Post flight checks on the three Wyoming particle counters (J6, J7, J8) recovered from the Concordiasi flights.

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1.0 Instrument description

Each Wyoming particle counter (WPC) uses scattered light to determine particle size. When a particle goes into the WPCs it passes into an open cavity laser. As the particle passes through both the side scattering and the forward extinction of the laser beam are measured. The amount of light scattered corresponds to the size of particles ≤ 1.0 µm in diameter. Larger particles cause a measureable attenuation/extinction of the laser intensity and are sized according to their extinction. Based on the amount of light scatter or extinction measured, a count is placed in the size bin fitting that particle's size. There are eight size bins or channels in each WPC ranging from 0.15 µm to 30 µm. To test the WPC calibrations, a known particle size and concentration need to be passed into the WPC. Because of the large range of sizes covered by the WPC, the tests required different test aerosol: ammonium sulfate and both wet and dry polystyrene latex spheres.

2.1 Ammonium Sulfate test (0.15, 0.30, 0.50 µm)

Particles to test the smallest three WPC sizes were created from an ammonium sulfate solution with a constant output atomizer and a differential mobility analyzer (DMA). The atomizer generates particles which are then dried, and neutralized before running through the DMA. The DMA separates particles based on their electric charge, which is related to their size, and outputs a nearly monodispersed distribution with a median size at the DMA selected particle size. Next, particles are run through a dilution chamber and then split with half going into a scanning mobility particle sizer (SMPS) and half going into a second dilution chamber. The SMPS is a combination of a DMA and a condensation particle counter (CPC). Within the

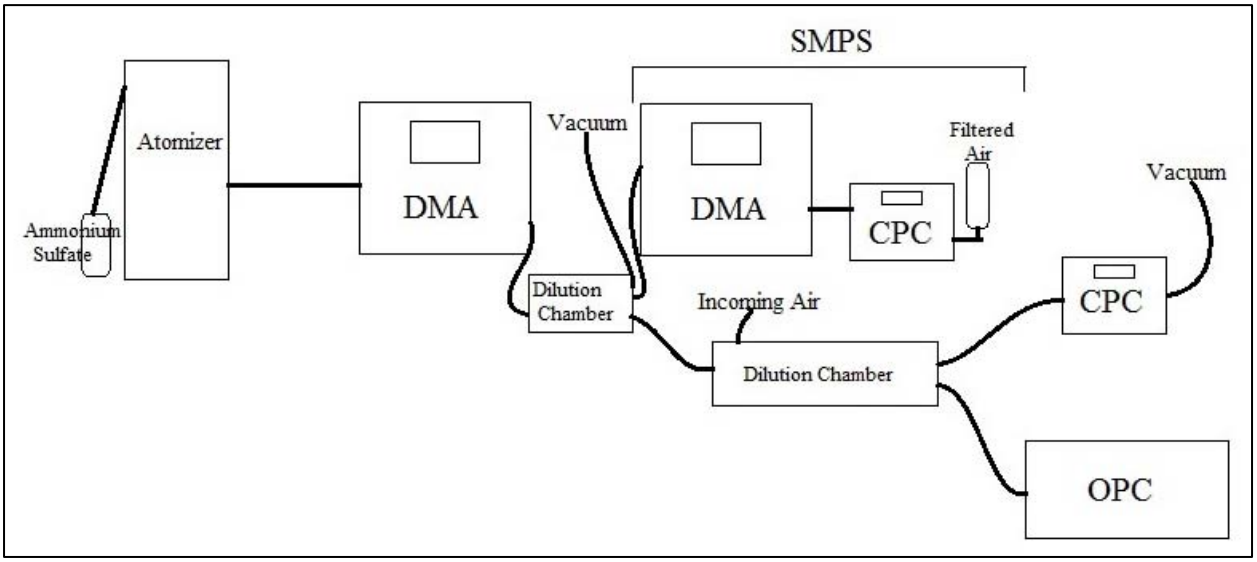

Figure 1: Lab set up for the DMA test. Sizes tested include: 0.150, 0.225, 0.300, 0.400, 0.500, and 0.600 µm.

