Overview on the cloud-radar-related research activities at TROPOS

Mira Workshop, Munich, 14-15 May 2014

Patric Seifert, Johannnes Bühl, Alexander Myagkov

TROPOS
Leibniz Institute for
Tropospheric Research

Outline

I. Remote Sensing at TROPOS

II. Our Focus

III. Results

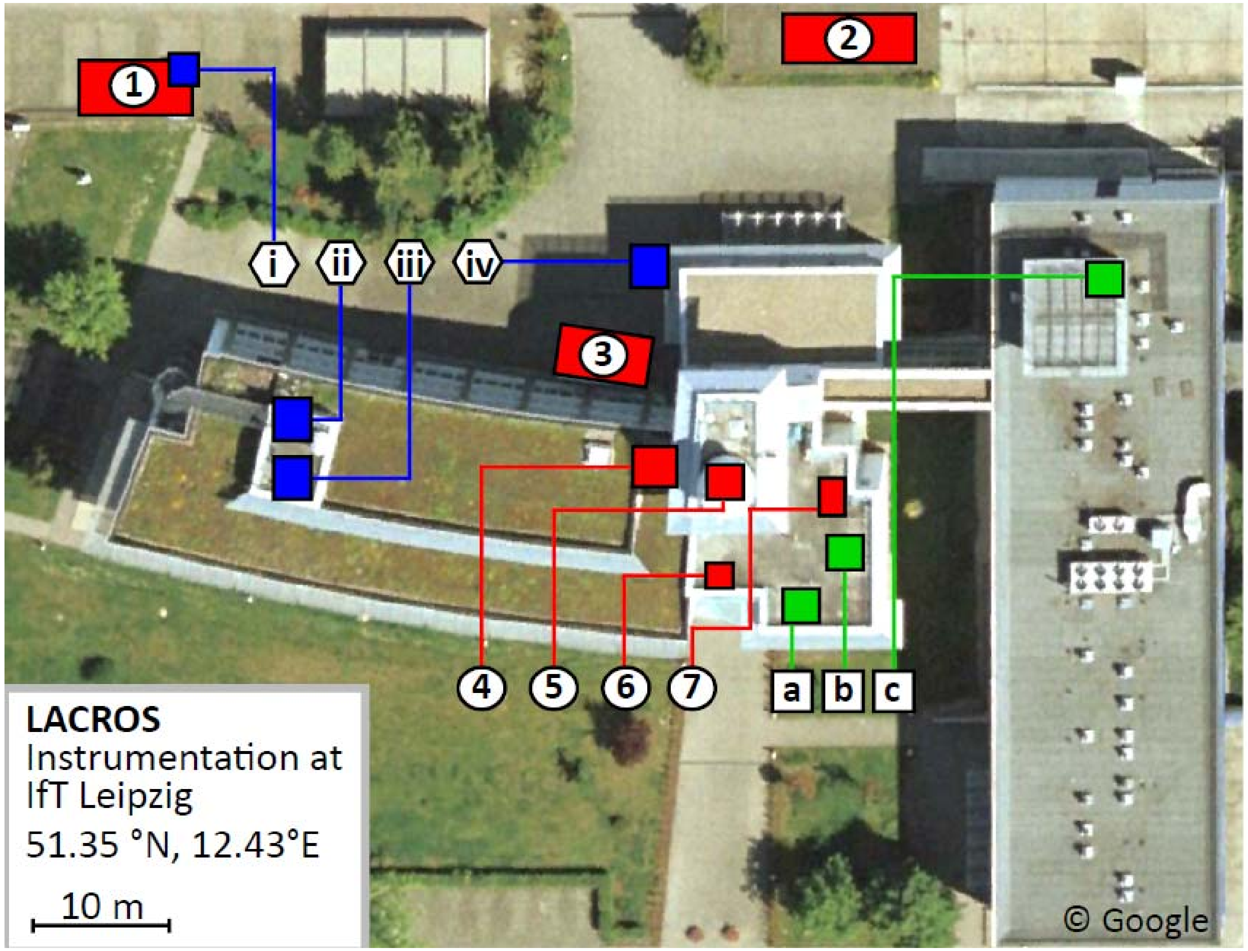
- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

IV. Outlook

- ACCEPT campaign

Instrumentation

- Mira35 runs as part of LACROS (Leipzig Aerosol and Cloud Remote Observations System)



Active instrumentation

① Cloud radar Mira-35 ←
② Raman/HSR lidar BERTHA
③ Doppler lidar WiLi ←
④ Raman lidar MARTHA[#]
⑤ SAEMS[#]
⑥ Ceilometer CHM 15kx ←
⑦ Raman lidar Polly^{XT} ←

Passive instrumentation

a AERONET Sun photometer ←
b Microwave radiometer HATPRO ←
c All-sky imager

In situ instrumentation

(i) Optical disdrometer ←
(ii) Meteorological surface station ←
(iii) Aerosol in-situ instrumentation
(iv) Sounding station Vaisala MW31

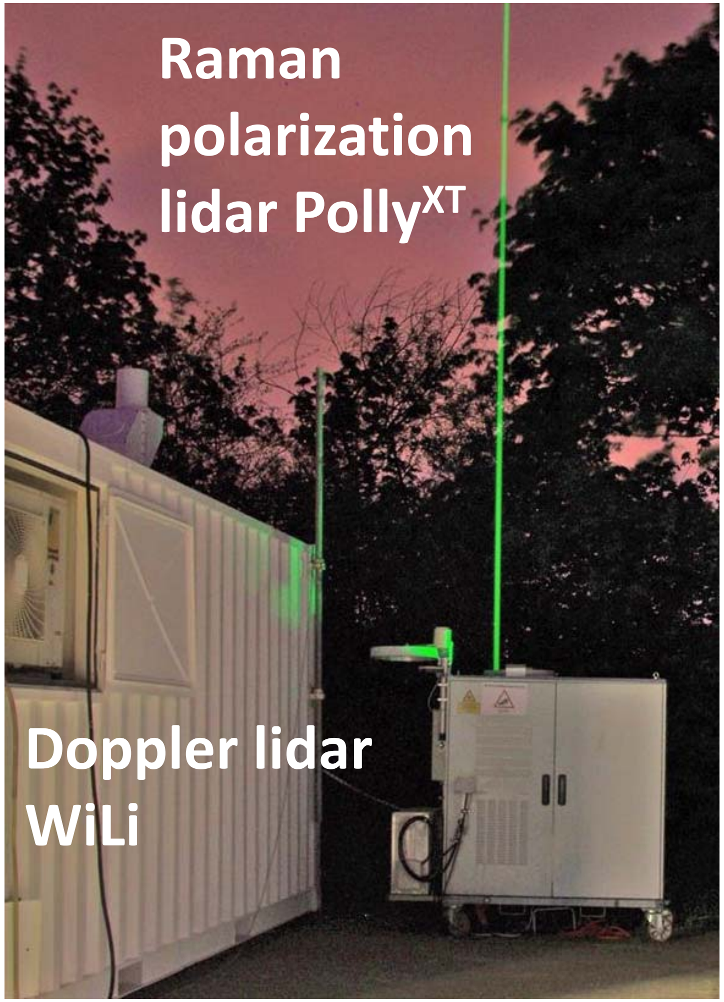
#: unmovable

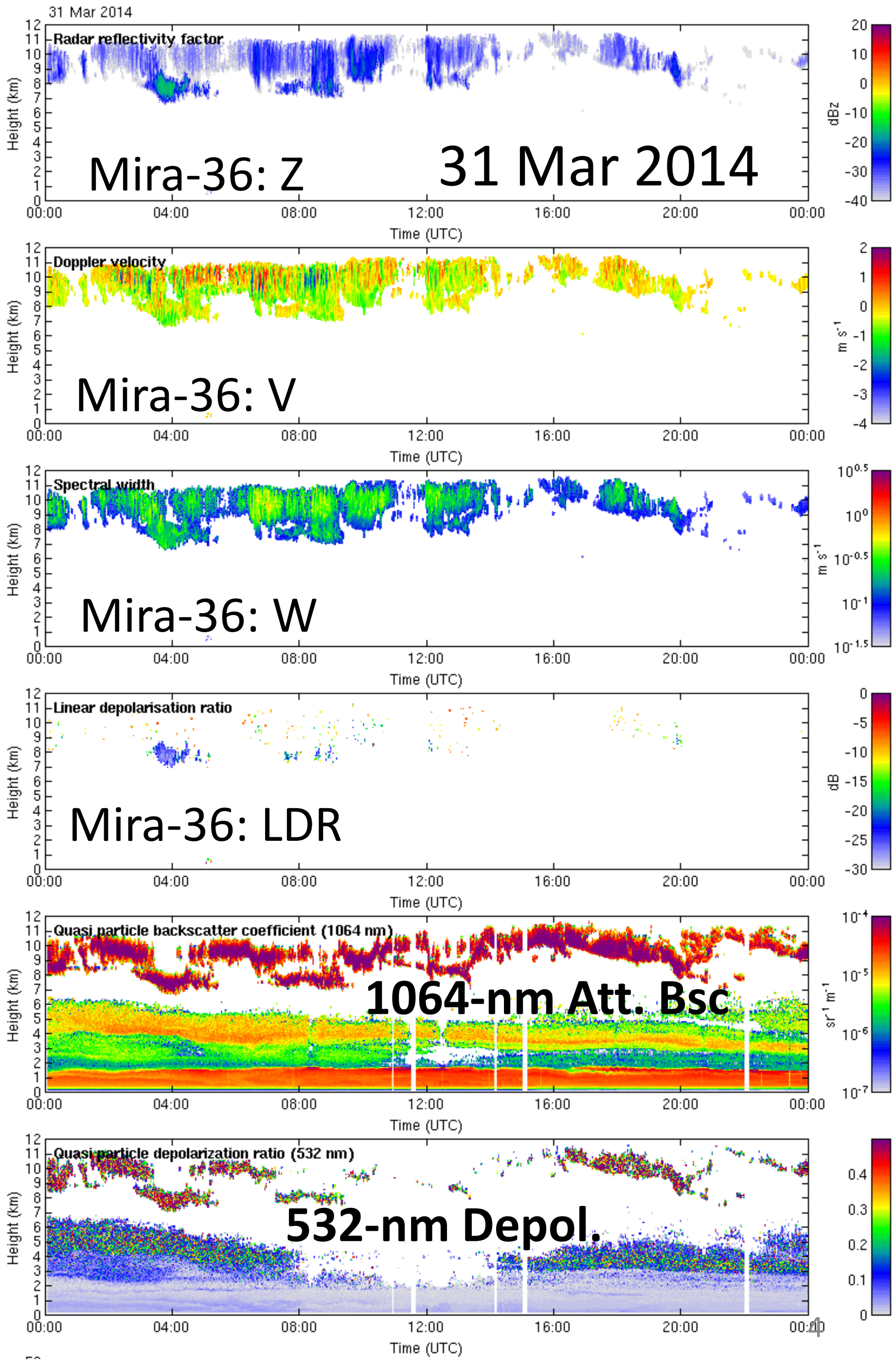
+ HALO Streamline Pro Doppler lidar

← : Instrument incorporated into cloudnet

„Specialities"

