Department of Earth and Planetary Sciences

Clouds' Mixing: a Continuous Description from the Core to the Non-Disturbed Environment

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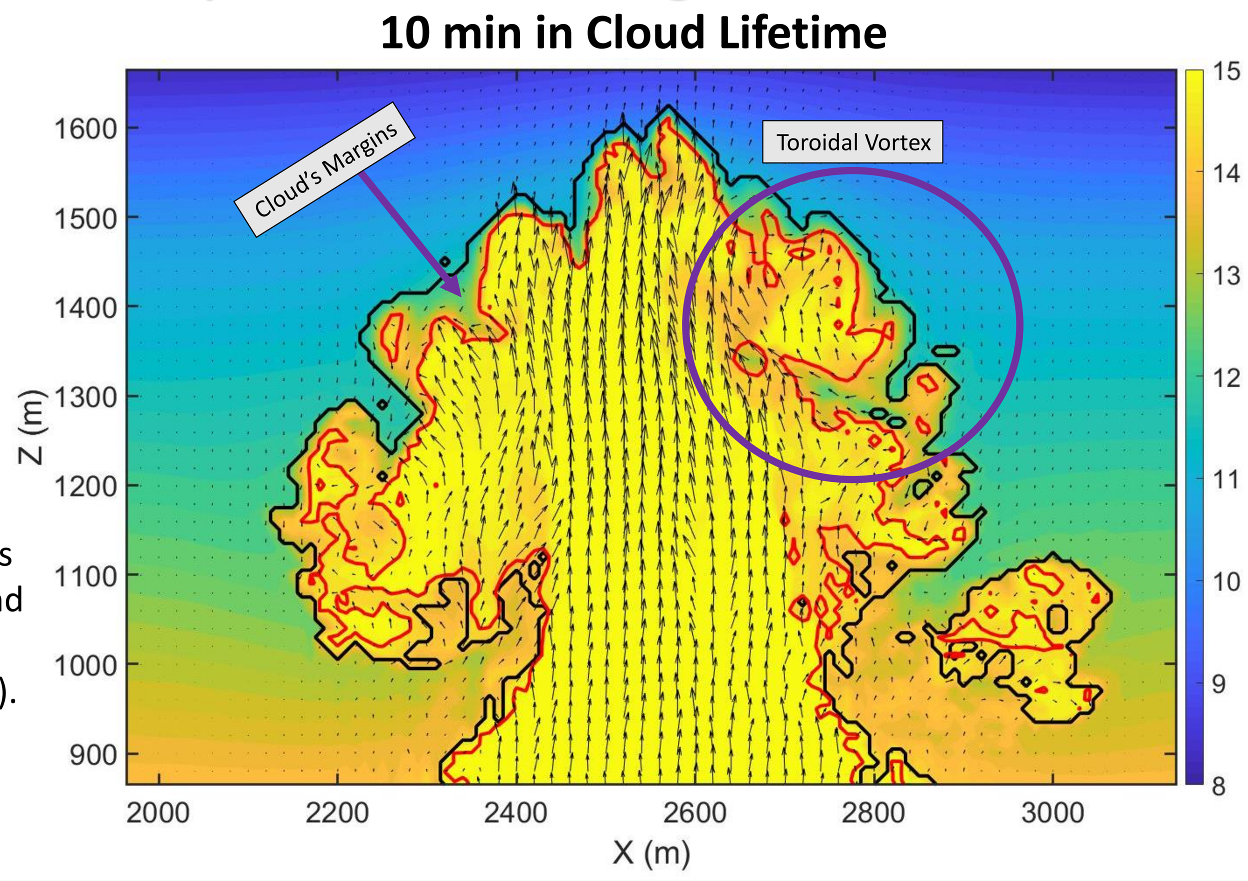
Abstract

