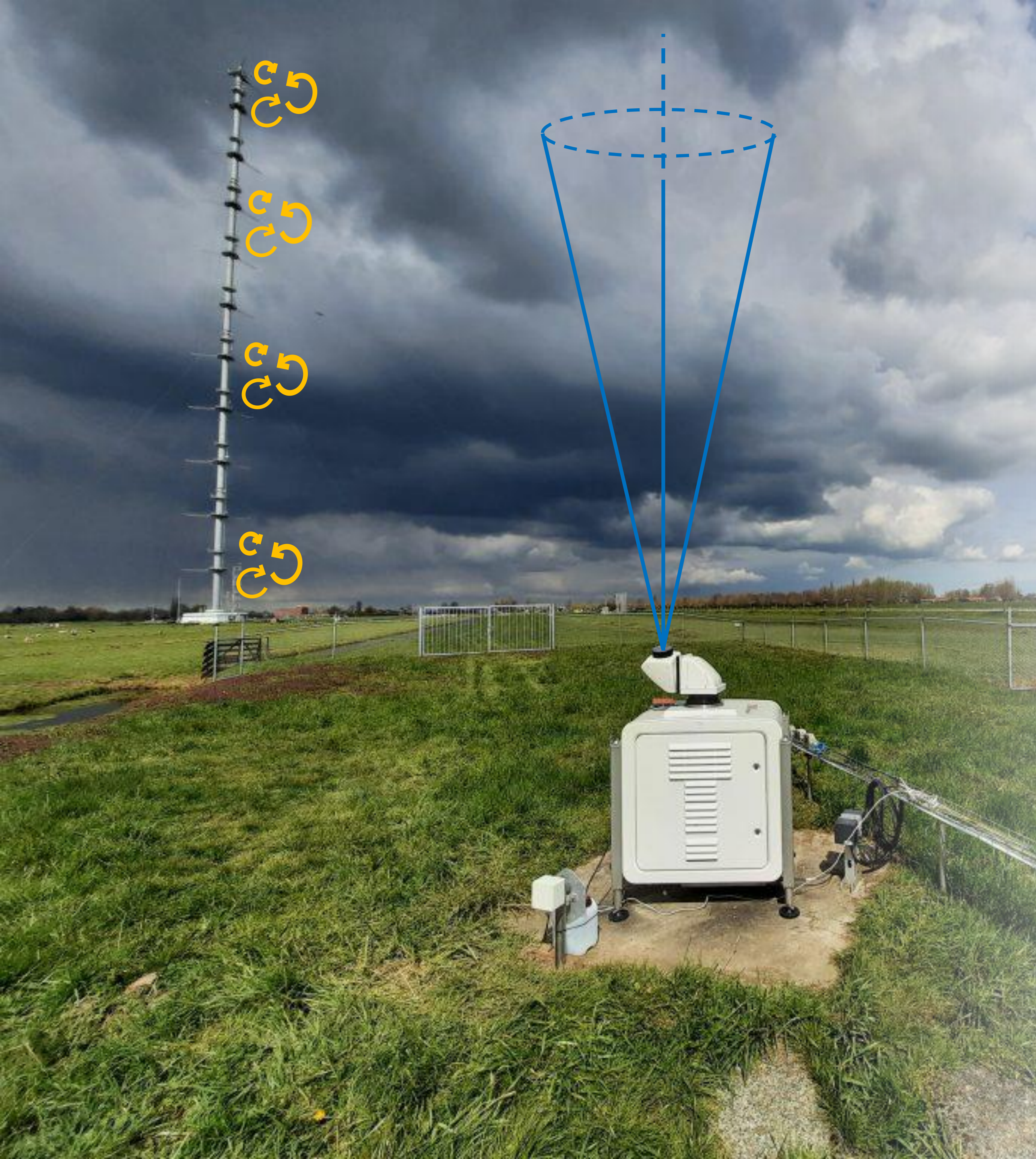

The role of eddy momentum flux on clouds and circulations

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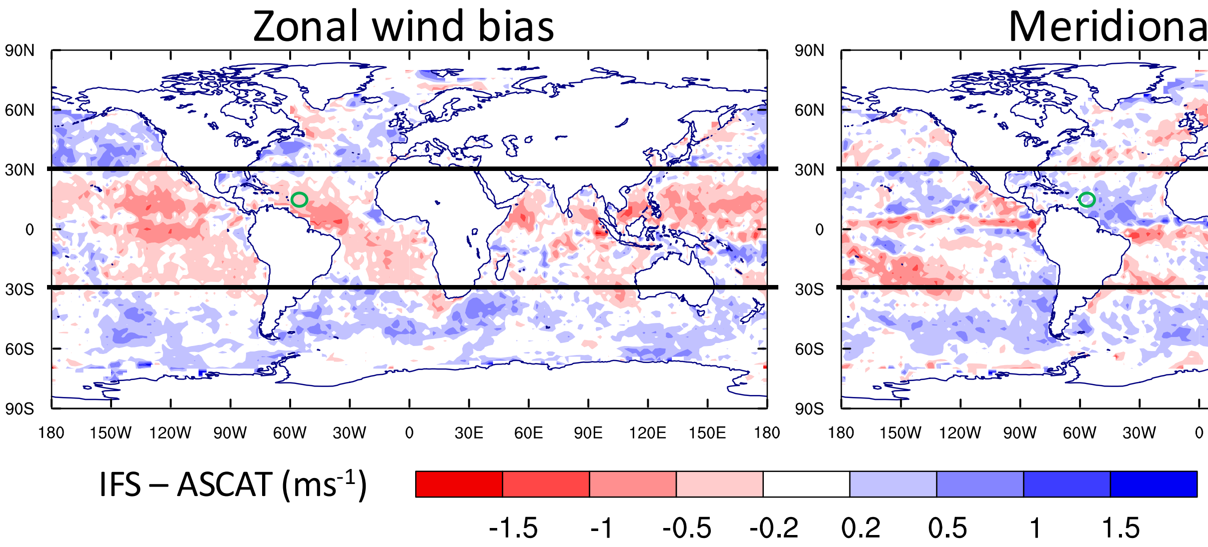
Reading 10-09-2024

ECMWF TUDelft NWO Netherlands Organisation for Scientific Research

- A wind bias exists in the lower troposphere, rooted in errors in:
  1. The large-scale circulation (bias reduces from cy47r2 to cy47r3)
  2. Parameterizations of momentum transport in the BL and SC schemes.

