SMEAR – atmospheric composition measurements (Part 1)

18.11. 2021

(remote)

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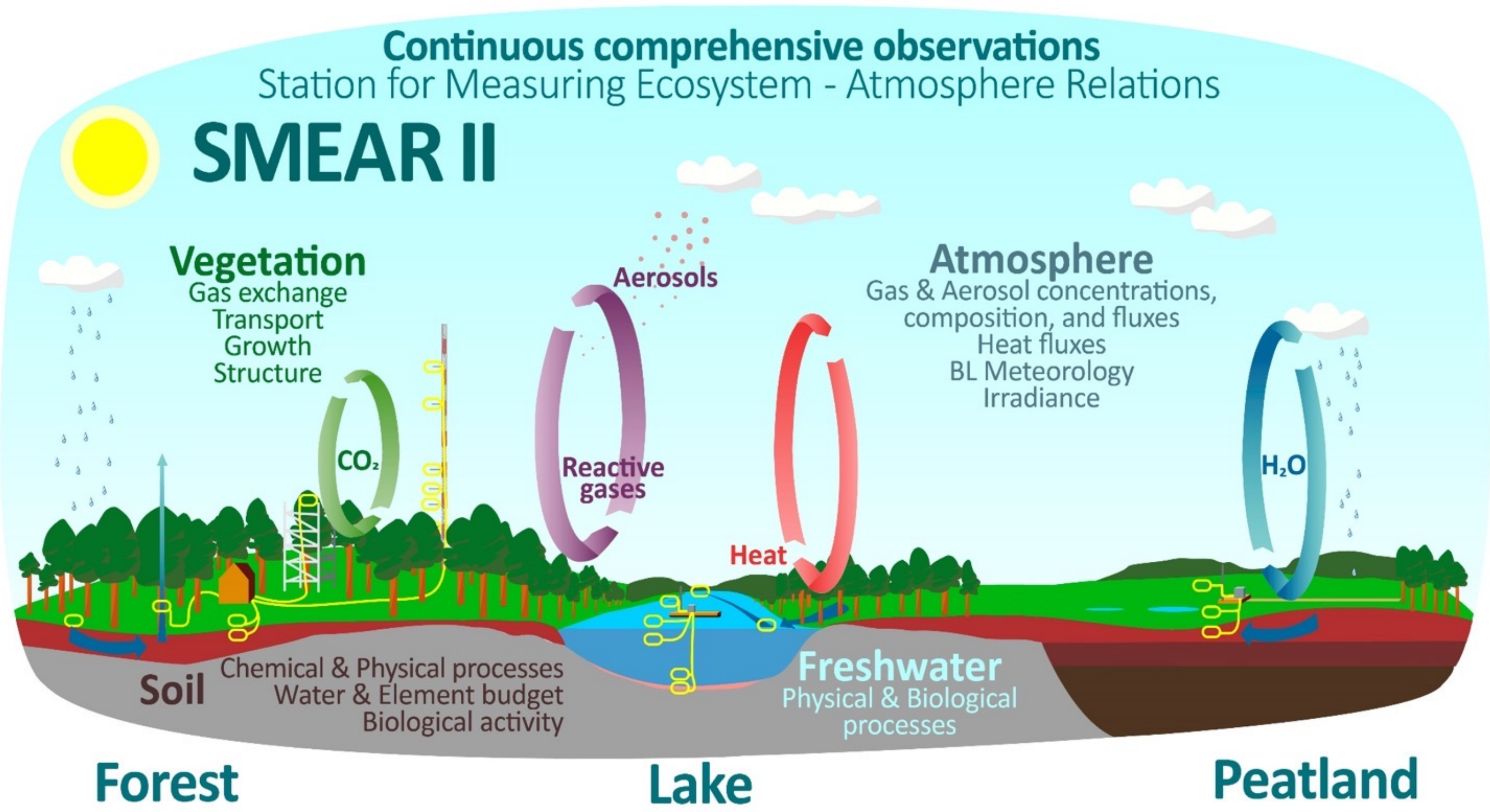
SMEAR II station in Hyytiälä, Finland

Over **1200** different variables



Flagship site for integration: combines all IPCC components.

Contributes to :

ACTRIS

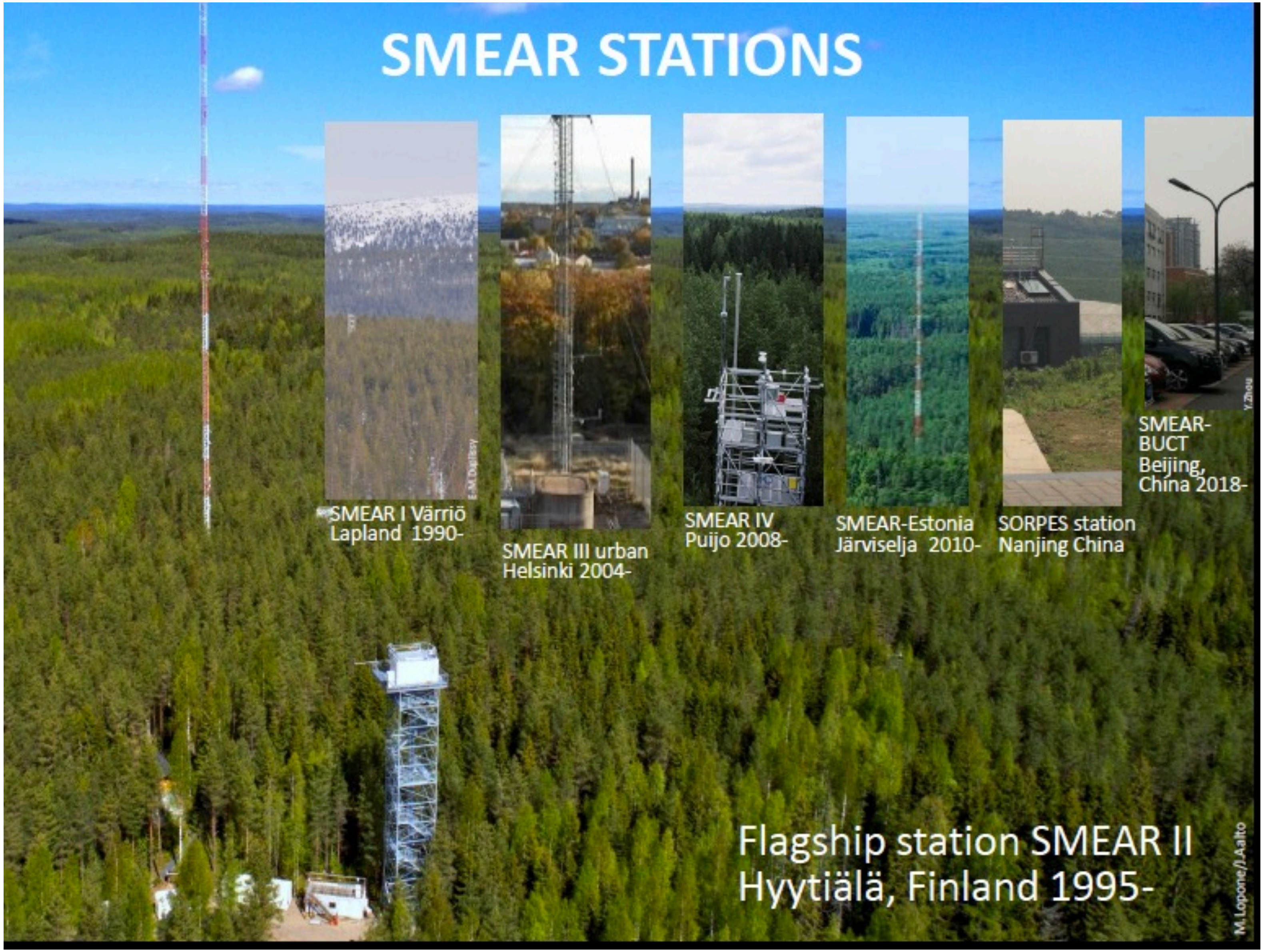
ICOS Integrated Carbon Observation System

AnaEE Analysis and Experimentation on Ecosystems

LTER europe

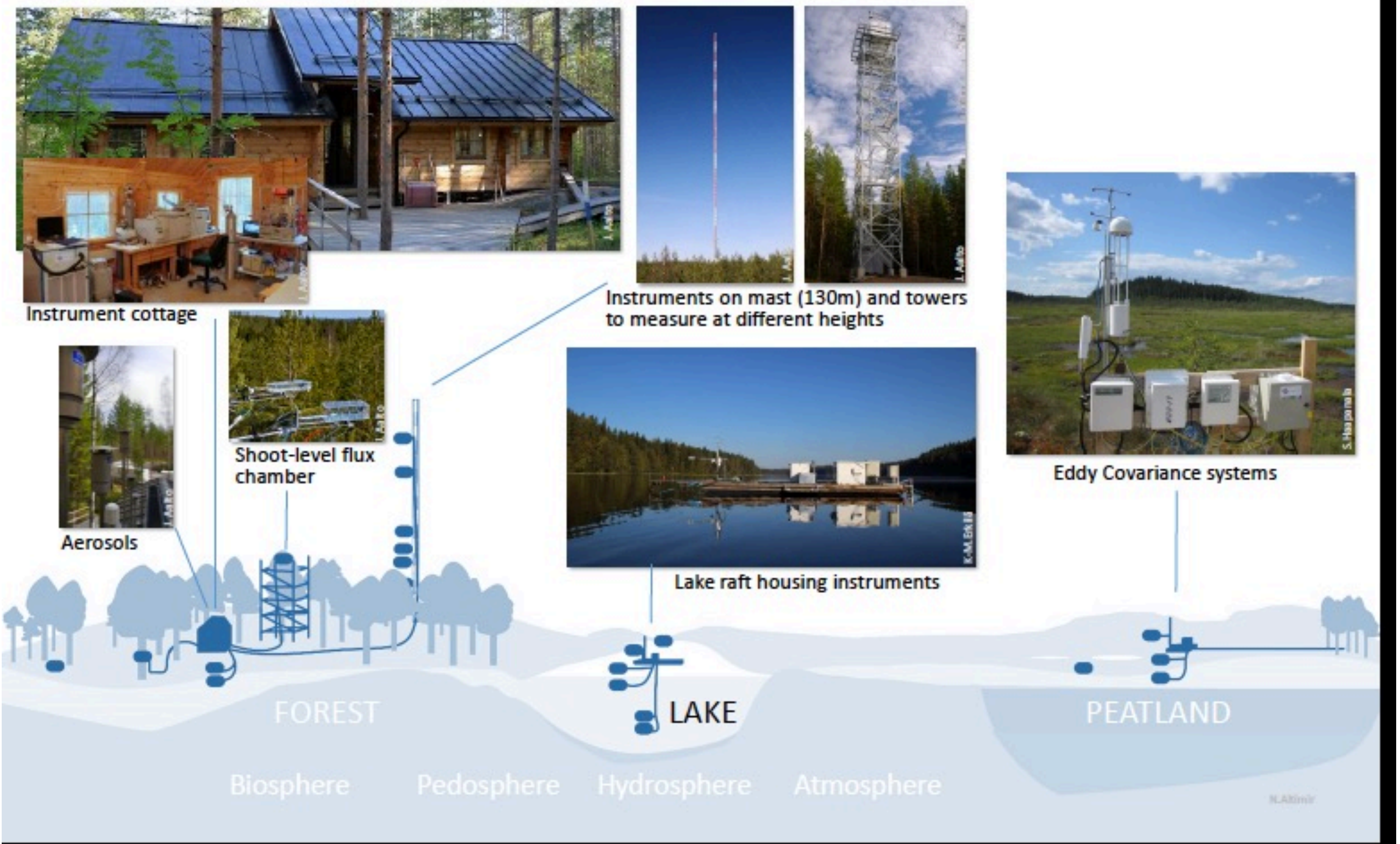
Pan-Eurasian Experiment PEEX

World Meteorological Organisation

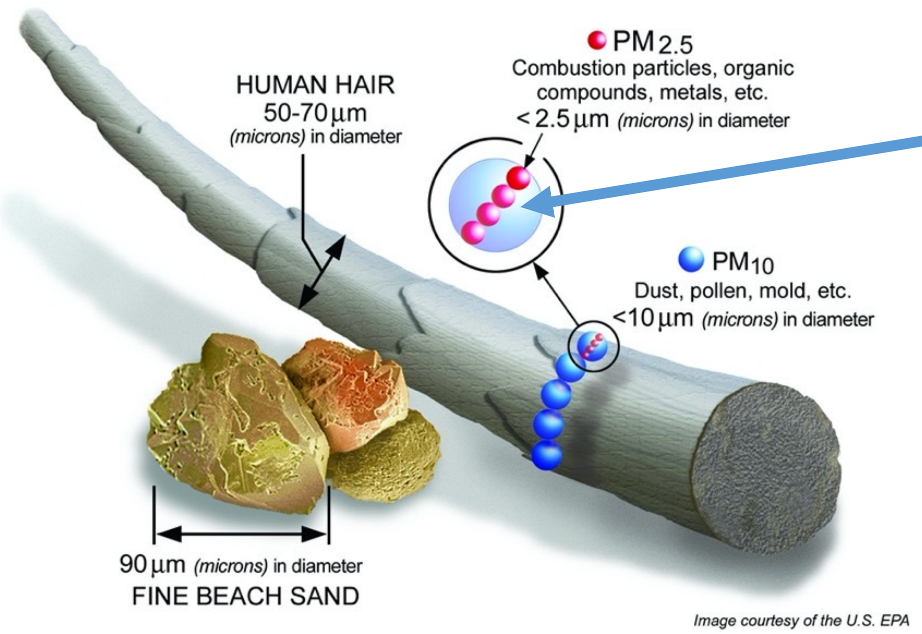

SMEAR STATIONS
SMEAR I Värriö
Lapland 1990-
SMEAR III urban
Helsinki 2004-
SMEAR IV
Puijo 2008-
SMEAR-Estonia
Järviselja 2010-
SORPES station
Nanjing China
SMEAR-
BUCT
Beijing,
China 2018-
Flagship station SMEAR II
Hyytiälä, Finland 1995-

