



Extending EDMF into the representation of PBL clouds

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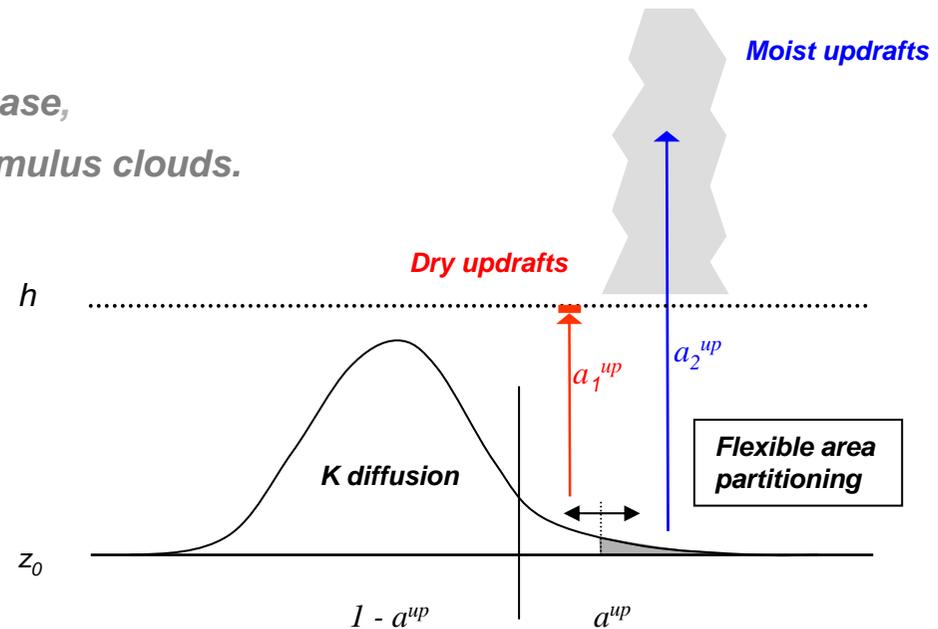
ECMWF

The eddy diffusivity - mass flux (EDMF) approach for turbulent transport

Extension for shallow cumulus: multiple updrafts

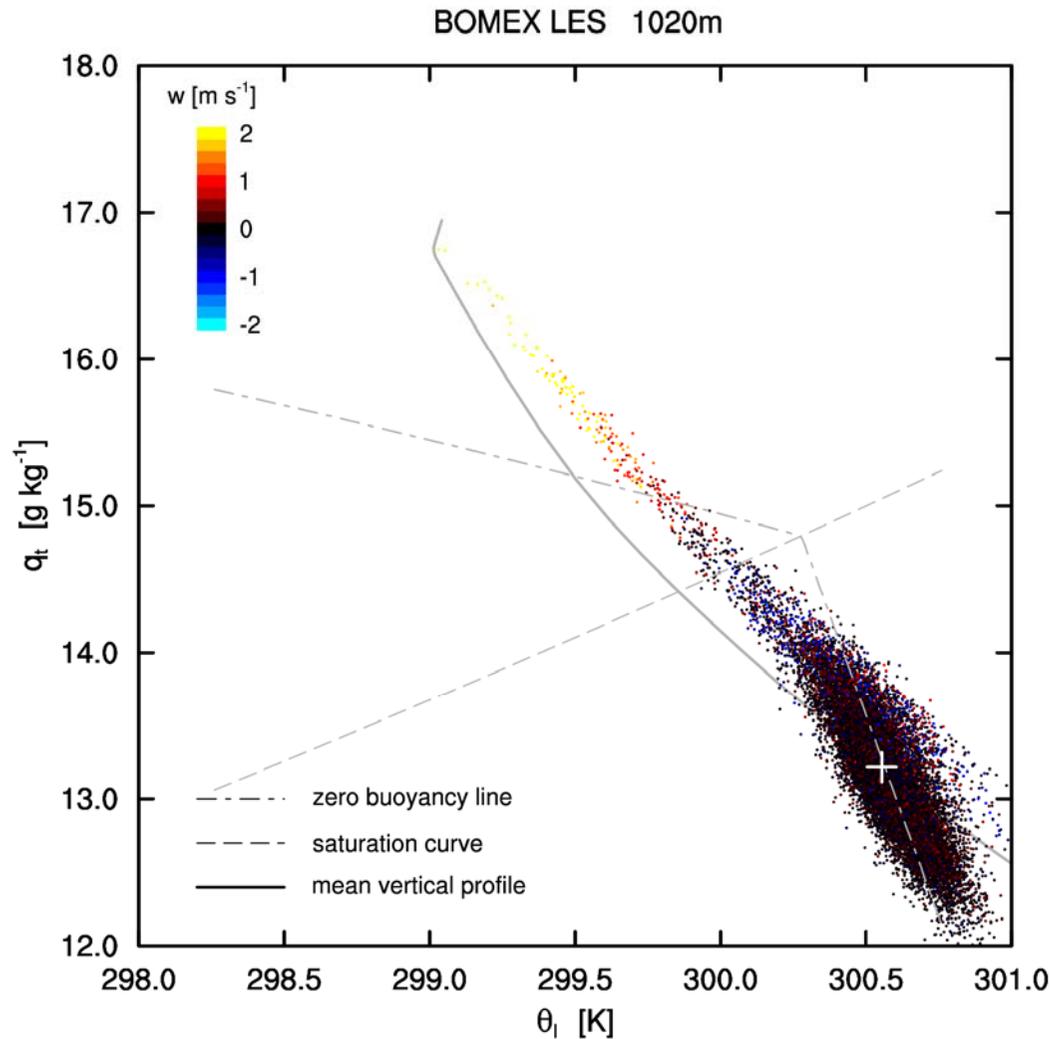
$$\overline{w'\phi'} = -K_\phi \frac{\partial \bar{\phi}}{\partial z} + \sum_{i=1}^I M_i (\phi_i - \bar{\phi}) \quad \phi \in \{\theta_l, q_t\}$$