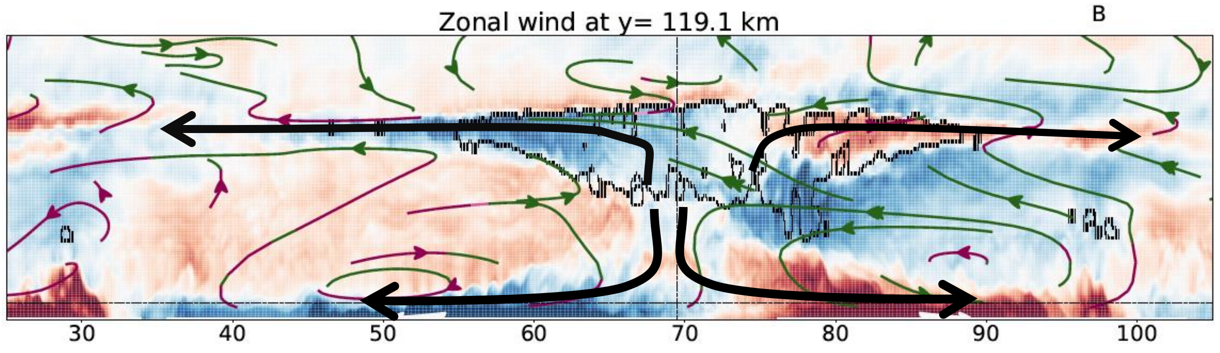
2. Parameterizations:
- Neglect cloud-circulation coupling and mesoscale heterogeneity,
- Are designed for grid spacing of ~50 km, raising issues in the grey zone.



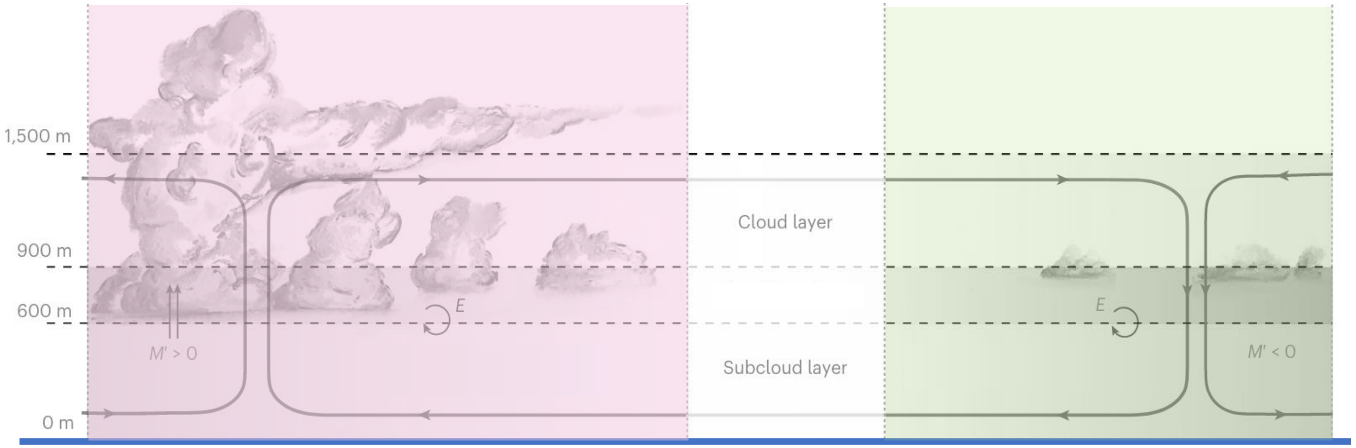
(Sandu et al. 2020)

Evidences of mesoscale circulations

- EUREC4A reviled the existence of shallow mesoscale circulations and provided tools to understand their dynamics.



- What is the role of mesoscale heterogeneity on the fluxes and cloudiness?
- How should models account for these circulations?

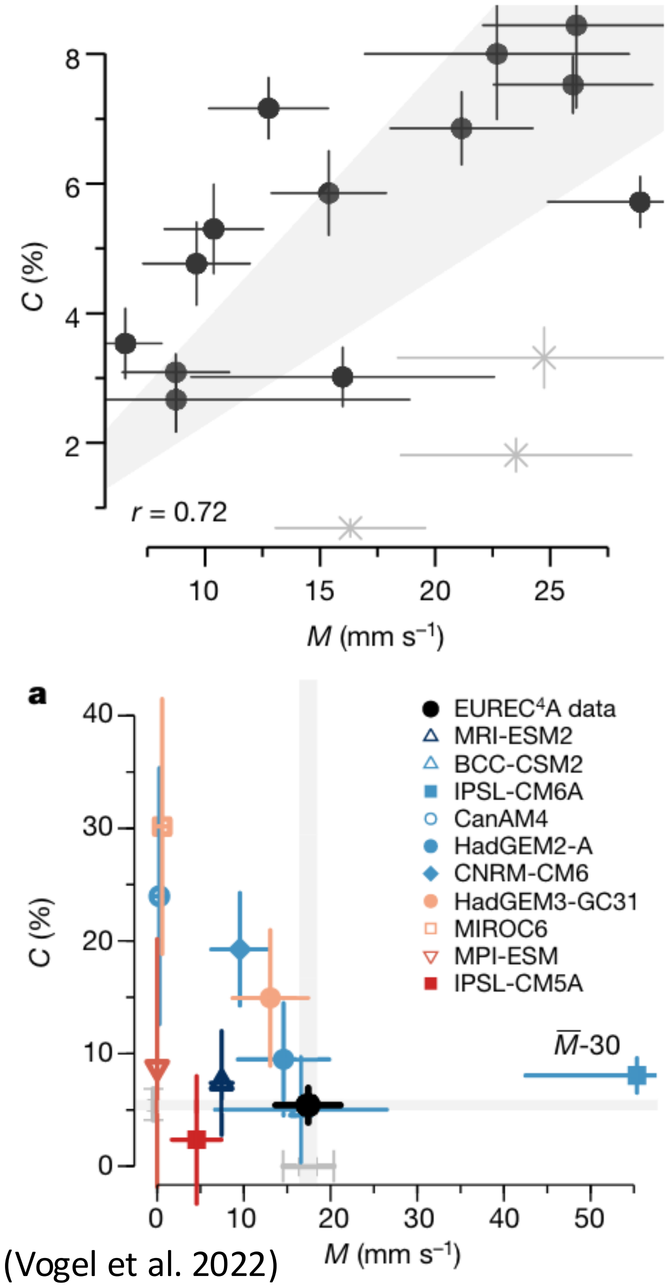


$D_{sc} > 0$ (George et al. 2023) $D_{sc} < 0$

Mesoscale circulations help control cloudiness

- Mesoscale circulations are not resolved in IFS and their effect is not accounted for in the parameterisations.

- Models underestimate the strong cloud–circulation coupling.



(Vogel et al. 2022)

The grey zone and the importance of having the right flux at the right scale

- Honnert et al. (2011) suggested a function to describe the scaling of resolved and subgrid fluxes.

- Based on simple LES cases they found that km-scale models resolve too much flux without a mass-flux contribution, but too little when mass-flux is active.

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How does momentum mixing by shallow convection influence the circulations coupled to clouds?

Process-oriented diagnostics to evaluate models in complex cloudy atmospheres, being mindful of scales, from turbulence to circulations.

Novel datasets – combining observations and models

1. **HARMONIE** – Regional model
   - The impact of SC parameterisation,
   - Statistics of the cloud field.

