# White Paper

FIRST INTERNATIONAL SYMPOSIUM ON

## SecoNdary Aerosol FormatioN and GrOwth-2023 (NANO-2023)


University of Hyderabad, INDIA

and

Finnish Meteorological Institute, FINLAND


प्रतिष्ठित संस्थान

INSTITUTION OF EMINENCE

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## Content:


## Executive Summary

Aerosols are tiny solid or liquid particles suspended in the atmosphere. Aerosols are either directly emitted into the atmosphere (referred to as primary aerosols) or formed in the atmosphere through chemical and/or physical transformation (secondary aerosols). Over the last three decades, much has been learned about atmospheric aerosols impact on weather and climate. In recent decades, it is becoming clear that aerosols not only impact weather and climate but also severely affect human health, air quality, fauna-flora, and water and food supply. Atmospheric aerosols influence climate; directly by scattering and absorbing solar radiation and indirectly by altering cloud properties via cloud condensation nuclei (CCN) activation, and thus perturb Earth’s radiative budget and hydrological cycle. While aerosols direct effects are sufficiently characterized, aerosol-induced changes in cloud macro- and micro-physical properties are still inadequately observed and utilized comprehensively in global climate models to make reliable future climate predictions. For India, the World Health Organisation (WHO) estimated about 1 million deaths in the year 2016 alone due to long-term exposure to ambient particulate pollution. Thus, aerosols have a critical importance.

# Need for National and International collaboration

Air pollution is a transboundary problem and a subject of local-to-global scale concern. Industrialisation and urbanisation, which are an integral part of a country's economic and infrastructure development in rapidly developing countries such as India and China, bring in its wake a number of challenges like an increase in the population of urban settlements, increase in construction activities, increase in energy demand, and increased vehicular movement, all of these cause increased pollution in the atmosphere (Martin et al., 2019). The Indo-Gangetic Plain (IGP) is one of the major global hotspots of the highly aerosol-laden environment with a complex mixture of local and regional-scale emissions (Hyvärinen et al. 2010, Hooda et al., 2016; Gani et al., 2019; Kanawade et al., 2020). Numerous studies have used in-situ measurements, satellite data, model reanalysis products, and modelling approaches to examine spatio-temporal variability of continental air pollution in India (Tripathi et al., 2006, Srivastava et al., 2012, Gaur et al., 2014, Babu et al., 2016, Wang et al., 2018, Guttikunda et al., 2019, Ravishankara et al., 2020, Vadrevu et al., 2020, Gunthe et al., 2021, Singh et al., 2021, Varaprasad et al., 2021, Mhawish et al., 2022, Shrivastava et al., 2017). But, the associated complexity and nonlinearity of aerosol processes in inaccurately presented in current models. Thomas et al. (2021) showed about a 10-25% reduction in aerosol loading over the IGP during COVID-19 enforced lockdown resulting in a 20-25% reduction in aerosol-induced radiative forcing over the IGP outflow region of the Bay of Bengal. This demonstrates the significant influence of IGP pollution outflow onto the Bay of Bengal and coastal regions further south. Another study also showed that the rate of increase in the number of hazy days is faster in southern peninsular India than in IGP (Thomas et al., 2019).

Haze formation and aerosol-climate interactions depend on the particle size distribution and its dynamical changes (Huang et al. 2014, Kulmala 2015). Atmospheric gas-to-particle conversion is a crucial or even dominant contributor to haze formation in Chinese megacities in terms of aerosol number, surface area, and mass, and the haze formation was faster when the subsequent growth of newly formed particles was enhanced (Kulmala et al., 2021).

Furthermore, for Chinese cities, their work also suggested that in practice almost all present-day haze episodes originate mainly from newly formed particles, since the direct emission of primary particles in Beijing has considerably decreased during recent years, but this could be different in India. Nonetheless, based on over one-year measurements in China, it was recommended that reducing the subsequent growth rate of freshly formed particles by a factor of 3–5 would delay the build-up of haze episodes by 1–3 days.

For Delhi's recent two studies, one by Mishra et al., (2023) demonstrated that the primary nanoparticles grew rapidly at night in Delhi driven by the physical condensation of fresh organic vapours from biomass burning, with sizes growing quickly into those relevant to the haze formation, and another of Gunthe et al. (2021) showed that high aerosol liquid water content offers an aqueous phase into which chloride can partition leading to aerosol growth in Delhi.

As concluded for Chinese cities, the understanding of new particle formation (NPF) (Kulmala et al., 2003; Zhang et al., 2010) in the context to control air pollution episodes in Indian cities is inevitable. NPF comprises a complex set of microphysical processes including the formation of nanometer-size clusters (1-2 nm) from gaseous vapours, the growth of these clusters to detectable size (nucleation mode, less than 25 nm), and the removal of growing clusters by coagulation with the pre-existing aerosol particle population (Kulmala et al., 2013). The survival probability of growing clusters in the atmosphere is often higher than their scavenging by pre-existing particles eventually surviving to grow to CCN-active sizes, and thereby can significantly contribute to the total aerosol mass.

