Joint Korea Australia VLab Centres of Excellence Regional Focus Group meeting

Application of GEO-KOMPSAT-2A Data for Severe Weather Detection

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KMA/NMSC

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Contents

1. Water Vapor images Interpretation

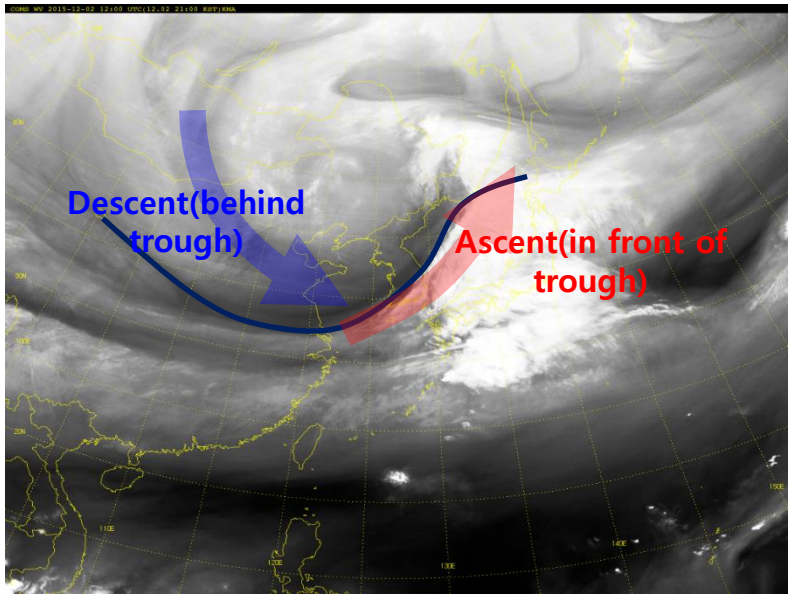
1. Trough analysis using Water Vapor Image

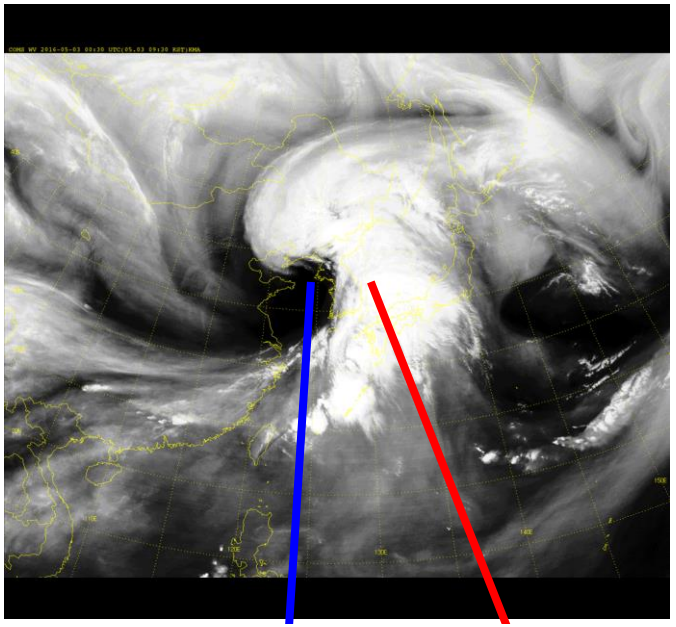
Trough: Vertical motion on WV around trough

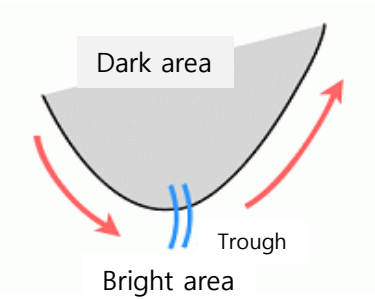
The vertical motion of the atmosphere can be estimated on wv images.

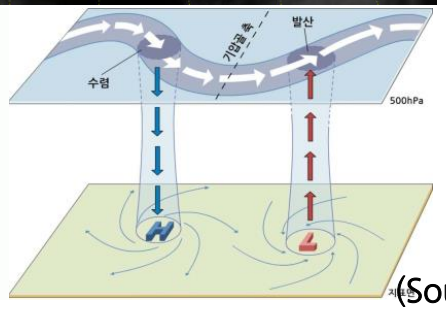
Sinking area: Darker in the image as the atmosphere becomes drier

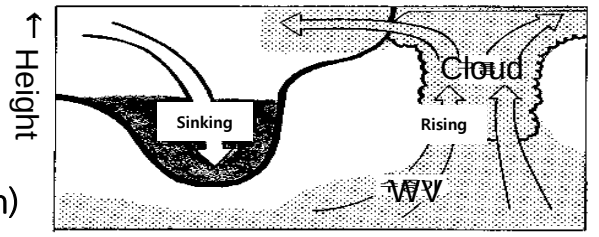
Rising area: transferred to the upper layer of water vapor, increasingly bright











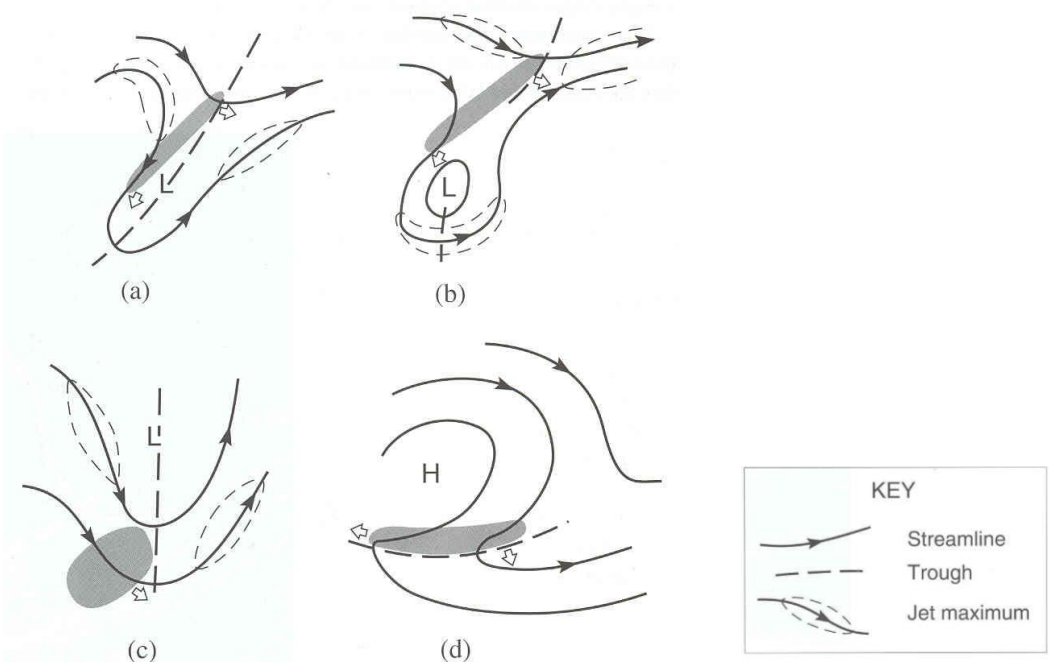
(Sources : Eumetrain)

2. Trough analysis using Water Vapor Image

Trough position with dry area

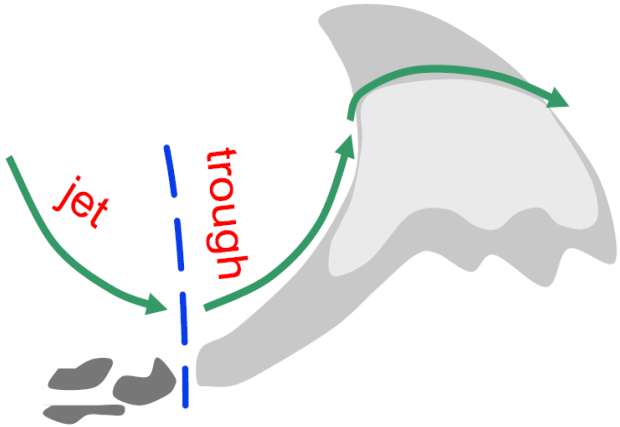
Schematic diagrams of the location of dry area and trough on water vapor images

- Trough tends to be located in front of maximum darkening dry area of water vapor image
- Clouds develop in front of the trough, and cloud bands associated with "warm conveyor belt" develop in front of the upper trough



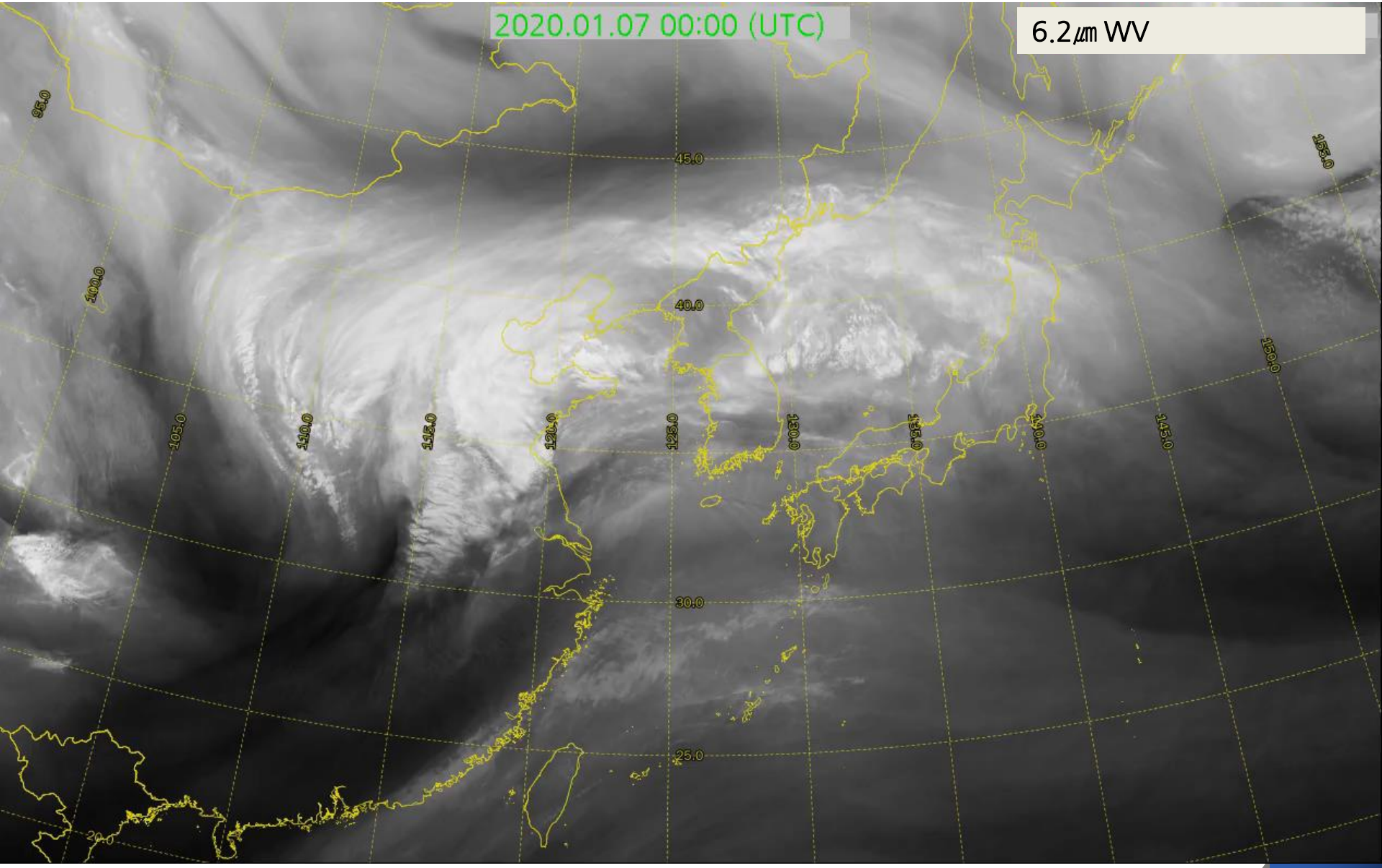
A schematic diagram of darkening dry area and upper air flow patterns
(Shaded: Darkening Zone)

