

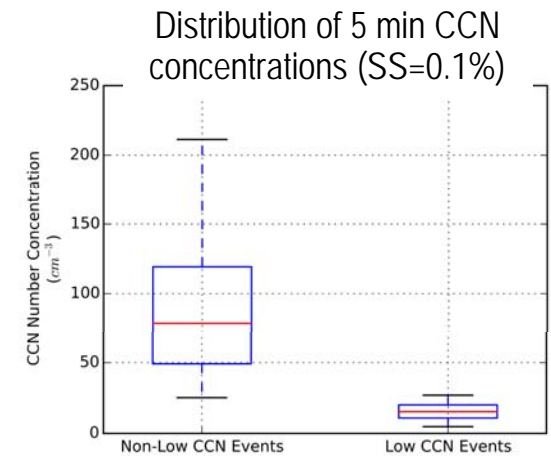
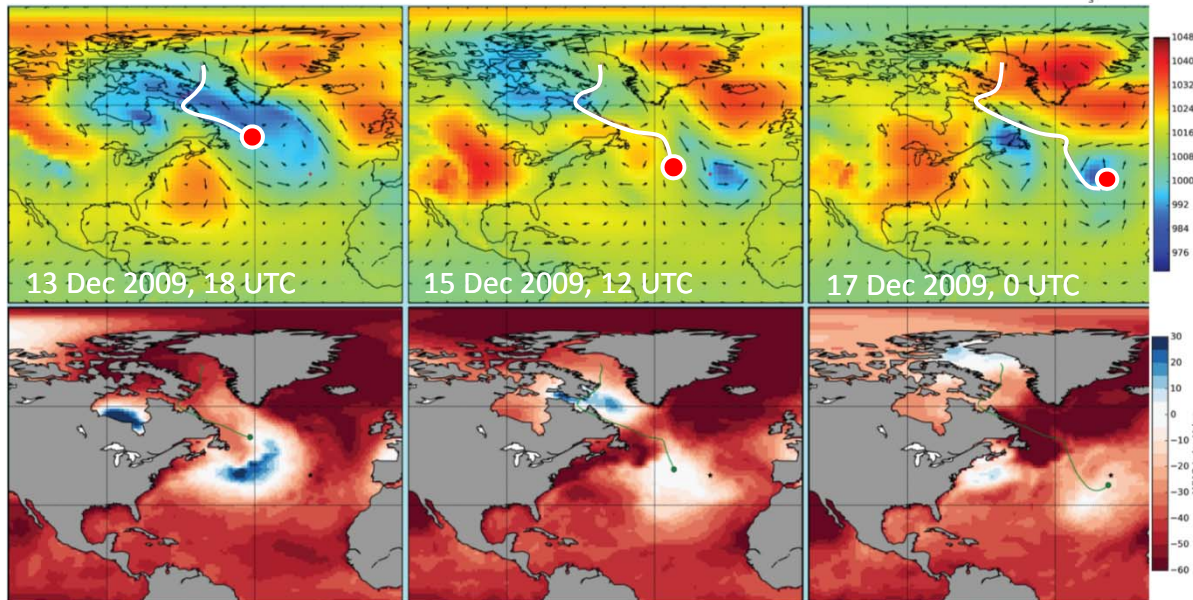
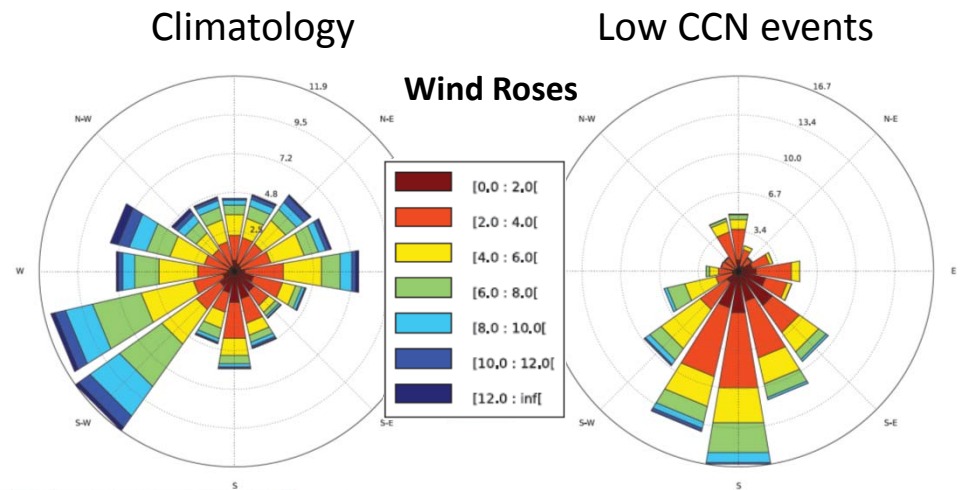
Low CCN concentration events over the ENA: seasonality, meteorology and drivers

