Post-cold frontal clouds: what have we learned?

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References: *Lamraoui et al.*, MWR 2018; *Naud et al.*, JGR 2018; *Lamraoui et al.*, JGR 2019

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Motivation

One major issue with GCMs involves the representation of low level clouds, esp. in cold sector of cyclones.
This work seeks to improve understanding of interactions between cloud physics and atmospheric dynamics.

Methods

1) Using the MCMS database, MERRA-2 reanalysis and sonde observations, define three classes of subsidence: PCF, northerly wind, southerly wind

2) Using ENA ARSCL observations, characterize clouds in these 3 subsidence regimes

* Limit analysis to low-clouds (CTH < 3km)

3) Use either met. station, sonde and/or MERRA-2 to characterize environmental properties:

- EIS: θ_{700}-θ_{surf} -Γ_m^{850}(Z_{700}-LCL) (RS/met.)
- MCAO M: θ_{skin}- θ_{800} (MERRA-2/RS)
- ΔT_{surf} = T_{skin}-T_{air} (MERRA-2/Met)
- Subsidence strength ω_{500} (MERRA-2)
- Surface RH and wind speed (met station)
- PW (MERRA-2/MWR)

1) Cloud macroscopic properties correlate with measure of stability M = θ_{skin}- θ_{800hPa}

Estimate the correlation between cloud properties and large-scale drivers in each subsidence regime.

Strong correlation between M and CBH and CTH.

Strong correlation between RH and CBH.

Some correlation between EIS and CTH.

