ENA observations of boundary layer clouds and atmospheric condition relationships: application to CAM6 evaluation

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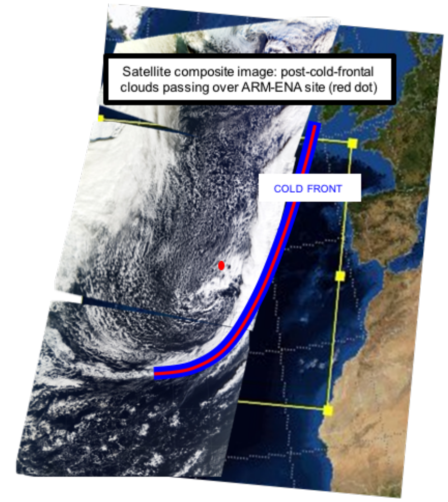
Motivation

- Current GCMs have difficulty representing low-level clouds, esp. shallow convection
- Causes a bias in cloud cover in southern hemisphere summer, especially in the cold sector of extratropical cyclones, in the wake of the cold fronts (post-cold frontal regions = PCF)
- Using WRF simulations of a cold front passage at the ENA, large variations in cloud cover in PCF when changing convection and boundary layer schemes [Lamraroui et al., JGR 2019 + **J. Booth, Wednesday 10.30 am breakout session 4**, “Marine cloud-topped boundary layer processes: cloud, aerosol, drizzle and turbulence”] Can we find metrics to guide choice of schemes for better representation of low-level clouds?
- Focus on large-scale conditions of <u>subsidence</u> (conducive to low-level clouds) at ENA and address questions:

- What are the large-scale drivers that relate best with cloud macroscopic properties in conditions of subsidence in extratropics?

- Can GCMs represent these relationships?



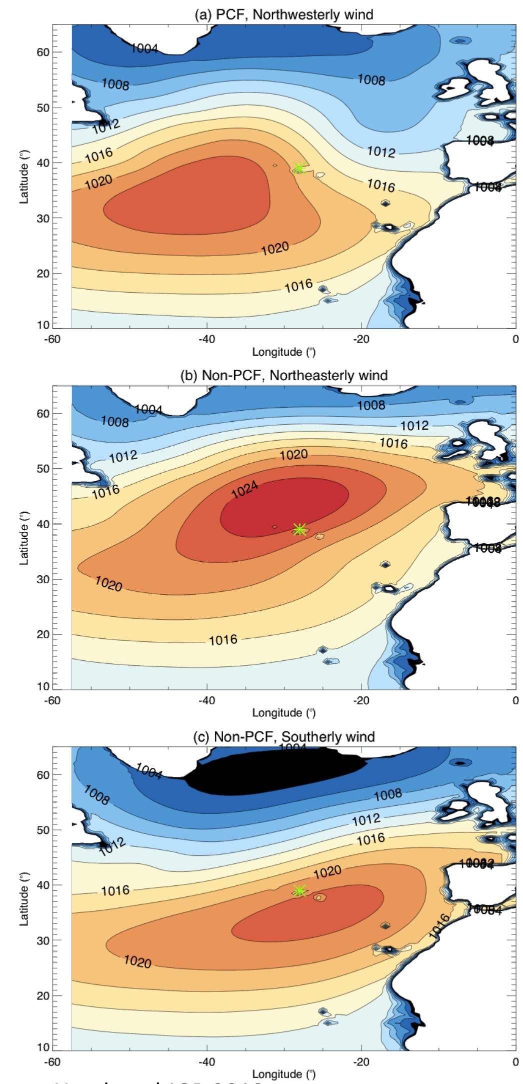
Lamraoui et al JGR2019

Method

- Collect ENA observations when MERRA-2 500 hPa vertical velocity indicates subsidence and radar indicates clouds below 3 km
- Separate subsidence conditions based on prevailing winds: northerly vs. southerly => different temperature contrast between air and surface & surface fluxes
- Further classify northerly wind conditions to isolate presence of extratropical cyclones: post-cold frontal conditions (PCF)

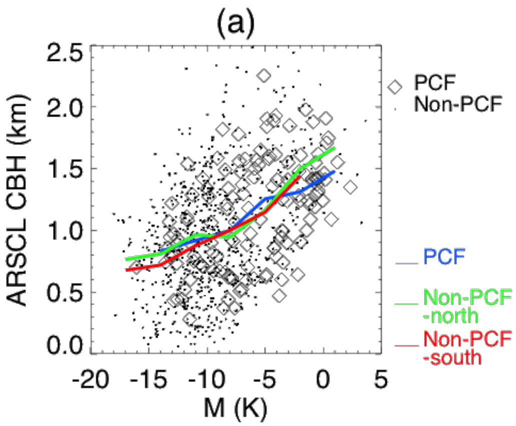
=> 3 classes: (a) PCF, (b) non-PCF-north (northerly wind but no storm), (c) non-PCF-south (southerly wind)

