Observational Evidence of the Effect of Large-scale Drivers on Marine Boundary Layer Precipitation during Subsidence in the Eastern North Atlantic

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Motivation and Goal

Issues with the representation of cloud cover in the Southern oceans in most CMIP5 models related to issues representing clouds in post-cold frontal regions

Problem is also present in northern hemisphere cyclones in the winter time

Clouds in these dynamical regimes are mostly low-level clouds, driven by shallow convection in conditions of subsidence

Naud et al. (2018) reported that post-cold frontal regions exhibit distinct cloud attributes related to the intensity of large-scale drivers

but so far little is known on the properties of precipitation during these periods

Here we exploit ENA observations to <u>explore the relationship between precipitation attributes and large-scale drivers during Post-Cold Frontal conditions</u>.

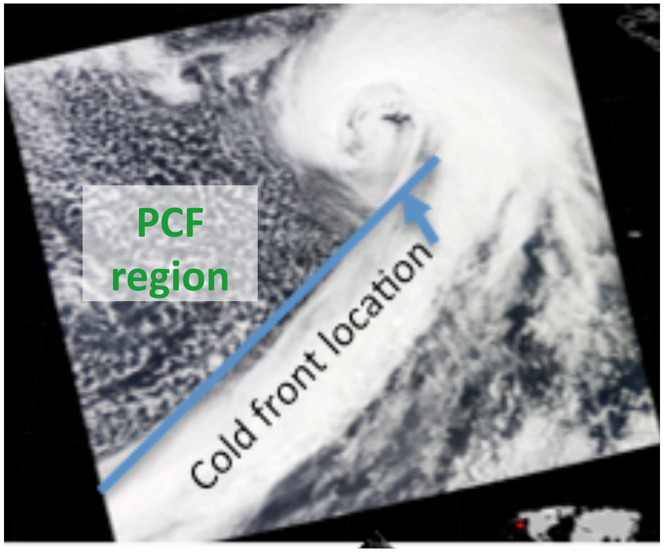
Methods

Collect ARM observations and reanalysis output centered on the ENA observatory between 10-2015 and 09-2018

Focus on periods with marine boundary clouds (cloud tops lower than 3km) and identified periods with subsidence associated or not with a cold front.

$\text{Subsidence}_{\text{North}}$ = subsidence with Northerly wind
$\text{Subsidence}_{\text{South}}$ = subsidence with Southerly wind
$\text{Subsidence}_{\text{PCF}}$ = subsidence after the passage of a cold front using MCMS database, MERRA-2 and Met. Station

Subsidence: standard definition, $\omega_{500} > 0$ hPa hr^{-1}



Methods

Establish correlation between **hourly-averaged precipitation attributes** and large-scale or cloud drivers:

Larger-scale drivers

- Surface relative humidity (RH_{surf}) [Met. station]
- Surface wind speed [Met. station]
- Subsidence rate (ω_{500}) [MERRA-2]
- ΔT_{surf} : T_{skin}-T_{air} [MERRA-2/Met. station]
- Estimated Inversion Strength (EIS): $\theta_{700}-\theta_{surf}-\Gamma_m^{850}(Z_{700}-LCL)$ [Sonde/Met. station]

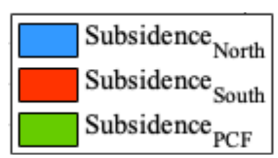
Cloud drivers

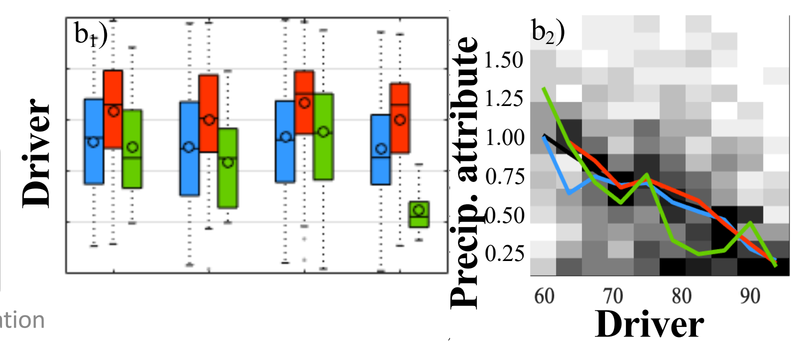
- Cloud base height [KAZR2+Ceilometer]
- Cloud top height [KAZR2]
- Cloud thickness [KAZR2+Ceilometer]

