

# 吸湿性粒子シーディングに 用いる物質の物理化学特性と 雲粒生成過程への影響

田尻 拓也, Tzu-Hsien Kuo, 折笠成宏,  
財前祐二, 村上 正隆

気象研究所 予報研究部

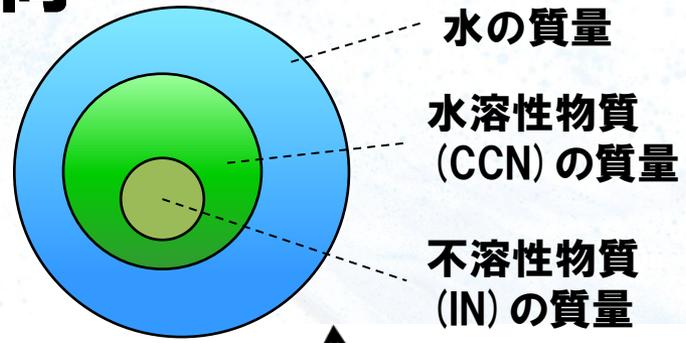
2017.2.17

(国立極地研究所 3階セミナー室)

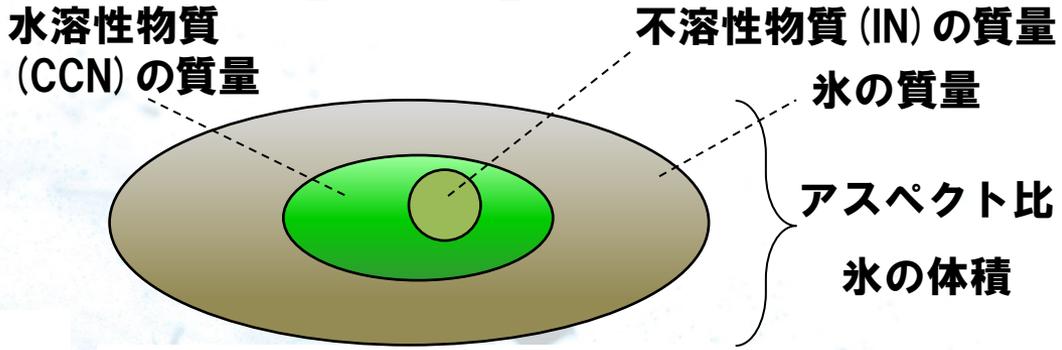


