# Evaluating the ECMWF model's clouds and radiation with ARM observations

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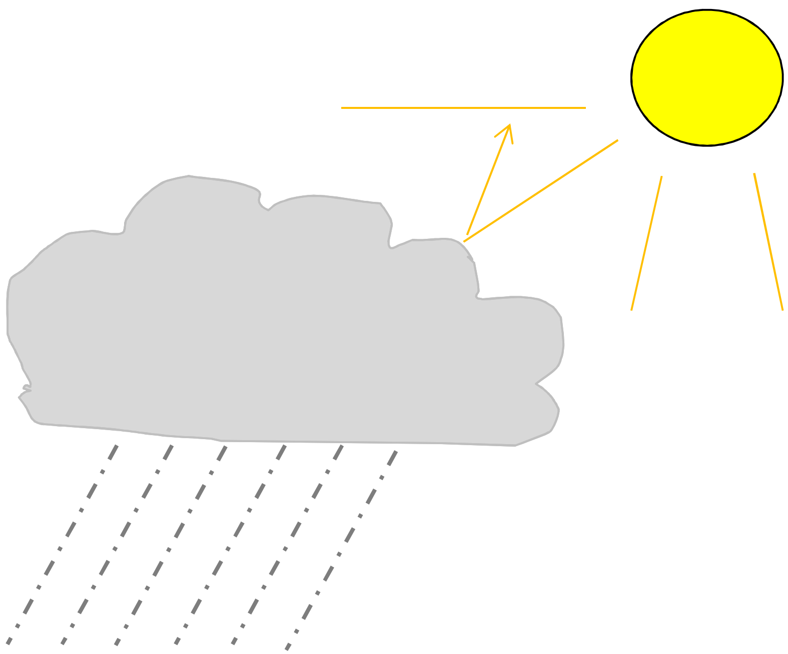
# Radiation and precipitation are two big reasons why we care about clouds in models

- Evaluation products for radiation (especially TOA fluxes) and precipitation are readily available and pretty well established
- Invariably, the model will fall short in some area

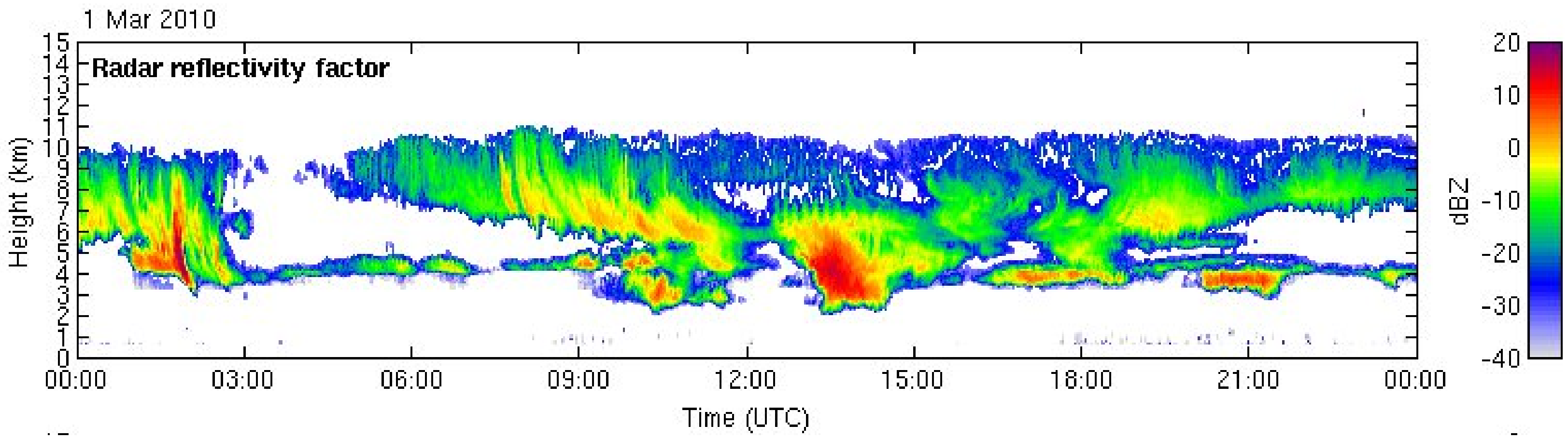


# Challenge: Link model errors to specific aspect of model that needs to be improved

- **Under what conditions does error occur?**
- **Can the error be linked to a particular parameterization or aspect of model?**
- **Compensating errors - need to identify, then address jointly**
- **“Right result for the right reason”**

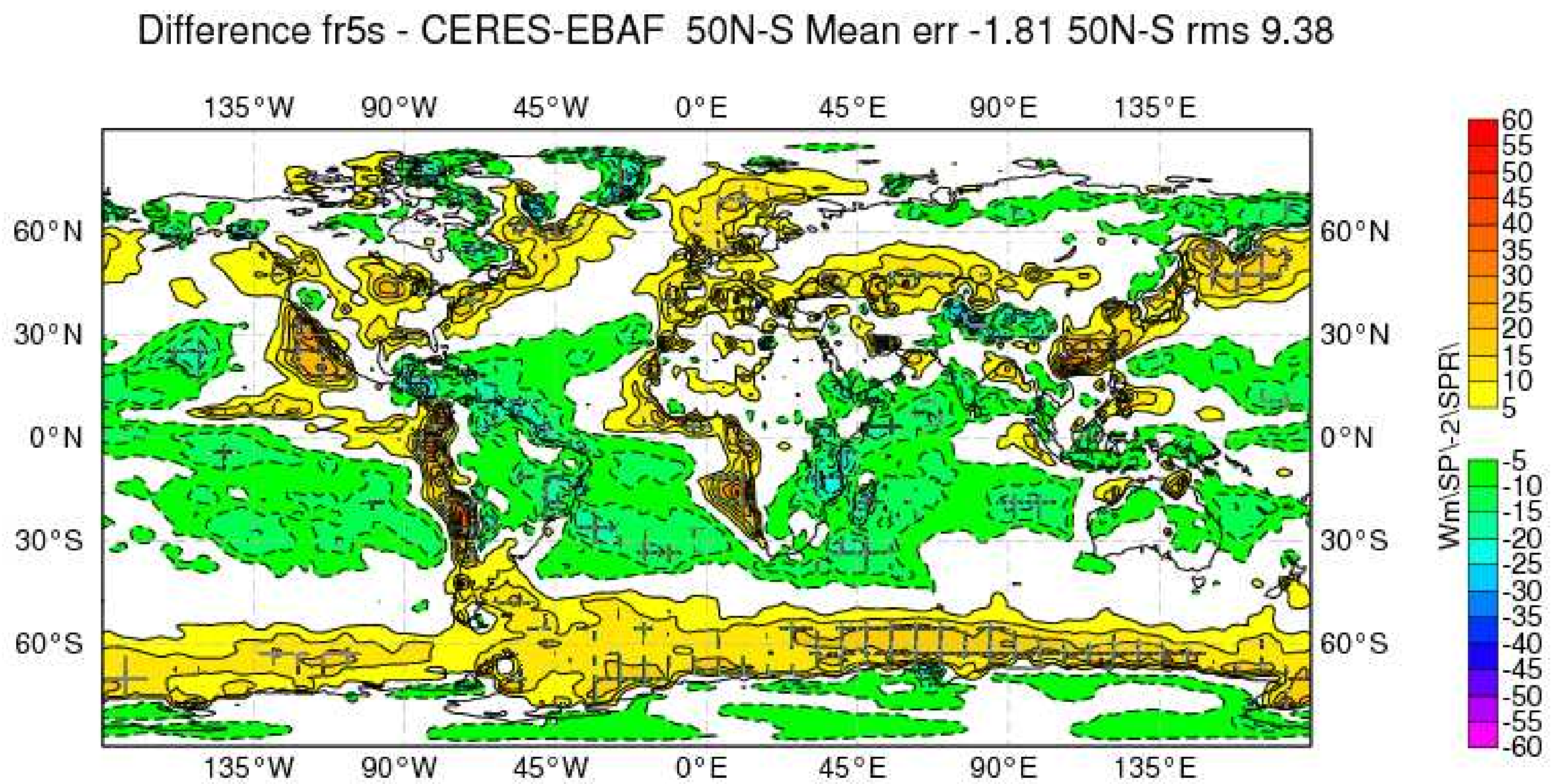
# Ground-based observations well suited to establish link with parameterized process

