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National Institute of Meteorological Sciences

Introduction of Developmental Techniques for Large dynamic Wall-based Double Structure Cloud Chamber in Korea

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Contents

1. Introduction

The first high-performance large double-structure cloud physics experiment chamber with dynamic wall temperature control in Korea

– (Temperature) -70 to 60°C, (Pressure) 1,013 to 30 hPa, (Humidity) 0.1 to over 95%

* The world's first copper-stainless steel dual-structure chamber built to maximize thermal efficiency

Cooling tower & Condenser

Aerosol Chamber

Wind Miller, Furnace

Fine particle collector

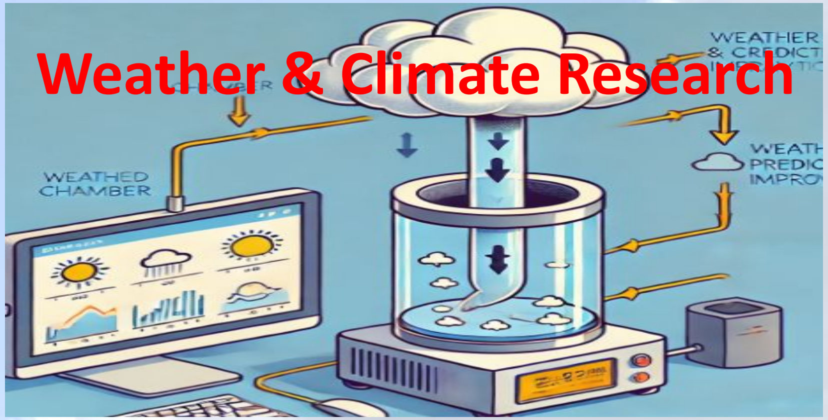
Cloud Chamber

Vacuum-thermal conductivity material Control system

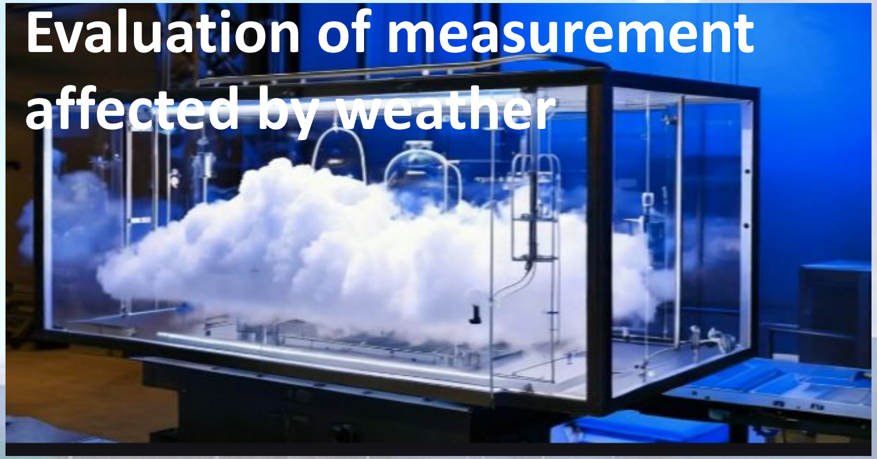
- We constructed a Cloud chamber, Aerosol chamber, wind miller, and Furnace in 2022
- K-CPEC are continuously upgrading the cloud chamber until now.

Multi-purpose Cloud Chamber

1.Disaster Response: Fundamental technologies for mitigating droughts, wildfires, and dense fog using weather modification.



2.Weather/Climate: Latest cloud microphysics processes for improving weather and climate forecasting technologies

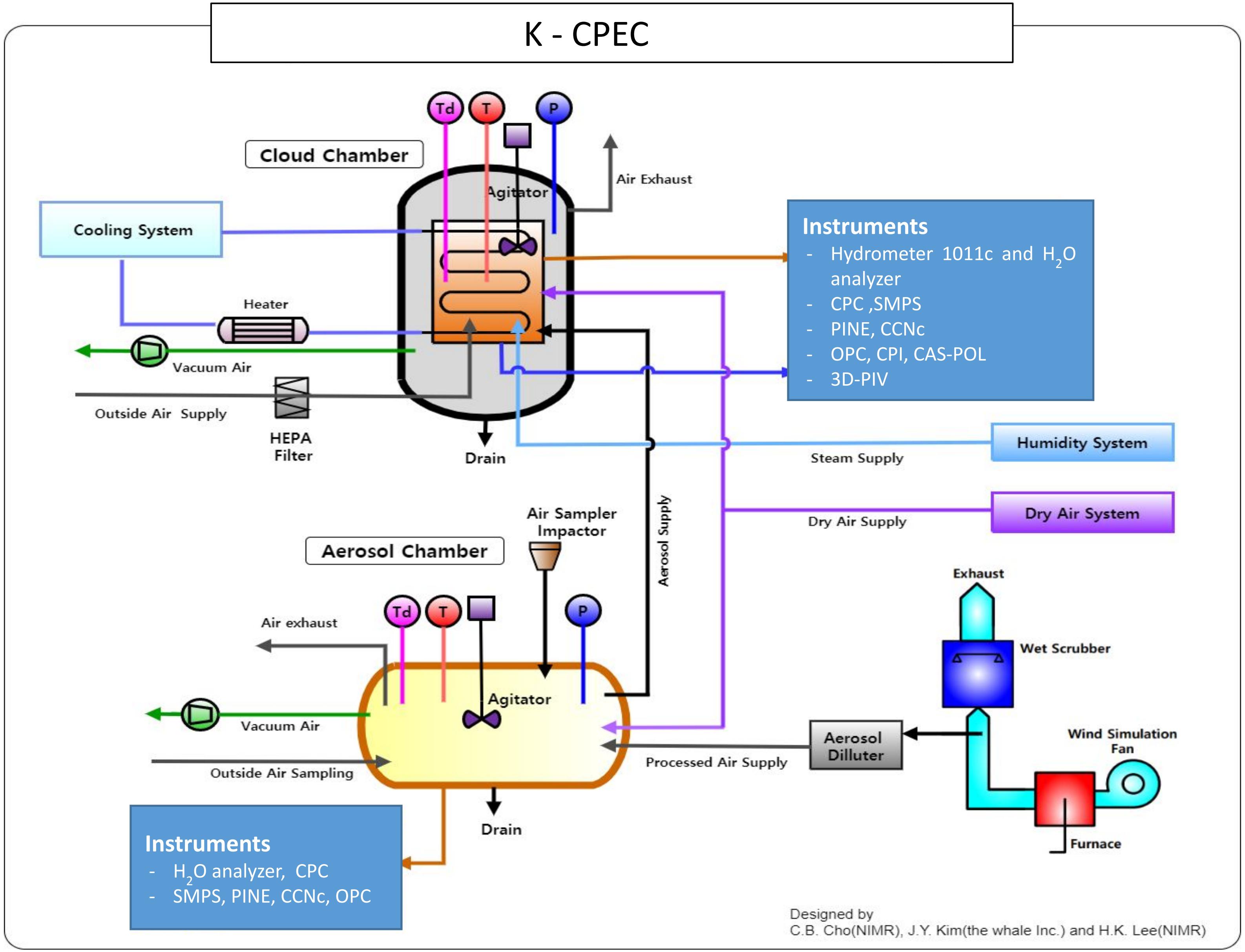


3.Industry: A performance evaluation technologies for weather observational equipment in cloud and rainfall observation fields

4.Environment: Microphysical basic technologies for understanding the causes of hazardous weather conditions such as fine dust event, black ice on a high way, and aircraft icing

Design of K-CPEC

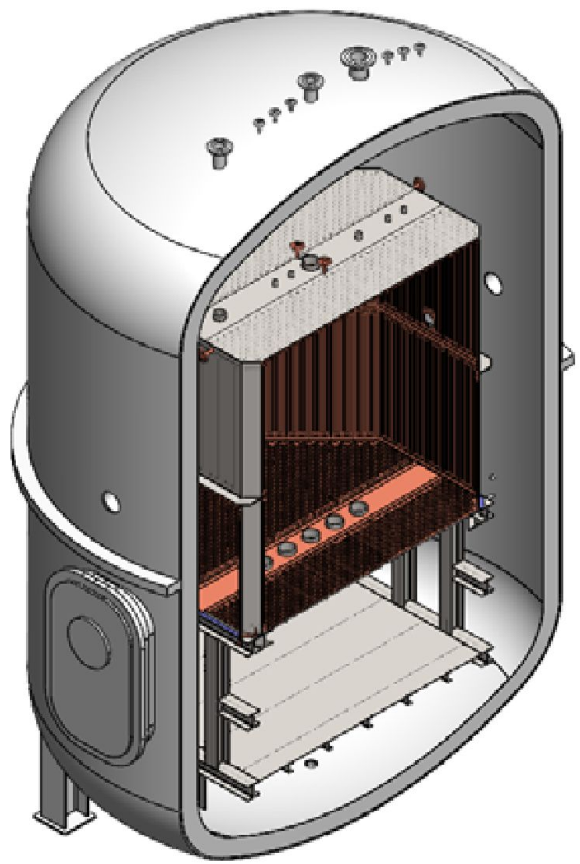
Design of K-CPEC



- The K-CPEC design integrates two main chambers: the **Cloud Chamber** and the **Aerosol Chamber**, working in tandem for comprehensive atmospheric research.
- The Cloud Chamber features can control temperature , humidity , pressure, and various instruments for particle analysis.
- The Aerosol Chamber is equipped with similar instruments and connects to cloud chamber and a combustion system.
- This setup, including a furnace and wind simulation, enables controlled experiments on aerosol reaction, cloud processes, and weather modification

Basic structure of K-CPEC

- Cloud chamber of K-CPEC is designed as an **adiabatic expansion type cloud chamber** and has the ability to adjust wall temperatures dynamically to minimize moisture flux from the warmer and ice-coated chamber wall.
- Cloud chamber of K-CPEC has a large volume compared to other expansion type cloud chambers with dynamic walls.