To overcome scatter emerging from the different time resolutions and measurement uncertainties, establish correlations using observations binned by ”driver intensity”

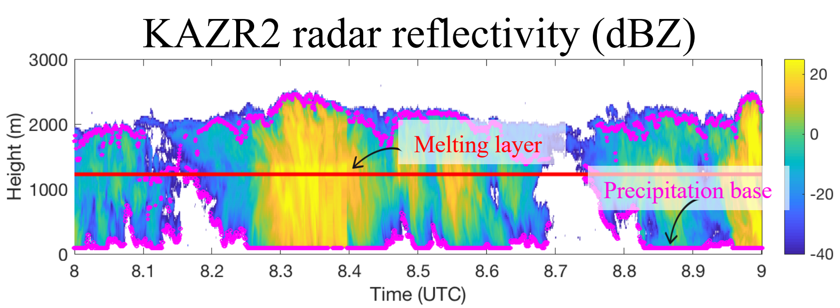
Seasonal cycle and regime differences per season

Correlation between precip. attribute and driver



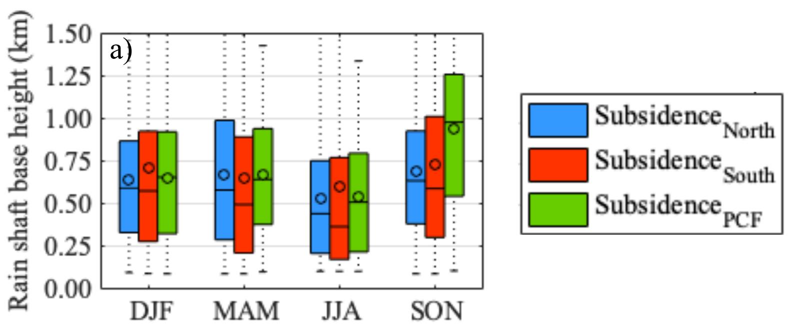


Lowest Height With Rain

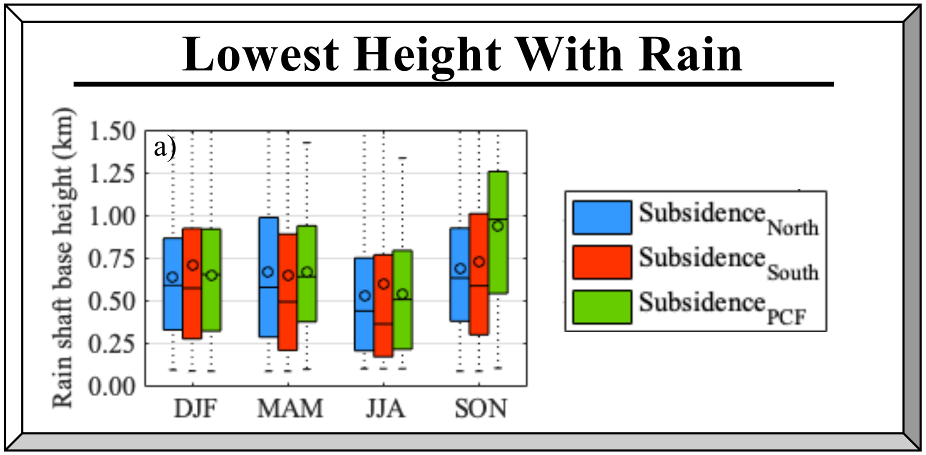


Estimate precipitation base height using 2-s resolution observations then take the hourly average

Lowest Height With Rain



Subsidence$_{\text{Post-Cold Front}}$ have rain that does not reach as far down especially in the fall

