SOUNDING DERIVED PARAMETERS ASSOCIATED WITH THUNDERSTORM

P12.14

DURING SUMMER PERIOD OVER SOUTH KOREA

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1. INTRODUCTION

Thunderstorms accompanied by cloud-to-ground lightning and heavy rainfalls during the summer period can be significant threat to the human life. In order to analyze and predict severe storms with large hails or strong gusts, there have been a lot of researches by using proximity soundings (Brooks *et al*. 1994; Craven and Brooks 2004; Doswell and Evans 2003; Groenemeijer and Delden 2007; Rasmussen and Blanchard 1998). These studies usually covered the tornado events or thunderstorm over the Europe and US.

The purpose of this study is to analyze the precipitation and lightning occurrence, to diagnose the possibility for the thunderstorm detection by using proximity soundings, and to adjust the threshold values or develop new indices appropriate for South Korea. We included the 5-year data (2002-2006) and the threshold values will be evaluated by using the recent data (2007).

2. DATA AND METHOD

a. LIGHTNING DATA

Lightning data (2002-2006) from Korean Meteorological Administration (KMA) are used. The location of lightning sensors and rawinsonde stations, currently operated in the South Korea are plotted in Fig. 1. In order to remove the lightning with incorrect locations, we only included the lightning observed from more than three sensors. Time-of-arrival (TOA) sensors do not discriminate multiple return strokes in a lightning, so multiple strokes occurred in 10km distance within 500 milliseconds are treated as a single lightning.

b. SOUNDING DATA

All of the sounding data are obtained from the department of atmospheric science at Wyoming University in the US (available online at http://weather.uwyo.edu/upperair/sounding. html). Although seven observatories make routine observations, four of them are used (Table 1) due to relative short history of observation and the quality of the data. Simple quality controls are applied. To exclude extreme soundings, the data greater that mean + 3sigma (or 99th percentile) or less than mean - 3sigma (or 1th percentile) were removed based on 10-year (1997-2006) climatology.

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Table 1. List of rawinsonde stations used in this study.

Stn.	Lat. N	Lon. E	Elv. (m)	Frq. of obs
Osan	37.10°	127.03°	52	4
Pohang	36.03°	129.38°	4	2
Gwangju	35.11°	126.81°	13	4
Jeju	33.28°	126.16°	73	2
Baeng.	37.96°	124.61°	162	2

Stn. = Station　Frq. = Frequency
Elv. = Elevation　Baeng. = Baengnyeongdo

c. PROXIMITY CRITERIA

Four times-daily (Osan and Gwangju) and twice-daily soundings are used. Proximity is defined as being within 100 km of the sounding release location and during the period (-2 hrs to + 1 hr from the release time). Table 2 shows the criteria used in this study. We examined the thunderstorm classified by its mean

Intensity in four regions. The first category (NO) is strictly defined as none of lightning with no precipitation and no convective potential available energy (CAPE). And the second categories are defined by using lightning cases.

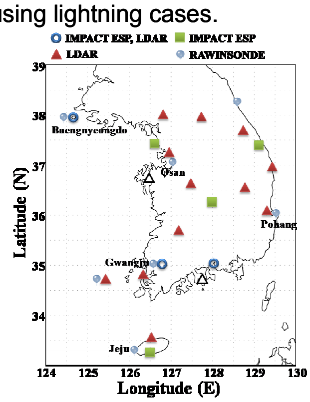

Fig. 1. Distributions of lightning detecting sensors and rawinsonde stations over South Korea.

Table 2. Definitions and number of proximity soundings for the two categories in five regions.

Category	CAPE	Precipitation	Lightning
NO	X	X	X
LGT	O	△	O

NO = No lightning case
LGT = Lightning case
O: Mandatory, △: Optional, X: None

d. PARAMETERS

A list of the parameters considered in this study is shown in Table 3. These parameters cover the instability (SSI, LI, and KI), the temperature of LCL, and water vapor contents in the air (mixing ratio and precipitable water). CAPE and convective inhibitions (CIN) are not included because CAPE and CIN during summer period over South Korea have relatively small values (Eom *et al.* 2008).

Table 3. List of parameters used in this study.