SMPS, the DMA scans through voltages to select particles between about 20 nm and 600 nm. The CPC then measures the concentration of particles coming out of the DMA for each different voltage. The concentration for each size, corresponding to the stepped through voltages, are plotted and the median of the particles that went through the SMPS is measured. This ensures that the first DMA is generating the expected median size of particles. The other half of the particles from the first dilution chamber enter the second dilution chamber and are split again with half going into a CPC and half to the WPC being checked (figure 1).

Comparing the WPC measurement with the CPC measurement at different DMA selected particle sizes determines if the WPC's size channels are working properly. When a particle size corresponding directly to an WPC channel size is being generated, the DMA creates a distribution with half of the particles smaller and half larger than the channel size. In addition each WPC channel is calibrated to count all particles larger than the channel; however, any WPC produces a distribution of pulses from a monotonic input, so when an exact channel size is being tested, only half the particles generated by the DMA should be counted. Therefore, the WPC channel being tested should measure 50% of what the CPC is measuring, because the CPC counts all particles. For these tests, particles were selected at each channel size as well as one particle size in between each channel. Because of the geometry of the DMA it is difficult to create particles larger than about 600 nm from an ammonium sulfate solution. The solution does not contain many larger particles and the DMA is not long enough to allow larger particles to pass through at the maximum rod voltage thus, only the smallest three size channels can be checked with this method leading to the need for other types of tests.

2.2. Polystyrene Latex Spheres in water (1.0, 2.0 µm)

To generate particles between 0.7 µm and about 2 µm polystyrene latex spheres (PSL) suspended in water are used. The water is aspirated into an evaporation and dilution chamber (in the ceiling). In the dilution chamber the water evaporates and the PSL particles pass down a tube and are drawn into the WPC inlet with the WPC pump (figure 2). The size of the PSL is known so the highest concentration measured by the WPC should be indicated in the size channel corresponding to the PSL size being tested. As long as the proper WPC size channel has the greatest measured concentration when particles are put through, the WPC is operating as expected. There will however be

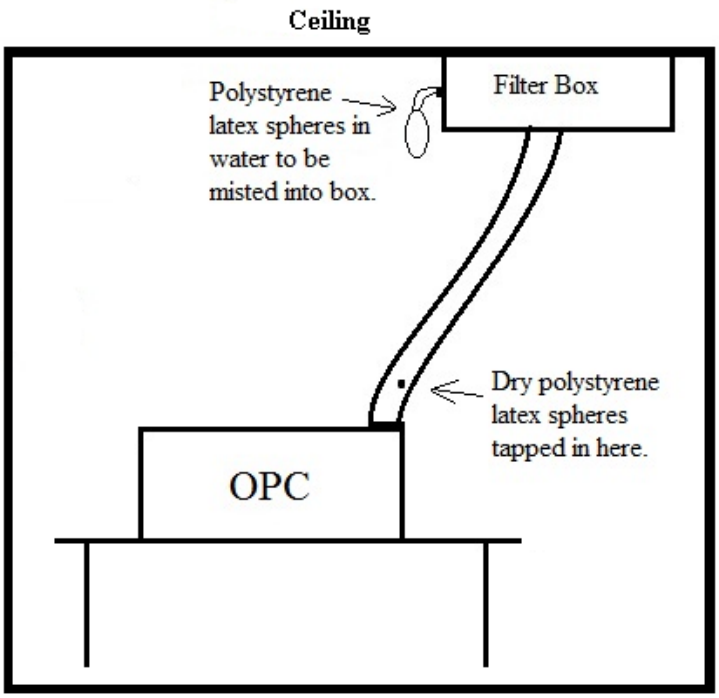

Figure 2: Set up for polystyrene latex sphere tests. (The pump is in the ceiling.)

counts in the lower channels due to contaminants in the water appearing as particles after the water evaporates. At around 2 µm it becomes difficult to suspend the particles long enough to get concentrations of PSL in water high enough to see that the WPC is responding, so dry PSL must be used to test the largest three size channels.