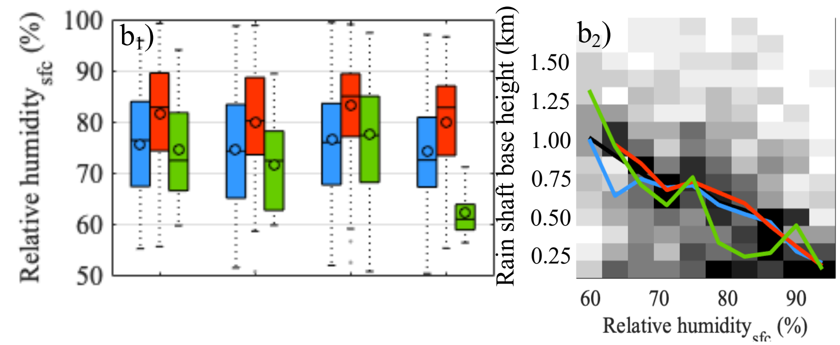


Subsidence$_{\text{Post-Cold Front}}$ have rain that does not reach as far down especially in the fall

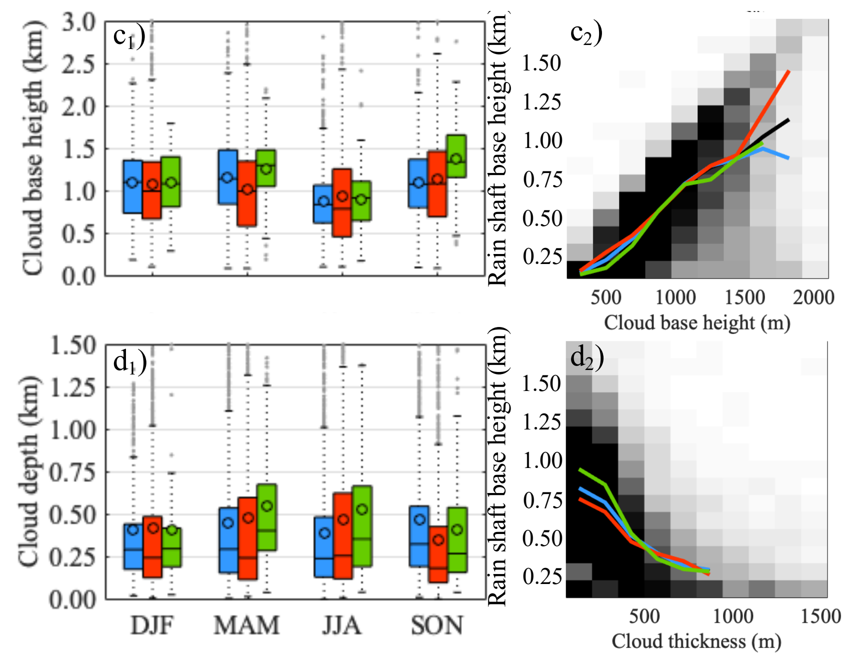
Sub$_{PCF}$ also presents: 1) lower RH$_{sfc}$, 2) higher CBH and 3) somewhat deeper clouds

From the correlations, only the RH$_{sfc}$ and CBH trends are consistent with the rain trend <u>suggesting that RH$_{sfc}$ and CBH play a more important role in determining the lowest height where rain can penetrate.</u>

