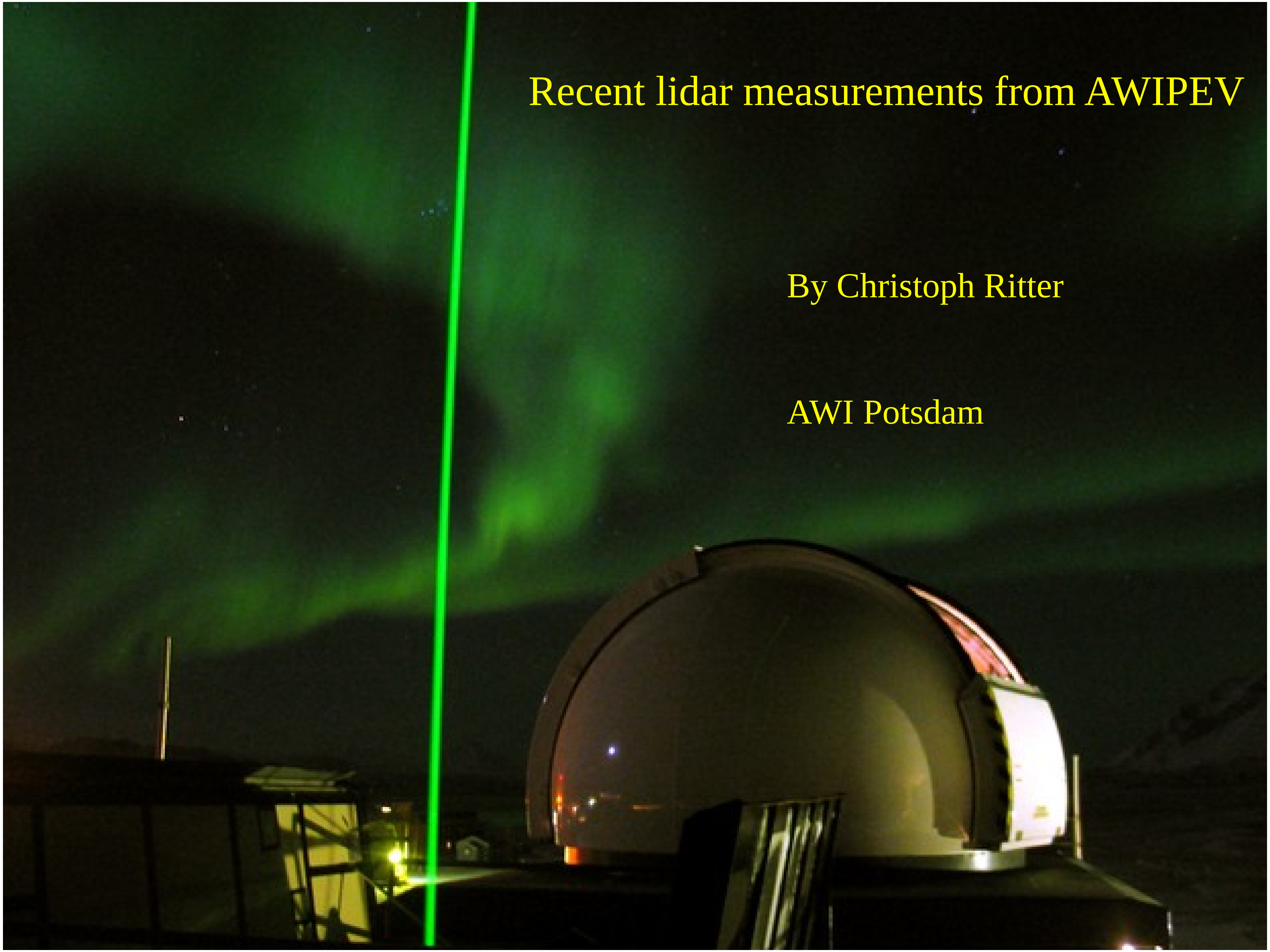
Recent lidar measurements from AWIPEV
By Christoph Ritter
AWI Potsdam

Aerosol and BL measurements

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HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Aims aerosol:
(remote sensing sun/star-photometer, Raman lidar)
Continue long-term measurements
Participate in aerosol closure experiments
… from aerosol to clouds ….

Aims BL:
Understand micrometeorol. influences on BL properties
Understand coupling between local and synoptic processes
… linkage aerosol to BL …

Instruments at AWI:

- Continuous instruments during campaign:

  wind lidar (50m / 10min, from ± 150 – 1000m), 3-D wind

  BSRN station: T, p, rh, wind, short – long-wave up and down

  radiometer (T: 50 -2000m, 20min, approx 100m resolution, humidity (same resolution, quality?)

  photometers at village & Zeppelin station (if sunny)

  Vaisala CL51 Ceilometer (910nm)

- Sporadic instruments:

  radiosonde (11UT each day)

  KARL lidar (clear sky)

Instruments at Rabben:

PI: Masataka Shiobara from NIPR (Tokyo)

Sky radiometer (photometer + 2 channels around 1.5µm) – many years starting in April

Depolar. resolved MPL lidar

(all sky camera) -All continuous

Yutaka Kondo: Univ Tokyo, BC since 2012

Status & aims:

no major flaw in data

detailed analysis to be done

KARL: 30 March – April 6 most interesting

air trajectories not easy

Ceilometer: backscatter up to 1000m

Master thesis → connection to Iwona

Wish:

Paper on event and / or paper on season

AWI: meteorology, remote sensing

Currently 3 lidars from AWI:

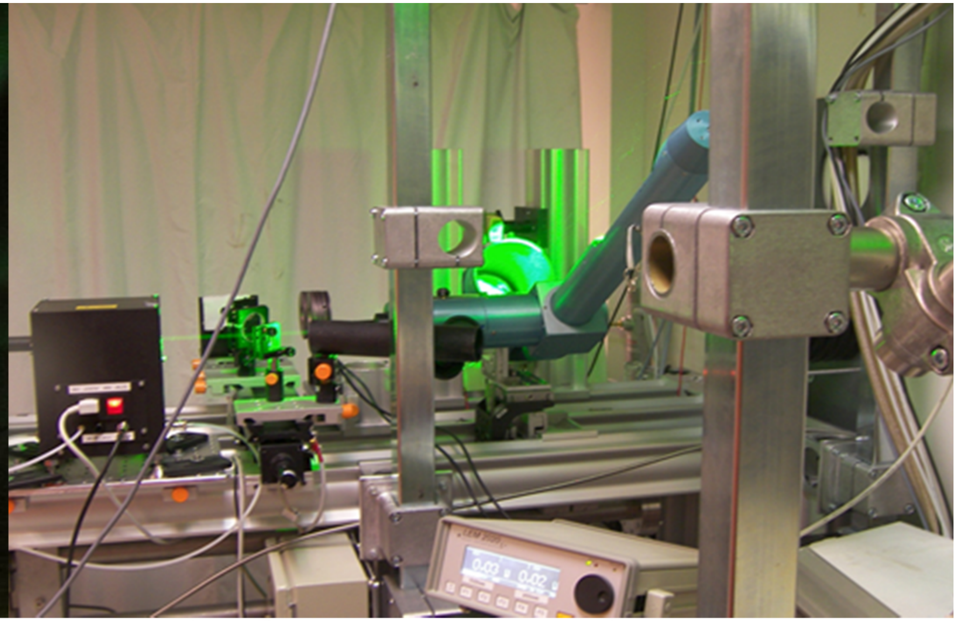
a) Koldewey aerosol Raman lidar (KARL), since 2001

b) a wind lidar (Leosphere) since Dec. 2012

c) different ceilometers (Vaisala), one each time, quasi continuously since 2001

Status of instruments
Recent data
Discuss abilities, shortcomings

Aim: invite you to develop strategy how to use these instruments for common, future projects, espec. for clouds!

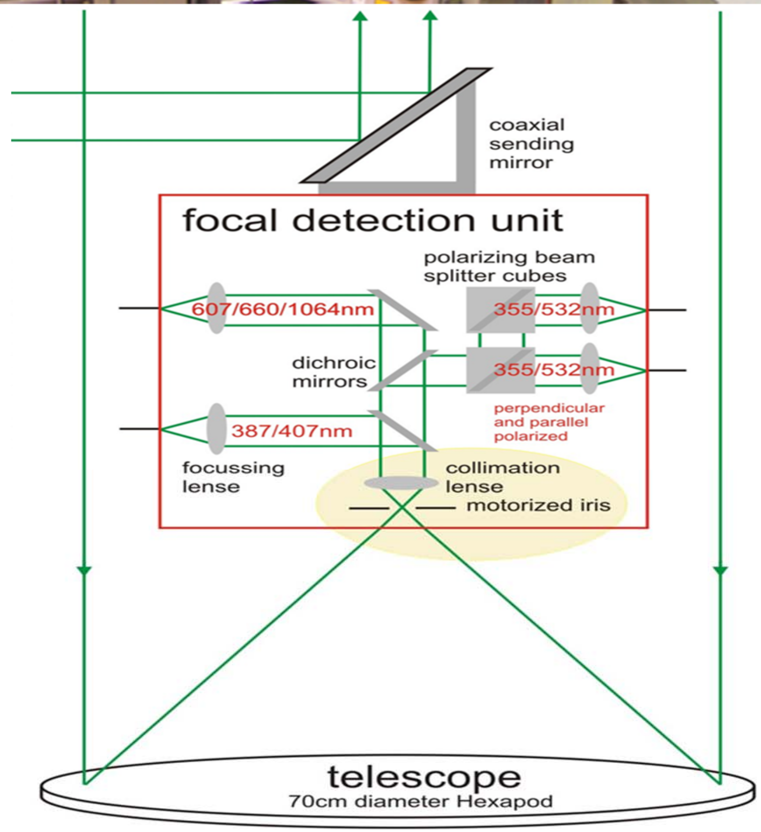


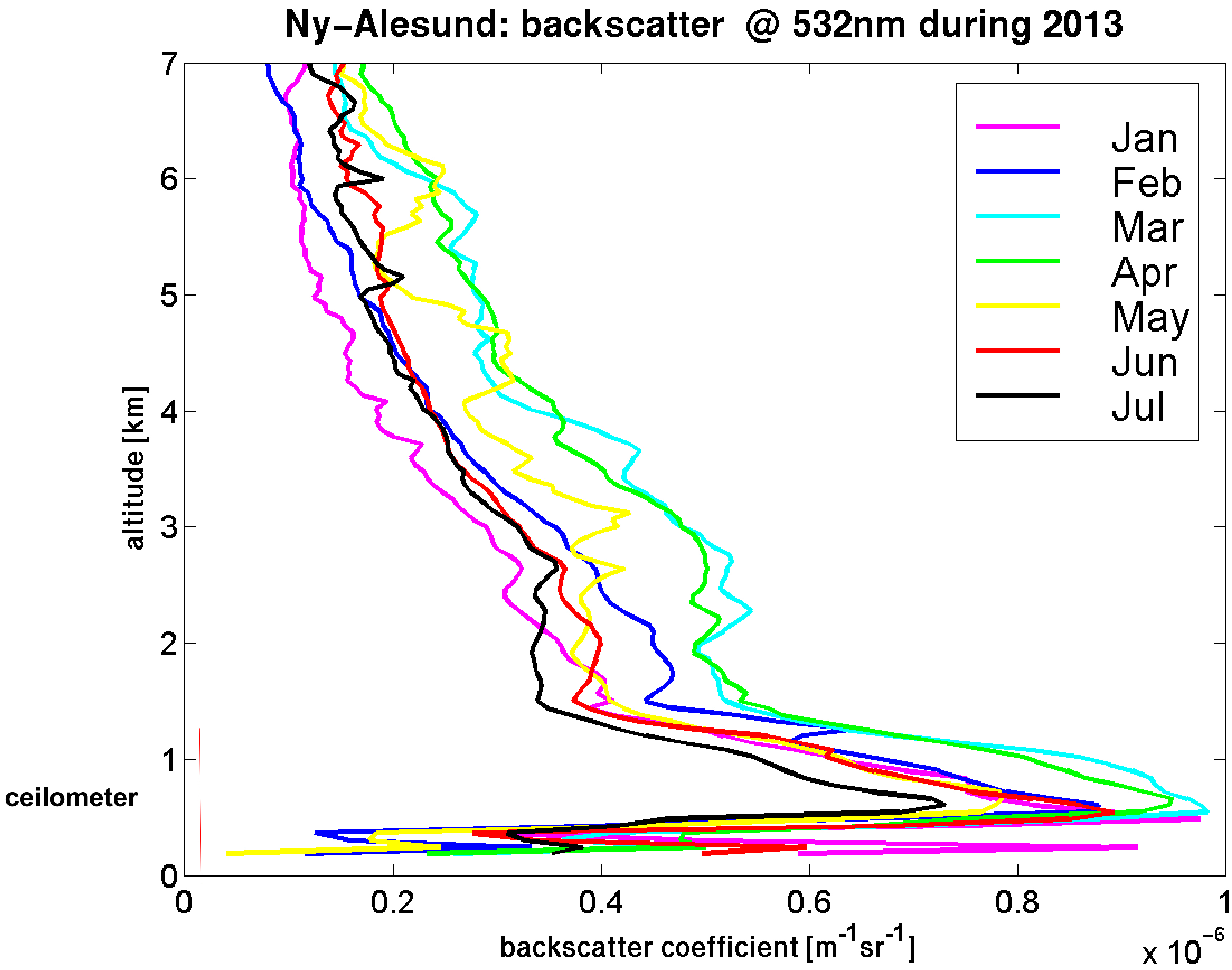
a) Koldewey Aerosol Raman Lidar (KARL)