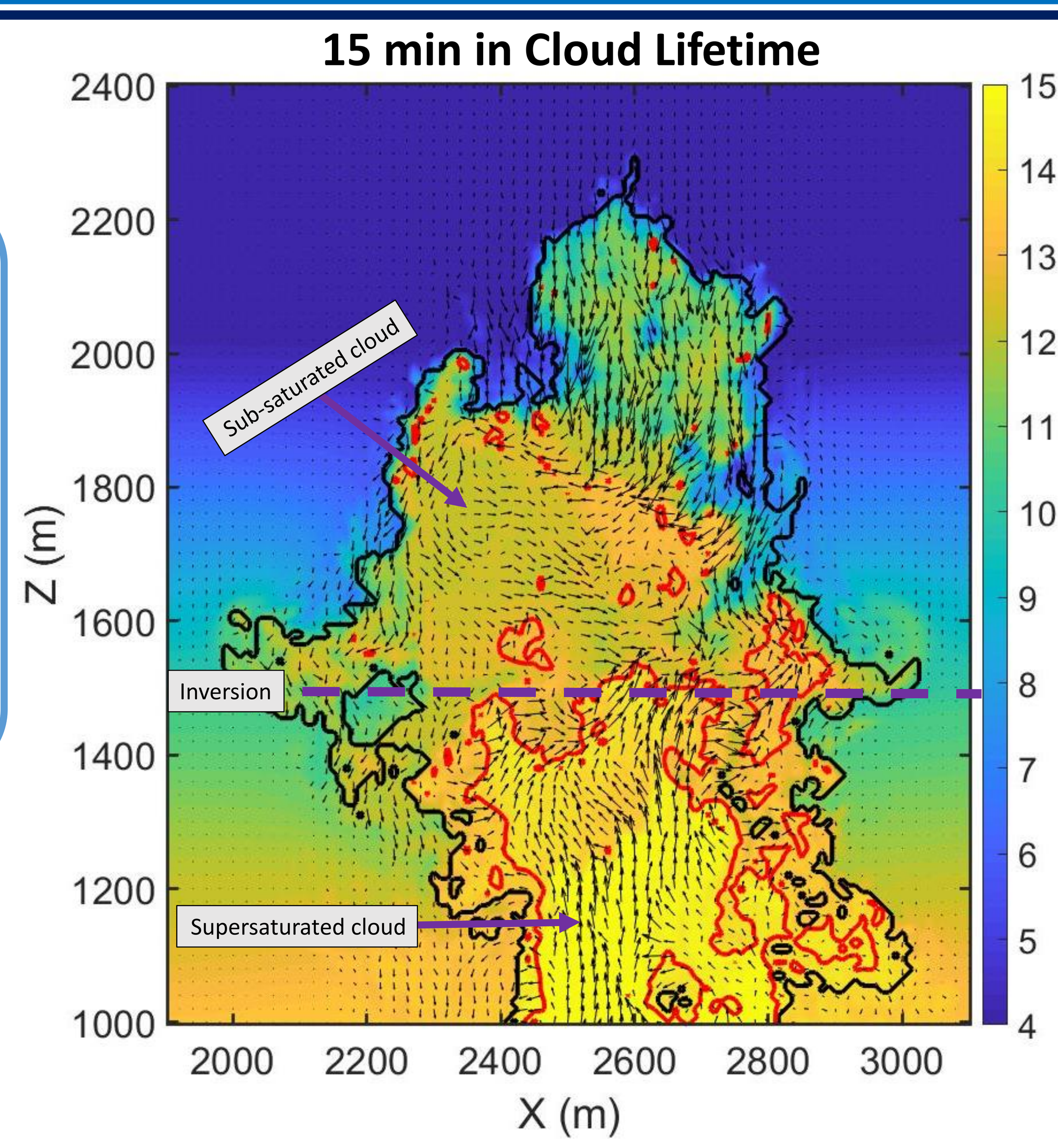
Clouds-Environment interactions via mixing has bi-directional effects: entrainment of dry air into the cloud influence its life time and changes its dynamic and microphysical processes which are important to its radiative effects and raining properties (Schmeissner et al. 2014, Korolev et al. 2016) . On the other hand, clouds change their environment by detrained hydrometeors, water vapor and processed aerosols and thus alter it's properties and thermodynamic conditions (Khain and Pinsky 2018, Austin and Zhao 2005, Perry and Hobbs 1996). Here we present a BOMEX case single cloud simulation with the SAM using the Hebrew University bin-microphysics, in 10m resolution, to investigate the different aspects and scales of mixing.

