Development and validation of the cirrus cloud mask method by using near infrared band observed from geostationary satellite

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Introduction 1 Cirrus cloud detection and satellite observation

- To clarify the processes of climate system, it is necessary to quantitatively understand the contribution of cirrus clouds (Ci) to the radiation balance and the amount of water vapor entering to the stratosphere.
- Ideally, the observation of cirrus cloud is required highly temporal and spatial resolutions due to its spatio-temporal variations (e.g., a few hours, a few meters for geometric thickness).

Satellite that can observe a wide area with the same accuracy is effective for observing cirrus clouds.

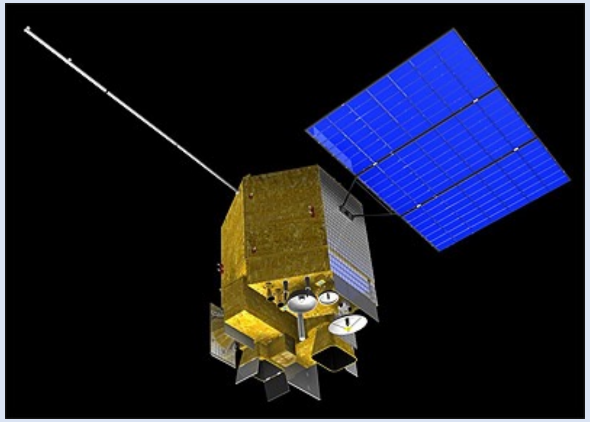
	Passive sensor (e.g., MODIS)	Active sensor (e.g., CALIOP)
Merit	• Wide field of view • high temporal resolution (especially geostationary satellites)	• Optically thin clouds can detect
Demerit	• Difficult to detect optically thin clouds	• Narrow observation field • low observation frequency

Cf. Mace and Zhang, (2014)

Introduction 2 Trends in upper level cloud detection with satellite

Increased number of on-board bands + effective Ci detection using near-infrared water vapor absorption bands
⇒ Recently, geostationary satellites mount 1.38μm (water vapor strong absorption) band

FY-4A(China) 2016～



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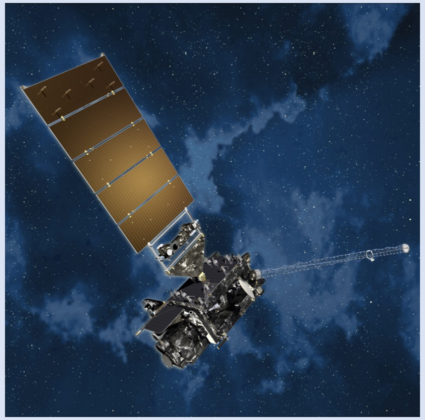
GOES-16(US) 2016～



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GK-2A(Korea) 2018～

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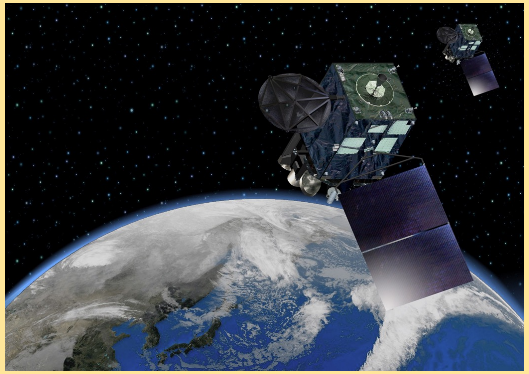
Not mounted on Himawari-8/9



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Introduction 3 Upper level cloud detection methods from satellite

Detection method of clouds including cirrus cloud

- Single-channel threshold method
  - 1.38 μm WV band (cf., *Gao et al., 1993*)
- Dual-channel threshold method
  - Split Window (cf. *Inoue, T., 1987)*
  - CO_2 slicing (cf. *Menzel et al., 2008)*
- Recently, machine learning (cf. *Samuel et al, 2020)*