(Sources : Eumetrain)



A schematic diagram of trough according to cloud distribution

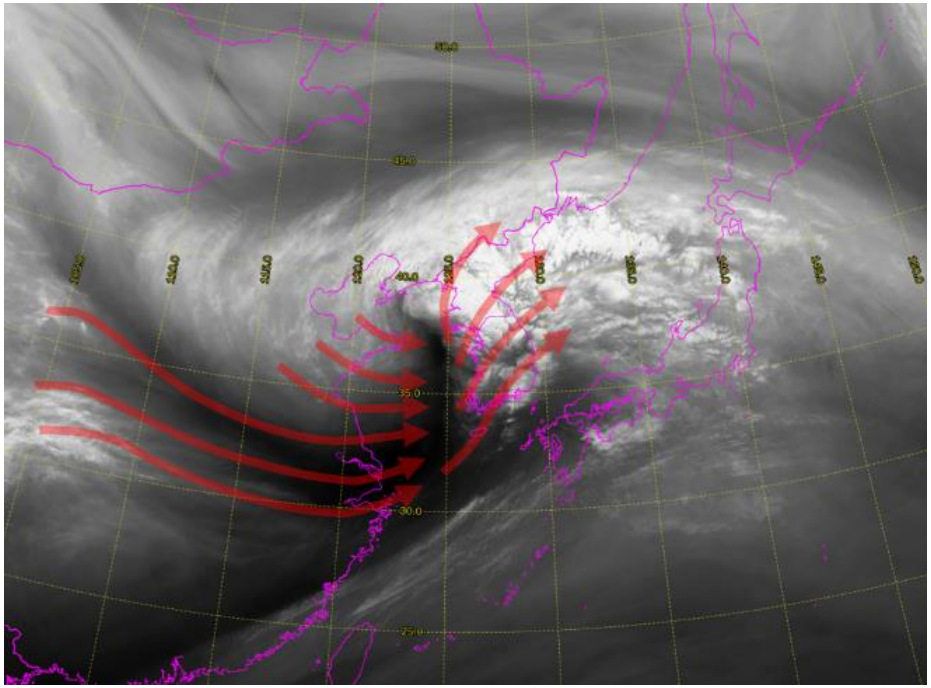
3. Trough analysis using Water Vapor Image



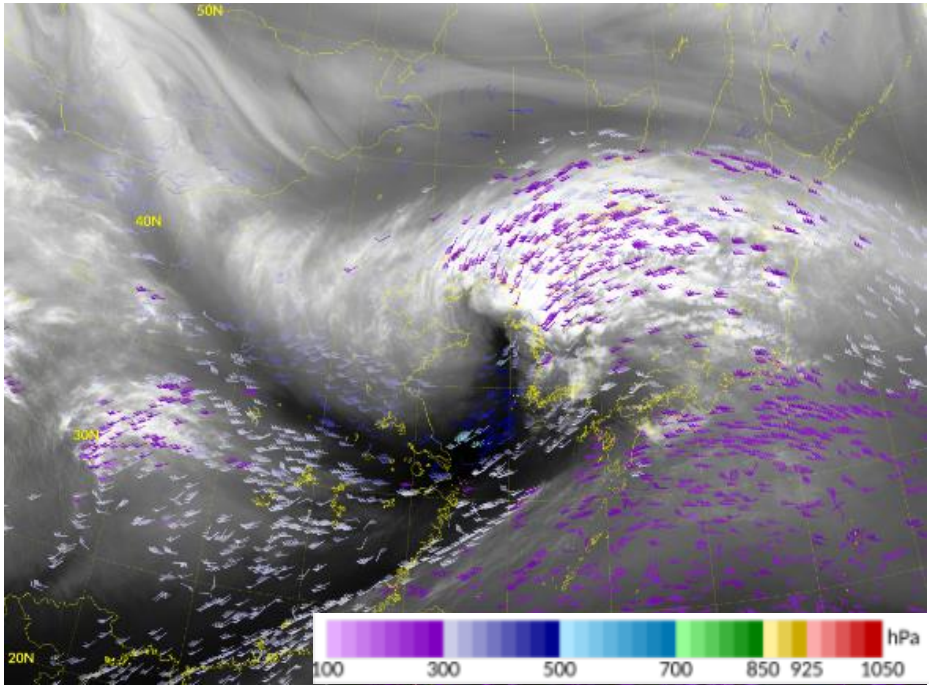
4. Trough analysis using Water Vapor Image

Trough analysis

- (Step 1) Identify low pressure curvature or low pressure rotational areas in the flow on water vapor images
- (Step 2) Identification of the vertical flow of falling (dry area) and rising (wet zone) from the upper(6.2), middle(6.9), and lower(7.3) water vapor images or AMV images



[Step 1] - WV(6.3 ㎛)



[Step 2] - AMV((6.3 ㎛)

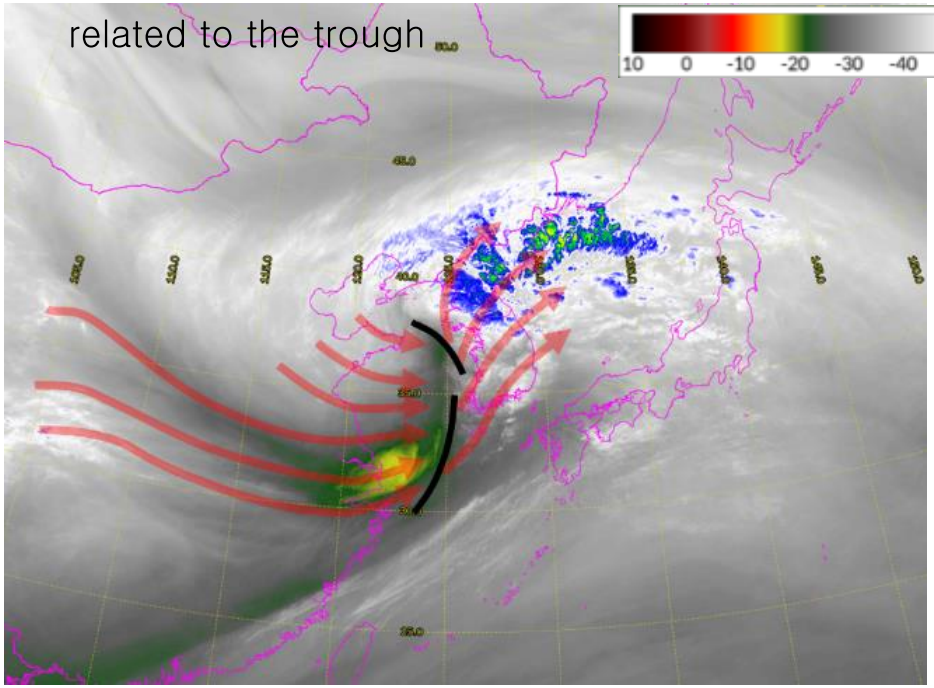
trough flow

2020.01.07. 21:00KST(12UTC)

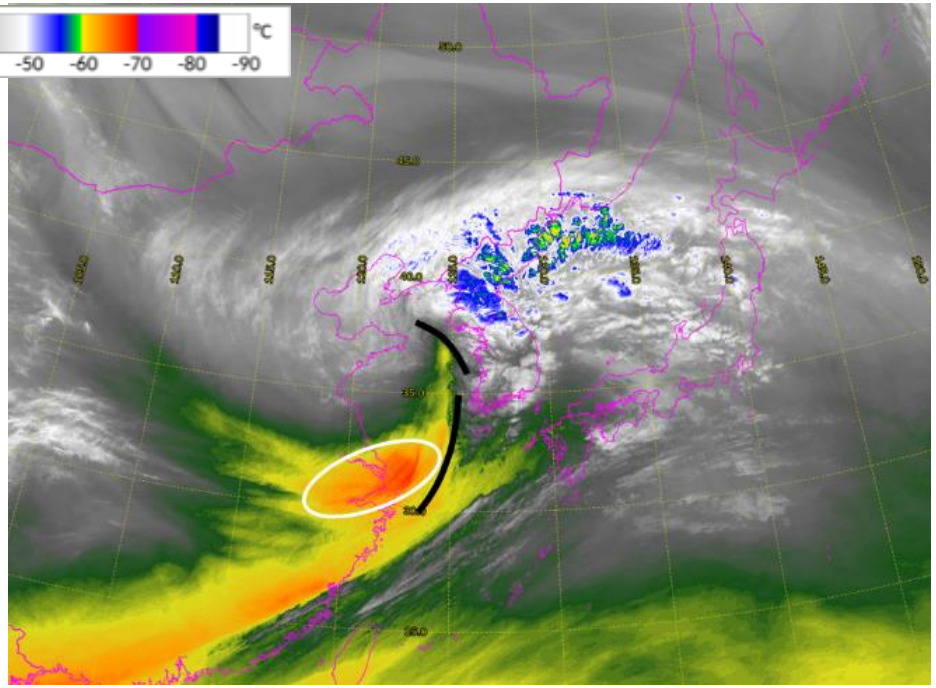
5. Trough analysis using Water Vapor Image

1) Trough analysis

- (Step 3)Determine trough at the lowest point of the low-pressure curvature with a falling and rising vertical flow
- (Step 4)In the color WV image, the front of the maximum brightness temperature in the dry area coincides with the trough. i.e., the area with high brightness temperature in the dry area is closely related to the trough



[step 3] - color WV(6.3 ㎛)



[step 4] - color WV(6.9 ㎛)

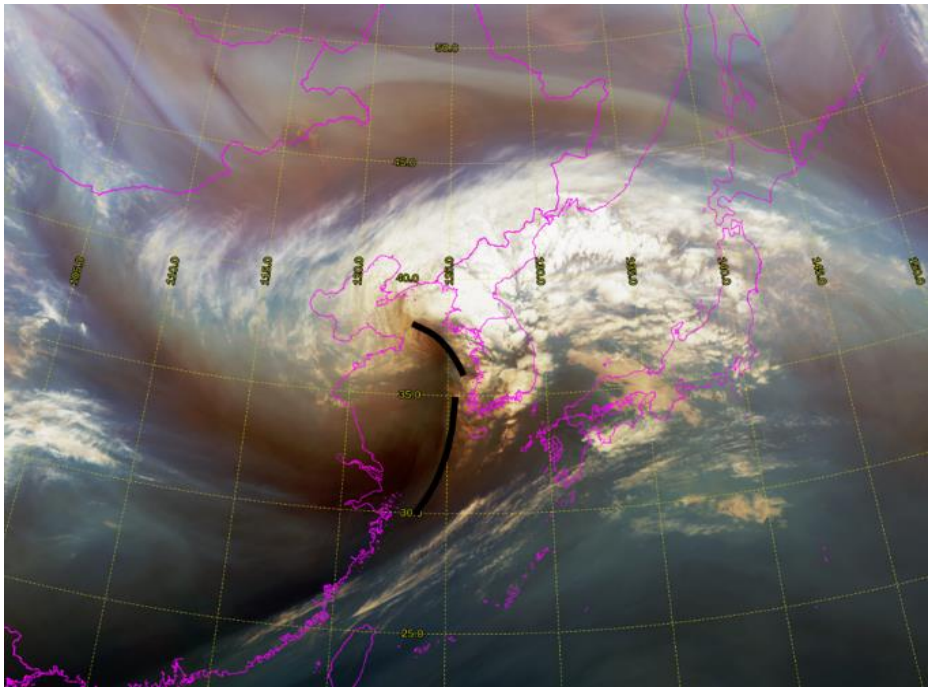
trough flow

2020.01.07. 21:00KST(12UTC)