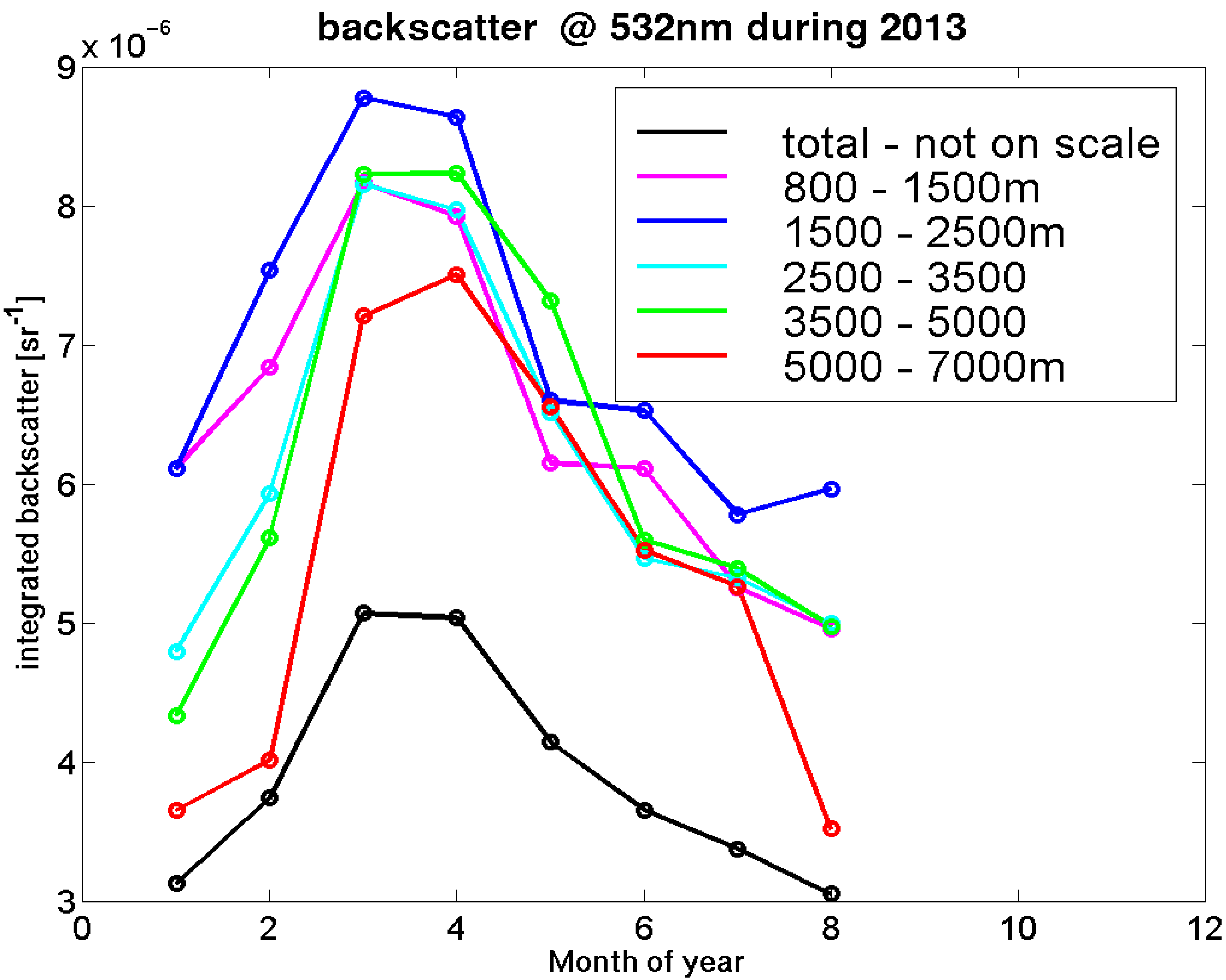
Measures:
Backscatter: 355nm, 532nm, 1064nm
Extinction: 355nm, 532nm (from N_2 Rot-Raman)
Depolarisation: 355nm, 532nm
Water vapor: 407nm, 660nm (from H_2O Rot-Raman)

Specs:
Nd:Yag laser with 10W / color
70cm recording telescope
Moveable aperture (diameter & position) for measurements in tropos- and stratosphere
Starting at “Zeppelin altitude”

Used: aerosol in tropo & stratosphere, H_2O in (lower) troposphere



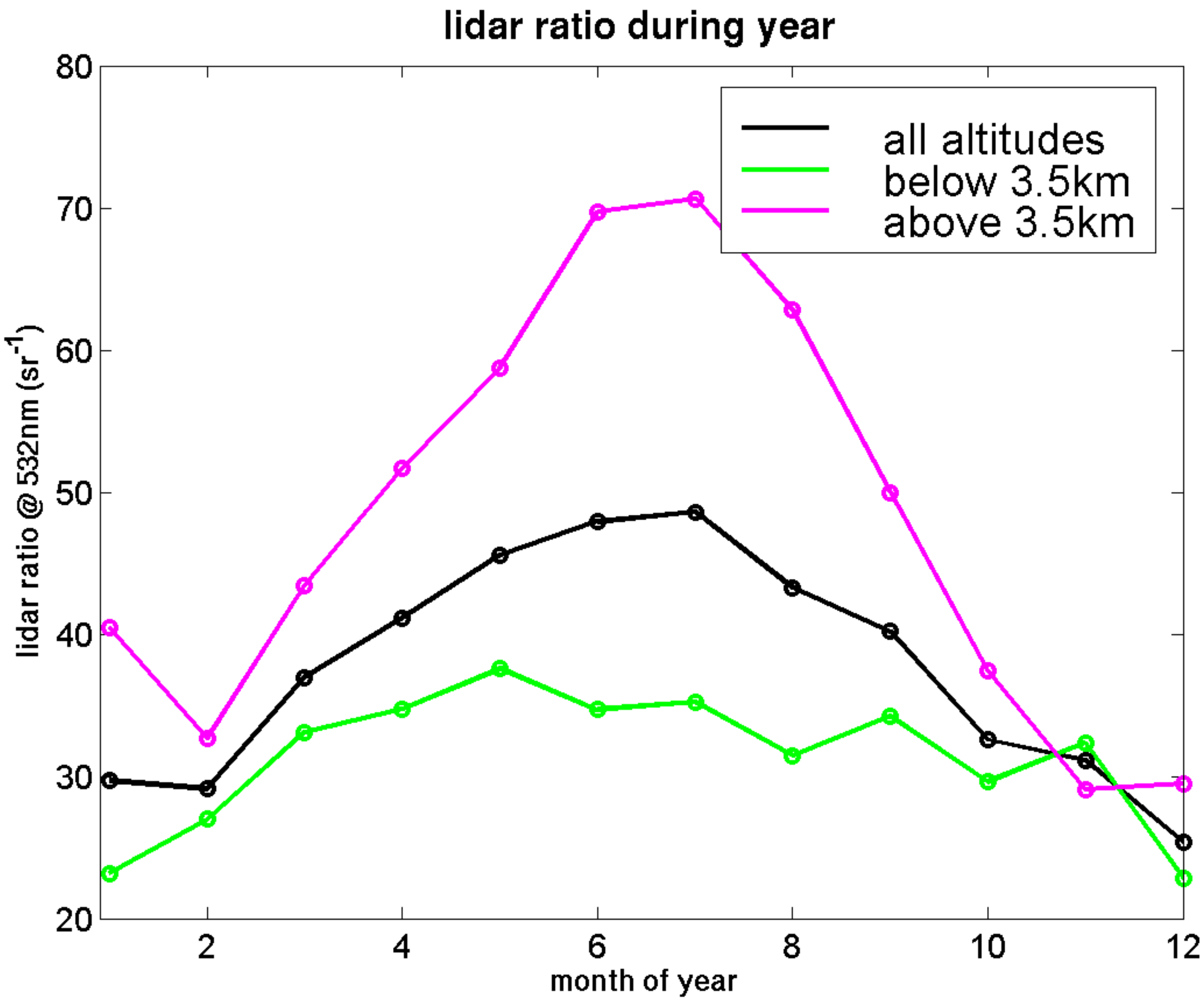

Ny-Alesund: backscatter @ 532nm during 2013
7
6
5
4
3
2
1
0
altitude [km]
ceilometer
0
0.2
0.4
0.6
0.8
1
backscatter coefficient [m-1sr-1]
x 10-6
Jan
Feb
Mar
Apr
May
Jun
Jul



optically detectable aerosol disappears from ground up during season

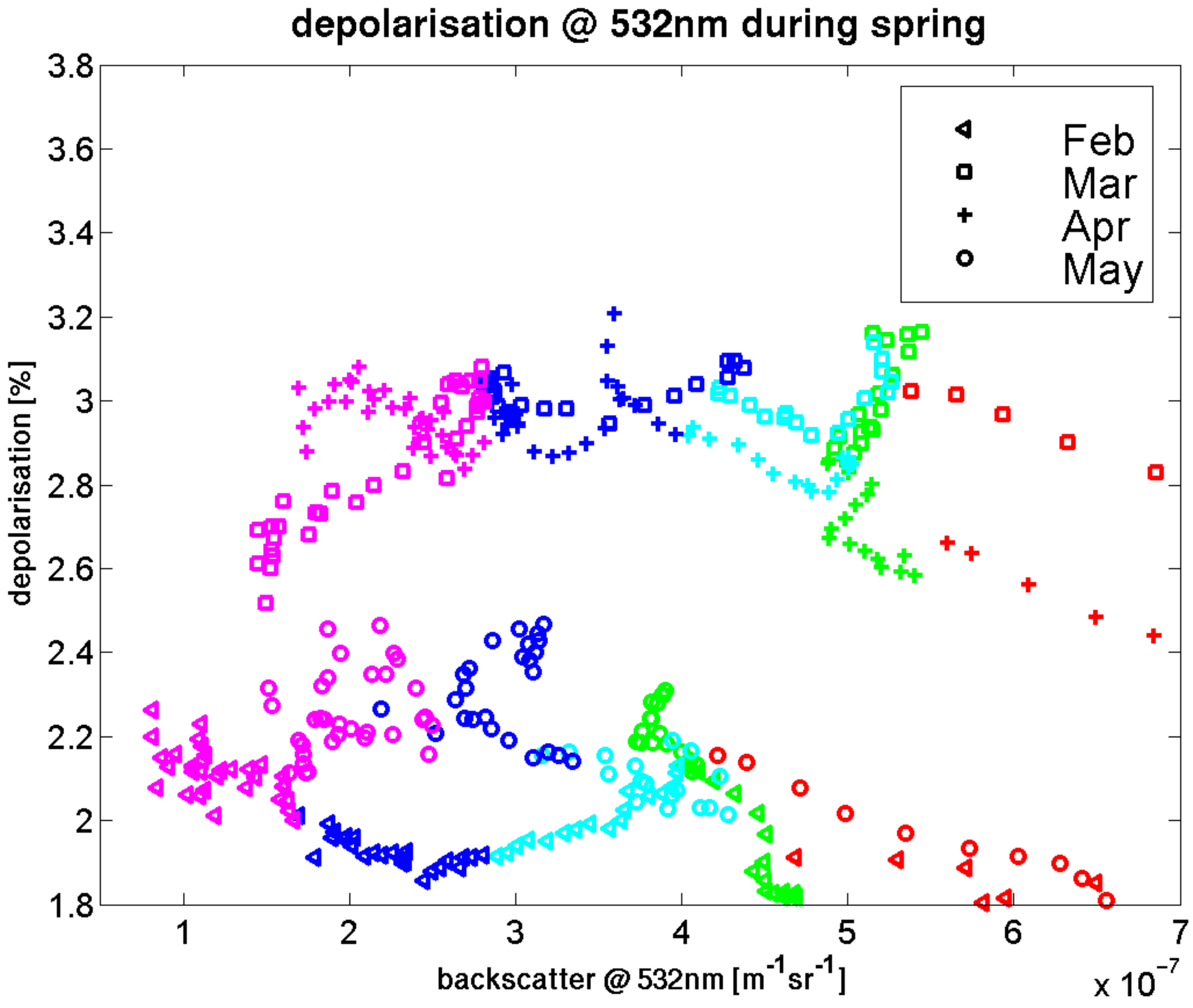
AOD from Rabben station shows max. in April

