Post-cold-frontal clouds over the ARM ENA site: observations and comparison with other locations

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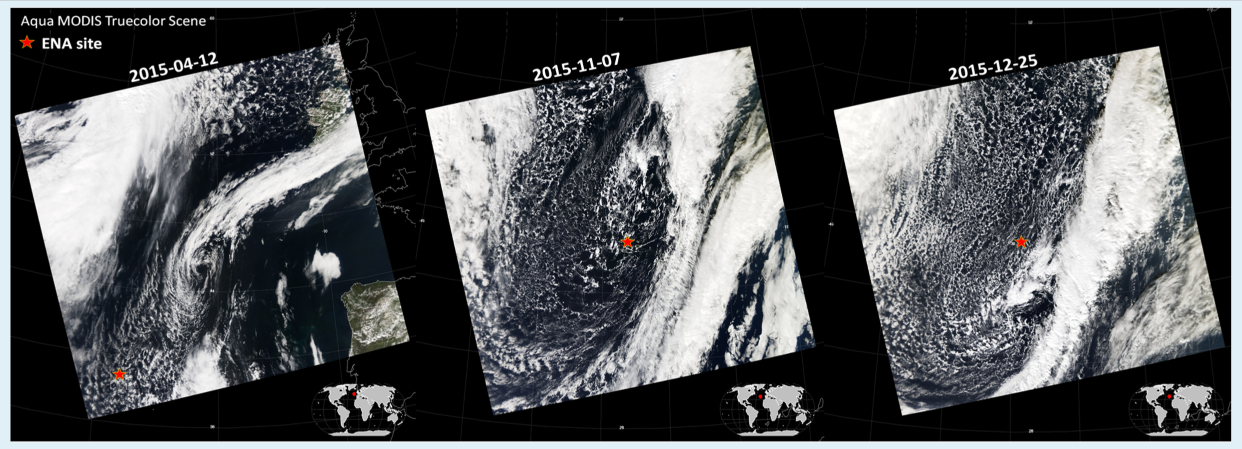
Goal: Improve understanding of cloud physics and atmospheric dynamics interactions in the sector of extratropical cyclones behind the cold fronts

Motivation: One major issue with GCMs: representation of low level clouds, esp. in cold sector of cyclones.

Work plan:

1. Study properties of **post-cold frontal (PCF)** clouds using ENA + CAP-MBL observations and relation with environmental conditions.
2. Contrast relation between cloud and large scale environment with Gulf stream and arctic coastal regions (Bear Island)
3. Test configurations of WRF + CAM models to evaluate relative importance of PBL, microphysics and convection for representation of post-cold frontal clouds (Talk by F. Lamraoui, Tuesday 11.30 am)



Part 1. Clouds vs. Environment at the ENA site: ground-observations

Data and metrics

Identify frontal passages during CAP-MBL and since 2013 at ENA:

Automated front detection: Use cyclone tracking database (MCMS Bauer et al., 2016) and cold front detection (Naud et al., 2016) to identify frontal passages (https://data.giss.nasa.gov/storms/obs-etc/); 2) examine wind direction change from south to northerly to fix start and end time of PCF conditions.

=> 77 cases identified lasting at least 2 hours

=> Non-PCF periods for comparison: NE wind + subsidence

Observations from ENA:

- Cloud base and top height, vertical extent: MPL Z. Wang product
- Radiosoundings, Met. Station for winds, surface temperature, pressure, precipitation, MWR PW
- MERRA-2 vertical velocity (500 hPa) + skin temperature

Metrics for environment characterization:

EIS: θ_{700}-θ_{surf} -Γ_m^{850}(Z_{700}-LCL) (RS/met.)