Flagship station SMEAR II

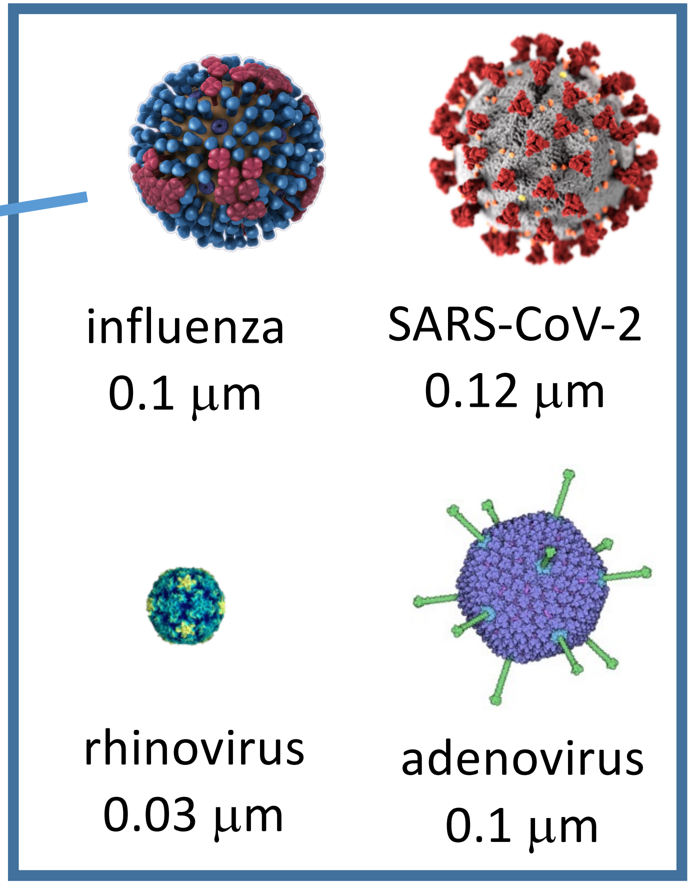
N 61° 50.845', E 24° 17.686', altitude 180 m a.s.l.



Different sizes of aerosol particles



Note that the viruses are shown here with a different size scale!



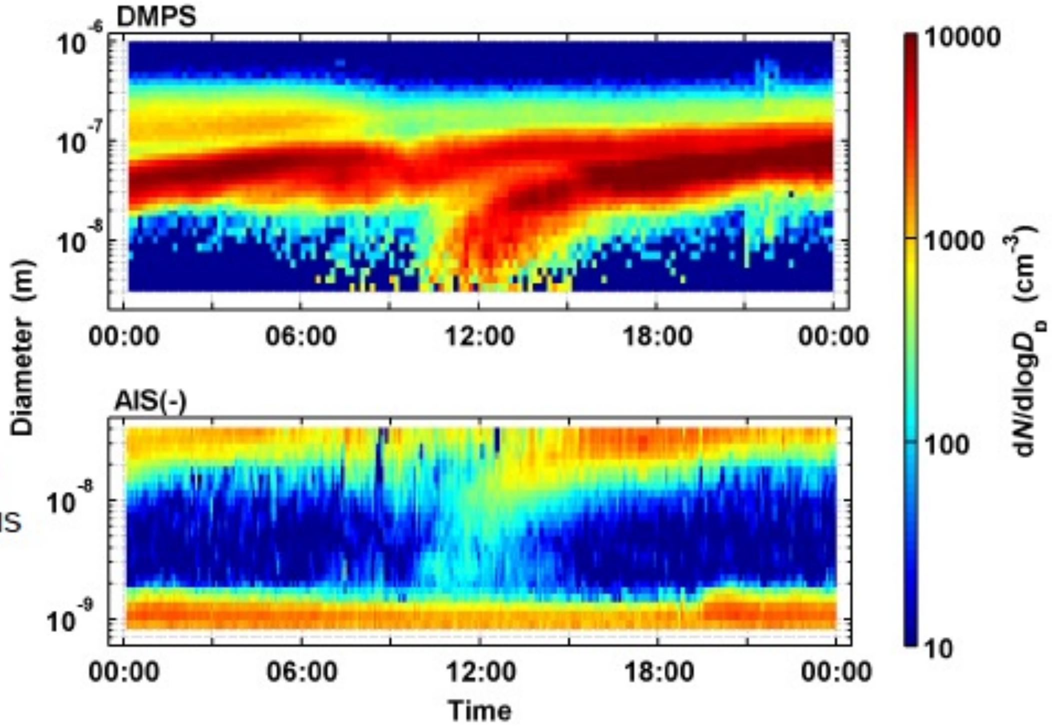
https://www.cdc.gov/flu/resource-center/freeresources/graphics/images.htm, http://solutionsdesignedforhealthcare.com/rhinovirus, https://phil.cdc.gov/Details.aspx?pid=23312, https://pdb101.rcsb.org/motm/132

Atmospheric new particle formation and growth events

Composition & concentration of:

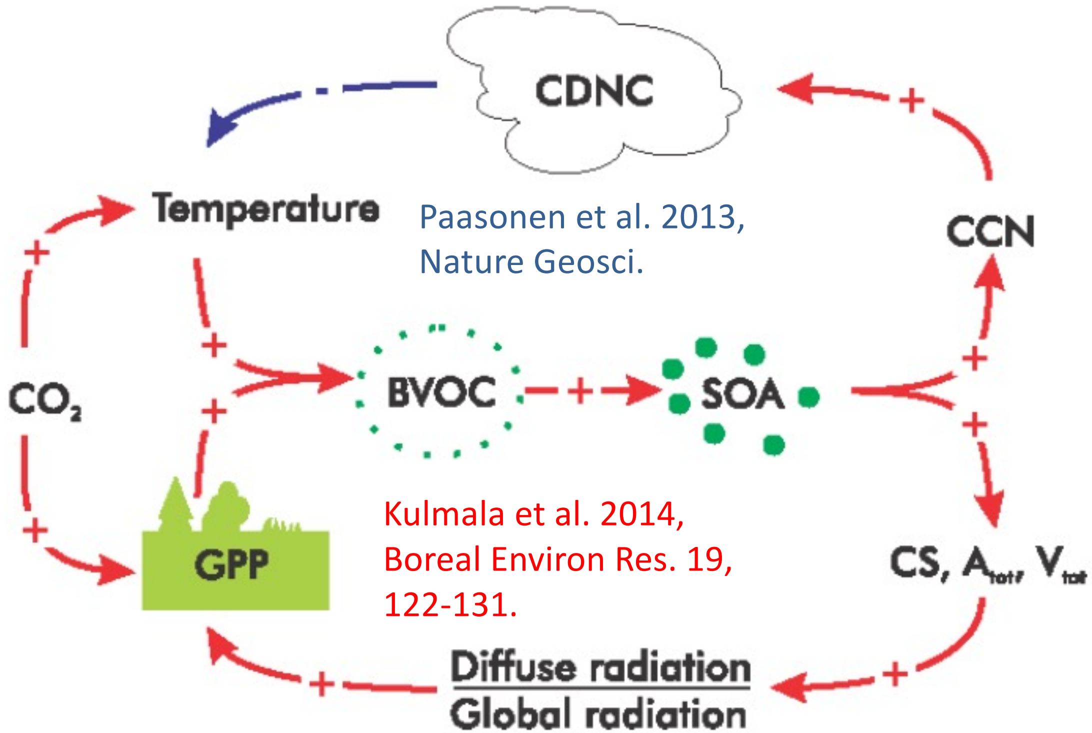
- precursor gases
- initial clusters
- gases responsible for the subsequent growth

From nano to global



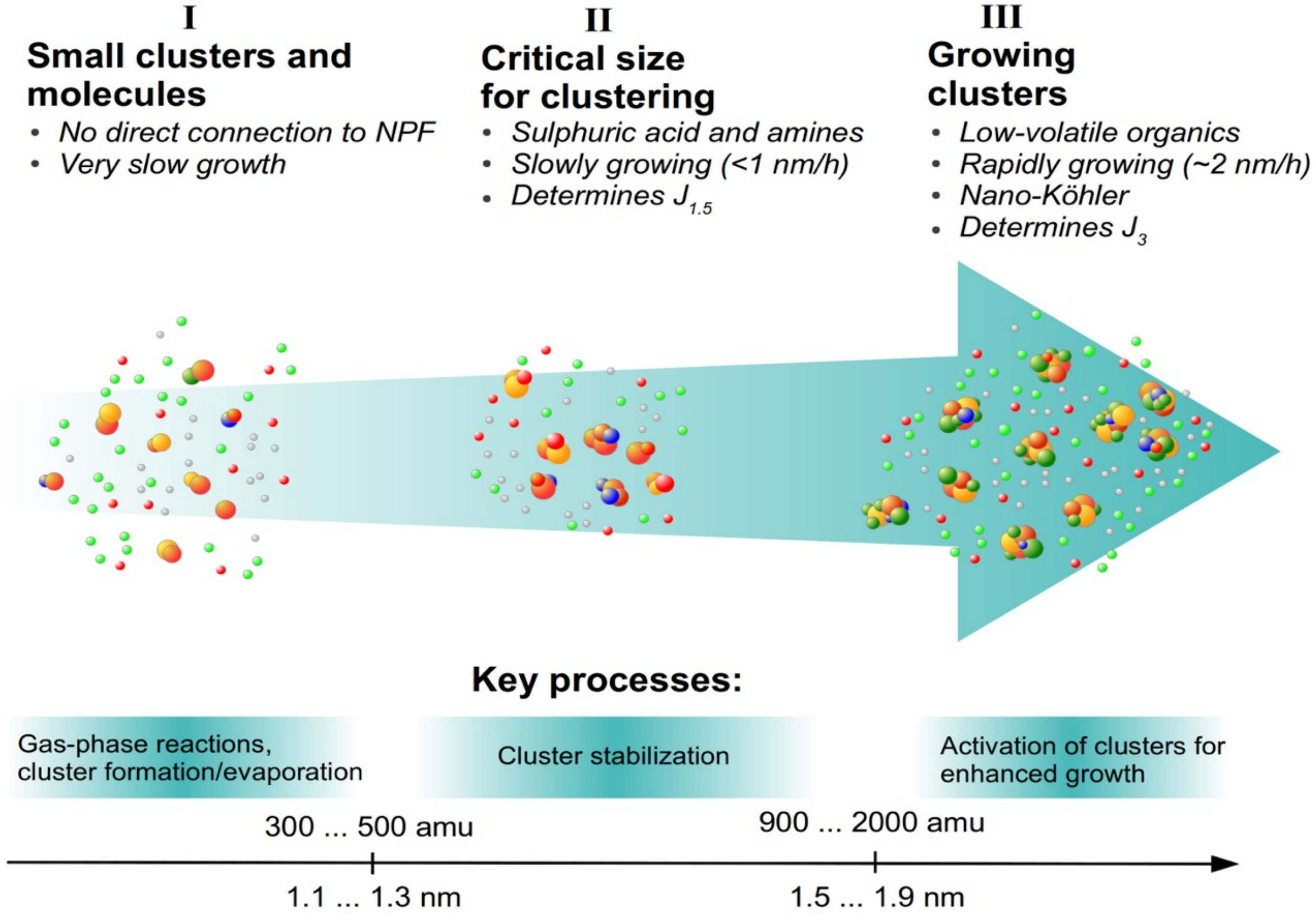
Mäkelä et al. 1997, GRL
Kulmala et al. 2001, Tellus

Quantification of natural feedback mechanisms slowing down climate change providing the society time to reduce the emissions of CO2.