No.	Abbreviation	Description	Unit
1	CAPE	Convective available potential energy	J kg^{-1}
2	SSI	Showalter stability index	K
3	LI	Lifted index	K
4	KI	K index	
5	LCLT	Temperature of lifting condensation level	℃
6	MLMR	Mixed layer ratio in the lowest 500 m (AGL)	g kg^{-1}
7	TPW	Total precipatable water	mm
8	0-1 km shear	Wind shear between 0 and 1 kme	m s^{-1}
9	0-6 km Shear	Wind shear between 0 and 1 kme	m s^{-1}

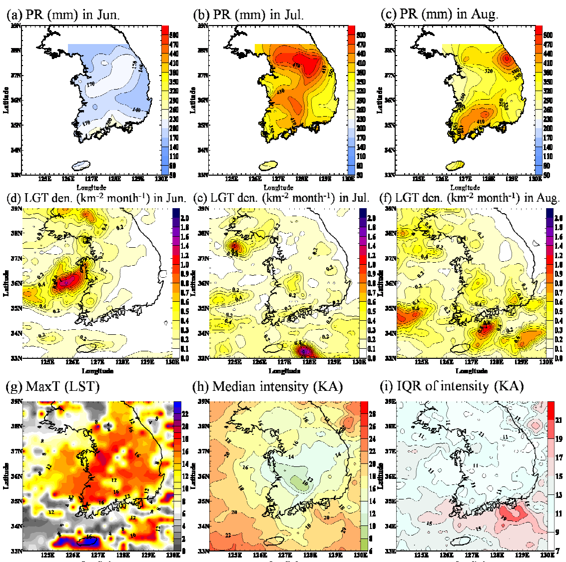

Fig. 2. Distributions of monthly (a) - (c) precipitation (mm $month^{-1}$), (d) - (f) total lightning density (km^{-2} $month^{-1}$), and three lightning characteristics ((g) the time of most frequent lightning occurrence, (h) median intensity, and (i) variability of intensity using IQR).

3. RESULTS

As shown in Fig 2, South Korea experiences a large amount of precipitation during summer period due to Asian monsoon. And it is seemed that a large amount of precipitation is not always accompanied by frequent lightning events.

The western and southern parts including the adjacent Sea are characterized by high density of lightning while eastern portions show low density. Depending on the regions, the time of most frequent lightning occurrence differs. Over land and near western coastal areas, mid-afternoon around 15 LST (but, early morning in mountainous area and northern portion) is the peak time of lightning while other areas under the impact of the ocean show early morning peak. The intensity of lightning and its variability vary region to region. Southwestern part of South Korea is characterized by relatively high density of lightning, and low intensity and its variability. More intensity variability expressed in IQR is found in the Sea.

Fig. 3 shows that lightning occurs under warmer and moister conditions than usual ones while negative anomalies of temperature and mixing ratio in case of no lightning are found. The amplitudes of temperature and mixing ratio vary according to the local time (largest at 00 UTC (09 LST)). Therefore, warmer and moister conditions in the low level (usually below 850 hPa) contribute to more favorable for lightning occurrence.

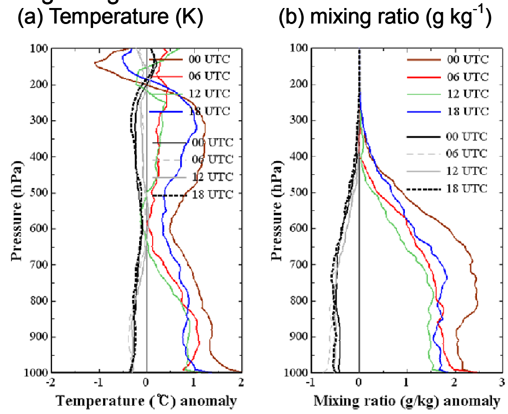

Fig. 3. Vertical anomaly profiles of (a) temperature (K) and (b) mixing ratio (g kg^{-1}) of no lightning cases (gray and black lines) and lightning cases (color lines) in Osan during JJAS for the years 2002-2006.

We analyzed the statistical distributions of each parameter for two categories using box and whisker plots (Fig. 4). Most striking result is considerable discrimination (box range, no overlap in the middle 50 percent) between NO and LGT categories except wind shears. In particular, LI, LCLT, and MLMR discriminate well.

Although the method of SSI is similar to that of LI, LI shows better separation between NO and LGT. The selecting MLMR rather than TPW could be a finer choice due to not only low-level moisture that plays an important role in developing convection but also its separated distribution. Higher temperature of LCL in case of lightning occurrence implies lower LCL, so it is closely related to moister condition in the low-level.

