

# Analysis and Numerical Simulation using ASAPS of the Localized Heavy Precipitation Event in South Korea on 16 August 2015

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# Background

## Precipitation change in recent years

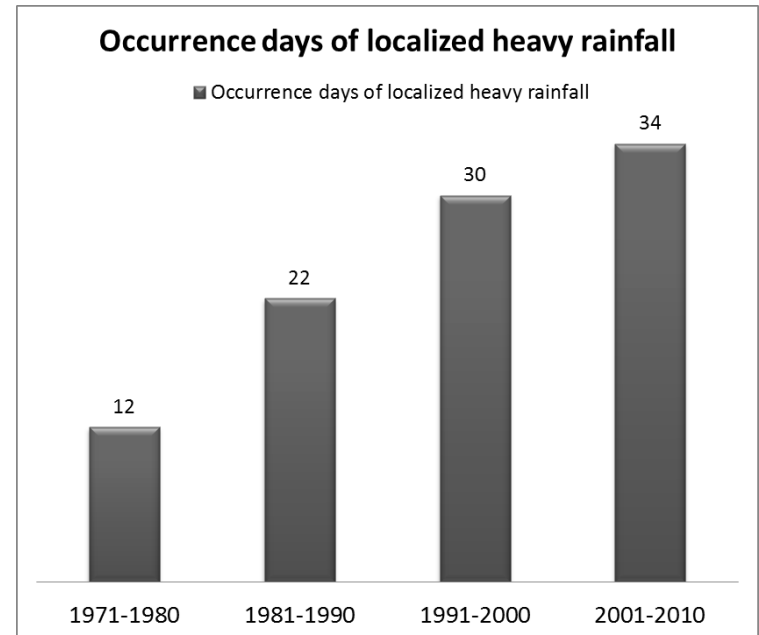
Abnormal weather/climate is generally believed to be a rare phenomenon that occurs once in 30 years or more, but recently such phenomena have become more frequent.

In particular, localized heavy rainfall for a short time period has increased remarkably in both frequency and intensity in some mid-latitude regions. [e.g., Groisman et al. 2005, Held and Soden 2006, Trenberth 1999, Allen and Ingram 2002, Emori et al. 2005, Mitas and Clement 2005]

## Localized heavy precipitation in Seoul metropolitan area

Localized heavy rainfall in Korea tends to be increased in terms of the intensity and the frequency in recent years.

Especially, localized heavy rainfall ( $\geq 30\text{mm/hour}$ ) in Seoul in warm-season have increased threefold in recent 30 years. (the frequency and the intensity of localized heavy precipitations have also increased in the 2000s.)



## Localized heavy rainfall over Seoul metropolitan area in warm-season

Localized heavy rainfall events in South Korea generally arise from mesoscale convective systems embedded in synoptic scale disturbances along quasi-stationary fronts, or from convective instabilities resulting from unstable air masses over the Korean Peninsula (including direct/indirect effect of Typhoon).

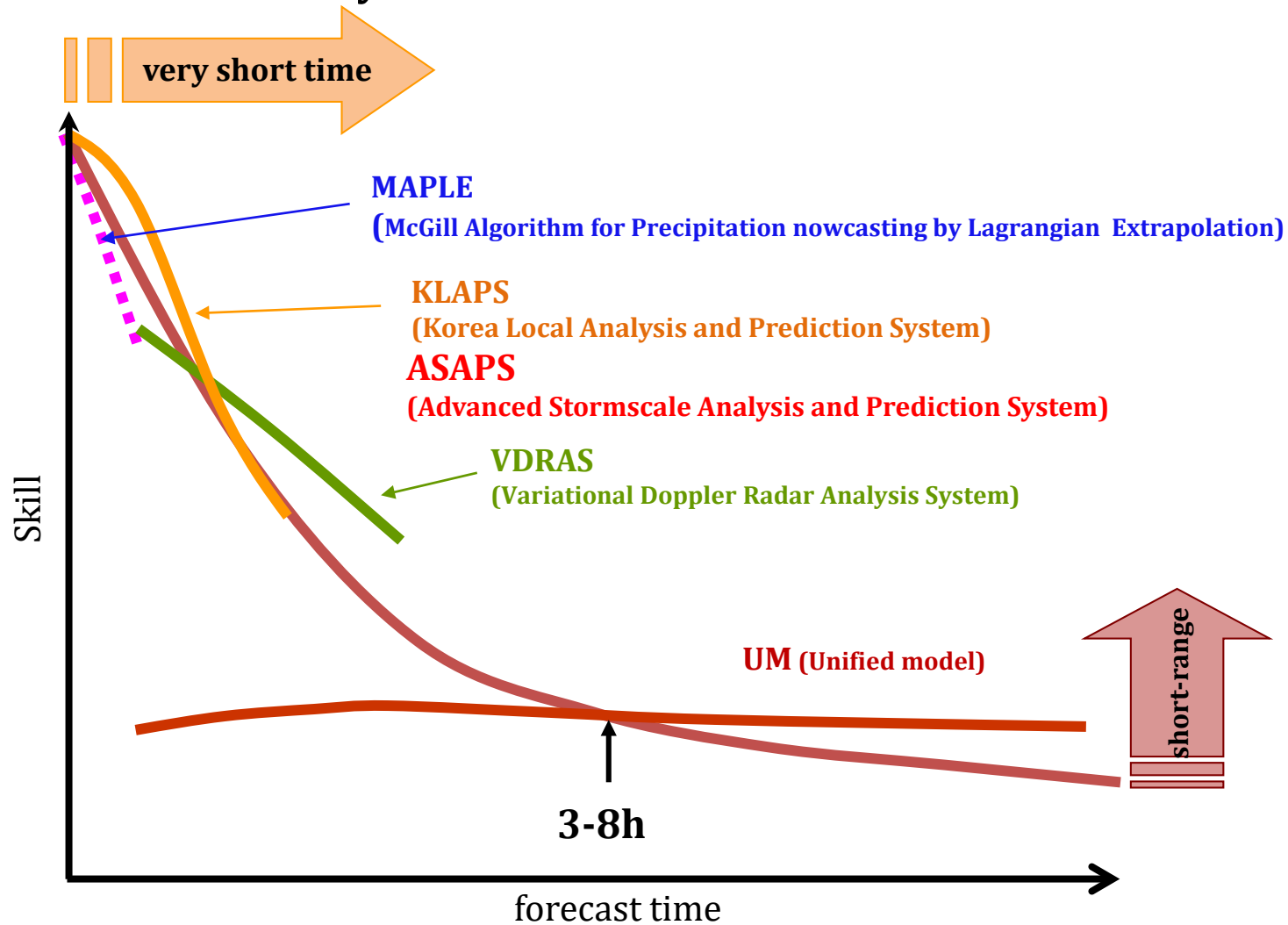
Localized heavy precipitation has occurred in very narrower zone in patches, and its period of life cycle of precipitations is very short.

In addition to, urban precipitations, which is increased slightly and relatively, are due to urban artificial heat sources, an increased roughness length by construction of high-rise buildings, and an increased aerosol. These factors have an effect on the change of low level air currents associated with urban precipitations.

Although our understanding of mechanisms for convective scale abrupt and intensive precipitation in Seoul metropolitan area is still insufficient, a dominant part of mechanism for the localized concentrated precipitation has been widely known due to various potential factors.

- ✓ In order to investigate fine spatial and very short temporal weather phenomena, especially localized heavy precipitations in Seoul area, a suitable storm-scale analysis and forecast system is needed.
- ✓ In the interest of improving diagnosis, analysis, and prediction of localized heavy precipitation, an appropriate meteorological diagnostic variable should be considered in storm-scale.

# Forecast skill for very short time forecast

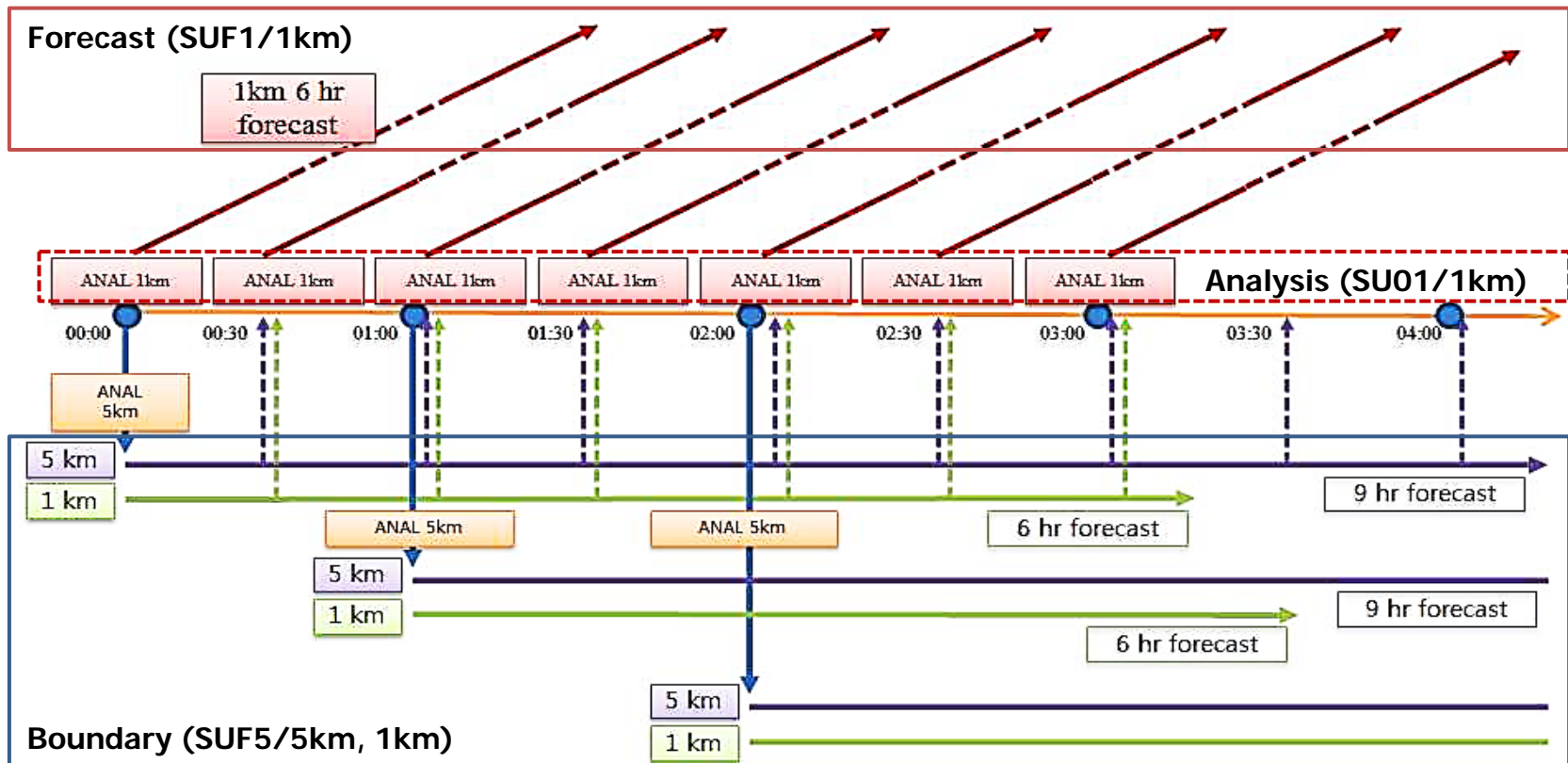


Development of an analysis and forecast system, which is target to storm-scale severe weather, should be needed.

