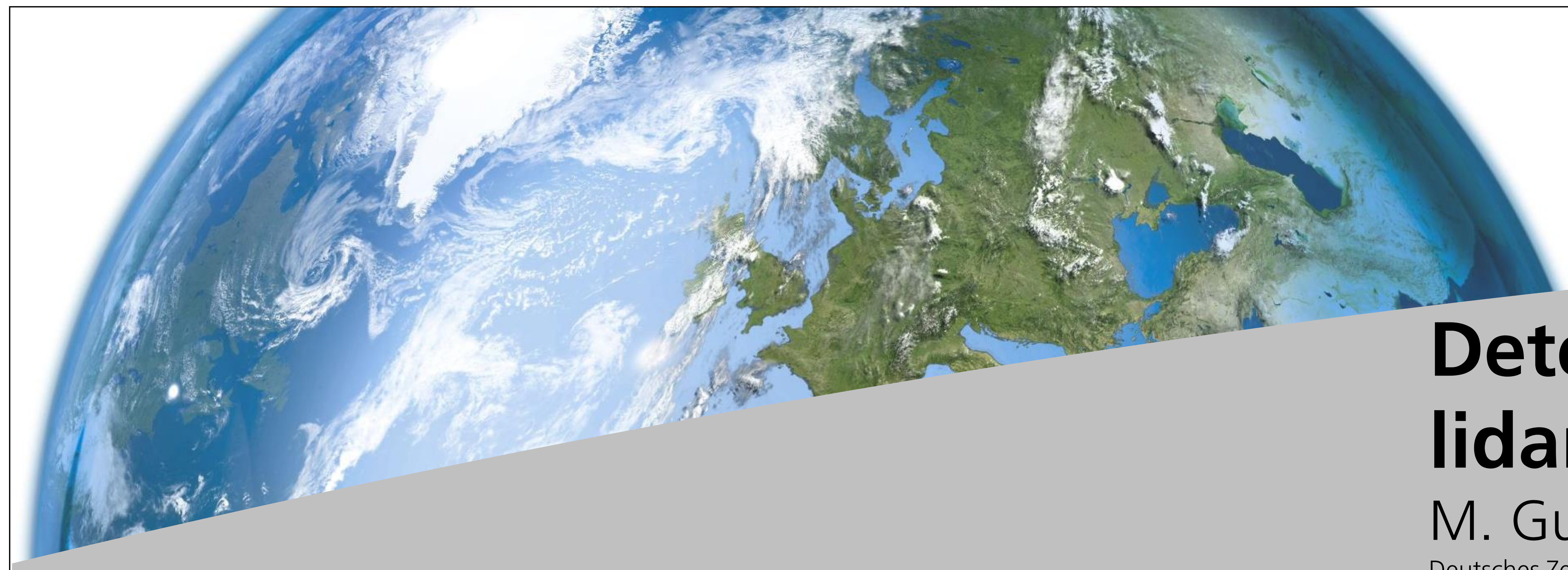

Detection of shallow marine cumulus convection with airborne and spaceborne lidar systems over the tropical North Atlantic Ocean

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Motivation

- Differences in the representation of shallow marine convection (SMC) in global climate models lead to large differences in climate sensitivity estimates *(Bony and Dufresne (2005)*
- Cumulus clouds are often of smaller extent than grid spacing of General Circulation Models ⟶ parametrizations needed

➡ **Study small scale shallow marine clouds with the advanced airborne lidar system WALES**

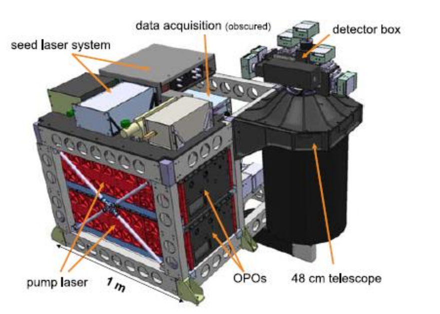
Scientific questions:

I. What are typical distributions of vertical and horizontal cloud extent in the subtropical Atlantic dry season and wet season?

