Design for representing shear-induced convection organization in CoMorph

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Paracon plenary Cambridge, UK, 16-17 Dec 2019

Background:

The mesoscale organization of tropical convection is an important atmospheric phenomenon,
It is often not represented in Convection Parametrization Schemes used in GCMs
and hence its influence on the global circulation is not accounted for

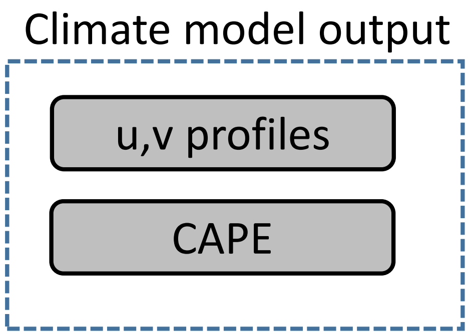
One aim of ParaCon project:

design changes to CoMorph so that it can represent some aspects of shear-induced organization of convection

We are following the study of Mark Muetzelfeldt (*Muetzelfeldt et al., 2021*).

1- Mark used a novel clustering procedure to produce a set of 10 Representative Wind Profiles (RWPs) based on wind profiles and CAPE from a climate model.

Clustering procedure used to produce a set of 10 Representative Wind Profiles (RWPs)



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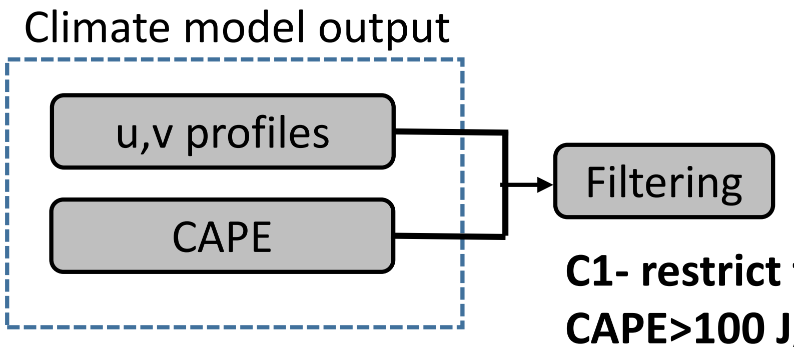

C1- restrict the profiles to ones where convection is likely to be active: CAPE>100 J/kg (vigorous convection)

C2- exclude the grid points where maximum shear (shear values upto 500 hPa) is less than the 75th percentile

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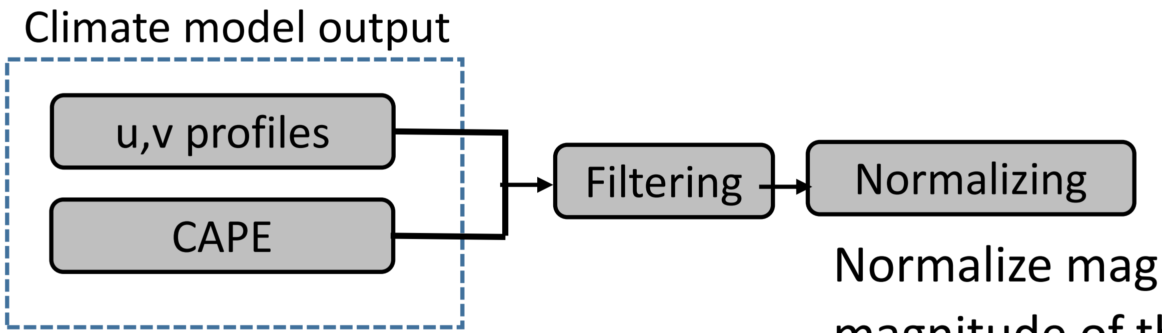

Normalize magnitude- normalizing each profile by the maximum magnitude of the wind at each level $\sqrt{(u^2 + v^2)}$

Normalize rotation: It is done by using the wind vector at 850 hPa to define a rotation angle. All profiles are then rotated so that this angle is zero,

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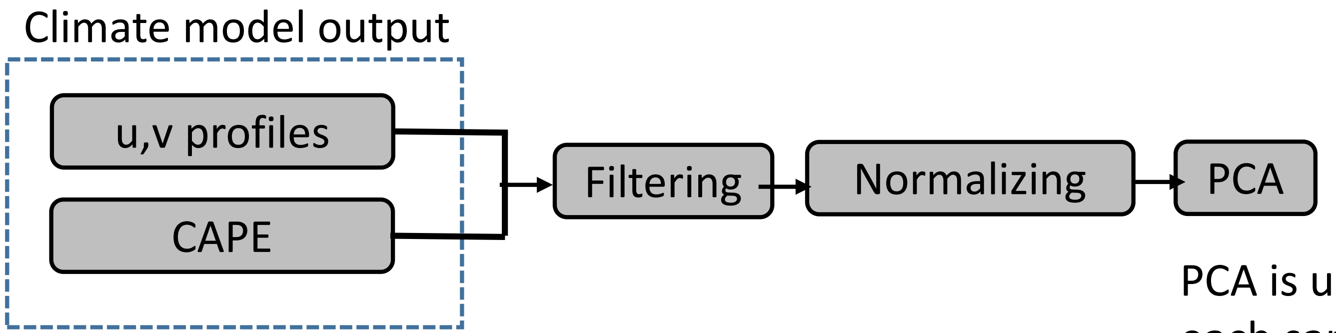

PCA is used to reduce the number of dimensions of each sample, by projecting each sample onto a truncated set of principal components

