Evaluations of cloud and precipitation using a satellite simulator

Woosub Roh[1], Masaki Satoh[1], Tempei Hashino[2]

[1]AORI, the univ. of Tokyo, [2]Kochi univ. of Technology

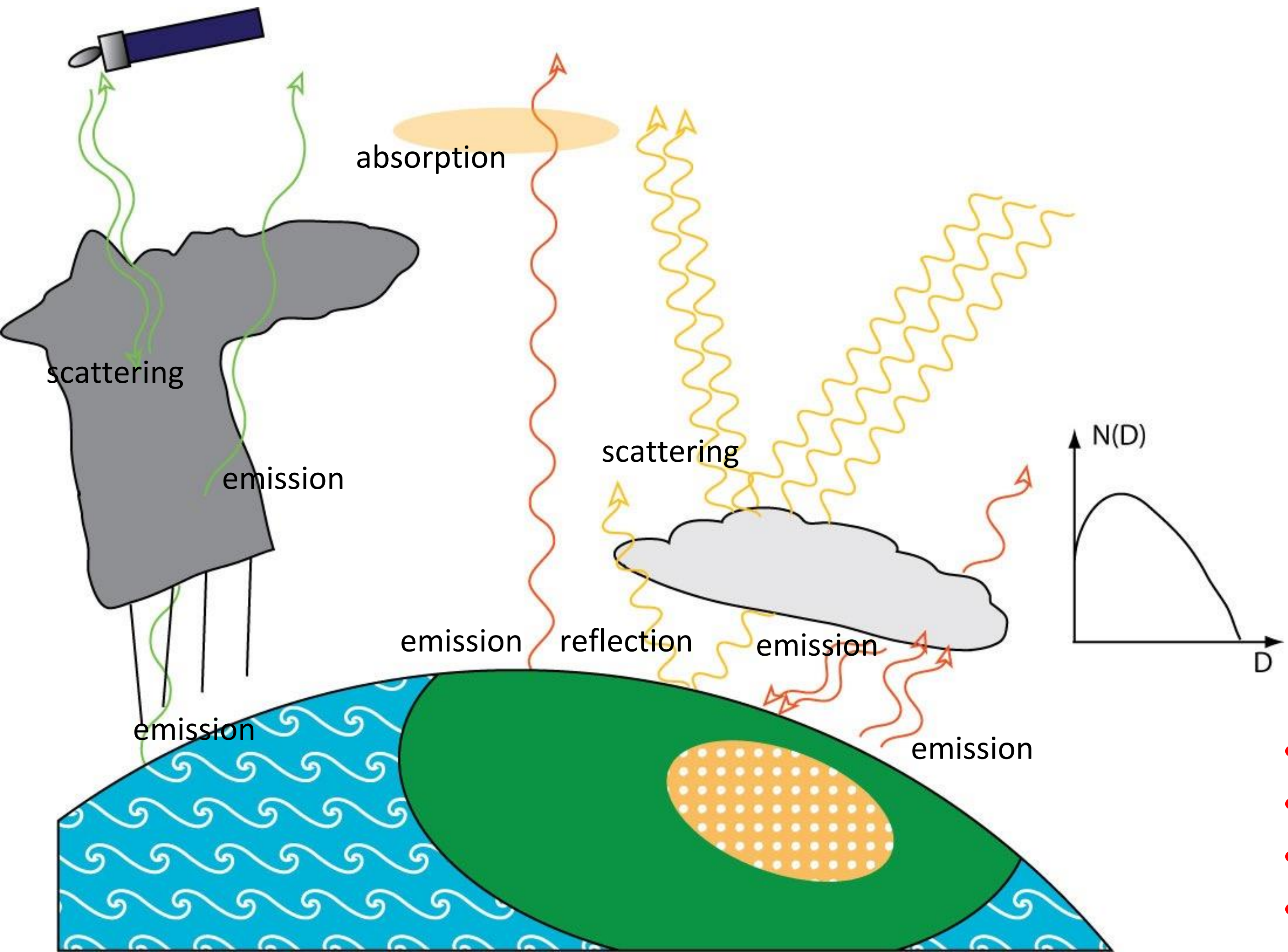
19th June. 2019

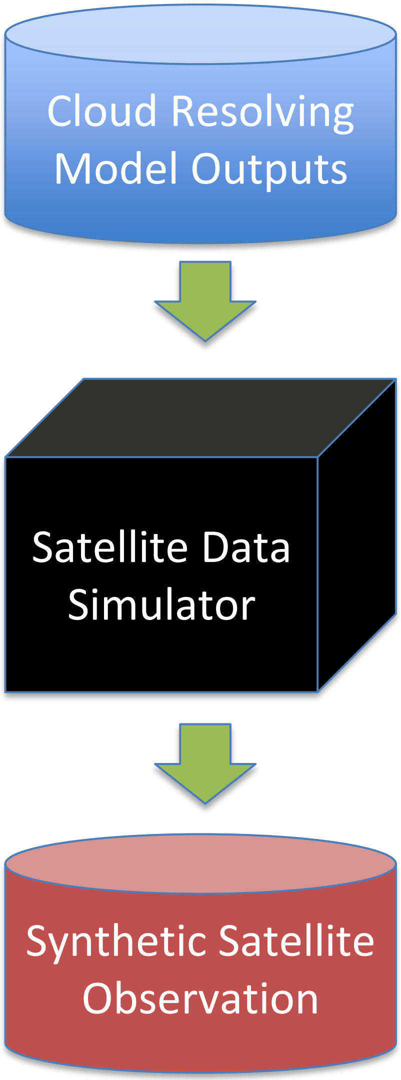
2nd DYAMOND-ESiWACE Hackathon in Mainz