$I=2$: **dry** updrafts stopping at cloud base,
moist updrafts continuing as cumulus clouds.



Q: What cloud scheme should be used?

The turbulent PDF in shallow cumulus cloud layers shows a distinct bimodal structure



1 updraft PDF (on mixing line)

1 passive PDF (on zero buoyancy line)

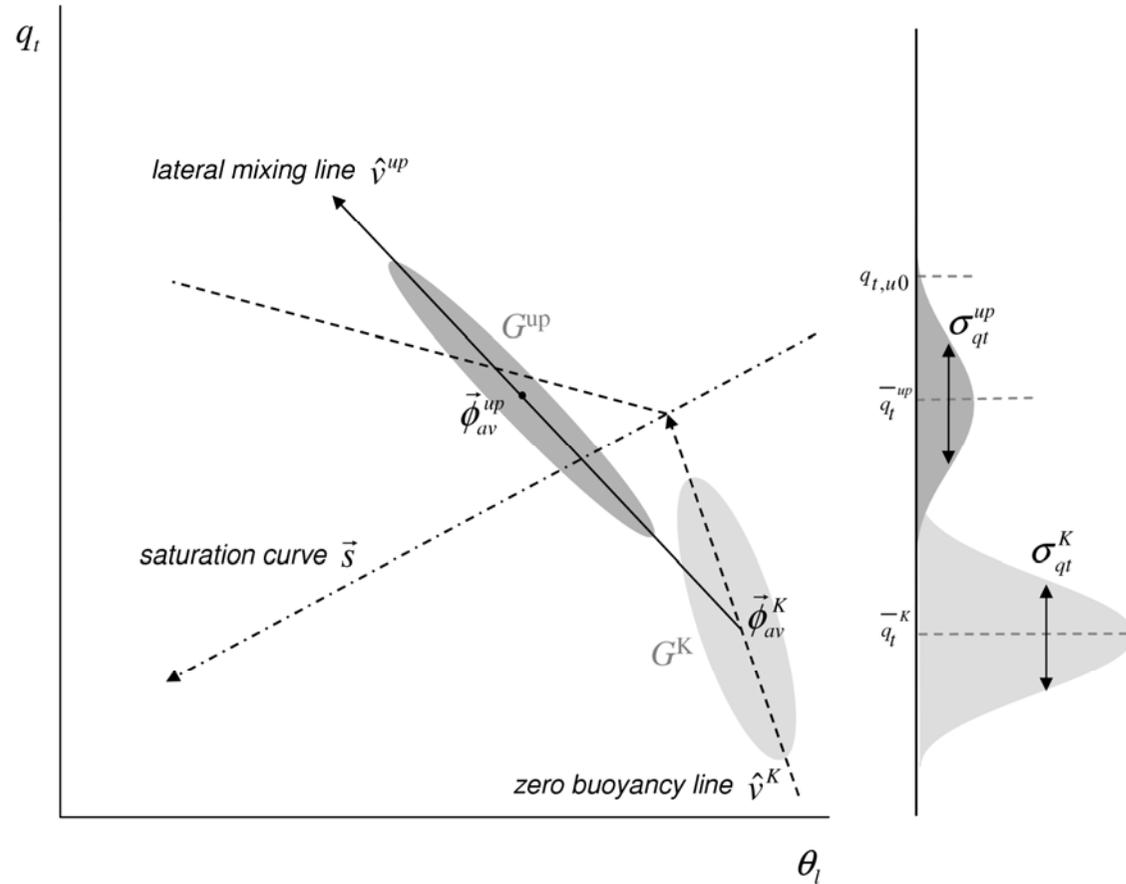
This suggests the EDMF decomposition can be extended into the statistical modelling of clouds



