Ground-based passive/active remote sensing of cloud processes

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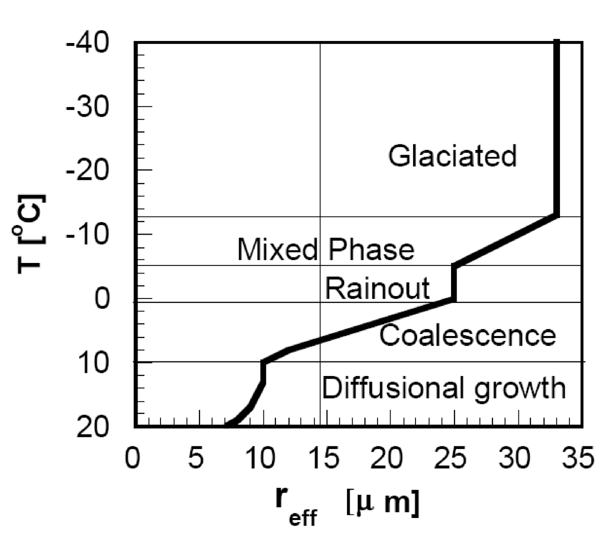
Remote sensing of cloud sides from the ground



from Rosenfeld and Woodley (2003)

Current possibilities

Insights into the microphysics of clouds, the formation of droplets and ice particles, and their vertical profile are needed to understand the onset of precipitation and aerosol effects.

- *in-situ* data is limited in temporal and spatial extent and mostly to shallow types of clouds
- common *satellite* passive remote sensing concentrate on cloud tops and are of limited in spatial resolution
- *active* microphysics retrievals based on
  - radar reflectivity profiles
  - lidar backscatter profiles

  depend on strong assumptions and carry large uncertainties.

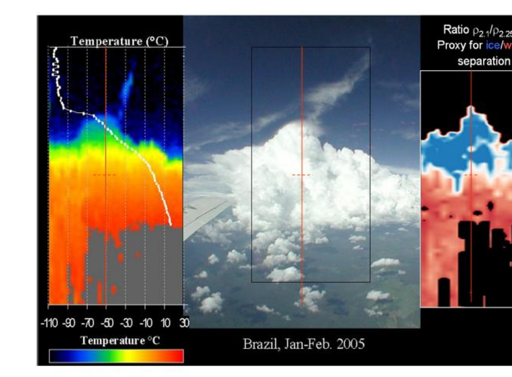
Proposed observations

Unlike "classical" *cloud top remote sensing,* we propose

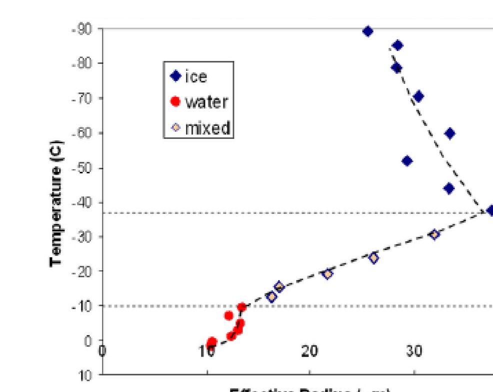
- ► passive *cloud side remote sensing*
- ► preferably in the solar principle plane (with the sun behind the sensor)
- ► possibly complemented by lidar or radar data

First Examples

These images (Martins et al., 2007) show comparable observed data from an *airborne platform*.

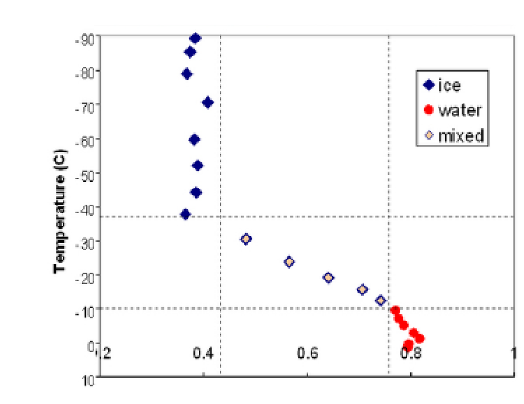


Height information is retrieved from the thermal IR information (**top-left**).



