Aerosol 3D Profile Measurement
using Compact Particle Measuring Instruments with Balloon, PM-Sonde, & Drone System

Kang-Ho Ahn
X. Querol*, Z. Wu**,
H. Eun, G. Lee, H. Lee, Y. Park, I. Hwang, W. Lee, and J. Bae

HANYANG University, R. of Korea
IDAEA-CSIC, Barcelona, Spain
**** Peking Univ., China***

CONTENTS

■ Sampling and Measurement Package System

1. Rotating Plate Impactor
2. Optical Particle Counter (Hy-OPC)
3. Total Particle Counter (Hy-CPC)
4. Scanning Mobility Particle Sizer (Hy-SMPS)
5. Iso-kinetic Sampling Probe
6. Ground Station Monitoring Program

■ Atmospheric Aerosol Measurement (Mobile type)

1. Tethered Balloon System
2. Sounding Balloon (PM-Sonde) System
3. Drone Measurement
4. Other applications

Particles Above and Inside the Planetary Boundary Layer

Altitude

100 km

10 km

Lidar

PBL

1 km

Very Limited Data

100 m

10 m

Human Activities

Ground Based Stations

0 m

sec min hour day mon

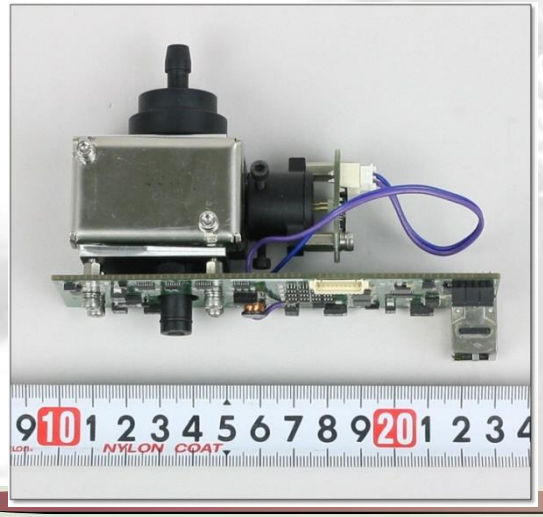
Time

❖ Miniaturized Instruments

(1) Rotating Plate Impactor

- Weight : **302 *g***
- 3 stages (10 μm, 2.5 μm, 1.0 μm~ or 0.5 μm)
- **24** TEM grids / stage

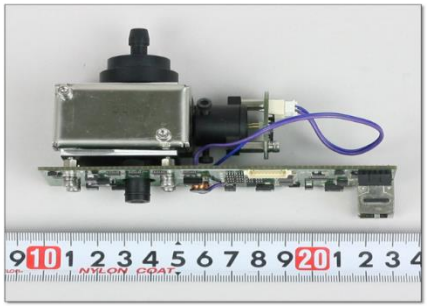
(2) Optical Particle Counter (Hy-OPC)



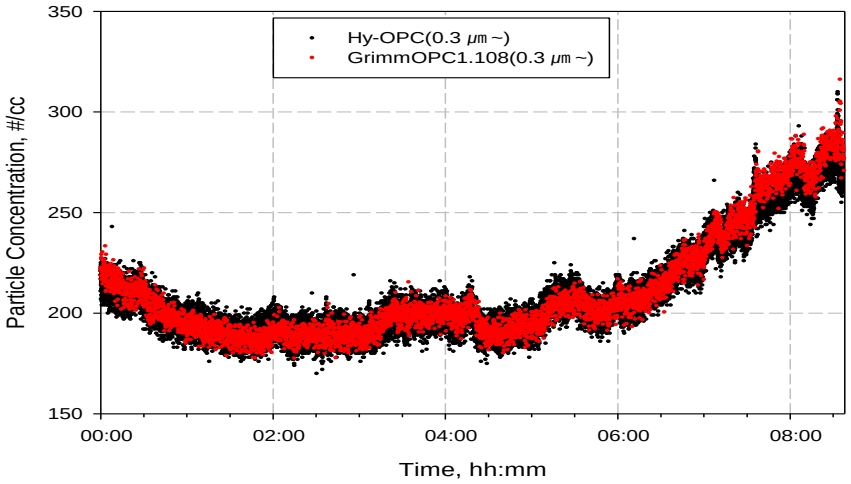
Particle Size	0.3/0.4/0.5/0.8/1.0/2.5/3.0/4.0/5.0 um
Count Range	18,000 #/cm^3
Sample Flow Rate	1,0 liter/minute, flow compensation at low pressure
Operating Temp. Range	-25 to 45℃
Dimensions	120 × 150 × 65 mm
Weight	256 g (w/o battery)
Input/Output	TCP/IP

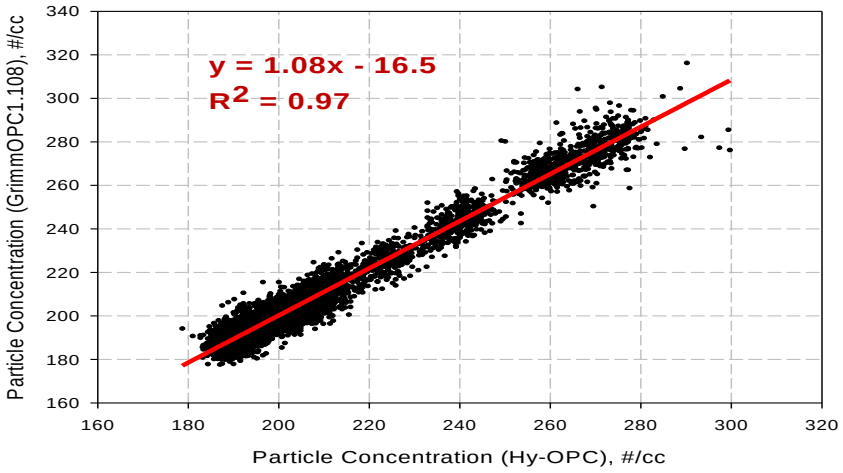
❖ Miniaturized Instruments

✓ Optical Particle Counter (Hy-OPC) Performance Evaluation



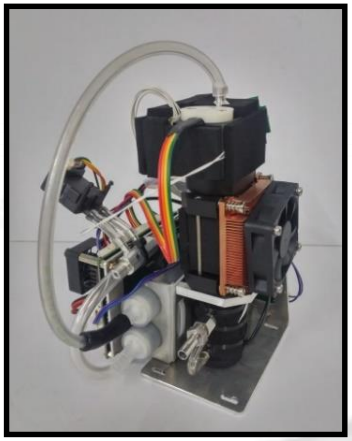
➢ Atmospheric Aerosol monitoring comparison with Grimm 1.108 for 8.5 hours.



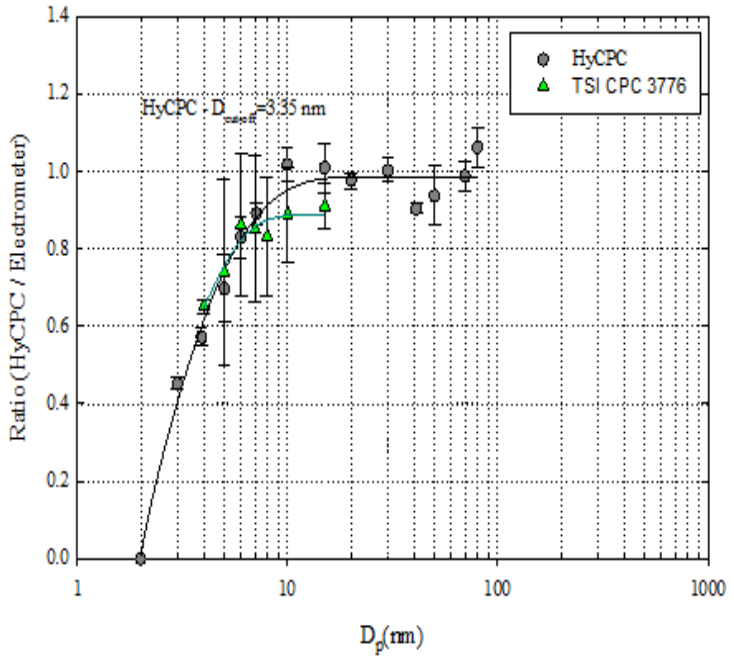


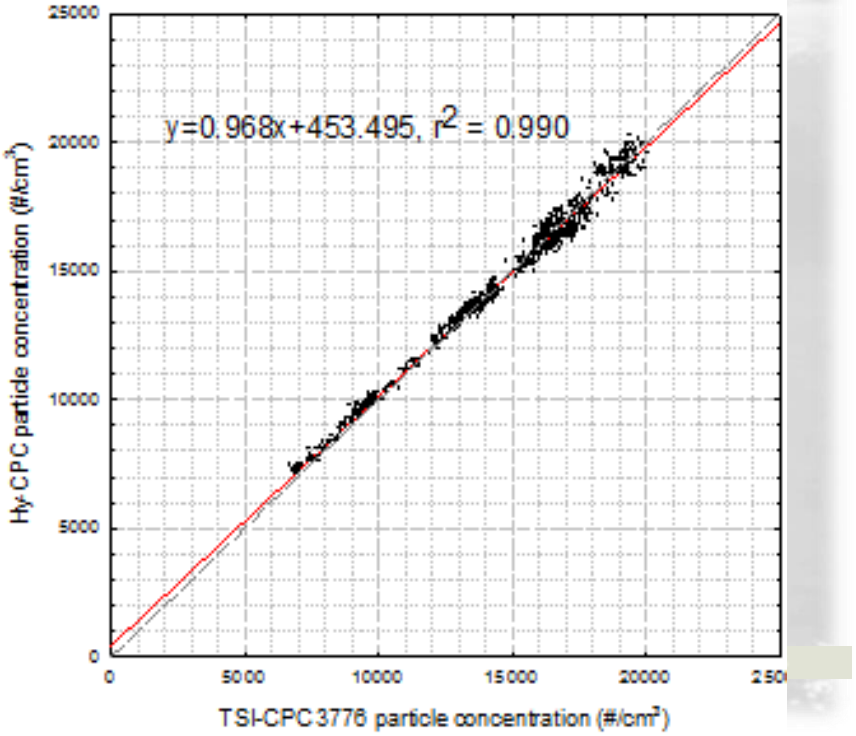
❖ Miniaturized Instruments

(3) Condensation Particle Counter (Hy-CPC)



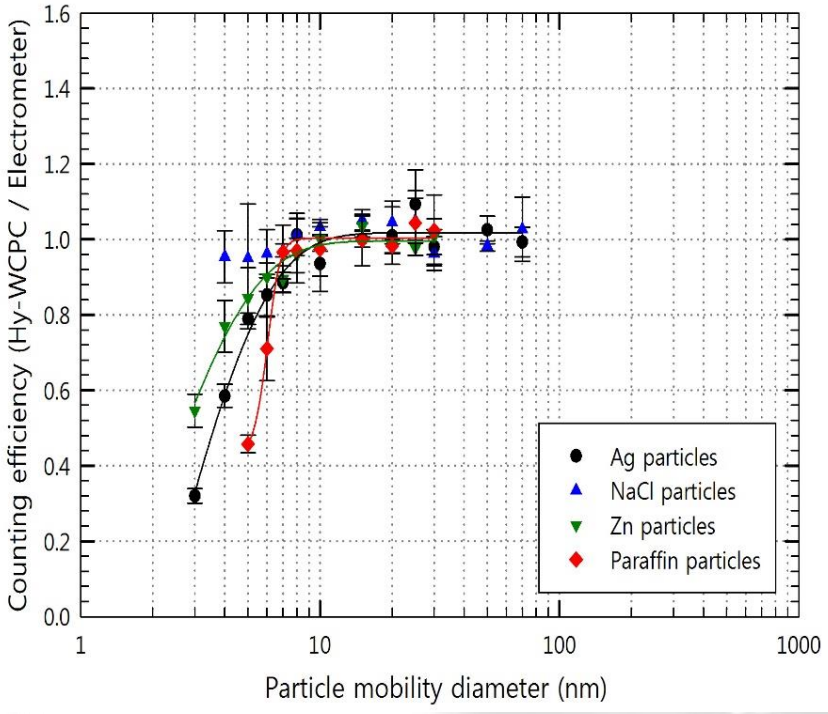
Cut-off Size	3.35 nm
Count Range	144,000 #/cm³
Sample Flow Rate	0.125 liter/min., Pressure compensation
Operating Temp. Range	-25 to 45℃
Weight	580 g (w/o battery)
Working Fluid	Water or n-Butanol

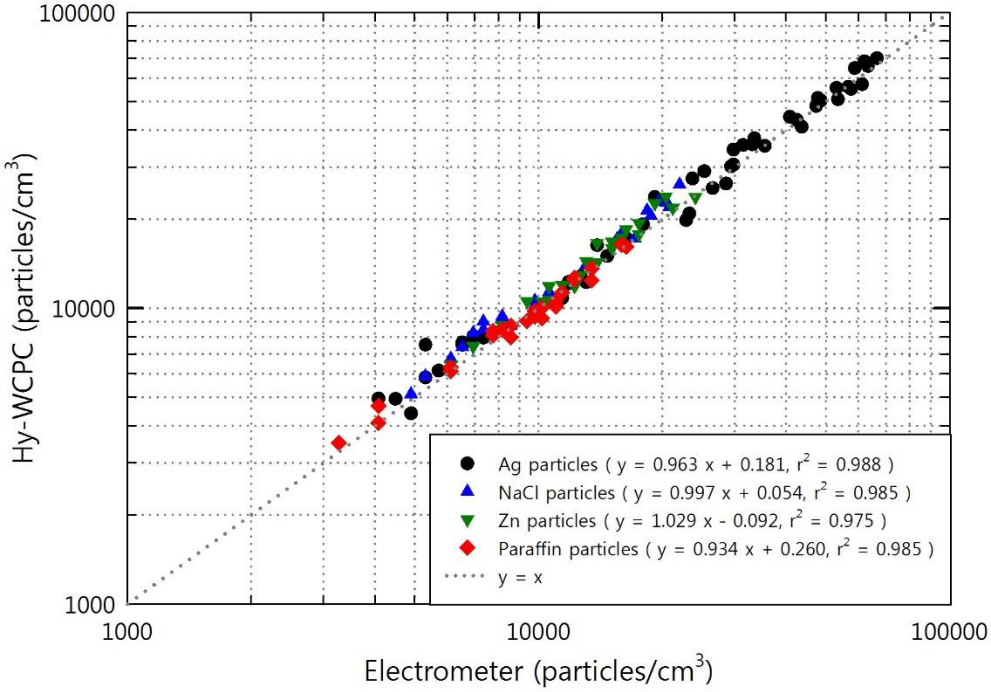




❖ Miniaturized Instruments

(3) Condensation Particle Counter (Hy-WCPC)

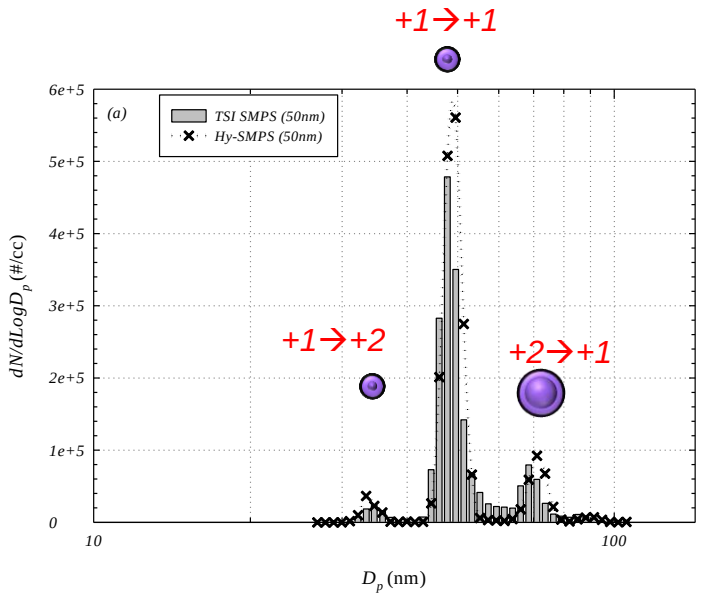


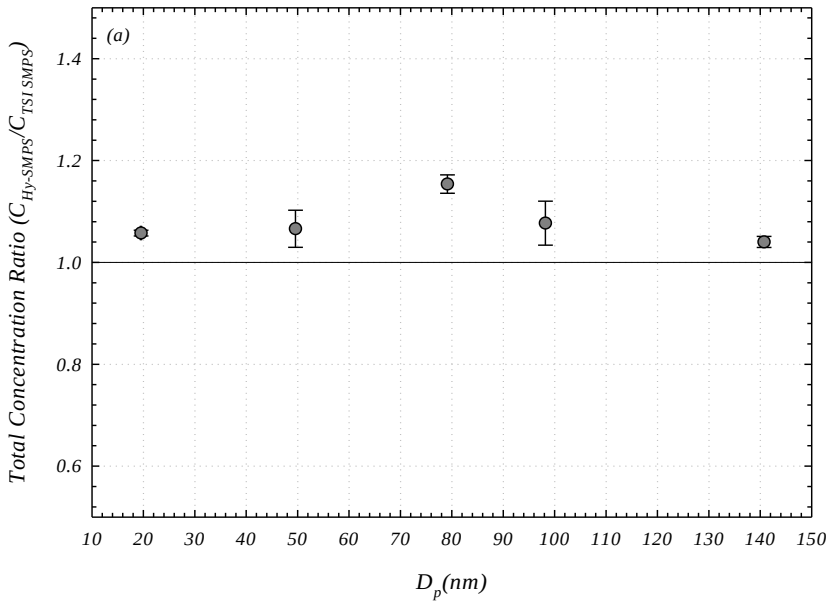


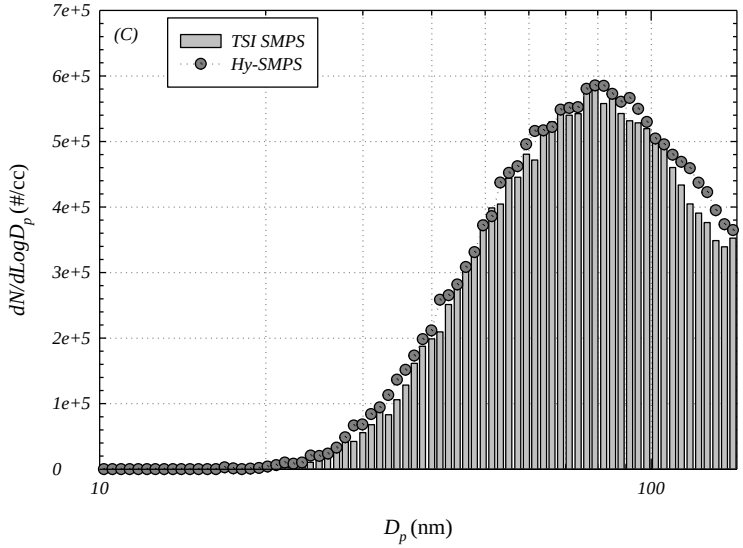
J. Aerosol. Sci., 113 (2017) 12-19

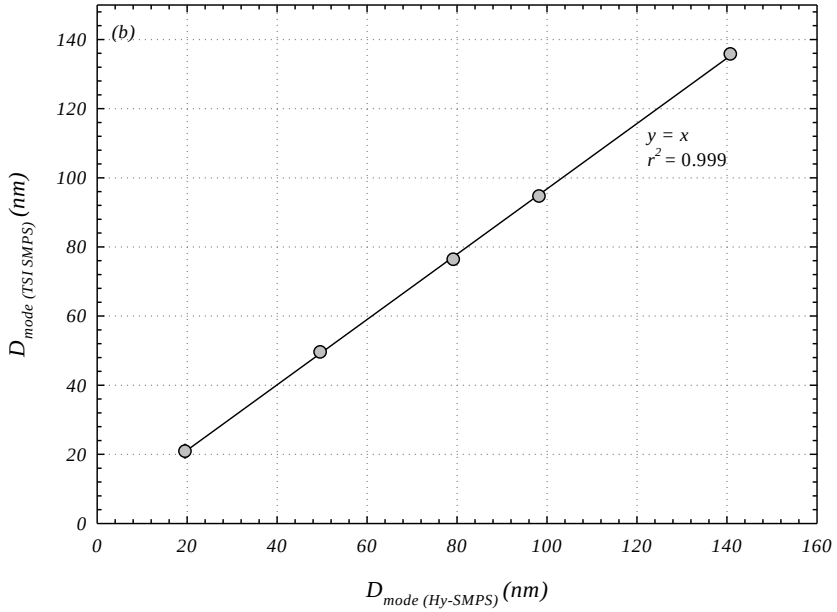
❖ Miniaturized Instruments

✓ Hy-SMPS Performance Evaluation





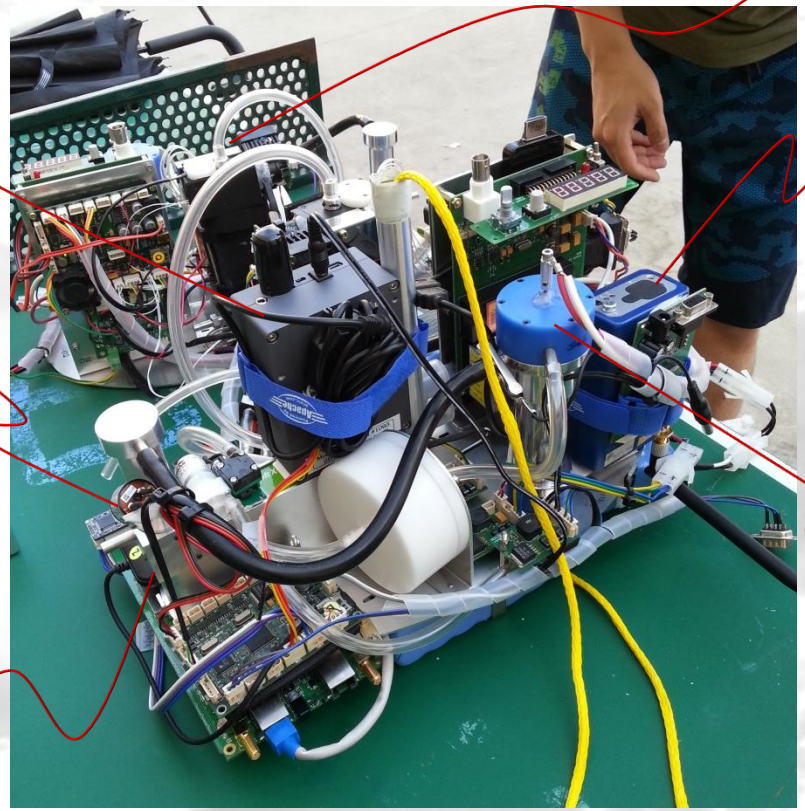


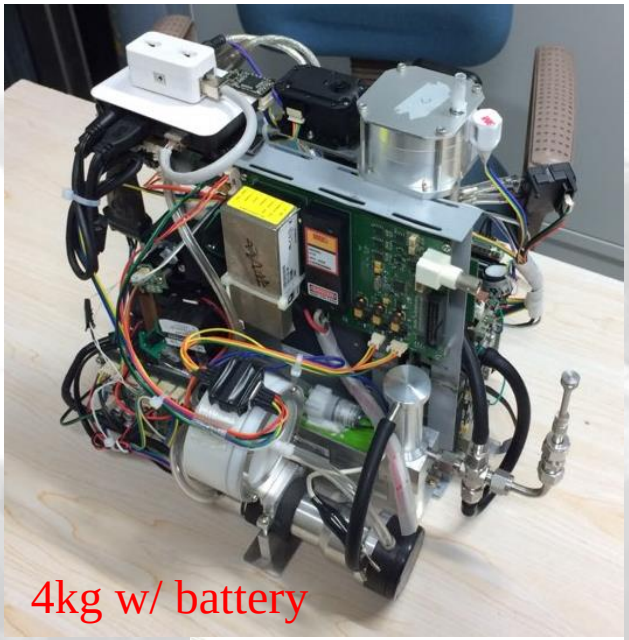


❖ Miniaturized Instruments

Hanyang University
Nanoparticle Control Lab.