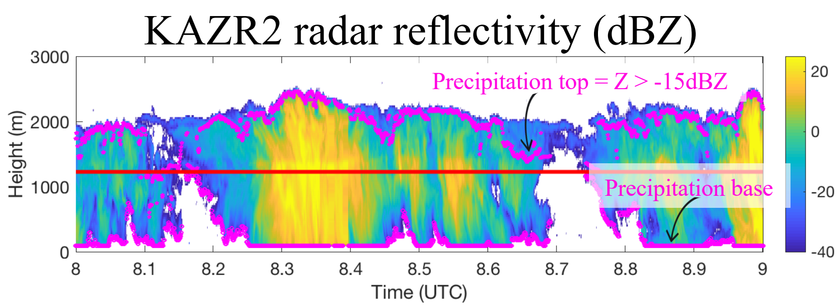
Correlated Large-Scale Driver



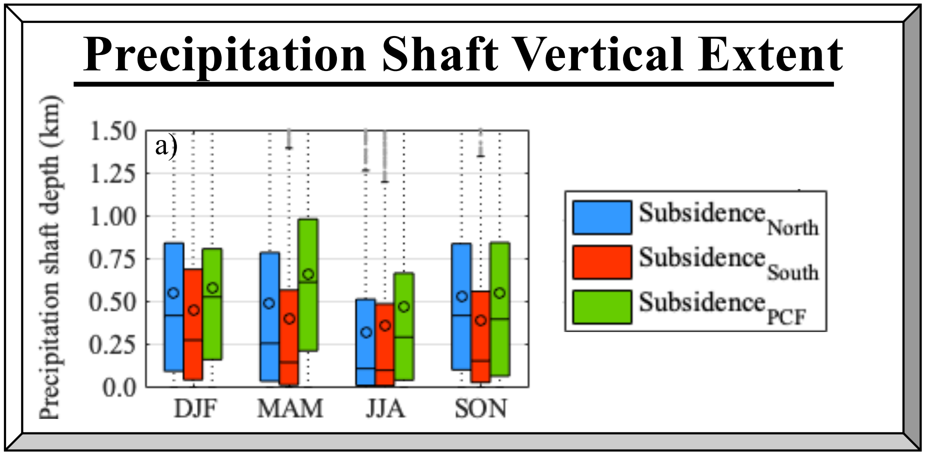
Correlated Cloud Attributes



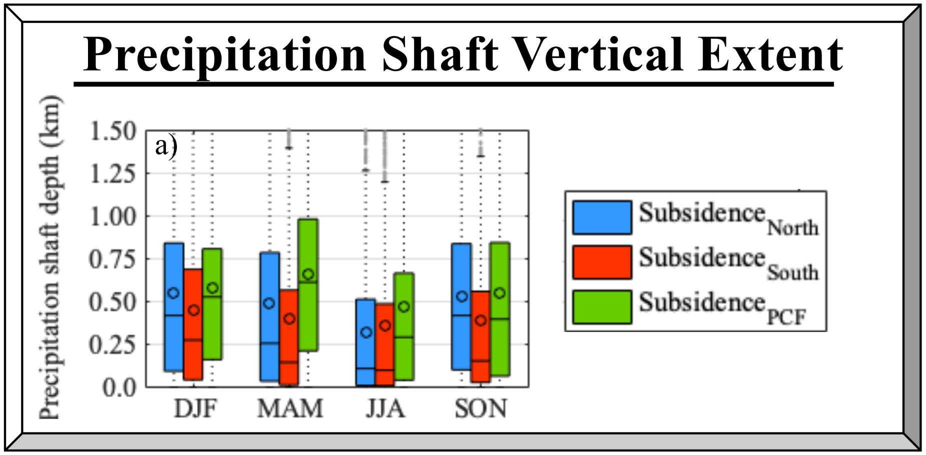
Precipitation Shaft Vertical Extent



Estimate distance between precipitation top and precipitation base height using 2-s resolution observations then take the hourly average



