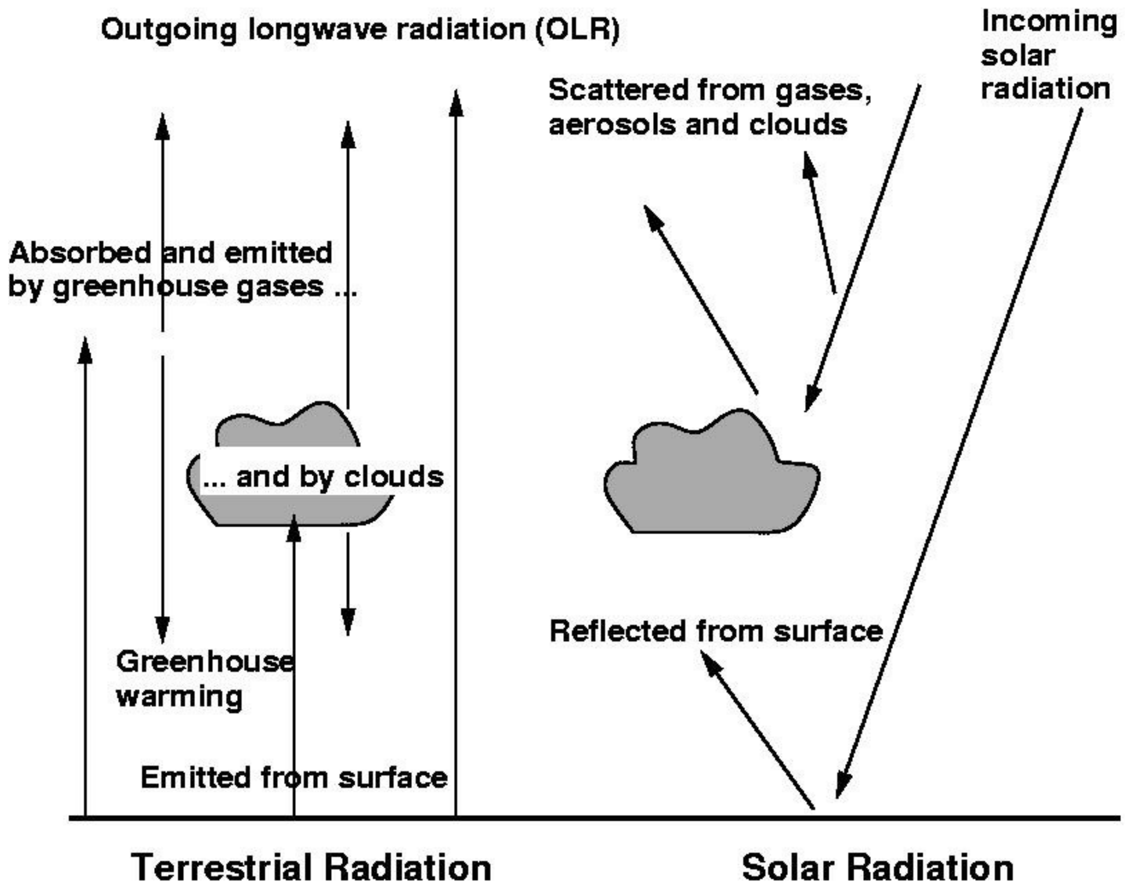
Clouds, climate, challenges

observation technologies and methodologies
for sensing the atmosphere

Herman Russchenberg

TU Delft
Delft University of Technology

Radiation balance of the atmosphere

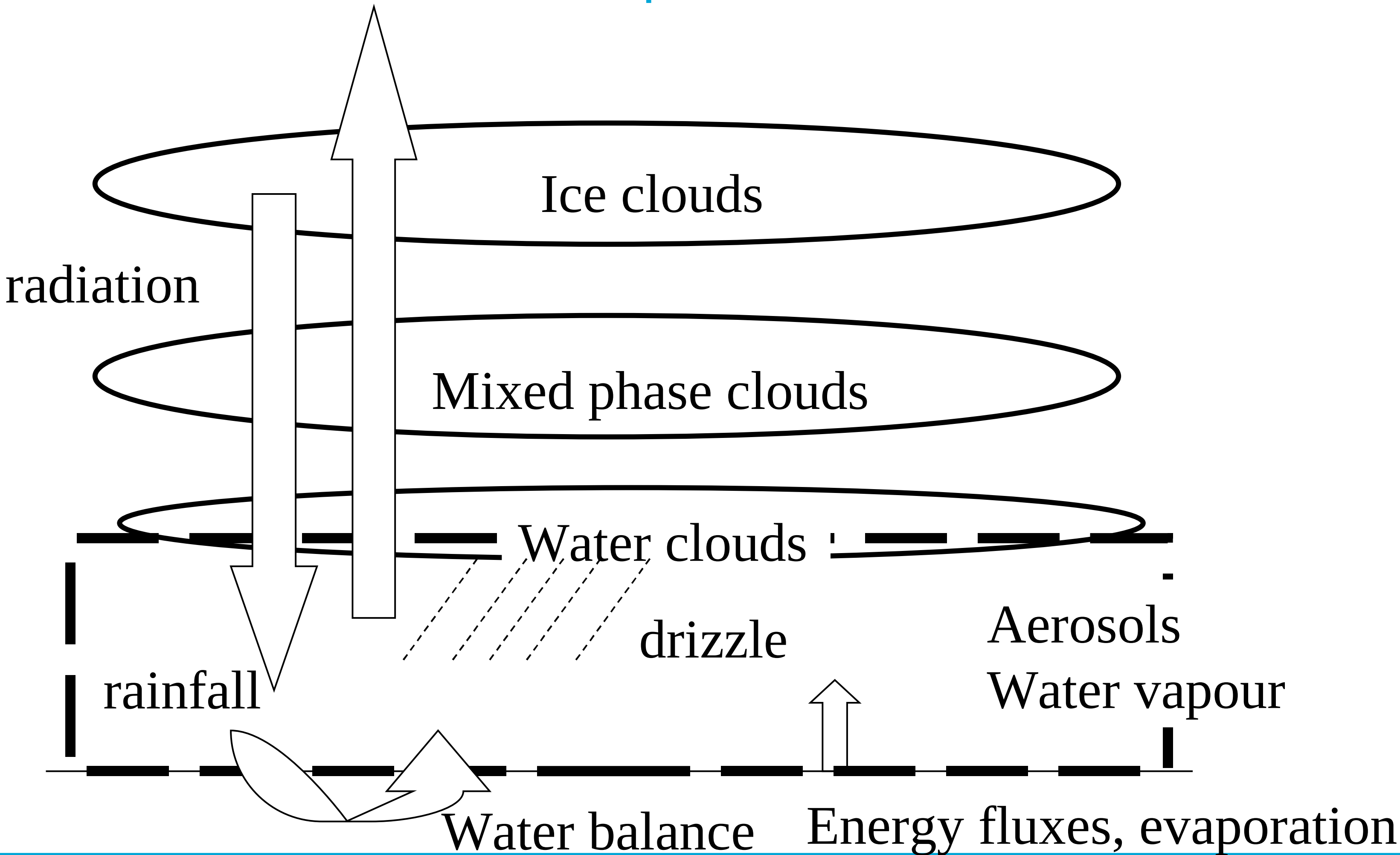


Schematic of the atmospheric radiation budget

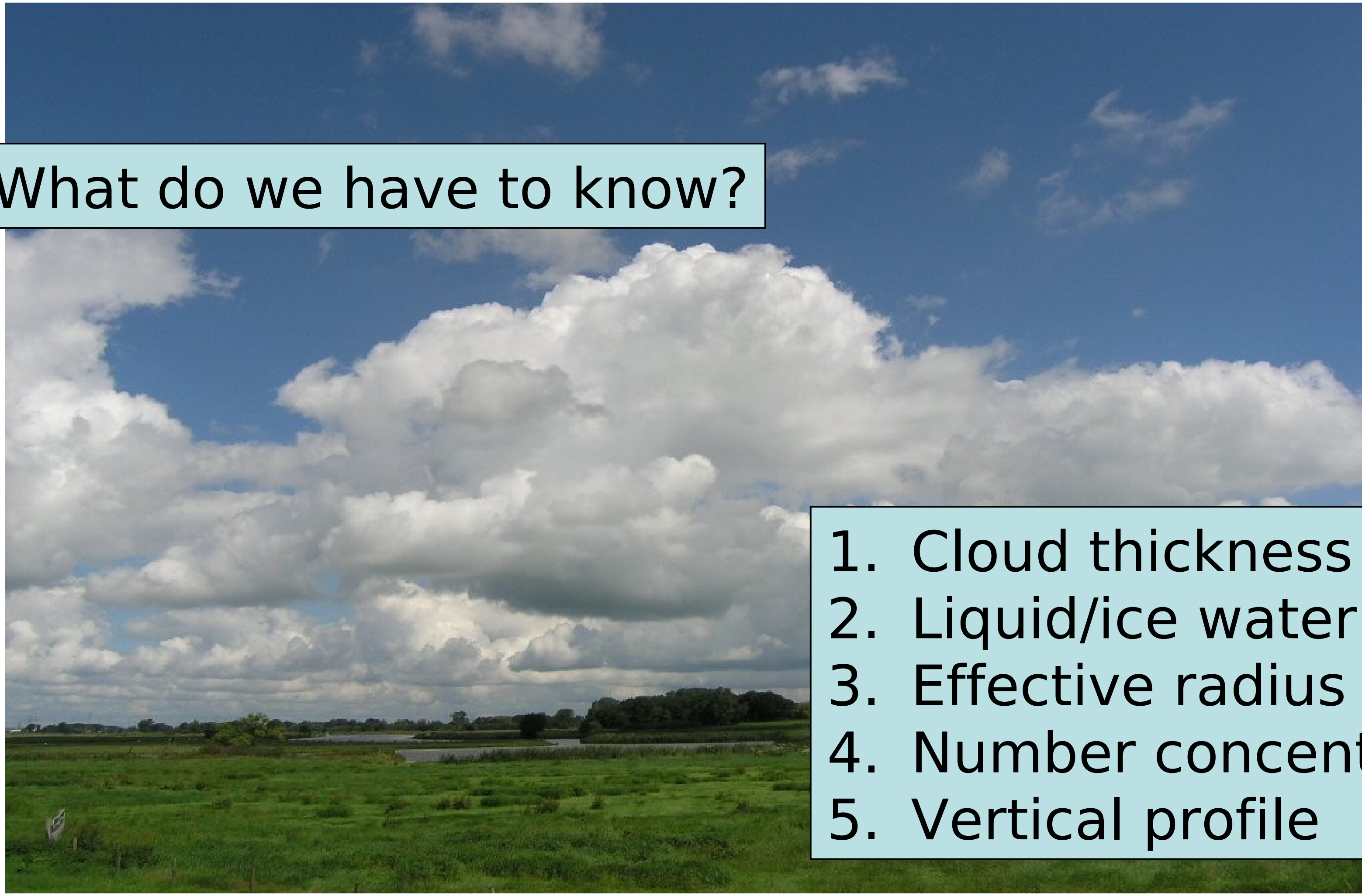
How to tackle this problem?

- Observations to understand the processes
- Improve the atmosphere models
- Observations to monitor long term trends

Integrated observation methodology to measure the atmospheric column



Case 1
Observation of water clouds

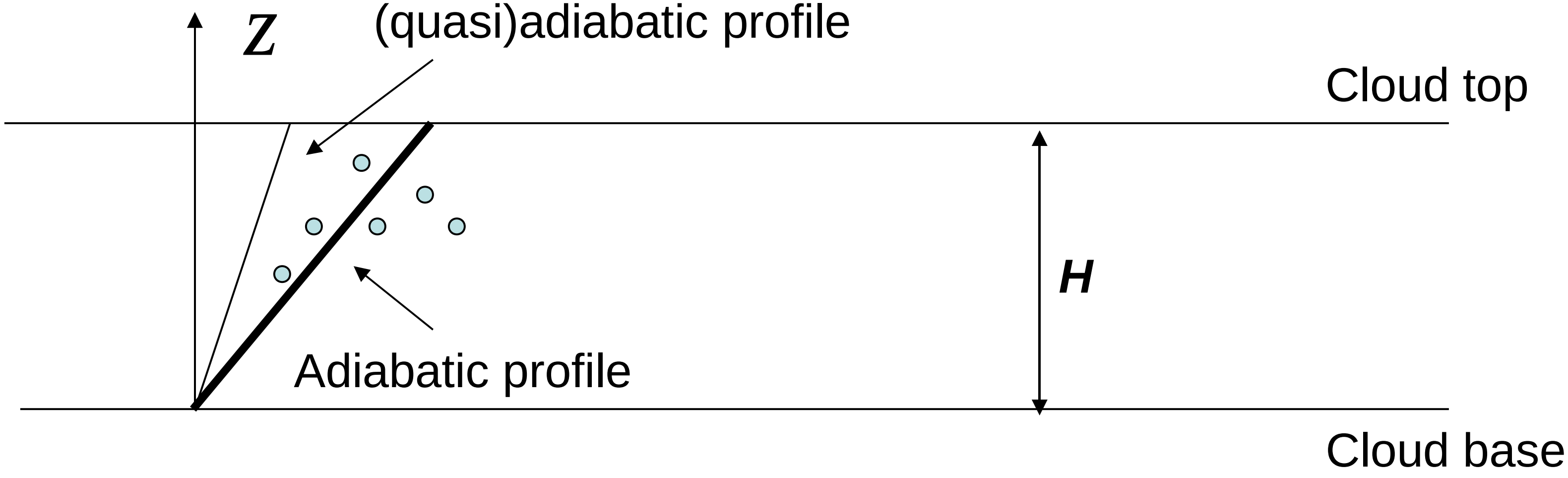


What do we have to know?

