SAND2022-13605C

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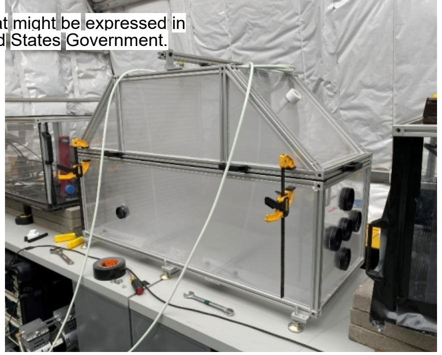
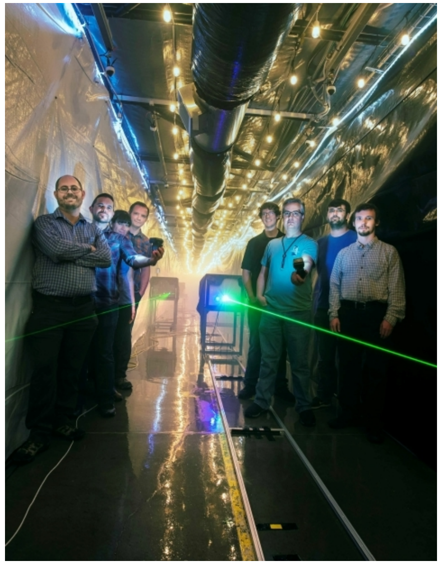
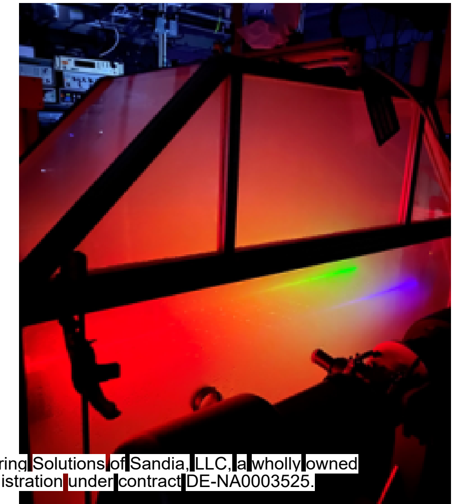
Optical Characterization of Atmospheric Aerosols in a Tabletop Chamber







Presented by: Christian A. Pattyn*

Jake Zenker, Jason Torchinsky, Pierce Warburton, Michael Schmidt, Peter Bosler, Andrew Glen, Andres L. Sanchez, Karl Westlake, Brian Z. Bentz, John D. van der Laan, Lyndsay Shand, Lekha Patel, and Jeremy B. Wright

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Raleigh, North Carolina, United States

U.S. DEPARTMENT OF ENERGY NNSA

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Monterey Area Ship Track Experiment (MAST)

P. A. Durkee, K. J. Noone, and R. T. Bluth, doi: 10.1175/1520-0469

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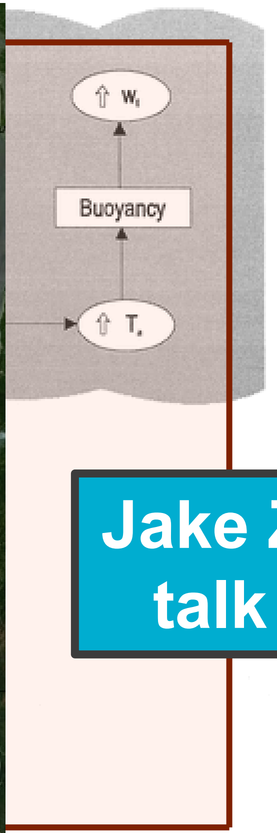
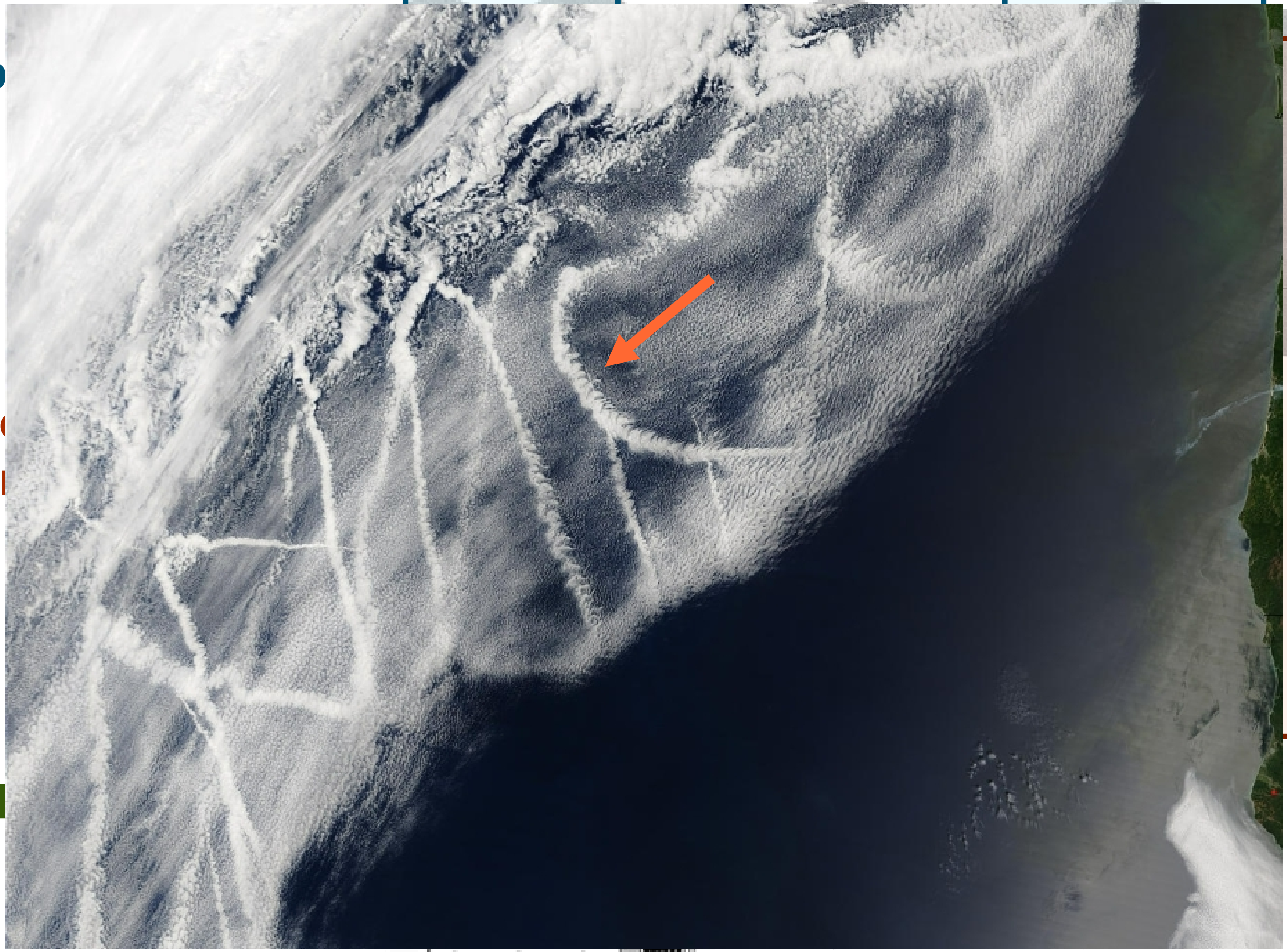




