UNIVERSITY OF LEEDS

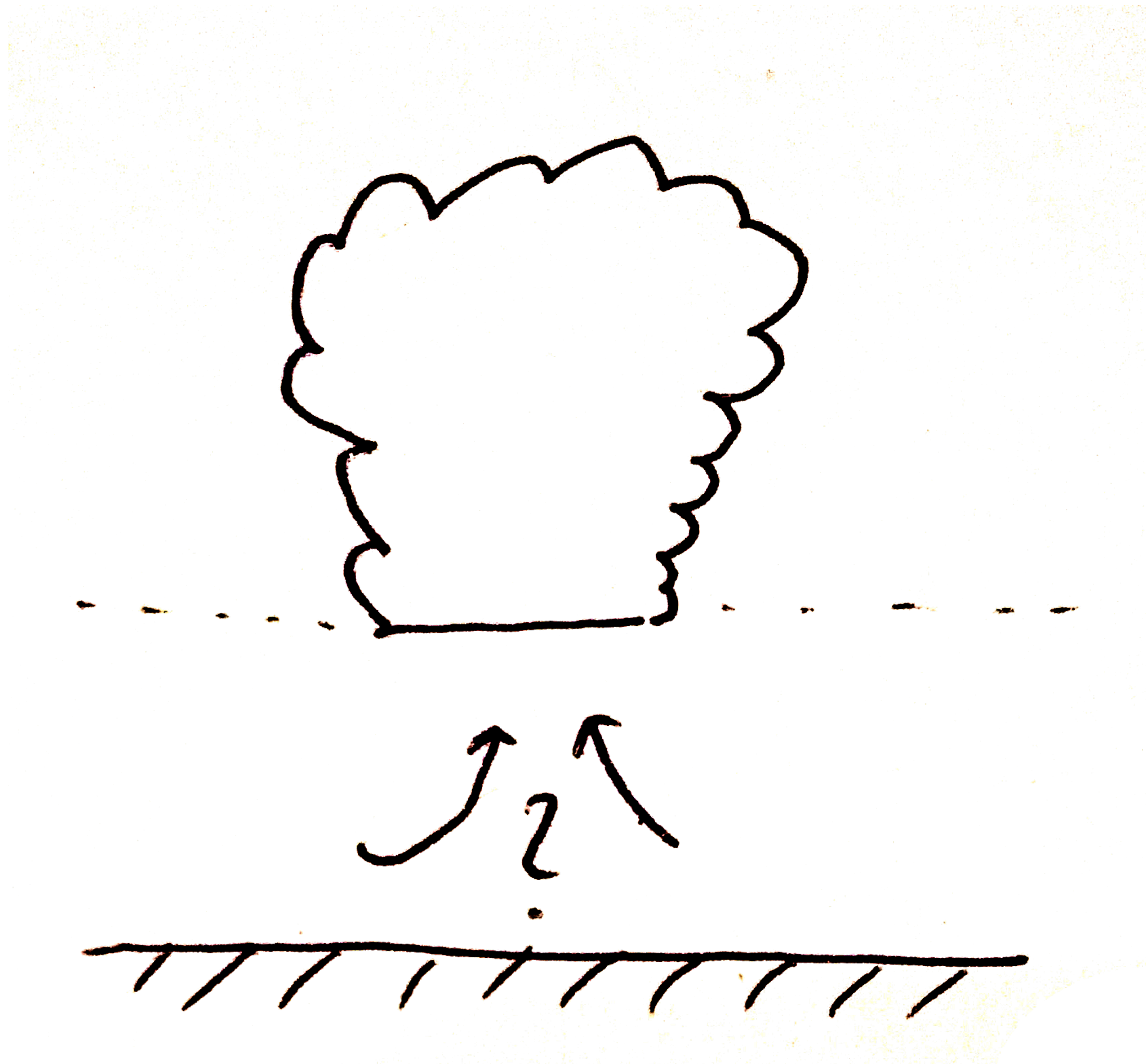
The GENESIS of convective organisation

Leif Denby, University of Leeds

25/4/2018, Neils Bohr Institute, Copenhagen

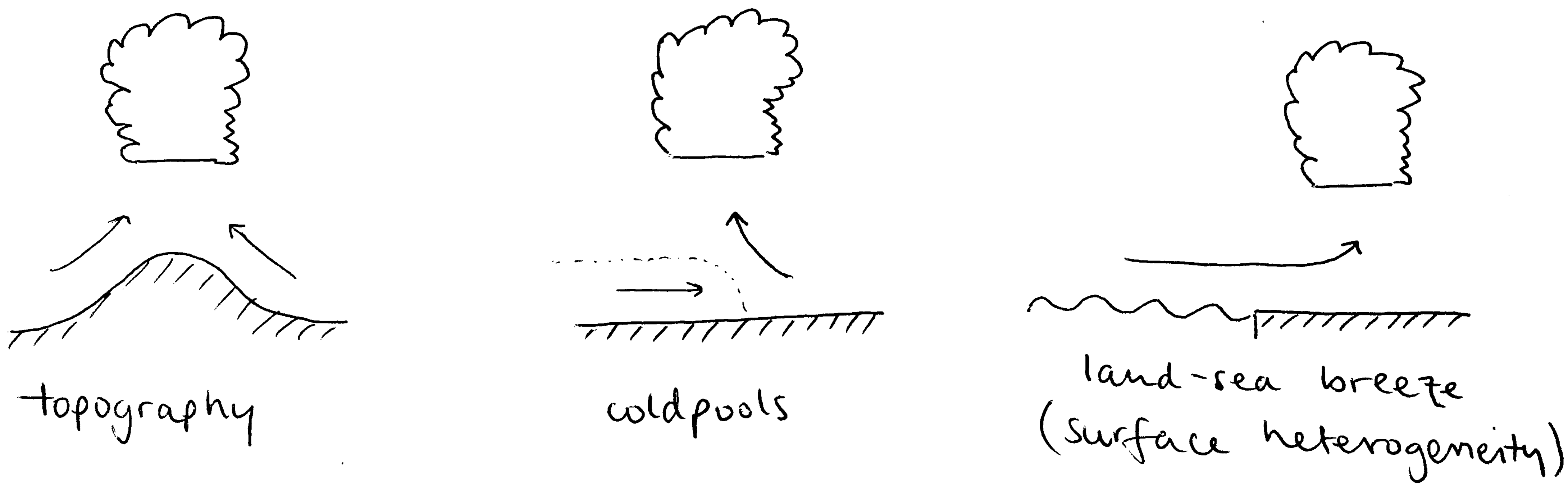
Workshop on Understanding Convective Self-organisation

Aim



Aim

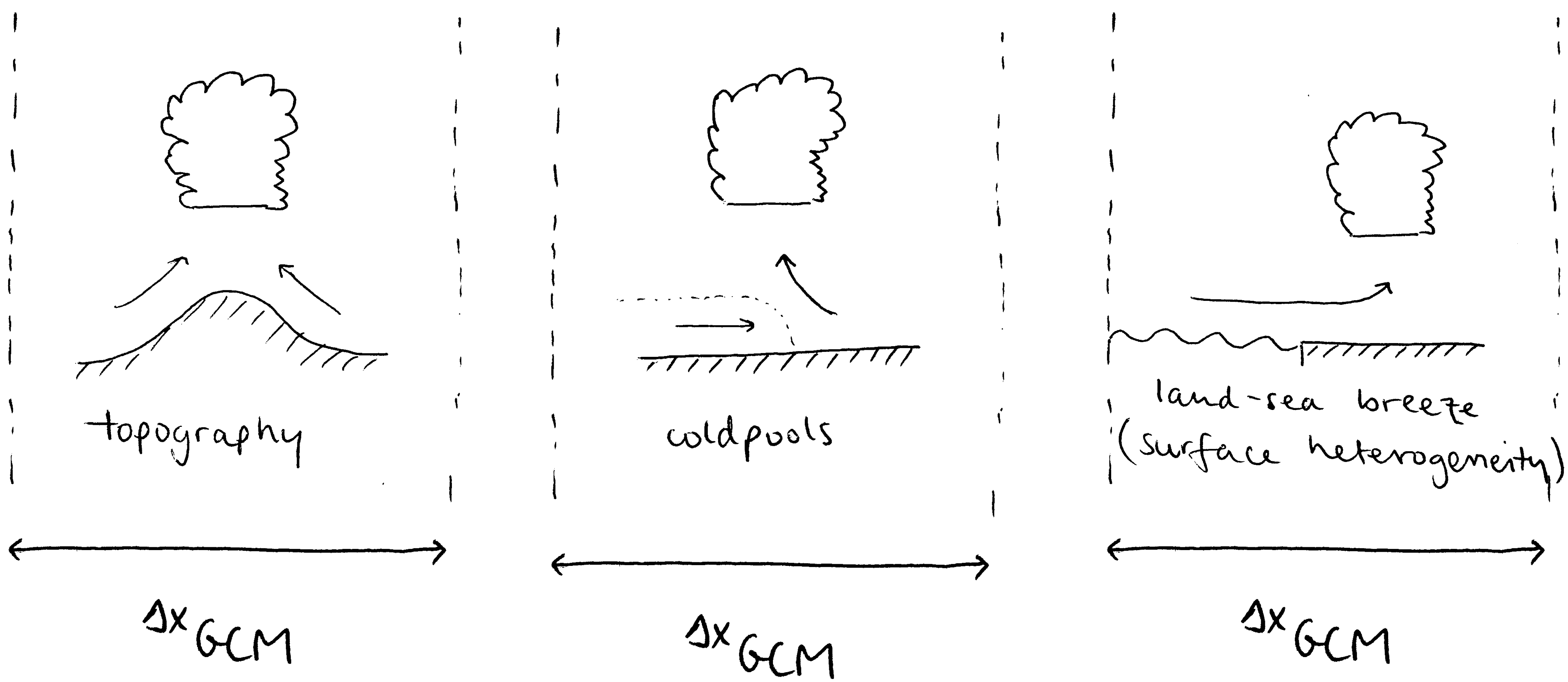
- Describe statistics of boundary layer relevant to triggering convection and the sensitivity to presence of different phenomena



