Poster #
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Drizzle as an Additional Diabatic Forcing Within the STBL

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Introduction

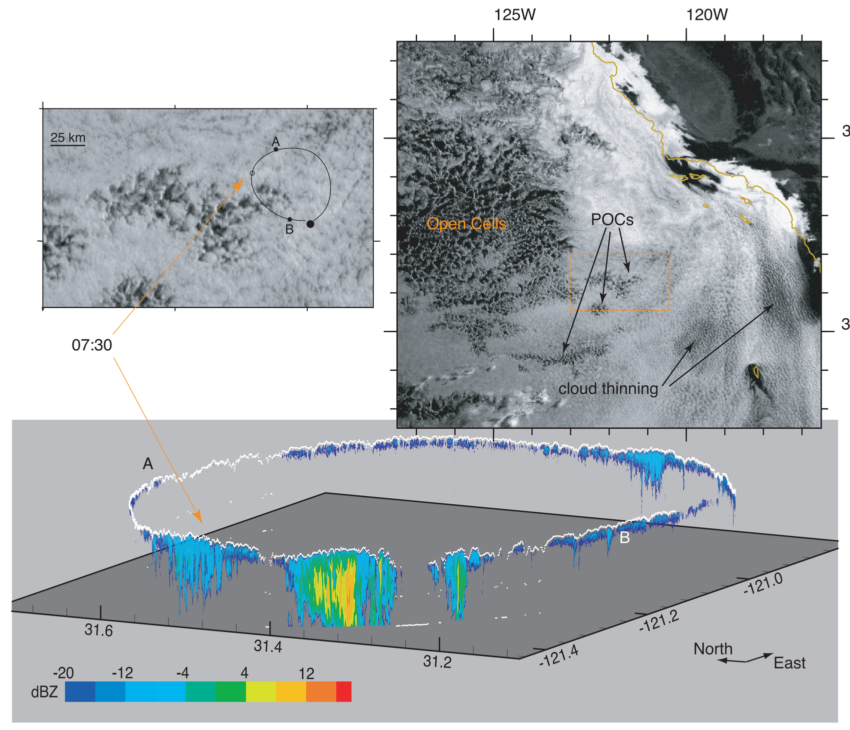


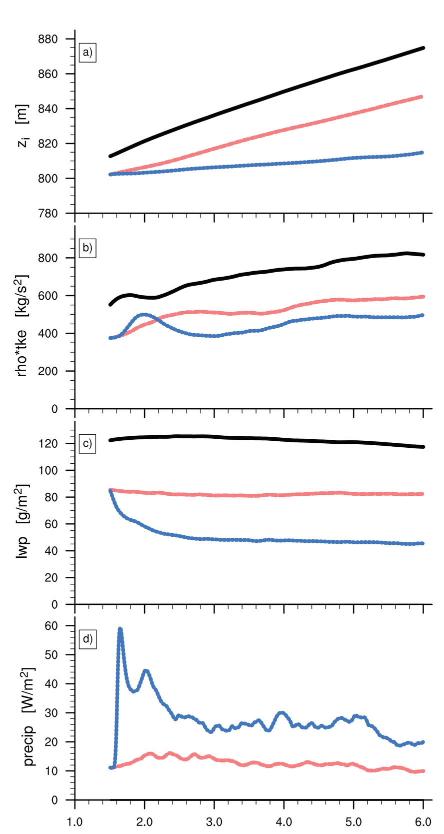
Figure 1: Upper right panel: GOES-10 image of the norteast Pacific. Upper left panel: zoomed GOES-10 image from the boxed region in the regional image, with overlaid a flight segment from DYCOMS-II RF02. Lower panel: Radar and lidar data from the above mentioned fligth segment. (After Stevens at al, 2005)

Recent field campaigns brought to our attention long-lived pockets of open cells (POCs) embedded in otherwise uniform stratocumulus. The observations indicate that the cells within a POC are comprised of precipitating cell walls and cell interiors with depleted cloud water, and even clearing. In contrast, stratiform, or unbroken cloud formations tend to be accompanied by less, or no drizzle, suggesting that precipitation is necessary for the livelihood of the POCs.

Figure 1. depicts the satellite image of the POCs observed during the second research flight of DYCOMS II field campaign as well as the radar and lidar data obtained during the flight segment indicated on the figure. The measurements from this flight have been adopted for the last GCSS LES intercomparison, with the objective to study the representation of drizzle in the LESs and the effects of drizzle on the STBL.

