Aerosol modeling at ECPL

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Global Cloud Condensation Nuclei (CCN) simulations: Robustness and implication for droplet formation

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Atmospheric Chemistry and Physics Discussions
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Evaluation of global simulations of aerosol particle number and cloud condensation nuclei, and implications for cloud droplet formation

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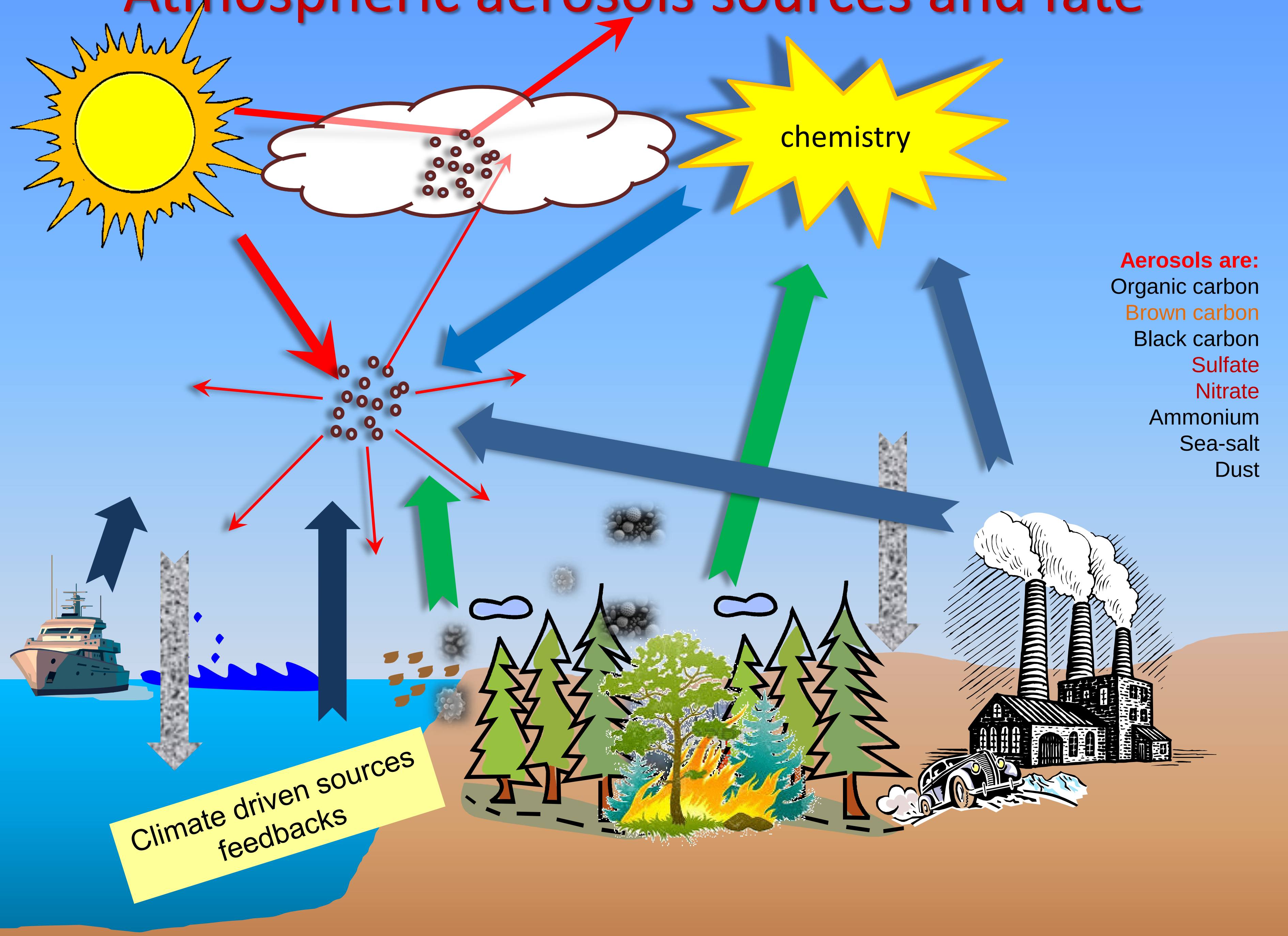
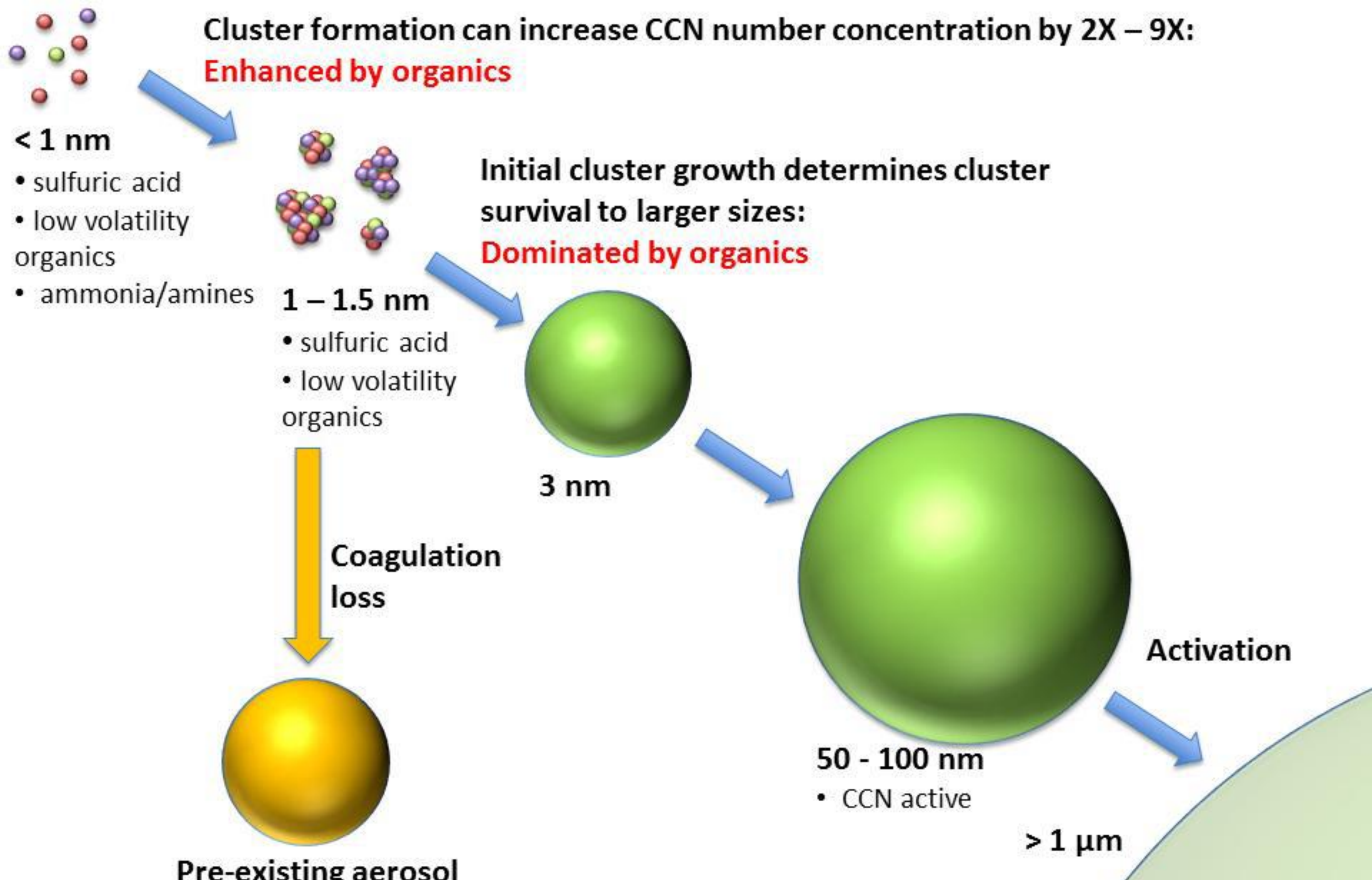
Atmospheric aerosols sources and fate



Aerosols are:
Organic carbon
Brown carbon
Black carbon
Sulfate
Nitrate
Ammonium
Sea-salt
Dust



Aerosol clouds interactions are one of the largest uncertainties in climate modeling

IPCC 2013

Shrivastava M, et al., Rev Geophys., 2017

aim of the study

Evaluate general circulation & global chemistry-transport models for their ability to simulate