- Cloudnet running since 08/2011
- We approach cloud radar applications from the lidar-perspective





People

Holger Baars
Aerosol optics
and classifciation

Johannes Bühl
Mixed-phase cloud microphysics, analysis of Doppler spectra

Alexander Myagkov
Cloud radar calibration, Polarization techniques, particle shape determination

Bernhard Pospichal
Liquid cloud properties

Ulla Wandinger
Instrument synergies,
Interface to EU

Ronny Engelmann
…to call in case of emergency

Albert Ansmann
The ‚Driver'

Patric Seifert
Instrument incorporation,
retrieval implementation

Satellite Remote Sensing at TROPOS:
Daniel Merk (OEM), Anja Hünerbein (Forward Modelling)

Outline

I. Remote Sensing at TROPOS

II. Our Focus

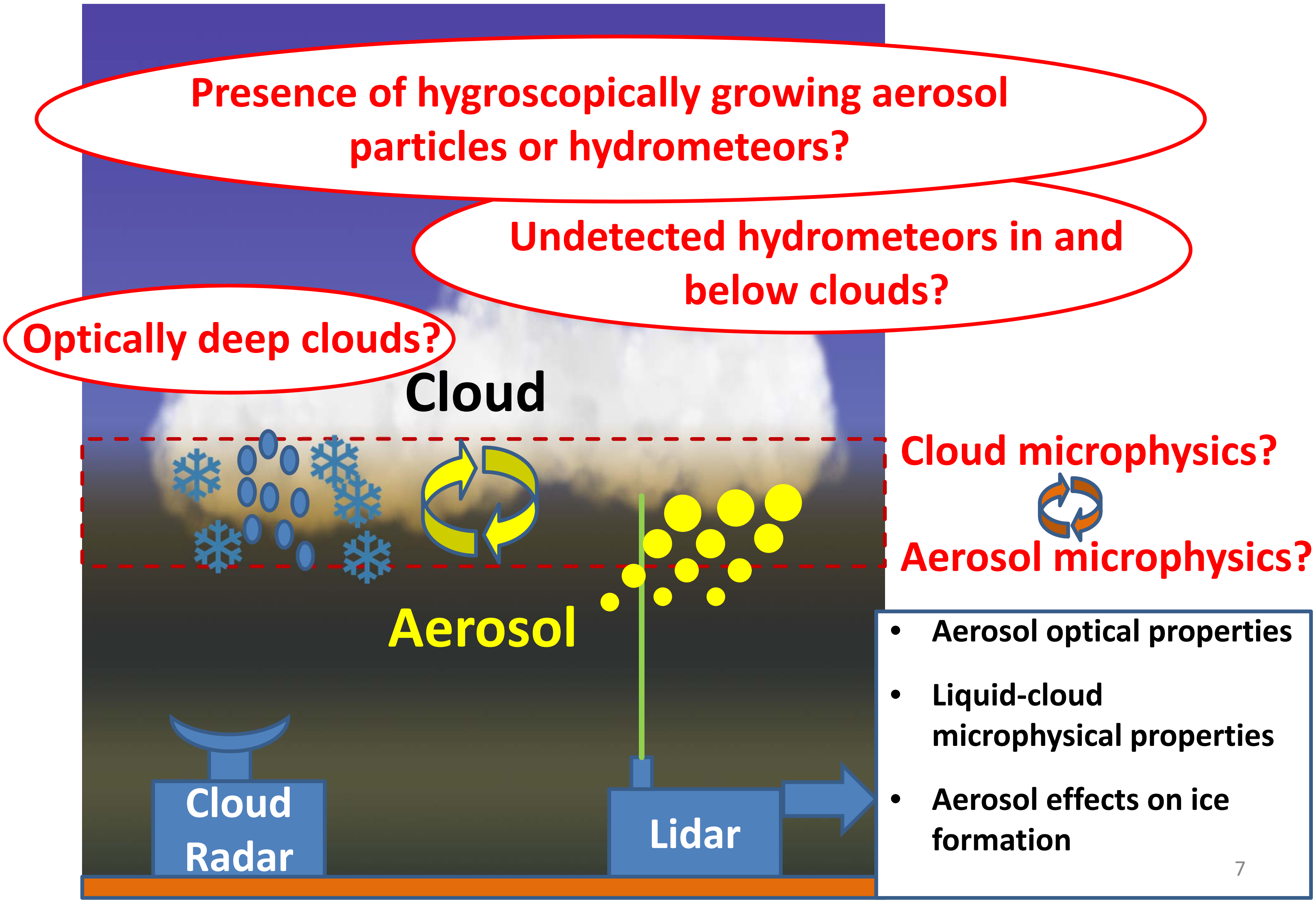
III. Results

- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

IV. Outlook

- ACCEPT campaign

FOCUS



- Aerosol optical properties
- Liquid-cloud microphysical properties
- Aerosol effects on ice formation

