Proceedings of ISAP'04, Sendai, JAPAN

ATMOSPHERIC PROFILING FOR CLIMATE STUDIES IN EUROPE

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1. Introduction

Climate change is a global phenomenon. It is for a large part governed by atmospheric processes, like the interaction between radiation and atmospheric components (e.g., clouds, aerosols, precipitation, green-house gases) and the earth surface – atmosphere interface. Studies of climate and climate change involve process studies, as well as the validation of satellite observations and the assessment of trends of relevant atmospheric quantities. Attribution of climate change to isolated atmospheric processes can only be accomplished if all relevant atmospheric parameters are measured at the same time at the same place. As of yet satellite data are insufficiently apt to perform this task, as it is difficult to collocate the required complex sets of instruments on space platforms. However, sustained observations of a comprehensive suite of atmospheric parameters can be accomplished from multiple coordinated remote sensing observatories. The need for such observations has been unambiguously asserted in the latest IPCC Third Assessment Report (2001): *"In particular, there is a need for additional systematic and sustained observations, modeling and process studies, (...) to sustain and expand the observational foundation for climate studies by providing accurate, long-term consistent data including implementation of a strategy for integrated global observations, (...) to improve understanding of the mechanisms and factors leading to changes in radiative forcing, (...) to understand and characterize the important unresolved processes and feedbacks in the climate system."*

There are only a few atmospheric observatories in Europe and worldwide sufficiently equipped to fulfill this task. Recognizing the need for both systematic observations and process studies as advocated by the IPCC, the initiative is now taken to set up a European network of advanced atmospheric monitoring and research observatories, thus building a network of European anchor stations for sustained observations in support of climate and weather studies and related atmospheric research. The network of observatories will be called EurAt Observatory.

2. Objectives of EurAt Observatory

The objective of the network is
To set-up, operate and provide a European network of advanced ground-based observational facilities with a comprehensive set of remote sensing and in-situ equipment to characterize the state of the atmosphere, its radiative properties and interaction with the land and water surface, for the study of atmospheric processes, climate monitoring, weather, and validation studies.

The organizing consortium will aim at

- coordinated provision of experimental facilities to the scientific community;
- co-operation in the development of the observatories towards atmospheric anchor stations in support of climate studies and related atmospheric research;
- harmonizing the quality of the parameters retrieved at the different observatories; this will be achieved by harmonizing routine operation of the instruments, coordinated calibration procedures and common data interpretation procedures;
- setting up a European data archive of the atmospheric parameters retrieved at the observatories;
- ensuring dissemination of the data by close collaboration with end users of the data;

ISBN: 4-88552-207-2 C3055©IEICE

- setting up a long term observation program for climate and weather studies
- scientific collaboration in experimental atmospheric science.

3. Structure of EurAt Observatory

EurAt Observatory consists of already existing observatories in Europe. Two categories are distinguished:

- *Core sites*, that employ an extensive suite of state-of-the-art remote sensing as well as in situ instruments to characterize the state of the atmosphere and the earth surface. The multi-sensor capabilities at these core sites enable detailed studies of the processes in all seven areas mentioned above. Physical phenomena can be studied in relation to the surrounding environment.
- *Associate sites*, which are instrumented with the aim to measure a limited selection of components of the atmospheric and land surface system.

Table gives an overview of the core and associate sites involved. Figure 1 gives the regional spreading of the sites. The infrastructure is embedded in a larger network of data users, data suppliers and commercial companies:

- users of satellite observations
- model communities: climate, numerical weather prediction, hydrology
- small and medium enterprises
- technical research institutes

Core sites	
Place	*Country*
Cabauw	The Netherlands
Chilbolton	United Kingdom
Palaiseau	France
Lindenberg	Germany
l'Aquila	Italy
Payerne	Switzerland
Associate sites	
Rome	Italy
Valladolid	Spain
Athens	Greece
Cardington	United Kingdom
Sodankylä	Finland
Norunda	Sweden
Bonn	Germany
Oberpfaffenhofen	Germany
Jungfrauhoch	Switzerland

