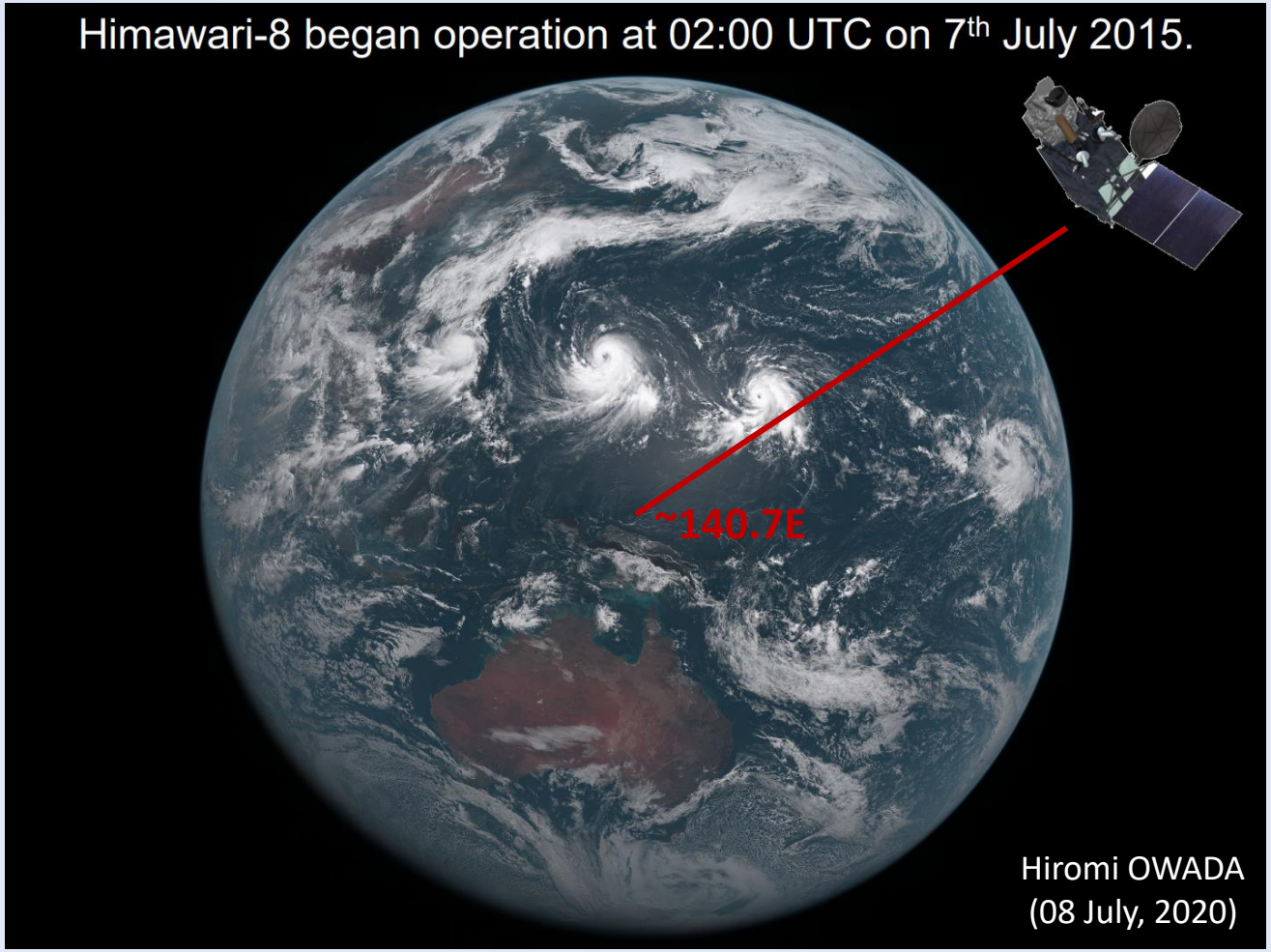
# 2025 Cloud and Environment

## Himawari 8/9 satellite: introduction & data processing

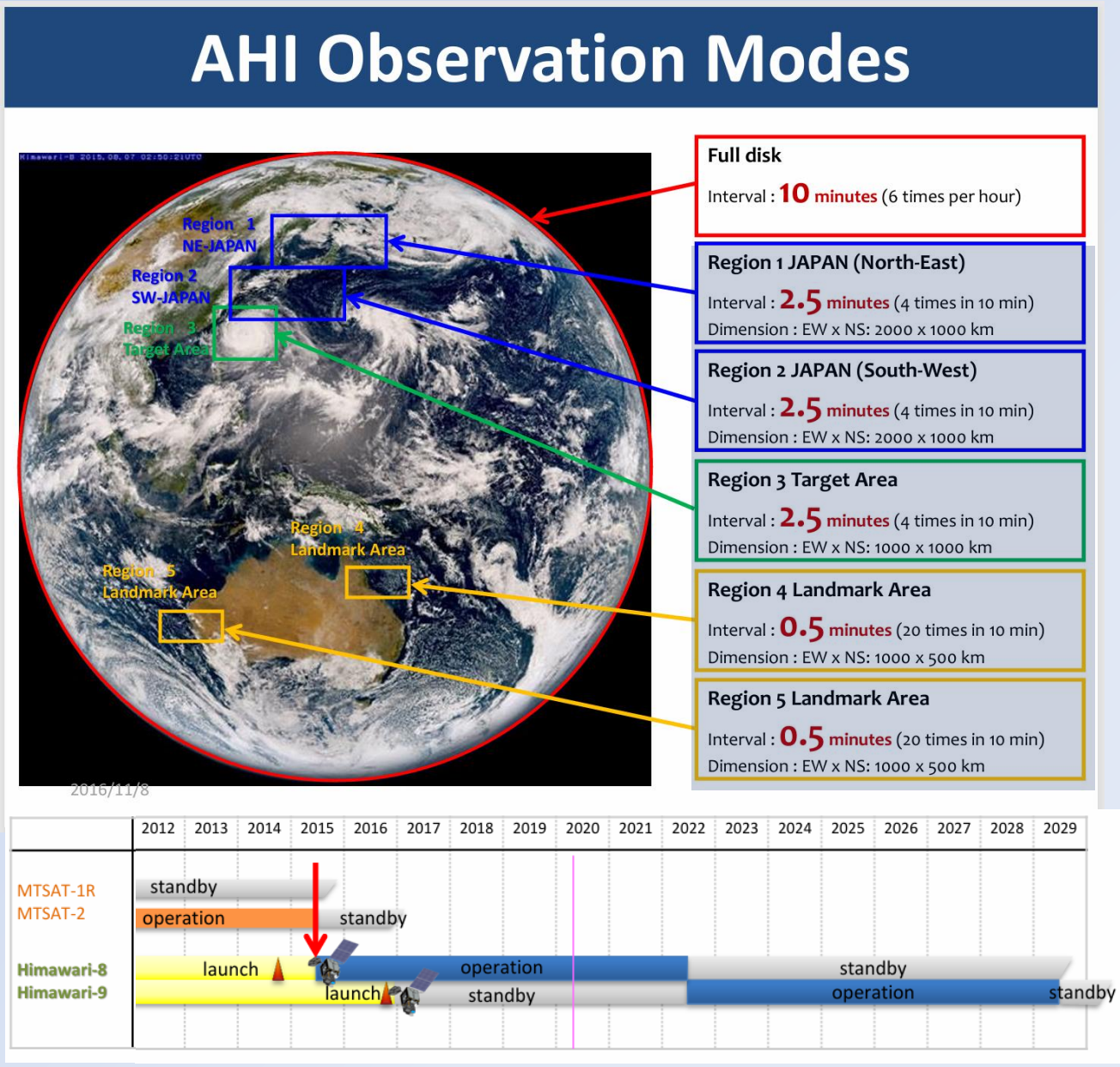
Peng Jen Chen & Shao Yu Tseng




## Outline

- Introduction of Himawari satellite
- Introduction of ael-satellite-tools module
  - Himawari data download and pre-processing
- Week 3: Introduction of True Color image & RGB composite product
  - RGB processing & plotting
- Week 4: Application of Himawari data processing by AEL-satellite-tools

# Himawari-8/9 data information







**Geostationary postiton:** ~140.7E
**Imaging sensor:** Advanced Himawari Imager (AHI)
**Original observation domain:** 85E – 205E, 60N – 60S
**Temporal resolution:** typically 10min

- except the routine maintain of the satellite
  - 02:40 and 14:40UTC, for monitor satellite status
  - Orbit control: every two weeks
  - Radiometer solar calibration: every two weeks
- Automatic sun avoidance function during spring and autumn eclipse periods
  - Stary light (band1~9)

