UNIVERSITY OF LEEDS

Update on understanding convective GENESIS

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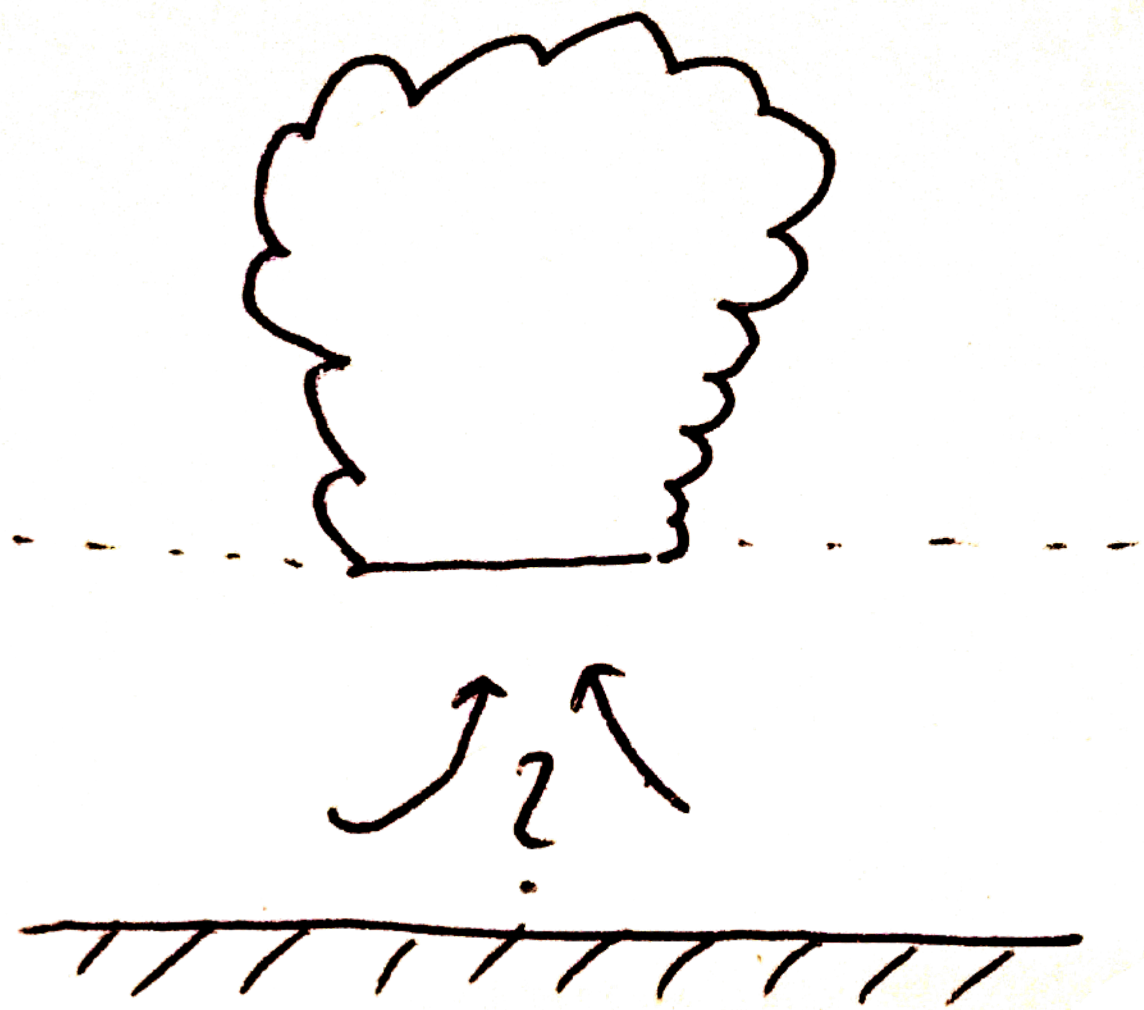
ParaCon Plenary, 19/12/17, Exeter

Outline

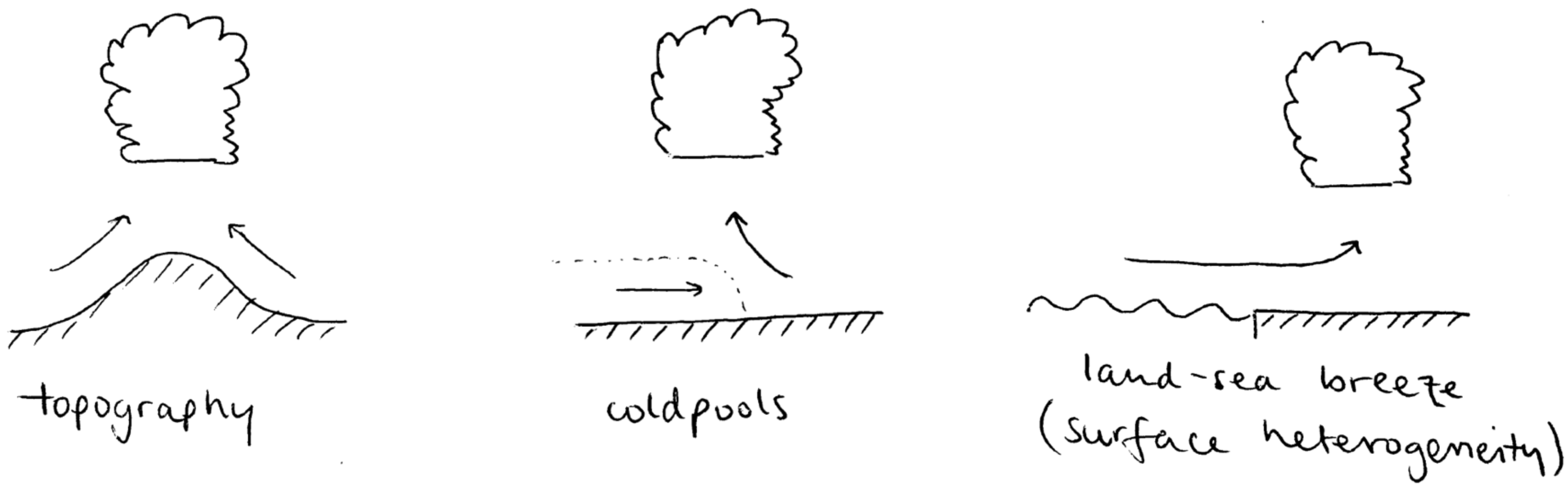
- What’s the aim?
- How does this fit into CoMorph?
- What’s new?
- What’s next?

Aim



Aim

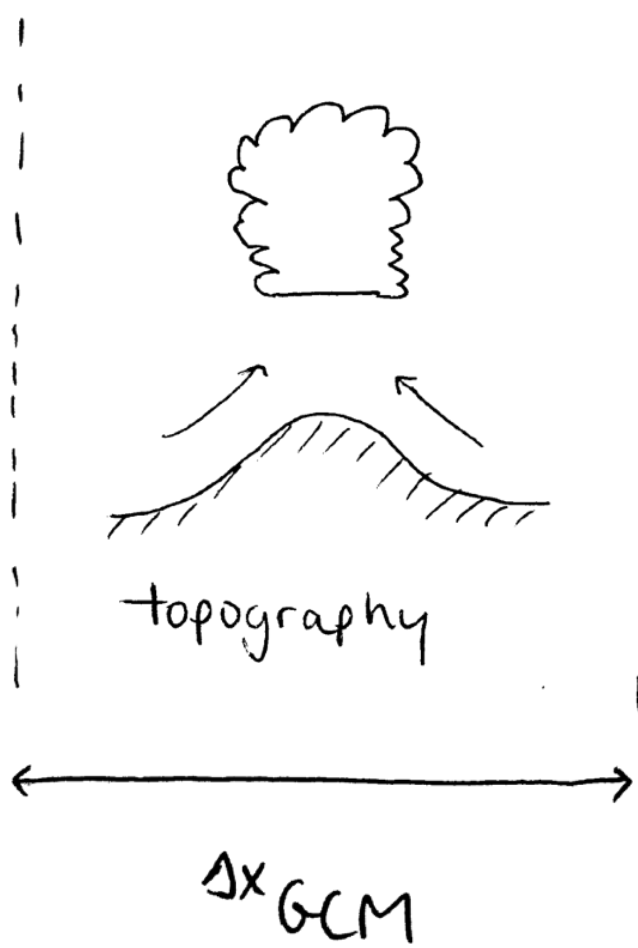
- Describe statistics of boundary layer relevant to triggering convection and the sensitivity to presence of different phenomena

