On the Drizzling STBL in LES

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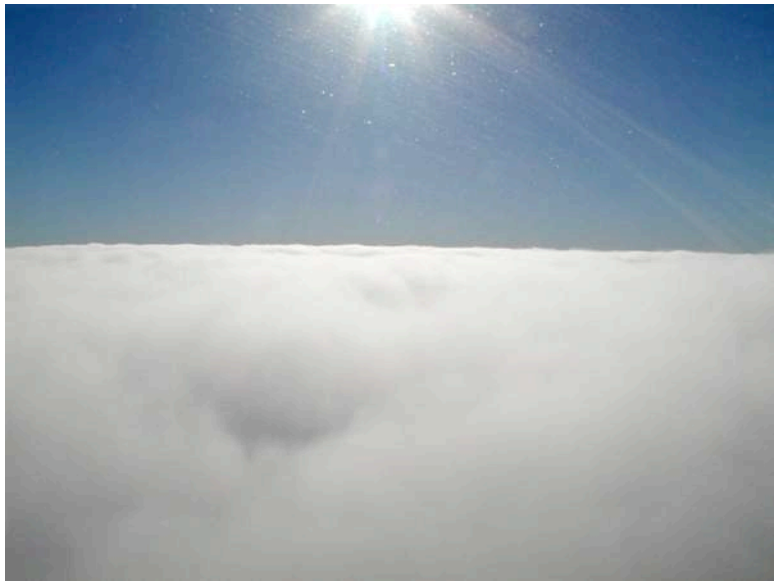
Thanks to my advisor *Bjorn Stevens* and my friends
Simona Bordoni, *Margreet van Zanten*, *Chris Holloway* and *Brian Medeiros*

Motivation and Background

Stratocumulus Clouds (Sc)

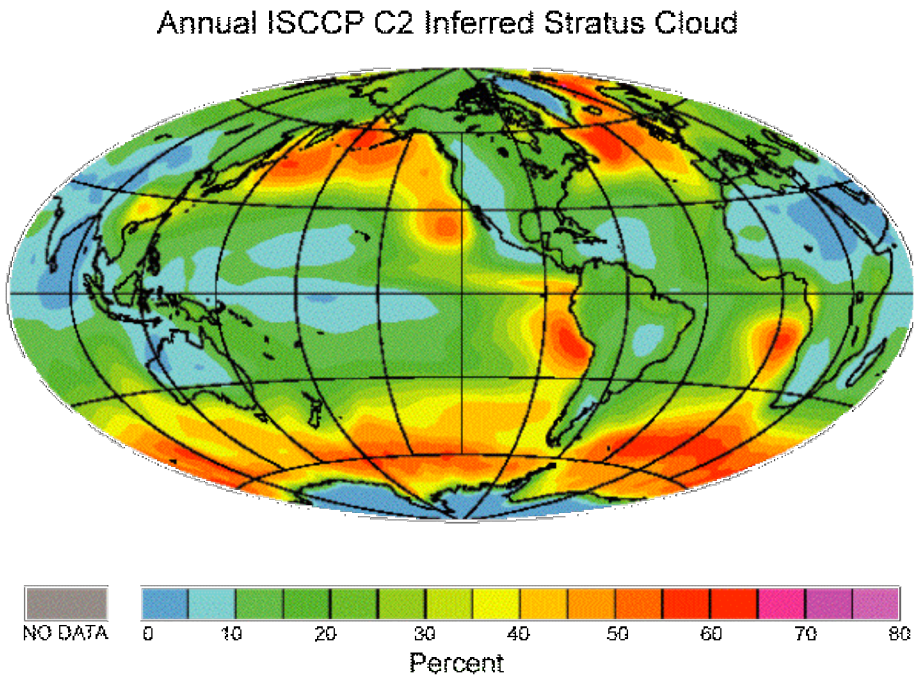
Underneath the cloud

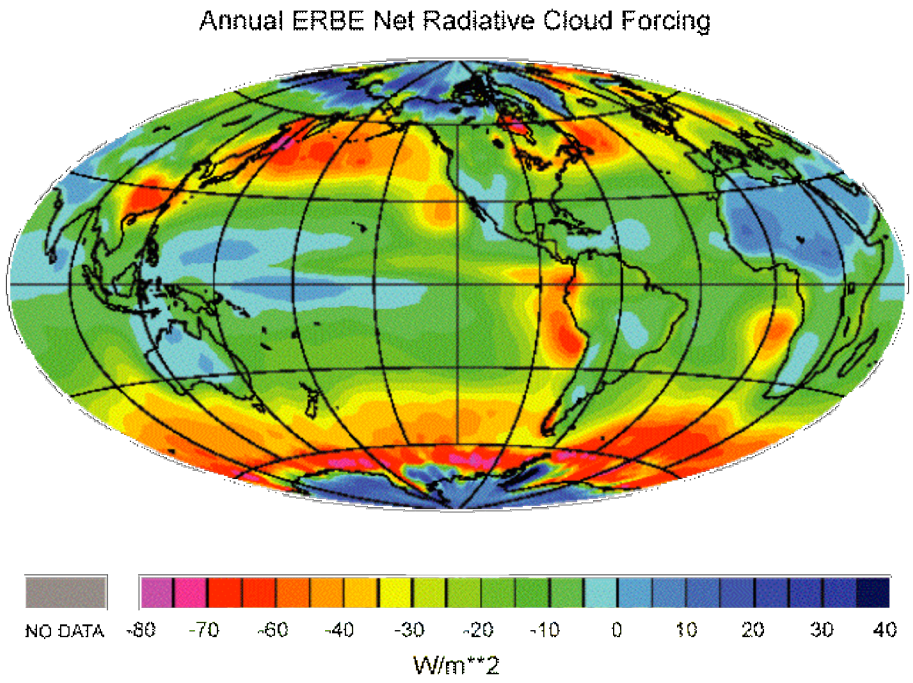
Above the cloud



Gabor Vali

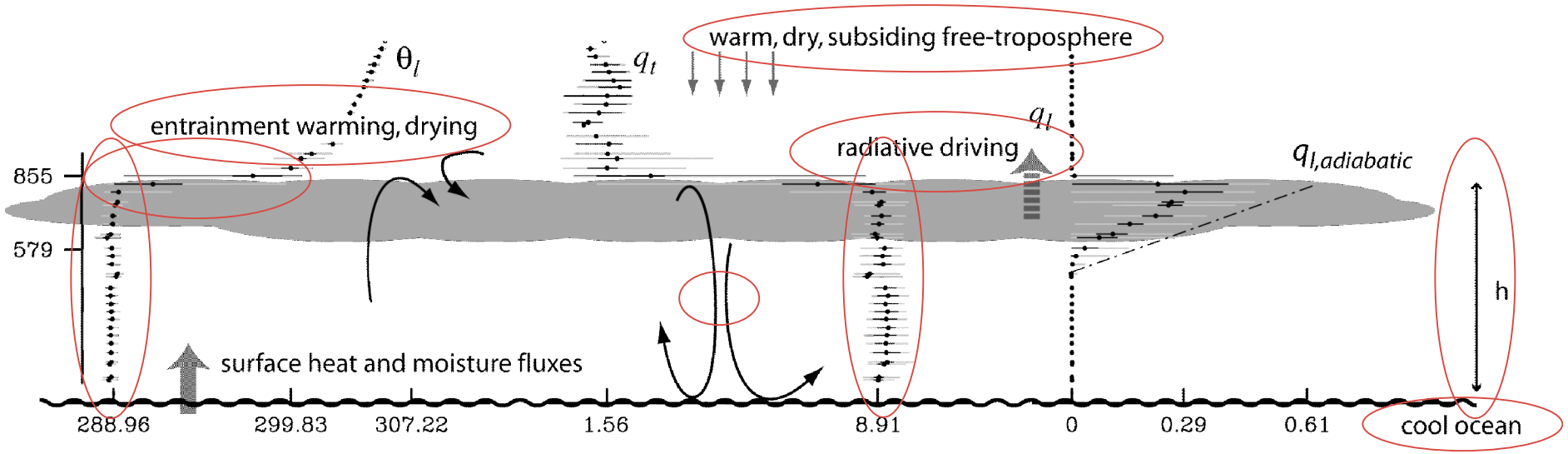
Stratocumulus and Climate





Dennis L. Hartmann

Stratocumulus Topped Boundary Layer (STBL)



