School of Earth and Environment

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An intercomparison and evaluation of size distribution among AeroCom global aerosol models of a range of complexity

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NATURAL ENVIRONMENT RESEARCH COUNCIL

Skeleton-draft of paper describing these results to be circulated among model contacts & data Pis with co-authorship

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Evolution of complexity in global aerosol models

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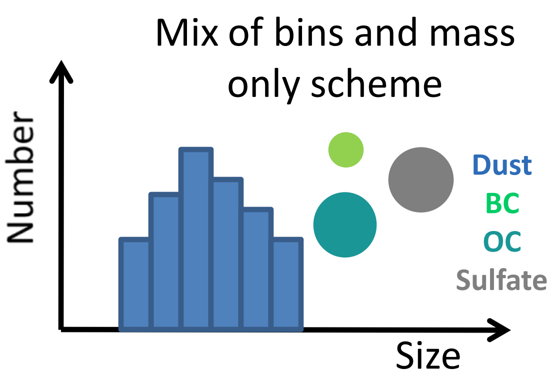
Most climate models have 1st generation "mass-only" aerosol schemes with externally-mixed types (sulphate, soot, biomass)

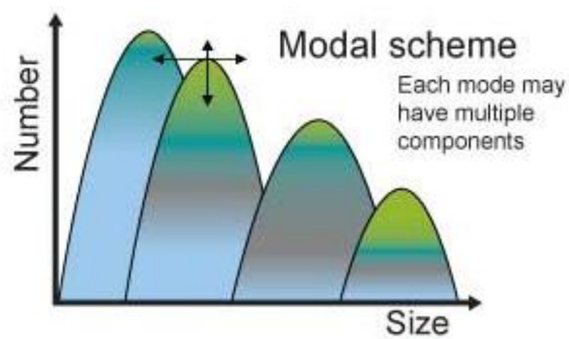
Direct/indirect effects based on prescribed size for each type.

Many climate models now implementing aerosol microphysics schemes that simulate the particle size distribution evolution.

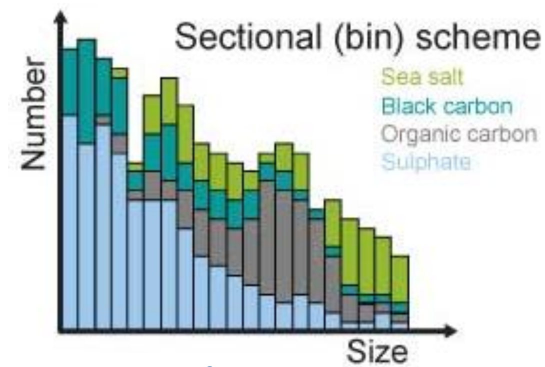
First generation mass-only schemes



Two-moment modal Aerosol μfx schemes



Two-moment sectional Aerosol μfx schemes



Increasing information on size-resolved aerosol properties

But increasing computational expense (more tracers)

Aerosol microphysics AeroCom working group

- Particle size distribution and resulting CCN concentrations are key determining factors for aerosol indirect forcings
- Aerosol microphysics working group established: intercompare and evaluate size distributions simulated by the new generation of aerosol microphysics schemes in global models.
- Models asked to output "all-aerosol-tracer" datasets at 3D-monthly and 0D-hourly at ~40 chosen site locations.
- Allows size distribution to be intercompared among different complexity models and different observations (cut-off sizes etc.)
- A2-SIZx sensitivity experiments also carried out with nucleation switched off and primary emissions off to intercompare the proportion of CCN from primary-emitted & nucleated particles.

12 global aerosol microphysics models submitted data

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Model	CTM/GCM	Scheme type	No. aerosol tracers	H. Res.	No. V. Levels	Year of data/met
GLOMAP-mode	CTM	2-mom mode	26	2.8x2.8	31	2006 (CTM)
ECHAM-HAM2	GCM	2-mom mode	45	1.9x1.9	31	2006 (GCMndg)
GISS-TOMAS	GCM	2-mom bin	72	4.0x5.0	9	5yr-mn (GMCfr)
GLOMAP-bin	CTM	2-mom bin	160	2.8x2.8	31	2006 (CTM)
EMAC	GCM	2-mom mode	41	2.8x2.8	19	2006 (GCMndg)
TM5	CTM	2-mom mode	25	3.0x2.0	34	2006 (CTM)
PNNL-CAM5-MAM	GCM	2-mom mode	15	2.5x1.9	30	5yr-mn (GMCfr)
HadGEM3-UKCA	GCM	2-mom mode	26	1.9x1.3	38	2006 (GCMndg)
FMI-SALSA	GCM	2-mom bin	65	1.9x1.9	31	2006 (GCMndg)
GISS-MATRIX	GCM	2-mom modal	60	2.5x2.0	40	2006 (GCMndg)
CCCma AGCM4	GCM	2-mom PLA	20	3.7x3.7	35	2006 (GCMndg)
GEOS-CHEM-APM	CTM	1-mom bin	87	2.5x2.0	38	2006 (CTM)

Each model has submitted the 3D-monthly-mean all-aerosol-tracer data for A2-CTRL-06

Several models also submitted the hourly all-aerosol-tracer and A2-SIZx results.

12 global aerosol microphysics models submitted data

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Date: 16 October 2012

An intercomparison and evaluation of CCN and size distribution among AeroCom global aerosol models of a range of complexity.

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Completed 1st phase of work to derive size distribution from each of the 12 models. Corresponded with each model contact to double-check approach and basic results.

Will soon circulate skeleton-draft of paper to all potential co-authors.

