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Satellite analysis and nowcasting applications in KMA NMSC: present and future

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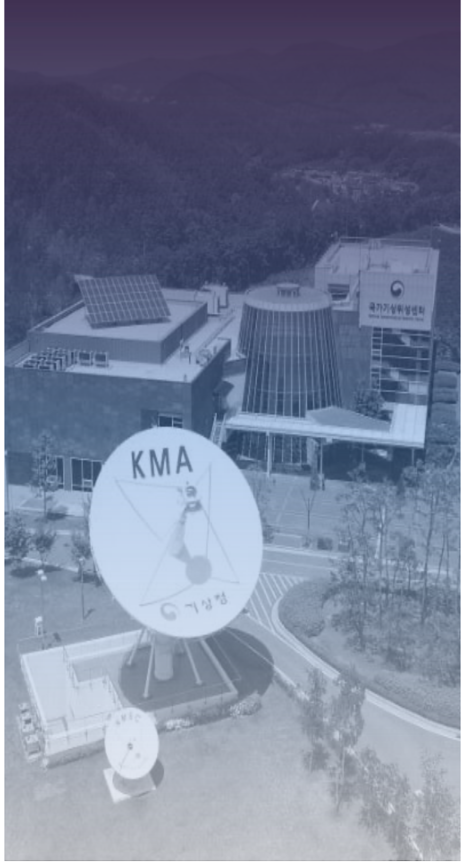
Korea Meteorological Administration (KMA)
National Meteorological Satellite Center (NMSC)



Contents

Convection & RDT

Convection detection status and problems

◆ Current status of GK2A

- Convective initiation(CI) and rapidly developing thunderstorm(RDT) monitoring based on GEO help forecasters predict thunderstorms with heavy rainfall and lightning

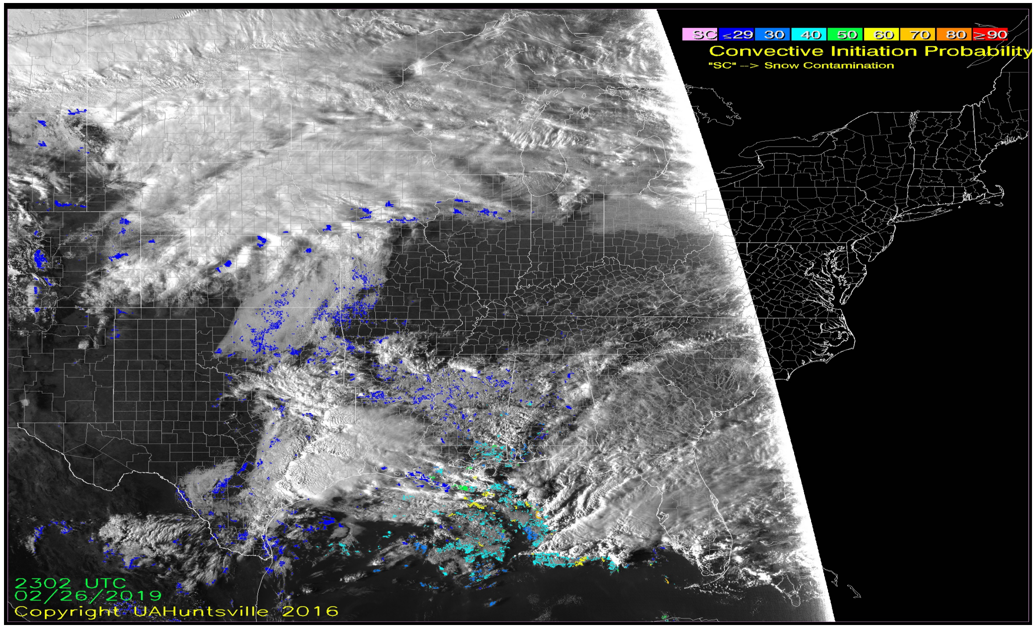
◆ Decreased lead time performance of convective clouds in KMA

- Detection accuracy (POD) of CI is high at 79.9%, but needs to be improved due to FAR 42.9%
- Currently, leading detection time is about 40 minutes : satellite detects ahead compared to radar(35 dBz)
- Using the convective cloud identification model in RDT, which does not reflect GK2A observation characteristics → need to improvement the model

◆ Reduced forecast utilization due to difficulties in interpreting the displayed image in KMA

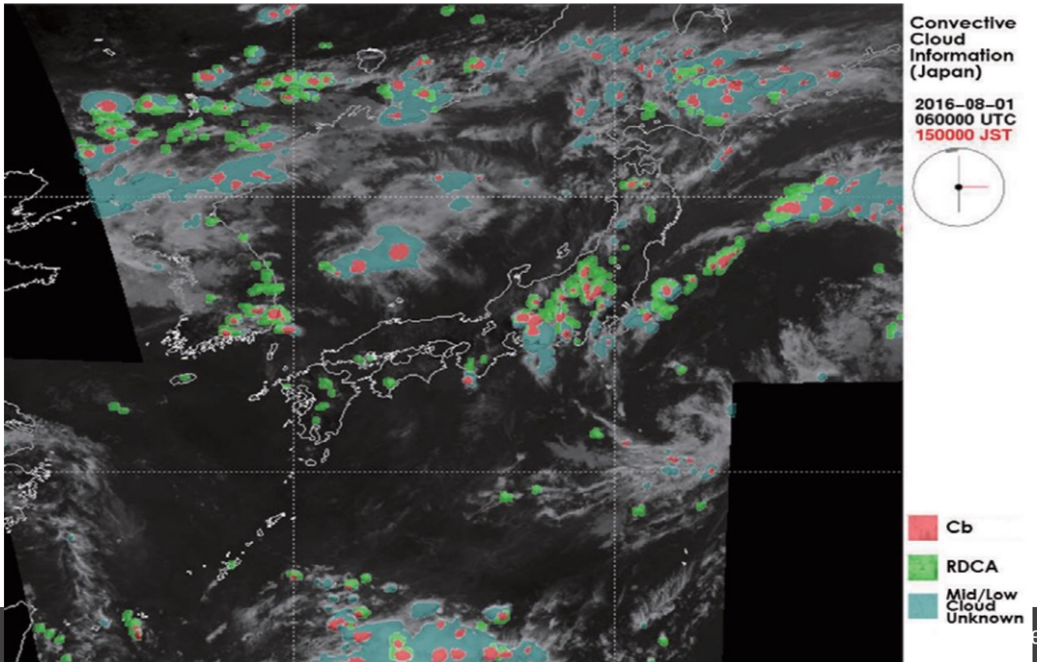
- Lack of support for forecasting decision-making by providing only simple information on changes in convective cloud cells
- Lack of experience in case-by-case analysis for continuous improvement of convective cloud analysis system and quantitative monitoring through it

Convective Initiation(CI) Information



◆ **NOAA GOES-R**

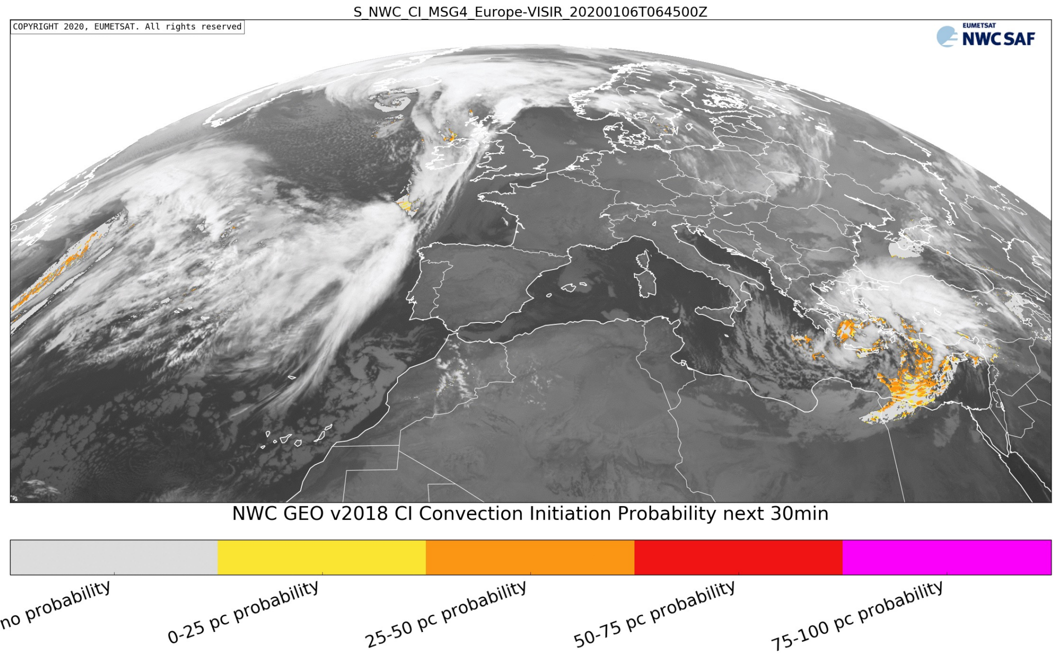
- Providing probability of CI less than 2 hours
- Displaying probability of CI with 30~100 %

