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Optical and geometrical properties of Arctic clouds over northern Finland during PaCE campaign in 2019

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SPONSORS:

KONE foundation

ACTRIS-2 - the European Union's Horizon 2020 research and innovation programme under grant agreement (No 654109)

ACTRIS PPP - the European Commission under the Horizon 2020 – Research and Innovation Framework Programme

H2020-INFRADEV-2016-2017 (Grant Agreement number: 739530)

Academy of Finland Center of Excellence programme (grant no. 307331)

Motivation

- In the Arctic areas the influence of climate change is being felt at a higher degree than elsewhere.
- Enabling a better understanding of the environment in region is of high importance.
- Clouds play a significant role in the energy budget and the hydrological cycle of the Earth’s atmosphere system.

Objective

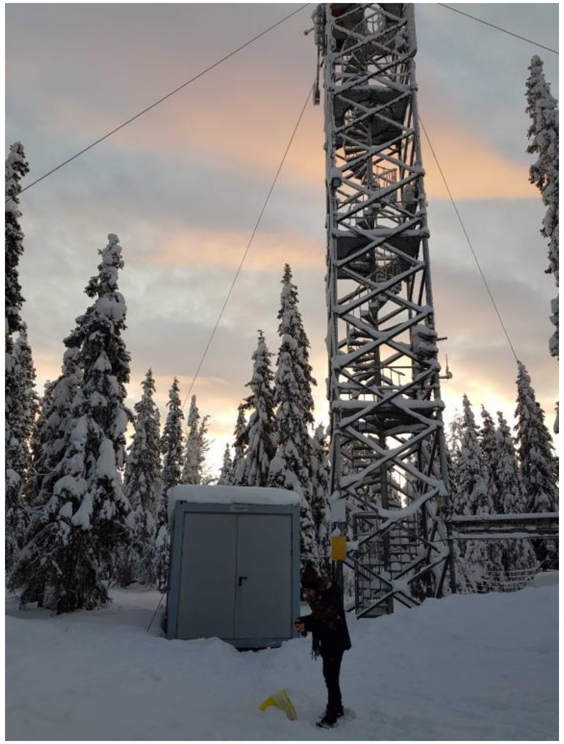
Field campaign PaCE (Pallas Cloud Experiment)

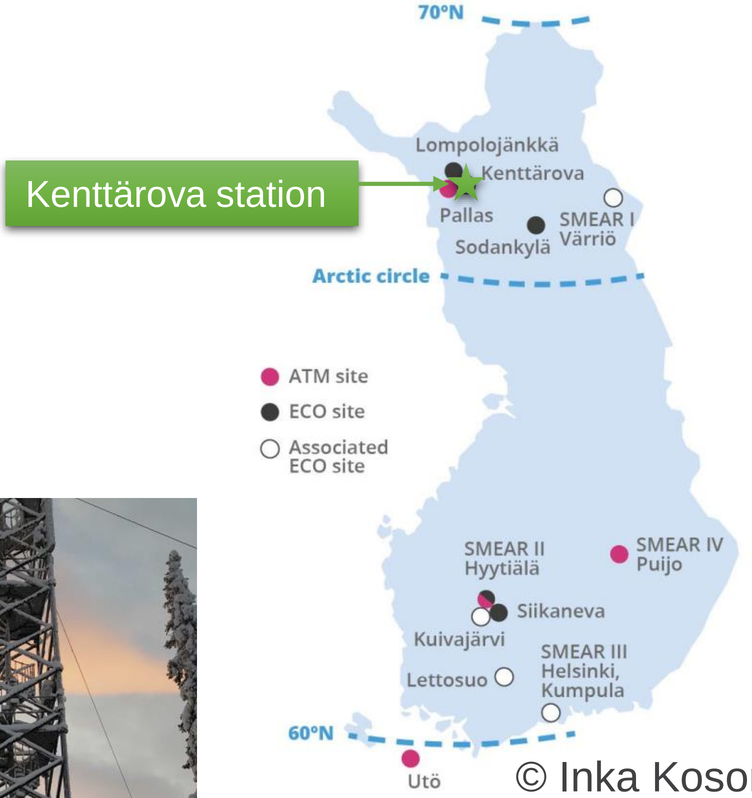
- ➢ Providing insights into Arctic cloud processes for Arctic cloud-climate studies
- ➢ Focusing on aerosol and cloud vertical profiling using in-situ and remote sensing techniques

Measurement site & Instruments

- Kenttärova station (N 67°59’14”, E 24°14’35”, 347 m above sea level) at Pallas, in the northern Finland.
- September to December, 2019.
- Multi-wavelength Raman polarization lidar Polly^{XT}

Elastic channels	355 nm, 532 nm, 1064 nm
Rotational vibrational Raman channels	387 nm, 607 nm
Linear depolarization channels	355 nm, 532 nm
Water vapor channel	407 nm