FIGURE 1

Over the annual-means of the central-8 of the 12 models

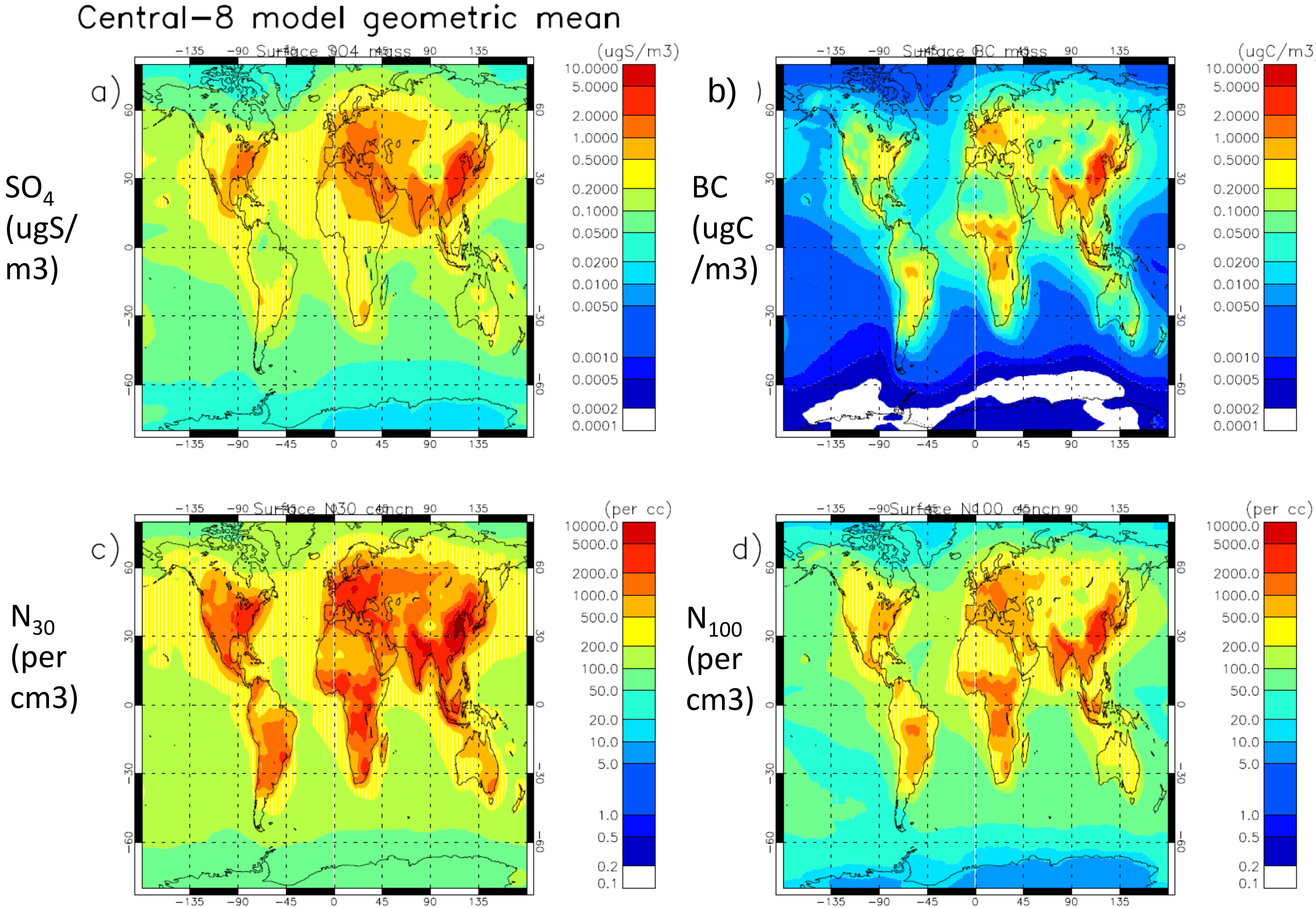


FIGURE 2

Over the annual-means of the central-8 of the 12 models

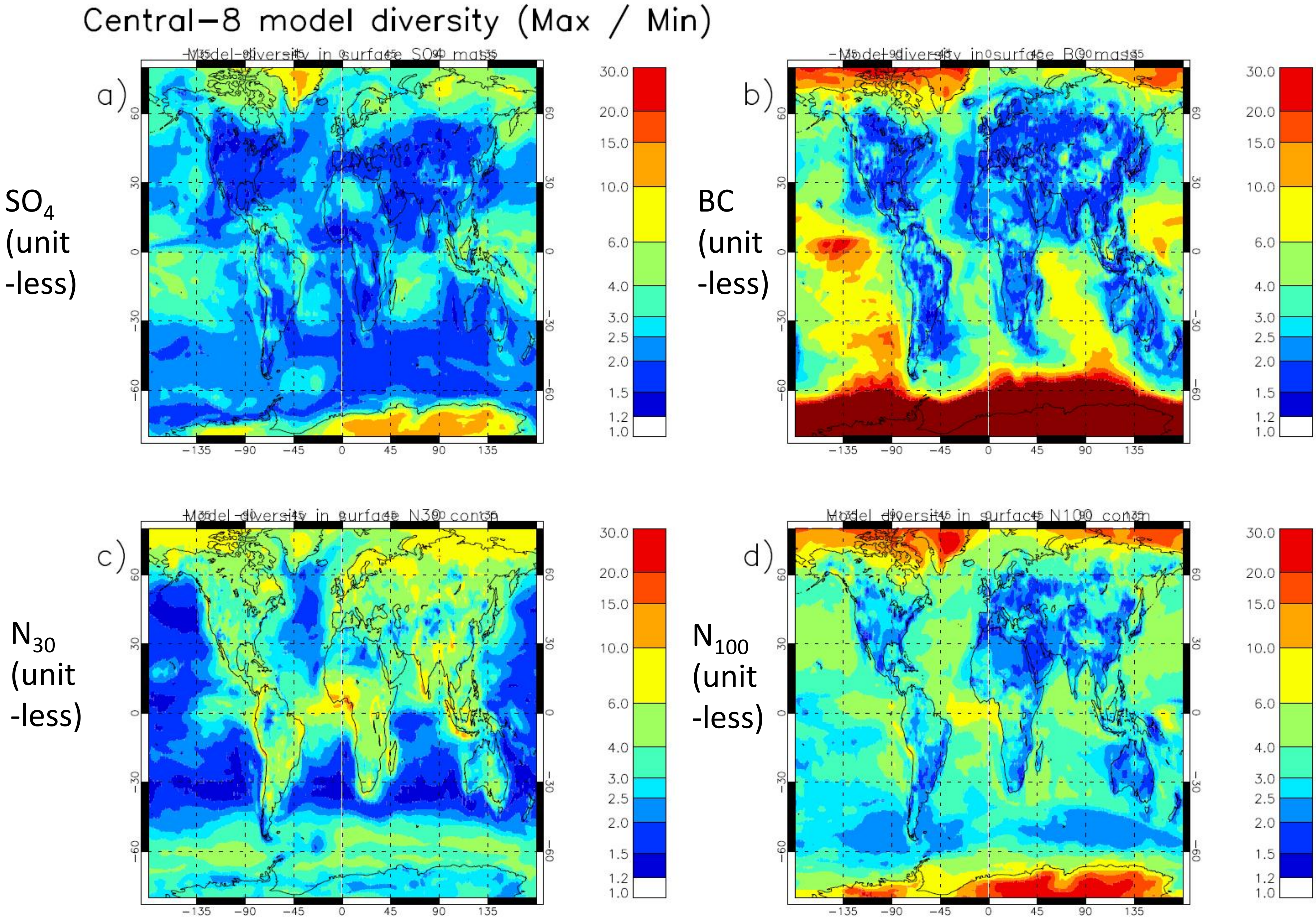
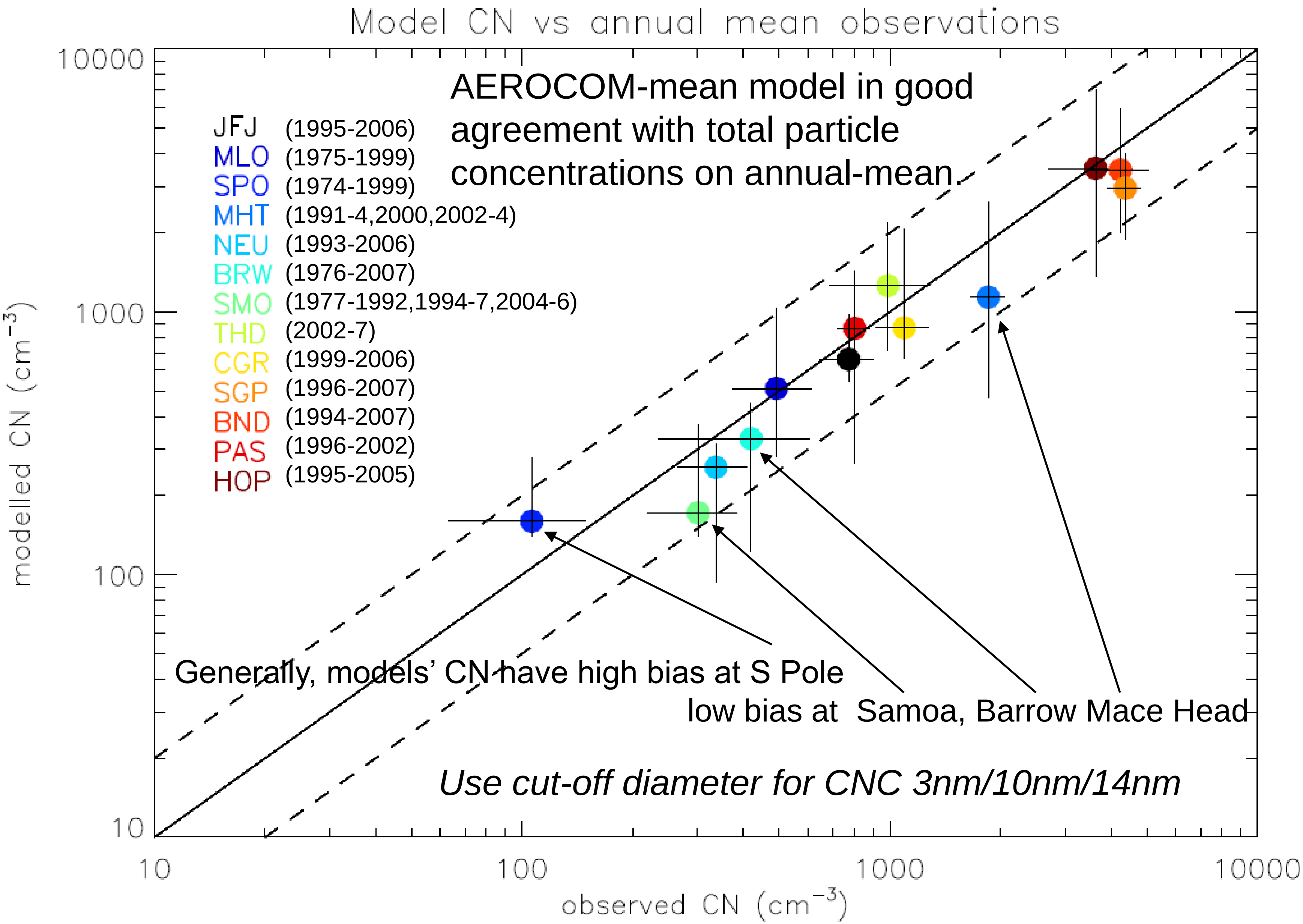
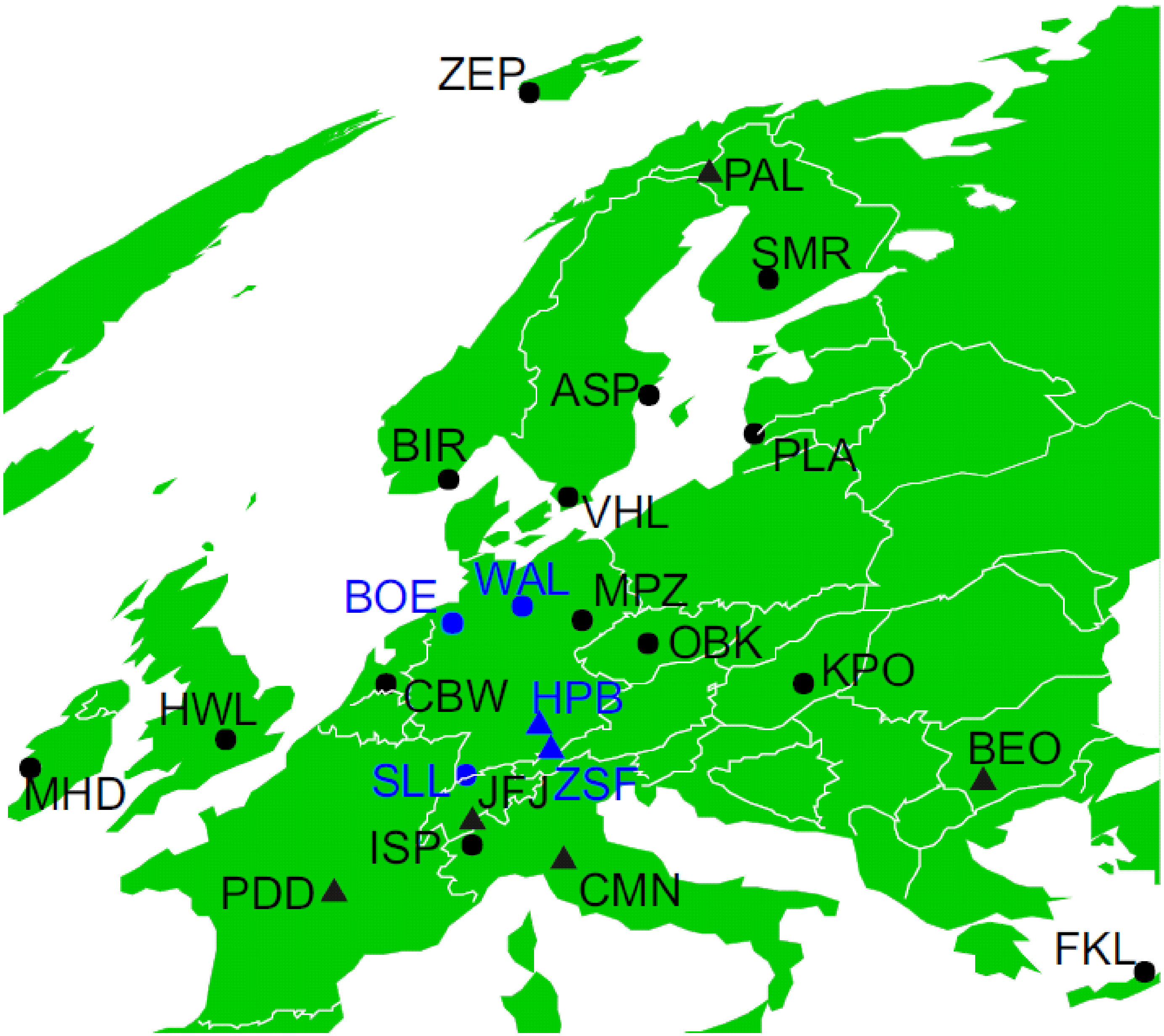


