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Regimes of Boundary Layer Structure in the Azores Using Data from the ARM Mobile Facility

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Introduction

Boundary layer (BL) marine cumulus and stratocumulus clouds play an important role in the Earth's radiation budget due to their high albedo compared to the sea surface and large cloud cover. Cloud cover and cloud vertical velocity structure are intimately tied to the thermodynamics of the BL. The deployment of the Atmospheric Radiation Measurement (ARM)'s Mobile Facility (AMF) on the island of Graciosa in the Azores provided a unique opportunity to sample the cloud structure and the associated BL thermodynamics in the region. Data from the vertically pointing W-band ARM Cloud Radar (WACR) were used to characterize the cloud structure while the data from the radiosondes were used to characterize the BL temperature, moisture and wind structure. As the facility is located on an island, ECMWF model simulated surface fluxes were used.

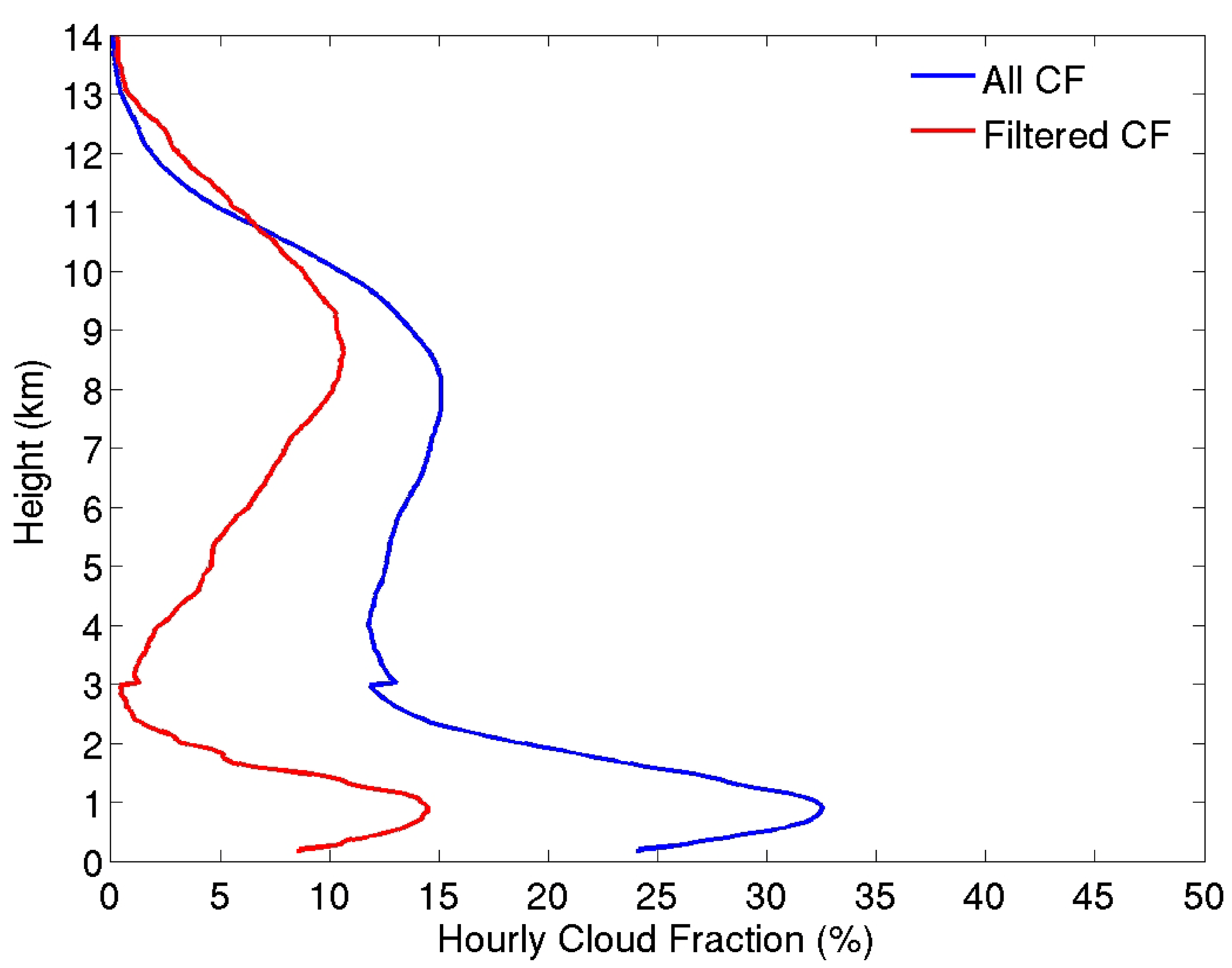