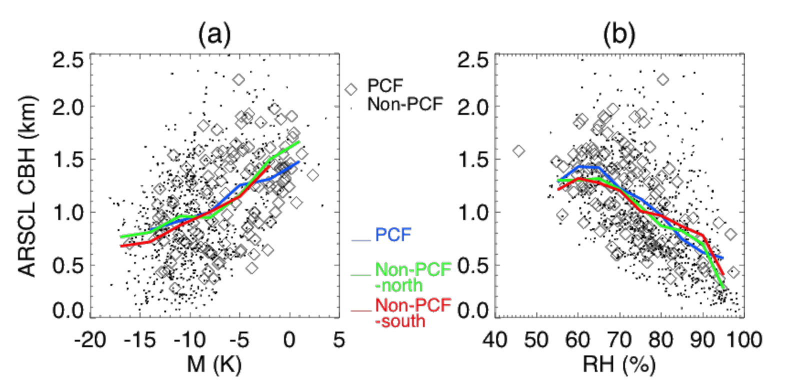

Figure 1. Cloud base height (CBH): M & RH

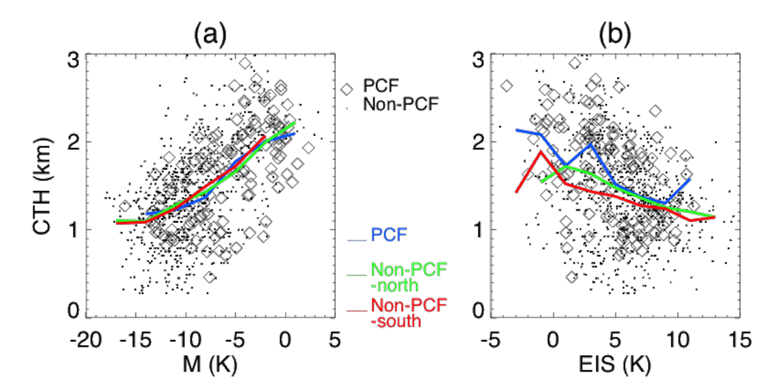

Figure 2. Cloud top height (CTH): M & EIS

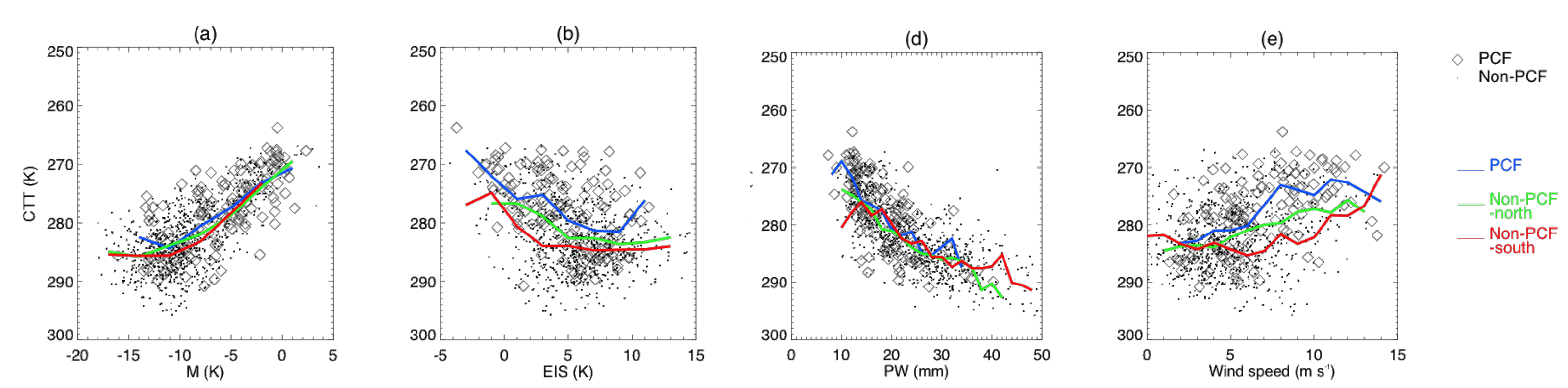

Figure 3. Cloud top temperature (CTT): M, EIS, PW & surface wind speed

CTT < 273.15 K when:
- large M/low EIS (unstable)
- low precipitable water (PW; dry)
- strong surface winds

2) PCF periods: reduced stability, stronger dynamics and drier air cause higher /cooler clouds

During PCF, relatively high CBH and CTH, relatively cool CTT occur more often than for other regimes

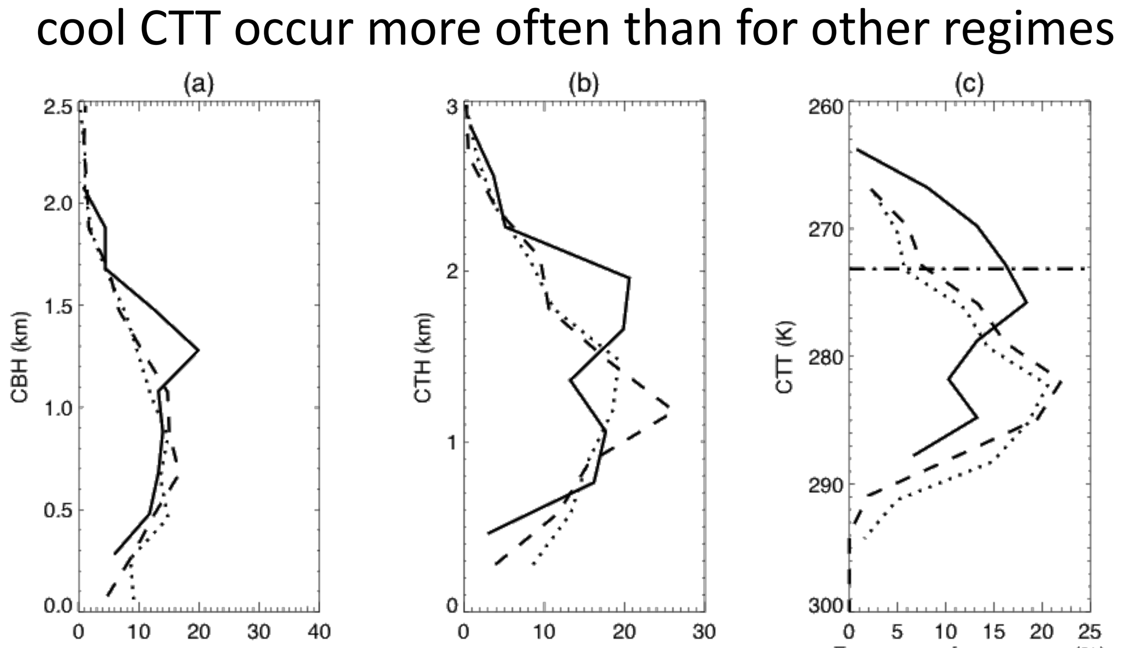

Figure 4. Distribution of CBH, CTH and CTT for the three regimes: PCF (solid), northerly wind (dashed), southerly wind (dotted).

