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Comparison between CCCM and CloudSat Radar-Lidar (RL) Cloud and Radiation Products

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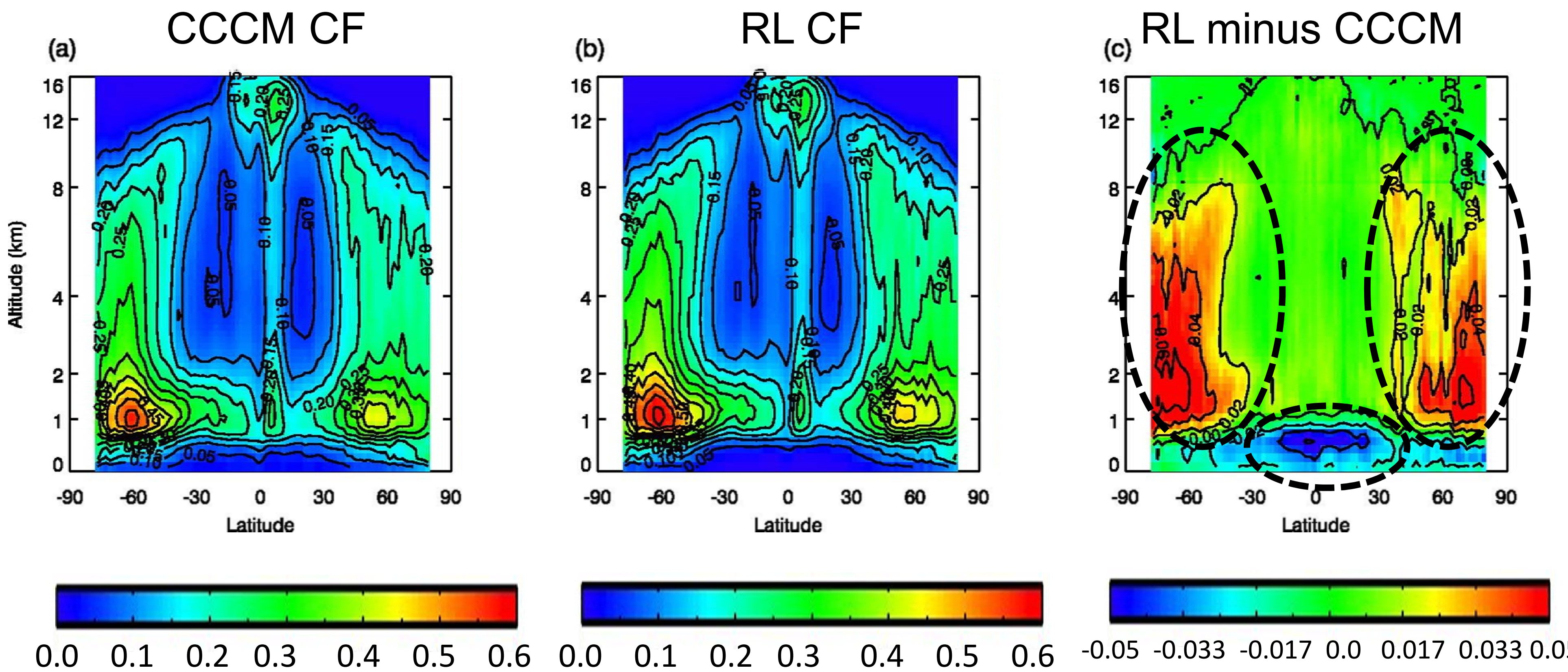
Background & Objectives

- A-train satellite measurements enable us to obtain more accurate cloud profiles from CALIPSO lidar, CloudSat radar, and MODIS imager. CERES group in NASA Langley and CloudSat group in CIRA developed their own combination method of cloud properties obtained from the active and passive sensors.
- Two algorithms put these sensors in different priorities and use different filtering method. This causes different cloud properties and their radiative impacts.
- We examine what cause the main differences in these two products, and check feasibility of each method from case study.
- The problems noted in this comparison can be taken into account in CCCM RelD1 algorithm.

CCCM versus RL Algorithms

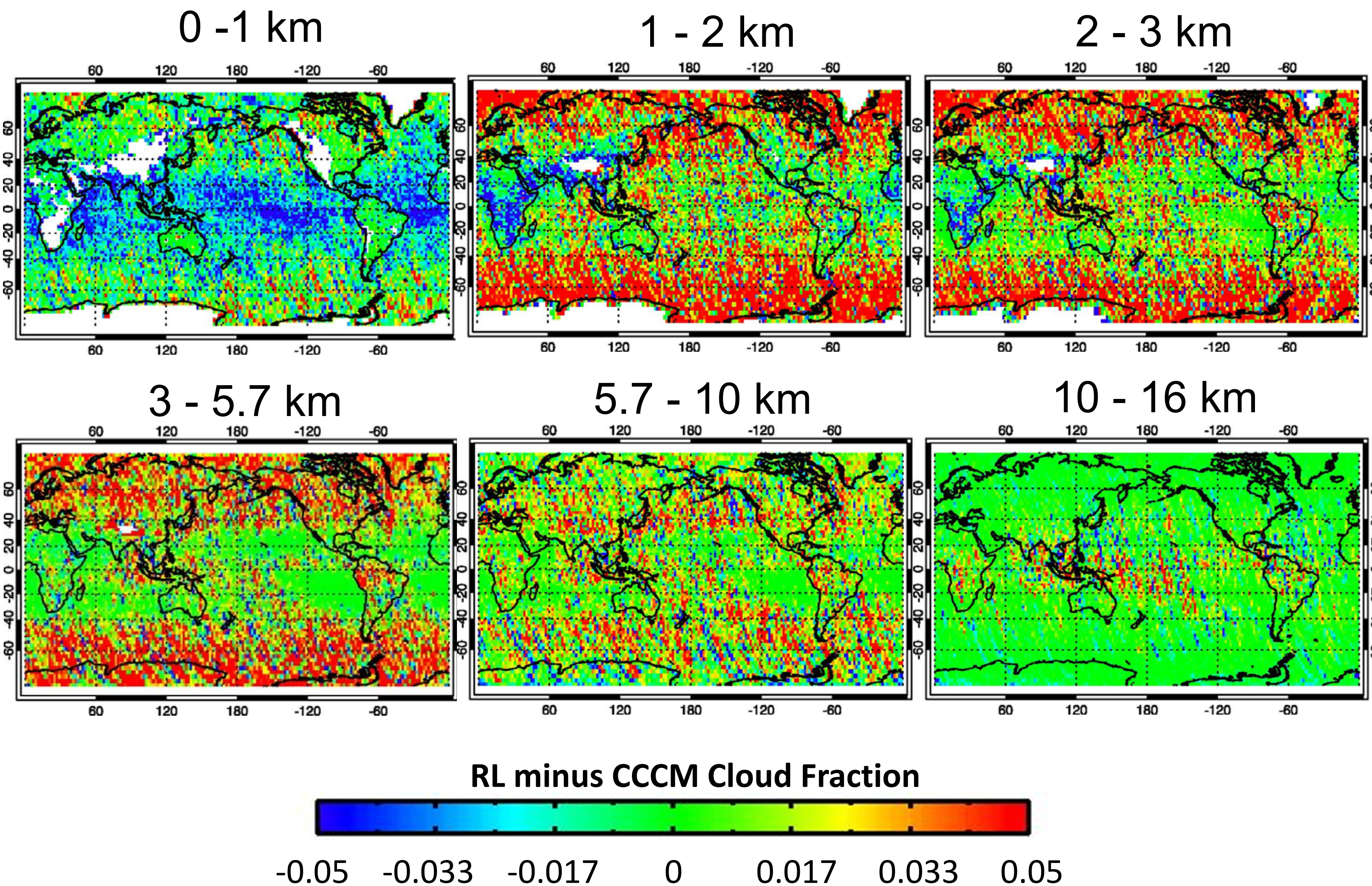
	CCCM (CERES-CALIPSO-CloudSat-MODIS)	RL (Radar-Lidar)
Distributer	CERES Team/LaRC	CloudSat Team/CIRA
Spatial Resolution	20 km x 20 km of CERES Field-of-View (FOV)	1.4 km x 1.1 km of CloudSat FOV
Vertical Grid Interval	30 m or 60 m of lidar bins	240 m of radar bins
Used Sensors	CERES broadband radiometer, CALIPSO lidar, CloudSat radar, and MODIS imager	CALIPSO lidar, CloudSat radar, and MODIS imager
Product Parameters	▪ Cloud top/base ▪ Cloud extinction coefficient ▪ Liquid/ice water contents ▪ Cloud optical thickness (COT) and effective radius ▪ Enhanced SW/LW Irradiance	▪ Cloud top/base (2B-GEOPROF-Lidar) ▪ Cloud extinction coefficient (2B-TAU) ▪ Liquid/Ice water contents (2B-CWC) ▪ COT and effective radius (2B-TAU) ▪ SW/LW Irradiance (2B-FLXHR-Lidar)
Note	▪ CCCM uses edge of vertical grid box as cloud top/base. ▪ CCCM considers additional layer if the layer shows > 480 m distance from the existing layers.	▪ RL uses center of vertical grid box as cloud top/base. ▪ RL considers additional layer if the layer shows > 960 m distance from the existing layers.

