A framework for Aerosol - Cloud Interactions Monitoring in liquid water clouds

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Aerosol-Cloud Interactions Studies

Table 1. References used in Fig 1b. All studies address low or liquid clouds.

	method/ instrument	parameters used	ACIτ	resolution	temporal averaging	L^*
Ground						
Feingold et al. (2003)	RS (remote sensing)		0.10	20 s		yes
Garrett et al. (2004)	RS+in situ		0.15	30 min		yes
Kim et al. (2008)	RS+in situ		0.15	5 min		yes
Lihavainen et al. (2008)	in situ		0.24	1 h		yes
McComiskey et al. (2009)	RS+in situ		0.16	20 s		yes
Airborne						
Twohy et al. (2005)	in situ		0.27	10–60 min		
Raga and Jonas (1993)	in situ		0.09	NA		no
Martin et al. (1994)	in situ		0.25	30 km		
Gultepe et al. (1996)	in situ		0.22	∼ 12 km		yes
O'Dowd et al. (1999)	in situ		0.20			
McFarquhar and Heymsfield (2001)	in situ		0.11			
Ramanathan (2001)	in situ		0.21–0.33			
Lu et al. (2007)	in situ		0.19	30 km		
Lu et al. (2008)	in situ		0.14	leg means		
Satellite						
Nakajima et al. (2001)	AVHRR	N_d; N_a	0.17	0.5°	4 months	
Bulgin et al. (2008)	ASTER-2	r_e; τ_a	0.10–0.16 (0.13)	1°	seasonal/3 months	no
Kaufman et al. (2005)	MODIS	r_e; AI	0.046–0.174 (0.0975)	1°	simultaneous/daily	no
Sekiguchi et al. (2003)	AVHRR	r_e; N_a	0.1	2.5°	daily	no
Lebsock et al. (2008)	MODIS	r_e; AI	0.07	1 km to 1°	simultaneous	no
Sekiguchi et al. (2003)	POLDER	r_e; N_a	0.07 (ocean)	2.5°	monthly	no
Quaas et al. (2006)	MODIS	N_d; τ_a	0.04	3.75°×2.5°	daily	
Quaas et al. (2004)	POLDER	r_e; AI	0.04 (ocean)/0.012(land)	3.75°×2.5°	simultaneous	no
Satellite + Model						
Breon et al. (2002)	POLDER + back trajectories	r_e; τ_a, AI	0.085 (ocean)/0.04 (land)	150 km	3 months	no
Chameides et al. (2002)	ISCCP + CTM	τ_c; τ_a	0.17 (all)/0.14 (low cloud)	280 km	annual	no