- **Provides vertically resolved cloud macrophysical and microphysical properties in conjunction with radiative observations**
- **Model parameterization based on (incomplete) understanding of processes, few idealized LES cases**

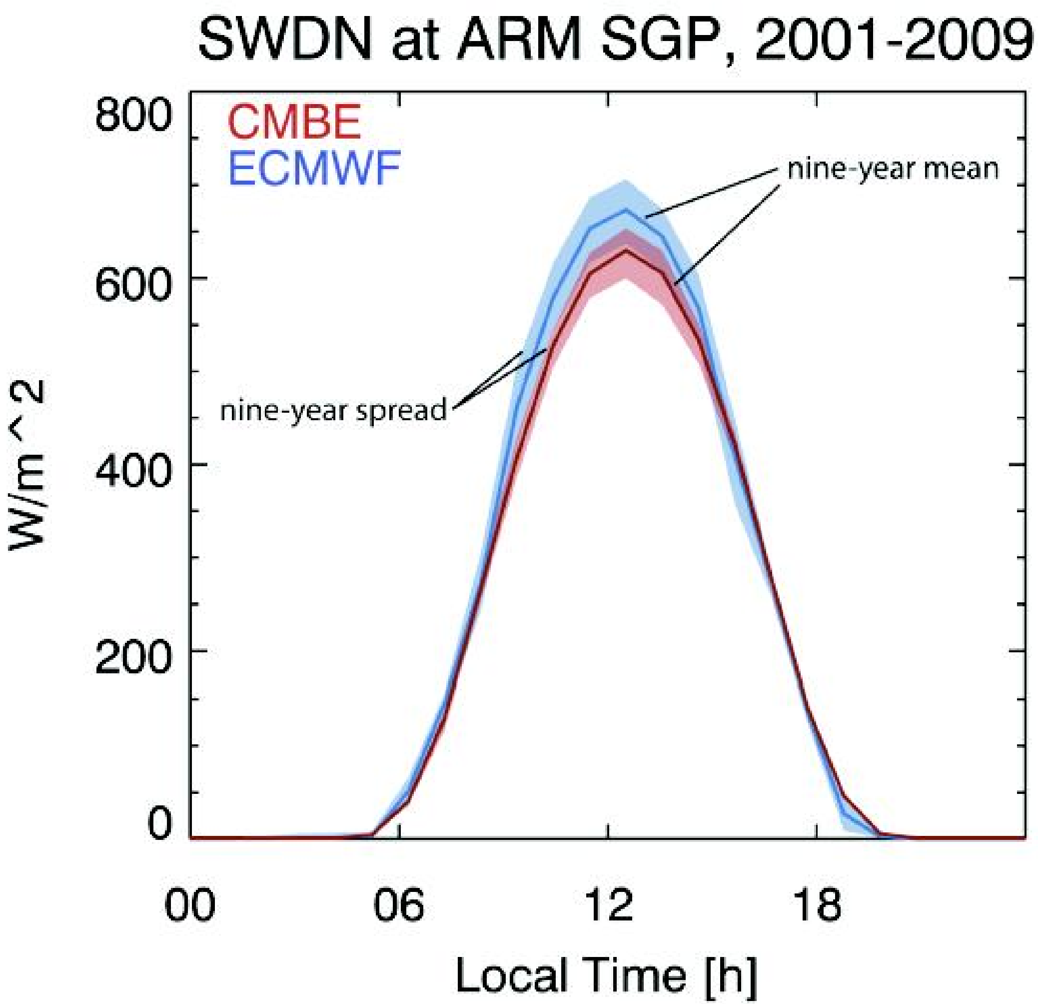


# Example: Identify bias in TOA net SW radiation

- **Cloud forcing underestimated in Sc regions, southern ocean, North American continent (ARM SGP site)**
- **Cloud forcing underestimated in trades**



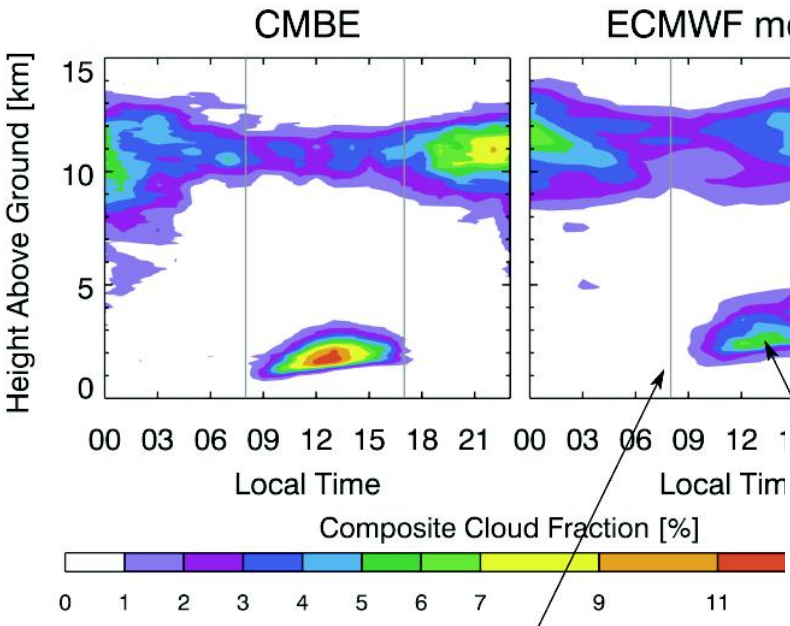
# Can same biases be found in ground based observations?



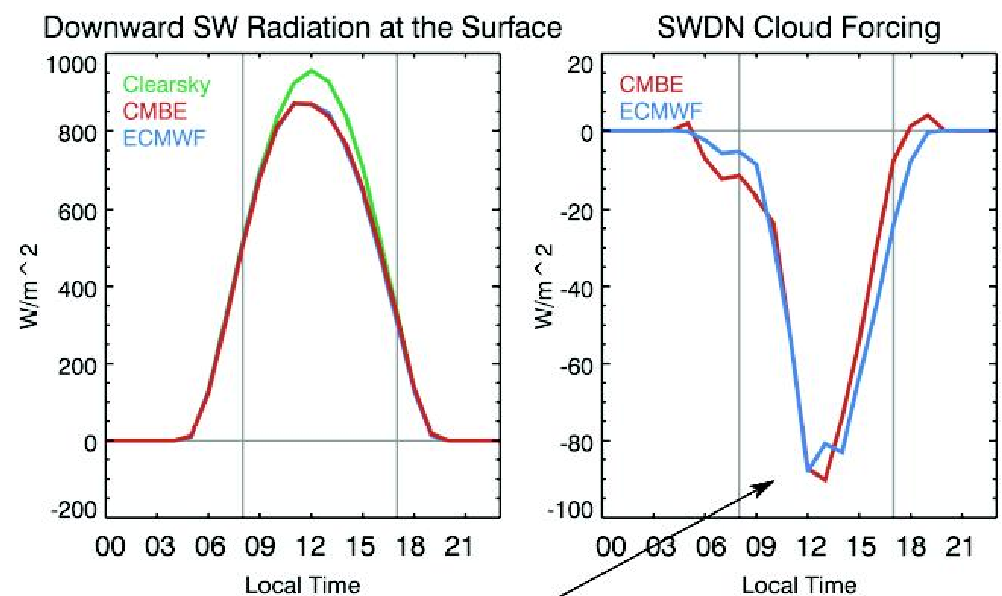

Yes!