1. Cloud thickness
2. Liquid/ice water conten
3. Effective radius
4. Number concentration
5. Vertical profile

TU Delft

Assume a cloud model,

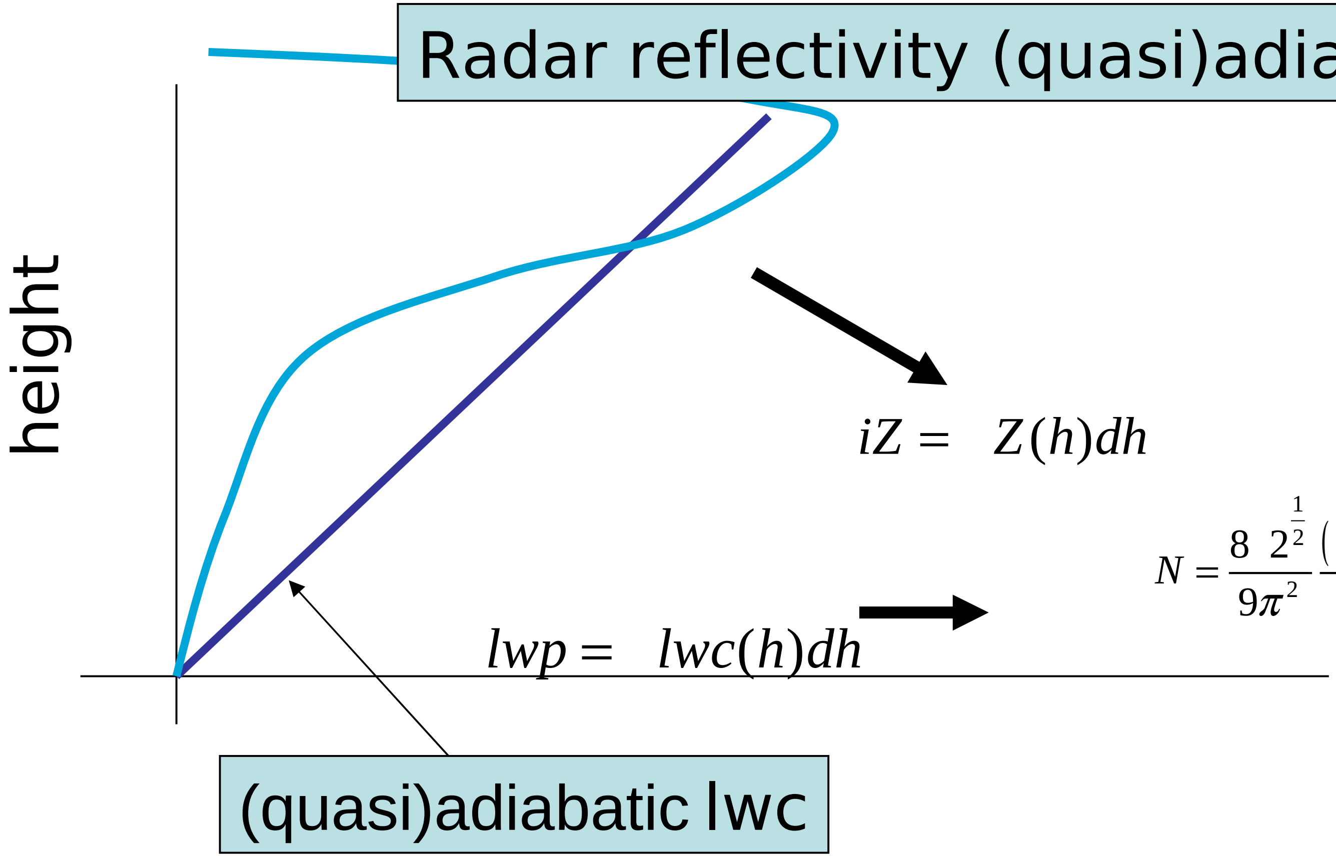


$$LWC(z) = \rho_a A_{ad} (1 - D) z$$

$$LWP = \frac{1}{2} \rho_a A_{ad} (1 - D) H^2$$

TU Delft

estimate expected observations,



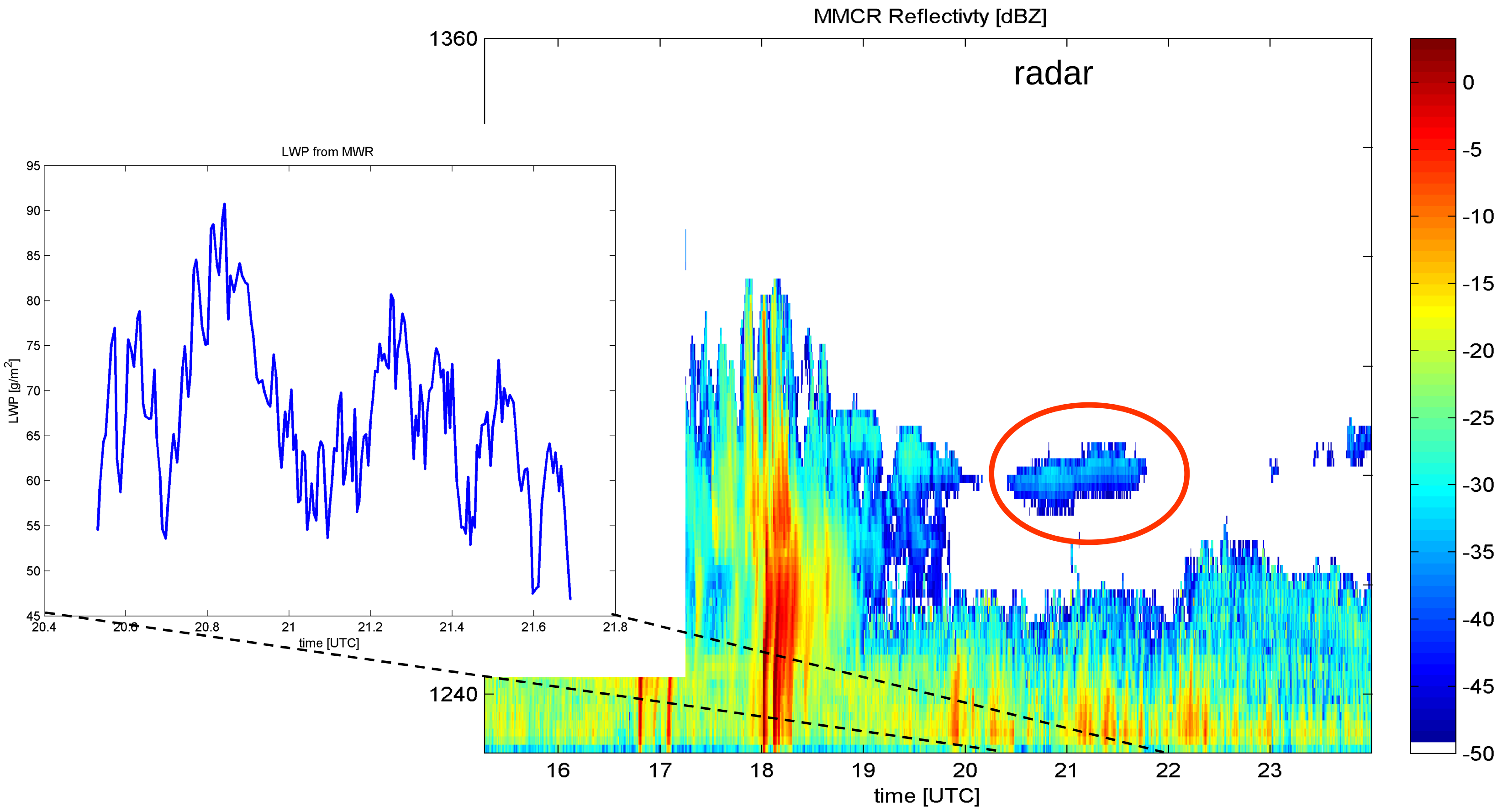
$$iZ = \quad Z(h)dh$$

$$lwp = \quad lwc(h)dh$$

$$N = \frac{8\ 2^{\frac{1}{2}}}{9\pi^{2}} \frac{\left(\rho_a A_{ad}\right)^{\frac{1}{2}}}{\rho_w^{\ 2}} k_6 \frac{LWP^{\frac{3}{2}}}{iZ}$$