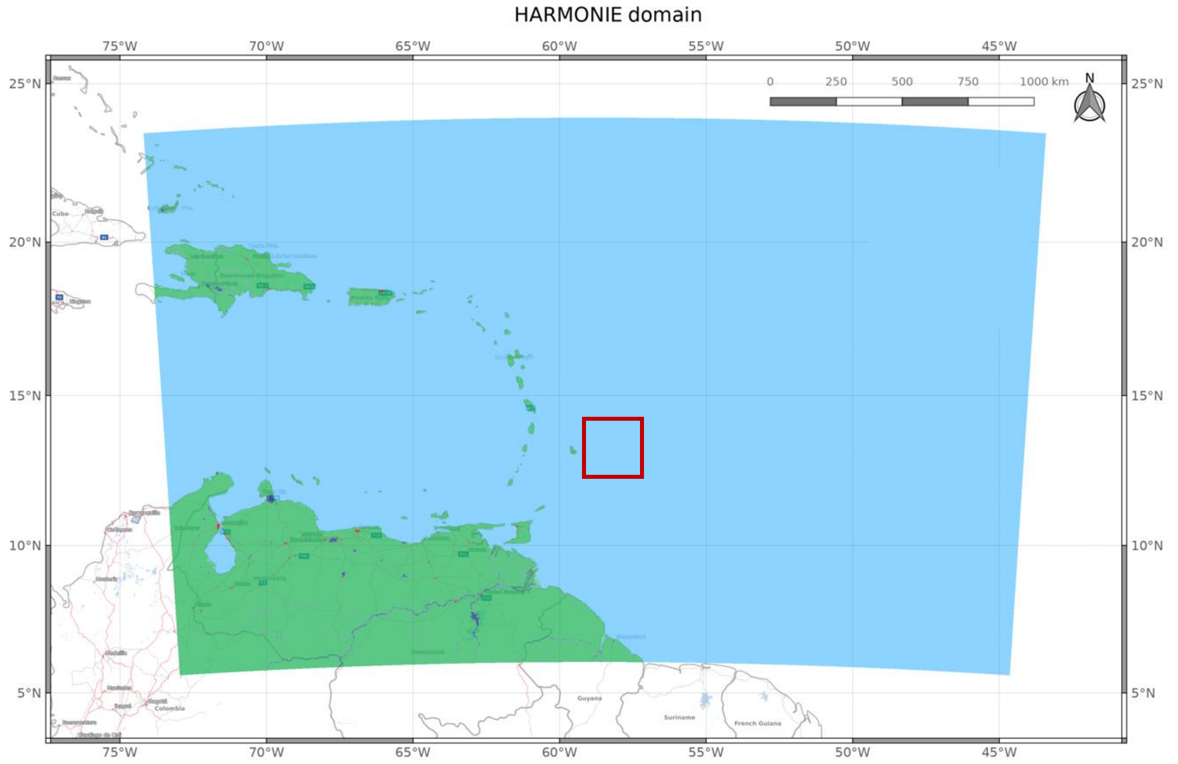
2. **DALES** - Large eddy simulations
   - The grey zone of momentum transport,
   - Flux partition into scales.

3. **CMTRACE** - Collocated lidar and radar retrievals
   - Evaluation of the unresolved momentum flux in IFS,
   - Variability and magnitude of the profiles.

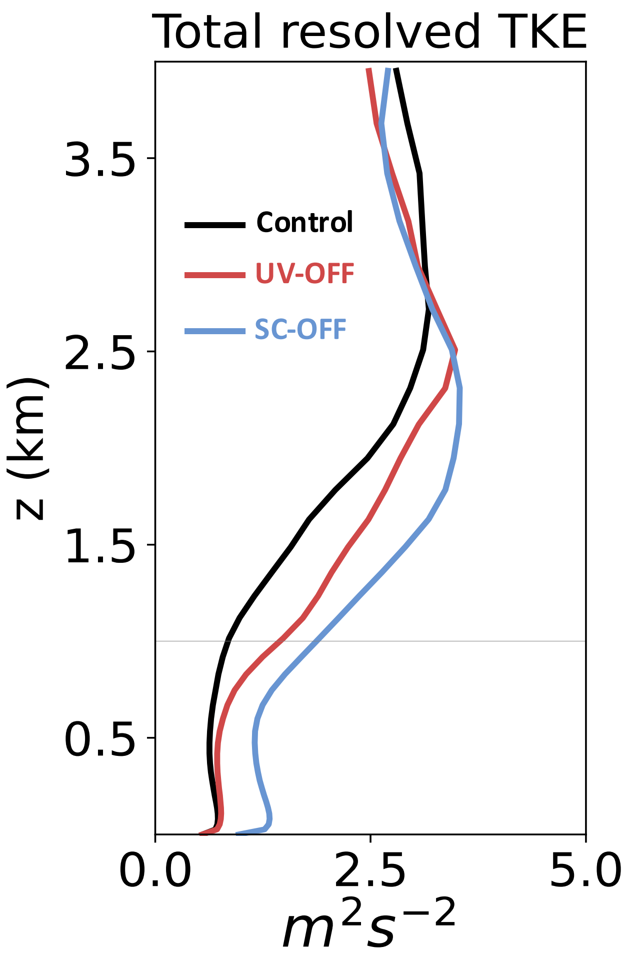
Trade wind region – EUREC4A January and February 2020

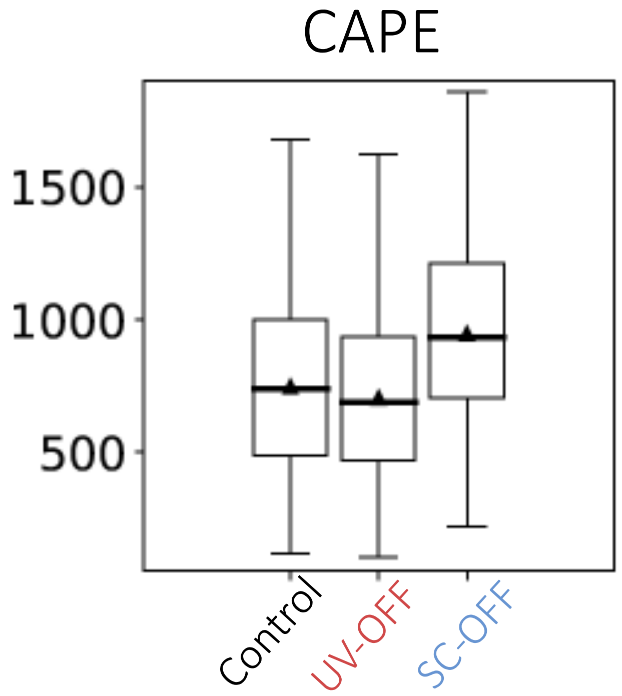
- **REGIONAL MODEL - HARMONIE**
  - Δx = 2.5 km.
  - Domain of 2025 x 3200 km^2 .
  - Analysis on 200 x 200 km^2 .
  - Climate runs.

