Primary & secondary biogenic aerosols serving as nuclei for cloud droplets & ice crystals

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Outline

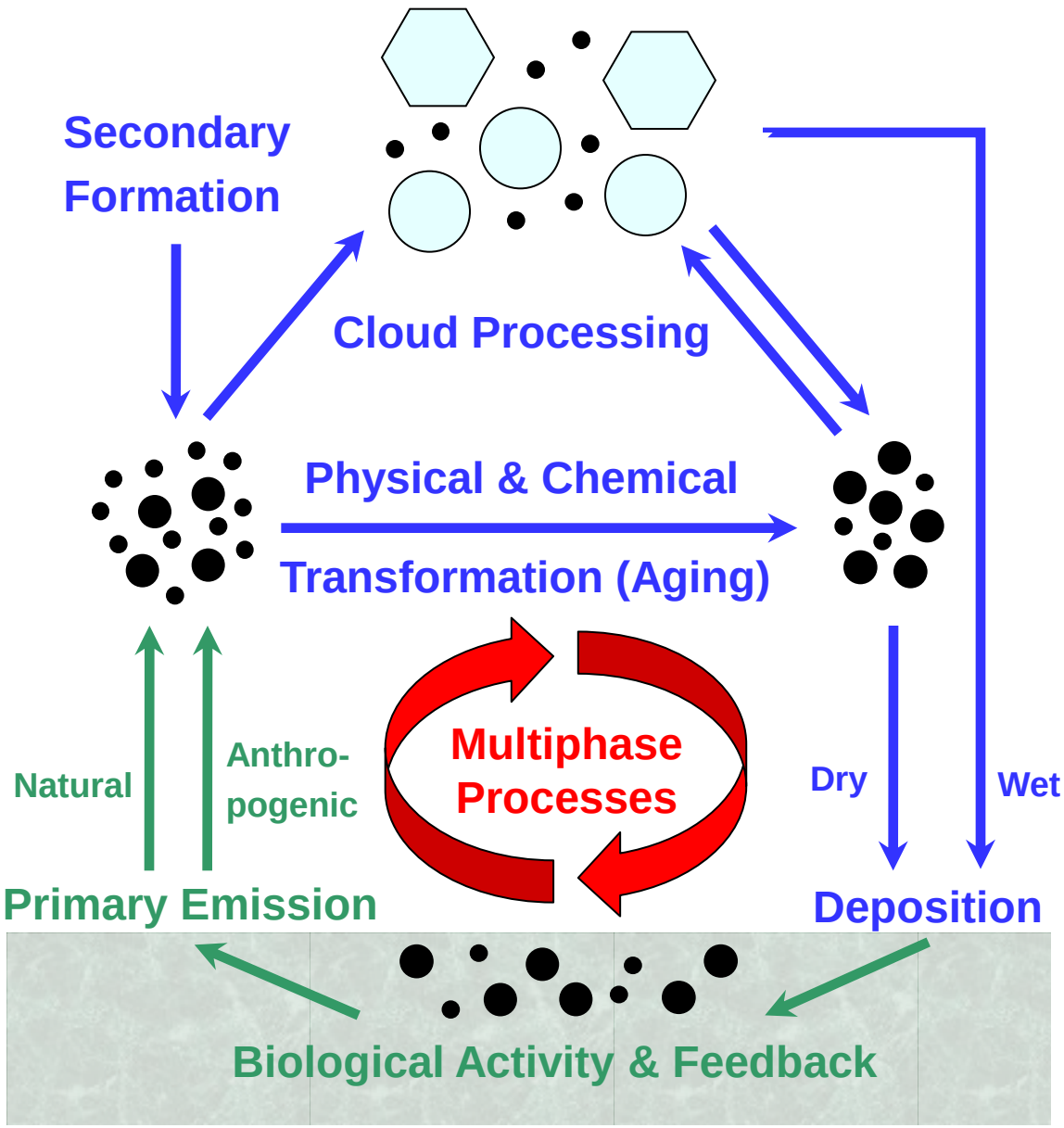
Introduction & Motivation

- bioaerosol cycling & effects
- rainforest aerosol composition & sources

CCN Activation in Pristine vs. Polluted Air

- characteristic parameters & regimes
- aerosol - cloud droplet closure

Aerosol Cycling & Effects



Atmosphere & Climate

- aerosols & gases
- clouds & precipitation
- radiation & dynamics

Mechanistic understanding, quantitative prediction & human influence ?

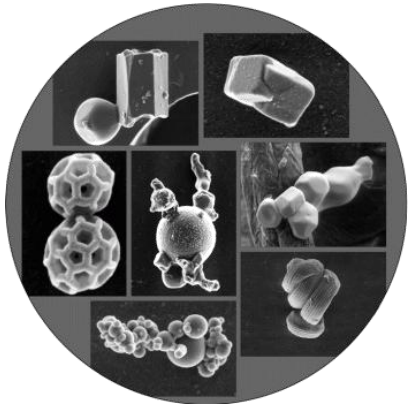
- spread & change of organisms & ecosystems
- human, animal & plant diseases

Biosphere & Public Health

Pöschl Angew Chem 2005

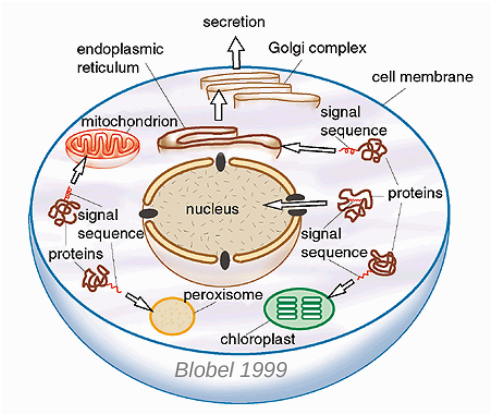
MPIC Atmospheric & Biological Particle Size

Aerosols: solid & liquid nano- & micro-particles



Clouds, Fog & Precipitation: dilute aqueous particles

Cells & Organelles: semi-solid & liquid nano- & micro-particles



Aerosol

Clouds & Fog

Precipitation (Rain, Snow, Graupel, Hail)

Gas Molecules

Proteins **Viruses** **Bacteria** **Spores** **Pollen**

Sulfate, SOA, Soot

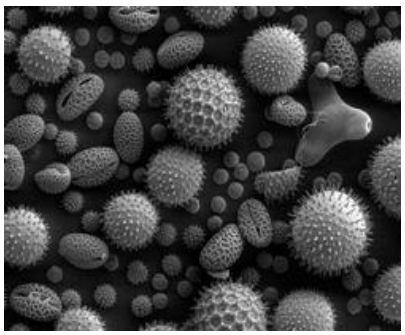
Mineral Dust, Sea Spray

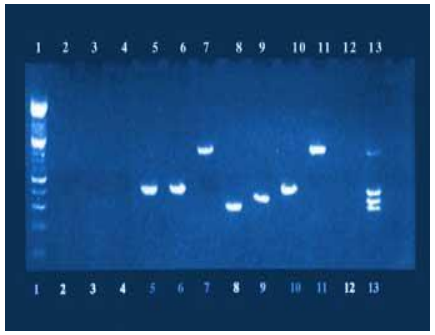
Diameter (m)

1.E-10	1.E-09	1.E-08	1.E-07	1.E-06	1.E-05	1.E-04	1.E-03	1.E-02	1.E-01
100 pm	**1 nm**	10 nm	100 nm	**1 μm**	10 μm	**100 μm**	1 mm	1 cm	10 cm
		- ultrafine -		*- fine -*	*- coarse -*				

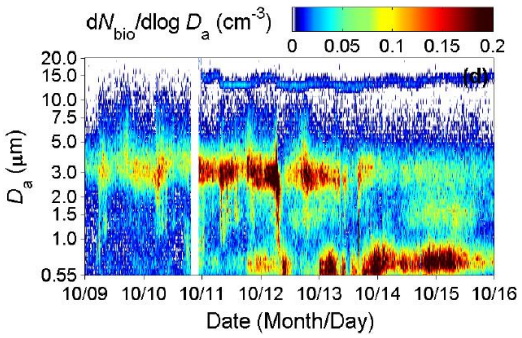
Pöschl Angew Chem 2005

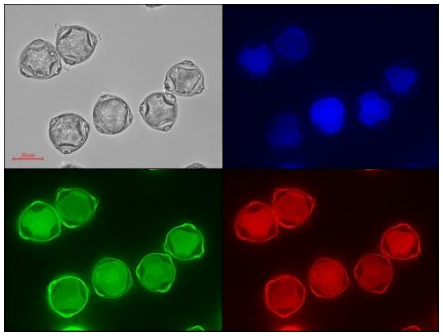
MPIC Bioaerosols & Bioprecipitation





DNA & Protein Analysis





Fluorescence Spectroscopy & Microscopy

High abundance, diversity & fluxes of airborne bacteria & fungi

~1 µg m^{-3}, ~10 L^{-1}, **~10^2 m^{-2} s^{-1}**, >10^3 species (urban PM)

Cloud condensation & ice nuclei:

co-evolution of life & climate

⇒ **bioprecipitation cycle**

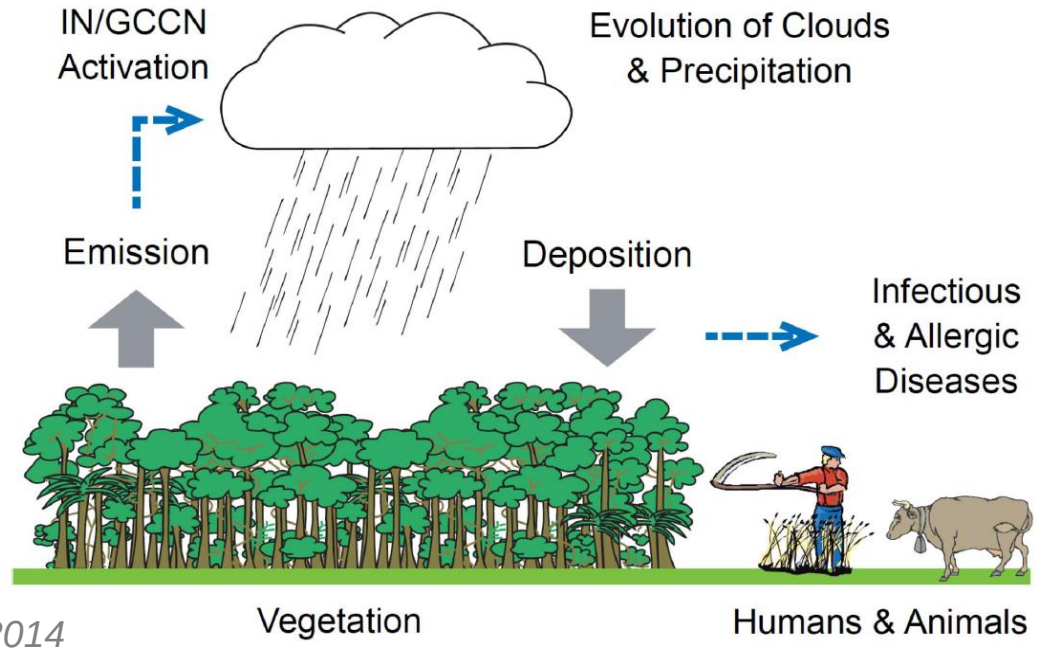
"Life is in the Air": ~10 ng m^{-3} DNA

⇒ inhalation of ~1 µg/day ≡

~10^8 bacterial genomes/day

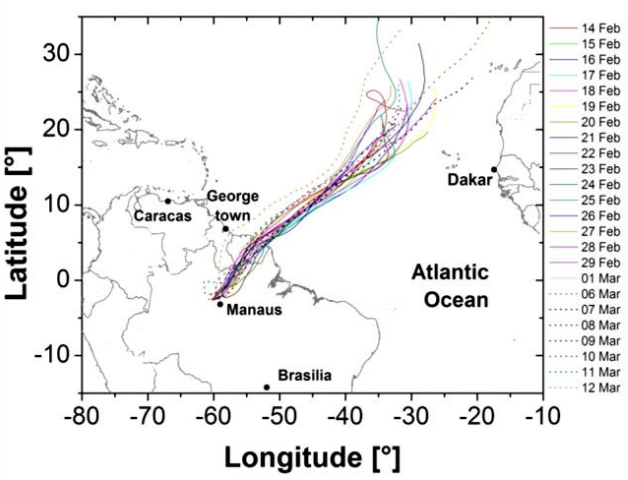
Pathogens: permanent challenge

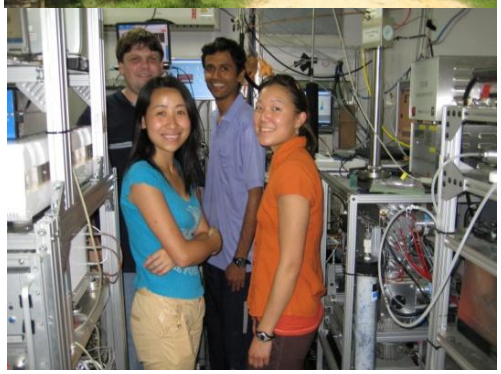
⇒ **infectious & allergic diseases**



Elbert ACP 2007, Despres BG 2007, Fröhlich PNAS 2009, BG2012, Pöschl Science 2010, Despres Tellus 2012, Pöhlker AMT 2012, Science 2012, Morris GCB 2014

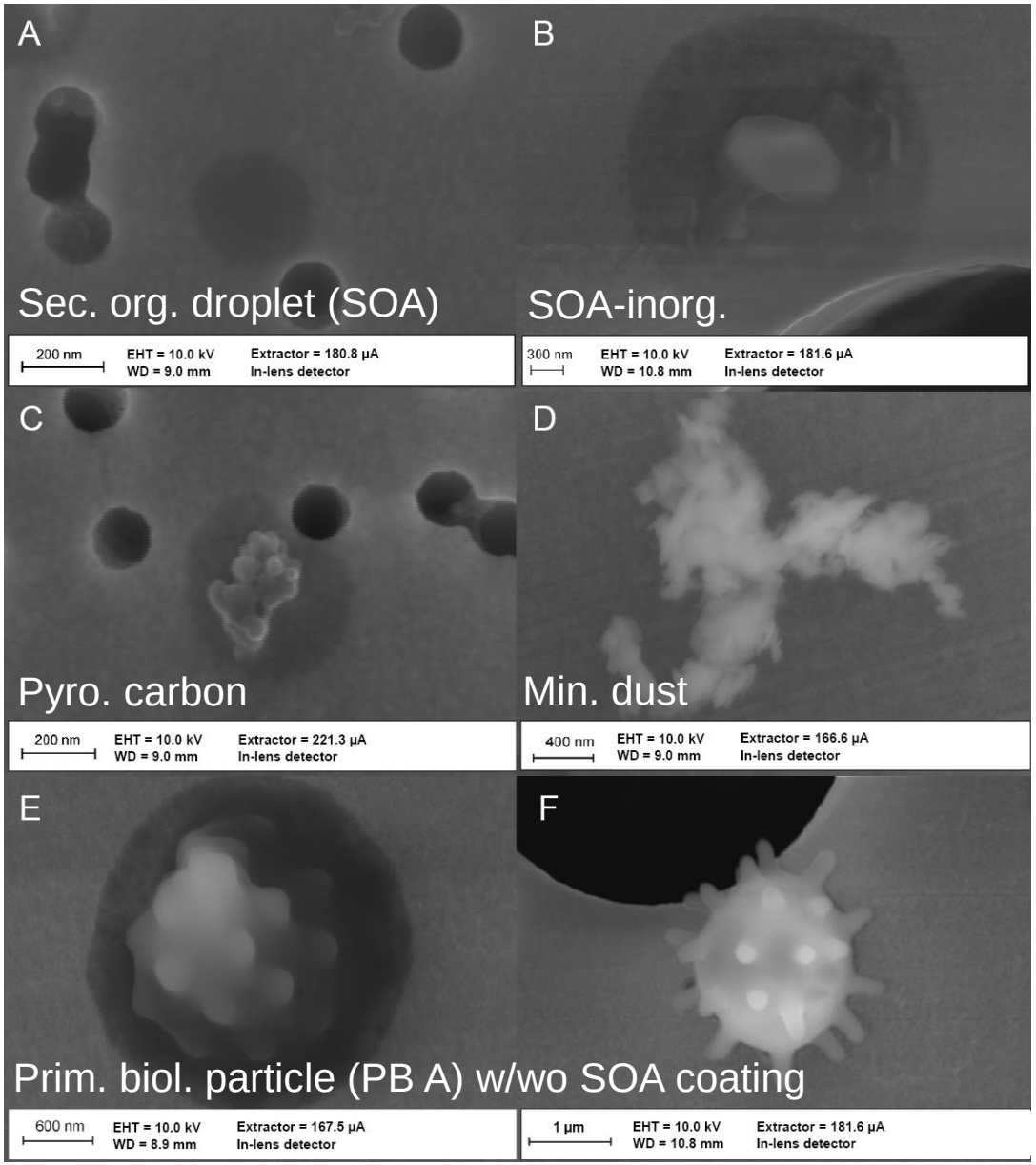
MPIC Pristine Rainforest Aerosol (AMAZE-08)





Martin ACP 2011,
Pöschl Science 2010

Characteristic particle types (3-13 March 2008)



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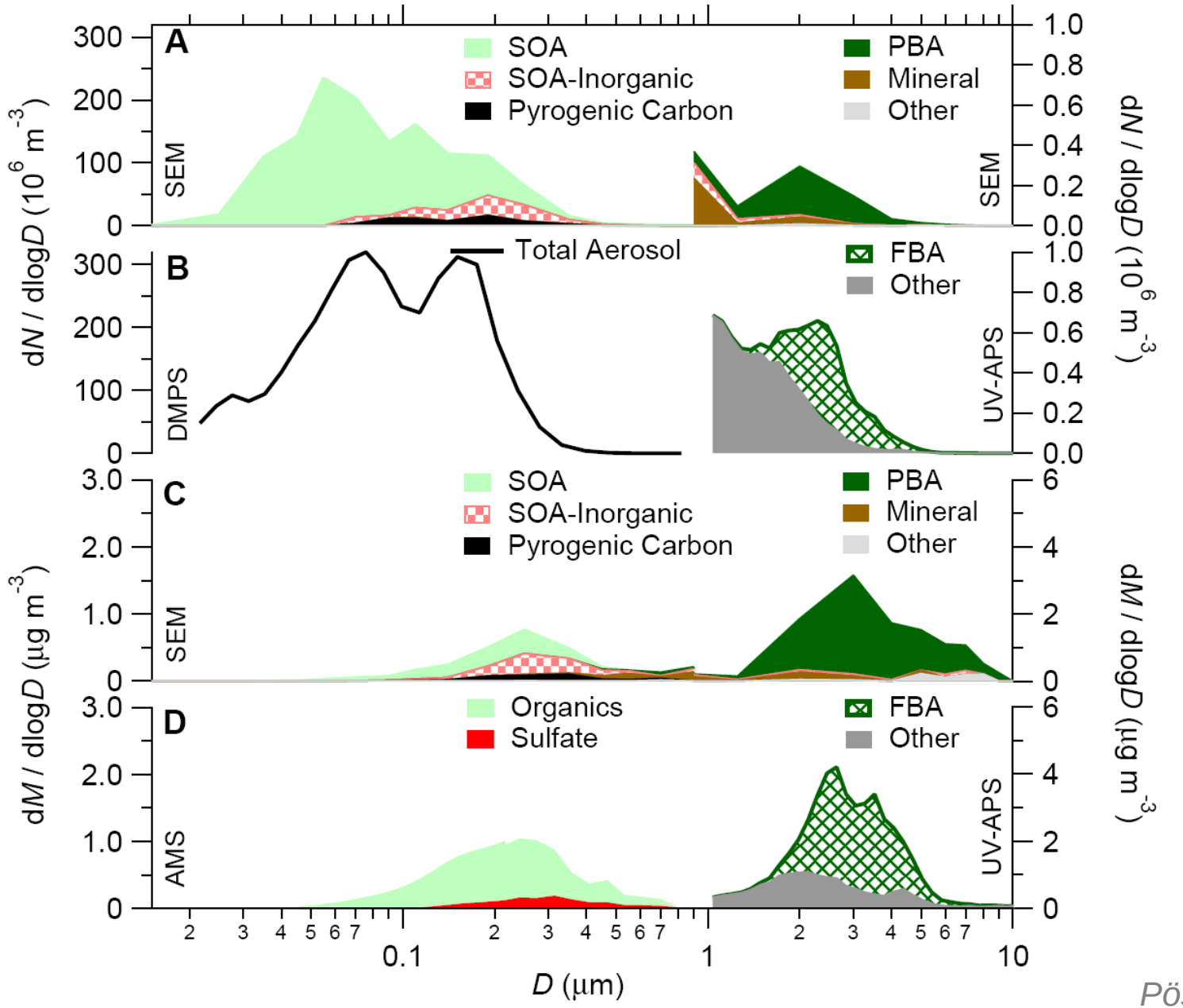
Rainforest Aerosol Size Distribution