TU Delft

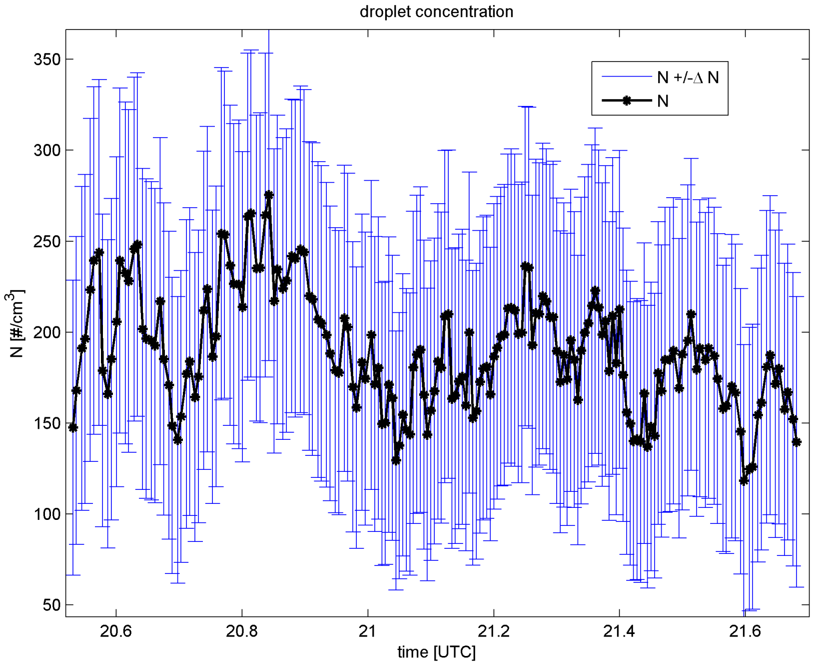
make the observations,



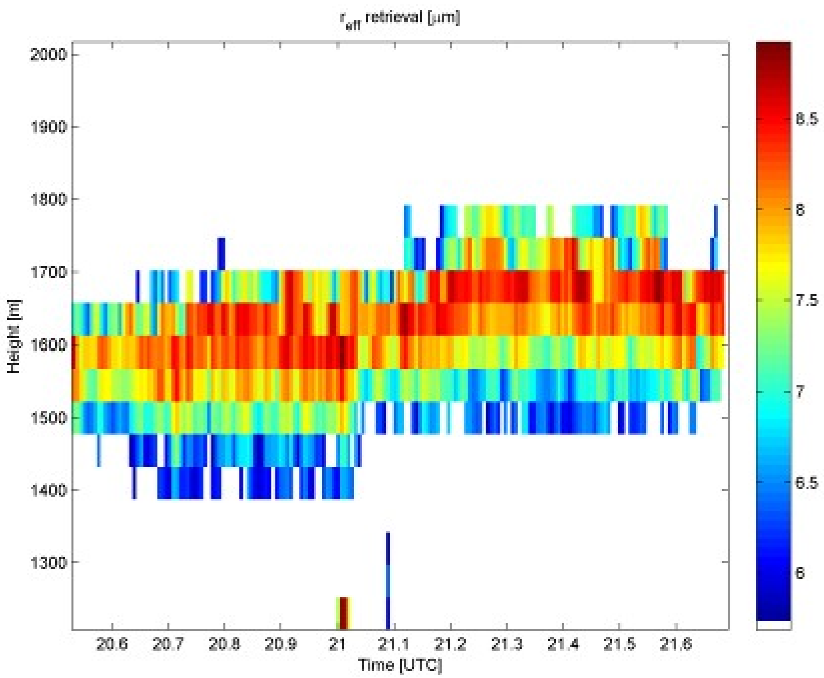
TU Delft

..estimate cloud microphysical parameters

Droplet concentration



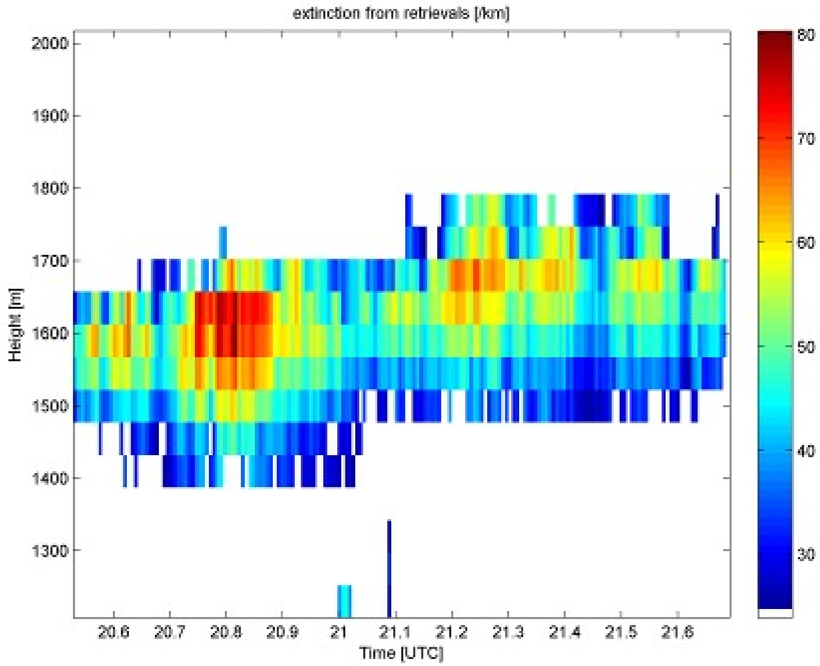
Profile effective radius



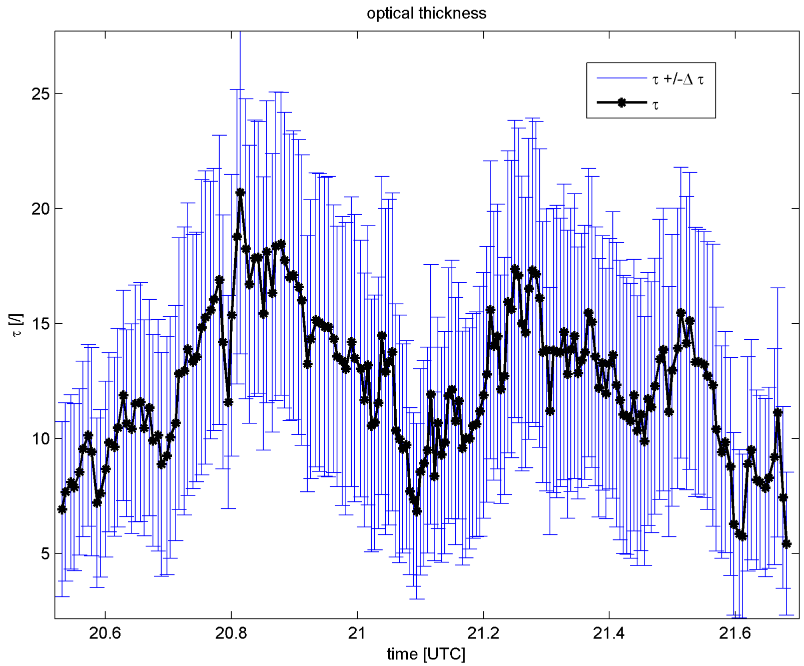
TUDelft

..and the radiative properties

Extinction



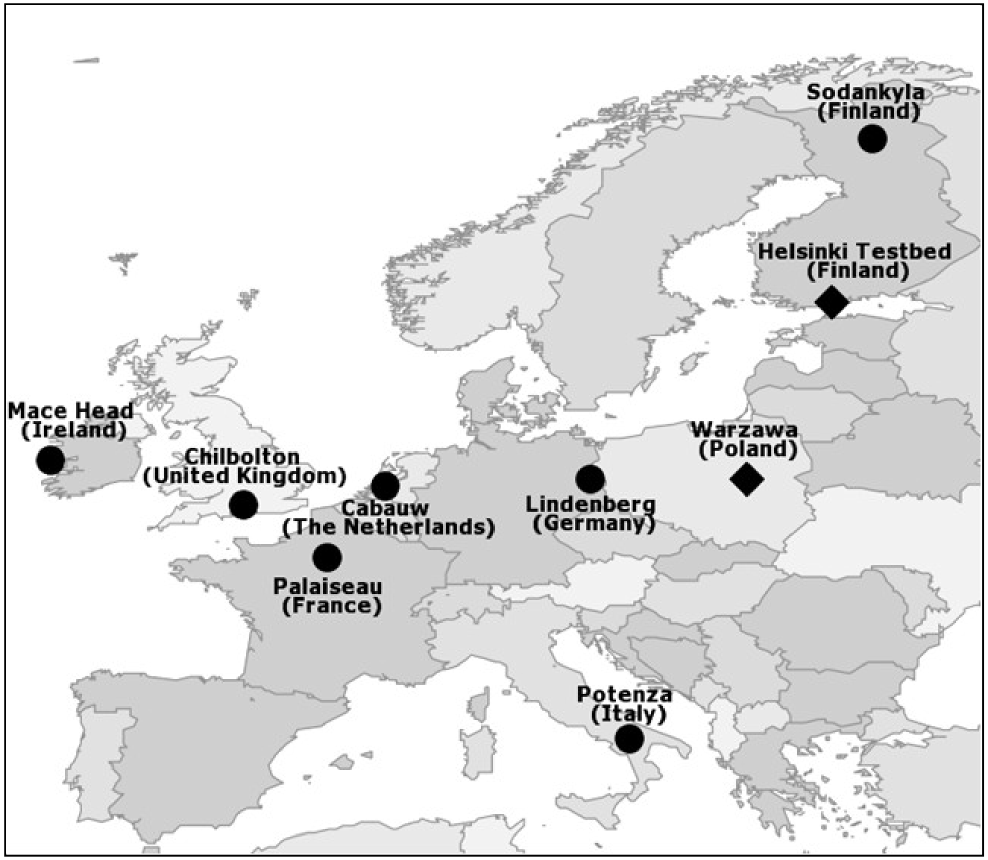
Optical thickness



Problem solved?