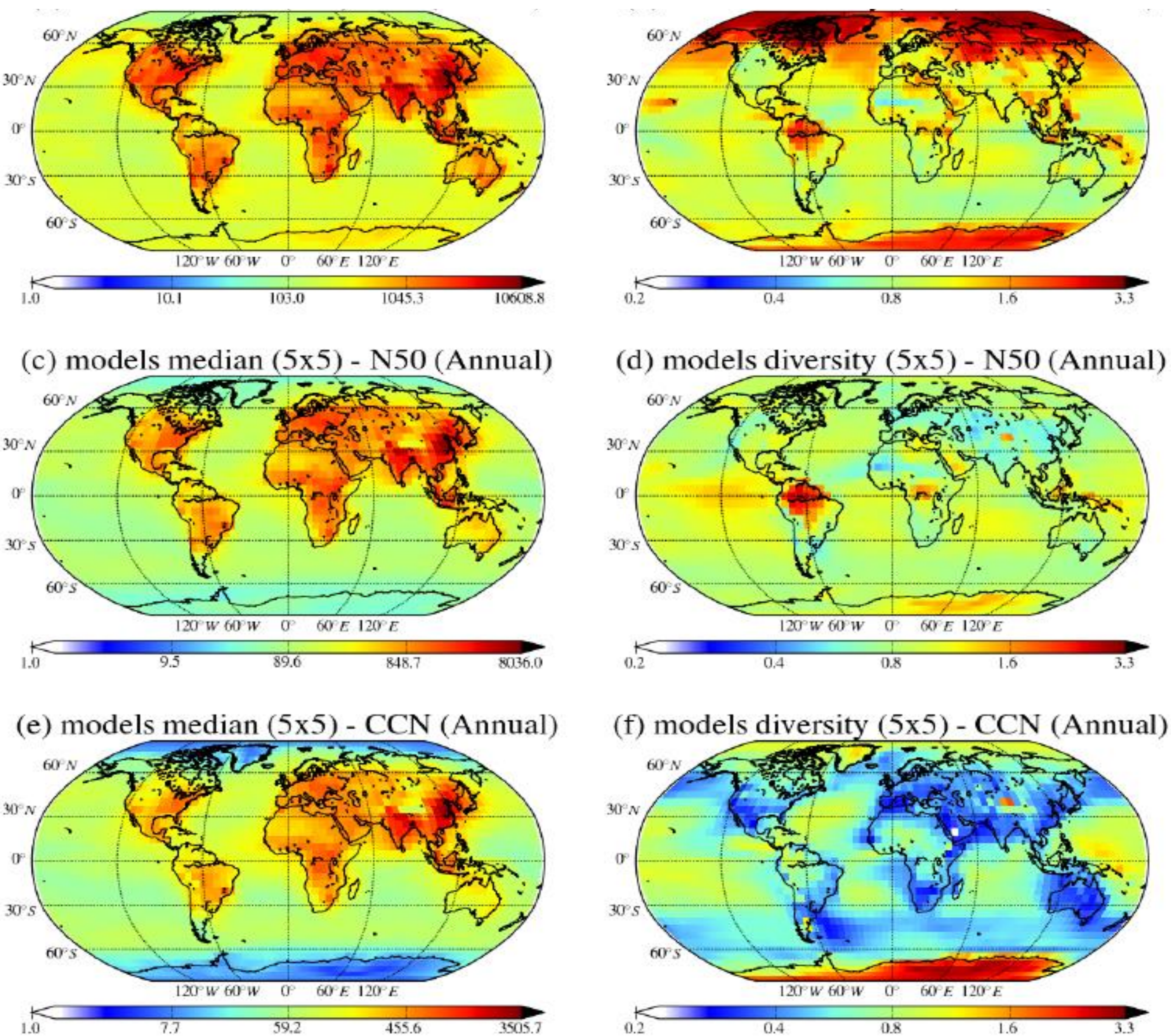
- ✓ Aerosol number concentrations (N_a)
- ✓ Cloud condensation nuclei (CCN)
- ✓ Cloud droplets number concentration (CDNC)
- ✓ the long-term seasonal variability & the short-term dynamical behavior of aerosol particles and CCN

- ➢ 15 global models (GCMs & CTMs) for the years 2010-2015
- ➢ 8 European observatories (from ACTRIS) and 1 site in Japan

Annual Multi-model median

Model diversity (stdev/mean)

