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To: NCAR RAF Staff (Pavel Romashkin, Project Supervisor)

Re: Post project preliminary report on aerosol measurements during ARISTO 2016

Background:

The SMPS (scanning mobility particle sizer) was designed in the early 2000's by Dave Rogers and Jim Smith and considered a "gap" instrument. It was built in 2011 prior to the DC3 Test campaign and was fully functional by 2012 when it flew on the NCAR GV during DC3. It also flew on NOMADSS (2013) and FRAPPE (2014). There are other aerosol instruments such as the wing-mounted and rack-mounted UHSAS, RAF CN counter and the University of Wyoming TSI 3025 CN counter. The original objective of this instrument was to be able to characterize particle number concentrations that were smaller than the detection limit of the UHSAS. By combining the SMPS, UHSAS, and CN counter, the entire particle size distribution and total particle concentration can, in theory, be determined. To my knowledge there hasn't been a systematic comparison of the instruments to see how well they agree with each other and if there are any systematic biases based on altitude, inlet, airplane speed or other conditions. We have used two different inlets during the previous campaigns: The HIML and the SMAI. So for this most recent campaign (ARISTO 2016) several of these instruments were all sampling ambient from the same inlet, which could be switched during flight. The overall goal of this exercise was to compare the different instruments and inlets from a wide-range of sampling conditions.

Instrumentation:

The configuration for the instruments is shown in Figure 1. The original plan was to have a total of 2^3 (or 8) combinations by switching:

1. Air inlet (SMAI or HIML)
2. Particle counter (TSI 3025 or TSI 3010)
3. DMA (nano for small particles (~10-100 nm) or regular for larger particles (~100-400 nm))

During installation and pre-flight testing it was determined that comparing 8 combinations in 20 total flight hours was overly complex, so plans were altered to make the TSI 3025 a stand-alone counter similar to the RAF CN counter. The comparisons then became the different inlets and the different DMA columns for a total of 4. This change in plans had the added benefit of being able to compare the TSI 3025 to the RAF CN counter under more controlled conditions and to add to the experience gained by J. Snyder of the University of Wyoming during the 2015 ARISTO campaign. The instruments were all mounted in a rack at the back left of the C130 and the inlets were installed side-by-side in the belly of the plan ~1 m from the rack.

Discussion:

As of this writing (October 7, 2016) the data is still being analyzed, so it's not yet clear how the instruments compared with each other and if any systematic biases occurred. Preliminary results indicate that the TSI 3025 and the RAF CN counter followed the same general trends, but there was significant disagreement in the number of particles counted with the 3025. This could be due to the changes in flow that the 3025 experiences at higher altitudes. This instrument has several different flow paths, which is different than the other CN counters, in which the total flow is the same as the aerosol sample flow. Figure 2 shows the various flows in the instrument as a function of sampling pressure. The nominal flow into the instrument is 1500 ml/min, and of that, 1200 ml/min is split off, with the rest being the "total aerosol flow". This latter flow is nominally 300 ml/min. This flow is split where 270 ml/min is filtered and re-combined as "sheath flow", which surrounds the remaining flow (30 ml/min) that contains the particles. Therefore, the particle concentration read is diluted by a factor of 10 (300/30). As seen in Figure 2, there are significant deviations in the sheath and aerosol flows at reduced pressure and the amount of flow that is actually counted is reduced by approximately 14% between 500 torr and 200 torr. These will be taken into account upon further data processing and corrections will be made. It is interesting to note that regardless of inlet pressure, the by-pass flow remains constant.

Overall, the objectives were met as we were able to sample from a wide range of conditions and all of the instruments seemed to operate well. These include clean air at both low and high altitudes, urban air over Denver and particles from the Beaver Creek fire near Walden. We were able to get representative data from both instruments and both of the DMAs. This data set should provide a good opportunity for comparing the inlets, the total number of particles counted as well as the size-resolved particle size distributions. This data analysis is a significant task and will take several months due to other obligations. A small publication could be written if the results are interesting and deemed worthy.

Figure 1: ARISTO 2016 Aerosol sampling diagram. In this configuration (bold lines), ambient air is taken in through the SMAI inlet and through the switching valves shown, the aerosol flow is directed into the long column (regular) differential mobility analyzer (RDMA). Monodispersed particles are then counted by the TSI 3010 condensation particle counter (CPC). The same air is sampled by the rack-mounted UHSAS (Univ. of Wyoming), TSI 3025 and the RAF CN counter. The pump stack on the right-hand side of the figure controls the flow through the TSI 3025 and the SMPS (including the 3010). The RAF CN counter and UHSAS have their own dedicated pumps.