II. How accurate can CALIOP, a spaceborne lidar system, resolve small scale shallow cloud regimes in contrast to WALES?

Method and Instrumentation

WALES



CALIOP

- Combined DIAL and HSRL system onboard the German HALO aircraft
- Resolution: 15 m (vertical), ~40 m (horizontal)

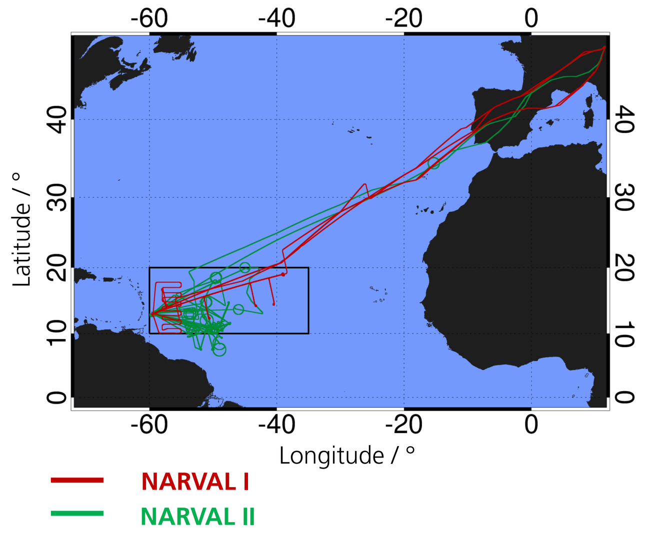
Wirth et al. (2009), Esselborn et al. (2008)

- Backscatter Lidar on-board CALIPSO
- Resolution: 30 m (vertical), 330 m (horizontal)

Winker et. al. (2007)

This study: WALES HSRL measurements (532 nm)
CALIOP Backscatter Lidar measurements (532 nm)

NARVAL campaigns



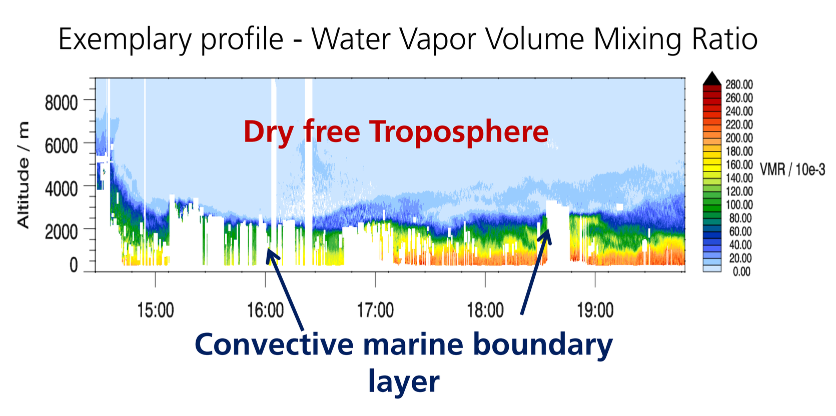
NARVAL I

- 10 to 20 Dec 2013 - **dry season**
- 65 flight hours within 8 research flights
- 6 CALIOP underflights over the subtropical North Atlantic Ocean

NARVAL II

- 8 to 30 Aug 2016 - **wet season**
- 85 flight hours within 10 research flights
- 5 CALIOP underflights over the subtropical North Atlantic Ocean

NARVAL I – dry season



- Clean and very dry free troposphere in winter months
- Sharp moisture gradient at trade wind inversion (2000– 2500 m)