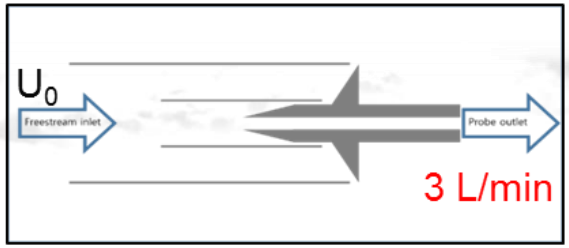
(4) Hy-SMPS with OPC, O_3, VOC, BC, PC, T, RH, WiFi, GPS, Wind speed & dir.





❖ Miniaturized Instruments

(5) Iso-kinetic Sampling Probe for *Variable Moving Speed*



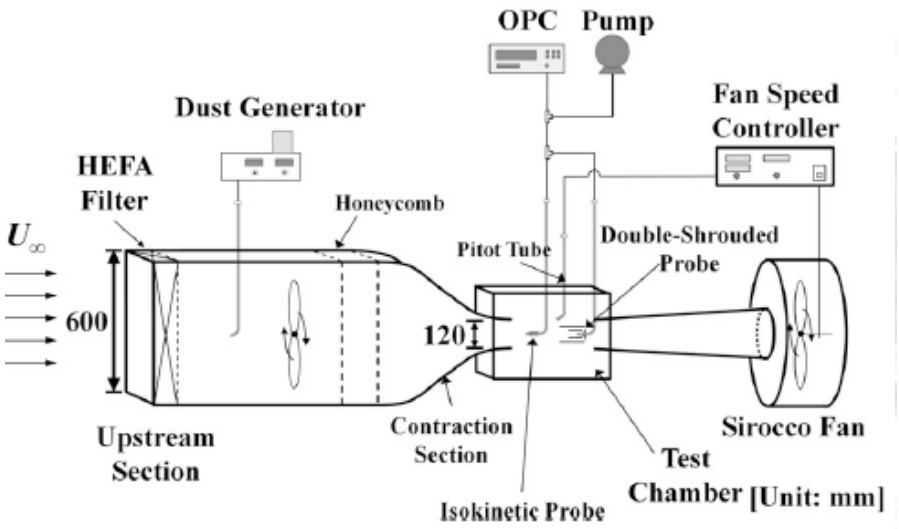


FIG. 3. Schematic of experimental setup using a high-speed wind tunnel.

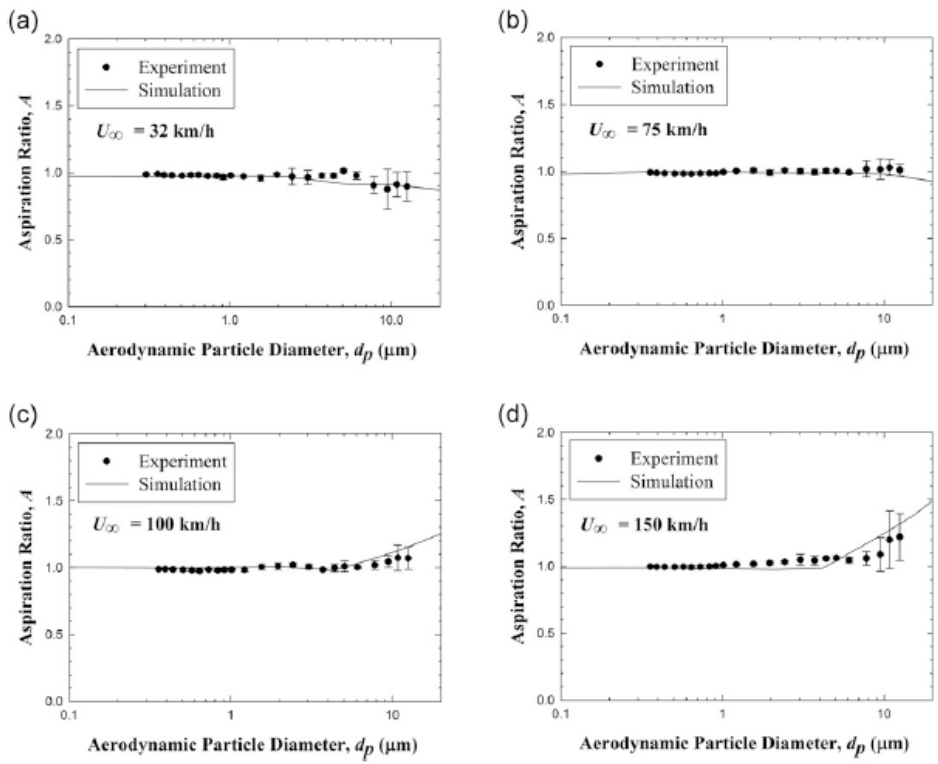


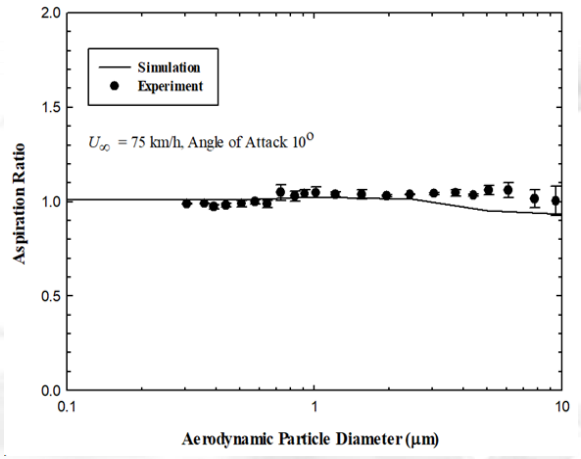
FIG. 6. Comparison of aspiration ratio for the miniaturized double-shrouded probe according to freestream velocity between the experimental data and numerical results: (a) $U_\infty = 32$, (b) $U_\infty = 75$, (c) $U_\infty = 100$, and (d) $U_\infty = 150\,\mathrm{km\,h^{-1}}$.

J. of Atmospheric and Oceanic Technology, 2018, V25, p727

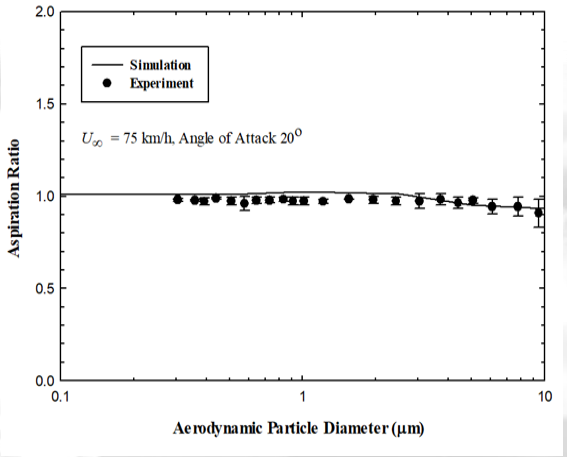
❖ Miniaturized Instruments

(5) Iso-kinetic Sampling Probe for Variable Moving Speed (different Angle of Attack)

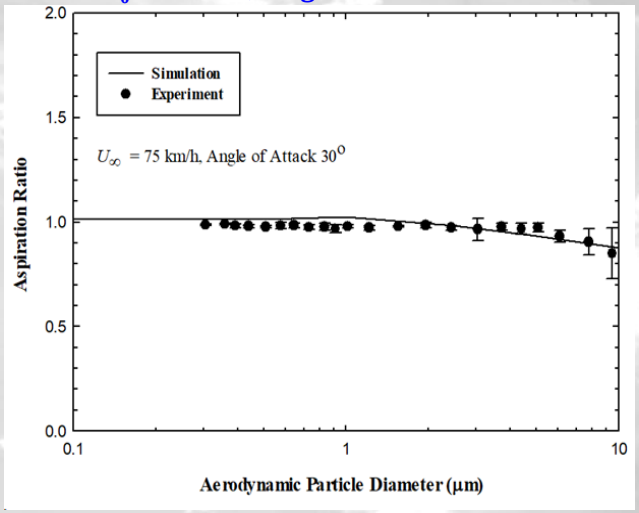
U_0=75 km/h, Angle of Attack 10º



U_0=75 km/h, Angle of Attack 20º



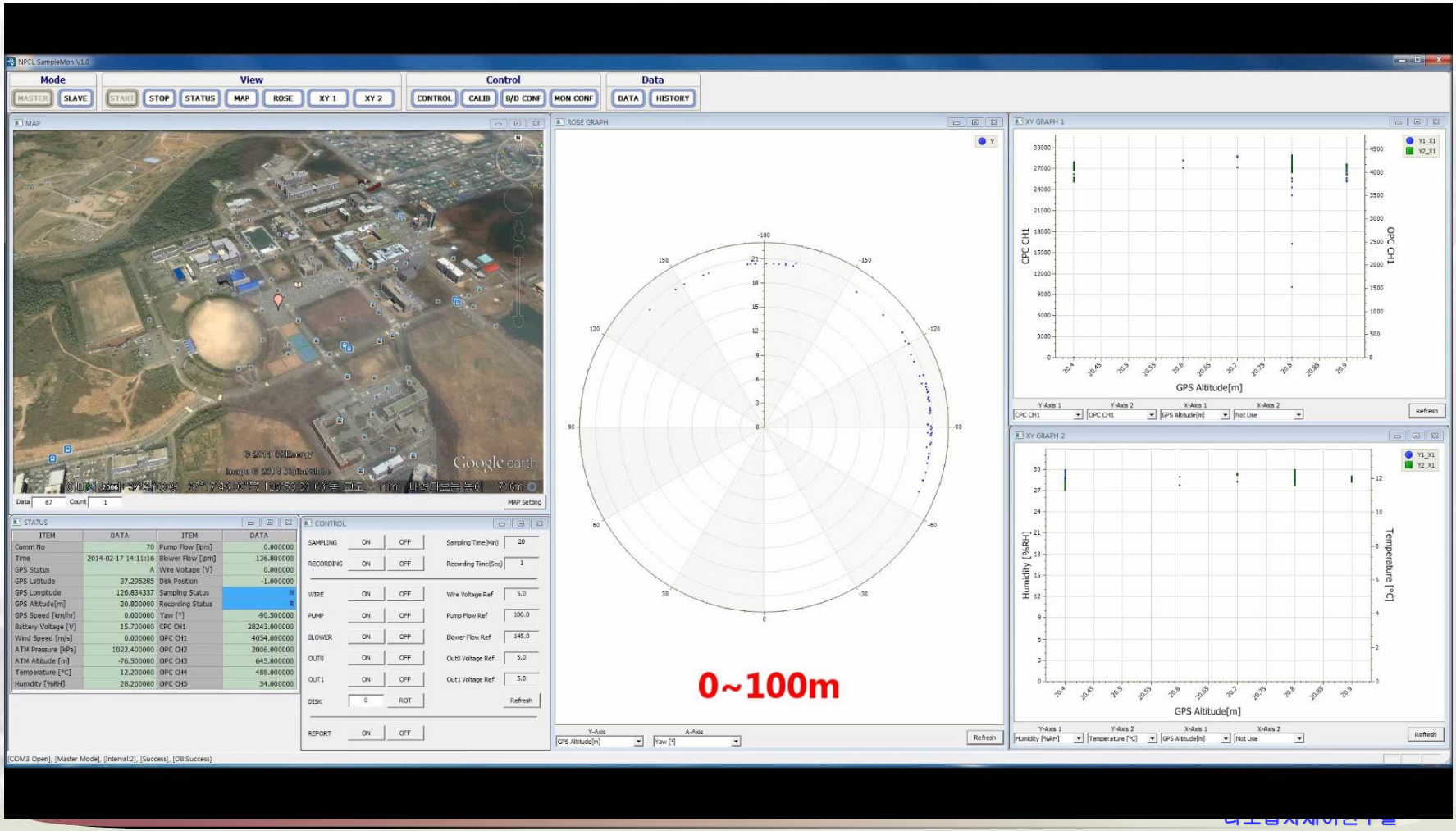
U_0=75 km/h, Angle of Attack 30º



J. of Atmospheric and Oceanic Technology, 2018, V25, p727

❖ Miniaturized Instruments

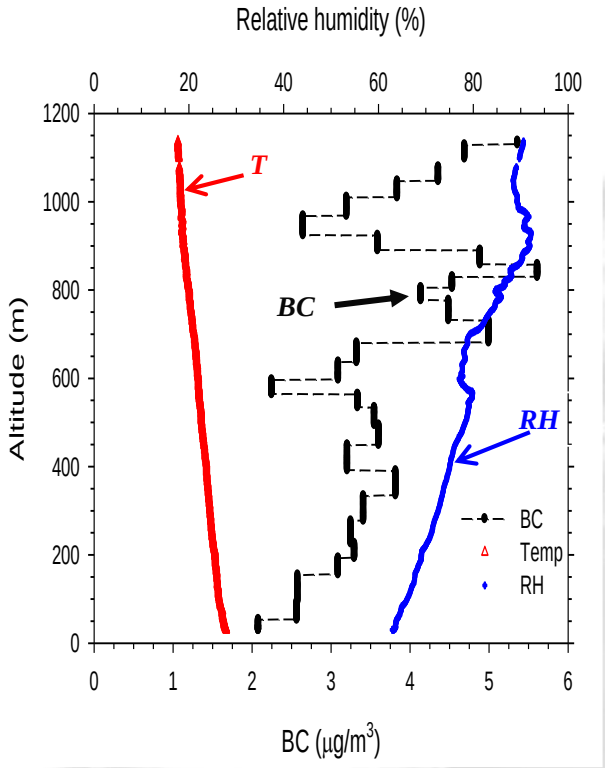
(5) Ground Control Station Monitoring Program

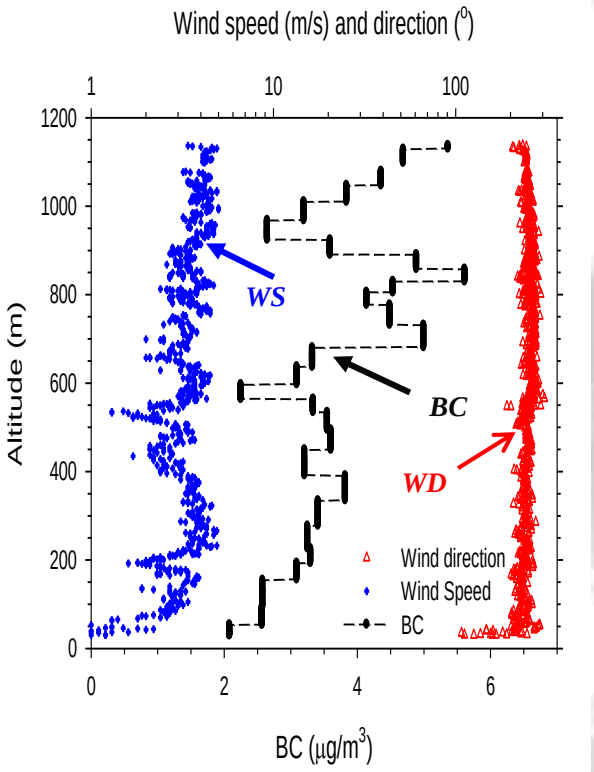


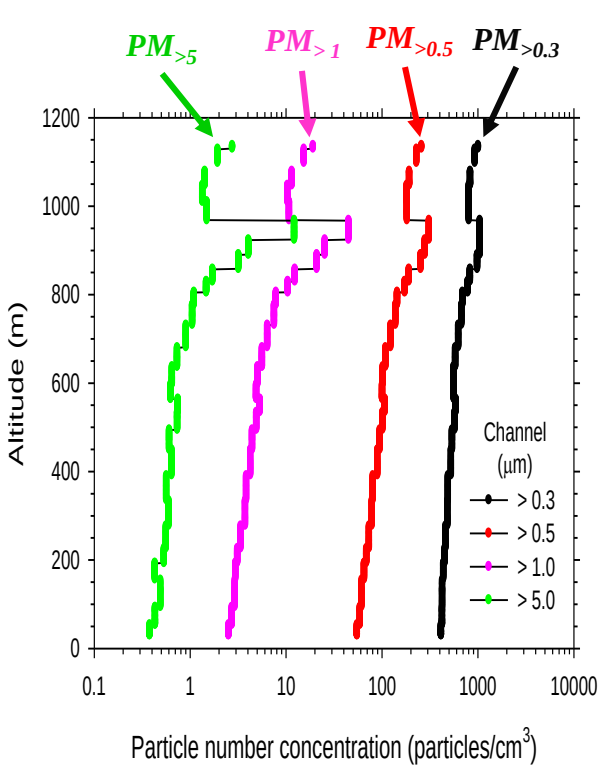
Tethered Balloon with Particle Instruments

Tethered Balloon Test

2013. June. 27 @ Seoul



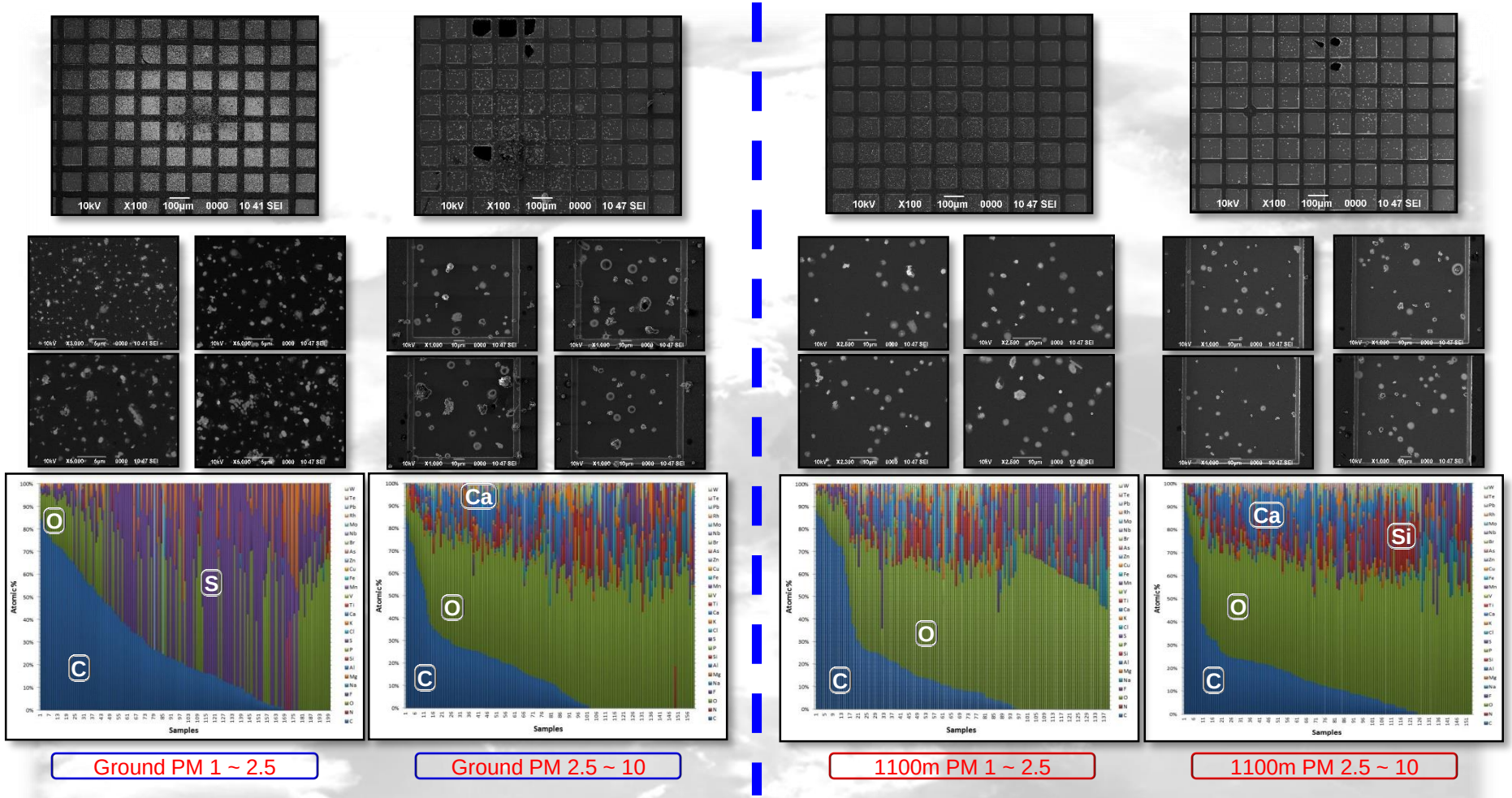




Tethered Balloon Test

❖ **Single Particle Element Analysis (*Sampled with Rotating Stage Impactor*)**

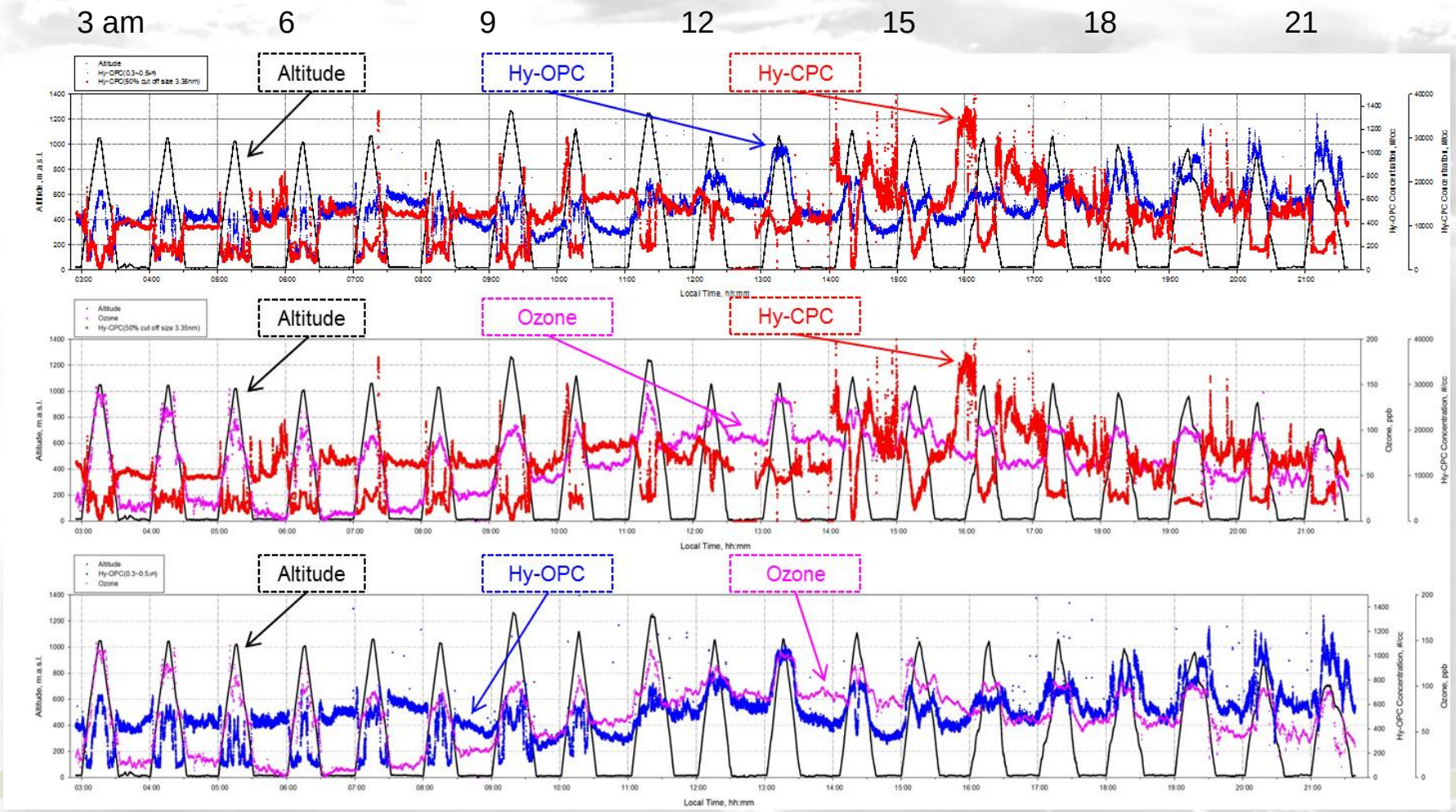
Sampling time : 2014.01.17(11:19~11:34) _Campus



