Aerosol influences on the radar signature of shallow maritime cumulus clouds?

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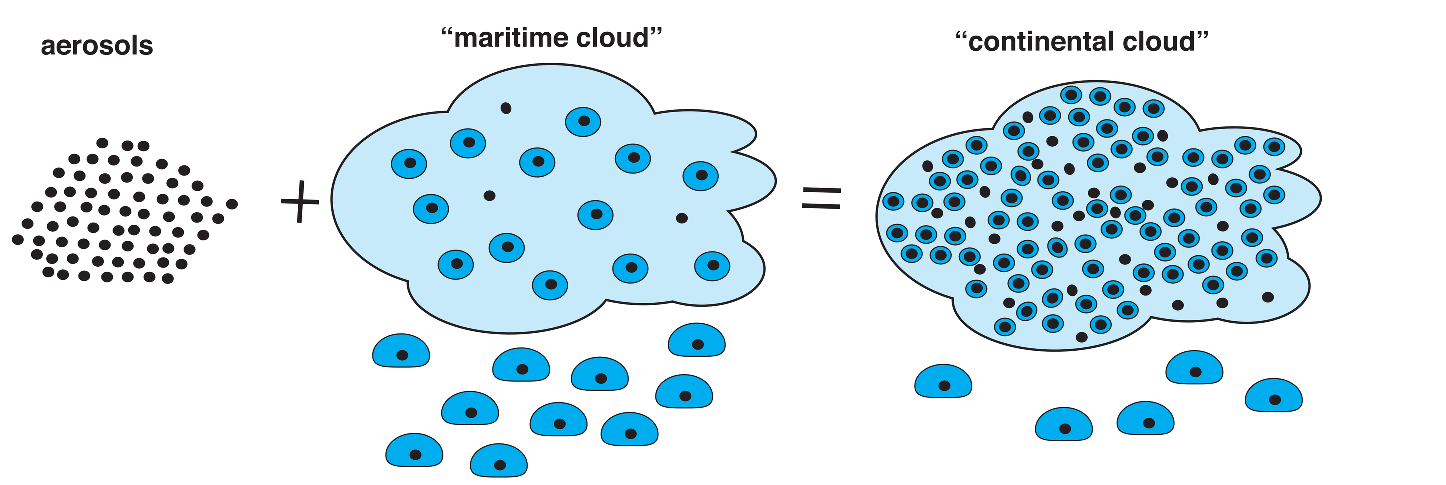
(i) Motivation

Numerous studies show that aerosols affect clouds, like altering their lifetime, thickness and precipitation behavior (**Zhanqing et. al. 2011**). In this study we use long-term measurements from a polarized Ka-band cloud radar sitting in Barbados to study the retrievals as a function of aerosol loading. Our analysis focuses on deriving statistical properties of the prevailing trade-wind cumulus clouds and gaining a better understanding of the interplay between clouds and aerosols.

(ii) Expectation

(a) Liquid water content [LWC] increases (and therefore cloud droplet sizes) with altitude.

(b) Higher aerosol concentration lead to smaller, but more numerous cloud droplets [when LWC = const.]. Clouds less likely precipitate (Twomey effect).



Barbados Cloud Observatory

Within our ongoing field campaign the Ka-band (35.5GHz) KATRIN cloud radar is one of several instruments deployed on Barbados. Together with the Caribbean Institute for Meteorology and Hydrology in Barbados, the Max Planck Institute for Meteorology in Hamburg established a cloud observatory on the east coast of Barbados, at a site called Deebles Point. As of April 1st, 2010 measurements of a Raman lidar, a DIAL lidar, a microwave radiometer, a MRR radar and of course of our scanning cloud radar built the foundation to our investigation of statistical properties of these clouds and the surrounding meteorological environment. More information can be found on http://barbados.zmaw.de

Source: http://de.wikipedia.org/wiki/Barbados

(iii) Methodology

To identify possible aerosol influences on trade-wind cumuli we distinguish the arriving airmass into two regimes being maritime and continental samples as indicated in Fig. 1. For this purpose we calculate 10-days backtrajectories with HYSPLIT using ERA-INTERIM reanalysis data, run every 6-hours. We sample the cloud radar data according to the airmass destination between five and ten days before reaching Deebles Point at an altitude of 3000 m. Maritime airmass are only labeled when backtrajectories never crossed land five to ten days before arriving in Barbados. We assume that these airmass have experienced different meteorology. Our first step is to see whether an aerosol signature is present despite these differences by sampling over a large dataset.

