Martian CO2 cloud formation as observed by MCS and radio occultation. Ananya Krishnan 1, 2 and Özgür Karatekin1. 1Royal Observatory of Belgium, Uccle, Belgium, 2Université Catholique de Louvain, Louvain-la-Neuve, Belgium.

Introduction: Clouds are a common feature on Mars. Martian clouds are mostly formed by ice crystals at an altitude of about 40 km. However, rarely we also observe Carbon dioxide (CO2) clouds which require very low temperature conditions to form. The CO2 clouds were first observed on polar nights at low altitude. Later, similar clouds were discovered at higher altitudes near the equator, primarily in the spring and summer seasons [1]. Further observations indicated their presence at northern mid-latitudes and in southern hemisphere in corresponding late autumn seasons. These clouds can have a variety of different forms, but most of them are cirrus-type, but some cumuliform clouds can also be observed, as a result of a mesospheric convection. CO2 clouds are unique in the sense that they are formed from major component of atmosphere unlike water vapor which is a minor component. CO2 polar clouds are convective clouds. Observations from various missions indicate that temperature profiles in the polar regions often follow the CO2 saturation curve up to 30 km, suggesting temperatures are buffered by CO2 condensation. Substantial cloud opacity between 0-25 km altitudes further confirm CO2 cloud formation. The Pathfinder mission observed that during equatorial descents, CO2 exceed saturation conditions around altitudes of 80 km [2]. This suggests that CO2 cloud formation in these regions could occur at significantly higher altitudes than in polar areas. The formation of equatorial CO2 clouds is also influenced by Martian mesospheric conditions. Martian mesospheric temperatures can fall well below the CO2 condensation point, particularly in the near-aphelion season when diurnal tides may cool CO2 down to ice cloud formation levels. Furthermore, two CO2 clouds were also detected at a solar longitude between 264° and 330° [3]. These clouds were detected above 90 km and are quite small, as their size are confined horizontally to 500 to 700 km.

Goal of the study: In this study investigate Martian CO2 cloud formations and its duration during the Northern hemisphere winter and dust season. For this we use the open access data from Mars Climate Sounder (MCS) on board Mars Reconnaissance Orbiter (MRO) as well as Mars Express (MEX) and Mars Atmosphere and Volatile EvolutionN (MAVEN) radio occultation (RO) to detect clouds in the atmosphere. We also explore the inter annual variations to see the impact of dust storms on CO2 cloud formation.

Methodology: To detect the clouds we use the CO2 saturation temperature on Mars. The temperature at which CO2 turns into a liquid or solid, considering the effect of supersaturation. When the temperature goes below the saturation temperature, the atmosphere cannot hold the excessive CO2 and so phase change occurs initiating the cloud formation, as shown in Figure 1. This can further lead to condensation of CO2, resulting in the formation of CO2 ice on the surface. This phenomenon can be inferred from the temperature vs pressure (or altitude) graphs as shown in Figure 1.

Figure 1: Formation of CO2 clouds in Martian atmosphere [4].

In this we use the temperature profiles obtained from MCS and radio occultation (RO) measurements from MEX and MAVEN. MCS “in track limb staring” mode measures vertical profiles of temperature, pressure, aerosols and water vapor by looking tangentially through the atmosphere. Whereas RO measures the doppler shifts in the radio link between the satellite and the ground state as the satellite occult behind the planet. This measured doppler shifts are later processed using the in-house ROB - RO analysis software to obtain the vertical temperature and pressure profiles [5].

Figure 2: Examples of MCS temperatures profiles (blue) with the CO2 saturation curve [6].

Summary: The data covering three different Martian Years 34 – 36, during winter in the northern hemisphere and dust storm season are analyzed. Typical results are shown on Figure 2 corresponding to presence of clouds and precipitation. The analysis included over 1 million
profiles. For the selected period, the highest concentration of clouds occurred at latitudes above 50°N, correlating with the winter season in the Martian North Pole. The equatorial region also showed mesospheric cloud formation. There were also some cloud detections in the Southern Hemisphere (see Figure 3). The clouds at the North Pole persist longer compared to those near the equator. The impact of dust storms on cloud coverage is also shown, associated with the changes in temperature.

Figure 3: Distribution of detected clouds. Each point corresponds to one profile [6].

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