Lee (2013) modified

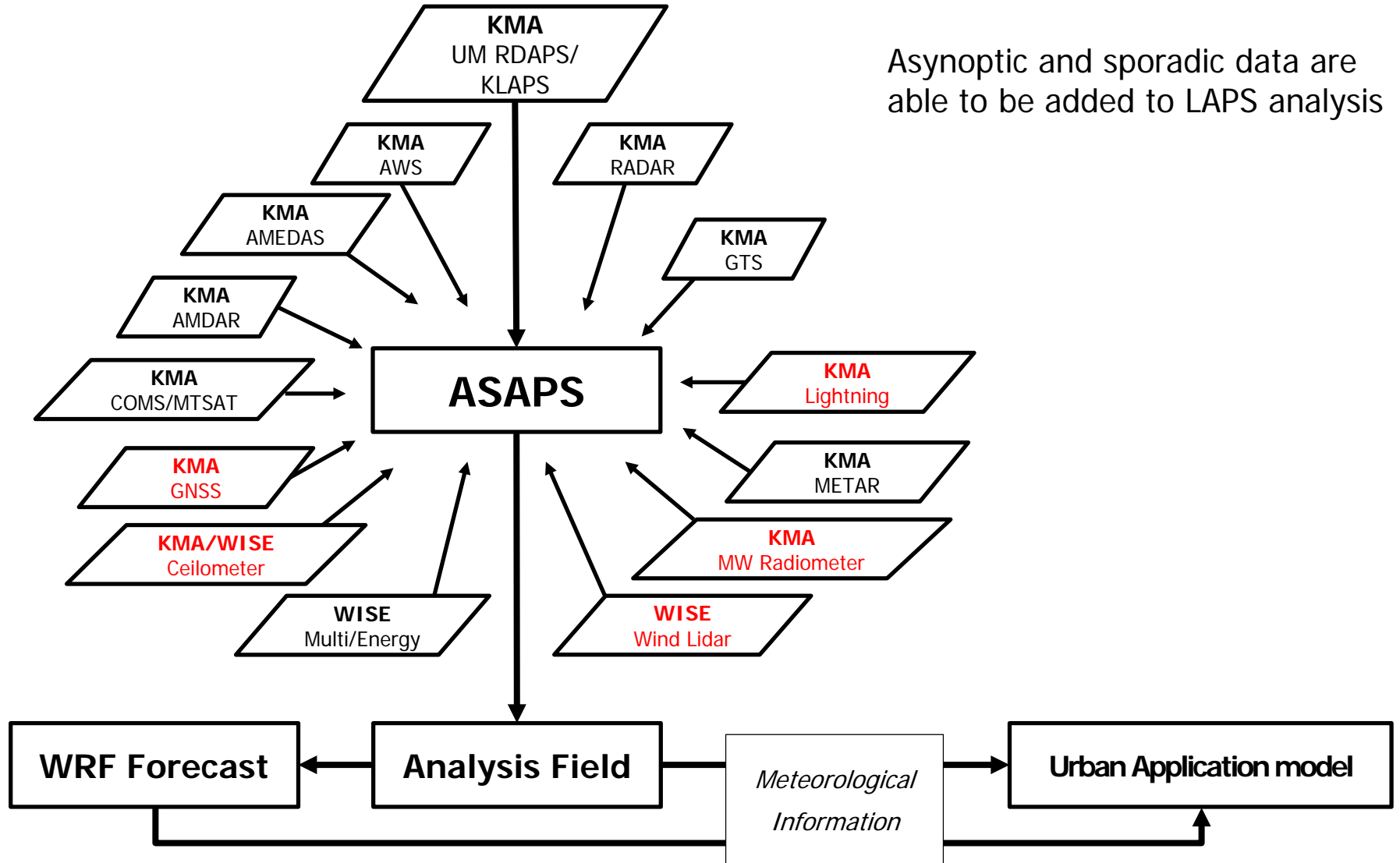
# Advanced Storm-scale Analysis and Prediction System (ASAPS)

- ASAPS v1 was developed in National Institute of Meteorological Sciences (NIMS; 2013)
- Improvement of initialization through analyzing observation data using Local Analysis and Prediction System (LAPS)
- Forecasting based on Weather Research and Forecast (WRF)
- There is based on Korea Local Analysis and Prediction System (KLAPS), which is an operational model in KMA.
- 1km horizontal resolution, every 1 hour, 6 hours Forecasting



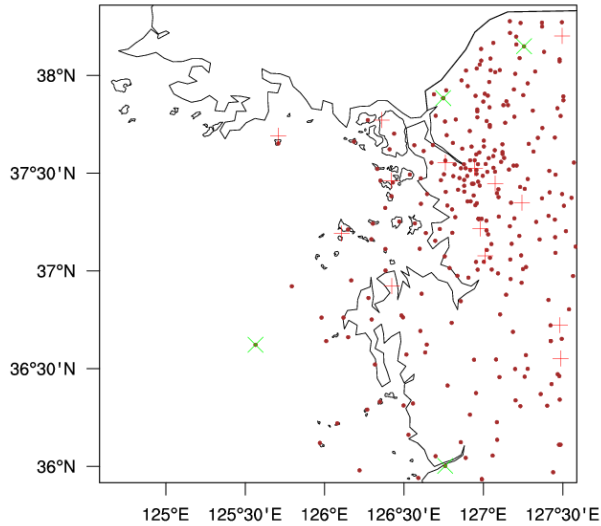
# ASAPS

Analysis based on LAPS



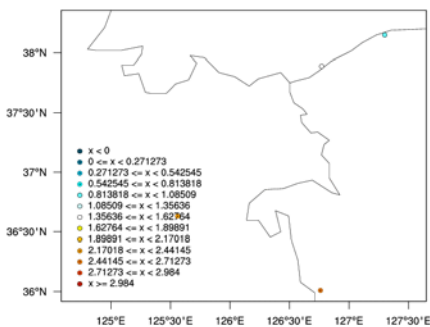
# OBS data for analysis and forecast in 1km analysis of ASAPS

