UMS-Seoul observation-based local circulation in the Seoul Metropolitan Area

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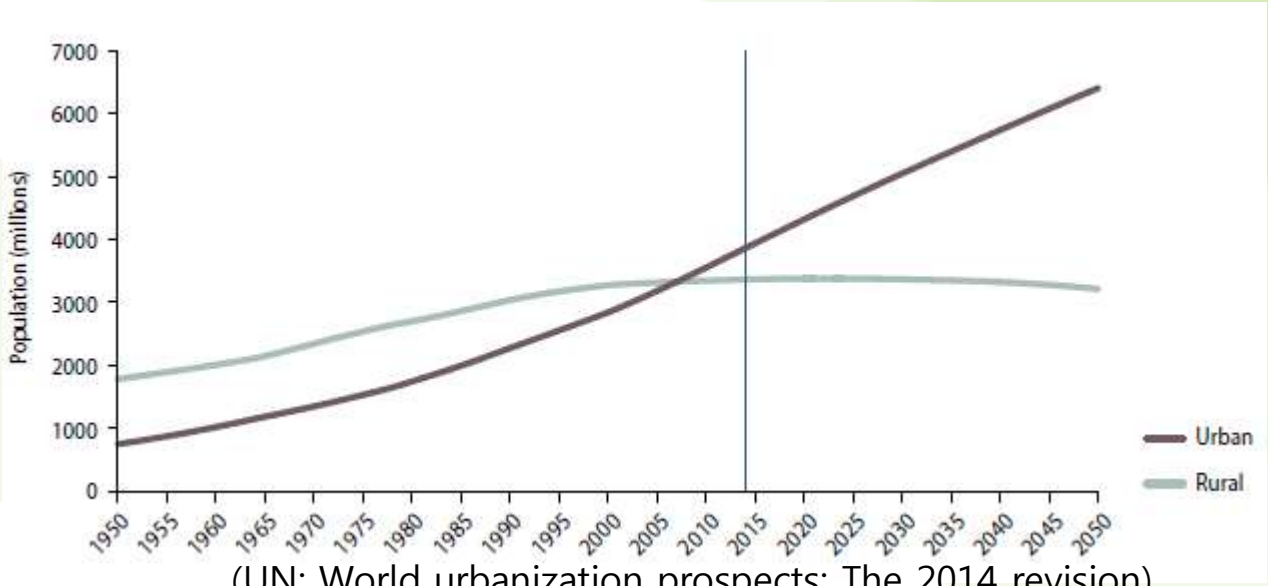
Lecture theatre 12, Academic Building 1, City University of Hong Kong

Urbanization

World

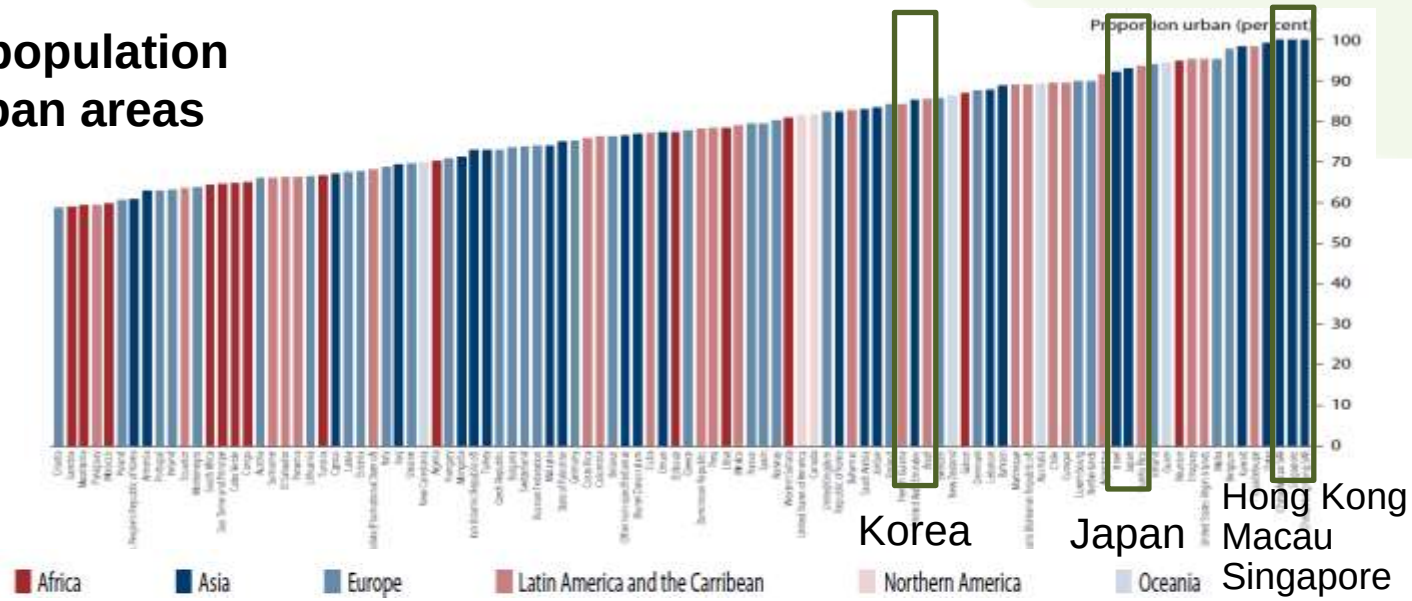
50 % in 2007
54 % in 2014
66 % in 2050



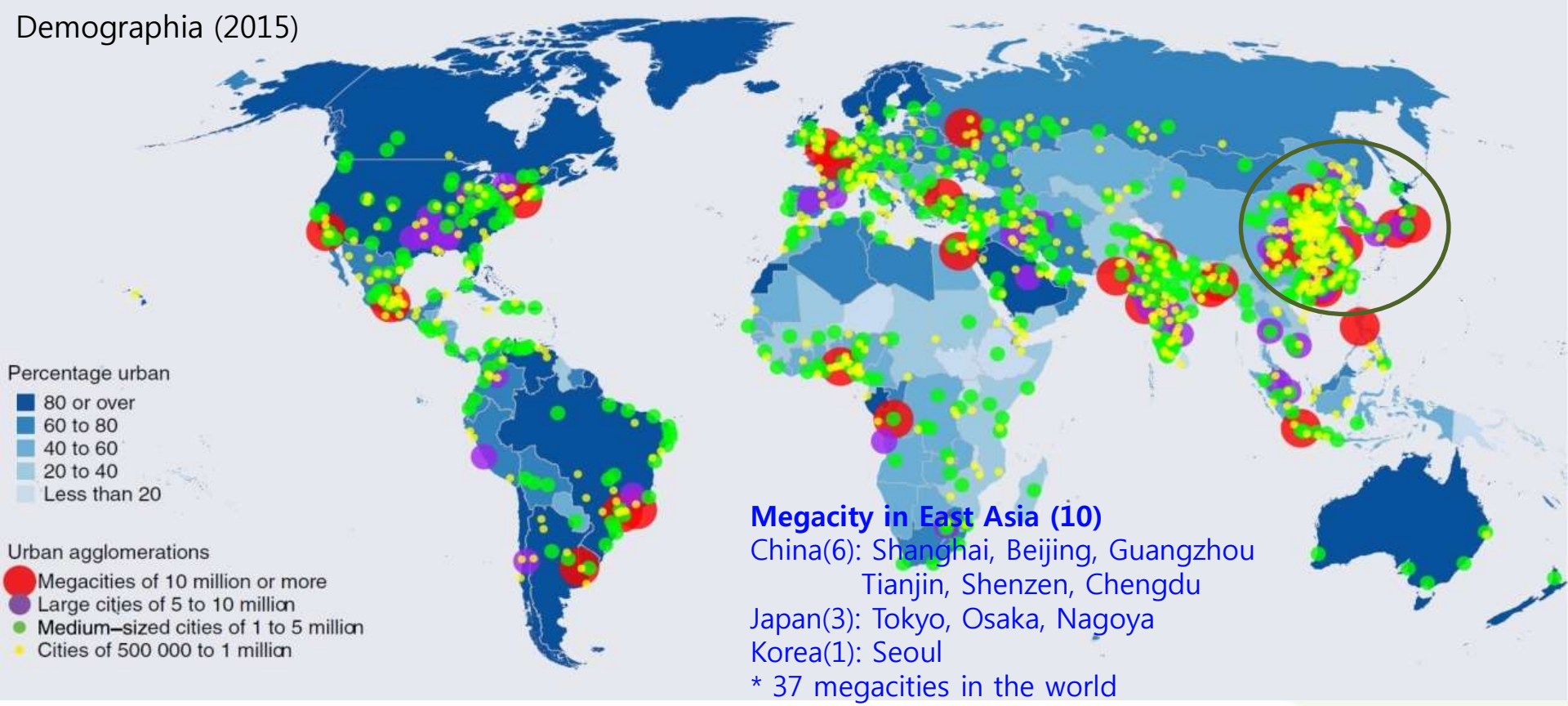
(UN: World urbanization prospects: The 2014 revision)

Percentage of population residing in urban areas

China 54 %
Korea 82 %
Japan 93 %
Hong Kong 100 %
Macau 100 %
Singapore 100 %



Demographia (2015)



Megacity in East Asia (10)
China(6): Shanghai, Beijing, Guangzhou
Tianjin, Shenzen, Chengdu
Japan(3): Tokyo, Osaka, Nagoya
Korea(1): Seoul
* 37 megacities in the world

Largest urban areas in the world: 2016

Urban Area	Population (million)	Urban Area	Population (million)
Tokyo-Yokohama	37.9	Shanghai	23.4
Jakarta	31.8	Mumbai	22.9
Delhi	26.5	New York	21.4
Manila	24.2	Sao Paulo	20.9
Seoul-Incheon	24.1	Beijing	20.4
Karachi	23.5	Hong Kong (51th)	7.3

Effects of urban on meteorology

Temperature and humidity

- Temperature ↑ ↑
- Humidity/evaporation ↓ ↓

Weather phenomena

- Haze, cloud, precipitation ↑ (Urban center, downwind)
- visibility ↓

Wind/Turbulence

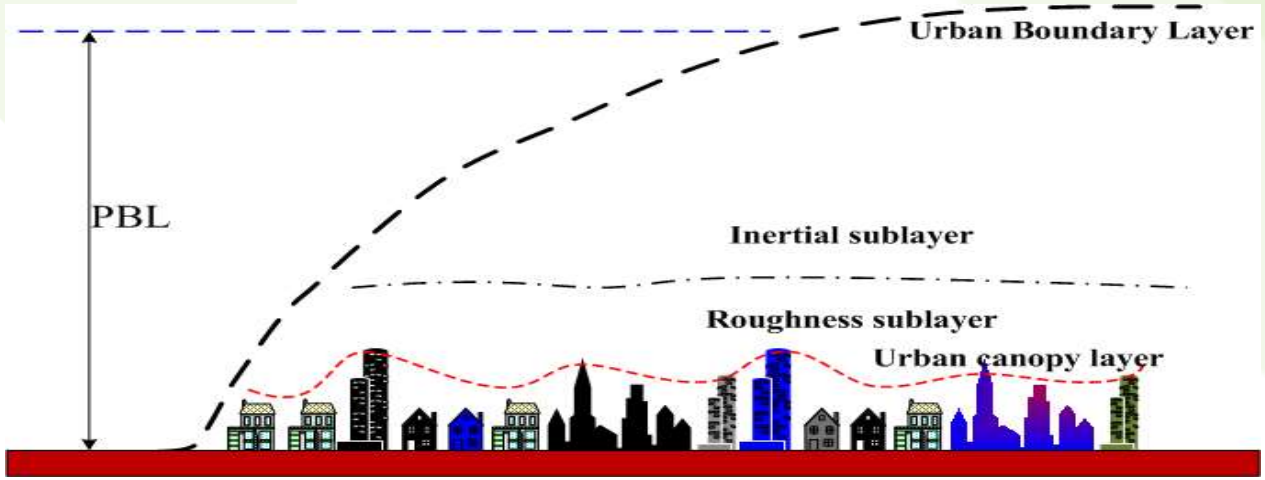
- Turbulence Intensity ↑ ↑
- Wind speed ↓(↑) when strong(weak) synoptic-scale wind dominants

Energy

- Solar radiation (UV) ↓
- Sensible Heat flux/Heat storage ↑ ↑

Precipitation according to wind

- Calm: Strong heat island ➔ Convergence (center) ➔ Max. Precipitation in urban center
- Weak wind: Weak convergence ➔ Max. Preci. in downwind region
- Strong wind: Divergence (upwind), Convergence (downwind) ➔ Max. precipitation in downwind region



Impervious surface ➔ Amplify flash flooding under heavy rainfall condition

Urban material (concrete, asphalt), Energy use ➔ Urban heat island and anthropogenic heat release

High-rise building ➔ Increase roughness and turbulence, and modify wind fields

Urban-rural circulation, aerosol emission ➔ Modify precipitation intensity and area

Severe storms with lightning and high-speed wind ➔ Cause power failure

Severe haze and mist events ➔ Increase mortality of respiratory patients

Repeated hazardous extreme weather phenomena at urban area

User-specific Meteorological Information → **Urban resilience and sustainability**

Weather Information Service Engine (WISE)

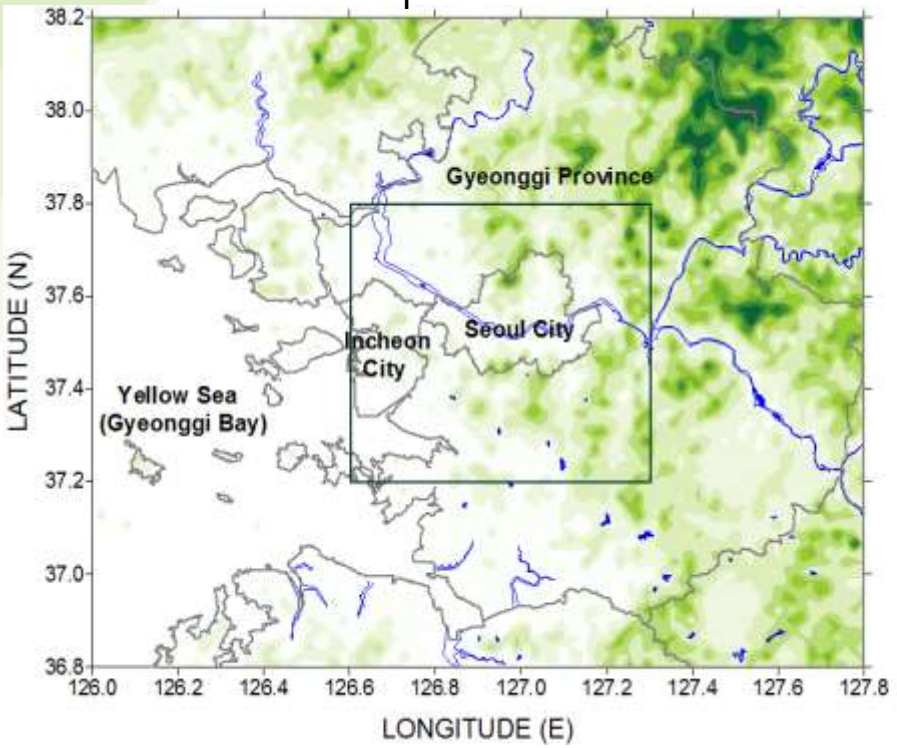
- **Vision: Urban resilience and Sustainability**
- **Purpose**: (1) User-specific meteorological information service, (2) Scientific advances in urban scale (meso-γ to micro-β scale, *terra incognita* or gray-zone problem) meteorology
- **Service**: urban heat island, flash flood, road weather(ice, wetness), urban planning, urban ecology, energy use, agriculture, air quality
- **Observation platform (UMS-Seoul)**: In-situ observation (above 1000 stations), surface energy balance (flux) (14 stations), ground-based remote sensing (6 wind lidars, 9 radiometers, 2 ceilometers, 2 aerosol lidars), radar (7 stations), wind profiler (2 stations), rawinsonde (2 stations)
- UMS-Seoul + multi-scale and ensemble meteorological model + service oriented application model + data platform ➔ **Weather Information Service Engine**

UMS-Seoul

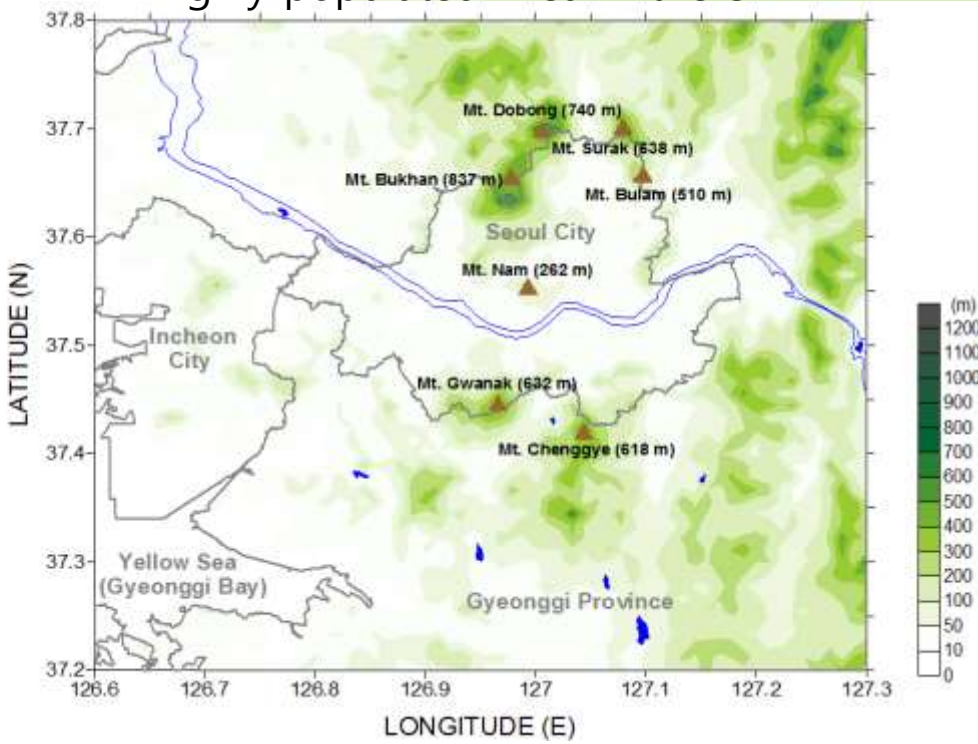
(High-resolution urban meteorological observation system networks in the Seoul Metropolitan Area)

