Adapting the convection scheme for the grey zone

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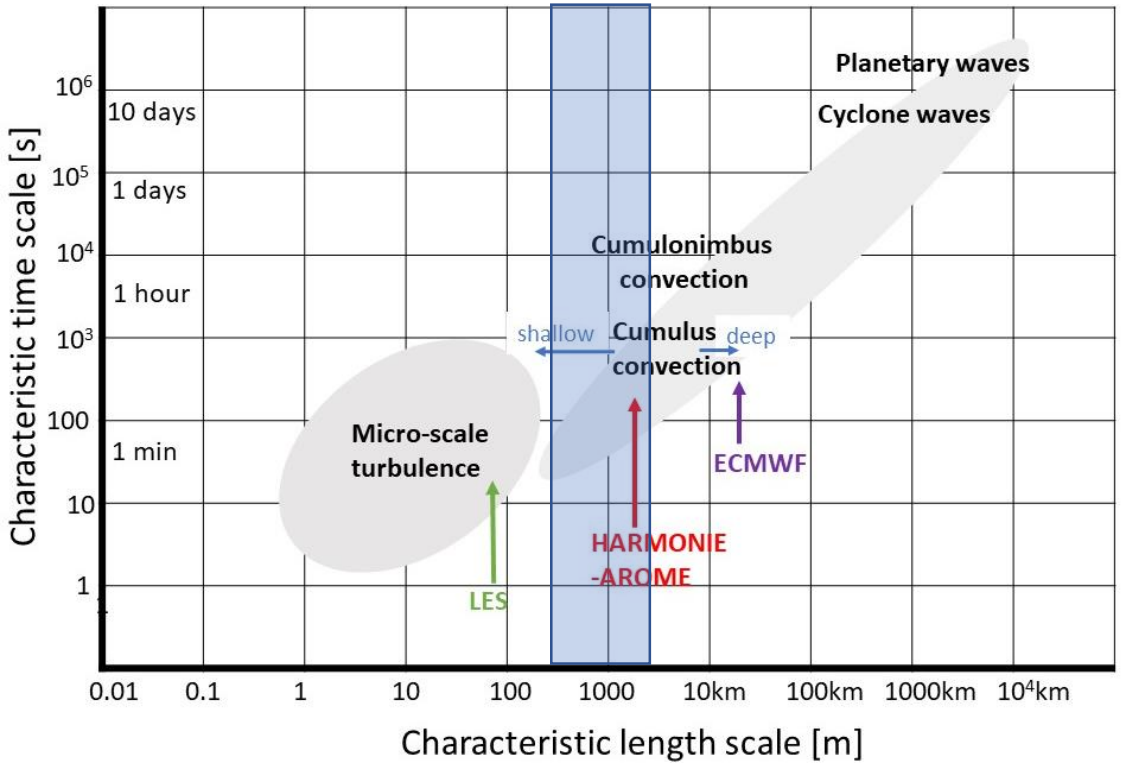
Fundamental question: Processes become partly resolved, what to do?

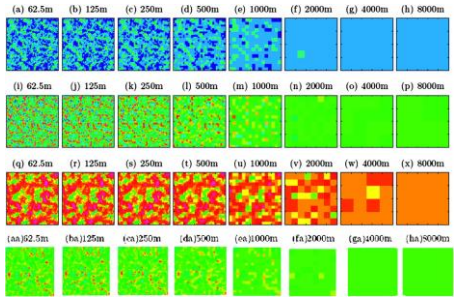


Among relevant schemes:

- convection ⟵ ≥ 500m
- turbulence
- cloud

Total turbulent transport (convection and turbulence) in the grey zone

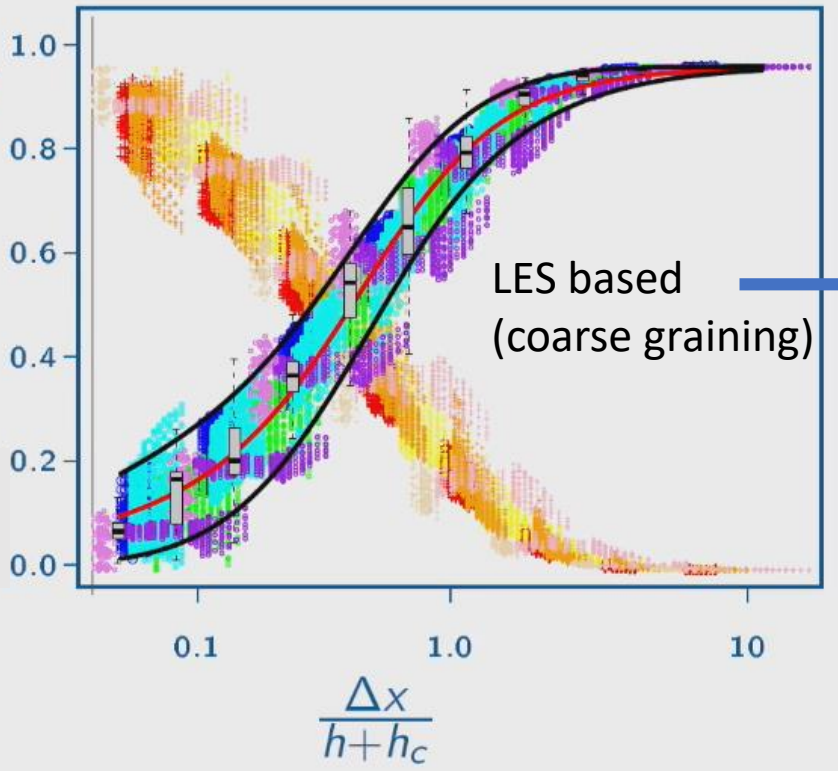
coarse graining LES



Rachel Honnert plot (e.g. Honnert 2011, JAS)