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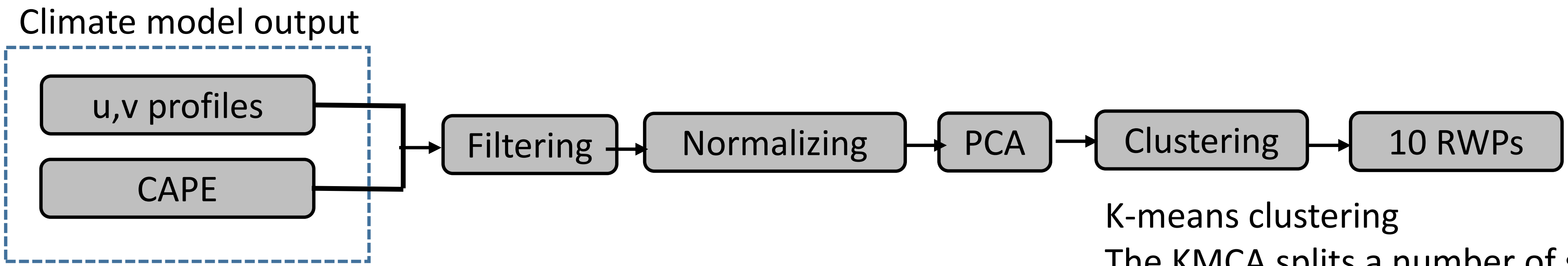
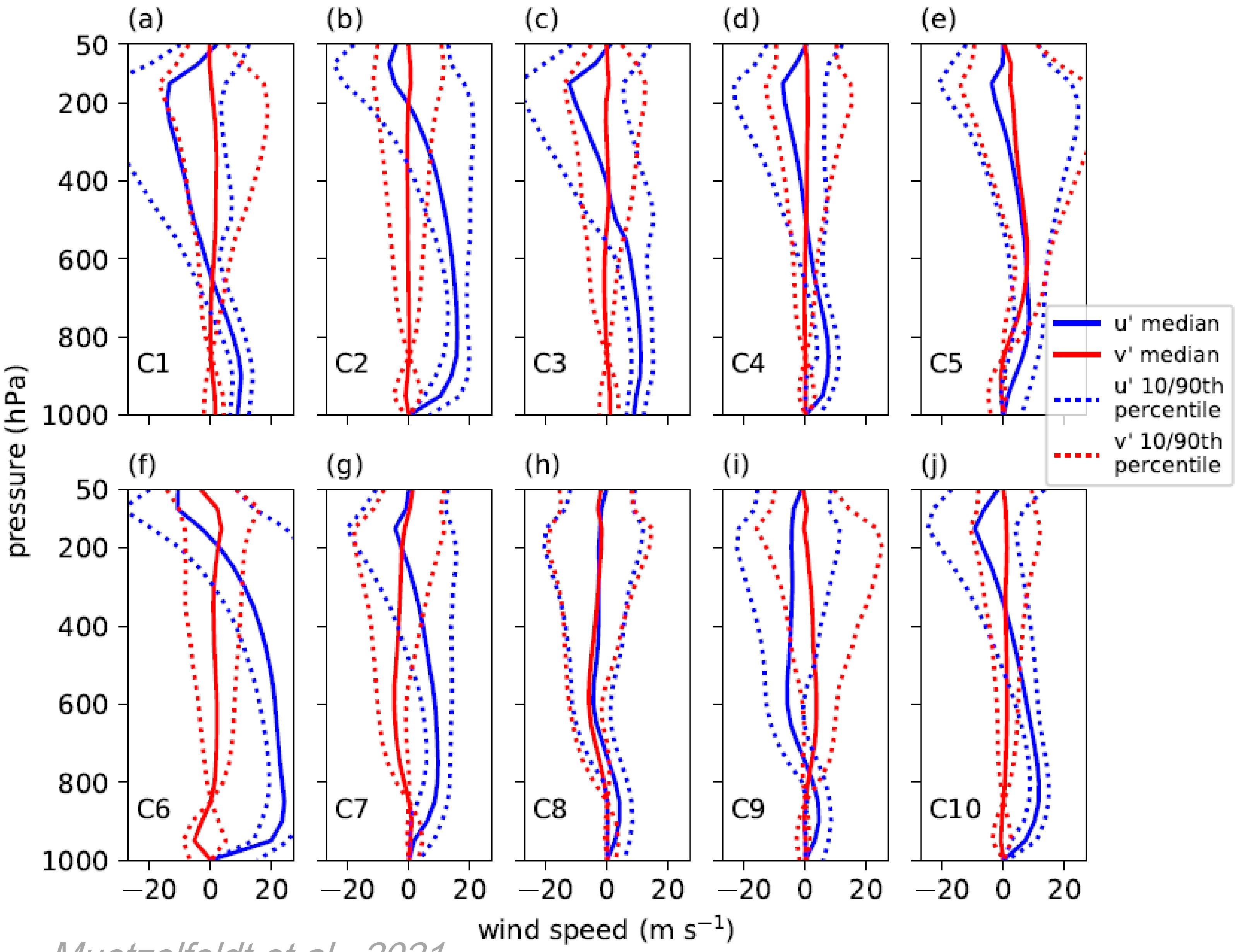


K-means clustering
The KMCA splits a number of samples into clusters based on how similar the samples are to other samples.
It does this in a way which minimizes the within-cluster variance.

10 Representative Wind Profiles (RWPs)



Name	SW (m/s)	LLWD (m/s)	MLWD (m/s)
C1	7.2	2.0	12.1
C2	6.7	8.7	3.2
C3	7.3	3.5	7.6
C4	3.7	3.4	6.2
C5	1.6	6.5	4.3
C6	11.3	11.9	3.5
C7	2.0	7.0	3.3
C8	1.9	1.6	6.8
C9	2.1	1.8	6.9
C10	4.8	6.6	6.2

