7.12 AEROSOL-CLOUD INTERACTIONS IN THE -UNITED ARAB EMIRATES

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1. INTRODUCTION

The Arabian Peninsula and the United Arab Emirates (UAE) in particular is a rainfall deficient region of the world. Few studies have been conducted in this region that relate to cloud processes and atmospheric chemistry and composition. A project was initiated in 2001 to study precipitation processes and aerosol-cloud interactions in clouds over the United Arab Emirates. Two intensive aircraft campaigns were undertaken in 2001 and 2002 during winter (January-March) and summer (June-September).

Emissions into the atmosphere in the United Arab Emirates were thought to be mostly aeolian desert dust that are considered to be inefficient cloud condensation nuclei.

Emissions of crustal Aeolian dust material, often termed mineral dust, are caused primarily by surface winds acting on dry soils where vegetation cover is or has become scarce (Tegen and Fung 1995). The term mineral dust refers to a large range of species that are highly variable in their chemical composition.

Climate effects due to mineral dust are complex and diverse, ranging from heating of the atmosphere in some parts of the world to a net cooling in other parts.

Industrial activities in the UAE are a large source of nucleation and accumulation mode sulphate type aerosols (Nucleation mode aerosols are those smaller than 0.1 micron not measurable by the PCASP while accumulation mode aerosols are those larger in the PCASP range but less than 1 micron).

Water-soluble aerosol particles in the atmosphere consist mostly of sulphate derived from anthropogenic activities. Anthropogenic sulphate in the atmosphere is produced mostly through gas-to-particle conversion of SO_2 emitted from fossil fuel combustion and metal smelting (Charlson *et al.,* 1992). Determining SO_2 emissions in a specific region is important in understanding their impacts on clouds through their CCN activity and subsequently their formation of droplets and precipitation.

Sulphates have the greatest potential to contribute to global aerosol forcing due to the fact that sulphate aerosols are smaller than dust and sea salt aerosols and thus have a longer lifetime in the atmosphere (tens of days) and through their impacts as CCN on clouds (indirect effect).

The data presented in this paper to study the distribution of atmospheric pollutants and their effects on clouds in the UAE were collected using airborne measurements, obtained from the King Air aircraft during the summer 2001 campaign.

2. MEASUREMENTS

An array of research instrumentation was installed in the King Air, and included: FSSP (SPP DMT modified), PCASP, PMS-2DC, PMS-2DP, King LWC, University of Wyoming Cloud Condensation Nuclei (CCN), Condensation Nuclei Counter (CN) for particle and cloud physics measurements. For trace gas measurements, SO_2, O_3 and NO_y analyzers were utilized

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3. OVERVIEW

SO_2 emissions in a specific region result in higher concentrations of sulfate particles that have important impacts on clouds, CCN activity and subsequent formation of droplets and precipitation. Pollutants have been shown to be concentrated around specific sources located in the UAE. SO_2 concentrations are highest in region of industrial activity and oil related industries. The highest average concentrations of SO_2 were concentrated around the Habshan industrial area in the southwestern UAE and the oil industries in the Arabian Gulf near Das and Zirku Islands (Figure 1).

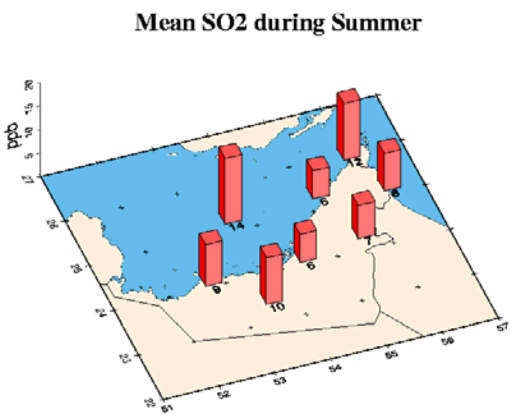

Figure 1. Average vertical column SO2 concentrations for seven regions in the UAE during summer 2001.

It is important to assess the fraction of nucleation and accumulation mode aerosols that act as CCN. Figure 2 displays the average vertical column CCN concentrations at 0.3 supersaturation (SS) over the UAE. The CCN concentrations in the summer time vary between 300 and 600 cm^{-3}. These concentrations are representative of a continental environment.

The measurements are still unclear in determining if large CCN exist, because they may increase the efficiency of the precipitation process. In particular, if desert dust is coated with sulphates, the resultant particles may play an important role in the formation of precipitation in clouds. Future detailed analysis should address this issue.

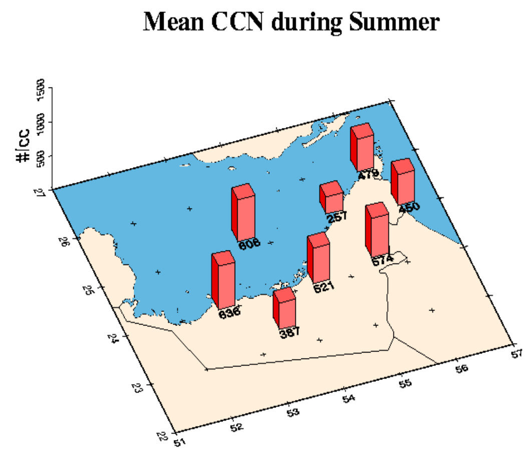

Figure 2. Vertical column average CCN concentration in cm^{-3}

4. Case study

A specific example of aerosol and cloud microphysical measurements is shown in figure 3. This flight was made on August 4th 2002. A storm developed over the Habshan oil fields, and provided an opportunity to study the interaction between aerosol and cloud properties in a polluted environment.