An analysis was done by the NEC SX supercomputer at Center for Global Environmental Research of National Institute for Environmental Studies.

What is Joint-Simulator?

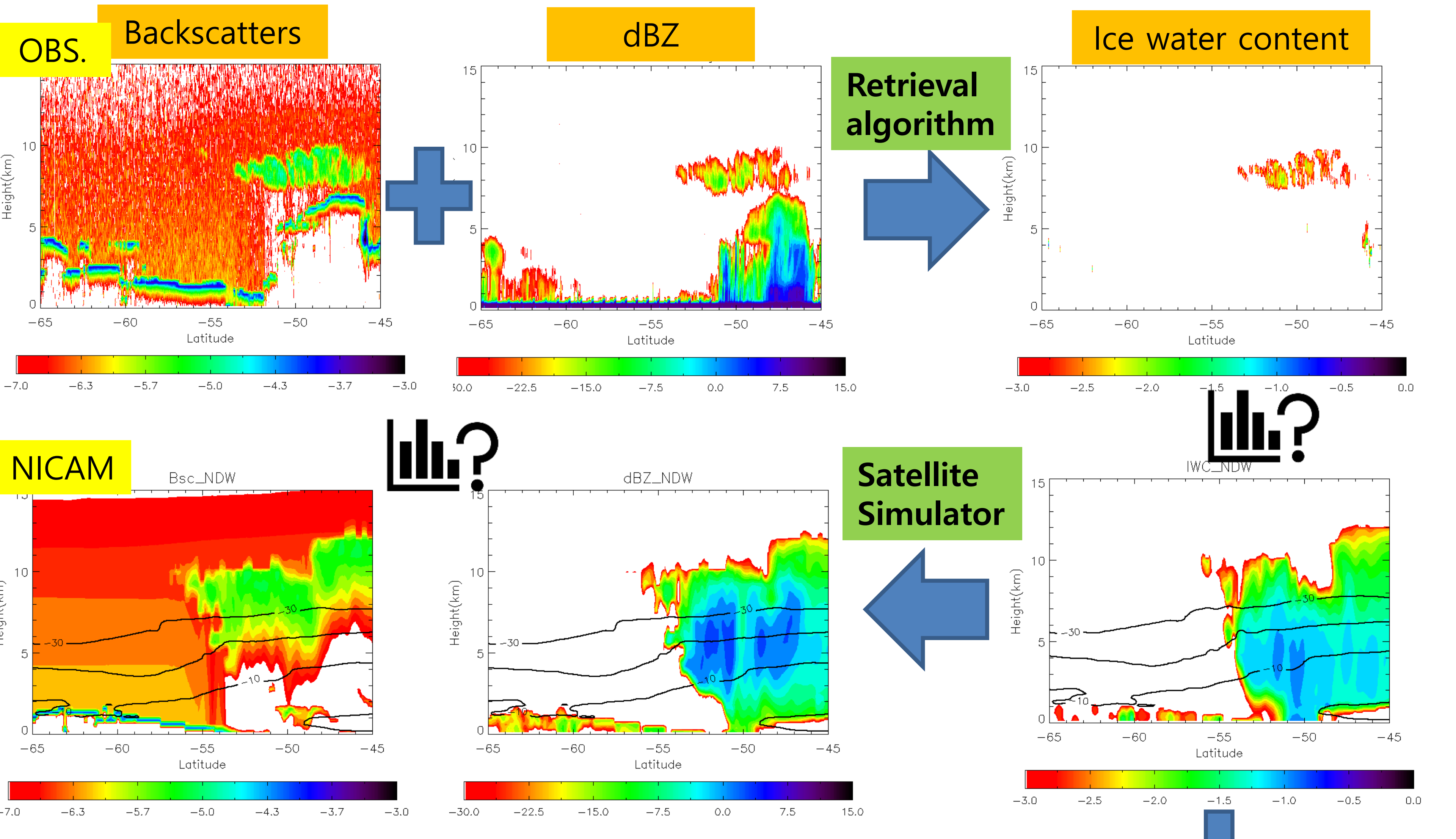
Joint-Simulator (Hashino et al. 2013) can simulate satellite radiances from numerical weather/climate model outputs, developed by the JAXA EarthCARE mission and the Joint-Simulator team.





