UNIVERSITY OF LEEDS

Poking at shapes and sizes in the boundary layer

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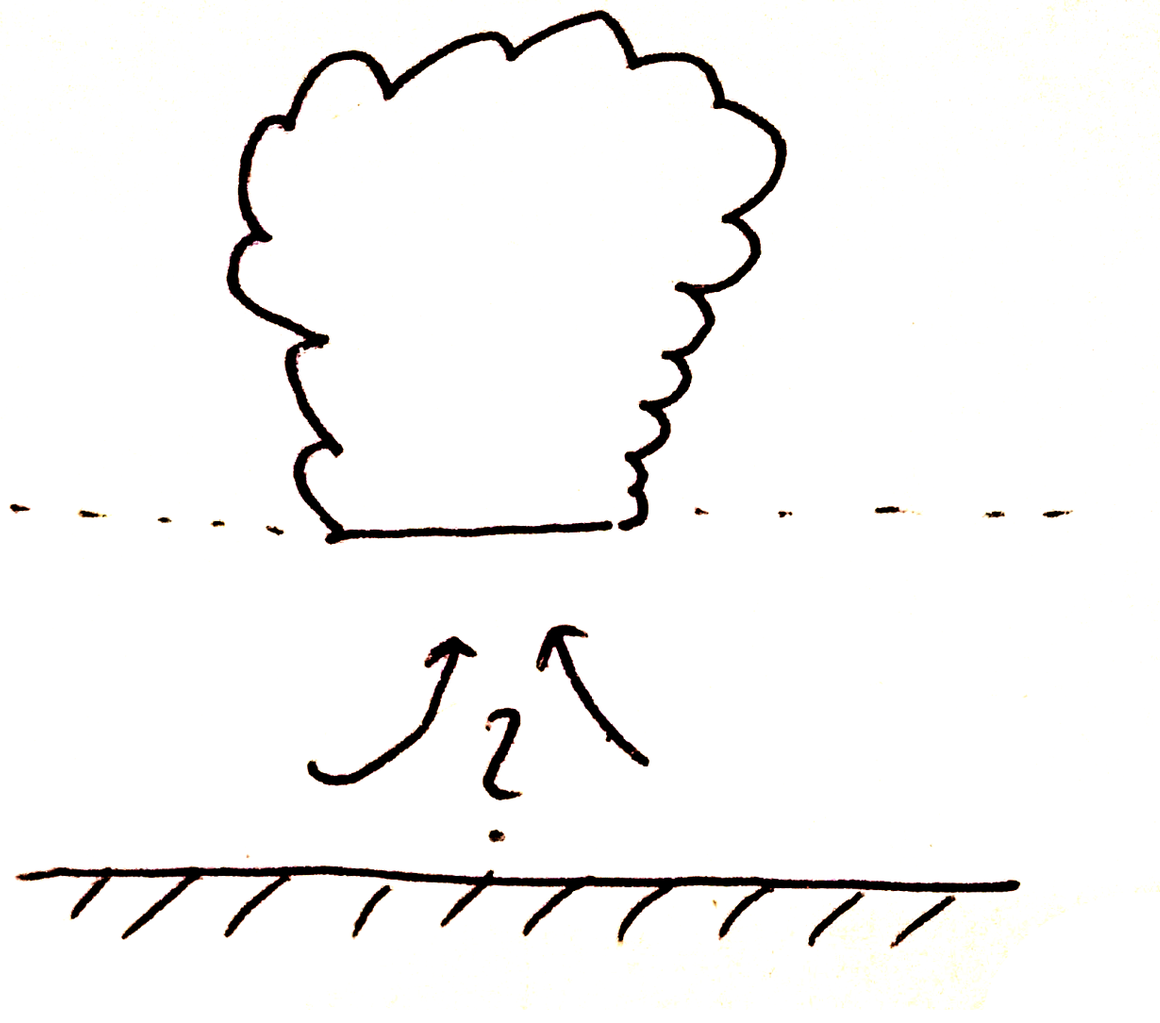
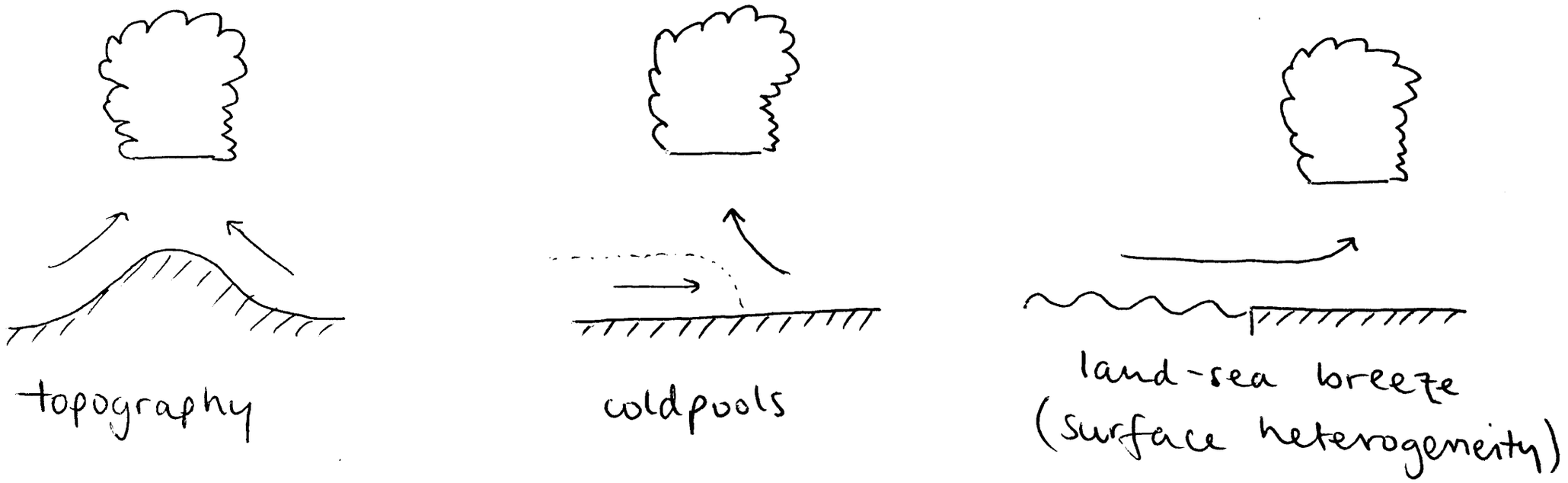
6th Oct 2017 Leeds Dynamics Seminar

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?"*

Aim

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

  - for example: *“What are the length-scales and magnitudes of perturbations which trigger convection?”*

