Final Report for DOE Grant DE-FG02-06ER64160

Retrieval of Cloud Properties and Direct Testing of Cloud and Radiation Parameterizations using ARM Observations.

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1. Introduction

This report briefly summaries the work performed at KNMI under DOE Grant DE-F602-06ER64160 which, in turn was conducted in support of DOE Grant DE-FG02-90ER61071 lead by E. Clothieux of Penn. State U. The specific work at KNMI revolved around the development and application of the EarthCARE simulator to ground-based multi-sensor simulations.

2. The EarthCARE simulator (ECSIM).

EarthCARE is an ESA/JAXA satellite mission to be launched in 2016. The mission is composed of a cloud profiling radar, an advanced cloud/aerosol lidar, a multi-spectral imager and a three-view Broad-Band Radiometer (See https://earth.esa.int/web/guest/missions/esa-future-missions/earthcare) . The combination of the active and passive sensor on one platform is a unique feature of EarthCARE and will enable the mission to probe the vertical structure of the atmosphere and relate the observed structure to the top of atmosphere radiances and fluxes. By doing so, EarthCARE will provide observations critical for the accurate modeling of 3-D radiation field. The unique combinations of co-located sensors will continue the record of active satellite (i.e. lidar+radar) cloud and aerosol observations begun with CloudSat and CALIPSO but also enable new and exciting cloud/aerosol related process studies to be carried out.

The EarthCARE (ECSIM) simulator was originally developed in support of EarthCARE. ECSIM is a comprehensive multi-instrument simulator framework together with various component models [1,2]. Central to the idea behind ECSIM is the idea of being able to conduct `end-to-end' simulations (Figure 1) . That is, based on a defined atmospheric scene simulated observations are generated using accurate forward and instrument models. Retrieval algorithms can then applied to the simulated observations and the accuracy and precision of the results may be compared to the input "truth". The direct comparison with the "truth" cannot be accomplished using real measurements. However, by conducting radiative transfer calculations based on retrieval products it is possible to compare e.g. surface or TOA fluxes and/or radiance against real measurements. The simulation environment can also be used to facilitate such studies enabling radiative closure strategies that could be applied to real measurements to be quantitatively evaluated in terms of accuracy and precision.

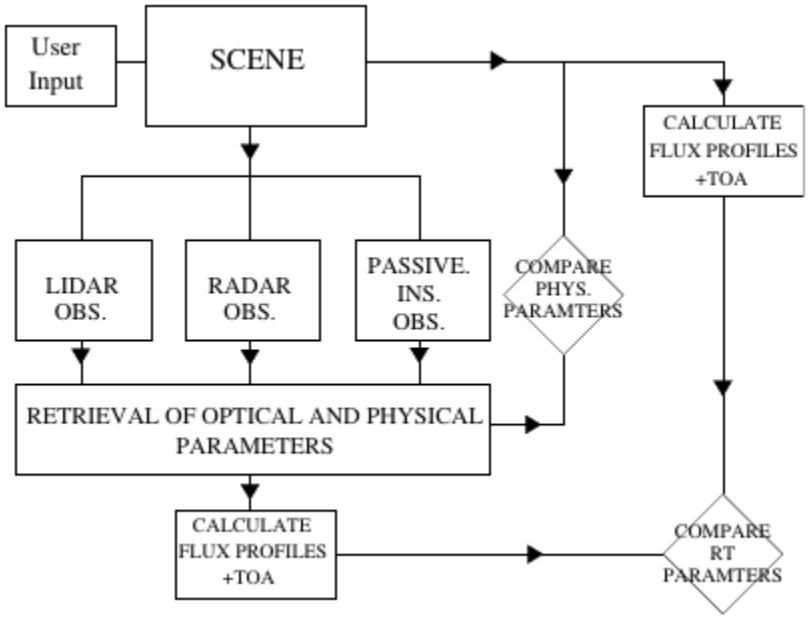

Figure 1: Schematic depiction of the 'end-to-end' simulation concept including the radiative closure assessment.

3. Achievements within the Project

Within the DOE-ARM funded project ECSIM was adapted to be able to perform ground-based radar reflectivity, lidar and SW and LW flux and radiance simulations. This process entailed a much more lengthy debugging process than initial anticipated. The resulting codes have been made available to the scientific community under a GPL license. However, due to time constraints, the opportunity to apply ECSIM to specific ARM measurement scenarios did not materialize within the project.

