PUTLS Data Reduction: A Sausage Recipe

Matthew Brown[1, 2], Michael Shook[1], Chuck Wilson[3], and Luke Ziemba[1]

[1]Chemistry and Dynamics Branch, NASA Langley Research Center, Hampton, VA 23681
[2]Science and Technology Corp., Hampton, VA 23666
[3]Self

PUTLS Instrument Paper

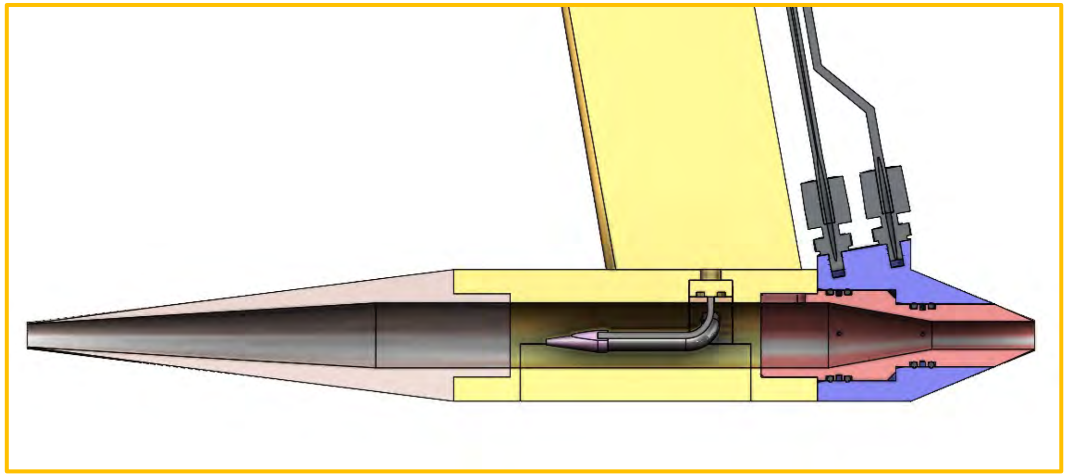
1. Instrument review
2. Introduction: PUTLS since ACCLIP
3. Data Reduction Algorithms
   - Coarse-mode aerosol
   - Fine aerosol
4. Application to ACCLIP features
5. Future

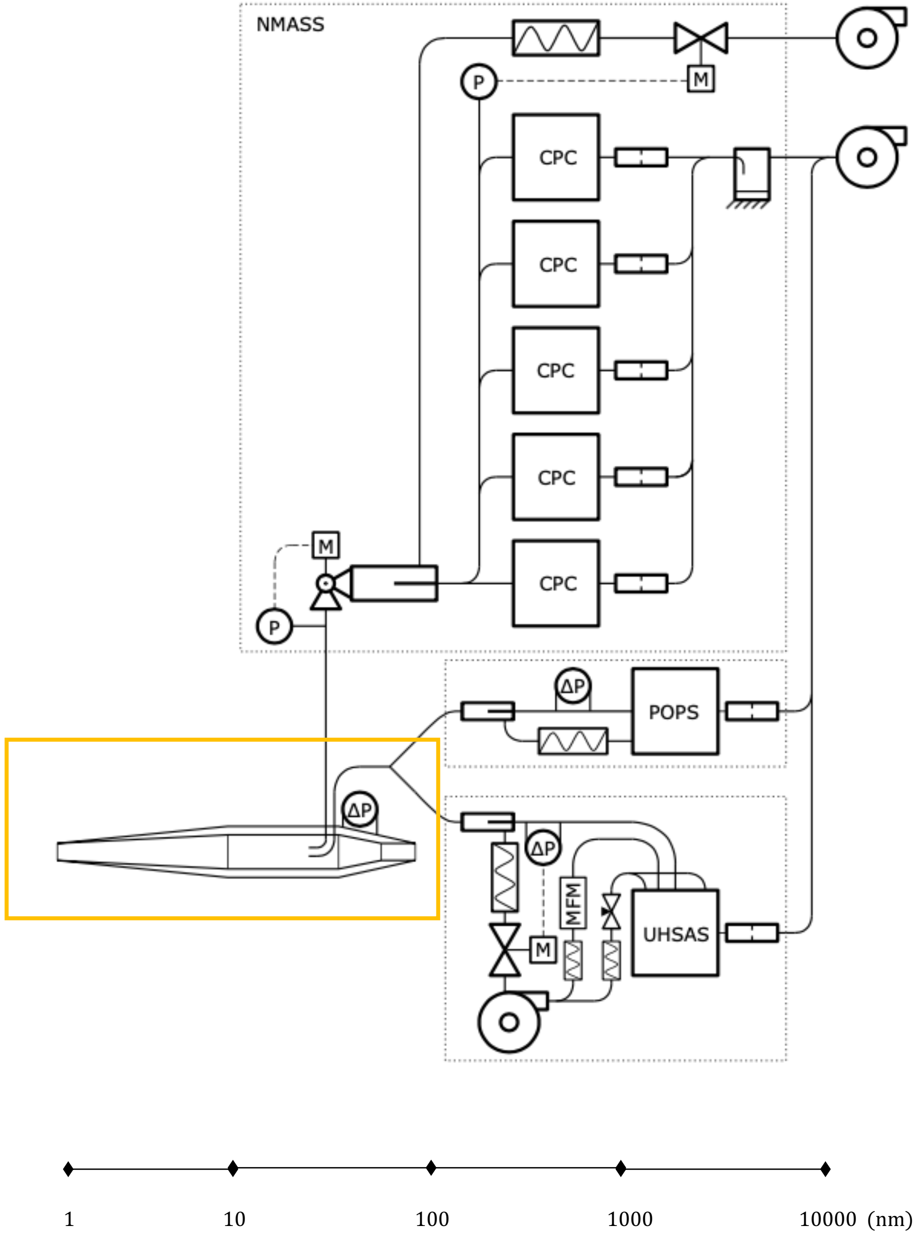
PUTLS Review

Particles in the Upper Troposphere, Lower Stratosphere (PUTLS) consists of:

Passive, Near-Isokinetic Inlet (PNII)

- Particle sampling inlet to bring ambient aerosol inside the aircraft to instruments, minimizing bias from particle inertia effects