The observational evidence of connection between precipitation and POCs presented in Stevens et al. (2005) motivated our modeling study. We employed the UCLA LES with implemented micro-physical scheme based on Seifert and Beheng (2001) to simulate three cases: a) no drizzle, b) light drizzle and c) heavy drizzle. The initial and boundary conditions, as well as the resolution follow the last GCSS LES comparison, while the domain is about 16 times larger. The simulations have been performed in the NCAR's supercomputing center as the final part of the DYCOMS II project. A time frame for the performance of one experiment is on the order several weeks, as only 15 min of the simulation can be performed at the time. For this reason our analysis is still in its origins.

Evolution of the Mean State



The evolution of the mean boundary-layer depth, the turbulence kinetic energy, the liquid-water path, as a proxy for the cloud depth, and the surface precipitation are presented at Fig. 2. As one would expect, when drizzle is present, the flow is less energetic on the average, which restricts the boundary layer from deepening (Fig. 2, a) and b)). The drizzle also depletes the average depth of cloud (Fig. 2, c)). However, there is no unique relationship between the strength of precipitation and the cloud depth (Fig. 2, c) and d)).

Figure 2: Timeseries of a) inversion height, b) turbulence kinetic energy, c) liquid-water path and d) precipitation for the three experiments. Colors and line patterns denote the runs: black solid line - no drizzle, red dashed line - light drizzle, and blue dotted line - heavy drizzle.

Mean State

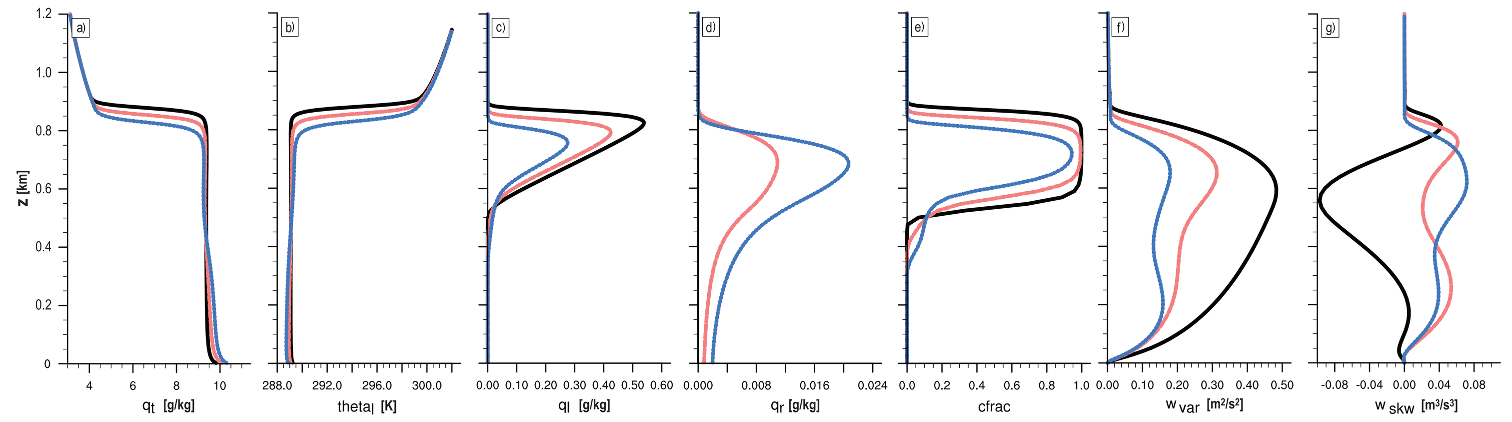


Figure 3: Mean profiles of a) total-water mixing ratio, b) liquid-water potential temperature, c) liquid-water mixing ratio, d) precipitable-water mixing ratio, e) cloud fraction, f) variance of vertical velocity and g) skewness of vertical velocity. The profiles are averaged over the 6[th] hour of simulation. Colors are as in Fig. 1.

The mean profiles averaged over the last hour of simulation shown at Fig. 3 indicate the drizzle-induced absence of well-mixedness through the depth of the boundary layer. The stronger the drizzle, the stronger the deviation from the well-mixed canonic picture of the STBL (Fig. 3, a), b)).