Complexity of Geography and Topography in Seoul

Seoul Metropolitan Area



Highly populated Area in the SMA



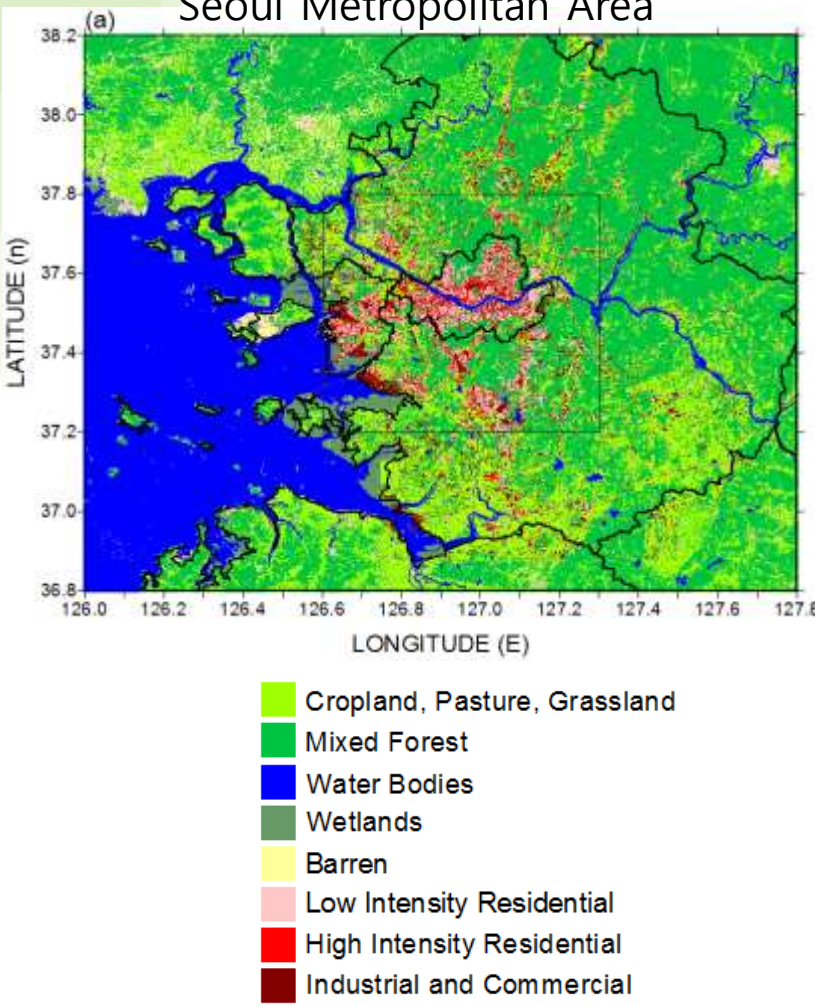
	Seoul	Incheon	Gyeonggi
Area (km^2)	605	1,010	10,184
Population	9,794,304	2,662,500	11,379,459
Population density (km^{-2})	16,188	2,588	1,119

Mountain	Height
Bukhan	837 m
Dobong	740 m
Surak	638 m
Gwanak	632 m

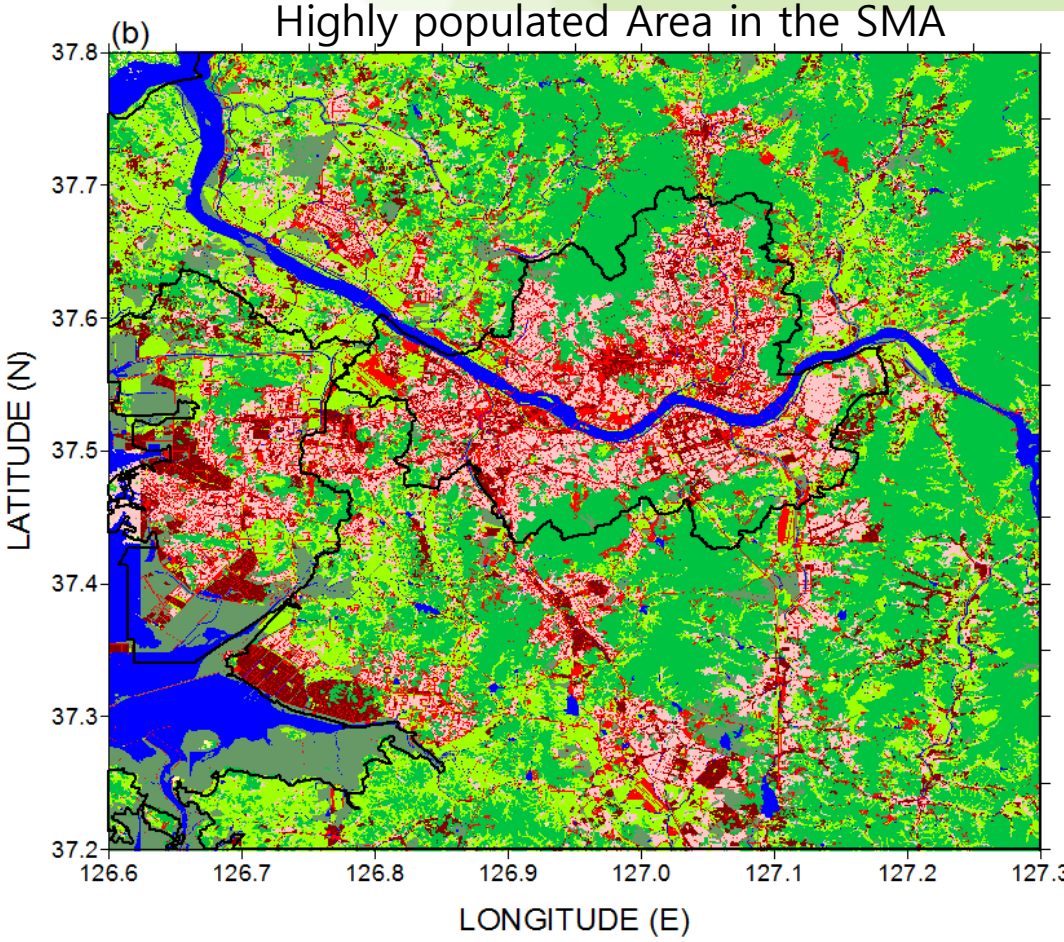
Mountain	Height
Cheonggye	618 m
Bulam	510 m
Nam	262 m

Complexity of Seoul land cover

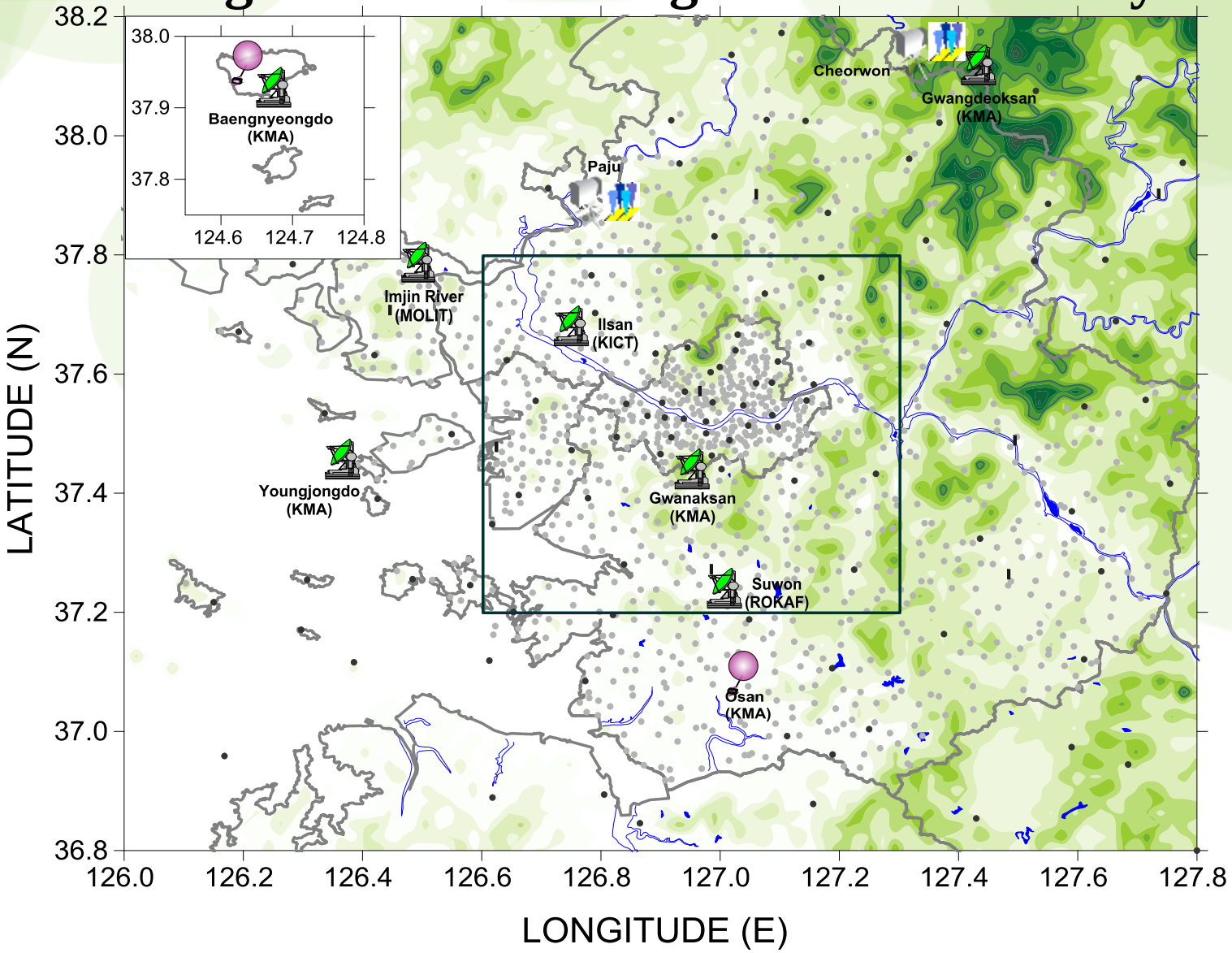
Seoul Metropolitan Area



Highly populated Area in the SMA

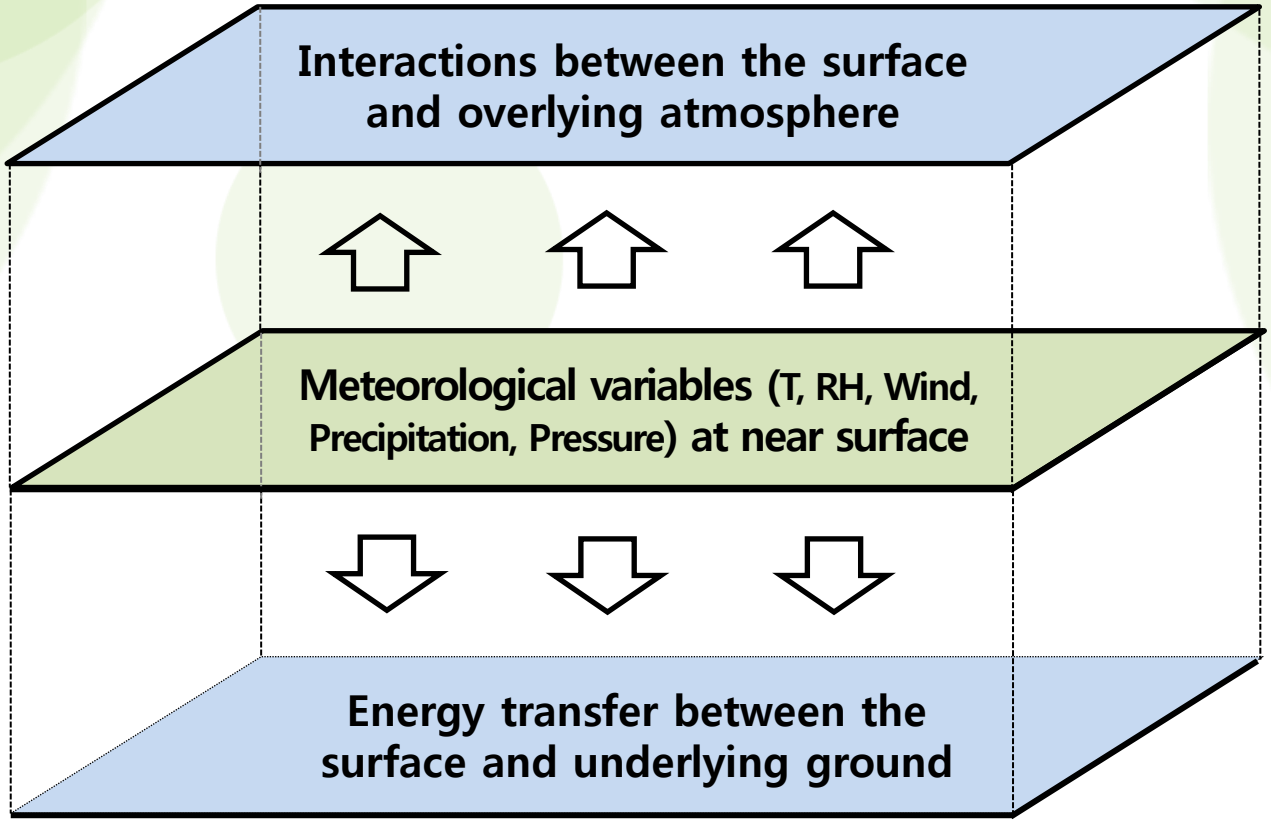


SMA background meteorological observation systems



Radar (7) Rawinsonde (2) Windprofiler (2) Radiometer (2) ASOS (7) AWS (108) SKP (1078)

For high-quality and high-resolution information



Vertical Profile

← Surface-based remote sensing system

- ceilometer
- aerosol lidar
- wind lidar
- microwave radiometer

Surface Energy Balance

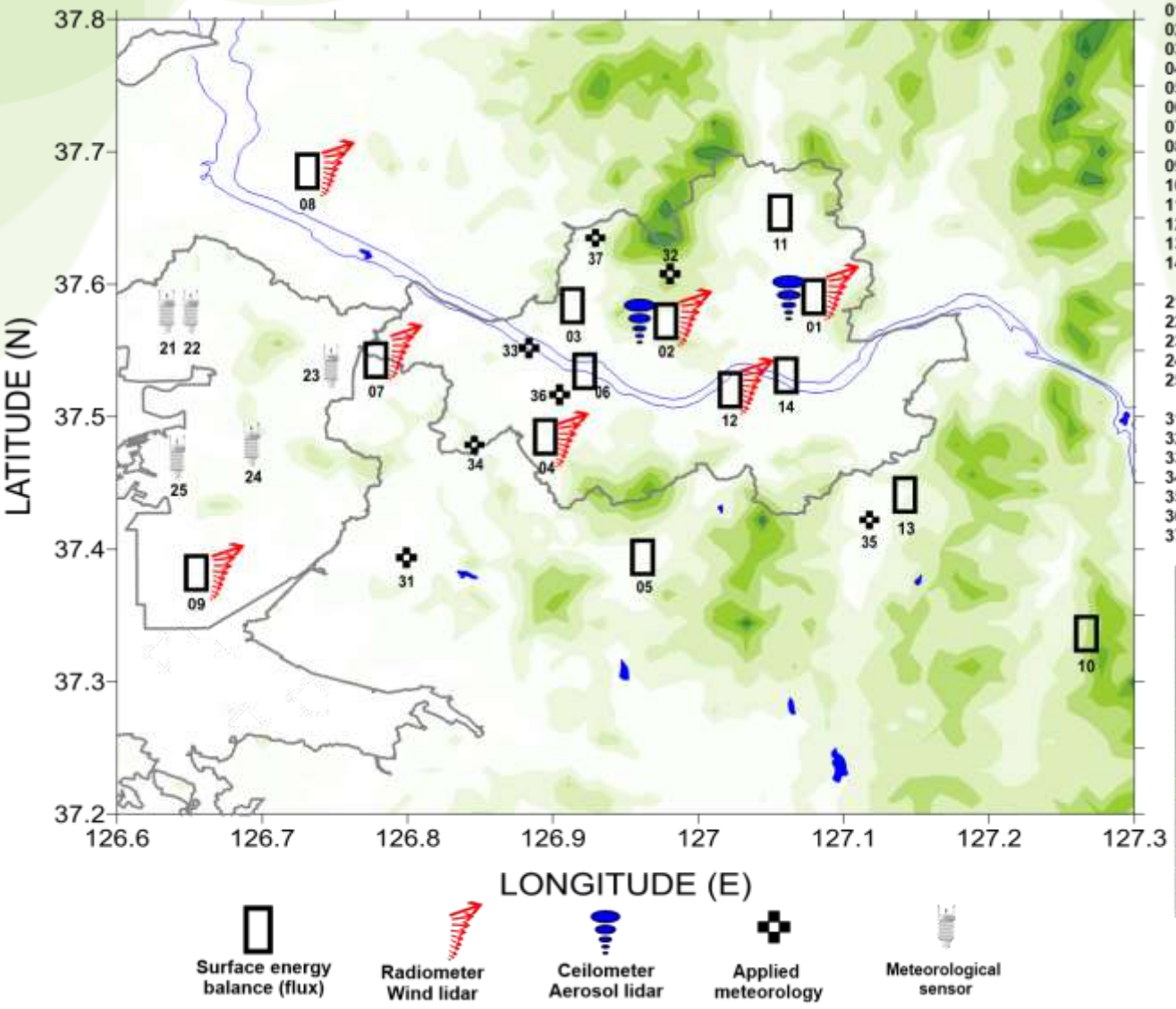
← Surface energy balance (flux) observation system