multi-model results at surface

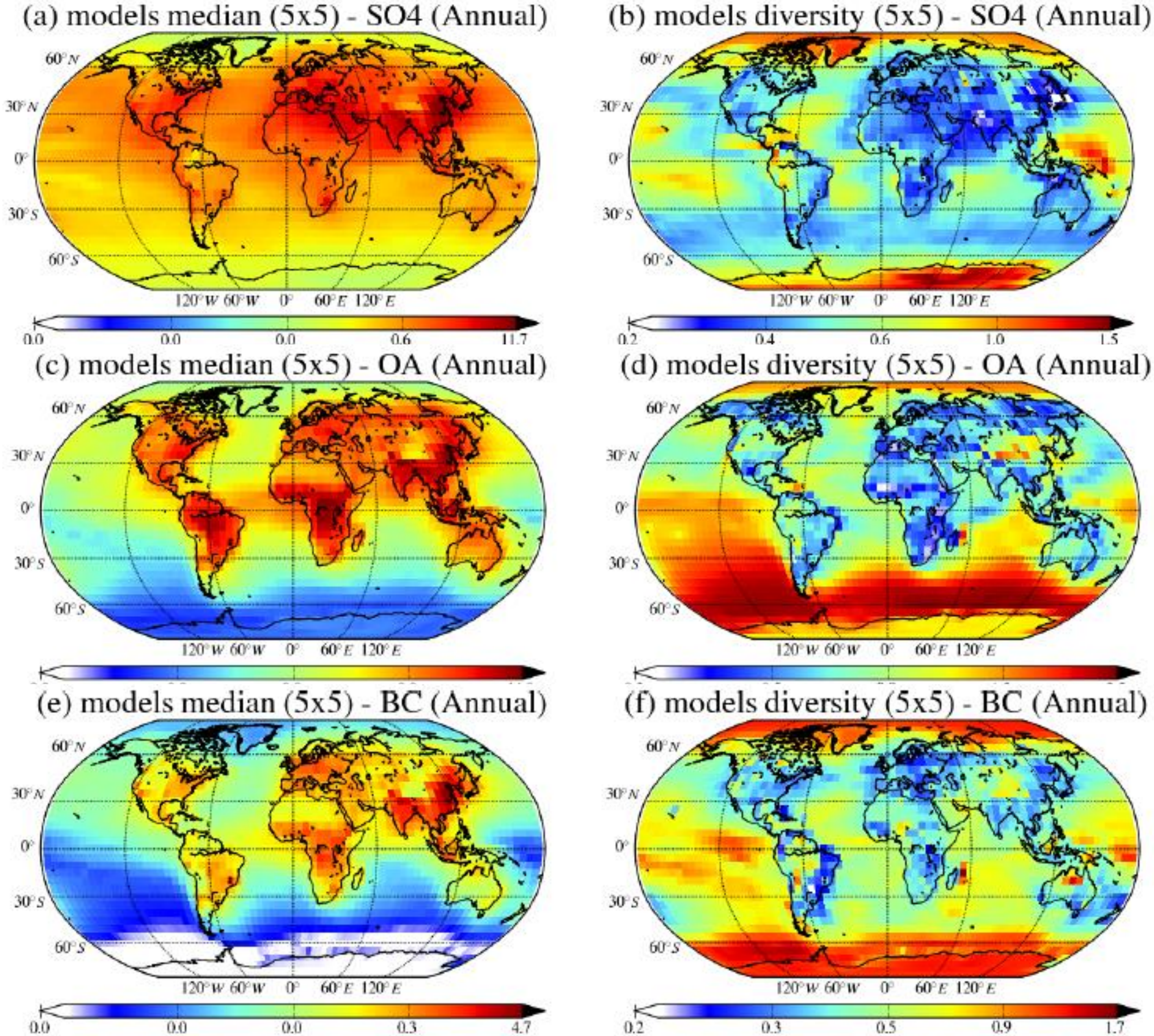


N3

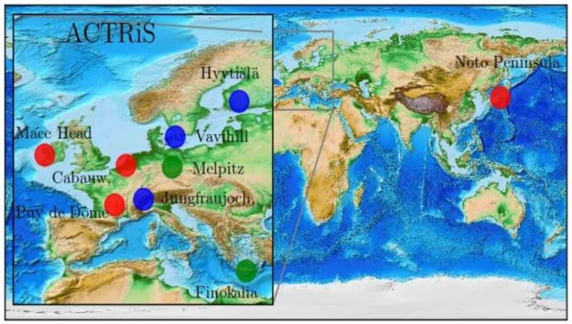
N50

CCN

PM_1 multi-model median chemical composition- surface

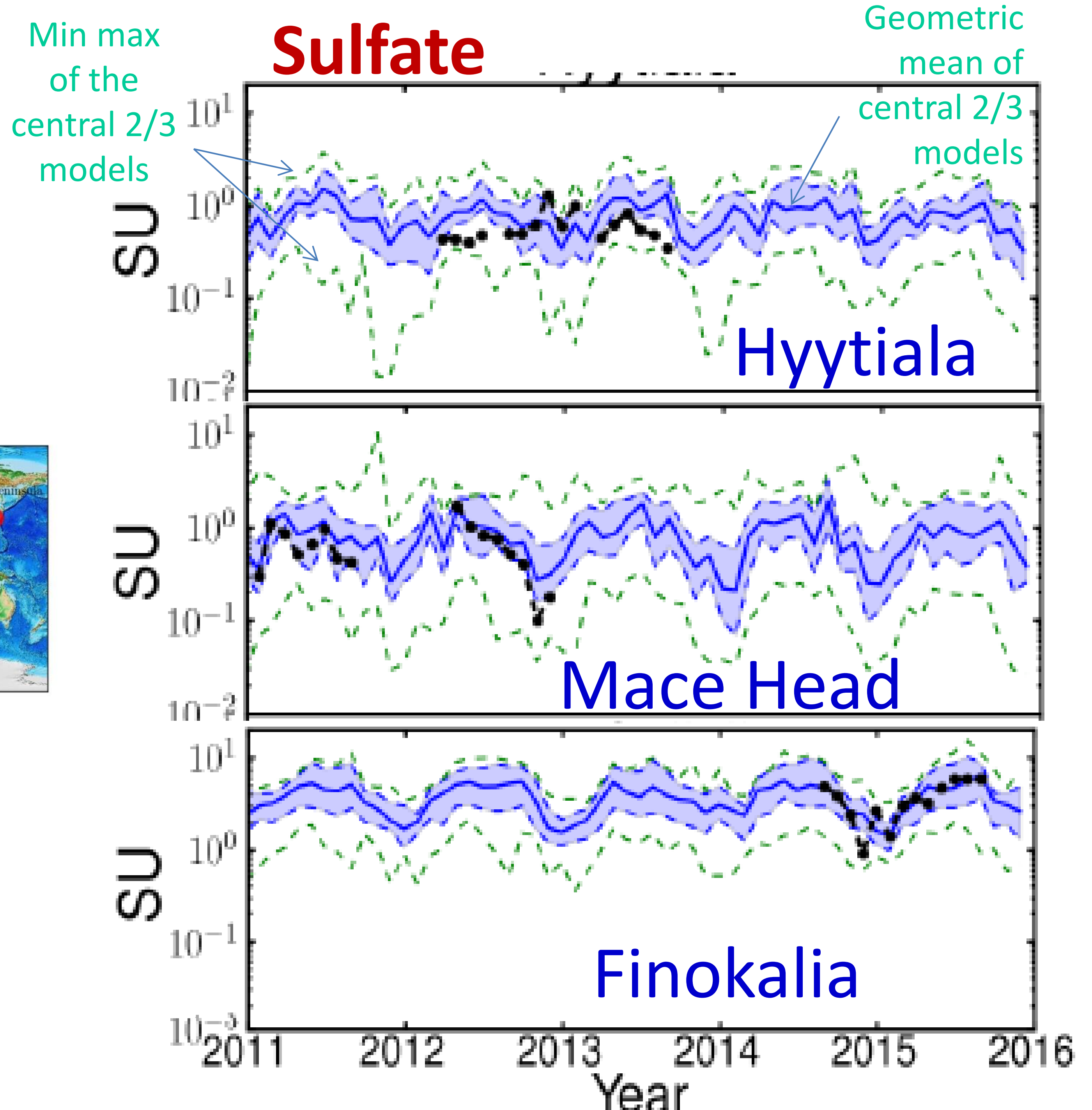


BACCHUS model intercomparison 15 models vs AMS- organics



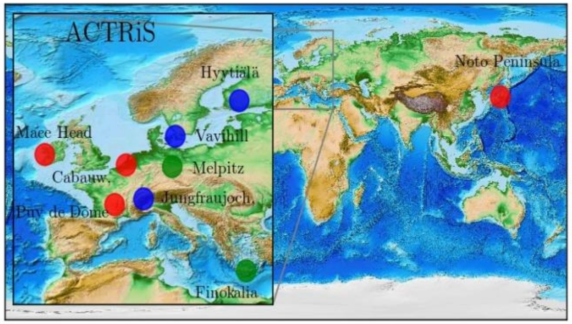
Data (black dots) from ACTRIS - Schmale et al. Scientific Reports, 2017

MMM – blue line
min, max model green dashed



Organics

BACCHUS model intercomparison 15 models vs AMS- organics



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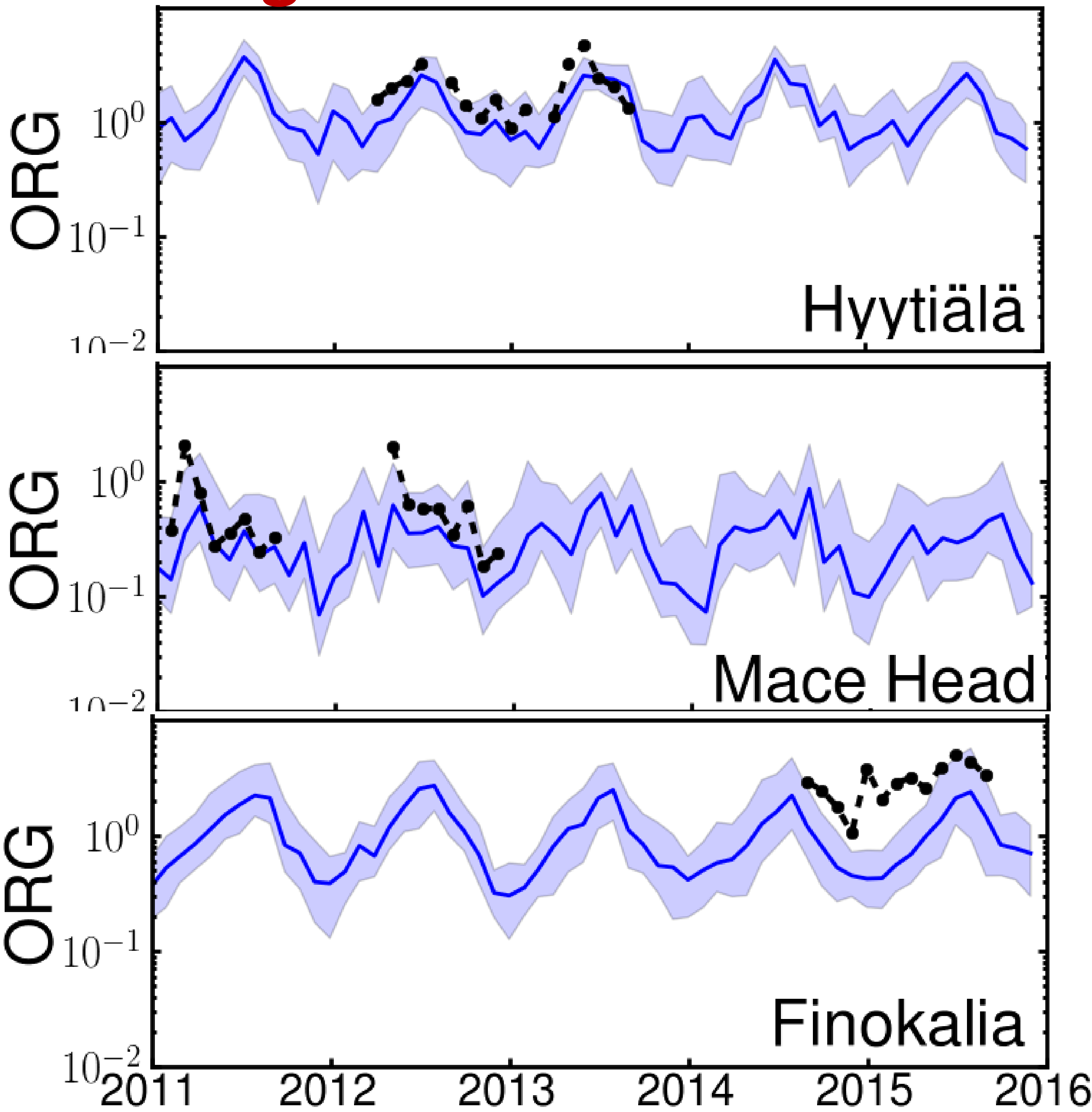
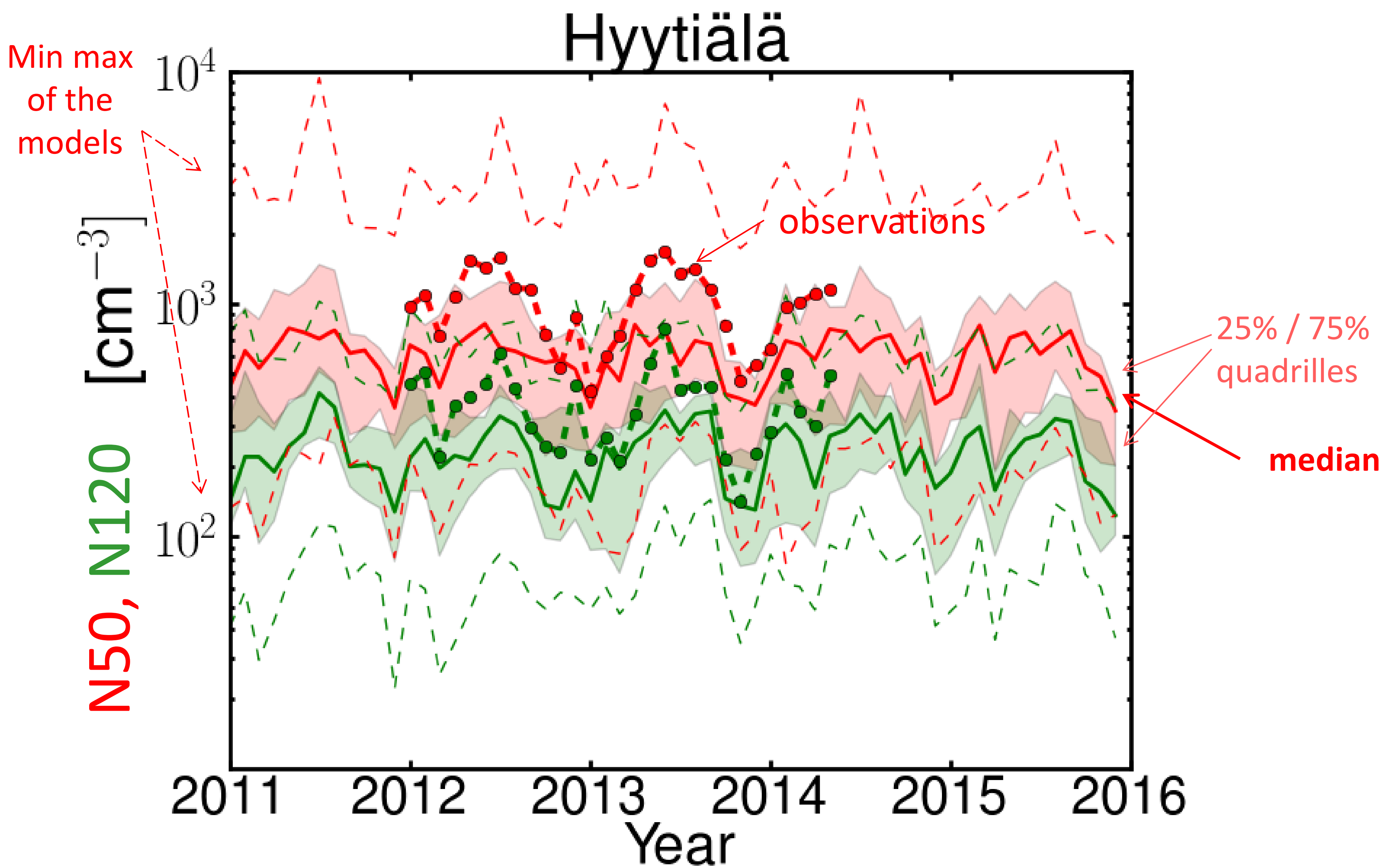
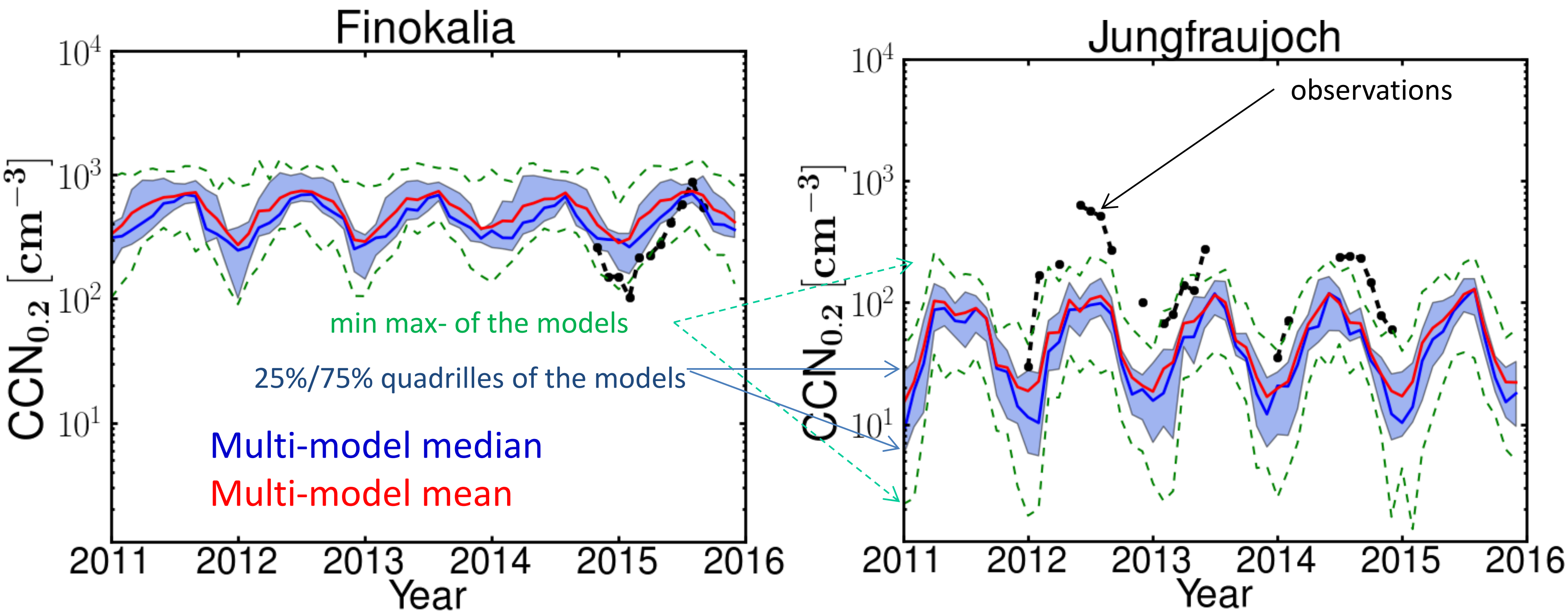