CCCM versus RL Cloud Fraction (Four-month Mean; Feb Apr Jul Oct 2010; Ocean/Day)



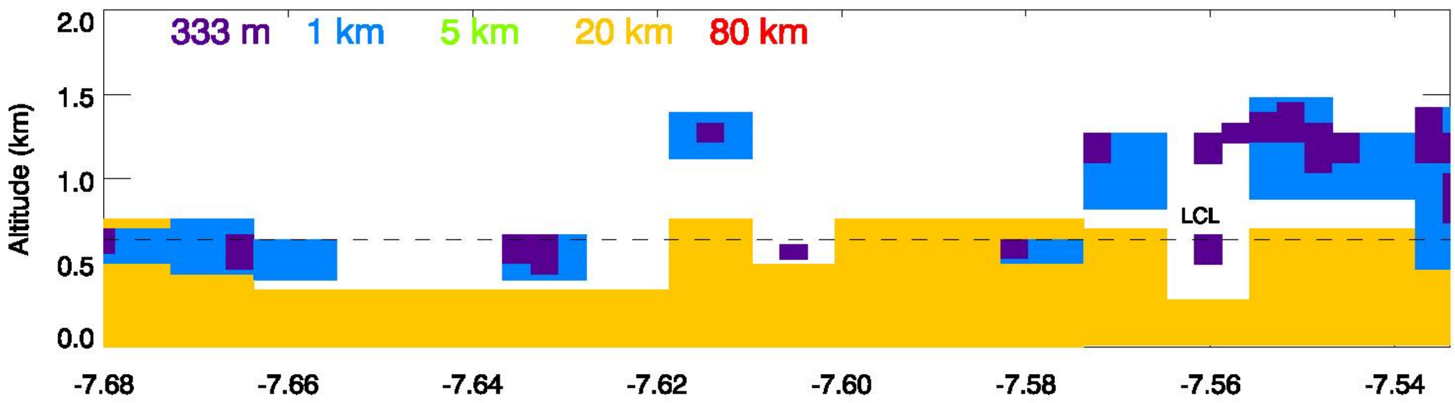
- CCCM CF > RL CF when |lat| > 40°, and 1 km < z < 8 km.
- RL CF < CCCM CF when |lat| < 30° and z < 1 km.

[RL] minus [CCCM] Cloud Layer Fraction

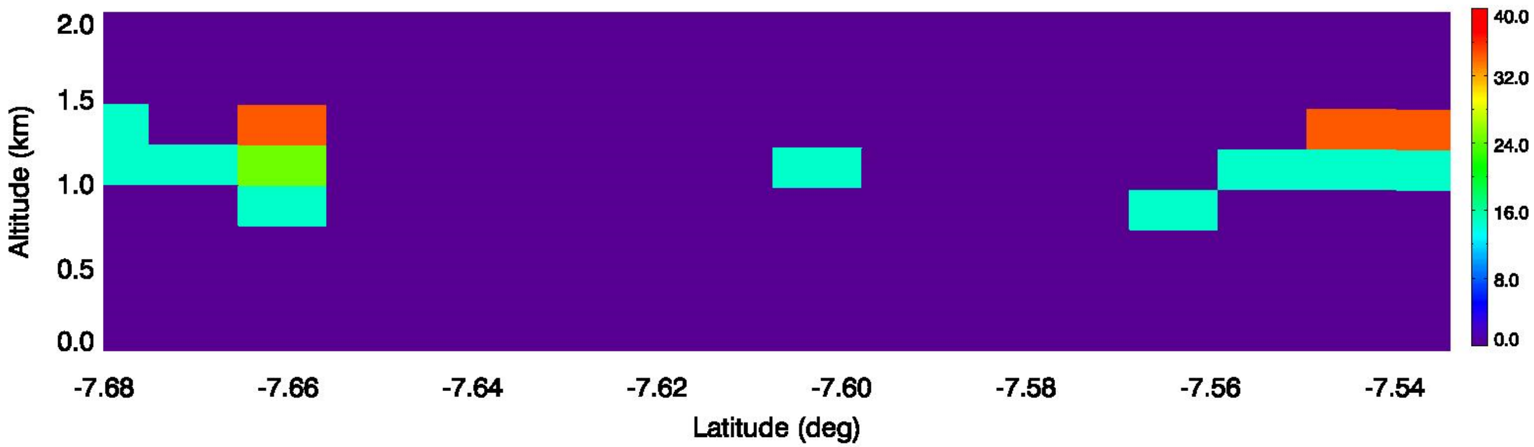


Low Clouds in CCCM but Missed in RL (Case 1)

Lidar Cloud Mask (Each Color represents size of space averaging for detection)



Radar Cloud Mask (≥ 20 is likely cloud; 0 is clear; 40 is overcast)

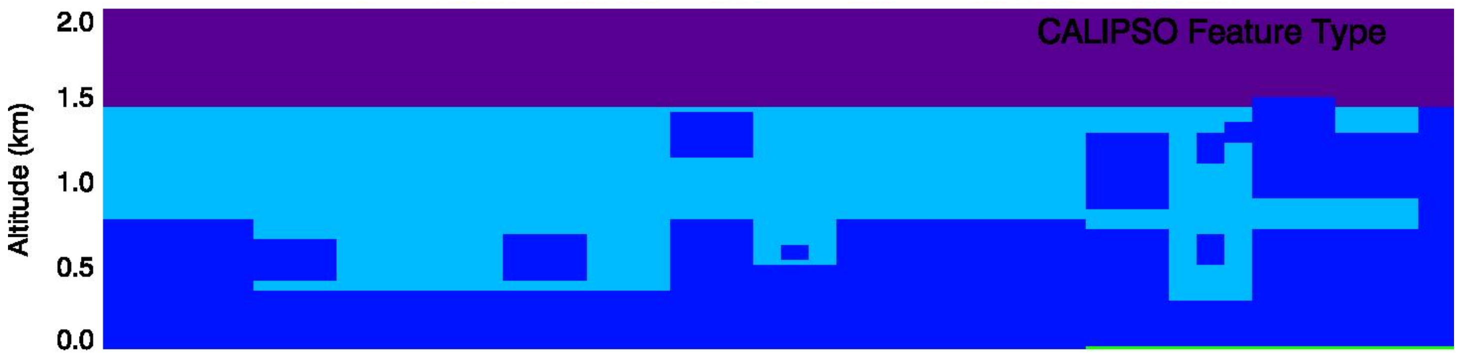


Lidar detects cloud layer from spatial averaging to reduce laser noise. As the layer is more tenuous, larger spatial averaging is needed.

Low Clouds in CCCM but Missed in RL (Case 1)

