# Tropical Convective Variability in UFS Simulations

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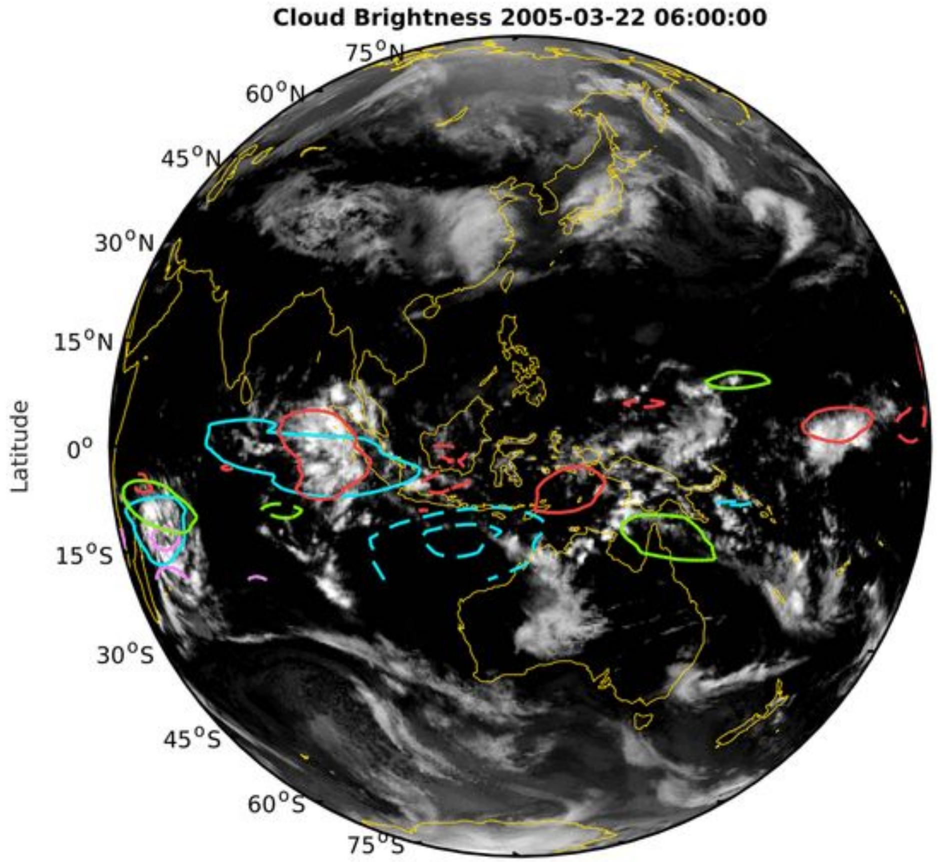
# Tropical convection is an important source of predictability at S2S timescales

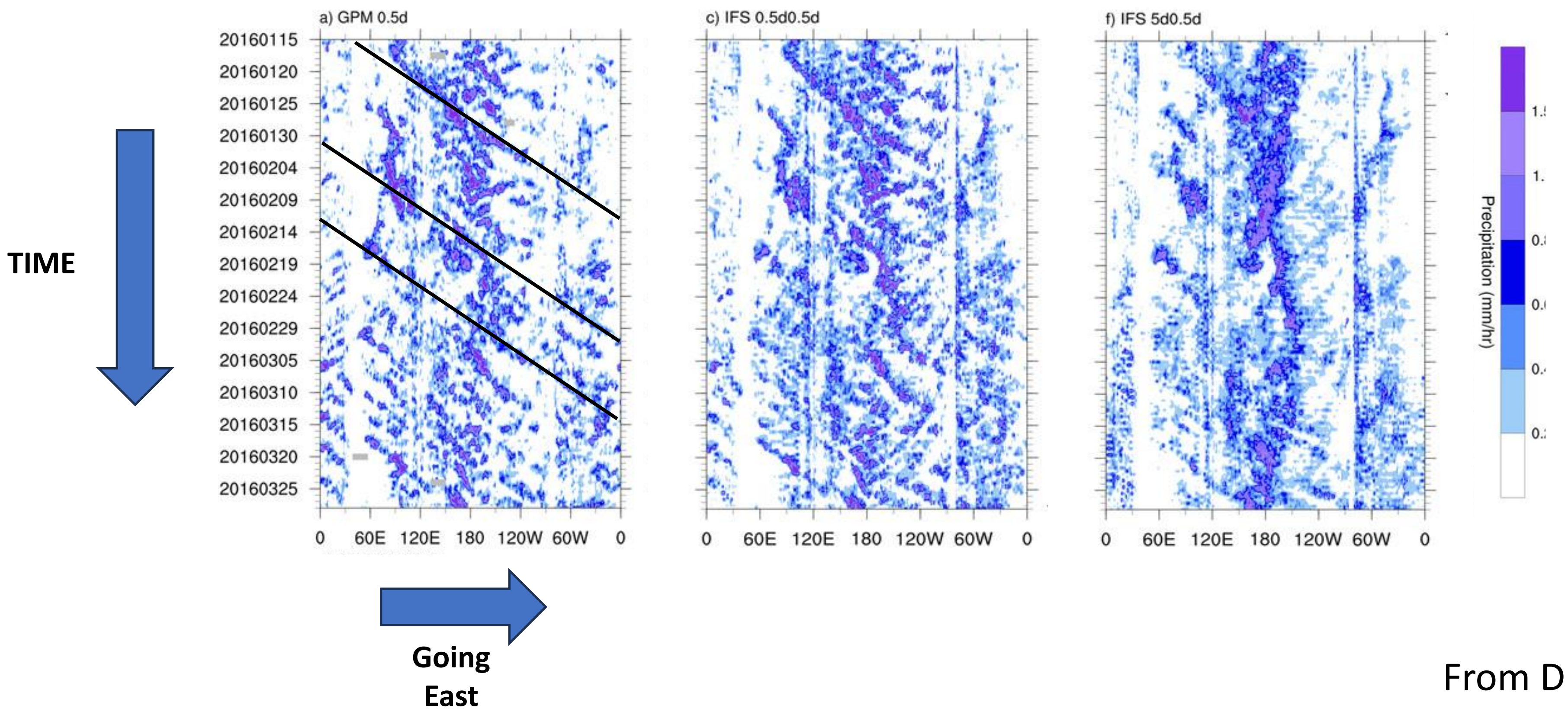



Madden Julian Oscillation (MJO)
Eq. Rossby
Kelvin

From Prof. Angel Adames-Corraliza

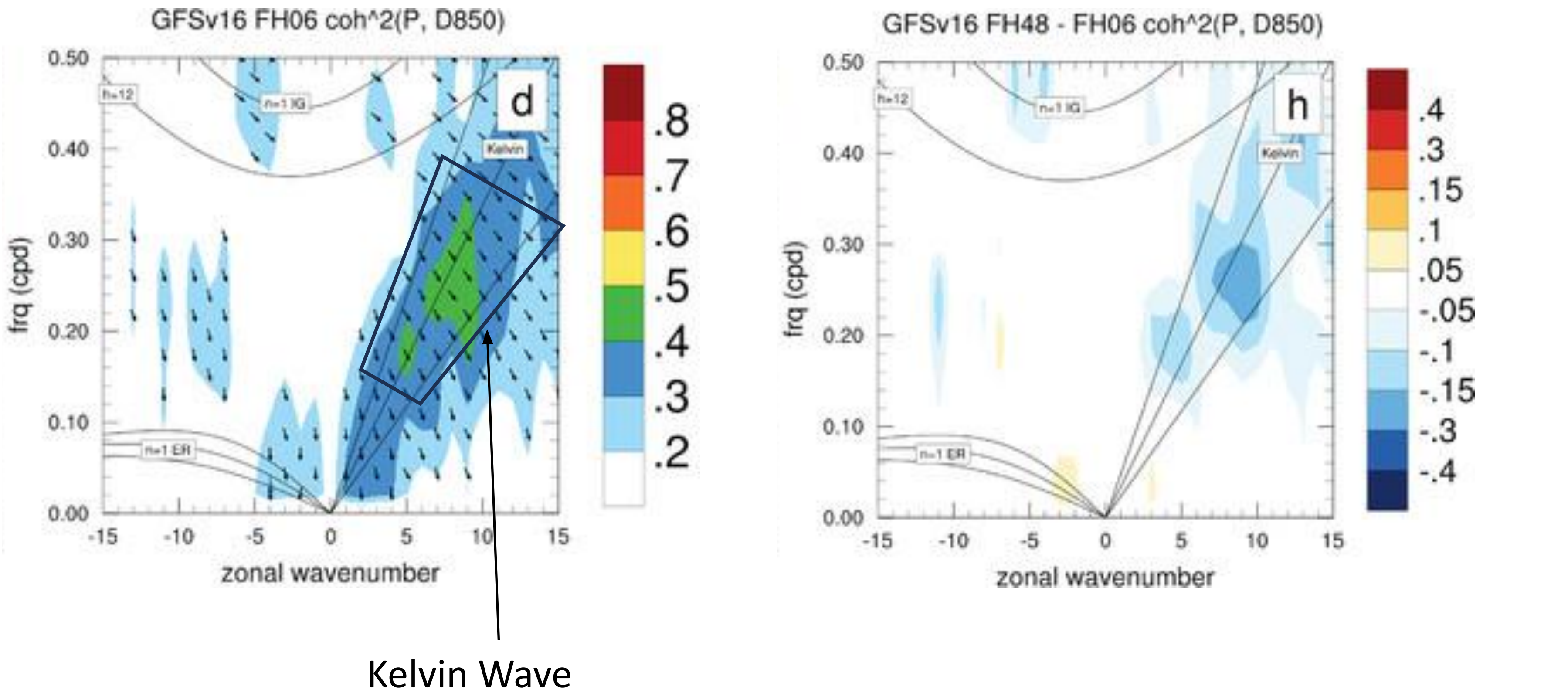
# Models often struggle in representing these organized modes well

