Effects of stratocumulus clouds on aerosols in the maritime boundary layer

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What were we looking for?

Aerosol are known to effect clouds in many ways but

what about the effects of clouds on aerosols?

We examine aspects of aerosols:

- The aerosol size distribution
- The salinity of drops - ratio between the aerosol mass and the total drop mass

What happens to the initial aerosol distribution during the life time of the cloud?

What microphysical processes effect the salinity of drops?

The model

MODEL

Dynamics

Microphysics

A trajectory ensemble with air parcels that cover the entire boundary layer

Turbulence-like 2D velocity field

Diffusion growth of aerosols and droplets

Collisions

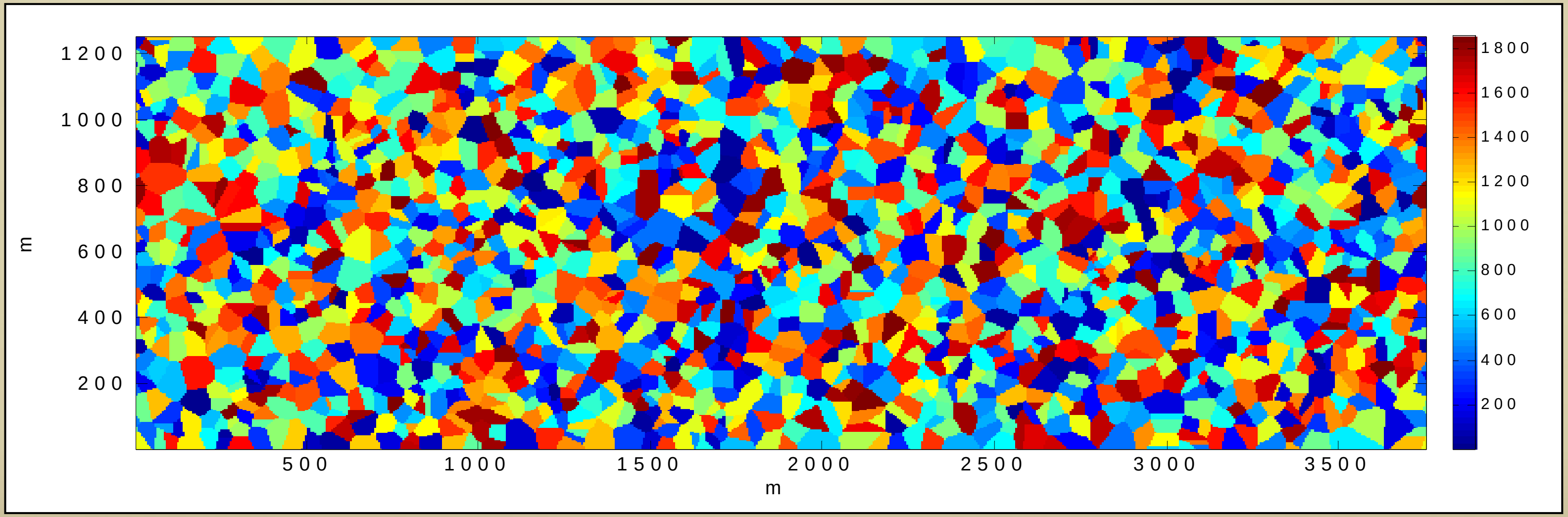
Advection of parcels within cloud and sub-cloud areas

Aerosols

Sedimentation of drops

Evaporation

The model tracks aerosols while inactivated and while inside drops



Input data for the simulation

Data was taken from the **DYCOMS-II** field experiment

which took place during July 2001 off the San Diego cost, California

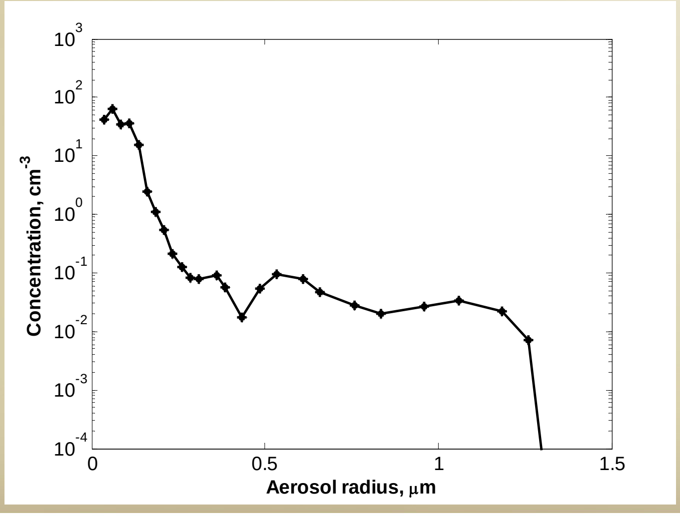
During the flight the boundary layer was well mixed and closed by a strong inversion

Velocity field:

- Vertical profiles of $\langle W^2 \rangle$ (Stevens et al., 2005)
- Lateral structure function (Lothon et al., 2004)

Aerosol distribution:

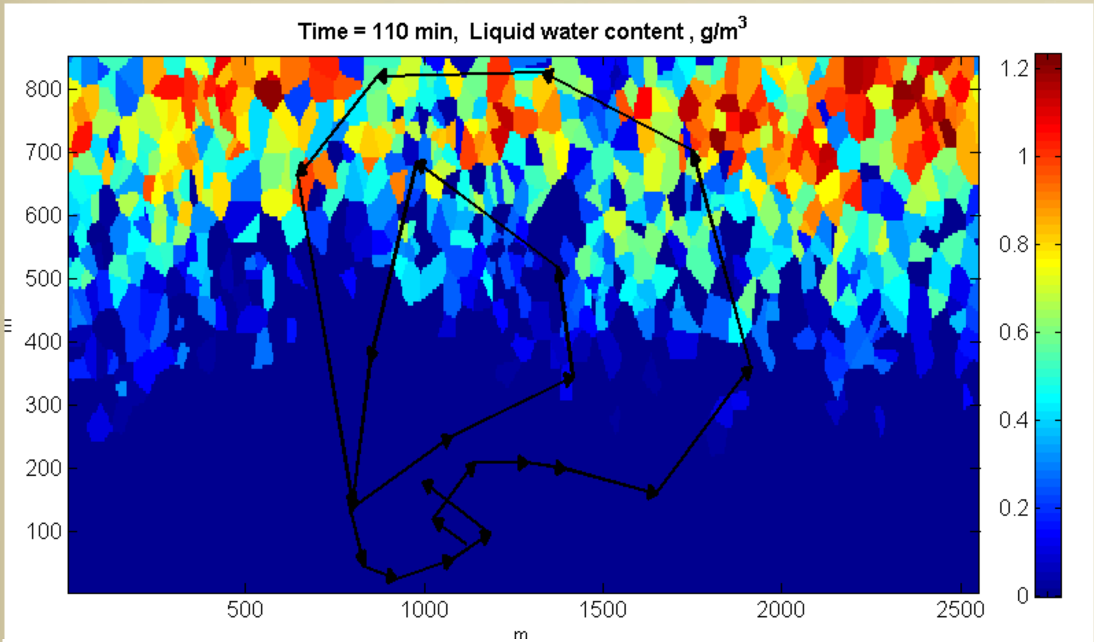
From measurements



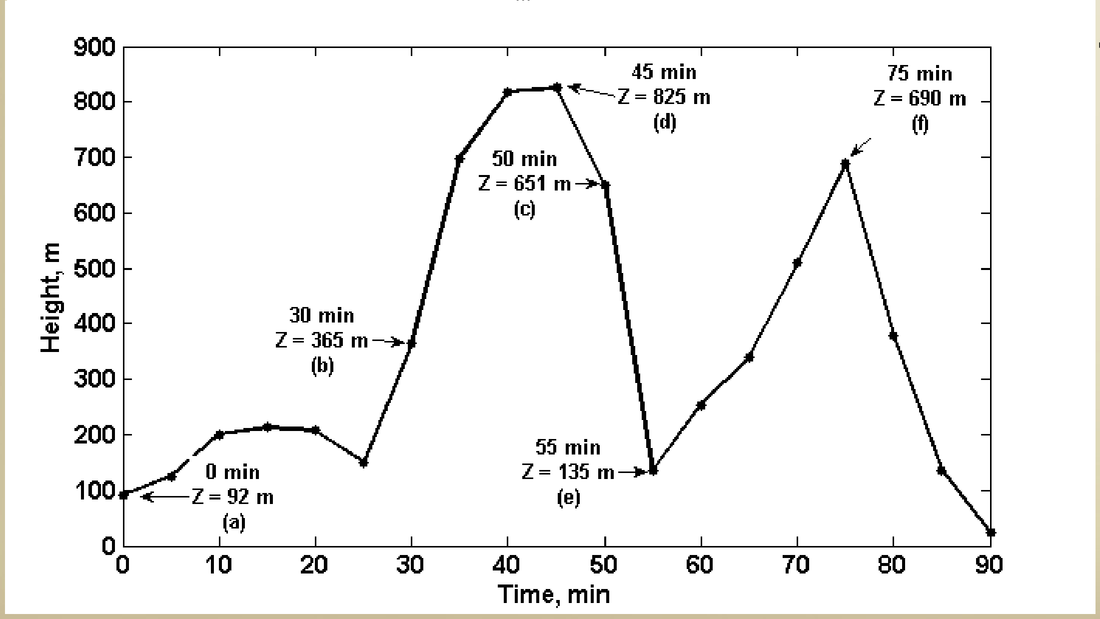
Initial humidity and temperature profiles:

adjusted so that the values in the mixed boundary layer will coincide with measured profiles

A single re-circulating Lagrangian parcel



We randomly select a parcel with the only requirement that it make several circulations in the boundary layer



The model allows us to examine:

- The DSD in the parcel
- The drop-aerosol relationship
- The salinity of the drops

