Global 3.5km-mesh NICAM experiment: cloud evaluation using Joint-simulator and TC genesis analysis

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Introduction

The Nonhydrostatic Icosahedral Atmospheric Model, NICAM, is used to simulate multis-cale structure of tropical convective system. During the Year of Tropical Convection (YOTC), we chose an event related to Tropical Cyclone Fengshen (2008) and performed a global nonhydrostatic simulation with mesh size approximately 3.5 km for the period June 15-25, 2008.

This paper discusses

- Genesis of TC Fengshen briefly (Nasuno et al. 2012)
- Methodology to evaluate cloud microphysical variables simulated by NICAM through use of a satellite signal simulator and direct comparison against satellite observation (Hashino et al. 2012)

Experiment design & Tools

NICAM (Satoh et al. 2008)

- Initial values interpolated from ECMWF YOTC operational analysis on 00UTC 15 June 2008.
- Horizontal mesh size: 3.5 km; vertical grid: 40 stretched layers.
- 10-day simulation executed on the Earth Simulator.
- cloud microphysical parameterization: NSW6 (Tomita 2002) 1-moment scheme with six categories (vapor, cloud droplets, rain, cloud ice, snow, graupel)

Satellite Observation: CloudSAT-CALIPSO merged data set（Hagihara et al. 2010）

- one moth observation (June 2008).
- Vertical resolution: 240m; horizontal resolution: 1.1 km
- Three cloud masks: Radar mask (C1) for cloud & precipitating particles; Lidar mask (C2) for cloud particles; Radar and Lidar mask (C3) for cloud particles.

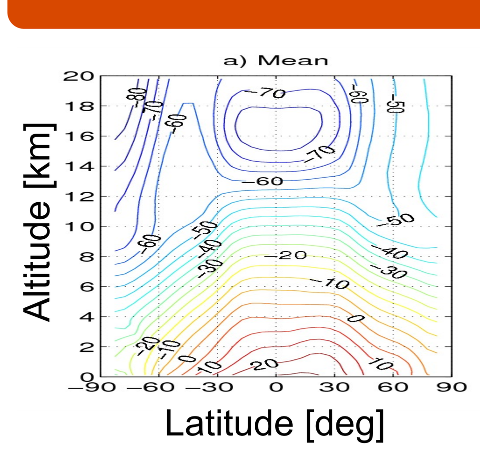
Joint Simulator for Satellite Sensors (Joint-Simulator)

- being developed under JAXA/EarthCARE mission.
- Inhereted from NASA Goddard Satellite Data Simulator Unit (SDSU) (Masunaga et al. 2010)
- EarthCARE Active Sensor simulator, EASE, (Okamoto et al., 2003, 2007, 2008; Nishizawa et al. 2008) used for simulating CloudSat CPR 94GHz radar reflectivity Z_e' and CALIPSO 532nm backscattering coefficient β_{532}'.
- created another merged data set from the simulation.