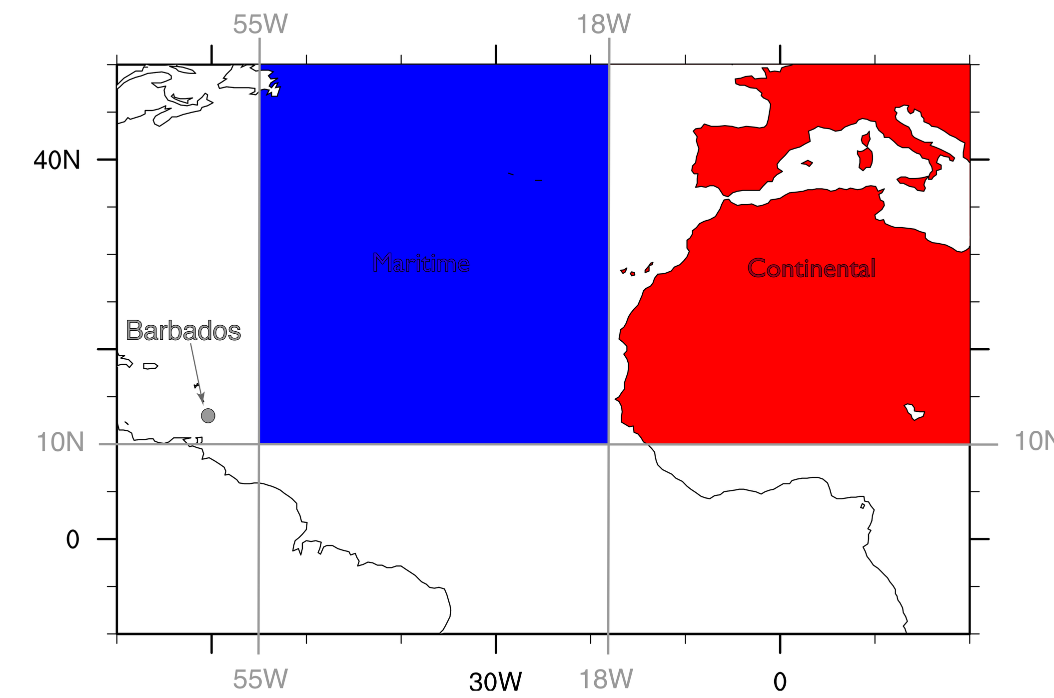


Figure 1 Map of airmass' origin. In blue the origins of maritime airmass are highlighted and in red continental airmass.

(iv) Regime Distribution

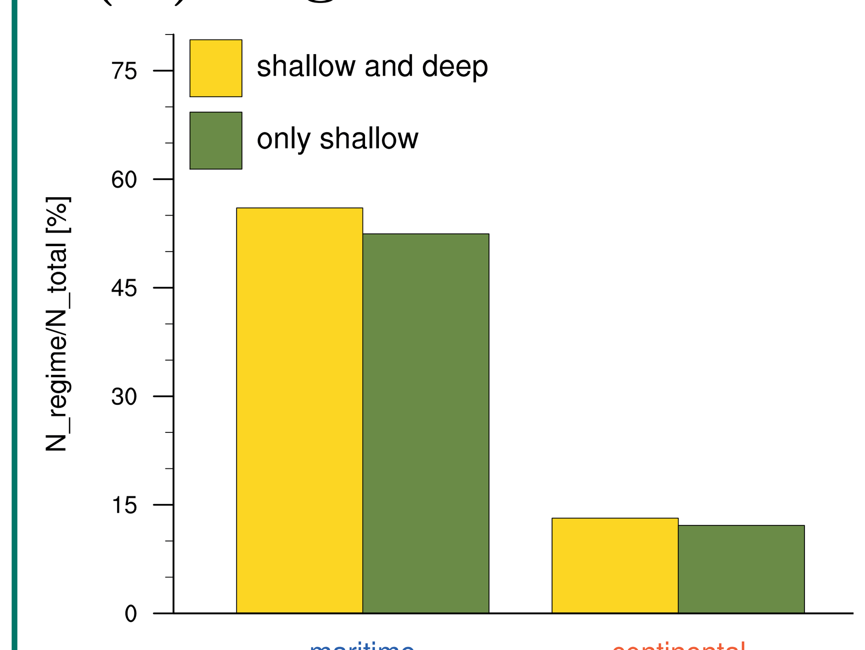


Figure 2 Frequency of occurrence of times for maritime and continental regimes, sampled according the airmass location as described in (iii) for all radar signals and echos from only shallow clouds.

