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Ice Nucleating Particle (**INP**) Measurements at YMC: ETH - PINC and HINC

Portable **I**ce **N**ucleation **C**hamber
Horizontal **I**ce **N**ucleation **C**hamber

Zamin A. Kanji

ETH – Zurich

Year of the Maritime Continent (YMC) Workshop
Centre for Climate Research Singapore
January 28 – 30, 2015

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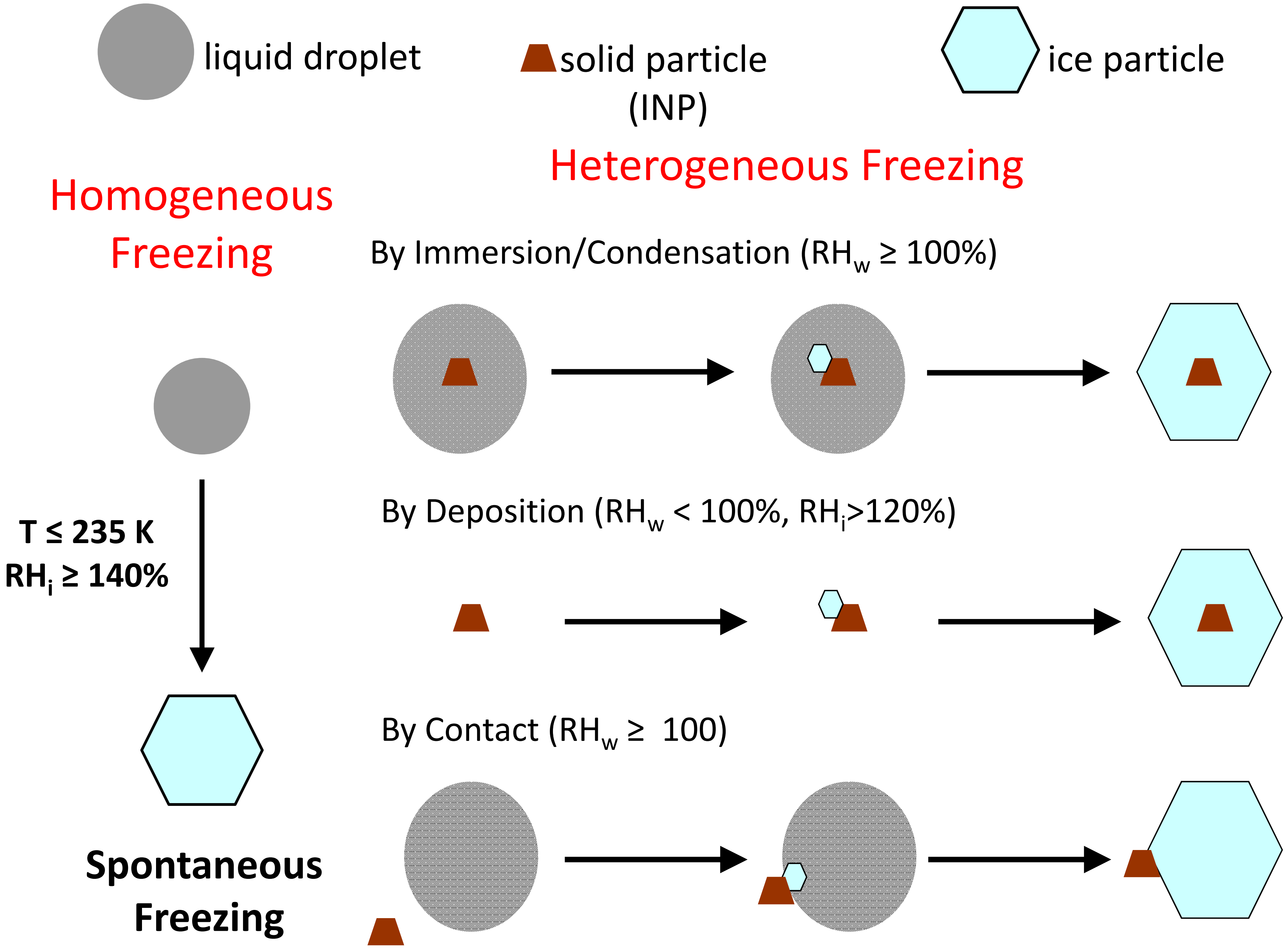
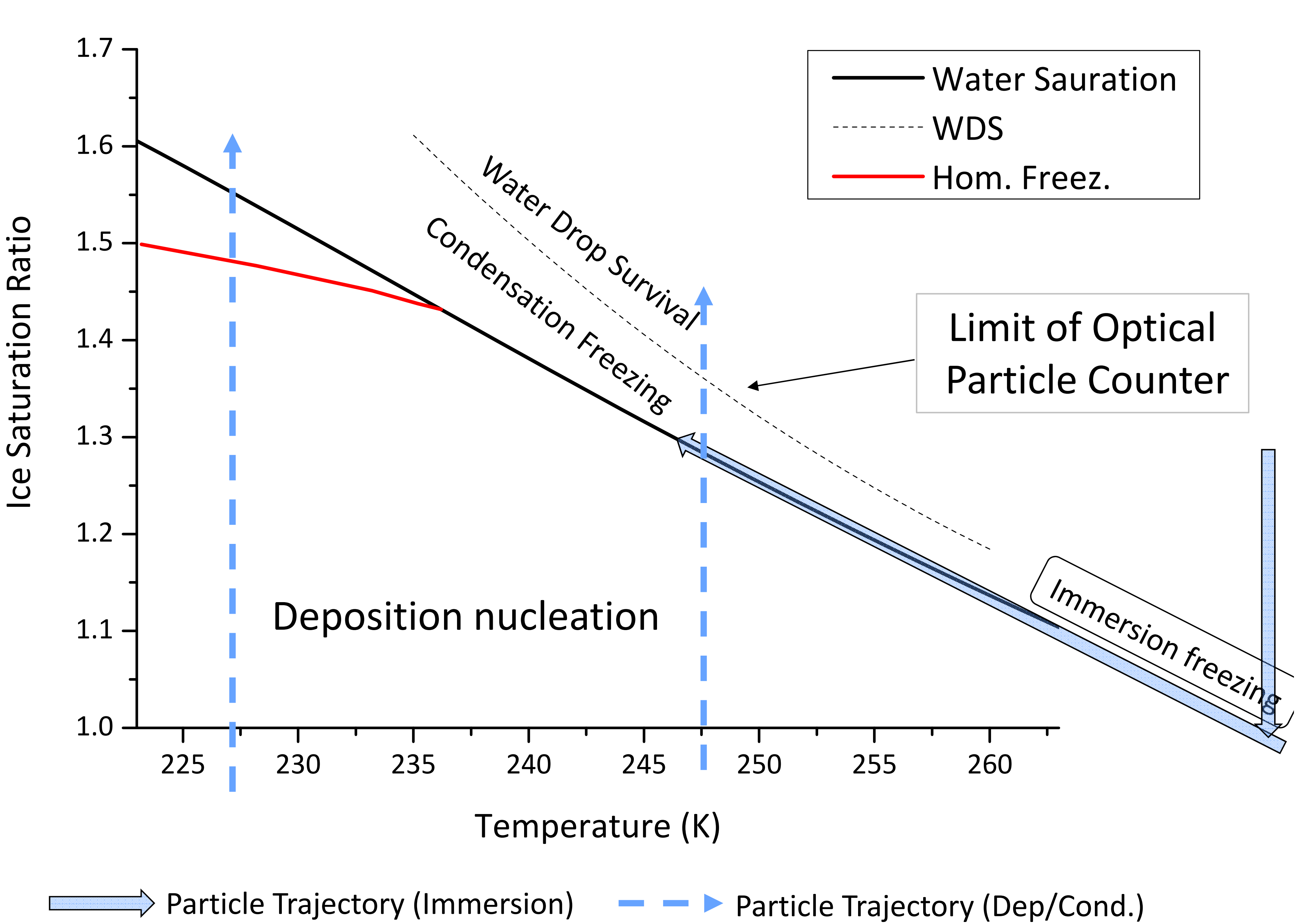