OBSERVATIONS | IFS at 12 hr lead time | IFS at 120 hr lead time



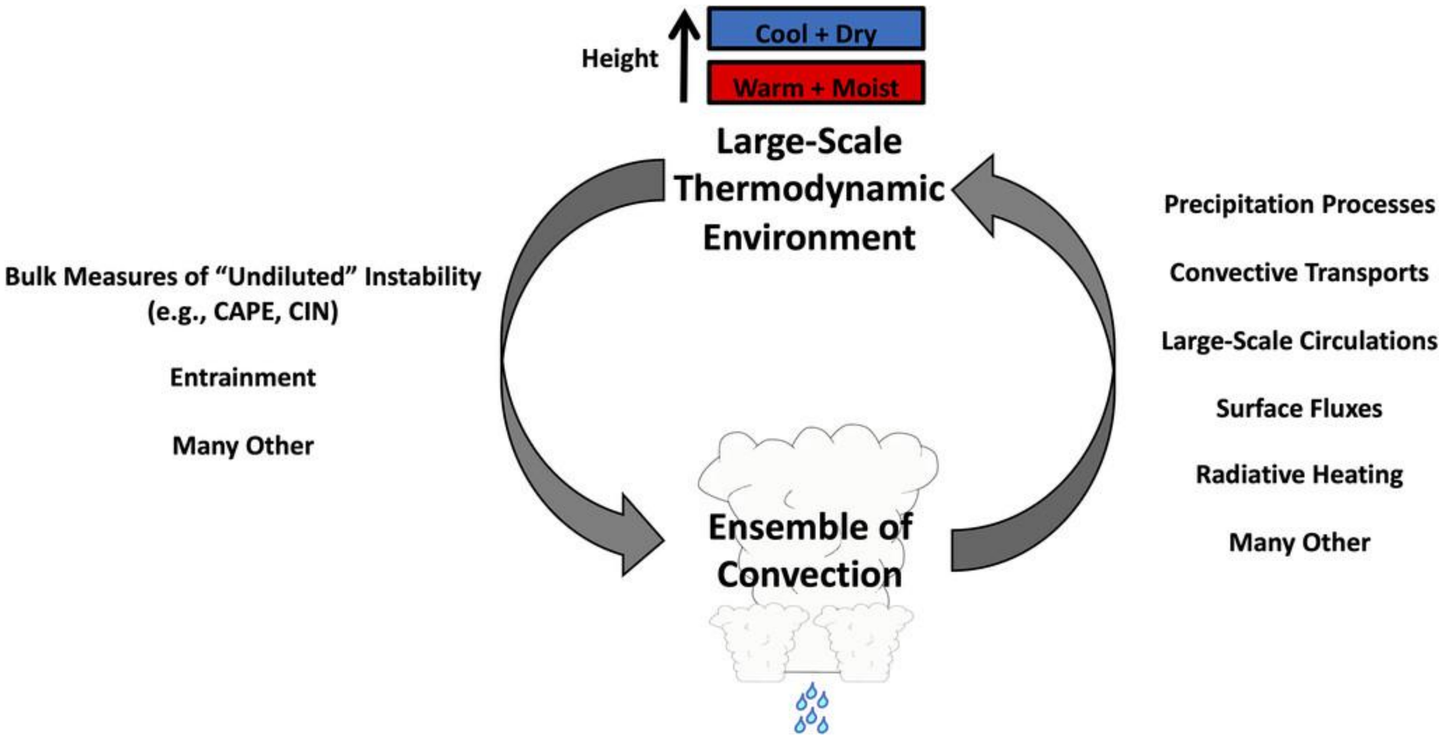

From Dias et al. 2018

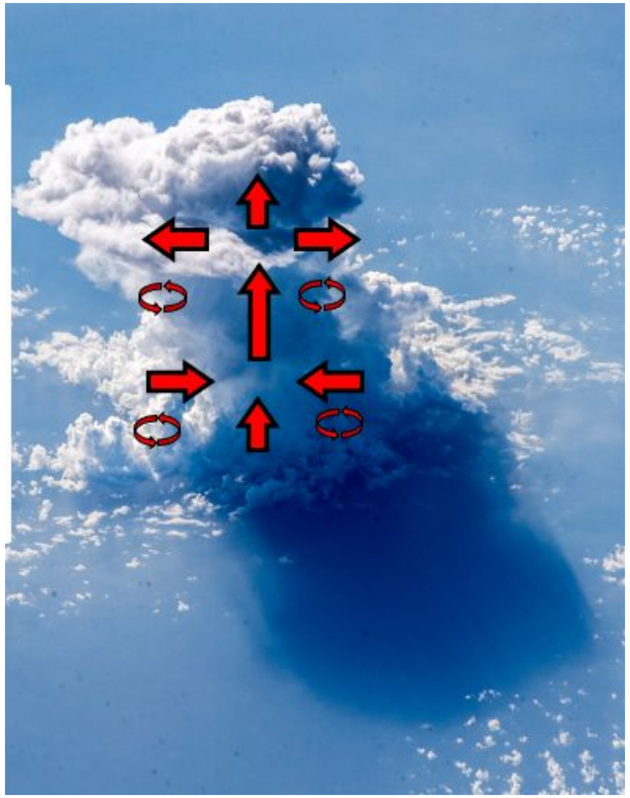
# Model performance can degrade much rapidly than expected




From Gehne et al. 2022

# Convection is tightly coupled with thermodynamics in the tropics



Schematic from Wolding et al. 2022

# Research goal

- What are the errors in representation of the thermodynamic environment in the model?
- What are the errors in precipitation-thermodynamic coupling?
- How do these errors propagate in the models with lead time?