The data shown in figure 3 was collected during two penetrations near cloud base. Cloud base altitude was 3200 meters with a temperature of 13°C.

The first panel on Figure 3 shows altitude vs. condensation nuclei counts, The concentration of nucleation mode aerosols as measured by the CNC below cloud base was ~1430cm^{-3}. The second panel shows aerosol concentrations measured by the PCASP and cloud droplet concentrations measured by the SPP (FSSP). Aerosol concentrations outside of cloud were 500-800 cm^{-3}. The average cloud droplet concentrations for both penetrations were around 720cm^{-3}. The third panel in figure 3 shows the liquid water content as measured by the KLWC (maximum lwc of 0.8 g/m^3) vs. the SO_2 concentrations (~10 ppb).

Figure 4 shows the CCN spectra plotted in the form of the Twomey relationship ($N=CS^k$) for the study case (August 4, 2002). This data was collected below an active convective cloud base, south west of the Habshan oil

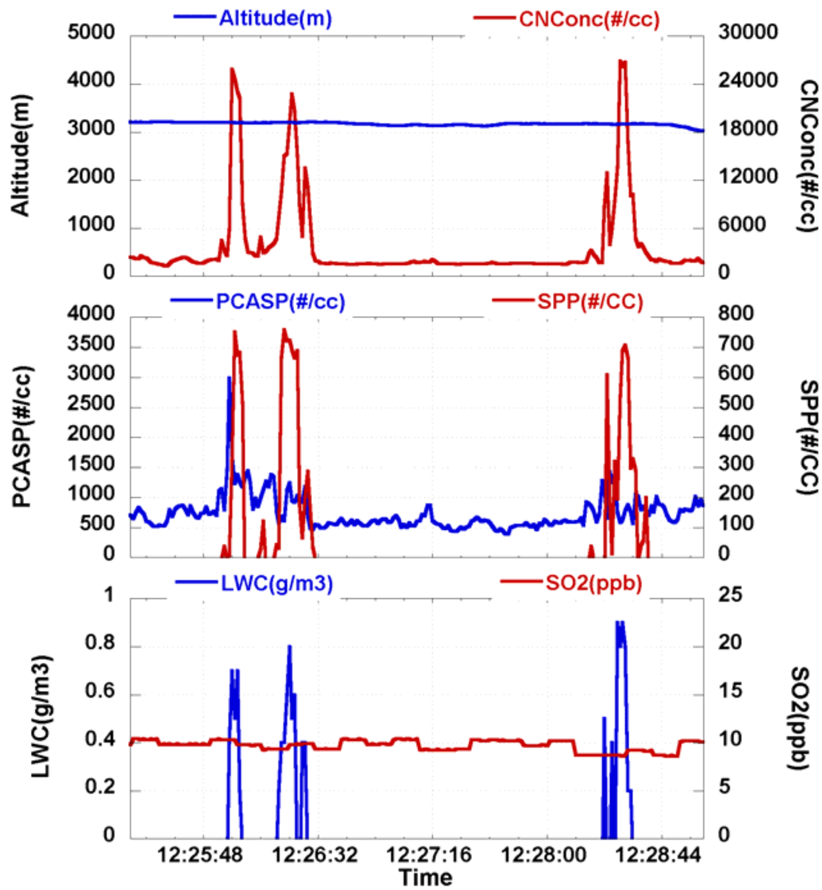

Figure 3. Aerosol and Cloud microphysical measurements on August 4th 2002 in a cloud near Habshan oil field.

field. According to Cooper et al. (1997) this values of slope k (0.4) and C (~800) represent moderate continental type of clouds. The occurrence of clouds in the UAE in the summer months is confined to the mountainous regions in the eastern UAE and Oman. During the summer months the region is under the influence of upper level easterly flow that provides moisture from the Arabian sea and Indian ocean as indicated in Figure 5 where backward air trajectories were calculated for 3 days for the August 4th case at 500, 100 and 1500 meters AGL ending near the Habshan oil field.

Cloud droplet and aerosol distributions in and below cloud base are shown in Figure 6. The spectra combines the measurements from the PCASP and FSSP probes. The cloud was penetrated at about 300 m above cloud base.