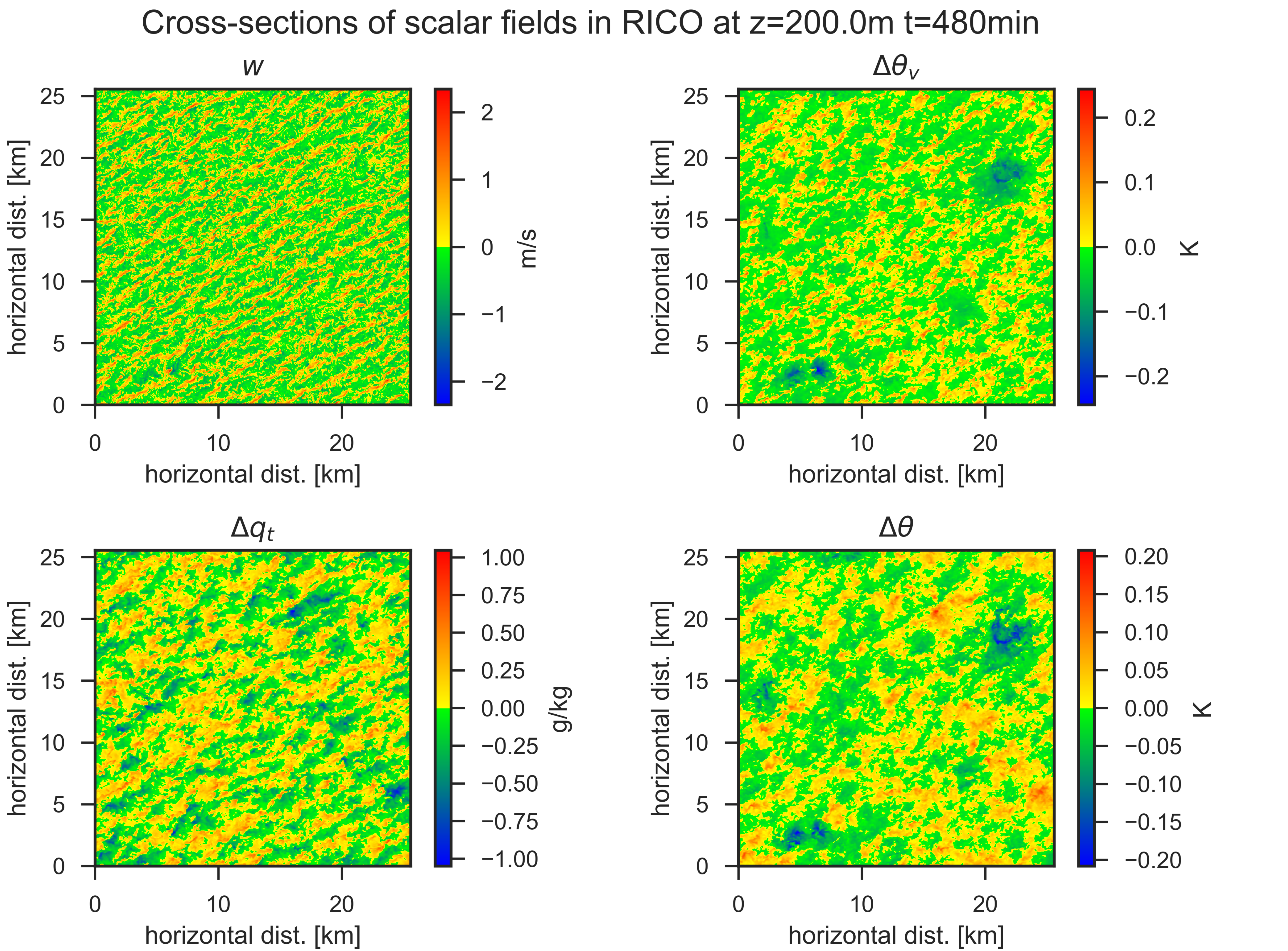
- *"What are the length-scales and magnitudes of perturbations which trigger convection?"*

Why?

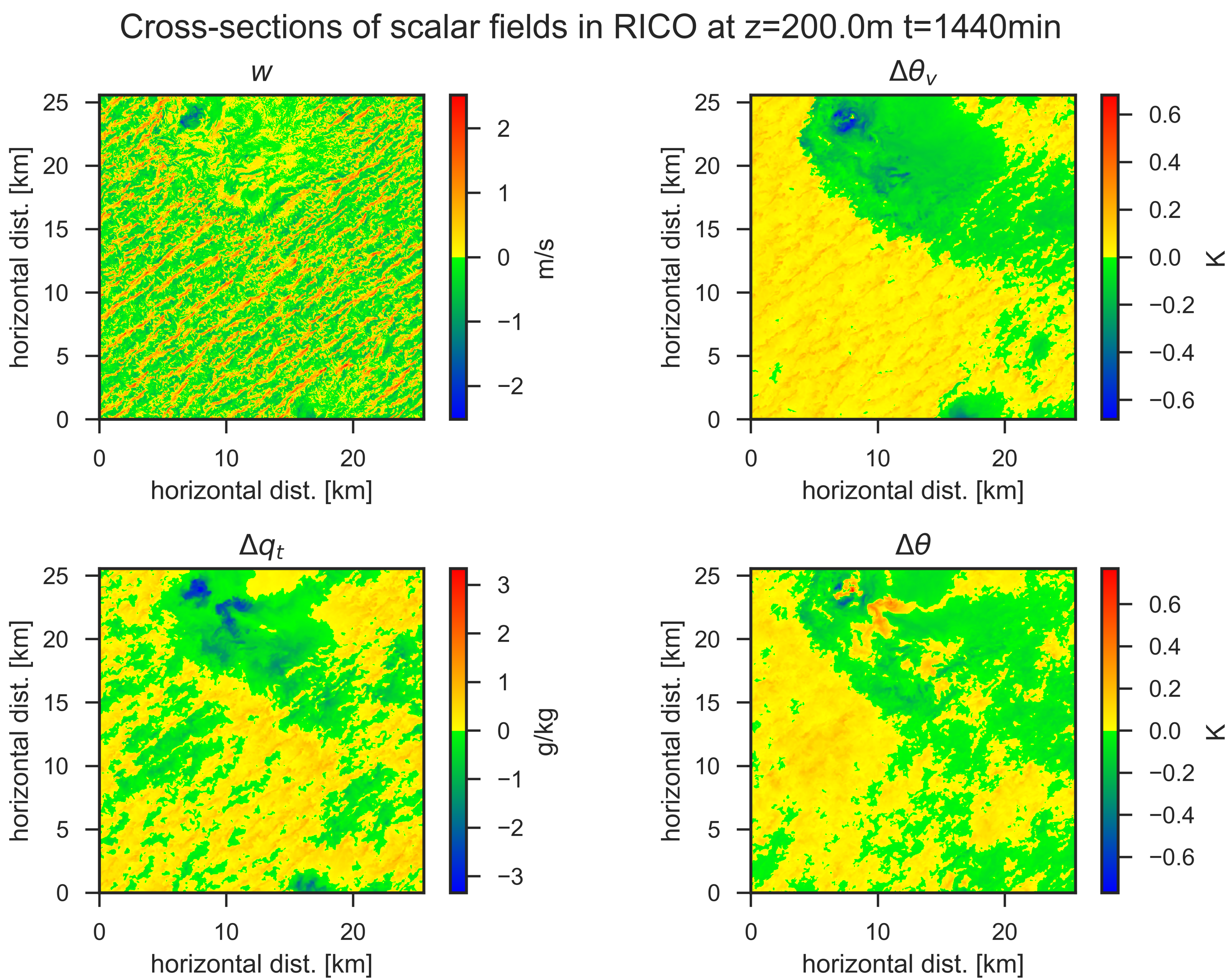
- GCMs have too coarse resolution to fully represent convection (O(km))
    - ➡ Trigger (and evolution) of convection must be parameterised
    - ➡ These *sub-grid* features are known to be critical in predicting formation of convection



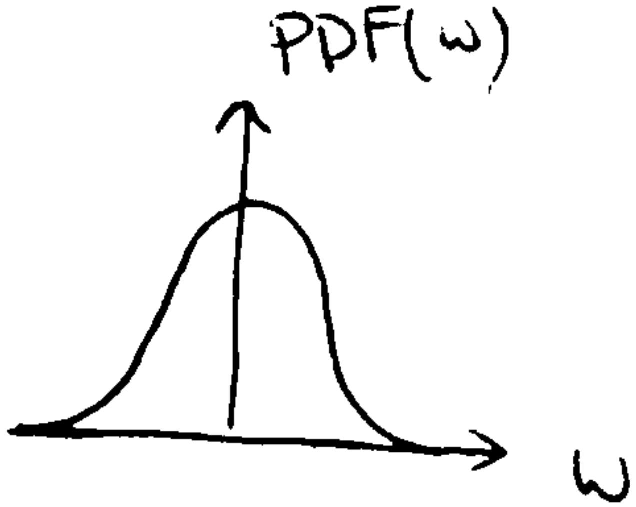
What are the length-scales of variability?



What are the length-scales of variability?



Researching things relevant to convective parameterisation

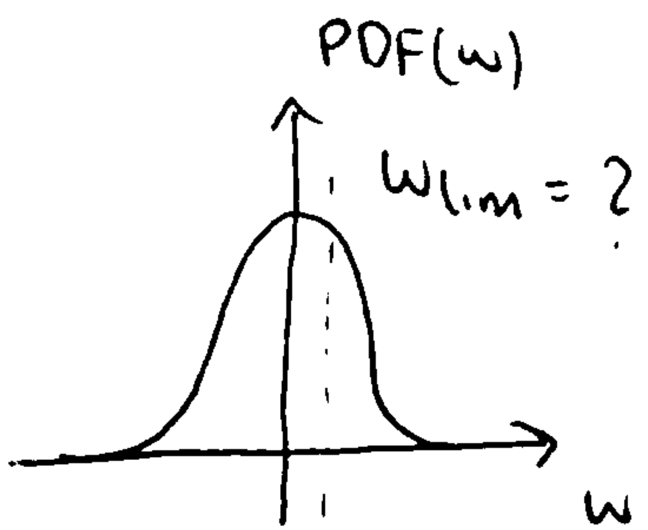


Hierarchy of analysis:

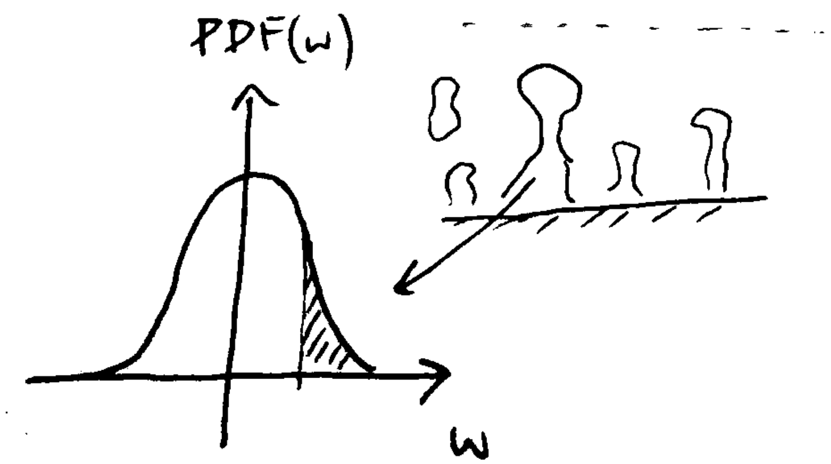
a) Vertical profiles of horizontally integrated properties, e.g. PDFs of scalars (without identifying triggering updrafts)

