ACCENT-AT2 workshop
on characterisation of the cloud diurnal cycle from space observations

METEO FRANCE
Toulouse
21-22 November 2005

Jean Louis Brenguier
Météo-France-CNRM

1. Opening and Aim of the Workshop.

The workshop was held on 21 and 22 November 2005 at the Conference Centre of Meteo-France in Toulouse. The objective was to investigate if the existing retrieval techniques of cloud properties from satellite observations are sufficiently accurate for quantifying the diurnal cycle of clouds, more specifically of extended boundary layer warm stratocumulus clouds, and how they can be improved.

There is now a consensus on how aerosol particles affect the droplet concentration in warm clouds, and the cloud radiative properties (Twomey effect). A possible aerosol impact on cloud dynamics, also referred to as the second indirect effect, is still however the matter of an animated debate. A variation in the diurnal cycle of clouds indeed could have a significant effect on the net radiation budget, even if the mean cloud properties remain unchanged.

Satellite monitoring could help at identifying changes in the diurnal cycle in relation with modifications of the background aerosol. During the past decade, various techniques have been developed for the retrieval of cloud macrophysical and microphysical properties from such observations, though most of these techniques are limited to day or night time. During the daytime, when the sun is relatively high, the information content of the radiances measured by geostationary satellite imagers permits reasonably accurate estimates of many cloud variables. As the sun approaches the horizon, the information obtained from reflected solar radiation becomes less reliable and the retrievable content of radiances from important channels, e.g., 3.9 µm, becomes ambiguous compounding the bidirectional and overlapping cloud effects. At night, the loss of reflected solar radiation further diminishes the amount of retrievable cloud information. Thus, quantification of the diurnal cycle of clouds from current geostationary satellites is limited by a number of serious roadblocks.

The workshop aimed at evaluating how different techniques may be combined to improve observations of the whole cloud diurnal cycle from space, especially for the night/day-time transition.

More specifically the workshop objectives were to
1) Provide an overview of the
   - available techniques for the retrieval of cloud macrophysical and microphysical properties (height, temperature, phase, particle effective radius, optical and geometrical thickness, water/ice content…) from geostationary satellites;
   - available retrieval techniques from other satellites for validation;
   - possible CALIPSO and CLOUDSAT contributions to the validation.
2) Identify specific issues relative to the observation of the cloud diurnal cycle.
3) Initiate collaborations to facilitate progress on these issues.

2. Scientific Presentations

Following an introduction of the retrieval of cloud microphysical properties from space, a series of presentations were made by the participants (see Appendix 2 and 3) on operational products from the geostationary satellites MSG and METOP and new developments dedicated to the retrieval of the time evolution of cloud properties, on operational products from the polar satellites imagers POLDER and

MODIS, and on the contribution of active remote sensing instruments on board satellite, such as lidar (GLAS), and radar (Aqua-train), or at ground sites (CLOUDNET).

The three principal topics that were discussed are the following:
- the characterisation of the cloud macrophysical and microphysical properties from active and passive remote sensing : Cloud type, height, top temperature, optical and geometrical thickness, number concentration, effective radius, liquid water content and path, precipitation estimation, tracking;
- the characterisation of the spatial and temporal variability of these properties and the future investigation necessary for a more accurate characterisation of their variability;
- the biases due to retrieval technique assumptions.

3. Discussion Points

Following the overview of the available techniques, the discussion focused on how retrieval techniques from geostationary satellites can be precisely calibrated using more accurate high resolution measurements from other sensors such as MODIS, from the forthcoming active remote sensing spatial instruments, as well from local measurements from ground remote sensing sites.

The discussion then moved to the key issue of the attribution of the observed evolution of cloud properties. Indeed, direct correlations between cloud properties and aerosol proxies, such as the aerosol optical depth, is not sufficient to conclude on the impact of aerosol on the cloud life cycle. Different aerosol types are necessarily associated to different air masses, hence different dynamical conditions. Moreover the aerosol optical thickness is an ambiguous parameters as it does not discriminate between aerosol types below cloud base, that impact cloud microphysics, and aerosol particles located higher than cloud top, that only interact with the radiative transfer above clouds.

