Testing of the NCAR PCASP for VOCALS

Jeff Snider, University of Wyoming, 17 June 2009

Deice Heaters

The PCASP has three inlet heaters. 1) at the tip of the inlet, 2) around a collar that the inlet diffuser mounts to, and 3) a cartridge heater mounted in close proximity (~5 mm) to the tube that transmits the aerosol to the scattering volume. On the NCAR C-130 these heaters are activated on take-off. A test performed in Laramie on 23 February 2008 revealed that the cartridge heater may no longer be operational. If the heater failed this may be consistent with Allen Schanot's observation that PCASP behavior, on exit from cloud, changed between rf02 and rf03. Further examination of the cartridge heater is needed.

Transit Time

The PCASP reports an average transit time which we archive and plot. For polystyrene latex (PSL) particles with diameter smaller than 199 nm this average is between 10 and 20 μs. For PSL particles of diameter 491 nm the transit time value increases to ~2000 μs. This behavior is a concern since we do not it in the UWYO PCASP data. It suggests that the flow through the scattering volume is not optimized.

PCASP Sizing

Laboratory testing of the PCASP was conducted in Laramie during 2008 and 2009; the first of these tests was in July 2008. After the July experiments the instrument was returned to Droplet Measurement Technologies where the alignment of the particle beam through the scattering volume was adjusted. Again in Laramie, during August and September, the bias voltage of the Baseline Restoration Module (high gain section) was adjusted while challenging the PCASP with 125 nm polystyrene latex particles (PSL). This improved the registration of the 125 nm PSL particles. The PCASP was flown in VOCALS during October and November 2008. The probe was returned to Laramie in February 2009 and the PSL sizing was reevaluated.

Also, the calibration relating the flow meter output signal and aerosol flow rate was evaluated in July 2008 and in February 2009. The latter tests are discussed in the next section of this report.

The PSL sizing tests are very encouraging. They show laboratory PSL particles registering in the same channels before VOCALS - subsequent to particle beam adjustment and the bias voltage adjustment - and after VOCALS. These results are presented online:

http://www-das.uwyo.edu/~jsnider/nasa06/pcasp_test_2008/test_5.pdf

The particle sizing experiments are summarized in Figures 1a, 1b and1c for the high gain, middle gain and low gain amplifiers, respectively. Here the dashed line is a fit of the factory size calibration (diamonds) and the triangle is what we observed in the laboratory when challenging the PCASP with 125, 152, 199 and 491 nm diameter PSL particles. These particles were prepared by atomizing PSL hydrosols (Duke Scientific), and size-selecting in an electrostatic classifier. The solid lines are what I am recommending for the NCAR PCASP when operated in our laboratory. Note that these lines are shifted upwards from the factory sizing calibration so that they pass through the laboratory data points.

The numbers above the graphs are the coefficients in the following relationships between the channel threshold ("x") and the PSL diameter ("D"). Two examples of the calibration equation, for high gain and middle gain amplifiers, are given in Equations 1 and 2, respectively.

$$D = 1.023 \cdot 10^{-1} + 2.248 \cdot 10^{-5} \cdot x - 2.304 \cdot 10^{-9} \cdot x^2 \quad (1)$$

$$D = -1.569 \cdot 10^{0} + 8.144 \cdot 10^{-4} \cdot x - 1.210 \cdot 10^{-7} \cdot x^2 + 6.030 \cdot 10^{-12} \cdot x^3 \quad (2)$$

Figures 1d and 1e show the factory size calibrations (diamonds) and the fits derived for the NCAR PCASP when operated in our laboratory (solid line).

Table 1 shows the particle size calibration I am recommending for the NCAR PCASP during VOCALS. The first column shows the NCAR PCASP thresholds and the second column shows the corresponding particle diameters, assuming a refractive index $n = 1.59$. This table was generated by inputting the NCAR PCASP thresholds into the fitting functions shown in Figures 1a, 1b and 1c. The VOCALS thresholds were provided by Allen Schanot of NCAR. The VOCALS thresholds are shown below.