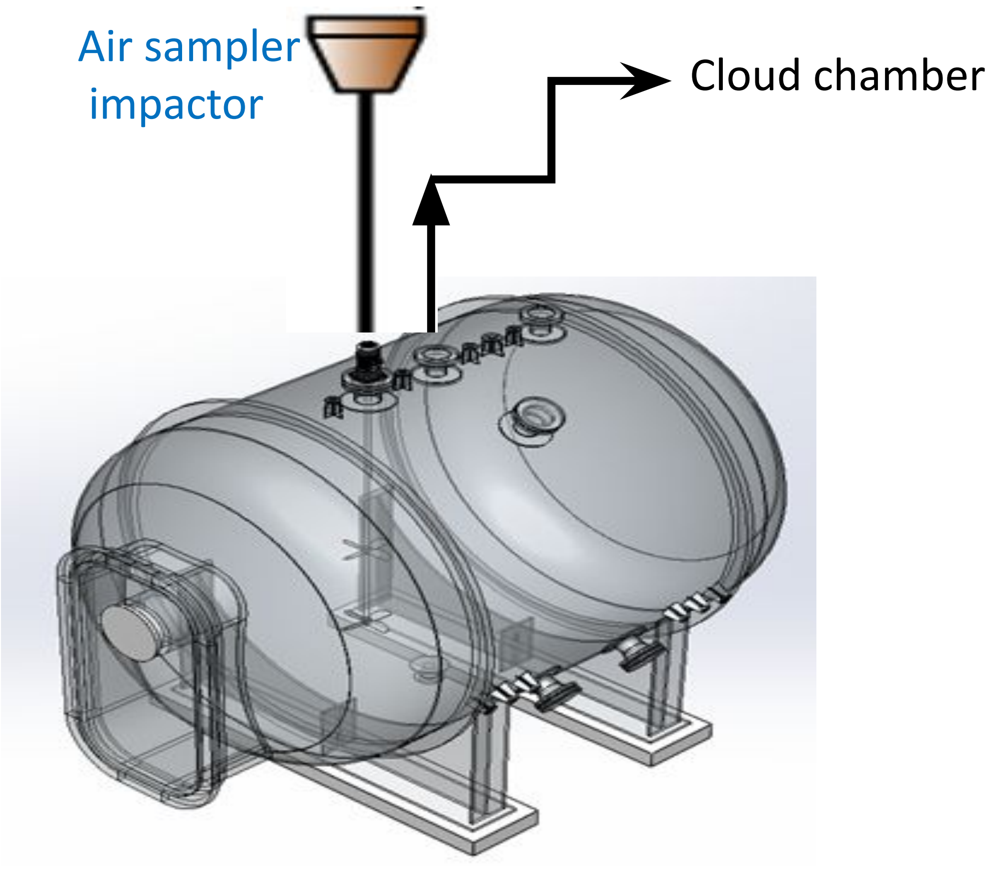


Cloud Chamber

Size	Outer chamber	5 m x 5 m
	Inner chamber	3 m x 3 m
Shape	Outer chamber	Cylinder
	Inner chamber	Octagonal prism
Volume	Inner chamber	21 m^3
Material	Outer chamber	Stainless steel
	Inner chamber	Copper (Cu) / Stainless steel
Temperature range	Range	60 to -70℃
	Static stability margin	≤±0.3℃
	Dynamic stability margin	≤±0.5℃
Pressure range	Range	1,013 to 30 hPa
	Margin of error	≤± 0.3 hPa
Heating/cooling time		≤ 45 min (-70 to 60℃) ≤ 45 min (60 to -70℃)

Basic aerosol chamber structure of K-CPEC

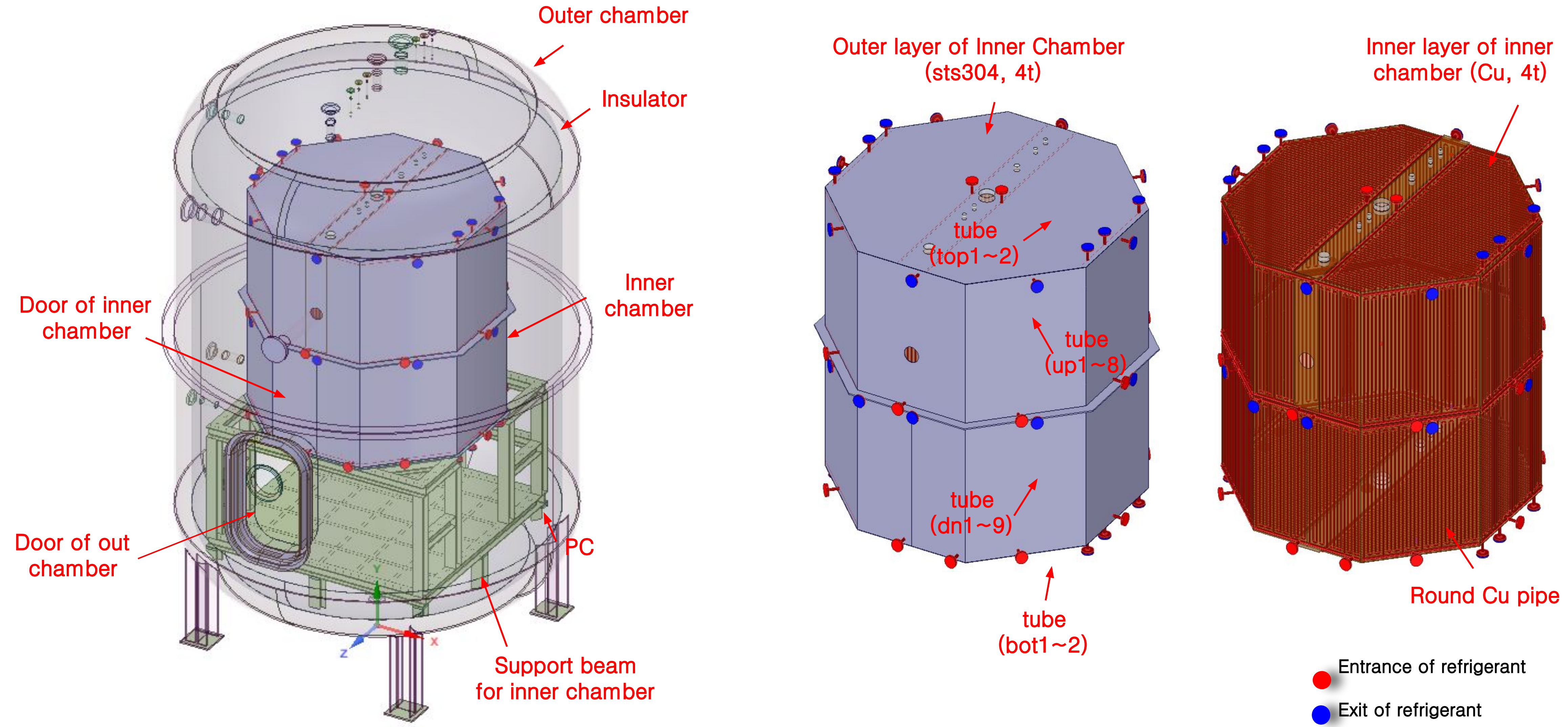
- Aerosol chamber of K-CPEC is designed as an reaction chamber and has the ability to adjust a pressure
- Aerosol chamber can apply for **monitoring an aerosol in the air**, **supplying experimental materials**, and **reacting test of aerosol**