Annual cycle in Lidar ratio? Data from 2013



$$LR = \frac{\alpha^{aer}}{\beta^{aer}}$$

Intensive quantity: aerosol depolarisation (shape)



800m – 1500m
1500m – 2500m
2500m – 3500m
3500m – 5000m
5000m – 7000m

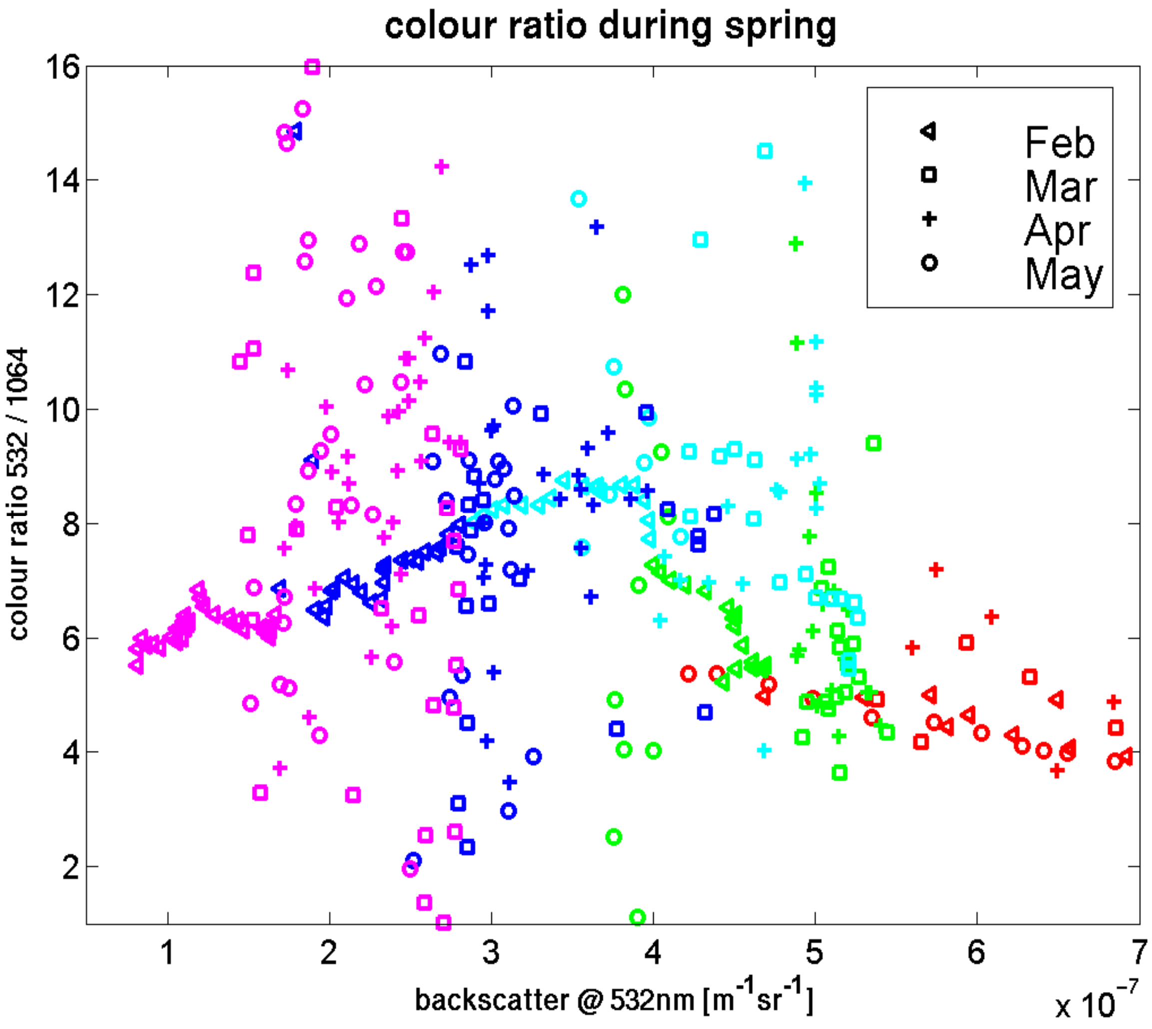
Particles more spherical outside haze season! (Mie better)

Extensive quantity

Intensive quantity: color ratio (size)

small

large



800m – 1500m
1500m – 2500m
2500m – 3500m
3500m – 5000m
5000m – 7000m

Size more uniform in Feb??

What does the aerosol lidar KARL deliver:

extensive quantities (dependent on aerosol number concentration):

backscatter (concentration, size, shape, refractive index)
extinction (concentration, size, shape, refractive index) !
(moreover specific humidity)

intensive quantities (not dependent on aerosol number concentration)

depolarisation $\delta = \frac{\beta_\perp}{\beta_=}$ (shape) [dipole moment]

colour ratio $CR = \frac{\beta_{\lambda 1}}{\beta_{\lambda 2}}$ (size) [$\beta \sim \lambda^{\text{Å}}$ $-4 < \text{Å} < 0$]

lidar ratio $LR(\lambda) = \frac{\alpha^{aer}}{\beta^{aer}}$ (index of refraction, size, shape)

Knowledge of δ, CR, LR allows a robust classification of aerosol type (dust, smoke, sea salt, cirrus…)

→ it's about getting the intensive quantities!

AWI

Inverting lidar data:

Aim: estimate size distribution n(r) (r_{eff}, σ, N_0) and refractive index m from lidar data
Assume spherical particles, Mie theory, efficiencies $Q_{ext/\beta}$ are known
→ set of Fredholm integral equations for extinction & backscatter

$$\alpha(\lambda) = \int_{R_{\min}}^{R_{\max}} Q_{ext}(\lambda, r, m)\, \pi r^2\, n(r)\, dr$$

$$\beta(\lambda) = \int_{R_{\min}}^{R_{\max}} Q_{\pi}(\lambda, r, m)\, \pi r^2\, n(r) dr$$

Retrieval of n(r) from Q, α, β is an ill-posed Problem
At least 2 α, 3 β needed

But:
Lidar is able to retrieve aerosol in accumulation mode: 0.1μ < r < 1.2μ

Shortcomings of lidar data:

Phase function missing: only info around Φ =180 °

Refractive index challenging: $m = m_{real} + i \cdot m_{imag}$

m_{real} ~ scattering m_{imag} ~ absorption
but we only have β, α

Weak absorption → ω insecure

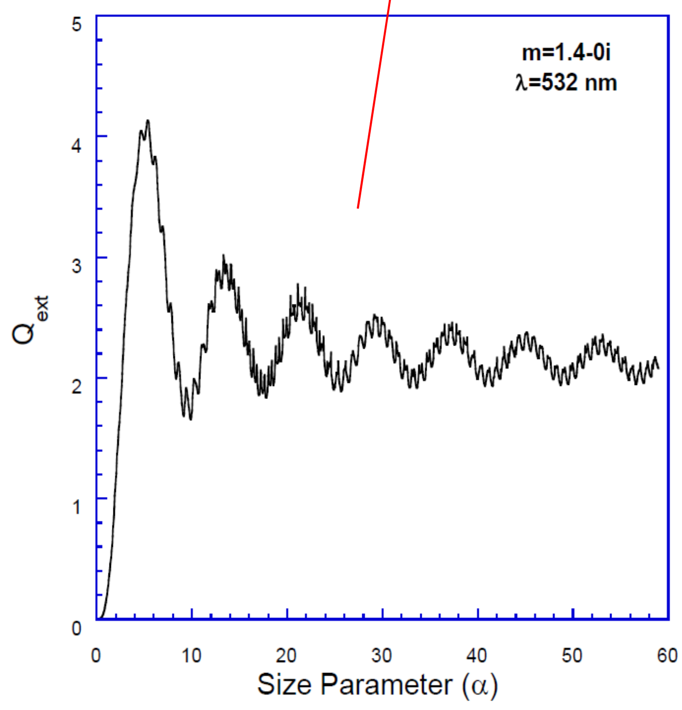
Only trustful info for accumu. mode:
Aitken: interacction too small
giant mode: Mie efficiency becomes flat

$$\alpha = \frac{2\pi r}{\lambda} \leftrightarrow r = \frac{\alpha\lambda}{2\pi}$$

$$\alpha \in [1 \ldots 12],\ \lambda=0{,}5\mu \rightarrow r \in [\frac{1}{4\pi} \ldots \frac{3}{\pi}]\ \mu$$

conclusion: aerosol, cloud particles

For broad size distribution function becomes smoother

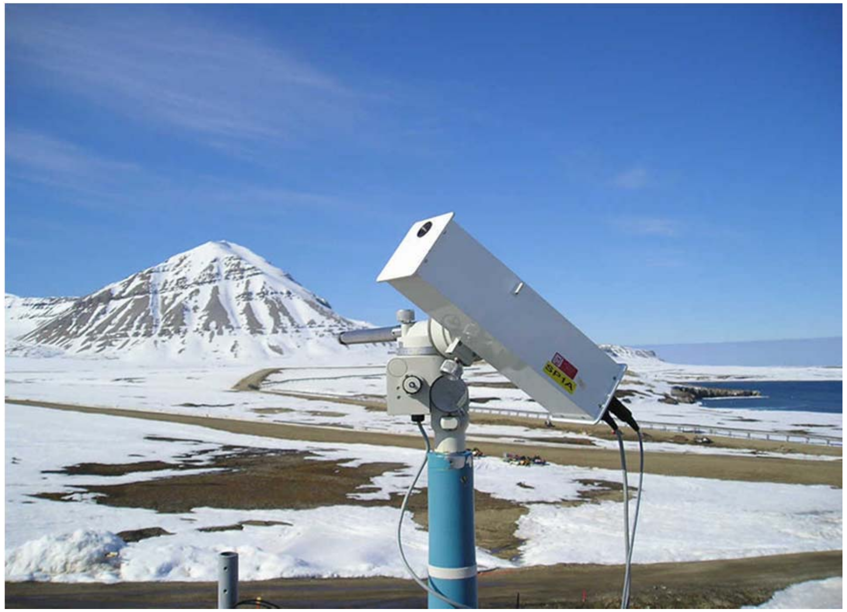


Status KARL:

Ongoing long-term monitoring of aerosol

Strong interest in closure experiments

Interest in comparison with photometer(s): vertical vs. inclined column, local effects of aerosol, hygroscopic growth, role of summits
→ aerosol – cloud – interaction

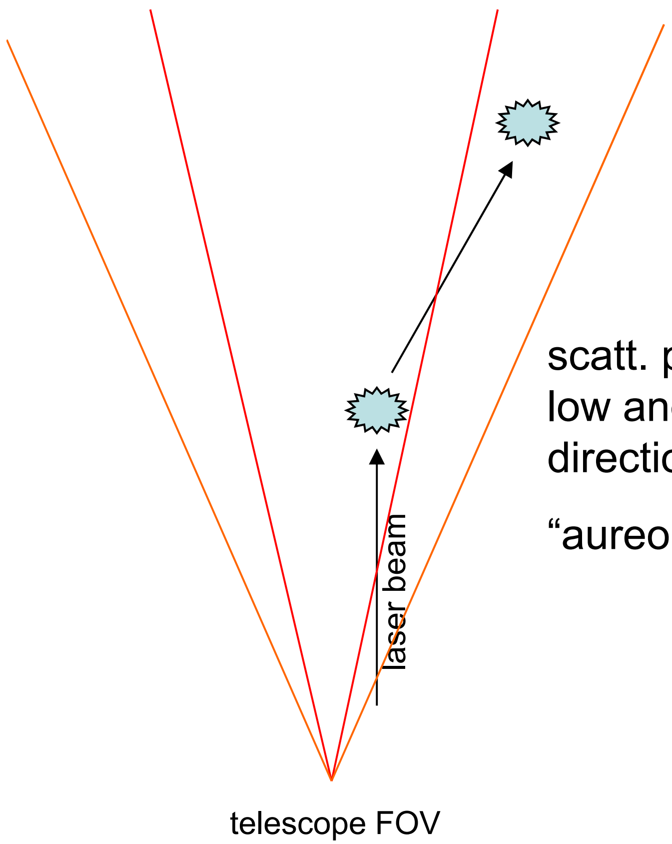


KARL good for particles in accumulation range
-Not in thick clouds, below, before and after clouds

“Multiple field of view measurements”