- Three experiments:
  - **Control.**
  - **UV-OFF**
  - **SC-OFF.**



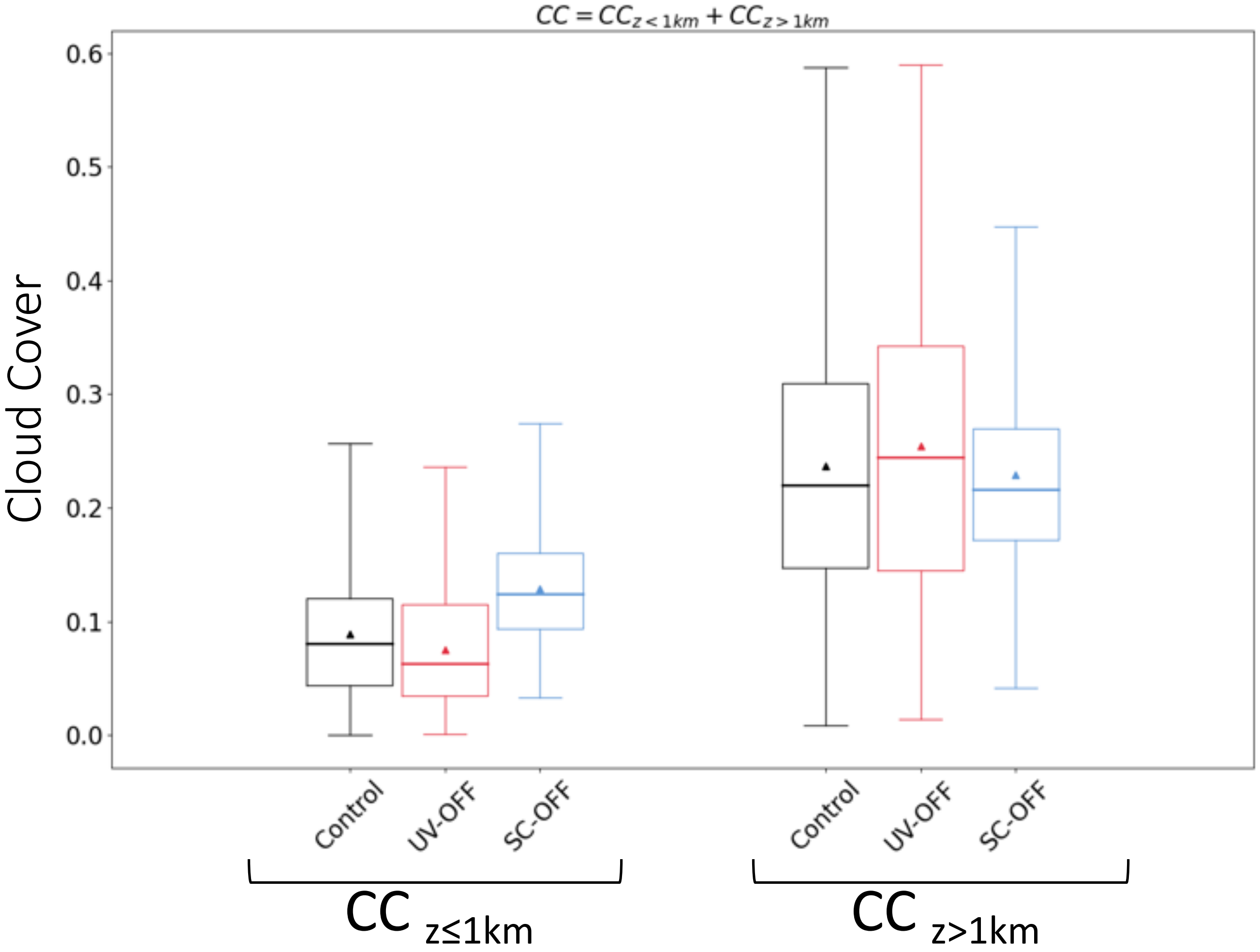
Without SCP the resolved convection takes over

