The role of momentum mixing in shallow cloud organisation

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Background

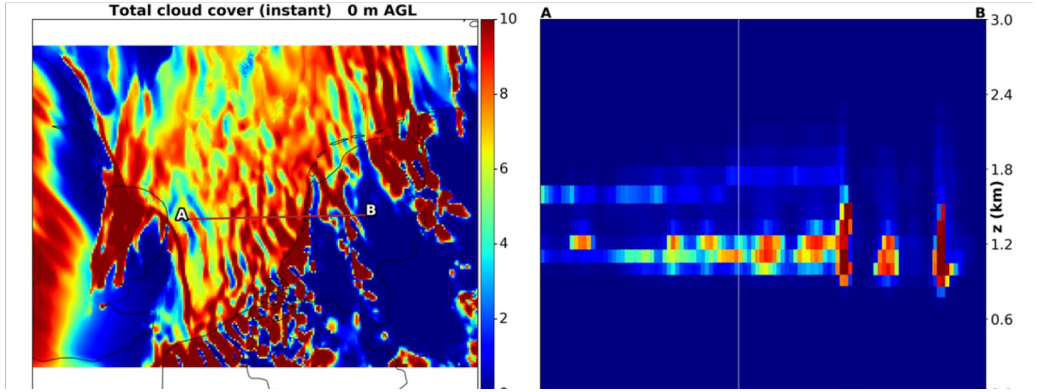
Experiments of a cold-air-outbreak **without convective momentum transport** (CMT) parameterisation show:

- a change of cloud structure **from close to open cells,**
- **increased precipitation.**

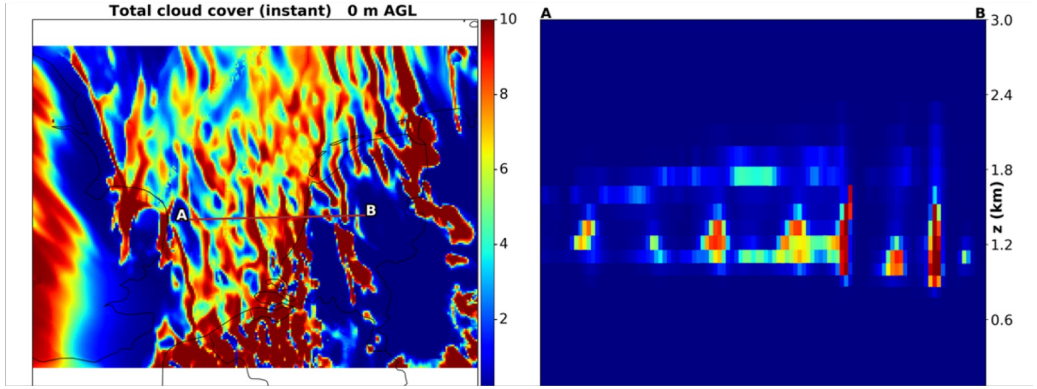
Hypothesis:

CMT acts to dampen circulations which may organize clouds into deeper more strongly precipitating cells.

With shallow CMT



Without shallow CMT



Figures courtesy: Wim de Rooy

Objectives

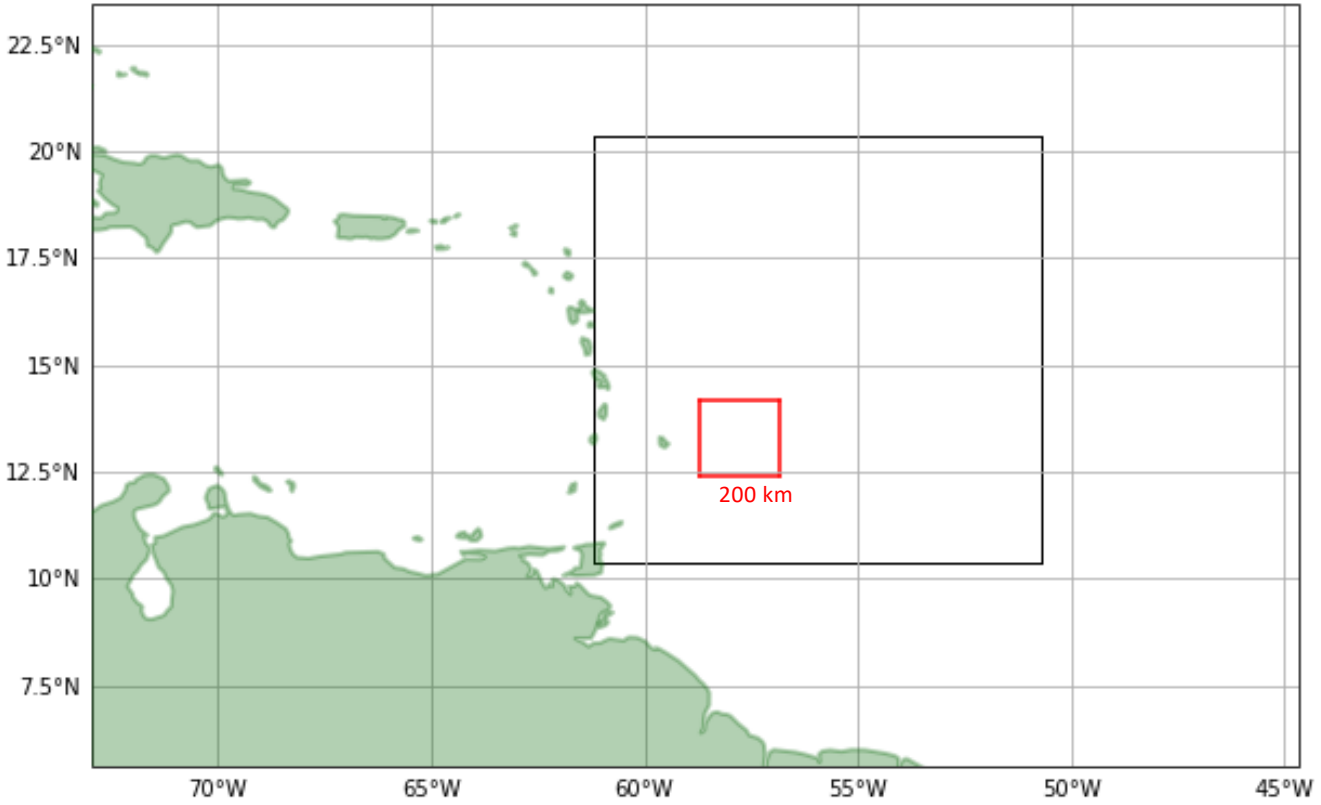
How does momentum transport by shallow convection influence shallow cloud organization?