Profile of liquid-water mixing ratio (Fig. 3, c)) indicates that both the cloud top and the cloud base subside when drizzle is present, comparing to the non-drizzling regime, resulting in the reduced amount of the total liquid water content when drizzle is active.

Cloud fraction profile (Fig. 3, d)) is a very clear indicator of the change of the cloud shape from horizontally homogeneous stratocumulus in the non-drizzling case, to the cumulus rising under stratocumulus in the drizzling one.

Differentiation between the sub-cloud and cloud layer in the presence of drizzle is evident in the profile of the variance of vertical velocity as well. Figure 3 e) shows the reduction of the variance and formation of 2 local maxima with drizzle. The profile of skewness of vertical velocity (Fig. 3, f)) indicates strong downdrafts through the depth of the non-drizzling STBL, which lack in the presence of drizzle.

Instantaneous Horizontal Fields

Instantaneous horizontal fields give a visual perspective of the overall structure of the flow. As the most natural choice of the field for the comparison with the observations of POCs, we plot the albedo for all three runs. As Fig. 4. shows, in non-drizzling simulation, cloud field has a remarkable resemblance of the satellite images of decks of stratocumulus. Drizzling-case albedo does not have the same grade of similarity with POCs regions, but it does show the emergence of the underlying open cell circulation. While doing this comparison, we are aware that our simulations struggle with the scales of POCs.

Figure 5. depicts the overall structure of the momentum and liquid-water potential temperature fields. Both fields show good correlation through the depth of the layer for non-drizzling run, and absence of, and even anti-correlation, in the drizzling runs. The anticorrelation is clearly evident in the temperature field. In the non-drizzling experiment, momentum field is dominated with deeply penetrating downdrafts, while in the drizzling runs one can see the emergence of the stronger updrafts only in the cloud layer. The thermal field shows overall less variation in the non-drizzling simulation comparing to drizzling ones.

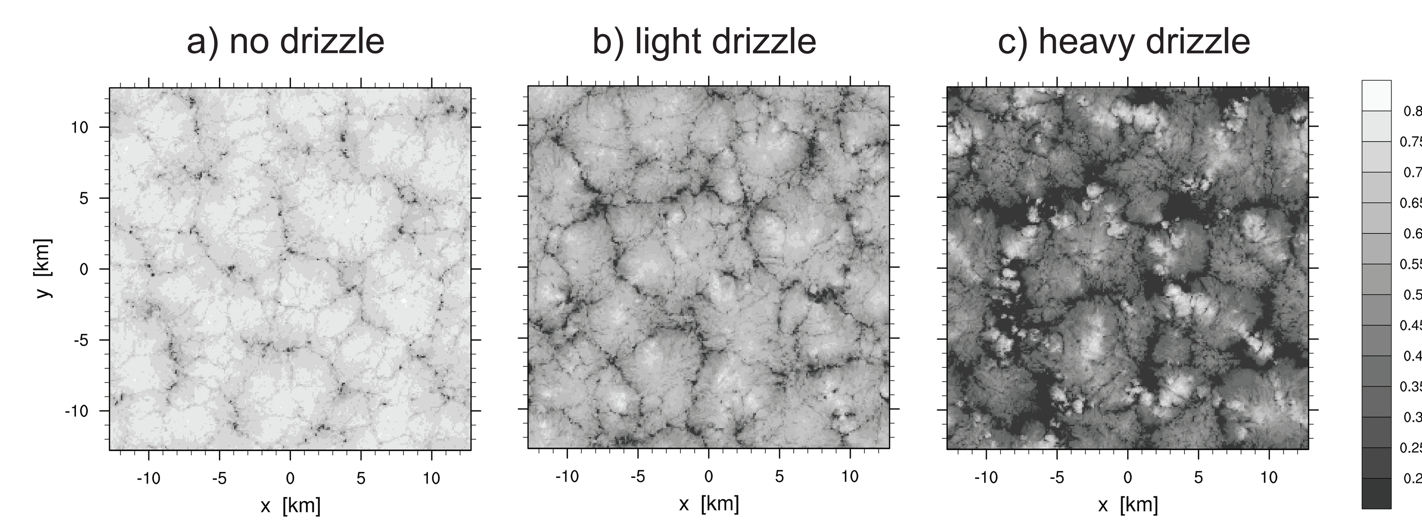


Figure 4: Snapshots of the albedo at the end of the 6th hour of simulation for the three experiments.