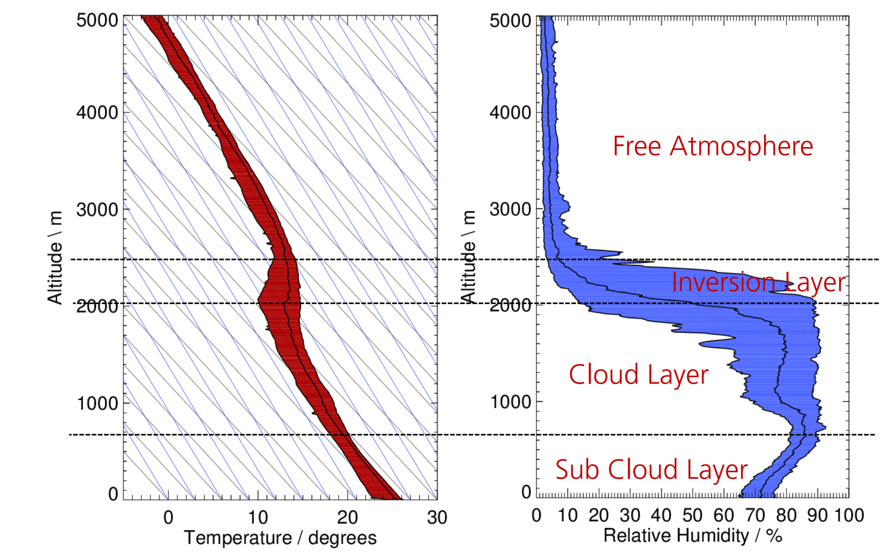
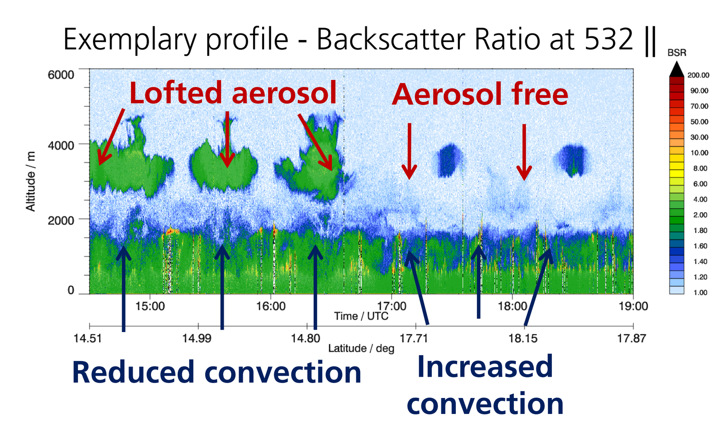


Figure: Temperature and relative humidity profiles from all dropped radiosondes during NARVAL I (shaded areas: Interquartile Range).

NARVAL II – wet season



- Moist and often aerosol loaded lower free atmosphere
- Weakly pronounced moisture gradient at trade wind inversion (1500 – 1800 m)

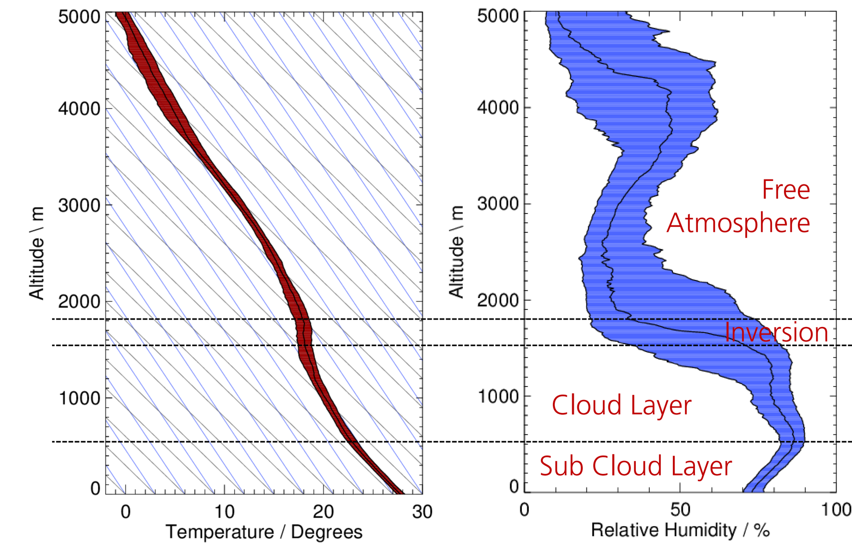
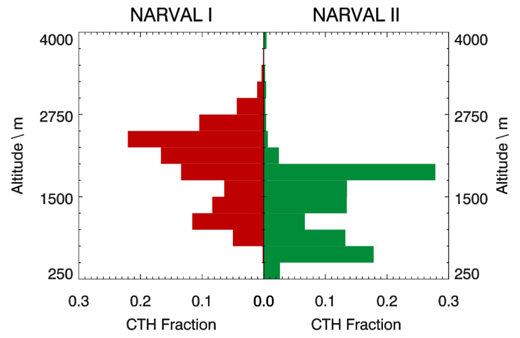


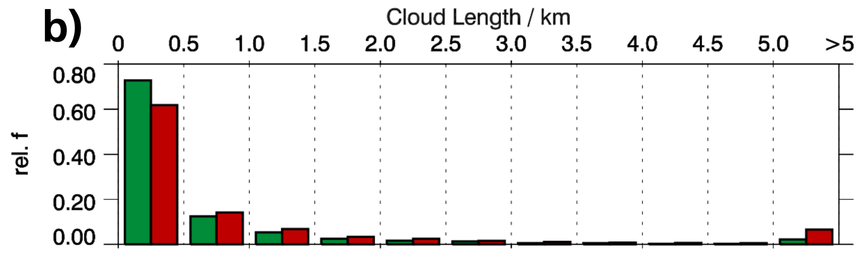
Figure: Temperature and relative humidity profiles from all dropped radiosondes during NARVAL II (shaded areas: Interquartile Range).