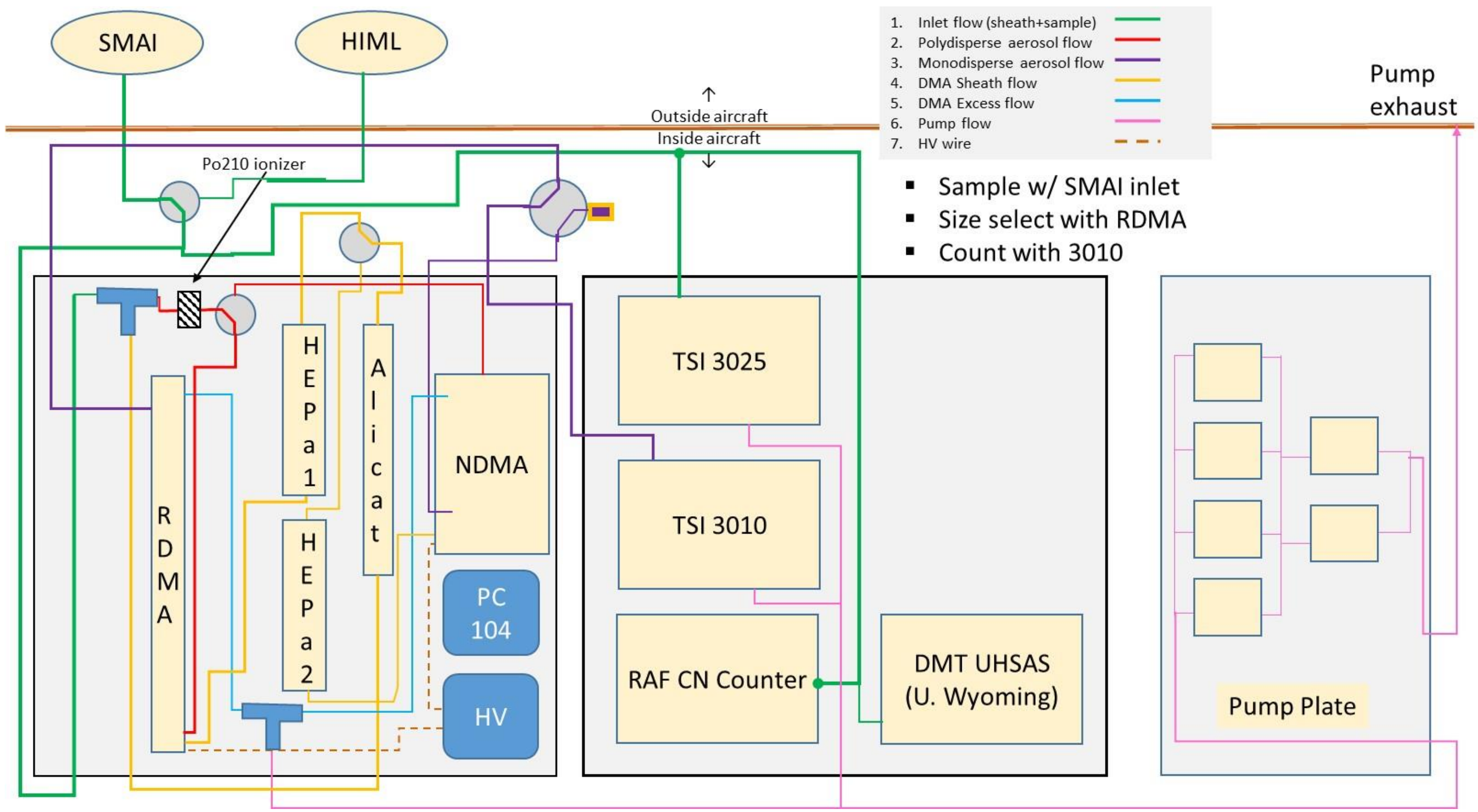

Figure 2: TSI flows at reduced pressures. Capillary flow, which counts the aerosol particles is on the 2nd y-axis. All flows deviate (are smaller) at reduced pressures.