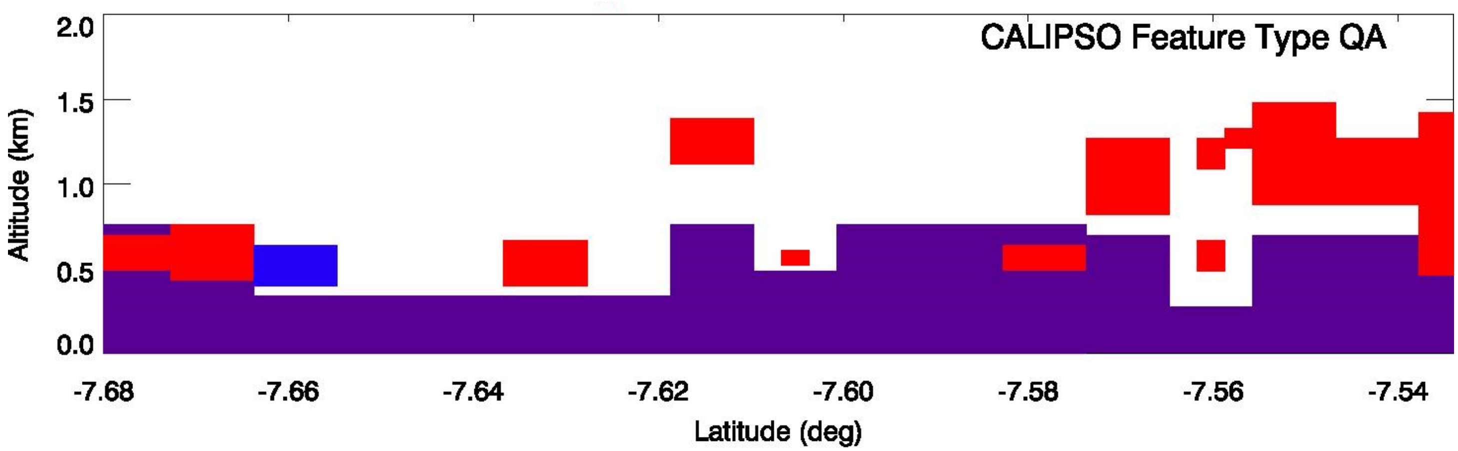
CALIPSO Feature Type

Missing Clear Cloud Aerosol PSC SFC SubSFC Attenuated



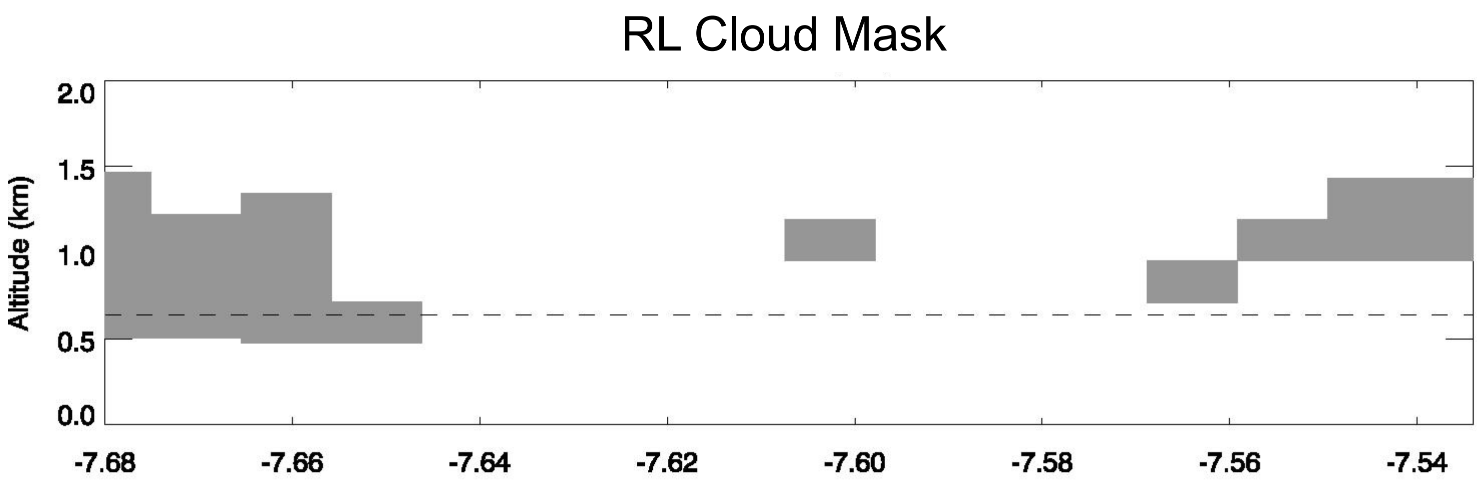
CALIPSO Feature Type QA

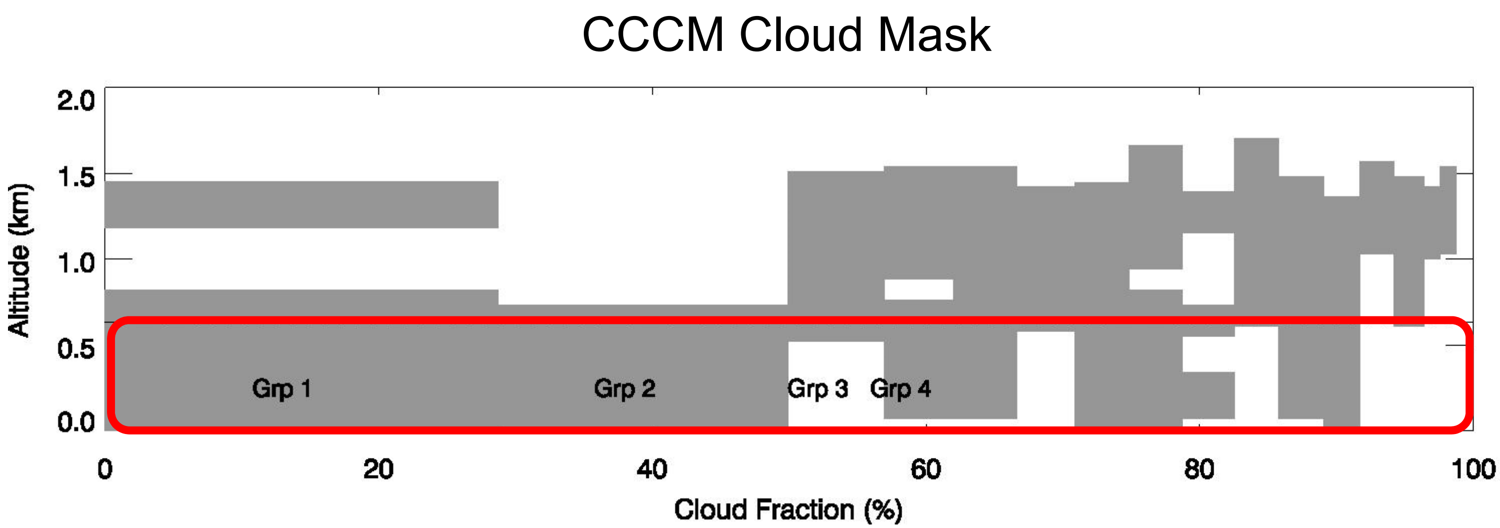
None Low Mid High



Cloud layers detected from 333 m or 1 km averaging have high confidence, while layers from 20 km averaging have zero confidence.

Low Clouds in CCCM but Missed in RL (Case 1)

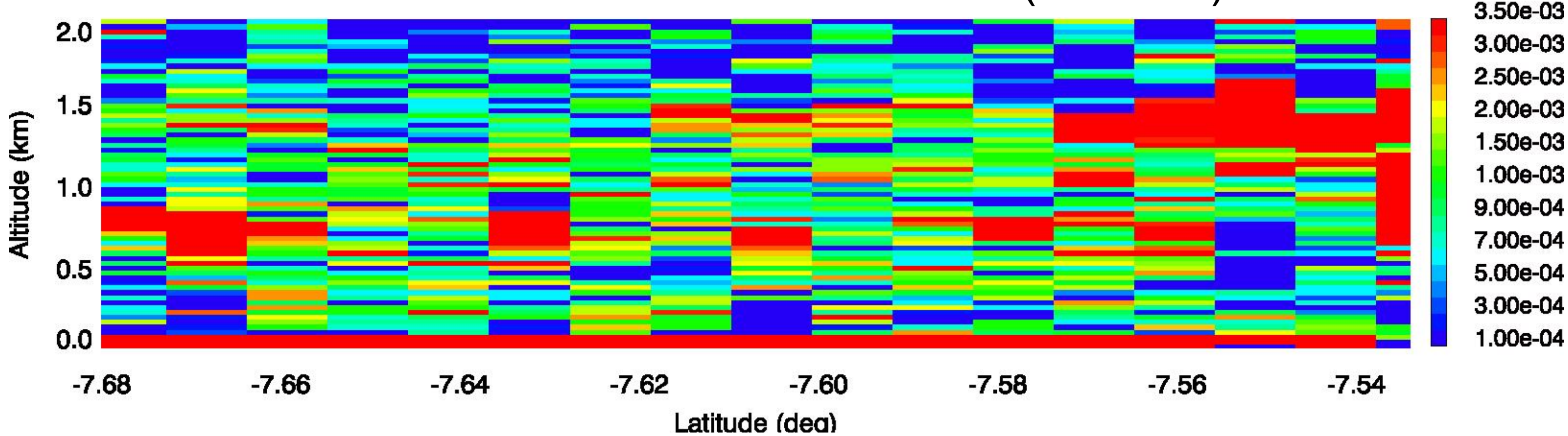




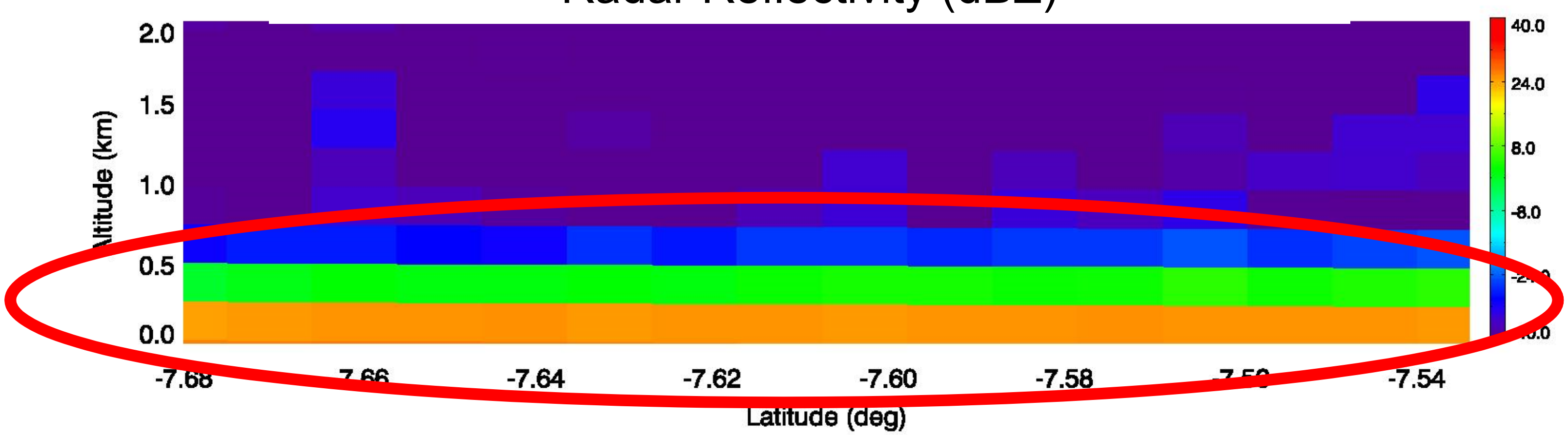
RL does not have cloud under 0.5 km, while CCCM does. This region is detected by Lidar with 20-km spatial averaging (low confidence of Lidar Mask).