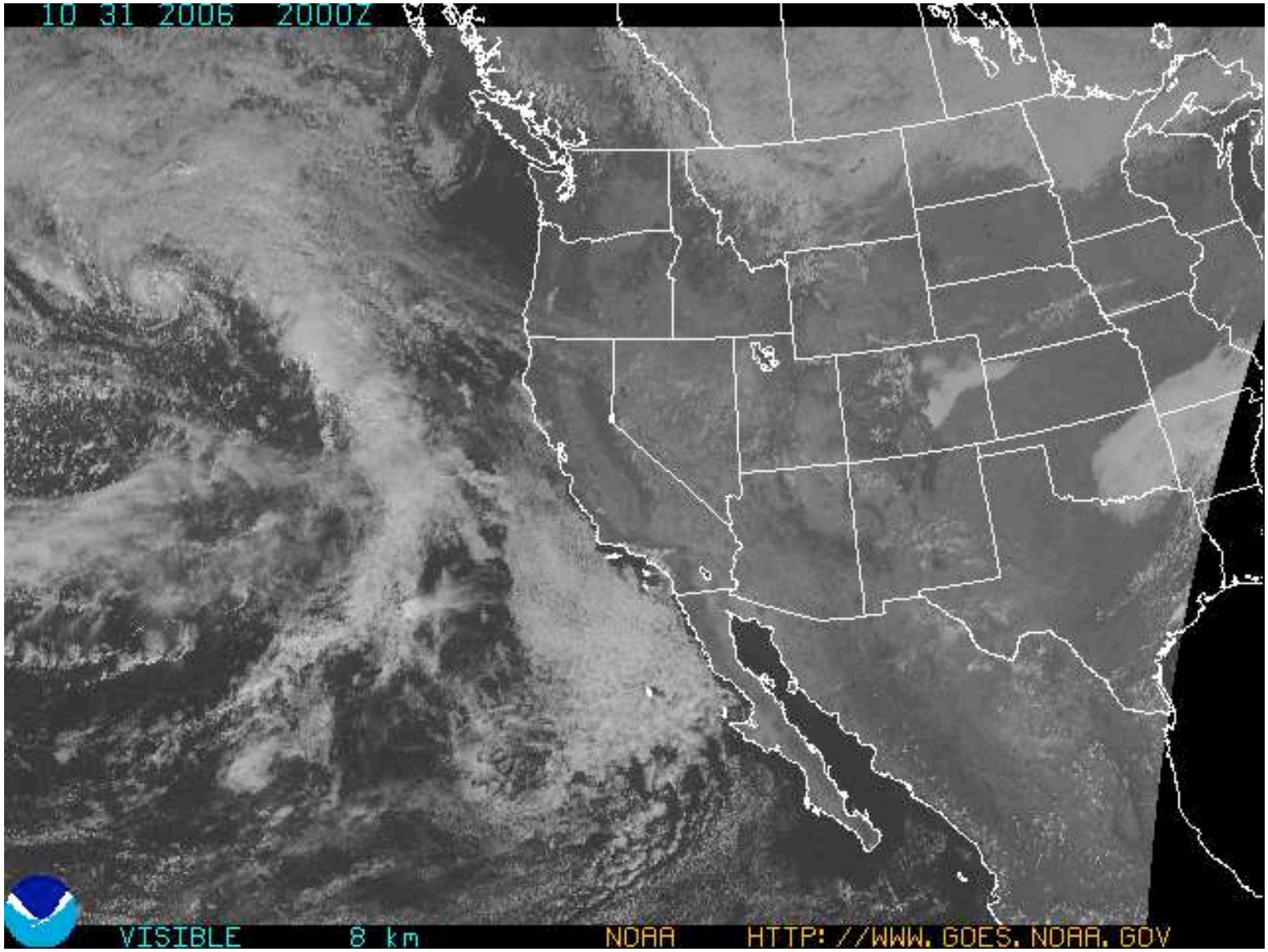
Stevens (2004)