Number

Submicron
~ 200 cm^{-3}
~ 85% SOA

Supermicron
~ 0.2 cm^{-3}
~ 80% PBA

Mass

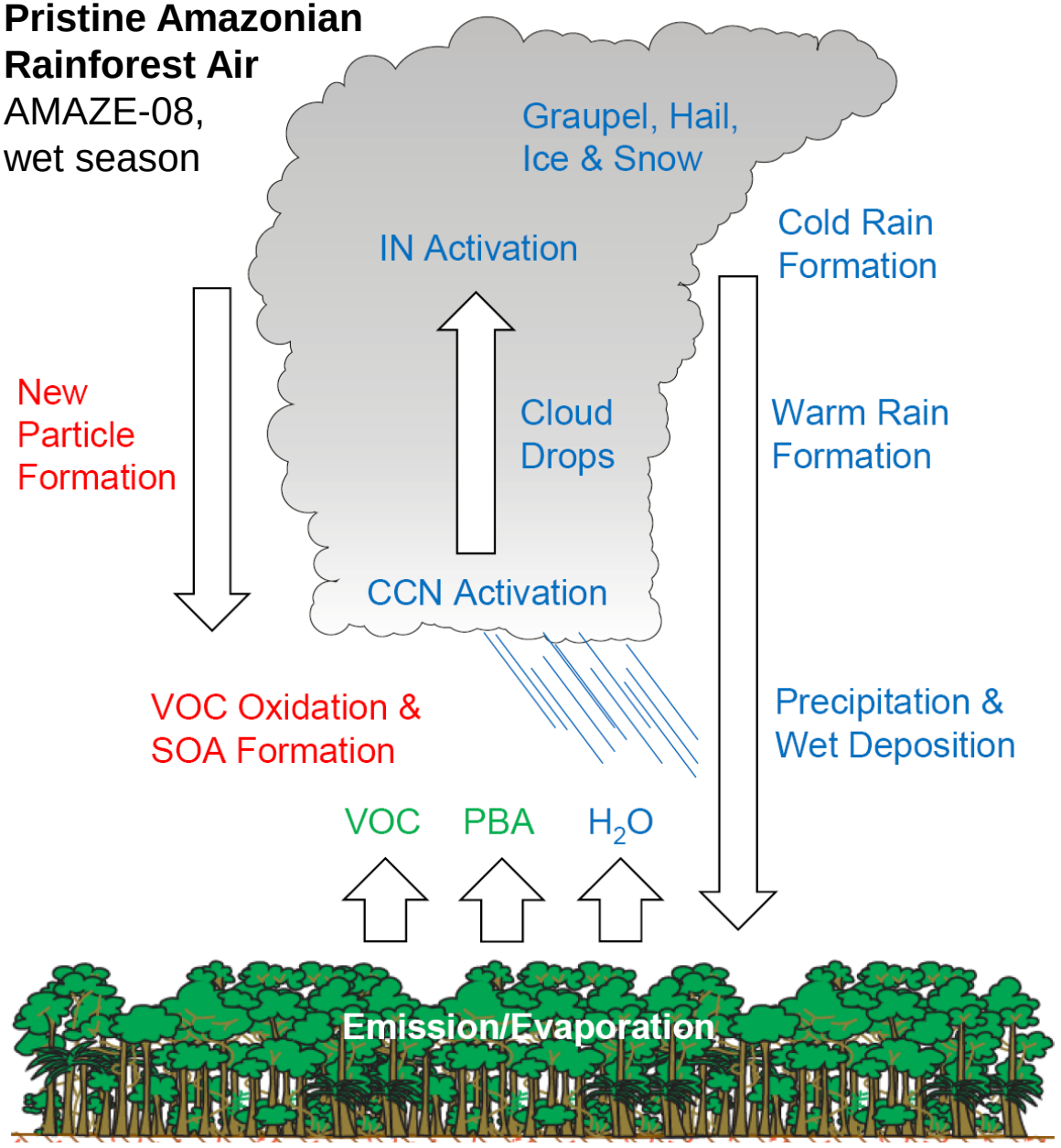
Submicron
~ 0.5 µg m^{-3}
~ 85% SOA

Supermicron
~ 1.5 µg m^{-3}
~ 85% PBA

Pöschl Science 2010

Biogeochemical Reactor I

Pristine Amazonian Rainforest Air
AMAZE-08,
wet season



Cloud Cond. Nuclei (CCN):
~10^2 cm^{-3}, <1 µm, mostly secondary organic aerosol (SOA) from biogenic VOC

Ice Nuclei (IN):
~10^{-2} cm^{-3}, ≥ 1 µm, mostly primary biological aerosol (PBA)

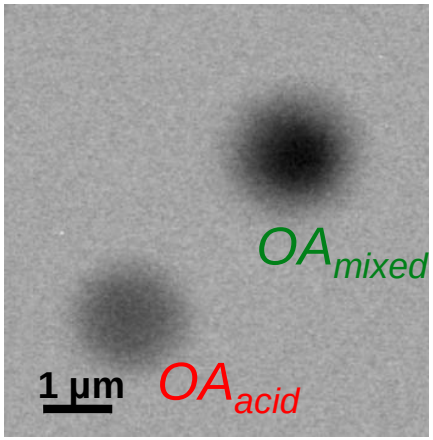
SOA: formation pathways & kinetics ?

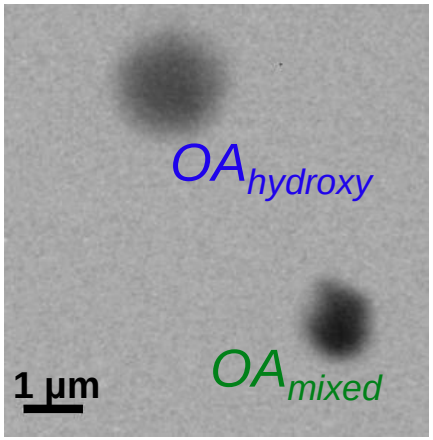
PBA: diversity, sources & water interactions ?

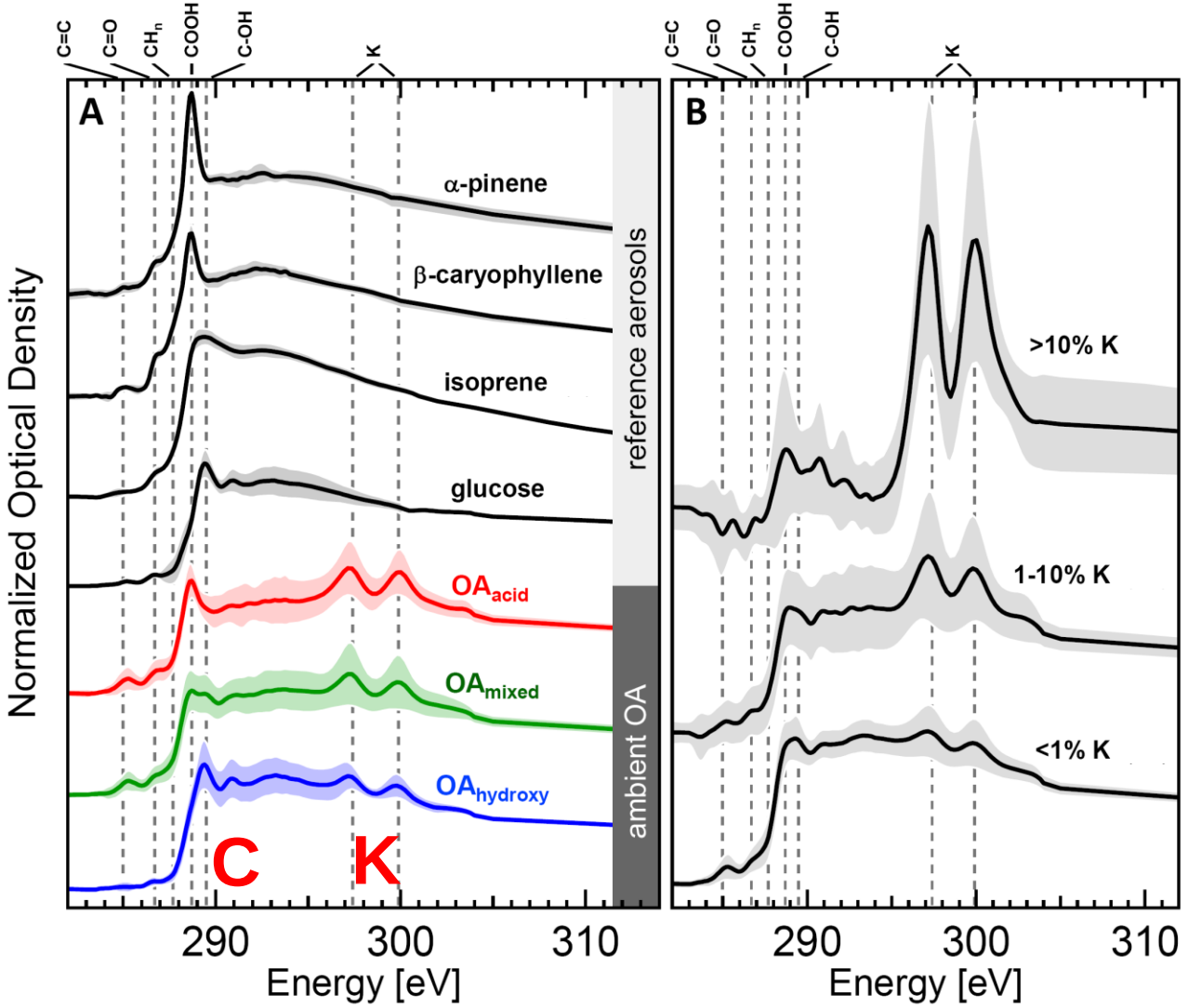
Bioprecipitation Cycle:
pristine tropical vs. polluted mid-latitude air ?