FIGURE 5 Model vs obs GAW sites with 6+ yrs of CNC data (ann mean)



CNC at GAW sites – data Pis: Ogren, Gras, Baltensperger, Kaminski, Jennings, Weller, Viisanen

Asmi et al (2011): Number size distributions & seasonality of sub-um particles in Europe



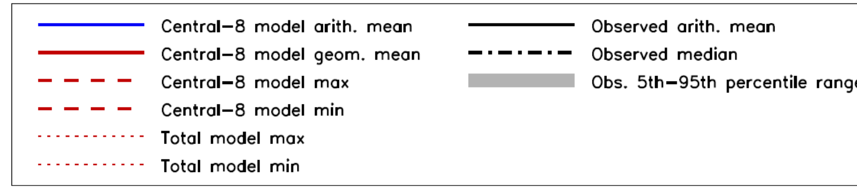
Triangles = mountain sites

Black are EUSAAR sites

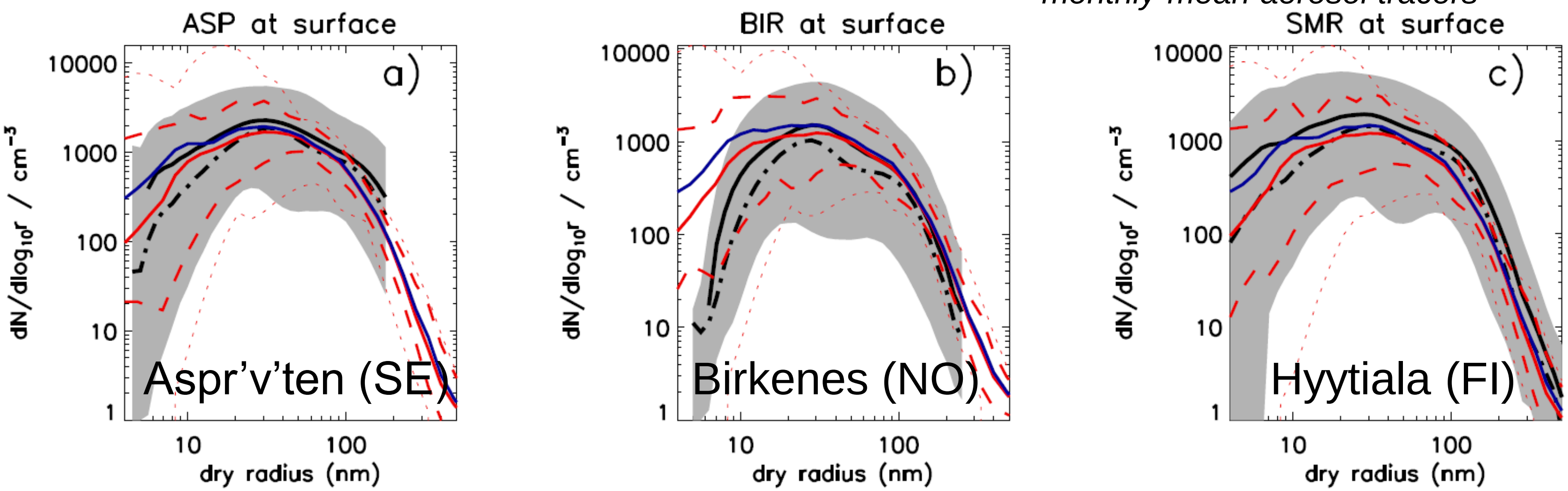
Blue are Germany GUAN sites

FIGURE 8a-f (Nordic & Baltic sites)

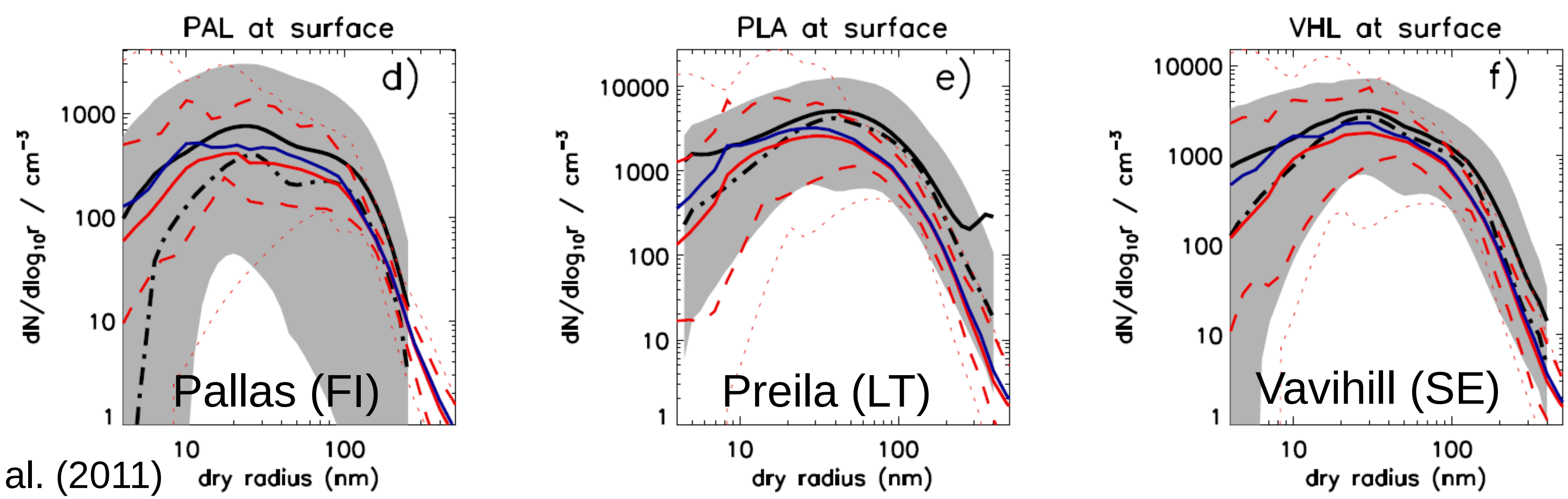
Mean-model (blue) compares well to arithmetic-mean observations (black solid) at Aspreveten, Birkenes. All other sites have moderate low-bias throughout 10-200nm dry-radius (worst in accumulation mode).