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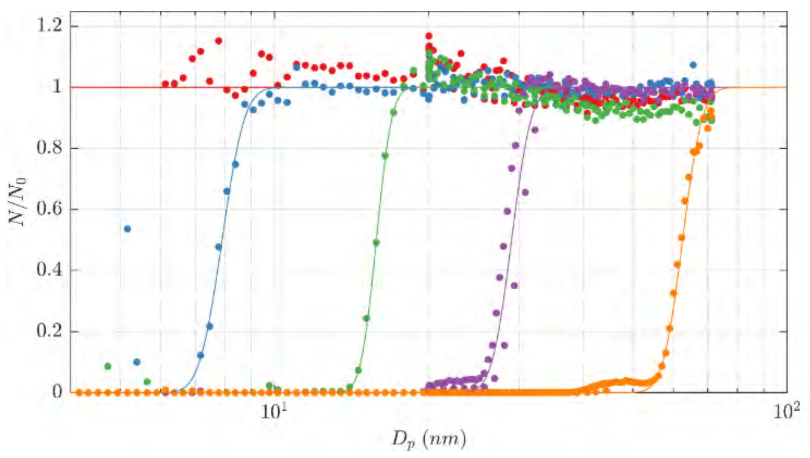
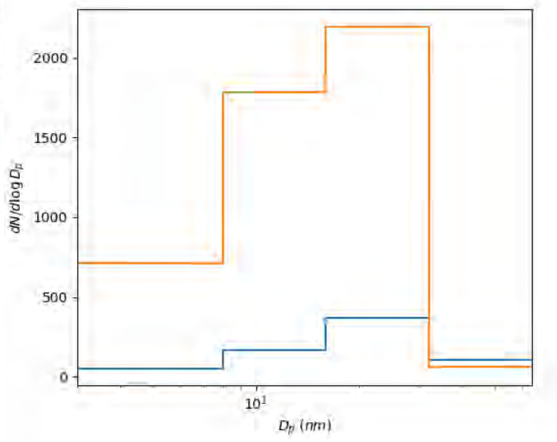
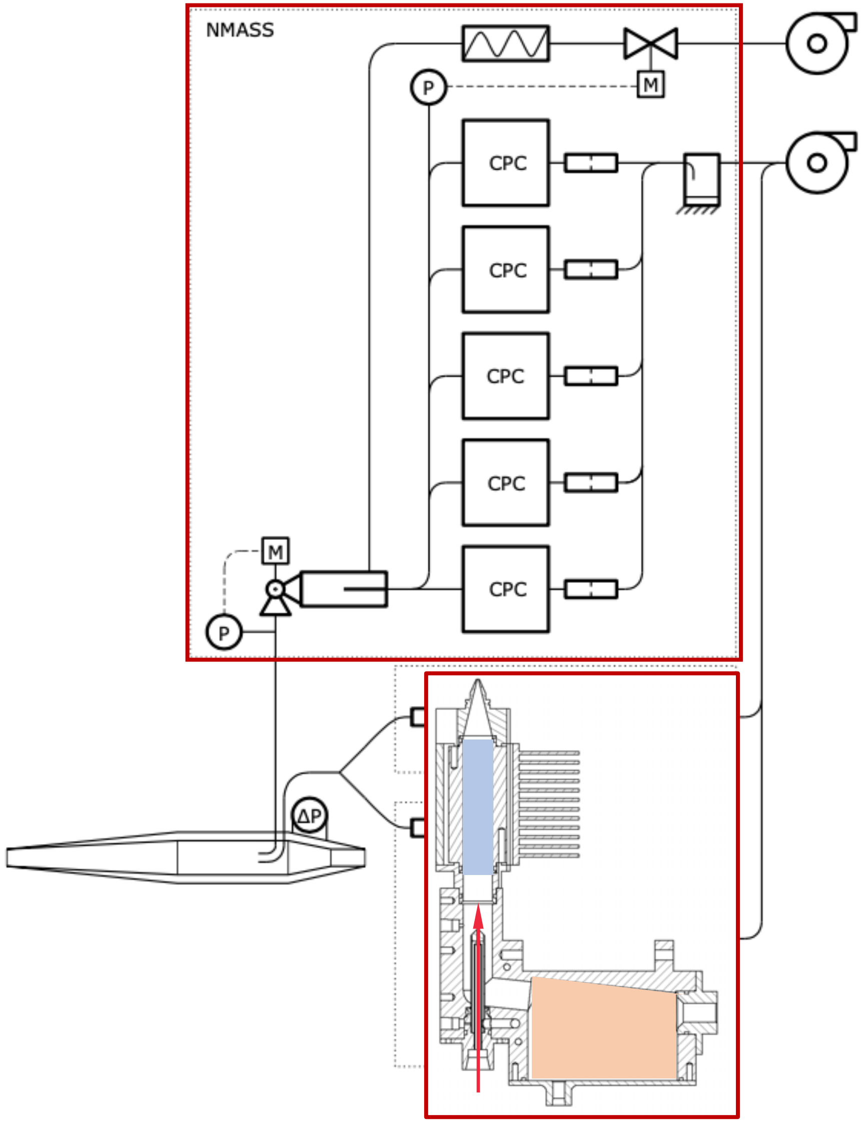
Nuclei-Mode Aerosol Size Spectrometer (NMASS)

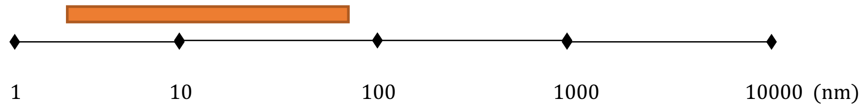
- Aerosol sizing instrument that thermodynamically grows particles via supersaturation to be counted by spectrometry technique
- Supersaturation determines cut-size of when particles grow and can be staggered to obtain a size distribution
- Nucleation mode particle sizing

$$D_p = 3 - 64\ nm$$









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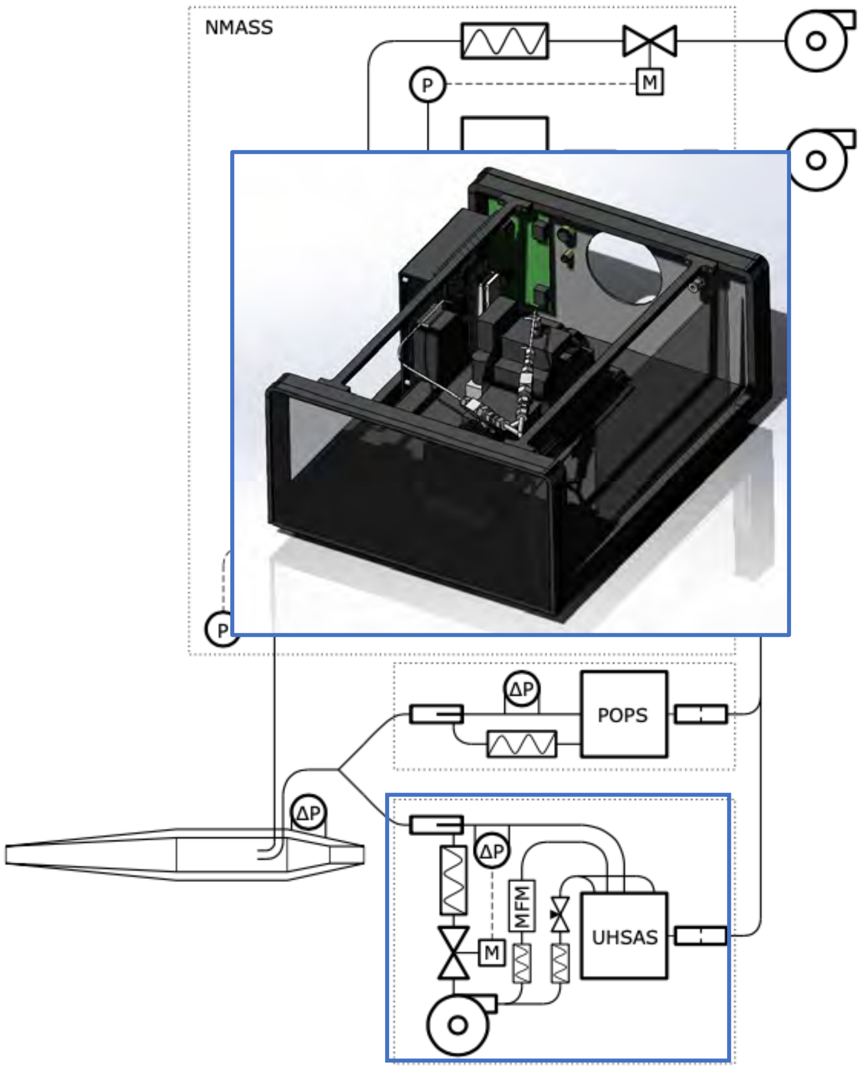
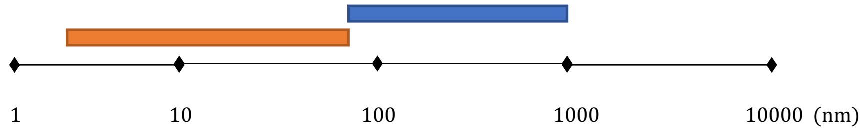
Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)