- Collect cloud macroscopic properties (ARSCL):
  cloud base height (CBH), cloud top height (CTH) and cloud top temperature (CTT; estimated with soundings)
- Explore relationships between cloud properties and different large-scale drivers:
  subsidence strength, surface wind speed, stability measures (EIS, $M=\boldsymbol{\theta}_{skin}-\boldsymbol{\theta}_{800hPa}$, $\boldsymbol{\Delta}T_{surf}=SST-T_{airsurf}$), moisture (PW, RH_{surf})
- Apply same classification method to CAM6 output and test whether CAM6 reproduces similar relationships and similar large scale climatology

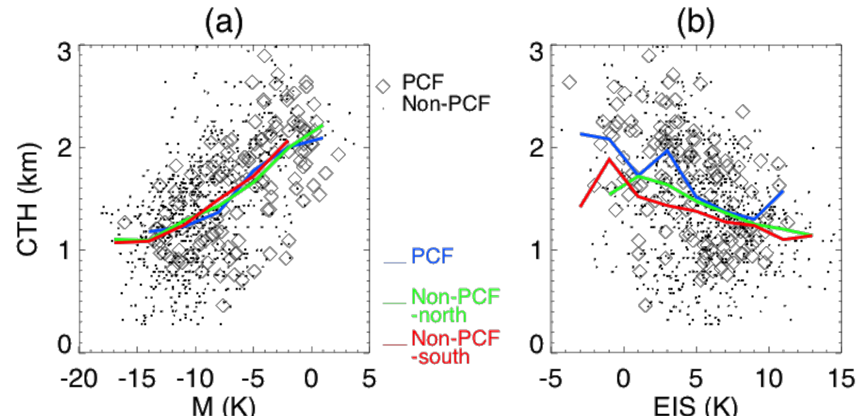


Naud et al JGR 2018

Observational analysis at ENA: relationships

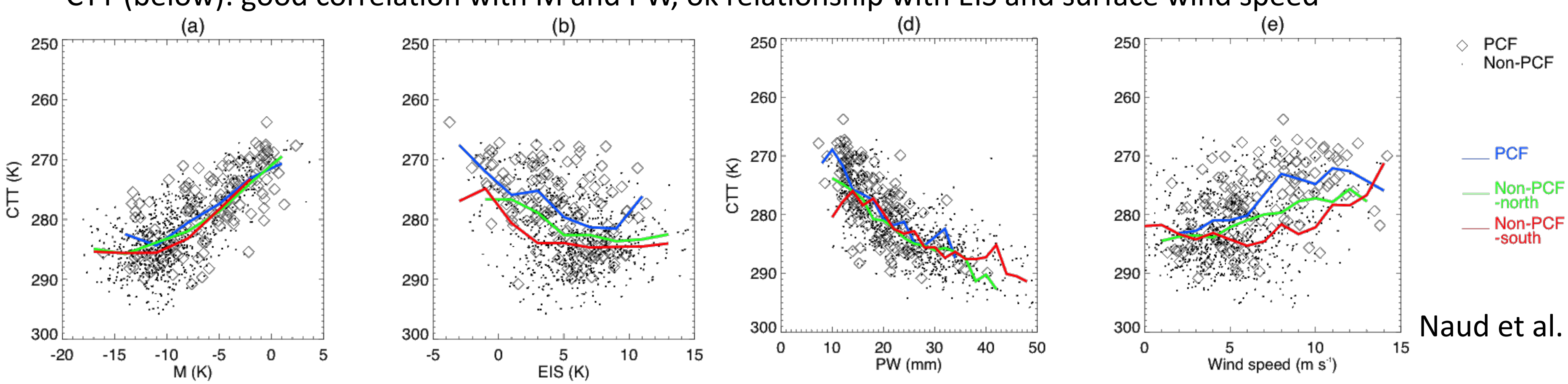


CBH (above): large correlation with M and RH



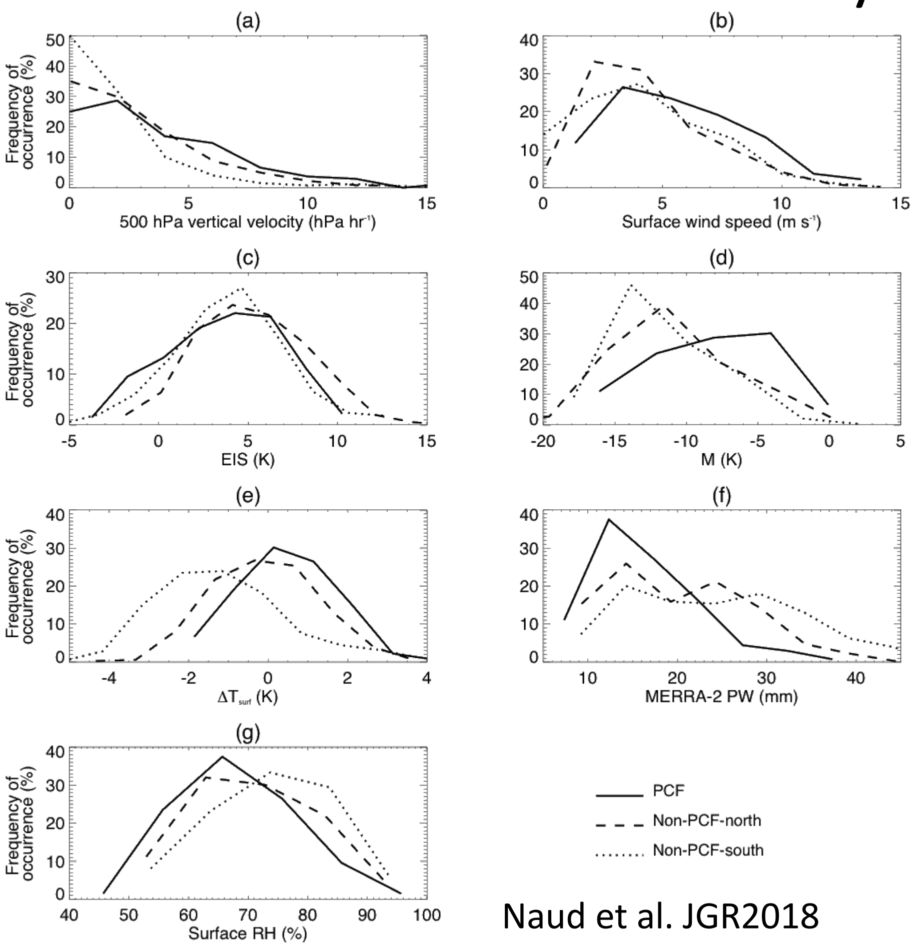
CTH (above): large correlation with M and with a lesser degree EIS

CTT (below): good correlation with M and PW, ok relationship with EIS and surface wind speed