MCAO M: θ_{skin}- θ_{800} (MERRA-2/RS)

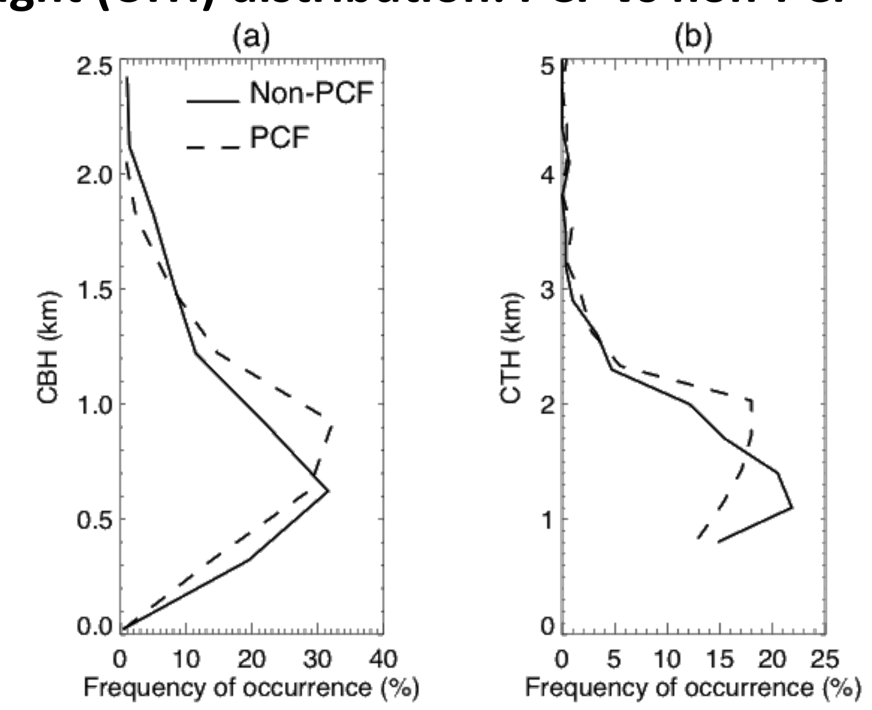
ΔT_{surf} = T_{skin}-T_{air} (MERRA-2/Met)

Subsidence strength ω_{500} (MERRA-2)

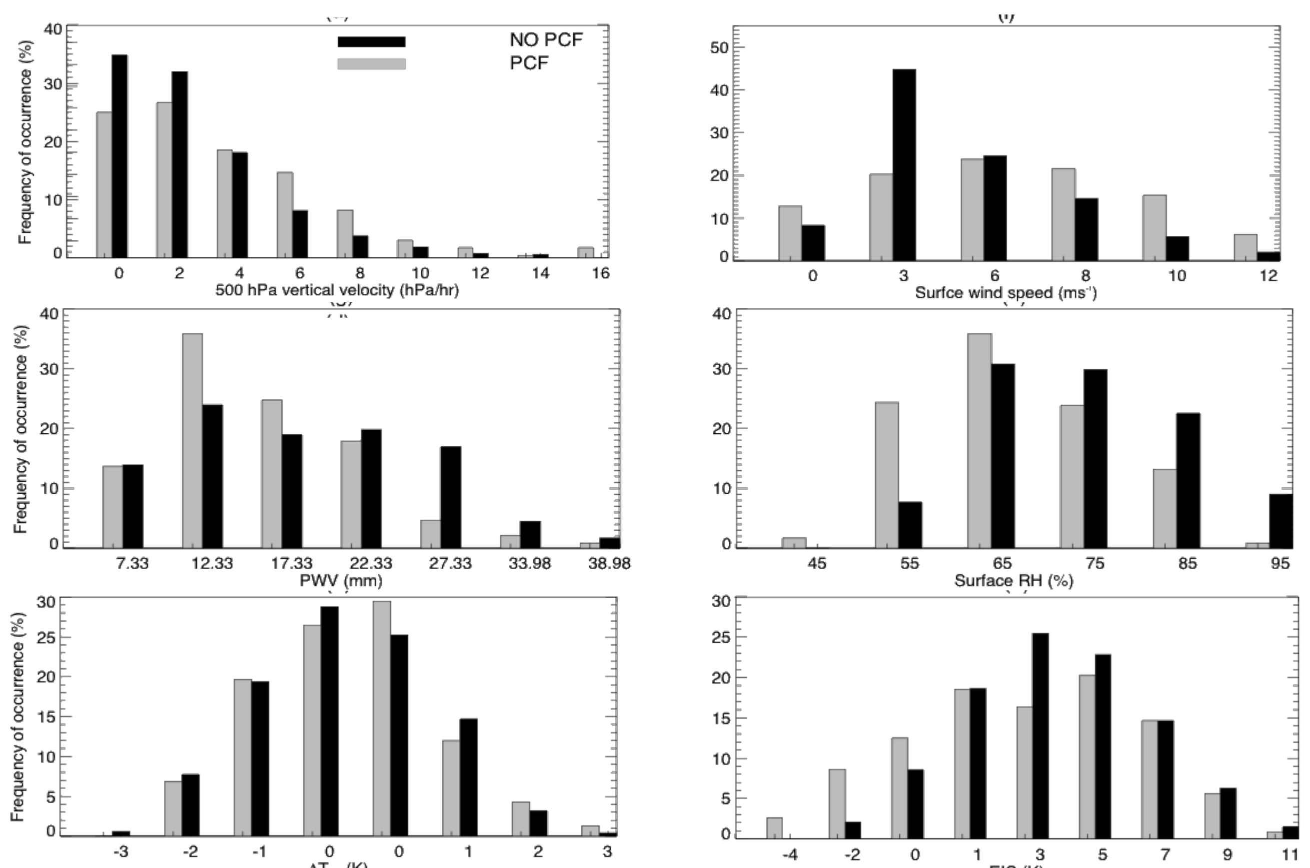
Surface RH and wind speed (met)

