Shallow convection cases from the Baltex BRIDGE Campaigns: Results from the WMO international cloud modeling workshop 2004

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During the WMO workshop in Hamburg 2004, two shallow convective cases were discussed. Extensive measurements were made during the Baltex BRIDGE Campaigns in the center of the Netherlands. From this dataset, two days were selected, namely 23 September 2001 and 21 May 2003. During 23 September 2001, there was a stratocumulus field in the morning that broke during the day, with the development of shallow cumulus in the early afternoon. During 21 May 2003, a more complex picture existed with different cloud layers at different heights and a cirrus shield appearing at the site at about 16UTC. Measurements from this campaign were used to evaluate atmospheric models.

1. Introduction

In recent years, two intensive cloud measurement campaigns were held in The Netherlands, namely BBC (August and September 2001) and BBC2 (May 2003). These campaigns were jointly organized by the University of Bonn and the Royal Netherlands Meteorological Institute (KNMI). BBC (BALTEX Bridge Campaign) was held in the framework of BALTEX (Baltic Sea Experiment), being in turn a continental-scale experiment of GEWEX, the Global Energy and Water Cycle Experiment, and as such a part of the WMO World Climate Research Program. The main focus of BALTEX was to explore and model the various mechanisms determining the space and time variability of energy and water budgets of the BALTEX area.

The BBC campaigns were performed around a central experimental facility at Cabauw (51°58' N, 4°55' E), in The Netherlands. Advanced remote sensing instruments (radar, microwave radiometer, IR radiometer and lidar) were operated at this central facility to derive the vertical cloud structure: Profiles of temperature, humidity, liquid water content (LWC) and effective radius were derived from these data using the integrated profiling technique (IPT, Löhnert et al., 2004). In addition, profiles of atmospheric variables from a meteorological 200m tower were measured and radiosondes were launched in both Cabauw and De Bilt.

Cabauw is part of a regional network consisting of ten remote sensing stations covering a region of 100 km by 100 km (Figure 1). Solar radiation, cloud liquid water path (LWP), cloud base temperature and height were observed in this network. For obtaining information on the spatial structure, satellite remote sensing data from different platforms, namely SEVIRI / Meteosat-8, MODIS / TERRA, MODIS / AQUA, MERIS / Envisat, can be utilised. Aircraft and tethered balloon measurements (ACTOS; IfT Leipzig) were used to measure cloud microphysical parameters and solar radiation below, in and above the cloud. These data are especially useful for the validation of the microphysical properties of liquid water clouds as modelled by spectral 1-D models.

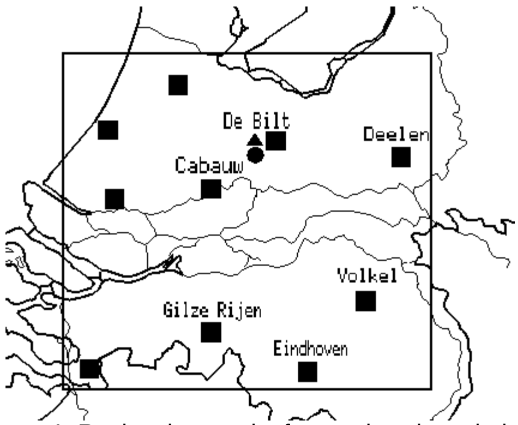

Figure 1: Regional network of ground stations during BBC located in The Netherlands.

During the workshop in Hamburg, we have worked with cases from the BBC dataset in order to evaluate the short-term cloud and precipitation forecasts of several regional atmospheric models. The models were run for a time period of 36 hours, and the first 12 hours of these integrations were disregarded. Fields from large-scale models or reanalyses were used to force the regional models from the lateral boundaries. Two days have been selected, namely 23 September 2001 and 21 May 2003. During 23 September 2001, there was a stratocumulus field in the morning that broke during the day, with the development of shallow cumulus in the early afternoon. Backward trajectories, which are going from Cabauw over Denmark backwards towards Germany, showed that the air was probably of continental origin and therefore polluted.

During 21 May 2003, a more complex picture existed with different cloud layers at different heights and a cirrus shield appearing at the site at about 16UTC. On average the lower layer (Cu/Sc) had a base at 2000 ft, and the second layer (Sc) at 6000 ft. This is a day with strong convective mixed phase clouds, with the cloud top at about 2.5 km and a melting layer at about 1.6 km. This case is very much influenced by large-scale advection, and therefore a realistic forcing needs to be prescribed at the lateral boundaries, even for the more idealised models.