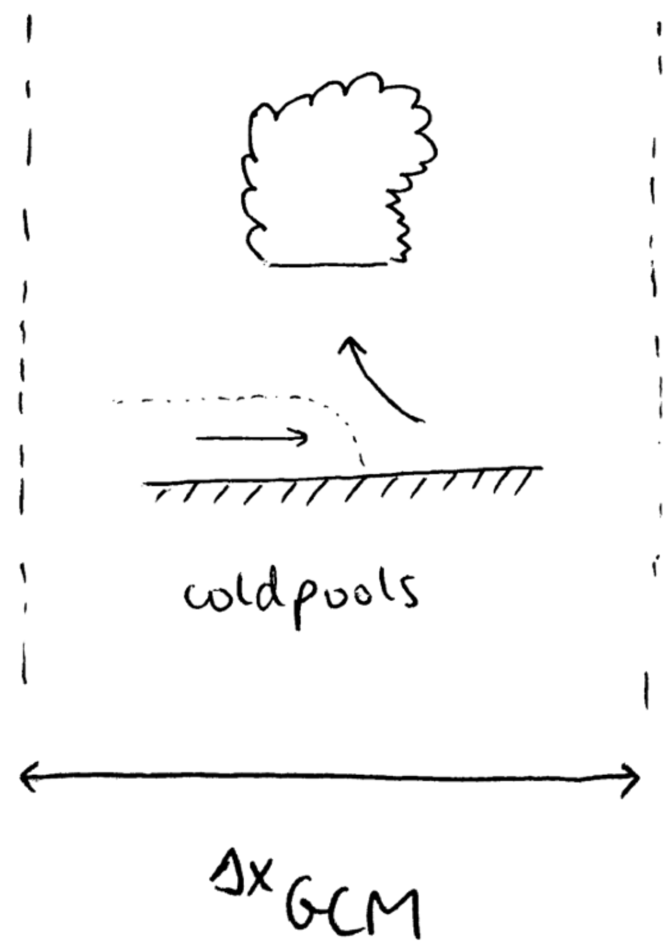


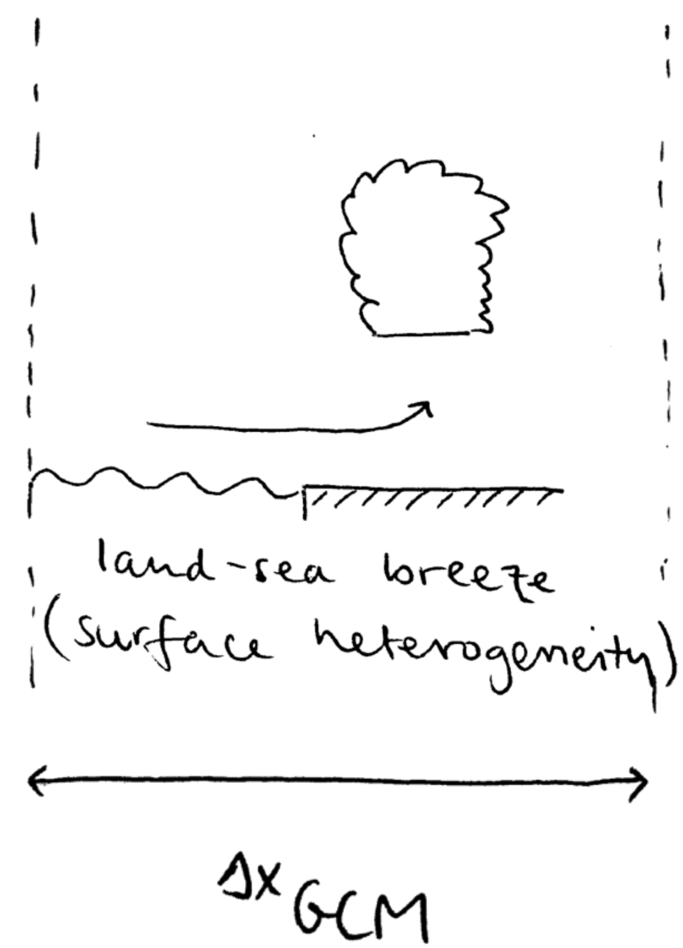
- *"What are the length-scales and magnitudes of perturbations which trigger convection?"*

Why?

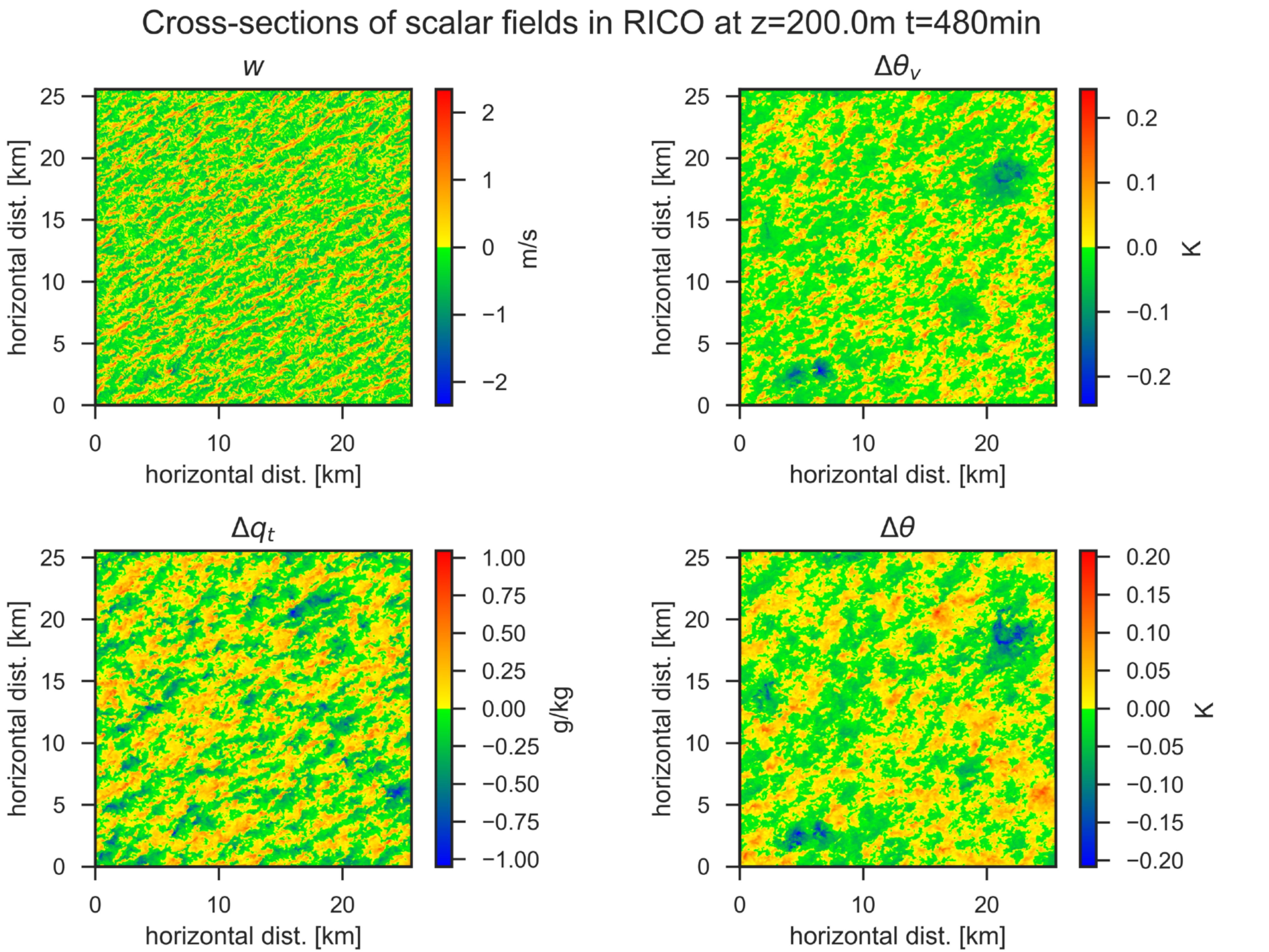
- GCMs have too coarse resolution to fully represent convection (O(km))
    - ➡ Trigger (and evolution) of convection must be parameterised
    - ➡ These *sub-grid* features are known to be critical in predicting formation of convection







What are the length-scales of variability?