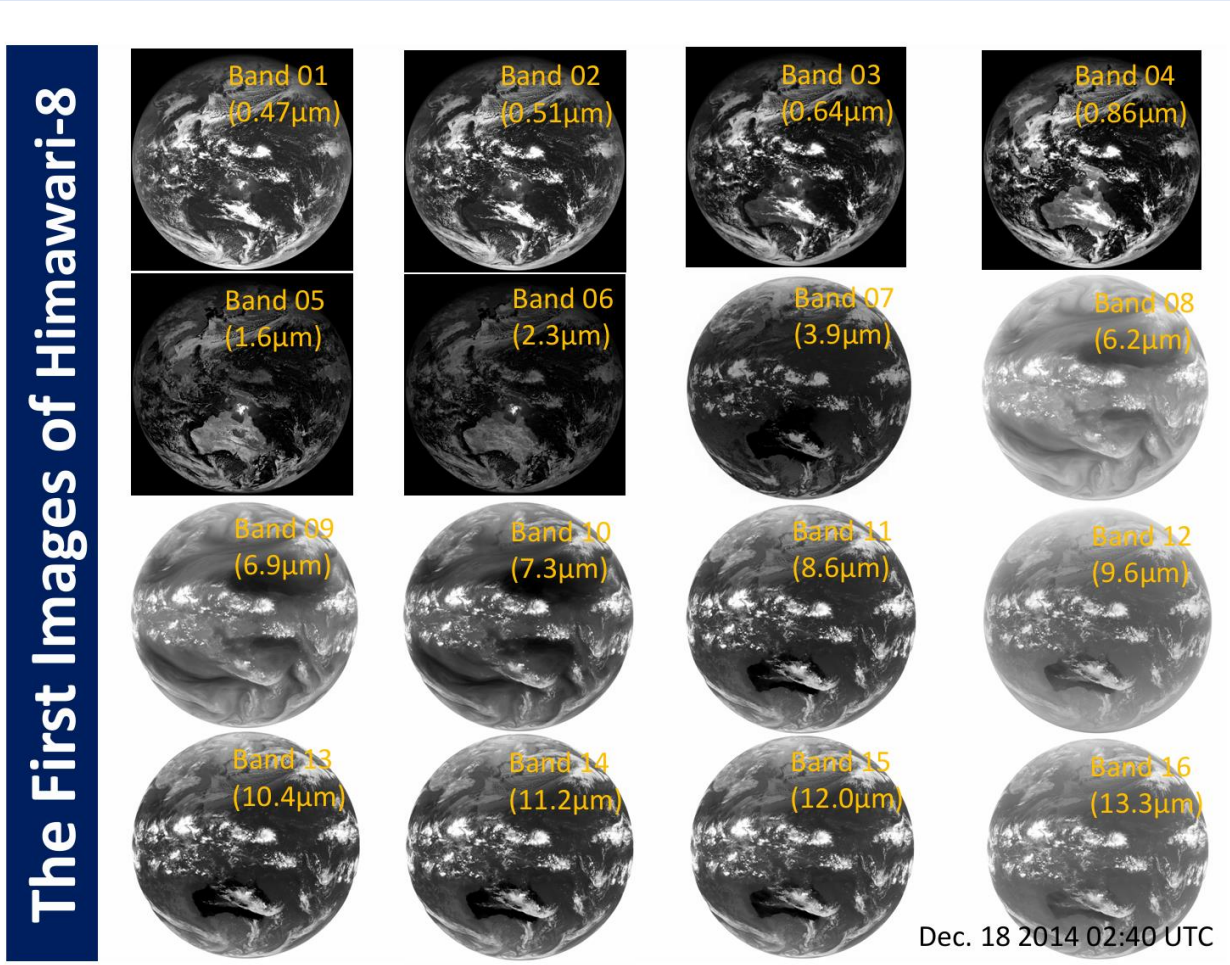
# Himawari-8/9 data information

**Provide data Spectral:** 16 bands VIS(3), NIR(3), and IR(10)
**Spatial resolution:** 0.5km/1km (VIS) ~ 2km (IR)

| CEReS gridded data Bands and Numbers | | JMA's Himawari8/9 Bands |
|---|---|---|
| EXT .5km | 01 | Band 03 (0.64 μm) |
| VIS 1km | 01 | Band 01 (0.47 μm) |
| | 02 | Band 02 (0.51 μm) |
| | 03 | Band 04 (0.86 μm) |
| SIR 2km | 01 | Band 05 (1.6 μm) |
| | 02 | Band 06 (2.3 μm) |
| TIR 2km | 01 | Band 13 (10.4 μm) |
| | 02 | Band 14 (11.2 μm) |
| | 03 | Band 15 (12.4 μm) |
| | 04 | Band 16 (13.3 μm) |
| | 05 | Band 07 (3.9 μm) |
| | 06 | Band 08 (6.2 μm) |
| | 07 | Band 09 (6.9 μm) |
| | 08 | Band 10 (7.3 μm) |
| | 09 | Band 11 (8.6 μm) |
| | 10 | Band 12 (9.6 μm) |

Unit:
**Albedo**

Unit:
**Brightness temperature**



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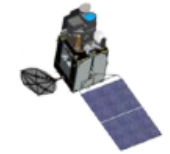
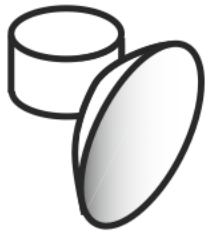
## Himawari-8/9 Imager (AHI)



| Band | | Spatial Resolution | Central Wavelength | Physical Properties | |
|---|---|---|---|---|---|
| 1 | Visible | 1 km | 0.47μm | vegetation, aerosol | 3 Visible Bands |
| 2 | | | 0.51μm | vegetation, aerosol | |
| 3 | | 0.5 km | 0.64μm | Vegetation, low cloud, fog | |
| 4 | Near Infrared | 1 km | 0.86μm | vegetation, aerosol | Addition of NIR Bands |
| 5 | | 2 km | 1.6 μm | cloud phase | |
| 6 | | | 2.3 μm | particle size | |
| 7 | Infrared | 2 km | 3.9 μm | low cloud, fog, forest fire | |
| 8 | | | 6.2 μm | mid- and upper-level moisture | Increase of WV Bands |
| 9 | | | 6.9 μm | mid-level moisture | |
| 10 | | | 7.3 μm | mid- and lower-level moisture | |
| 11 | | | 8.6 μm | cloud phase, $SO_2$ | Increase of TIR Bands |
| 12 | | | 9.6 μm | Ozone content | |
| 13 | | | 10.4 μm | cloud imagery, information of cloud top | |
| 14 | | | 11.2 μm | cloud imagery, sea surface temperature | |
| 15 | | | 12.4 μm | cloud imagery, sea surface temperature | |
| 16 | | | 13.3 μm | cloud top height | |

# Theoretical Basis of Satellite Remote Sensing of the Atmosphere

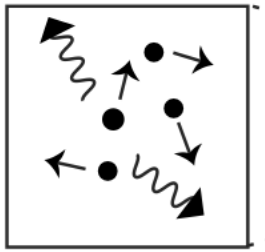


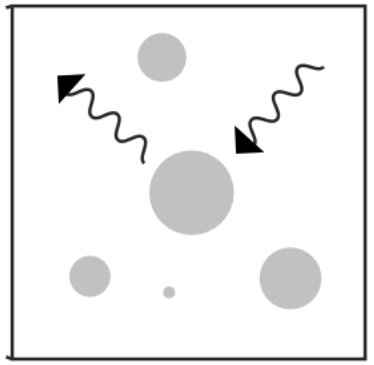
Satellite sensors only receive electromagnetic wave signals

Radiative Transfer:
Theories to translate the satellite-received signals into geophysical variables