Jake Zenker, talk 7IM.3

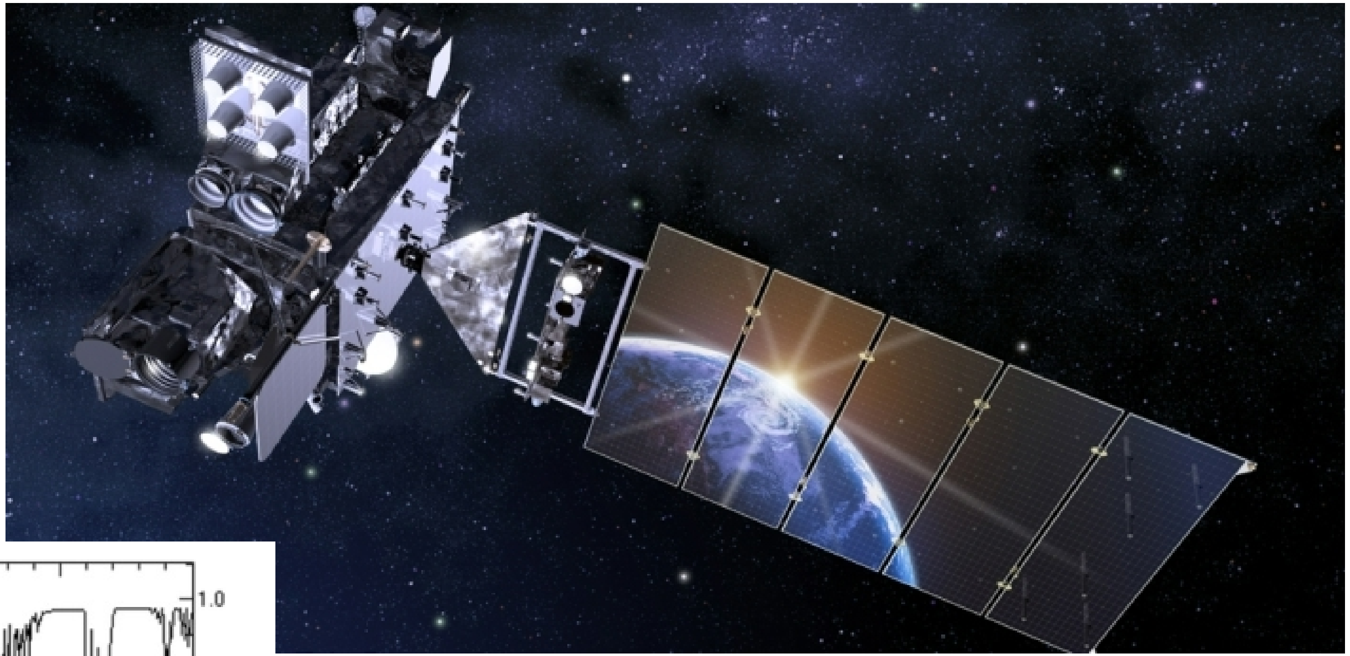
Schematic: P. A. Durkee, K. J. Noone, and R. T. Bluth, "The Monterey Area Ship Track Experiment,", Journal of the Atmospheric Sciences, vol. 57, no. 16, pp. 2523-2541, 01 Aug. 2000, doi: 10.1175/1520-0469(2000)057<2523:Tmaste>2.0.Co;2.

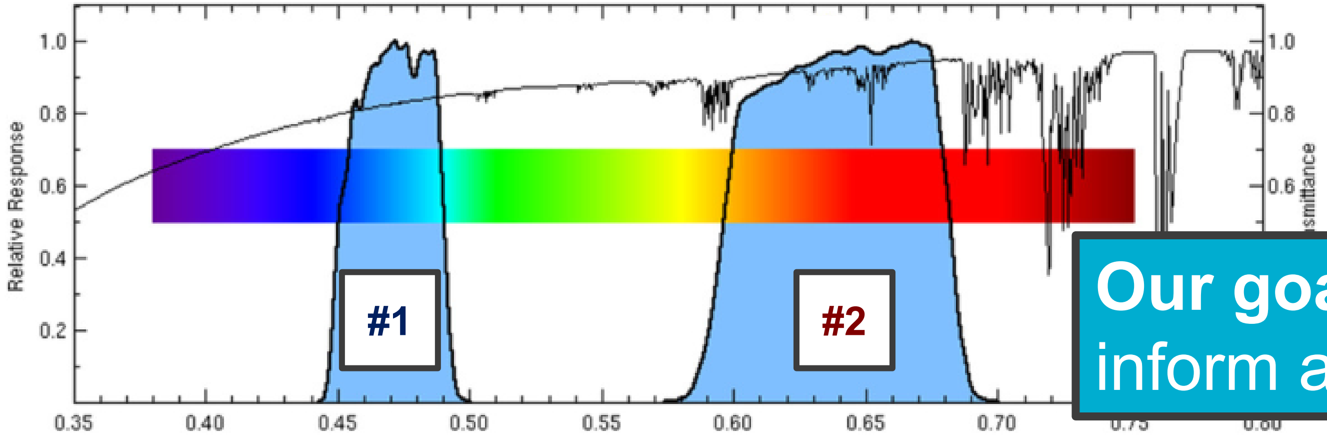
Geostationary Operational Environmental Satellites (GOES)

- Began in 1975 as a joint program between NOAA and NASA

16 band imaging platform

1. "Blue" band
2. "Red" band





Our goal: leverage GOES data products to inform atmospheric dispersion models

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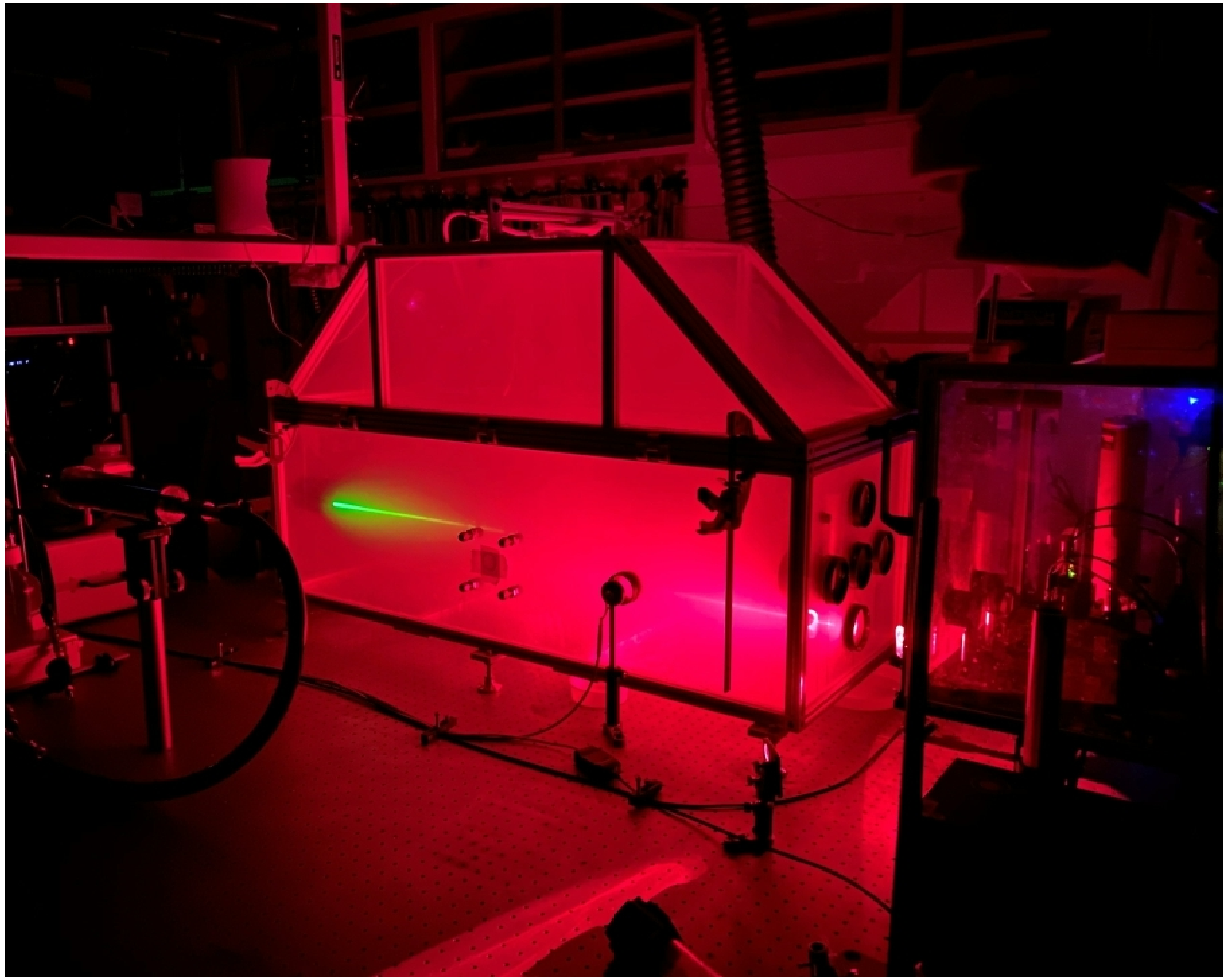
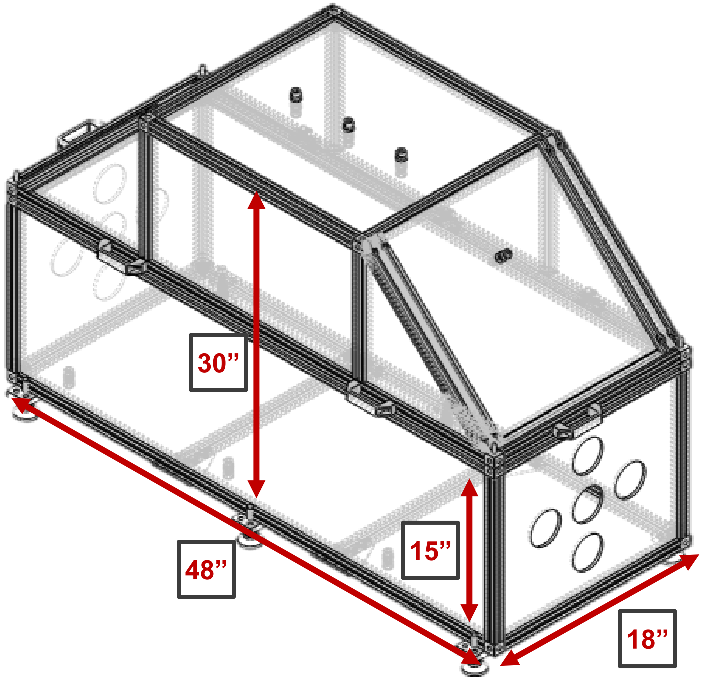
Satellite: R. Garner, "GOES-R," https://www.nasa.gov/content/goes-overview/index.html, Ed., ed: National Aeronautics and Space Administration, 2021.