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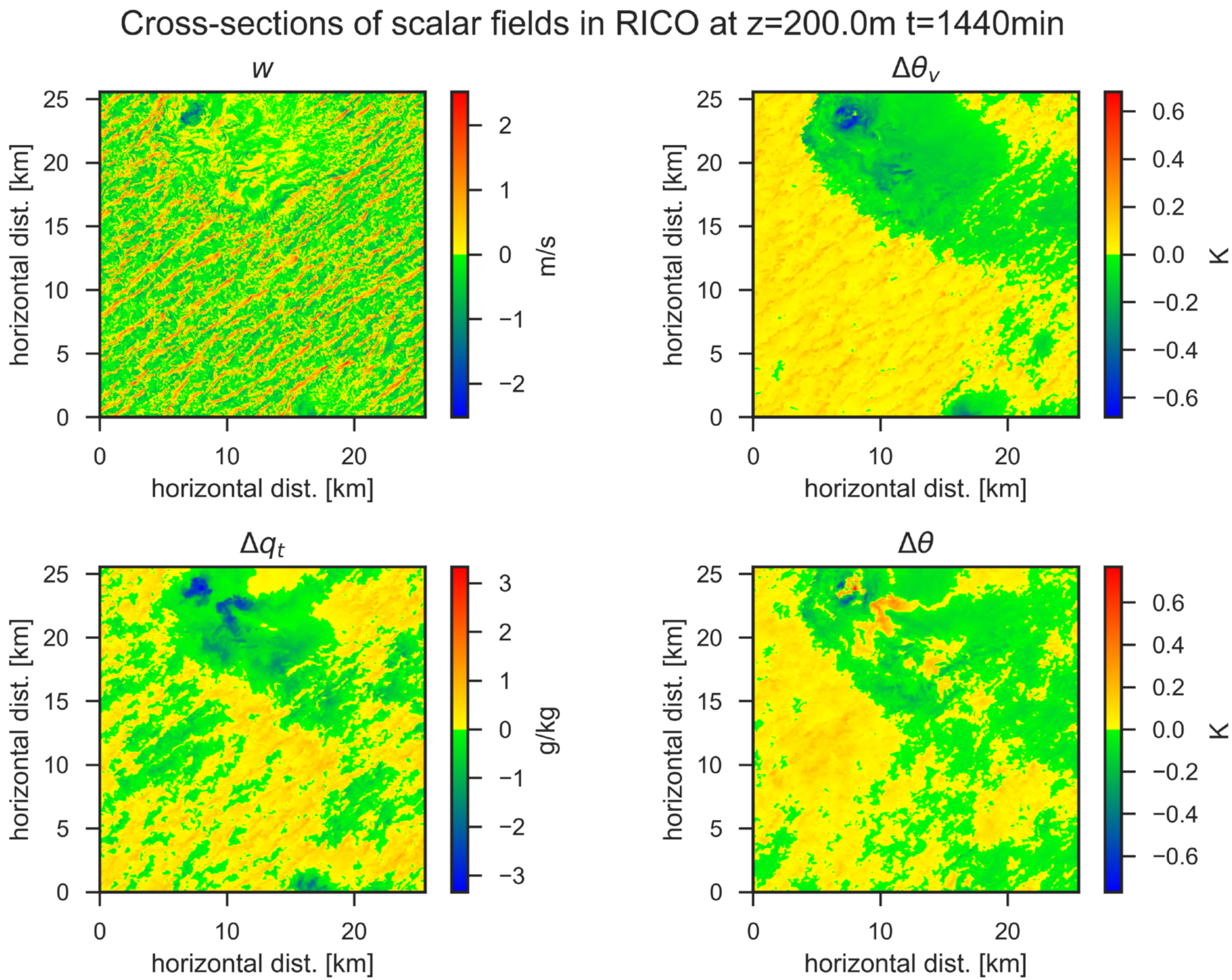
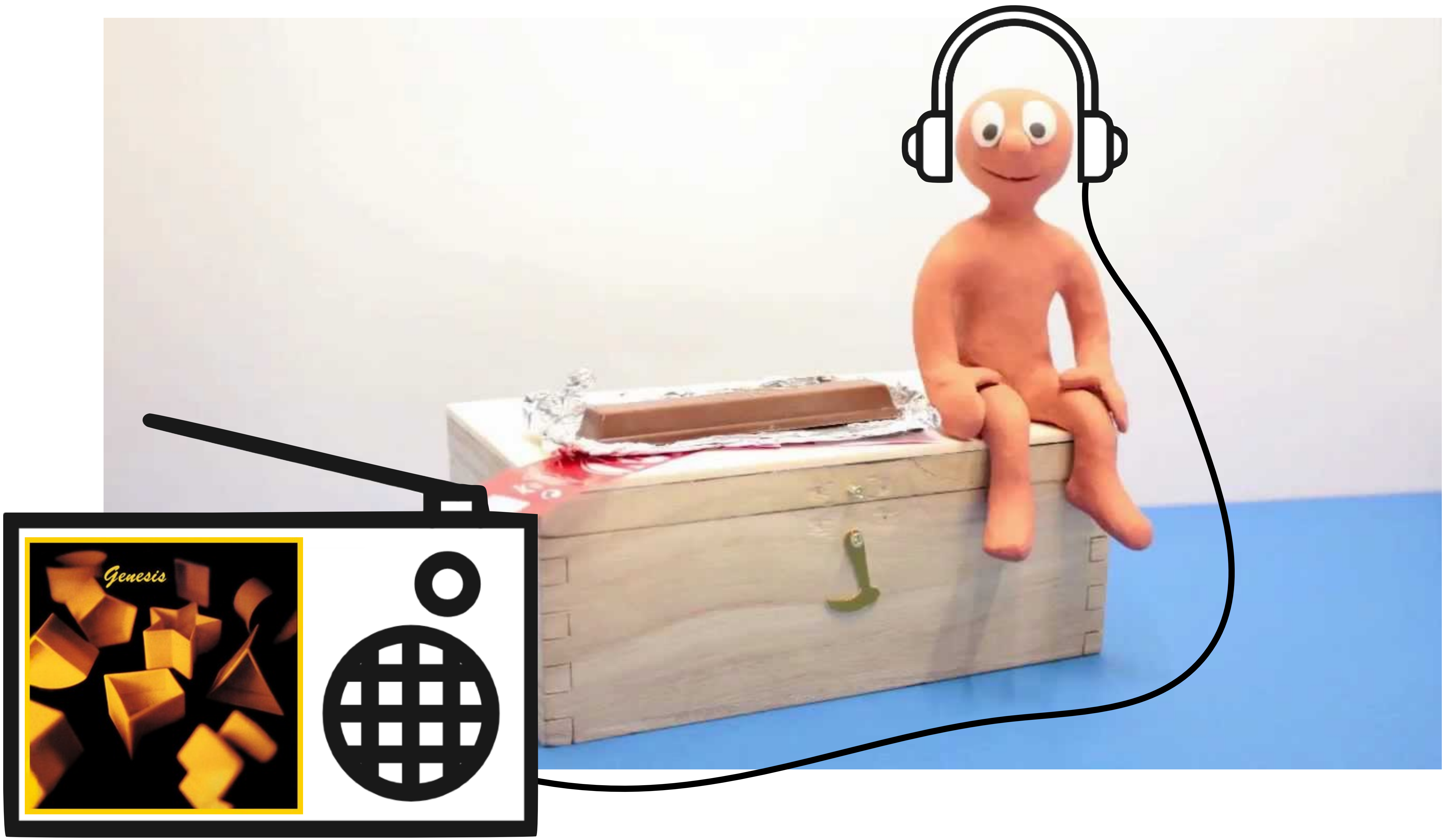
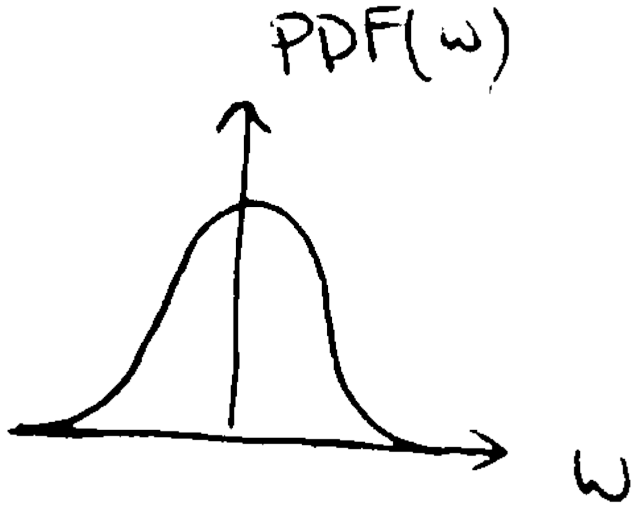


How does GENESIS fit into CoMorph?



How does this fit into CoMorph?

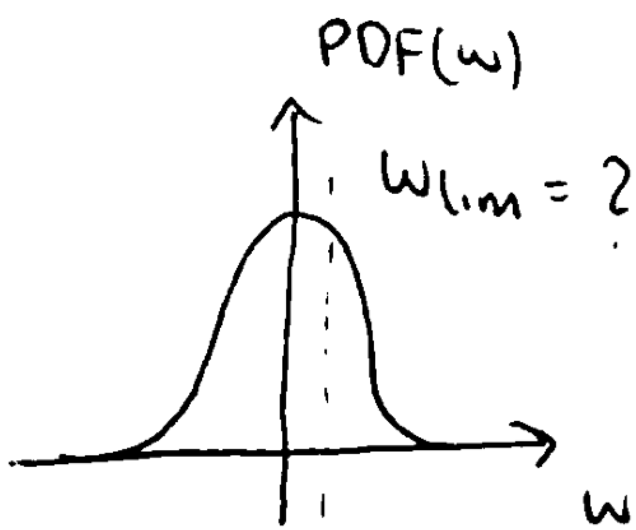


Hierarchy of analysis:

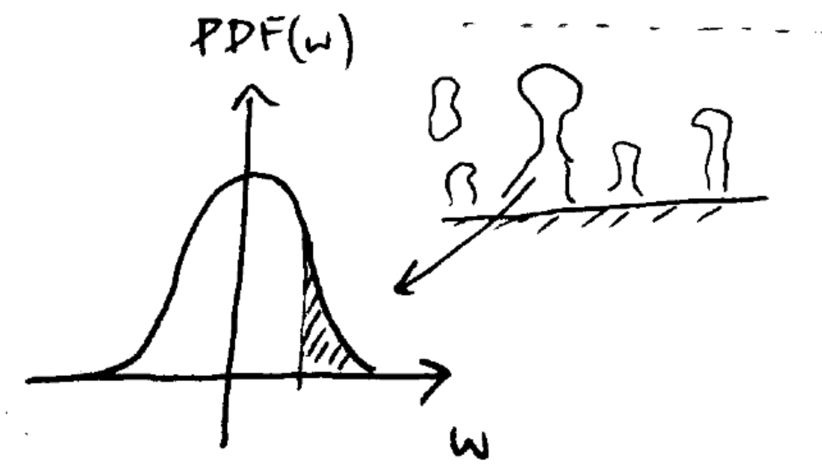
a) Vertical profiles of horizontally integrated properties, e.g. PDFs of scalars (without identifying triggering updrafts)

