Role of atmospheric aerosols in climate and human health: Indian perspective

Sachin S. Gunthe
Indian Institute of Technology Madras
Chennai, INDIA
s.gunthe@iitm.ac.in

Collaborators and Acknowledgements

M. O. Andreae, Ulrich Pöschl, D. Rose, H. Su, C. Pöhlker, and team
Max Planck Institute for Chemistry Mainz

J. A. Huffman, University of Denver, CO, USA

S. Suman, Harish Gadhavi, N. Dashora, A. Jayaraman……**NARL Gadanki**

S. T. Martin…… **Harvard University**

S. M. Shiva Nagendra and R. Ravikrishna……**IIT Madras, Chennai**

E. Mikhailov…… **University of St. Petersburg**

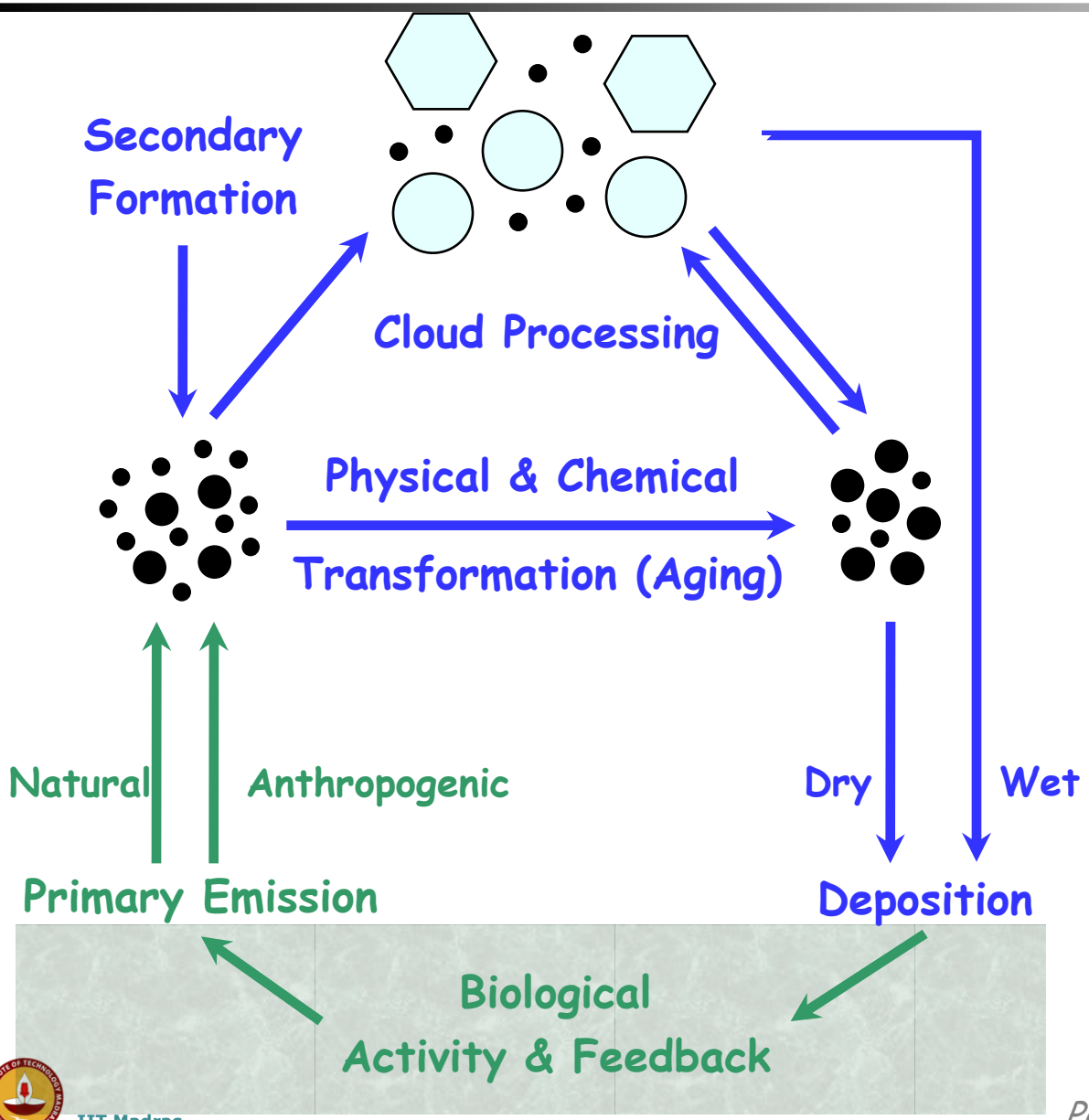
C. Venkataraman…… **IIT Bombay, Mumbai**

D. Rosenfeld …… **Hebrew University, Israel**

Outline

- Introduction
  - → Motivation and background
- Past measurement results (contrasting environments)
  - → Amazon
  - → Chinese megacity
- Aerosol and Rainfall over India
- Aerosol field measurements
- Bioaerosols
  - → Fluorescence detection; fungal spore and bacteria
  - → DNA analysis
- Summary and outlook

Aerosol Cycling and Effects



Atmosphere & Climate

- radiation & dynamics
- precipitation
- trace gases

Mechanistic understanding, quantitative prediction & human influence ?

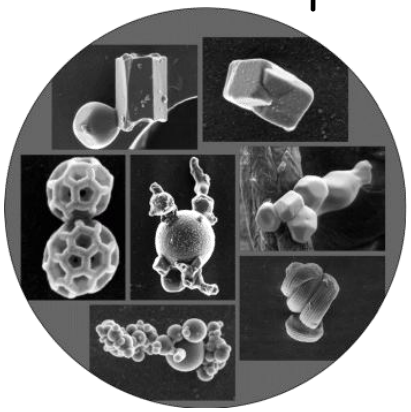
- human, animal & plant diseases
- spread of organisms

Biosphere & Human Health

Pöschl Angew Chem 2005

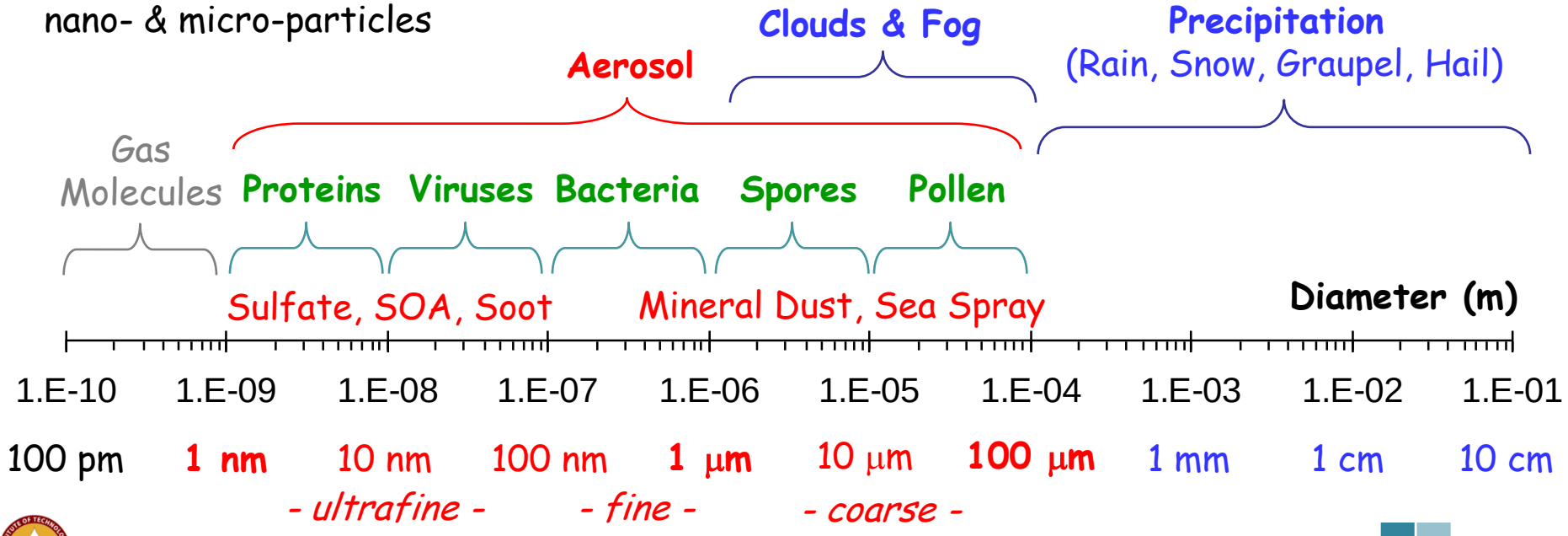
Atmospheric Particle Size

Aerosol – a dispersion of solid and liquid particles suspended in gas (atmosphere)



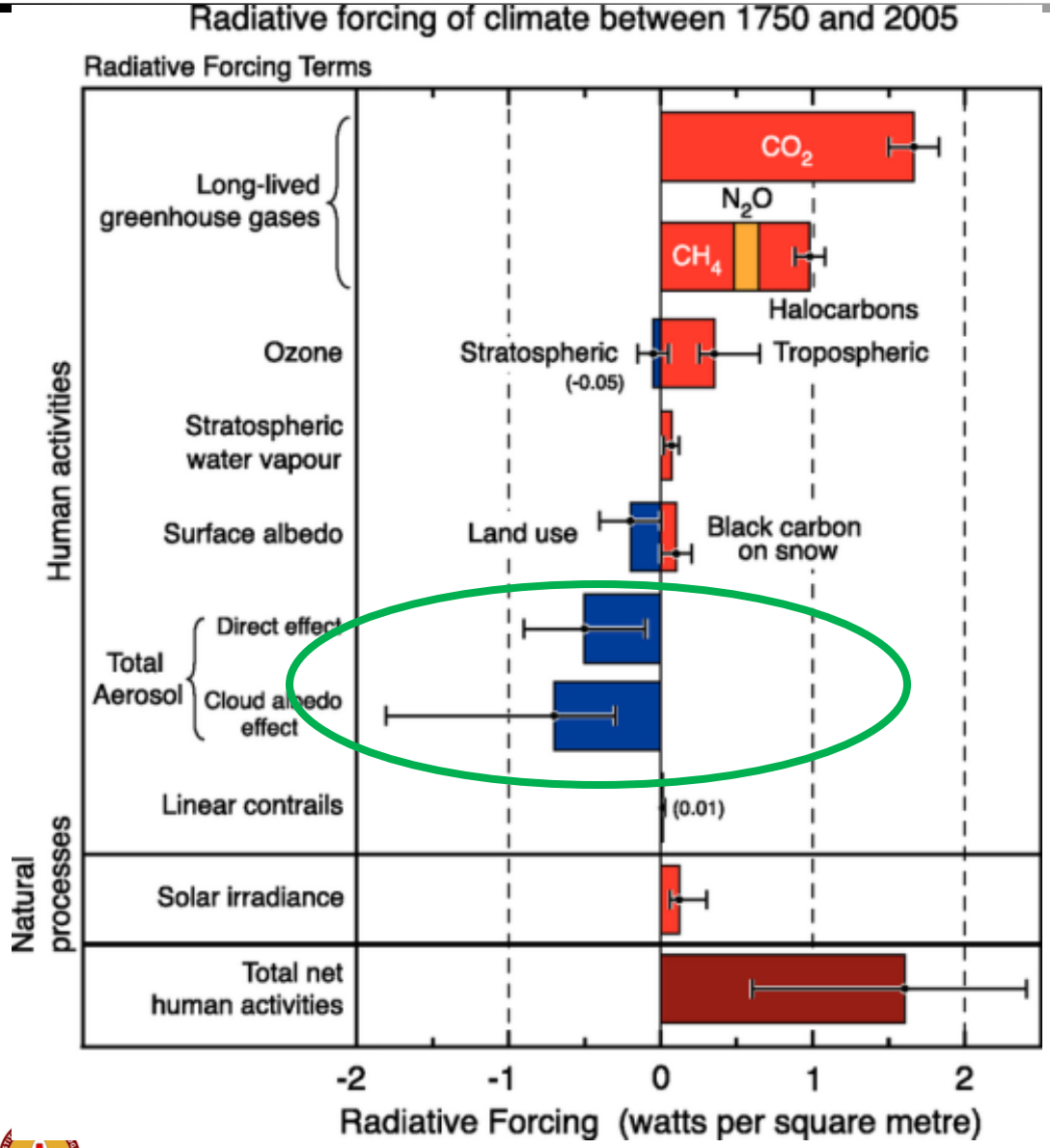
Aerosols: solid & liquid nano- & micro-particles