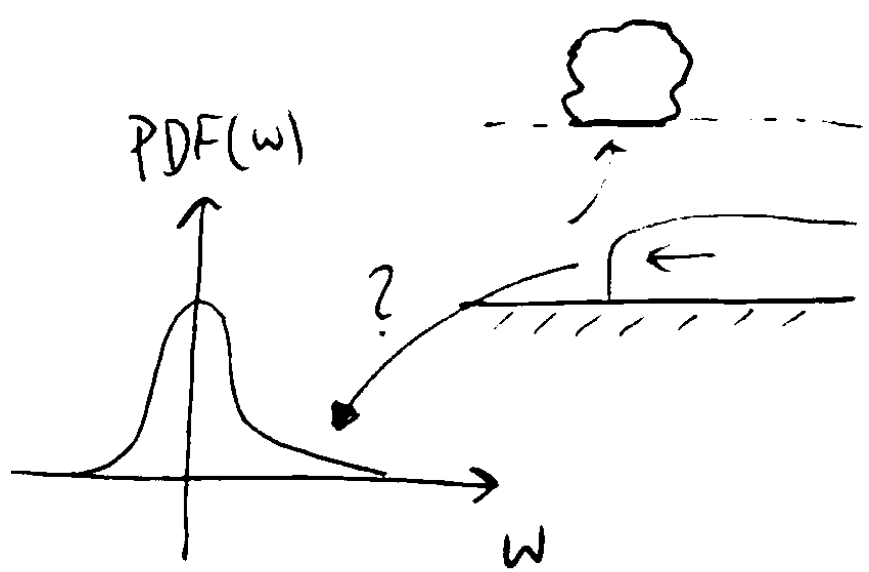
b) Vertical profiles of identified updraft regions (e.g. *two-fluid* partitioning)

- Is there an optimal partitioning of fluid between updrafts/environment?
- Interested in total BL vertical transport or only thermals which trigger convection?



Researching things relevant to convective parameterisation





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* $\alpha\Delta\theta_v$

Three coldpool questions

1. Do coldpools alter the bulk statistics in the boundary layer?

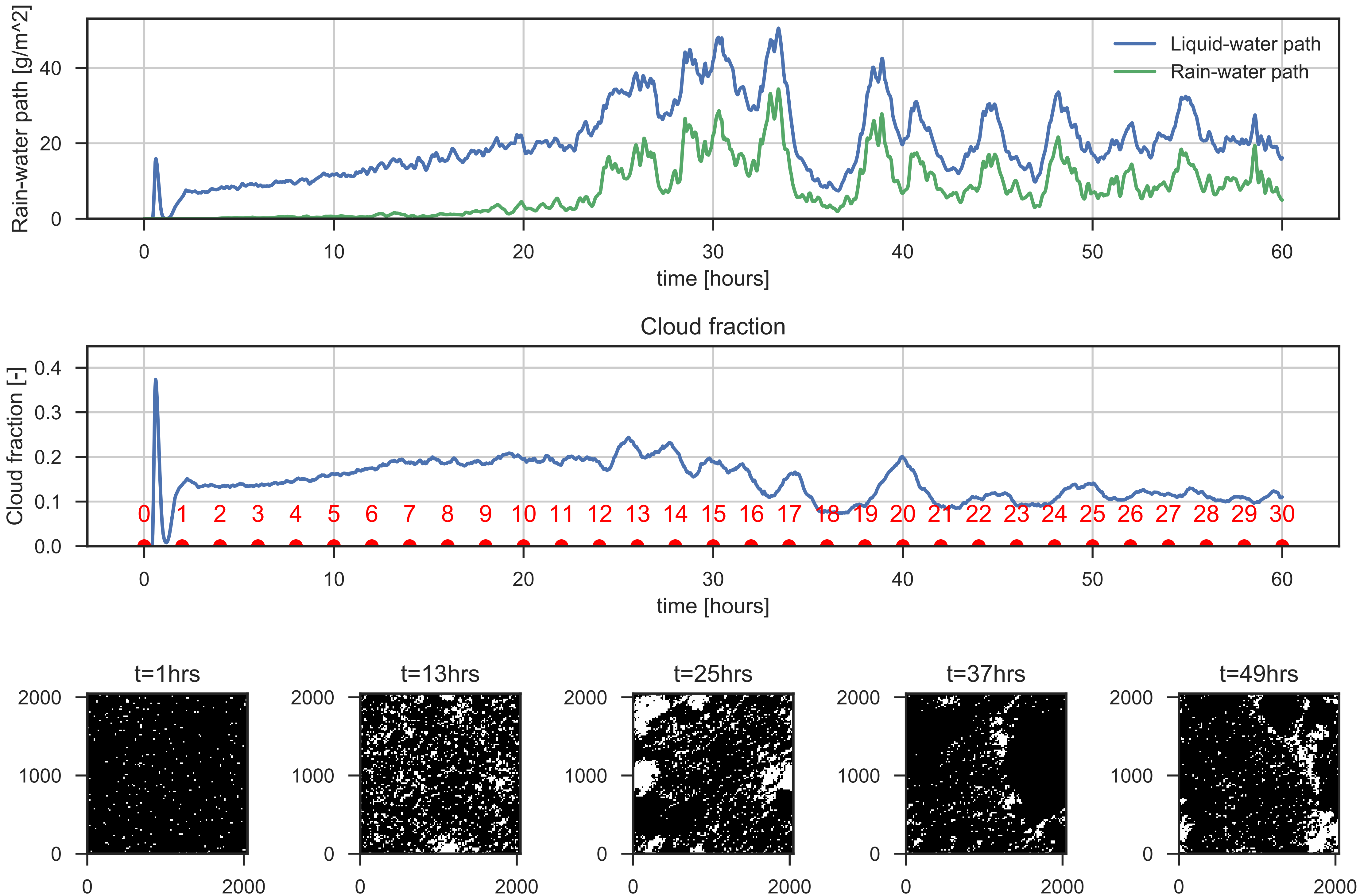
2. Spatial (horizontal) variation in coherent length-scales?

   - different length-scales within, outside or near coldpool edge?

3. Time variation of coherent length-scales?

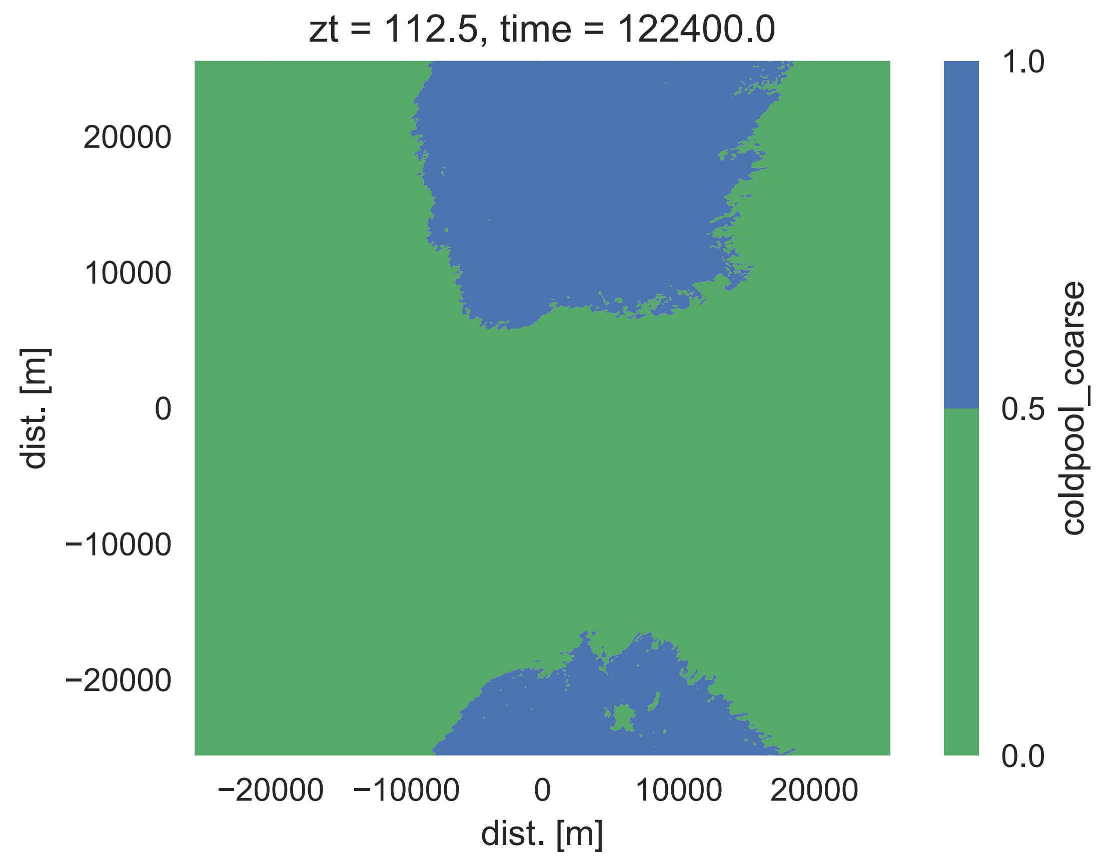
   - does formation of coldpools affect coherence outside of them?

