Influence of clouds on aerosol particle number concentrations in the middle and upper troposphere in different climatic regions

A.Weigelt[1], M. Hermann[1], F. Höpner[1], P. F. J. van Velthoven[2], C. A. M. Brenninkmeijer[3], J. Heintzenberg[1], and A. Wiedensohler[1]

[1] Leibniz Institute for Tropospheric Research, 04318, Leipzig, Germany
[2] Royal Netherlands Meteorological Institute (KNMI), 3730, AE De Bilt, Netherlands
[3] Atmospheric Chemistry Department, Max Planck Institute for Chemistry, 55128, Mainz, Germany
Contact: weigelt@tropos.de or hermann@tropos.de

http://www.caribic-atmospheric.com

MOTIVATION

Analyzing the interaction between aerosol and clouds is a major field of current research. While most studies analyze the influence of aerosol particles on clouds, only a few studies deal with the influence of clouds on aerosol particles. This study investigates statistically the influence of clouds on submicrometer particles in the upper troposphere in different climatic regions round the world.

DATASET AND METHODS

From 1997 to 2008, 125 flight sequences on four intercontinental flight routes were conducted as part of the CARIBIC project (Civil Aircraft for Regular Investigation of the Atmosphere Based on an Instrumentation Container) (Ref. 1). On these flights between Germany and the Caribbean, South America, the Maldives/ Sri Lanka, and the Philippines (Fig. 1), aerosol number concentrations were measured in two size ranges at altitudes between 8 and 12 km (nucleation mode (4 to 12 nm, N_{4-12}) and Aitken plus accumulation mode (> 12 nm, N_{12})). To check whether the analyzed air were in contact with a cloud recently, 3D kinematic 2-day backward trajectories were calculated every three minutes along the flight tracks. These trajectories were analyzed for cloud contact (Ref. 3), using ISCCP satellite pictures (Ref. 2). With the cloud contact information, a statistical analysis was carried out. To distinguish climatic regions, the data were divided into 11 different regions. Figures 2 to 8 compare the cloud-influenced concentrations of N_{4-12}, and N_{12} particles (blue) with the corresponding values without cloud contact (red) for five regions. Table 1 summarizes results of all analyzed regions.