4. Current Status

Since the official close of the DOE-ARM funded project ECSIM has continued to develop and be applied in the context of ground-based cloud multi-sensor remote sensing. A recent example is the evaluation of several multi-sensor retrieval procedures targeting water cloud properties. A sample scene is shown in Figure 2 while various resulting forward modeled simulated observations are shown in Figures 3 and 4. The difference between the corresponding "true" LWC and Reff fields and those retrieved via the application of a particular radar+lidar+microwave radiometer approach are shown in Figure 5. Further information on the role ECSIM have been playing in the development and testing of ground-based retrieval algorithm relevant to ARM goals can be found in the final report of recent EU-COST action (http://wiki.eg-climet.org/index.php?title=Main_Page) and a publication further detailing the ECSIM based algorithm intercomparision activity is planned.

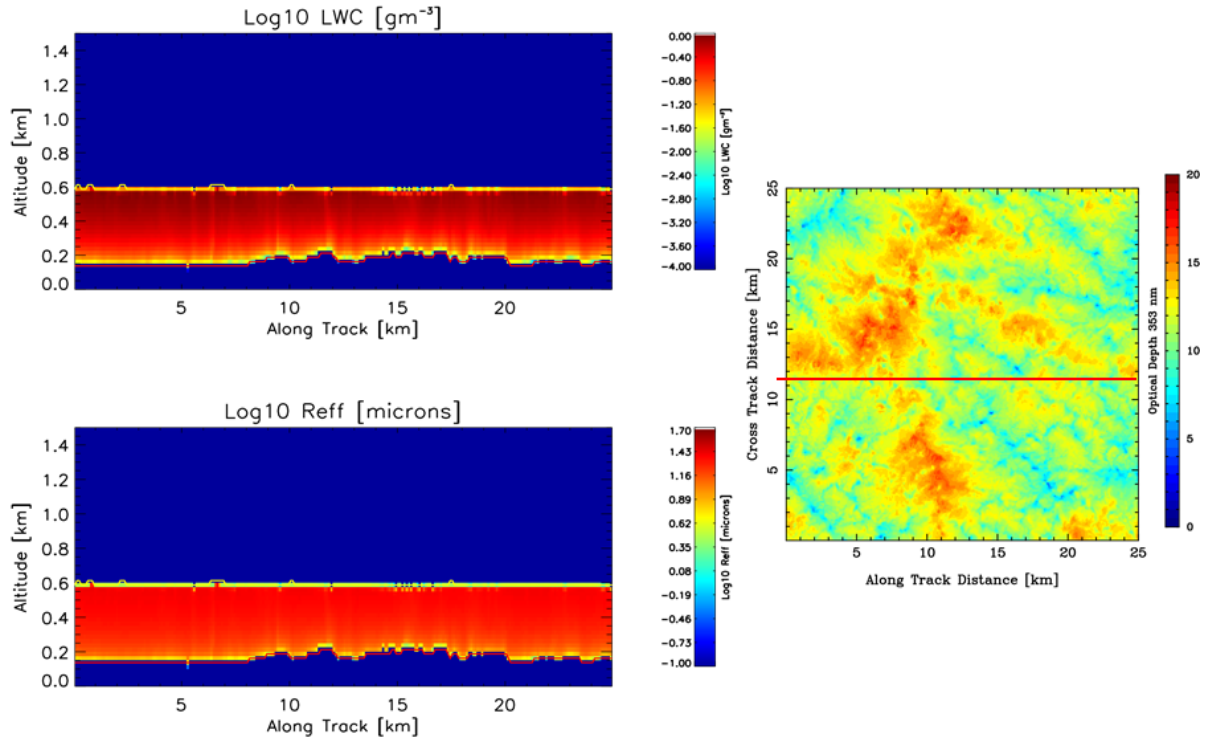

Figure 2: Example input simulation scene. Right-Panel : Optical depth field based on LES output. Left-Top: 2-D vertical slice of corresponding Liquid Water Content (LWC) field. Left-Bottom: Corresponding cloud droplet effective radius field.

