A composite study of cloud structures

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Representation of vertical fluxes

- Bulk mass-flux approximation substantially under-estimate the vertical fluxes. To represent the sub-grid vertical transport as accurate as possible, we need to know how the vertical velocity and transported variables distribute within the clouds.

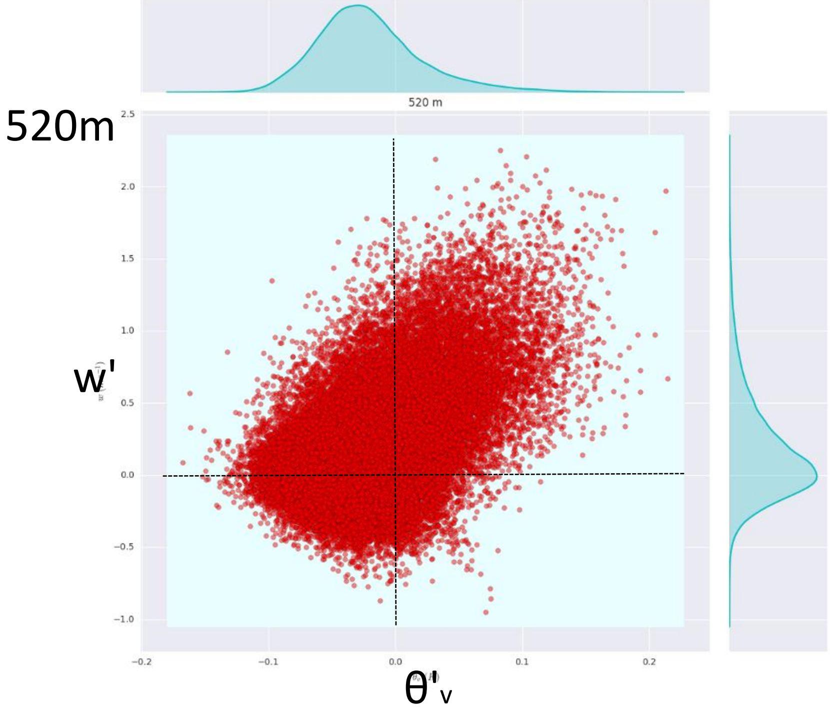
- One possible solution is to recover the sub-plume variability with some assumed joint distribution of vertical velocity and transported variables. However, it is not clear what kind of structures of clouds/plumes contribute to the joint distribution.

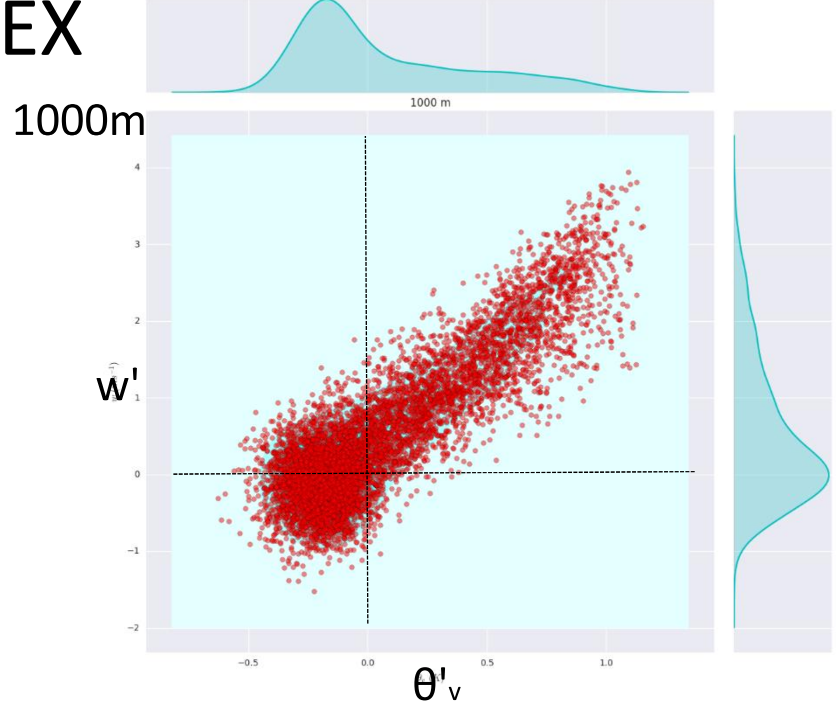
- Detailed understanding on the distribution of variables within the clouds/plumes is of benefit for our project. (Mike's updraft model assumes the pdfs for w, qt, theta_l can be collapsed but has not been verified; Dan is looking at the joint pdf for a two-fluid decomposition; George uses the joint pdf to define the coherent structure. People in Cambridge and Leeds also study the updraft dynamics.)

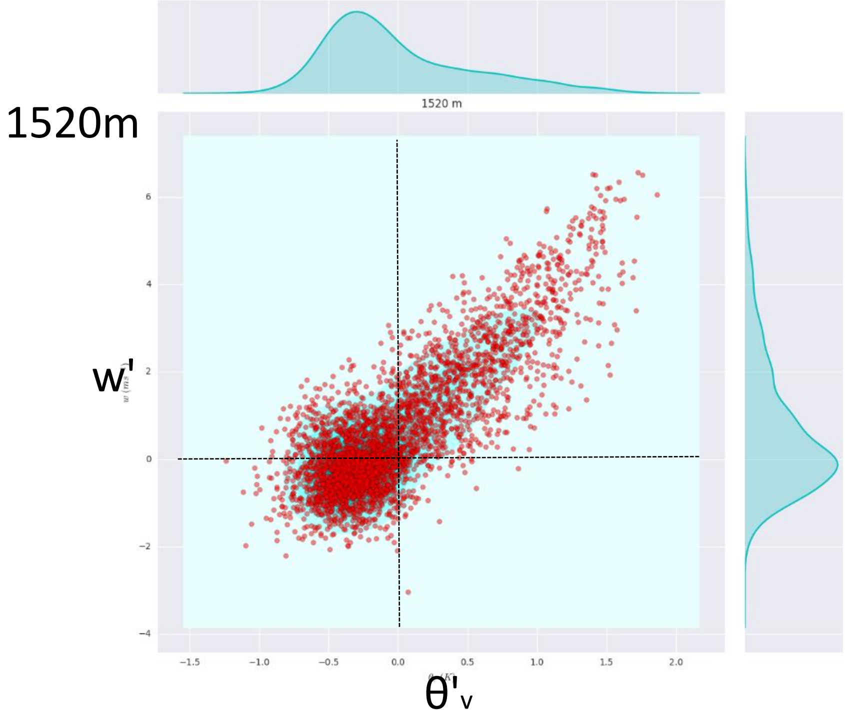
BOMEX

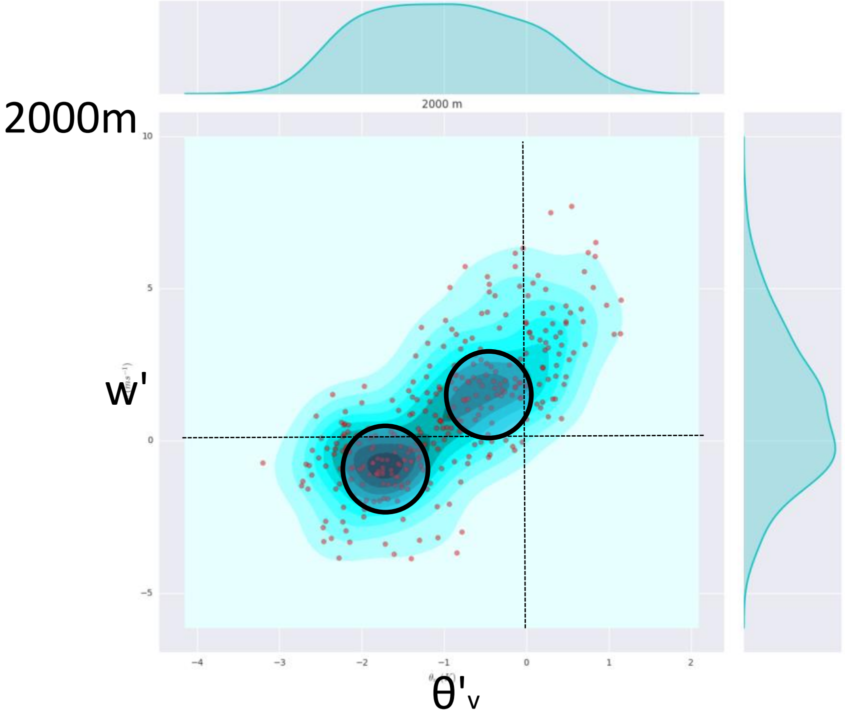
w’, θ’v

Cloud (q_l > 1e-5)