Mesoscale Cloud Organization

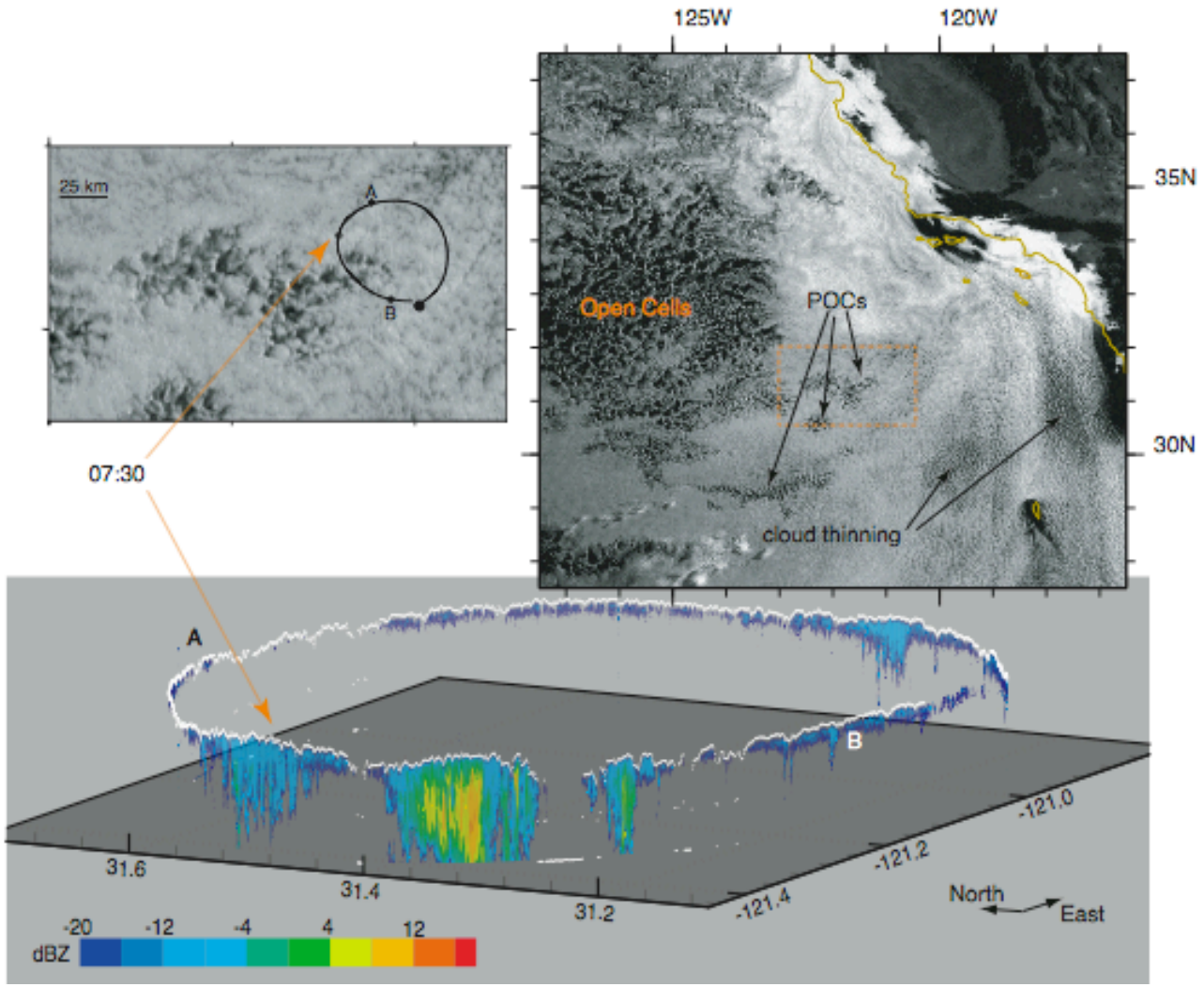
Closed Cells

Open Cells

Stratocumulus Yesterday

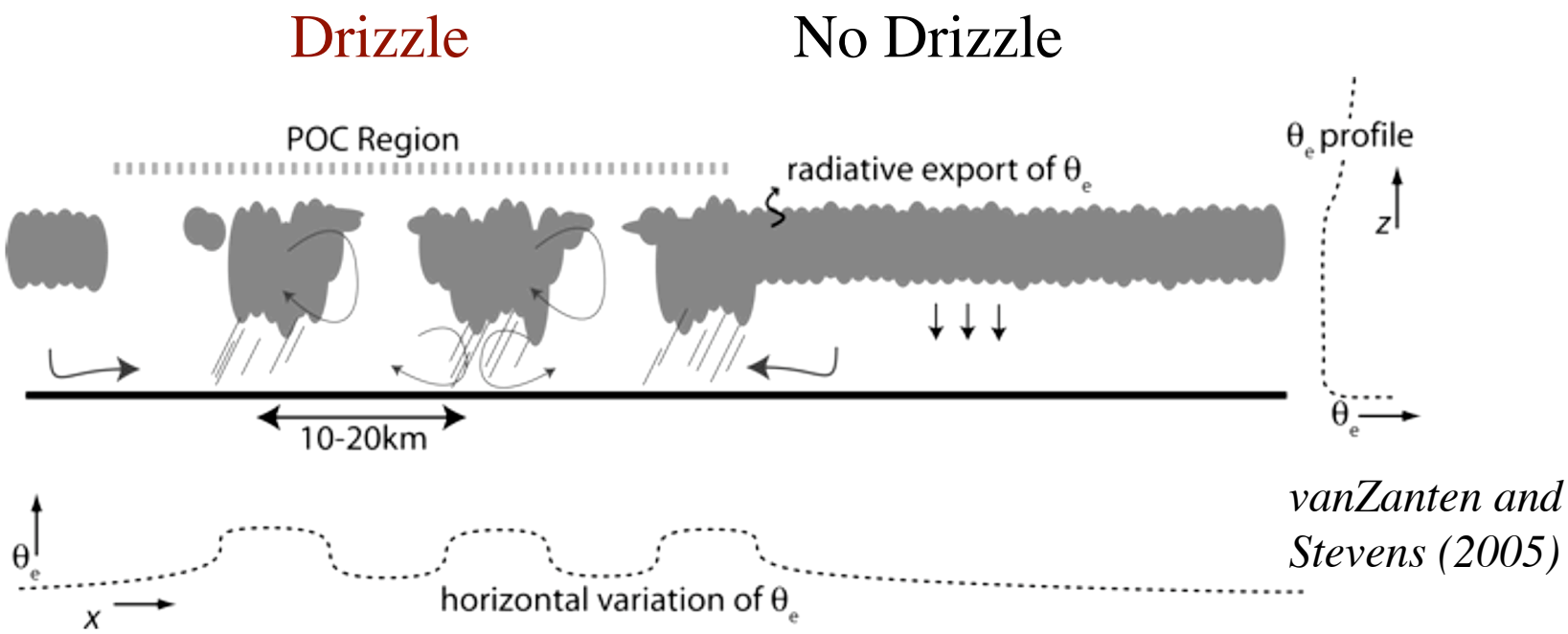


Drizzle



Stevens et al. (2005)

Pools of Elevated θ_e



vanZanten and Stevens (2005)

Equivalent potential temperature:

$$\theta_e = \theta \exp(\frac{Lq_v}{c_p T})$$

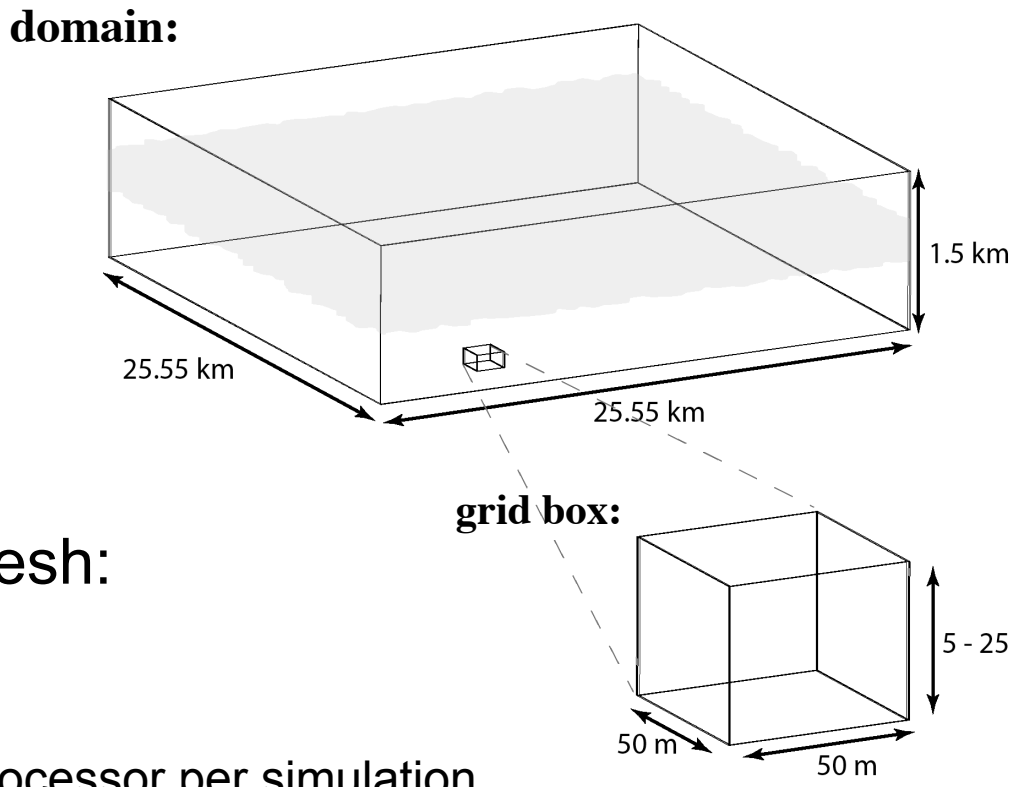
- a thermodynamic variable conserved during the reversible moist adiabatic processes
- a potential temperature the parcel would have if all the water vapor in it would be condensed

Questions

- To what extent drizzle affects the cloud and flow organization?
- What processes underlie pools of elevated θ_e in the drizzling STBL?

Large-Eddy Simulation (LES)

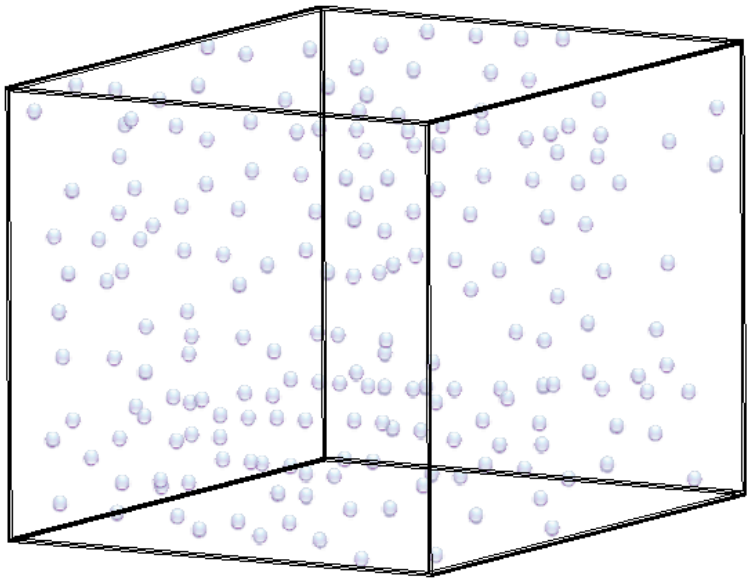
LES Set Up



- Large domain with fine mesh:
  - 512 x 512 x 97 points
  - 64 processors
  - 120 h of wall-clock time per processor per simulation
  - ~70 GB of data per simulation
- Basic state and large-scale forcing from DYCOMS-II RF02
- Simple microphysical scheme for the precipitation