PCF events are more dynamic, less stable and drier than other regimes.

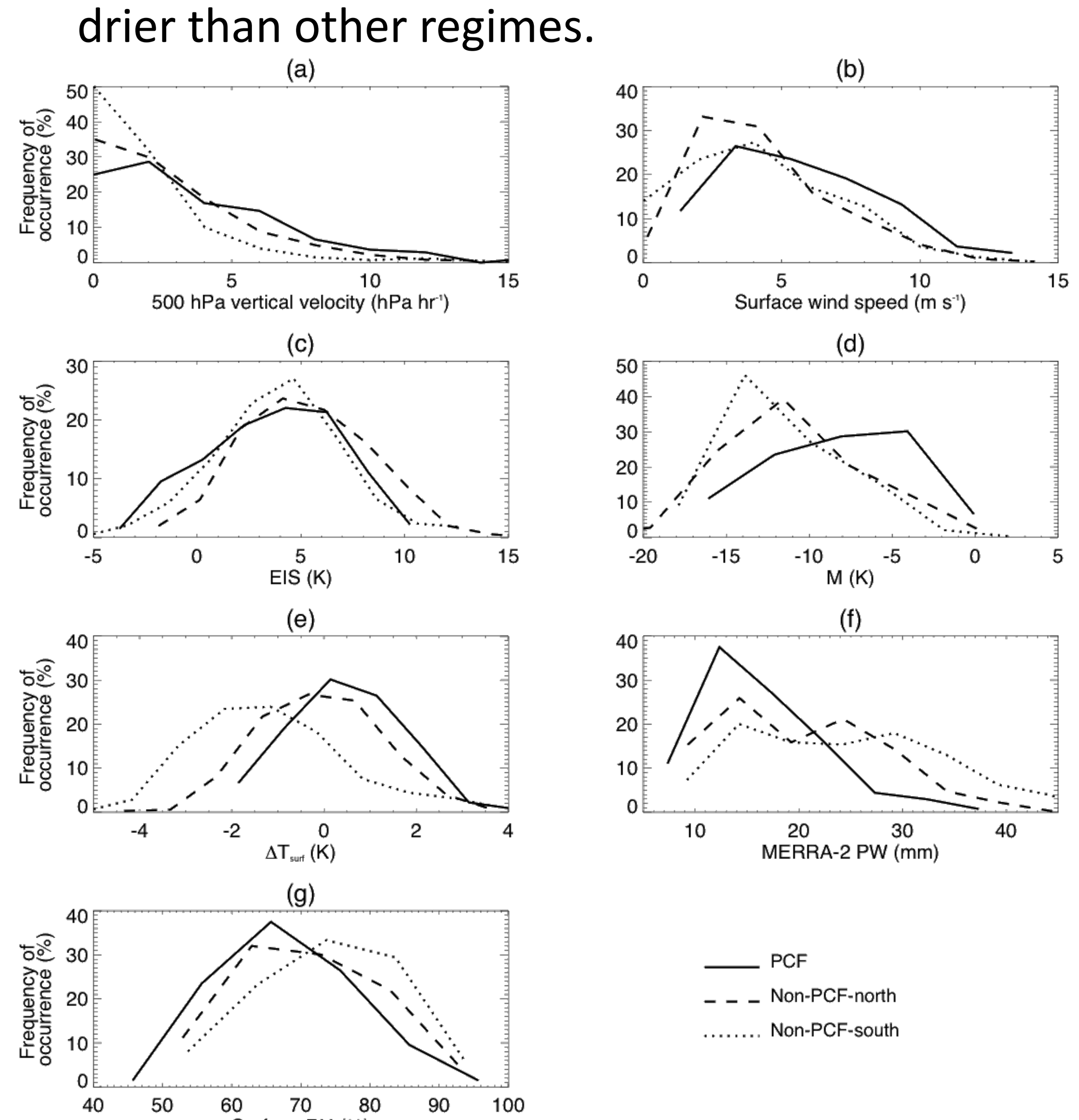

Figure 5. Distribution of large-scale properties for the three regimes.