**Radiative Transfer:**
*Solar radiation (visible/near infrared)*

**Electrodynamics:**
*Particle scattering/absorption*





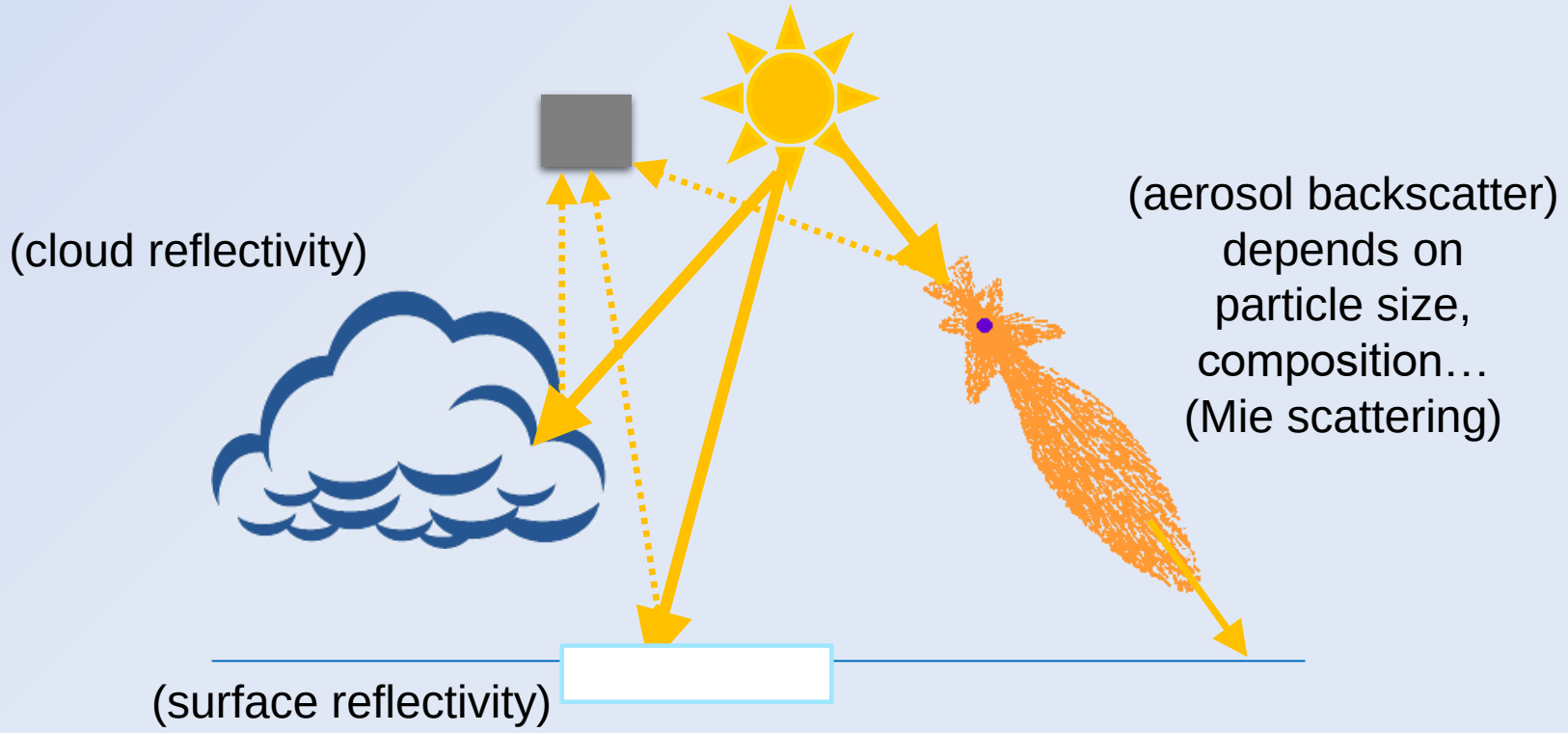
**Statistical/Quantum Mechanics:**
*Thermal/Radiative processes of the atmosphere*

**Radiative Transfer:**
*Earth's thermal radiation (thermal infrared/microwave)*

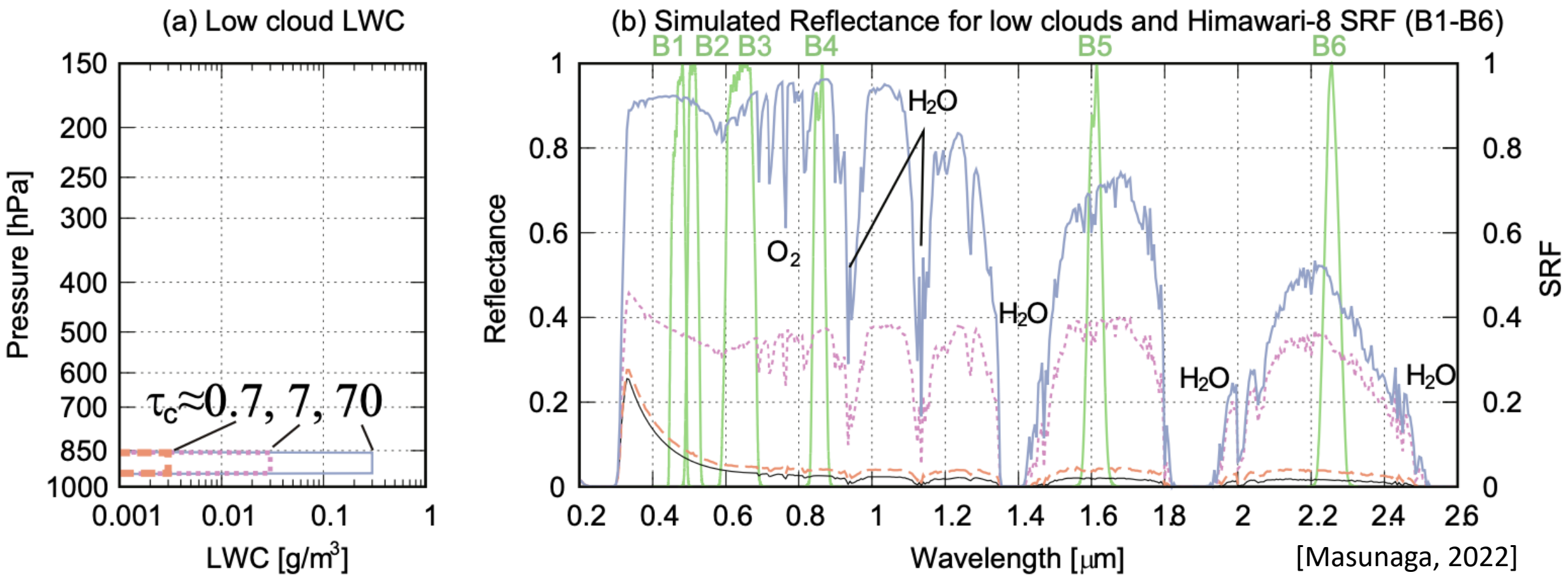
**Geometrical Optics:** *Surface emissivity/reflectivity*

[Masunaga, 2022]

- 可見光 (VIS, 0.4-0.7 um)
  - 雲（凝結的水量越多、雲滴粒子越小，反射越強）
  - 地面（反照率越強 ，反射越強，冰雪>沙土>森林>海洋… ）
  - 氣膠（氣膠量越多、粒子越小，背向散射散射越強）

