

Determination of mixing-layer, stable-layer, and residual-layer heights with the use of radiosonde observations

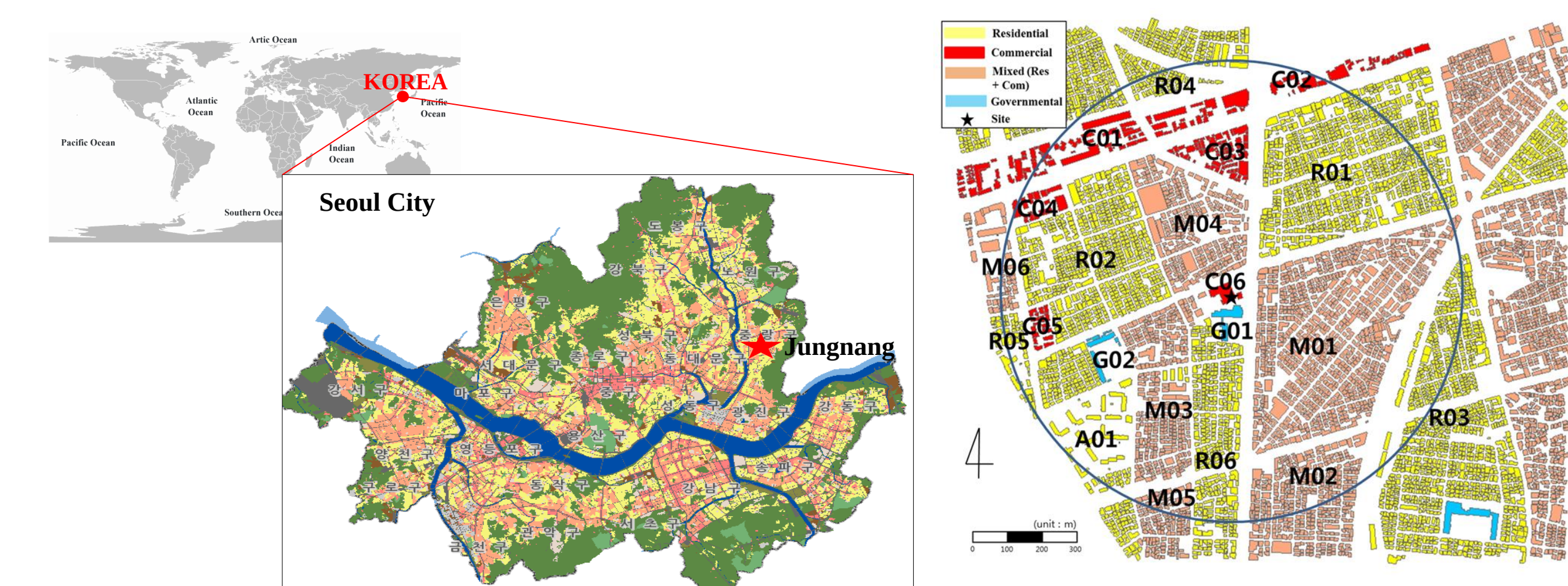
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Introduction

- ◆ The planetary boundary layer (PBL) height is a key parameter in air pollution models determining the volume available for pollutants to dispersion and the structure of turbulence in the boundary layer.
- ◆ The PBL is classified into the convective boundary layer composed of the surface layer, the mixed layer, and the capping inversion at daytime, and the stable boundary layer and the residual layer at nighttime.
- ◆ The traditional method for determining PBL height are utilisation of radiosoundings. since this method have advantages and disadvantages depending on the state of atmosphere, we compared each method to find the optimal method according to each atmospheric condition.

Site and Data

- ◆ At the Jungnang site, which is located on the roof of a 22 m tall building in an urban residential area in the eastern part of Seoul, 157 times radiosonde observations were conducted through several observation campaigns from 2014 to 2016.
- ◆ This site has various observation equipments for studying urban meteorology such as microwave radiometer, wind lidar, aerosol lidar, ceilometer, and 18.5 m high flux tower.



Surface Code	Cover area(%)	Z _H (m)	λ _p	λ _f	Z _d (m)	Z ₀ (m)
Residential	48	9.8	0.48	0.47	7.28	0.55
Mixed	37	10.0	0.49	0.45	7.53	0.52
Commercial	8	12.8	0.50	0.39	9.48	0.56
Government	1	15.1	0.31	0.18	8.72	1.06
Apartment	6	40.5	0.33	0.60	23.94	5.85



Methods

PBL height estimation

- ◆ Using six methods for PBL height estimation (Holzworth, 1964; Seidel, 2010; Zhang, 2014)
 1. The base of an capping inversion
 2. The top of a surface-based temperature inversion
 3. The parcel method
 4. The level of the maximum vertical gradient of potential temperature
 5. The level of the minimum vertical gradient of mixing ratio
 6. The bulk Richardson number (R_i) method

$$R_i = \frac{\left(\frac{g}{\theta_v}\right)(\theta_{vz} - \theta_{v0})z}{u_z^2 + v_z^2}$$

Statistical analysis

- ◆ Case classification (Eresmaa, 2006; Seidel, 2010)
 1. We divided case into day time(11~14 LST), night time(20~05 LST), and the other times to compare PBL heights according to time.
 2. We divided case into stable and unstable conditions to compare PBL heights according to atmospheric stability.
 - stable : lapse rate of θ_v and value of R_i are positive at an altitude of less than 200m
 - Unstable : lapse rate of θ_v and value of R_i are negative at an altitude of less than 200m
- ◆ We classified the data according to the case classification conditions and compared the PBL heights calculated by the above six methods for each case.