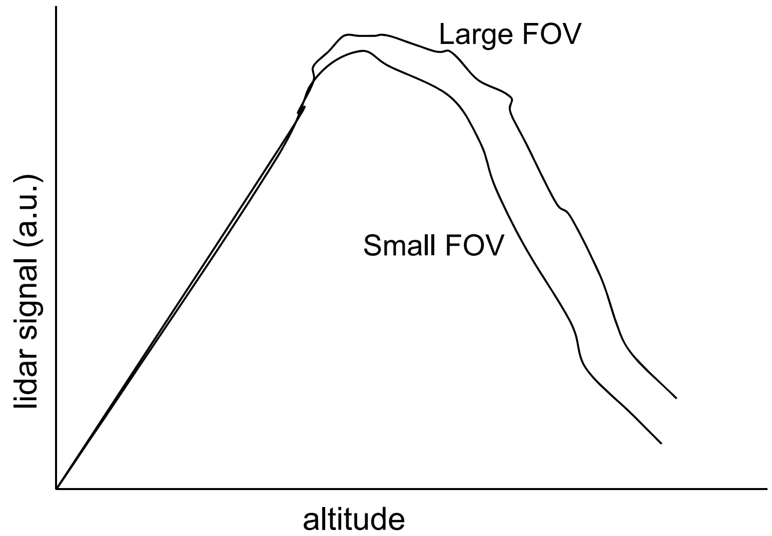
Sense of MFOV measurements

In an ideal world the count rate in a lidar increases with its field of view because more multiple scattered light will be collected.



scatt. prob. high for low angle forward direction

“aureole peak”



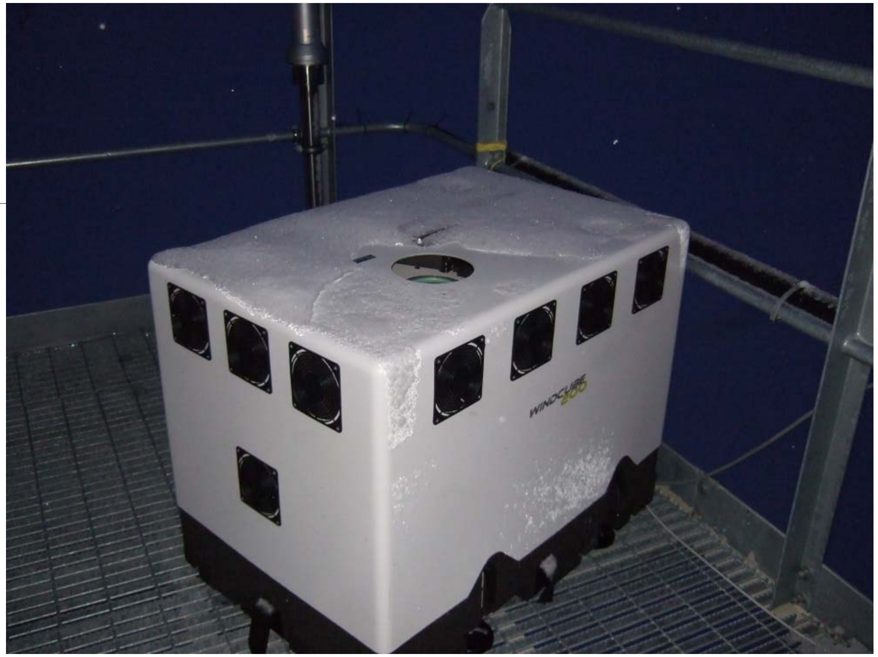
A larger FOV should collect more light in and after a cloud. The aureole peak mainly results from large, crystal particles which cannot be analysed by Mie code inversions

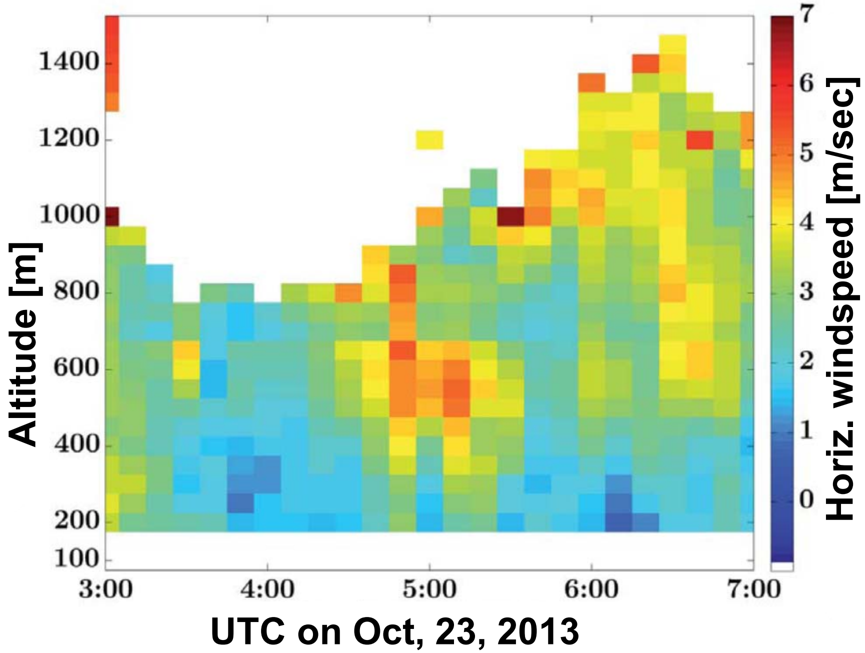
b) The wind lidar

A commercial instrument from Leosphere
Measures the 3-dim wind with 50m / 10 min resolution
from approx. 150m …± 1200m
(backscatter at 1.5µm, Doppler effect ⟶ aerosol as tracer)

Master thesis S. Burgemeister:
U,V components reliable
Wind channeled along Fjord in lowest ±600m
Passages of fronts detectable
Several short living LLJ detected

Meanwhile:
Also W component (vertical)
But, particles still tracer?)





Reliability of the vertical wind (?)
Case 5 July, 2014

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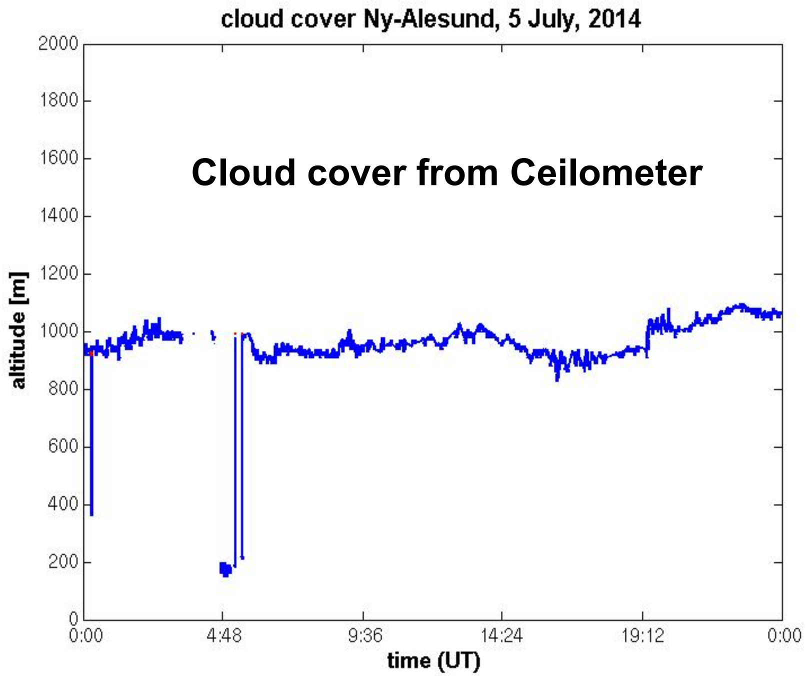
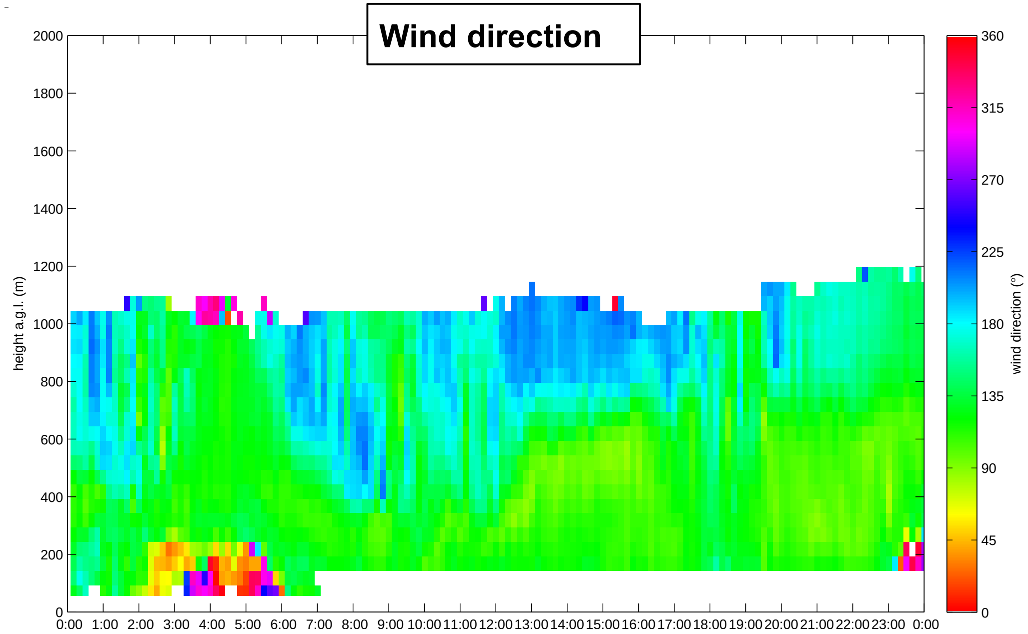
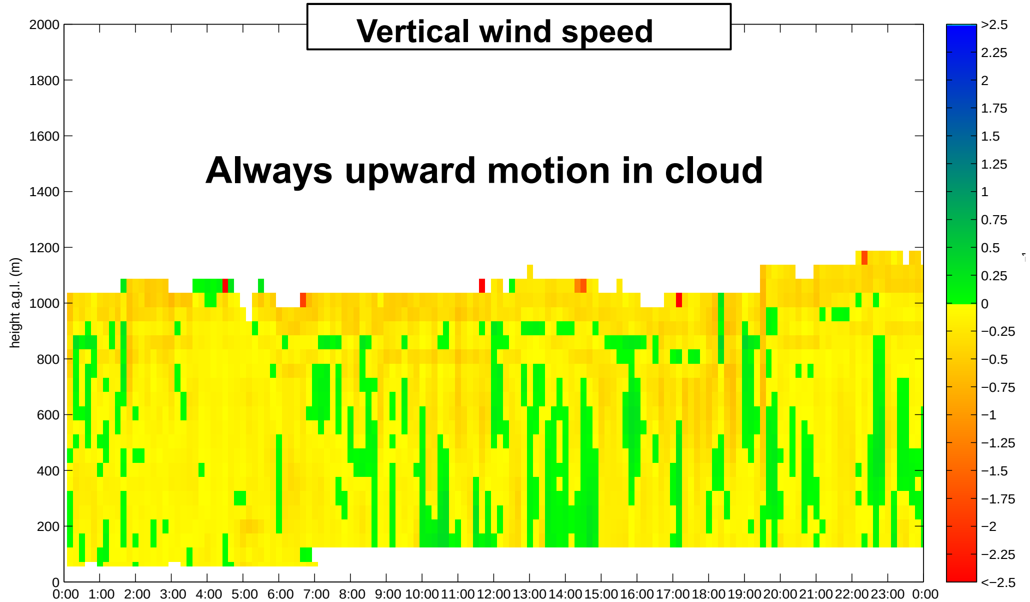
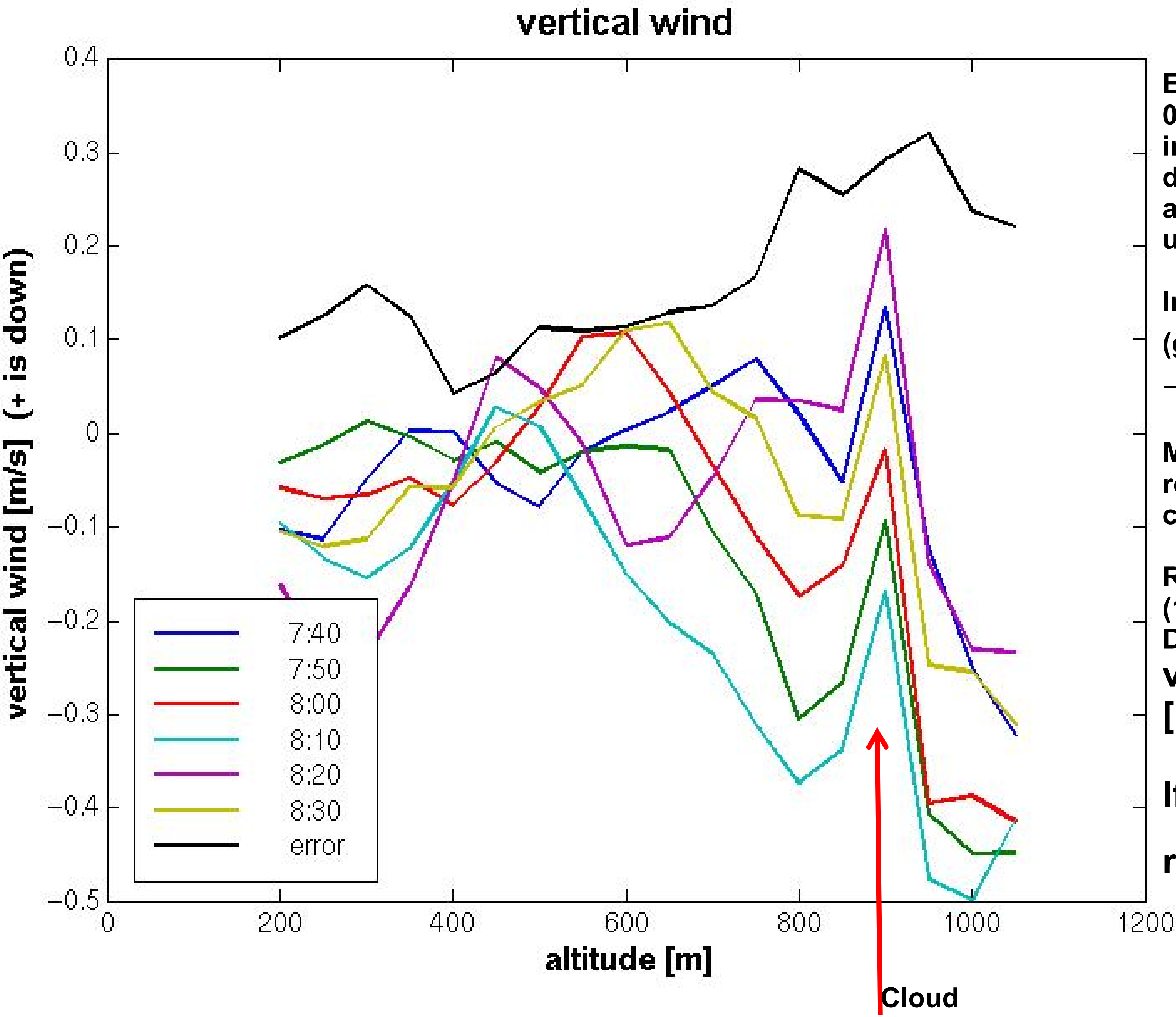






