Cirrus clouds and ice supersaturated regions observed by Raman lidar and radiosondes.

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With our mobile Aerosol Raman Lidar (MARL) we have performed field campaigns in the mid latitudes in 2003 (Lindenberg/Germany, 53°N, 15°E) and in the tropics in 2004/05 (Paramaribo/Suriname, 6°N, 55°W). The lidar system detects aerosols and clouds in the UTLS region. It is capable of detecting thin cirrus including extremely thin clouds with optical depth below 10-3. The system measures cloud altitudes with high vertical and temporal resolution and determines the depolarisation and optical depth. It operates day and night. During daytime cloud types including contrails are classified with the help of a video camera. During the campaigns, water vapour was measured by means of balloon borne sondes (Vaisala RS80/RS90, 'Snow white' frost point hygrometer) and by the LIDAR using the Raman technique. We investigated the occurrence of ice supersaturated regions and their relation to the occurrence of clouds. The accuracy of the water vapour measurements needs to be critically evaluated for this purpose. The cloudiness in the upper troposphere was found to be very high in the tropics where in about 90% of all measured profiles cirrus was present. In the mid latitudes cirrus were found in 55% of the measurements.

Mid latitudes

According to the radiosonde data, ice supersaturated regions (ISSRs) occur most often between 6 and 9 km altitude. In about 25% of all radiosoundings ISSRs were detected. However these were most often very thin layers, so in total only 4% of the upper troposphere (h> 6 km) was supersaturated with respect to ice. The lidar detected only in a few cases ice particles in these layers. On the other hand, cirrus clouds were frequently detected in the upper troposphere above 9 km. About 35% of these clouds were subvisible. They occurred regularly during stable high pressure regimes, which were predominant during the exceptionally hot and sunny summer 2003. More than 60% of the contrails that were identified with a CCD camera,

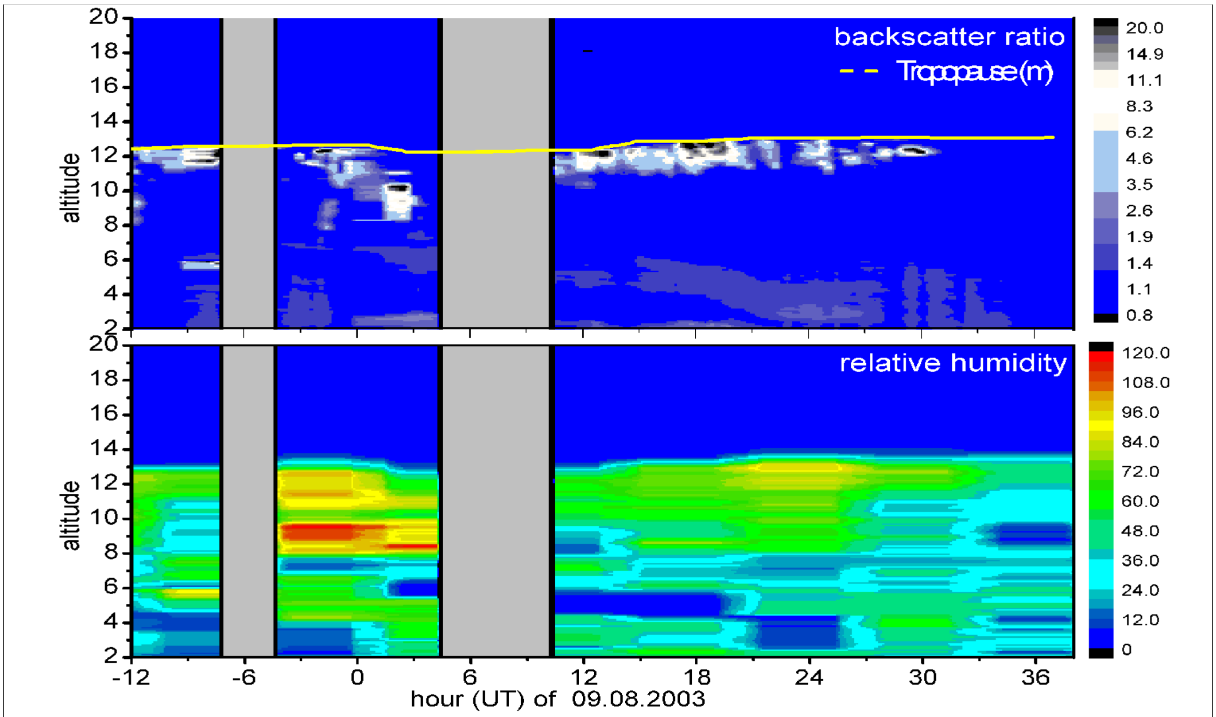

Figure 1: Measuerment of cirrus clouds by a lidar (upper panel) and water vapour by radiosondes (lower panel) form 08.08.03 12:00 UT to 10.08.03, 14:00 UT at Lindenberg.