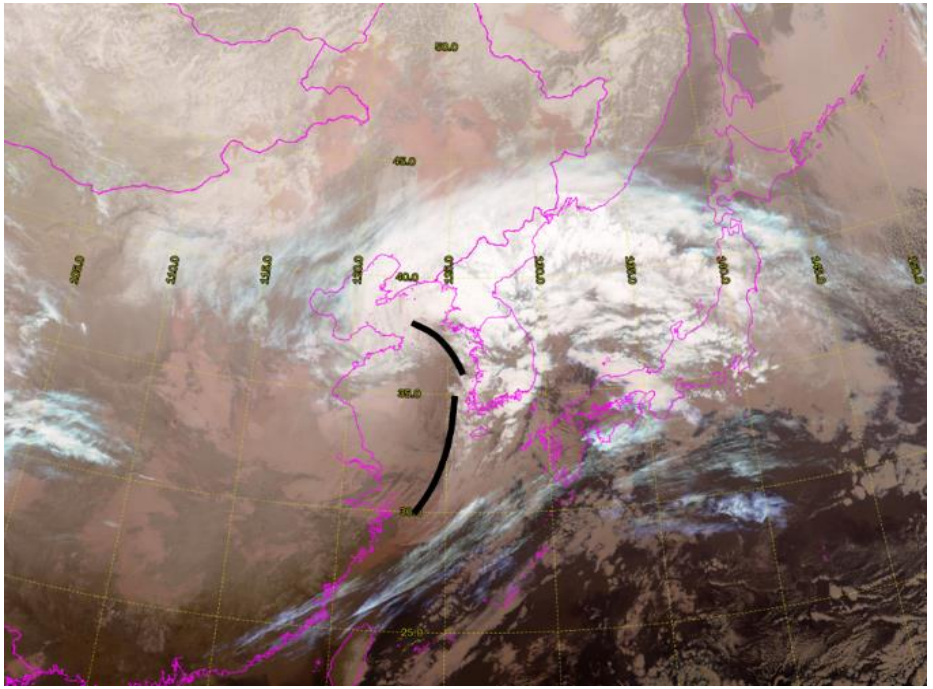
6. Trough analysis using Water Vapor Image

1) Trough analysis

- (step 5) In the RGB 3-channel water vapor image, the front of the trough is positioned in an orange shade, and the dark brown/navy area on the rear of trough
  (step 6)In the RGB IR &VIS composite image, clouds generate and develop in front of the trough, and dissipate and weaken in the rear of it



[step 5] - RGB 3-channel WV



[step 6] - RGB IR & VIS composite image

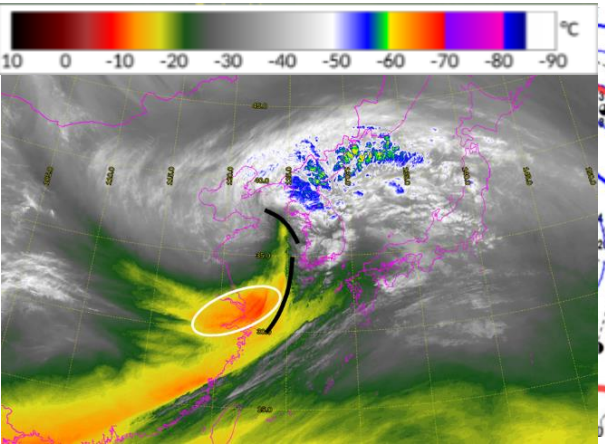
trough flow

2020.01.07. 21:00KST(12UTC)

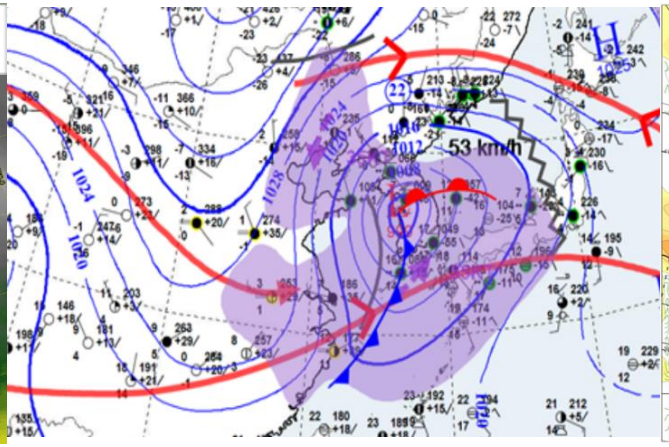
7. Trough analysis using Water Vapor Image and Chart

1) Trough Comparison in chart

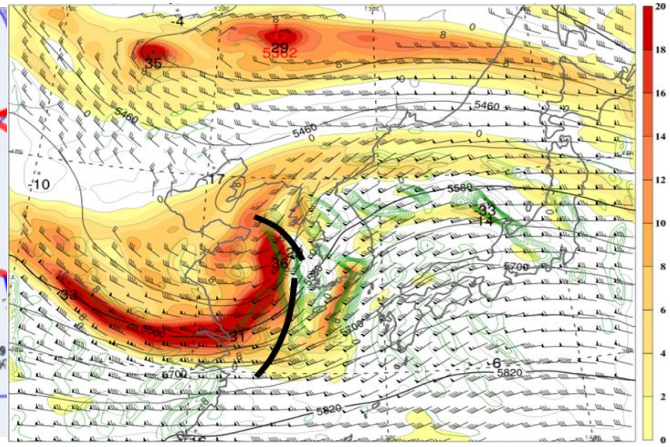
- Wind-changing areas in 500 hPa wind field / the lowest areas in 500 hPa height
- Relative vorticity Maximum area / Just behind relative vorticity Maximum area



[color WV(6.9 ㎛)]



[surface chart]



[500 hPa vorticity & vorticity adv. (UM)]

trough

2020.01.07. 21:00KST(12UTC)

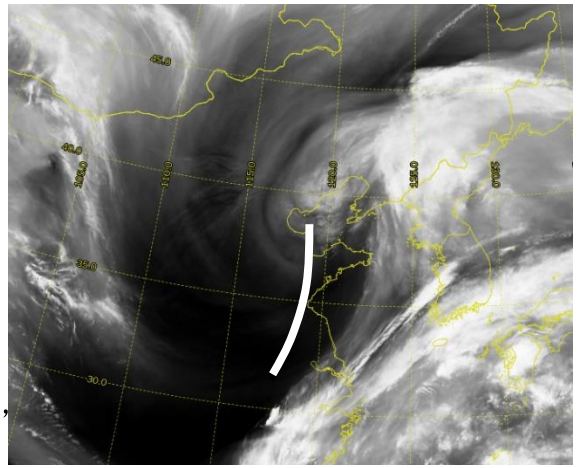
8. Trough analysis using Water Vapor Image: Case study

1) Trough case study (deep trough case, 2020.05.18.)

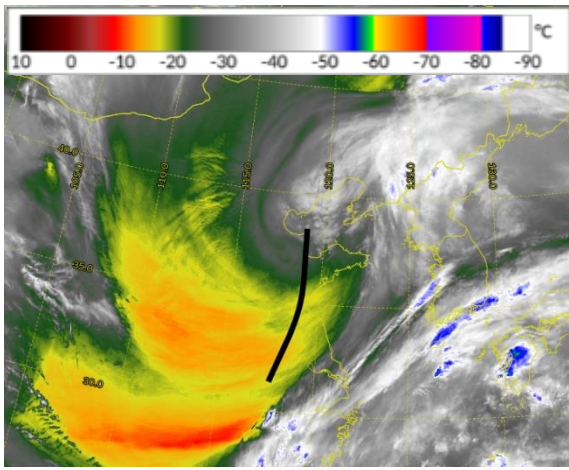
Developing (2020.05.18. 09 KST(00UTC)) : Dry slot

- Low pressure curvature deeper
- Dry slot appears where dry air penetrates into the head cloud area along the low-pressure rotational cloud
- Expansion of wet areas in front of dry areas
  Dry area are strengthened green, yellow, and red areas in the color water vapor image
- In the RGB 3-channel water vapor image, the front of the trough gradually brightens to orange, and the rear gradually darkens to dark brown/navy area
- Thick clouds generate and develop in front of the trough

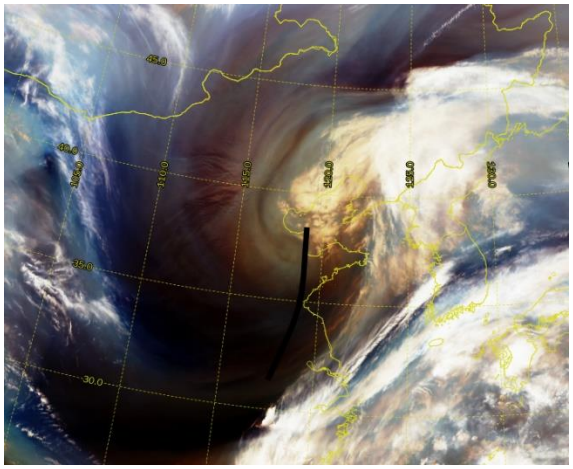
[6.3 ㎛ WV]



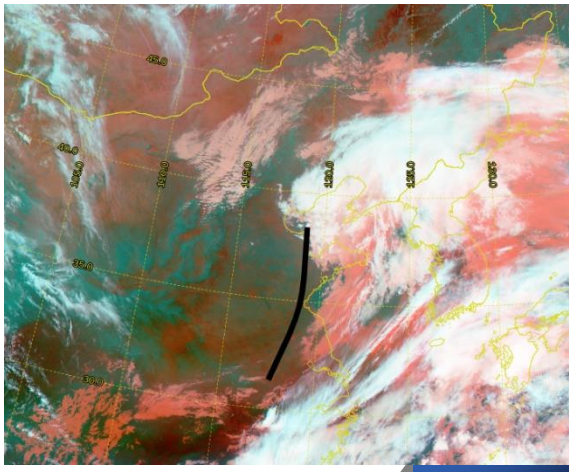
[color WV(6.9 ㎛)]



[RGB 3channels WV]



[RGB composite]



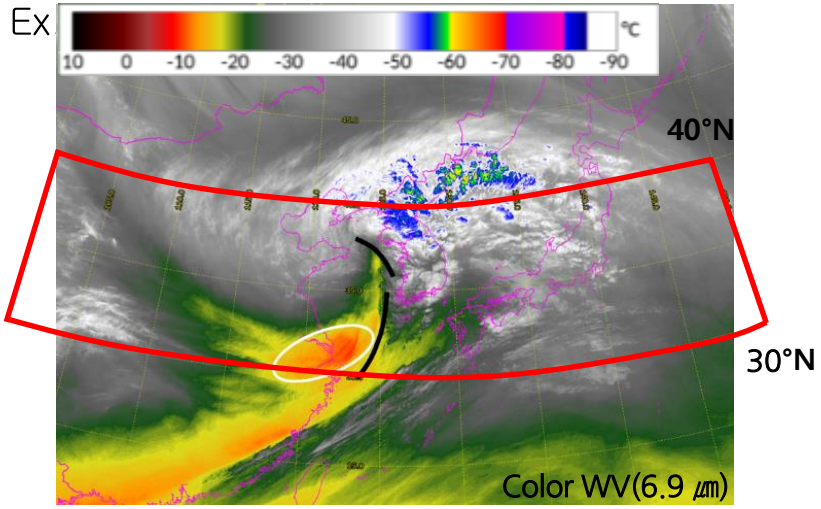
9. Trough analysis with dry area track of WV data