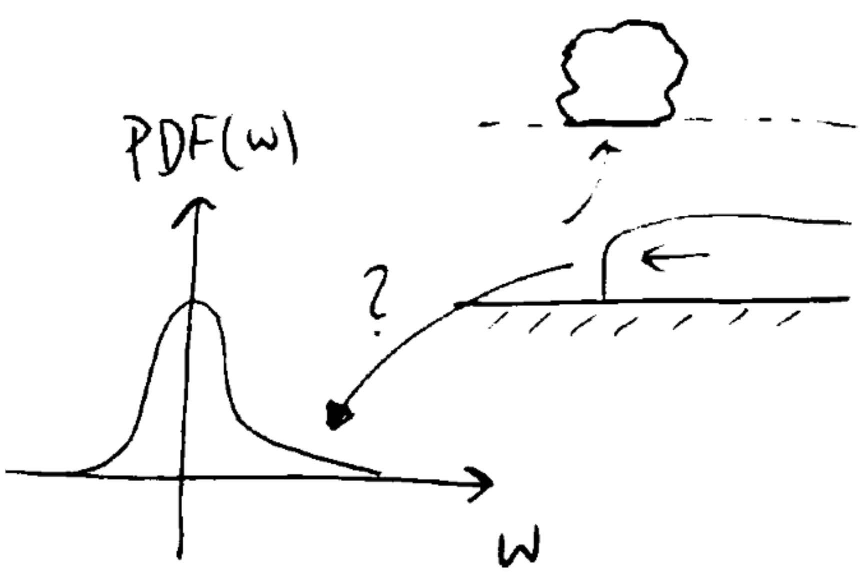
b) Vertical profiles of identified updraft regions (e.g. *two-fluid* partitioning)

- Is there an optimal partitioning of fluid between updrafts/environment (cf George's talk)?
- Interested in total BL vertical transport or only thermals which trigger convection?



How does this fit into CoMorph?





Hierarchy of analysis:

…

c) Object-based decomposition of horizontal variability

- e.g. reconstruct PDFs using only *N-largest* objects, construct *object size* vs *scalar perturbation* PDFs or identify triggering objects

d) Identify cause of change in vertical profiles and new scalar quantities which parameterise change

- e.g. *the presence of a cold pool with magnitude* $\Delta\theta_v$ *modifies the skewness of the PDF(w) by* $\alpha\Delta\theta_v$

How does this fit into CoMorph?

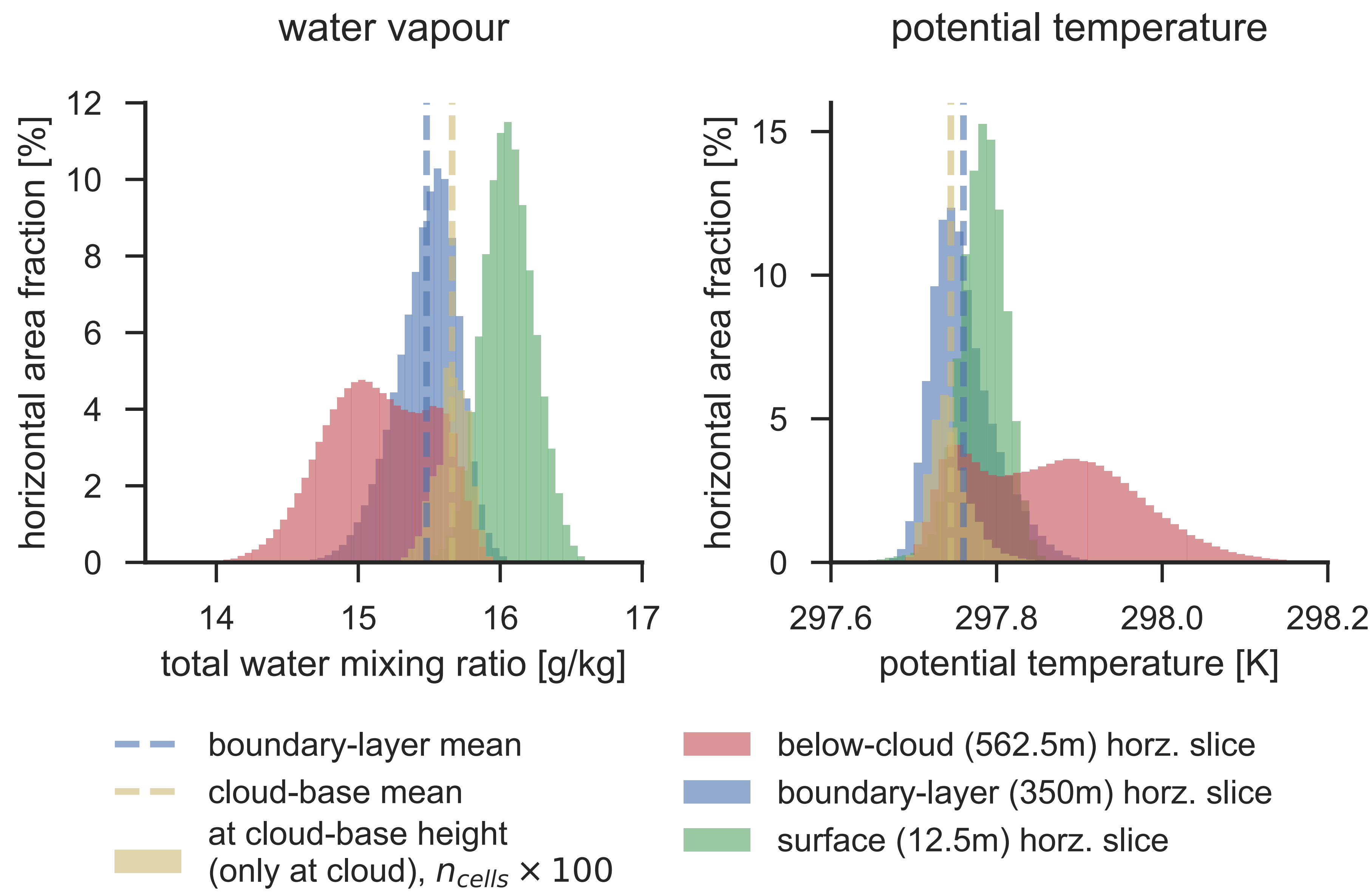
Identified three specific things to measure in LES:

1. PDF(w, q_t, θ_v) std. div. vertical profile in boundary-layer
   - $\overline{w^2}$ currently predicted from BL scheme (*$K_m(z)$, $\tau_{BL}(z)$*) used for "mass-source" in plume model, is this valid when sub-grid *phenomena* are introduced?

2. PDF(w, q_t, θ_v) skewness vertical profile
   - Higher skewness => more parcels with large w => more parcels available to overcome CIN? Is pure Gaussian (no skewness) a reasonable assumption?

3. JPDF($\overline{w^2}$, λ) vertical profile in boundary-layer
   - Does vertical velocity variability depend on object size?

What are the magnitudes variability?