Table1 : Cloud detection using GK-2A threshold method

GK2A Cloud Mask ATBD 2019

	μm	explanation
Single-channel		
Reflectance	0.6, 0.8	Cloud presence (compared to clear sky)
Brightness Temperature	10.4	Cloud presence
Reflectance	1.38	Cirrus clouds
Dual-channel		
Brightness Temperature	10-12.3	Atmospheric window region : cirrus clouds, thick clouds
	10.4-3.9	Lower clouds
	10.4-8.6	Highly transparent clouds in the upper layer
	10.6-6.2 or 10.4-7.3	Multilayer clouds
	10.4-13.3	CO_2 absorption band : Upper clouds

Purpose of this research

Development of upper level cloud detection method using L1b products of geostationary satellites including 1.38 wavelength band

Data

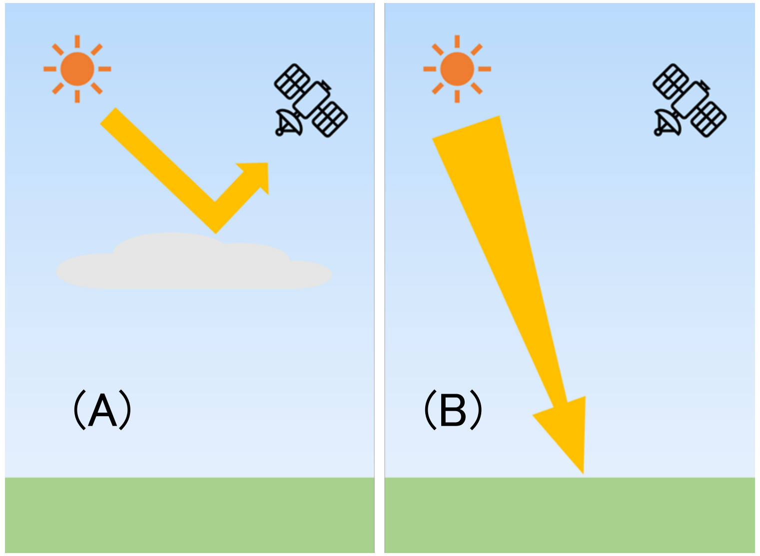
Cirrus cloud mask Input data				
Product	Observation area	Temporal Resolution	Horizonal Resolution	Spectrum (㎛)
GK-2A L1B data	Full disk	10 min	2 km	1.38 (Relectance) 11, 6.9, 3.9 (Brightness Temperature)
GK-2A L2 product Total precipitable water	Full disk	10 min	6 km	
Comparison product				
GK-2A product Cloud Detection (Cloud Mask)	Full disk	10 min	2 km	
Himawari-8 L2 product Cloud properties	Full disk (60S-60N, 80E-160W)	10 min	5 km	
CALIPSO Clay 5km ver4.2	Analysis period: 2019-08-01 4:35:00 to 4:45:00 UTC			
CALIPSO Vertical Feature Mask – Ver4.1	Analysis period: 2019-08-01 4:30:16.2 to 4:57:44.9 UTC			

Method 1 cirrus cloud detection by using 1.38㎛ WV absorption band

Cirrus cloud detection by using the threshold method

A) Scatter light from upper clouds ⇒ Observed by satellite

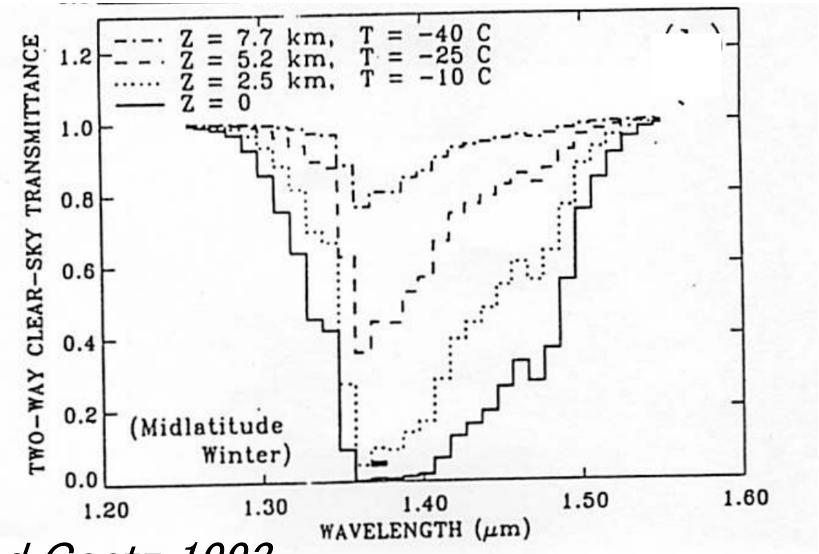
B) No scattered light from ground surface ⇐ Absorbed by water vapor, under the case of sufficient water vapor (WV)