- radiation balance
- sensible/latent heat flux
- ground heat flux/storage

✓ Applied meteorological observation system

✓ Intensive field observation campaign

UMS-SEOUL



Surface Energy Balance (Flux)

Ceilometer

Aerosol lidar

Wind lidar

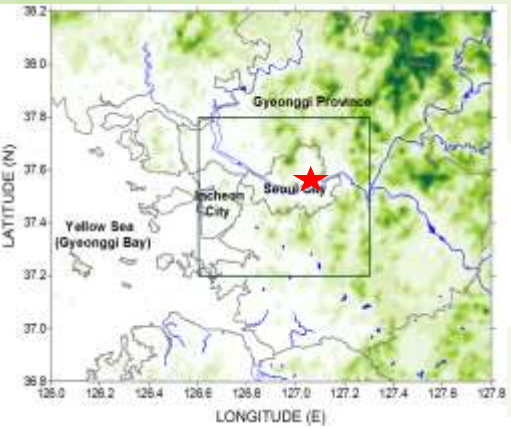
Microwave radiometer

UMS-Seoul based Local Circulation

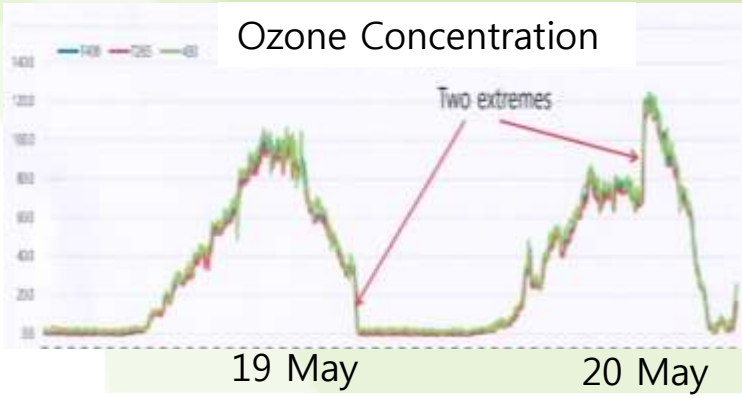
(period: 18-20 May 2016, Seoul Metropolitan Area)

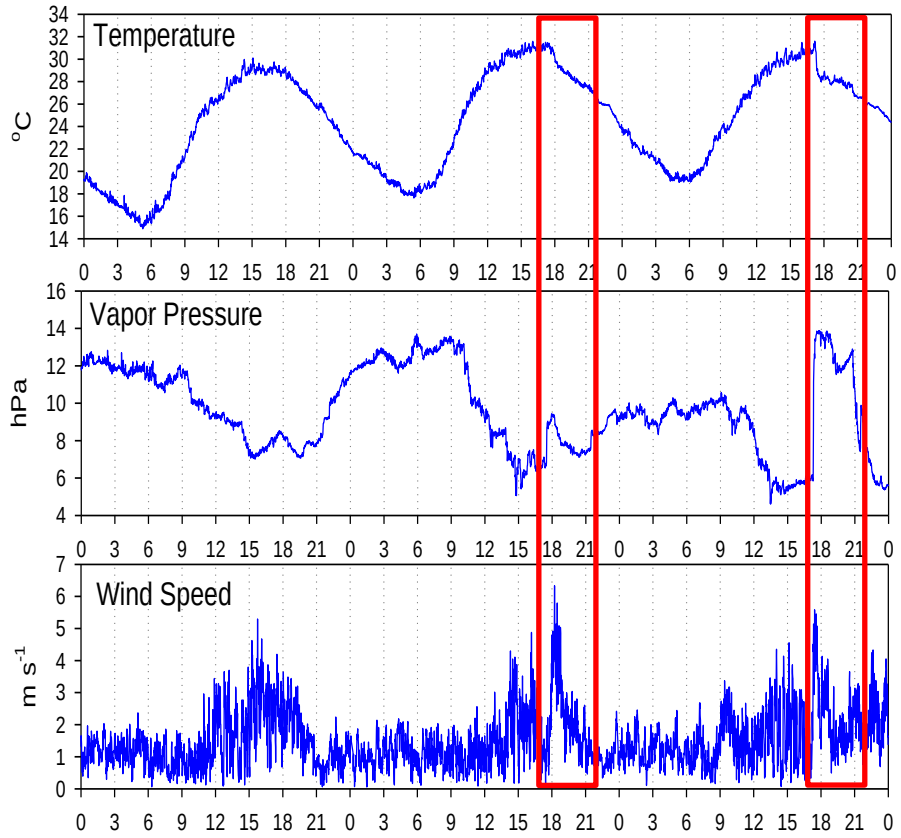
- ✓ **Meteorological surface variables**
- ✓ **3-D Meteorological Observation System**
- ✓ **Boundary-Layer structure**

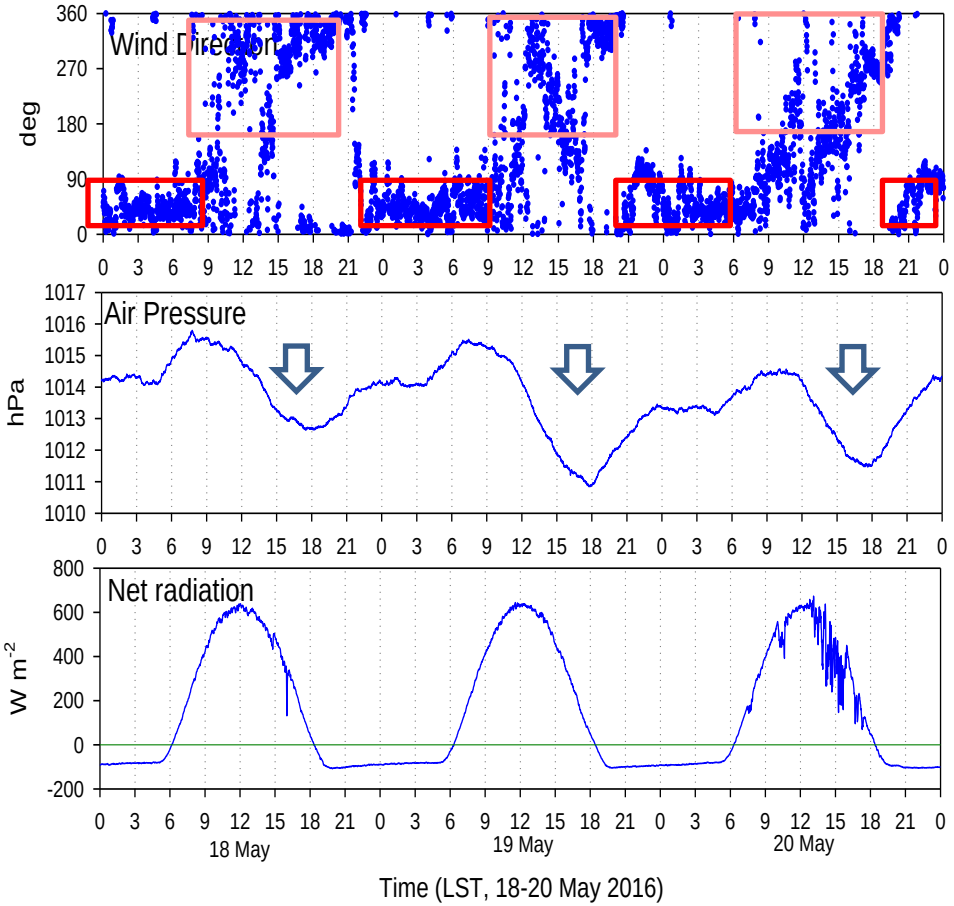
Meteorology



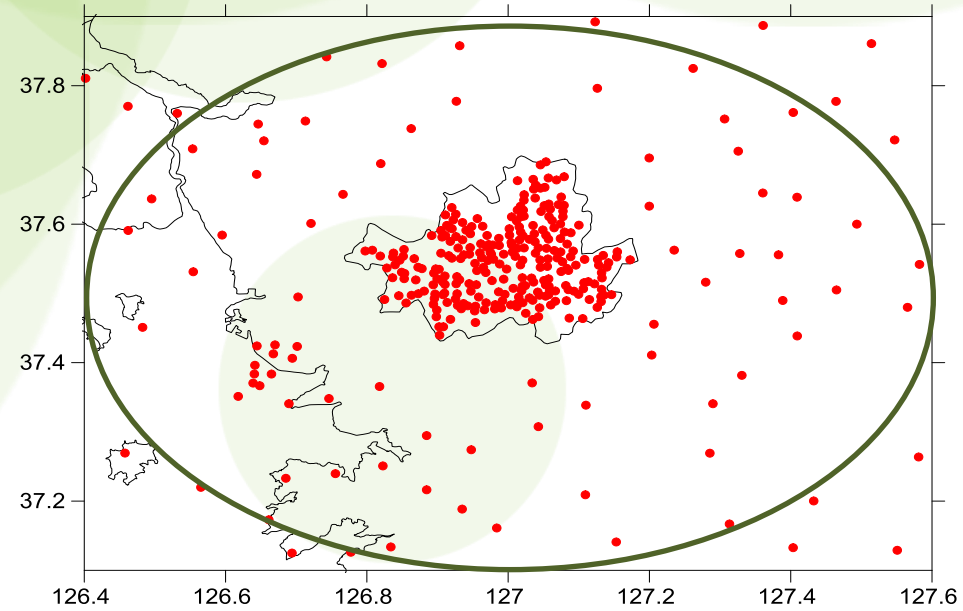
18-20 May 2016
Distance from seashore line: 45 km
Clear and no strong synoptic winds

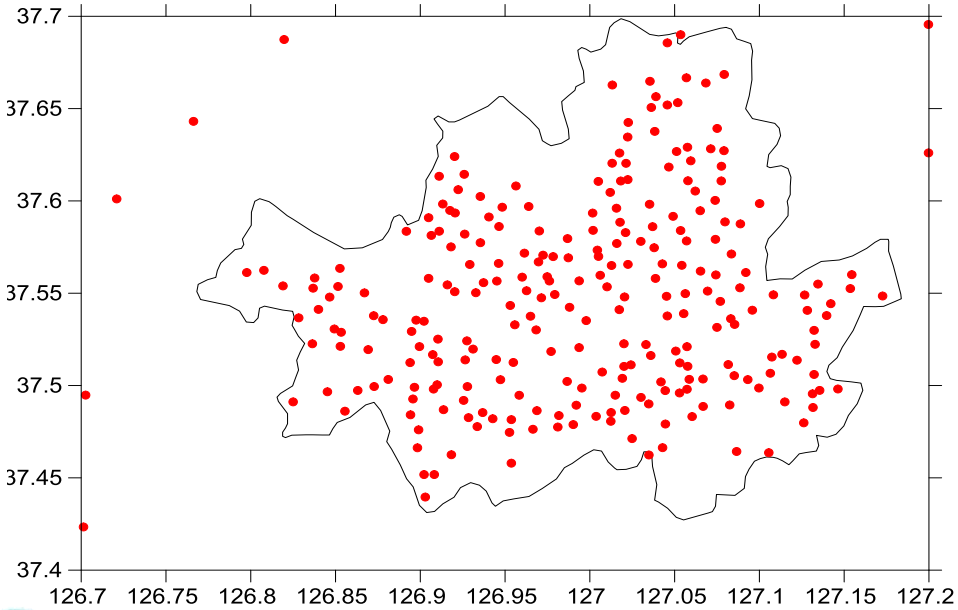




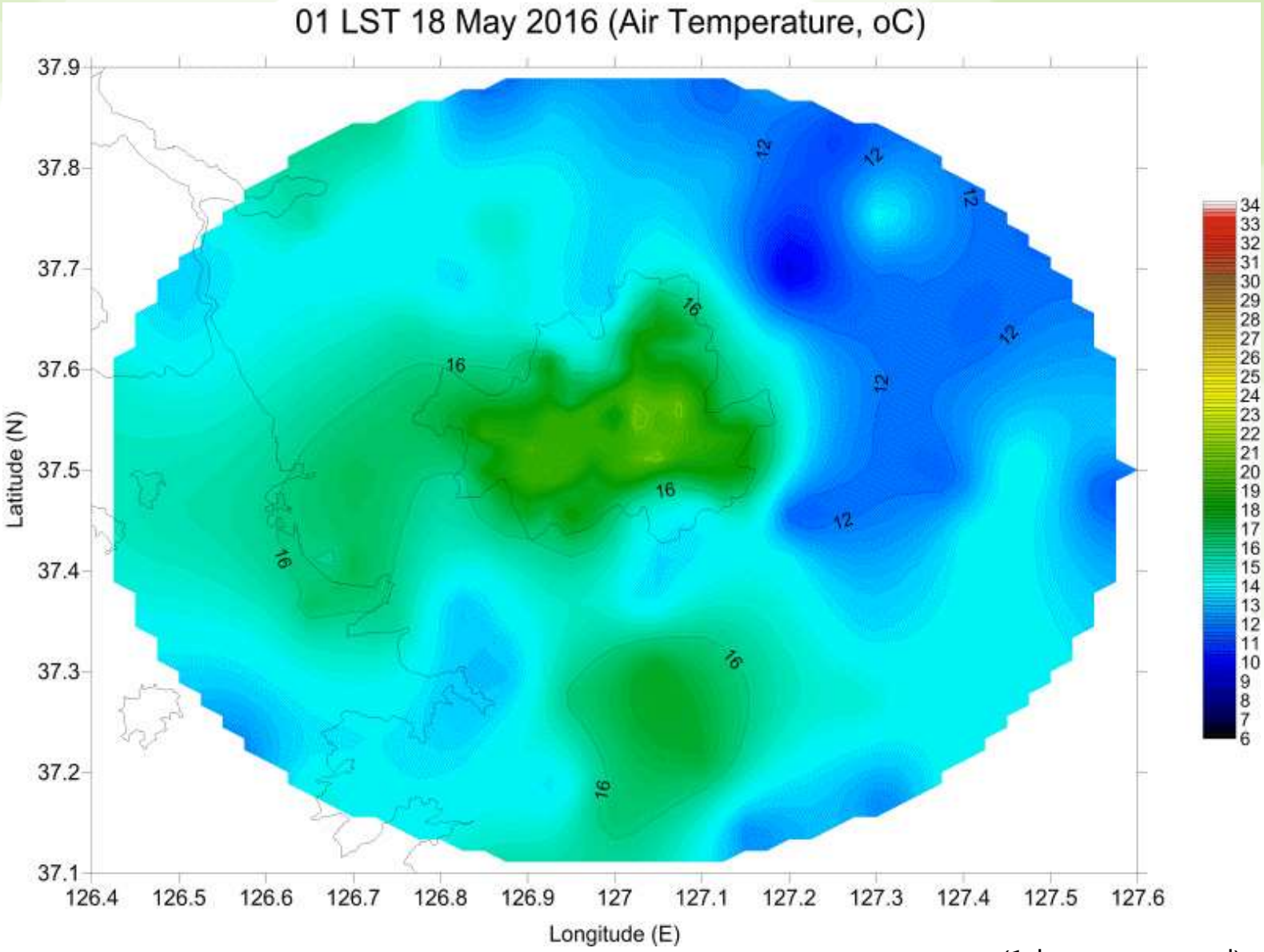


Surface Observation (SKP Data)