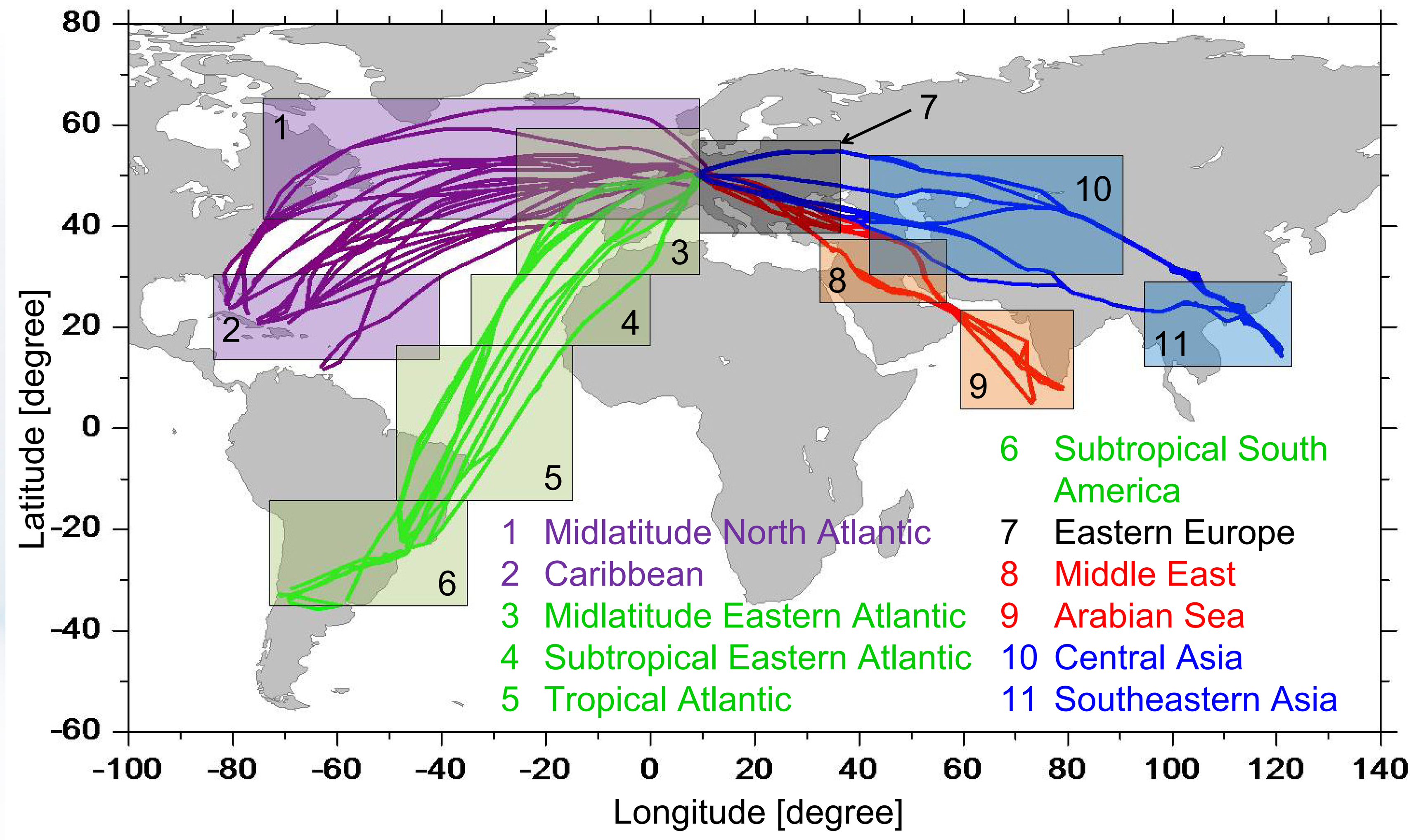
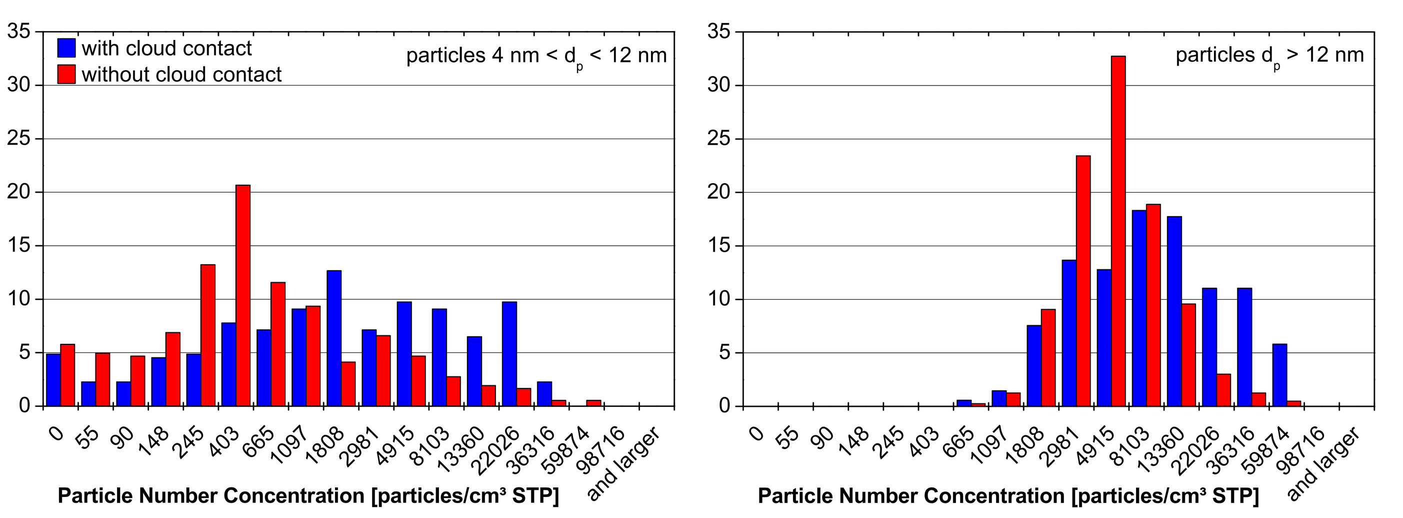


