Model Uncertainty-Model Intercomparison Project (MU-MIP)

A dataset for model physics intercomparison and model error

Linking CAPE and precipitation rate non-stationarity during spin-up across NWP physics packages

Edward Groot[1] & MU-MIP core team: Hannah Christensen[1], Xia Sun[2], Kathryn Newman[2], Wahiba Lfarh[3], Kasturi Singh[4,5], Romain Roehrig[3], Hugo Lambert[4], Jeff Beck[2] and Keith Williams[5]
1: University of Oxford; 2: Developmental Testbed Center; 3: Meteo France; 4: University of Exeter; 5: UK MetOffice

Contact: edward.groot@physics.ox.ac.uk

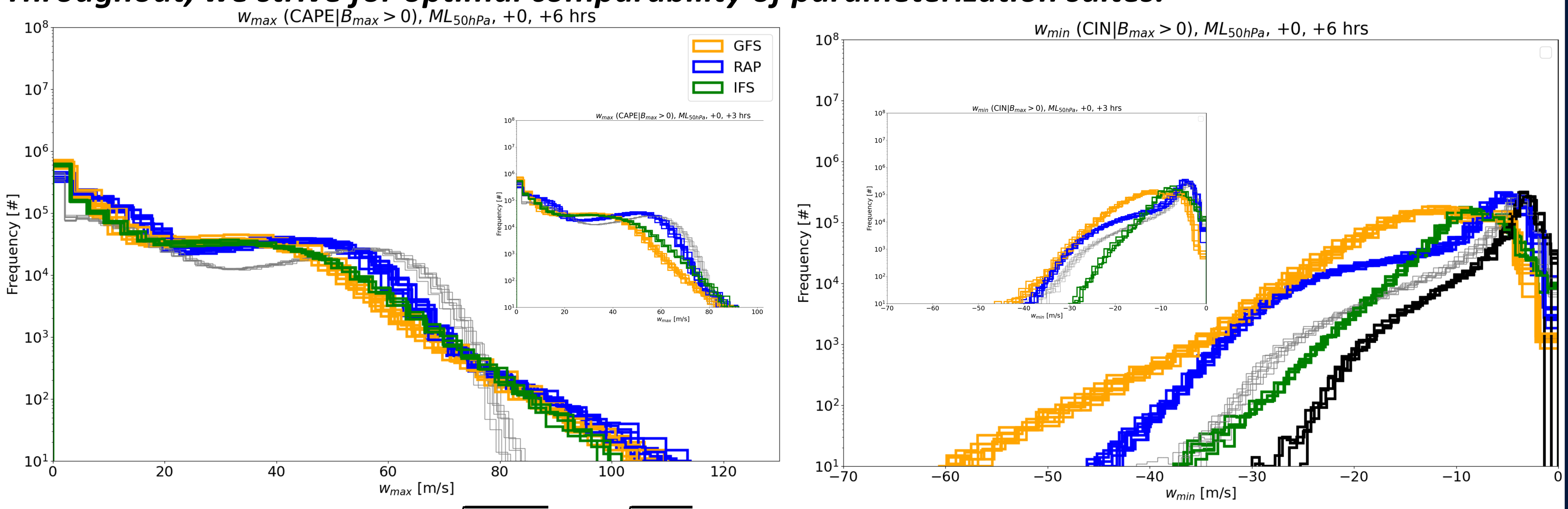
mumip.web.ox.ac.uk

Introduction

MU-MIP is ***an intercomparison project for model uncertainty*** *in which we intercompare the physics* ***parameterization suites*** *used in numerical weather and climate modelling. Each physics suite consists of a package of parameterizations, e.g. for turbulence, convection, radiation, surface exchange with land/ocean and cloud processes. These are thought to be* ***the dominant contribution to model uncertainty*** *across all GCMs and numerical weather prediction models.*