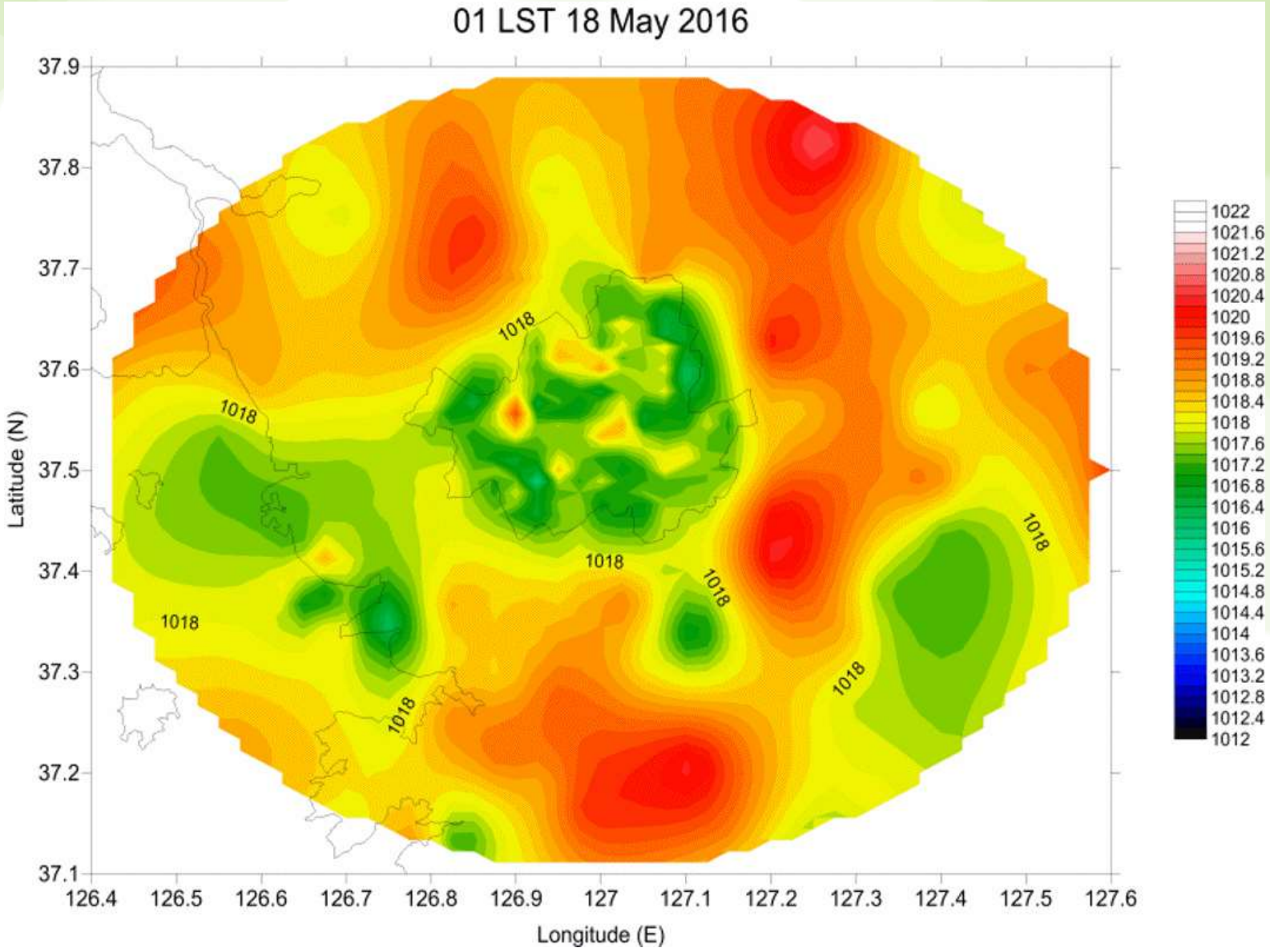


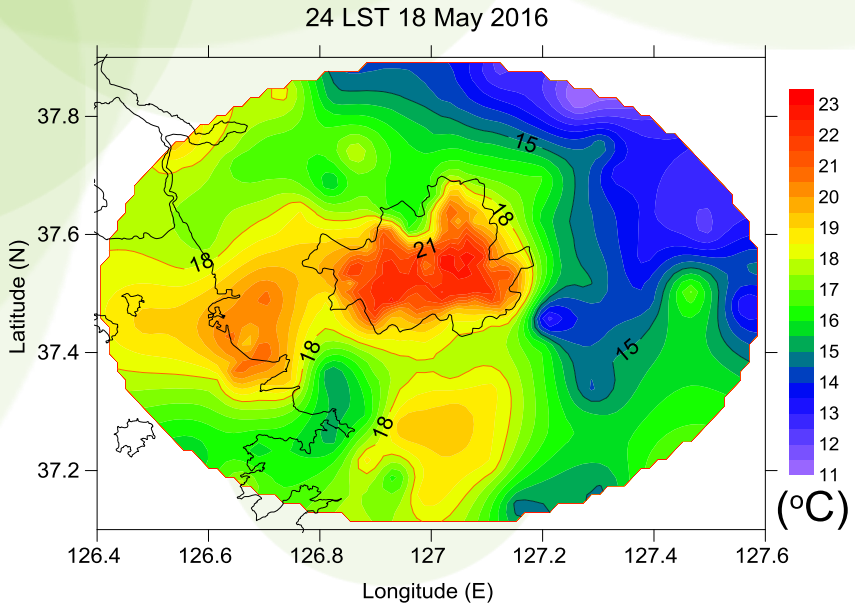


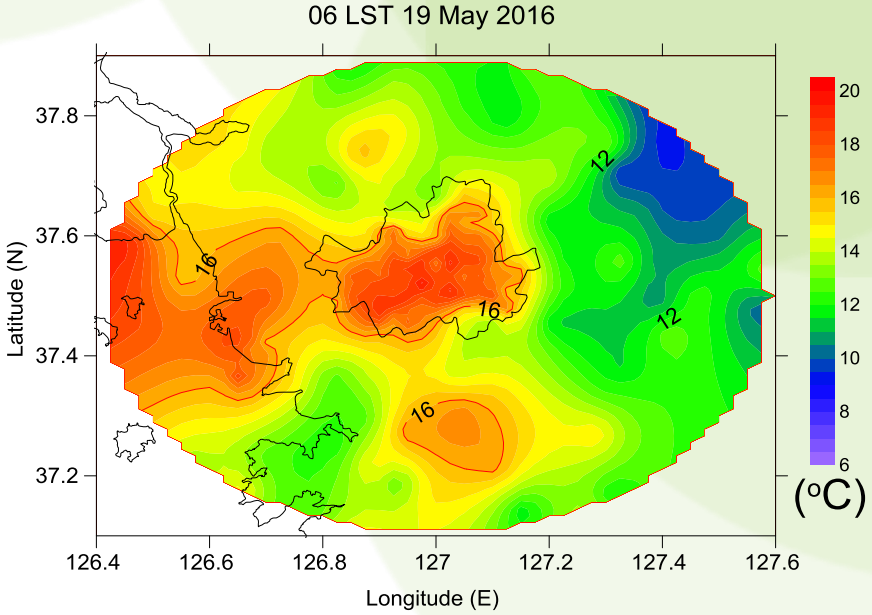
- ✓ Data interval: 1 minute
- ✓ Sensor: Integrated meteorological sensor (air temperature, relative humidity, wind speed, wind direction, air pressure), precipitation
- ✓ Stations: 381 (257 Seoul city)
- ✓ Data period: 18 to 20 May 2016

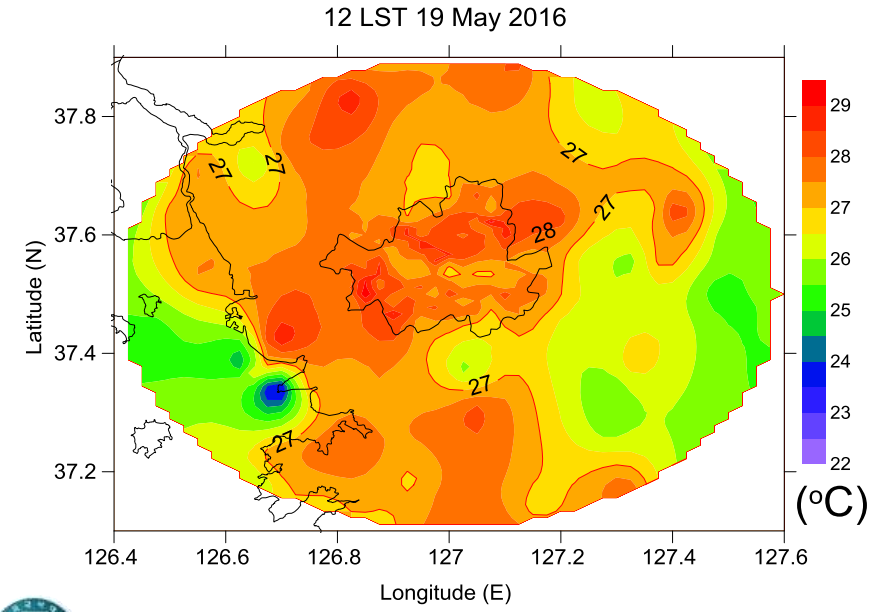


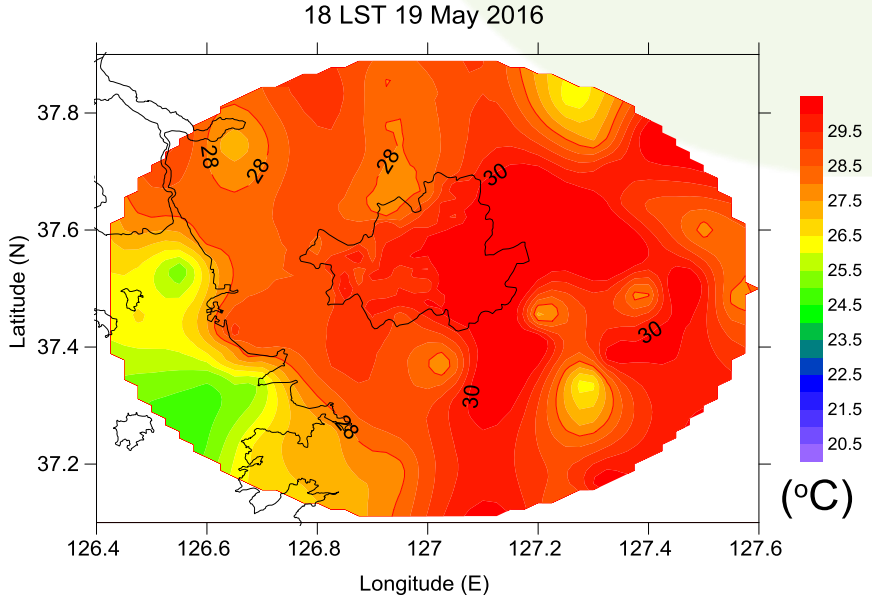
(1 hour averaged)

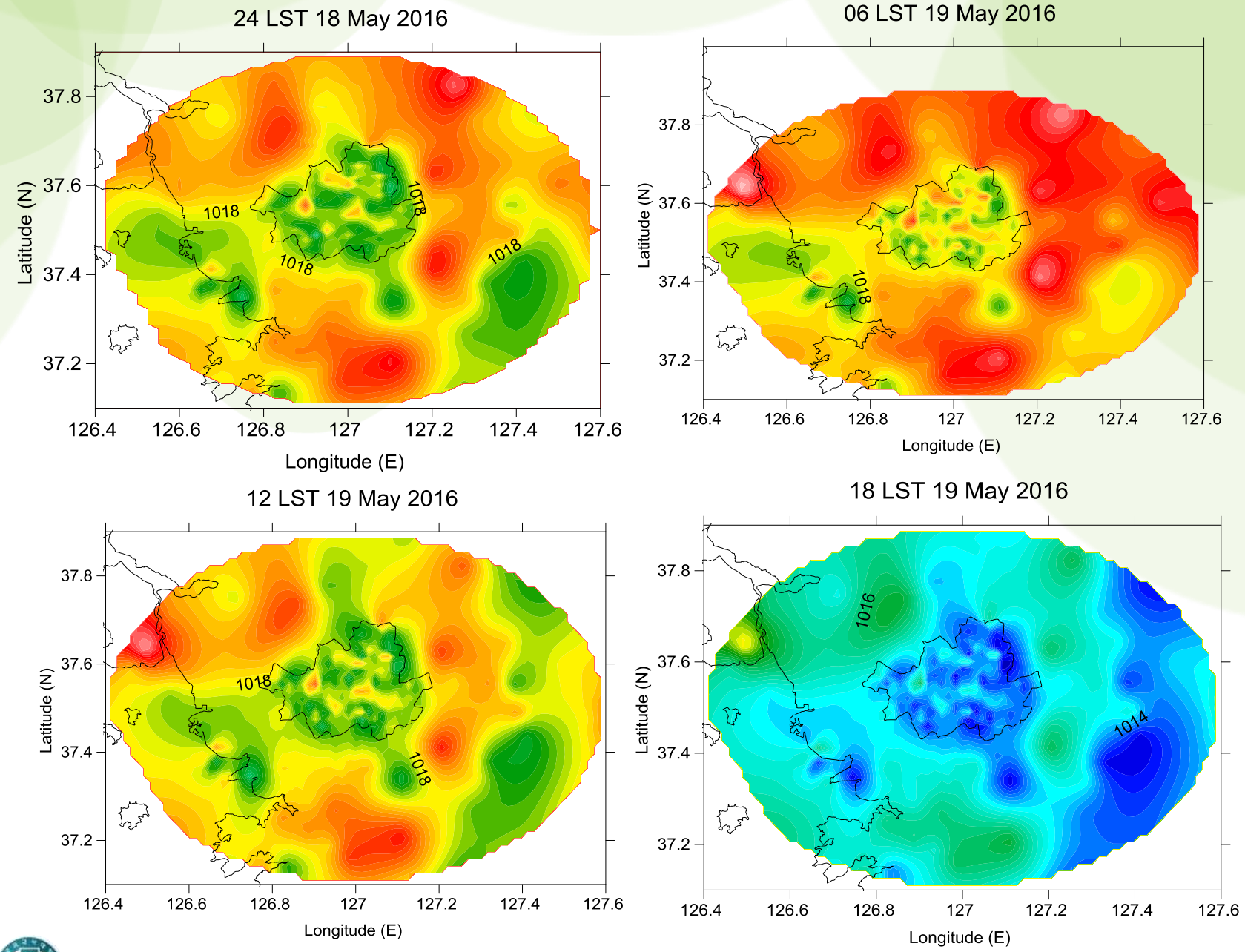

01 LST 18 May 2016
Latitude (N)
Longitude (E)
37.9
37.8
37.7
37.6
37.5
37.4
37.3
37.2
37.1
126.4
126.5
126.6
126.7
126.8
126.9
127
127.1
127.2
127.3
127.4
127.5
127.6
1018
1022
1021.6
1021.2
1020.8
1020.4
1020
1019.6
1019.2
1018.8
1018.4
1018
1017.6
1017.2
1016.8
1016.4
1016
1015.6
1015.2
1014.8
1014.4
1014
1013.6
1013.2
1012.8
1012.4
1012