## Satellite

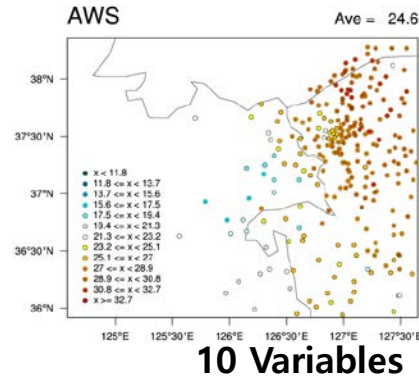


- AWS
- ✚ METAR
- ✚ Wind profiler

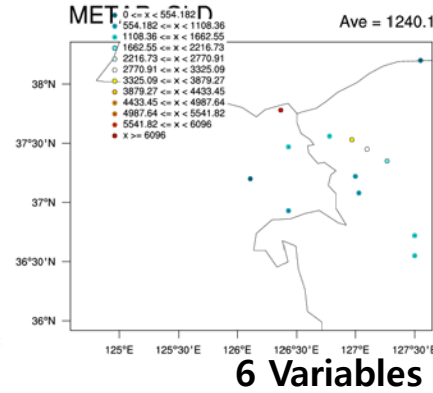
Wind Profiler Ave = 1.5



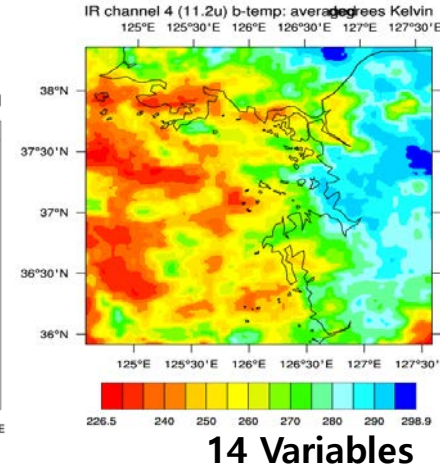
2 Variables



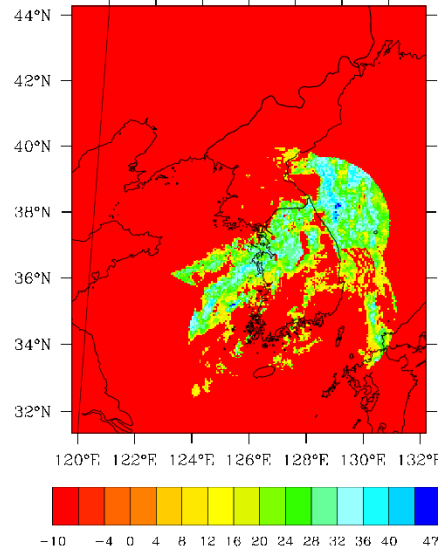
10 Variables



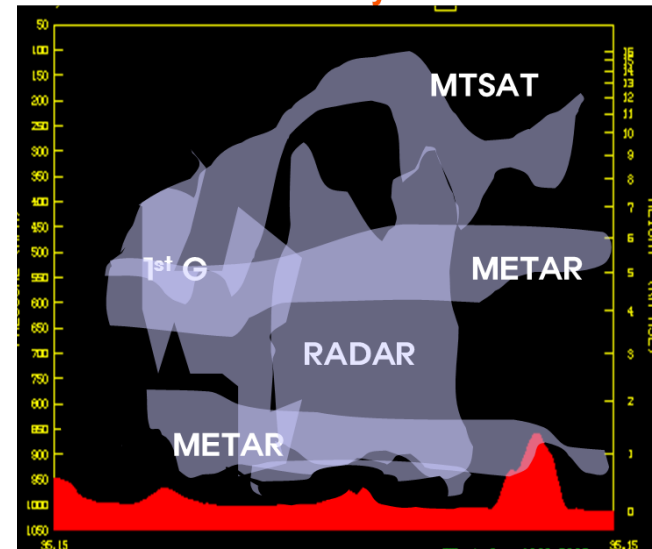
6 Variables



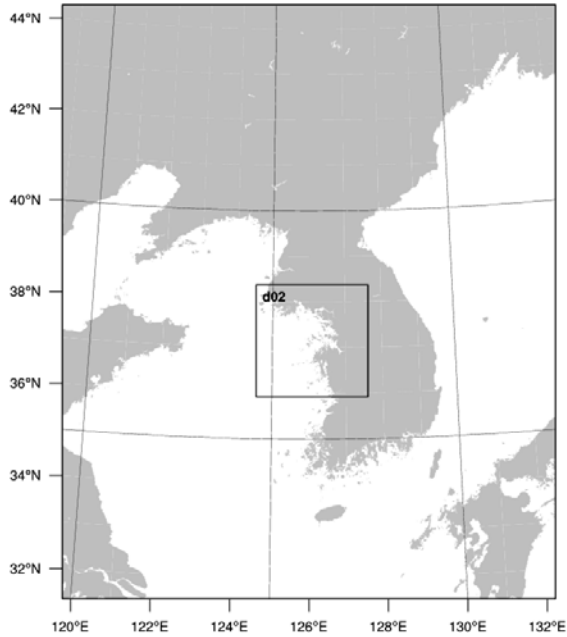
## RADAR VRZ(8)



## Cloud Analysis



## ASAPS Domain (1km)

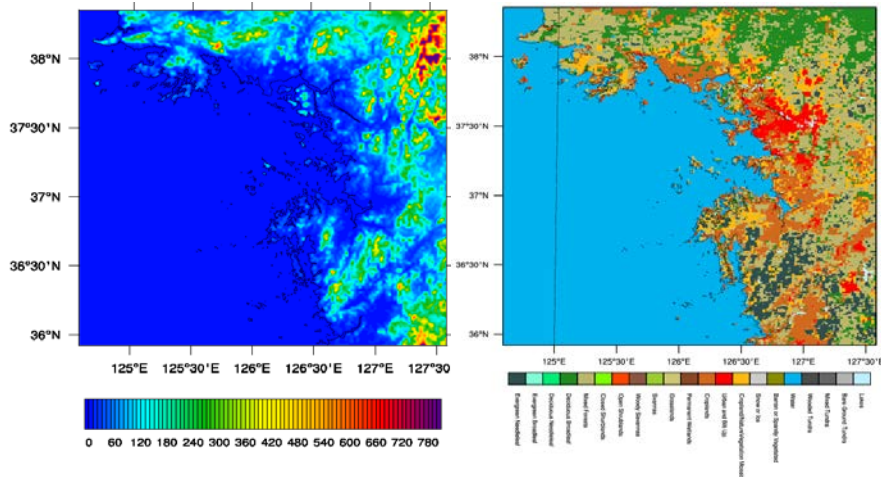


Parameter	V1.0
Forecast Model	WRF V3.4.1
Horizontal grids	335 X 283 (5km) / 266 X 266 (1km)
Land use & Topography	USGS 30s (900m)/MODIS 21cat
Initial/ Boundary Condition	KLAPS 15 km, 5km (KMA)
Vertical grid	40 layers/ Top 50hPa
Integral time	12s/4s
Radiation	Dudhia SW / RRTM LW
Microphysics	WDM 6-class
Surface layer	Revised MM5 Monin-Obukhov scheme
Land surface	Unified Noah LSM
Planetary Boundary layer	YSU PBL
Cumulus	-
Urban	-
Analysis	KLAPS v3.0
Prediction	12 hour (5km)/ 6hour (1km)

## SUF1 (1km) topo and Land use

USGS30(900m)

MODIS(21cat)



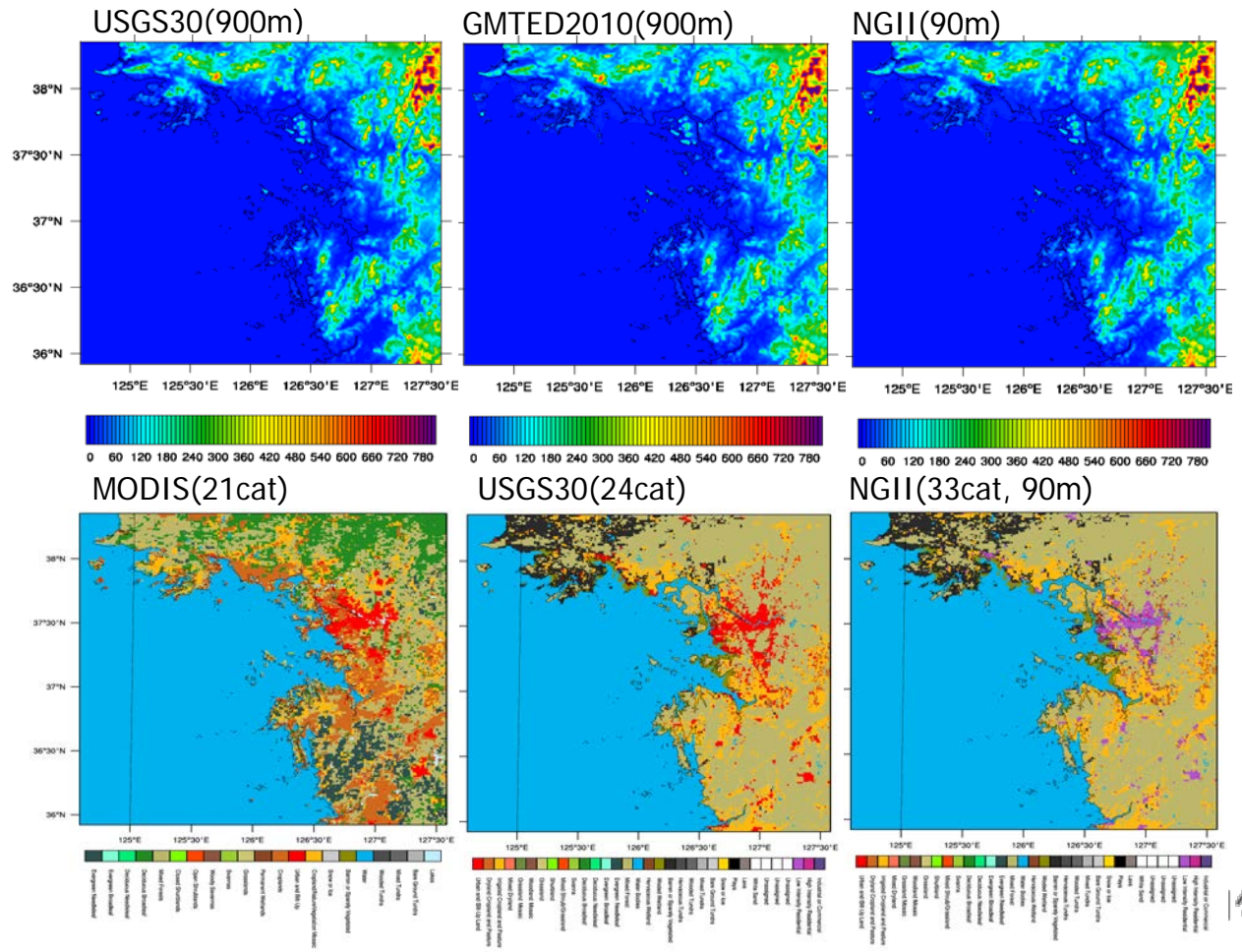


# Upgrade of ASAPS: the combination of upgrade options

Parameter	V1.0	V2.0	UCM
Forecast Model	WRF V3.4.1	WRF v3.8	
Land use/ Topography	USGS 30s (900m)/ MODIS 21cat	GMTED2010/ USGS 24cat(900m)	NGII/ NGII 33cat (90m)
PBL	YSU PBL	YSU PBL/ Shin-Hong PBL	
Urban	-	-	SLUCM
ETC		SST_SKIN, OML	

ASAPS v2.0 is current real time operating system from this year.

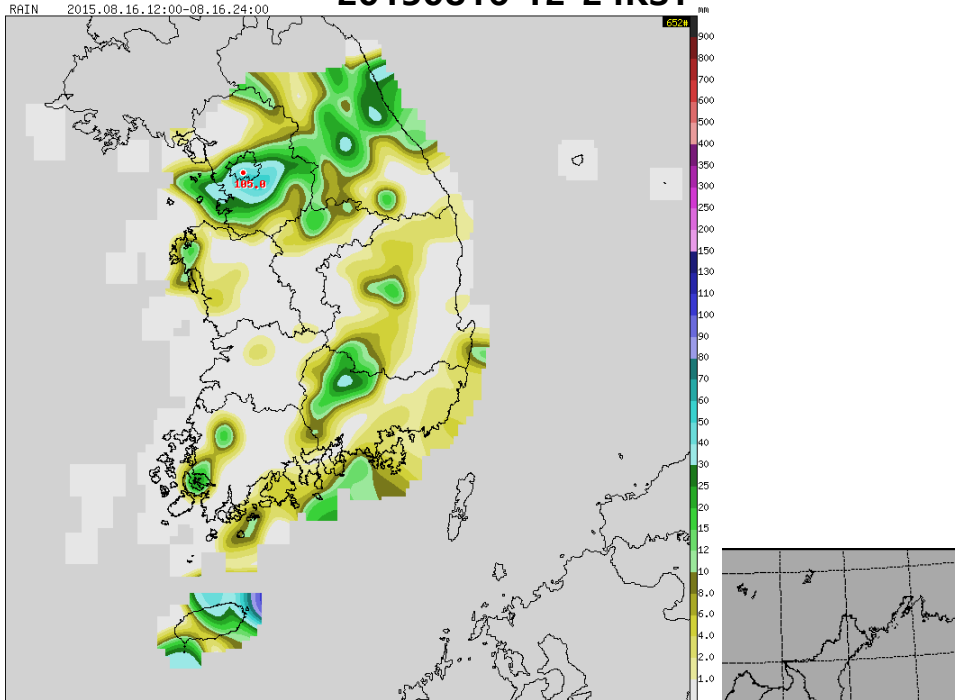
*(Please, see the poster presentation of Dr. Jee : Poster ID B02)*