Figure 1: Average vertical profile of hourly cloud fraction for the year 2010. The blue curve includes all samples, while the red curve is from hours that have reflectivity less than 10 dBZ and a fall velocity of less than 3 ms^{-1}.

Table 1: General conditions during uniform stratus (104), broken stratus (98), cumulus (70) and clear sky (292) soundings.

Regime	LCL (m)		ECMWF SHF (Wm^{-2})		ECMWF LHF (Wm^{-2})		ECMWF ω_{700} (mb day^{-1})		IWV (cm)	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Uniform Stratus	628	320	7.14	6.85	59.9	40.3	41.1	83.5	3.38	1.76
Broken Stratus	720	277	7.50	10.2	70.6	45	28.6	84.2	3.0	1.60
Cumulus	719	215	10.7	10.1	99.7	61.5	58.6	89.2	2.54	0.72
Clear Sky	768	253	5.32	9.05	64.2	37.8	31.9	122	2.70	2.21

Table 2: Mean and standard deviation of inversion base height, inversion top height, potential temperature jump and mixing ratio jump across the inversion, and the depth of inversion for different BL cloud regimes.

Regime	Inversion Base (m)		Inversion Top (m)		Δθ (k)		-Δq (g kg^{-1})		Δh (m)	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Uniform Stratus	1291	442	1547	461	6.84	3.17	3.46	2.68	256	156
Broken Stratus	1321	510	1582	527	6.80	3.0	3.77	2.30	260	177
Cumulus	1356	497	1670	515	5.85	2.40	3.93	2.17	314	187
Clear Sky	1231	496	1548	523	6.26	2.88	4.07	2.06	316	204