Dry area track

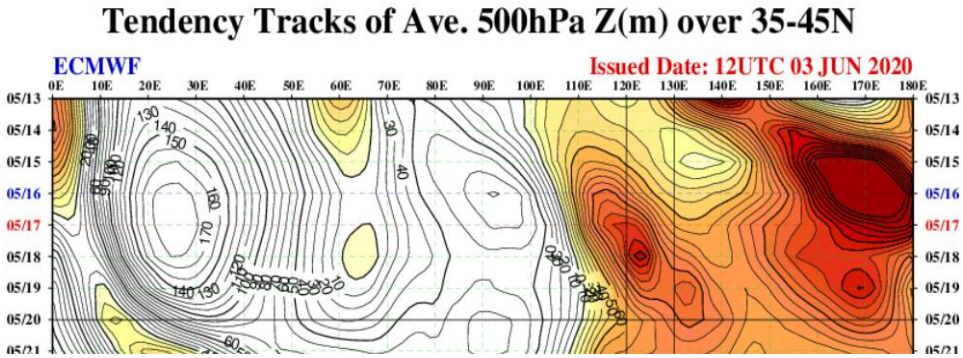
- Dry area track : By expressing the BT of the water vapor channel over time like the Hovmoller diagram, it is easy to track the dry and wet areas of water vapor and to analysis of development and weakening tendency of the dry area and trough
- Dry area track produce in a similar way to the “Tendency Tracks of Average 500hPa height” provided by KMA

- Hovmoller diagram : An analysis technique developed by Hovmoller in 1949 that has the latitude or longitude as the x-axis or y-axis for any variable and the other axis represents the change over time

Ex



30~40N Average Latitude



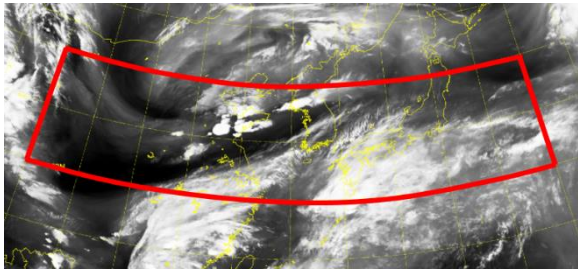
Tendency Tracks of Ave. 500hPa height” by KMA

10. Trough analysis with dry area track on WV data

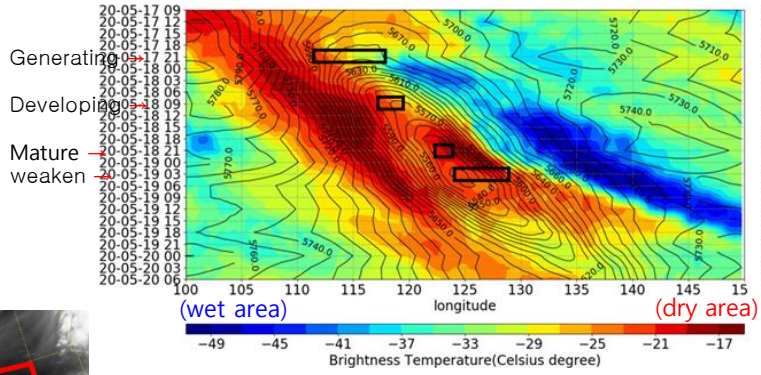
Comparison with Max. BT & trough (case 2020.05.18.)

- BT ↑ (dry area strength ↑) as the reddish color gets darker, and BT ↓ (wet area strength ↑) as the bluish color gets darker.
- Generating time (2020.05.17.21KST), Developing (2020.05.18.09KST): Water vapor maximum BT area (darker red area) is located at the rear of the trough
- Mature (2020.05.18.21KST), weaken (2020.05.19.03KST): Water vapor maximum BT area and trough area are match

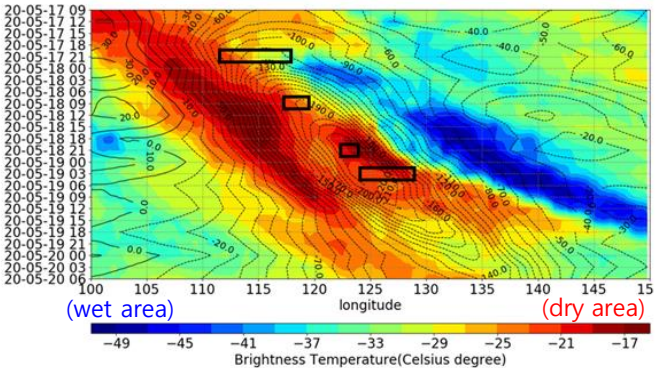
Mean latitude (30-40°N)



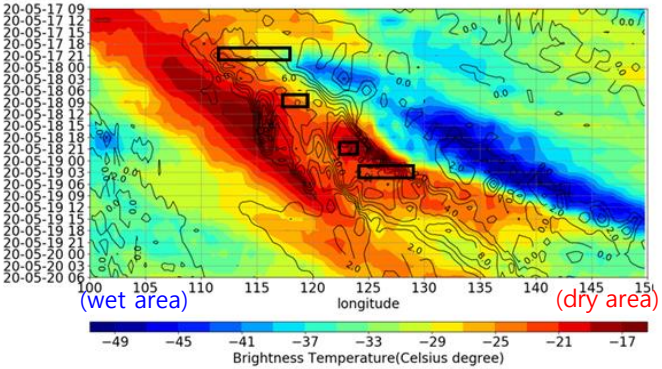
▭ : Trough area in sysnoptic chart
- When trough is located from west to east, length of the box is long horizontally
- When trough is located from north to south, length of the box is short
- In weakening time the trough axis may differ from trough on the weather chart



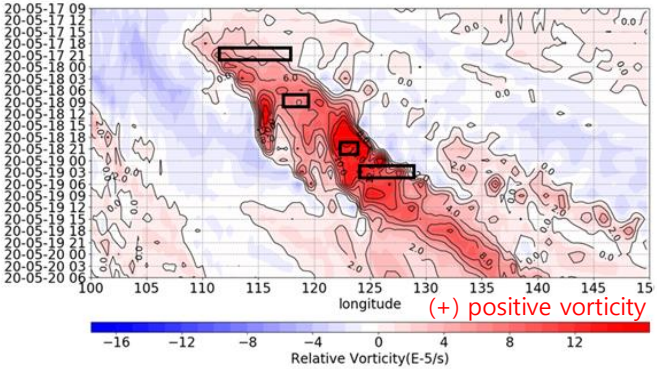
(a) Dry area track map+ 500hPa Height



(b) Dry area track map+ 500hPa Height difference



(c) Dry area track map+ 500hPa relative vorticity

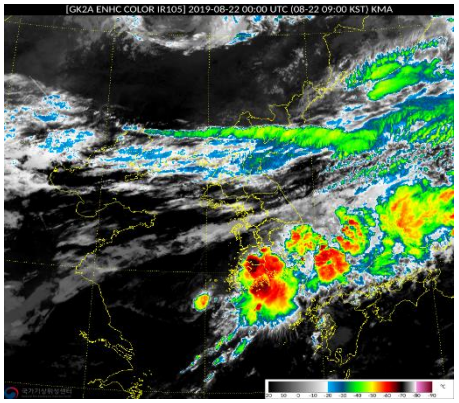


(d) 500hPa relative vorticity

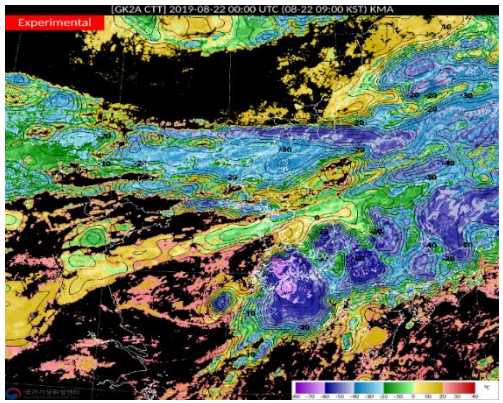
2. Heavy Rainfall Analysis with satellite images

1. Satellite products for heavy rain analysis

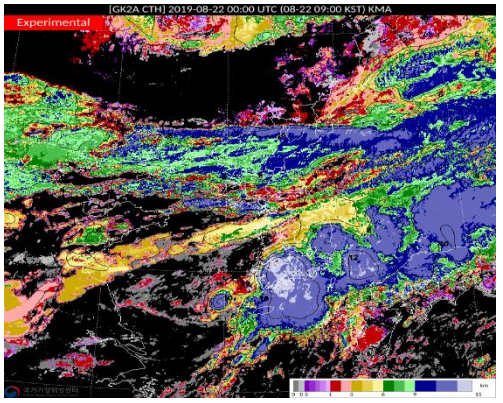
- **products for heavy rain analysis : IR, VIS, WV, and composite images, Rain rate, total precipitable water**



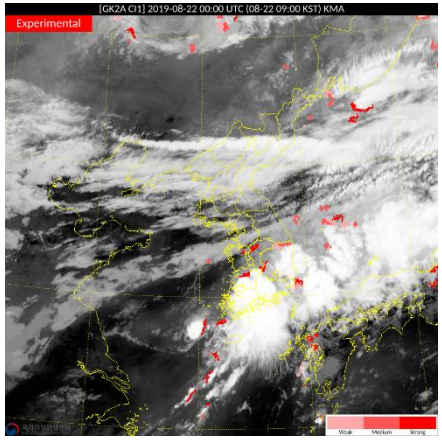
Enhanced IR



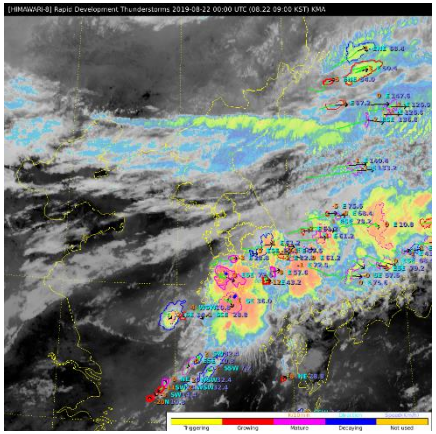
CTP



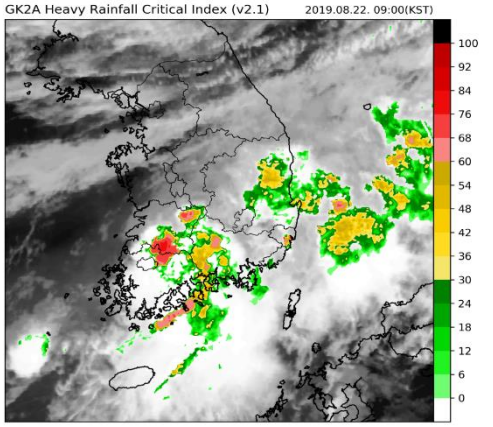
CTH



CI(convective Initiation)



RDT(Rapid developing thunderstorm)



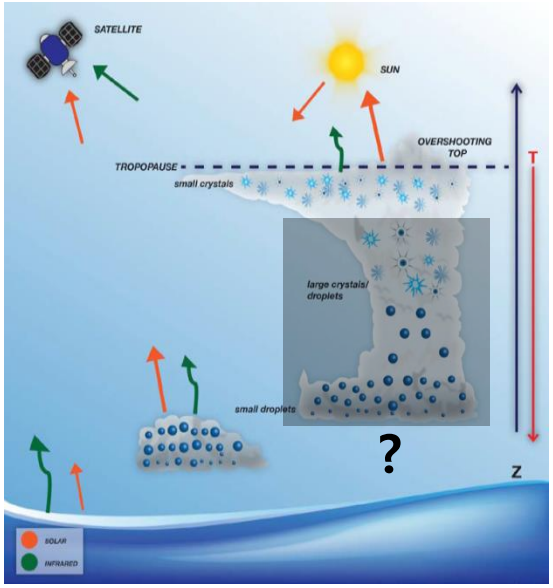
Heavy rain index

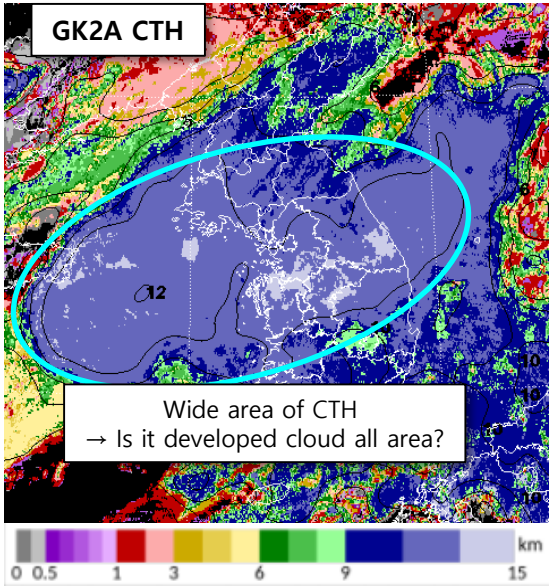
⇒ The products provide information of cloud top temp. & height.

