Evaluation and Use of Purple Air Sensors for Air Quality Network Assessment

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The low cost sensor that needs no introduction…

- PurpleAir sensor converts light scattering signal to particle size and number concentration
  - Conversion to PM2.5 requires particle shape and density assumption
- Uses a plantower sensor, also used in other commercially available low cost AQ sensors
- Are the most widely used low cost sensors by the general public
  - Also used by research groups and regulatory agencies
- Have been evaluated by a number of west coast groups
  - SC AQMD
  - LRAPA
  - PSCAA

Image stolen from LRAPA – might even be Lance's hand

The general consensus is… PA sensors are precise, but not accurate

They correlate well with FRM, FEM, and other optical PM2.5 measurements (R^2>0.9), but overpredict PM2.5 by 50% to 100%

- SC AQMD (Southern CA) found PA sensors correlated to FEM sensors with R^2 >0.93, but over-predicted PM2.5 by a factor of 1.5 to 1.7
- LRAPA (Central Oregon) tested at 4 locations against Ecotech/Ambilab nephelometer PM2.5 measurement
  - R^2 > 0.94 and Purple Air over-predicted PM2.5 by a factor of 2 (higher for wildfires) *communication with Lance Giles (LRAPA)*
- PSCAA also found high correlation and an over-prediction by a factor of 2 relative to nephelometer/FEM/FRM measurements

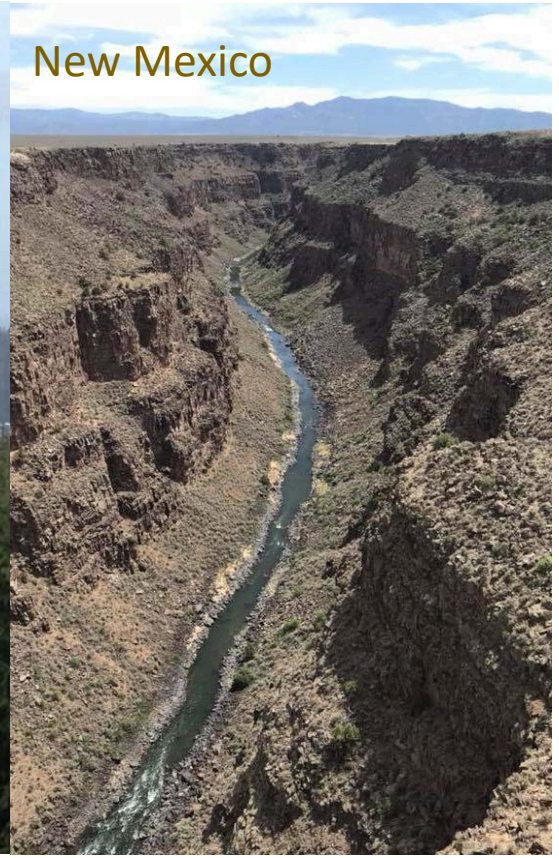
Nephelometers and PM2.5

Nephelometers make up the bulk of WA state's air quality network

- Measurement based on light scattering
- PM2.5 calculated using site specific correlation between neph and FRM/FEM
- Most sites have a different bscat to PM2.5 conversion calculation
- Chemical composition, size distribution, particle shape affect light scatter
- Density affects PM2.5 (mass/volume concentration)
- High relative humidity can cause particles to swell and scatter more light
  - ➢ Nephelometers are heated to less than 50% RH to ensure all PM2.5 is evaluated independently of ambient RH
  - ➢ PurpleAir sensors may be affected by changes in RH

Do different environments affect how PurpleAir sensors compare with FRM/FEM analyzers? Nephelometers?

- EPA conducted Purple Air vs. TEOM comparison studies in three different cities
  - Slope ~2.1 (+/- 0.2) Atlanta; $R^2 = 0.9$
  - Slope ~1.7 (+/- 0.1) in Research Triangle Park; $R^2 = 0.94$
  - Slope ~1.2 (+/- 0.1) Phoenix; $R^2 = 0.8$
- Factor of 2 is a consistent result in higher humidity environments