Compare to observed arithmetic-mean here since each model size-distbn from monthly-mean aerosol tracers



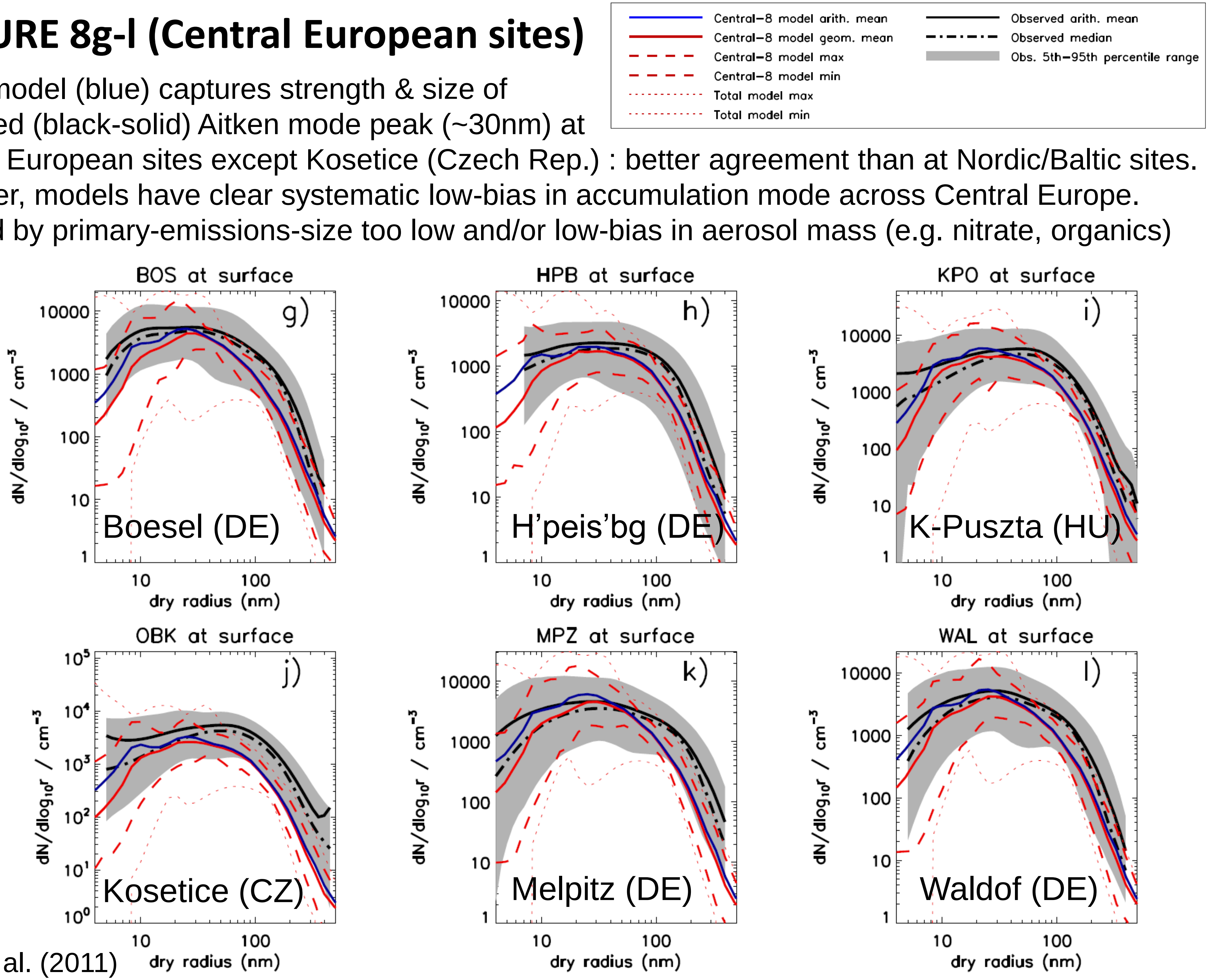
Largest diversity among models in Aitken sizes (<50nm dry-radius). Better consensus among models ~100nm.



Asmi et al. (2011)

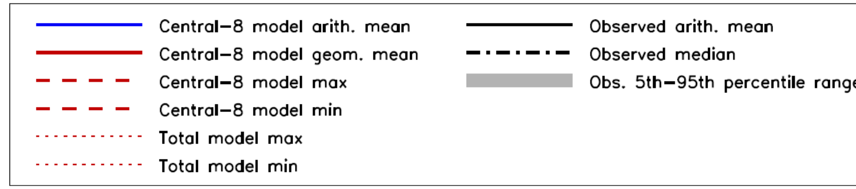
FIGURE 8g-l (Central European sites)

Mean-model (blue) captures strength & size of observed (black-solid) Aitken mode peak (~30nm) at Central European sites except Kosetice (Czech Rep.) : better agreement than at Nordic/Baltic sites. However, models have clear systematic low-bias in accumulation mode across Central Europe. Caused by primary-emissions-size too low and/or low-bias in aerosol mass (e.g. nitrate, organics)

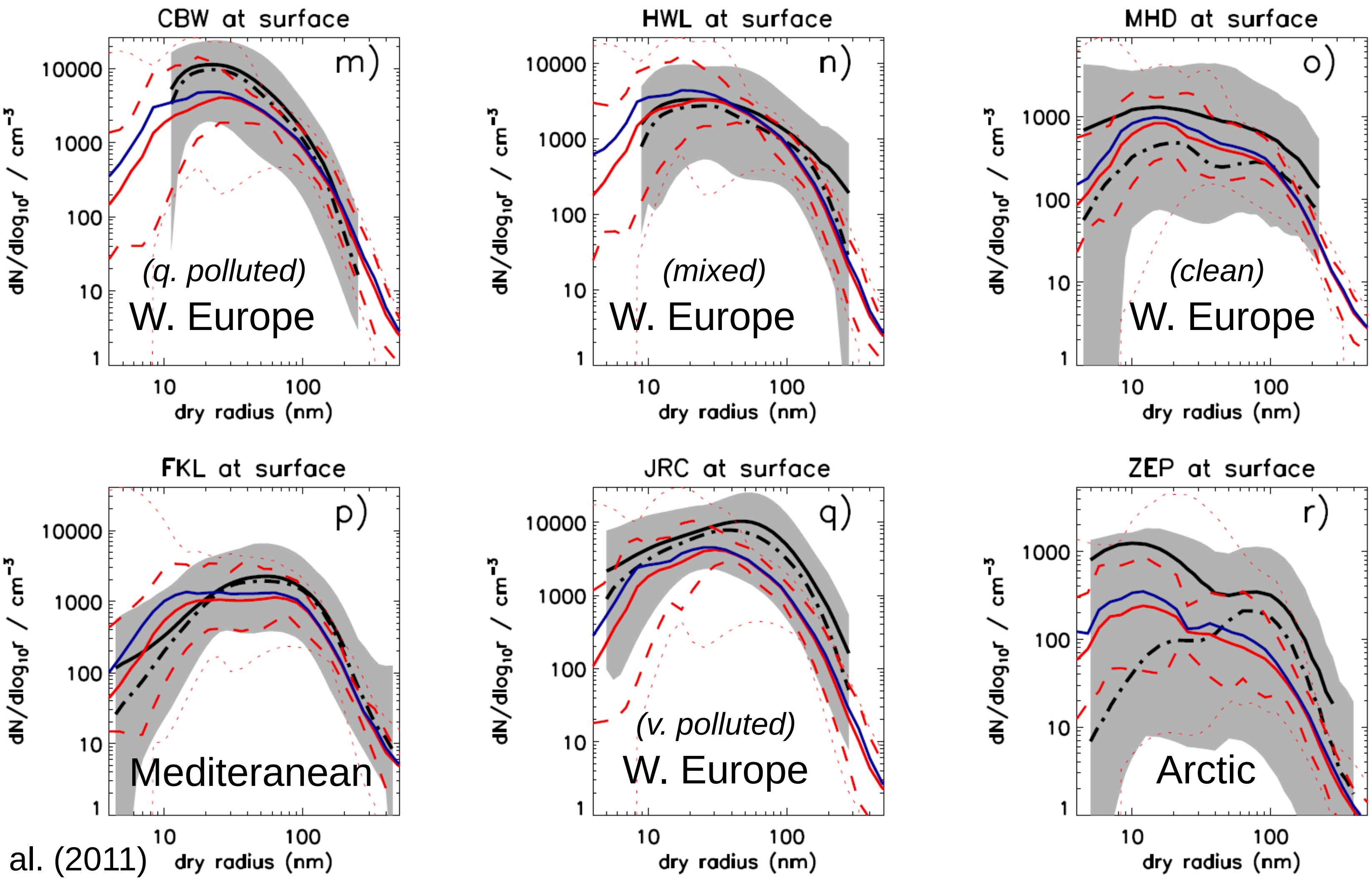


Asmi et al. (2011)

FIGURE 8m-r (W. Europe & other)



Among Western European sites, although mean-model compares well at Harwell (UK), most underpredict <100nm at Cabauw (NL) & across 10-200nm dry-radius range at Mace Head (IE). However, some models in central-8 of 12 do capture those 3 W. European sites, not at JRC. Mean model fails to capture at Finokalia & Zeppelin: poor agreeement with observed size dist'b'tn.