24 LST 18 May 2016
Latitude (N)
Longitude (E)
(°C)

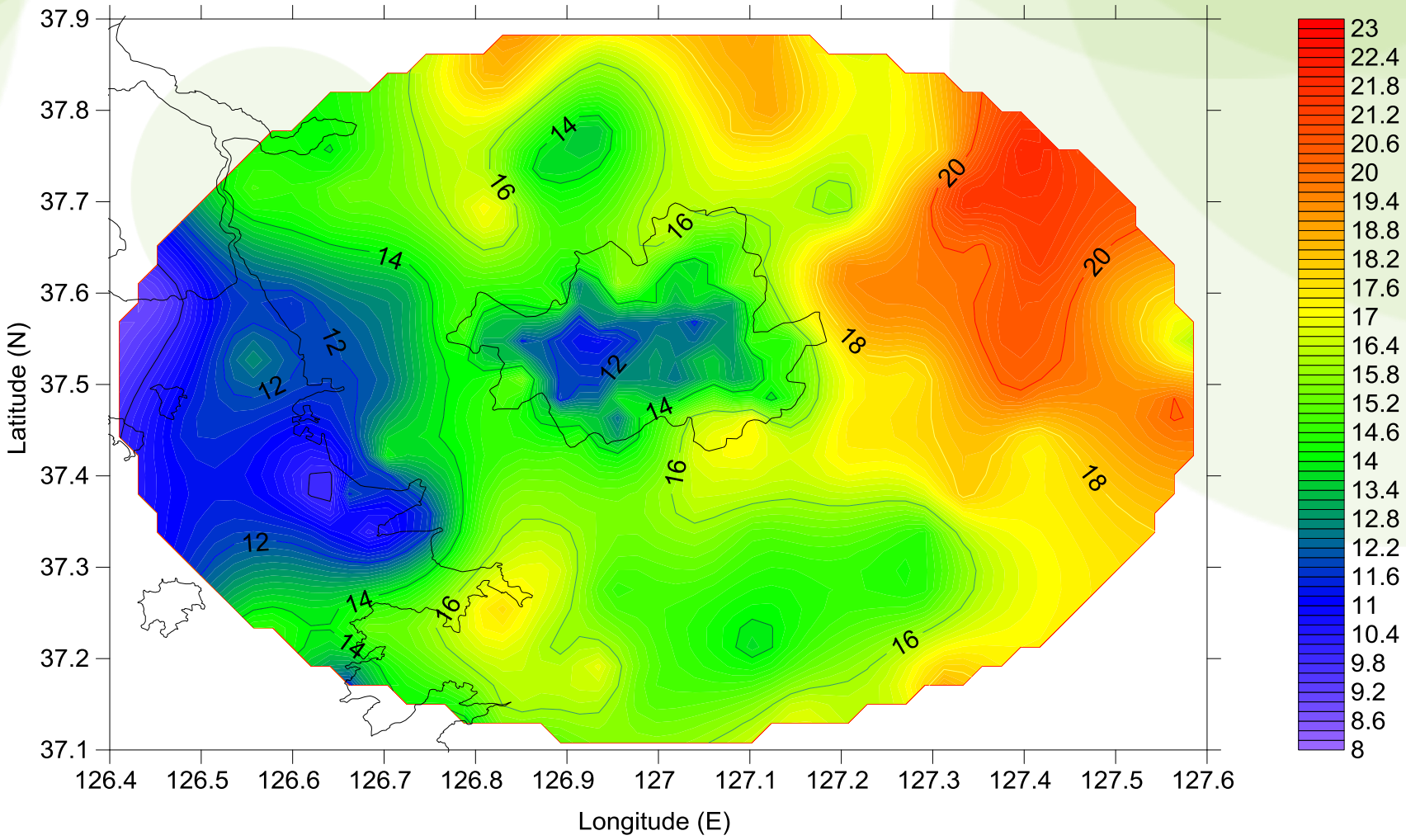

06 LST 19 May 2016
Latitude (N)
Longitude (E)
(°C)

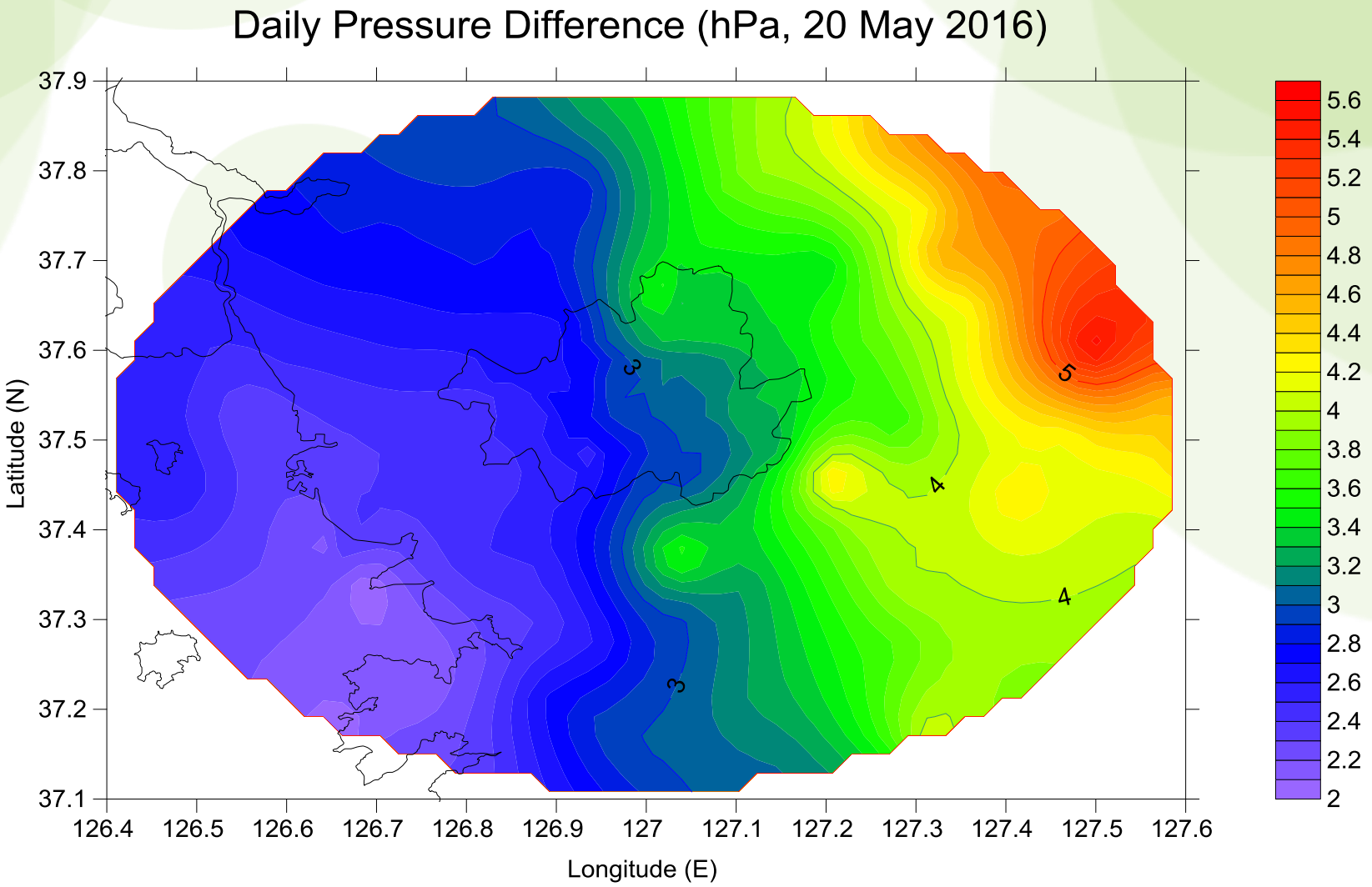

12 LST 19 May 2016
Latitude (N)
Longitude (E)
(°C)

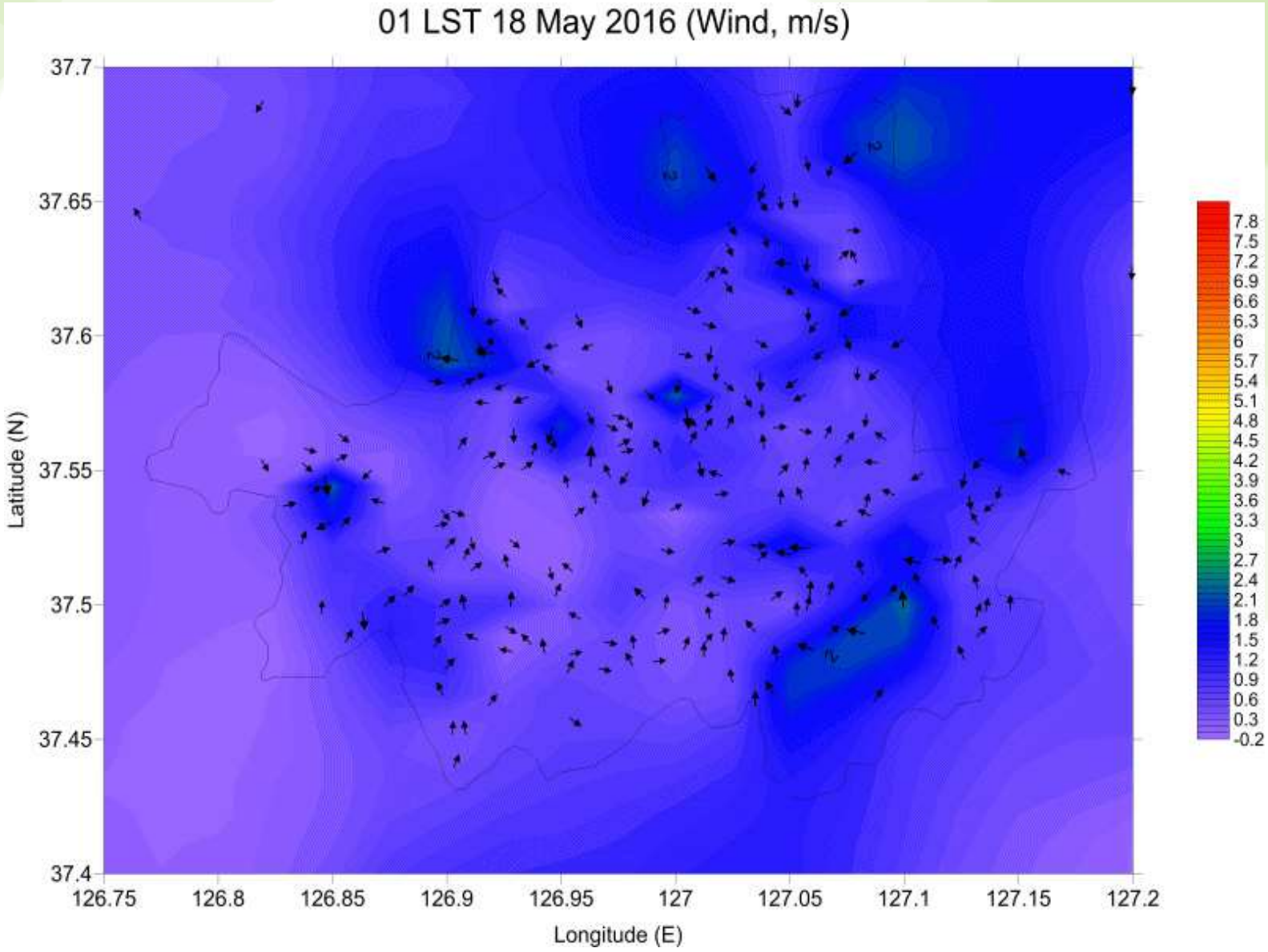

18 LST 19 May 2016
Latitude (N)
Longitude (E)
(°C)


24 LST 18 May 2016
06 LST 19 May 2016
12 LST 19 May 2016
18 LST 19 May 2016
Latitude (N)
Longitude (E)
37.8
37.6
37.4
37.2
126.4
126.6
126.8
127
127.2
127.4
127.6
1018
1016
1014
1022.0
1021.6
1021.2
1020.8
1020.4
1020.0
1019.6
1019.2
1018.8
1018.4
1018.0
1017.6
1017.2
1016.8
1016.4
1016.0
1015.6
1015.2
1014.8
1014.4
1014.0
1013.6
1013.2
1012.8
1012.4
1012.0
(hPa)

Daily Temperature Difference (oC, 20 May 2016)




Daily Pressure Difference (hPa, 20 May 2016)
Latitude (N)
37.9
37.8
37.7
37.6
37.5
37.4
37.3
37.2
37.1
126.4
126.5
126.6
126.7
126.8
126.9
127
127.1
127.2
127.3
127.4
127.5
127.6
Longitude (E)
3
3
4
4
5
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2


01 LST 18 May 2016 (Wind, m/s)
37.7
37.65
37.6
37.55
37.5
37.45
37.4
Latitude (N)
126.75
126.8
126.85
126.9
126.95
127
127.05
127.1
127.15
127.2
Longitude (E)
7.8
7.5
7.2
6.9
6.6
6.3
6
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
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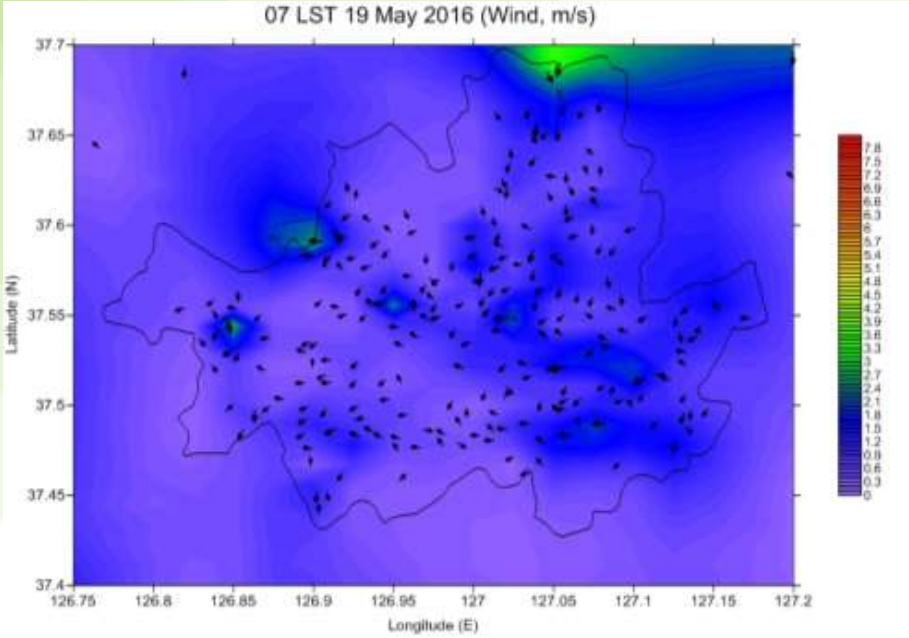
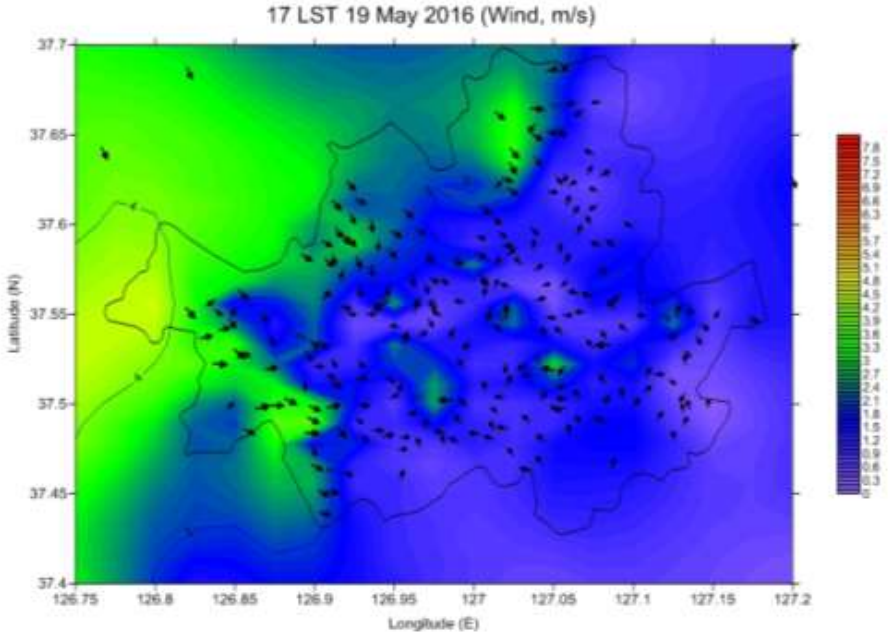
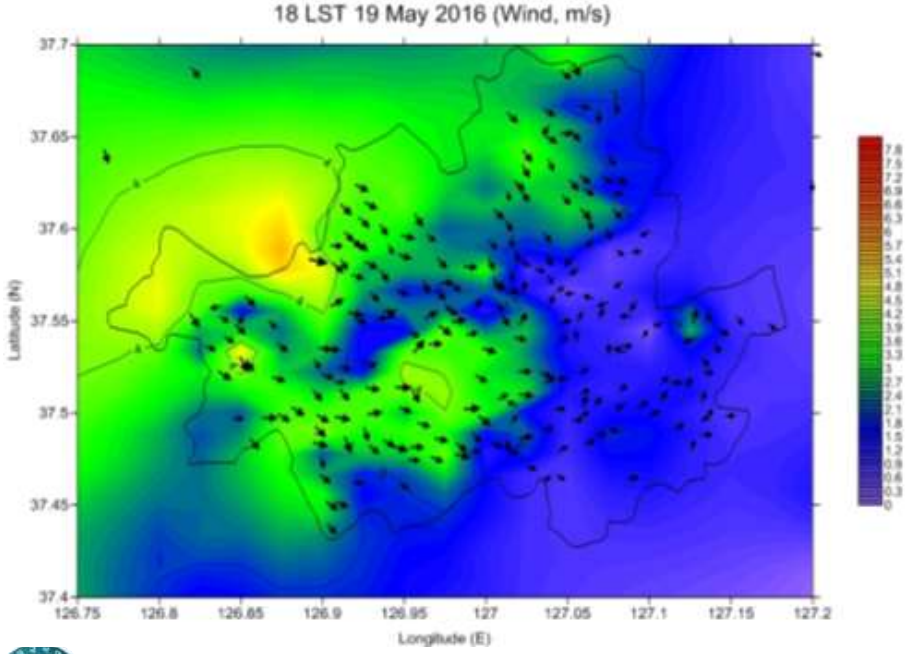
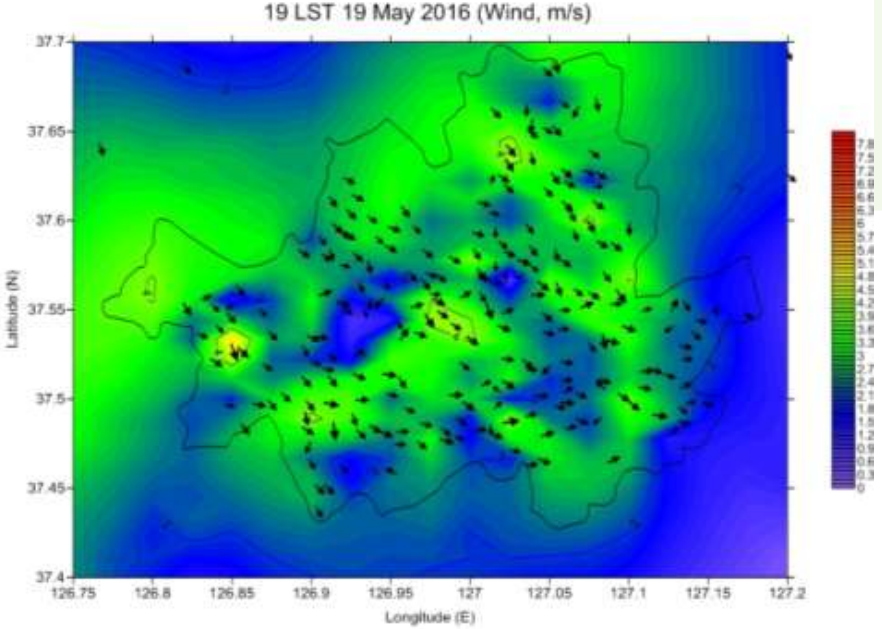
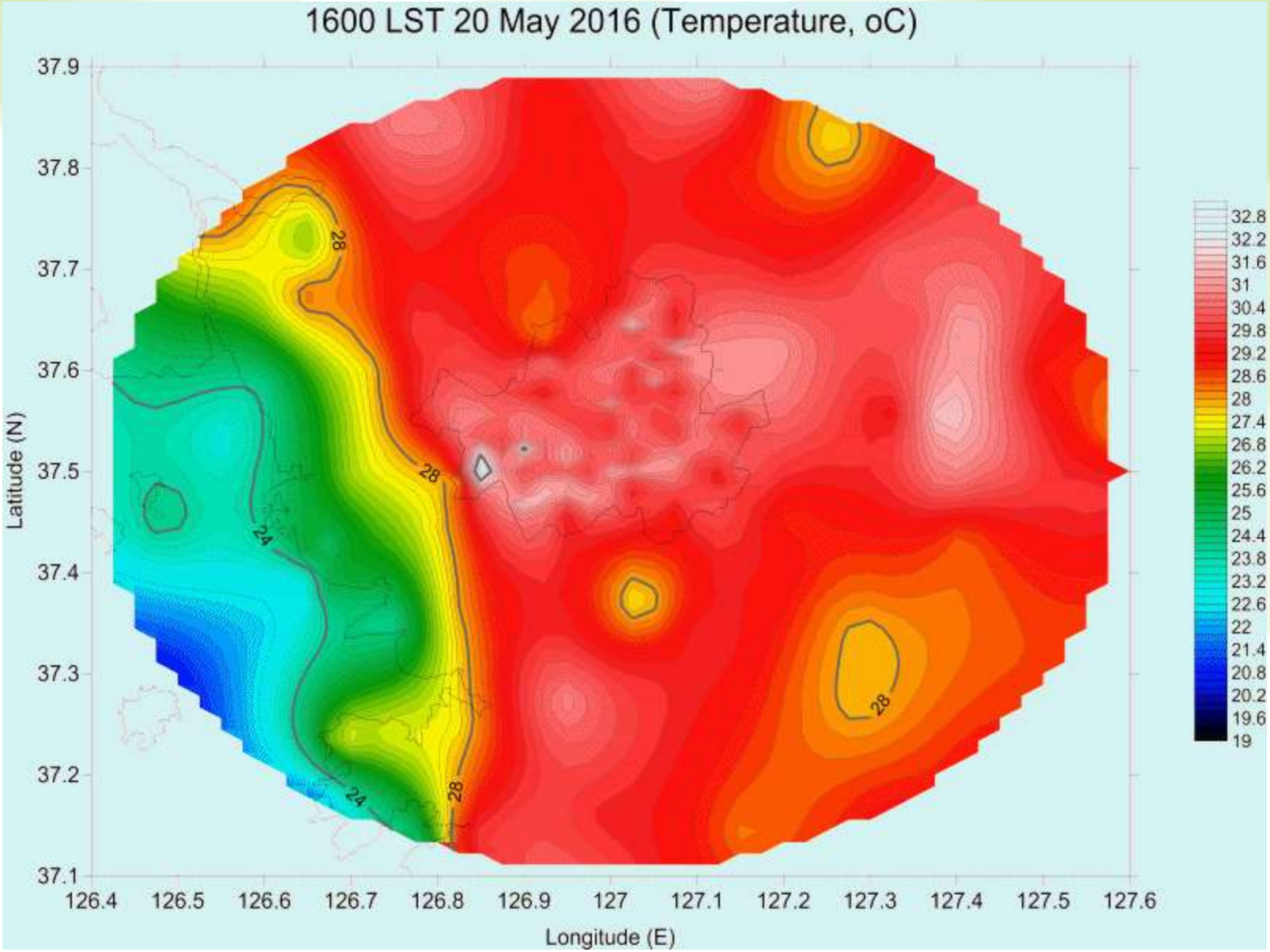
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
-0.2


