How Can We Use Lidar And Radar To

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Aerosol-Cloud Interactions

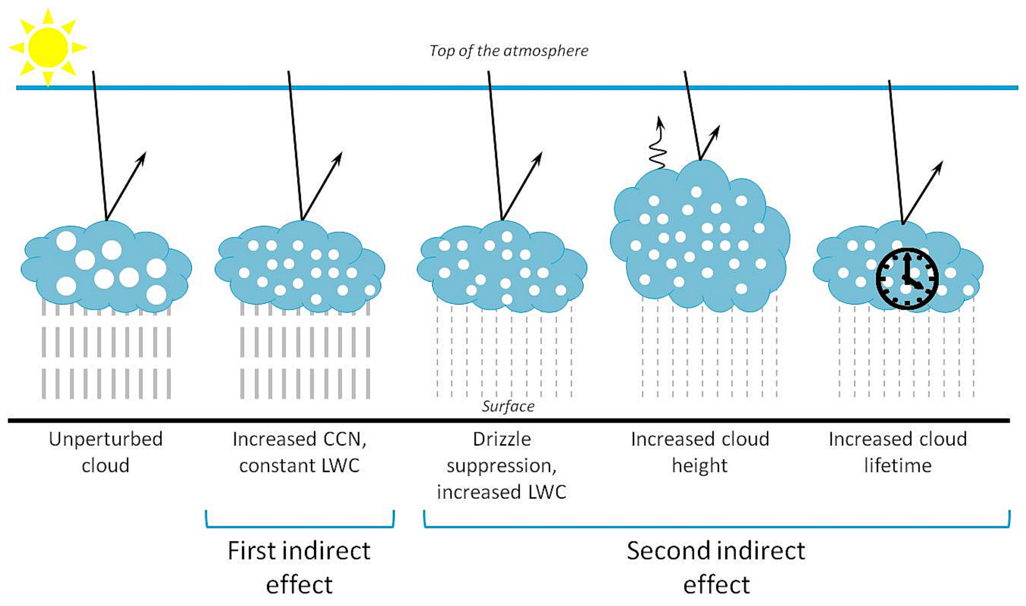


Figure 1. Schematic of the aerosol indirect effects. CDNC stands for cloud droplet number concentration and LWC stands for liquid water content.

The first indirect effect of aerosols on clouds has a well established underlying physical process. If the same amount of water is available, an increased amount of aerosols in the atmosphere will result in more cloud condensation nuclei for the cloud droplet formations. That will lead to an elevated concentration of cloud droplets and consequently the formed droplets will be smaller.

How to monitor ACI?

To observe interaction between aerosols and clouds we need three components: the cloud properties, the aerosol properties below the cloud and the amount of water available.

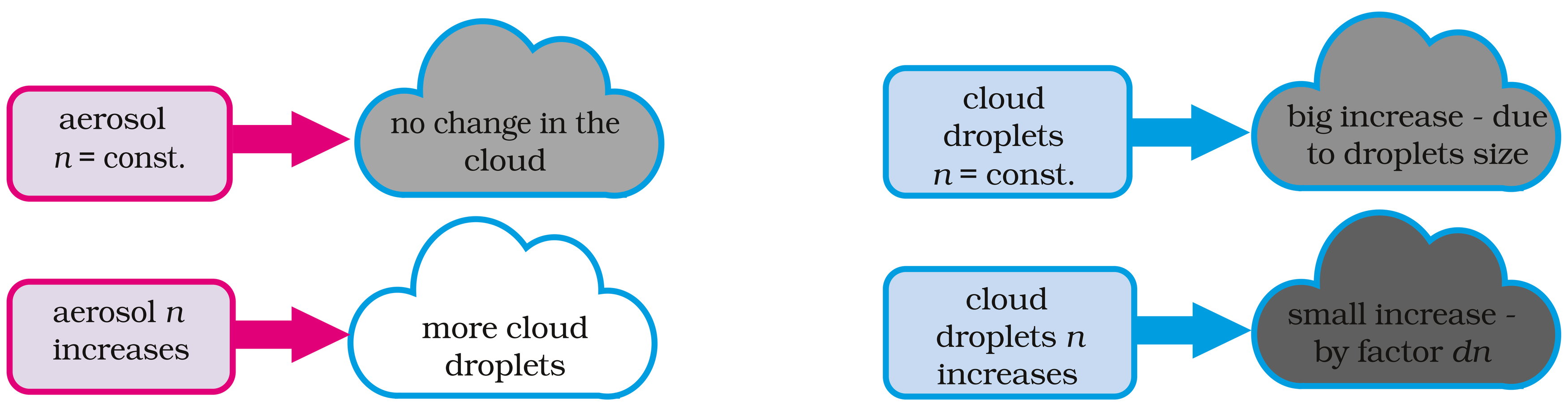
We propose a method of ACI monitoring based on the direct measurements from widely available instruments. For an aerosol proxy we propose to use **Attenuated Backscatter Coefficient** from lidar. To obtain information about changes in the cloud we use **Radar Reflectivity Factor** from a cloud radar. We supplement these observations with **Liquid Water Path** from a radiometer.