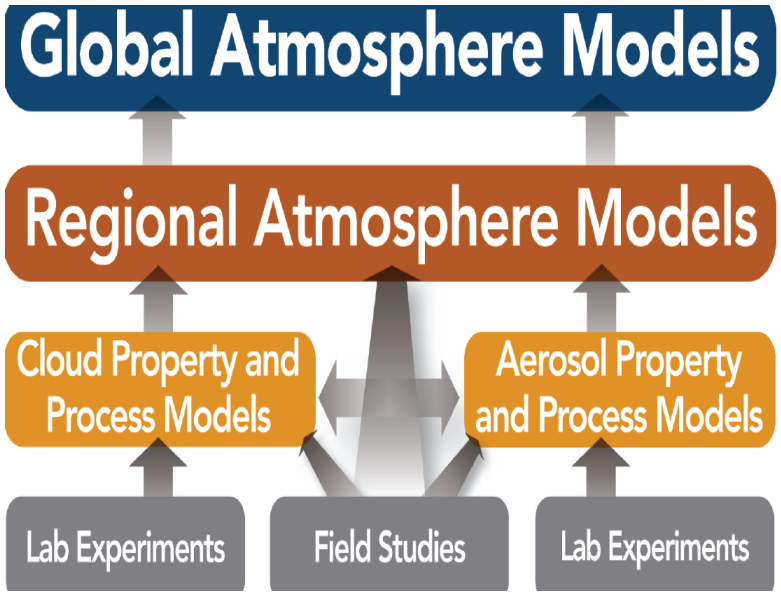
Clouds, Fog & Precipitation: dilute aqueous particles



Pöschl, personal communication

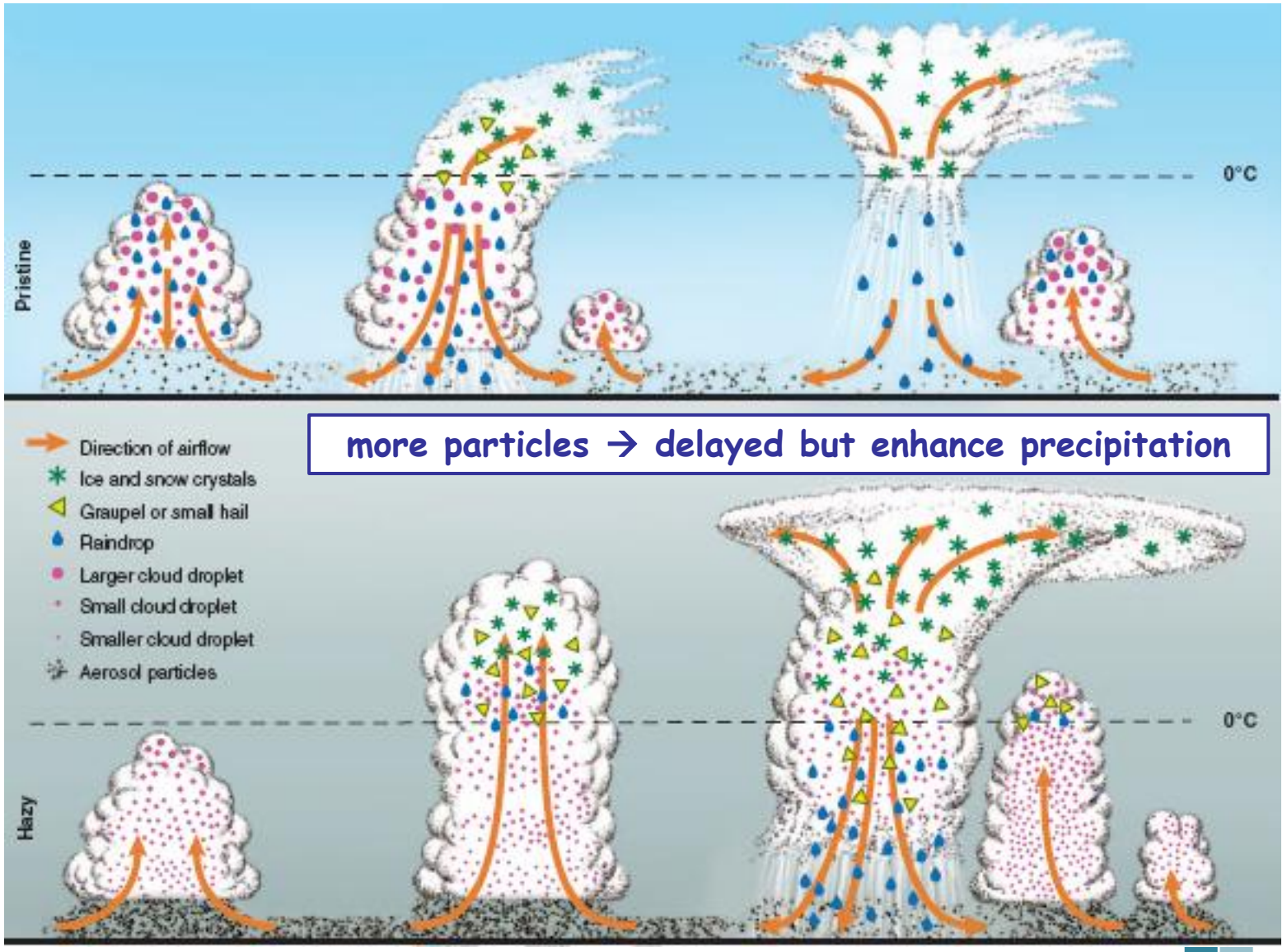
Radiative Forcing of Climate Change





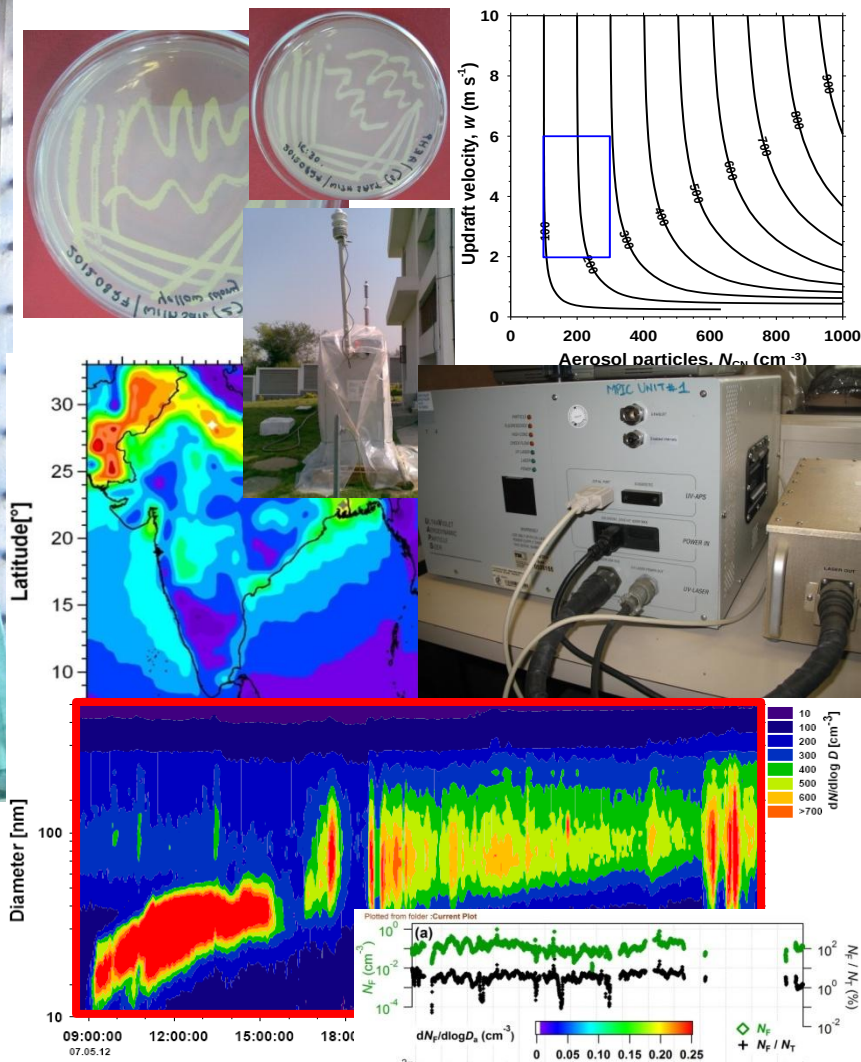
→ Robust spatial and temporal data to validate and improve models

Water cycle and severe weather



Rosenfeld et al. 2008

Research approach and team



Shika S., Hema P., T. Ansari, Aswathy E.

Planned - Multidisciplinary approach

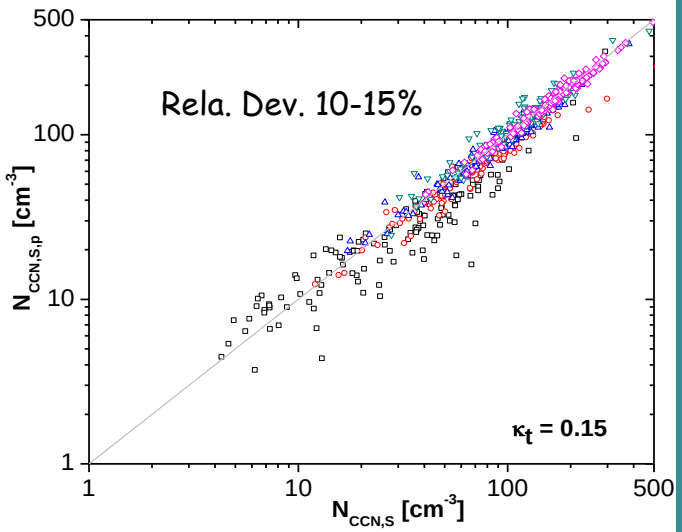
Laboratory, field, remote sensing, and model studies using chemical, physical, and biological techniques

Outline

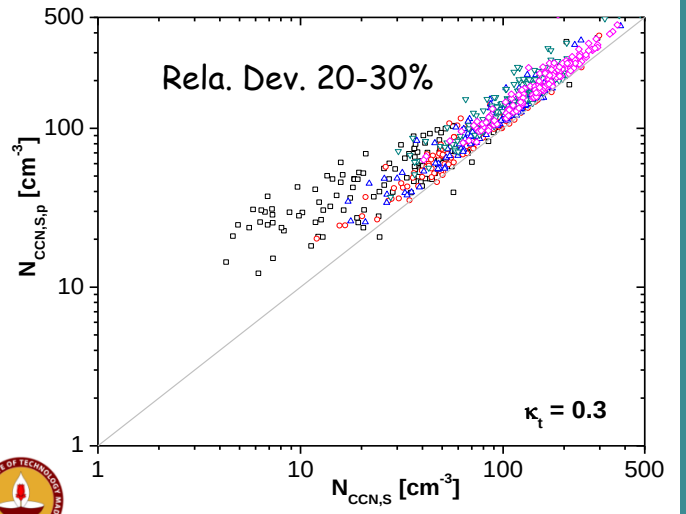
- Introduction
  - → Motivation and background
- Past measurement results (contrasting environments)
  - → Amazon
  - → Chinese megacity
- Aerosol and Rainfall over India
- Aerosol field measurements
- Bioaerosols
  - → Fluorescence detection; fungal spore and bacteria
  - → DNA analysis
- Summary and outlook

Prediction of CCN number concentration (Amazon vs. Chinese megacity)

Average campaign κ

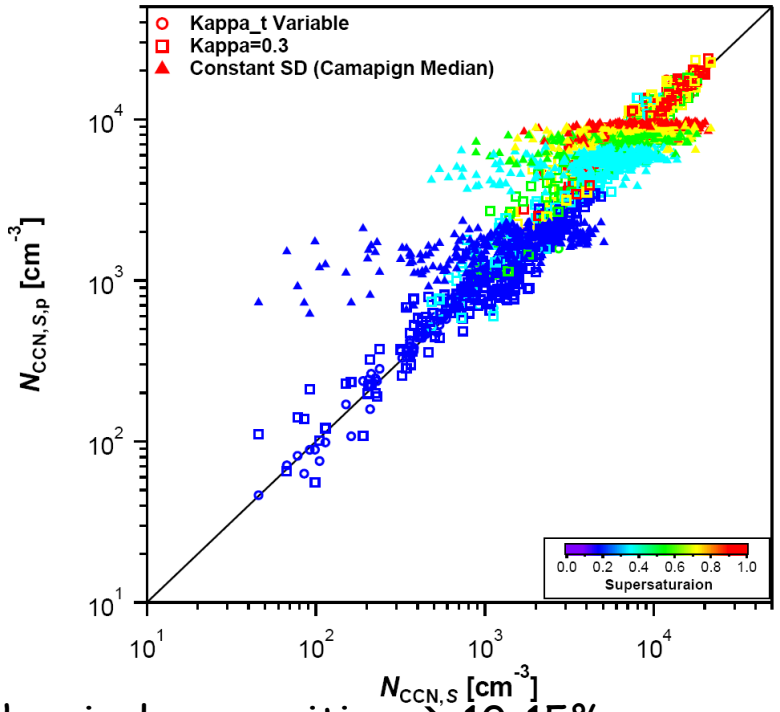


Average campaign κ from chemical composition



Amazon rainforest (Pristine)