Number concentration of aerosols

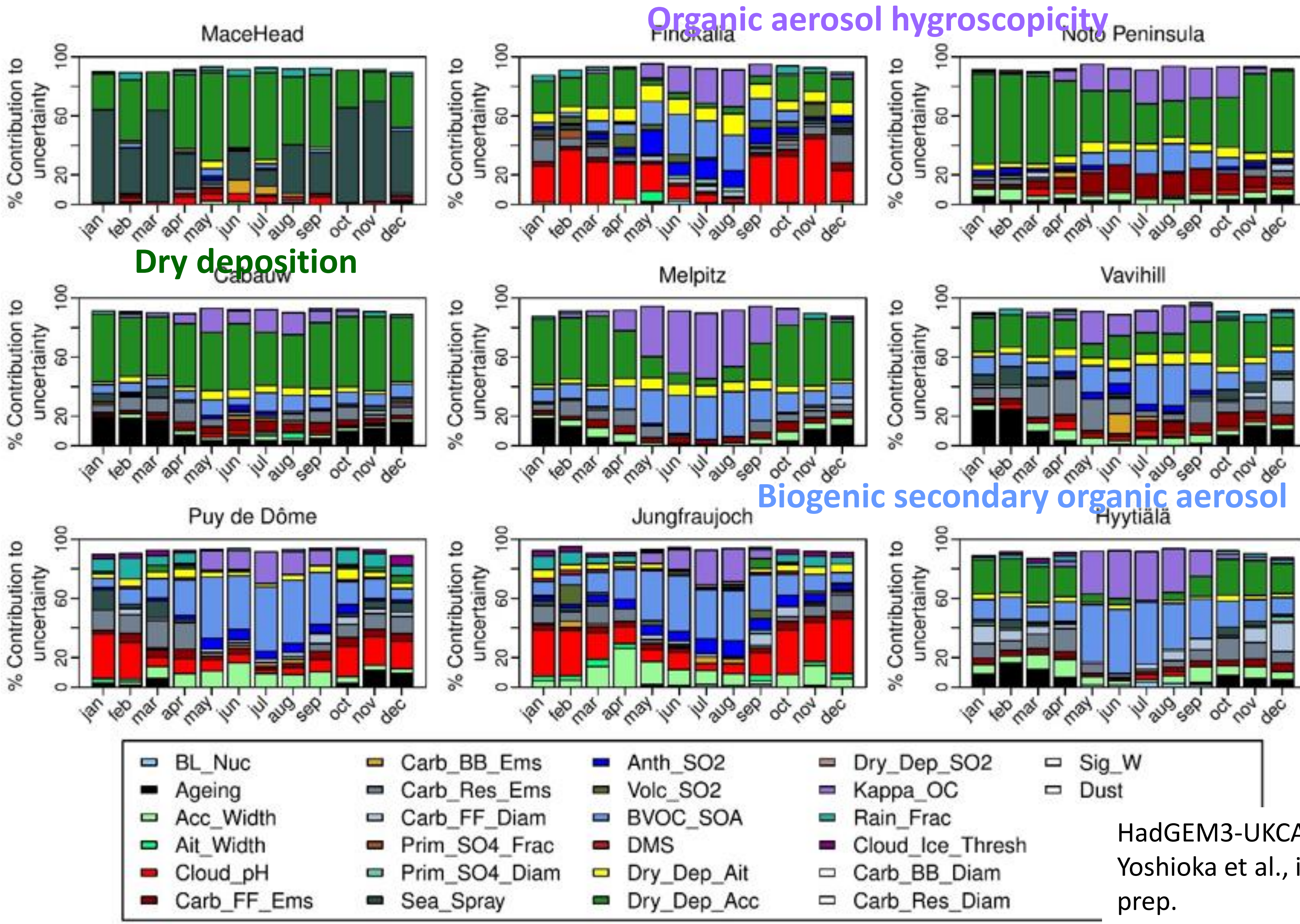


CCN at 0.2% supersaturation



Overall NMB -37%

Major contributors to model uncertainty –
perturbed parameter ensemble



HadGEM3-UKCA
Yoshioka et al., in prep.

How the CCN uncertainty reflects in CDNC (cloud droplet number concentration) calculations?

modelled CCN spectra
CCN=f(ss)

observed CCN spectra
CCN=f(ss)

Compute CDNC as a function of

- *f(CCN)*
- *Pressure*
- *Temperature at the base of the cloud*
- *Updraft velocity (ω)*