Attenuated Backscatter Coefficient

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

Radar Reflectivity Factor

$$Z \approx n_{cloud} * D^6_{cloud}$$

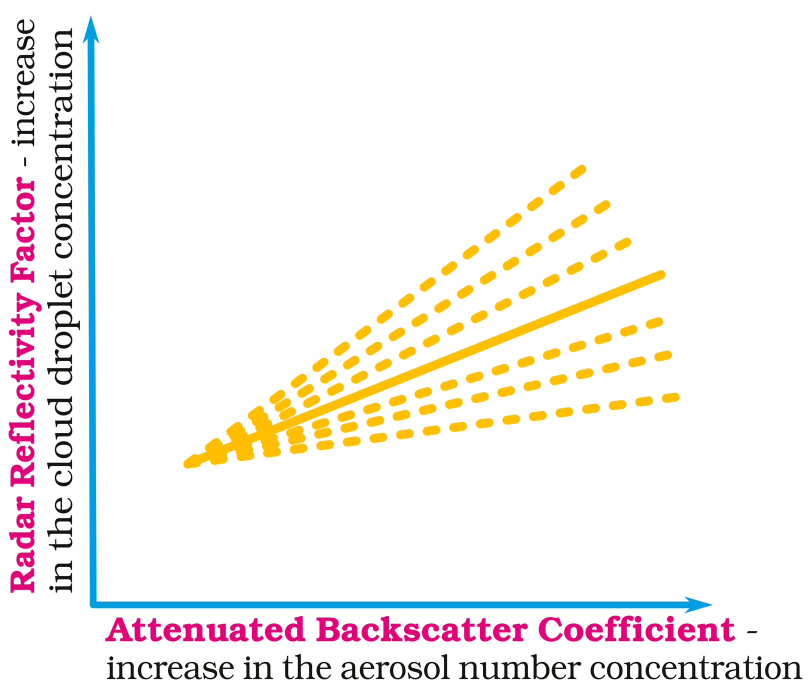


Number concentration of cloud droplets depends on number concentration of aerosols with some factor gamma. If we combine the formulas for reflectivity and backscatter coefficient and add to that the equation for the Liquid Water Content, we can derive a relation between the Attenuated Backscatter Coefficient and the Radar Reflectivity Factor.

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

$$LWC \approx n_{cloud} * D^3_{cloud}$$

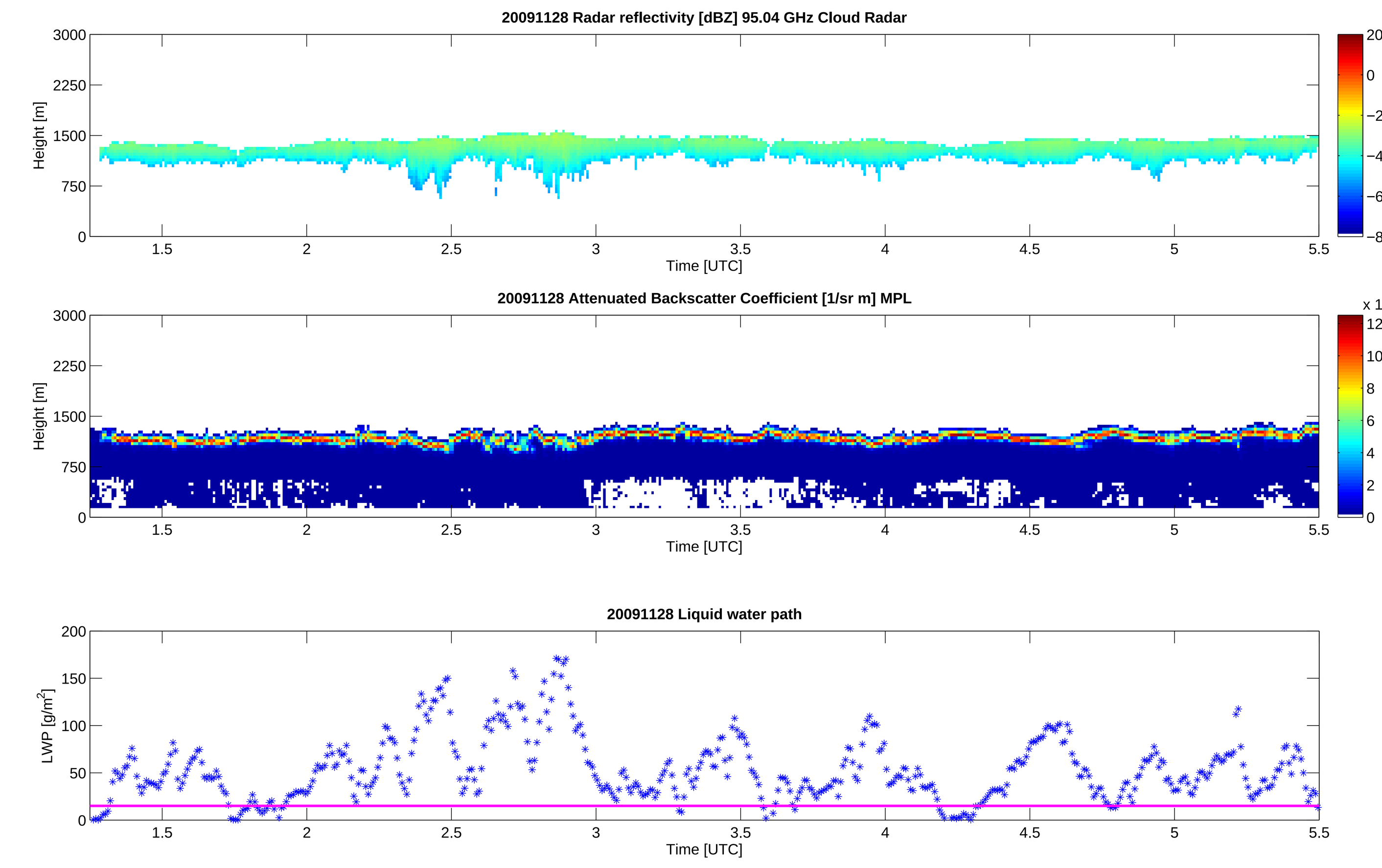
$$Z \approx \frac{\beta * LWC^2}{\gamma' * D^2_{aerosols} * n^2_{cloud}}$$

