High altitude cloud physics laboratory (HACPL)

Ice Nuclei Concentration Measurements and Characteristics at High Altitude station in India

SPIN

- SPIN (Spectrometer for Ice Nuclei), is a continuous flow diffusion chamber (CFDC) (Rogers, 1988), having parallel plate geometry.
- Counting ice nuclei by exposing the aerosol particles to controlled temperature and RH conditions.
- Temperature can vary from -25 to -45 °C.
- SS_{ice} can vary from 0 to 50 %.
- Consist of a parallel plate chamber, coated with thin layer of ice (1 mm).
- A temperature difference between plate leads to supersaturation condition with respect to ice between the two walls.
- Aerosol are allowed to pass through the chamber at a narrow range temp. and SS at which nucleation can take place.

Instrument performance valuation

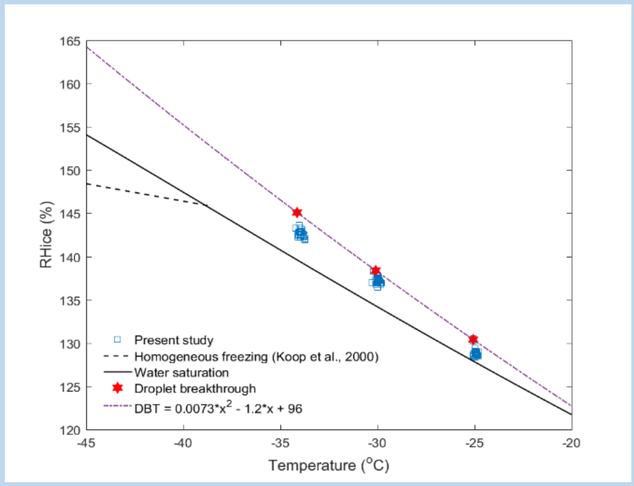


Figure 1: Result obtained from droplet breakthrough experiment. Red star displays the droplet breakthrough limit obtained at different temperatures, blue squares are the points where ice nucleation experiments conducted.

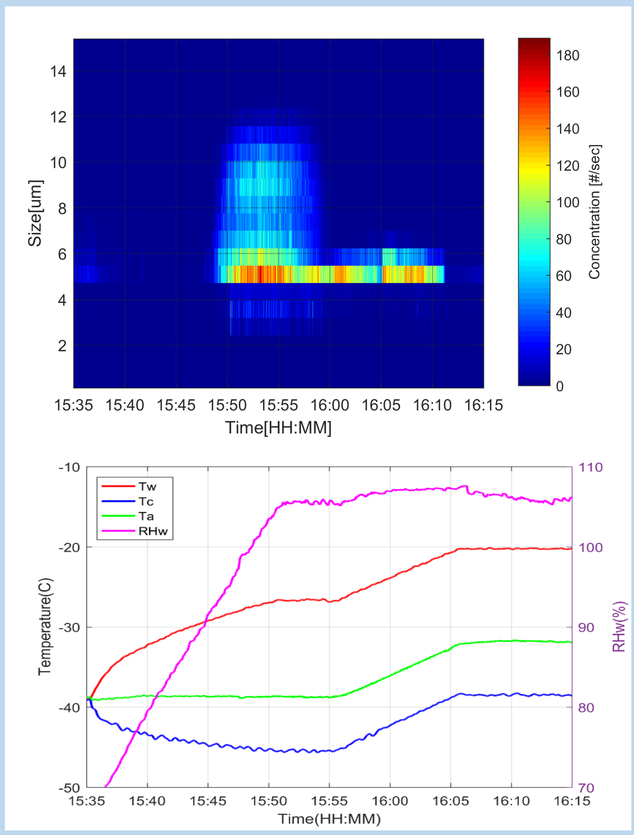


Figure 2: Top panel shows the particle number concentrations in different size bins of SPIN OPC. Temperature and supersaturation with respect to water inside the SPIN chamber(bottom panel). RH_w initially increased up to 106% at -39°C (below homogeneous freezing temperature), observed ice formation when RH_w crossed 100%. Then keeping RHw at 106% and increasing the temperature to above -37°C, upper threshold temperature for homogeneous freezing (Pruppacher and Klett, 1997), leading to the disappearance of ice.