- Calculates particle size by measuring the amount of laser light scattered
- Accumulation mode particle sizing

$$D_p = 60 - 1000\ nm$$





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- Aerosol sizing instru
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- Nucleation mode pa
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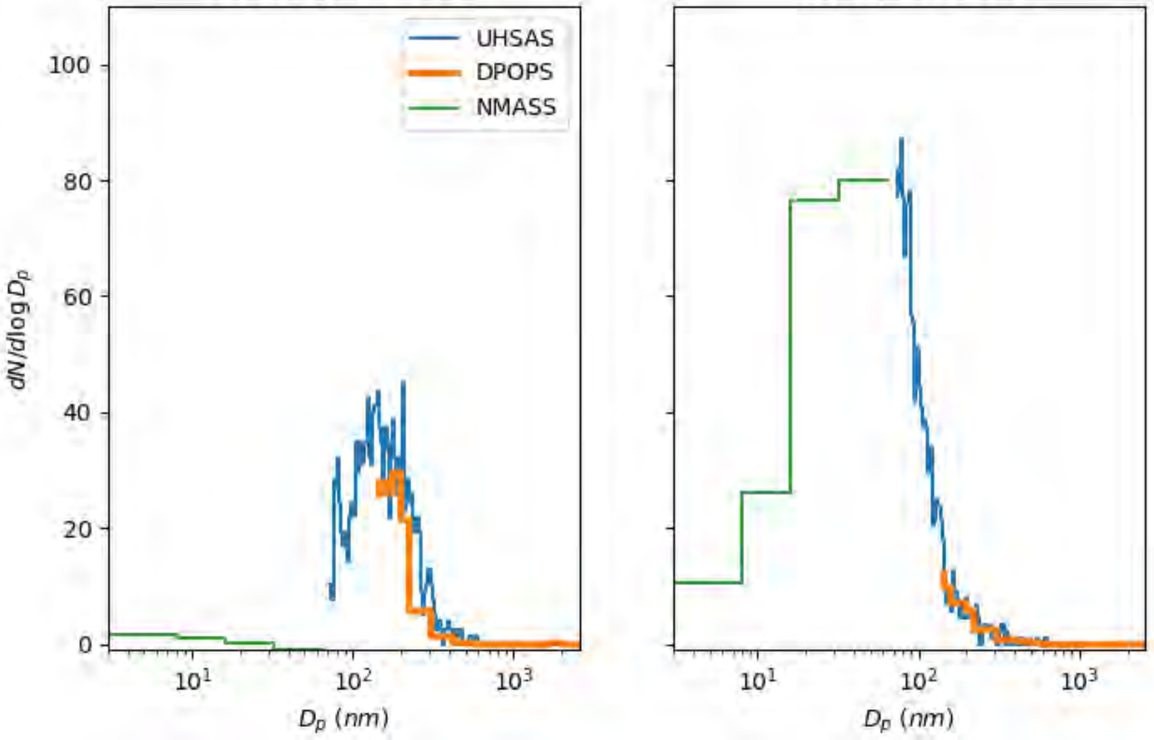
Ultra-High Sensitivity Aer
- Calculates particle s
  scattered
- Accumulation mode
  D_p

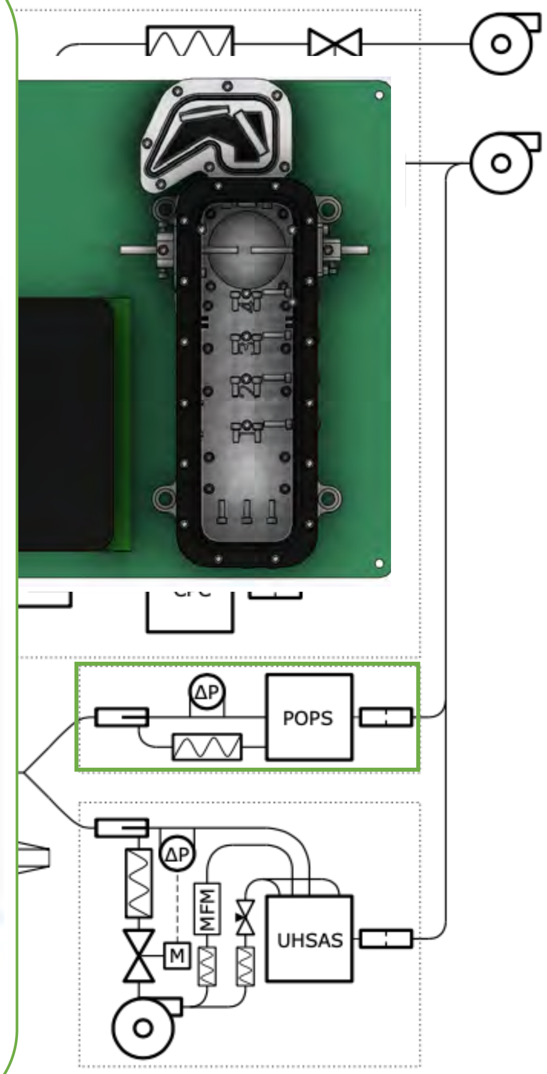
Printed Optical Particle S
- Calculates particle s
  scattered
- Lower resolution, but
- Accumulation and coarse mode particle sizing
  $D_p = 200 - 3000\ nm$

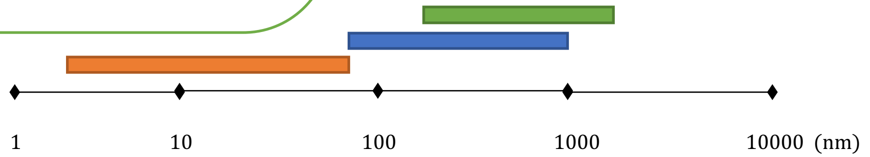
The POPS data has not been archived

We had an electronics failure on one of the transits, causing us to run our spare OEM POPS during the campaign



UHSAS is sufficient to characterize stratospheric aerosols





PUTLS since ACCLIP

1. Data Reduction Algorithms: ACCLIP was the inaugural mission for PUTLS

   Coarse-mode aerosol

   - Inlet anisokinetic sampling corrections
   - Tubing deposition losses (turbulence, gravity, tube bend)

   Fine aerosol

   - Single CPC coincidence corrections (TSI vs. Collins')
   - Create a size distribution (Poisson Statistics and Relative Difference) from NMASS channel binning
   - Diffusion loss correction using NMASS size distribution
   - Monodisperse continuous size distributions from NMASS channels
2. Integrated payload to 4 platforms (WB-57, MACH-2, DC-8 for EcoDemonstrator, P-3 for ARCSIX)
3. Instrument Development

Coarse Aerosol Corrections

Inlet inertial sampling corrections

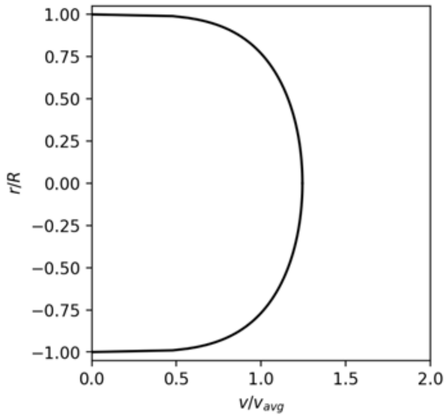
- Adiabatic compressible flow equations:

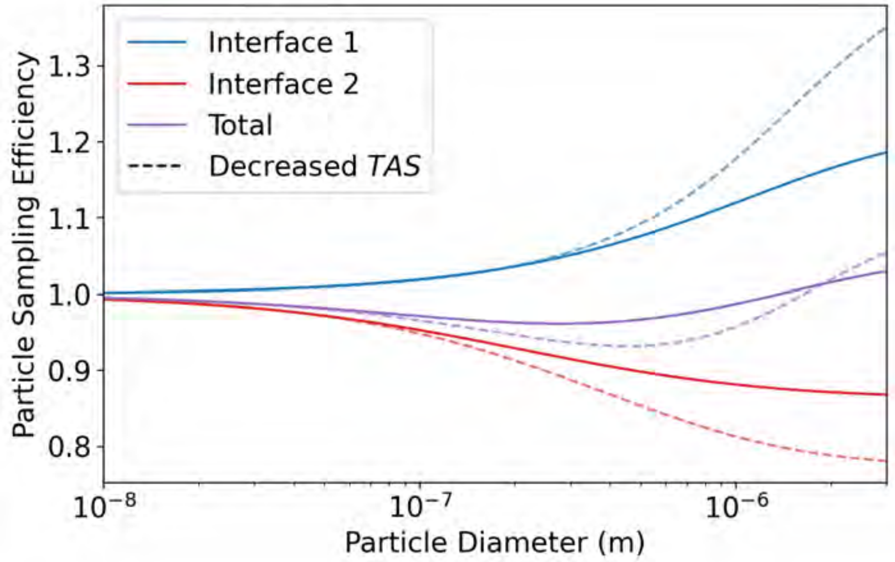
$$\dot{m}, Ma_x, P_x, T_x$$

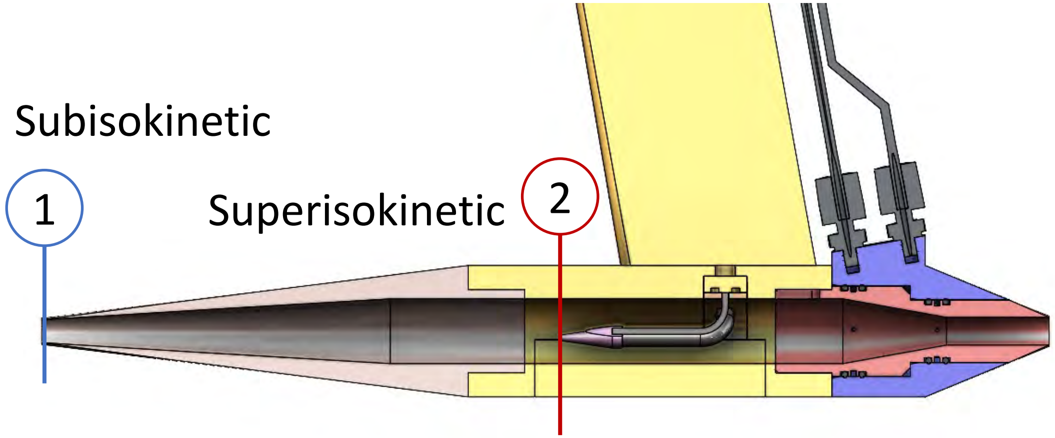
- Particle aspiration efficiency:

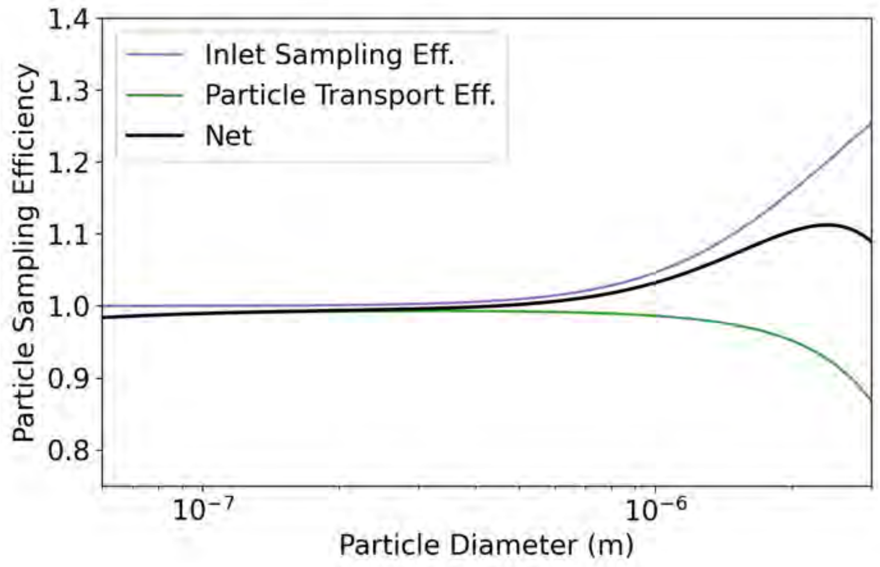
$$\eta_1(D_p) \propto \frac{\dot{m}}{\dot{m}_{free}(\psi(A_{in}))} \qquad \eta_2(D_p) \propto \frac{v_{sam}}{v_{2,cen}}$$

- Velocity profile: $v(r) = f(Re)$





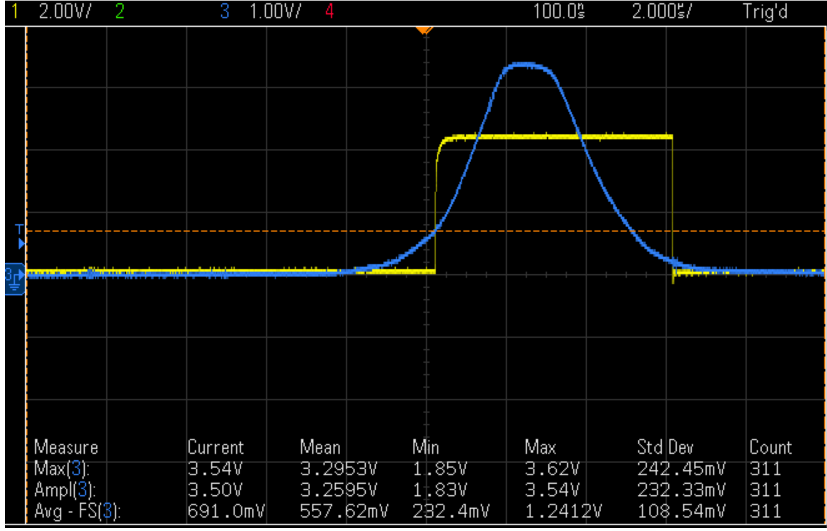




Tubing deposition losses (diffusion, turbulence, gravity, tube bend, etc.)

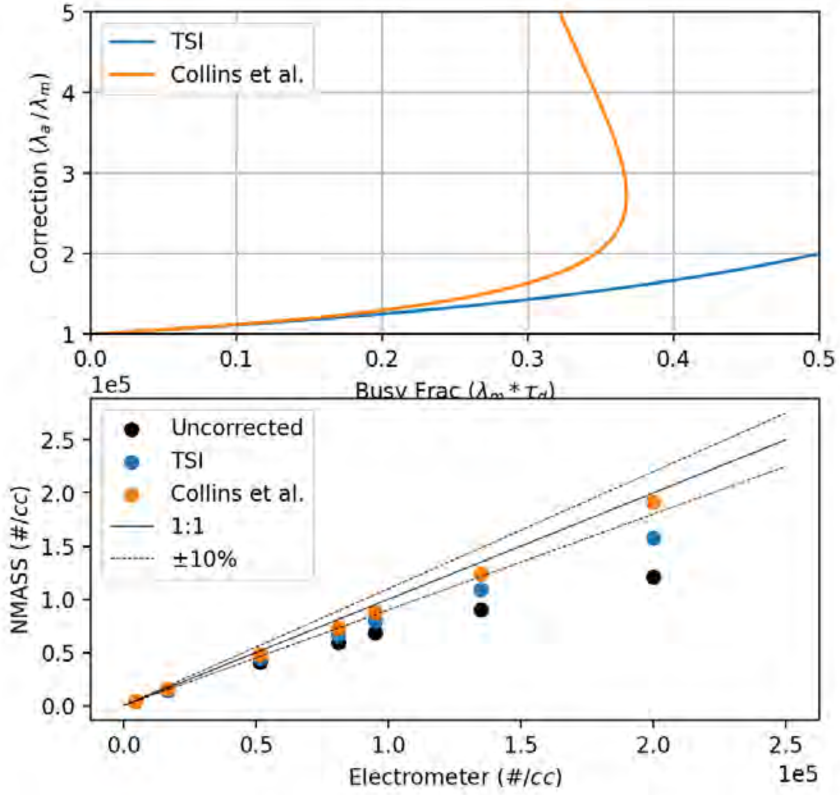
$$\eta_{Total} = \prod \eta_i\left(D_p, P, T, Q, d\right)$$