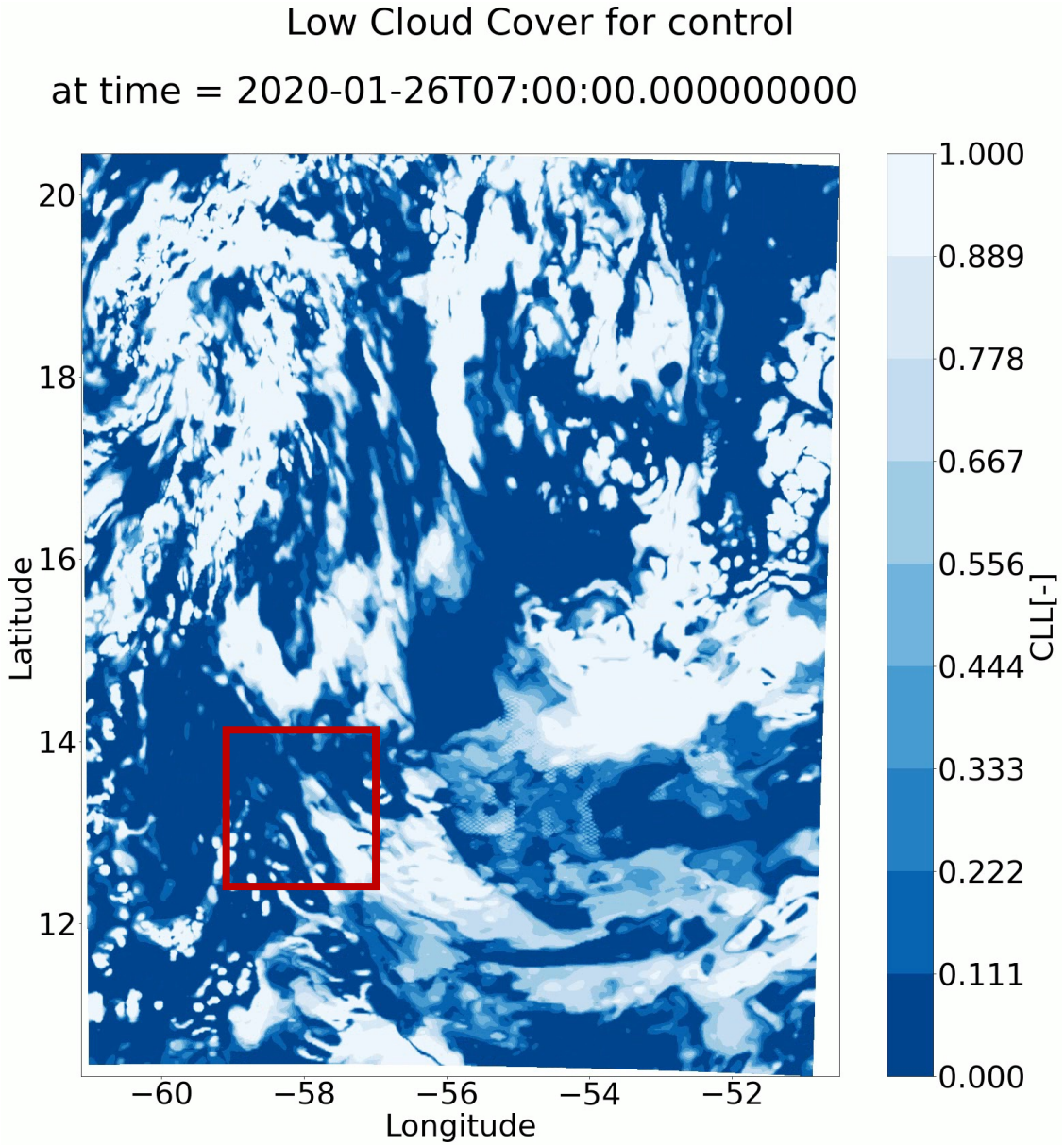
- How does it influence cloudiness and precipitation?
- How does it influence the circulations coupled to clouds?