Persistent clouds around 1km altitude
Vertical winds from -0.5 m/s (upward)
To +0.5m/sec (downward)

Time 7:40 – 8:30 constant cloud height
925m



Error around 0.3m/s max.
in cloud: downward, above / below upward motion

Inclination?

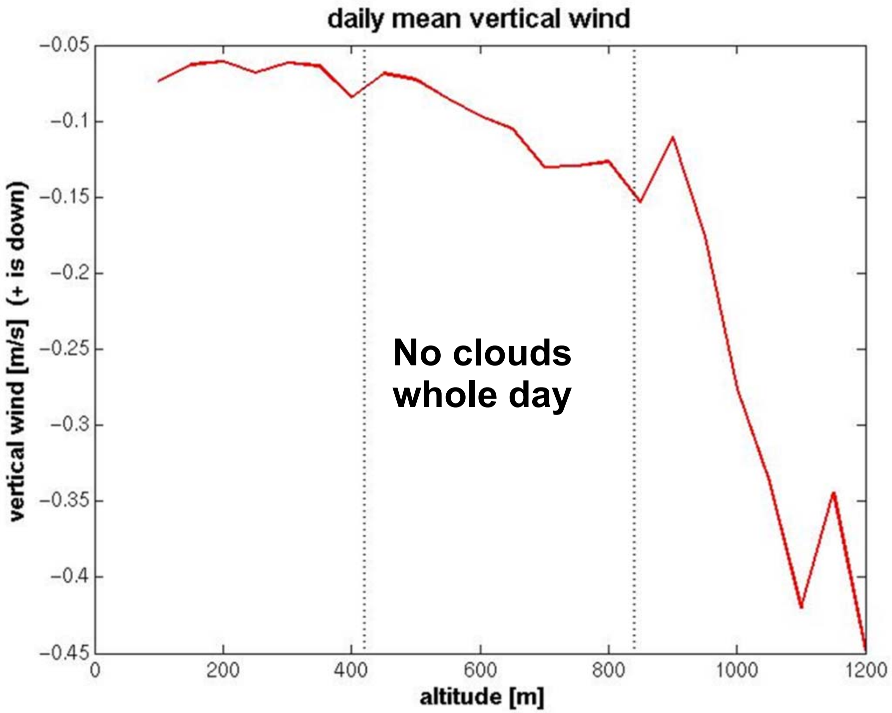
(green ⟶ red ⟶ cyan)

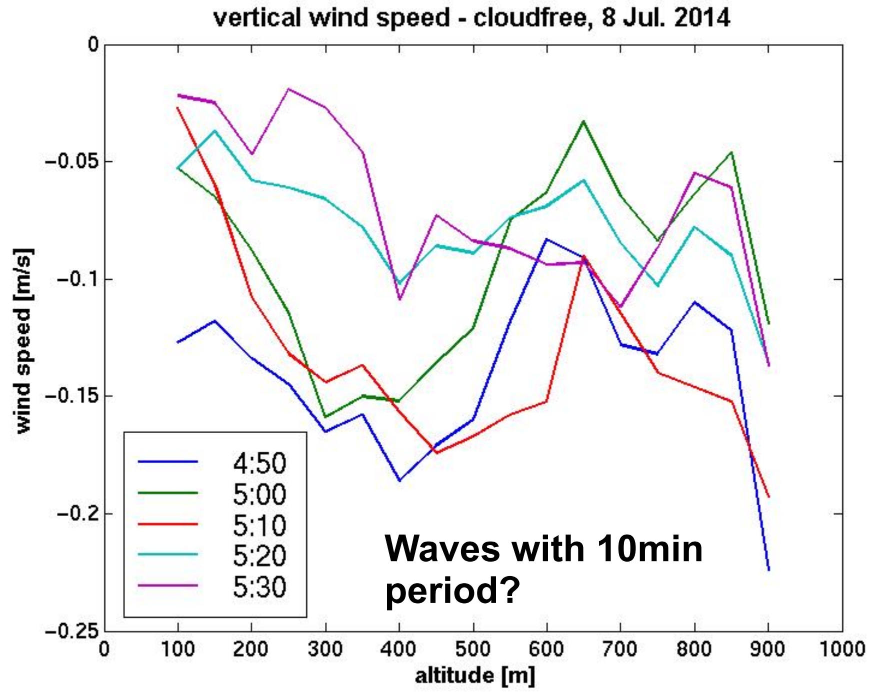
Method more reliable outside clouds?

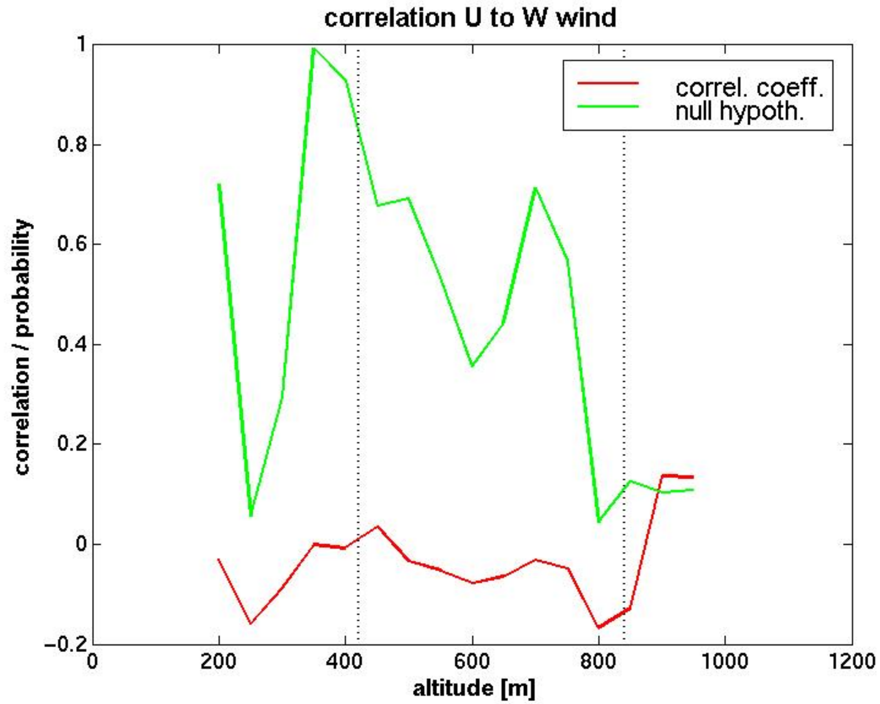
Rogers & Yau (1989):
Drizzle fall speed v:
$v = 1.19\ 10^8\ r^2$ [m s^{-1}]

If v= 0.2 m s^{-1}

r = 41µm







Summary wind lidar so far:

U,V wind are very reasonable

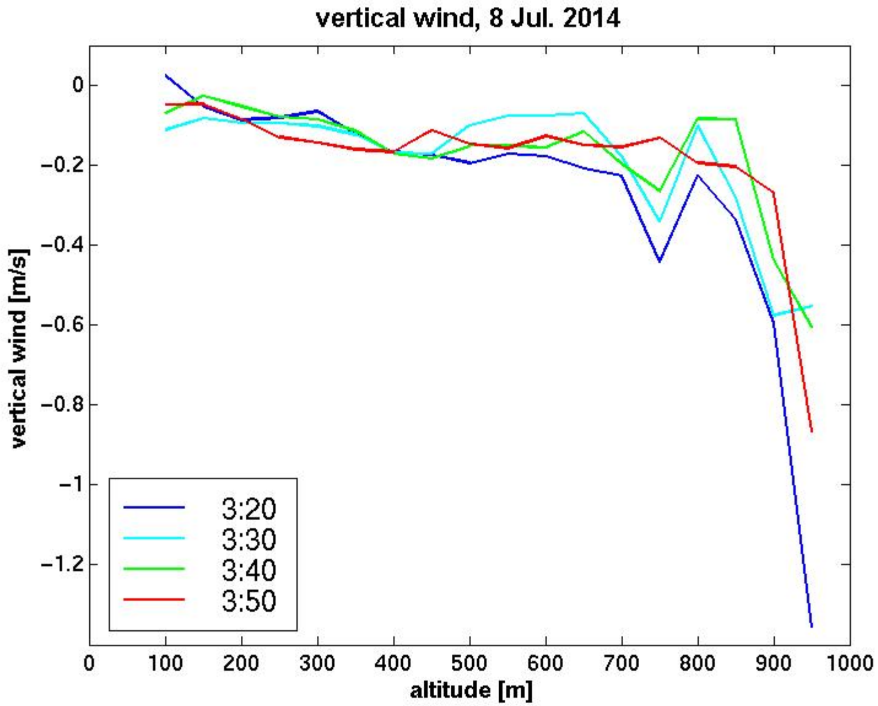
Vertical wind is evaluable, measurement precision (0.1 … 0.3 m/s)