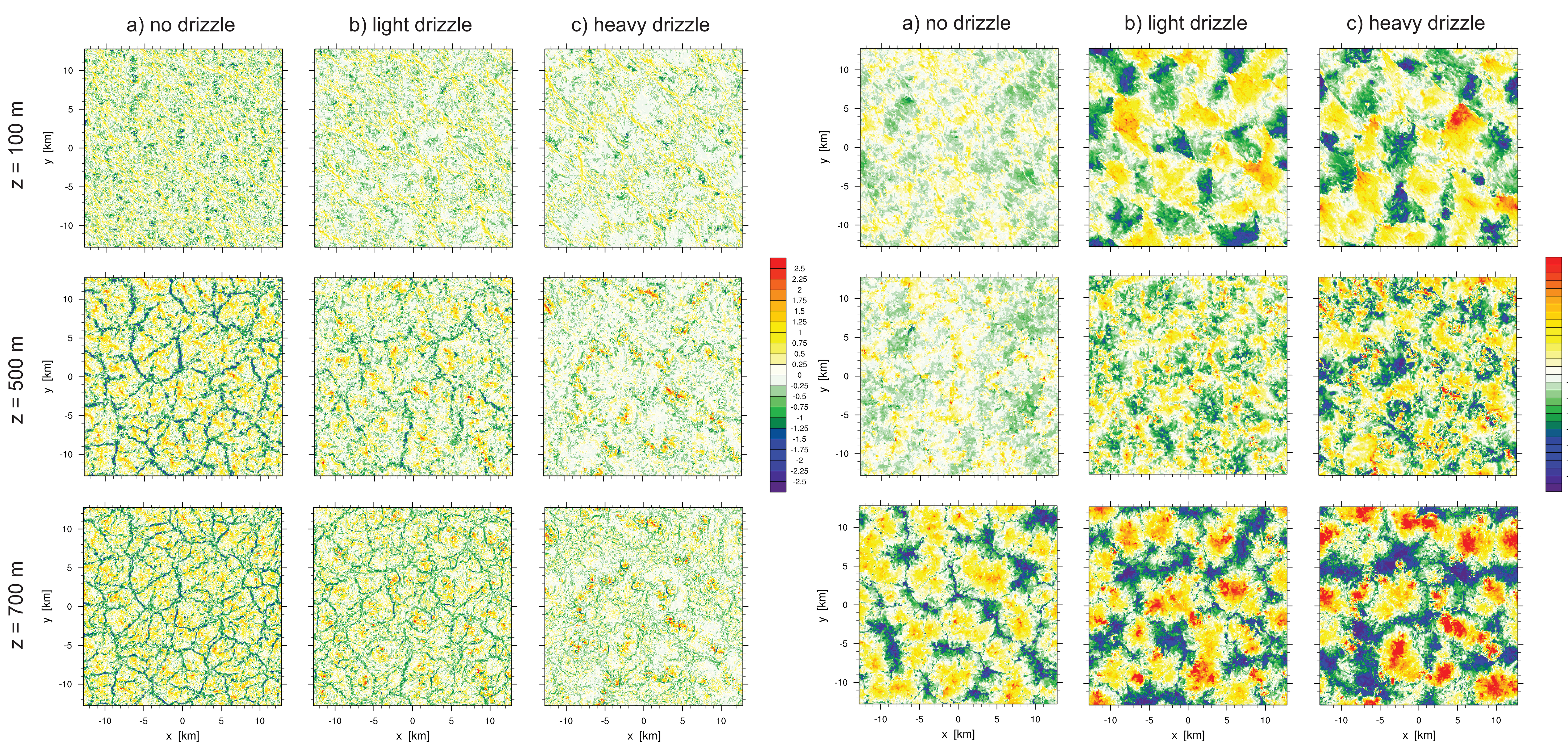
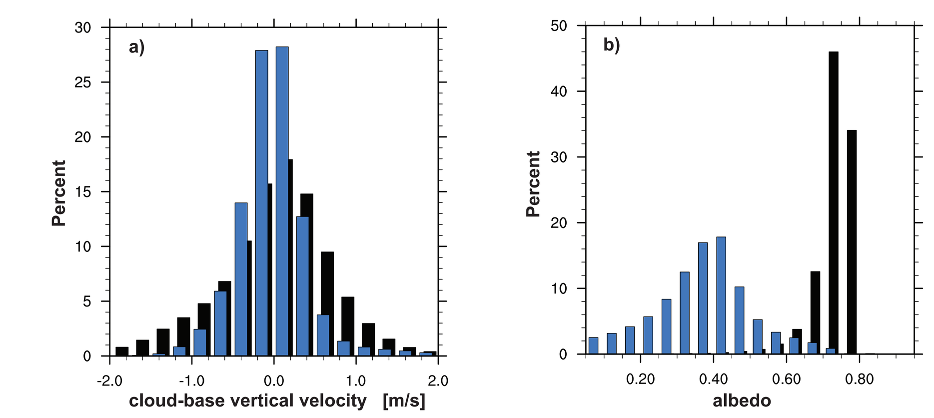


