5. Weekly report – MARIA S MERIAN - MSM89 09. – 17.02.2020

Understanding clouds, rain, weather and climate

Clouds are one of the greatest uncertainties when it comes to predicting the extent of global warming by the end of the century. Cumulus clouds in lower layers of the atmosphere reflect the energy of sunlight and thus cool the Earth's surface. This type of cloud covers large areas of the Earth, especially in the trade wind regions of the oceans. The cloud team on the Maria S. Merian, consisting of researchers from the Institutes of Physics and Meteorology at the University of Hohenheim, the Max Planck Institute for Dynamics and Self-Organization (Göttingen, MPIDS) and the Institute of Geophysics and Meteorology at the University of Cologne, are investigating the dynamics of clouds in collaboration with the Max Planck Institutes for Chemistry (Mainz, MPIC) and Meteorology (Hamburg, MPIM). An important goal is to better understand how the cloud cover changes with climate change. The team is part of the large-scale, almost six-week field study EUREC4A (Elucidating the role of clouds-circulation coupling in climate, www.eurec4a.eu). This measurement campaign is taking place in the trade wind region off the Caribbean island of Barbados, as the tropics are particularly rich in low cumulus clouds, which have a strong influence on the climate. Several research aircraft and ships as well as satellites, a measuring station on Barbados, a mobile weather radar and autonomous gliders are involved in the measurements. Several remote sensing instruments are also installed on Maria S. Merian. These include the cloud radar of the University of Cologne and lidars of the University of Hohenheim, one of which is particularly high-resolution. The data from these instruments will be compared with in-situ measurements carried out with the Max Planck CloudKite (balloon kite) of the Max Planck Institute in Göttingen.

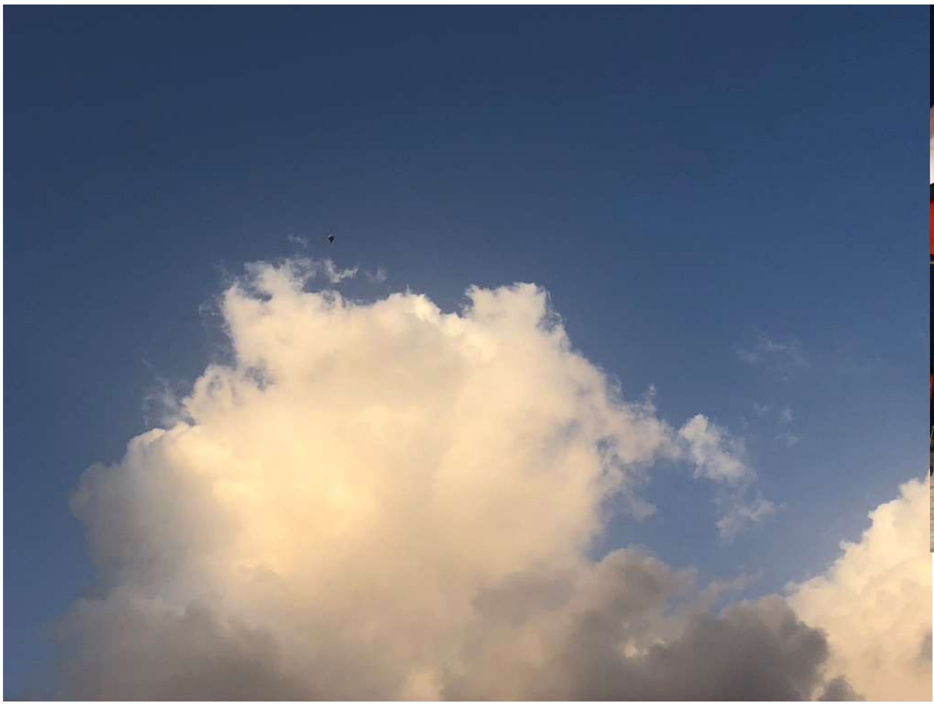

Figure1) February 10, 2020 6:35 am: A rain cloud has passed Maria S. Merian and the Max Planck CloudKite - followed by another cloud just behind it (see Figure 4). Insertion: Max-Planck CloudKite: a 15m long, 10m high and 10m wide combination of helium balloon and kite. The measuring instruments are fixed in front of the keel.

The weather in the trade wind region is relatively predictable. Every day from sunrise the temperature rises and falls again at sunset. At the same time, a lot of water evaporates into the atmosphere which causes clouds to form and rain. Cloud droplets, and thus clouds, are formed when water vapor condenses on aerosols (i.e. the smallest dust particles). An example of the size distribution of aerosols measured with the Max Planck CloudKite on 14.2.2020, 22:35 in the evening, 900m above the ship is given in Figure 2A. Figure 2B shows the measured size distribution of the cloud droplets for the cloud from Figure 1.

