Retrieval of multilayer cloud physical and optical properties from infrared measurements

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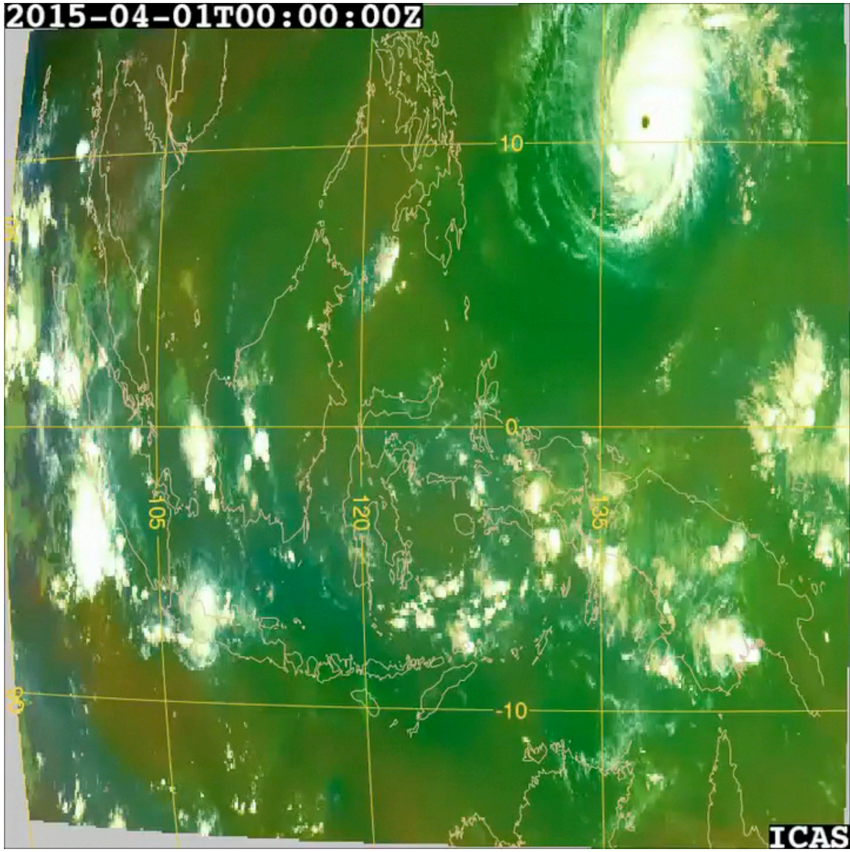
Introduction

- Multiband, frequent observations by the Himawari-8/AHI enable to study diurnal cycle of cloud system and cloud evolution during the lifetime

- For consistent retrieval of cloud-properties, we use a multiband cloud retrieval based on the optimal estimation method, which fits physics-based model simulations to the observation signals (e.g., Iwabuchi et al., 2014)

R = 8-10, G = 12-13, B = 8



Cloud retrieval overview

- MODIS/AHI measurement data
- MERRA atmosphere data
- Ocean/Land surface data
- Prior information (Climatology)

Optimal estimation (Rodgers, 2000) to minimize

$$J(\mathbf{x}) = [\mathbf{x}-\mathbf{x}_a]^{\mathrm{T}} S_a^{-1} [\mathbf{x}-\mathbf{x}_a] + [\mathbf{y}-\mathbf{F}(\mathbf{x})]^{\mathrm{T}} S_e^{-1} [\mathbf{y}-\mathbf{F}(\mathbf{x})]$$

Inversion → Estimated cloud state

Single/Double-Layer Cloud
Cloud Phase (Liquid/Ice)
Cloud-Top Pressure (CTP)
Cloud Water Path (CWP)
Cloud Optical Thickness (COT)
Cloud Effective particle Radius (CER)
Cloud-Top Temperature (CTT)
Cloud-Top Height (CTH)

Retrieval algorithm features

- Forward model
  - Rigorous radiative transfer solver (multi-layer, CKD, 2-stream raditive transfer)
  - Ice particle optical models: Yang et al.’s (2013) ice database, Liu et al.’s (2015) two-habit model
- Simultaneous use of 8–10 TIR bands
  - Window bands and H_2O, CO_2, and O_3 absorption bands