# CASE: 2015-08-16 Localized heavy precipitation

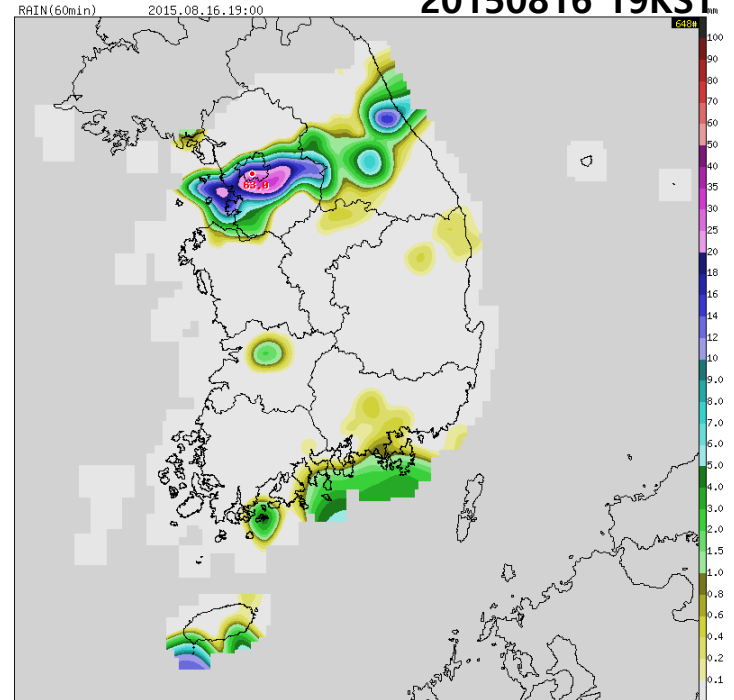
KMA AWS

20150816 12-24KST

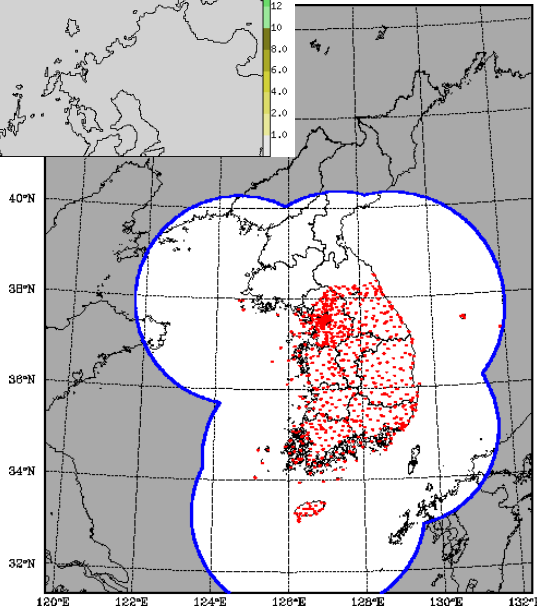


12-hr Acc. precipitation

20150816 19KST



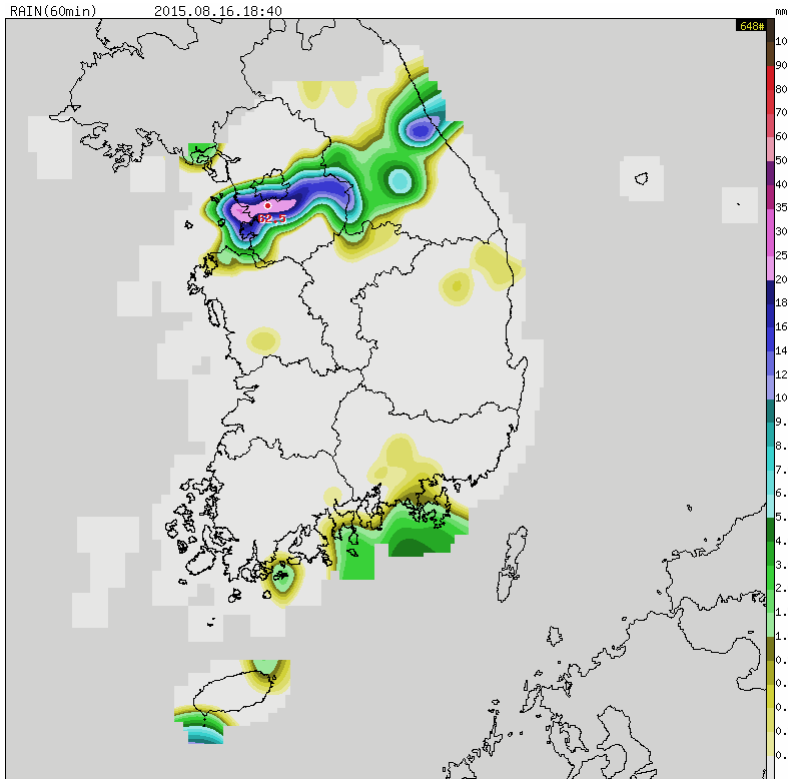
1-hr acc. precipitation on time: 63mm



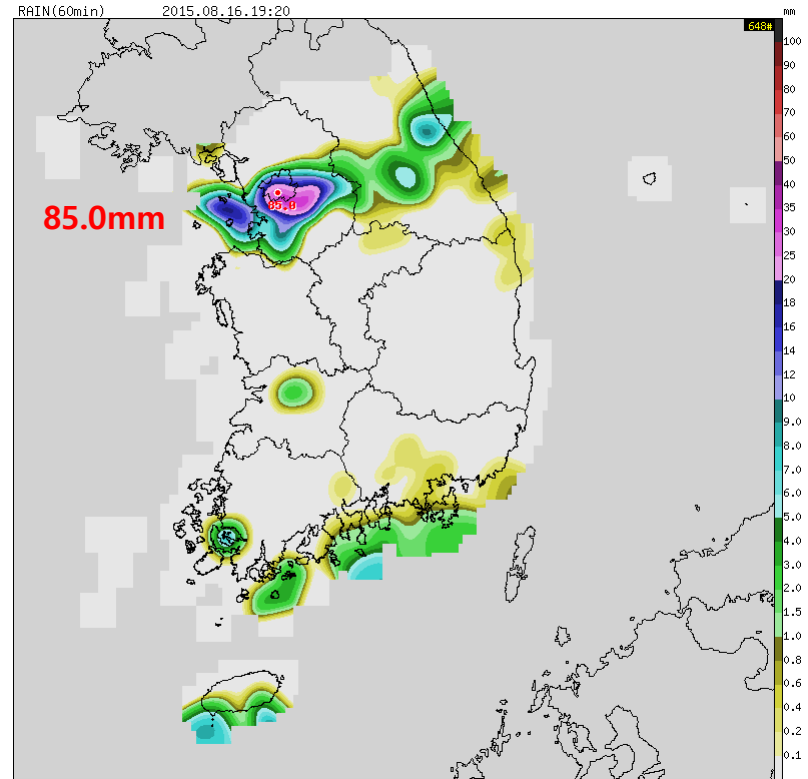
The AWS networks (red dots) and the areal coverage of the 10 radars for precipitation estimates (white region with blue curved line as the boundary)

# AWS observed precipitation

Distribution of 1-hr acc. precipitations for every 5 minute from 0940 to 1045UTC 16 AUG 2015