Figure 5: Snapshots of the vertical velocity (left panel) and liquid water potential temperature (right panel) at three vertical levels - close to surface (100 m), close to cloud base (500 m) and close to the mid-cloud level (700 m) - at the end of the 6[th] hour of simulation for the three experiments.

Statistics of the Horizontal Fields



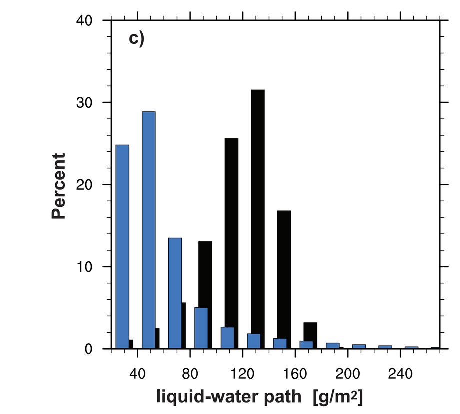


Figure 6: Histograms of the instantaneous fields of a) cloud-base vertical velocity, b) albedo and c) liquid-water path. Colors denote the runs: blue stands for heavy- and black for non-drizzling run.

We compare the non- and heavy-drizzling simulations by analyzing the histograms of horizontal fields of cloud-base vertical velocity, albedo and liquid water path.

An interesting feature of the vertical-velocity histogram (Fig. 6, a)) is the absence of the strong downdrafts and the dominance of the weak vertical motion in the heavy- comparing to non-drizzling run. However, the updrafts are of the comparable strength in both simulations, although in smaller amount in the heavy-drizzling case.

The largest difference in the distributions between the two runs is present in the albedo. While the heavy-drizzling case has large variety of the albedo values, the non-drizzling run has very narrow distribution centered at high values, although both distribution show negative skewness.

Histograms of liquid-water path, Fig. 6 c), reveal the presence of the deeper clouds in the heavy- comparing to non-drizzling run, although the non-drizzling run has over-all deeper clouds.

Summary

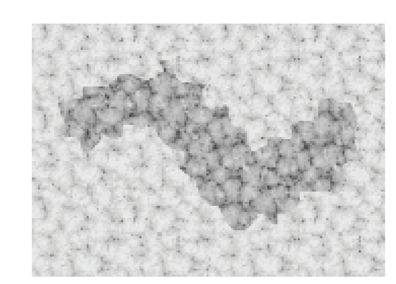


Figure 7: Composite albedo field from the non-drizzling experiment, overlaid with the tilda-shaped composite albedo field from the lightly drizzling experiment. The figure is not an attempt to imply that this is the direct result of the simulation. It is a mere attempt to visualize the results in the relation to the GOES-10 images that our eyes are used to.

Three LESs have been performed to study the impact of an additional diabatic forcing within the STBL in the form of drizzle.

There is a noticeable loss of vertical homogeneity in the drizzling comparing to non-drizzling simulations.

The emergence of the underlying open cellular convection is evident in the drizzling runs. It is more prominent in the heavy drizzling case.

Circulation is stronger in the non-drizzling than in the drizzling CTBL. In the absence of precipitation the circulation is dominated with the deeply penetrating downdrafts, while in the presence of drizzle there is an emergence of stronger updrafts only within the cloud layer.

Depletion of the liquid water in the presence of drizzle does not result in the final overall absence of cloud, but in the sparser distribution of locally deeper clouds.

Future work: Performing more thorough analysis of the described simulations as well as getting the Fig. 7 from the simulations without using the Photoshop.