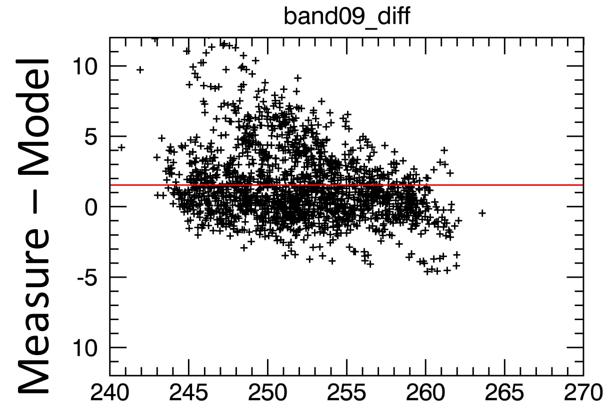
Measurement and model errors

Error covariance matrix

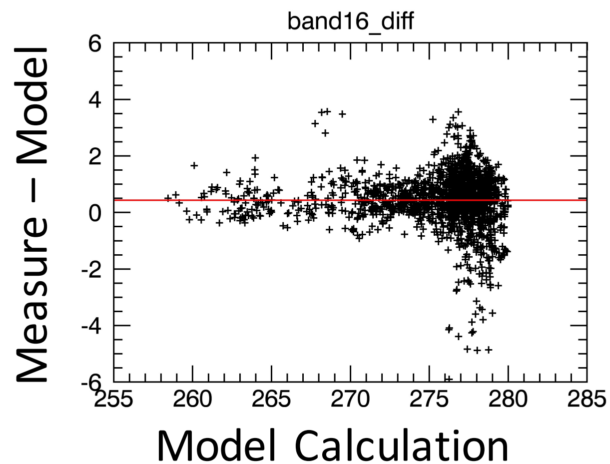
$$S_e = S_{e,noise} + S_{e,RTM} + S_{e,atm} + K_b S_b^{*} K_b^{\mathrm{T}}$$

- Measurement noise
- Error in radiative transfer modeling (CKD model and approximate solver)
- Errors in atmosphere (MERRA) data
- *Errors in background surface emissivity (e.g., ocean optical constants and wind velocity)
- *Cloud optical and physical model (e.g., cloud base pressure)