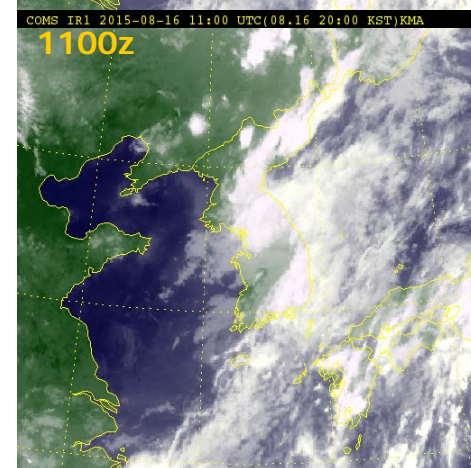
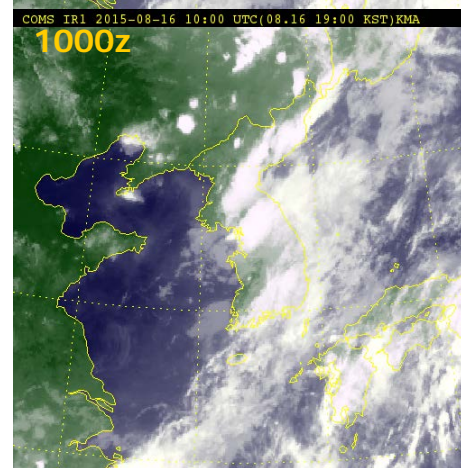
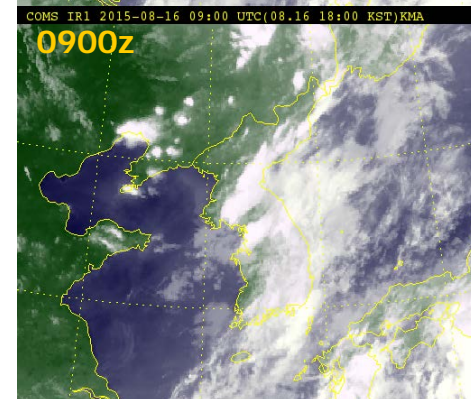
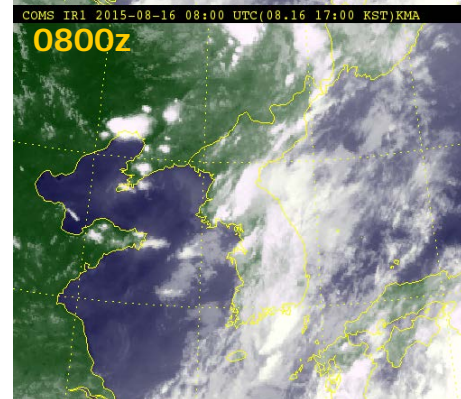
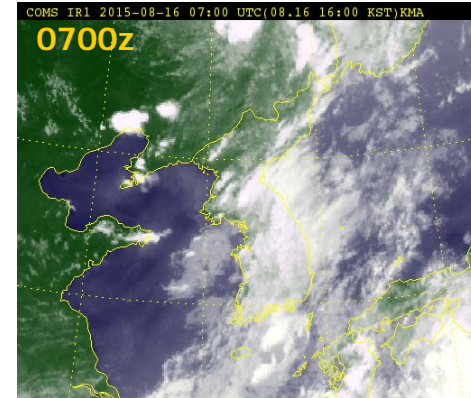
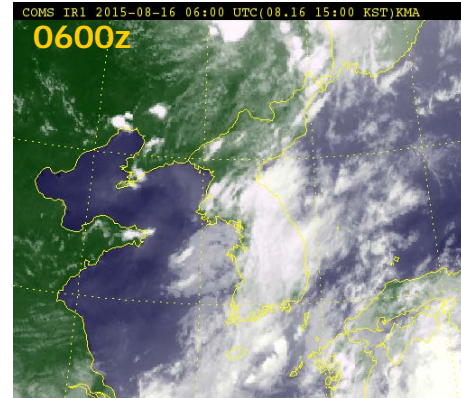
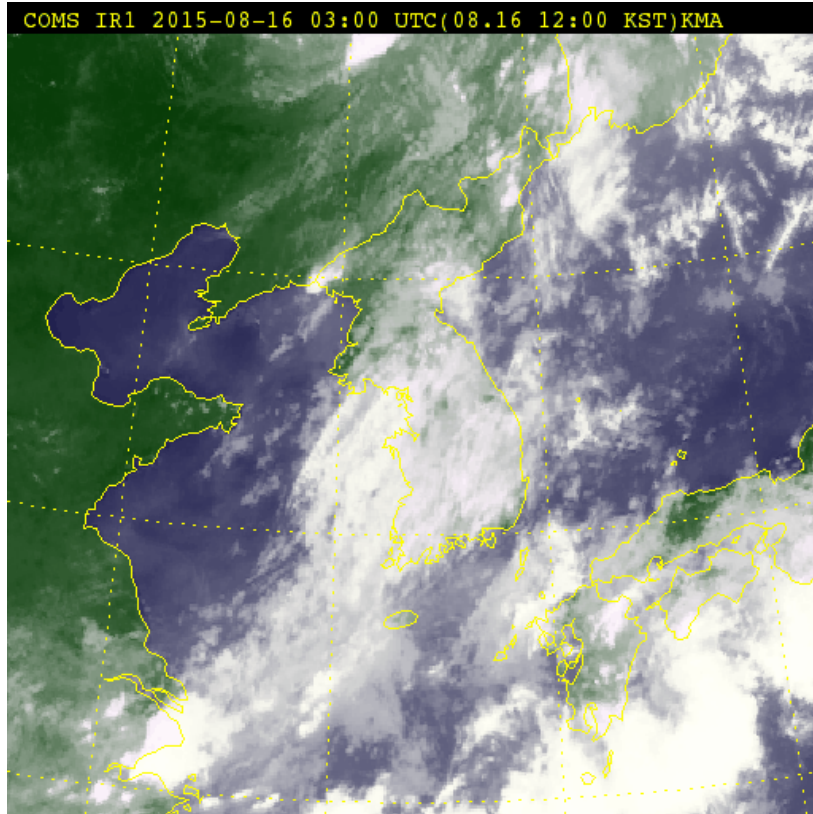
Distribution of 1-hr acc. precipitation from 0920 to 1020 UTC 16 AUG 2015





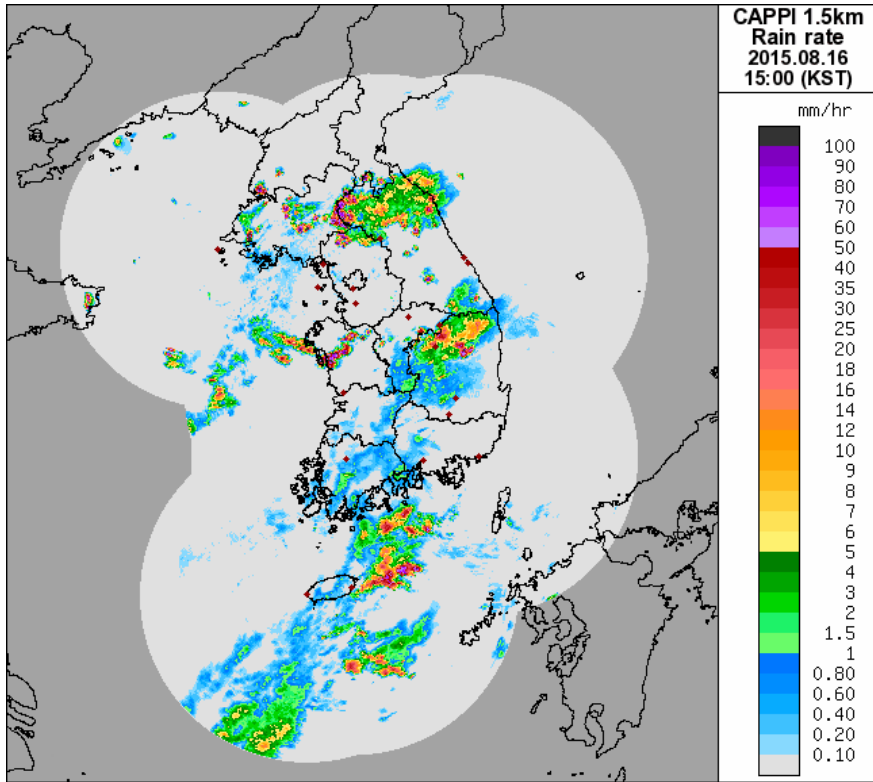
# Satellite images

COMS-IR from 0300 to 1200UTC 16 AUG 2015

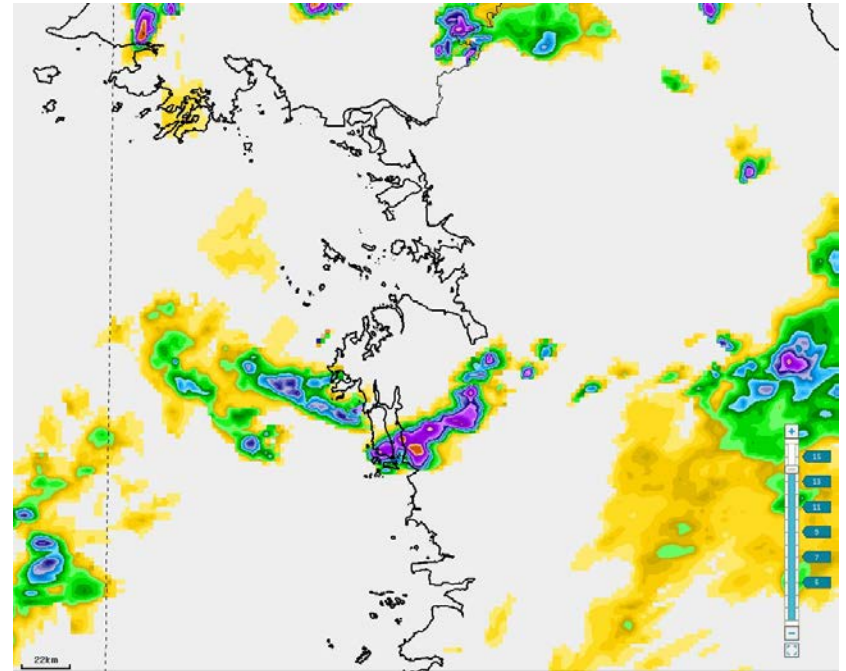


# Radar images

Composite images from 10 KMA radars every 10 minutes from 0300 to 1200UTC (1500 to 2100KST) 16 AUG 2015

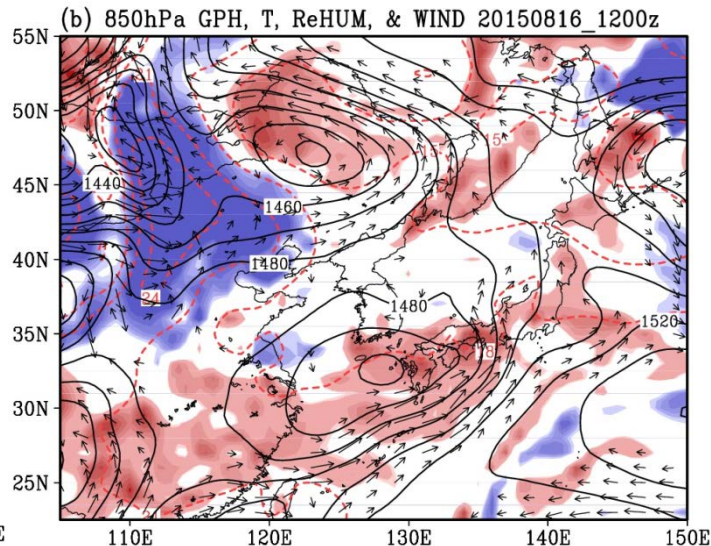
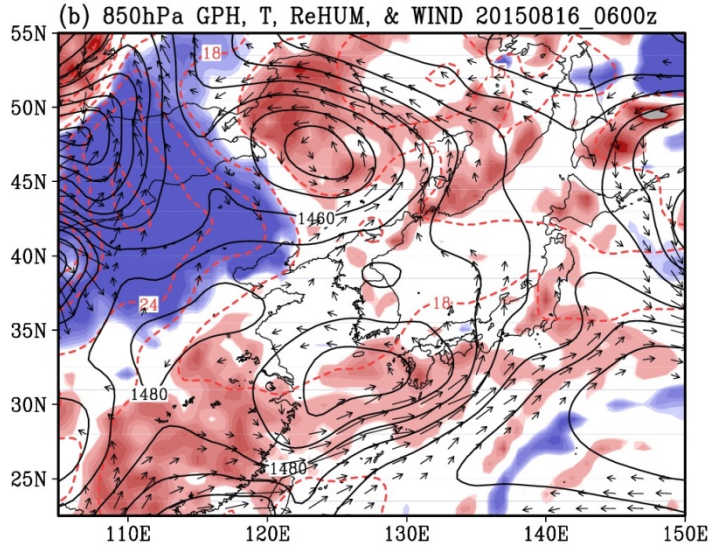