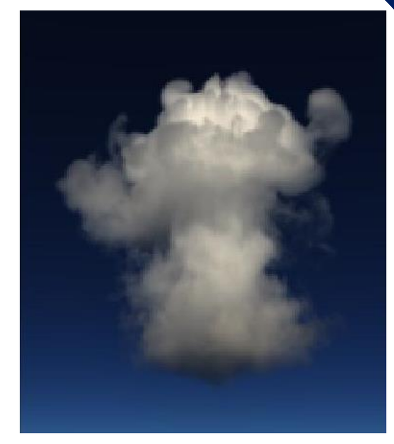
Dynamical Mixing Features Down to 10m Scale

After 10min in cloud lifetime, it shows coherent flow patterns such as core's updraft, toroidal vortex, and thin margins (the area between the two contours).



Specific humidity field (g/kg) with cloud edge marked in black (LWC>0.01g/kg) and supersaturated core in red.



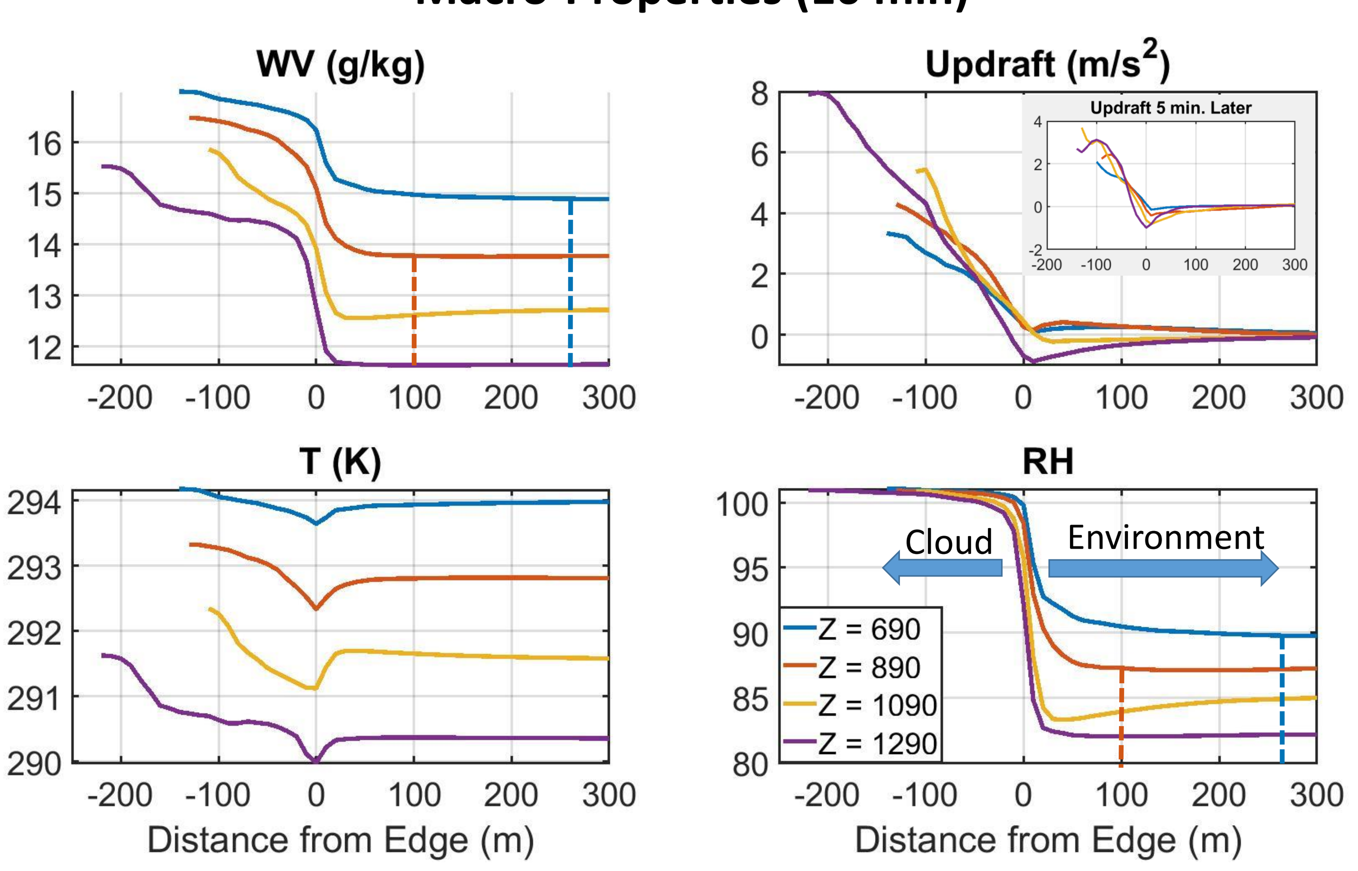


After 15min in cloud's lifetime, its top is sub-saturated and drizzle forces a downdraft that entrains dry air from the free troposphere.

Single cloud simulation in 10m resolution reveals fine structures in cloud's properties due to turbulence and the sharp gradients at it's margins. The visualization was done using 3D radiation transfer model (SHDOM).

