Development of a new simulator on COSP2 for vertical doppler velocity of EarthCARE CPR

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1. Summary

- A simulator of vertical doppler velocity is developed for observation by newer CPR on EarthCARE.
- The results shed light on droplet fall velocity of cloud microphysics and cumulus mass flux in GCM, MIROC6.
- Comparing to ground-based radar observations, MIROC6 shows slower fall speed around melting layer.
- There is a significant impact on climate when fall velocity is tuned to match observation.

2. Simulator design

- COSP2 (CFMIP observation simulator package; Swales et al. 2018 GMD)
- The doppler velocity v_d is calculated as follows:

$$v_d = \underline{w} + \frac{\int \underline{n(r)}\,\underline{C_{bk}(r)}\,\underline{v_f(r)}\,dr}{\int n(r)\,\underline{C_{bk}(r)}\,dr}$$

- And droplet fall velocity v_f is:

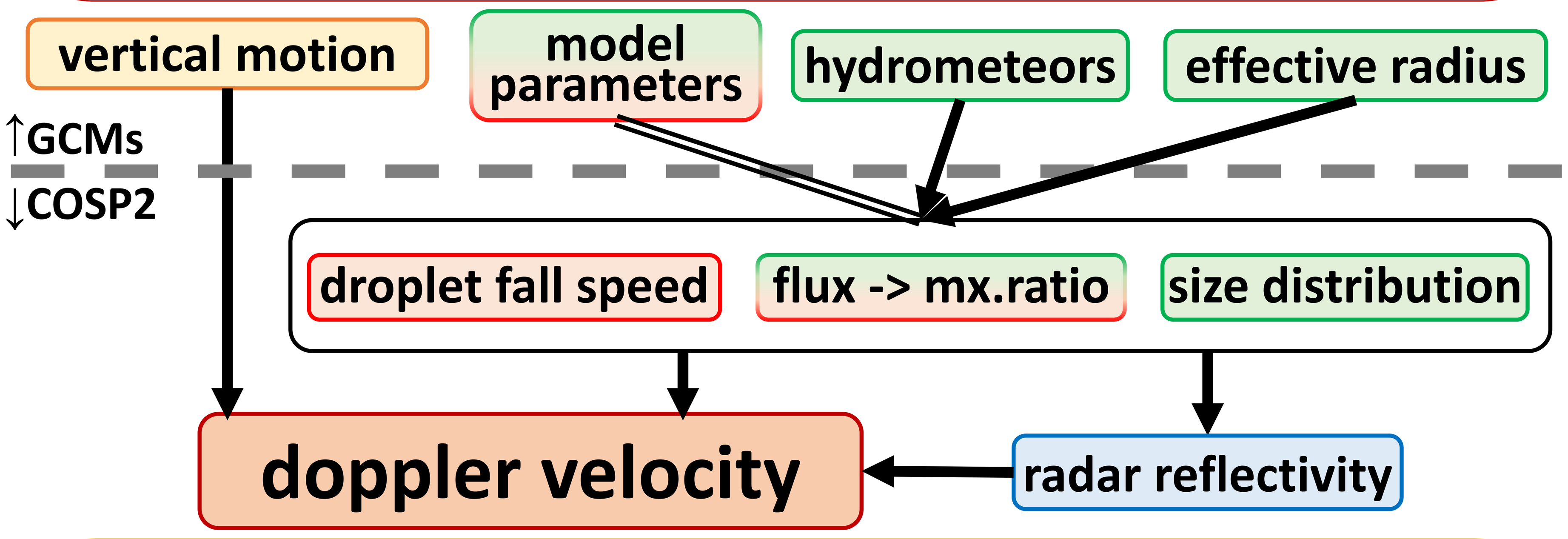
$$v_f = \text{viscous drag} \times \text{formulation}$$

✓ **viscous drag**

$\sqrt{\rho_0/\rho}$: on/off switchable

✓ **formulation**

1. power law: aD^b
2. Posselt and Lohmann (2008, ACP), eq.11: $b_1 - b_2\exp(-b_3 D) + (b_2 - b_1)\exp(-5 b_3 D)$