Robert Wood, University of Washington

Jayson Stemmler, Jasmine Rémillard, Anne Jefferson

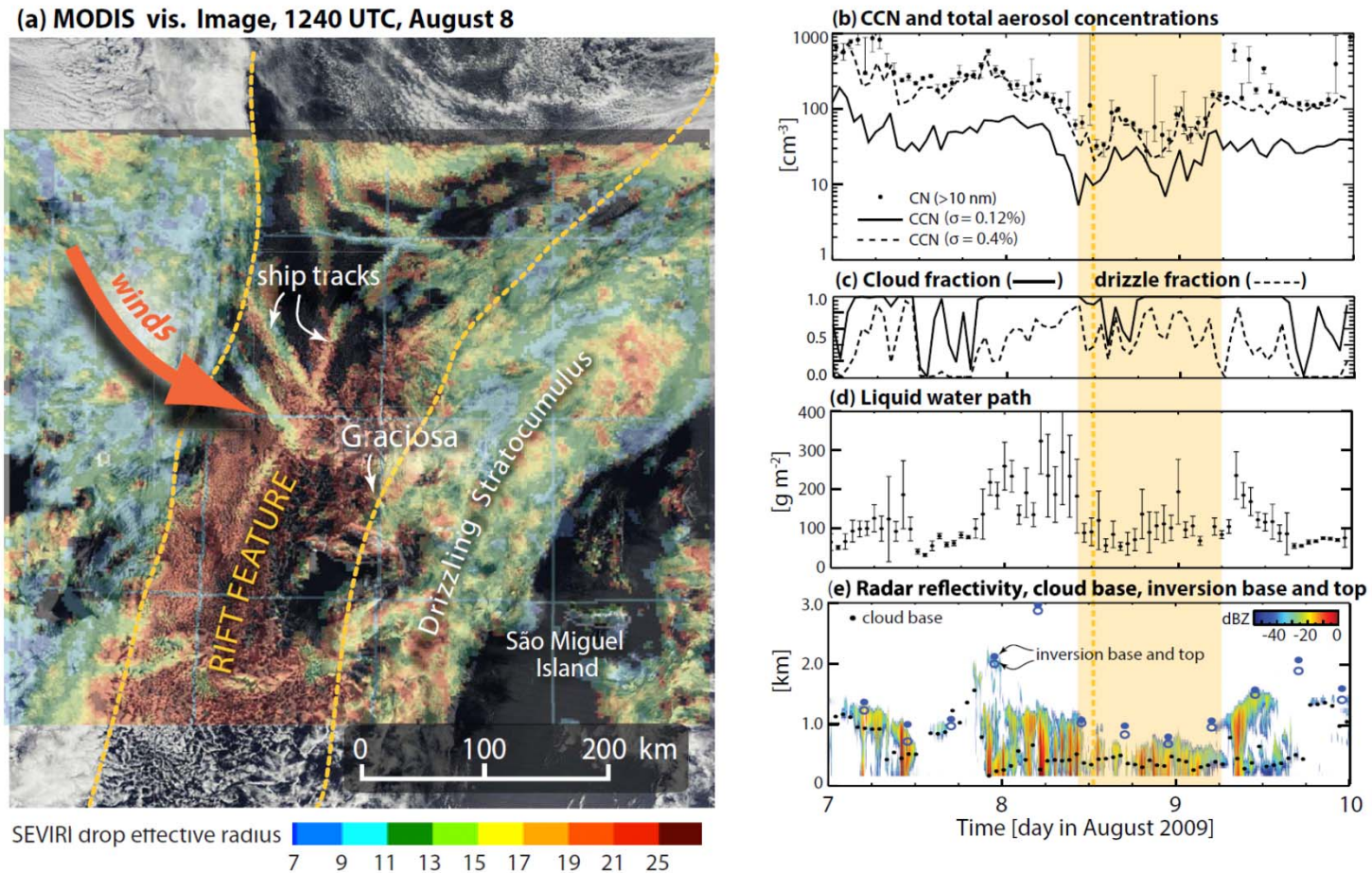
Low CCN events in CAP-MBL (2009-2010)

- Defined as 6 hourly mean $N_{\text{CCN},0.1\%} < 20 \text{ cm}^{-3}$
- Total of 56 events occurring on 36 individual days
- Weak southerly flow associated with most events
- Link with marine cold air outbreaks



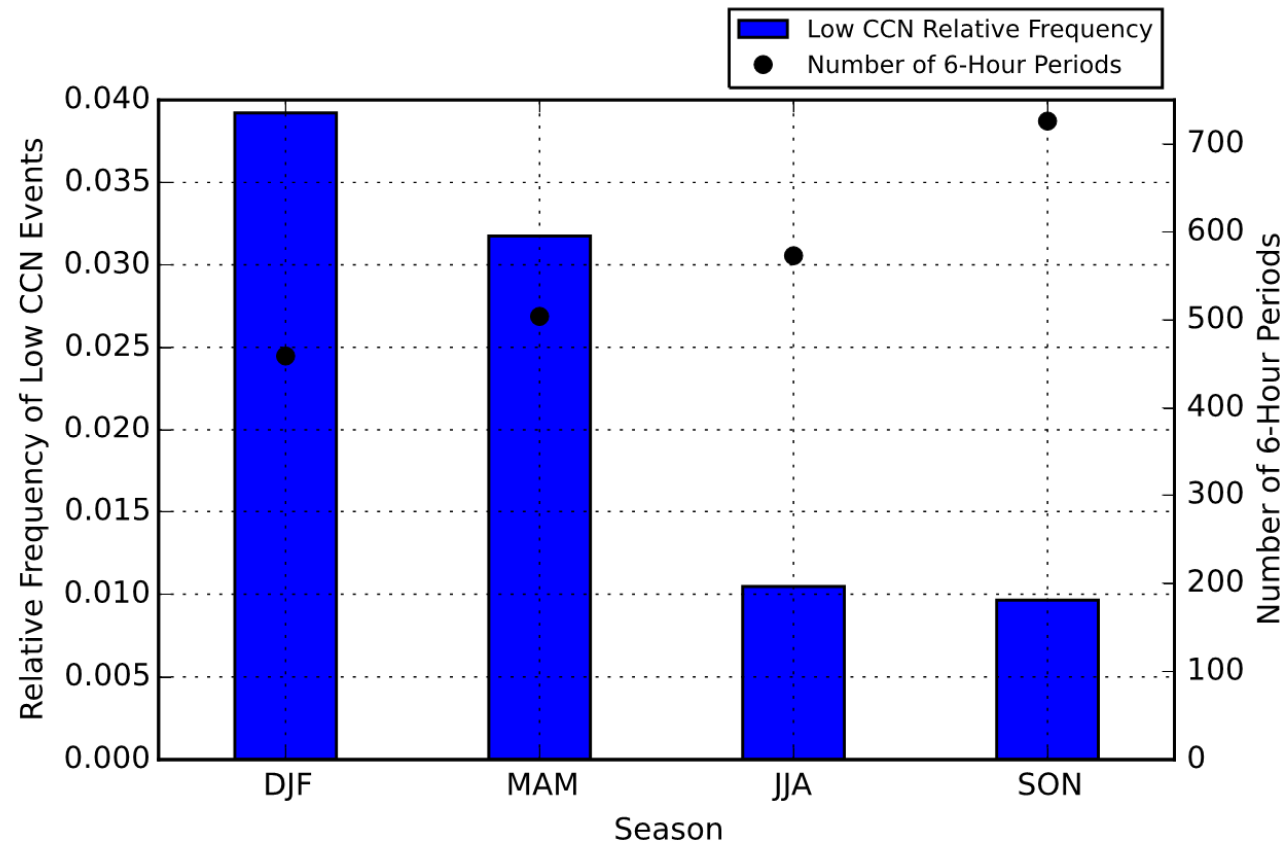
See also ENA Site Science poster, Tuesday