2.3 Dry Polystyrene Latex Spheres (5.0, 10.0, 30.0 µm)

Testing with dry PSL is almost the same as testing with PSL in water, except that the particles are placed in a small hole in the tube going to the WPC inlet, rather than into the dilution chamber (figure 2). The ceiling dilution chamber is flushed so just filtered air is passing down the tube to the WPC inlet. PSL are placed on a toothpick, inserted through a small hole in the tube, and gently tapped to release them into the WPC. Just as with PSL in water, the particle size is known, so as long as the size channel that is being tested has the most counts, the WPC is responding properly. Particle sizes tested with dry PSL ranged in size from around 5 µm to 50 µm so the largest three size channels can be tested with this method.

3.0 WPC check results

3.1 Ammonium Sulfate test results

Optimal results for the ammonium sulfate test would have an WPC/CPC concentration ratio of 0.5 at particle sizes corresponding to each channel size. For particles larger than a channel size the WPC/CPC ratio should approach one, while for smaller particles the WPC/CPC ratio should approach one, while for smaller particles the WPC/CPC ratio should approach zero. All WPC's tested with ammonium sulfate showed the expected increase in WPC/CPC ratio as particle size increased, but the WPC/CPC ratio for particles at each channel size was never 0.5. This could be due to experimental error or calibration error with the channel size set to a slightly smaller or larger size than the proper channel size. The results for all three WPC's can be seen in figures 3, 4, and 5. (Hereafter the three WPC's will be referred to as J6p, J7p, and J8p.) Using a linear

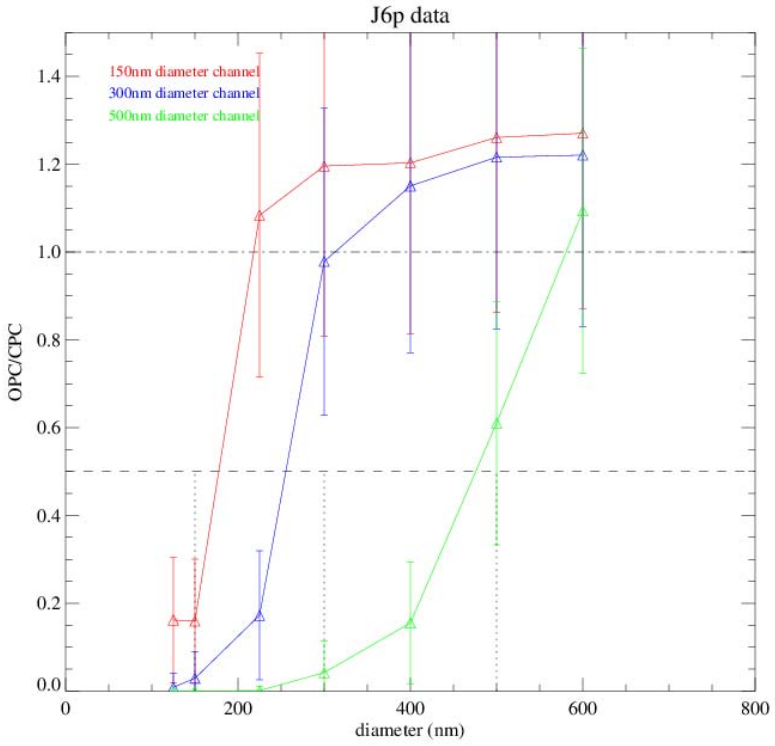

Figure 3: J6p DMA test results for first three channels. Triangles indicate the OPC/CPC ratio for size tested.