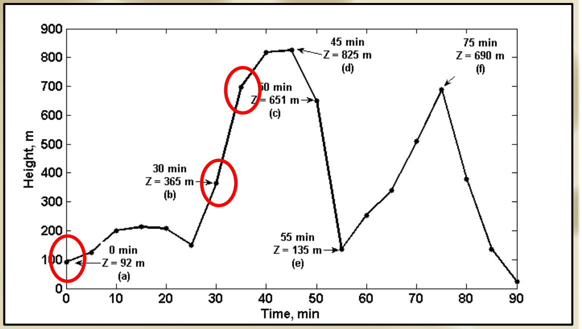
A single re-circulating parcel

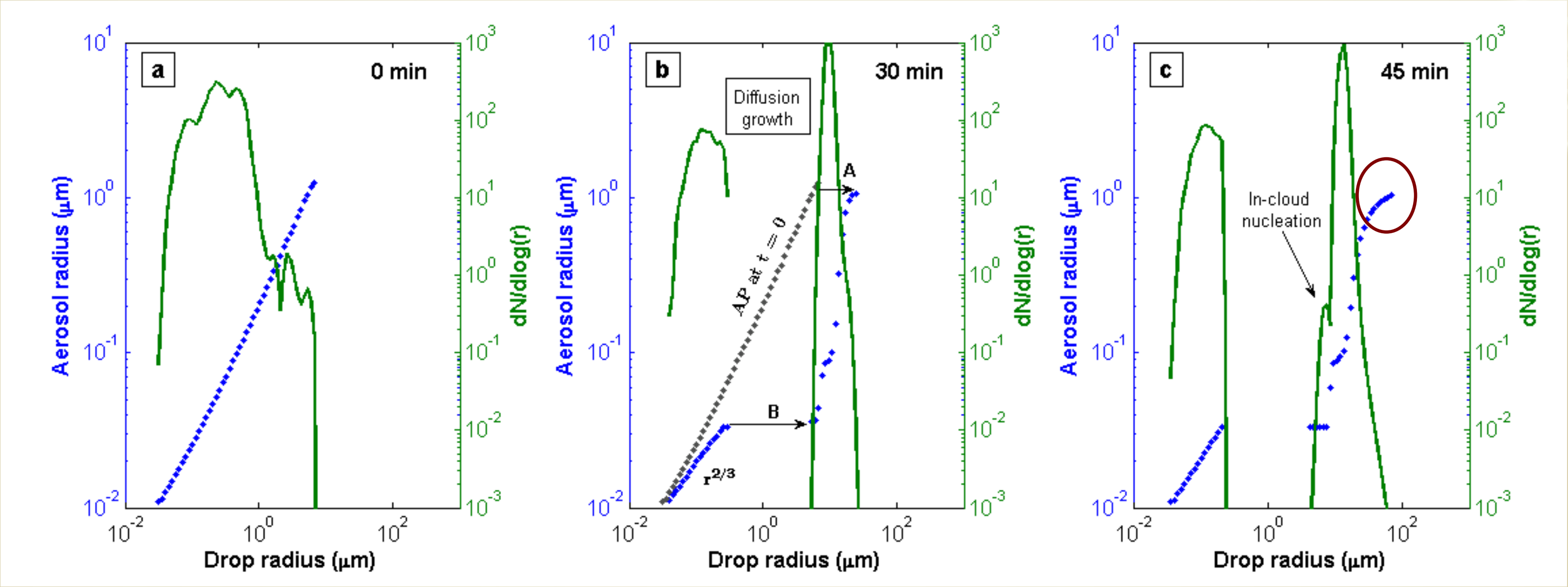
DSD and drop-aerosol relationship

$$r\frac{dr}{dt} = \frac{1}{F}\left(S - \frac{A}{r} + \frac{Br_N^3}{r^3 - r_N^3}\right)$$

In equilibrium with the environment

$$S - \frac{A}{r} + \frac{Br_N^3}{r^3 - r_N^3} = 0$$





Diffusion growth

Increase in water mass but no change in the mass of the aerosol

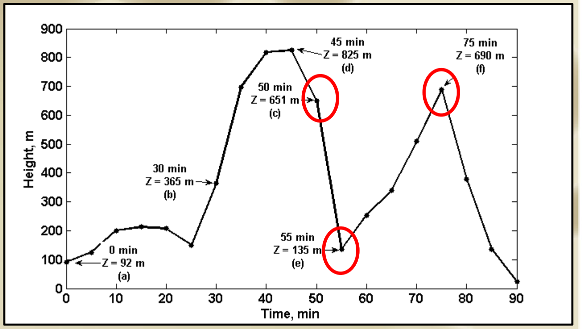
Haze particles

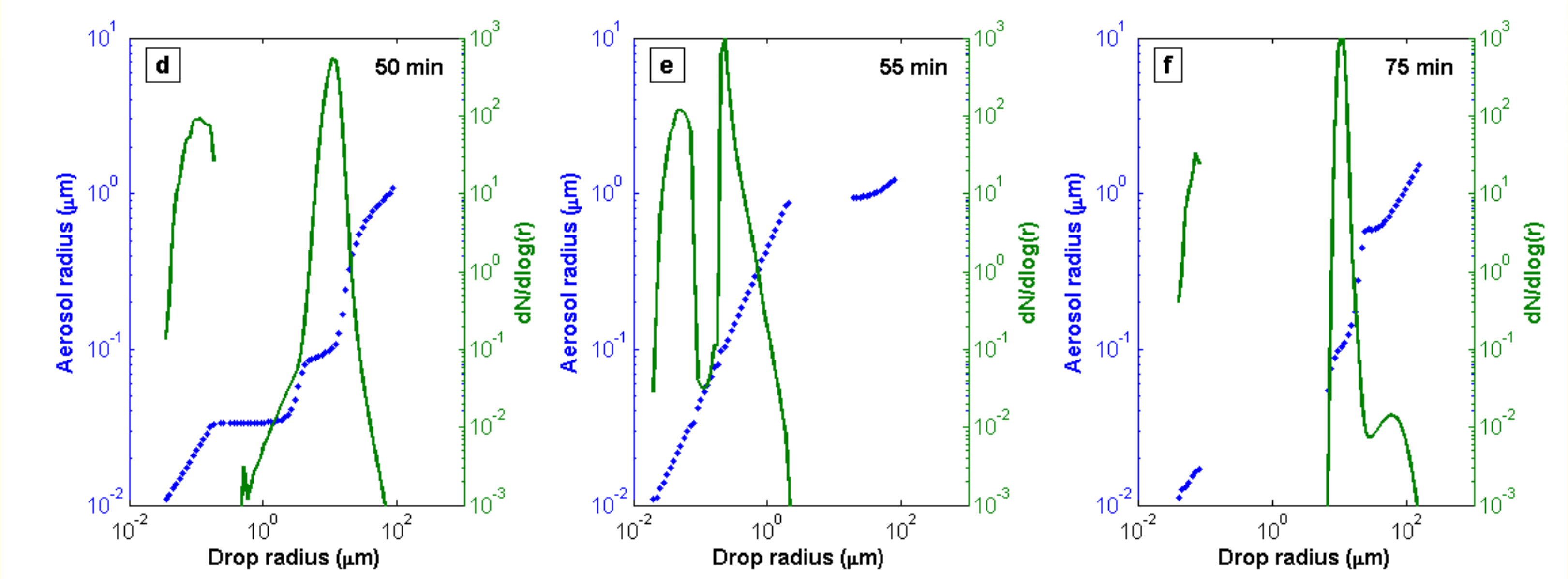
Small radius → $r_N = \left(\frac{A}{B}\right)^{1/3} r^{2/3}$

