The impact of liquid cloud vertical profile and cloud top entrainment on droplet size retrieval from 3MI

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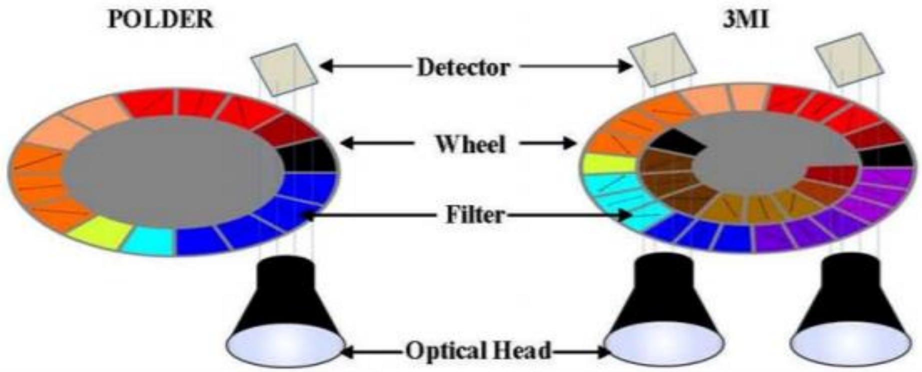
I. Motivation

☐ The multi-angle polarization and infrared measurements can be combined in cloud observations



POLDER

	Central Wavelength (nm)	Bandwidth (nm)	Polarisation
VIS-NIR			
	443	20	N
	490	20	Y
	565	20	N
	670	20	Y
	763	10	N
	765	40	N
	865	40	Y
	910	20	N
	1020	20	N
SWIR			

3MI

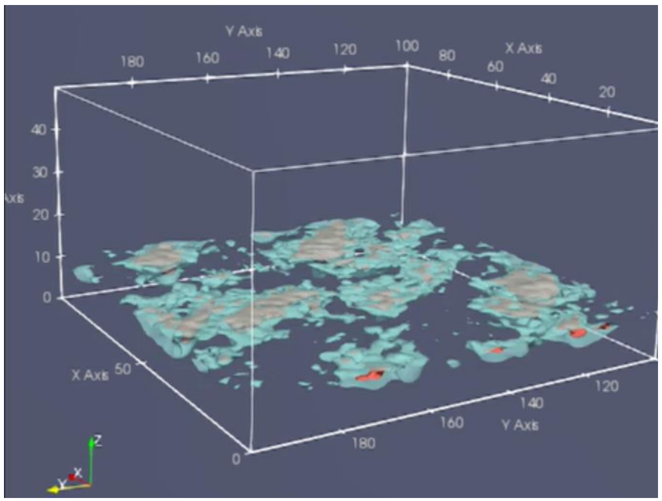
	Central Wavelength (nm)	Bandwidth (nm)	Polarisation
VNIR	410	20	Y
	443	20	Y
	490	20	Y
	555	20	Y
	670	20	Y
	763	10	N
	754	20	N
	865	40	Y
	910	20	N
SWIR	1370	40	Y
	1650	40	Y
	2130	40	Y

- **In which condition 3MI observations could be used to constrain simplified cloud profile retrievals?**
- **If entrainment at cloud top and turbulent mixing can create detectable signatures?**

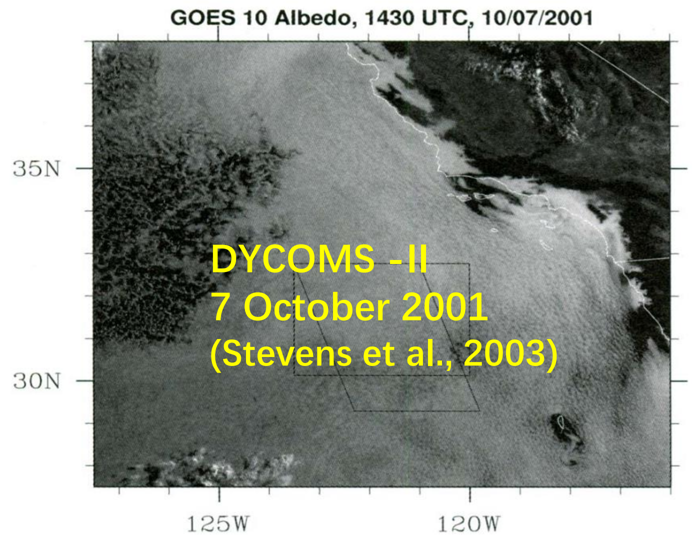
II. Stratocumulus simulation from RAMS

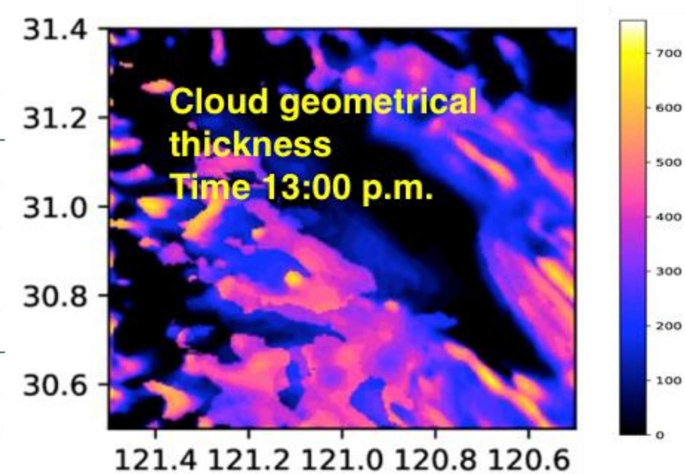
- Stratocumulus is one important kind of shallow boundary layer clouds
- Two cases from Regional Atmospheric Modeling System (RAMS) are investigated