- Pseudo L1 product
- Model evaluation
- Model improvement
- Assimilation

Merits of satellite simulators



Free to sampling problems, different size distributions

Temperature, LWC, water vapor, pressure, winds and so on

Blue: SDSU modules
(http://precip.hyarc.nagoya-u.ac.jp/sdsu/index.html)

Green: NASA Goddard SDSU extension
(http://opensource.gsfc.nasa.gov/projects/G-SDSU/index.php)

Orange: Joint-Simulator extension
(https://sites.google.com/site/jointsimulator/home)

Visible and infrared imager
- RSTAR6b (Nakajima & Tanaka 1986, 1988)
  - Discrete-ordinate method/adding method
  - K-distribution table with HITRAN2004
- RSTAR7
  - The nonspherical scattering process,
  - - Hexagonal column (Yang et al. 2000, 2005)
  - - Spheroid (Dubovik et al. 2002)

Microwave radiometer and sounder
- Kummerow (1993)
  - Eddington approximation
- Liu (1998)
  - Four-stream discrete ordinate method

Radar
- Masunaga & Kummerow (2005)
- EASE (Okamoto et al. 2007, 2008; Nishizawa et al. 2008)

Lidar
- Matsui et al. (2009)
- EASE (Okamoto et al. 2007, 2008; Nishizawa et al. 2008)

Broadband radiometer
- CLIRAD (Chou and Suarez 1994, 1999; Chou et al. 2001)
- MSTRN-X (Sekiguchi and Nakajima 2008)
- RRTMG (Iacono et al. 2008)

Joint-Simulator Activities of NICAM

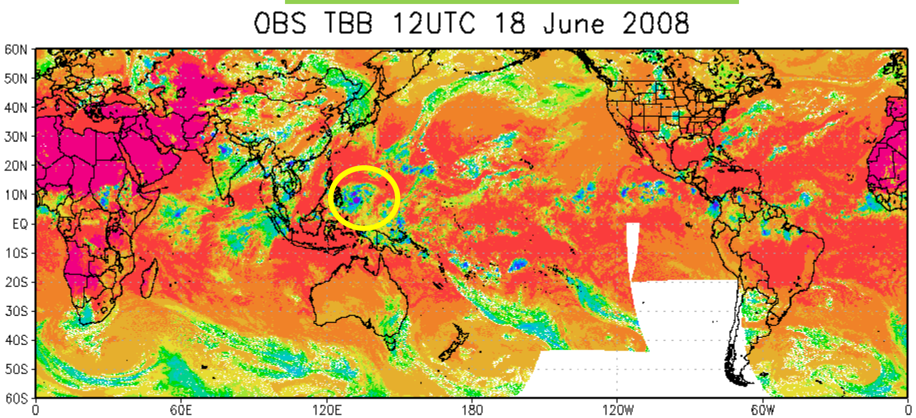
Satoh, M., Roh, W., Hashino, T. (2016) Evaluations of clouds and precipitations in NICAM using the Joint Simulator for Satellite Sensors. CGER's Supercomputer Monograph Report. Vol. 22, http://www.cger.nies.go.jp/publications/report/i127/en/

- Evaluation of clouds
  - Hashino et al.(2013,2016, JGR) using CALIPSO and CloudSat
  - Roh and Satoh (2018, JMSJ) using AMSR-E and geostationary satellites
- Improvement of cloud schemes
  - Roh and Satoh (2014,2017,JAS) using TRMM and MTSAT
- Understanding of microphysical process of warm clouds using bin microphysics scheme
  - Kuba et al. (2014 JGR,2015 JAS) using MODIS and CloudSat
- Assimilation by NICAM-LETKF
  - Kotsuki et al.(2017 SOLA) using GPM
- Evaluation of mixed-phases clouds using CALIPSO (in preparation)

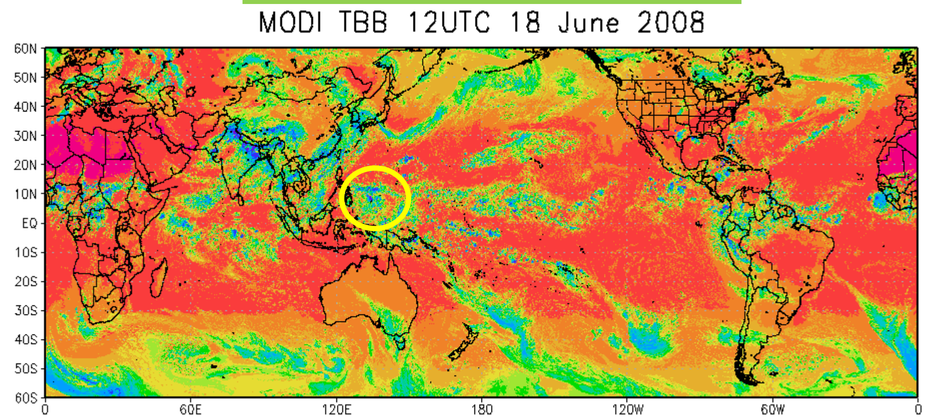
Examples of Joint-Simulator (J-SIM)