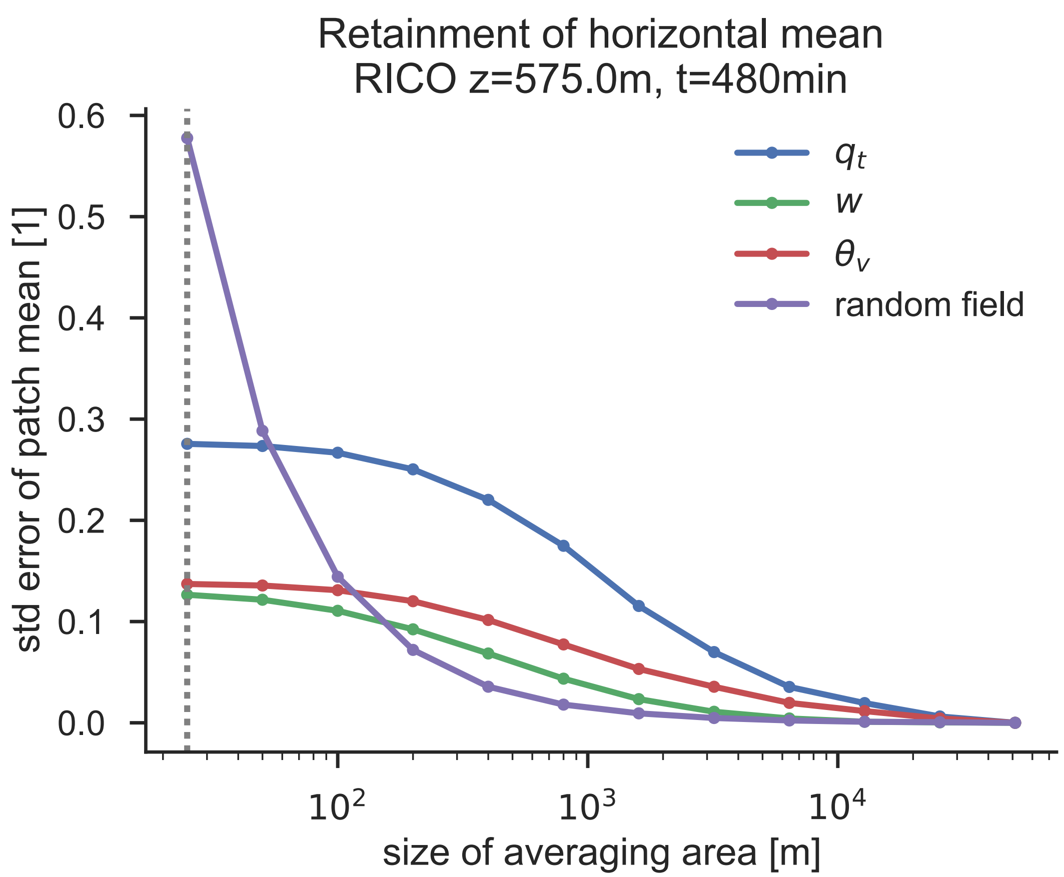


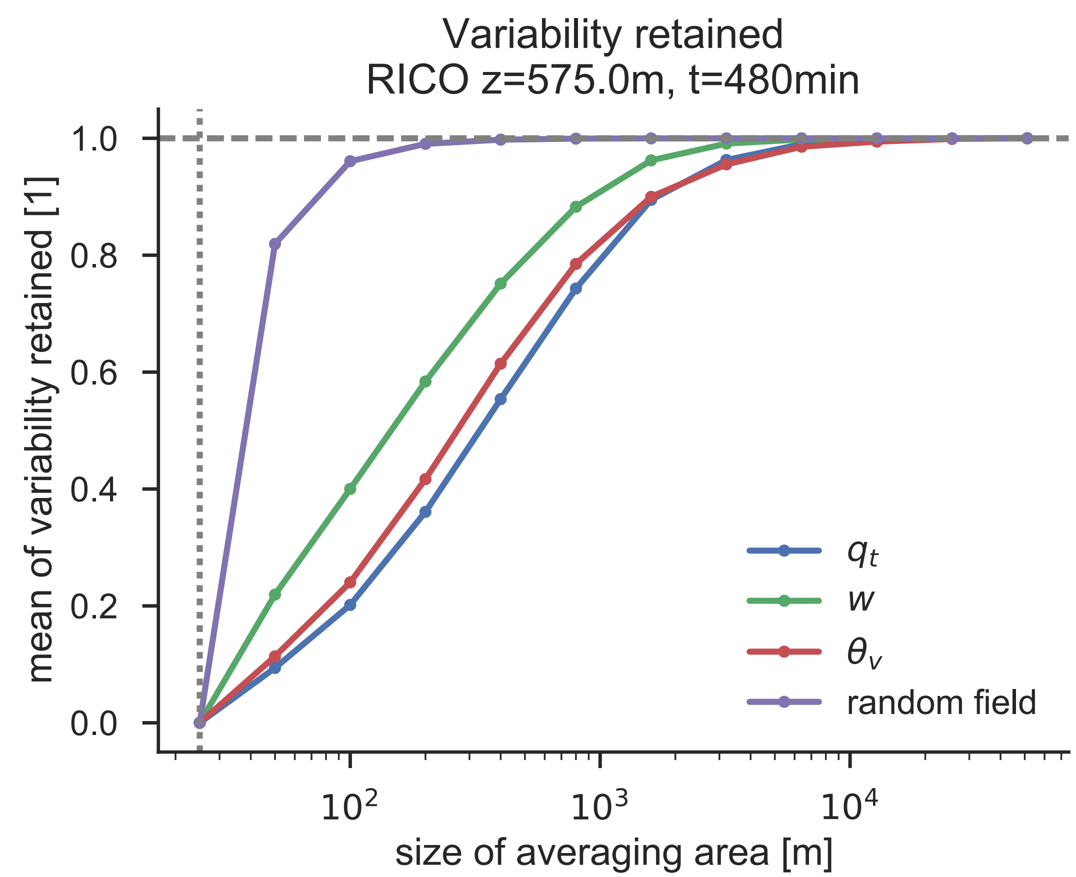
- Separating out properties of cloud-triggering air from boundary layer PDFs

What's new?

- Working on RICO-setup in MONC
  - Producing write-up of UCLA-LES formulations of surface fluxes, has 5 formulations including *bulk-aerodynamic* (which is missing in MONC). Aim to implement in MONC
- Been looking at scales of variability in boundary-layer
- Tool for 3D/2D object identification and calculation of characteristic properties
  - Example usage by contrasting shear vs no-shear RICO-like setup
- High time-resolution 3D output (Δt=1min) simulations and tracking tool to extract sub-domain datasets containing only single cloud (and trigger region)
  - Will be used to study properties of air triggering individual clouds

What are the length-scales of variability?





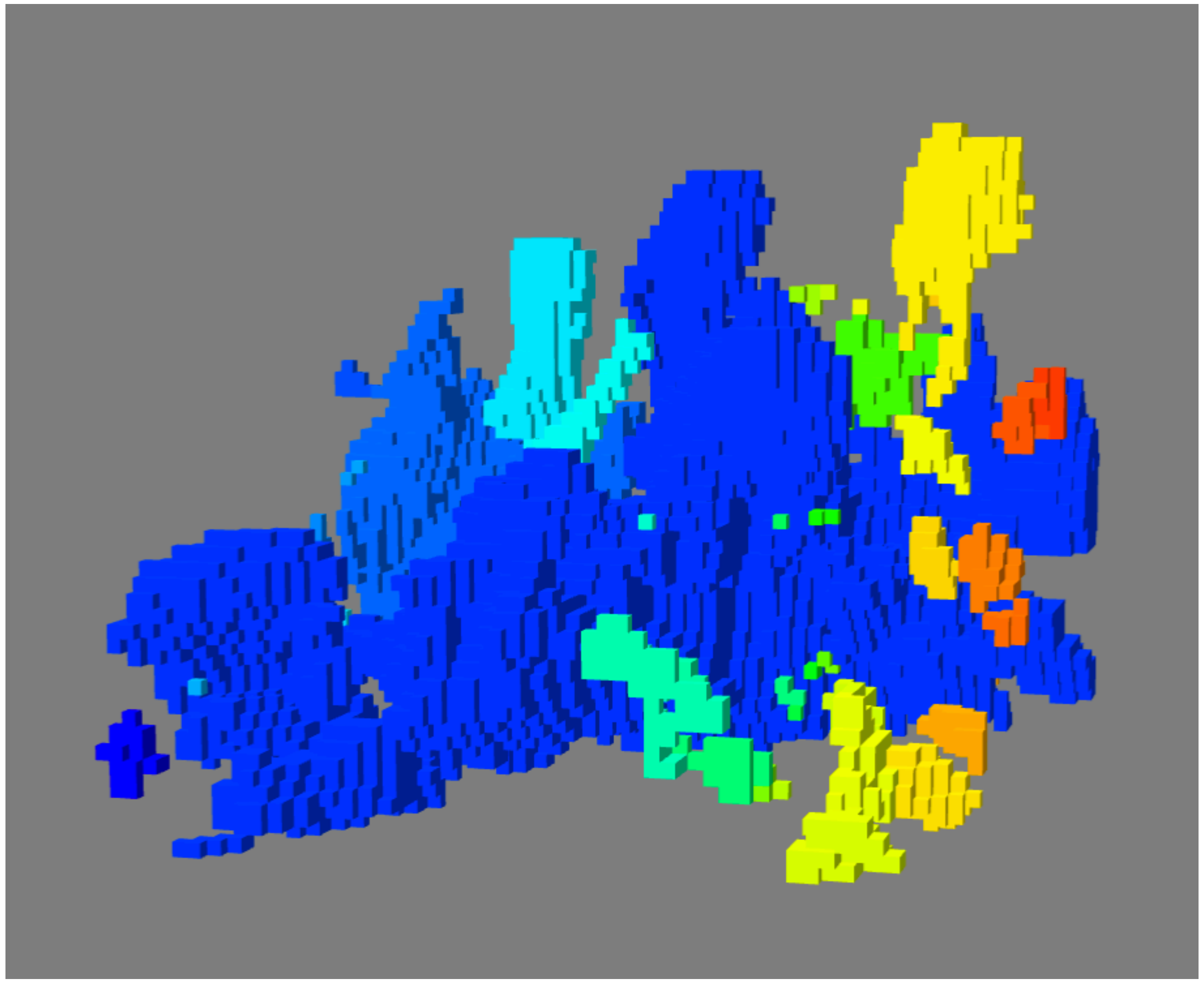
- Split domain into successively smaller patches to evaluate change in statistics

➡ scales of variability are different for different scalar fields

➡ ~90% of variability retained with L~1000m for θ_v and q_t, ~95% for w

Identifying individual triggering objects

- Identify (and later, track in time) boundary layer structures which cause convection to trigger
  - ➡ Developing cloud-tracking code with Steven Boeing
- Use to partition distributions of variability by individual objects (of specific size, volume, shape, etc)



Buoyant elements defined by w > 0.5m/s in boundary layer of RICO simulation at t=480min

➡ Investigating using object topology as means of classification (Contour-tree analysis by Hamish Carr, Leeds)

What are characteristic sizes of objects in the boundary layer?