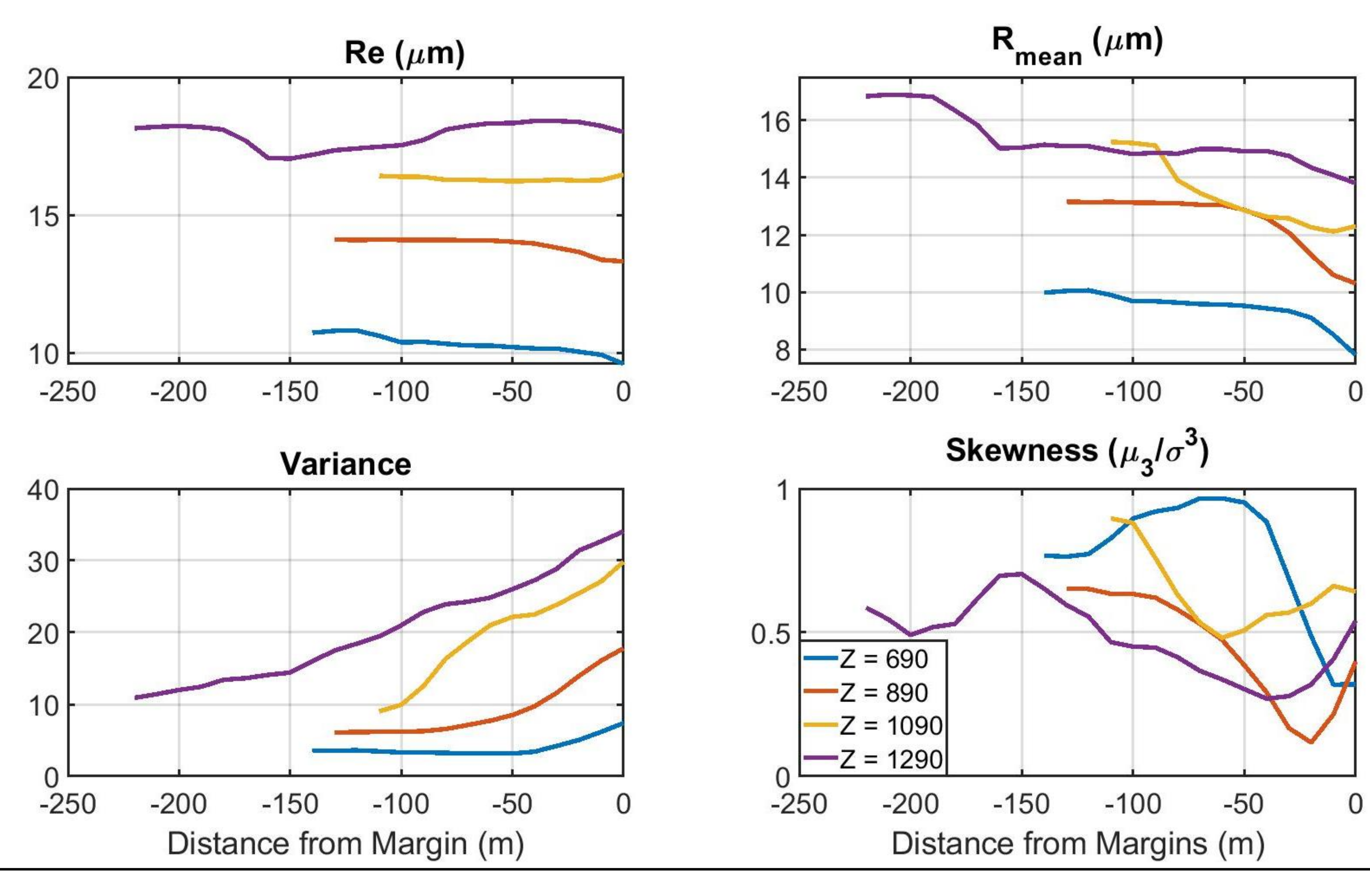
The Gradients on the Edge of the Cloud

Macro-Properties (10 min)



Turbulent diffusion of the high water vapor concentration together with evaporative cooling forms a humid shell in addition to the subsiding shell. This can be seen in the decrease of RH and WV from the cloud edge (X=0) to the constant environment values (marked in dashed lines), it extends to 100s of meters from cloud.