Pöschl Science 2010

SOA Composition



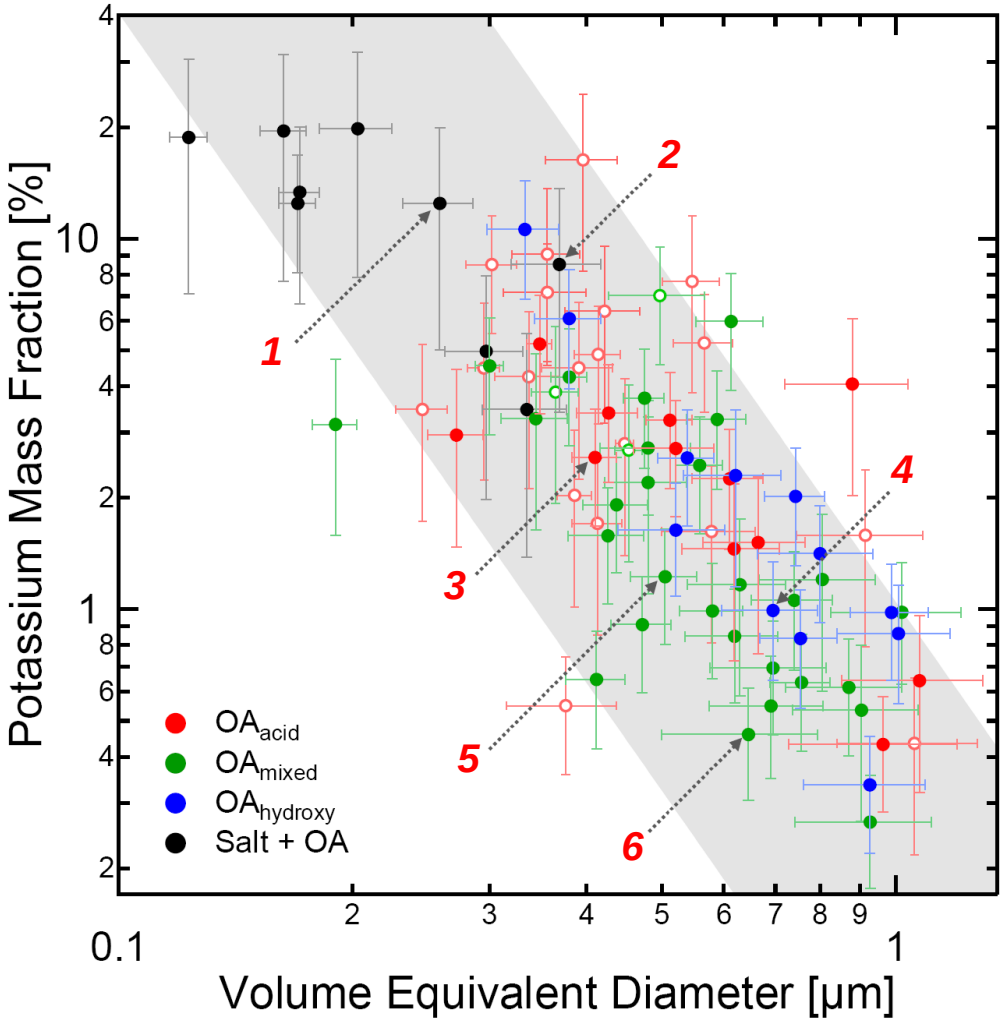


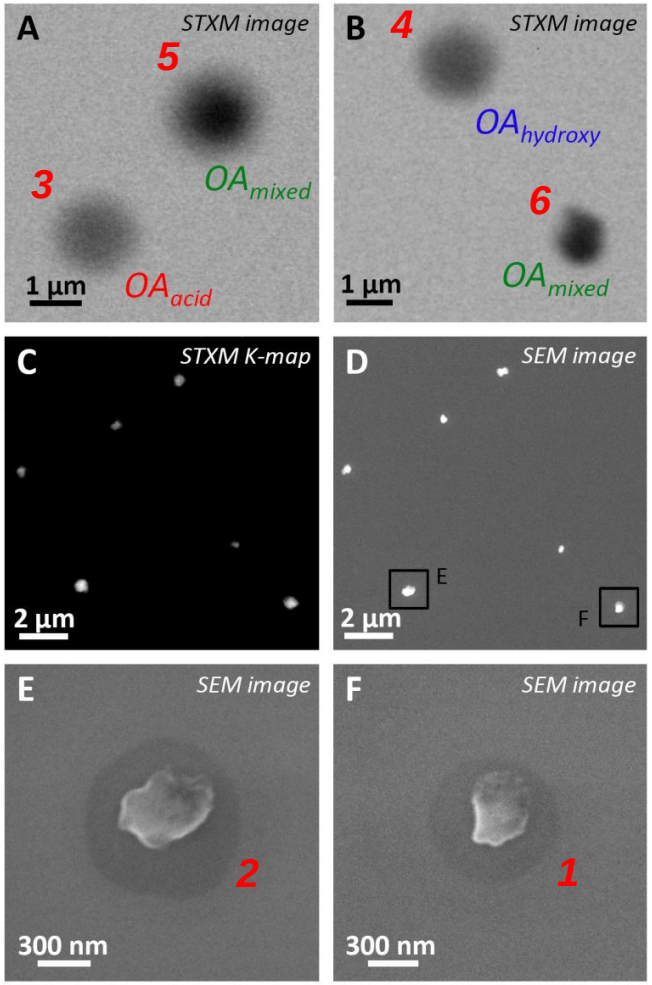


- STXM-NEXAFS: 3 SOA classes – acid (terpene), hydroxy (isoprene), mix
- potassium (K) in almost all SOA particles

Pöhlker Science 2012

Potassium Salt Seeds

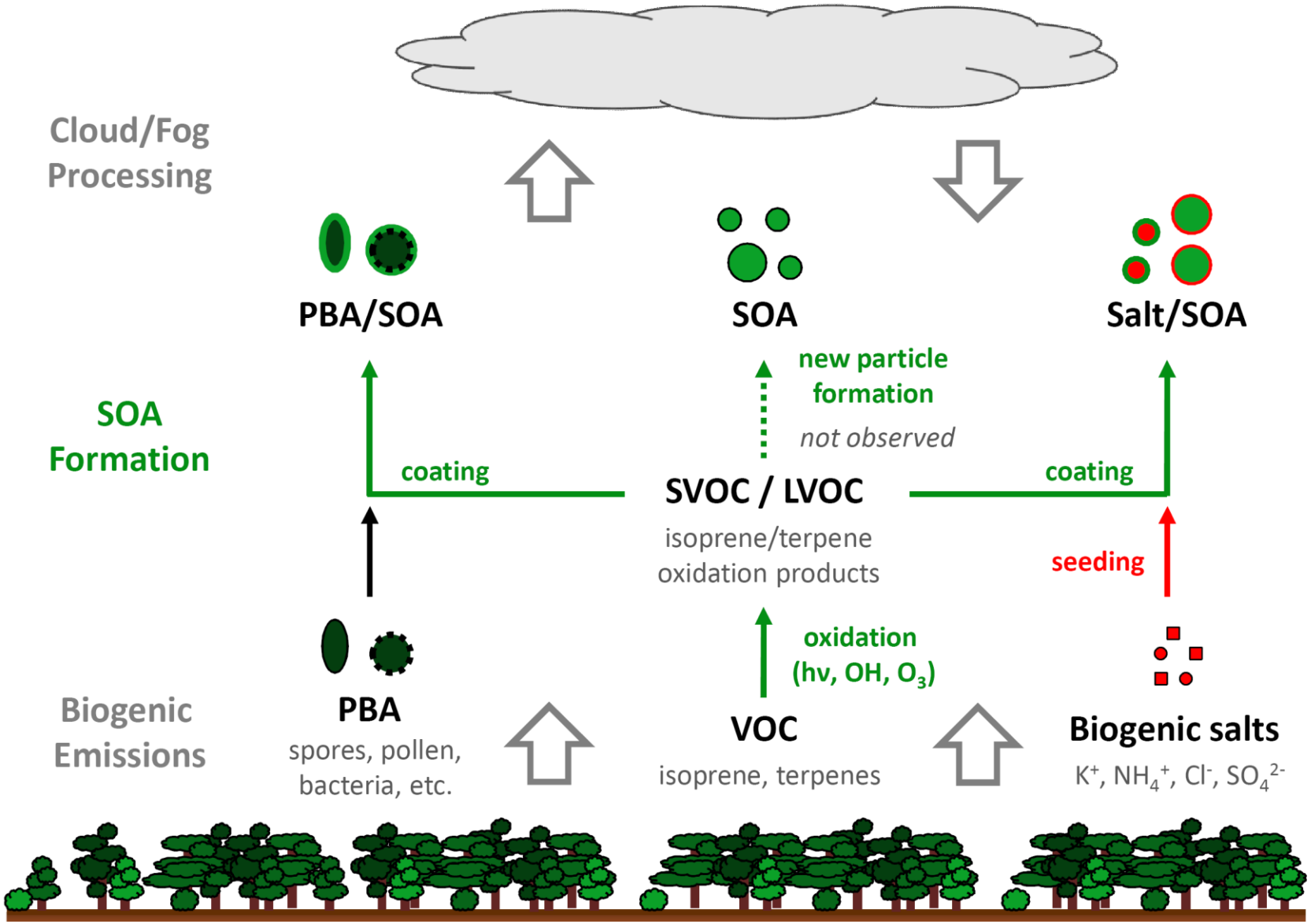




- Small potassium-rich salt particles with low organic content
- Dilution of primary potassium content upon SOA particle growth

Pöhlker Science 2012

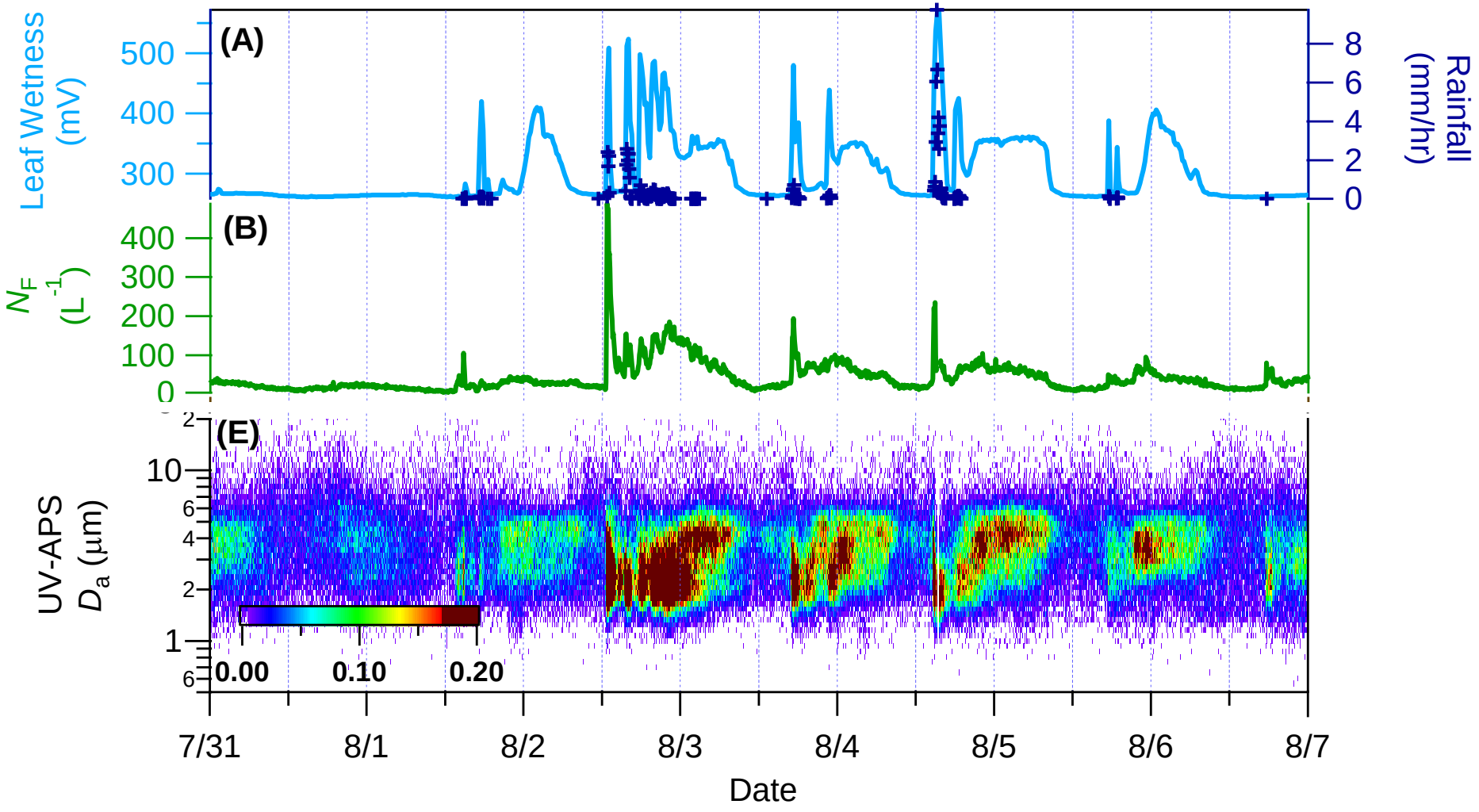
Biogeochemical Reactor II



- CCN & IN numbers directly controlled by primary emissions ?

