UNIVERSITY OF LEEDS

Convection and wind-shear

How do they interact?

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14th Nov Convection Group meeting, Leeds

What am I interested in?

Affect of shear on:

- Boundary-layer structure
- Convective triggering
- Convective development

Taken out of the window on the train :)

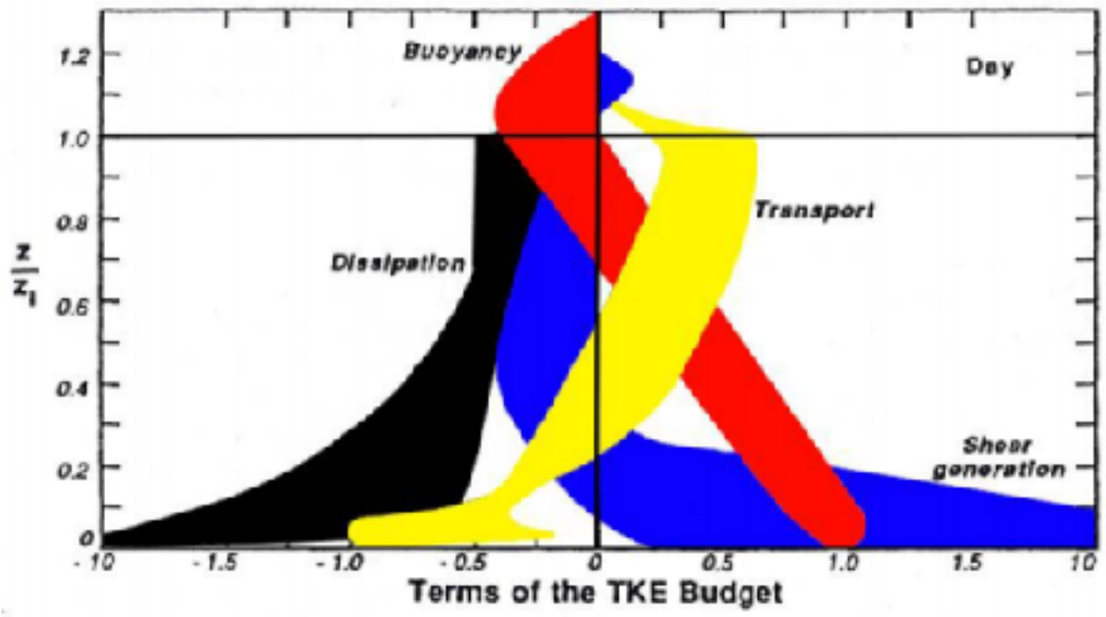
Boundary-layer structure

$$\frac{\partial \overline{e}}{\partial t} = \frac{g}{\overline{\theta}_v}\left(\overline{w'\theta'_v}\right) - \overline{u'w'}\frac{\partial \overline{U}}{\partial z} - \frac{\overline{w'e}}{\partial z} - \frac{1}{\overline{\rho}}\frac{\partial \overline{w'p'}}{\partial z} - \epsilon$$