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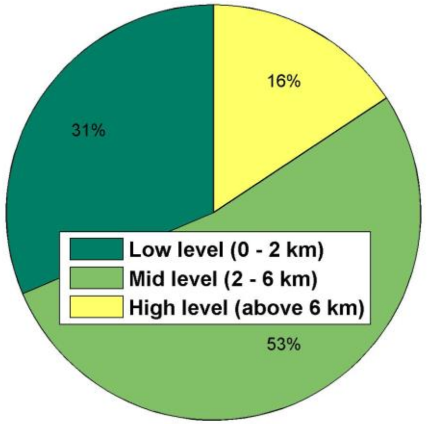
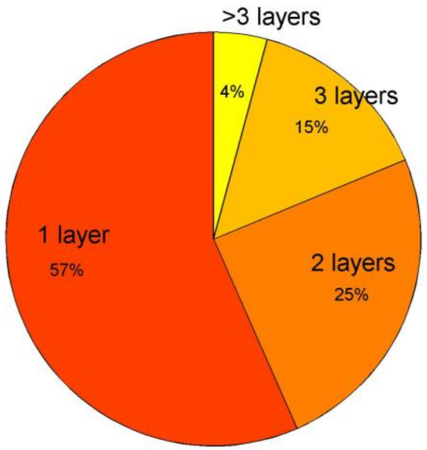
Geometrical properties

484 layers detected from 288 lidar profiles (2 hours averaged)



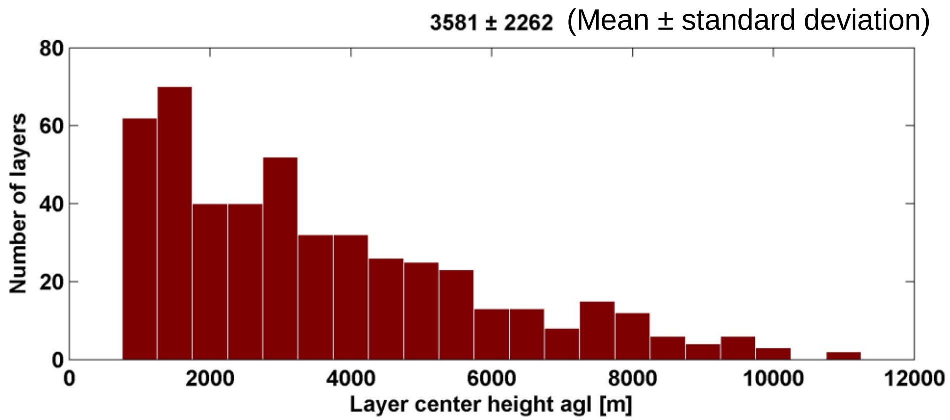
484 layers

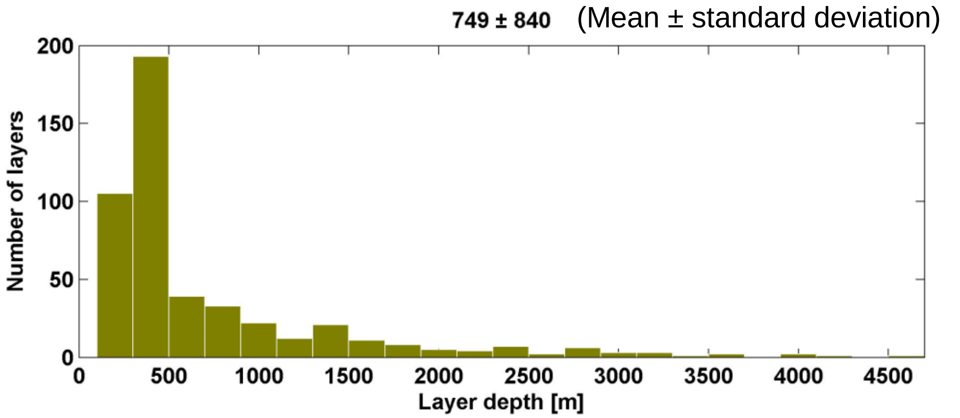
Pie plot of detected layer center height agl

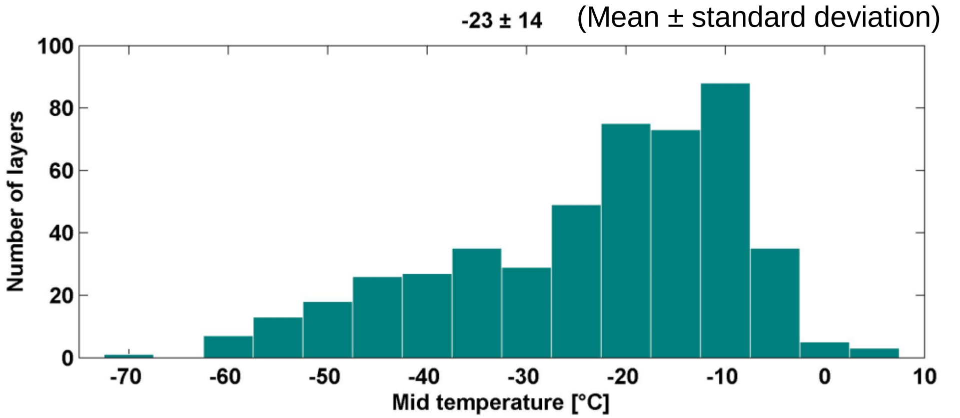


288 profiles
(2 hours averaged)