Subsidence$_{\text{Post-Cold Front}}$ have deepest rain, especially in spring

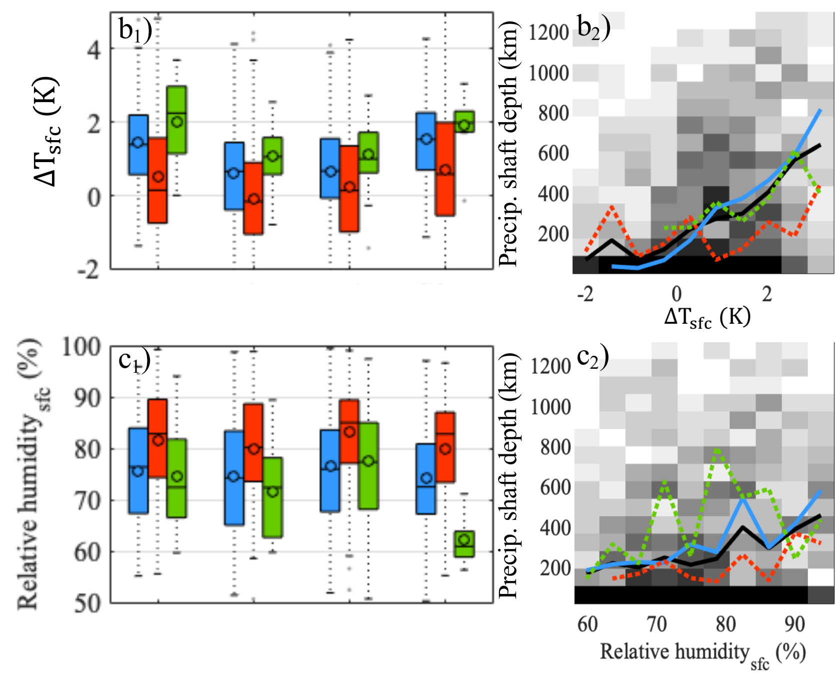


Subsidence$_{\text{Post-Cold Front}}$ have deepest rain, especially in spring

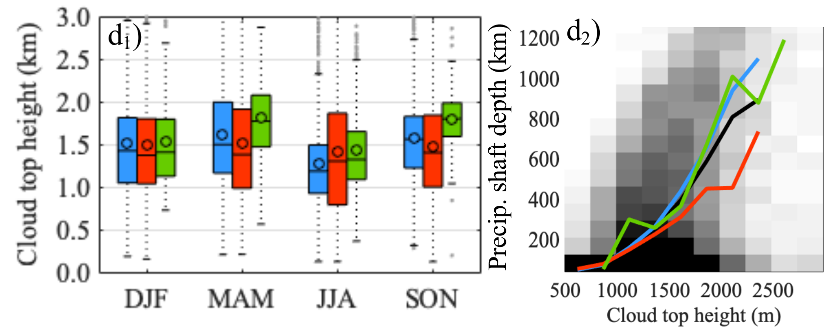
Sub$_{\text{PCF}}$ also presents: 1) higher sea-air temperature contrast (ΔT_{surf}), 2) lower RH_{sfc} and 3) somewhat higher cloud top height

Only changes in ΔT_{surf} and CTH are consistent with the rain trend suggesting that ΔT_{surf} and CTH play a more important role in determining the depth of precipitation shaft.

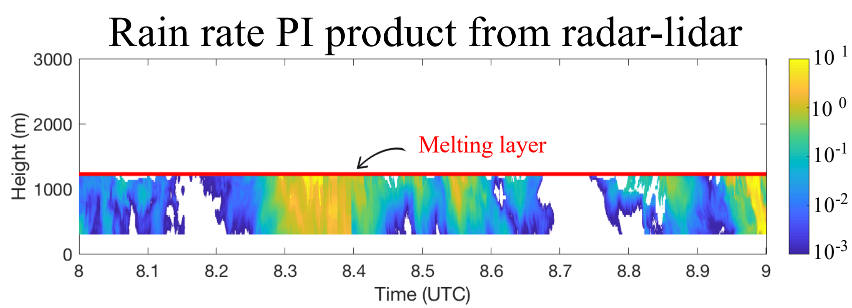
Correlated Large-Scale Drivers



Correlated Cloud Attribute

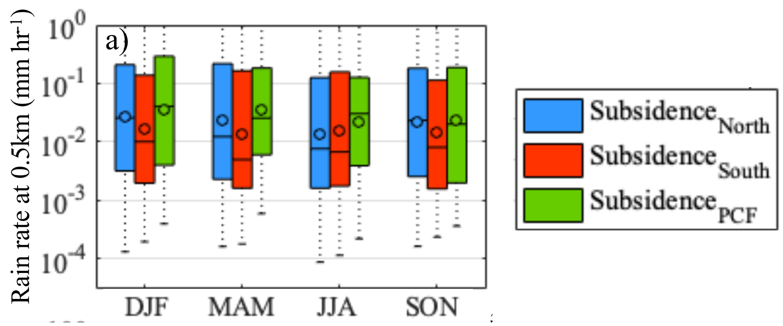


In-rain rain rate 0.5 km a.g.l.