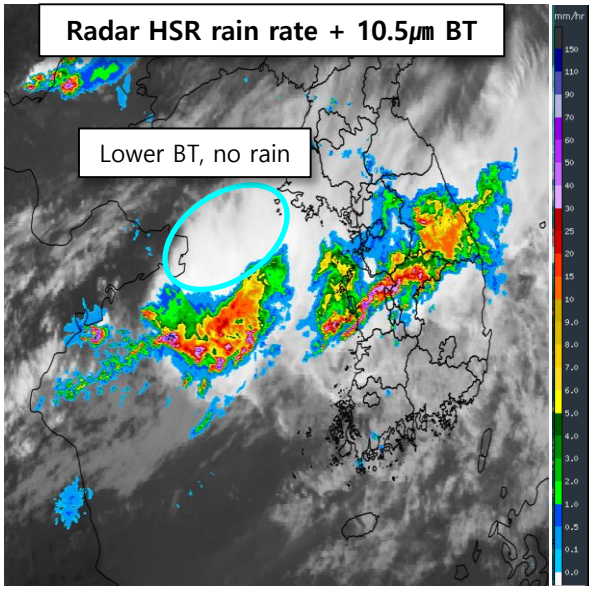
⇒ It is difficult to identify cloud development situations on the ground.

2. Production of CBH & CGH

Background







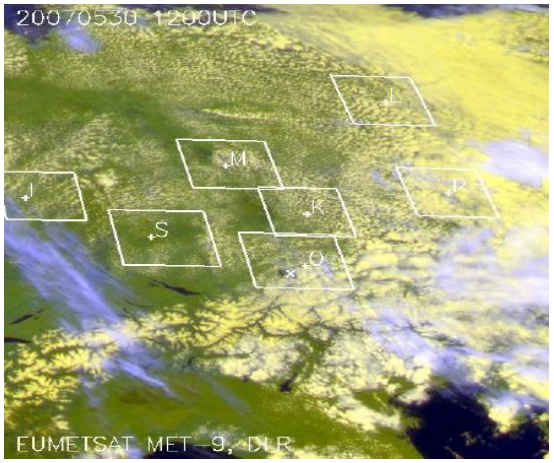
- We can only see the cloud top information on satellite images.
  It is difficult to distinguish that developed cloud or not using only cloud top information
- What if we could estimate the cloud thickness and the cloud elevation to determine the vertical distribution of the cloud?

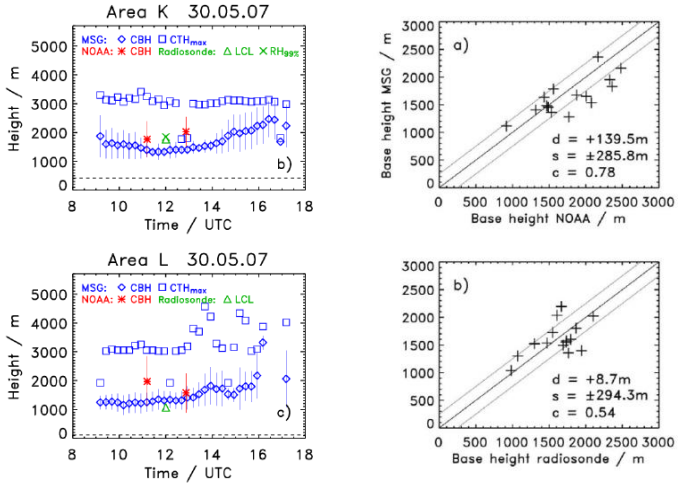
  - CBH: Cloud base height
  - CGH: Cloud Geometrical Thickness

3. Production of CBH & CGH

Prior research

- Meerkötter and Bugliaro (2007): Analysis of cloud base height of developing convective cloud in MSG/SEVIRI





- Seaman (2017): Cloud base height estimation using Suomi-NPP/VIIRS data and validation using CloudSat(operation in NOAA)

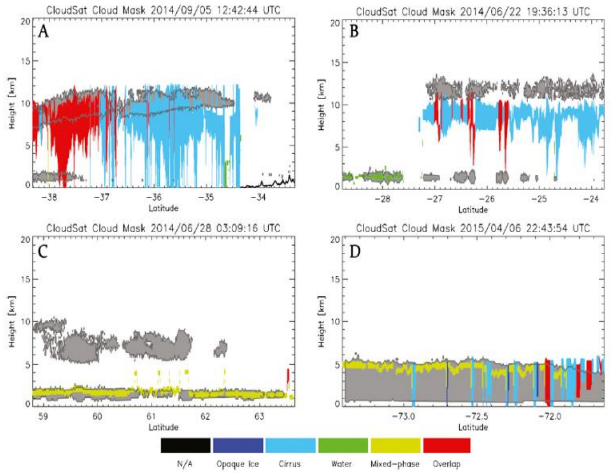


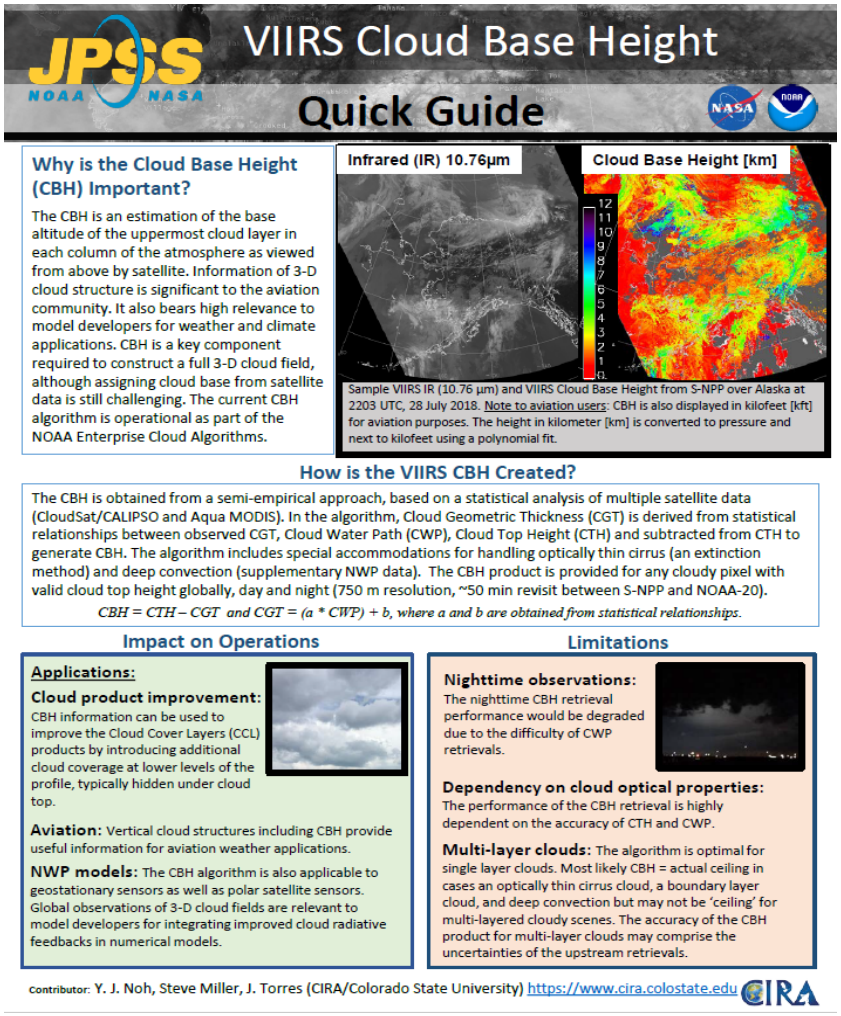
TABLE 5. Statistics of VIIRS CBH retrieval performance as compared to *CloudSat* observations for the subset of valid matchup points where the CTH retrieval was Within CTH Spec and all clouds were assumed to have a CGT of 2 km. Bold values indicate improvement over the IDPS CBH retrieval results shown in Table 4. Note that a negative error means the VIIRS CBH value is less than the *CloudSat* CBH value.

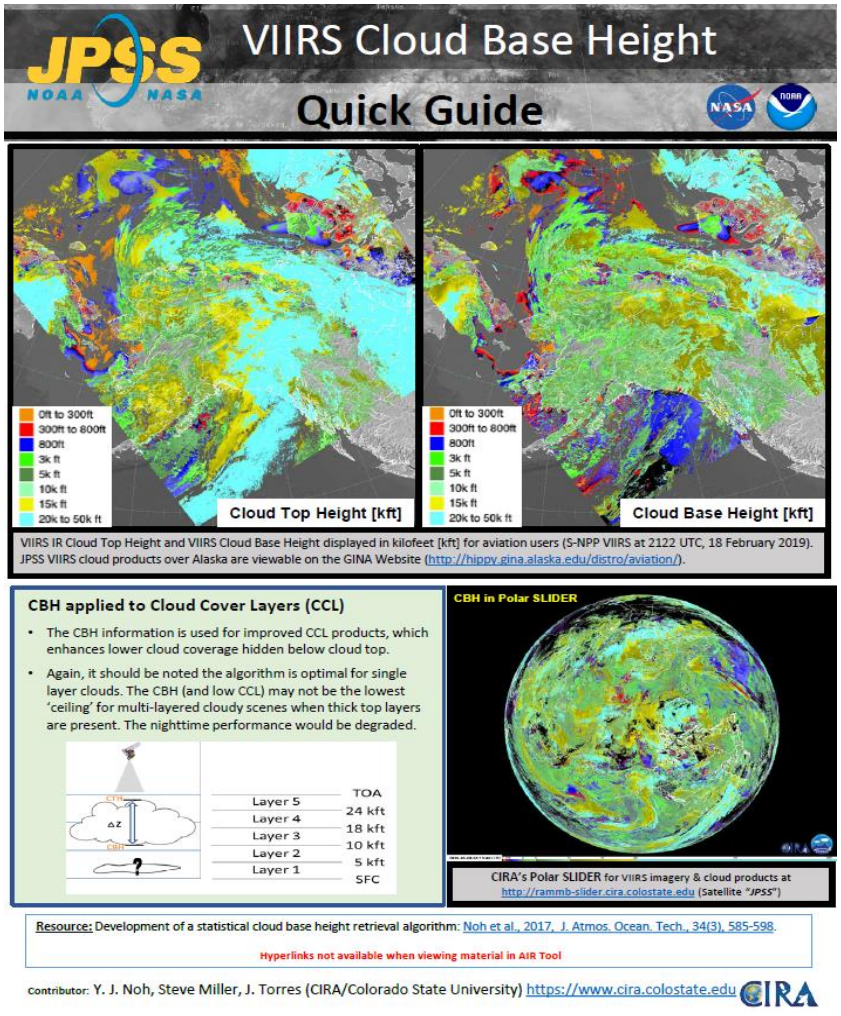
Cloud Phase	All clouds	Cirrus	Opaque ice	Mixed phase	Water	Overlap
Matchup points	154 205	69 361	16 230	22 298	4292	42 024
Bias (km)	**0.1**	**−0.3**	1.0	**−0.2**	−0.8	**0.6**
Median error (km)	−0.2	**−0.5**	0.9	**−0.2**	−0.8	**0.2**
Std dev of error (km)	**1.9**	**1.7**	**2.2**	**1.2**	1.2	**2.2**
RMSE (km)	**1.9**	**1.7**	2.4	**1.2**	1.5	**2.3**
r^2 correlation	**0.634**	**0.598**	**0.273**	0.367	0.791	**0.417**
Percentage of Correct retrievals	11.3%	**9.8%**	8.2%	20.5%	15.9%	**9.4%**