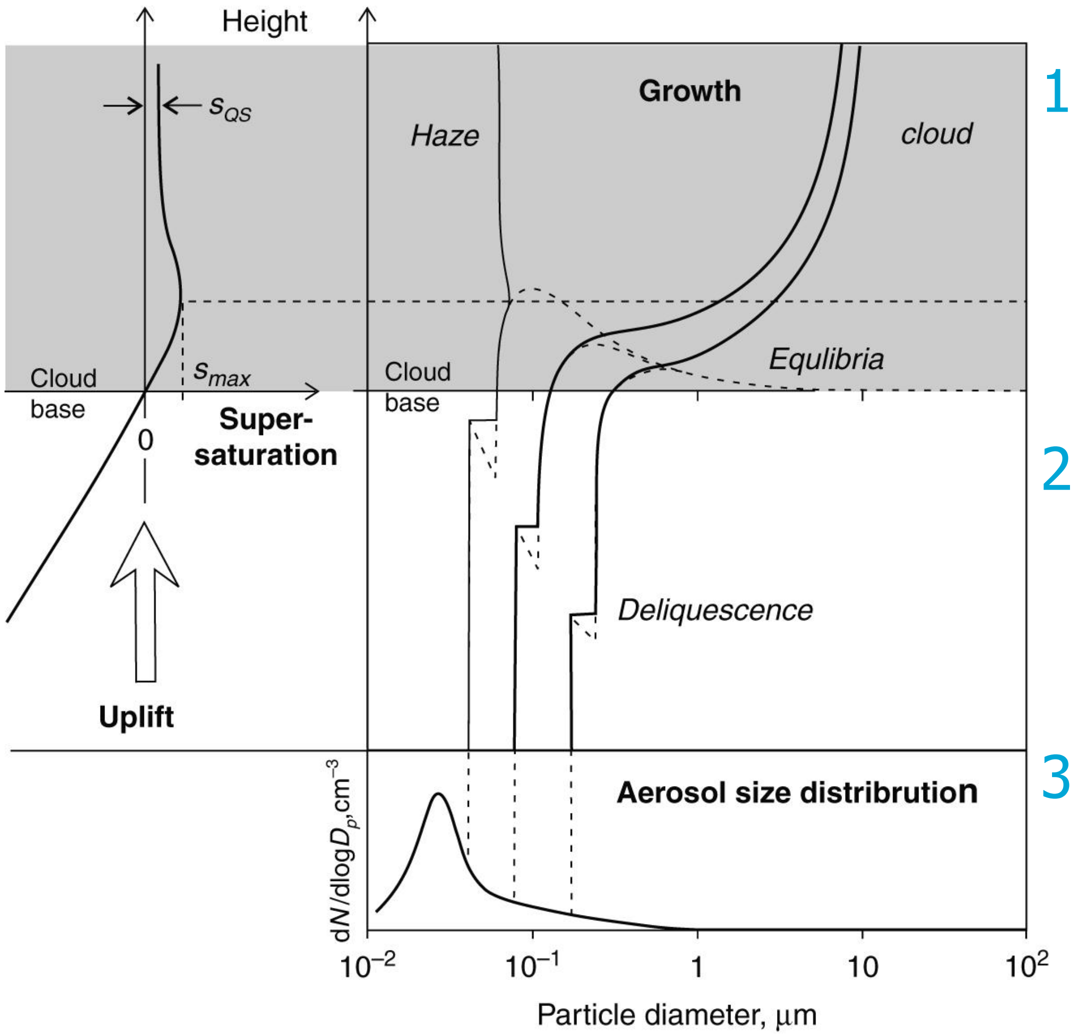
* *L*-constraint used in calculation of ACI.

Source : McComiskey, A., and G. Feingold. "The Scale Problem in Quantifying Aerosol Indirect Effects." Atmos. Chem. Phys. 12, no. 2 (January 23, 2012)

How to monitor ACI?

- Aerosol - Cloud Interactions represent first indirect effect which in fact represents the **activation process**
- This process takes place **below the cloud base** and should be observed from the ground
- It is a microphysical process and thus should be observed on a **local scale**
- For a large coverage one should use **widely available instruments**
- Use **direct observables** to bypass assumptions of the microphysical properties retrieval algorithms

Evolution of a liquid water cloud



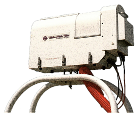
Source: *Lamb D., Verliende J. "Physics and Chemistry of Clouds"*

1. Aerosol become cloud droplets when they **grow through the peak of the Köhler** function
2. **Aerosol diameter** does **not matter** much for the resulting **cloud droplet size**
3. **More aerosol** result in **more cloud droplets**

How to monitor ACI?