T- RH Space we can Investigate



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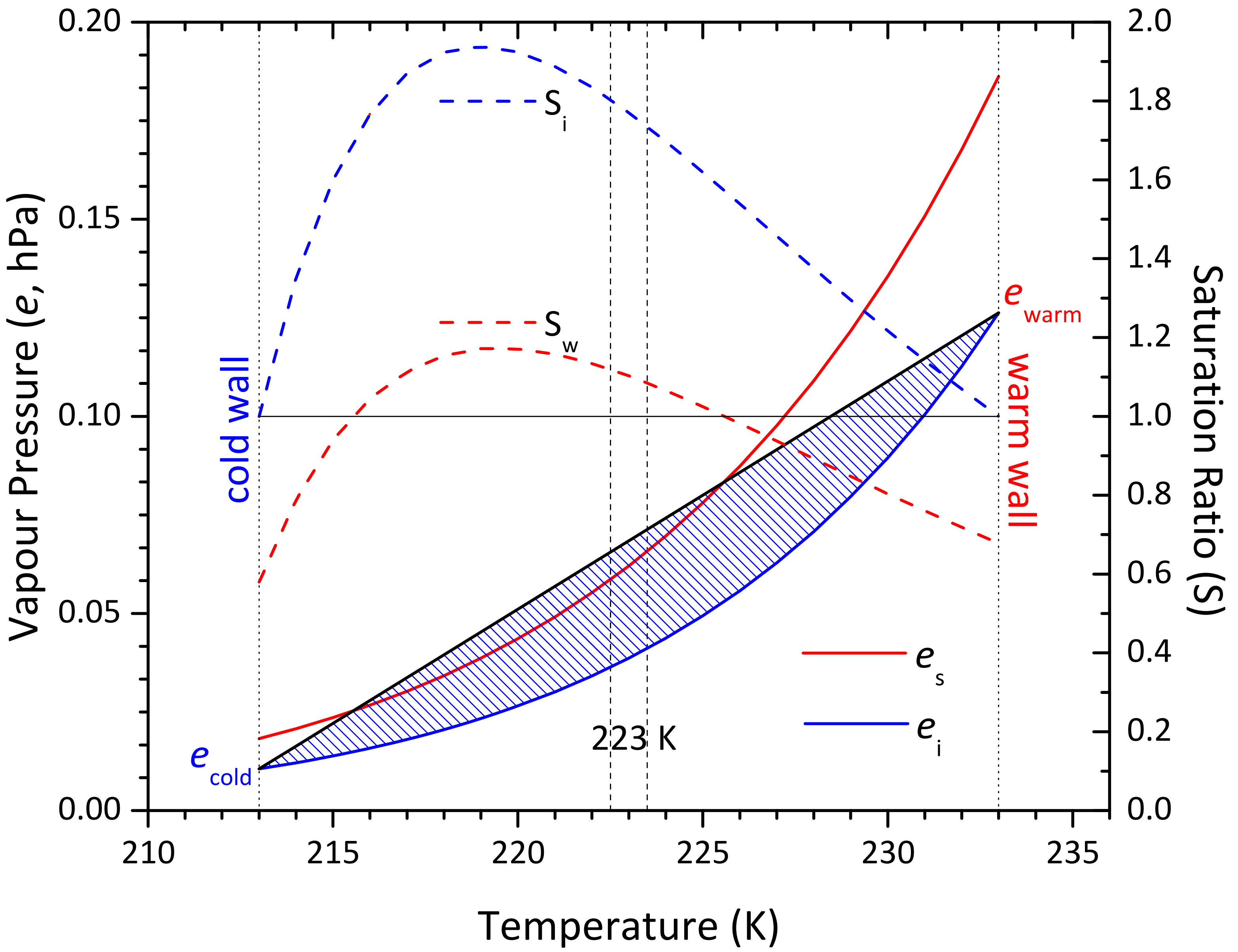
Thermal Gradient Diffusion Principle

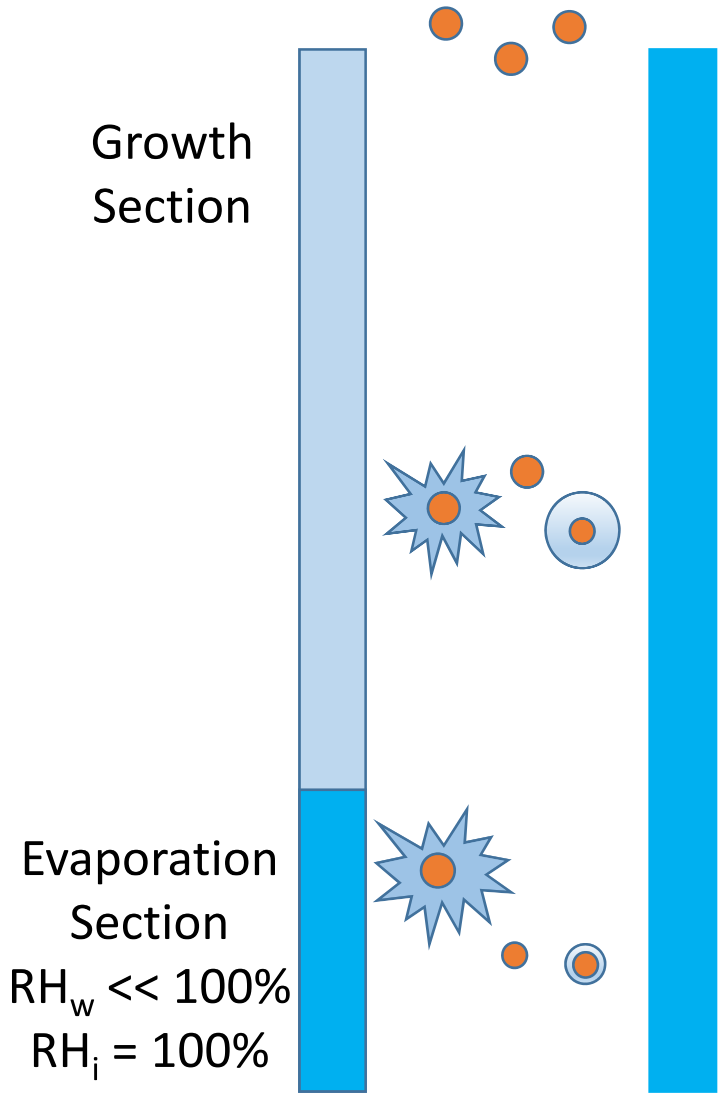


RH calculated at sample position (mid-way between chamber walls).

Residence time:
HINC: 3 – 28 s
Kanji and Abbatt, AS&T (2009)