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THRESHOLDS_30  692, 1040, 1517, 2157, 4096, 4231, 4348, 4537, 4825, 5251,
               5859, 6703, 8192, 8345, 8502, 8682, 8872, 9070, 9252, 9432,
               9544, 9737, 9937, 10166, 10471, 10797, 11162, 11499, 11852,
               12288
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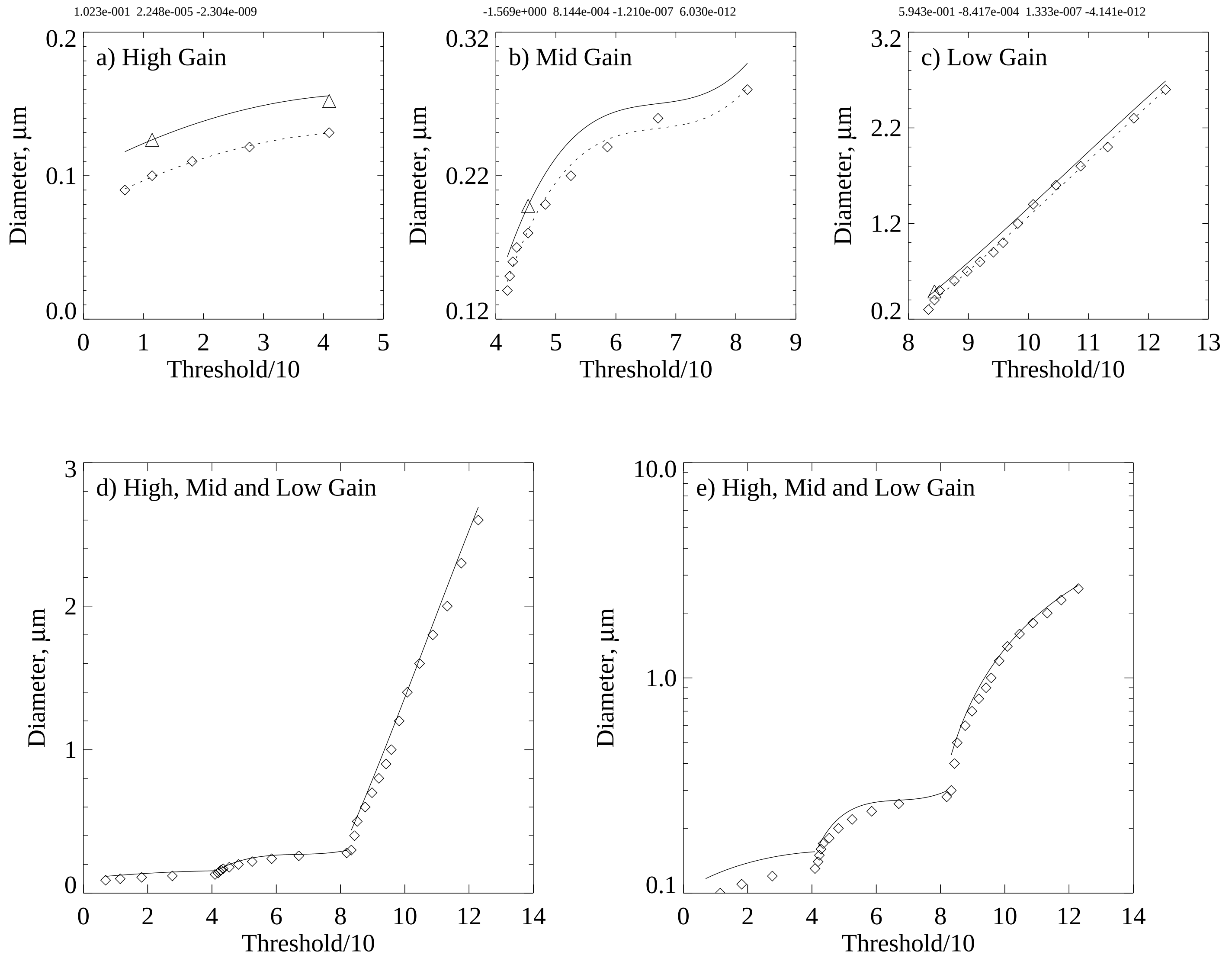

Figure 1 – Polystyrene latex (PSL) sizing calibrations. The size calibration is for the NCAR PCASP when operated in our laboratory.