RICO: overview

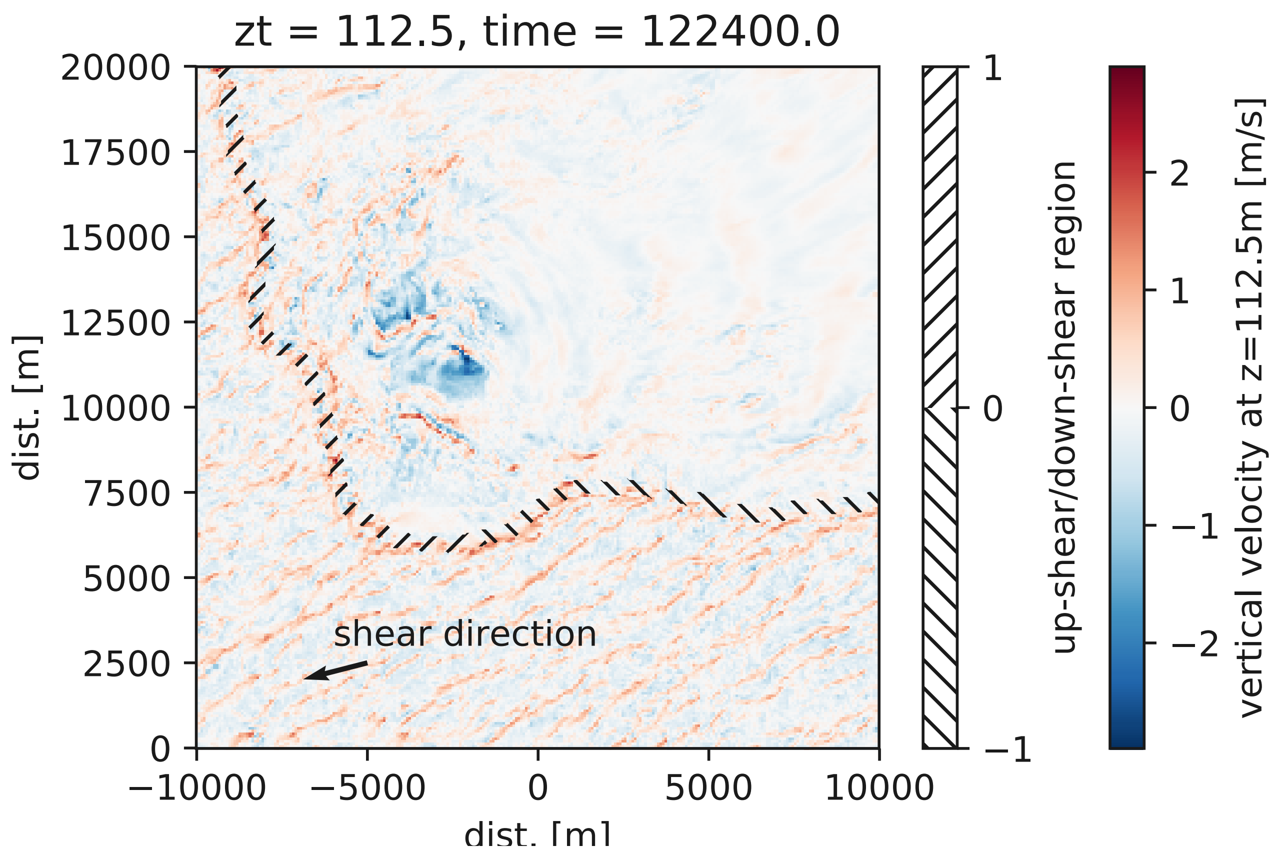


Domain decomposition

Identifying interesting regions to study



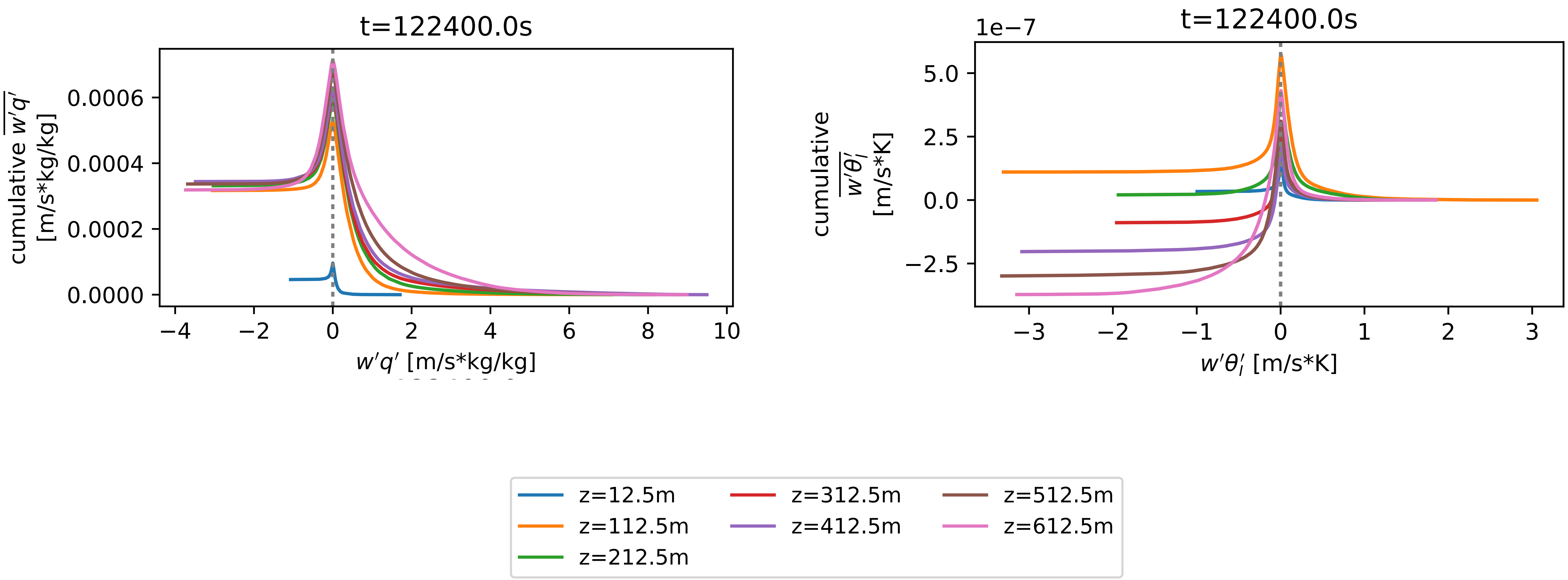
Using density anomoly ($\theta_v' < -0.1K$) to define coldpool region



Using mean direction of ambient shear and coldpool edge orientation to identify up-shear/down-shear edge

