# MCS response to storm environment in convection permitting simulations

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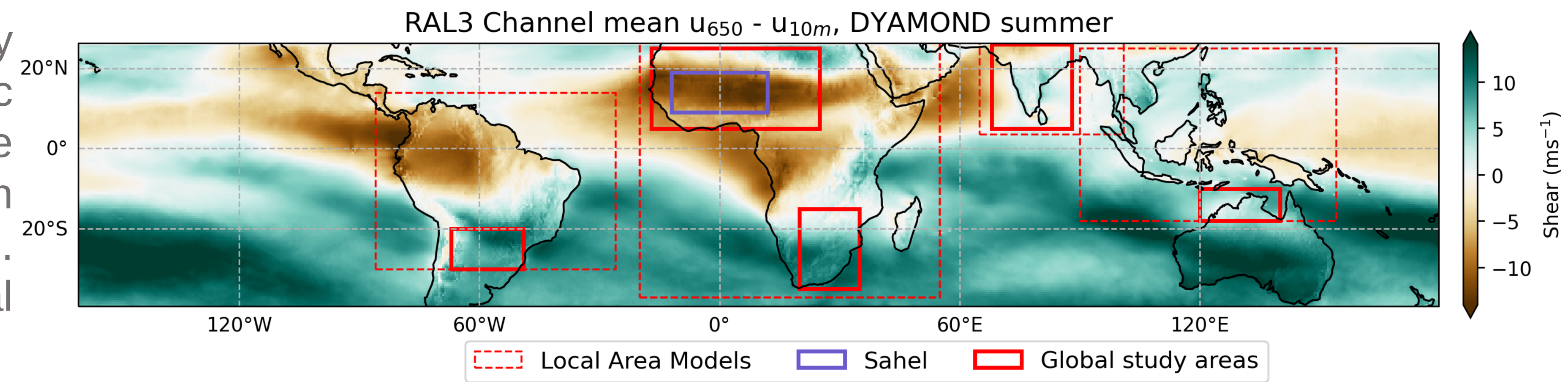
## Motivation

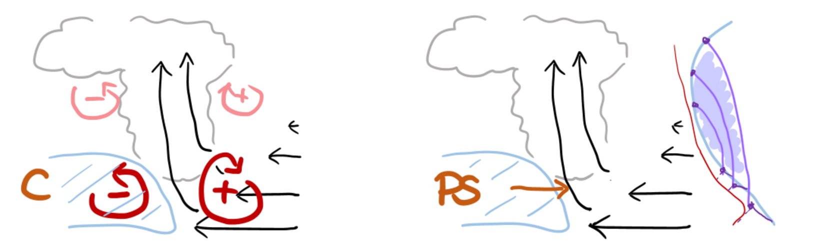
Observations show that variability in extremes of rainfall and convective intensity in Mesoscale Convective Systems (MCSs) predominantly depend on atmospheric moisture and low-level vertical wind shear[1]. Convection permitting (CP) km-scale modelling should capture these dependencies; yet a previous 10 year, 4.4km run of the Met Office Unified Model (UM) over Africa showed poor shear response[1,2]. Here we explore if new, updated UM runs show improved storm environmental responses, and how results fit with theoretical mechanisms for MCS dynamics.




## The LMCS project

The balance of mechanisms whereby shear affects MCS dynamics is not fully understood. Nor are crucial land-surface interactions, which influence low level shear and mature MCSs[3]. The LMCS project is investigating these interactions in global observations and CP simulations. New 40 day, 1.5km grid UM run over Sahel currently running.

**Key model Q**: does theory explain observed land-MCS coupling? Need to test aspects of shear response in explicit models; not seen in previous UM run!



**RKWM88[4]: vorticity balance** | **LLMC[5]: control of relative inflow**

## The K-Scale UK project, led by Met Office

Met Office developing very large domain regional and global convection permitting modelling capacity at the km grid-scale (K-Scale). Lead: **Huw Lewis**.

Existing pan-Africa run: **CP4-A**; 10years past + future climate, 4.4km. Showed greatly improved MCS populations vs parametrised convection (PC) [2,6].

New km scale runs for 40 day DYAMOND summer and winter: 10km global driving model; four Local Area Models (LAMs); and novel Cyclic Tropical Channel. Hourly data on common 0.1° grid shared via JASMIN platform.

Key change vs CP4-A: **RAL3 configuration**. CASIM microphysics (5 phase, 2 moment) + improved BL turbulence scheme and land surface representation.

## Results: Sahel, 12°W – 12°E, 9 – 19°N

**OBS**

20 years 10.8µm Meteosat brightness T, 01/08 – 09/09.
+ IMERG precipitation
+ ERA5 reanalysis environment.