Outline

I. Remote Sensing at TROPOS

II. Our Focus

III. Results

- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

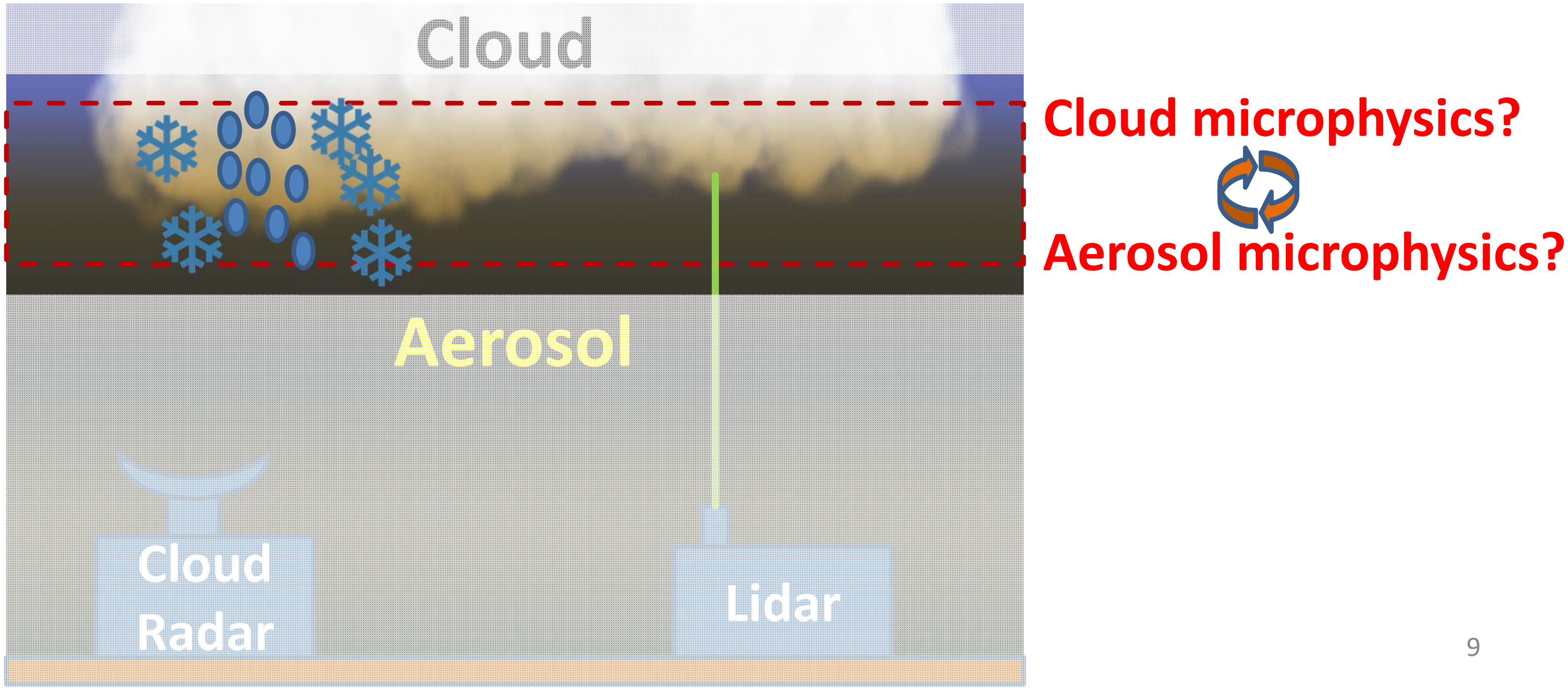
IV. Outlook

- ACCEPT campaign

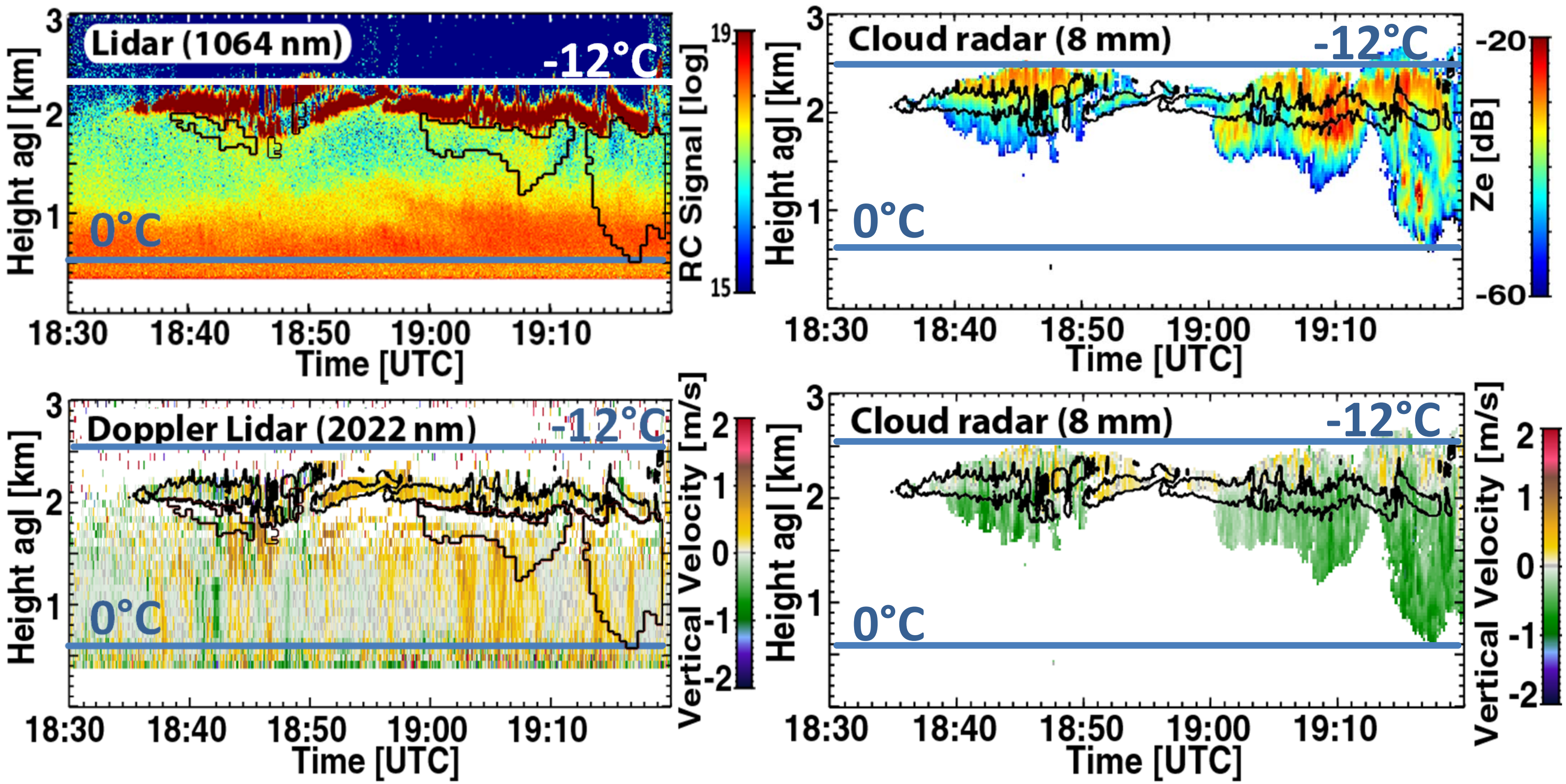
Motivation

Precipitation, ice virgae, or drizzle may remain undetected for lidar

→ **Questions:** - How often remain hydrometeors below clouds undetected for lidar?
- What is the impact of the undetected hydrometeors on the lidar-derived optical aerosol properties?



Case Study: Leipzig on 07 December 2011, 18:30-19:20 UTC



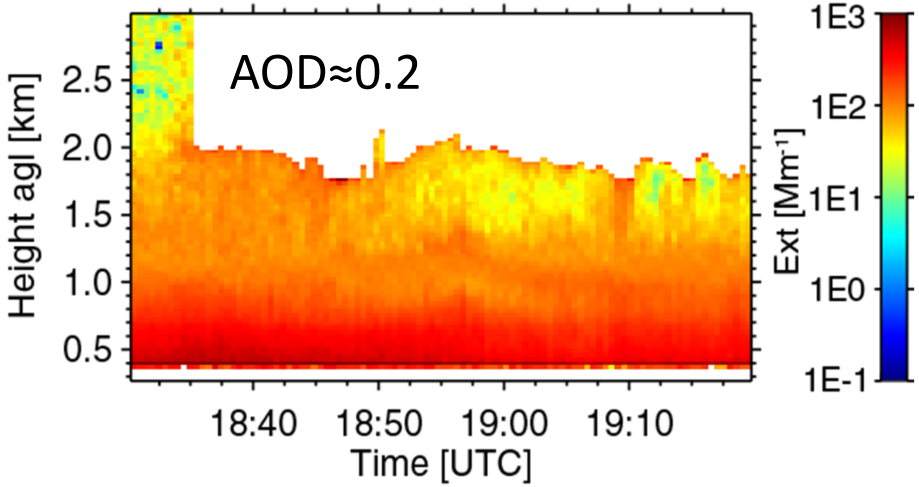
→ **Ice crystals precipitate out of a liquid-water cloud layer**

→ **Presence of ice crystals only detected by MIRA**

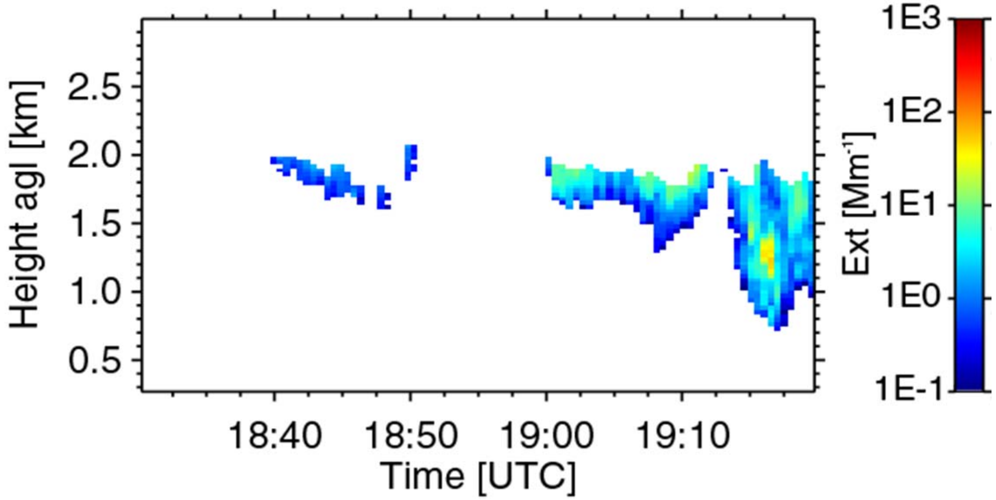
→ **Doppler lidar shows air motion even in precipitation region**

Contribution of precipitation to optical extinction

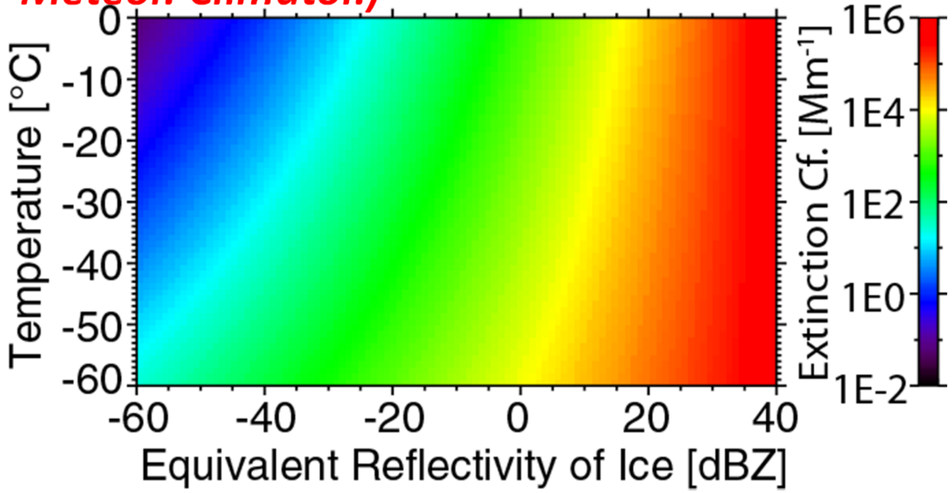
Aerosol optical extinction from combined Raman-elastic lidar method



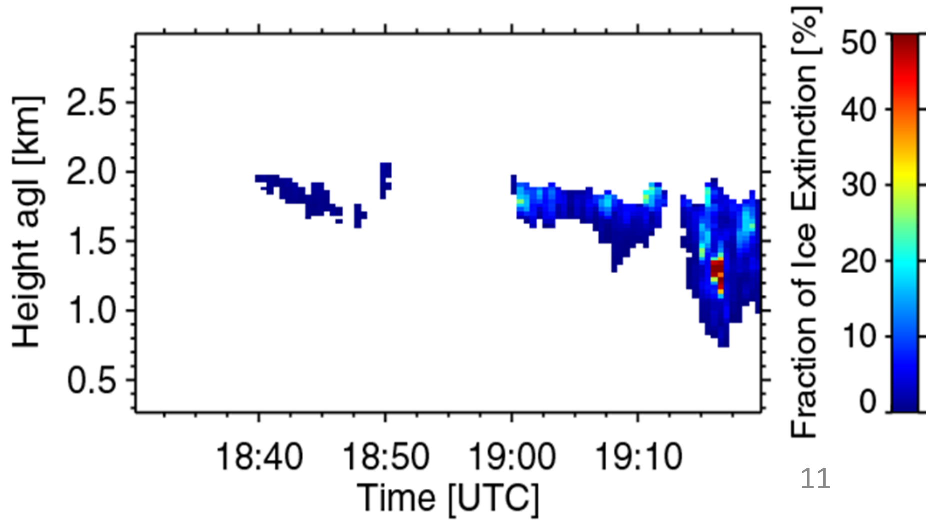
Ice optical extinction from extinction-temperature-reflectivity relationship



Extinction-temperature-reflectivity relationship of *Hogan et al. 2006* *(J. Appl. Meteor. Climatol.)*



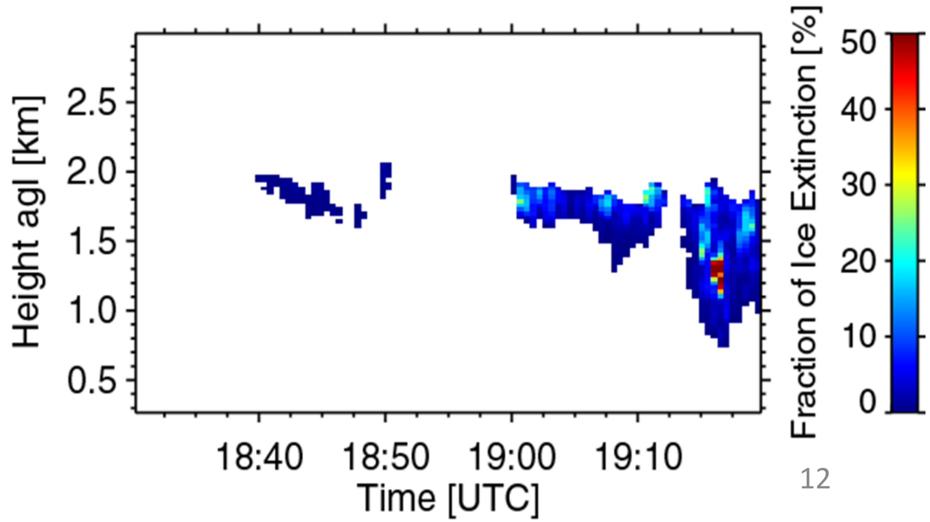
Contribution of precipitation to lidar-derived aerosol extinction



Contribution of precipitation to optical extinction

- **Crystals contribute up to 40% to lidar-derived aerosol extinction**
- **However: Overall contribution is usually less than 10%**