$$\frac{humidity\ flux\ resolved}{total\ humidity\ flux}$$

$$\frac{humidity\ flux\ subgrid}{total\ humidity\ flux}$$



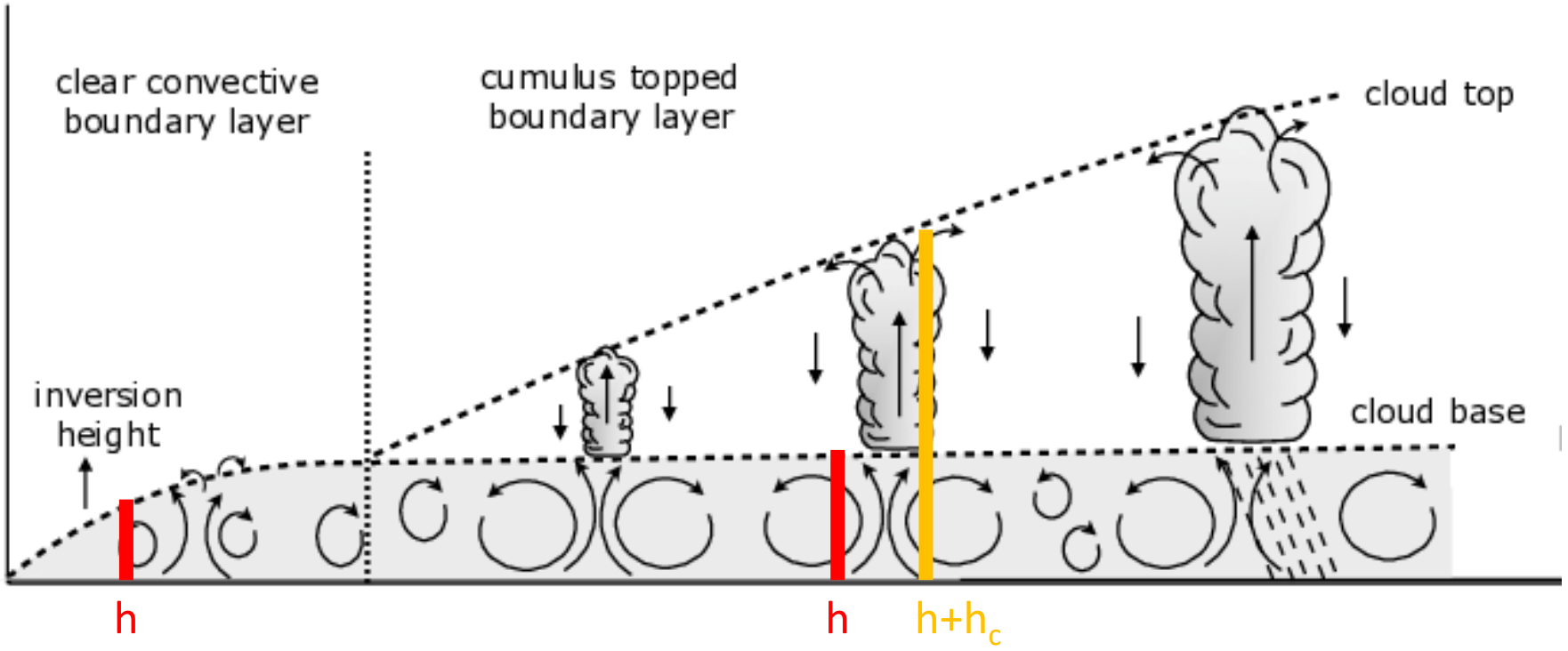
unresolved

resolved

LES based (coarse graining) → We want similar behavior in NWP

$h+h_c$ is an estimate of the relevant (dominant) scales

Boundary layer height h or $h+h_c$ as an estimate of the scales



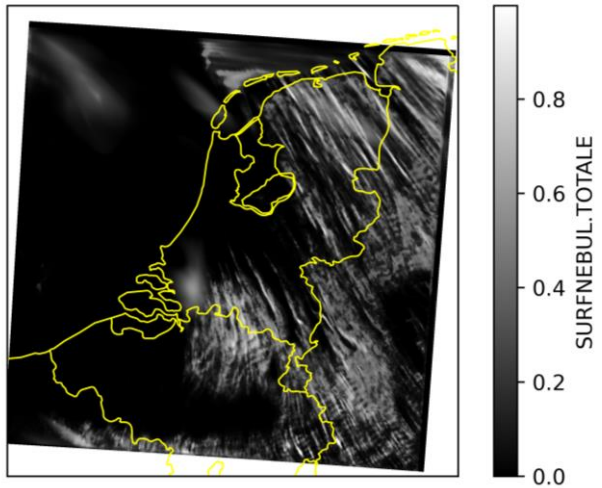
Harmonie-Arome: h or $h+h_c$
Very simple: Termination height moist and/or dry updraft.
Moist ↔dry → New possibilities!

Decrease Mass flux with $f(\Delta x/h)$ *(Lancz et al. 2018)*
But
Separately for dry (h) and moist ($h+h_c$)

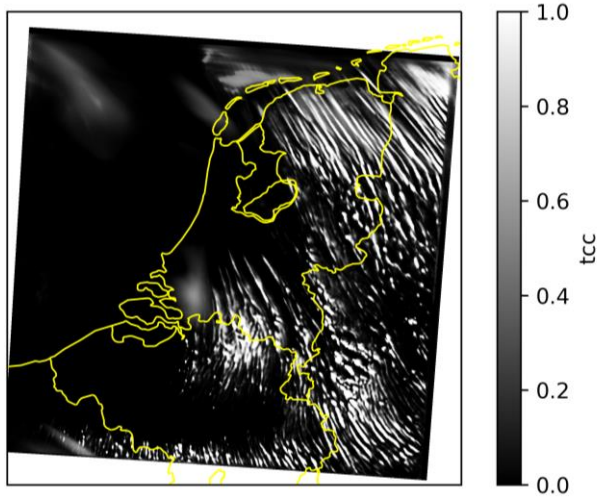
Simple shallow convection case with HARMONIE-AROME

Satellite

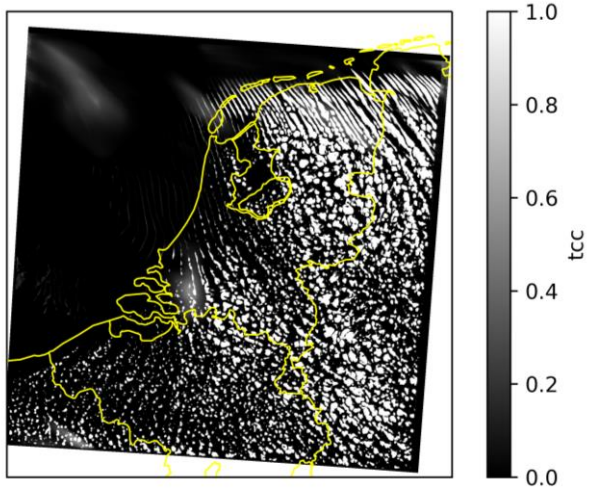
500x500m^2 resolution total cloud cover



convection scheme on

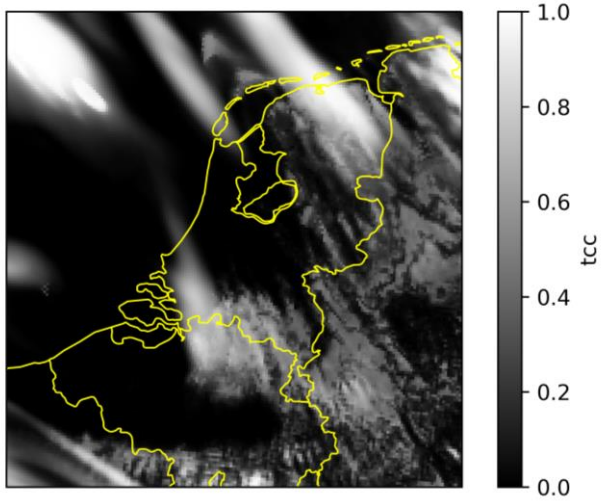


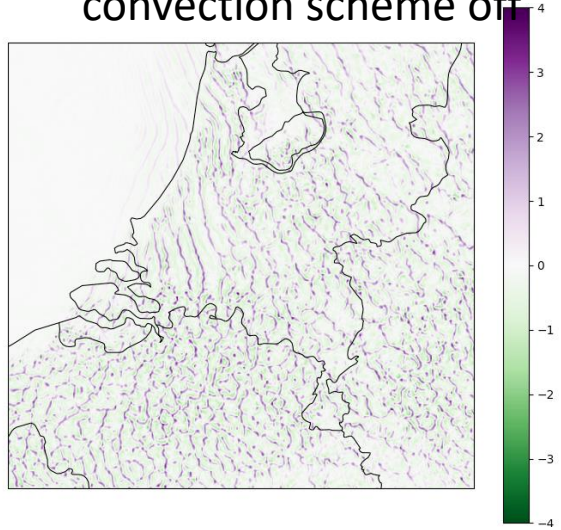
scale-aware convection



convection scheme off

2.5km run (conv. on)