**UM runs**

**CP4-A**

10 years August + Sept.; 4.4km grid, sandy soils, sing. moment microphys.

**DYAMOND summer**
01/08/16 – 09/09/16

**Channel**

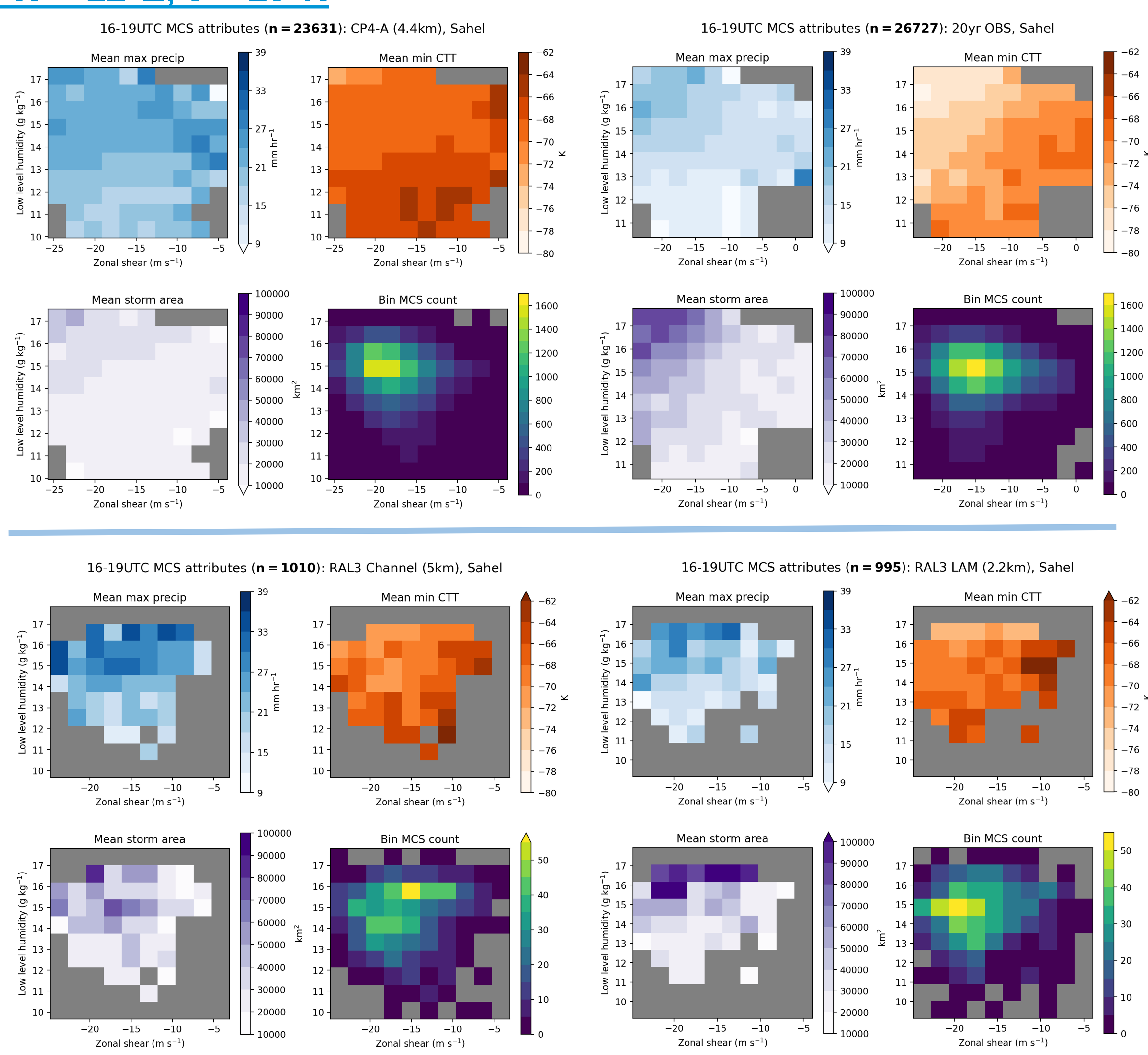
5km trans-tropics, cyclic domain. Both RAL3 (CP) and GAL9 (PC).

**LAM Africa**

2.2km grid spacing, RAL3 CP configuration.