Conclusion

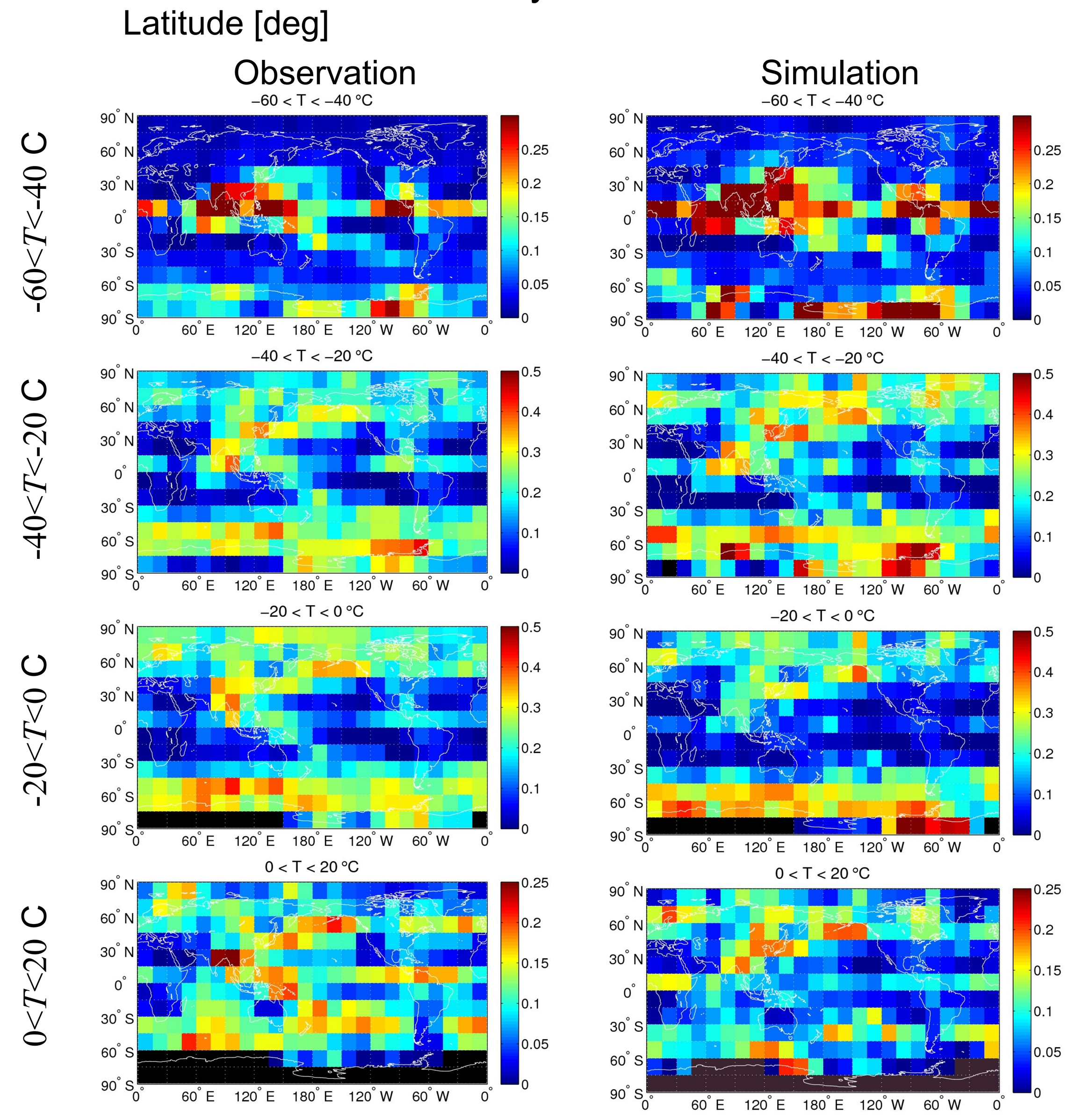
- The Troipcal Cyclone genesis and track for Fengshen has been successfully simulated with NICAM. It was found that an initial low-level vortex did not attain to typhoon intensity with deep axisymmetric structure until a westward-propagating disturbance with vertically coherent structure in the lower to middle troposphere came across this region. The analysis of band-pass filtered data suggests that this disturbance was associated with a synoptic-scale wave trough.
- Qualitatively speaking, cloud fractions simulated NICAM agree well with the observation. The direct comparison of the radar and lidar signals simulated from NICAM against CloudSat-CALIPSO observation indicates that there is a strong in-cloud bias in cloud ice and snow. Use of temperature as the vertical axis gives new insights on cloud microphysical aspects.

Cloud fraction analysis



Left figure: Zonal mean air temperature of ECMWF versus altitude in June 2008.