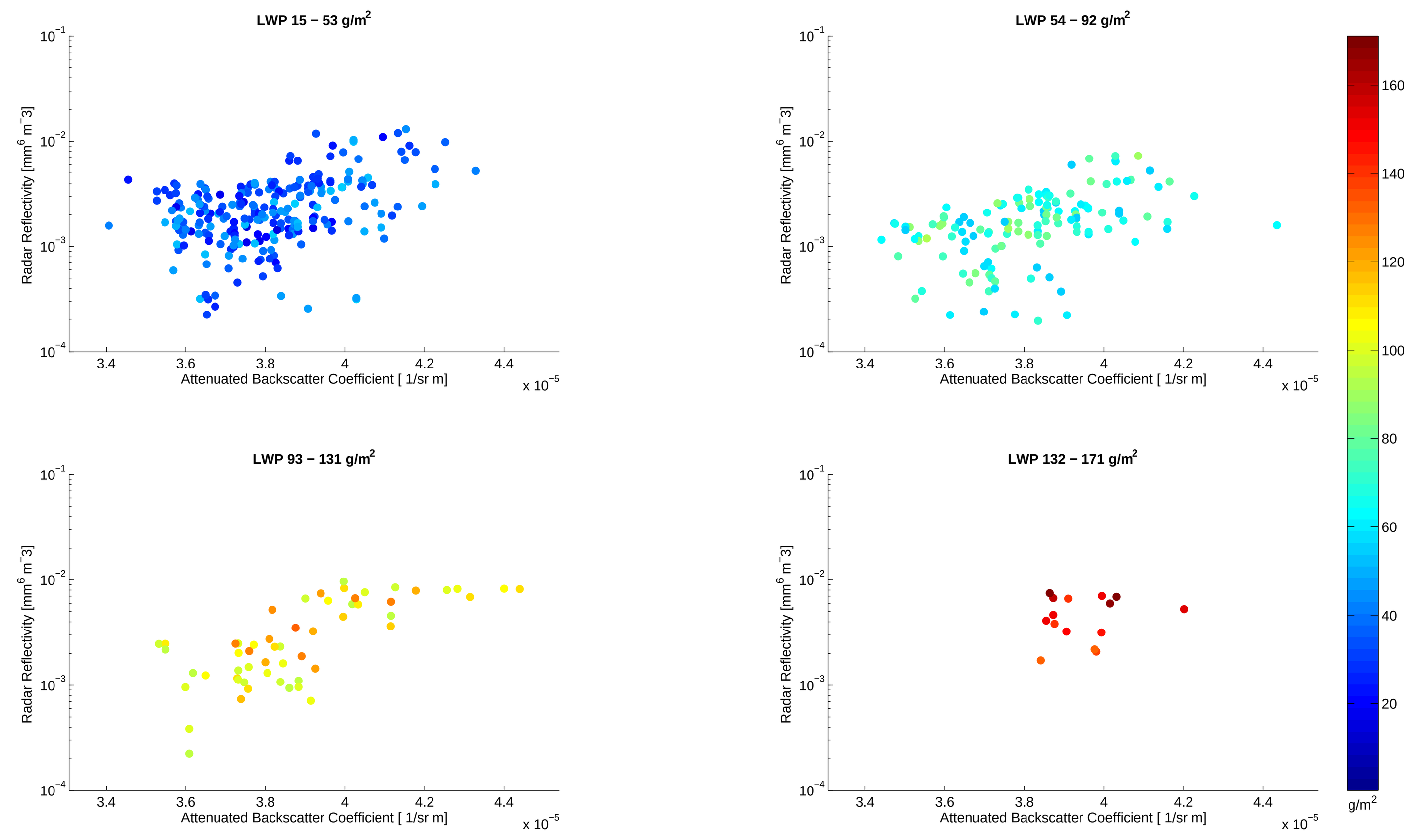


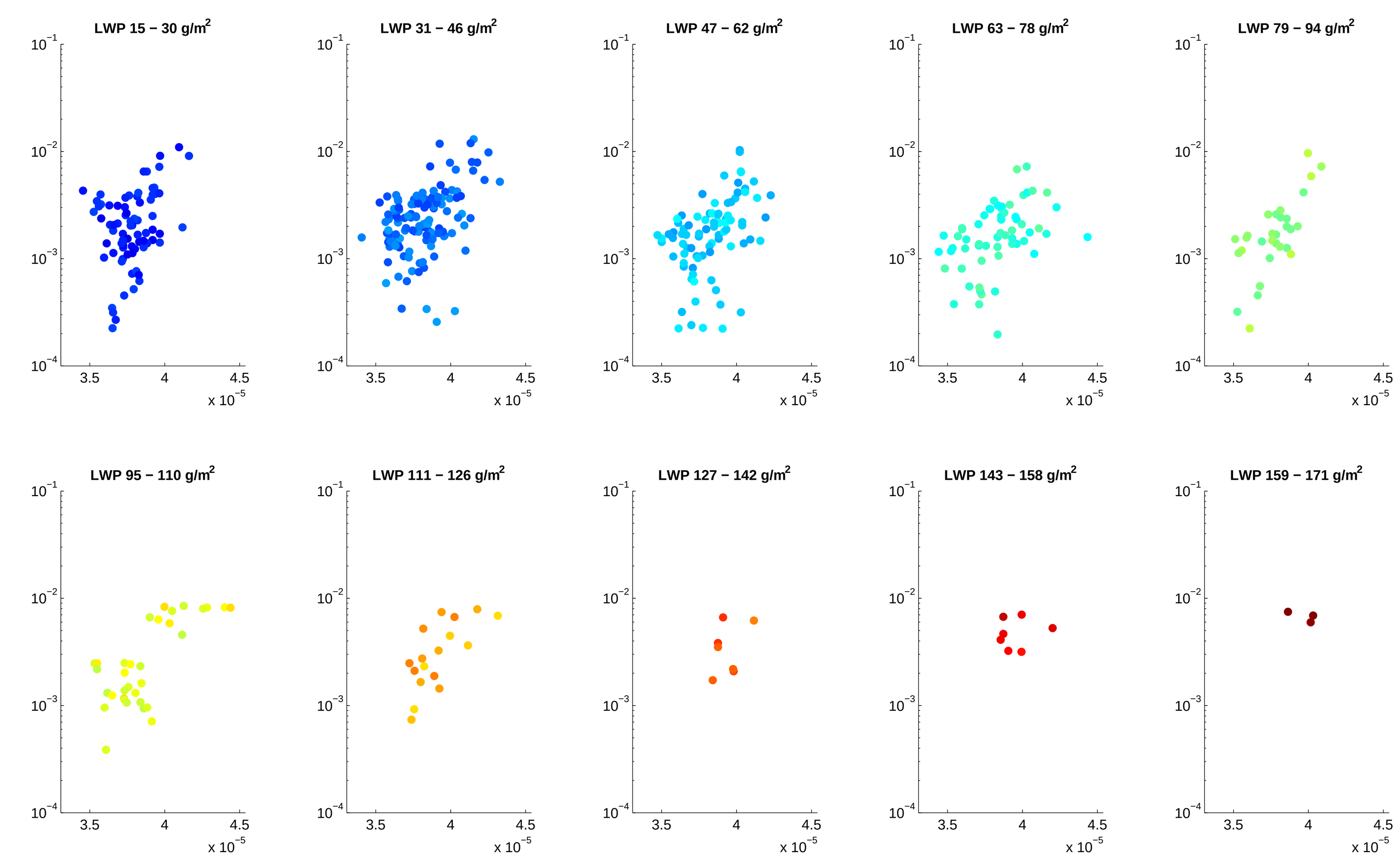
We expect that an increase of the Attenuated Backscatter Coefficient will correspond to an increase of the Radar Reflectivity Factor. However, the **slope** of this correlation **will vary.**