Chinese megacity



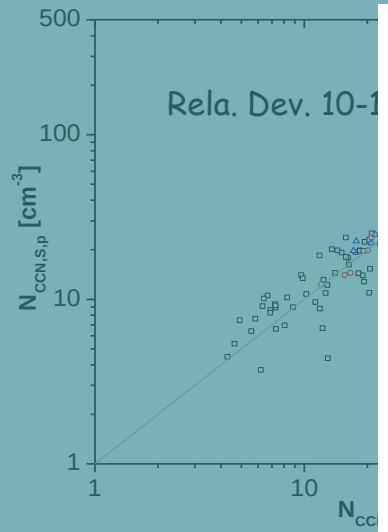
- Average chemical composition → 10-15%
- AMS derived κ → 15-20%
- Global average for Amazon (κ=0.3) → 40%

- Average size distribution → 60%

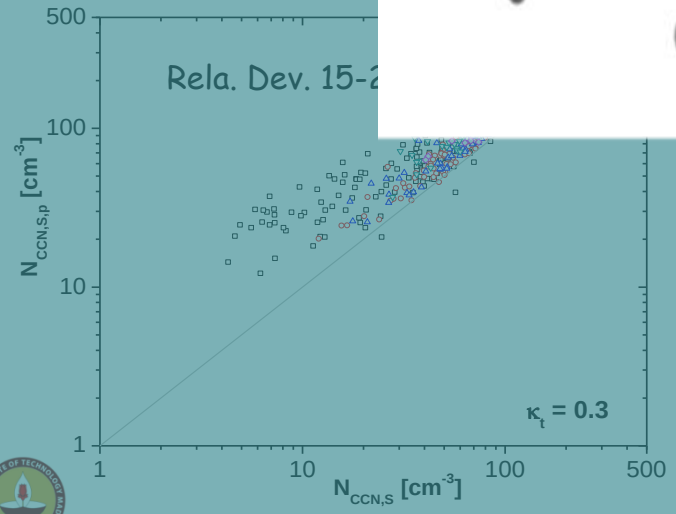
Precise chemical composition and size distribution

Prediction of CCN number concentration (Amazon vs. Chinese megacity)

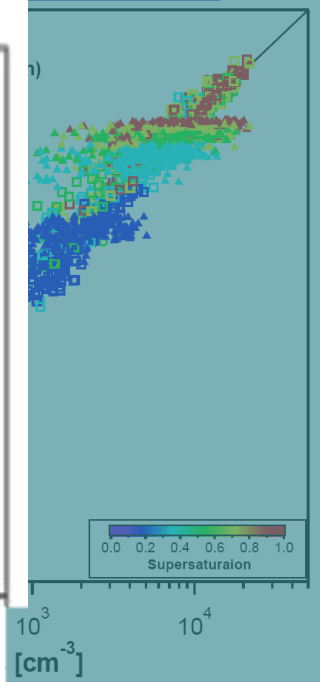
Average campaign κ



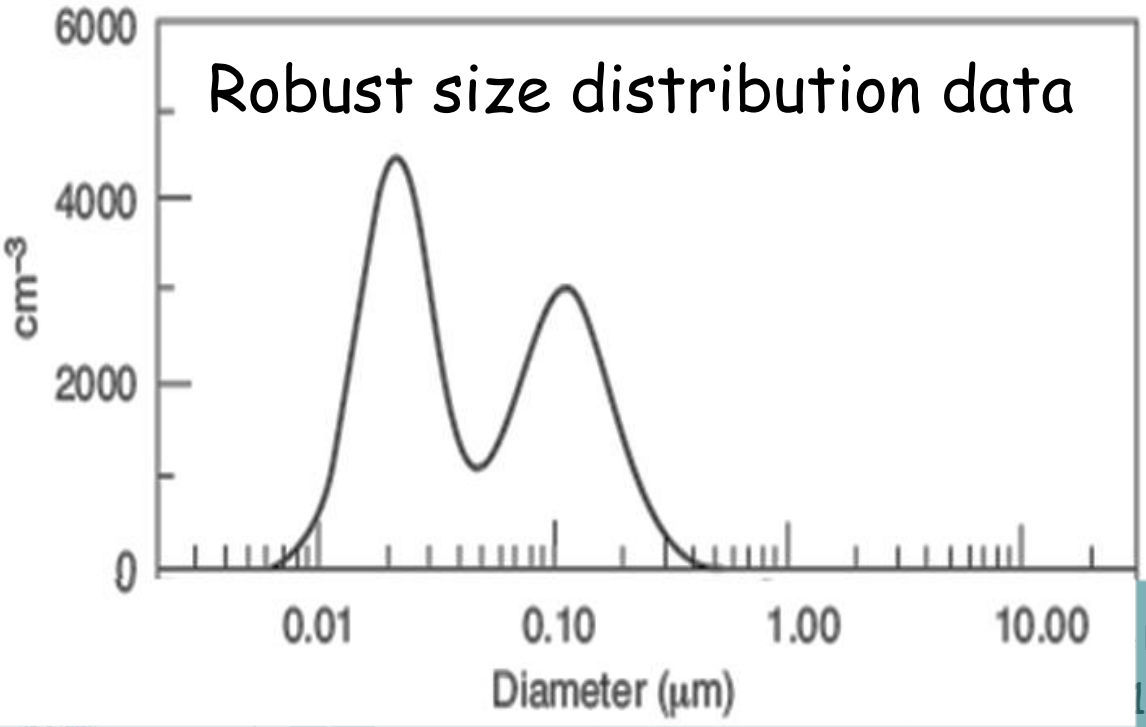
Average campaign κ
composi



Chinese megacity



Robust size distribution data



10-15%

- AMS derived κ → 15-20%
- Global average for Amazon (κ=0.3) → 40%

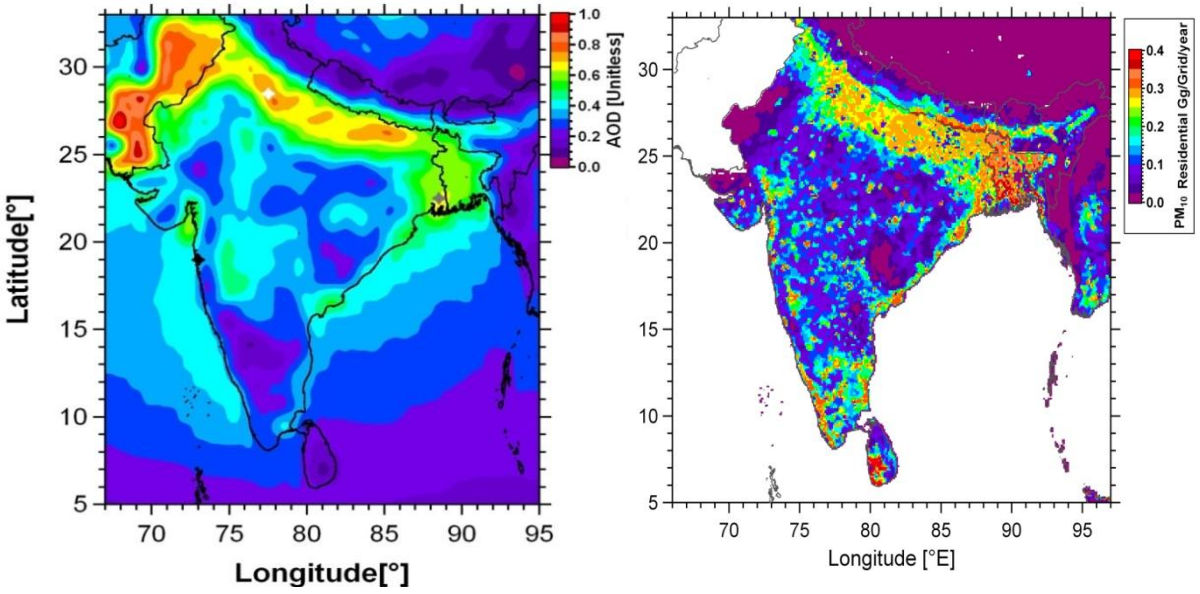
- Average size distribution → 60%

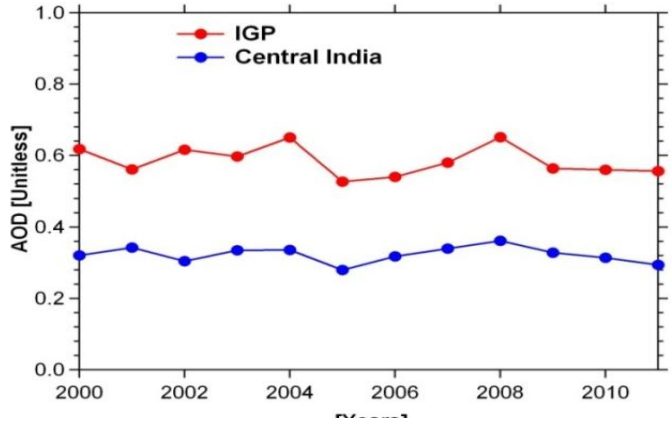
Precise chemical composition and accurate size distribution

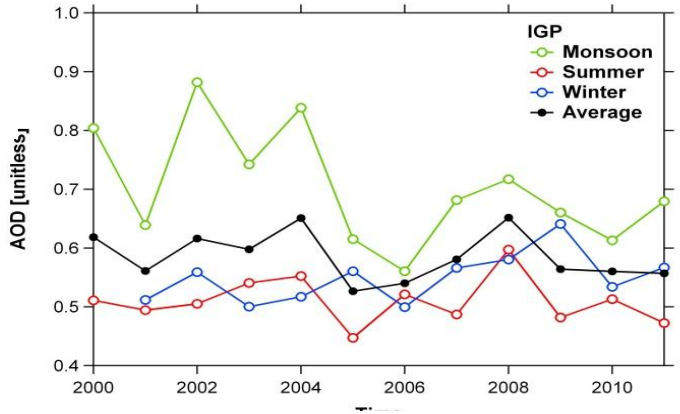
Outline

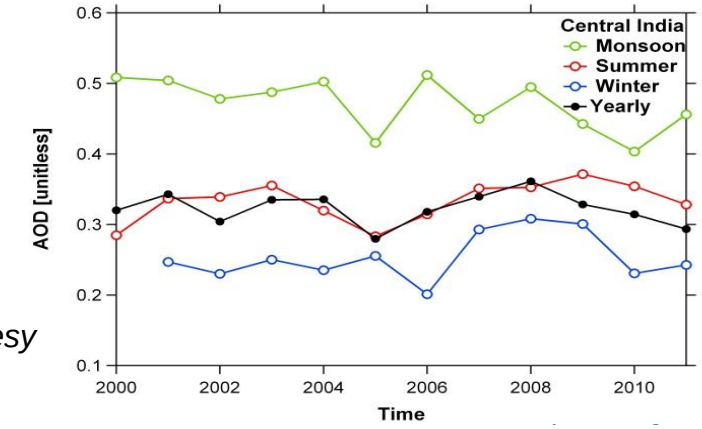
- Introduction
  - → Motivation and background
- Past measurement results (contrasting environments)
  - → Amazon
  - → Chinese megacity
- **Aerosol and Rainfall over India**
- Aerosol field measurements
- Bioaerosols
  - → Fluorescence detection; fungal spore and bacteria
  - → DNA analysis
- Summary and outlook