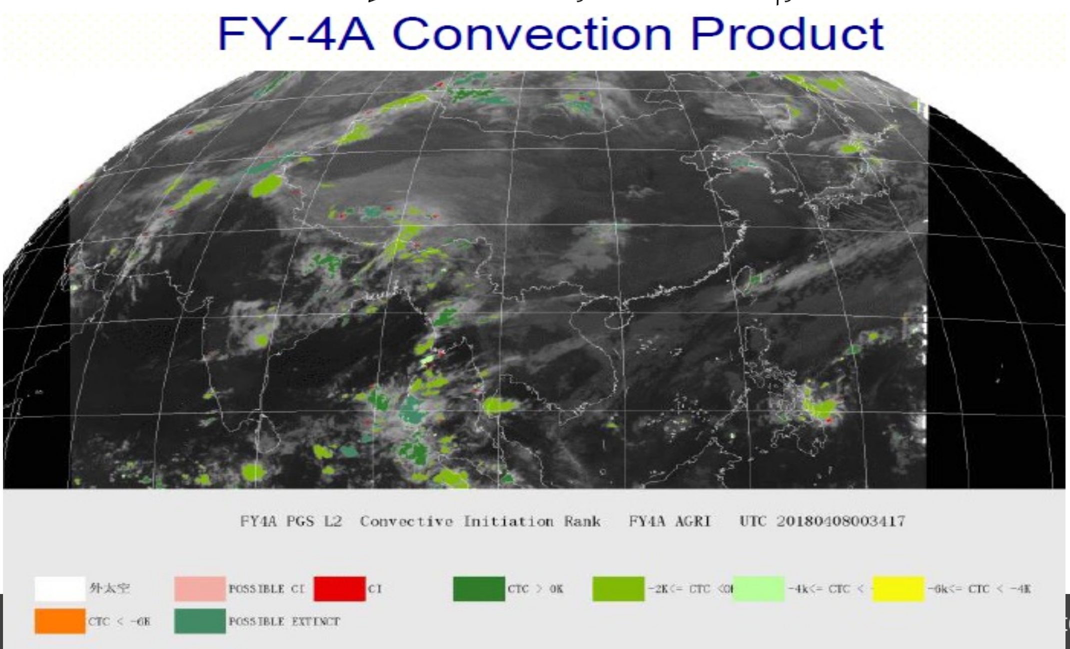


◆ **JMA Himawari-8**

- Goal : To monitor CI before radar measurement
- Rapidly developing cumulus area(RDCA), cumulonimbus (Cb), Mid/low cloud unknown are displaying

Convective Initiation(CI) Information





◆ EUMETSAT NWCSAF

- Providing probability information of each cloud pixel
- Displaying CI probability divided with 4 steps

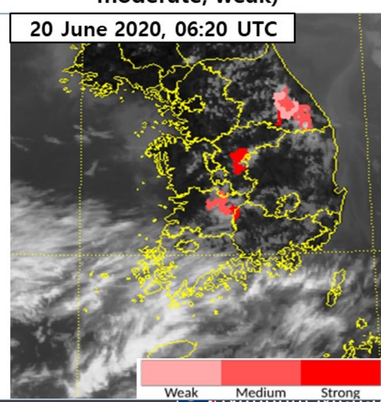
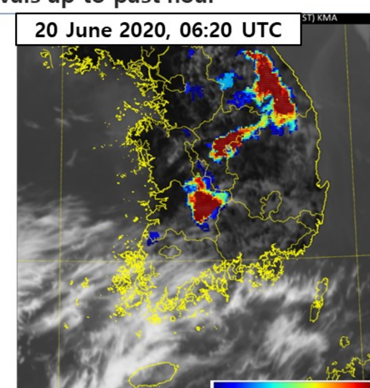
◆ CMA FY-4A

- Displaying CI and Cloud top cooling rate(CTC)

GK2A CI improvement

◆Convection Initiation(CI) algorithm update

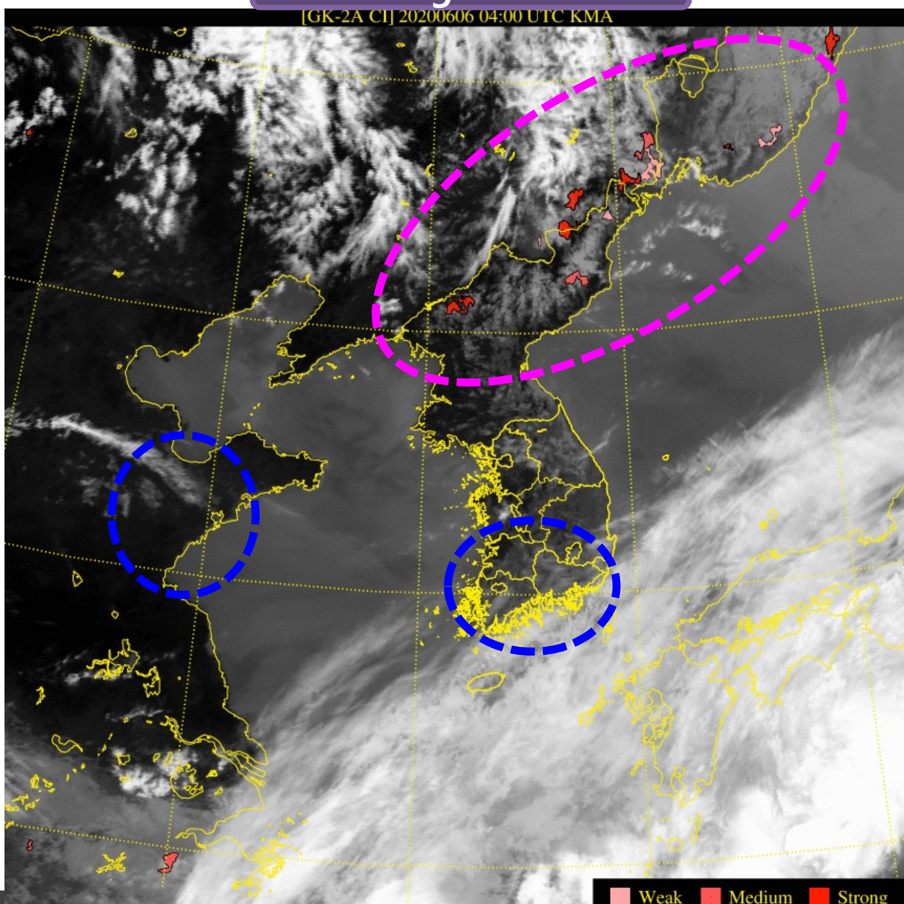
- CI algorithm threshold optimization and calculating probability of CI using machine learning to improve false detection and provide probability information on the possibility of convective cloud occurrence
- Improved discontinuous detection through past 1-hours overlap of probability CIs