Low CCN event



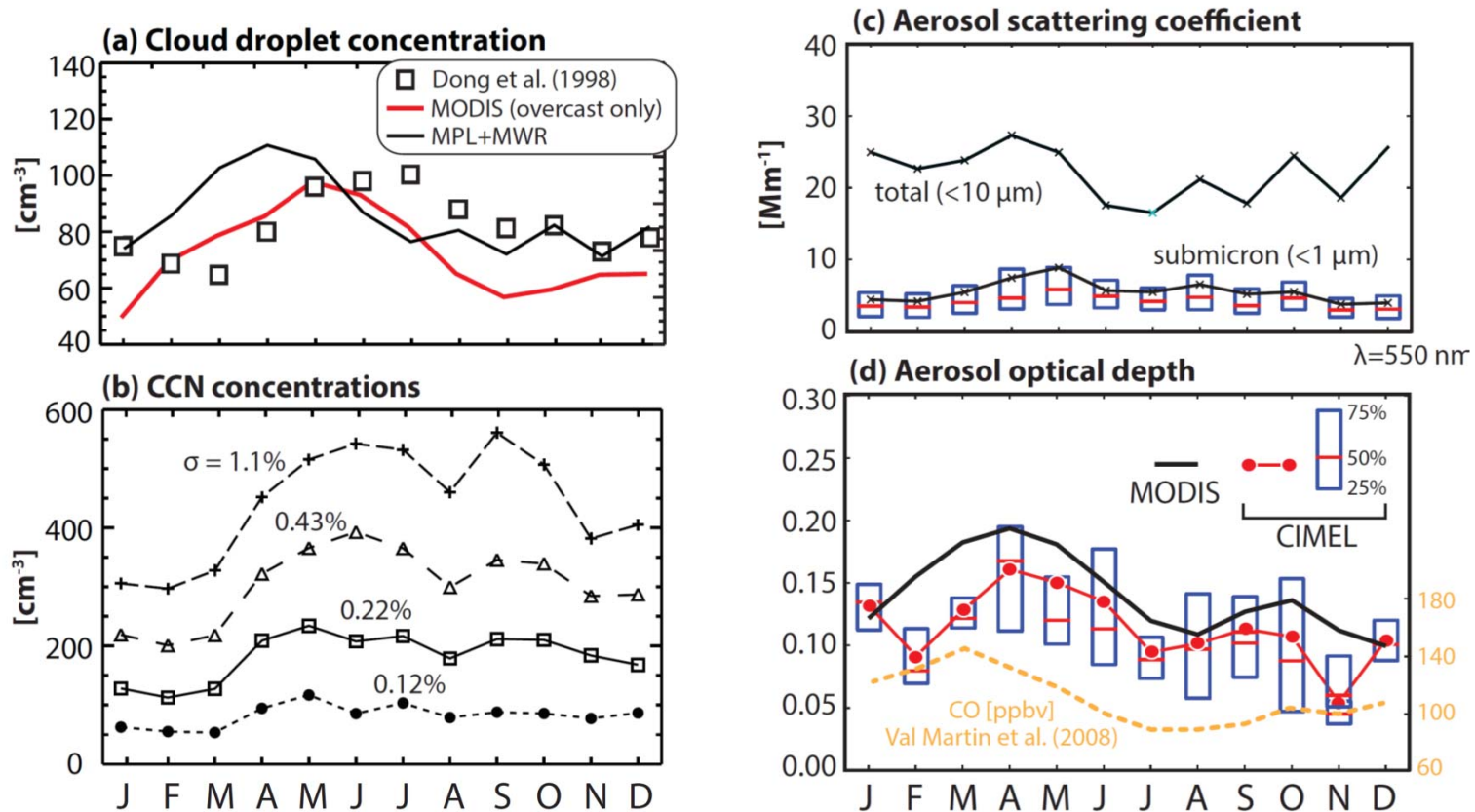
- Often associated with open cell structures over Graciosa

Seasonality of low CCN events



- 80% of low CCN events occur during winter and spring

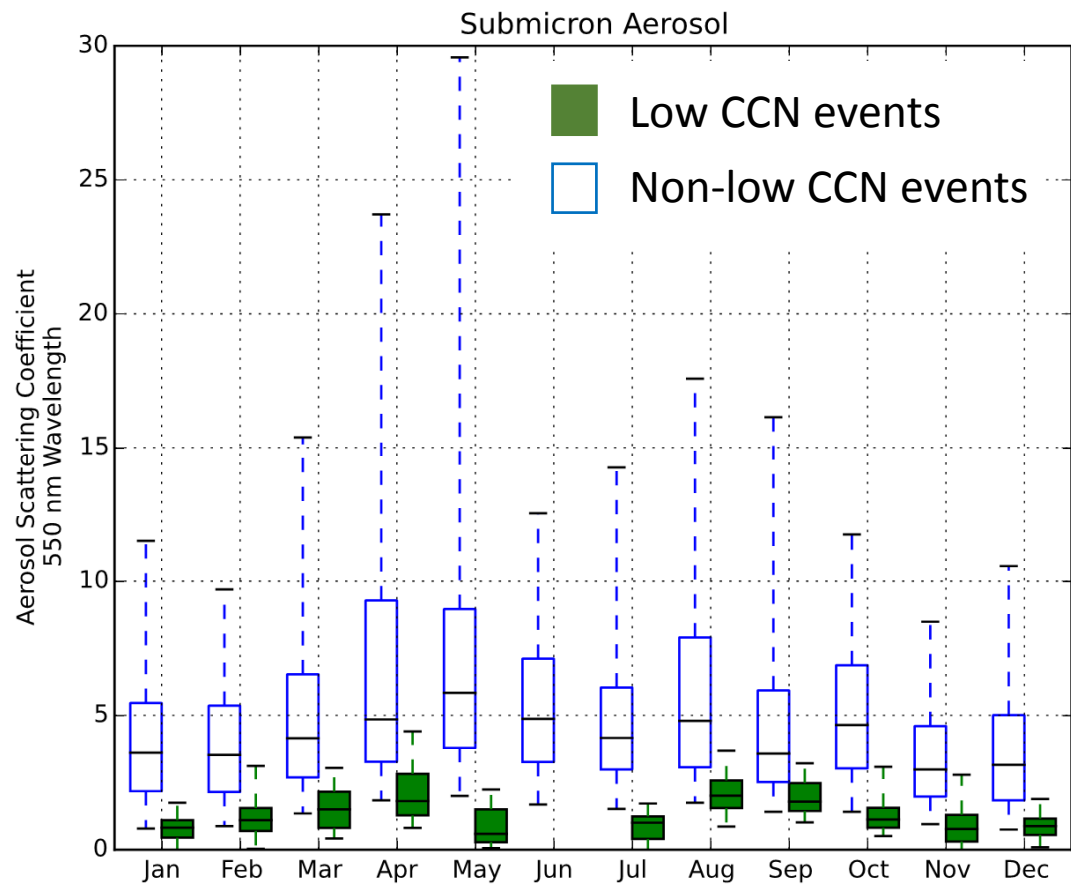
Seasonal cycle: aerosol and cloud microphysics



Wood, R., M. Wyant, C. S. Bretherton, J. Rémillard, P. Kollias, J. Fletcher, J. Stemmler, S. deSzoeko, S. E. Yuter, M. Miller, D. Mechem, G. Tselioudis, C. Chiu, J. Mann, E. O'Connor, R. Hogan, X. Dong, M. Miller, V. Ghate, A. Jefferson, Q. Min, P. Minnis, R. Palinkonda, B. Albrecht, E. Luke, C. Hannay, Y. Lin, 2015: **Clouds, Aerosol, and Precipitation in the Marine Boundary Layer: An ARM Mobile Facility Deployment.** *Bull. Amer. Meteorol. Soc.*, **96**, 419-440.