2. The measurements

Product	Details
1 near true colourimages, cloudmask	
2 cloud optical thickness	
3 cloud droplet effective radius	3 over oceans and warm boundary layer clouds
4 LWP	4 as 3
5 integrated water vapour (IWV)	5 over land surfaces and clouds
Near real time processor	http://wew.met.fu-berlin.de/nrt

Table 1: Products available from satellite remote sensing data. The only instrument available for BBC is MODIS / TERRA (descending, resolution at nadir 1 km, 1-2 overpasses over central Europe per day). Note that the overpass time for BBC2001 is approximately 10:45 UTC and for BBC2003 10:00.

A comprehensive list of available measurements during BBC was presented by Susanne Crewell (Meteorological Institute University Munich, Germany) at the WMO workshop in Hamburg. This list is given by Crewell et al. (2004). Markus Quante (GKSS,Germany) gave a very nice overview of the ground based in-situ, ground based remote sensing, and aircraft measurements available for the BBC cases. All data are available on demand, but some data still needs to be processed. It was pointed out that two additional products can possibly be derived: i) Aerosol contamination derived from the lidar data (Volker Matthias has expertise on this topic), and ii) The vertical velocity of droplets ensembles from the radar. Note that the vertical velocity is the sum of the fall speed of the droplets and the vertical velocity field due to turbulence. Marc Schröder gave an overview of available satellite remote sensing data. This overview is given in Table 1.

3. The models

Matthieu Leporini (Laboratoire de Météorologie Physique, France) performed integrations for polluted versus clear cases using a 3D warm cloud model based on the detailed microphysical model DESCAM (Flossmann, 1985). This model was linked to the three-dimensional non-hydrostatic mesoscale model of Clark et al. (1996). The model was initialised using radiosonde data, but no synoptic scale forcing was used. A “steady-state solution” was obtained for the cloud field. Cases where the synoptic forcing is small, can be realistically represented with such a model, and for such cases the model is suitable to study in detail the underlying mechanisms for cloud formation and aerosol-cloud interaction. The initialisation is currently done with a radiosonde launched at 00UTC in de Bilt on 23 September 2001, and a cloud develops at 4 km height, which is not found in the observations. Different initialisation radiosonde launches are available and need to be used in following integrations.

Naomi Kuba (Frontier Research Center for Global Change, Japan) used a cloud resolving model with a microphysical model (using bin method) linked to the 3D non-hydrostatic mesoscale model CReSS. Initial cloud droplet size distribution was parameterised. The cloud droplet number and rain fall amount can be predicted with so small error that they are useful for implementation in a non-hydrostatic cloud resolving model. The rain water generation efficiency and optical properties of clouds are largely dependent on the number and size distribution of cloud droplets, which in turn are parameterised using a parcel model. The number and size distribution of cloud droplets are affected by CCN spectrum and updraft velocity near the cloud base. The problem is the initialisation of the model with aerosol data, since limited information is available from the BBC cases. Therefore integrations for the BBC cases have not been performed yet.

Wolfram Wobrock (Laboratoire de Météorologie Physique, France) used the Clark-Hall cloud scale model with parameterised microphysics and a horizontal grid spacing of 2km. The model is suitable to study mechanisms of cloud formation for homogeneous cloud fields.

Integrations with two non-hydrostatic atmospheric models have been performed for these cases. Jean-Pierre Chaboureau (Laboratoire d’Aérologie, France) has performed simulation using Méso-NH in its standard configuration with 3 nested models, the inner one having a 2.5 km grid