In order to reach firm conclusions, these ambiguities shall be resolved. Aerosol vertical profiling and backward trajectories with aerosol transport models may help at characterizing the various components of the total aerosol column, and their respective altitude levels. The characterization of the dynamical forcing is more difficult because present meteorological analyses (ECMWF) are not accurate enough to establish the dynamical contribution to the time evolution of a cloud layer. Indeed, a relative reduction of 1/100 (0.2 g/kg)of the total water content in the boundary layer, is sufficient for the total dissipation of a 100 m thick cloud layer over the North-Eastern Atlantic.

4. Conclusions and Recommendations

The characterization of the cloud diurnal cycle is potentially feasible with geostationary satellite instruments. It requires a synergy between these instruments and more accurate measurements from polar satellites for cross-calibration. Ground remote sensing sites may also contribute to the calibration of retrievals over the continent, especially the European CLOUDNET network at Chilbolton (UK), SIRTA (FR) and Cabauw (NL).

For the attribution of the observed changes to the aerosol, fine resolution LES models with explicit parameterizations of the dynamics, radiation, aerosol and cloud microphysics are needed to quantify the respective contributions of the dynamics and of the aerosol, including both its microphysical and its light absorption impacts.

There is a consensus that, as a first step, the simplest cases shall be selected, namely extended boundary layer warm cloud systems, embedded in a general circulation that exhibits homogeneous conditions over a spatial scale much larger than the domain of interest (>100 km), and a time scale of more than 48 hours. In particular, the contributions of latent and sensible heat advections to the system shall be minimized.

In order to cross-compare and validate the different retrieval schemes, by using the synergy between independent techniques, the participants decided to select at least two case study on which each participant can apply his own expertise and techniques.

The two case studies must correspond to a relatively stationary (48 hours) and homogeneous (> 100 km) cloud system. One case study will be selected over the North-Eastern Atlantic ocean in an area covered by all spatial instruments available to the participants. The second case study will be selected over one of the three ground sites Chilbolton (UK), SIRTA-Palaiseau (FR) or Cabauw (NL) that provide lidar and radar observations.

Jürgen Fischer, Rene Prusker and Genevieve Seze will propose a pre-selection two the case studies and submit it to the other participants for final selection.

Moreover, it was agreed to enlarge the number of participants to this validation exercise by circulating these plans to additional potential participants.

5. Contribution to the current aims of AT2 and ACCENT

This workshop establishes a short term framework for validation and comparison exercises to verify and improve the quality of satellite retrieval techniques of cloud properties. It will reinforce the co-ordination and optimisation of the efforts of European scientists in the retrieval of the data products for tropospheric research from the measurements by instrumentation aboard orbiting satellite platforms, and its further exploitation for tropospheric research on the impact of aerosol on the cloud life cycle within the European Research Area.

On the medium term, this exercise will provide the European community on clouds and aerosol with a demonstration of the level of accuracy that can be obtained via the synergy between complementary observation techniques and numerical models. It will help at the design of the forthcoming field experiment that will soon be organised in Europe as part of the integrated project on the impact of aerosol on climate

On the long term it will develop durable means of communication and collaboration within the European scientific community, to facilitate this research and to optimise the interactions with policy-makers and the general public.

Appendix 1 Participants and Affiliations

Jean Louis Brenguier	Météo-France-CNRM	jlb@meteo.fr
Marjolaine Chiriaco	IPSL-SA	marjolaine.chiriaco@lmd.polytechnique.fr
Frederick Chosson	Météo-France-CNRM	frederick.chosson@cnrm.meteo.fr
Jürgen Fischer	Freie Universität Berlin	juergen.fischer3@gmx.net
Qingyuan Han	University of Alabama	han@nsstc.uah.edu
Damien Josset	IPSL-SA	damien.josset@aero.jussieu.fr
Olivier Jourdain	LAMP	olivier.Jourdan@opgc.univ-bpclermont.fr
Alexander Kokhanovsky	IEP-Bremen	alexk@iup.physik.uni-bremen.de
Lydie Lavanant	Météo-France-CSM	lydie.lavanant@meteo.fr
Rene Preusker	Freie Universität Berlin	rene.preusker@wew.fu-berlin.de
Marc Schroder	Freie Universität Berlin	marc@amor.met.fu-berlin.de
Irina Sandu	Météo-France-CNRM	irina.sandu@cnrm.meteo.fr
Genevieve Seze	IPSL-SA	genevieve.seze@lmd.jussieu.fr
Odile Thouron	Météo-France-CNRM	odile.thouron@cnrm.meteo.fr