Aerosol Chamber

Aerosol chamber		
Size		**3 m x 3 m**
Material		**Stainless steel**
Pressure range	**Range**	**1,013 to 30 hPa**
	Margin of error	**≤± 0.3 hPa**

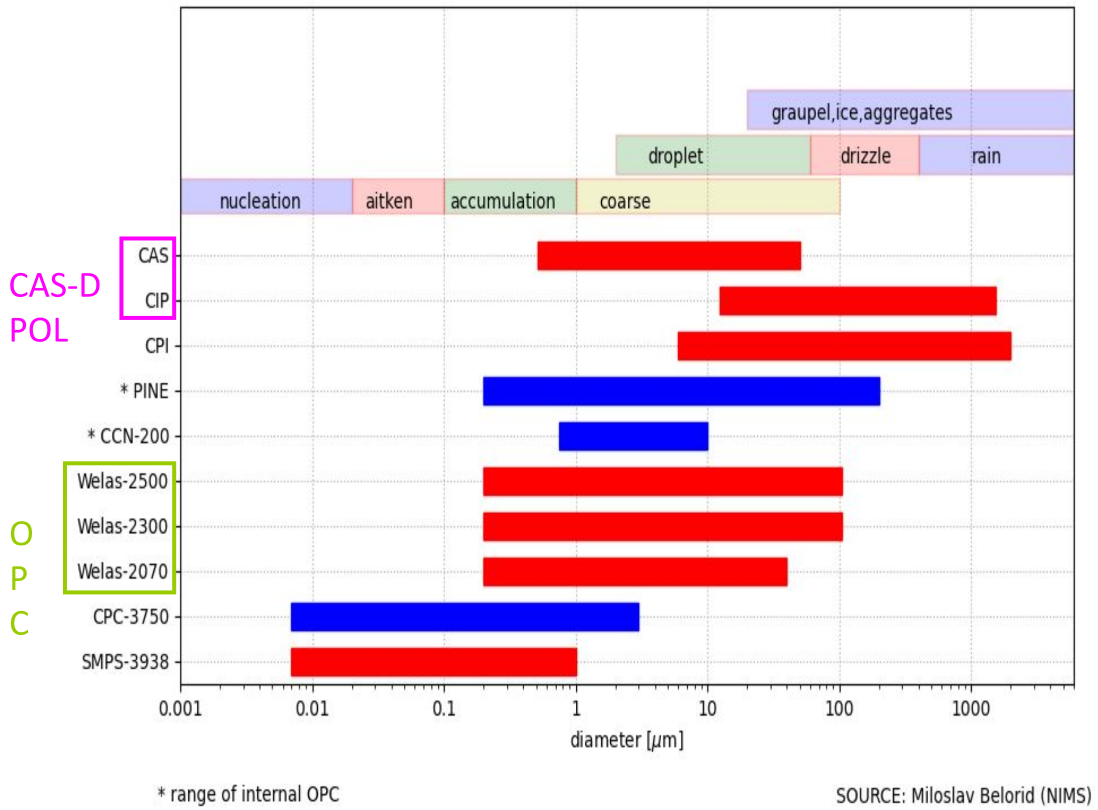
Detailed Internal Structure of the Cloud Chamber in K-CPEC



- Inner and outer layers of inner cloud chamber are made of a copper to improve heat transfer efficiency and a stainless steel to support chamber structure, respectively

Advanced measurements of K-CPEC

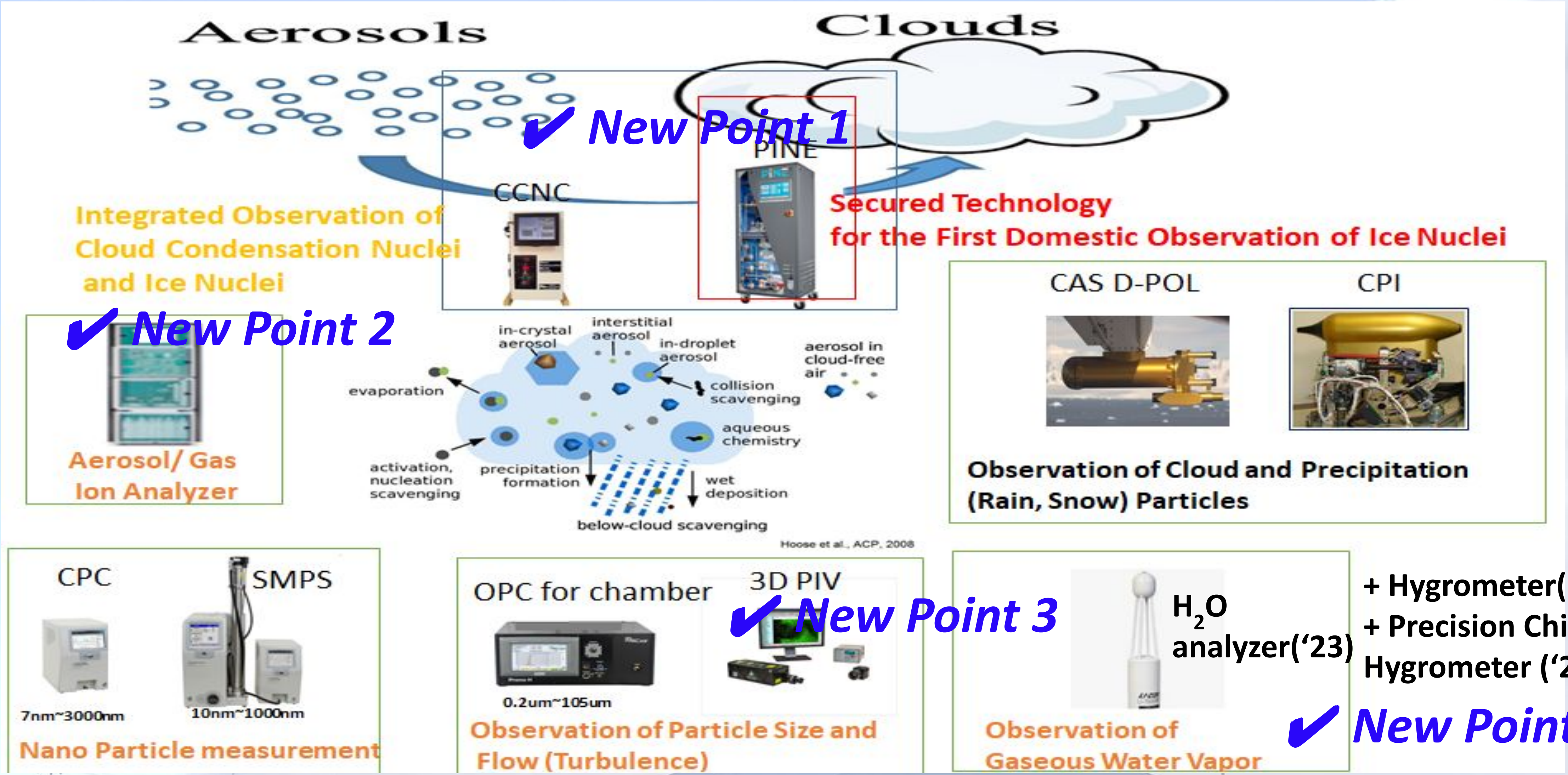
Observation Range and Advanced Equipment for Clouds and Aerosols in K-CPEC



- **the various observational instruments** installed in our cloud chamber and the specific particle size ranges they measure.
- we have particle diameters ranging from 0.001 to 10,000 micrometers. This covers everything from the smallest nucleation particles to large rain droplets and ice aggregates.

  - **CAS-DPOL** system, which includes: **CAS (Cloud and Aerosol Spectrometer) and CIP (Cloud Imaging Probe),** capable of measuring particles from nucleation size to coarse mode.
  - CPI (Cloud Particle Imager), providing additional measurements for larger particles.
  - **PINE** (Portable Ice Nucleation Experiment) and **CCN-200**, which are specialized for certain internal particle ranges.
  - **Welas OPC series (2500, 2300, 2070),** which effectively cover the accumulation and coarse particle ranges.
  - **CPC-3750 and SMPS-3938**, focusing on smaller particles extending into the nucleation and Aitken modes.

- our cloud chamber is equipped with a variety of sophisticated instruments, each targeting specific particle size ranges, enabling us to thoroughly analyze cloud microphysical properties.



+ Hygrometer('22)
+ Precision Chilled Mirror Hygrometer ('24)

✔ New Point 4

- These technologies allow for detailed study of aerosol-cloud interactions, including processes like activation, nucleation, evaporation, and formation of cloud.

New point 1: integrated CCN + INP obs.