(Aerosol) Pollution scenario over India





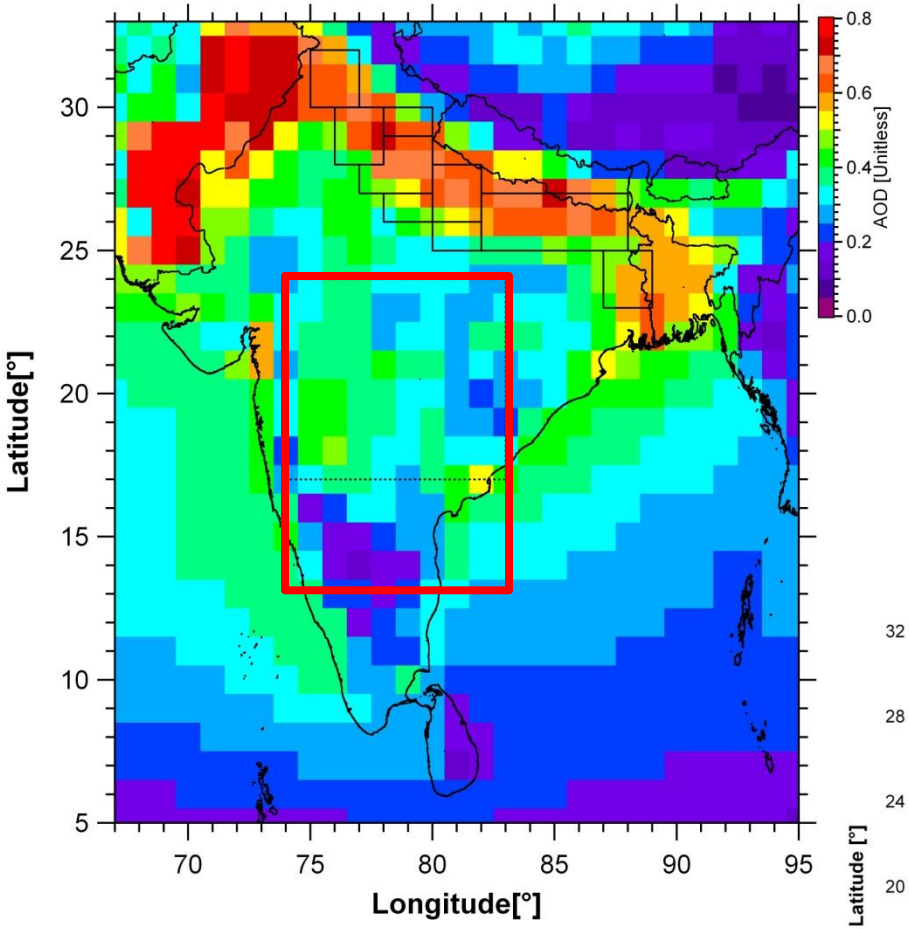




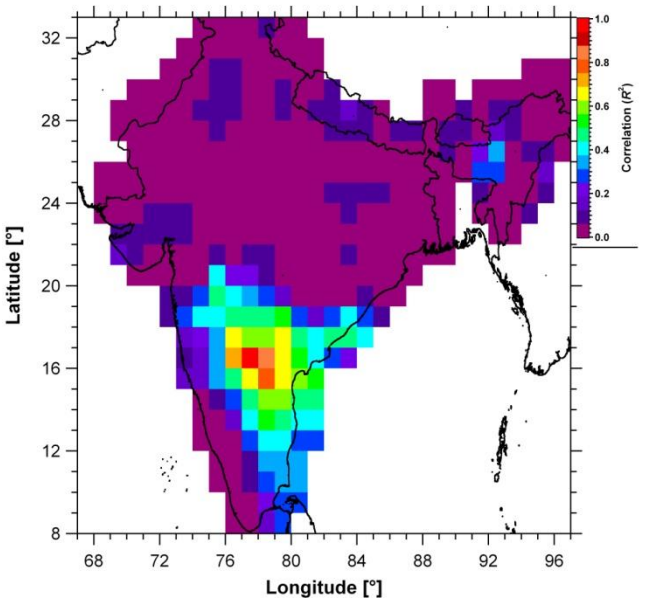
- Strong emissions sources over IGP and southern coastal India
- IGP Consistent with high concentration
- Lower concentration in southern India
- Role of meteorology and topography

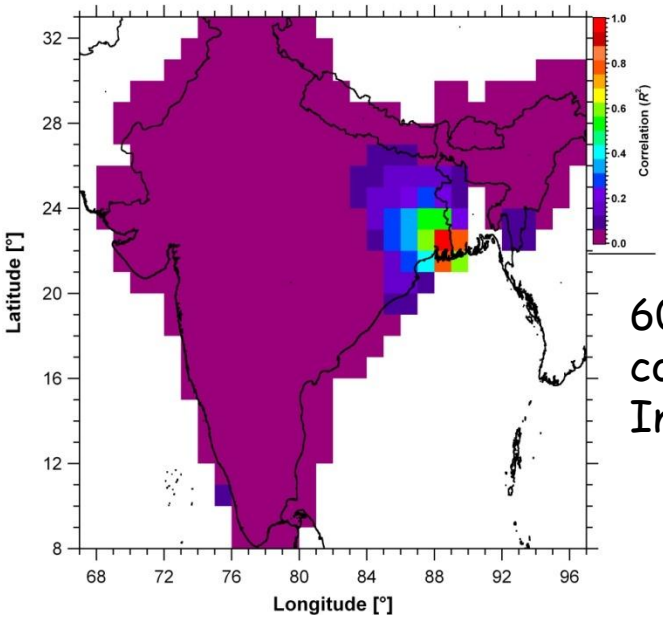
Gunthe et al., to be submitted, 2013; SEAC4RS emission courtesy Yafang Cheng, Z. Lu, D. Street, Qiang Zhang, Greg C.

Rainfall patterns in high and low ADO regions



Modis AOD 555 nm (2000-11)



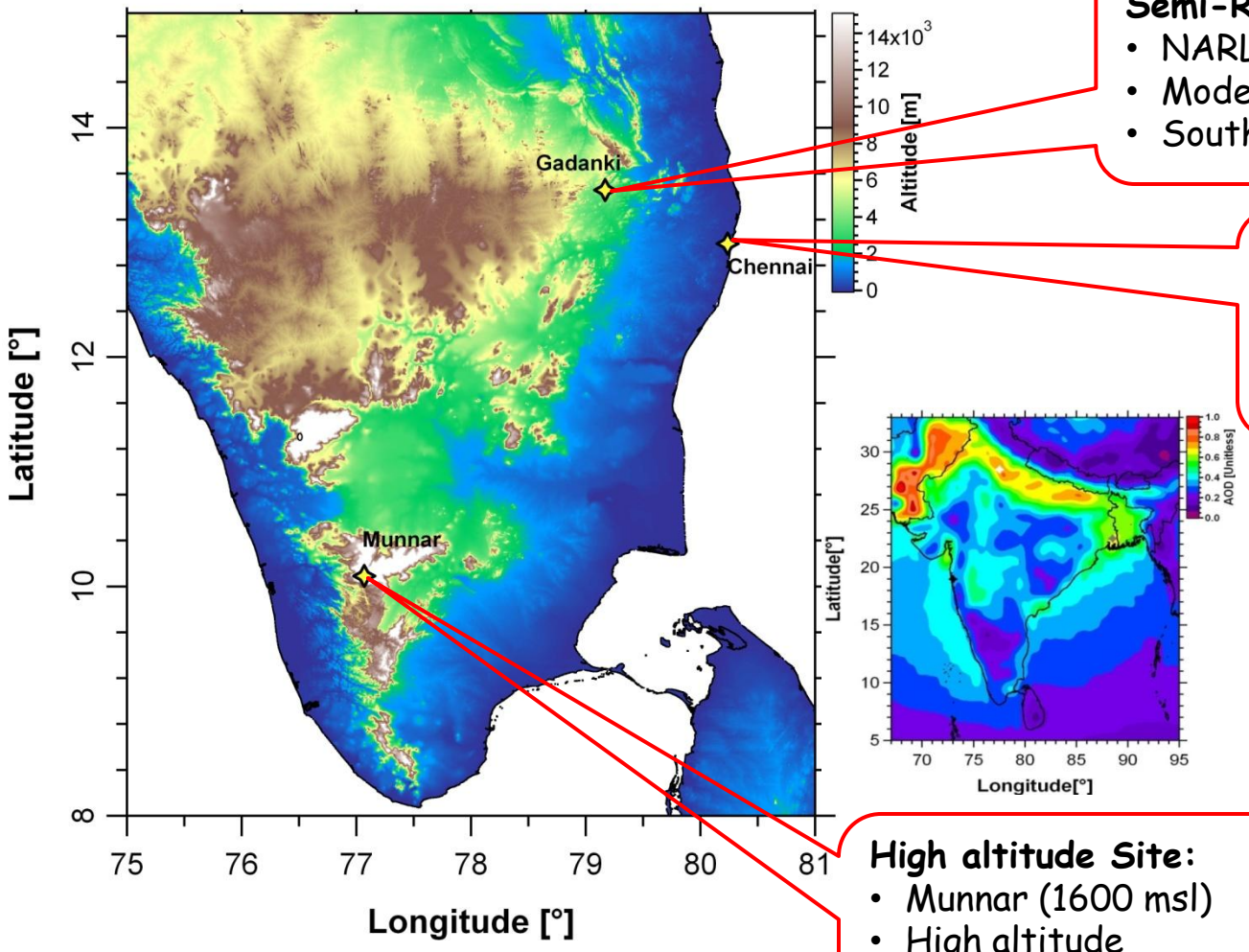


60 years spatial correlation; Central India and Kolkata

Outline

- Introduction
  - → Motivation and background
- Past measurement results (contrasting environments)
  - → Amazon
  - → Chinese megacity
- Aerosol and Rainfall over India
- Aerosol field measurements
- Bioaerosols
  - → Fluorescence detection; fungal spore and bacteria
  - → DNA analysis
- Summary and outlook

Sites in South India-I phase of measurements



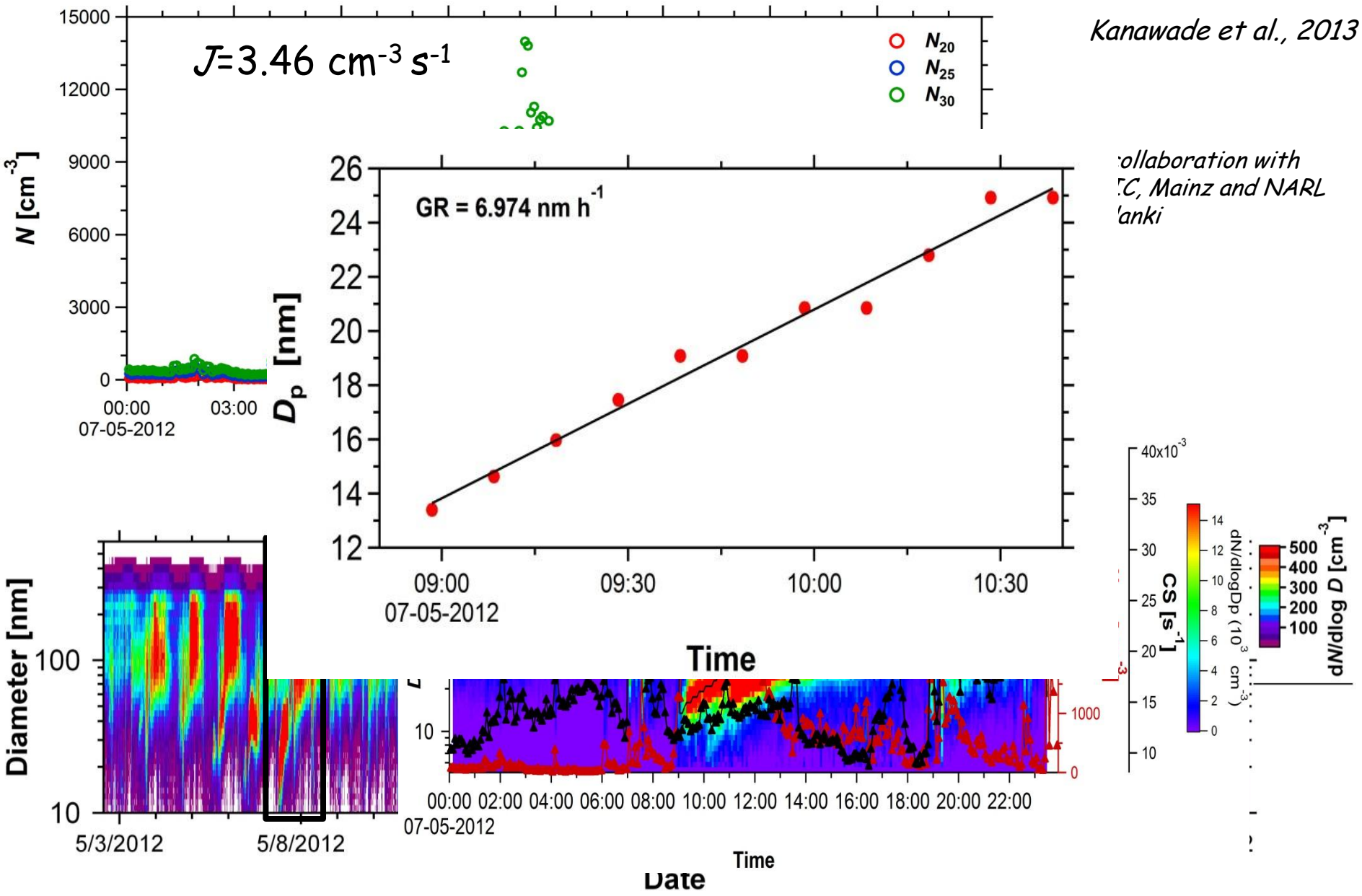
Semi-Rural Continental Site:
- NARL, Gadanki
- Moderate altitude and rural
- South-west monsoon (and north east)