Pöhlker Science 2012

MPIC Semi-Arid Forest (BEACHON-Rombas 2011)

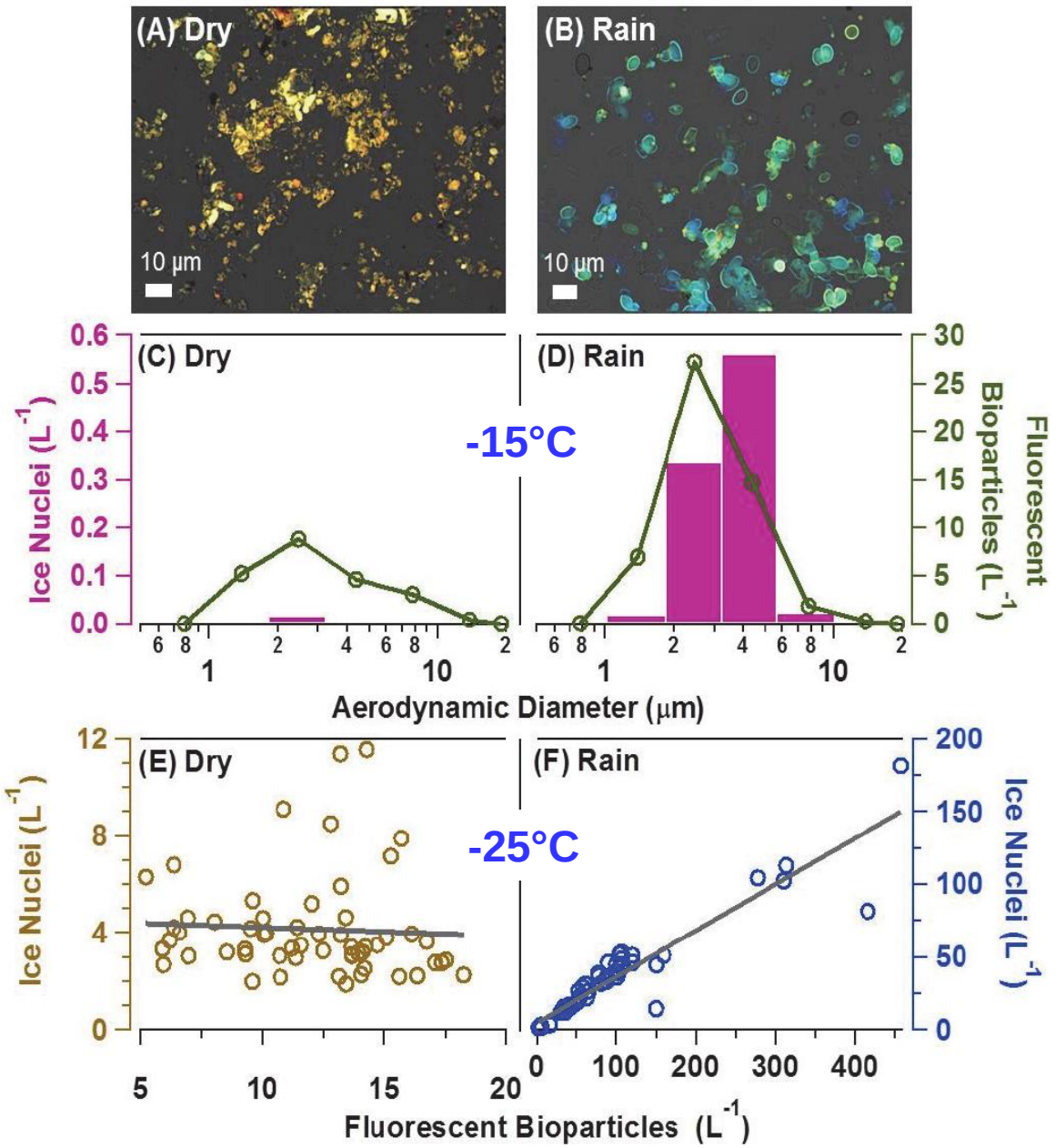


UVAPS & Humidity Measurements (Manitou Forest, Colorado, USA, August 2011)**:**

- strong bursts of bioaerosol concentrations during & after rain (FBAP)
- intial release of bacteria (~2 µm) & subsequent growth of fungi (~4 µm) ?

Huffman ACPD 2013

Biological Ice Nuclei

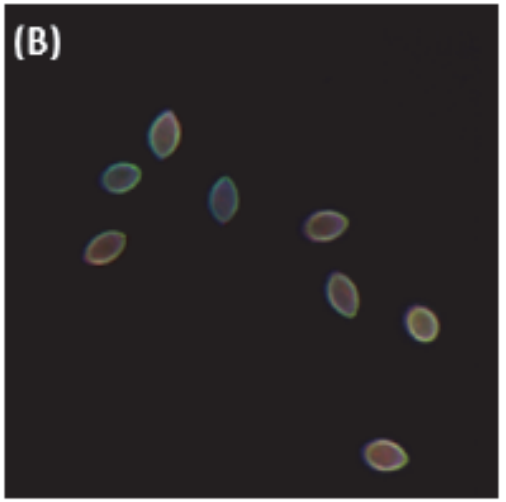


FBAP Bursts during Rain:

→ strong increase of FBAP & IN at -15°C at 2-6 µm (bacteria & fungal spores?)

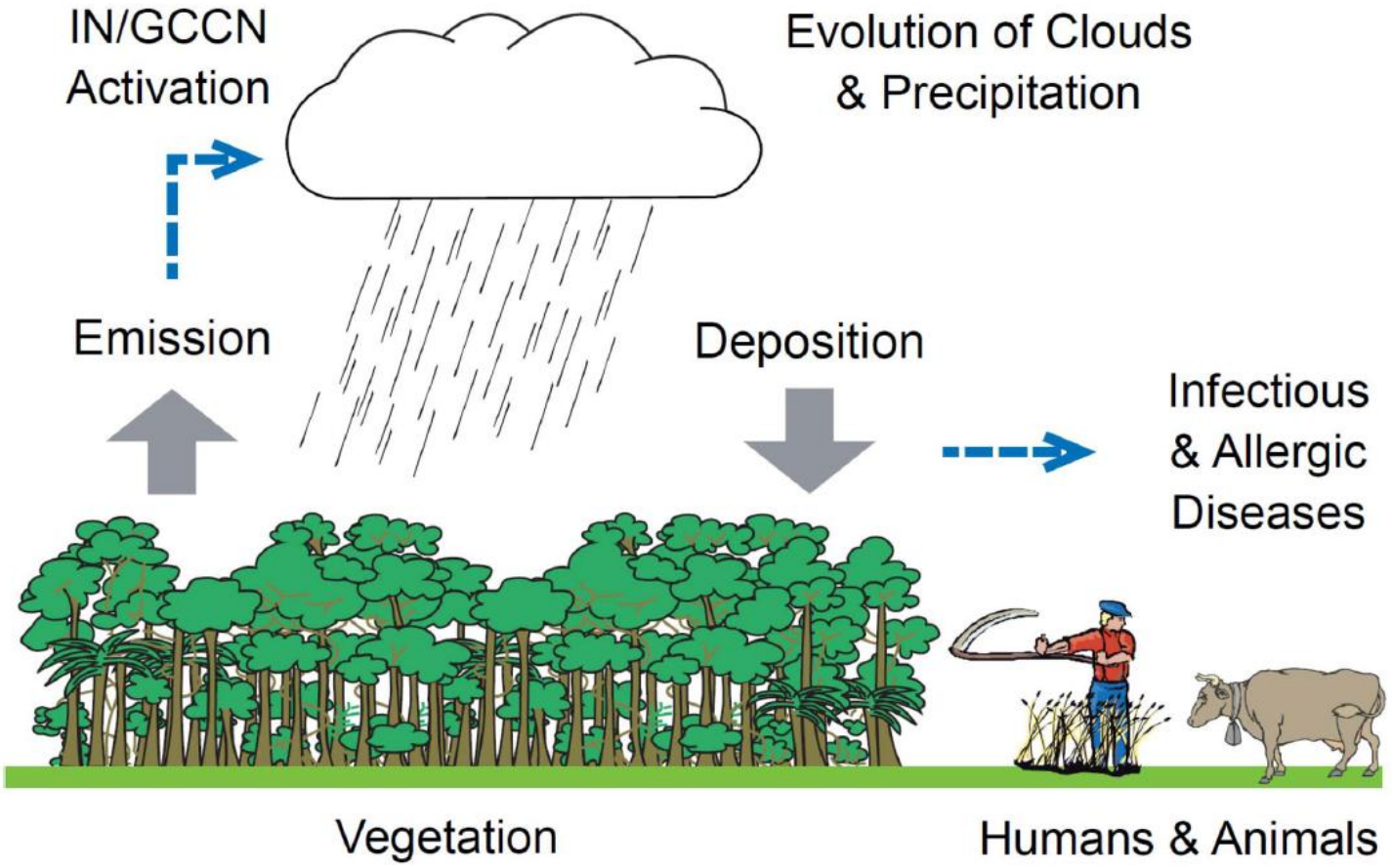
→ strong increase & correlation of FBAP & IN at -25°C

→ identification of new fungal IN (fluoresc.):



Huffman ACPD 2013

Bioprecipitation Cycle



Life is in the air and it does interact with precipitation.