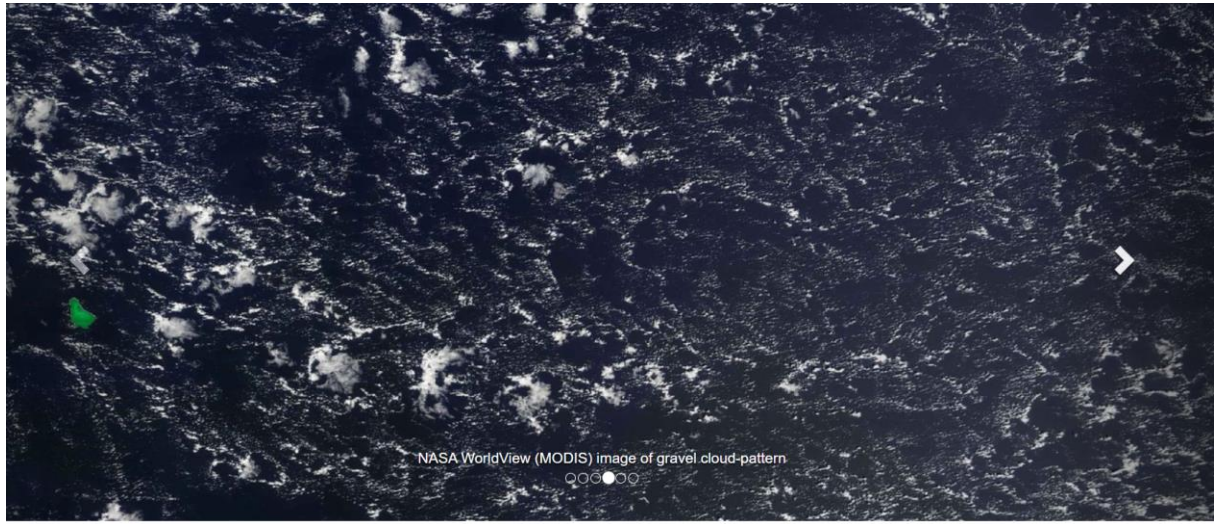


resolved vertical velocity

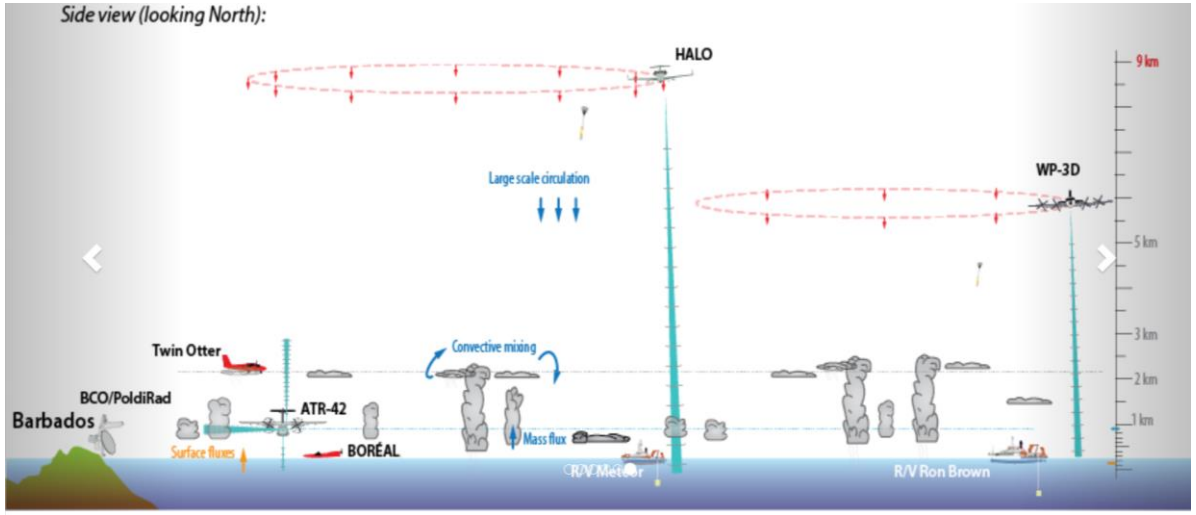
- First impression: scale aware scheme behaves as expected: In-between convection on and off

EUREC4A Field campaign: Investigate cloud organization

Gravel



EUREC⁴A, the Field Study, aims at advancing understanding of the interplay between clouds, convection and circulation and their role in climate change. It is a European initiative that, together with a US contribution through ↗ ATOMIC, constitutes a cap-stone study in support of the World Climate Research Programme's Grand Science



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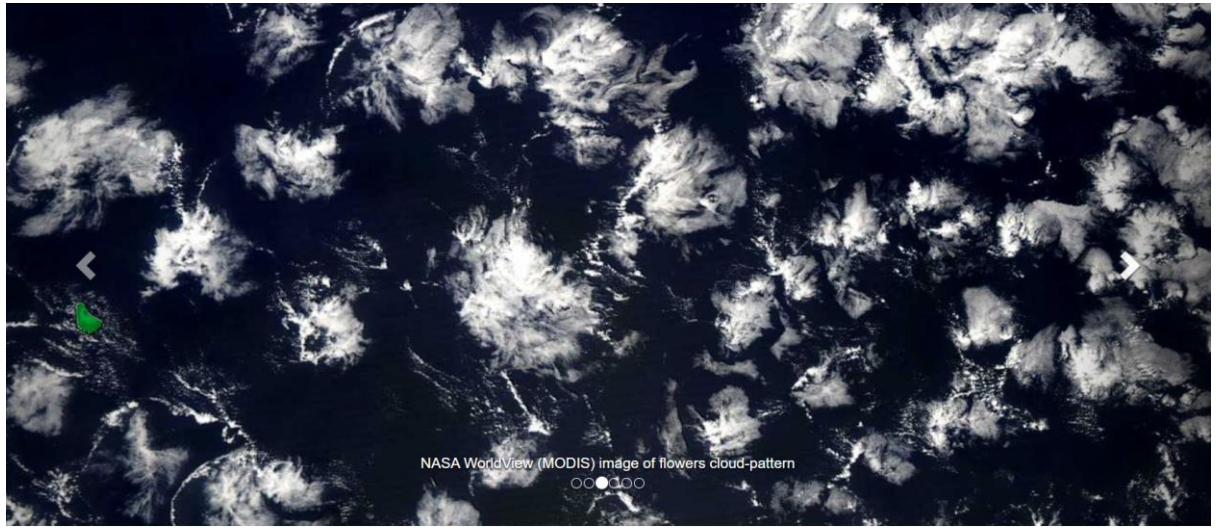
Flowers