KMA Radar images every 30 minutes from 0600 to 1200UTC (1500 to 2100KST) 16 AUG 2015

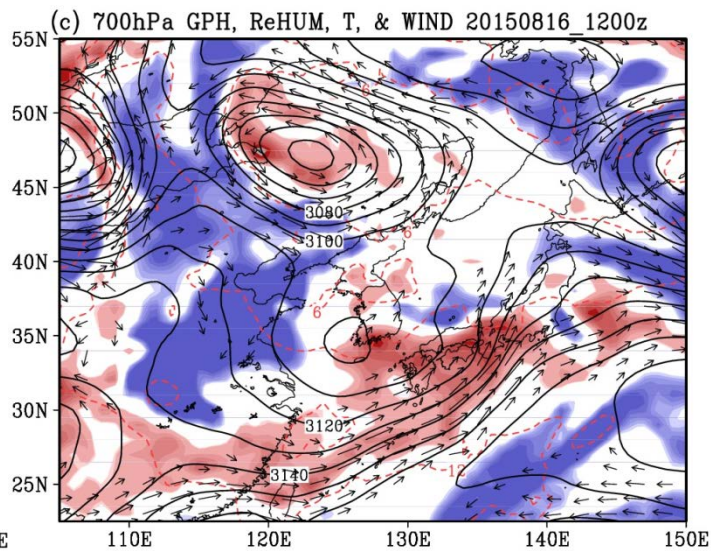
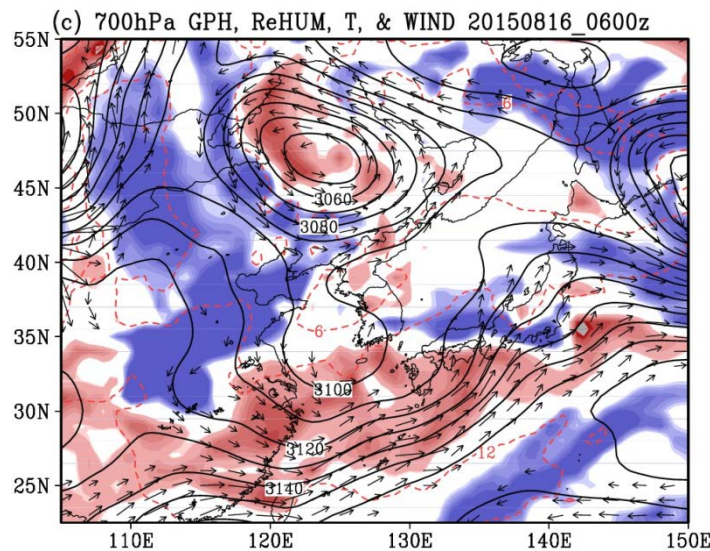




# 850hPa and 700hPa Weather charts in 0600 & 1200 UTC 16 August 2015 :



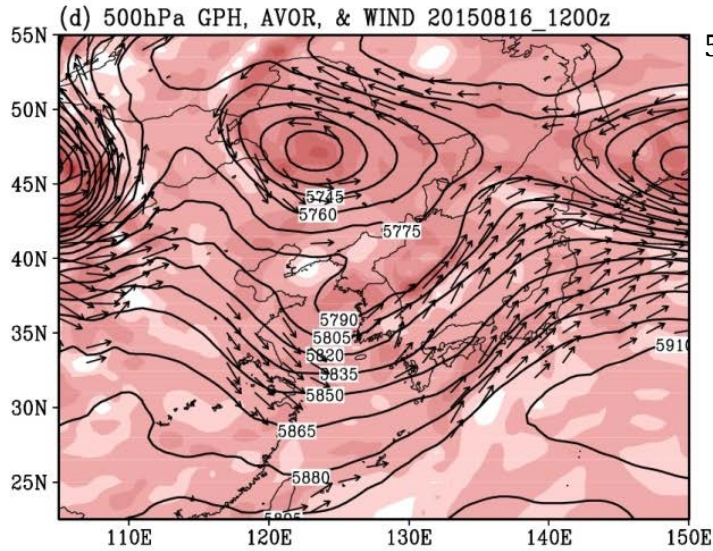
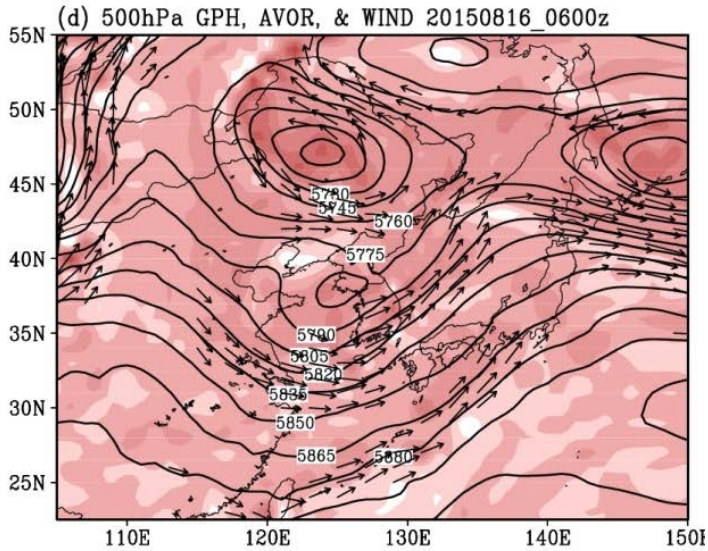
850hPa GPH (contoured at 10 gpm interval with solid line), temperature (contoured at 3 [°C] interval with red dashed line), relative humidity (blue shaded in 36~51% and red shaded in 80~100%), and wind > 4m/sec (vector)



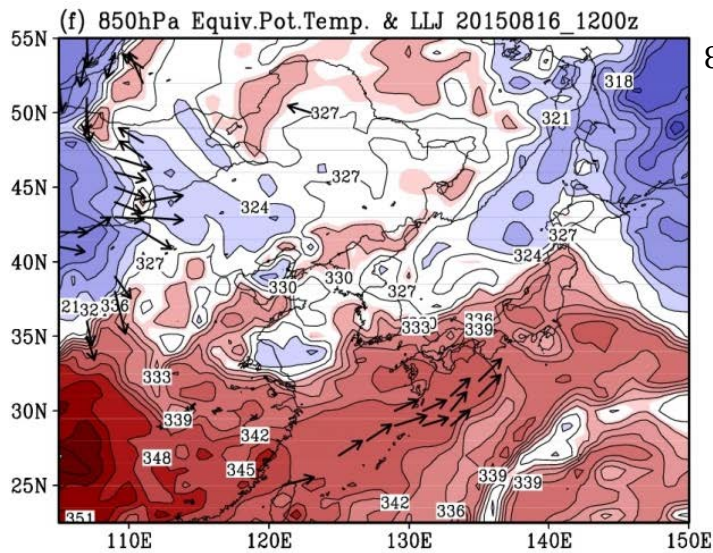
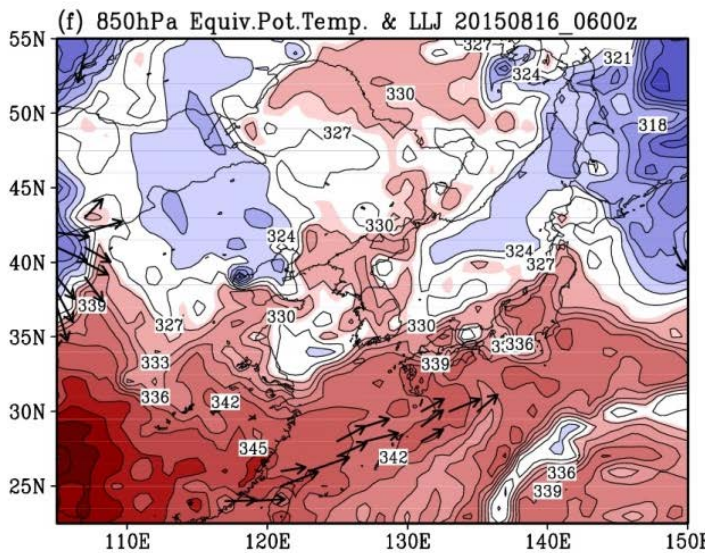
700 hPa GPH (contoured at 10 gpm interval with solid line), temperature (contoured at 3 [°C] interval with red dashed line), relative humidity (blue shaded in 36~51% and red shaded in 80~100%), and wind > 5m/sec (vector)



# 500hPa Weather charts and 850hPa Equiv.Potential T in 0600 & 1200 UTC 16 August 2015



500 hPa GPH (contoured at 20 gpm interval with solid line), absolute vorticity (red shaded over  $1 \times 10^{-4} \text{sec}^{-1}$ ), and wind > 12m/sec (vector)

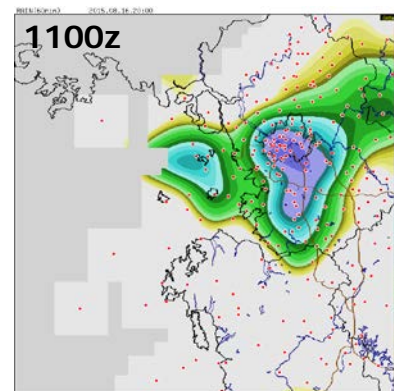
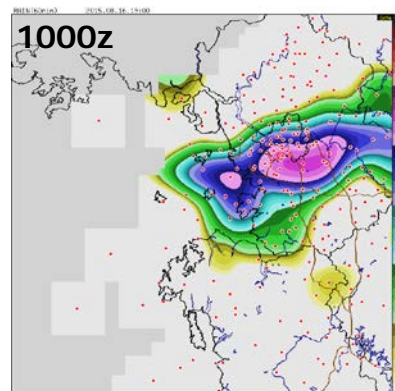
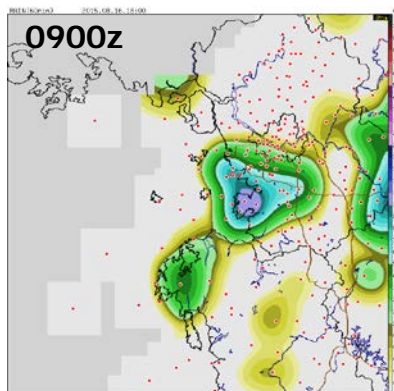
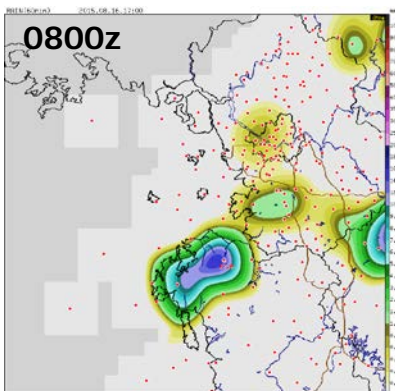