Lidar → **Aerosol Properties** → **Attenuated Backscatter Coefficient**

Cloud Radar → **Cloud Properties** → **Radar Reflectivity Factor**



Radiometer → **Available Water** → **Liquid Water Path**

Attenuated Backscatter Coefficient

$$\beta \approx n_{aerosol} * D^2_{aerosol}$$

same amount of liquid water is available

if the Attenuated Backscatter Coefficient is increasing

aerosols n = const. → *aerosols D increases* → no change in the cloud

aerosols n increases → *aerosols D = const.* → more cloud droplets

Attenuated Backscatter Coefficient

$$Z \approx n_{cloud} * D_{cloud}^{6}$$

same amount of liquid water is available

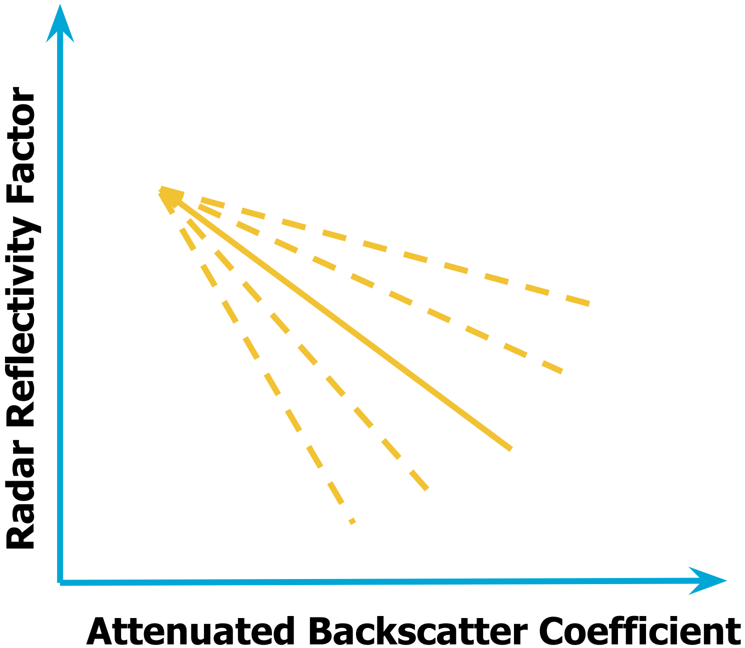
if the Radar Reflectivity Factor is increasing

n = const. → *D increases* → increase of the reflectivity - bigger droplets

n increases → *D = const.* → decrease of the reflectivity - smaller droplets

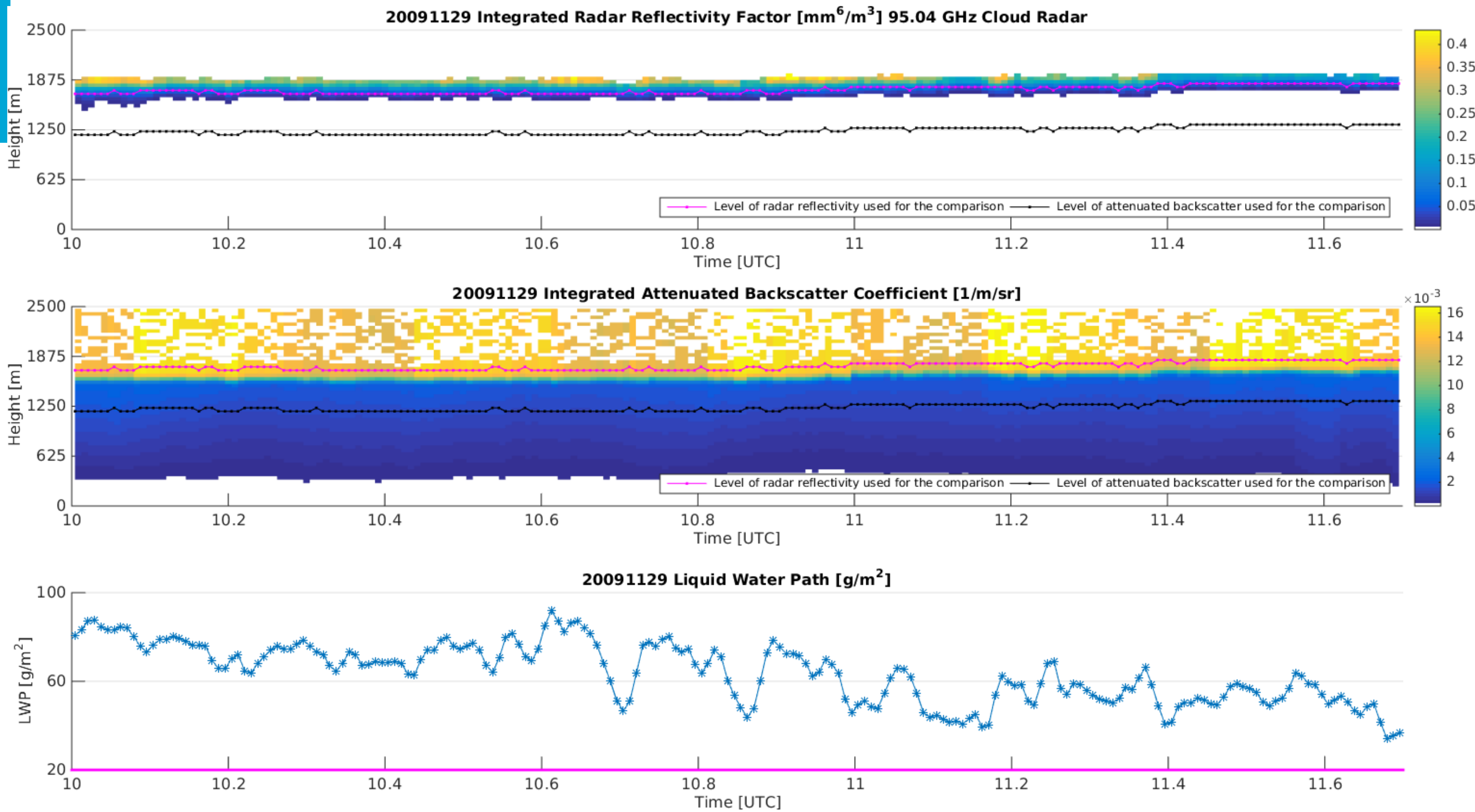
How to monitor ACI?