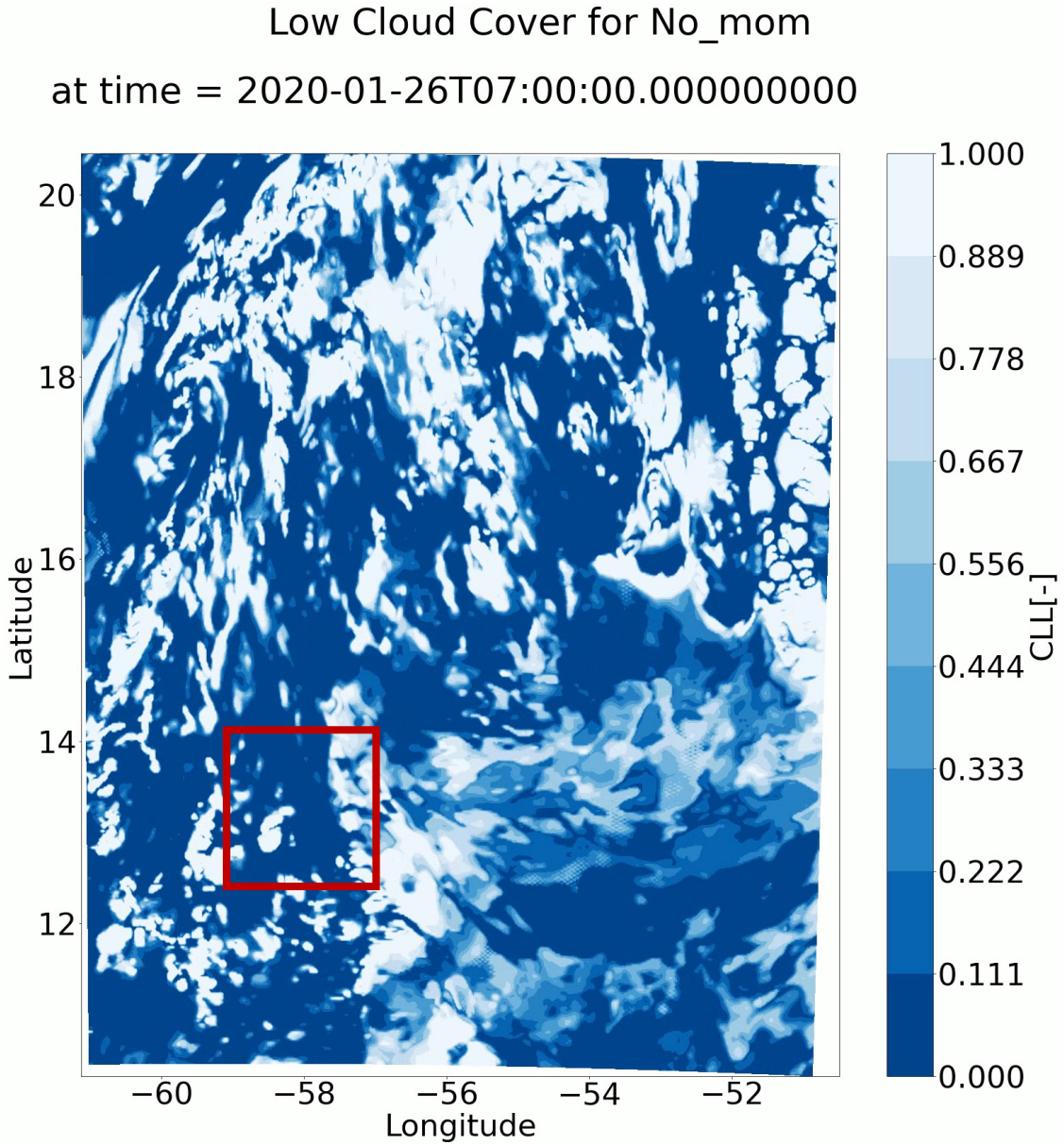
HARMONIE-AROME

- REGIONAL MODEL
  - Δx = 2.5 km.
  - Domain of 2025 x 3200 km^2 .
  - Analysis on 200 x 200 km^2 .
  - Climate runs.

- Two experiments:
  - Control.
  - UVmixOFF.




Low Cloud Cover for control
at time = 2020-01-26T07:00:00.000000000
Latitude
Longitude
CLL[-]
20
18
16
14
12
−60
−58
−56
−54
−52
1.000
0.889
0.778
0.667
0.556
0.444
0.333
0.222
0.111
0.000

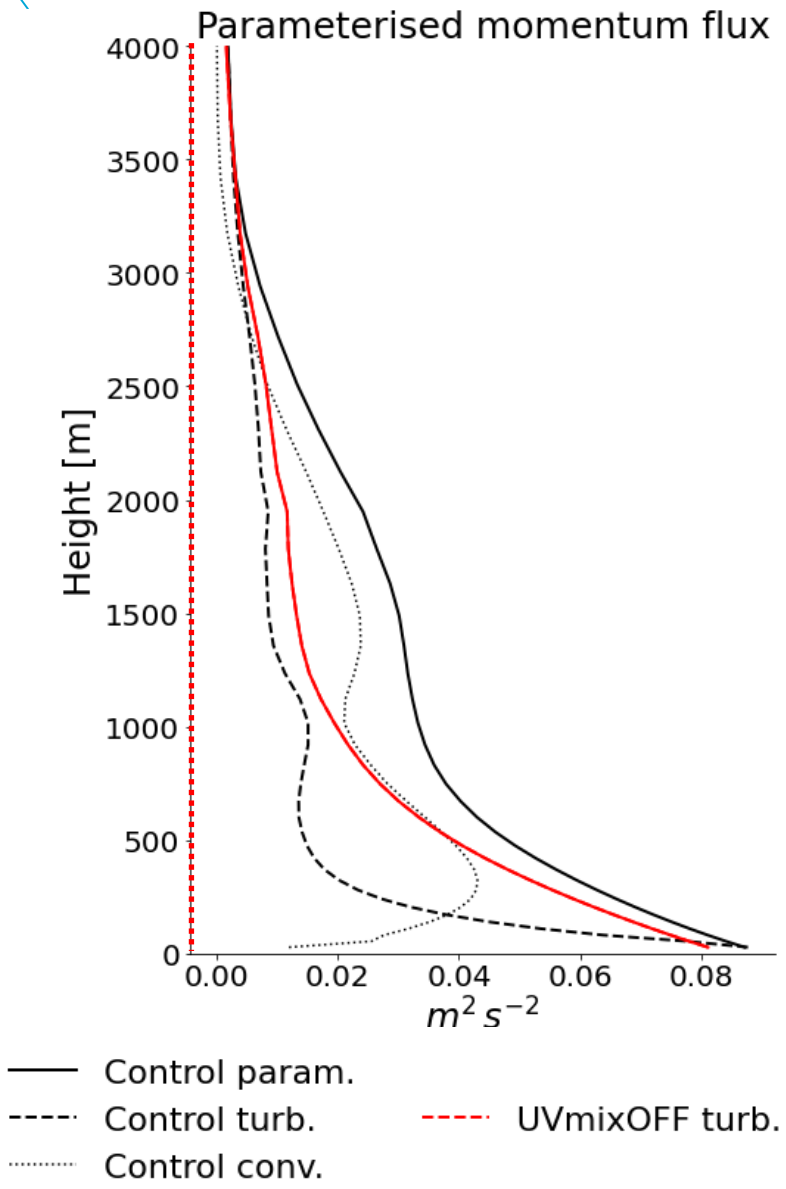

Low Cloud Cover for No_mom
at time = 2020-01-26T07:00:00.000000000
Latitude
Longitude
CLL[-]
20
18
16
14
12
−60
−58
−56
−54
−52
1.000
0.889
0.778
0.667
0.556
0.444
0.333
0.222
0.111
0.000

Model response to a missing flux

The parameterised momentum flux

Removing convective momentum mix leads to:

- Increased turbulence mixing.
- Reduced total parameterised flux.