Collisions

The beginning of collisions can be seen by the formation of larger aerosols and a change in the slope of drop-aerosol relationship

A single re-circulating parcel
DSD and drop-aerosol relationship





In downdrafts **evaporation** changes drop-aerosol relationship

→ formation of a **"plateau"** in the relationship

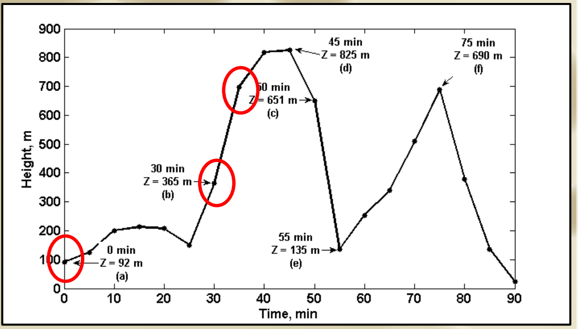
At the bottom of the boundary layer all droplets evaporate and only **large drops remain** → These drops have **large aerosols** in them

When the parcel ascends again there is activation of aerosols that were not activated before – higher supersaturation

The parcel contains large drops and large aerosols

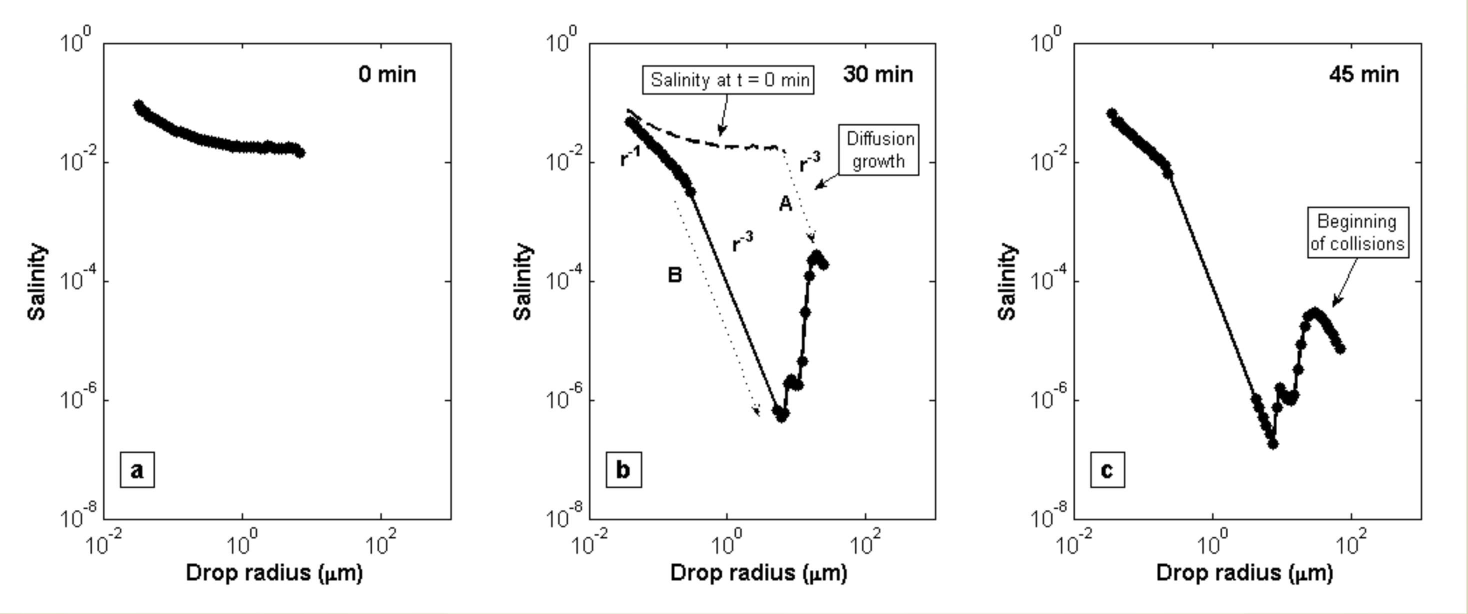
A single re-circulating parcel

Salinity distribution



$$r\frac{dr}{dt}=\frac{1}{F}\left(S-\frac{A}{r}+\frac{Br_N^3}{r^3-r_N^3}\right)\approx\frac{1}{F}\left(S-\frac{A}{r}+B\gamma\right)$$