3) At synoptic scale, linear relationship between CTT and M also found

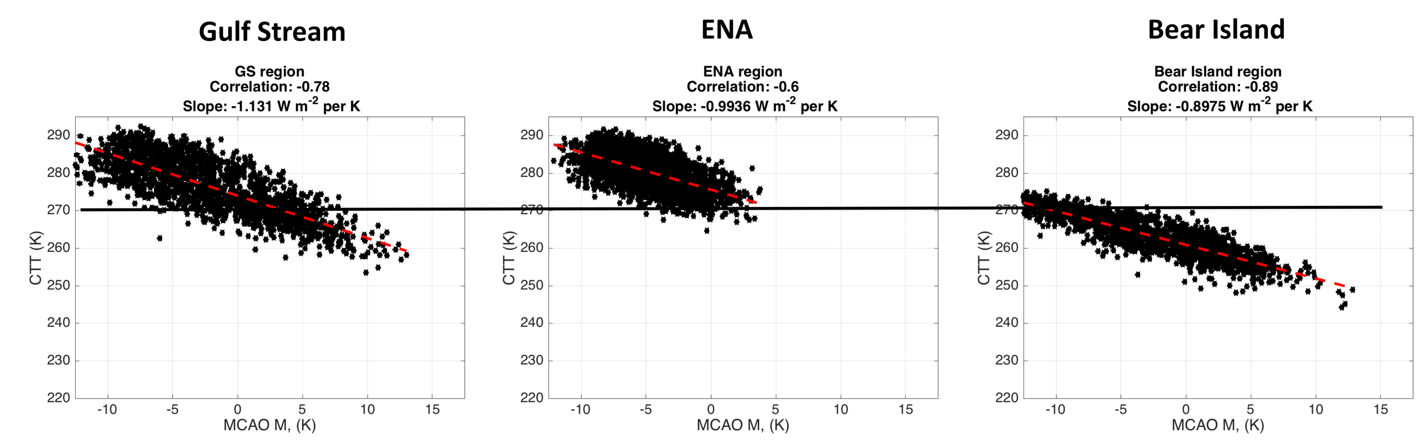

Figure 6. Synoptic scale MODIS CTT versus ERA-interim derived M

For three distinct North Atlantic locations - Gulf Stream, ENA and Bear Island (near Norway, c.f. ARM COMBLE campaign), when ERA-interim indicates subsidence, the relationship between MODIS CTT and ERA-interim derived M is also linear

4) CAM6 reproduces similar relationships but more stable during PCF than observed at ENA

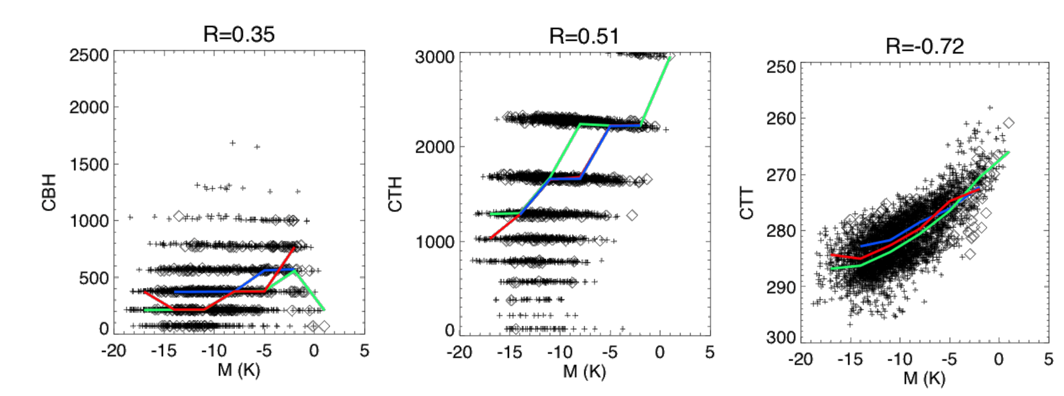

Figure 7. CAM6 CBH, CTH and CTT versus M for three subsidence regimes at ENA.