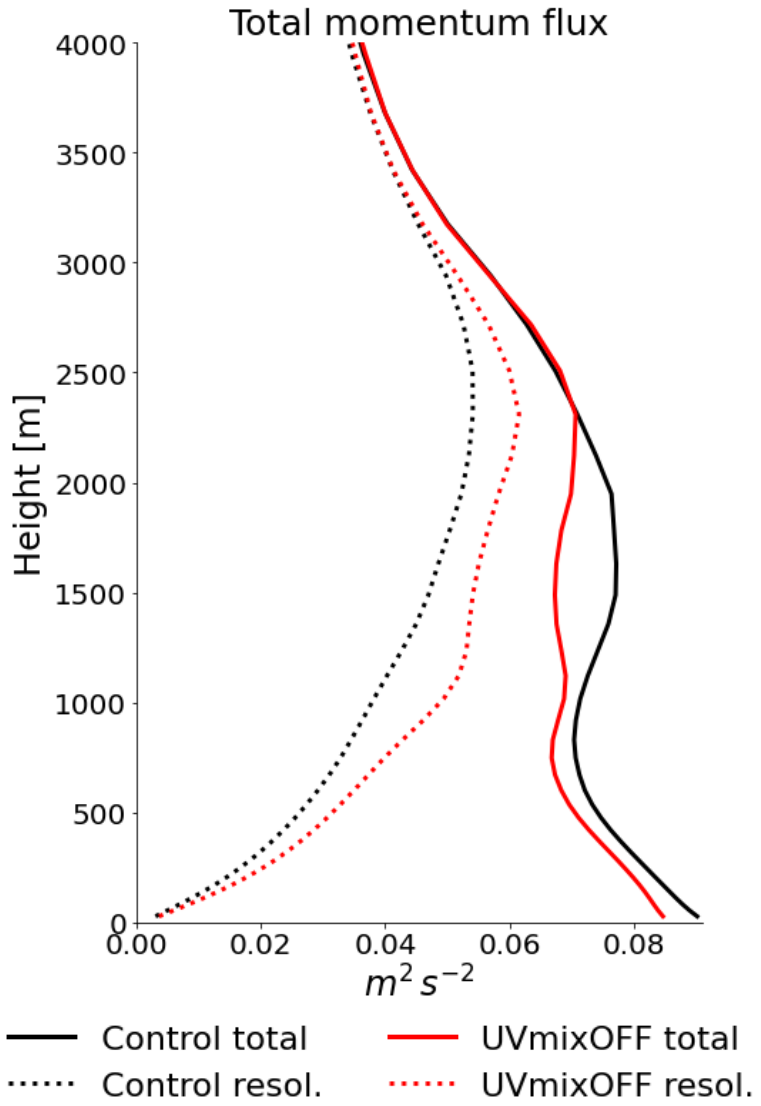
Model response to a missing flux

The resolved momentum flux

Removing convective momentum mix leads to:

- Increased resolved fluxes (dynamics), suggesting a change in resolved circulations.
- Overall reduced total momentum transport.

Turbulence and dynamics partly compensate for the lack of parameterised convective momentum transport (CMT).



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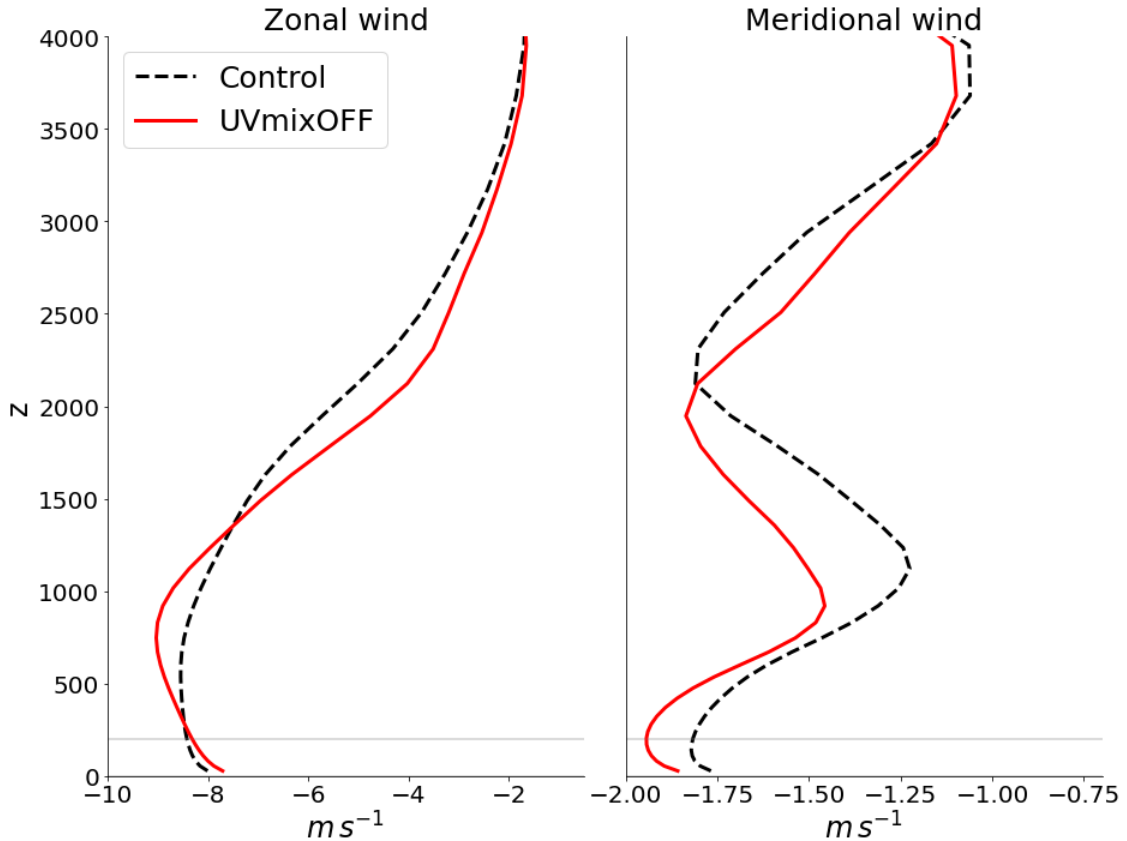
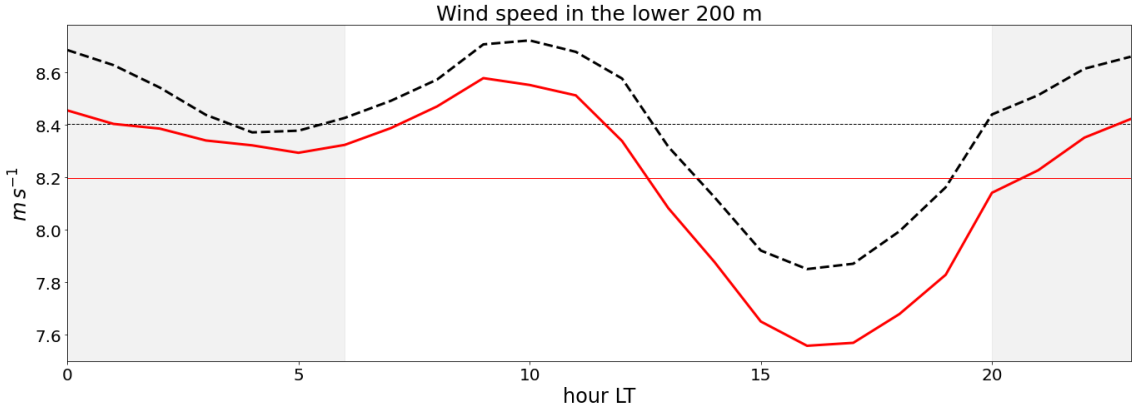
Shallow convection alters the winds