- Cloud fractions calculated for 15°x15° by 20°C based on C1 mask.
- Use of temperature shows more information on phase of hydrometeors and ice nucleation.



Overestimate high ice clouds especially over India & south Asia.

Good agreements

Less clouds (possibly mixed phase) over Asia, more over southern mid-high latitudes.

Less low-level liquid clouds over land and ocean.

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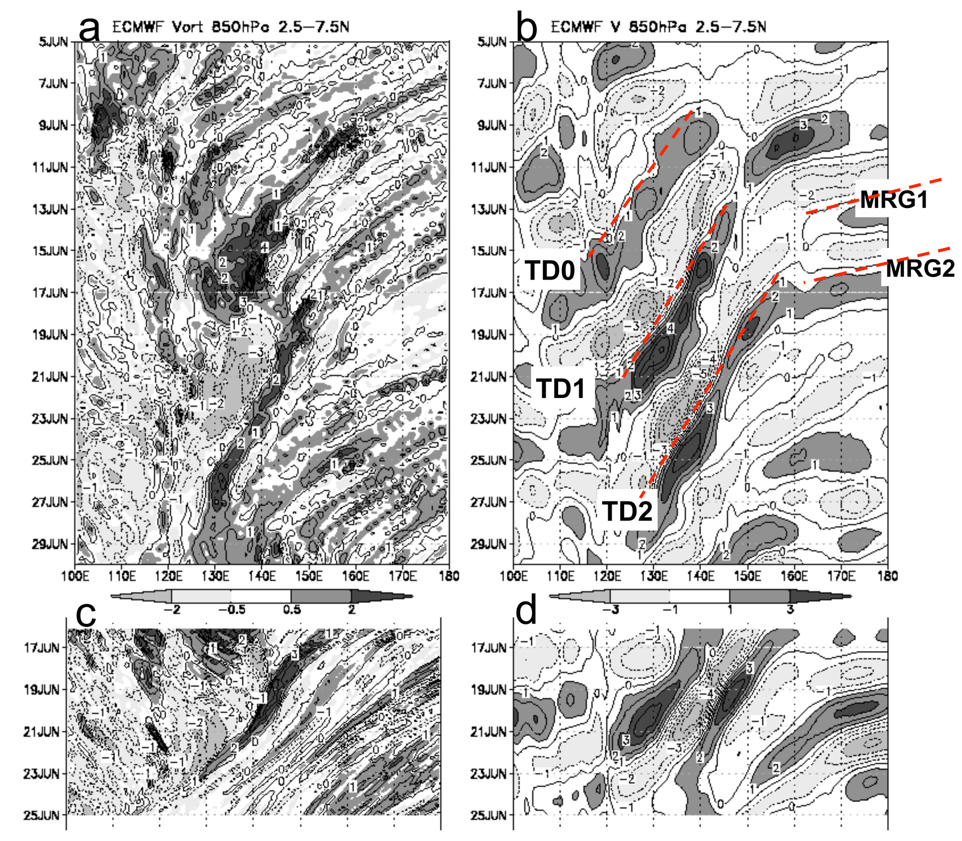
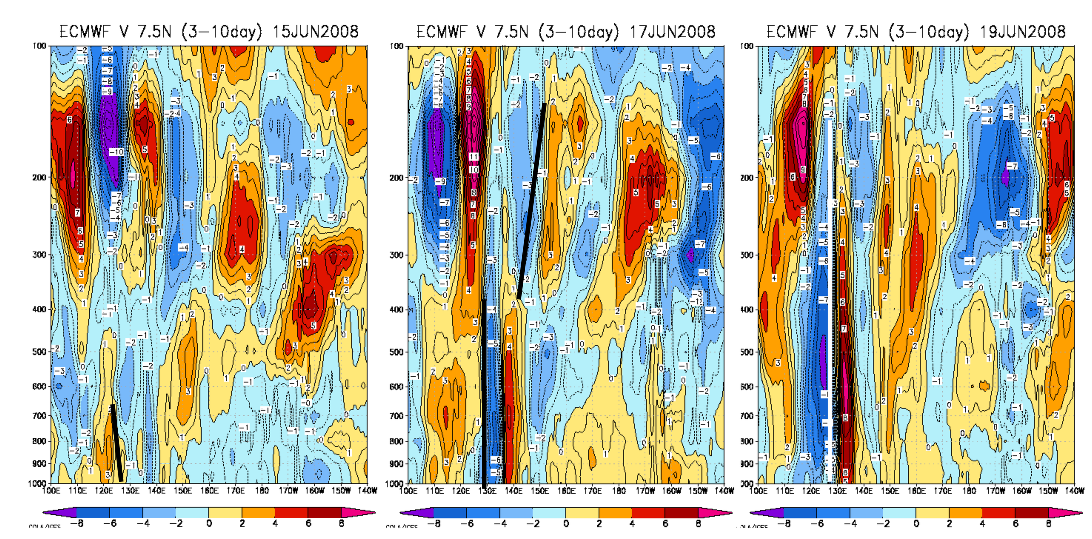
Genesis of Fengshen