The cloud phase is characterized by the ratio $R_{2.1}/R_{2.25}$ (**top-right).**

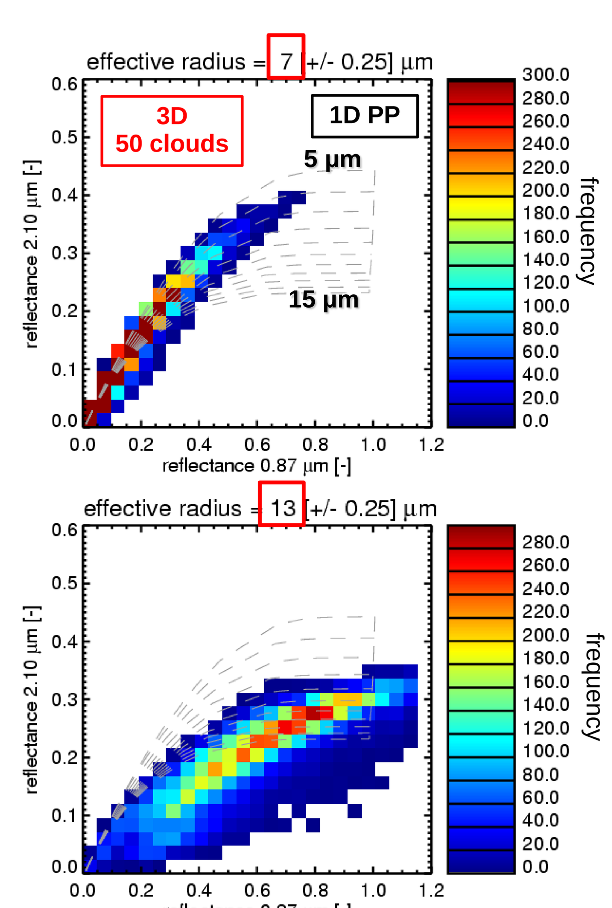
A preliminary retrieval illustrates profiles of cloud droplet size (**center**) and $R_{2.1}/R_{2.25}$ (**bottom**).



High spatial resolution retrievals for cloud sides

- ► A combination of VIS and NIR gives a signature of droplet and ice particle r_{eff} and $\sigma(r_{eff})$ even under complex 3D conditions like convective clouds.
- ► 3D radiative transfer based on large number of realistic 3D distributions of cloud microphysics provides a database for a **statistical Bayesian retrieval of r_{eff}** and a reliability measure $\sigma(r_{eff})$.
- ► Additional NIR and thermal IR channels can provide **cloud phase detection** and **height**.

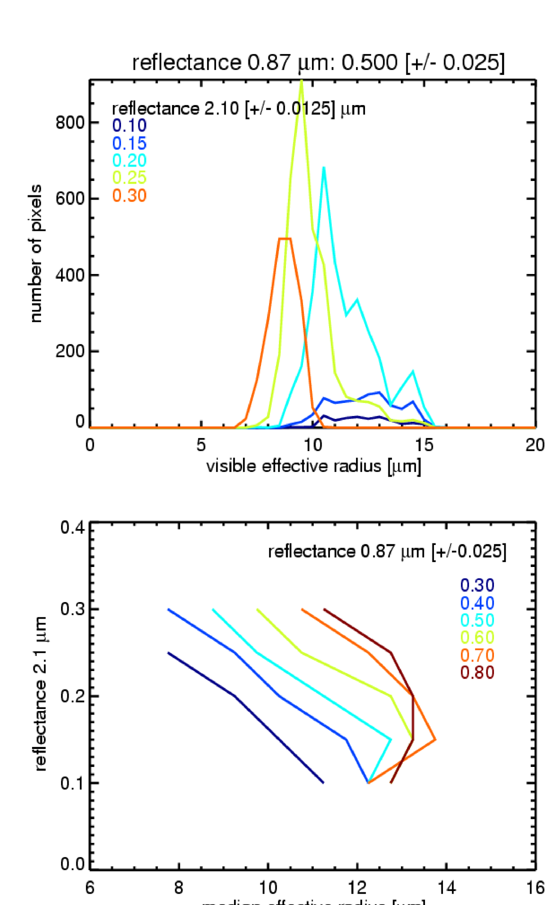
Effective Particle Size



← "Nakajima-King Plot" for 1D plane-parallel RT compared to 3D RT simulation for 50 scenes using Monte Carlo.