fit with the points surrounding (or closest to) the 0.5 WPC/CPC ratio for each channel, the diameter at which each channel has an WPC/CPC ratio of 0.5 is calculated. Table 1 shows the calculated diameters for 50% counting efficiency, as well as the WPC/CPC ratio at the expected channel size. Even though most of the channels were not hitting the 0.5 mark exactly on the channel size, all WPCs showed the expected responses below 0.5 for smaller particle and approaching 1 for larger sizes. Therefore, despite the fact that channel size calibrations were found to be off by as much as 50 nm, the WPCs showed expected results and the measured particles will at least be close to the channel sizes specified.

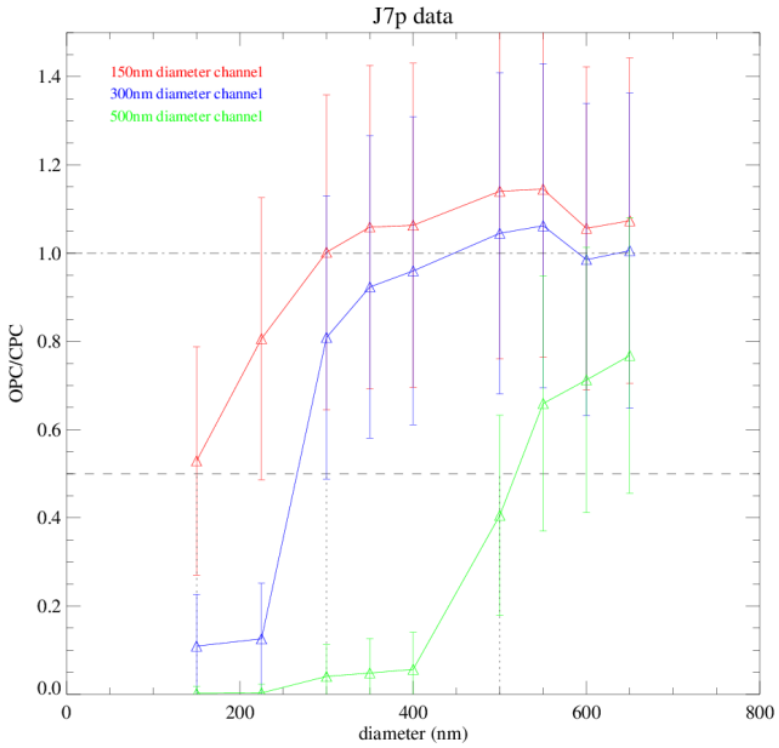

Figure 4: J7p DMA test results for first three channels. Triangles indicate the OPC/CPC ratio for size tested.