There are several gaps in understanding the role of NPF, primary emissions, and secondary aerosol formation on the deteriorated air quality in India. Firstly, the chemical mechanisms responsible for NPF have not been explored in India due to the unavailability of state-of-the-art instrumentation for the quantification of gas- and particle-phase compounds. Secondly, the particle sizes of primary anthropogenic aerosol emissions applied in air quality as also in India are most probably drastically overestimated (Kontkanen et al., 2020, Hakala et al., 2022). Thirdly, the growth of sub-30 nm particles, originating from NPF and anthropogenic primary emissions, to sizes large enough to act as CCN and form haze, is not quantified and the particle-phase processes are not known (Paasonen et al., 2018). In fact, there are a scanty number of studies on secondary nanoparticle formation and growth in the entire Indian literature (Kanawade et al., 2022). Therefore, secondary aerosol formation and growth have received growing attention in recent decades, particularly in India, with their implications for air quality, human health, weather, and climate.

Based on all the above, there is an evident need to simultaneously entangle the air pollution and climate change challenges in India, and the need of considering the complex nature of air pollution and climate from local, regional to a global scale. Furthermore, given the large geographical extent of India with varying environments and climatic zones, it is evident that there is a need for National and International collaboration for a consolidated determination of aerosol effects over India.

With this motivation, however, an initiative is already established between the University of Hyderabad, India and the Finnish Meteorological Institute (FMI), Finland through signing a Memorandum of Understanding (MoU) in 2020 to collaborate in the areas of the above-said research domain. Furthermore, the Indian Institute of Technology Madras, India and FMI Finland also signed a MoU in 2022 to work together in the areas of process-level understanding of secondary aerosol formation and growth utilizing observation-constrained regional computational simulations. Recently, the Indian Institute of Technology Delhi, India and the University of Helsinki, Finland has signed a MoU in 2023 to strengthen capacity and support for air pollution studies in one of the global hotspots region (IGP).

With growing concern for the Government of India and of Conference of Parties (COP) discussions over the years and geo-political situations, the demand for process-level understanding of the climate change problems and a sustained open discussion on the needed technological solutions to the envisaged local to regional problems is a must. To provide a platform for India's Nationally Determined Contributions (NDCs) for climate change implications in India to the United Nations Framework Convention on Climate Change through the process-level understanding of the aerosol phenomenon and local processes, an international symposium on atmospheric aerosols and related topics was proposed to be organized annually with a consortium of leading academic and research institutions in India and abroad.

## NANO objectives

University of Hyderabad, India and Finnish Meteorological Institute, Finland organised the First International Symposium on "Seco**N**dary **A**erosol Formmatio**N** and Gr**O**wth **2023** (**NANO-2023**)" during 13-14 March 2023. The first Symposium of the proposed annual series was hosted by the Centre for Earth, Ocean and Atmospheric Sciences, School of Physics, University of Hyderabad. The symposium covered broadly the following three themes:

- Secondary aerosol formation and growth
- Measurement techniques and modeling for nanoparticles
- Implications to air quality, human health, and climate change

# NANO outcomes and the way forward

NANO-2023 organised different sessions to brainstorm and identify gaps in understanding the role of secondary aerosol formation on air quality, human health, and climate in India. The idea is to determine the objectives of future studies (up to 2030 and beyond) and maximize the impactful results through national and international collaborations. The main thrust areas to focus should be on the effect of air pollution on human health through exposure-response understanding for the indigenous population, applications of quantum powered simulations for actionable steps to mitigate climate change, and better earth system models for low uncertainty predictions of the climate system and an integrated approach for climate change-air quality-human health through potential research partnerships.

The following are the major recommendations given based on discussions at NANO-2023:

1. Create a network linked to the existing efforts of DST (*Network on Climate Change and Aerosol*), MoES (*Atmospheric Research Test Bed in Central India, Cloud Aerosol Interaction and. Precipitation Enhancement Experiment, Winter Fog Experiment*), MoEF&CC (*National Clean Air Programme, National Carbonaceous Aerosols Programme*), Health Ministry, and International collaborations for capacity building, and perpetual hosting and dissemination of field observations, laboratory experiments, emission inventory datasets, and climate modelling initiatives.

