WP22- JRA3: A framework for cloud-aerosol interaction studies

Deliverable D22.5: Tools to identify the relation between aerosol sources and cloud-aerosol interaction

The aim of this work package is to establish a strategy for monitoring aerosol - cloud interactions. In the Task 22.4 the focus is put on defining the procedure and the needed set of data tools. Central to the procedure are the ACTRIS-Cloudnet data products which are available for multiple ACTRIS observatories (as developed in WP2). Starting point is the Instrument Synergy/Target Categorization data set. It is a product that facilitates the application of multi-sensor algorithms by performing much of the required pre-processing. It includes radar, lidar, microwave radiometer, rain gauge and model data with regridding, correction for attenuation, reporting of measurement errors, data quality flags and categorization of targets (Hogan, R.J, O'Connor, E.,J., 2004).

Aerosol - Cloud Interactions Data Procedure

1. **Data selection: water clouds.** The Cloudnet categorization system contains information on the nature of the targets in each resolution volume. . The information is in the form of an array of bits, each of which states either whether a certain type of particle is present (e.g. aerosols), or the whether some of the target particles have a particular property. The data with categorization Bit 0 (Small liquid droplets are present) and Bit 4 (Aerosol particles are present and visible to the lidar) can be analysed. Is some cases also Bit 1 (Falling hydrometeors are present) can be used, but only if it's small drizzle particles. This should be checked manually based on the other variables. Data should be further evaluated based on the "quality bits" variable, which contains information on the quality of the data at each pixel.

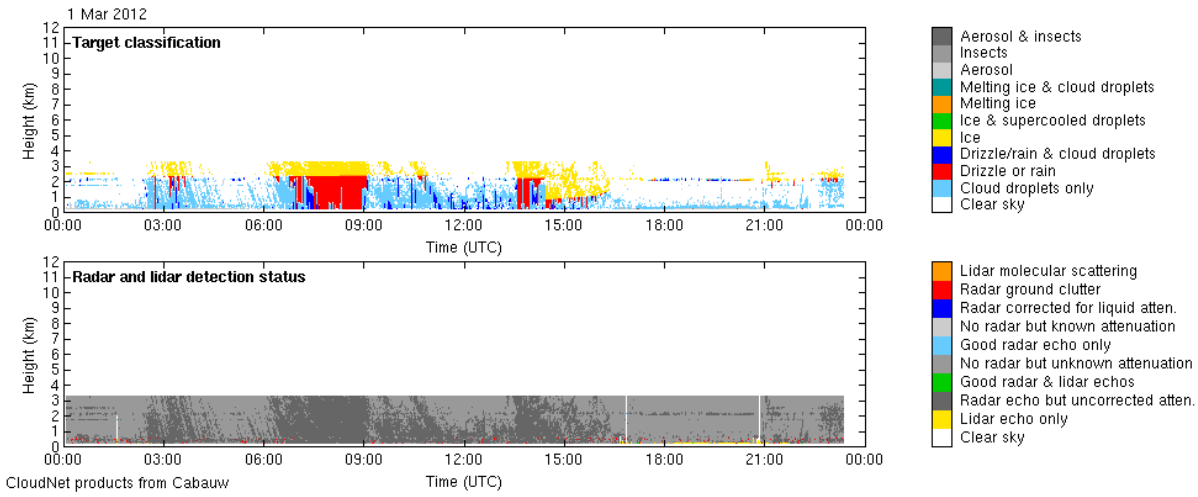

Figure 1. An example of a Cloudnet Target Classification and Radar and lidar detection status products. *Source: http://www.cloud-net.org/radar/cloudnet/quicklooks/cabauw_products.html#classification*

2. **Instrument availability.** Data from all relevant instruments is examined. The data sets of interest include: Microwave radiometer liquid water path, radar reflectivity factor, lidar attenuated backscatter coefficient and the related error estimates. Furthermore the selected data is limited to non-precipitating clouds with no drizzle present by putting a constraint on the value of the radar reflectivity factor (only process data if it is smaller than -20dBZ).