# 詳細雲微物理（リファレンス）モデルの改良

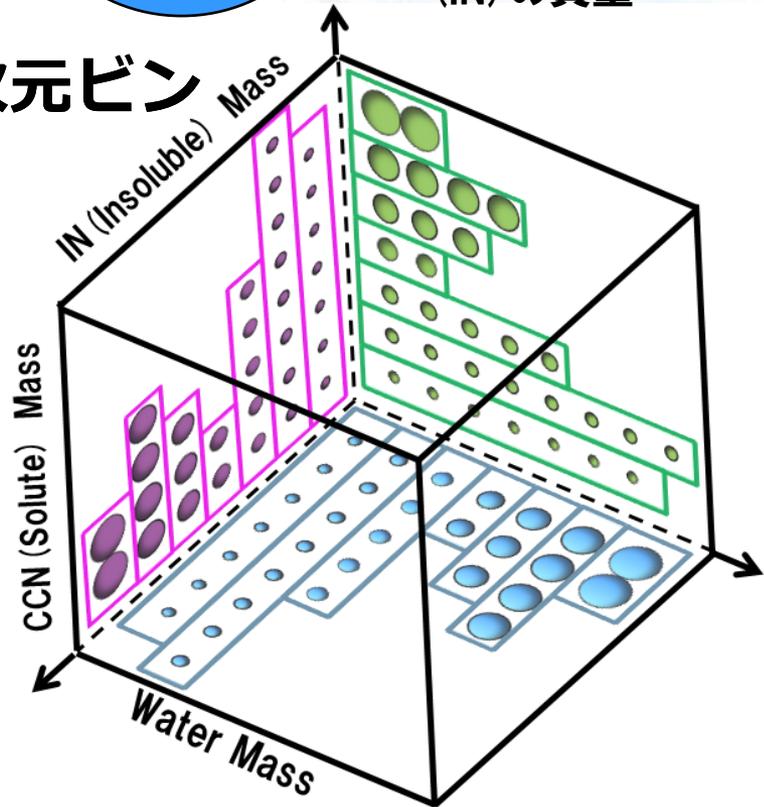
## 水滴



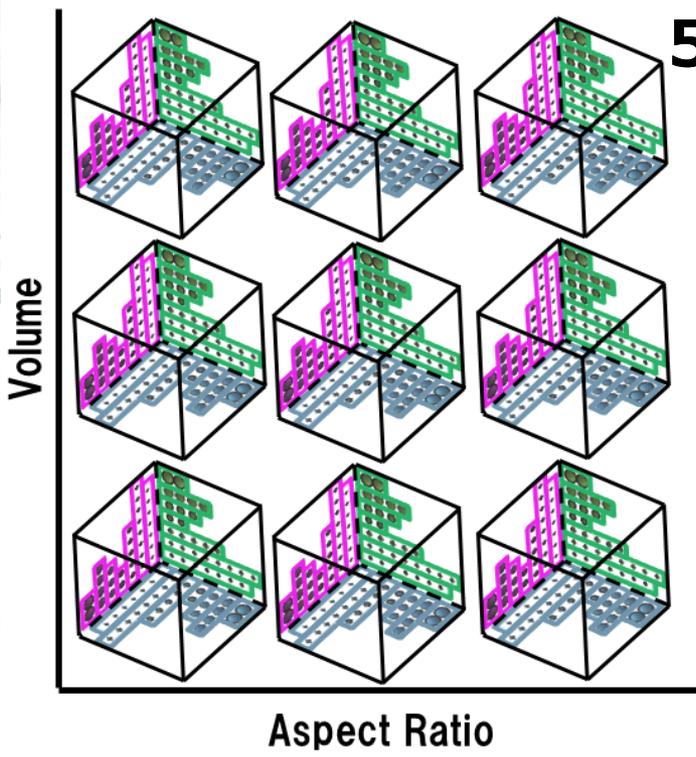
## 氷粒子



## 3次元ビン



## 5次元ビン

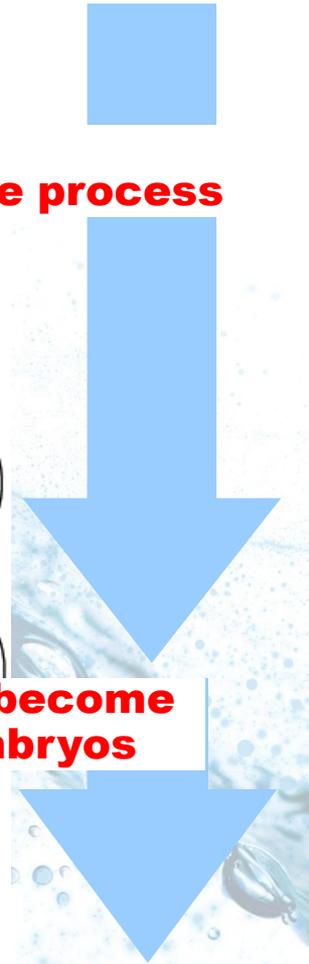
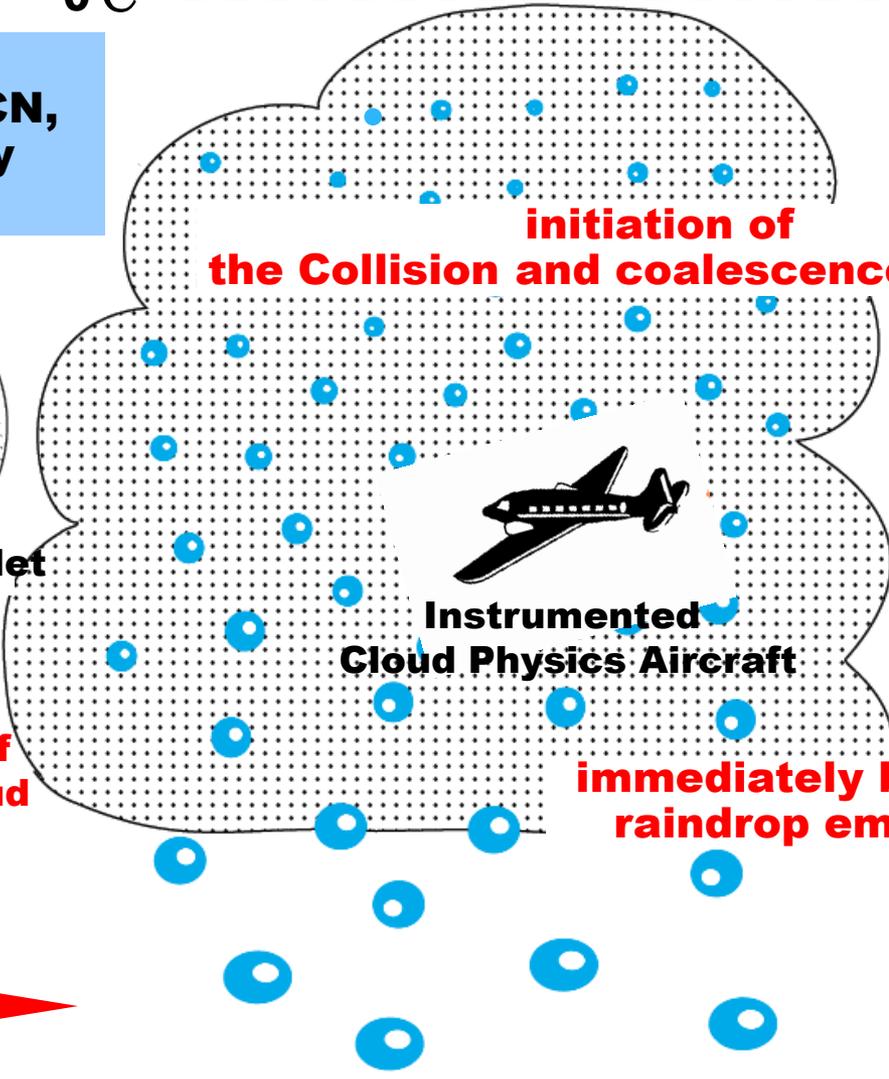
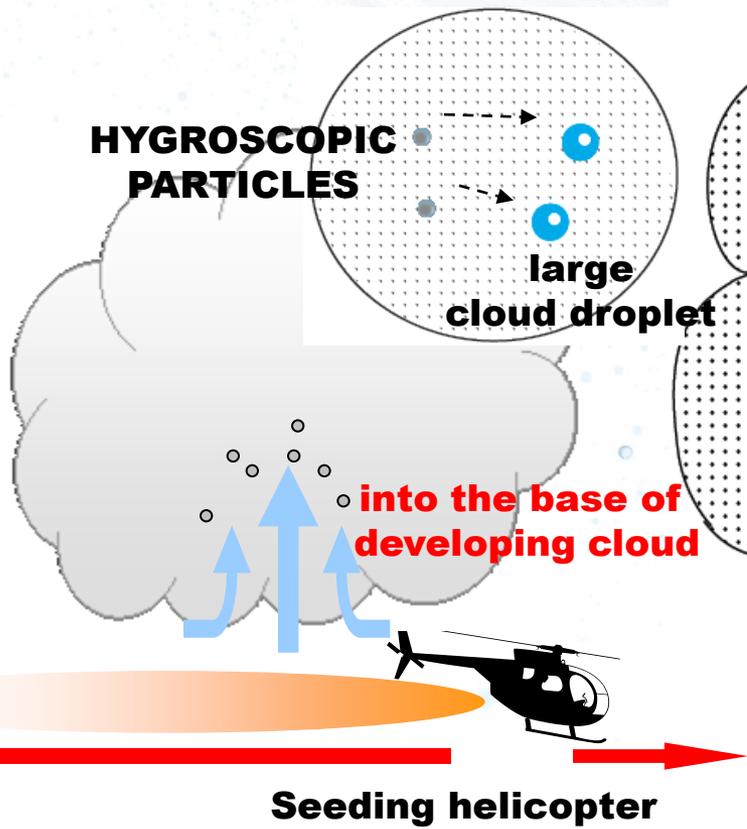