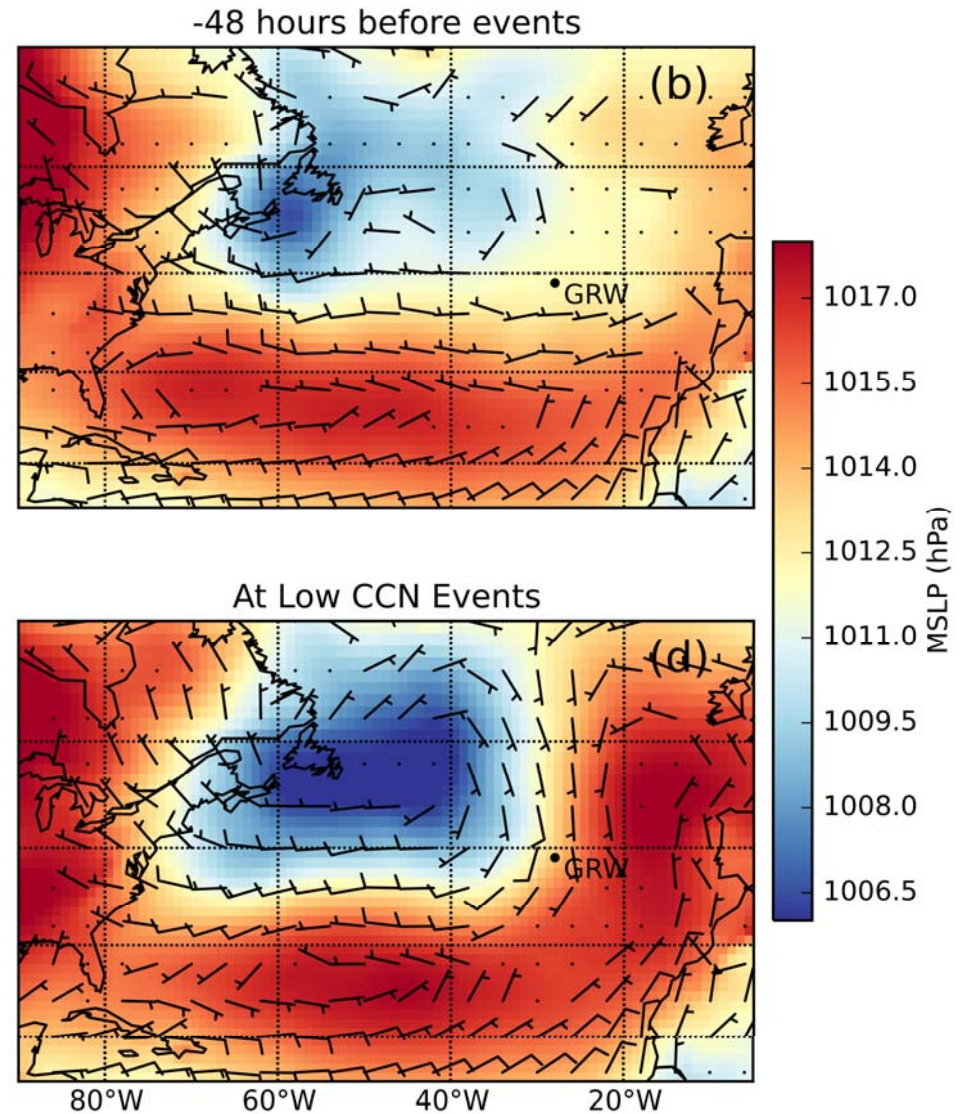
Low submicron scattering during low CCN events

- Low events associated with factor of 2-3 reduction in submicron scattering
- Similar fractional reduction for total scattering (not shown), suggestive of reduced sea-spray aerosol



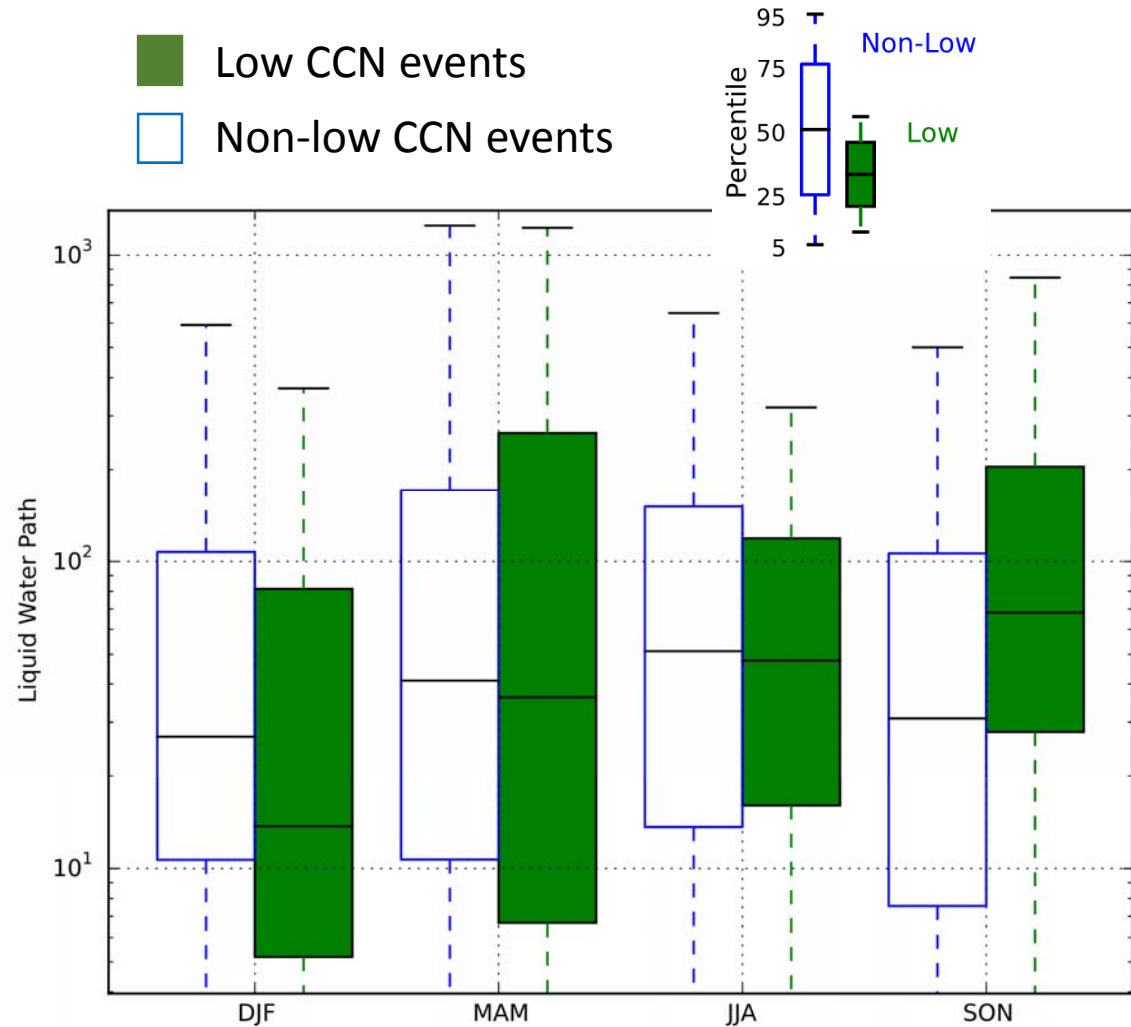
Low CCN events associated with development of synoptic scale low pressure to west and north of Azores