- **About 50Wm$^{-2}$ SW bias at noon**
- **Which clouds/ situations/ conditions contribute to the radiation bias?**

# A priori guess: fair weather cumulus clouds?




Composite of 146 days with fair weather cumulus



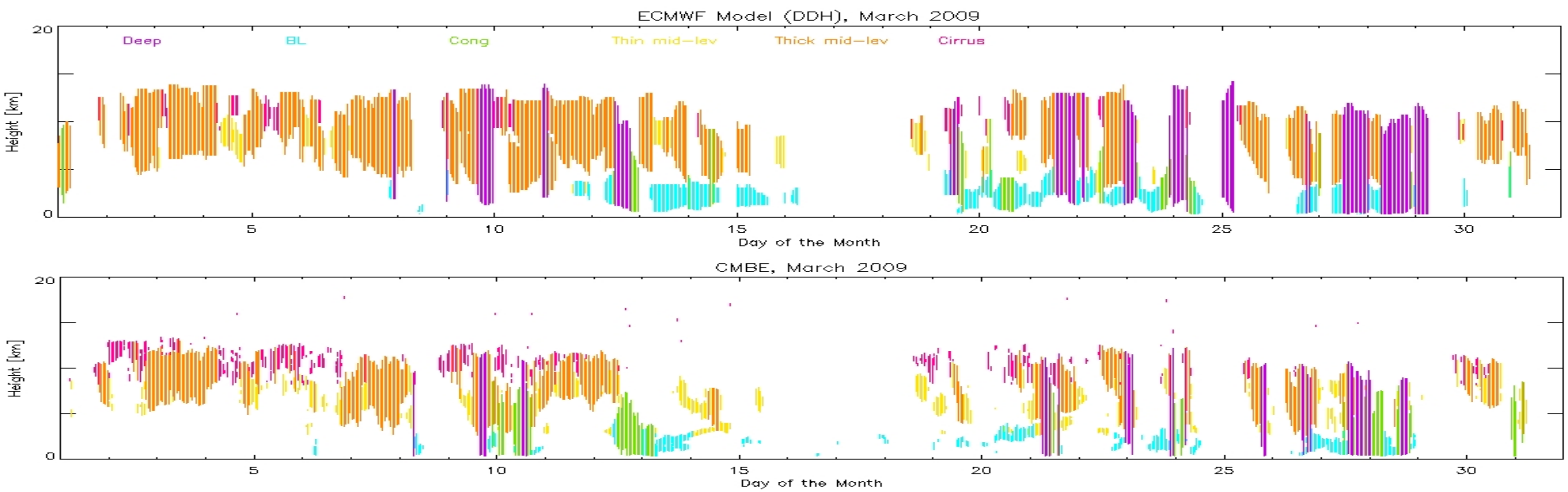

Cloud forcing spot-on but cloud fraction low

-> identified compensating errors, but not the cause of SW bias

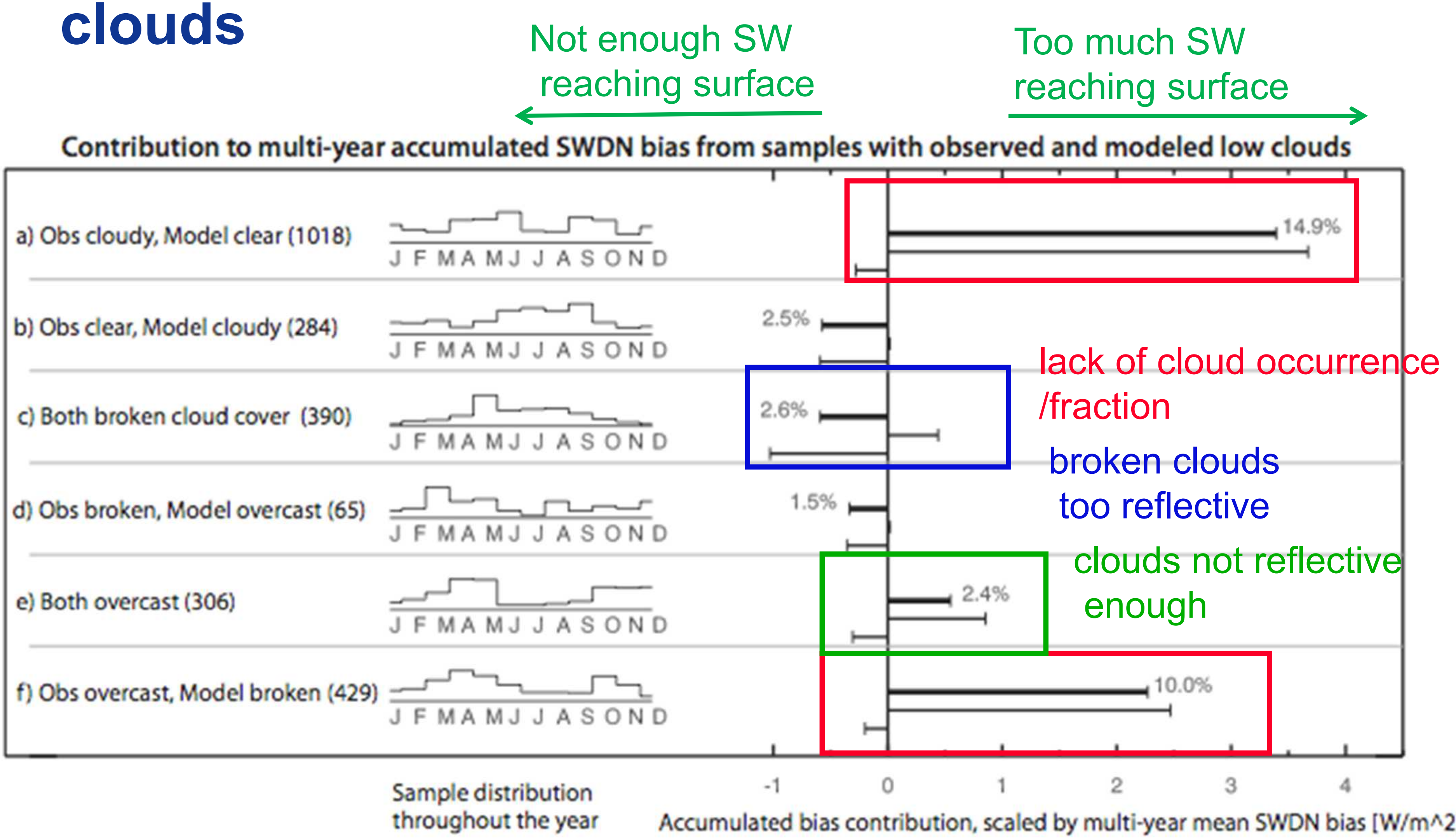
# Can we identify a cloud type that systematically contributes to the SW bias?