Contribution of precipitation to lidar-derived aerosol extinction



Outline

I. Remote Sensing at TROPOS

II. Our Focus

III. Results

- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

IV. Outlook

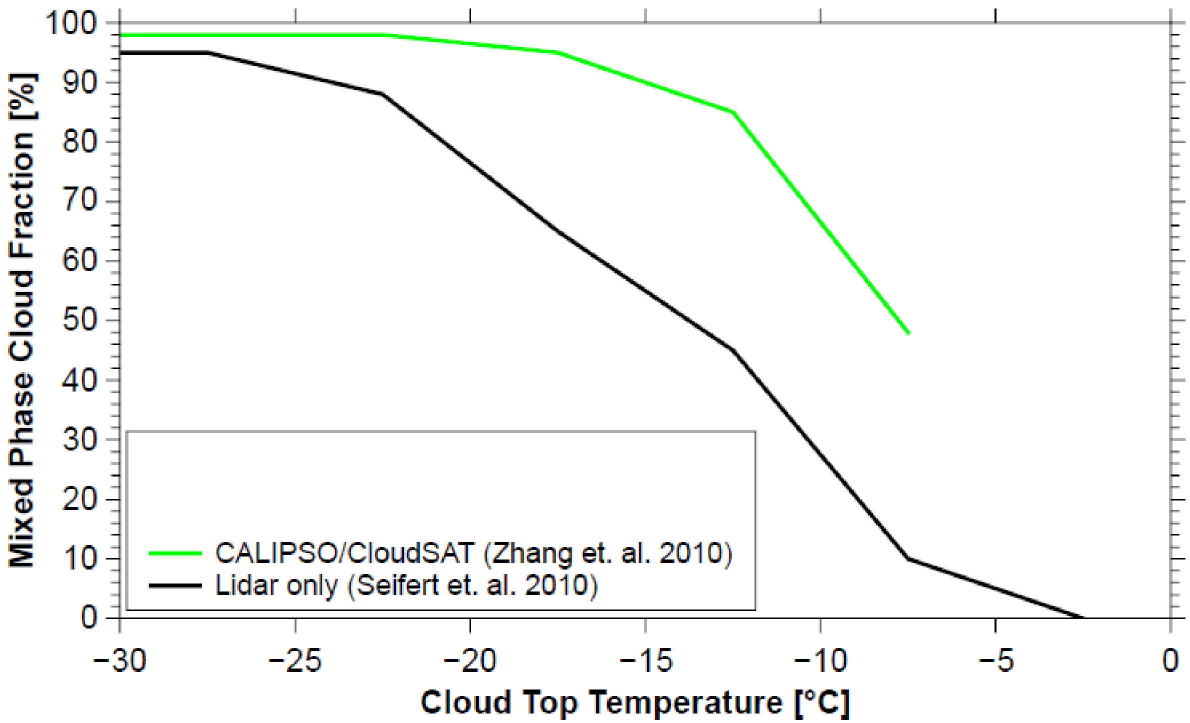
- ACCEPT campaign

Toward a quantitative characterization of heterogeneous ice formation with lidar/radar: Comparison of CALIPSO/CloudSat with ground-based observations

J. Bühl,[1] A. Ansmann,[1] P. Seifert,[1] H. Baars,[1] and R. Engelmann[1]

Received 29 May 2013; revised 21 July 2013; accepted 25 July 2013; published 19 August 2013.

- Explain the differences in observed mixed-phase cloud fraction of lidar alone and of combined lidar-radar observations

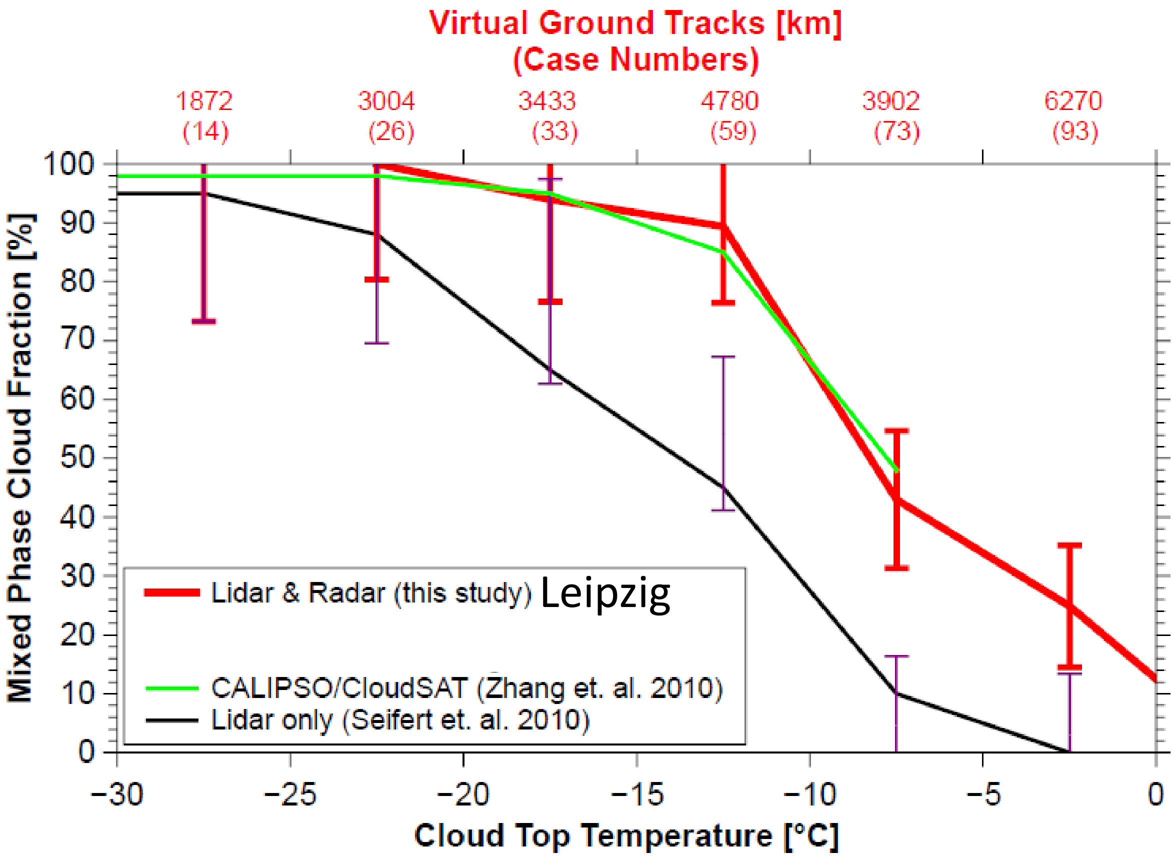


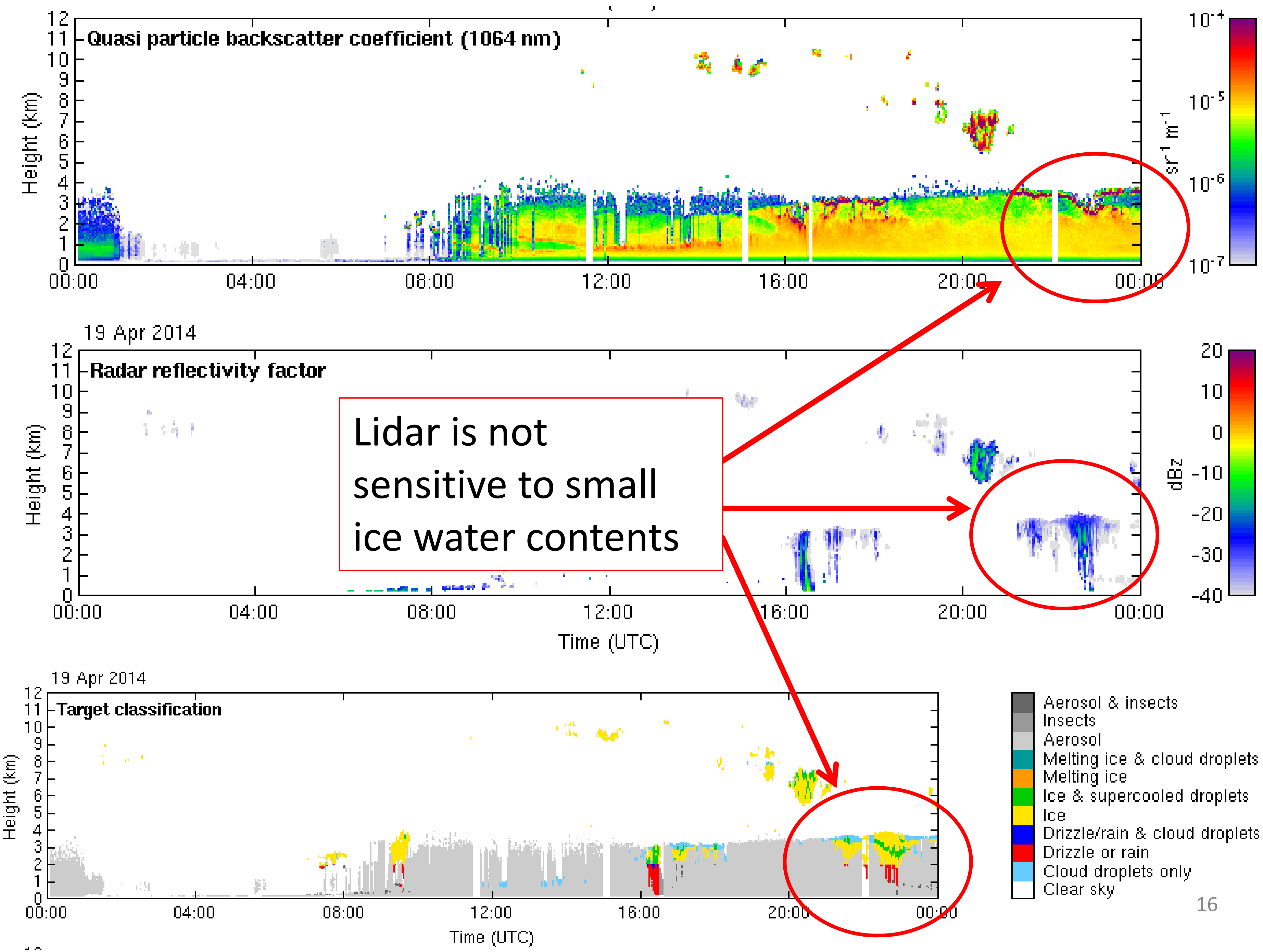
Toward a quantitative characterization of heterogeneous ice formation with lidar/radar: Comparison of CALIPSO/CloudSat with ground-based observations

J. Bühl,[1] A. Ansmann,[1] P. Seifert,[1] H. Baars,[1] and R. Engelmann[1]

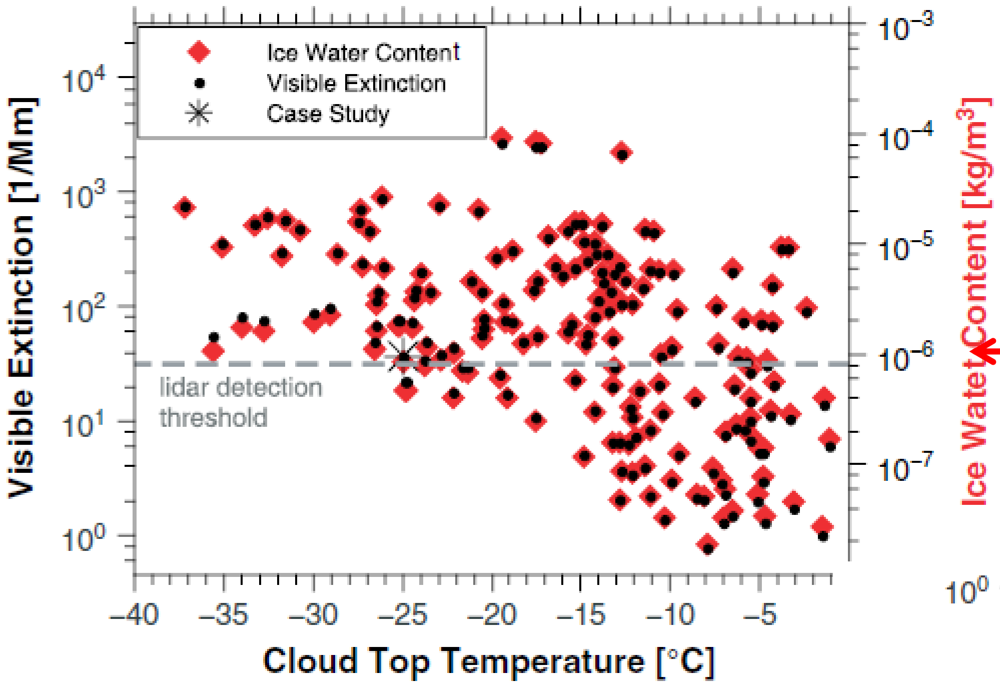
Received 29 May 2013; revised 21 July 2013; accepted 25 July 2013; published 19 August 2013.