**Global**

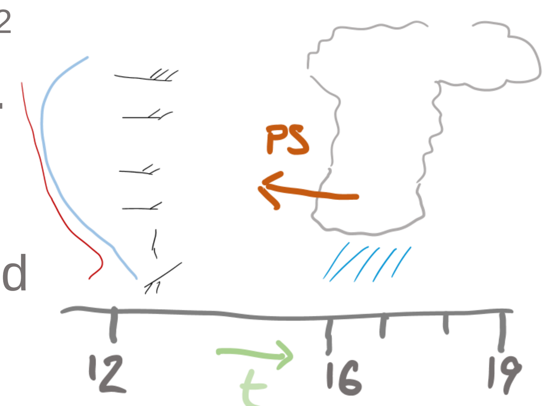
10km driving model; GAL9 PC configuration.

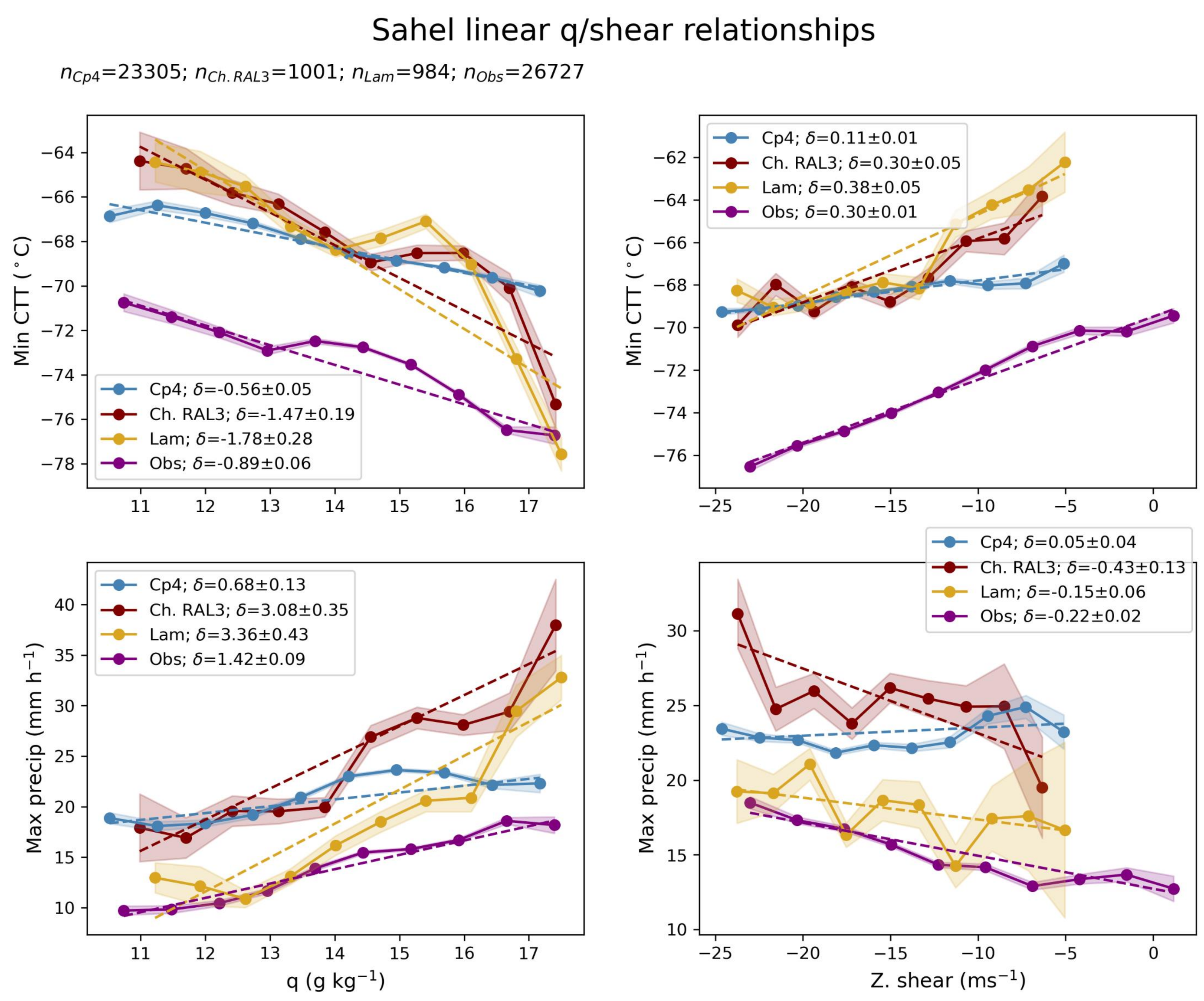



**GAL9 results (not shown)**: show far fewer storms, with lower rain rates, somewhat higher CTTs & similar areas.

## Methods

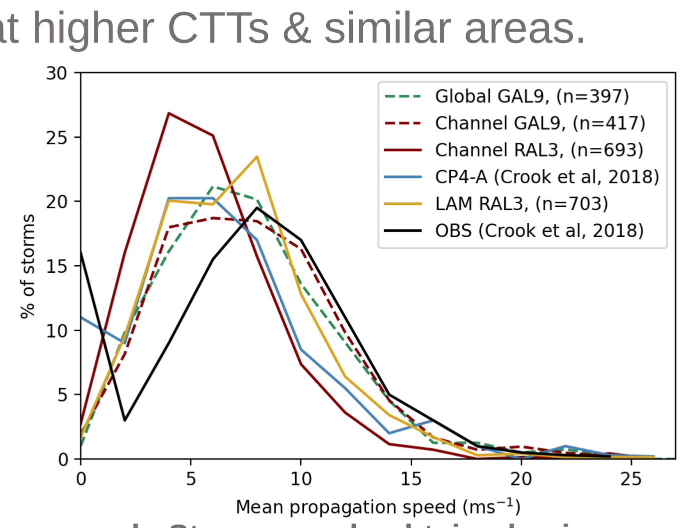
- MCS = contiguous area > 5000km$^2$ of Cloud Top Temp. (CTT) < -50°C.
- Hourly snapshots, 16–19UTC.
- Environment = 12UTC **pre-storm profile**. Use TCW or 925hPa *q*, and zonal shear = u650 – u925.
- Require max precip > 1mm/h.






**New RAL3 runs show generally improved MCS responses to environmental *q* and shear vs previous CP4-A, c.f. observations.** Rainfall rates too high in Channel, and CTTs too low in all. But critically, correct shear responses now seen for precipitation. **Why?**

- Importance of **low-level inflow**? LLMC[5] depends on storm propagation speed – improved in LAM vs CP4-A; but not in Channel.