Muetzelfeldt et al., 2021

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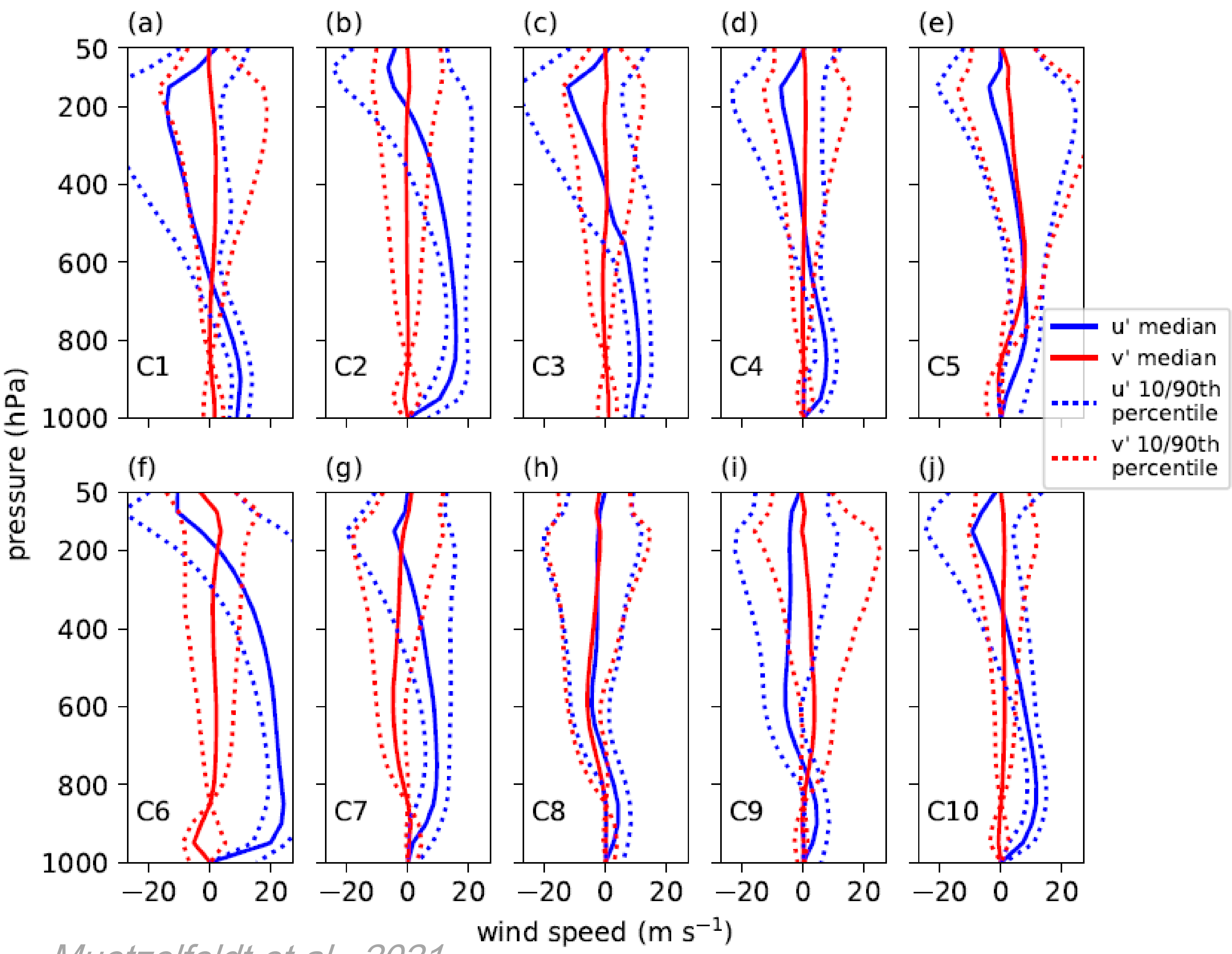


Muetzelfeldt et al., 2021

Idealized RCE simulations using the UM in cloud-resolving mode.

Control simulation:
S0W0→ low level wind shear (LLWD) =0m/s and surface wind (SW) =0m/s → (u,v) both relaxed to 0 m/s)

10 RCE forced simulations (simulations with varied wind profiles): → (u,v) relaxed to RWP

3 additional simulations:
S4W0→ LLWD=4m/s and SW =0m/s
S0W5→ LLWD=0m/s and SW =5m/s
S4W5→ LLWD=4m/s and SW =5m/s

Results from his analysis → evidence that **RWPs are associated with the organisation of convection**

For our study

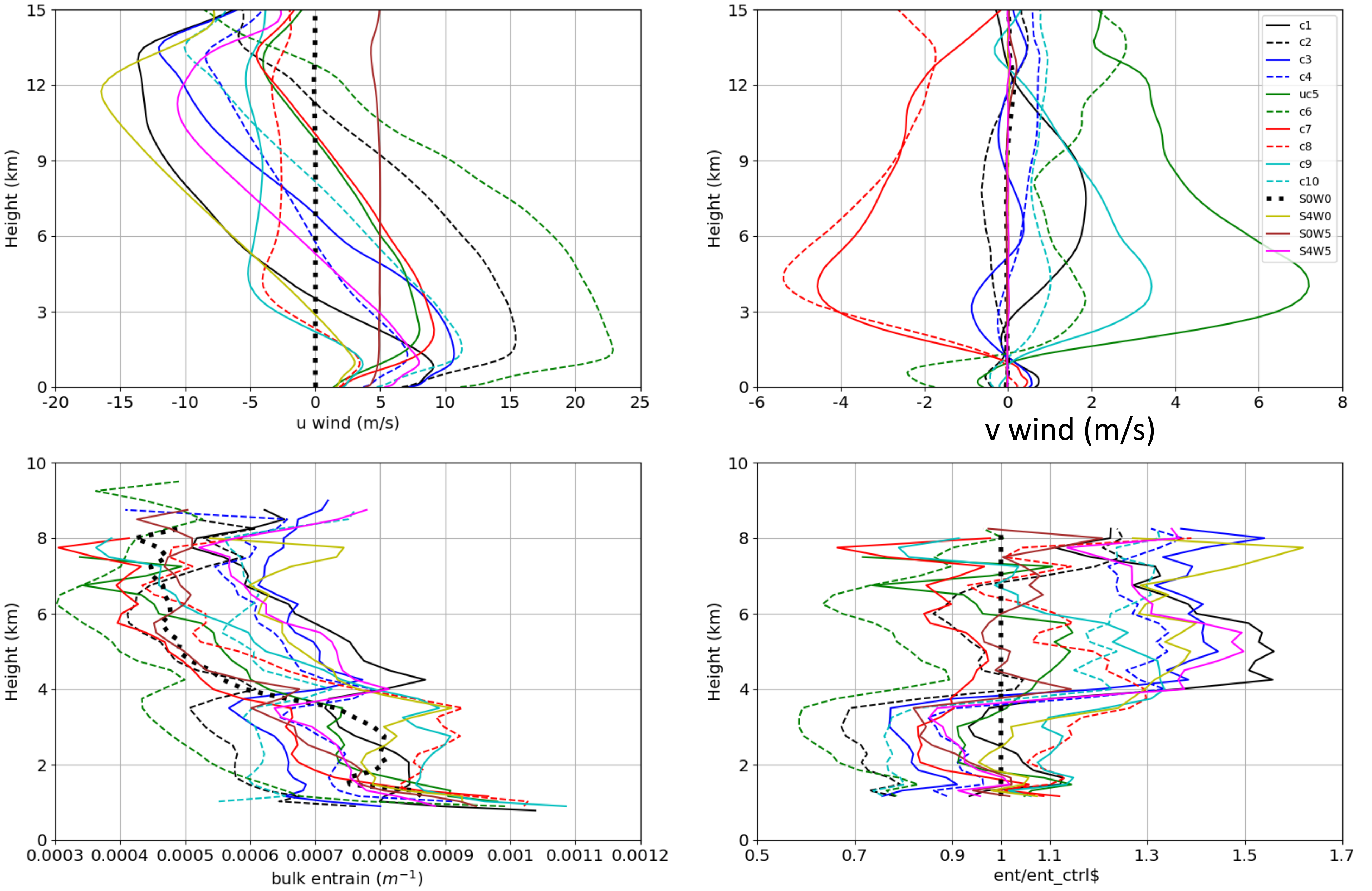
1- use Mark’s high-resolution simulations (control + experiments)

2- Investigate the effect of shear on entrainment (evidence of a relationship?)