- Explain the differences in observed mixed-phase cloud fraction of lidar alone and of combined lidar-radar observations




Quasi particle backscatter coefficient (1064 nm)
Height (km)
sr⁻¹ m⁻¹
19 Apr 2014
Radar reflectivity factor
dBz
Time (UTC)
Lidar is not sensitive to small ice water contents
19 Apr 2014
Target classification
Aerosol & insects
Insects
Aerosol
Melting ice & cloud droplets
Melting ice
Ice & supercooled droplets
Ice
Drizzle/rain & cloud droplets
Drizzle or rain
Cloud droplets only
Clear sky

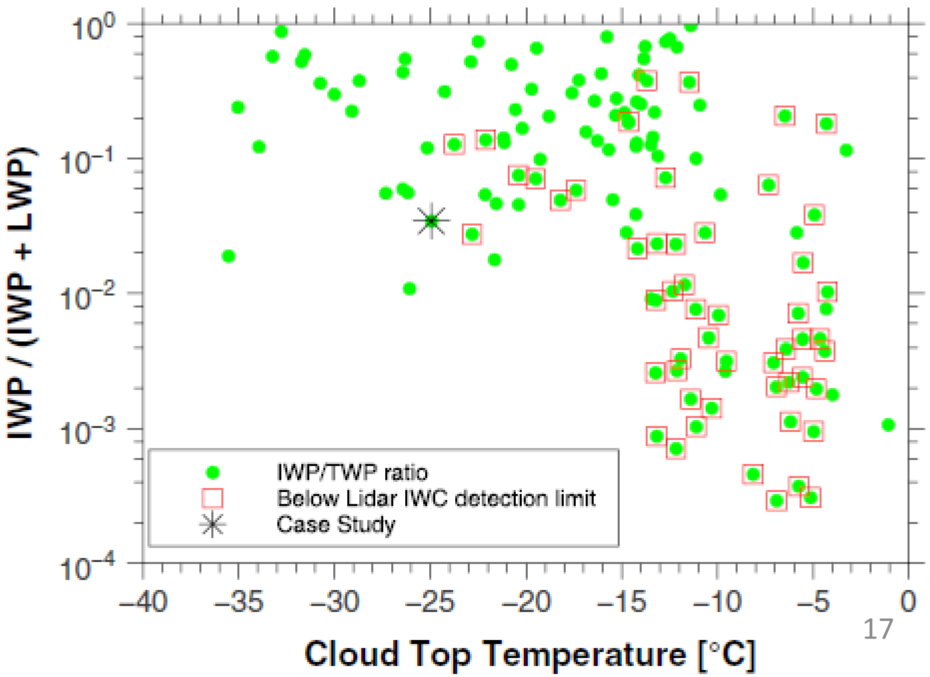
- **Use Hogan‘s relationships of Z-T-IWC and Z-T-Extinction to identify detection threshold**



- 352 single cloud cases observed between 08/2011 and 01/2013

Lidar detection limit

- Especially in ‚warm‘ clouds rather low ice water contents are produced

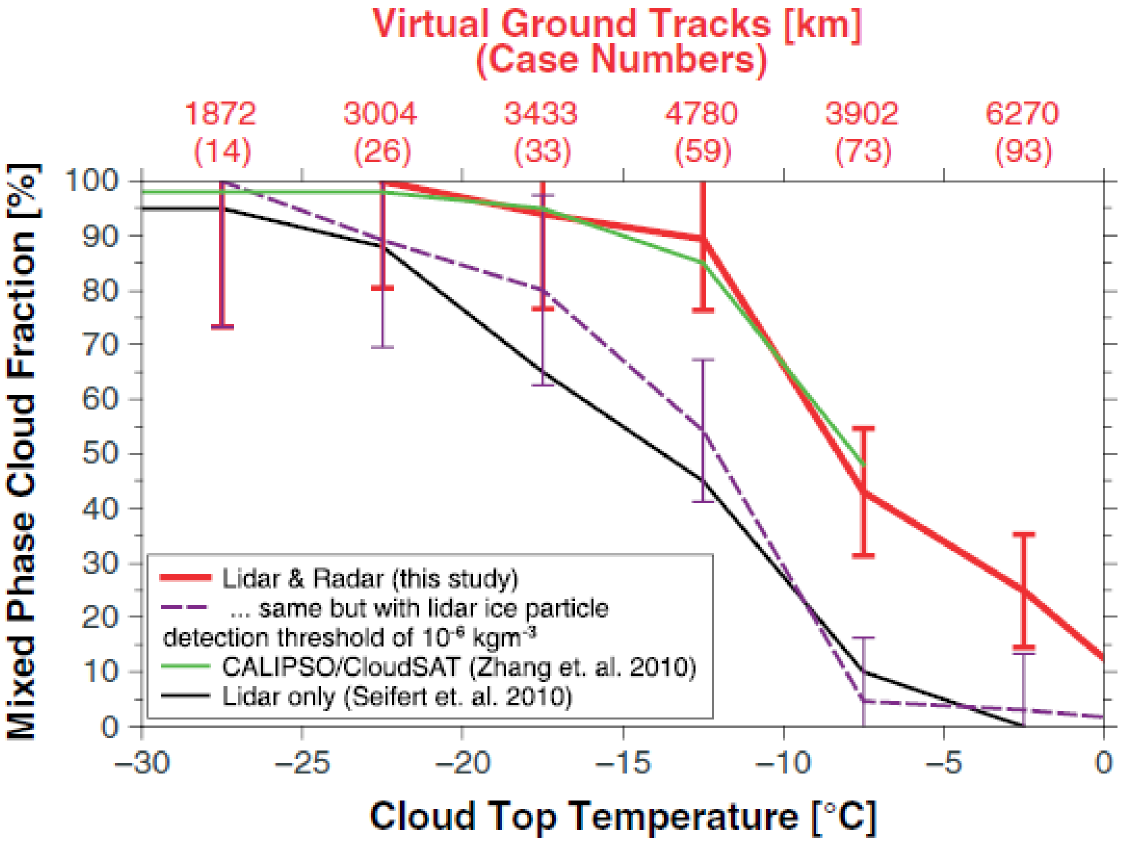


Toward a quantitative characterization of heterogeneous ice formation with lidar/radar: Comparison of CALIPSO/CloudSat with ground-based observations

J. Bühl,[1] A. Ansmann,[1] P. Seifert,[1] H. Baars,[1] and R. Engelmann[1]

Received 29 May 2013; revised 21 July 2013; accepted 25 July 2013; published 19 August 2013.

- Classifying all mixed-phase clouds with IWC below lidar-detection threshold as pure liquid clouds result in lidar-only curve!