Sands J Hung Met Serv 1982, Christner Science 2008, Pöschl Science 2010, Pöhlker Science 2012, Huffman ACPD 2013, Morris 2013

Outline

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- characteristic parameters & regimes
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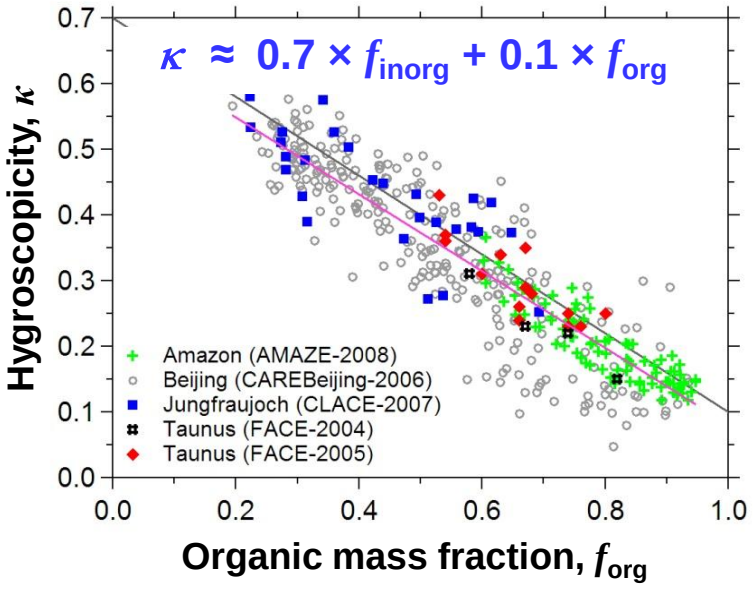
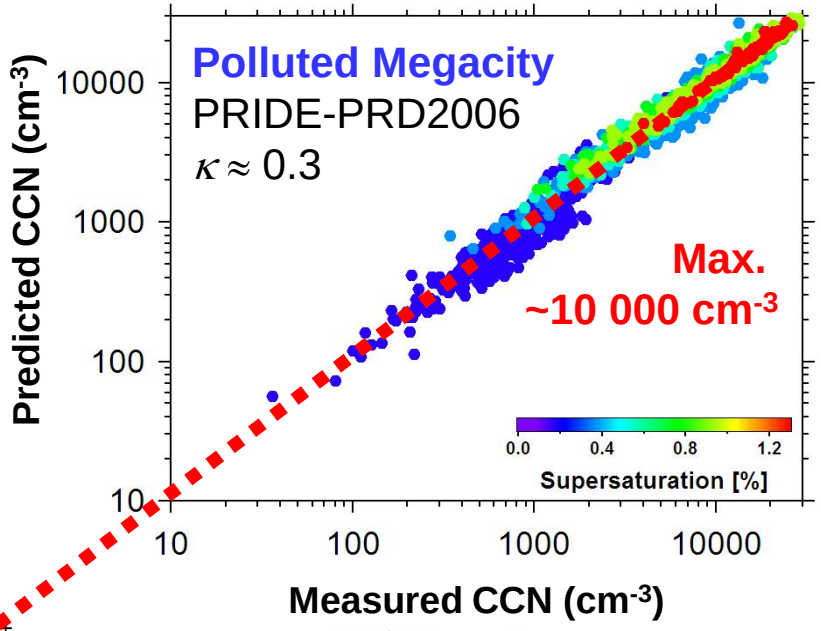
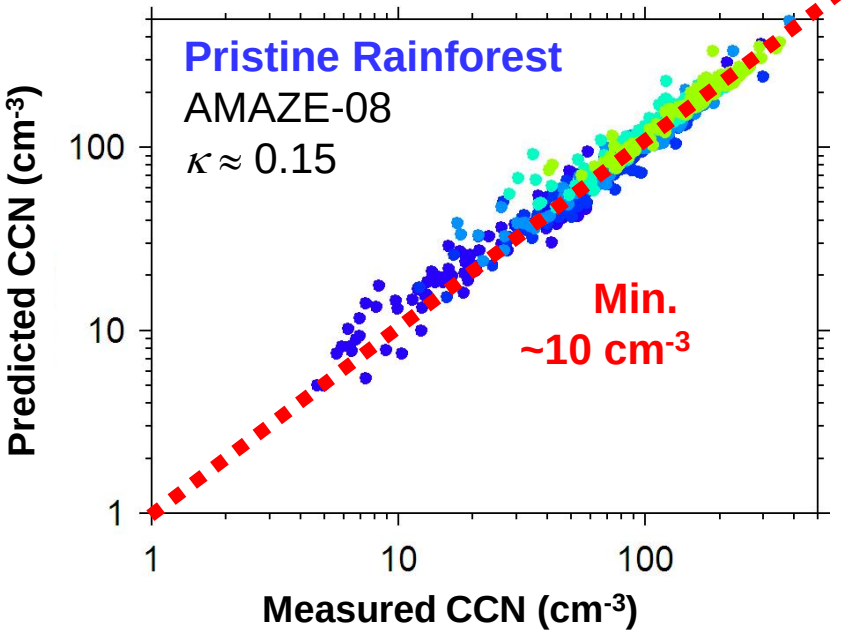
CCN Measurement & Prediction







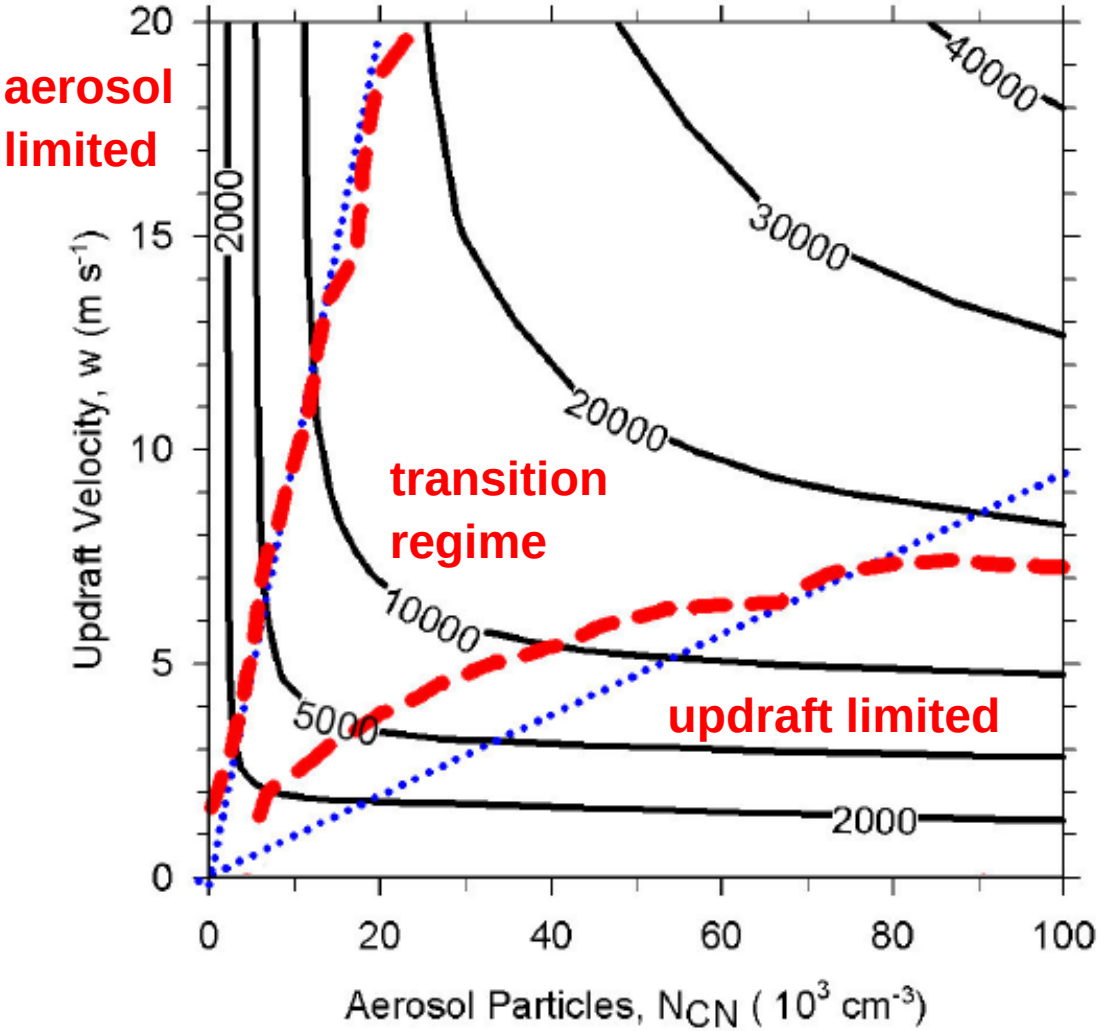
Simple κ-Köhler Model:
good agreement with κ_p from AMS & complementary data (TDMA)

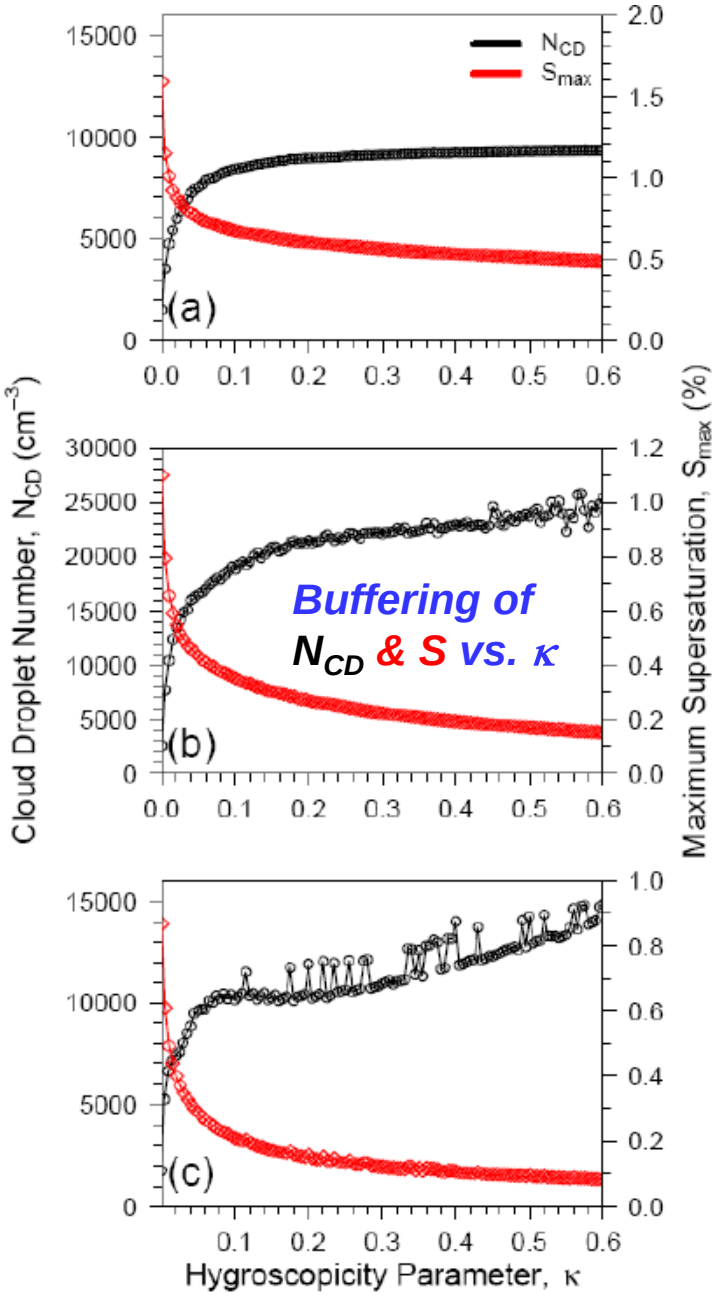
⇒ **aerosol parameters of CCN activation well constrained**

⇒ **meteorological parameters ?**

Gunthe ACP 2009, Rose ACP 2010, Pringle ACP 2010, Su ACP 2010

Prediction & Regimes of CCN Activation





Cloud Droplet Number N_{CD} = f(N_{CN}, w)