# Data

**UFS REPLAY**

- Model run continuously being nudged towards ERA5

**S2S REFORECASTS**

- Set of past model forecasts at S2S timescales

**UFS CLIMATE**

- Long term free running model runs

Errors in the model accumulate over

Hours — Days/weeks — Years

# Data

**UFS REPLAY**

- Model run continuously being nudged towards ERA5
- UFS HR1 coupled prototype at 100km resolution
- Daily means over 10 years at 2.5 degree resolution

**UFS CLIMATE**

- Long term free running model runs
- UFS v17_p8 with stochastic physics
- Daily means over 10 years at 1 degree resolution

Errors in the model accumulate over

Hours → Days/weeks → Years

# Buoyancy as measure of thermodynamic environment

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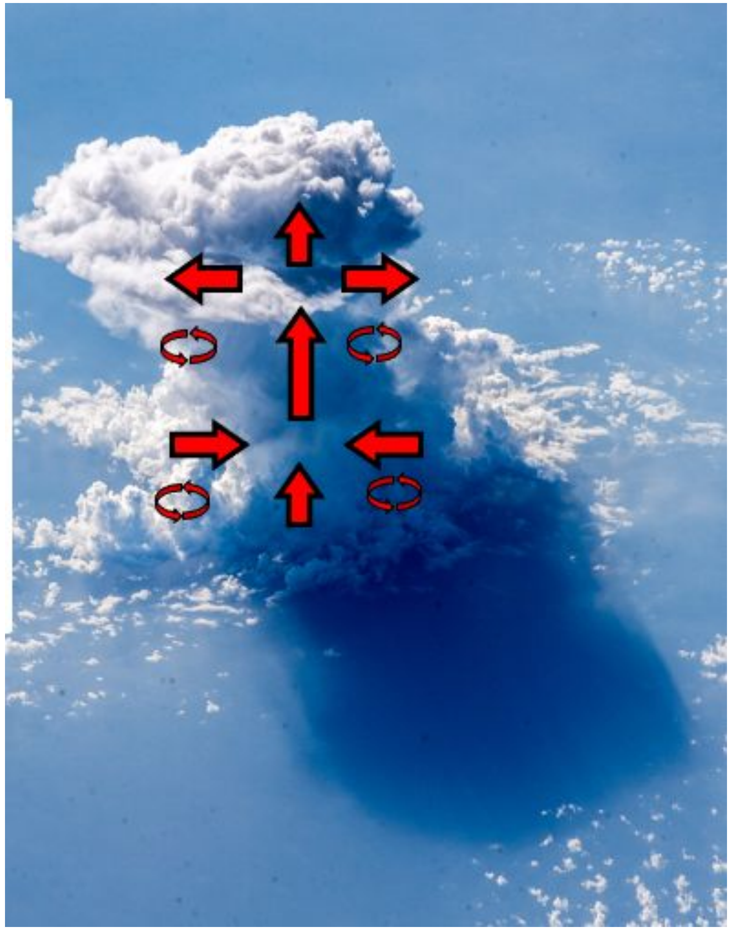
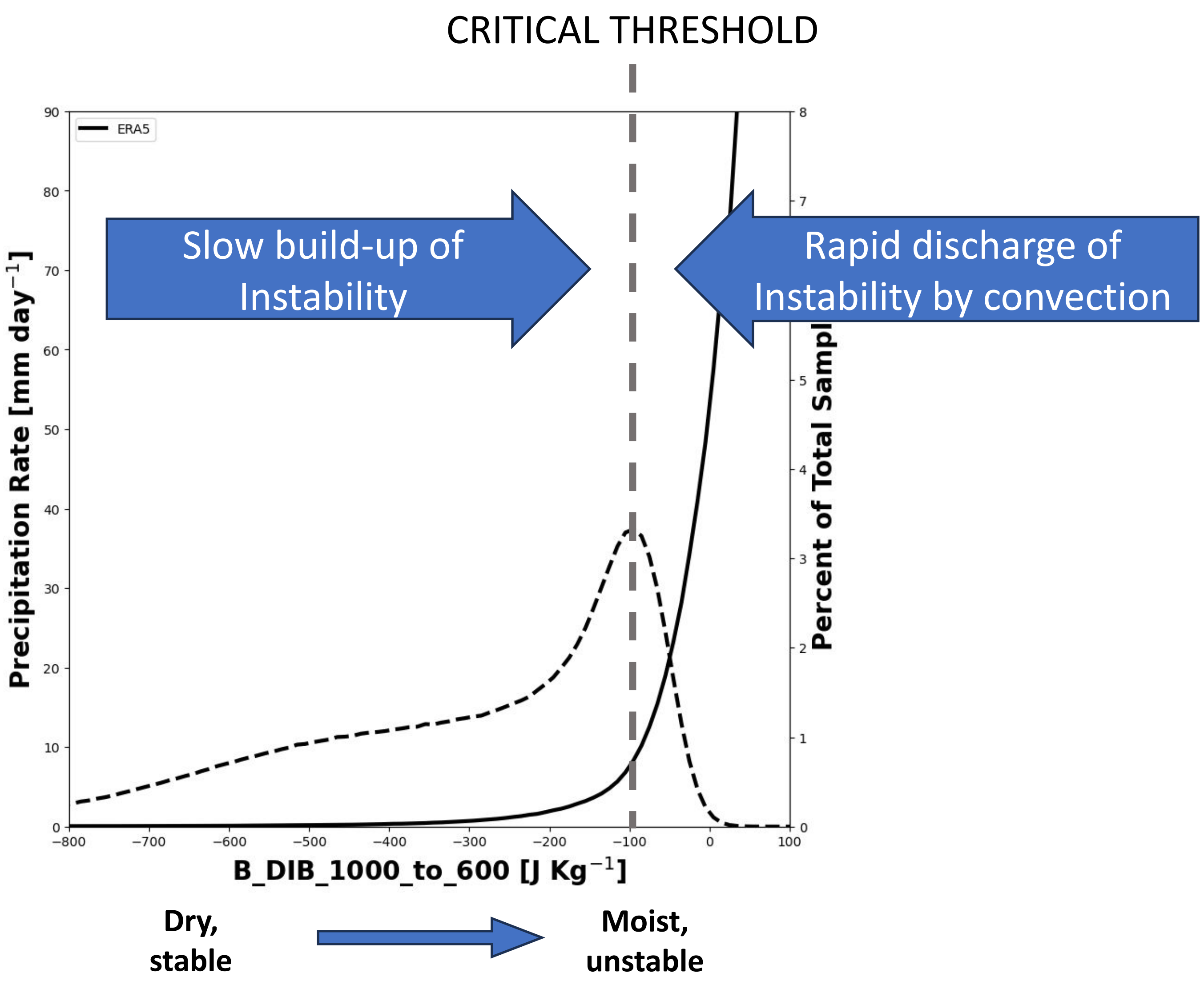
- Lower troposphere entraining Plume Buoyancy

$$B\_DIB = \int_{1000hPa}^{600hPa} R_d(T_{v,p} - T_{v,e})dlnp + Ent.mod$$

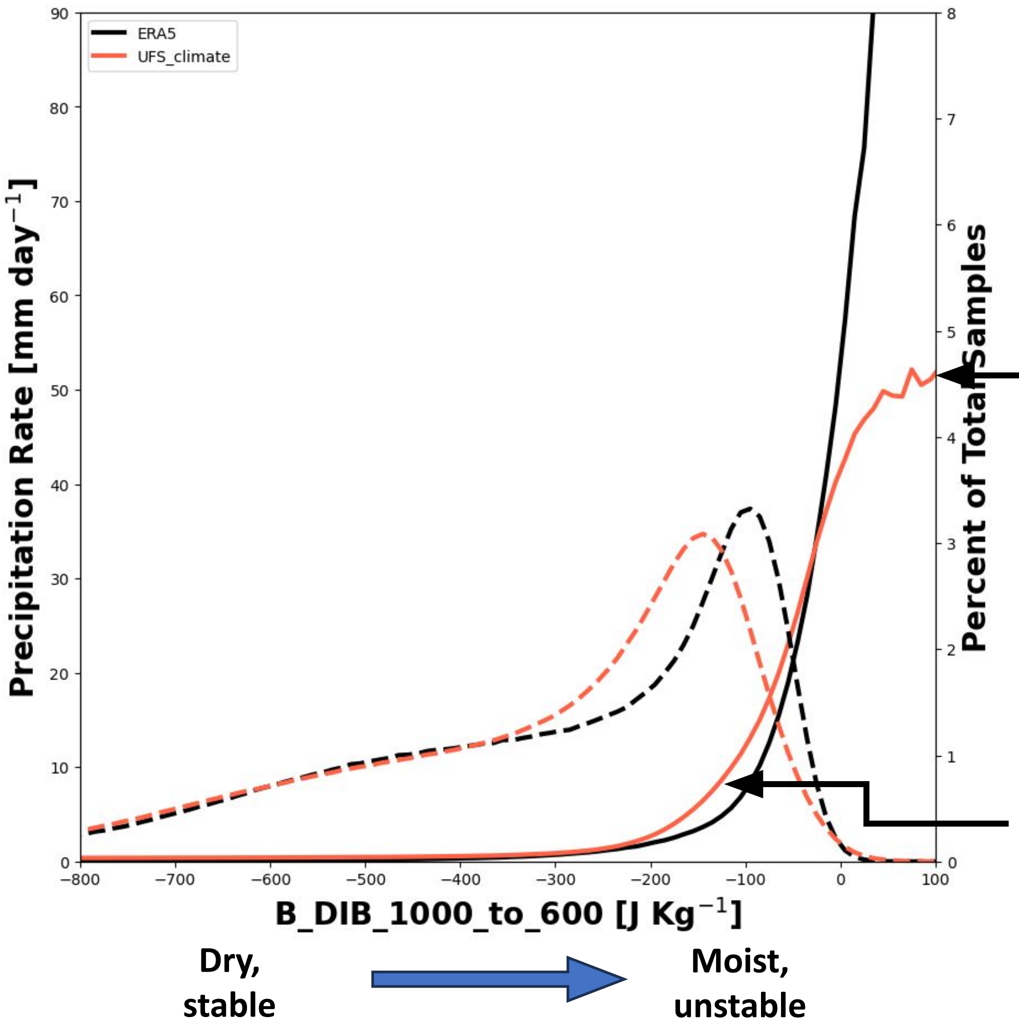
  - Vertically integrated over 1000hPa – 600hPa
  - Accounts for lower tropospheric temperature, moisture, and mixing with the environment