3.5 km simulation for June 2008 case

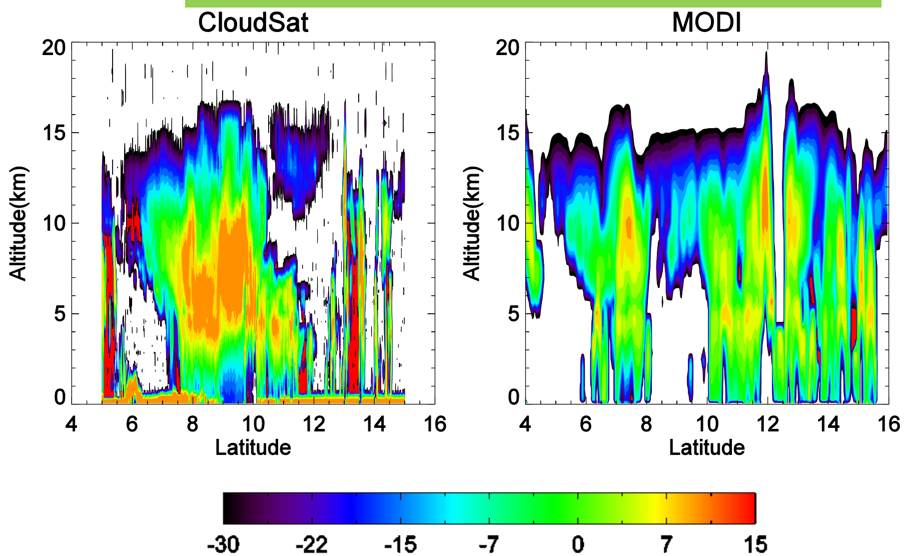
Merged 11μm TB



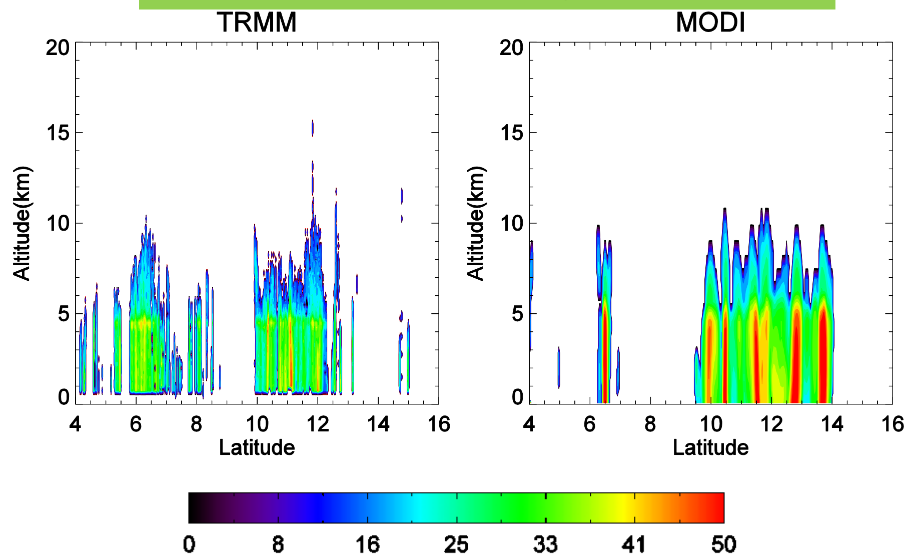
NICAM 11μm TB



ClouSat For TC Fengshen



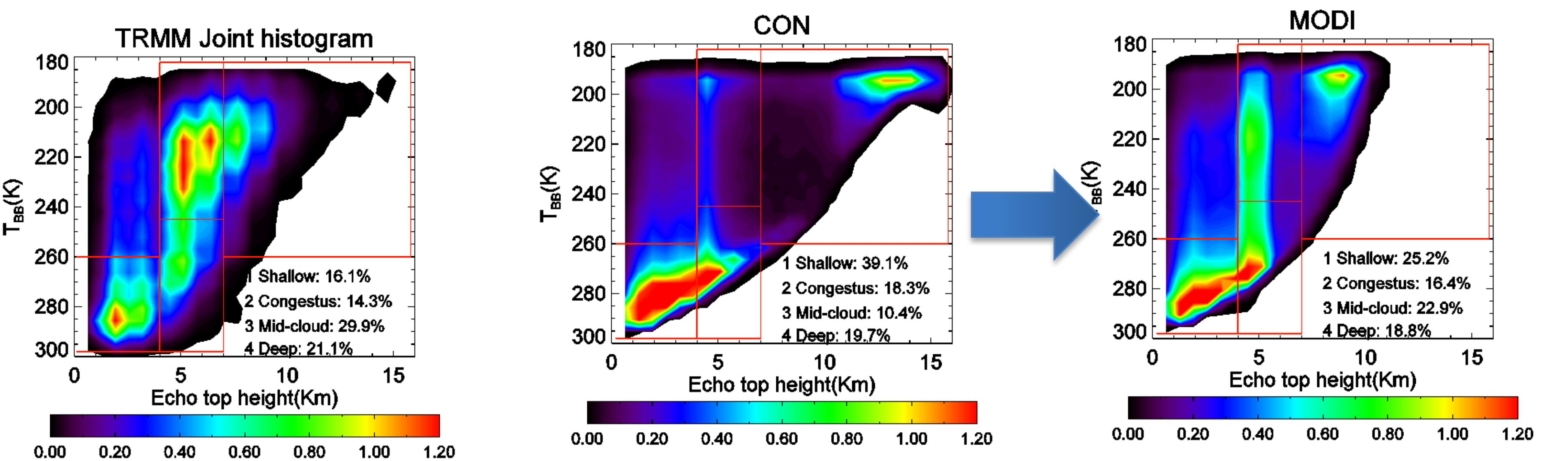
TRMM For TC Fengshen



Example about Improvement of microphysics in NICAM

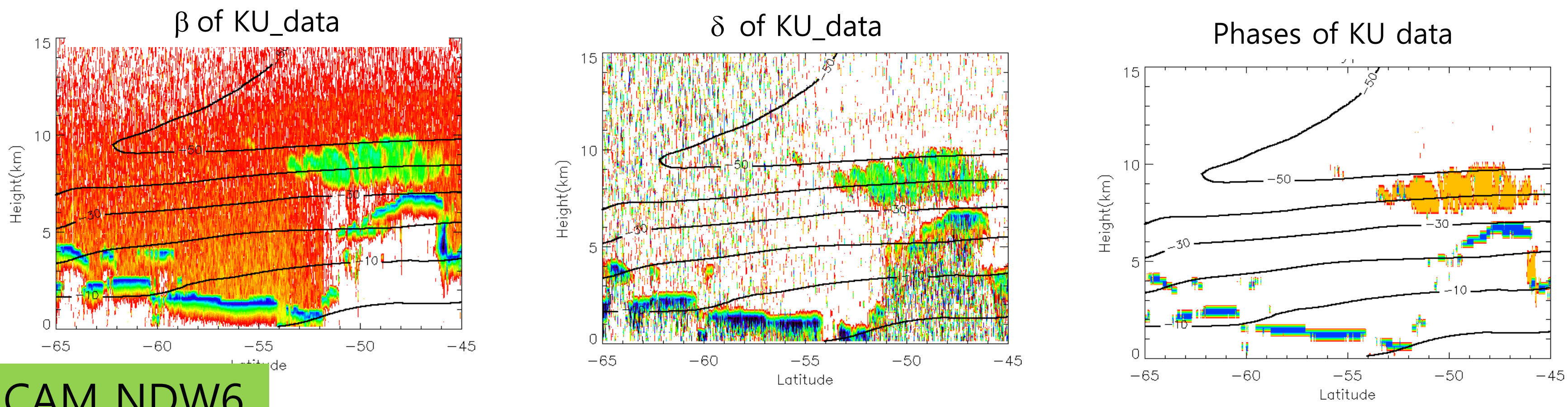
Change of microphysics in NICAM (Roh et. al 2014, 2017)

Saturation adjustment for cloud ice → Ice nucleation and ice deposition (Hong et al. 2004)
Turn off collection terms of snow and ice by graupel (Lang et al. 2007) → To increase stratiform precip.
Size distribution of precipitating hydrometeors → realistic size distribution
Snow → Bimodal size distribution, $m(D) \propto D^2$ (Field et al. 2005)
Graupel → Increased N_{0g}
Rain → Marshall-Palmer distribution and Zhang et al. 2008