07 LST 19 May 2016 (Wind, m/s)
Latitude (N)
Longitude (E)

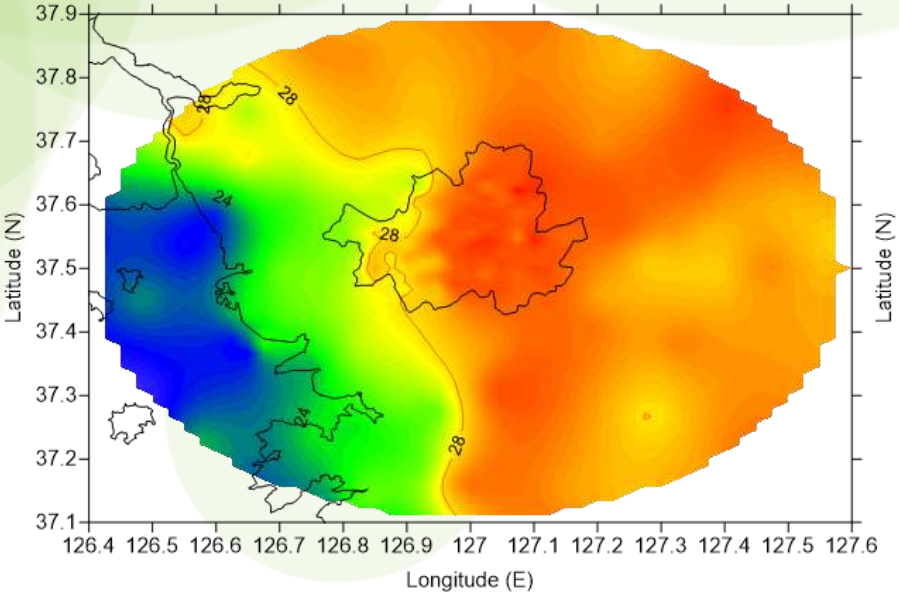

17 LST 19 May 2016 (Wind, m/s)
Latitude (N)
Longitude (E)


18 LST 19 May 2016 (Wind, m/s)
Latitude (N)
Longitude (E)

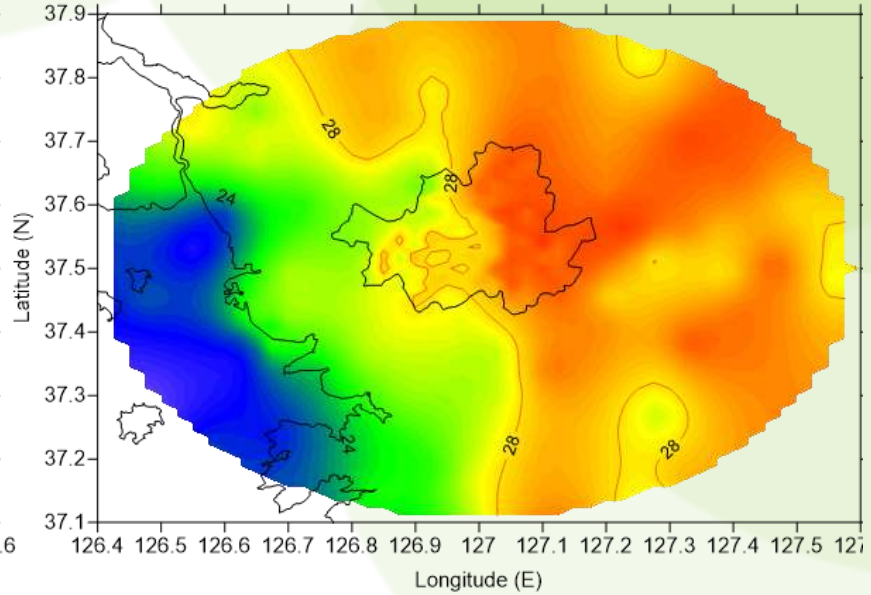

19 LST 19 May 2016 (Wind, m/s)
Latitude (N)
Longitude (E)


1600 LST 20 May 2016 (Temperature, oC)
Latitude (N)
Longitude (E)
37.9
37.8
37.7
37.6
37.5
37.4
37.3
37.2
37.1
126.4
126.5
126.6
126.7
126.8
126.9
127
127.1
127.2
127.3
127.4
127.5
127.6
28
24
32.8
32.2
31.6
31
30.4
29.8
29.2
28.6
28
27.4
26.8
26.2
25.6
25
24.4
23.8
23.2
22.6
22
21.4
20.8
20.2
19.6
19

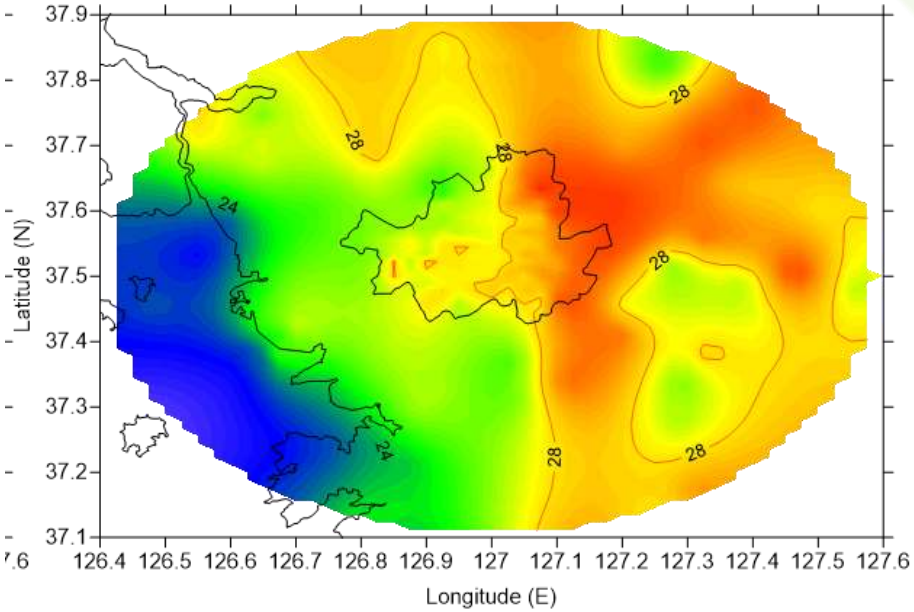
1730 LST 20 May 2016 (Temperature, oC)

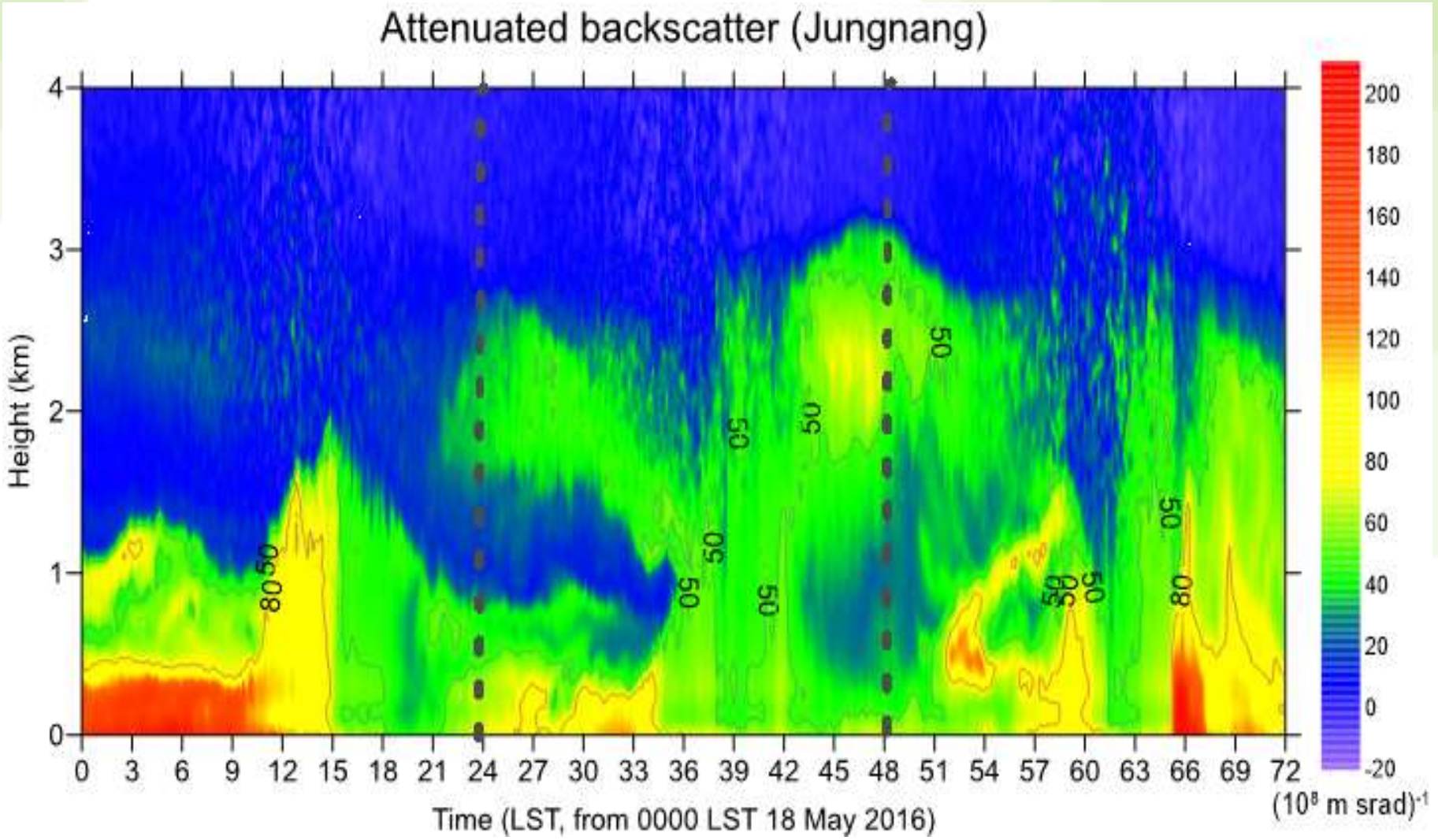


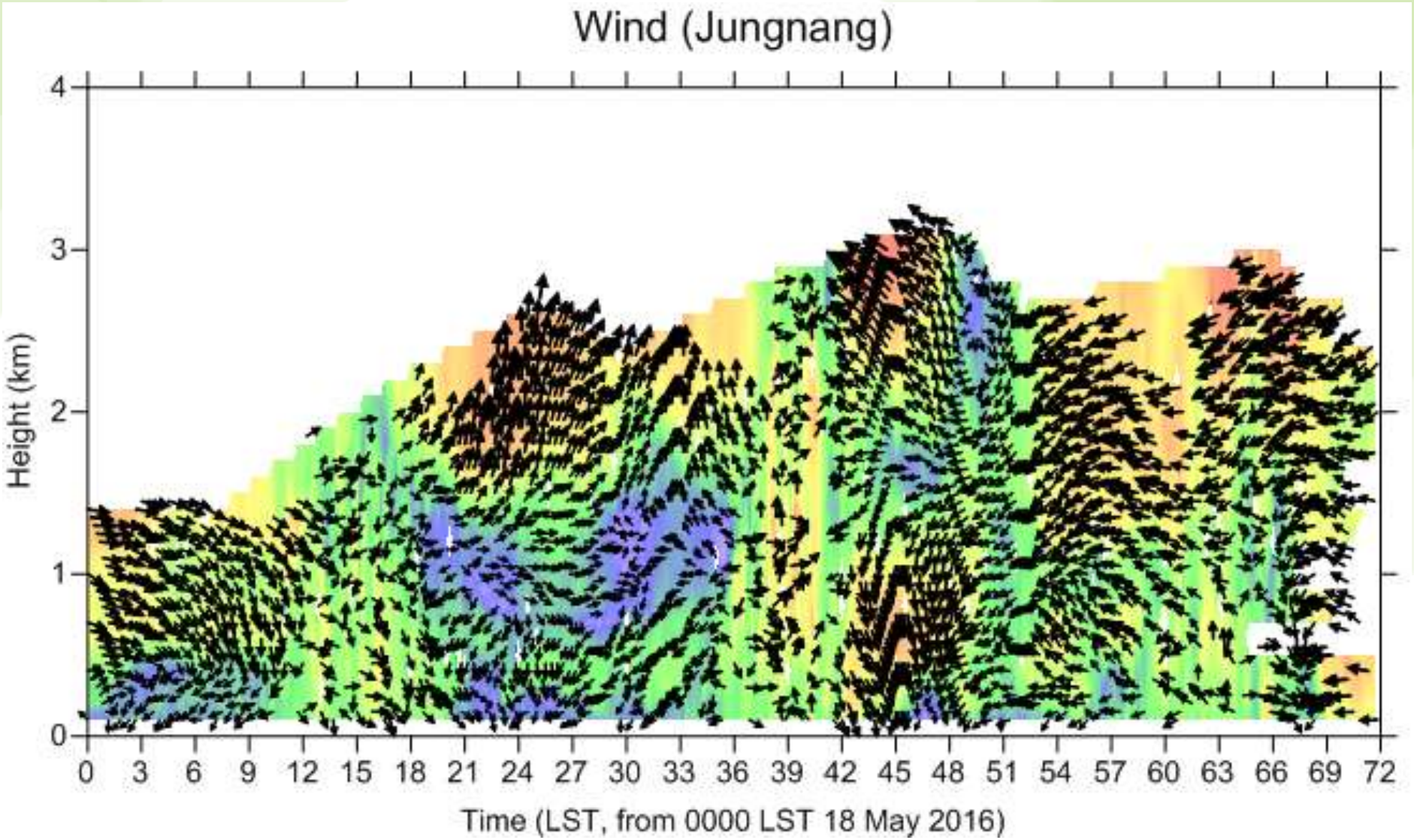
1800 LST 20 May 2016 (Temperature, oC)

