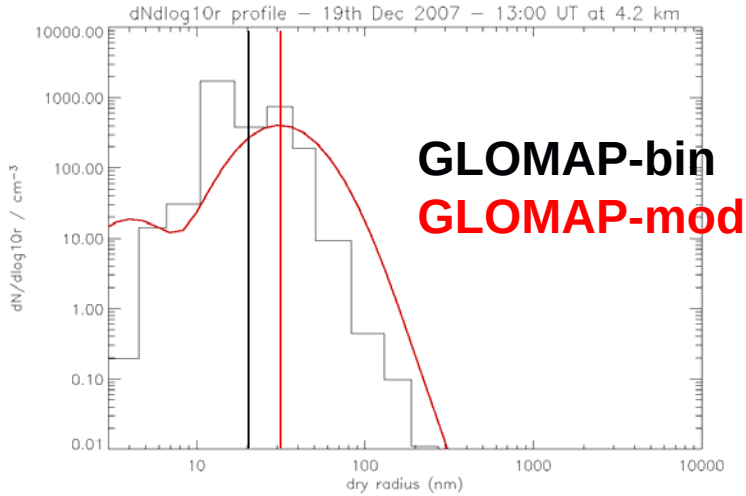
Hourly-mean size distributions GLOMAP-bin/-mode

UNIVERSITY OF LEEDS









Maria Frontoso (Leeds)

GLOMAP-bin

GLOMAP-mode

Example of simple model vs model at different levels @ pt – compare growth

Will compare against EUCAARI & ADIENT aircraft size-distbn observations

Need to constrain simulated size, number concentrations as well as mass/AOD.

UNIVERSITY OF LEEDS

But what observations can we use to constrain particle size?

1) AERONET size distributions.

But still column integrated product --- better to compare to in-situ observations

2) CN concentrations: Many GAW/ARM sites made total-aerosol number concentration measurements since ~2000

Cape Grim has 20+ years record of CN & CCN showing increasing CN but decreasing CCN. Do we understand the cause?
Can AC&C hindcast also focus on understanding long-term trends in number?

3) CN/CCN concentrations from field campaigns and some monitoring sites.
-- Aircraft vertical profiles of CN (e.g. Clarke & Kapustin (2002) [Pacific]
CCN (e.g. Anderson [many regions])
-- MBL climatology of size distribution, number (Heintzenberg et al, 2000)
-- surface CCN from many field campaigns measured @ many supersaturations

4) EUSAAR supersites with DMPS & AMS for EMEP intensive years 2006 & 2008

5) EUCAARI & ADIENT aircraft observations from May-June 2008?

Other field campaign climatologies to use? (suggest or email gmann@env.leeds.ac.uk)

Challenges when comparing particle size

UNIVERSITY OF LEEDS

Models characterise size distribution in many different ways
-- mass-only in size modes, fixed size distribution (10-15 aerosol tracers)
-- number & mass concentrations in size modes (20-30 aerosol tracers)
-- number & mass in concentrations size bins (100-200 aerosol tracers)

Different treatment of nucleation, primary sizes & growth processes (coag'n, cond'n)

CCN observations retrieve CCN at many different supersaturations
(Not possible to make simple CCN diagnostics for models to output.)

CN measurements can use different minimum diameter (e.g. 3nm or 10nm).

Size distribution observations made across different size ranges.

How do we intercompare size distribution & processes controlling size distribution in a consistent way among these models and to observations?

Proposed approach: ask modelers to output all aerosol tracers at ~50 sites.
-- Use existing IDL routines to back out size distribution from aerosol tracers.

Ensures consistent CN, CCN, mean-size, size-resolved N/composition diagnostics

Can afford high temporal sampling: ~50 data pts c.f. 3D gridded data (~500,000)
-- makes separation of size distribution into different air mass types possible
-- potential to back out scattering/absorption at sites to compare with neph./aeth.