Low Clouds in CCCM but Missed in RL (Case 1)

Lidar Total Attenuated Backscatter (km^{-1} sr^{-1})

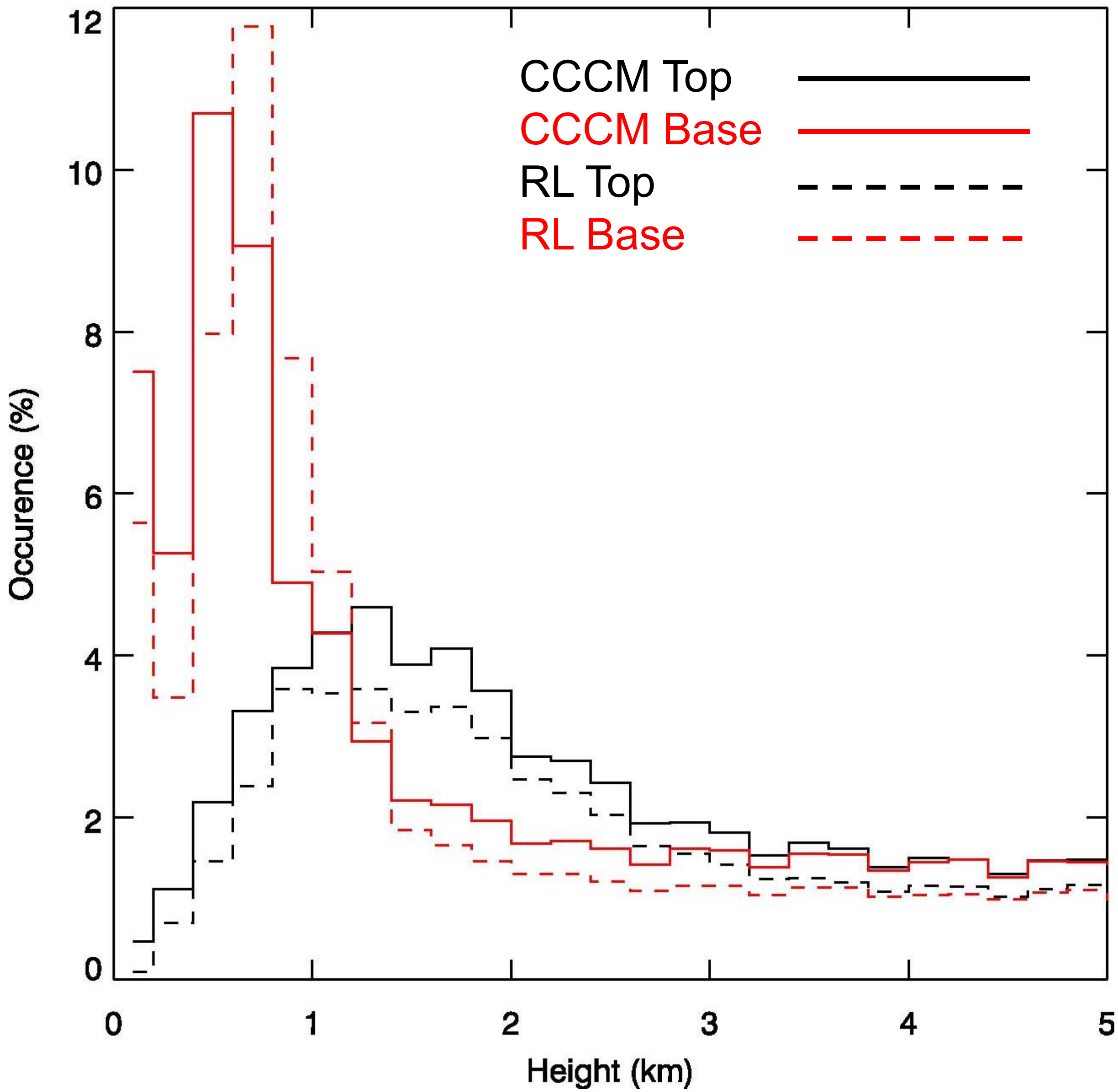


Radar Reflectivity (dBZ)



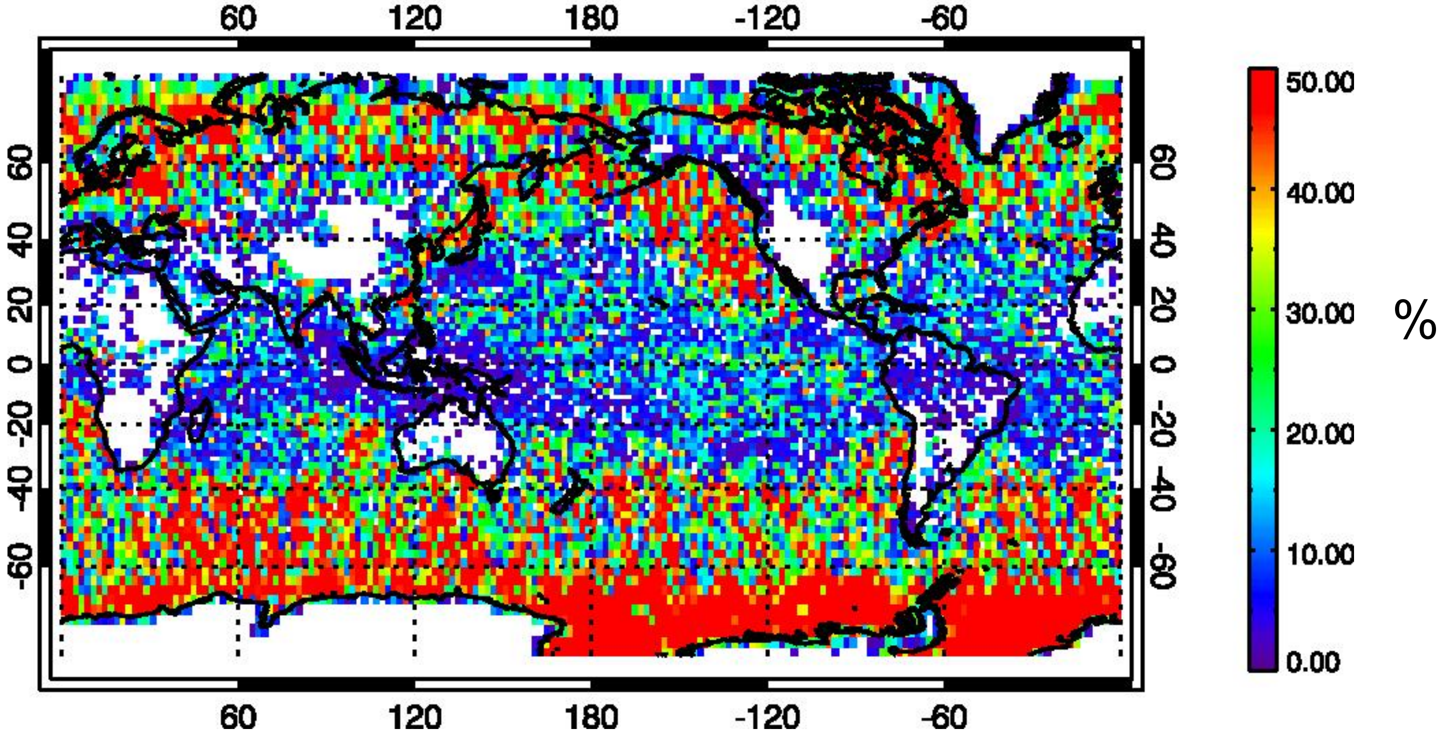
Radar reflectivity indicates some feature near the surface. Is it aerosol, or thin clouds?

Cloud Top and Base from RL and CCCM



- Cloud tops obtained from RL and CCCM are comparable.
- CCCM cloud bases are lower than RL bases.
- The differences are due to different treatment of **lidar-detected low cloud layers (which usually has low confidence).**

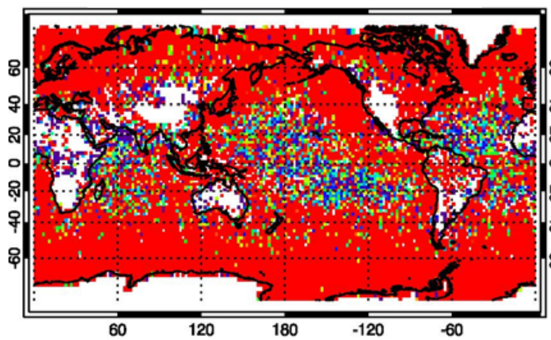
Occurrence of Low (<1 km) Clouds According to Lidar



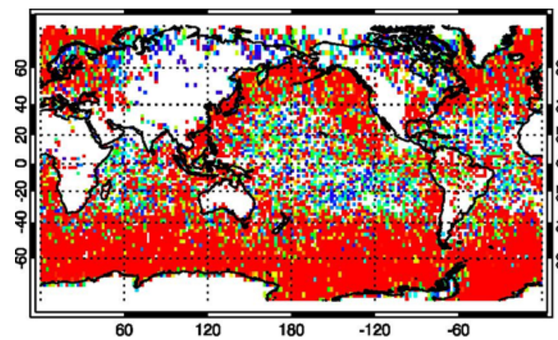
- Eastern side of pacific ocean and southern storm track frequently involve low marine stratus.
- Note that sampling frequency of A-train measurements is higher in higher latitude region.

