P1.17 COMPARISON OF MODEL AND CLOUD RADAR DERIVED CLOUD OVERLAP

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1. INTRODUCTION

The vertical distribution of clouds has a large impact on the radiative heating and cooling rates of the atmosphere and the surface. Assumptions regarding the vertical cloud overlap in a grid column are required in climate models for the radiative transfer calculations. These various assumptions can lead to large differences in subsequent radiative heating rates of the atmosphere and the surface. The cloud overlap assumption can be validated comparing the model output with ground based cloud profiling radar data. In this study, data from the EU Cloud Liquid Water Network project (CLIWA-NET) is used.

CLIWA-NET focuses on observations of cloud liquid water and cloud vertical structures, and on the evaluation and improvements of model parameterizations. Three two-month long observational campaigns have taken place during 2000 and 2001. In the BALTEX BRIDGE Campaign (BBC) of August and September 2001, all ground based instruments, such as microwave radiometers, cloud radars and lidar celiometers were brought together in a 100*100 km**2 area centered around Cabauw in the Netherlands. Satellite based measurements and regular rawinsonde soundings were also made. A full description of the project can be found at www.knmi.nl/samenw/cliwa-net and more results for the cloud liquid water evaluation are presented in paper 2.1 at this conference.

In CLIWA-NET we will evaluate different overlap assumptions and assess their radiative impact. We will use the observed 3D cloud fields derived from cloud radars, in an attempt to verify cloud overlap assumptions and investigate alternative overlap methods that might be more generally applicable and sensitive to the thermodynamic and dynamical setting the clouds are embedded in. The model overlap is dependent on the horizontal and vertical resolution of the model and the radar-derived overlap is dependent on the vertical and temporal averaging of the data. The sensitivity of the results to different spatial and temporal resolutions will therefore be presented and the impact on the temperature and the longwave and shortwave heating rates and surface fluxes will be discussed.

2. MODELS

Model data from three European institutes, the ECMWF (European Centre for Medium range Weather Forecasts), KNMI (Royal Netherlands Meteorological Institute) and SMHI (Swedish Meteorological and Hydrological Institute) are used. The ECMWF global forecast model was run with 55km horizontal resolution and 40 vertical eta levels, and the two regional climate models were run with 18km horizontal resolution and 24 vertical eta levels, the RACMO model at KNMI, and RCA at SMHI all for the BBC time period. Boundary data for the regional models were obtained from the ECMWF analysis.

Numerical models diagnose a fractional cloud cover in a model grid box. In most models this cloud fraction is assumed to fill the grid box fully in the vertical. The horizontal portion of the grid box is then assumed fractionally filled. In order to accurately model the radiative effects of a vertical cloud structure one needs to make certain assumptions pertaining to how cloud fractions are overlapped with each other. These assumptions determine how cloud layers interact with each other and with the total radiative flux field.

The assumption of plane-parallel homogeneous clouds means there is a strong potential for a strong sensitivity of modeled cloud fields to the assumed vertical resolution of a model. Thin layers will more easily be able to resolve cloud layers. The RCA model has been integrated with two vertical resolutions for the entire BBC campaign period. The standard integration with 24 levels (RCA24) has an identical vertical grid structure to the RACMO model. A 40 level version of RCA (RCA40) was designed that exhibits the same vertical layer structure as the ECMWF model in the troposphere.

3. OBSERVATIONS

Millimeter wavelength radars are very useful for obtaining information on cloud structure. The advantage of cloud radar over satellite observations of clouds is that one gets more accurate information of the vertical structure of clouds, which is crucial for determining their radiative impact. One disadvantage is that the ground based radar only measures at a point. The sampling characteristics of the radar have to be considered, when comparing an observed cloud fraction to that from a numerical model. The high frequency radar observations have to be averaged over an appropriate time period, guided by observed wind speeds, to obtain some spatial averaged value.

In this study, we will combine measurements from several different instruments such as cloud radar, lidar celiometer, wind profiler and rawinsonde measurements. Observations of wind, temperature and humidity can also be obtained for other points in the BBC area to make sure the point measurements are representative of the area corresponding to the model grid boxes. There are other factors that also need to be considered for radar derived cloud amounts, e.g. ground clutter, the radar signal being attenuated by precipitation, the relative penetration depth and the threshold sensitivity of the radar.