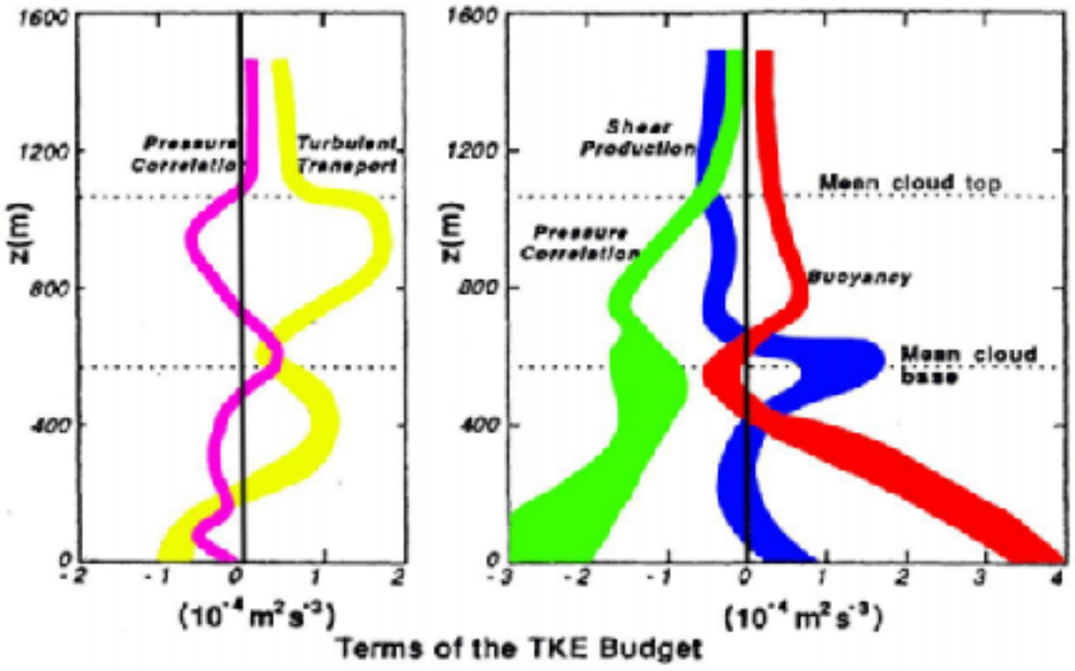
- Boundary-layer TKE (which is associated with transport) can be created by both buoyancy and shear

Boundary-layer structure

Cloud-free



Cloudy



Stull 1988

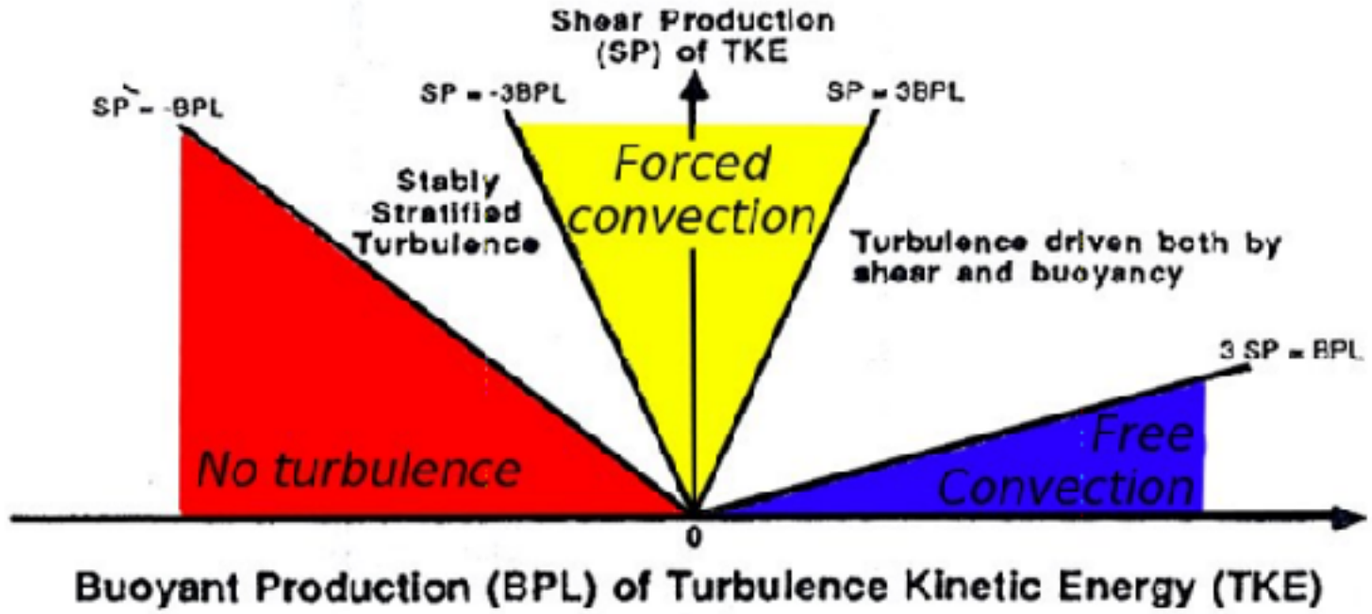
- High shear typically at:
  - Surface, drag against surface features
  - Near cloud-base, boundary-layer wind orients towards geostrophic winds