1000 m

w’, θ’v

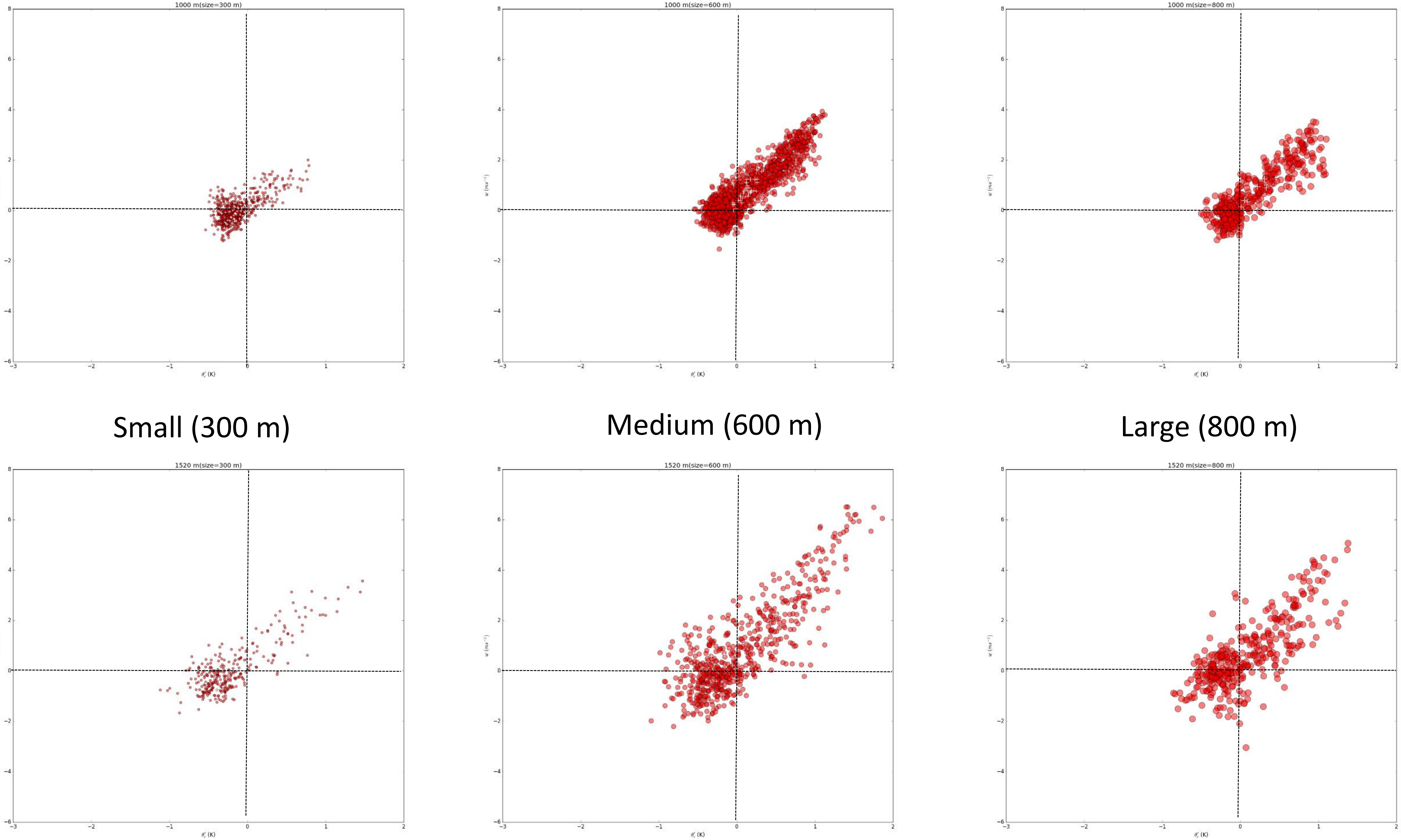
Cloud (q_l > 1e-5)

Small (300 m)

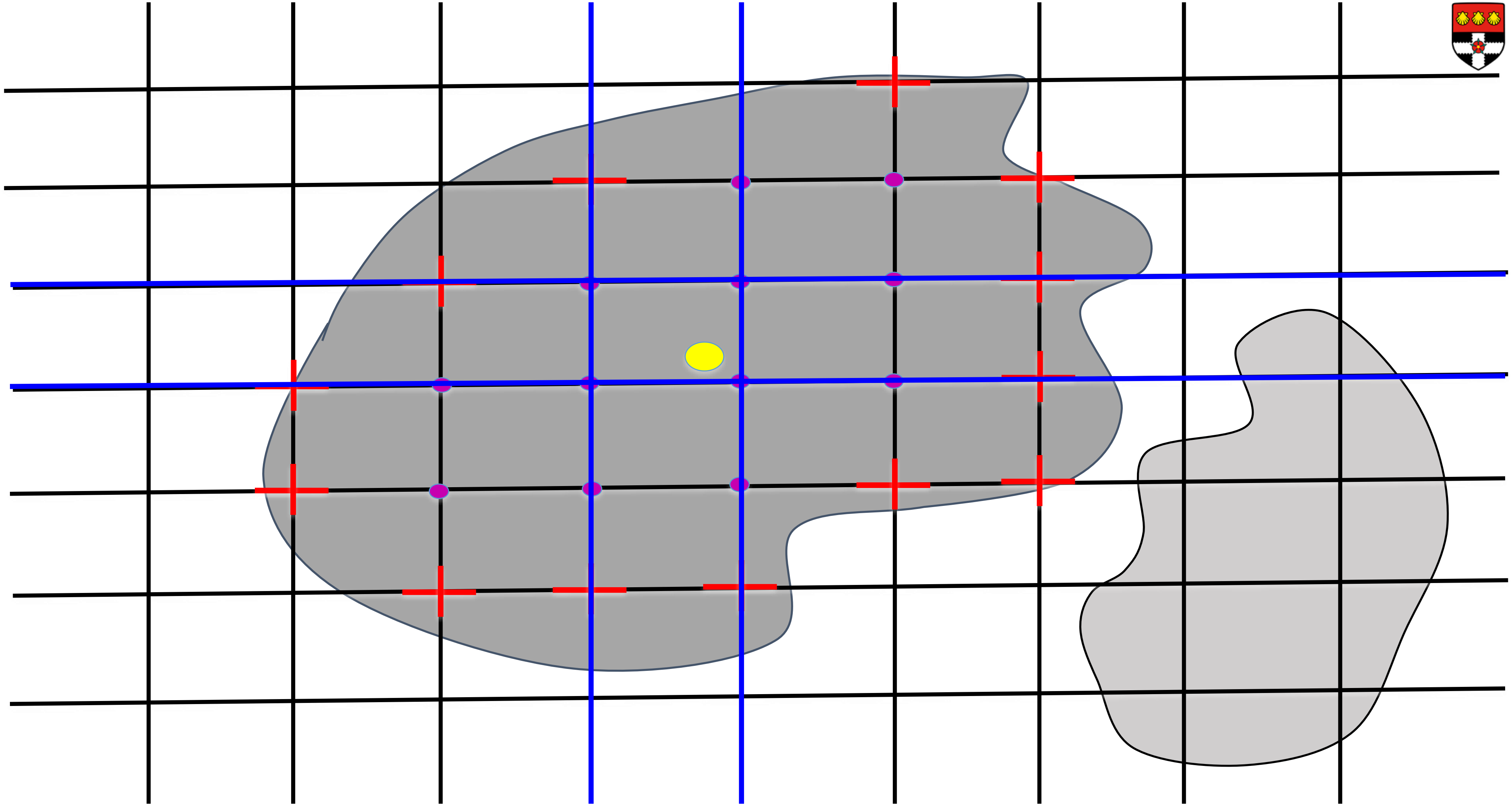
Medium (600 m)

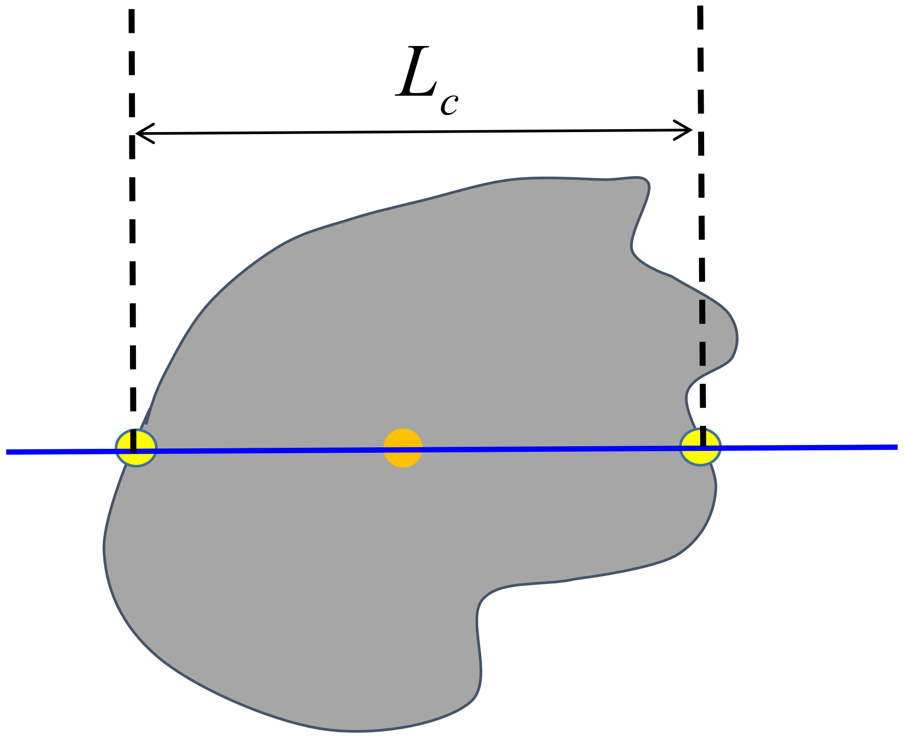
Large (800 m)

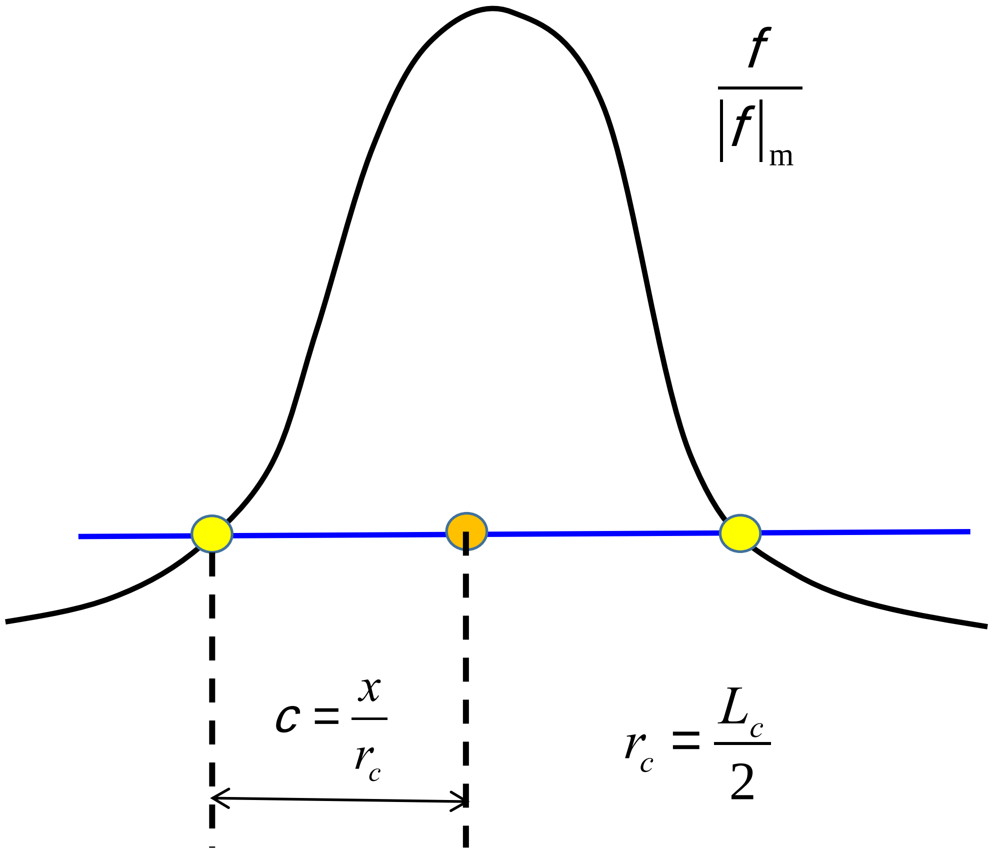
1520 m



The shape of distribution of w and buoyancy seems to be independent of cloud size, suggesting consistent distribution within the cloud