A consistent treatment of transport and cloudiness throughout the PBL

PDF reconstruction in $\{\theta_l, q_t\}$ – space

Orientation of each PDF reflects its unique properties



Relations between moments

$$\bar{\phi} = a^{up} \phi^{up} + a^K \phi^K$$

$$\sigma^2 + \bar{\phi}^2 = a^{up} (\sigma^{up^2} + \phi^{up^2}) + a^K (\sigma^{K^2} + \phi^{K^2})$$

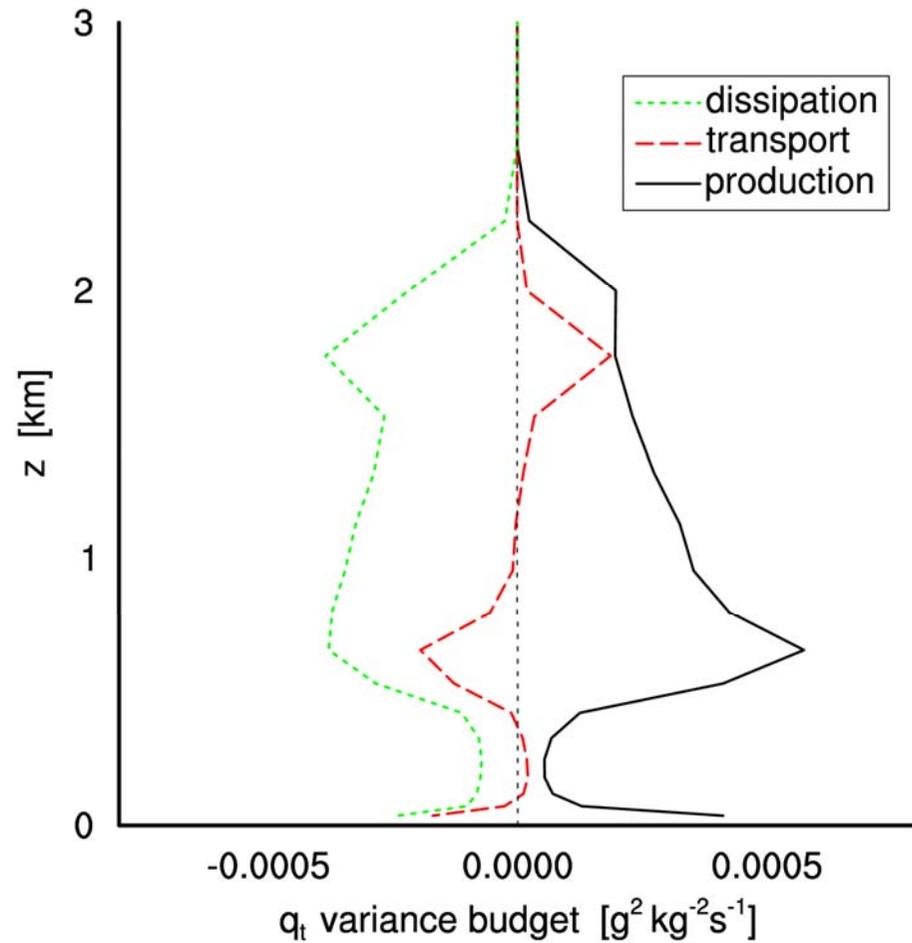
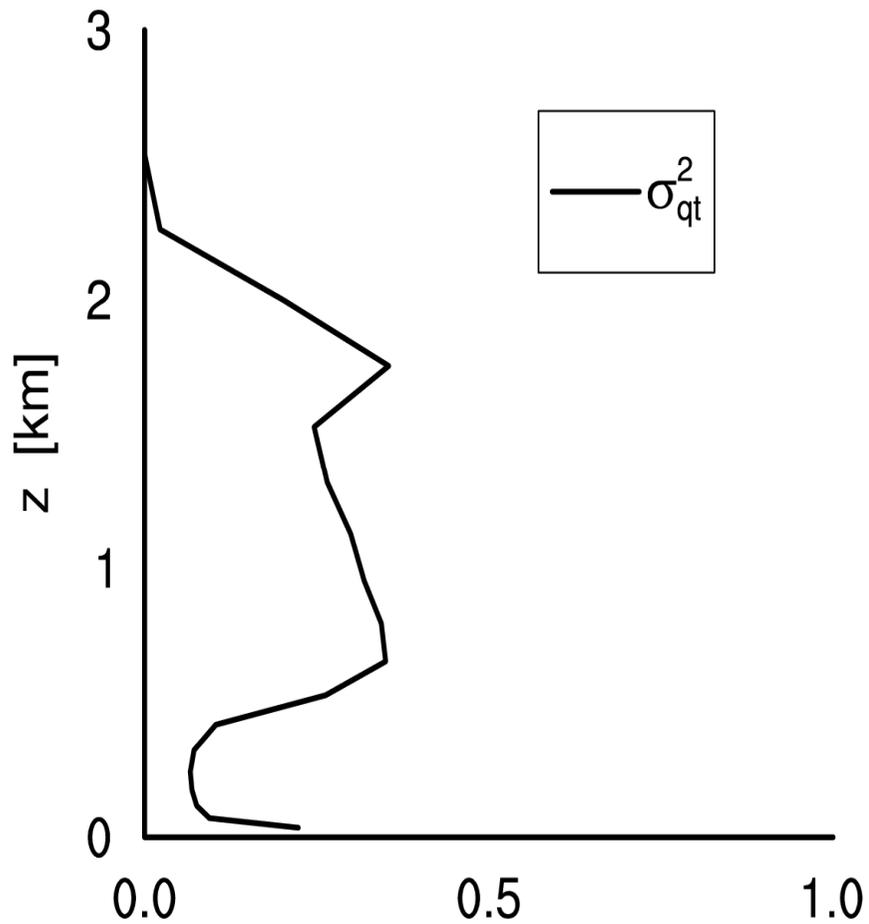
Lewellen & Yoh (JAS,1993)