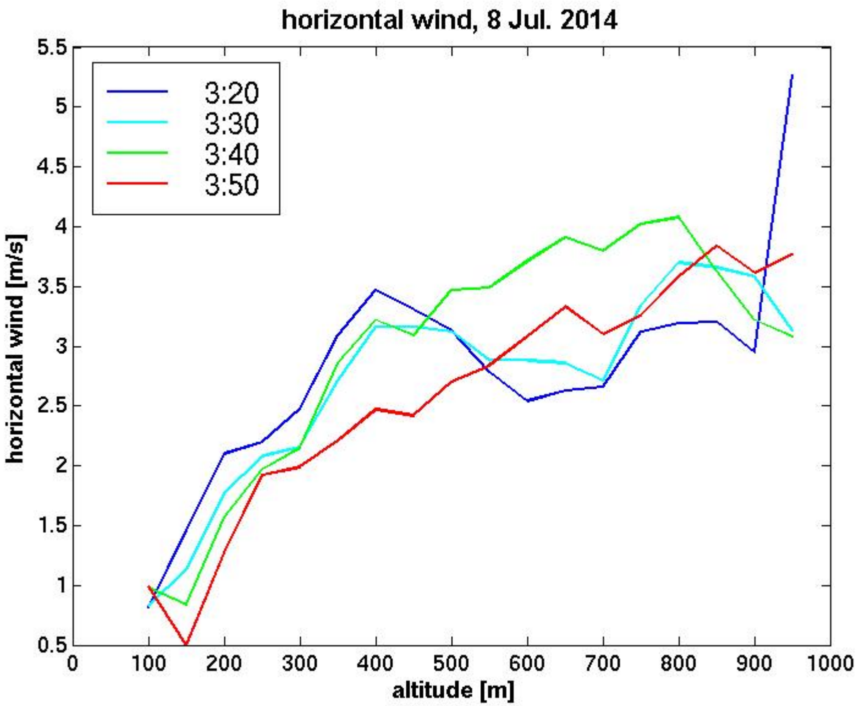
We see updraft in /around clouds

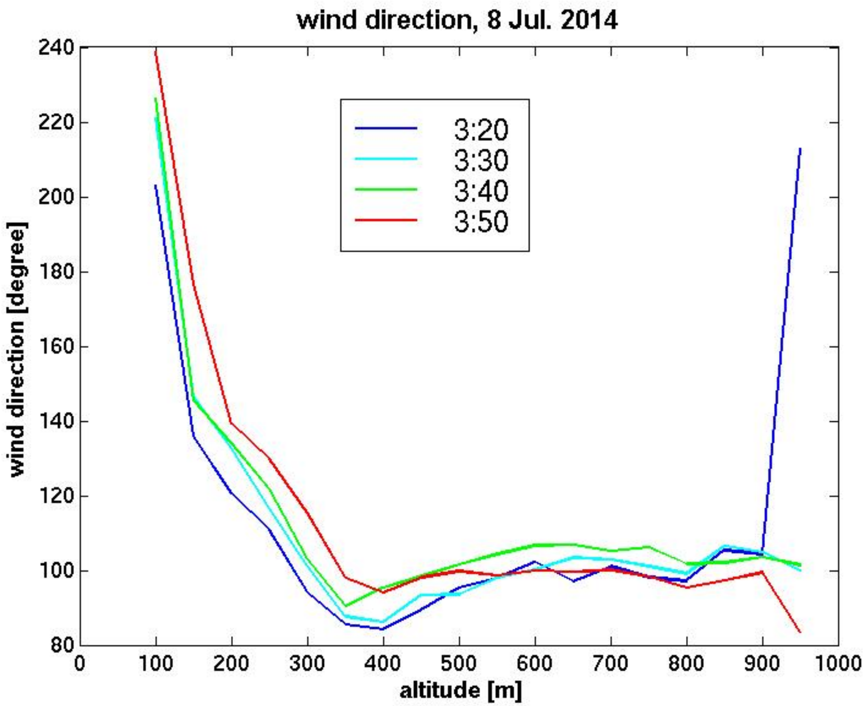
Droplets > 10µm have sedimentation rates that produce noticeable different velocities compared to air

Disintegration of a cloud
8 Jul. 2014

Ceilometer sees a cloud at 860m that suddenly disappears at 3:41.





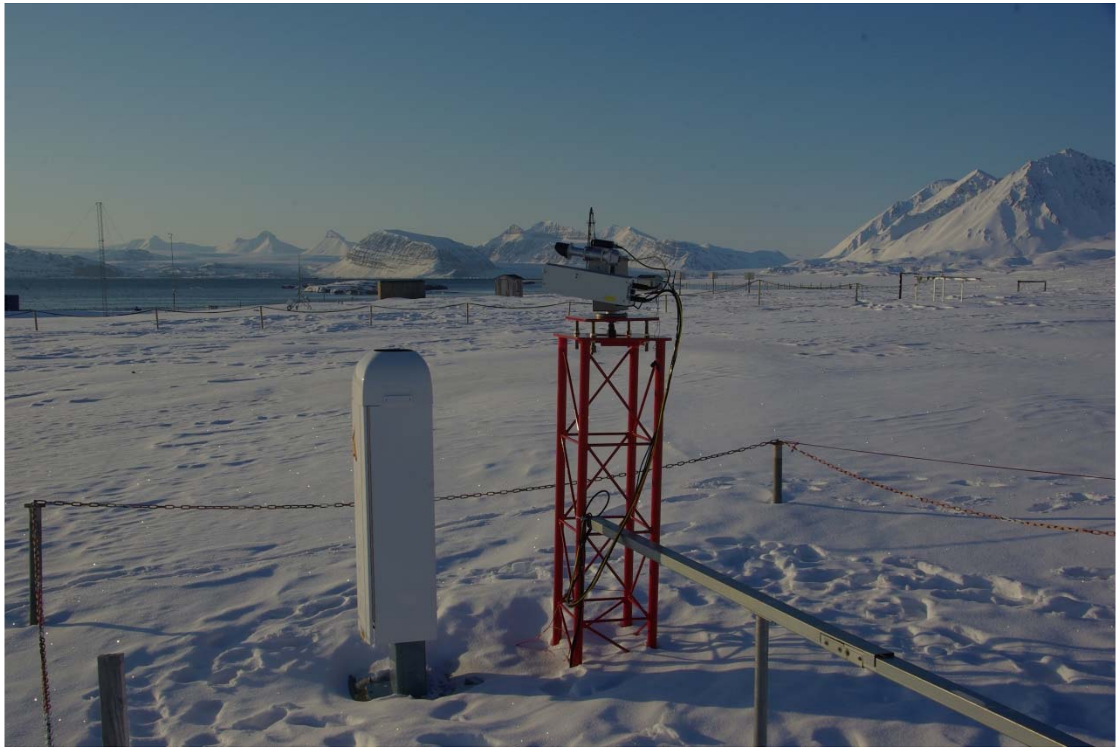


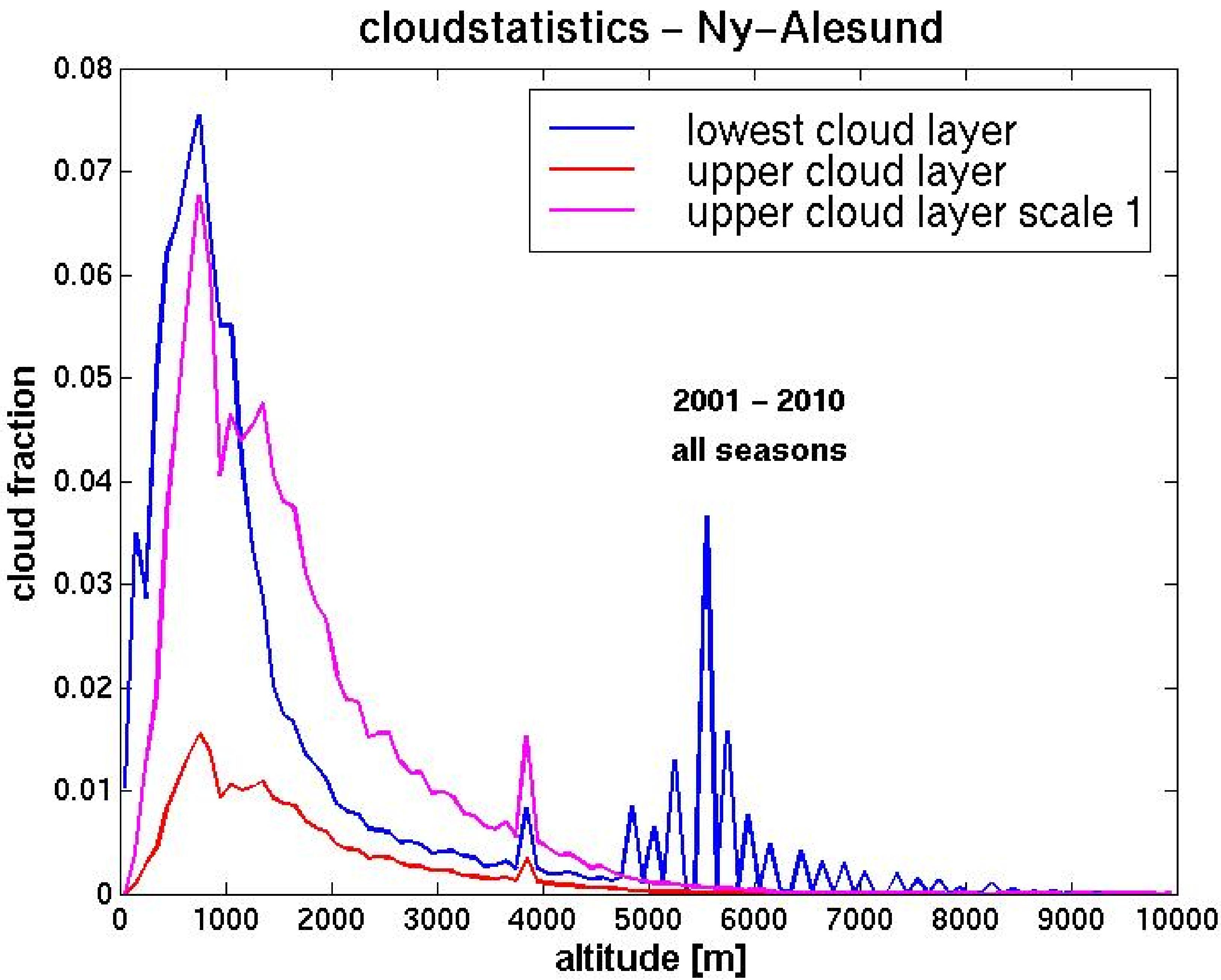
Part c: ceilometer

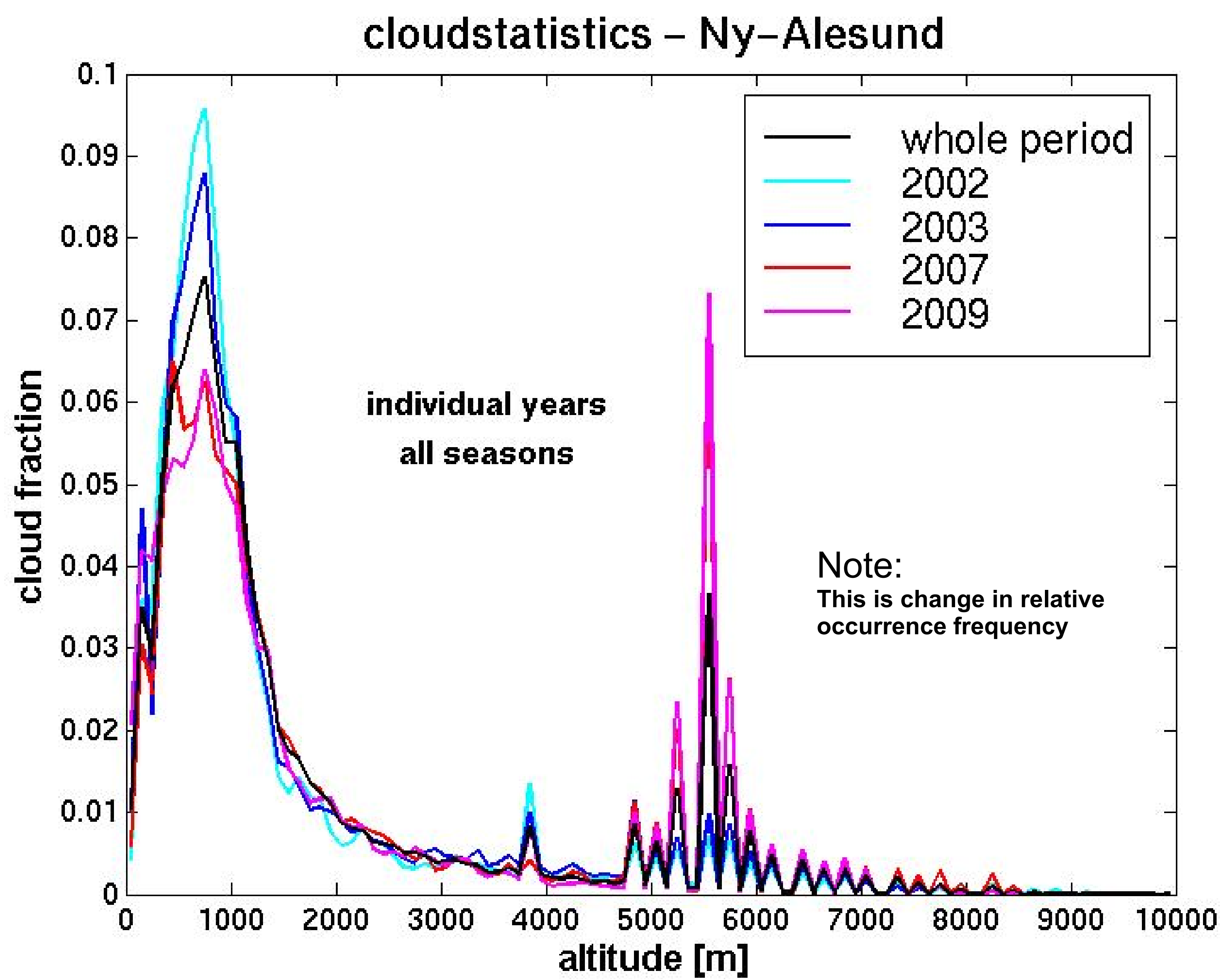
Always Vaisala
2000+ LD 25 LD 40
Since 2011 CL 51