- Composite mean sea-level pressure (MSLP) for low CCN events 48 hr before low CCN events and at the start of events at Graciosa.
- Mean barbs indicate mean wind speeds in knots (full barb=10 kt; half barb=5 kt).

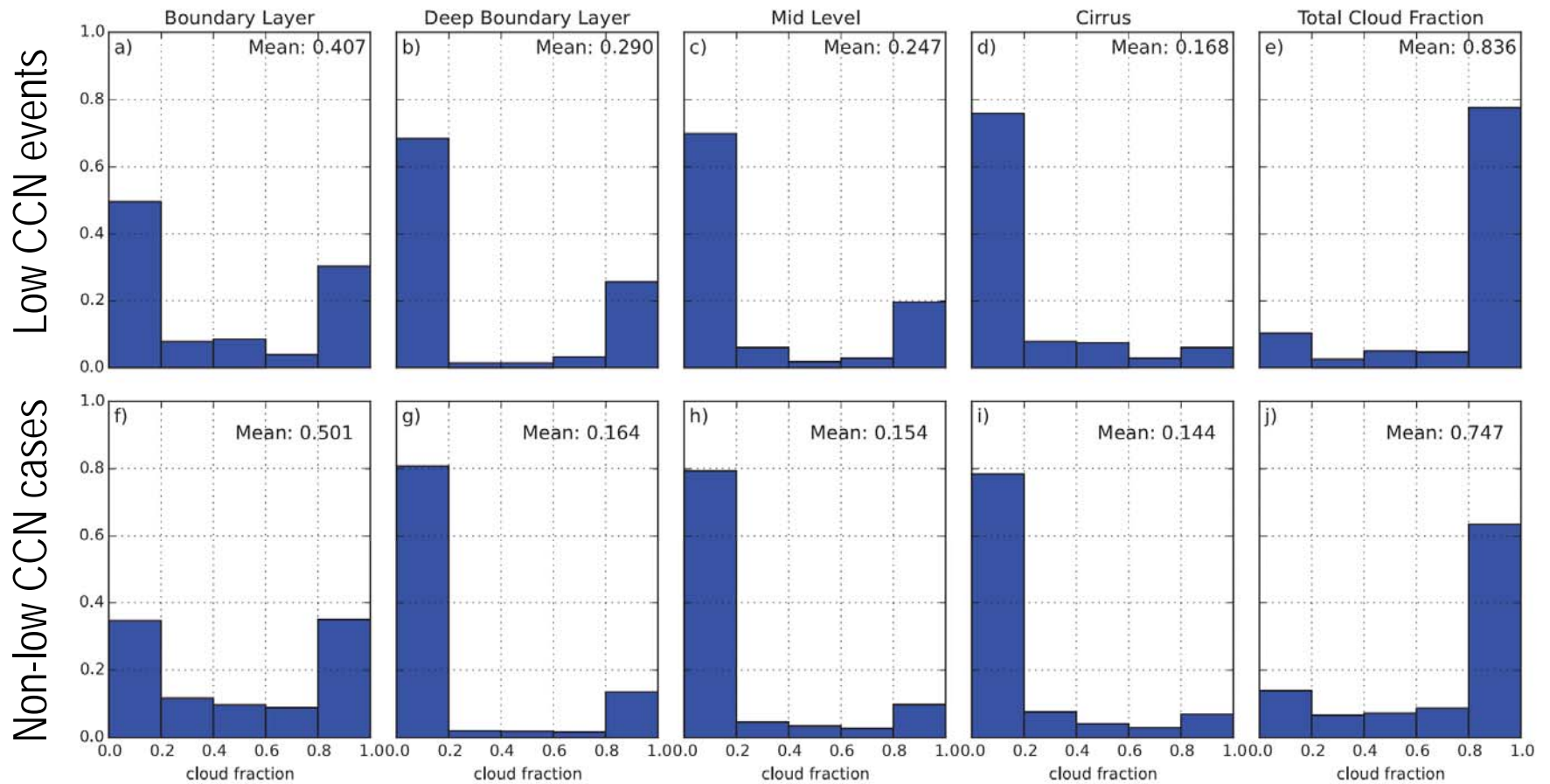


No systematic difference in LWP at Graciosa during low CCN events

- LWP pdfs not markedly different for low CCN and non-low CCN events

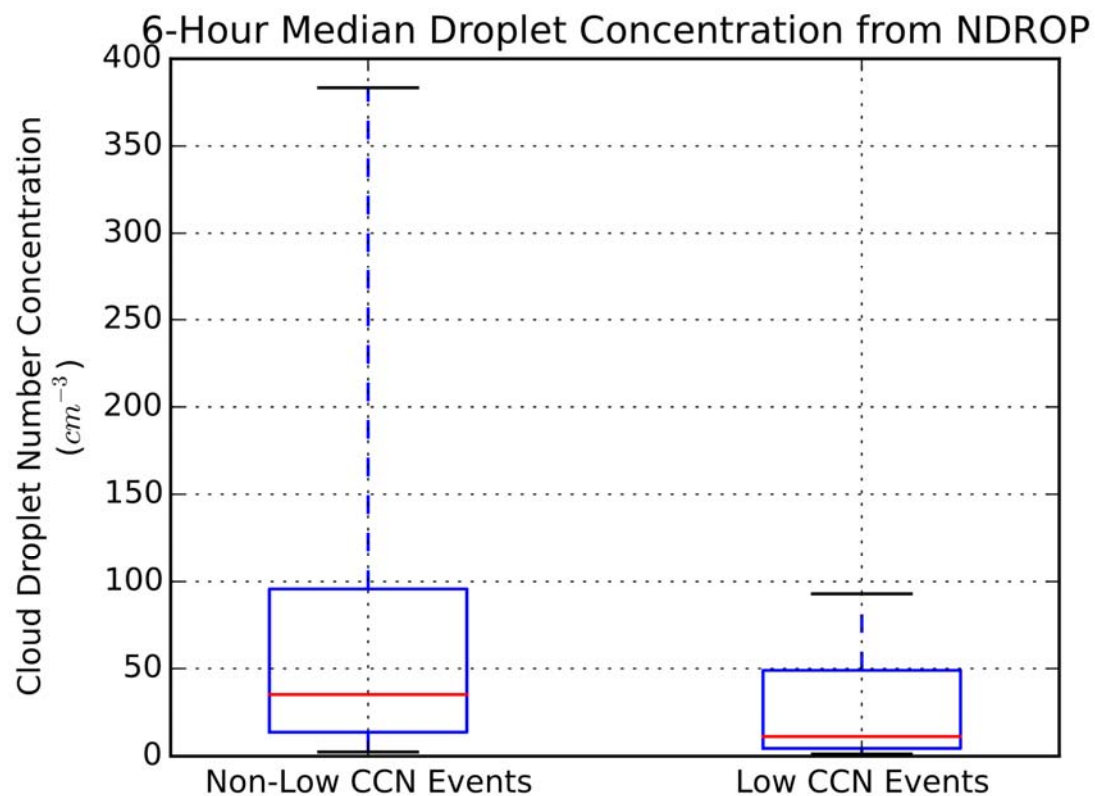