- To formulate a new convection trigger model for the MetOffice Unified Model

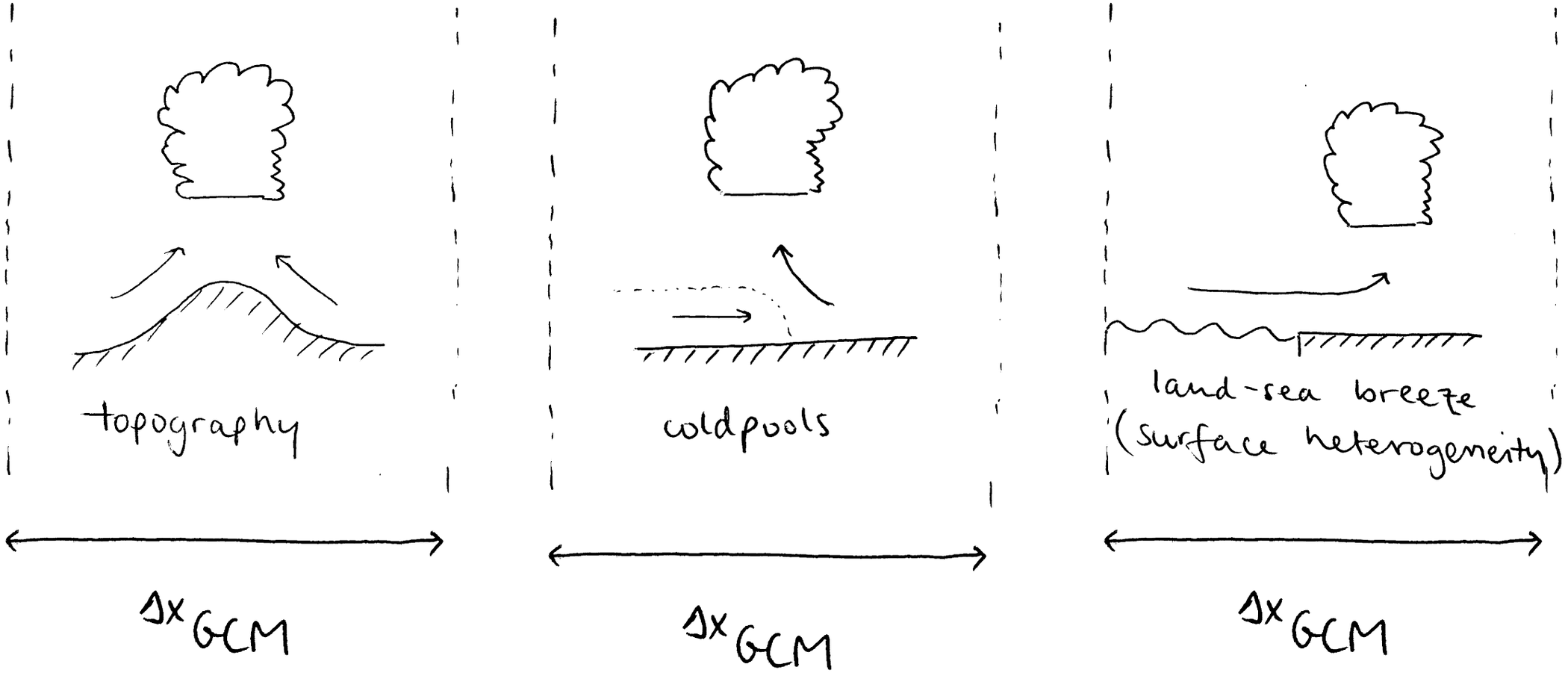
  ➡ Part of 5-year NERC/MetOffice ParaCon project to provide a new convection parameterisation for the MetOffice model

Why?

- GCMs have too coarse resolution to fully represent convection (O(km))

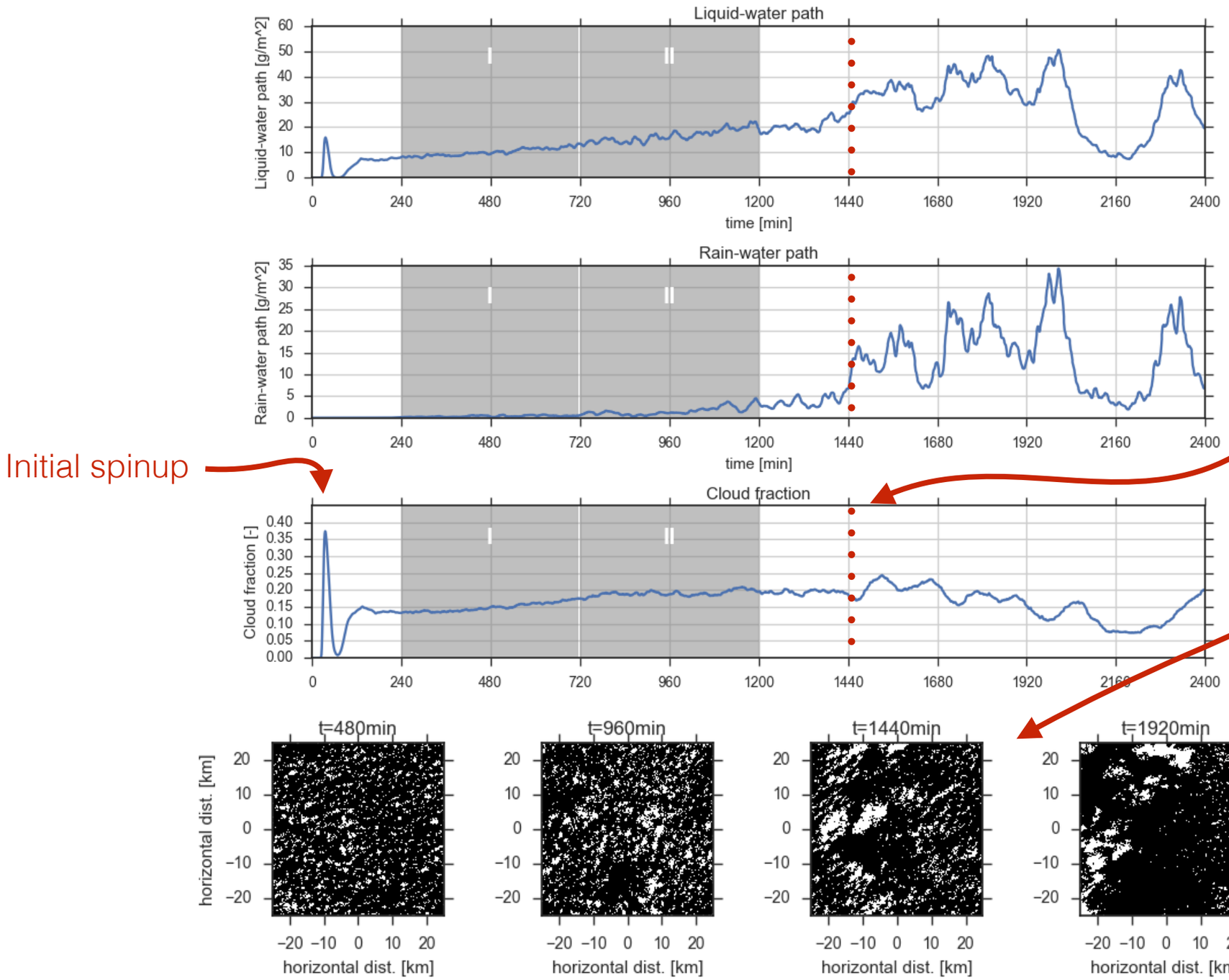
  ➡ Trigger (and evolution) of convection must be parameterised

  ➡ These *sub-grid* features are known to be critical in predicting formation of convection