Table 1 - Size calibration is for the NCAR PCASP when operated on the C-130 during VOCALS

VOCALS Thresholds High Gain Channels	VOCALS PSL Diameter, n=1.59 μm
692	0.117
1040	0.123
1517	0.131
2157	0.140
4096	0.156
VOCALS Thresholds Mid Gain Channels	VOCALS PSL Diameter, n=1.59 μm
4231	0.168
4348	0.181
4537	0.199
4825	0.222
5251	0.245
5859	0.262
6703	0.270
8192	0.298
VOCALS Thresholds Low Gain Channels	VOCALS PSL Diameter, n=1.59 μm
8345	0.444
8502	0.526
8682	0.622
8872	0.724
9070	0.833
9252	0.935
9432	1.036
9544	1.100
9737	1.211
9937	1.326
10166	1.459
10471	1.638
10797	1.830
11162	2.044
11499	2.240
11852	2.444
12288	2.690

PCASP Aerosol Flow Rate

The PCASP is an optical particle counter. The PCASP concentration is derived as the ratio of the measured particle count rate divided by the aerosol flow rate through the PCASP scattering volume. The latter is reported by the PCASP as an integer representation of an airflow rate. In the data processing the integer is converted to a voltage (12 bit DA converter) and the voltage signal is converted to a mass flow rate expressed in units of standard cubic centimeter per second (sccps). Three calibrations of flow meter output are shown in Figures 2a and 2b. Figure 2a shows the calibrations we evaluated in Laramie before and after the VOCALS campaign, and Figure 2b shows the calibration function archived in the 1 Hz VOCALS NetCDF file. The Laramie calibration is based on a flowrate measurements made at the local pressure (~780 hPa); converted to a sccps flowrate.

The Laramie pre- and post-VOCALS calibrations were validated by comparing concentration values, reported by two condensation particle counters, to the concentration reported by the PCASP. For these experiments the test particles were prepared at a size larger than the minimum detected by the PCASP. The PCASP concentration varies inversely with the aerosol flow rate. These comparisons reveal a relative agreement (CPC to PCASP) of better than ±5%. Therefore, we are confident in the UWYO calibration, at least when it is used to process data collected in our laboratory.

The Figure 2c shows a time series of the sccps flowrate from one of the 1 Hz VOCALS NetCDF files (rf06). These values were converted to the flowmeter signal and the result is shown in Figure 2d. Figure 2e shows the relative difference derived using the pre-VOCALS Laramie flowrate calibration and the NCAR flowrate calibration, and derived using the post-VOCALS Laramie flowrate calibration and the NCAR flowrate calibration. The relative difference is as large as +0.6 at high altitude and as small as -0.1 at the sea surface. The results shown in Figure 2e are representative of the whole VOCALS campaign.

Because the PFLW_LWO to PFLWC_LWO calculation is done subsequent to the calculation of the PFLW_LWO the discrepancy between the UWYO and the NCAR flowrate calibrations (Figure 2e) propagates into error in both PFLWC_LWO and PCASP concentration (CONCP_LWO). It follows that both PFLWC_LWO and CONCP_LWO are uncertain in the range +60 to -10 %.

For the reasons discussed above (comparison of PCASP concentrations to two CPCs, in the laboratory), I trust the Laramie flowrate calibrations. For the VOCALS campaign I am recommending a fit of the Laramie calibration data. It is also recommended that this “best-possible” calibration curve be used to reprocess the archived NetCDF values PFLW_LWO, PFLWC_LWO and CONCP_LWO.

The above recommendations were implemented in the processing of the 1 Hz data released in early March 2009. Figure 3 shows the effect of the flowrate correction. In panel “a” the fit of the combined Laramie flowrate calibrations is shown (dotted line), in panel “b” the NCAR implementation of the Laramie flowrate calibration (solid line) is shown with the dotted line from panel “b”.