Fewer low clouds during low CCN events, more deep PBL clouds



Rémillard et al., 2012: Marine Boundary Layer Cloud Observations in the Azores." *Journal of Climate* **25**, 7381–98.

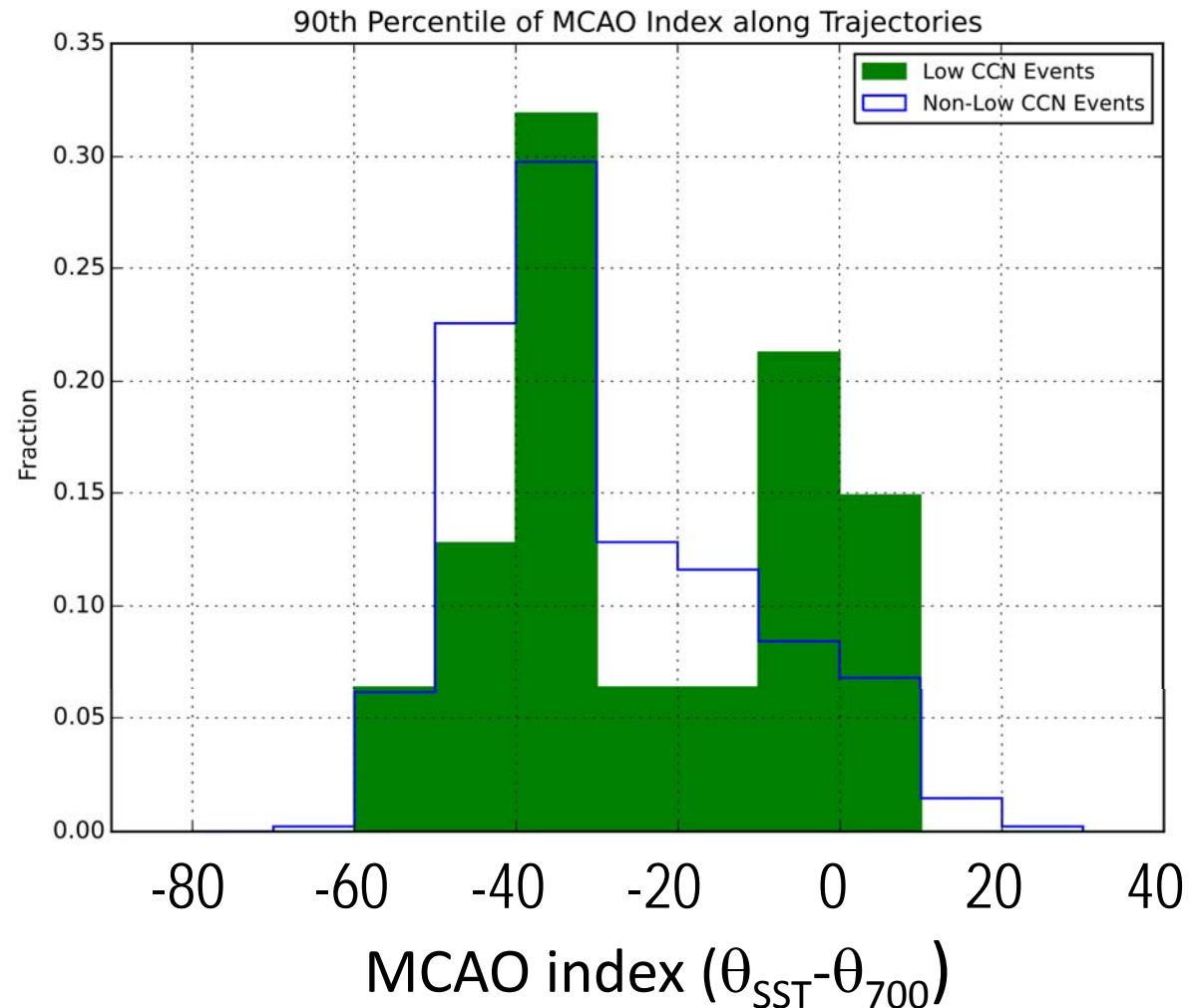
Cloud droplet concentration reduced during low CCN events



Riihimaki, L., S. McFarlane, and C. Sivaraman (2014), Droplet Number Concentrations Value-Added Product, *US Department of Energy Report, DOE/SC-ARM-TR-140*, 29 pp.