Boundary-layer structure

Stull 1988

- Balance of buoyancy and shear TKE source captured in *gradient Richardson number:*

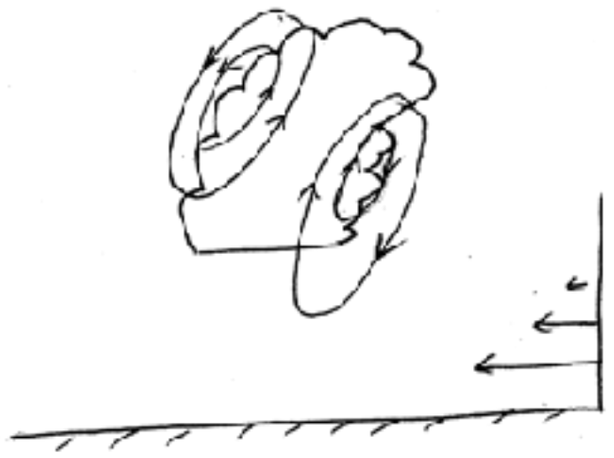
$$R_i = \frac{\frac{g}{\theta_v}\frac{\partial \overline{\theta_v}}{\partial z}}{\left|\frac{\partial \overline{u}}{\partial z}\right|^2 + \left|\frac{\partial \overline{v}}{\partial z}\right|^2}$$



- Shear produces TKE primarily in horizontal directions, buoyancy vertical

Wind-shear and single cloud

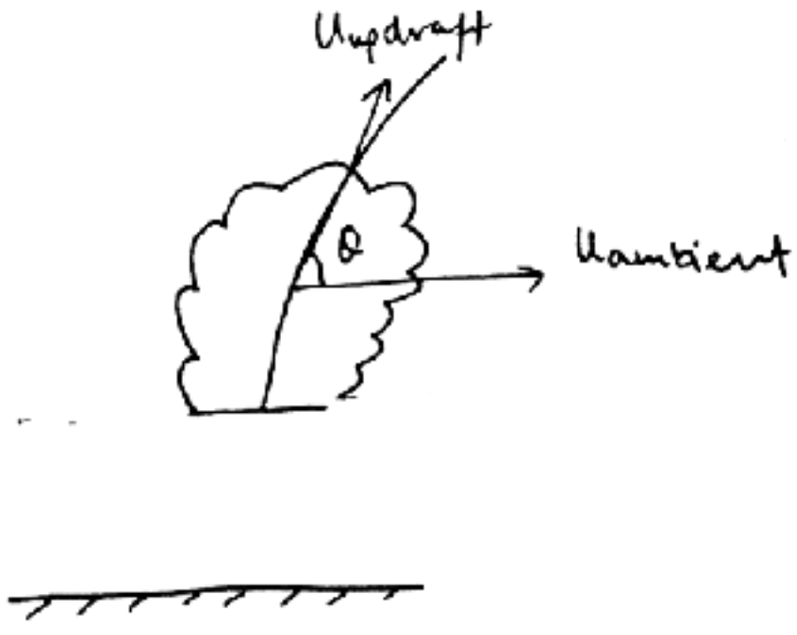
- Shear causes updraft to tilt in sheared direction



- Leads to enhanced entrainment, plume parameterisation:

$$U_\epsilon = \alpha|U_{ambient} sin\theta| + \beta|U_{updraft} - U_{ambient} cos\theta|,$$
$$\alpha \approx 1.0, \beta \approx 0.2$$