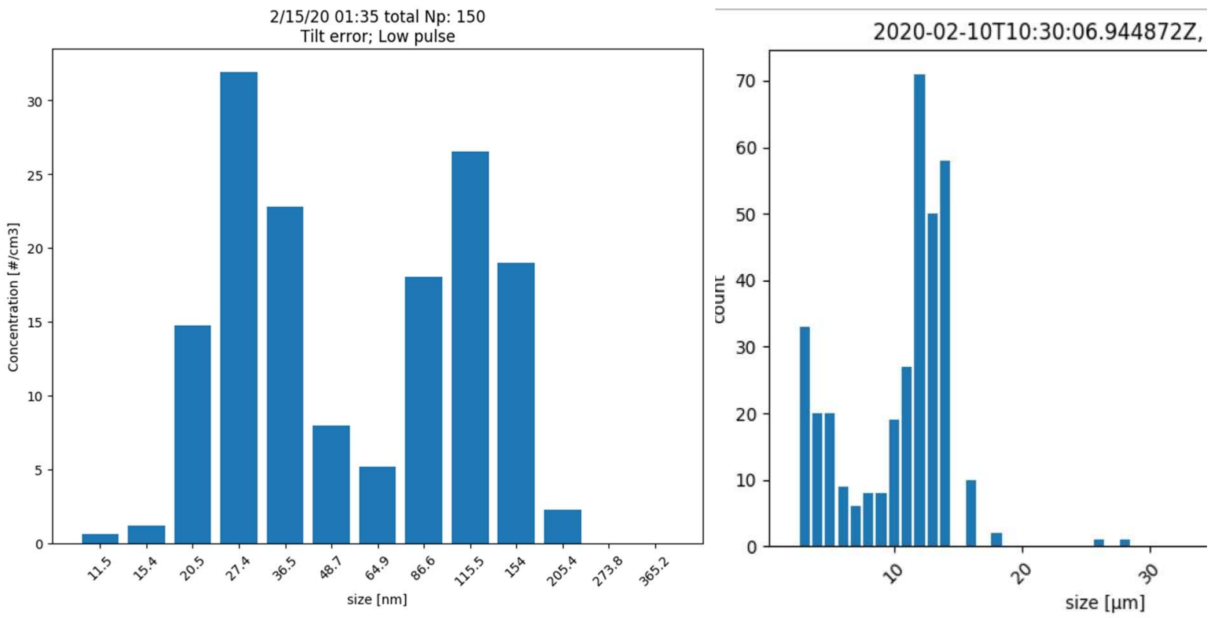

Figure 2) Left the size distribution of the measured aerosols from 11 to 250 nanometers (MPI Chemistry/MPIDS). Right the size distribution of the measured cloud droplets of the cloud in figure 1) from 5 to 30 micrometers (MPIDS). Both were recorded by the Max Planck CloudKite at about 900m above sea level.

At the same time, the Max Planck CloudKite can record cloud droplets as a 3D hologram at 75 frames per second. These holograms help to understand when and how quickly the smallest droplets become big ones. The researchers can measure the position and size of the droplets in a volume of cloud air that is approximately the diameter of a thumb and the length of an envelope. Another high-speed camera is used to measure the speed of the drops. To do this, the cloud volume is illuminated with a fan of light from a powerful laser. The speed is obtained by shifting the drops from one image to the next (see Figure 3). If the researchers do not know the local and global meteorological background, the movement of the drops alone will not help them. Therefor they measure the local meteorological background, such as wind speed, air pressure, temperature and humidity with additional instruments at the Max Planck CloudKite.