Comparison for clear-sky pixels



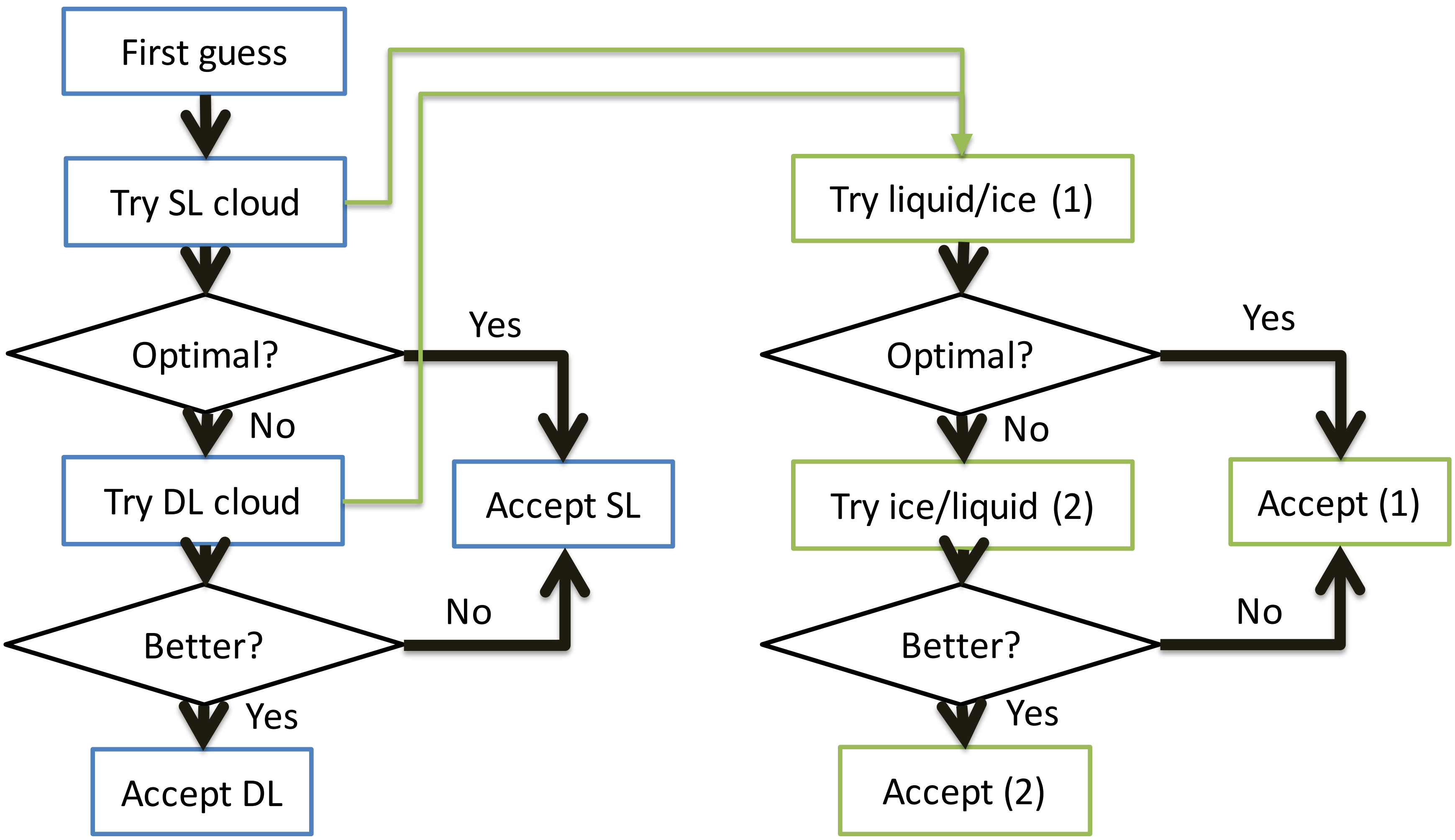
Band 9
H2O band



Band 13
Window
band

Inversion algorithm

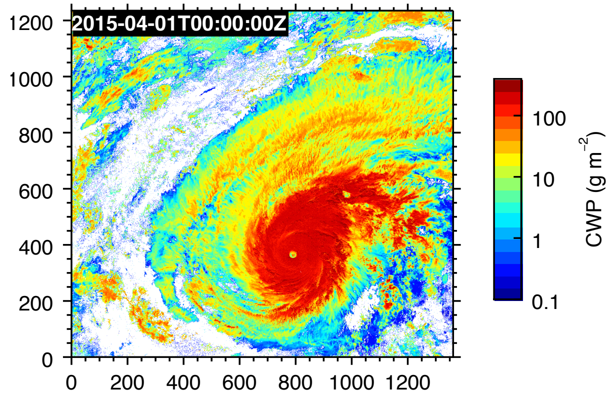
From adjacent pixel or *a priori*



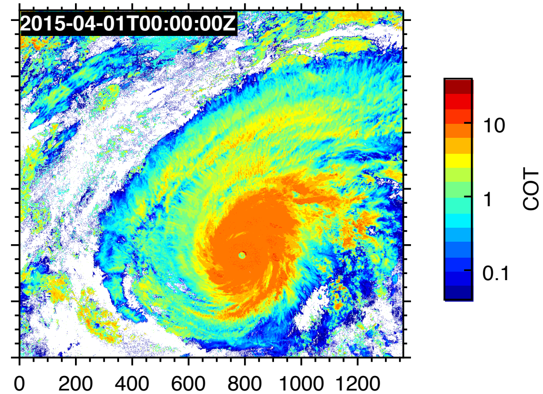
Typhoon “Maysak”