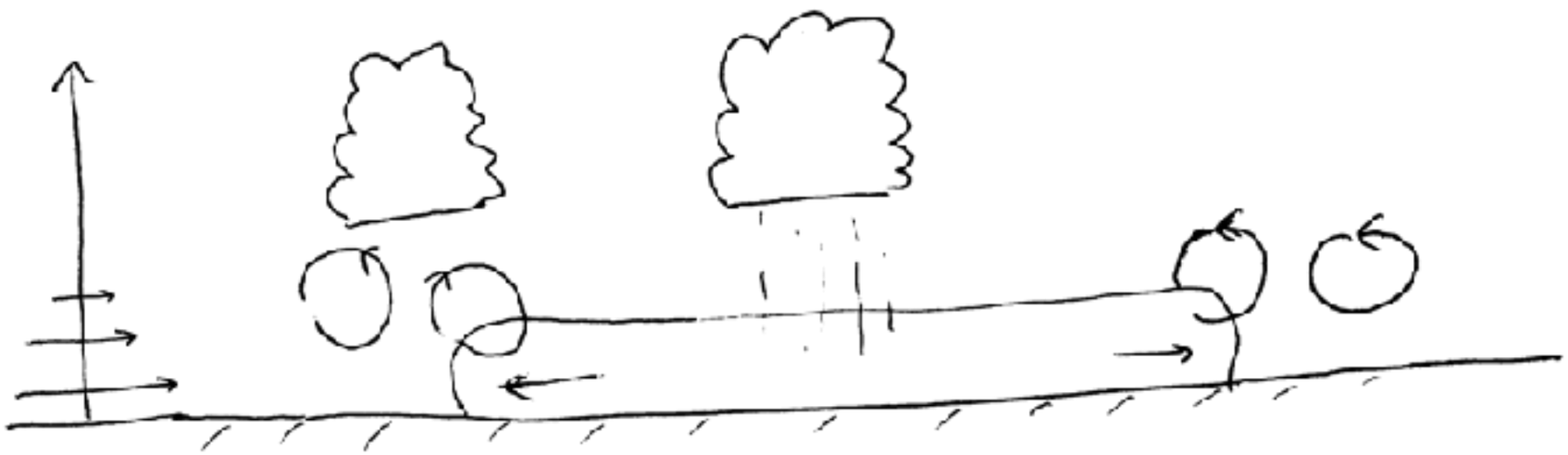
Hewitt 1971



- Retards cloud growth, reduce cloud-top height and cloud dissipates faster

RKW-theory (precipitating clouds)