	Original CI	Probability CI (new)
Input data	(GK2A L1B) 0.64, 6.2, 8.6, 10.4, 11.2, 12.4, 13.3µm (GK2A L2) Atmospheric instability index(CAPE, LI, SSI, KI, TTI) (Ancillary) NWP(UM) forecast field (6-11hr forecasts with 1hr interval) → Use NWP data when L2 atmospheric instability index data are not available	(GK2A L1B) 0.64, 3.8, 6.2, 7.3, 8.6, 10.4, 11.2, 12.4, 13.3µm (GK2A L2) Atmospheric instability index(CAPE, LI, SSI, KI, TTI), Precipitable water(total, high level, middle level, low level), Atmospheric T/Q profile (Ancillary) NWP(UM) forecast field (6-11hr forecasts with 1hr interval) → Use NWP data when L2 atmospheric instability index data are not available
Method	Static thresholds	Machine learning(logistic regression), some static thresholds
Range	1~7 (Number of updraft strength tests passed)	0~100%
Expression	Expressing the 10-min updraft strength of the cloud object by dividing it into 3 stages(strong, moderate, weak)	1) Expressed from a probability of 50% or more 2) Expressed by accumulating probability Cis at 2-min intervals up to past hour
Image		

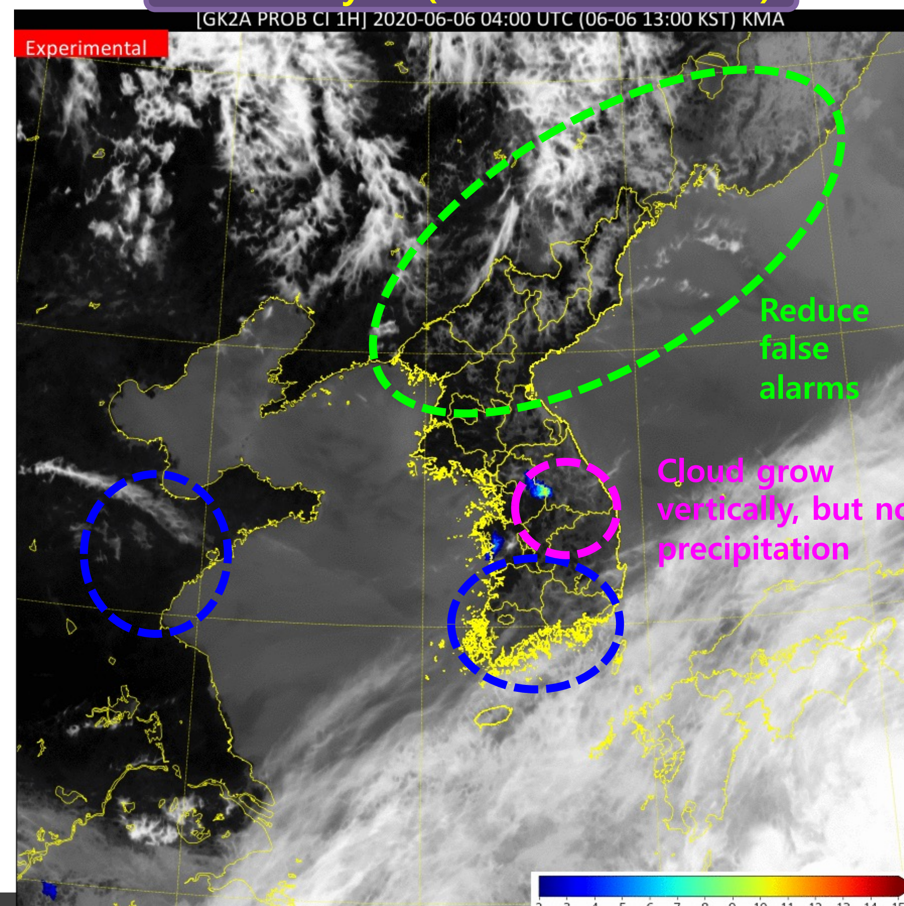
GK2A CI Improvement(Verification Result)

- Cases of convective clouds caused by low-level wind convergence and thermal instability
- After the improvement, Existing false alarm signals are decreasing and being continuously detected

Original CI



Probability CI (1 hr accumulation)



GK2A CI improvements

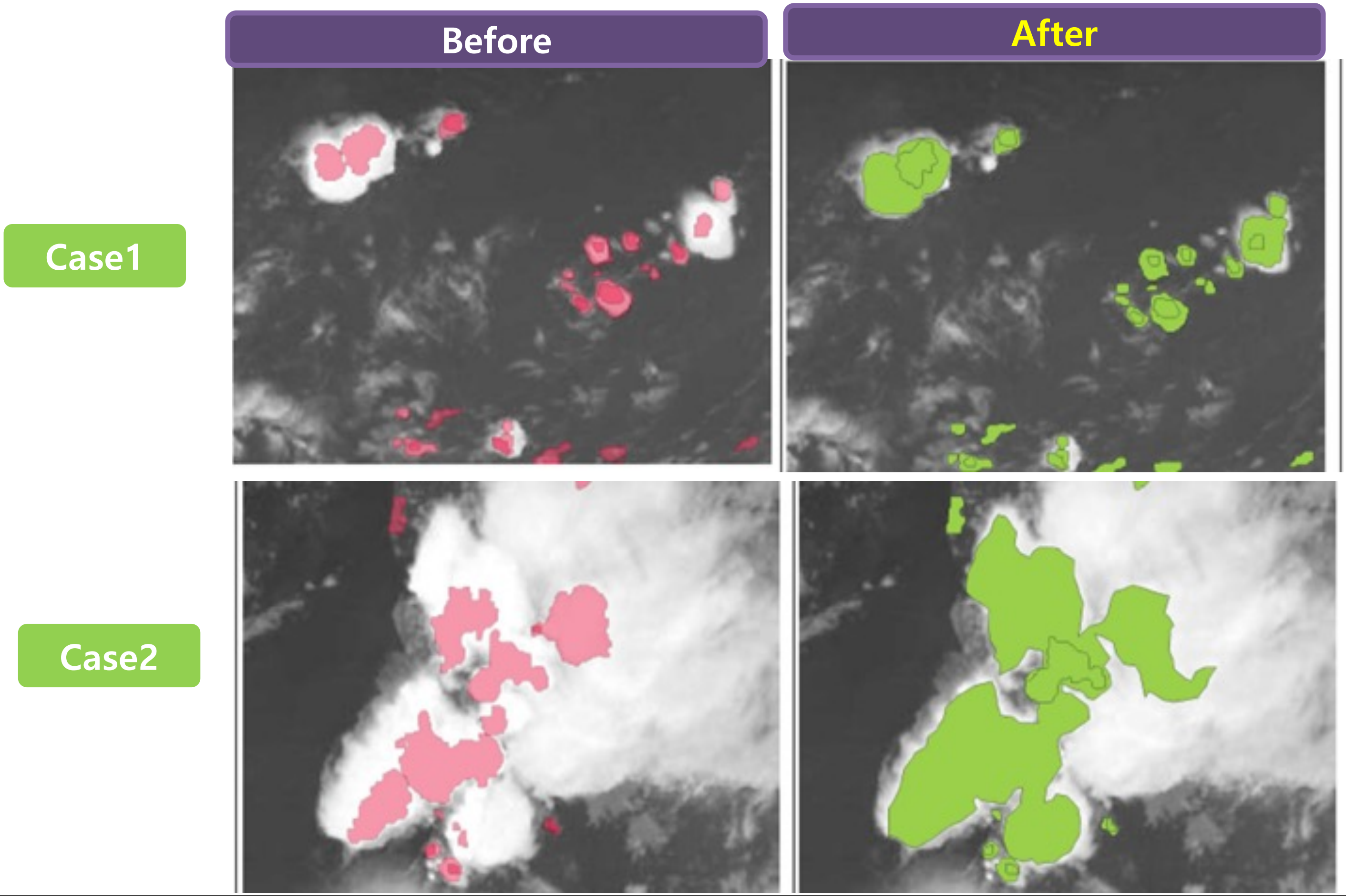
- This product will be useful for short-term forecasting as it predicts CI before lightning and radar events occur.
- Probability of CI shows high POD and low FAR compared to original CI, and the mean lead time is slightly shorter or similar
- CI area can be continuously monitored by accumulating probability CI every 2 minutes from past 1 hour to the present
- Improving false alarms that are difficult to eliminate with static threshold methods using machine learning

	POD	FAR	Mean lead time
Original CI	54.17%	72.84%	**46.38 min**
Probaility CI > 50%	**58.62% (4.45%p↑)**	**63.79% % (9.05%p↓)**	45.13 min (1.24min↓)