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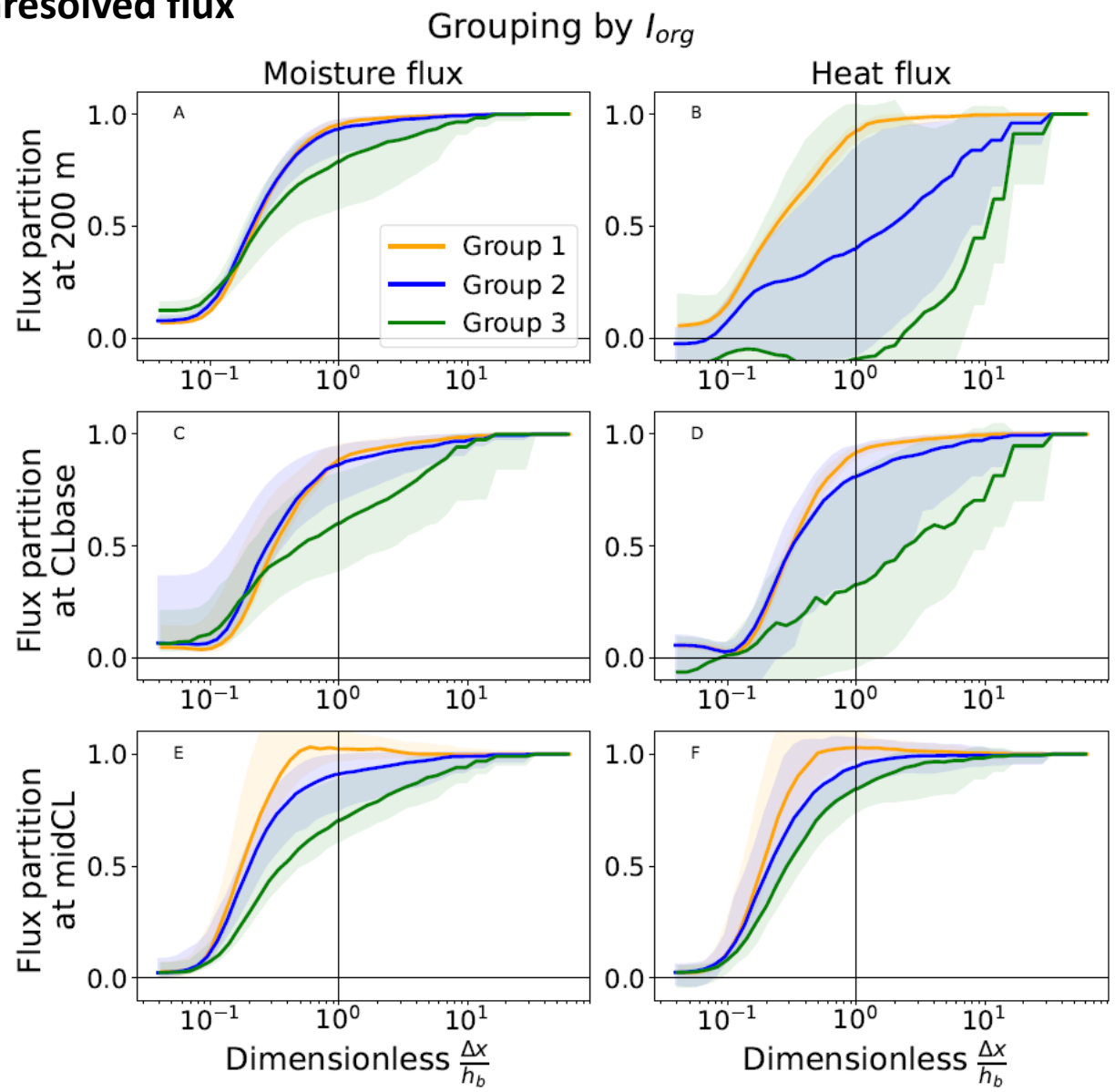
rec4a.eu/#carousel-example-generic

LES coarse graining for EUREC4A (containing all kind of conditions)

Unresolved flux



group 1 unorganized
group 2 in-between
group 3 (very) organized

Boundary layer height often not a good indicator for scale size!

Meso-scale organization
Horizontal scales

What to do?

Precipitation ↔ Organization

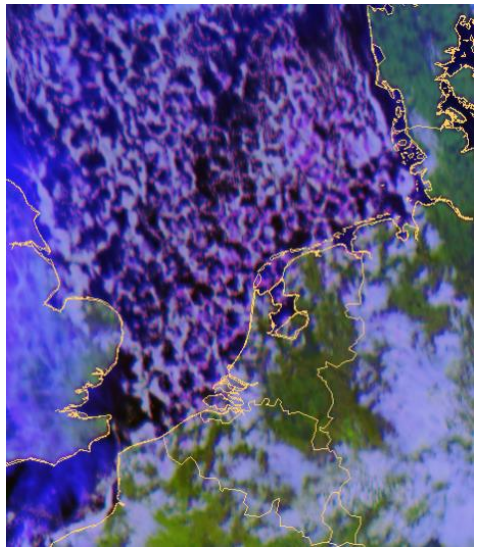
Chicken ↔ Egg

Alessandro Savazzi et al., 2023 JAS: Momentum Transport in Organized Shallow Cumulus Convection

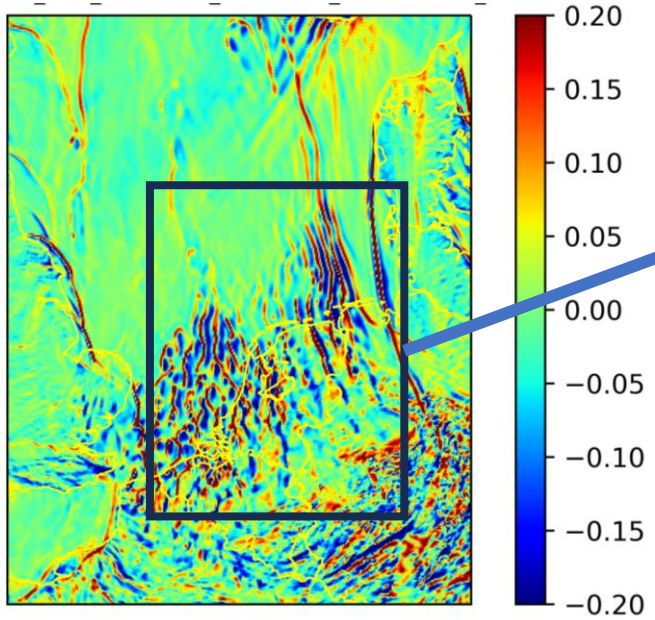
Another illustration h is not always suitable:
Harmonie-Arome at **2.5km** resolution: open cell convection case.

PBL height is small compared to Δx but still at this resolution and with default configuration signs of resolved convection !