echo % of shallow clouds	all	maritime	continental
all	20.1	19.2	16.8
"clouds" (Ze $\leq$ 5dB)	18.2	17.3	15.5
"rain" (Ze $\geq$ 5dB)	1.9	1.9	1.3

Table 1 Echo fraction % of shallow cases (below 3 km) for different regimes, defined according the airmass location as described in (iii).

We have more maritime than continental samples and most data sampled are shallow cumuli events (radar scans without retrievals between 3 and 7 km).

Acknowledgement
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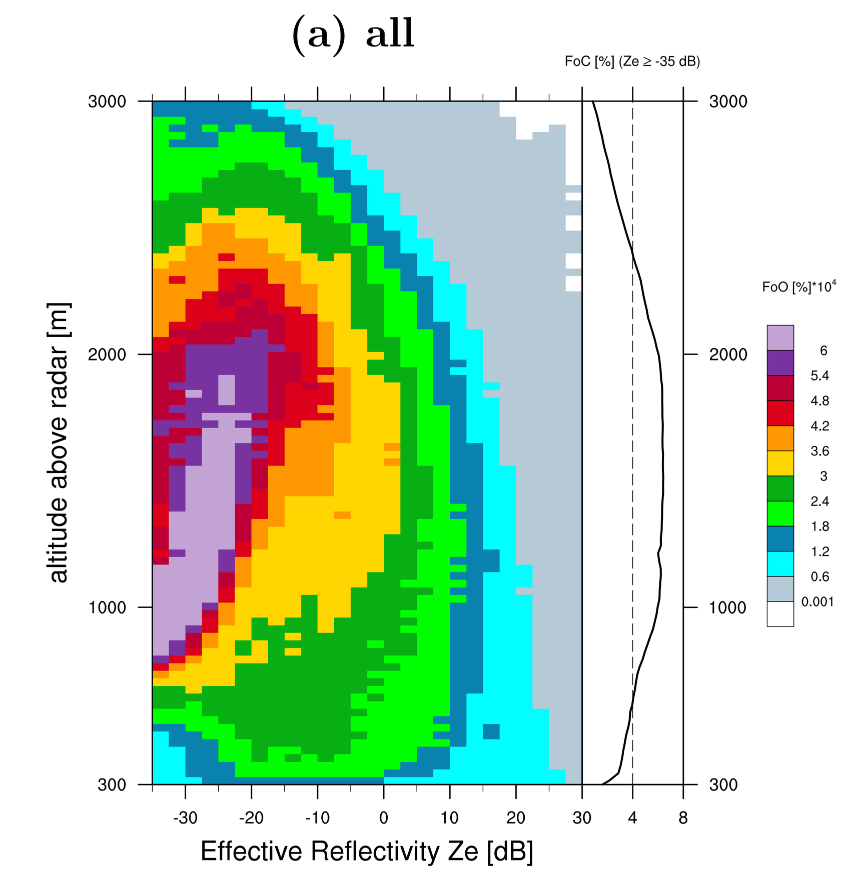
References
Zhanqing et. al. Long-term impacts of aerosols on the vertical development of clouds and precipitation. Nature,DOI:10.1038/NGEO1313 (2011).

(v) Reflectivity-Height Histograms



Main features for shallow cumuli cases:

- Reflectivitiy values $\leq$ -10dB increase as a function of altitude up to 2 km [as expected, see (ii)(a)].

Differences in regimes:

- In **maritime** conditions we sample more clouds at higher altitudes (more frequently deep clouds), and have echoes of higher reflectivities (bigger cloud droplets + more rain drops) [Fig. 3b/d].
- In the **continental** regime we find mostly retrievals with small reflectivity values between 1 - 2 km [Fig. 3c].
- No difference in increase of reflectivity with height [see (ii)(b)].