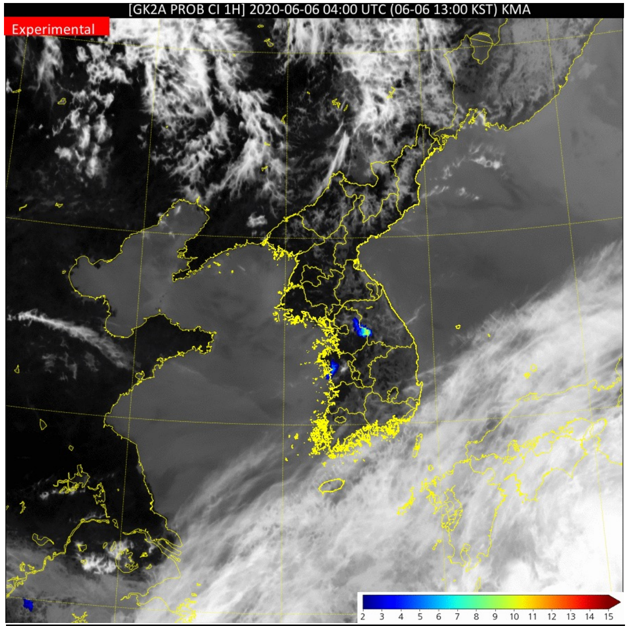
RDT Improvement (in progress)

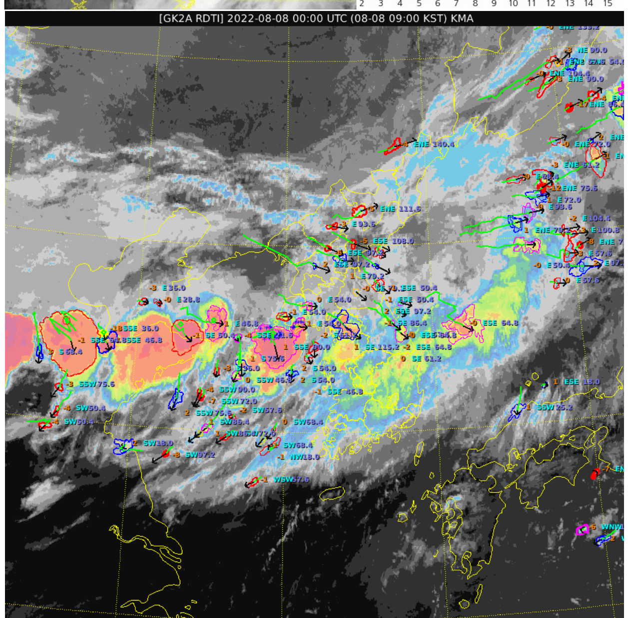
◆ **Improvement of non-convective cloud false detection using vertical temperature and humidity profile data**

⇒ Apply by analyzing the temperature difference between the upper and lower layers and the wet condition of the lower layer during summer



Future plan for CI & RDT improvements





CI improvement

- probability Ci calculation using machine learning
- Improved discontinuous detection through past 1-hour overlap of probability of CIs

RDT Improvement

- Optimizing ML for classify convective cells
- Classifying cloud cells and applying to dynamic threshold value

Fusion of CI+RDT+Threshold

- Optimizing Early detection
- Improving fusion algorithm

Typhoon

KMA Typhoon Operational Structure

Operational Forecast

Nominal: 1 forecaster 12-hr shift
Korea effect: 4 forecasters 24-hr shift

National Typhoon Center
Typhoon monitoring, forecasting, and report

Satellite based Analysis

National Meteorological Satellite Center
Center, Intensity, Wind Radii

Nominal: 1 operator 12-hr shift
Korea effect: 2 operators 24-hr shift

Radar based Analysis

Weather Radar Center
Center of the storm

Nominal: 1 operator 12-hr shift
Korea effect: 2 operators 24-hr shift

Satellites/Sensors

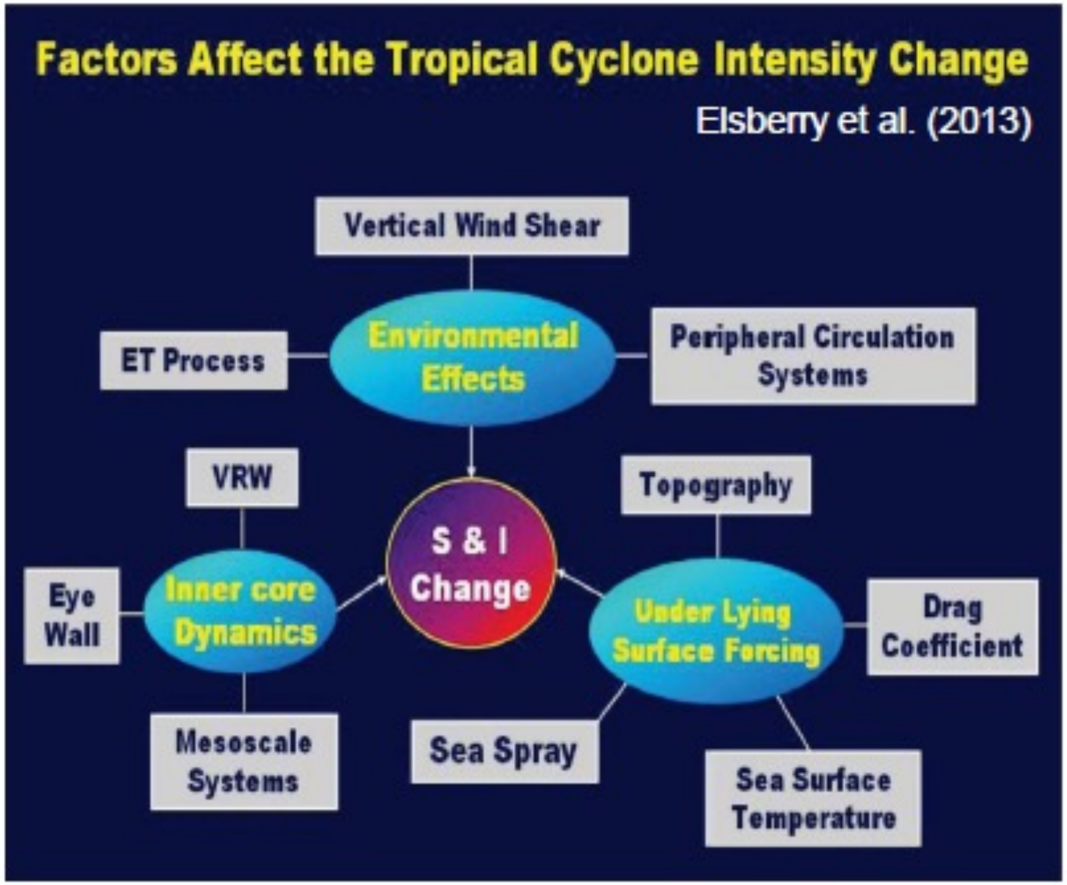
Satellite/sensor	Source	Software	Use	Comments
GK2A/AMI Himawari-8/AHI	KMA JMA	Cast/Cloud	Operational Occasional	Rapid Scan service
MetOp-B,C/ASCAT	Direct receive EUMETCast	AWDP Official Level-2	Operational	EOL(MetOp-A)
HY-2B,C/SCAT	EUMETCast	Official Level-2	Operational	
NOAA/AMSU, MHS NOAA,SNPP/ATMS	Direct receive	CSPP HEAP	Operational	
DMSP/SSMIS	FTP	Official EDR	Operational	
GCOM-W1/AMSR-2	FTP	Official Level-2	Operational	
GPM core/GMI,DPR	FTP	Official Level-2	Operational	

※ Many other satellite data used to create GK2A composite products like SST, OHC, Winds

Satellite-based Techniques

Technique	Source	Use	Comments
Subjective Dvorak	CIMSS	Operational	Every 1, 3, 6-hr
ADT K-ADT	CIMSS KMA	Operational	Every 10-min
ARCHER	CIMSS	Occasional	Every 3-hr
Multi-platform products GK2A Winds GK2A SST GK2A TDI GK2A DI GK2A PCT	KMA	Operational	Every 1-hr Once a day Once a day (OHC, T80/100/120, MPI, POT) Once a day (VWS, LVWS, CON, DIV, VOR) Every 6-hr (Rain, Wind)