Satellite



Vertical (resolved) velocity at 750m height



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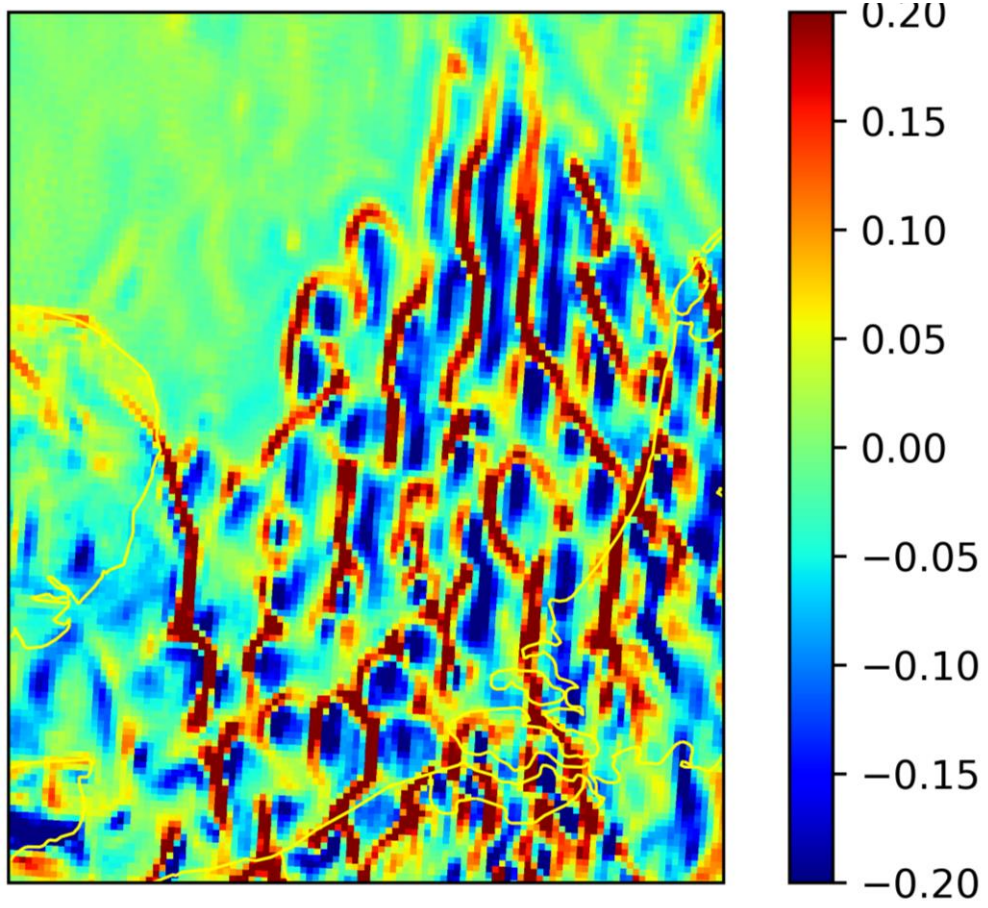
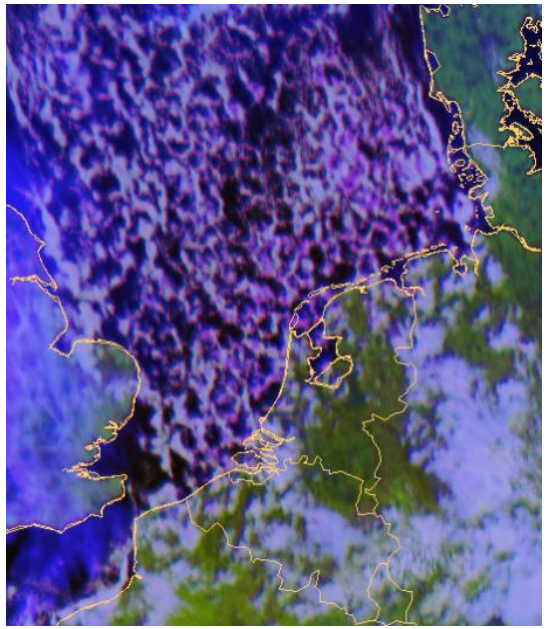
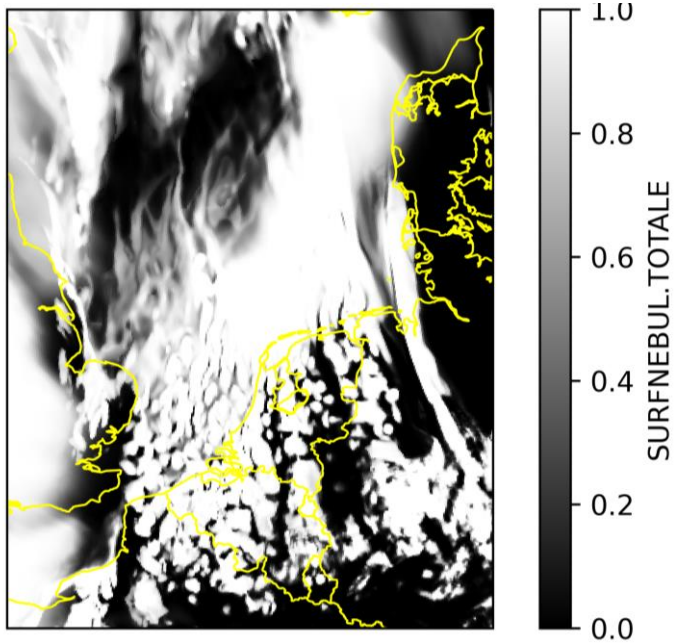


Harmonie-Arome at 2.5km resolution: open cell convection case.

Satellite



cloud cover



Some organization in cloud structures but too little and related to that underestimation of precipitation

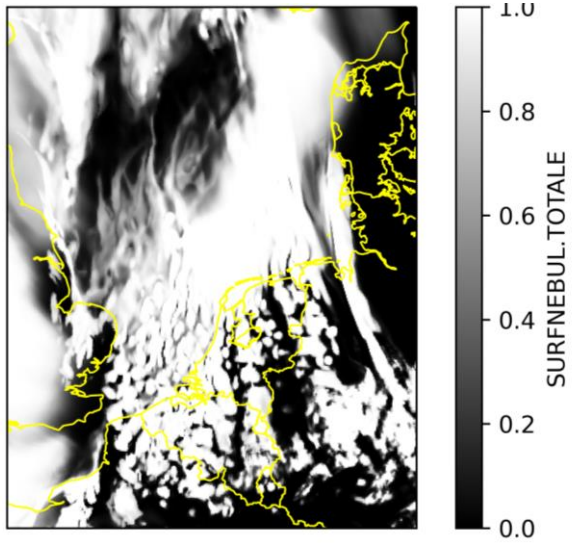
Model at 2.5km starts to resolve convection (indicated by resolved vertical velocity) but too little
→ continuous leaking of instability by convection scheme

Khain et al., AR 2021 introduced shut down convection parameterization if w>w_threshold:

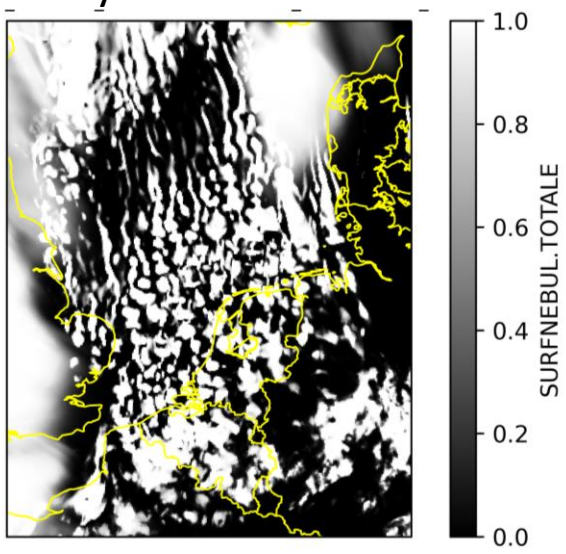
Implementation: In every grid point shut down convection where |w|>w_threshold =f(grid size)

Impact of shutting down convection scheme if |w| > wthreshold at 2.5km

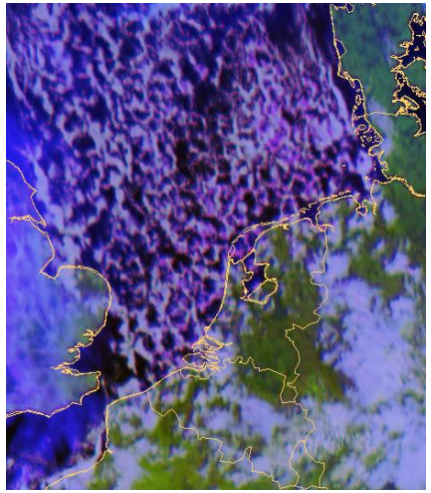
cy46 REF 2.5km



cy46 W-THRESH 2.5km



satellite cloud



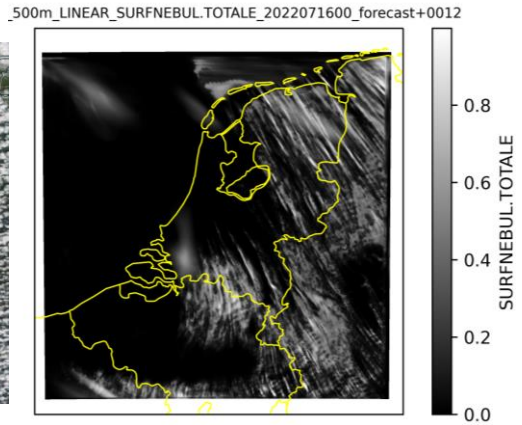
Clearly more organization with w-threshold

Also, more precipitation, in better agreement with radar (not shown)

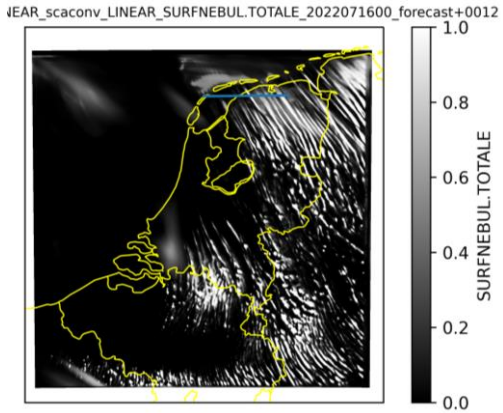
Impact of w-threshold at 500m. Simple shallow convection case

