Aerosol Particles from Cirrus Anvils and Cloud Bases: TEM results

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Introduction

Aerosol particles work as CCN and IN, affecting cloud formation. Efficiency as CCN and IN depends on their compositions, sizes, crystal structures, and mixing states. Individual particle analysis using TEM is uniquely suited for obtaining such information. The combination of energy-dispersive X-ray spectrometry (EDS) and energy-dispersive X-ray microanalyzer (EDX) enables detailed characterization of individual aerosol particles.

We are studying aerosol particles collected from cirrus anvils and bases as well as outside of the clouds. Characterization using TEM and comparison between different kinds of aerosol samples provides insights regarding formation and processing of particles inside clouds.

Coatings of metal-rich particles

Compositions of coating materials are variable, but all are rich in S. K, Ca, Fe, Na and Cl are common.

The compositions are similar to those of round S-rich particles.

Metal-rich particles

- Flakes, some are large
- Variable Si/Al ratio
- Angular or irregular shape

S-rich particles

- Round shape, look like droplets.
- All samples. Most are Zn-rich.
- Na and Cl are also common.

C-rich particles

- Round or rectangular grains
- Some coexist with sea salt
- Commonly coexist with sea salt
- Some aggregated with sea salt (clays, feldspar etc.)

Aerosol from cirrus anvils

(Upper troposphere, 1-3 km high)

Sampling

Aerosol particles were directly deposited onto Cu TEM grids using single-stage multiple aerosol collection systems (MAGS) on board the WB77E and Twin Otter aircraft.

Examples: July 28th samples

Sampling periods of grids #1, #18, and #22 are shown as blue bands in the above graph. Number and volume of analyzed grids increase in the order #16 - #18 - #22.

These values appear to correlate with ice concentrations.

Sampling grids increase in the order

9-16 (of 84)

Among samples.

Relationship to aerosols in the lower stratosphere?

Some sulfate particles in the samples from the lower stratosphere (blue in the above table) contain minor amounts of Zn and Fe.

Water droplets

Most droplets enclosing sea salt are rich in Ca, Na, Cl and S. Co- and Na-sulfate particles commonly occur in such droplets.

Na-sulfate particles

- Round or rectangular grains
- Some coexist with sea salt
- Some aggregated with sea salt, sodium, soot

(SO4)2- particles (mostly Zn)

- Flakes, some are large
- Variable Si/Al ratio
- Angular or irregular shape

Ca-sulfate particles

- Round or rectangular grains
- Some coexist with sea salt
- Commonly coexist with sea salt
- Some aggregated with sea salt (clays, feldspar etc.)

Relationship to aerosols from anvils?

Two of the Twin Otter samples contain unusually abundant metal-rich particles similar to those in the anvil samples. The relationship is currently unknown.

Variations of aerosol compositions

Proportions of sea salt, sulfates, soil particles, and dust differ considerably among samples.

Example: July 28th samples

Based on the CCN-counter data, both grids #2 and #15 collected abundant CCN. But the particle compositions differ. Sea salt particles predominante on grid #2, while NaHSO4 particles predominante on grid #15. On grid #6, sampled when the CCN concentration was low, sea and CaSO4 particles occur in higher proportion than on grids #2 and #3.

Summary

Samples from anvils contain abundant metal-rich (mostly Zn) particles. The amount is apparently related to the amount of ice crystals detected during sampling.

Artifacts resulting from ice crystals hitting the airplane?

Aerosol particles from cirrus anvils

(Upper troposphere, 13-14 km high)

We used CAPS/MASP and water-content data to determine which samples are from ice clouds. Nine samples were collected when large volumes of ice crystals were detected.

Aerosols from cloud bases

(Lower troposphere, 1-3 km high)

Sampling

Aerosol particles were directly deposited onto Cu TEM grids using single-stage multiple aerosol collection systems (MAGS) on board the WB77E and Twin Otter aircraft.

Ongoing work

Clarify origin of the metal-rich particles

- Analysis of airplane material possible?

Further systematic analyses necessary for better understanding of processes in clouds

- Check with the data of other instruments

- Analysis of more grids

- More intense survey for such grid

Further comparison of

Pre- and post cloud processing

particles at anvils and cloud bases

particles from the upper troposphere and lower atmosphere