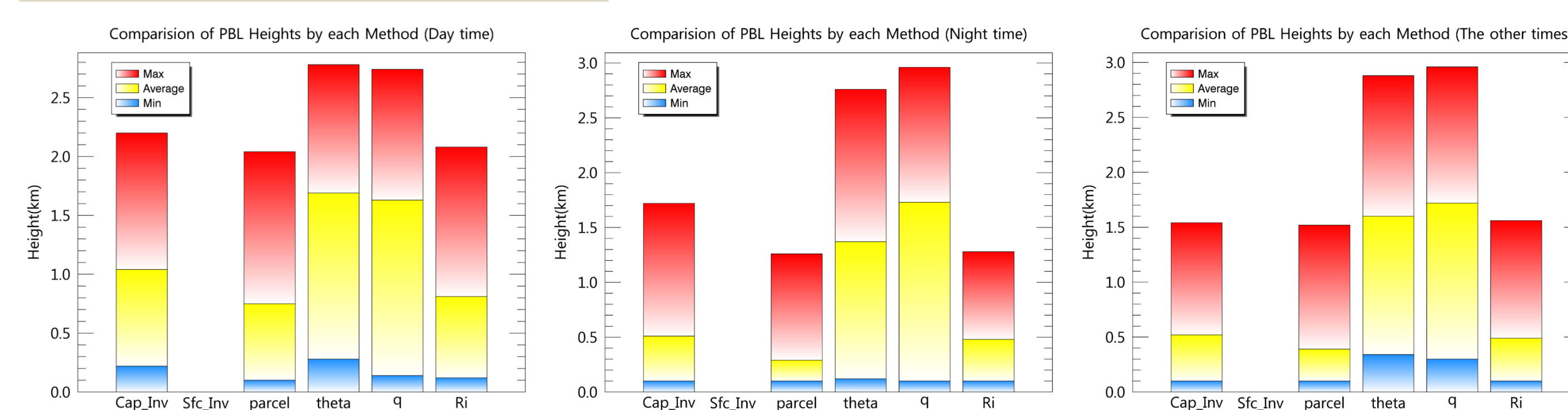
Results

Case classification

- ◆ The frequency of stable and unstable conditions is shown 5:5 for day time, 9:1 for night time, and 6:4 for the other times.

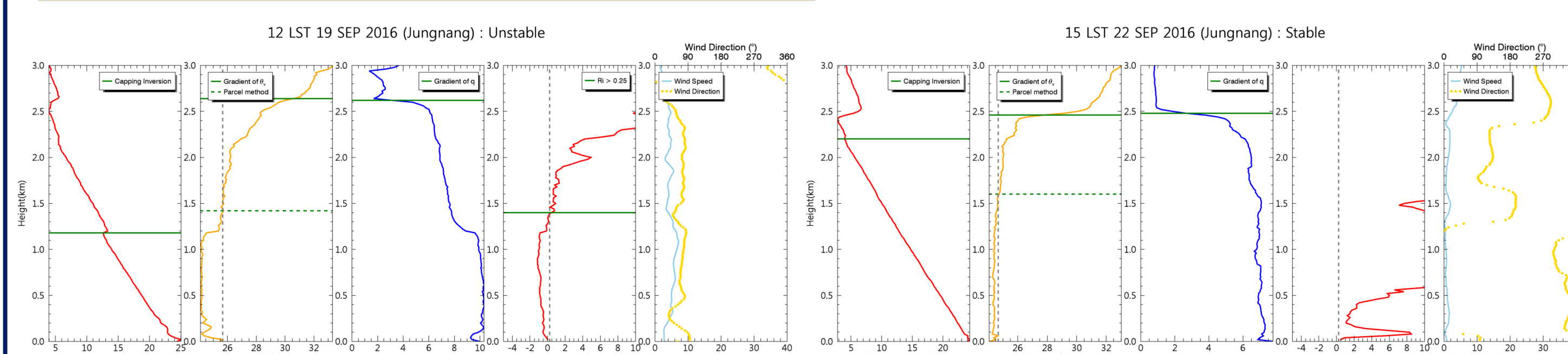
Stability \ Time	Day time	Night time	The Other times	All time
Stable condition	21	59	30	110
Unstable condition	19	7	21	47
All condition	40	66	51	157