CASE 1: Idealized case



CASE 2: DYCOMS-II





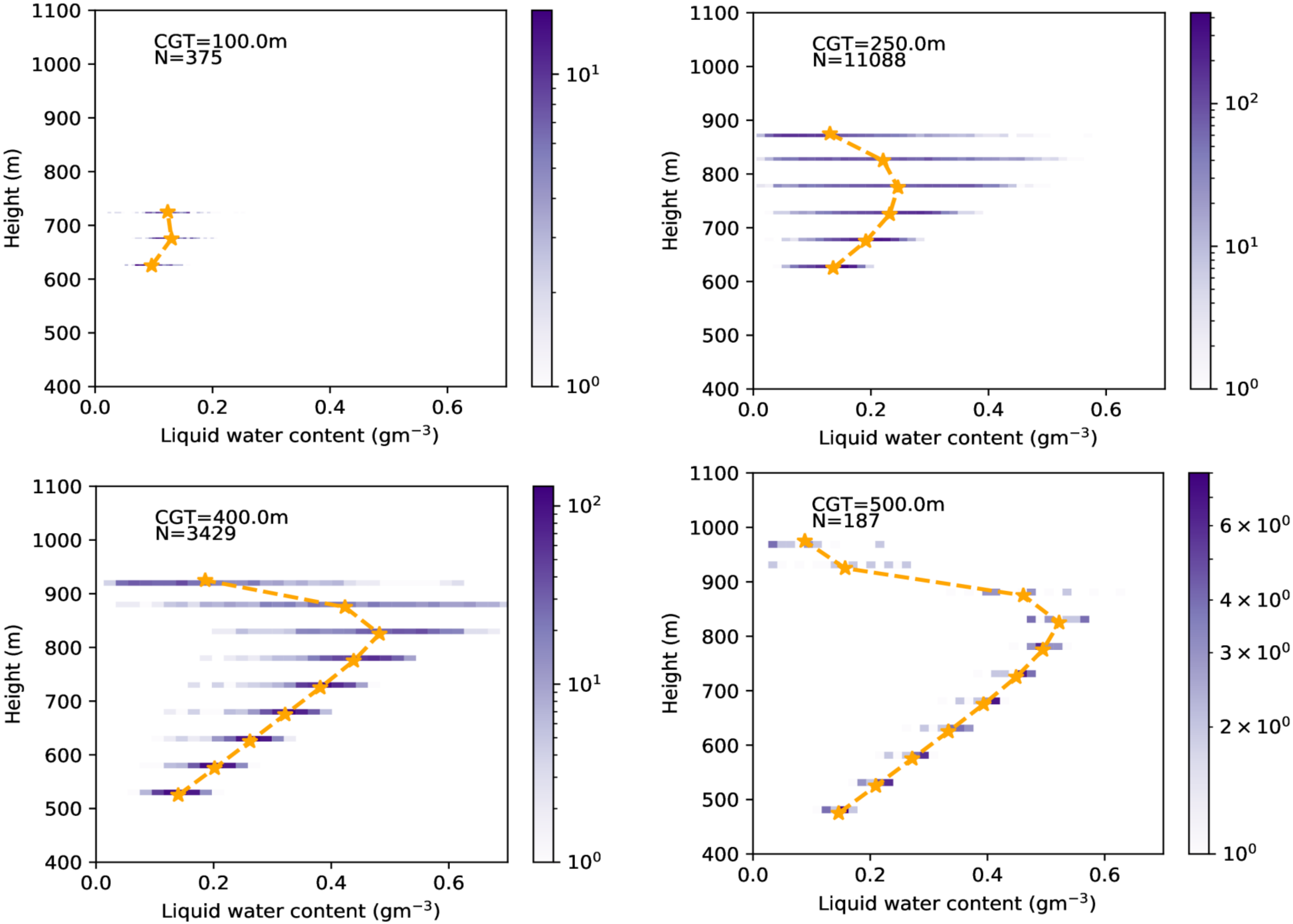
dx=dy=100m
dz=50m
outputs= 5 minutes
total simulation= 4 h

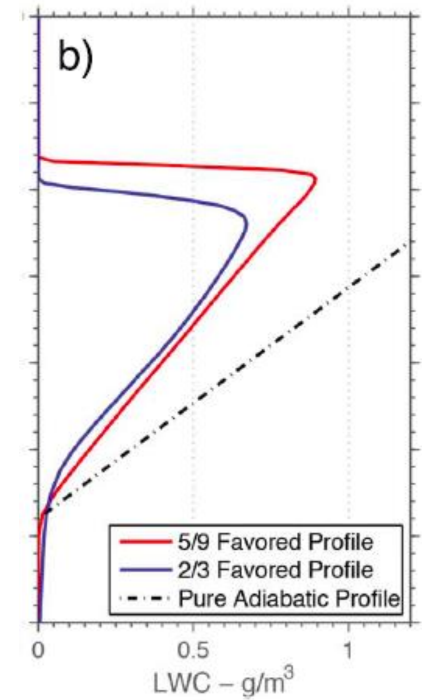
dx=dy=0.25 degree
dz=20m (<970m) and ~50 m (>970 m)
outputs= 15 minutes
total simulation= 12 h

- CASE 1: Simplified cloud profile analysis
- CASE 2: Effect of cloud top entrainment on cloud profiles

III. LWC profile statistics

□ Simplified triangle shape of LWC profiles with increasing cloud geometrical thickness