Appendix 2 Workshop Programme

November 21

9h30	Reception
10h00	Welcome address
10h45	**Remote Sensing of Cloud Diurnal Cycle and Aerosol Indirect Effect.** *Qingyuan Han, University of Alabama in Huntsville, USA*
11h45	Break (15 min)
12h00	**MSG and METOP cloud classifications at Meteo-France.** *L. Lavanant, Meteo France, France.*
13h00	Lunch Time (1h30)
14h30	**Restitution of cloud geometrical thickness and droplet number concentration : effect of 3D cloud heterogeneity and microphysical variability** *F Chosson, Meteo France, Toulouse, France*
15h30	**Retrieval of cloud microphysical and geometrical characteristics from backscattered light measurements using asymptotic solutions of radiative transfer theory** *A. Kokhanovsky, Institute of Environmental Physics, Bremen, germany*
16h30	**Contribution of active remote sensing to improve cloud properties.** *M. Chiriaco-Amiaud, Laboratoire Météorologie Dynamique, Palaiseau, France*
17h30	

November 22

9h00	**Low cloud cover in the descending branch of the Hadley cell: first obervations with the lidar GLAS.** *G. Sèze, Laboratoire Météorologie Dynamique, Palaiseau, France*
10h00	**Convective cloud development analysis : comparison of observations and model forecast.** *D. Josset, Service d'aéronomie, Paris, France*
11h00	Pause (15 min)

11h15	**Temporal evolution of cloud properties deduced from SEVIRI observations (I).** *Schroder Marc, Institut für Weltraumwissenschaften, Berlin, Germany*
12h15	**Temporal evolution of cloud properties deduced from SEVIRI observations (II).** *Preusker Rene, Institut für Weltraumwissenschaften, Berlin, Germany*
13h15	Lunch Time (1h15)
14h30	Open Discussions, conclusions and recommendations
17h00	

Appendix 3 Individual Scientific Contributions

Title: **Remote Sensing of Cloud Diurnal Cycle and Aerosol Indirect Effect**
Authors: **Qingyuan Han**
Abstract: An overview of remote sensing of cloud diurnal cycle is presented together with discussions of the possible error sources. The overview shows that the cloud diurnal cycle study has been focused mostly on cloud amount variations, which are dependent on regions and seasons. For the study of aerosol indirect effect, diurnal cycles of cloud properties other than cloud amount are proposed. It is followed by the impact of cloud variations on evaluations of the aerosol indirect effect.

Title: **MSG and METOP cloud classifications at Meteo-France**
Authors: **L. Lavanant , M. Derrien, H. LeGléau**
Abstract: The Centre de Météorologie Spatiale (CMS) of Météo-France is involved in the development of cloud description operational packages within the two EUMETSAT NowCasting SAF and Ocean and Ice SAF context. The aim is to support nowcasting applications for MSG and global sea surface temperature retrieval for NOAA and METOP.

Three cloud parameters are extracted: the cloud mask, the cloud type and the cloud top temperature and height from MSG SEVIRI imagery over European areas. In addition, the product provides information on the presence of snow/sea ice, dust clouds and volcanic plumes. The cloud mask and type are given from NOAA and METOP AVHRR data in a global scale. Also the development of an algorithm for retrieving cloud phase from MSG SEVIRI has started in collaboration with LMD and NASA Langley Research Center, whereas algorithms for cloud optical thickness and effective droplet size retrieval are planned.

We will present the main characteristics of the softwares and the validation performed by comparison with interactive target databases, SYNOP, radiosonding and Lidar/radar from SIRTA.