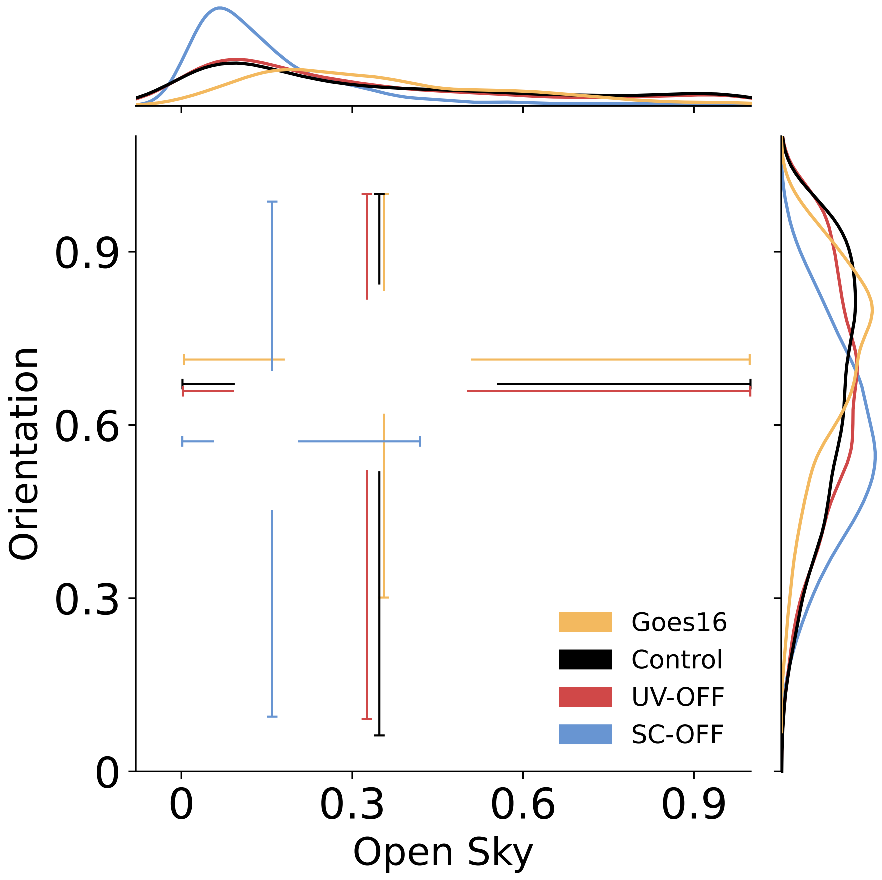




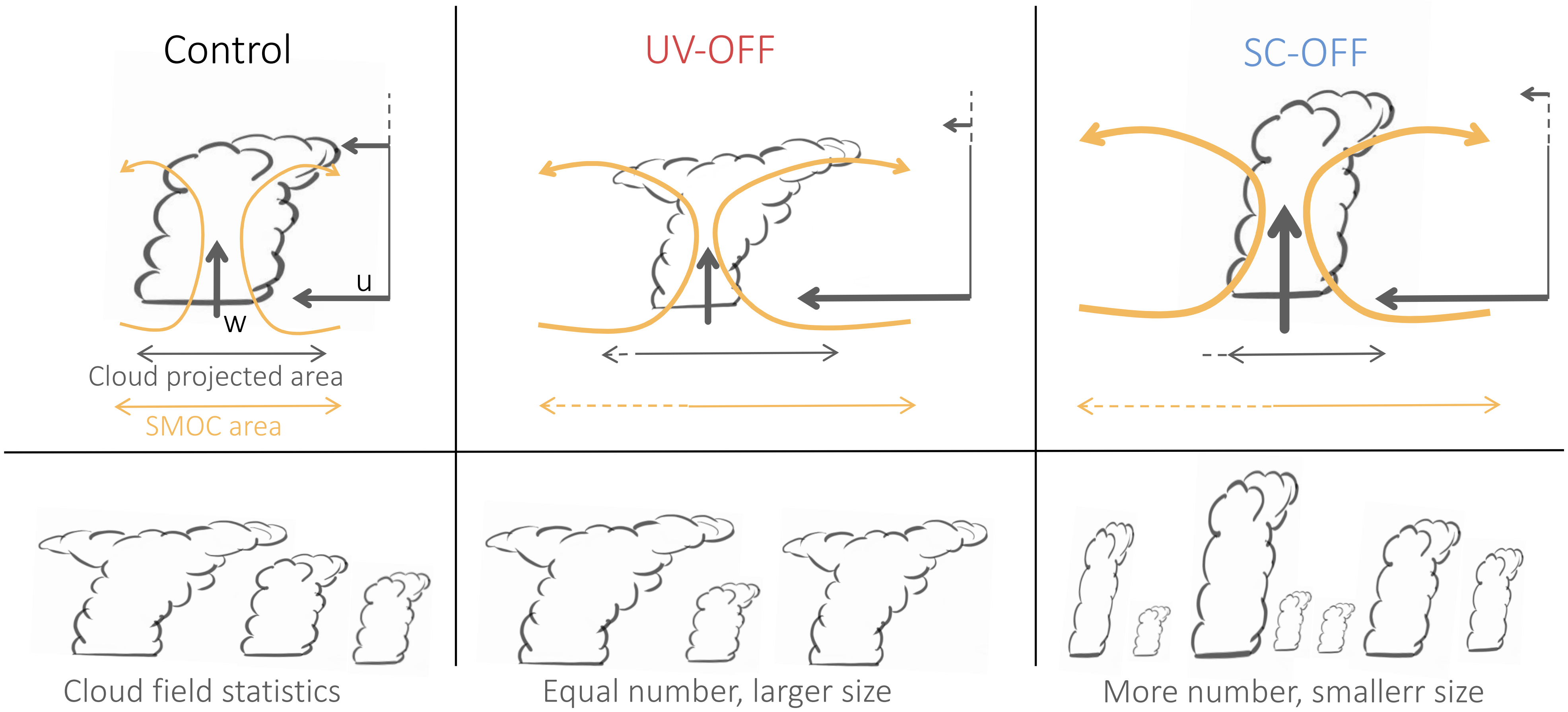
- Stronger shear and resolved momentum fluxes **increase resolved TKE**
- **CAPE builds up and** resolved convection **bursts** with large vertical velocity.