**Instead of starting with a priori guess of cloud type, be guided by SW bias.**

- **Classify cloud layers based on cloud base and thickness**
- **Sort sample pairs** (consisting of one hourly sample each from obs and model) **into categories based on cloud type combinations**
- **Rank cloud type combinations by how much they contribute to the SW bias** (using cumulative SW bias of each combination as measure)



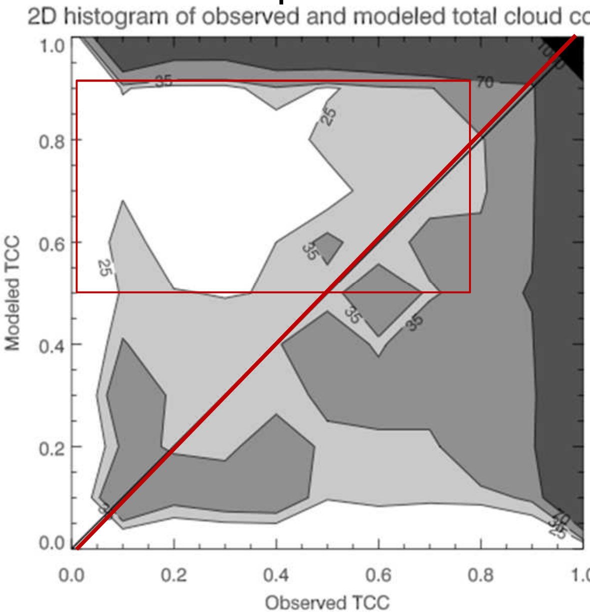
# Use radiation bias to identify regimes of interest. Subset: observed and modeled low clouds



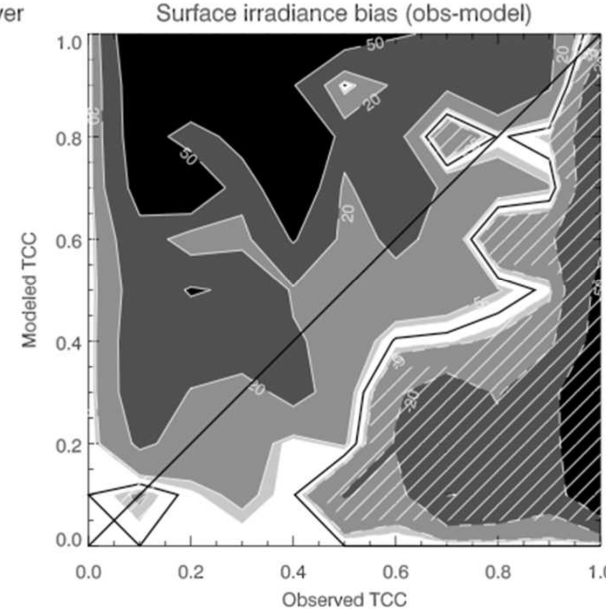
# Do conclusions apply at other locations?

Joint PDFs of modeled and observed total cloud cover from Graciosa

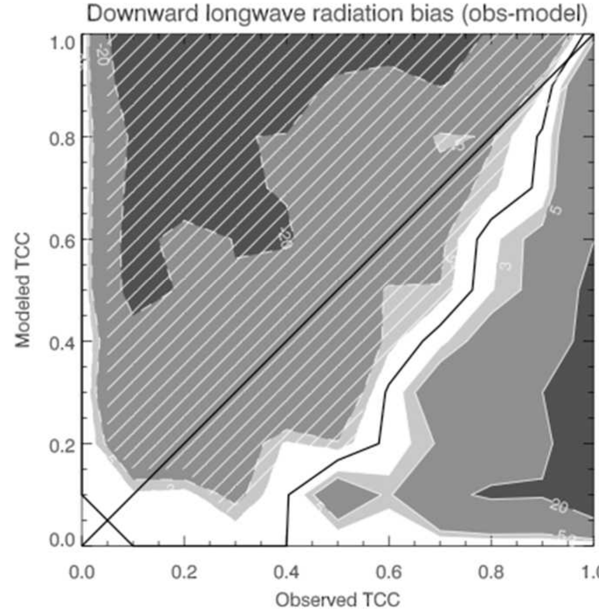
Sample number




Surface irradiance




downward longwave



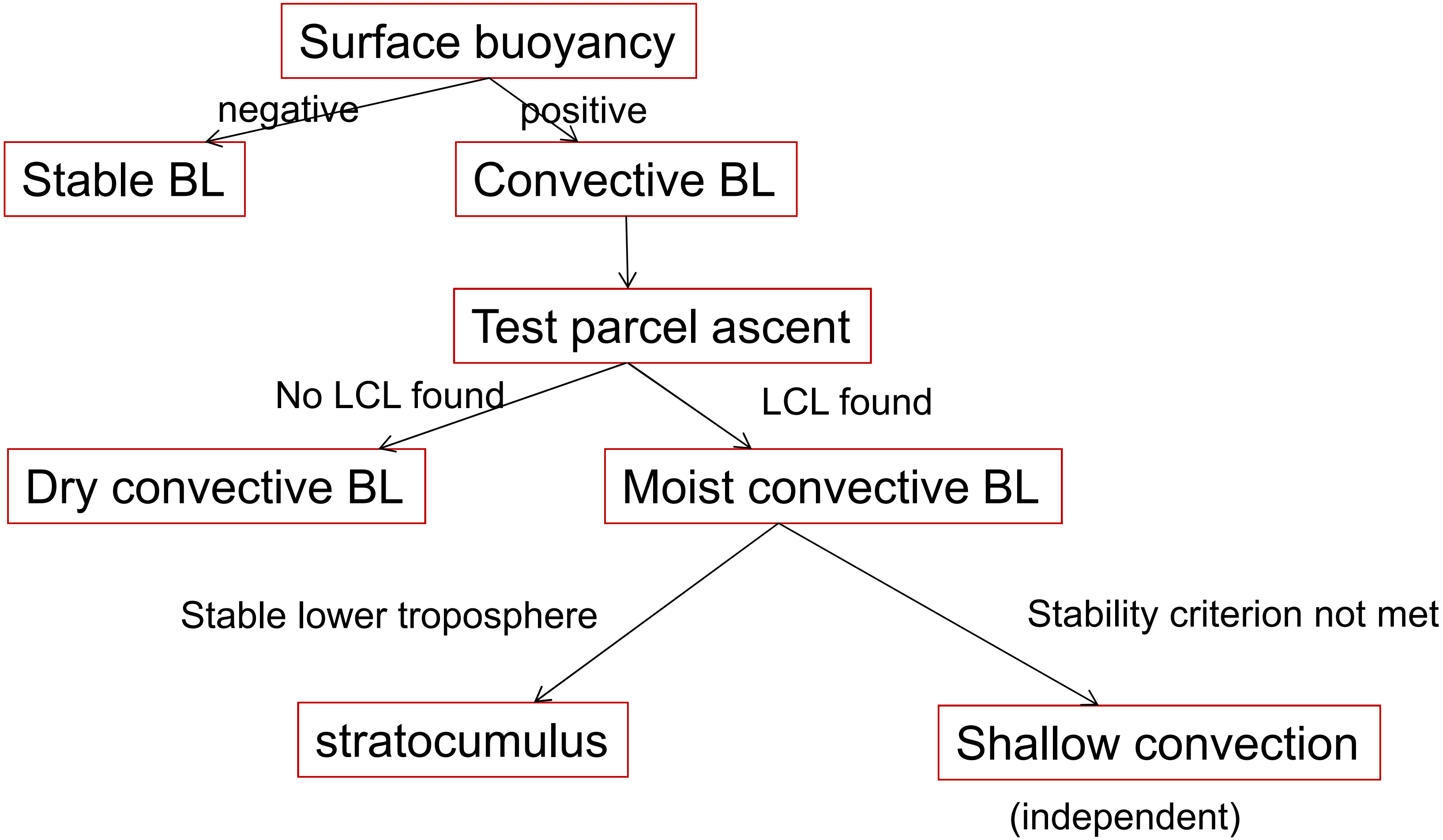

Model rarely has fractions between 50-90%

Even for correctly forecast cloud fraction, <80% CF clouds too optically thick, >80%CF too optically thin