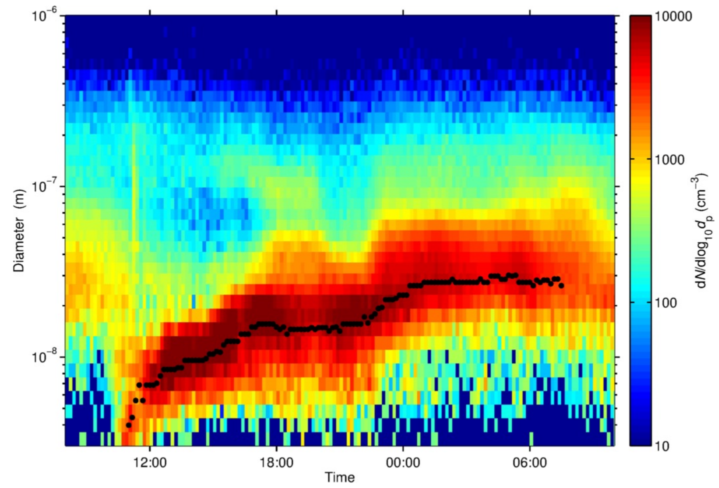
- Kulmala et al. (Boreal Environ Res) based on 18 years of SMEAR II data from Hyytiälä
- Paasonen et al. (Nature Geosci) based on global aerosol data and cloud albedo parameterization, feedback strength varies from location to location. The highest gain in clean boreal environments.

Atmospheric nucleation / clustering processes



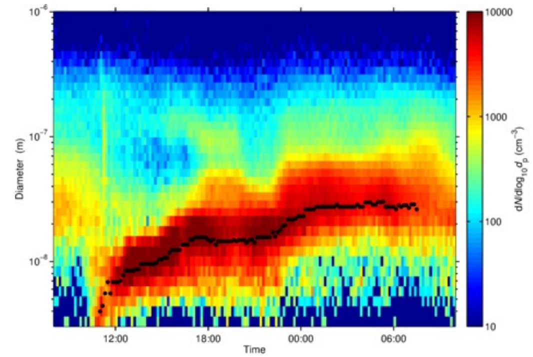
From gas phase precursors to nanoparticles (solid or liquid) suspended in air

Aerosol particle sizes from 1 nm to 1000 nm

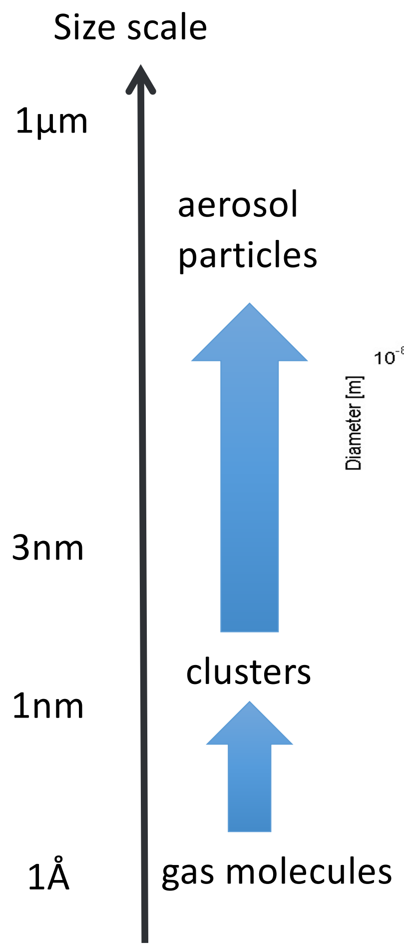


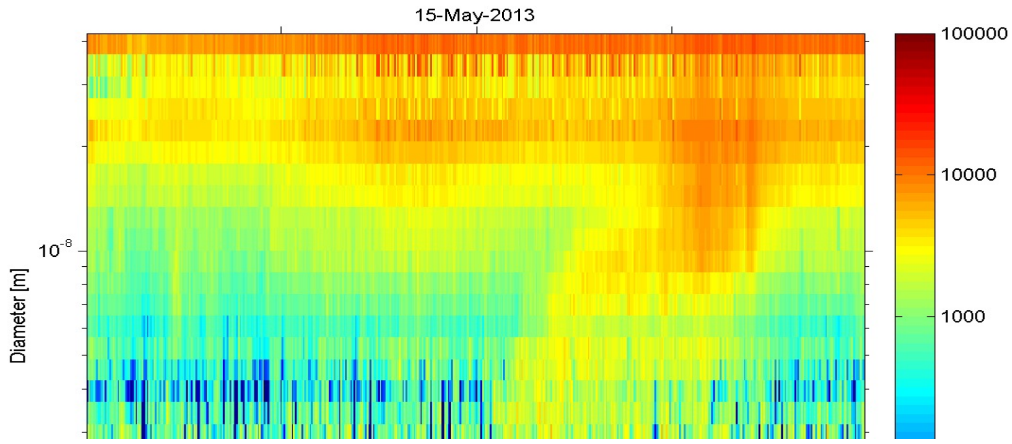
Kulmala et al., Science, 2013

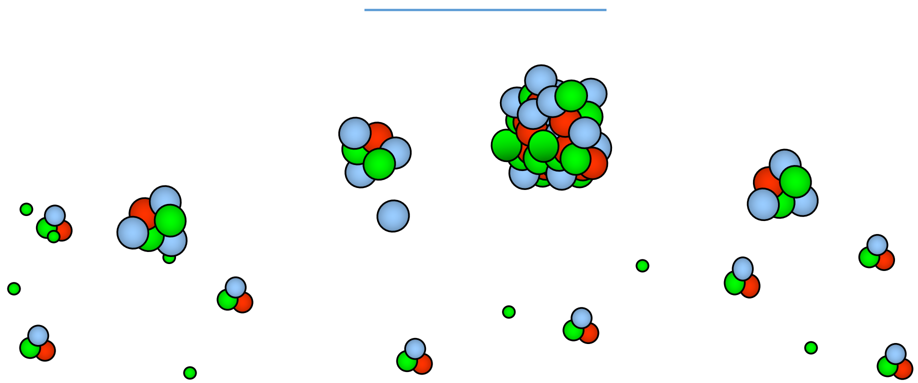
Problem:
how to measure new particle formation?



Hyytiälä 15th May 2013:

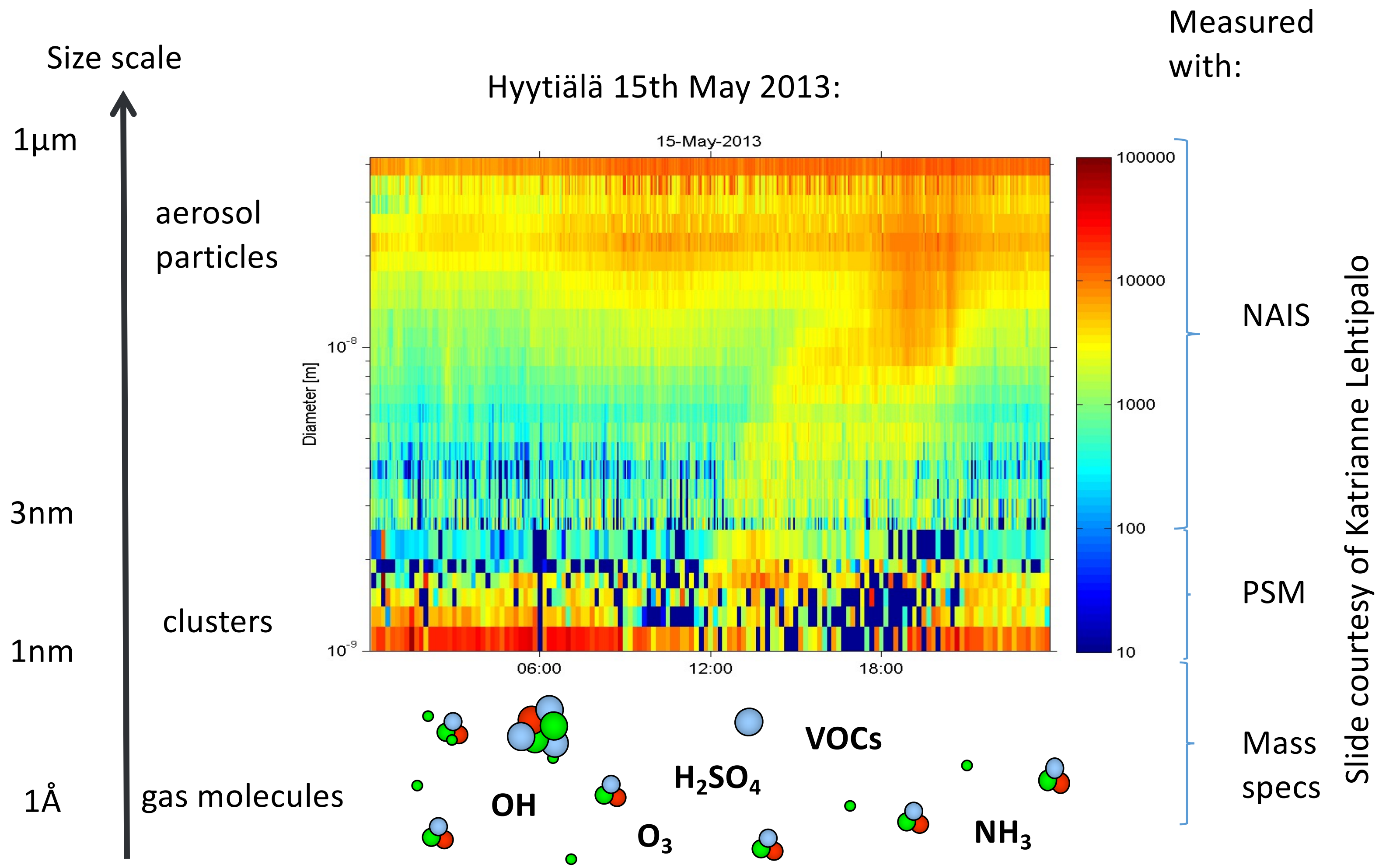






Slide courtesy of Katrianne Lehtipalo

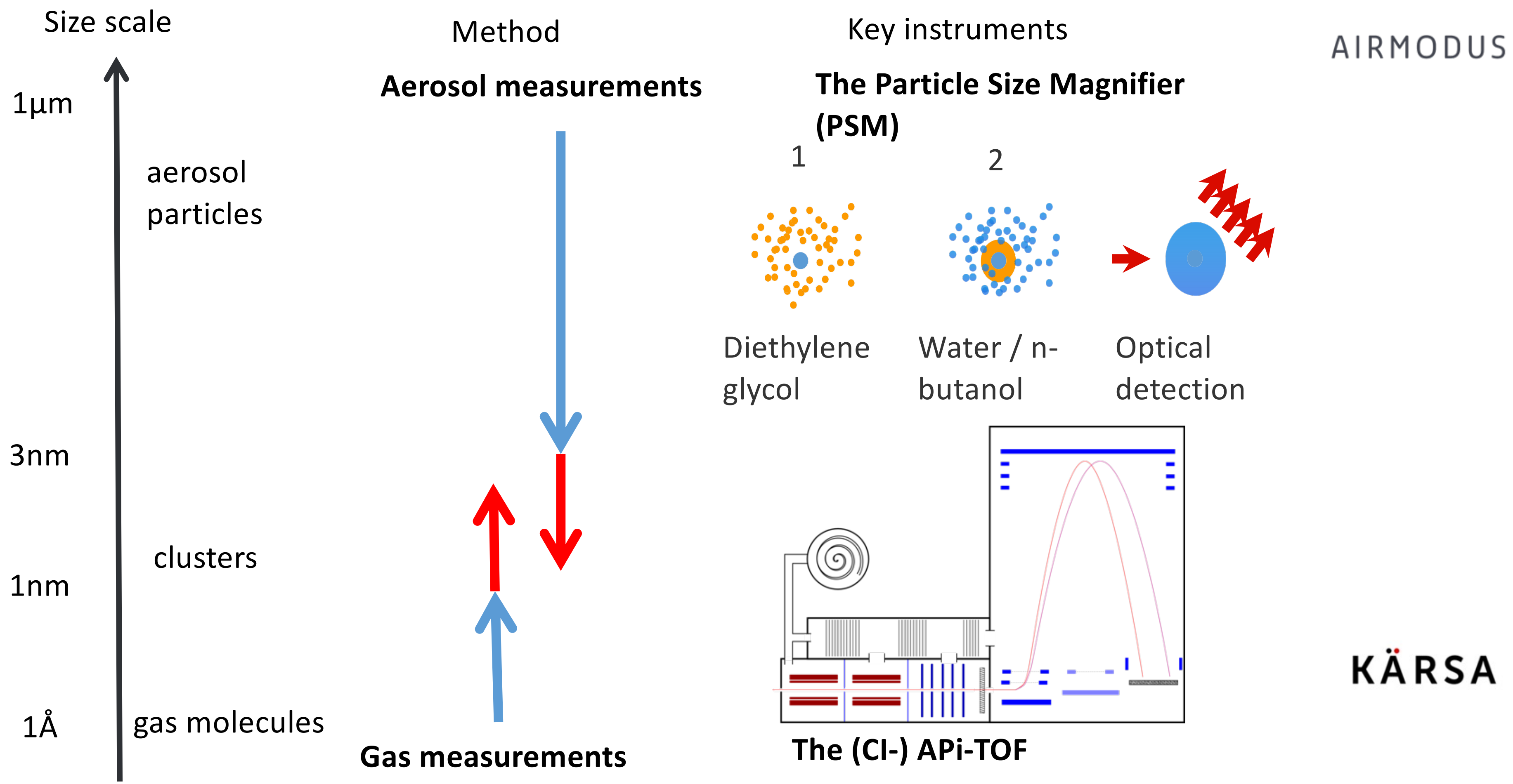
Discovering the world below 3 nm



New technologies for reaching the sizes of nucleating clusters

Slide courtesy of Katrianne Lehtipalo

Spin-off companies

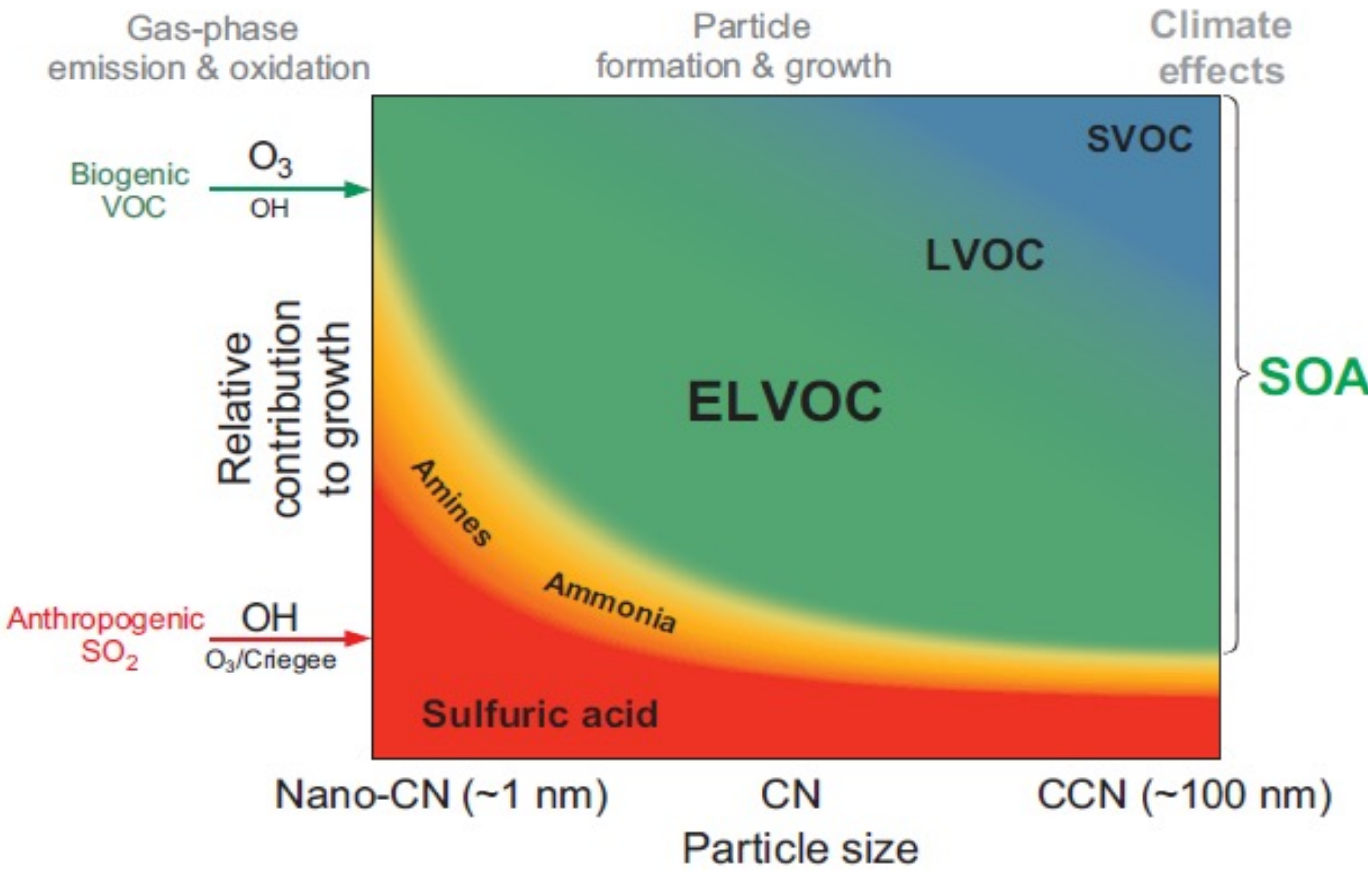


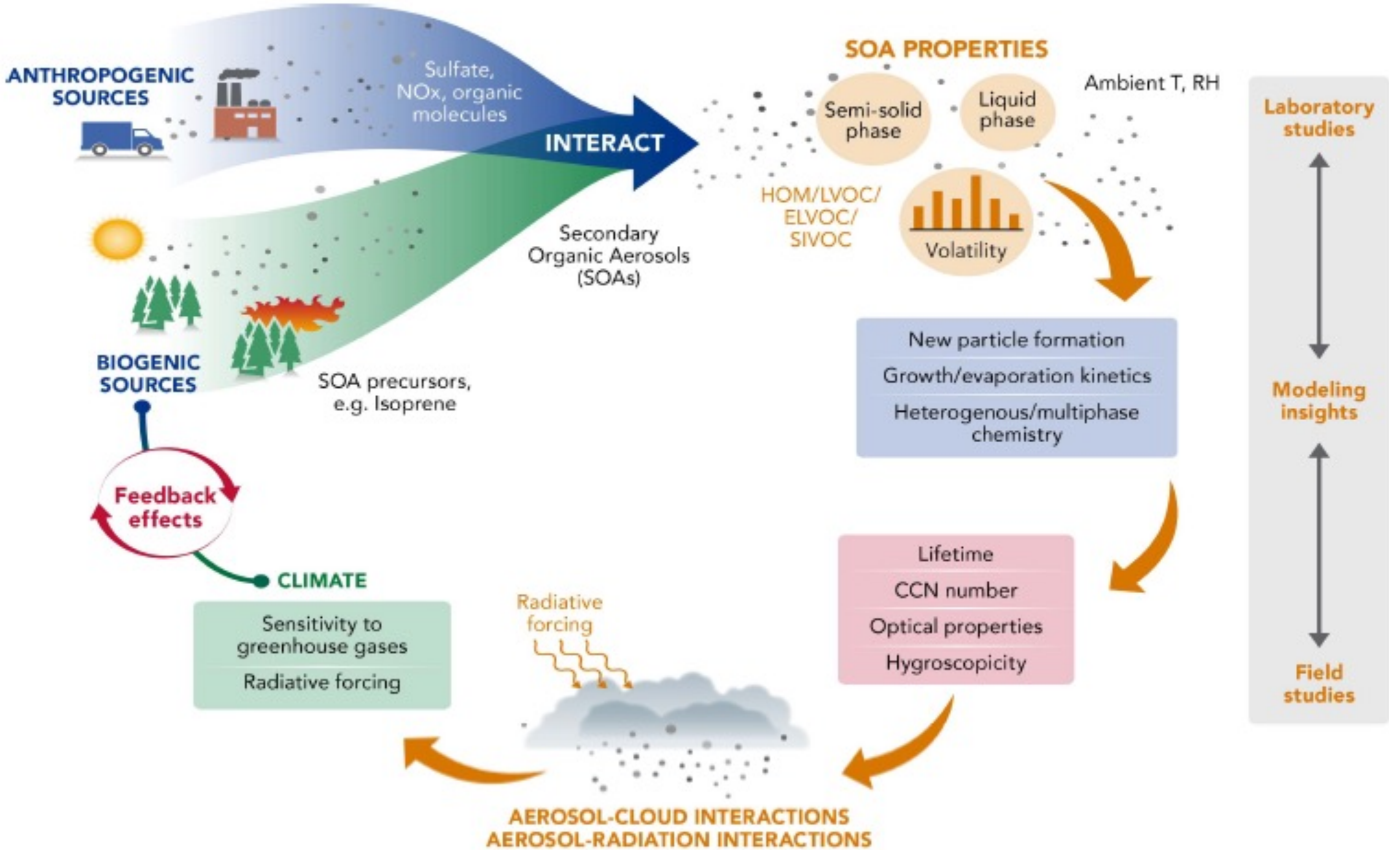
A large source of low-volatility secondary organic aerosol

Ehn et al. (2014) Nature

Oxidation Products of Biogenic Emissions Contribute to Nucleation of Atmospheric Particles

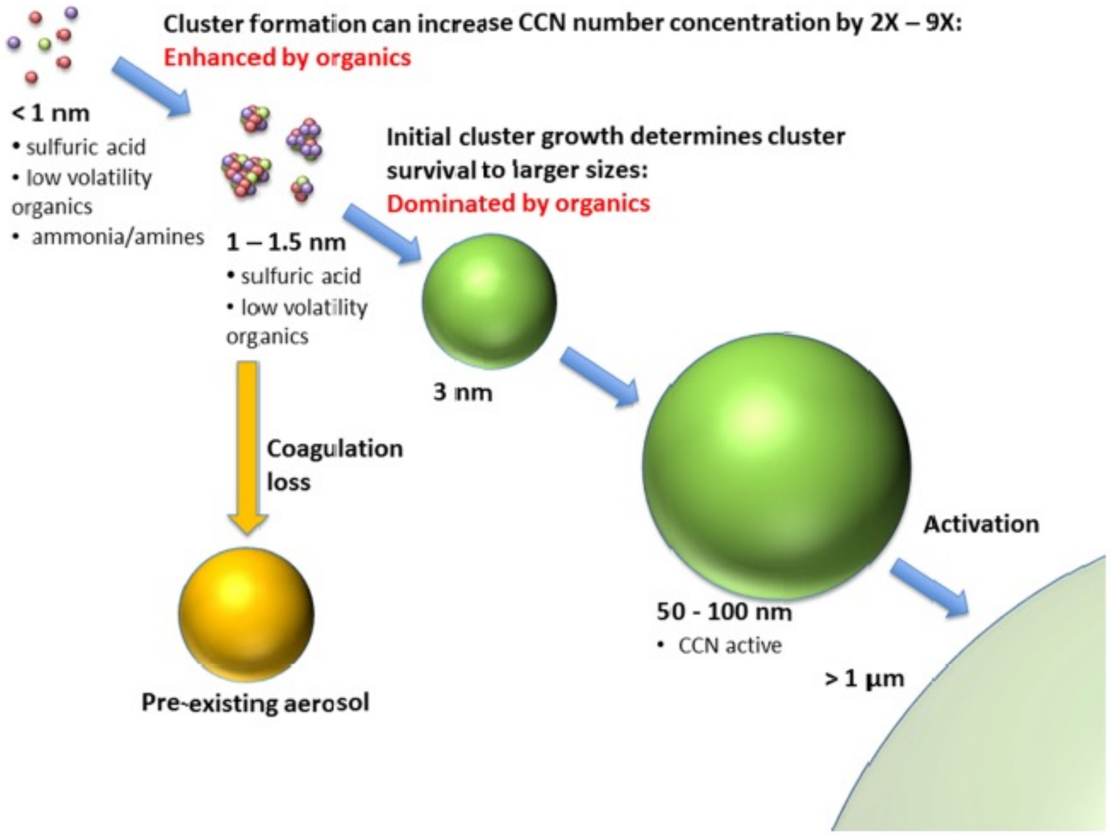
Riccobono et al. (2014) Science





Shrivastava et al. (2017)
Reviews in Geophysics

Recent advances in understanding secondary organic aerosols: implications for global climate forcing