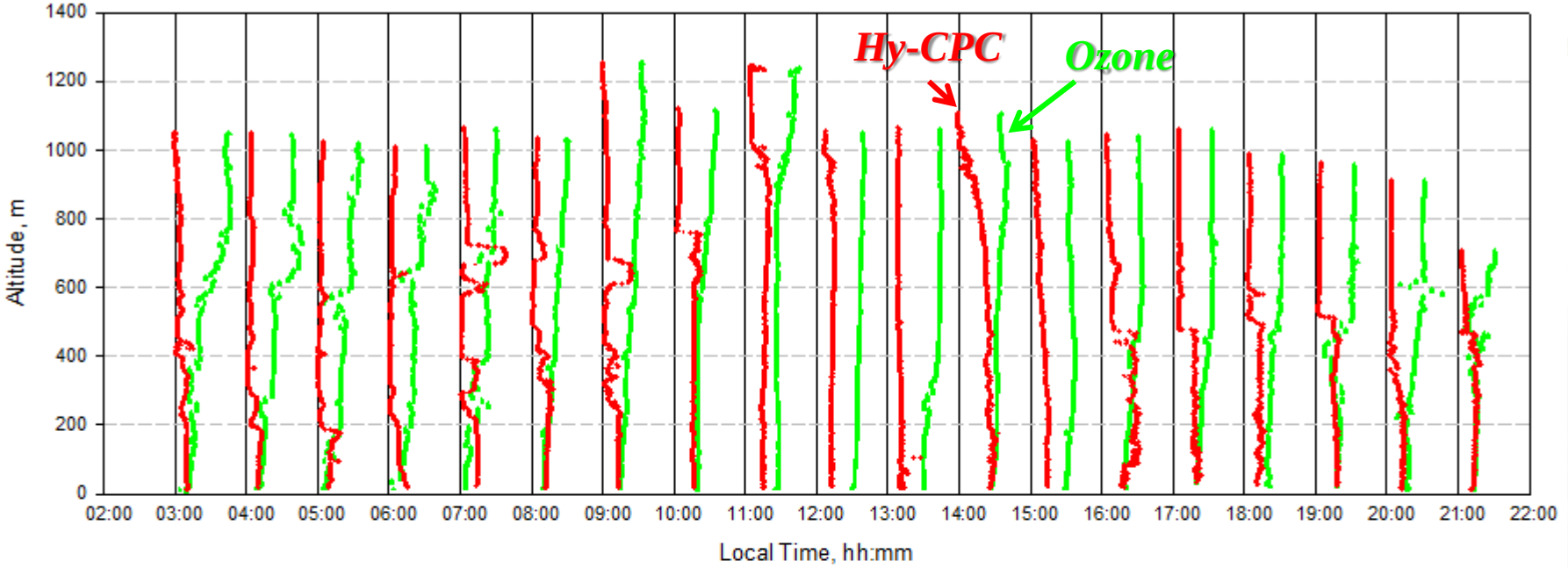
Ground PM 1 ~ 2.5 | Ground PM 2.5 ~ 10 | 1100m PM 1 ~ 2.5 | 1100m PM 2.5 ~ 10

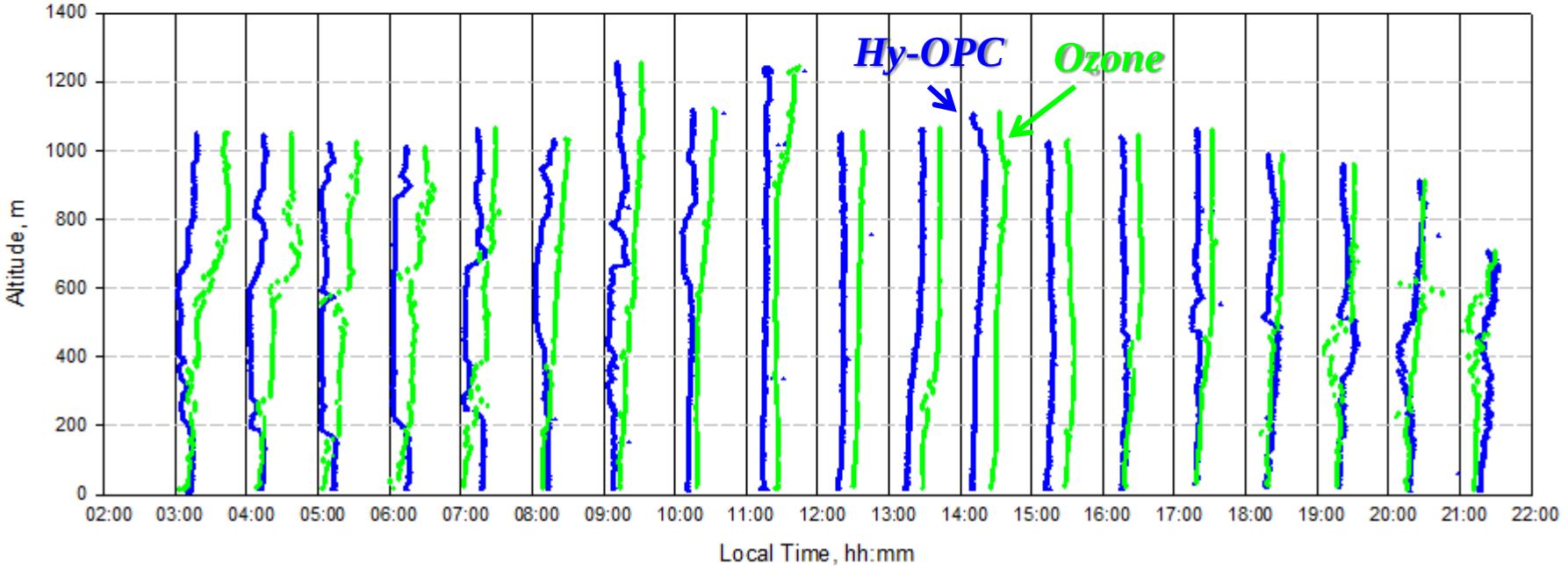
Tethered Balloon Test

2016. June 10 @ campus



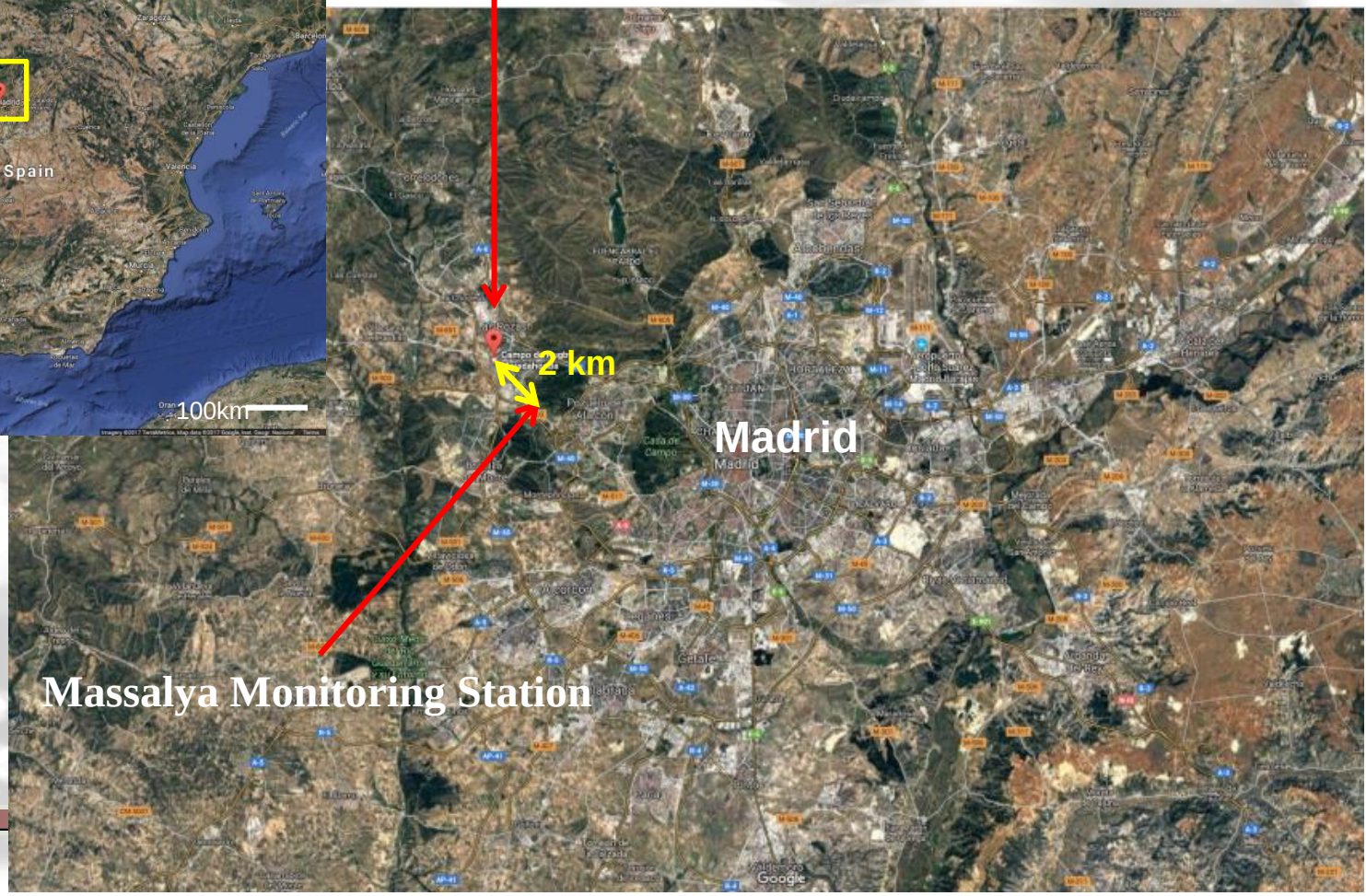
2016. June 10


Hy-CPC
Ozone
Altitude, m
Local Time, hh:mm


Hy-OPC
Ozone
Altitude, m
Local Time, hh:mm

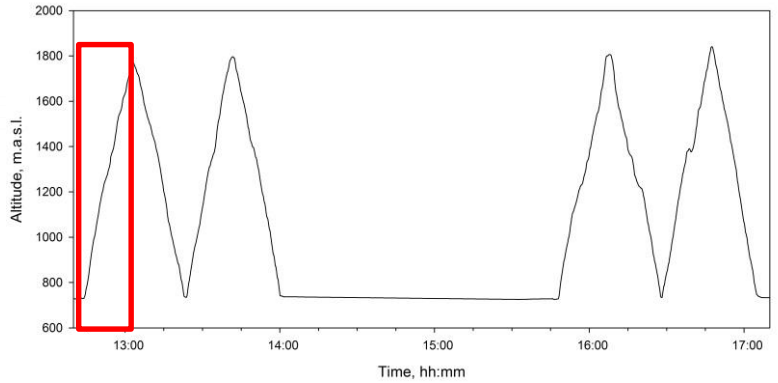
Tethered Balloon Test

Tethered Balloon Test Site

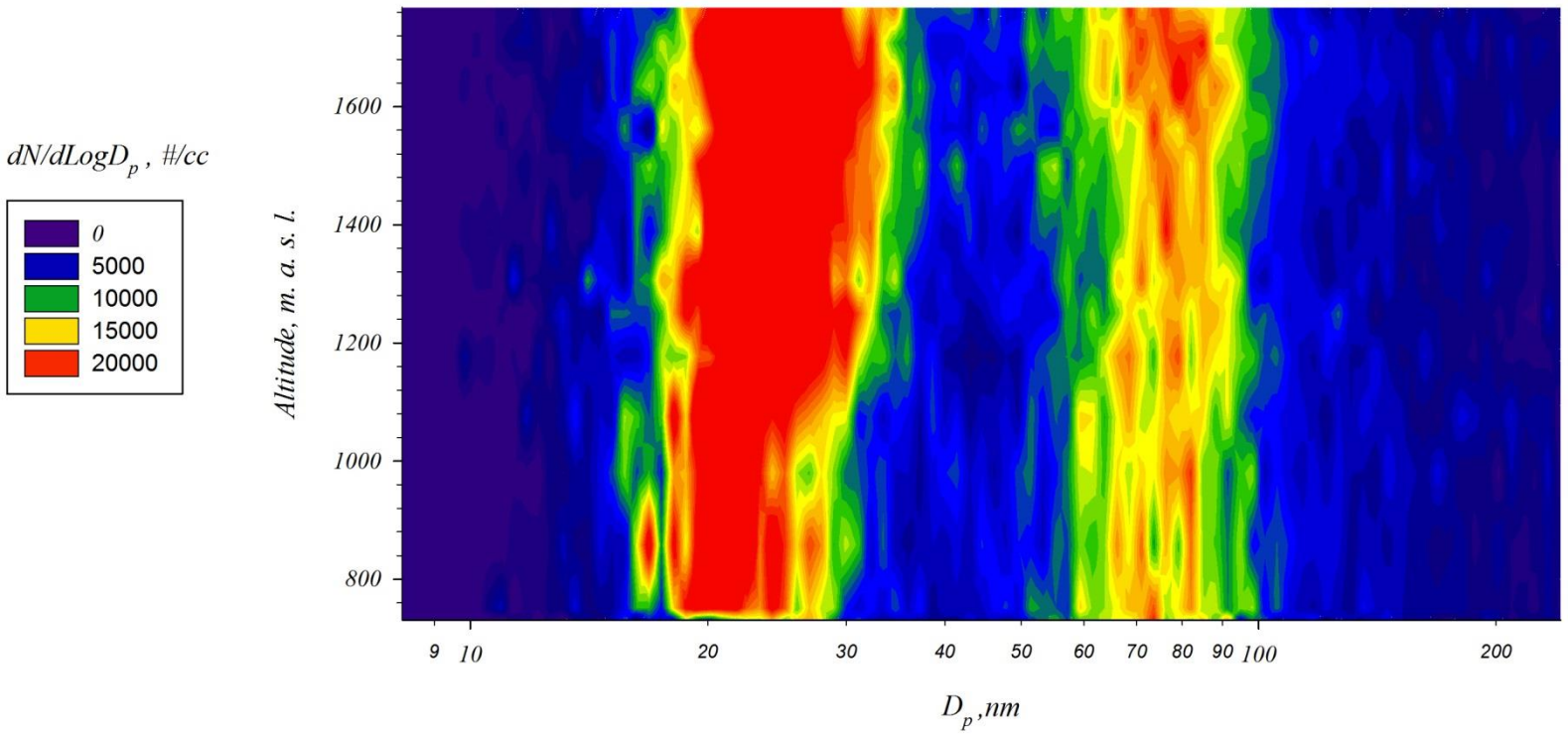


Tethered Balloon Measurement

2016 July 13 (Majadahonda, Spain)



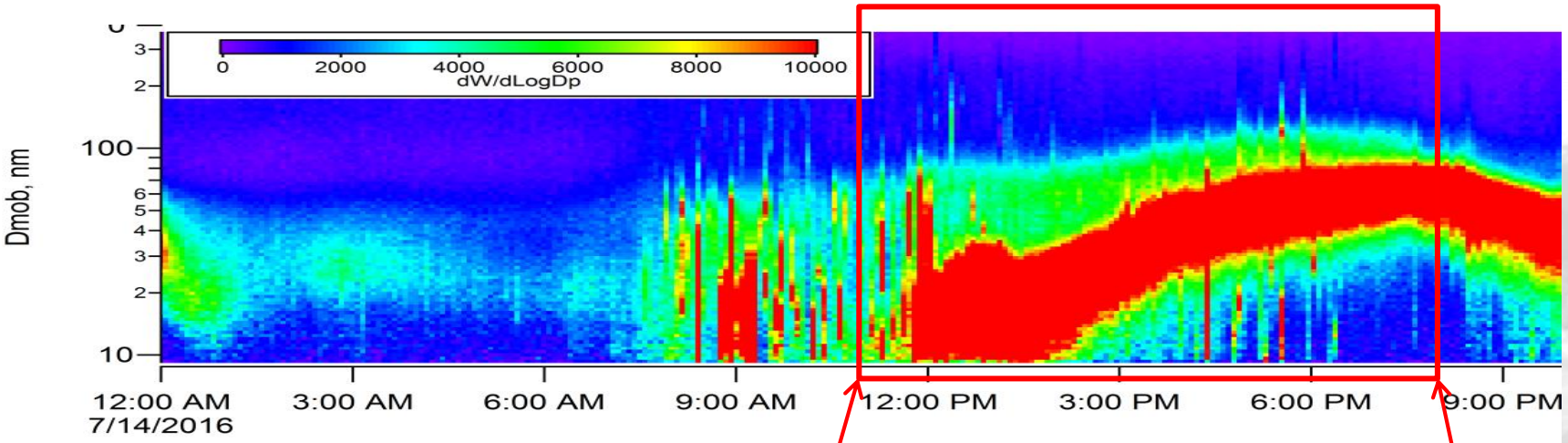
Vertical Profile by Hy-SMPS



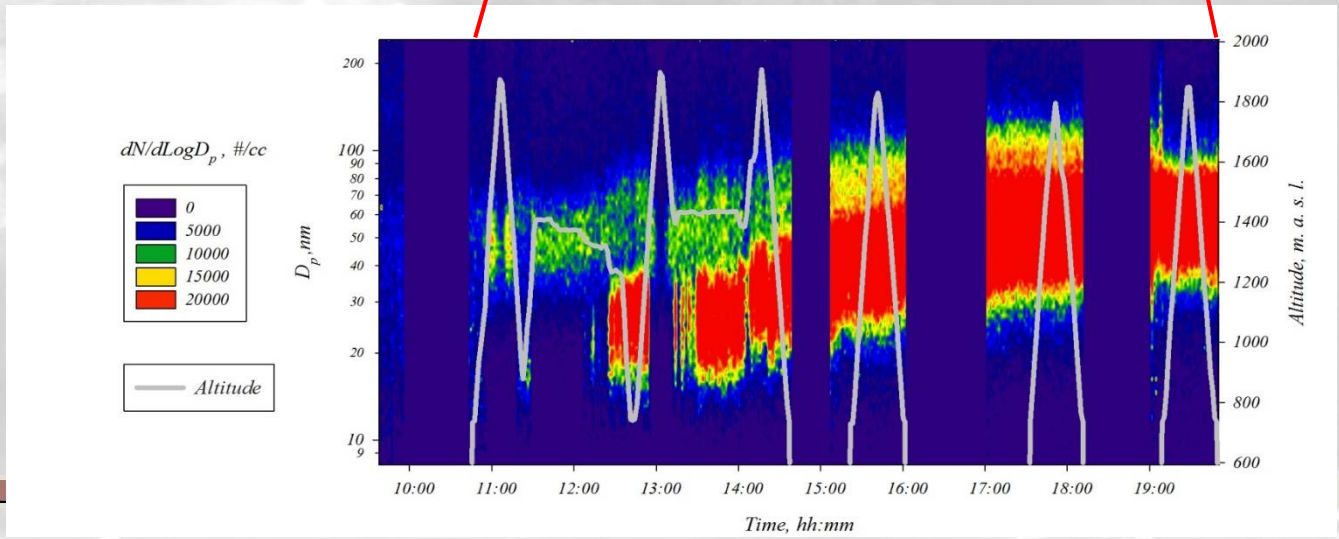
Tethered Balloon Measurement

Hanyang University
Nanoparticle Control Lab.