Difficulties in Tropical Cyclone Intensity forecast



Additional Difficulties

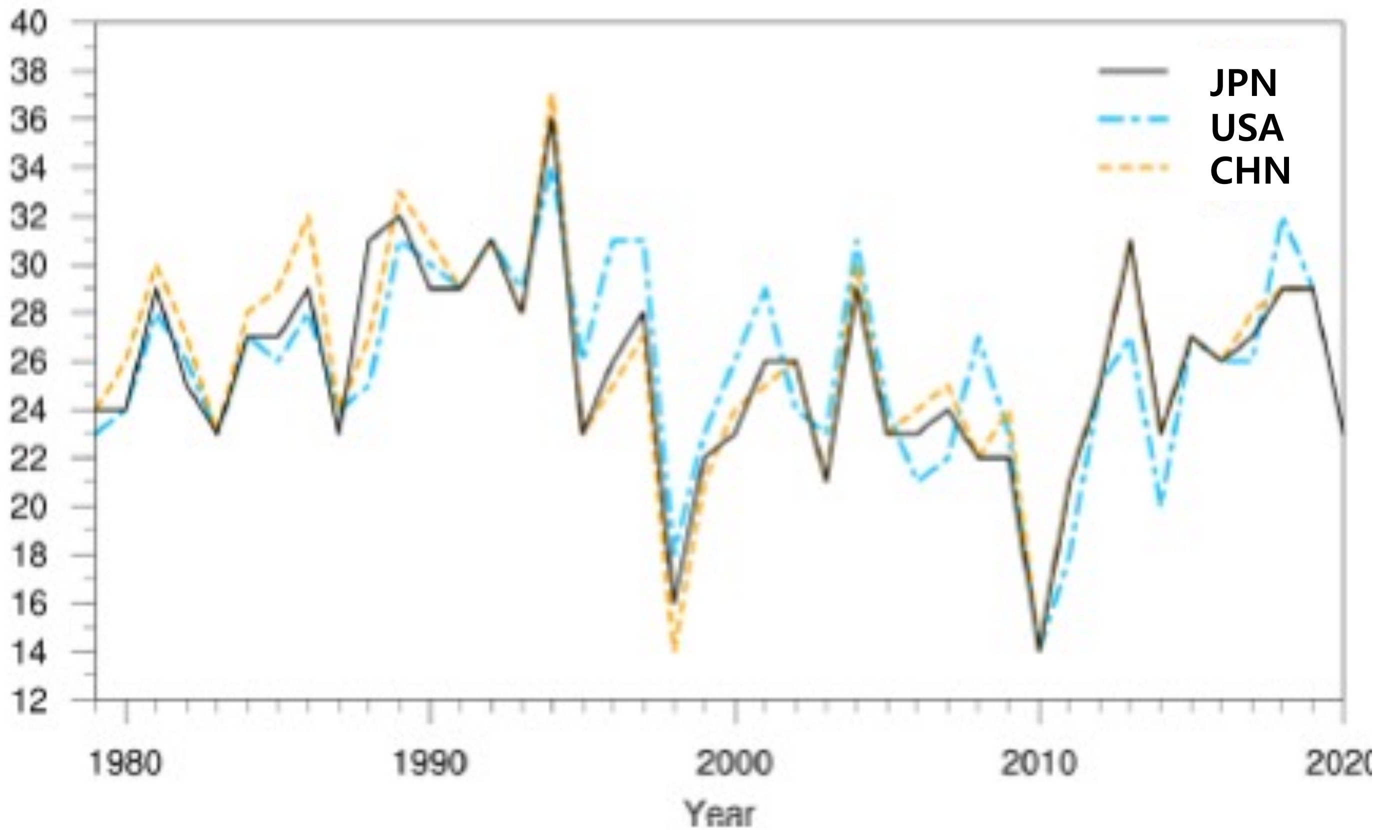
- ✓ TC Track errors
- ✓ Slow improvements in dynamical TC intensity prediction model
- ✓ Inaccurate intensity measurements

- ✓ TC intensification is influenced by various factors
- ✓ These impacts are not completely understood

Source: Prof. Ilju Moon, Jeju Univ.

Difficulties in Tropical Cyclone Intensity Estimation

◆Annual Typhoon occurrence in North-West Pacific

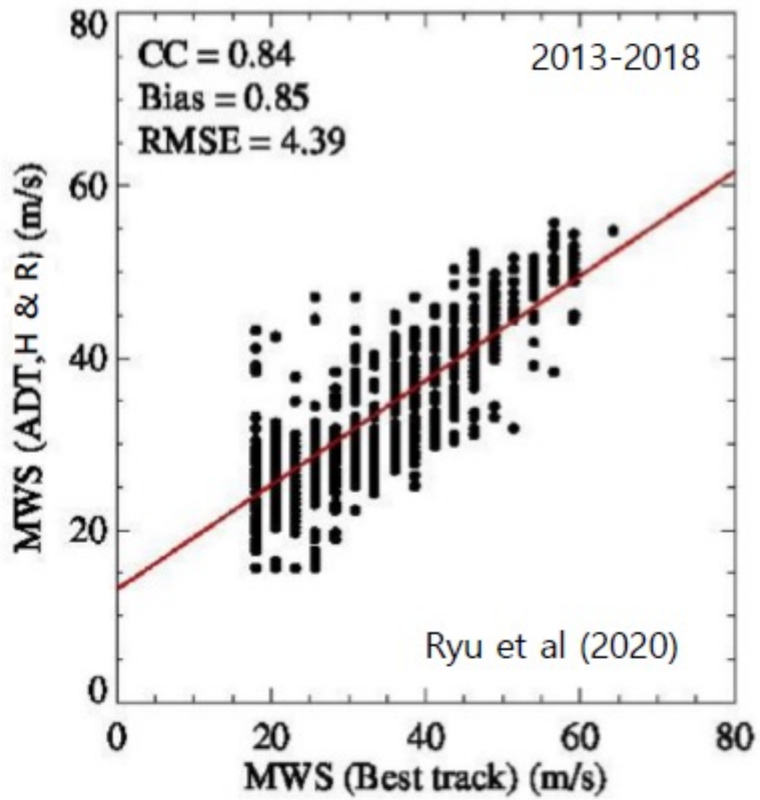


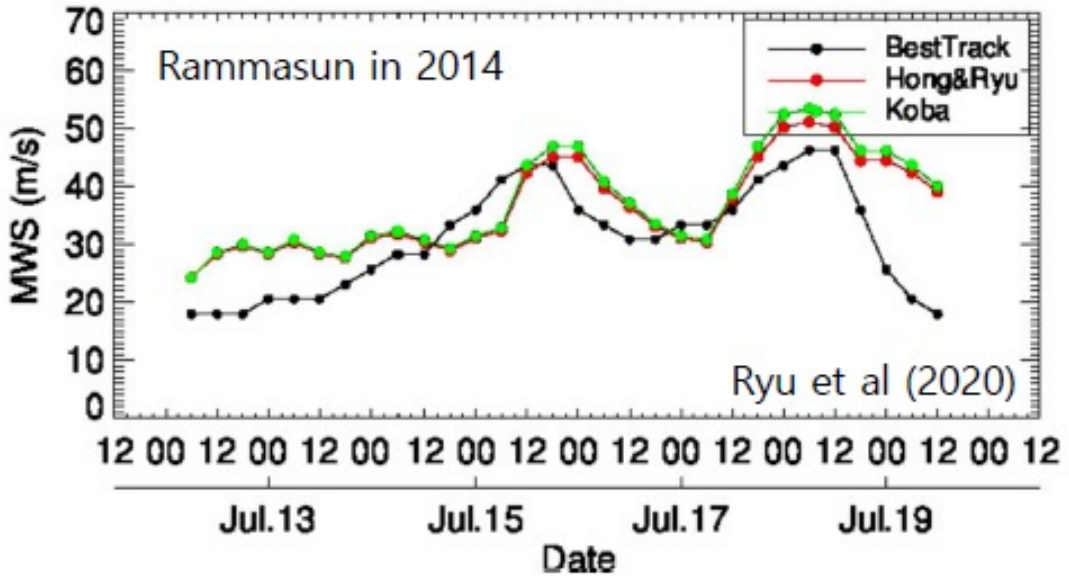
◆Intensities for same tropical cyclone estimated by JMA, CMA, and KMA etc are different

◆Therefore, three nations reported different number of typhoons

Source: Prof. Ilju Moon, Jeju Univ.