# 意図的気象改変

## “Warm Cloud” Hygroscopic Seeding Process

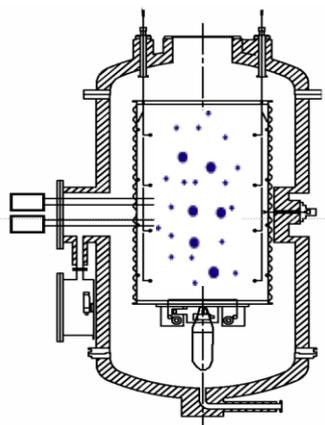
0°C -----

**Hygroscopic particles (A few micron size) act as CCN, activated and readily grow by vapor deposition**



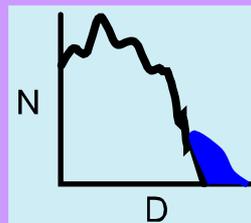
# 意図的気象改変

## MRI CLOUD SIMULATION CHAMBER



Hygroscopic seeding experiment

Background CCN



+

cloud seeding agents



Hygroscopic Flare

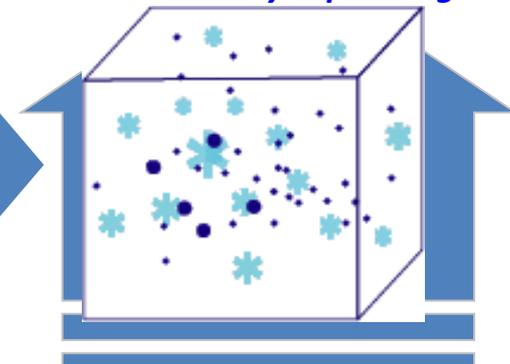


Micro-Powder

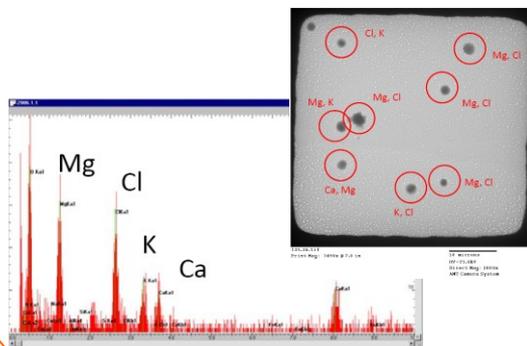
⋮

Improvement of detailed (bin) microphysics model

Growth of cloud droplets  
In an adiabatically expanding air



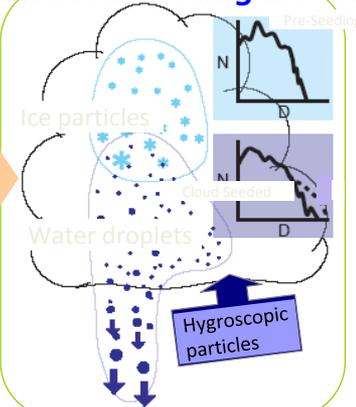
Sample analysis using  
Electron microscope



Development of  
numerical seeding model

Bin-type cloud physics +  
Seeding processes

Quantification of  
the hygroscopic  
seeding effects



## 吸湿性シーディング物質と手法

### ○ Salt micro-powder( *MP* )

NaCl微粒化技術

粉碎した数 $\mu\text{m}$ の粒子を雲底下に直接散布（散布量の低減）  
散布粒子の選択（粒度、固結防止剤）、散布率の調節が可能

### ○ Pyrotechnic (Hygroscopic flare )

シーディング物質と火薬の配合された発炎筒

燃焼により気化-凝結を経て吸湿性粒子を散布

軽量（1kg $\times$ 24本）、操作の簡便性（2~3分/本）

サブミクロン粒子が多く生成される



Seeding helicopter



MP disperser



Burning flare

# Seeding agent

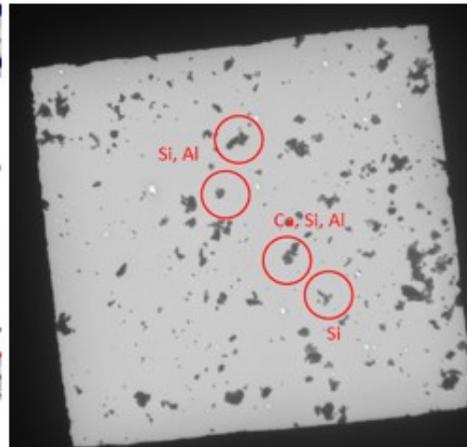
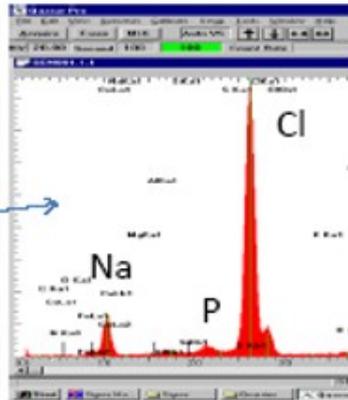
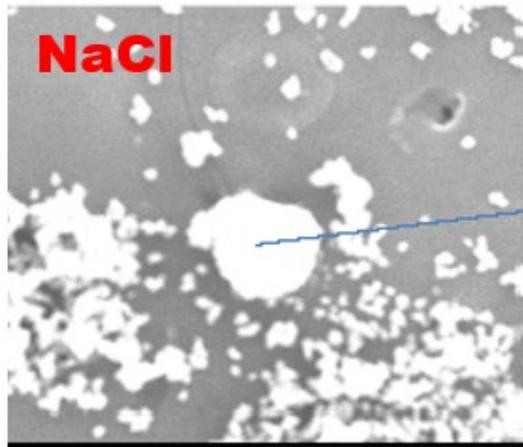
## *MP method*

### Tested particles

	<b>MS10</b> (Ako Kasei)	<b>T0</b> (Ako Kasei)	<b>MP</b> ( Israel )
Peak Size ( spectrum width )	<b>0.7um</b> (0.3-5um)	<b>1.5um</b> (0.5-20um)	<b>0.3,2,15um</b> ( -30um)
Chemical Components	NaCl	NaCl、SiO <sub>2</sub> 、CaCO <sub>3</sub>	NaCl、SiO <sub>2</sub> 、Ca <sub>3</sub> (P <sub>04</sub> ) <sub>2</sub>



**Israel MP**



**Japanese MP**

composition	wt %
NaCl	95
SiO <sub>2</sub>	3
Ca(CO) <sub>3</sub>	2

# Seeding agent

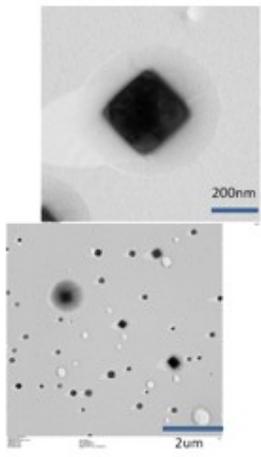
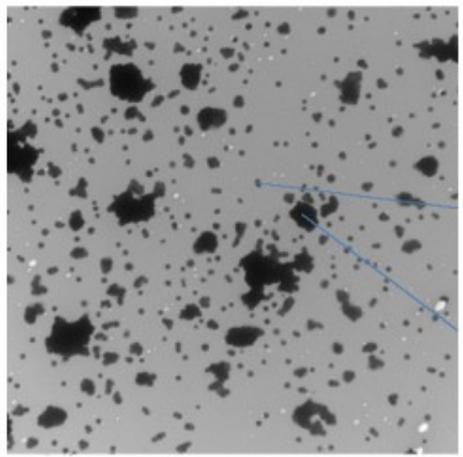
# Flare method