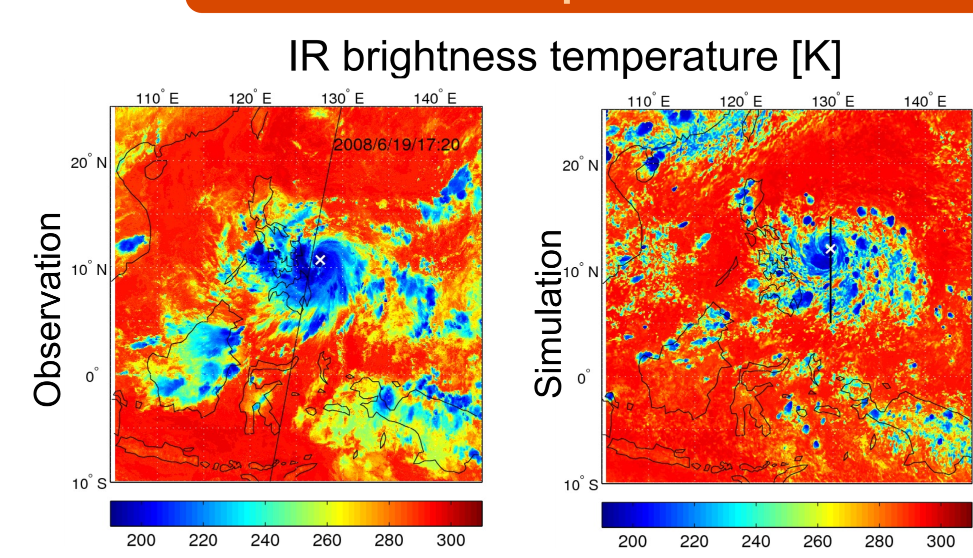
Time-longitude section at 850hPa (7.5ºS-7.5ºN average) in ECMWF YOTC data for 3-10 day filtered (a) relative vorticity and (b) meridional velocity averaged in 2.5º-7.5ºN for June 2008. The corresponding simulation results are also shown in (c) and (d), respectively (the first 24 hour, the spin-up period, is omitted).

