TROPICAL CONVECTIVE VARIABILITY IN UFS REPLAY SIMULATIONS – A PROCESS LEVEL ASSESSMENT

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BIG PICTURE GOAL

Systematically understand sources of errors and bias in model representation of processes associated with variability of rainfall in the tropics, particularly those related to thermodynamic coupling between convection and the large scale environment.

WHY IT MATTERS

Better representation of tropical convection in models is not just important for improving weather and climate prediction in the tropics, but tropical convection is also an important source of S2S predictability and forecast errors outside the tropics.

DATA

"Replay" runs from NOAA Unified Forecast System (UFS)[1] coupled prototype model HR1 (100km resolution) – errors (as compared to ERA5) in temperature, moisture, and horizontal winds in the model are being continuously offset through an increment forcing. ERA5 and IMERG precipitation used for comparison. Three years of daily averaged data interpolated to a 2.5° x 2.5° grid from data 2010-12.

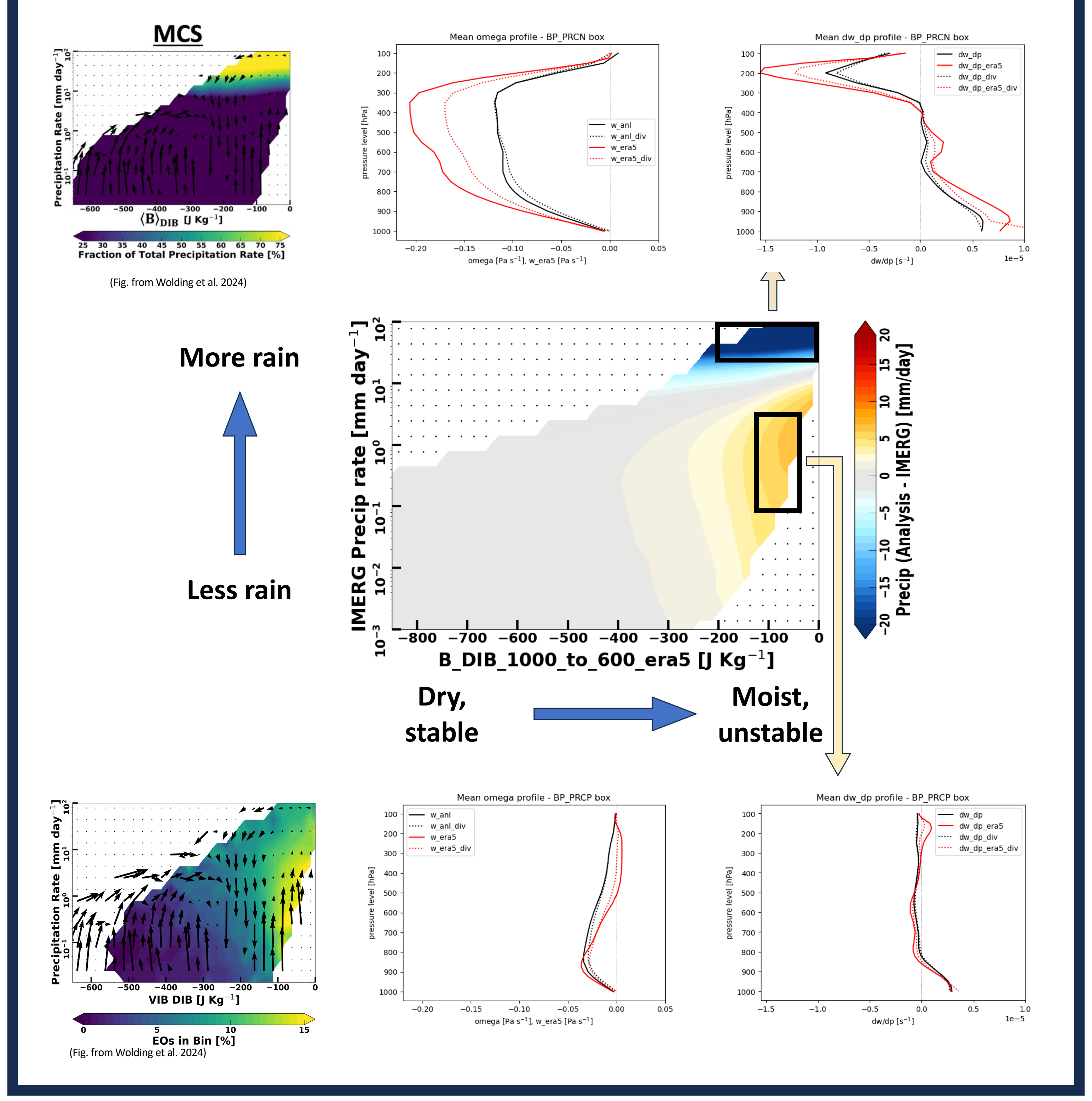
AIM FOR THIS POSTER

Compare evolution of precipitation and large scale thermodynamic fields in UFS Replay with ERA5 and IMERG precipitation.

FUTURE WORK

Apply diagnostics to a suite of UFS simulations include long term climate runs, and sub seasonal reforecast simulations to understand how these errors propagate in the model across different timescales.

Model strongly underestimates precipitation and upper level divergence associated with MCS's and overestimates precipitation associated with congestus despite nudging[1].



(Fig. from Wolding et al. 2024)