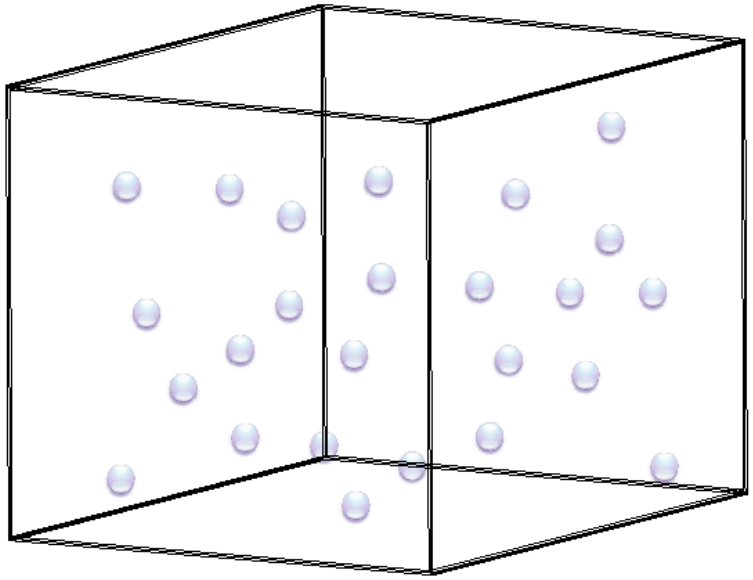
Experiments

No drizzle



N = 200 cm^{-3}

Drizzle



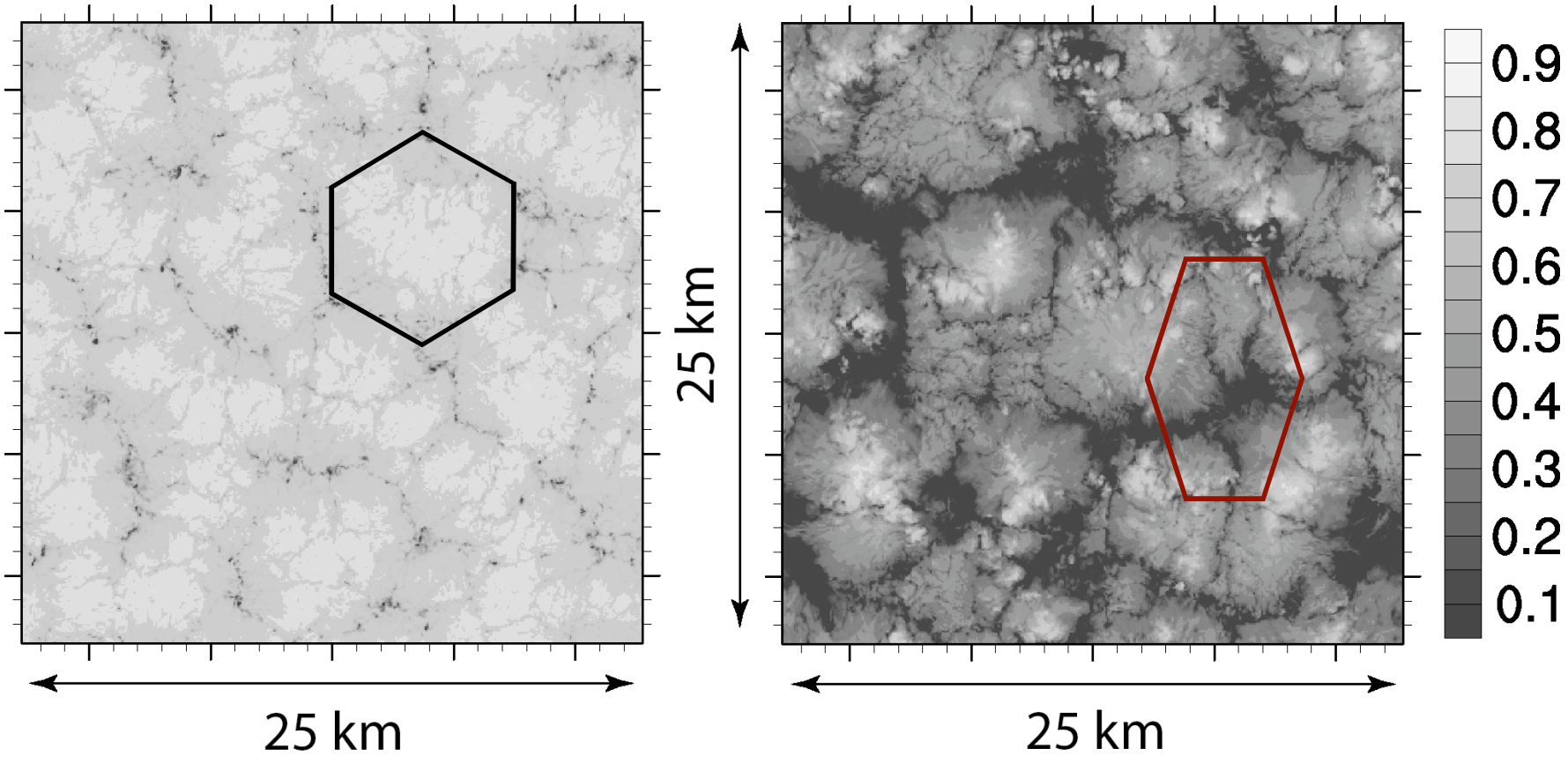
N = 25 cm^{-3}