$$n_{cloud} \propto n_{aerosols}^{\gamma}$$

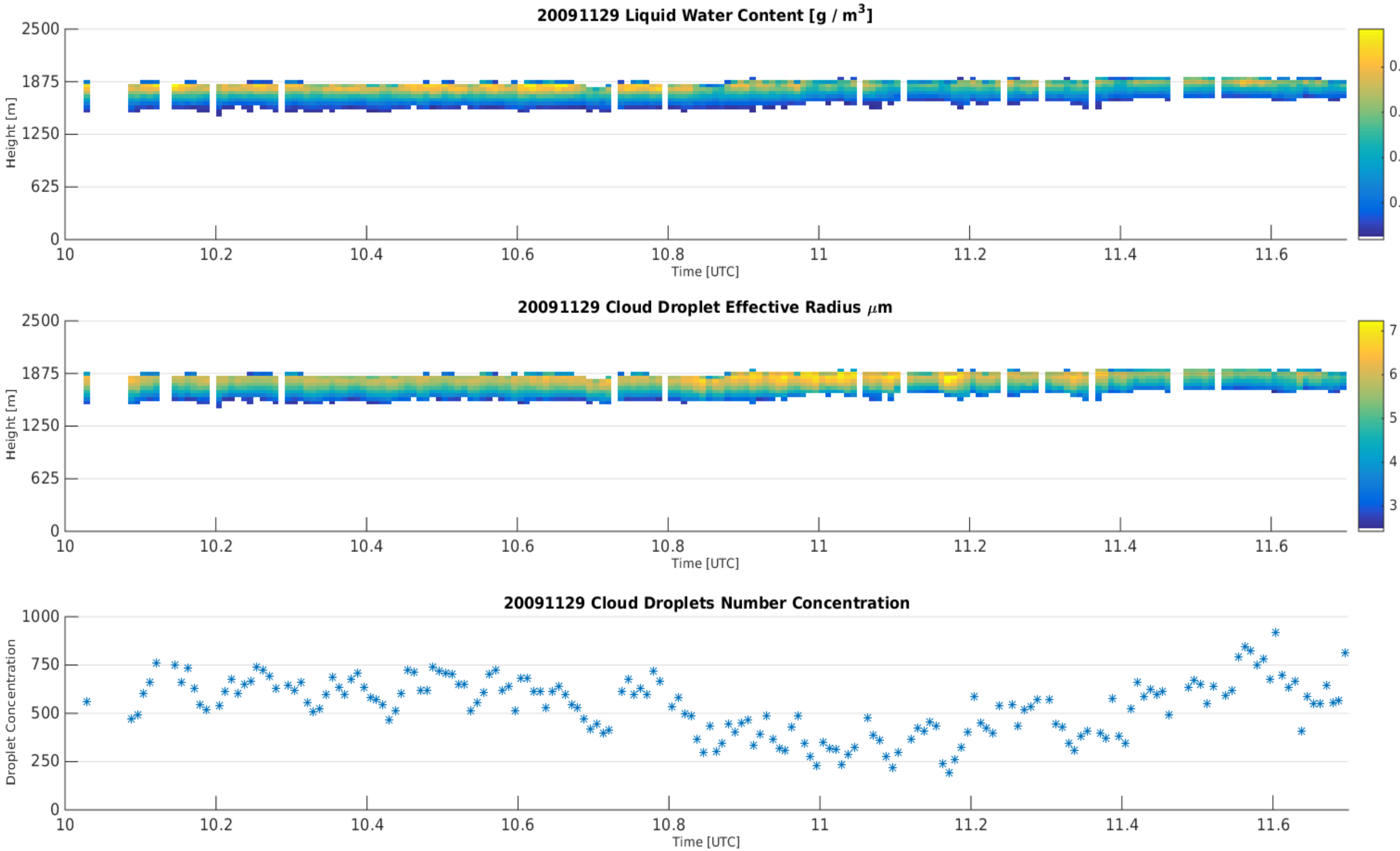


- We expect that an **increase** of the **Attenuated Backscatter Coefficient** will correspond to a **decrease** of the **Radar Reflectivity Factor**
- However, the **slope** of this correlation **will vary**