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Two different cloud radars, the 35 GHz radar from KNMI and the 95 GHz MIRACLE cloud radar from GKSS will be used to derive cloud information for the BBC period. Here some preliminary results for a case study with the KNMI radar will be presented. This radar operates at two modes to increase the sensitivity. A cloudmask will be generated using both modes combined. For this preliminary study, only the uncoded mode with a vertical resolution of 149m was used. The reflectivities for this mode are recorded approximately every 10s at non-equidistant times. The minimum detectable reflectivity varies with height and is -42 dBZ at 5km. Any signal exceeding the cloud detectable threshold is used to generate a binary cloud mask according to Hogan and Illingworth (1999).

The radar observations were averaged over 15 minutes periods, to mimic the 18km horizontal resolution of the models, and averaged in the vertical corresponding to RACMO and RCA 24 vertical levels. The number of cloud filled pixels are counted in each 'grid box' thereby generating a cloud fraction which can be compared with the values for the closest model grid column. The temporal average corresponds to a model mean mid-tropospheric wind speed of ~20 m/s. An example of the radar derived cloud fraction for the 18th of September 2001 from the BBC campaign is shown in Figure 1a. After about 16 local time the radar signal was dominated by rain in the lowest three kilometres and the cloud base height cannot be determined. This spurious signal will be removed by using lidar ceilometer cloud base estimates for periods of precipitation.

4. RESULTS

Figure 1 illustrates the type of comparison that will be used to assess the role of model vertical resolution for the cloud structure. Here the two versions of the RCA modeled cloud fractions for one day in the BBC campaign, are compared to radar derived observations and to the ECMWF and RACMO models. All 3 models simulate the gross cloud structure for the day with some high level clouds descending during the day and thin, low-level clouds slightly ascending at midday. The observations have more overcast clouds when they are present.

RCA, RACMO and ECMWF are all independently derived models with numerous differing parameterization schemes. It is interesting to note that the cloud field in RCA24 shares many similarities to that from RACMO with 24 levels, while the RCA40 cloud field looks closer to the ECMWF 40 levels derived field. As expected the model vertical resolution play a key role in determining the cloud fraction a particular model simulates. Far more case comparisons are needed to determine if the difference in the RCA cloud field, with increased vertical resolution, are systematic and lead to clear improvements.

The daily mean vertical cloud profiles for the 18th of September 2001 are shown for the observations and for RCA, in Figure 2. The simulated cloud fraction is in reasonable agreement with the radar data above 6km, RCA40 is slightly overestimating and RCA24 underestimating the clouds. There is a large discrepancy at lower levels, which most likely is due to the radar signal being dominated by precipitation rather than by clouds towards the end of the day.

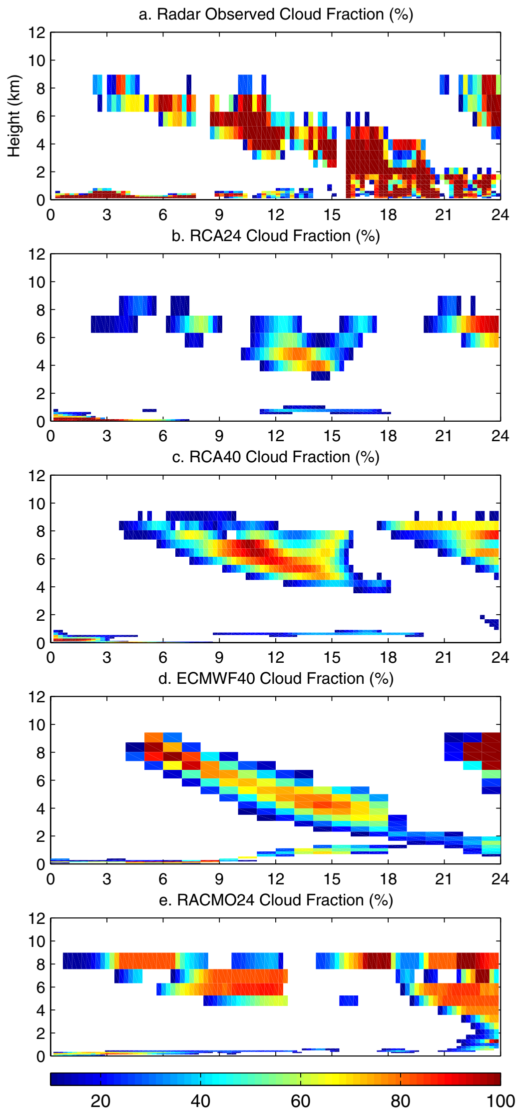

Figure 1. Cloud fraction for the 18th September 2001 at Cabauw a. the KNMI 35 GHz radar derived cloud fraction, b. RCA24, c. RCA40, d. ECMWF40 and e. RACMO24 for the same time period (Local time in hours).