- Limited representativeness (only water clouds)
- One dimensional solution, while the problem is three-dimensional
- Integrated observations of the context to unravel all concurrent processes
- Cloud lifetime due to aerosol changes: drizzle formation

International context

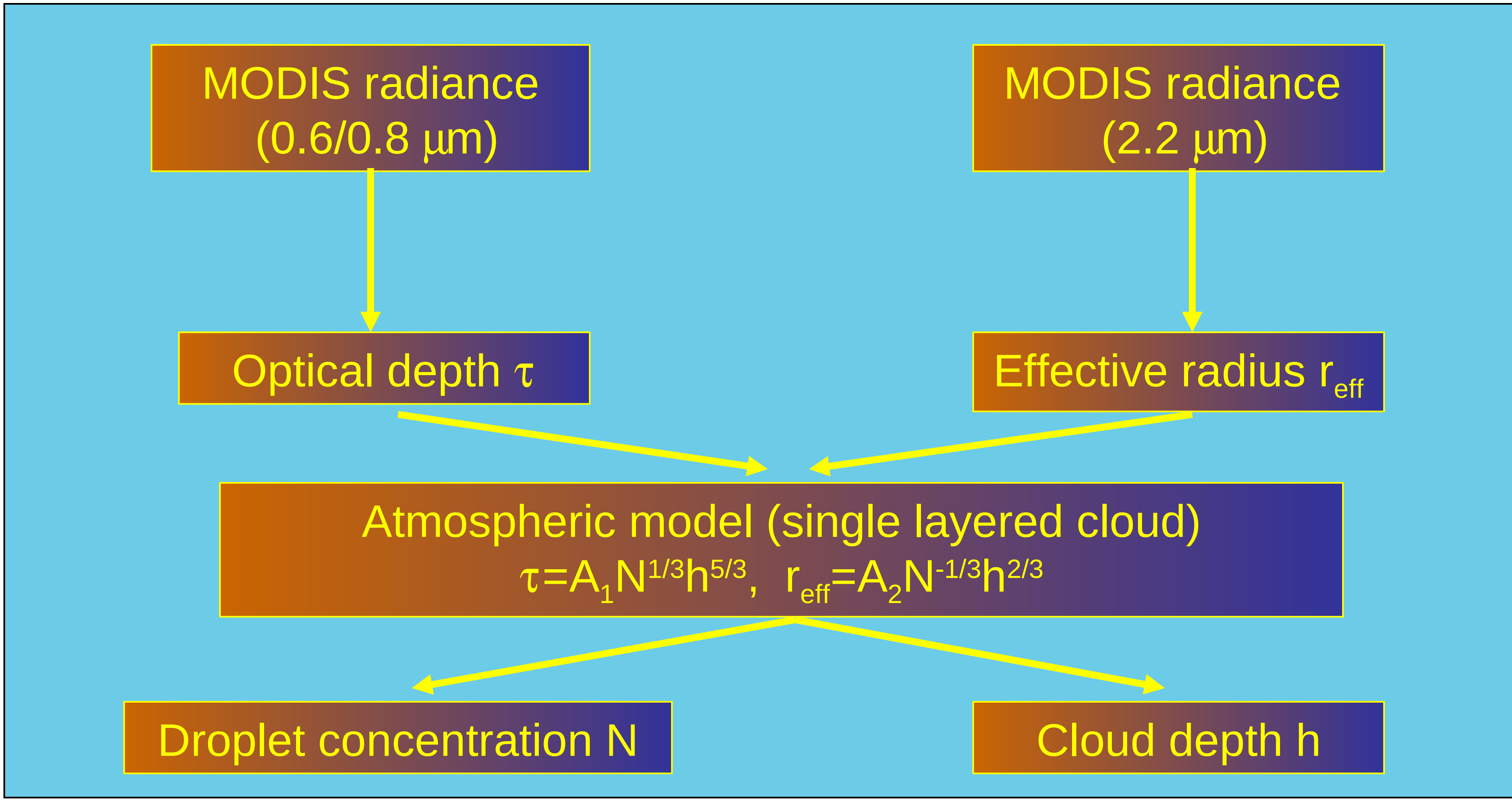


Challenges

- Increase representativeness of ‘one-site’ observations
- Use satellite observations to retrieve vertical cloud properties anywhere