12UTC VIS satellite

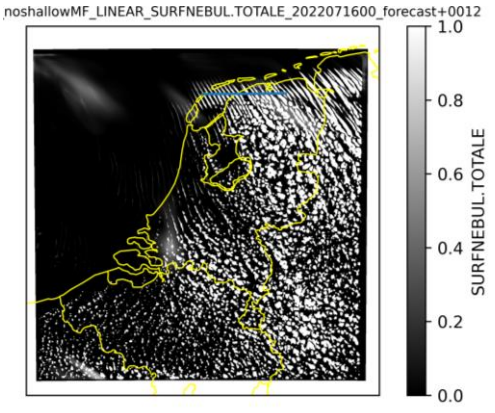
REF (MF on)



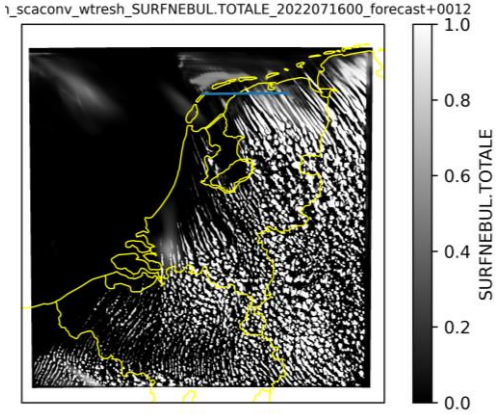
scale aware MF



no MF



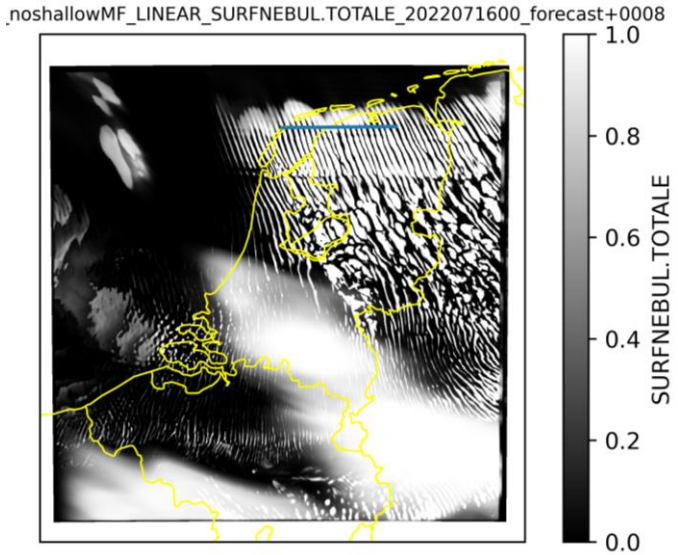
scale aware MF + Wthresh



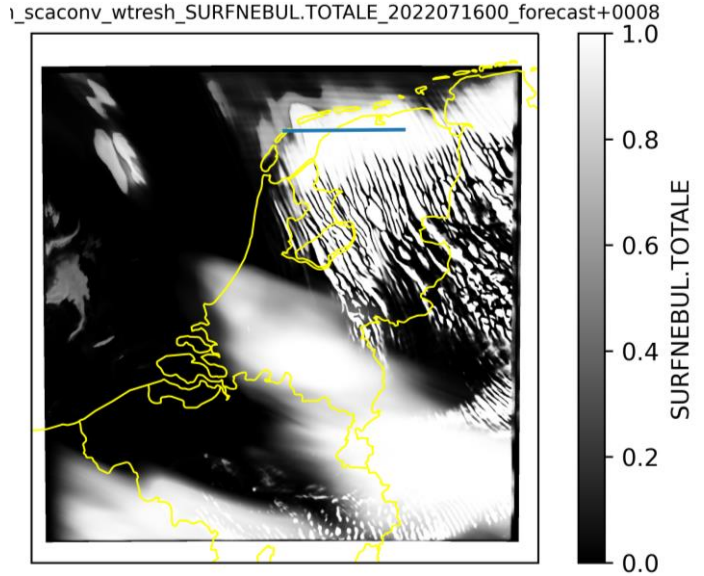
Unrealistic patterns without convection scheme
Clearly visible at e.g. +8h forecast.

Absent with other options

no MF

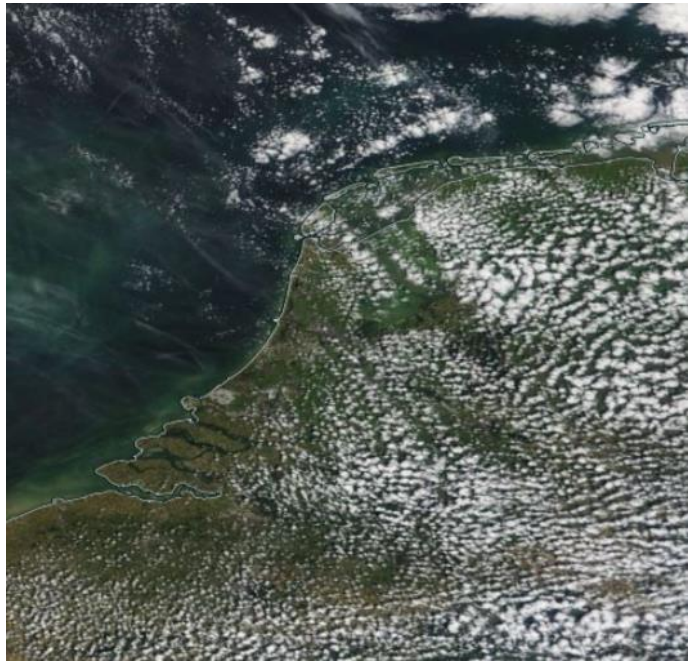


scale aware MF + Wthresh

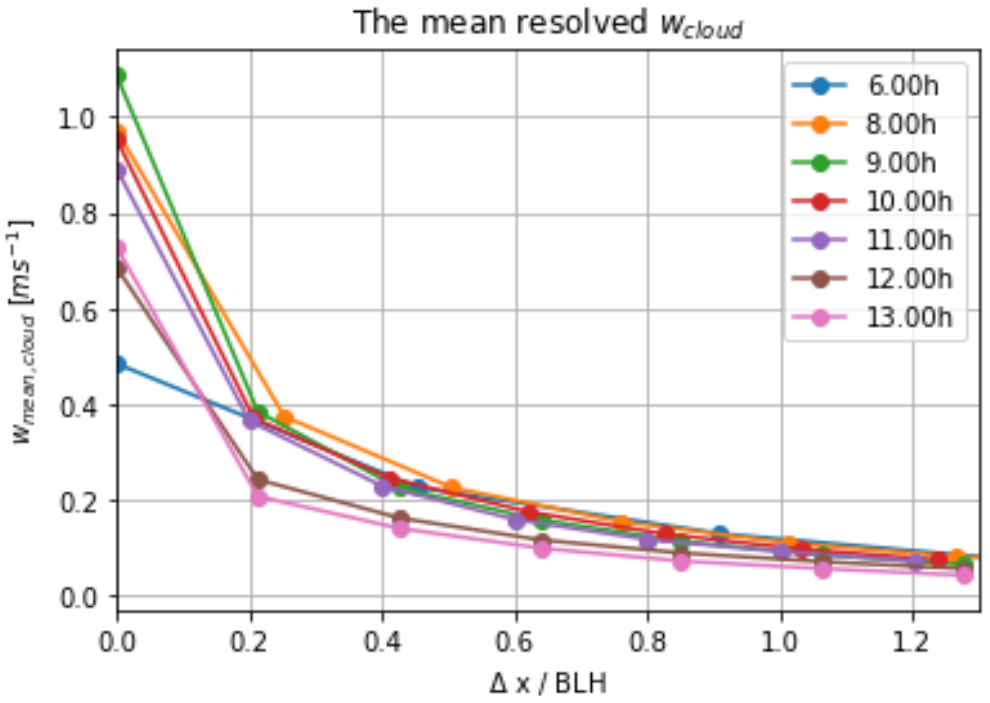


Suitable value for w_threshold?