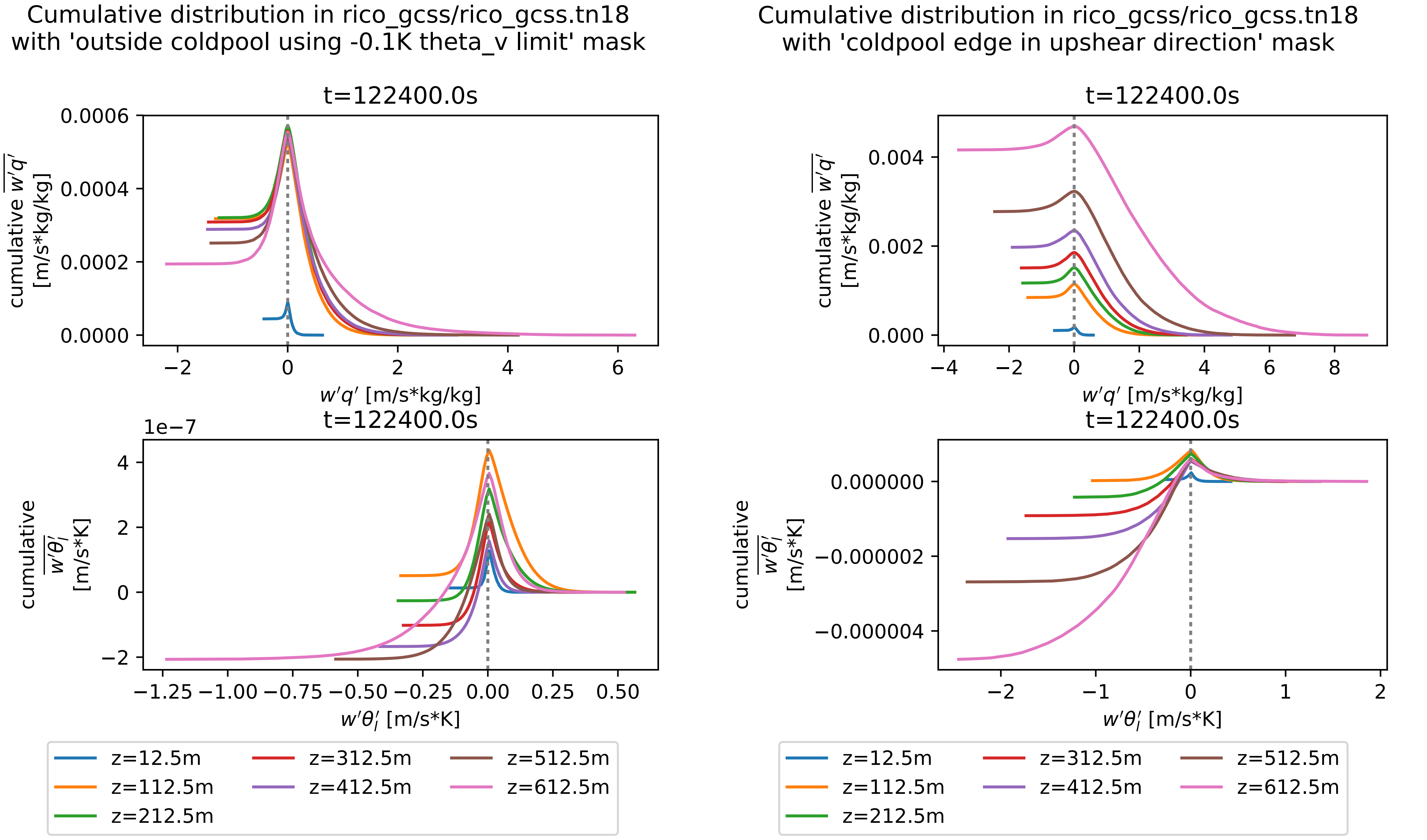
Bulk statistics

Cumulative distributions of moist and heat fluxes



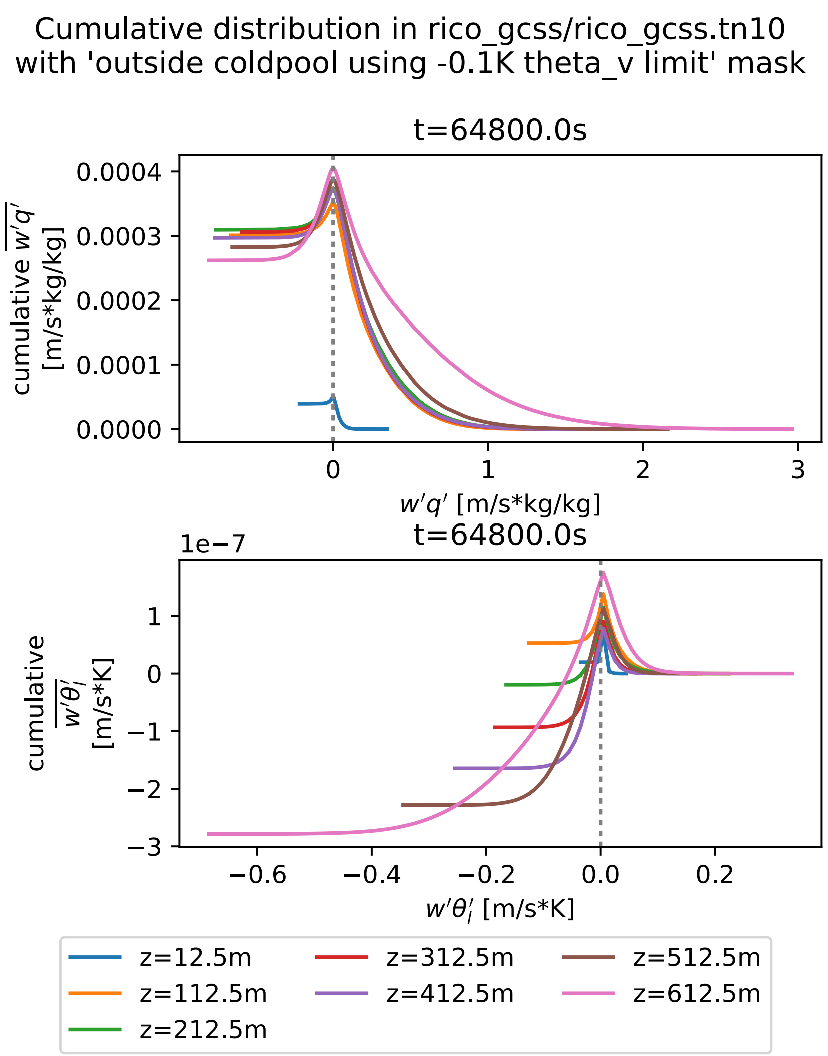
Bulk statistics

Outside coldpool and up-shear coldpool edge

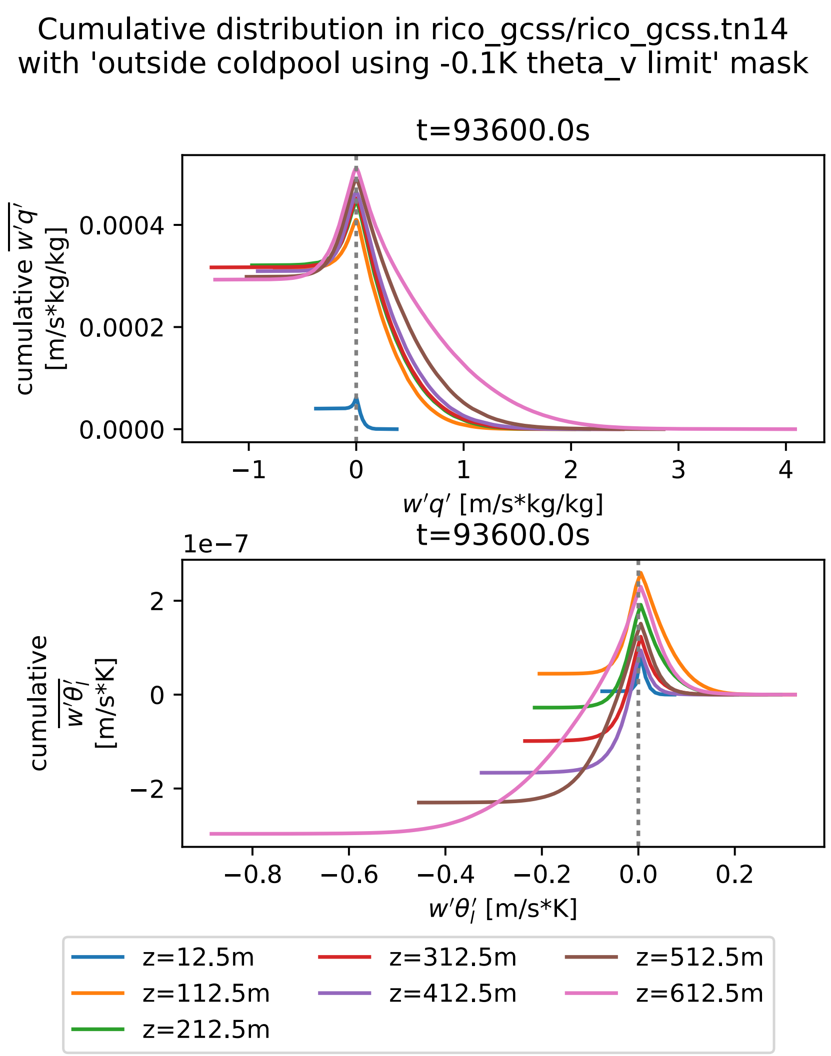


Bulk statistics

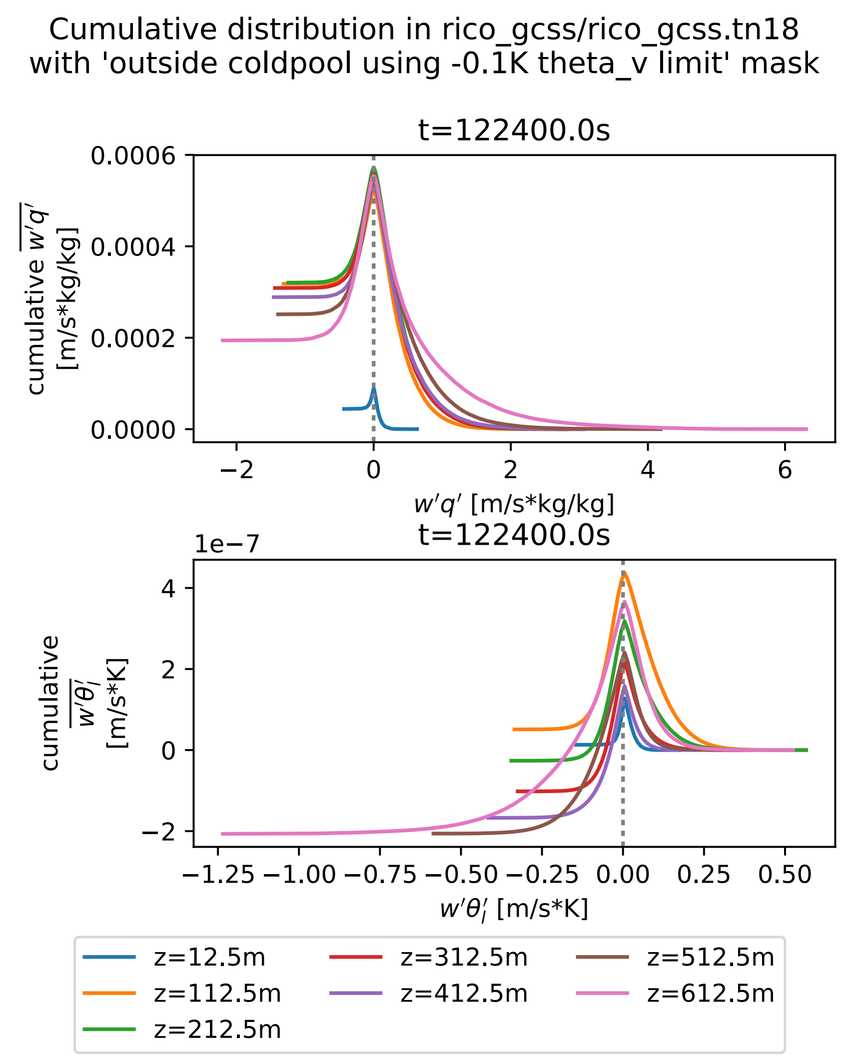
Before and after convective organisation



No organisation



Isolated coldpools



Convection arc

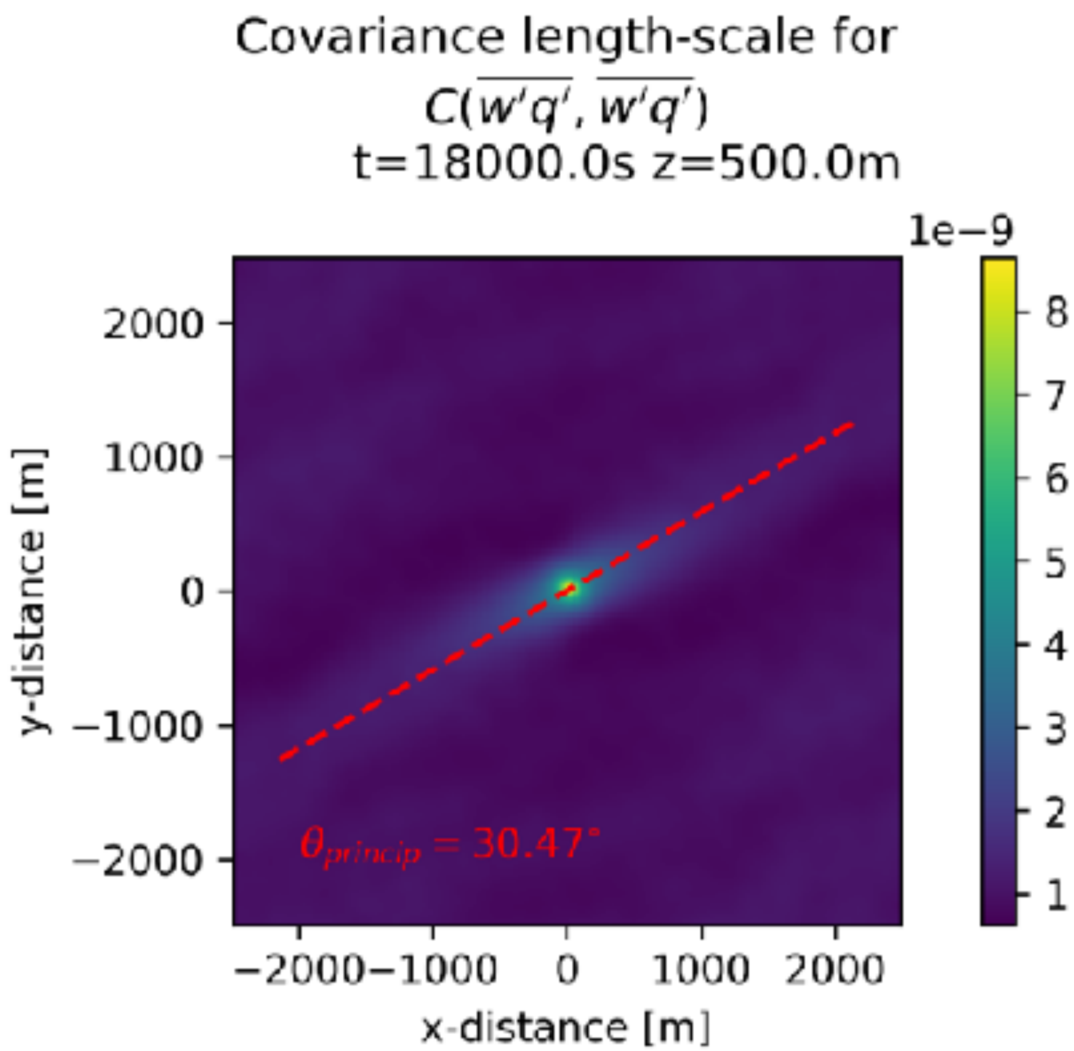
Use of cumulants to study characteristic scales