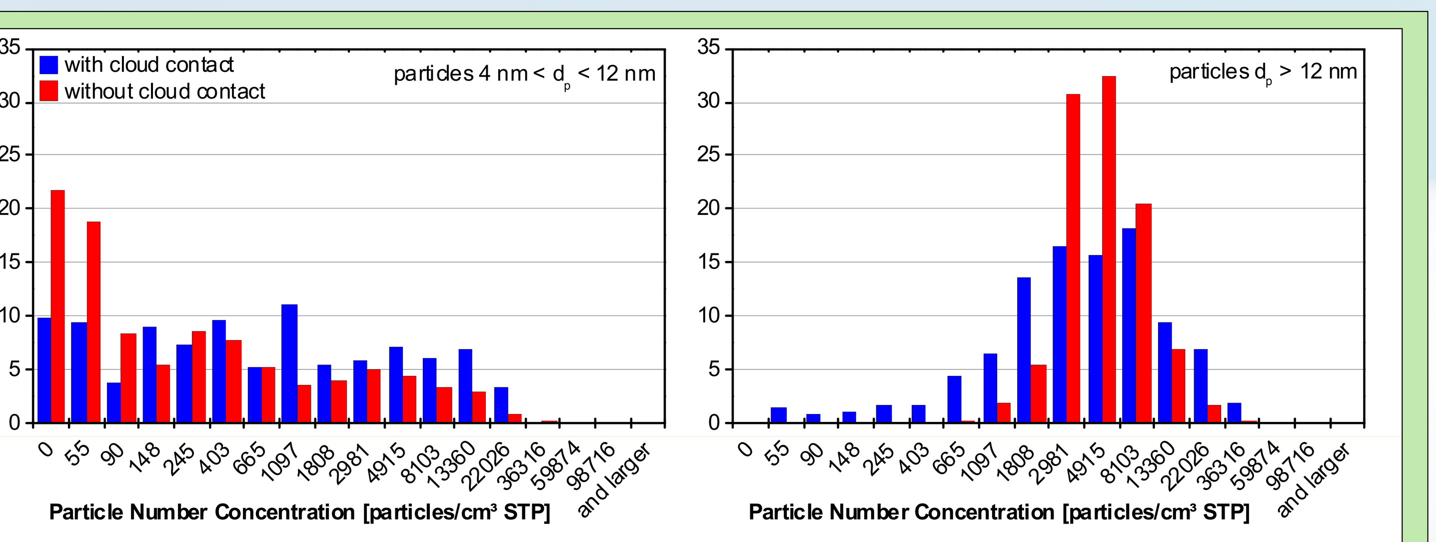
Fig. 1: *Analyzed flight routes of the CARIBIC aircraft between 1997 and 2008 to the Caribbean (purple), South America (green), the Maldives/ Sri Lanka (red), and the Philippines (blue). Data were analyzed for 11 regions.*

Fig. 2: *Normalized histograms of particle number concentrations over the Caribbean (2). Air masses (i.e. trajectories) which had a cloud contact within the last 48 hours are indicated in blue (344 cases), without cloud contact in red (397 cases).*



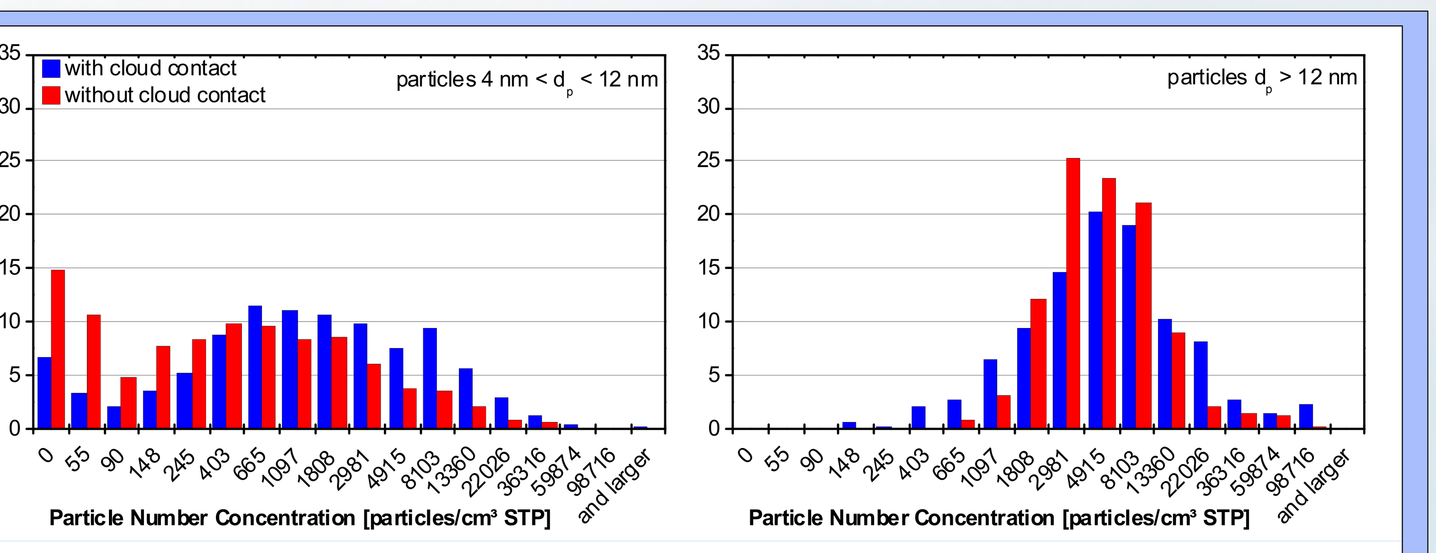
- **Cloud influenced medians ~480% (N_{4-12}) and ~78% (N_{12}) increased**