Outline

I. Remote Sensing at TROPOS

II. Our Focus

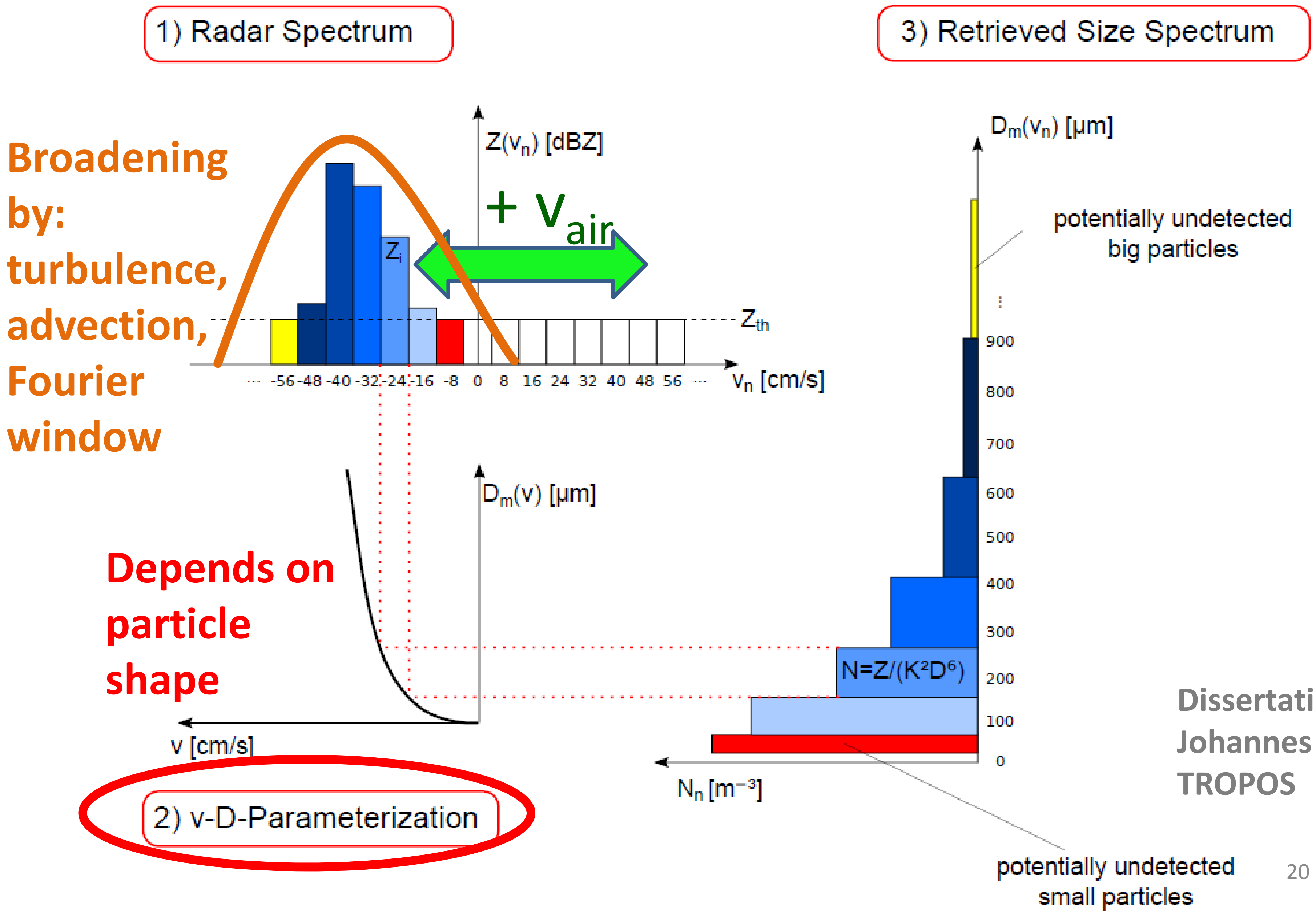
III. Results

- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

IV. Outlook

- ACCEPT campaign

Relating cloud Doppler spectra to microphysical properties

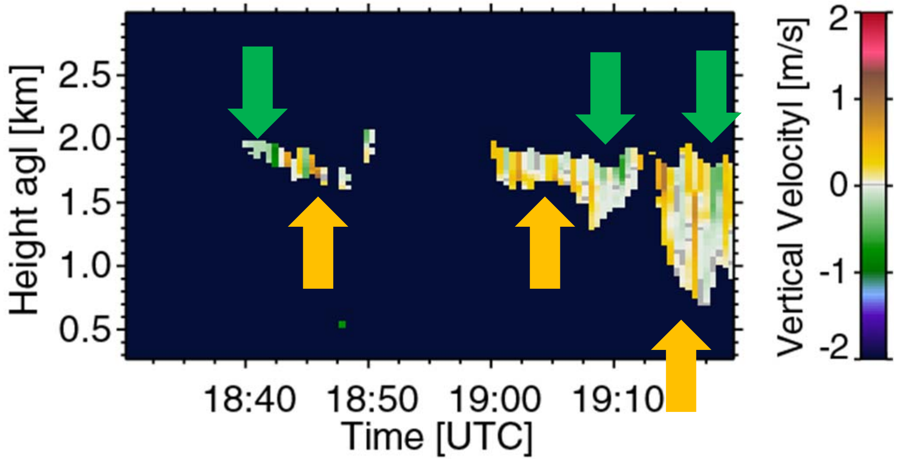


Dissertation of Johannes Bühl, TROPOS

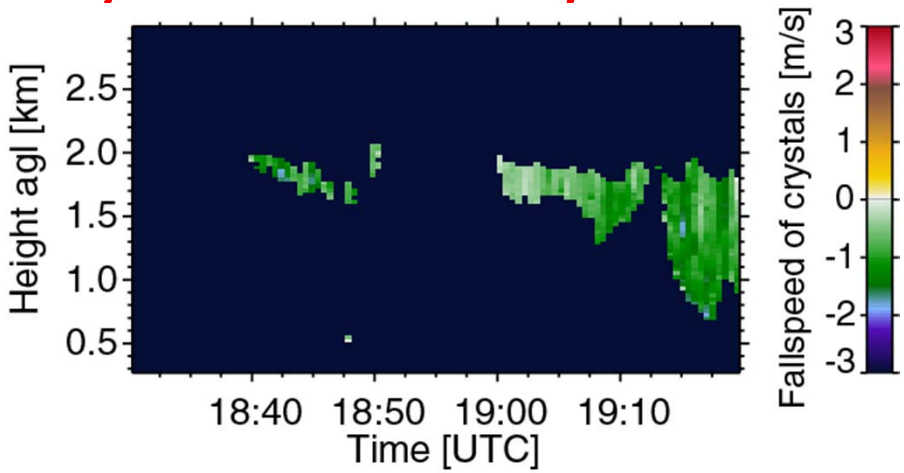
Correction of hydrometeor fall velocity

- Vertical air motion modifies radar-derived fall velocity of ice crystals
  → Strong impact on microphysics retrievals that rely on fall velocity

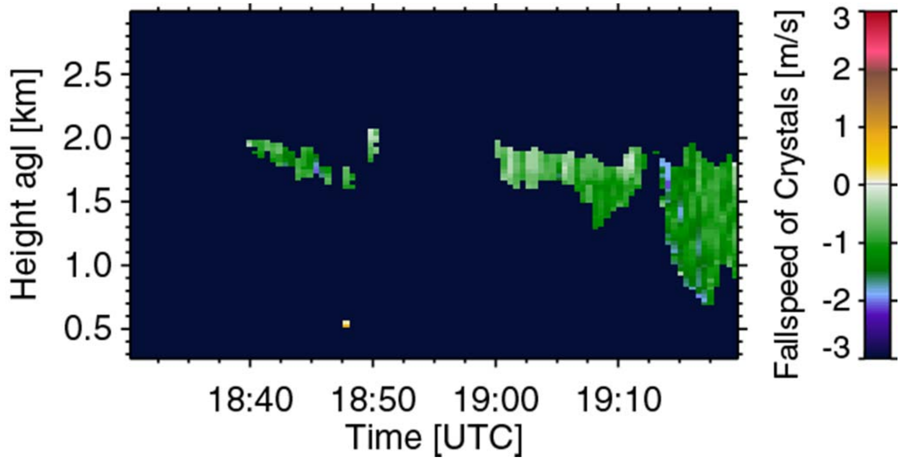
Doppler lidar measures vertical air motions in precipitating region



Doppler-radar-measured ice crystal terminal velocity

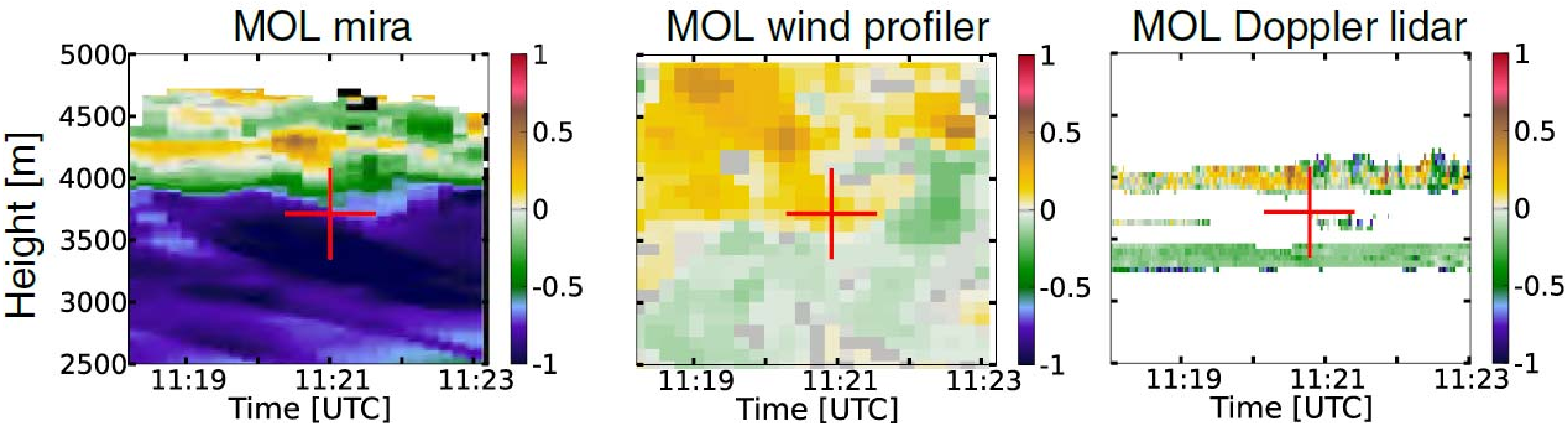


Corrected fall velocity of ice crystals



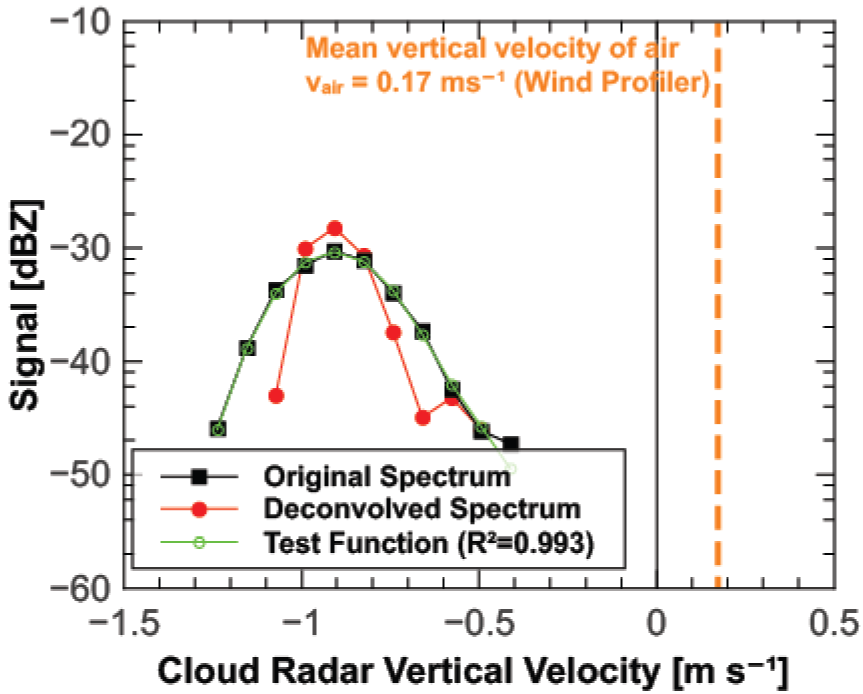
Correction of hydrometeor fall velocity

- Use wind profiler to derive vertical air motion within clouds and precipitation
- Cooperation with Meteorological Observatory Lindenberg