850 hPa equivalent potential temperature (blue shaded below 324K and red shaded over 330K), wind > 12.5m/sec (vector)

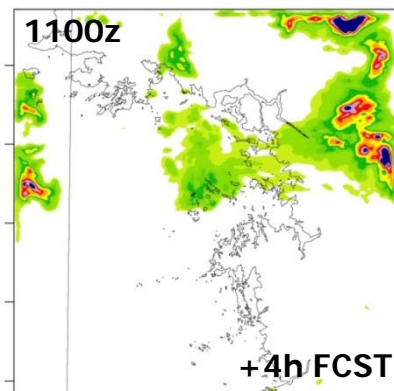
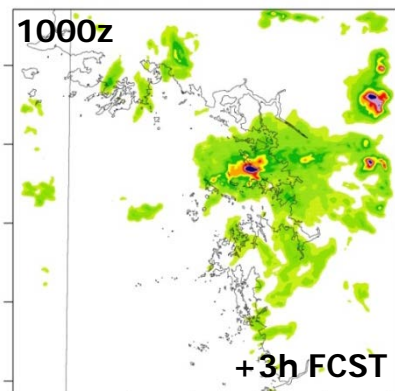
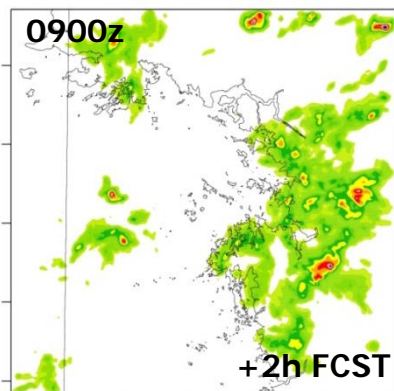
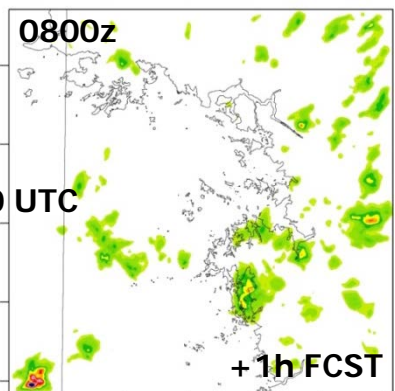


# Precipitation distributions of OBS and ASAPS1.0 (2015-08-16)

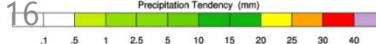
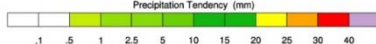
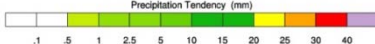
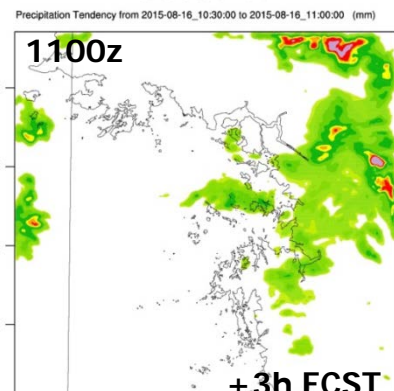
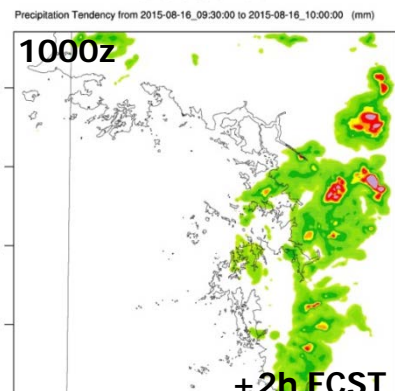
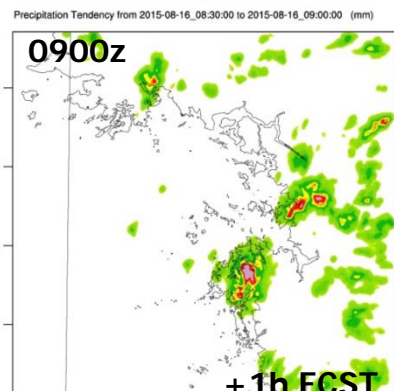
**OBS  
KMA AWS**



**17  
INIT: 0700 UTC**



**18  
INIT: 0800 UTC**



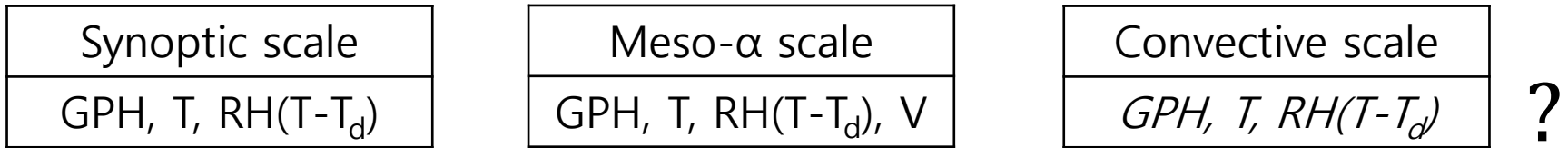


# An application of ASAPS data

## Convective scale meteorological data

High resolution meteorological data are required for diagnosis and analysis of urban meteorological phenomena

Improvement of highly dense observation networks and high resolution numerical models is able to provide convective scale meteorological data



.....>.....>.....>.....>.....>.....>.....

MSLP	V <sub>850</sub> , V <sub>250</sub>	$\zeta_{850}$ , $\zeta_{250}$
GPH <sub>850</sub> , GPH <sub>250</sub>	T <sub>850</sub> , T <sub>250</sub>	PV <sub><math>\theta=330K</math></sub>
	$\theta_{PV=2}$	
	$\omega_{500}$	

(Hoskins and Hodges 2002)

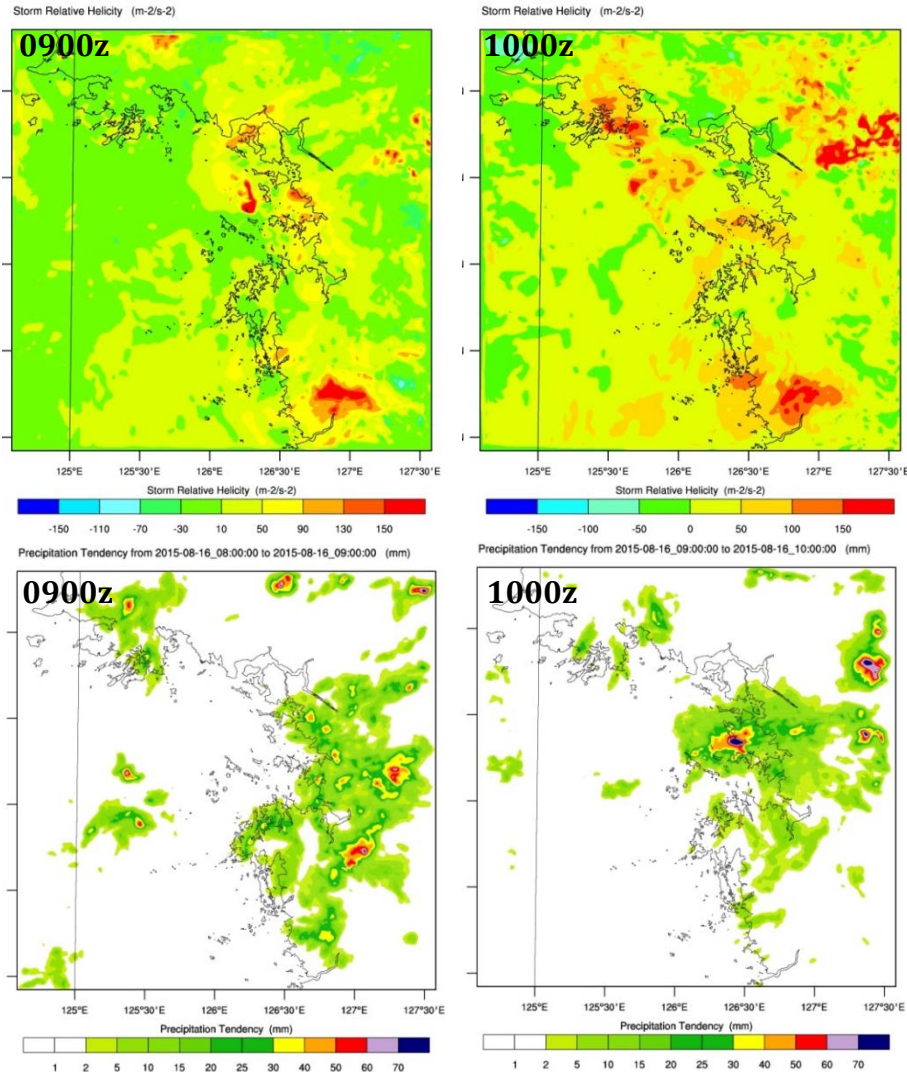
What is a suitable variable in order to investigate localized heavy precipitation in convective scale?

In order to investigate a part of mechanisms of localized heavy precipitation in this case, a diagnostic variable, which is helpful to understand the physical structures for convective scale, is considered.

# Storm Relative Helicity (SRH)

(e.g., Davies-Jones 1990)

## 0-3km Storm relative helicity [-150, 150] [m<sup>2</sup> S<sup>-2</sup>]



$$\begin{aligned}
 SRH &= -\int_0^h \left[ (\vec{v} - \vec{c}) \cdot \vec{k} \times \left( \frac{\partial \vec{v}}{\partial z} \right) \right] dz \\
 &= -\int_0^h \left[ -(u - c_x) \left( \frac{\partial v}{\partial z} \right) + (v - c_y) \left( \frac{\partial u}{\partial z} \right) \right] dz
 \end{aligned}$$

SRH is defined as the component of the 3-D vorticity vector in the direction of the storm relative flow.