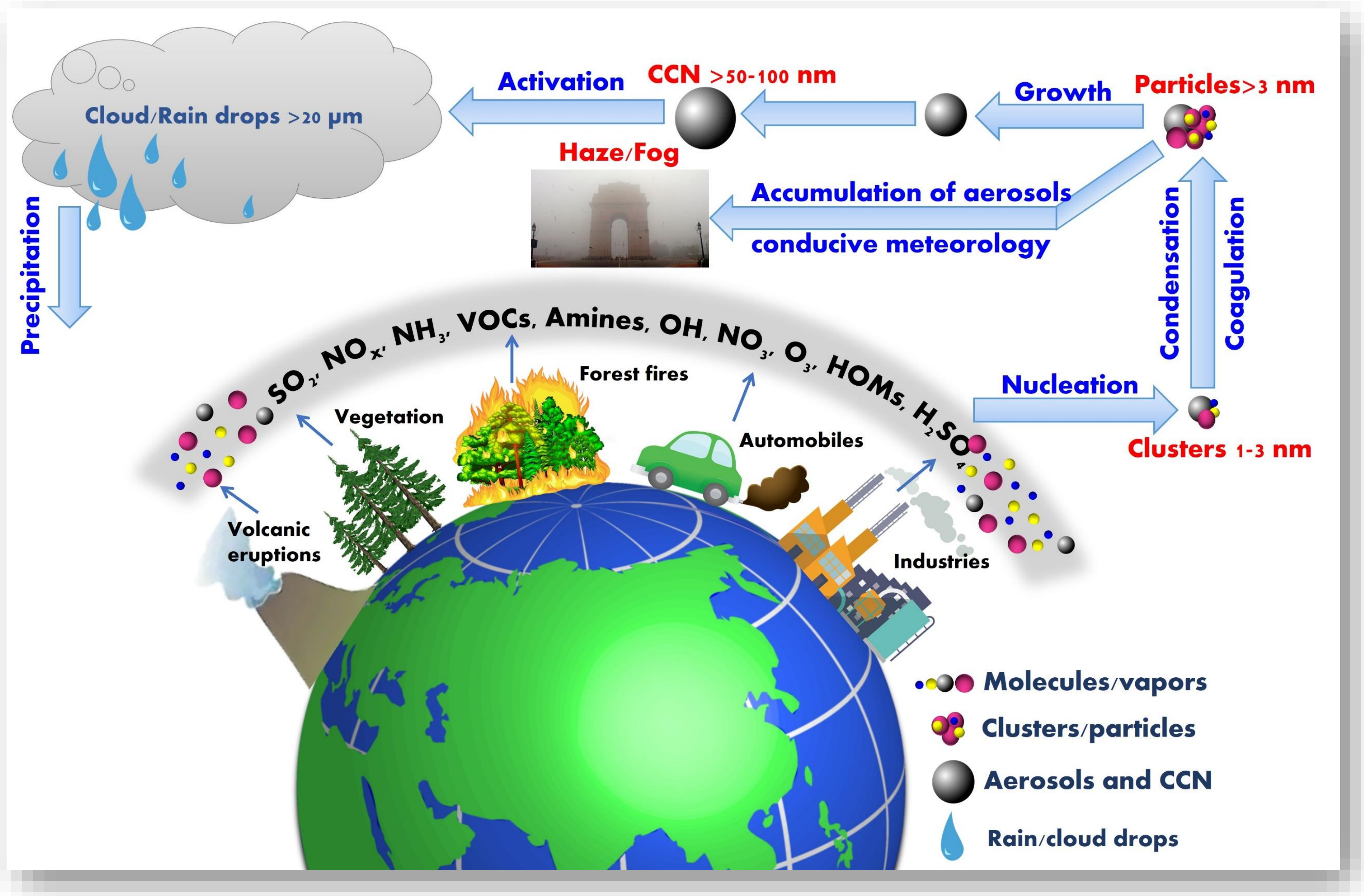
2. Dedicated efforts to measure aerosol metrics (number concentration, emission rate, and size distribution) to reduce current uncertainties in governing equations of aerosol chemical and/or physical transformation processes in the models.

3. Developing adequate capacity for aerosol phenomenon and key process level studies and encouraging synergy between observations and modelling research, with the application of machine learning or deep learning techniques.

4. Developing modeling capacity to include the likely importance of biomass burning secondary organic aerosol (SOA) formation and aqueous chemistry in fog in the current models to reduce uncertainties to accurately predict future climate sensitivity to greenhouse gases.

5. Dedicated continuous long-term measurements of aerosol, its precursors and meteorology, and understanding of various feedback mechanisms (through multi-site, multi-instrument, and stationary and/or mobile platform) for model development to quantifying the contribution of primary and secondary aerosols and analysing the impact on air quality, human health, Earth's radiation budget, and hydrological cycle.

6. Development of indigenous gas/aerosol chemistry transport model in conjunction with campaign-based observations and chamber studies to be coupled with the General Circulation Model or Regional Climate Model with a focus on aerosol microphysical behaviour (nanometer to tens of micrometer size range) in the atmosphere which has critical importance to human health, air quality, weather, and climate.

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***Participants of NANO-2023 symposium at Dr. Zakir Husain Lecture Hall Complex, University of Hyderabad, India during 13-14 March 2023***

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