Growth and Detection of Ice Crystals

PINC/(HINC) – Deposition/Condensation

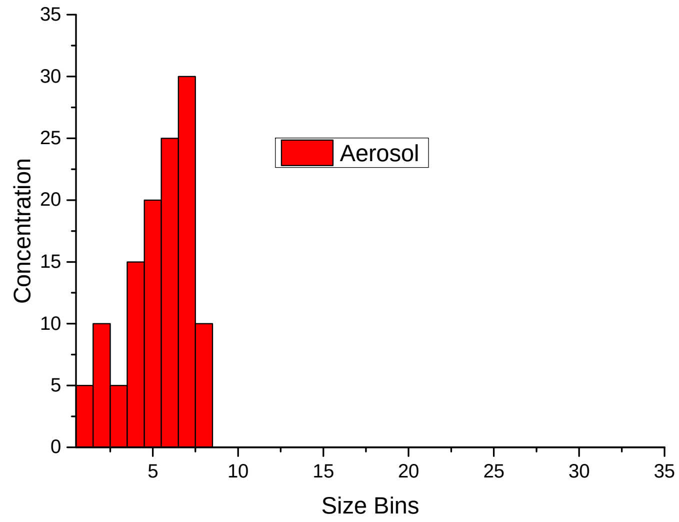


$T < -20$ °C
$RH_w < 100\%$
Deposition

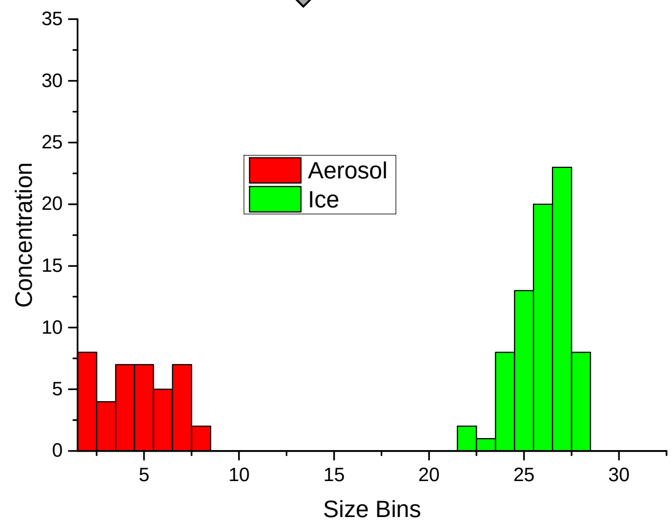
OR

$T < -6$ °C
$RH_w > 100\%$
Condensation

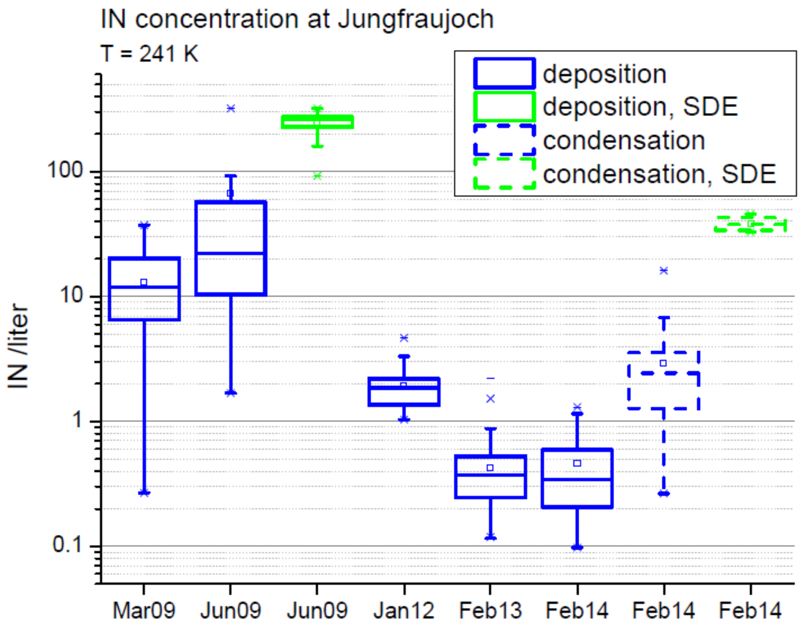
OPC: Large particles → Ice!

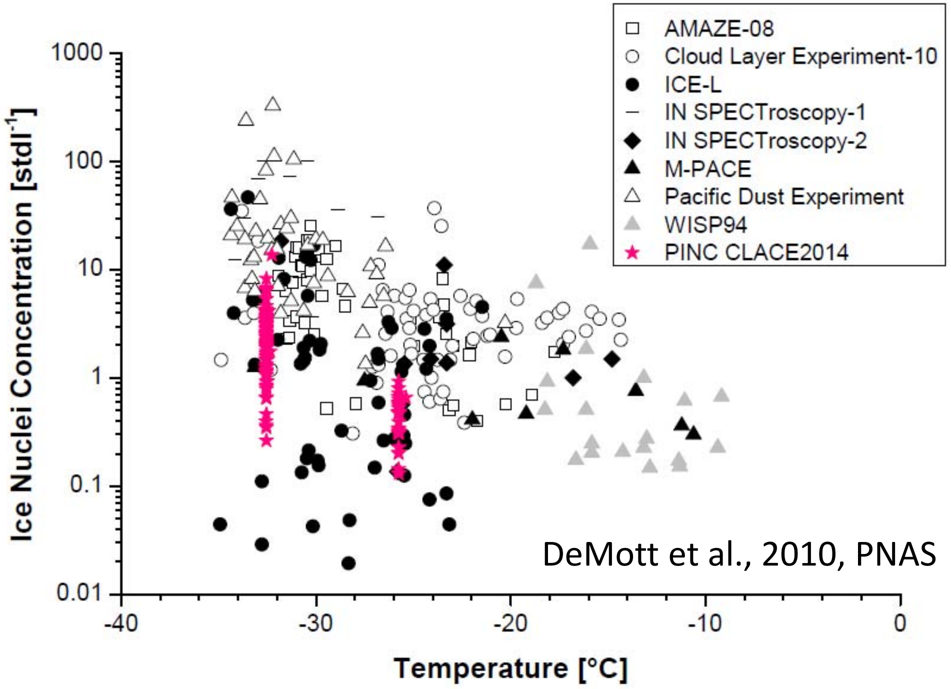


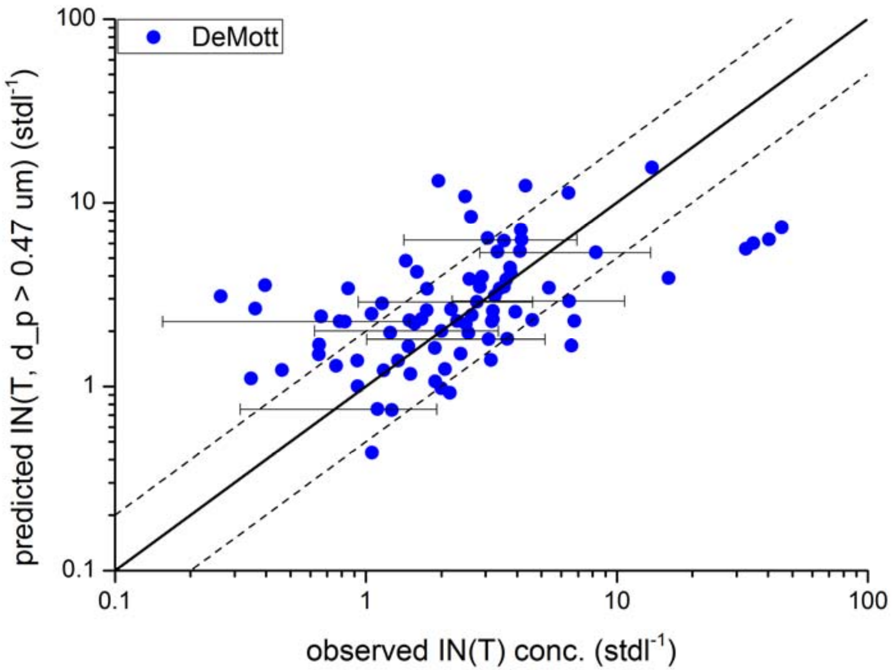
Ice Nucleation



Type of Data Collected:

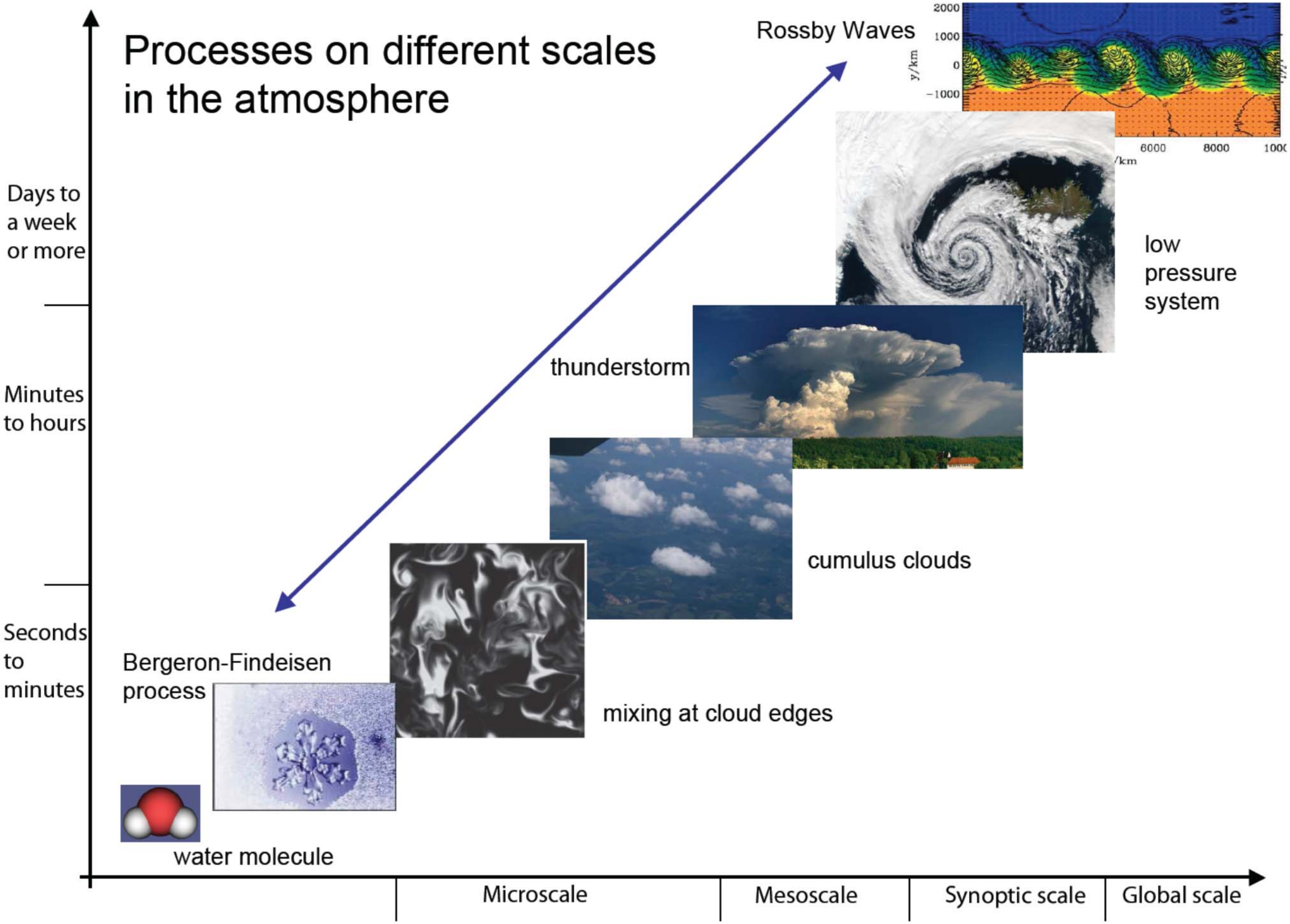




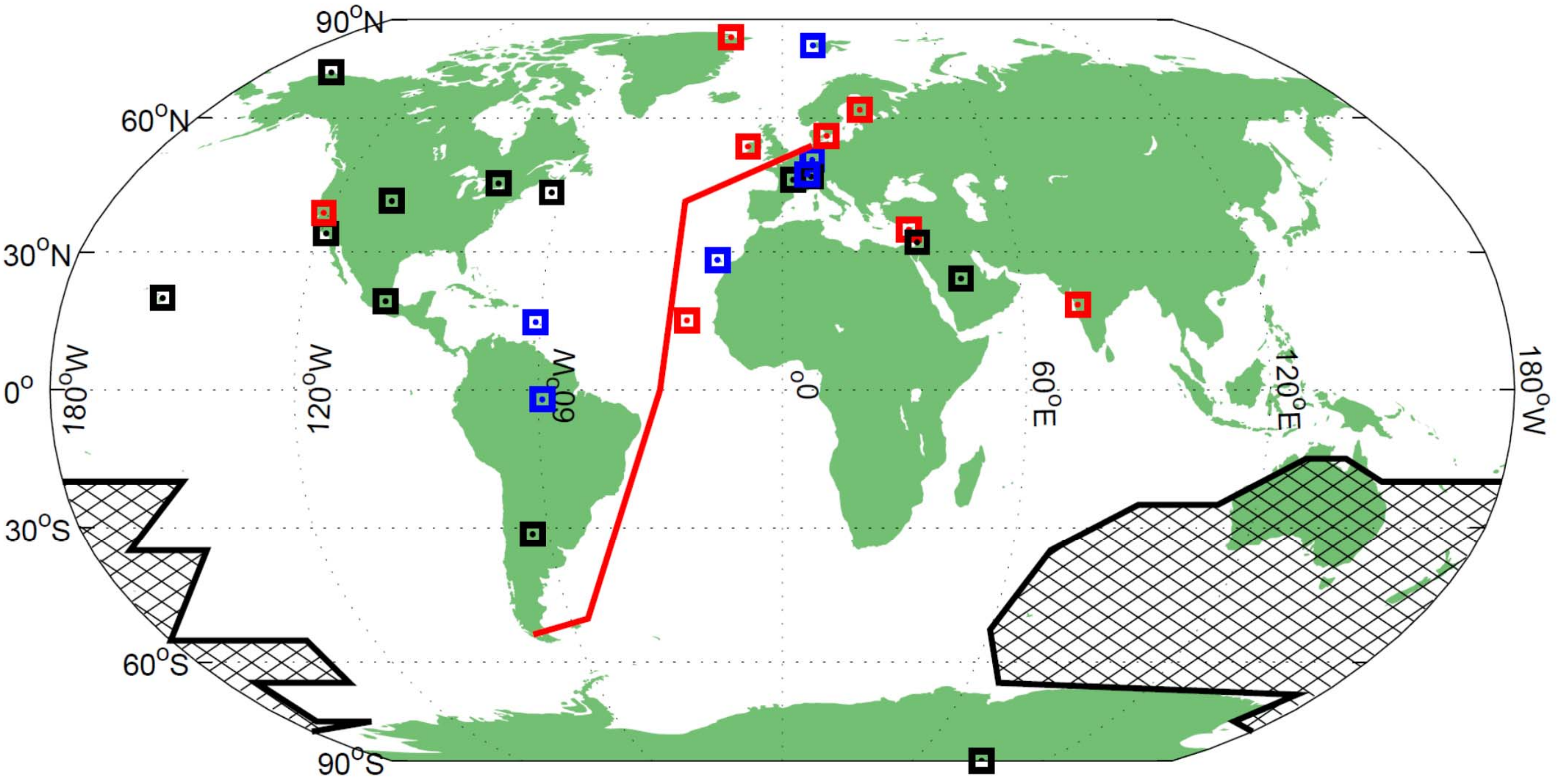


- Test existing param.
- Come up with new typically based on aerosol physical properties (size, number, surface area) and at time chemical properties