Cloud Statistics: NARVAL I vs. NARVAL II

- Threshold of **BSR = 90** is defined for single layer cloud detection

➡ **Decrease in cloud top height in wet season compared to dry season**





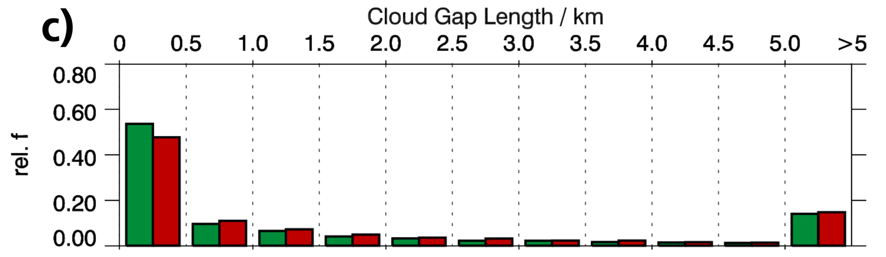


Figure: Distributions of cloud top heights **(a)**, cloud lengths **(b)** and cloud gap lengths **(c)** deduced from WALES measurements during **NARVAL I (red)** and **NARVAL II (green).**

WALES vs. CALIOP

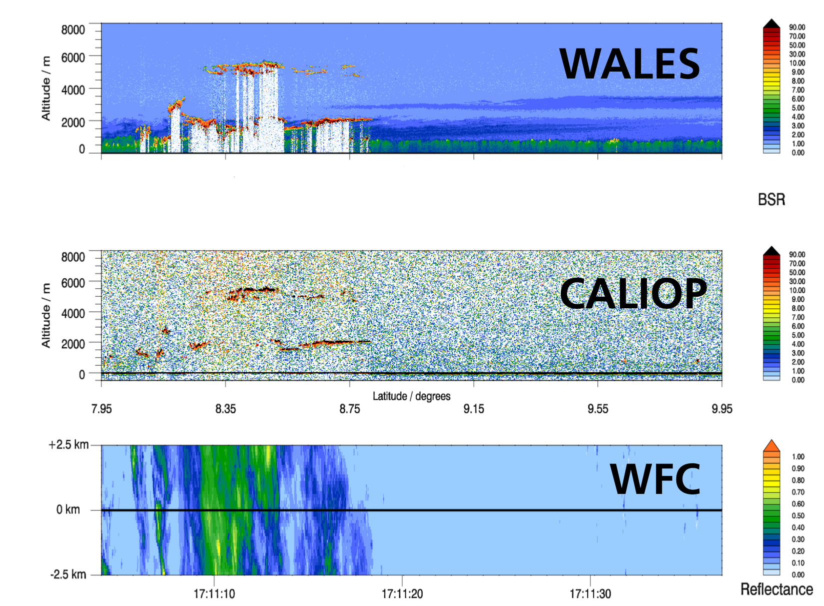


Figure: Exemplary underflight on 15 Aug 2016 (WFC: Wide Field Camera onboard CALIPSO)