γ – *Salinity*



<u>Diffusion growth</u>

Salinity of drops will decrease

Since r_N is constant salinity of drops will decrease with a slope of ~ r^{-3}

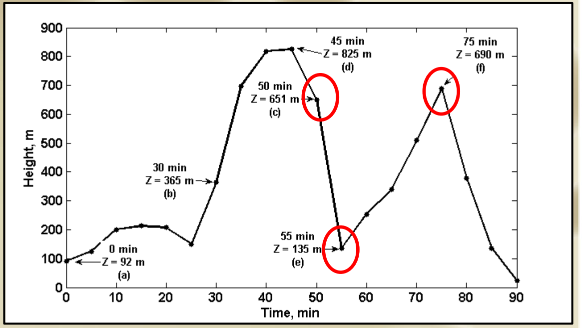
<u>Collisions</u>

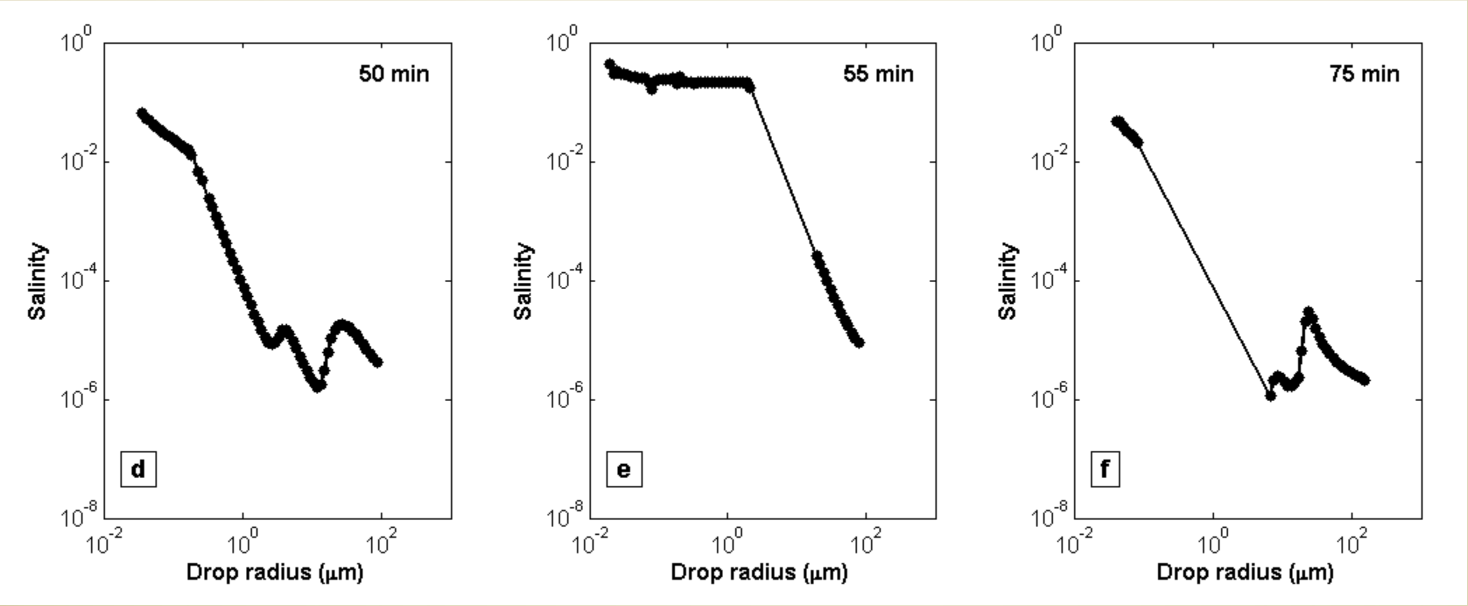
The beginning of collisions can be seen by a decrease in the salinity of large drops

<u>Haze particles</u>

Small radius → $\gamma\sim\frac{r_N^3}{r^3}=\left(\frac{A}{B}\right)r^{-1}$

A single re-circulating parcel
Salinity distribution





In downdrafts **evaporation** reduces the minimum value caused by diffusion growth

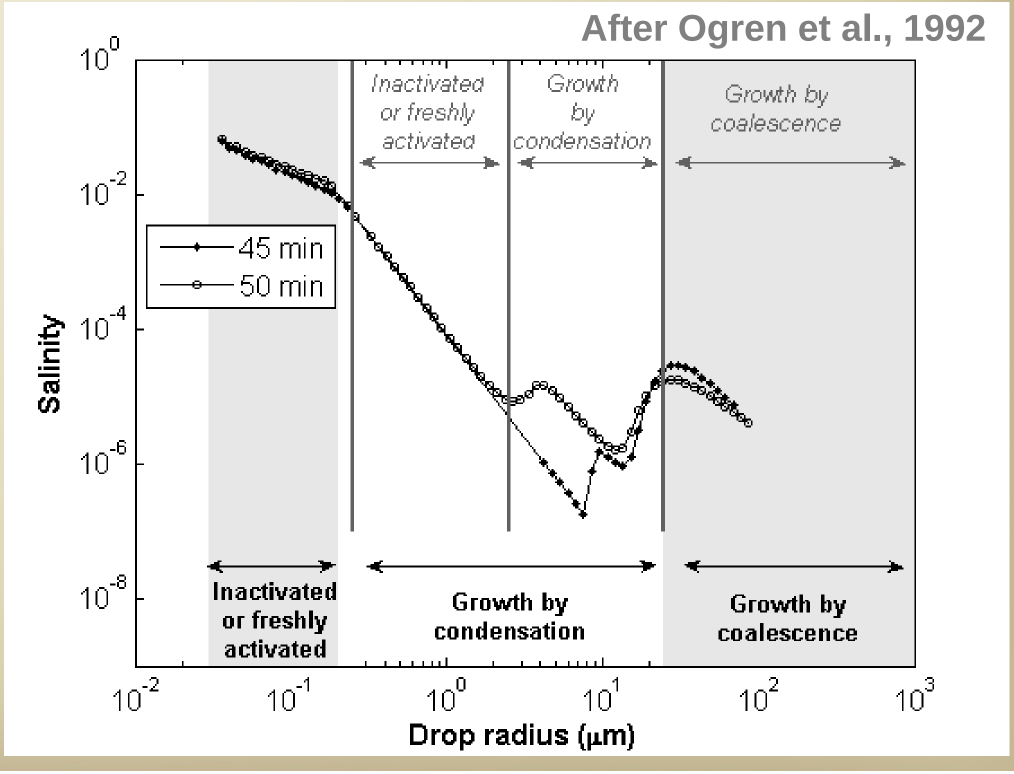
At the bottom of the boundary layer all droplets evaporate and only **large drops remain**

When the parcel ascends again it contains large drops, the minimum value of the salinity distribution is not as pronounced