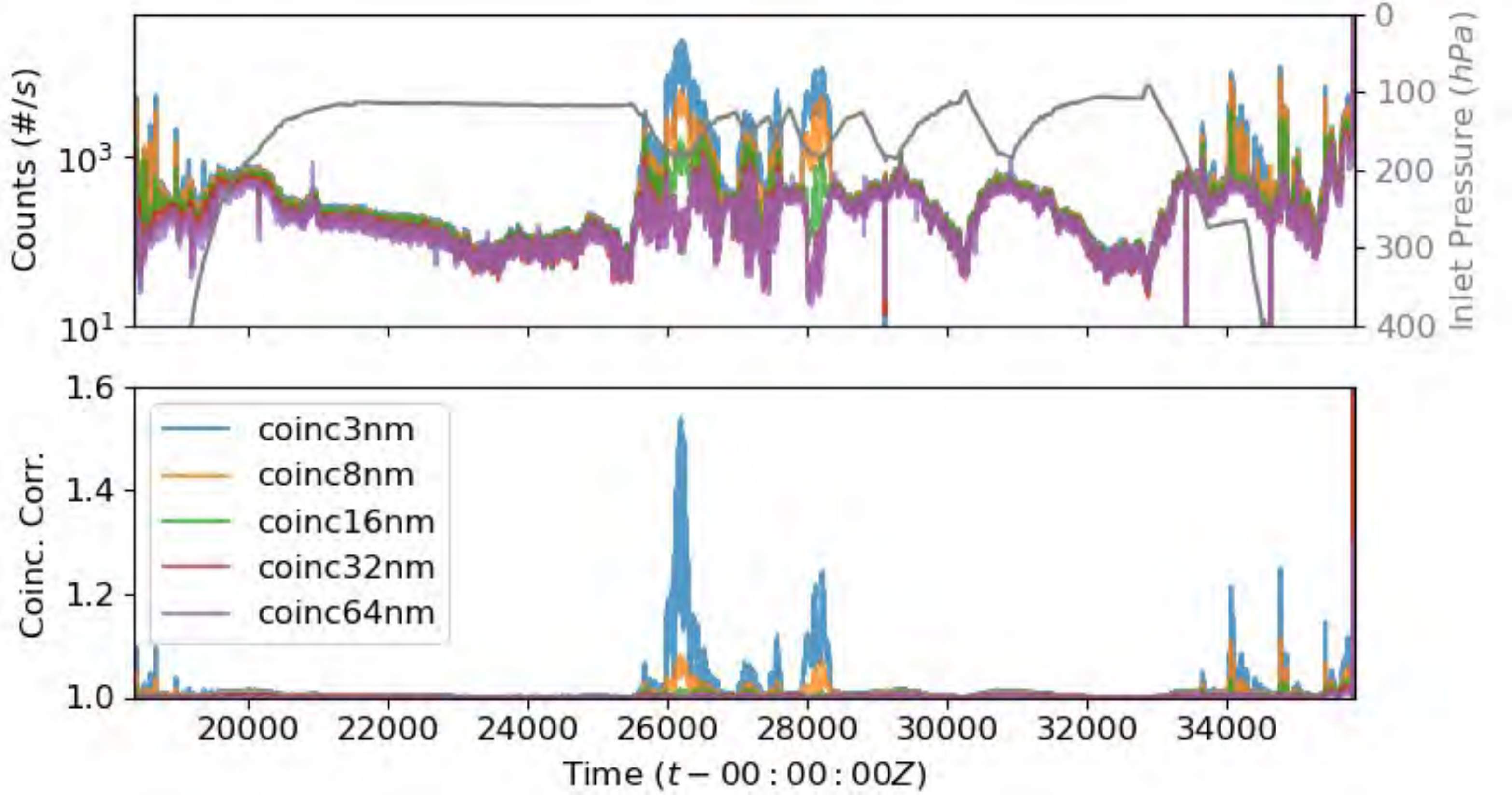
Fine Aerosol Corrections: Coincidence



Single CPC coincidence corrections (TSI vs. Collins')

- A particle travels across the counting laser for a finite time.
- While the detector voltage is "high" from a particle, any additional particles passing through are not counted. This is known as the busy or dead time of the circuit.
- These events become more significantly probable as the number of counts per second increases.