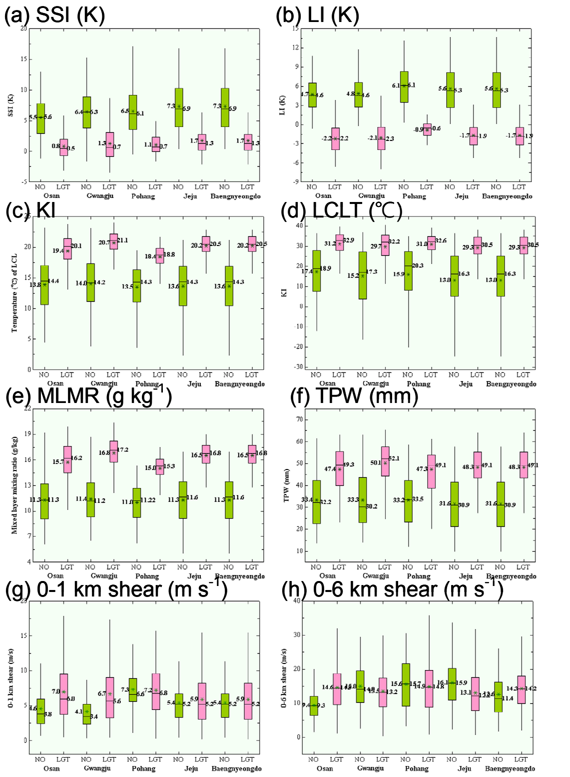

Fig. 4. Box and whisker plots of (a) SSI, (b) LI, (c) KI, (d) LCLT, (e) MLMR, (f) TPW, (g) 0-1 km shear, and (h) 0-6 km shear for no lightning cases and lightning cases in the vicinity of five regions. The mean and median values for each box are plotted in the left and right of the boxes, respectively.

The product of MLCAPE and 0-6 km shear (Davies and Johns 1993) and 0-1 km shear could be used to discriminate severe storm (Craven *et al*. 2002) in the US. However, two kinds of wind shears show disappointing separation over South Korea and the product cannot be useful parameters because South Korea has an environment with low values of CAPE during warm season (Eom et. al. 2008).

Fig. 5 shows the validation results of single parameters (e.g. SSI and MLMR). BIAS, ACC, POD, and FAR vary according to the threshold values. However, CSI and skill score (HSS) ranges 0 to 0.25. This figure shows forecasting lightning by using single parameter has limitations.

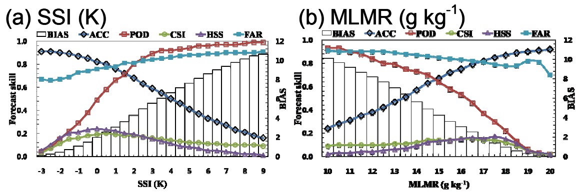

Fig. 5. Validation results of (a) SSI and (b) MLMR according to simulated threshold values

To improve the forecast skill, we tried the combined use of two parameters. In other words, lightning is forecasted (or expected) if all of the two parameters satisfy their own threshold to forecast lightning. Fig. 6 is the validation results of KI and LI. CSI and HSS more than 0.3 are found in LI range of 1~3 without regards to KI values. In fig. 7, CSI and HSS are dependent on LI and MLMR values. If the values of SSI decrease more, lightning could be occurred in the more dry conditions.

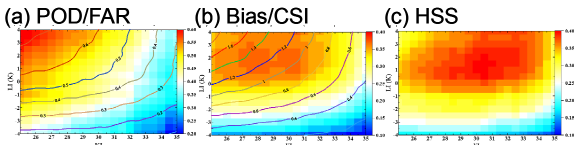

Fig. 6. Validation results of combined use of KI and LI. FAR, CSI, and HSS are shaded.

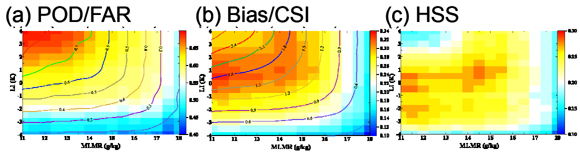

Fig. 7. Same as in Fig. 6, except for MLMR and LI.

4. SUMMARY

This study inspected lightning events during warm season over South Korea and environmental characteristics of lightning, and we evaluated them using scalar attributed method. These are summarized into;

1) Areas with much rainfall during warm season are not always accompanied by frequent lightning events over South Korea. The western and southern parts have high density of lightning.

2) Lightning is more favorable to occur when warmer and moister conditions in the low-to-mid level. And the amplitude of increase varies time to time.

3) Thermodynamic parameters shows considerable discriminations between NO and LGT categories, but kinematic ones such as wind shear exhibit lot of overlaps.

4) The forecast skill using Bias, POD, FAR, CSI, and HSS are examined. Single parameter has limitations to improve forecast skill, so combined use of parameters was tried. This approach produces better forecast skills such as CSI and HSS. And more works to combine other parameters should be made.

ACKNOWLEDGEMENTS

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