First case: RICO (*Rain In Cumulus over the Ocean)*

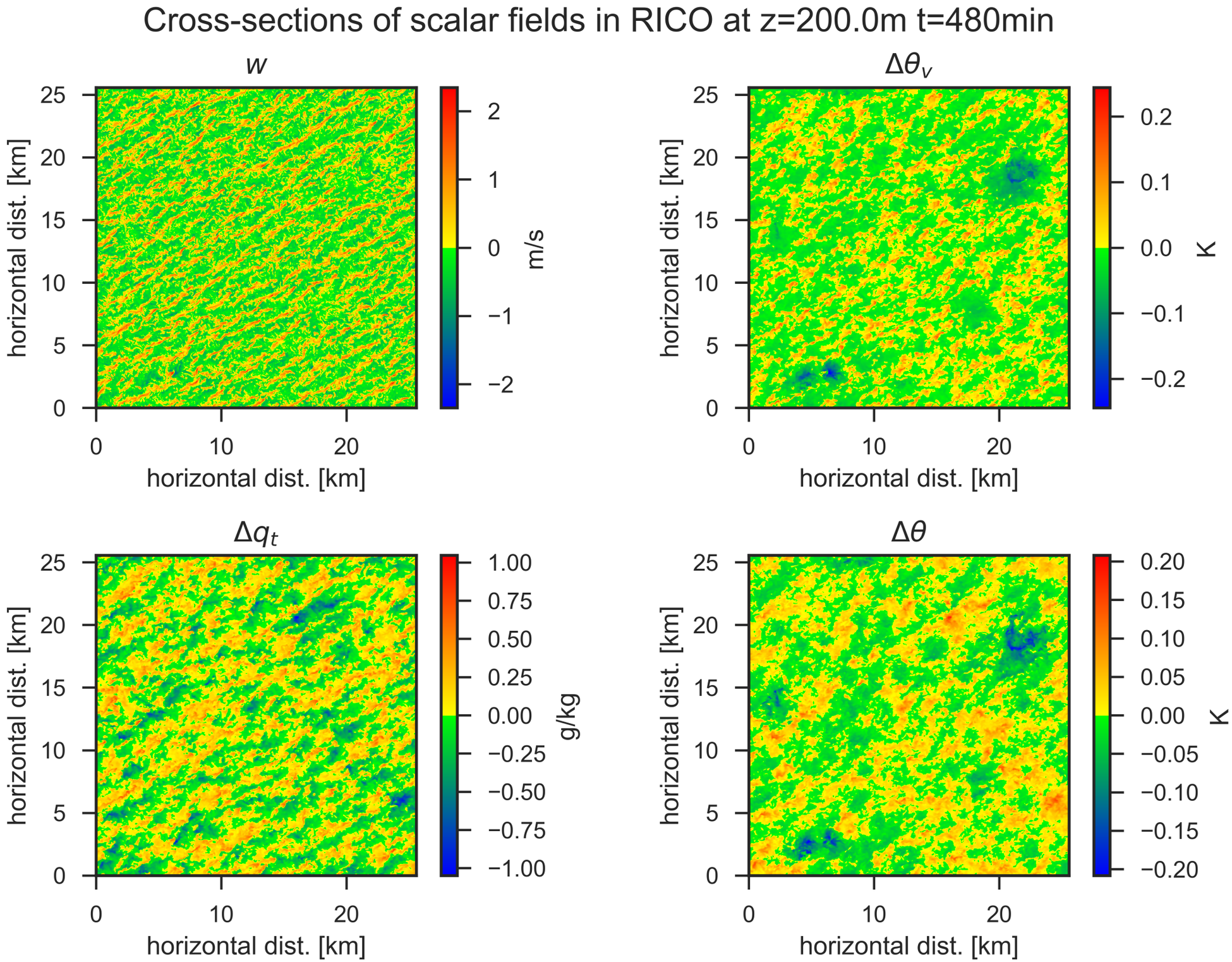
Shallow cumulus over surface with no surface heterogeneity



M. vanZanten et al 2011

simulation carried in UCLALES out by Cathy Hohenegger, MPI, Hamburg

What are the length-scales of variability?



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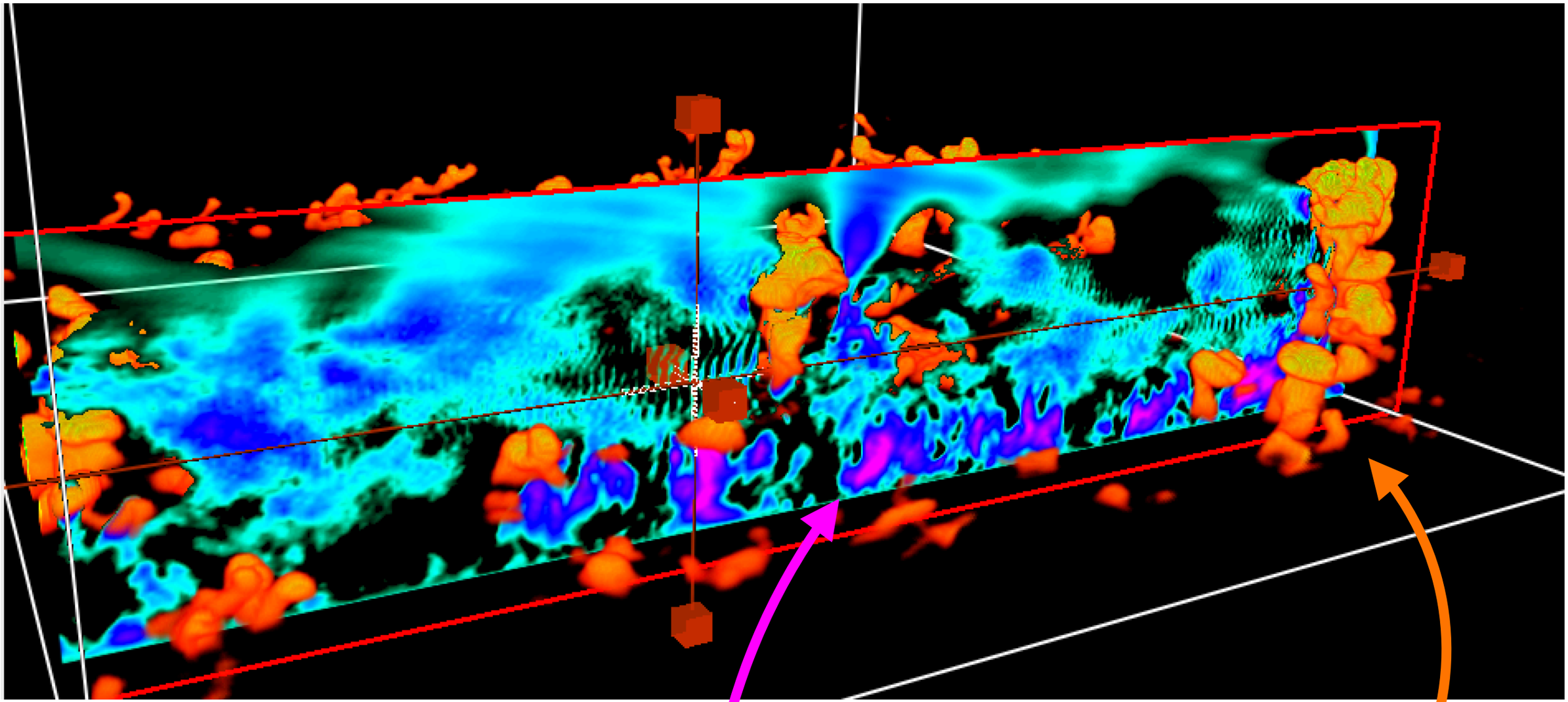
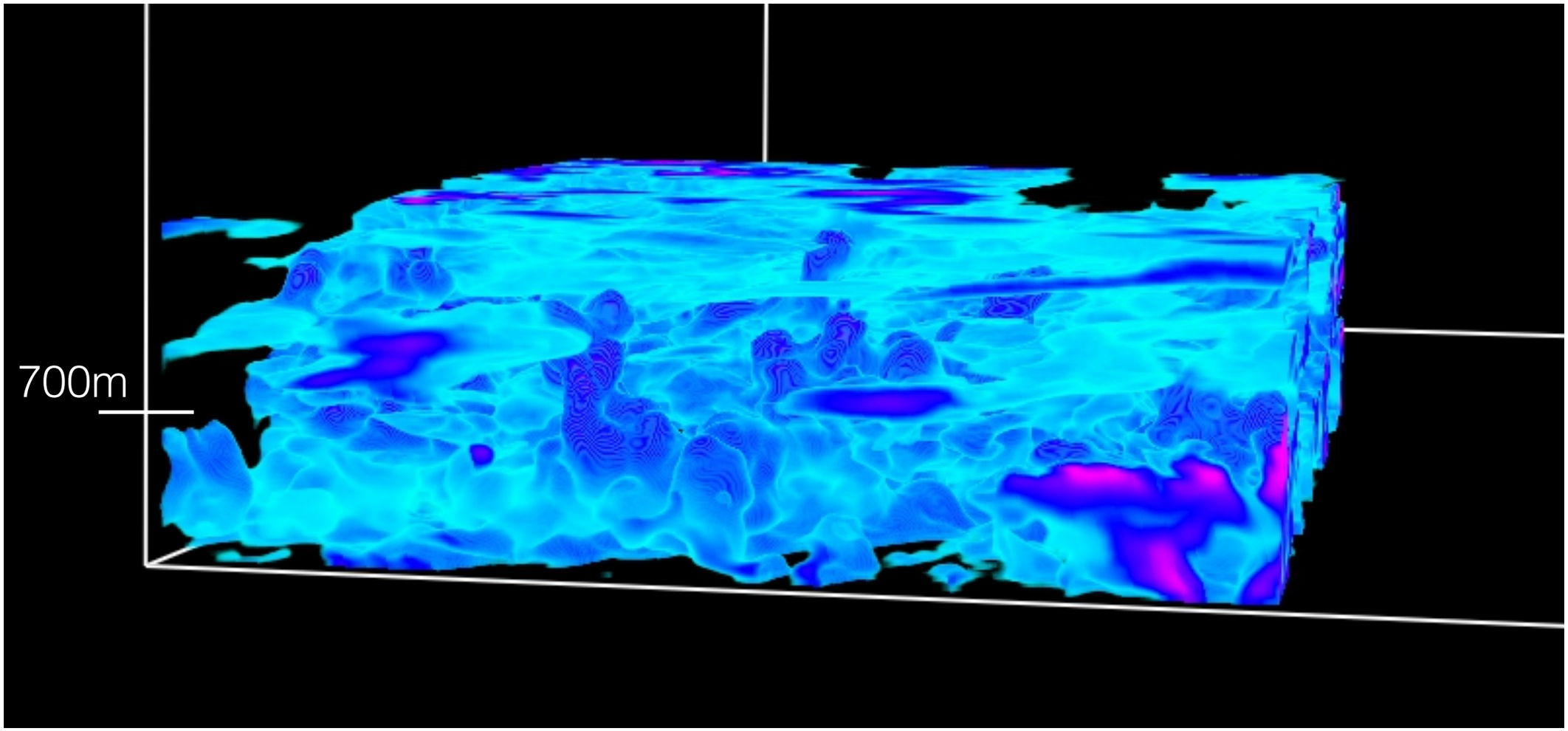