ORCAA uses Purple Air sensors for AQ study: the good

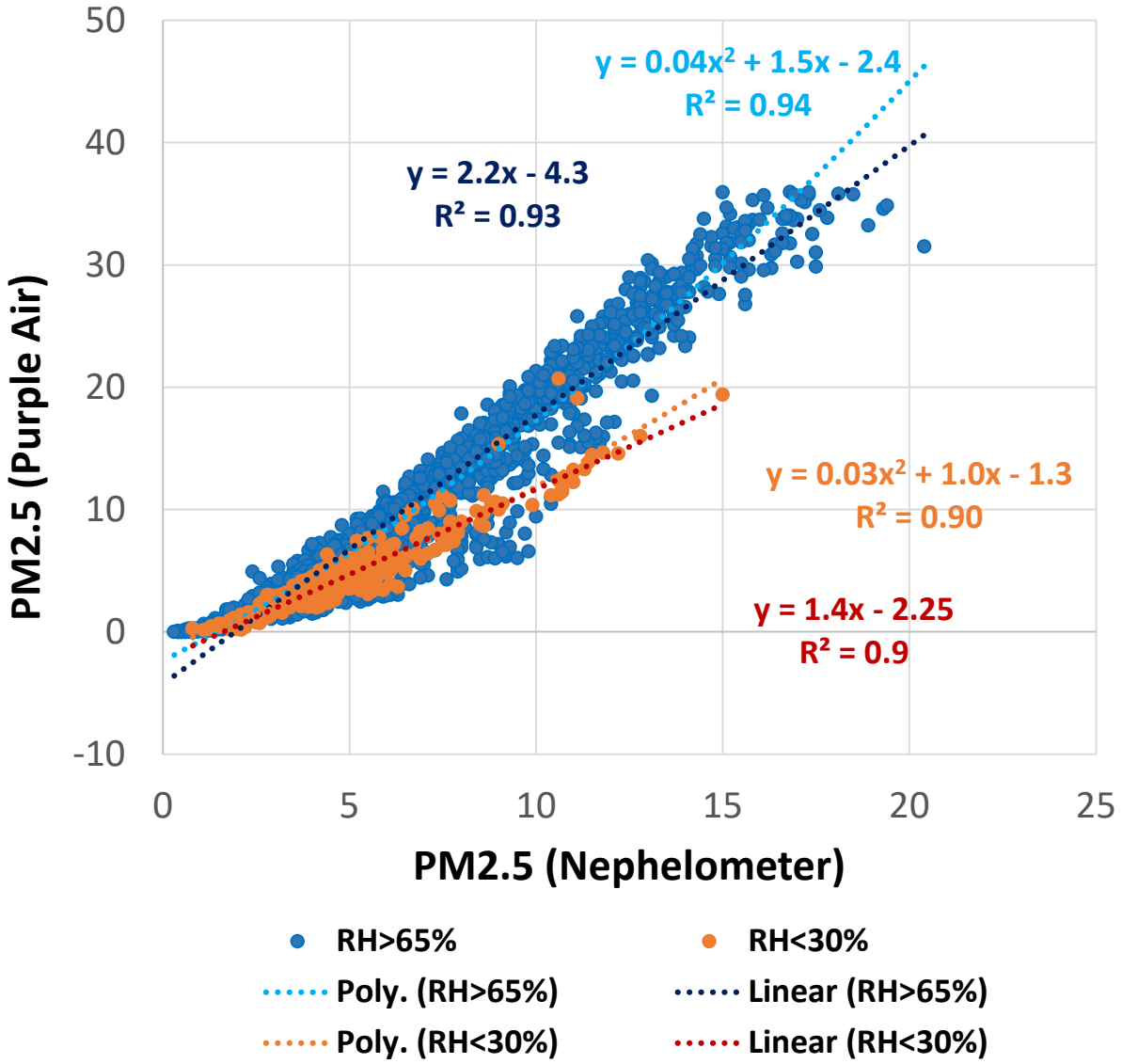
- Used 4, MetOne (profiler 212) optical particle counters (OPC) to conduct year-long studies in Clallam, Jefferson, and Thurston Counties
- Replaced MetOne OPC with Purple Air sensors in 2018 for the Mason Co study
  - The datalogging software stopped playing nicely with the operating system
  - Annual maintenance and recertification of MetOne OPCs cost more than 4 new Purple Air sensors
  - Purple Air data is logged to the cloud and available to the public in real time
  - Purple Air website includes optional correction for PM2.5:
    - LRAPA: (PM2.5 = 0.5PA-0.66)
    - AQ&U (PM2.5 = 0.77PA +2.6)
- Collocated one Purple Air with the M903 permanently located in Shelton, Mason Co

Purple Air Sensors: the bad

- It’s easy for members of the public to misread the data or become concerned when there is a discrepancy between state air monitors and the PurpleAir data map
- The corrections, LRAPA and AQ&U, are offered without much guidance on how/when they should be used
- The corrections are not applied to downloaded data and this is not made clear
- LRAPA, PSCAA, or anyone else feel free to jump in with any additional issues you may have found