Connecting Both Ends of Scale

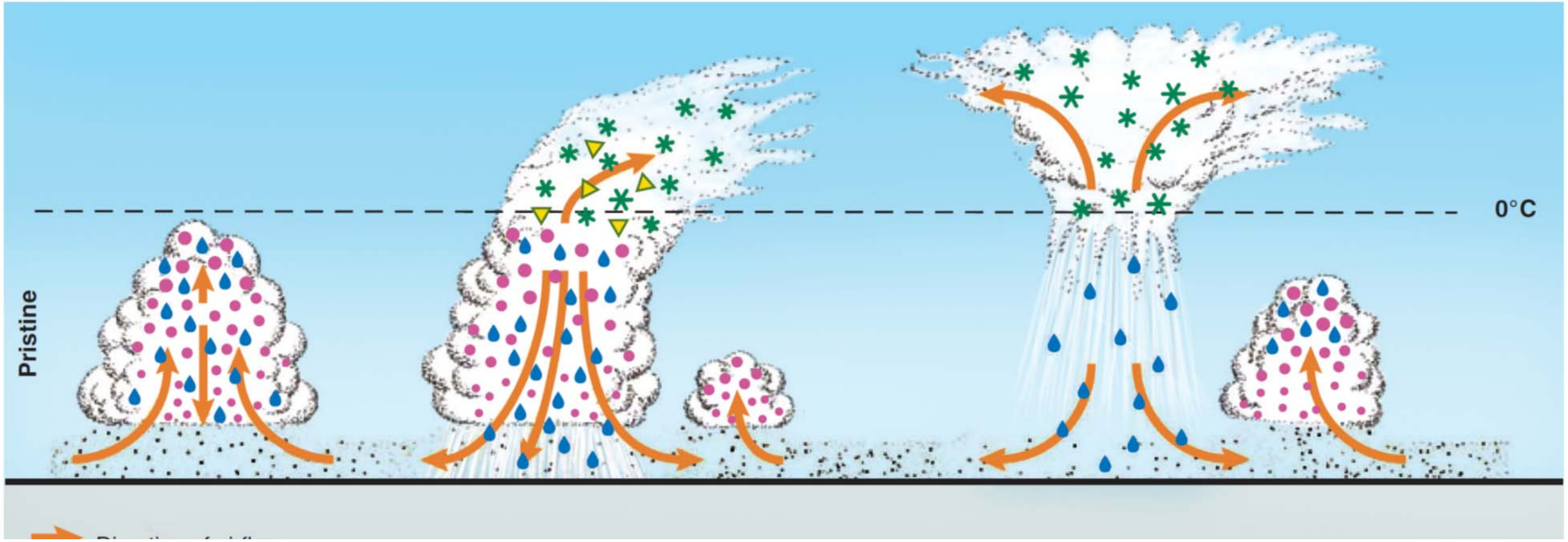


Motivation: INP Measurement Sites

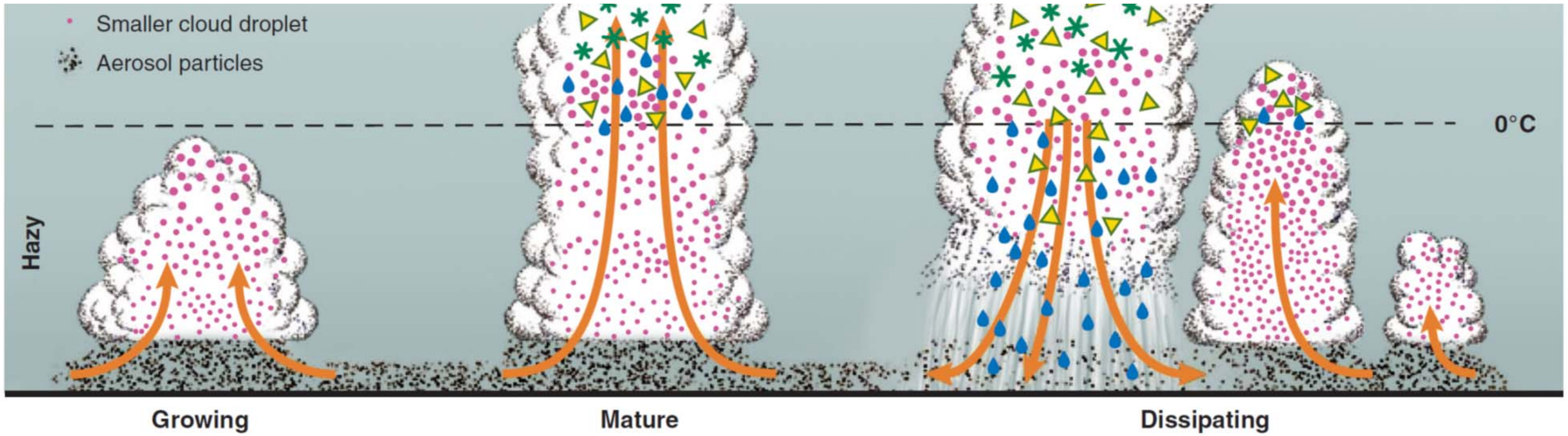


Increase Network/Density of Observations

Motivation: Convection



At YMC: marine (biological), industrial/urban and biomass burning



Rosenfeld et al., 2008 (Science)

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Transport of Aerosol to Mid – Upper (Free) Troposphere by Convection

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Major Research Question at YMC:

What is the contribution of the changing aerosol environment to [INP]?

Specific Questions (1)

- What is the INP concentration?
  - Mixed phase regime (T > -38 °C, RH_w > 100%)
  - Cirrus Regime (T < -38 °C, RH_w < 100%)

- How do [INP] change with environmental and meteorological conditions?
  - Ocean biological activity/Marine air masses
  - Precipitation events contributing to INP
  - Air masses from urban polluted/dust regions

Specific Questions (2)
Chemical & Physical Properties

- Is there a correlation of IN with particle properties?
  - Size, concentration, PM mass
  - Composition
    - Organics vs. inorganics
    - BC or Dust
    - Biologically active material
  - Is the Sea Surface Microlayer (SML) – a source of IN particles
    - Chance (permission from Federal Research Office?) to sample the SML?

Wish List of Auxiliary Measurements

Instrument	Information Acquired	Time Resolution
HINC/PINC	IN	~ 20 mins
SMPS	Aerosol SD	~ 3 mins
APS	Aerosol SD > 0.7µm	~ 20 seconds
CPC	Aerosol Conc.	5 – 10 seconds
WIBS/UV-APS	Biologically active Aerosol SD/Conc	20 seconds
PM10/2.5	Mass Conc. Chemical Comp?	12 or 24 hours?
AMS SP – AMS?	Chemical Composition Aerosol mixing state BC?	~ 1 – 3 mins
ATOFMS/LAABTOFMS	Single particle Refractory Material	~ 3 minutes
Lidar/Cloud Radar	Cloud Phase above measurement site	