PW (MERRA-2/MWR)

1.A) Cloud Base Height (CBH) and cloud top height (CTH) distribution: PCF vs non-PCF

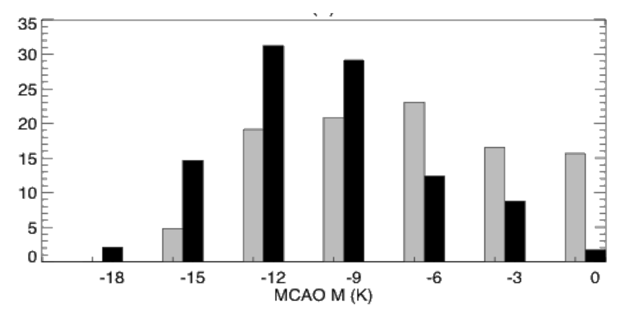


=> CBH and CTH higher in PCF

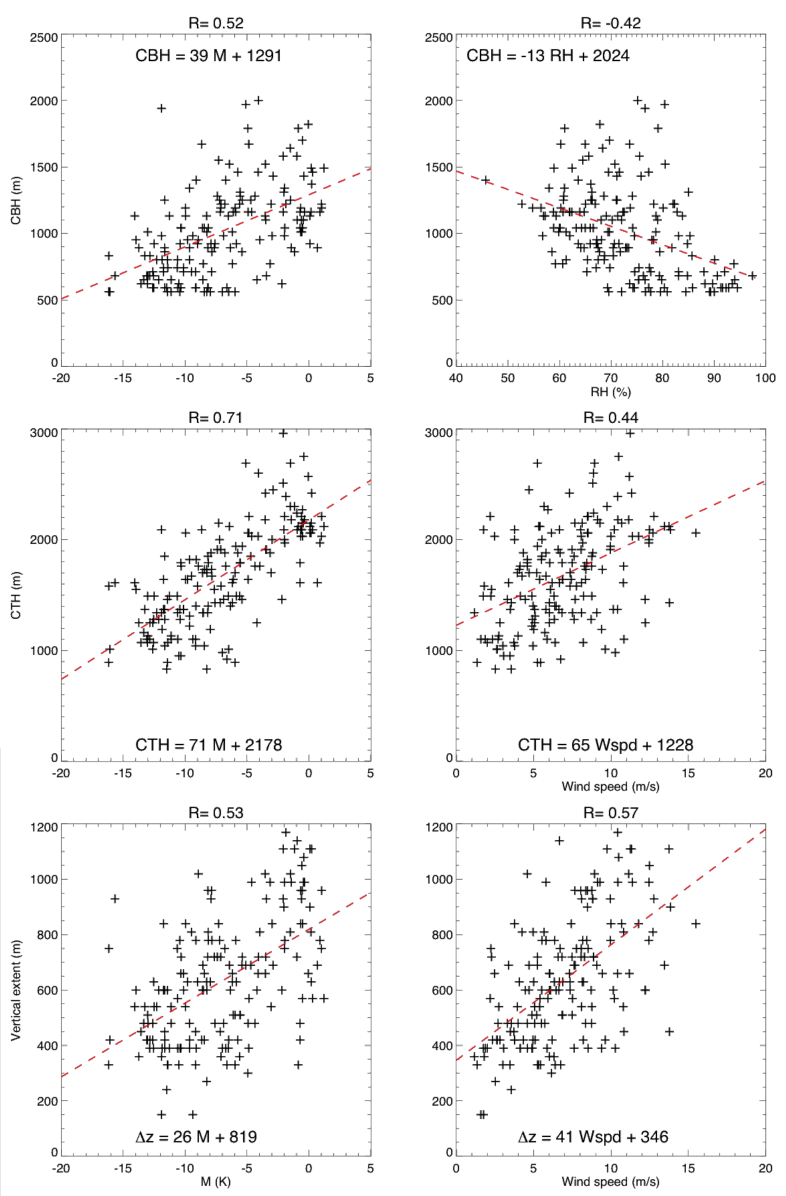


1.B) PCF vs. NON-PCF: Environmental conditions

- PCF= stronger subsidence / surface winds
- PCF = drier
- PCF = weaker inversion strength & static stability



1.C) PCF: largest correlations between cloud and metrics



R PCF (*non-PCF*)	EIS	M	ΔT_{surf}	ω_{500}	Wind speed	RH	PW