A single re-circulating Lagrangian parcel

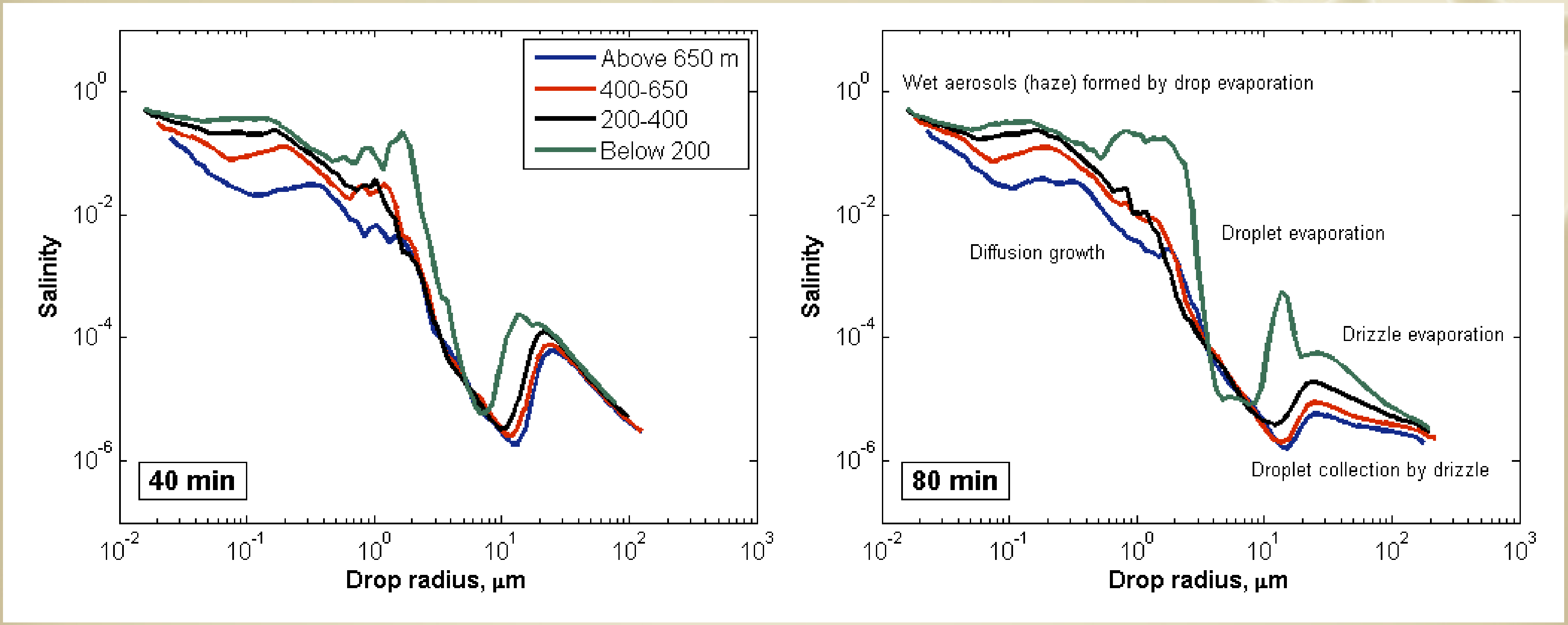
- Collisions lead to formation of large aerosols - larger than the maximum size of aerosol in the initial distribution
- Due to evaporation a "plateau" of aerosol sizes forms in the drop-aerosol relationship
- Salinity distribution is different in updrafts and downdrafts

- The salinity distribution differs from the conceptual model



Cloud processing of aerosol distribution

Averaged salinity distribution



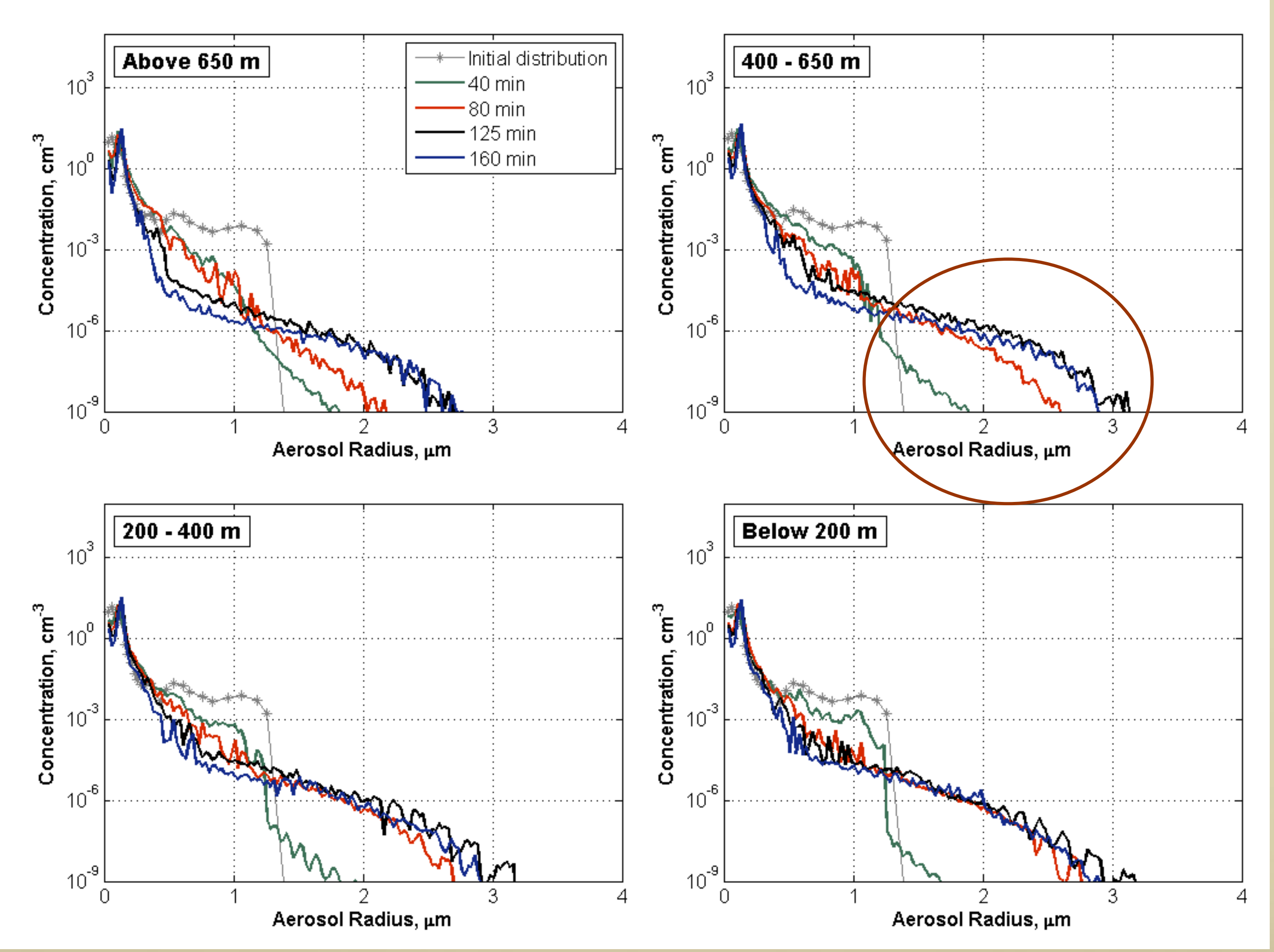
Averaged salinity distribution is similar to distribution seen in a single parcel