Microphysic (10 min)

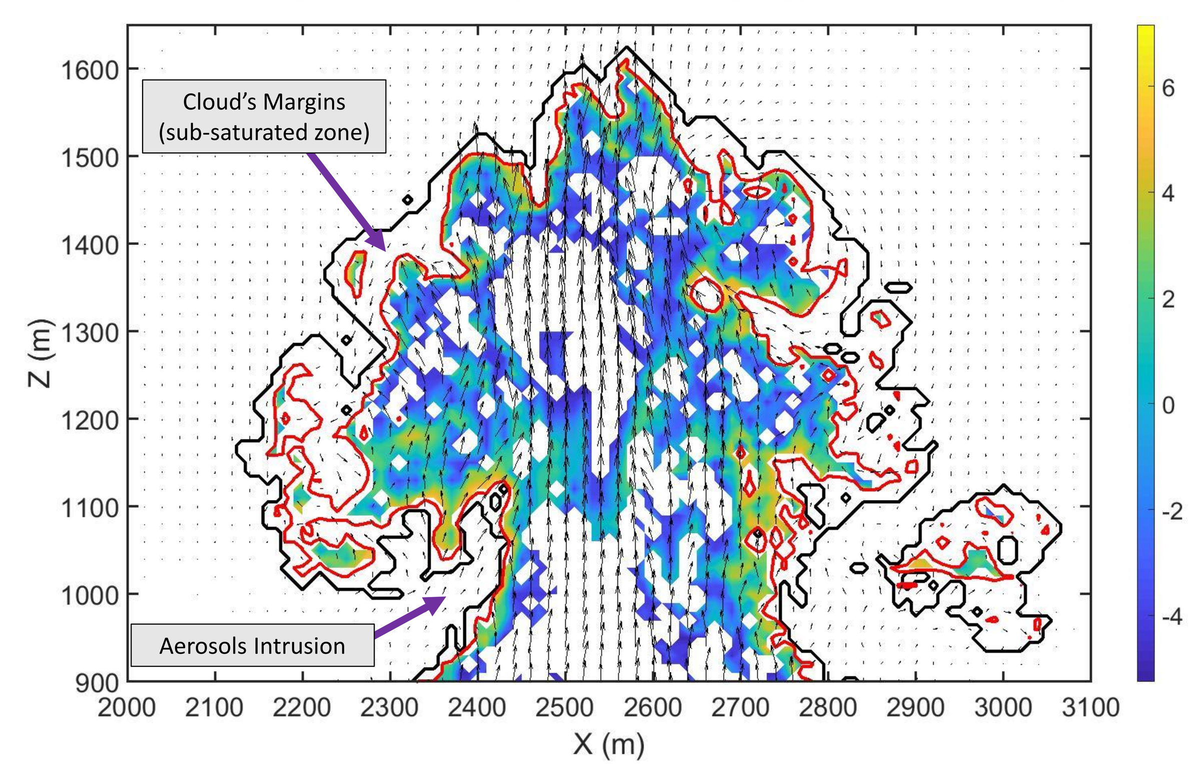


Closer to the edge the different measures for radii show different behavior, while r_e remains almost constant (consistence with observations), the mean radii decrease due to evaporation. The variance of the droplets size distribution increase since the decrease of smaller droplets to smallest is faster the shrinking of the large ones.