Without SCP the cloud field changes



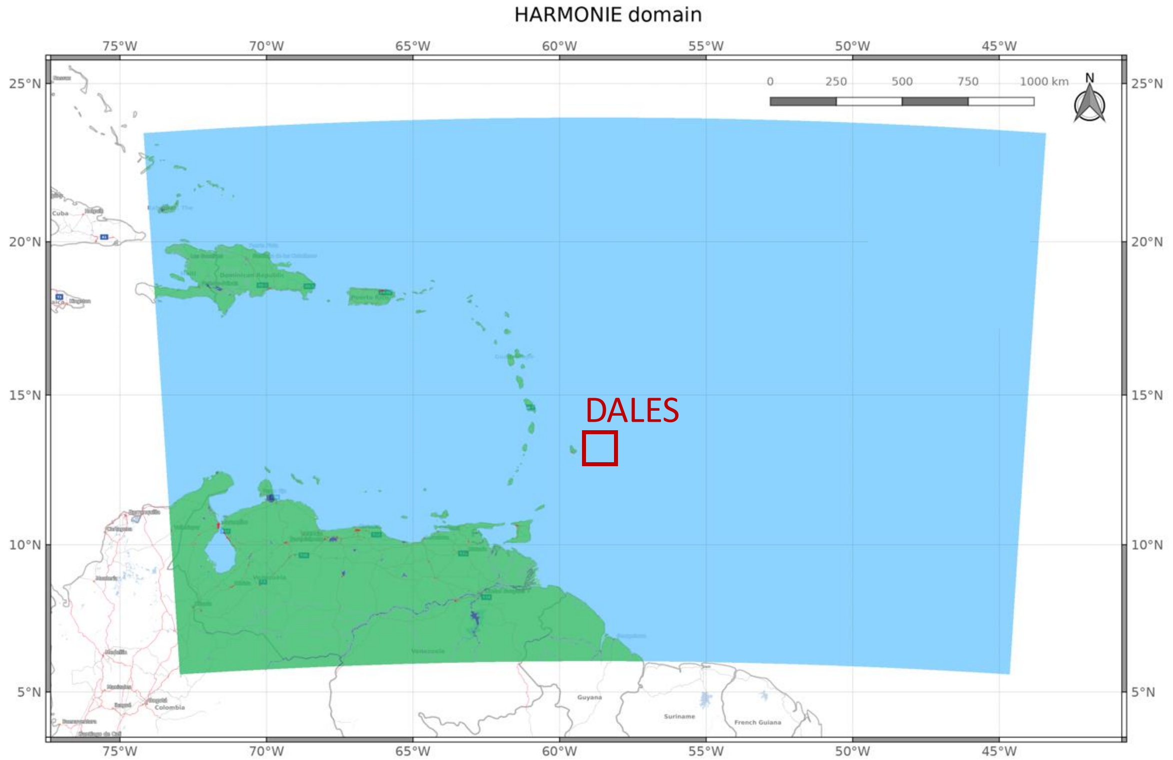


Without SCP more outflows and larger circulations



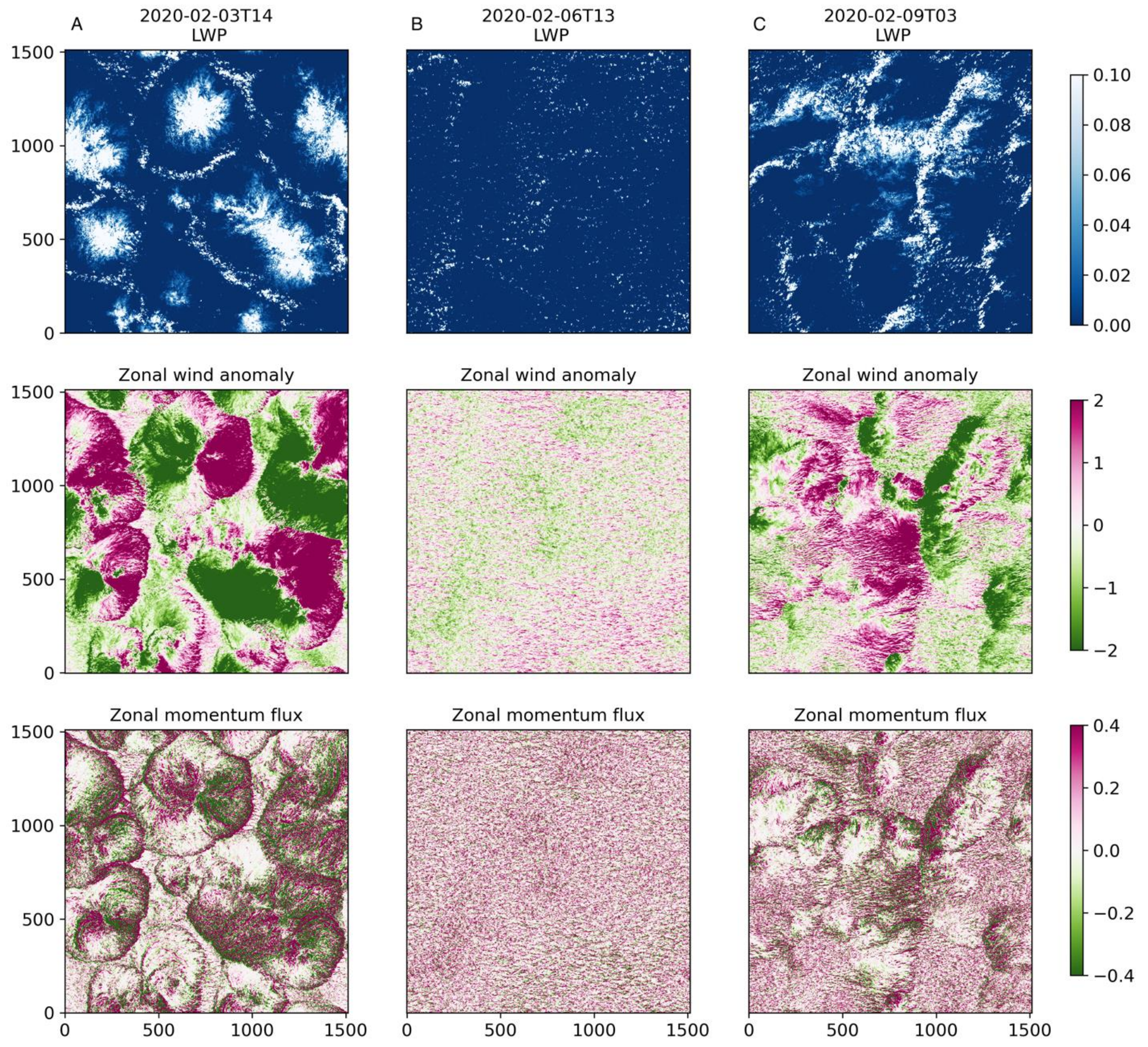
Trade wind region – EUREC4A January and February 2020

- **Large eddy simulation – DALES**
  - $\Delta x = 100$ m.
  - Domain of 150 x 150 km^2 .
  - Periodic boundary.
  - Large scale tendency from HARMONIE.



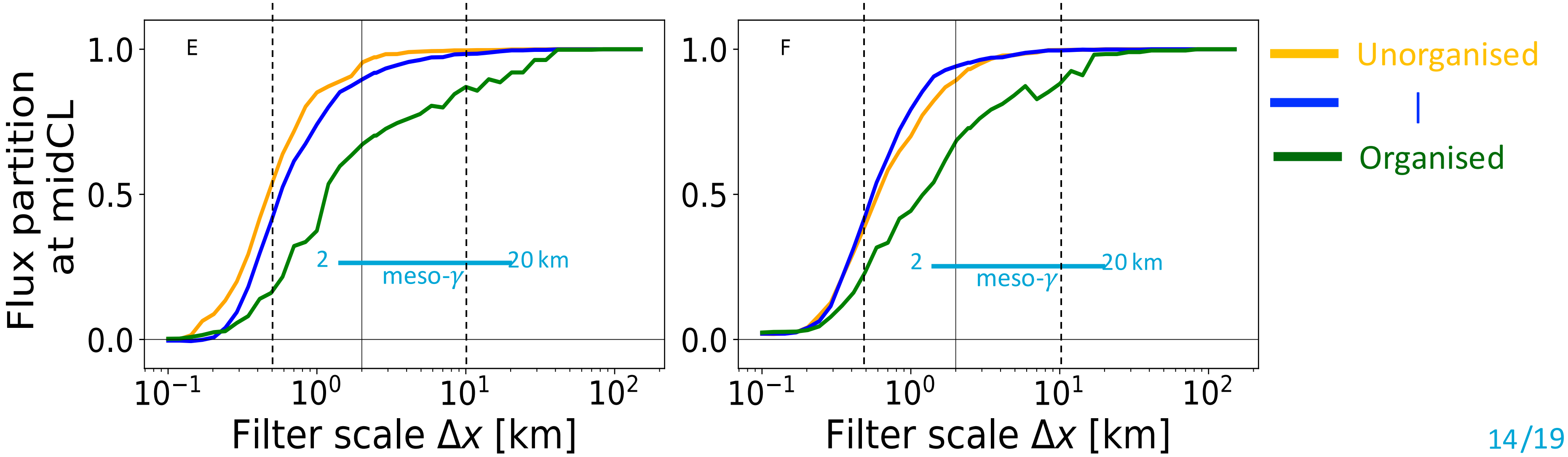
Momentum flux from LES

- Great **spatial variability** and co-existence of positive and negative fluxes.
- Structures in the flux field resamble strucutres in the cloud field.
- In organised cloud fields the small scales are less important.



Scale contribution to mesoscale momentum flux

- There is not a universal function to describe the momentum flux partition at the mesoscales.
- 60% of the flux is carried at scales smaller than 2.5 km.
- Organization explains most of the variance.