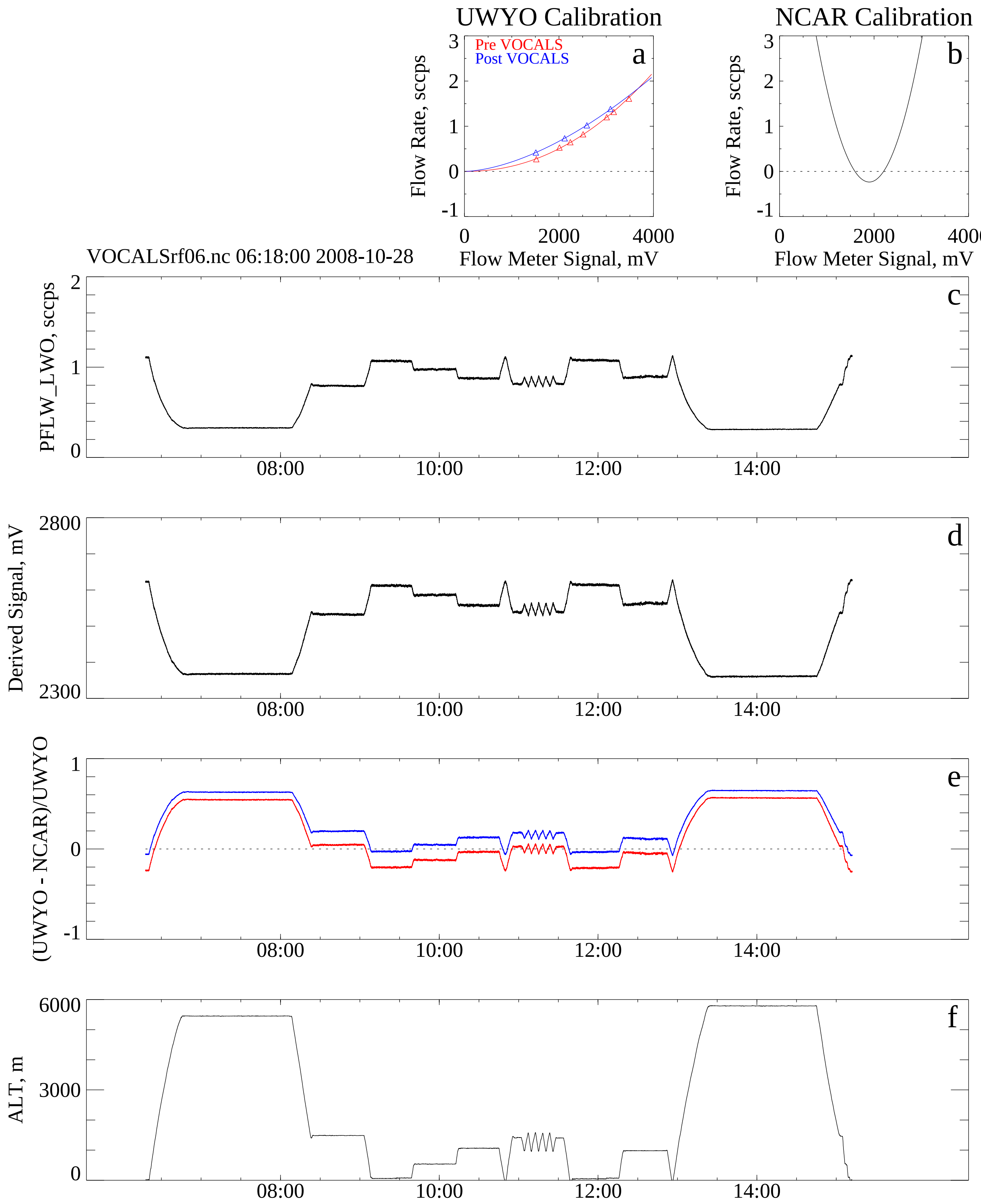

Figure 2 – Aerosol flow rate calibrations (panel "a" and "b), the NetCDF variable PFLW_LWO (panel "c", the flow meter signal derived from PFLW_LWO and the PFLW_LWO:calibrationCoefficients (panel "d"), relative difference between the UWYO and NCAR values of PFLW_LWO (panel "e") and C-130 altitude (panel "f"). This result is for preliminary data, released in November 2008.