3. Comparative experiments

Observations

i. NICT

National Institute of Information and Communications Technology

ground-based radar at Koganei city, Tokyo provided by Horie-san (NICT)

ii. MOSAiC (not shown in this poster)

Multidisciplinary drifting Observatory forthe Study of Arctic Climate
details: https://mosaic-expedition.org

ship-borne radar observed in Arctic provided by ARM

GCM

- **MIROC6** (Tatebe et al.2019, *GMD*) with **prognostic precipitation scheme** (Michibata et al. 2019, *JAMES*).
- 2020 JJA, in area corresponding to observation sites.

4. Results

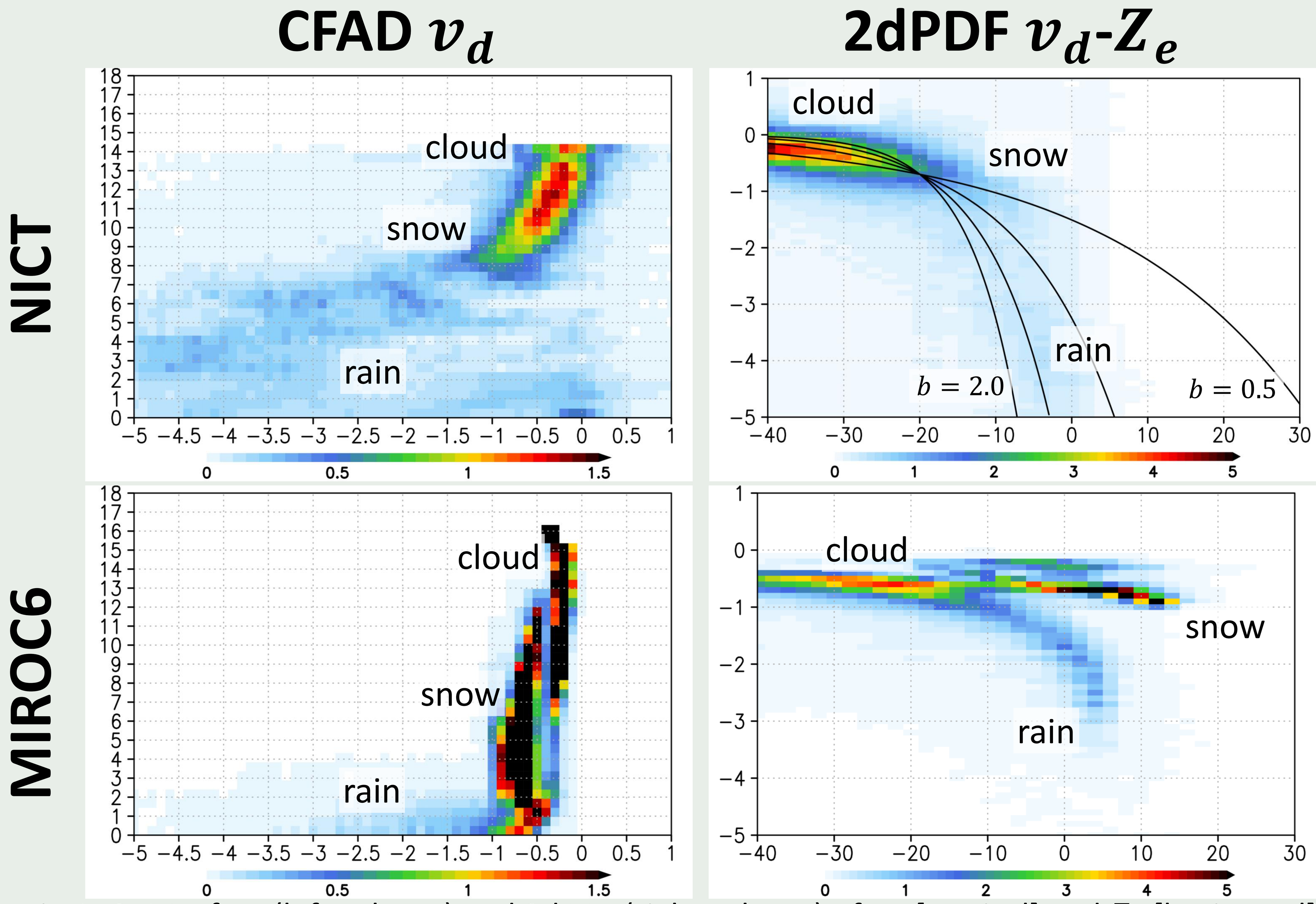