Fig. 3: *As Fig. 2, but over the Tropical Atlantic (5). In 459 cases, the air masses had a cloud contact within the last 48 hours and 705 trajectories had no cloud contact.*



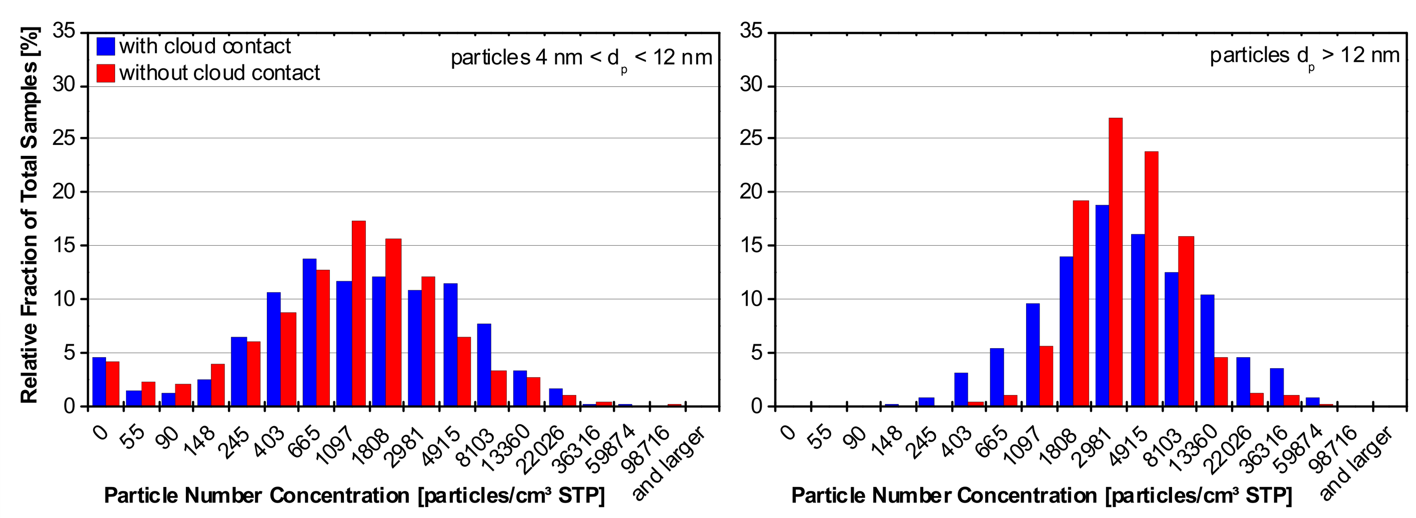
- **Cloud influenced median (N_{4-12}) ~450% increased**
- **Cloud influenced median (N_{12}) increased from -68% difference to background level within 48 h**

Fig. 4: *As Fig. 2, but over South-eastern Asia (11). In 837 cases, the air masses had a cloud contact within the last 48 hours and 1009 trajectories had no cloud contact.*