Cloud and Flow Organization

Cloud Organization

No drizzle

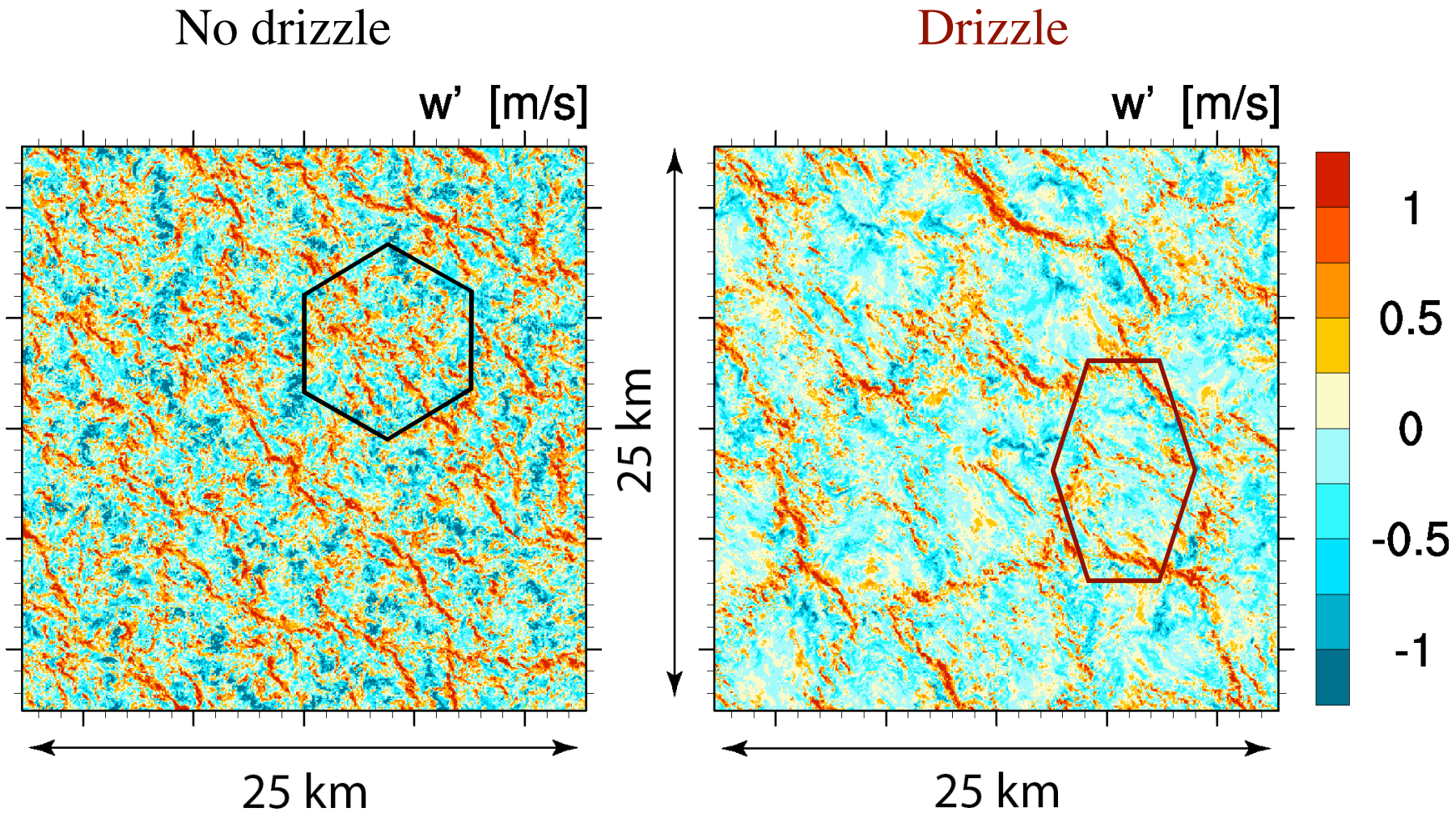
Drizzle



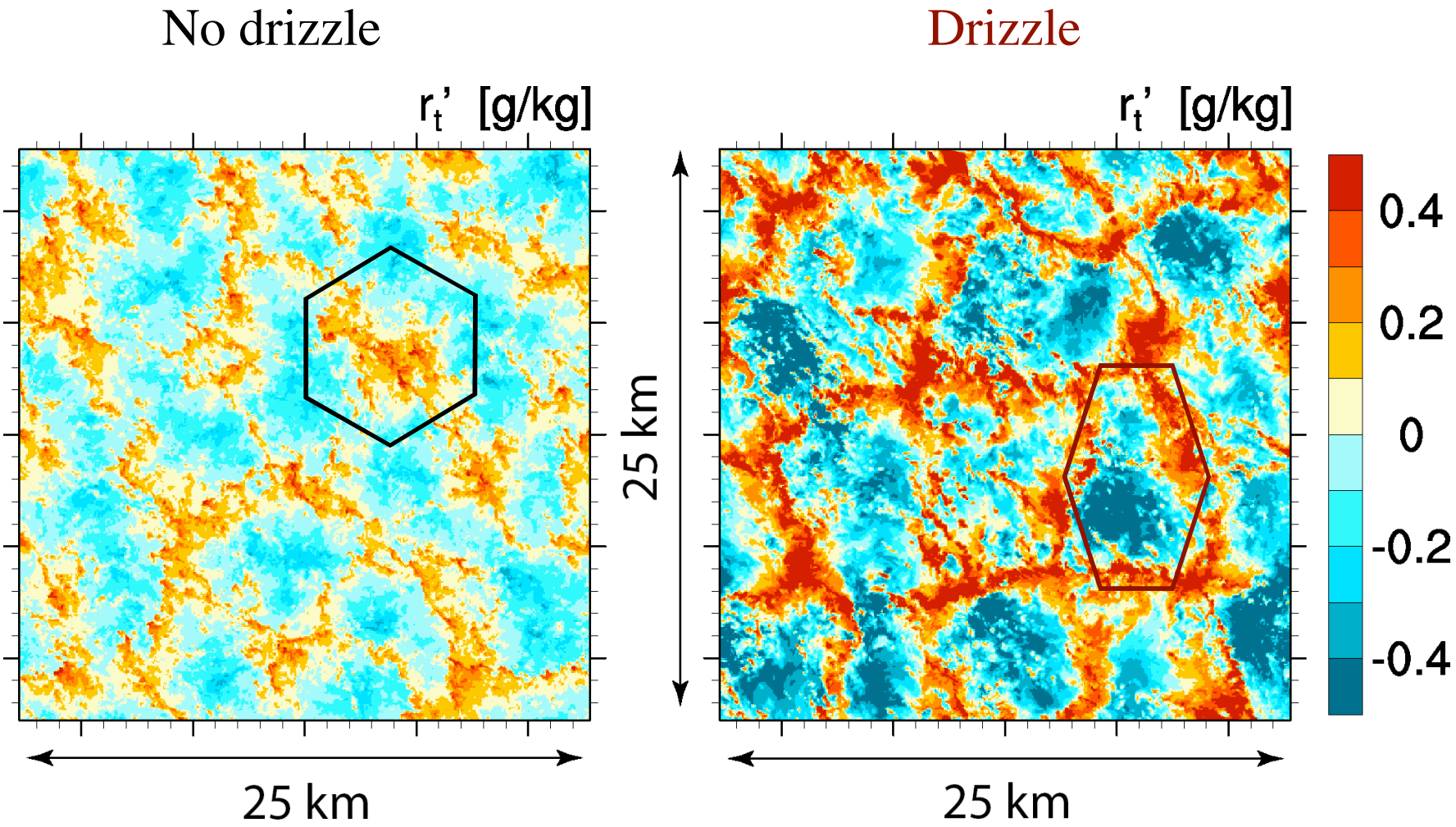
Closed Cells

Open Cells ?