Relative Frequency of 5-km, 20-km, and 80-km Spatial Averaging for Low (<1 km) Clouds

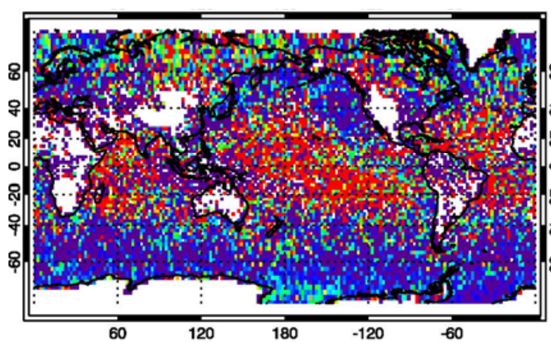
5-km Lidar Averaging



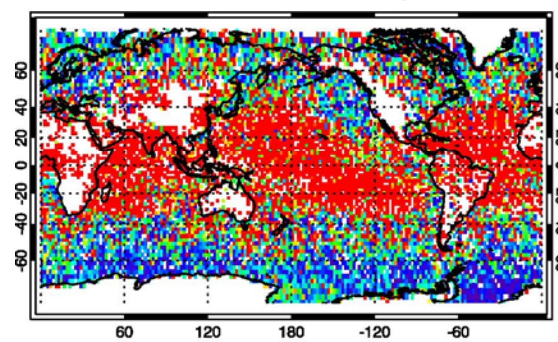
Opaque Clouds (Lidar Totally Attenuated)



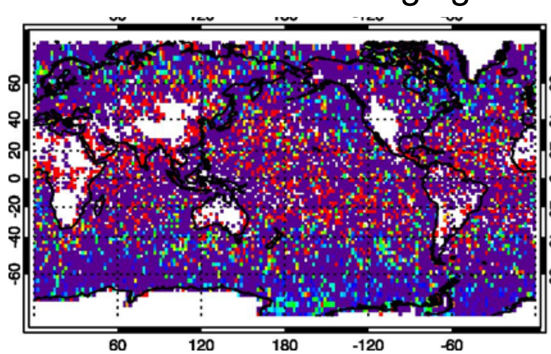
20-km Lidar Averaging



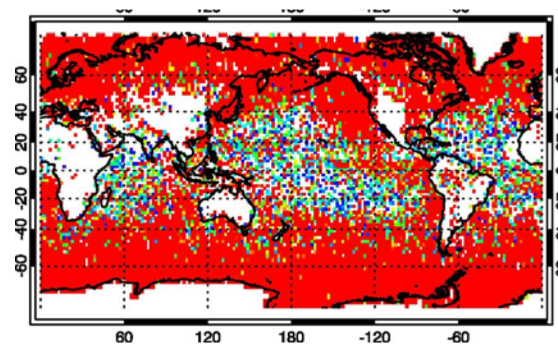
Feature Confidence: Low (0≤CAD<70)



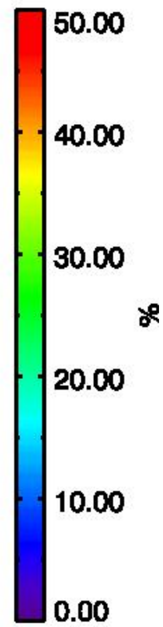
80-km Lidar Averaging



Feature Confidence: High (70≤CAD≤100

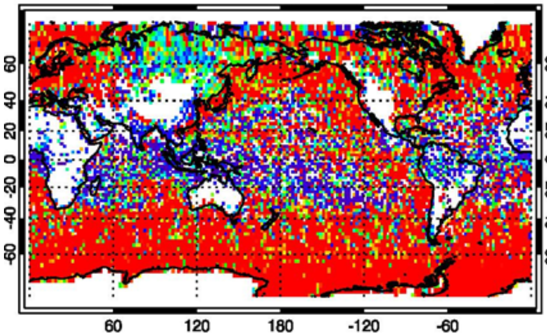


Low clouds with large uncertainty of lidar detection (large spatial averaging or low CAD score) are mostly over tropical ocean. It seems to be related to very thin marine stratus, not aerosol.

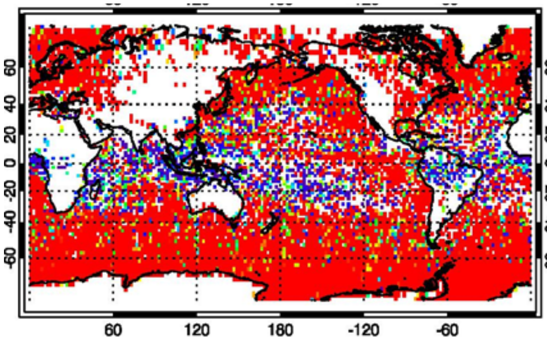


Lidar Cloud Optical Depth of Low Clouds (< 1km)

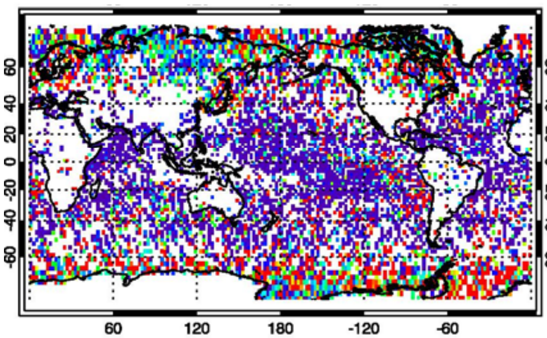
5-km Lidar Averaging



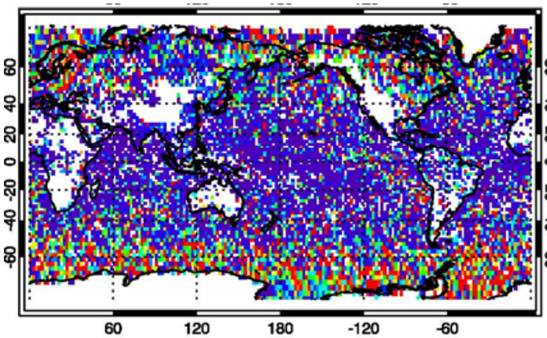
Opaque Clouds (Lidar Totally Attenuated)



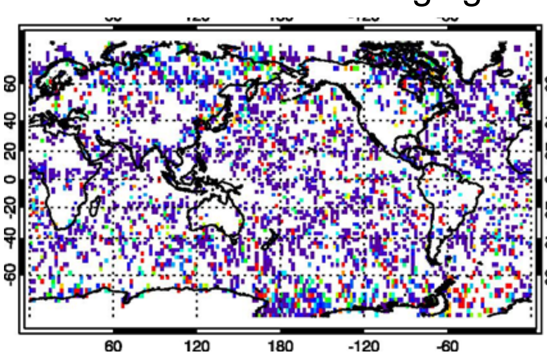
20-km Lidar Averaging



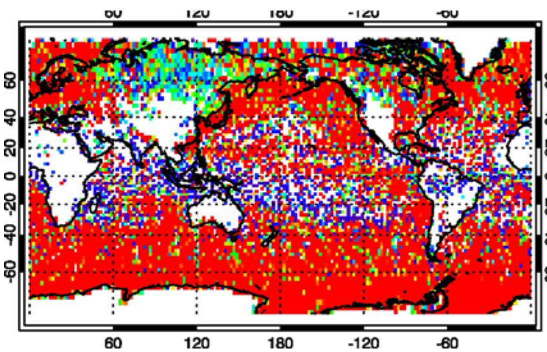
Feature Confidence: Low (0≤CAD<70)