# Buoyancy – Precipitation coupling in ERA5



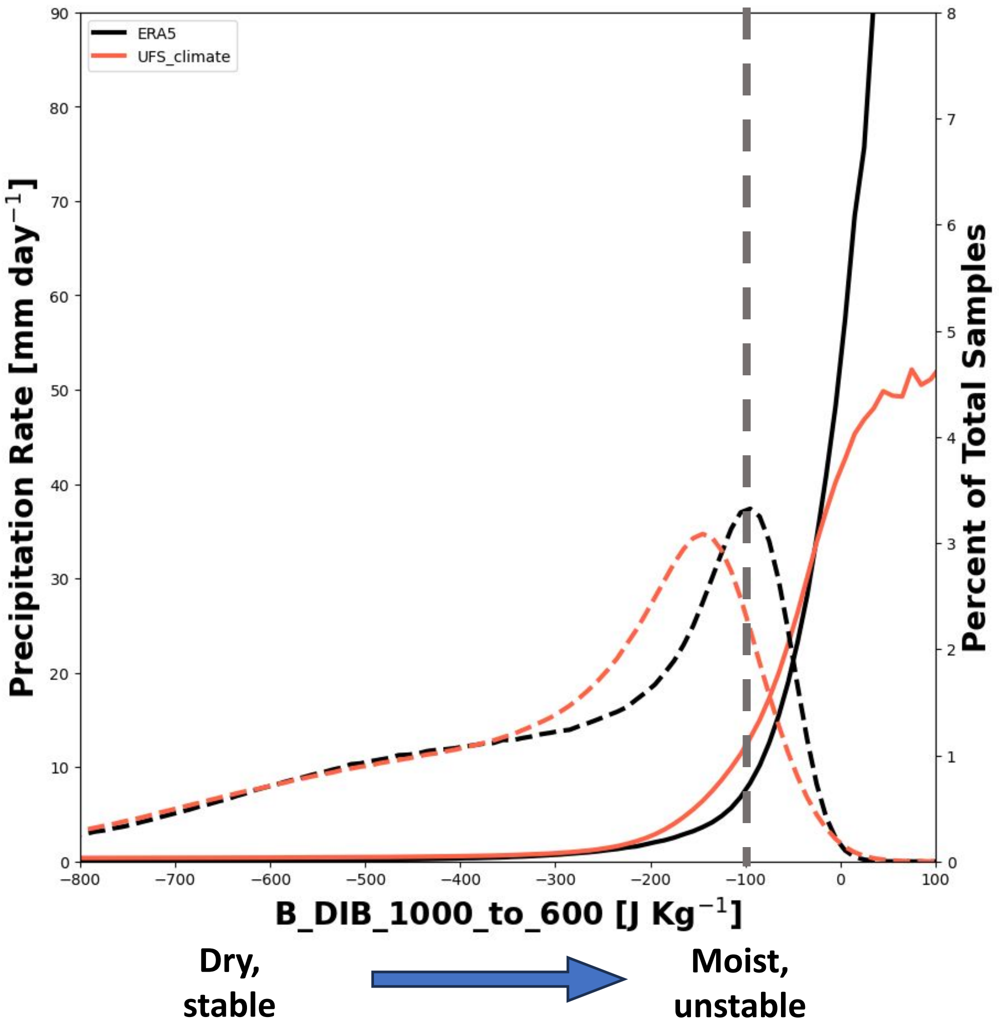
# Buoyancy – Precipitation coupling in UFS Climate run