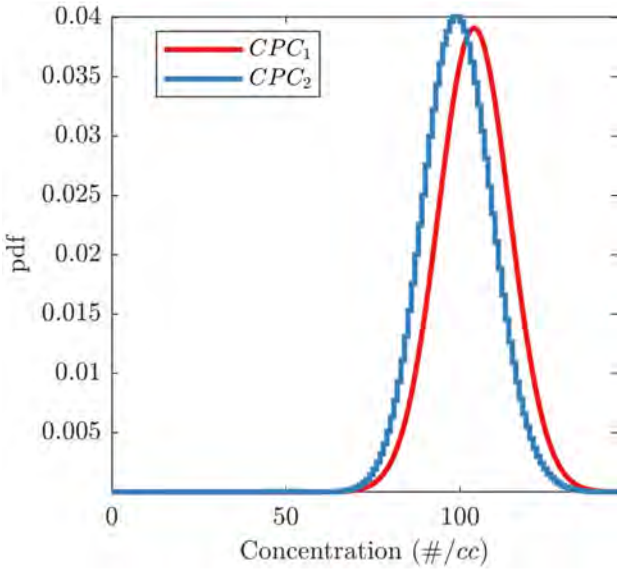


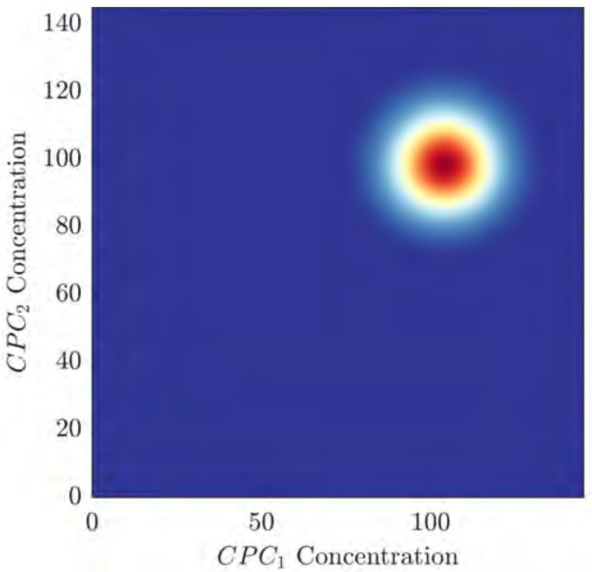


Fine Aerosol Algorithm: Size Distributions

Creating a size distribution from discrete NMASS channels

- Poisson Statistics from a discrete integers of randomly arriving particles



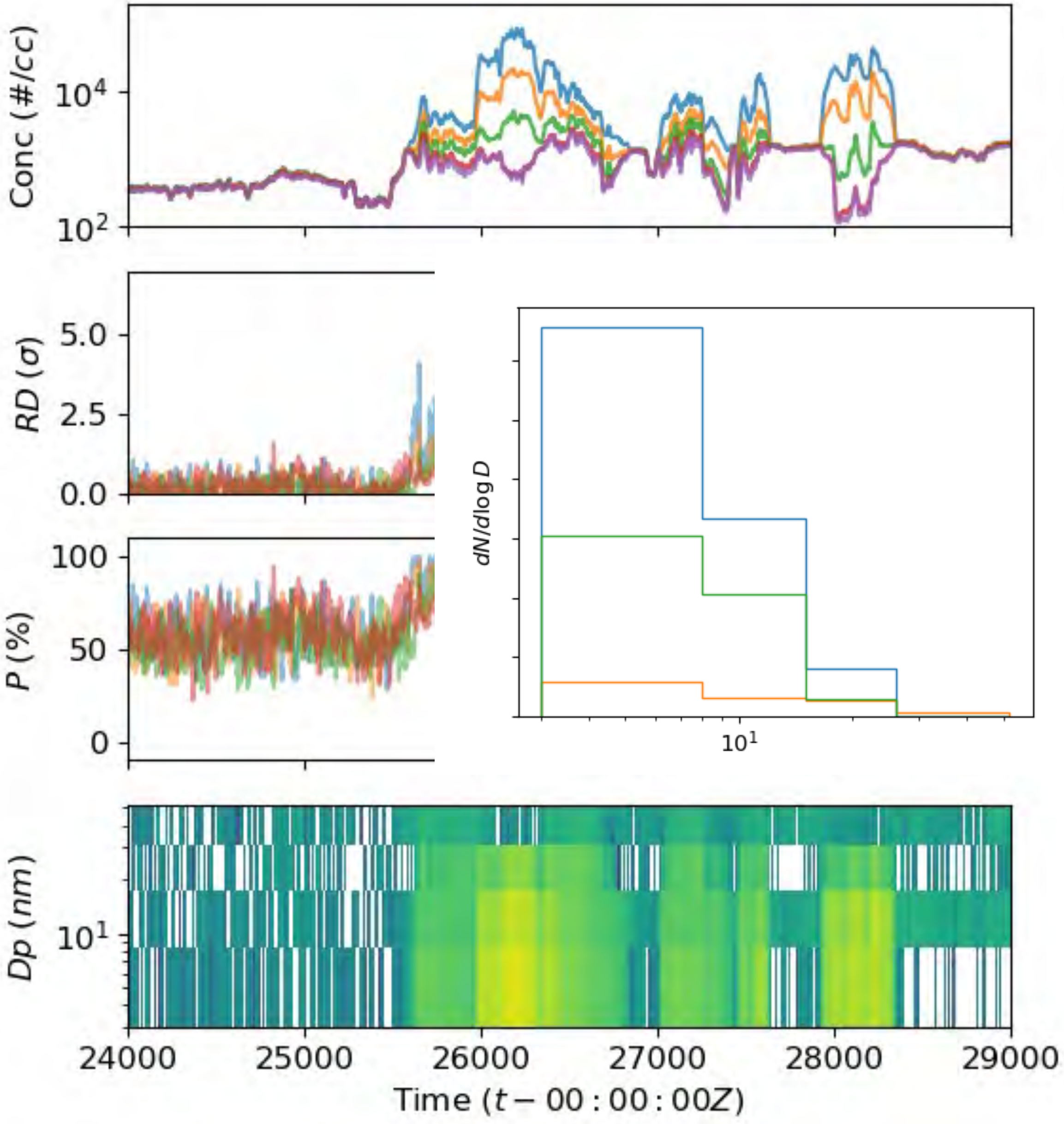


- Relative Difference between NMASS channels calculates the magnitude in standard deviations that e.g., Ch1 > Ch2

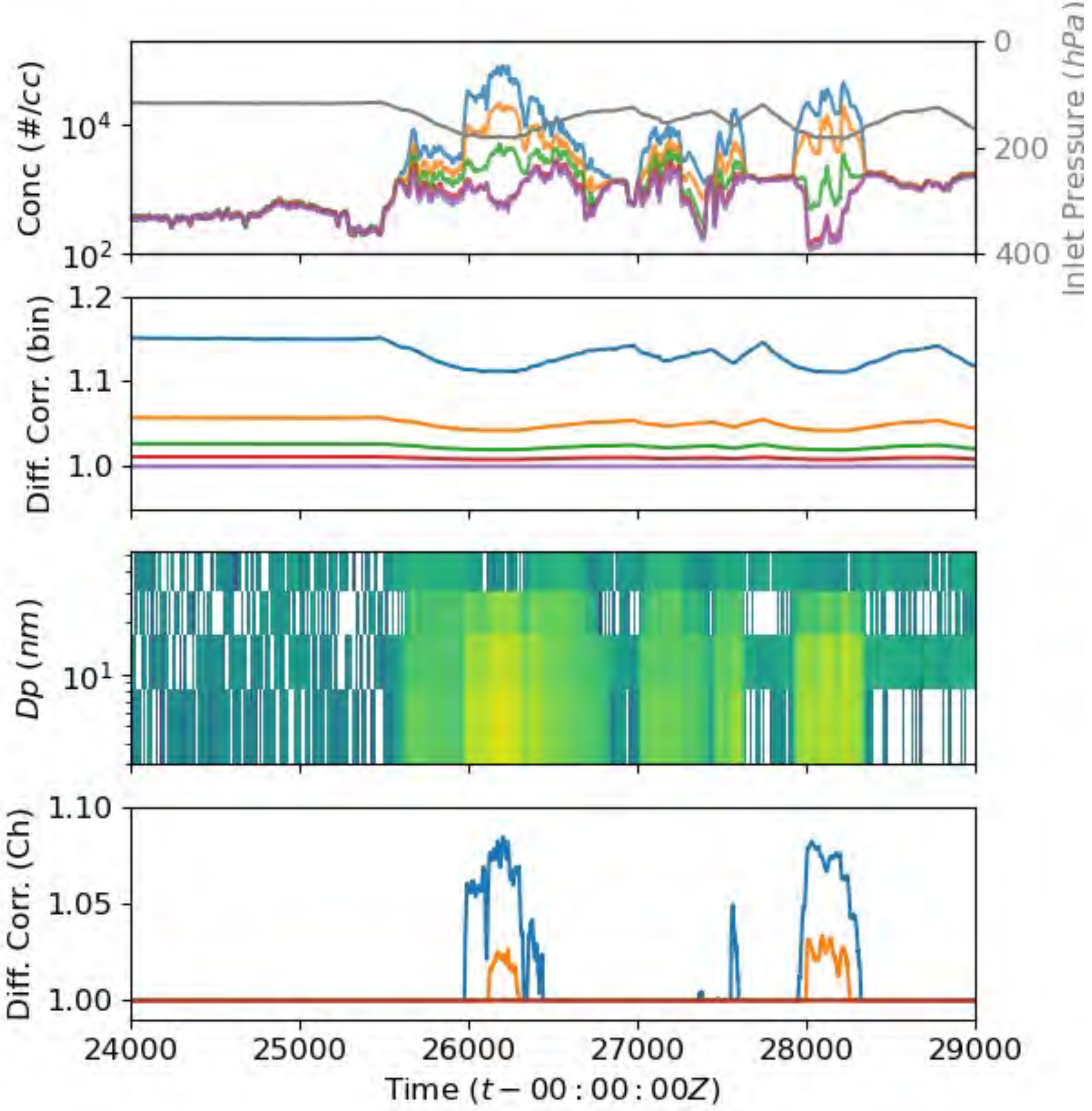
$$RD = \frac{(M_1 - M_2)}{\sqrt{(M_1 b_1 + M_2 b_2)}}$$

- Equivalent to the probability that CPC1 > CPC2 is the integral of the triangular matrix

$$C_{bin} = P(C_1 > C_2) * (C_1 - C_2)$$



Fine Aerosol Corrections: Diffusion



Diffusion loss correction using NMASS size distribution

Line loss corrections are not normally applied to Particle Counters because they do not contain any information about the size distribution.

We can subtract NMASS channels, and accounting for Poisson statistics, develop a probability of particle numbers sized between two channels.