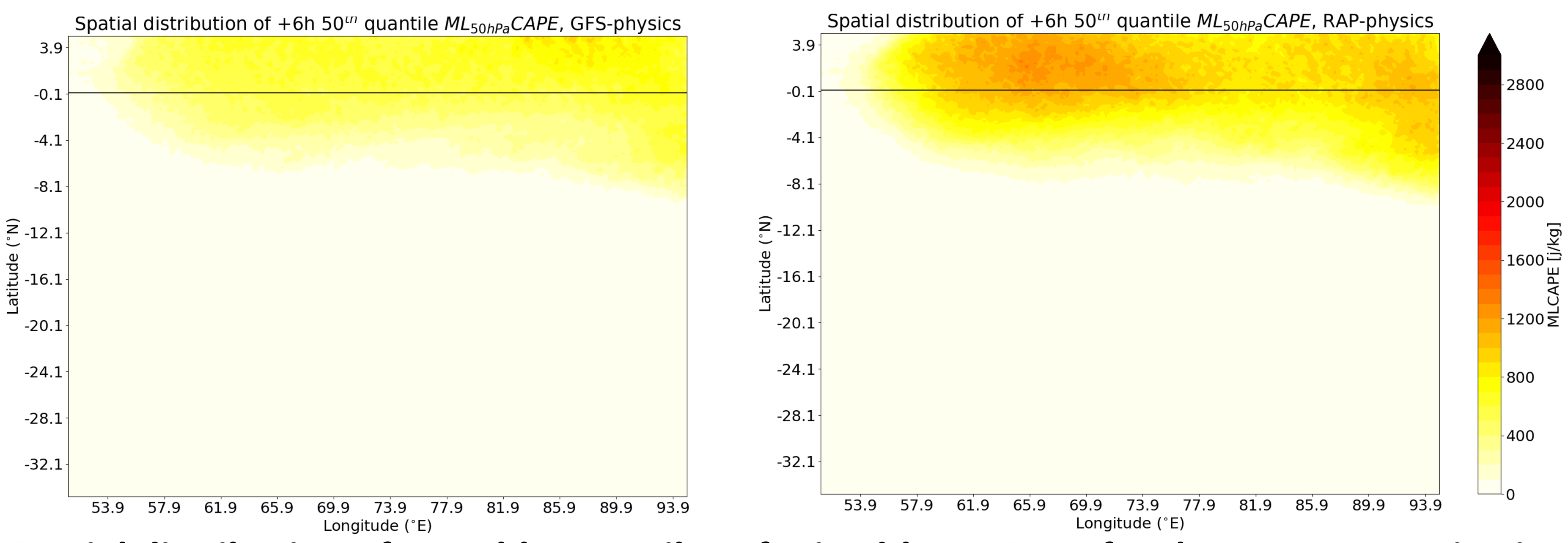
We run the simulations with parameterization suites by utilizing the single-column version of operational models (SCM) over the Indian Ocean domain about ten million times. To ensure fixed and representative dynamical constraints, we assume a ground truth derived from DYAMOND simulations and insert its dynamics as initial and boundary conditions in the SCMs. One month of 2016 is covered based on the storm-resolving ICON ($\Delta X = 2.5$ km) and driven by three-hourly archived dynamics.

After re-gridding to 0.2 degrees, we currently carry out an ocean-only intercomparison over a subdomain of 44.000 tiles. Two physics suites utilizing parameterizations from the Common Community Physics Package have been compared: ***RAP and GFS*** *(proto. version 17).*
The ***OpenIFS-SCM*** *dataset with cycle 48 physics is near completion (as of August 2024) and MeteoFrance and UK MetOffice/University of Exeter will follow.*
Throughout, we strive for optimal comparability of parameterization suites.