Spectrum: T. J. Schmit, P. Griffith, M. M. Gunshor, J. M. Daniels, S. J. Goodman, and W. J. Lebair, "A Closer Look at the ABI on the GOES-R Series," (in English), *Bulletin of the American Meteorological Society, vol. 98, no. 4, pp. 681-698, 01 Apr. 2017 2017, doi: 10.1175/bams-d-15-00230.1.*

How do we generate clouds in the desert?





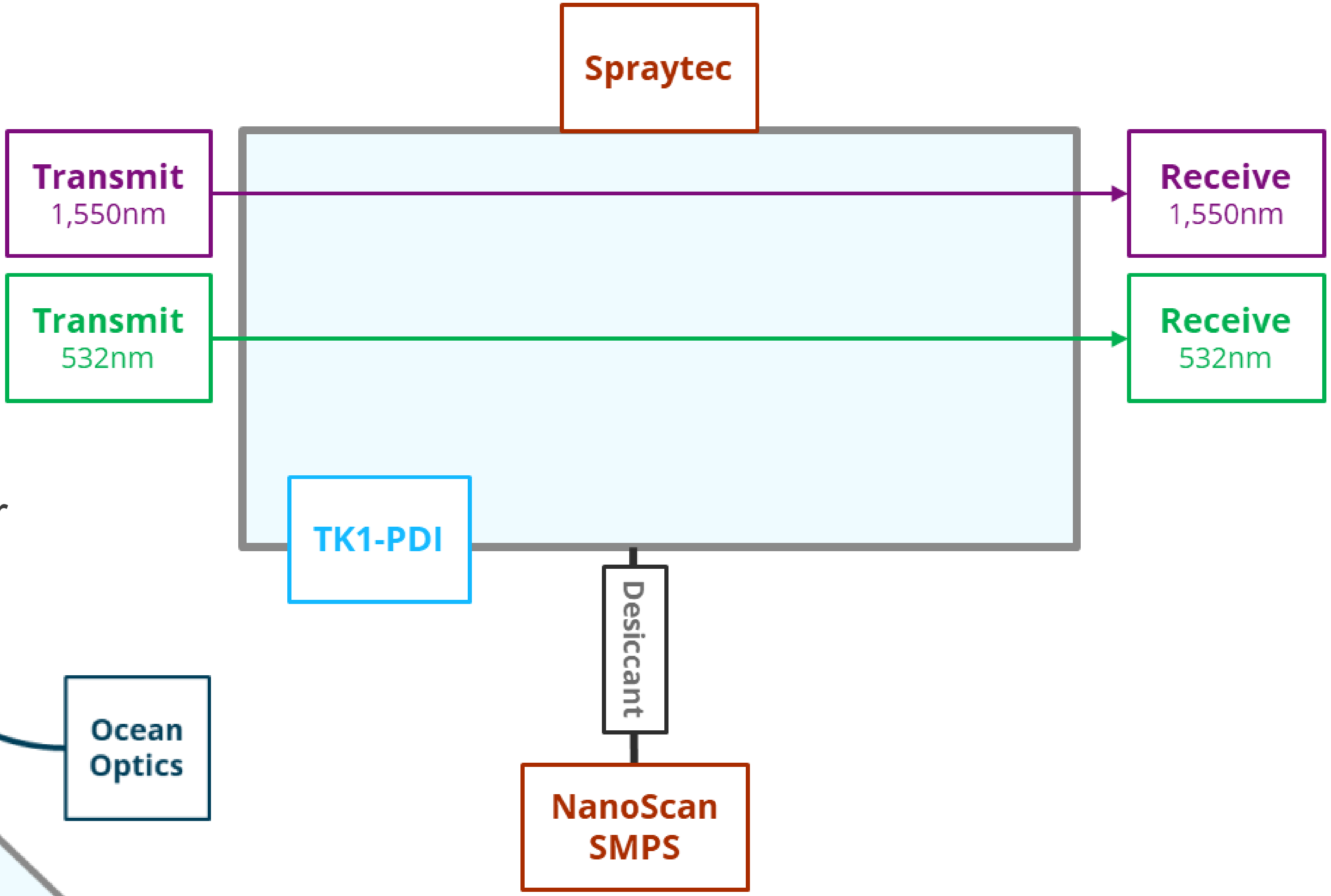
Tabletop “MiniFog” Fog Chamber

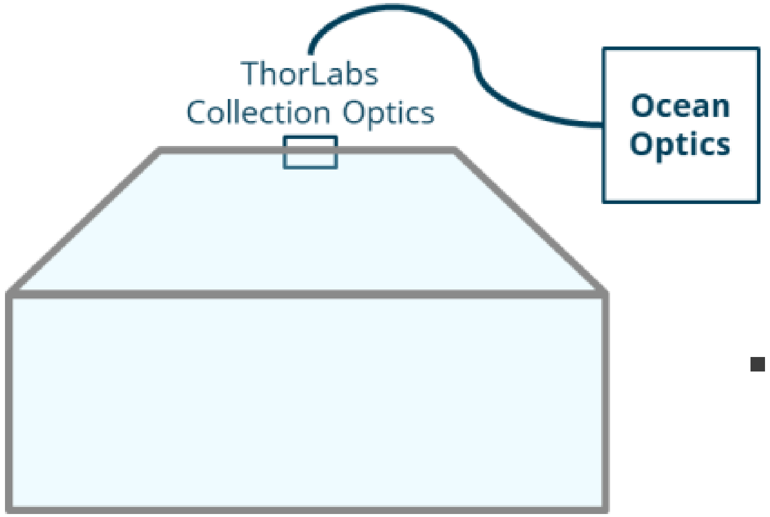
- Lightweight, 48” x 18” x 30” chamber
- Able to support a suite of characterization equipment

How do we generate clouds in the desert?