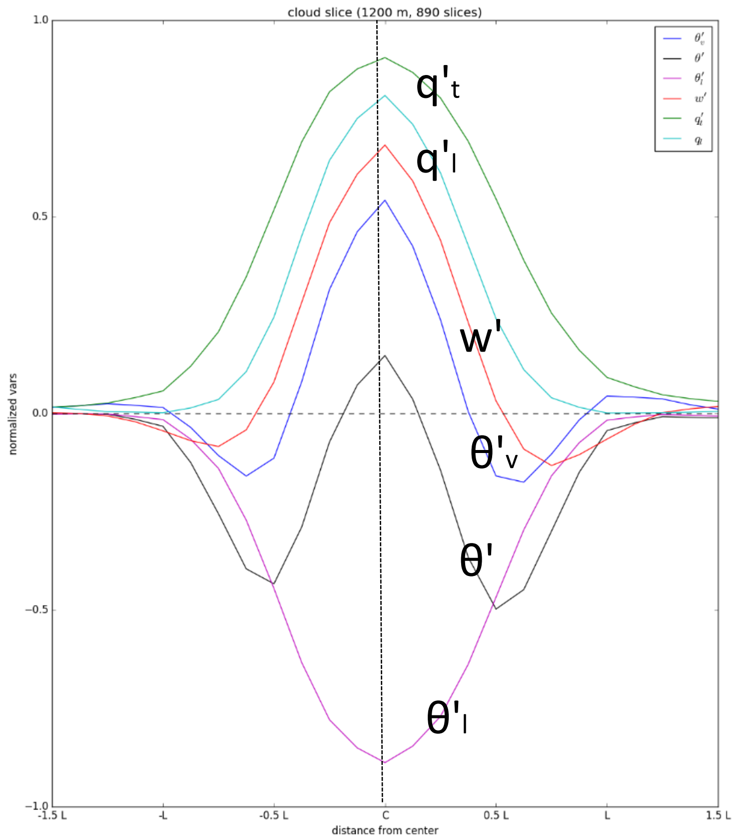


Normalize the variables with their maximum value (absolute value);

Normalize the distance to the slice centre with half the width of each intersection;

BOMEX

q_l > 1e-5



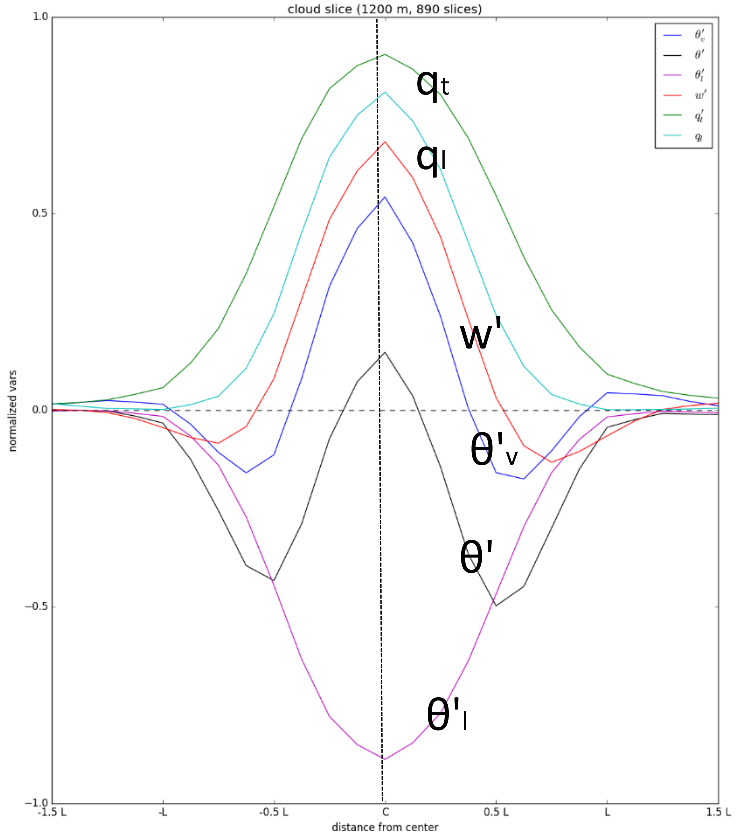
1200 m

Clear transition zone near cloud edge

To some extent, distributions of different variables (except θ) agree well

BOMEX

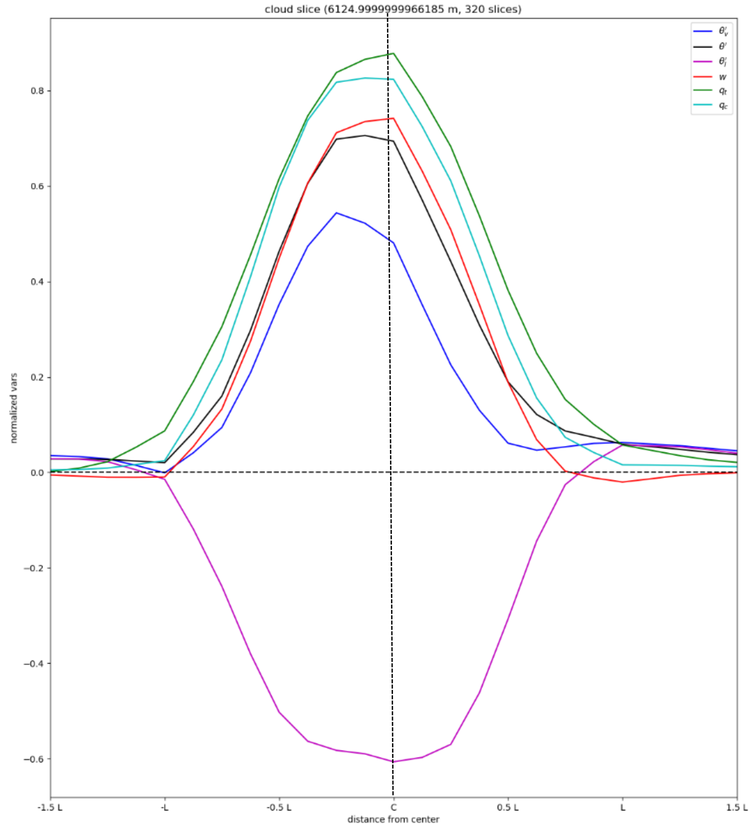
$q_l > 1e\text{-}5$



1200 m

RCE

$q_l + q_i > 1e\text{-}5$



6100 m

Distributions of different variables (except θ) agree better in deep clouds because the shell structure is not obvious.

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An alternative PDF method?

- The normalized distributions of vertical velocity, cloud liquid water, liquid water potential temperature seem to be similar and are independent on vertical levels at mid-level cloud layers for both shallow and deep convection (especially for deep convection in that shell structure only occurs at low levels).
- The calculation of vertical fluxes based on assumed joint PDF could be converted to a spectral representation of maximum values within the cloud.

$$\overline{w'\phi'} = \iint w'\phi' p(w',\phi')\,dw'\,d\phi'$$

$$= \int_0^{\infty}\int_0^{r_c} p(r_c)\,w'(r)\,\phi'(r)\,dr\,dr_c$$

$$= \int_0^{\infty}\int_0^{1} p(r_c)\,w'_m(r_c)\,\phi'_m(r_c)\,f^2(\chi)\,d\chi\,dr_c$$