4. Production of CBH & CGH

Operational Use in CIRA

- Quick guides of cloud base height using VIIRS data





5. Methodology

CBH with GK2A data

$$LWP = \int_{z=0}^{\infty} \rho_{air} r_L dz'$$

LWP is the sum of the fluid content of the atmosphere as a concept to describe the radiative transfer process

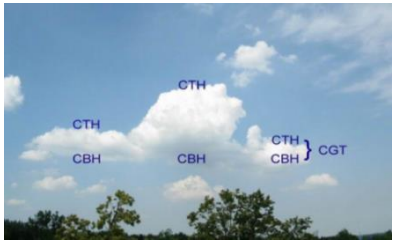
- CBH estimation using Liquid/Ice Water Path & Liquid/Ice Water Content
- CIRA method(Seaman et al. (2017) based on Suomi-NPP/VIIRS → Apply to GK2A data

water phase

$$LWP = \frac{2}{3} \rho_{liq} \tau r_e$$

$$CGTP = Min(\frac{LWP}{LWC}, 15)$$

Cloud type	LWC ($g\,m^{-3}$)
Altocumulus/altostratus	0.455
Cirrus	0.01
Cirrocumulus	0.01
Cumulus	0.580
Cumulonimbus/nimbostratus	0.01
Stratus	0.293



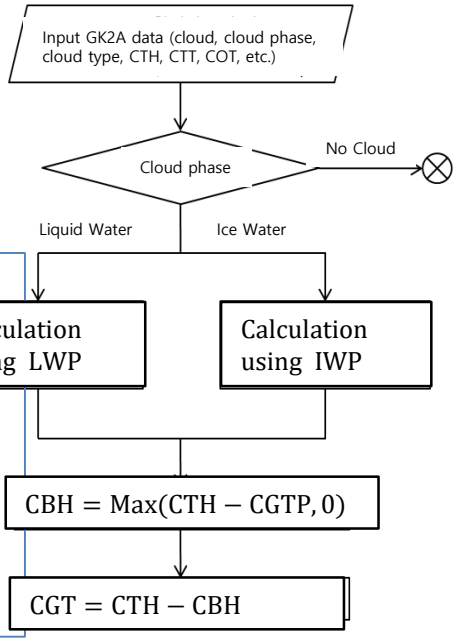
ice phase

$$IWP = \frac{COT}{-0.006656 + \frac{3.686}{D_e}}$$

$$D_e = 326.3 + 12.42\,CTT + 0.197\,CTT^2 + 0.0012\,CTT^3$$

$$CGTP = Min(\frac{IWP}{0.1}, 15)$$

ρ_{liq} : density of liquid water
τ: cloud optical thickness
r_e : effective radius(liquid)
D_e: effective radius(ice)
LWP: Liquid Water Path
LWC: Liquid Water Content
IWP: Ice Water path
IWC: Ice Water Content
CTT: Cloud Top Temperature
CGTP: Cloud Geometrical Thickness Parameter
CGT: Cloud Geometrical Thickness
CTH: Cloud Top Height
CBH: Cloud Base Height



$CBH = Max(CTH - CGTP, 0)$
(cloud base height)

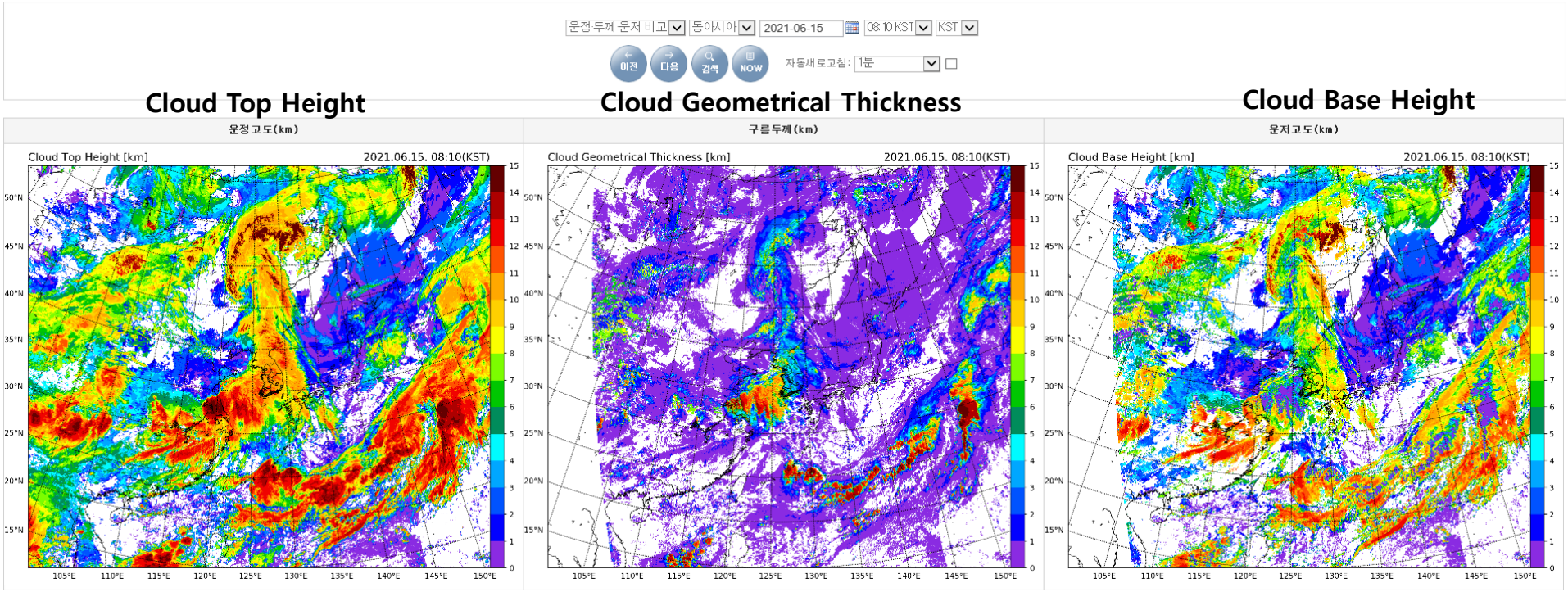
$CGT = CTH - CBH$
(Cloud Geometrical thickness)

Flow chart

6. Products

Experimental operation of CBH & CGT images with CTH

- NMSC (http://172.19.16.20:8080/html/intranet/ko/anal_main.do)



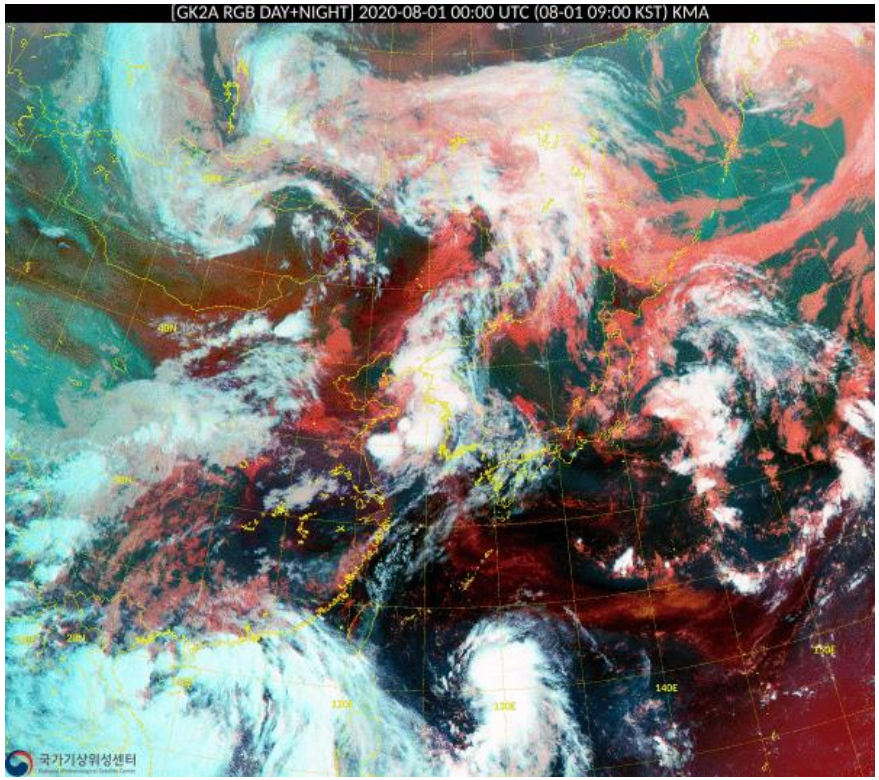
Cloud Top Height **Cloud Geometrical Thickness** **Cloud Base Height**

7. Products

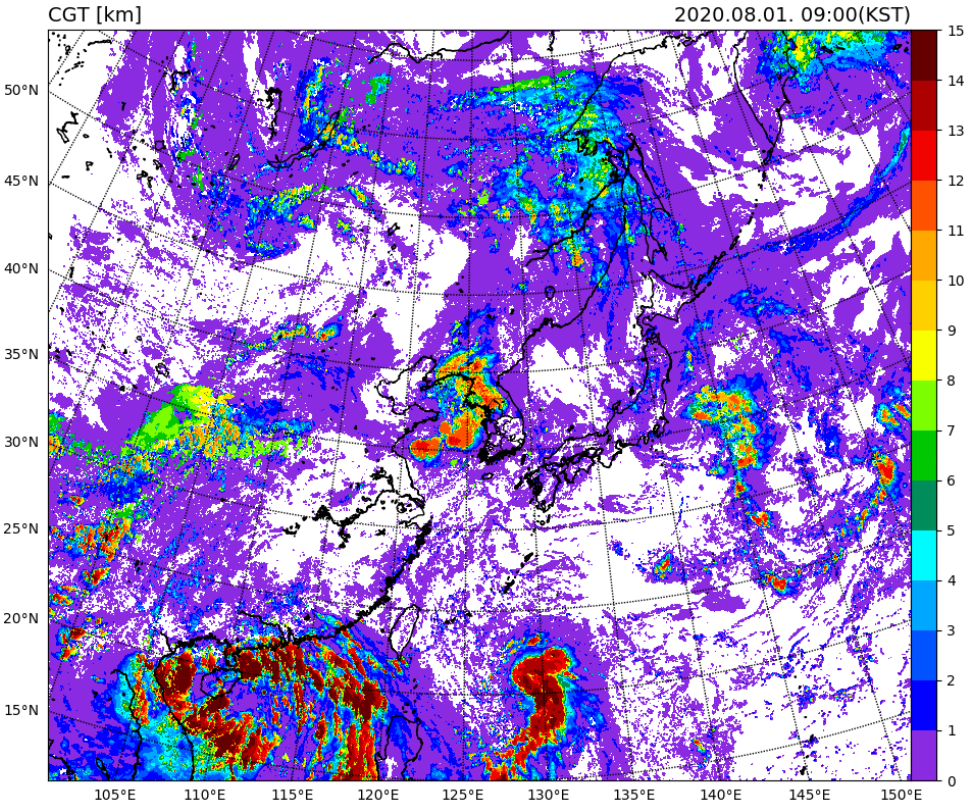
Animation

- summer monsoon front case(2020. 8. 1. 09KST(00UTC) ~ 2020. 8. 5. 03KST(8. 4. 18UTC))