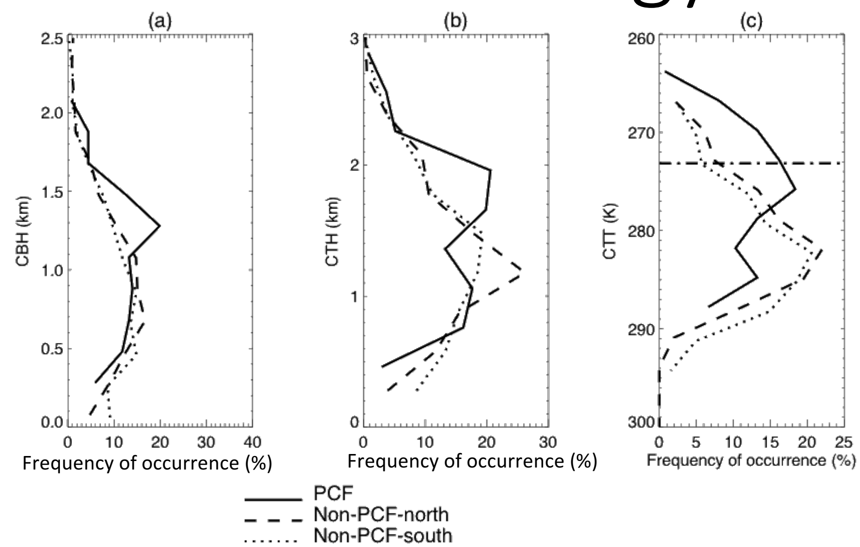


Naud et al. JGR2018

Observational analysis at ENA: climatology



Naud et al. JGR2018



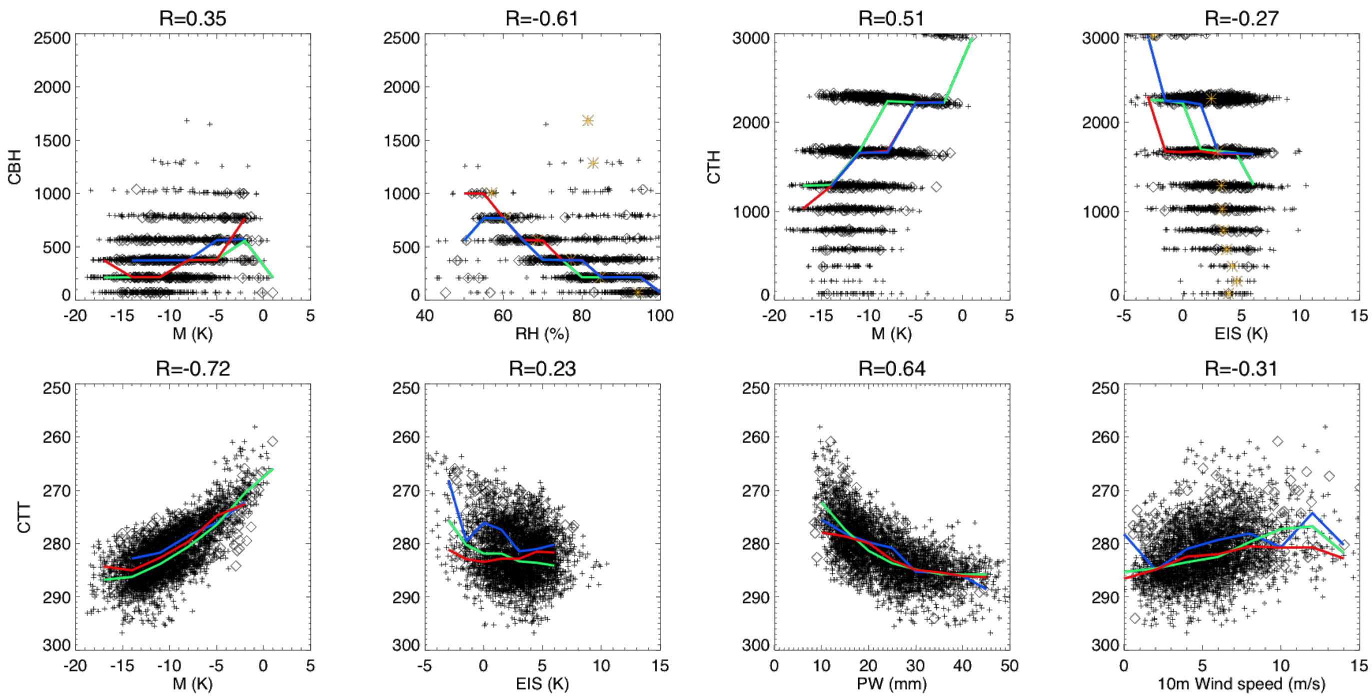
Left:

Depending on type of circulation, variations in dynamics, stability, and moisture => PCF conditions are more dynamically active, drier and less stable.

Above:

As a result, while no significant differences in distributions of cloud base and top locations, PCF conditions tend to have more often high base and top heights, and cloud top above the melting level.