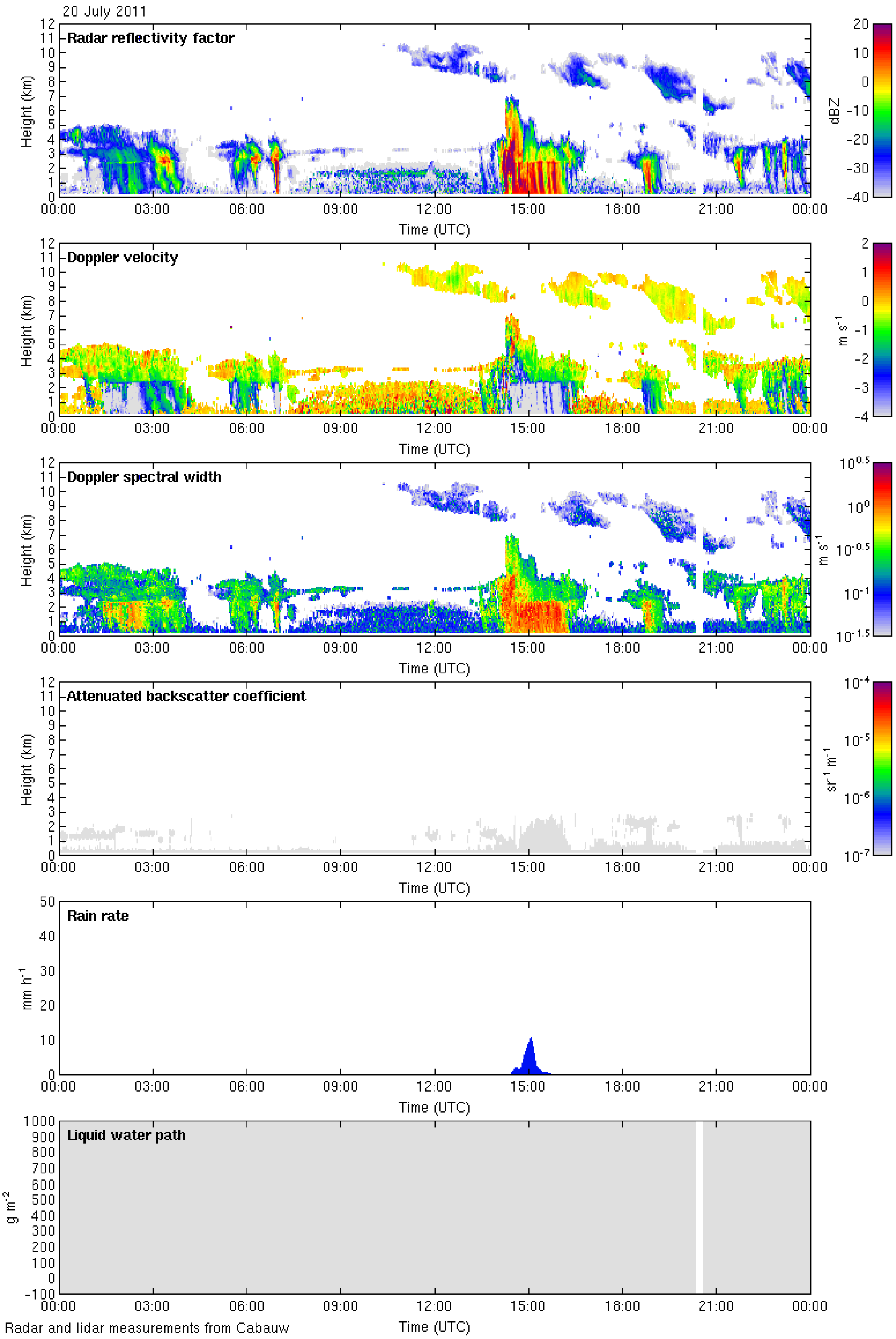

Figure 2. An example of Cloudnet Processed radar and lidar measurements (Level 1c) product. *Source: http://www.cloud-net.org/radar/cloudnet/quicklooks/cabauw_measurements.html*

3. **Instrument cross-correlation.** The lidar and radar signals are cross-correlated, based on direct observables from the instruments: the lidar attenuated backscatter coefficient as an aerosol proxy and the radar

reflectivity factor as the cloud proxy. As a number of factors can influence changes in cloud, such as meteorology or cloud drop microphysical properties, a constraint on the liquid water path is put, as suggested by Twomey (Twomey, 1974). This limitation ensures that the variability in the cloud will be primarily due to changes in microphysical properties associated with variation in aerosol.