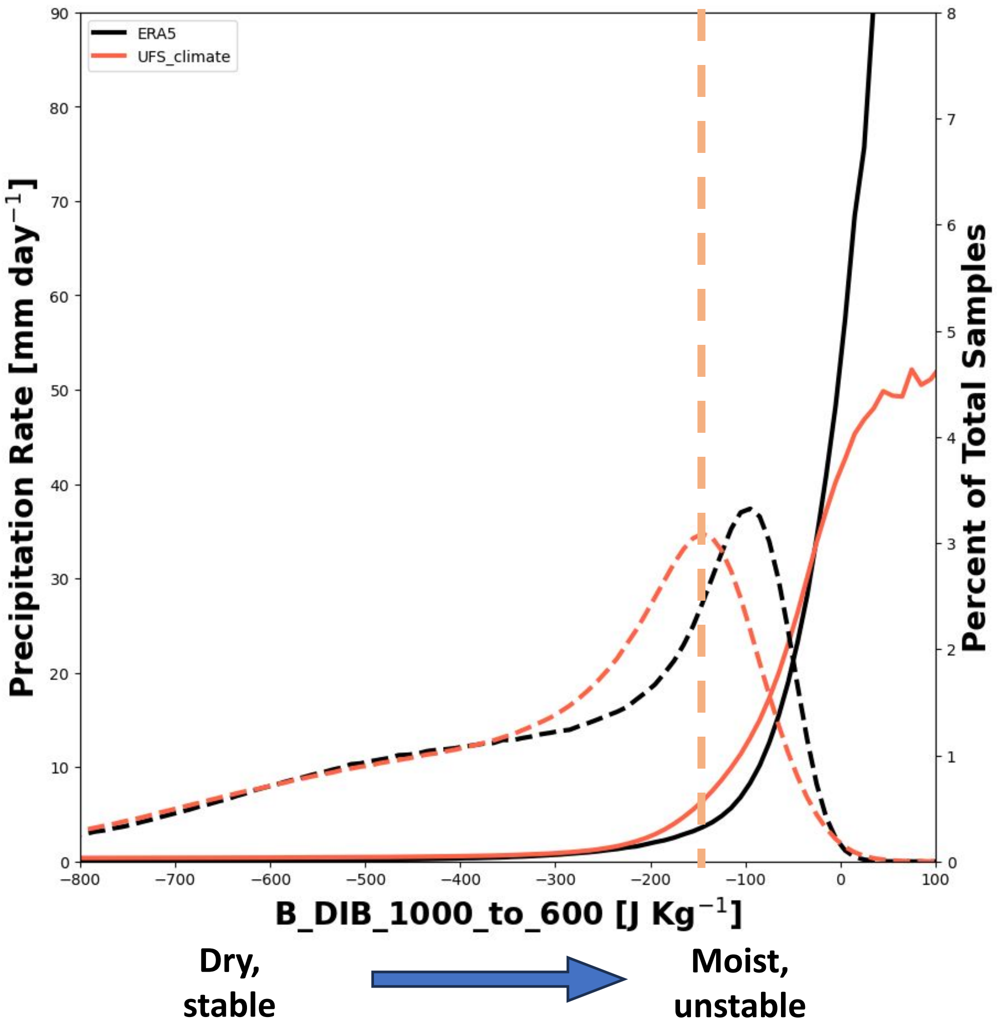

High precipitation rain rates not observed

Precipitation picks up earlier at more stable conditions

# Buoyancy – Precipitation coupling in UFS Climate run



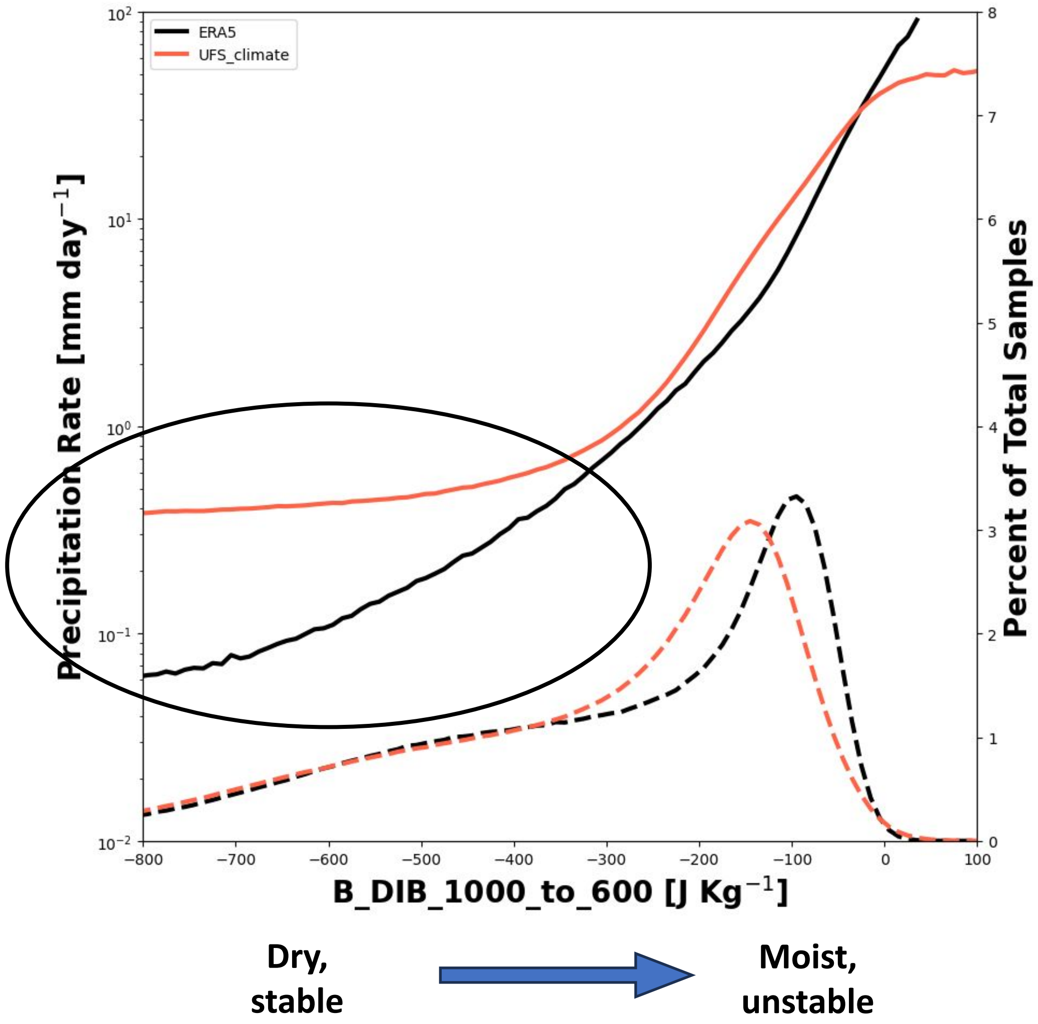
# Buoyancy – Precipitation coupling in UFS Climate run




Model prefers to stay in a more stable mean state

# Shallow convection in UFS Climate

Too much precipitation at lower rain rates – possible drizzle bias

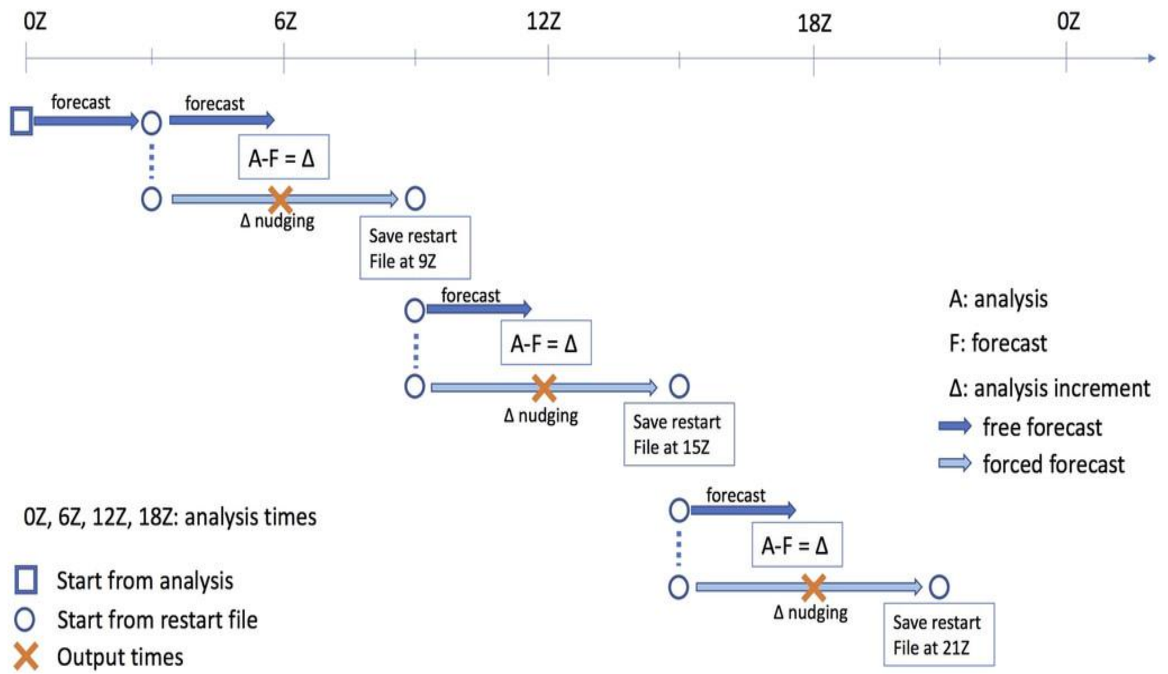


# Replay simulations – thermodynamic errors are constrained

Temperature, moisture, horizontal winds are nudged towards ERA5.

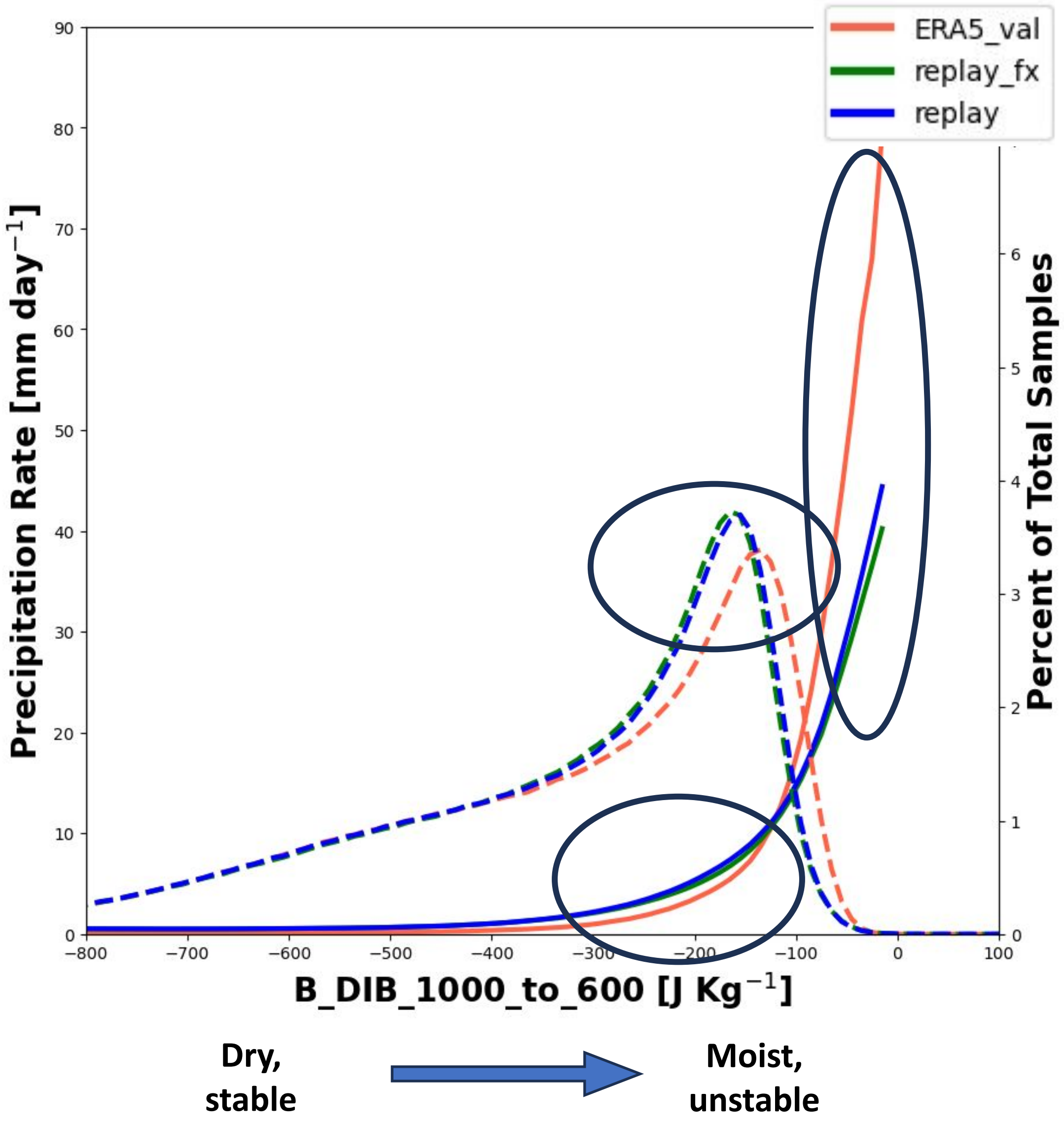
Fast developing errors in the model expected to be prominent