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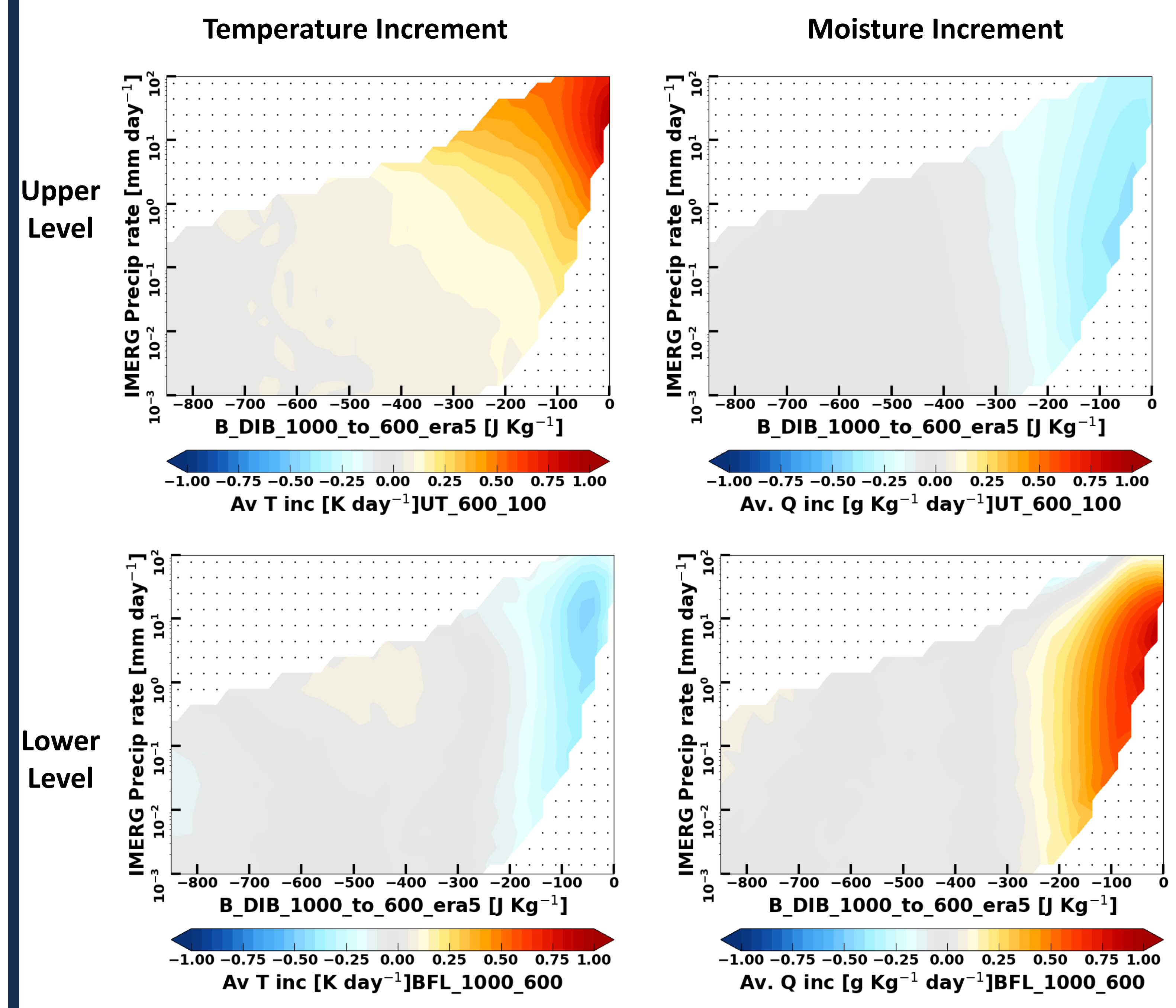
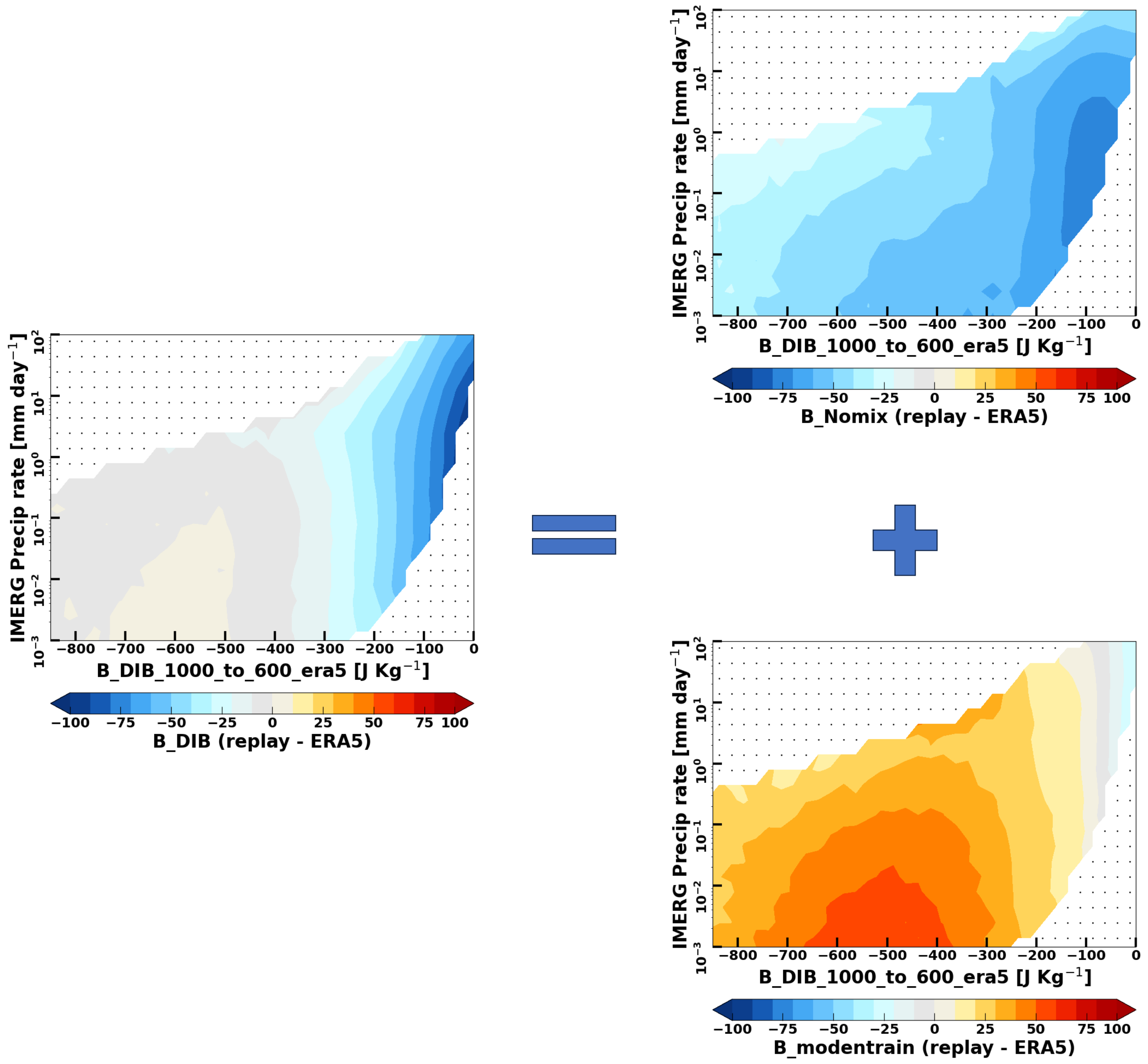
Precipitation biases are collocated with a cold and moist bias at upper levels, and warm and dry bias at lower levels.