- Should depend on grid size
- Guideline by LES? (many cases)



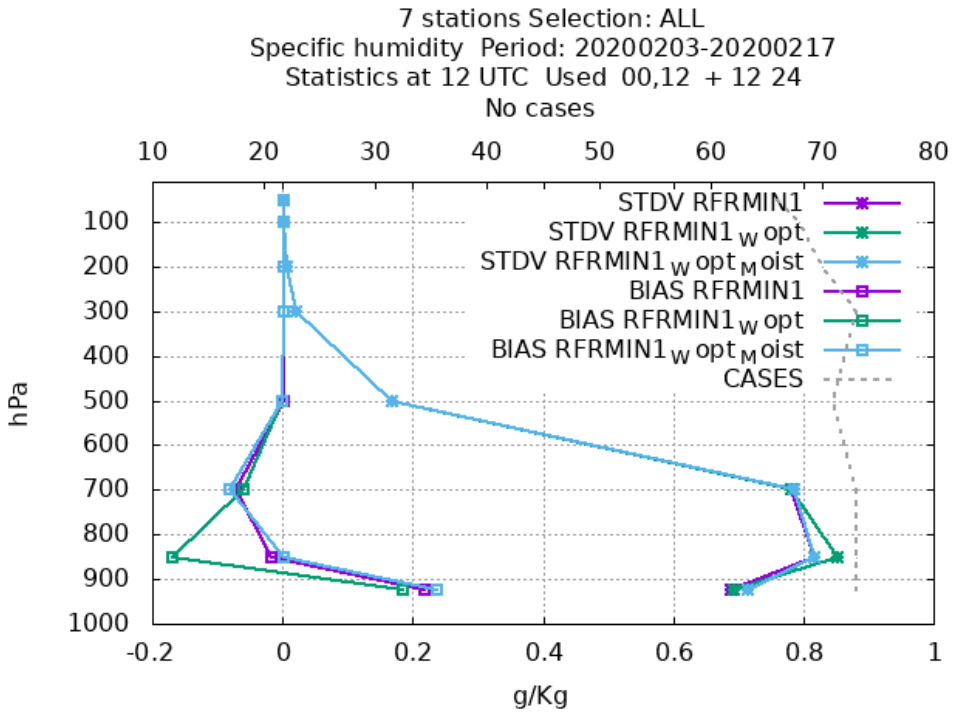
Conditional sampling in LES: Mean convective w



Charlotte Raven

Long term verification runs at 750m and 2.5km with convection scheme options

- Shutting down shallow convection completely is worst option
- W-threshold option reveals underestimation non-local mixing in dry PBL (most clearly at 2.5km)



If w > w_threshold: dry and moist convection are shut down.

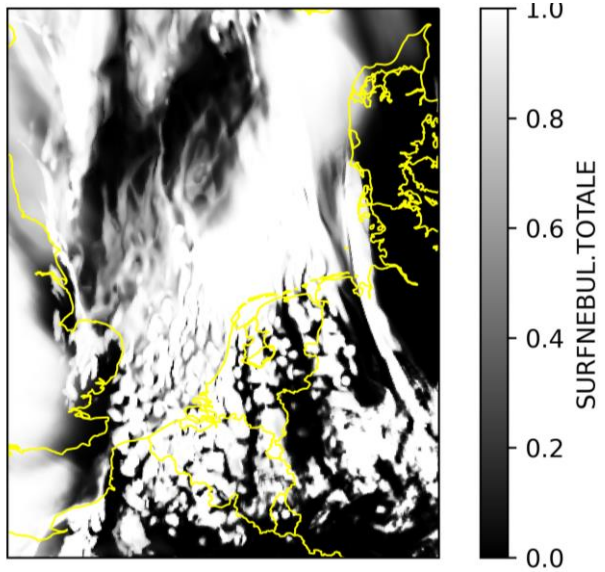
But should we shut down dry convection based on w_threshold?

Dry convection is associated with smaller scales → only turn off moist convection (w_thresholdmoist option)