Output includes
- Model forecast – “Replay_fx” – free running 3 hr forecast
- Model Increment – “Inc” or IAU – Difference between ERA5 and model forecast
- Model Analysis - “Replay” – forced forecast with the increment forcing applied



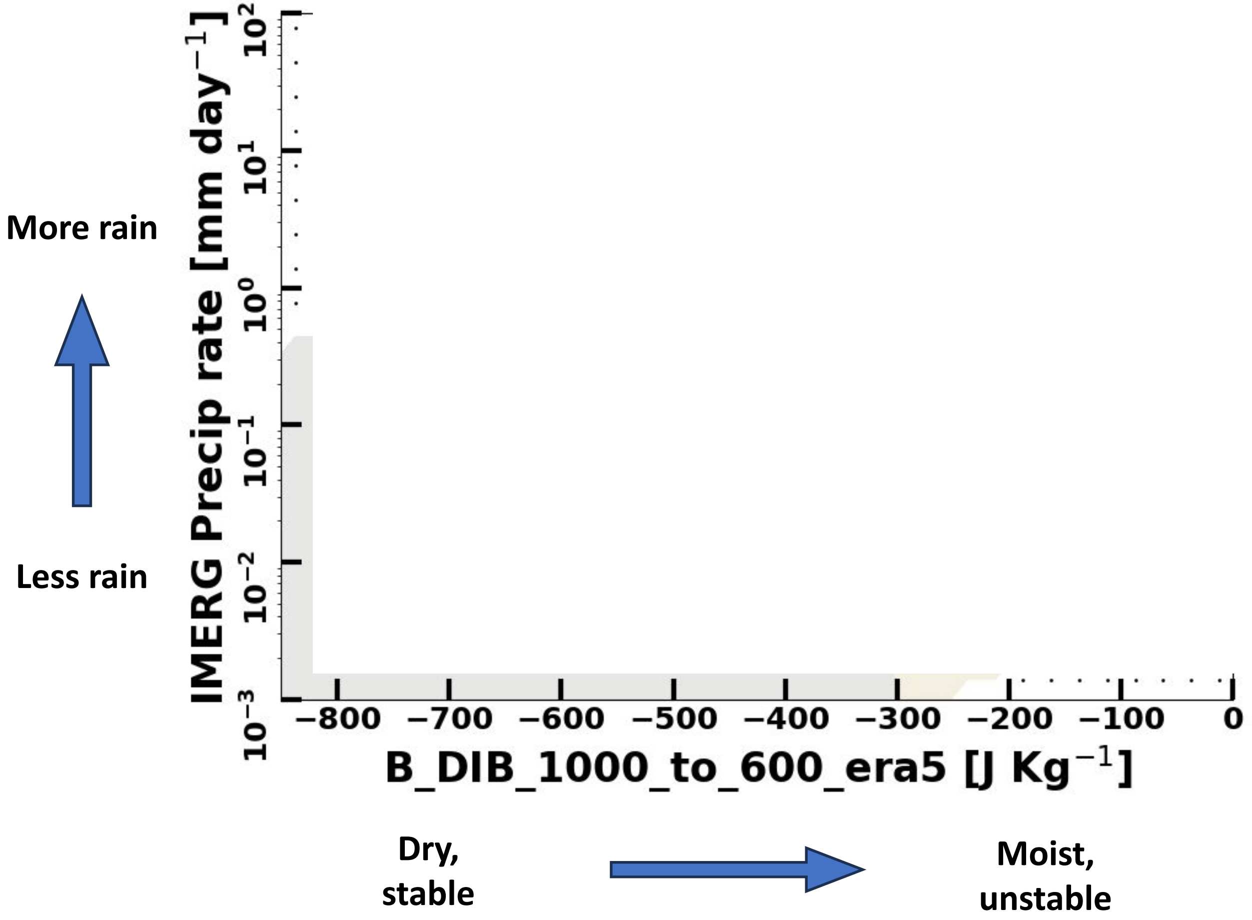

Schematic from Dias et al. 2021

# Buoyancy – Precipitation coupling in UFS Replay




Shows similar features as the UFS climate runs indicating their rapid development in the model