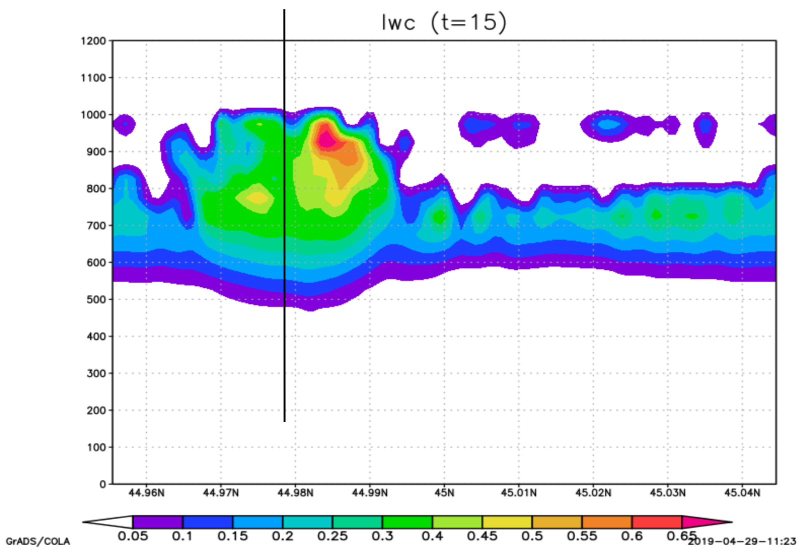


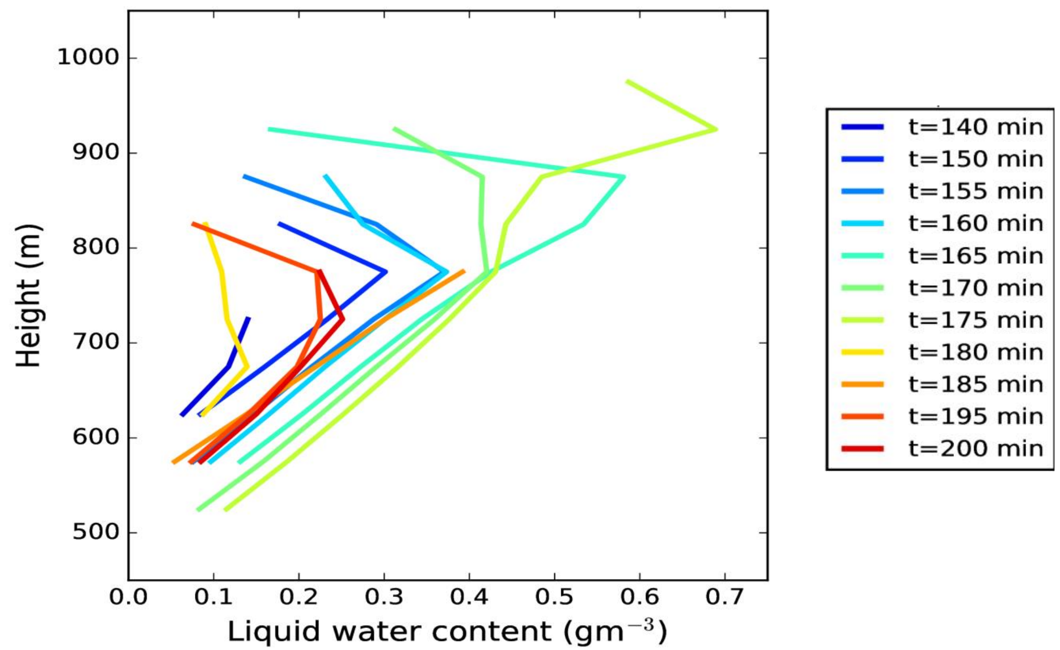
Miller et al JGR 2016

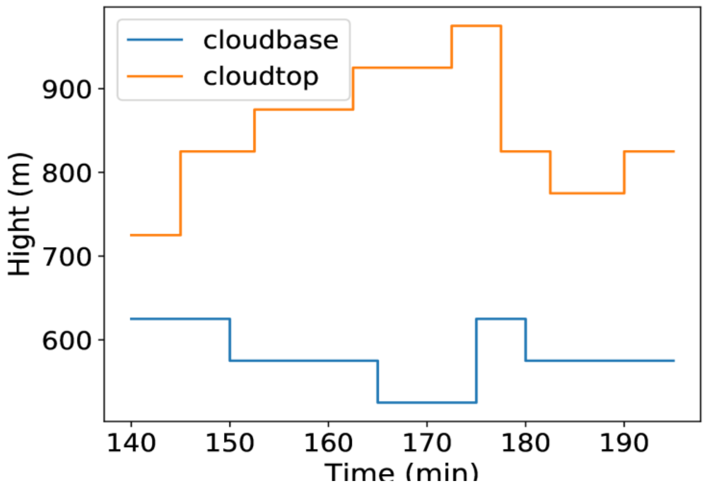
Idealized stratocumulus case

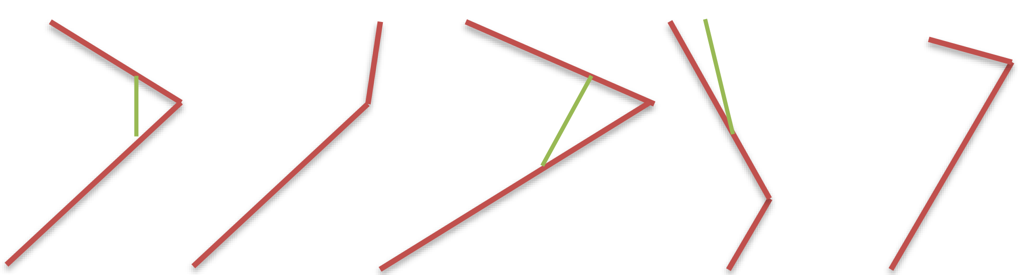
III. LWC profile statistics

- **The individual profiles also show the triangle shape LWC profiles**





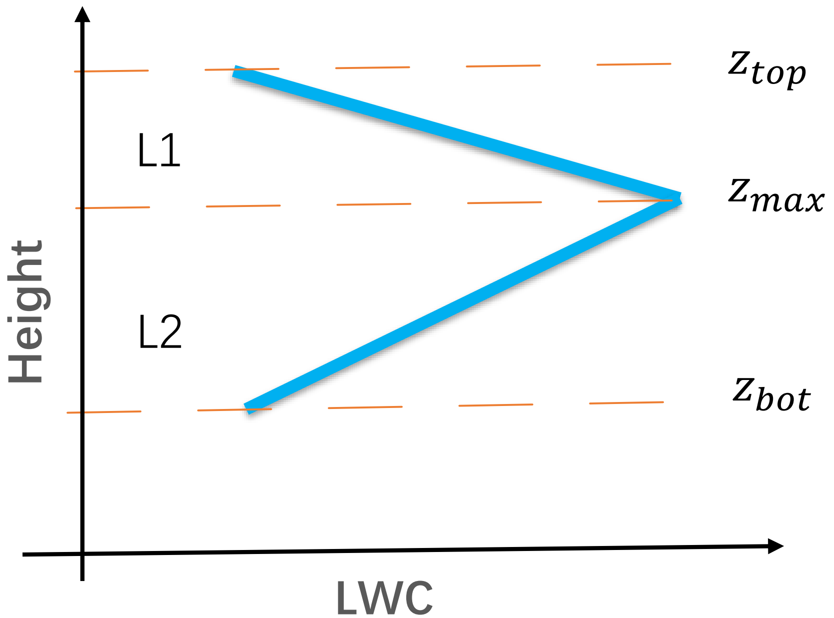




Idealized stratocumulus case

III. LWC profile statistics

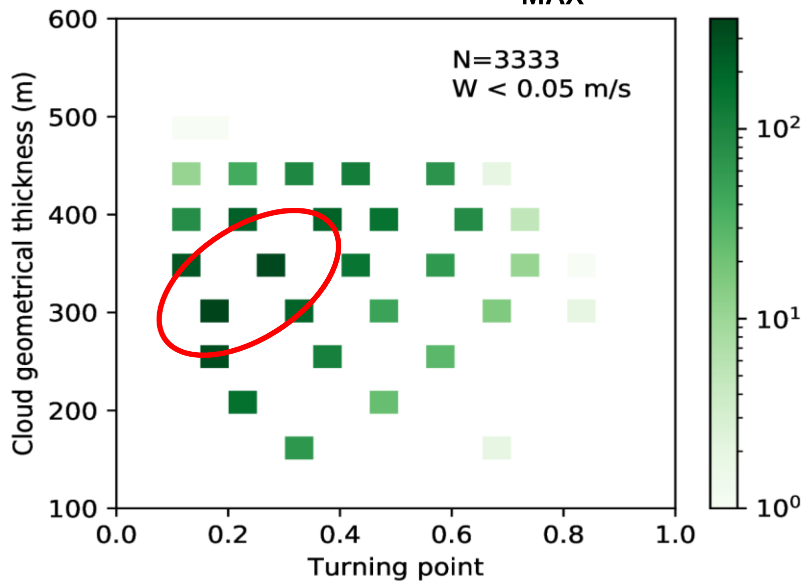
□ Introduce the turning point to describe the simplified LWC profiles