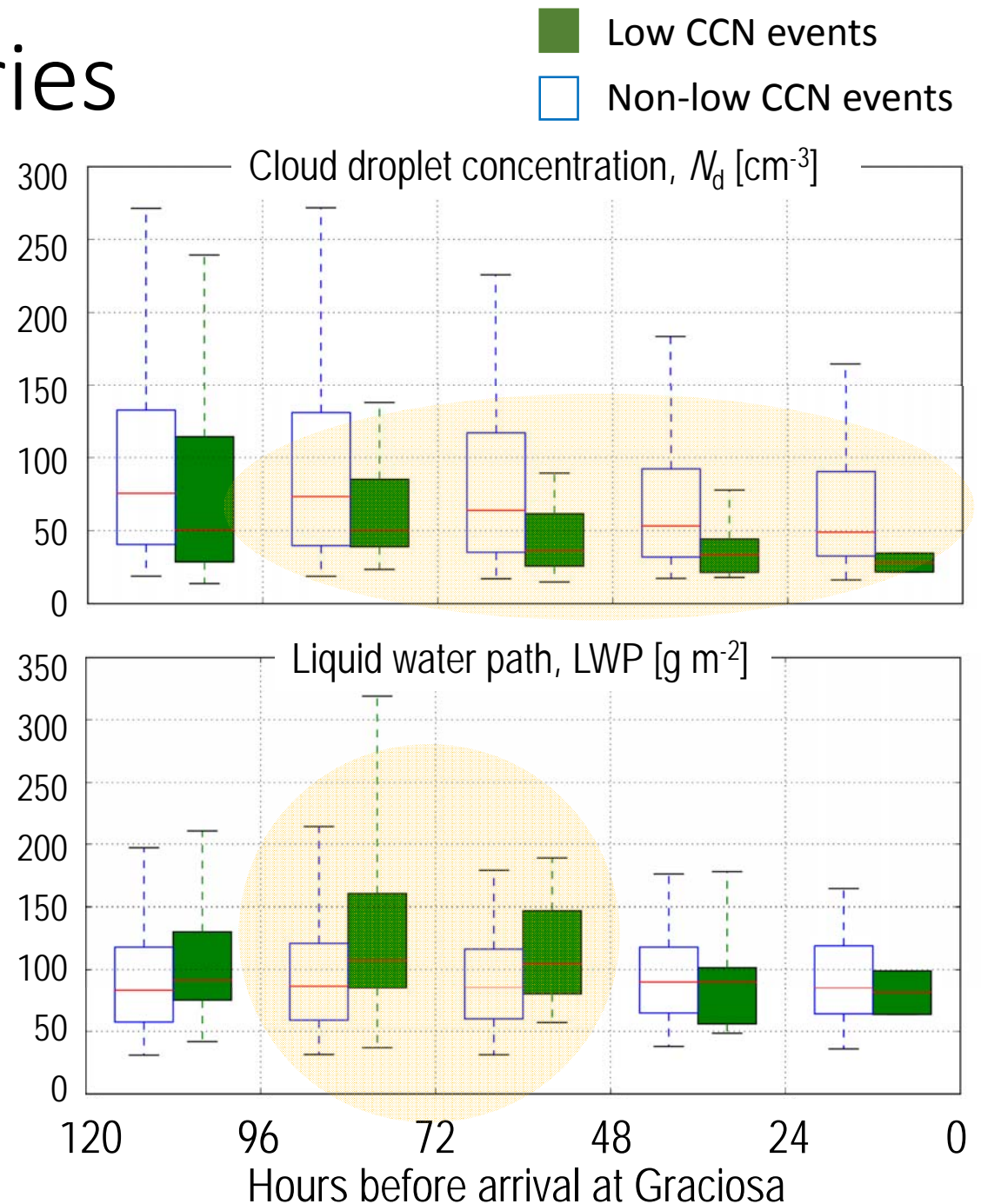
Low CCN events often associated with cold air outbreaks

- Marine Cold Air Outbreak (MCAO) index
 $\mu = \theta_{\text{SST}} - \theta_{700}$