# Create link to model's parameterization

- **Which model routines contribute to the generation of the clouds?**
- **Is the scheme intended to deal with regime producing cloud? (Triggering)**
- **If the intended scheme is active, is it producing the clouds as observed? (No, or we wouldn't have a problem!)**
- **Can we find measurements to constrain parameterized processes in parameterization?**

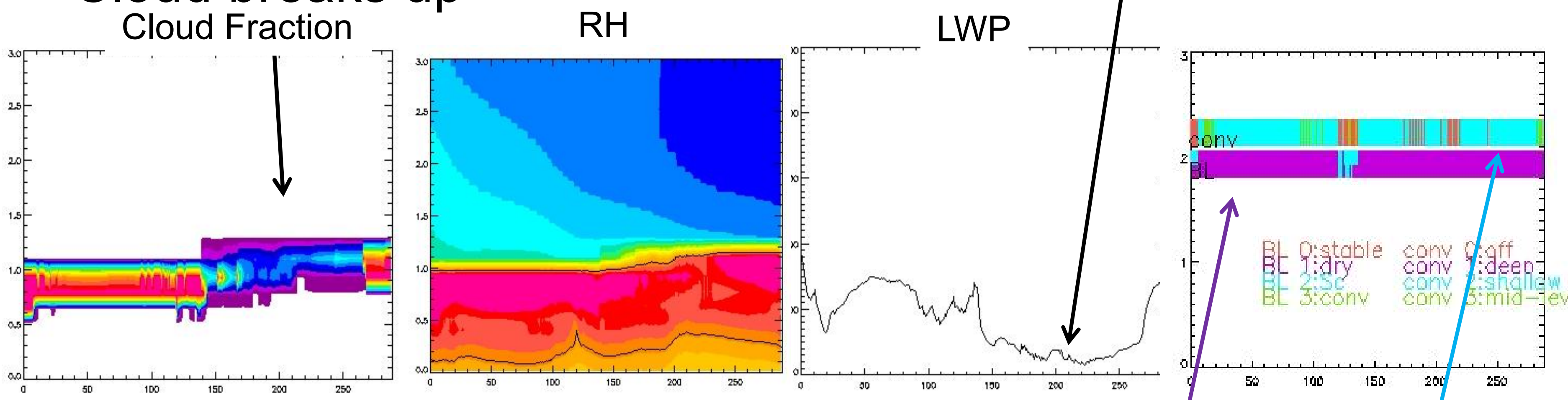
# Overview of BL/low cloud parameterizations (EDMF scheme)