What are the length-scales of variability?

deviation of total moisture from horizontal mean



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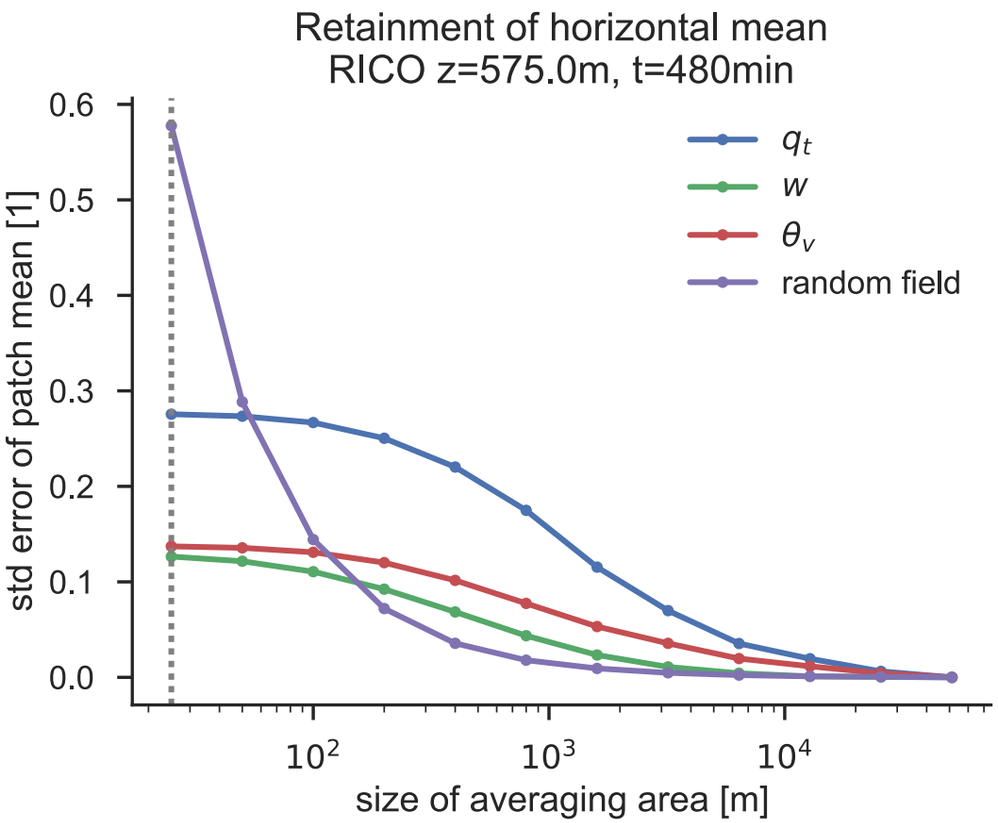
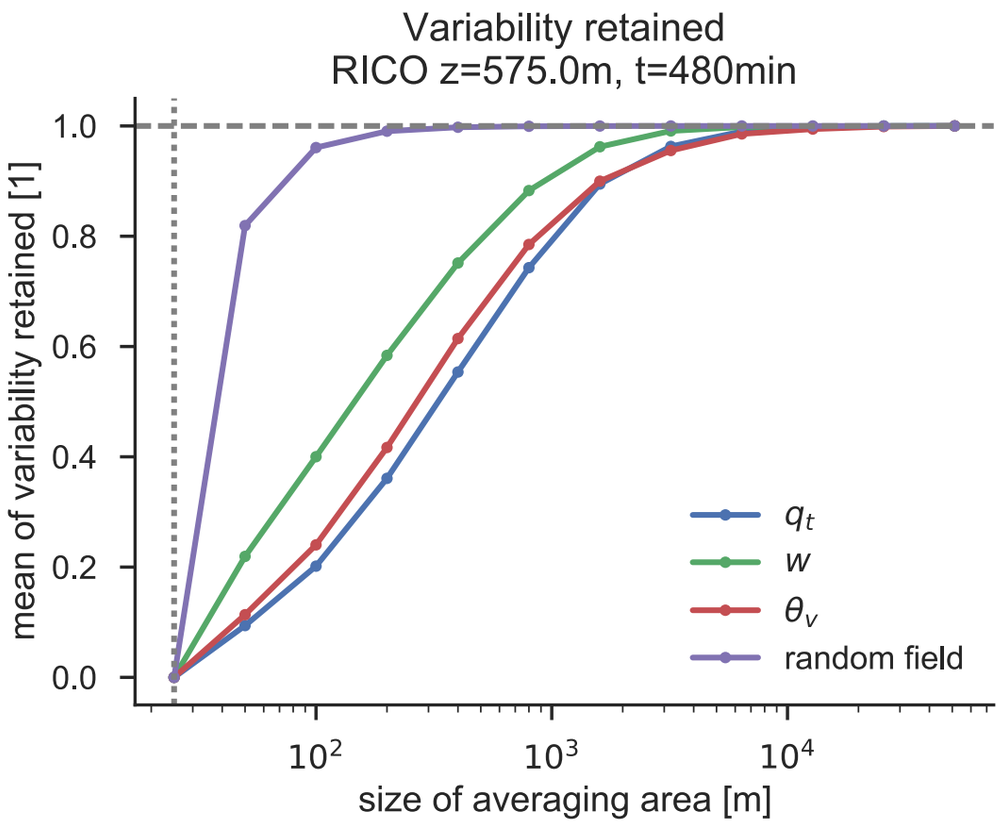