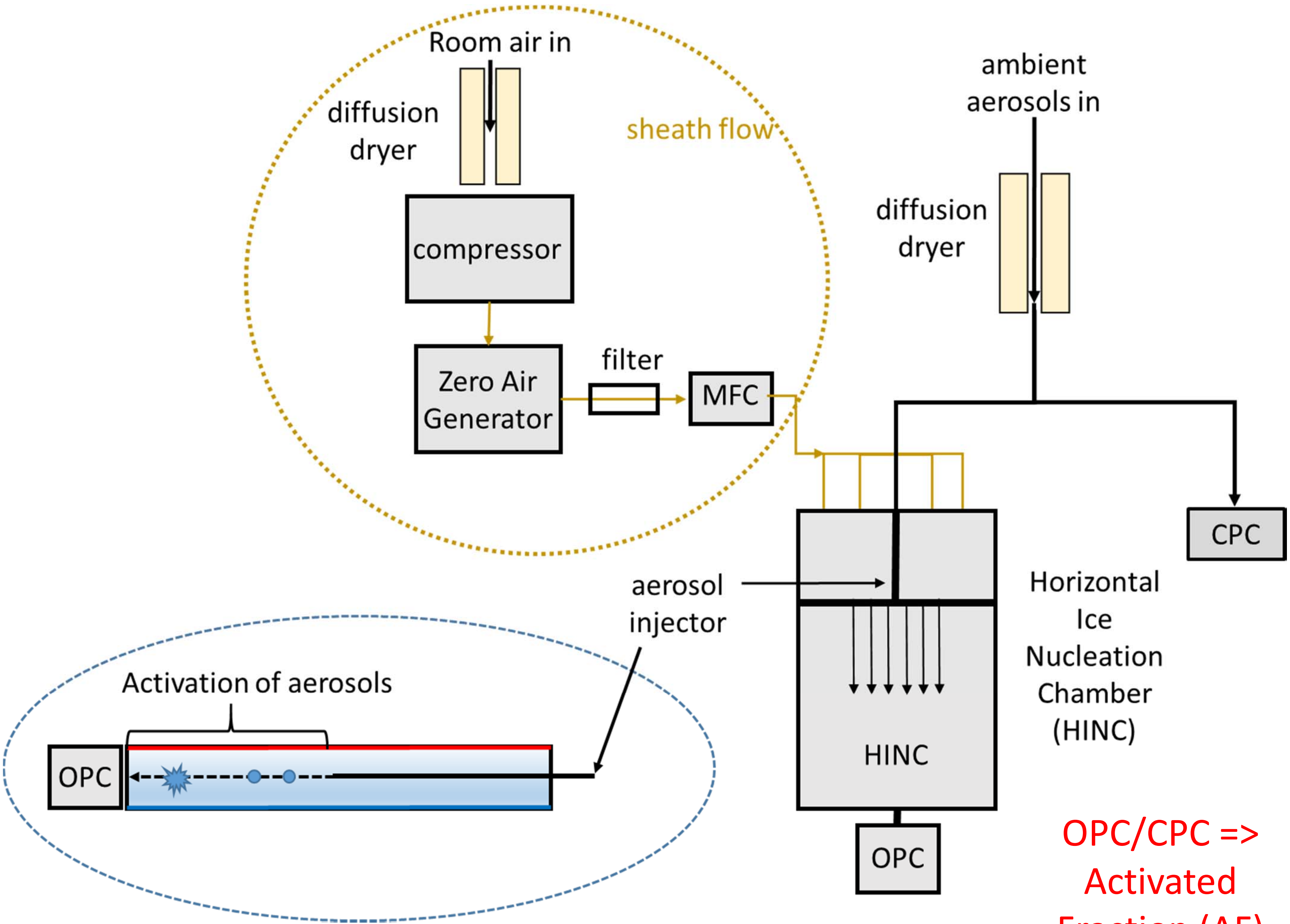
Questions

- How do INP measurements inform contribute the YMC framework?
  - Aerosol – (cold or mixed-phase) cloud interactions?
  - Are ice forming processes represented? Are there *precipitation* forming mechanisms dependent on ice phase formation? Importance for cumulus?
  - Ice nucleation – important for dehydration/water vapour budget in UT
    - Exchange for UT/LS

Mechanisms Investigated in Field

- Both PINC and HINC use an OPC to distinguish ice from interstitial particles by size discrimination
  - Homogeneous Freezing – can be used for in-field calibration
  - Deposition Nucleation
  - Condensation/Immersion Freezing

HINC Schematic – Field



OPC/CPC => Activated Fraction (AF)

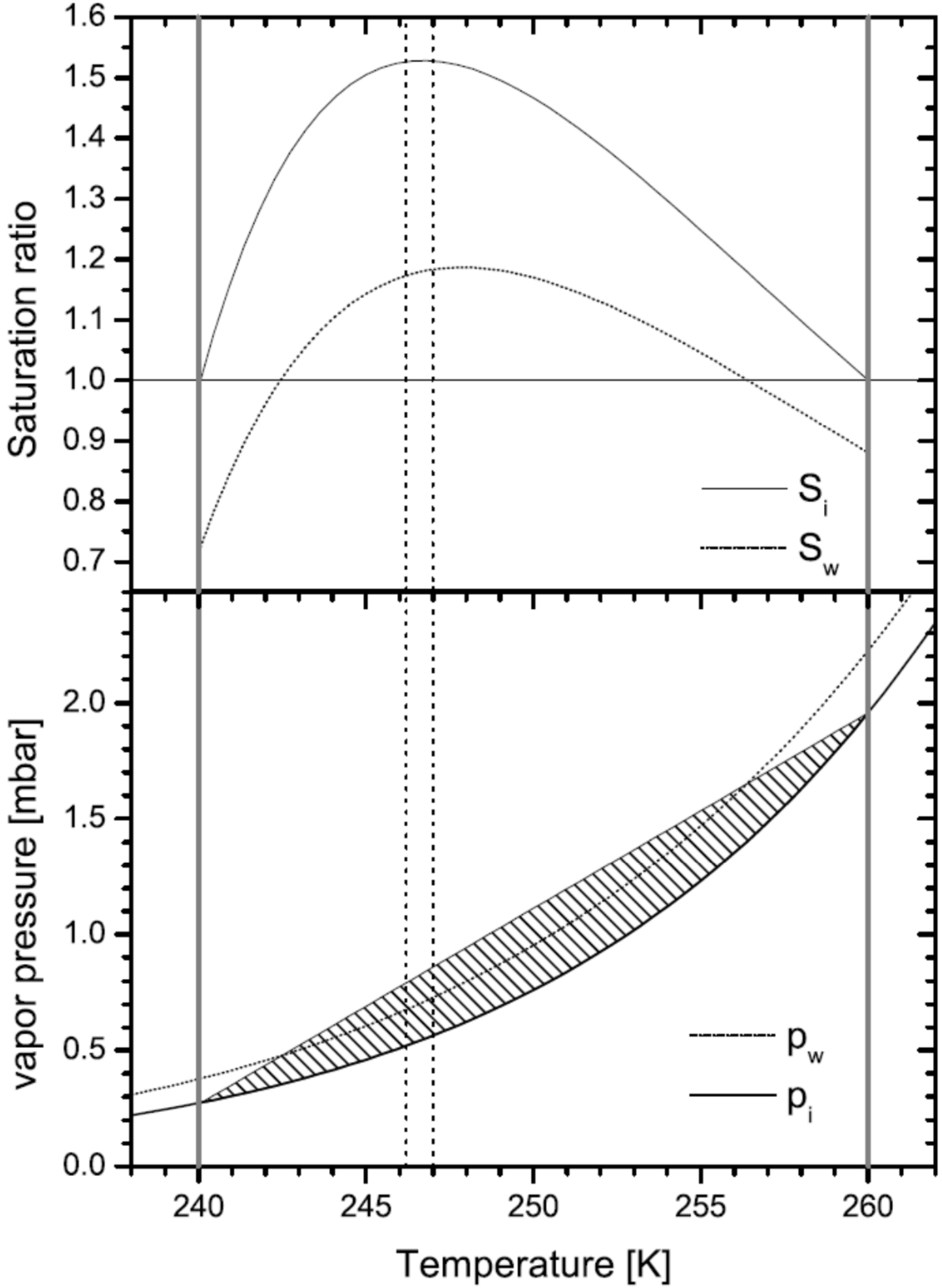
Courtesy of Larissa Lacher

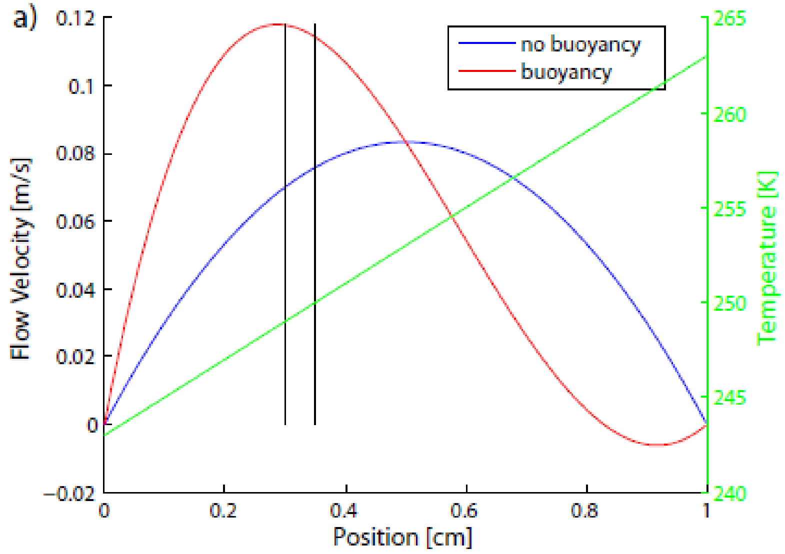
Power and Chemical Requirements for IN

- Chemicals Required
  - Nitrogen, Ethanol, Molecular sieves/Silica gel
  - Drying oven on site to regenerate drying agent
- CPC/SMPS 200 W each, 2 laptops 100 W
- Compressor with Zero-air generator (220 W)
- Re-circulating Chiller 3.5 kW (max)
  - R404a and R508a (refrigerants, in permanent sealing)
  - Ethanol used as a re-circulating fluid

Total Power Required 4.3 kW

Ice Nucleation – CFDC Principle





Residence time:
PINC: 5-6 s

RH calculated at sample position accounting for displacement due to buoyancy in vertical chamber

Stetzer et al., AS&T (2008)
Kanji et al., ACP (2013)