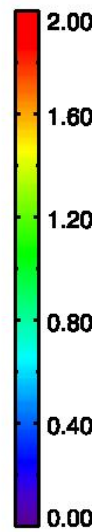
80-km Lidar Averaging



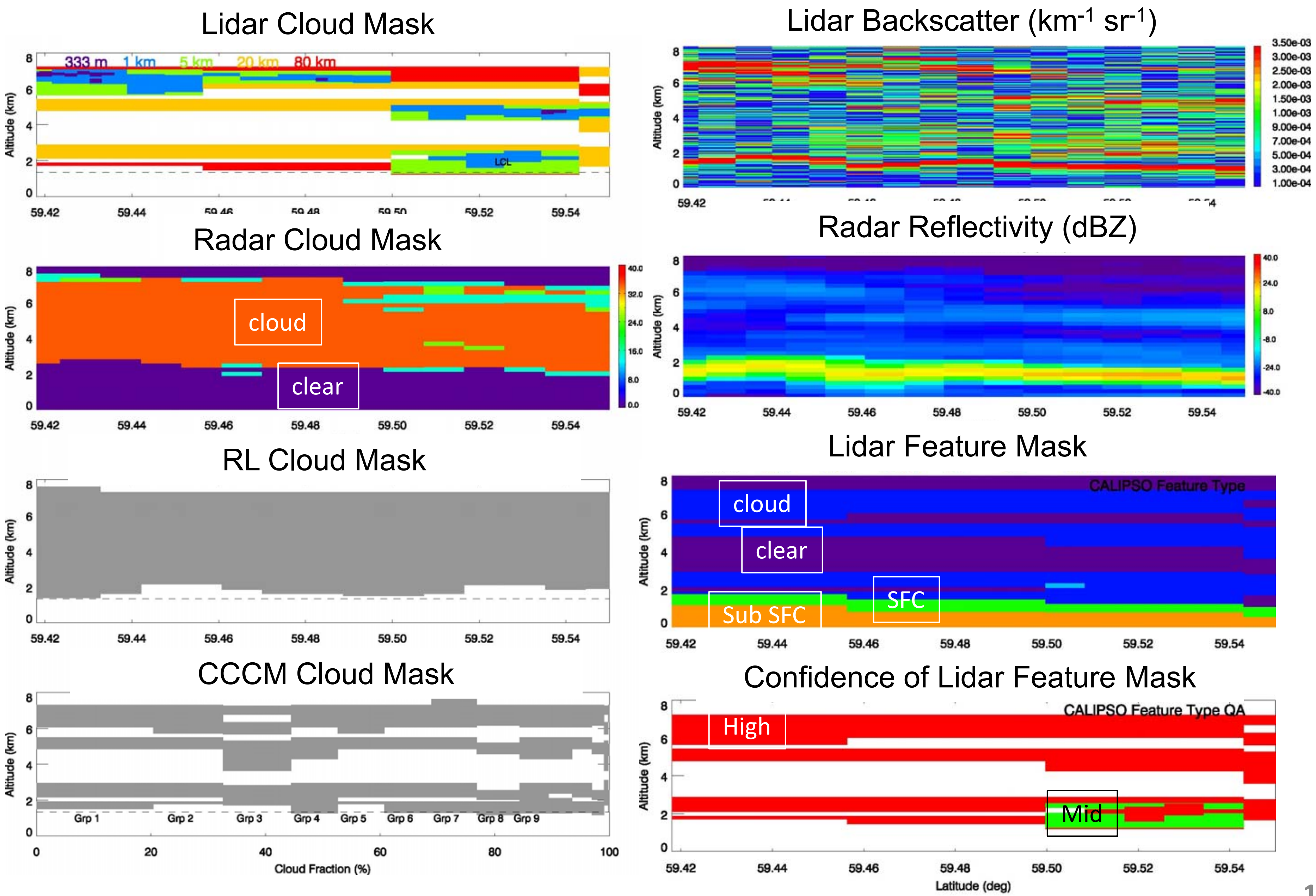
Feature Confidence: High (70≤CAD≤100)



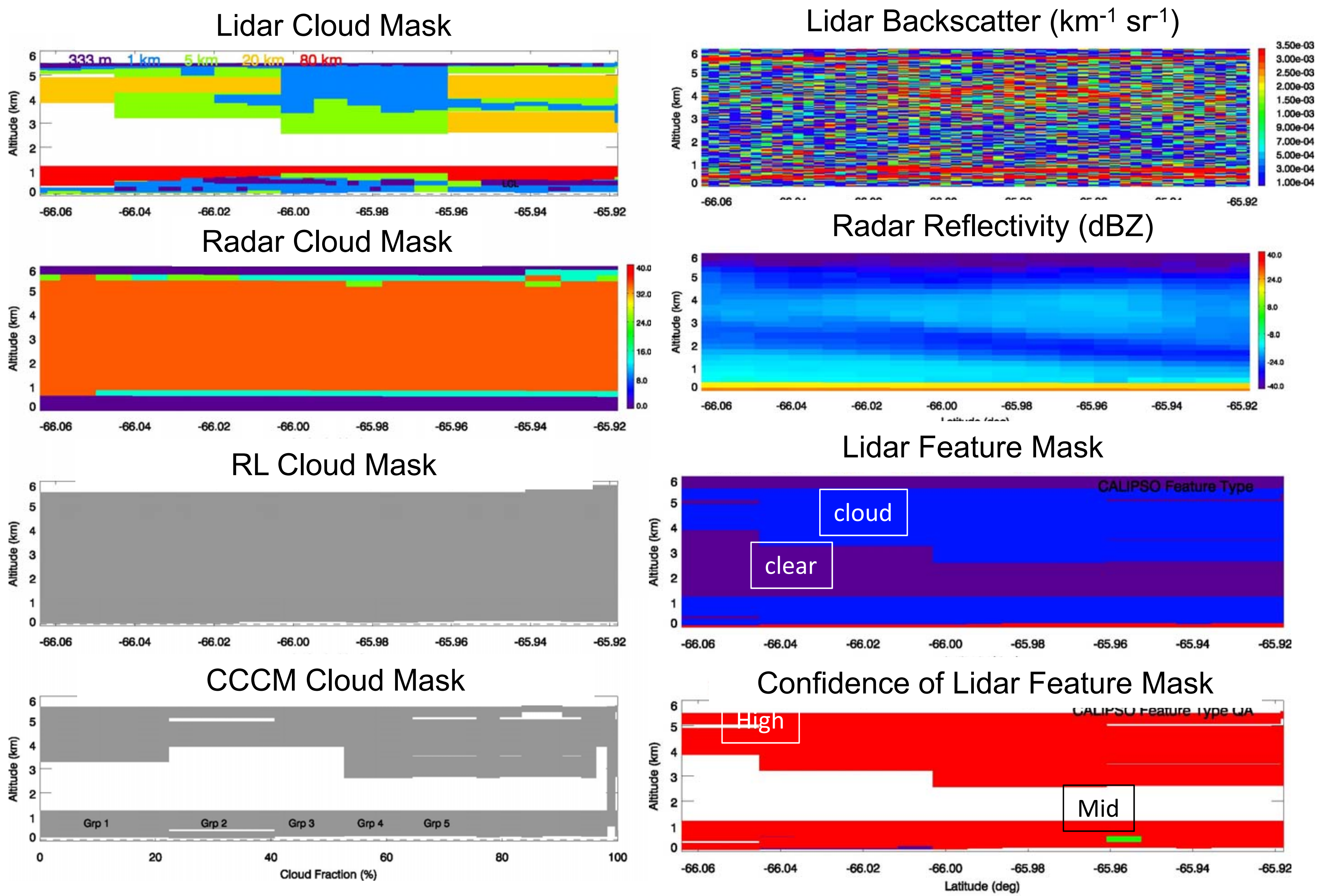
- Optical thickness of tropical marine stratus is < 0.4.
- Proper characterization of broken cumulus clouds is need in both algorithm.



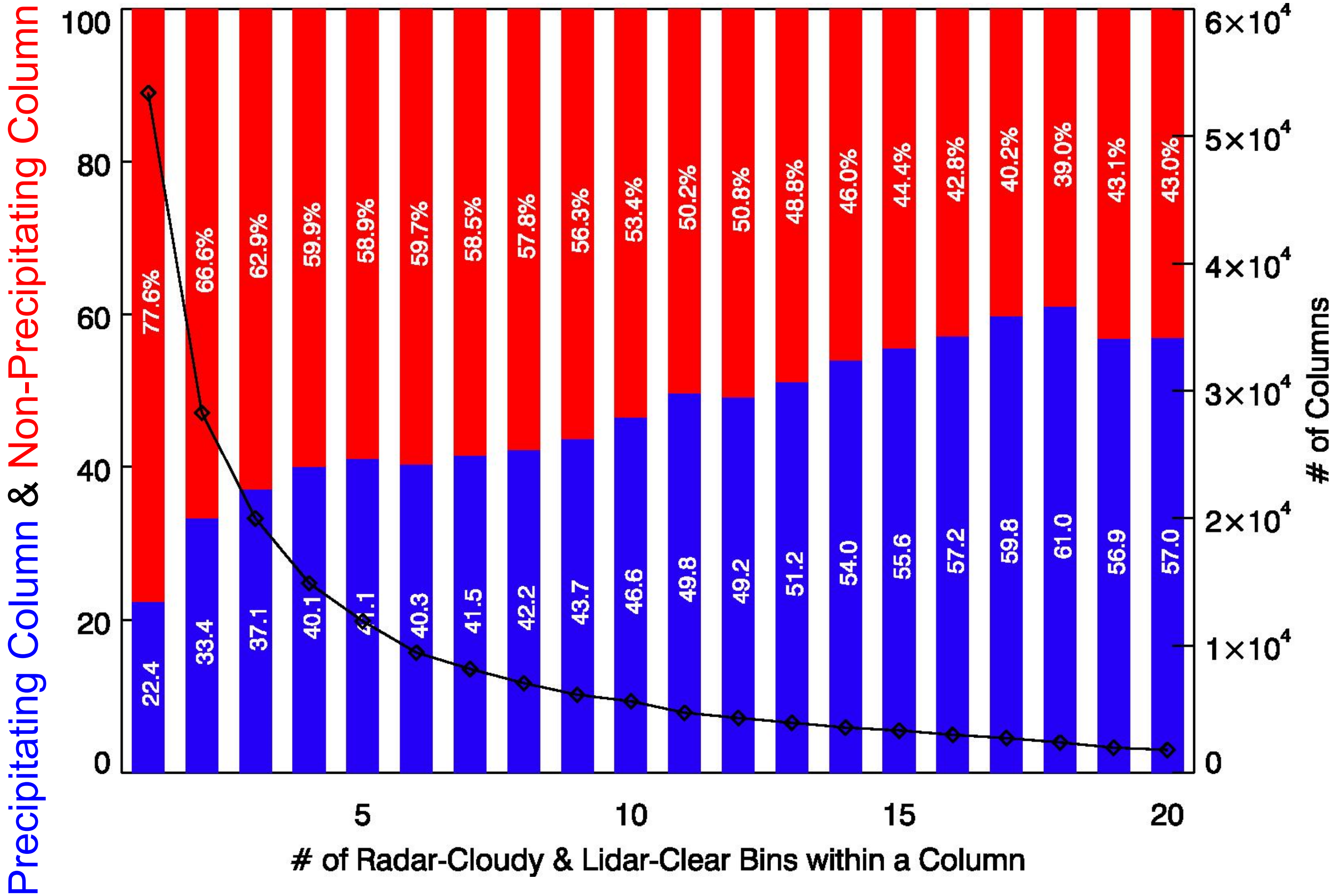
Multilayered Clouds in CCCM but Single layer in RL (Case 2)