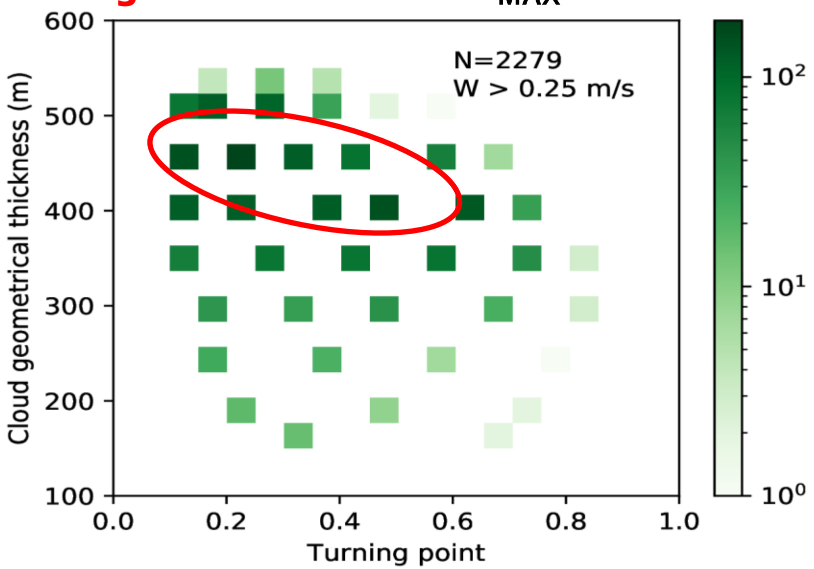
$$Turning\ point\ (p) = \frac{z_{max} - z_{bot}}{z_{top} - z_{bot}} = \frac{L1}{L1 + L2}$$

□ Cloud geometrical thickness-turning point relation

Weak vertical air flow W_{MAX} < 0.05 m/s



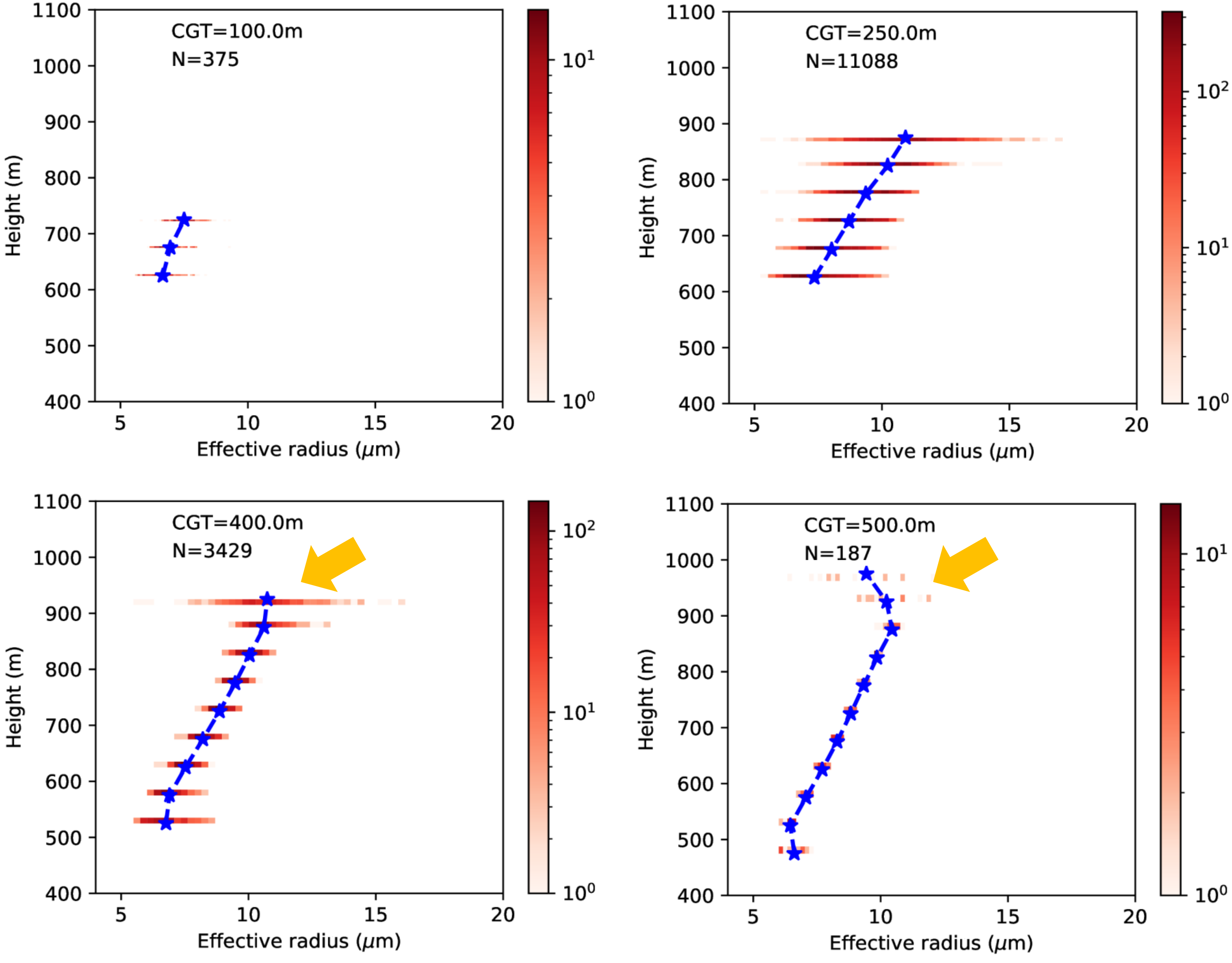
Strong vertical air flow W_{MAX} > 0.25 m/s



Idealized stratocumulus case

III. Cloud droplet profile statistics

❑ Adiabatic and non-adiabatic cloud droplet profiles



Idealized stratocumulus case

III. Cloud entrainment

ECMWF cloud entrainment calculation   Bechtold et al. (2008)