Urban Site:
- IIT Madras, Chennai
- Coastal (marine)
- North-east monsoon

High altitude Site:
- Munnar (1600 msl)
- High altitude
- Relatively pristine
- South-west monsoon

Shika S. et al., 2013

Preliminary NPF results from NARL, Gadanki

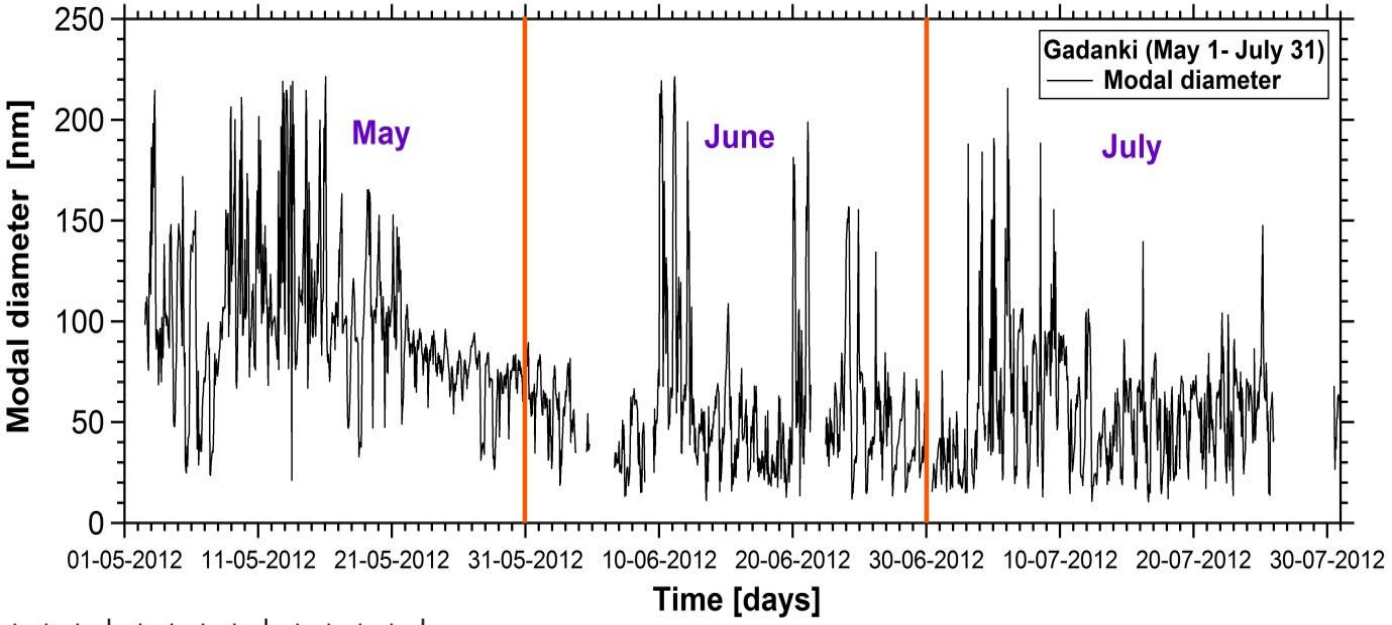


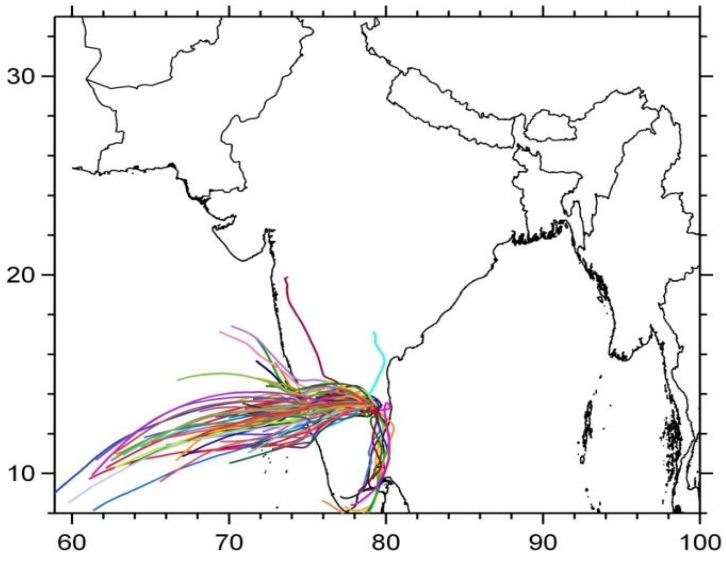
Kanawade et al., 2013

collaboration with TC, Mainz and NARL Gadanki

Gadanki measurements

Appears to be strong wind (season) dependent

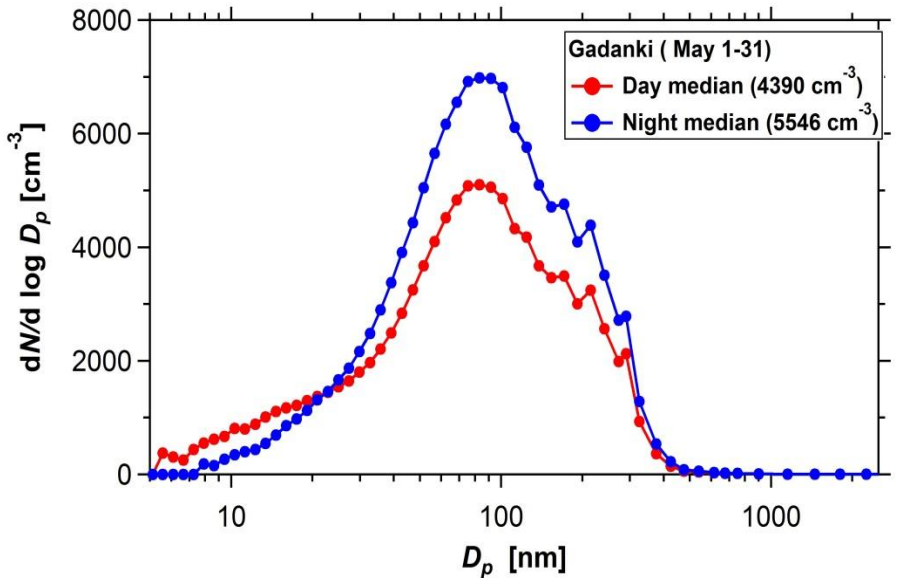


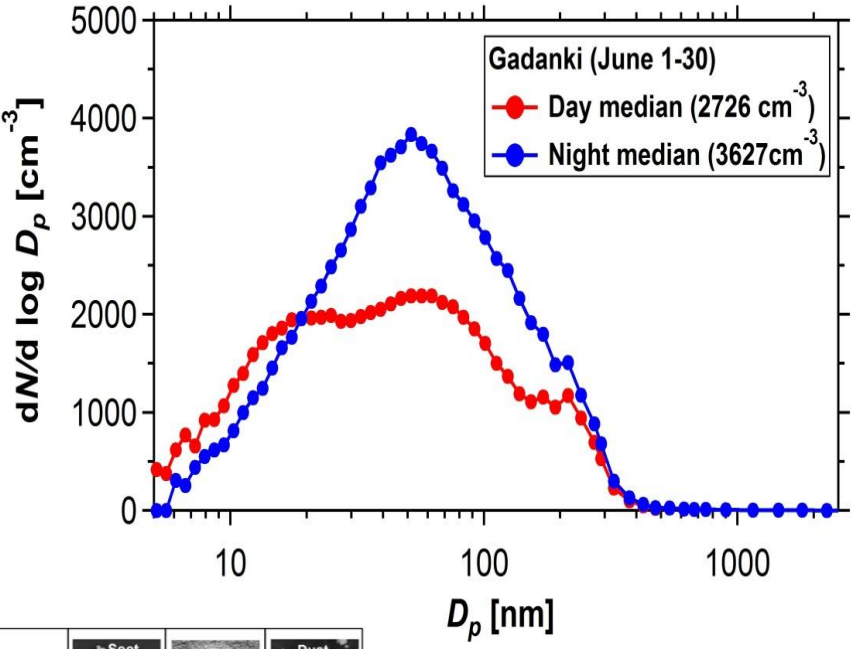


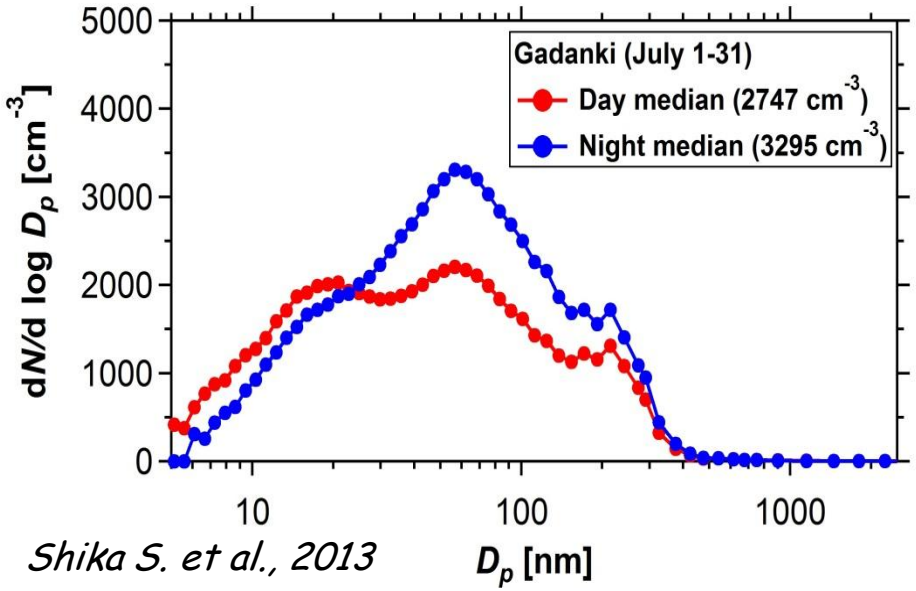
Preliminary clustering of wind direction analysis for Gadanki

Shika S. et al., 2013

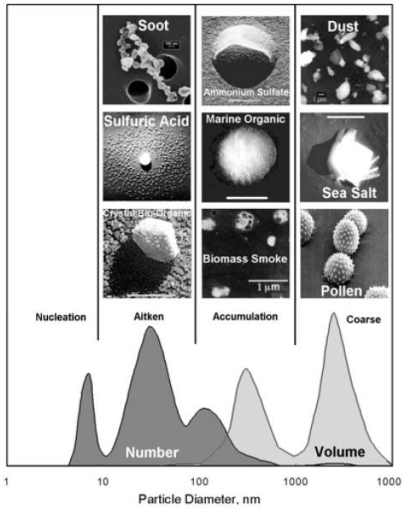
Size distribution; useful for identifying cloud formation regimes