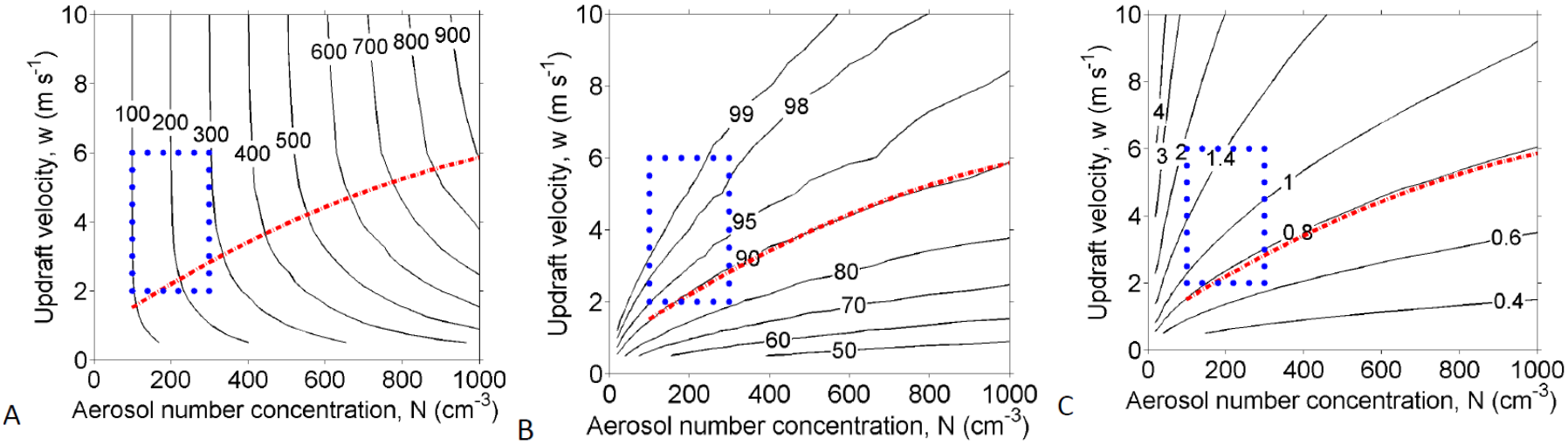
sensitive to κ (chem. composition) only at

κ < 0.1 and/or $S \leq 0.1\%$

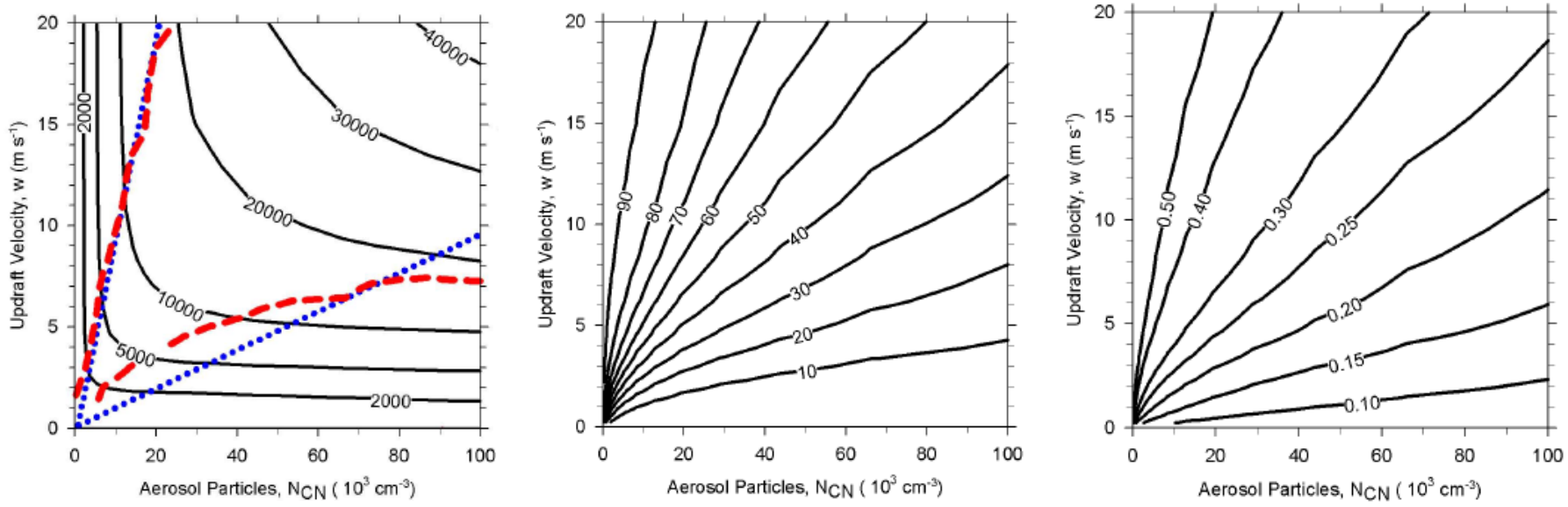
Reutter ACP 2009

Cloud Droplet Number (N_{CD}) **Activated Fraction (N_{CD}/N_{CN})** **Peak Supersaturation (S_{peak})**

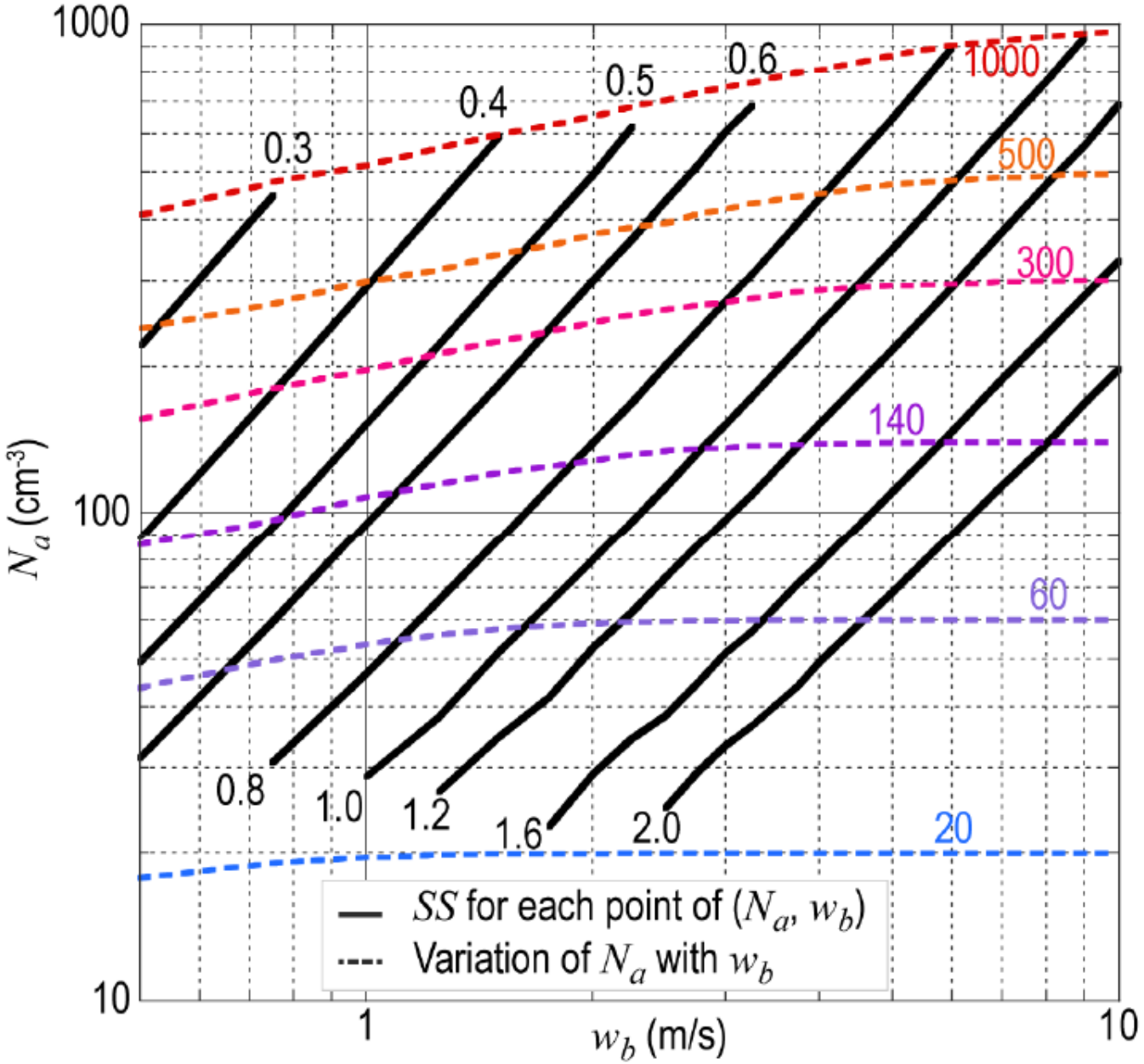
Pristine: < 1000 cm-3, pristine aereosol SD, $\kappa = 0.15$**,** Pöschl et al. Science 2010



Polluted: up to 100,000 cm-3, biomass burning aerosol SD, $\kappa = 0.3$**,** Reutter et al., ACP 2009



Aerosol - Cloud Droplet Closure



Chemistry & Microphysics

↕

Meteorology

N_{CN}
(SD, κ)

↓

w

↓

S/SS

↓

N_{CD}/N_a

ACRIDICON-CHUVA Perspectives

Biogenic Aerosols (PBAP & BSOA):

altitude profile of number, size & composition

- Filter samples & STXM analysis
- DMPS, AMS, SP2, ...
- CCN & IN activity
- FBAP (from FINCH)

Aerosol - Cloud Closure:

CDN/IPN vs. CCN/IN properties

- CCN vs CN vs. CDN (BSOA vs. others)?
- IN vs. CN vs. IPN (PBAP vs. others)?
- inference of S_peak
- Cloud Parcel, ATHAM, BRAMS, WRF-CHEM ...

- connections to ATTO science team ...