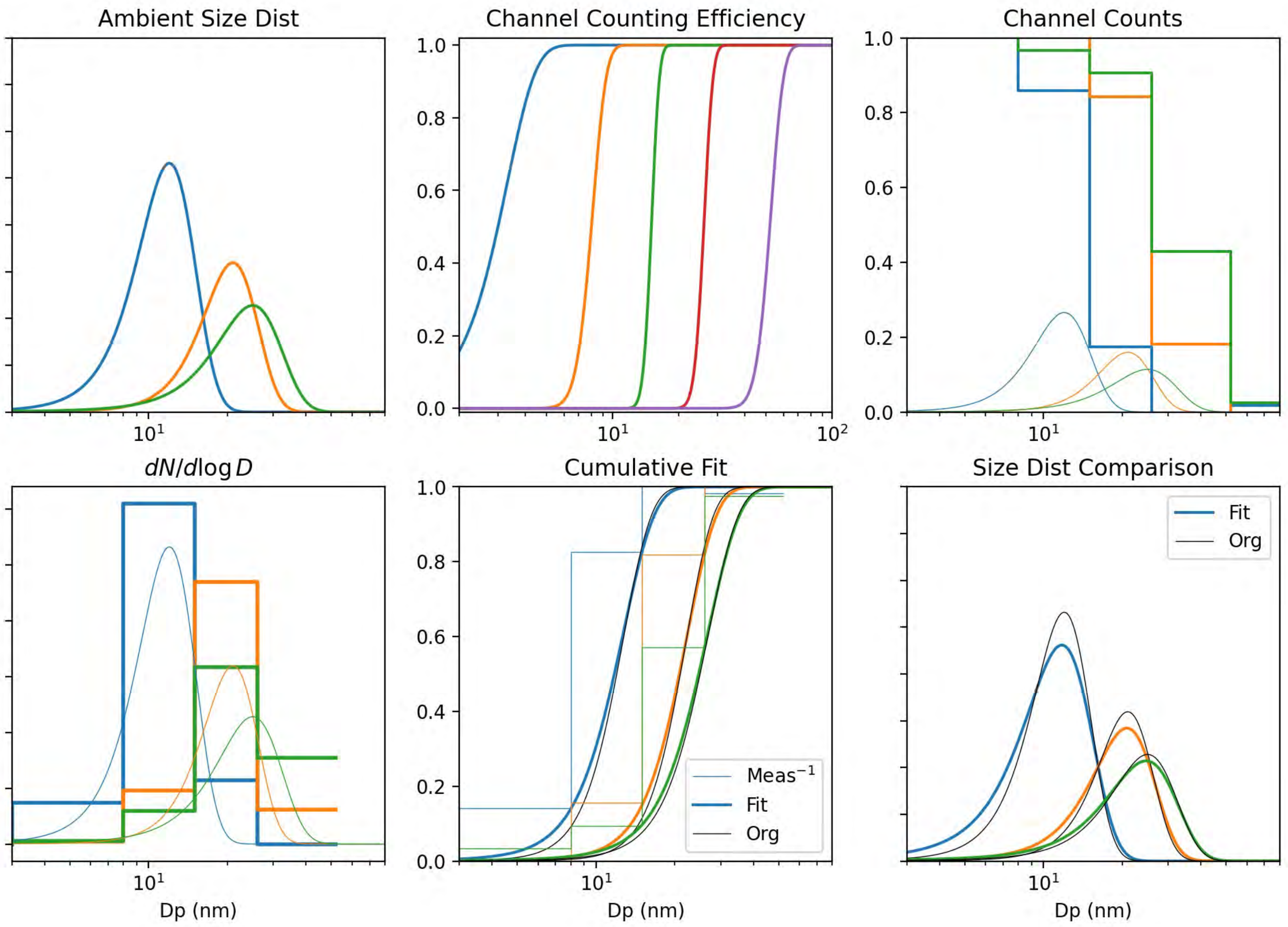
We can use each bin to obtain the size distribution and apply the normalized corrections to each CPC.

Archived data is diffusion corrected!

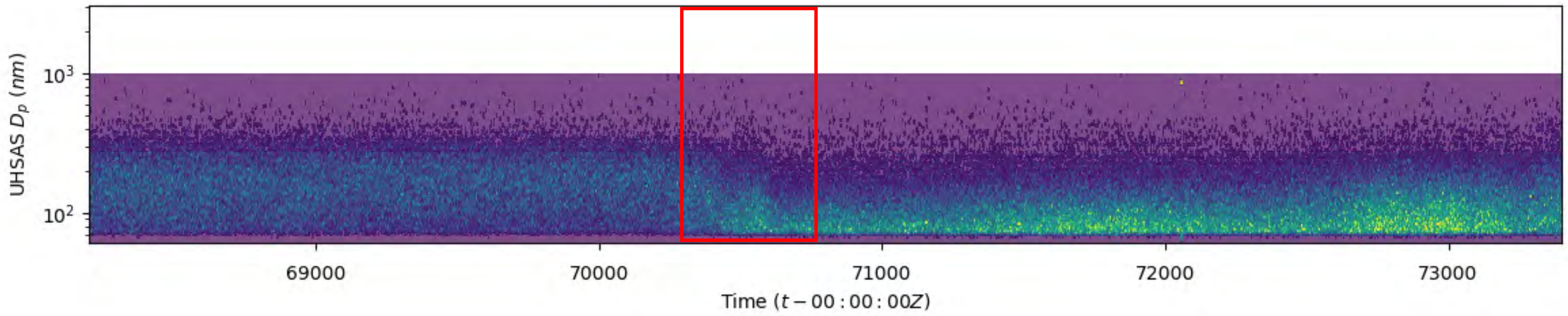
Fine Aerosol Algorithm: Continuous Sizing

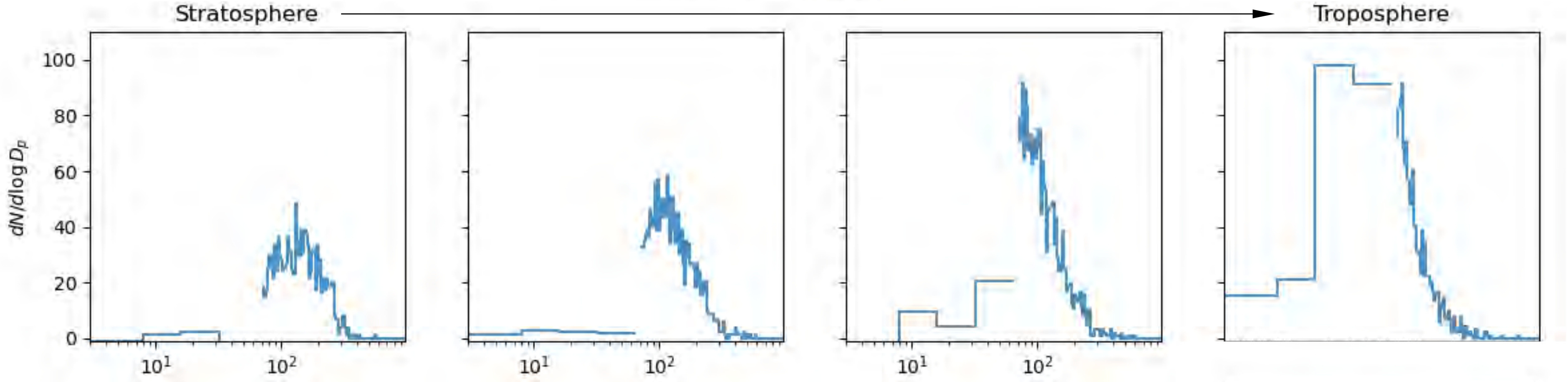
Monodisperse continuous size distributions from 5 NMASS channels

1. Suppose some size distributions
2. NMASS channels have non-step-response in counting efficiency
3. Simulated instrument response to the ambient size distribution, with added noise for Poisson statistics
4. Size distributions calculated from our previous techniques
5. What if, instead, we invert the instrument measurement response, normalize, and fit a cumulative distribution
6. Use the fit values to recreate the original size distribution



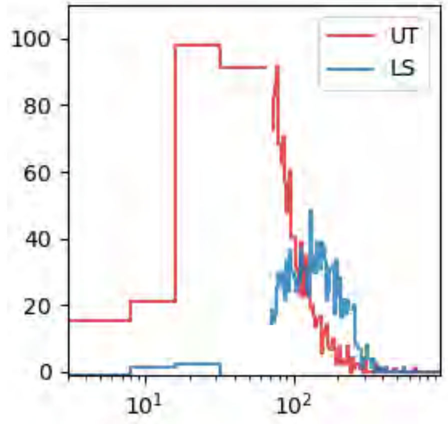
"Aeropause"