- Split domain into successively smaller patches to evaluate change in statistics

  ➡ scales of variability are different for different scalar fields

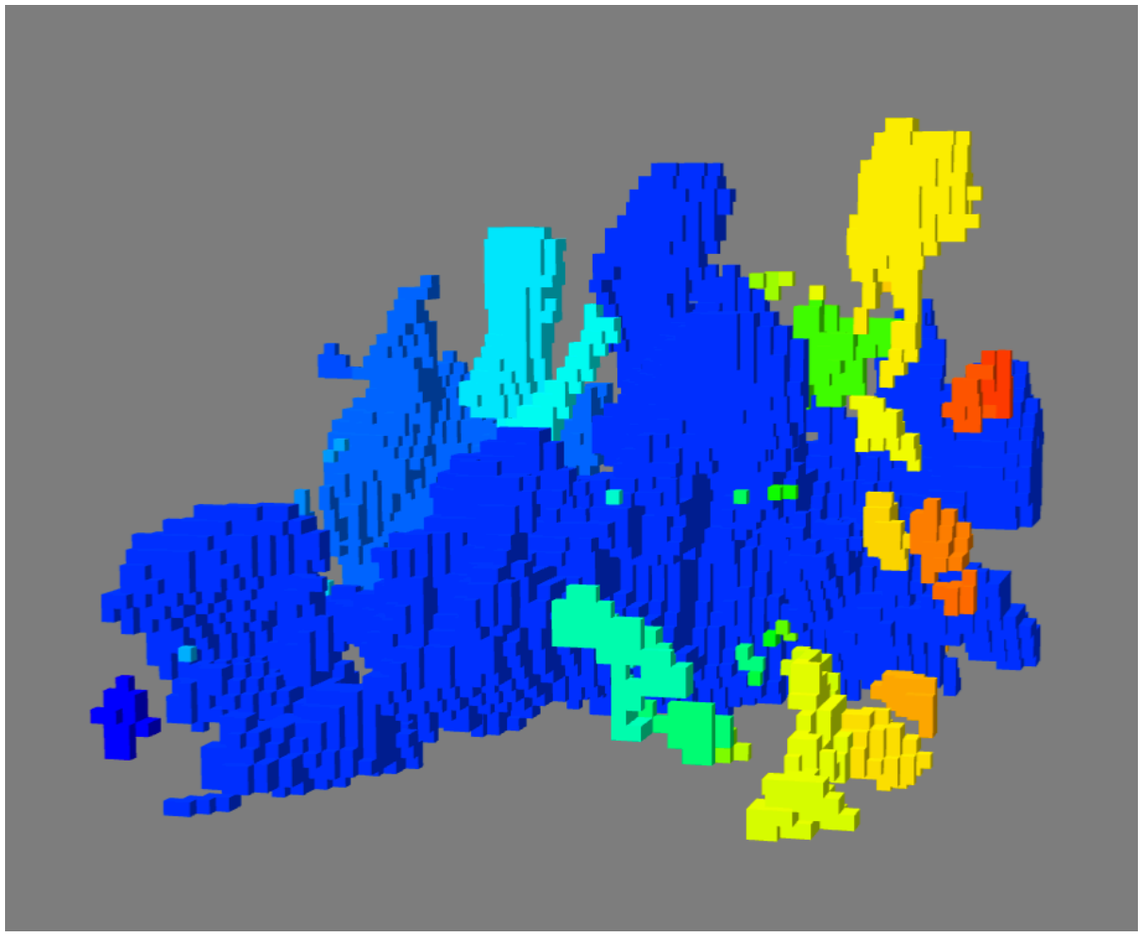
  ➡ ~90% of variability retained with L~1000m for θ_v and q_t, ~95% for w

Can we identify 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

$$V_0 = V = \int dV$$

$$V_1 = \frac{A}{6} = \frac{1}{6}\int dS$$

$$V_2 = \frac{H}{3\pi} = -\frac{1}{6\pi}\int dS \nabla \cdot \hat{n} \quad \Rightarrow \quad L = \frac{3V_2}{4V_3}$$