Fig.1: CFAD of v_d (left column) and 2dPDF (right column) of v_d [vertical] and Z_e [horizontal] for NICT observation (upper row) and MIROC6 simulation in corresponding area (lower row). Negative values of v_d is descending. Black lines in the upper right panel indicate Z_e-v_d relation based on modified gamma distribution with $b = 0.5, 1.0, 1.5, 2.0$.

- Slower fall speed, especially around melting level.
  → Partially melted particles are not represented.
- Overestimated radar reflectivity Z_e in MIROC6.
- 2dPDF implies scaling exponent of the v_f formulation.
  ✓ Different scale between cloud, rain, and snow?

Impact on climate of tuned fall velocity

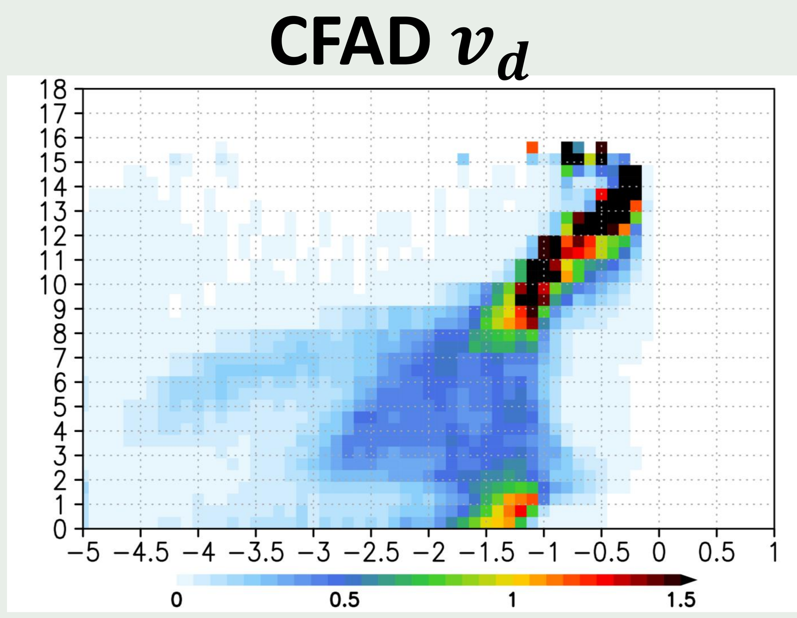


Fig.2: CFAD of v_d tuned to match observation in Fig.1.