Pie plot of detected layer number for each profile







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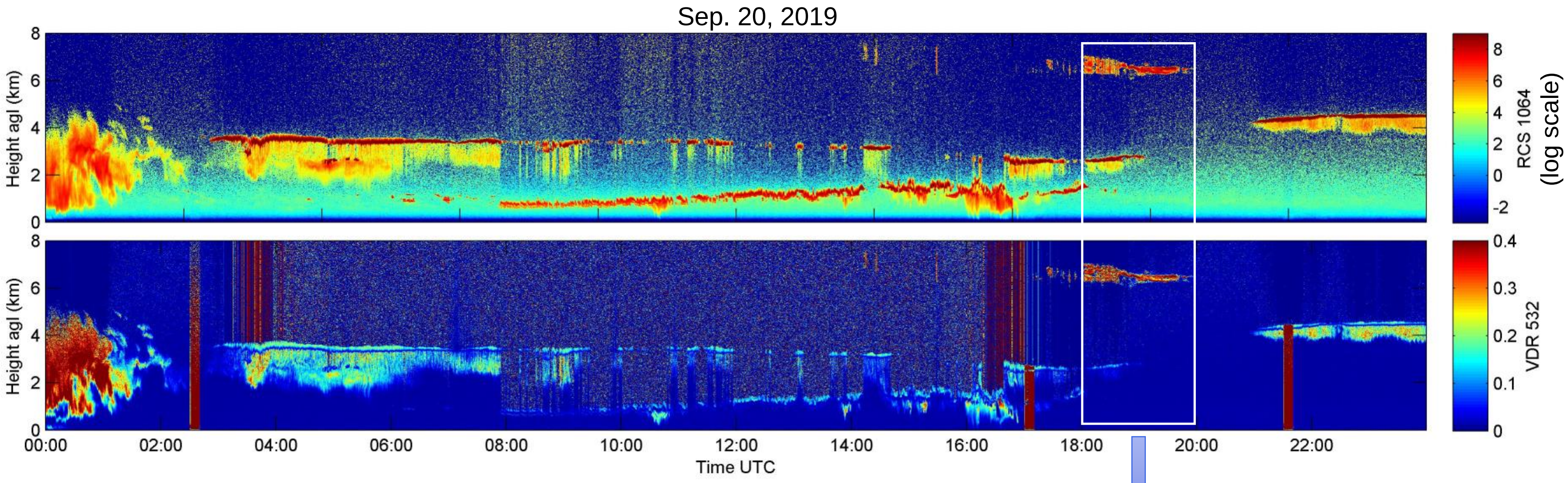
Case example

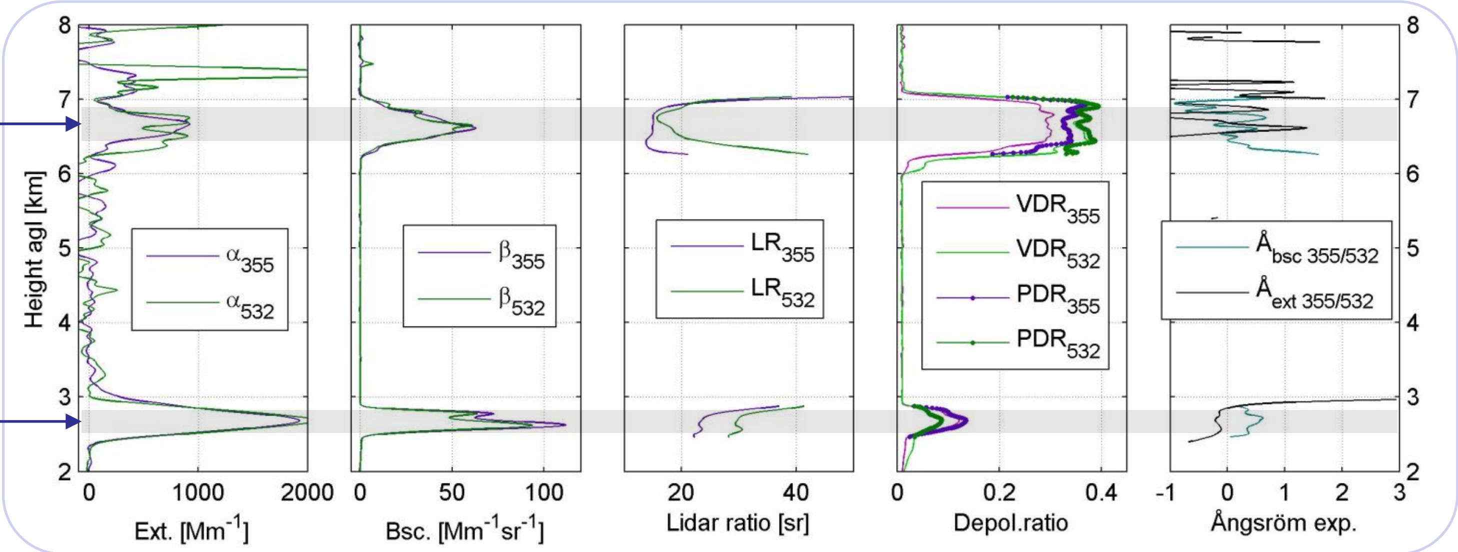
Lidar Observations: (30s time resolution)



Ice cloud

Lidar-derived vertical profiles: (2-h averaged)

Liquid cloud



These are effective values, no multiple scattering correction done for this example.

