Hybrid-DNS to GCM: Dispersion Based Microphysical Parameterization

(To bridge between Observation and Climate Model)

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Importance

Challenge: Realistic distribution of convection and rainfall in present generation coupled climate models during summer monsoon.

Problem: Accurate representation of probability distribution (humidity, cloud) and insufficient growth of cloud droplets and processes responsible for the cloud to rain water conversion, to distinguish between shallow to convective clouds.

Solution: Realistic information of cloud drop size distribution is incorporated in the microphysical parameterization scheme of climate model using the Eulerian-Lagrangian particle-by-particle based Hybrid-DNS model .

Initial Setup & design of experiments

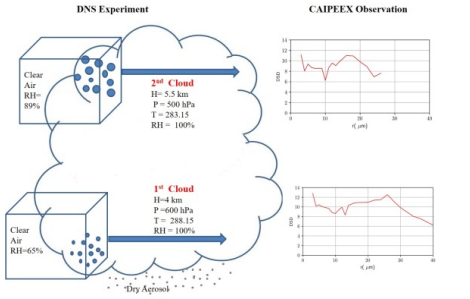
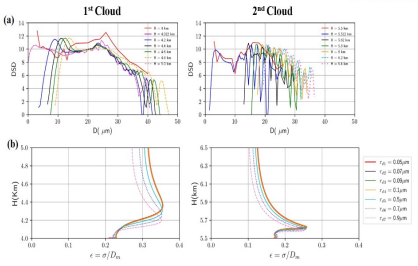


Figure: Schematic diagram of the DNS experiment at two maximum levels the parcels attained through ascent. These two cloud passes were considered from **CAIPEEX observation.**

Modified Diffusional growth equation (Bhowmik et al., 2022,; Korolev, 1995):

$$\frac{dr(\mathbf{X},t)}{dt} = \frac{K}{r(\mathbf{X},t)+\xi}\left(S(\mathbf{X},t)+1-\left(1+\frac{ar_d^3}{r(\mathbf{X},t)^3+br_d^3}\right)exp\left(\frac{2\sigma}{\rho_l R_v Tr(\mathbf{X},t)}\right)\right)$$

Water Activity/Solute Effect — Curvature Effect



Relative Dispersion Based Parameterization

- Liu-Daum autoconversion parameterization: (Proposed scheme)

$$P_D = a_1\left[\frac{(1+3\epsilon^2)(1+4\epsilon^2)(1+5\epsilon^2)}{(1+\epsilon^2)(1+2\epsilon^2)}\cdot N_c^{-1}LWC^3\right]\beta,$$

$$\beta = 0.5(x_c^2+2x_c+2)(1+x_c)\,exp(-2x_c)$$

$$x_c = a_2NC^{3/2}LWC^{-2}$$

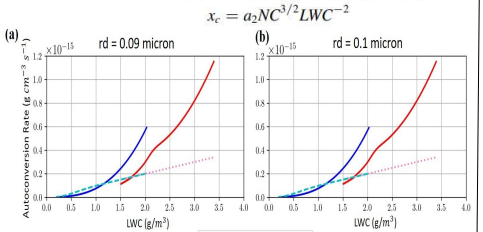
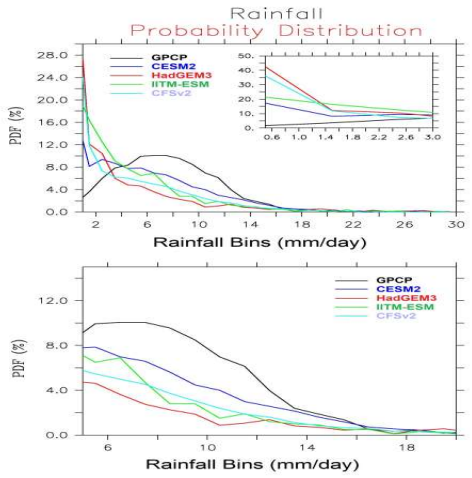


Figure: Comparison of Liu-Damn and Sunquivst type parameterization for shallow and deep cloud using Hybrid-DNS.