Multilayered Clouds in CCCM but Single layer in RL (Case 3)



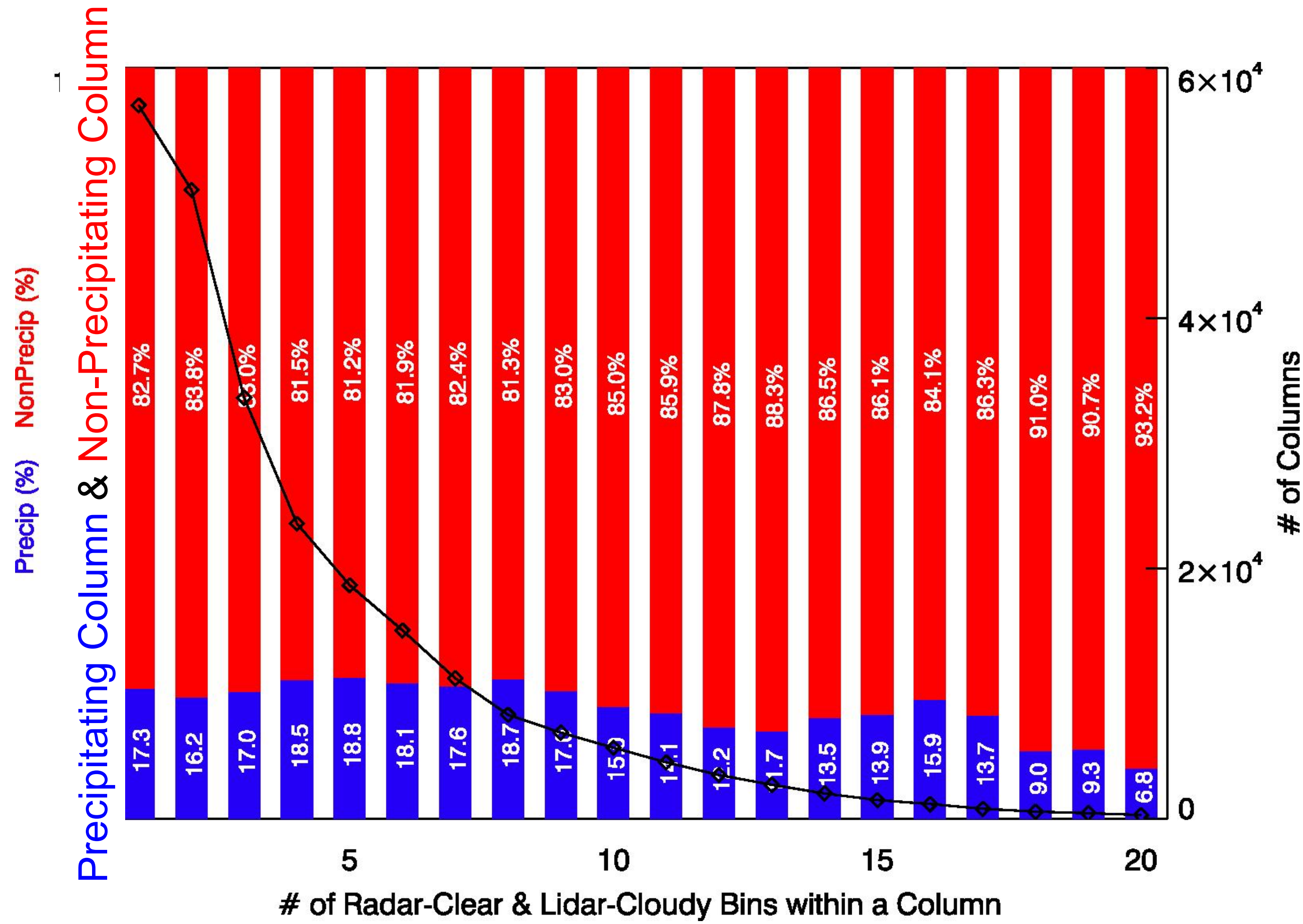
Cloudy According to Radar & Clear According to Lidar



Longer vertical extent showing Radar-Cldy and Lidar-Clr

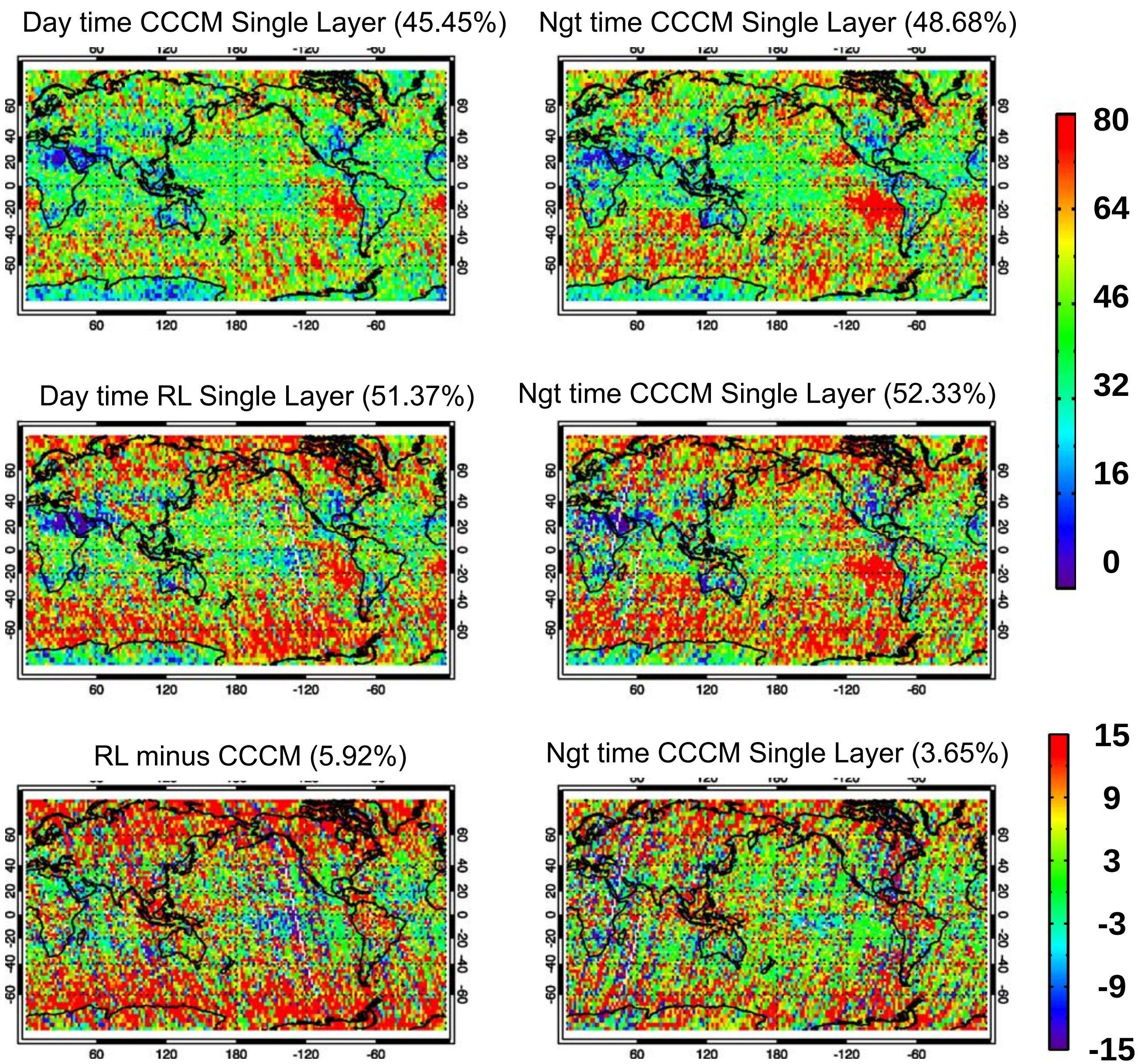
- Precipitating cases show larger radar cloud fraction than lidar fraction.
- Precipitation is provided from CloudSat CLDCLASS Products.