**ICE HF**  
**CaCl<sub>2</sub> type Flare**  
**KClO<sub>4</sub> 70%**  
**Included Mg**

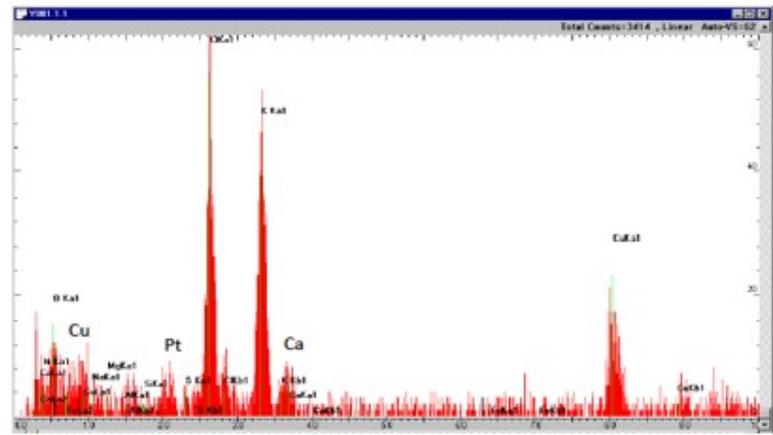
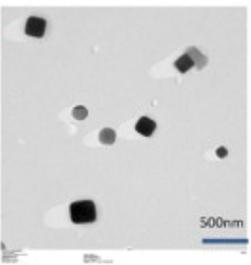


**KCl and CaCl<sub>2</sub> rich**  
**D > 1μm → Mg dominant**



フレア粒子の形状(HIT7700で撮影)

Fine particlesは、ほとんどがcubic.





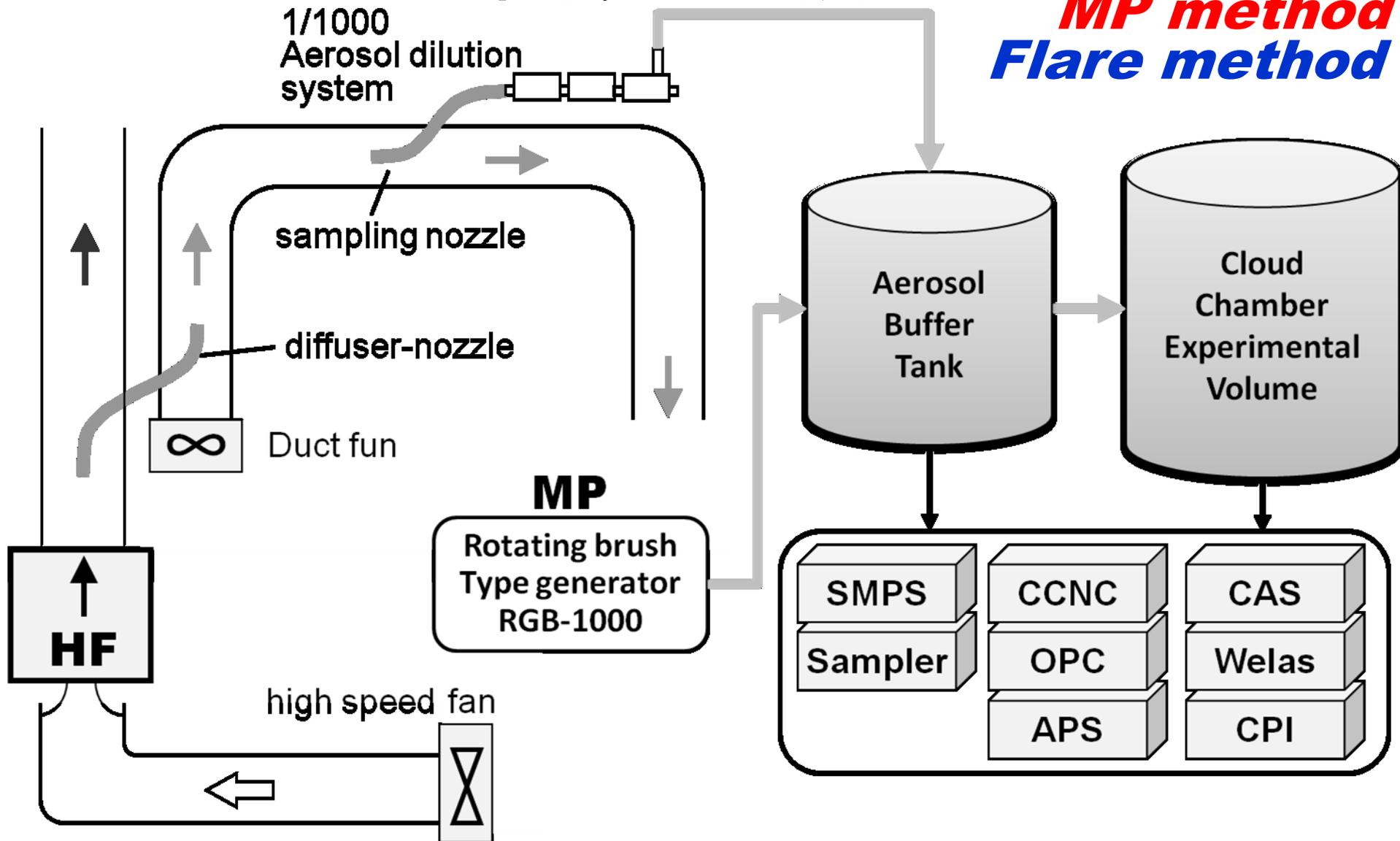
## Tested seeding agents

No.	Sample (Supplier)	anti-caking agents	Major Compositions	Density $\text{g}^2 \text{cm}^{-3}$
1	Silicon Dioxide ( AKO KASEI Co. )	Yes	$\text{SiO}_2$	2.65
2	Calcium Carbonate ( AKO KASEI Co. )	Yes	$\text{CaCO}_3$	2.71
3	Tricalcium Phosphate ( AKO KASEI Co. )	Yes	$\text{Ca}_3(\text{PO}_4)_2$	3.14
4	Sodium Chloride ( AKO KASEI Co. )	No	$\text{NaCl}$	2.16
5	MP Israel type ( Rosenfeld et al. 2010 )	Contained in	$\text{NaCl}$ $\text{Ca}_3(\text{PO}_4)_2$ , $\text{SiO}_2$	2.19
6	MP T-0 type ( AKO KASEI Co. )	Contained in	$\text{NaCl}$ $\text{Ca}_3(\text{PO}_4)_2$ , $\text{SiO}_2$	2.19
7	Hygroscopic Flare (Ice Crystal Engineering)	No	$\text{KCl}$ , $\text{CaCl}_2$ with metal-oxide	----