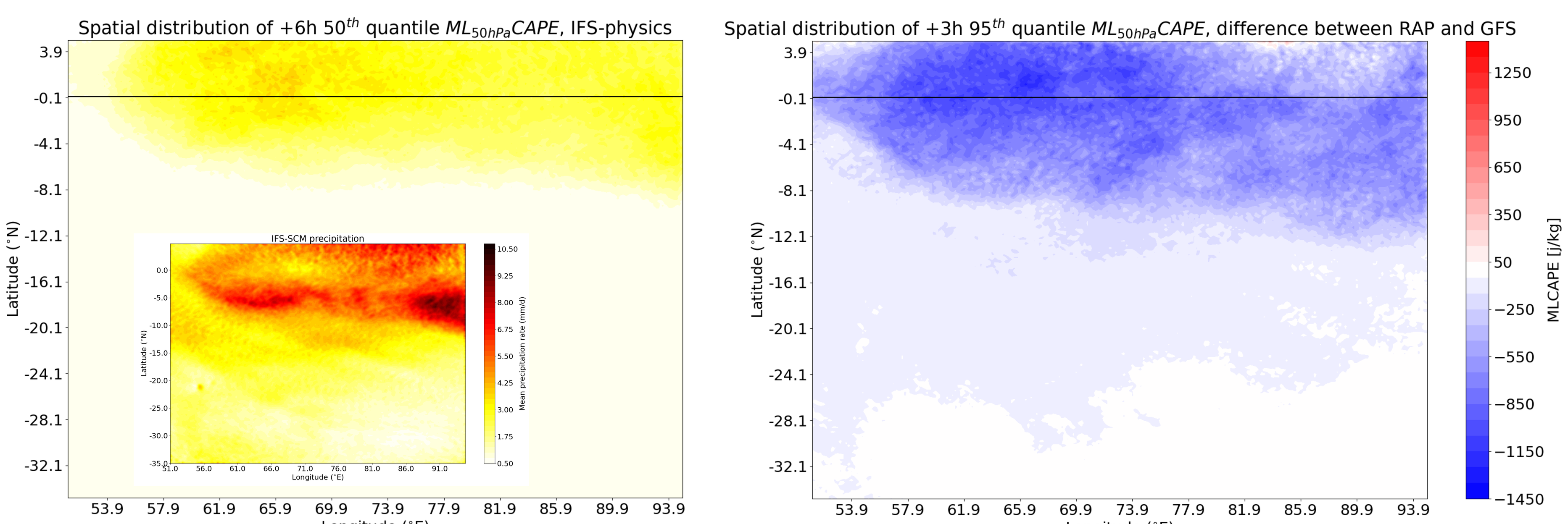


PDF of Mixed-layer (ML) values of $\sqrt{2CAPE}$ and $\sqrt{2CIN}$ from three parameterization suites on a log-axis at 6 hour lead time (enclosed: 3 hours). The lines indicate PDFs across variation across the diurnal cycle.
Grey: *ground truth* (ICON 2.5km-derived conditions prescribed as initials)
Right, black: *same ground truth* MLCIN following slightly different IFS levels define the ML (further investigation needed)

We intercompare conditional PDFs of tendencies and the model state to learn about multi-model uncertainty, eventually at benefit of stochastic perturbation schemes (Christensen, 2020, QJRMS).