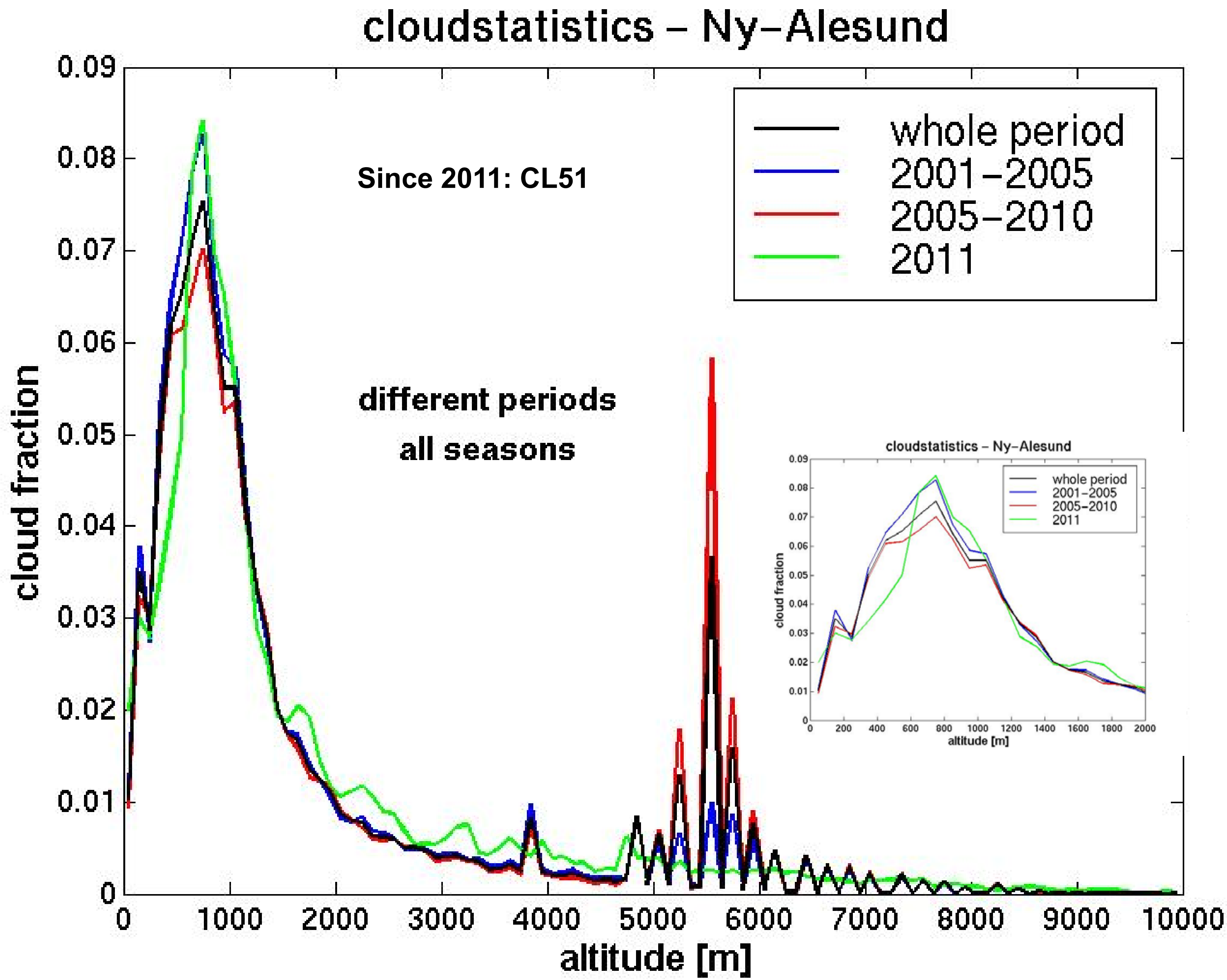
Use for cloud occurrence and backscatter
(control overlapp for KARL)

λ = 910nm
β useful up to 1km

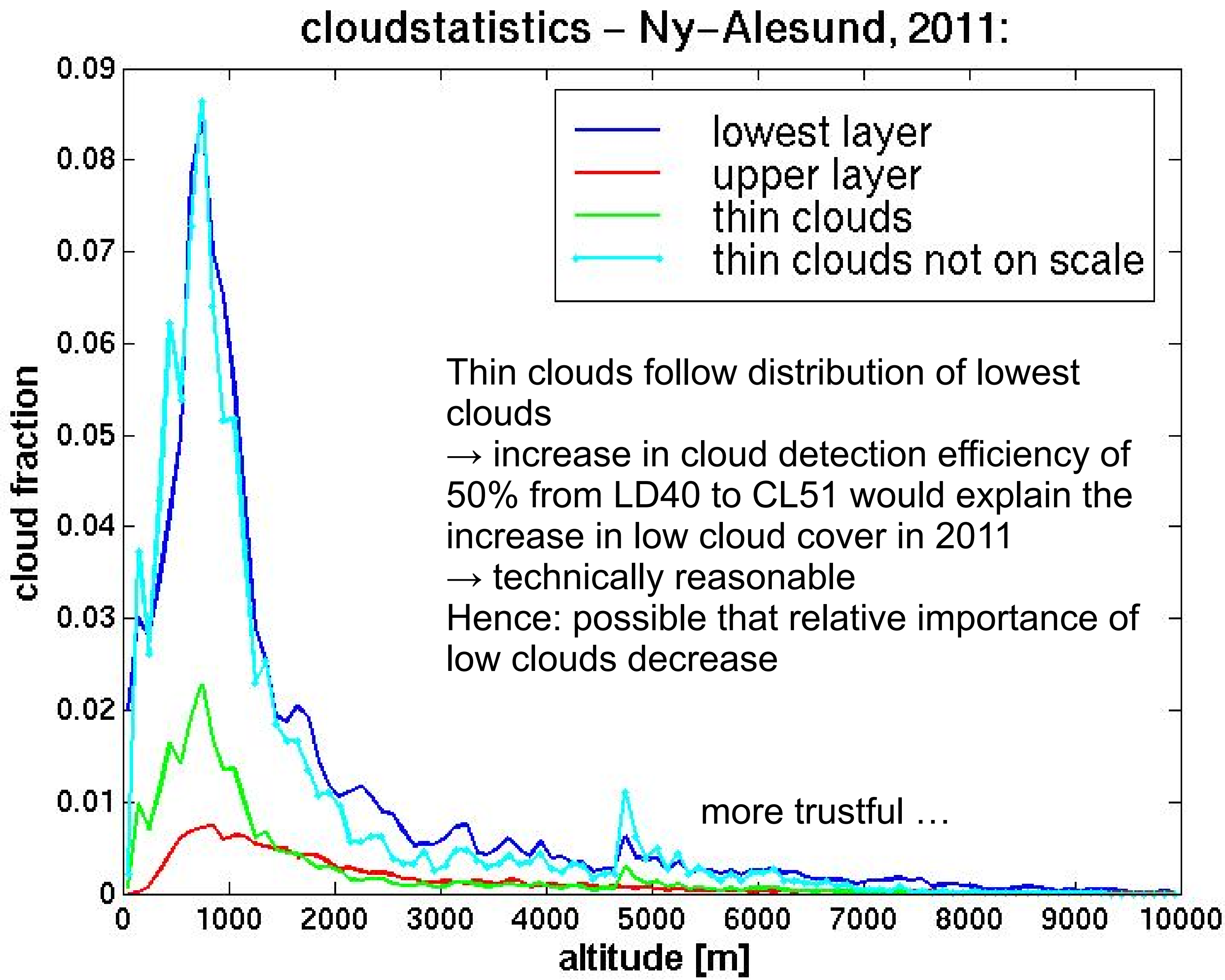


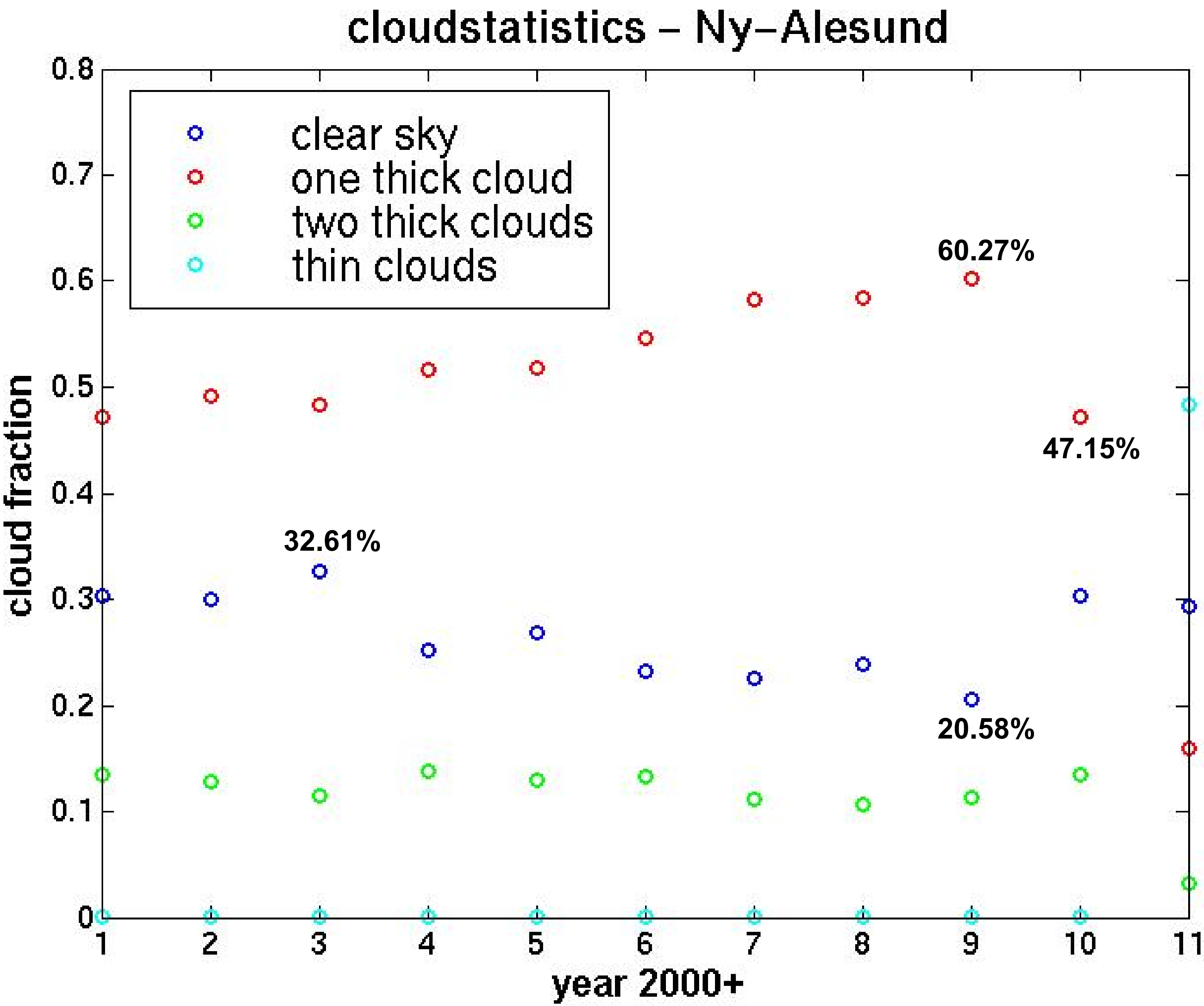

cloudstatistics – Ny–Alesund
lowest cloud layer
upper cloud layer
upper cloud layer scale 1
2001 – 2010
all seasons
cloud fraction
altitude [m]
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


cloudstatistics – Ny–Alesund
cloud fraction
altitude [m]
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
whole period
2002
2003
2007
2009
individual years
all seasons
Note:
This is change in relative occurrence frequency



Are low clouds and ice clouds "anti-correlated"?


cloudstatistics – Ny–Alesund, 2011:
cloud fraction
altitude [m]
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
lowest layer
upper layer
thin clouds
thin clouds not on scale
Thin clouds follow distribution of lowest clouds
→ increase in cloud detection efficiency of 50% from LD40 to CL51 would explain the increase in low cloud cover in 2011
→ technically reasonable
Hence: possible that relative importance of low clouds decrease
more trustful …



cloudstatistics – Ny–Alesund
clear sky
one thick cloud
two thick clouds
thin clouds
60.27%
47.15%
32.61%
20.58%
cloud fraction
year 2000+
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
11

Our knowledge so far:

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Cloud statistics depend on the quality of instrument (optics and software)
Definition of “thin clouds” worst