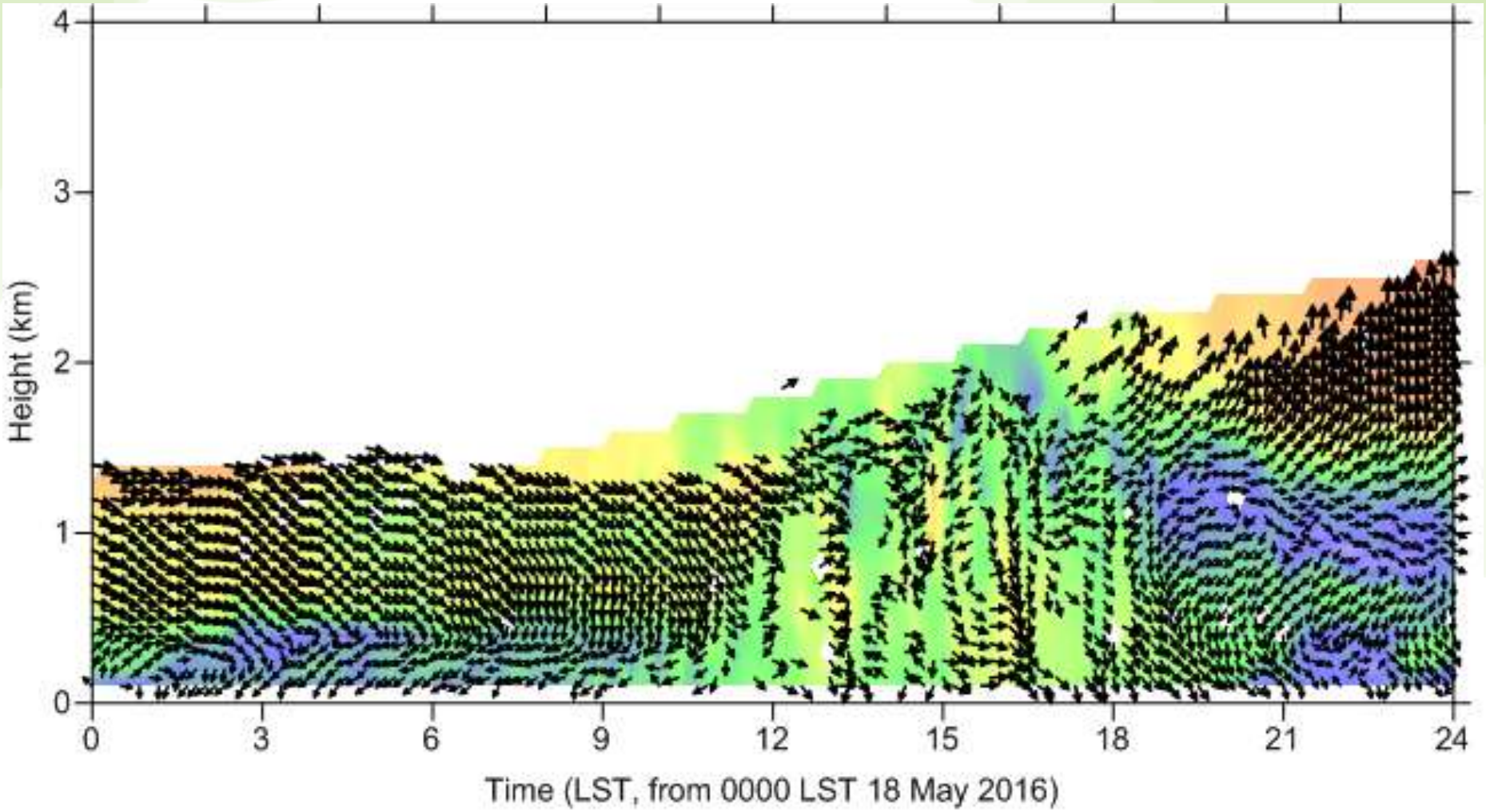


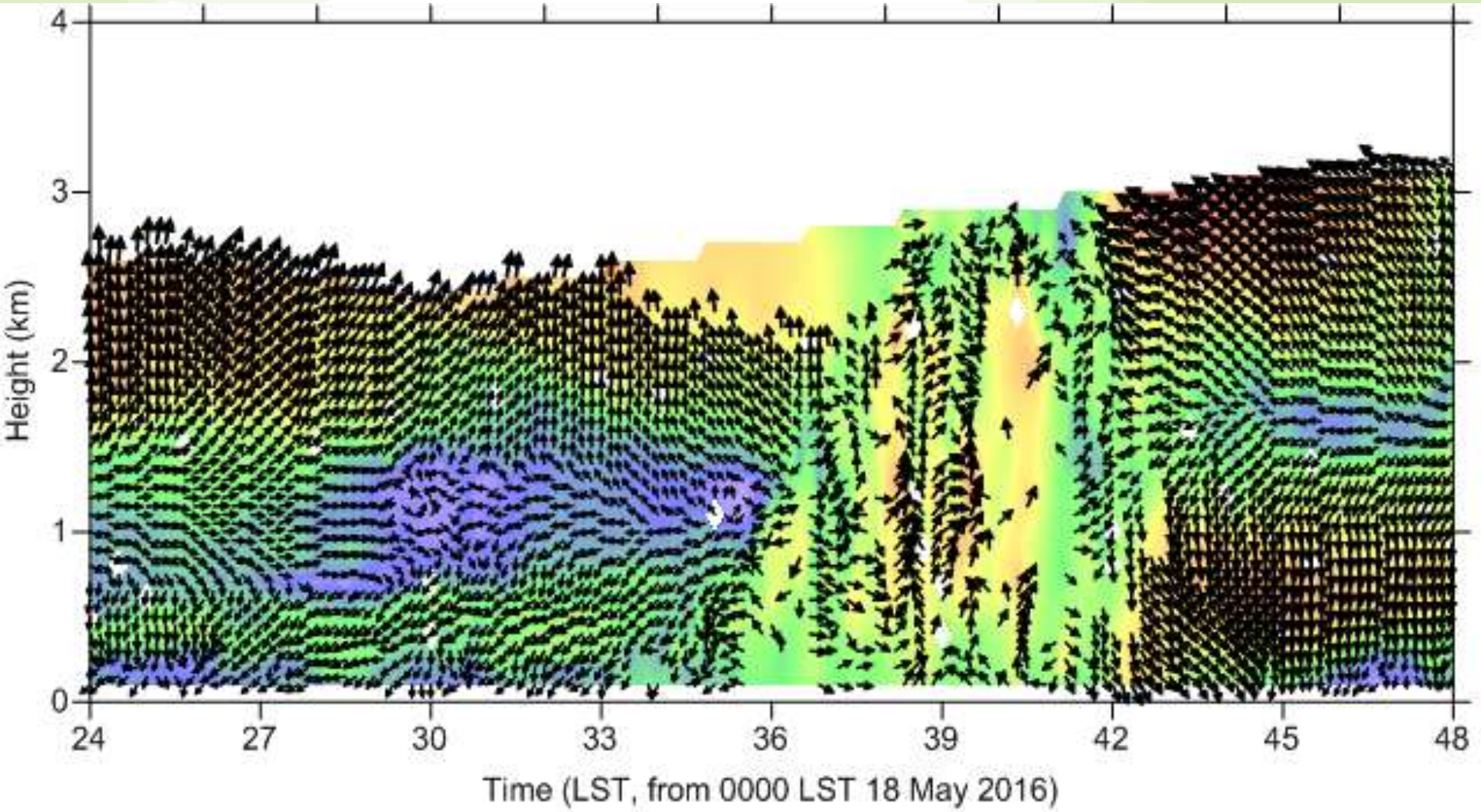
1830 LST 20 May 2016 (Temperature, oC)

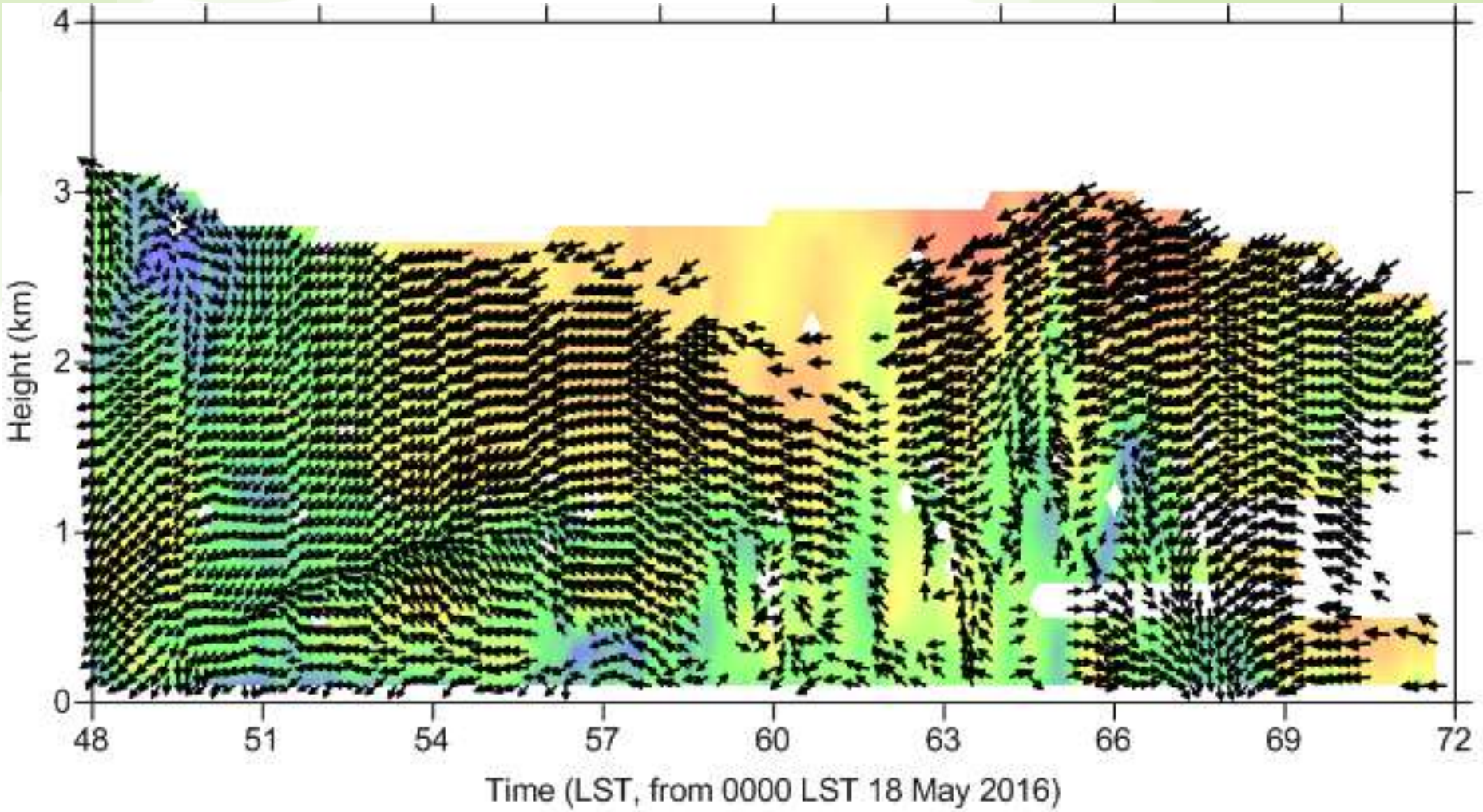


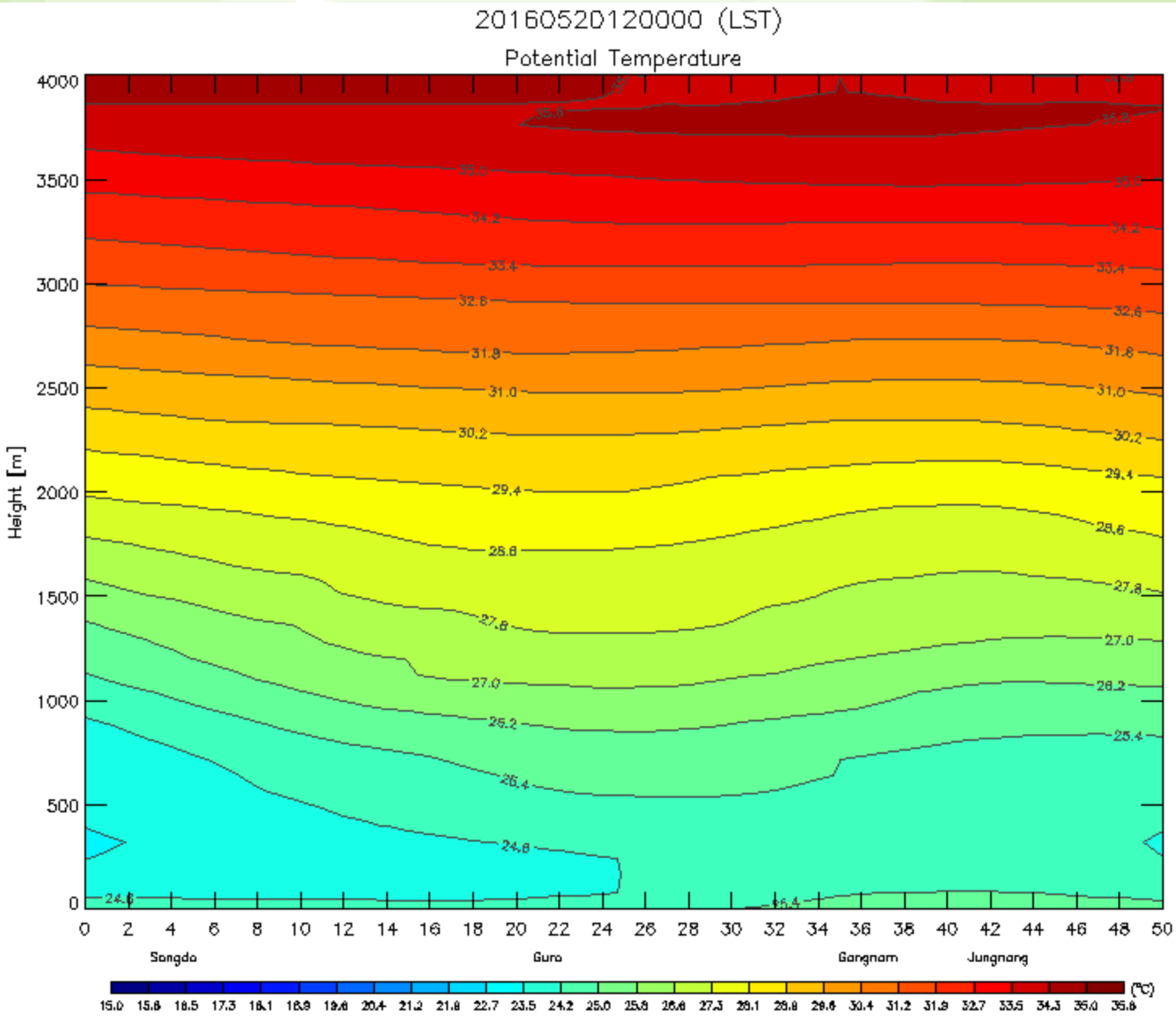

Attenuated backscatter (Jungnang)
Height (km)
0
1
2
3
4
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72
Time (LST, from 0000 LST 18 May 2016)
200
180
160
140
120
100
80
60
40
20
0
-20
(10⁸ m srad)⁻¹