New point 2: add chemical analyzer

New point 3: new application of 3D Particle Image Velocimetry (PIV)

New point 4: a SS estimation research using three different instruments

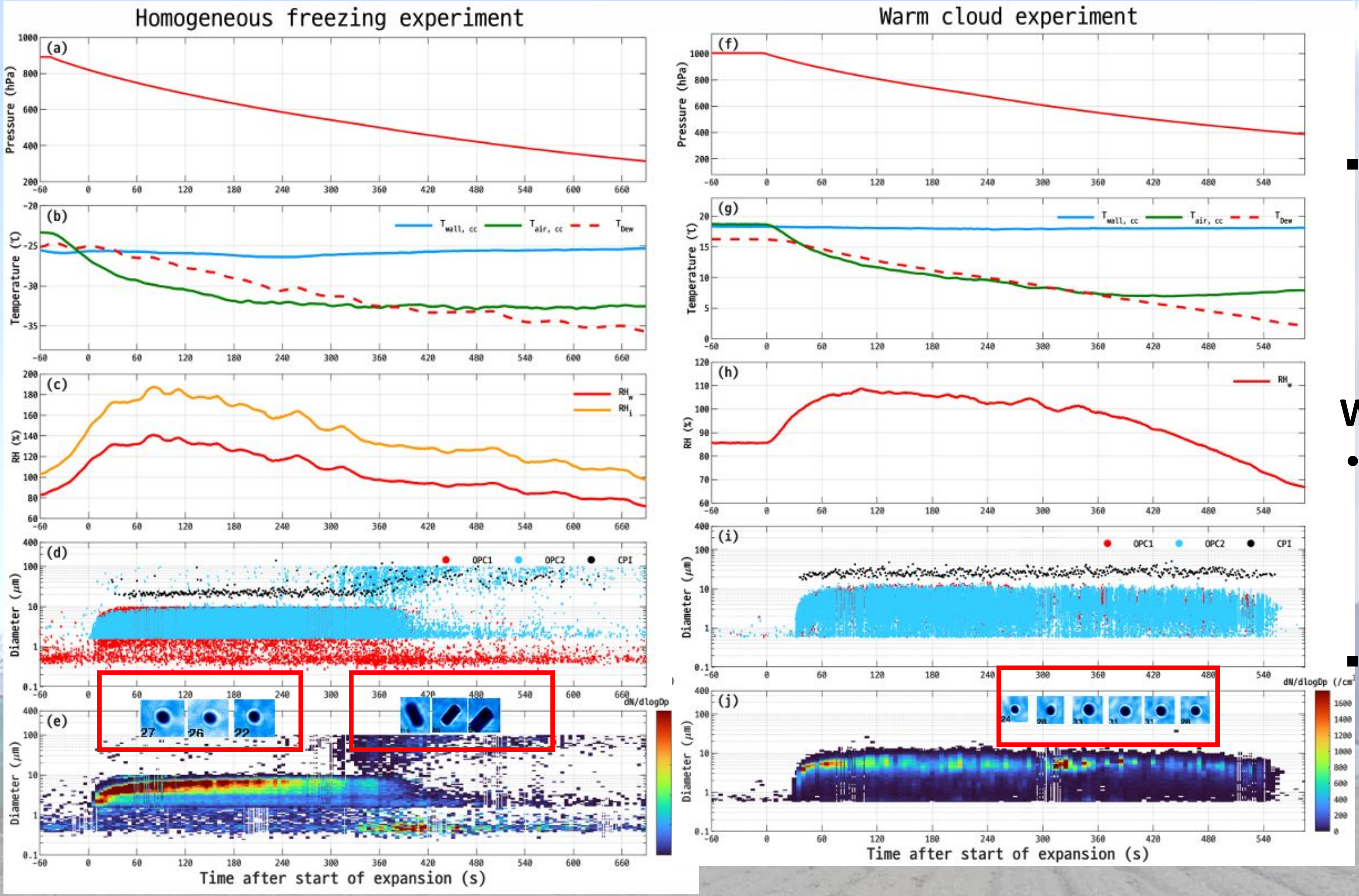
Application of K-CPEC

1. Weather and Climate
2. Weather modification
3. Industry : Development of observation instruments
4. Environment : Cloud scavenging for air pollutant material
5. Field campaign

1. Weather and Climate : Cloud physics (Homogeneous Freezing)

Table 2. Initial environmental conditions for homogeneous freezing experiment and warm cloud experiment.

Homogeneous freezing experiment				Warm cloud experiment			
P	T(T_d)	RH	N_c	P	T(T_d)	RH	N_c
890 hPa	-25.0℃ (-22.8℃)	84.38%	340/cm³ (Ammonium sulfate)	1,000 hPa	18.5℃ (15.3℃)	81.64%	340/cm³ (Ammonium sulfate)



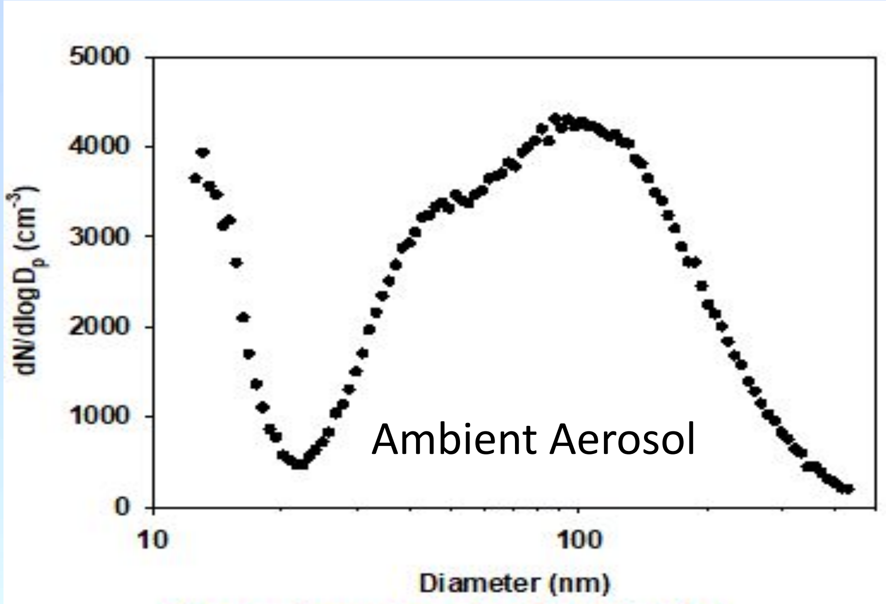
Homogeneous Freezing Experiment:

- Conducted under conditions of 890 hPa, -25.0°C temperature, 84.38% relative humidity, and 340/cm³ ammonium sulfate aerosol concentration.
- Observed trends include decreasing pressure and temperature, with particle diameter and number increasing during the freezing process.

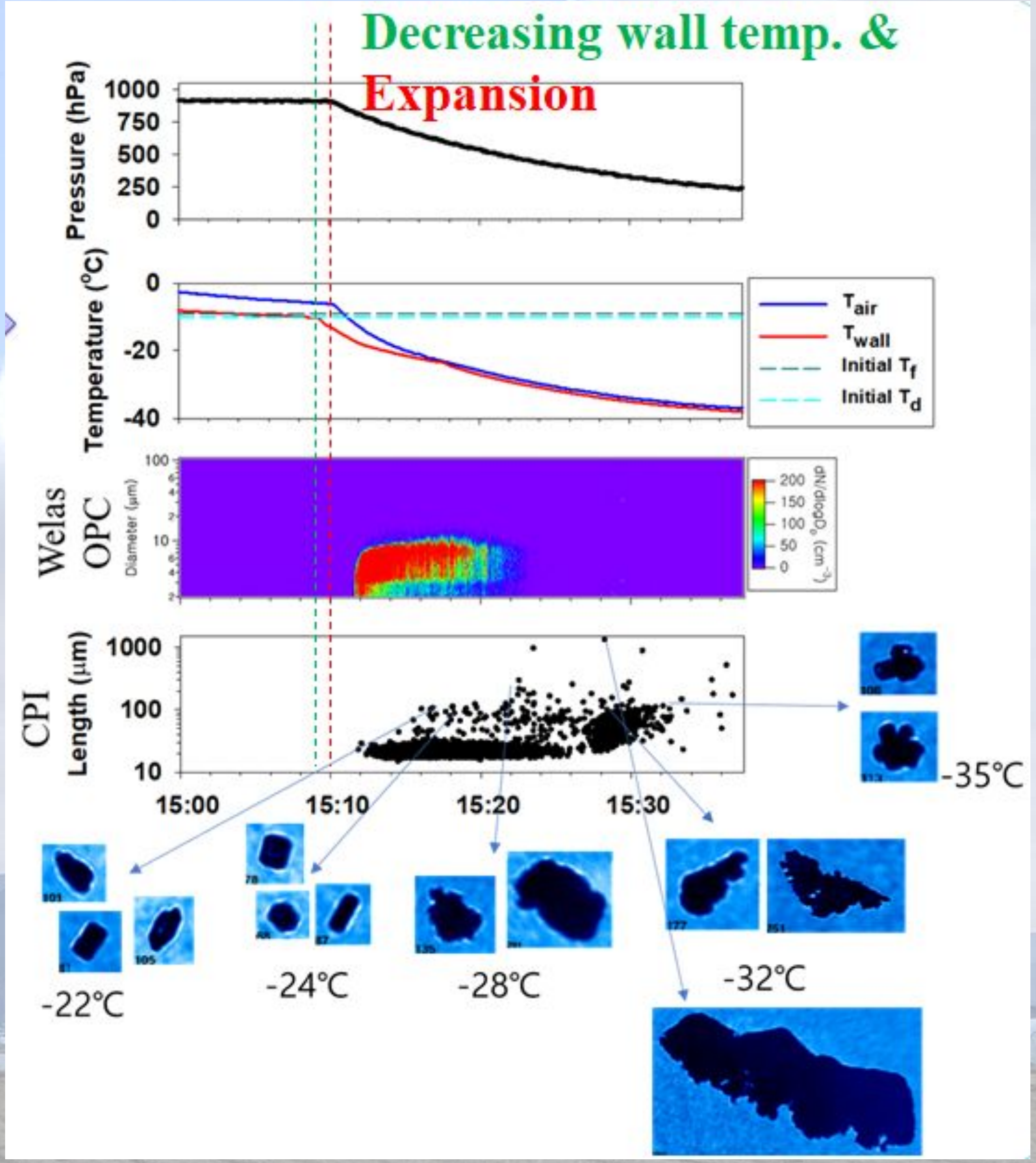
Warm Cloud Experiment:

- Conducted under conditions of 1,000 hPa, 18.5°C temperature, 81.64% relative humidity, and 340/cm³ ammonium sulfate aerosol concentration.
- Observed trends include decreasing pressure and stable temperature, with consistent particle diameter and number properties throughout the experiment.

1. Weather and Climate : Cloud physics (Heteogeneous Freezing)



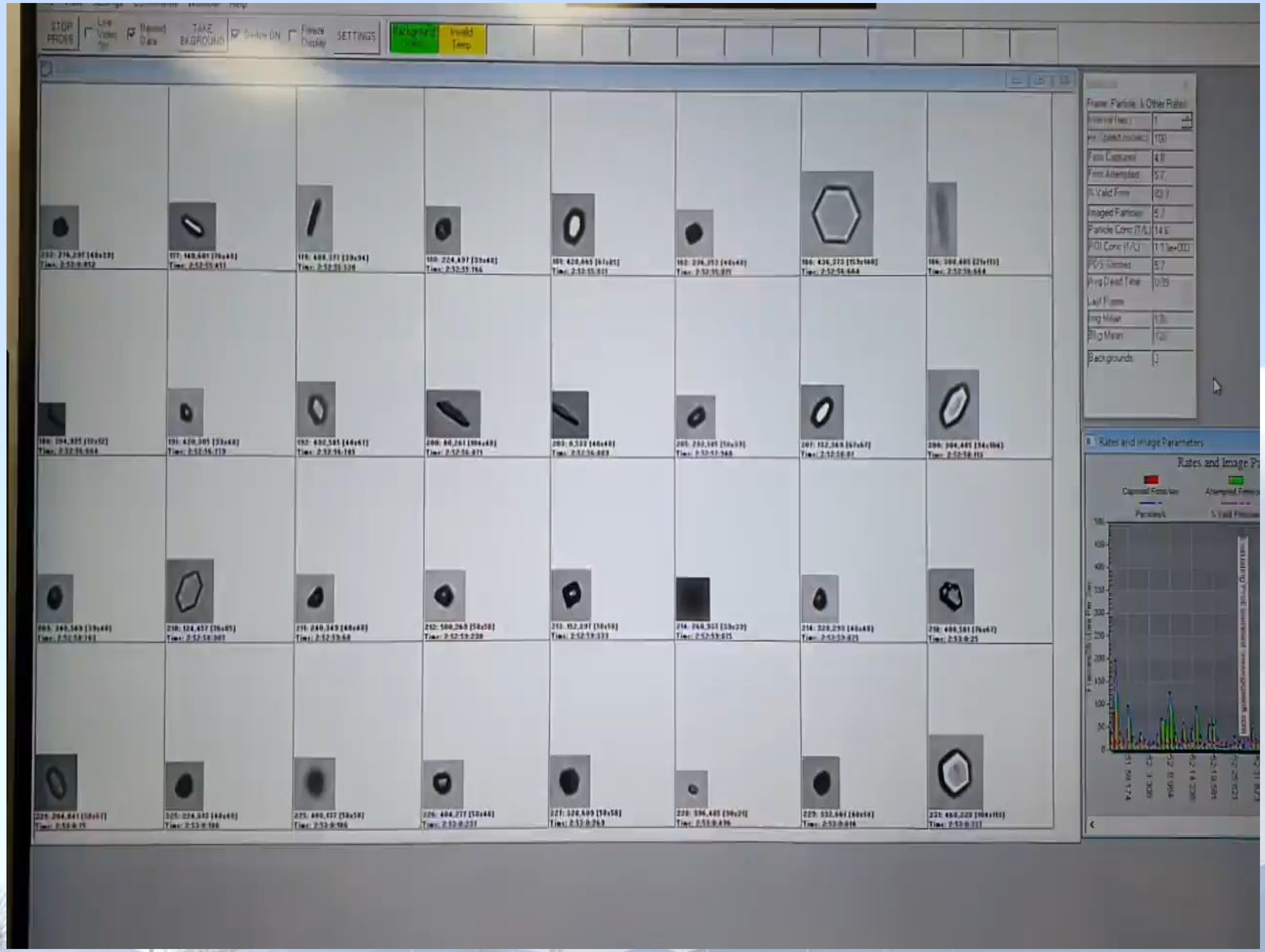
Aerosol number size distribution (Before experiment)

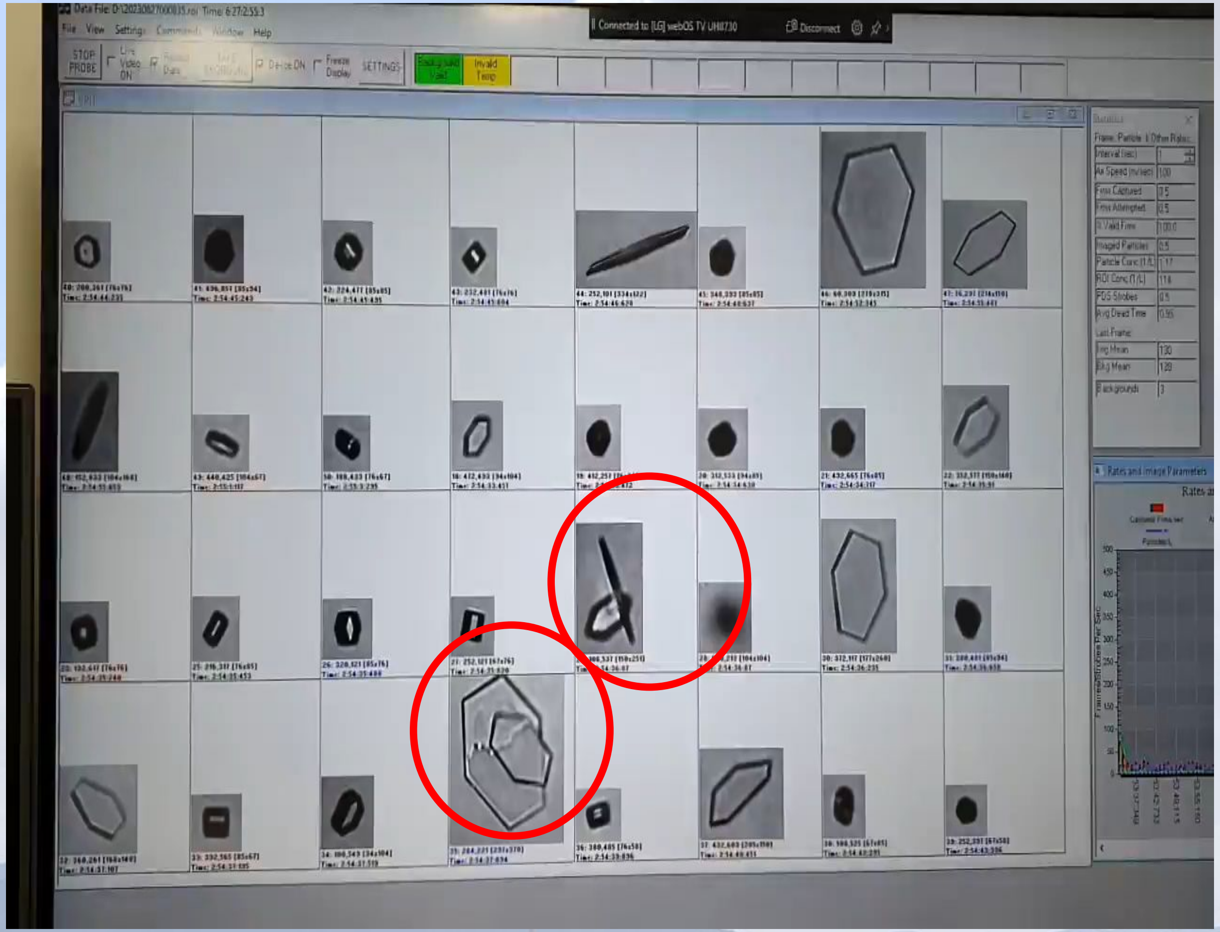


- The experiment shows ambient aerosol distribution, decreasing wall temperature, and expansion, with pressure and temperature changes monitored over time.
- Ice particle detection and imaging reveal changes in size and shape from -22°C to -35°C, highlighting Ice particle evolution during the cooling process.