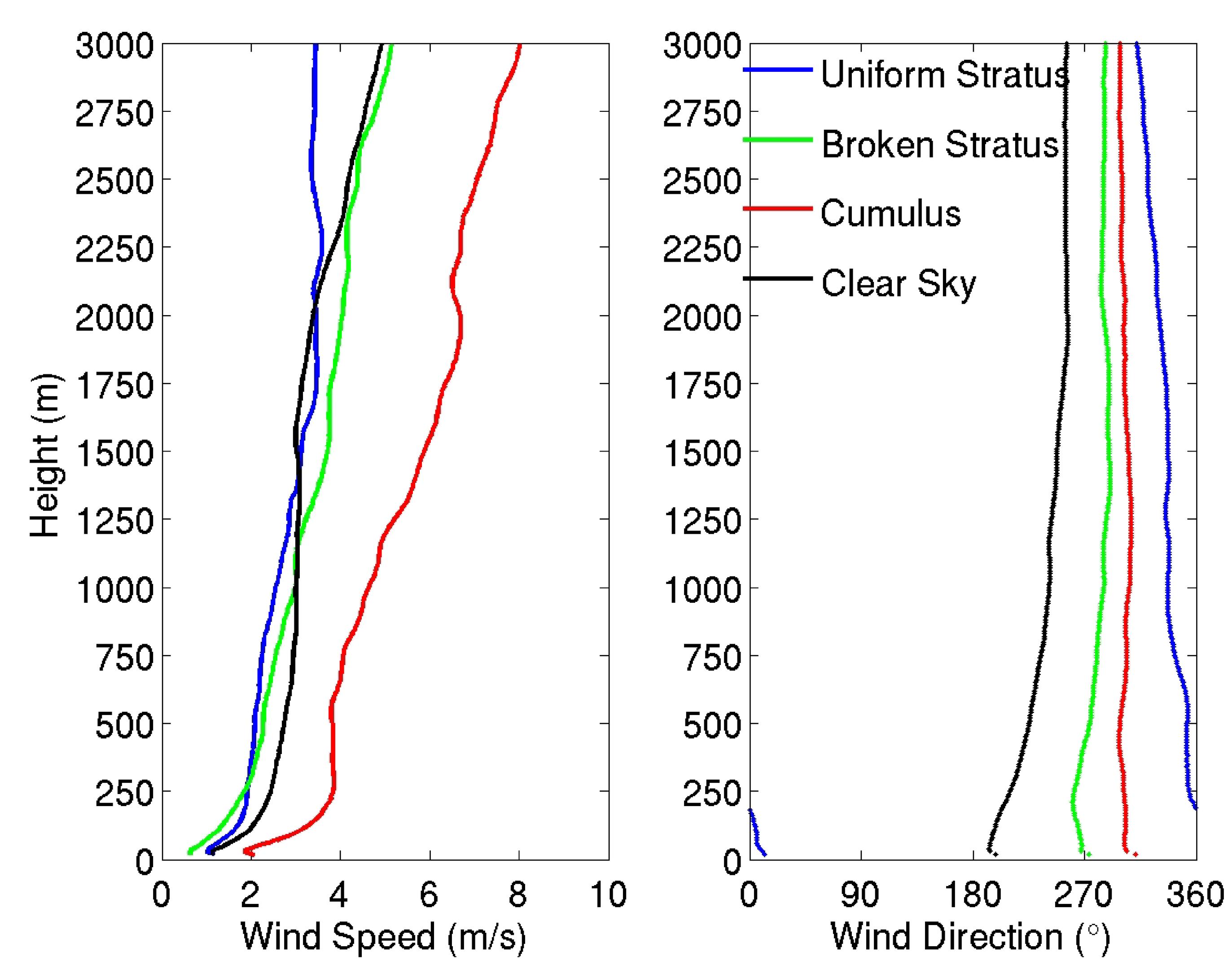

Figure 2: Mean wind speed (left) and wind direction (right) for different BL cloud regimes.