Characterization Equipment

- Custom multi-band transmissometer
  - 532nm and 1550nm bands
- Malvern Spraytec droplet sizer
- TSI NanoScan 3910 scanning mobility particle sizer (SMPS)
- Artium TK1 phase doppler interferometer (PDI)





- OceanOptics HR4Pro spectrometer
  - ThorLabs F810APC-543 collimating optic

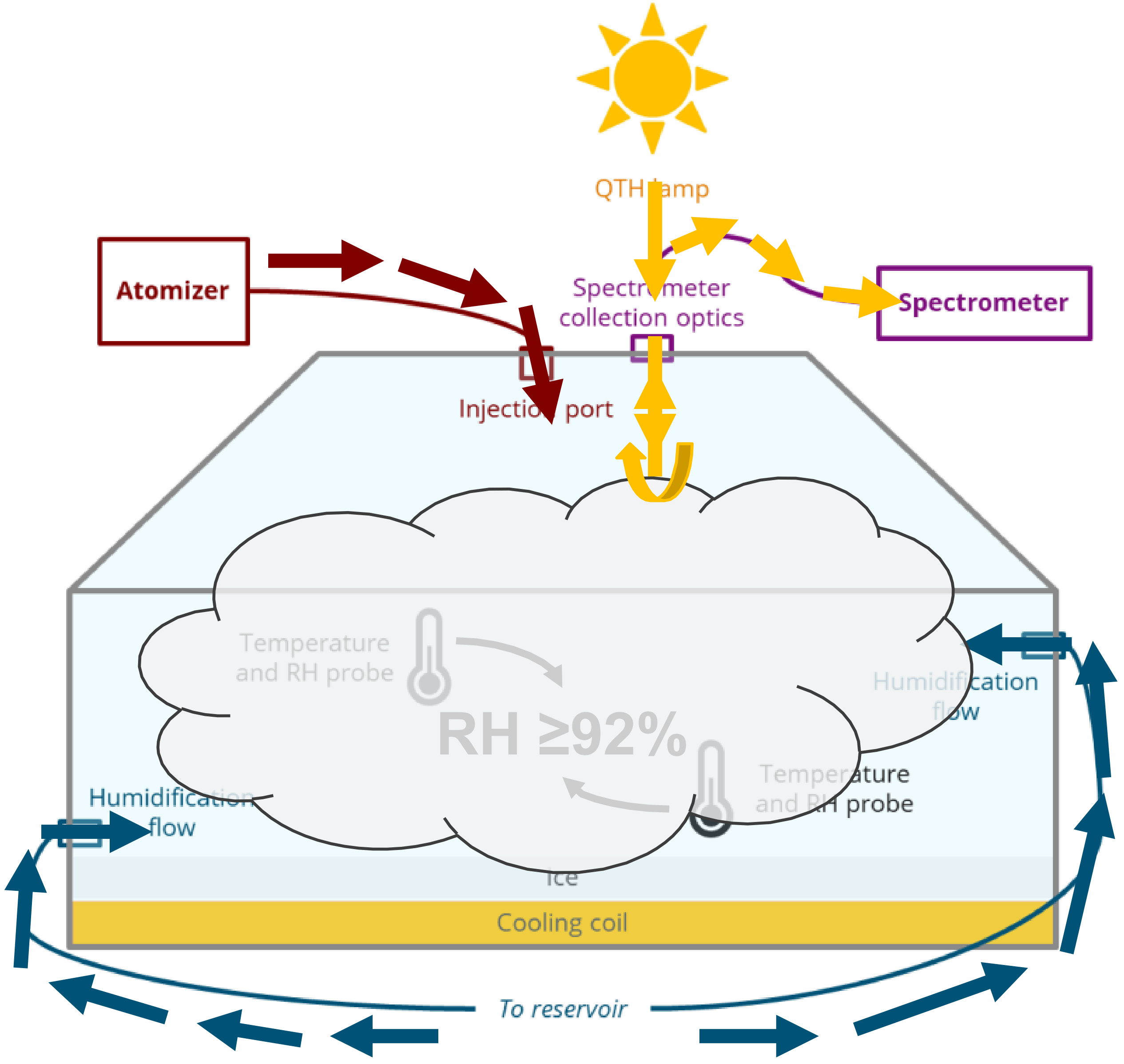
How do we generate clouds in the desert?

Raise the humidity

- Humidified flow generated using a bubbler in a heated reservoir of distilled water
- Flow pumped into the MiniFog until chamber relative humidity (RH) ≥92%

Inject a dry aerosol

- Different volumes of dry particulate were injected over a 50-second period
  - **High:** ~7.5 x 10^9 NaCl particles
  - **Medium:** ~4.4 x 10^8 NaCl particles
  - **Low:** ~1.5 x 10^8 NaCl particles
- Chamber was allowed to restabilize before another injection occurred



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How do we characterize our aerosol?

Malvern Spraytec

Volume distribution ($\boldsymbol{v}$)

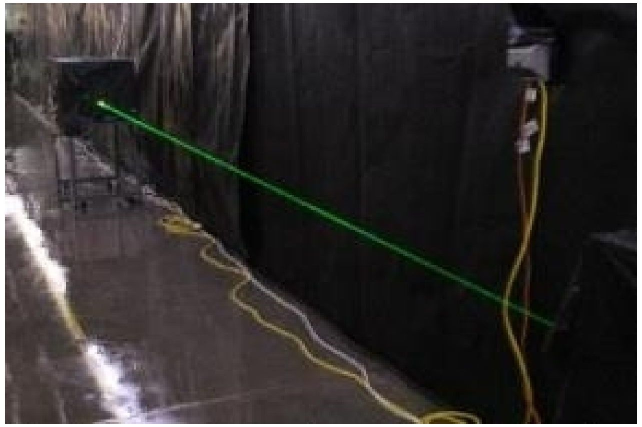
Mie Theory

Scattering efficiency ($\boldsymbol{Q}(\boldsymbol{\theta})$)

Bulk scattering coefficient ($\boldsymbol{\mu_s}$) and mean scattering angle ($\boldsymbol{g}$)

Number density ($\boldsymbol{N_d}$) and size distribution ($\boldsymbol{N}(\boldsymbol{d})$)

Liquid water content ($\boldsymbol{LWC}$)



Transmissometer (532 nm, 1550 nm, 9.68 μm)

Normalized transmission ($\boldsymbol{\Phi_n}$)

$$\boldsymbol{LWC} = \frac{-2\ln(\Phi_n)}{3L\sum_i \frac{Q_i \cdot v_i}{d_i}} \rho_{water} \qquad \boldsymbol{N}(\boldsymbol{d}) = \frac{6v \cdot \mathrm{LWC}}{\pi d^3}$$