Optical properties

Mean values for night-time (265 layers)

LR_{355} [sr] *	21 ± 6
LR_{532} [sr] *	25 ± 9
PDR_{355} [%]	28 ± 16
PDR_{532} [%]	27 ± 16
Å ext $_{355/532}$ *	-0.1 ± 0.5
Å bsc $_{355/532}$	0.4 ± 0.8
Ext_{355} [Mm^{-1}] *	543 ± 781
Ext_{532} [Mm^{-1}] *	571 ± 808
Bsc_{355} [$Mm^{-1}sr^{-1}$]	30 ± 46
Bsc_{532} [$Mm^{-1}sr^{-1}$]	27 ± 46

*Effective values

Ext: Extinction coefficient

Bsc: Backscatter coefficient

Å bsc: Backscatter-related Ångström exponent

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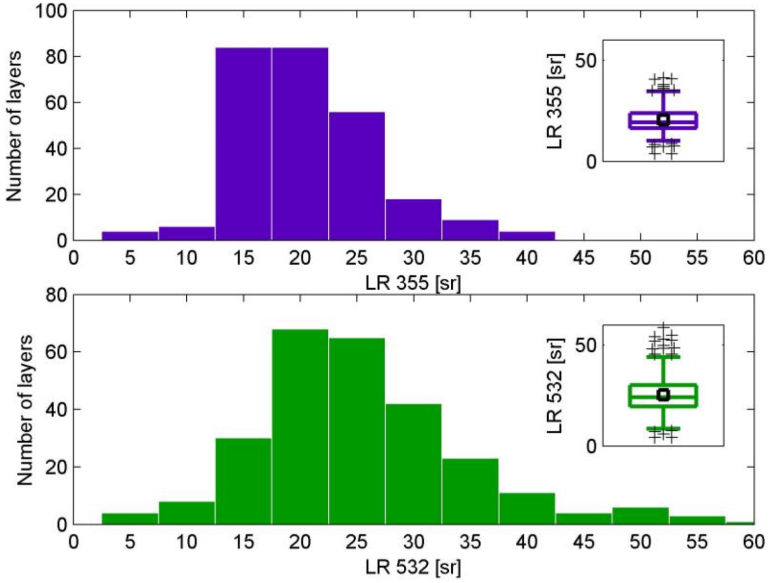
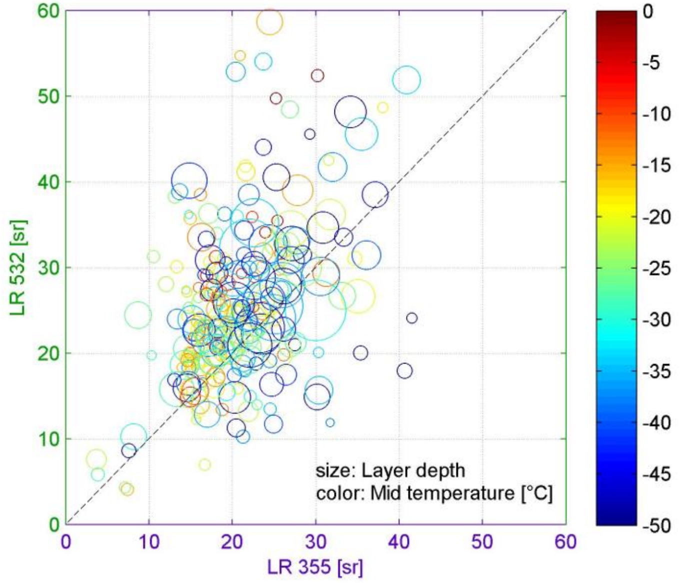
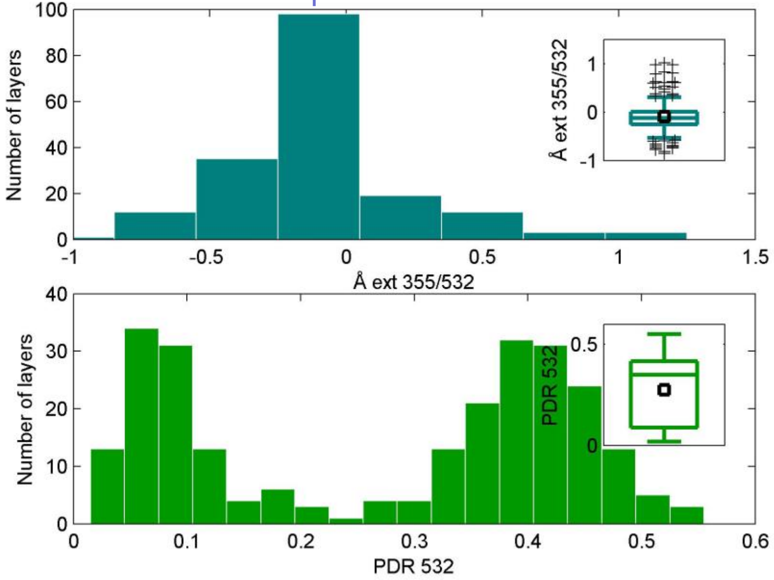
LR: Lidar ratio