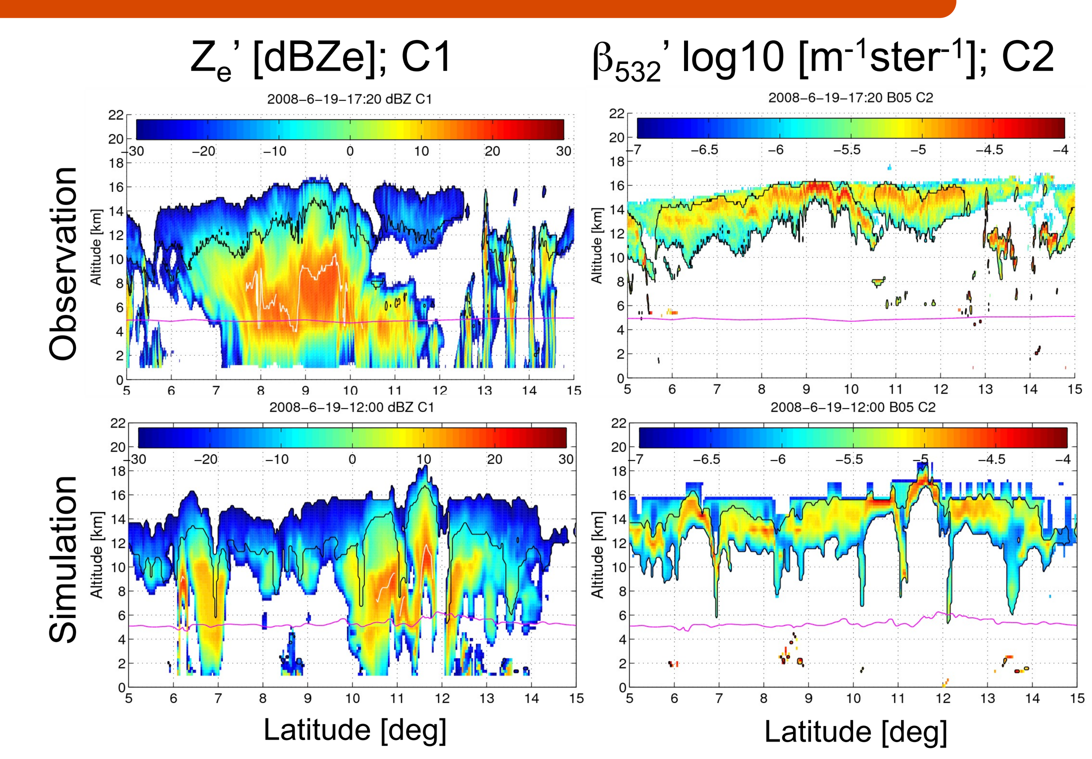


Vertical section of 3-10 day filtered meridional velocity along 7.5ºN on (a) 15 (b) 17 and (c) 19 June 2008.

- Rapid growth of Fengshen occurred at the timing when a westward-propagating disturbance associated with a synoptic-scale wave trough came over the incipient vortex of Fengshen. The vertically tilted phase structure of the wave gradually became upright, decreasing vertical wind shear.