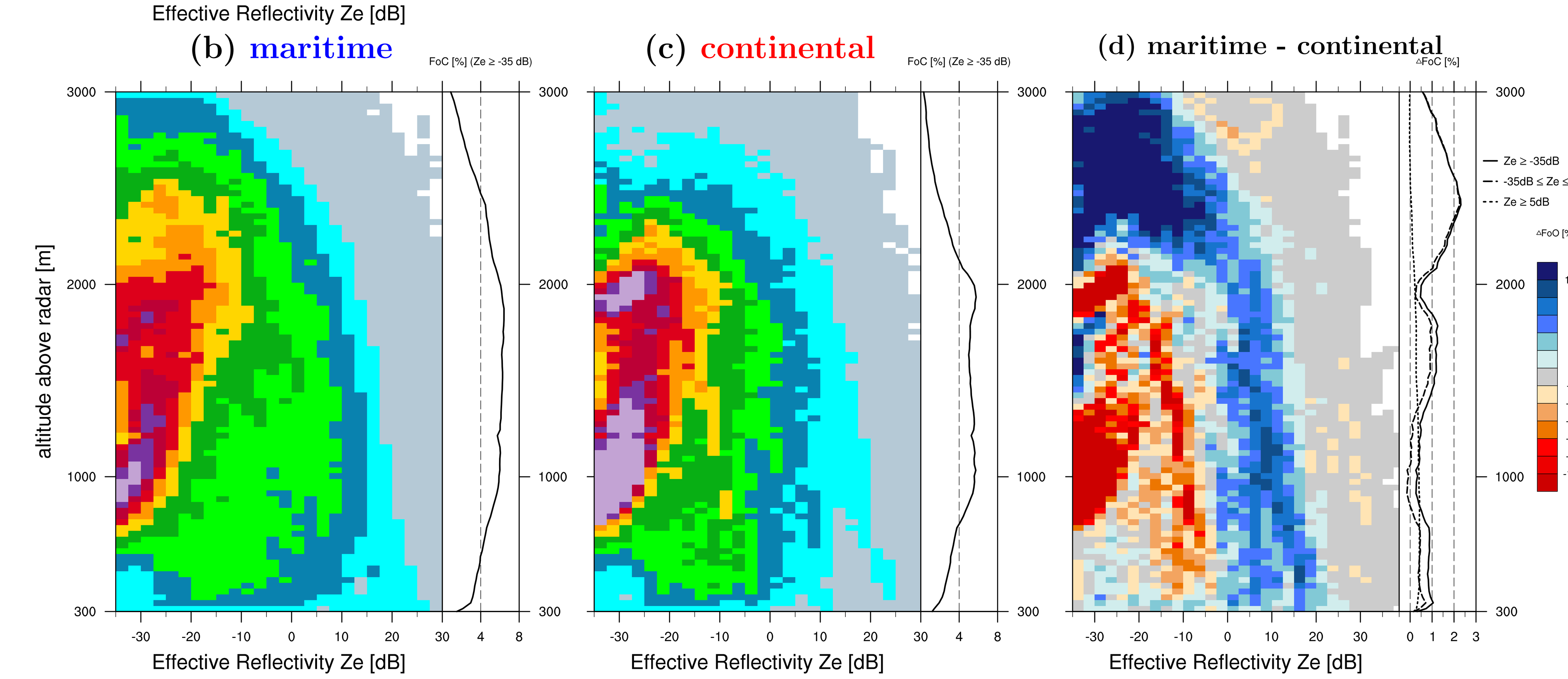


Figure 3 Each subfigure shows joint reflectivity-height histograms normalized by the sum over number of all actual retrievals. On the right hand side, the frequency of occurrence [FoO] of retrievals is displayed as a function of height normalized by all possible retrievals, when regime existed. All radar scans are sampled according to the airmass location as described in (iii).

(vi) Preliminary Results for cases where clouds are shallow (below 3km)

- **18% cloudiness for shallow trade-wind cumuli** [see Tab. 1]
- **Bigger droplets more likely to be found at top of clouds.** [see Fig. 3a]
- **More rain events and deeper clouds for maritime conditions.** [see Fig. 3d]
- **Seperating airmass by their history shows no evidence of aerosol signature.** [see (ii)(b)]

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