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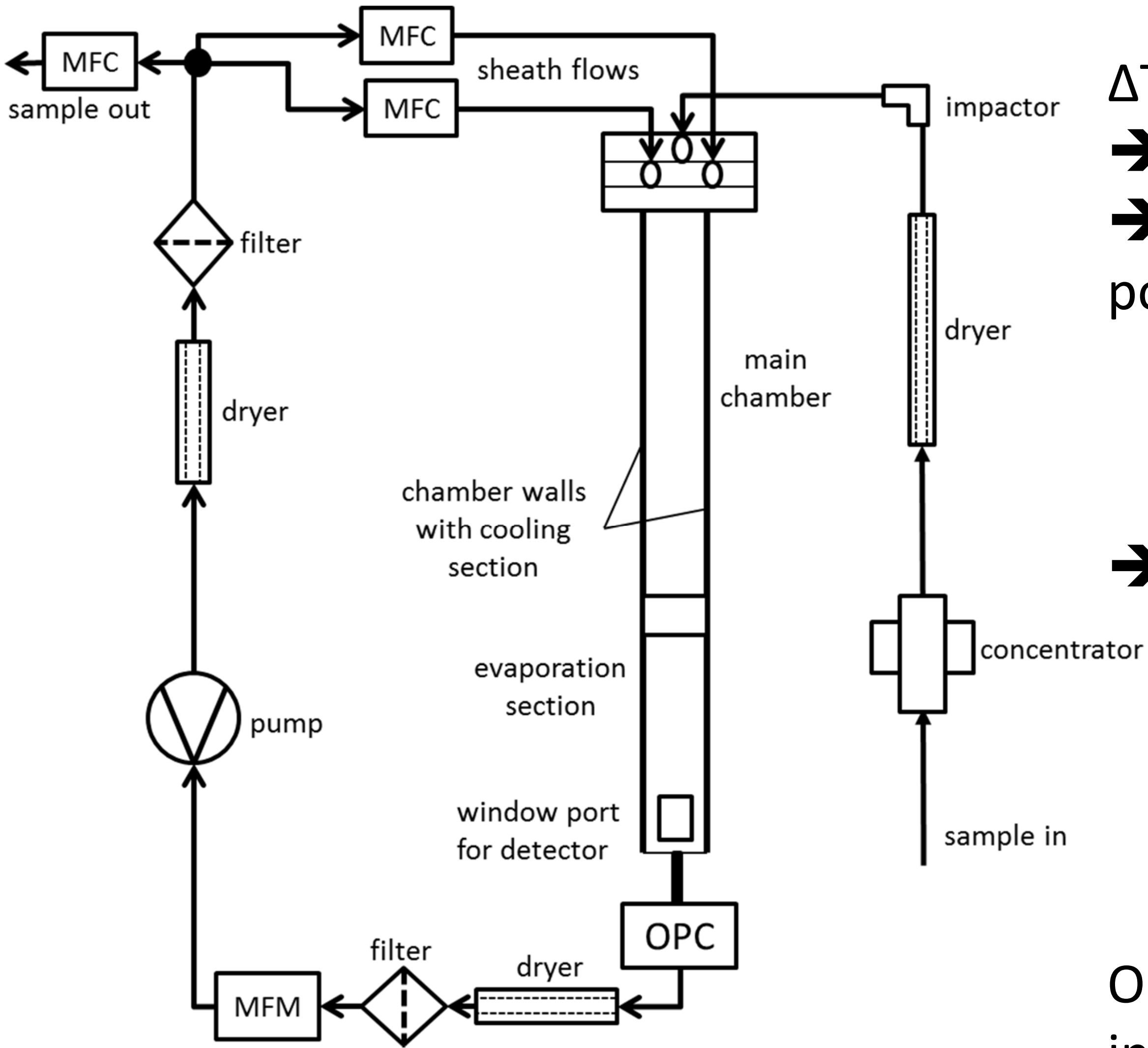
PINC – Schematic



ΔT between ice coated walls
➔ ice evaporates
➔ creates S_i at sample position

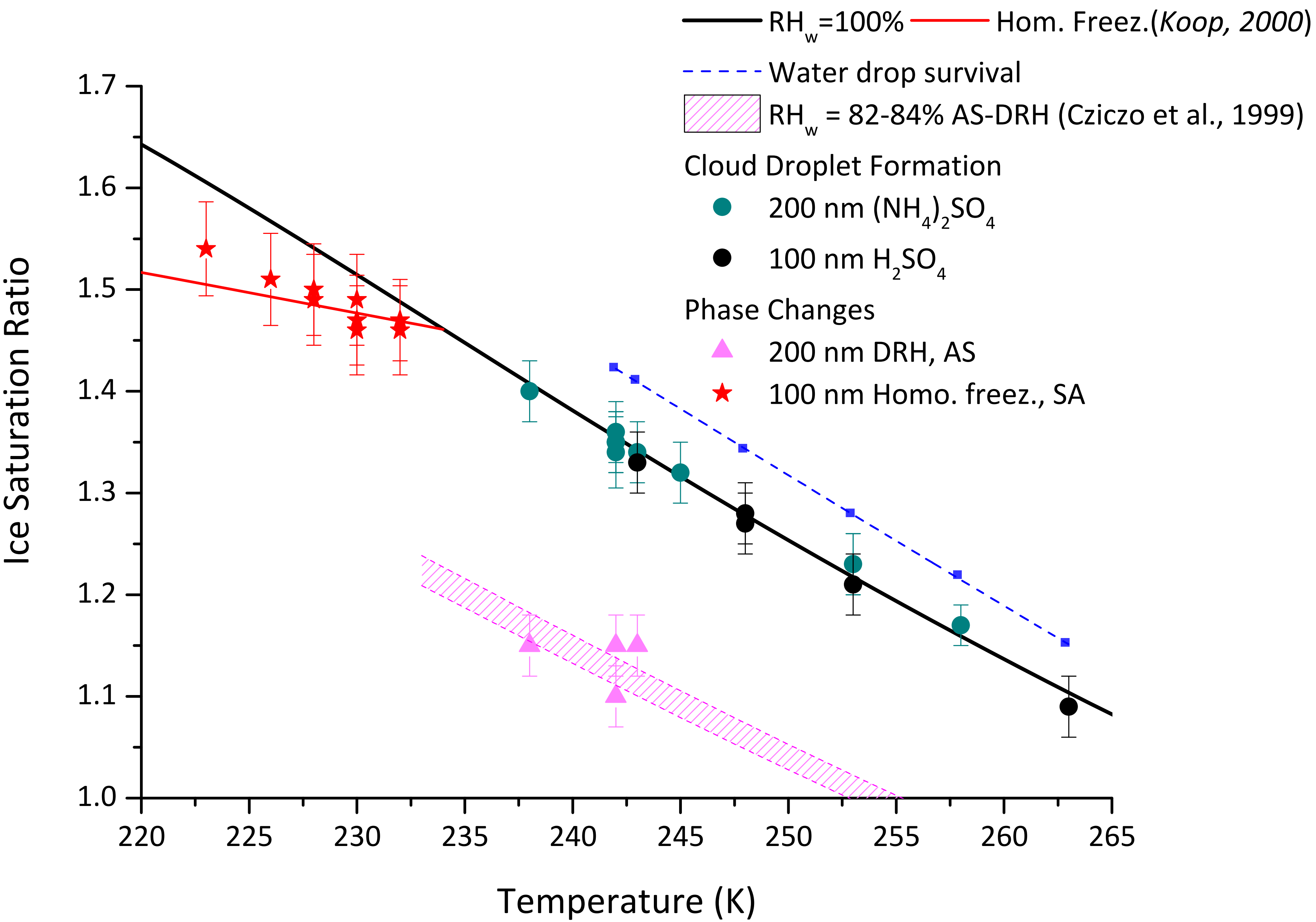
➔ freezing initiation,
ice crystal growth