- Use Minkowski functionals to compute characteristic length-scales

$$V_0 = V = \int dV$$
$$V_1 = \frac{A}{6} = \frac{1}{6}\int dS$$
$$V_2 = \frac{H}{3\pi} = -\frac{1}{6\pi}\int dS \nabla \cdot \hat{n}$$
$$\left(V_3 = \frac{1}{4\pi}\int (\kappa_1 \kappa_2) dS \right)$$

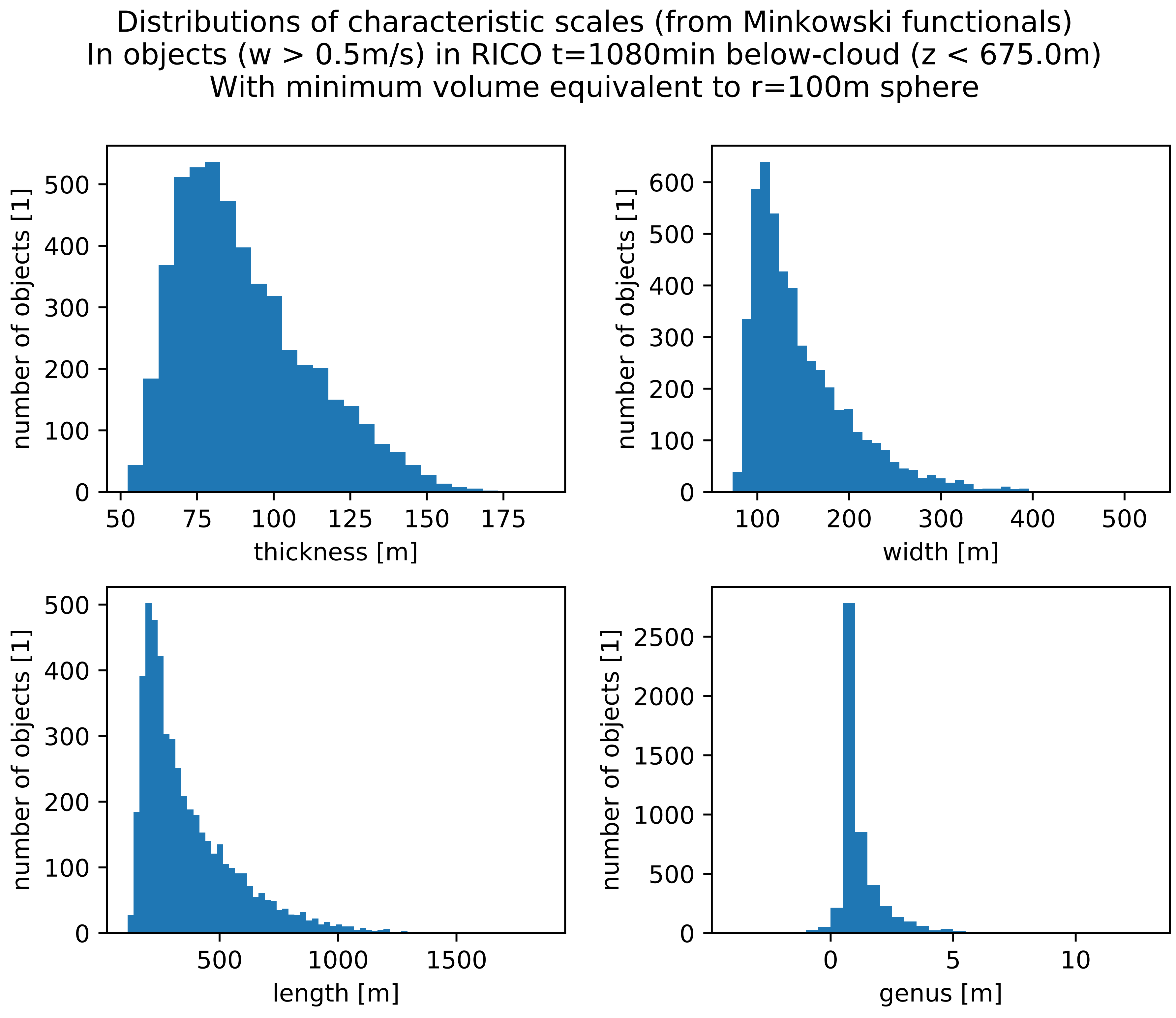
$$\Rightarrow$$

$$L = \frac{3V_2}{4V_3}$$
$$W = \frac{2V_1}{\pi V_2}$$
$$T = \frac{V_0}{2V_1}$$

$L \geq W \geq T$ *by construction*

V: volume, A: area, H: mean curvature, κ_1 and κ_2 intrinsic local curvature ($\nabla \cdot \hat{n} = \kappa_1 + \kappa_2$)

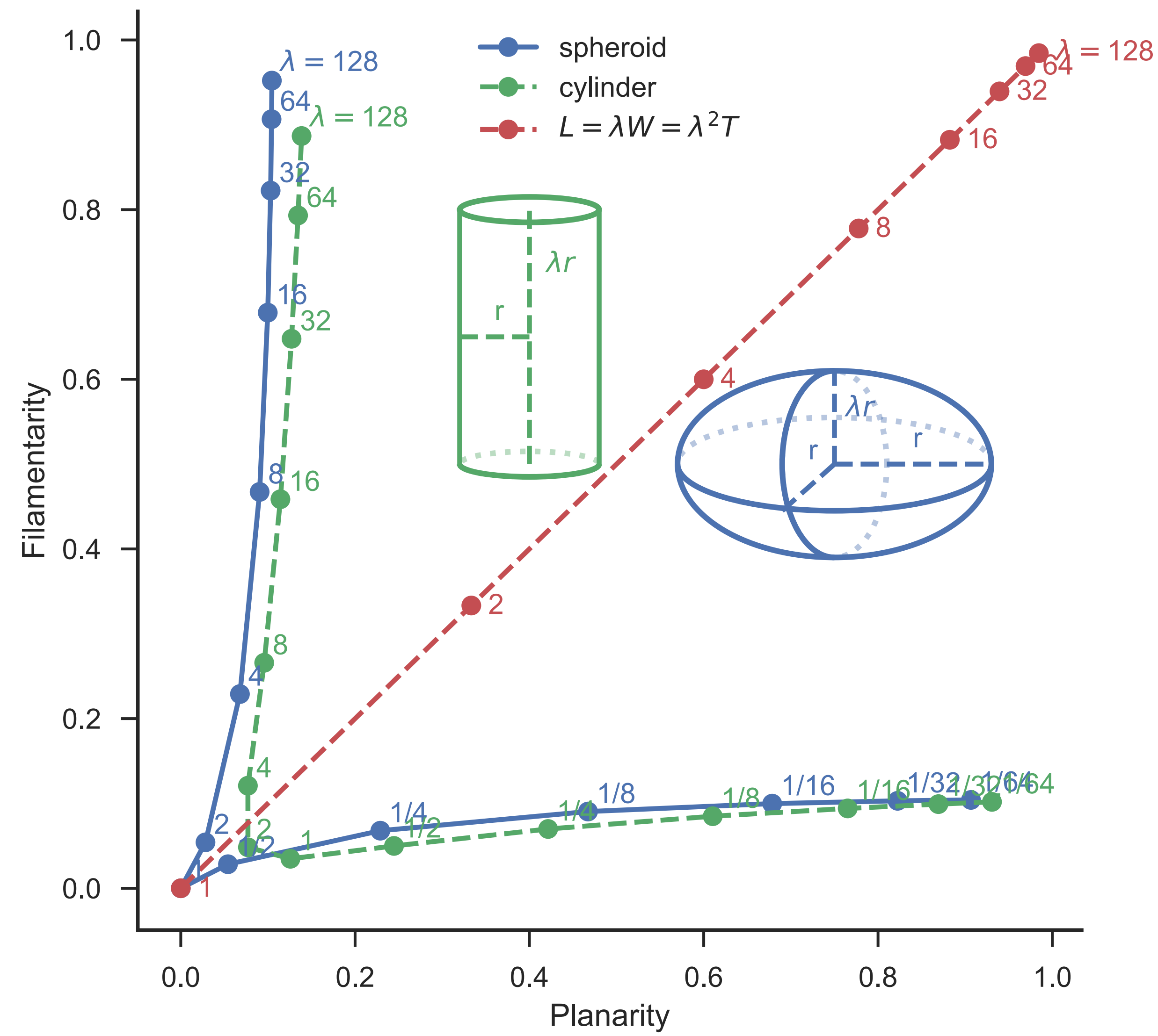
What are the characteristic length-scales of boundary layer structures?



What is shape of objects in the boundary layer?