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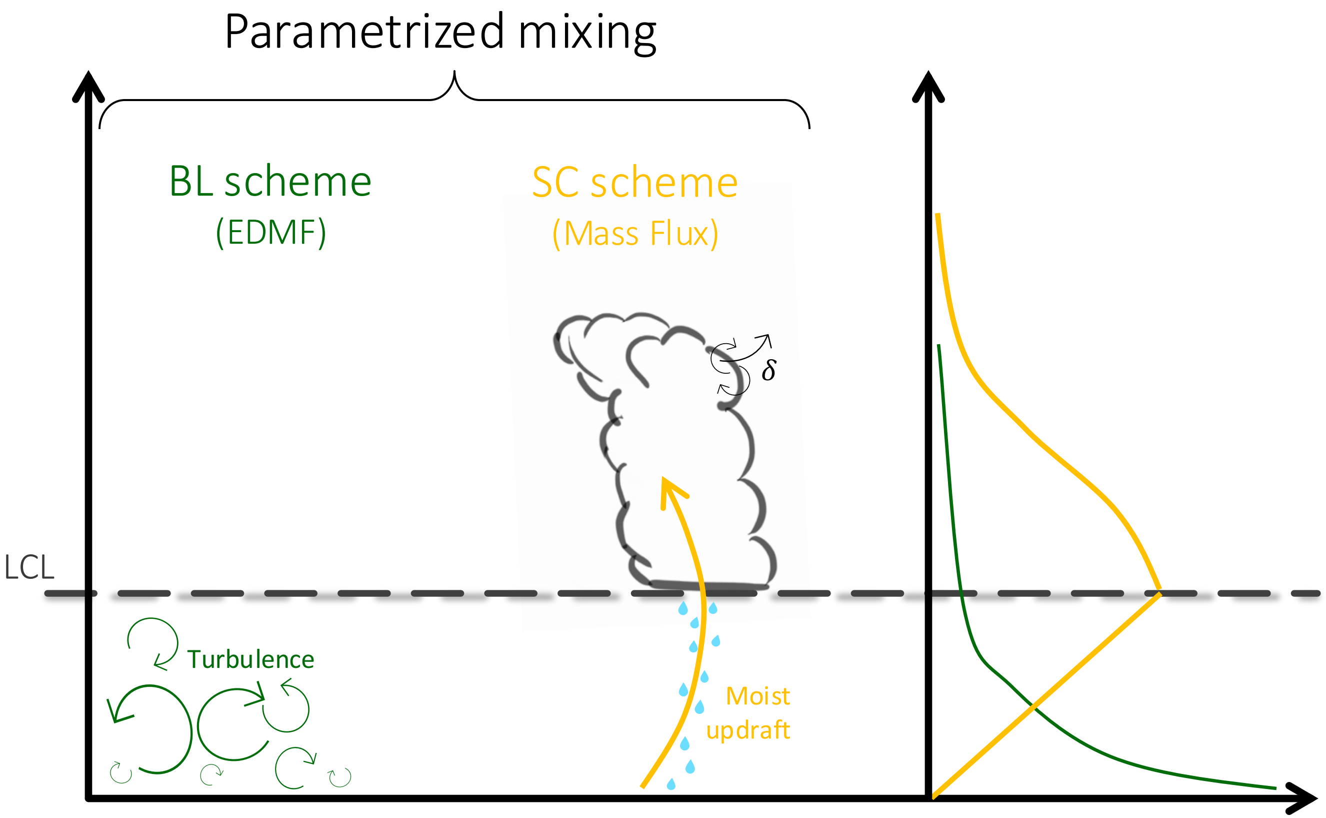
Parameterised momentum transport in IFS



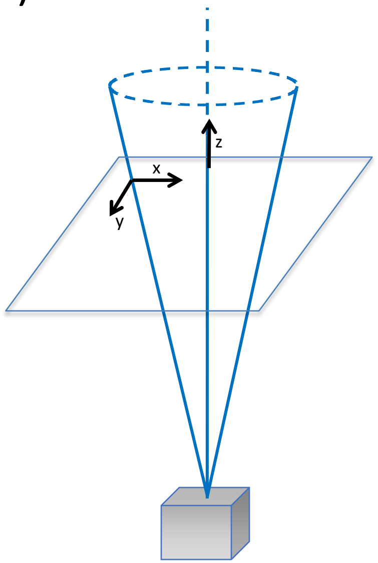
- The split into BL and SC schemes is conceptually different from a partition based on scales.

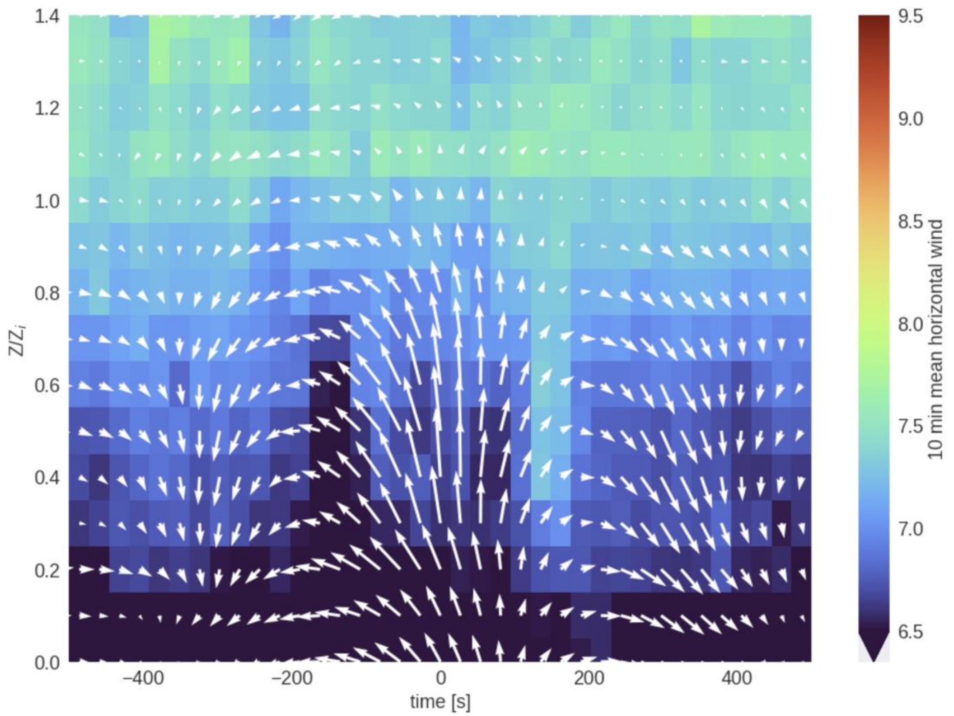
- How does subgrid momentum flux in IFS compare with observations?

Cabauw supersite – CMTRACE Sep 13th to Oct 3rd 2021

- Wind Lidar (Vaisala scanning WindCube 200s) and Cloud radar for profiles of horizontal and vertical wind from the surface into the cloud layer.
    - For all turbulent motions between ~1min (~1km) and ~30min (~ 9km).
    - From surface up to ~ 2km.

- Sonic anemometer on the tower.
    - For turbulent motions down to 0.1s (~1m)
    - At 100m, and 180m.