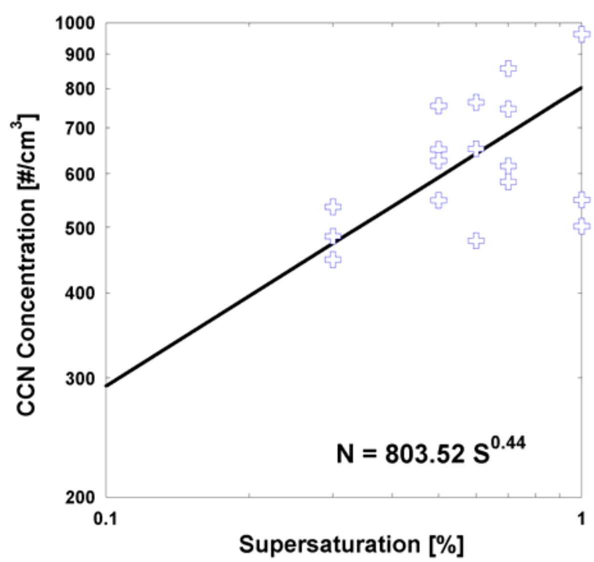

Figure 4. CCN spectra below cloud base for the August 4th case.

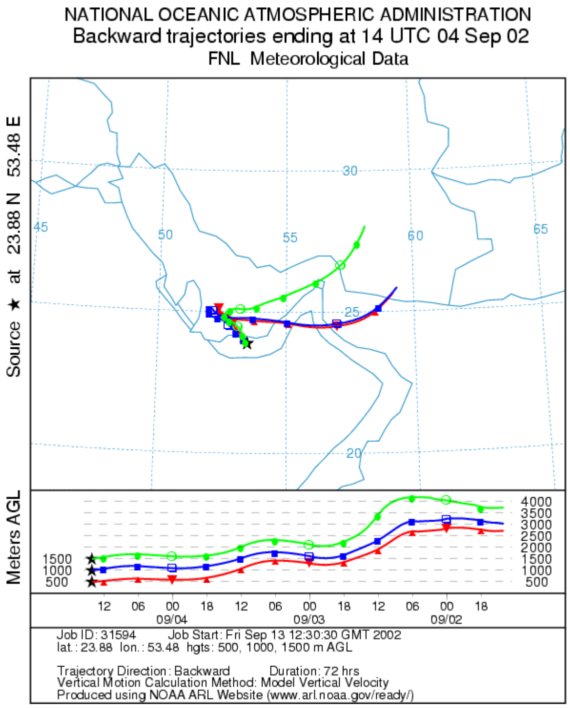

Figure 5. Air trajectories for 3 days, ending near Habshan oil field for August 4, 2002.

The cloud droplet distribution represents a 5 seconds average around the peak droplet concentrations with a total concentration of 720 #/cm^3, a Mean Volume Diameter (MVD) and Effective Radius (ER) of 9.5 and 5.14µm respectively, a LWC of 0.4 g/m^3 and a standard deviation (σ) of 2.8, a mean diameter of 8.6µm and a dispersion of 0.3.

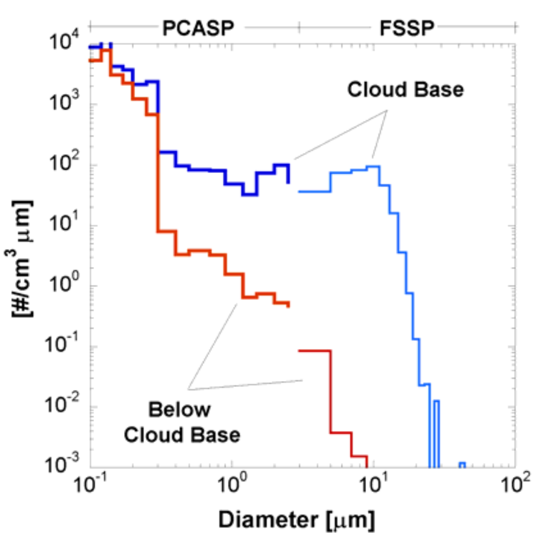

Figure 6. Cloud droplet and aerosol number distributions below and at cloud base.

The aerosol size distribution below cloud base shown in Figure 6 represents a one minute average spectra below cloud base with a total PCASP average concentration of 526 #/cm^3. These aerosols measured by the PCASP are representative of continental type conditions. The FSSP size distribution shows a broader droplet spectra extending to sizes larger than 40µm.

5. Conclusions

This case represents a fairly typical convective summer time type of cloud. It is generally continental in nature with the cloud droplet concentrations approximately equal to CCN concentration measured at 0.5 to 0.7% S.S. However, FSSP measurements near cloud base over the summer season shows considerable variability in FSSP concentrations as well as in CCN. Further analysis should be concentrated in understanding this variability.

Although this is a typical convective type of cloud, the storm developed in an area, where convection rarely occurs. Most of the convection in the UAE in the summer time is concentrated in the Eastern part of the country where the Oman Mountains are located.
The data indicates that background levels of CCN are enhanced due to local pollution sources in the region and this translated in higher cloud droplet concentrations.

The environment in which the storm developed had high concentrations of CCN that is reflected in the cloud droplet concentrations. The background aerosol distribution show that large particles (1µm) are been entrained in to the cloud, this particles could be a combination of sulphate particles from pollution and NaCl from the oceans that are acting as very efficient CCN.
Further analysis will be presented at the conference.

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