Condition

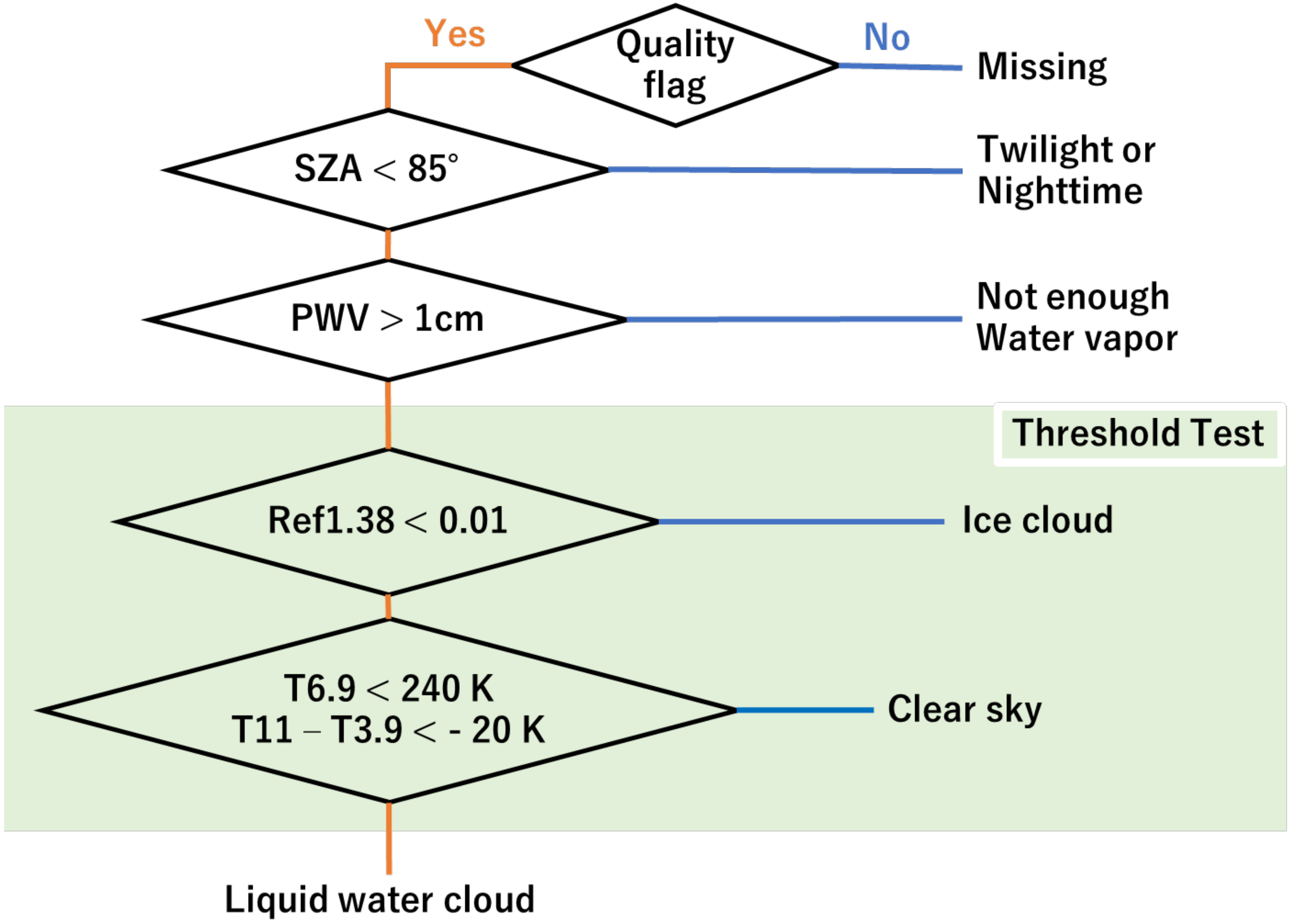
Observed Reflectance ＞ Clear sky Reflectance + Offset

