Effect of cloud microphysics on particle growth under mixed phase conditions

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1. Introduction

- Ice and liquid phase coexist within a mixed-phase cloud.
- The interaction of phases leads to an enhanced growth of the ice particles.
- Understanding those growth processes is important – main processes for precipitation formation.
- Ground based remote sensing is able to capture such small scale microphysical processes – processes can be identified studying radar Doppler spectra.
- Problem: limitation of the instrumental synergy to detect the super-cooled layers.
- Problem: Different particle population present within a height cross section → Fall-streak correction (following the same particle population).

➢ Tracking particle growth processes along the trajectory within mixed-phase using data based on ACCEPT campaign.

2. Main instruments

The Transportable Atmospheric Radar (TARA) of the Delft Technical University is an advanced FMCW radar profiler

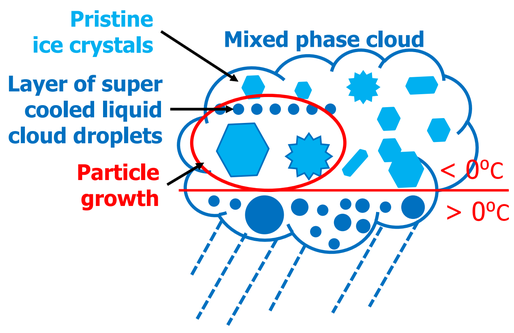
- Height temporal (≥ 3 s) and spatial resolution (≥ 7.5 m)
- 3 GHz, λ=9.1cm → sensitive to large hydrometeors → ice crystal
- 3 beam configuration → retrieve 3D-wind vector
- Fully polarimetric → particle shape
- Doppler capabilities → particle dynamics, particle modes

Lidar data for the liquid-layer retrieval based on de Boer *et al.* 2009 [2]

Analysis of the Composition of Clouds with Extended Polarization Techniques campaign:
Measurement during the **ACCEPT** campaign were done in cooperation with TROPOS, Royal Dutch Meteorological Institute (KNMI), Ludwig-Maximilian University Munich (LMU), Germany, and Metek, Germany, Oct – Nov 2014, Cabauw, the Netherlands.
AIM: Observe and understand microphysical processes within mixed-phase clouds.
Instruments: Fully polarimetric, Doppler capable radars – Mira (Ka-Band, 35GHz) and TARA (S-band, 3 GHz), Raman lidars (PollyTX), UV-lidar, microwave radiometers, and radiosondes.

Shows the measurement setup of the ACCEPT campaign at the Cabauw experimental side for atmospheric research, Cabauw, the Netherlands.

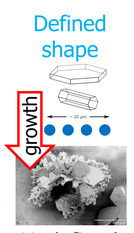
3. Ice particle growth processes [1][3][4]



Fast growth of ice crystals when falling trough the liquid layer

➢ increase of Z → grow in size

➢ change polarimetric signature →lose defined shape



4. Methodology of fall-streak tracking

Fall-streaks are due to cloud dynamics effects.

Wind retrieval

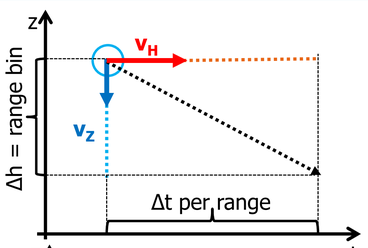
- 3 beam configuration of TARA
- Retrieval of 3D-wind vector

➢ Outputs: mean horizontal Doppler velocity, mean vertical Doppler velocity, wind direction (every 3 seconds)

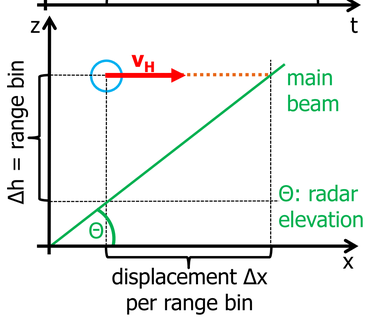
Assumption: same dynamic conditions in all 3 beams
Limitations: fare range, turbulent systems, small clouds

Fall streak tracking

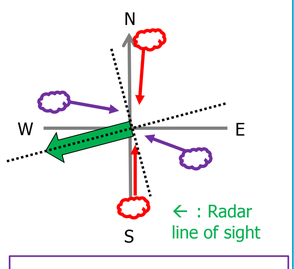
1.Relation vertical displacement to time:
Constant v_Z per range bin
➢ $\Delta t_Z = \Delta h / v_Z$
Assumption: only down drafts
➢ up-drafts = 0



2. Relation horizontal displacement to time:
Constant v_H per range bin
➢ $\Delta x = \Delta h * \tan(\theta)$
➢ $\Delta t_H = \Delta x / v_H$