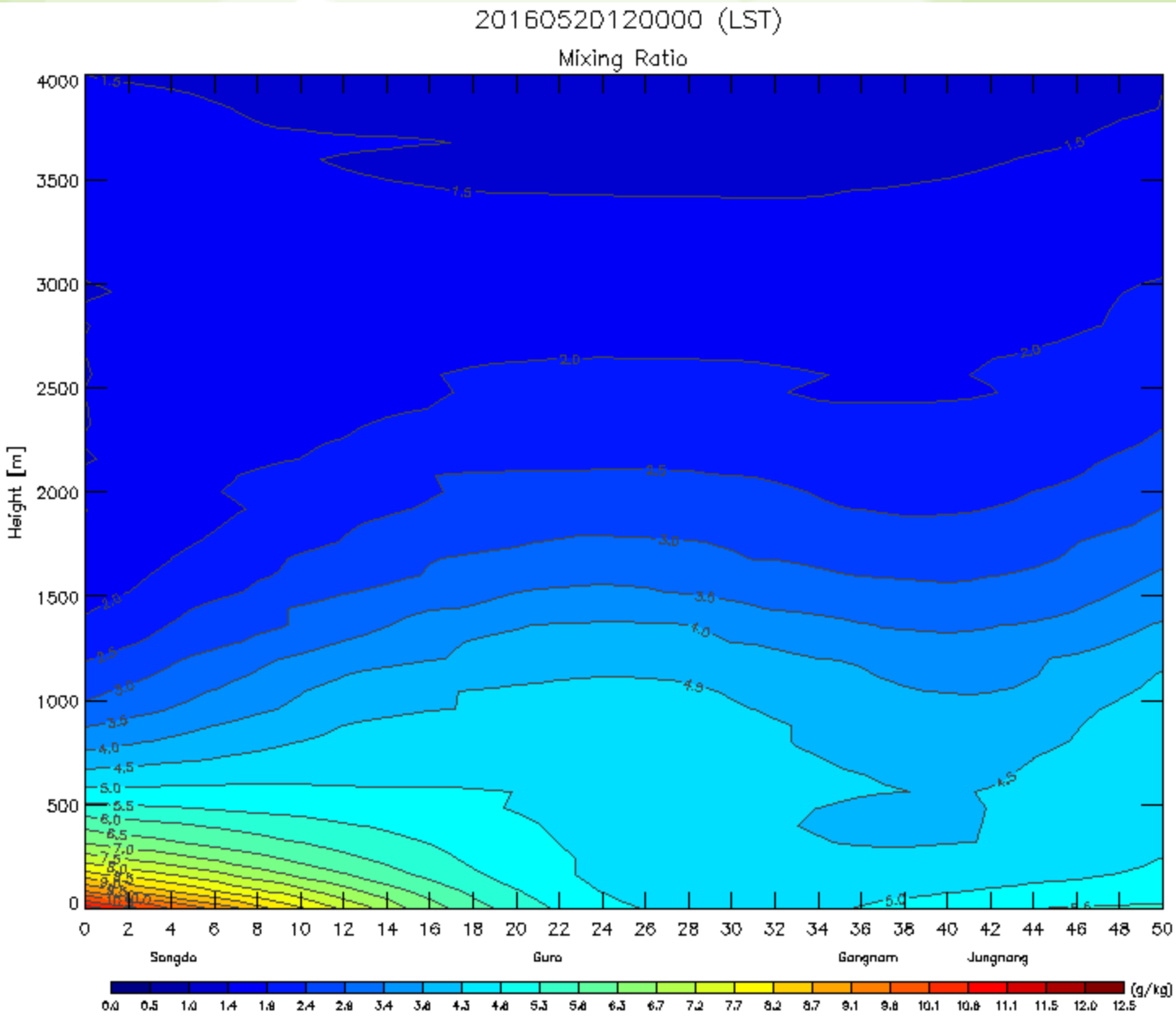

Wind (Jungnang)
Height (km)
0
1
2
3
4
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72
Time (LST, from 0000 LST 18 May 2016)

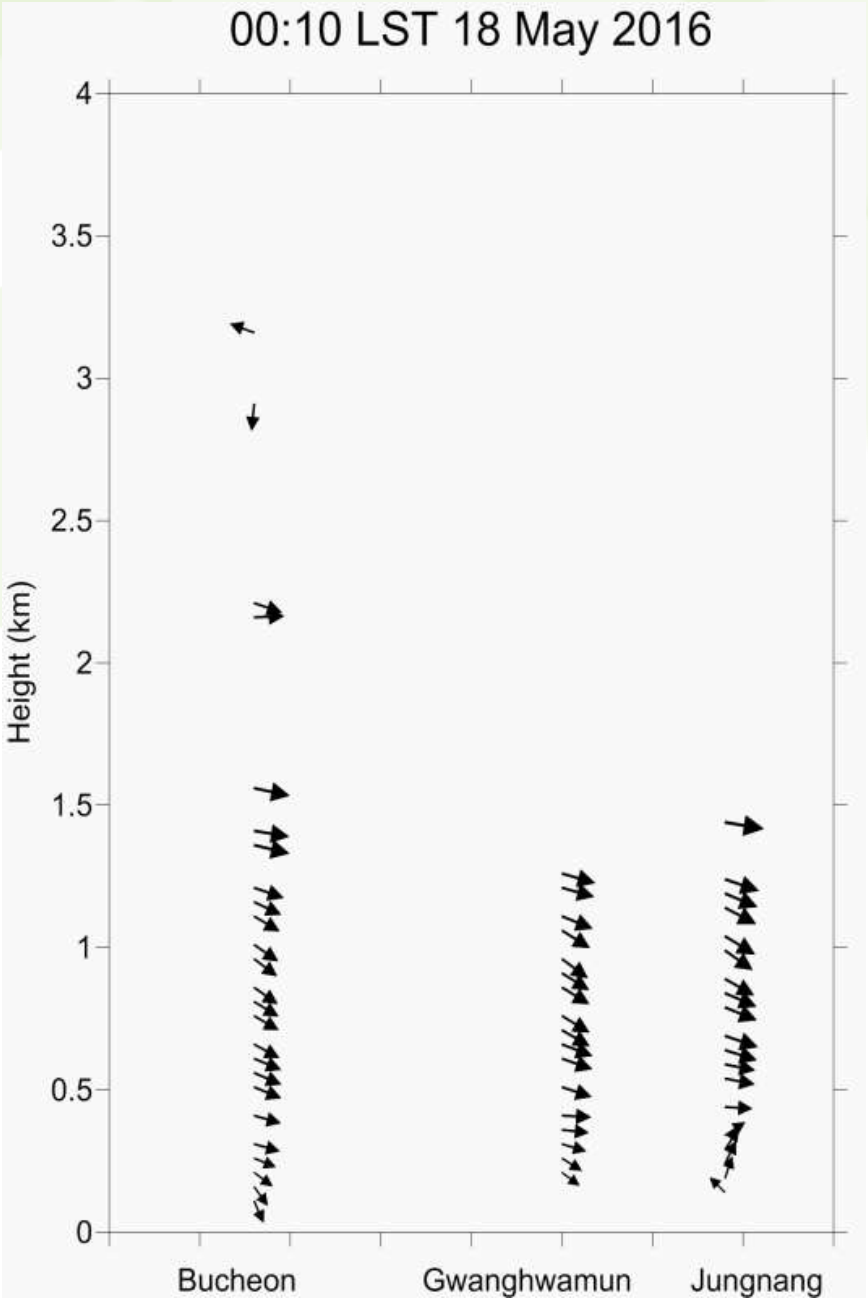

Height (km)
0
1
2
3
4
0
3
6
9
12
15
18
21
24
Time (LST, from 0000 LST 18 May 2016)

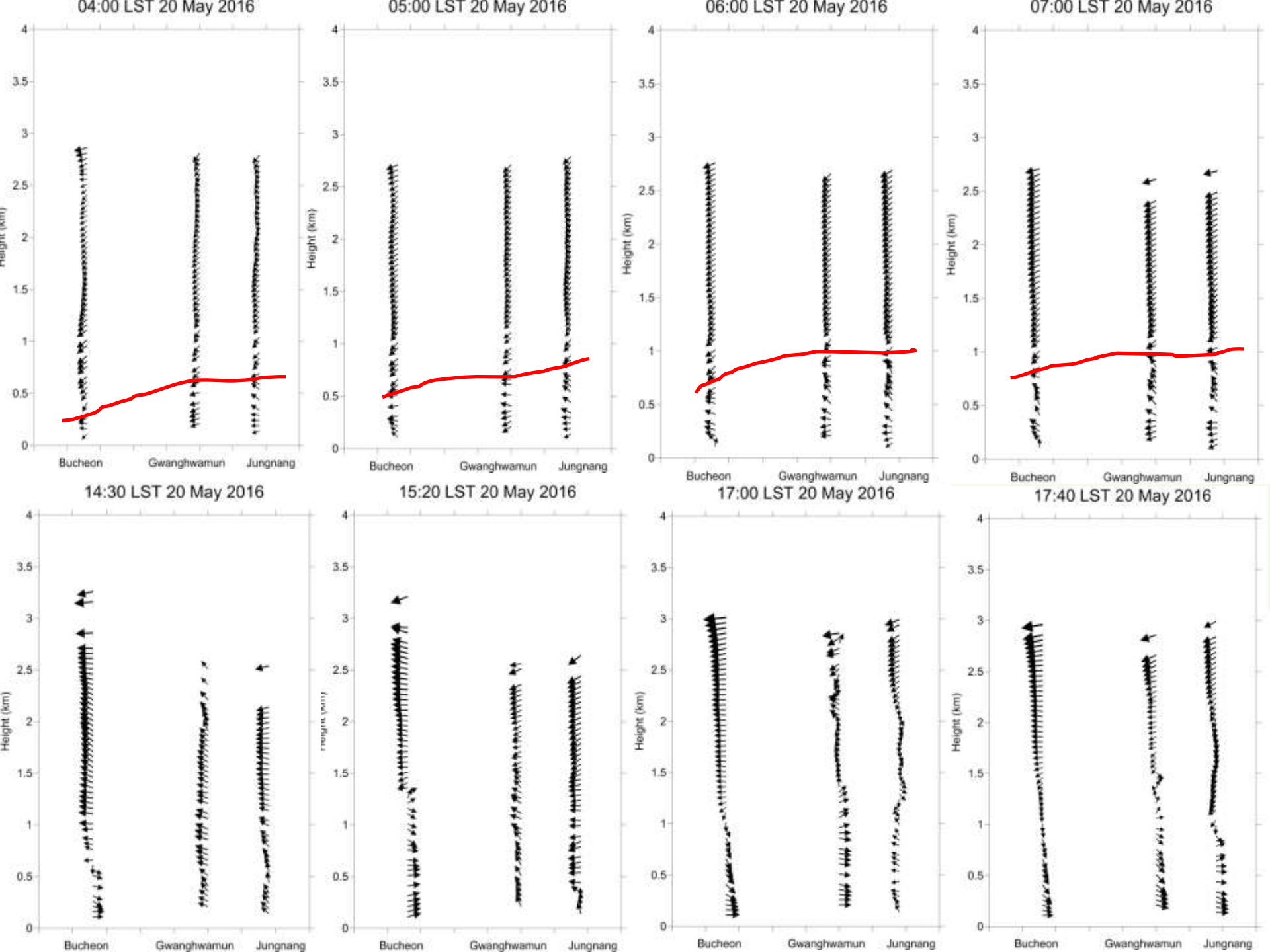

Height (km)
0
1
2
3
4
24
27
30
33
36
39
42
45
48
Time (LST, from 0000 LST 18 May 2016)

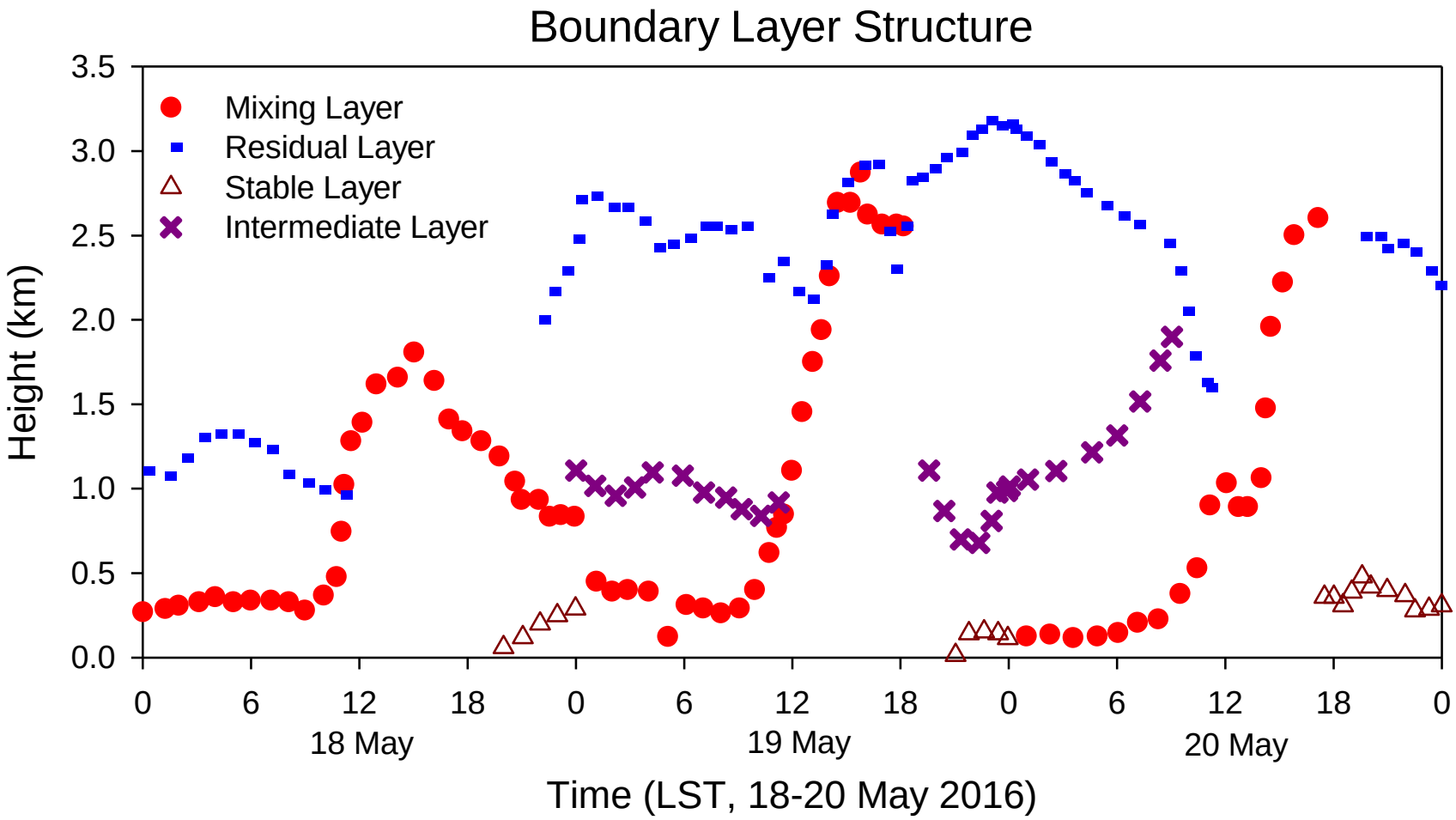

Height (km)
0
1
2
3
4
48
51
54
57
60
63
66
69
72
Time (LST, from 0000 LST 18 May 2016)


20160520120000 (LST)
Potential Temperature
Height [m]
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Songdo
Guro
Gangnam
Jungnang
35.8
35.0
34.2
33.4
32.6
31.8
31.0
30.2
29.4
28.6
27.8
27.0
26.2
25.4
24.6
(℃)
15.0 15.8 16.5 17.3 18.1 18.9 19.6 20.4 21.2 21.9 22.7 23.5 24.2 25.0 25.8 26.6 27.3 28.1 28.9 29.6 30.4 31.2 31.9 32.7 33.5 34.3 35.0 35.8


20160520120000 (LST)
Mixing Ratio
Height [m]
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Songdo
Guro
Gangnam
Jungnang
(g/kg)
0.0 0.5 1.0 1.4 1.8 2.4 2.8 3.4 3.8 4.3 4.8 5.3 5.8 6.3 6.7 7.2 7.7 8.2 8.7 9.1 9.8 10.1 10.8 11.1 11.5 12.0 12.5


00:10 LST 18 May 2016
Height (km)
4
3.5
3
2.5
2
1.5
1
0.5
0
Bucheon
Gwanghwamun
Jungnang


04:00 LST 20 May 2016
05:00 LST 20 May 2016
06:00 LST 20 May 2016
07:00 LST 20 May 2016
14:30 LST 20 May 2016
15:20 LST 20 May 2016
17:00 LST 20 May 2016
17:40 LST 20 May 2016
Height (km)
0
0.5
1
1.5
2
2.5
3
3.5
4
Bucheon
Gwanghwamun
Jungnang


Boundary Layer Structure
Mixing Layer
Residual Layer
Stable Layer
Intermediate Layer
Height (km)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
6
12
18
0
6
12
18
0
6
12
18
0
18 May
19 May
20 May
Time (LST, 18-20 May 2016)

Summary

- The UMS-Seoul (high-resolution Urban Meteorological observation system networks in the Seoul Metropolitan Area) is one of the most intensively integrated and well-organized urban meteorological observation networks to deliver high-quality meteorological information customized for users' demands for the purpose of urban resilience and sustainability in the Seoul Metropolitan Area.
- The UMS-Seoul incorporates 14 surface energy balance (EB) systems, 7 surface-based three-dimensional (3-D) meteorological observation systems, applied meteorological observation systems, and the existing surface-based meteorological observation network.
- The SMA is strongly affected by the local circulation such as land-sea breeze, urban-rural breeze. That is, the westerly winds (sea breeze) are dominant from afternoon to early evening, while easterlies (land breeze) are dominant before morning time. The higher temperature in urban areas is a strong evidence on the urban heat island, while the lower pressure in urban areas can be a convective storm track path.
- Atmospheric boundary layer structure are very complex. The mixing-layer heights show a diurnal variation with a maximum in late afternoon and a residual layer is often located over the top of mixing-layer in the evening.
- The UMS-Seoul is expected to give a key not only to produce many useful meteorological-related information in urban areas practically for reducing the damage from various disastrous weather phenomena, but also to solve the meso-γ to micro-β scale meteorological phenomena (*terra-incognita* or gray zone problem) scientifically in highly populated urban areas.

Thank You for listening!

For further inquiries on observed data,
please contact me (ngeograph2@gmail.com, moonsoo@hufs.ac.kr).