Increased salinity in the bottom layer is a result of evaporation

Peak in salinity decreases due to collisions

Cloud processing of aerosol distribution
Averaged aerosol distribution

Collisions lead to the formation of large aerosols that did not exist in the initial aerosol distribution



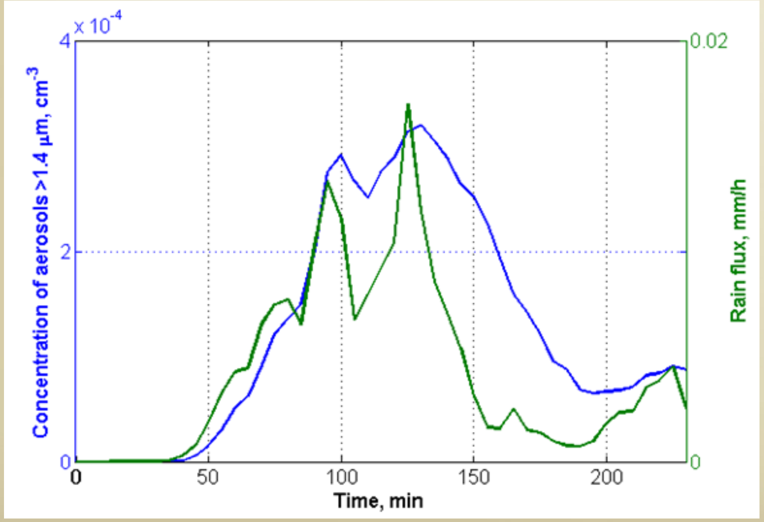
Cloud processing of aerosol distribution

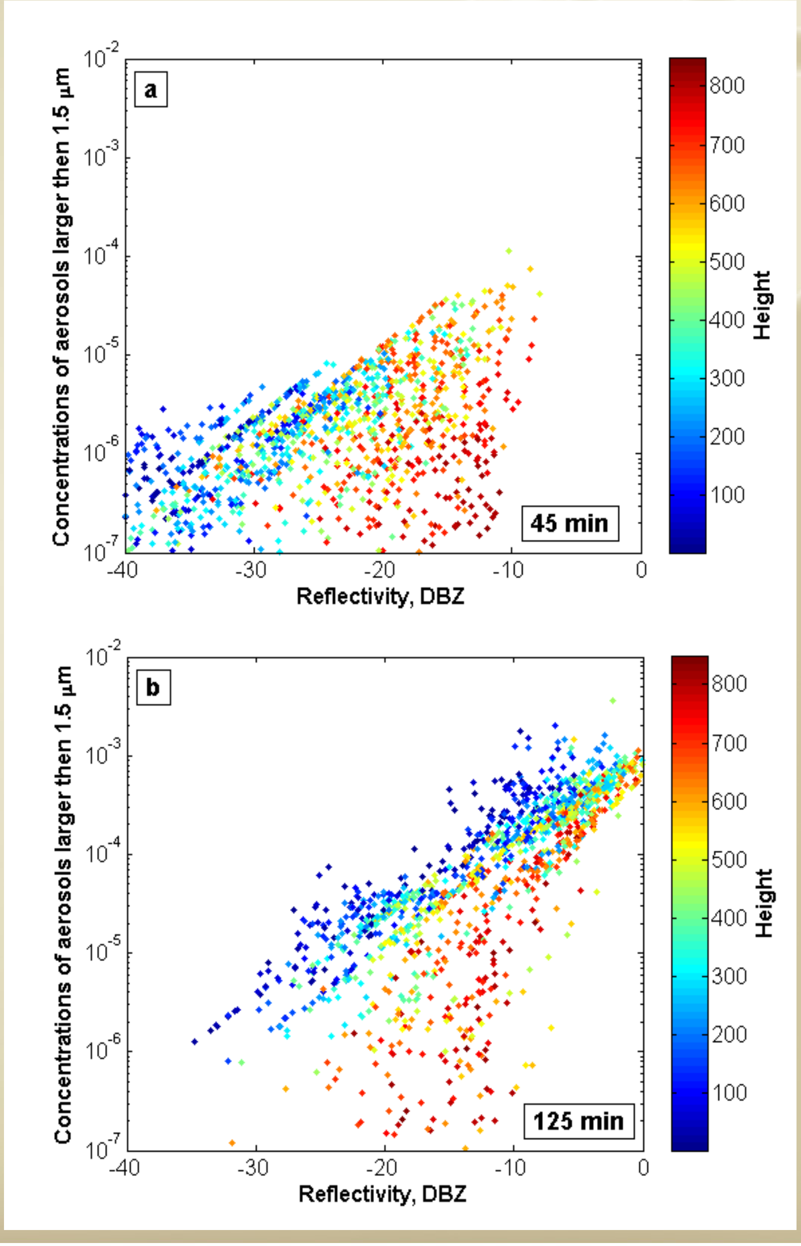
Large aerosol formation

Large aerosols form first inside the cloud layer in parcels with high reflectivity