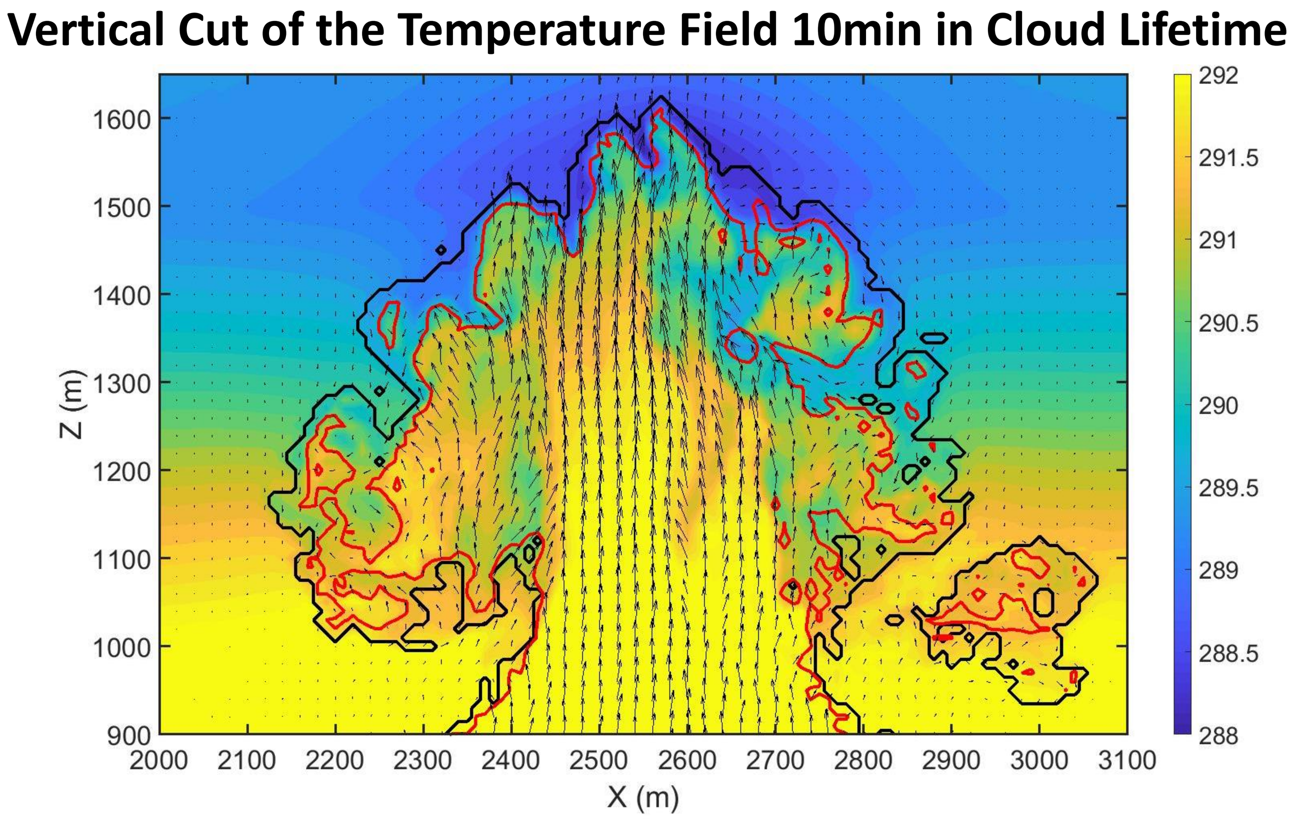
Nucleation at Cloud Margins

Vertical Cut of Nucleation Rate (log scale) 10min in Cloud Lifetime

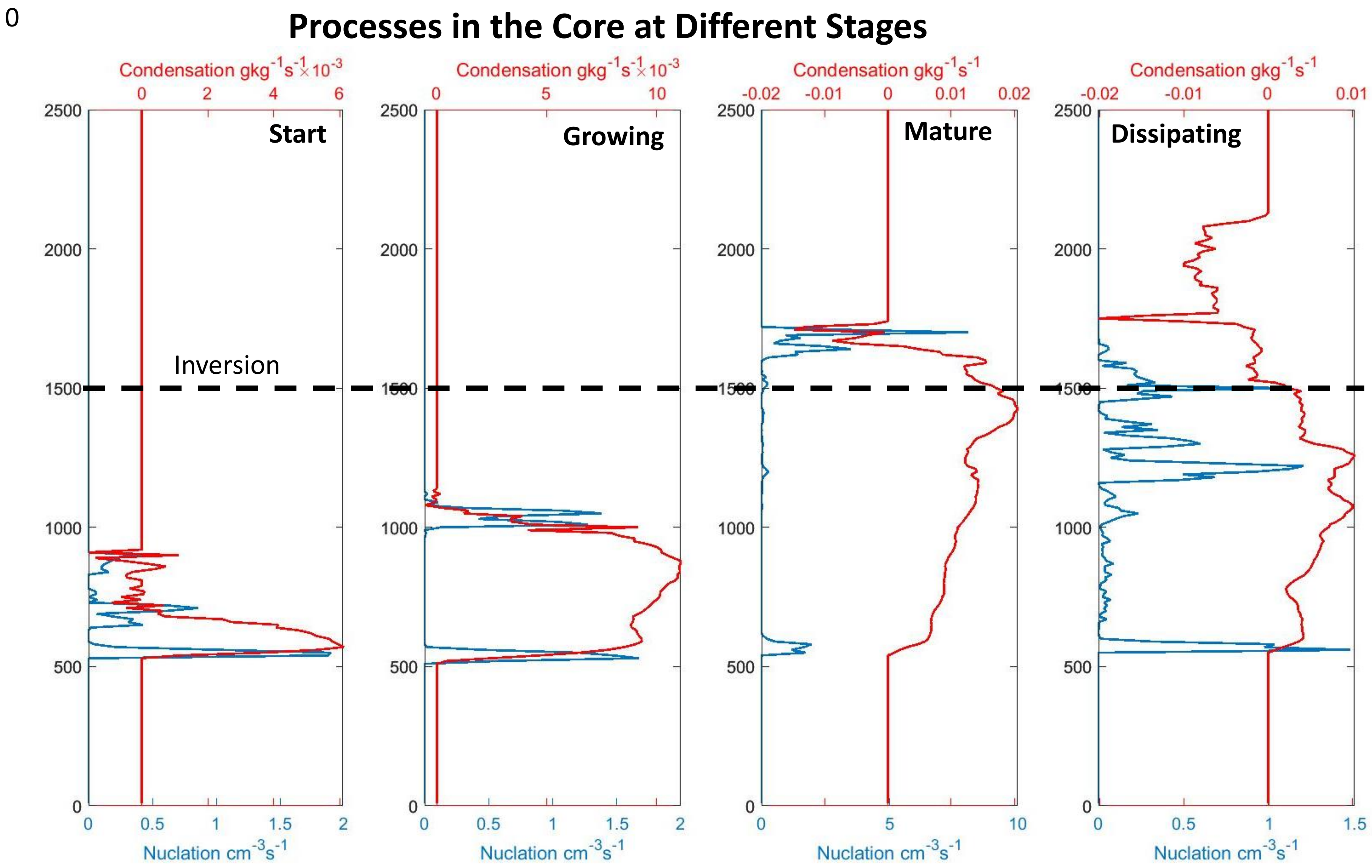
black contour marking the cloud edge (LWC>0.01 g/kg) and red marking supersaturation = 0



Vertical Cut of the Temperature Field 10min in Cloud Lifetime



Processes in the Core at Different Stages



Profiles of nucleation and condensation-evaporation rates at the cloud's core reveal that the nucleation occurs in a few levels in the cloud. Together with the nucleation at cloud base, there is also nucleation below the cloud's top and in some mid-levels of the cloud. Looking at a vertical cut reveals that nucleation occurs mostly on the interface of the supersaturated core and margins. Theses areas are colder due to evaporative cooling which increase the supersaturation of the neighboring supersaturated parcels. The entrainment also has the potential to bring fluxes of new aerosols into the cloud and thuds promote secondary nucleation.