# SCM stratocumulus study on triggering: Which parameterization is active?

Low LWP

Cloud breaks up




“dry” BL, no cloud base found,

Shallow convection active

“borderline” stratocumulus case

# Parameterization trigger: SCM experiment

Parcel rises higher, finds cloud base

Stratocumulus parameterization active

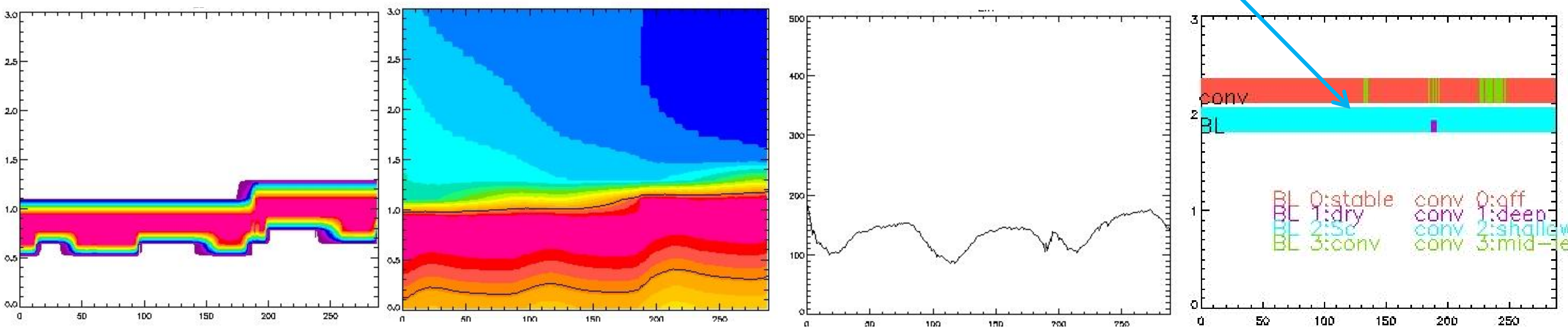
higher cloud fraction and LWP

Lower entrainment in test parcel

Cloud Fraction

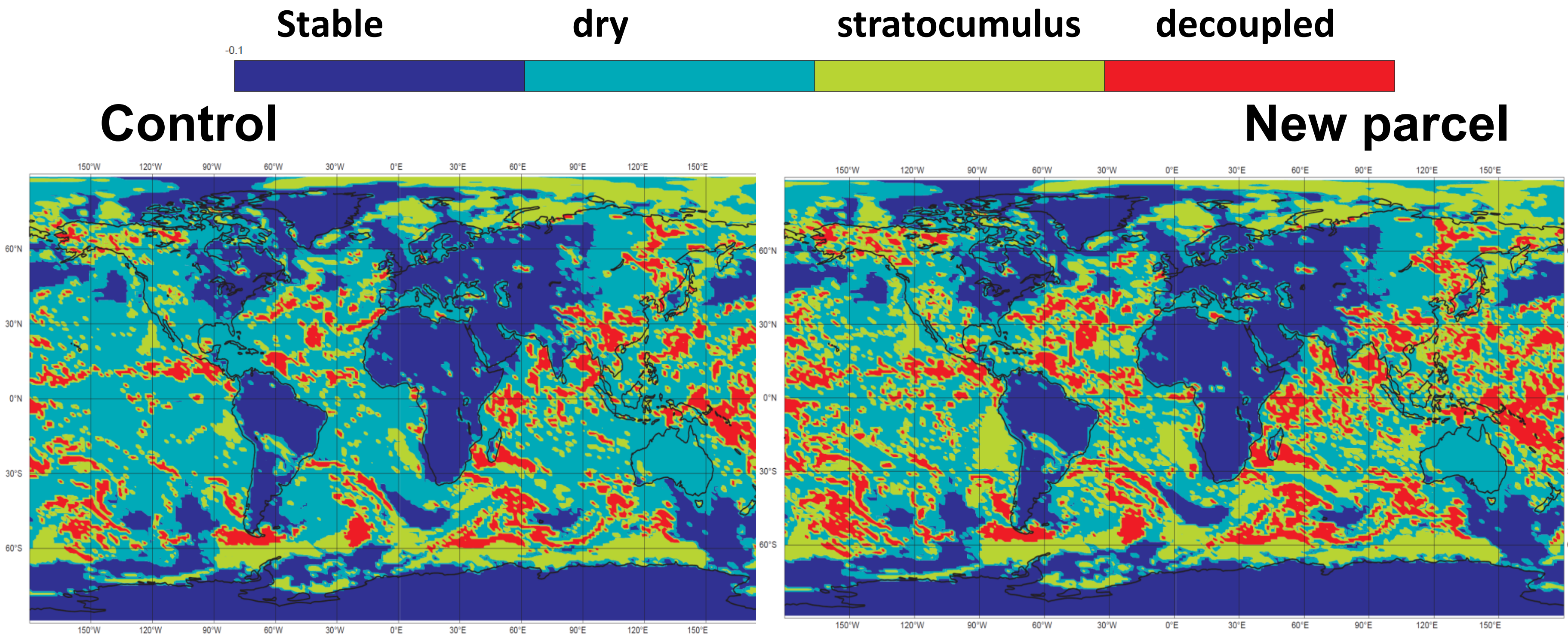
RH

LWP



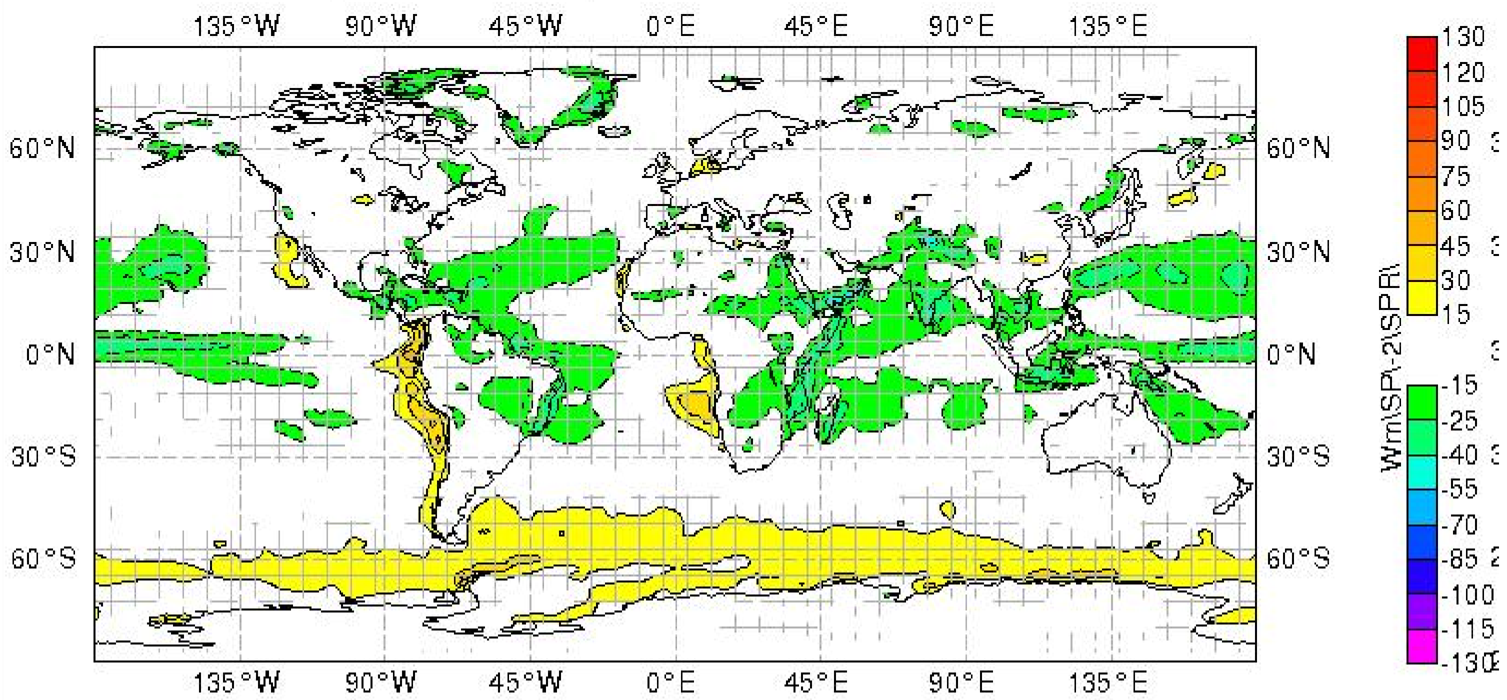
# Impact of trigger experimentation on BL type

Test parcel reaches cloud base more frequently, stratocumulus and decoupled BL more common.



# Impact of trigger experimentation on TOA SW radiation

Difference fqzh - CERES aqua (Apologies, older CERES version)



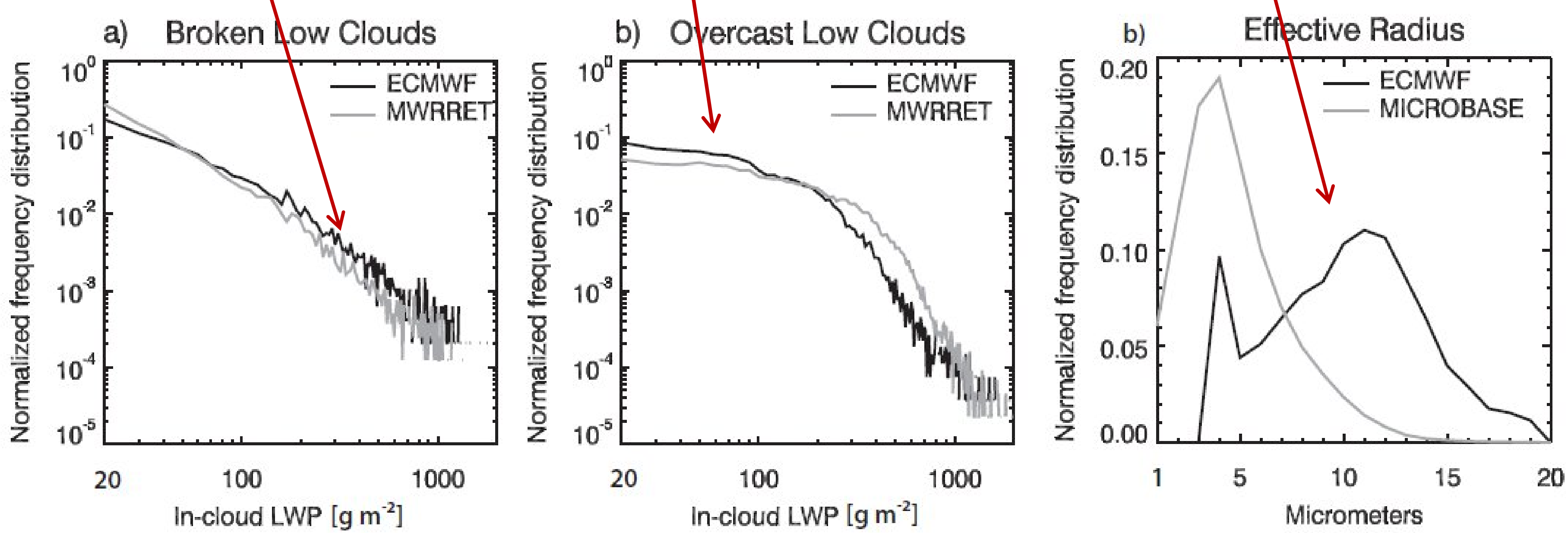

Improved TOA radiation for stratocumulus!