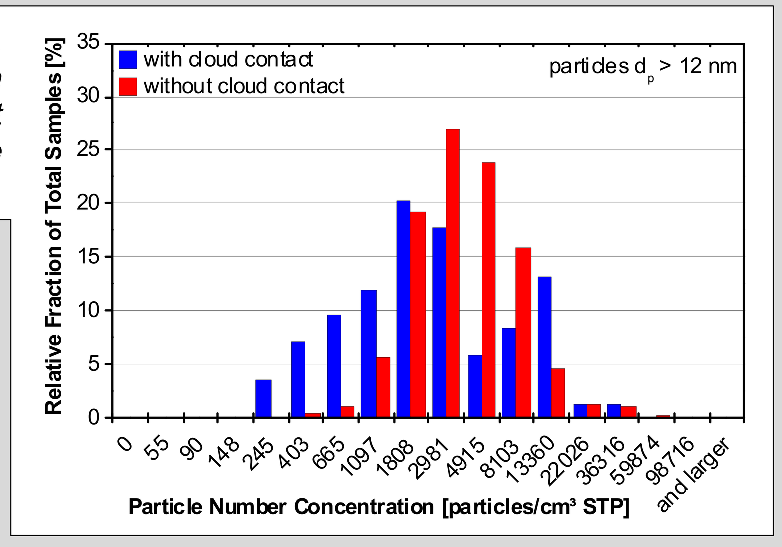
- **Cloud influenced medians ~240% (N_{4-12}) and ~18% (N_{12}) increased**

Fig. 5: *As Fig. 2, but over Eastern Europe (7). In 1079 cases, the air masses had a cloud contact within the last 48 hours and 1065 trajectories had no cloud contact.*



- **Cloud influenced medians increased from -32% (N_{4-12}), and -25% (N_{12}) difference to background level within 48 h**

Fig. 6: *As Fig. 5, but only data with a cloud contact within 3 to 5 h are shown.*



- **Bimodal structure in concentration distribution**

→ cloud as source and sink

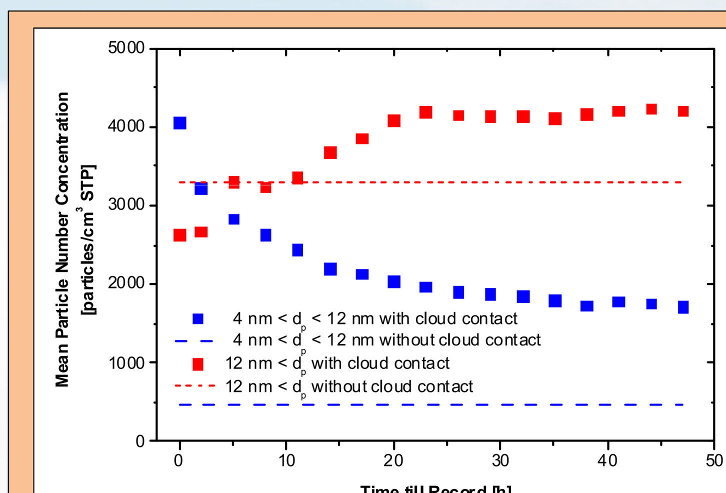


Fig. 7: *Dependency of N_{4-12} (blue) and N_{12} (red) particle number concentrations on the time between the last cloud contact and the measurement. Each point includes all values for which the last cloud contact fell into the time period indicated at the x-axis. The corresponding values, which are not influenced by clouds, are indicated as dotted and dashed line in the same color, respectively.*