OPC detects crystals & interstitial
➔ distinction by size

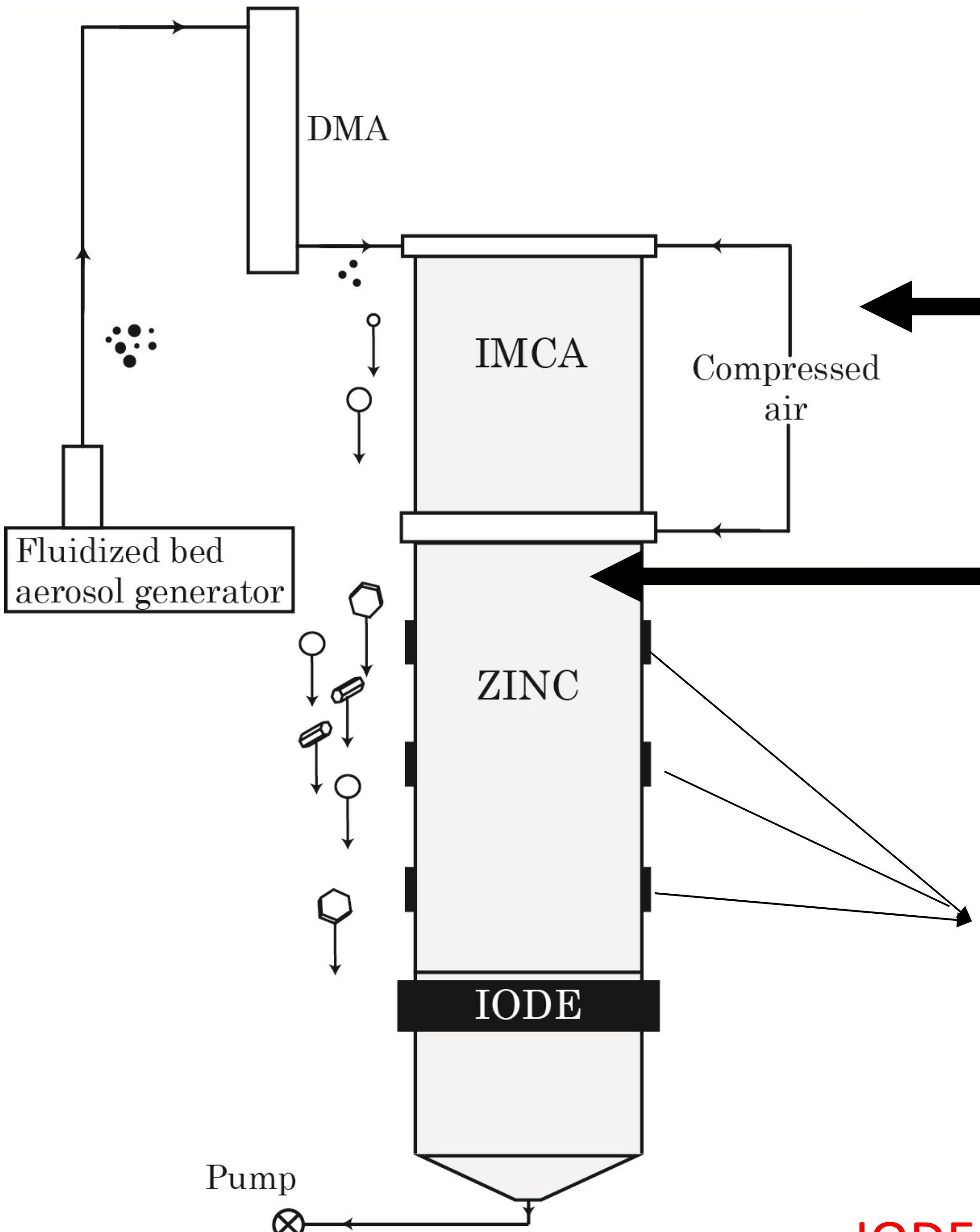
Modified from Stetzer et al., AS&T (2008)
Kanji et al., ACP (2013)

OPC/CPC counts => Activated Fraction (AF)

Calibration of INP Chambers



IMCA – ZINC: Immersion mode



Particles singly immersed in IMCA 'forced' CCN activation

Supercooled region (ZINC) maintained at $RH_w = 100\%$

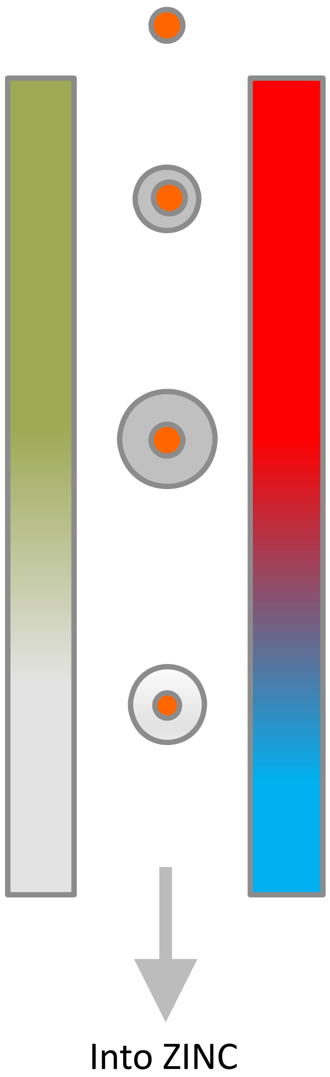
Detection Ports for kinetic studies (time dependence)

IODE gives a Frozen Fraction (FF)

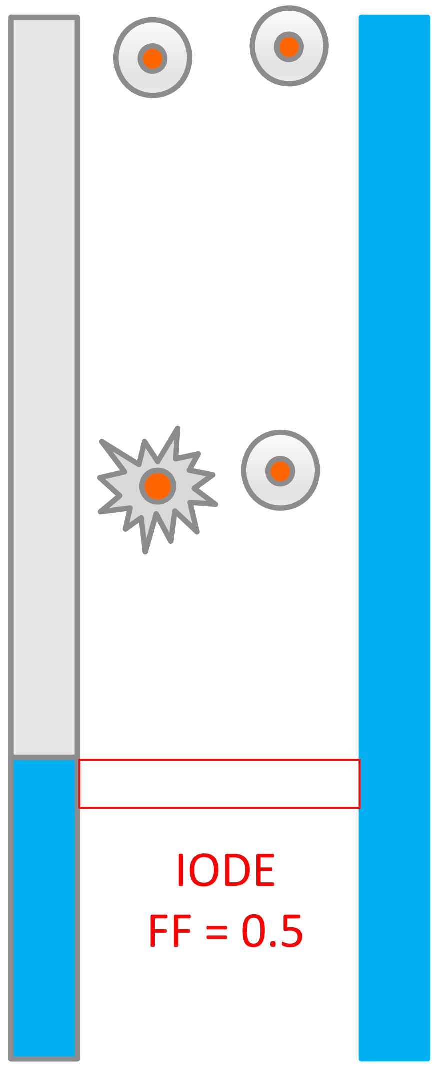
Welti et al., ACP (2012)

Growth and Detection of Ice Crystals

IMCA



ZINC - Immersion

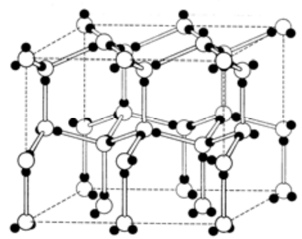


Motivation to study ice nucleation in the atmosphere

- interest in understanding the primary formation of ice in clouds (and how it can be modified)

- characterisation (of requirements) and spatial distribution of ice forming nuclei
  - Insolubility
  - Size
  - Active-sites
  - Chemical bonding
  - Crystallography

- functional description of ice nucleation e.g. for modelling.



General Research Objectives (Lab)

- Understand ice nucleation mechanisms
  - Can theory predict empirical observations?
    - Test CNT and non-CNT based models to describe data
- Understand behaviour of IN with changing size
  - Size represents change in surface area for homogeneous surfaces
  - For complex particles like mineral dust, size represents change in composition or soluble material
- Effects of particle type (composition and ageing of particles)
  - Natural mineral dusts (ozone – aged, SOA – coated), soot particles, clay minerals, biological IN, AgI

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