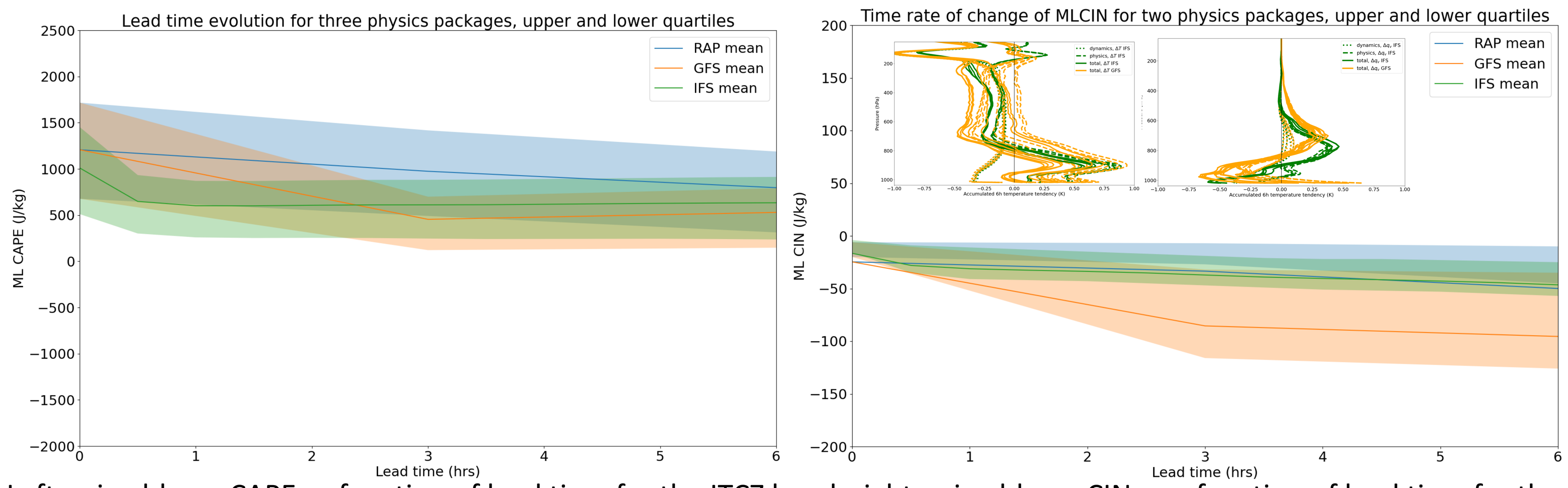
Spatial distribution of monthly quantiles of mixed-layer CAPE for three parameterization suites (median) and high CAPE (difference map, lower right)



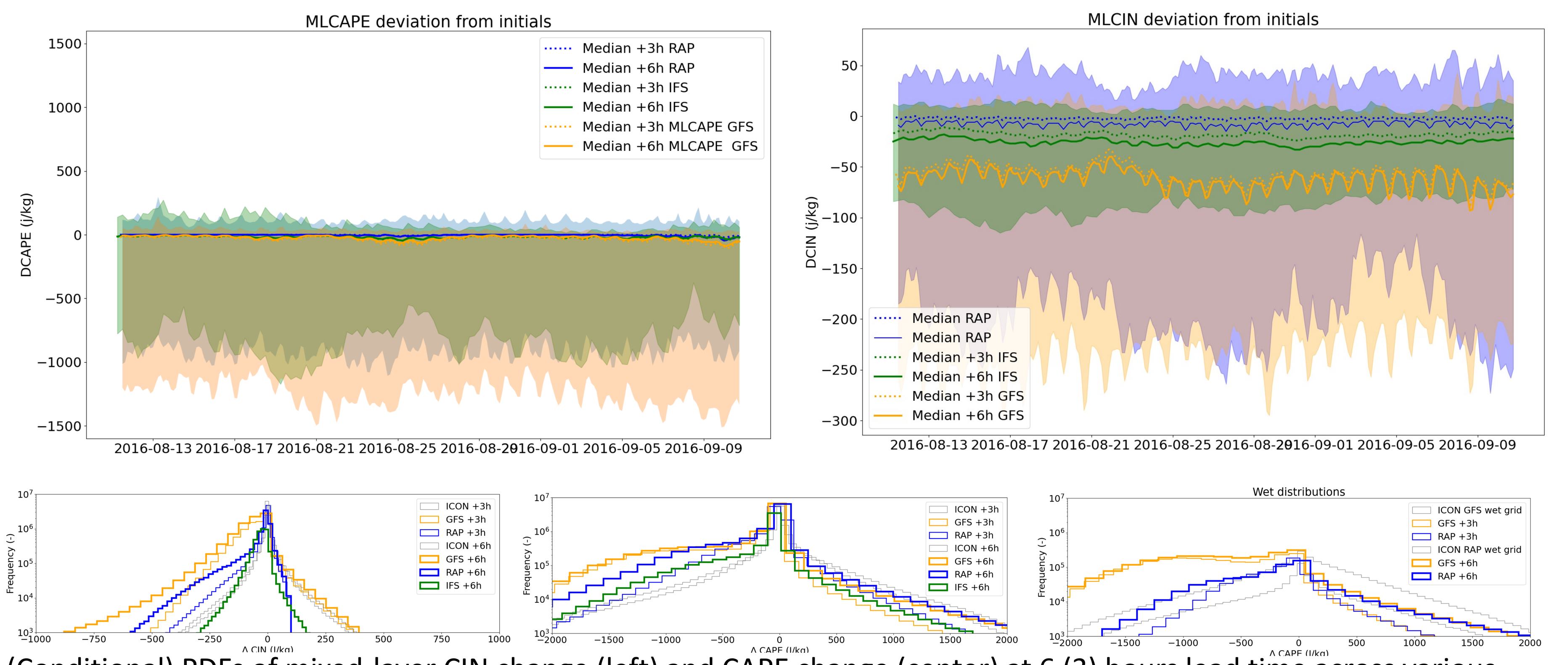
References:
Christensen, H., 2020 Constraining stochastic parametrisation schemes using high-res simulations, QJRMS, https://doi.org/10.1002/qj.3717
Buschow, S., 2024 Tropical convection in ERA5 has partly shifted from parameterized to resolved, QJRMS, https://doi.org/10.1002/qj.4604