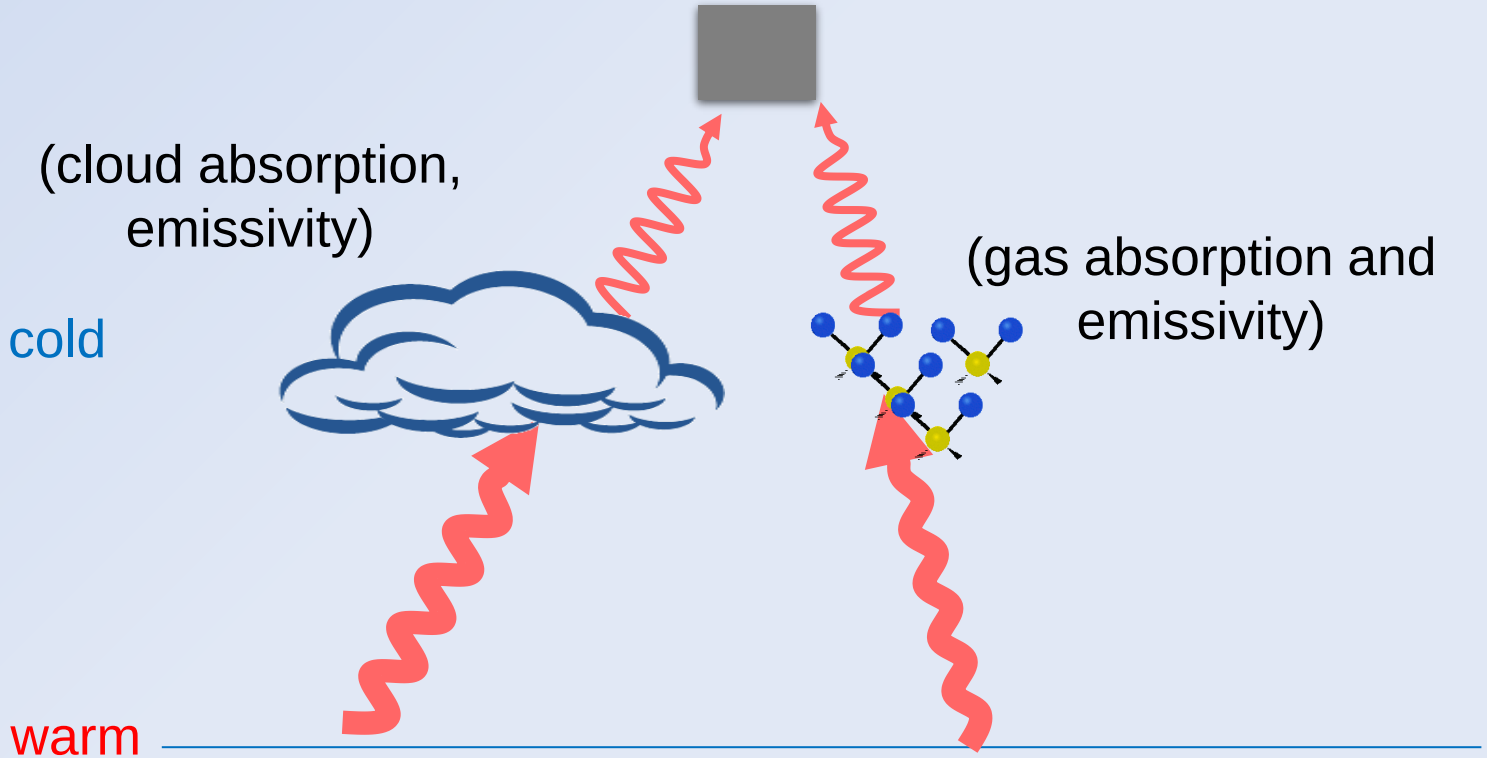


# Simulated spectrum from VIS to Near-IR with a layer of low cloud

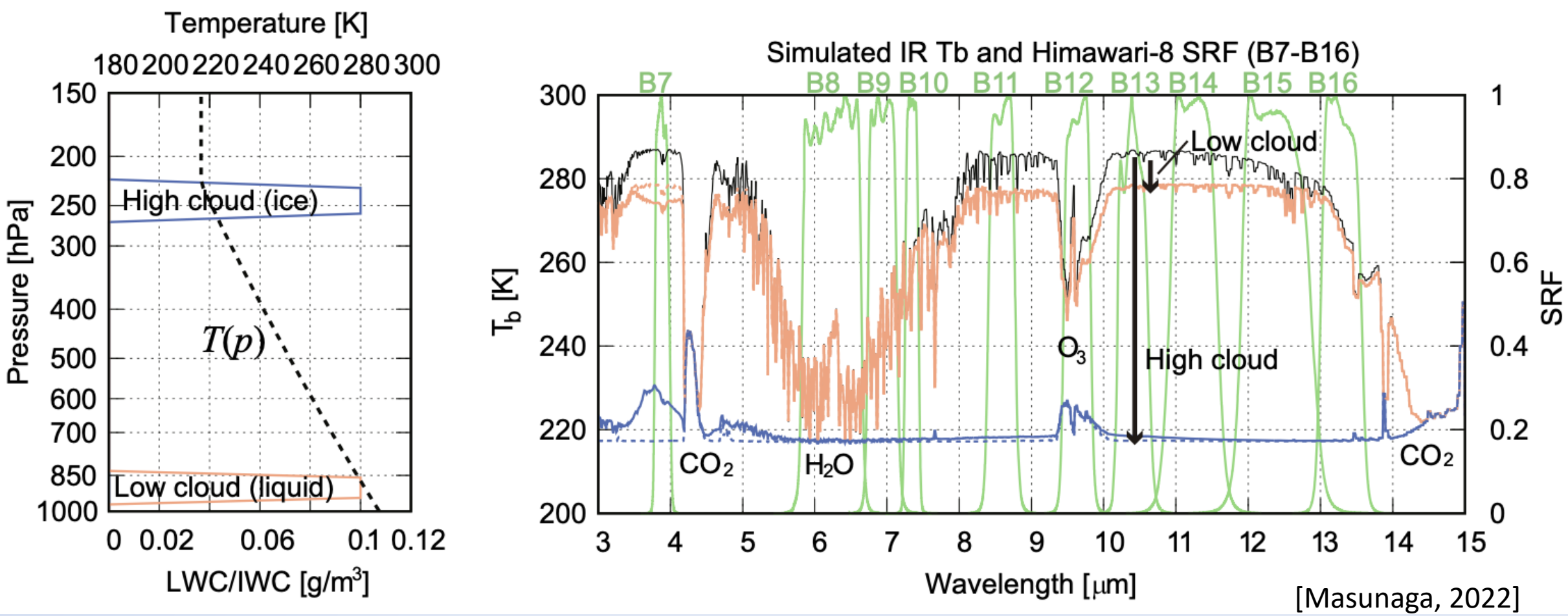



(a) The vertical profile of low-cloud LWC for three different values of $\tau_{c,0.65}$.
(b) Simulated radiance spectra with low clouds having different LWCs as well as the clear-sky case (black curve). The Spectral Response Functions (SRFs) of Advanced Himawari Imager (AHI) Bands 1–6 are plotted together (Green Curve)