Example of satellite observation on June 19th

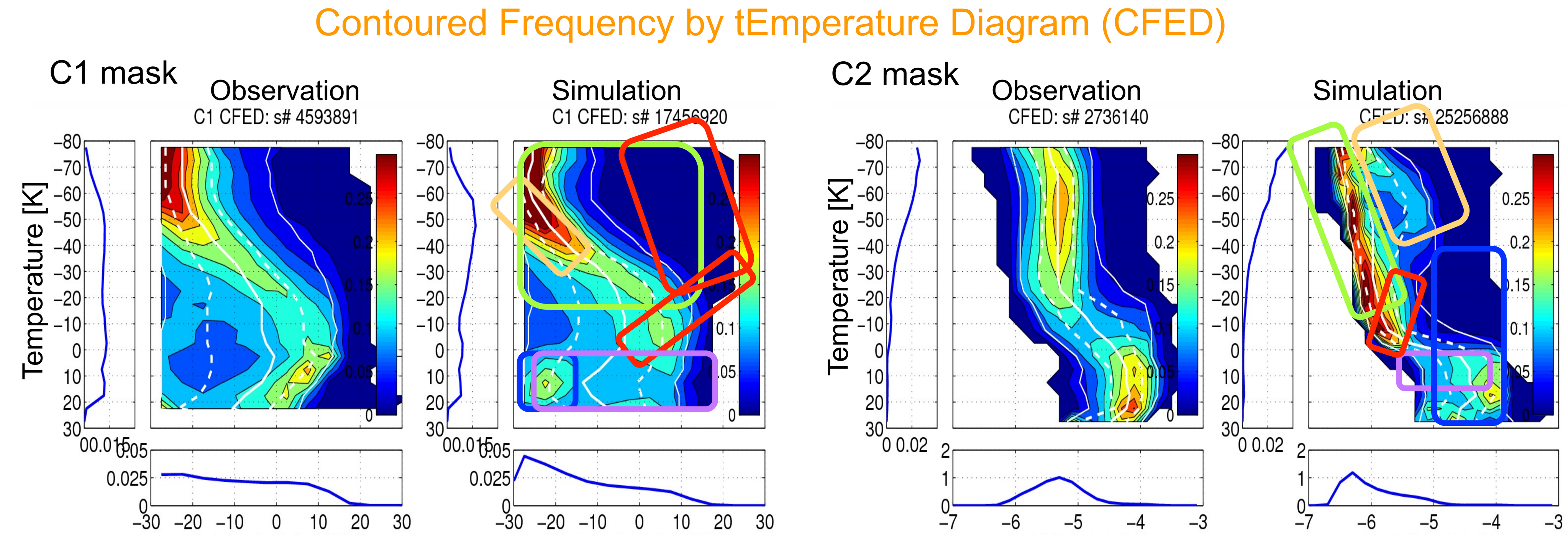




- North-south asymmetry of TC is simulated with NICAM.
- The cloud organization appears different: simulation has less spread of detrainment, suggesting stratiform portion of convective systems is not well simulated.
- Overall, the radar reflectivity is well simulated with signatures of convective and stratiform clouds, while the backscattering seems to be underestimated.
- Overlap regions of C1 and C2 mask (black lines) extends up to ~4 km both in OBS and NICAM.
- Multiple scattering (altitude below white lines) in the radar can be significant in convective cores, which is not parameterized in the radar simulator.

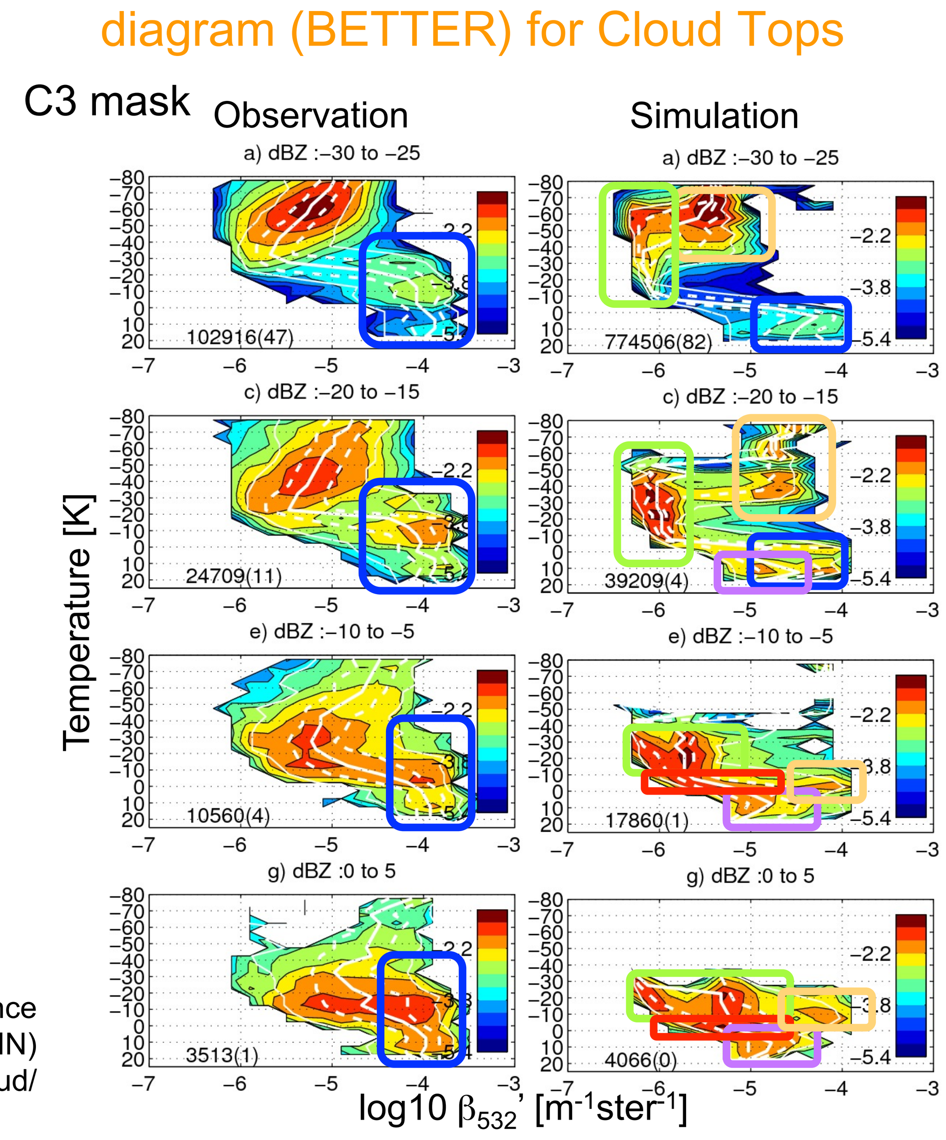
In-cloud statistics for the signals constructed in Tropical Western Pacific (5°S-20°N, 70°E-150°E)