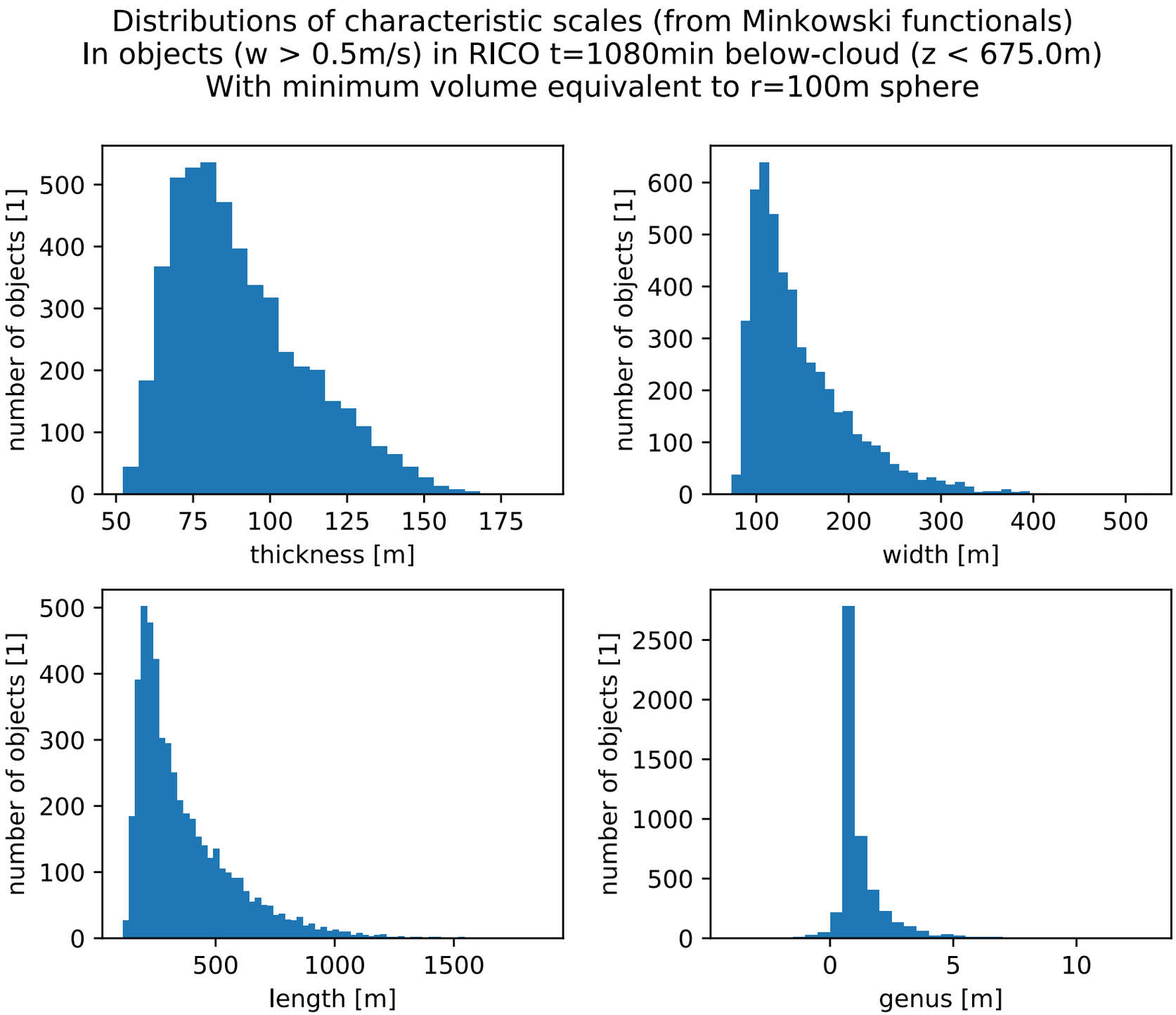
$$W = \frac{2V_1}{\pi V_2}$$

$$T = \frac{V_0}{2V_1}$$

$$\left(V_3 = \frac{1}{4\pi}\int (\kappa_1 \kappa_2) dS \right)$$

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

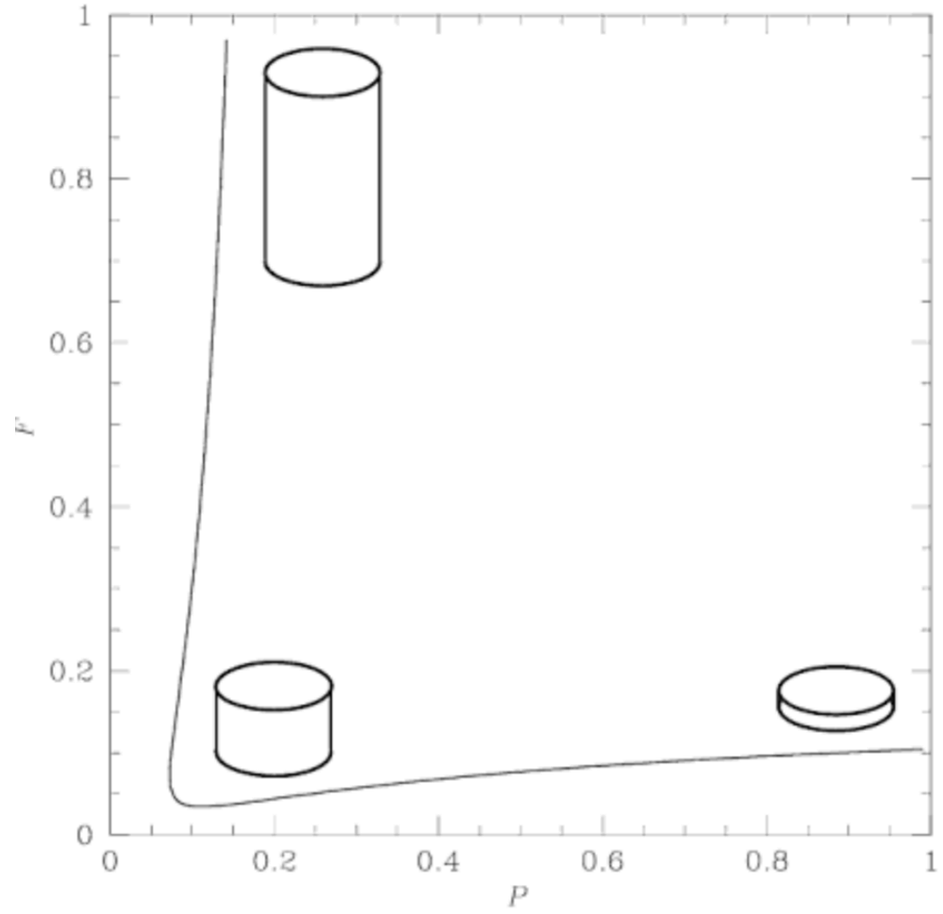
What are the characteristic shapes of boundary layer structures?



What is shape of objects in the boundary layer?

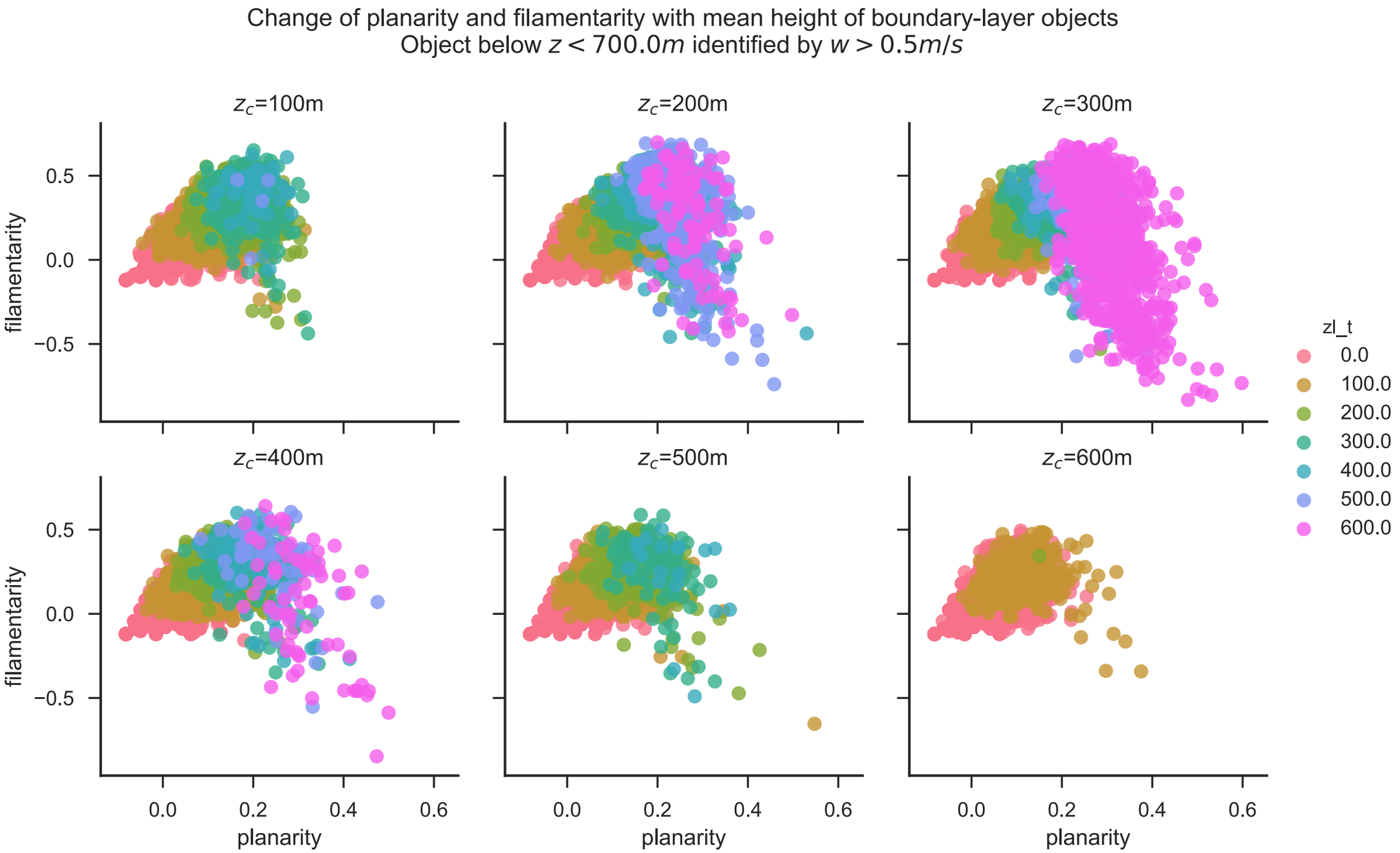
Calculate the planarity (P) and filamentary (F) from Minkowski functional length-scales