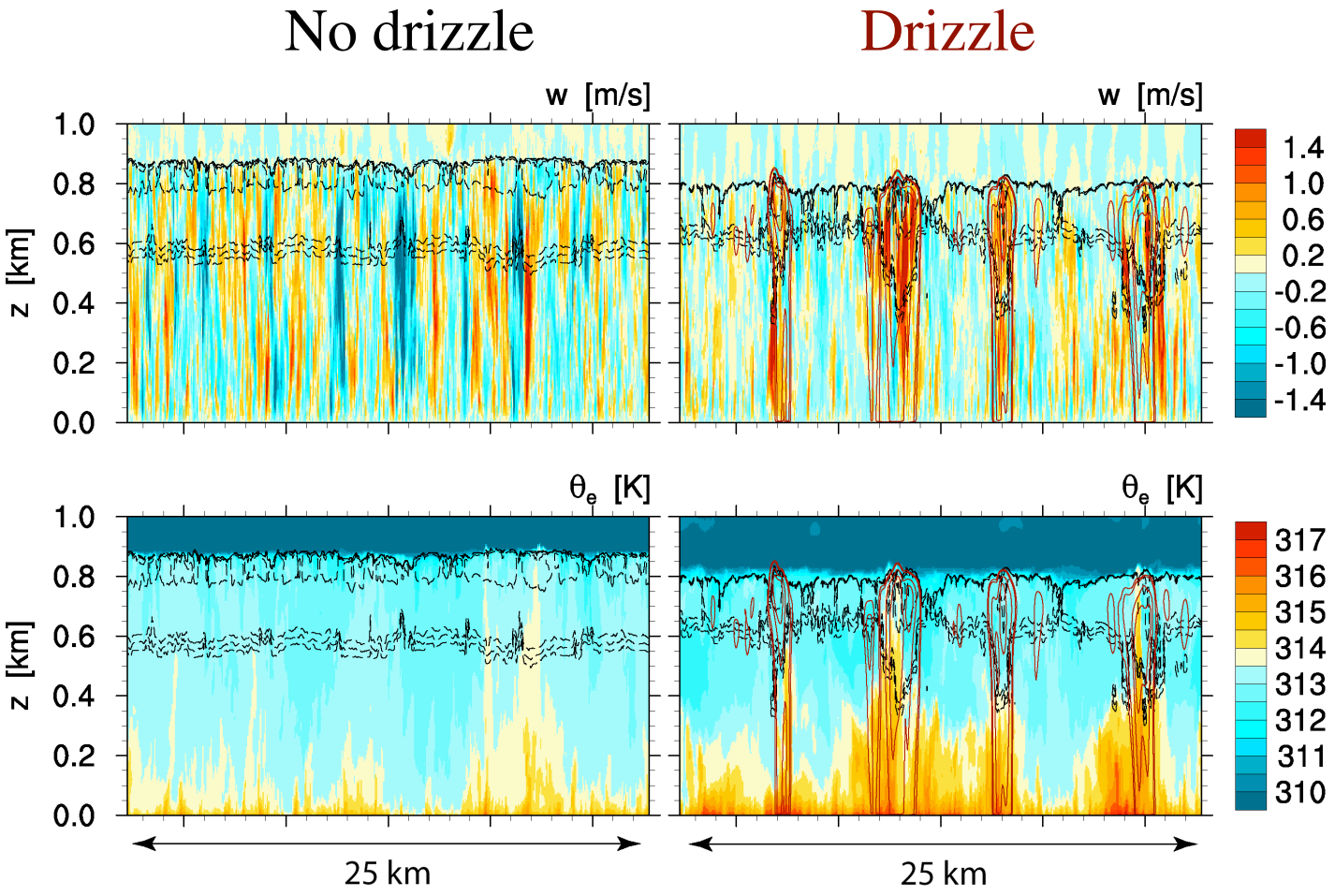
Horizontal Structure of w



Horizontal Structure of r_t



Vertical Structure



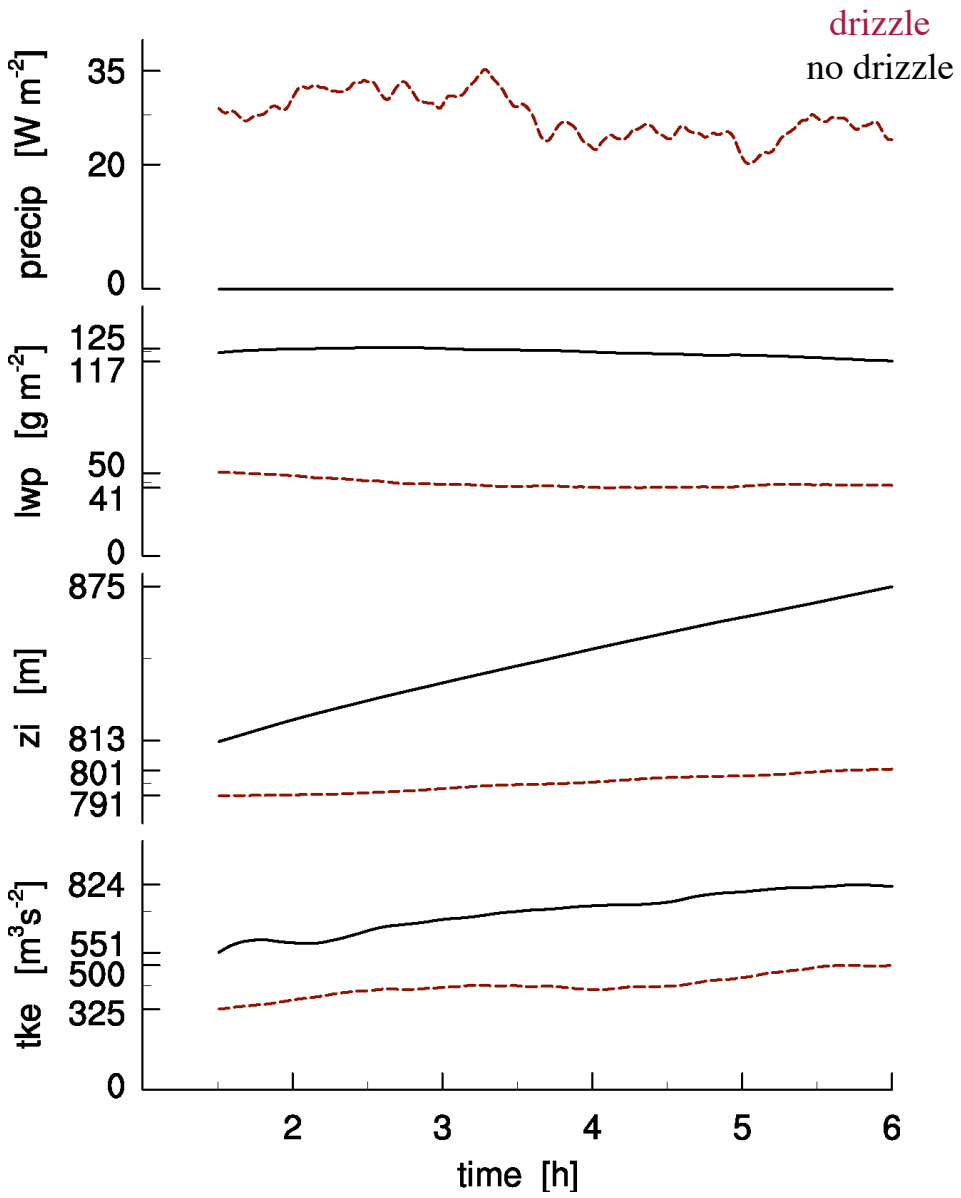
Drizzling STBL:

- More variability in the cloud top height
- Larger vertical gradient of θ_e

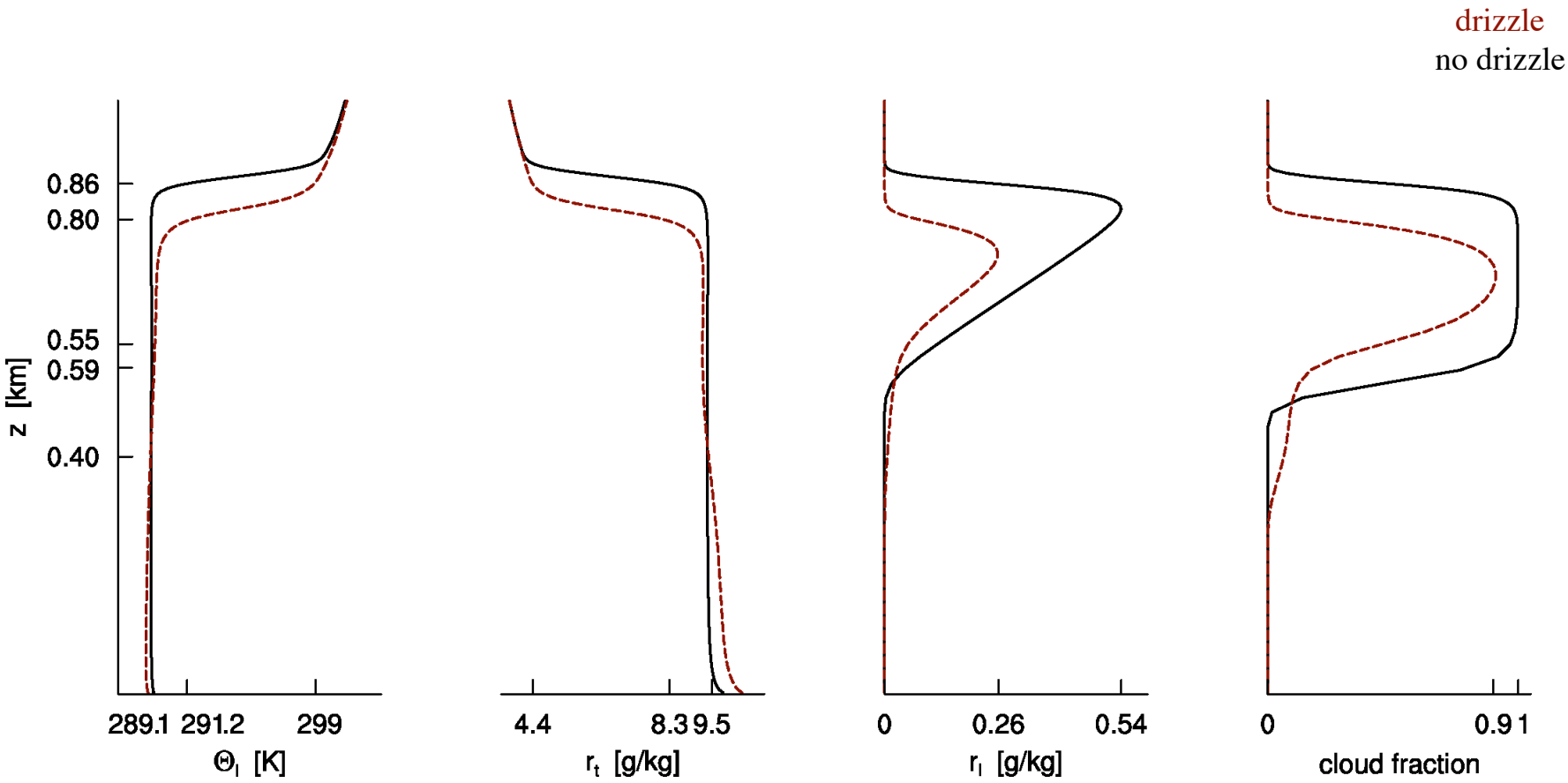
Evolution of Bulk Properties

Drizzling STBL:

- –Steady Precipitation
- –Lower, but steady LWP
- –Slower Growing BL
- –Less Energetic BL