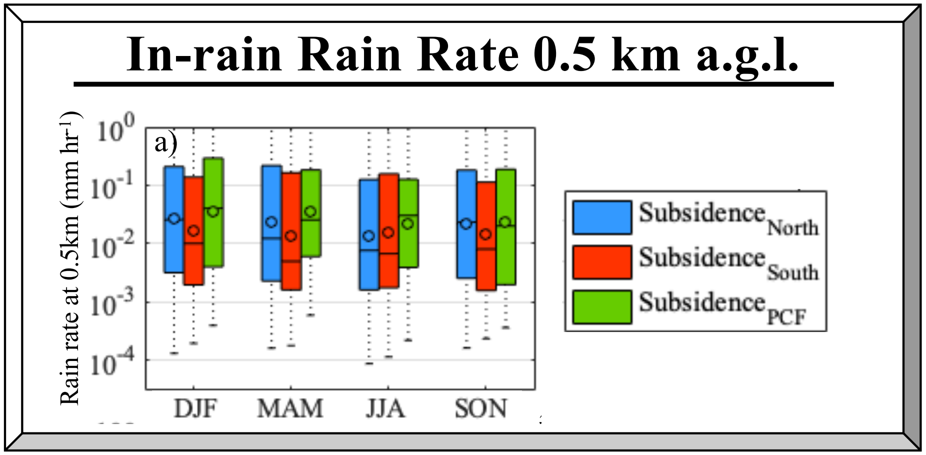


Average the rate of only rain shafts reaching 0.5 km during the hour

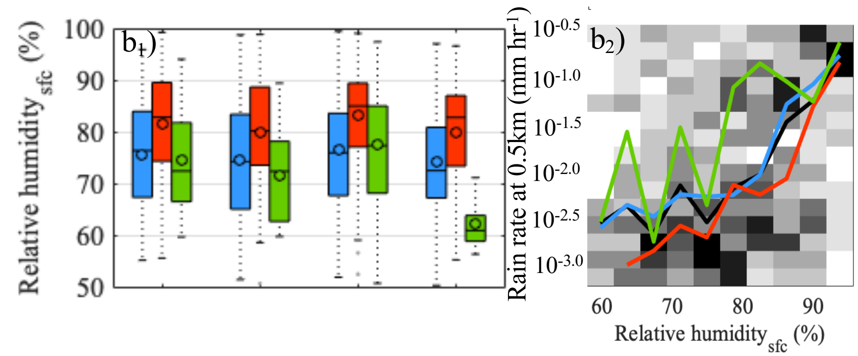
In-rain Rain Rate 0.5 km a.g.l.



No distinction across subsidence regimes and seasons



Correlated Large-Scale Driver



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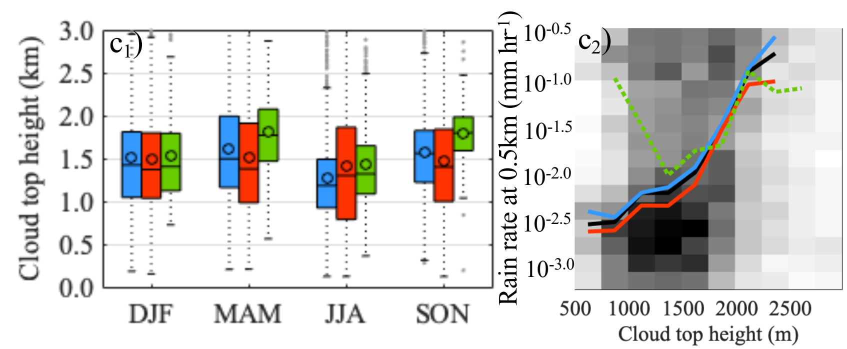
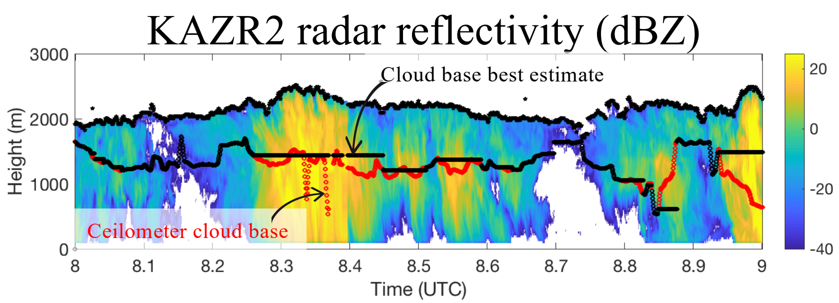
Correlated Cloud Attribute