⇒ **Presence of cirrus clouds**



Gao and Goetz 1993

Method 2 Flow of cirrus cloud detection



SZA : Solar Zenith Angle

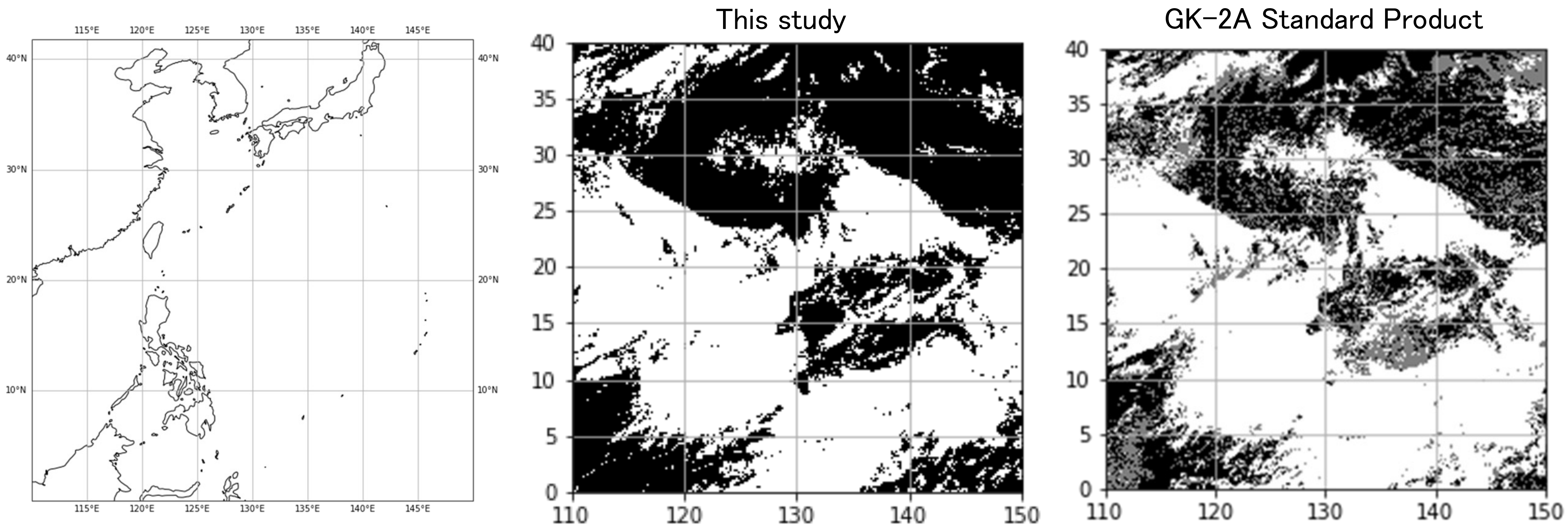
PWV : Precipitable Water Vapor

Ref : Reflectance

T: Brightness Temperature

cf. MOD35 ATBD 2010

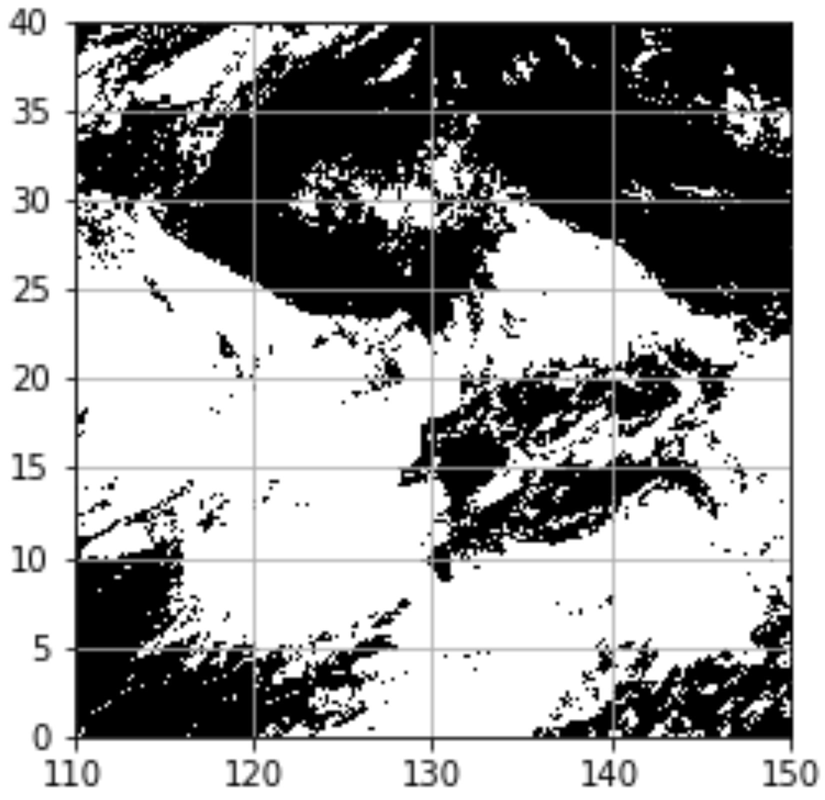
Comparison of the GK-2A cirrus mask developed in this study with the standard product