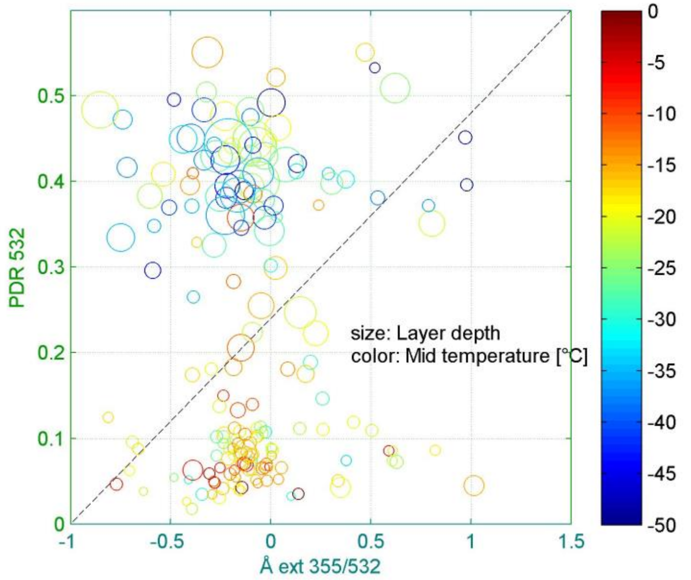




Å ext: Extinction-related Ångström exponent

PDR: Particle depolarization ratio





Optical properties

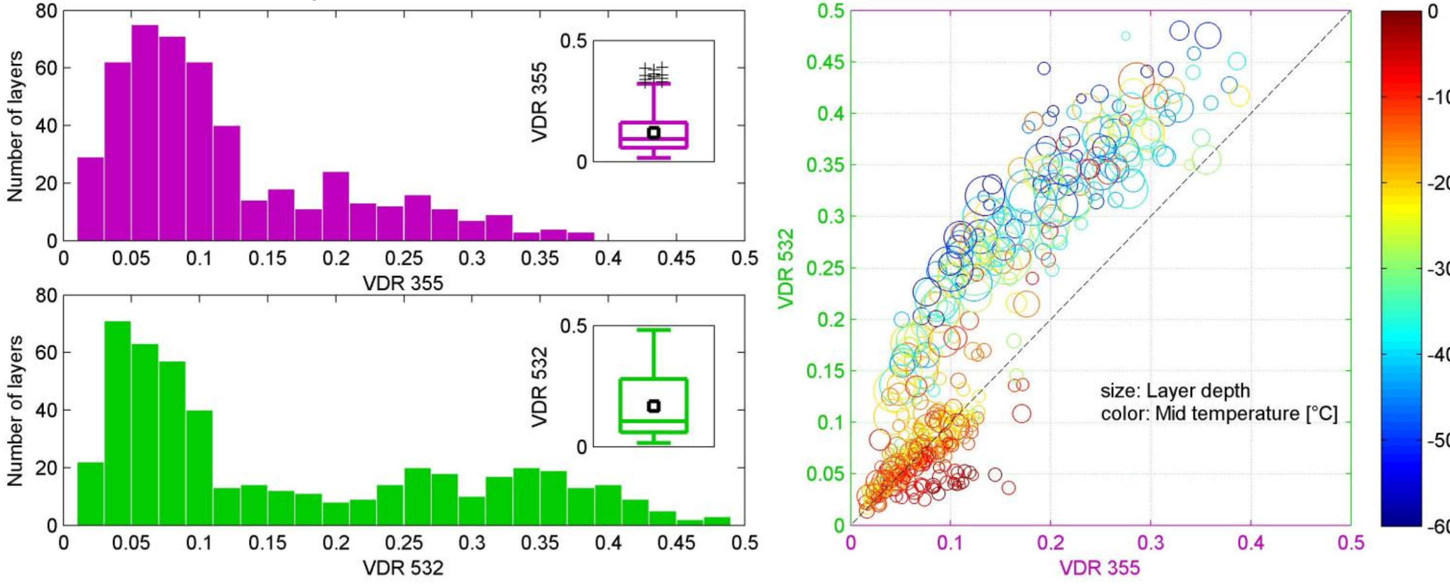
Mean values for all time (484 layers)

PDR_{355} [%]	22 ± 17
PDR_{532} [%]	22 ± 17
$Å_{bsc\ 355/532}$	0.6 ± 0.6
$Å_{bsc\ 532/1064}$	0.9 ± 0.7
Bsc_{355} [$Mm^{-1}sr^{-1}$]	46 ± 74
Bsc_{532} [$Mm^{-1}sr^{-1}$]	38 ± 87
Bsc_{1064} [$Mm^{-1}sr^{-1}$]	16 ± 22