parameterization of 2 out of 3 variances required →

I. Total variance budget

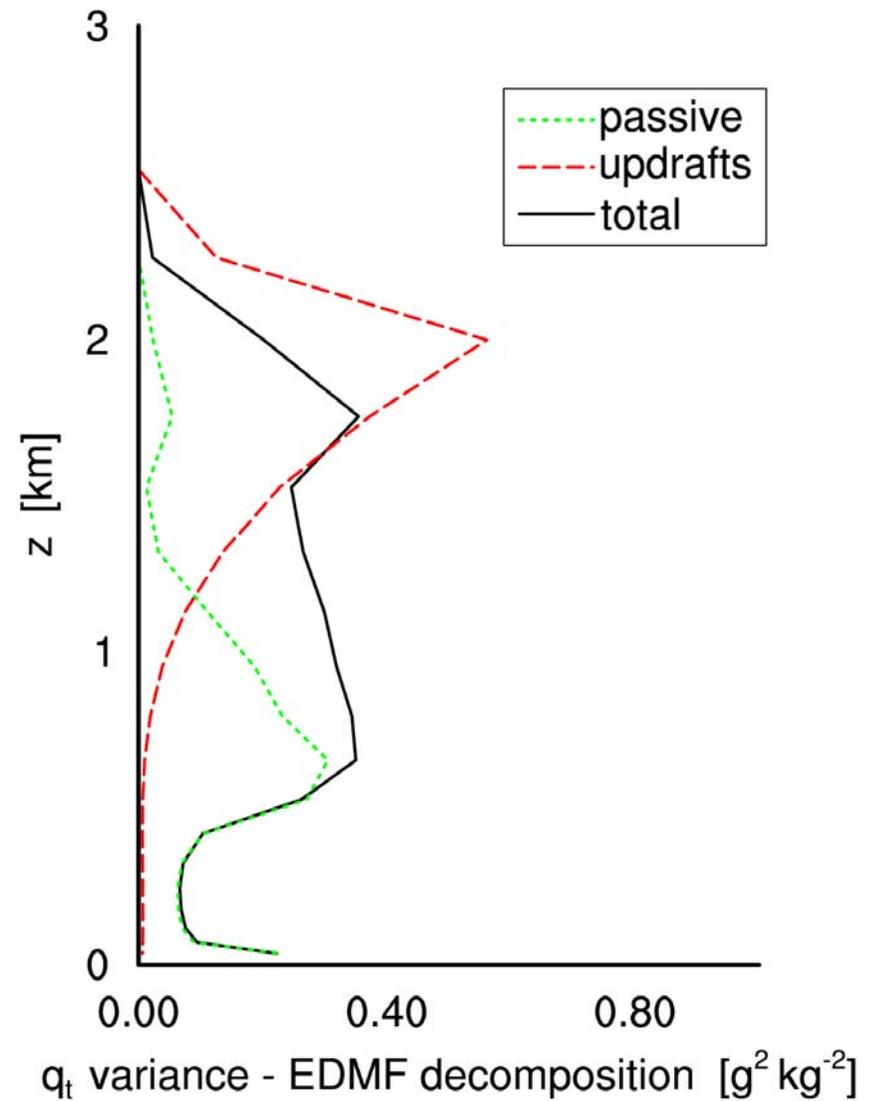
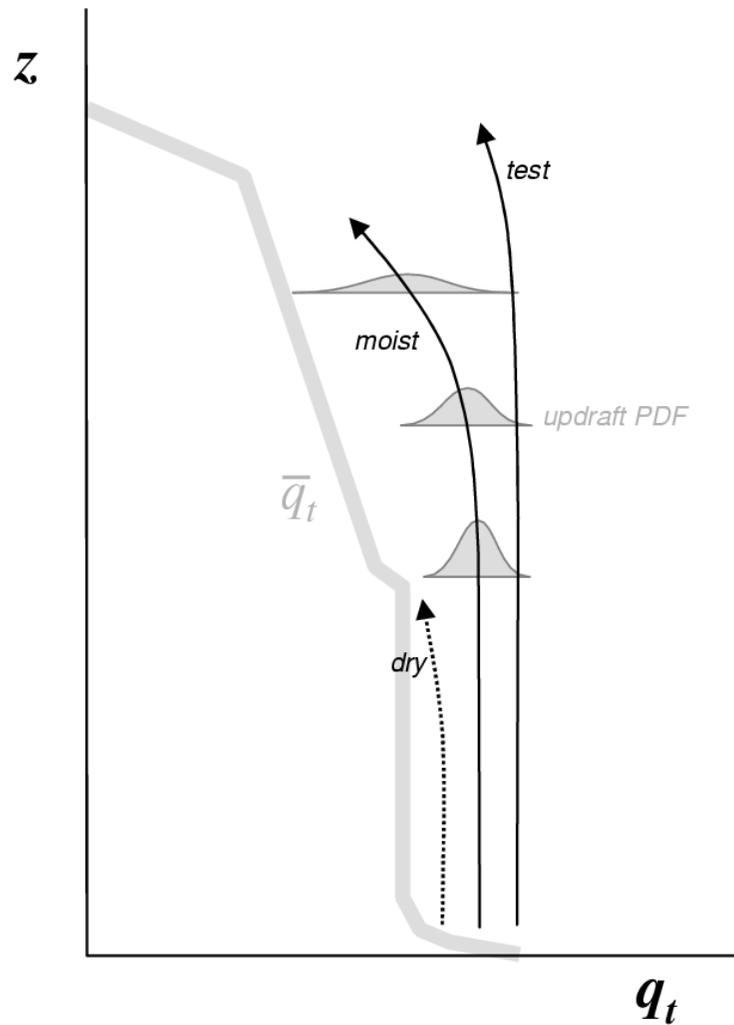
Including transport

$$\frac{\partial \sigma_{\phi}^2}{\partial t} = -\overline{w'\phi'} \frac{\partial \bar{\phi}}{\partial z} - \frac{\partial \overline{w'\phi'\phi'}}{\partial z} - \frac{\sigma_{\phi}^2}{\tau}$$