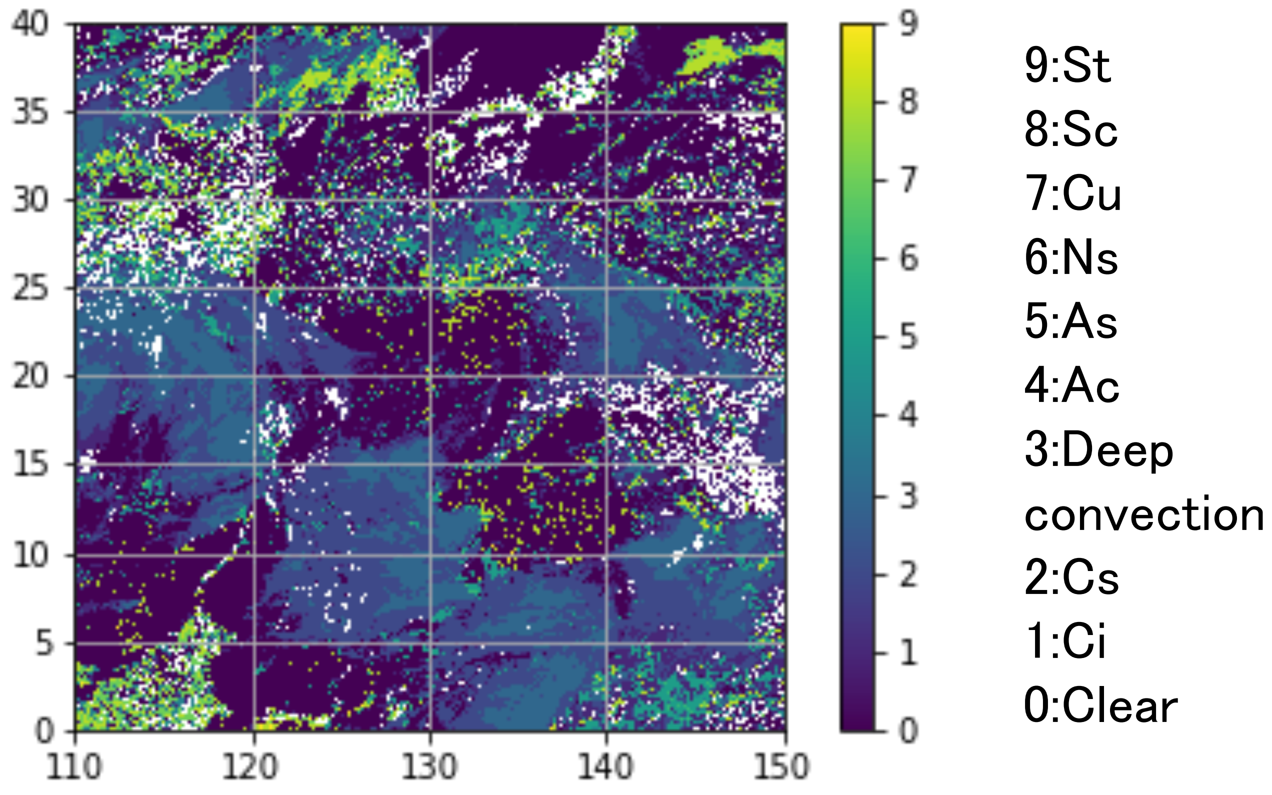


0–40N, 110E–150E observation area (left), August 1 2019 (4:40UTC) GK-2A cirrus mask developed in this study by using L1B data (center), GK-2A L2 cloud mask (right)

- The area with cirrus clouds generally coincides with the area identified as having clouds by the standard product.
- Discriminates upper clouds in cloud regions that cannot be identified by standard products alone