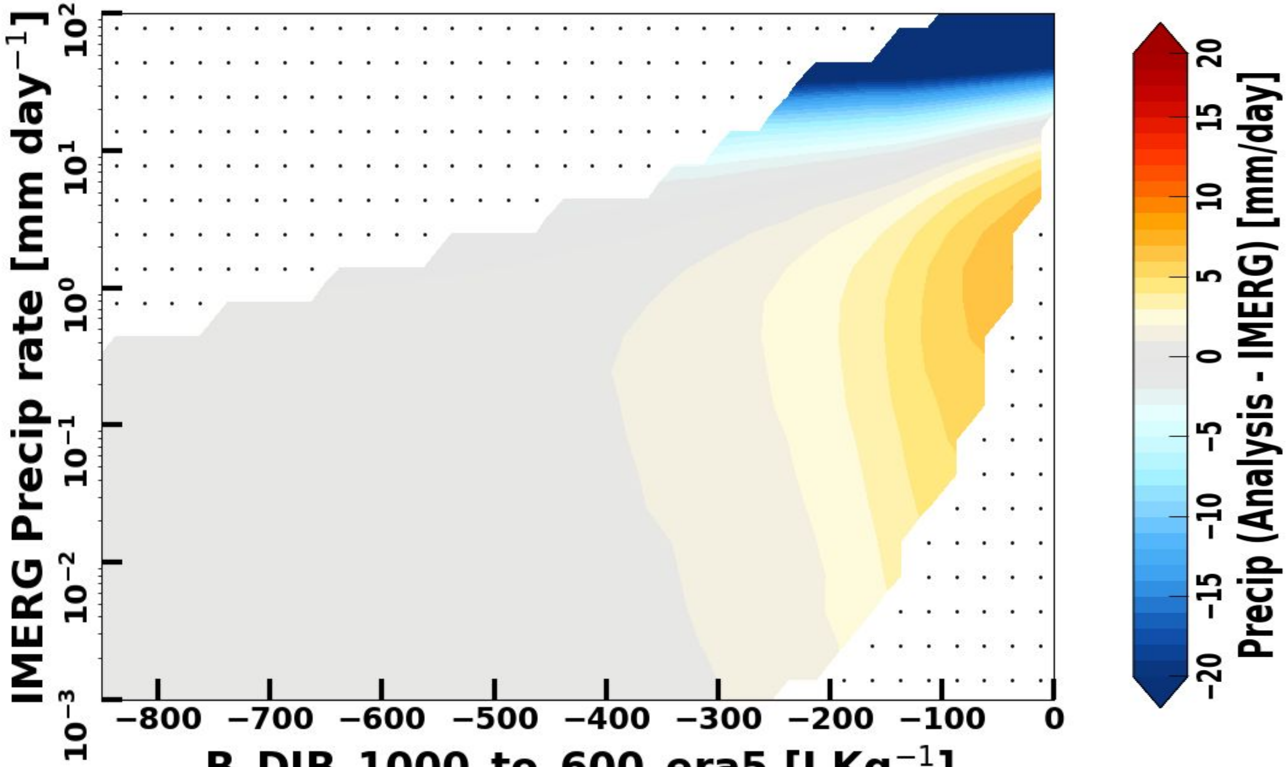
# 2D Buoyancy-Precipitation phase space



# Precipitation biases in UFS replay

More rain

Less rain



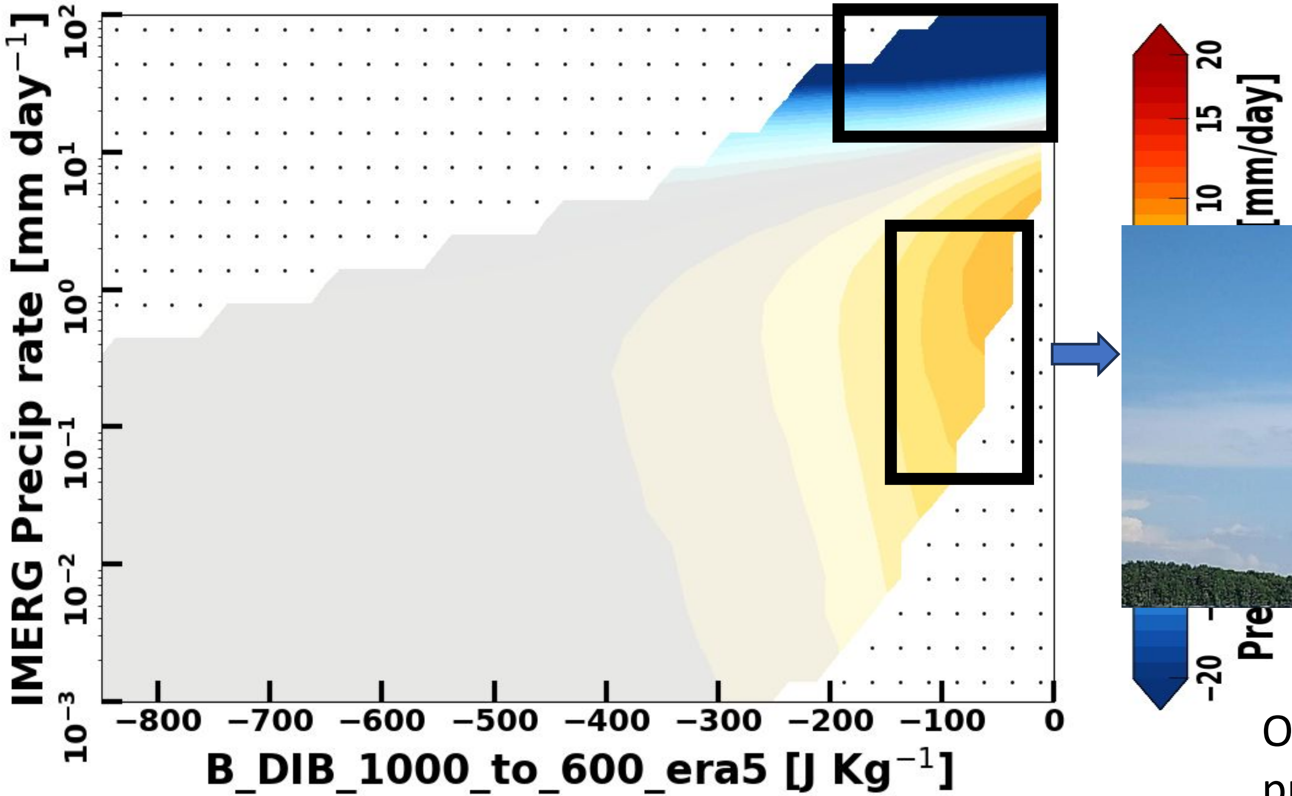

**Dry, stable**

**Moist, unstable**

Strong underestimation of precipitation associated with MCS

More rain

Less rain

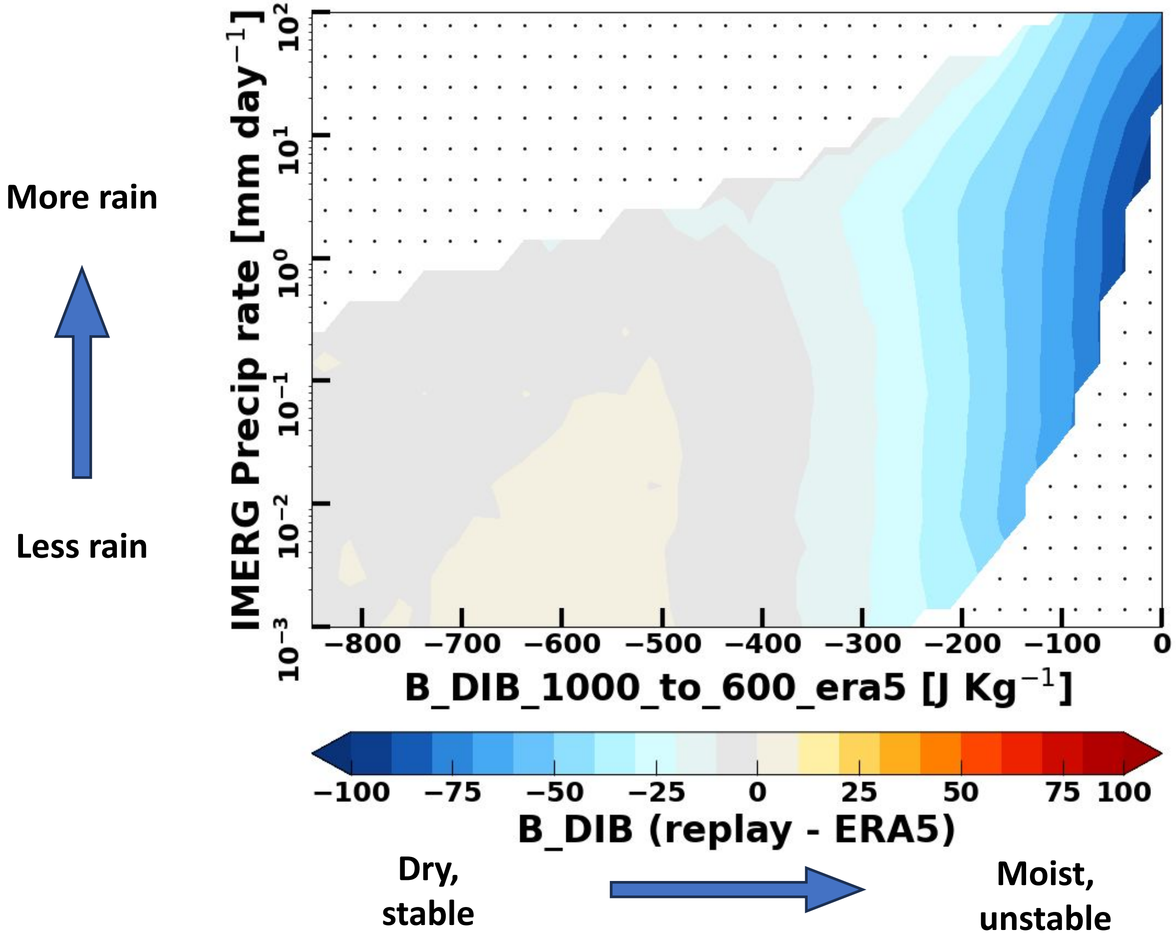



Overestimation of precipitation associated with congestus

Dry, stable

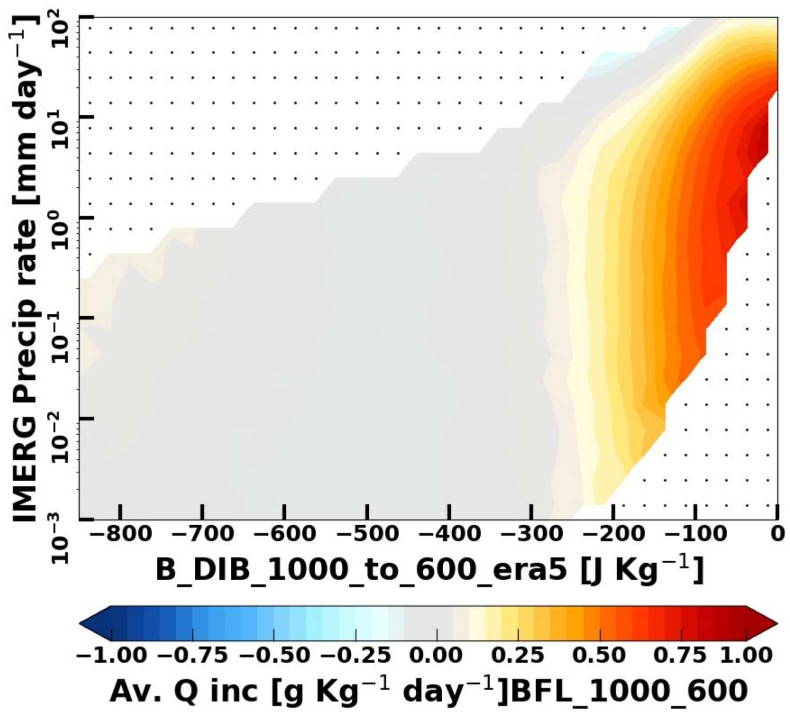
Moist, unstable

# Replay runs also show increased stability

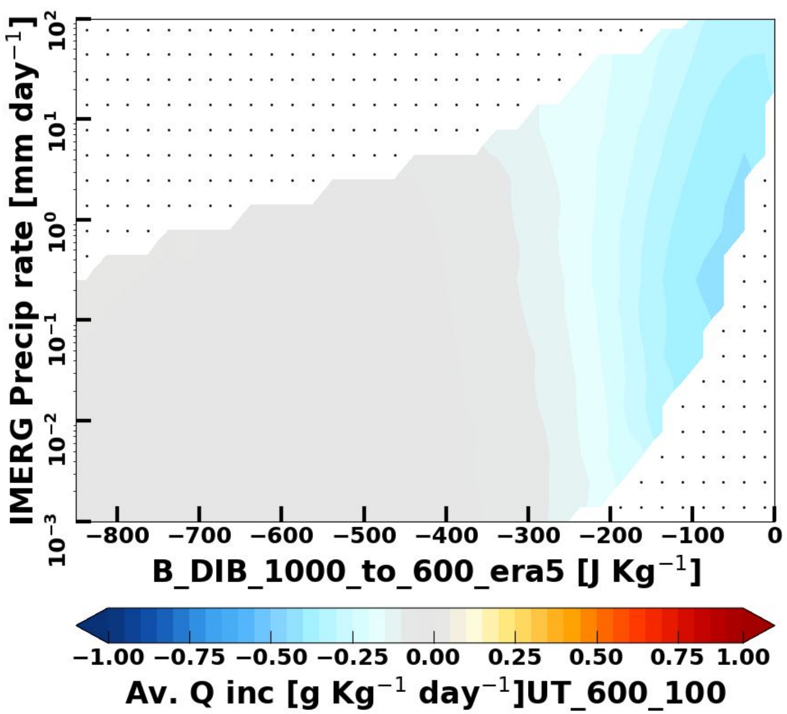


# Moisture increments show tendency of the model to go to a preferred more stable state

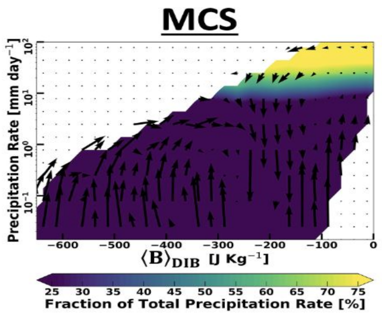
Lower troposphere moisture increment



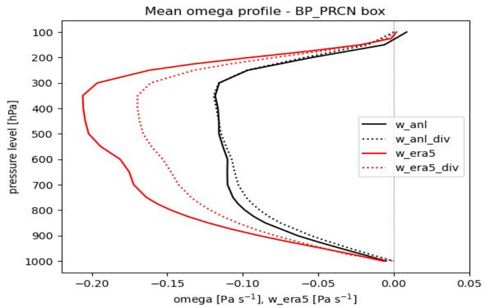

Upper troposphere moisture increment

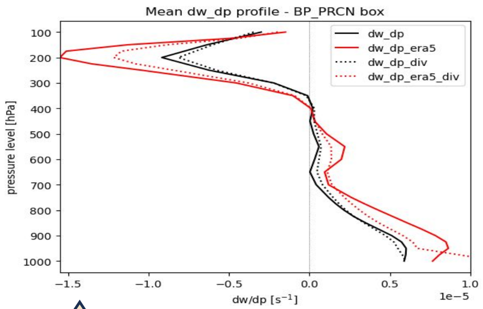



Model stays too dry below freezing level and too moist above it