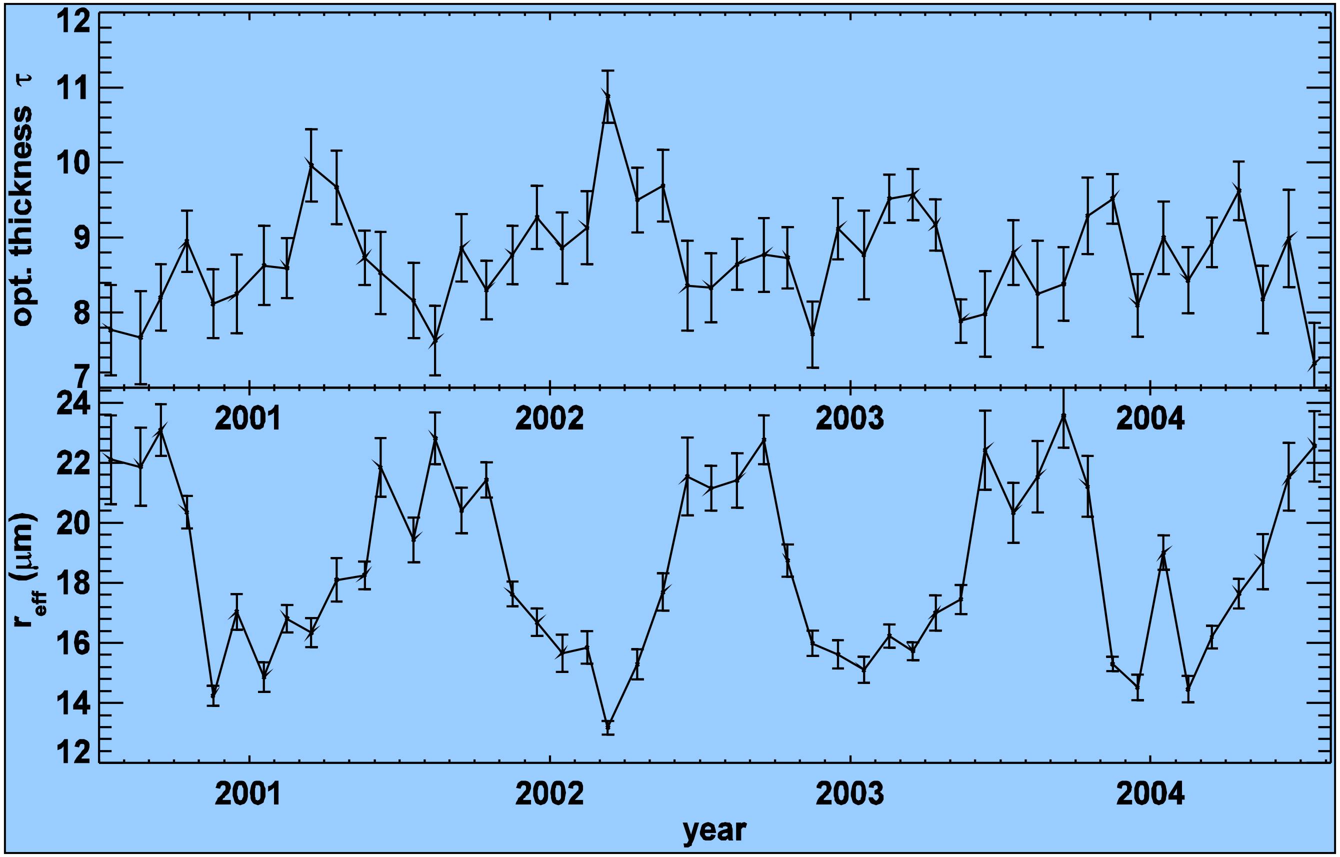
TU Delft

Retrieval procedure



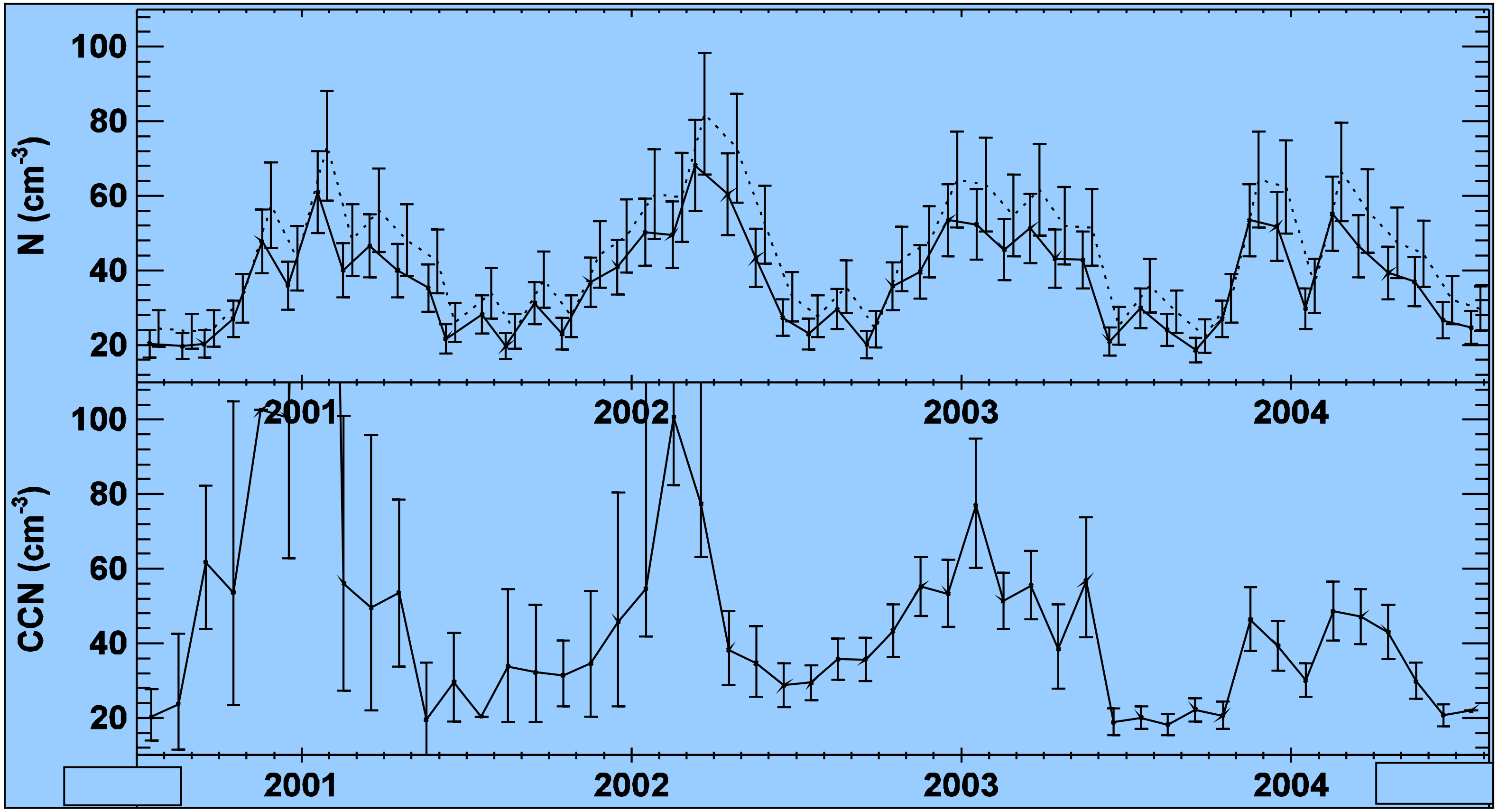
TU Delft

Optical thickness and effective radius



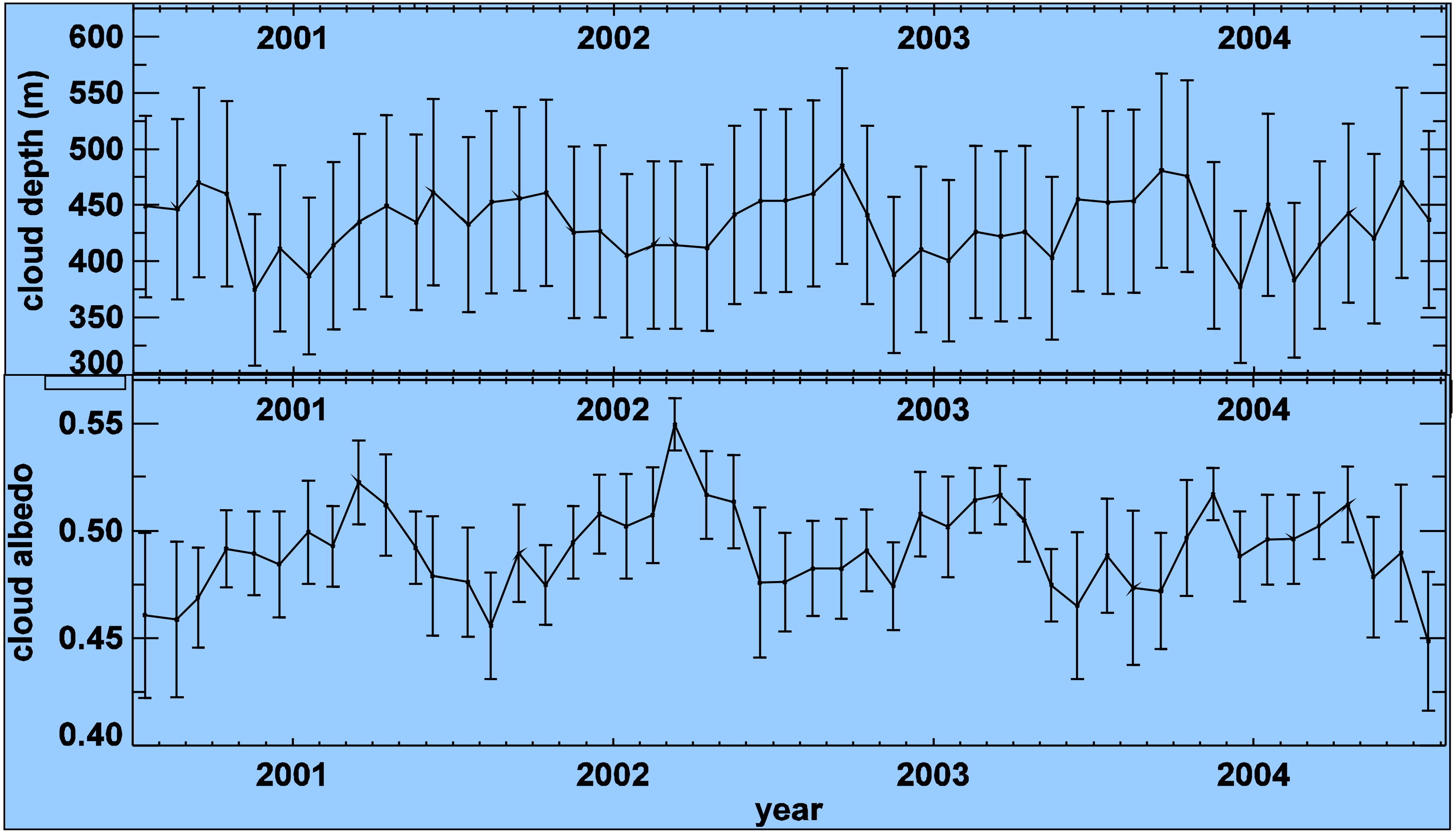
Error bars: ***Std. of the monthly mean as calculated from the daily averages***

Retrieved concentration compared to CCN at Cape grim

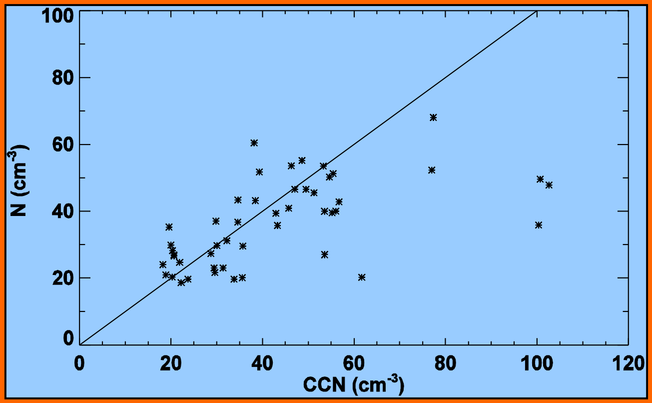