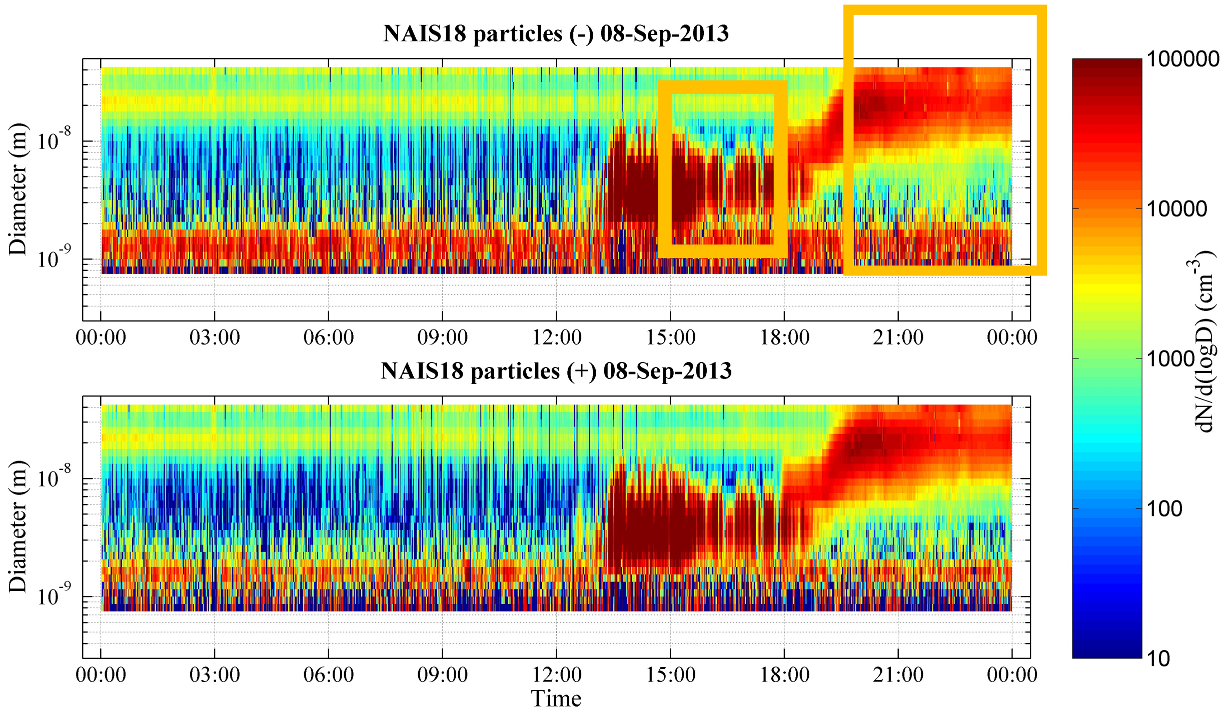
- Biogenic emissions, SOA formation (mass and number)
- LVOC and ELVOC in SOA growth
- Particle phase state
- Biomass burning SOA
- Laboratory systems
- SOA interactions with clouds
- Optical properties of SOA


PEGASOS
JÜLICH

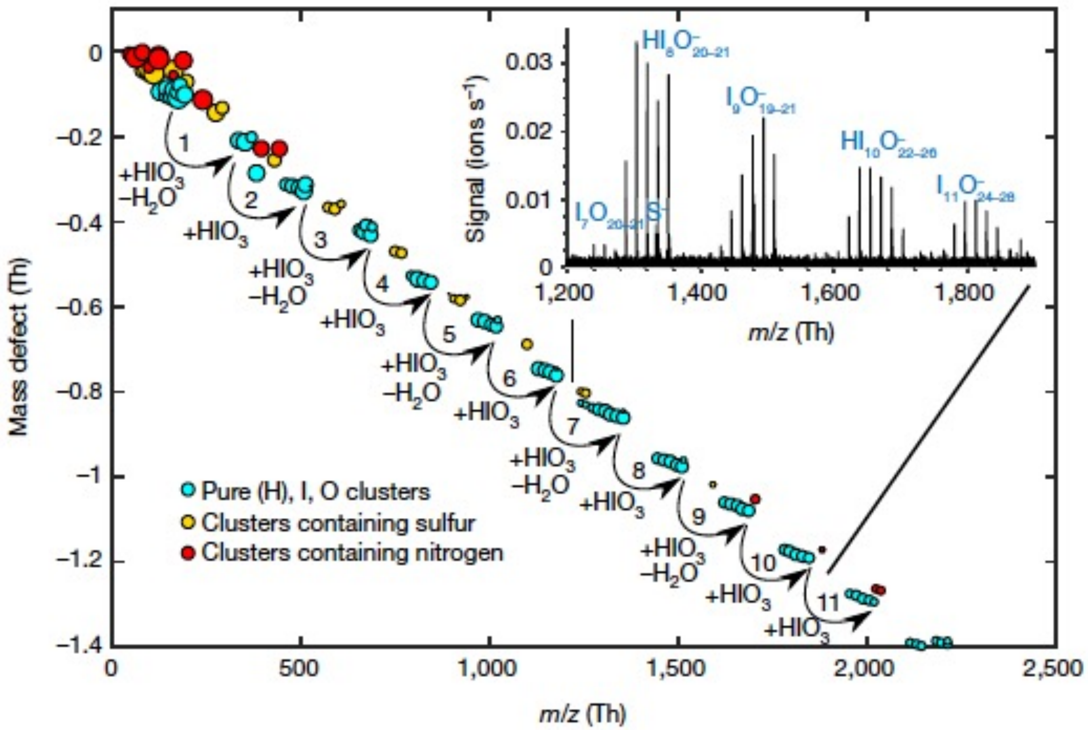
CELTIC EXPLORER



Mace Head: coastal and continental nucleation.



Mass defect plot from CI-APi-TOF (neutral clusters) during coastal event. Nucleation due to iodine oxides



Molecular-scale evidence of aerosol particle formation via sequential addition of HIO_3

Mikko Sipilä[1], Nina Sarnela[1], Tuija Jokinen[1], Henning Henschel[1], Heikki Junninen[1], Jenni Kontkanen[1], Stefanie Richters[2], Juha Kangasluoma[1], Alessandro Franchin[1], Otso Peräkylä[1], Matti P. Rissanen[1], Mikael Ehn[1], Hanna Vehkamäki[1], Theo Kurten[3], Torsten Berndt[2], Tuukka Petäjä[1], Douglas Worsnop[1,4,5,6], Darius Ceburnis[7], Veli-Matti Kerminen[1], Markku Kulmala[1] & Colin O'Dowd[7]

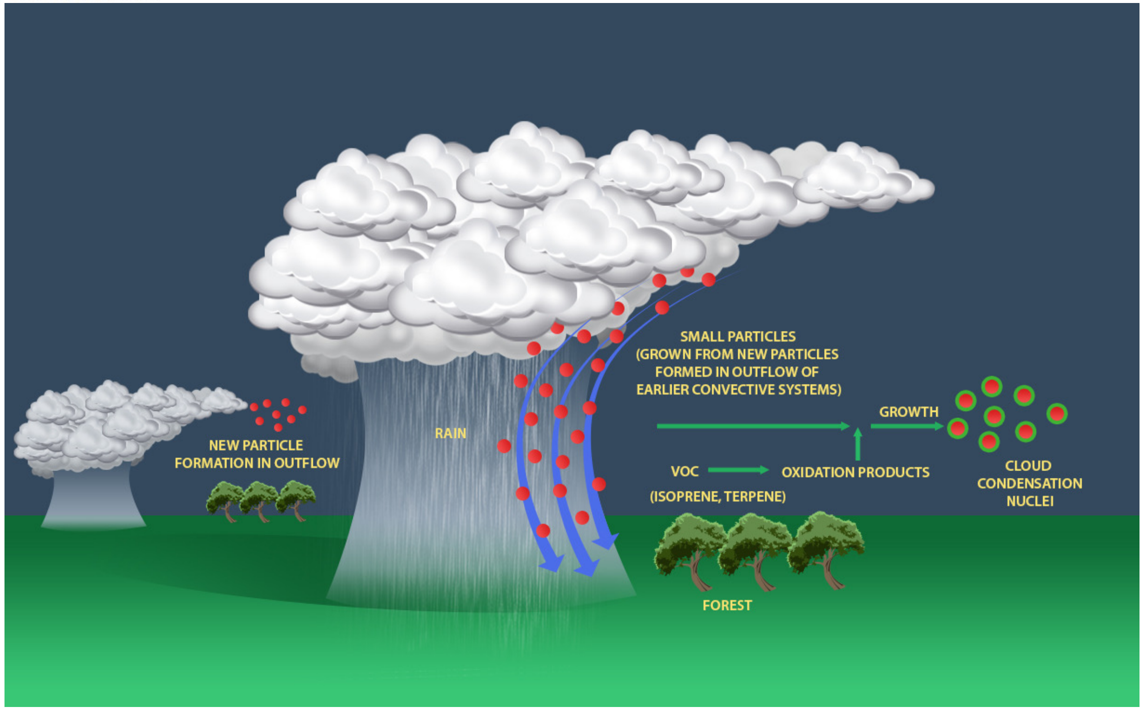
LETTER

LETTER

doi:10.1038/nature19819

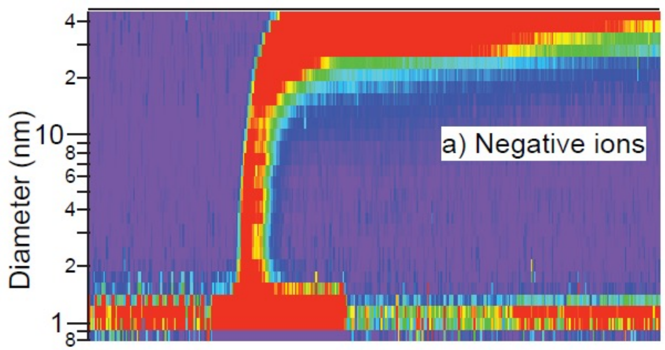
Amazon boundary layer aerosol concentration sustained by vertical transport during rainfall

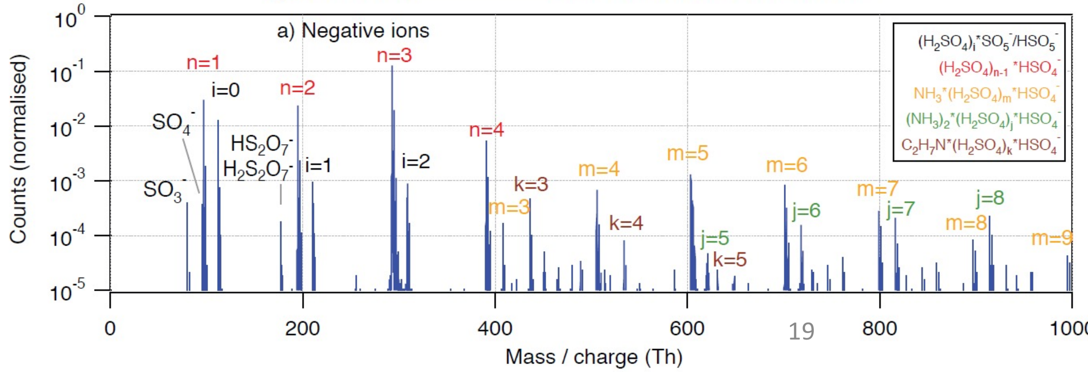
Jian Wang[1], Radovan Krejci[2], Scott Giangrande[1], Chongai Kuang[1], Henrique M. J. Barbosa[3], Joel Brito[3], Samara Carbone[3], Xuguang Chi[4,5], Jennifer Comstock[6], Florian Ditas[4], Jost Lavric[7], Hanna E. Manninen[8], Fan Mei[6], Daniel Moran-Zuloaga[4], Christopher Pöhlker[4], Mira L. Pöhlker[4], Jorge Saturno[4], Beat Schmid[6], Rodrigo A. F. Souza[9], Stephen R. Springston[1], Jason M. Tomlinson[6], Tami Toto[1], David Walter[4], Daniela Wimmer[8], James N. Smith[10], Markku Kulmala[8], Luiz A. T. Machado[11], Paulo Artaxo[3], Meinrat O. Andreae[4,12], Tuukka Petäjä[8] & Scot T. Martin[13]