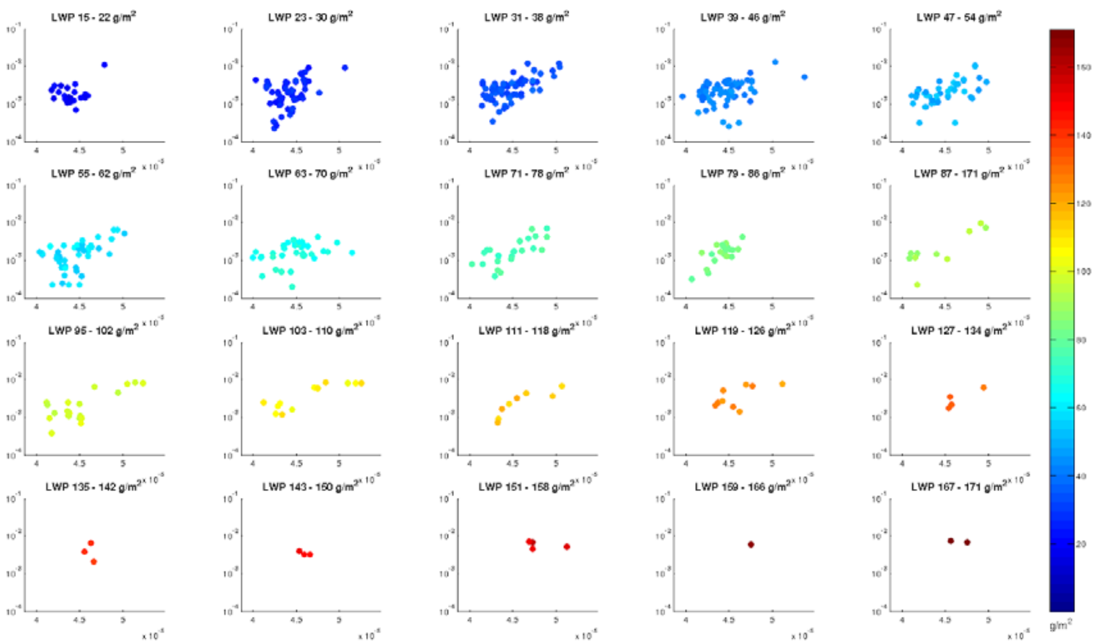

Figure 3. An example of a scatter plots comparing Lidar Attenuated Backscatter Coefficient (x axis) and Radar Reflectivity Factor (y axis). Data is divided into bins of LWP. *Source: Sarna Karolina, Russchenberg, H.W.J., "Framework for monitoring aerosol-cloud interactions in liquid water clouds" 4th ACTRIS General Meeting, June 10-13 2014, Clermont-Ferrand, France*.

4. **Aerosol source evaluation.** To evaluate the source of the aerosols a back trajectory analysis is performed. Archive trajectories can be computed with the HYSPLIT Trajectory Model (Draxler and Rolph).

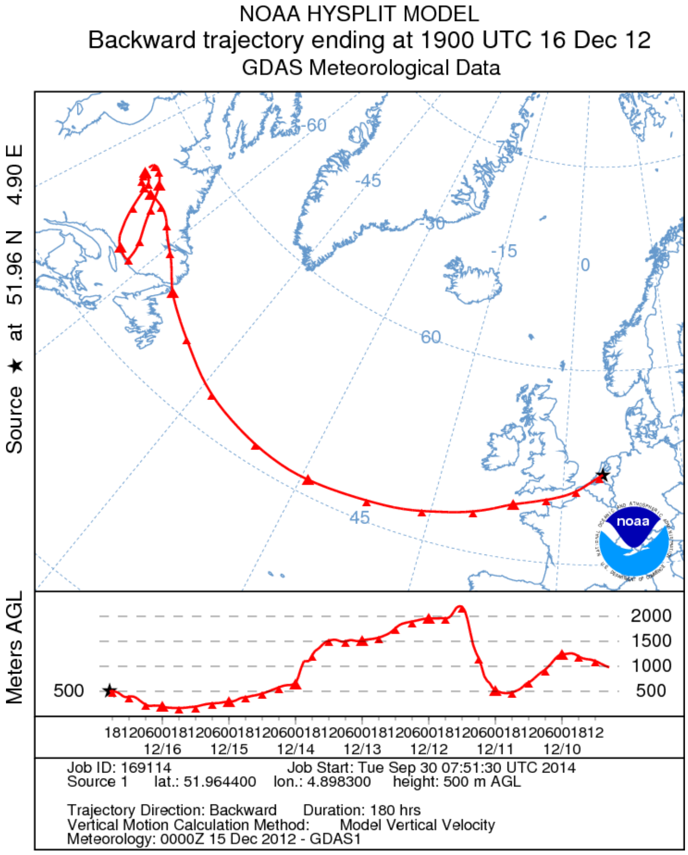

Figure 4. An example run of a HYSPLIT back trajectory model for Cabauw.