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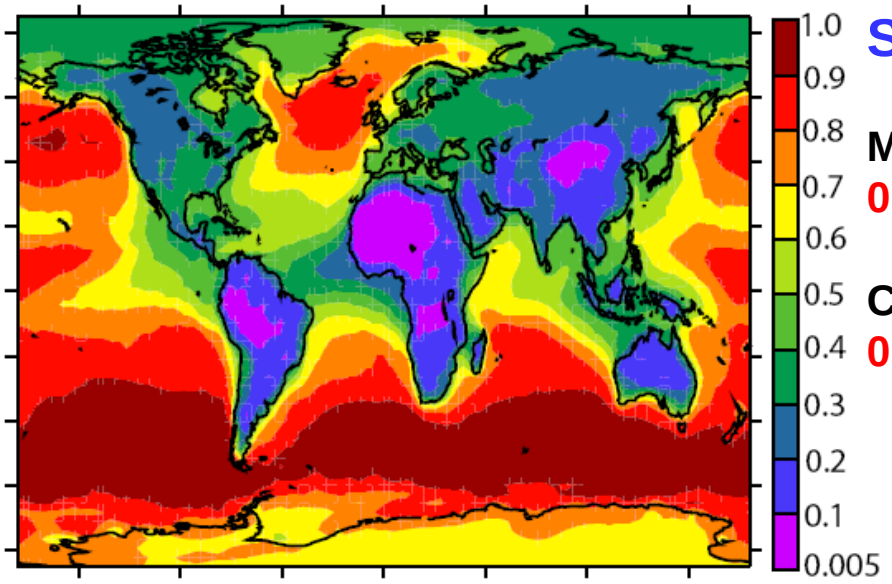
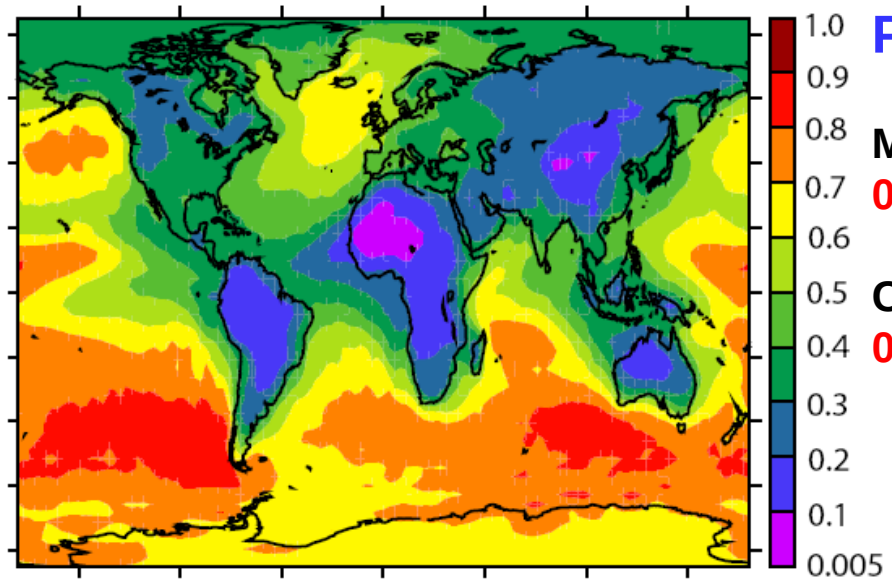
Global Distribution of Kappa



Surface

Marine
0.7 ± 0.2

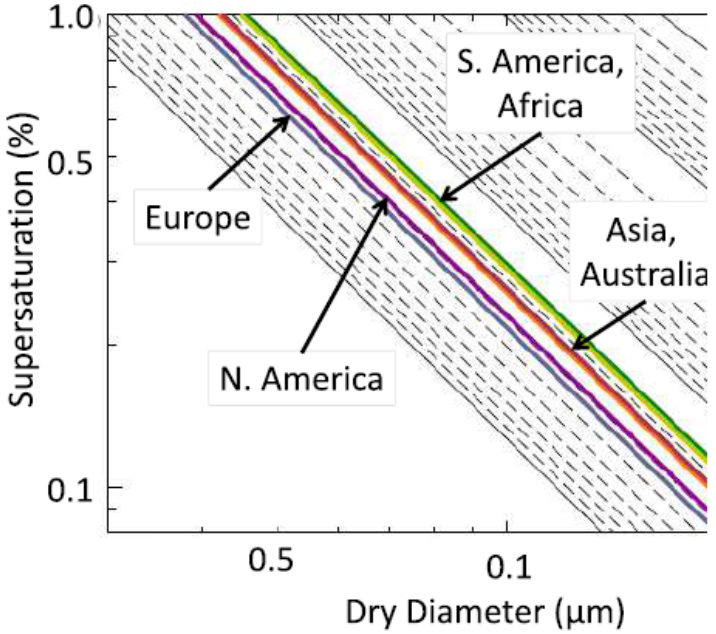
Continental
0.3 ± 0.2

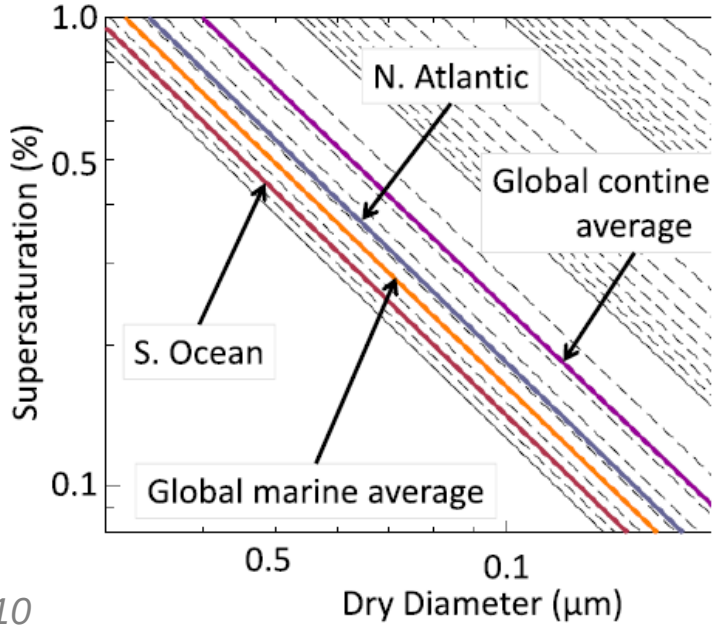


PBL Top

Marine
0.6 ± 0.2

Continental
0.3 ± 0.2



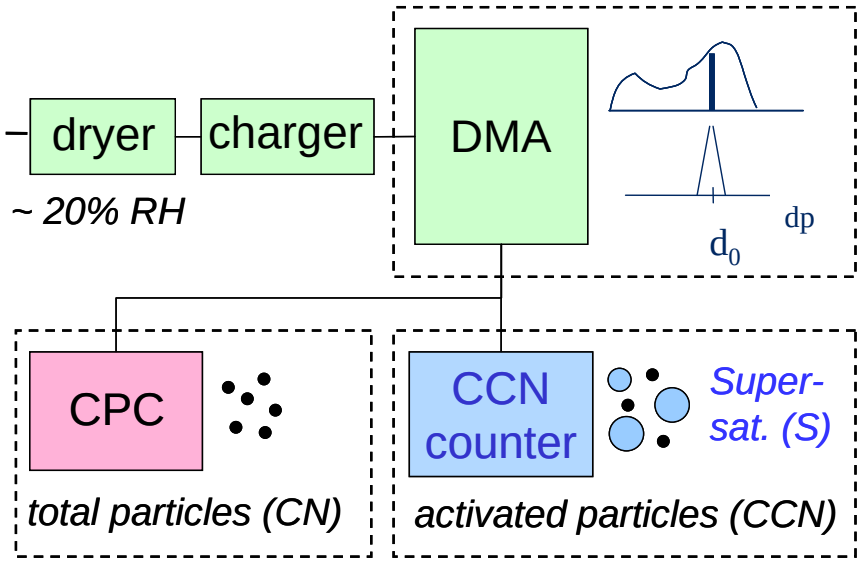


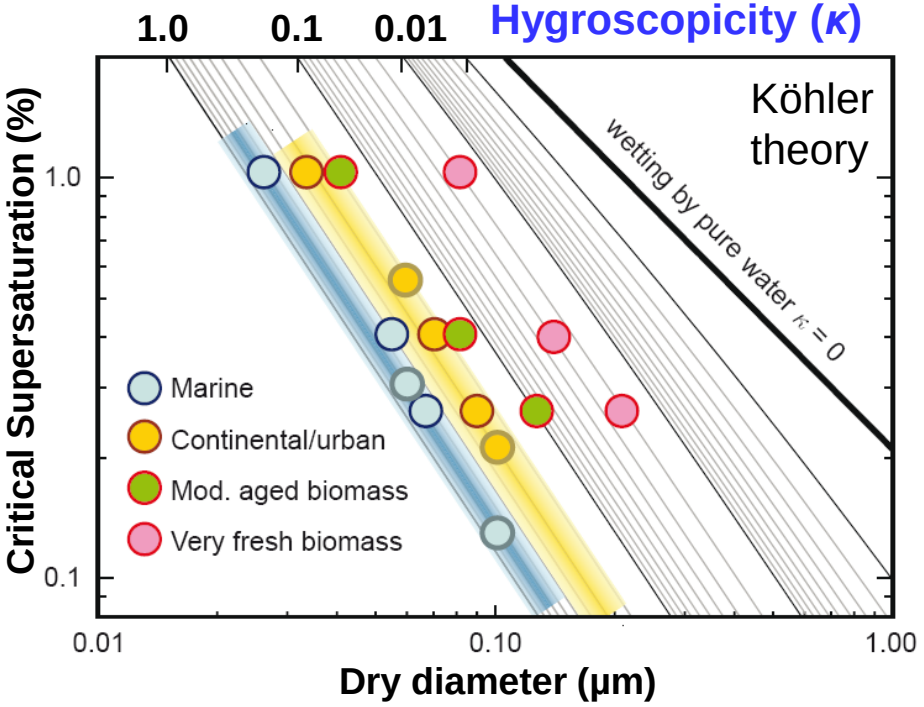
EMAC (T42, ~250 km)

Pringle ACP 2010

MPIC Cloud Condensation Nuclei (CCN)

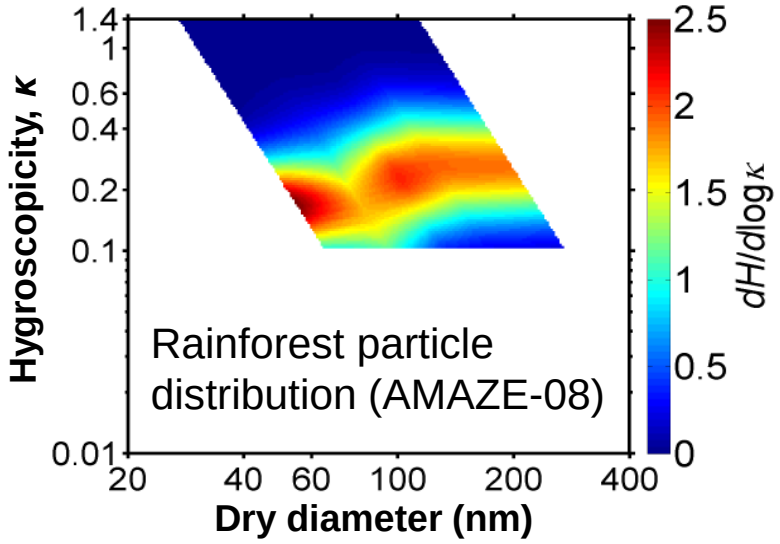
Size-resolved CCN measurements





Effective hygroscopicity parameter *κ* summarizes thermodynamic properties & relates particle diameter to supersaturation required for activation ($\kappa \approx$ 0-1)

Molecular interaction parameters & hygroscopicity distribution $h(\kappa, D_d)$: non-idealities & particle mixing state



Rose ACP 2008,2010,2011, Gunthe ACP 2009, Pöschl FIAS 2009, Su ACP 2010, Mikhailov 2011