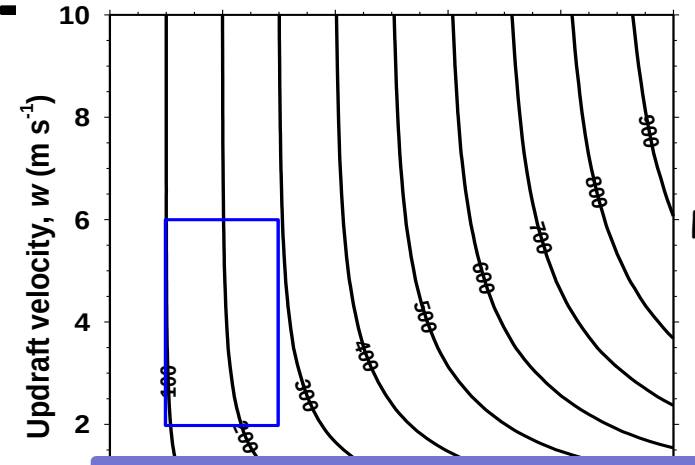
Shika S. et al., 2013



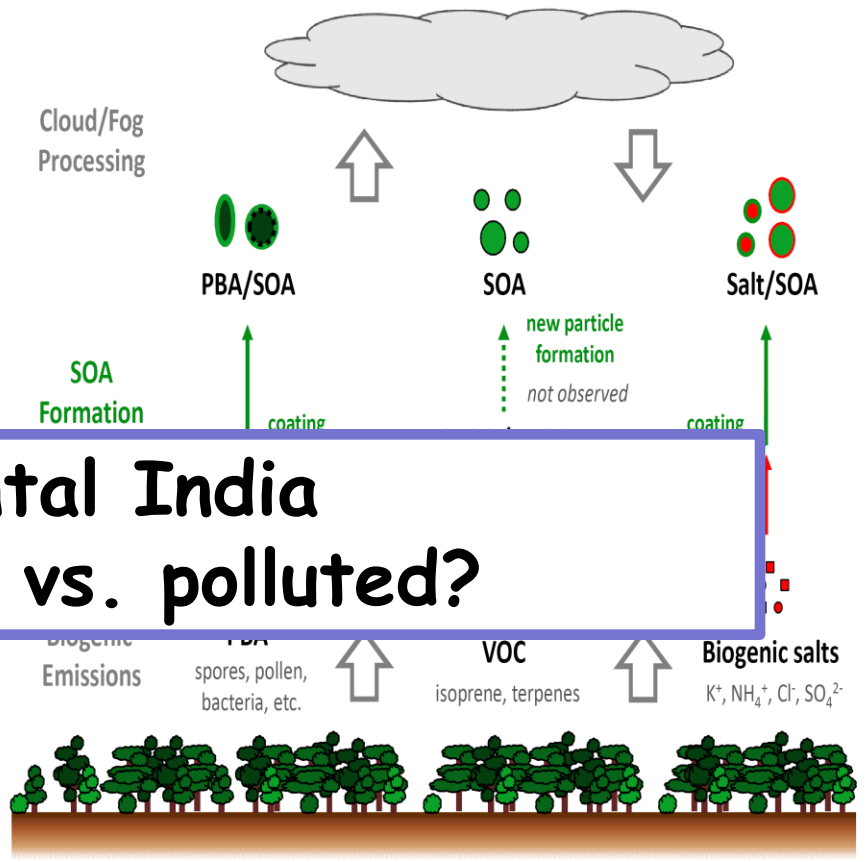
Brasseur et al., 2003

SEM analysis for morphological studies

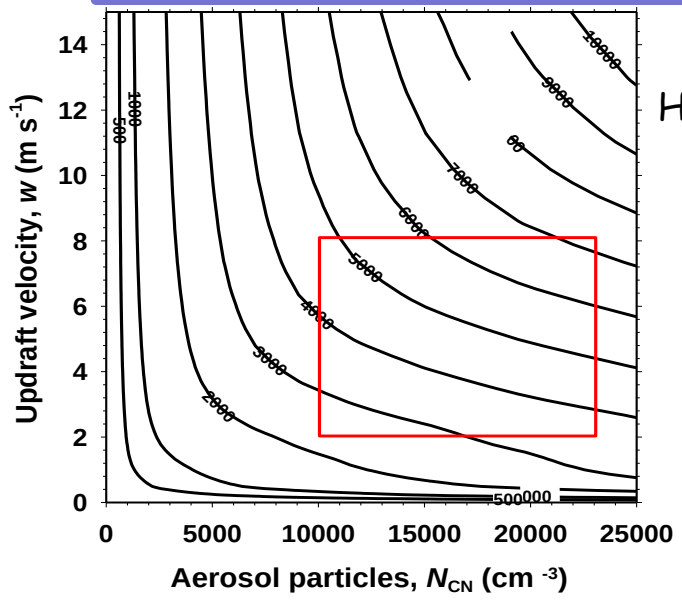
Identification of Cloud Formation Regimes using Cloud Parcel Modeling; Requires Size Distribution



Pristine (Amazon)



Over continental India
Relatively pristine vs. polluted?



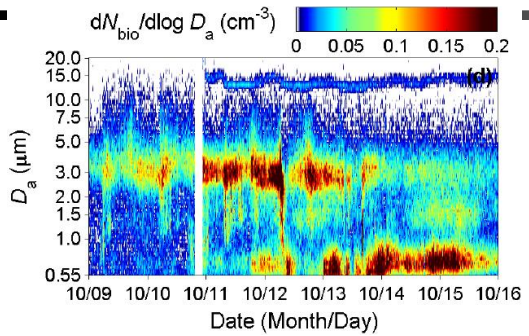
Highly polluted (Beijing)

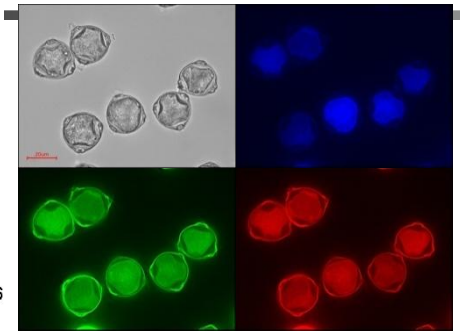
Number of aerosols may play an important role in deciding the cloud formation regimes under different ecosystem

Pöschl,….Gunthe., et al., Science, 2010; Gunthe et al., Atmos Chem Phys, 2011, 2012; Pohlker…Gunthe., et al., Science, 2012

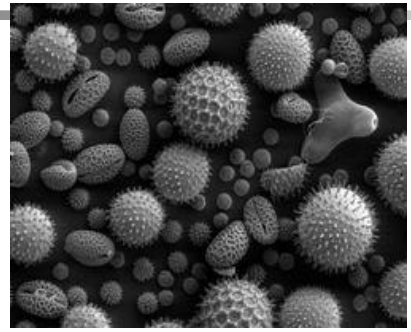
EWRE Division
Civil Engineering

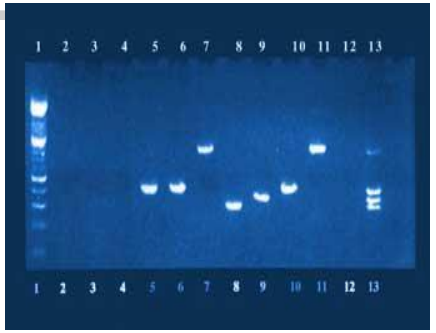
Bioaerosols





Fluorescence Detection,
Microscopy & Spectroscopy





Bioparticle Sampling,
DNA & Protein Analysis

High abundance & diversity of bacteria, fungal spores & pollen:

~1 μg m^{-3}, ~10^4 m^{-3}, ~1-100 μm, >10^4 species

IN & GCCN: certain bacteria & fungal spores...

DNA: ~10 ng m^{-3} DNA , ~100 ng m^{-3} protein (urban PM2.5)

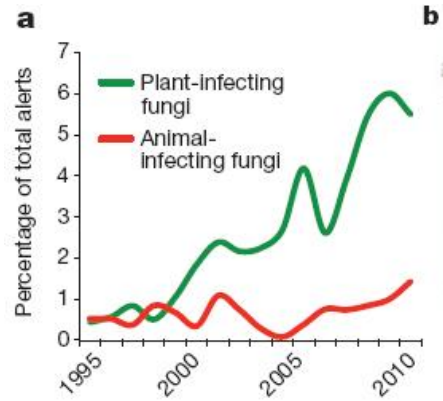
$\Rightarrow$ inhalation of ~1 μg/day $\equiv$ ~10^8 bacterial genomes/day

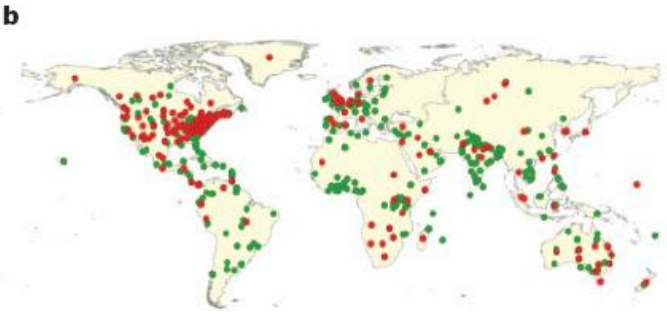
Pathogenic species: permanent challenge for immune system

$\Rightarrow$ infectious & allergic diseases

Despres BG 2007, Fröhlich-Nowoisky PNAS 2009, Huffman ACP 2010, Pöhlker 2011

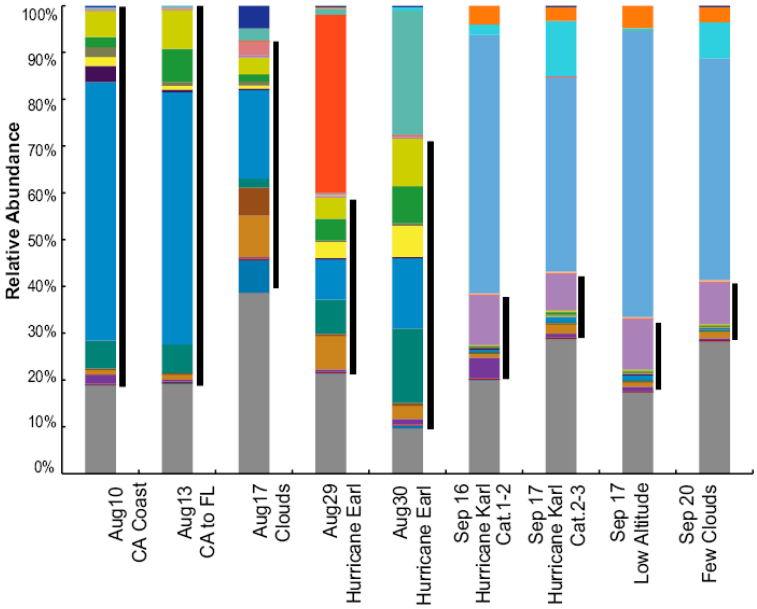
Health impacts; plants and animal (including humans) and climate impacts

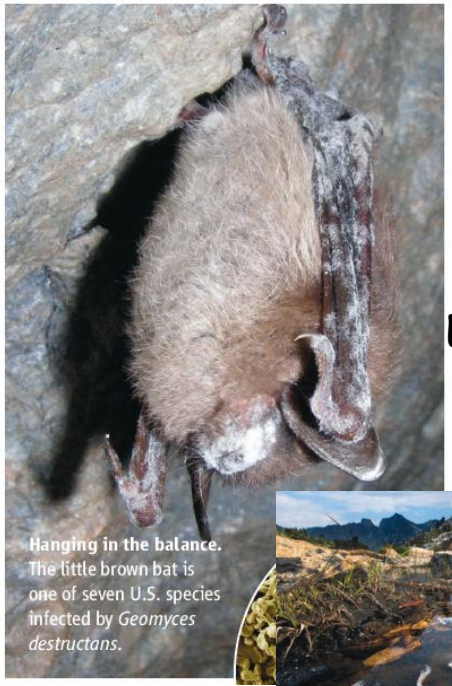




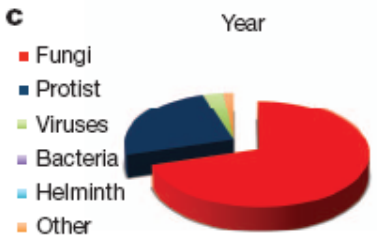
Fisher et al., Nature, 2012

Rodriguez et al., PNAS, 2013





Hanging in the balance. The little brown bat is one of seven U.S. species infected by *Geomyces destructans*.



Emerging Infectious Deceases

Kai, Science, 2012

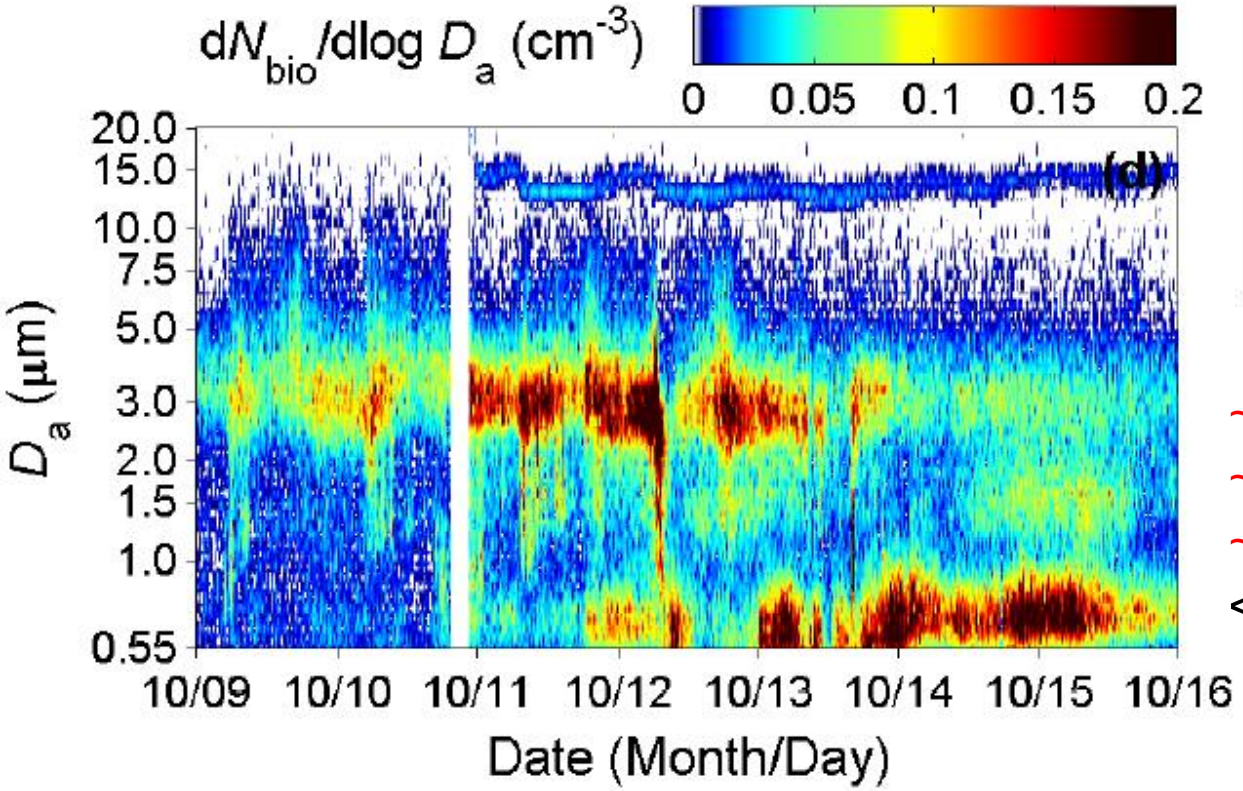
Drained of life. A fungal disease has almost wiped out the mountain yellow-legged frog population in Kings Canyon National Park in California.