Without shallow momentum mixing:

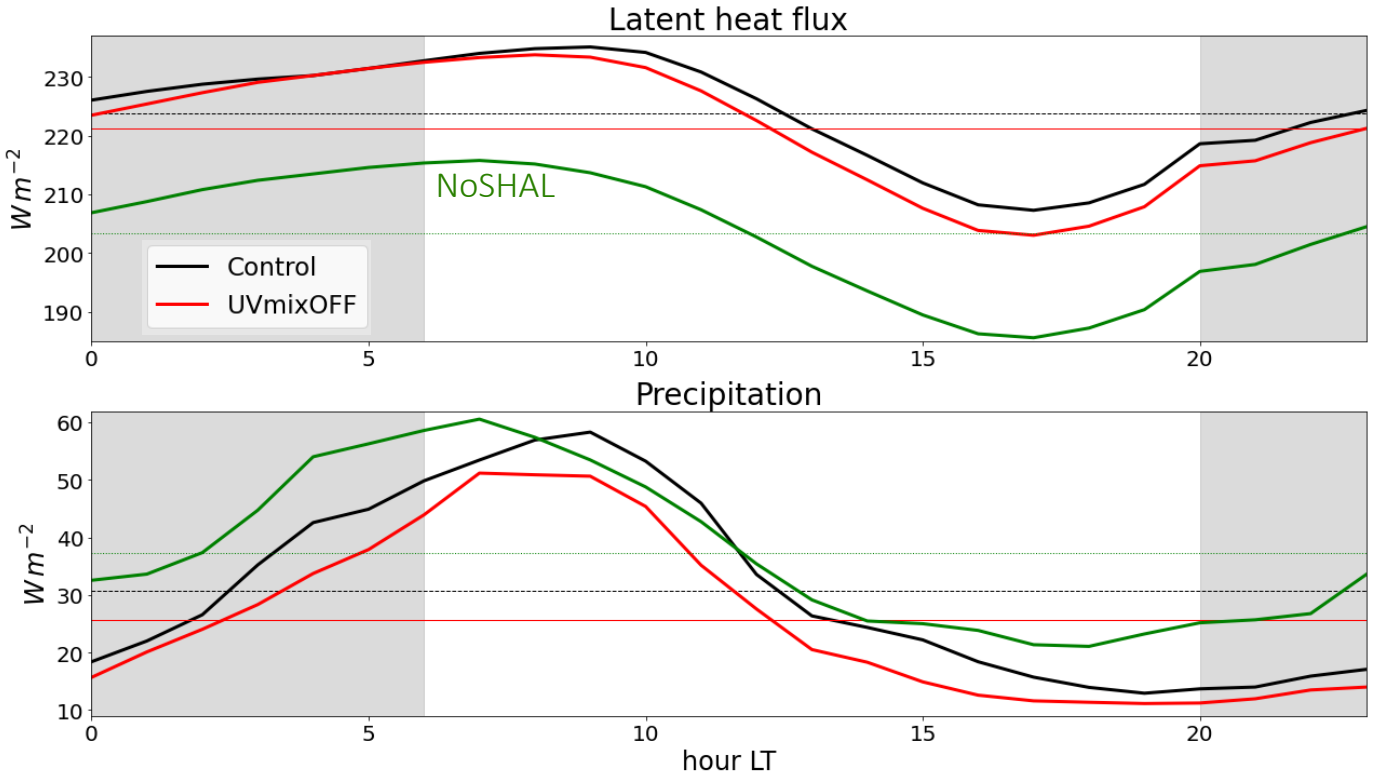
- Stronger zonal wind jet and zonal wind shear.
- Increased wind turning.
- Weaker surface winds.





Surface winds affect surface fluxes

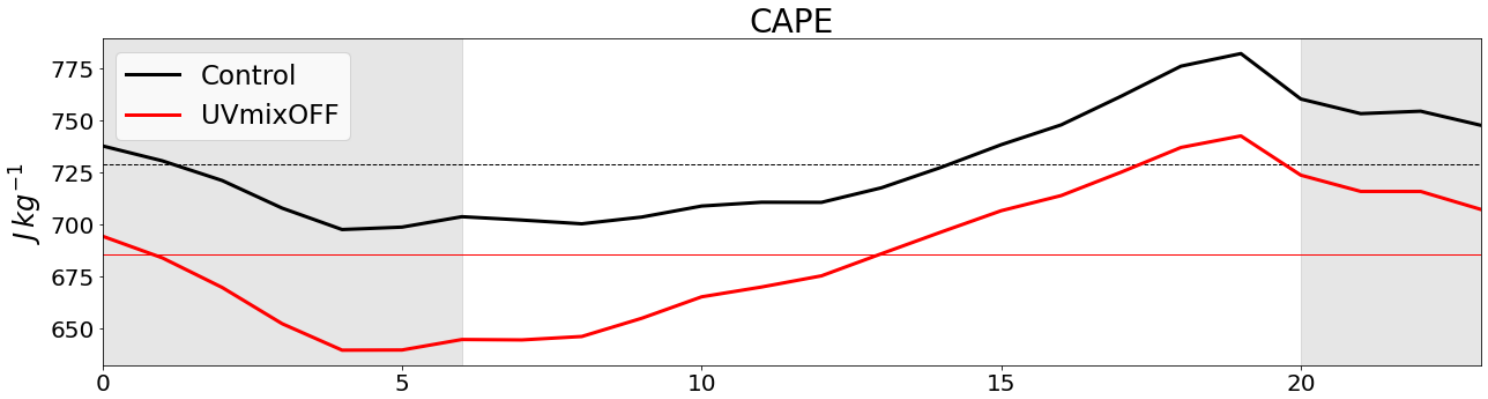
- Less evaporation, could imply less precipitation.
- The strength of convection and circulations can also control precipitation.