CBH	-0.52 (*-0.36*)	0.55 (*0.51*)	0.03 (*-0.05*)	0.16 (*0.12*)	0.20 (*0.01*)	-0.42 (*-0.27*)	-0.29 (*-0.27*)
CTH	-0.56 (*-0.42*)	0.72 (*0.70*)	0.24 (*0.14*)	0.24 (*0.22*)	0.45 (*0.19*)	-0.37 (*-0.21*)	-0.44 (*-0.39*)
Vertical extent	-0.28 (*-0.16*)	0.52 (*0.43*)	0.37 (*0.34*)	0.24 (*0.22*)	0.56 (*0.28*)	-0.12 (*0.04*)	-0.42 (*-0.28*)

=> PCF and non-PCF show good correlation between cloud and M. PCF CBH show some correlation between CBH/RH and CTH+extent/wind speed, but not happening in non-PCF

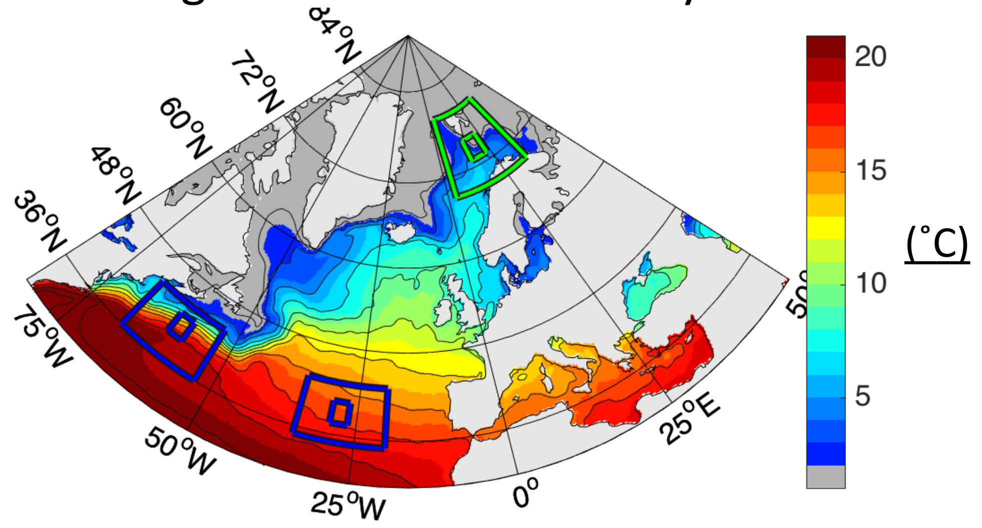
Part 1, Summary:

1) Subsidence/wind strength + larger M => deeper PBL in PCF => CBH & CTH higher than non-PCF

2) M (=θ_{skin}- θ_{800}) well correlated with CBH/CTH/thickness, but in PCF wind speed show correlation for CTH/thickness and RH/PW for CBH => impact of SHF?

Part 2. Comparing ENA, Gulf Stream, and Bear Island: large-scale perspective

Sea Surface Temperature Climatology & Regions used for the analysis



Season DJF, Time period: 1982 – 2006.

Blue and green boxes indicate the Gulf Stream, ENA, and Bear Island study regions. For each location: small boxes used to test for relationships at mesoscale; large boxes used to test synoptic scale. Synoptic scale is shown in all figures. At mesoscale, a similar relationship occurs but is is always much noisier.

SST source: AVHRR

2.A) Composites using 500-hPa vertical velocity

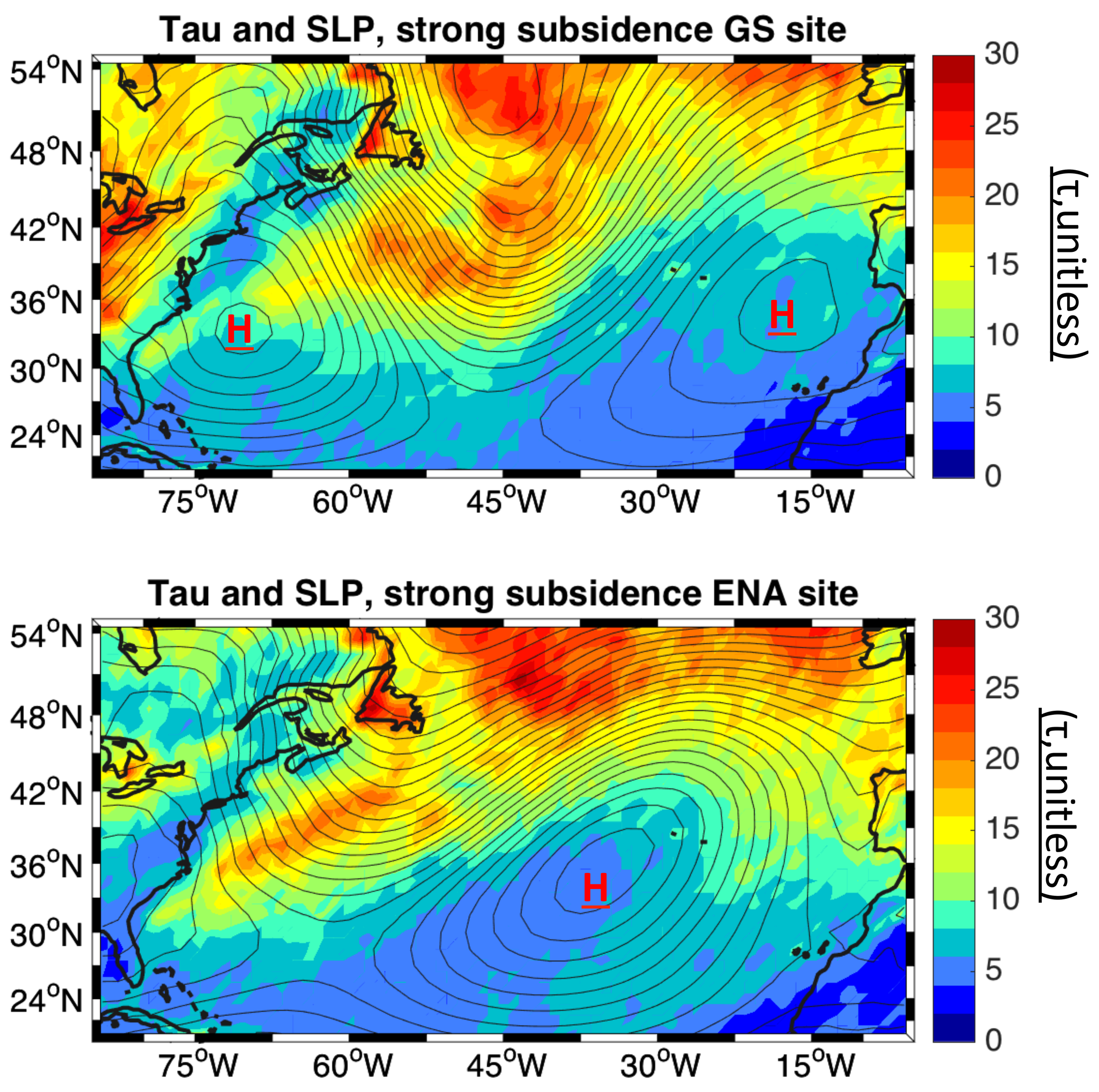
Top: 100 strongest subsidence events over the Gulf Stream region. **Bottom**: same as top, for the ENA region.