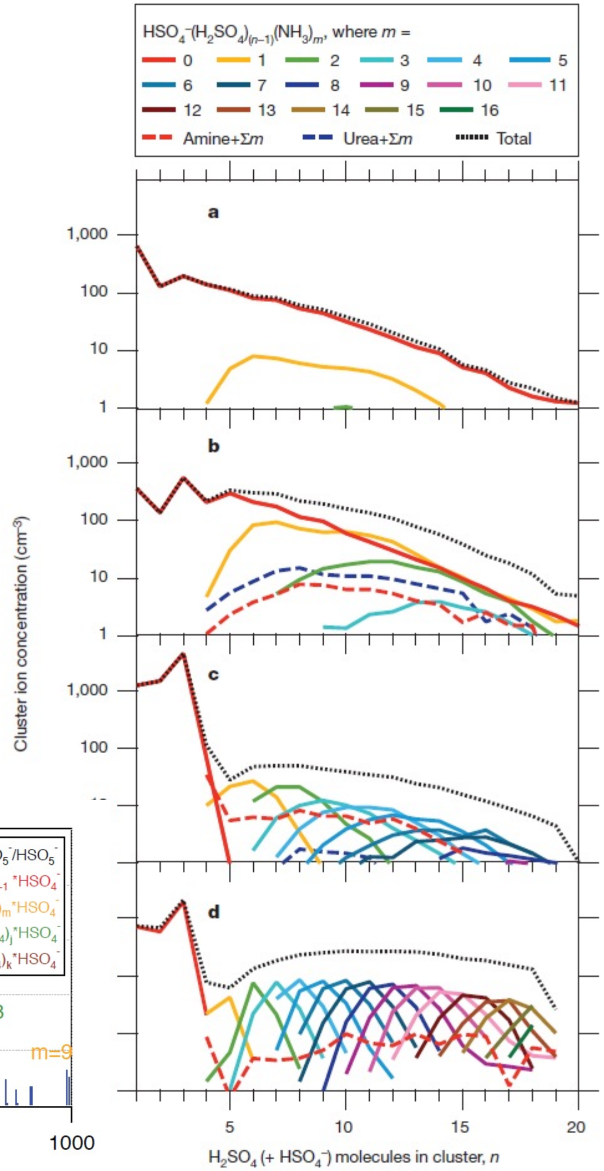


CLOUD project in CERN
Kirkby et al., 2011, Nature

- Mass spectrometric measurements of nucleating ion clusters







Airmodus products

1µm

aerosol particles

A20 CPC

A23 CPC

Air quality research
Vehicle emissions
Ambient aerosol monitoring

Condensation Particle Counters

3nm

clusters

A10 PSM

A11 nCNC

Aerosol research
Vehicle emission research

1nm

Particle Size Magnifiers and nano particle sizing

1Å

gas molecules

Improved
Mass Spec-sampling

Aerosol research

KÄRSA

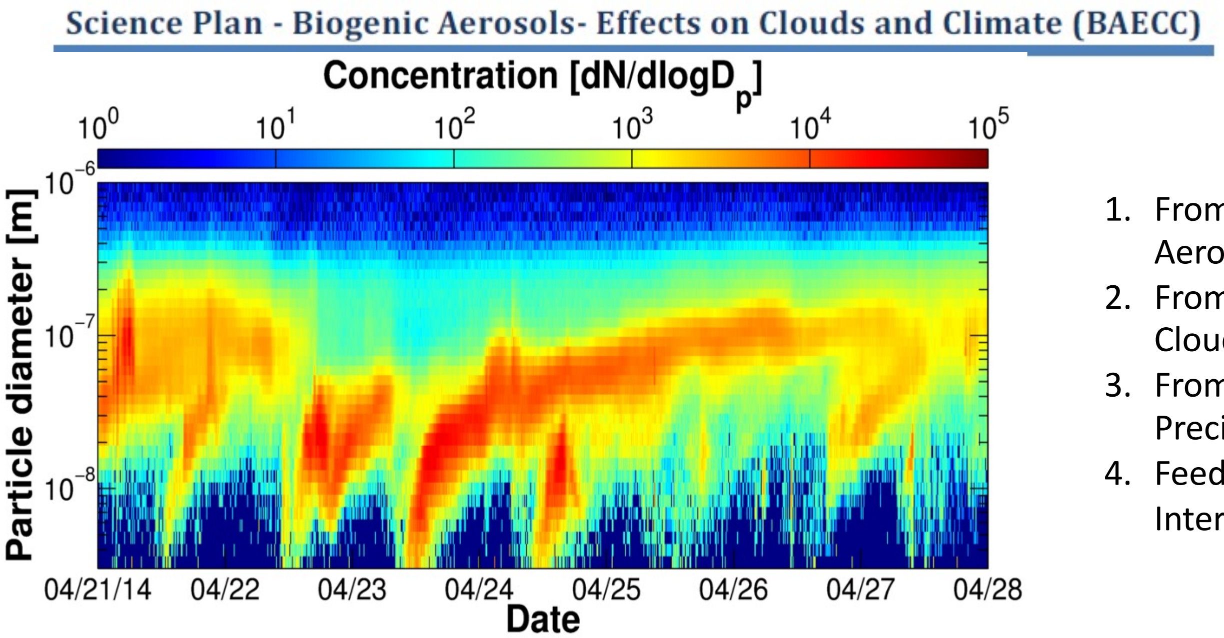
KÄRSA

Innovation in Molecular Explosives Detection

Most Accurate detection with Scenthound Complex

Molecular Analysis of Explosives with Tarkka TOF +

Reduce queues and enhance security with K1000 +



1. From Emissions to Aerosols
2. From Aerosols to Clouds
3. From Clouds to Precipitation
4. Feedbacks and Interactions

- What is the role of newly formed particles in the cloud activation *in-situ*?
- Do they alter the cloud properties / precipitation?

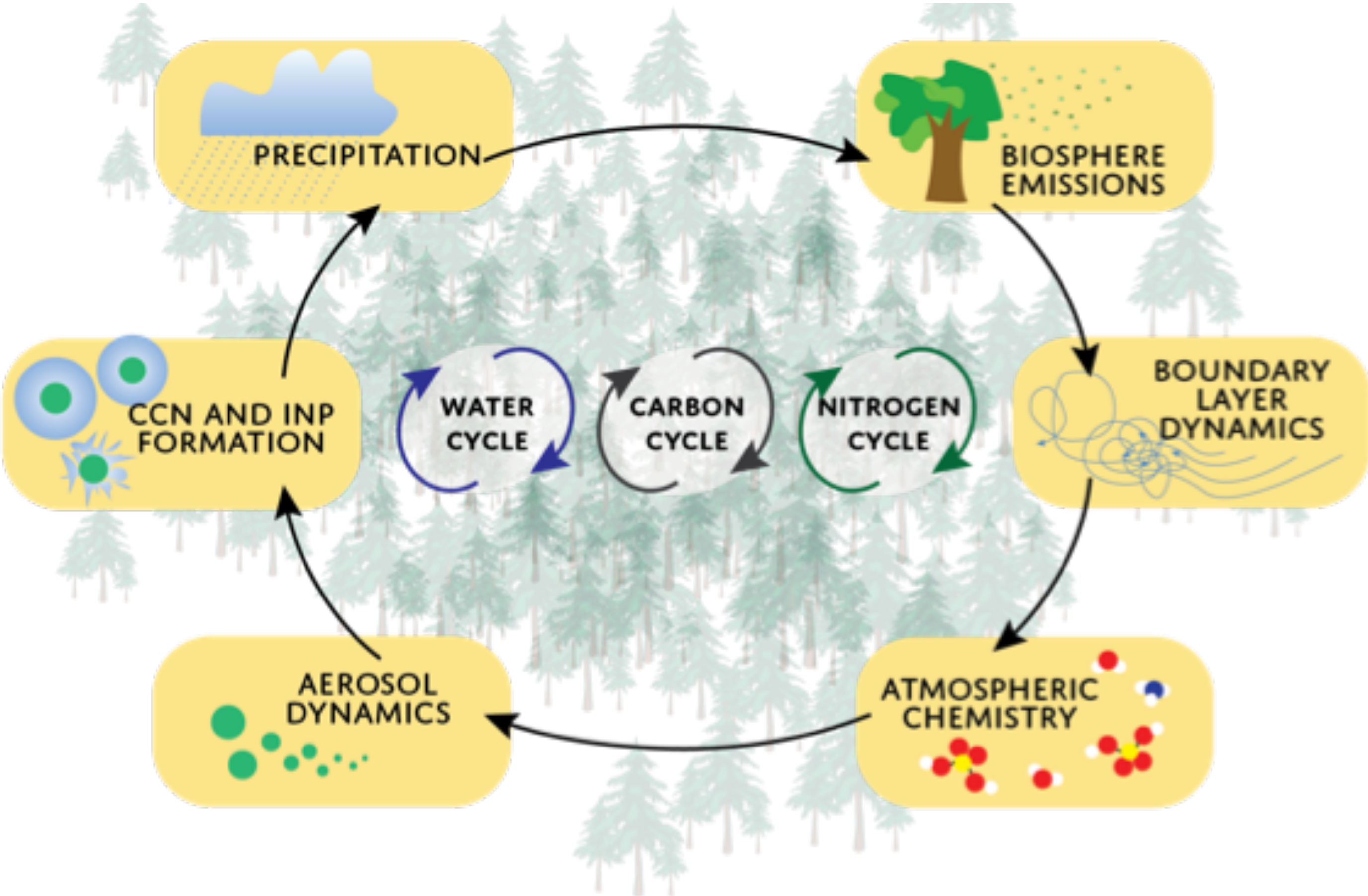
Petäjä, T. (2013) Science Plan Biogenic Aerosols – Effects on Clouds and Climate (BAECC), US Department of Energy, Office of Science, DOE/SC-ARM-13-024.

ARM
CLIMATE RESEARCH FACILITY

Biogenic Aerosols: Effects on Clouds and Climate (BAECC)

The **Atmospheric Radiation Measurement (ARM) Climate Research Facility** is a U.S. Department of Energy scientific user facility, providing data from strategically located in situ and remote sensing observatories around the world.

ARM Mobile Facility 2 in Hyytiälä, Finland, February 2014 – September 2014
Goal: To understand the impact of biogenic aerosol formation on cloud properties and climate
Tools: Aerosol Observing system (AOS), Balloon-borne sounding system, laser distrometer, micropulse lidar, microwave radiometer, high spectral resolution lidar, Scanning W-band and Ka-band cloud radars (SWACR, M-WACKR, Ka-band zenith radar (KAZR)
Principal investigator: Tuukka Petäjä, UHEL