The large aerosols fall to the ground with the drizzle drops

A maximum concentration of large aerosols forms and then disappears

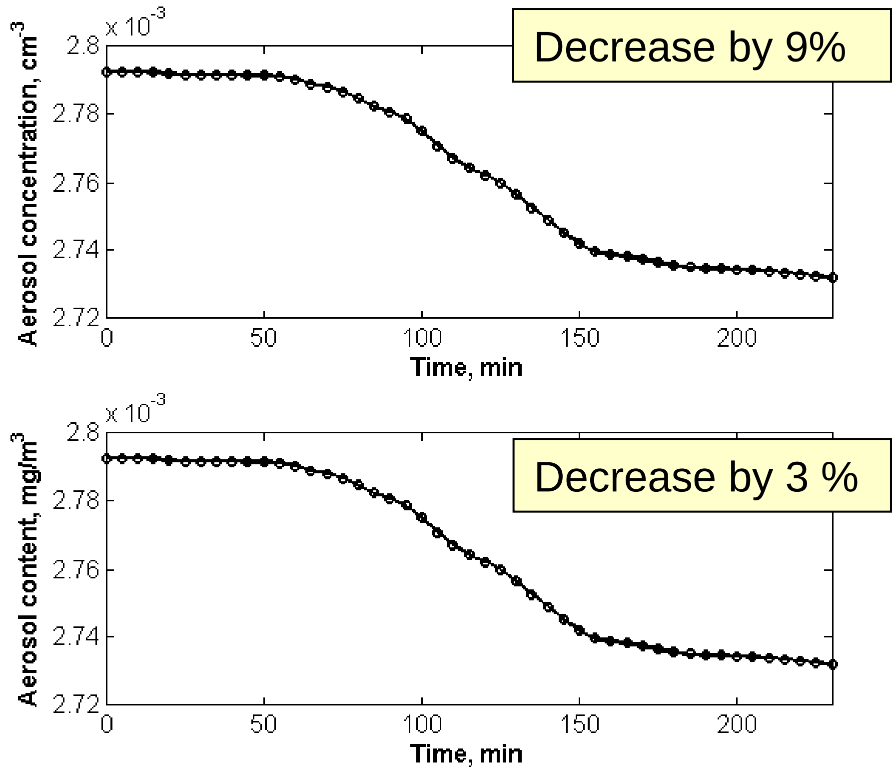


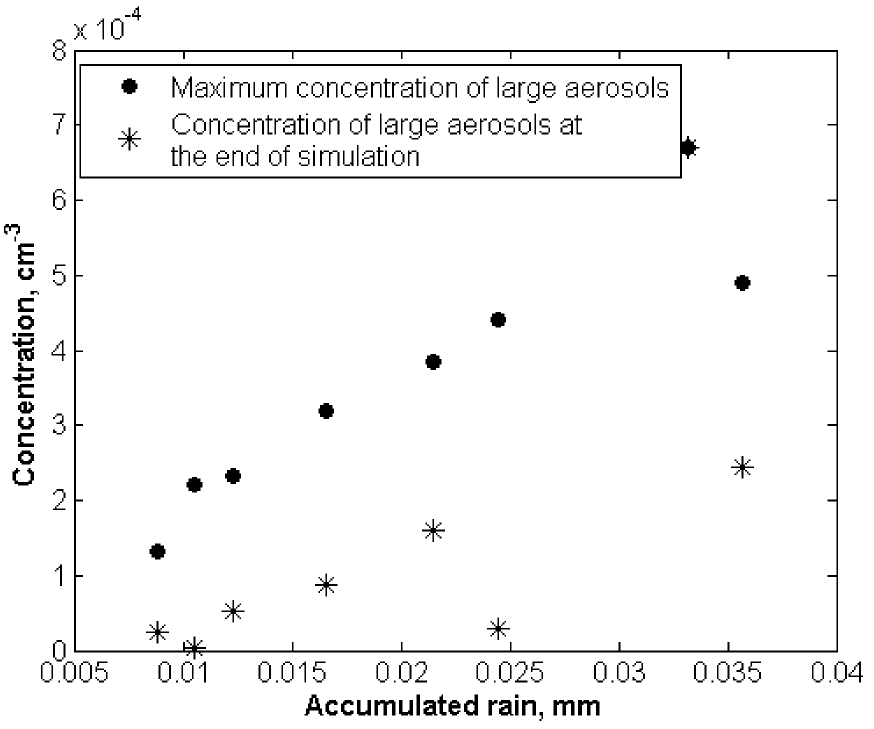


Cloud processing of aerosol distribution
Loss of aerosol mass and concentration

Mass can only be lost by **sedimentation** to the ground inside drizzle drops

Concentration can be decreased by **sedimentation as well as collisions**





Comparing several simulations:

Increase in accumulated rain leads to **higher maximum concentration** of “new” aerosols

At the end of the simulation, most of the large aerosols fall and exit the BL

Conclusions

Clouds lead to changes of the aerosol distribution

- Collisions lead to the formation of aerosols larger than the maximum aerosols that existed in the initial spectrum
- Evaporation leads to the formation of “plateaus” in the drop-aerosol relationship
- Large aerosols form in the cloud layer and sediment to the ground with falling drizzle
- Concentration of large aerosols forming in the boundary layer increases with accumulated rain
- At the end of the simulation most of the large aerosols are washed out of the boundary layer

Salinity

- Salinity distribution changes in updrafts and downdrafts
- We present an adjustment to the conceptual model

Thank you