Model tends to drift towards a more stable state[4]. Minor differences in temperature and moisture profiles can lead to significant differences in vertically integrated buoyancy[2,3,4].

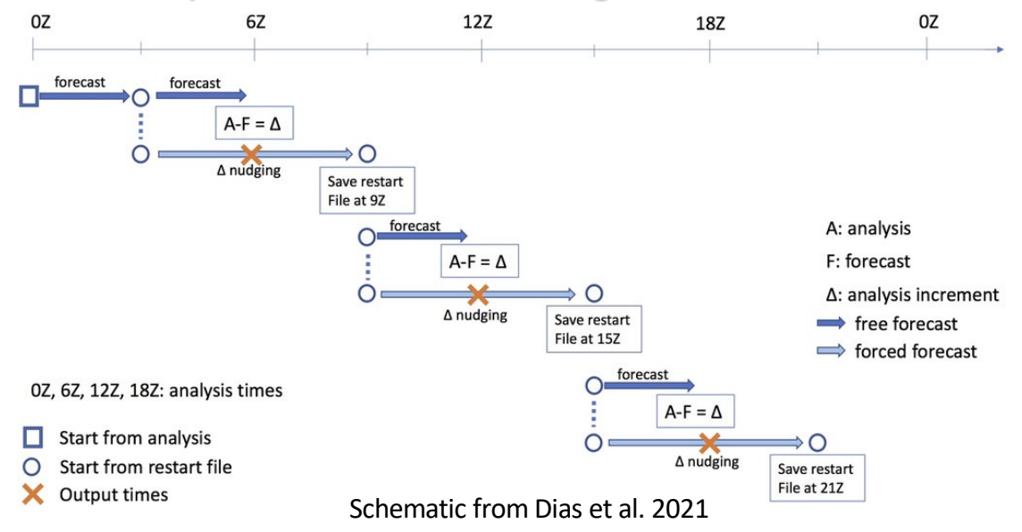


1) Replay run setup

Increment computed as difference between a free forecast run and ERA5. Model is re-run with the increment applied.

Increment updated every 6hours.

Temperature, moisture zonal and meridional wind fields are the only variables that are nudged.



Schematic from Dias et al. 2021

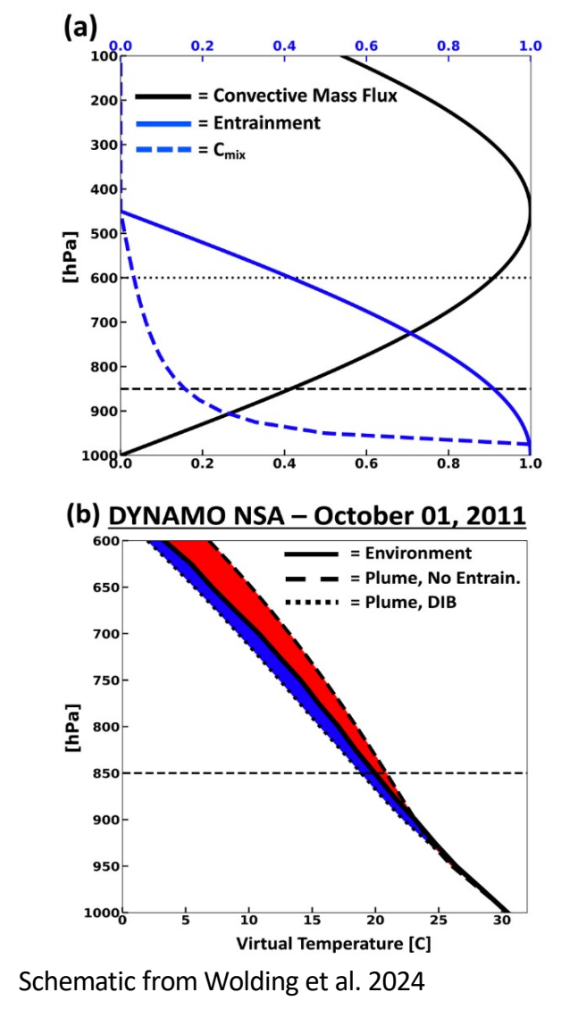
2) Entraining Plume Buoyancy, B_DIB

- Metric to estimate low level convective instability for a rising plume that undergoes mixing/entrainment. Calculated from the large scale temperature and moisture profiles
- Acts as a state function that characterizes the different types of thermodynamic environment in terms of their stability to convection.