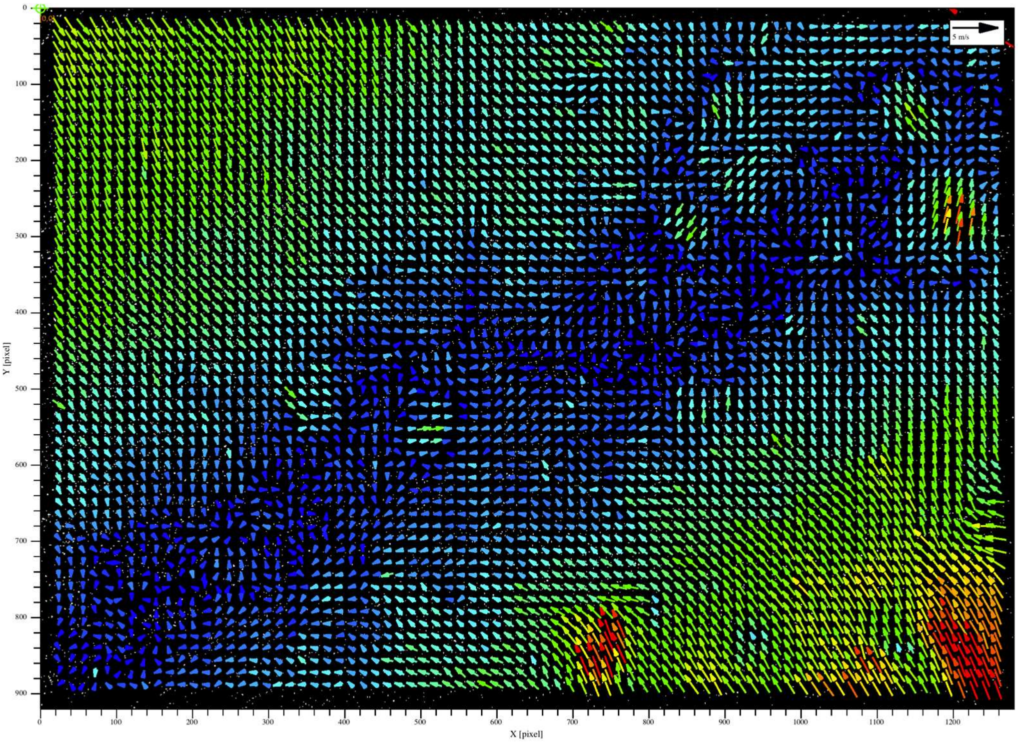

Figure3) Velocity of cloud droplets relative to the mean flow(10m/s) measured on 12.2.2020 900m above sea level. Blue 0 m/s, green 2 m/s, red 4m/s (MPIDS).

The global meteorological background is as important for understanding clouds as the local one. For this purpose, a cloud radar is operated on the Maria S. Merian by researchers from the University of Cologne, which looks vertically upwards and, via the backscatter of the radar beams, provides information about the water content of the cloud, the size of the cloud droplets and the local air speed. A special feature of the radar is that it always looks vertically upwards, even when the ship is swinging with the waves. Figure 4 shows the backscatter and the water content above the radar (i.e. the ship).

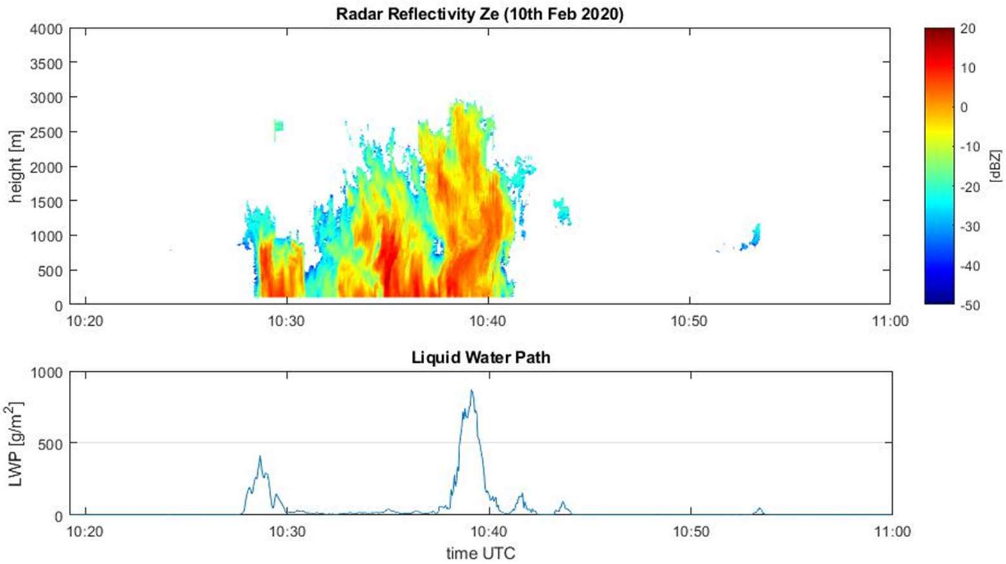

Figure 4) The backscatter and the liquid water content as a function of time. The backscatter is particularly high in areas of precipitation (red). Since the CloudKite flies behind the ship, the arrival of the cloud is somewhat delayed. Figure 1) shows the first cloud (at 10:30 UTC, 6:30 local time) from behind.