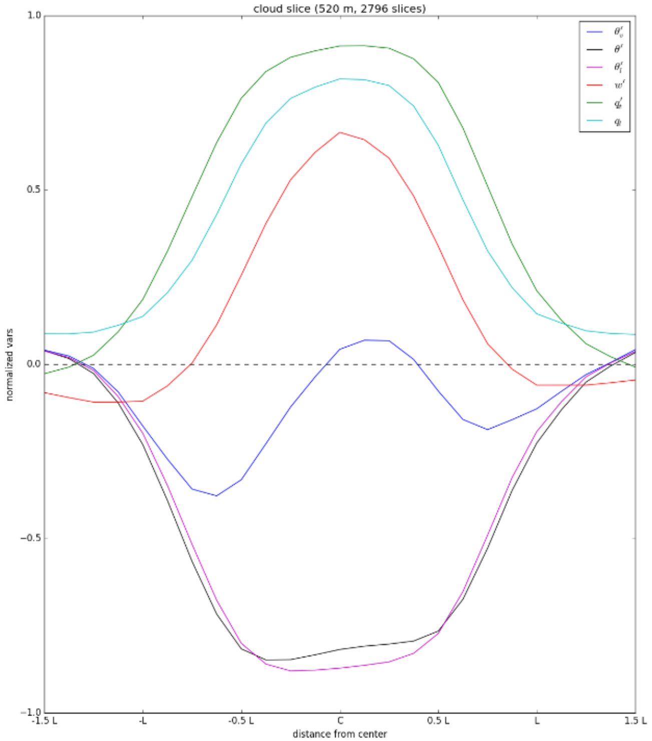
$$w'(r) = w'_m(r_c)f(\chi)$$

$$\phi'(r) = \phi'_m(r_c)f(\chi)$$

$p(r_c)$ and $f(\chi)$ do not change significantly with height

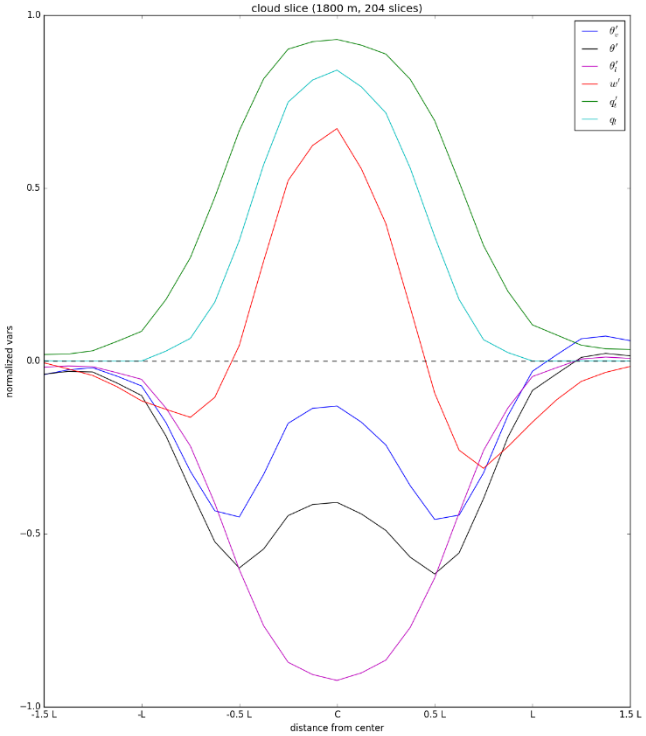
But what about the distributions near cloud base and cloud top?