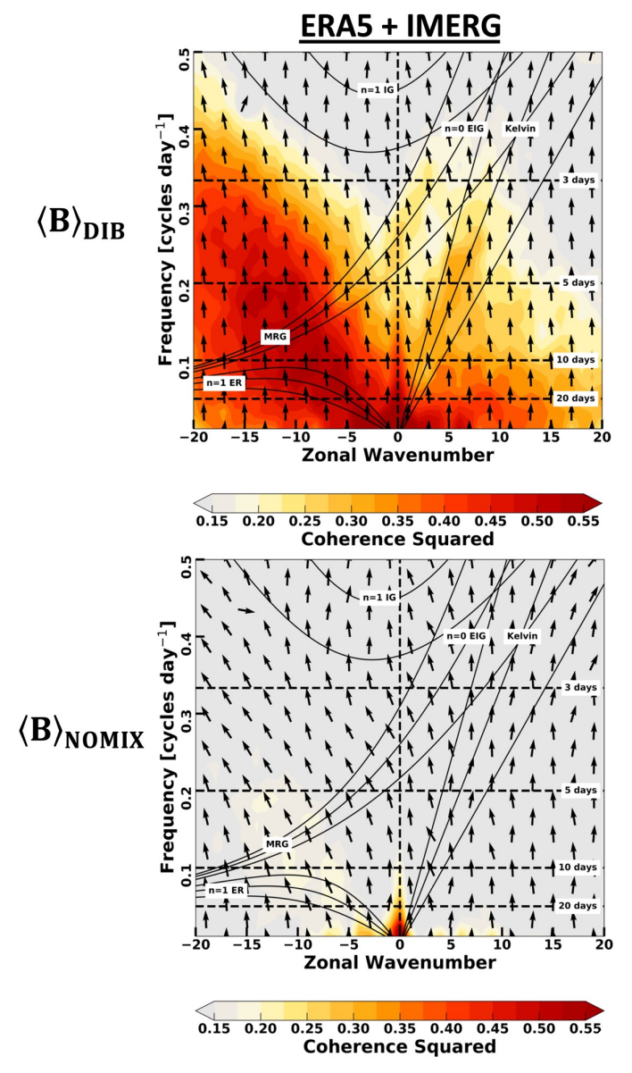
$$B = \int_{1000hPa}^{600hPa} R_d\left(T_{v,p} - T_{v,e}\right)dlnp$$

- Plume virtual temperature profile computed based on two mixing profiles
  - No mixing → B_NOMIX
  - Idealized deep inflow mixing profile → B_DIB
- Impact of mixing with environment on plume buoyancy given by