# Cloud microphysics: water path and radiative properties

Low LWP too frequent

Model overestimates Reff

High LWP too frequent



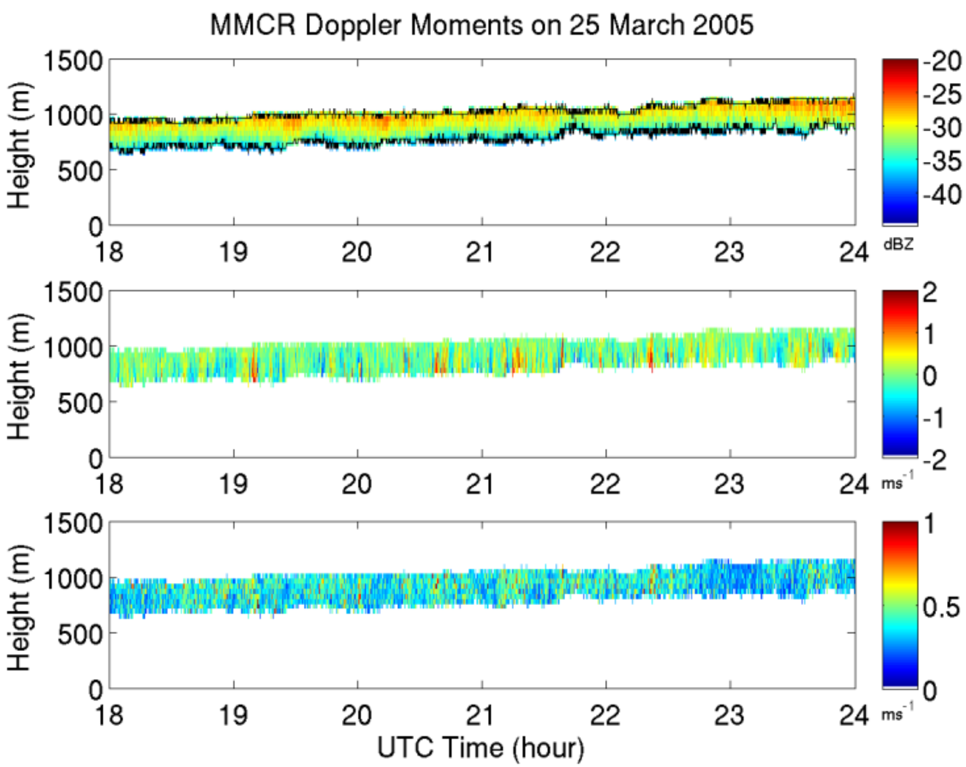

ARM SGP

# Summary

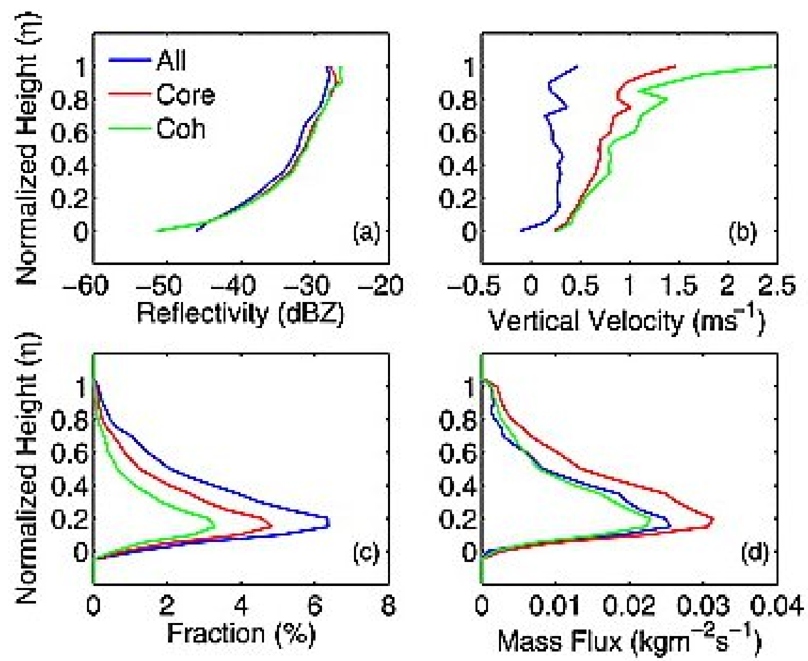
- Example of a strategy to link model error directly to parameterization
  - Stratify observations by meteorology/regime/type that is relevant to model error and parameterization/scheme
  - Identify compensating errors
  - Address all aspects at the same time, else lack of compensation leads to worse results
- Ground-based obs from multiple instruments may provide statistics of quantities (or their distributions) parameterized in GCM based on few LES cases – over long time period and many "real life" conditions

# Other observational products potentially useful to constrain model parameterizations

# Doppler Radar – mass flux, higher order moments

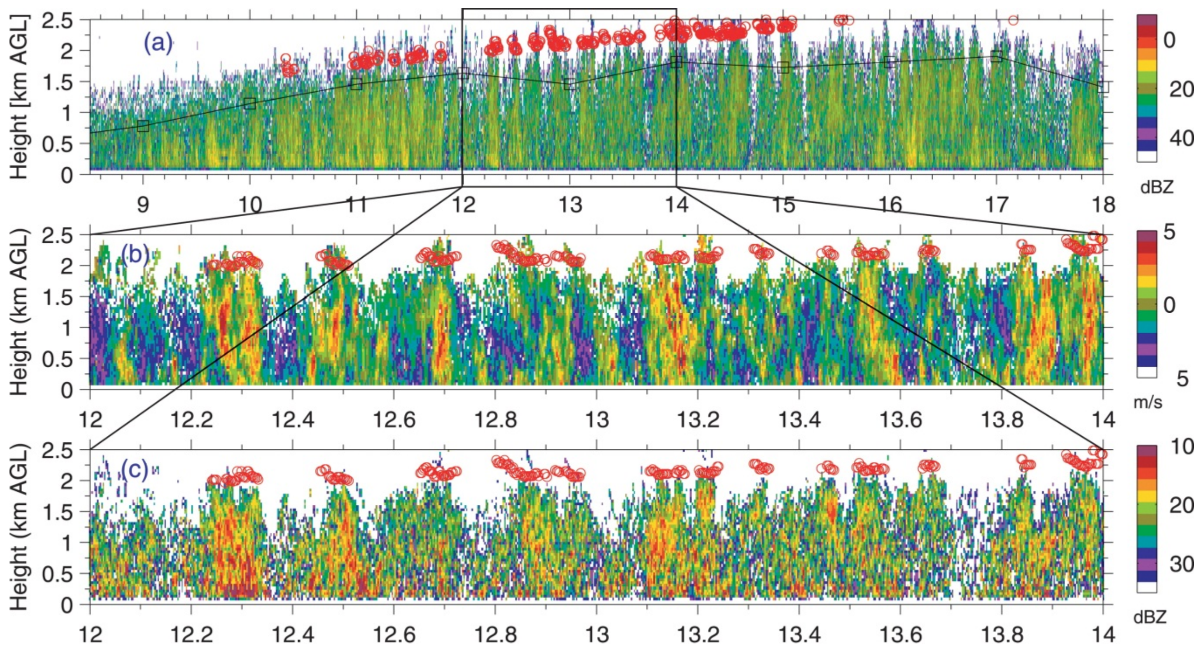



Example of MMCR recorded Doppler spectral moments. (top) Reflectivity, (middle) Doppler velocity, and (bottom) spectrum width as observed on 25 March 2005. Also shown are the determined cloud boundaries




BL depth normalized profiles of hourly averaged (a) reflectivity, (b) vertical velocity, (c) fraction, and (d) mass flux for all, core, and vertically coherent updraft samples. Ghate et al. 2011