The provisional analysis here is based on data provided by E. Groot and X. Sun with great support from K. Newman and H. Christensen. Further data to follow.

How can we learn about model physics, and what the numerical models do?

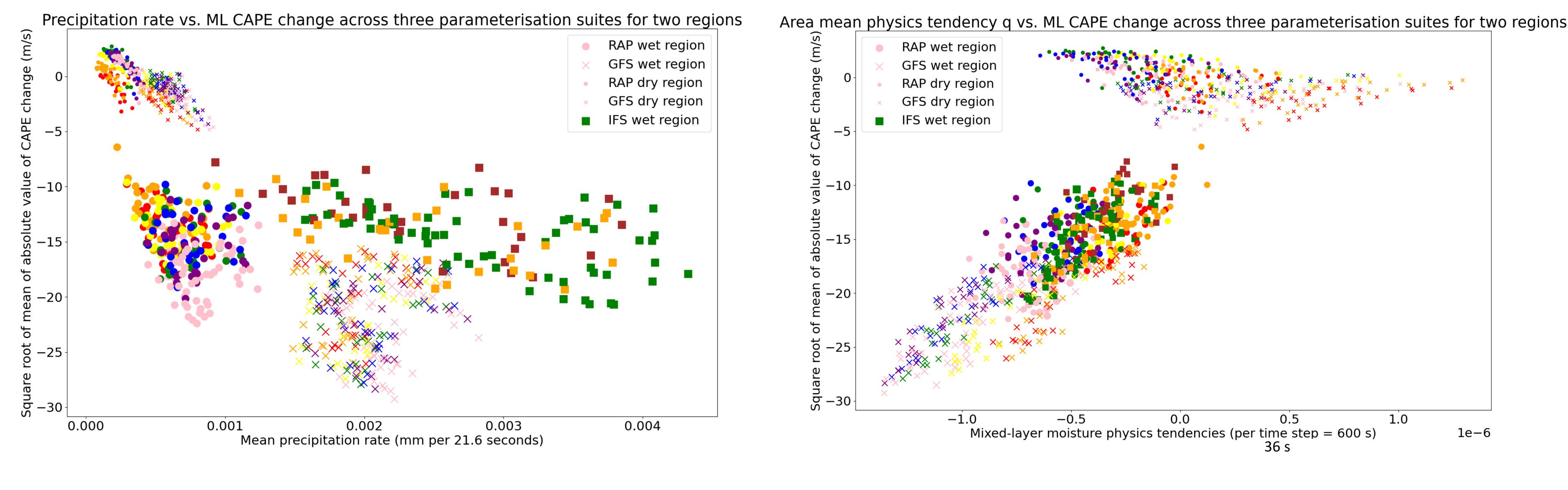


Left: mixed-layer CAPE as function of lead time for the ITCZ band; right: mixed-layer CIN as a function of lead time for the entire domain, with enclosed net physics and dynamics tendencies of IFS across the diurnal cycle.
Below: time evolution of 3 and 6 hour change of mixed-layer CAPE (left) and CIN (right) over the full domain.