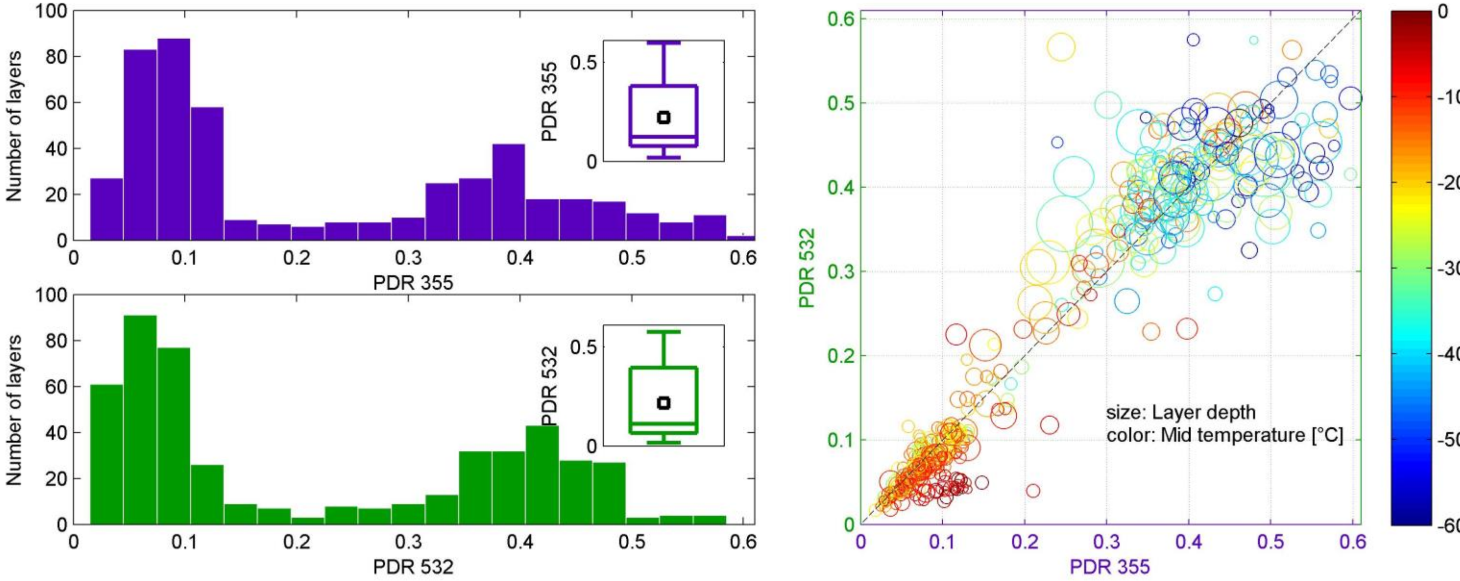
Bsc: Backscatter coefficient

Å bsc: Backscatter-related Ångström exponent

VDR: Volume depolarization ratio



PDR: Particle depolarization ratio



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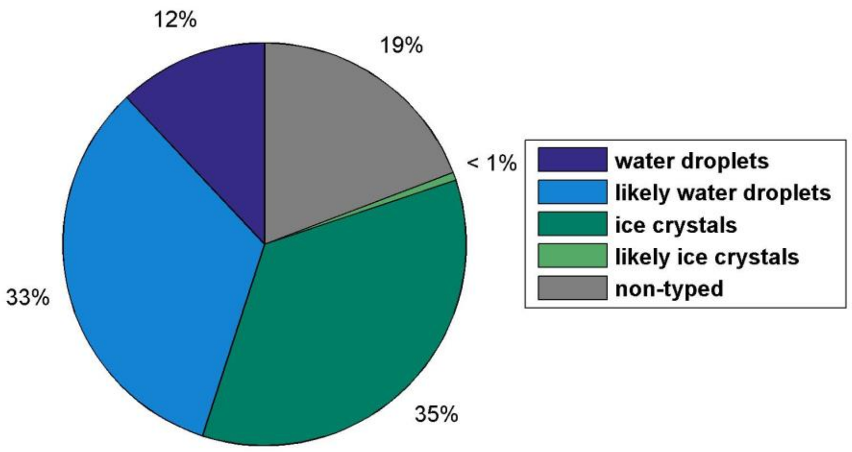
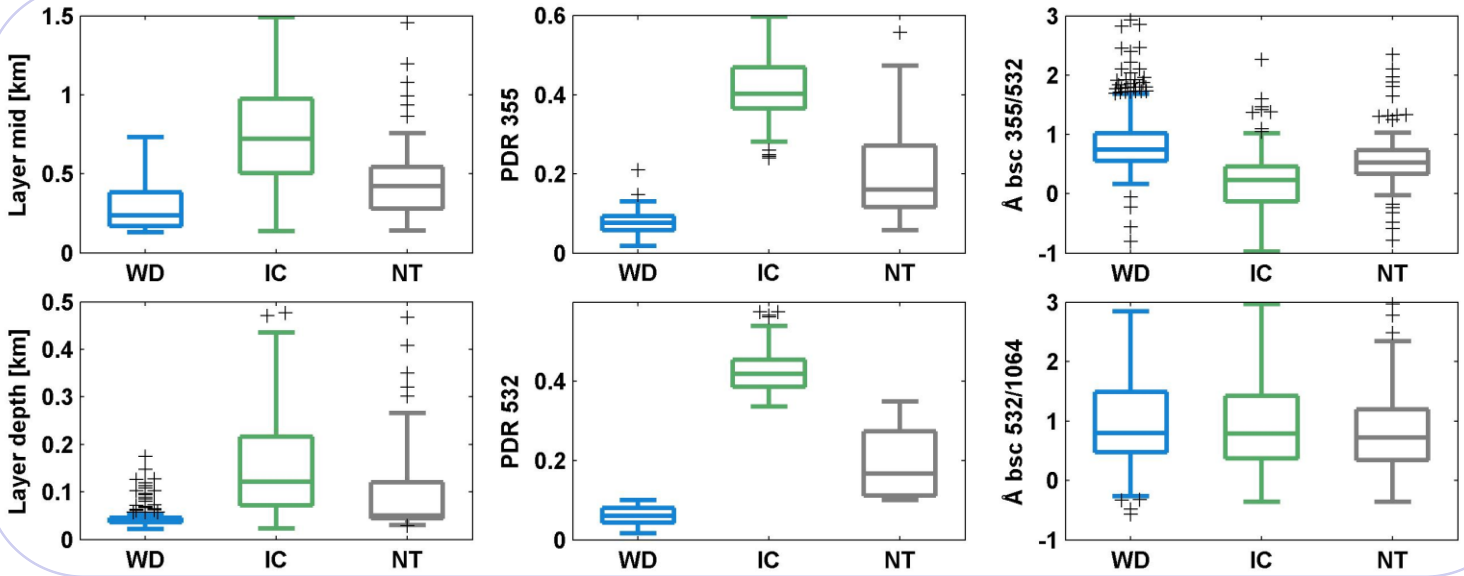
Cloud typing