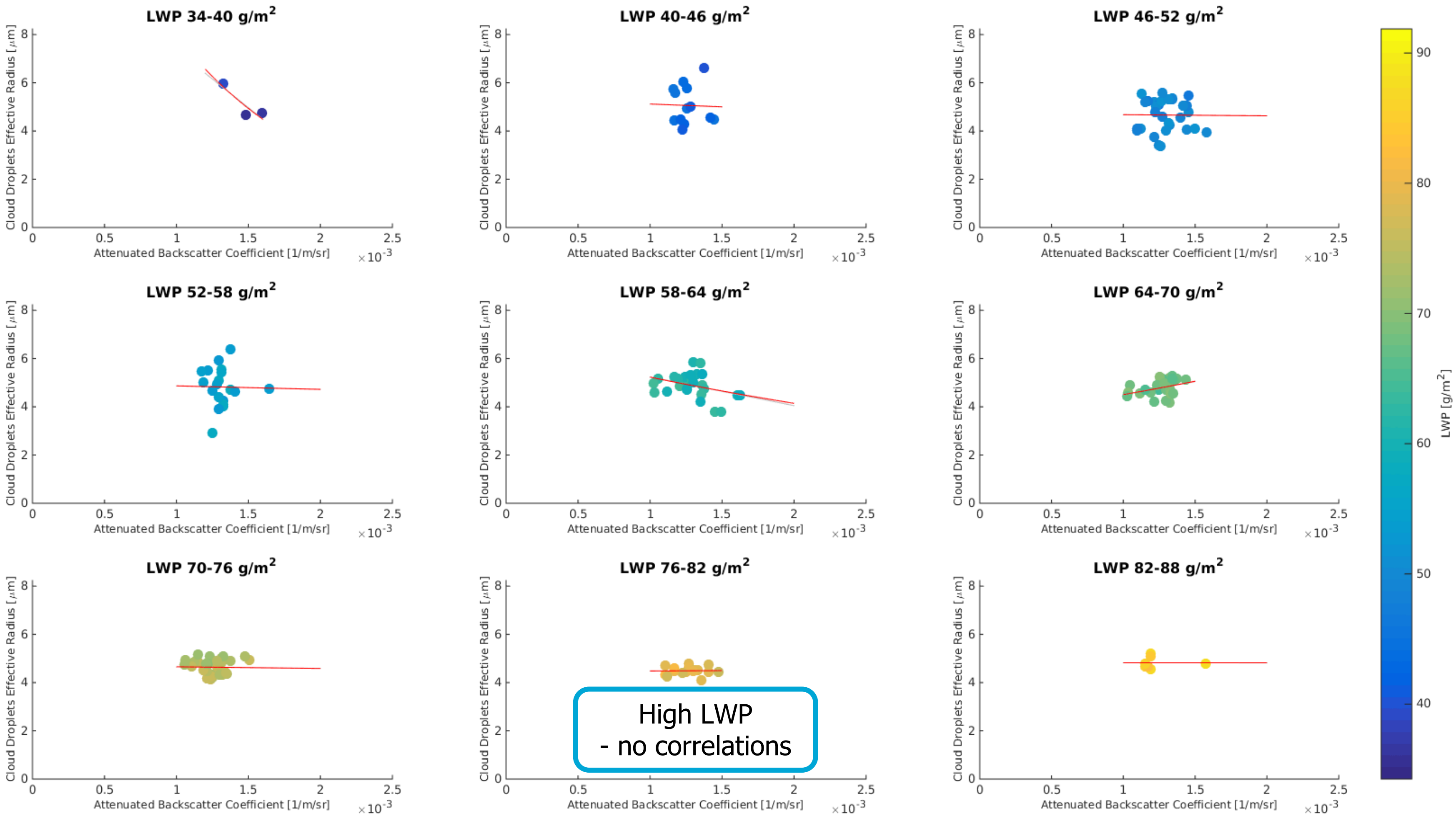
Study case 2009-11-29



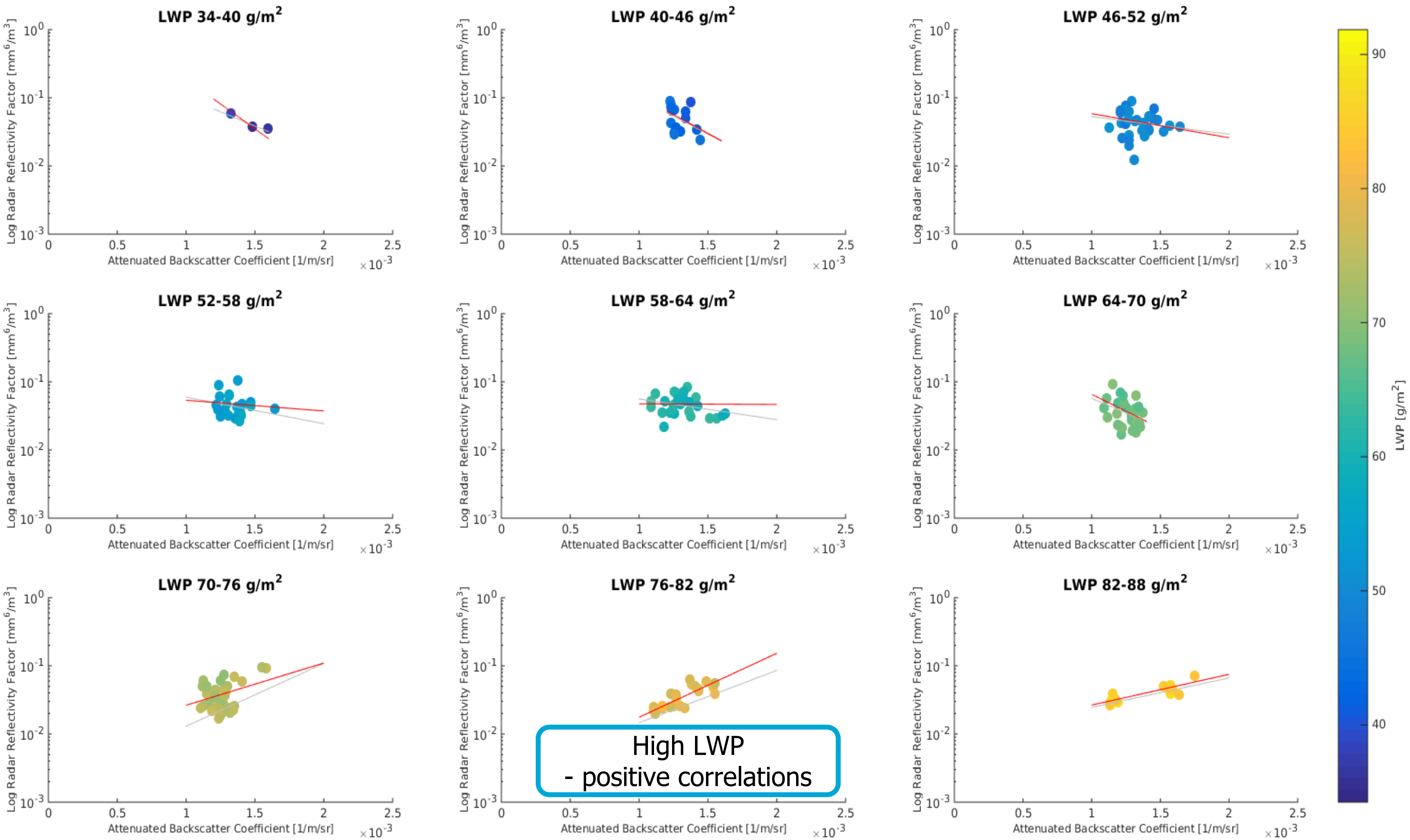
Microphysical retrieval



Attenuated Backscatter vs Effective Radius



Attenuated Backscatter vs Radar Reflectivity

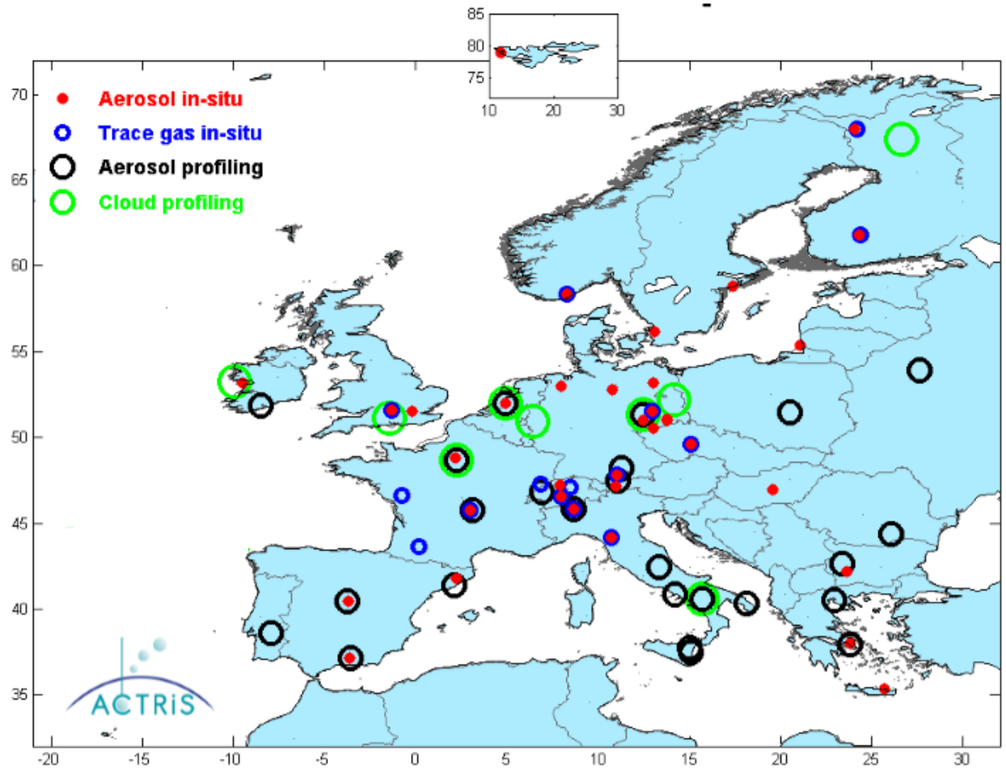


Benefits and limits of the method

1. Use of **direct observables**
2. Use of **widely spread remote sensing instruments**
3. **No assumptions** about the microphysical properties of clouds
4. It is **less restrictive** in the selection of study cases which will allow to analyse more data
5. It is **sensitive to the level in and below the cloud** where the measurements are compared
6. It is necessary to **consider other processes** that may influence the change in observables

Application

- This framework will be implemented at the cloud profiling sites of the ACTRIS network in Europe to enable monitoring of the Aerosol-Cloud Interaction close to real-time.



- It is based on the CloudNet data standard and can easily become one of the products