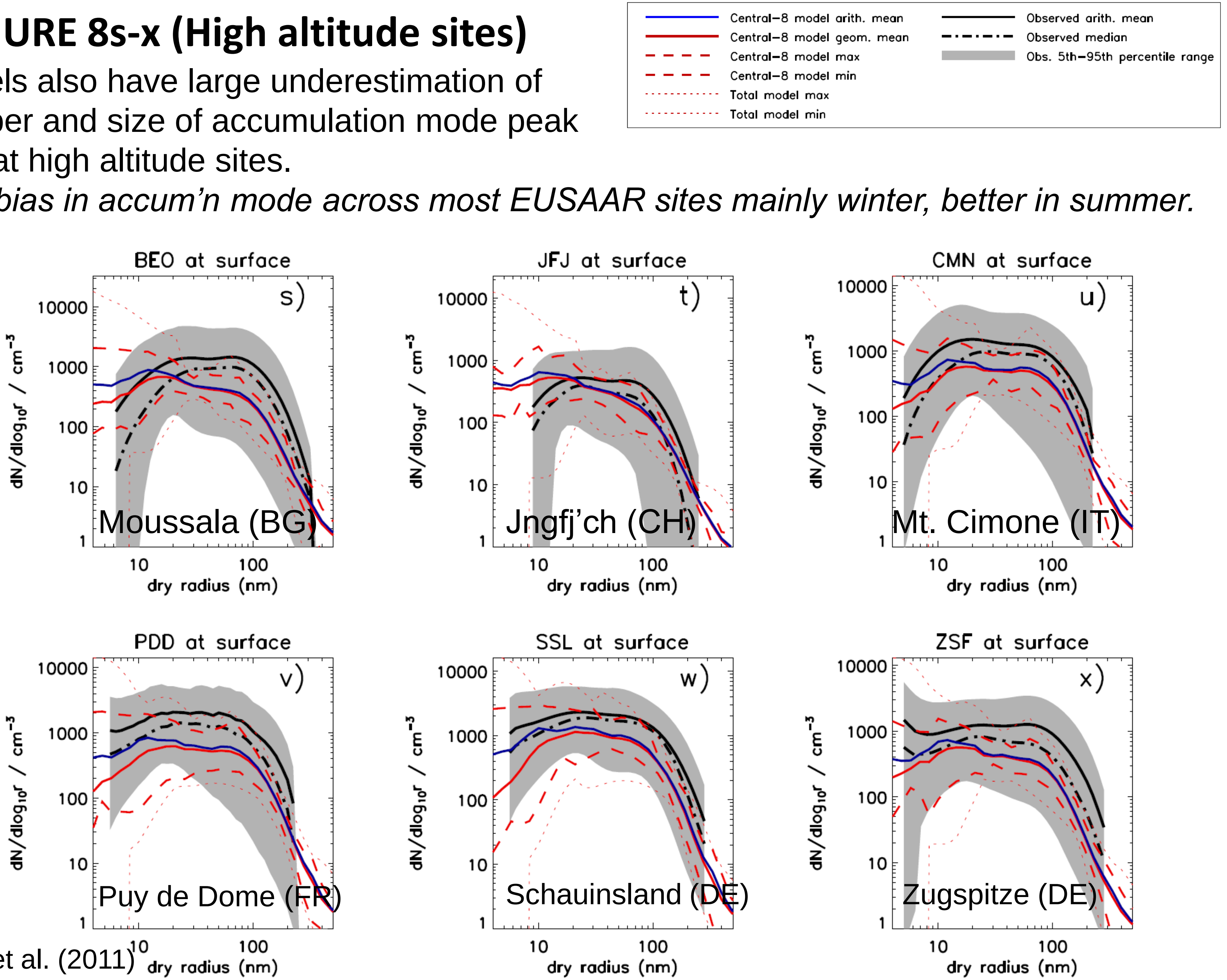


Asmi et al. (2011)

FIGURE 8s-x (High altitude sites)

Models also have large underestimation of number and size of accumulation mode peak also at high altitude sites.

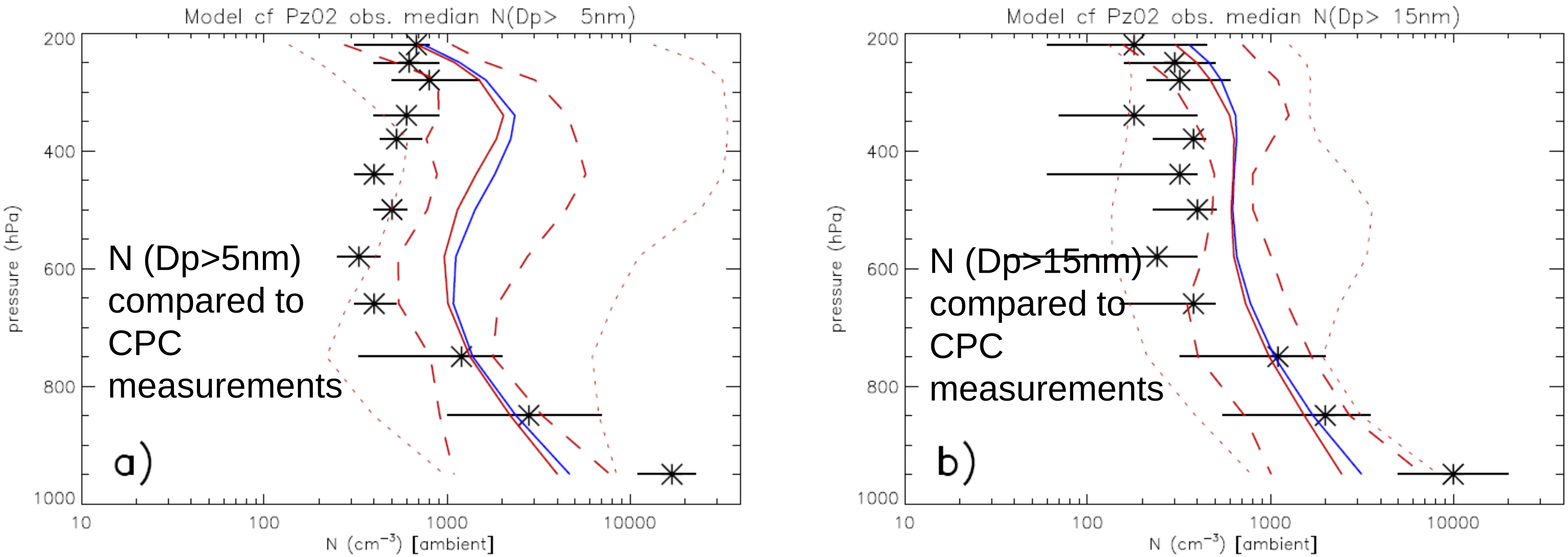
Low-bias in accum'n mode across most EUSAAR sites mainly winter, better in summer.

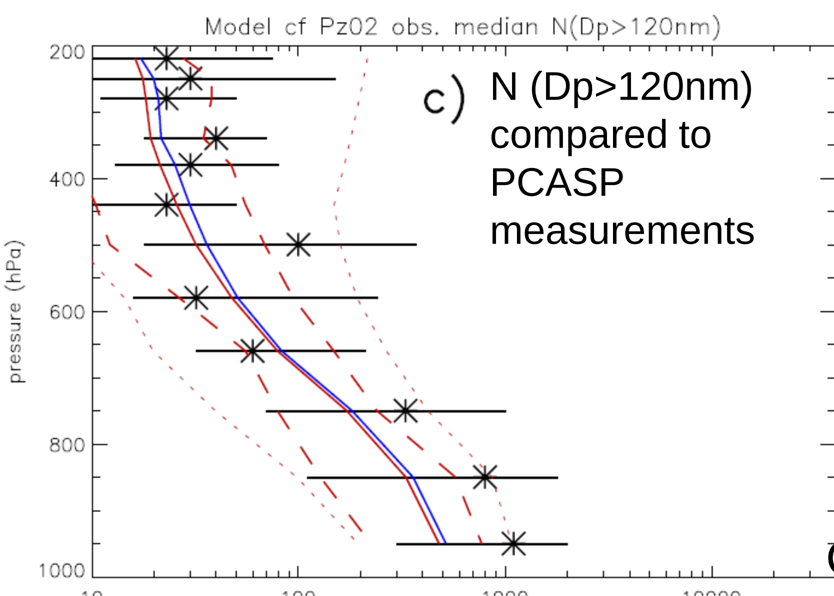


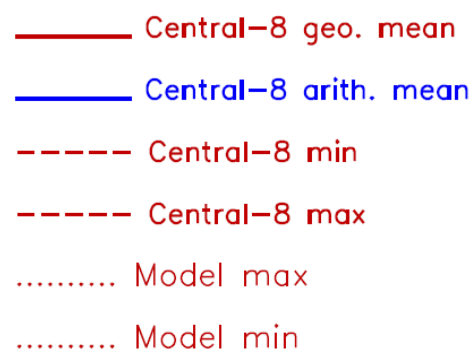
Asmi et al. (2011)

FIGURE 9

Continental size-resolved particle concn profiles







LACE field campaign (Germany)