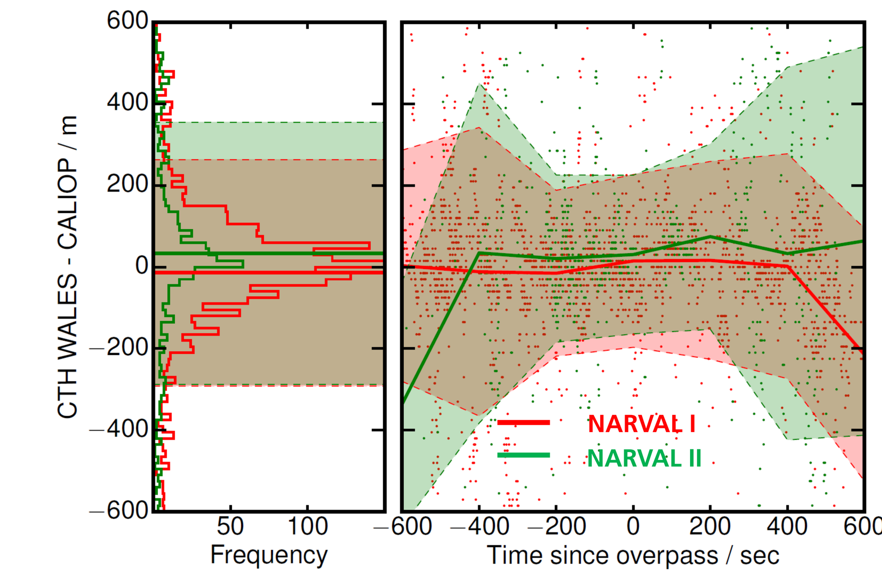
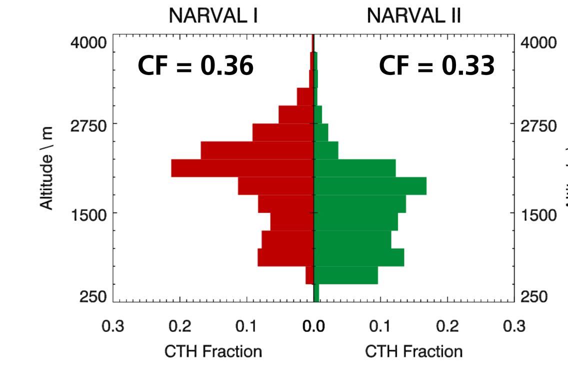


Figure: Distributions of differences in detected cloud top heights (CTH) from CALIOP and WALES from all underflights (shaded: 1σ).

➡ **Good agreement of cloud structure and cloud top frequency in WALES and CALIOP underflight measurements**

➡ **Differences in detected cloud top heights of CALIOP and WALES are smallest, when the temporal separation between the two instruments is small.**



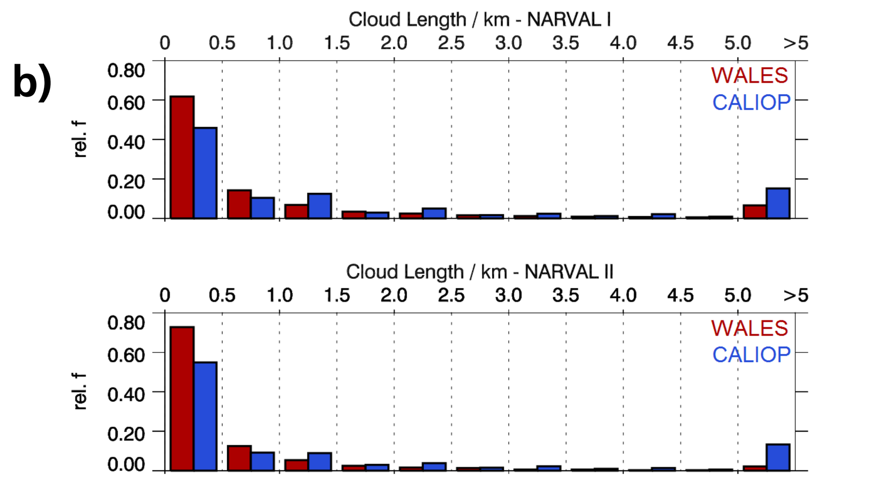


Figure: Distributions of cloud top heights deduced from CALIOP measurements **(a)**; Cloud length distributions derived from WALES and CALIOP measurements **(b)**.

➡ **CALIOP measurements underestimate small cloud amount. This may be caused by missing information on the inter-profile region between two consecutive CALIOP lidar shots.**

References

Bony and Dufresne, 2005: Marine boundary layer clouds at the heart of tropical cloud feedback uncertainties in climate models, *Geophysical Research Letters*, 32 **| Esselborn et al., 2008**: Airborne high spectral resolution lidar for measuring aerosol extinction and backscatter coefficients. Appl. Opt., 47 (3) **| Wirth et al., 2009**: The airborne multi-wavelength water vapor differential absorption lidar WALES: system design and performance. Applied Physics B, 96 (1) **| Winker et al., 2007**: Initial performance assessment of CALIOP. Geophys. Res. Lett., 34 (19).

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