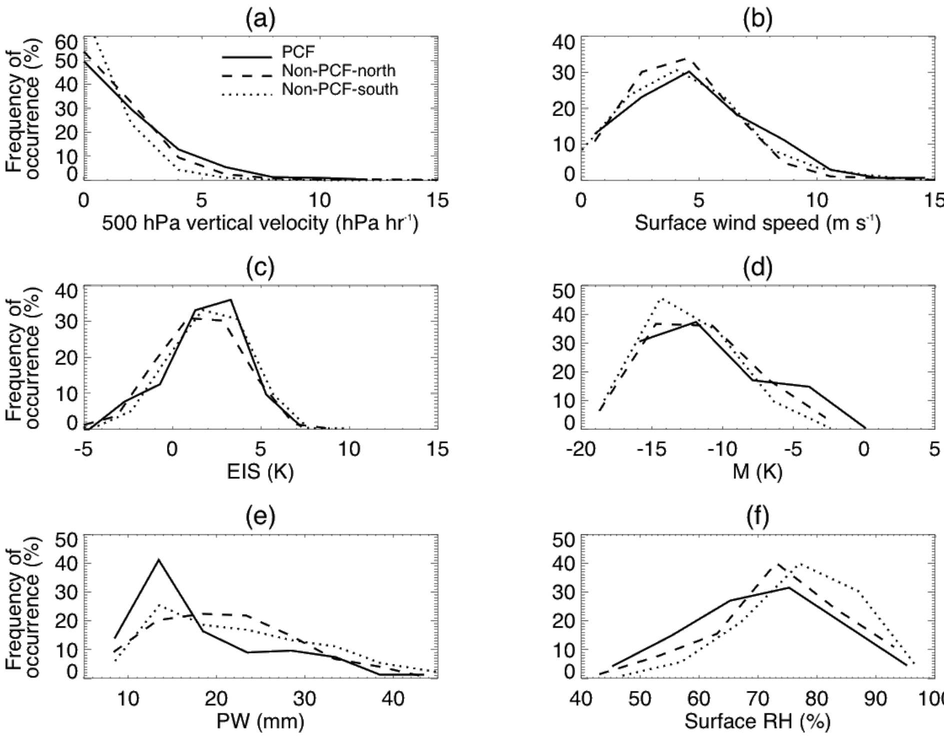
Relationships in CAM6

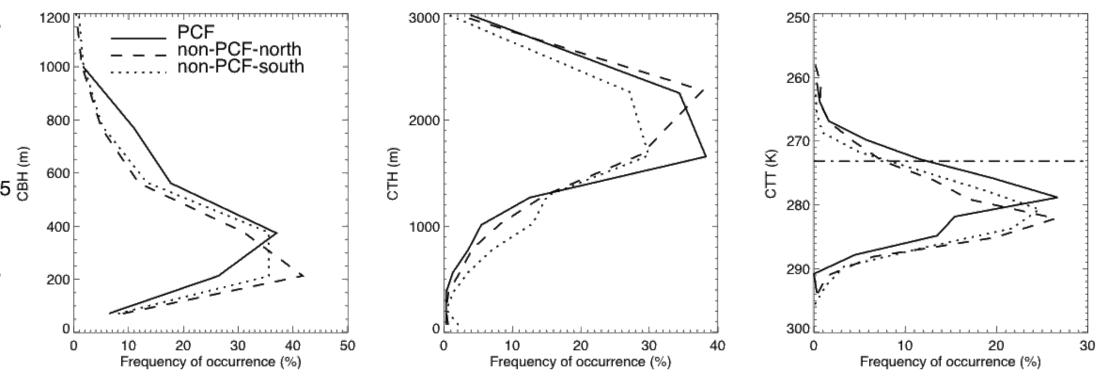


Issue: visible striping caused by fixed model levels for CBH, CTH
+ not the same as what the radar observes (footprint size, time scale, detectability,...)

But relations observed at ENA tend to be reproduced with CAM6:
CBH: tends to be much lower than in the observations and less well correlated with M
CTH: relations emerge above 1 km but consistent with observations.
CTT: M and PW also show good correlation, with fit very close to observations (not so much EIS)

Histograms per subsidence regime





Left: similar separation per regime for dynamical and moisture variables, similar for M but differs for EIS
Maybe EIS in model affected by vertical resolution?

Above: PCF CBH and CTT separate from other regimes as in observations, but not CTH above 2 km
Could it be because M not as large in CAM6? => peak does not separate from other regimes
=> Suggests that differences in stability (model less unstable than observations, c.f. M and EIS) could affect depth of shallow convection and thus cloud level

Conclusions

- Clouds in subsidence regimes at the ENA show good relationships with measure of stability M for base and top heights and CTT. For CBH, RH is well correlated and for CTT PW also shows strong correlation
  => potential temperature contrast between 800 hPa and surface appears to be a good metric of cloud macroscopic properties in subsiding extratropical regions:
  - preliminary analysis of SH data indicates still valid there
  - study by K. Lamer shows that also good predictor for precipitation (c.f, **K. Lamer, Wednesday 10.30 am breakout session 4**, "Marine cloud-topped boundary layer processes: cloud, aerosol, drizzle and turbulence" + **Poster Wed. 5pm**, session B2]
- CAM6 shows similar relationships between cloud properties and large scale drivers, but some discrepancies for stability measures: not as unstable in PCF as observed, suggest potential issues with shallow convection?
- Next:
  - explore why M is such a good predictor and why CAM6 has issues producing enough situations with $\boldsymbol{\theta}_{skin} > \boldsymbol{\theta}_{800hPa}$
  - explore southern ocean data to establish whether these results apply at other locations than just ENA