3- if yes,

Design changes in CoMorph based on that relationship (between entrainment and change in entrainment rate)

Effects of shear on entrainment rate



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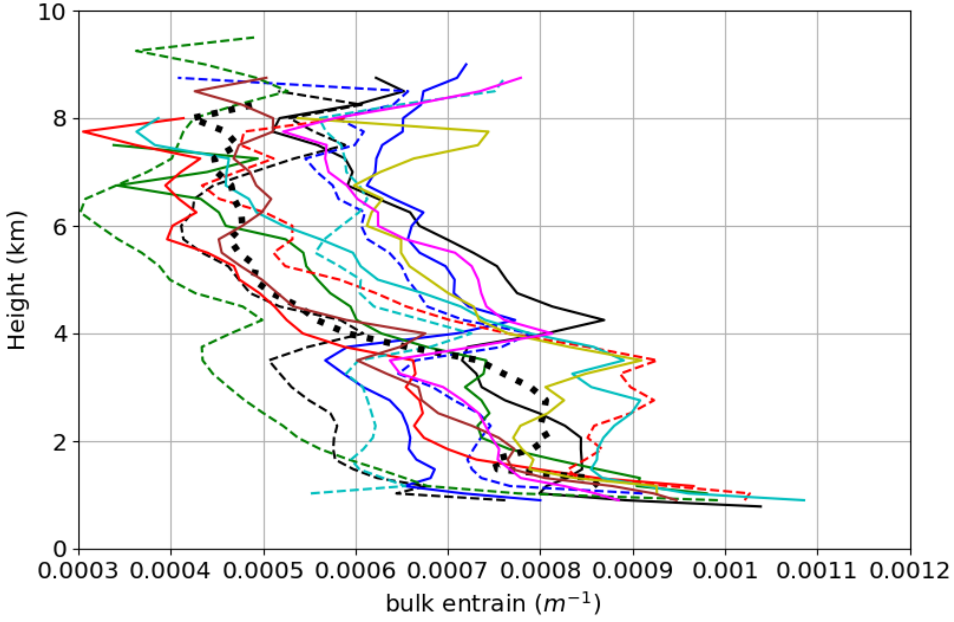
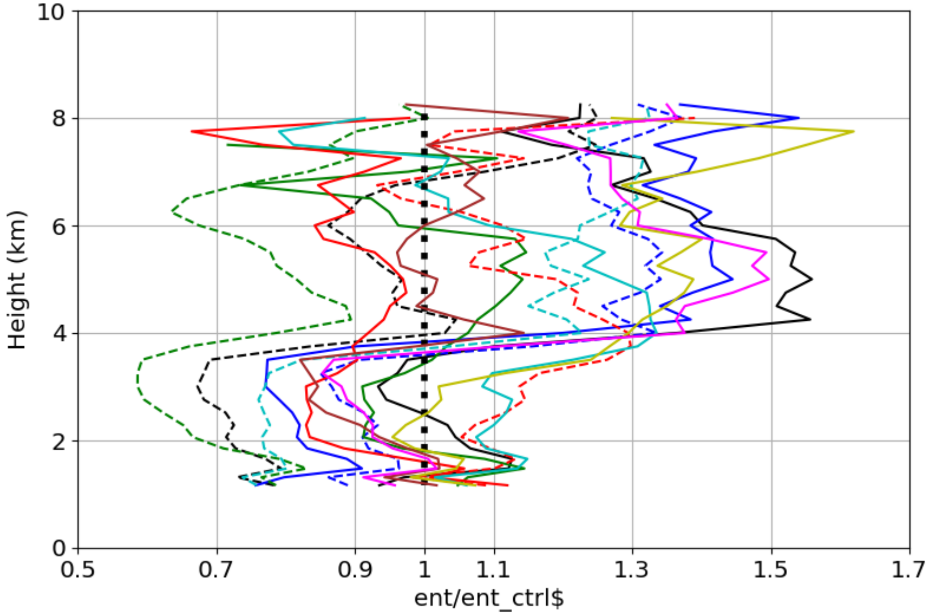
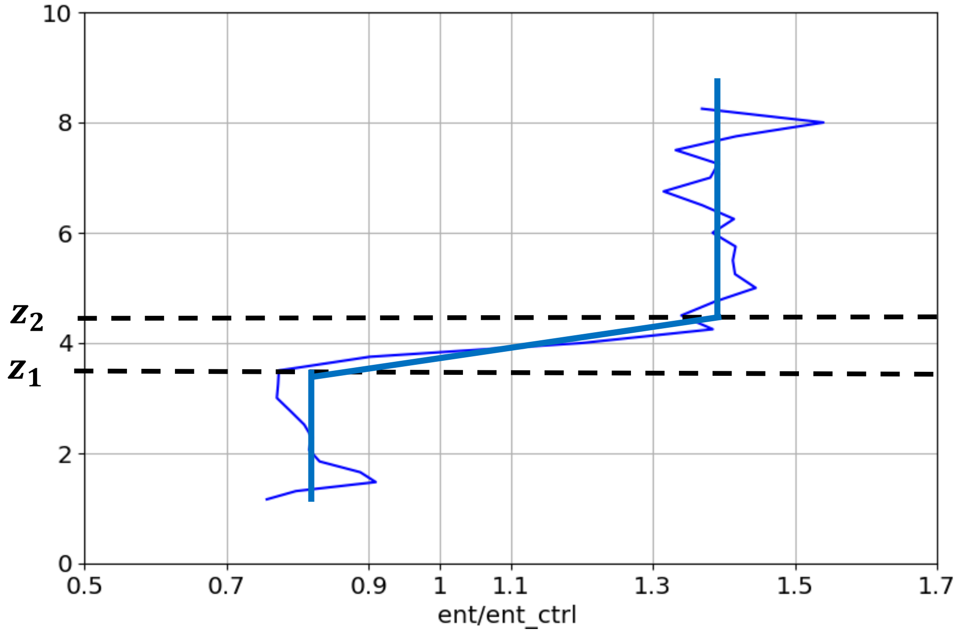