Ex) Cold cloud formation experiment using the mixed INs in ambient air and environment Unknown aerosol

- T= -15℃~ 26.7 ℃, P=640hPa ~100hPa, RH=100%



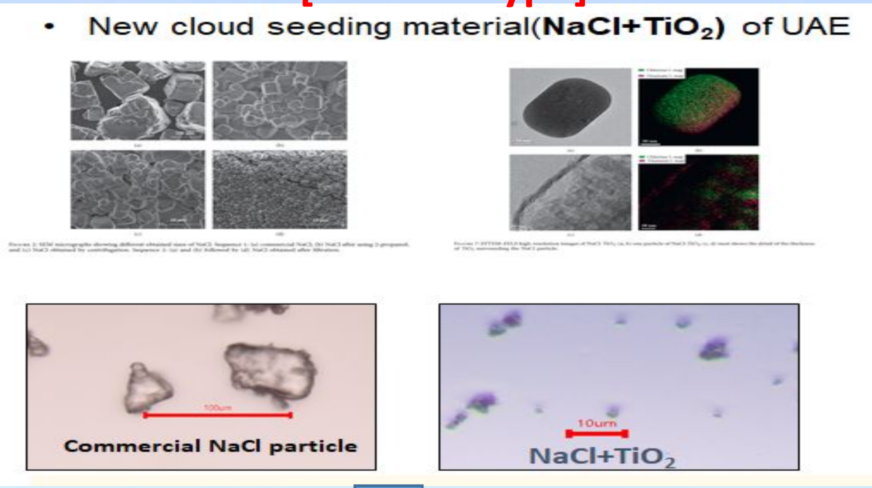


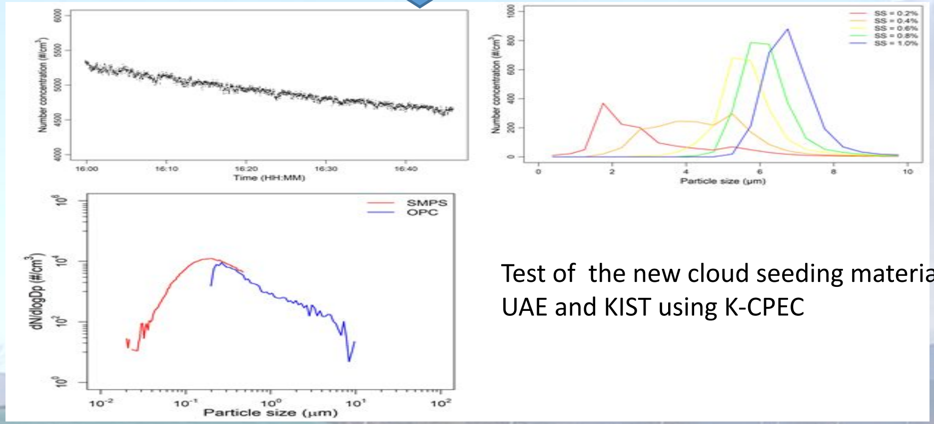
Observed Maximum size of Ice particle is more than several hundred micrometers

- This is a video of Ice particle observation during a cloud experiment.
- Some ice particles were observed undergoing the collision and coalescence process

2. Weather modification : Cloud Seeding materials

[Powder Type]





Test of the new cloud seeding materials of UAE and KIST using K-CPEC

- **This experiment aims to evaluate the effectiveness of the new cloud seeding material in promoting cloud formation** under various atmospheric conditions, which is crucial for weather modification efforts in arid regions like the UAE

[Burning Flare Type]

Figure 3: Total of 15 $CaCl_2$ Tarhunna MK1 (Cloud Technologies GmbH) seeding flares were installed and burned during the field experiment.

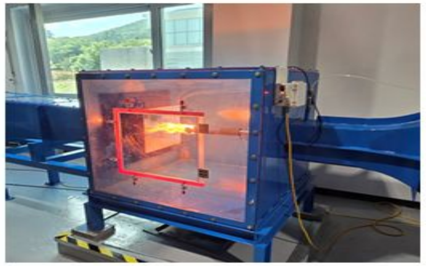


Figure 4: In order to initialize the Fast-SBM microphysics in WRF model, the flares were burned and analyzed in wind tunnel at 10m/s wind speed.

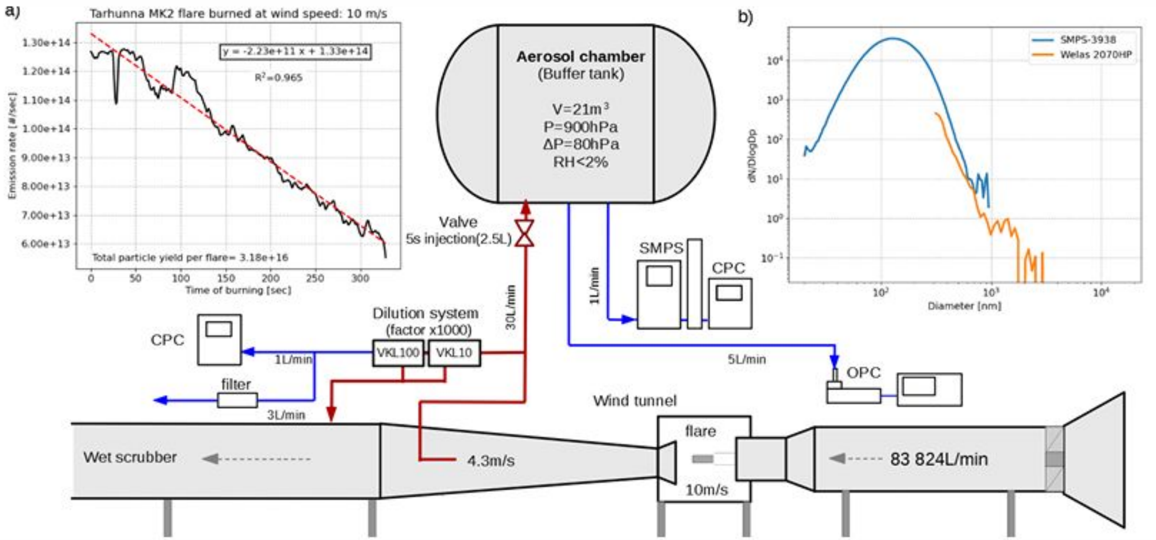
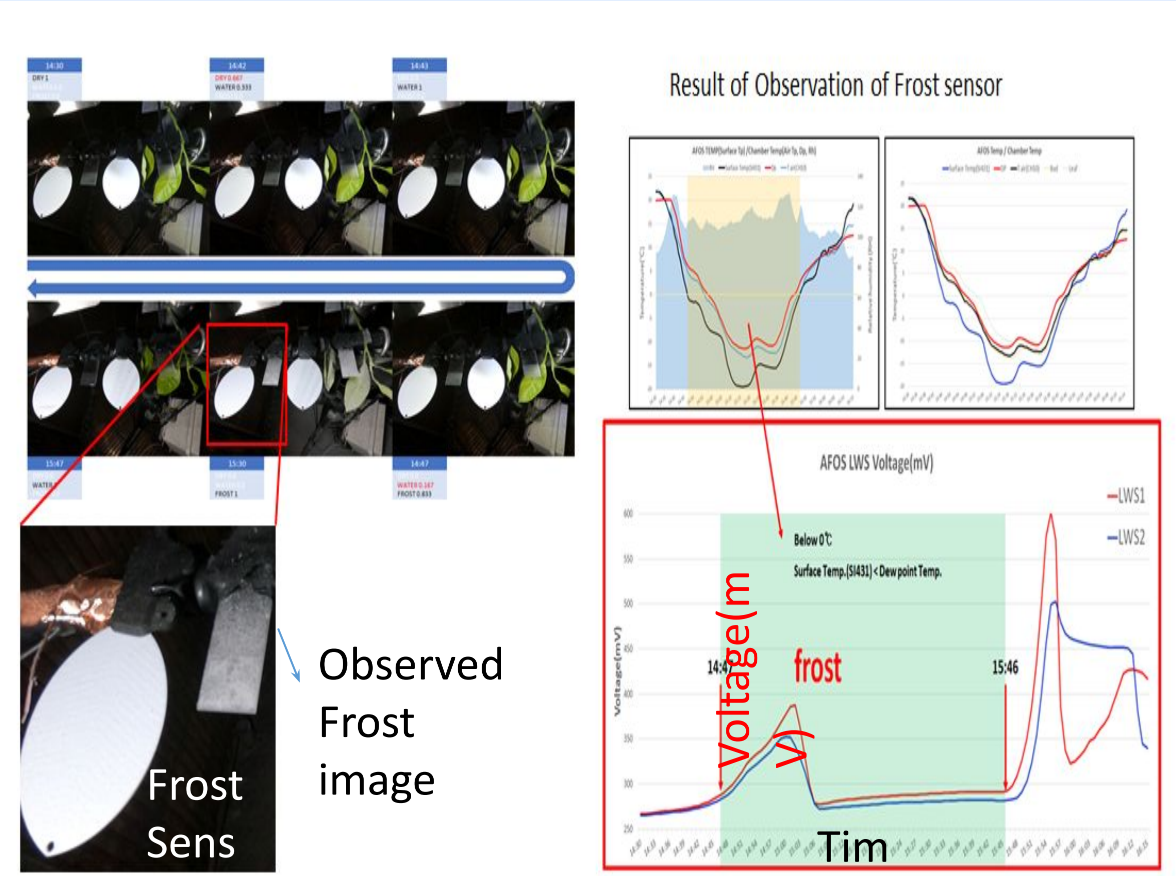