Accuracy of typhoon intensity estimated by ADT





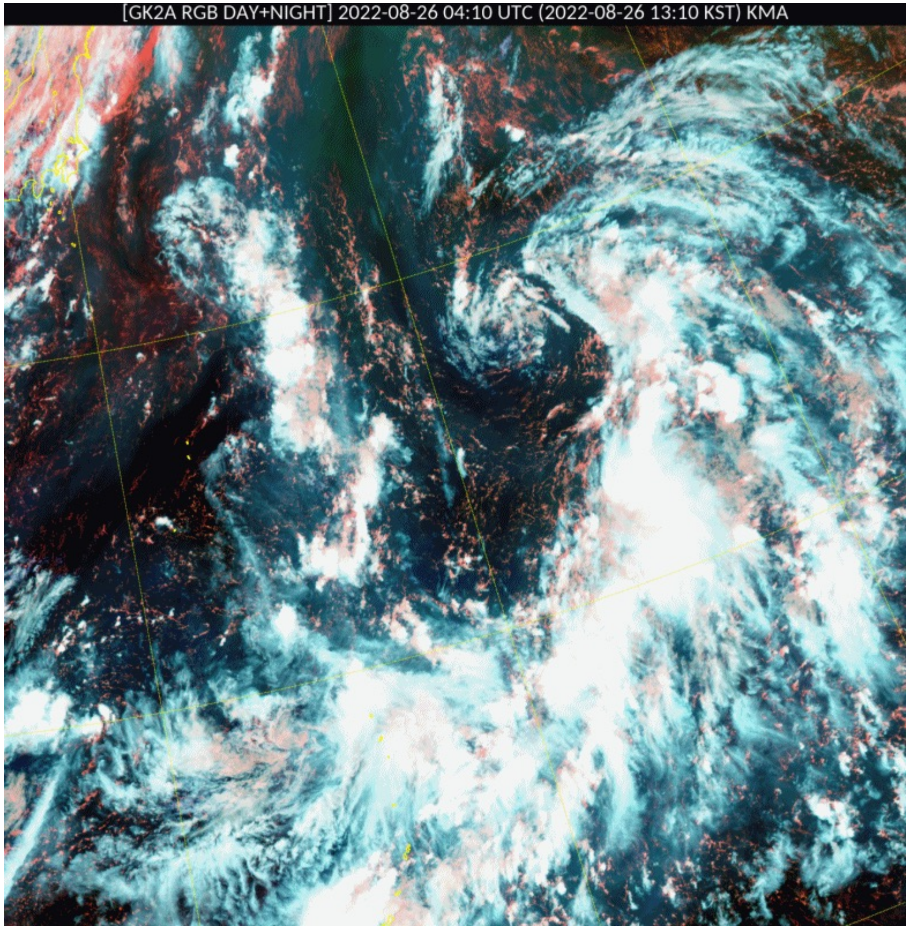
◆**Accuracy of ADT: r=0.84, RMSE=4.39m/s**

◆**Specially, large error for weak typhoons**

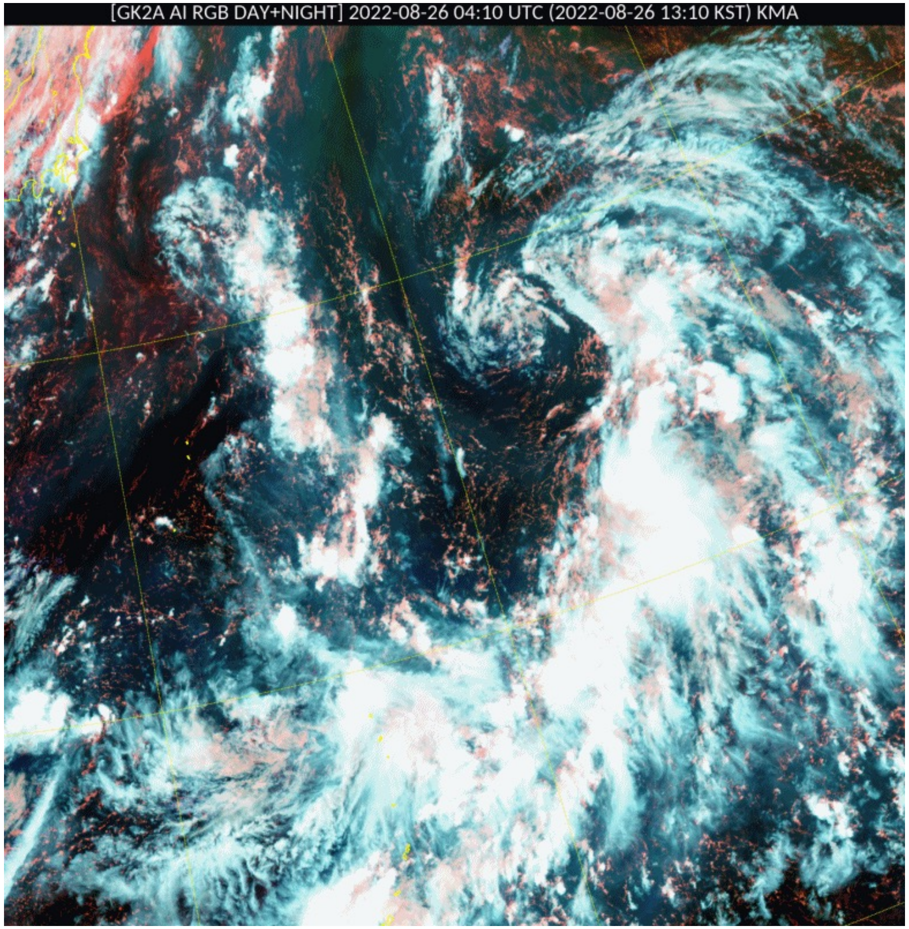
Source: Prof. Ilju Moon, Jeju Univ.

Typhoon Hinnamnor(2022)