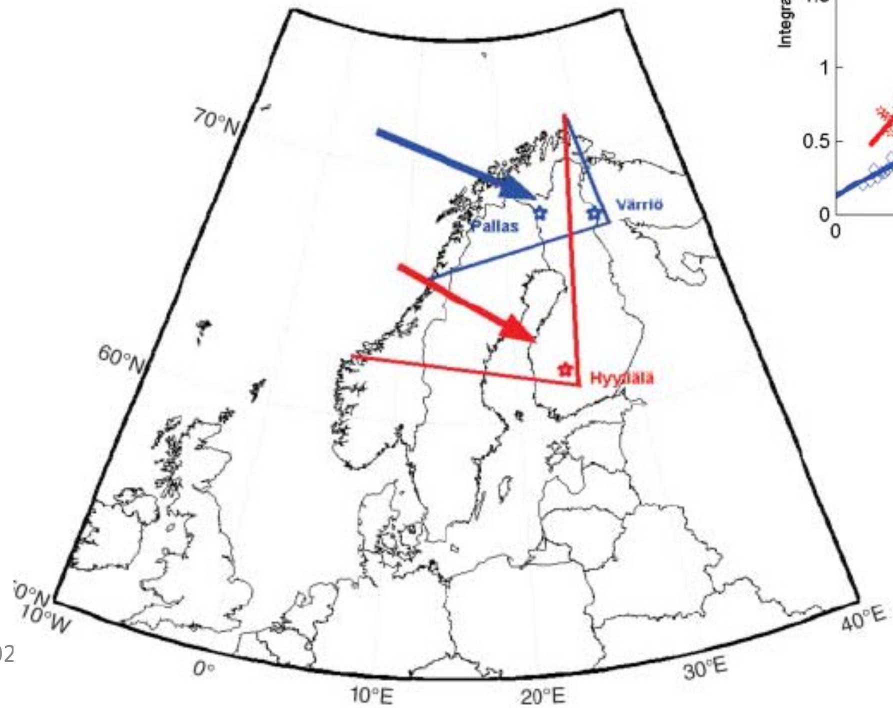


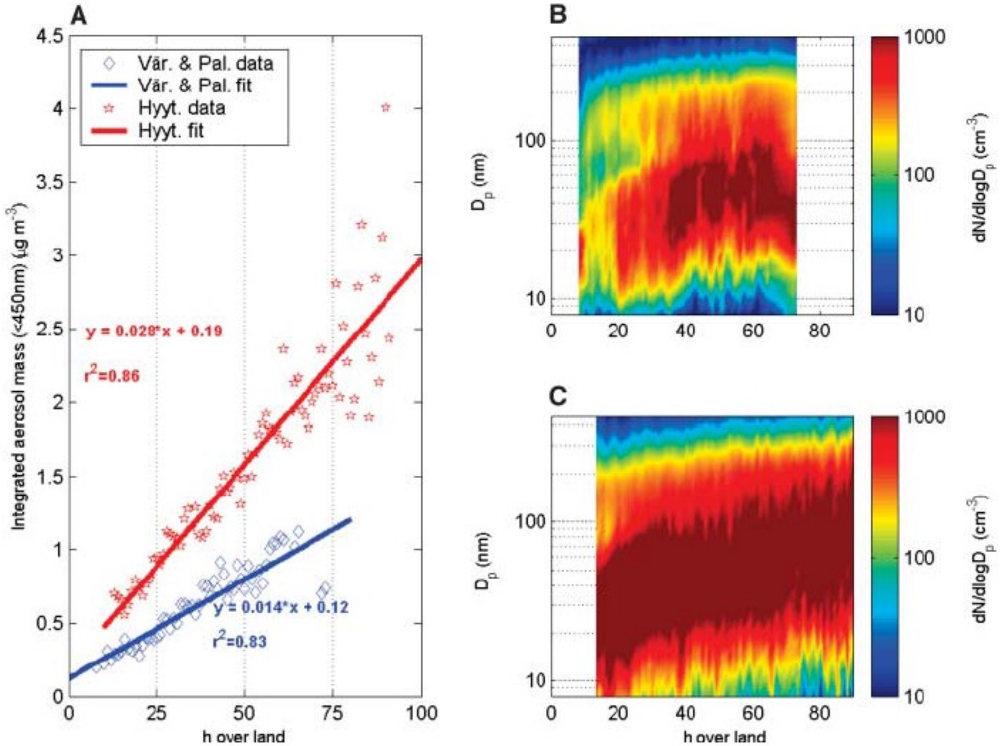
The key scientific questions:

- What is the minimum spatial scale of boreal forest that can produce its own clouds and thereby produce its own precipitation and modify the regional water cycle and sustain forest growth?
- Under which conditions is the water cycle self-sustained on the regional scale?

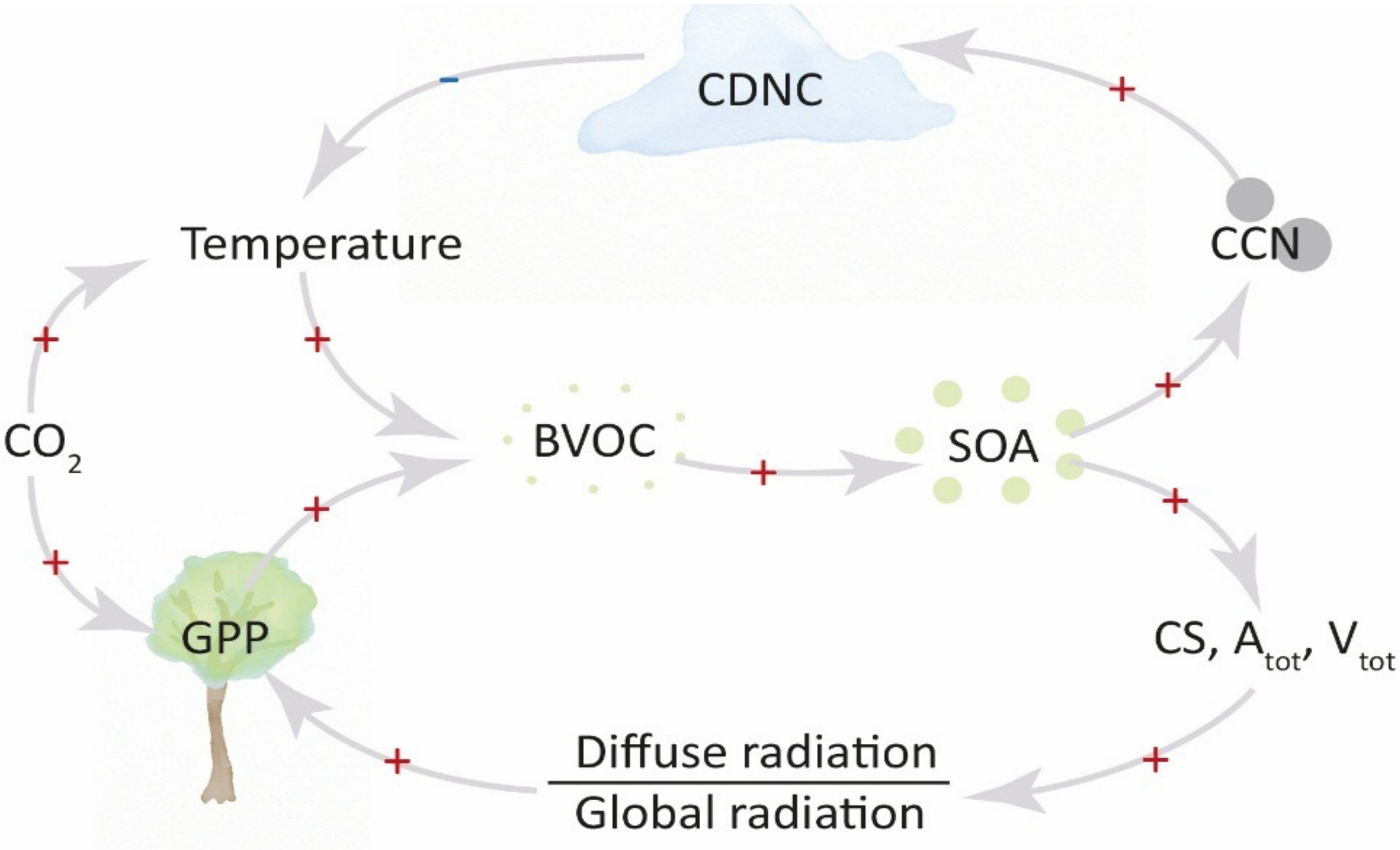
High Natural Aerosol Loading over Boreal Forests

P. Tunved,[1]* H.-C. Hansson,[1] V.-M. Kerminen,[2] J. Ström,[1] M. Dal Maso,[3] H. Lihavainen,[2] Y. Viisanen,[2] P. P. Aalto,[3] M. Komppula,[2] M. Kulmala[3]





CONTINENTAL BIOSPHERE–AEROSOL–CLOUD–CLIMATE (COBACC) FEEDBACK



BVOC=biogenic volatile organic compounds
SOA=secondary organic aerosol
CS=the condensation sink
A_{tot}=total aerosol surface area
V_{tot}=total aerosol volume
CCN=cloud condensation nuclei
CDNC=cloud droplet number concentration
GPP=gross primary productivity

Kulmala et al., 2014, BER

Development of Aerosol and Haze laboratory at BUCT

November, 2017

January, 2018

Feedbacks and interactions can slow down (negative) the change, or enhance it (positive).

These need to be verified against observations and monitored in a continuous, systematic manner.

ATMOSPHERIC SCIENCE

Clean the Air, Heat the Planet?

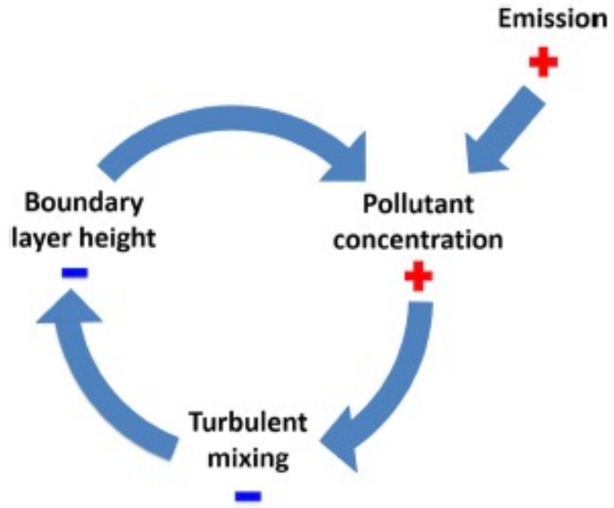
Almut Arneth,[1,2*] Nadine Unger,[3] Markku Kulmala,[2] Meinrat O. Andreae[4]

Science, 2009

SCIENTIFIC REPORTS

Enhanced air pollution via aerosol-boundary layer feedback in China

T. Petäjä[1,2], L. Järvi[1], V.-M. Kerminen[1], A.J. Ding[2], J.N. Sun[2], W. Nie[1,2], J. Kujansuu[1], A. Virkkula[2,3], X.-Q. Yang[2], C.B. Fu[2], S. Zilitinkevich[1,3,4,5,6] & M. Kulmala[1]

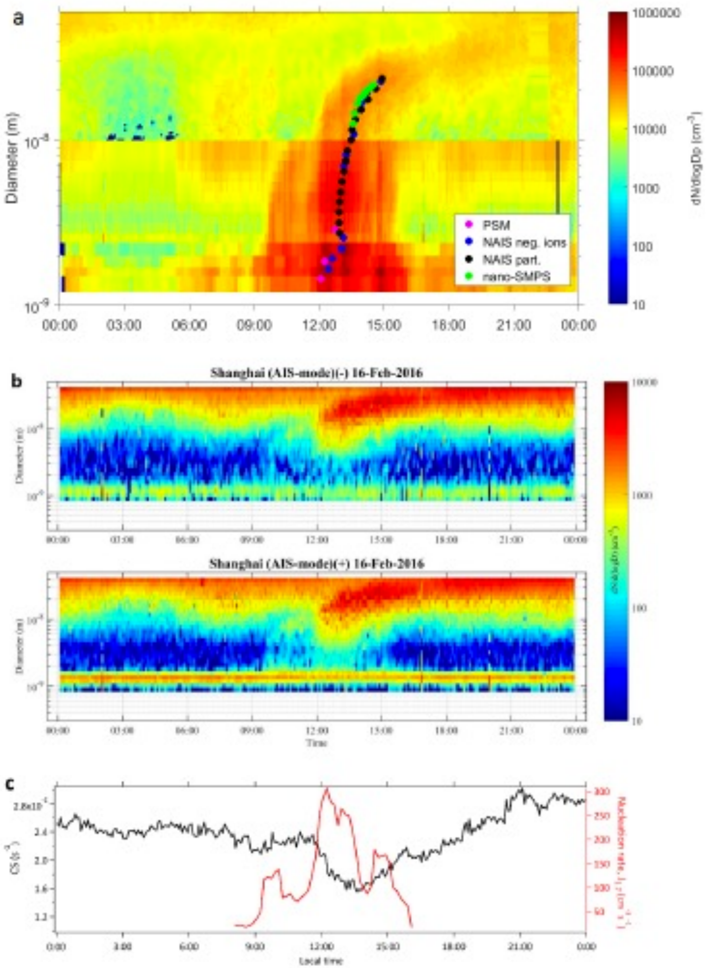


Example:

Control measures to improve air quality can reduce the amount of cooling sulfate aerosols.

Good for the health, bad for the climate.

Poor air quality episodes are amplified by the feedback mechanisms!