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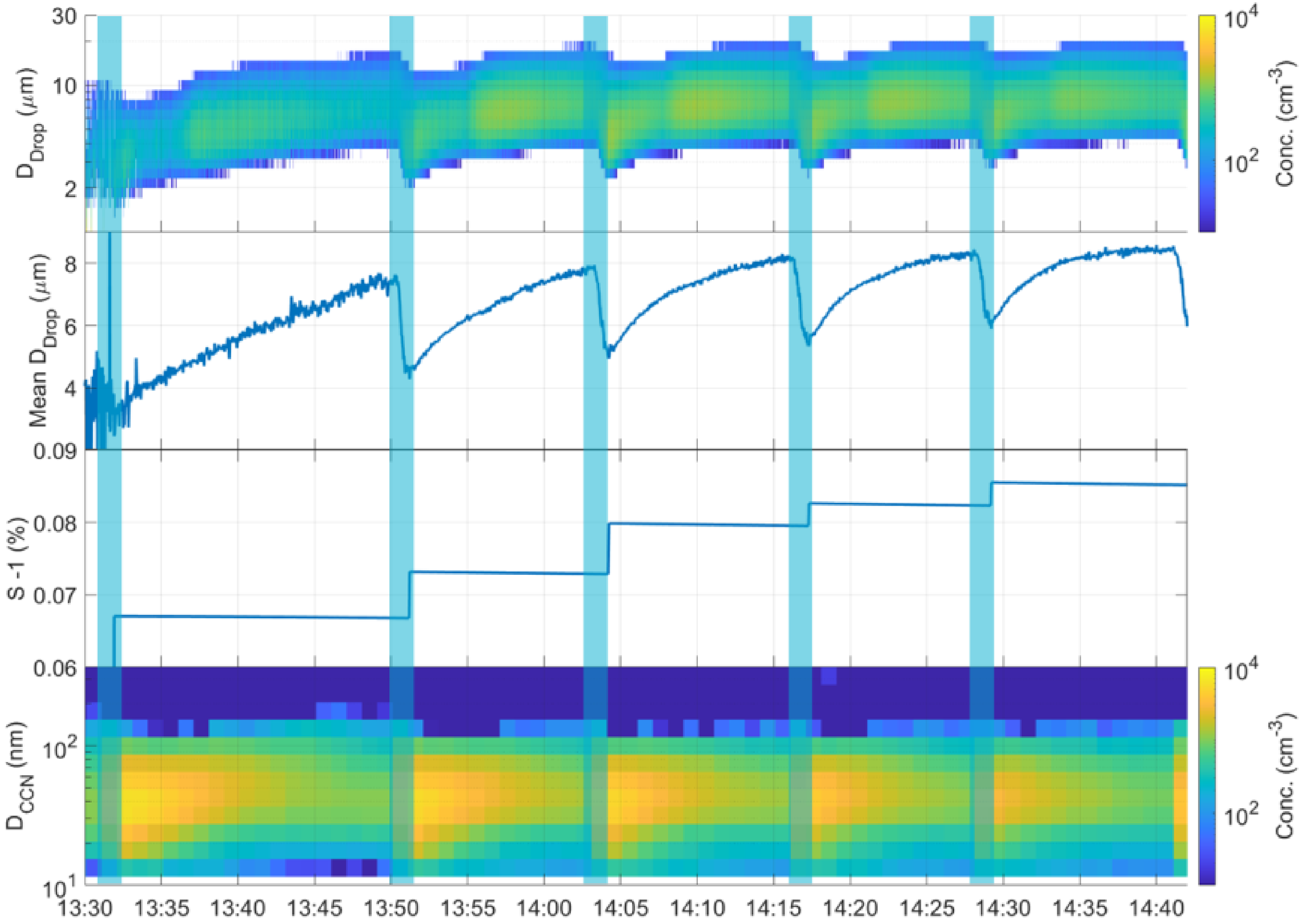
[1] J. B. Wright, J. D. v. d. Laan, A. Sanchez, S. A. Kemme, and D. A. Scrymgeour, "Optical characterization of the Sandia fog facility," Proceedings of SPIE 10197 (2017).
[2] B. J. Redman, and J. D. van der Laan, "Measuring resolution degradation of long-wavelength infrared imagery in fog," Optical Engineering , 58(05), (2019).

A Cost-Effective Tabletop Chamber to Evaluate Cloud Microphysical and Optical Properties

Jake Zenker, talk 7IM.3



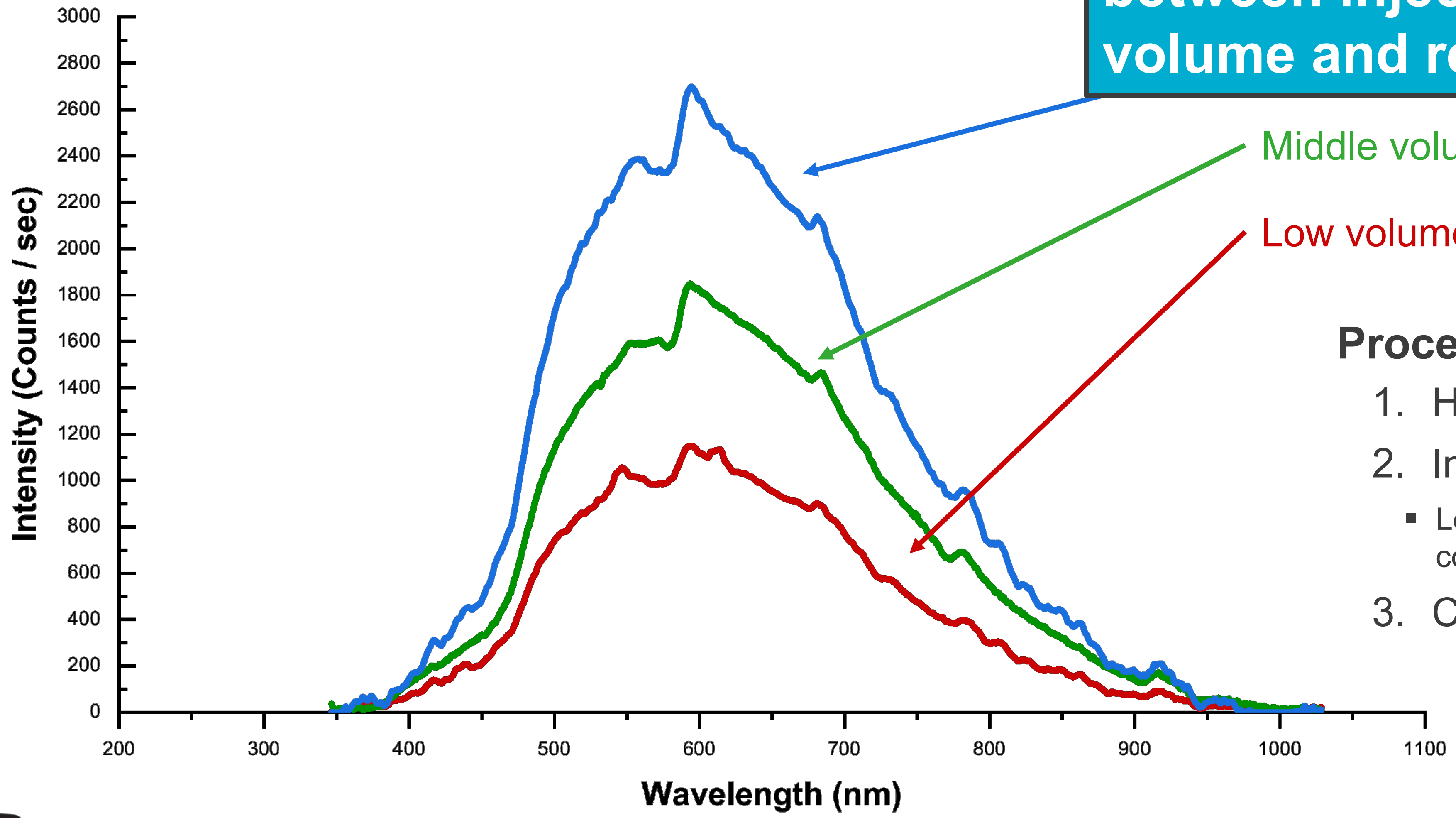
Cloud microphysics

- Multiple injections of varying length at each concentration
- System residence time
- Mean vertical velocity
- Characterization of droplet supersaturation by adapting the approach from Krueger, 2020
  - doi.org/10.5194/acp-20-7895-2020

J. Zenker et al., "A Cost-Effective Tabletop Chamber to Evaluate Cloud Microphysical and Optical Properties," in AAAR 40th Annual Conference, Raleigh, North Carolina, USA, 2022: American Association for Aerosol Research.