- 熱紅外線 (Thermal IR, 3-100 μm): 雲、水氣



# Simulated Tb spectra with a layer of low cloud or of high cloud



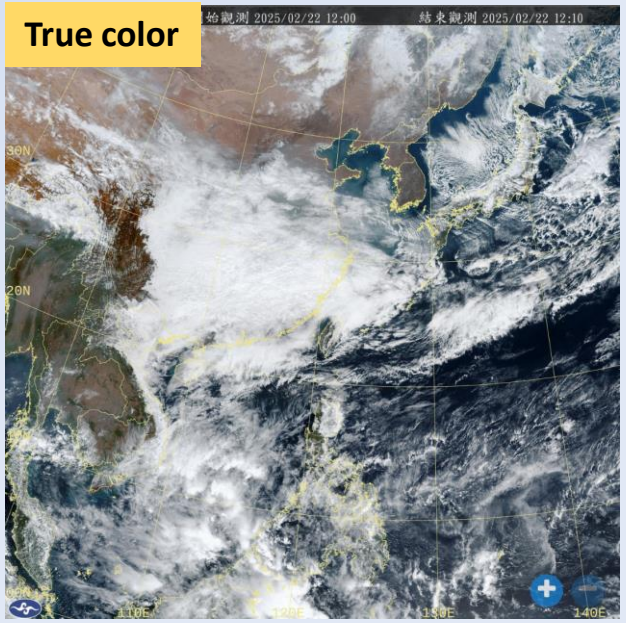

[Masunaga, 2022]

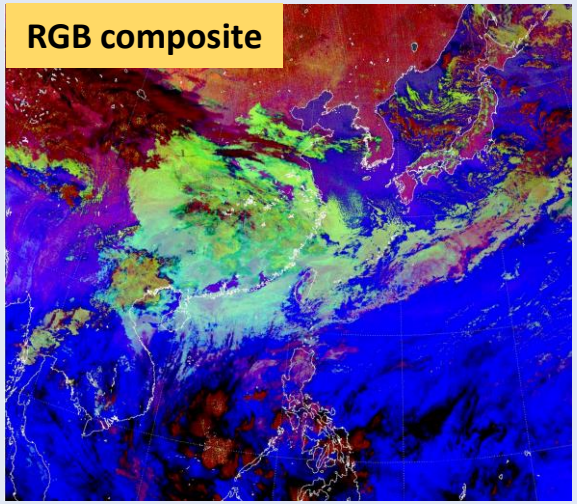
Model atmospheric profiles of temperature (dashed) and LWC/IWC (shaded) in the left. Simulated Tb spectra for the low-cloud and high-cloud cases as well as the clear-sky case (black curve).

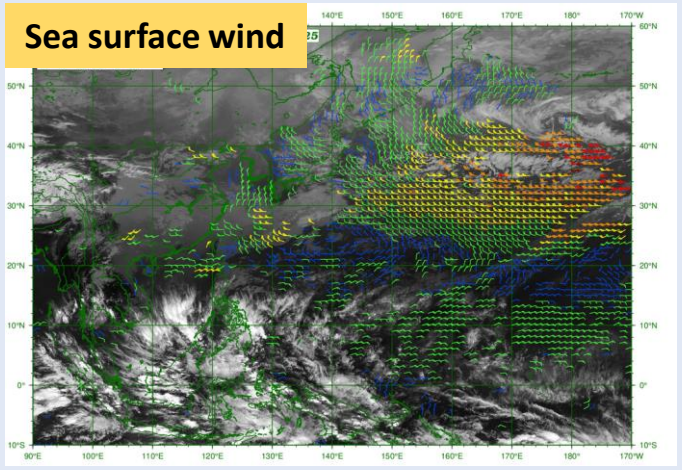
# Himawari-8/9 application product

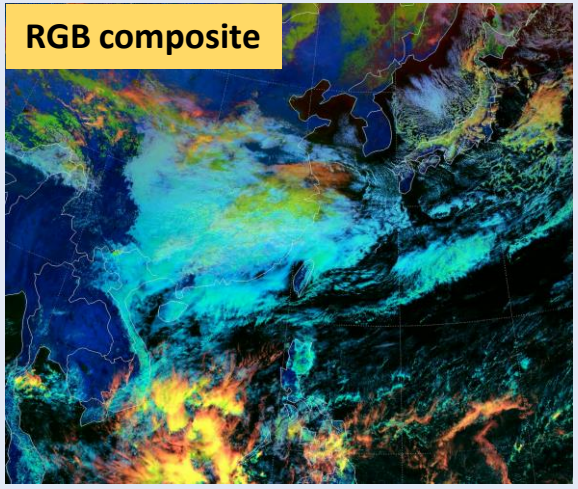
- RGB image
  - **True color**
  - **RGB composite product**
- Level 3 data
  - Sea surface temp.
  - Sea surface wind
  - Aerosol optical depth
  - Cloud optical depth
  - Cloud type