RGB ir & vis composite Images



Cloud Geometrical Thickness

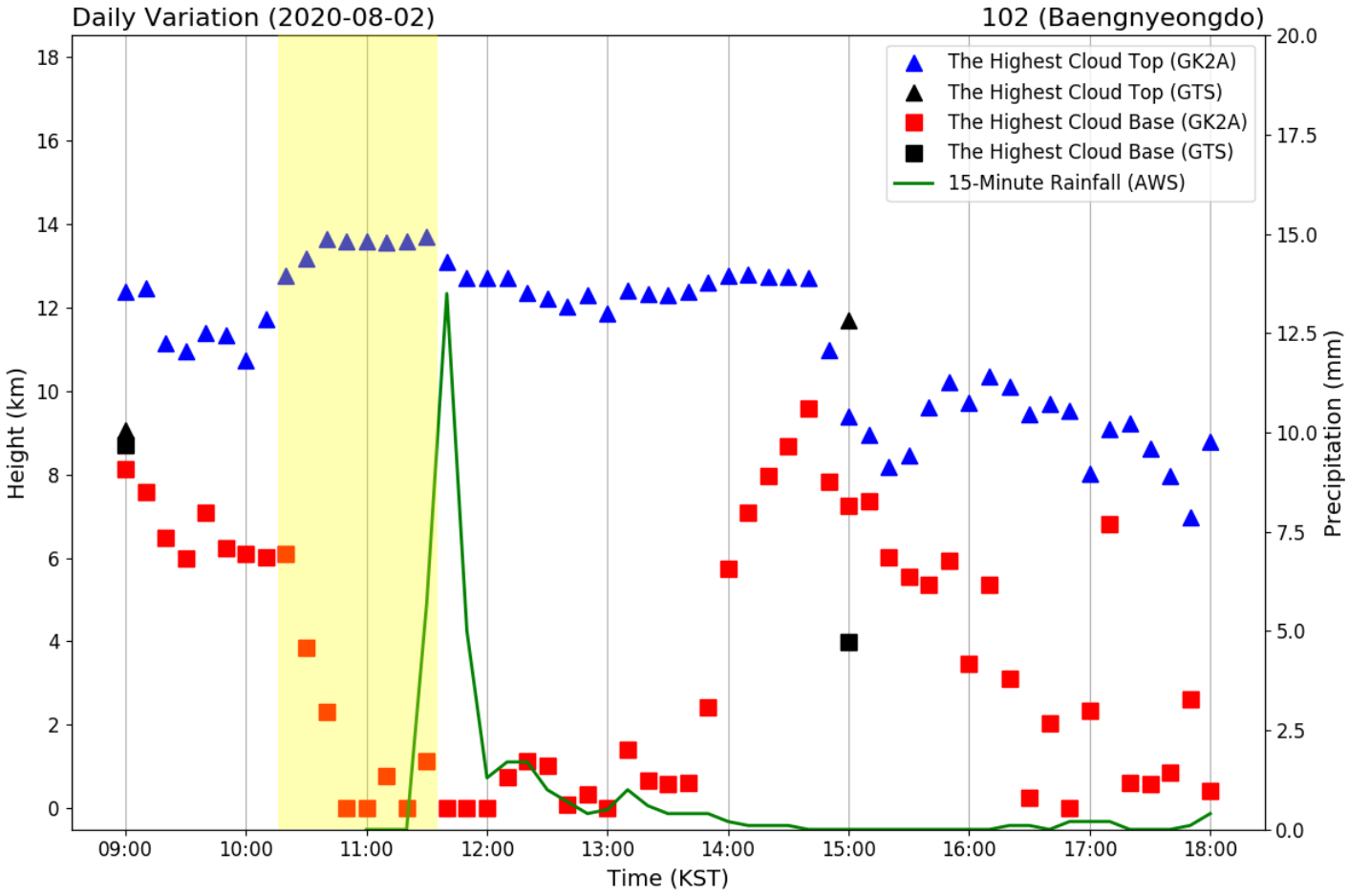


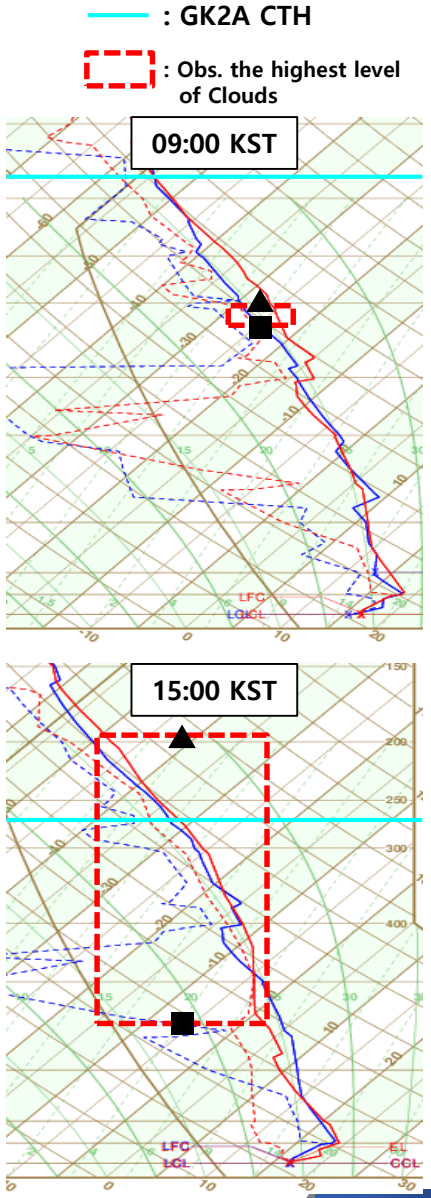
8. Verification & Accuracy

Relationship between developing clouds and precipitation

- August 2, 2020.(Baengnyeongdo)

The Thicker Cloud(developing) → the more precipitation ↑

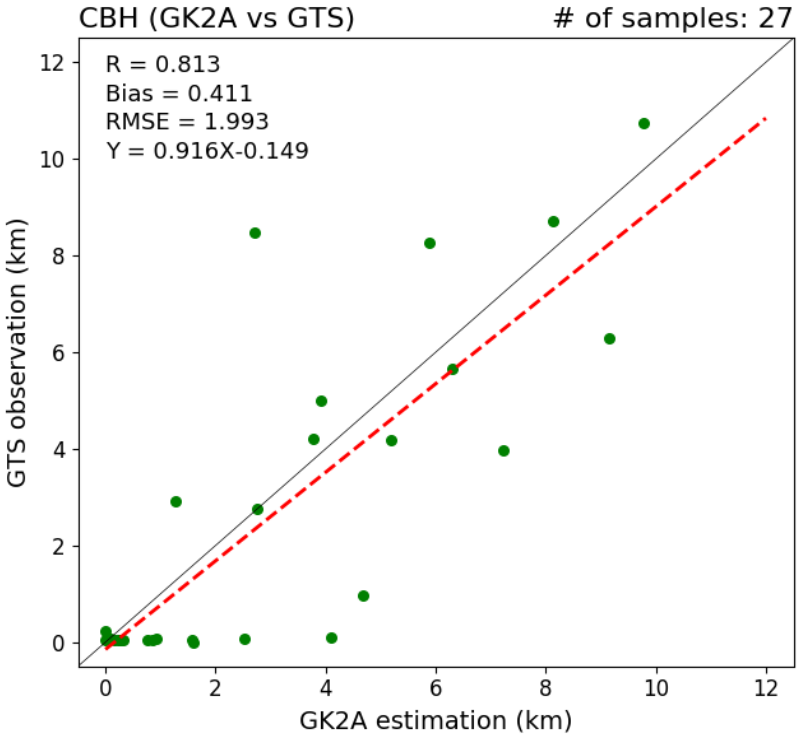




9. Verification & Accuracy

Comparison of Obs. Cloud height and GK2A Estimated CBH

- CBH of upper level observation data(GTS) and GK2A are compared for cases where radar echoes with a rainfall intensity of more than 5 mm/hr have passed at major upper level observation points for June to September of 2019-2020.
- CBH of GK2A tends to overestimate when the actual cloud elevation is near the ground
- The correlation index is 0.8 or higher.
- Bias and RMSEs are 0.411 and 1.993 respectively, similar to Bias in operational CTH, RMSE is slightly higher



※ [KMA] GK2A CTH verification score (source: NMSC system-2 quickguide)

		Target accuracy		Verification			
				MODIS/TERRA		MODIS/AQUA	
		Bias	RMSE	Bias	RMSE	Bias	RMSE
CTT	[K]	5	7	-0.16	9.16	1.64	9.45
CTP	[hPa]	50	100	3.43	86.29	11.69	86.25
CTH	[km]	0.6	1.0	-0.24	1.60	-0.46	1.67

※ [CIRA] VIIRS verification score (source: Seaman et al., 2017)

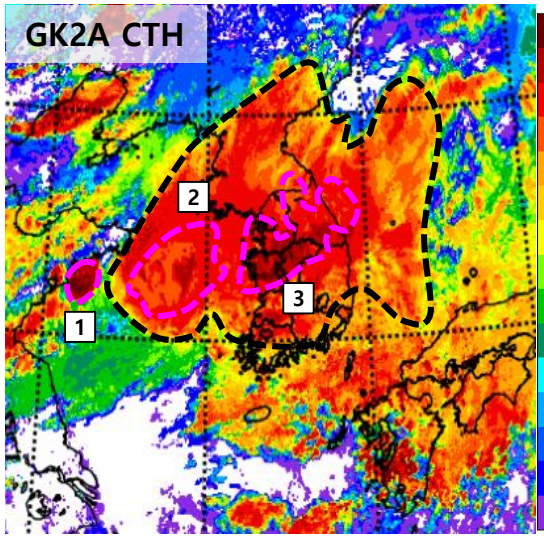
TABLE 5. Statistics of VIIRS CBH retrieval performance as compared to *CloudSat* observations for the subset of valid matchup points where the CTH retrieval was Within CTH Spec and all clouds were assumed to have a CGT of 2 km. Bold values indicate improvement over the IDPS CBH retrieval results shown in Table 4. Note that a negative error means the VIIRS CBH value is less than the *CloudSat* CBH value.

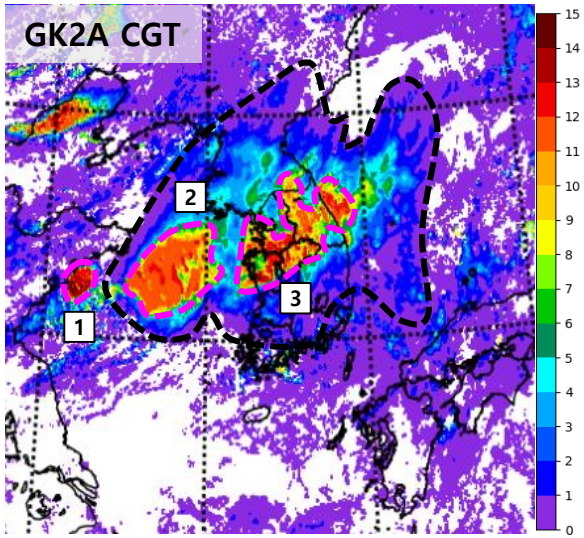
Cloud Phase	All clouds	Cirrus	Opaque ice	Mixed phase	Water	Overlap
Matchup points	154205	69361	16230	22298	4292	42024
Bias (km)	**0.1**	**−0.3**	1.0	**−0.2**	−0.8	**0.6**
Median error (km)	−0.2	**−0.5**	0.9	**−0.2**	−0.8	**0.2**
Std dev of error (km)	**1.9**	**1.7**	**2.2**	**1.2**	1.2	**2.2**
RMSE (km)	**1.9**	**1.7**	2.4	**1.2**	1.5	**2.3**
r^2 correlation	**0.634**	**0.598**	**0.273**	0.367	0.791	**0.417**
Percentage of Correct retrievals	11.3%	**9.8%**	8.2%	20.5%	15.9%	**9.4%**