# Vertical motion in subcloud layer: VV statistics, plume dimensions

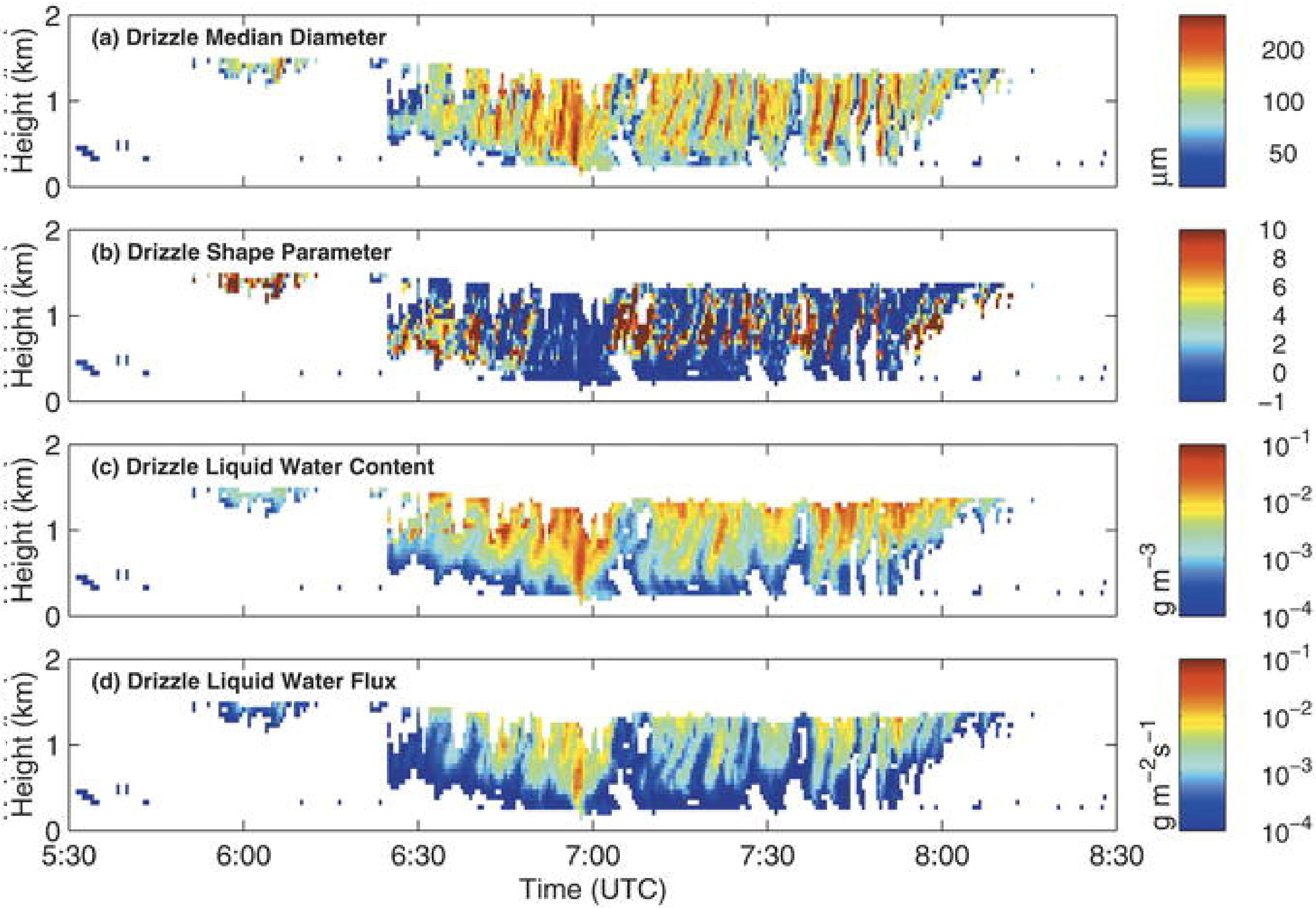



Reflectivity factor

Example of time–height mapping of (a) MMCR reflectivity factor during a cumulus-topped event on 22 Jul 2006. Red dots indicate the cloud bases measured from a ceilometer. Black lines indicate the objectively defined hourly ILH. (b) MMCR Doppler velocity for the period 1200–1400 LST. (c) MMCR reflectivity for the period 1200–1400 LST.

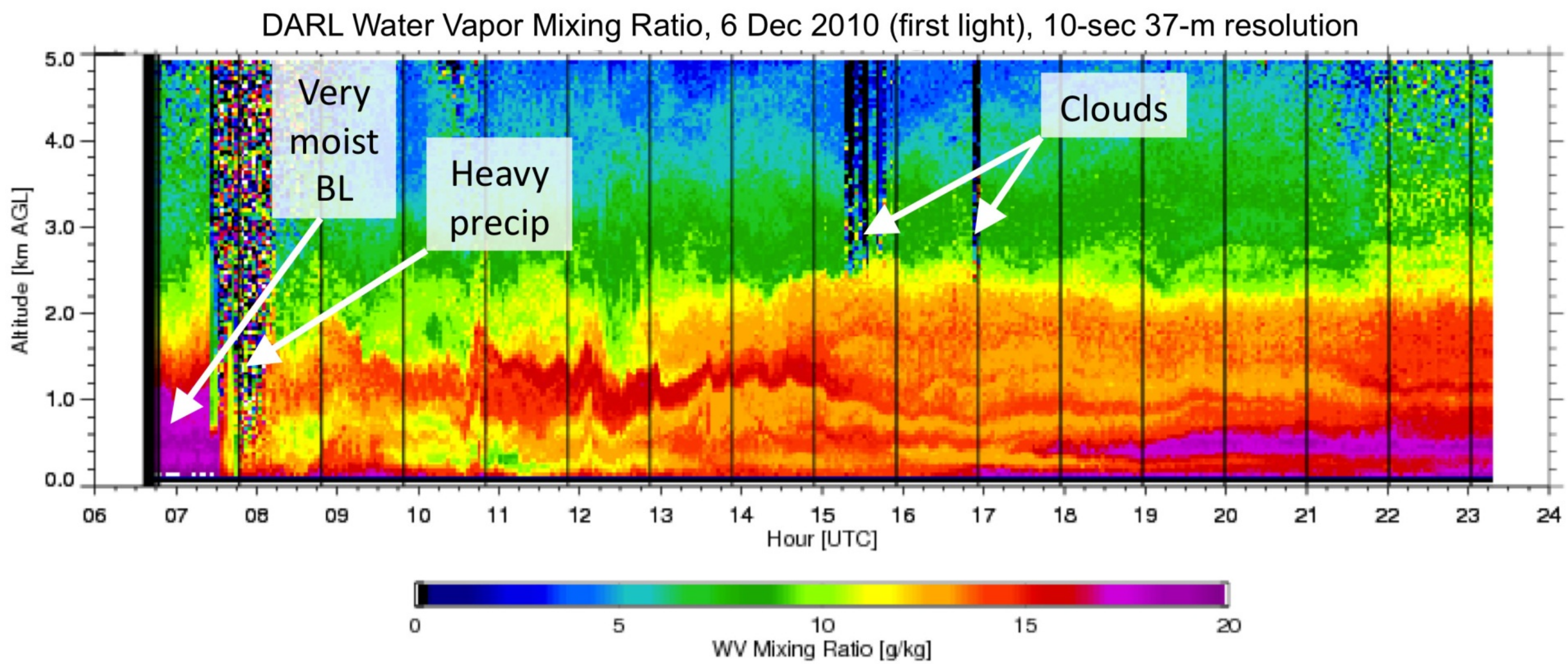
Chandra et al. 2010

# Drizzle retrievals




O'Connor et al. 2005

# High-resolution water vapour retrievals




Question whether variability in time translates into variability in space (Johannes).

http://www.arm.gov/news/facility/post/11211

# References

Ghate VP, BA Albrecht, and P Kollias. 2010. "Vertical velocity structure of nonprecipitating continental boundary layer stratocumulus clouds." Journal of Geophysical Research – Atmospheres, 115, doi:10.1029/2009JD013091.

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O'Connor, Ewan J., Robin J. Hogan, Anthony J. Illingworth, 2005: Retrieving Stratocumulus Drizzle Parameters Using Doppler Radar and Lidar. J. Appl. Meteor., 44, 14–27.

 