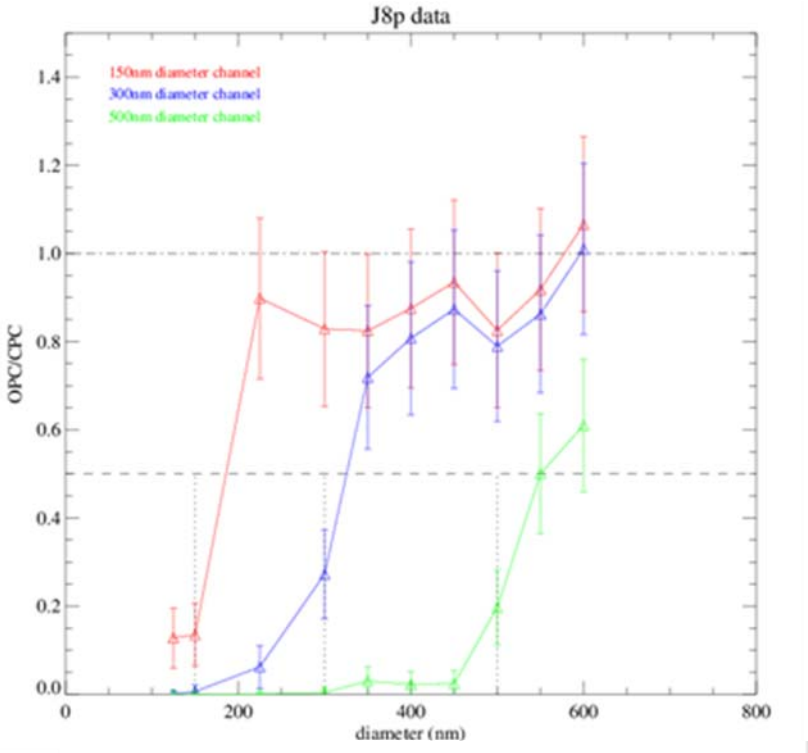

Figure 5: J8p DMA test results for the first three channels. Triangles indicate the OPC/CPC ratio for the size tested.

	J6p		J7p		J8p	
Channel Diameter (μm)	WPC/CPC ratio	Diameter @ 0.5 ratio (μm)	WPC/CPC ratio	Diameter @ 0.5 ratio (μm)	WPC/CPC ratio (μm)	Diameter @ 0.5 ratio (μm)
0.15	0.16	0.18	0.53	0.14	0.13	0.19
0.30	0.99	0.26	0.81	0.27	0.27	0.33
0.50	0.62	0.48	0.41	0.52	0.20	0.55
1.00	Responding		Responding		Not Responding	
2.00	Responding		Responding		Not Responding	
5.00	Responding		Responding		Not Responding	
10.00	Responding		Under Responding		Not Responding	
30.00	Under Responding		Under Responding		Not Responding	

Table 1: OPC calibration check results for three recovered instruments.

3.2 PSL Sphere test results

Ideal results for tests with PSL would show counts in all channels smaller than the test channel size with nearly the same concentration, and all larger channels would have a concentration of zero. In the real world, however, there are multiple sizes of particles indicated because the tests are prone to experimental error as well as contaminants that come from the evaporated water so other particle sizes often show up in the results.

Only J6p and J7p were checked with larger particles because the larger size channels in J8p were not responding after recovery. The results for the PSL in water test for J6p and J7p are shown in figure 6. As the input particle size increases, the 1.0 μm channel measures concentrations closer to the smaller channels, as it should. The size of the PSL being inserted into the WPC is listed between the horizontal dotted lines. Figure 7 shows the results for the dry PSL test. The results indicate that all the J6p channels, with the exception of the 30 μm channel, are responding to particles as expected. When PSL sizes larger than 30 μm were tested the measured concentrations for both J6p and J7p were not very close to the smaller channel sizes indicating an under-response. The results for all channels and all three WPC's are listed in table 1. These tests show that most of the channels in J6p and J7p are responding properly with the exception of the largest one or two channels. However, testing such large particle sizes has its own problems.

4.0 Conclusion of WPC check results

All three WPC's showed expected responses after recovery with the exception of the large channels in J8p. Despite the fact that none of the channel sizes had an WPC/CPC ratio of exactly 50%, the calculated diameters at 50% counting efficiency were within about 0.05 µm of the nominal channel size. J6p and J7p both showed responses in all extinction channels; however, the largest channels showed very low responses even when PSL larger than their channel size was being tested. Therefore, the measurements from J6p and J7p can be trusted, because their channels showed proper responses after recovery. The first three channels in J8p can also be trusted, but the extinction channels were found to be poorly calibrated by a large amount that could not have occurred due to a rough landing, so only data from the three smallest channels can be analyzed.