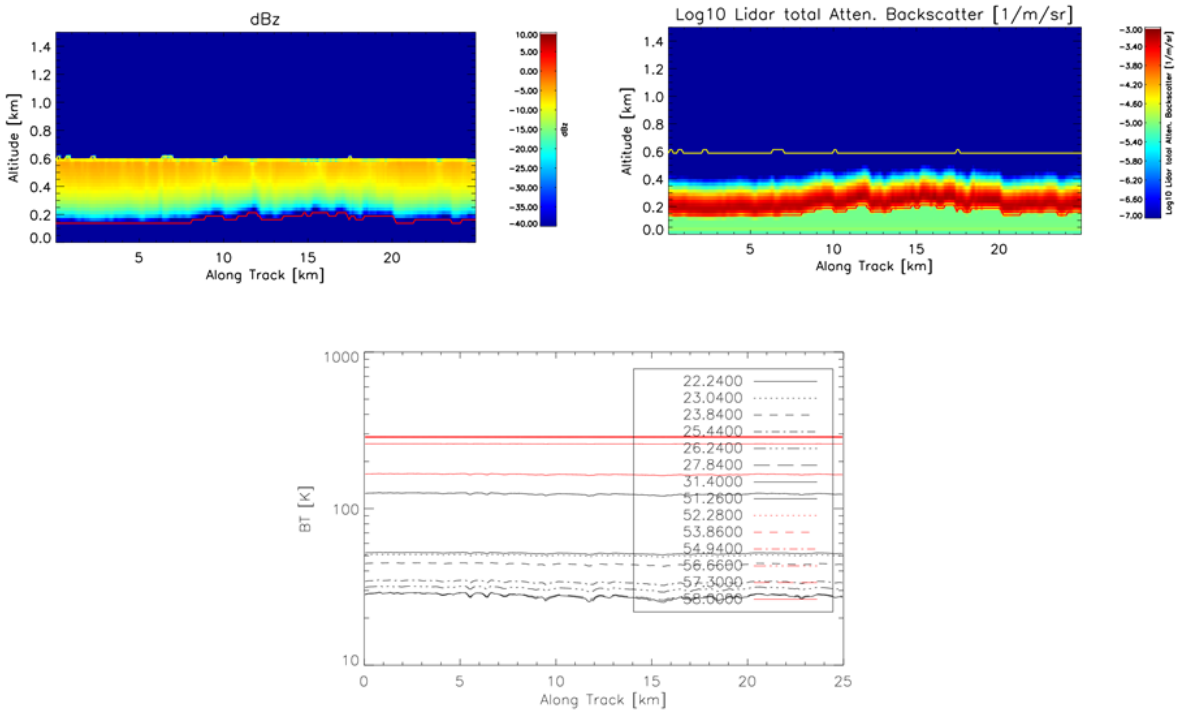

Figure 3: Example simulated measurements based on the scene shown in Figure 2. Top-Left: Simulated cloud radar reflectivity field. Top-Right: simulated Lidar attenuated backscatter. Bottom-Left: Simulated microwave brightness temperatures at various frequencies.