Preliminary data seems to confirm MAST hypothesis

Clear direct correlation between injected dry aerosol volume and reflectivity



Middle volume

Low volume

Procedure

1. Humidify chamber
2. Inject dry aerosol
   - Low, middle, and high concentration plumes
3. Characterize stable cloud

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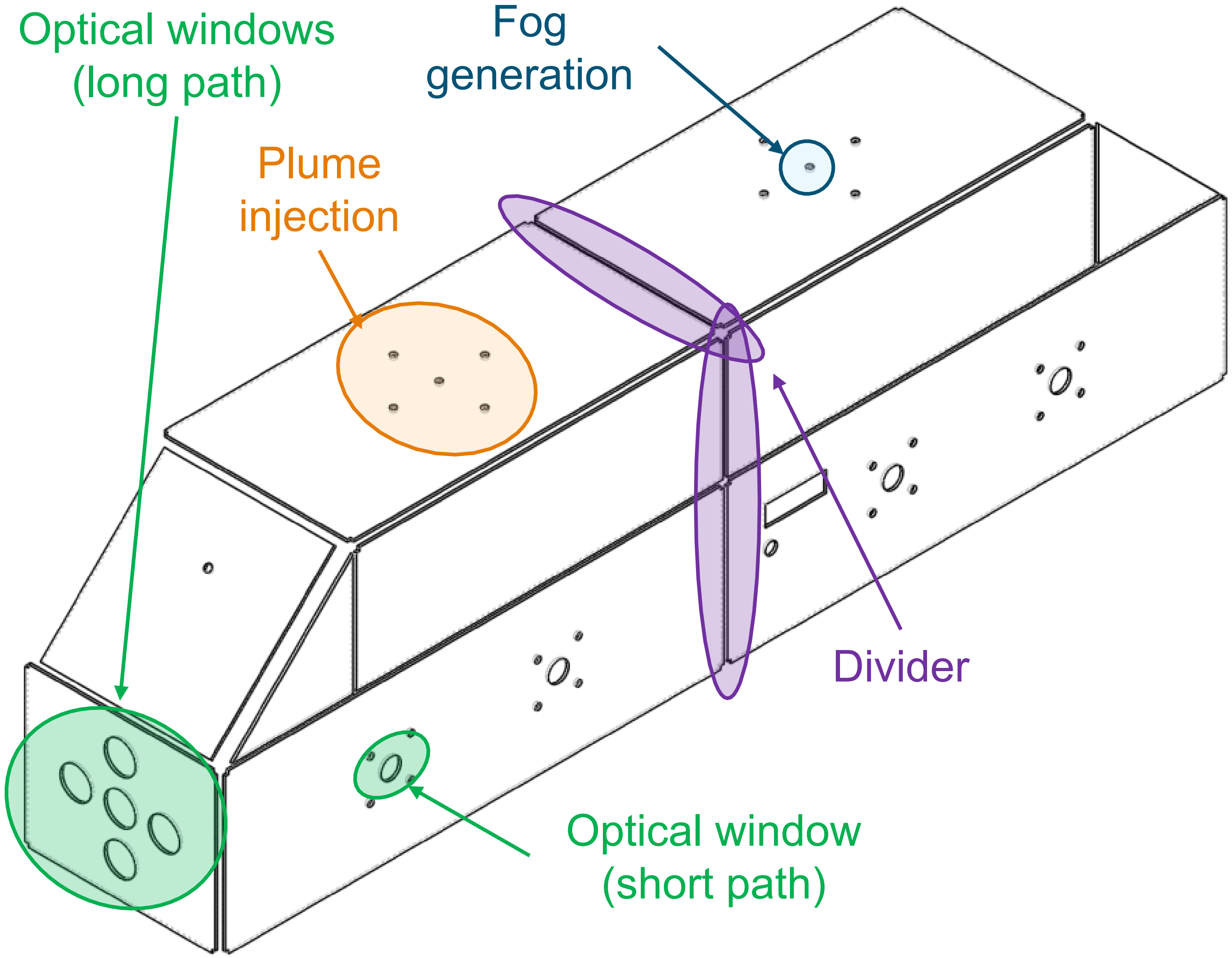
Next Steps: Mid-scale Diffusion Study



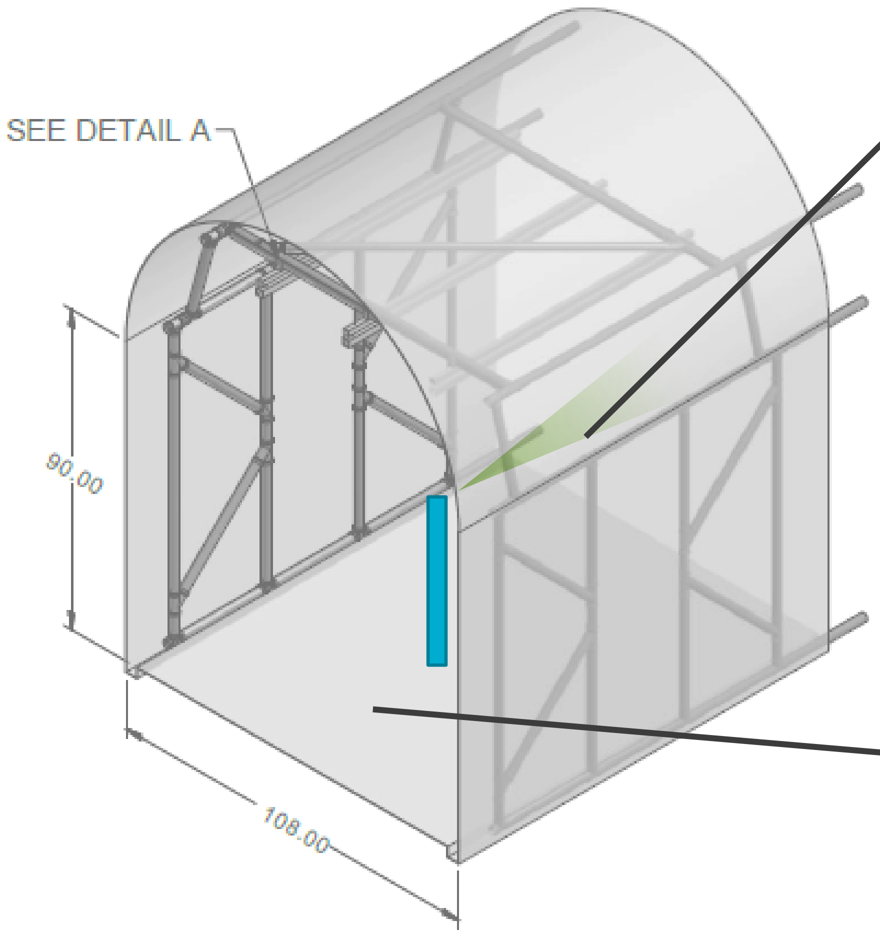
Pollutants in the atmosphere

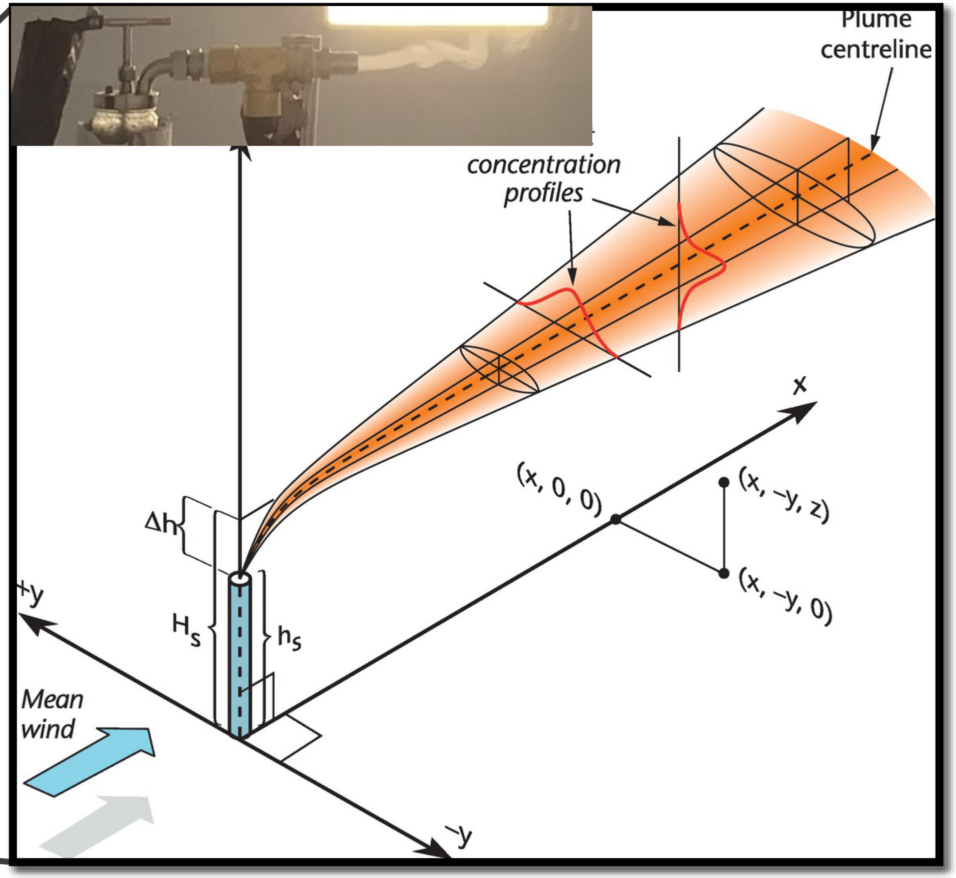
- Mimic mixing of chemical plumes with atmospheric aerosols (clouds, fogs, etc.)
- Inform stand-off analysis