were embedded in thin or subvisual cirrus. Cirrus occurrence is correlated to high humidity as shown in fig.1. However, according to the radiosonde data, saturation is generally not reached. This is most likely due to a dry bias of the radiosonde data. This bias is found when comparing humidity measured by the radiosonde with the results from the Raman lidar. Accordingly, there is a significant dry bias of the RS80 at temperatures below 230 K . A precise determination of the conditions at which subvisible cirrus and contrails form, require more precise water vapour measurements than currently available.

Tropics

During the STAR pilot study from 20 Sept to 15 Nov 2004 numerous measurements were made by the same lidar in Paramaribo. Cirrus were present in almost 90% of all cases. Compared to the midlatitudes, the frequency of subvisible cirrus is enhanced in the tropics. Often subvisible cirrus occur at the cold point tropopause (CPT). We define the tropical tropopause layer (TTL) as the region between the CPT and an upper tropospheric inversion (UTI) which frequently occurs about 2-3 km below the CPT. We investigated the occurrence of cirrus in the TTL with a trajectory model which was recently developed at the AWI (Tegtmeier et al., 2004). This model derives vertical transport from diabatic heating rates rates which were calculated with a radiative transfer model. Further, we derive the relative humidity from the backward trajectories by assuming that the air is dehydrated to saturation vapour pressure when supersaturation occurs upon adiabatic cooling. The cirrus occurrence determined with the lidar as well as the relative humidity measured by the Snow White frost point hygrometer agree amazingly well with the model output. We conclude that vertical transport in the TTL is determined mainly by diabatic heating. Also, the cirrus in the TTL dehydrate the air efficiently. The humidity of air entering the stratosphere is therefore determined by the saturation vapour pressure at the coldest point of the trajectory of an air parcel. This result is in good agreement with the results obtained by Fuelistaler et al. (2005). However it remains an open question, why cirrus can form so easily and does not seem to require high supersaturations. The results are discussed in detail by Immler et al., 2005.

References:

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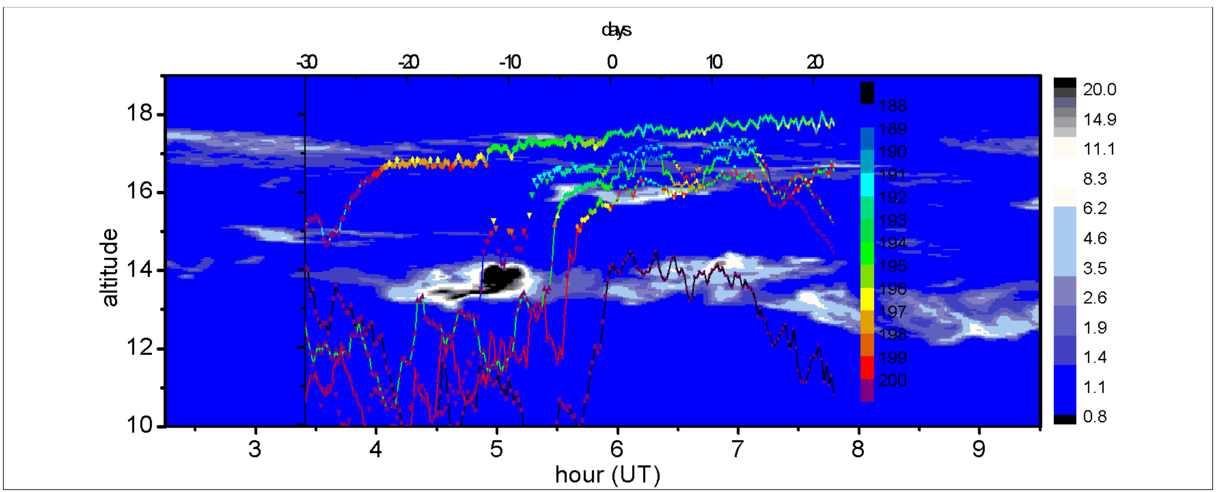

Figure 2: Cirrus measurement by lidar in Paramaribo from 02.10.2004 and trajectories calculated for 06:00 UT by the AWI trjectory model. Colour coded is the Temperature in K.