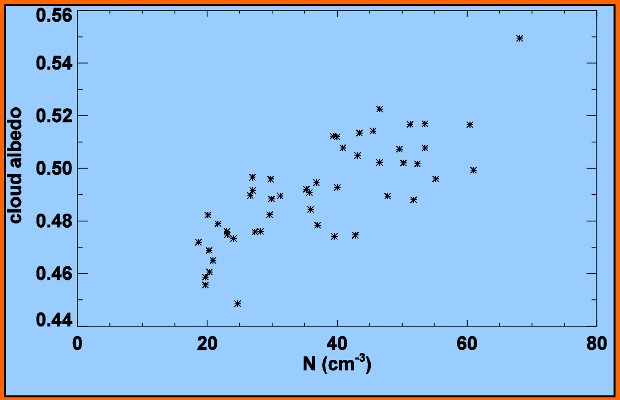
TU Delft

Retrieved cloud thickness and albedo



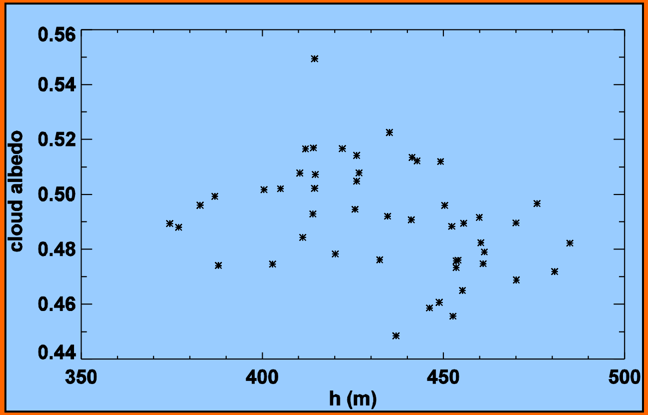
Correlation studies





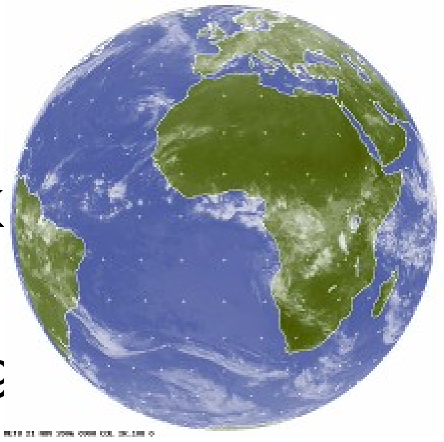
Albedo vs concentration

Concentration vs CCN



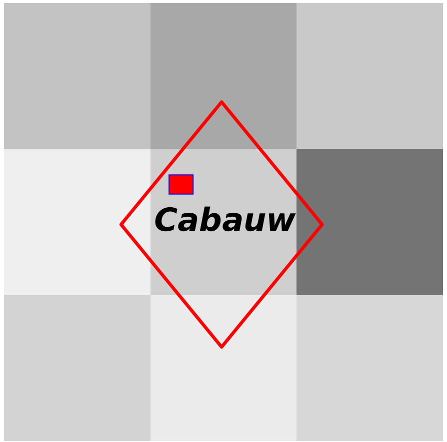
Albedo vs cloud depth

It can also be done with Meteosat SG!