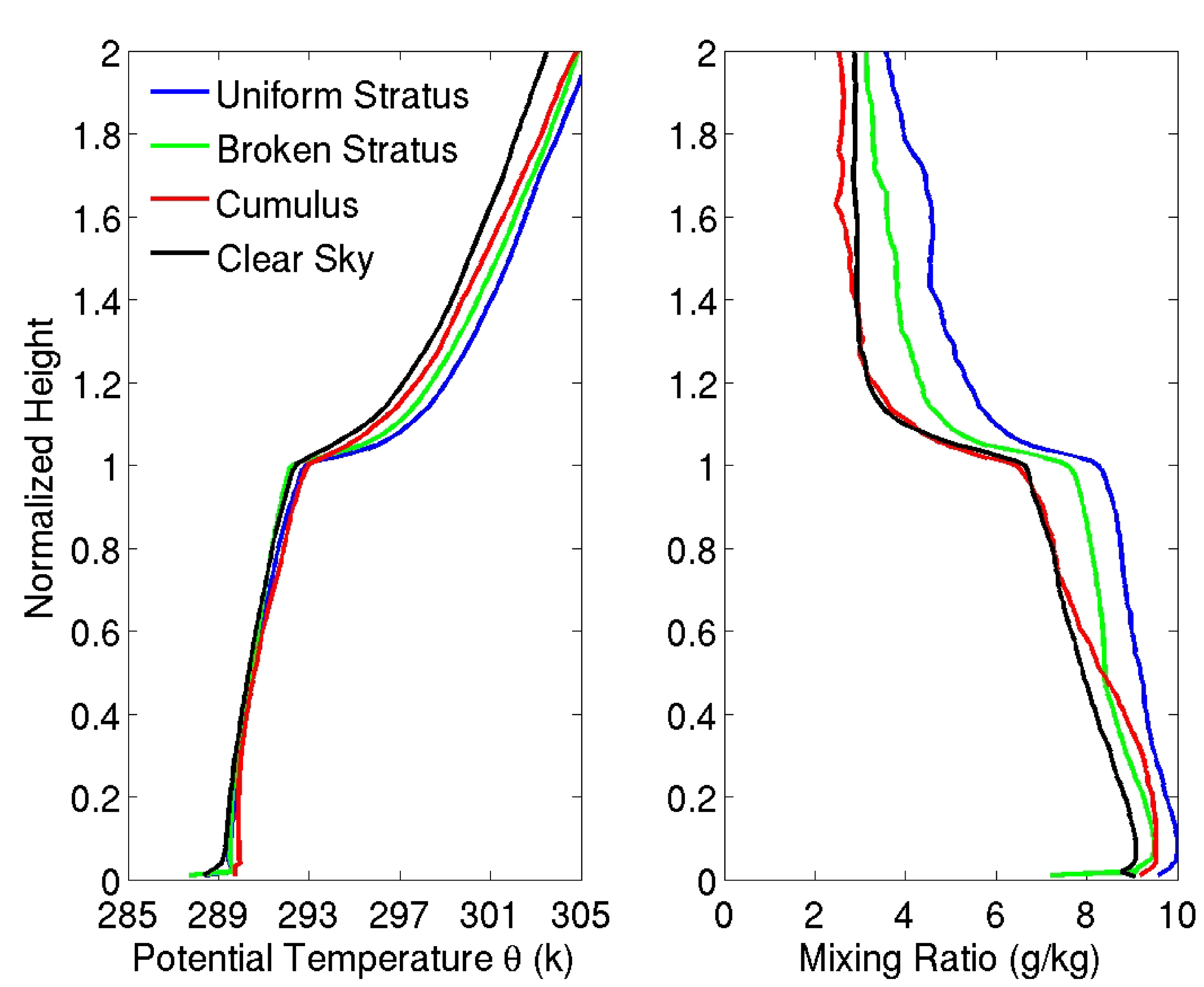

Figure 3: BL depth normalized profiles of potential temperature and mixing ratio for different BL cloud regimes.

Summary

During the 19 month deployment of the AMF1 at the island of Graciosa in the Azores, the WACR was operating for 13,200 hours and 2,258 radiosondes were launched. Undisturbed subtropical oceanic cumulus and stratocumulus conditions were observed during 7,763 hours (~58% and 1,197 radiosondes, ~53%). Soundings launched during undisturbed subtropical conditions were classified according to the cloud structure observed during the launched hour. Clear sky conditions were observed during 292 hours, with uniform stratocumulus conditions during 104 hours, broken stratocumulus during 98 hours and trade cumulus conditions during 70 hours. The preliminary results suggest that the inversion height, depth and strength did not vary significantly between different BL regimes. The average wind speed and surface fluxes were higher in a cumulus topped BL as compared to others. On average the winds were Southerly during clear sky periods and Northerly during uniform stratocumulus topped BL. The BL depth normalized profile of potential temperature did not exhibit significant change between different BL regimes, while the mixing ratio did exhibit significant variations.