Table 1

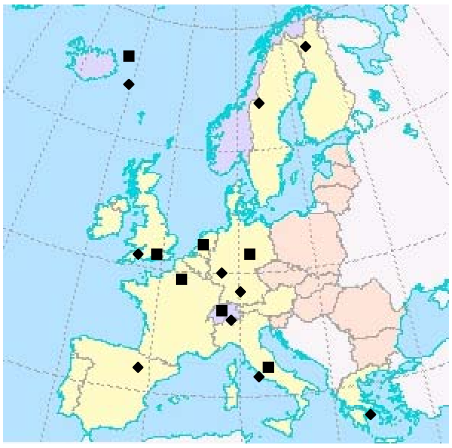


Figure 1. The sites in Eurat Observatory; squares are core sites and diamonds associate sites.

4. Example of a core site: the CESAR Observatory in The Netherlands

The Cabauw Experimental Site for Atmospheric Research consists of a 213 m tall meteorological tower, a remote sensing terrain and a field for micro-meteorological observations. In-situ measurements are done of soil hydrology, surface fluxes of wind, temperature, humidity as well as CO2, the radiation budget, rain, and aerosols. The available ground based remote sensing instruments are a scintillometer, a 1290 MHz windprofiler/Rass, a 3 GHz Doppler-polarimetric radar, a 35 GHz cloud radar, a lidar system, a spectral UV instrument and a GPS system. The Cabauw site is located 25 km South-West from De Bilt where a radiosonde is operational and a C-band Doppler weather radar covers the area around the CESAR site.

Soil hydrology
The grassland site at Cabauw has a managed water table level. This offers special opportunities to do water budget studies in cooperation with the local water management authorities.

Rain
The presence of cloud and precipitation radars at the location, the C-band weather radar at the synoptical station De Bilt and the detailed soil hydrological program gives fine opportunities to study the horizontal structure of rainfall and its impact on the hydrological balance of the region.

Land-atmosphere interaction
Cabauw has a long history of land-atmosphere monitoring. A complete set of surface flux observations is operational including all surface radiation and energy components, momentum and CO2. A continuous program of profile measurements is operational along the tower. A scintillometer is used to measure the path-averaged sensible heat flux.

Boundary layer structure
Cabauw has been the site for a number of important experiments on the structure of the convective and stable boundary layer. The tower forms a unique infrastructure for stable boundary layer observations. The wind profiler/RASS system and a lidar system gives important information on the structure of the convective boundary layer. These measurements are augmented by radiosonding at the synoptical station De Bilt, 25 km.

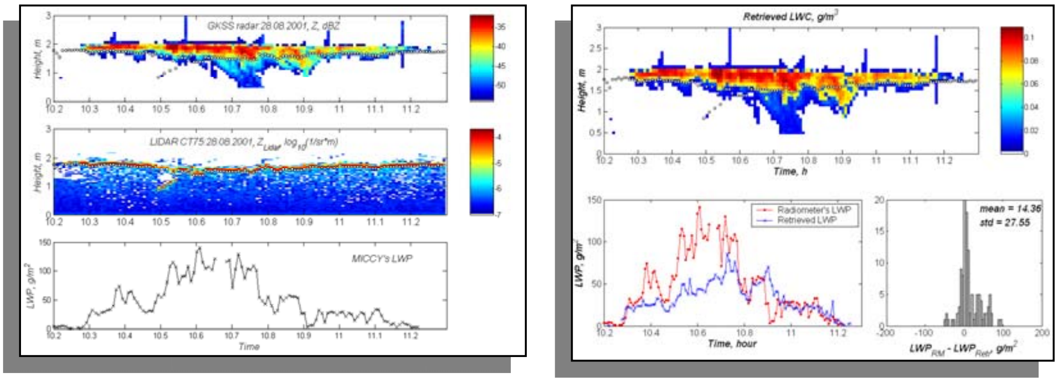
Clouds spatial and microphysical structures
The combination of cloud radars operating at different frequencies (3 and 35 GHz) and a lidar system which are operational at the site permits the application of sensor synergy to derive cloud properties which can never be retrieved by a single instrument. A number of experiments on cloud structure and radiative properties have been performed over the last years. In 2001 and 2003 Cabauw hosted the Baltex Bridge Cloud campagne.