◆ GK2A RGB day+night



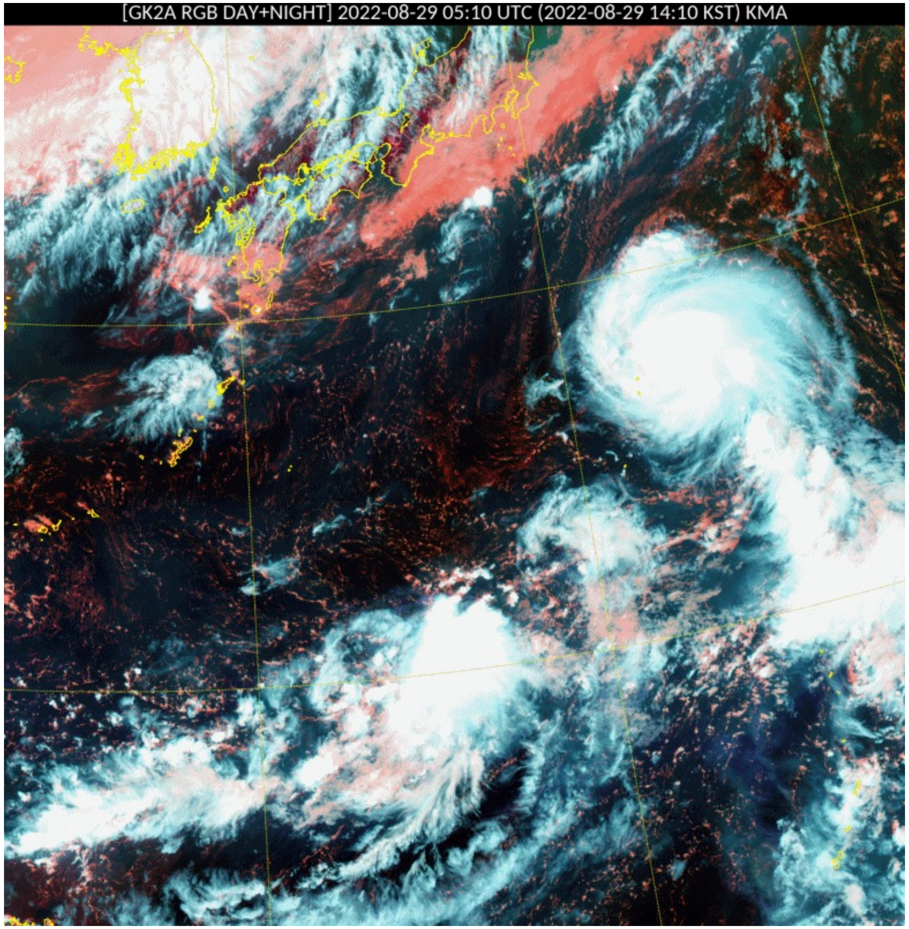
◆ GK2A **AI** RGB day+night



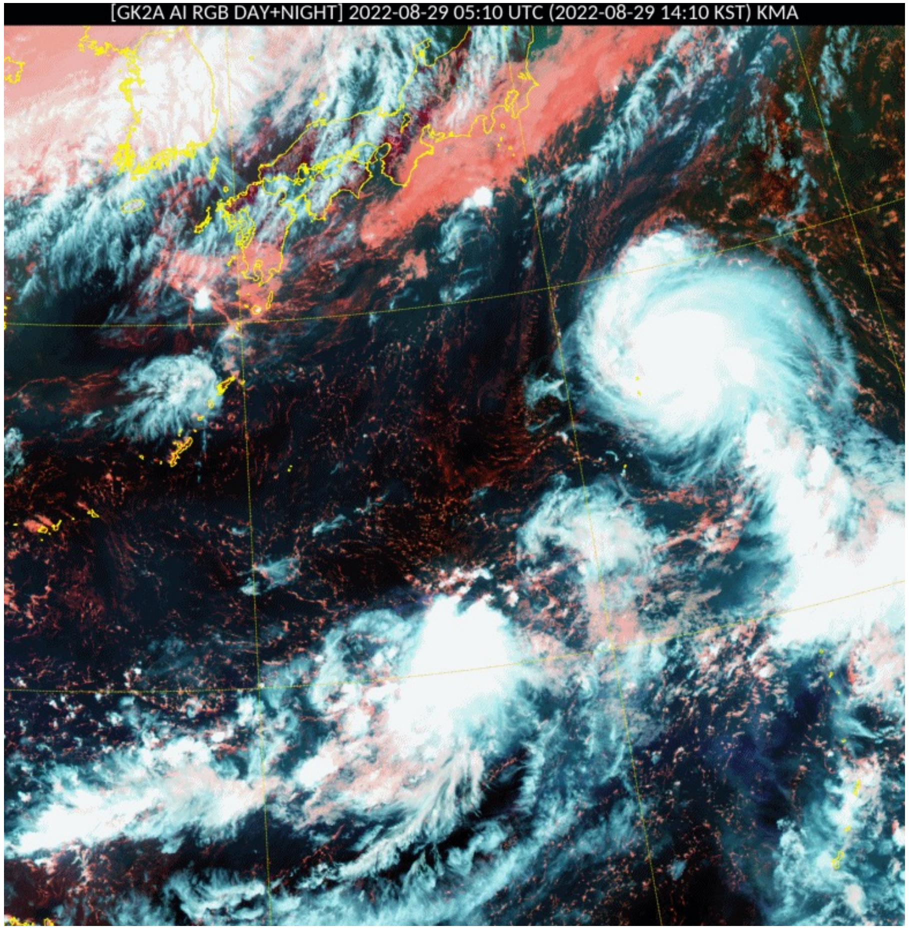
Aug. 26 04:10 ~ Aug. 28 01:10, 2022 (UTC)

Typhoon Hinnamnor(2022)

◆ GK2A RGB day+night



◆ GK2A **AI** RGB day+night



Aug. 29 05:10 ~ Aug. 31 01:10, 2022 (UTC)

Future plan for Typhoon intensity and size

- Currently, estimation of a typhoon's size in CNN model is created using COMS MI data. But a CNN model can be constructed with GK2A AMI when GK2A AMI data is accumulated. Transfer learning technology will be used with 5 channels of COMS MI + GK2A MI training data as an initial condition.
- In future, the maximum intensity estimated by artificial intelligence (AI) and equation of strong wind radii(Knaff et al. , 2017) can be used to estimate the size of the typhoon, which is an asymmetric long and short axis, or construct an AI model that directly estimates the asymmetric typhoon size with respect to the quadrant.
- By training various ocean atmospheric factors affecting typhoon intensity and size together with satellite data, it is possible to construct an AI model for predicting intensity and size with high accuracy.

Fog

Methods of Fog detection

◆ **For real-time fog detection over a wide … techniques using satellites have been devel…**

1. Mostly composed of small water droplets or supercooled water droplets

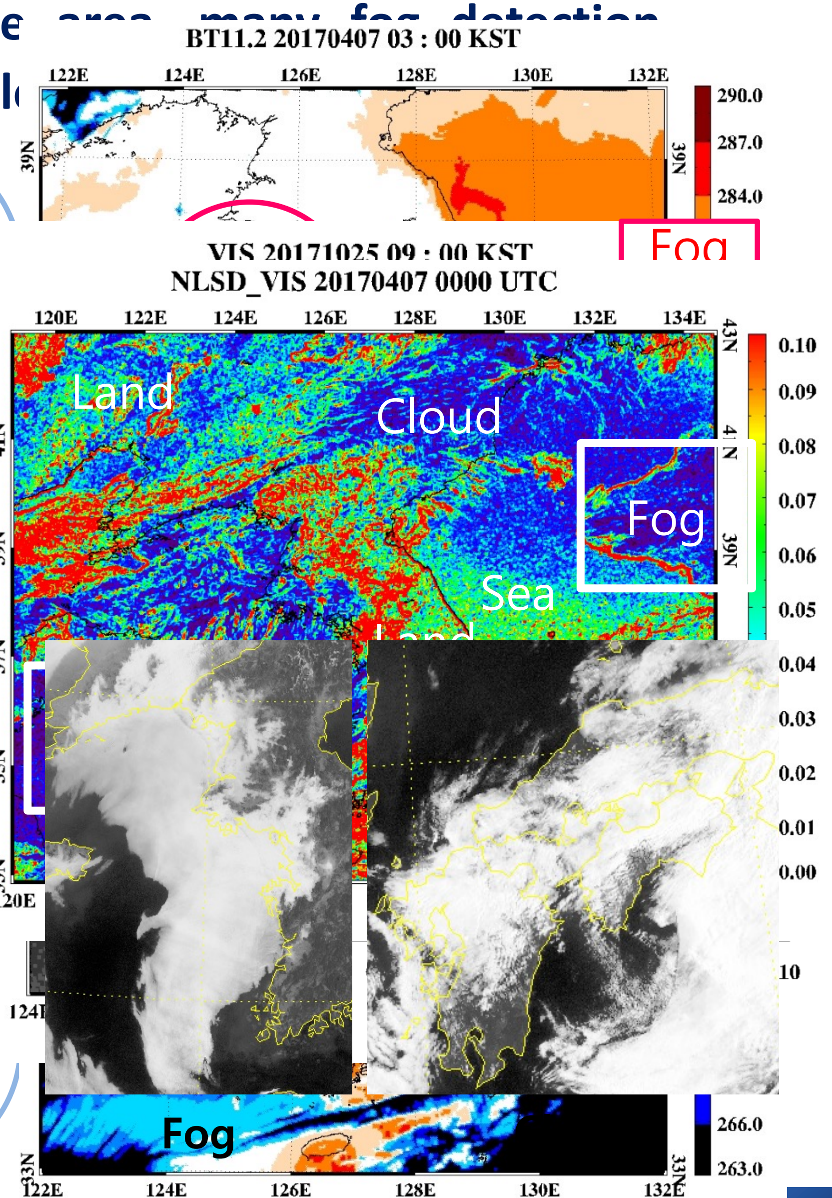
2. Although there is a difference depending on the size and concentration of the droplet, the emissivity of 3.9 µm is less than 11.2 µm(Eyre et al., 1984).