1. HARMONIE

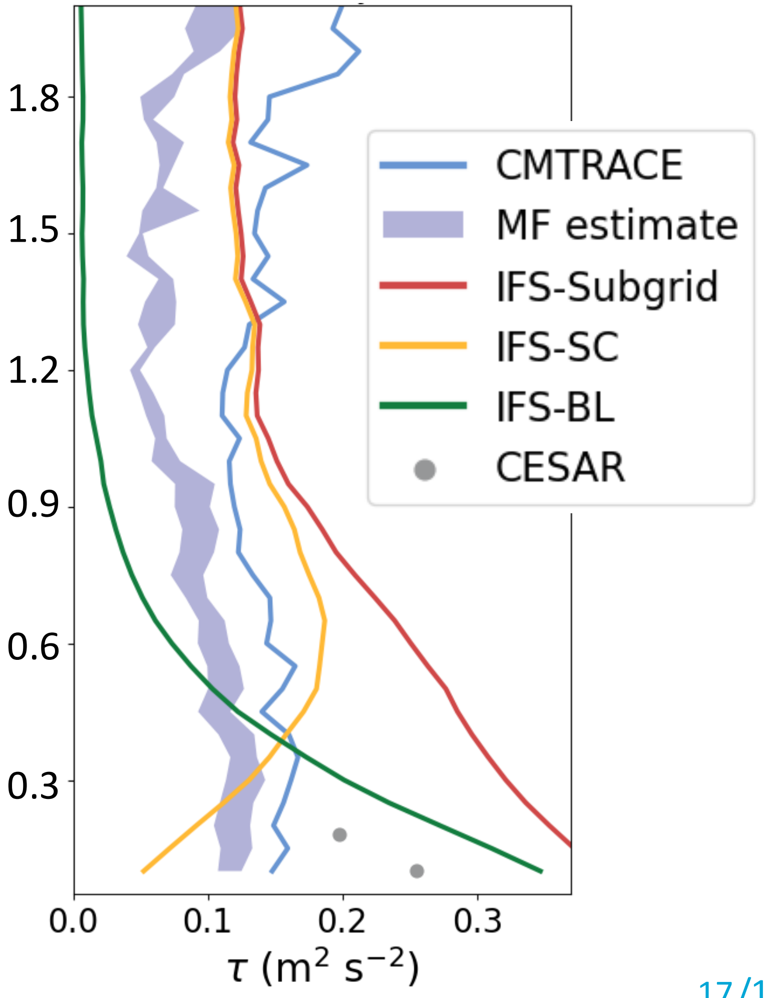
2. DALES

3. CMTRACE

Parameterised momentum flux is too strong in IFS

- The mass-flux approach does not diagnose the full flux in observations.
- Even by adding the missing small-scale turbulence to CMTRACE we observe less flux than modeled by IFS.
- The boundary layer scheme is too active.

Dates with more active convection



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Summary

- Combining models and observations we study the role of **momentum transport and mesoscale circulations in convective cloud fields** and evaluate its representation in IFS.

- We use:
  - Statistics and metrics of the cloud fields.
  - Scale partitioning of momentum flux across the grey zone.
  - Novel observational dataset from CMTRACE.

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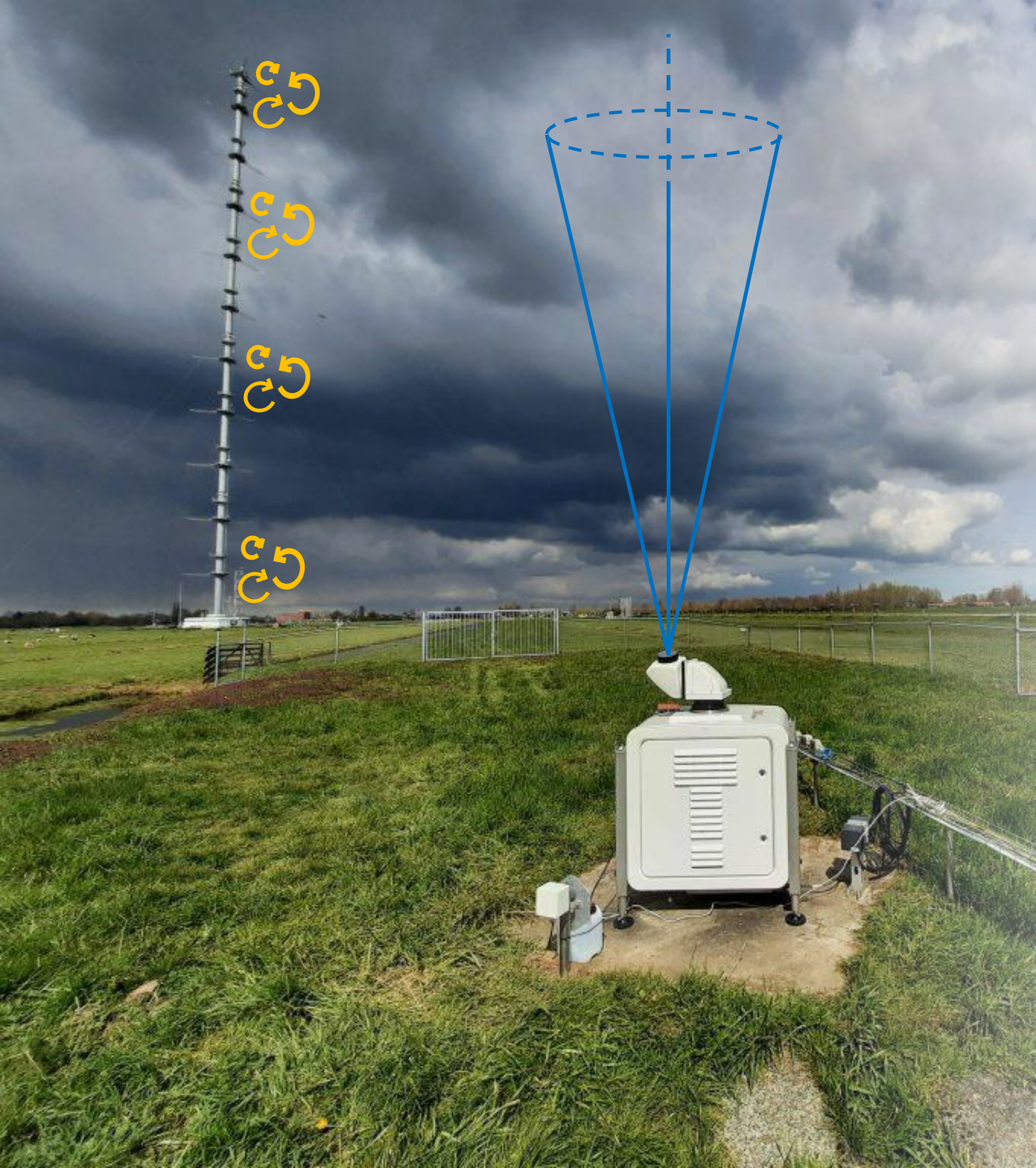
Conclusions

We should be mindful of scales when parameterise fluxes.

1. In a km-scale model, the parameterisation of shallow convection dampens mesoscale circulations.
2. Without the parameterisation of SC, CAPE builds up and burst into too many, too small resolved clouds.

1. The scale dependence of the momentum flux is not explained by changes in boundary layer depth,
2. rather by spatial heterogeneity and increasing horizontal length scales in the presence of organized convection.

1. The mass-flux approach does not diagnose the full momentum flux.
2. Parameterized momentum fluxes in IFS are too active



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