Building fog diffusion chamber

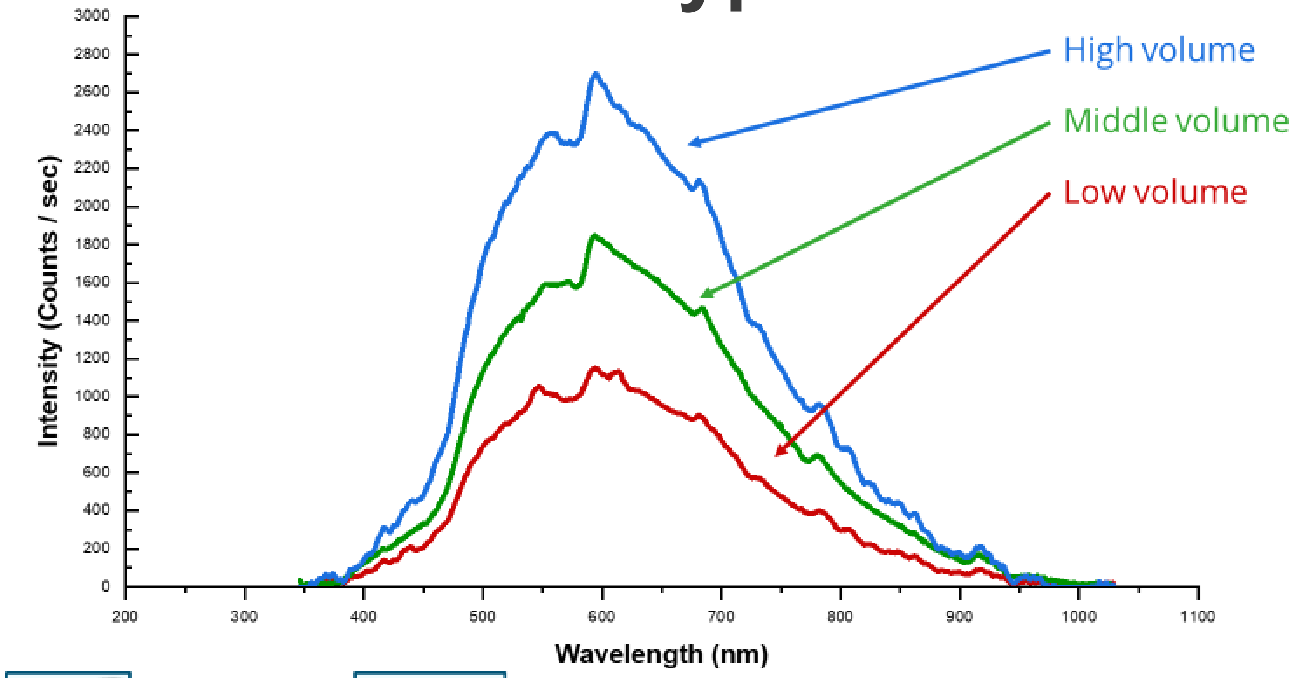
- Longer path length for longer equivalent distances
- Divided into two sections for diffusion studies
- **Direct chemical injection of hazardous plumes**

Long term goals: Large-scale Diffusion Study





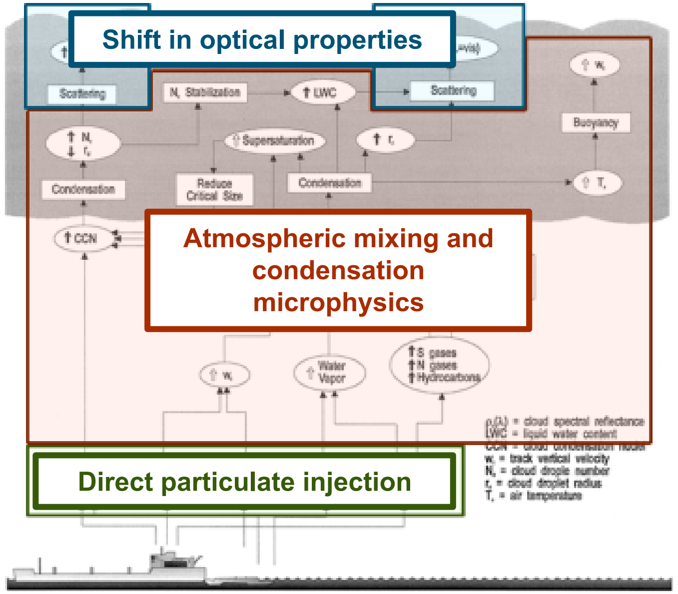
Initial experimental verification of MAST hypothesis

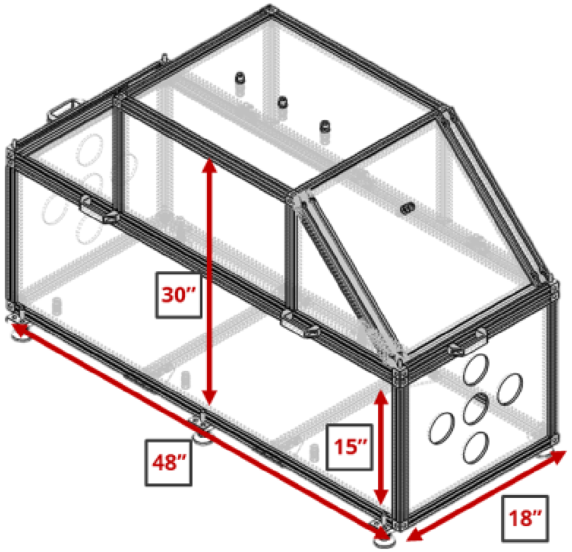


An increase in injected particulate leads to an increase in overall reflectivity

Moving forwards

- Use these findings and future work to inform optical data from GOES
- Use resultant analysis to better understand and analyze atmospheric dispersion





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Thank you.

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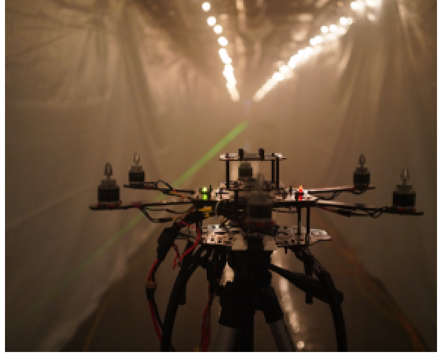