Contoured Frequency by tEmperature Diagram (CFED)



- Each category of ice particles contributes to the different part of the CFED: see the colored rectangles cloud droplets, rain, cloud ice, snow, graupel

BETa-TEmperature Radar-conditioned diagram (BETTER) for Cloud Tops



- CFEDs for the Ze':
  - ✓The observation has three peaks in the marginal pdf of T, corresponding to Deep convection, cumulus congestus, and shallow cumulus).
  - ✓The simulated marginal pdf of T is dominated by the high level clouds (T~-50C).
  - ✓The non-precipitating mode of the shallow cumulus (~-20dBZ) is more frequent than the observation.
- CFEDs for the β_{532}':
  - ✓ Two modes in the simulation, one mode in the observation below -40C.
  - ✓ Simulated ice and liquid particles: smaller β_{532}'.
- BETTER for cloud tops
  - ✓ For a given range of Ze', the smaller β_{532}' means larger $R_{m,eff}$ and smaller IWC (Okamoto et al 2003).
  - ✓Cloud ice: smaller $R_{m,eff}$ and larger IWC (-20<Ze'<-15)
  - ✓Snow: larger $R_{m,eff}$ and smaller IWC
  - ✓Cloud droplets: larger $R_{m,eff}$ and smaller LWC

References: Hagihara, Y., H. Okamoto, and R. Yoshida, 2010: Development of a combined CloudSat-CALIPSO cloud mask to show global cloud distribution. *J. Geophys. Res.*, **115**. Hashino, T., M. Satoh, and co-authors, 2012: Validation of cloud microphysical statistics simulated by a global cloud-resolving model with active satellite measurements, in preparation. Nasuno, T, and co-authors (2012) in preparation. Nishizawa, T., H. Okamoto, T. Takemura, N. Sugimoto, I. Matsui, and A. Shimizu, 2008: Aerosol retrieval from two-wavelength backscatter and one-wavelength polarization lidar measurement taken during the MR01K02 cruise of the R/V Mirai and evaluation of a global aerosol transport model, J. Geophys. Res., 113.

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