Distributions of vertical motion and variables do not collapse well



520 m

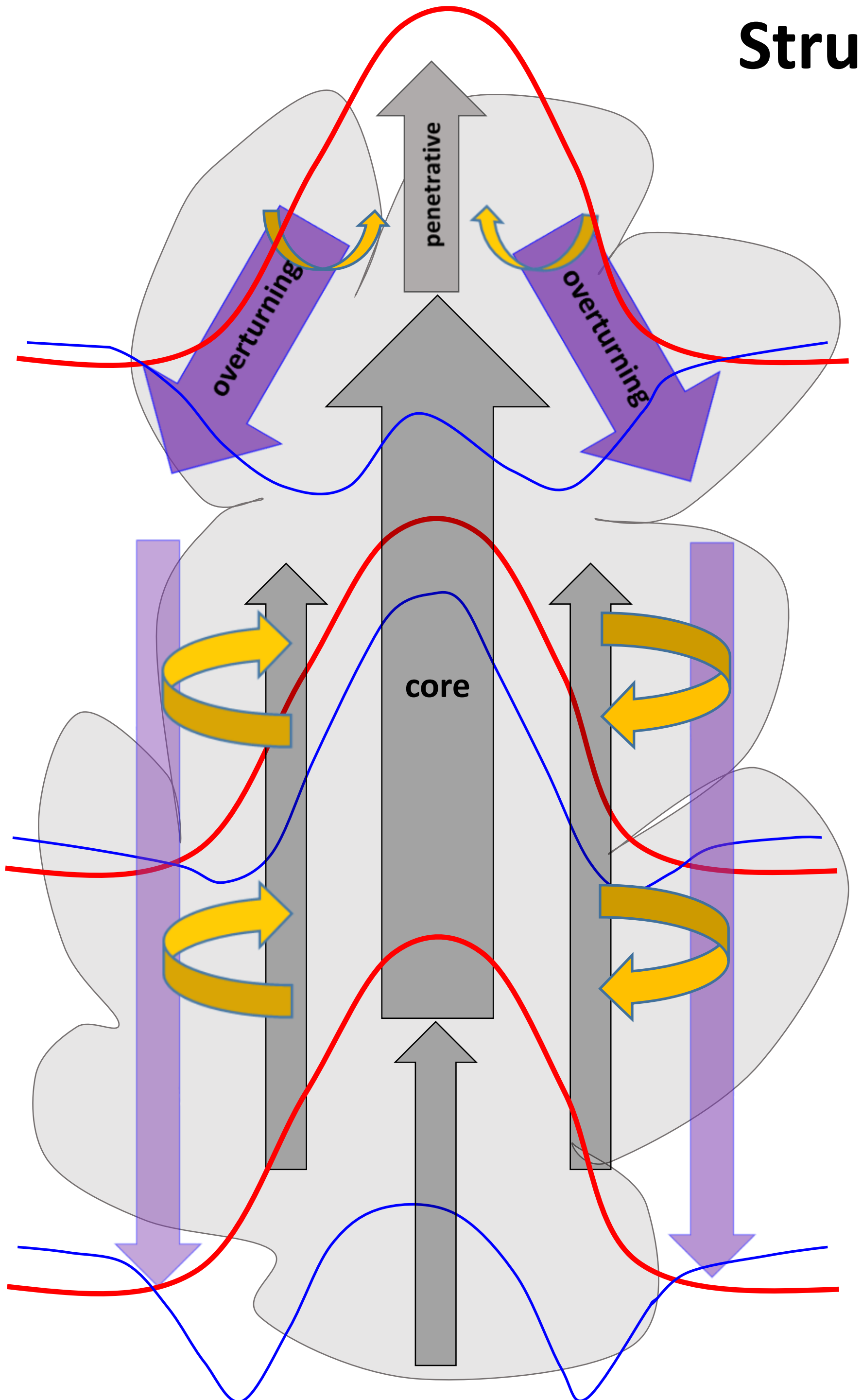
Cloud base

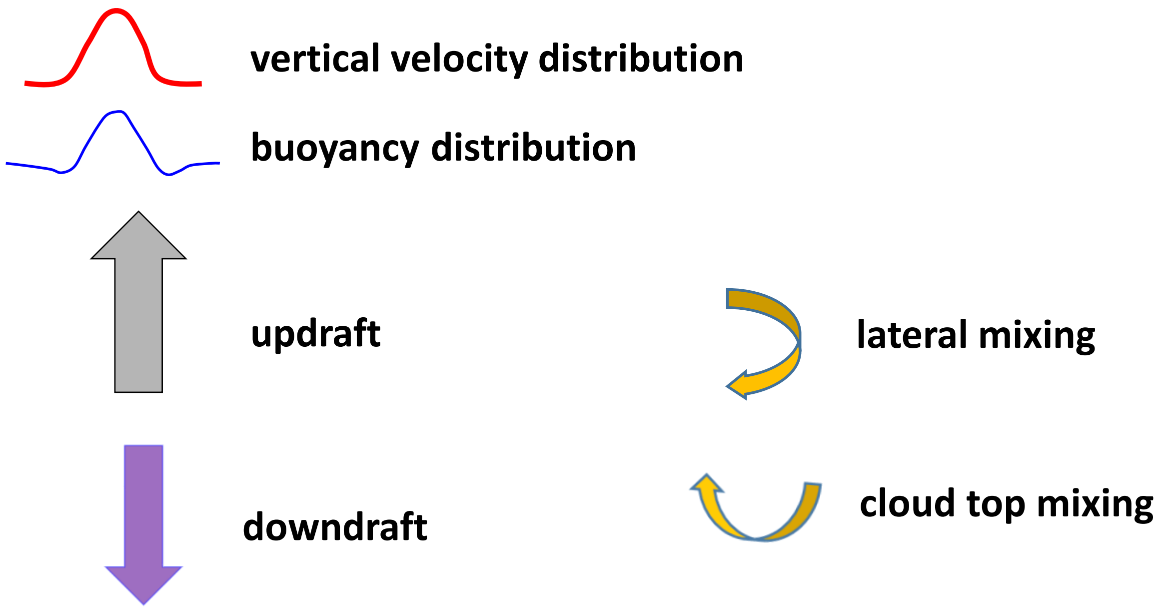


1800 m

Cloud top

Structure for shallow clouds



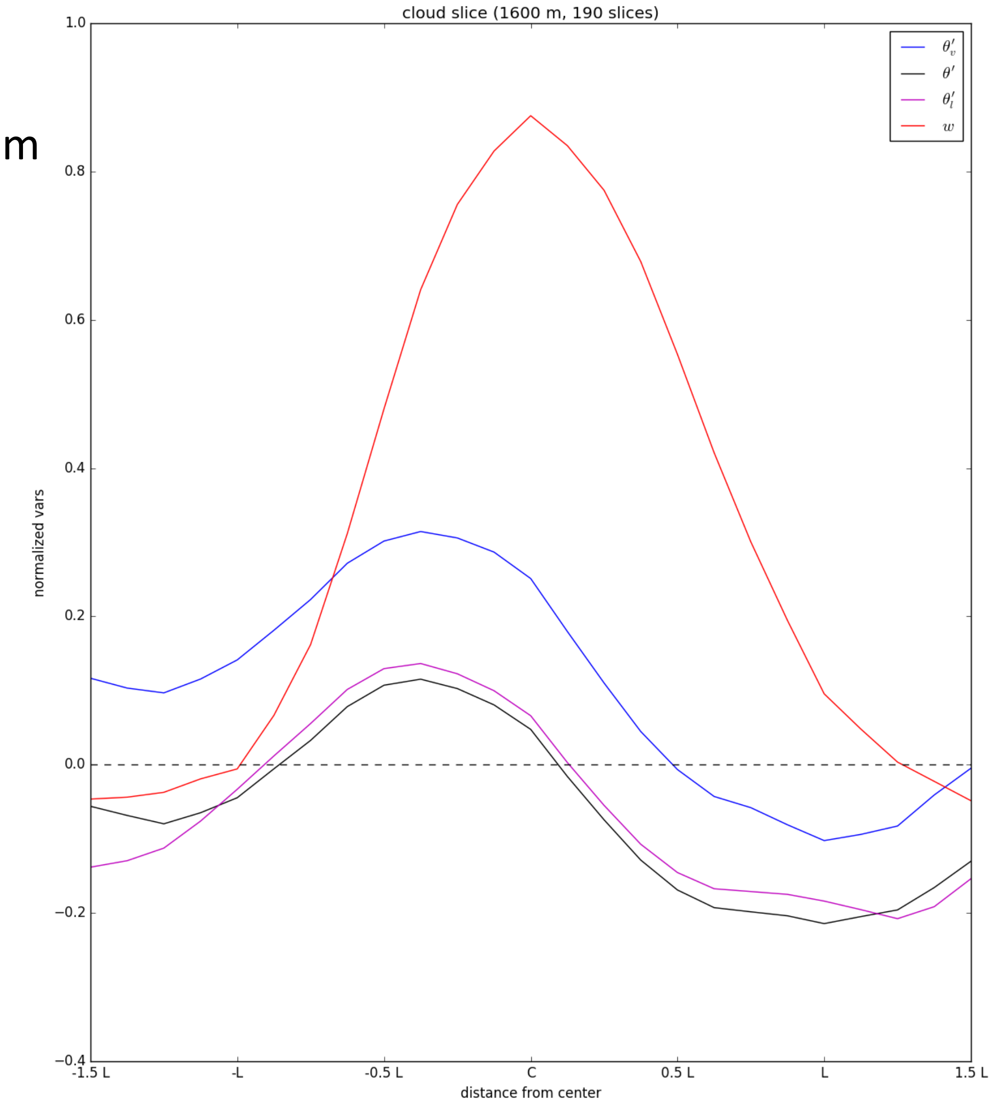


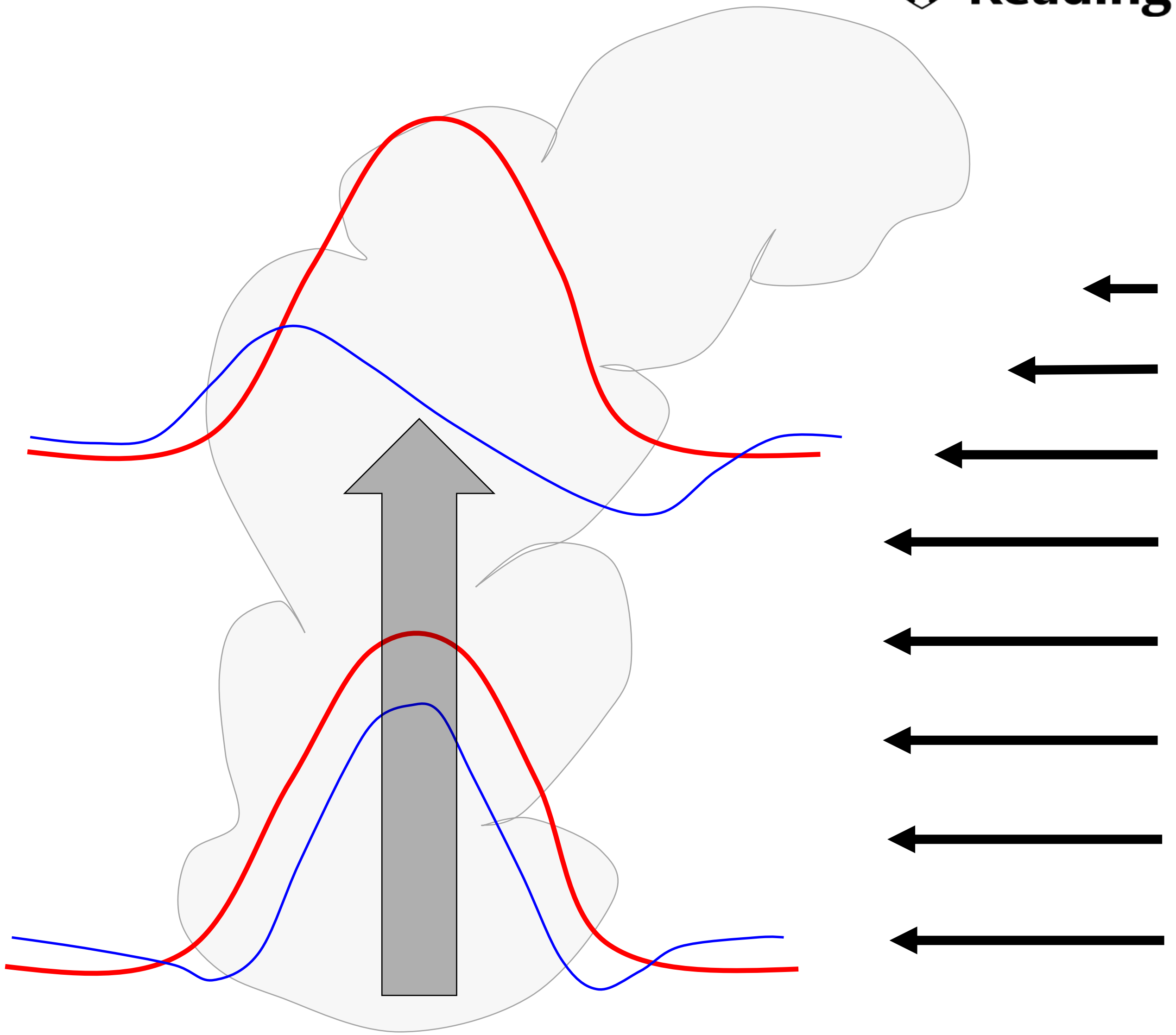
Downdraft near cloud top is important for estimating the vertical fluxes due to in-plume variabilities, but may not be easily represented through assumed PDF method.

It may be reasonable to parameterize these structures in the plume model. **CoMorph** code has provided a framework for this possibility through ***updraft_fallback*** calls.

Dry updrafts (top 5%) not overlapped with cloud)

1400 m





What causes the asymmetry of thermodynamic variables within dry updrafts?

Summary

- We develop an algorithm to composite the cloud slices near cloud center and study the distributions of variables within the cloud.

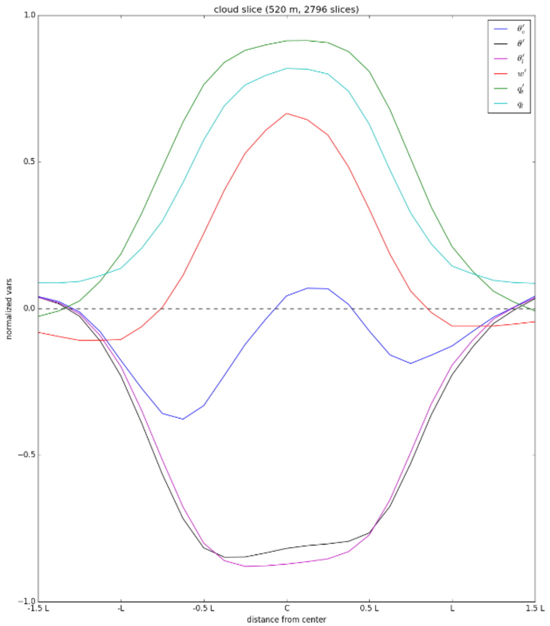
- The distributions are similar at mid-level, especially for deep convections. This may lead to an alternative PDF method for the parameterization of vertical fluxes.

- However, near the cloud base and cloud top, the distributions deviate from each other due to some distinct structures. We may need more careful treatment of these structures in the parameterization.

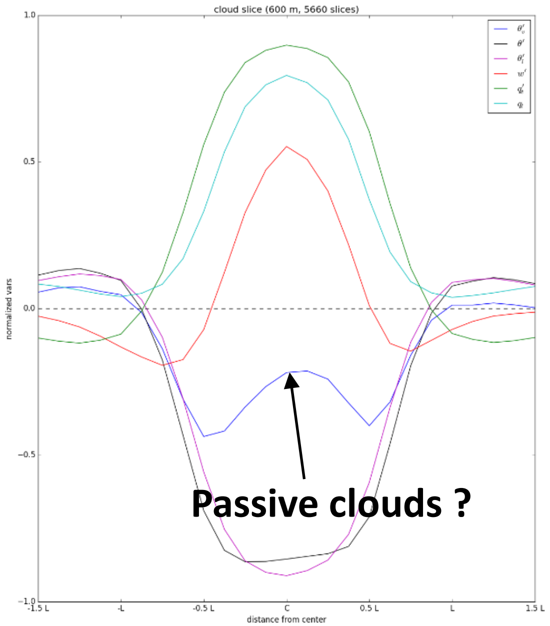
- Some interesting structure features are found for dry updraft under vertical wind shear but haven’t been well understood.

But what about the distributions near cloud base and cloud top?