Institute de Salud Carlos III Campus, Majadahonda, Spain, 14 July 2016
Massalya Monitoring Station

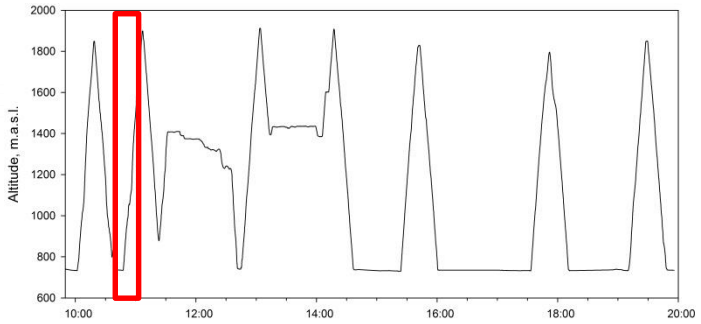


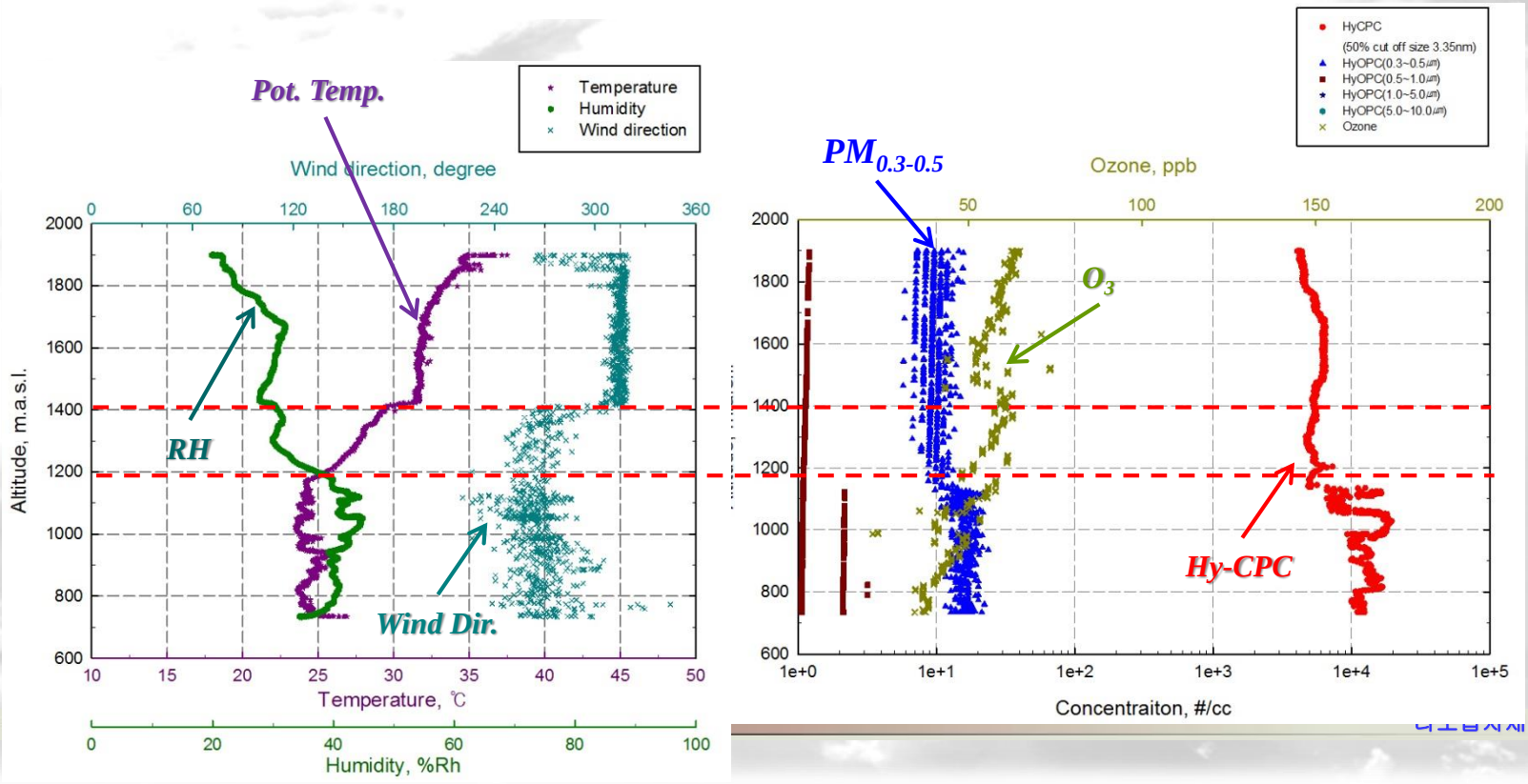
Hy-SMPS
Tethered Balloon
Majadahonda, Spain
July 14, 2016



Tethered Balloon Measurement

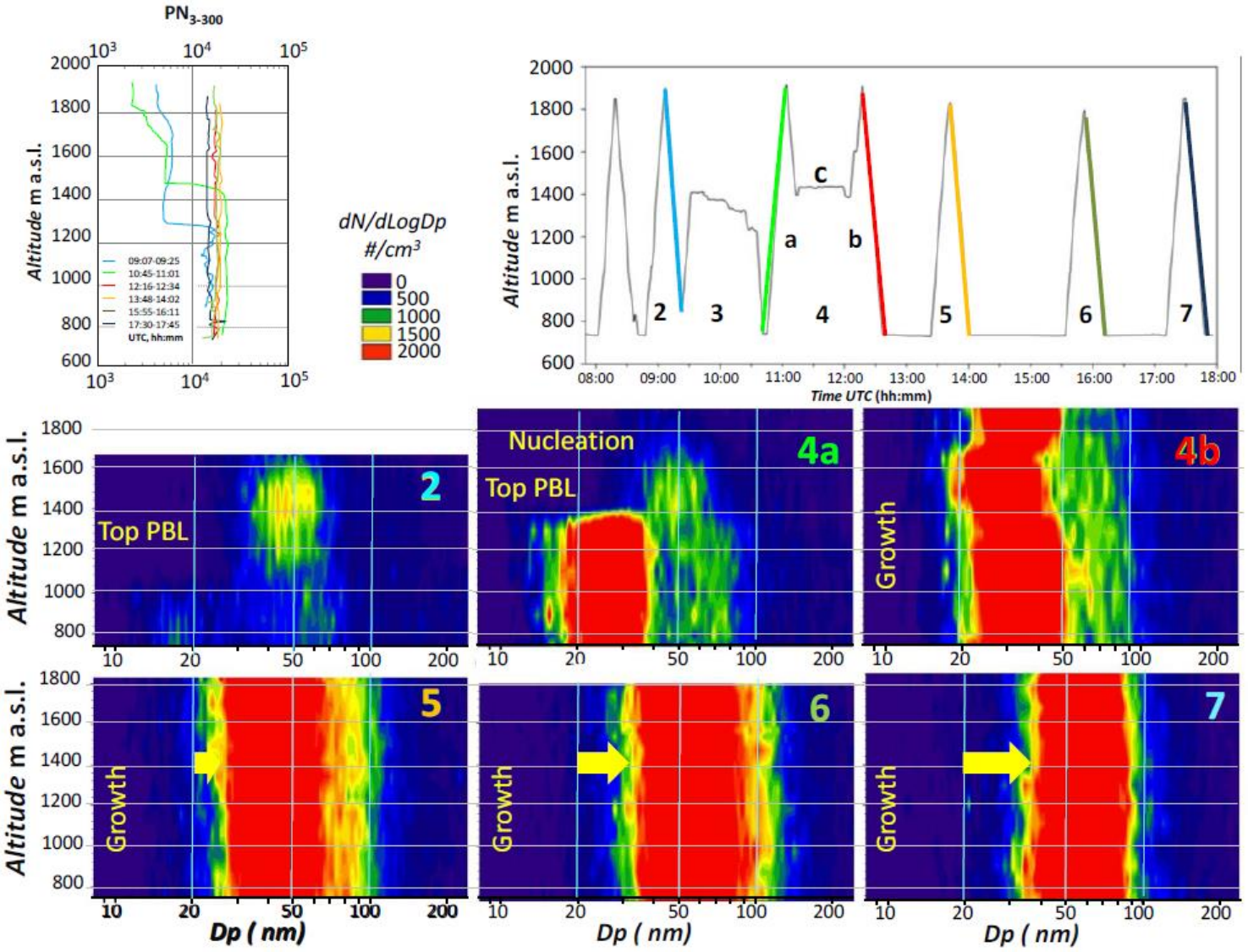
2016 July 14 (Majadahonda, Spain)





Tethered Balloon Measurement

2016 July 14 (Majadahonda, Spain)

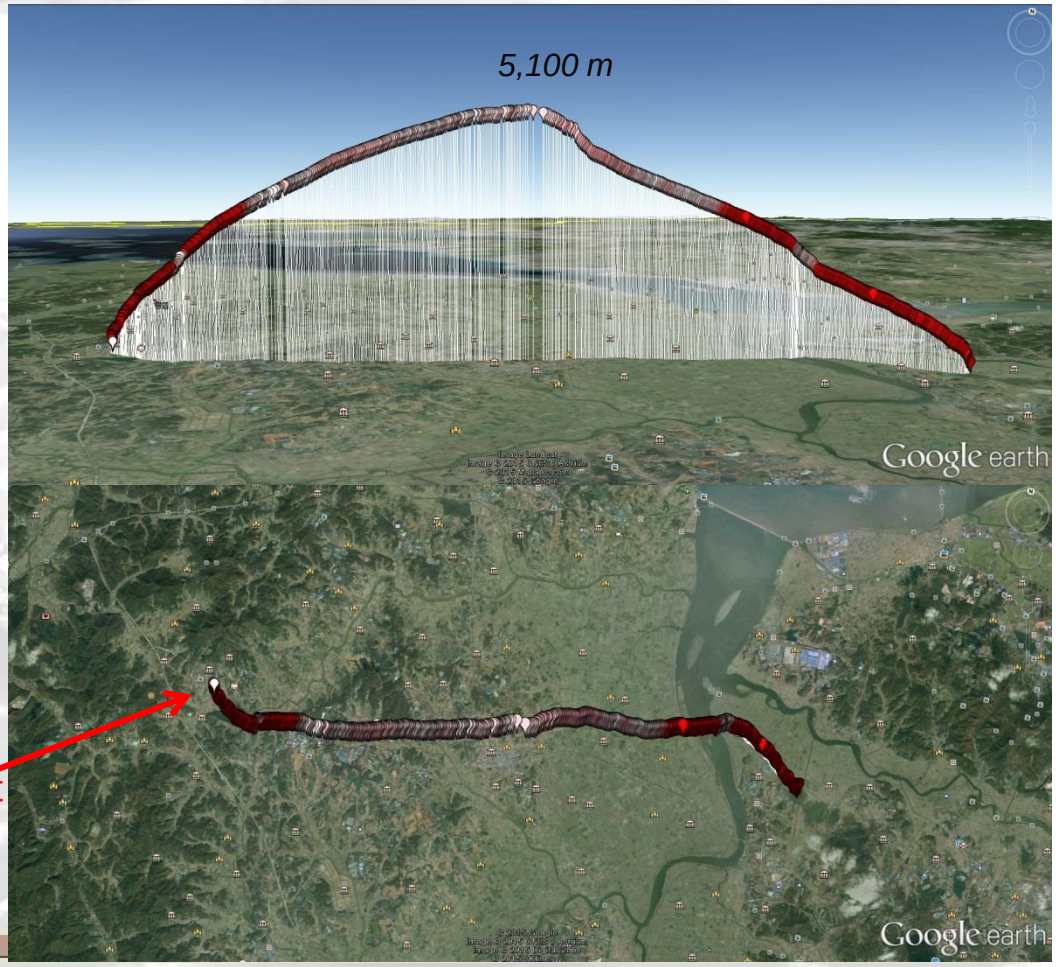


Sounding Balloon with Particle Instruments

Sounding Balloon Measurement

Sounding Balloon Measurement

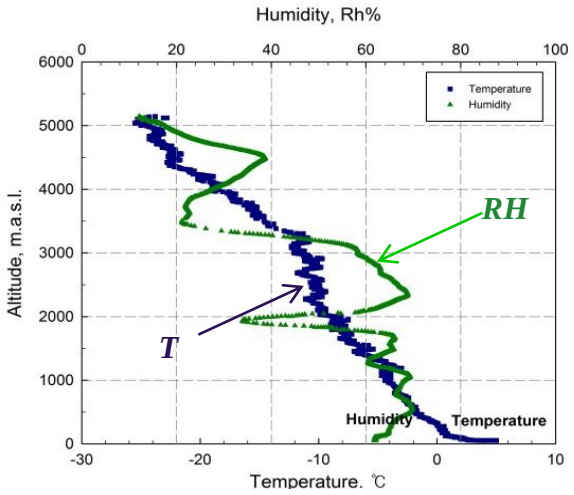
04/Feb/2015

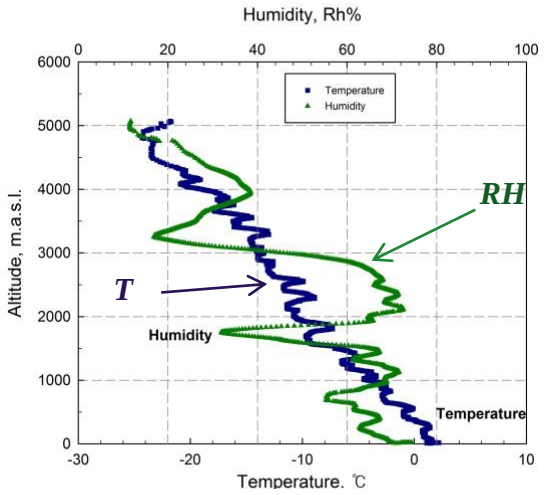


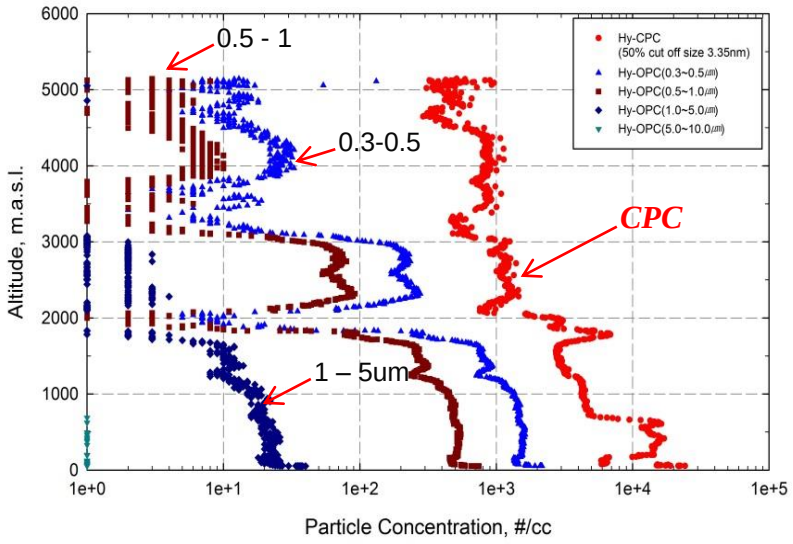
3D Map (04/Feb/2015)

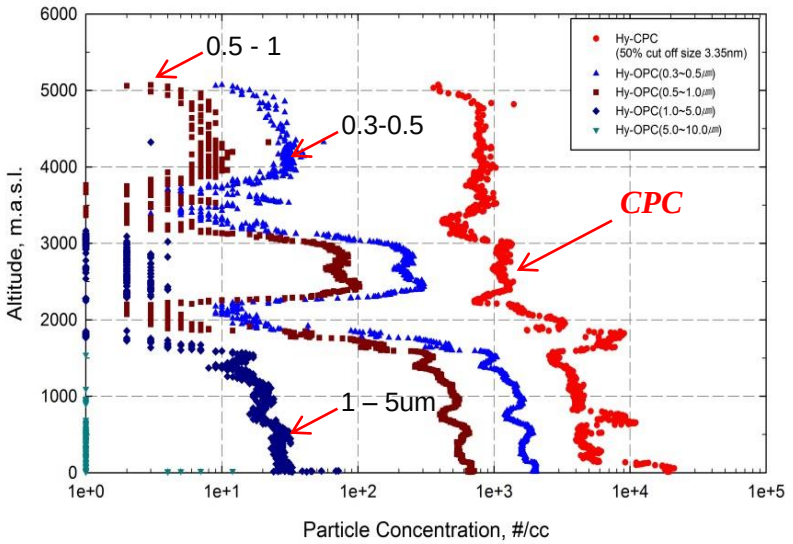
Sounding Balloon Measurement

04/Feb/2015









- Vertical profiles of Hy-OPC(04/Feb/2015)_Ascending

- Vertical profiles of Hy-OPC(04/Feb/2015)_Descending

Drone with Particle Instruments

1. Drone Performance and *Safety* Evaluation

2. Sensor Evaluation

3. Vertical Profile Measurement

❖ Drone *Safety* Evaluation

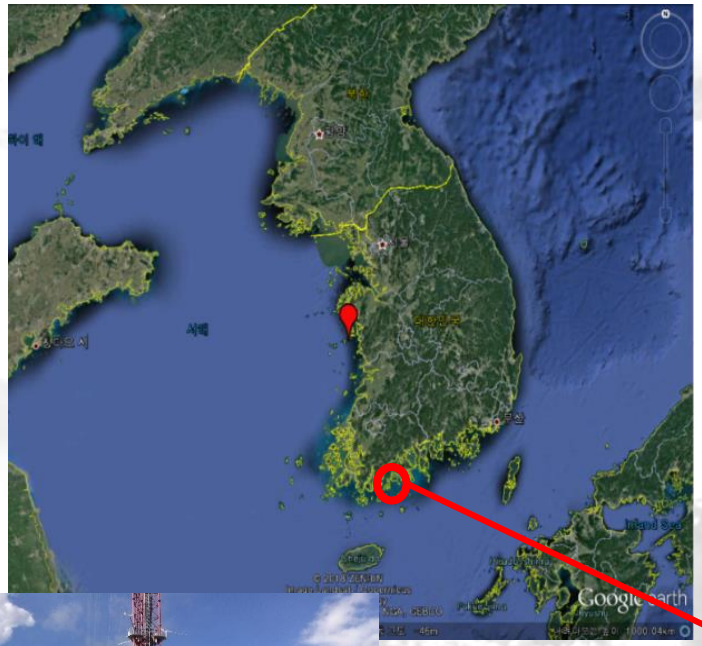
■ **Vertical wind (Vertical Wind Tunnel Test)**

■ **Horizontal wind (Horizontal Wind Tunnel Test)**

- **Motor Fail test**
- **GPS signal lost test**
- **Geo Fencing test**
- **Night Flight test**
- **Fully Automatic Take-off and Landing**

❖ Sensor Performance Evaluation

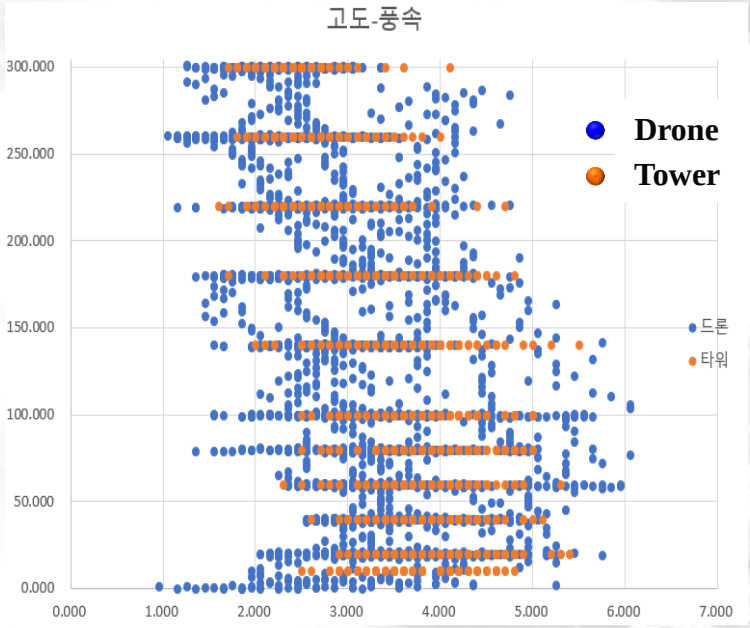
■ Comparison with the Meteorological Tower Sensors



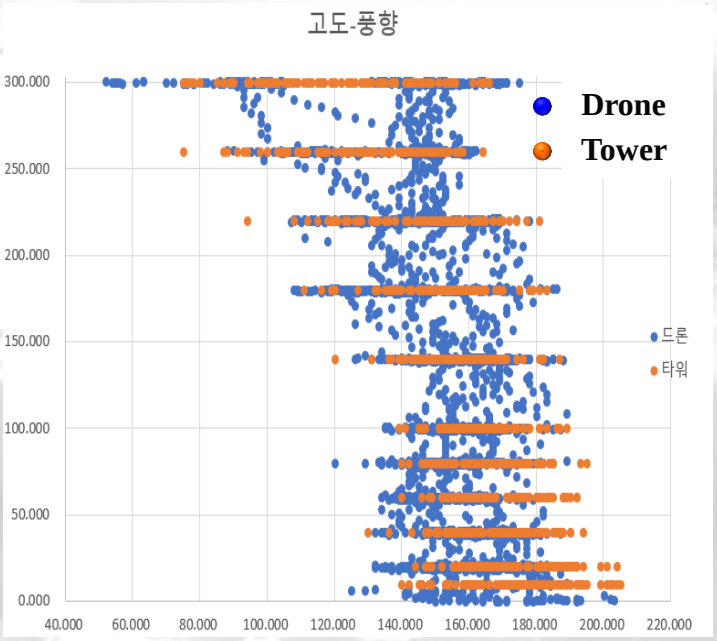
❖ Sensor Performance Evaluation

(Comparison with Meteorological Tower Sensors)