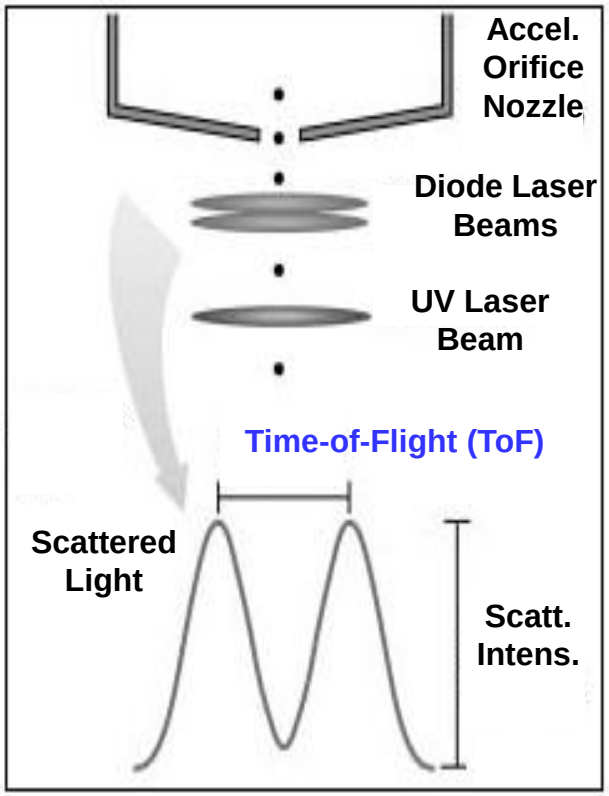
Fungal victims. Chestnut blight (*left*) has killed billions of trees in the United States. Corn smut, potato blight, and wheat stem rust (*right, top to bottom*) threaten the world's food supply.

There is no room – up and above

Ultraviolet Aerodynamic Particle Sizer (UVAPS)

- light scattering & time-of-flight: *0.5-20 µm*
- fluorescence: *355 nm ⇒ 420-575 nm*
- charact. metabolites: *NAD(P)H, riboflavin*
- **fluorescent bioparticle (FBAP) size distribution**:
  exemplary time series, Mainz 9-16 Oct 2006



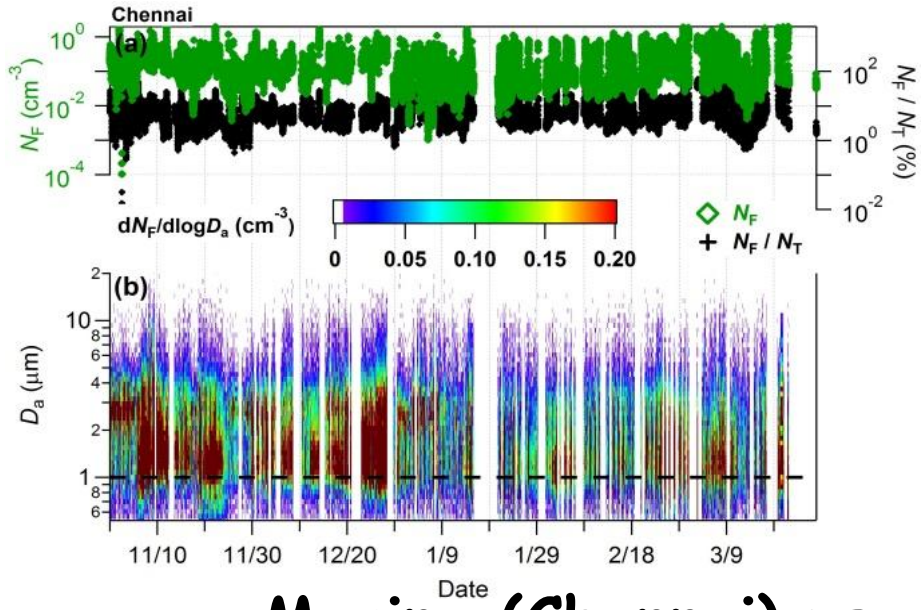


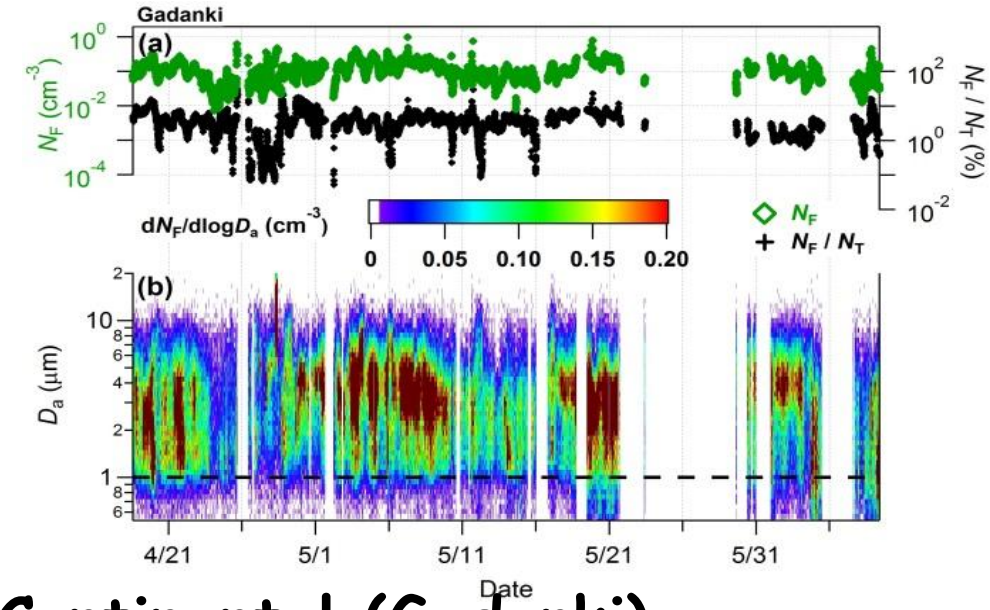
TSI Inc., 2003

~15 µm: **Pollen ?**
~ 3 µm: **Fungal Spores ?**
~ 1 µm: **Bacteria ?**
< 1 µm: Soot/PAH ?

Prenni Nature Geosci 2009,
Huffman ACP 2010

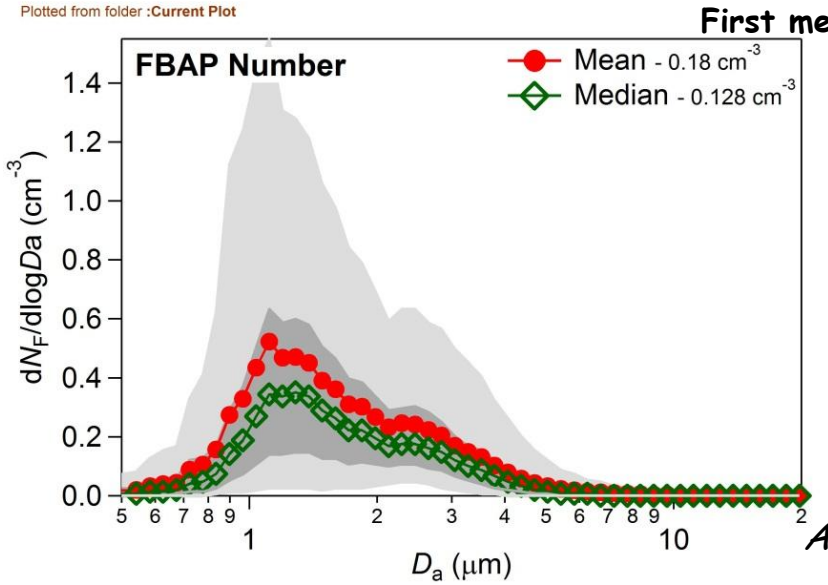
Number size distribution of fluorescence biological particles

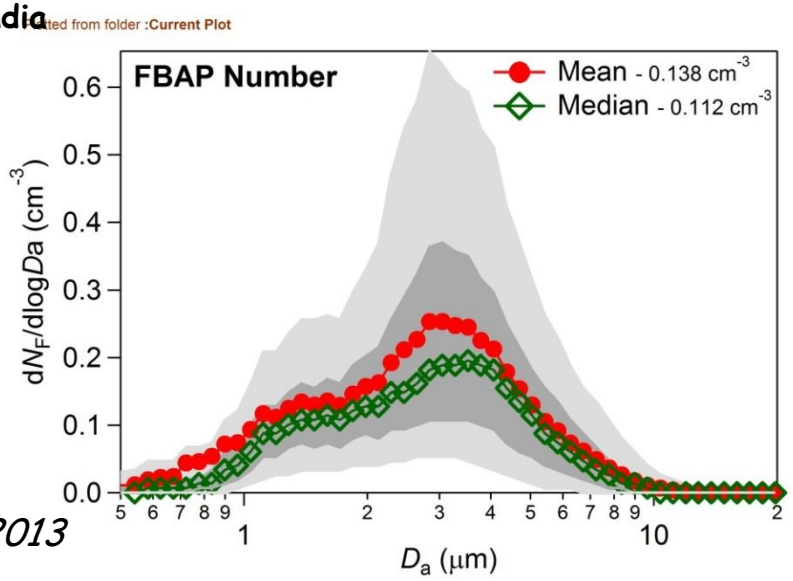




Marine (Chennai) vs. Continental (Gadanki)