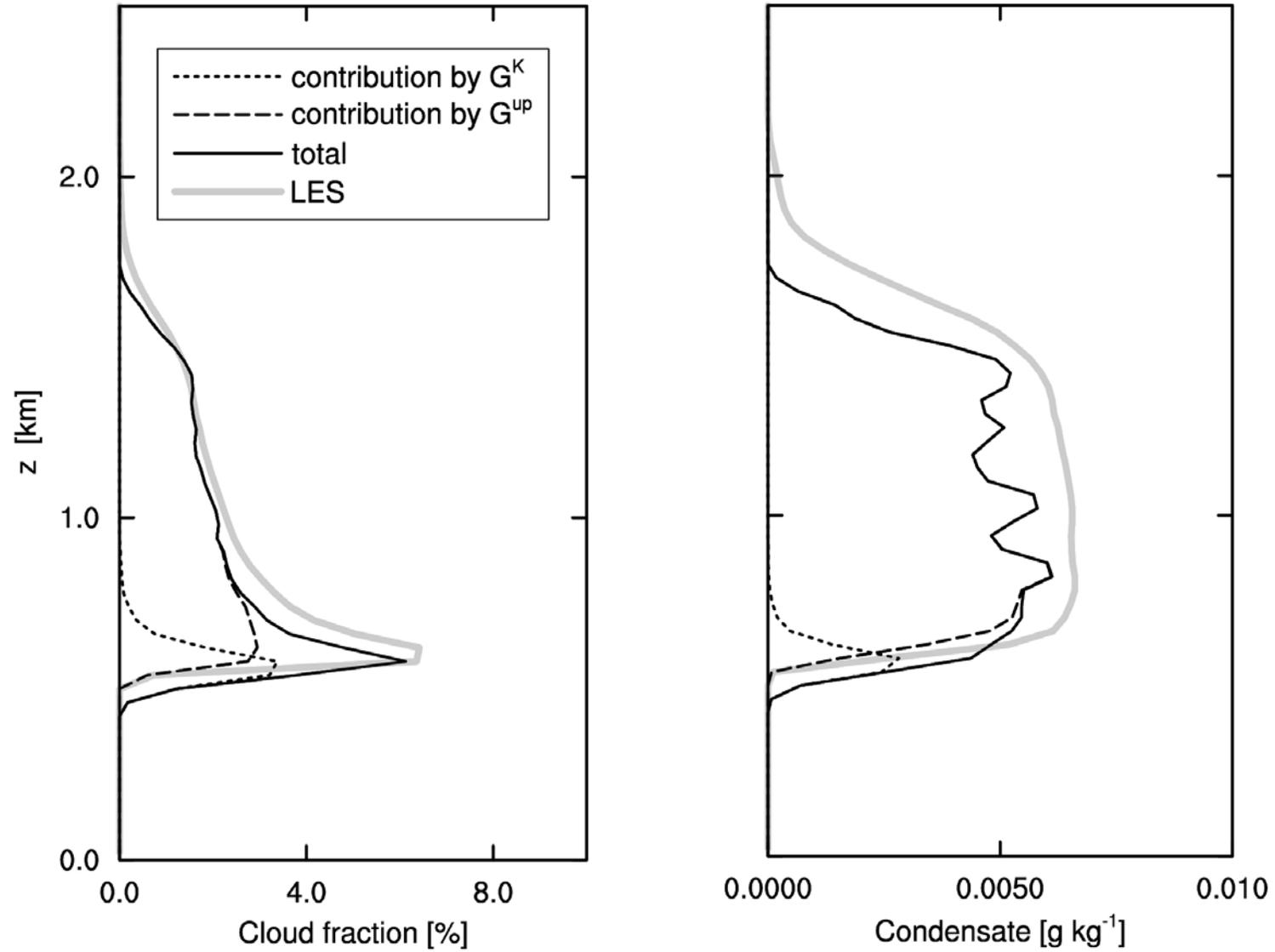


II. Updraft variance

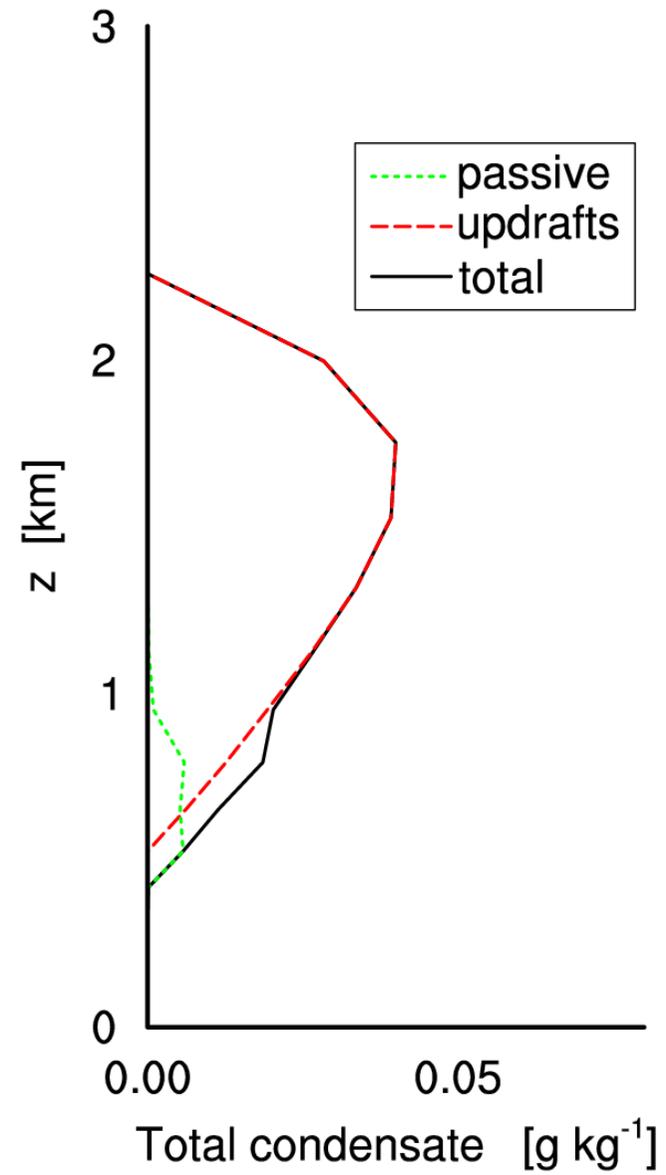