Comparison of GK-2A cirrus mask with Himawari-8 Cloud type mask

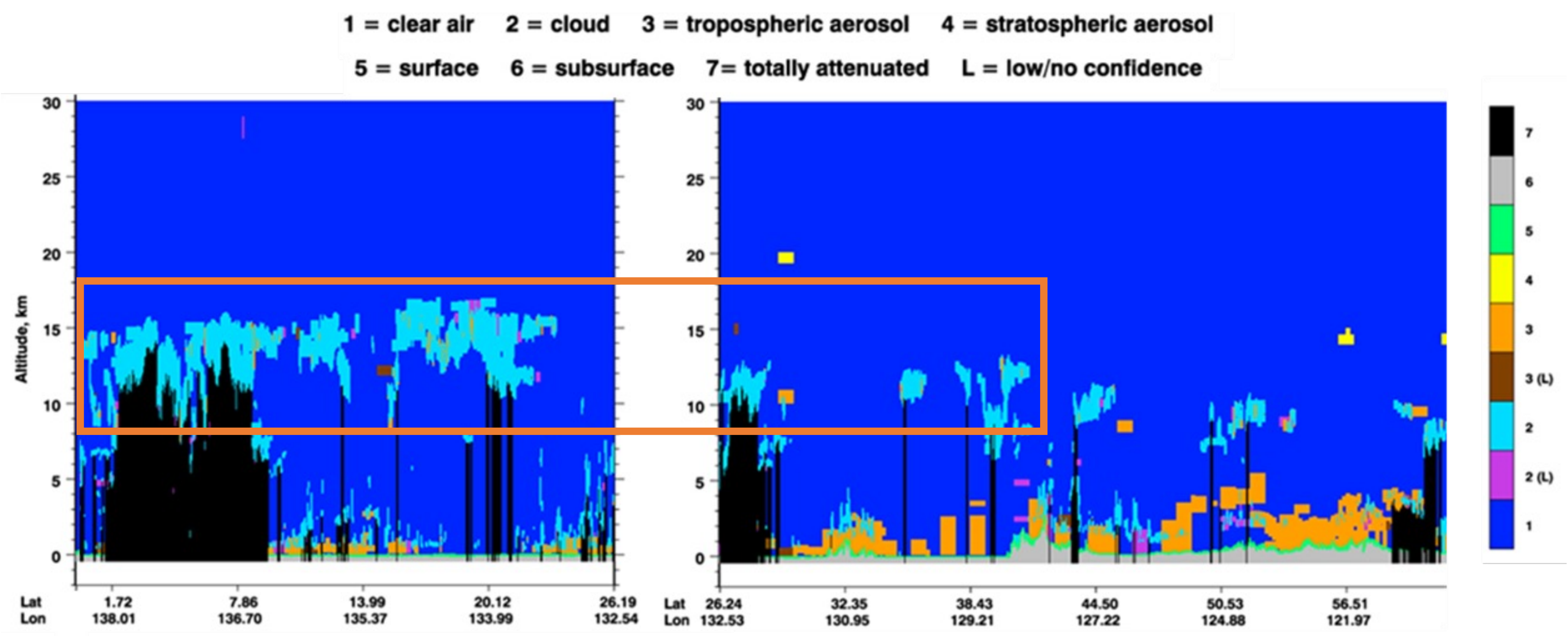




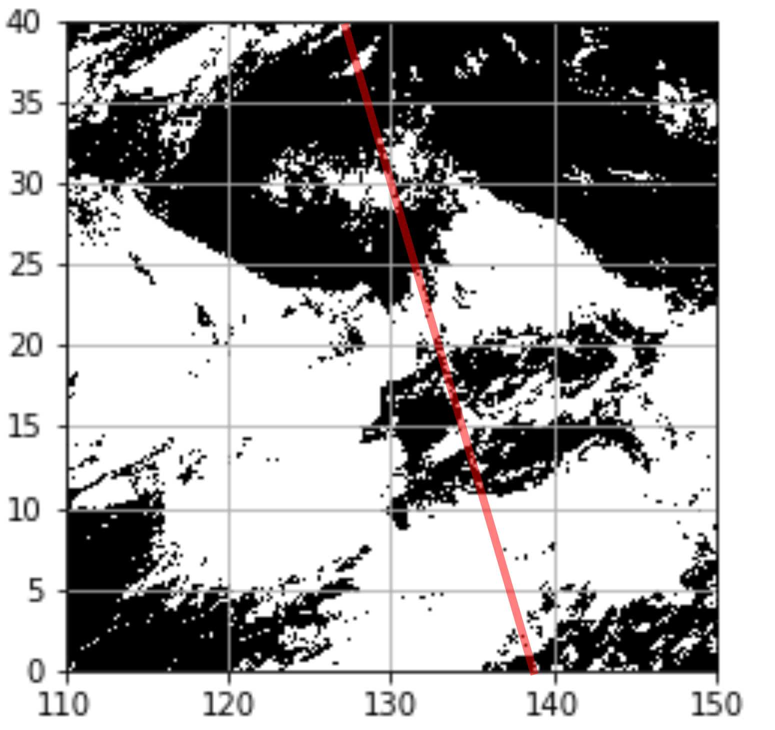
GK-2A cirrus mask developed by using L1B data including in 1.38㎛ (left)
August 1 2019 (4:40UTC) Himawari-8 L2 Cloud type mask 0-40N, 110E-150E (right)

- Roughly coincides with the location of the upper clouds in Himawari-8
- Overall, the number of GK-2A products detecting cirrus clouds is high ⇒ verification required