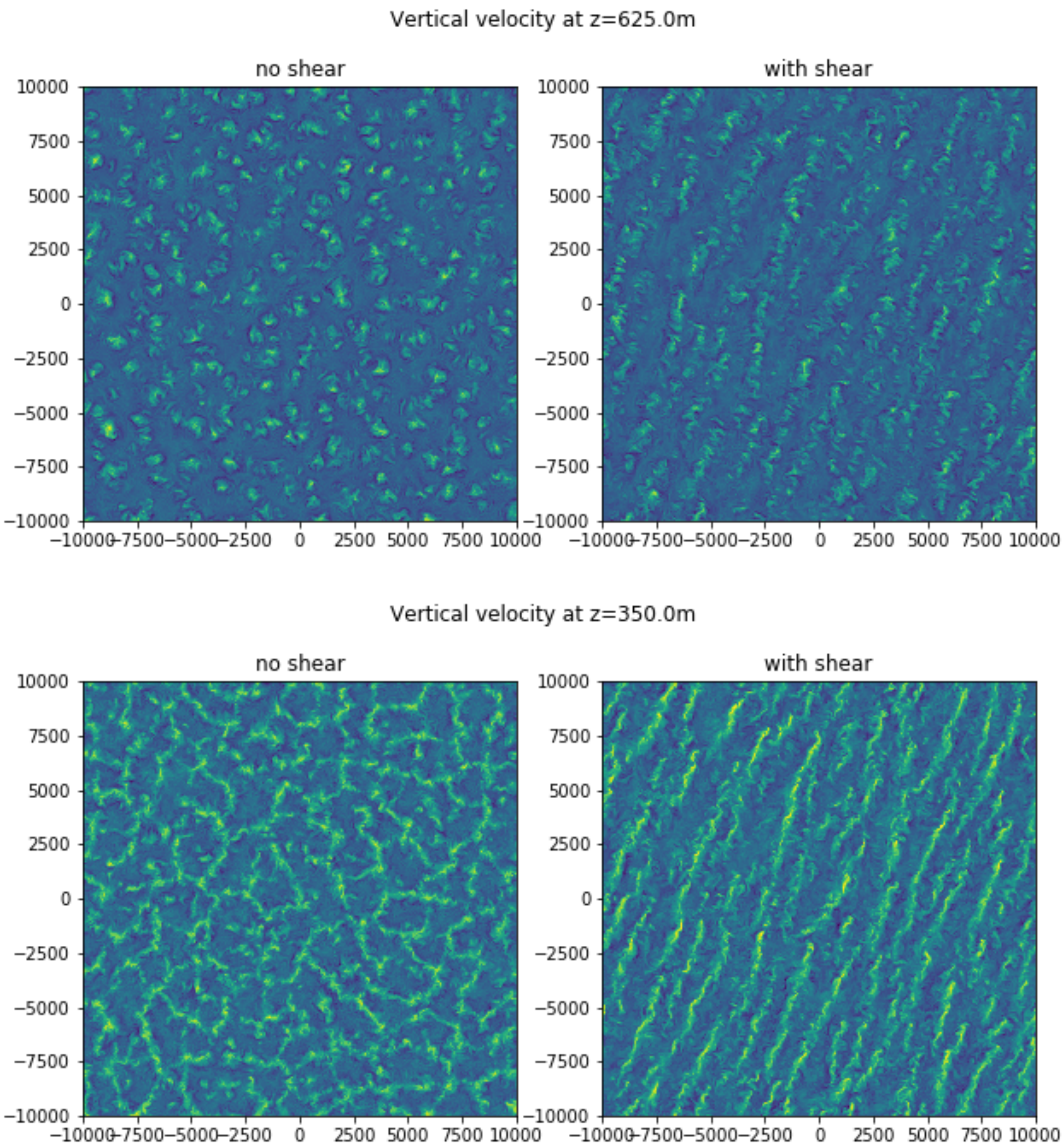
Calculate the planarity (P) and filamentary (F) from Minkowski functional length-scales

$$P = \frac{W-T}{W+T}, F = \frac{L-W}{L+W}$$



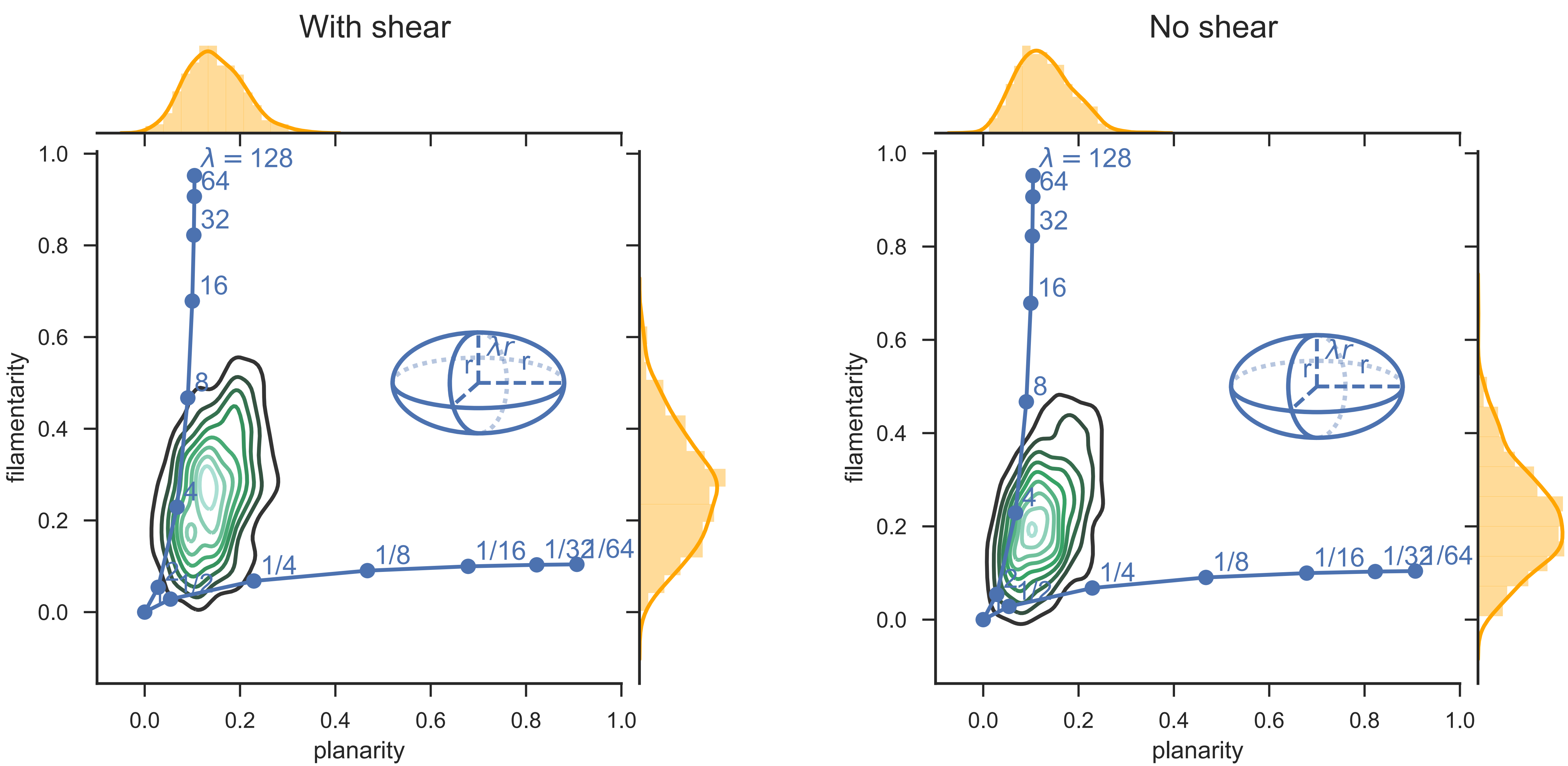
➡️ Measures how pencil or disc-like an object is