For each case we calculated

- $[e/e_{ctrl}]_{ll}$ for $z < z_1$ → averaging e/e_{ctrl} between 1.5-3.5km
- $[e/e_{ctrl}]_{ml}$ for $z > z_2$ → averaging e/e_{ctrl} between 4.5-8 km
- $[e/e_{ctrl}]_{ll} + \frac{([e/e_{ctrl}]_{ml} - [e/e_{ctrl}]_{ll})(z - z_1)}{(z_2 - z_1)}$ for $z_1 < z < z_2$



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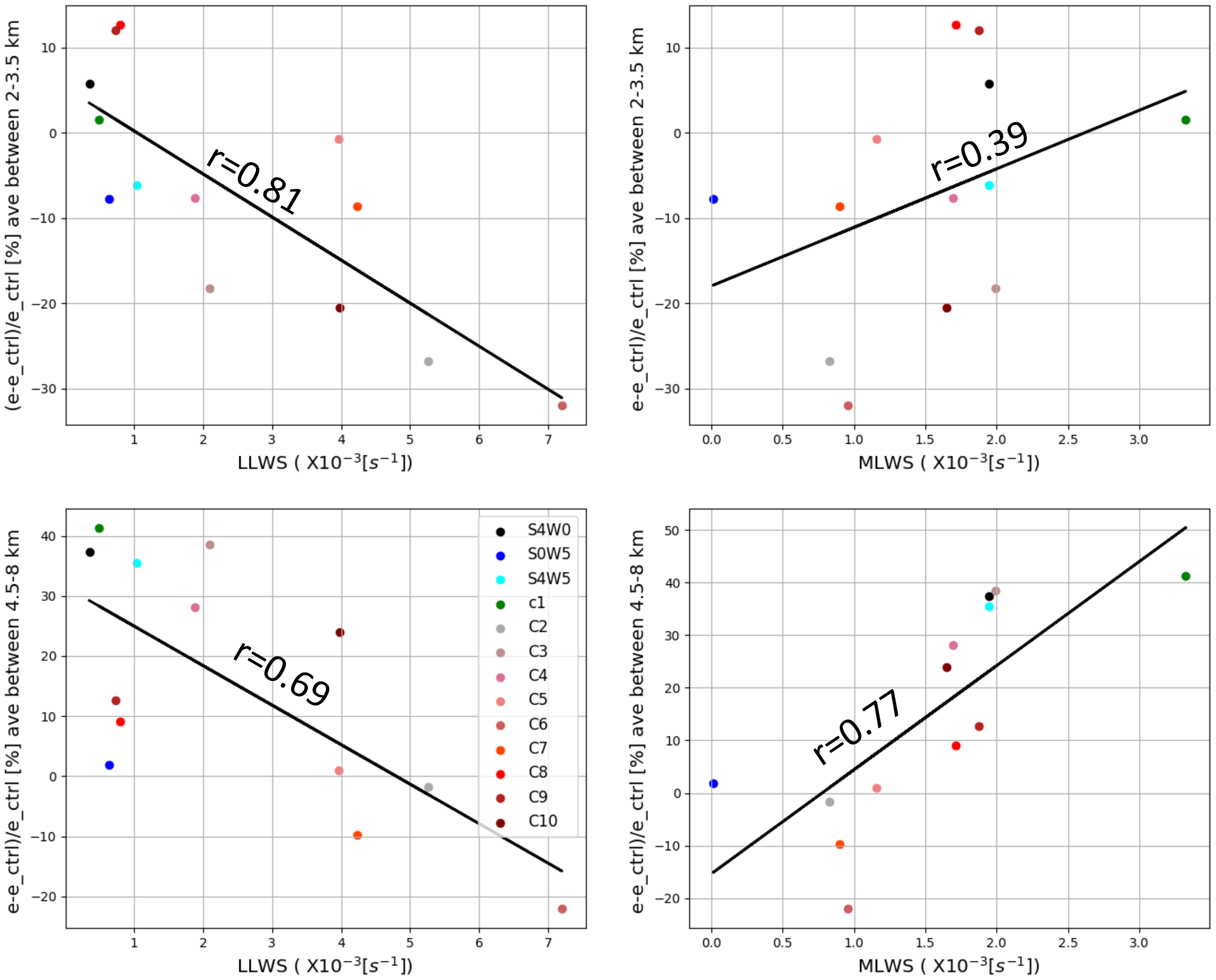
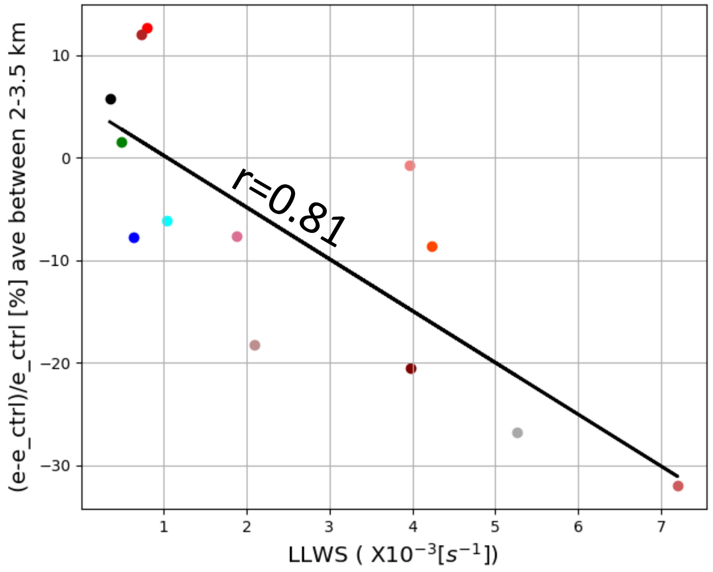


Effects of shear on entrainment rate

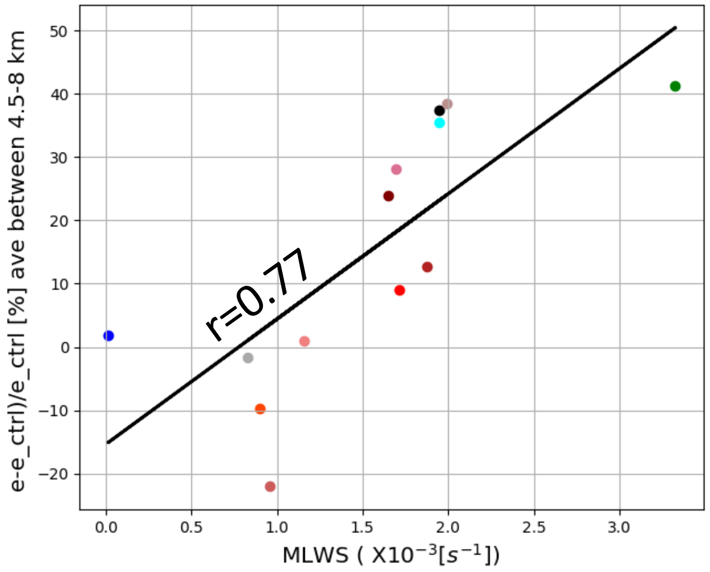
$$[\Delta e/e_{ctrl}]_{ll} = -0.05 * LLWS + 0.053$$

with $\Delta e = e - e_{ctrl}$



Next step:

where and *how* to apply these changes in CoMorph?