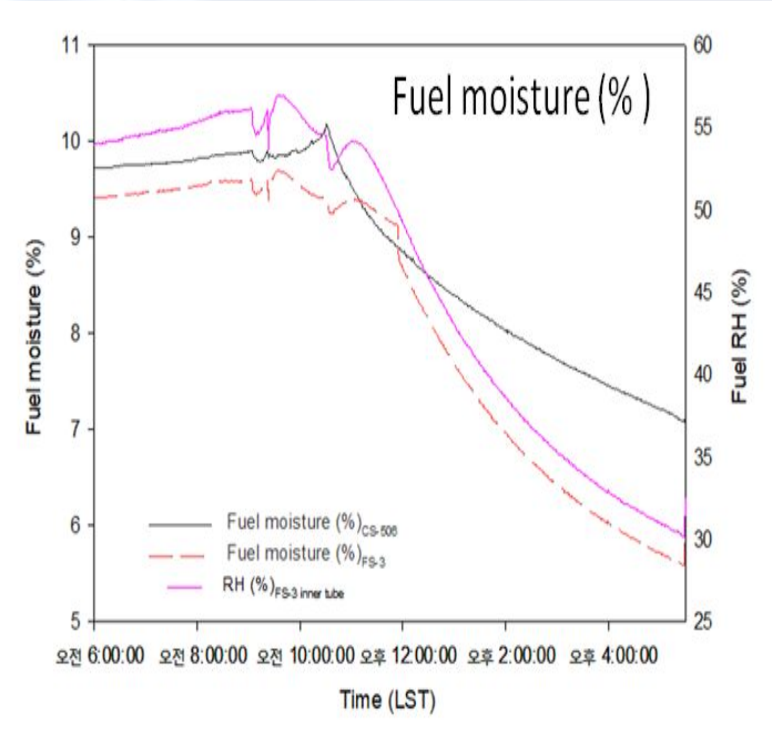
Figure 7: Setup of the wind-tunnel experiment and measurements: emission rates using CPC3750 (TSI) (a) and size distributions using SMPS 3938 (TSI) and Promo 2000/Welas 2070 OPC (Palas) (b). A sample of undiluted aerosol was injected directly into the aerosol chamber for size distribution analysis, while diluted aerosol was sampled for emission rate analysis during the entire burning period.

3. Industry : Development of observation instruments

EX1) Test of Frost observation Sensor for an agriculture



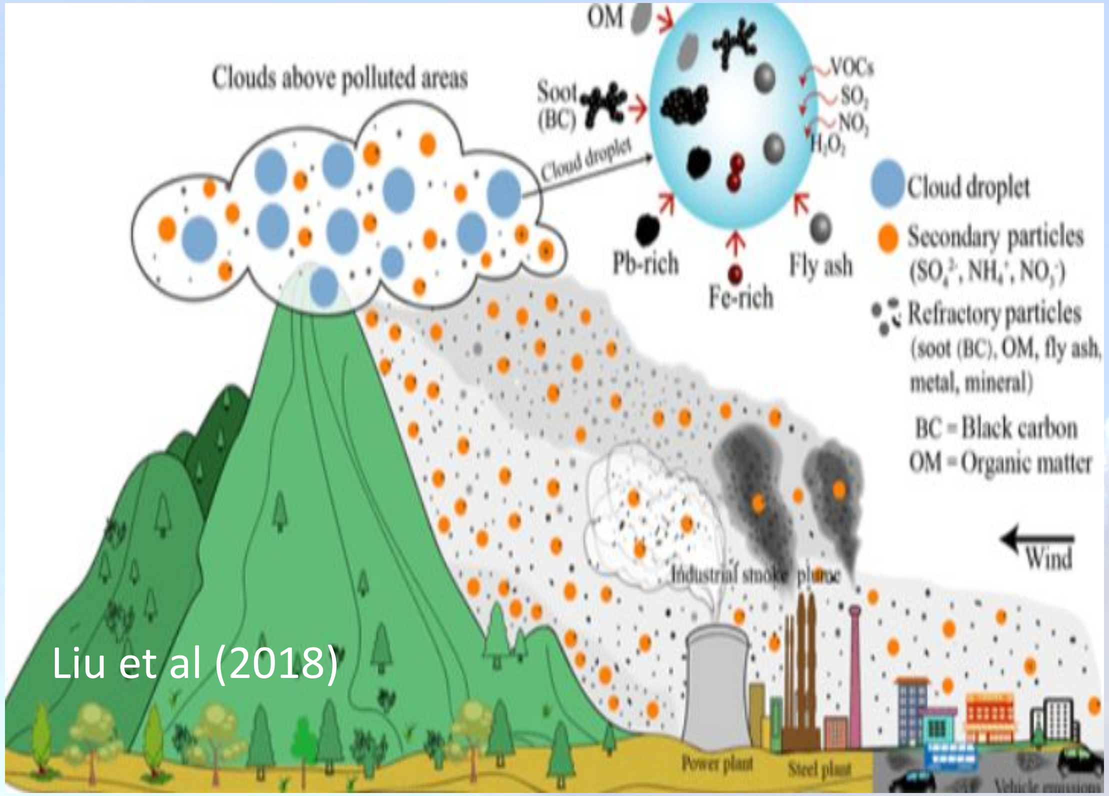
EX2) Test of Fuel humidity sensor for a forestry



- **This experiment demonstrates the effectiveness of the frost observation sensor in detecting and measuring frost formation**, which can be crucial for various industries including agriculture, transportation, and meteorology.

- **This experiment tested the performance of the Fuel humidity observation sensor for monitoring wildfire prevention.**

4. Environment : Cloud scavenging for air pollutant material



The diagram shows how pollutants from industrial activities are captured by cloud droplets and removed from the atmosphere through precipitation (Liu et al. 2018)

- Initial condition: T= -8.6℃, P=875hPa, RH=63%
- Target condition: T= -15.6℃, P=400 hPa, RH=100%
- Injection materials : NH_3SO_4 => 700 #/cm^3

- **This experiment shows an very simple example of cloud scavenging for air pollutant materials such as NH_3SO_4 .**

- In the Future, we will test a lot of different air pollutant using K-CPEC for cloud scavenging effect

5. Field campaign : First observation of ice nucleation particle(INP) from Korea to Artic

	PINE-c
Chamber type	Aluminium, thin walled
Thermal insulation	Vacuum chamber
Chamber length	57 cm
Chamber diameter	18 cm
Chamber volume	10 L
Cooling system	Stirling (Thales, LPT9310)
Wall temperature range	0 to −60 °C
Measurement temperature range	−10 to −65 °C
Temperature uncertainty	±1 °C
Wall cooling rates	0.6 °C min^{-1}
Wall heating rates	0.6 °C min^{-1}
Particle detector	fidas-pine
Inlet dryer	Perma Pure, MD-700-24S-1
Detection limit at 6 min time resolution (single run)	0.5 L^{-1}
Detection limit at 1 h time resolution (10 runs)	0.05 L^{-1}
Detection limit at 24 h time resolution (240 runs)	0.002 L^{-1}