Nenes and Seinfeld JGR, 2003 & Fountoukis and Nenes, JGR, 2005

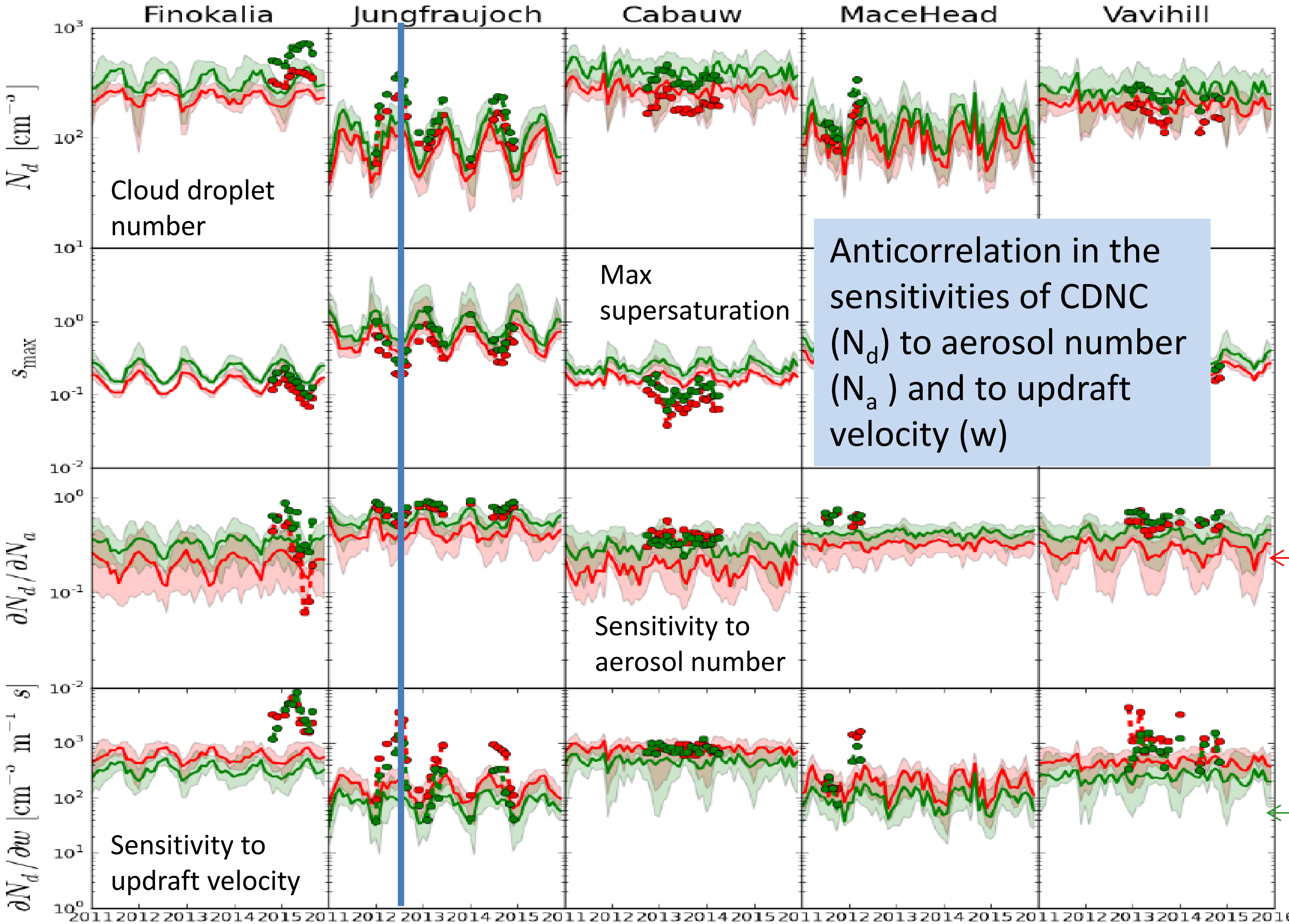
modelled CDNC

observed CDNC

ω = 0.3ms^{-1} typical for stratiform clouds

ω = 0.6ms^{-1} typical for cumulus clouds

Cloud droplet number and its sensitivity to aerosol number and updraft velocity



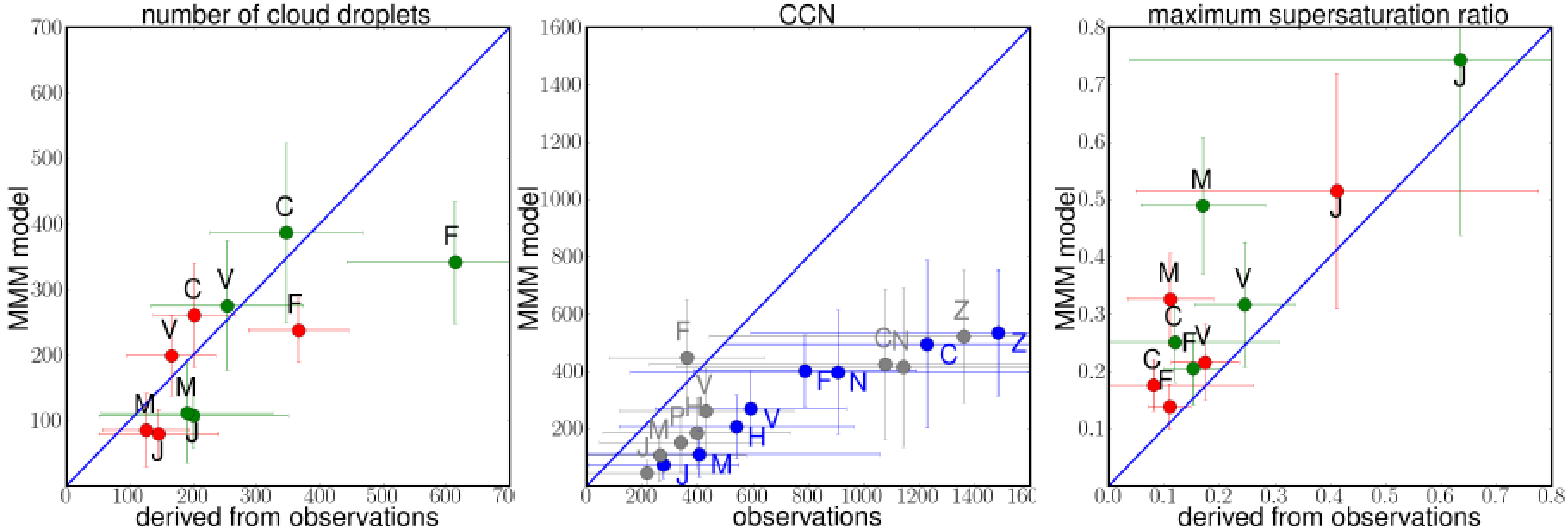
CDNC calculated from observations and from models

Nenes and Seinfeld JGR, 2003 & Fountoukis and Nenes, JGR, 2005

For ω = 0.3ms^{-1}

For ω = 0.6ms^{-1}

Cloud droplet number and its sensitivity to aerosol number and updraft velocity



updraft velocity 0.6 m s^{-1}	CCN at supersaturation 0.2%	updraft velocity 0.6 m s^{-1}
updraft velocity 0.3 m s^{-1}	CCN at max measured supersaturation (0.8%-1.0%)	updraft velocity 0.3 m s^{-1}

The number of CCN at a prescribed supersaturation cannot be used as indicator of CDNC, as supersaturation is dynamically determined and can vary considerably for a given site

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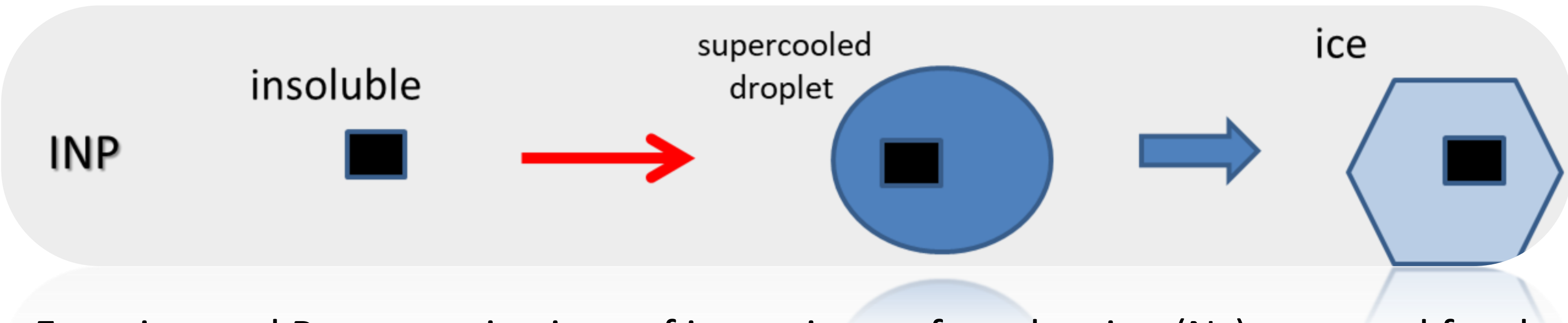
Summary

AEROCOM : Aerosol Comparisons between Observations and Models

- First comparisons of model results with experimentally derived CDNC.
- **The spread of models for CDNC is smaller than the spread for N_a and for CCN**
- The sensitivities of CDNC to N_a and to updraft velocity, ω, are negatively correlated. **The variability in N_a and ω, is controlling that of CDNC**
- The models underestimate
  - i) N50, N120, CCN
  - ii) Organic aerosol mass in PM1
- **OA is important contributor: ▯ to CCN**
  ▯ to summer time uncertainty in CCN
- More N3 particles in the models with higher diversity between models over the NH continents than CCN indicating differences in the **size distribution of the primary emissions and/or in the NPF and growth.**

Ice Nuclei simulations Chatziparaschos et al 2018



Experimental Parameterizations of ice active surface density (Ns) are used for the simulations:

INPs :

- Marine OA (ocean biota) ➡ ➢ Wilson et al., 2015 (Numbers/TOC)
- Dust (feldspar) ➡ ➢ Atkinson et al., 2013 , Niemand et al., 2012, Boose et al., 2016 ($/m^2$)
- Pollen
- Soot
- Fungal
- Bacteria