- Shear decreases **entrainment dilution** of updraft cores[8]; improved in model? Look at differences between anvil heights and LNB, $\theta_e$ profiles.
- Importance of **microphysics**? CASIM is 2-moment scheme, vs CP4-A single.

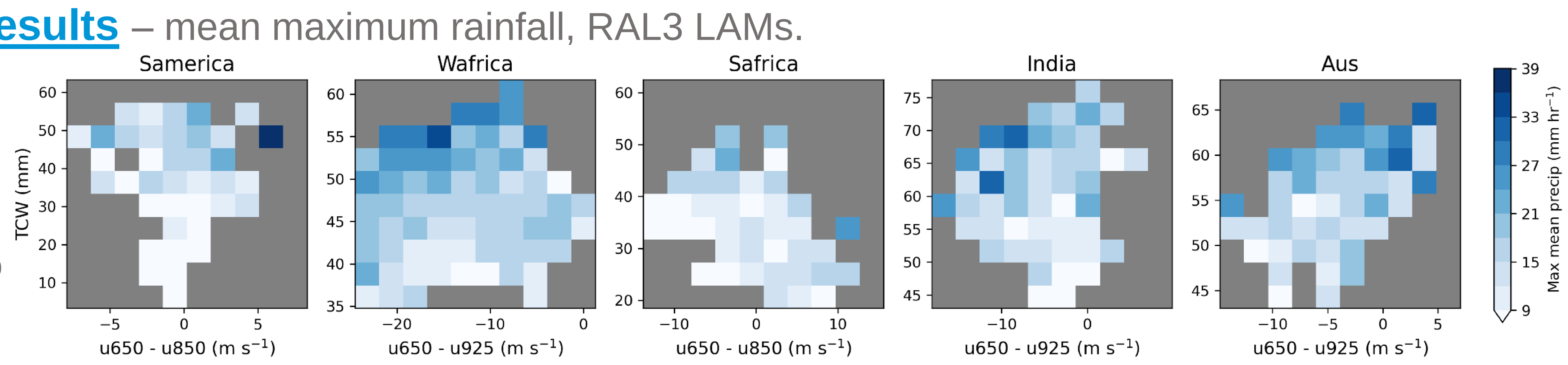



**n.b. Storm speeds obtained using a Lagrangian tracking algorithm[6,7].**

## Global results – mean maximum rainfall, RAL3 LAMs.

N. hemisphere: **DYAMOND summer**.

S. hemisphere: **DYAMOND winter**, 20/01/20 – 28/02/20.




- **LMCS**: project investigating MCS dynamics + land interactions in observations and explicit models.
- Upgraded model configuration (RAL3) and improved resolution (2.2km) improves shear response of max rainfall rates from MCSs.
- Correct shear response in km scale models essential for confidence in upscale projections.
- **Next steps**: explore mechanisms responsible for improvements.

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