In order to gain further insight into the global meteorological background, the University of Hohenheim has deployed three lidar measurement systems on board the R/V Maria S Merian. A lidar is a remote observation system (similar to radar) that emits laser light into the atmosphere. The particles and molecules in the atmosphere (dust, gases, etc.) reflect the light back to a telescope which collects all the light. The first lidar from the University of Hohenheim, ARTHUS (Atmospheric Raman Temperature and Humidity Sounder), enables the measurement of the temperature and humidity of the atmosphere. ARTHUS is an extraordinary tool for observations in the atmospheric boundary layer during day and night with a very high time resolution (10s). The other two Doppler lidars measure wind speed.

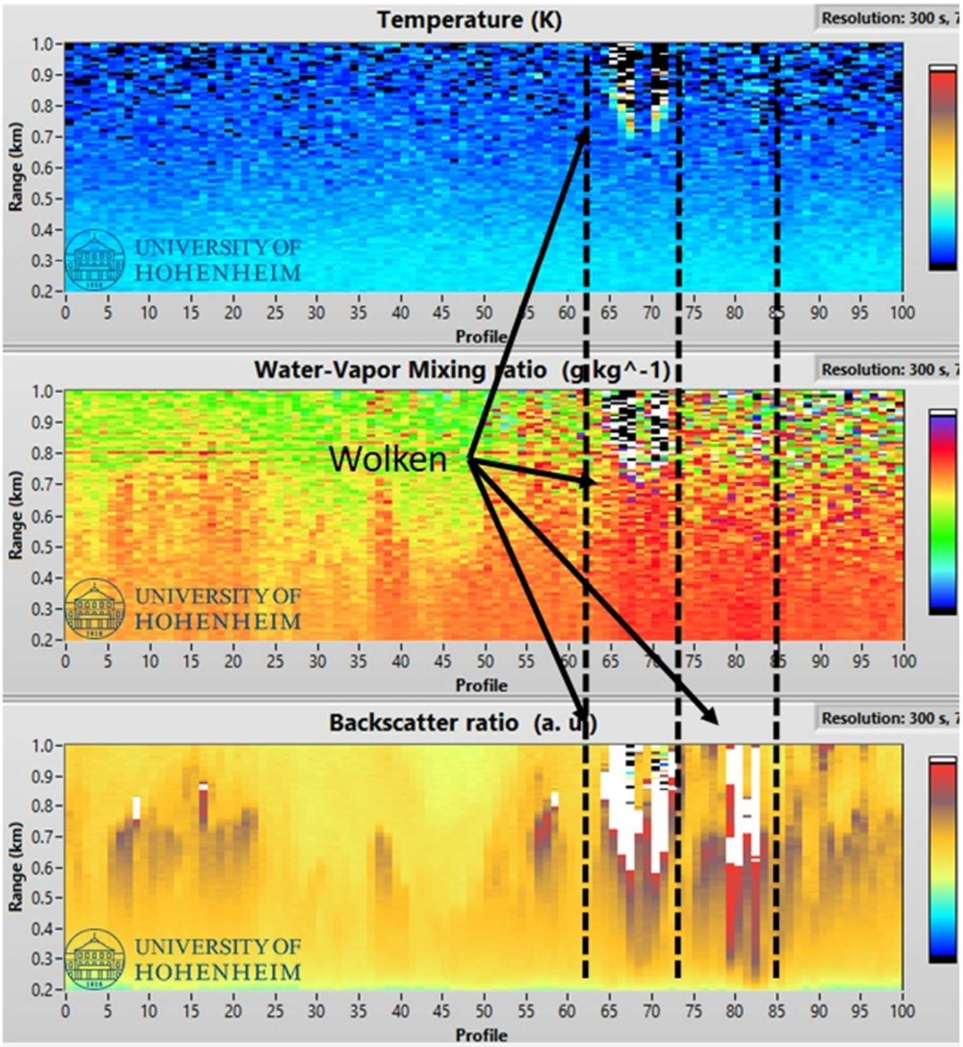

Figure 5) Temperature, humidity and aerosol backscatter as a function of time measured with ARTHUS from 5:45 to 6:45 local time on 10 February 2020

Thanks to these lidars, the radar and the CloudKite, it is possible to study the influence of the ocean on the atmosphere through variations in temperature, humidity and wind with unprecedented precision. The results obtained so far by Maria S. Merian promise a deeper understanding of atmospheric processes and a validation or improvement of weather, climate and earth system models.

Greetings from,

Chief-scientist (Dr. Gaute Lavik, MPI for Marine Microbiology, Bremen) and all members of the MSM89 campaign