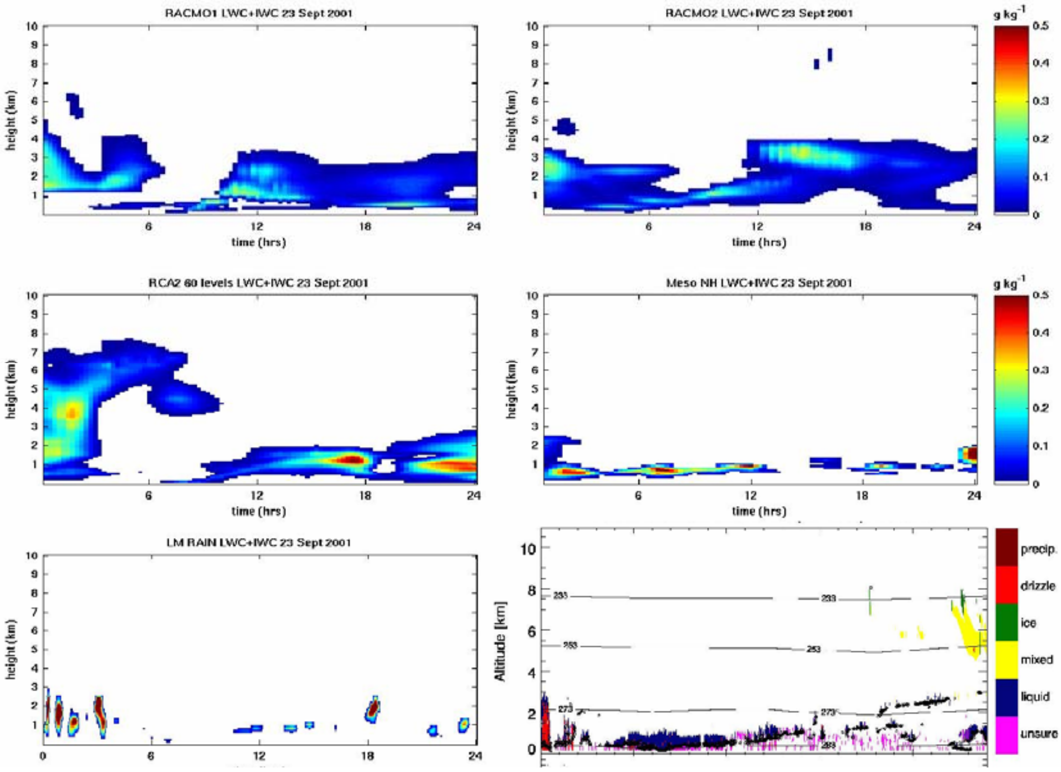

Figure 2: Temporal evolution of the vertical distribution of the liquid water content for 23 September 2001 in the models RACMO (with parameterisations from ECHAM4 and ECMWF), Lokal Modell (LM), RCA and Méso-NH, together with cloud classification as derived from a microwave radiometer, a cloud radar, a lidar-ceilometer and a radiosonde temperature profile (IPT).

mesh. The model uses a mixed-phase bulk microphysics (Pinty-Jabouille) with five hydrometeors: cloud water, rain, ice, snow and graupel. Felix Ament (University Bonn, Germany) performed integrations with the Lokal Modell of the Deutscher Wetterdienst at a horizontal grid spacing of 2.8 km.

Several hydrostatic models, used for operational weather forecasting, have been used to simulate the BBC cases. Erik van Meijgaard (KNMI, The Netherlands) performed integrations with the regional atmospheric model RACMO, using parameterisation of physical processes from both the ECHAM4 and from the ECMWF global models. A horizontal grid spacing of 18 km was used. Ulrika Willén (SMHI, Sweden) used the regional atmospheric model RCA to simulate the cases. Volker Matthias (GKSS, Germany) has planned integrations with the MM5 model. This work will be done at GKSS with the purpose of air quality modelling, but the BBC cases are relevant for evaluation of the shallow cumulus clouds in the model.

Figure 2 shows the vertical distribution of clouds during 23 September 2001 as derived from a combination of measurements namely a microwave radiometer, a cloud radar, a lidar-ceilometer and a radiosonde temperature profile (IPT). During the morning, low level water clouds exist with the cloud base moving up during the course of the day. At night, some mixed phase higher level clouds drift over the site. The liquid water path, as measured with the radiometer, is largest during the period 5UTC-10UTC. Méso-NH is able to represent the shallow cloud layer and the upward moving cloud base best. The other models have a cloud layer that is much thicker than the measurements indicate. The Lokal Modell has a very patchy cloud structure, which is not found in the measurements.

Figure 3 shows the clouds during 21 May 2003 as measured using IPT and as simulated by the models. The day is characterized by a two layer cloud system with a front coming in around 16UTC. All the models represent the front and the associated high level ice clouds. RACMO1, RCA2 and LokalModell have a hint of the two layer cloud structure at lower levels, whereas RACMO2 and MesoNH have only one cloud layer. Again, the clouds in MesoNH are much thinner than in the other models and Lokal Modell has a very patchy cloud structure.To study the effect of the vertical resolution on the model output, integrations have been done with RCA by Ulrika Willen with 24, 40 and 60 levels. The number of vertical levels does not substantially alter the vertical distribution of clouds in the model, and in all integrations the cloud layer is thicker than in the measurements. In a forthcoming paper the causes for these findings will be investigated.