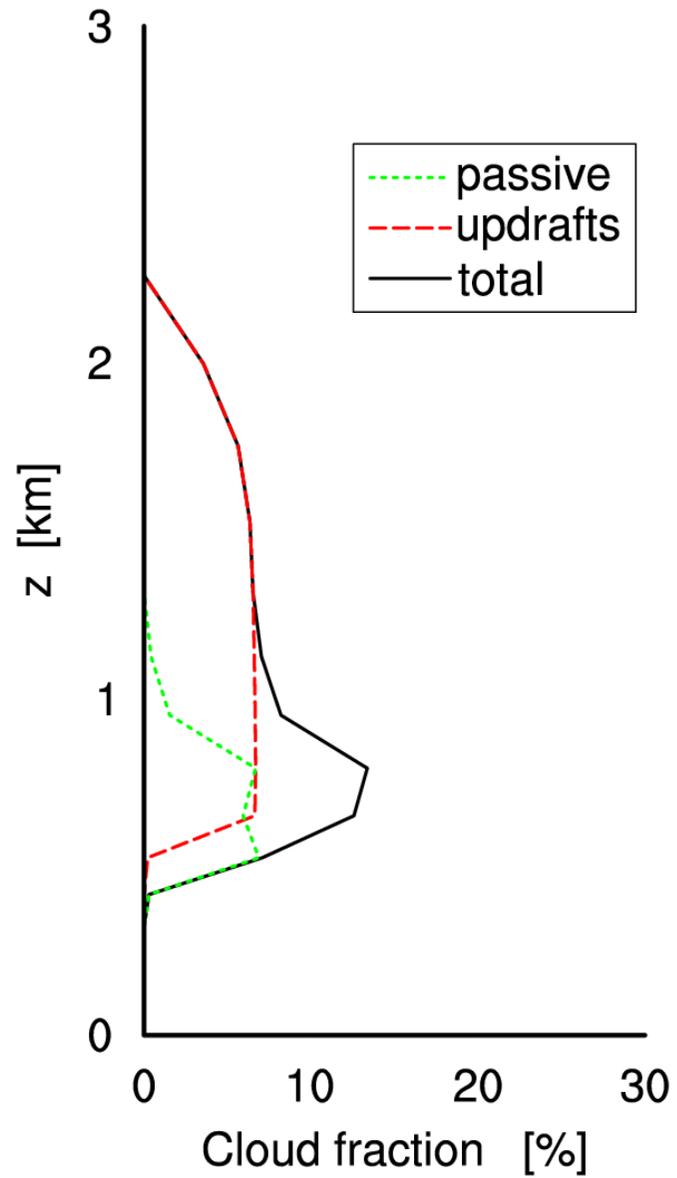
The spread created by the multiple rising updrafts contains information on updraft variance