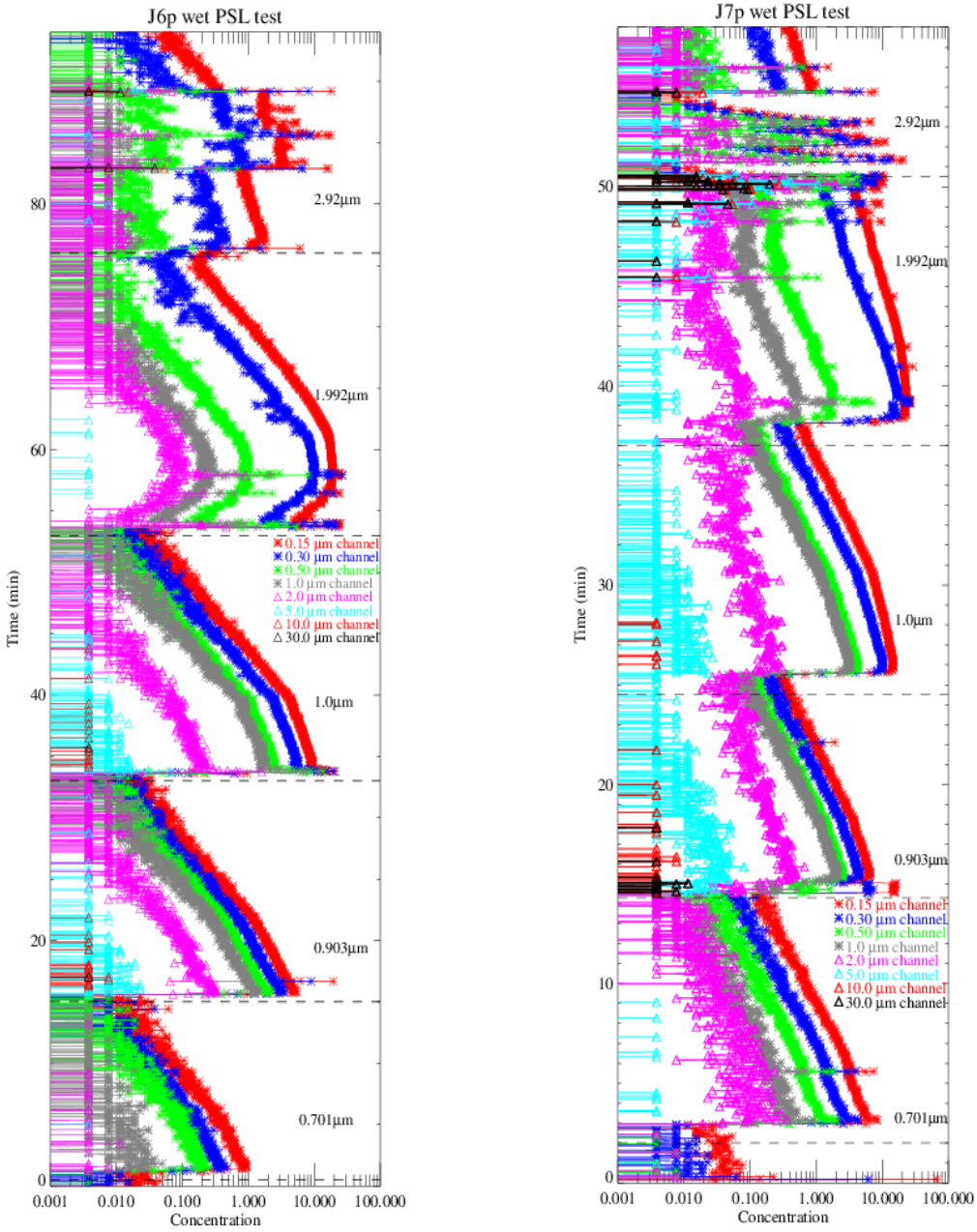

Figure 6: J6p (left) and J7p (right) wet PSL test results. Time is along the y-axis with the logarithm of concentration along the x-axis. Each color corresponds to a different channel (as indicated in figure)

