SOCRATES CVI Data Quality Report (Cynthia Twohy and Darin Toohey)

Overview:
The counterflow virtual impactor (CVI) measures droplet and ice crystal properties via virtual impaction, which rejected interstitial water vapor and particles inside of cloud via a counterflow of dry air out the inlet tip. When the counterflow is on, the size of unit-density particle or droplet collected with 50% efficiency is the “cut size”, which is given in the netcdf files as CVRAD in microns radius. In SOCRATES, instruments measuring behind the CVI included a tunable diode laser hygrometer, a Ultra-High Sensitivity Aerosol Spectrometer a TSI 3010 condensation nucleus counter, a continuous-flow diffusion chamber for ice nucleating particles (DeMott PI), and an impactor where particles were collected on transmission electron microscope grids and STXM windows. The CVI was sometimes used as an ambient inlet in SOCRATES by turning off the counterflow outside of clouds, so the data set consists of both clear-air and in-cloud data and the data signals are not necessarily continuous. A CVINLET flag is set to 1 when the counterflow is turned off, and CVCWCC and CONCUD (see below) are set to missing data during these periods.

One of the primary CVI variables in the netdf files is CVCWCC, the water content measured by the tunable diode laser hygrometer behind the CVI, corrected via the enhancement factor (CVCFACTC) back to cloud condensed water content. CVCWCC may sometimes be lower than water content from the hot-wire probe or cloud droplet probe due to cut size effects, or higher when drizzle and ice are present, as it is measuring those hydrometeor sizes as well. It was sometimes impacted by icing during SOCRATES (see Data Issues, below).

CONCU_CVIU and CONCUD are particle number concentrations and droplet residual concentrations, respectively, from the Ultra-High Sensitivity Aerosol Spectrometer (UHSAS). The UHSAS is an optical particle counter that uses an intracavity approach to count and size submicron particles with high resolution and high sensitivity. Calibrations are performed with polystyrene latex spheres and are classified by size into 99 bins over the range 55 nm to 1000 nm in optical diameter. For SOCRATES, the size bins were further calibrated against size-selected spherical ammonium sulfate to provide a more accurate physical size from 60 nm to 1030 nm. The typical error in optical diameter is around 5%. The UHSAS experienced no losses of data during the SOCRATES campaign. Investigators interested in full size distributions should contact Darin Toohey for the latest version of the particle size spectra.

Note that for SOCRATES, CONCUD may vary from CONCD, the droplet concentration from the cloud droplet probe, for various reasons. CONCUD may be larger than CONCD due to drizzle or ice crystal breakup in the CVI inlet, or less if many droplets are smaller than the CVI cut size, residual particles are smaller than ~60 nm, or the UHSAS detector has saturated (see below). A condensation nuclei counter measured particles down to about 10 nm, but these data have a high susceptibility to artifacts in drizzle and ice and so were not sent to the aircraft data system. However, these small particles may be important for cloud nucleation during SOCRATES and are available upon request from Cynthia Twohy.

Data Issues:

1) *Inlet Icing.* The CVI inlet experienced some icing in supercooled clouds between about -7 to -20C, particularly on flights 3, 7, 8, 9, 10 and 14. This resulted in a steady degradation of the water and particle signals over time in cloud. An empirical correction was developed based on the ratio of the CVI condensed water signal to the King Probe (or CDP when the King also exhibited icing effects) at the beginning of a cloud run and then over subsequent elapsed time in cloud. This ratio was applied to the CVI enhancement factors (CVCFACTC and CVCFACTTDL) and then to the corrected CVI water content (CVCWCC) and UHSAS residual concentration (CONCUD). This worked well in most cases, but we estimate that the uncertainty of the corrected CVI water content during these periods increases from about 15% at the beginning of the supercooled in-cloud runs to a maximum of about 50% at the end of long runs. Effects on the droplet residual concentration (CONCUD) have not been thoroughly investigated. A new variable, CVIFLAG was implemented for total counts to warn to use these periods with caution (1=normal, 0=icing conditions). A few sequential cloud periods where the automatic icing correction failed were corrected manually. Flight 9 had the worst icing and a two periods during this flight could not be corrected and were replaced with missing data (-32767).

