Single Particle Studies of Ice Crystal Residue During CRYSTAL-FACE

Daniel J. Cziczo, David S. Thomson, Paula K. Hudson, and Daniel M. Murphy

CRYSTAL-FACE Science Team Meeting

Salt Lake City, UT

February 24-28, 2003
• Particles are acquired through an aerodynamic focusing inlet.
• Dual YAG laser beams are used for *particle sizing* and to trigger an excimer laser which ablates and ionizes material.
• A complete positive or negative *mass spectrum* is produced for each analyzed aerosol \(0.2 - 2.0 \mu m\) in diameter.
The CVI / PALMS Method

- The Counterflow Virtual Impactor (CVI) stops crystals <~7 µm diameter whereas those >~25 µm impact and are not sampled.
- Crystals are then evaporated and ice residue from 0.2 - 2.0 µm analyzed.
- When the CVI is not used particles 0.2 - 2.0 µm are sampled (cloud interstitial aerosol).
- The normal mode of operation outside cloud was to have no counterflow.
**CVI Performance**

- **Within cirrus** rate was 1-2 Hz at ~5 crystals per liter (max of 5Hz).
- On 07092002 a total of 718 hits in 880 seconds CVI time = 0.85 Hz average.

- **Outside cirrus** rate was ~0 Hz.
- On 07262002 only 1 hit in 3080 seconds CVI time for CAPS counts < 1 per liter = 0.0003 Hz
Three Case Studies: 1

- Cirrus just under tropopause (most data at FL 475).
- Positive and negative spectra in and out of CVI mode in the same cirrus.
Case 1: Southern Flight

- Note the bimodal distribution outside cloud and for the Ice Residue (IR) but not in the interstitial aerosol.
- Large IR particles more varied and tropospheric in origin. Small mode is consistent with tropopause particles (I, etc.). Sulfate particles with meteoritic material were frozen in the cloud.
- Consistent with our understanding of homogeneous freezing.
Case 1: Southern Flight

- An example of an IR which is of meteoritic origin.
- These particles are common in the stratosphere (~50%) but not in the troposphere.
- Consistent with a \textit{stratospheric source} of particles forming cirrus ice.
Case 1: Southern Flight

- Histogram of the area of the sodium peak in each positive polarity mass spectrum.
- This area can be used as a rough indicator of particle type.
- Most IR, particles outside cloud, and interstitial aerosols are sulfate/organics: homogeneous freezing.

Sulfates plus Organics (~70%)

Mineral Dust, Fly Ash, Meteoritic, Etc. (~25%)

Sea Salt (<5%)
Case 1: Southern Flight

- Particles outside of cloud and IR contain considerable sulfate.
- Unactivated interstitial particles contain less sulfate but more organics.
- ‘Fractionation’ of particle composition during homogeneous freezing.
Three Case Studies: 2

- Convection along gulf coast and peninsula (most data FL 400 - 450).
- Spectra from ~16 different cirrus events over two flights.
Case 2: Moderate Dust

- Considerable sea salt as IR but a much smaller fraction (15%) than on 07072002 (not shown, 30%). Sulfates and organics ~30%.
- No significant difference between over-water and over-peninsula flights.
- Free tropospheric aerosol is typical sulfate / organic mix.
- A considerable fraction of IR of crustal or fly ash origin (~55%).
Three Case Studies: 3

- Convection along gulf coast (most data FL 400-440).
- Spectra from ~12 different cirrus over two flights.
Case 3: Dust Event

- Ice residue from July 28 -29 2002 have a much higher sodium signal than out of cloud particles or interstitial aerosol.
- ~20% are consistent with frozen sea salt. <10% Sulfates and organics.
- Most of the remainder (70%) are consistent with mineral dust or fly ash - heterogeneous freezing...
Ice Residual Size Distribution

- The IR in the Florida area was larger than on the southern flight, consistent with sea salt and mineral dust / fly ash initiating freezing.
- IR on the southern flight contained a large mode consistent with mixed origin tropospheric particles and smaller tropopause particles.
In positive polarity, the majority of the particles analyzed during the mission were mixed sulfates/organics/potassium.

The IR on the southern flight were roughly consistent with the ‘All Mission Data’ whereas those sampled in the Florida area were not.

IR in the Florida area show enhancements in sea salt and mineral dust / fly ash - notably on the dust event flights.
In negative polarity, the majority of the particles analyzed during the mission were mixed sulfates/organics.

Mineral dust / fly ash and elemental carbon (EC) were enhanced in the Florida area.

Organics, notably category 6, were depleted in all IR types.
Conclusions

• The cirrus cloud sampled during the first *southern flight* was consistent with homogeneous freezing of the background aerosol with a) *input from stratospheric particles* with b) *higher organic content aerosols* preferentially excluded from IR.

• Ice Residue sampled on *moderate dust days* were 30% sulfate/organics, ~15% sea salt, and ~55% mineral dust /fly ash composition.

• Ice Residue sampled during the *dust event* on the last two flights were dominated by particles consistent with a *mineral dust / fly ash* origin.
Future Work

- Take a more in-depth look at flight-to-flight variability and particle differences.
- Elucidate the effect of organics on ice nucleation during CRYSTAL-FACE.
- What role did the presence of mineral dust play in the structure of the cirrus being sampled (crystal sizes, densities, etc.)?
- In depth discussions with other researchers.
Acknowledgements

- NASA and NOAA Funding
- Darrel Baumgardner for the CAPS data and Paul DeMott for useful discussions.
- Mission management and the air and ground crews of the WB-57F without whom this mission would not have been possible.