Distributions of vertical motion and variables do not collapse well

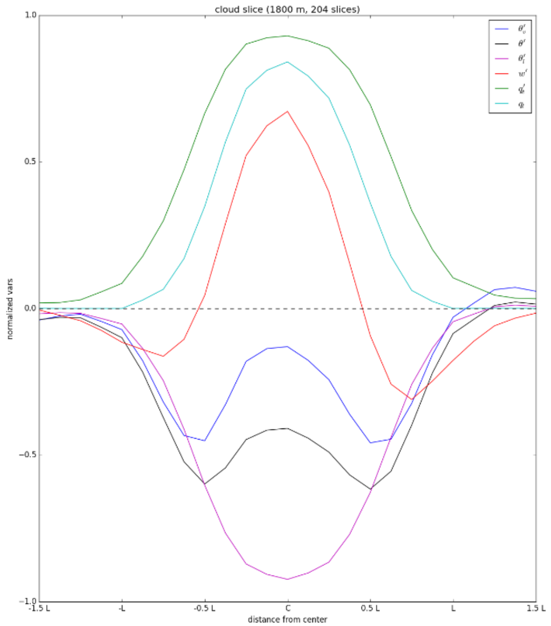


520 m

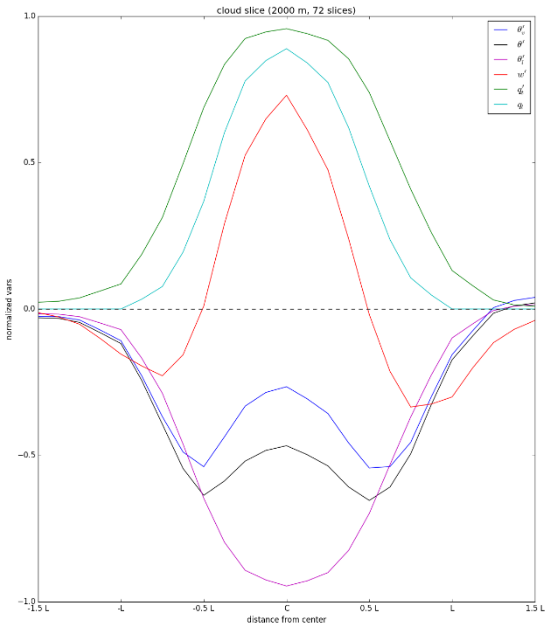


600 m

Cloud base



1800 m

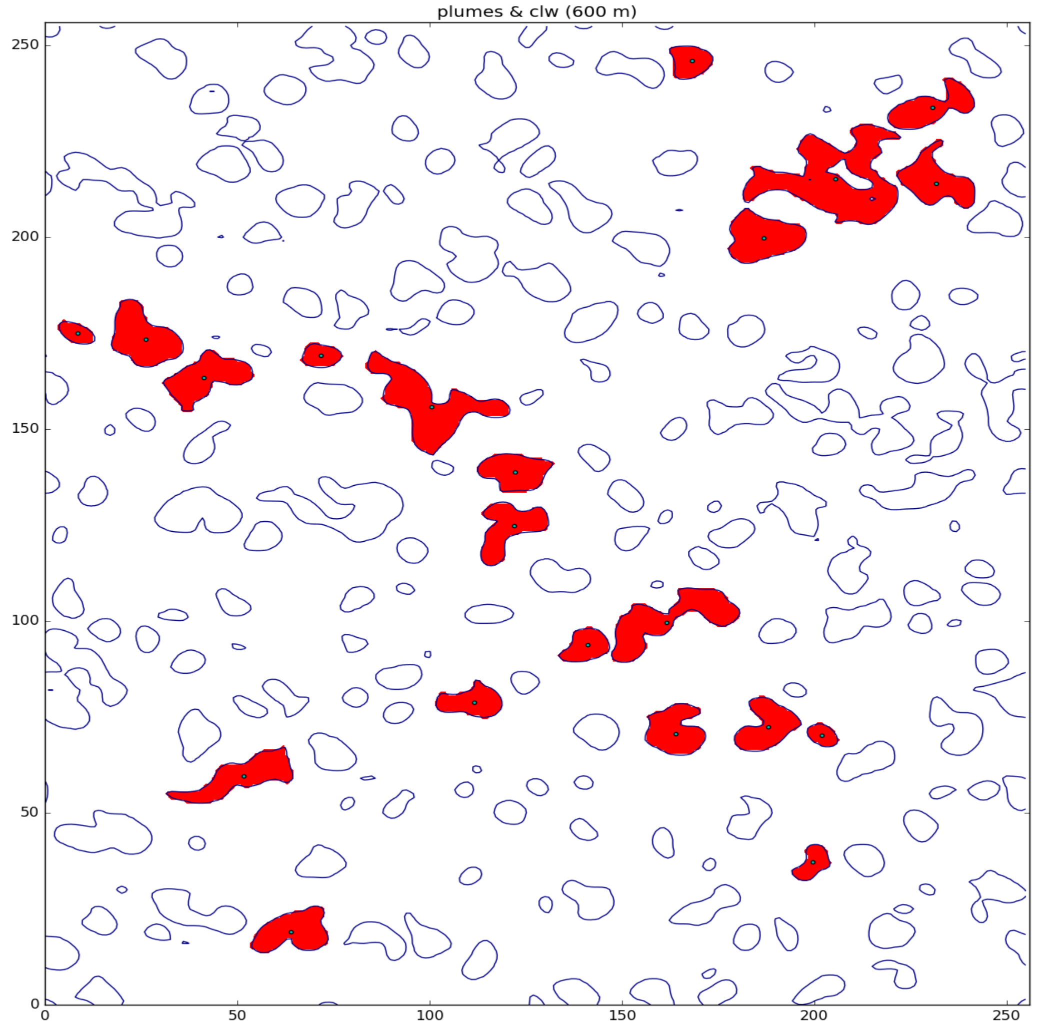


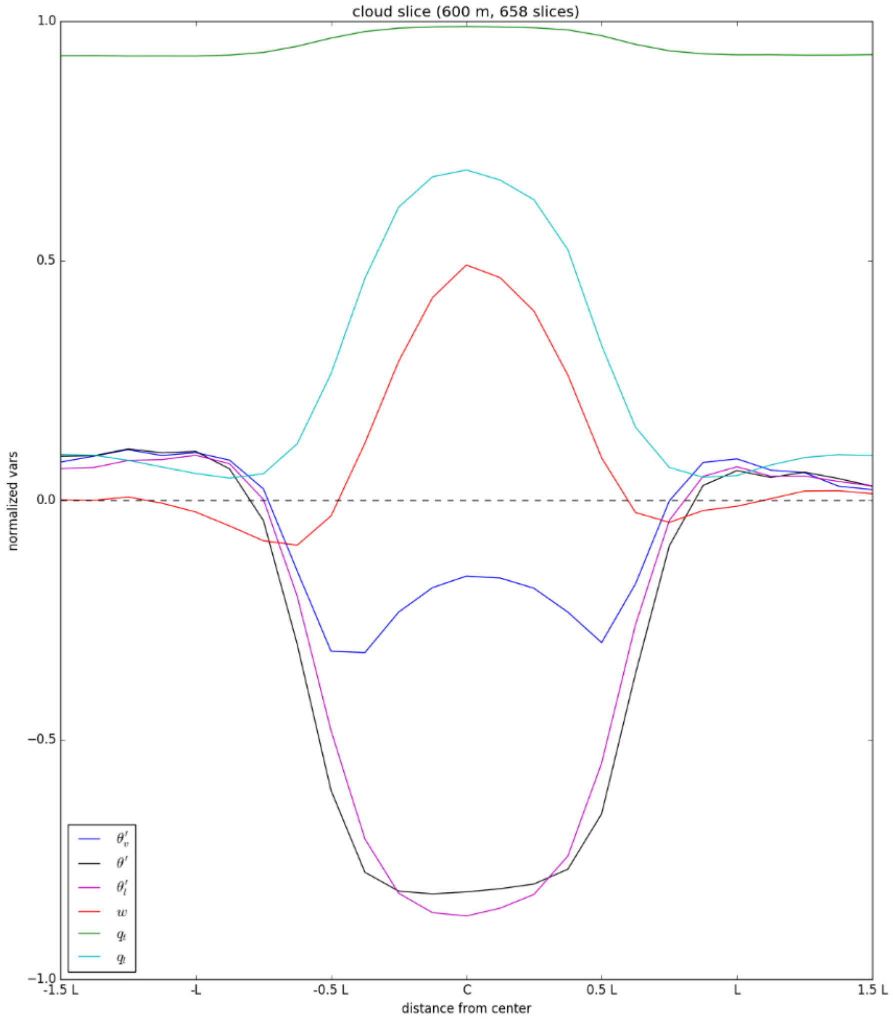
2000 m

Cloud top

BOMEX

q_l > 1e-5

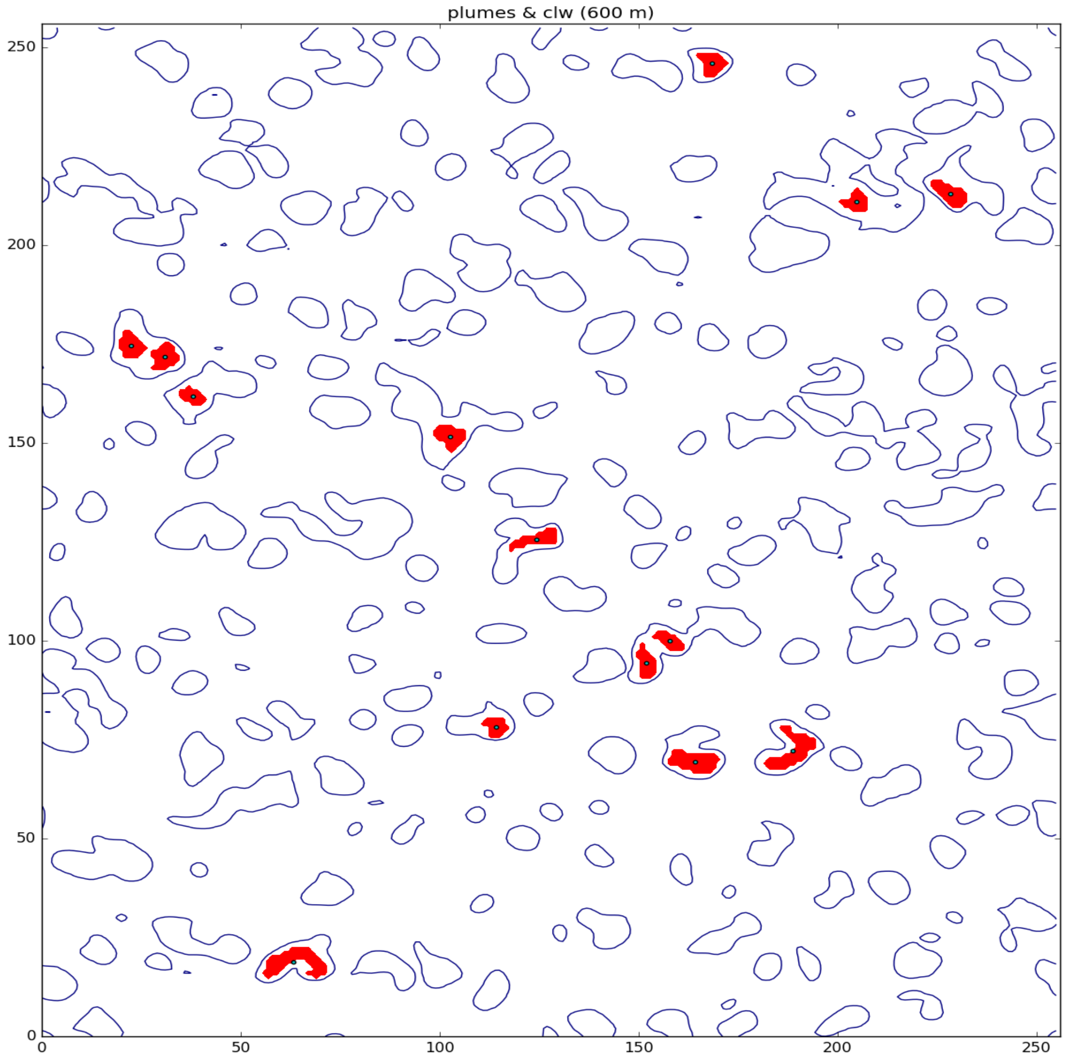