Larger values of 0-3 km SRH (greater than 250 m<sup>2</sup>/s<sup>2</sup>) and 0-1 km SRH (greater than 100 m<sup>2</sup>/s<sup>2</sup>) do suggest an increased threat of tornadoes with supercells.

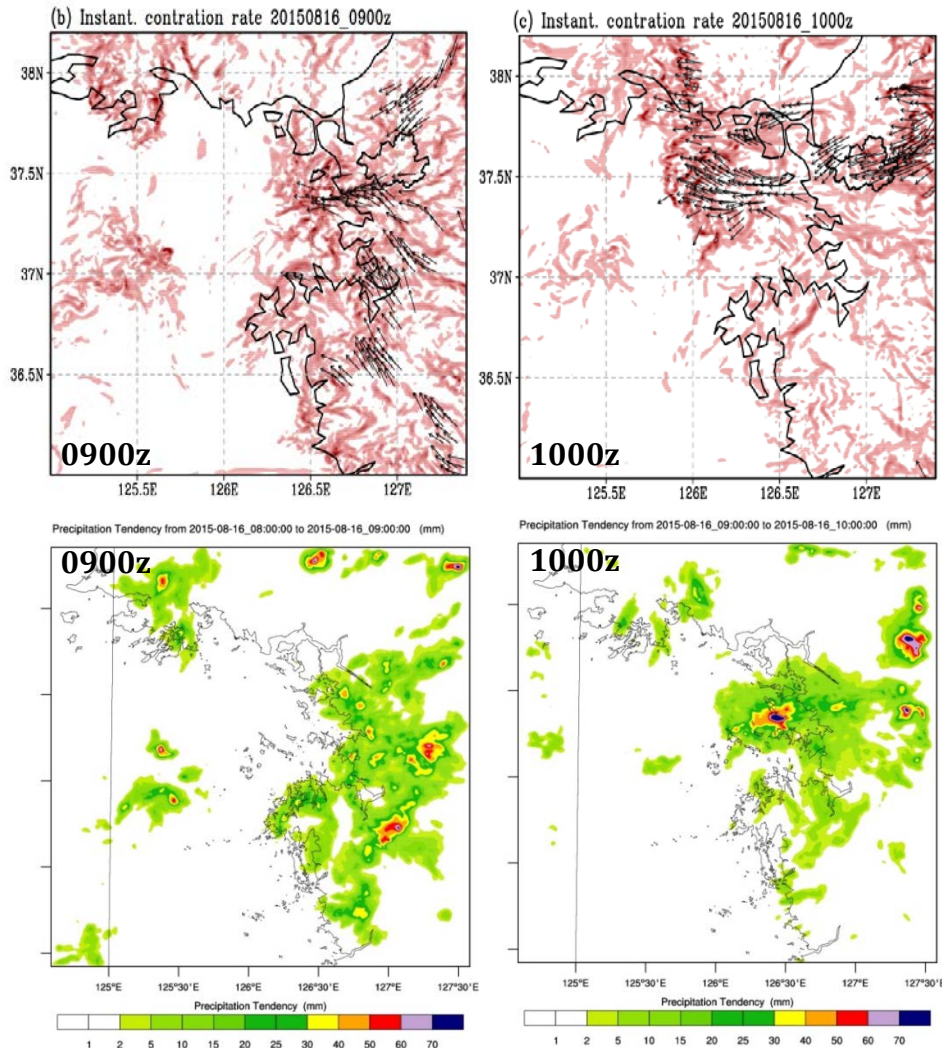
Large value of helicity is favorable for the formation of many kinds of extreme weather phenomena of synoptic scale to meso-β scale such as heavy precipitation and thunderstorm (Jincai et al. 1996).

SRH was applied as a parameter for heavy precipitations and gust wind in Shanghai area (Jincai et al. 1996).

In spatial distribution of SRH, negative SRH area is positioned to the west area of relatively high positive SRH. In comparison with the SRH value of threshold of 250, which is possible to be supercells, SRH value of this case is relatively small.

# Instantaneous Contraction Rate (ICON)

(e.g., Cohen, R. A., and D. M. Schultz, 2005)



$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \quad \text{Divergence}$$

$$ICR = \frac{1}{2}(E - D)$$

$$E = \sqrt{(E_{st}^2 + E_{sh}^2)} \quad \text{Resultant deformation}$$

$$E_{st} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} \quad \text{Stretching deformation}$$

$$E_{sh} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \quad \text{Shearing deformation}$$

ICON is a measure of the instantaneous rate of change of the distance between two adjacent air parcels (Cohen and Shultz 2005).

It is related to the process of frontogenesis, which involves an increase of the gradient in some property of the air, such as temperature or moisture, as contraction proceeds.

A region, which is large value of ICON, is likely to experience frontogenesis, if there is some pre-existing least change in some property of the air, like temperature or moisture, in the area experiencing contraction.

The application with ICON is more suitable to analyze this case of localized heavy precipitation. Divergent factors are the more dominant forcing role in comparison to rotational factors (SRH) for this case



# Updraft helicity (UH)

(e.g. Drogemeier et al., 1993; Kain et al., 2008)

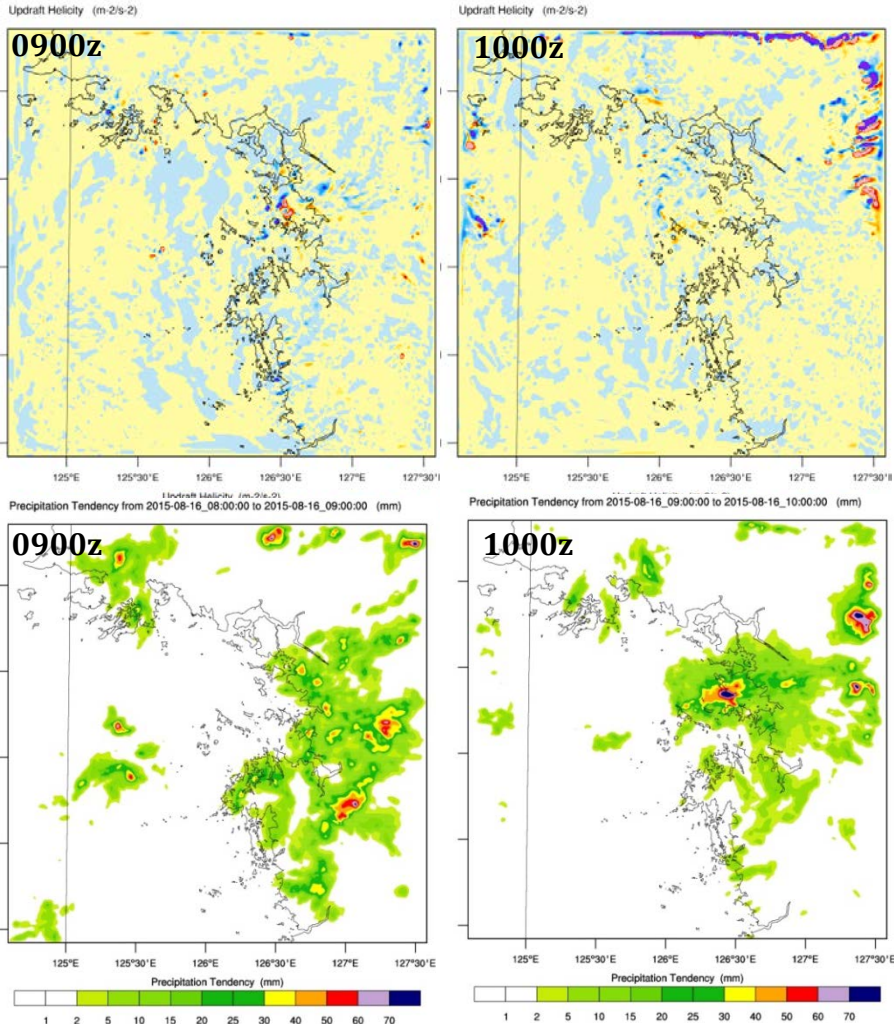
$$UH = \int_{z_0}^{z_t} w\zeta dz$$

$$UH \approx w \sum_{z=2000m}^{z=5000m} \overline{w\zeta} \Delta z = (\overline{w\zeta}_{2,3} + \overline{w\zeta}_{3,4} + \overline{w\zeta}_{4,5}) \times 1000$$

In order to detect meso-cyclones, a algorithm is based on the concept of helicity, which is a scalar measure of the potential for helical flow to develop in a moving fluid.

The horizontal component of the environmental helicity, commonly expressed within a storm-relative framework, is often used by forecasters to assess the potential for rotating thunderstorms, or supercells. UH is measurement of the vertical component of helicity.

Since the primary interest is on storm rotation in the lower to middle troposphere, 'UH' was integrated vertically from 2km to 5km AGL using a midpoint approximation.



# Summary

In order to watch, monitor, and predict severe weathers like frequent heavy precipitation events in the metropolitan area, Advanced Storm-scale Analysis and Prediction System (ASAPS) was developed.

A case in 16 August 2015, which is a localized heavy precipitation in the metropolitan area, was analyzed through ASAPS and its application.

The weather pattern of this case is seen to be mainly caused by short-wave trough, which is associated with baroclinic structure in the northwest of Korea, and moisture and warm advection induced by low system over the south of Korea. The localized heavy precipitation is represented in more detail through high resolution meteorological data.

Through investigating a case study of a localized heavy precipitation in the Korea Peninsula, the ASAPS forecast shows the reasonable and good performance in this case.

As the higher resolution in OBS and numerical model simulation, the more suitable atmospheric variables and structures should be found in order to improve the application of fine resolution in weather phenomena.

ASAPS with convective-scale resolution showed primary physical structure related to localized heavy precipitation in patches and occasionally on Seoul metropolitan area using diagnostic variable, which are storm relative helicity, instantaneous contraction rate, and updraft helicity.

The application with instantaneous contraction rate is more appropriate to describe this localized heavy precipitation case, i.e., the divergent factors are the more dominant forcing than rotational factors.

감사합니다.

Thank you.

본 연구는 기상청 차세대도시농림융합스마트기상서비스개발(WISE) 사업  
(KMA-2012-0001-1)의 지원으로 수행되었습니다.

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Weather Information Service Engine(WISE) project, KMA-2012-0001-1.