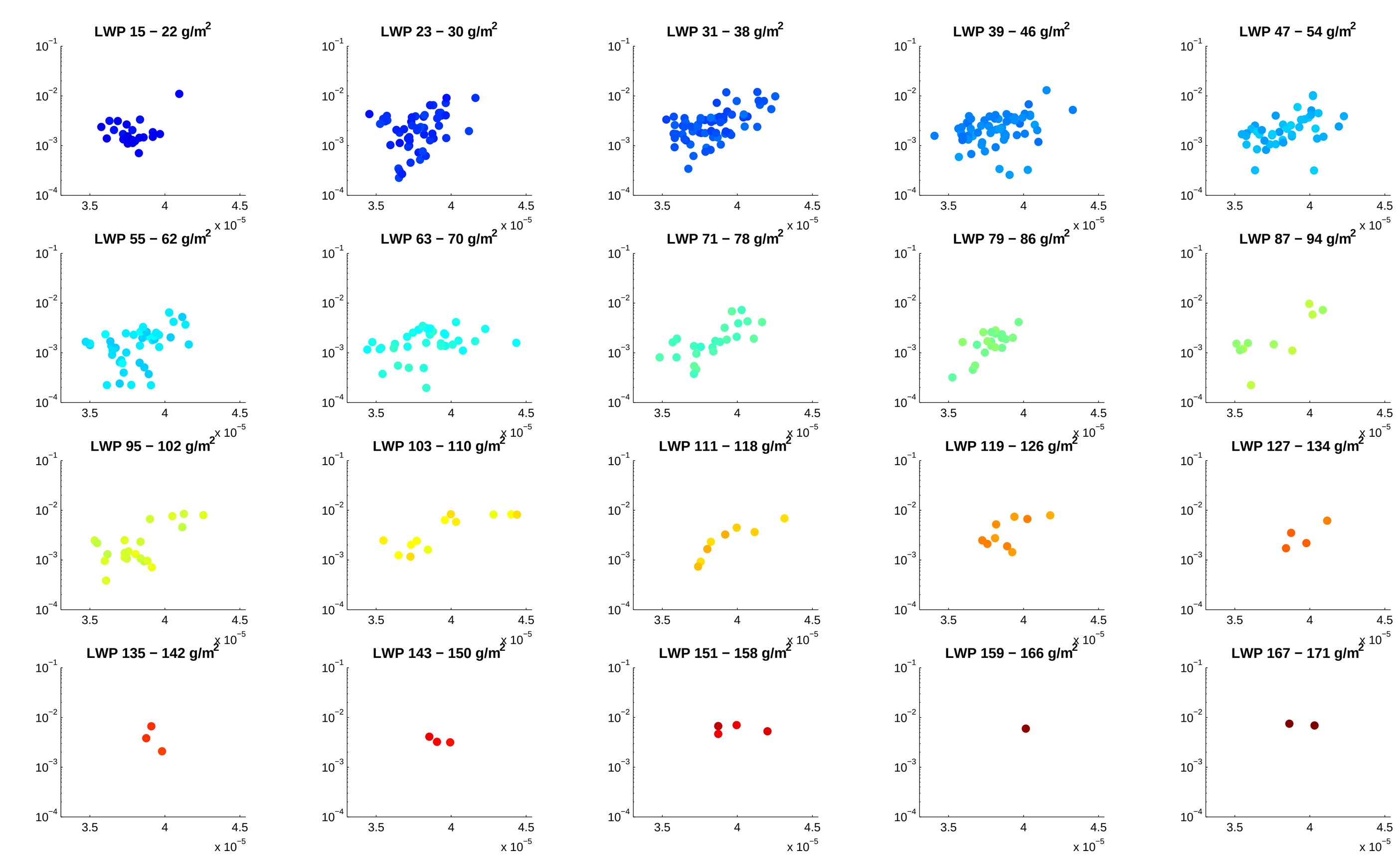
Study Cases

28 November 2009



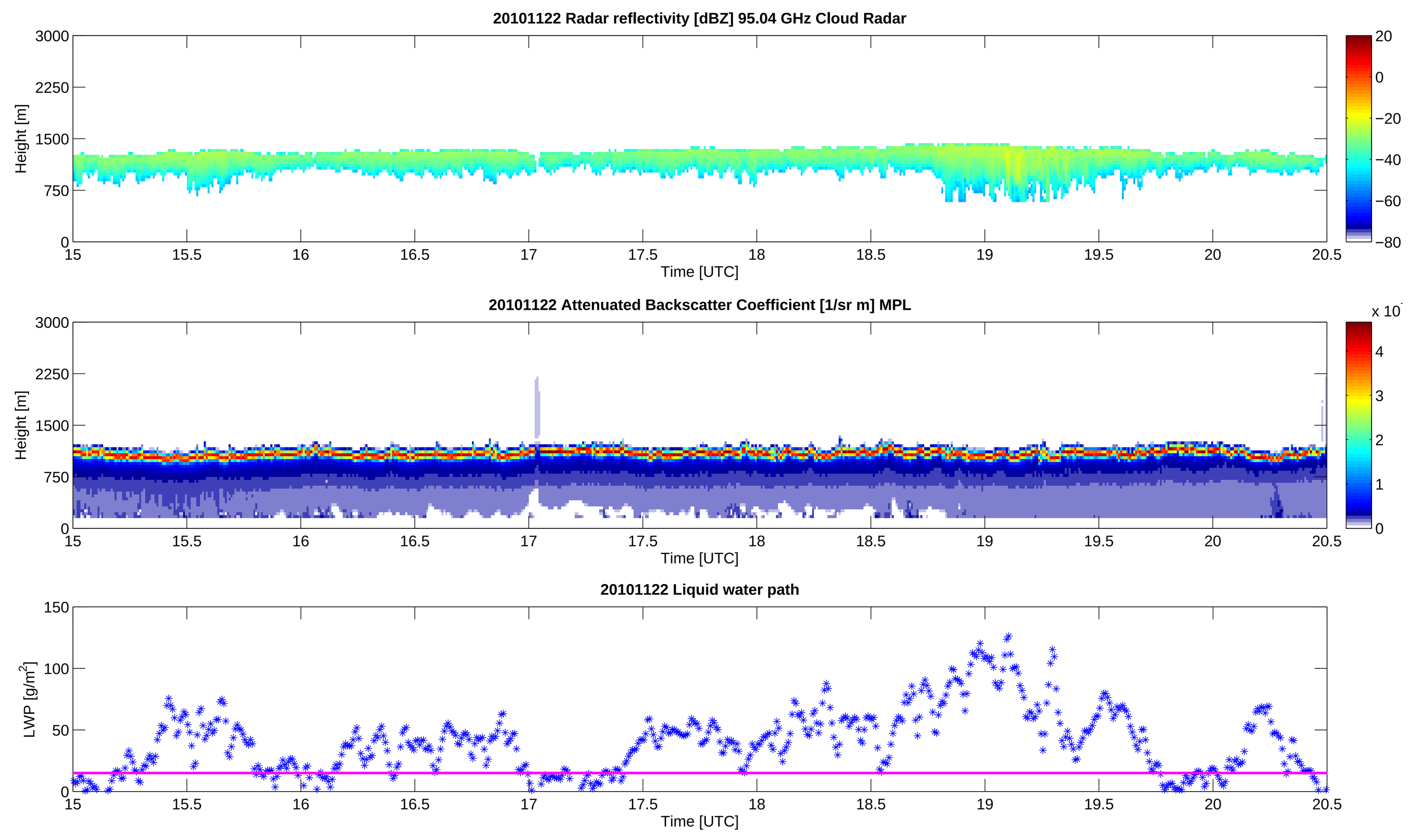


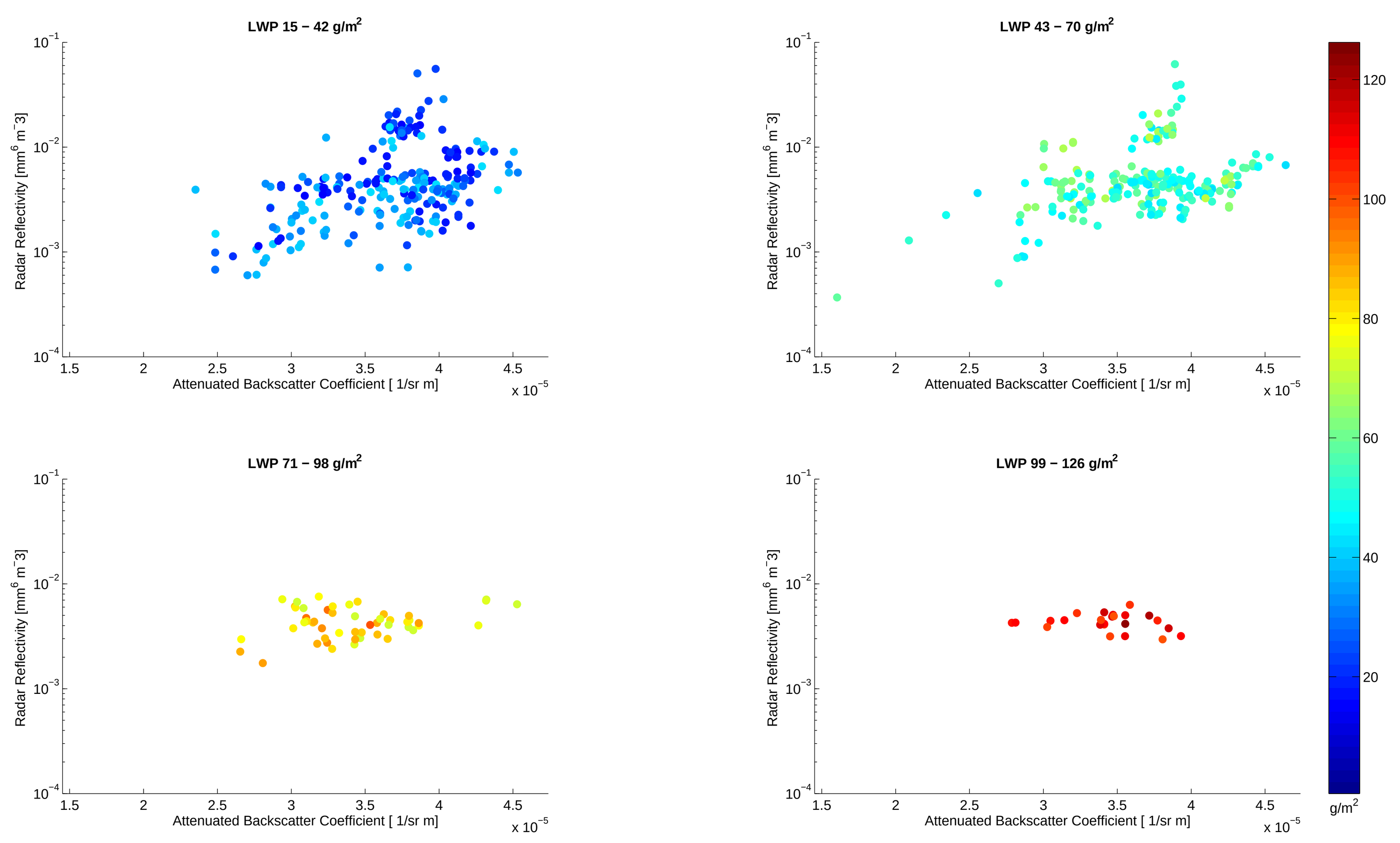


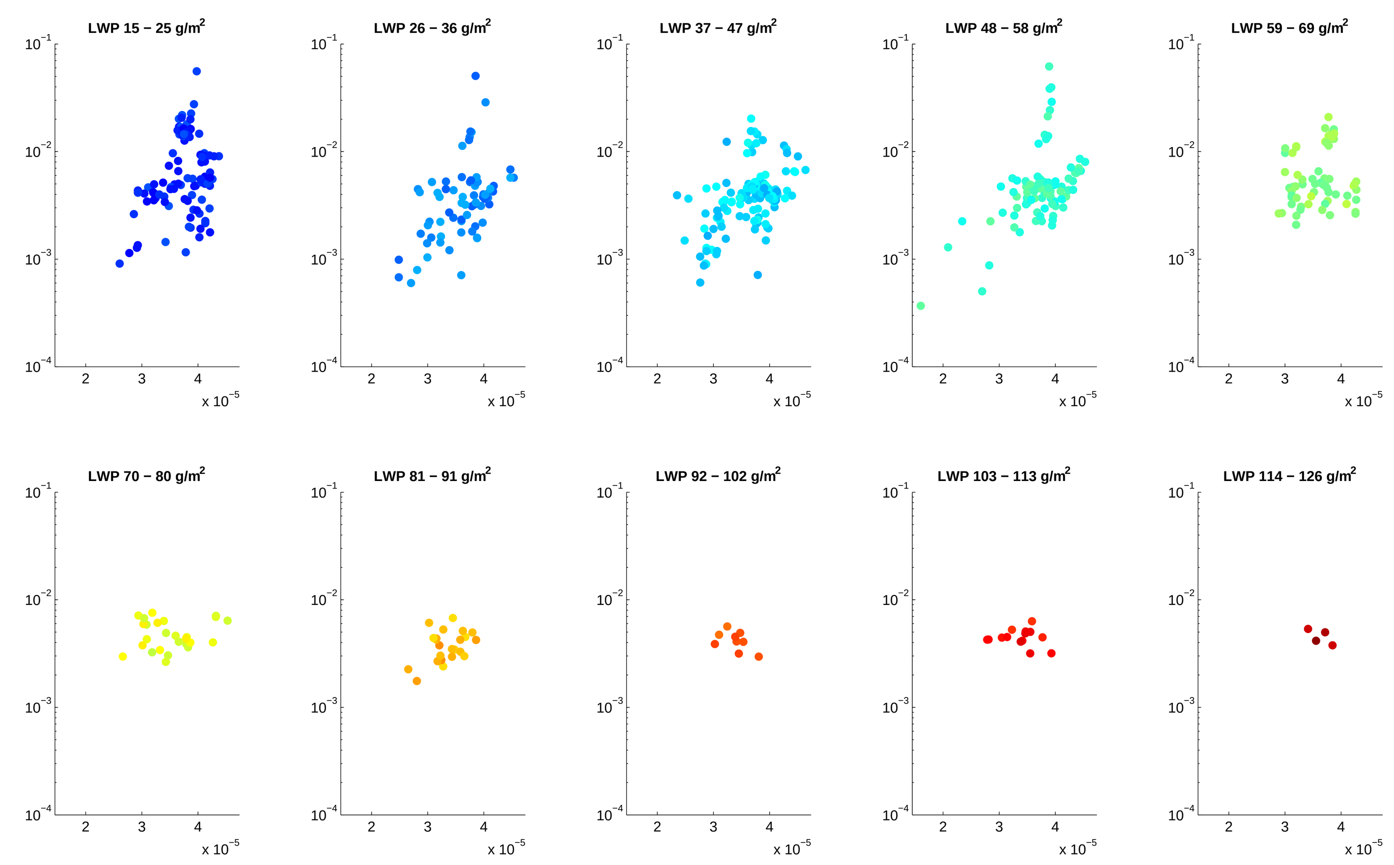


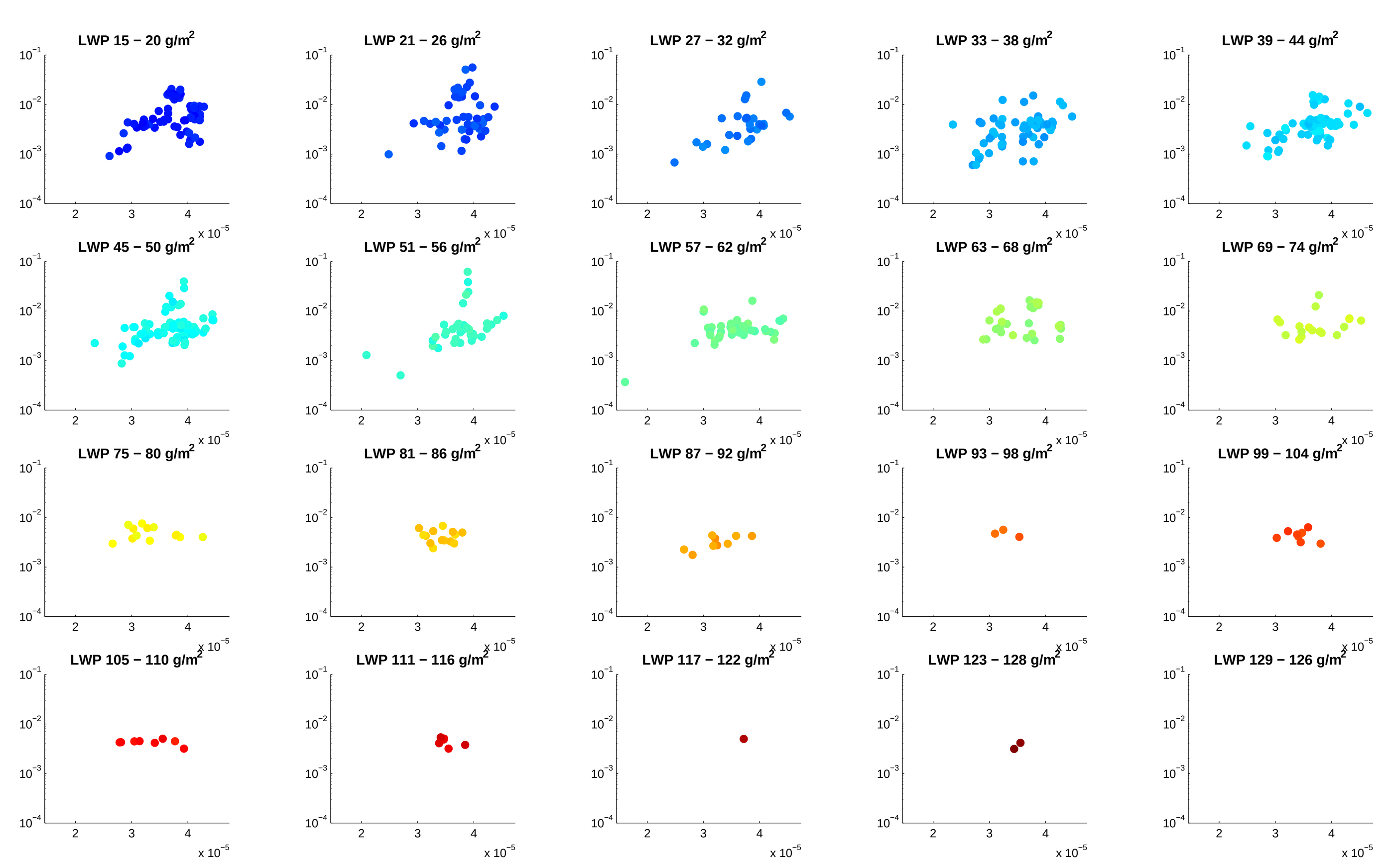
Monitor Aerosol-Cloud Interactions?

22 November 2010









Compared measurements

The adjacent graphs present two study cases of Stratocumulus clouds. The meteorological conditions during both episodes were similar. Variables we compare are:

1. **An integrated value of the Attenuated Backscatter Coefficient**. This value is integrated over a column starting at the height of the complete overlap to 400 m below the cloud base;