3. The reflectance of the visible channel is larger than that of the surface and the sea and is similar to that of clouds(Wen et al., 2014)

4. The temperature at the fog top is similar to the surface temperature(Sin et al., 2013; Suh et al., 2017)

5. The upper surface of the fog is more homogeneous than the cloud or the ground surface(Park and Kim, 2012)

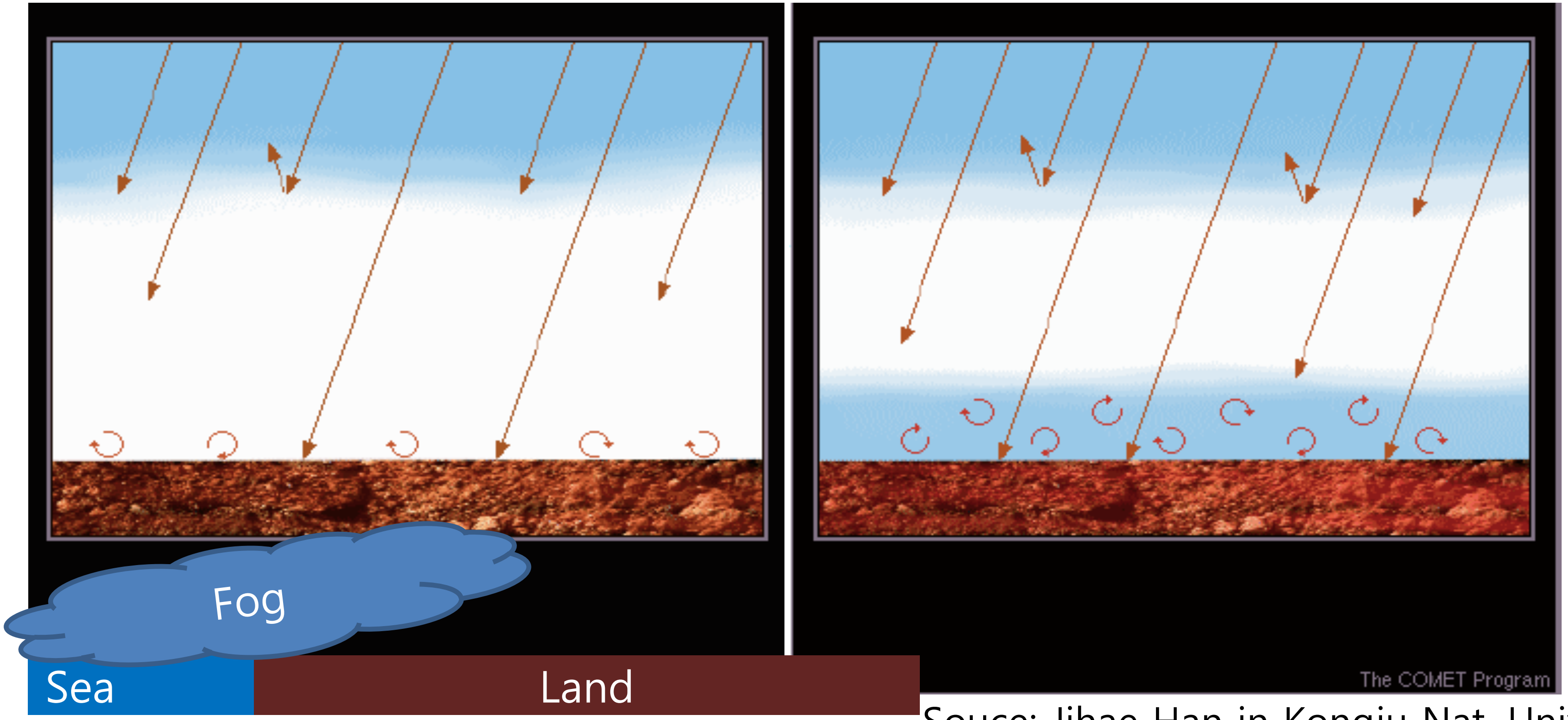
6. Sea fog has clearer boundaries and less movement than clouds



Limitation of Fog detection

◆Issues of fog detection

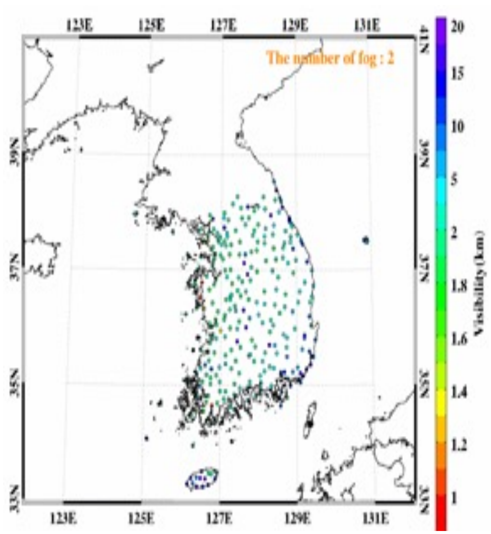
- When fog is dissipated from the ground by radiative heating of the ground → Fog and haze cannot be distinguished from the satellite
- When sea fog moves to land, rising due to the difference in densities between the ground and the atmosphere → Classifying low clouds or haze not fog.

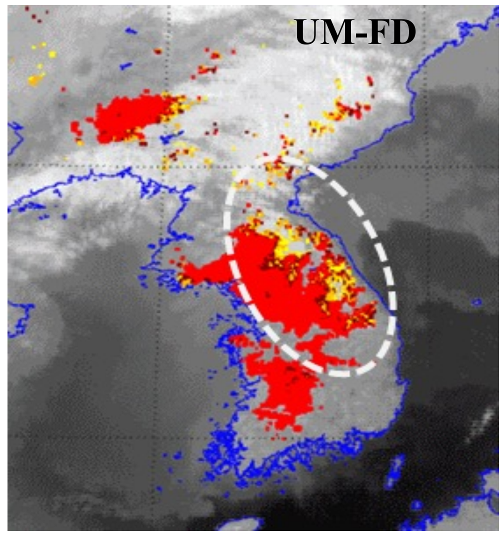


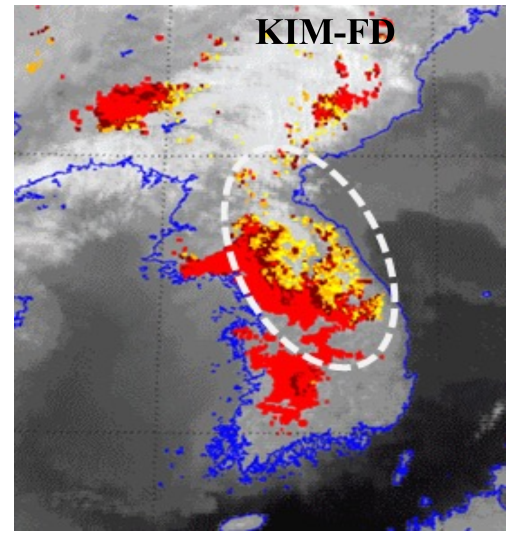
Souce: Jihae Han in Kongju Nat. Univ.

GK2A Fog detection Improvement

- Solving false detection using numerical model improvement (decrease in false fog detection areas in KIM-FD due to low clouds)
- Data : validation analysis for input data in numerical model of UM and KIM







Model	Threat Scores of 7 fog cases in 2022							
	3. 16.	3. 27.	4. 4.	5. 3.	6. 10.	6. 17.	6. 21.	**Total**
UM-FD	0.205	0.332	0.063	0.211	0.112	0.119	0.107	**0.1641**
KIM-FD	0.203	0.329	0.063	0.206	0.111	0.126	0.107	0.1636
KIM-meso	0.197	0.330	0.063	0.207	0.110	0.119	0.107	0.1619
Optimized KIM-FD	0.203	0.332	0.063	0.212	0.110	0.123	0.107	**0.1643**

Future plan for fog detection

◆ Verification of fog

- Using polar orbiting satellites such as CALIPSO even if verification is possible only when the corresponding satellite passes to the area where the haze occurred
- Utilization of many visibility measurement on land

→ Developing meteorological observation systems such as fog, visibility over high-ways

→ Fog observation having high-resolution with a few hundred meters supporting a new transportation, Urban Air Mobility(UAM)

- Accuracy problems of visibility measurement

→ Need to build an integrated DB of fog observation data

Thank you for your attention!