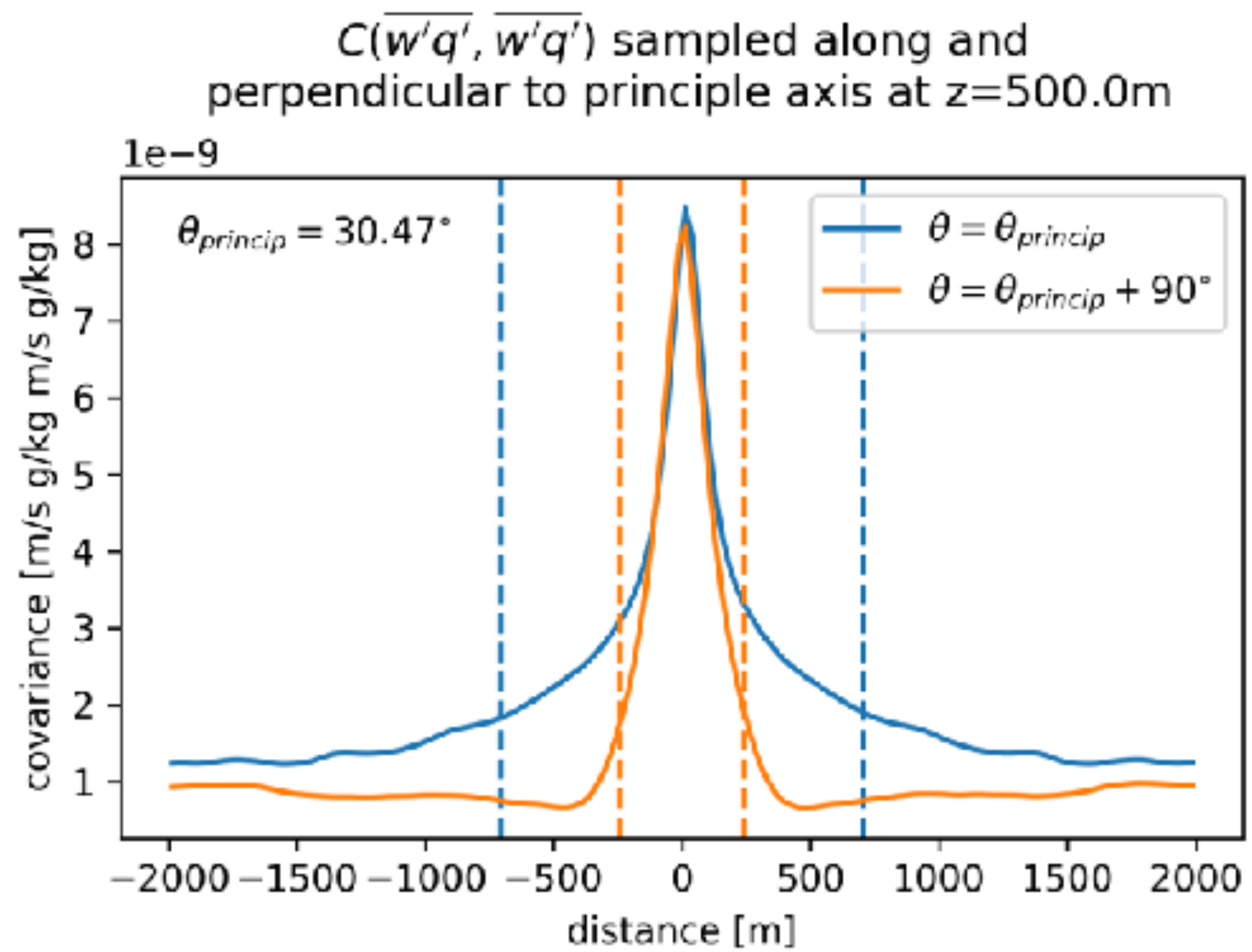
- Two-point correlation of two scalar fields (ϕ and ψ), here taken at same height (z) for both fields

$$c_{\phi\psi}(\xi, \mu, z) = \frac{1}{L_x L_y} \int_0^{L_x} \int_0^{L_y} \phi'(x, y, z)\psi'(x + \xi, y + \nu, z) dx dy$$

- Measures how correlation with distance (in xy-plane) of scalar fields
- Used by Tobias and Marston 2016 to identify principle length-scales in 3D cuvette flow