(Conditional) PDFs of mixed-layer CIN change (left) and CAPE change (center) at 6 (3) hours lead time across various suites; left and center: full PDF; right: conditioned PDF for mixed-layer CAPE over precipitating parts of the grid (at least 1.7 mm per 6h). GFS has much more of such precipitating cells than RAP.

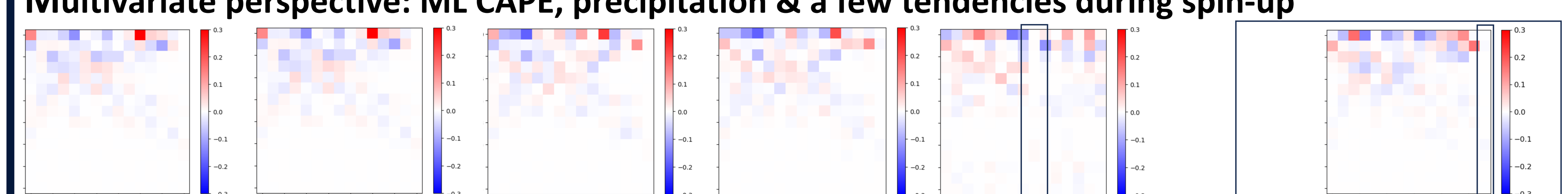
Convective adjustment from a model's non-native regime is linked to precipitation intensity, which could link to non-stationarity in parameterized precipitation rates manifested by parameterized deep-convection (Buschow, 2024, QJRMS).



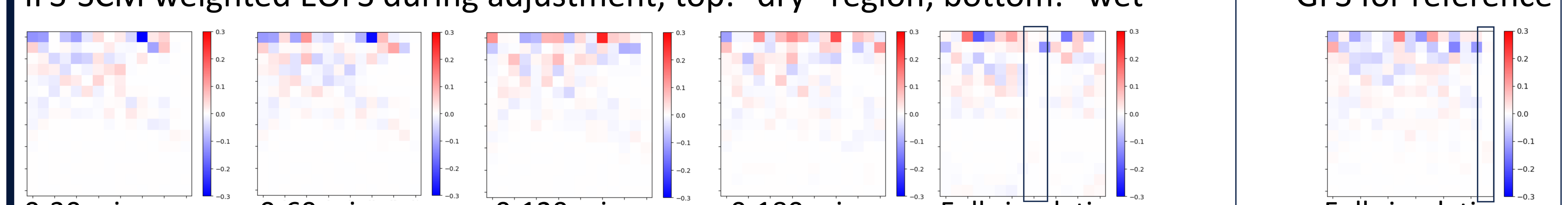
Relation between area mean changes of CAPE and precipitation rate (left) and CAPE vs. water vapor tendency (all ML) from the physics suites (right) for two regions – the equatorial band ("wet") and the southern half of the domain ("dry"). Colours indicate the variation of area means across a diurnal cycle.

Refined understanding of model assumptions across parameterization suites, variation in spin-up behaviour, and their relation with physical drivers could be of large benefit for our interpretation of MU-MIP data as well as improvement of suites. Although parameterization suites should converge towards reality, this is not apparent.

Multivariate perspective: ML CAPE, precipitation & a few tendencies during spin-up



IFS-SCM weighted EOFS during adjustment, top: "dry" region; bottom: "wet" GFS for reference



0-30 min | 0-60 min | 0-120 min | 0-180 min | Full simulation | Full simulation