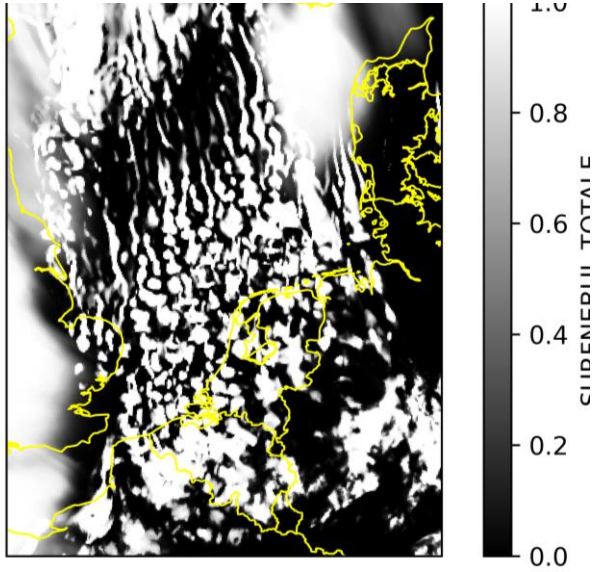
Emily Gleeson

Open cell case at 2.5km including wthreshold_moist option

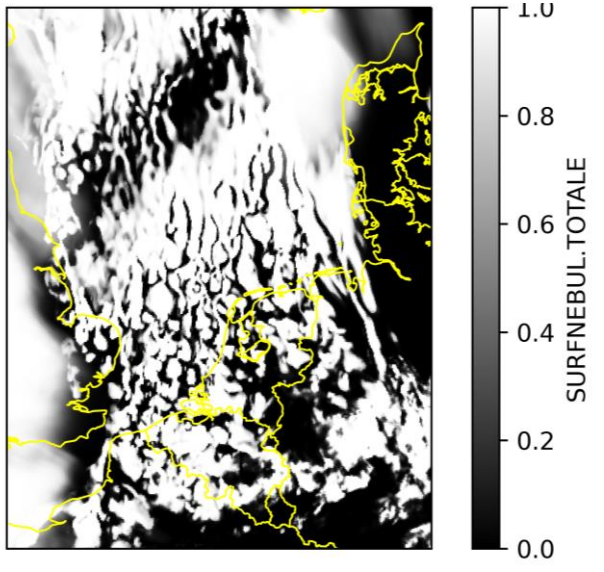
cy46 REF



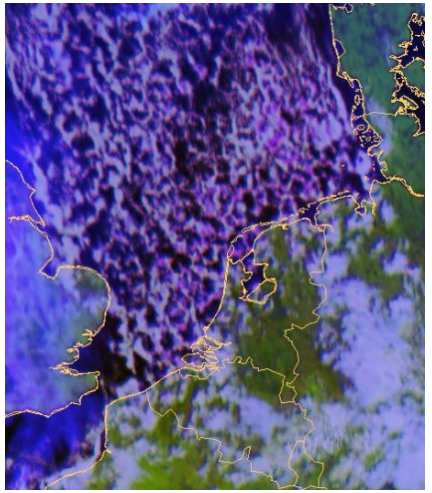
WTHRESH



WTHRESH MOIST



satellite cloud

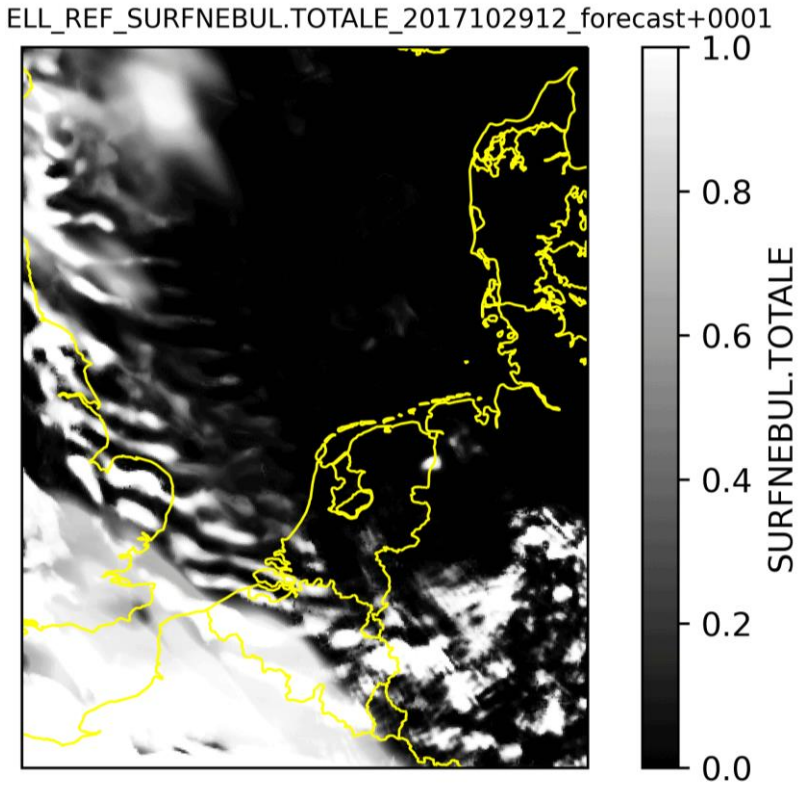


Wthreshold_moist (only moist updraft are shut down) in-between ref and wthreshold

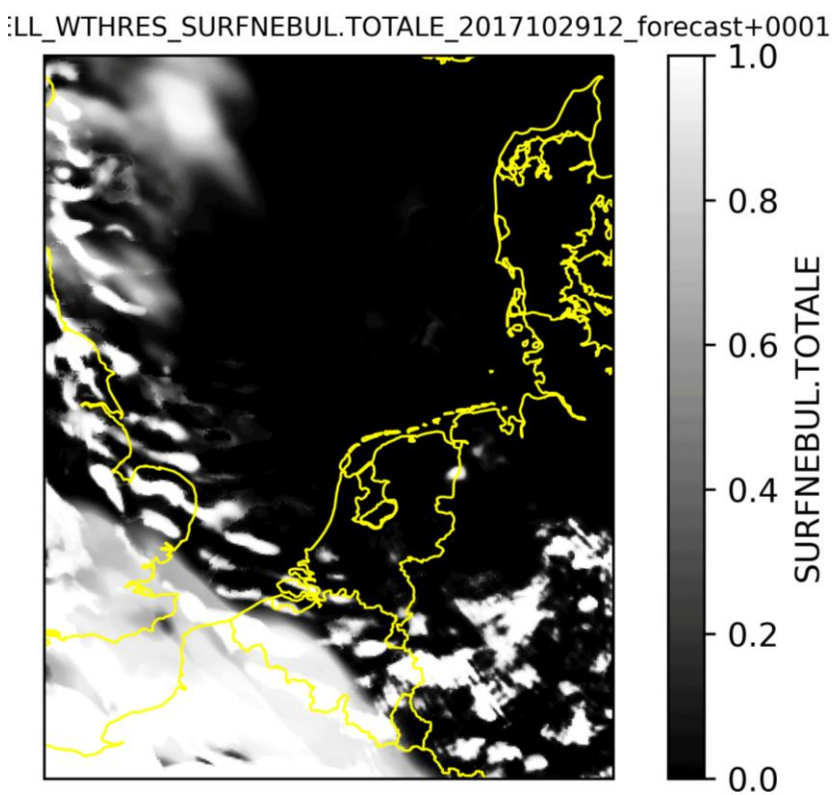
Impact dry updraft is increased CIN and building up moisture near inversion

Movies open cell case 2.5km resolution:
Beginning, increased stratus with wthreshold_moist

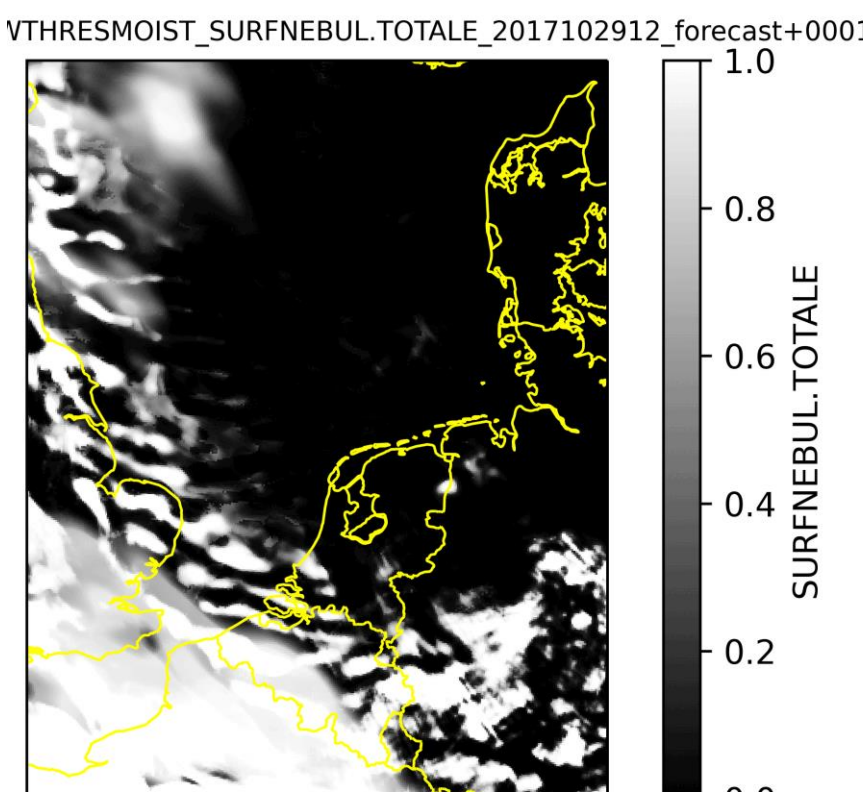
cy46 REF



WTHRESH



WTHRESH MOIST



Discussion, outlook

- Work in progress!
- LES are an important tool to develop scale-awareness in our models
- Shutting down shallow convection for resolutions ≥ 500m seems sub-optimal
- PBL height often not suitable as measure of scales. Honnert type of scale aware convection scheme is not enough.
- W-threshold(moist) is a promising approach to support model to build up resolved convection. If the model starts build up convection, it should! Exclude stratosphere diagnosing w>w_threshold
- Separate treatment dry and moist convection provides more options.

Discussion, outlook

- No shallow convection at too low resolution: Model builds up huge instability (no means to consume it) and than “explodes” → artificial structures, too heavy precipitation
- Shallow convection at too high resolution: Continuous leaking of instability. Model cannot build up resolved convection itself (enough).
- Is there still a need for scale aware convection (type Honnert) if we use w_threshold? Yes: Scale aware active before w_threshold (influences build up instability).


Danke, fragen?
www.cloudappreciationsociety.org