Motivation

- Prediction of ice nuclei (IN) in cloud models is challenging.
- The main reason for this uncertainty is the lack of understanding as only few observations from different regions exist. Also different ice nucleation pathways through which the ice particles are formed in the atmosphere.
- More observations of natural airborne ice nuclei at different environmental conditions are required to parameterize for models (Hoose and Mohler 2012) .

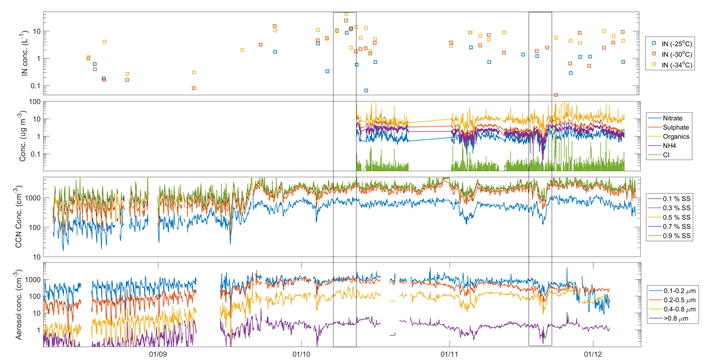
Objective

- **To measure and characterize the ambient ice nucleating particles (INP).**
- **To investigate the factors that favours the activation of IN.**
- **To study the aerosol properties (physical and chemical) affecting IN activation.**

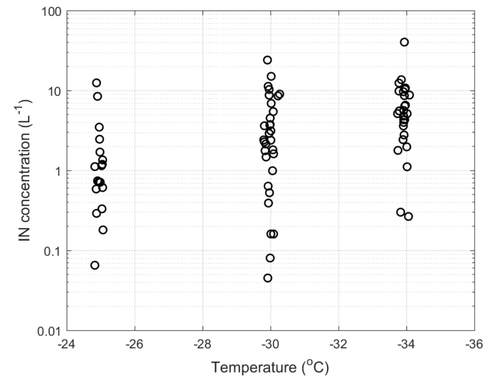
Instrumentation

- Concentration of ice nuclei was measured with Spectrometer for Ice nuclei (SPIN).
- Aerosol size distributions are simultaneously measured using a SMPS.
- Time of Flight-Aerosol chemical speciation monitor (ToF-ACSM; Aerodyne), utilized to obtain the chemical composition of non-refractory particulate matter.
- The CCN counter was configured to operate at five different supersaturations, 0.1, 0.3, 0.5, 0.7 and 0.9 %.
- A 3 stage MOUDI cascade impactor (MSP Corp. 125-NR) was used to collect aerosol particles of size between 0.1 and 0.56 µm, on to a carbon filter, for elemental and morphological analysis by Scanning Electron Microscope (SEM).

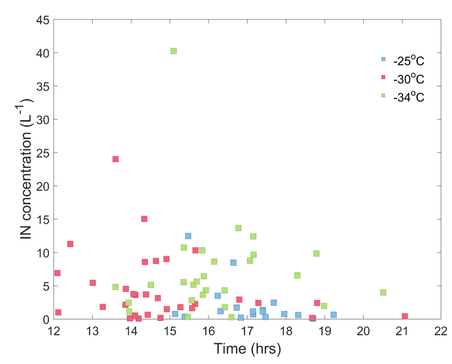
Results



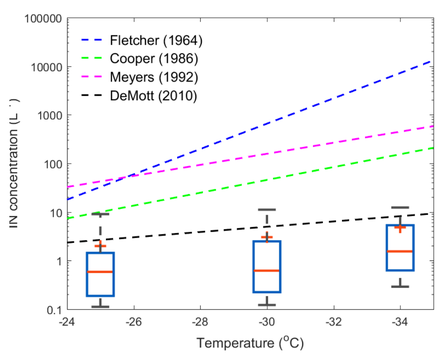
a) Time series of 1) IN concentration at three temperatures, 2) mass concentration of aerosol chemical composition (nitrate, sulphate, organics, NH4 and Cl), 3) CCN concentration at different supersaturation (0.1, 0.3, 0.5 0.7 and 0.9 %) and 4) concentration of aerosol at different sizes.