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

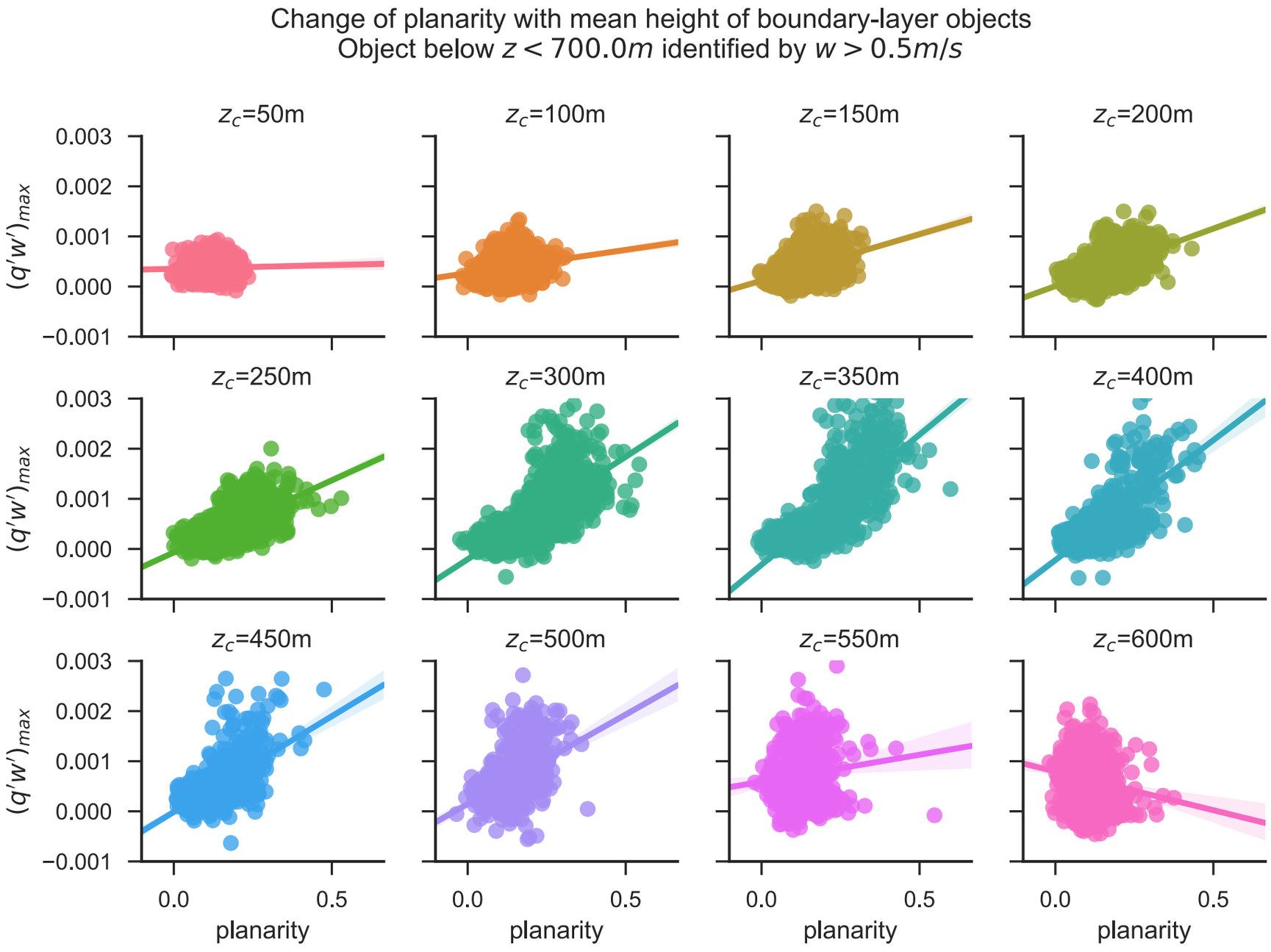


- Measures how pencil or disc-like an object is

What are the shapes of objects in the boundary layer?



What are the shapes of objects which carry most moisture flux?



- Objects with largest vertical moisture flux become more planar towards boundary layer centre