Use of cumulants to study characteristic scales

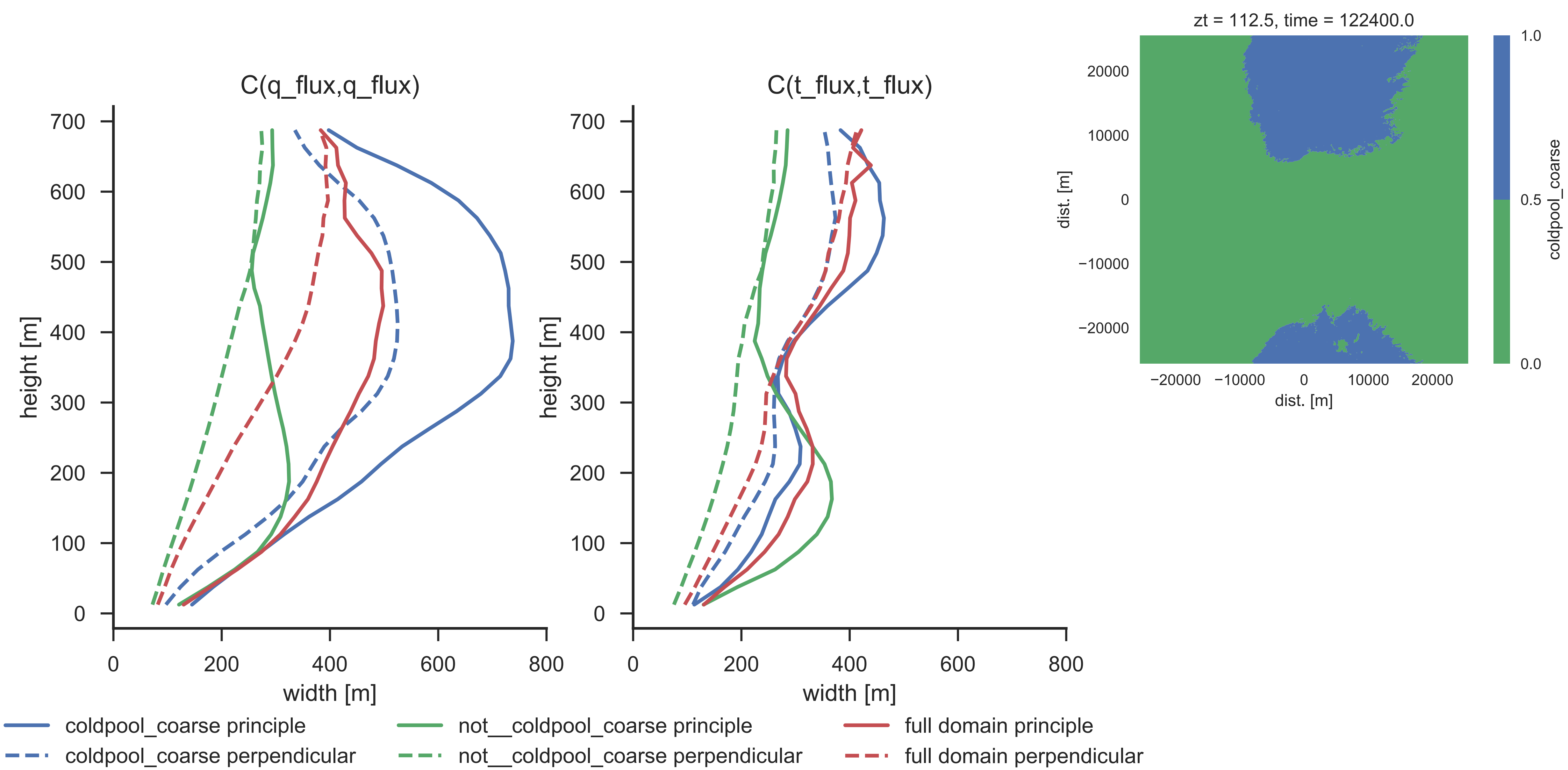




- Principle axis identified from principle axis of moment of inertia tensor

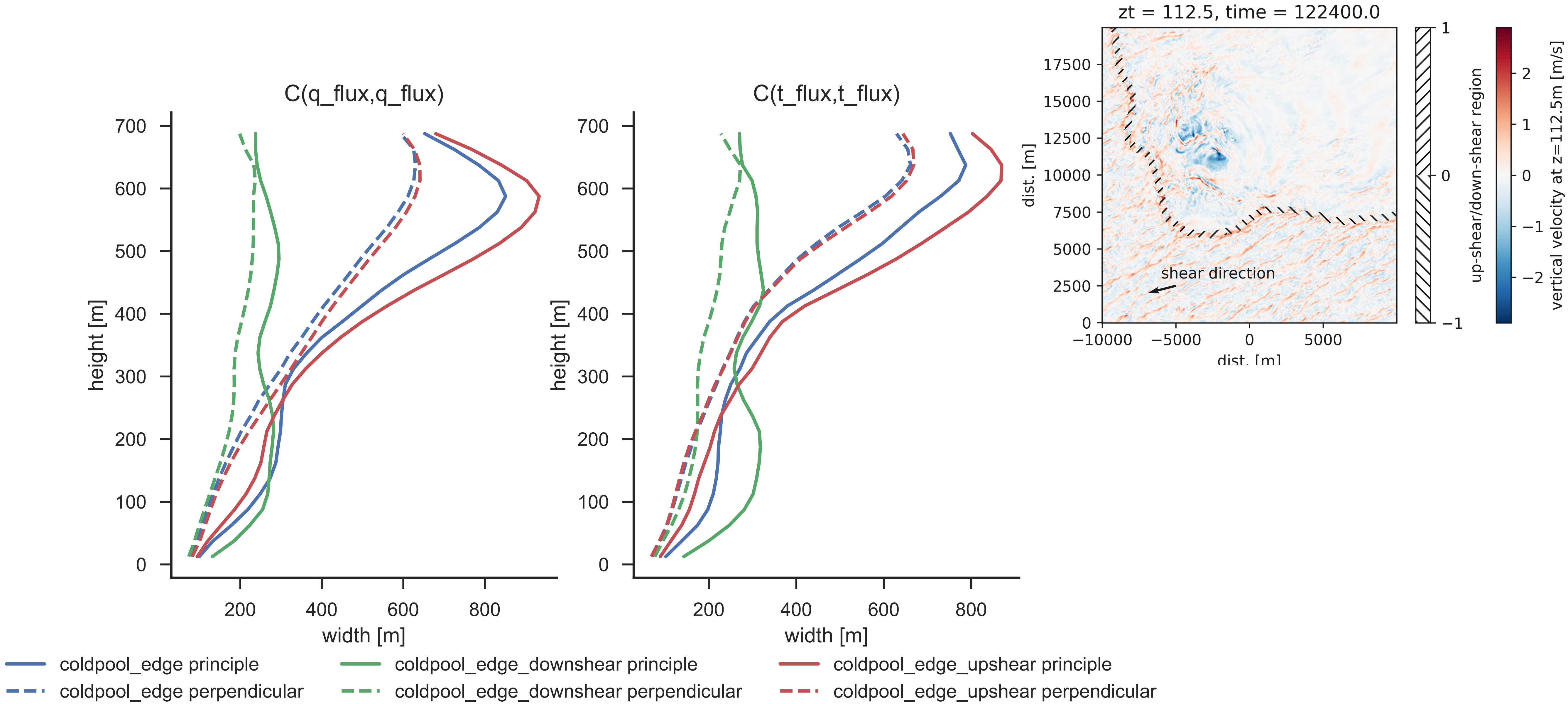
Coherence length

Inside and outside coldpool



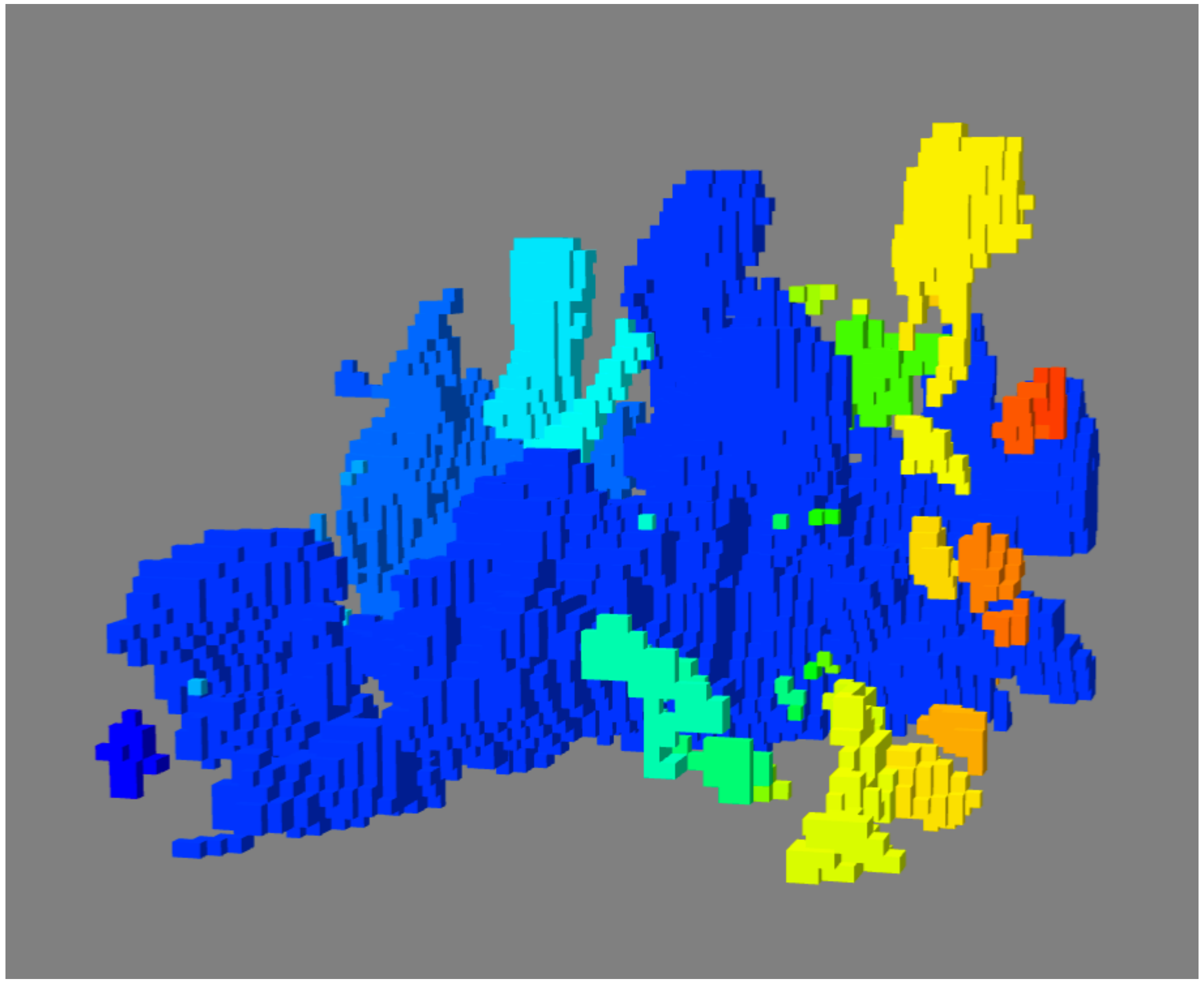
Coherence length

Upshear and downshear coldpool edge



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

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

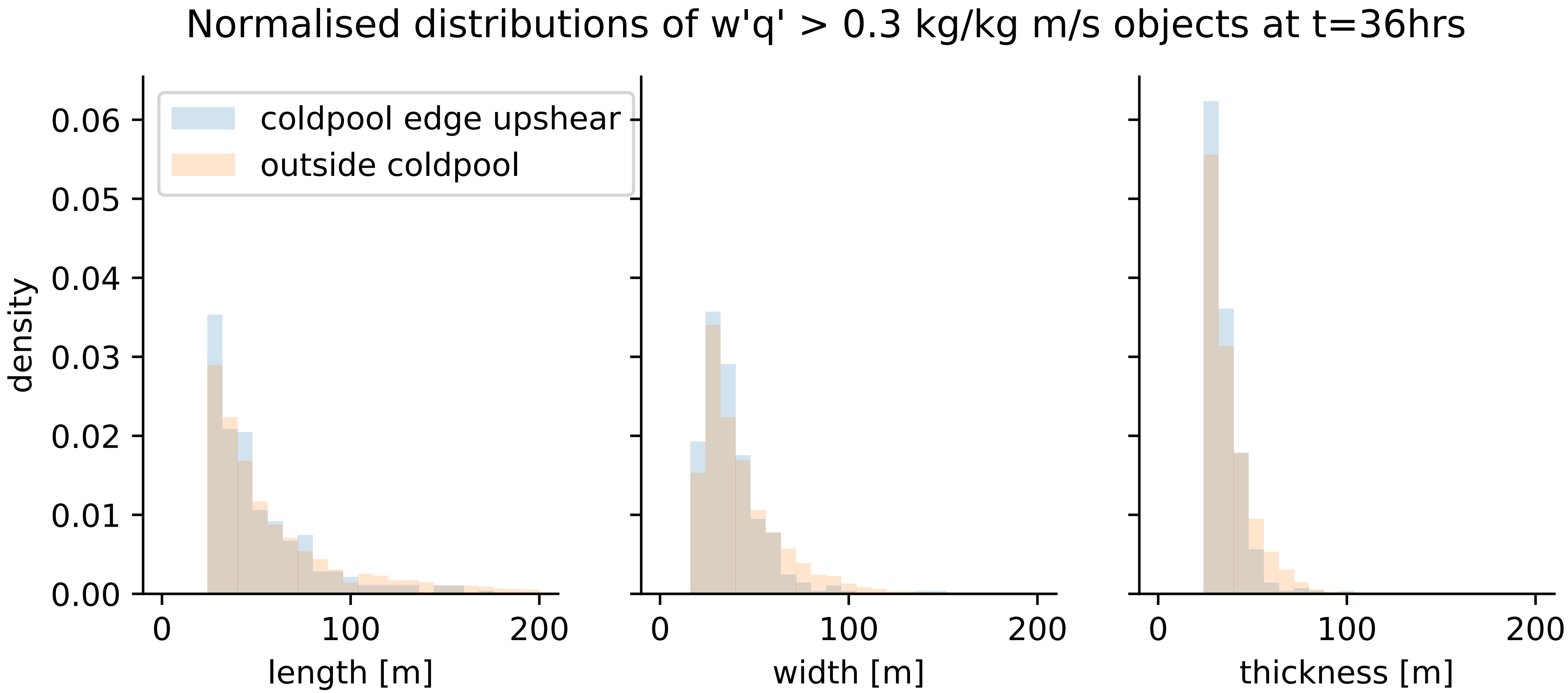
$$\Rightarrow$$

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

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

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

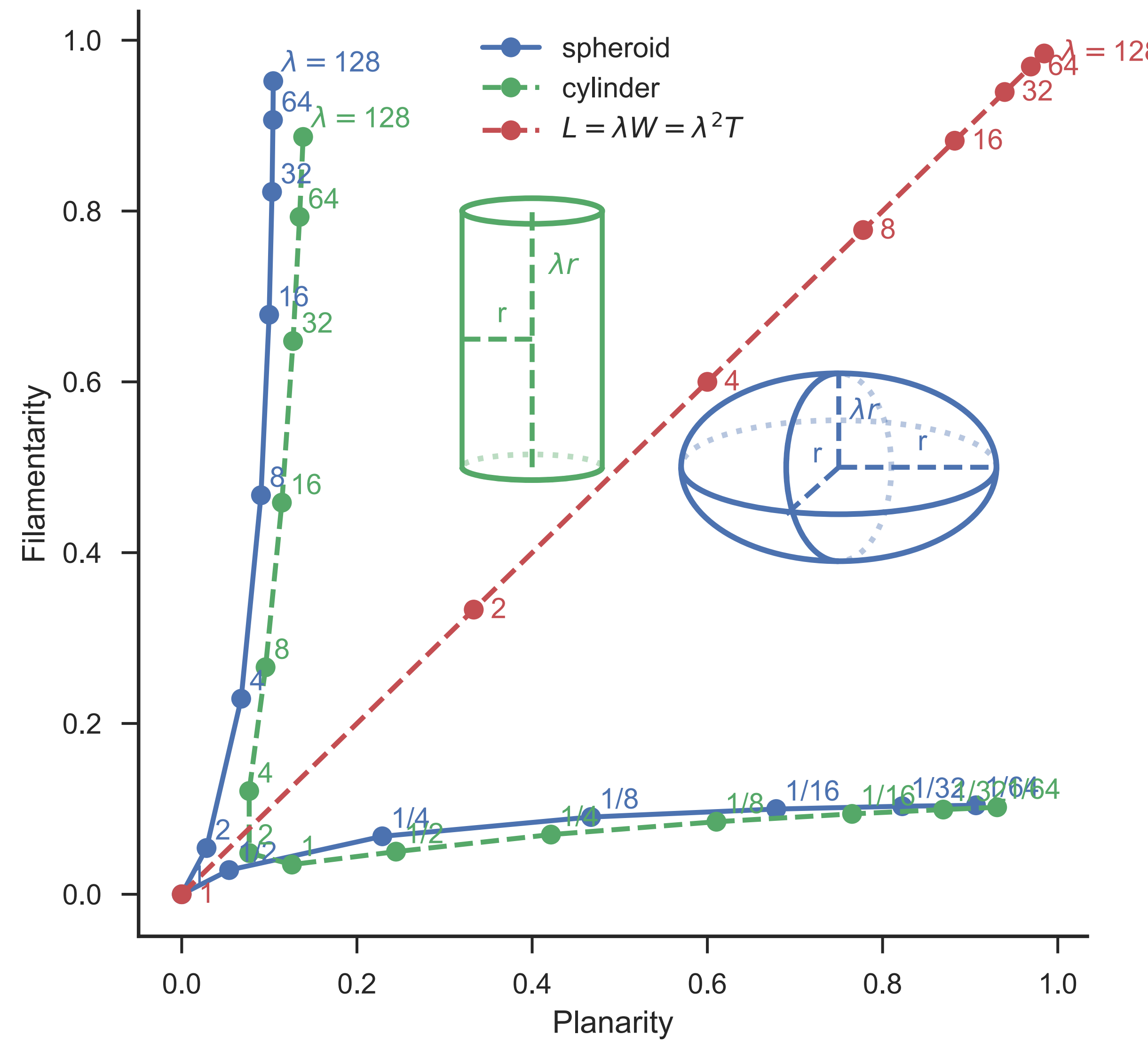
What are the characteristic length-scales of boundary layer structures?