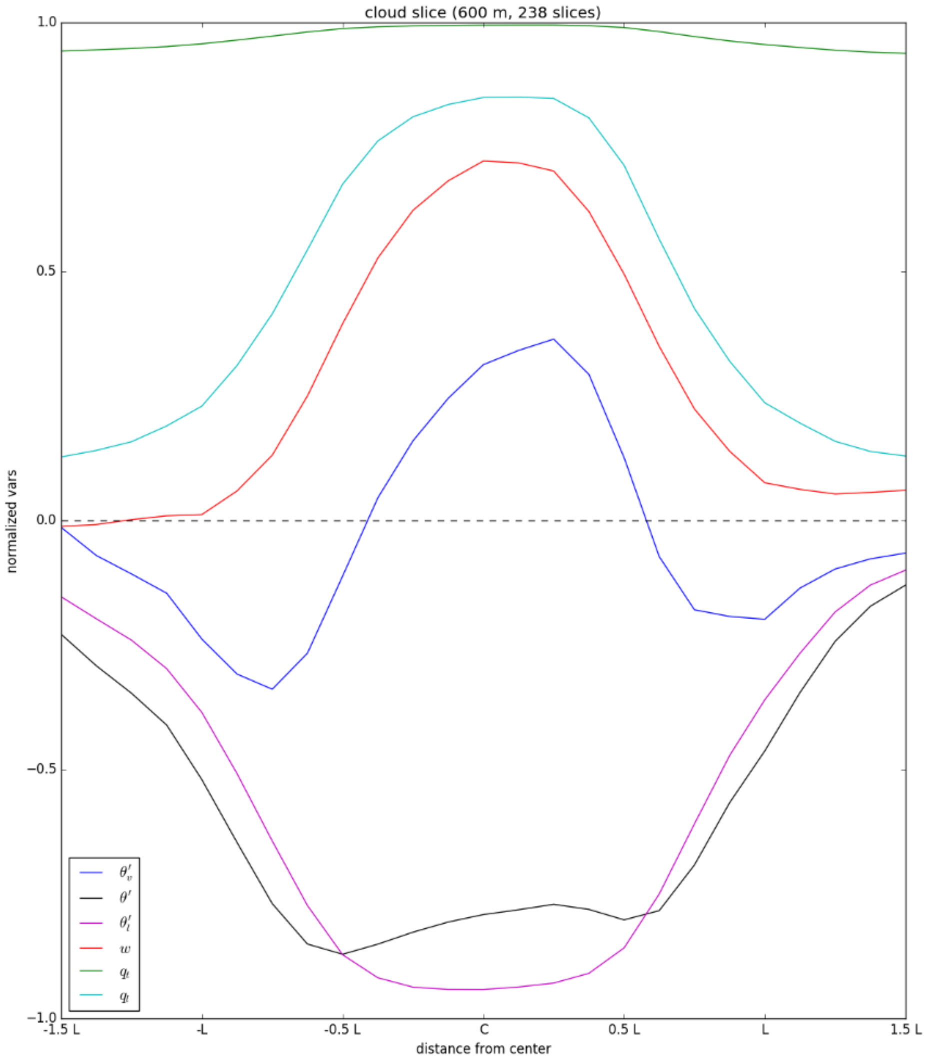


Cloud top > 1600 m

BOMEX

$q_l > 5e\text{-}5$

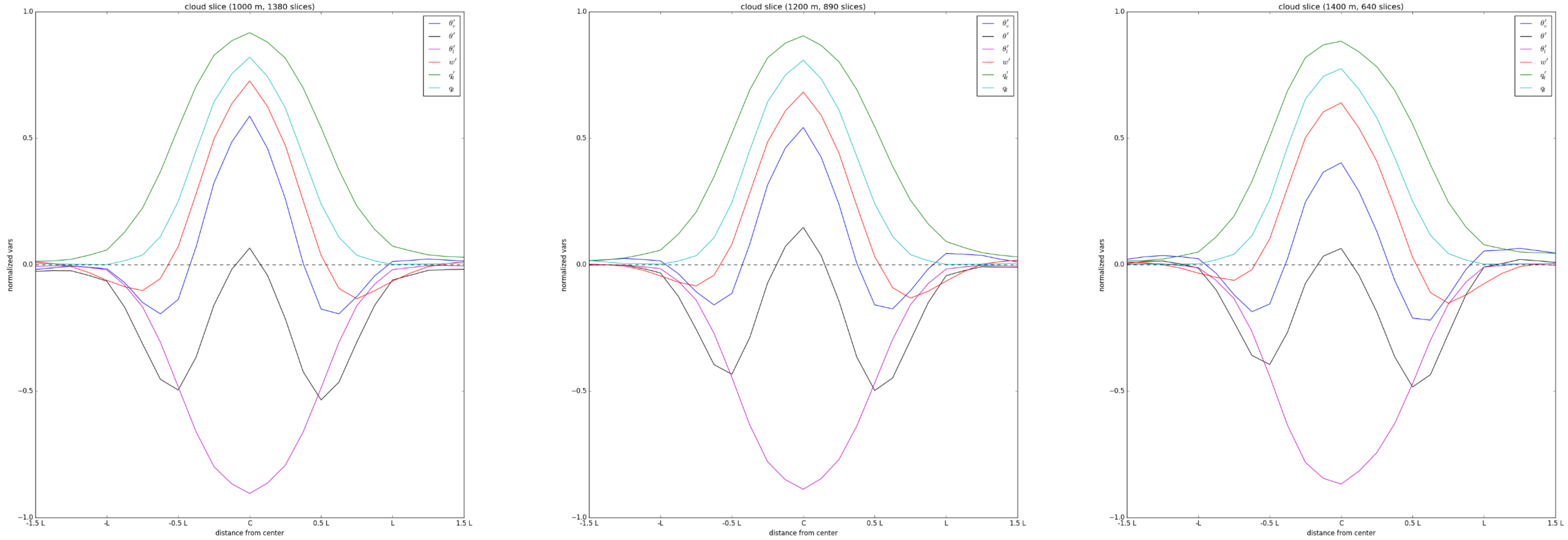




Cloud top > 1600 m

BOMEX

$q_l > 1e\text{-}5$



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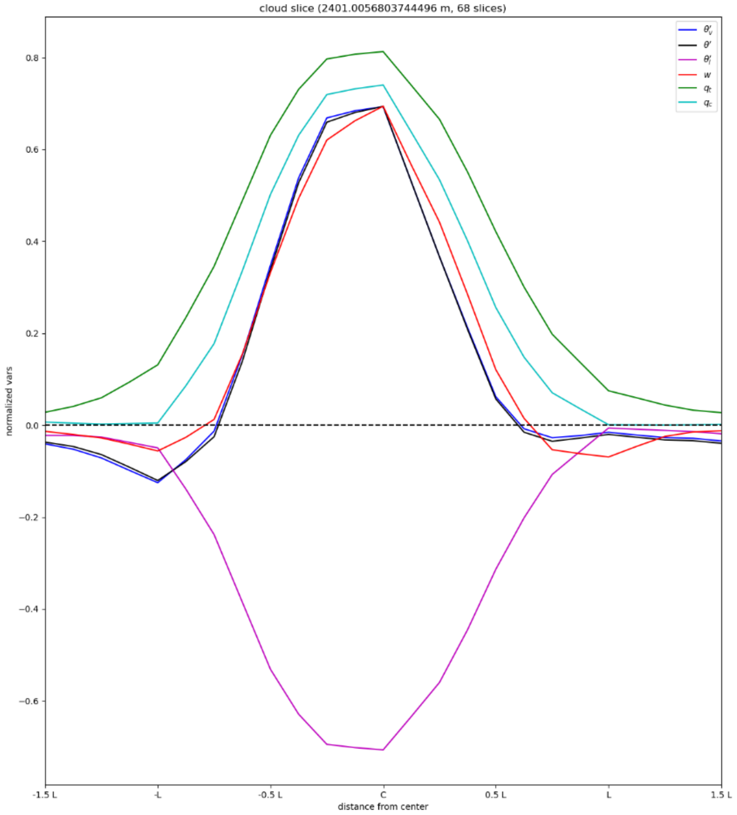
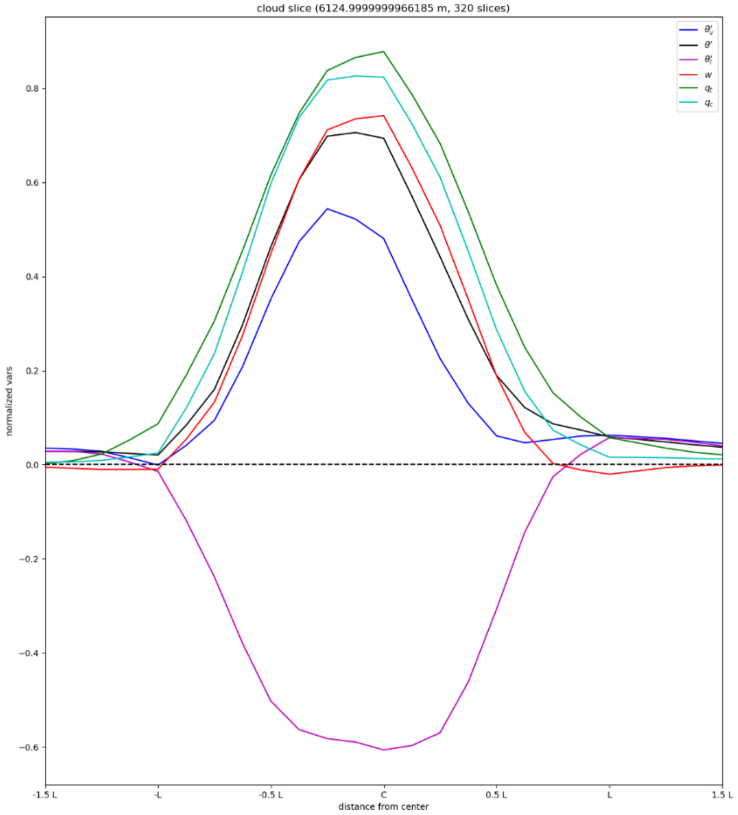
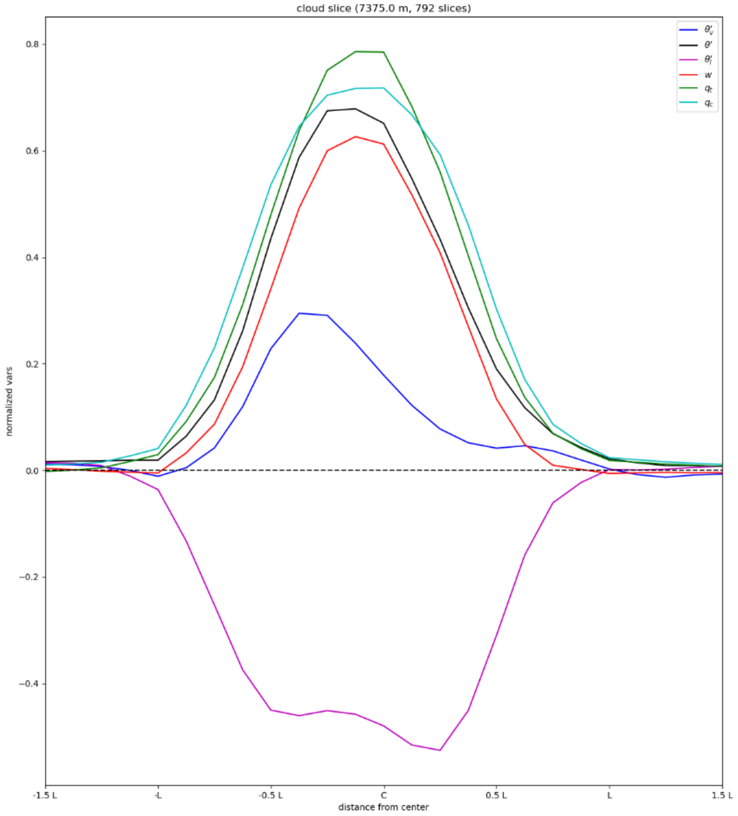
$q_l + q_i > 1\text{e-}5$