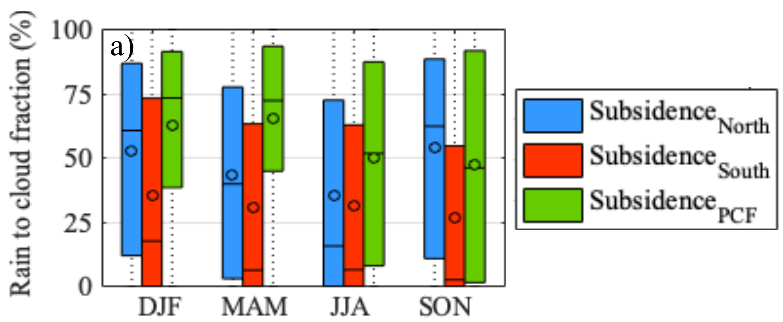
Sub$_{PCF}$'s lower RH$_{sfc}$, which is related to a reduction in rain rate at 0.5 km, seems balanced by the presence of higher cloud tops (i.e., deeper clouds) which tend to produce more intense rain at 0.5 km.

Rain to Cloud Fraction

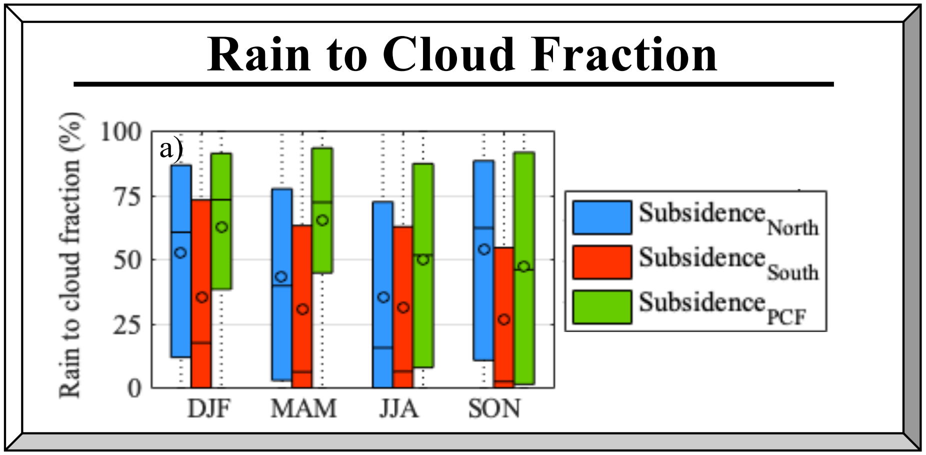


In an hour, #profiles with precip. divided by # profiles with cloud

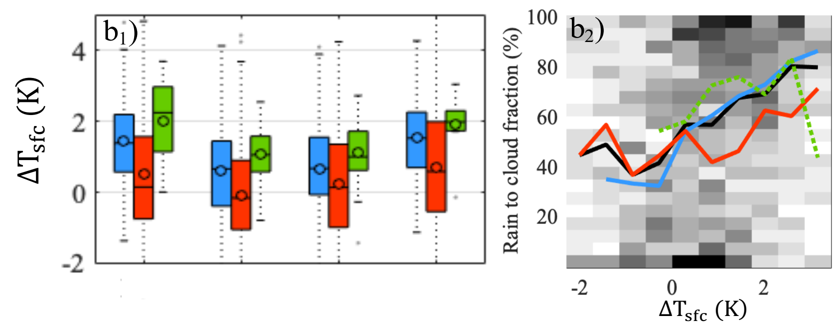
Rain to Cloud Fraction



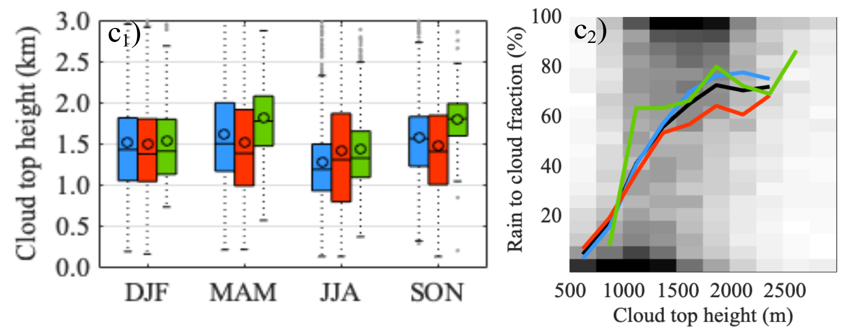
Subsidence Post-Cold Front have higher rain to cloud fraction, highest in winter and spring



Correlated Large-Scale Driver



Correlated Cloud Attribute



Subsidence $_{\text{Post-Cold Front}}$ have higher rain to cloud fraction, highest in winter and spring

Sub_{PCF} also presents: 1) higher sea-air temperature contrast (ΔT_{surf}) and somewhat higher cloud top height

Both changes in ΔT_{surf} and CTH are consistent with the rain trend <u>suggesting that ΔT_{surf} and CTH are both related to cloud propensity to precipitate.</u>

Can One Large-Scale Driver Explain it All?