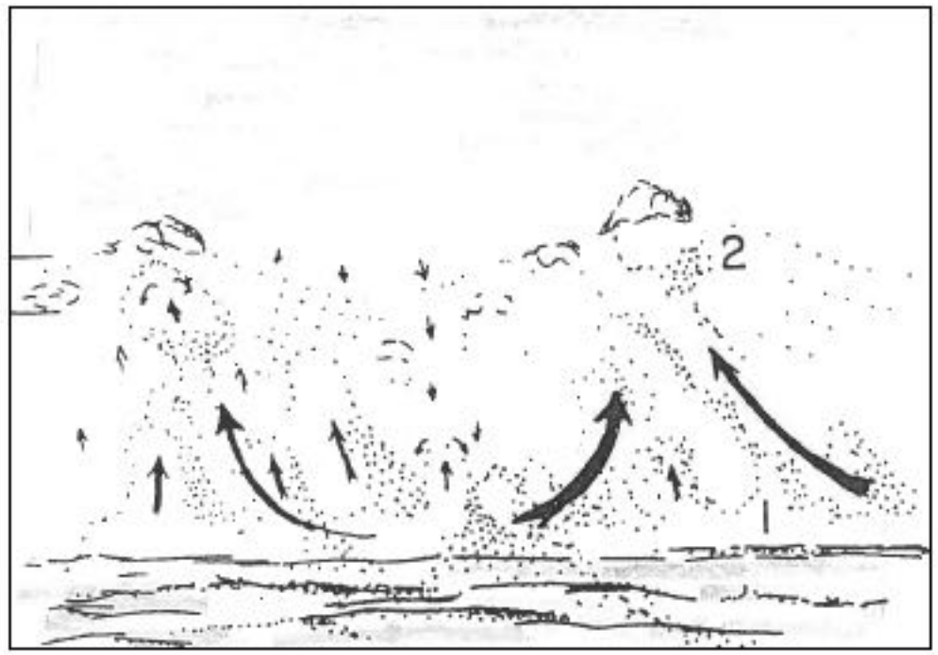
Rotunno, Klemp & Weisman 1980s



- Evaporation of rain creates density current
- At edge of spreading current (gust front) air is lifted, inducing local vorticity
- When combined with shear of opposite vorticity convection is more strongly forced, can trigger new clouds or self-reinforce existing (super-cells)

Roll structure & cloud streets (shallow Cu)

(a)



(b)

LeMone/NCAR

Roll structure & cloud streets (shallow Cu)

Asai 1972, Brown 1980, Brown 1983

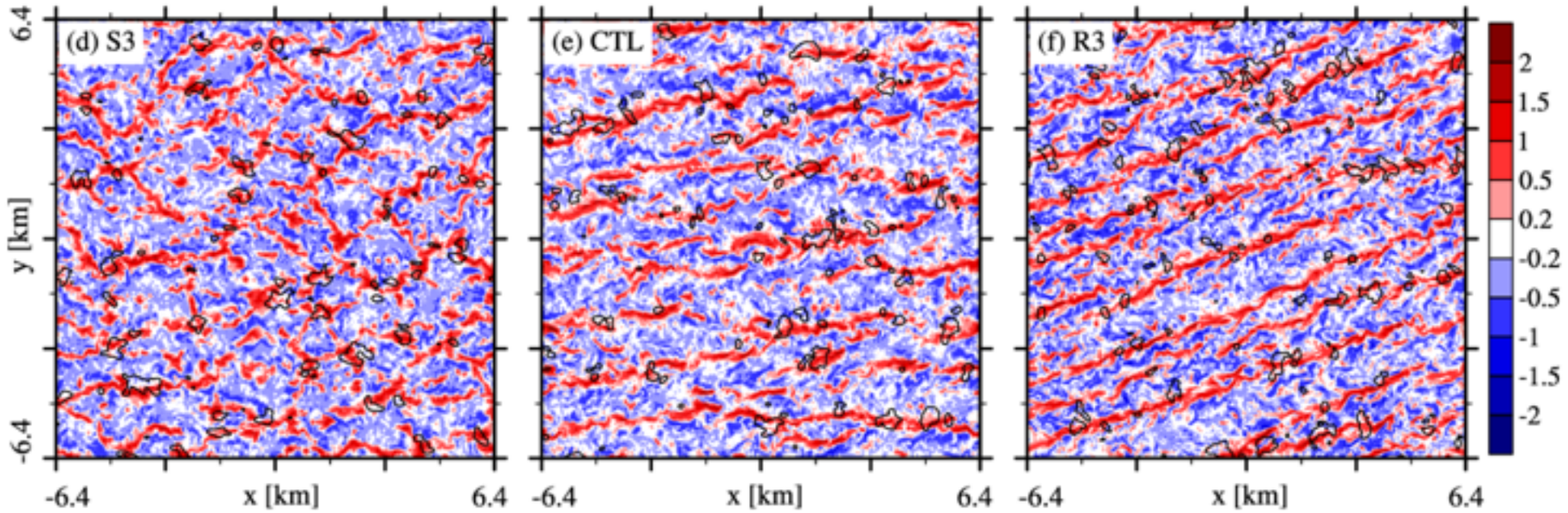
Profile	Roll orientation	Roll characteristic wavelength
Pure speed shear	Perpendicular to flow	~ 2 h_{BL}
Pure turning shear	~ parallel to flow	~ 2-4 h_{BL}