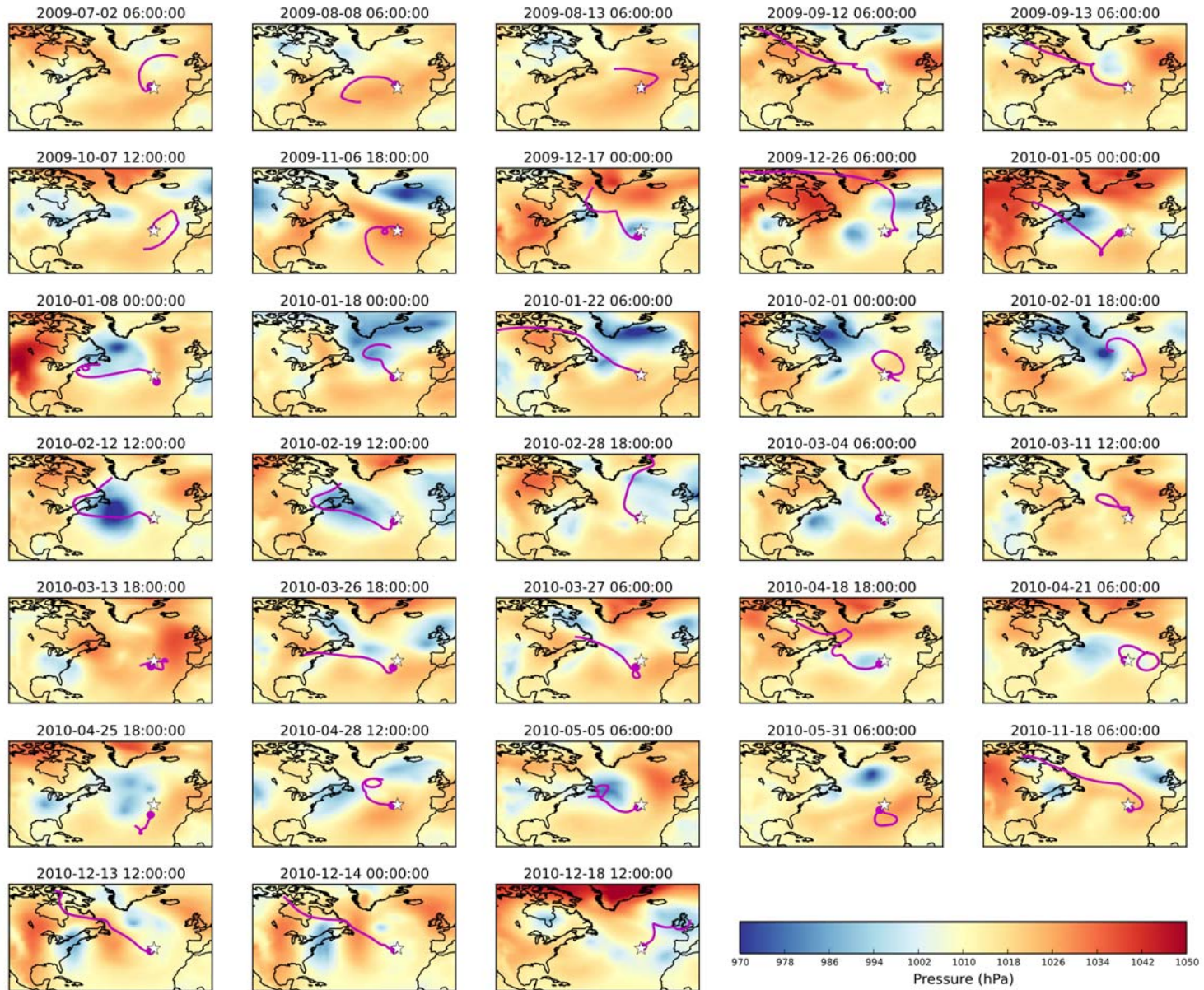


Air mass histories

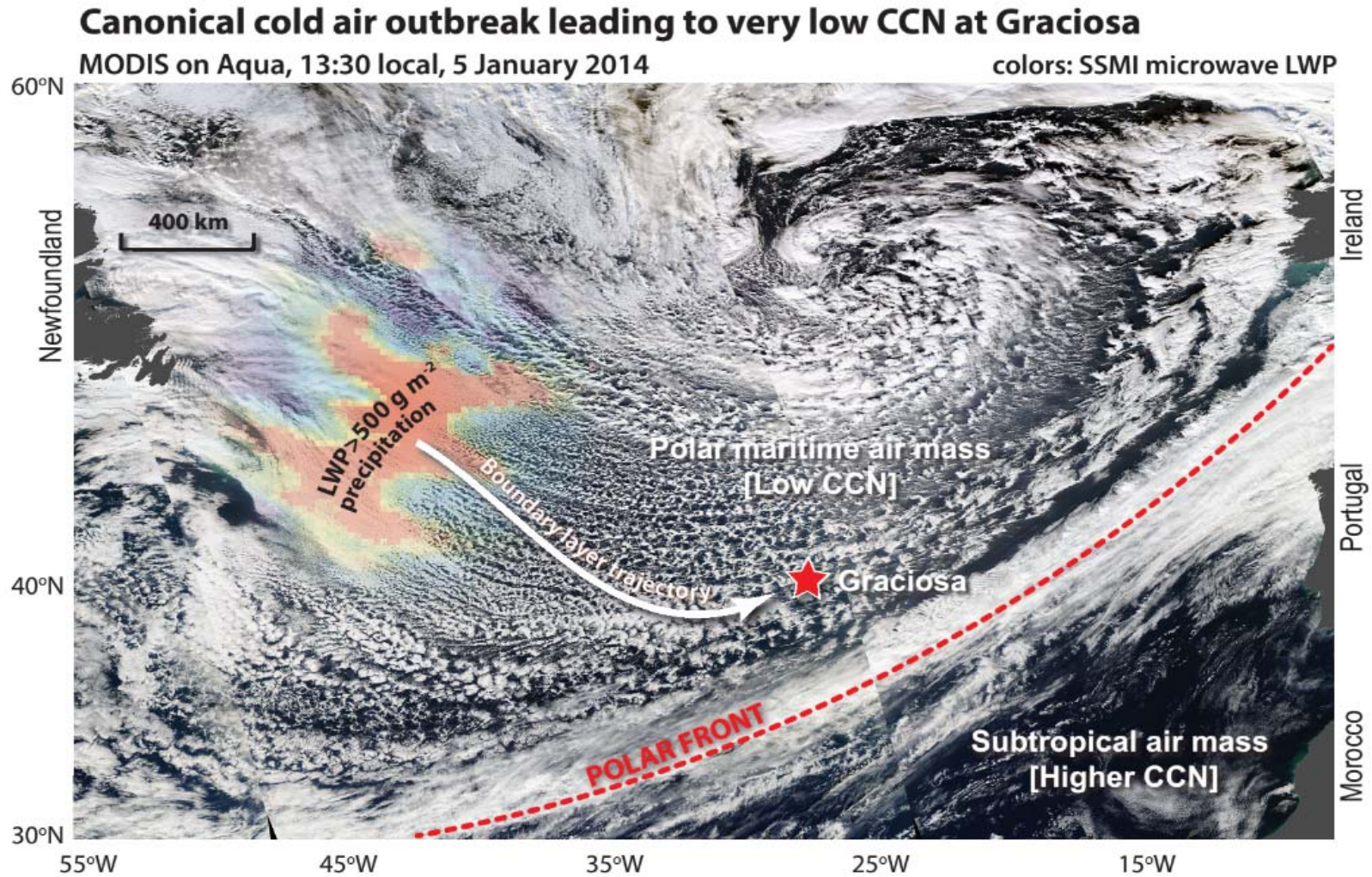
- MODIS satellite observations interpolated onto back trajectories arriving at Graciosa
- Low CCN events show low N_d several days upwind of Graciosa
- LWP enhanced for low CCN events 2-4 days prior to reaching Graciosa
- Coalescence scavenging loss rates scale strongly with LWP ($\sim LWP^2$) and LWP differences are sufficient to explain N_d differences



148 hour back trajectories and MSLP for low CCN events



“Canonical low CCN event”



Summary

- Examined very low CCN events ($<20 \text{ cm}^{-3}$ CCN at 0.1% supersaturation) at Graciosa
- Low CCN events most frequent during winter and spring, often tied to cold air outbreaks
- Depletion of CCN in high LWP upstream of Graciosa, together with low wind speeds, may be key factors for formation of pristine air masses, but need information about other CCN source terms (e.g. free troposphere) is needed.

Distinguishing characteristics of low CCN events

Characteristic	low CCN events	non-low CCN conditions
Seasonality	Three-quarters of events during DJF and MAM	Occur all year round
CCN concentrations (0.1%)	median 15 cm^{-3} ; 90% from $5\text{-}25 \text{ cm}^{-3}$	median 80 cm^{-3} ; 90% from $25\text{-}215 \text{ cm}^{-3}$
Aerosol scattering	Low values (both submicron and total) suppressed in approximate proportion to $N_{\text{CCN},0.1\%}$	Larger and more variable scattering
Wind direction (10 m) at Graciosa	Most cases from SW through SE.	Wide range of directions, many from SW clockwise through NW
Wind speed (10 m) at Graciosa	Median wind speed 3 m s^{-1}	Median wind speed 5 m s^{-1}
Back trajectory history	More trajectories experiencing cold air outbreak conditions	Fewer cold air outbreak encounters
Cloud droplet concentration N_d	20-50% lower N_d beginning several days upstream	Higher N_d beginning several days upstream
Liquid water path (LWP)	Little difference at Graciosa, but large values 2-3 days prior to trajectory arrival at Graciosa	Little difference at Graciosa; upstream distributions flat.

Additional slides

Aerosol scattering and CCN are well correlated

- Could base “pristine” case selection on scattering instead of CCN
- Case selection would not be identical, but many events would be the same