$$[\Delta e/e_{ctrl}]_{ml} = 0.2 * MLWS - 0.15$$

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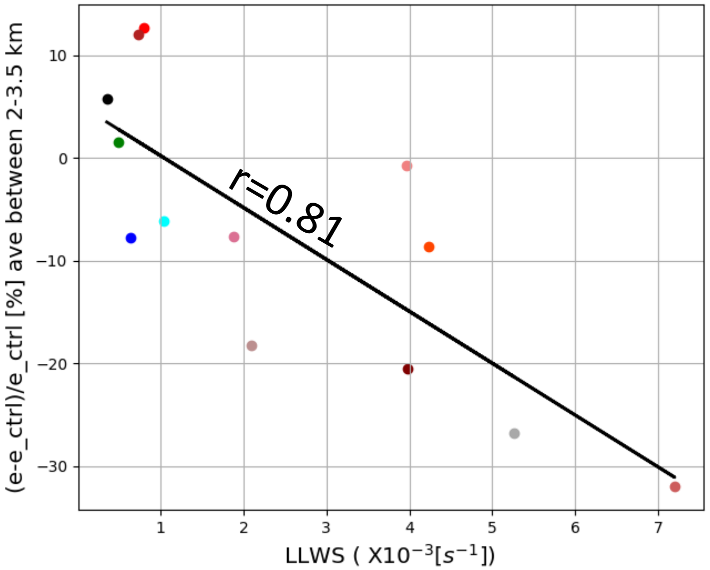


Next step:

Where: src/atmosphere/convection/comorph/plume_model/set_ent.F90

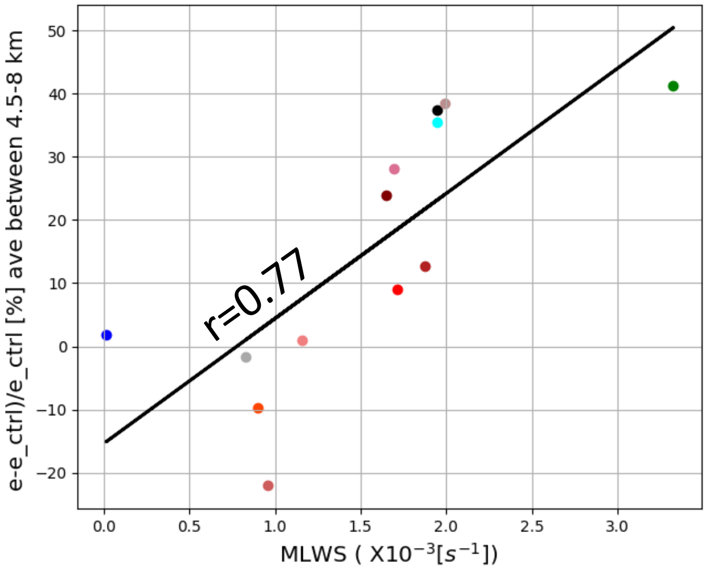
ent_mass_d(ic) = ent_coef / par_radius(ic)

How?

ent_mass_d(ic) =F × ent_coef / par_radius(ic)

with

$$F = \begin{cases} F_{ll} = 1 + [\Delta e/e_{ctrl}]_{ll} & for\ z < z_1 (= 3.5km) \\ F_{ml} = 1 + [\Delta e/e_{ctrl}]_{ll} & for\ z > z_2 (= 4.5km) \\ F_{ll} + \dfrac{(F_{ml} - F_{ll})(z - z_1)}{(z_2 - z_1)} & for\ z_1 < z < z_2 \end{cases}$$



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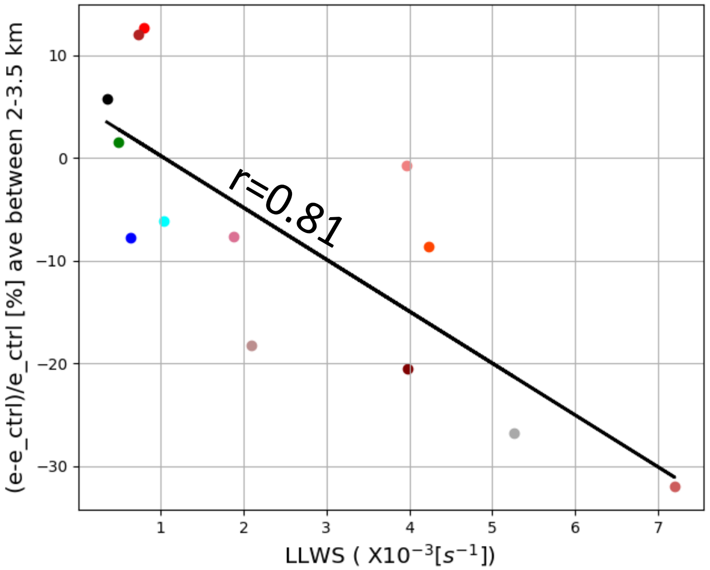

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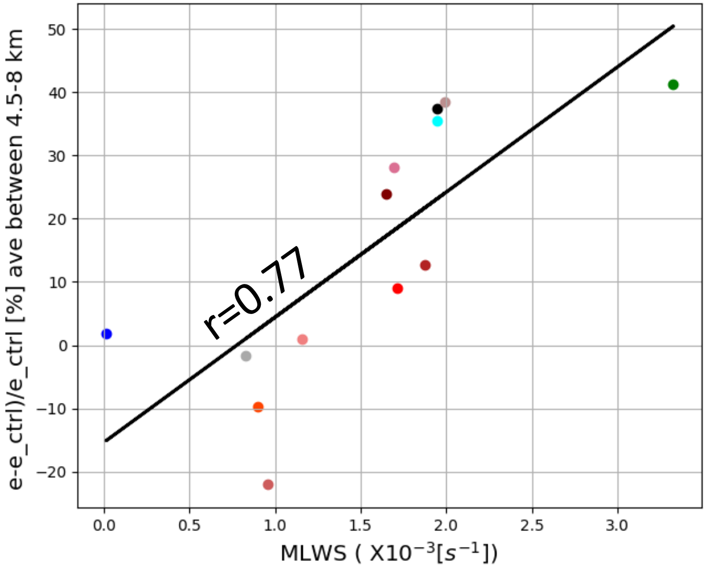
Note that $\boldsymbol{F_{ll} > 0}$ for $\boldsymbol{LLWS \leq 0.02\ s^{-1}}$