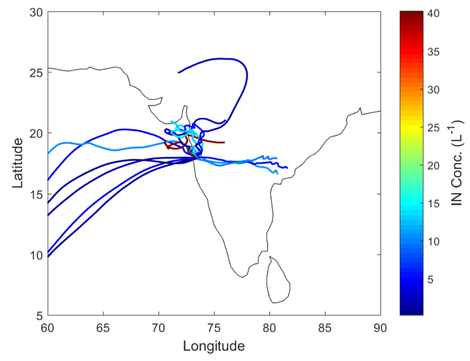
b) IN concentration measured at different temperatures -25 °C, -30 °C and -34 °C.



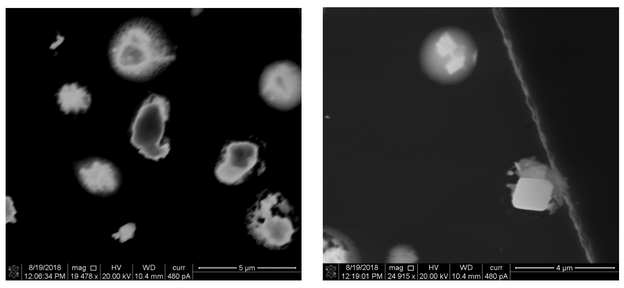
c) Variation of IN concentration with time, higher concentration observed during afternoon.



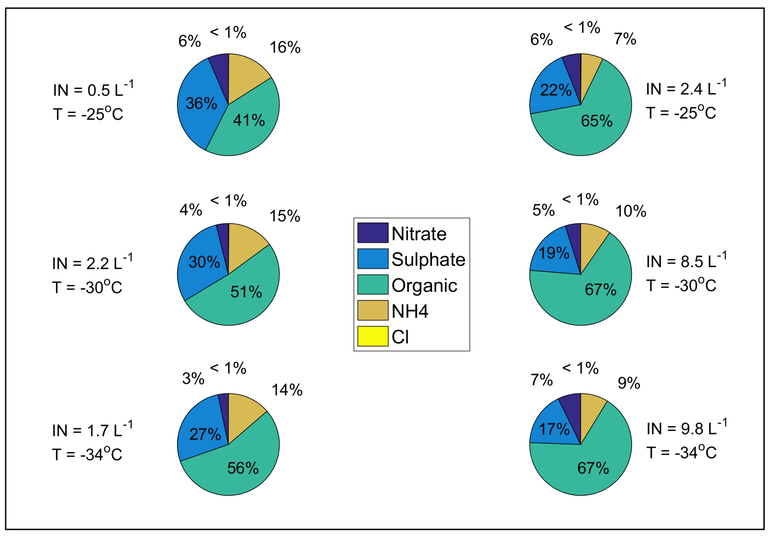
d) Comparison of measured IN concentration with other ice nuclei schemes



e) 5 day air mass back trajectory ending at the site using HYSPLIT data, continental air mass contains more IN.



f) A sample scanning microscope image of aerosol particles measured from the site.



g) Aerosol NR-PM1 inorganic and organic mass composition during low and high ice nucleation period for all temperatures.

Results

1) **This is the first study in India, utilizing CFDC for measuring IN online.**
2) **Average IN concentration observed is 4.8 L^{-1} ± 6.04 L^{-1}.**
3) **Higher IN concentration observed when aerosol particles > 0.2 µm is present.**
4) **Continental air mass contains more IN than in maritime air mass.**
5) **Our observation found match with DeMott (2010) parameterization of IN.**
6) **The concentration of IN was found to increase with decreasing temperature.**
7) **Exemplary images of diverse aerosol types observed at the site.**
8) **Higher IN concentration observed during afternoon than in the evening.**
9) **Ice nucleating ability of the particle seems to reduce if particles are coated with inorganic species such as sulfate and nitrate.**
10) **Significant variation in nucleation behavior is observed with the changes in aerosol chemical composition.**
11) **The large variability in IN concentration may be depending on its various origin, chemical composition, transportation and ageing processes.**

T	Size resolved aerosol concentration v/s IN concentration			
(°C)	< 0.5 µm	> 0.5 µm	< 0.2 µm	>0.2 µm
-25	0.01	0.13	0.04	0.5
-30	0.01	0.07	0.04	0.62
-35	0.02	0.21	0.1	0.52

Table 1: Correlation coefficient (R^2) between IN concentration measured at different temperatures and size segregated aerosol concentration.

(Anil et al., Manuscript under preparation)