3. Direction of cloud movements:
Perpendicular movement to the radar line of sight
➢ vertical movement dominates
➢ correction factor for wind direction
Wind ahead or behind the radar line of sight
➢ Sign of the horizontal wind



4. Time shift per range bin

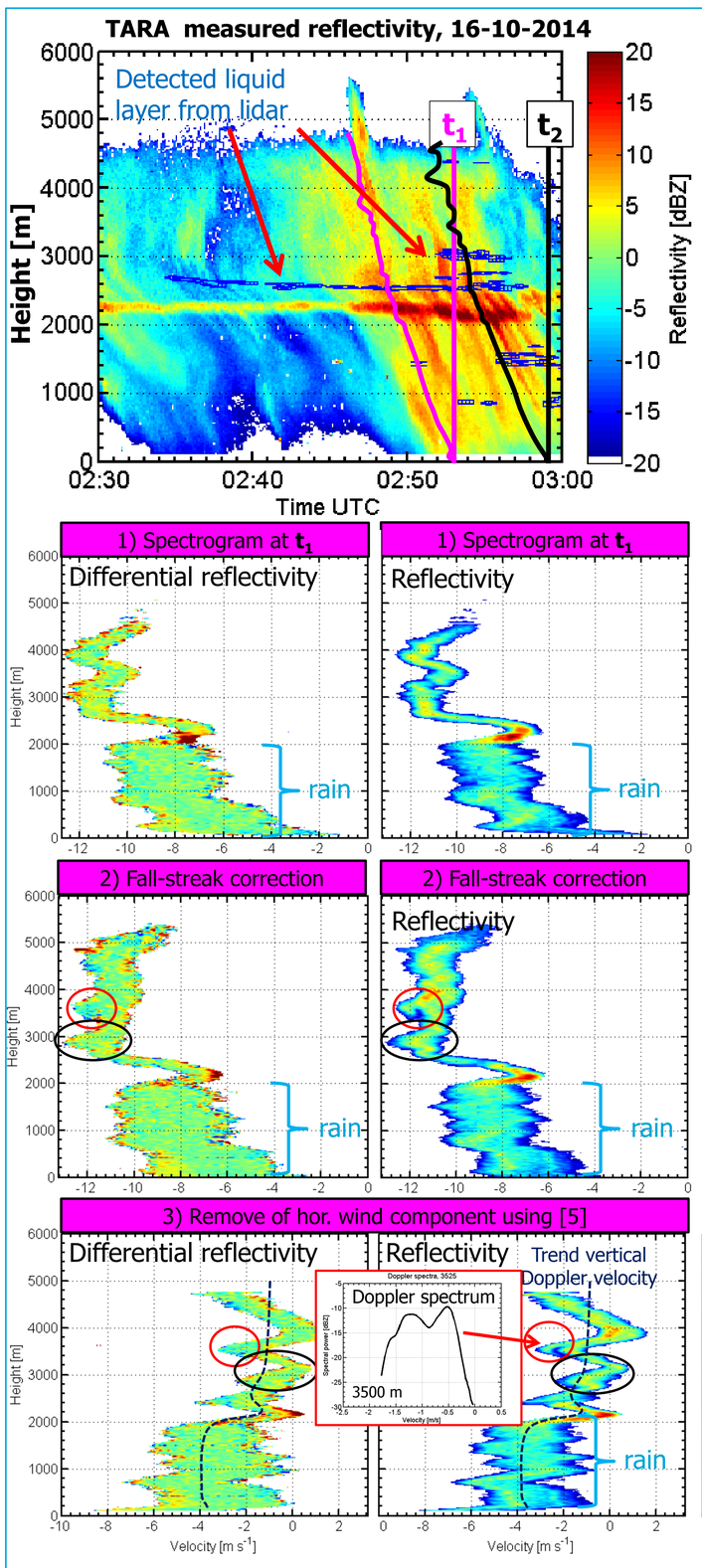
$$\Delta t(H) = t_{start} + \sum_{h=1}^{H} d_H(h)\Delta t_H(h) + \Delta t_Z(h) + \sum_{h=1}^{H} d_Z(h)\Delta t_Z(h)$$