Initial efforts to use the lidar ceilometer cloud base data gave much better agreement for levels below 4km and this analysis will be continued. An initial effort to include snow in the model similar to Hogan et.al. (2001), to mimic what the radar observes, have been done. They found an underestimate of model clouds at mid atmospheric levels, comparing the ECMWF cloud fraction with U.K. radar derived values for a 3 months period. They modified the model cloud fraction to include snow, since the radar is not able to distinguish precipitating snowflakes from nonprecipitating ice crystals. This modification has also been tested for RCA, and it gives somewhat better agreement with the radar data above 4 km.

The 'true' observed cloud profile (OBS), without any vertical averaging is also shown in Figure 2, together with the 24 (OBS24) and 40 (OBS40) levels observed averages. For OBS24, the vertical layers between 6 and 10 km height are 1 to 1.7 km thick. However, in reality many clouds are thinner, e.g. Mace et.al. (2001) found that one-half of all cirrus during one year observed with a cloud radar at Oklahoma, U.S., were thinner than 1-2 km. OBS40 give a better representation of thin clouds at 6km, now the levels between 6 and 10km height are thinner, 0.6-0.8km. This has implications for the overlap calculations.

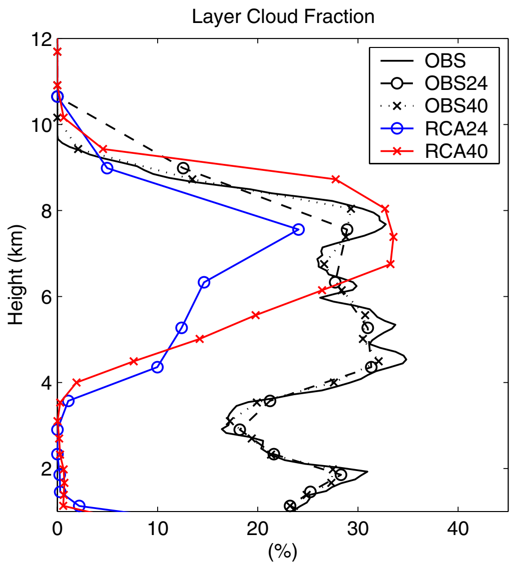

Figure 2. Vertical daily mean cloud profiles for the 18th September 2001, at Cabauw, the 'true' observed cloud structure, OBS, the observed averages OBS24 and OBS40 and from RCA24 and RCA40.

Different existing overlap formulations can be calculated for the model and compared with the overlap calculated for the observations. The calculated overlap, ranging from maximum to minimum, can also be compared with the 'true' overlap, which is obtained from the observations without any vertical or temporal averaging. None of the calculated overlap assumptions fit the 'true' overlap. The observed 'true' overlap is even smaller than the minimum overlap for OBS24 for this day (not shown). This is due to the fairly coarse vertical averages, and since the clouds are assumed to fill the grid boxes vertically. The observed clouds are thinner and more spread out in the horizontal, not thick enough to fill the vertical grid boxes. For OBS40, the true overlap lies between minimum and maximum random overlap, which is the more commonly assumed type of overlap. The model overlap will be compared with the observed overlap when the radar data has been fully processed. The impact of the different overlap formulations on the actual radiative fluxes should also be investigated.

5. DISCUSSION

Cloud vertical structure affects the atmospheric circulation by determining the vertical gradients of radiative heating and cooling. Cloud radar observations can give high resolution observed cloud vertical structures. This preliminary study suggest that not only the model vertical resolution but also the observational vertical averaging should be taken into account when making cloud overlap assumptions.

It may be necessary to parameterise vertical sub layer cloud thickness to obtain proper overlap assumption and more detailed radiative heating profiles e.g. Stubenrauch et.al. (1997).

To obtain overlap statistics much longer time periods have to be considered and other observations can be used to improve the comparisons, using combinations of satellite, rawinsonde, lidar and radar data.

6. REFERENCES

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