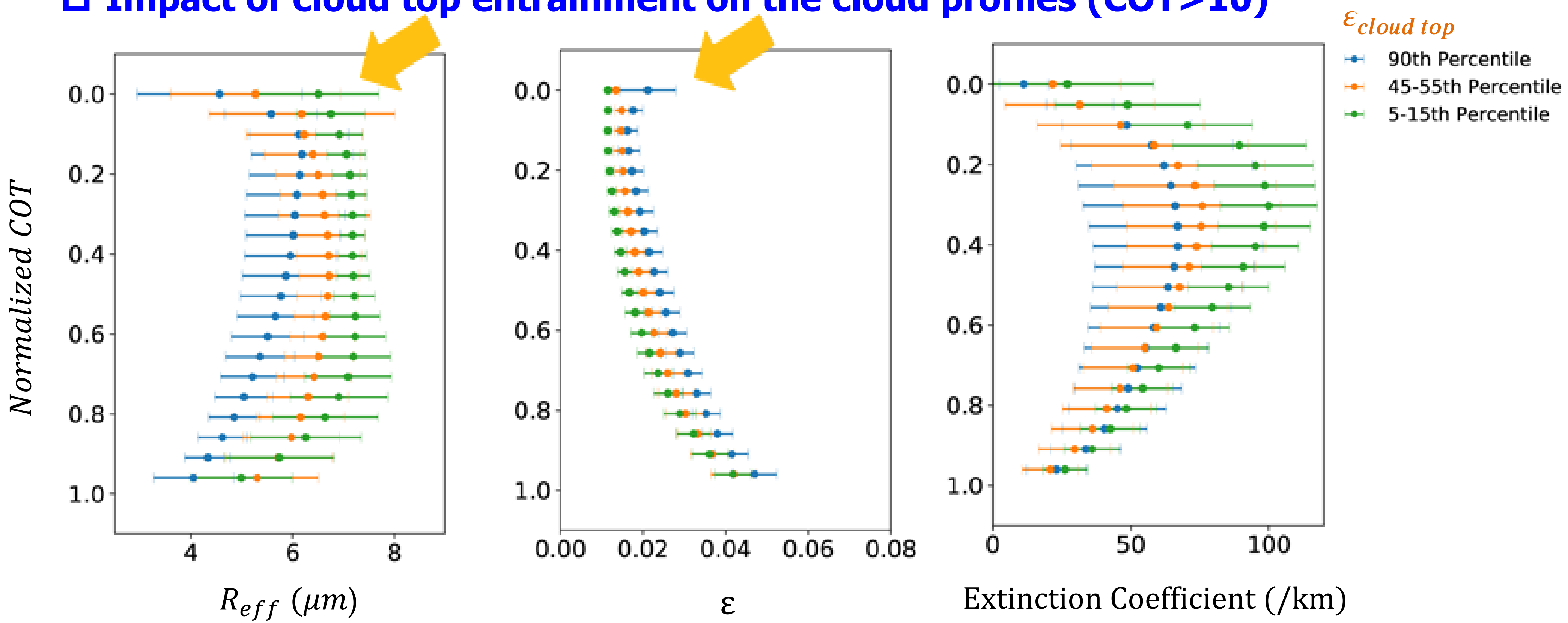
$$\varepsilon = 1.8 \times 10^{-3}\{1.3 - RH(z)\}f_{scale}$$

ε: **fractional entrainment rate**   **RH: relative humidity**

$$f_{scale}=\left\{\frac{q_{sat}(z)}{q_{sat}(z_{bottom})}\right\}^3$$

q_{sat}: **saturation humidity at level z**

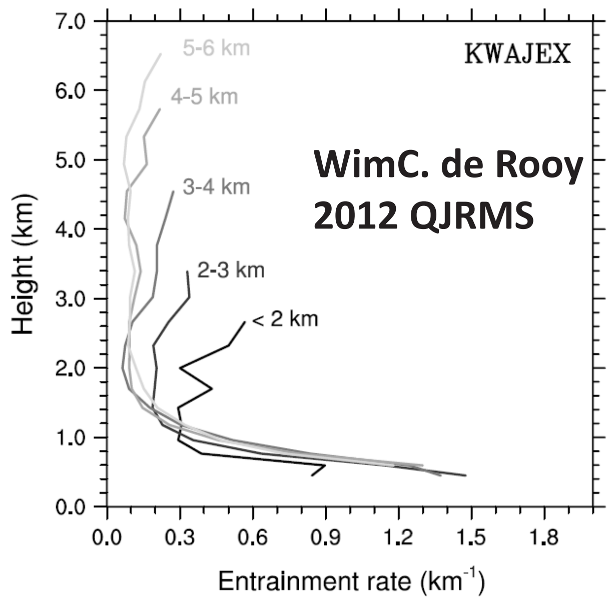
Impact of cloud top entrainment on the cloud profiles (COT>10)