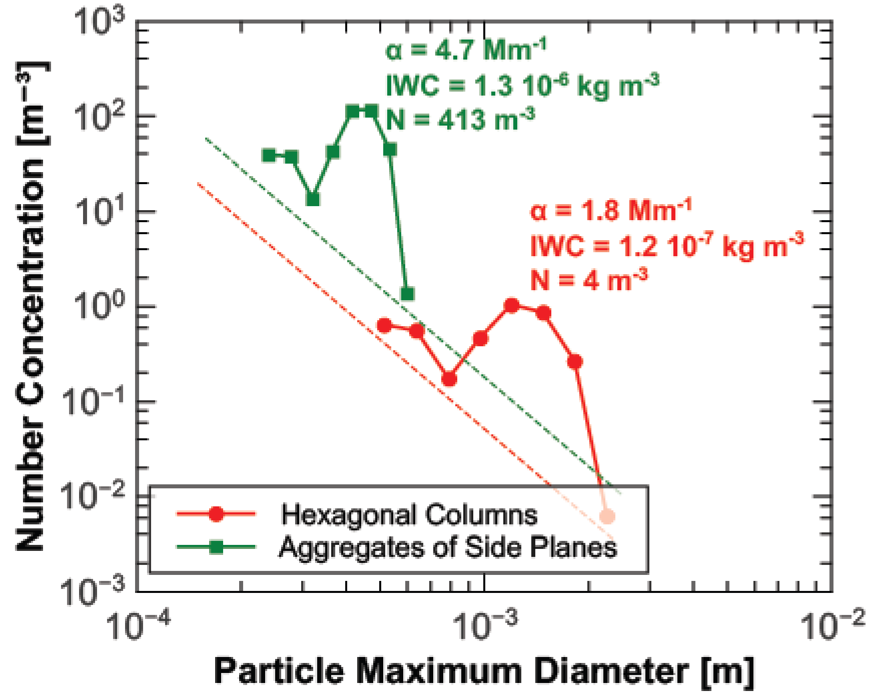


Dissertation of Johannes Bühl, TROPOS

Deconvolution and transformation of Doppler spectra

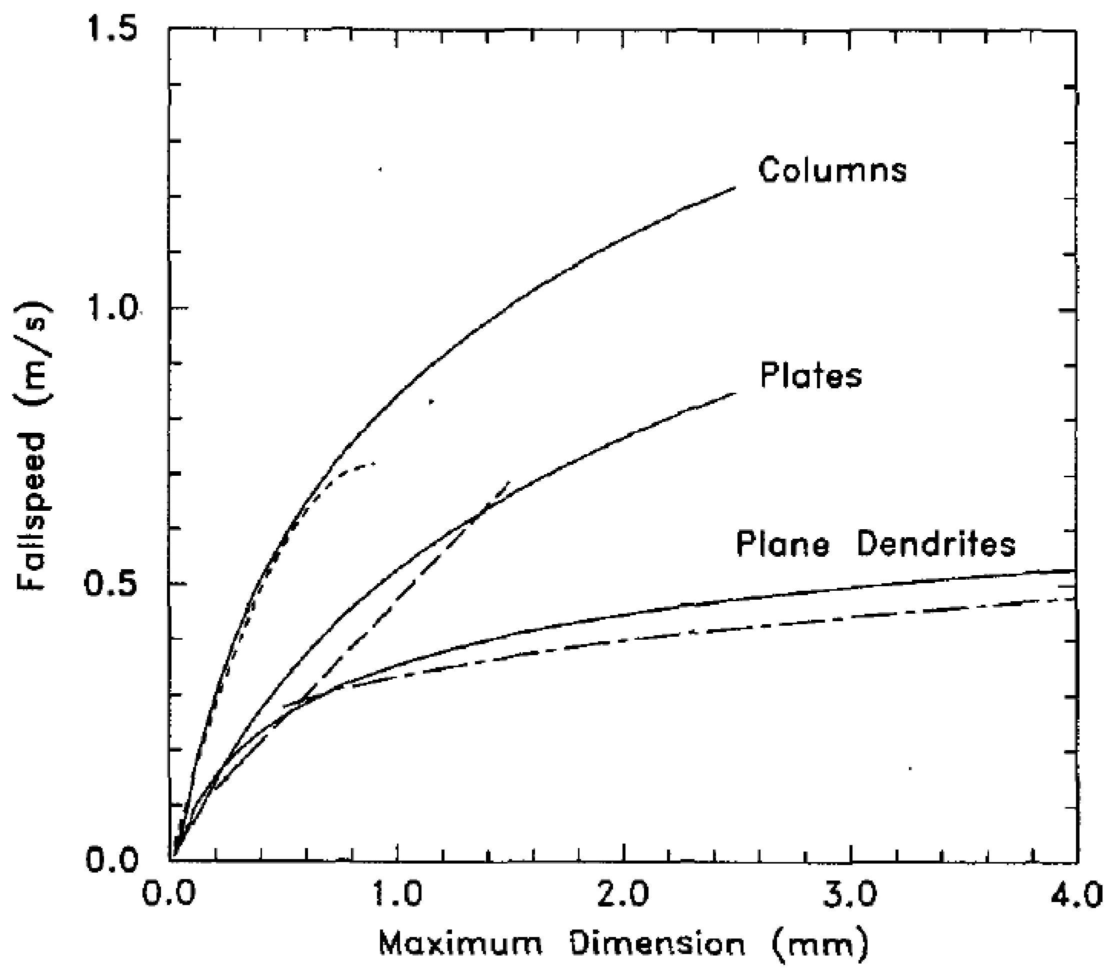


Strong effect of crystal shape



Dissertation of Johannes Bühl, TROPOS

Size-falling velocity relationships for different particle shapes

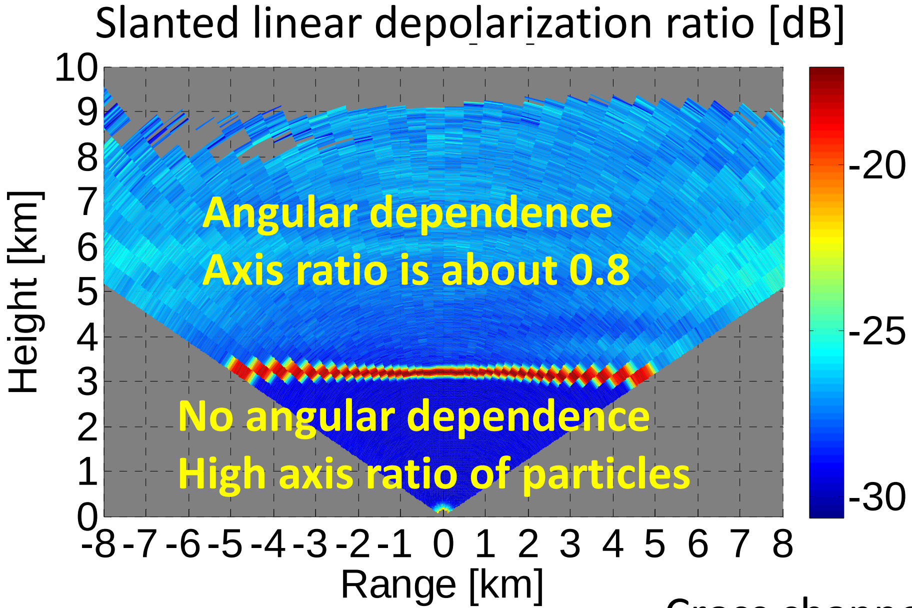


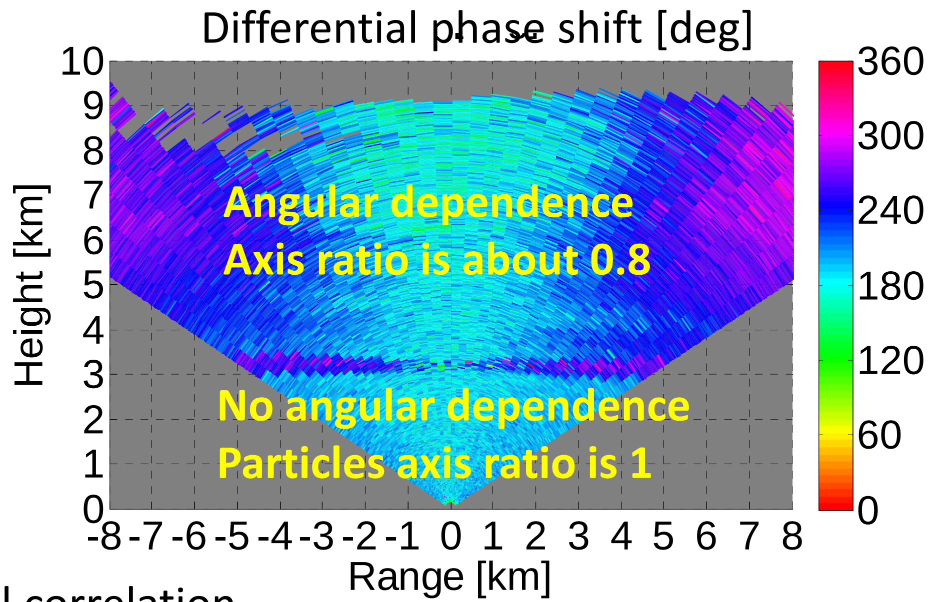
Resource: http://www.its.caltech.edu/

Mitchell, D. L. Journal of Atmospheric Sciences, 1996

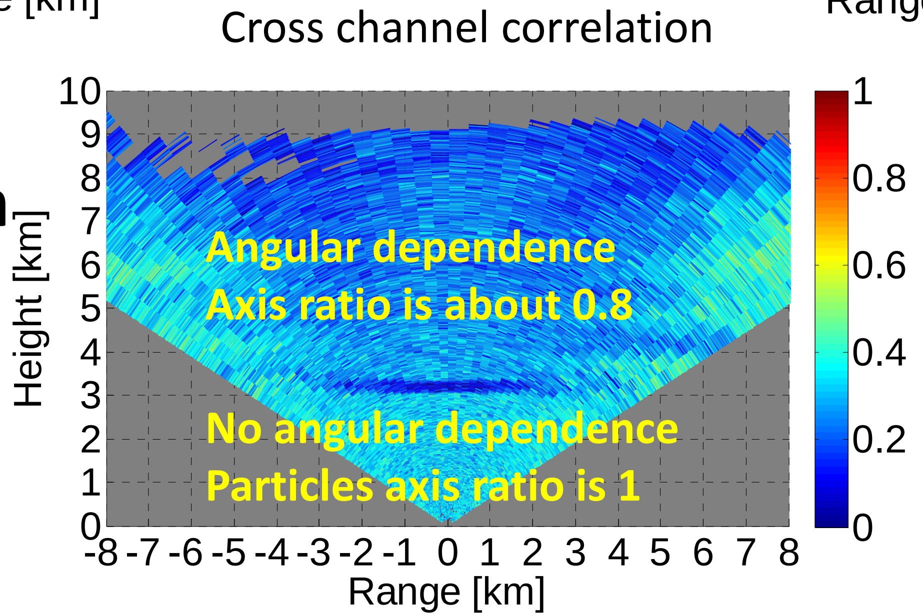
Alexander Myagkov

Measurement case, 11:29 – 11:36, 08.09.2013, Elmshorn, Germany





Scanning from 35 to 145 degrees



0.8

1

Alexander Myagkov

Outline

I. Remote Sensing at TROPOS

II. Our Focus

III. Results

- Effect of hydrometeors on lidar measurements
- Ice-water detection threshold for lidar systems
- Doppler spectra vs. cloud microphysics