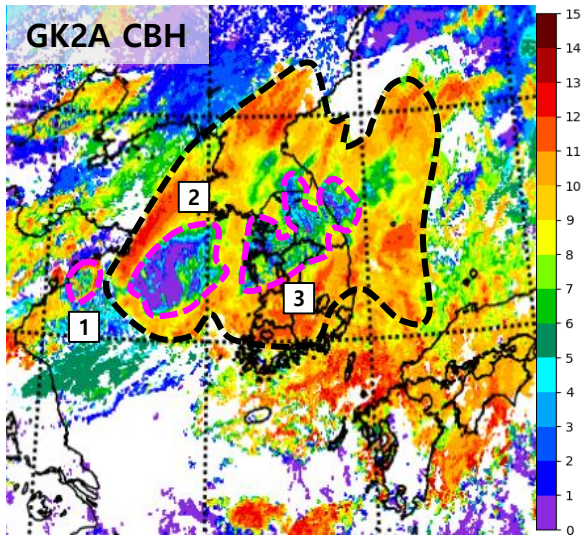
10. Heavy rain case

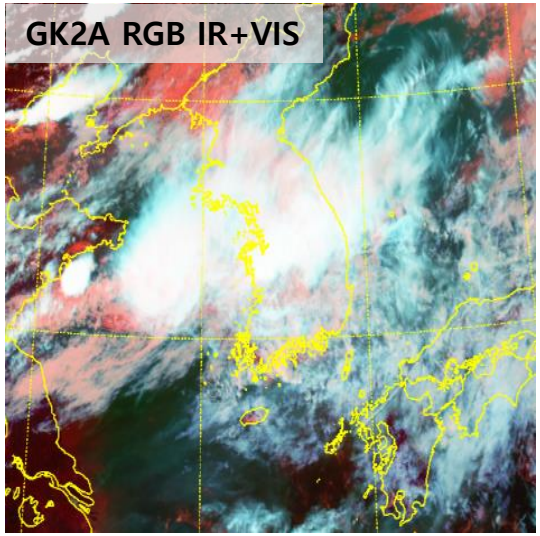
August 3, 2020 15:00 KST

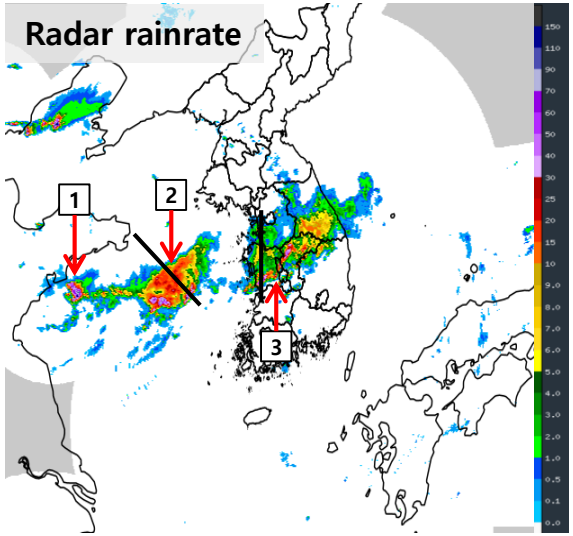
--- : Clouds expected to develop high in CTH
--- : Clouds developed from lower to upper layers in CGT(cloud thickness) and CBH





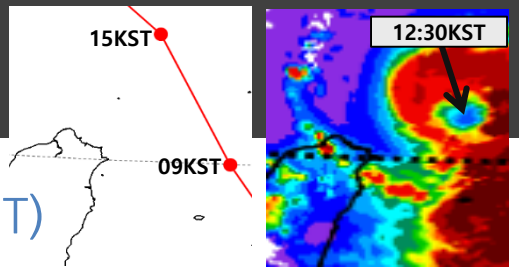




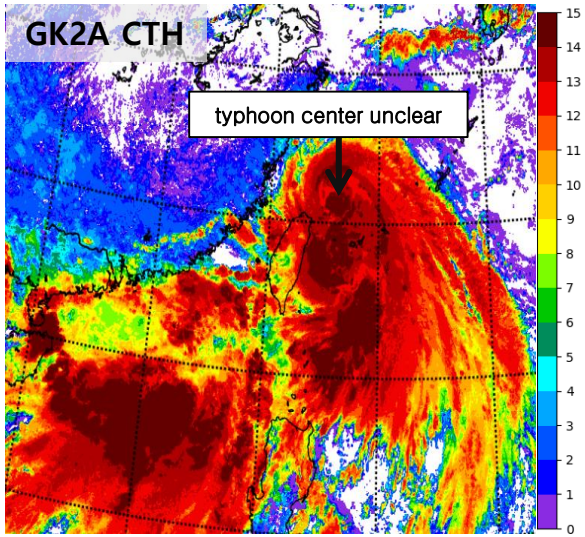


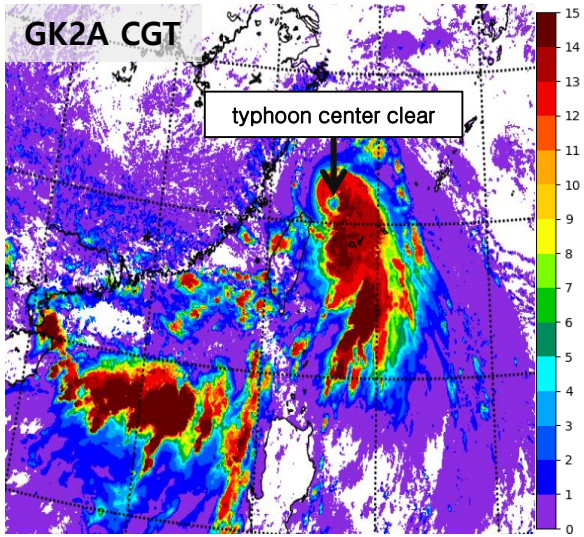
- 1 : Small convective cells are developing in the south of Shandong Peninsula.
- 2: A big convective cell(CGT 11 km) developed than 1 is moving toward Korea
- 3: Convective cells are located Chungcheong-do and Gangwon-do, with cloud thicknesses of 11 km to the north and 15 km to the south

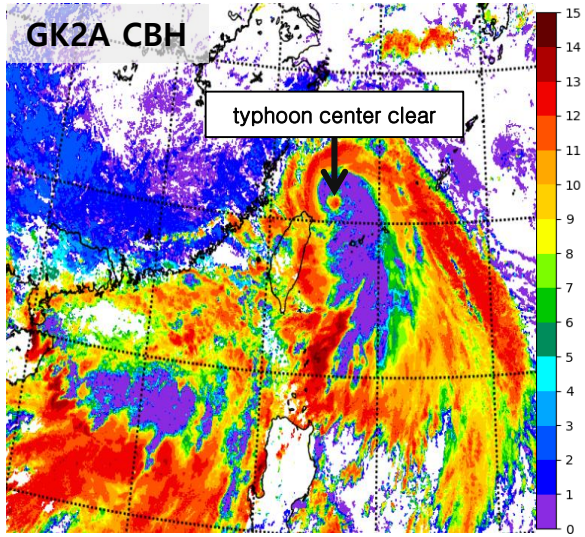
11. Typhoon Case

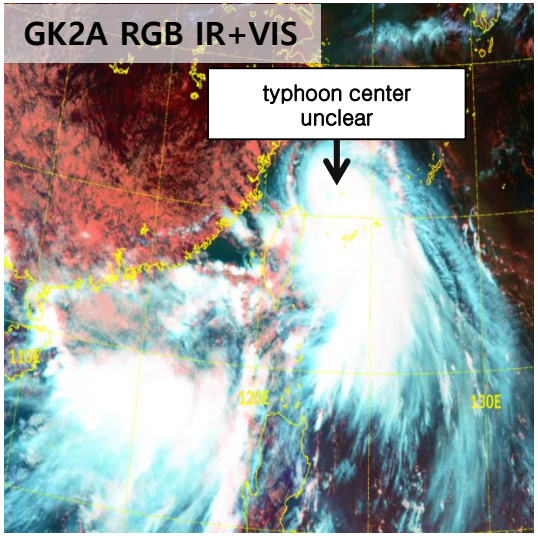


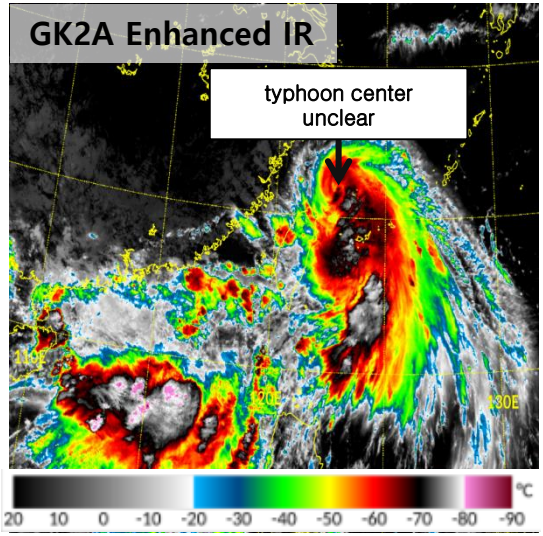
August 3, 2020 12:30 KST(2004-HAGUPIT)

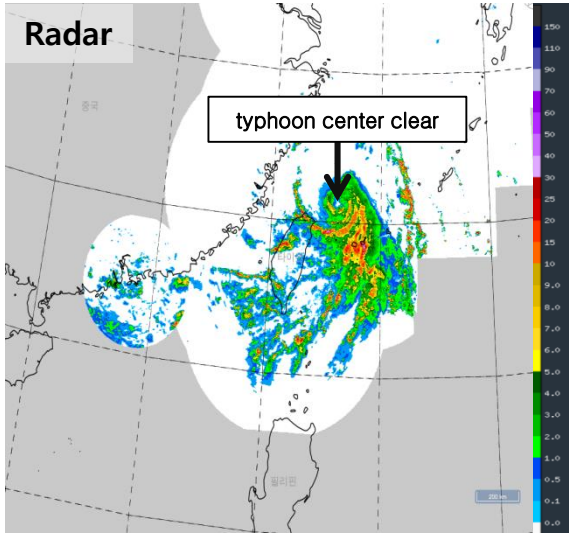






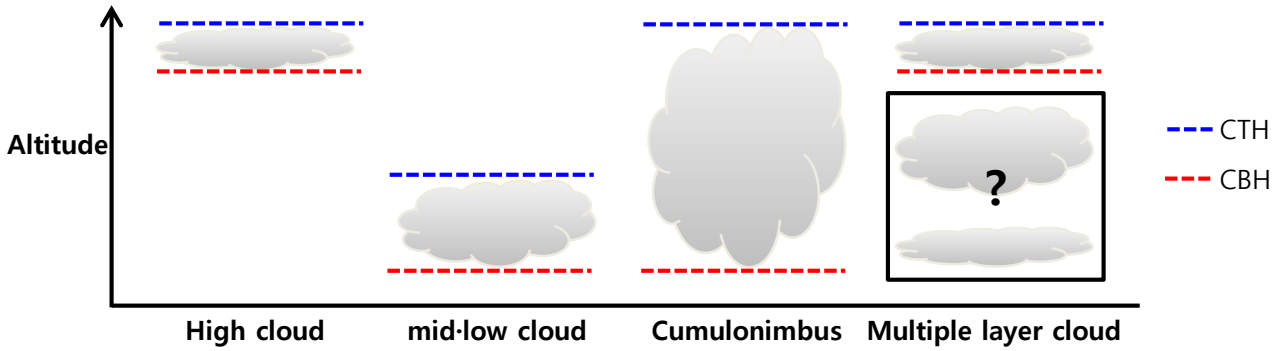






12. Summary of application of CBH & CGT

- CGT and CBH are estimated and analyzed for cases of convective clouds and typhoons of 2020 ~2021.
- Vertical distribution of clouds that could not be found in existing output such as CTH, CTT can be identified using CBH and CGT.
- The thicker cloud can be identified the distribution similar to the radar echo(rain rate).
- Rainfall tends to increase as cloud thickness increases and lower CBH of cloud.
- Quantitative verification shows that the bias of the GK2A CBH ceiling is similar to existing GK2A CTH and RMSE is slightly higher. It is similar to the verification results of CIRA.



- CBH and CGT is useful to analysis the deep developed heavy rain clouds from the bottom to the top.
- The height of CBH means the cloud ceiling from the top. It is difficult to use in multiple layered clouds.
  We will monitor the CBH and CGT outputs for heavy rain and typhoon cases in this year and apply it in operational work.

Thank you

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National Meteorological Satellite Center