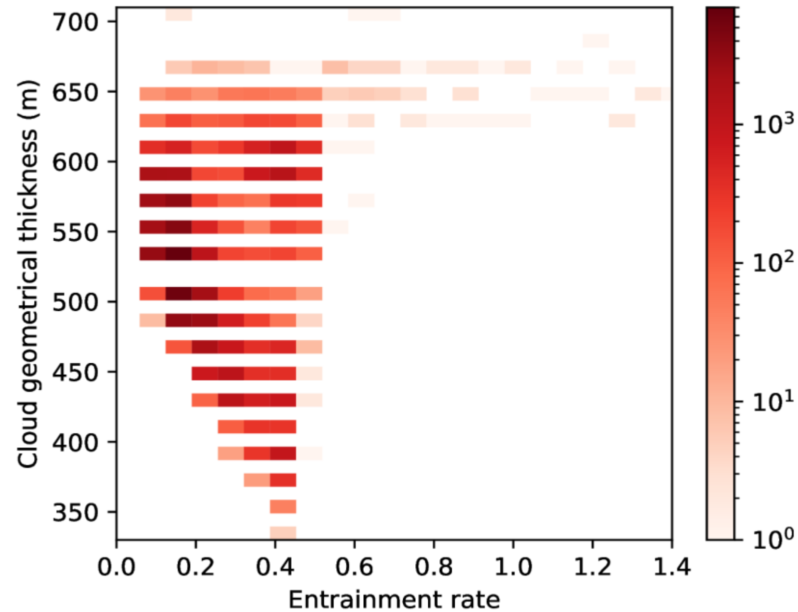


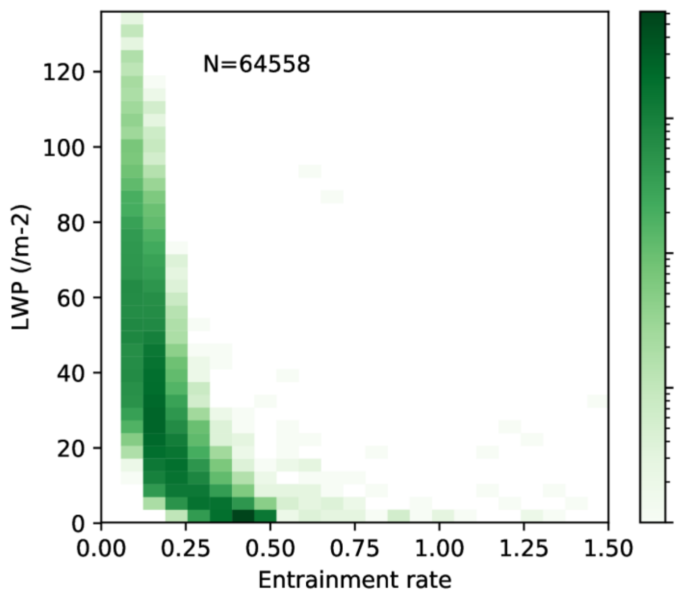
DYCOMS-II case

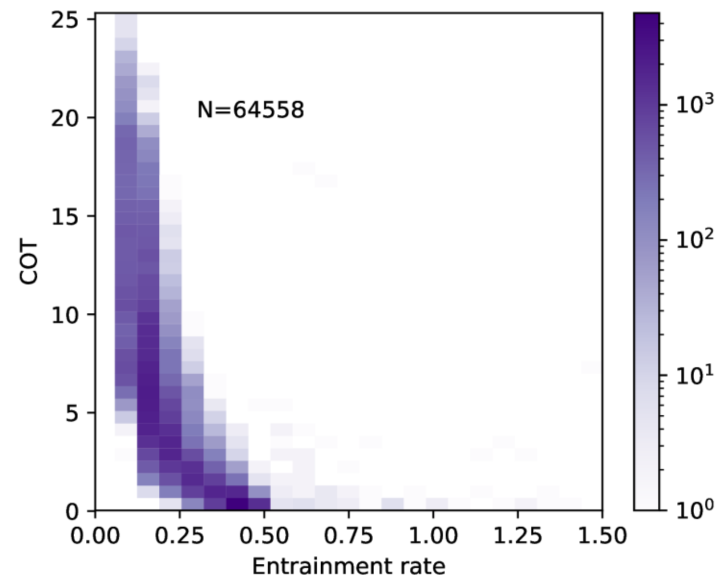
III. Cloud entrainment

□ COT/LWP has a negative relation with cloud top entrainment









DYCOMS-II case

☐ Cloud profile scheme in the sensitivity studies

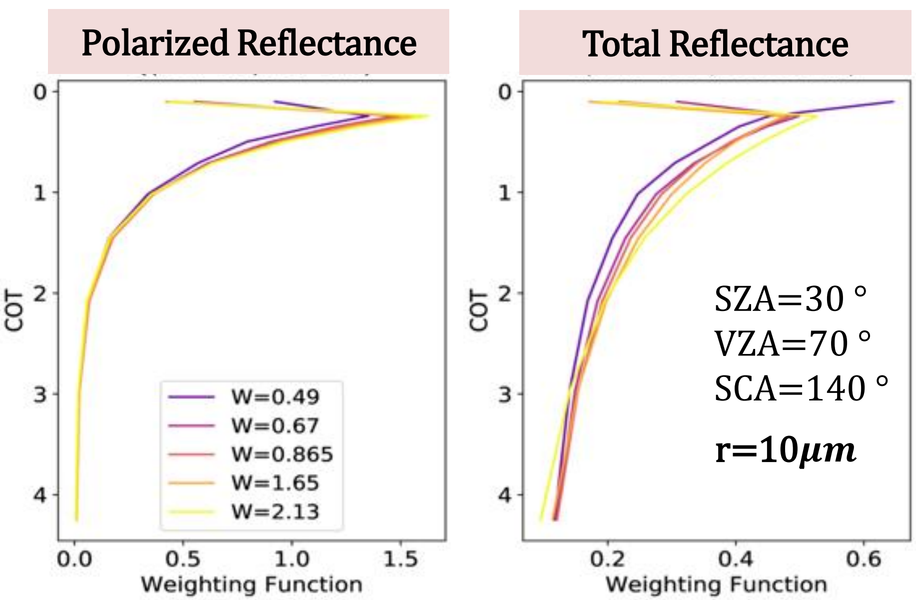
$$Cloud\ geometrical\ thickness\ (CGT) = z_{top} - z_{bot}$$

$$Turning\ point\ (P) = \frac{z_{max} - z_{bot}}{z_{top} - z_{bot}}$$

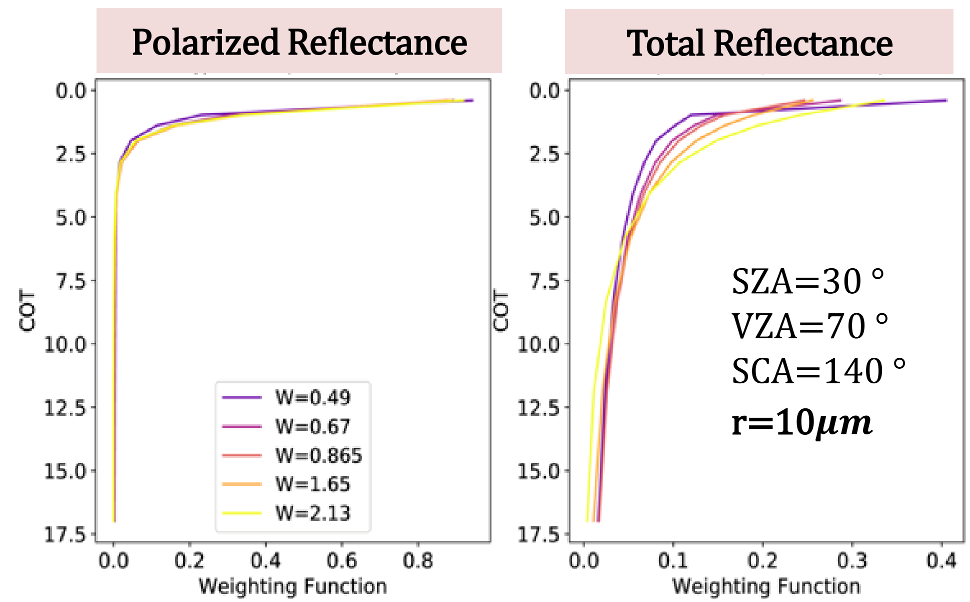
$$Cloud\ optical\ thickness\ (COT) = \frac{3}{5} \times (z_{top} - z_{bot}) \times \sigma_{ext,max}$$

$$Liquid\ water\ path\ (LWP) = \frac{1}{2} \times LWC_{max} \times (z_{top} - z_{bot})$$

