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THE CHEMISTRY AND ROLE OF CLOUD CONDENSATION NUCLEI IN THE AMAZON BASIN

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INTRODUCTION

Although the importance of cloud condensation nuclei (CCN) for cloud formation and the subsequent effects on hydrology and climate has long been recognized, measurements of CCN in the tropics, where this vital subset of aerosol probably exerts its greatest impact, have largely been neglected. Only two publications are known to have presented results of CCN in tropical continental regions. Aircraft measurements of CCN over various regions of Africa, Australia and North America showed no significant intercontinental variations in the median CCN spectrum (Twomey and Wojciechowski, 1969). In the Ivory Coast, Africa, a seasonal variation of the CCN spectrum was observed (Désalmand, 1985), but no information on CCN concentrations (N_{CCN}) or their relationship to other aerosol measurements was presented. With only two limited data sets, the properties and roles of CCN remain unclear, as the interaction of CCN in the Amazon Basin is part of a complex system that involves cloud microphysics and aerosol chemistry. We will discuss the results of CCN measurements, in light of other aerosol measurements, and provide insight of their fundamental role in the Amazon Basin and the chemical and physical properties that enable activation and subsequent growth into cloud droplets.

EXPERIMENTAL

The measurements were performed during several field campaigns during 1998 and 1999 as part of the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). Sampling occurred at ground-based sites in the states of Amazonas and Rondônia, Brazil. Airborne measurements of N_{CCN} were taken throughout the Amazon Basin during the 1999 dry season. CCN measurements between 0.15% and 1.5% supersaturation (S_c) were performed using static thermal gradient CCN chambers. The CCN instruments were equipped with a photodiode laser and digital camera to directly determine N_{CCN} from image processing and the calibrated illuminated volume.

Number concentrations of $CCN_{1.0}$ (at 1% S_c) during the wet season averaged 267 cm^{-3} with only few measurements (less than 1%) above 600 cm^{-3}. The mean CCN spectrum is summarized in Table 1.

S_c (%)	0.15	0.30	0.60	1.00	1.50
N_{CCN} (cm^{-3})	33 ± 24	101 ± 60	182 ± 92	267 ± 132	320 ± 164
$f_{CCN/CN}$	0.08 ± 0.05	0.26 ± 0.12	0.50 ± 0.17	0.71 ± 0.20	0.86 ± 0.20

Table 1. Average wet season CCN spectrum and ratio of CCN to total aerosol concentration ($f_{CCN/CN}$).

These results show a stronger resemblance to previous CCN measurements over the ocean than those in continental regimes. Low N_{CCN} supports the observations of the warm precipitating clouds in the Amazon Basin, where mesoscale convective systems contribute to most of the rainfall during the wet season (Mohr *et al.*, 1999). These systems exhibit a less-developed cloud structure normally associated with oceanic distributions.

Modification of cloud properties, such as cloud thickness (Pincus and Baker, 1994) and albedo, cloud fraction and lifetime (Albrect, 1989), is most sensitive at low N_{CCN}. Hence, changes in N_{CCN} through biomass burning and anthropogenic activity could have a greater impact in the Amazon Basin than other continental regimes. Recent measurements in Rondônia showed a distinct difference in the cloud structure between clouds influenced by biomass burning and those in cleaner areas. The clouds in cleaner areas had warmer and larger drops than the non-precipitating clouds affected by the smoke (Rosenfeld, 1999). During the same period, biomass burning smoke aerosol dramatically increased CCN concentrations, which will likely increase colloidal stability and cloud lifetime, resulting in the observed well-developed, non-precipitating clouds. $f_{CCN/CN}$ also decreased by at least a factor of three for biomass burning aerosol compared to wet season fractions.

In recent years, much attention has been focused on the effect of organic material on CCN activity and the subsequent growth of cloud droplets (Novakov and Penner, 1993; Shulman *et al*, 1996). To identify physical and chemical properties responsible for CCN activation, number and mass size distributions were measured using a scanning mobility particle sizer and a multiple stage cascade impactor, respectively. In the fine mode (i.e. diameter < 1 μm), 18 elements were detected using proton-induced x-ray emission (PIXE) analysis with elemental sulfur being the most abundant. The mean CCN spectrum (Table 1) correlates well with the estimated CCN activation based on the number and mass size distribution closure. Hence, the results suggest that the soluble, inorganic component (i.e. NH_4HSO_4) accounts for CCN activity during the wet season.

CONCLUSIONS

The response of cloud droplet concentration to changes in N_{CCN} is the basis for the modification of precipitation, cloud fraction and indirect forcing, which play an important role in regulating the heat flux into the rainforest, which is, in return, the primary driver of convective cloud formation. The modification of CCN concentrations through anthropogenic activity, such as industrial emissions and biomass burning, could contribute to imbalances in the meteorological cycle and affect the climate in the Amazon Basin.

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