Meeting Summary: Issues on Inlets for Air Sampling from Aircraft

NCAR/RAF - Jeffco, February 17, 2006

Attending: Fred Eisele, Jim Smith, John Ogren, Pat Sheridan, Dan Murphy, Ru-shan Gao, Jeff Stith, Jørgen Jensen, Chuck Wilson, Al Cooper, Mike Cubison, Jose Jimenez, Tony Clarke, Dave Rogers, Barry Huebert (phone)

1. Compressional heating and its effect on volatile particles

Adiabatic heating of decelerating air is predictable from thermodynamics and can be as large as ~25K for high speed research aircraft. This can lead to evaporation of volatile components from aerosol particles, leading to errors and bias of particle measurements. Two approaches may help ameliorate this problem: Vonnegut's "vortex thermometer" and force-cooling of inlet/piping walls.

The vortex thermometer looks like a small cyclone, and although it may work as advertised for temperature, it may not be suitable for sampling aerosol particles because of inertial losses. Force cooling is a heavy duty approach. It adds complexity, weight and power. No one at the meeting reported trying it yet. Some passive cooling may be helpful.

Dan Murphy presented a nice analysis of the compression heating problem, including the response of water/ice particles. His PPT presentation was distributed to the email list – please contact Dan for a copy if you missed it. His conclusions were:

- accept adiabatic heating, it's unavoidable;
- don't warm the air any further (for example in a warm cabin). Use short tubing lengths with high flow speeds and mount instruments close to aircraft skin or in pods.
- slow flying aircraft have an advantage

2. Sampling "interstitial" air in clouds

There is a need for innovative design and testing to develop an inlet that can selectively sample aerosols and not cloud particles. For example, a recent design by Dhaniyala (2003) combines CVI and moveable blades that can be adjusted in-flight to admit or preclude particles. An older flow-through design by Bradshaw is cylindrical with an interior bulge. Several people report that it excludes cloud particles and is not much affected by cloud particle shattering. Flow and particle trajectories through the Bradshaw inlet have not been modeled.

3. Excluding spray artifacts when sampling in liquid clouds

Cloud and precipitation particles splat on inlet tips and create artifacts that can leave residual particles upon evaporation. Several studies have documented this phenomenon. Some inlets are less affected because of location/alignment on the aircraft or favorable particle trajectories inherent with their design. The CVI is less prone to this problem because counter-flow will exclude the smaller fragments; it is not, however, immune.

Comments by Participants

All inlets (gas or particle) should be tested and characterized for sampling efficiency.

HIAPER will have an assortment of inlets including ones with basic features, specialized versions, and some with unique capabilities. There will be opportunities for flight testing inlets on HIAPER.

An inlet that will sample large particles efficiently is as important or more important than #1-3 (Twohy).

We ought to be able to sample most of the sea salt size distribution (up to 6 - 10 um?) and high-altitude dust (up to 5 um?) without inlet wall contact losses exceeding 10%. (Huebert)

Is it practical to build an LTI (Low-Turbulence Inlet) for HIAPER?

Conclusions

The attendees agreed to stay in communication and to collaborate on these issues. Flow and particle trajectory modeling have advanced considerably in the past few years. Modeling tools can be used to help estimate the effects of ram heating and the response of volatile components. Modeling particle breakup is more complicated. Droplet and particle interactions at small sizes and short time scales are not intuitive. The complications outlined here suggest that data interpretations should be made with caution.

References

Dhaniyala, S; Flagan, RC; McKinney, KA; Wennberg, PO. 2003: Novel aerosol/gas inlet for aircraft-based measurements. *Aerosol Science and Technology*, 37 (10): 828-840.

Vonnegut, B., 1950: Vortex thermometer for measuring true air temperatures and true air speeds in flight, *Rev. Sci. Instrum.*, 21, 2, pp 136-141.

Vonnegut paper is available at *http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=RSINAK000021000002000136000001&idtype=cvips&prog=normal*

and

http://www.eol.ucar.edu/~dcrogers/Instruments/Vonnegut-1950.pdf