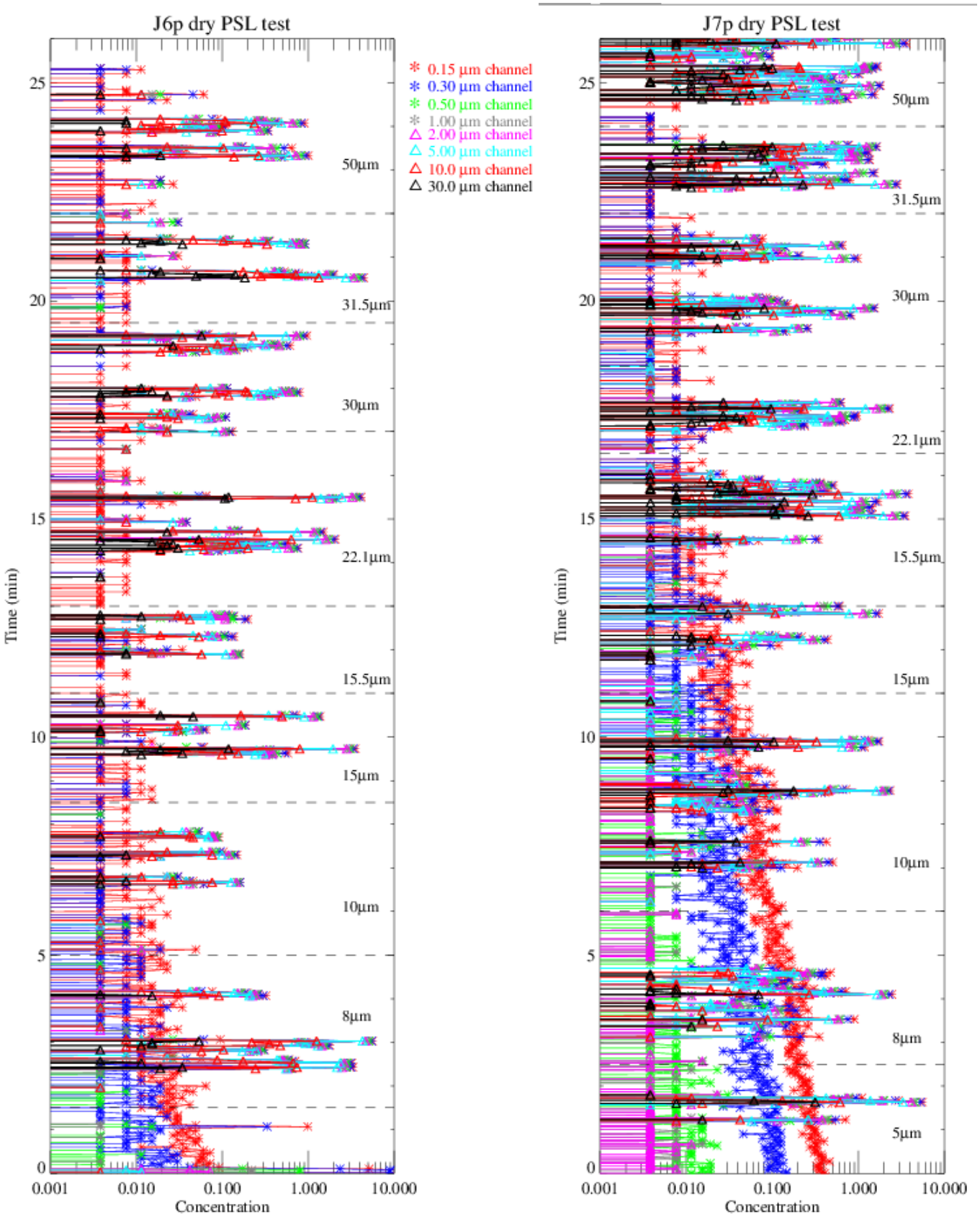

Figure 7: J6p (left) and J7p (right) dry PSL test results. Time is along the y-axis with the logarithm of concentration along the x-axis. Each color corresponds to a different channel (as indicated in figure).