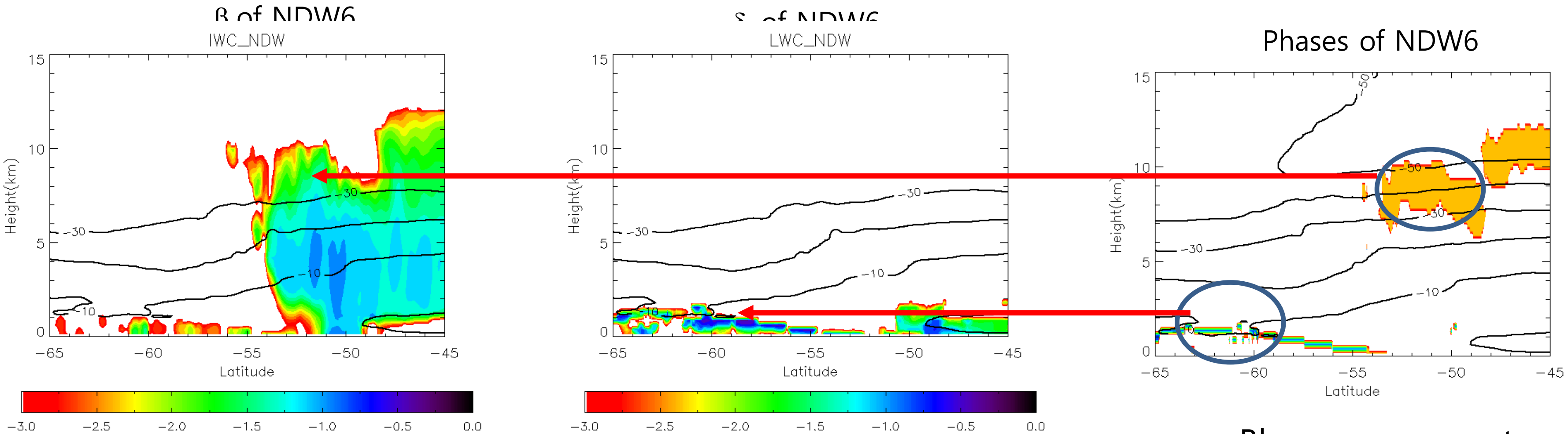


Example about thermodynamics phases over the Sothern Ocean (Roh et al. in preparation)

Observation



NICAM NDW6



Blue or green: water clouds
Orange: ice clouds

We evaluated the thermodynamic phase using an approach of Yoshida et al.
The evaluation results depend on microphysics scheme (not shown).

Variables and information to run J-SIM

- 3D data

 - temperature, pressure, winds, hydrometeors (mixing ratio, number concentration for cloud water, cloud ice, rain, snow, graupel, hail)

- 2D data

 - surface temperature, sea level pressure, temperature at 2m, water vapor at 2m, horizontal winds at 10m altitude

- Information about microphysics scheme
- Size distribution, density, non-spherical assumption for ice particles

- Topography data and vegetation data

My suggestions using J-SIM and DYAMOND data?

We found the DYAMOND data simulated the synoptic cloud systems and tropical cyclone well in the previous presentation.

How about the detail structure of cloud and precipitation systems in DYAMOND like

- Storm structures using GPM or CloudSat
  - convective or stratiform precipitation structure
  - precipitation and anvil clouds

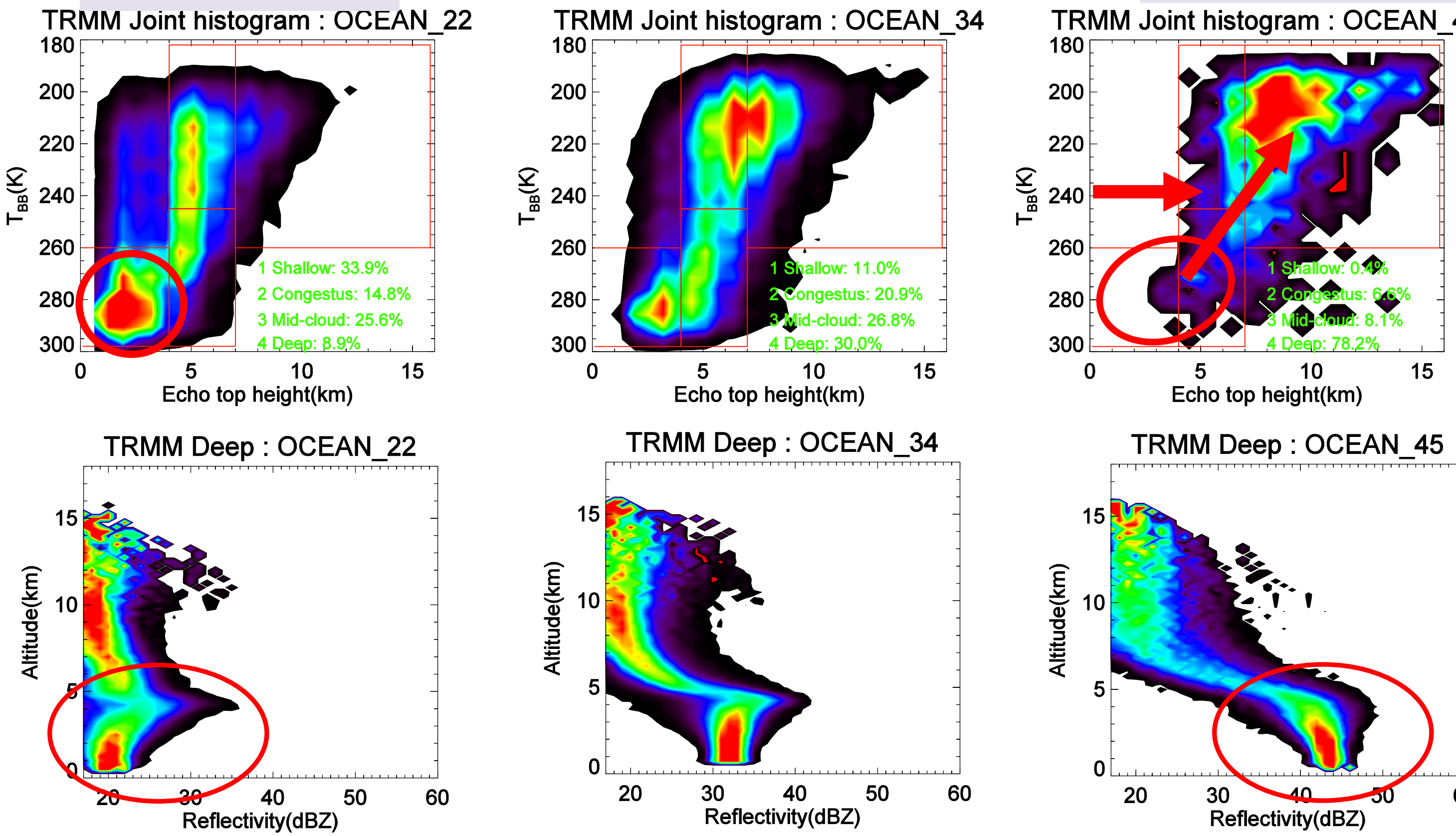
- How about extreme precipitation cases using GPM?
  - precipitation amount
  - geolocation
  - vertical structures of radar reflectivities