Aerosol/water vapour vertical structure
The tools are installed to quantify the direct effect of aerosol on the radiation balance. In addition, the origin of the aerosols has been traced using state of the art atmospheric models that describe formation and outwash of aerosols in combination with their transport over Europe. The instrumentation and the tools are now in place to extend the research to a more systematic, climatological observation and analysis, and to help develop the international monitoring networks that are needed to quantify the role of aerosol in the regional (European scale) climate system. A lidar system is available that gives information on aerosols. Accurate solar radiation observations are foreseen to measure aerosol optical depths.

The radiation balance
All components of the surface radiation budget are measured. The current radiation observation program at Cabauw is currently being upgraded to the standard of the Baseline Surface Radiation Network. This will include state-of-the- art measurements of direct and diffuse solar radiation.
More information in the CESAR Observatory can be found at www.cesar-observatory.nl.

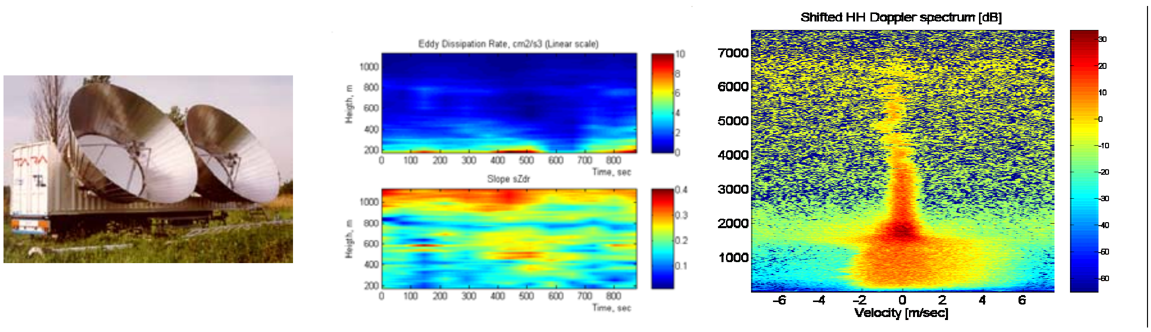
5. Examples of data

The advanced instruments at a core site enable a multitude of possibilities for atmospheric profiling. In this section we will show two examples, dealing with monitoring (long term observations) and process studies.



Example of sensor synergy

On the left panel a combined radar-lidar-microwave radiometer measurement of slightly drizzling stratocumulus is shown. By combining these instruments the internal distribution of liquid water inside the cloud can be obtained. This is not possible with any of the instruments individually. These observations were taken at the CESAR Observatory, but are also possible at other core sites in Europe. Long time series of such cloud parameters are very important for climate studies, as they are dominant in the atmospheric radiation balance. The data of this example was obtained by GKSS and University of Bonn in Germany, KNMI in The Netherlands. The analysis was done by IRCTR, The Netherlands.



Example of a radar process study of rain

The right figure is a spectrogram of stratiform rain, observed with the Doppler-polarimetric radar TARA- shown on the left. With the combination of Doppler and polarization measurement, information about the intensity of turbulence in rain can be obtained. An example is shown in the middle panel. Apart from monitoring, as shown in the first example, also in-depth studies like these are performed at the core sites. The data in this example was obtained by IRCTR, The Netherlands. The analysis was done by the Aviation University of Kiev, Ukraine.

6. Conclusion remarks

Driven by the need for reliable atmospheric data for climate studies, European research institutes are in the process of joining forces and capacity. This is materialized in setting up a network of atmospheric observatories spread over the continent. Many groups are involved, partially funded by the European Union in past and present framework programs. This is an important development, which has its international counter part in the US ARM Program. Intense cooperation between European and US partners is foreseen, which will lead to a global network of observatories. The first steps in this direction have already been taken: to set up a working group for advanced atmospheric profiling stations under the flag of the Global Energy and Water Cycle Experiment GEWEX.

7. References

Third Assesment Report Intergovernmental Panel on Climate Change, 2001, WMO-UNEP, http://www.ipcc.ch/