IV. Outlook

- ACCEPT campaign

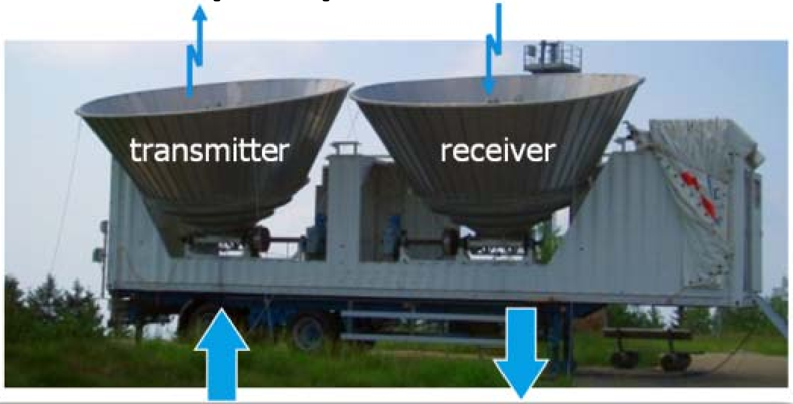
ACCEPT-campaign: October 2014 – mid November 2014

Metek Polarization cloud radar
Operating in STSR-mode

KNMI-Messmast Caba

LACROS

TARA 3-GHz precipiation radar



Labview™ Solution

- signal generation
- timing and synchronisation
- data acquisition and visualisation

MATLAB™

- real-time data processing

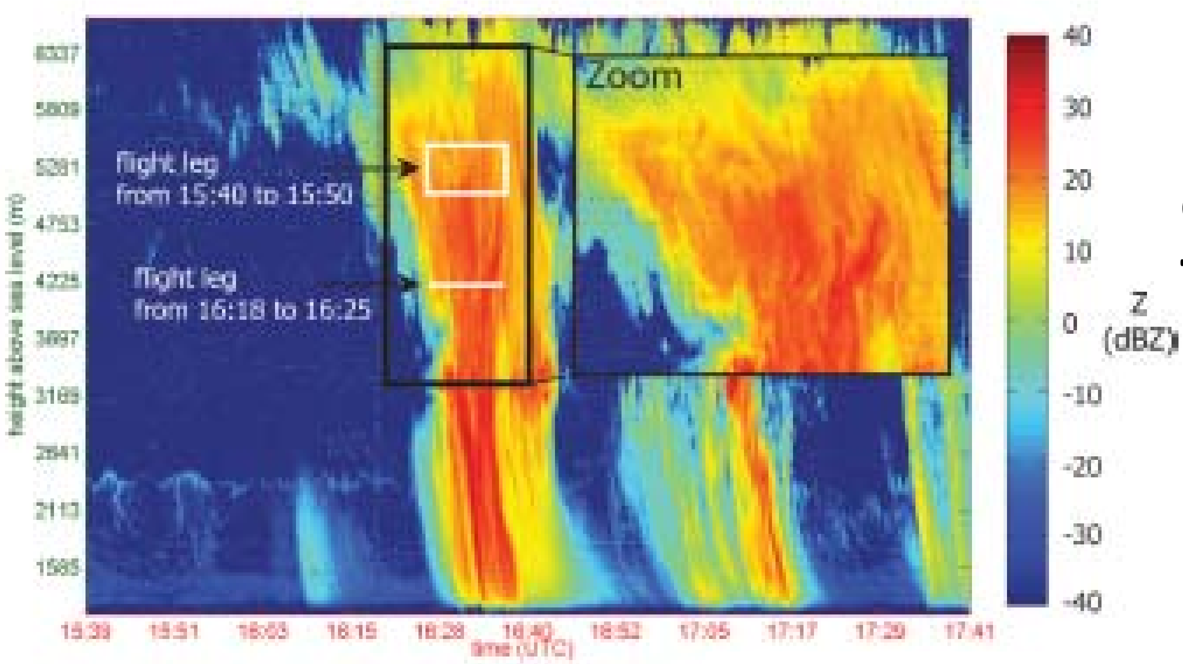
- data storage (NetCDF)

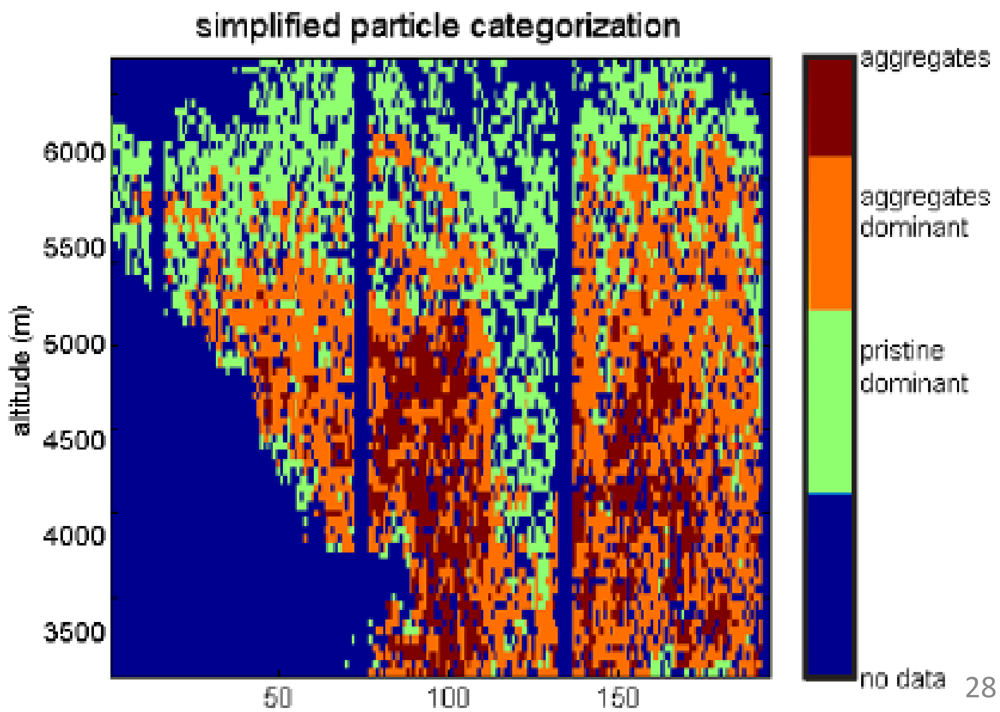
ACCEPT:
Analysis of the Compositon of Clouds with Extended Polarization Techniques

Partner of ITaRS

Combined initiative of TROPOS and TU Delft

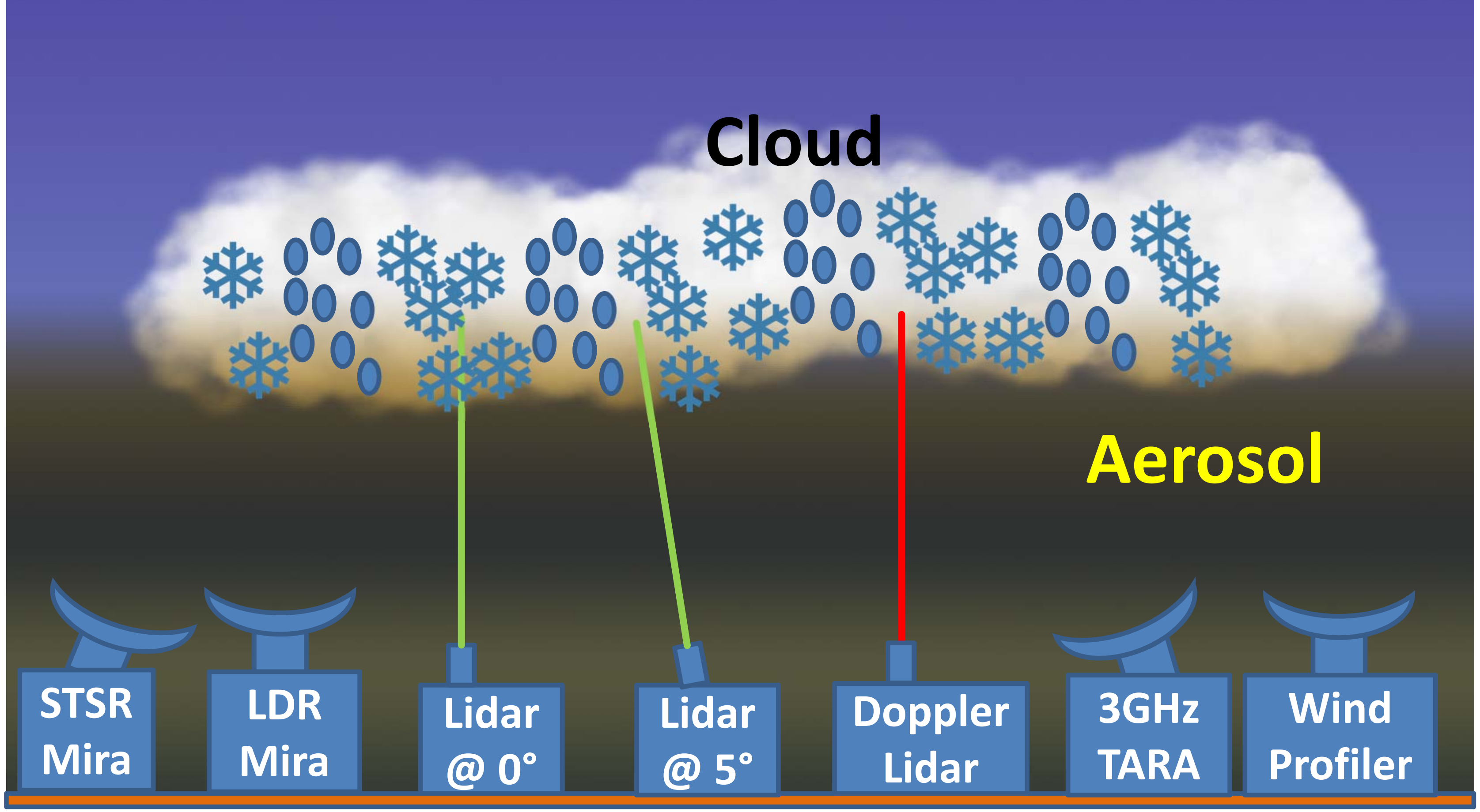
Particle shape determination from TARA measurements





Dufournet, Y. and Russchenberg, H. W. J.: Towards the improvement of cloud microphysical retrievals using simultaneous Doppler and polarimetric radar measurements, Atmos. Meas. Tech., 4, 2163-2178, doi:10.5194/amt-4-2163-2011, 2011.

Analysis of the Compositon of Clouds with Extended Polarization Techniques



STSR Mira	LDR Mira	Lidar @ 0° / Lidar @ 5°	Doppler Lidar	3GHz TARA	Wind Profiler
Shape	Spectra of term. vert. velocity	Ice and aerosol optical Properties; Identification of horizontally aligned crystals	Vertical air motion	Shape of large particles	Vertical air motion

Summary

- Investigation of comparability of lidar- and radar measurements
  - Characterization of the effect of large particles on aerosol observations with lidar
  - Characterization of detection thresholds

- Focus on mixed-phase clouds
  - Exploit Doppler spectra to derive ice crystal microphysics
  - Apply polarimetric measurements to derive ice crystal shape

- Challenges
  - Spectral method relies on absolute calibration of radar
  - Gridding multi-angle multi-volume data of lidar and radar