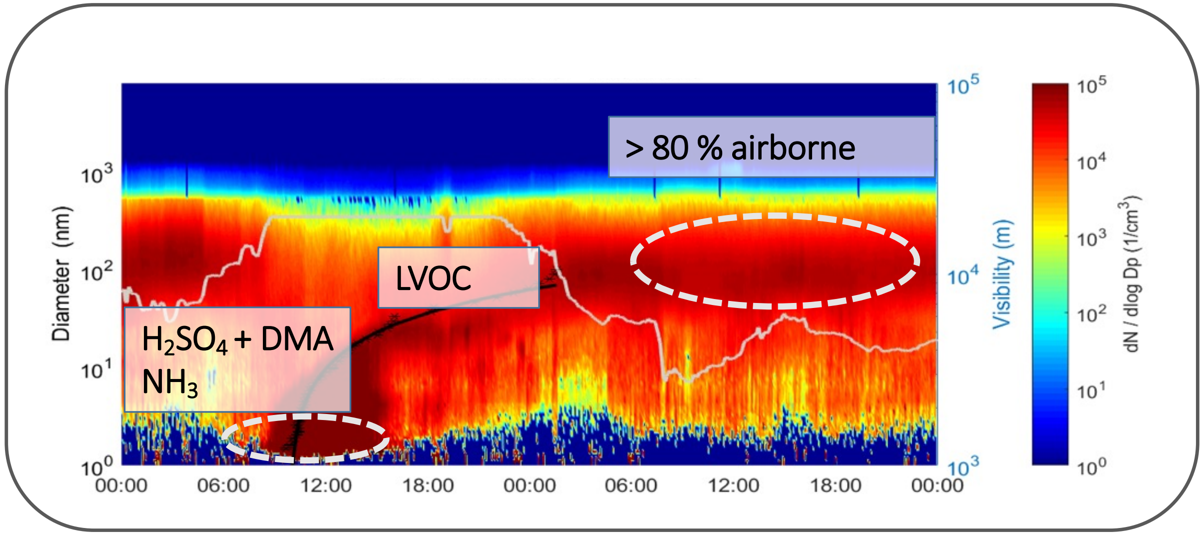
ATMOSPHERIC CHEMISTRY

Atmospheric new particle formation from sulfuric acid and amines in a Chinese megacity

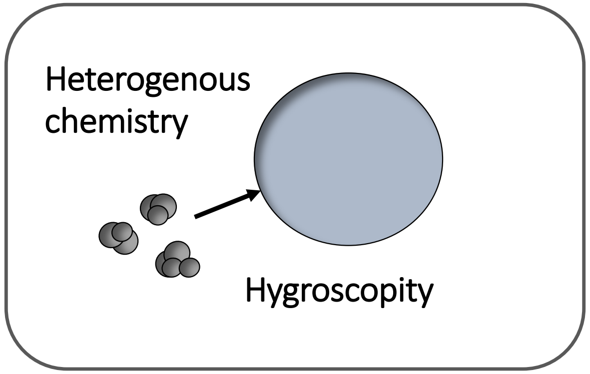
Lei Yao[1]*, Olga Garmash[2]*, Federico Bianchi[2,3], Jun Zheng[4], Chao Yan[2], Jenni Kontkanen[2,5], Heikki Junninen[2,6], Stephany Buenrostro Mazon[2], Mikael Ehn[2], Pauli Paasonen[2], Mikko Sipilä[2], Mingyi Wang[1]†, Xinke Wang[1], Shan Xiao[1]‡, Hangfei Chen[1], Yiqun Lu[1], Bowen Zhang[1], Dongfang Wang[7], Qingyan Fu[7], Fuhai Geng[8], Li Li[9], Hongli Wang[9], Liping Qiao[9], Xin Yang[1,10,11], Jianmin Chen[1,10,11], Veli-Matti Kerminen[2], Tuukka Petäjä[2,12], Douglas R. Worsnop[2,13], Markku Kulmala[2,3], Lin Wang[1,10,11,14]§

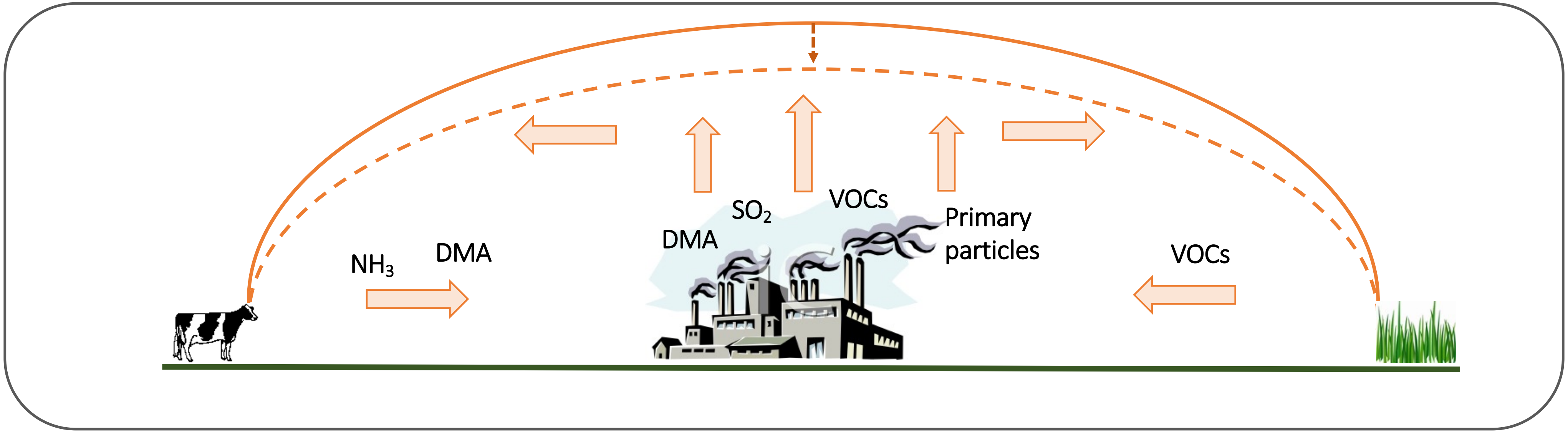
Trace concentrations of sulfuric acid, amines and condensable organic vapors control formation of new aerosol particles

Yao *et al.*, *Science* **361**, 278–281 (2018) 20 July 2018



SA + DMA mechanism: Lei Yao et al. 2018 Science





BLH - air pollution feedback: Petäjä et al., 2016, Sci Rep

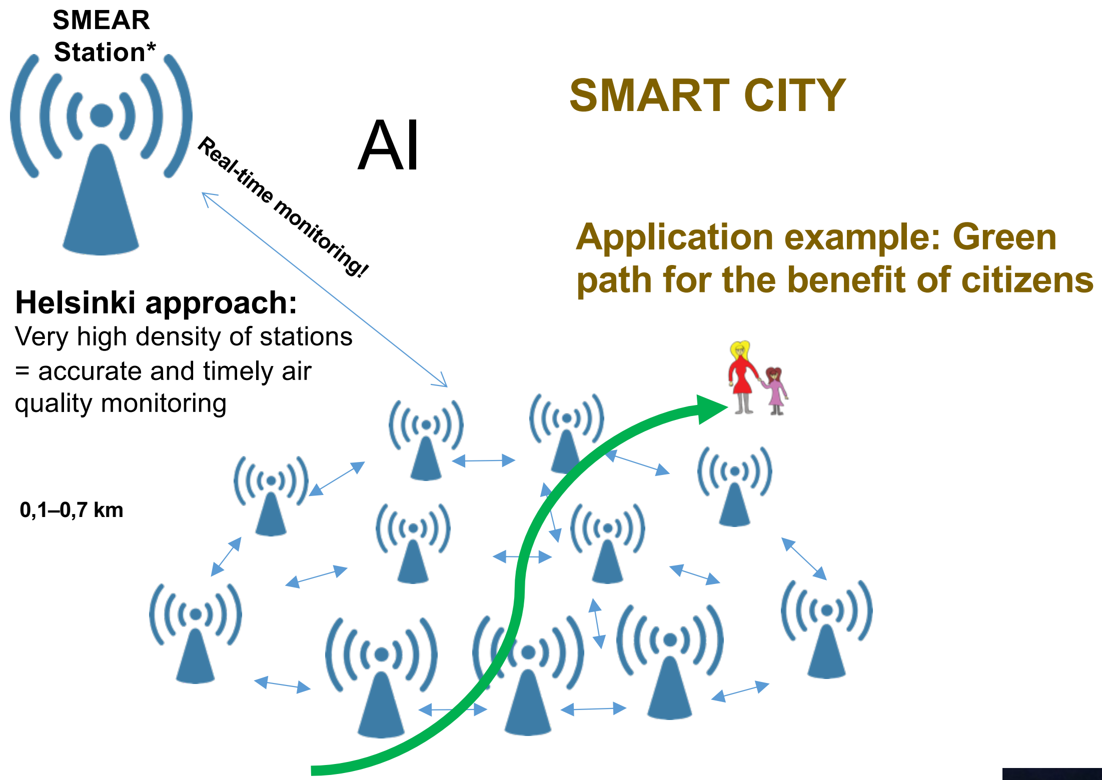
Kulmala et al., in prep.

HIGH DENSITY OF MEASUREMENT STATIONS & AUTOMATICALLY CALIBRATED SENSORS PROVIDING REAL-TIME MEASUREMENT DATA

- Low-cost mini- & micro-sensors and base stations across the environment supported by 4G NB-IOT network leading to a viable 5G service
- Field calibration by highly accurate atmospheric science SMEAR Station

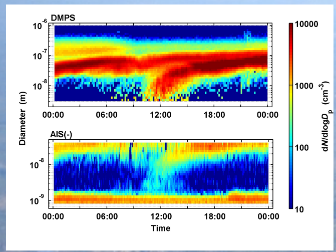
Enables multiple applications:

- City planning, health and wellbeing, wearable and fitness devices, vehicular technology, mobile apps, HD-maps
- High quality maps and calibration technique that takes into account correlations across environments.



Monitoring stations in urban and rural areas. Multiple ways to use sensors.

SMEAR* = Station for Measuring Earth Surface-Atmosphere Relations (SMEAR)
https://www.atm.helsinki.fi/SMEAR/



Main message:

1) **Commitment to comprehensive and continuous environmental observations**

2) **Continuous method development (instrumentation, models)**

3) **Active and open collaboration across various boundaries**

4) **Willingness to tackle and solve grand challenges together**

SMEAR II station
(boreal) 1995 -

https://www.helsinki.fi/en/inar-institute-for-atmospheric-and-earth-system-research

Thank you! Спасибо!

https://www.atm.helsinki.fi/peex

Vipuvoimaa
EU:lta
2014–2020

Euroopan unioni
Euroopan aluekehitysrahasto

Contact:
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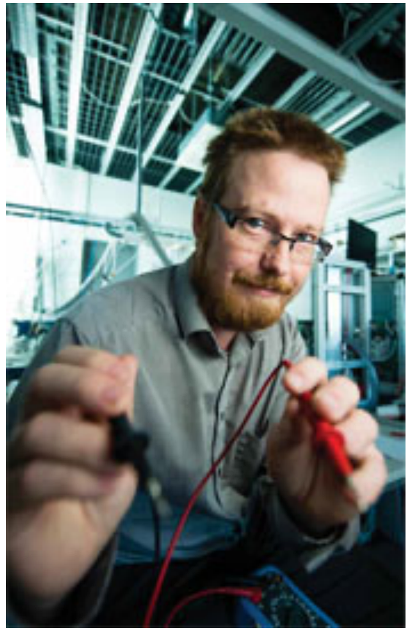
tuukka.petaja@helsinki.fi
+358 50 41 55 278

ACTRiS

Support from Academy of Finland, European Commission, Regional Council of Lapland, Helsinki-Uusimaa Regional Council, and Business Finland are gratefully acknowledged.

Prof. Tuukka Petäjä



- Full Professor of experimental atmospheric sciences
- Vice director of INAR institute
- Head of Aerosol laboratory, Head of SMEAR research infrastructure
- Pan Eurasian Experiment (PEEX) Science director
- over 480 peer reviewed publications, 19 in Nature or Science
- H-factor 73, total number of citations over 24 900
- Vaisala award for development of scientific instrumentation for nanoparticles and trace gases
- Thompson Reuters Highly Cited scientist since 2014
- Science and Technology in Society Future Leader, New York Academy of Sciences
- Academician, International Eurasian Academy of Sciences
- Research areas: 1) Aerosol-cloud interactions, 2) Development of mass spectrometric methods for atmospheric aerosols and trace gases; 3) Measurement techniques, aerosol particles; 4) Long-term and field campaigns; 5) Aerosol-cloud-climate-biosphere interactions;
- Cumulative personal research funding 7.0 M EUR, as a PI or co-PI 32.7 MEUR