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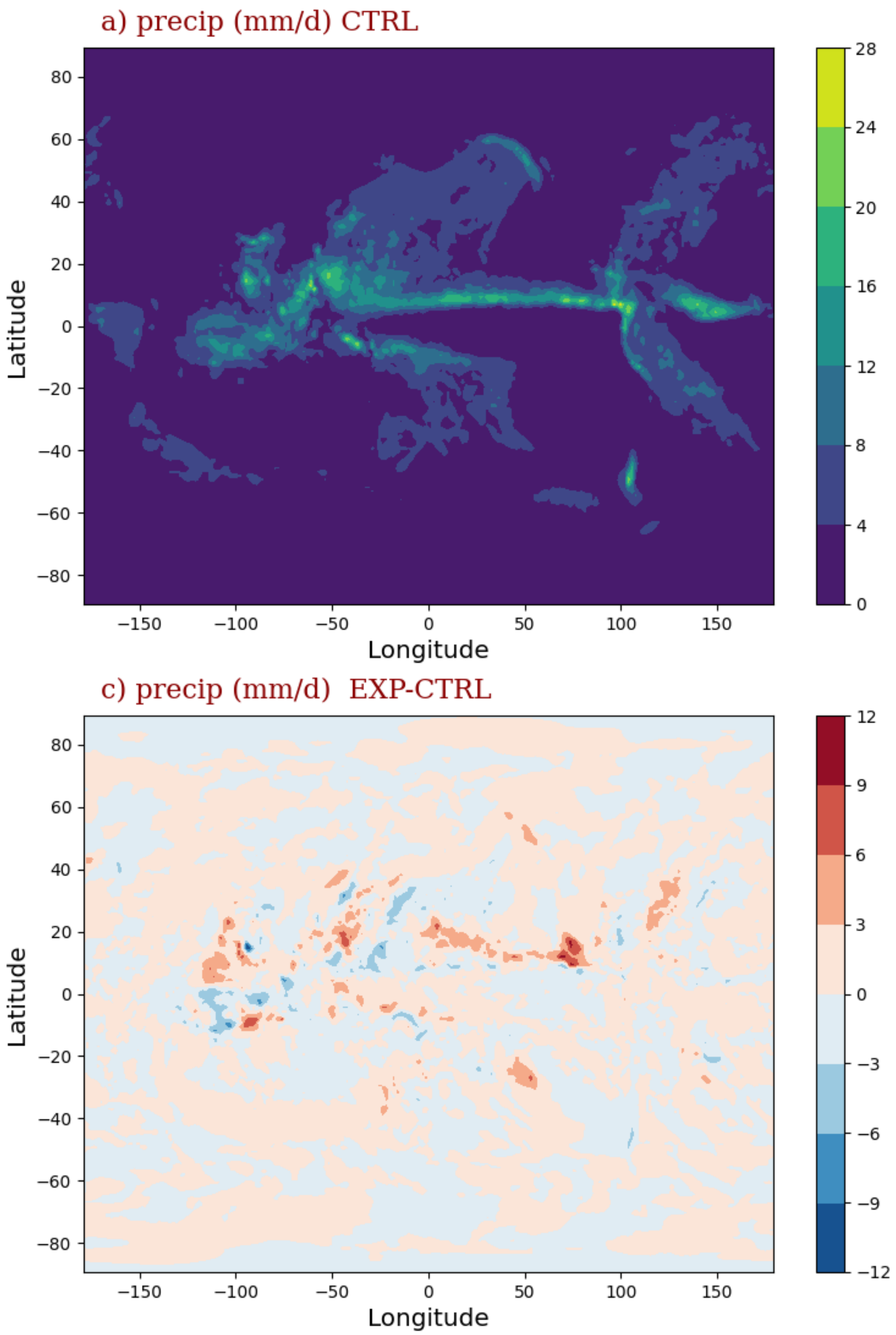
Let’s assess it impact in simulated climate

Control simulation
Using one of Adrian’s standard global tests (without coupled ocean):
MetUM11.8 with CoMorph
AMIP (20 years; N96)