Compared to obs. CAM6 has a tendency to be more stable during PCF

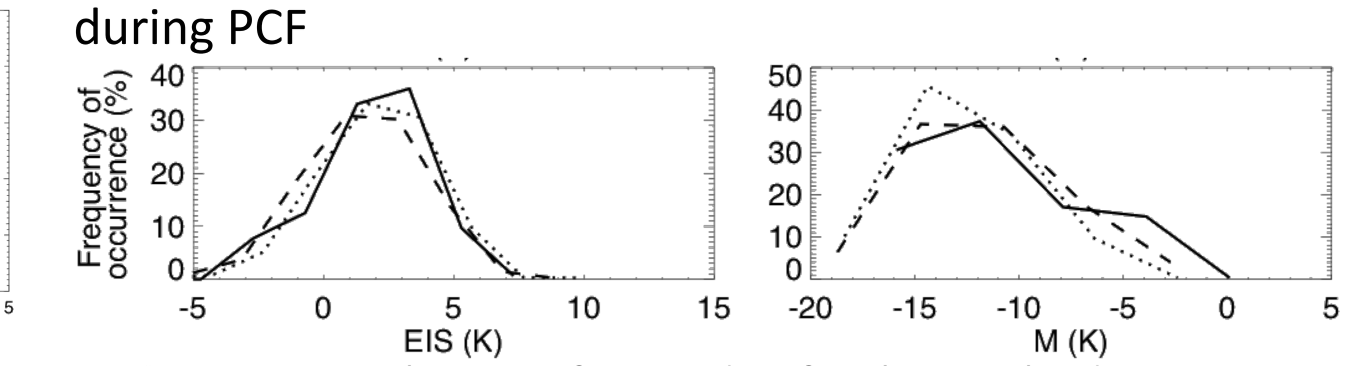

Figure 8. Distribution of EIS and M for three subsidence regimes in CAM6 at ENA (c.f. Fig. 5)

5) WRF tests suggest that the choice of convection scheme dominates variability in cloud properties over the choice of PBL scheme, and perturbed physics dominates the variability over initial conditions because of the importance of mass flux and entrainment for PCF clouds (=> shallow convection)

— 3 convection schemes —

3 PBL schemes

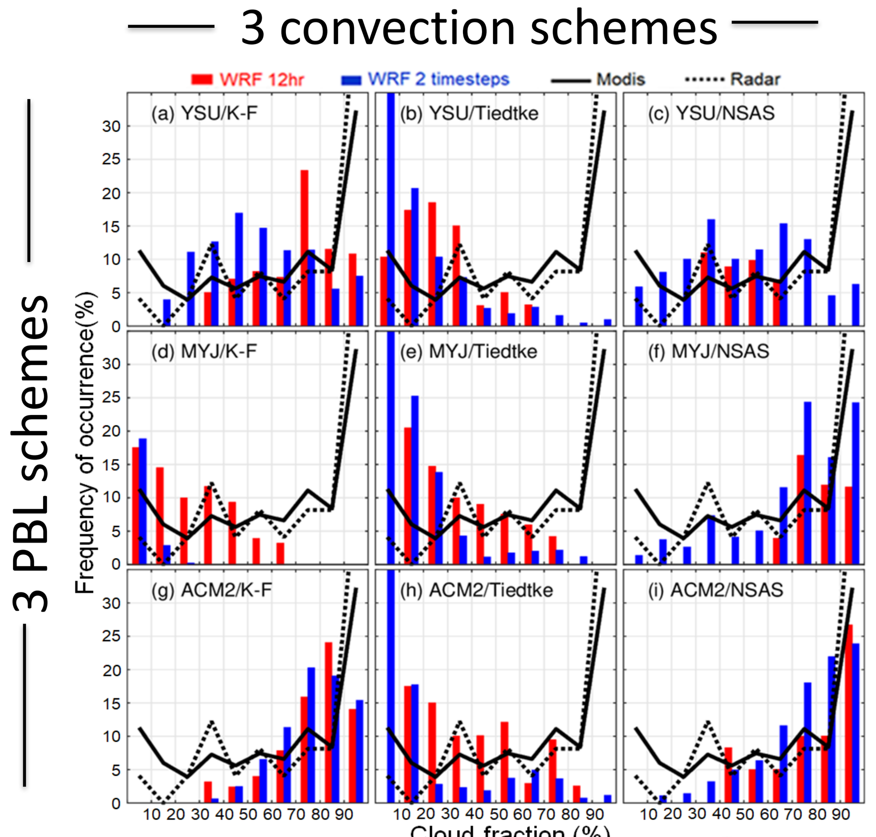

Figure 9. FoO of cloud fraction derived from: MODIS data (solid black), ENA Radar (dotted black); WRF 12-hours (Shaded red); WRF 2 time steps (Shaded blue)