B_MODENTRAIN = B_DIB – B_NOMIX



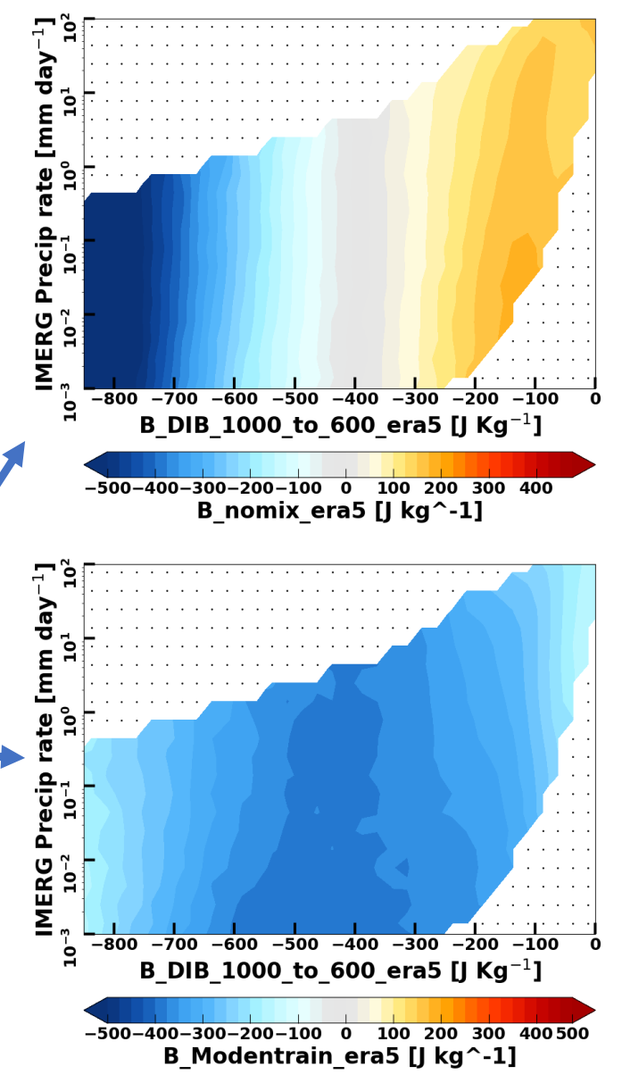
Schematic from Wolding et al. 2024



3) Why Entraining Plume Buoyancy?

B_DIB = B_NOMIX + B_MODENTRAIN

- In the tropics, large scale precipitation does not covary with B_NOMIX. Updrafts undergo strong mixing and B_DIB is a better correlated with precipitation.
- Generally, plume entrains relatively drier air which makes the plume more stable.
- There is a competition between unstable B_NOMIX and the stabilizing B_MODENTRAIN.
- As a result, most unstable environments (max B_DIB) are associated with most moist environments and not most unstable B_NOMIX.



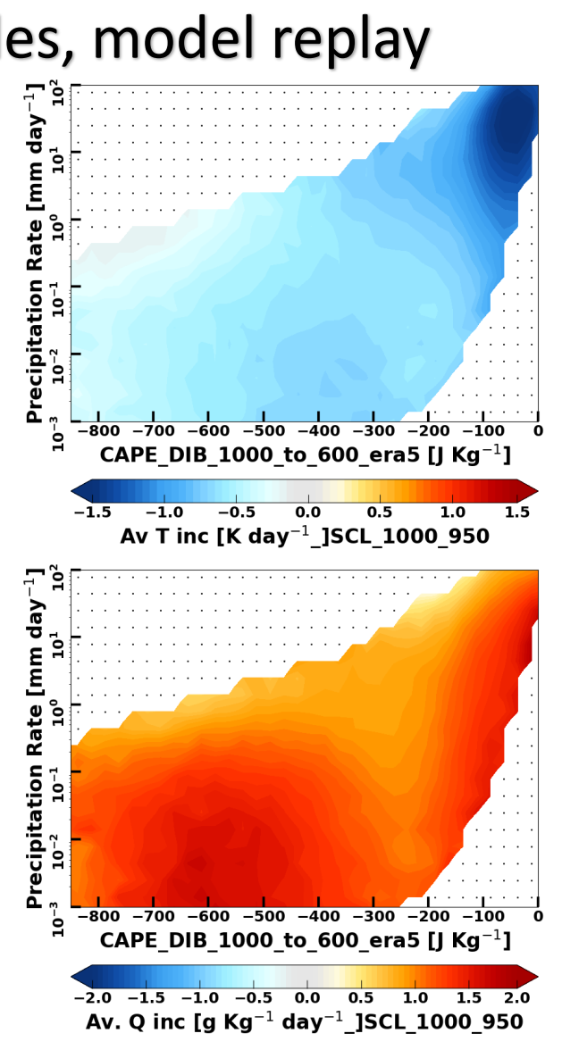
4) Some possible connections between thermodynamic profiles, model replay increments and plume buoyancy differences

Increased stability in model seems to be primarily related to increased stability through B_NOMIX.

Entrainment of dry air has a smaller stabilizing effect on the plume in the model compared to ERA5. Since the model tends to have a dry bias at lower levels, smaller B_MODENTRAIN could be related to smaller B_NOMIX.

Increased stability in B_NOMIX can be related to different processes

- Dry bias in boundary layer reduces virtual temperature of plume leading to more stable B_NOMIX
- While a warm bias in boundary layer should make the model more unstable, combined with the dry bias it could lead to decrease in saturation which makes B_NOMIX more stable.



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1) Wolding, B., and Coauthors, 2023: Atmosphere–Ocean Coupled Energy Budgets of Tropical Convective Discharge–Recharge Cycles. *J. Atmos. Sci.*, **81**, 3–29, https://doi.org/10.1175/JAS-D-23-0061.1.

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