5. **Cloud microphysics.** Further analysis requires obtaining the microphysical properties of the cloud in order to evaluate if the change in the lidar attenuated backscatter coefficient and the radar reflectivity factor correspond with the change of the number concentration and cloud droplet size. It can be achieved by two methods:
   a. Retrieval of Liquid Water Cloud Properties - as described in Knist, 2014.
   b. By estimating an extinction coefficient at the cloud base. To retrieve the extinction coefficient a stable lidar profile inversion can be used (Klett, 1981), taken into account the effects of multiple scattering.. The extinction coefficient is used to estimate the size of cloud droplets in the lower part of the cloud only.

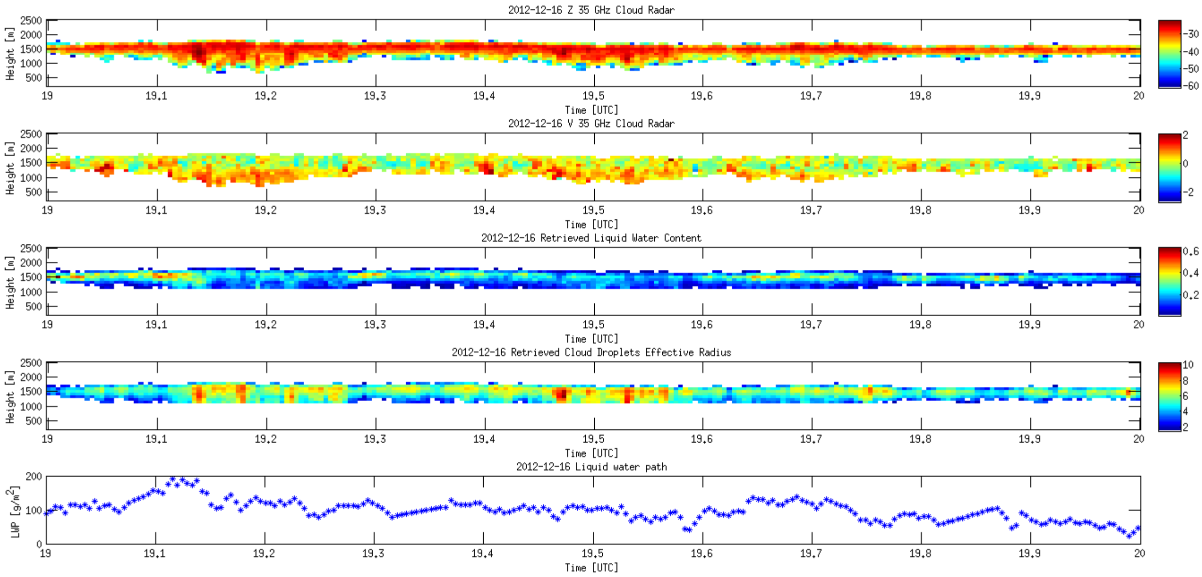

Figure 5. An example of the output from the Liquid Water Cloud Properties Retrieval.

Tools and algorithms for the steps above are available and will be published at the ACTRIS website at the end of the project.

References:

Draxler, R.R. and Rolph, G.D. HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/HYSPLIT.php). NOAA Air Resources Laboratory, College Park, MD.

Hogan, R. J., O'Connor, E. J., "Facilitating cloud radar and lidar algorithms: the Cloudnet Instrument Synergy/Target Categorization product", http://www.cloud-net.org/data/products/categorize.html.

Klett, James D. "Stable Analytical Inversion Solution for Processing Lidar Returns." Applied Optics 20, no. 2 (January 15, 1981): 211–220. doi:10.1364/AO.20.000211

Knist, C. L., "Retrieval of liquid water cloud properties from ground-based remote sensing observation", Phd thesis, Geosciences and Remote Sensing, Delft University of Technology.

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Twomey, S. "Pollution and the Planetary Albedo." Atmospheric Environment (1967) 8, no. 12 (December 1974): 1251–1256. doi:10.1016/0004-6981(74)90004-3.