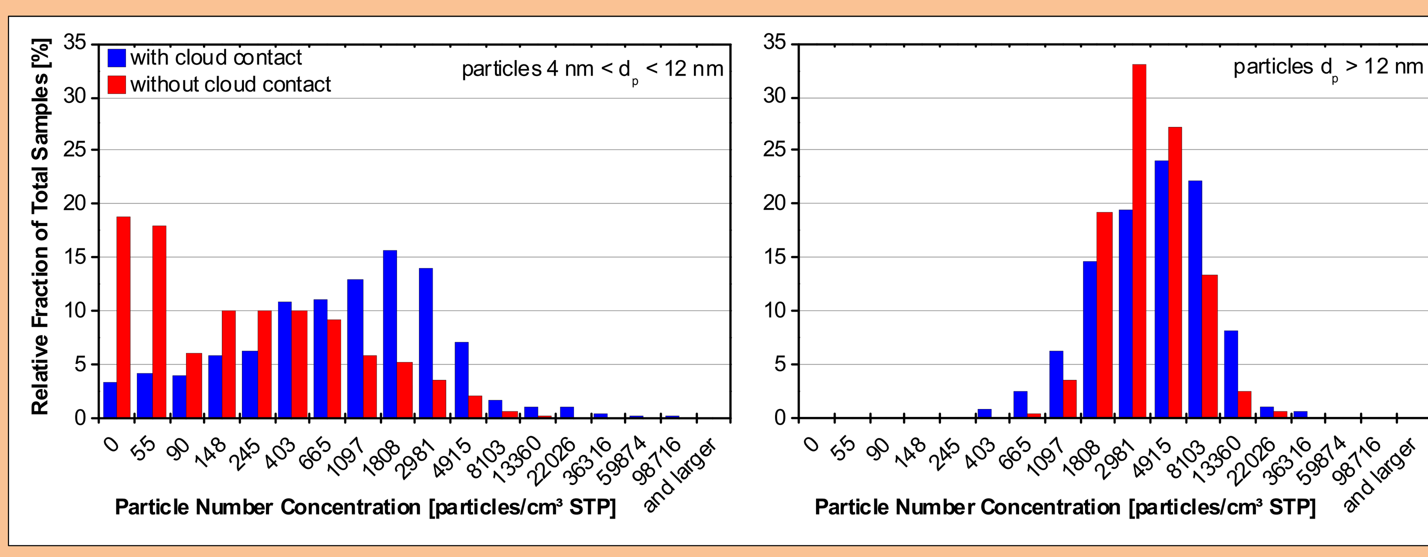


Fig. 8: *As Fig. 2, but over the Arabian Sea (9). In 1069 cases, the air masses had a cloud contact within the last 48 hours and 1416 trajectories had no cloud contact.*

- **Cloud influenced medians ~600% (N_{4-12}) and ~30% (N_{12}) increased**

Acknowledgement:

We thank LTU International Airways, Lufthansa Passage, and Lufthansa Technik for enabling CARIBIC. Furthermore we thank ISCCP, NOAA, and EUMETSAT for providing satellite pictures. CARIBIC was funded by the German Ministry for Research and Education within the AFO2000 research program (07ATF17) and by the Environmental Technologies RTD Program of the Commission of the European Communities DG XII under FW 4, 5, and 6.

References:

(1) Brenninkmeijer C.A.M., et al. (2007), Civil aircraft for the regular investigation of the atmosphere based on am instrumented container; the new CARIBIC system, *Atmos. Chem. Phys.*, 7, 4953-4976.; http://www.caribic-atmospheric.com

(2) Rossow, W. B. and Schiffer, A. (1999), Advances in Understanding Clouds From ISCCP. *Bull. Am. Meteorol. So.*, 80, 2261-2287.
(ISCCP = International Satellite Cloud Climatology Project; http://isccp.giss.nasa.gov/).

(3) Weigelt A., M. Hermann, P. F. J. van Velthoven, C. A. M. Brenninkmeijer, G. Schlaf, A. Zahn, and A. Wiedensohler (2009), Influence of clouds on aerosol particle number concentrations in the upper troposphere. *J. Geophys. Res.*, 114, D01204.

CONCLUSION

Tab. 1: Overall conclusions from all analyzed regions. On average, within 48 hours clouds do influence the particle number concentration as given in the columns.

	Geographic region (number in map in Fig. 1)	Average influence on particles 4 nm < d_p < 12 nm	Average influence on particles 12 nm < d_p
Midlatitudes	Midlatitude North Atlantic (1)	no effect	sink
	Eastern Atlantic and West-Europe (3)	source	sink*
	Eastern Europe (7)	sink*	sink*
	Central Asia (10)	sink	sink
Subtropics/Tropics	Caribbean (2)	source	indirect source
	Subtropical Eastern Atlantic (4)	source	sink*
	Middle East (8)	no effect	sink
	Tropical Atlantic (5)	source	sink*
	Arabian Sea (9)	source	indirect source**
	Southeastern Asia (11)	source	indirect source**
	Subtropical South America (6)	source	indirect source**

* increased within 48 hours to background level
** sink in first instance and indirect source by growth of nucleation mode particles

Leibniz Institute for Tropospheric Research

Physics Department, Aerosol Group