For this convection scheme, **PBL decoupling** dominates

For these two schemes, cloud fraction changes with **wind shear** above cloud and **entrainment**

Convection dominates variability compared to PBL, but physics (Convection + PBL schemes) dominates variability (here in CTH) compared to initial conditions

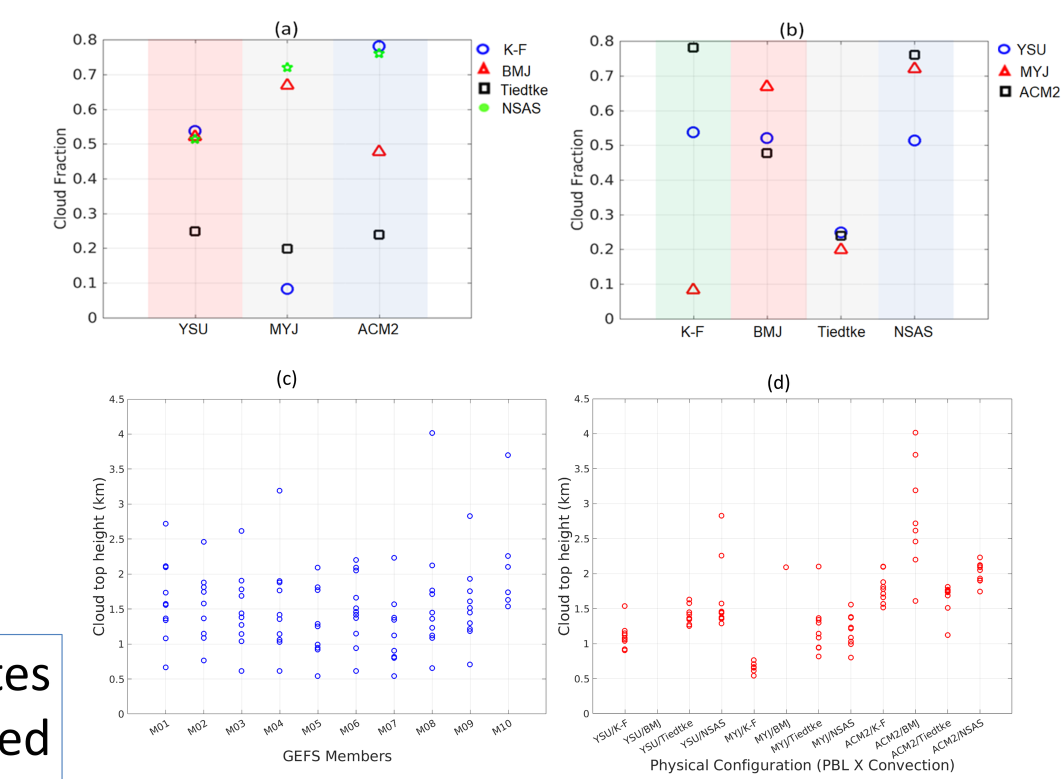

Figure 10. Sensitivity of cloud fraction for: (a) fixed PBL schemes with different convection schemes, (b) Fixed convection schemes with different PBL schemes, (c) Fixed inital conditions with different CuxPBL schemes and (d) Fixed CuxPBL schemes with different initial conditions

Overall conclusions

- In subsidence regimes, cloud macroscopic properties scale linearly with stability measure M.
- PCF periods are less stable, more dynamic, and drier causing more elevated low-level clouds
- For coarse scale models, the shallow convection scheme plays an important role for PCF clouds

Outlook

Preliminary work also indicates that stability measure M is correlated with precipitation characteristics including depth and intensity in subsidence regimes. See *Katia Lamer*'s poster for more information.