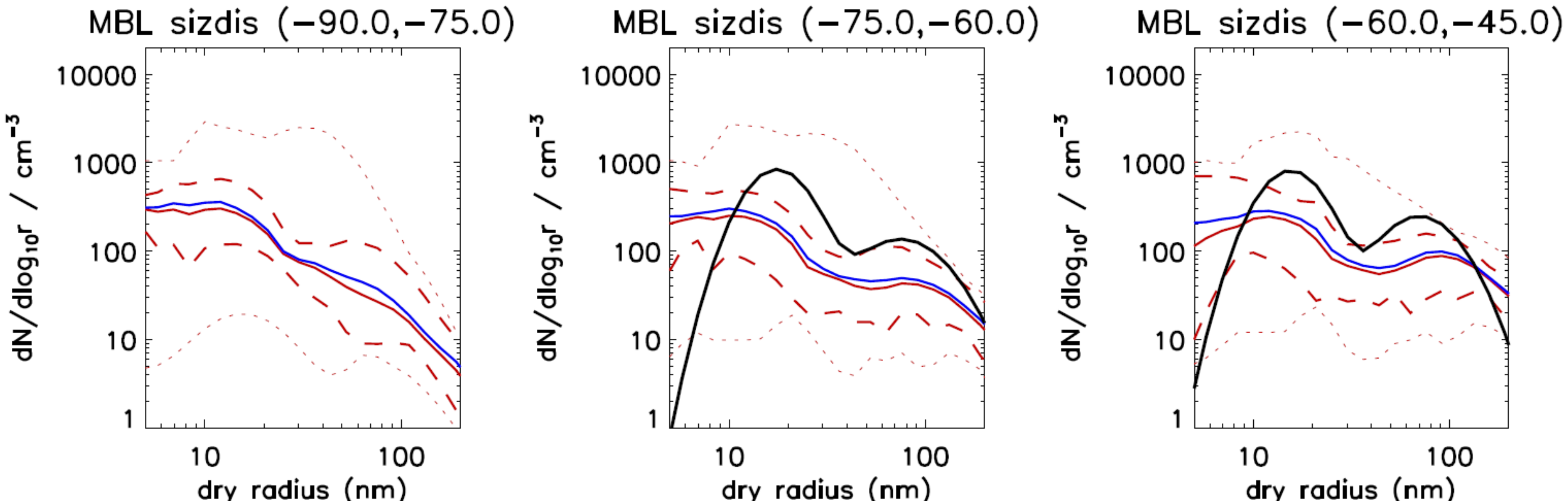
Models capture shape of size-resolved N profile but have strong low-bias in N5 & N15 in central Europe but high-bias in free-troposphere

Central Europe low-bias in N120 restricted to BL

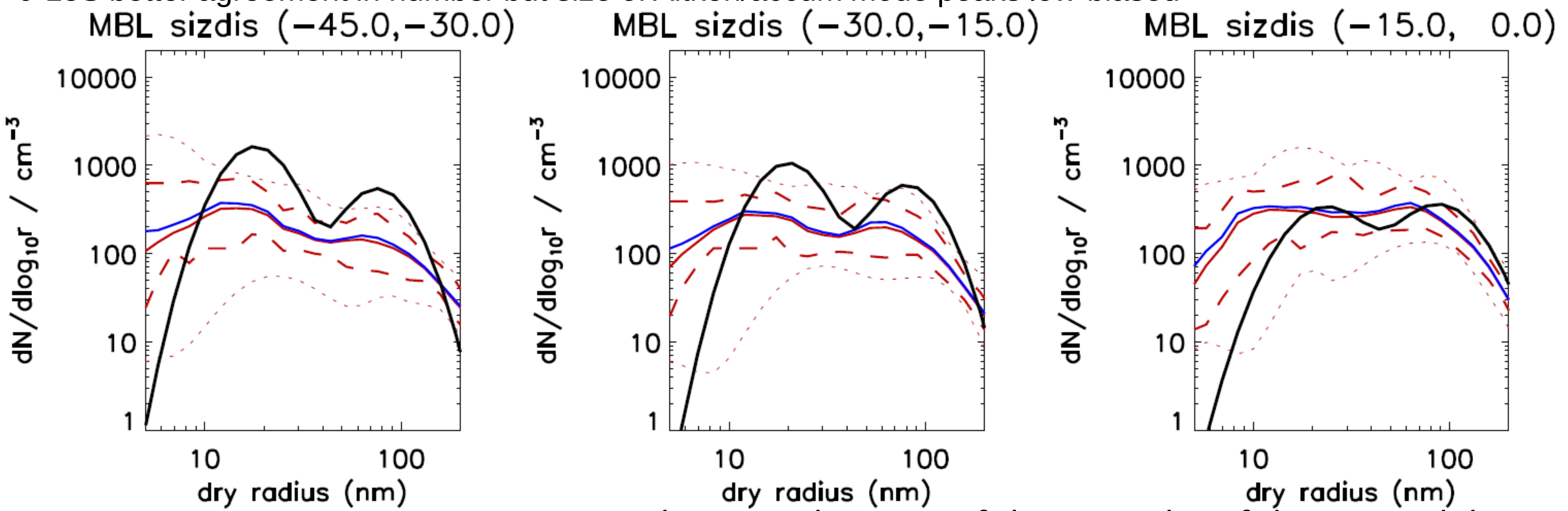
Petzold et al. (2002); Lauer et al. (2005)

Over the August-means of the central-8 of the 12 models

FIGURE 10 a-f Marine size-resolved particle concentrations



At latitudes > 15S size of Aitken/accum mode peaks captured well but number has substantial low-bias.
0-15S better agreement in number but size of Aitken/accum mode peaks low-biased

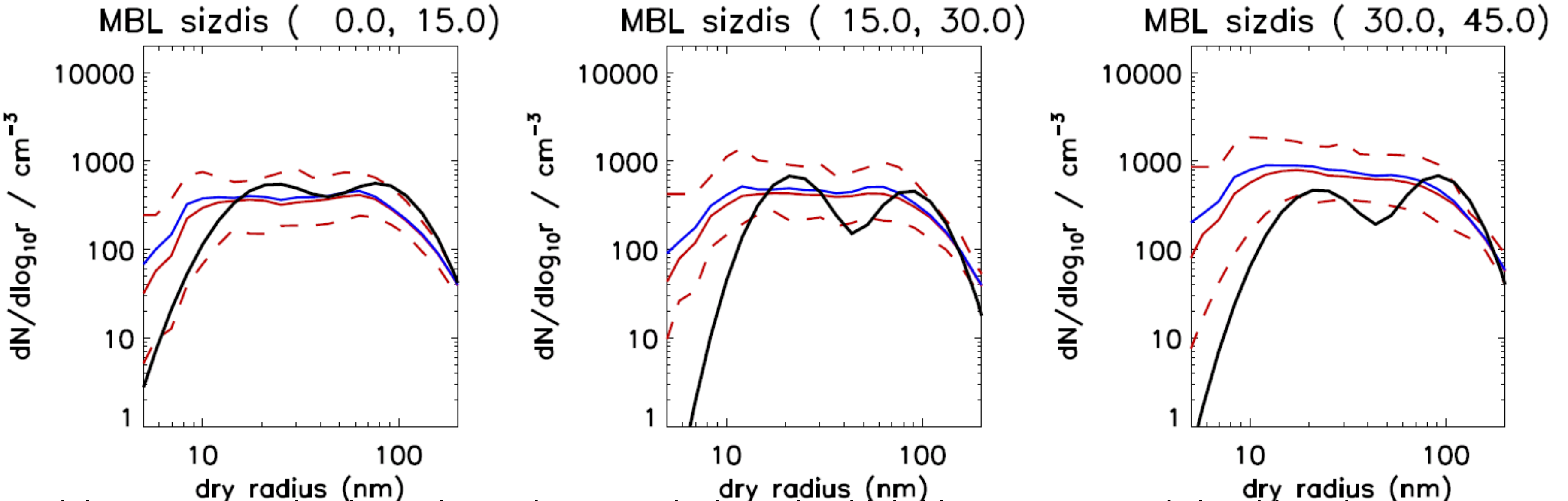


Heintzenberg et al. (2000)

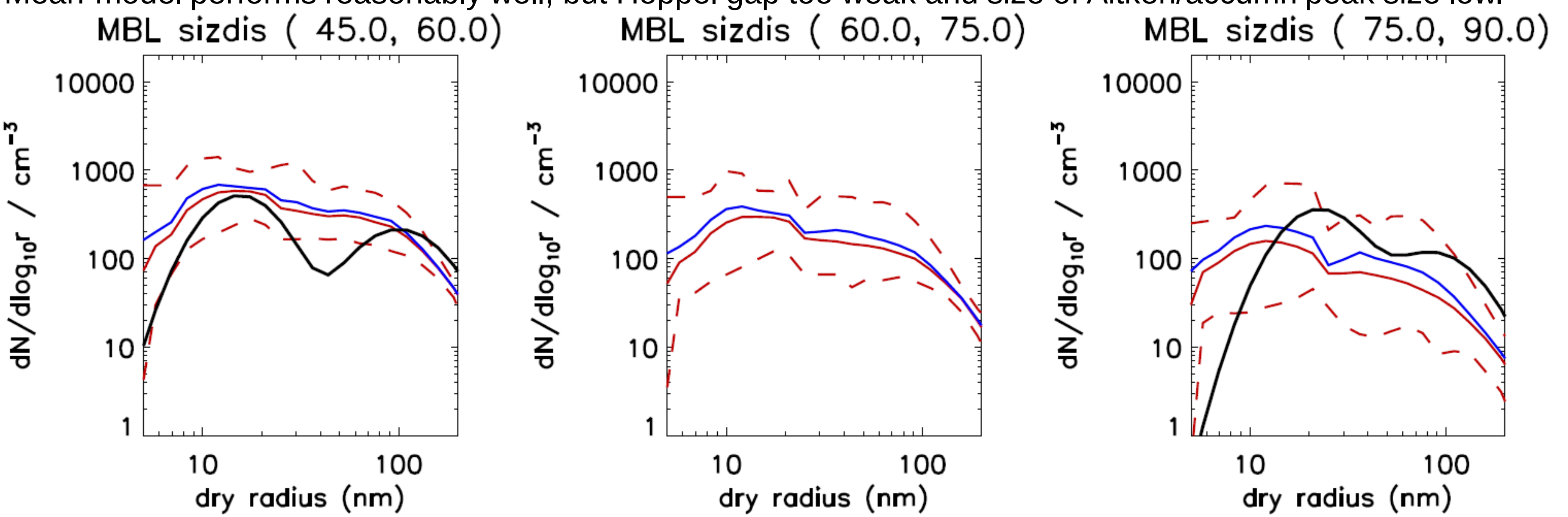
Over the annual-means of the central-8 of the 12 models