2400 m

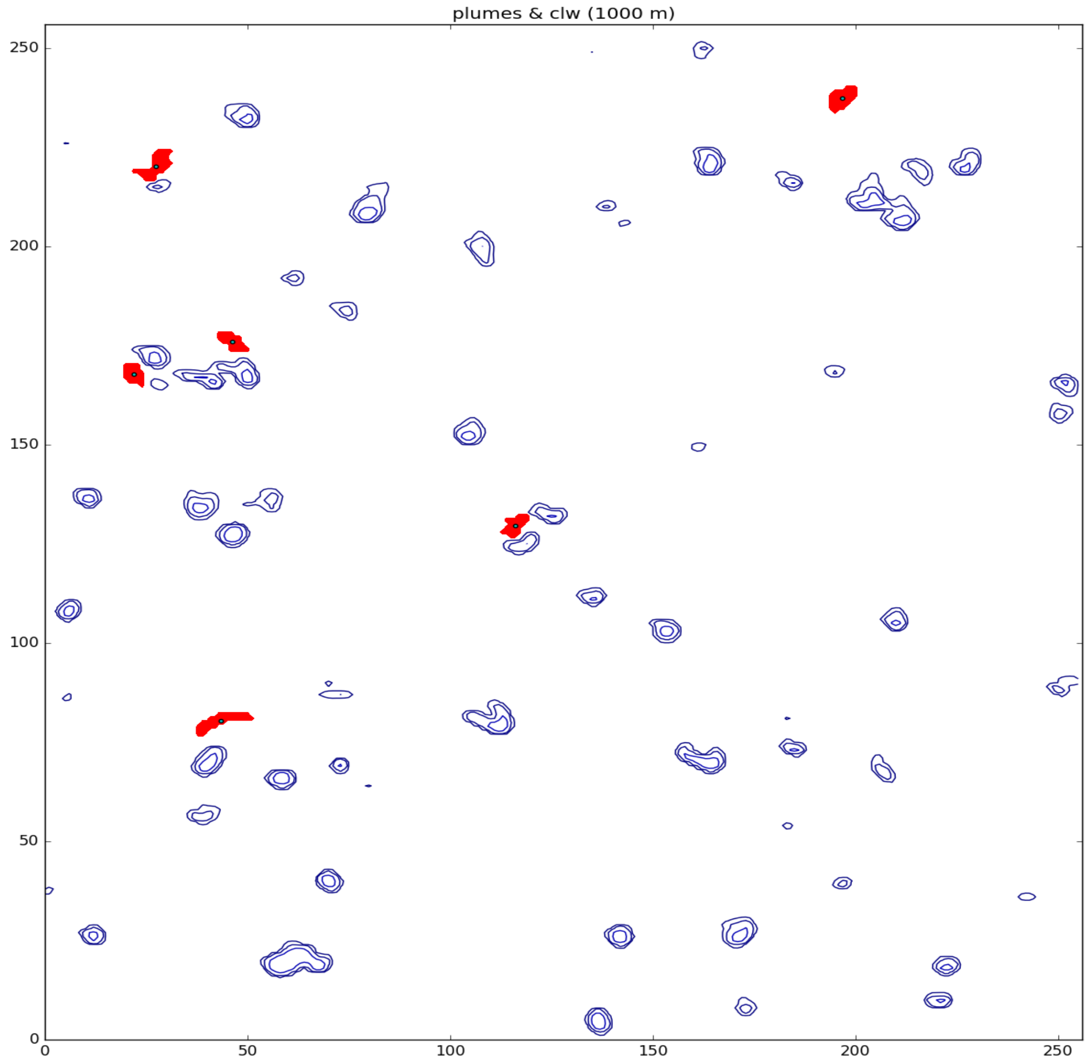


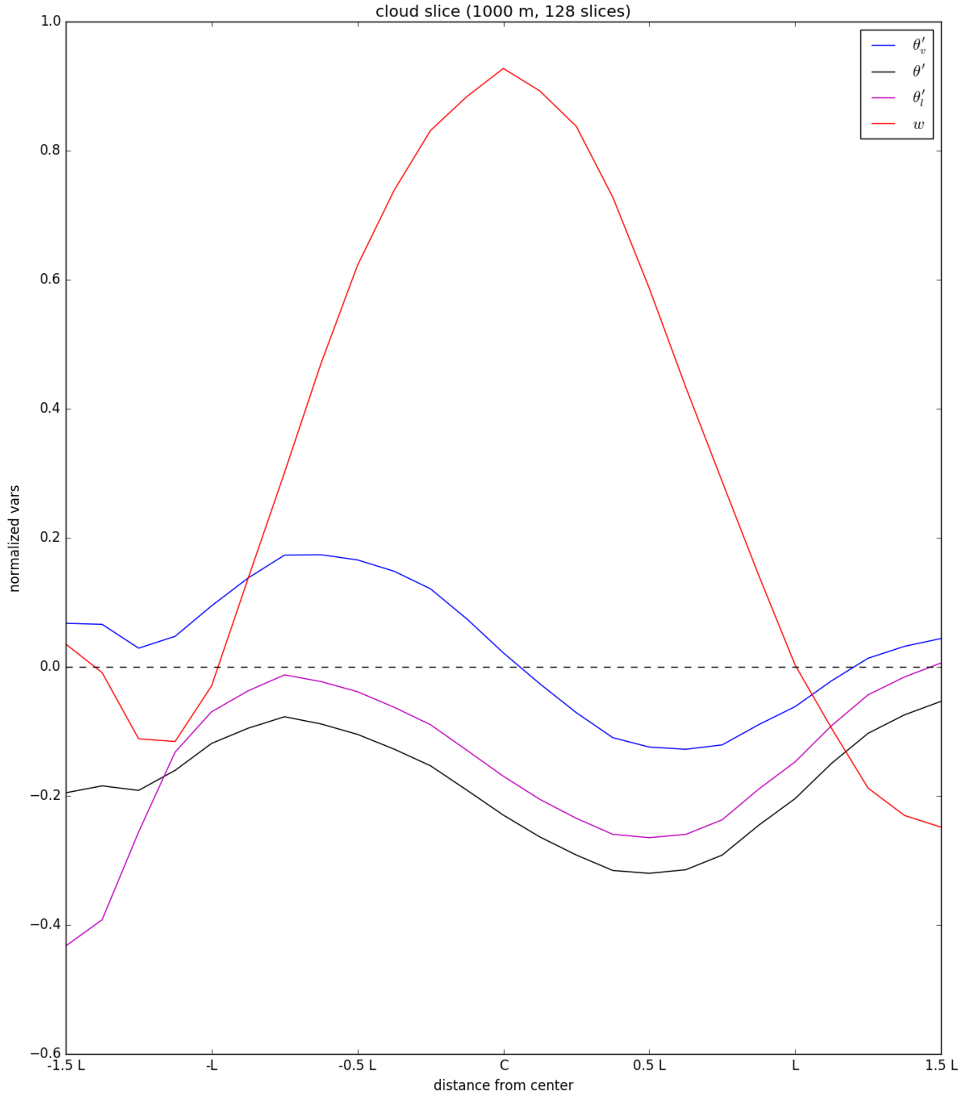
6100 m



7400 m

Dry updrafts (top 5% ud) not overlapped with cloud)





1000 m