■ Wind Speed



■ Wind Direction



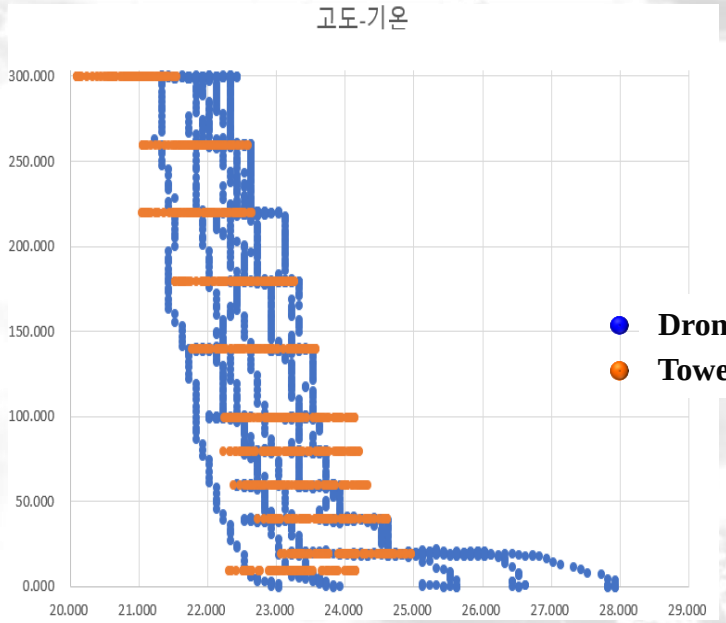
	M. Tower	Drone	Δ WS
Average	3.5 m/s	3.0 m/s	**0.5 m/s**
SD	0.8 m/s	0.8 m/s	**0.0 m/s**

	M. Tower	Drone	Δ WD
Average	155.7°	150.7°	**5.0°**
SD	22.2°	18.1°	**4.1°**

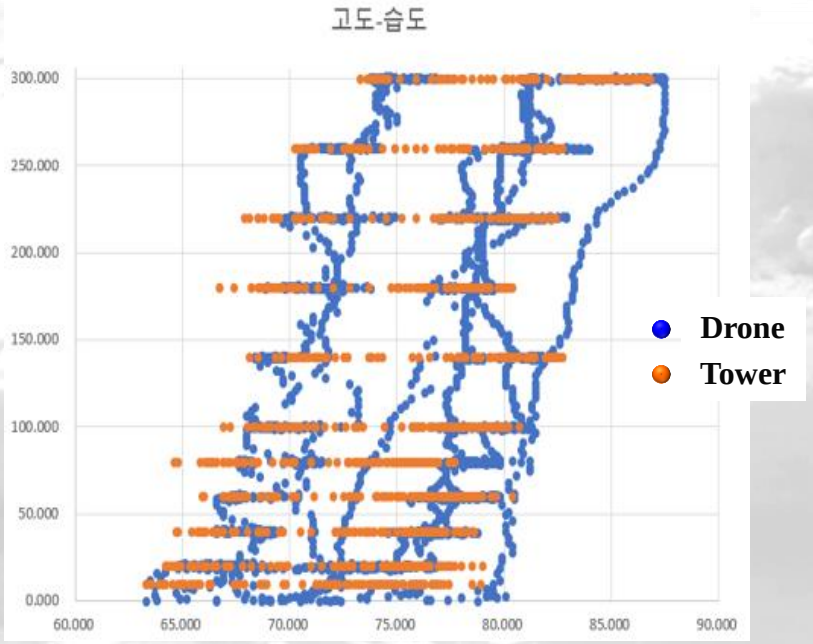
❖ Sensor Performance Evaluation

(Comparison with Meteorological Tower Sensors)

■ Temperature



■ Relative Humidity



	M. Tower	Drone	Δ T
Average	22.7°C	23.0°C	**- 0.3°C**
SD	1.0°C	1.0°C	**0.0°C**

	M. Tower	Drone	Δ RH
Average	75.1 %	75.9 %	**- 0.8 %**
SD	5.1 %	5.0 %	**0.1 %**

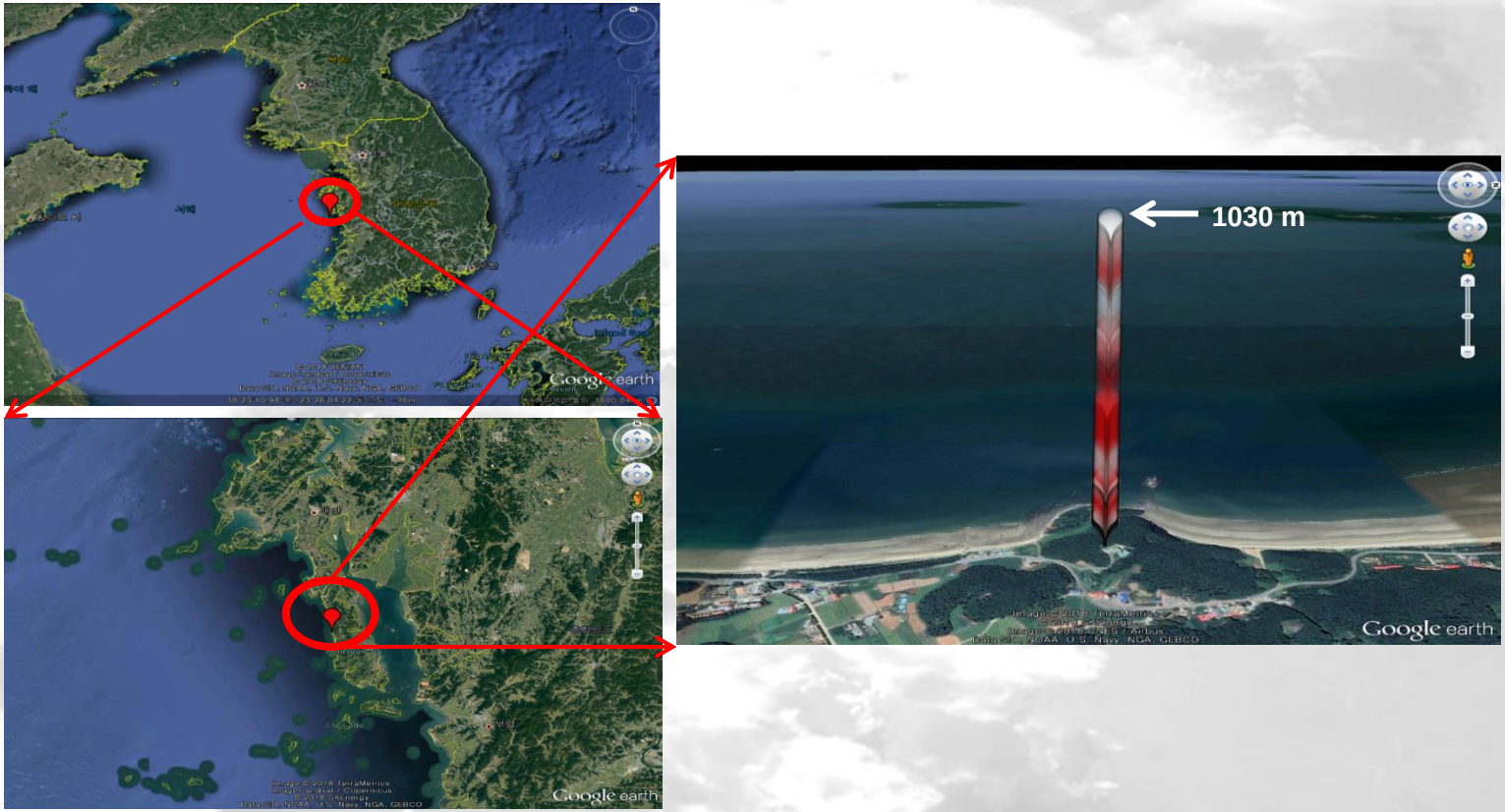
❖ Low Temp. Test in Mongolia

❖ Vertical Profile Measurement (1,030 m)

Korea Global Atmosphere Watch Center

Longitude : E 126.33º
Latitude : N 36.538º

2018 June 7

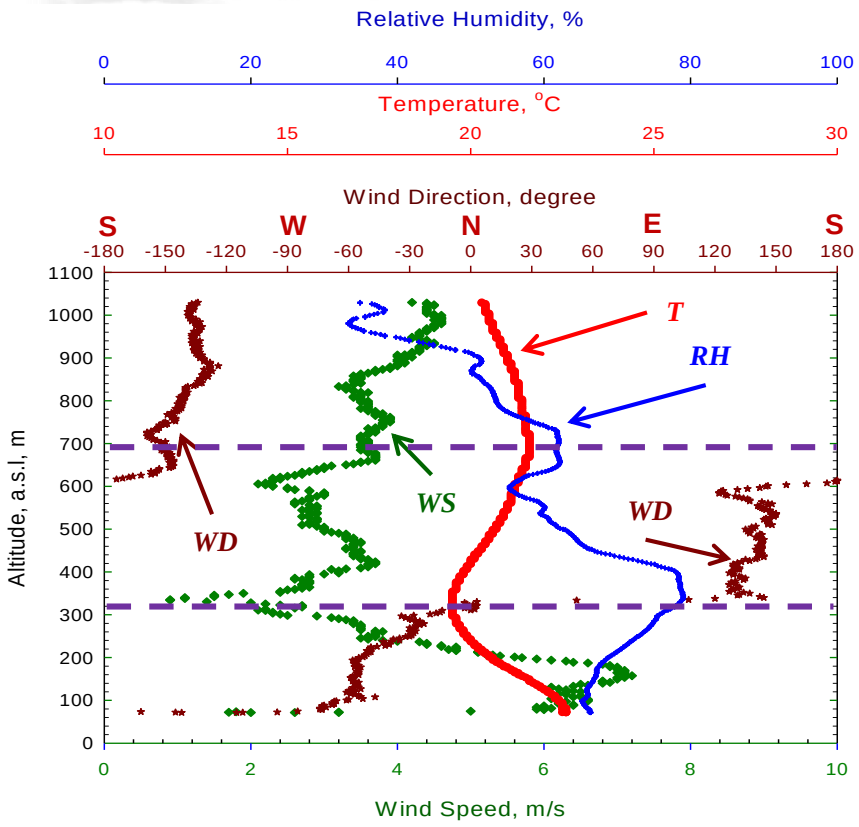


❖ Vertical Profile Measurement (1,030 m)

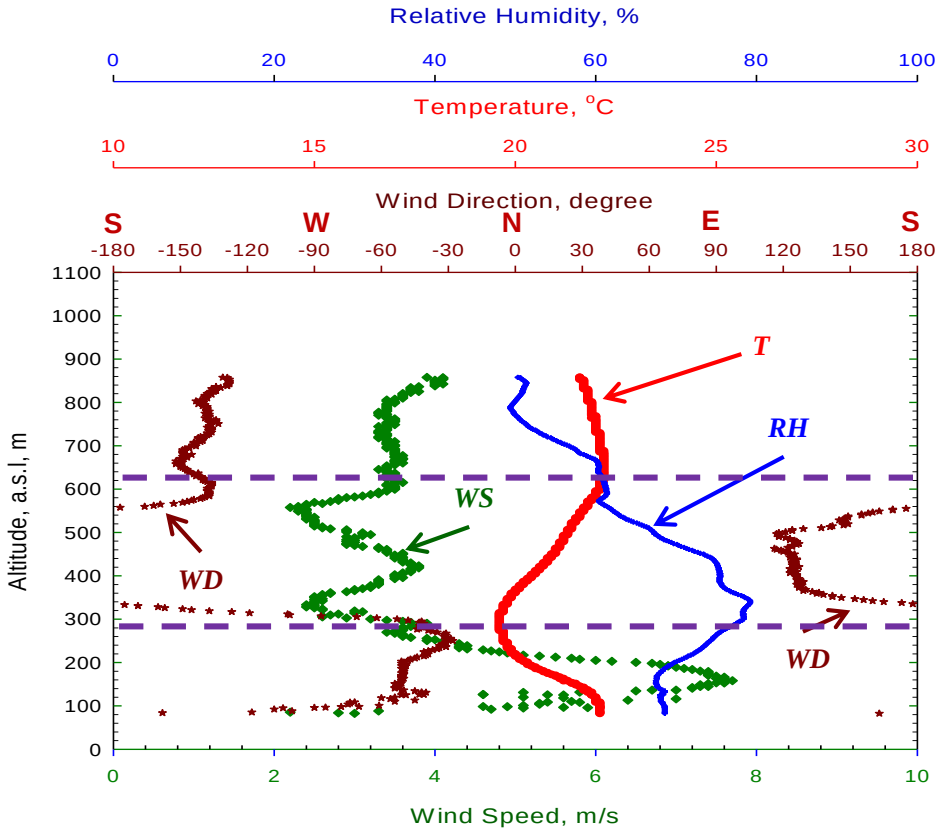
Hanyang University
Nanoparticle Control Lab.

2018 June 7

14:38 – 14:45



15:18 – 15:24

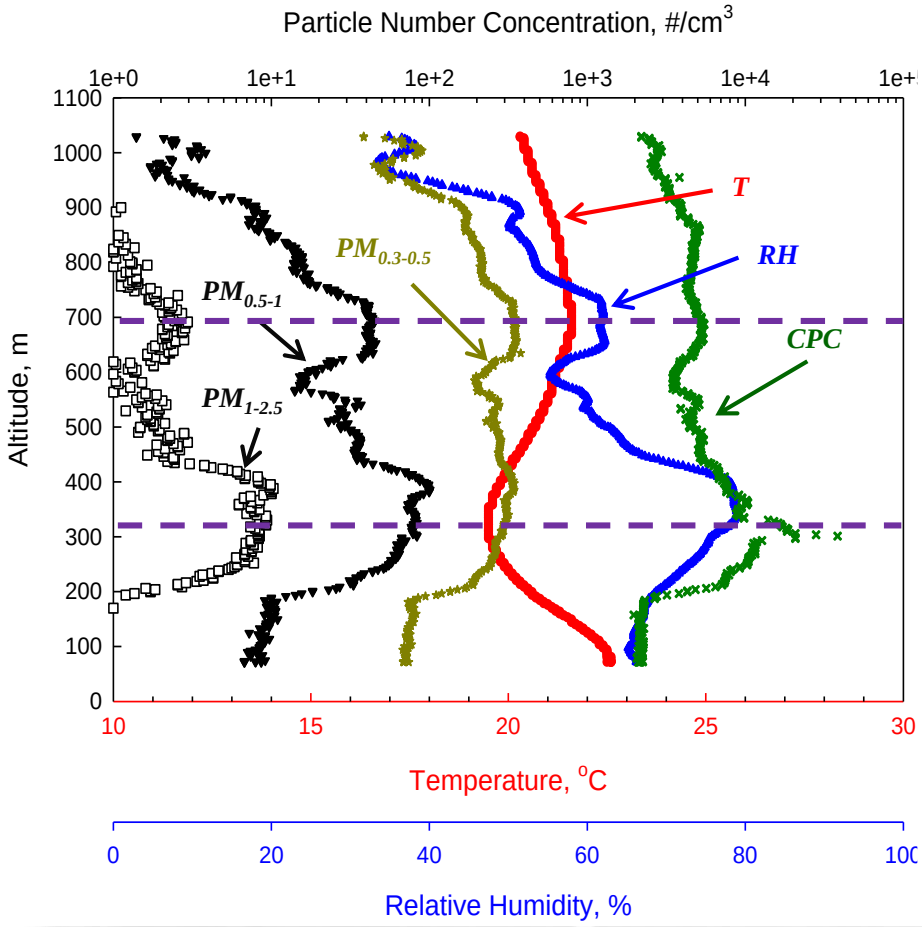


❖ Vertical Profile Measurement (1,030 m)

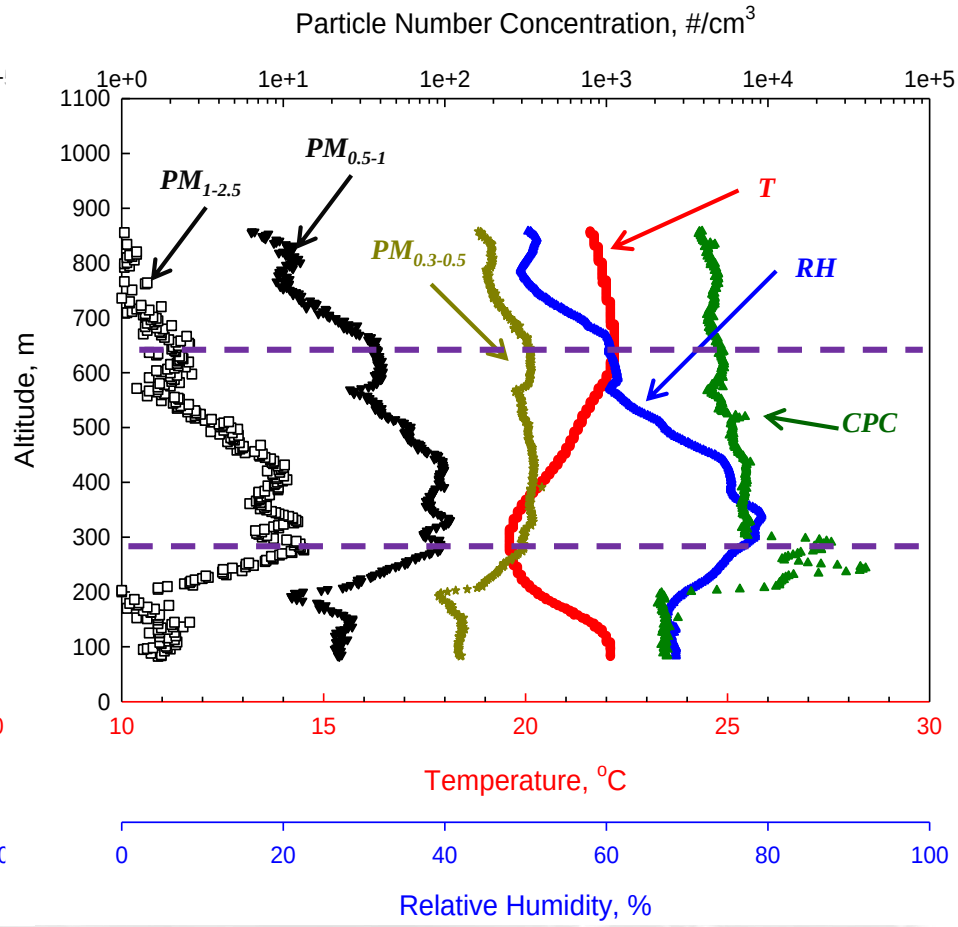
Hanyang University
Nanoparticle Control Lab.