Title: **Restitution of cloud geometrical thickness and droplet number concentration : effect of 3D cloud heterogeneity and microphysical variability.**
Authors: **Chosson, F., J.-L. Brenguier, L. Schüller**
Abstract: Diurnal cycle of boundary layer clouds can be characterized by liquid water content cycle and cloud droplet number variability. As a result, knowledge of those two parameters is required. In this study, a retrieval scheme of cloud geometrical thickness (or liquid water path) and cloud droplet number concentration (CDNC) is tested against 3D simulated radiances from various realistic and heterogeneous L.E.S. boundary layer cloud fields. Internal microphysical variability is modelled assuming either homogeneous or heterogeneous mixing. Sources of error on retrieval are identified and quantified. 3D radiative effects are found negligible at low sun zenith angle, even in fractional, highly heterogeneous cloud field. Biases on retrieved geometrical thickness is mainly determined by discrepancy between adiabatic assumption made in the retrieval scheme and simulated column water content. Biases on retrieved droplet number concentration depend on internal microphysical variability and on the Look-up table of the retrieval scheme rather than on cloud geometrical heterogeneity or initial CDNC. Using brightest pixels of the cloud field reduces biases on retrieved CDNC in case of highly heterogeneous cloud fields. The retrieval scheme is also applied at lower resolution ($1km^2$) comparable to MODIS resolution. No significant bias arise from restitution of geometrical thickness, but substantial under-estimation of CDNC is made when pixel include cloud-free fraction. Importance of use of an accurate cloud mask in restitution is emphasized. The retrieval scheme actually uses visible and near-infrared radiances, but

will be extended in future works to infrared radiances in order to cover nocturnal part of the cloud diurnal cycle.

Title: **Retrieval of cloud microphysical and geometrical characteristics from backscattered light measurements using asymptotic solutions of radiative transfer theory**

Authors: **Kokhanovsky, V. V. Rozanov, M. Vountas, J. P. Burrows**

Abstract: Determination of cloud properties from space (and, in particular, studies of cloud diurnal cycles) require fast retrieval schemes. Therefore, pre-calculated look-up tables (LUTs) or neural networks are used for this purpose. It is computationally very demanding to solve the inverse problem using the exact radiative transfer equation an each step of the inverse iteration algorithm.

However, one can apply approximate asymptotic solutions of the radiative transfer equation to derive cloud properties from optical instrumentation on airborne and space platforms. This allows to avoid the problem of interpolation between grids and also it is of a special importance for the case, when multispectral measurements (e.g., around 100 spectral points in the oxygen A-band) are of concern. Then LUTs are too large to be used in operational retrieval schemes involving processing of large volume of satellite measurements.

In this paper the Semi-Analytical CloUd Retrieval Algorithm (SACURA) developed by authors for SCIAMACHY/ENVISAT is described. The algorithm is based on the analytical solution of the radiative transfer equation valid for optically thick weakly absorbing media. The applications of the algorithm for the determination of cloud properties such as cloud top height, optical thickness, liquid water path, and effective radius of droplets using measured top-of-atmosphere reflectance are presented.

Title: **Contribution of active remote sensing to improve cloud properties retrievals**

Authors: **M.Chiriaco-Amiaud, H. Chepfer, J. F. Daloze, M. Haeffelin, Y. Morille, V. Noel, J. Pelon, A. Protat**

Abstract: Abstract: Active remote sensing contributes to improving the retrieval of cloud properties through for example an improved determination of the altitude of cloud boundaries. Several techniques of cloud property retrieval using lidar and/or radar have been developed using SIRTA data (Site Instrumental de Recherche en Télédétection Atmosphérique): algorithms to retrieve cloud macrophysical properties (cloud boundaries and phase) from lidar, or from the coupling of lidar and radar; techniques to retrieve cloud microphysical properties using (i) the coupling of an Infrared Imager (IIR) and a lidar, (ii) the coupling of IIR and radar, (iii) the coupling of lidar and radar, (iv) the radar alone. Such techniques are pertinent for different sorts of clouds (thin or thick, ice cloud or liquid water clouds…) and will be applied to spatial measurements with satellite from the Aqua-Train. Cloud macrophysical retrievals from lidar and radar were used in a recent study to evaluate the MSG (Meteosat Second Generation) cloud detection and altitude retrievals developed by the Centre de Météorologie Spatiale de Lannion as part of the Eumetsat Nowcasting Satellite Application Facility (NWCSAF).