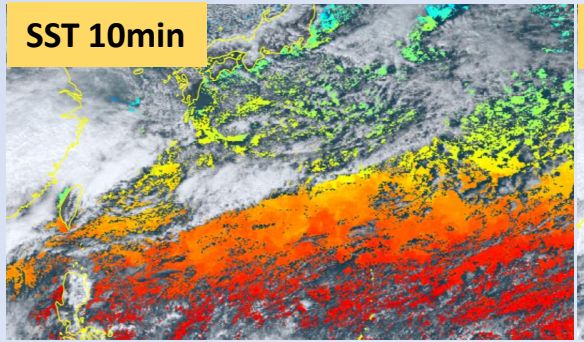
⋮

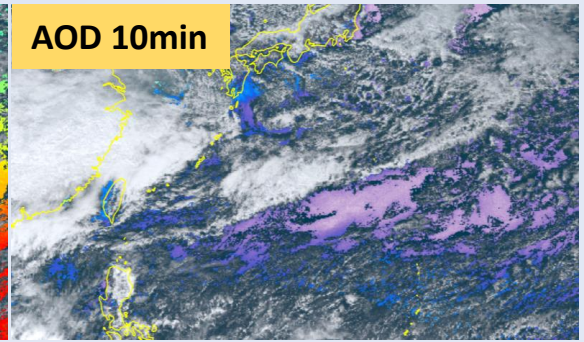


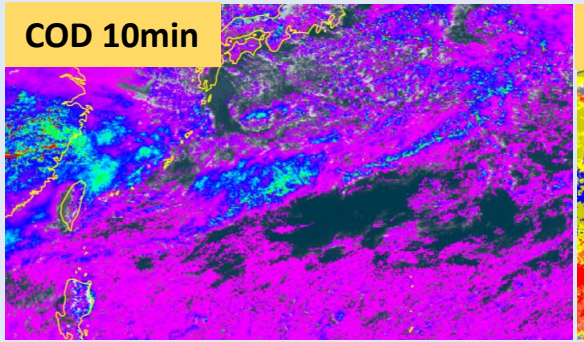



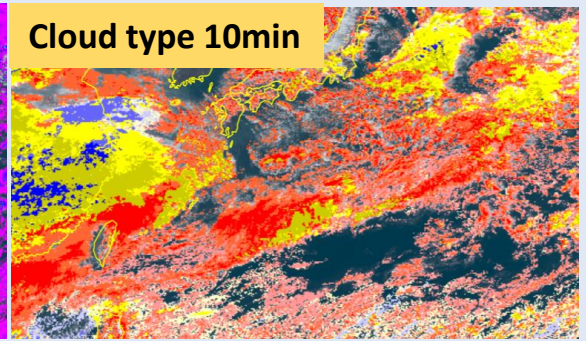



# AEL satellite module – Himawari pre-processing part

In this section, you will learn…

- How to download Himawari data (VIS + IR, 16 bands & geometries data)
  - VIS: 0.5km or 1km; IR: 2km; geo: 4km
- Process original Himawari data into easy-accessing format

**Work flow:**

1. **Download** → compressed_data/
   - yyyymmddhhmm.**ext.01**.fld.geoss.bz2
   - yyyymmddhhmm.**geo**.fld.4km.bin.bz2
   - ⋮
2. **Decompress**
3. **Convert binary to Albedo or TBB**
4. **Extract sub domain**
5. **Output .nc file** → sub_domain_data/
   - yyyymmddhhmm_**band_03**.nc
   - yyyymmddhhmm_4km_**geo**.nc
   - ⋮

**Original shell script for download and convert data:**

- /data/C.jerryjerry9/hima_download/cldenv_shell_script
- 1. Copy all files in the cldenv_shell_script folder; 2. set date and band; 3.then run download.sh
- Only generate converted full disk data (.dat) and geo data (.bin)

# AEL satellite module – Himawari pre-processing part

- **pip install ael_satellite_tools**
- from ael_satellite_tools.preprocess import Himawari
- lat = [-10, 50]
- lon = [90, 180]
- data_path = '/data/cloud2025/[Your_path]/[himawari_data_folder]'
- himawari = Himawari(data_path=data_path, lat_range=lat, lon_range=lon)

Course demo
- /data/cloud2025/homework_data/
- https://github.com/jerryjerry9/cldenv_2025

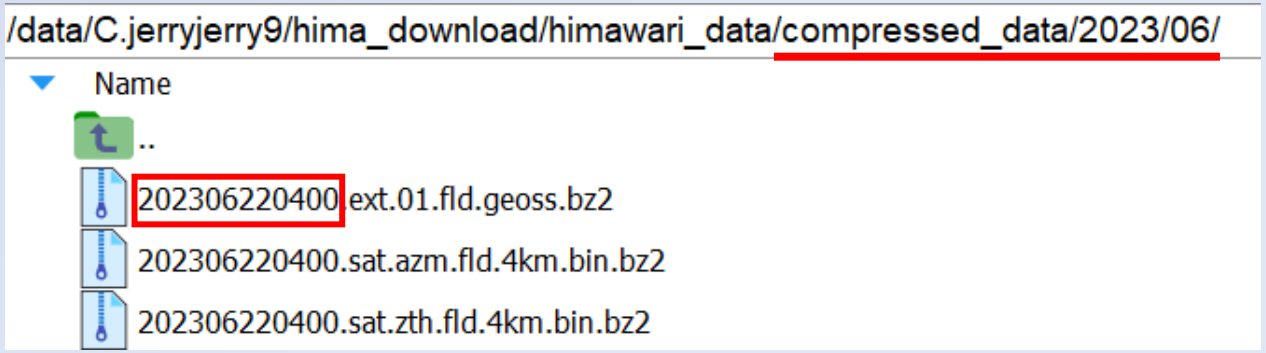
**0. Generate data list**

- himawari.generate_list()
  - According to selected time period and band data generate file list for downloading
  - Would not access FTP server
- himawari.check_exist_sub_domain_file()
  - Check whether the sub domain nc files have been processed and if the data spatial coverage fits our target region

# AEL satellite module – Himawari pre-processing part

## 1. Download

- himawari.download()
  - Would access FTP server
  - Create compressed_data folder under data_path
  - Check whether the bz2 files have been downloaded
  - No data on FTP or download failed would write message to “no_file.txt”




## 2. Decompress

- himawari.unzip()
  - Decompressed data temporary store in the machine memory

# AEL satellite module – Himawari pre-processing part

## 3. Convert binary to Albedo or TBB

- himawari.read_binary()
  - Use band (ext, vis…) and data (geoss, bin…) name as reference to read binary data into np.array
  - Ouput array shape would be (24000),(24000) in ext, (12000),(12000) in vis …. , (3000),(3000) in 4km
  - 4km datasets can be directly used after processed by this function
- himawari.convert()
  - Use LUTs to convert digits into albedo or TBB
  - Valid range of albedo: **0 ~ 120%**
  - Valid range of TBB: **69 ~ 330K** (typical range: **180~320K**)
- himawari.generate_binary()
  - **Experimental function** for output binary data at the data_path folder
  - Converted band data also can ben output (**must** change the file extension into .dat)