CL 51 since 2011 much more powerful than precursor instrument

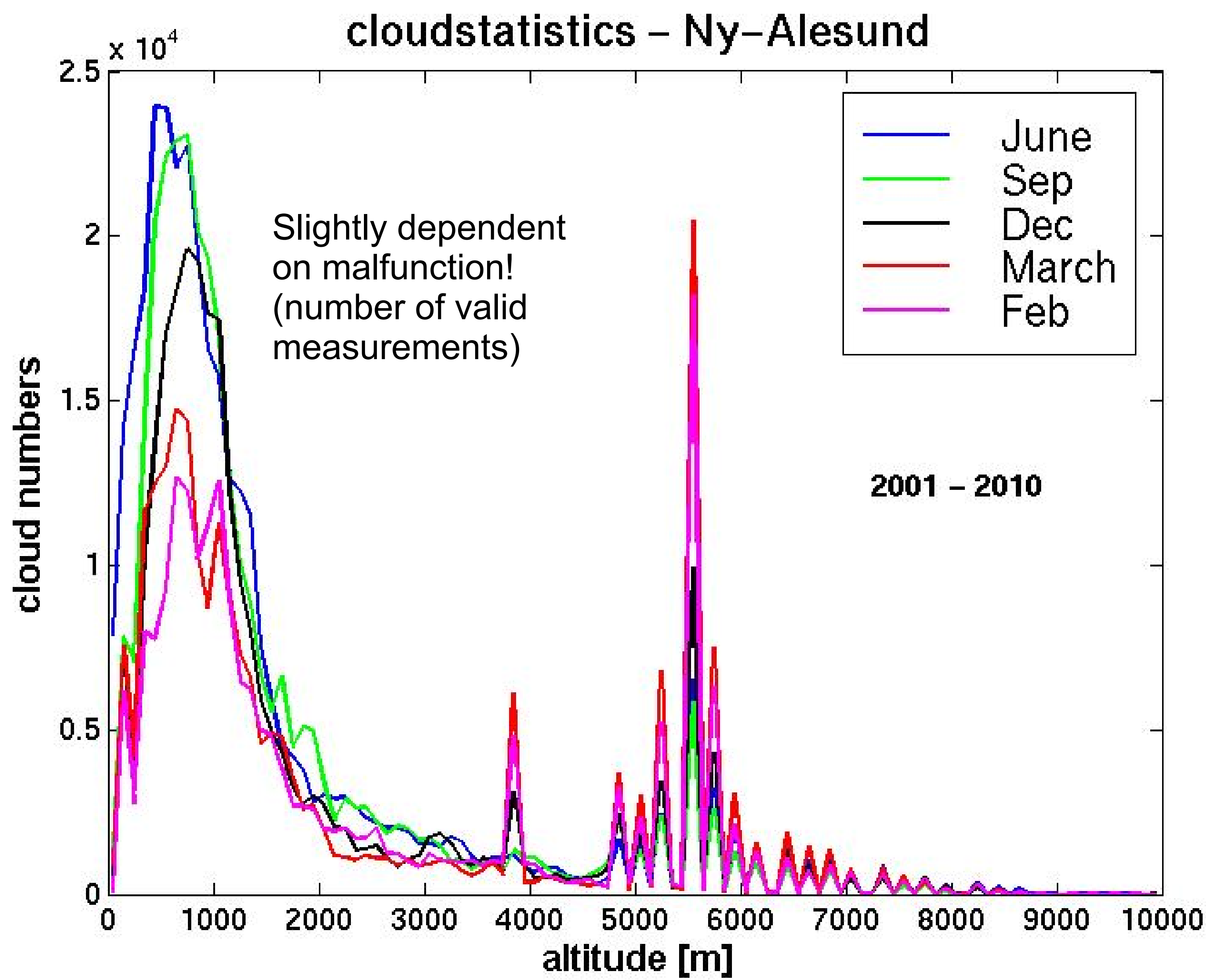
Can only consider years 2001 – 2010 easily
(By the way: the Christoph Ritter foundation donates a nice German sausage for suggestions to obtain a homogeneous data set)

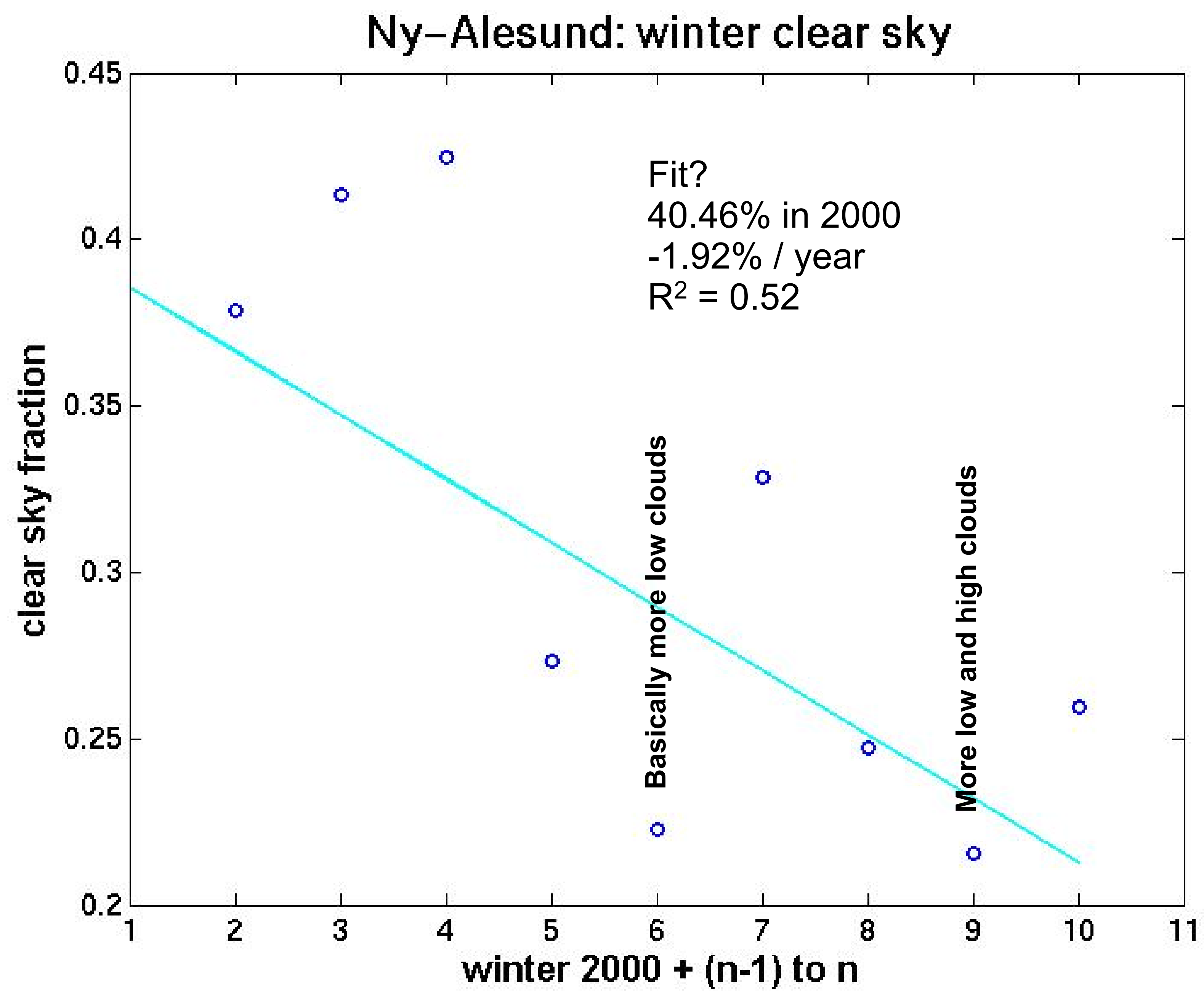
Low clouds around 750m dominate, their importance might decrease

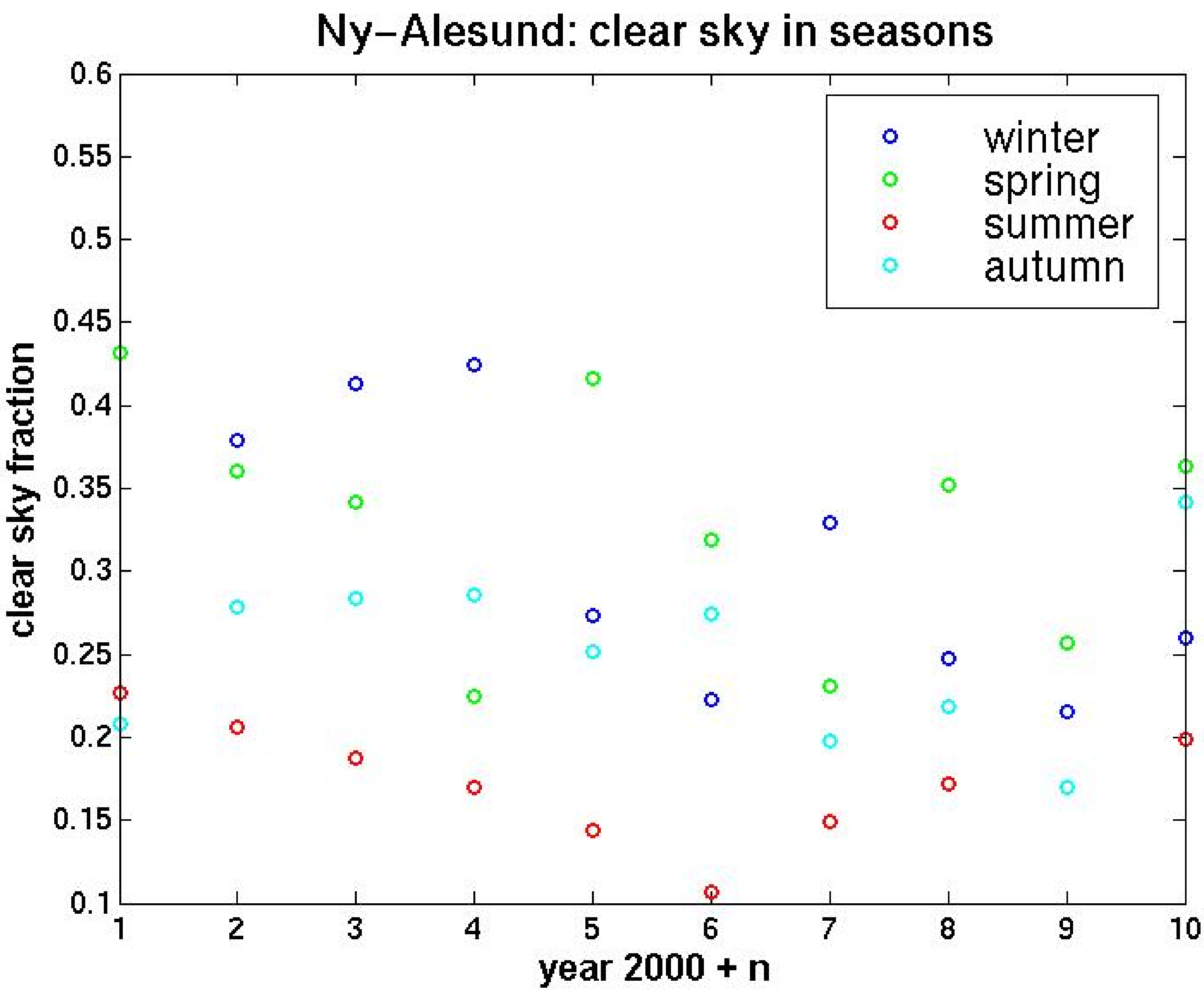
Low clouds and high clouds seem to be anti-correlated: high clouds seldom occur over low clouds (independent on instrument’s power!)

Does fraction of clear days decrease?

HELMHOLTZ
GEMEINSCHAFT


cloudstatistics – Ny–Alesund
x 10^4
2.5
2
1.5
1
0.5
0
cloud numbers
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
altitude [m]
June
Sep
Dec
March
Feb
Slightly dependent
on malfunction!
(number of valid
measurements)
2001 – 2010


Ny−Alesund: winter clear sky
Fit?
40.46% in 2000
-1.92% / year
R² = 0.52
Basically more low clouds
More low and high clouds
clear sky fraction
winter 2000 + (n-1) to n
0.45
0.4
0.35
0.3
0.25
0.2
1
2
3
4
5
6
7
8
9
10
11


Ny−Alesund: clear sky in seasons
clear sky fraction
year 2000 + n
winter
spring
summer
autumn
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
2
3
4
5
6
7
8
9
10

Conclusions & evident things

Comp MPL to Ceilo: homogeneity

MPL or Ceilo with Windlidar & BSRN define interesting moments for cloud radar

Have to use KARL lidar “around” clouds as much as possible, +cloud radar: prove usefulness of remote sensing for clouds

For Ny, satellite val. elsewhere: need homogeneous equipment, same calibration, evaluation

KARL + photometers (Rabben, AWI) local and seasonal variability of haze, contribution to closure studies

Clouds reduce range of understanding …