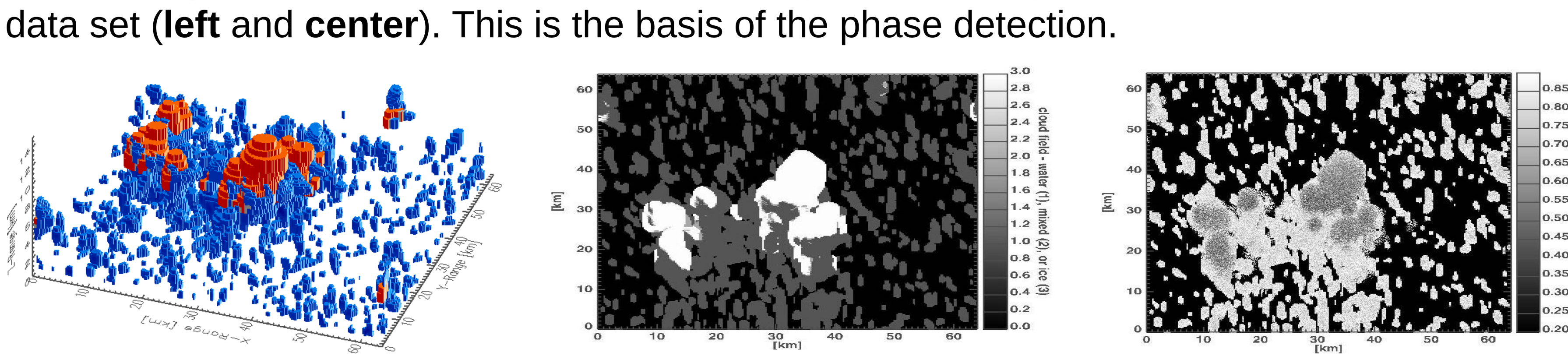
PDF of r_{eff} for $R_{0.87}$/ $R_{2.1}$ bins (and median values). → PDFs are basis for Bayesian cloud microphysics retrieval:

e.g., observed
$R_{0.87}$= 0.5 ±0.025
$R_{2.1}$= 0.25 ±0.0125
→ median r_{eff} = 9.6 μm
σ (r_{eff}) =1.15 μm



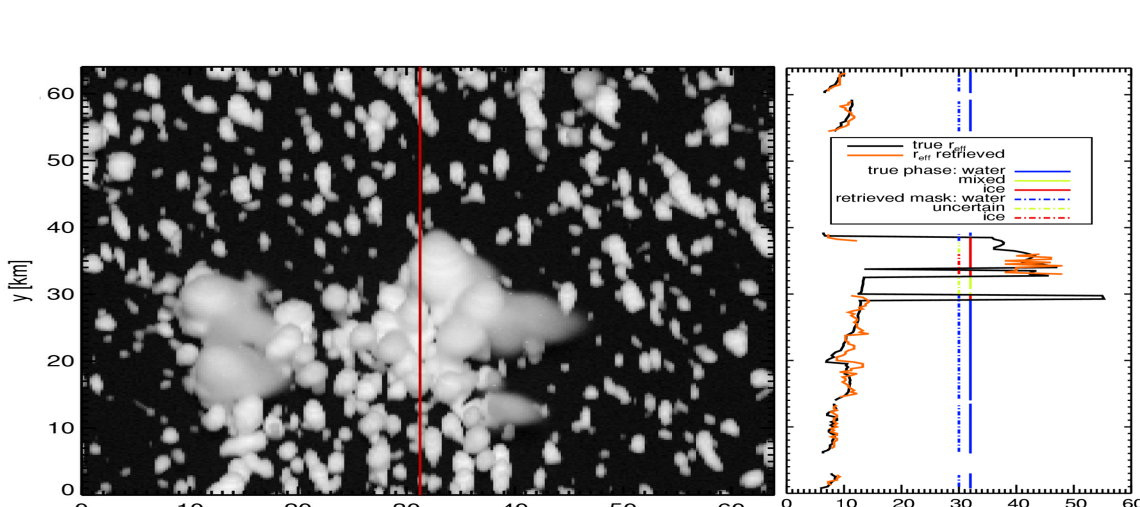
Phase Detection

For a 3D RT simulation the ratio of NIR results for $R_{2.1}/R_{2.25}$ (**right**) shows a distinct difference between liquid water (ratio≈0.8) and ice clouds (ratio<0.5) in good agreement with the original data set (**left** and **center**). This is the basis of the phase detection.