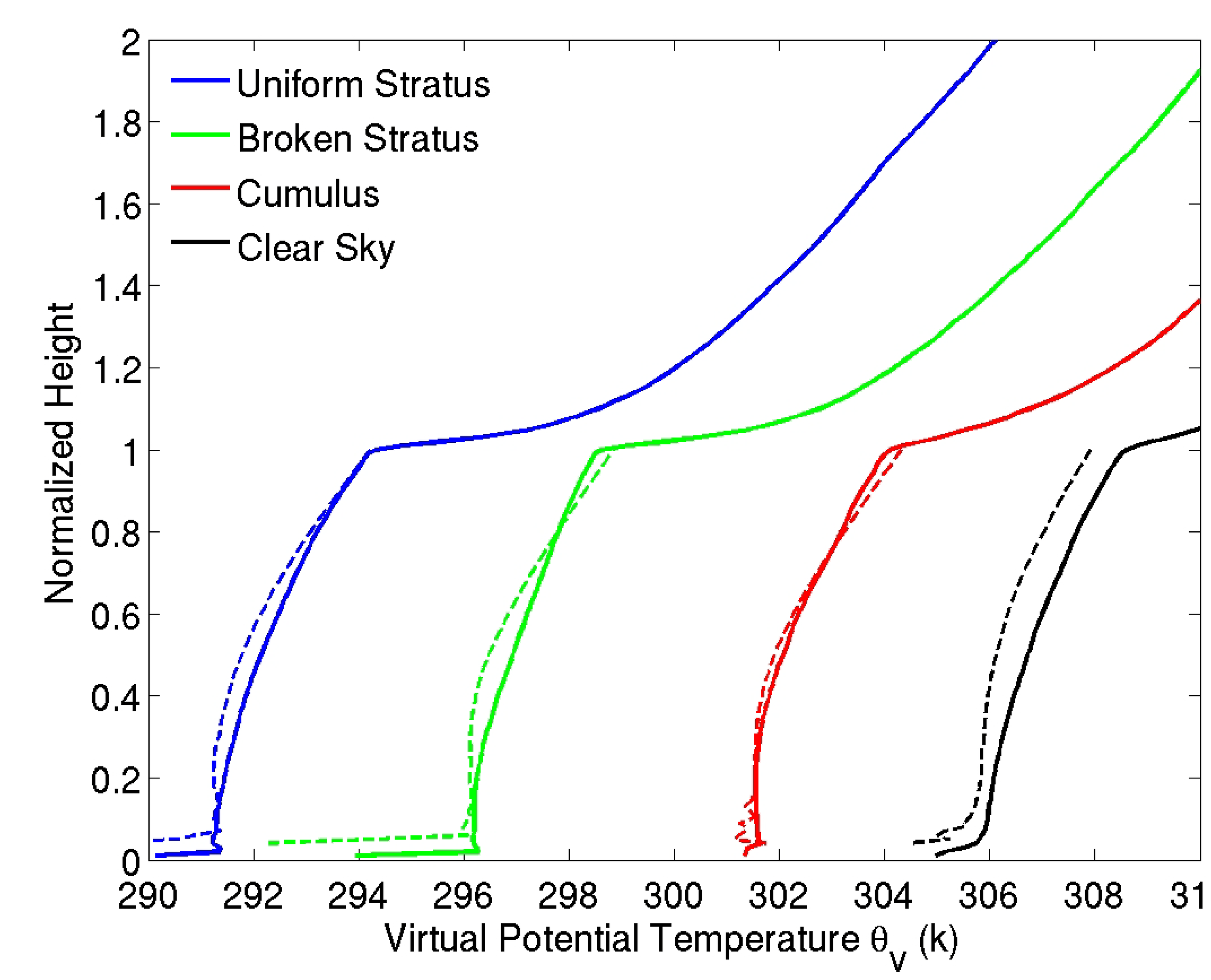

Figure 4: Normalized profiles of mean virtual potential temperature for different BL cloud regimes (solid) and the mean profiles of a parcel raised adiabatically from 100 m till the BL inversion base. For clarity purpose, an offset of 5 k was added to each profile.

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