What is shape of objects in the boundary layer?

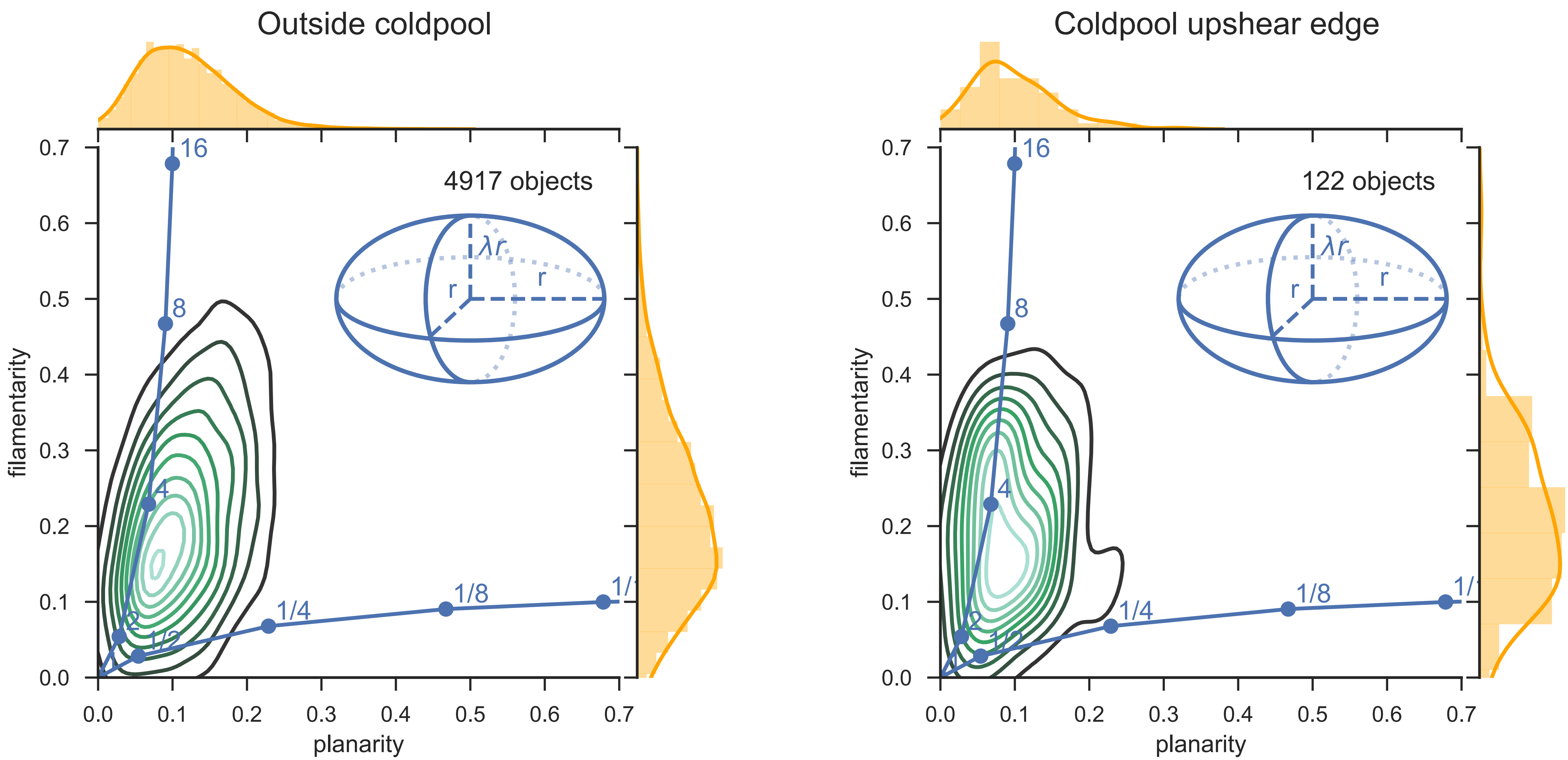
Calculate the planarity (P) and filamentary (F) from Minkowski functional length-scales

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



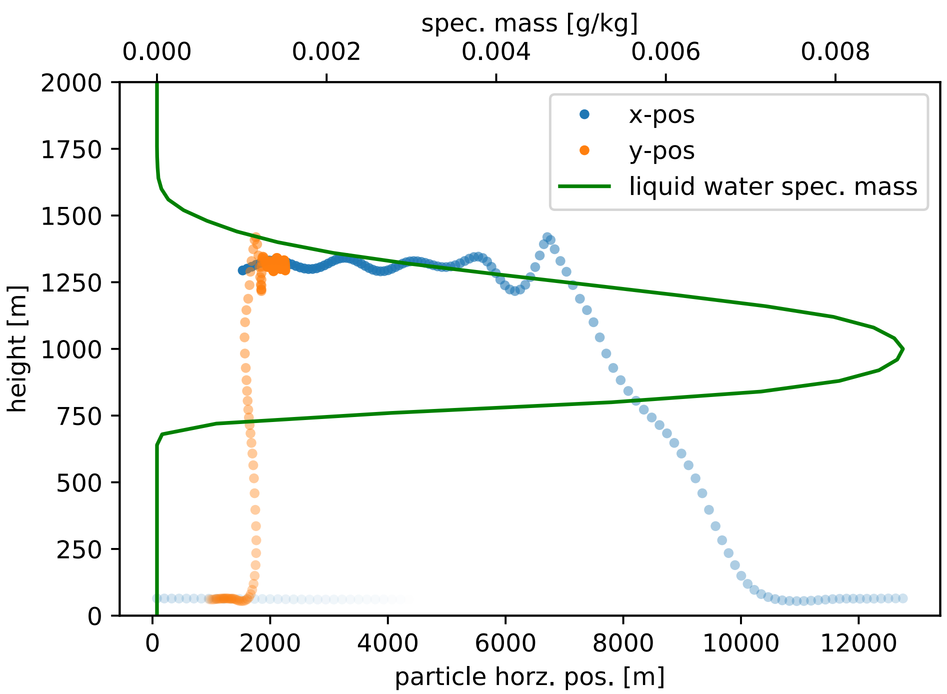
➡️ Measures how pencil or disc-like an object is

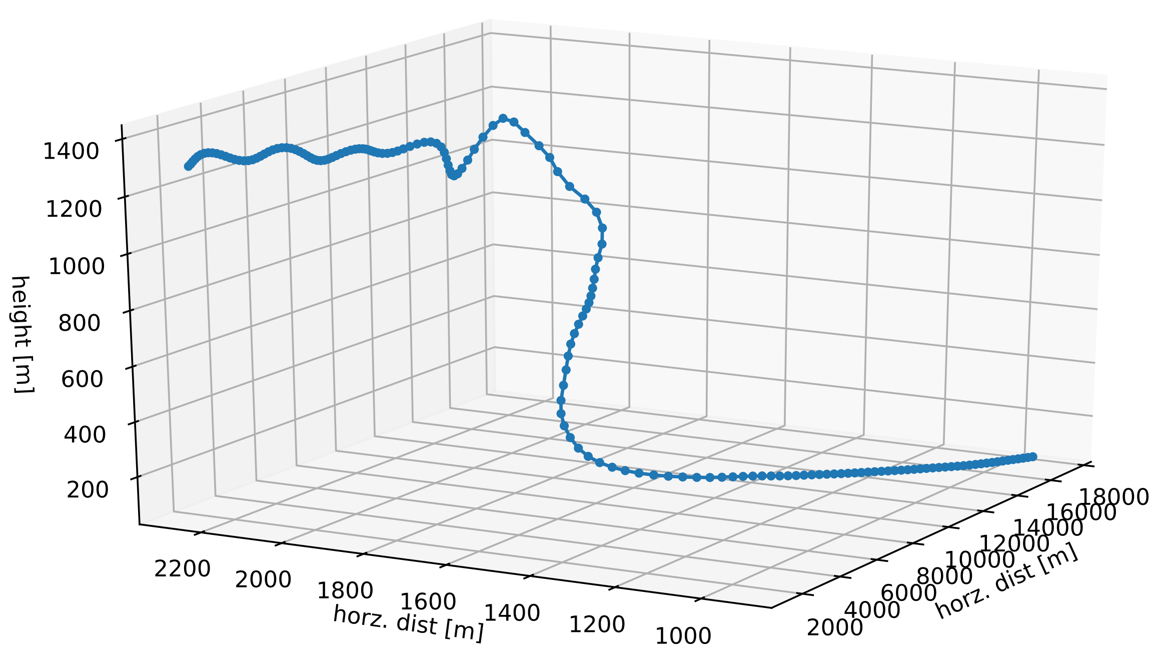
What is shape of objects in the boundary layer?



Next steps

- Identify triggering air using Lagrangian particles
  - Use to identify appropriate criteria for defining triggering objects





- Analyse simulations with temporal evolution (diurnal cycle and transition to deep convection)