COT=5



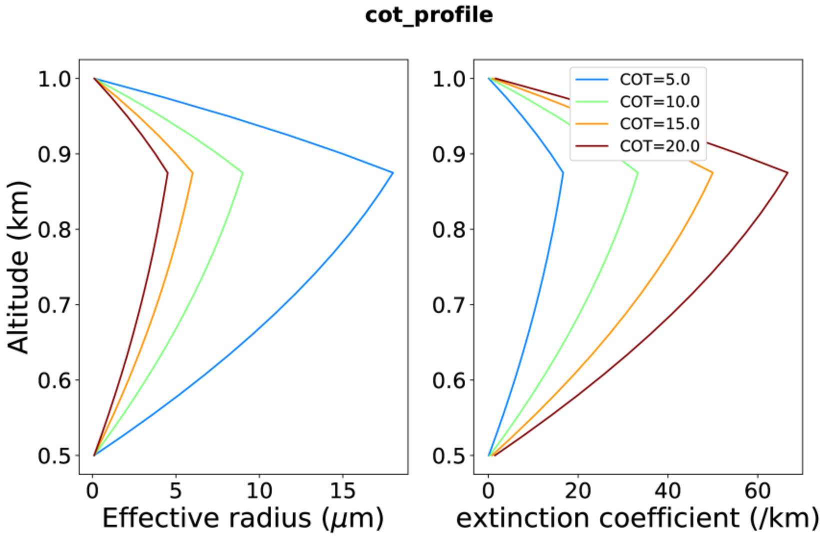
COT=20

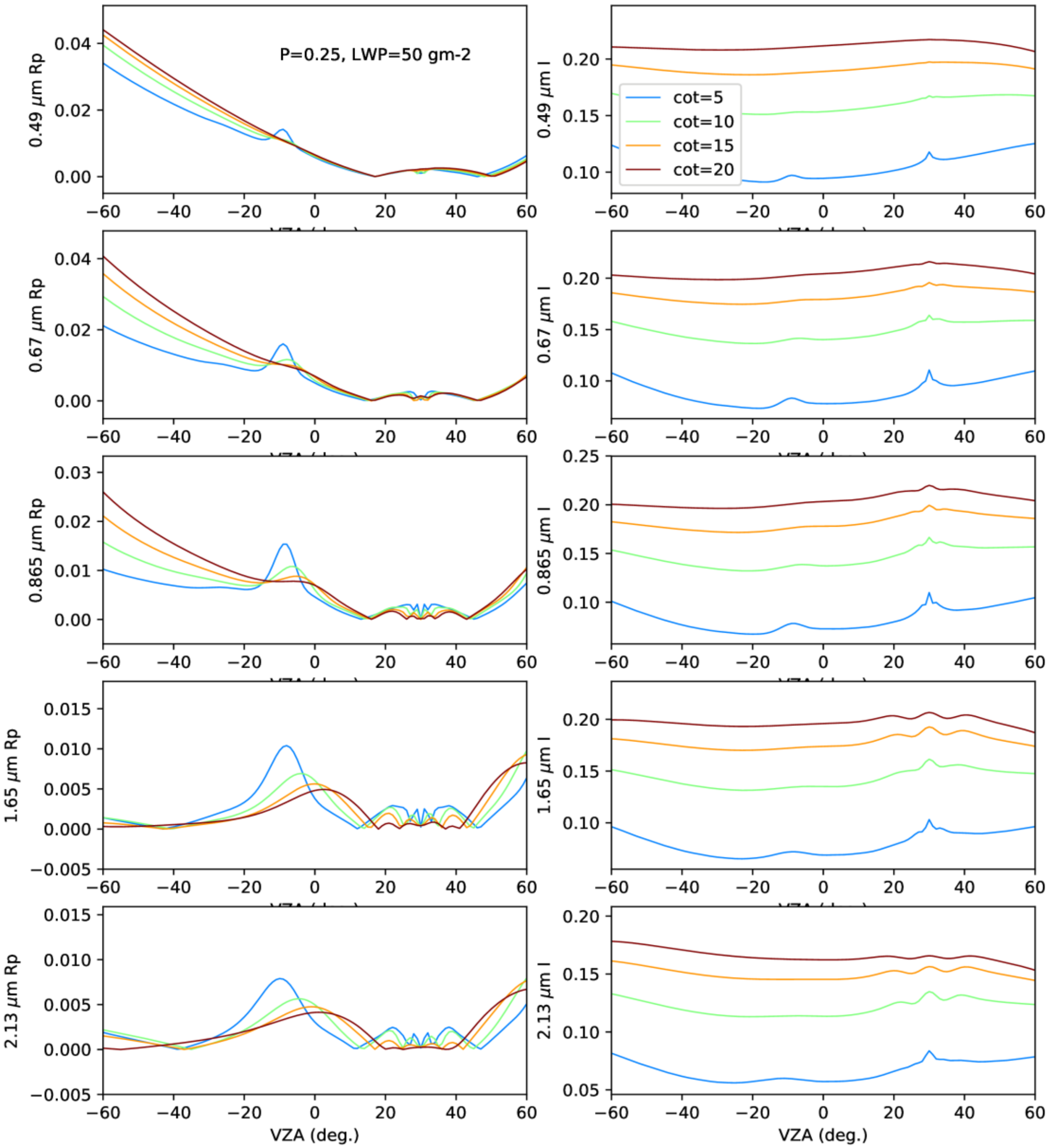


RT MODEL: ARTDECO URL:http://www.icare.univ--lille1.fr/projects/artdeco

IV. Sensitivity study of cloud profiles

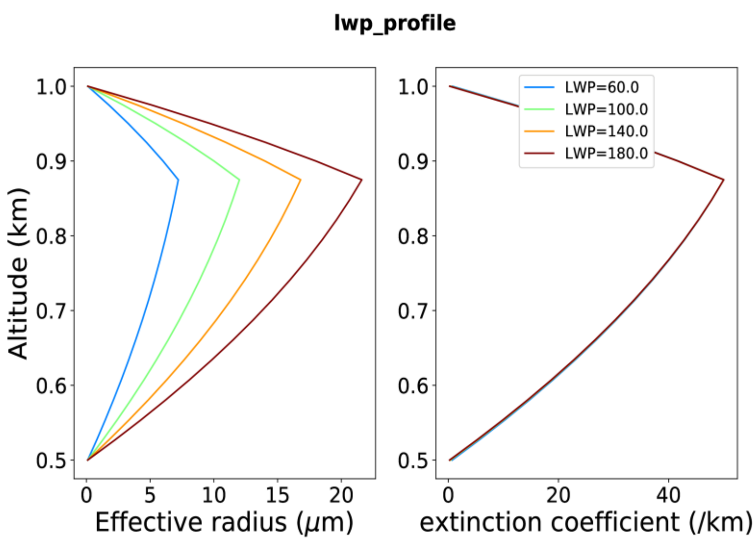
□ Impact of COT on the 3MI polarized and total radiance