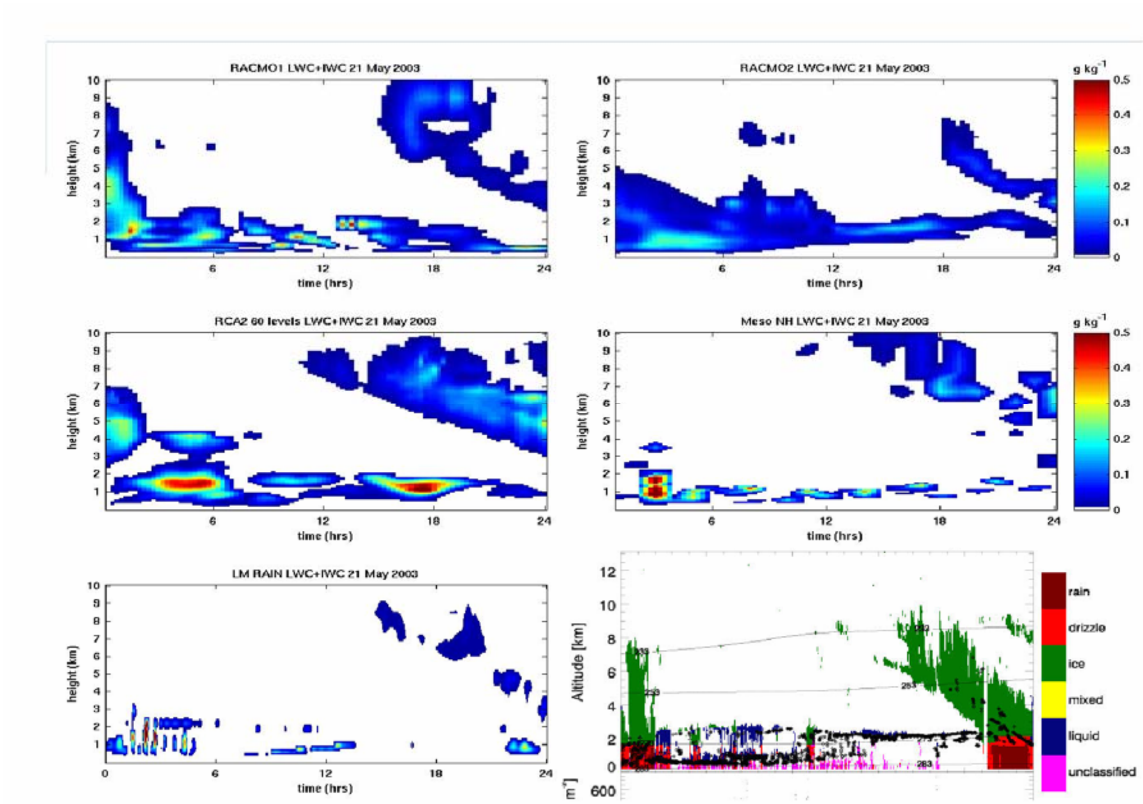

Figure 3: Same as Figure 2, but for 21 May 2003.

4. Conclusions and future work

In summary, this workshop was successful in bringing the observationalists and modellers together. This case is in its initial phase, and the workshop was a good starting point. Any interest or comment is welcome.

For the special issue of this workshop, a paper is planned: 'The representation of hydrometeors in atmospheric models: A case study using data from an intensive field campaign in The Netherlands during 2001 and 2003. The goal of this paper is i) to present the BBC cases 23 Sept 2001 and 21 May 2003, that are discussed during the WMO workshop, ii) to study whether different regional atmospheric models can represent low-level clouds in summer (stratiform and shallow convection) in The Netherlands, iii) to get a grib on what is needed/essential in atmospheric models to get a good representation of warm low level clouds in summer, and iv) to determine weaknesses and strengths in atmospheric models in representation of cloud parameters.

Initially, model output will be compared with: Radiosoundings at Cabauw (T, u, v, q); the surface energy balance for Cabauw; temporal evolution of the vertical distribution of hydrometeors, as derived from radar, radiometers and cloud base lidar; temporal evolution of IWV and LWP at the stations of the regional network; spatial distribution of cloud properties and IWV as derived from satellites remote sensing instruments (MODIS). Contributions to this paper welcome.

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