Test of Methods

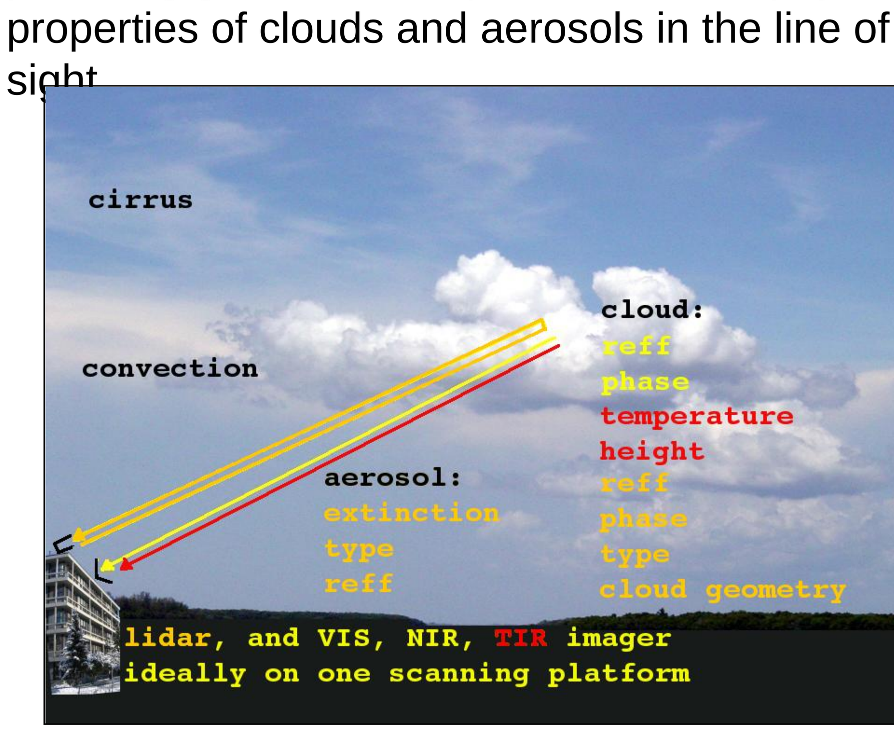
For the simulated cloud scene (**left**, solar zenith 45°, and viewing zenith 60° both tilted to the "South") the above described retrievals give the results as shown on the **right** along the red line in the left image.



Planned Sensor-Systems

A **cloud spectrometer** covering the solar spectrum from 0.4 to 2.5 μm and the thermal from 8 to 14 μm will collect (polarized) images of high spatial resolution (~50 m) of cloud sides and cloud bottom sides (cirrus). Several spectral camera systems will provide spectral resolutions of ~10 (solar) and ~100 nm (thermal).

This imaging passive system will be complemented by the University of Munich **lidar systems** POLIS and MULIS (2 and 3 wavelengths, depolarization, Raman) providing geometrical, optical and microphysical properties of clouds and aerosols in the line of sight.



A unique observing system measuring cloud and the interacting aerosol microphysics at the same time will be in place to provide new insights into the development of convective clouds as well as cirrus

References

- •Rosenfeld, Woodley: *Spaceborne Inferences of Cloud Microstructure and Precipitation Processes: Synthesis, Insights, and Implications*. Meteorol. Monographs: Vol. 29, No. 51 pp. 59, 2003.
- • Martins et al.: *Remote sensing the vertical profile of cloud droplet effective radius, thermodynamic phase, and temperature*, ACPD, 7, 4481- 4519, 2007.
- • Zinner, Marshak, Lang, Martins, Mayer: *Remote sensing of cloud sides of deep convection: towards athree-dimensional retrieval of cloud particle size profiles*, ACP, 8, 4741-4757, 2008.