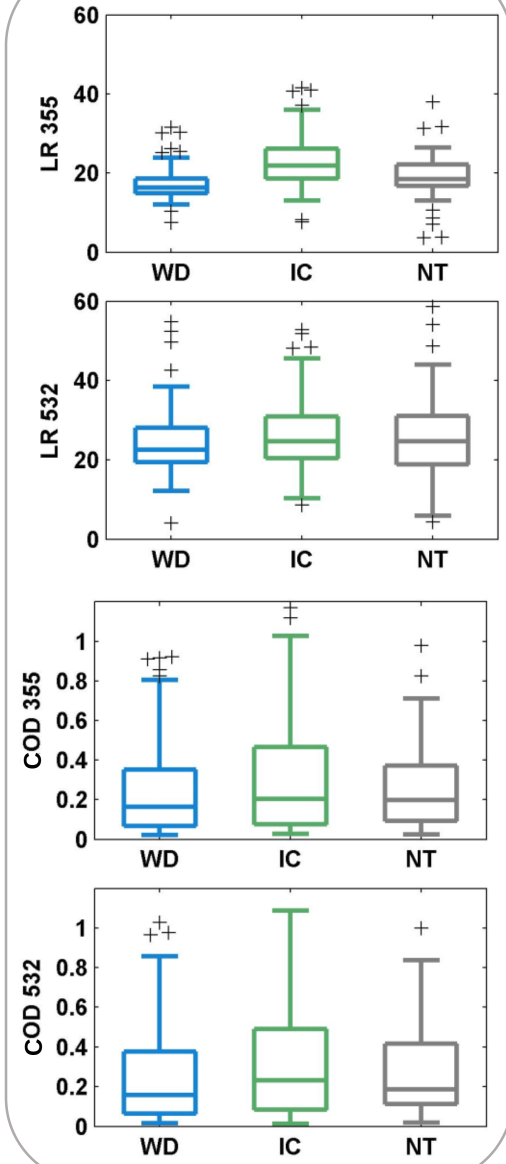
Cloud typing and the criteria for the feature classed.

	Detected feature	
WD	water droplets	$PDR_{532} \leq 0.1$ $Å_{bsc\ 532/1064} \leq 0.5$
	likely water droplets	$PDR_{532} \leq 0.10$
IC	ice crystals	$PDR_{532} \geq 0.35$
	likely ice crystals	$VDR_{532} \geq 0.30$
NT	non-typed (mix-phase, snowfall, etc.)	