- SEVIRI imager onboard Meteosat-8
- Geostationary satellite: 0° N, 3.4° W at 35600 K
- 12 Spectral bands:
  - 4 visible and near infra-red (0.6 – 3.9
  - 8 thermal infra-red (3.9 – 12 μ m)
- Time resolution: every 15 minutes
- Spatial resolution   sub-satellite: 3x3 Km

  at CESAR: 3x6 Km
- Pixel shape: diamond, sampled: square



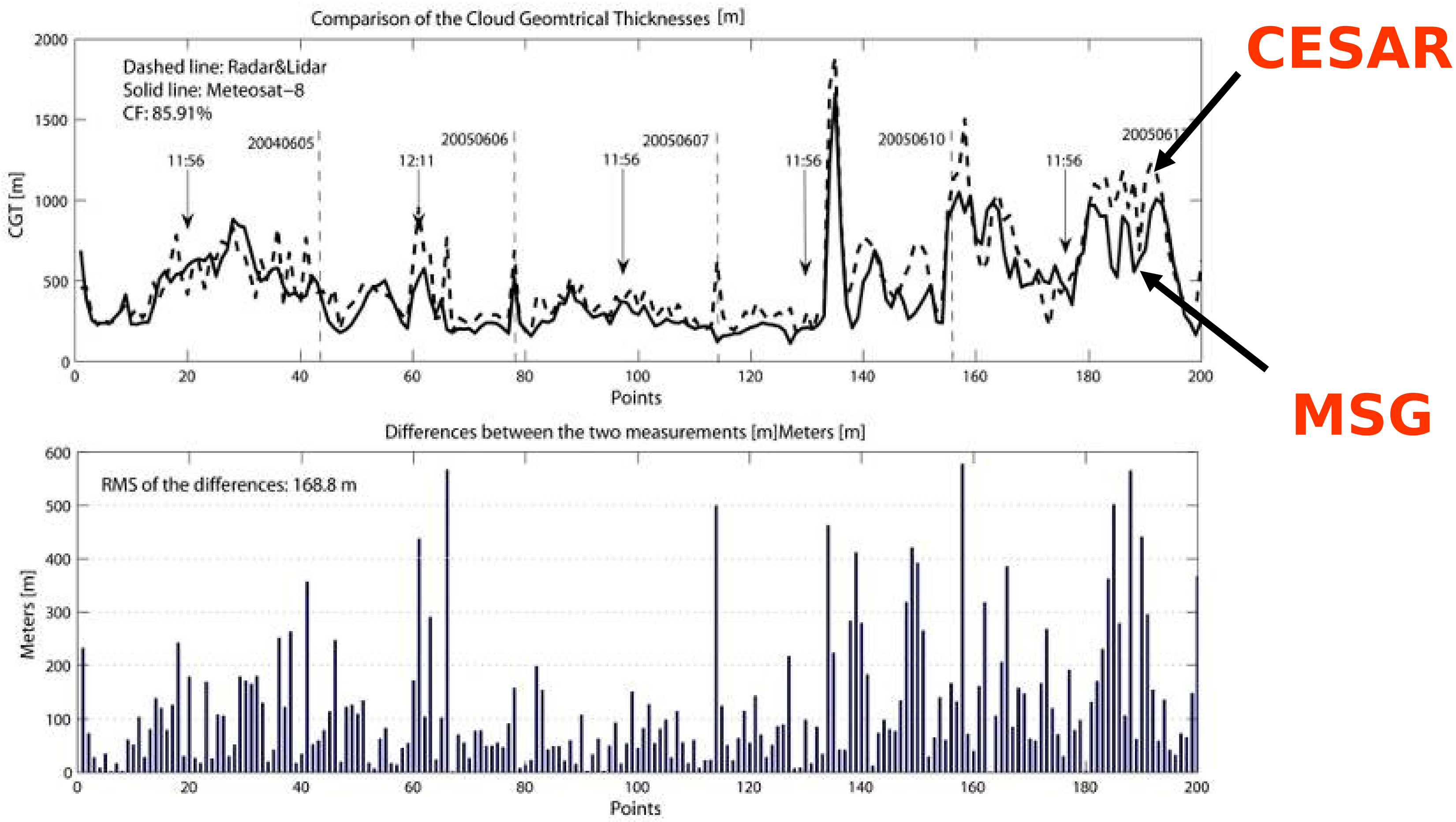
- **Products: Optical Thickness, Effective Radius, Liquid Water Path, Geometrical Thickness, Channels: 1 , 4, 9**

Main differences Modis – Meteosat SG

Geostationary
Higher time resolution
Lower space resolution

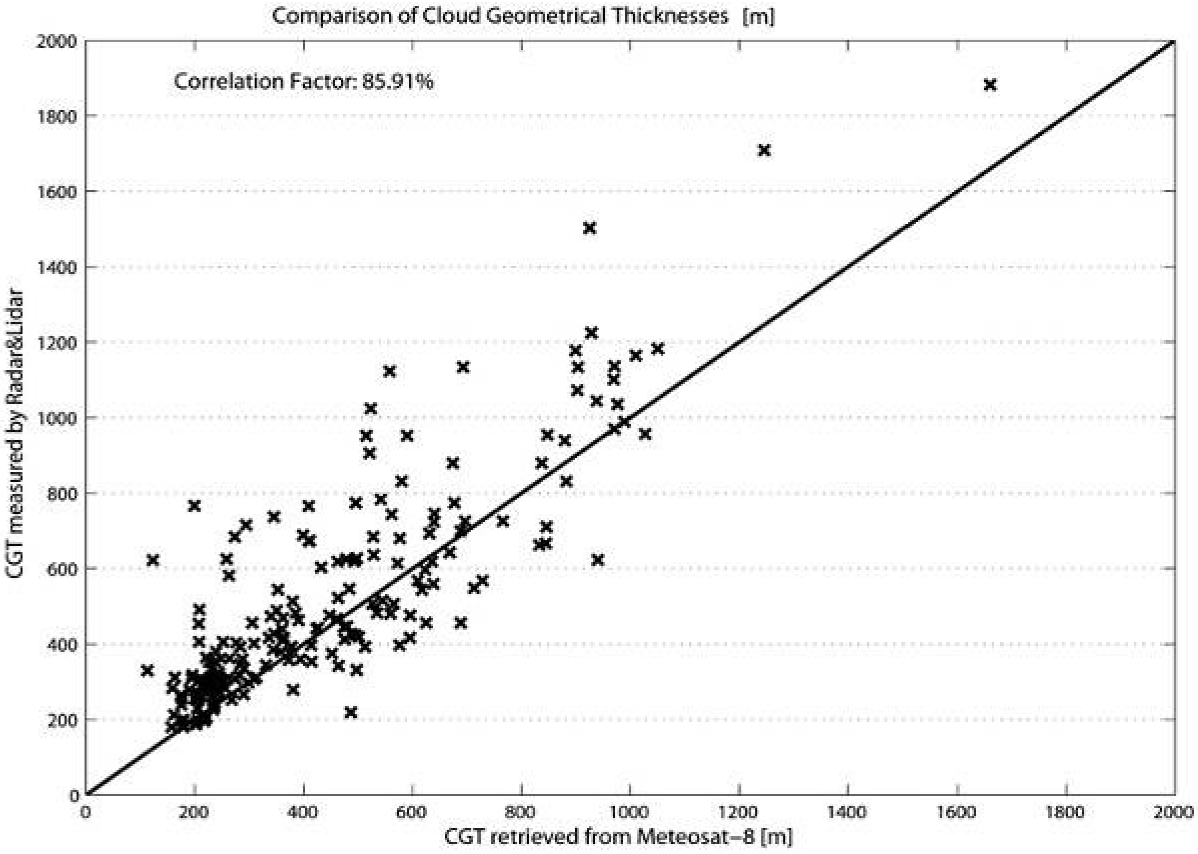
1) In Europe ground-truthing possible
2) Anchor stations for synergy