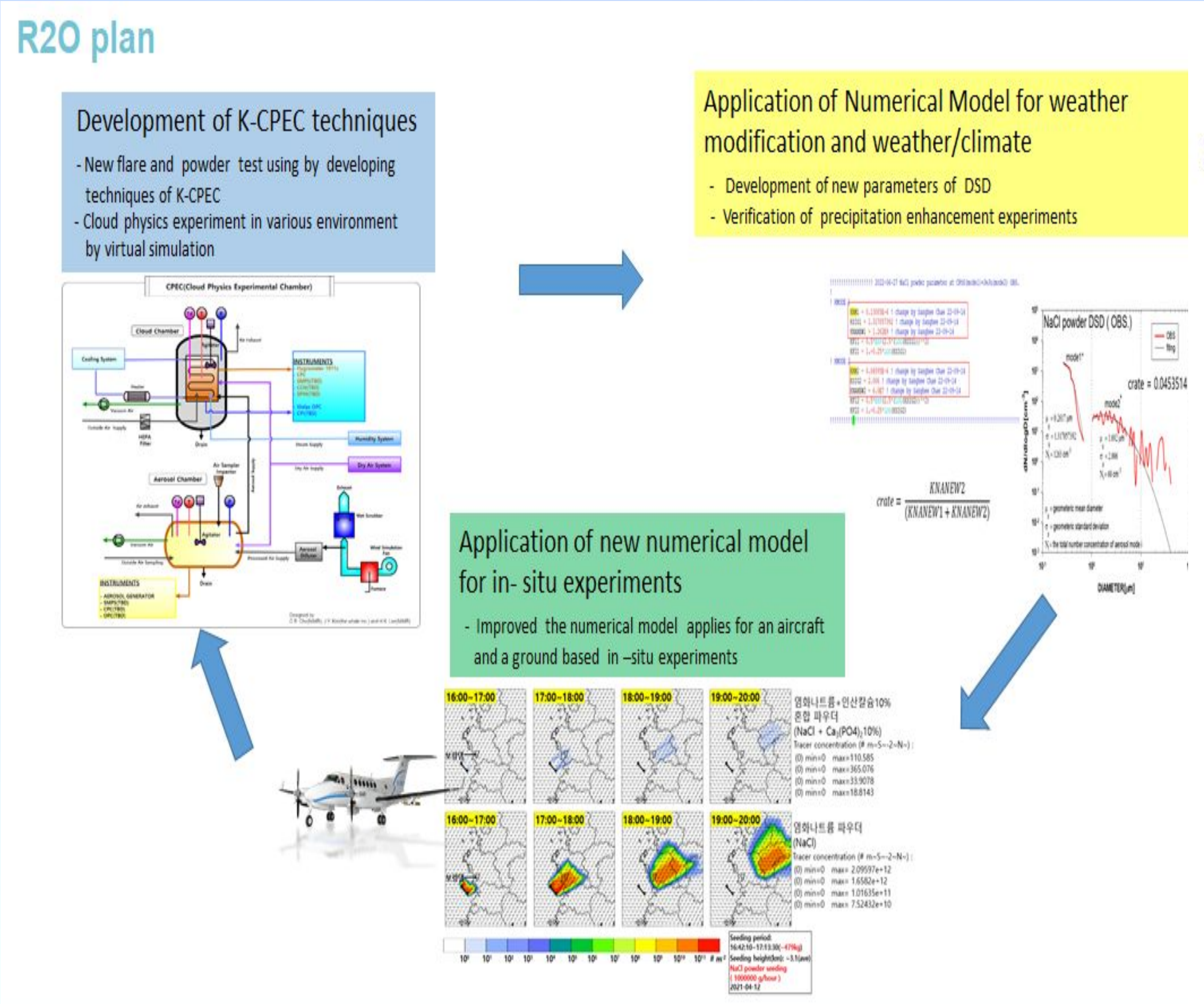
ARAON : the Ice-breaking Research Vessel
Korea Polar Research Institute

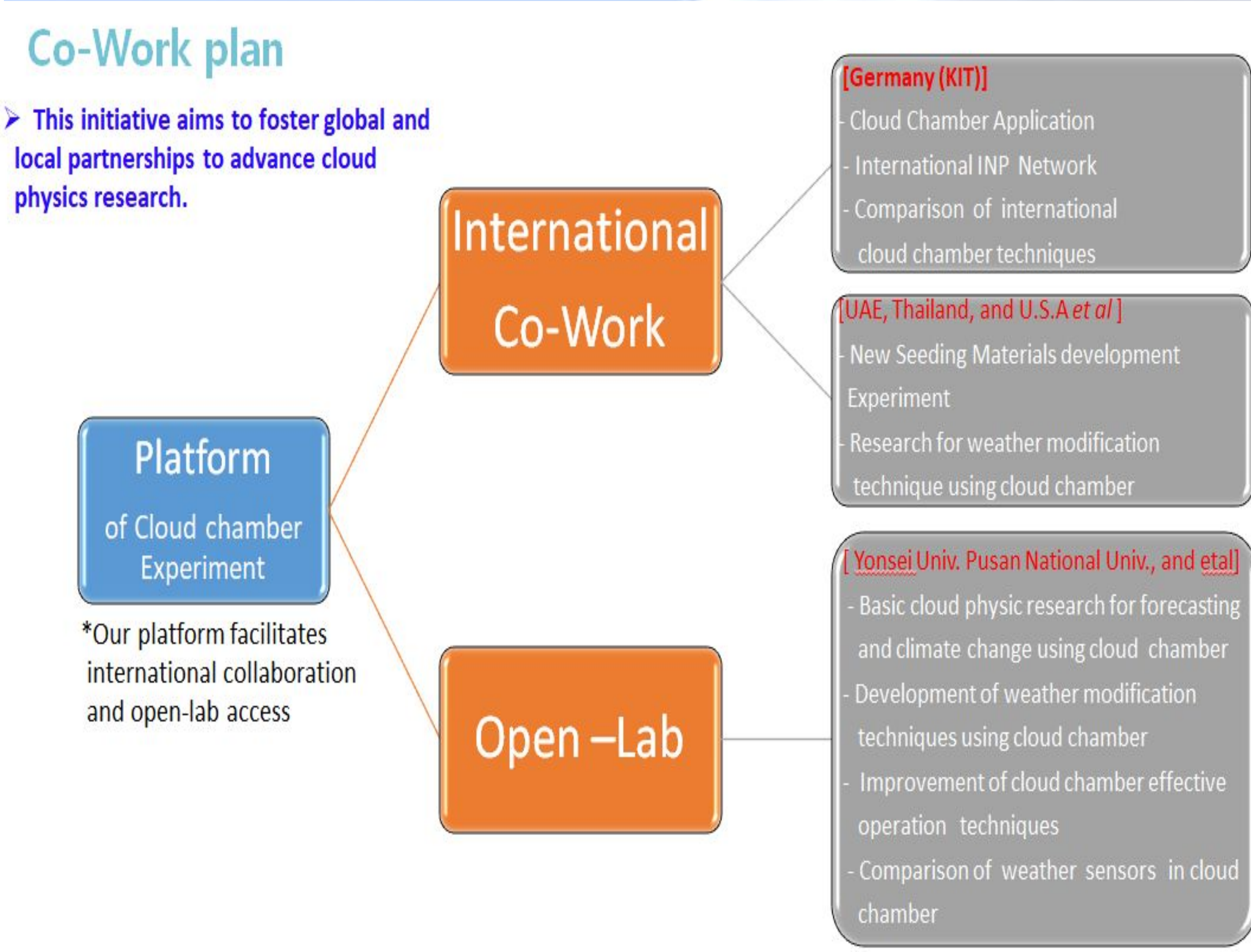
- We will research for our field campaign on the first observation of ice nucleation particles (INPs) from Korea to the Arctic.
- Using the PINE chamber, we measured INPs on the ice-breaking research vessel ARAON.
- Our campaign, conducted from July 10th to August 31st, targeted areas from Korea to the Arctic.
- This study helps us understand how INPs influence cloud formation and climate

https://www.youtube.com/watch?v=k_oQzfuQLzs

In the future, NIMS will launch a new pilot research project of **intensive CCN and INP measurements from Korea to Artic** with Korea Polar Research Institute and Pukyong university to understand the **characteristics of IN and CCN by latitude zones in the Northern Hemisphere**

Future Plan of K-CPEC





- Our chamber experiments are being developed in conjunction with numerical models and field experiments.

- K-CPEC aims to ultimately address the increasingly severe weather and climate issues through collaboration with numerous domestic and international institutions

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Thank you so much