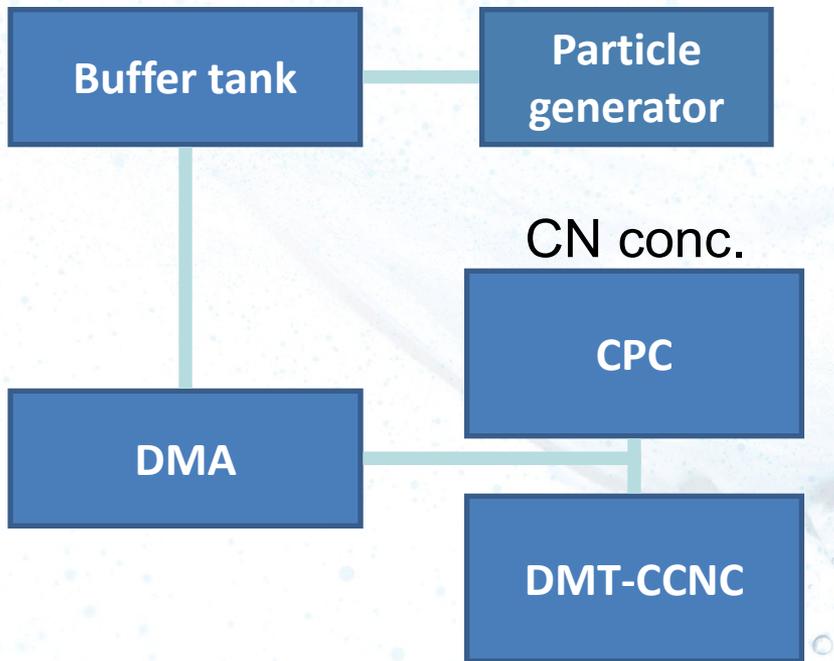
# 実験手法

## 粒子発生と前処理

*MP method*  
*Flare method*



# 吸湿度計測

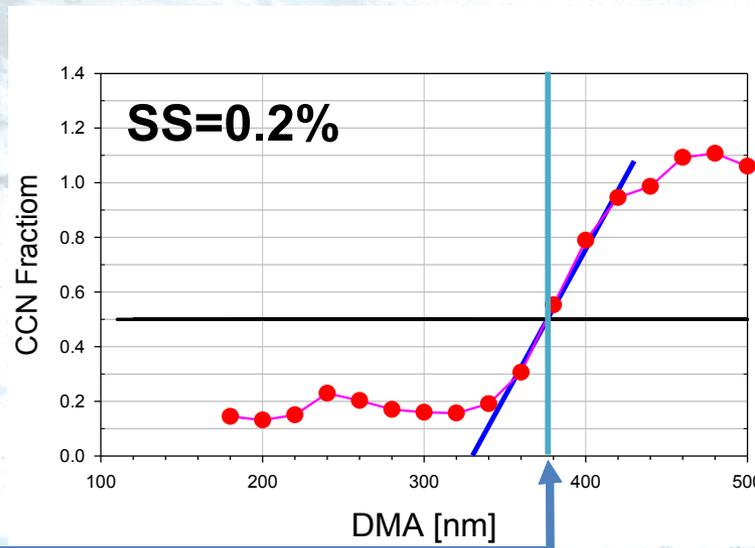
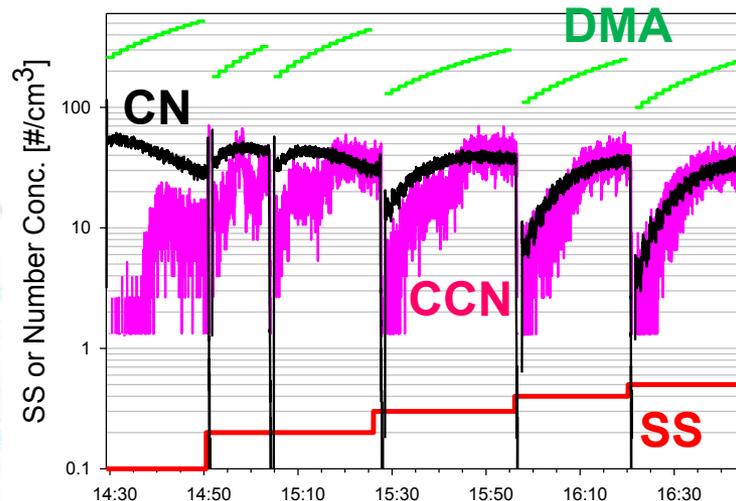


CCN conc. @SSw

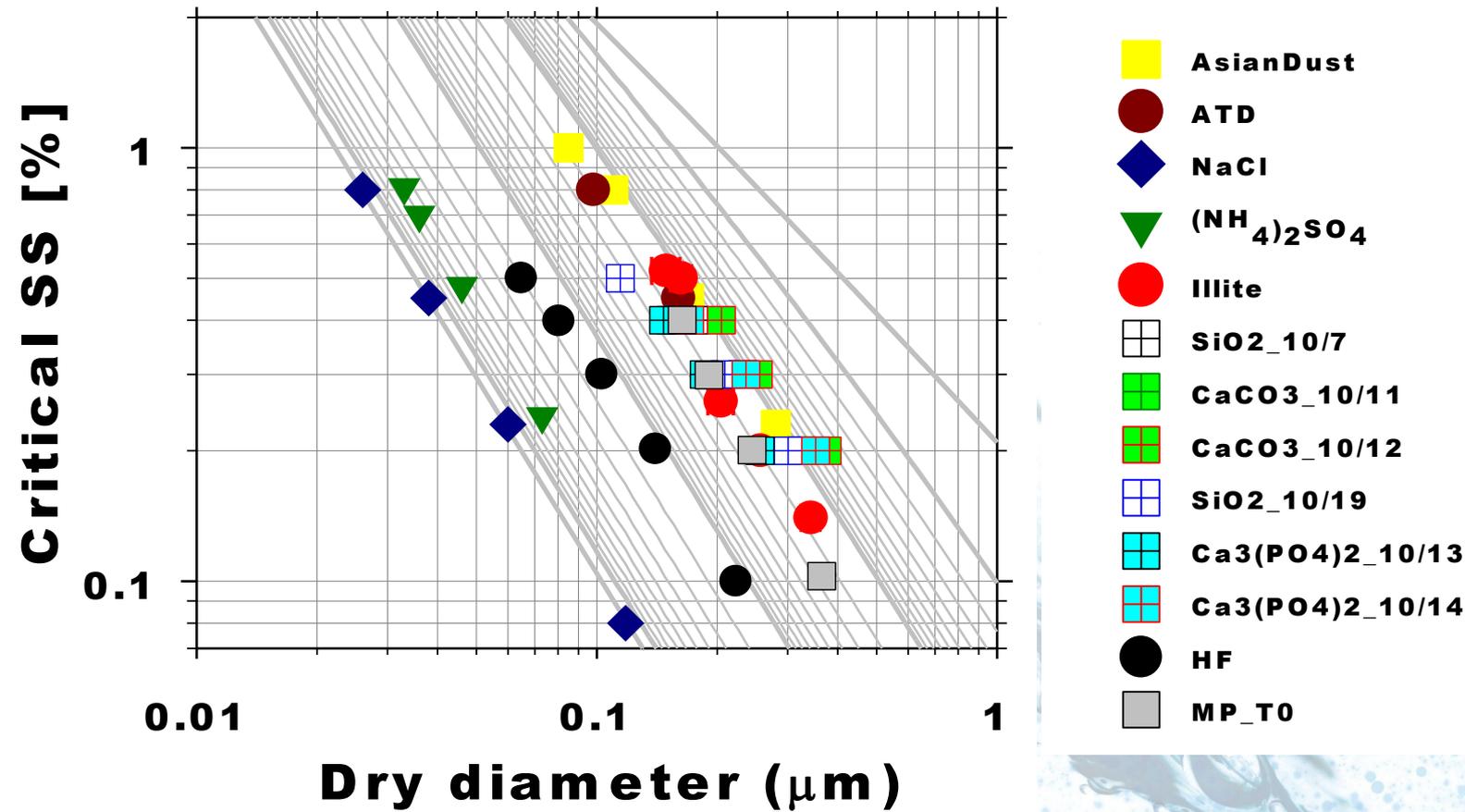
Activated Fraction(AF)