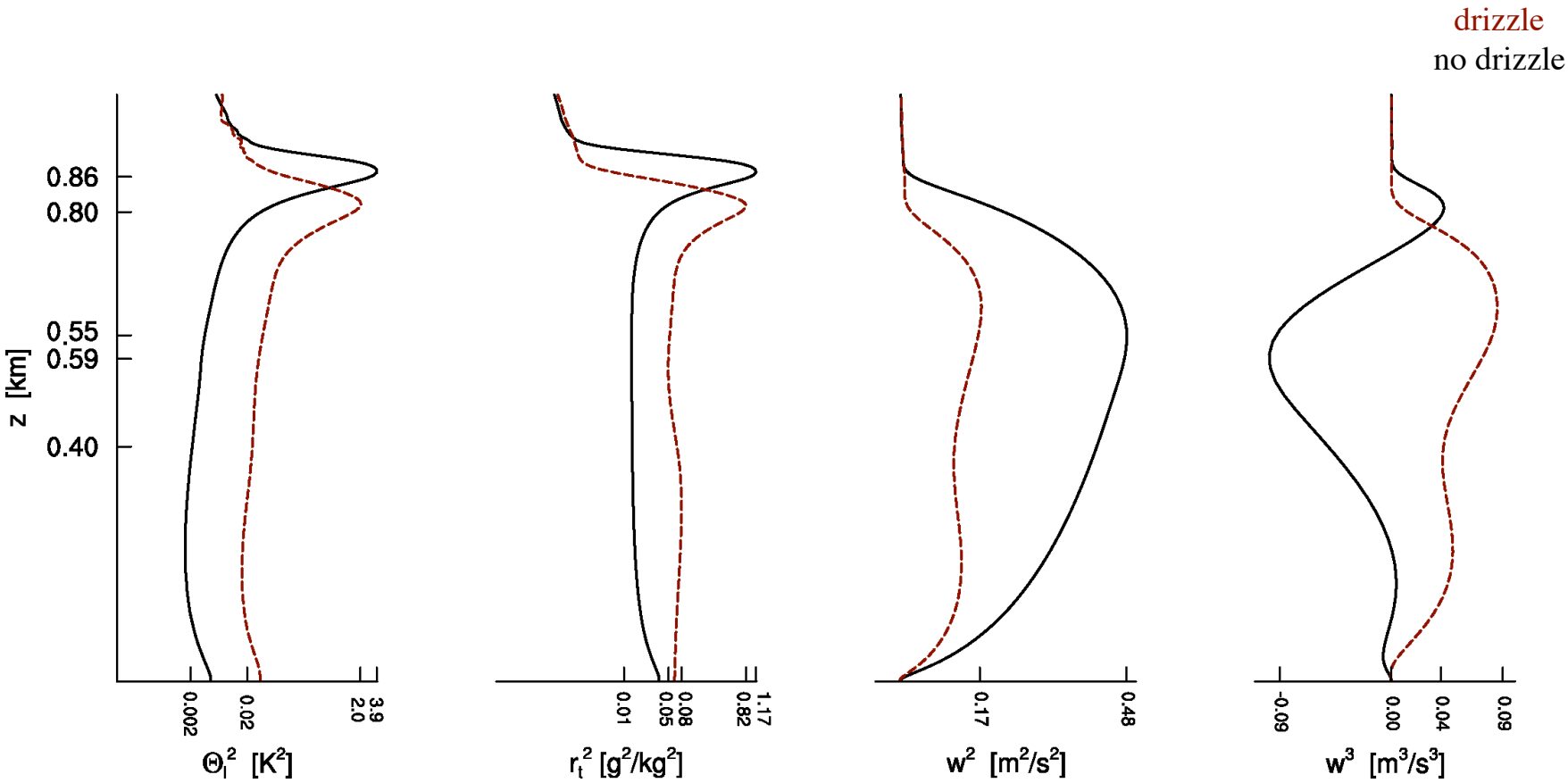
Mean Vertical Structure



Drizzling STBL:

- Differentiation between cloud and subcloud layer in θ_l and r_t - decoupling
- Indication of more variable cloud base - Cu rising into Sc

Profiles of Higher Moments



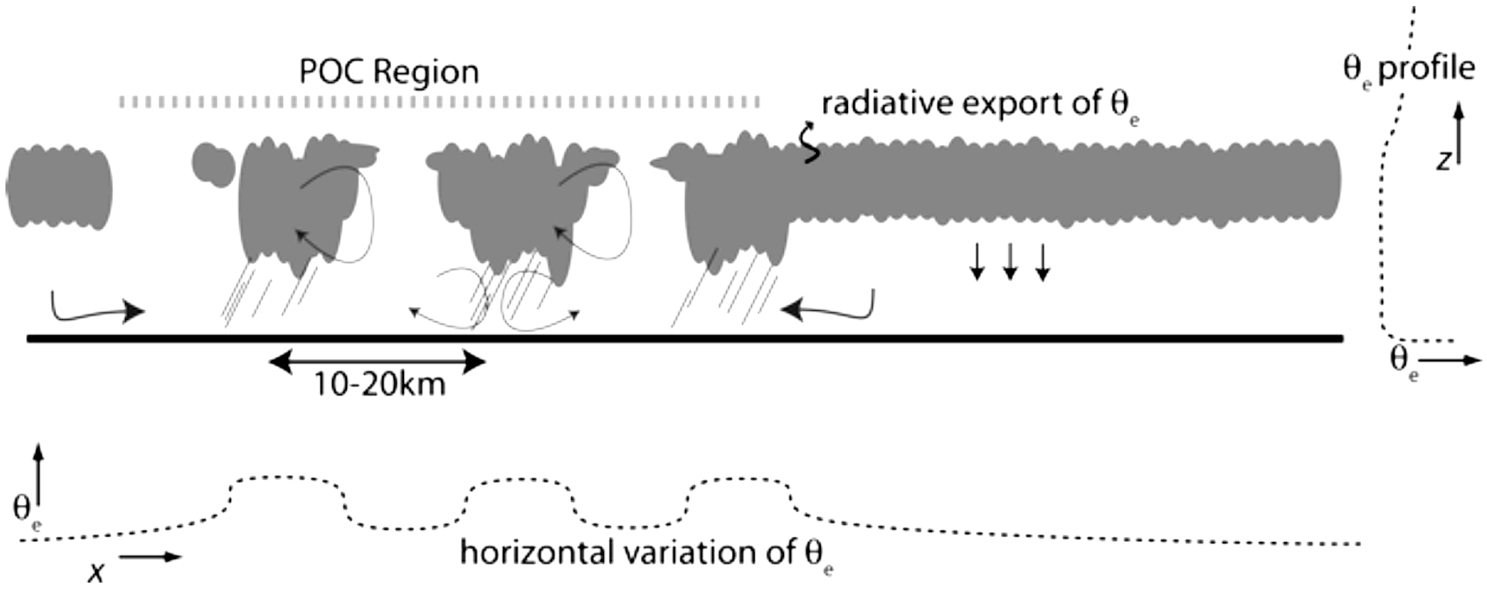
Drizzling STBL:

- Less horizontally homogeneous θ_l and r_t
- Reduced variance of w, with signal of decoupling
- Prevalence of updrafts

Pools of elevated θ_e

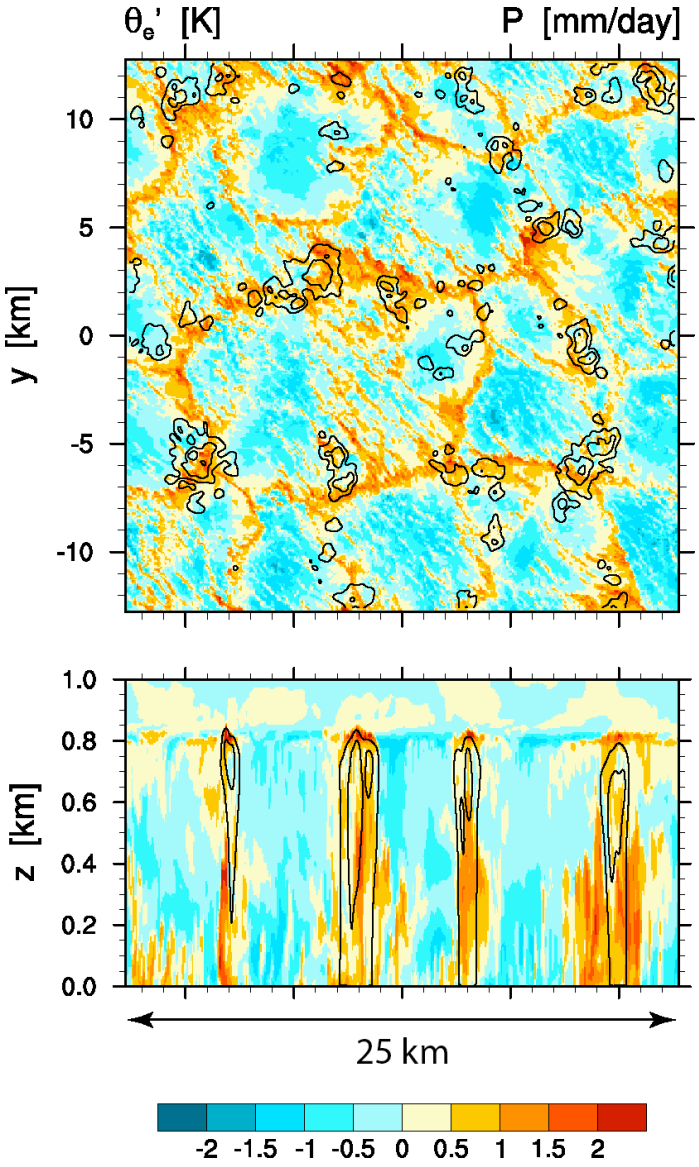
Observed Pools of Elevated θ_e

Drizzle No Drizzle



vanZanten and Stevens (2005)