Average of PBL heights

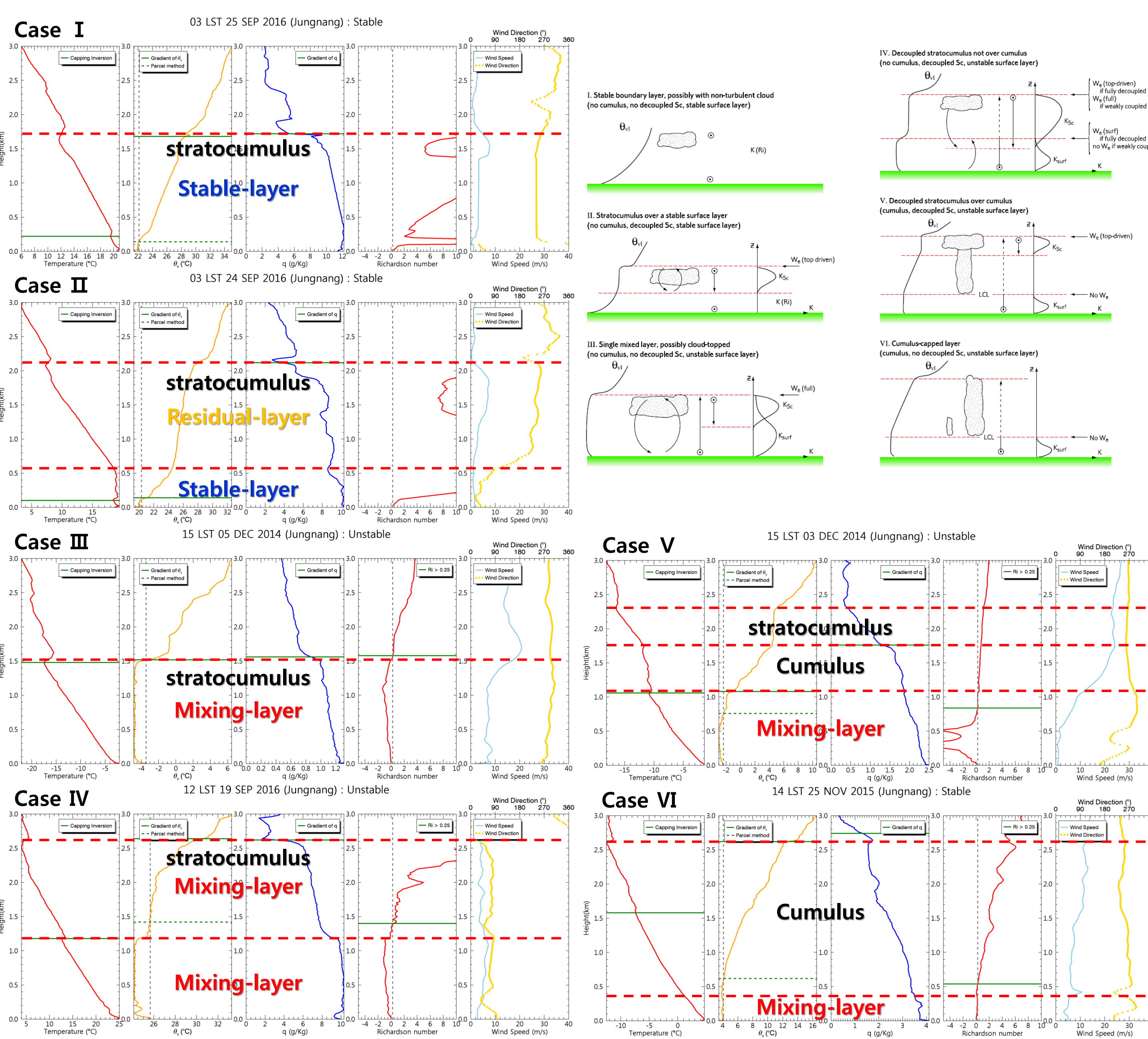


- ◆ No surface-based temperature inversion was observed due to the location and observation environment of the observatory.
- ◆ The PBL height calculated by most of methods at day time is higher than the result at night time, but the gradient method using the mixing ratio shows the opposite result.
- ◆ The PBL height calculated by the gradient method using the temperature and mixing ratio is higher than the result by the capping inversion, parcel and R_i method. Here we can see that the PBL height can be divided by the effect of clouds in addition to the effects of surface radiation and wind shear.

Determination of PBL height



- ◆ PBL height can not be calculated by the R_i method on the day when wind speed is weak.
- ◆ Since PBL height is calculated differently depending on the characteristics of each method, it is often difficult to determine the PBL height as one.
- ◆ Lock et al. (2000) showed Schematic representation of the six boundary layer types.
- ◆ According to this graphical representation, the different PBL heights calculated through each method can be described as follows.



Discussion

- ◆ The PBL height calculated using radiosonde is different depending on the characteristics of each method.
- ◆ In this study, we compared the calculation methods and decided the PBL to be several layers instead of one layer considering the effect of clouds.