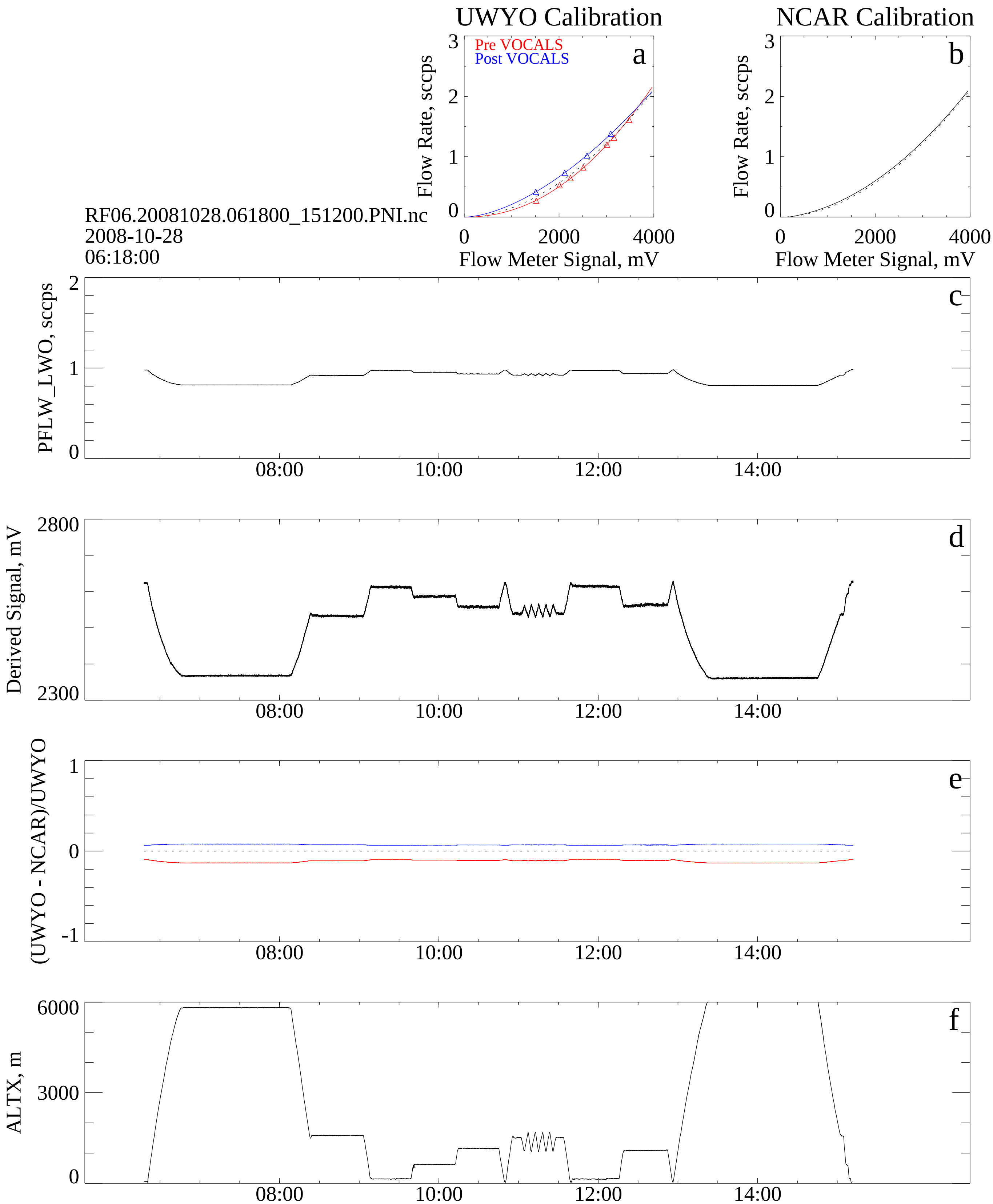

Figure 3 – Aerosol flow rate calibrations (panel “a” and “b), the NetCDF variable PFLW_LWO (panel “c”, the flow meter signal derived from PFLW_LWO and the PFLW_LWO:calibrationCoefficients (panel “d”), relative difference between the UWYO and NCAR values of PFLW_LWO (panel “e”) and C-130 altitude (panel “f”). This result is for NetCDF data, released March 2009.