Maysak: 2015/3/28~4/5, Lifetime of 204 hours

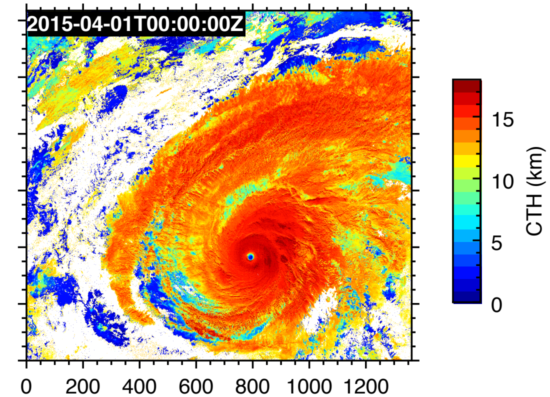
Cloud Water Path



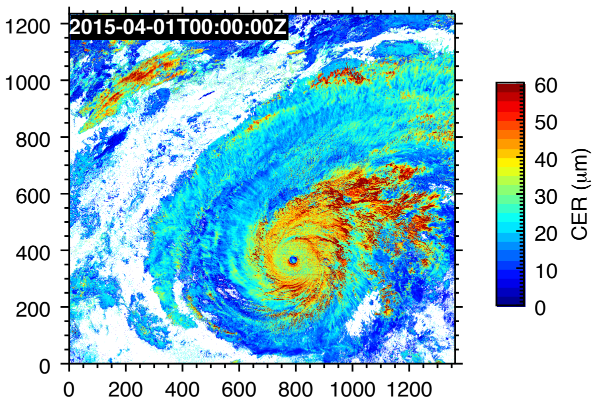
Cloud Optical Thickness



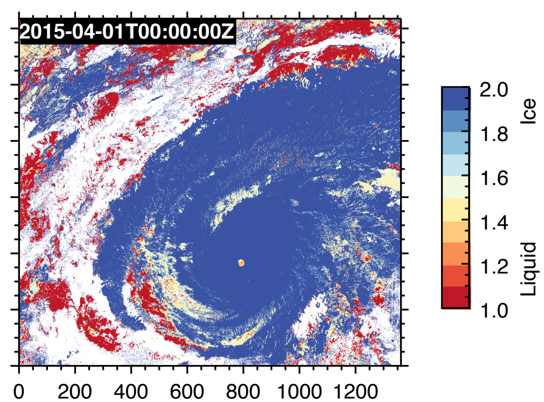
Cloud Top Height



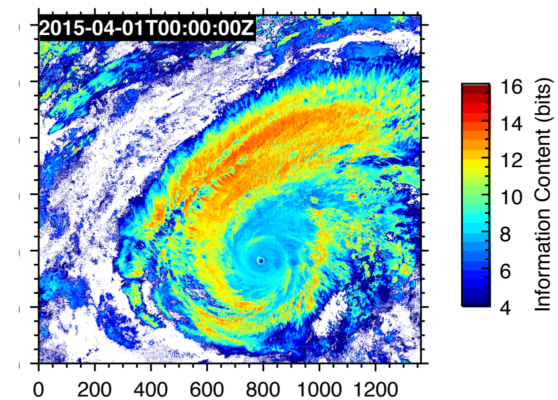