shear/no-shear RICO simulations

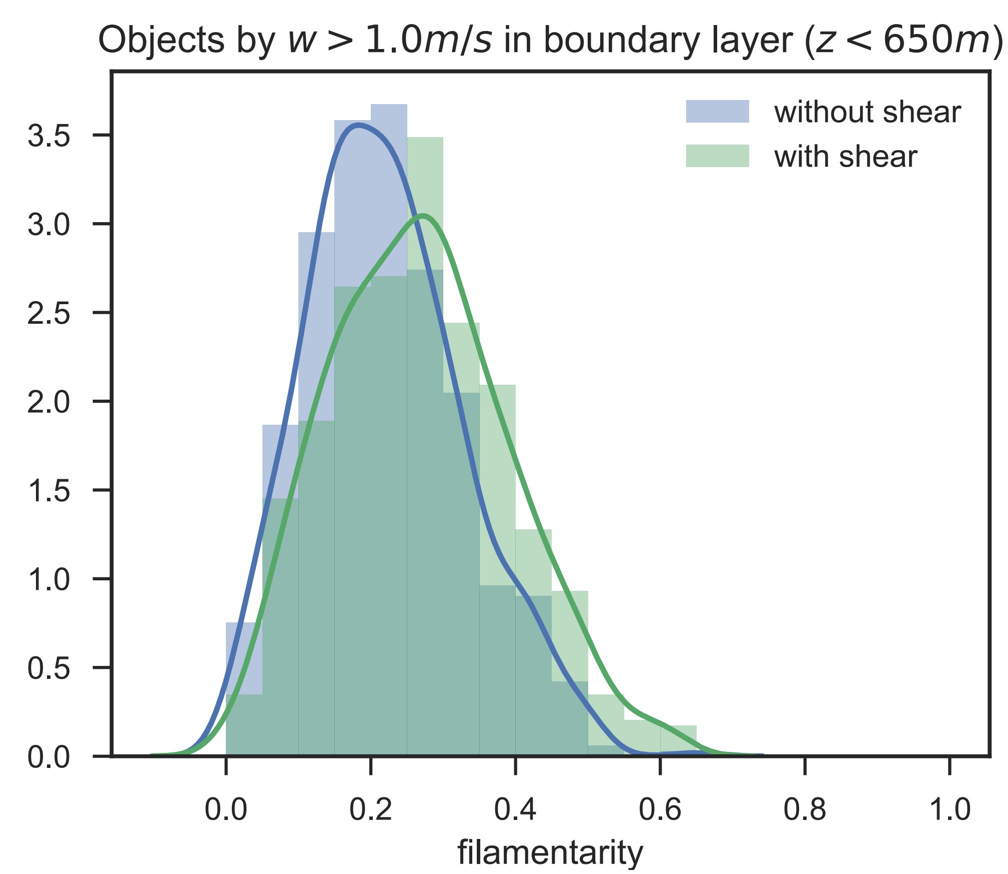


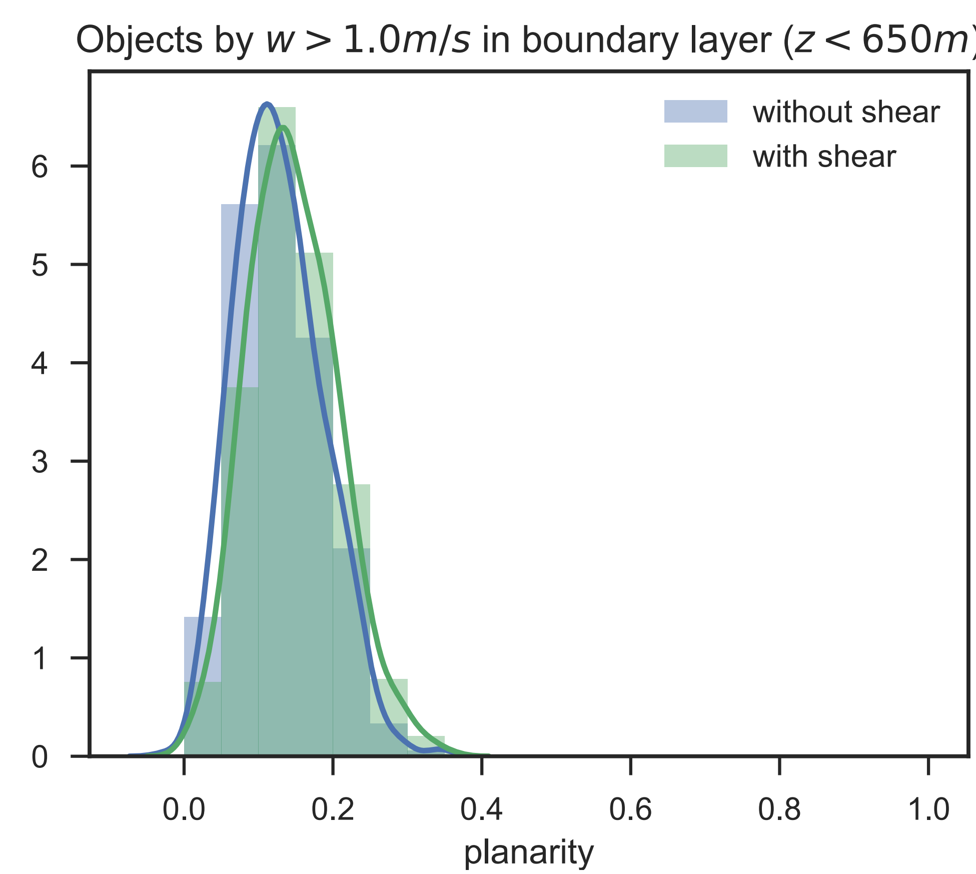
- Fixed fluxes (F_s=150W/m^2, F_l=7.0W/m^2)
- Convective cells instead of rolls in boundary layer
- In shear convection appears at ends of rolls?
- Without shear at nodes of cells?

Shear/no-shear affect on topology



Shear/no-shear affect on topology

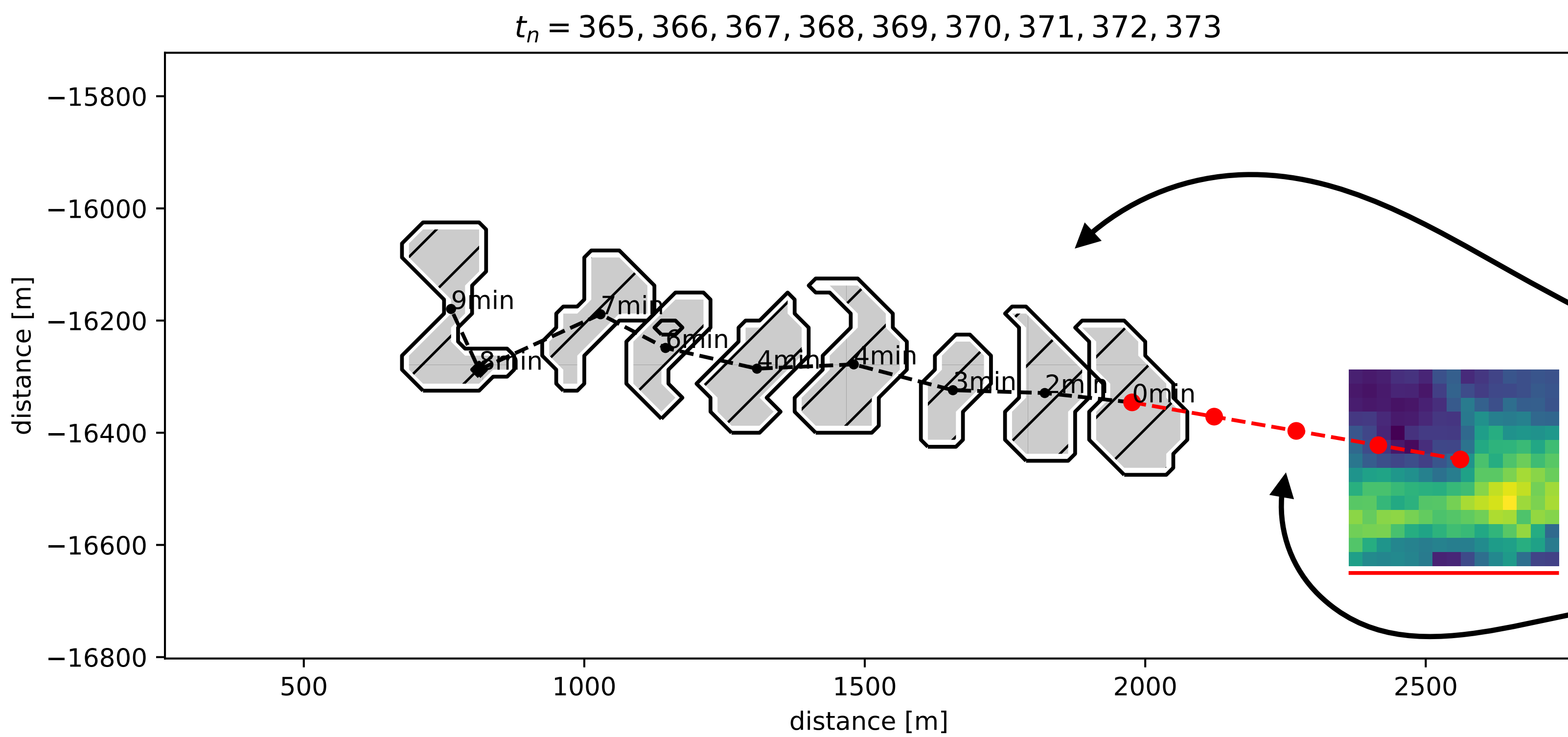


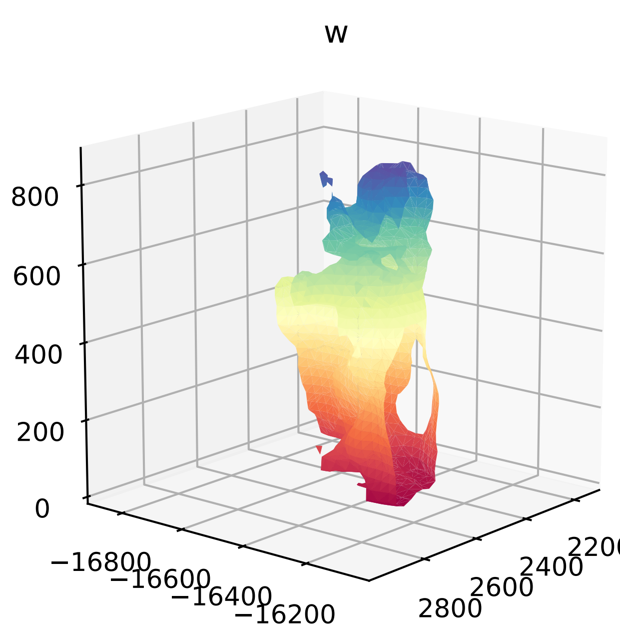


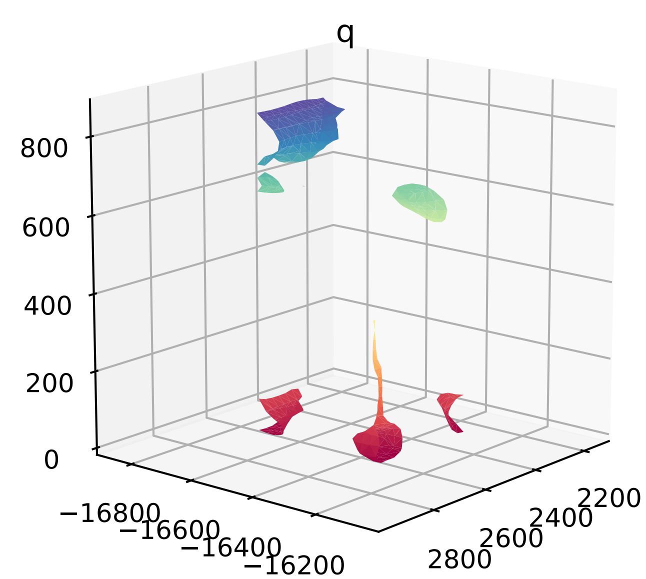
➡️ Shear appears to elongate boundary layer thermals

- Does this correlate with properties of triggering thermals?

Analysing BL properties in cloud-trigger region







- Cloud tracked over time
  - Cloud-base region plotted
  - Cloud-base horizontal velocity integrated back in time to estimate trigger region
- Iso-surfaces of vertical velocity and water-vapour deviation

What's next?

- Make new setups which introduce sub-grid phenomena into existing ParaCon setups where missing (e.g. cold pools, topography and surface flux heterogeneity)

- Use ParaCon setups in MONC (or even better *simulation output*) to compute profiles mentioned relevant to CoMorph

- Re-run ParaCon setups at high time-resolution in MONC to study boundary-layer air triggering individual clouds