$$AF = CCN/CN$$

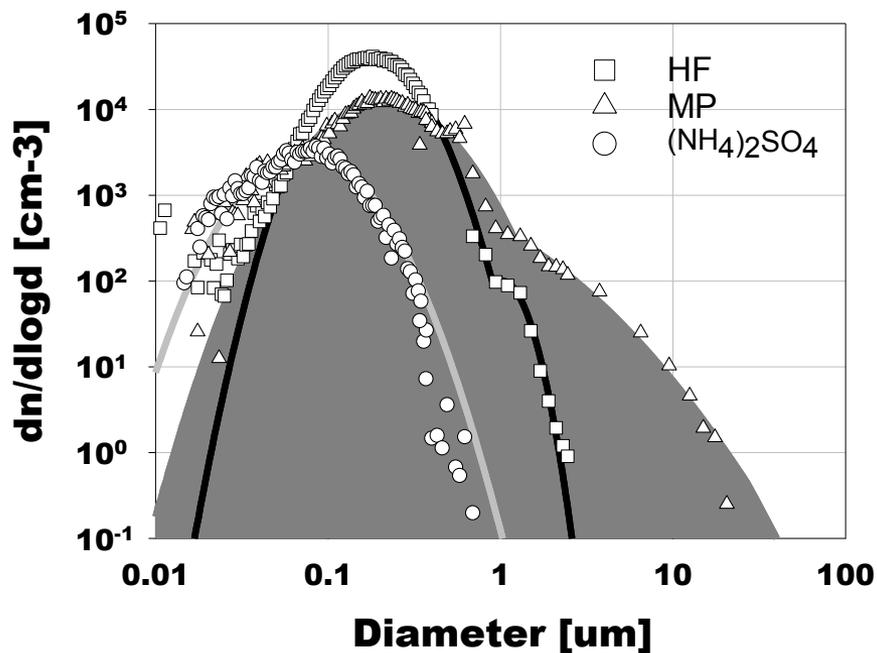
Critical Dry diameter: AF = 0.5



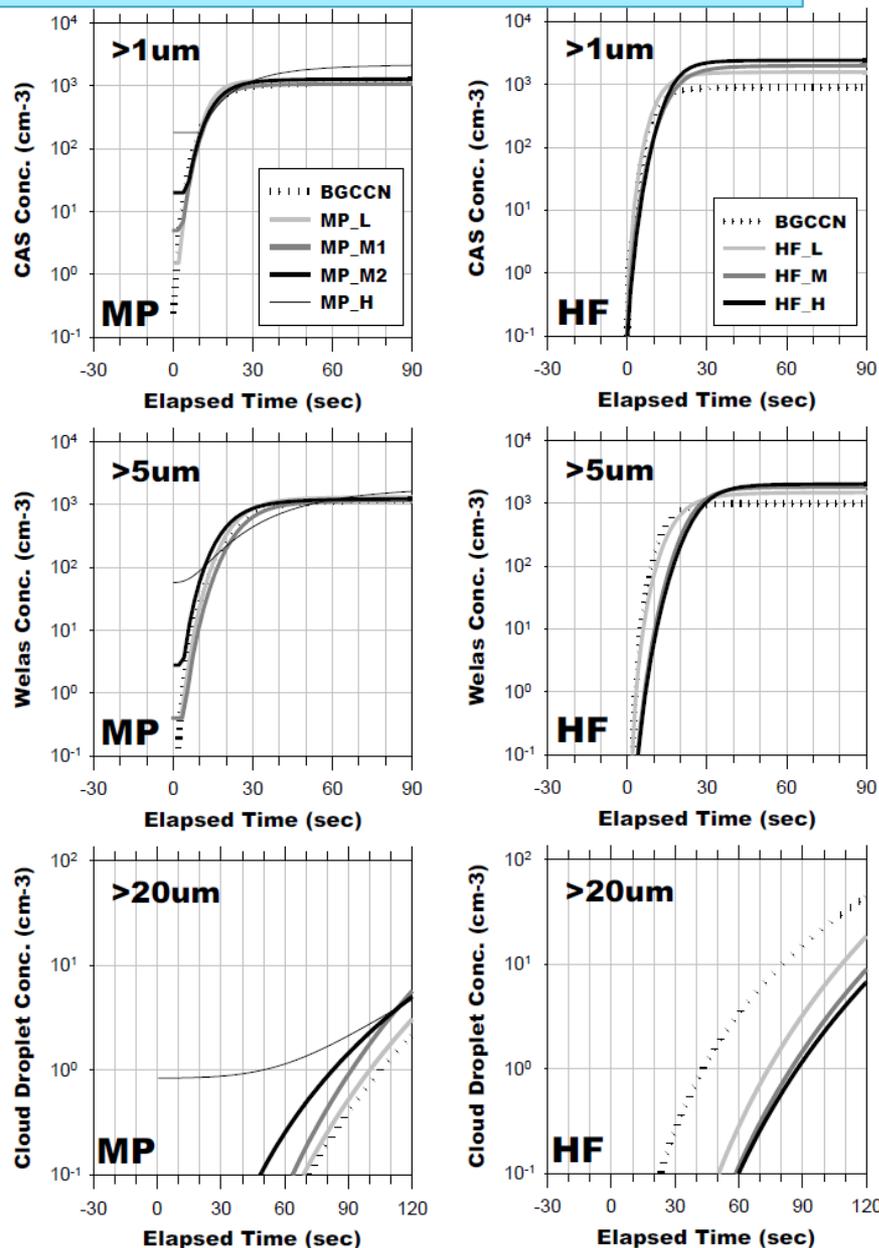
# 吸湿度計測（まとめ）



# 吸湿性粒子シーディング実験



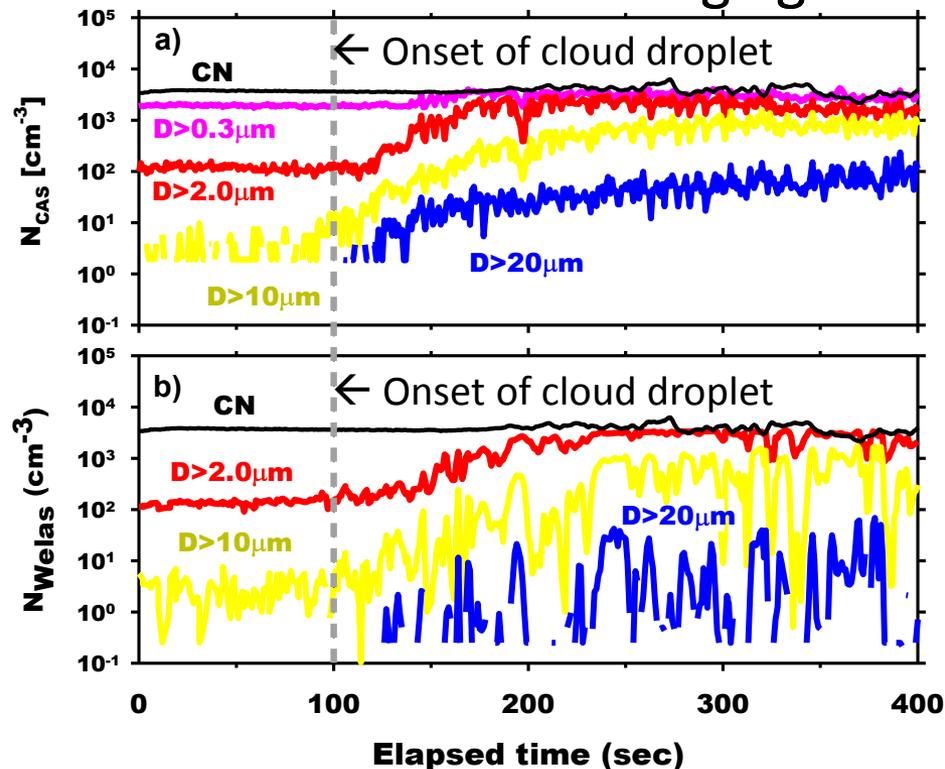
雲生成チェンバー実験 →



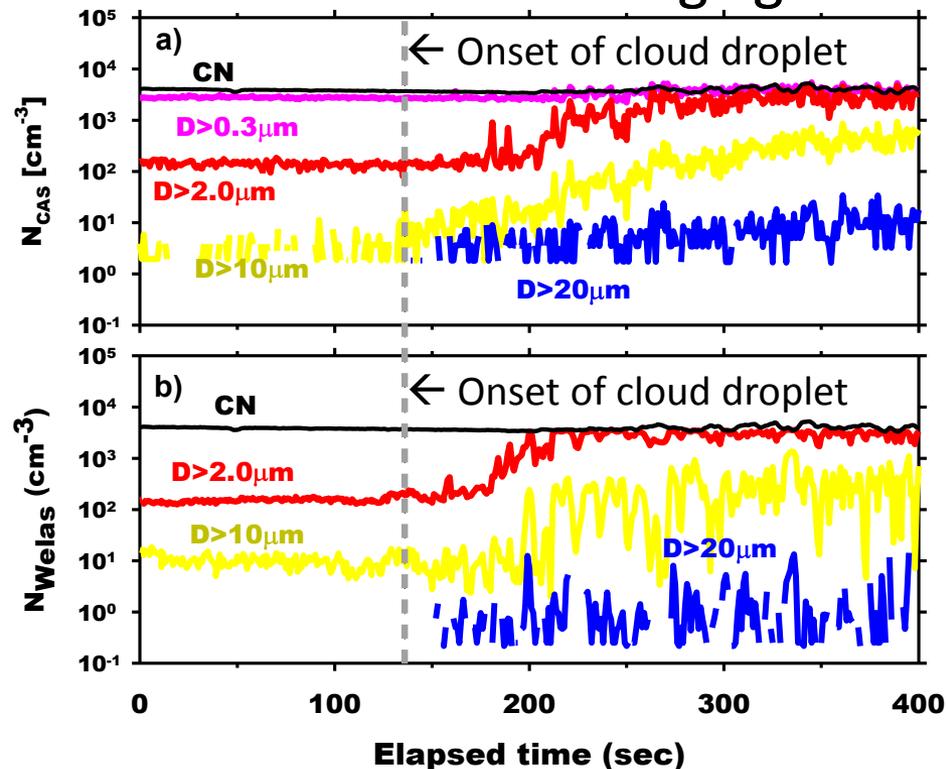
# 吸湿性粒子シーディング実験

## 雲生成チェンバー実験

MP without anti-caking agents



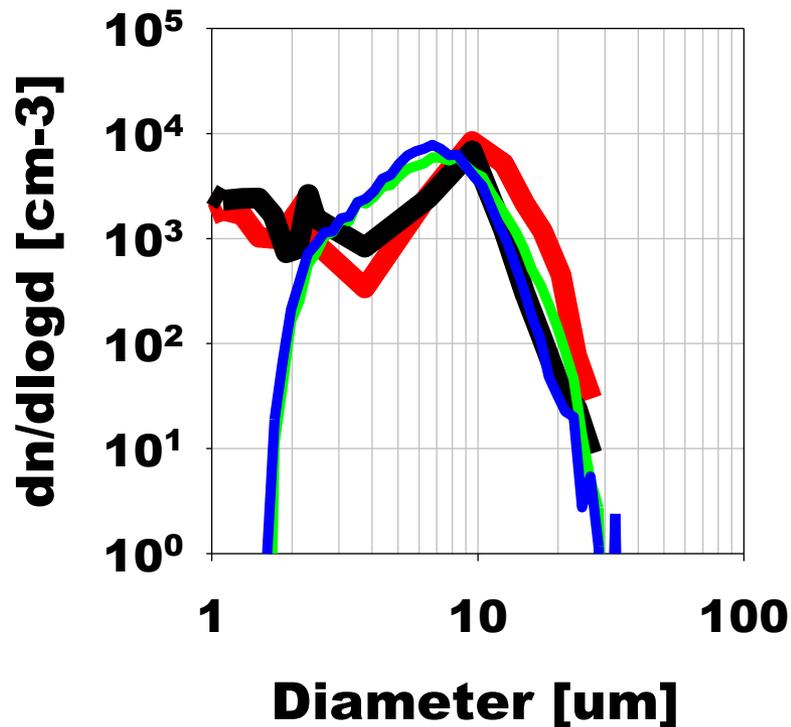