FIGURE 10 g-l

Over the annual-means of the central-8 of the 12 models



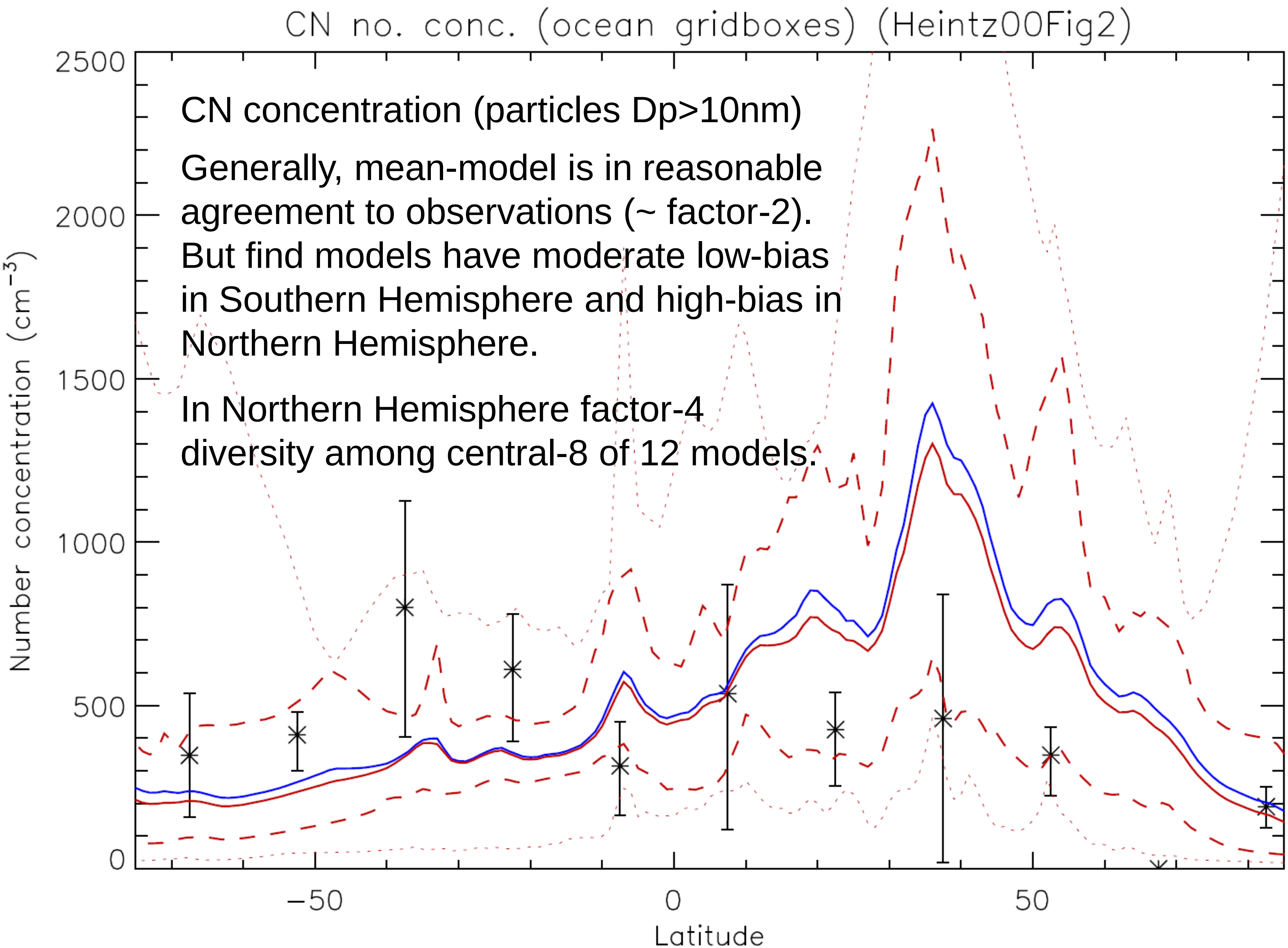
Models capture number better in Northern Hemisphere, but high-bias 30-60N, Arctic low-biased.
Mean-model performs reasonably well, but Hoppel gap too weak and size of Aitken/accumn peak size low.



Heintzenberg et al. (2000)

FIGURE 11a

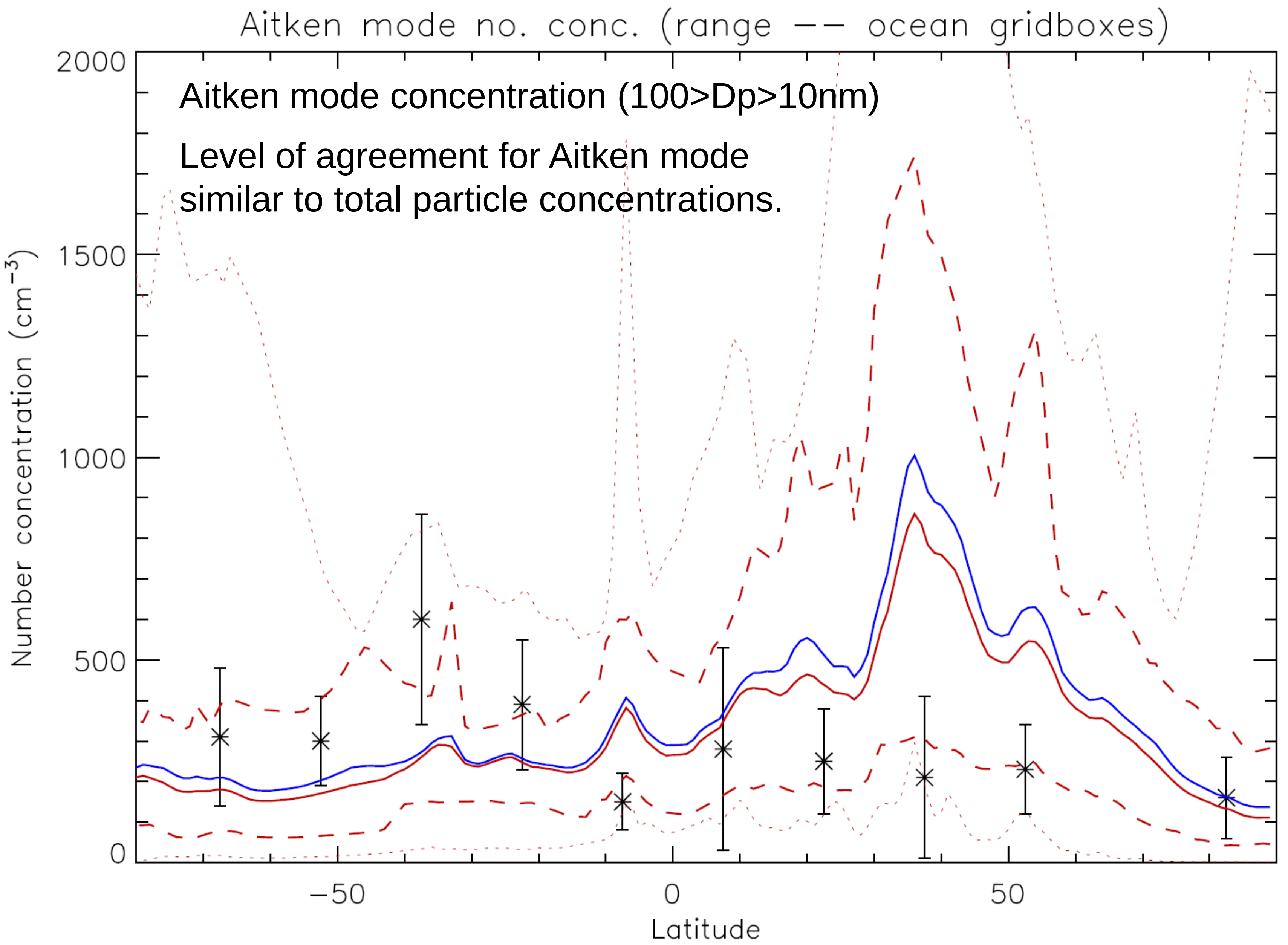
Over the annual-means of the central-8 of the 12 models



Heintzenberg et al. (2000)