Supersite list compiled by Julian Wilson (after discussion with GAW SSC)

UNIVERSITY OF LEEDS

GAW & ARM sites (CPC, nephelometer, aethalometer, some with lidar)
Alert, Barrow, Bondville, Mauna Loa, Neumayer, Samoa, South Pole, Southern Great Plains,

21 EUSAAR supersites (many with DMPS, AMS, lidar)
Aspreveten, Auchenworth, Birkenes, Cabauw, Finokalia, Harwell, Hohenpeissenberg, Hyytiala, Ispra, Jungfraujoch, Kosetice, K-puzta, Mace Head, Melpitz, Montseny, Moussala, Pallas, Preila, Puy de Dome, Valvihill, Zeppelin.

Additional sites with observations
Cape Grim, Cape Point, Capo San Juan, Elandsfontein, Guangzhou, Manaus, Monte Cimone, Mount Waliguan, Paverne, Shang Dianzi, Sonnblick, Summit, Tahkuse, Trinidad Head, Varrio

Total 54 in this draft list --- revisit list & check for finalise re: potential availability

Proposed diagnostic requirements for participants

UNIVERSITY OF LEEDS

All-aerosol-tracer output (please also mass-only models – test if microphysics worth it!)

HCA-IPCC – 0D-daily mean @ 54 sites and global 2D monthly mean.
(for free-running GCMs just climatological 2D monthly means)

Get global seasonal trends in surface CN, CCN concentrations from 2D data stream
Compare models to CN observations with daily variability @ GAW/ARM sites.

Ask models to change to more frequent & profile all-tracer output over 2 years 2006-7:
Intensive Period 0D-hourly @ 50 sites (compare to in-situ DMPS, AMS)
1D-daily @ 50 sites (compare growth & to ground-based lidar?)
3D monthly mean (compare vertical size distribution & aircraft obs)

Ensures synergy with intensive measurement initiatives (EMEP intensive 2006).

Also enable size-resolved organic aerosol comparison with AMS (organics group).

Potentially also extend to 2008 with same 2007 emissions to compare to
EMEP-intensive 2008 and EUCAARI and APPRAISE-ADIENT field campaigns.

Suggest also invite EUCAARI regional/global models to join 2006-8 output
(EUCAARI WP5.3 has mandatory benchmark test for aerosol size)

Feedback & discussion --- do all models have facilitiy to easily interpolate to sites?
--- are mass-only models also willing to give size distributions?

Already have several models agreed to submit results

UNIVERSITY OF LEEDS

Model	Aerosol Dynamics	# of aerosol tracers	Hindcast?	06/07 IOP?	Contact
GLOMAP-bin	Bin-resolved (N,m)	~200	No	Yes	Dominick Spracklen (Leeds)
GLOMAP-mode	Modal (N,m)	30	Yes	Yes	Graham Mann (Leeds)
UKCA-UM	Modal (N,m)	30	Yes	Yes	Graham Mann (Leeds)
ECHAM-HAM	Modal (N,m)	25	Yes	Yes	Sebastian Rast (MPI-Hamburg)
ECHAM-HAMMOZ	Modal (N,m)	25	Yes	Yes	Sebastian Rast (MPI-Hamburg)
GISS-MATRIX	Moments (N,m)	60	Yes	Yes	Susanne Bauer (GISS)
EMAC [ECHAM-MESSy]	Modal (N,m)	30+	No	Yes	Kirsty Pringle (MPI-Mainz)
NCAR CAM3-MAM	Modal (N,m)	31/15	Yes	Yes	Xiaohong Liu (PNNL)
TM5	Modal (N,m)	25	Yes	Yes	Elisabetta Vignati (JRC)
CCCma AGCM4	PLA-bin (N,m)	240	Yes(F-R)	No	Knut Van Salzen (Env Canada)

Hope that all AEROCOM modellers will submit results for 0D-daily HCA-IPCC

Potential interest also from 2 EUCAARI modellers -- Peter Adams and Spyros Pandis.