MP with anti-caking agents



# 吸湿性粒子シーディング実験

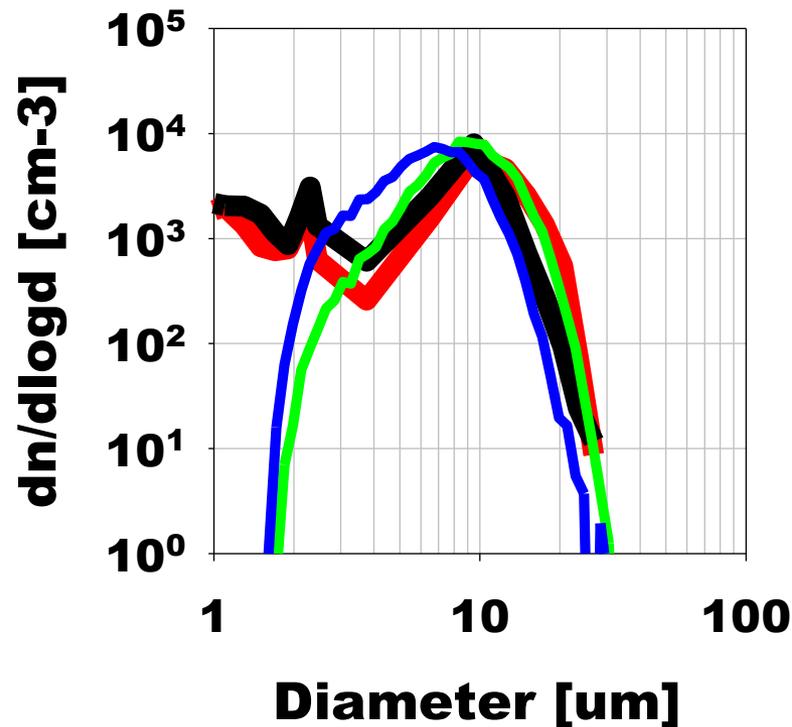
## 雲生成チェンバー実験

300sec



- Pure NaCl (CAS)
- MP with anti-caking (CAS)
- Pure NaCl (Welas)
- MP with anti-caking (Welas)

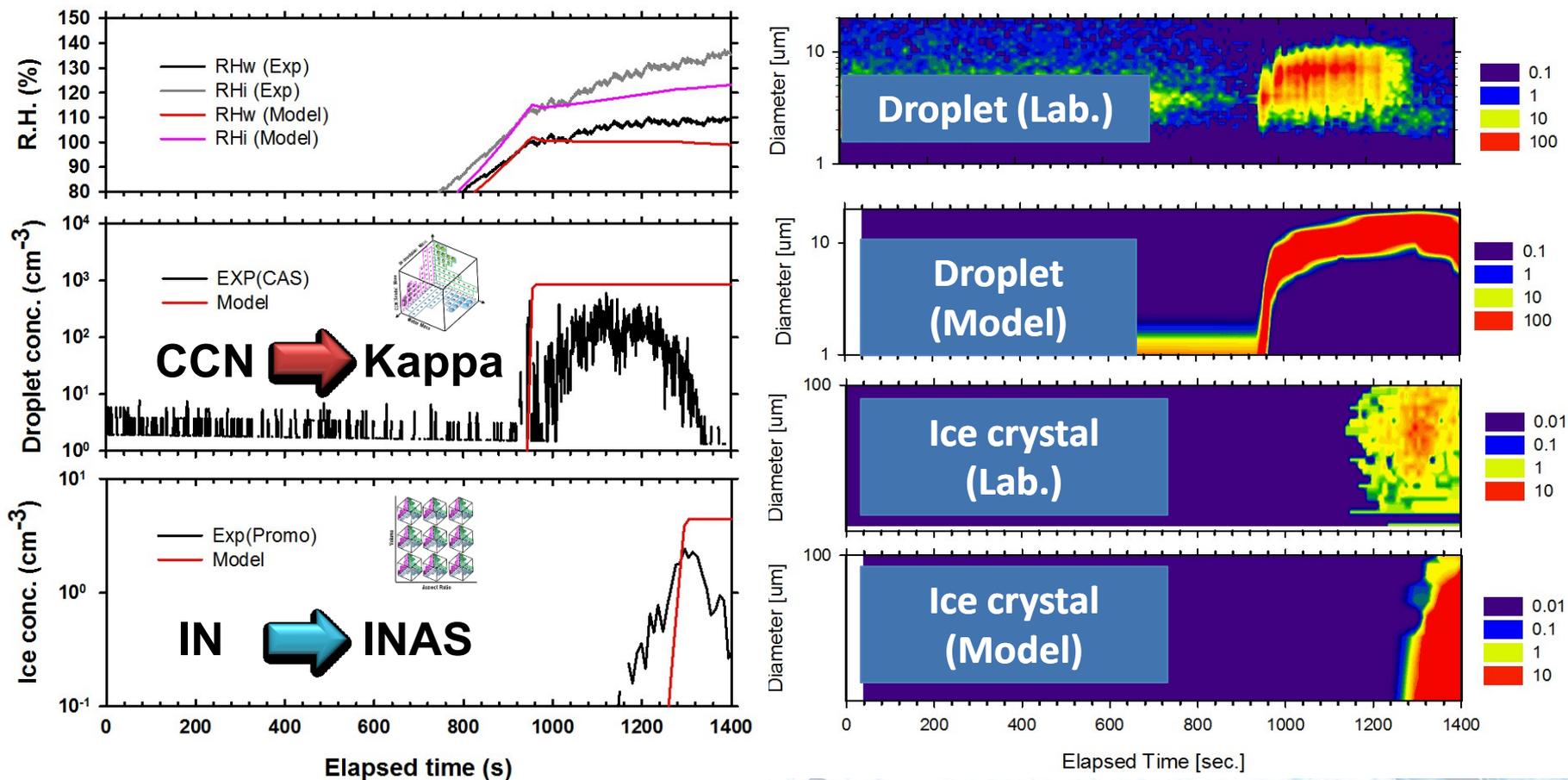
350sec



- Pure NaCl (CAS)
- MP with anti-caking (CAS)
- Pure NaCl (Welas)
- MP with anti-caking (Welas)

# 詳細雲微物理（リファレンス）モデルの改良

## 雲生成チェンバー実験との比較検証



## Summary

- 純粋なNaClと固結防止剤を含むMPおよび吸湿性フレアー粒子の物理化学特性（粒径分布、CCN能、IN能）を調査
- 先行研究からの進展、CCN能およびIN能のパラメータとして、モード径ごとの吸湿度  $\kappa$  およびINAS densityの気温依存性に着目
- 雲生成チェンバーを用いて、発生初期の雲粒粒径分布の時間発展を純粋なNaClと固結防止剤を含むMP粒子について実施
- 計測に基づくパラメータ $\kappa$ を適用したパーセルモデル計算の結果を雲生成チェンバーの実験結果と比較検証することにより、外部混合状態における競合的な雲核活性化に関する知見を蓄積し、吸湿性粒子シーディングの最適化を図る