FIGURE 11b

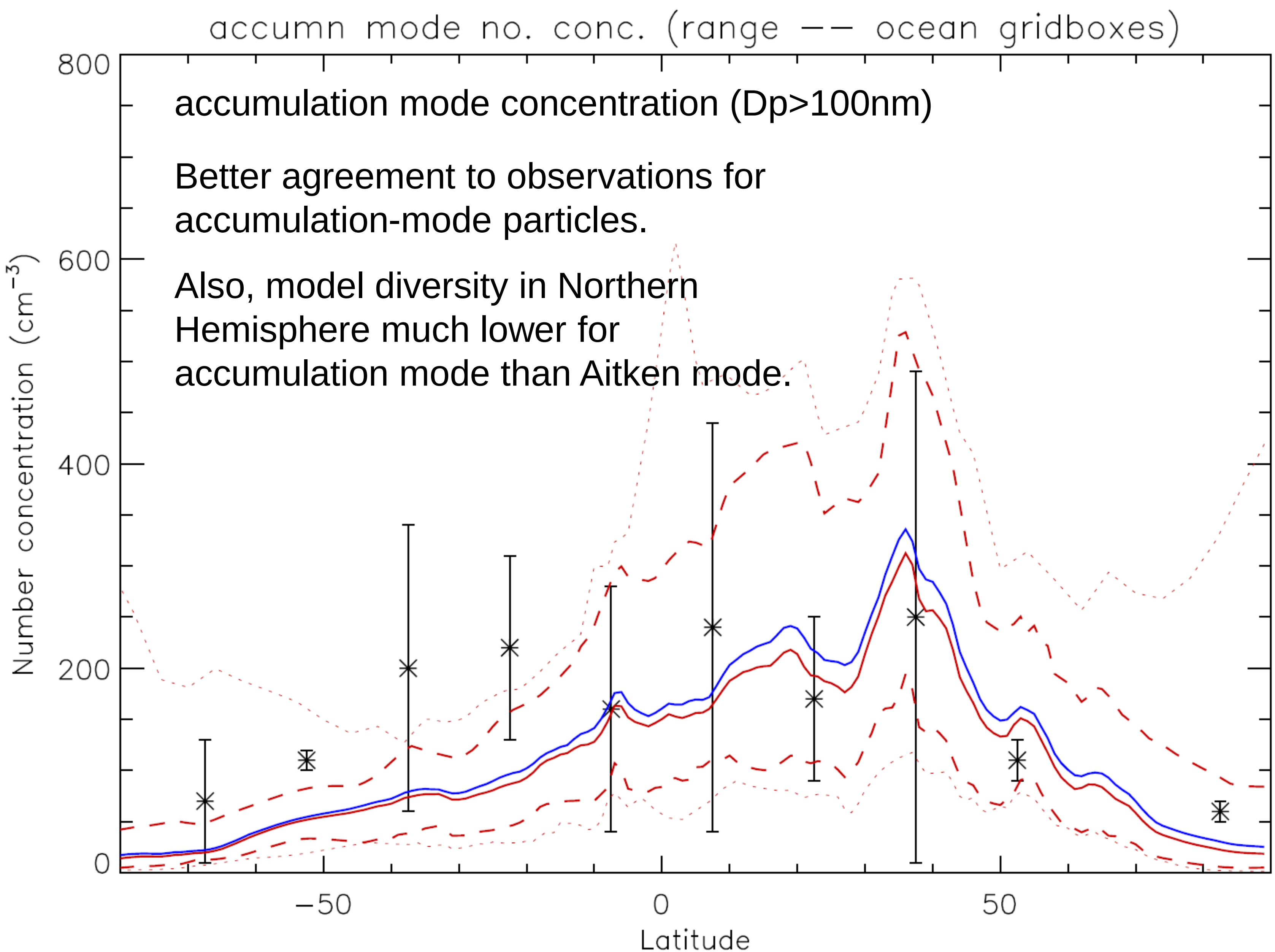
Over the annual-means of the central-8 of the 12 models



Heintzenberg et al. (2000)

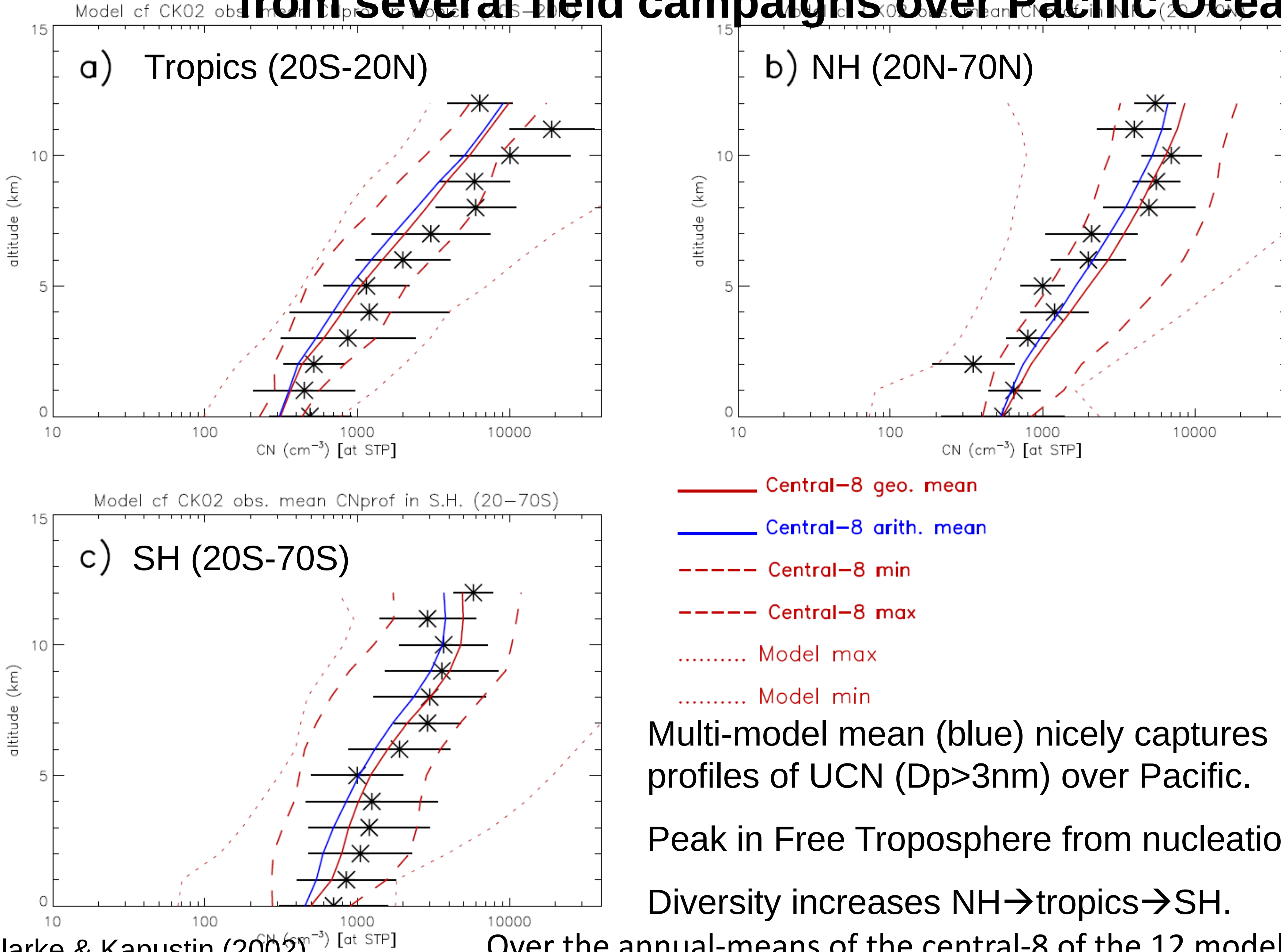
FIGURE 11c

Over the annual-means of the central-8 of the 12 models



Heintzenberg et al. (2000)

FIGURE 12 Compilation of aircraft-borne CNC measurements from several field campaigns over Pacific Ocean



Multi-model mean (blue) nicely captures profiles of UCN (Dp>3nm) over Pacific.

Peak in Free Troposphere from nucleation.

Diversity increases NH→tropics→SH.

Clarke & Kapustin (2002)

Over the annual-means of the central-8 of the 12 models

Summary and conclusions

-- AEROCOM's first intercomparison of global aerosol microphysics models giving a best multi-model distribution of size-resolved aerosol number concentrations.

-- By requesting all-aerosol-tracers have information-rich model datasets allowing great deal of flexibility to intercompare against different measurements (not just size-resolved number -- can also be used to evaluate size-segregated mass)

-- For N100, model diversity lowest in source regions → increasing with transport
For N30, see that diversity is highest in the main industrialised regions and high sea-spray regions. Lowest diversity where nucleated particles dominate

-- *Illustrates that processes controlling global distribution of CCN are different from those controlling aerosol mass.*

-- Multi-model mean predicts well the global variation of particle size distribution

-- Main features of vertical profiles of aerosol number represented
-- Marine: clear maximum in particle concentrations in FT due to nucleation.
-- Cont'l: S-shaped curve of particle concentrations with BL and FT maxima.

-- Comparing to observations, the multi-model microphysics model compares better to the observations than any single model.

-- Some biases however → accumulation mode size and number in Europe.

-- Use multi-model-mean as benchmark for evaluating & improving model versions

Future planned/potential studies

1. Derive cloud droplet number concentrations for each model from all-aerosol-tracer 3D monthly-mean data – use mechanistic CDNC param (Nenes & Seinfeld, 2002).

   Derive present-day 1st indirect radiative effect for each model using offline radiative transfer model and prescribed clouds (approach as Spracklen et al., 2011, ACP).

   → best estimate & diversity for 1st indirect effect from aerosol microphysics models.

2. Use 0D-hourly datasets to generate pdf of N30, N50 and N100 for each site for each model → compare the full variation in the models against the observations.

   Examine the statistics through each hour of the daily cycle.

3. Intercompare pre-industrial CCN & CDNC among microphysics models (A2-PRE).

   Compare against those from mass-based models.

4. Analyse A2-SIZx → what proportion of CCN from primary and secondary CCN? Role of aerosol processes (e.g. growth by coag/conden) in different models.

Encourage others to take advantage of size-resolved aerosol model datasets.

Opportunity for range of studies comparing obs to info-rich model datasets.