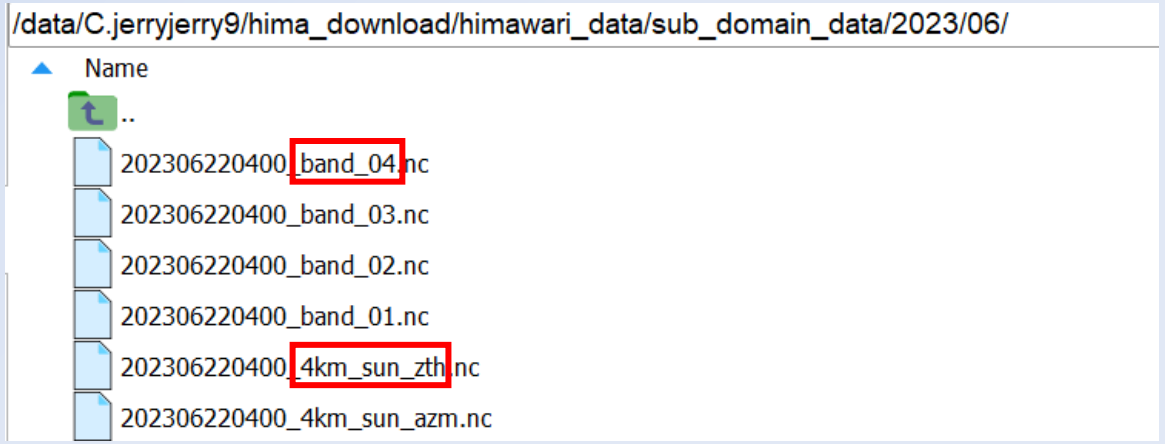
# AEL satellite module – Himawari pre-processing part

## 4. Extract sub domain

- himawari.sub_domain_extract()
  - Follow the **initial setting of lat, lon range** to extract sub domain data
  - Three output: **sub_domain_data, sub_domain_lon, and sub_domain_lat**

## 5. Output .nc file

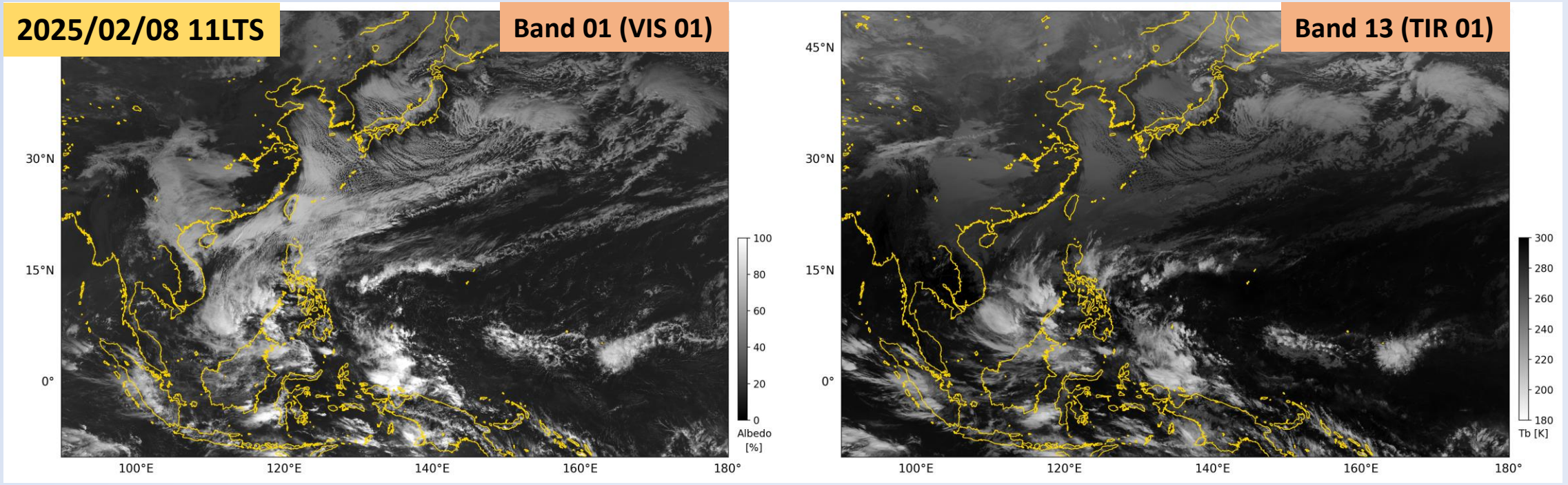
- himawari.generate_nc()
  - .nc file naming rule will shift to AHI band number (band_01 ~ band_16)
  - Variable detail (ex. long name, unit, missing value…) can be seem in the .nc file



# HW2

**Download and process with satellite module**

- Plot at least one band data over your target domain
- recommend setting:
  - Albedo: 0 ~ 100%
  - TBB: 190K ~ 300K
  - Color map: ‘gray’ or ‘binary’



# Online resource

- Near-real time image
  - https://himawari8.nict.go.jp/
- JMA Himawari home page
  - https://www.data.jma.go.jp/mscweb/en/index.html
- JAXA Himawari Monitor
  - https://www.eorc.jaxa.jp/ptree/index.html
- CHIBA Univ. gridded full-disk(FD) data page
  - http://www.cr.chiba-u.jp/databases/GEO/H8_9/FD/index.html
- CWA 衛星產品整合系統
  - https://satimage.cwa.gov.tw/SPD/home
- RGB composite product
  - https://www.jma.go.jp/jma/jma-eng/satellite/RGB_TL.html
- CWA True color description page
  - https://www.cwa.gov.tw/V8/C/W/OBS_Sat_Description.html
- Satellite Measurements of Clouds and Precipitation
  - https://doi.org/10.1007/978-981-19-2243-5

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