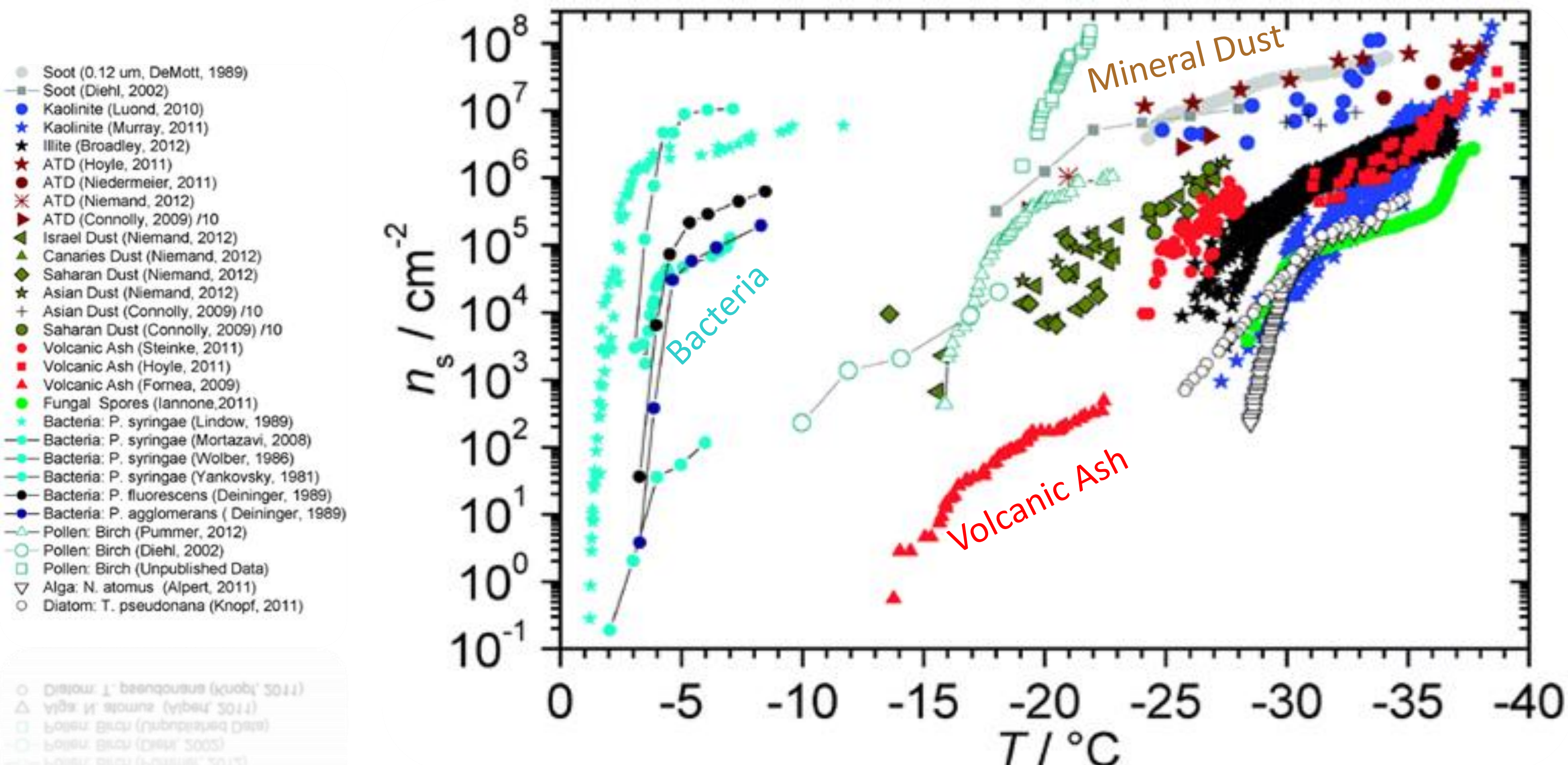
(functional groups via hydrogen bonds with -OH, -NH2)

➢ McCluskey et al., 2018 (Terrestrial) ($/m^2$)

Singular description of Active sites

- describes ice active variability of different particles
- ice nucleation based on Temperature $n_s(T)$
- experimentally derived
- T_c is the critical temperature below which the multiple active sites present on an IN surface activate to form ice

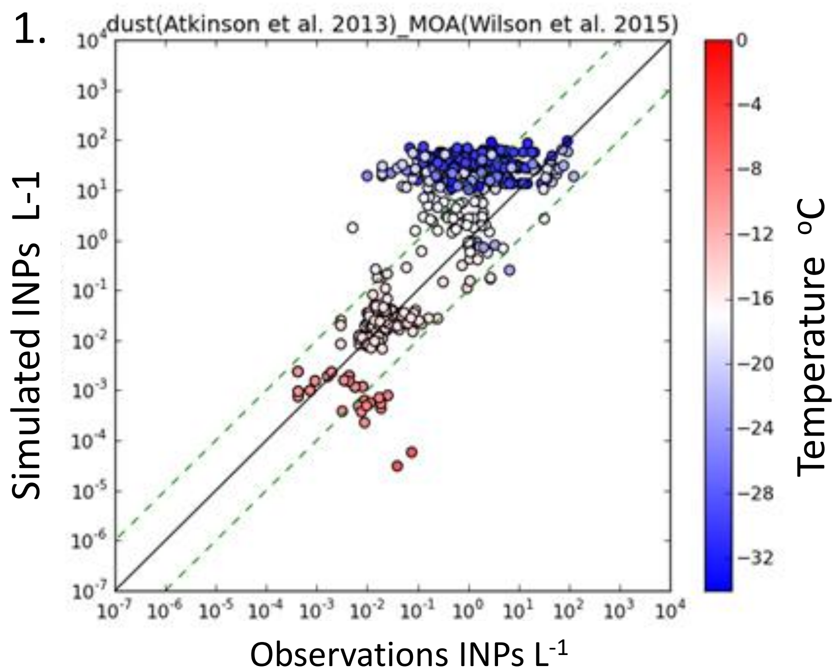
Active sites : *surface has*
steps and cavities as a result of mechanical fracture of natural weathering, which have functional groups Hydroxyl–OH and act as hydrophilic sites (Freedman et al., 2015)



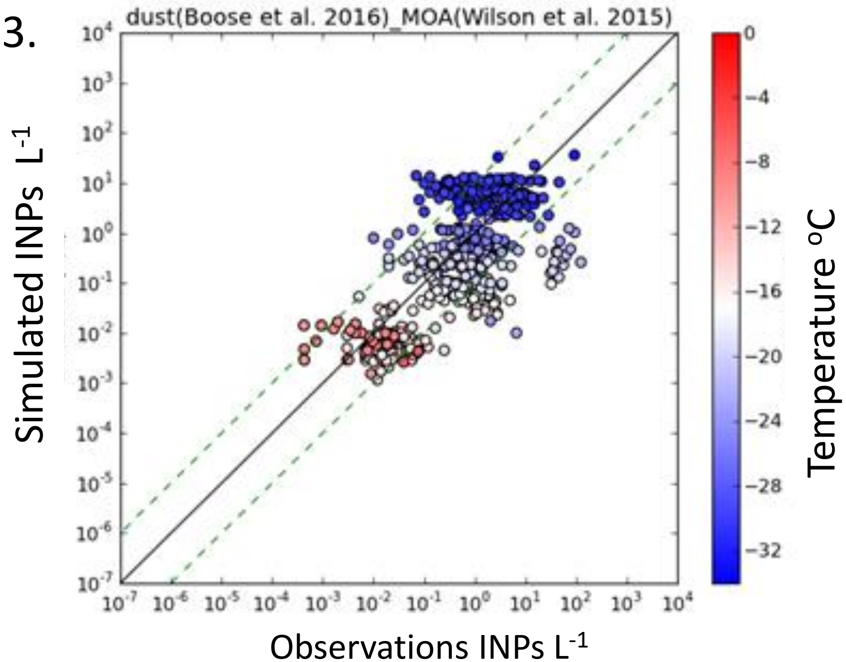
Testing parameterizations for dust INPs

INPs category	Equation	Reference
Marine OA	$n_m = e^{11.2186-(0.4459*T_c)}$	Wilson et al., 2015
Dust-Feldspar	$n_s = e^{(-1.038*T_k+275.26)}$	Atkinson et al., 2013
	$n_s = e^{(-0.517*(T_k-273.15)+8.934)}$	Niemand et al., 2012
	$n_s = e^{(-0.33*(T_k-273.15)+15.64)}$	Boose et al., 2016

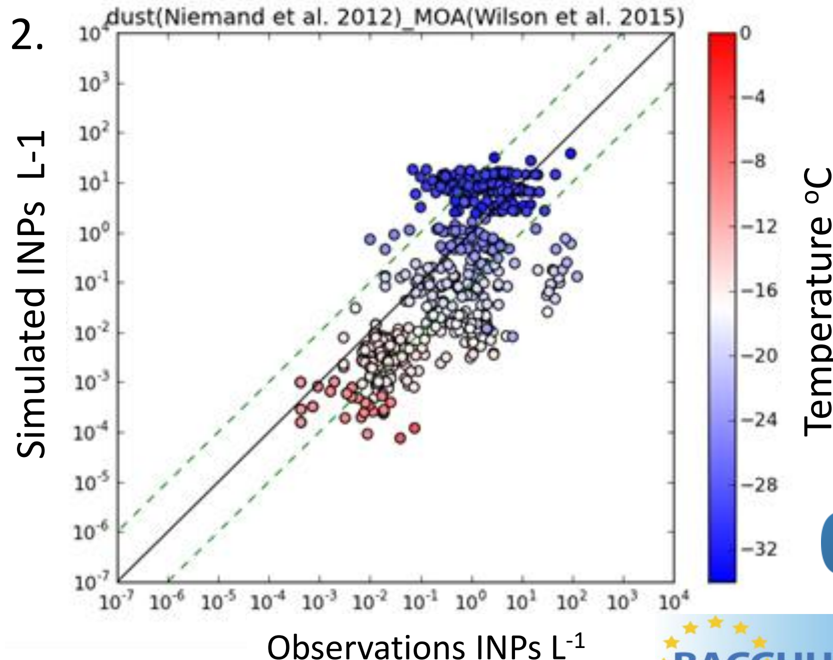
1.



3.



2.