A less favourable thermodynamic environment

Hypothesis:

Parameterised momentum mixing by shallow convection acts to dampen circulations.

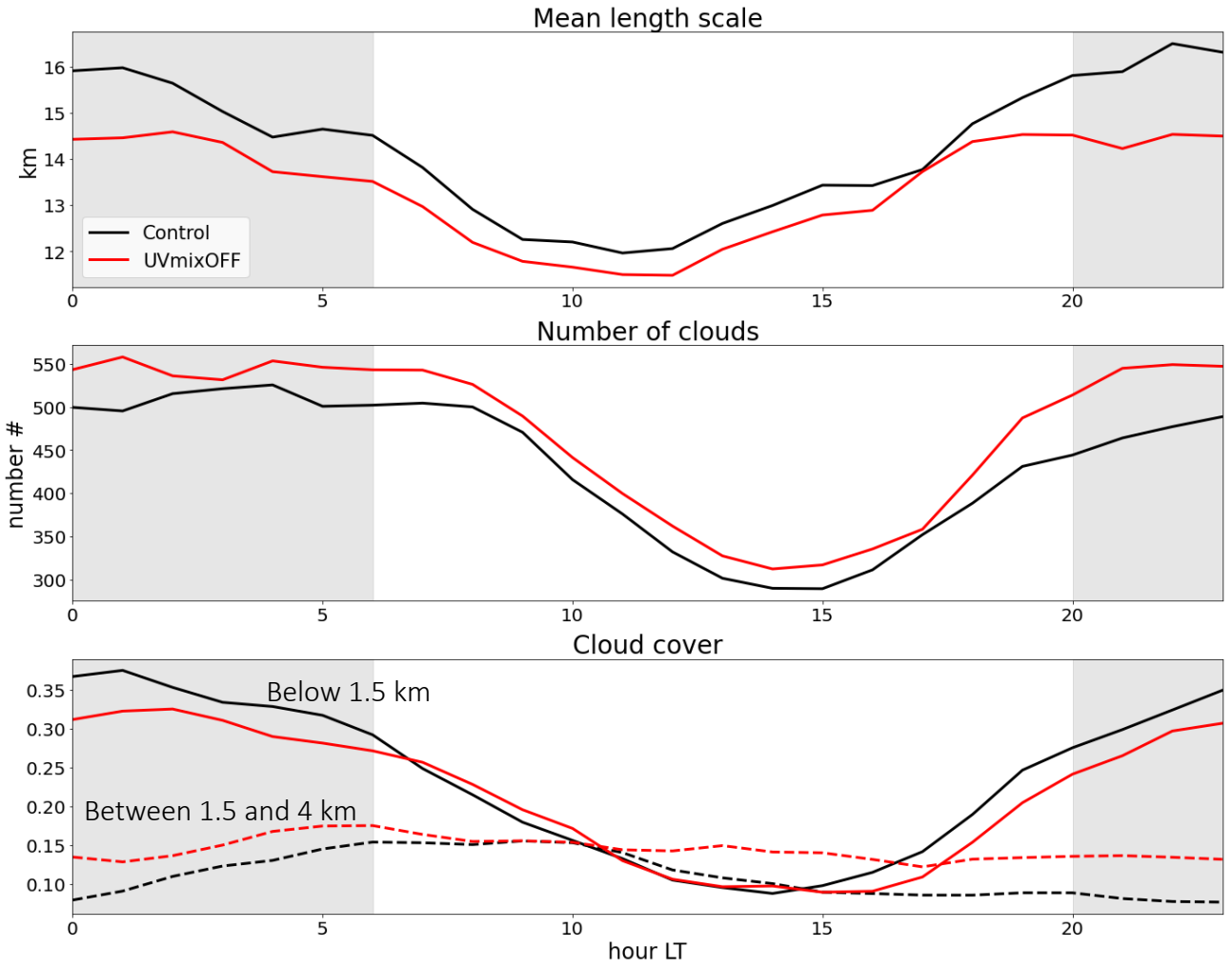


The effect on clouds – Projected fields

Without mom. mixing clouds are:

- Smaller,
- More numerous,
- Top-heavy: with more anvils.

At night, the low cloud cover is reduced but aloft, non-overlapping clouds compensate.