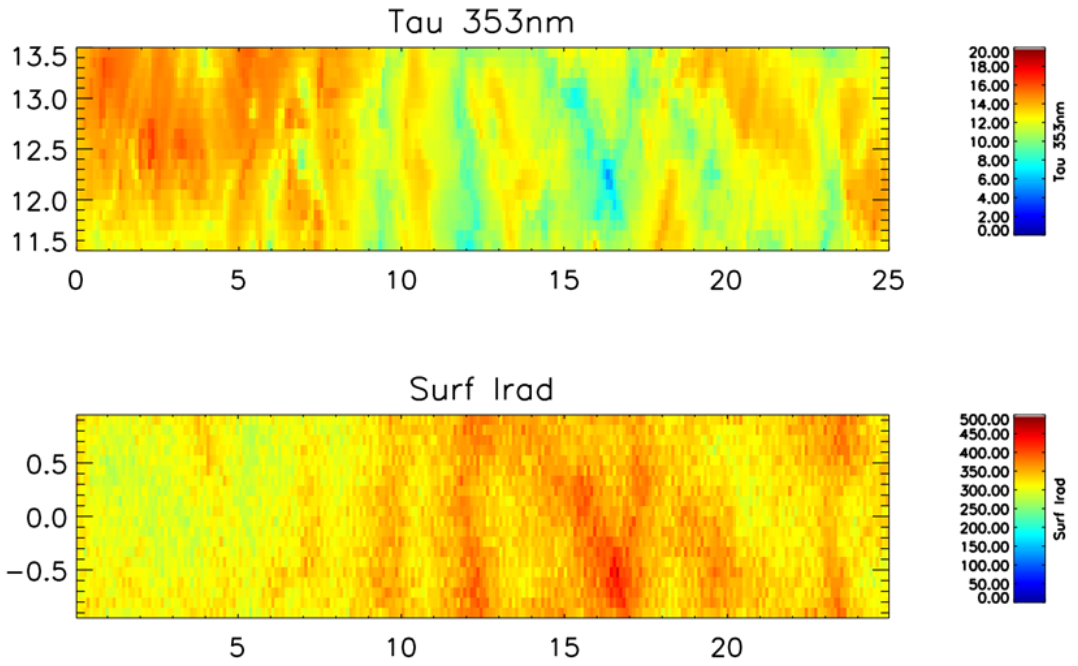

Figure 4: Top Panel: Optical depth at 355nm and simulated SW surface irradiance corresponding to a section of the scene shown in Figure 2 calculated using the 3D-MC ECSIM Short Wave model.

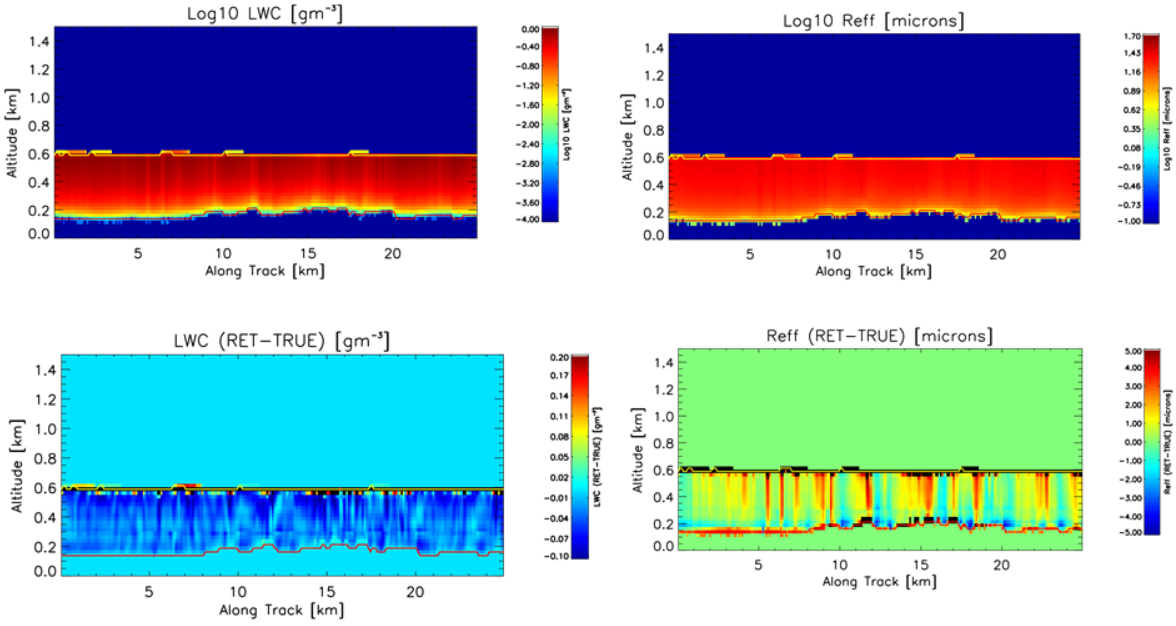

Figure 5: Top-Panels "true" LWC and Reff fields compared with the results of a particular Radar-lidar-Radiometer water cloud retrieval procedure.

References.

[1] Robert Voors ; David Donovan ; Juan Acarreta ; Michael Eisinger ; Raffaella Franco, et al. "ECSIM: the simulator framework for EarthCARE", Proc. SPIE 6744, Sensors, Systems, and Next-Generation Satellites XI, 67441Y (October 17, 2007); doi:10.1117/12.737738; http://dx.doi.org/10.1117/12.737738

[2] Donovan, D.P., R.H. Voors, G.J. van Zadelhoff and J.R. Acaretta, ECSIM Model and Algorithms Document external project: 2008, Technical Report EarthCare Simulator, http://www.knmi.nl/~zadelhof/file/ECSIM-KNMI-TEC-MAD01-122-R.pdf