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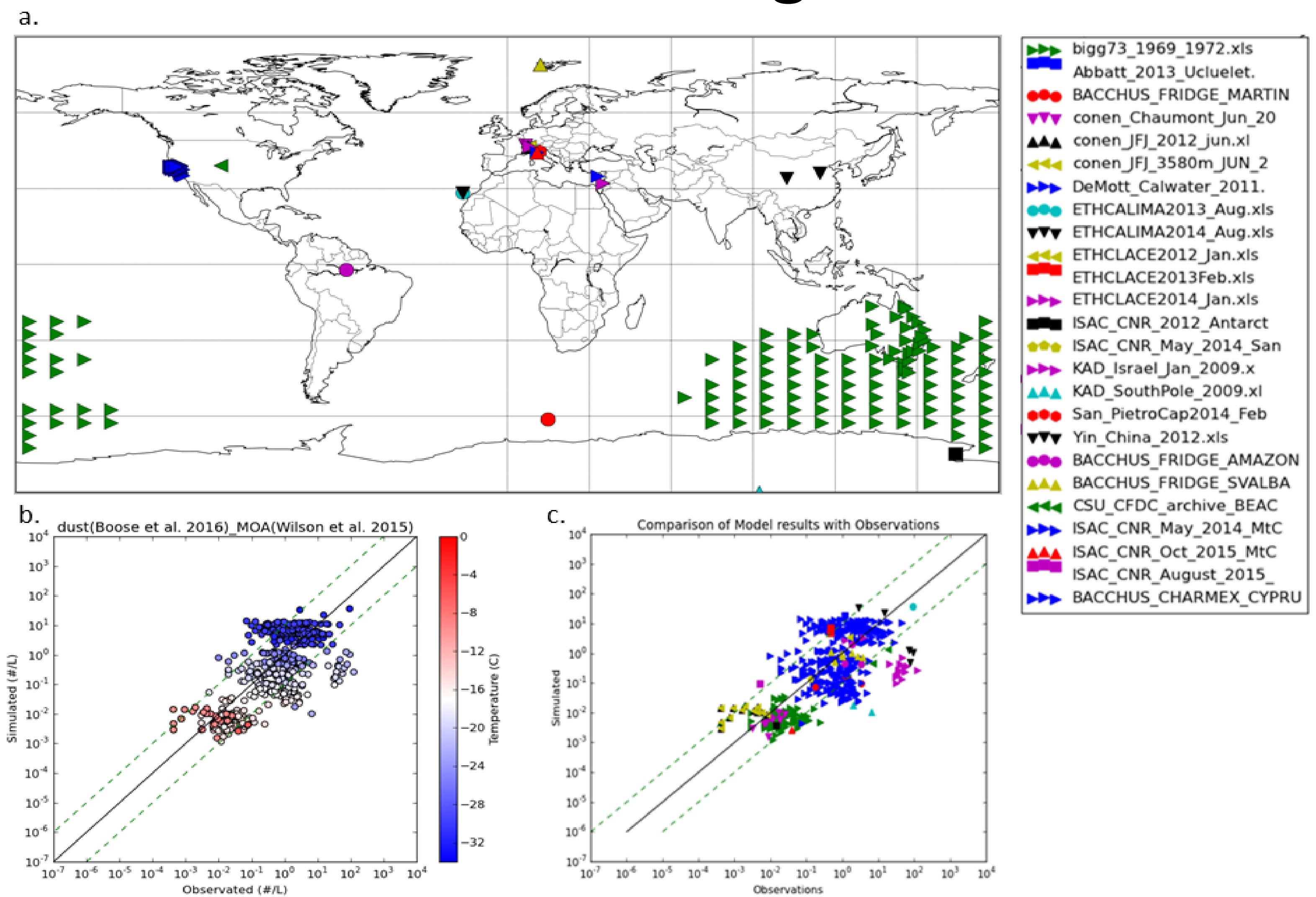
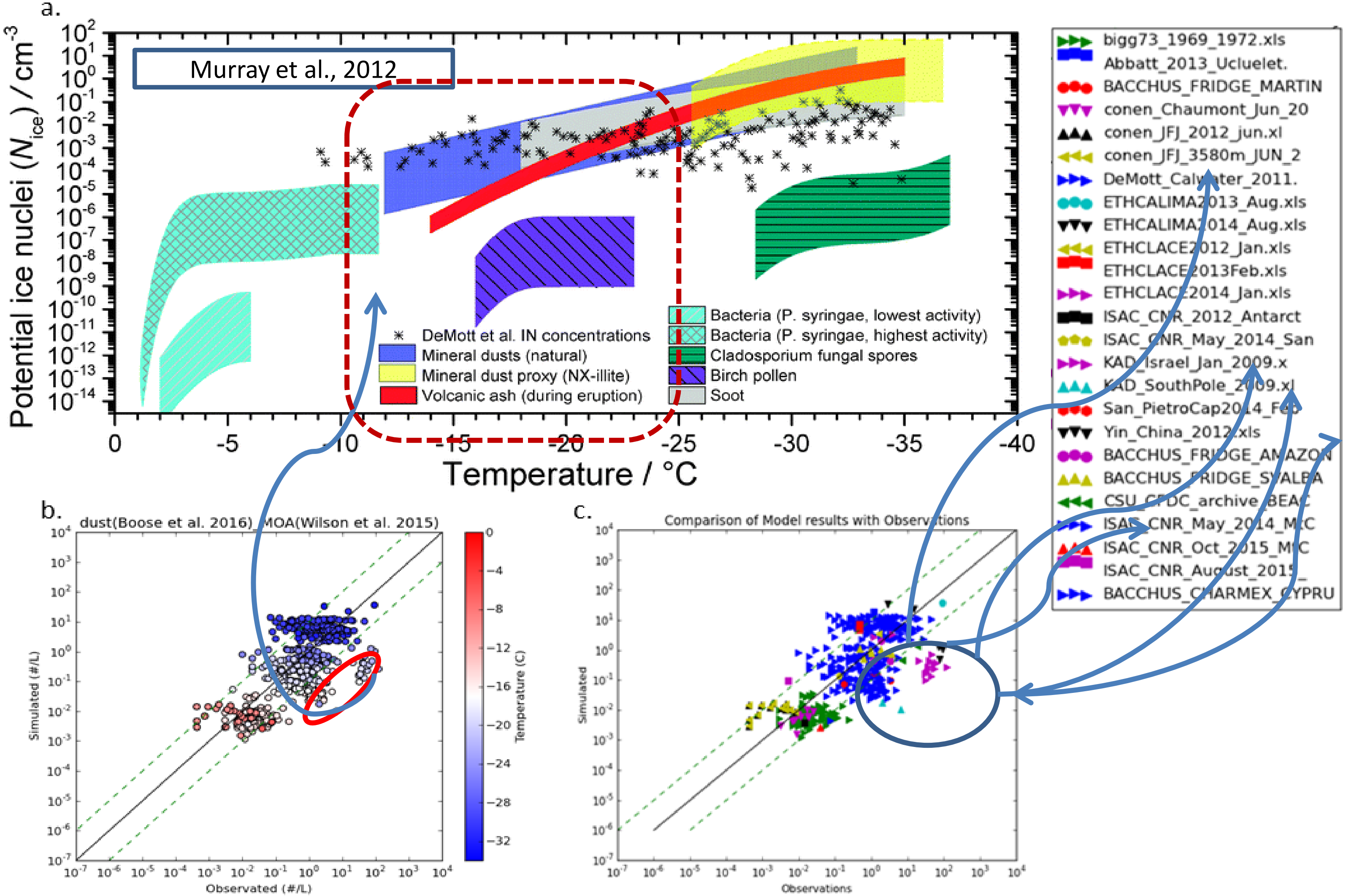
Accounting only for marine organics and dust INPs : missing sources



Chatziparaschos et al COMECAP 2018

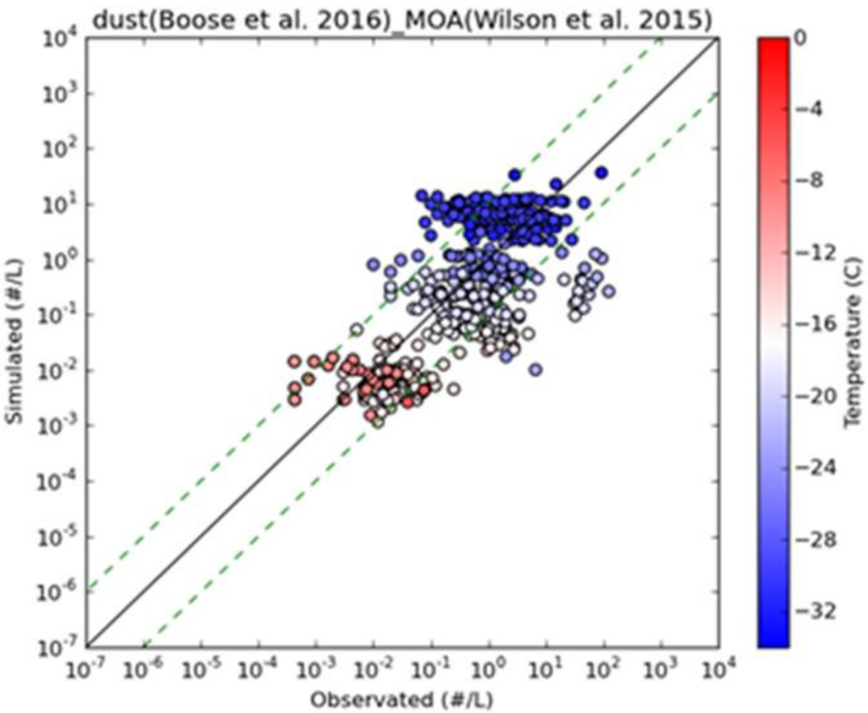
Accounting only for marine organics and dust INPs : missing sources