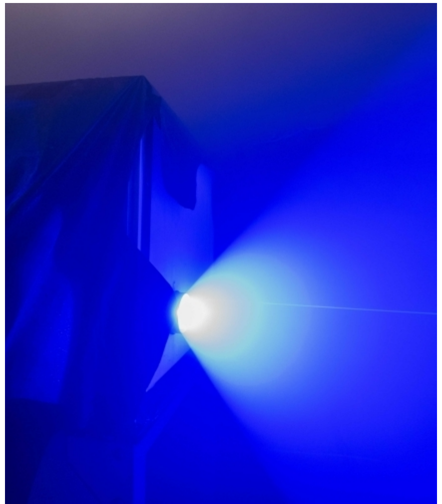

Extra Slides

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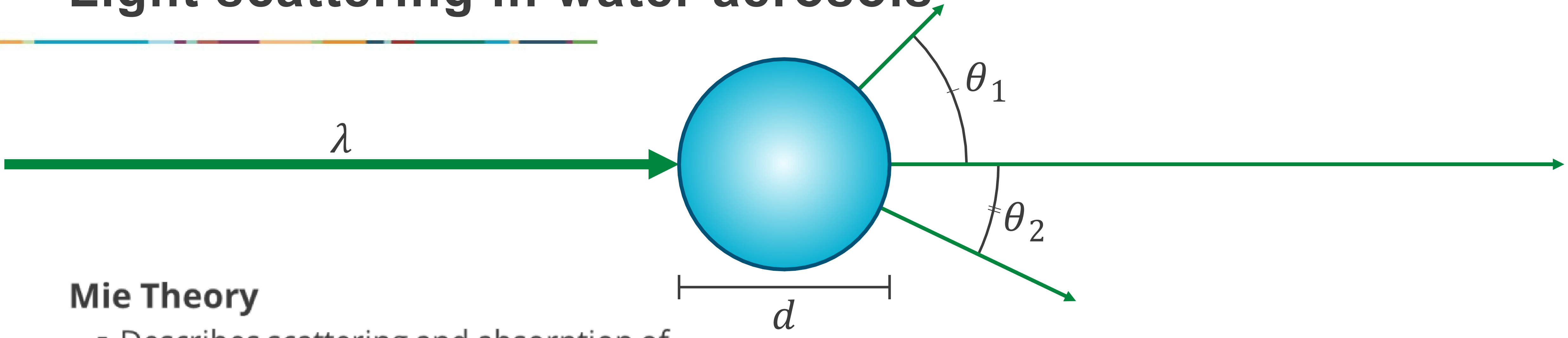
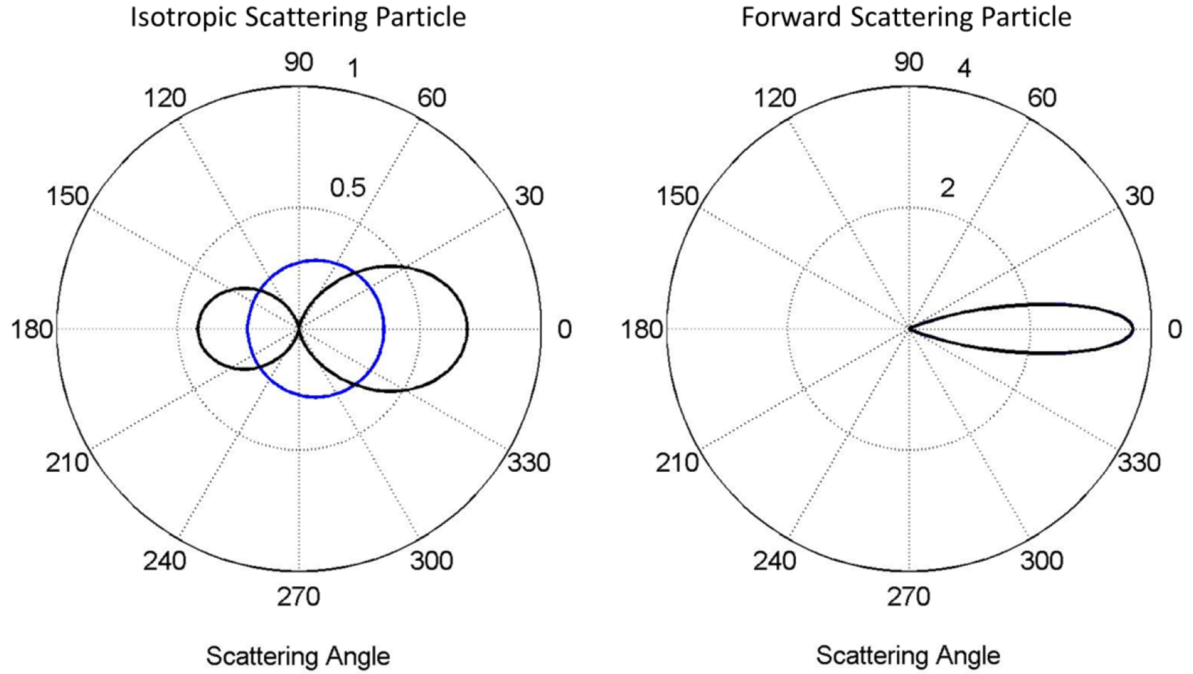
Light scattering in water aerosols



Mie Theory

- Describes scattering and absorption of light by spherical droplets
- Input
  - Droplet diameter (d)
  - Wavelength of light (λ)
  - Droplet refractive index
- Output
  - Bulk scattering coefficient (μ_s)
  - Bulk absorption coefficient (μ_a)
  - Scattering angle (θ)



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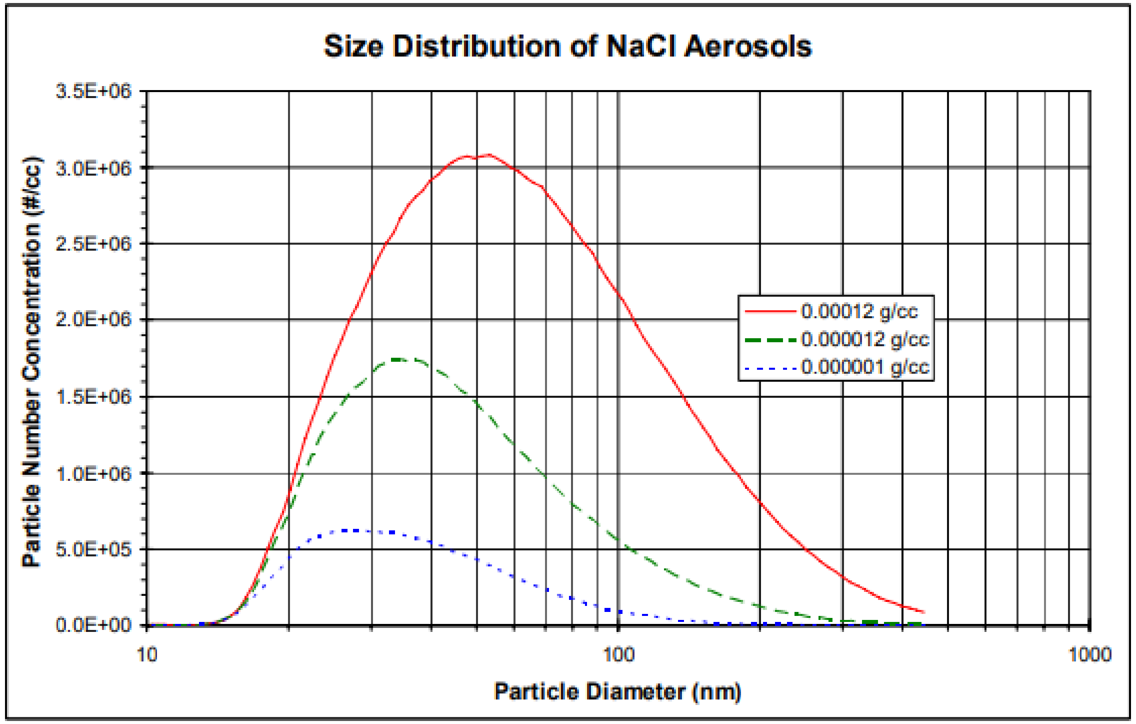
[1] J. D. van der Laan, J. B. Wright, S. A. Kemme, and D. A. Scrymgeour, "Superior signal persistence of circularly polarized light in polydisperse, real-world fog environments," Applied Optics, 57(19), 5464-5473 (2018).

Dry particulate generation

TSI 3076 Atomizer

- Operating pressure: 35 psig
- Nominal flow rate: ~50 cc/sec



Injection information:

- High:
  - Mean diameter: 50 nm
  - Rate: 1.5×10^8 particles / second
- Medium:
  - Mean diameter: 35 nm
  - Rate: 8.8×10^7 particles / second
- Low:
  - Mean diameter: 28 nm
  - Rate: 3.0×10^7 particles / second

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Graph: TSI, "Model 3076 Constant Output Atomizer", Instruction Manual. Rev. J, *June 2005*