Transform to High Resolution Regional model and Global Climate Model

Generic Problem of all climate models:



Probability Distribution

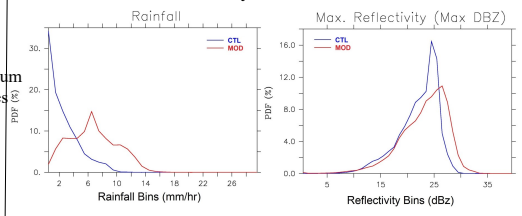


Figure: The high resolution (**1 km horizontal resolution**) **WRF** for 3-day simulation for convective cloud during Indian summer monsoon (ISM) is used for preliminary understanding of rainfall and maximum reflectivity PDF.

Coupled Forecast System V2 (T382) ~ 38 km res.

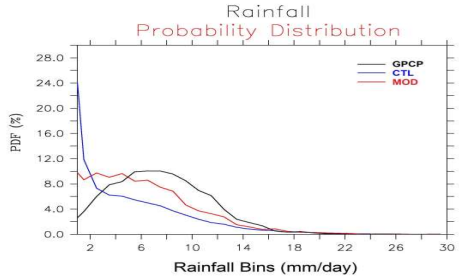


Figure: The probability distribution of rainfall (mm/day) over central India.

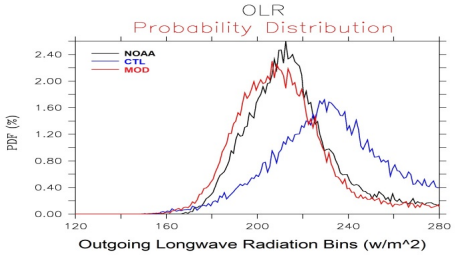


Figure: The probability distribution of outgoing long-wave radiation (OLR) over Extended Indian Monsoon Region.

Global Mean Rainfall (T382)

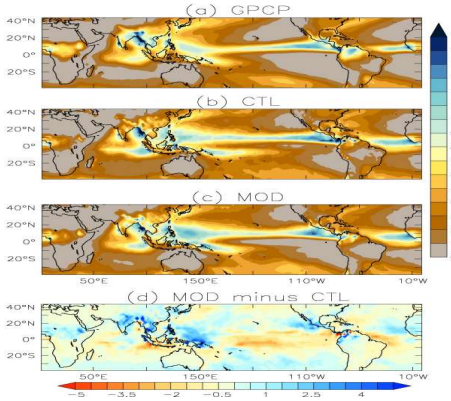
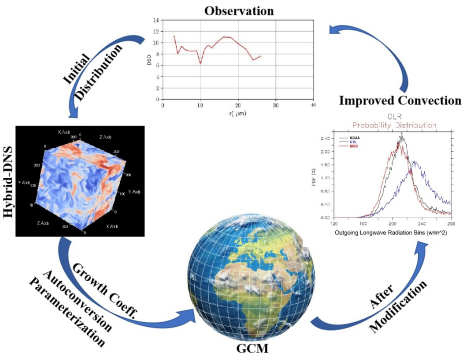


Figure: The JJAS (June to September) mean rainfall (mm/day) over global tropics for observation (GPCP) and CFSv2 control (CTL), modified (MOD) and difference

Summary

Hybrid DNS to GCM

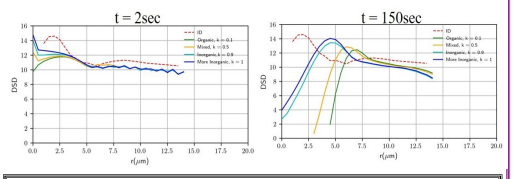


Key Points:

- The study has unveiled the linkage between observation and climate model though Hybrid-DNS.
- Diffusional growth rate coefficient is calculated using Eulerian-Lagrangian Hybrid-DNS model.
- Dispersion based "autoconversion" scheme for Indian region is proposed based on Hybrid-DNS model.
- New parameterization implemented in climate model (WRF and CFSv2), which is obtained from particle-by-particle based small-scale model simulation.
- Modified parameterization in climate model shows improvement in PDF of rainfall, and OLR.
- High fidelity in OLR simulation with better specific humidity leads to the improved mean ISM.

Future Plan:

Aerosol Chemistry For Radiation Parameterization



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