Offline evaluation against LES BOMEX



SCM results for RICO





Updraft clouds



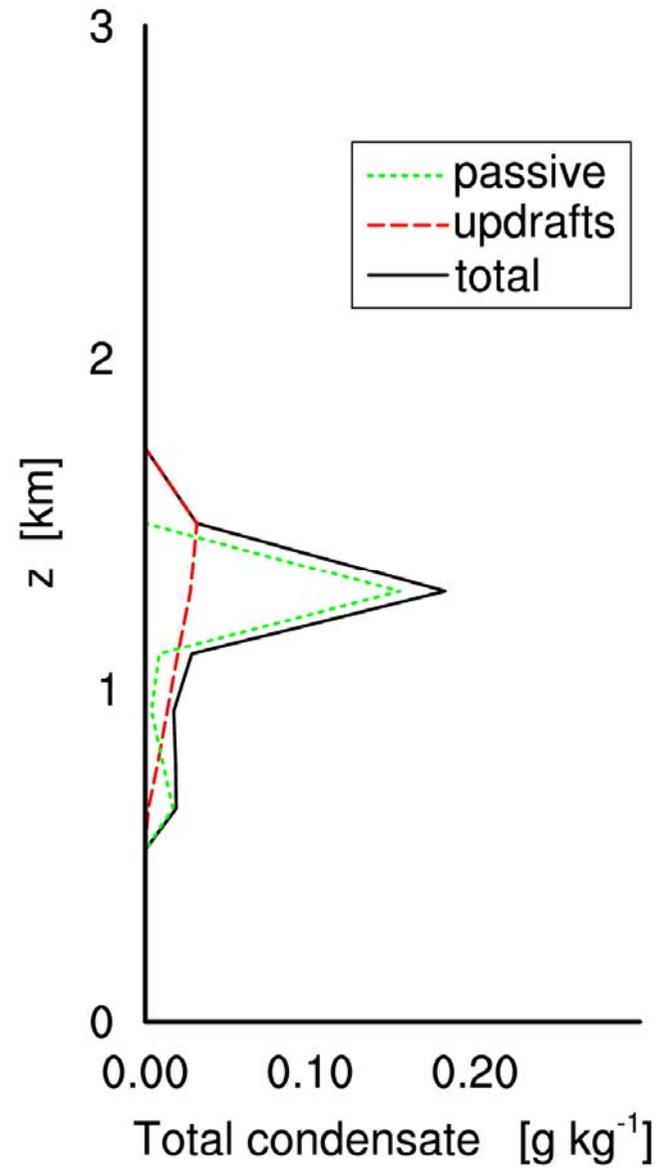
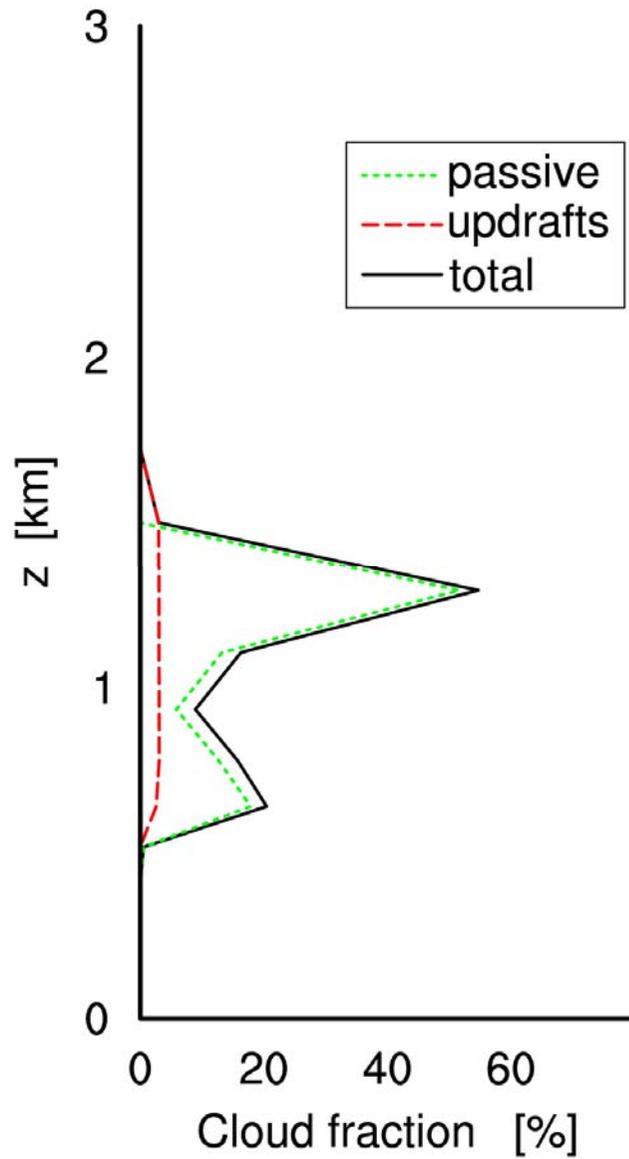
Passive clouds



Cumulus rising into stratocumulus



SCM results for ATEX



Summary

The EDMF approach for PBL transport is extended into the modelling of clouds

This makes the treatment of PBL transport and clouds fully integrated and consistent

Contributions by the advective (updraft) PDF and the diffusive (passive) PDF are modelled independently

The distinct bimodal structure of cumuliform and stratiform cloud fraction and condensate is reproduced by the SCM

The extra degree of freedom introduced by the second PDF could be used in schemes for other physics, such as radiation, microphysics and precipitation