SYNERGISTIC RETRIEVALS OF STRATOCUMULUS CLOUD PROPERTIES FROM SPACE- AND GROUND-BASED OBSERVATIONS

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ABSTRACT Satellite derived information on cloud optical thickness and effective radius are used for the simultaneous retrieval of cloud depth and droplet concentration in order to monitor the first indirect aerosol effect. This study validates the METEOSAT-8/SEVIRI retrieved cloud depth for stratocumulus clouds with ground truth. The retrieved cloud depth is compared to the ground-based cloud depth measured in the CloudNet sites equipped with active remote sensing sensors as cloud radars and lidars. The consistency of cloud depth retrieval with ground-based observations suggests that SEVIRI may be used to study the first indirect aerosol effect from space. CloudSat data will be ingested to have the satellite measured cloud top height and the retrievals will be simulated and validated with ECSIM.

➢ Satellite Retrieved Cloud Depth:

- Algorithm: "Satellite Monitoring of the First Indirect Aerosol Effect: Retrieval of the droplet concentration of water clouds", (Boers et al, 2006), [1]
- Applicable only for single layer stratocumulus clouds assuming quasi-adiabatic vertical profiles of the liquid water content
- Essential Points of the algorithm:

$$R_{eff} \sim N^{1/3} h^{1/3} \quad \& \quad \tau \sim N^{1/3} h^{5/3}$$

$$N = A_1 \tau^{1/2} R_{eff}^{-5/2} \quad \& \quad h = A_2 \tau^{1/2} R_{eff}^{1/2}$$

- A1 and A2 adjustable factors depending on thermodynamic and microphysical assumptions about:

1. Quasi-adiabatic character of the cloud
2. Shape of the liquid water profile
3. Link between volume radius and R_{eff}
4. Mixing model (vertical variation)

Reff: Effective Radius [μm]
τ: Cloud Optical Thickness
N: Droplet Concentration [# / cm-3]
h: Cloud Depth [m]

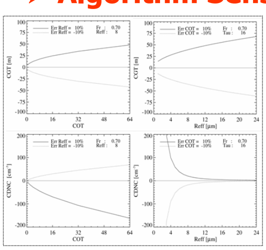
➢ Meteosat-8/SEVIRI Observations:

- Geostationary Satellite: 0° N, 3.4° W at 35600 Km
- Spectral bands: 12 from visible to infra-red (0.6 ÷ 12 μm)
- Time resolution: every 15 minutes
- Spatial resolution at Cloudnet sites: ~ 3x6 Km

Products from DAK - Doubling-Adding KNMI Radiative Transfer Model:

- Effective Radius, Optical Thickness, Cloud Phase, Liquid Water Path

➢ Algorithm Sensitivity Analysis:

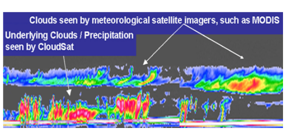


The sensitivity analysis of cloud depth (CGT) and cloud droplet concentration (CDNC) to errors in τ and R_{eff} shows that only for Reff < 5 microns the algorithm shows unacceptable behaviour

The errors for the sensitivity analysis have been set to 10% and Fr to 0.7

For the work, Fr = 0.72, since it seems the value that gives the best retrieval

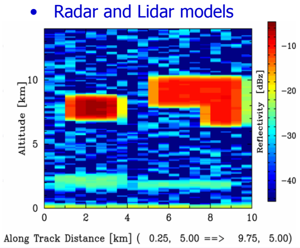
➢ CloudSat and ECSIM:



- NASA launched CloudSat on April 28, 2006
- First Satellite with Cloud Profiling Radar (CPR)
- Polar Orbiting Sun-synchronous Satellite in the A-Train formation
- Clouds seen from top-down

¤ The retrievals will be simulated and validated with ECSIM, the EarthCARE end-to-end SIMulator. ECSIM is a collection of models to simulate what the instruments would see:

- Orbit model
- Radar and Lidar models
- MSI & BBR models
- Retrievals (synergy and L2)



The 4 main steps to use ECSIM:

1. create the atmospheric scene
2. create a simulation defining which instruments and models to use
3. create a session to setup the parameters, inputs, outputs and tools
4. run the session to obtain the simulation results

➢ Ground-Based Measured Cloud Depth:

Synergy Radar / Lidar – R&L

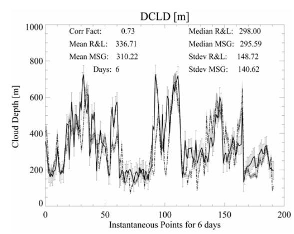
Radar and lidar profiles show a great complementarity for the observations of stratocumulus clouds composed by spherical liquid droplets:

- **with Radar**: sensitive to particle diameter --> Cloud Top Height
- **with Lidar**: sensitive to number concentration --> Cloud Base Height

Cloud Top Height – Cloud Base Height = Cloud Depth

¤ **Ground-based sites:** Cloudnet [2], ARM

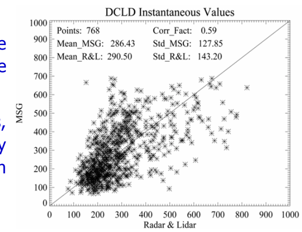
➢ Validation Results:



The temporal variations in the observed cloud depth (DCLD) are well reproduced by SEVIRI during the selected 6 days with single layer stratocumulus clouds

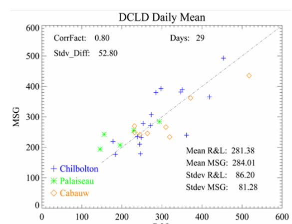
The gray shading indicates the estimated range of uncertainty due to the errors in τ and R_{eff}

The solid line describes the ground-based measurements with estimated error bars of 50 meters



The scatter plot shows that all the points are below 800 m, confirming the theory on the thickness of water clouds

The mean values differ only for about 4 meters, showing that the algorithm can describe very accurate values of the cloud depth, even though the correlation factor is around 60%



The correlation factor for daily mean values for all the 29 days increases up to 80%.

The mean values and the standard deviations are very close to each other

The correlation for daily mean values increases since the limitations in comparing and matching satellite passive observations with ground-based active measurements are overcome

➢ Conclusions:

This work shows the ability and the accuracy of the described algorithm to retrieve the cloud depth from passive satellite, starting from satellite derived information on optical thickness and effective radius.

Ground-based and satellite retrieved cloud depths show very good agreement. Very similar mean values for cloud depth can be achieved. The correlation for instantaneous points is about 73% increasing up to 80% for daily mean values.

The correct retrieval of cloud depth leads to a better calculation of the cloud droplet concentration in order to monitor the first indirect aerosol effect.

The future step will make use of the CloudSat cloud top height in order to have a larger spatial resolution and almost full satellite observations. Finally, all the retrievals will be implemented in ECSIM and simulated/validated for an EarthCARE future development.

➢ **References:**

[1] Boers, R., J.R. Acarreta, and J.L. Gras (2006), Satellite Monitoring of the First Indirect Aerosol Effect: Retrieval of Cloud Droplet Concentration, *J. Geophys. Res., 111*, D22208, doi: 10.1029/2005JD006838

[2] Illingworth, A.J., and co-authors (2007), CLOUDNET Continuous evaluation of cloud profiles in seven operational models using ground based observations, *Bull.Amer.Meteor.Soc, 88*, 883-898

[3] Roebeling, R. A., S. Placidi, D.P. Donovan, H.W.J. Russchenberg and A.J. Feijt, Validation of liquid cloud property retrievals from SEVIRI using ground-based observations, Geophys. Res. Lett., 2008, 35

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