2) *UHSAS Saturation.* The UHSAS has a known issue with undercounting particles smaller than 200 nm whenever the detector becomes saturated and smaller pulses cannot be adequately discriminated from background by the electronics. Particles larger than 200 nm are unaffected by this artifact, which occasionally occurred during SOCRATES when the count rate exceeded about 6000 s^{-1} (usually in-cloud). A new variable, UFLAG_CVIU was implemented for total counts (TACTU_CVIU) > 6000, and users are warned to use these periods with caution. Investigators interested in empirical corrections to the count rate during these periods should contact Darin Toohey. The flight-by-flight specifics identity approximate time periods when this is known to have occurred, primarily during in-cloud periods.

3) *Time Lags*. A long sample line was used between the CVI inlet and rack to accommodate the lidar installation, so there were significant lags for the TDL sensor measuring condensed water and the UHSAS sensor measuring particle concentrations. By comparison with other RAF cloud sensors, these lags were determined to be about 3 seconds for the TDL and 9 seconds for the UHSAS (except for flight 1, when it was about 13 seconds due an initially slower flow rate.) These lags were accounted for in the nimbus code in outputs of variables CVCWCC, CONCU_CVIU, and CONCUD.

Flight by Flight specifics:

Flights 1-4. The CVI laptop code inadvertently used mass instead of volume flow for calculation of CVRAD (cut size in microns radius) for these flights. CVRAD was replaced with missing data (-32767) in the netcdf. One can assume that CVRAD was approximately 4 microns radius (8 microns diameter) for cloud sampling at low altitude, except for when impactor or CFDC was put on CVI, when it briefly increases to about 8 microns radius (16 microns diameter).

Flight 2. UHSAS detector saturation affecting small particle end of distribution: 6:03:20-6:04:00, 6:13:30-6:18:30.

Flight 3. Some icing periods. UHSAS detector saturation affecting small particle end of distribution: 2:32:44-2:34:00.

Flight 6. UHSAS detector saturation affecting small particle end of distribution: 23:13:00-23:14:55, 5:30:50-5:36:00.

Flight 7. Some icing periods. UHSAS detector saturation affecting small particle end of distribution: 6:28:00-6:28:30.

Flight 8. Some icing periods. UHSAS detector saturation affecting small particle end of distribution: 4:16:35-4:17:30, 5:19:37-5:20:43.

Flight 9. Missing data due to heavy icing at 03:01:20-03:32:15 and 04:10:30-04:35:00. Also, at other times CVCWCC may be overcorrected by icing correction. UHSAS detector saturation affecting small particle end of distribution: 4:35:00-4:36:25, 4:50:50-4:51:25.

Flight 10. Some icing periods. UHSAS detector saturation affecting small particle end of distribution: 3:52:40-3:53:38.

Flight 11: UHSAS detector saturation affecting small particle end of distribution: 3:22:12-3:22:35, 4:02:40-4:04:05.

Flight 12: Air cylinder ran out in one cloud run, CVCWCC baseline manually corrected 04:35-04:47. UHSAS detector saturation affecting small particle end of distribution: 4:01:25-4:02:52 and 4:34:10-4:35:36.

Flight 14. Some icing periods, with overcorrection between 02:52-02:55. CVTAI (CN counter temp) noisy due to bad connection so turned heaters off for a while until 052455. This noise may propagate into some of CVI flow rates and other variables. (Fixed before flight 15).

Flight 15. Air cylinder ran out during two cumulus passes, CVCWCC baseline manually corrected 05:15:09-05:17:35. UHSAS detector saturation affecting small particle end of distribution: 7:22:57-7:25:30, 7:33:13-7:33:57, 8:15:23-8:16:07.