2018 June 7

14:38 – 14:45

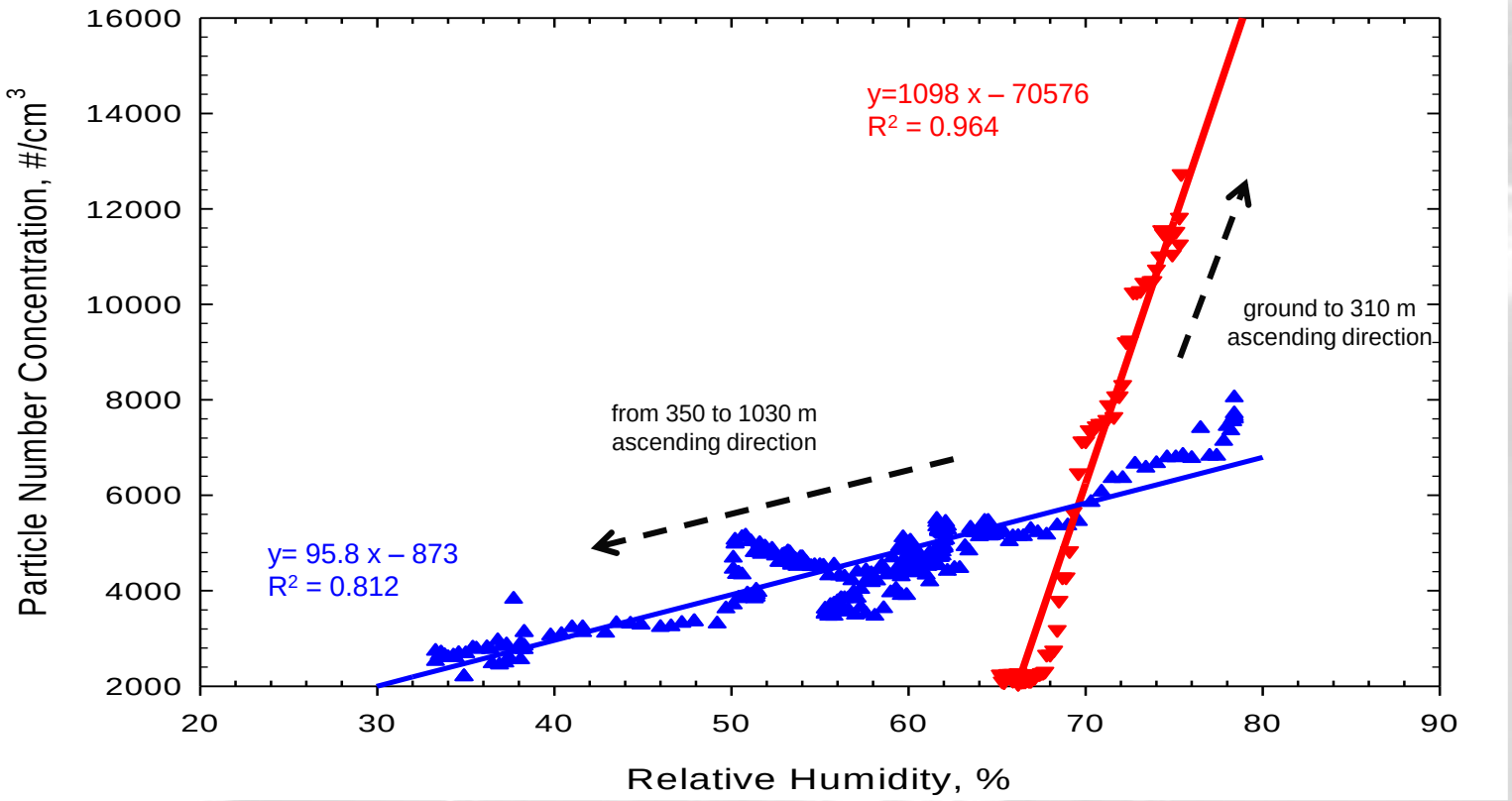


15:18 – 15:24



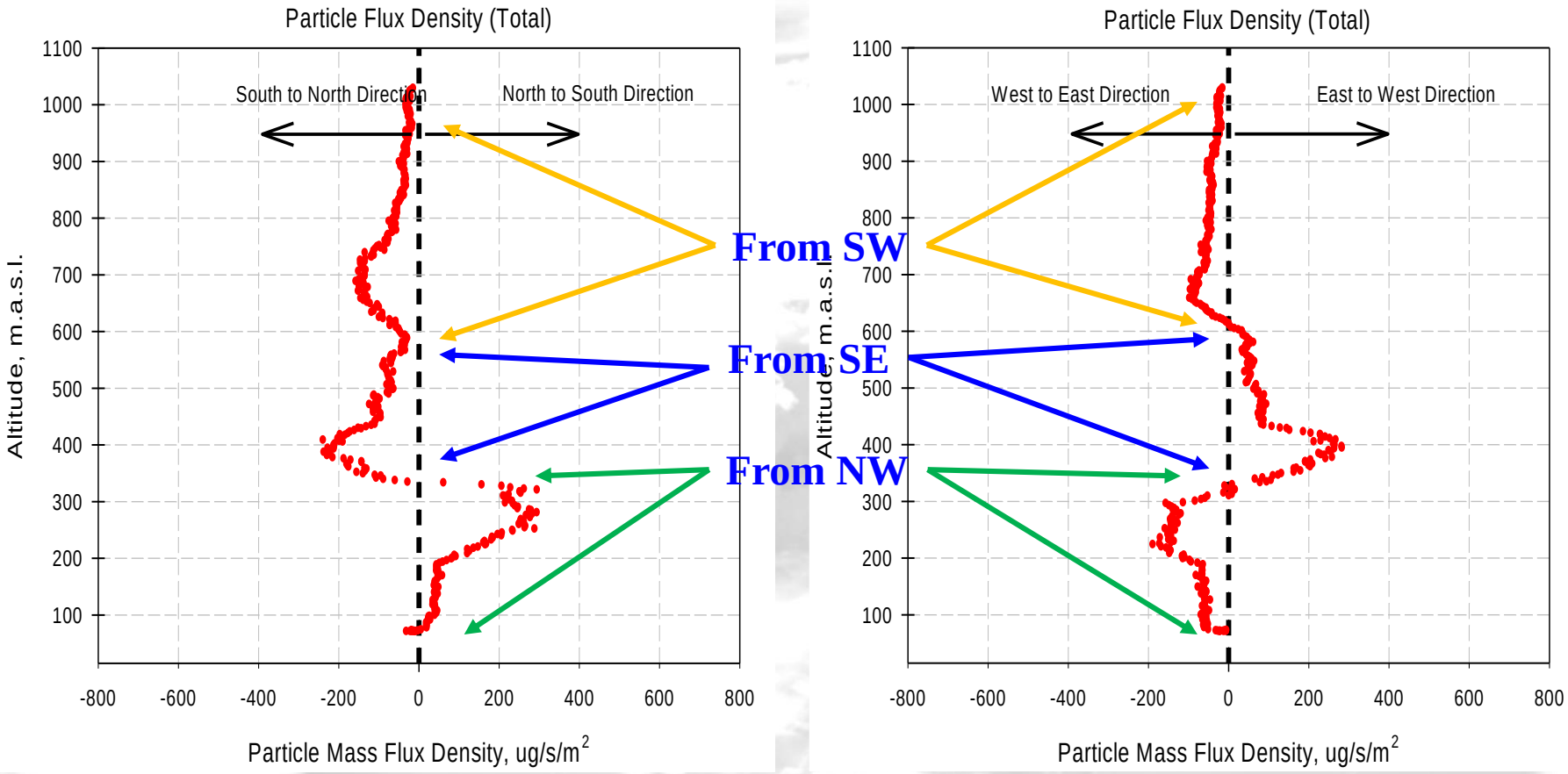
❖ Total Particle Number Conc. & RH

June 7, 2018
14:38 – 14:45



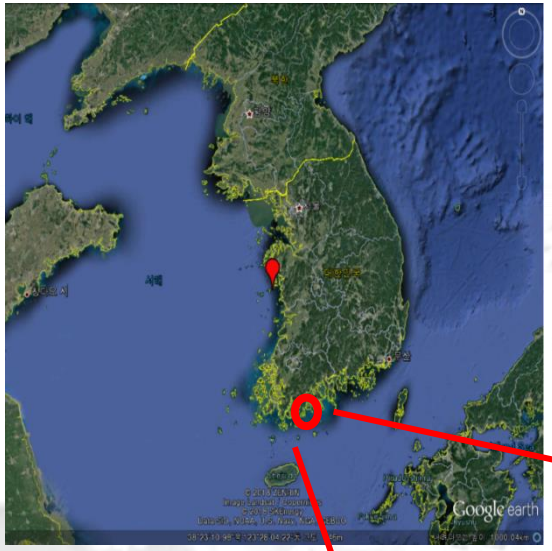
❖ Vertical Profile Measurement (1,030 m)

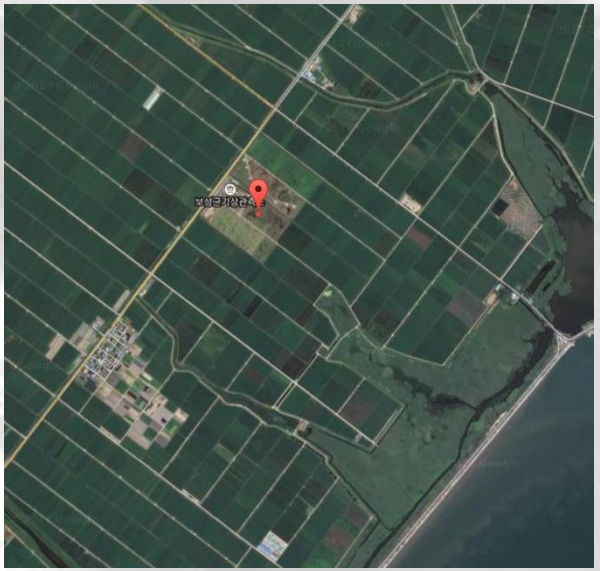
Horizontal Particle Flux Profile



❖ Vertical Profile Measurement (2,500 m)

Dec. 10, 2018

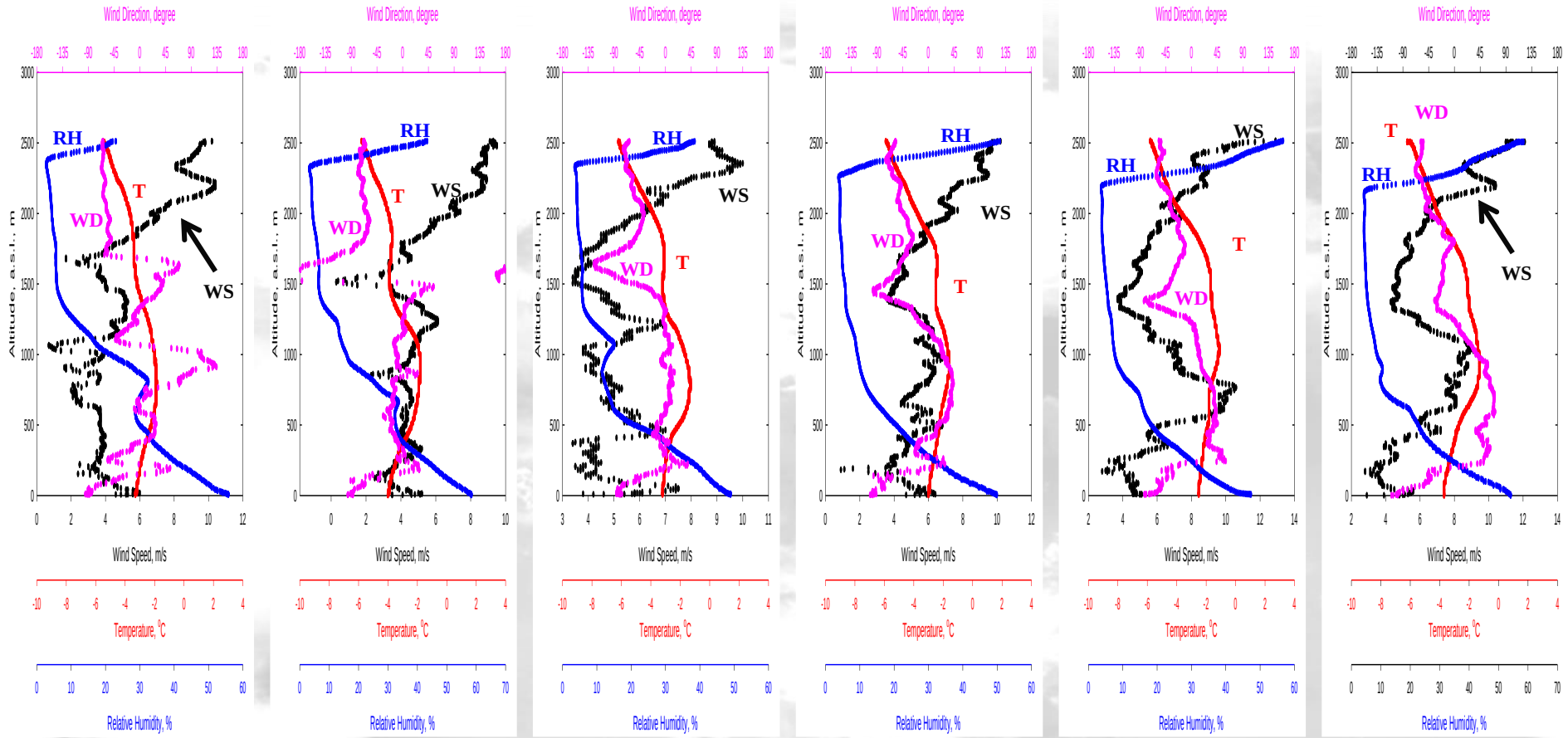




❖ Vertical Profile Measurement (2,500 m)

2018 Dec. 10

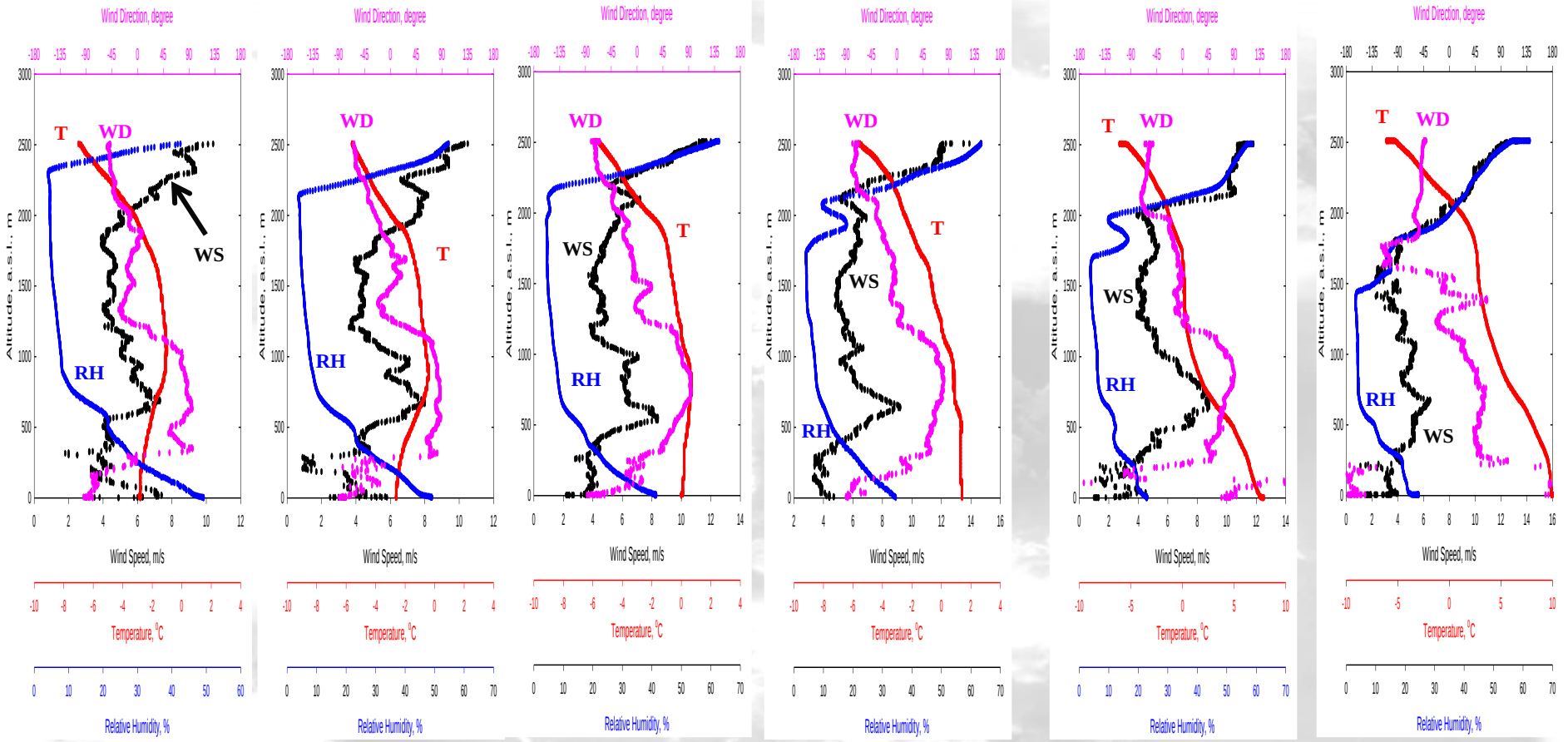
01:00 02:00 03:00 04:00 05:00 06:00



❖ Vertical Profile Measurement (2,500 m)

2018 Dec. 10

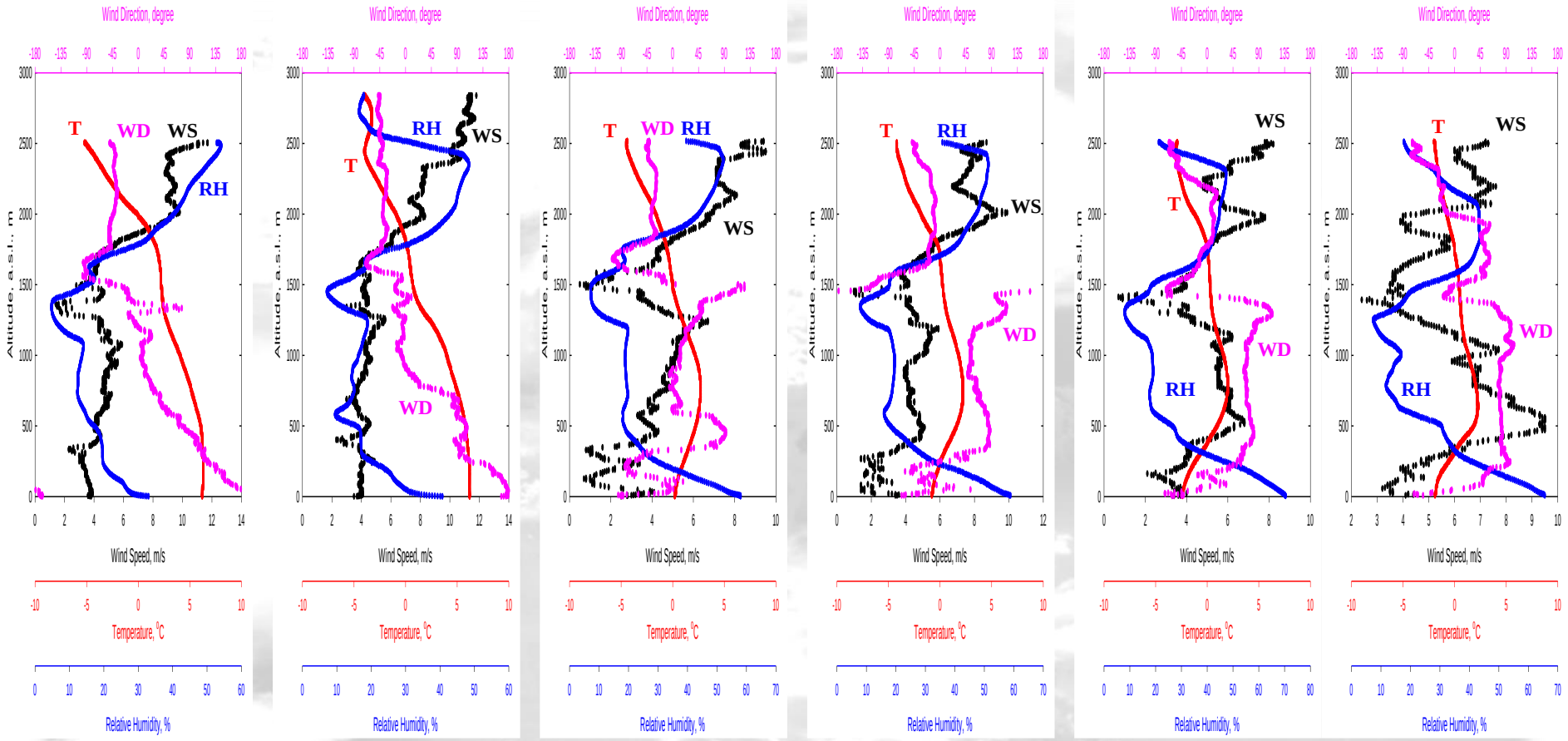
07:00 08:00 09:00 10:00 11:30 14:00



❖ Vertical Profile Measurement (2,500 m)

2018 Dec. 10

15:00 16:00 17:00 18:00 19:00 20:00

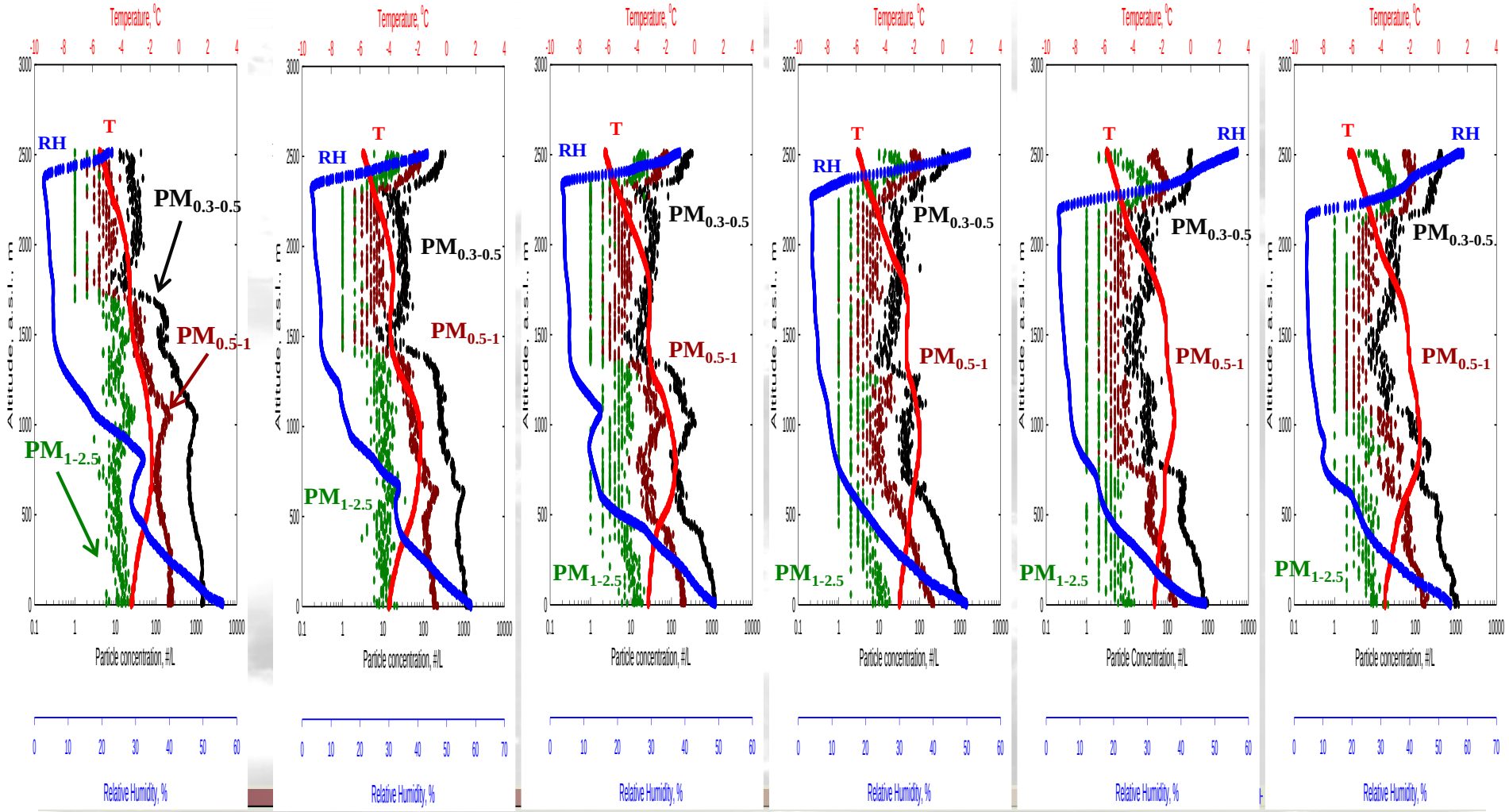


❖ Vertical Profile Measurement (2,500 m)

Hanyang University
Nanoparticle Control Lab.