- Estimation of vertical velocity using Himawari-8 (Hamada and Dakayabu 2016)

Dependency of surface radar reflectivity on precipitation systems

Case : 2008 June case

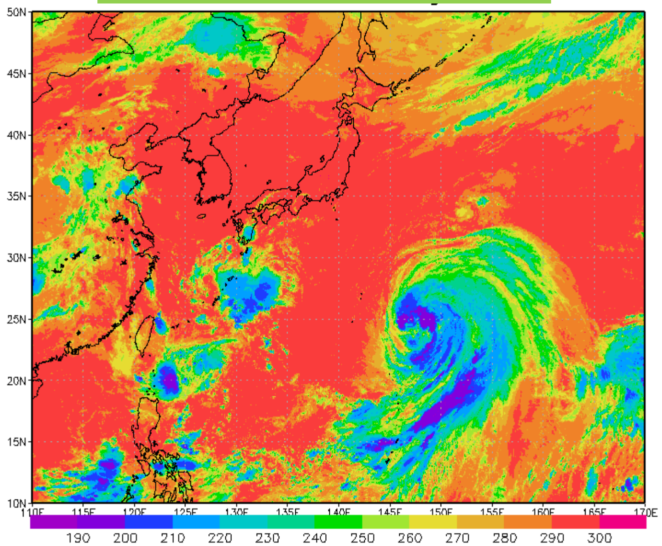
19 ~ 22 dBZ (~1 mm/hr)	34 ~ 37 dBZ (~ 4 mm/hr)	43 ~ 45 dBZ (~20 mm/hr)



Averaged surface dBZ of 3 layers from the surface.