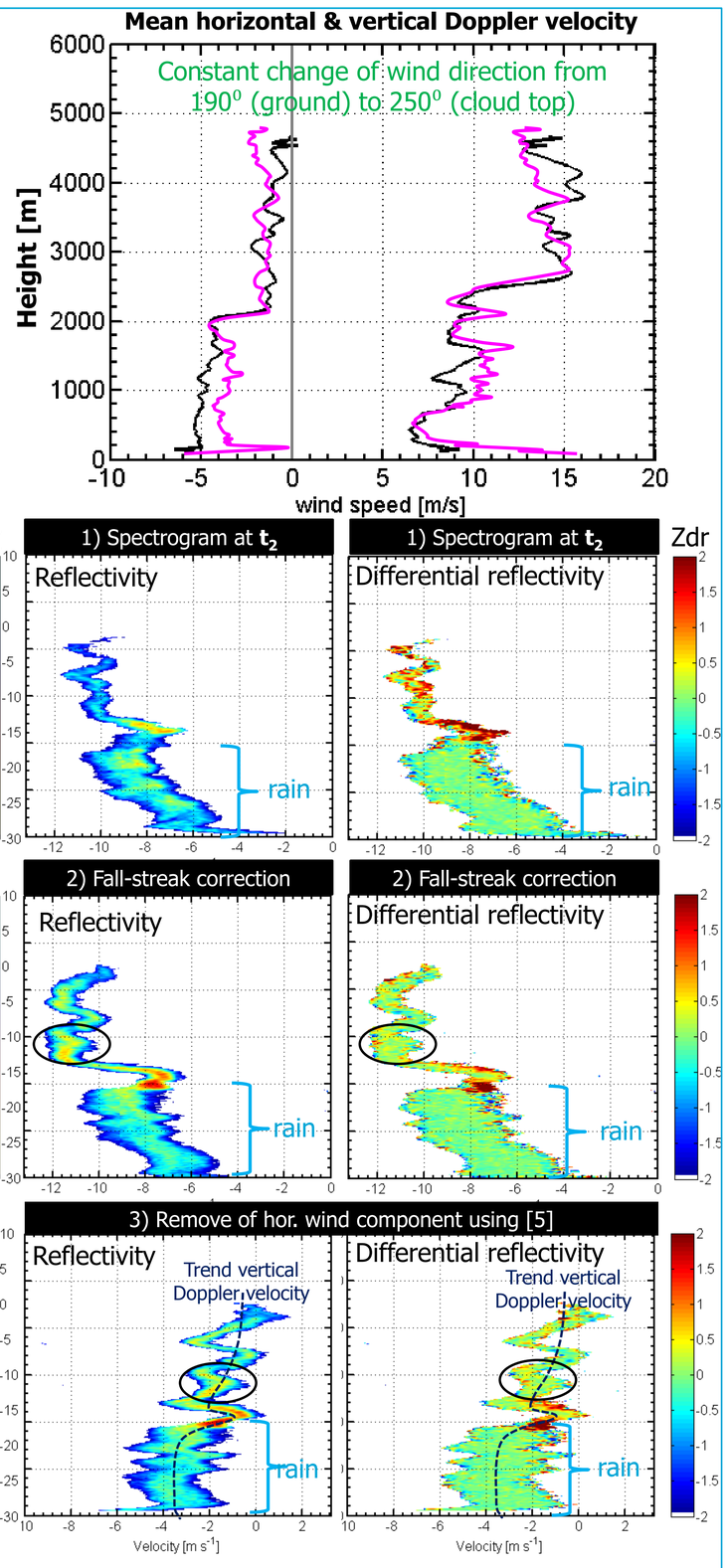
- $\Delta t(H)$: time shift per range bin
- t_{start}: Start time
- $\sum_{h=1}^{H} d_H(h)\Delta t_H(h)$: *horizontal displacement*
- $\Delta t_Z(h)$: *vertical dis-place-ment*
- $\sum_{h=1}^{H} d_Z(h)\Delta t_Z(h)$: *correction for perpendicular wind directions*

d_H, d_Z wind direction correction factor

Issues:
- Averaged profile of the wind retrieval as input – limitations of the wind retrieval
- Wind shear is not completely resolved by the fall-streak

5. Case study 16th October 2014





increased Doppler width (no wind shear) → second particle mode → vertical Doppler velocity increases →RIMING
increased Doppler width (no wind shear)→ liquid layer detected → vertical Doppler velocity increases → GROWTH
increased Doppler width→ vertical Doppler velocity increases → spherical shape → RAIN

6. Conclusion and outlook

- On going work: Cloud dynamic correction of Doppler spectra
- Allow a better understanding of cloud microphysical processes.
- Further work: study microphysical processes using Doppler spectra information – enhancing the detection of liquid layers and growth process studies

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The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013): People, ITN Marie Curie Actions Programme (2012-2016) in the frame of ITaRS under grant agreement n° 289923.z And My colleagues for the collaboration.

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[2] De Boer *et al. 2009* – Arctic mixed-phase stratiform cloud properties from multiple years of surface-based measurements at tow high-latitude locations
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