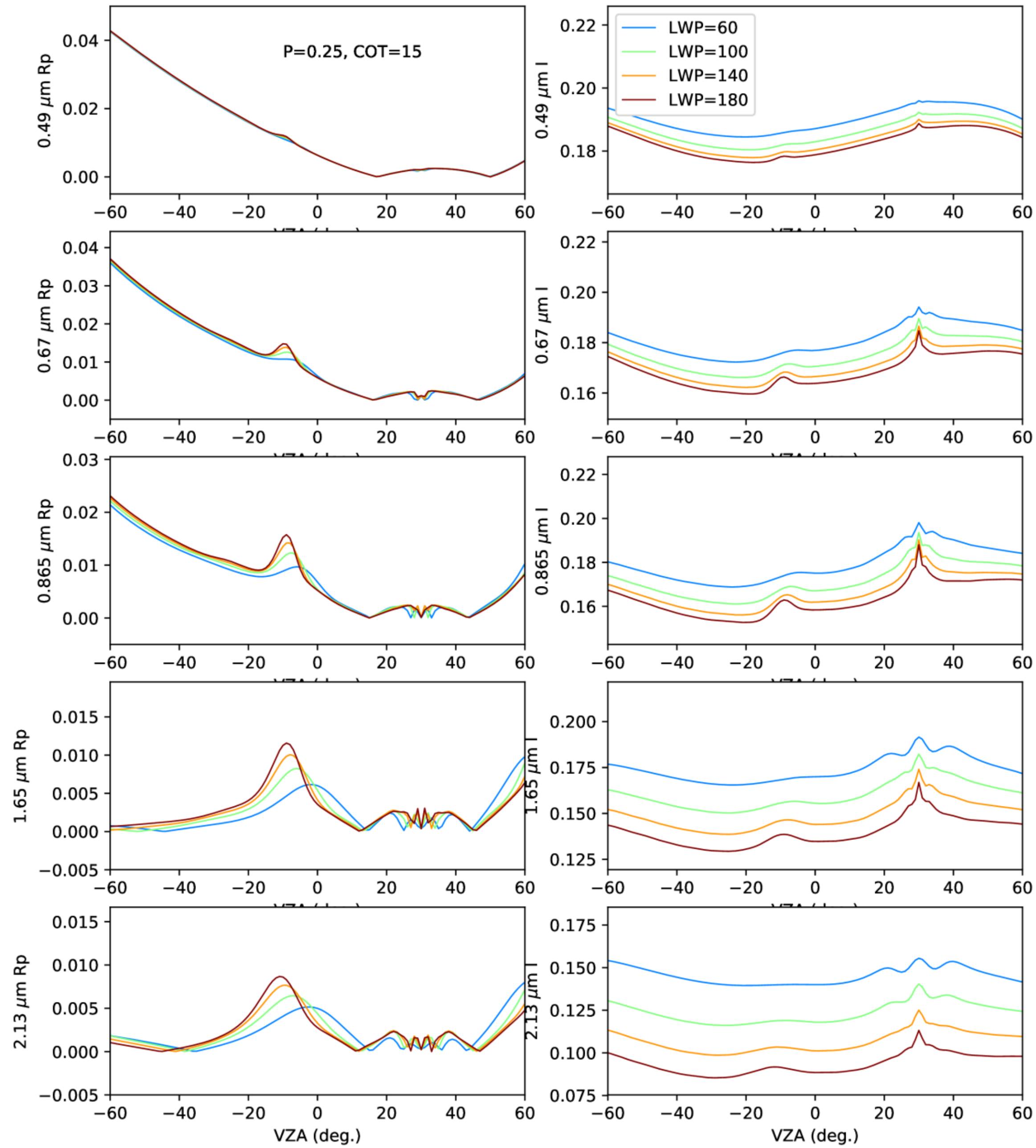




IV. Sensitivity study of cloud profiles

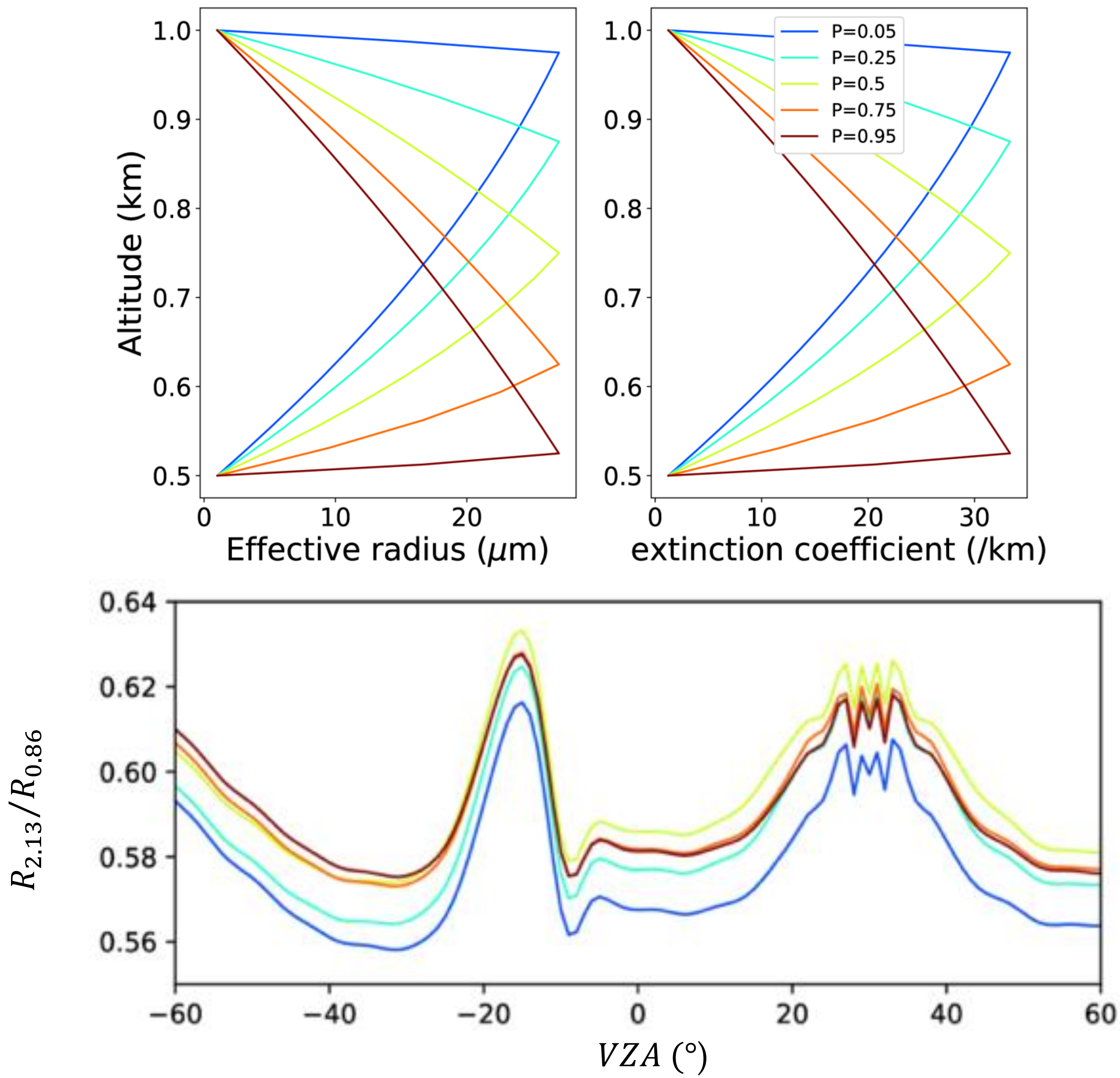
☐ Impact of LWP on the 3MI polarized and total radiance





IV. Sensitivity study of cloud profiles

☐ Impact of turning point (p) on the 3MI measurements



V. Summary and Outlook

- **Typical cloud profiles at different stages of cloud development are analyzed from RAMS model, droplets in thin stratocumulus mostly follows adiabatic growth**

- **Adiabatic cloud profiles can be changed by the entrained air at cloud top, where cloud droplets are smaller than the lower level**

- **The intensity of cloud top entrainment determines the droplet profile at cloud top, the effective radius profile at cloud top can be used to estimate the level of cloud turbulence mixing**

- **A cloud profile scheme is proposed using the typical triangle shape of LWC profiles, and sensitivity studies indicate that 3MI is sensitive to cloud profiles with different COT, LWP and turning point values.**

Outlook:

- **Analyzing cloud profiles from model simulations and refine the constrains of cloud profiles**
- **Developing a algorithm of estimating simplified cloud profile from 3MI**

Thank you for your attention

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