- Intrinsically unstable when $R_i < 1/4$

Roll structure & cloud streets (shallow Cu)

Vertical velocity at z=250m

Park, Boeing and Gentine 2017



Increasing shear

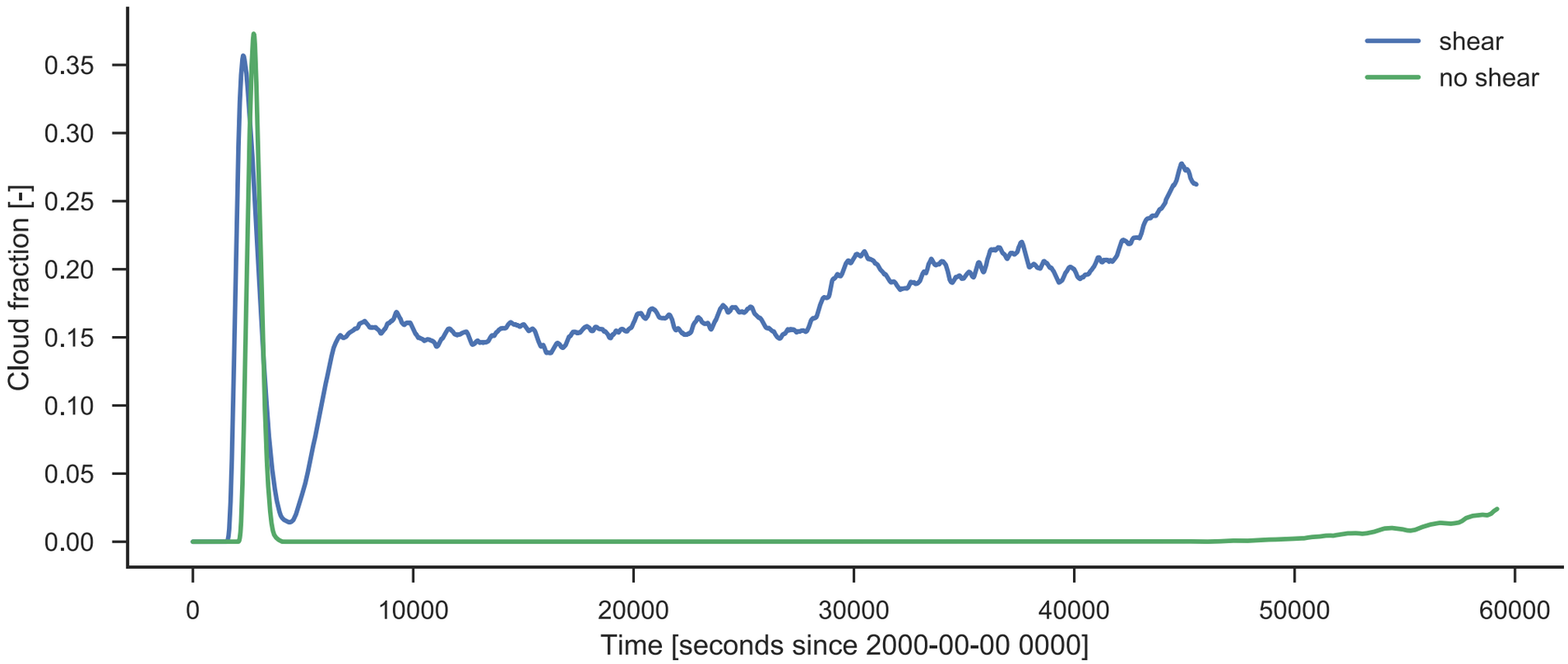
(through surface friction)

Stronger roll structures
more sub-cloud vertical transport

More cloud-base mass-flux,
but shallower cloud-extent

Now onto simulations with/without shear

But…



Forgot to think about how surface flux is generated