2018 Dec. 10

01:00 am | 02:00 | 03:00 | 04:00 | 05:00 | 06:00

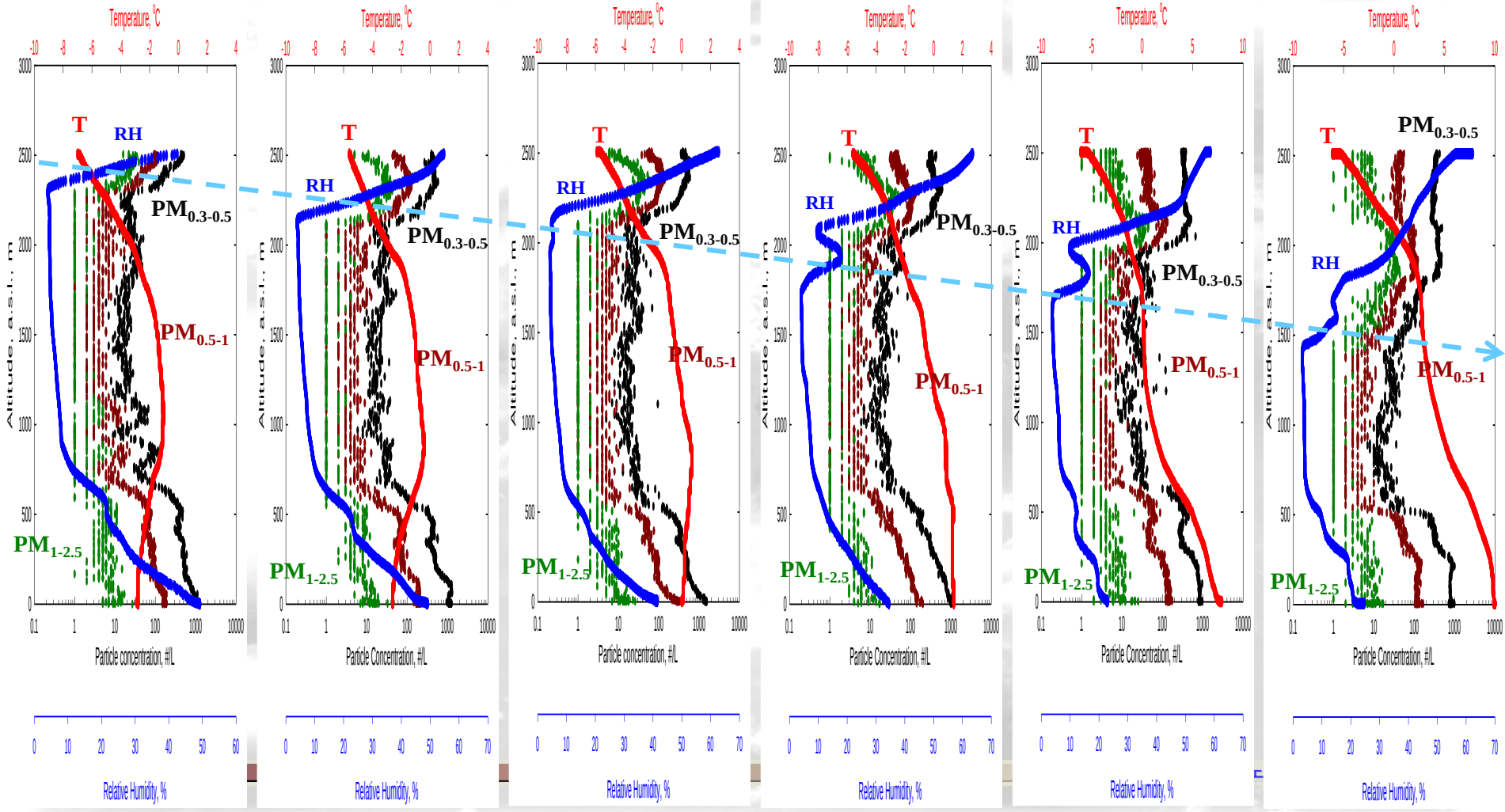


❖ Vertical Profile Measurement (2,500 m)

Hanyang University
Nanoparticle Control Lab.

2018 Dec. 10

07:00 08:00 09:00 10:00 11:30 14:00

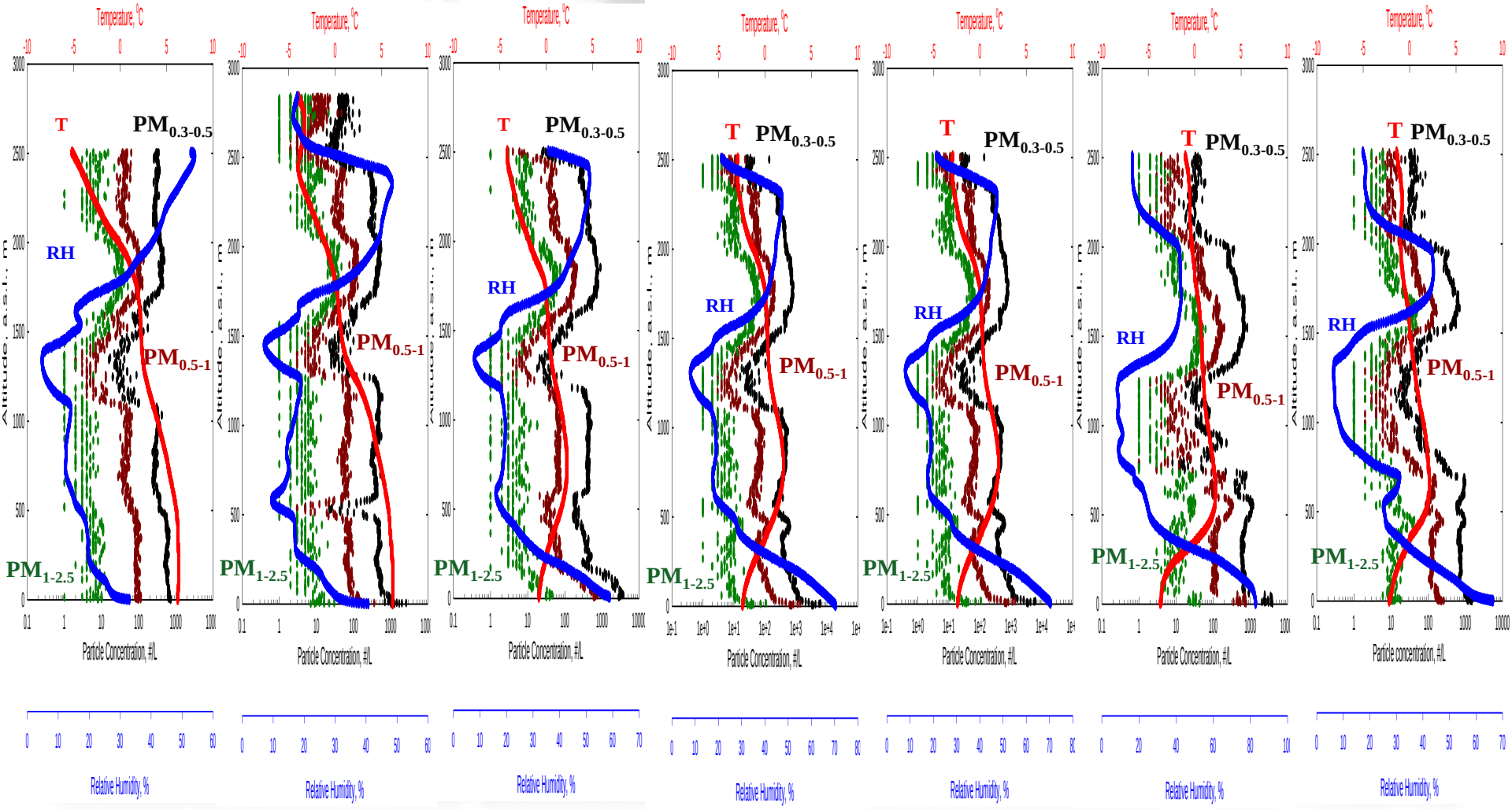


❖ Vertical Profile Measurement (2,500 m)

Hanyang University
Nanoparticle Control Lab.

2018 Dec. 10

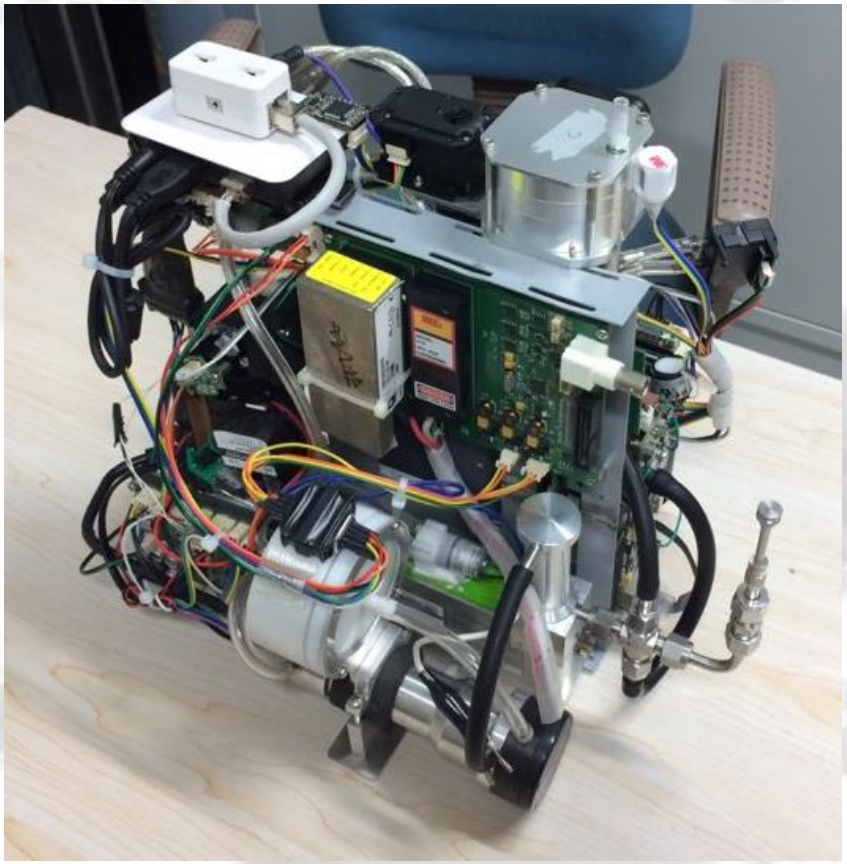
15:00 16:00 18:00 19:00 20:00 21:00 22:00



❖Vertical Profile Measurement

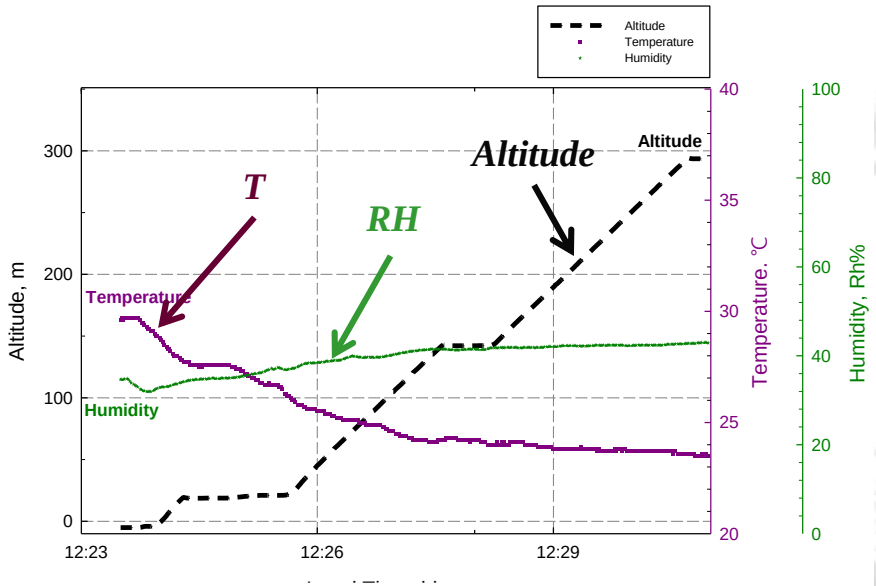
■ Drone + Hy-SMPS + OPC + Impactor Test

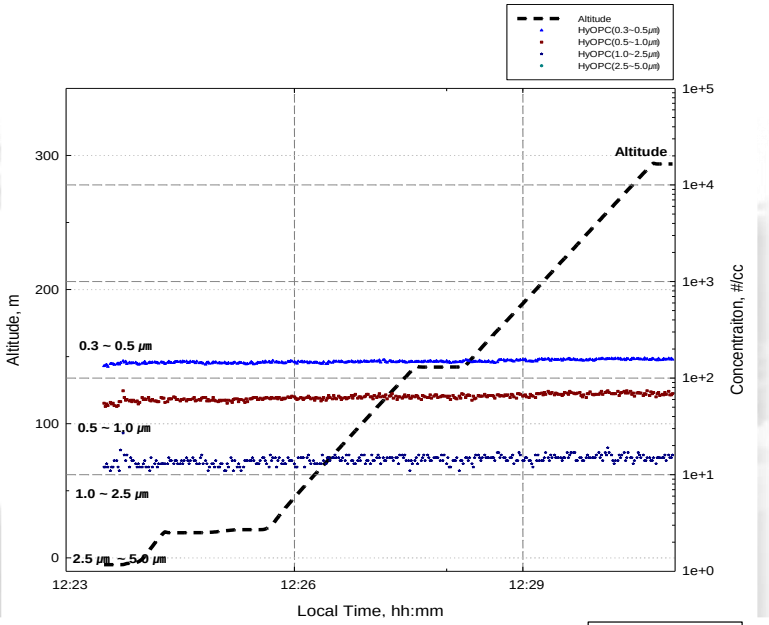
- Location : Tianjin
- May 2, 2017

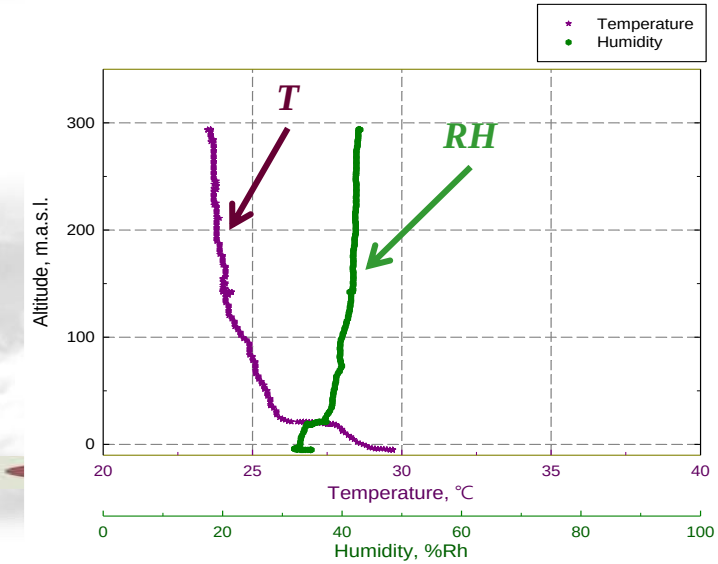


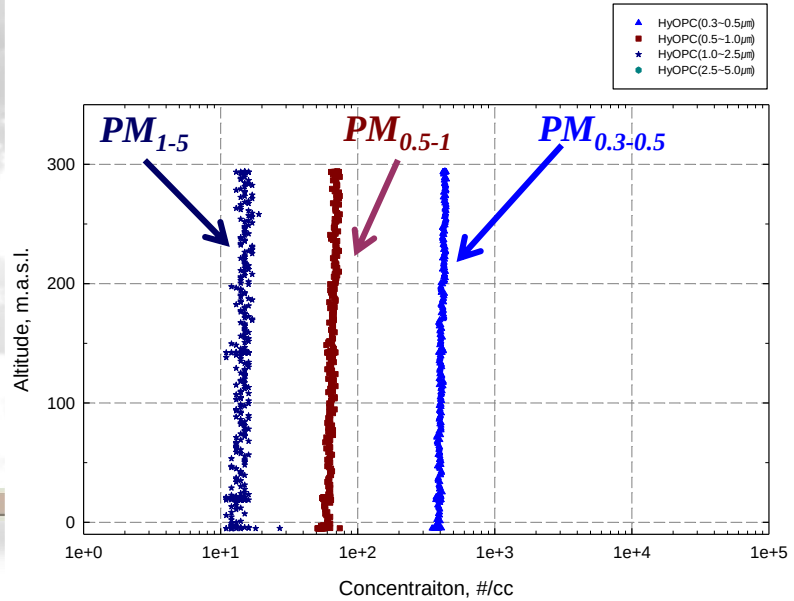
❖Vertical Profile Measurement

■ Drone + Hy-SMPS Test









❖Vertical Profile Measurement

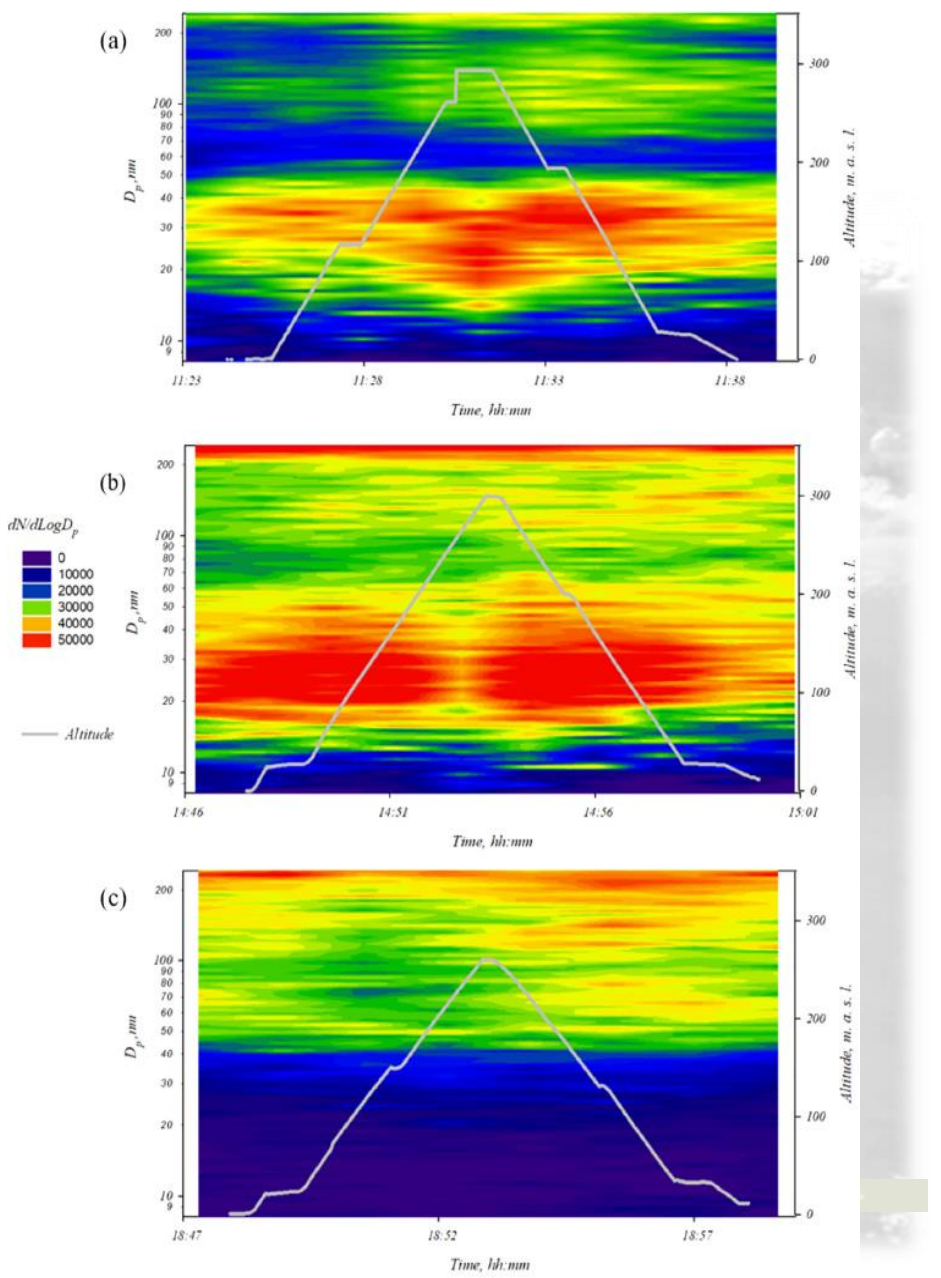
■ Drone + Hy-SMPS Test

- Location : Tianjin
- May 2, 2017

11:23-11:39

14:47-15:02

18:48-19:00



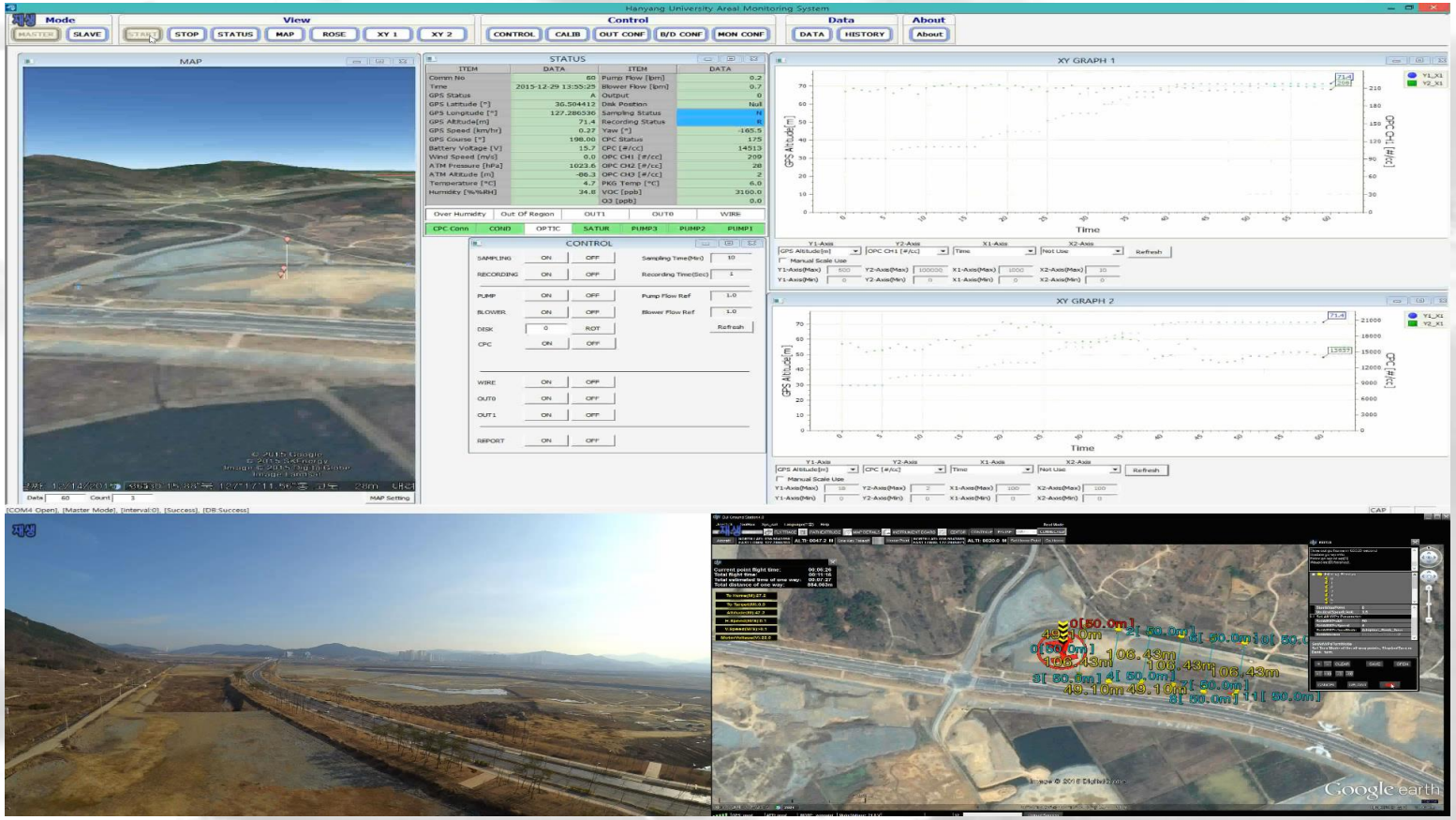
Sci. Total Environ., 665 (2019) 1095-1102