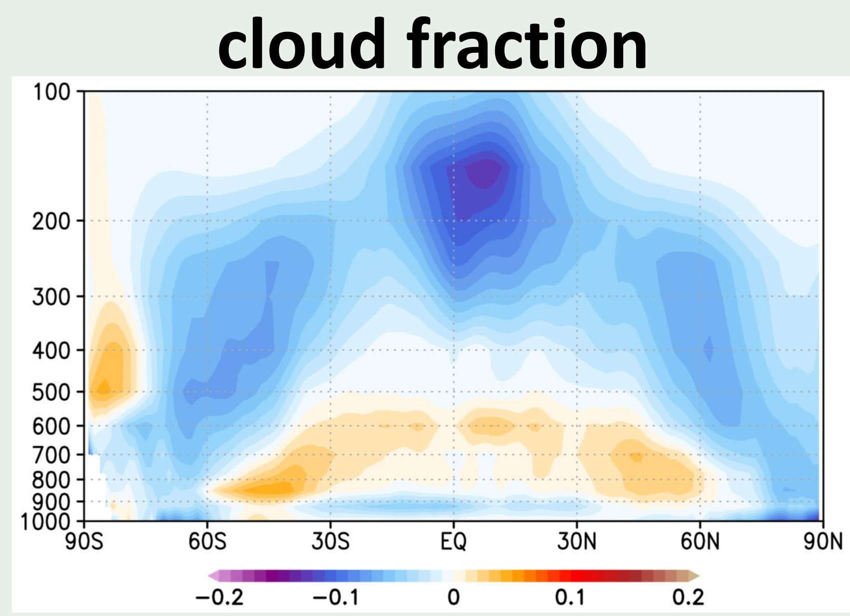


Fig.3: cloud fraction anomaly of tuned simulation from the control simulation.

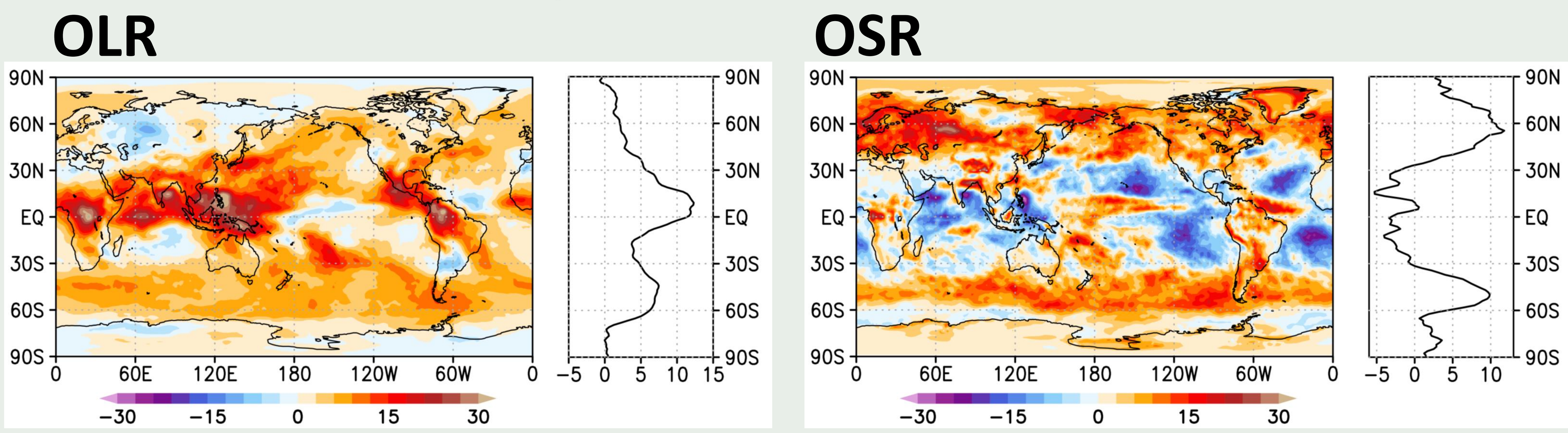


Fig.4: OLR (left) and OSR (right) anomalies of tuned simulation from the control simulation.

- Upper cloud lifetime ↓ → OLR ↑ → strong cooling
- Lower cloud ↑ → OSR in mid-latitude ↑ → strong cooling
  - Maybe due to the difference in the amount of tuning.
- Best tuning to match observations vs. Best performance
- Other microphysics parameters can also be tuned.
  ✓ for liquid: autoconversion, background CCN
  ✓ for ice: WBF process, shape, melting, INP, and mode…
- 5-year run would not reach equilibrium state of climate.

New Point of this simulator…

- Doppler velocity is calculated in CPR simulator, **quickbeam** and **quickbeam_optics** routines.
- The vertical motion is required as additional input variable from the parent GCMs.
- Parameters and the formulation of droplet fall velocity should be consistent to the parent GCMs.
- 2-moment and prognostic scheme allows to construct completely consistent simulator to the parent GCMs.
- We suggest that **cosp_precip_mxratio** should be consistent to doppler velocity simulators.