Fletcher et al. (2016) presented the Marine Cold Air Outbreak (MCAO) parameter M

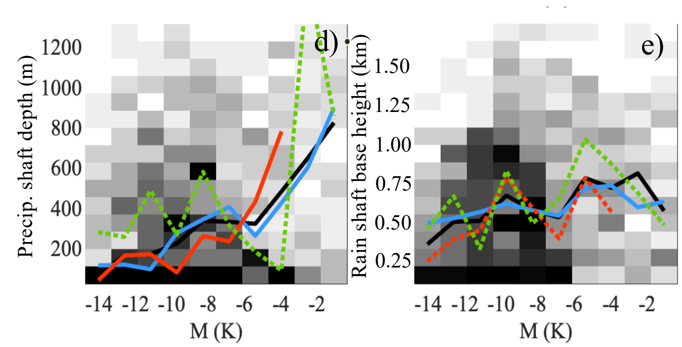
M parameter = θ_{skin}- θ_{800hPa} [MERRA-2/Sonde]

Higher M = Higher frequency of open cells (*McCoy et al.*, 2017)

Higher M = Higher cloud top height (*Naud et al.,* 2018)

Higher M = Higher cloud base height (*Naud et al.,* 2018)

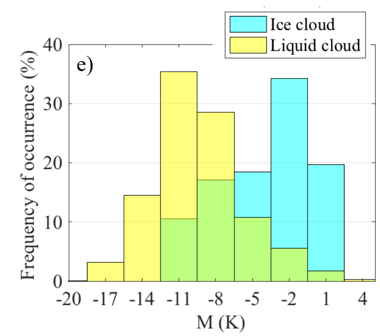
Higher M = Deeper clouds (*Naud et al.,* 2018)



Here we found:

Higher M = Deeper rain shafts that do not penetrate as far down

Higher M = Rain produced through mixed-phase microphysics

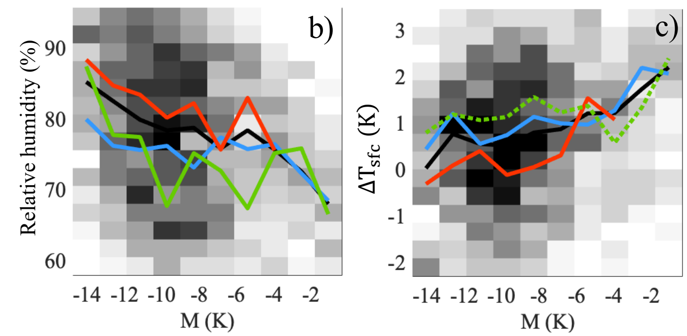


While relationships are significant they are not as clear as with clouds

Conclusions

Come see our poster this afternoon

The success of the M parameter could lie in its relationship to both the sea-air temperature contrast and surface relative humidity which were both found to be highly correlated to several precipitation characteristics in subsidence regimes.



Post-Cold Frontal conditions relative to general subsidence

- rain that does not reach as far down especially in the fall
- deepest rain shafts, especially in spring
- higher rain to cloud fraction, highest in winter and spring
- no distinction in intensity of rain reaching 0.5 km across subsidence regimes and seasons

Drizzle PI product available in the ARM archive

For the Eastern North Atlantic Observatory

For the period 2015-10-01 and 2018-09-29

Retrievals of:

- Rain Rate with its uncertainty
- Melting layer height
- Drizzle water content with its uncertainty
- Drizzle diameter (D_0) and its uncertainty
- Drizzle number concentration (N) with its uncertainty
- Shape of drizzle drop size distribution (Mu)
- Drizzle fall velocity with its uncertainty
- Eddy dissipation rate with its uncertainty