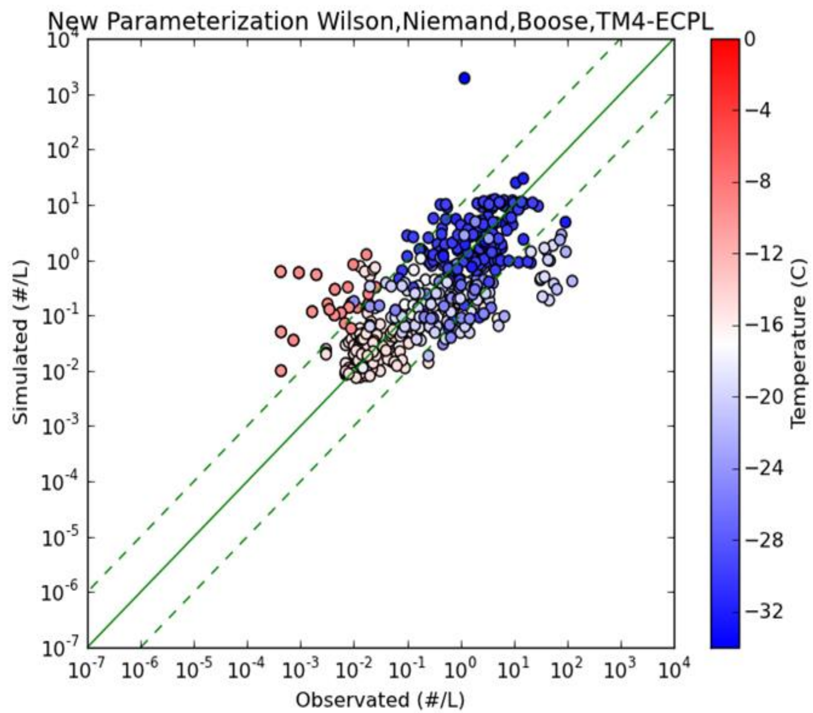
Chatziparaschos et al COMECAP 2018

Improvements: adding terrestrial bioaerosol

Dust feldspar & marine aerosol

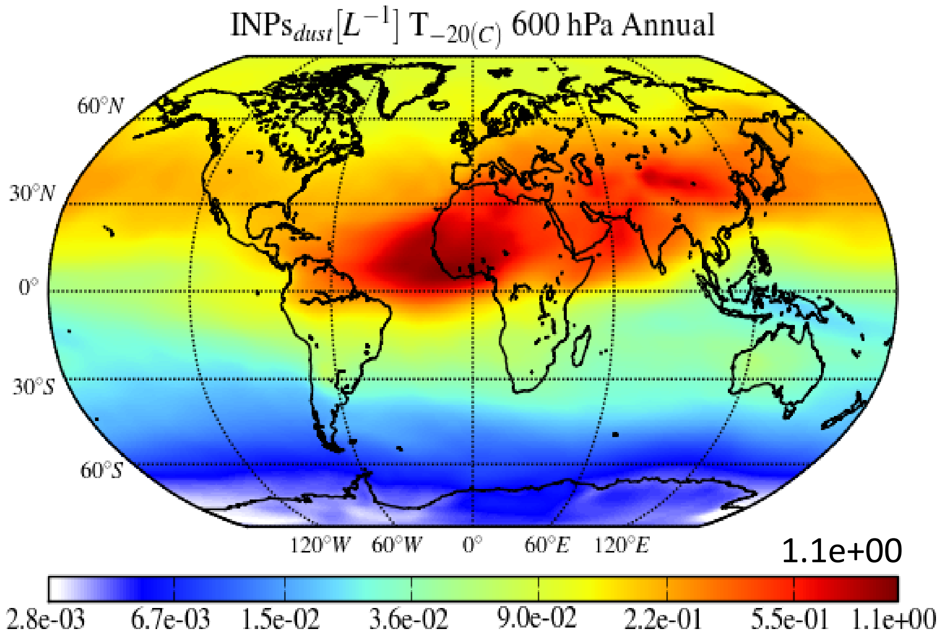


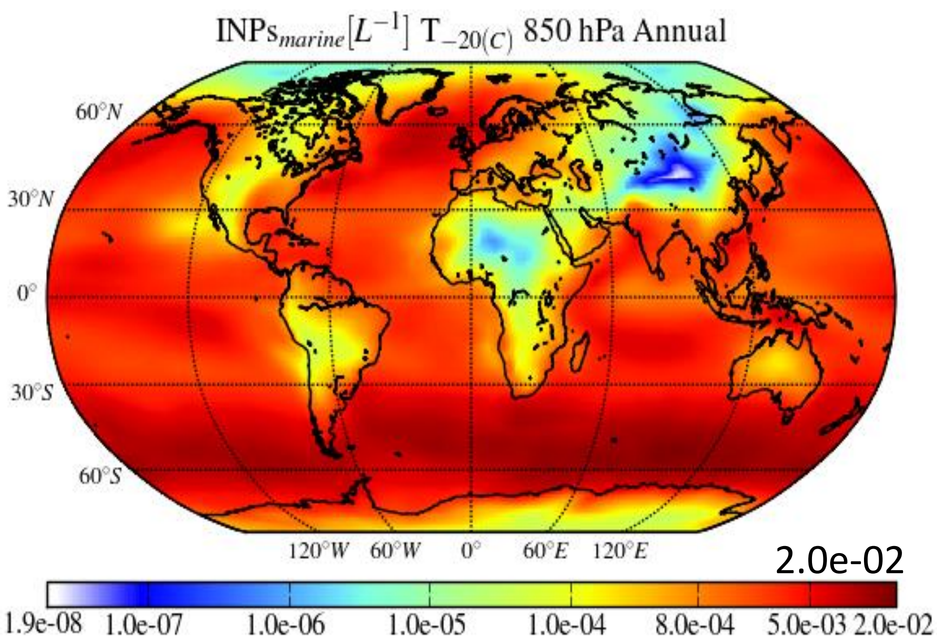
Adding also terrestrial bioaerosol



Using McCuskey et al., 2018 based on number of insoluble bacteria, pollen, fungii

Annual Mean Distribution of INPs





Simulation year 2008

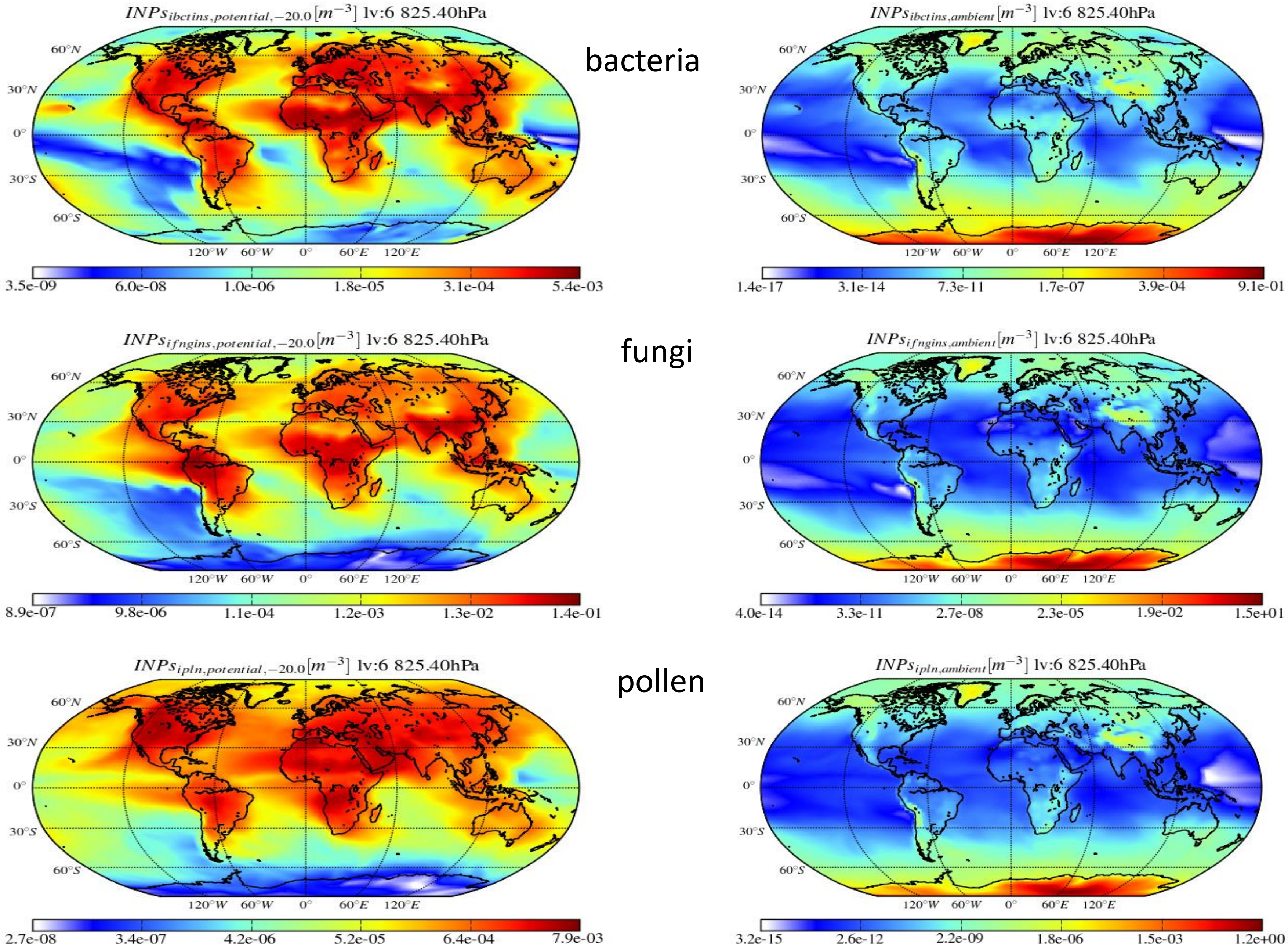
INPs from mineral Dust:

- Dominate across Northern Hemisphere, North Africa (Sahara), Asia (Gobi)
- More abundant in number than marine INPs
- Transported to mid and high-altitudes
- Affect regions far from their emission point

INPs from Marine Organic:

- Dominate across Southern Hemisphere, (remote oceans)
- Several spots → oceanic biota activity
- Generally lower number concentration than dust INPs
- Affect regions close to their emissions
- Important in coastal regions → (North East Coast of America -North Atlantic) → comparable concentrations with dust INPs

at -20C ← [INP] → at ambient temperature



Perspectives of INP/CCN modeling

- further implemented parameterizations for INPs missing sources improve discrepancies between model and measurements

- the simulated number concentrations of CCN and of INPs are compared and their significance for precipitation rates, cloud lifetime and cloud coverage and albedo will be investigated.