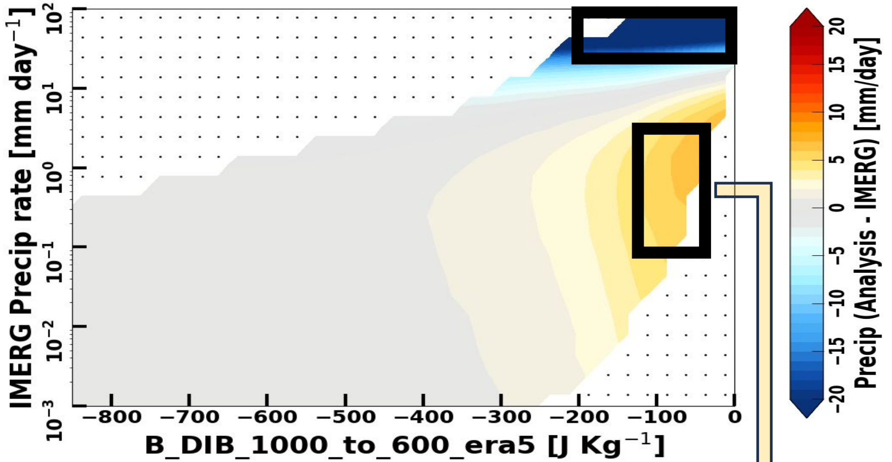

(Fig. from Wolding et al. 2024)



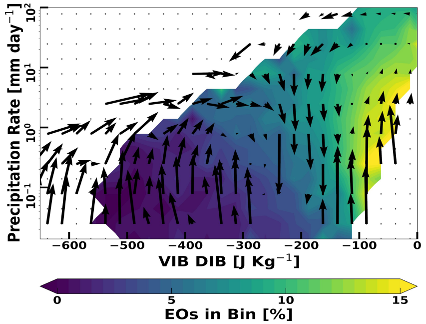

More rain

Less rain

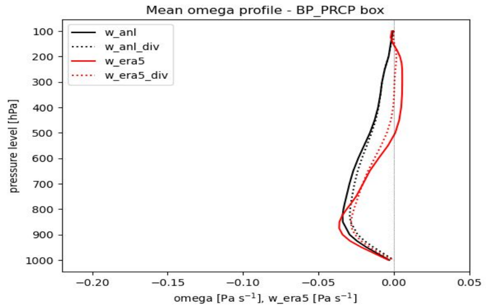


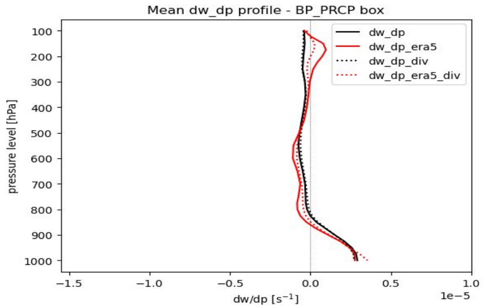

Dry, stable

Moist, unstable




(Fig. from Wolding et al. 2024)



# Conclusions

- Possible precipitation drizzle bias in UFS for low rain rates. High rain rates underestimated.
- UFS model prefers a more stable state in the long climate run. Model starts drifting towards stability almost immediately in the short run too.
- Model seems very efficient at removing low tropospheric moisture which increases the stability.
- Potential hypothesis

Model triggers deep convection too easily → Does not allow instability to build up sufficiently → Leads to a more stable mean state and misrepresentation of organized precip

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