Shading: cloud optical depth using MODIS gridded data.

Contours: sea level pressure

Message: subsidence and surface H are linked, suggesting synoptic scale organization.

Data source: MODIS for clouds and Reanalysis for circulation

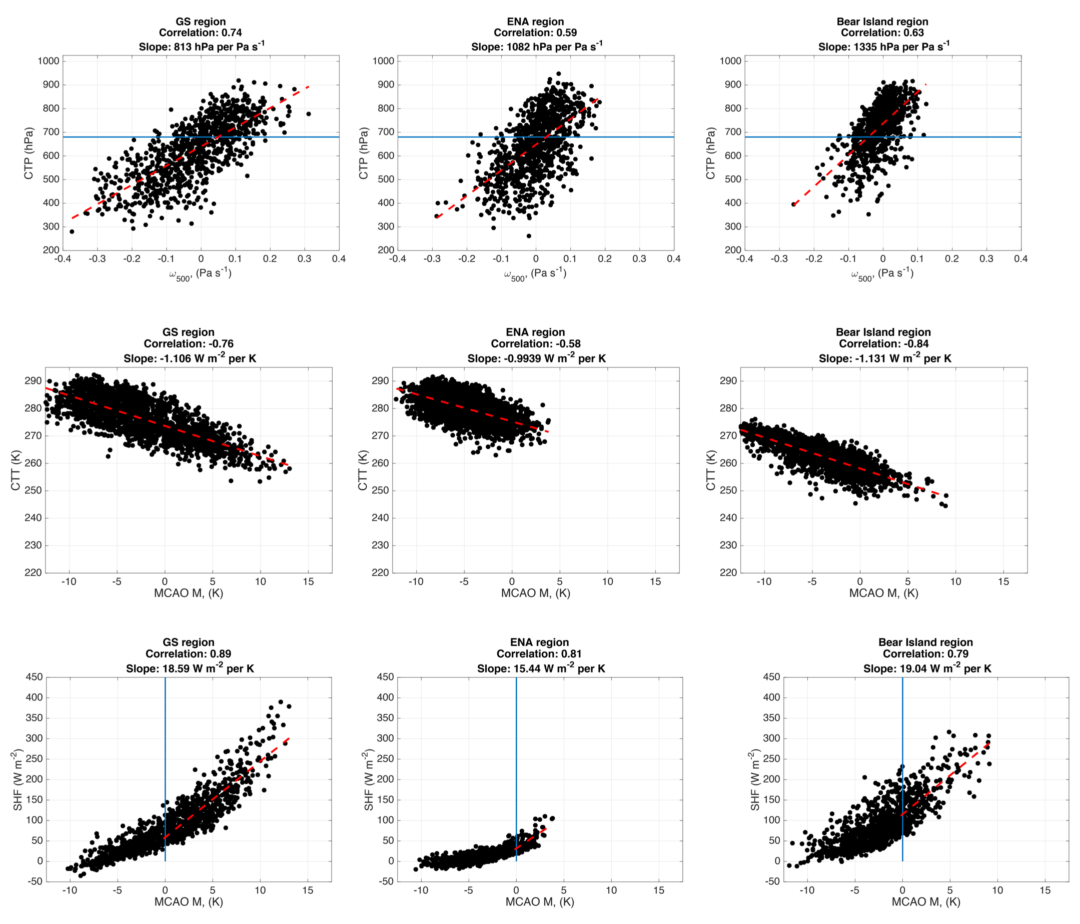


2.B) Clouds vs. environment

500-hPa vertical velocity (ω) vs. cloud top pressure. All clouds.

Lower troposphere stability (M) vs. cloud top temperature. Low clouds only (CTP > 680 hPa)

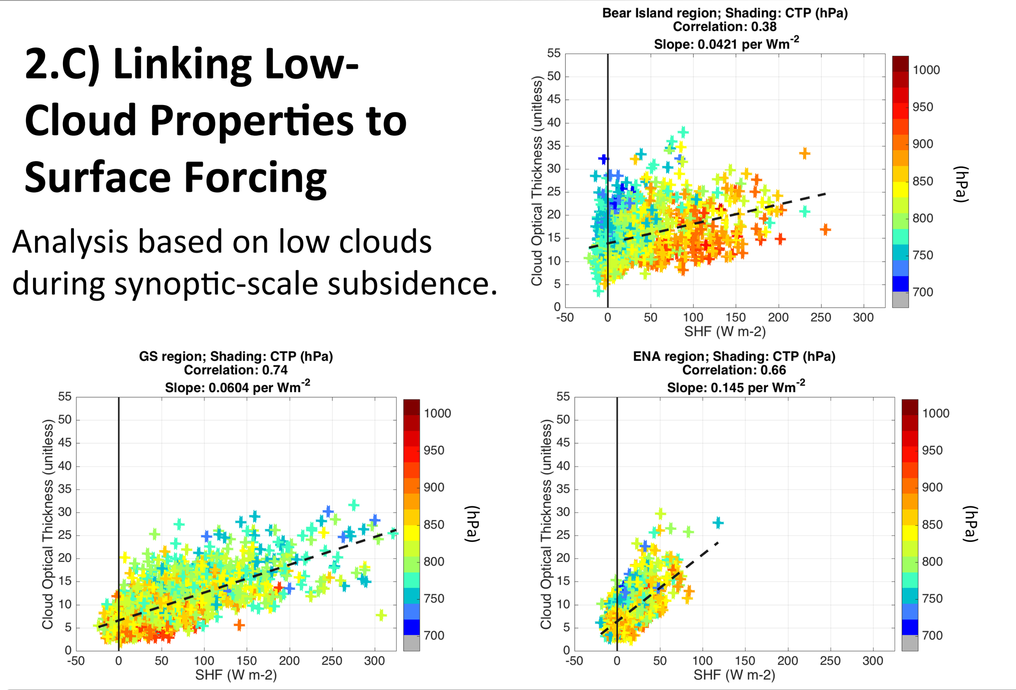
Lower troposphere stability (M) vs. surface sensible heat flux.



Interpretation. top row shows CTP relationship with circulation consistent with extratropical cyclone circulation. Middle row show CTT for low clouds relate to lower troposphere stability (M). Bottom row confirms others' results on relationship between SHF and M

2.C) Linking Low-Cloud Properties to Surface Forcing

Analysis based on low clouds during synoptic-scale subsidence.



Overall Conclusions:

- Synoptic forcing within PCF results in deeper low-clouds as compared to typical conditions.
- In regions of synoptic-scale subsidence, cloud properties scale linearly with inversion strength and surface forcing, as shown by parameter M.
- The range of surface forcing is weakest at the ENA site, likely due to ocean location; maybe an analog to southern hemisphere.