Other Applications

❖ Horizontal Profile Measurement

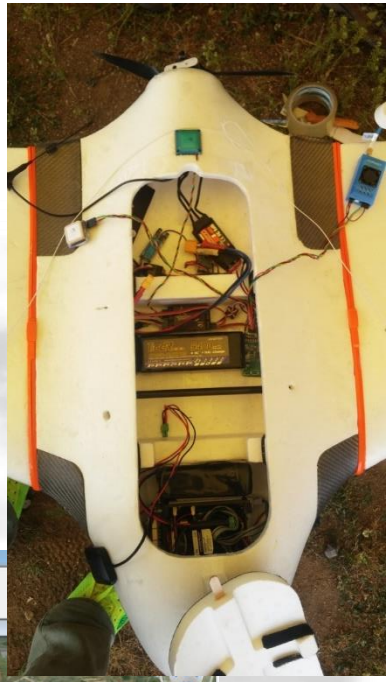
Construction Site

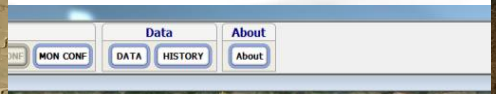
(Octocopter + Real-time monitoring view)

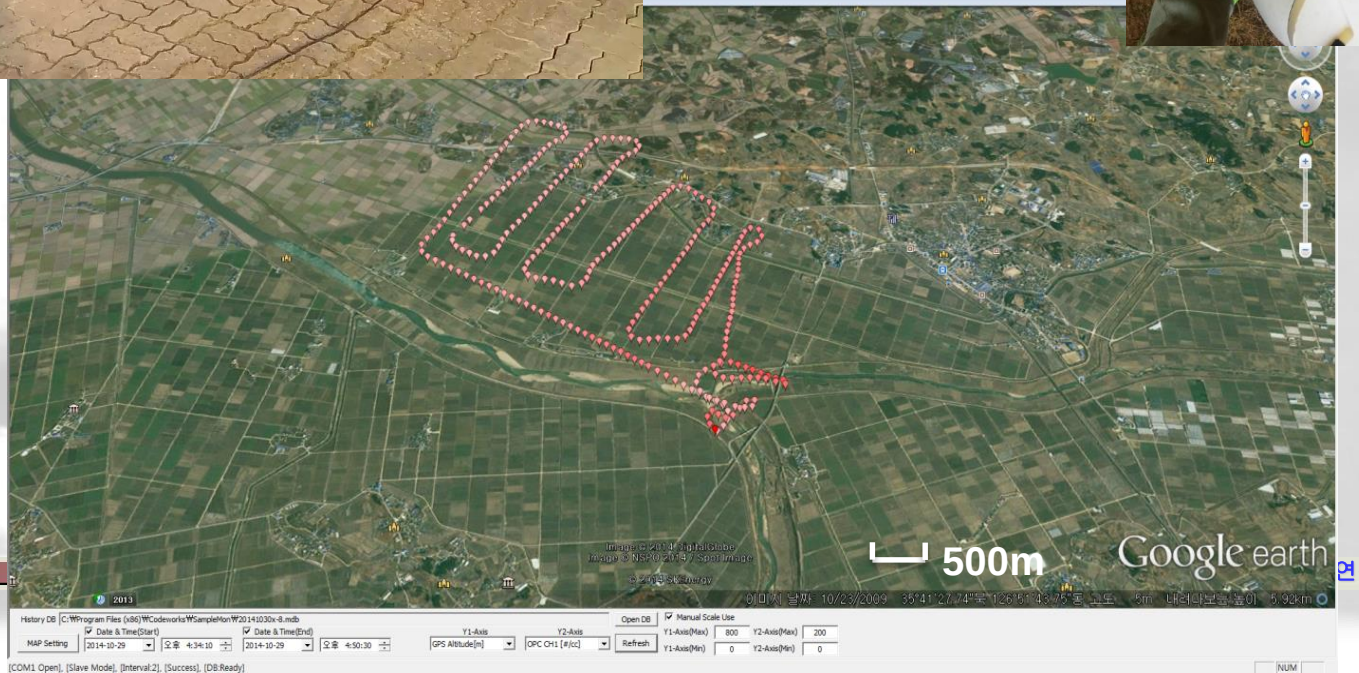


❖ Horizontal Profile Measurement

with fixed wing drone



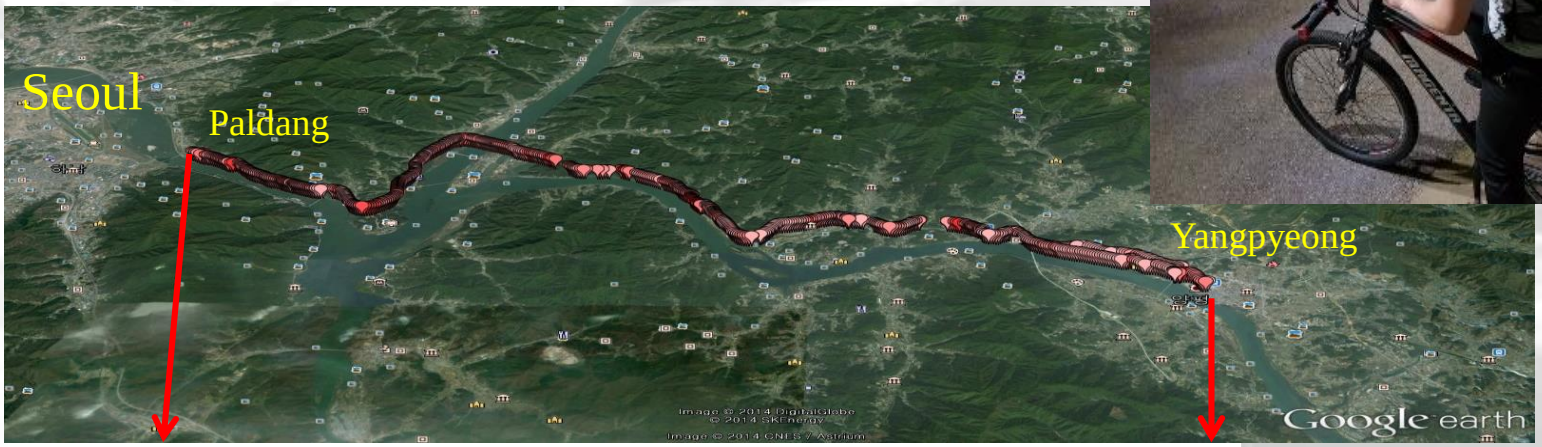


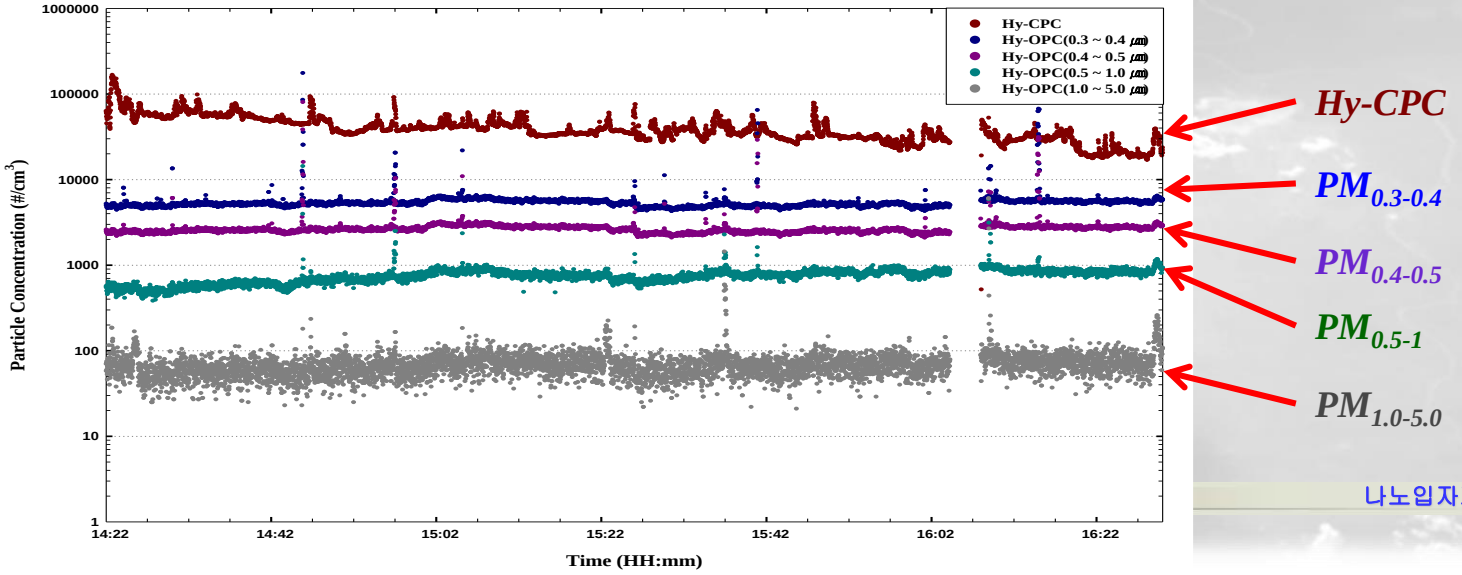


❖ Ship Emission Measurement with Drone & Hy-OPC

❖ Aerosol distribution on Biking Trail

❖ 2014. Feb. 27





Hy-CPC

$PM_{0.3-0.4}$

$PM_{0.4-0.5}$

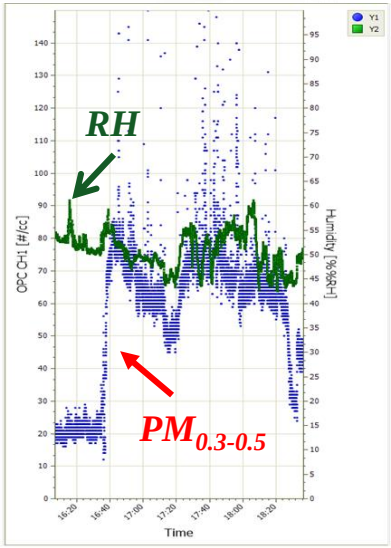
$PM_{0.5-1}$

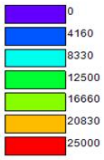
$PM_{1.0-5.0}$

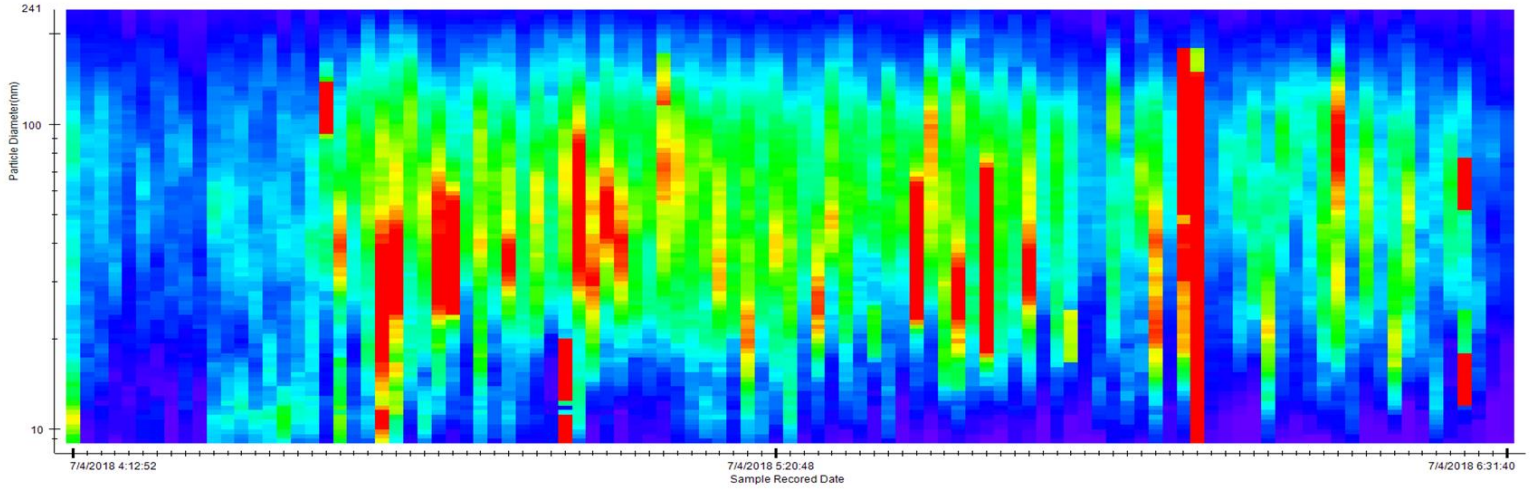
❖ Commuter Exposure Measurement with Back-pack system (Hy-SMPS, Hy-OPC)

Hanyang University
Nanoparticle Control Lab.

July. 5, 2018
AM_Walk
Barcelona, Spain



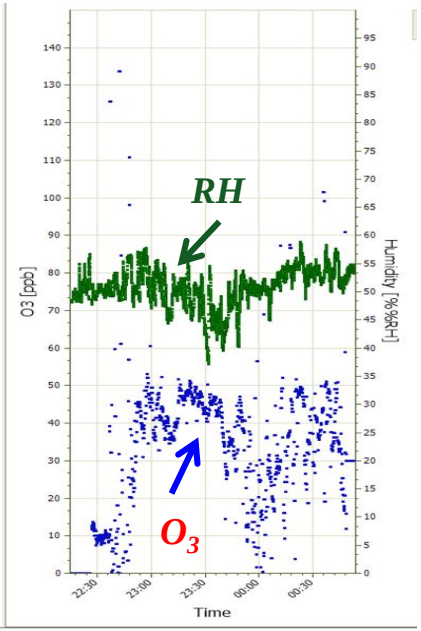


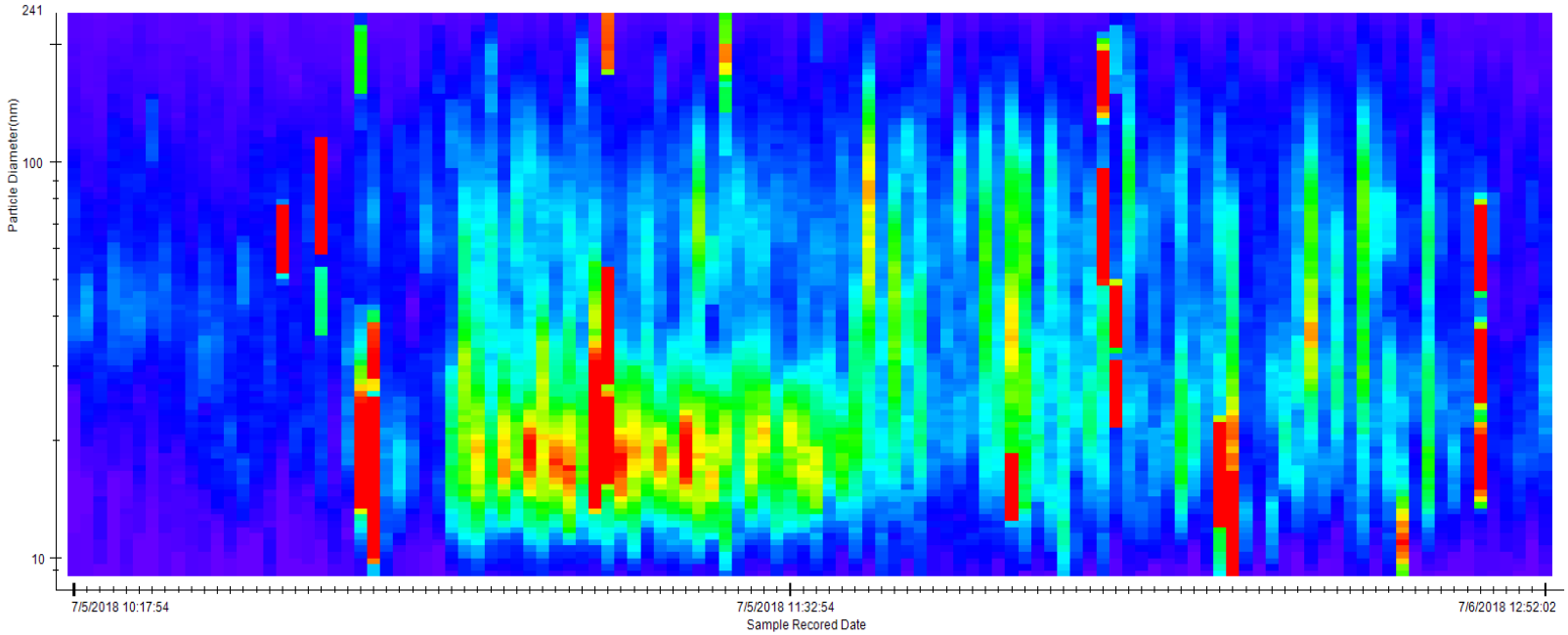


❖ Commuter Exposure Measurement with Back-pack system (Hy-SMPS, O_3)

Hanyang University
Nanoparticle Control Lab.

July. 5, 2018
PM_Walk
Barcelona, Spain

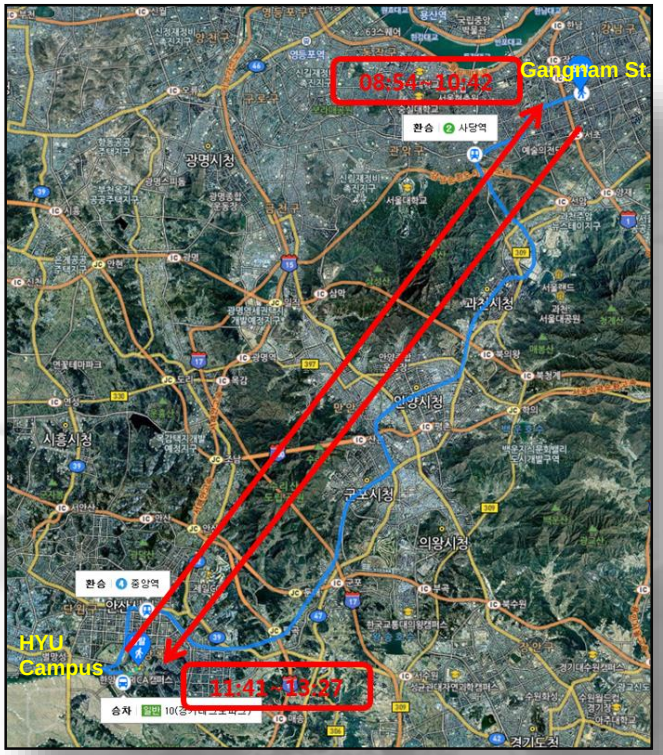


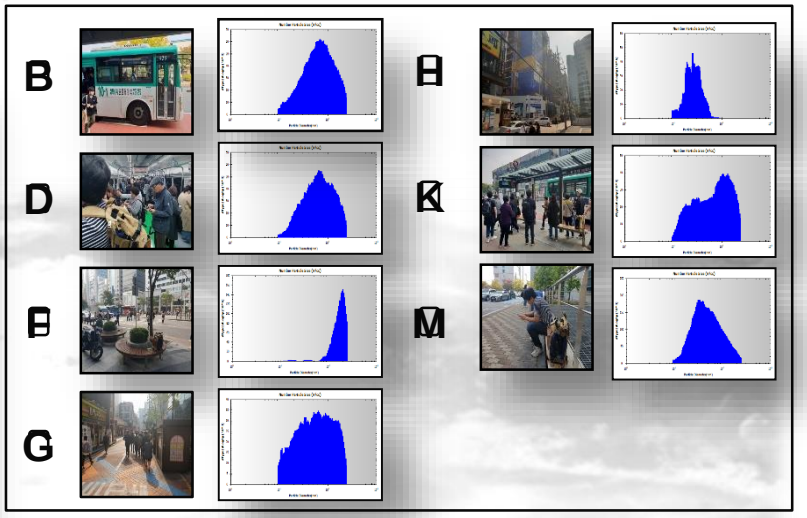


❖ Commuter Exposure Measurement with Back-pack system (Hy-SMPS, OPC)

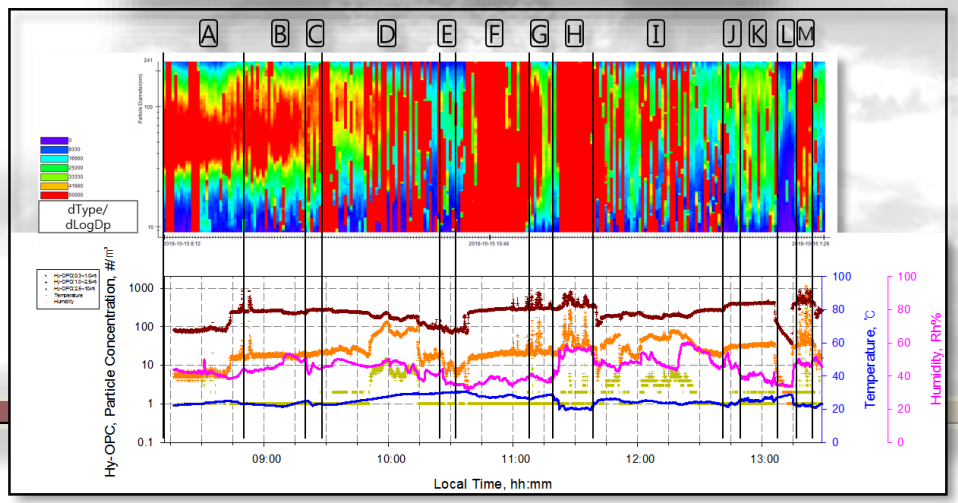
Hanyang University
Nanoparticle Control Lab.

2018. 10. 15
(08:12~13:27)





	Location
A	Road
B	Bus
C	Subway Platform
D	Subway
E	Subway Turnstile
F	Next to the driveway
G	An alley between buildings
H	construction site
I	Subway
J	Road
K	Bus Platform
L	Taxi
M	Smoking area



Conclusions

1. ***Portable aerosol measuring instruments*** **are successfully developed.**

2. **Using balloon and UAV, the aerosol vertical distributions are successfully measured.**

3. **A vertical aerosol flux distribution can be measured.**

4. **A new particle formation in the PBL is measured.**

5. **This will be *a new tool for the atmospheric aerosol researchers*.**

Thank You!

CSIC, Spain

Hanyang University, Korea

Peking University, China