Ground-truthing the cloud thickness

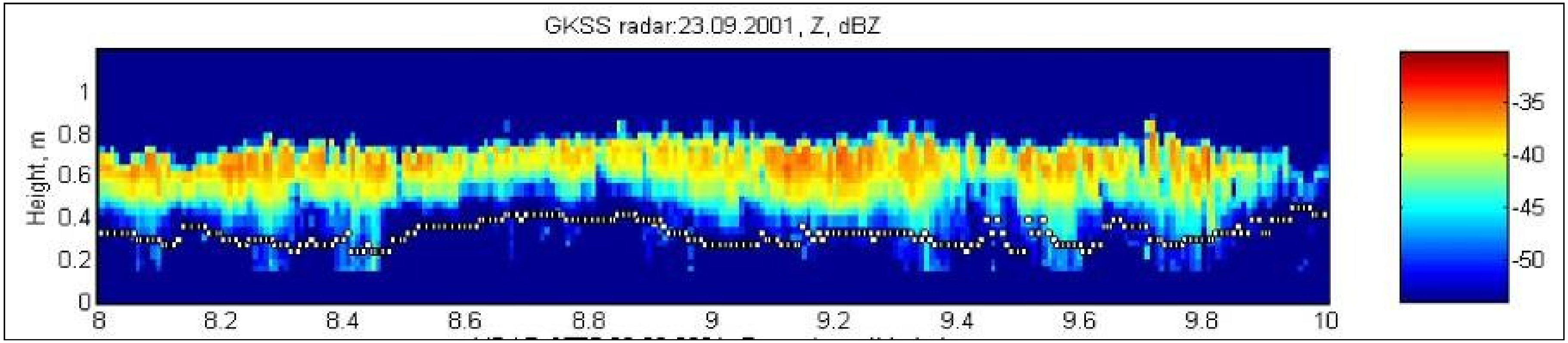


TUDelft

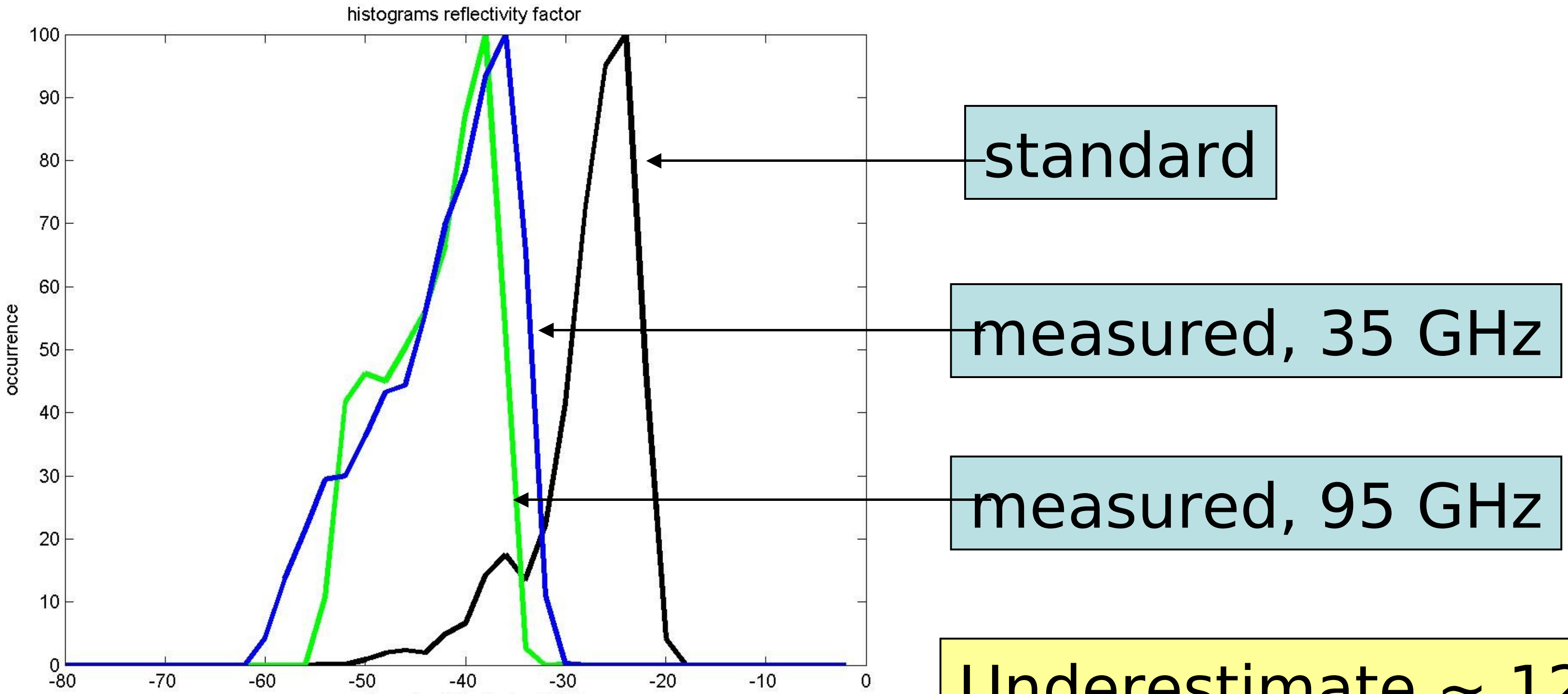
A passive sensor can give the cloud thickness at the radar footprint



Scattering by random media: Radar and stratocumulus


GKSS radar:23.09.2001, Z, dBZ
Height, m
1
0.8
0.6
0.4
0.2
0
8
8.2
8.4
8.6
8.8
9
9.2
9.4
9.6
9.8
10
-35
-40
-45
-50

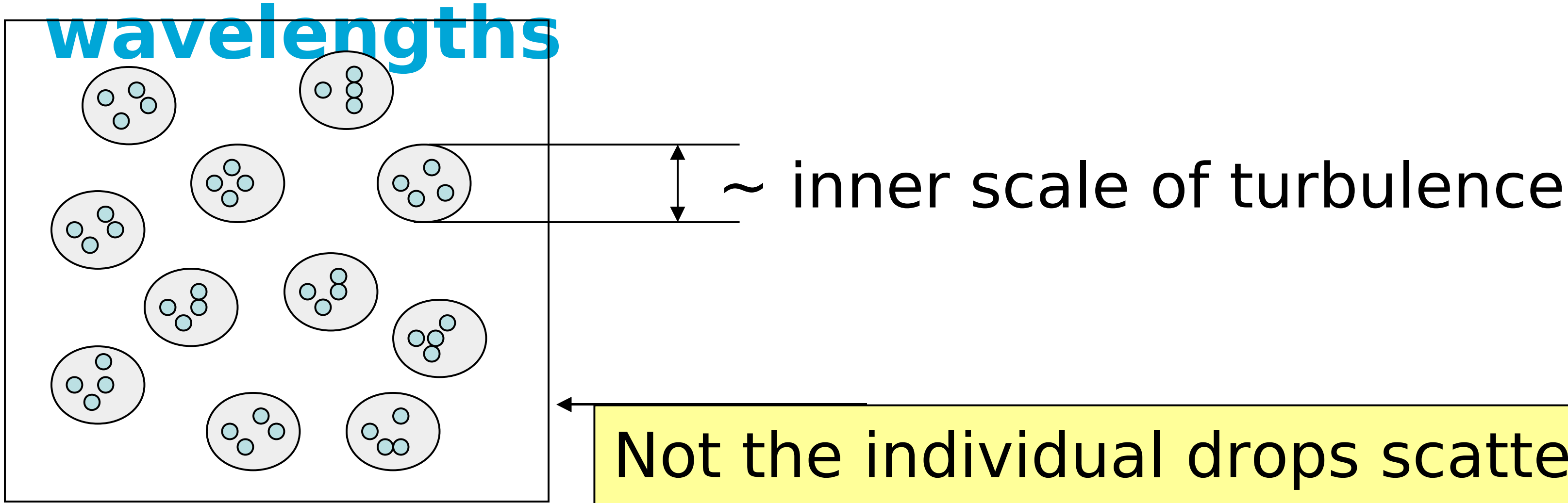
Standard theory vs observations



Radar reflectivity factor [dBZ]

Underestimate ~ 12 dB

Hypothesis: a cloud is a quasi-continuous medium at radar wavelengths



Not the individual drops scatter rada
waves, but clusters of them -

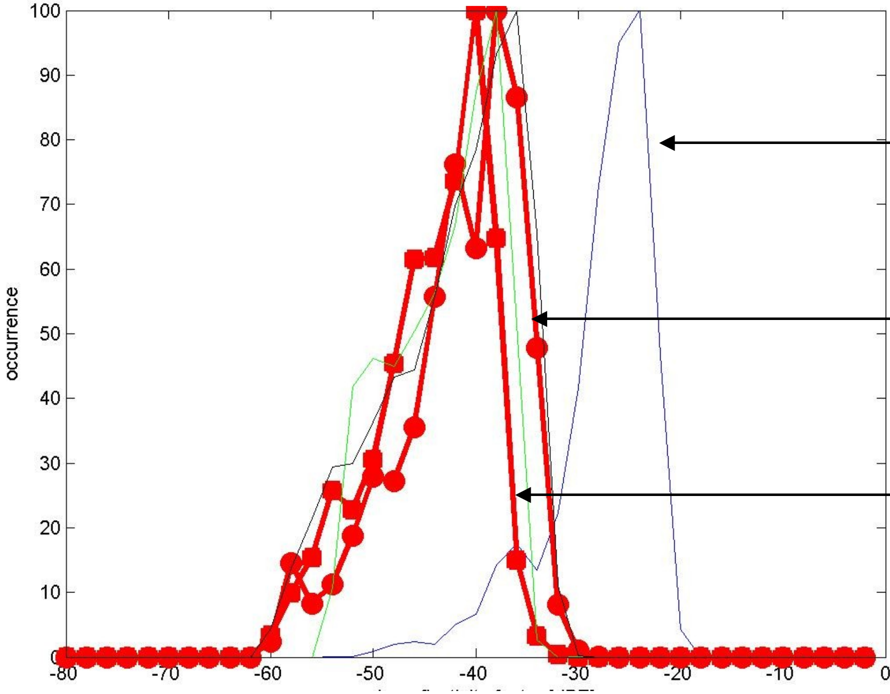
with spatial scales of the order of, or
smaller than the radar wavelength

many droplets
per wavelength

TUDelft

Preliminary results of model

Histograms expected and modelled radar reflection



Radar reflectivity factor [dBZ]

expected

model, 35 GHz

model, 95 GHz

Underestimate ~ 13 dB

Challenges

- New theory of radar scattering by realistic quasi-continuous media
- and the development of a corresponding method to observe small-scale atmospheric dynamics and cloud microphysics

STSM's

- Satellite – ground synergy (TU Delft, ETH Zurich)
- Testing radar scattering theory (U Cologne, U Helsinki, TU Delft)

WG4

- Discussion STSM’s
- Identification of tasks for cooperation (studies, ideas for campaigns (with WG3))

TUDelft