Title: **Low cloud cover in the descending branch of the Hadley cell: first obervations with the lidar GLAS.**

Authors: **Geneviève Sèze, Jacques Pelon, Mathieu Lalande**

Abstract: For the first time, the forty five days in October-November 2003 of lidar measurement from GLAS (Geoscience Laser Altimeter System) onboard the ICESAT platform, give the opportunity of a global observation of the spatial and diurnal variation of the low cloud top height. First, a quick presentation of the low cloud cover global maps will be

given and the incertitudes in the low cloud amount which remain due to the presence of upper cloud thick layer, will be evaluated. Then, we will concentrate on the analysis of the low cloud cover properties observed by GLAS over ocean in the descending branch of the Hadley cell, special emphasis will be given to the "EUROCS" Pacific ocean region . The same analysis will be performed with the ISCCP (International Satellite Cloud Climatology) data set for the same period. The results obtained with ISCCP will be compared with those obtained with the lidar active measurements

Title: **Convective cloud development analysis : comparison of observations and model forecast**

Authors: **Damien Josset, Jacques Pelon**

Abstract: A case study has been conducted on the period from the 22nd to the 26th March 2004 on the diurnal cycle of boundary layer clouds leading to intense convective developments. The diurnal cycle of cloud has been analysed using remote sensing (ground based radar and lidar) and satellite observations (MODIS). Results have been compared with forecasts from three numerical models (METEOFRANCE ARPEGE, UKMO Unified Model and ECMWF). Two cases of more intense convective development have been studied (March, 22nd and 24th). A delay in the onset of convection is observed between models and between models and observations (cloud structure and cloud total water content). On the third day of observation (March 26th) only shallow convection was observed with stratocumulus formed at the top of the boundary layer. This case also shows significant differences between model results and observations of cloud properties in the afternoon.

The dynamics of the cloudy boundary layer in the morning phase is critical to the development of clouds in a more convective phase in the afternoon. High spatial resolution data are needed to analyse the related variability in the transition phase. Besides ground-based observations (remote sensing and in situ), observations performed with the AQUA-Train between 12:00 and 13:30 UTC over France, correspond to a critical period for the transition. It is expected that these observations combined to meteorological analyses will provide a statistical basis to extend the local analysis to a larger domain. Furthermore, this should help to address the analysis of cloud structure evolution with latitudinal forcing.

Title: **Temporal evolution of cloud properties deduced from SEVIRI observations (Part 1)**

Authors: **Marc Schröder, Rene Preusker, Jürgen Fischer**

Abstract: We present a tracking algorithm that utilises SEVIRI brightness temperature (BT) measurements. Convective systems are defined by applying a threshold to BT observations and are tracked by finding the minimum in the difference of area and position between two successive images. Furthermore, we developed and present an algorithm capable to retrieve cloud optical thickness, effective radius, and liquid water path. Together with cloud top pressure these parameters are monitored during tracking of convective systems in summer 2005. We present typical paths and the temporal evolution of the cloud properties of convective systems over Africa. In particular, we analyse the evolution of the convective systems with brightness temperature / radiance scatter plots (Hertzsprung-Russell diagrams).

Title: **Temporal evolution of cloud properties deduced from SEVIRI observations (Part 2)**

Authors: **Rene Preusker, Andi Walther, Ralf Bennartz, Jürgen Fischer**

Abstract: In this work we investigate the diurnal cycle of precipitation events by means of radar observations and compare these findings with the diurnal cycle of indicators of precipitation from highly resolved satellite data. Data sources are temporally and spatially highly resolved measurements from the infrared sensor SEVIRI onboard METEOSAT8 and ground based radar data from the north European network BALTRAD. To quantify and characterize the diurnal cycle of atmospheric values we defined appropriate parameters, such as the time of day with maximum precipitation and the significance of the diurnal and semidiurnal cycles.

We will present results of studies with a series of different thresholds for infrared cloud top temperature by means of the infrared channels of SEVIRI. Our study provides diurnal as well as seasonal information of the comparison between the findings of the precipitation method using radar and the examination of clouds.