Transect of the Tropopause: spatial range of approximately 3km

- Aerosol size distribution correlates strongly with identifying the troposphere, mixing region, and stratosphere
  - Mode size at 150 nm to mode at 30 nm
  - Total concentration increasing from 20 #/cc to 150 #/cc

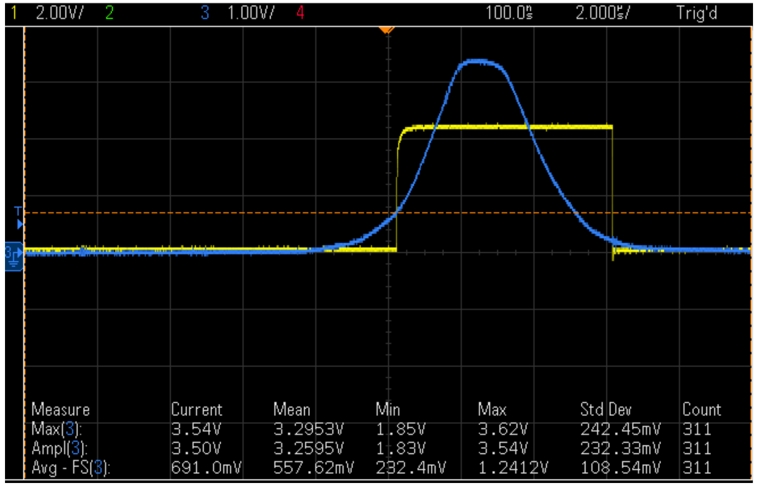


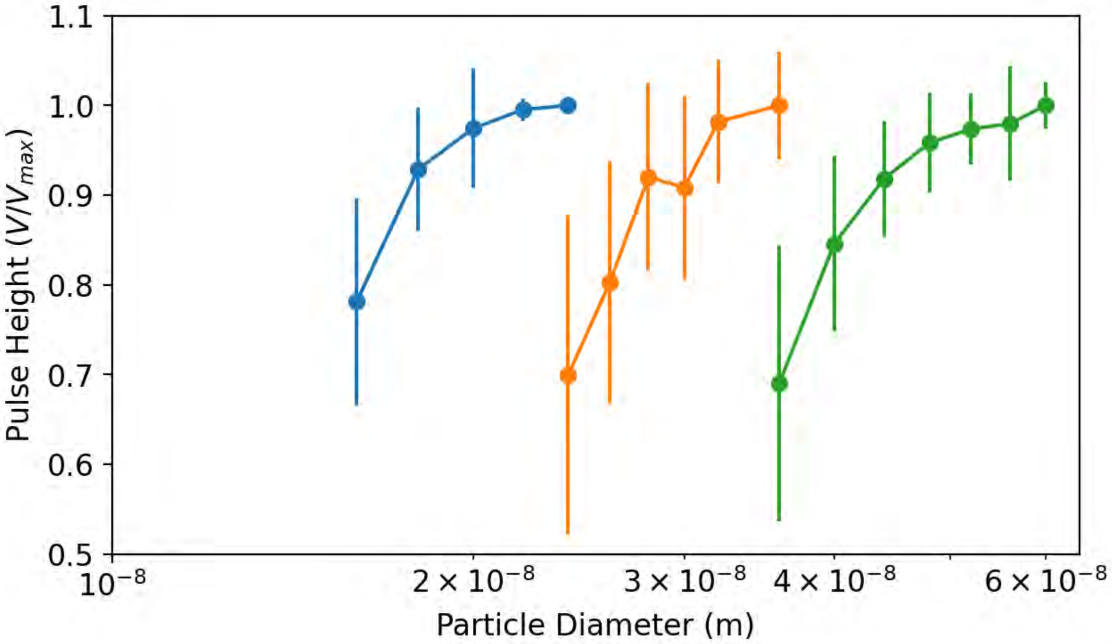
Future Direction

Analysis: Stitching instruments for continuous size distributions

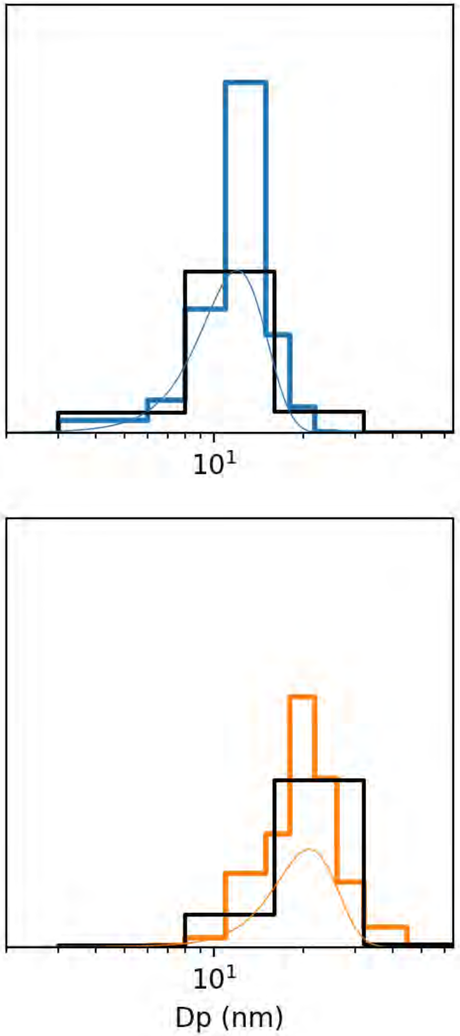
Publications:

- "Particles in the UTLS: Observations and Microphysical Properties of Aerosol"
- ATAL observations paper





Simulated response for visual representation



Future Developments:

- NMASS pulse height analysis, new photodiode circuit and data acquisition technique
  - Allows for potentially 3x the binning resolution per CPC

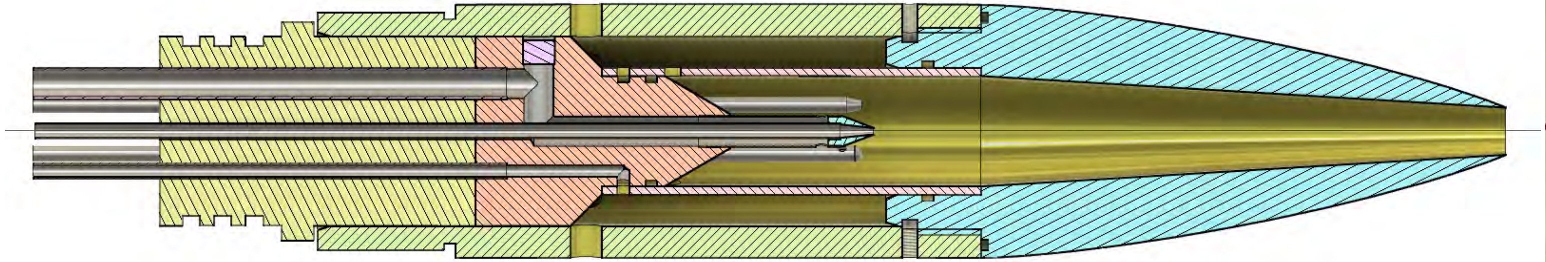
Future Direction / Lessons Learned

Back on Course!

- The idea: Build up PUTLS for a couple years, then move to science
- The reality: PUTLS is continually evolving platforms and capabilities, leaving no time for data analysis

Expanding the PUTLS team, enabling science *and* development

- Instrument support, enhancement, new technique development, and integration will become a dedicated role
- Focus: Science analysis of previous data sets



Lessons applied to upcoming ARCSIX

- New inlet developed for NASA P-3 and Boeing 777 platforms based on the PNII isokinetic correction technique
- Updated machined POPS optical cell
    - Focus: sealing techniques, particle flow alignment, laser and optics alignment tools
    - Multiple spares!