Clear According to Radar & Cloudy According to Lidar



More vertical bins showing cloudy area only by Radar

Occurrence of Single-layered Clouds According to RL and CCCM (Oct 2010)



- Different treatment for precipitating area results in different frequency of single (or multilayered) clouds.
- RL has more single layer clouds, and CCCM has more multi-layered clouds.

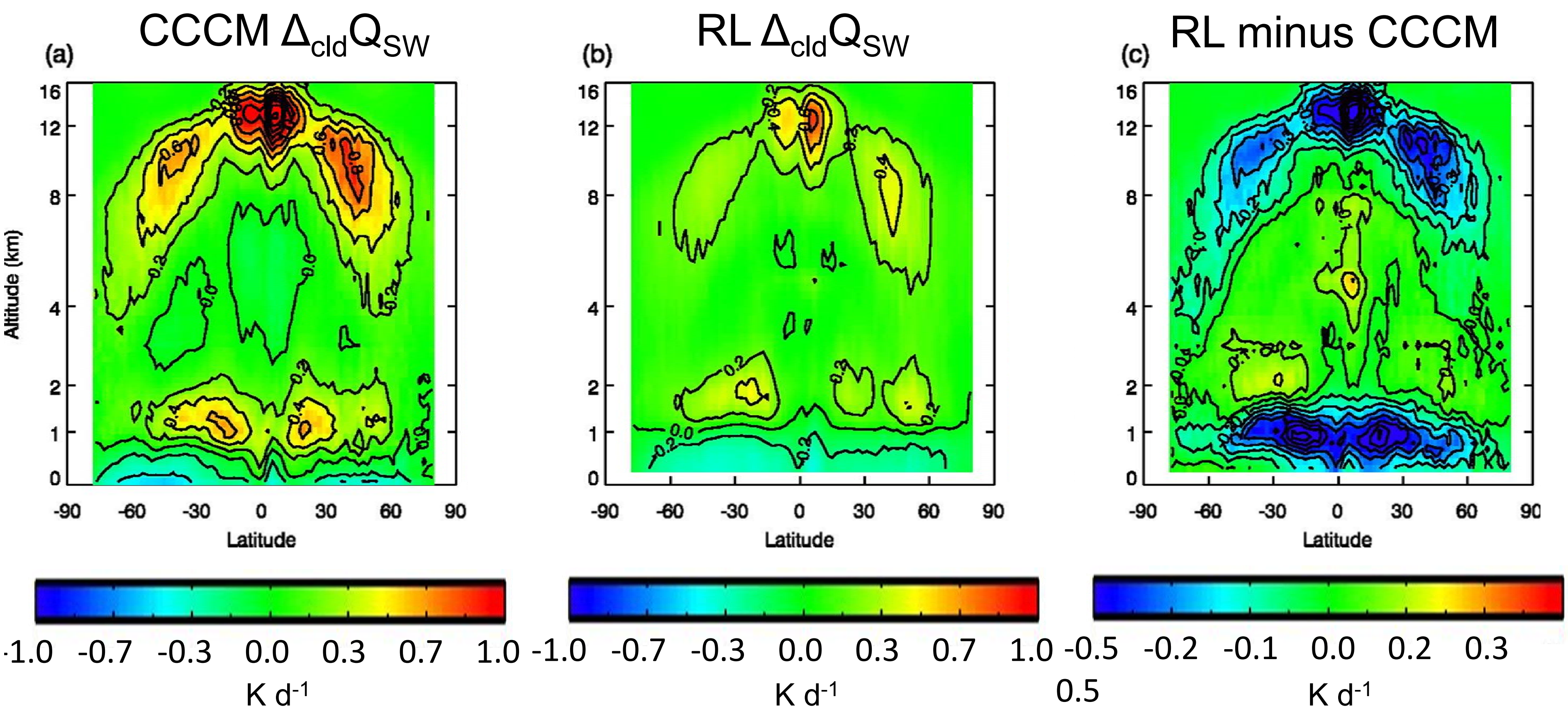
Cloud Radiative Effects on Heating Rates

Net flux [W m^{-2}] $F(z) = F_{up}(z) - F_{dn}(z)$

Heating rate Q [K d^{-1}] $Q(z) = -\frac{1}{\rho c_p \Delta z}[F(z + \Delta z/2) - F(z - \Delta z/2)]$

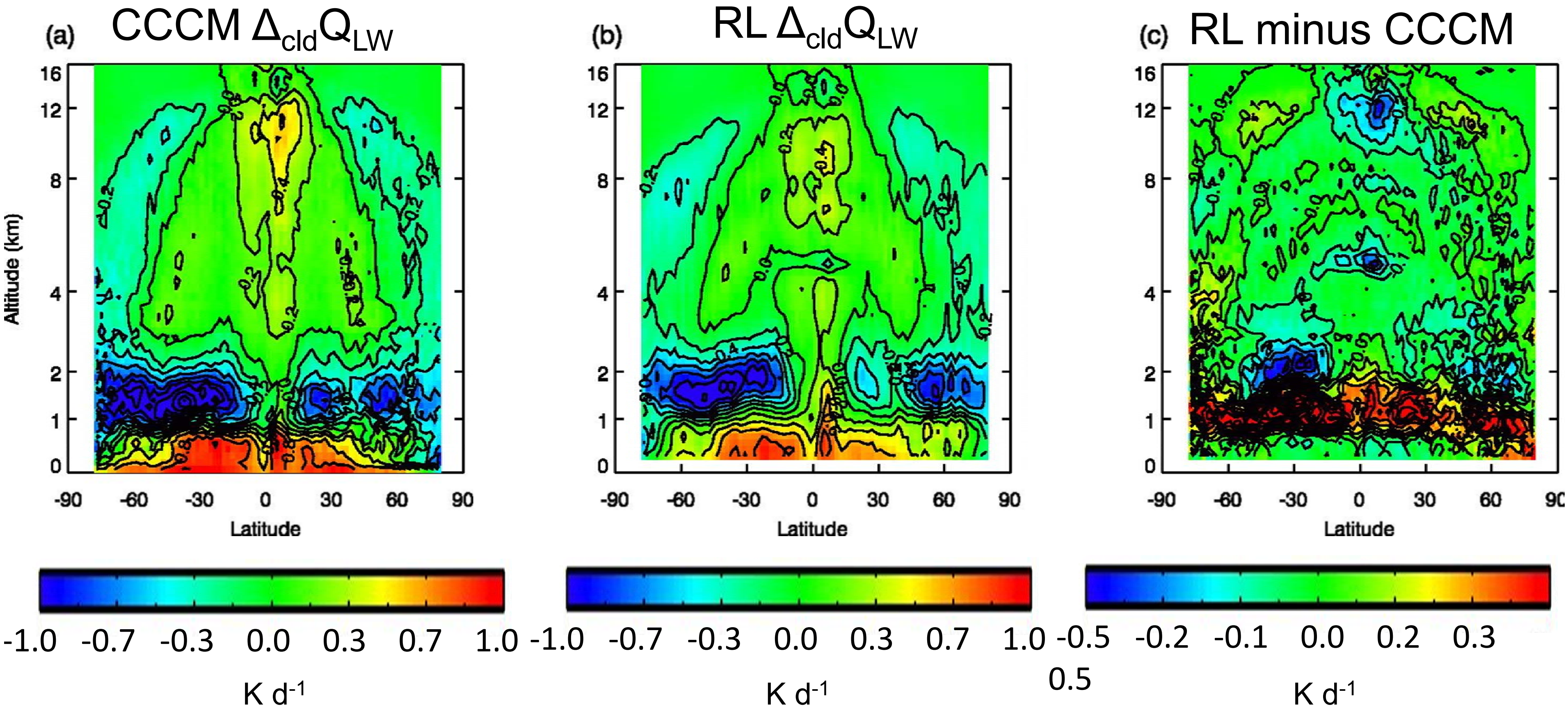
CRE on heating rate Q [K d^{-1}] $\Delta_{cld} Q(z) = Q_{all}(z) - Q_{clr}(z)$

Cloud Radiative Impact on SW Heating Rates (Q_{SW})



- Cloud produces SW radiative heating due to cloud absorption of sunlight.
- As particle increases, cloud absorption increases too.
- RL has smaller SW radiative heating by clouds, implying that particle size is smaller than the one used in CCCM.

Cloud Radiative Impact on LW Heating Rates (Q_{LW})



- Cloud produces LW radiative cooling at cloud top and warming within the cloud layer.
- As the cloud top is higher, LW warming is larger.

Summary and Conclusion

- CCCM has more low (< 1 km) clouds in tropics, while RL has more mid-level (1-8 km) clouds in high latitude region.
- It is hard to detect small scale cumulus or stratus clouds over tropic ocean. These clouds are observable by lidar with low confidence level. This type of clouds are not included in RL algorithm.
- RL has more single-layered clouds than CCCM (or CCCM has more multilayered clouds than RL in high-latitude region.) This is cause CCCM primarily use lidar, while RL uses radar cloud boundary. Precipitating layer is only detected by radar.
- Cloud radiative impact on SW heating rates is mostly determined by assumption cloud particle size. LW heating rates is more driven by cloud altitude.