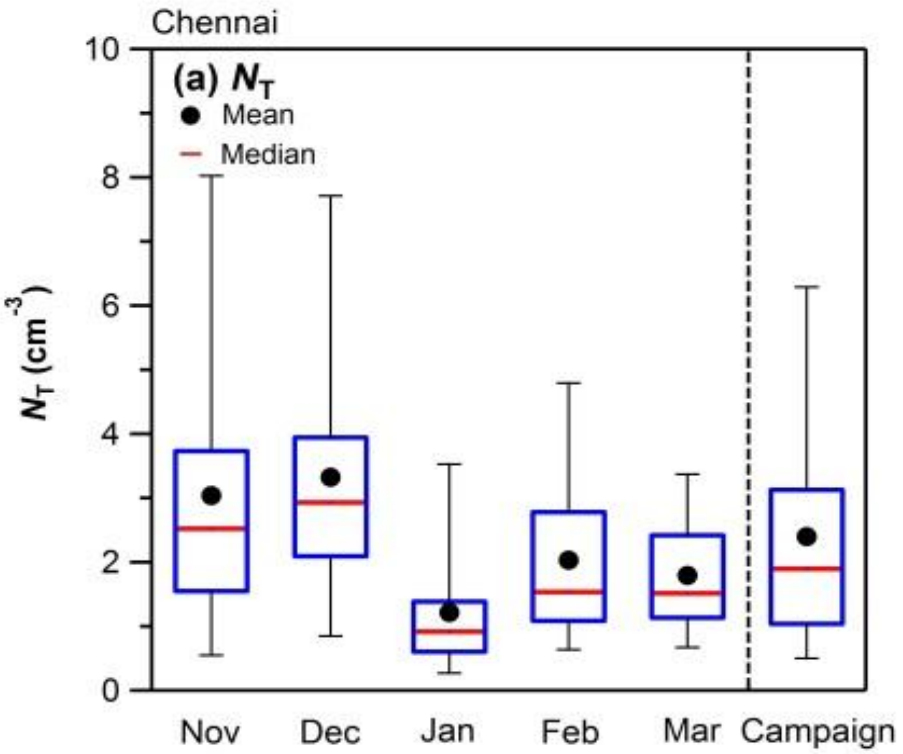
First measurements in India

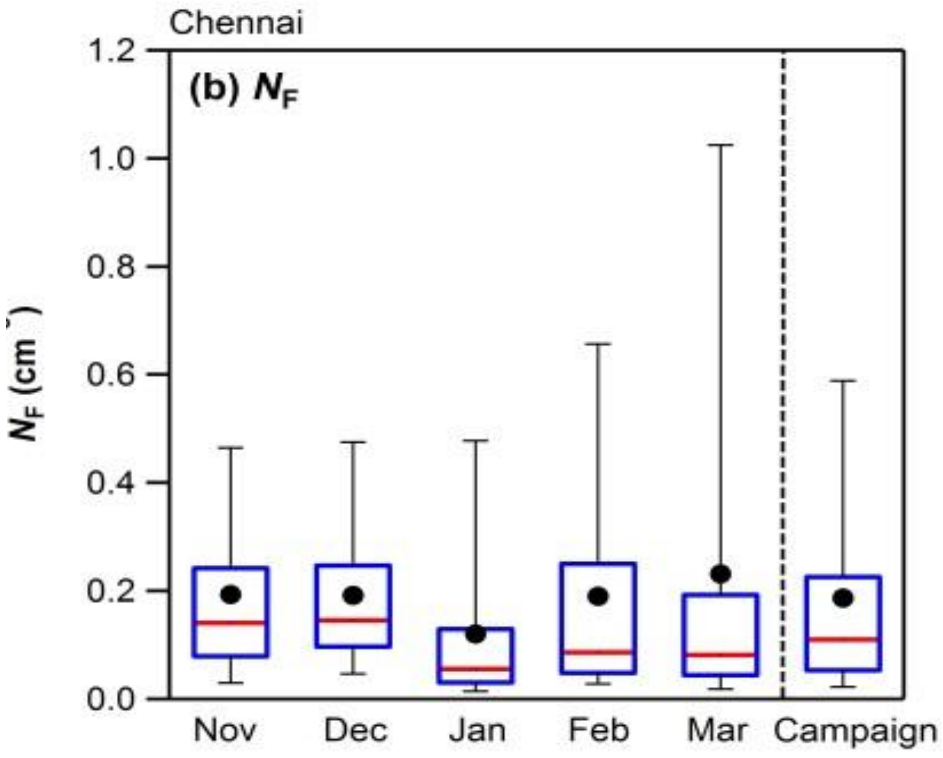




Aswathy et al., 2013

Statistical distribution of total and biological number concentrations





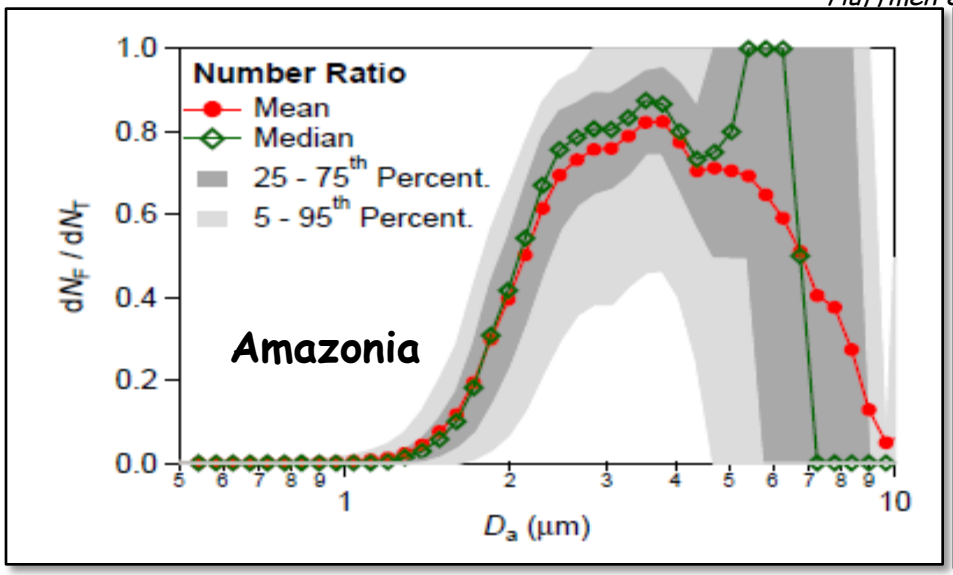
Factor of 3 variations

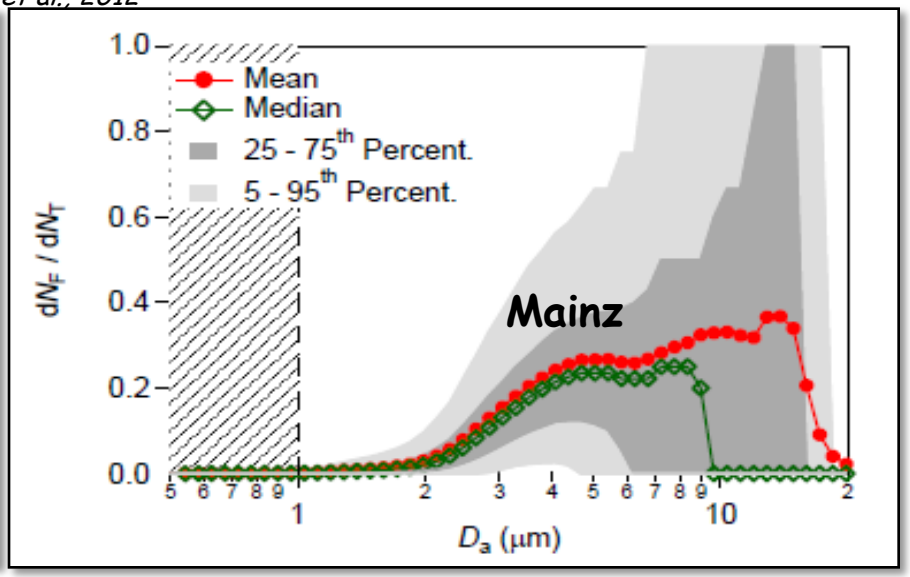
More consistent

Gadanki exhibited consistency in total as well as bio aerosol number concentration

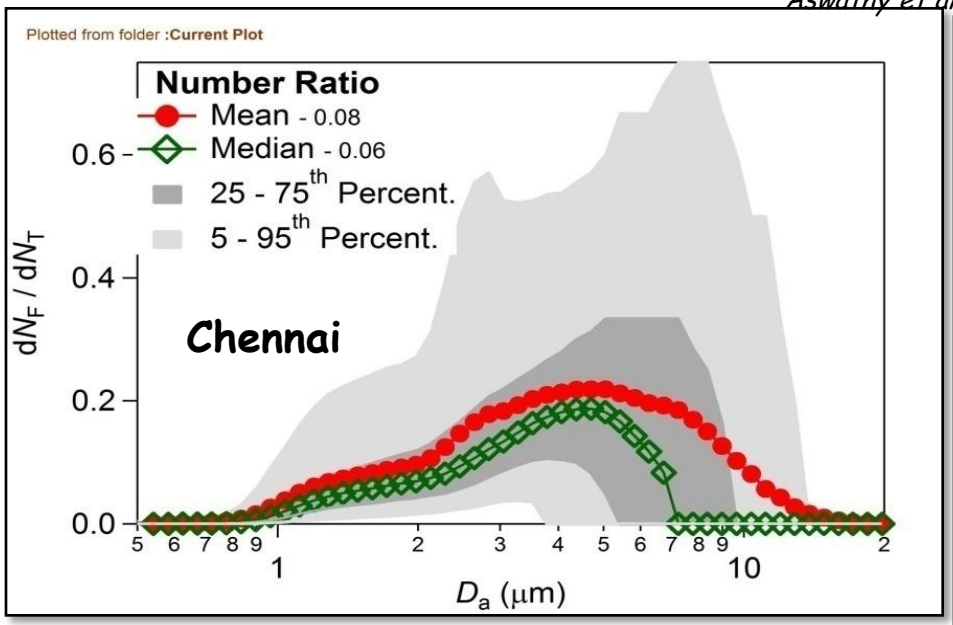
Average number ratio of biological to total aerosols

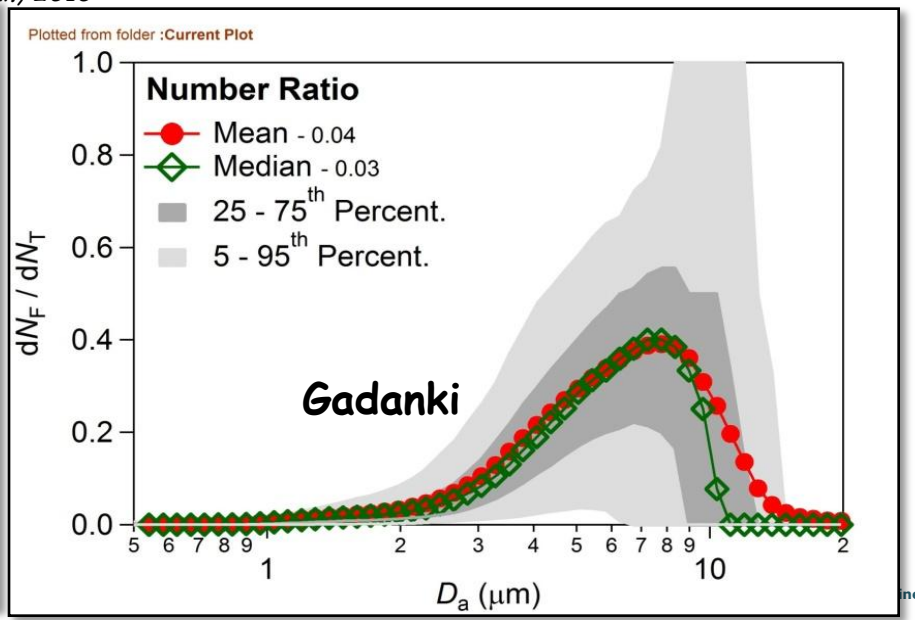
Huffmen et al., 2012





Aswathy et al., 2013



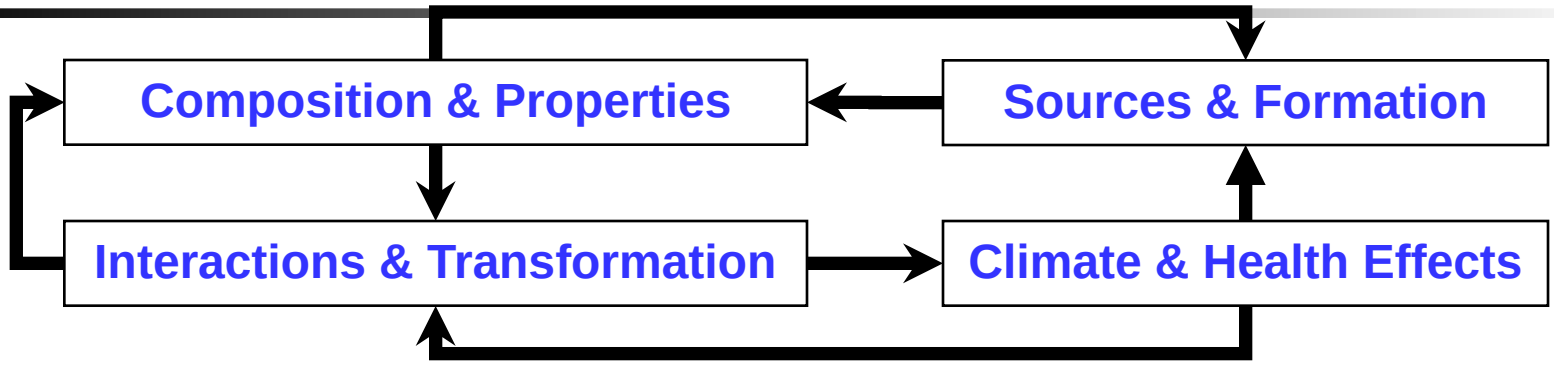


Complimentary offline techniques

Literature
and
sampled in
Chennai
DNA Analysis is
necessary to
identify type and
quantify the
diversity of
biological fraction
in air

Aswathy et al., 2013

Summary & Outlook



Satellite measurements

High spatial and temporal coverage
Efficient in identifying measurement sites

Bioaerosols

Fluorescence online measurements; DNA analysis; SEM analysis, and Fluorescence microscopy

Challenges: IN & GCCN activity, biodiversity & global change, effects of air pollution on viability & pathogenicity ?

Cloud Condensation Nuclei

Aerosol & updraft limited regimes of CCN activation & cloud droplet formation

Need: size-resolved CCN measurements ?

Under contrastgin enviroments-simultanously