Drizzle and Elevated θ_e



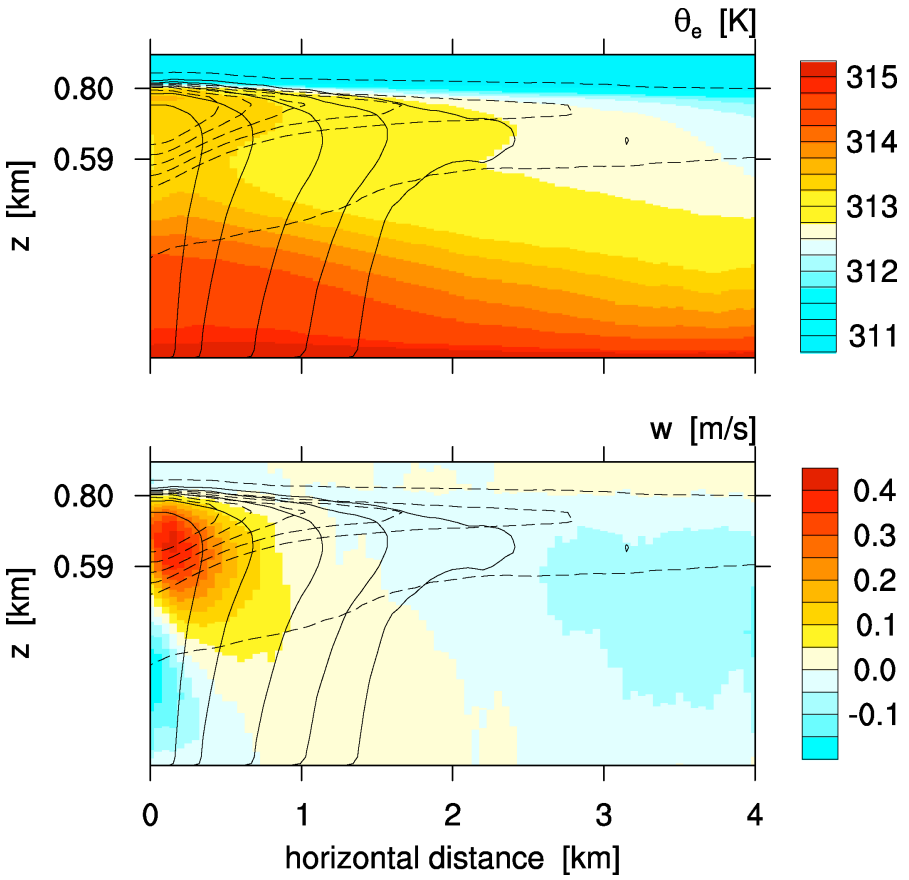
Signal of elevated θ_e is present not only in the subcloud layer, but through the depth of drizzling STBL.

Conditional Compositing

Summary of the analysis process:

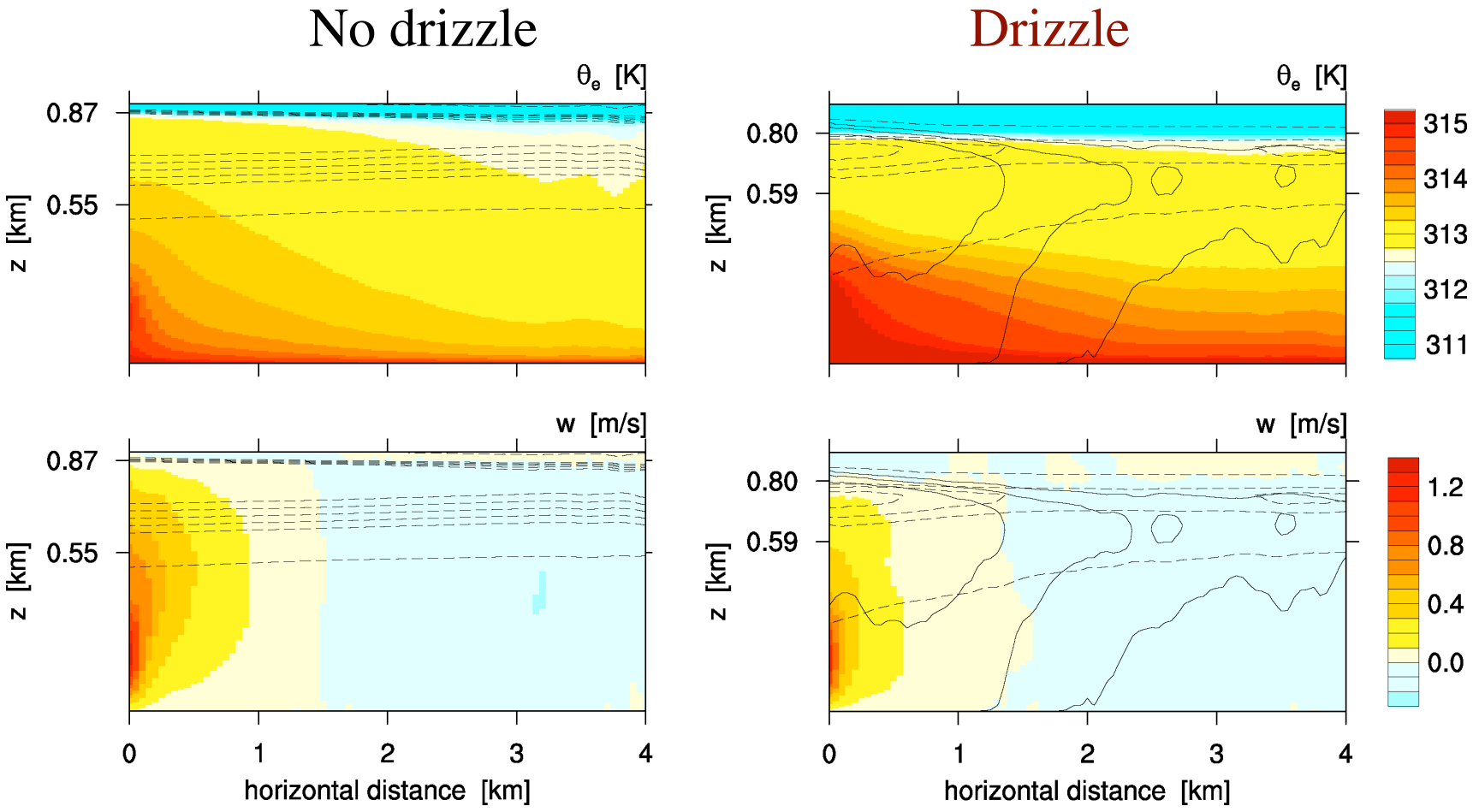
1. Choose the variable that defines the condition (precipitation or θ_e)
2. Define the conditioning events:
   a) locate the events stronger than given threshold
   b) isolate the strongest events by excluding the nearby weaker events
   c) map each point in the domain to its closest event
3. Choose the variable to be composited (w, θ_e, r_l and precipitation)
4. Composite the chosen field:
   a) bin the variable by the horizontal distance from the closest event
   b) average the variable within each bin

Properties of Drizzling Cell



- Updraft core is within the cloud with downdraft in the subcloud layer
- Updraft connected to the surface
- Outflow of elevated θ_e in the upper part of the cloud

θ_e Cells

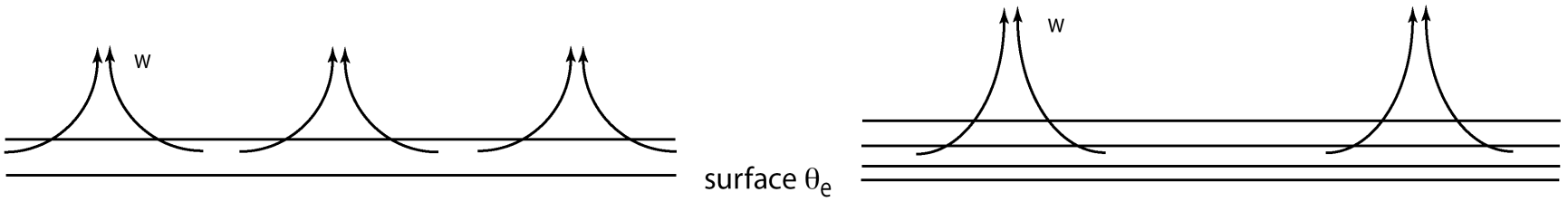


- Vertical gradient in θ_e is stronger in drizzling STBL.
- Updraft core is in the subcloud layer.
- Core of updraft is broadening with height in nonprecipitating STBL

Flow Organization

No drizzle

Drizzle

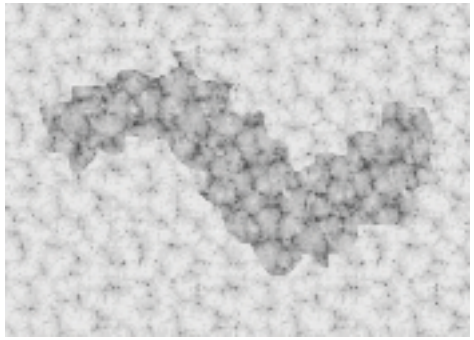


Drizzling STBL:

- Stronger vertical gradient in θ_e
- Localized, narrower and more intense updrafts
- Flow organized in Cu-coupled type of circulation

Summary

- Drizzle induces the change in the cloud organization by affecting the flow organization
- Pools of elevated θ_e are signal of open-cell, cumulus-coupled organization introduced by drizzle



THANK YOU