All-day



Night-time
Effective values



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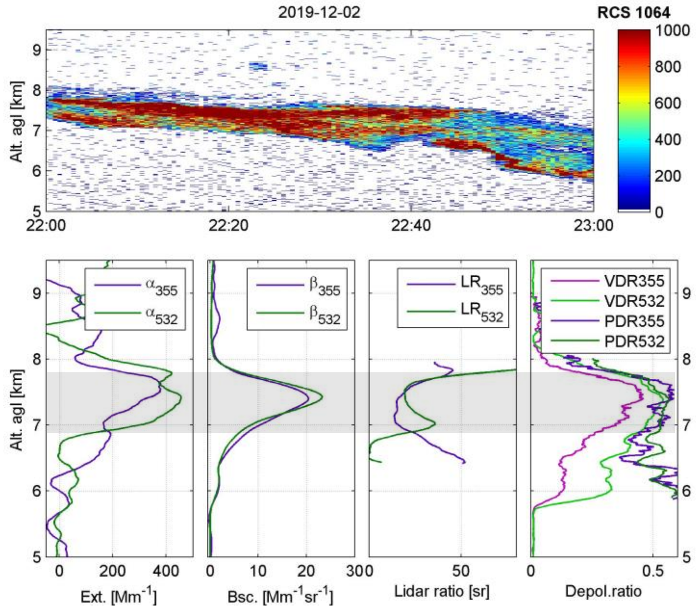
Multiple scattering:
case example

Lidar measurements



Lidar derived vertical profiles of optical properties. These are effective values.

Bias of ~15 sr is found for lidar ratio at both 355 nm and 532 nm

MS simulation

Multiple scattering parameter

$$a_{\mathrm{eff}}(z) = (1 - F(z)) * a(z)$$

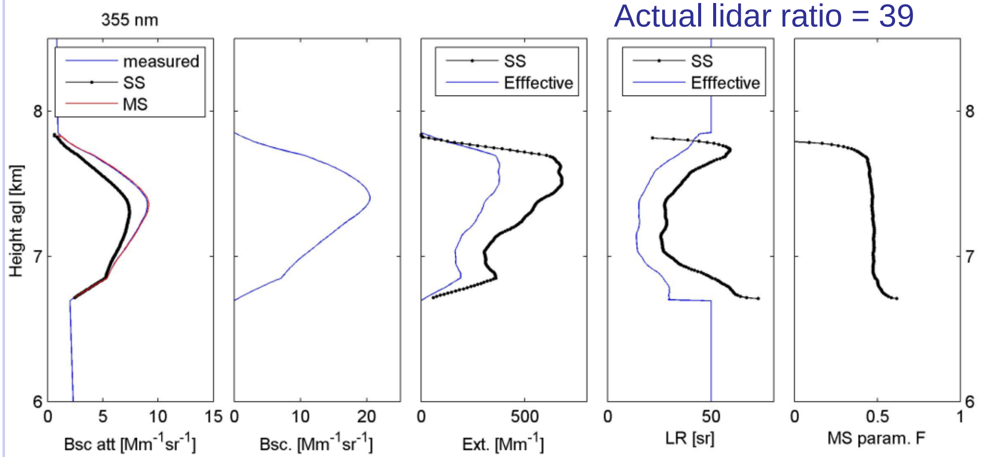
Actual (single-scattering) coefficient

Giannakaki et al., 2007

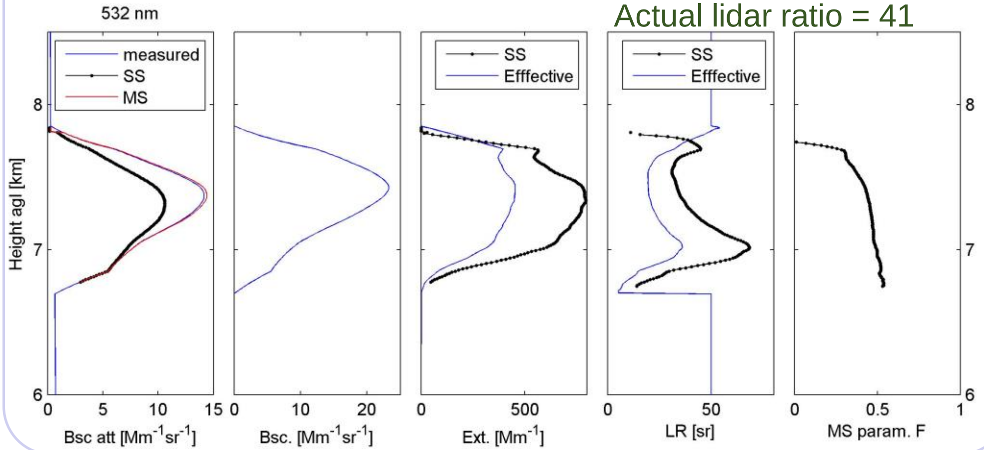
For MS simulation:
- Mid temperature: -50 °C
- Effective radius: 45 um
- Field-of-view = 1 mrad

SS: single scattering
MS: multiple scattering

Effective lidar ratio = 22
Actual lidar ratio = 39



Effective lidar ratio = 25
Actual lidar ratio = 41



Multiple scattering effects should be corrected for cloud optical properties.

Conclusion

- Four months campaign provided good dataset for the Arctic cloud
- Optical and geometrical properties of clouds have been determined from lidar analysis.
- A first cloud typing was applied and related properties were retrieved.
- Multiple scattering effect was studied.

Future work

- ➢ Multiple scattering correction
- ➢ The temperature and thickness dependencies on optical properties
- ➢ Combine the ceilometer measurements
- ➢ Combine the drone measurements