2. **An integrated value of the Radar Reflectivity Factor**. In both cases this value is integrated over the whole cloud.

The colours of the dots on the plots represent the values of the Liquid Water Path in an observed column.

Benefits of the method

Many different strategies have been used to investigate the Aerosol-Cloud Interactions. Unfortunately, the wide scope of methods and scales applied makes it difficult to quantitatively compare results from different studies. We propose a new scheme of measurements that will provide more consistent observations. The main benefits include:

1. It is a simple method. We use **direct observables** from widely spread remote sensing instruments.
2. We make **no assumptions about the microphysical properties** of clouds.
3. We use **widely available instruments**. This method can be easily implemented at other observatories.
4. It is **less restrictive** in the selection of study cases which will allow us to analyse more data.
5. It can (and should) be **complemented by microphysical properties** for the interpretation of the data.

Outlook

Figure 2. CESAR Observatory in the Netherlands

We plan to implement this framework over the cloud profiling sites of the ACTRIS network in Europe to enable monitoring of the Aerosol-Cloud Interaction close to real-time. In the next step we will use back-trajectory models to identify the aerosol sources. We will also analyse study cases based on similar meteorological and microphysical conditions.

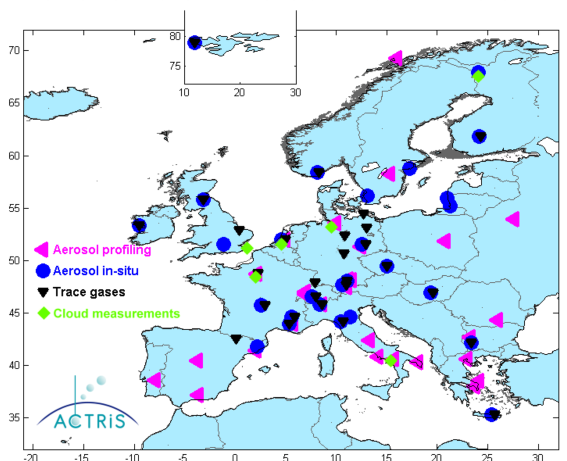


Figure 3. Map of ACTRIS sites

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ACTRIS

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