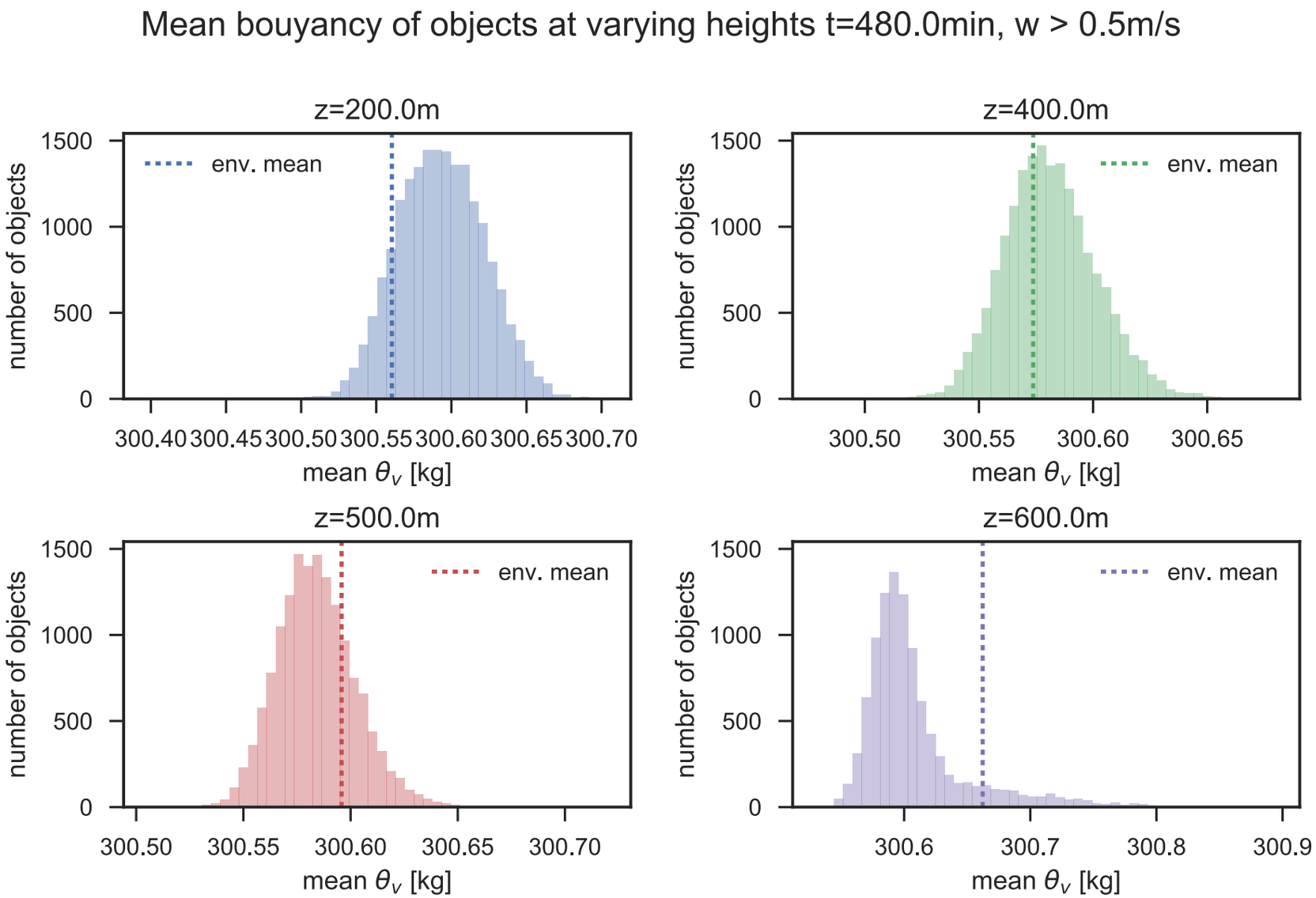
Next steps

- Develop and converge on analysis methods to be used for analysing boundary layer structures
- Set up and run LES simulations (in MONC) which contain phenomena of interest
- Analyse structures and share results with rest of ParaCon
- Develop a model of convective triggering for the future :)

Thank you!

How does buoyancy change with height?

Or, what can we do with object identification?

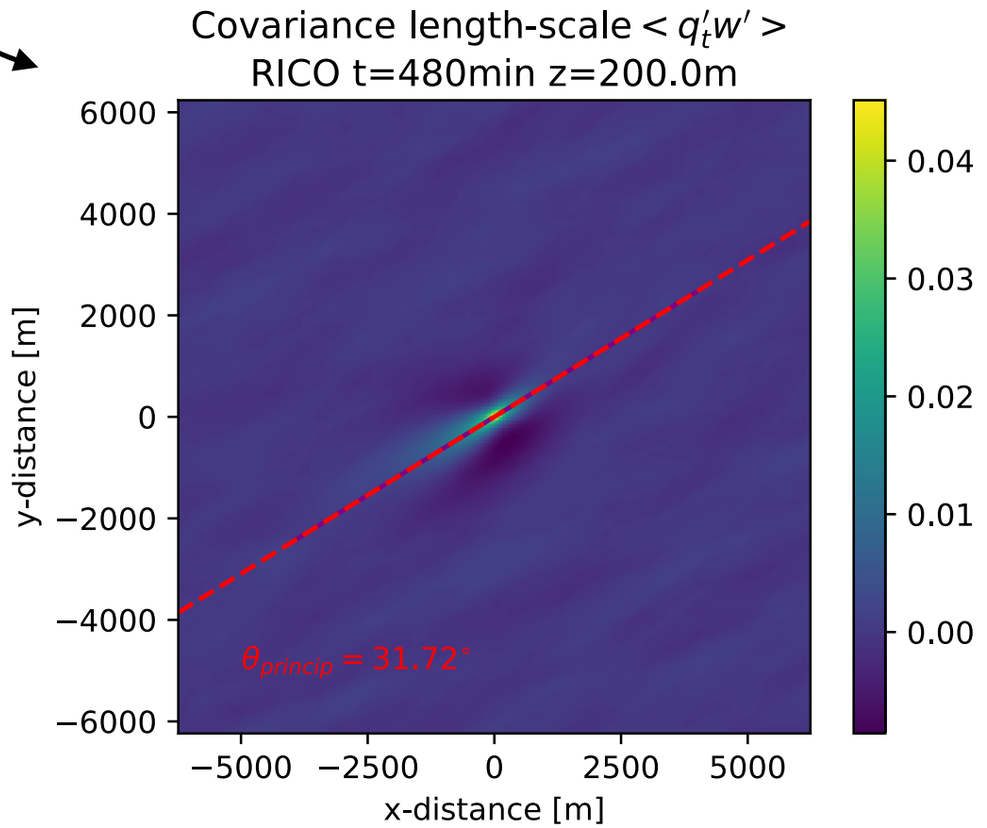


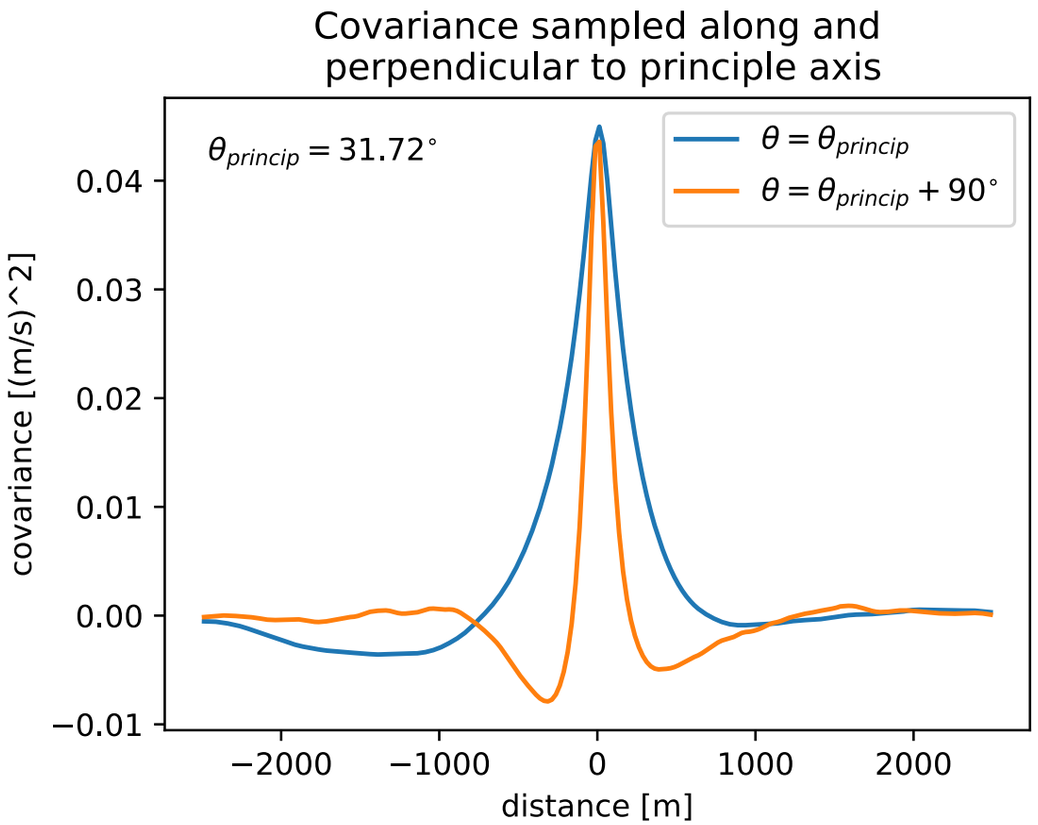
- Change to non-buoyant regime above z~400m, rising elements must have momentum to overcome barrier, analogy to quantum tunneling?

Other methods of analysis

- Cumulant-based analysis to find length-scales of correlation between different scalar fields (with Steven Tobias, Leeds)

  ➡ Currently developing wavelet decomposition, since solution is not periodic and so local correlations may be more relevant





What are the length-scales of variability in the aggregated state?