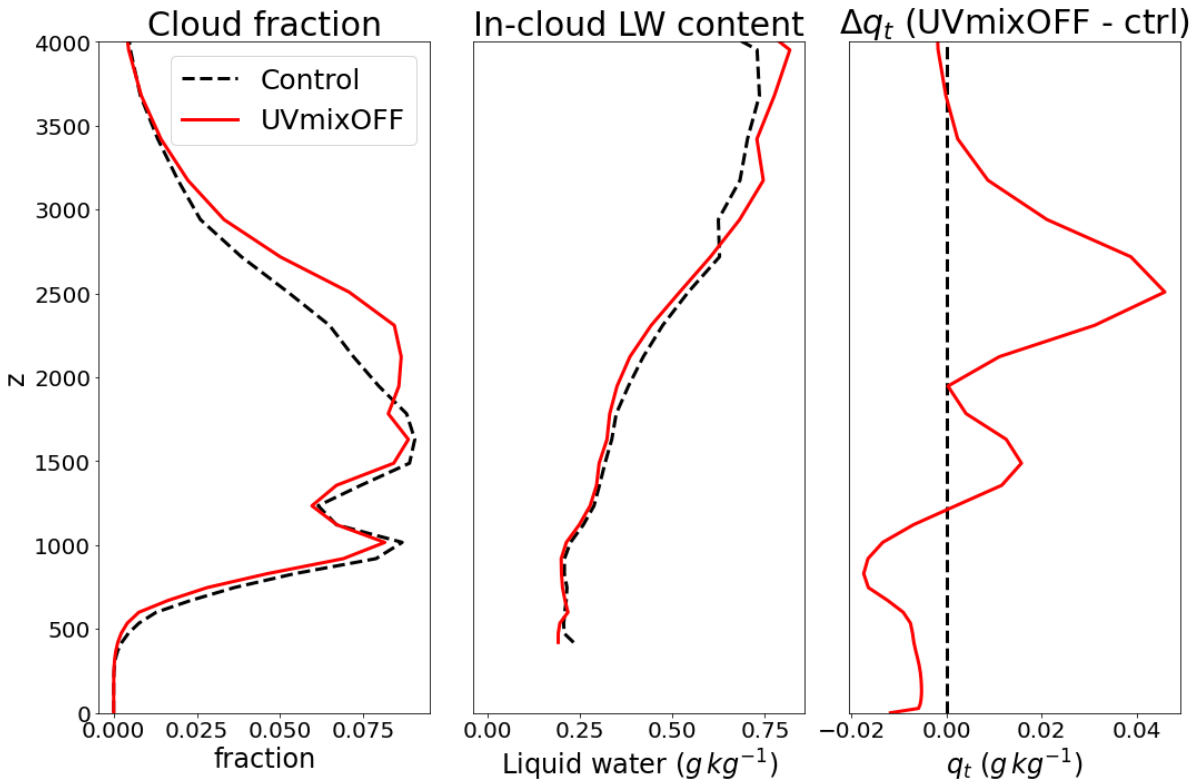
The effect on clouds – Mean profiles

Without momentum mix:

- Cloud fraction reduces slightly below 2 km but increases between 2 - 3 km.
- In-cloud liquid water content is similar.
- Clouds transport more moisture to the upper cloud layer.
- The mixed layer is drier.

More and smaller clouds which detrain **more** at the top.

Deeper or with more anvils?

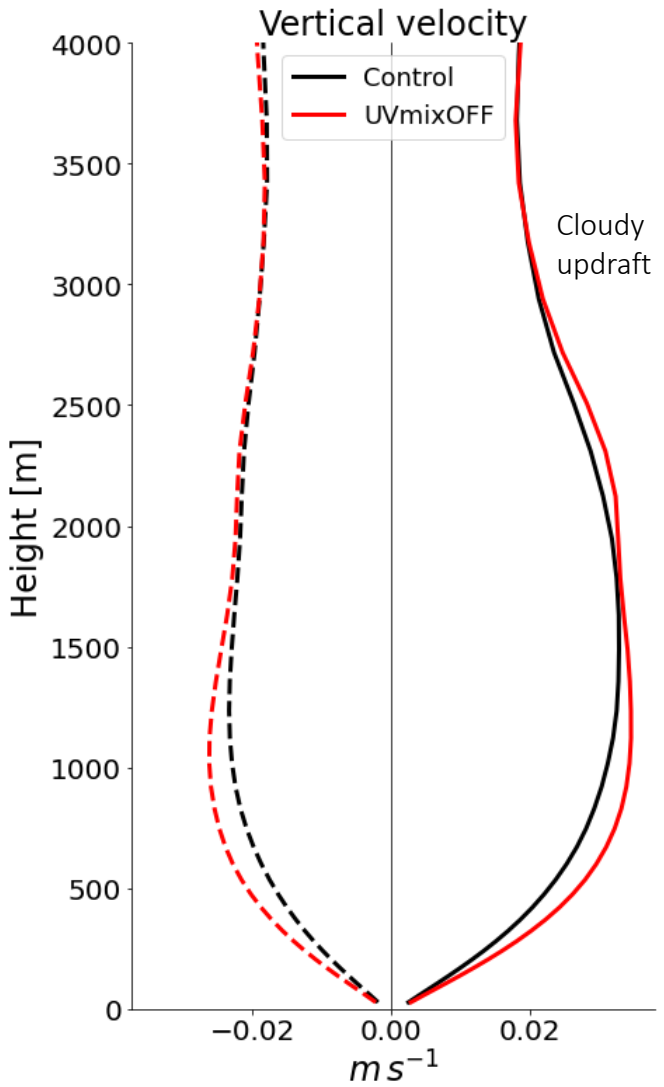


More vigorous updrafts

Without momentum mix:

- Stronger cloudy updrafts.
- Stronger subsidence.

Suggesting stronger circulations.



What is the effect on circulations?

Hypothesis:

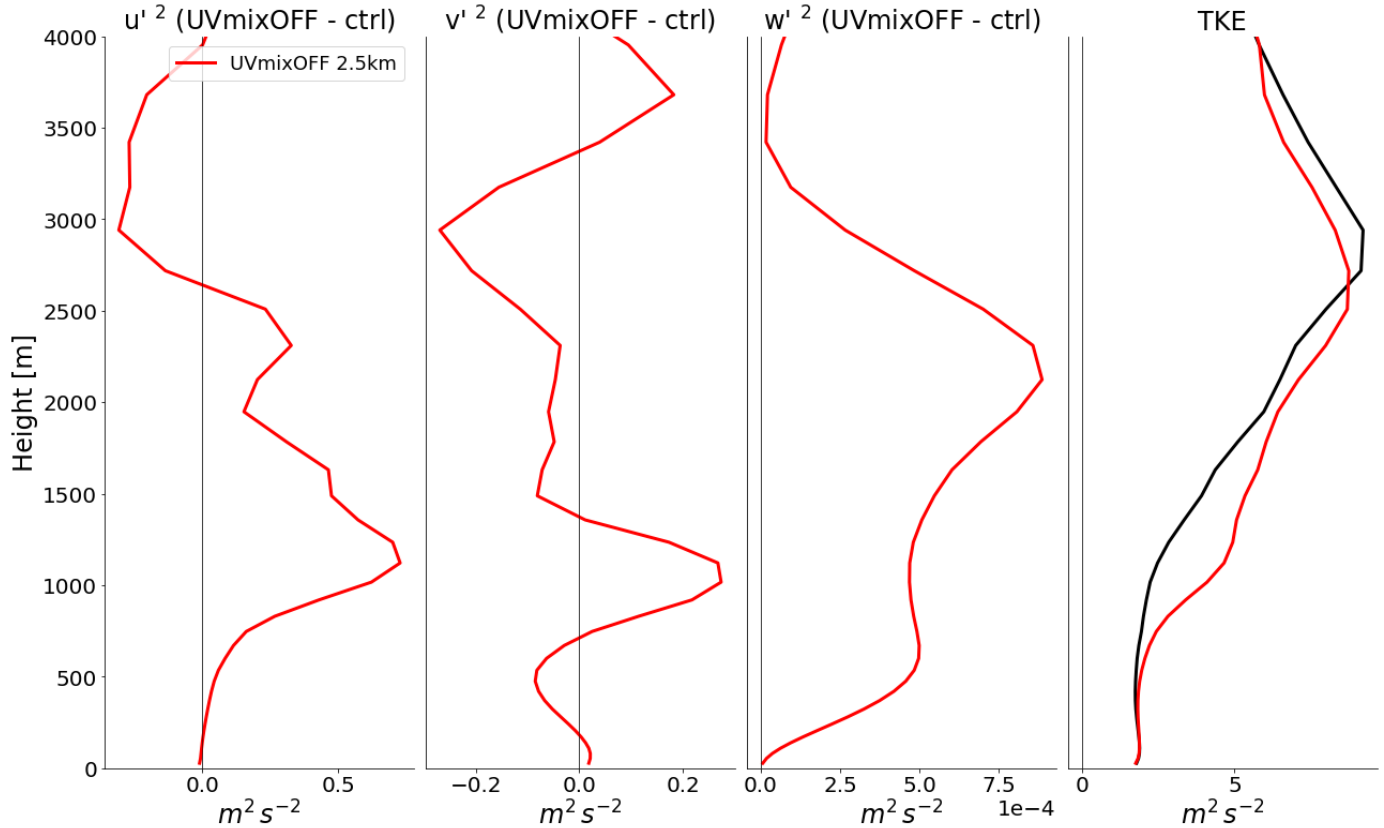
Parameterised momentum mixing by shallow convection acts to dampen circulations.