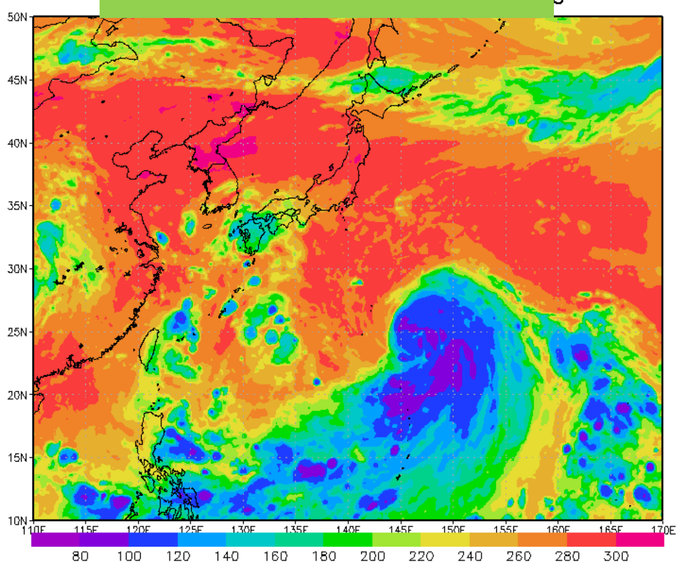
Comparison between Himawari-8 and OLR

Himawari data

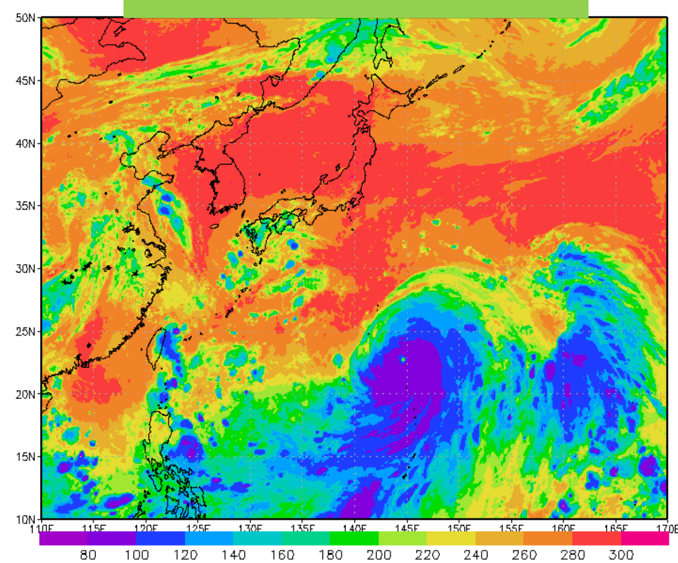


Himawari data have higher temporal resolution like 10 min or 2.5 min.
→ It is good for the tracking of cloud systems

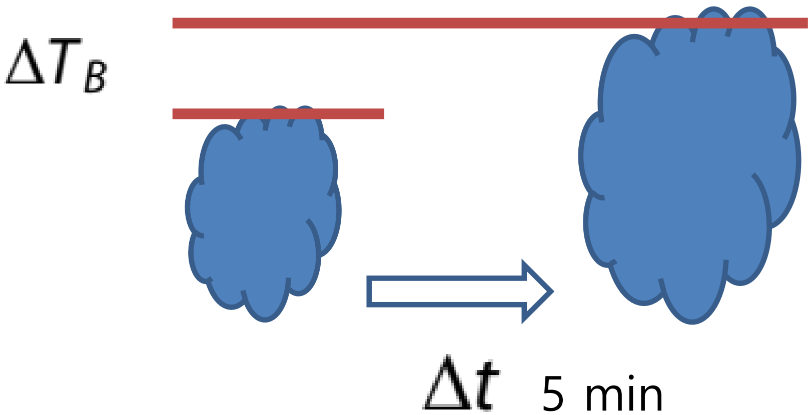
7 km NICAM OLR



3.5 km NICAM OLR

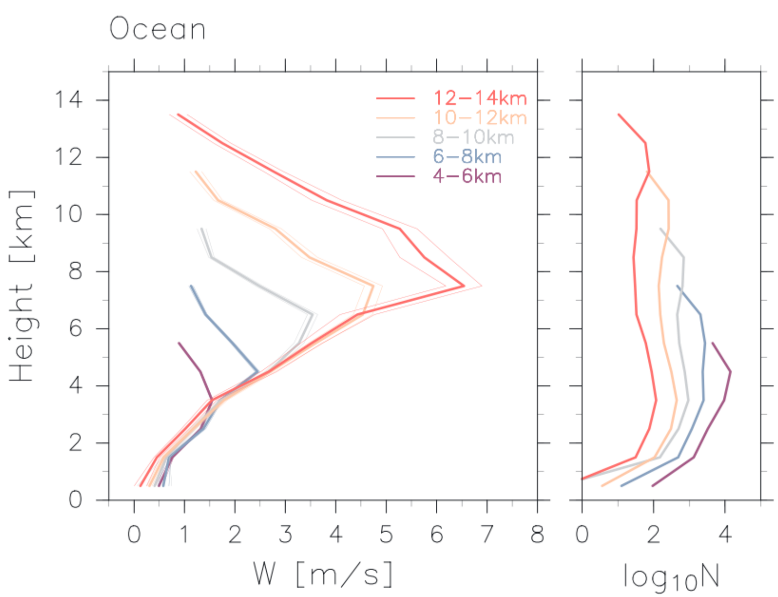


Estimation of vertical velocity using Himawari-8 data (Hamada and Takayabu 2016)



$$\frac{dT_B}{dt} \approx \frac{dT}{dt} \approx w\frac{\partial T}{\partial z} \approx w \cdot \gamma_m$$

$$w \approx \gamma_m^{-1}\frac{dT_B}{dt} \approx \gamma_m^{-1}\frac{\Delta T_B}{\Delta t}.$$



It is interesting to intercompare the vertical velocity of DYAMOND data.

→ However, we need higher temporal DYAMOND data for a specific case.

Summary

- Joint simulator is a one of tools to evaluate DYAMOND data using satellite observation.
  - Horizontal distribution of clouds using geostationary satellite data
  - Statistics of clouds or precipitation systems using GPM
  - Thermodynamics phases of clouds using CALIPSO

- We need more variables and information to use Joint simulator.

- If we simulate the higher temporal resolution data (2.5 min or 10 min), we can evaluate the vertical velocity using Himawari data.

Thank you