Comparison of GK-2A cirrus mask with CALIOP Vertical Feature Mask



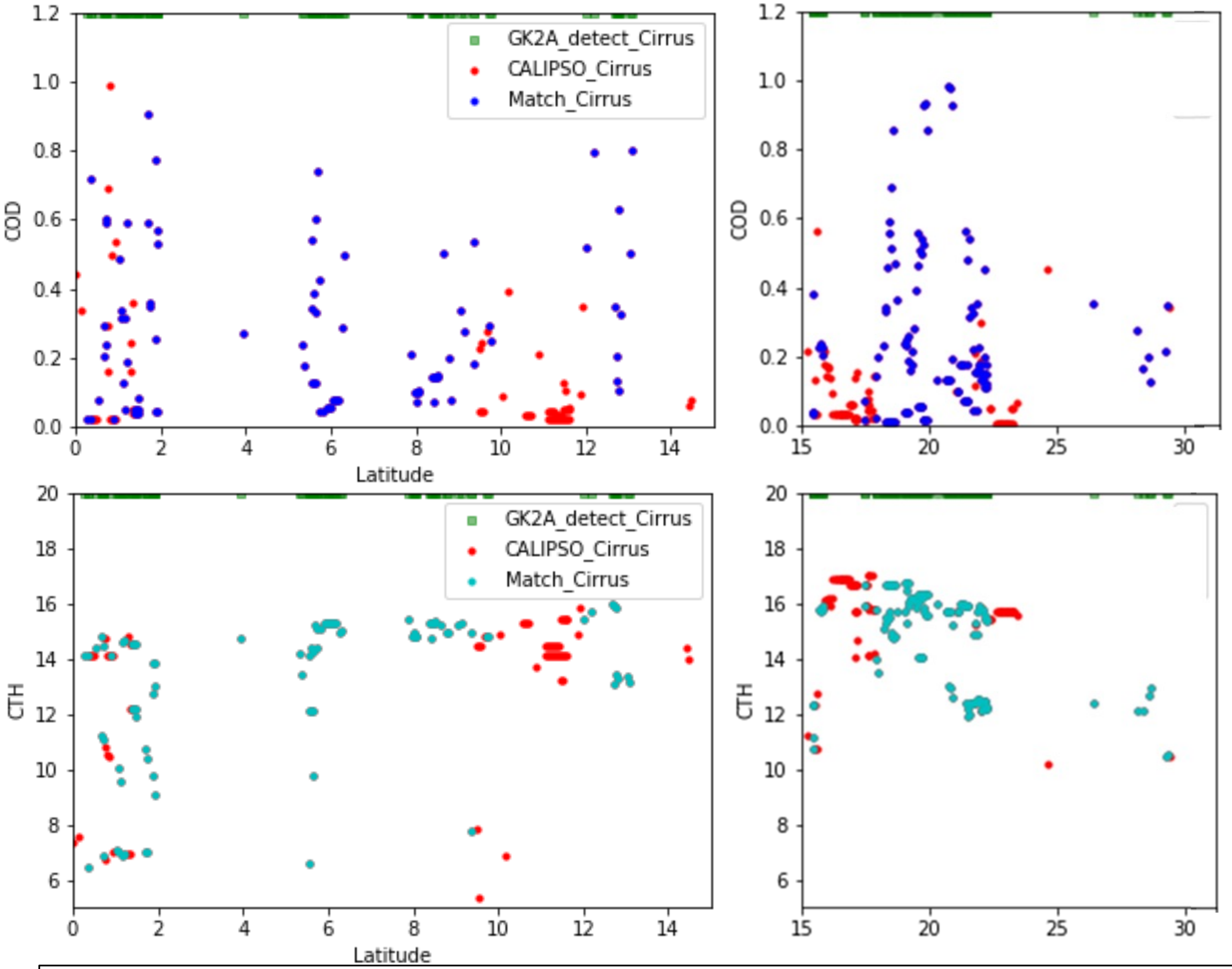
CALIPSO Vertical Feature Mask
2019-08-01 04:30:16.2 to 04:57:44.9 UTC



CALIPSO orbit at 0-40N, 110E-150 (red line) and August 1 2019 (4:40UTC) cirrus cloud

- Possibility of detecting not only thick cloud but also thinner upper cloud
- few detections in high latitude ⇒ verification required

Comparison of GK-2A cirrus mask with CALIOP Clay product



- Ci Detection rate

$$\frac{The\ number\ of\ Ci\ \ CALIOP}{The\ number\ of\ Ci\ \ GK2A} \sim 66\ \%$$

- The possibility to detect multilayer and thick clouds well

⇔ Single layer and COD less than 0.1 clouds are few detections

⇒ Need to review the threshold considering the surface type and higher latitude

Ci detected by GK2A (Green), CALIOP Cloud Optical Depth (COD) (Red dots) , Matched with GK2A (Blue dots)
CALIOP Cloud Top Height (CTH) (Red dots) , Matched with GK2A (Cyan dots)
2019-08-01 04:35:00 to 04:45:00 UTC at 0-15N, 15-30N

Summary and near future works

Summary

- Develop the cirrus cloud detecting method by using water vapor absorption band's 1.38μm
- Compared among GK-2A, Himawari-8, and CALIPSO cloud mask products, qualitatively, the detection of upper clouds was confirmed

Future works

- Quantitative validation of the threshold method developed in this study by comparing it with cloud information obtained from the CloudSat-CALIPSO combined analysis KU product (Hagihara et al., 2010)
- Set thresholds based on observation location (impacted PWV)
  - Surface type Land/ocean/desert
  - Viewing / Solar zenith angle
- Discussed the usefulness of cloud mask products for other geostationary satellites

e.g., Himawari-8