We assume mesoscale circulations to increase wind variances.

More vigorous circulations?

Without momentum mix:

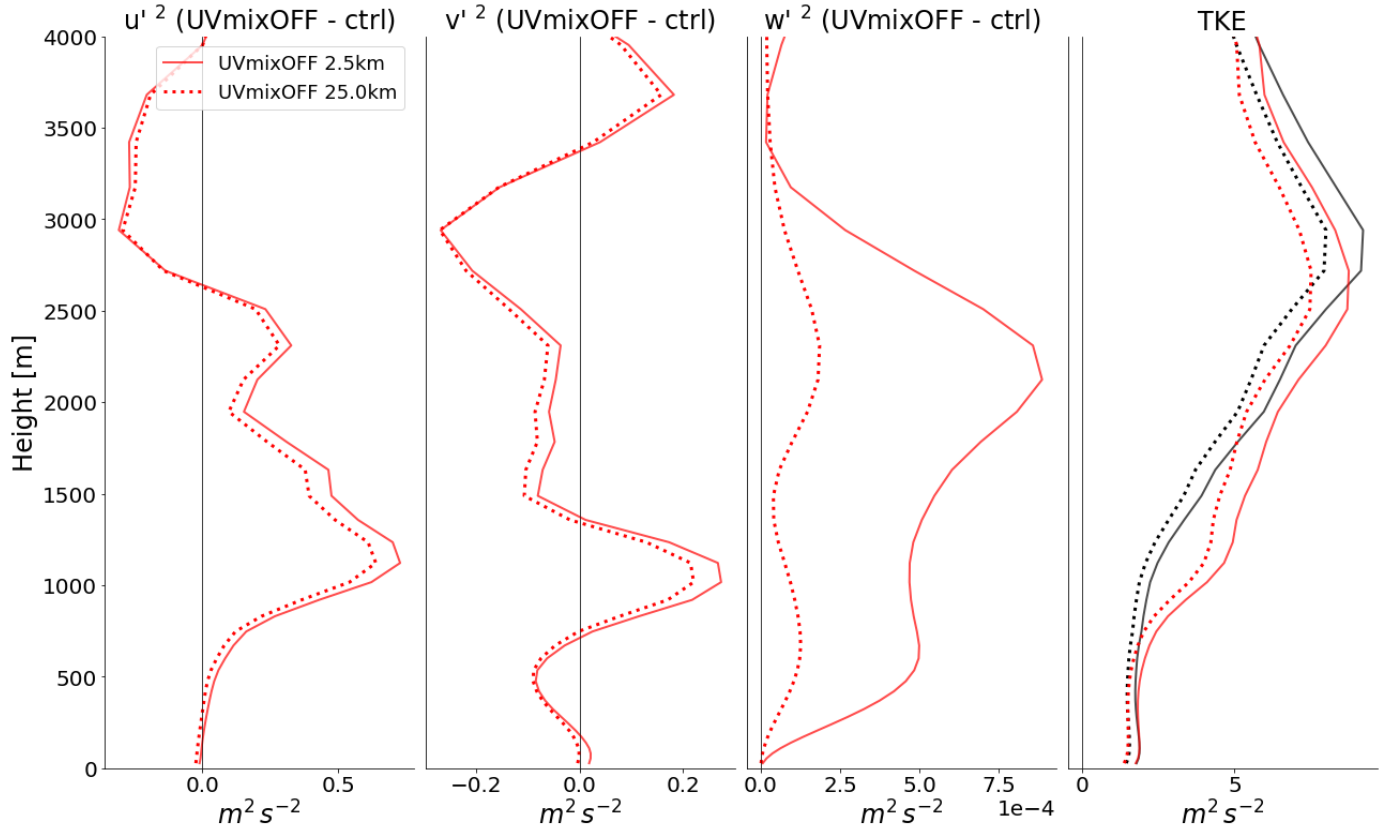
- Larger wind variances in the cloud layer.
- Larger resolved TKE (dominated by the variance in zonal wind).



The mesoscales are more active

Most horizontal wind variance is carried by scales larger than 25 km.

Thus, removing shallow convective mom. mix affects circulations in the meso-β scales.



Conclusions

Even in a thermodynamically less favourable environment, promoting mesoscale circulations is possible.

Removing parameterised shallow CMT leads to:

- **Increased wind variances** on scales beyond 25km, suggesting stronger mesoscale circulations.
- **More and smaller clouds** with stronger updrafts which detrain more at the top.
- **Reduced precipitation**, explained by weaker surface evaporation.

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