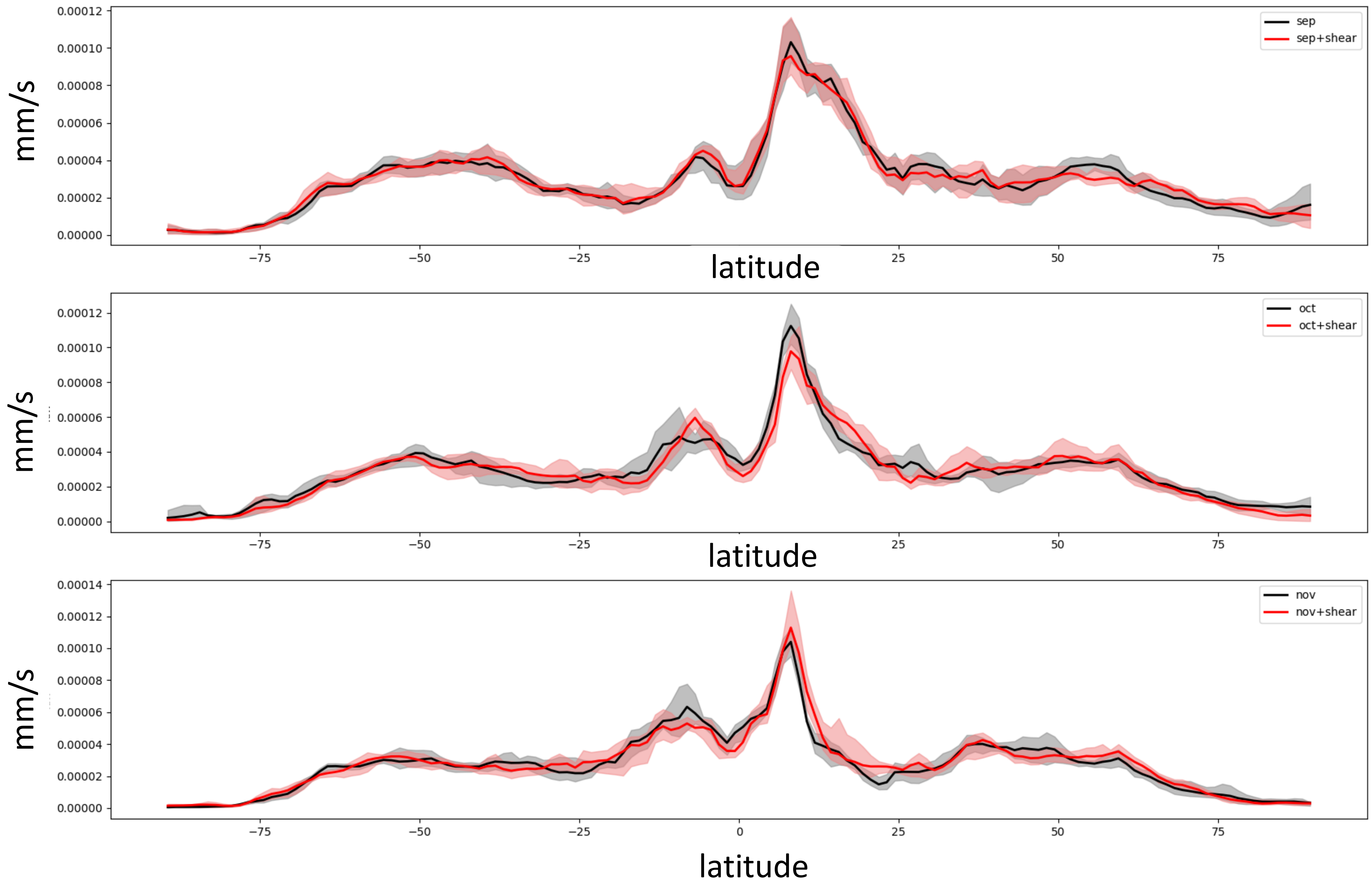
Experiment: repeating the simulation with shear-aware active

Let’s assess it impact in simulated climate



Let’s assess it impact in simulated climate

University of Reading



Summaries:

High-resolution RCE simulations driven by RWPs of various shears

evidence that shear is associated with changes in entrainment rate

LLWS reduce entrainment rate at low levels

MLWS increases entrainment rate at mid and upper levels

These results was used to modify CoMorph so that it can represent some aspects of shear-induced organization of convection

preliminary assessments reveal

we have effects on the model but

relatively small change on the global precipitation patterns

Limitations

1- shear-aware not active for $LLWS > 0.02\ s^{-1}$. **How to treat stronger LLWS?**

2-Shear aware is active **anywhere** (as long as LLWS and/or MLWS is different from 0)

target grid columns within which convection is more likely to be active

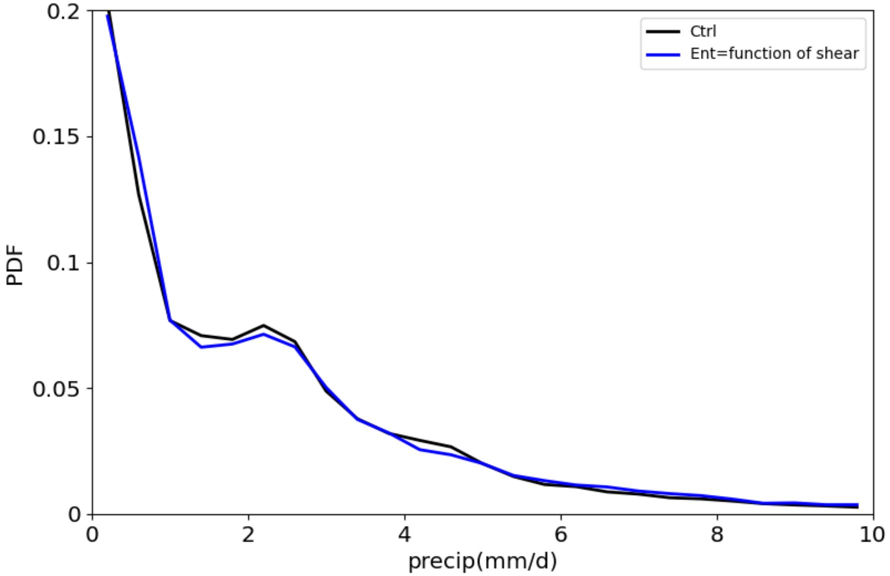
It is within those grid-column that changes to make CoMorph shear-aware will be active

next steps:

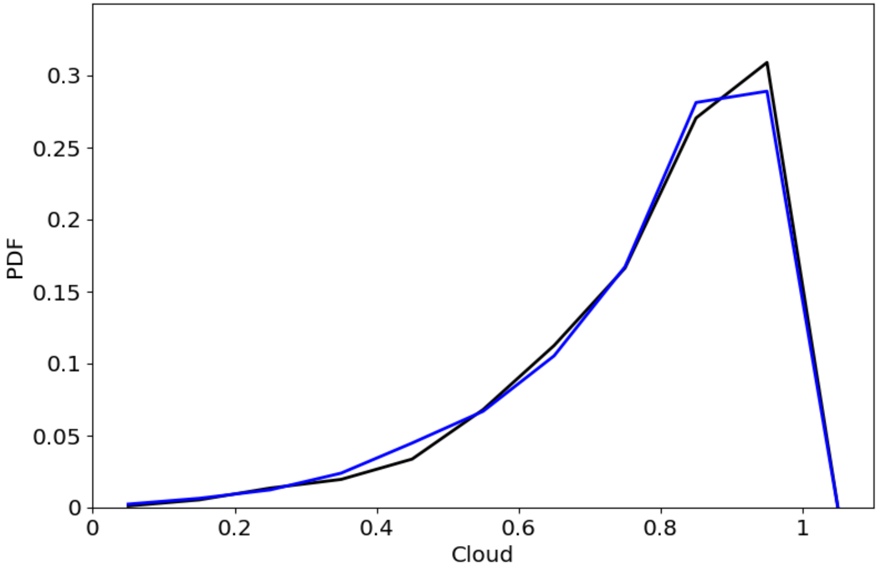
1- Investigate the change using different output e.g., **precipitation from convection** instead of total precipitation

3- Our design is very simple → how to improve (**please get in touch if you have idea**)

Effects of shear



PDF of precipitation for the control simulation and simulation with rescaled entrainment rate



PDF of cloud fraction for the control simulation and simulation with rescaled entrainment rate