Cloud Effective Radius



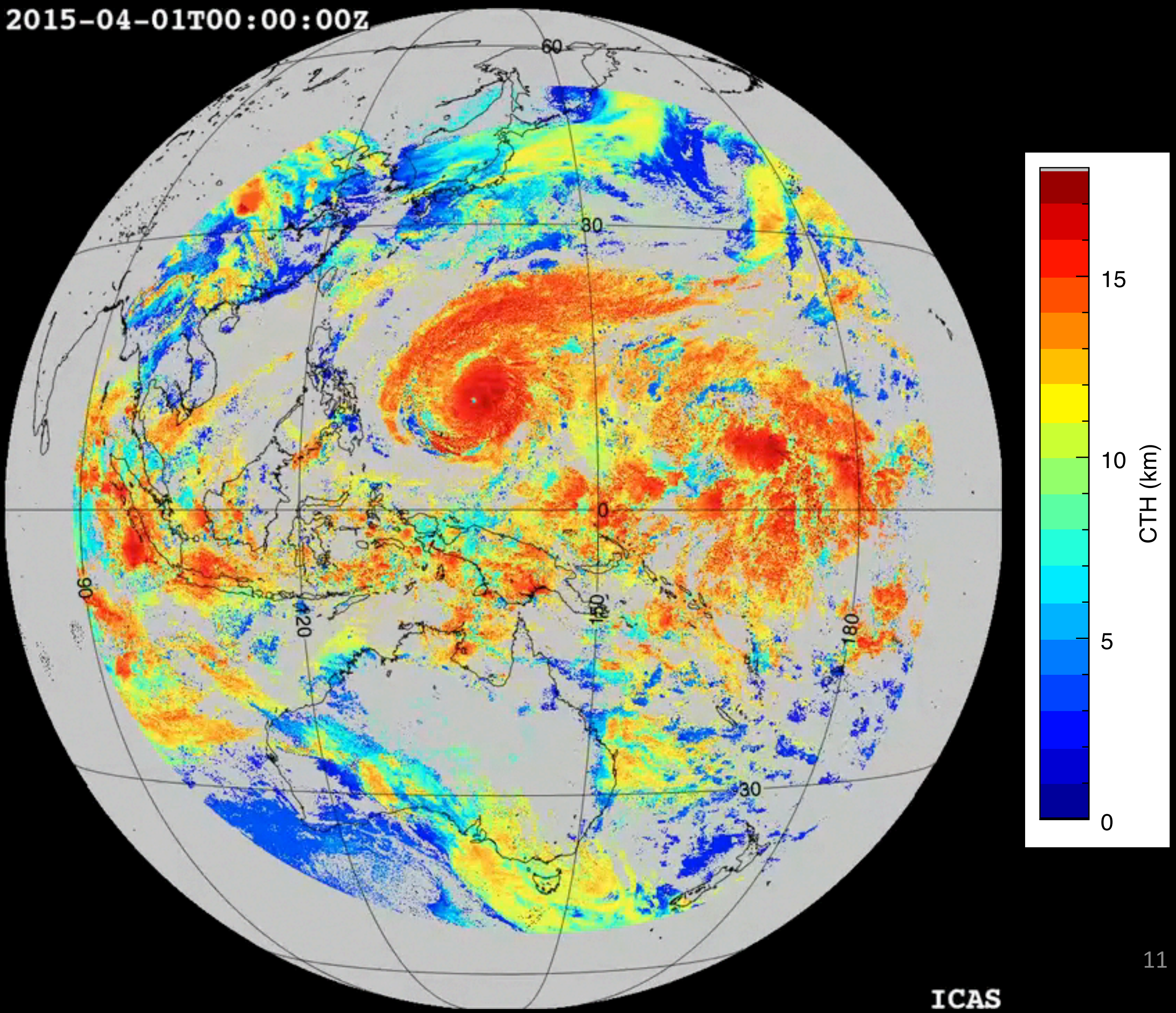
Cloud Phase



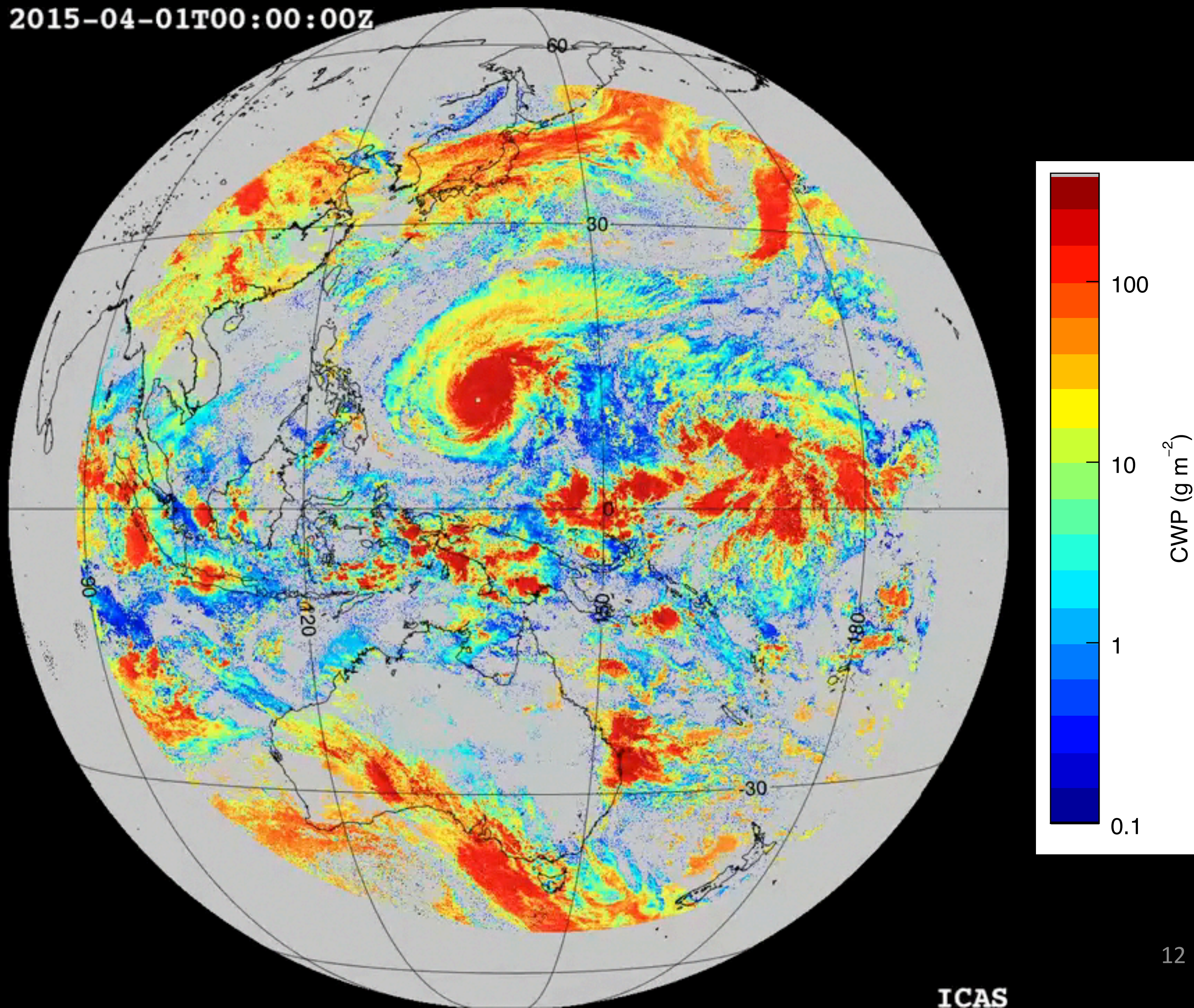
Information Content



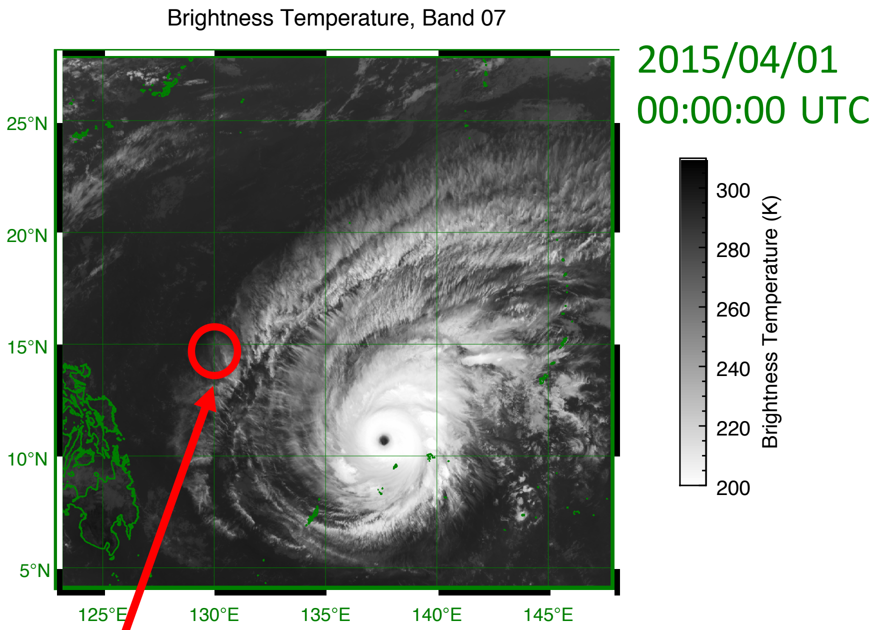
Cloud-Top Height



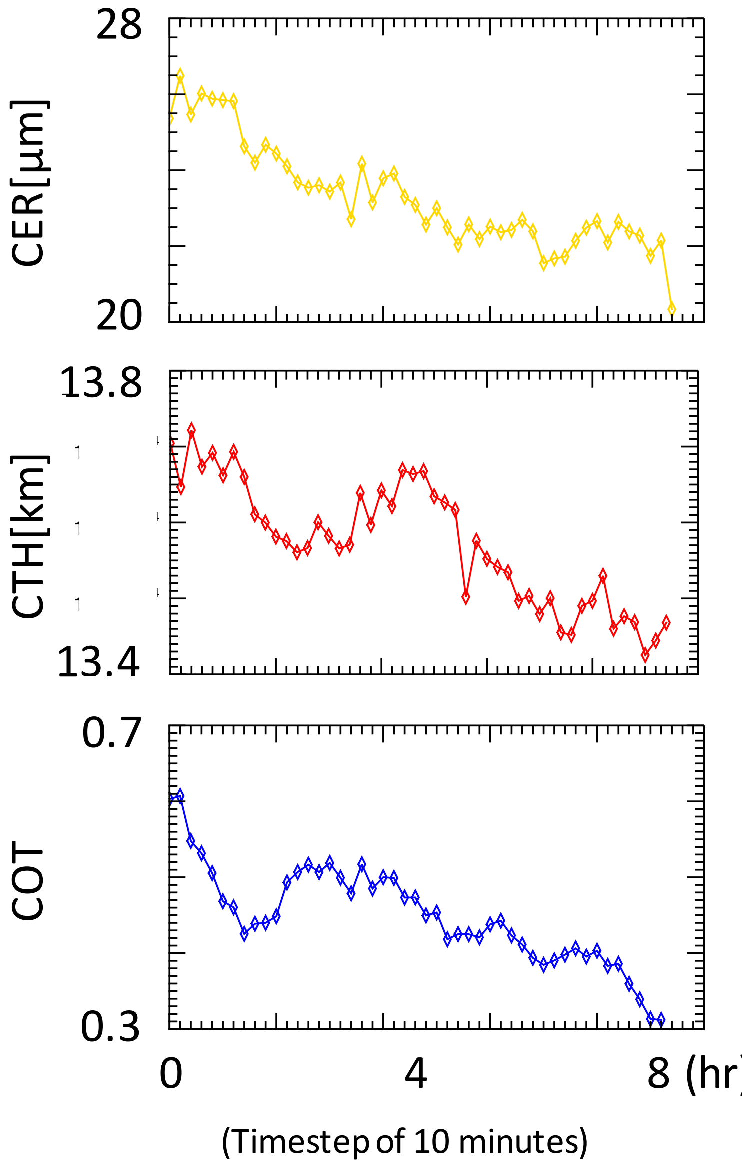
Cloud Water Path



Cloud evolution studied using the cloud tracking



Traget tracked by the Cross Correlation Method



-Target variable: Cloud-top hight
-Using high quality retrievals (Total Retrieval Cost < 16, Relative Error < 100%)
-Combining 3 successiv timesteps

Conclusions

- Simultaneous use of thermal IR bands enables to <u>better infer cloud-top of optically thin cloud</u>
  - The cloud retrieval performs well when COT=0.15–10 and CER=2–150 μm for ice cloud
- Frequent observations by the Himawari-8/AHI provide a new dimension to study cloud system evolution