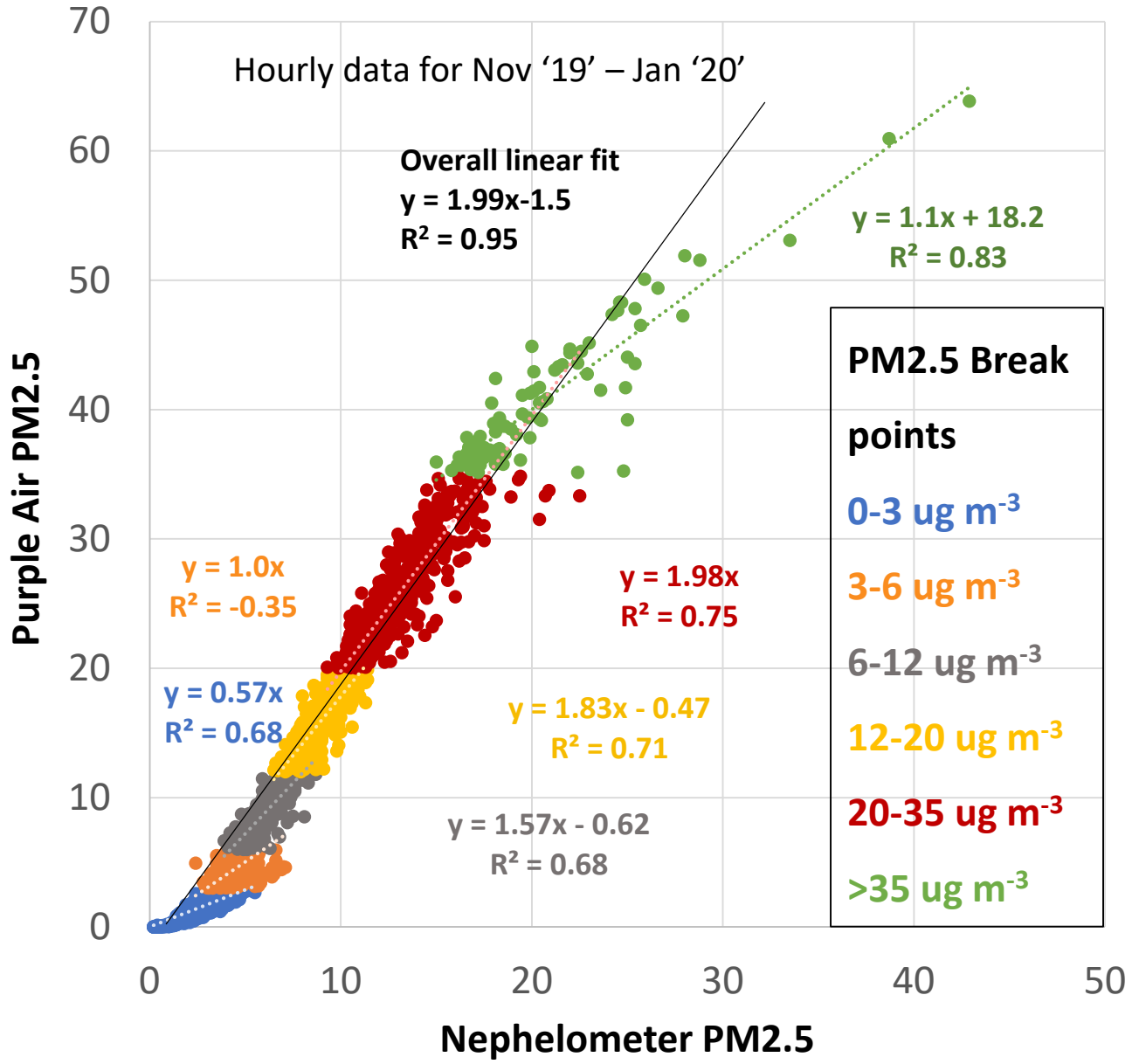
Purple Air Vs. Nephelometer: the ugly

- Polynomial fit might be better than linear fit for PM2.5 < 20 ug m^{-3}
  - PurpleAir biased low relative to nephelometers at low PM2.5 concentrations
  - Purple Air PM2.5 measurement bias increases as PM2.5 values increase
- Purple Air accuracy generally improves at lower RH
  - There are exceptions
  - Need to look at other variables like temperature and season

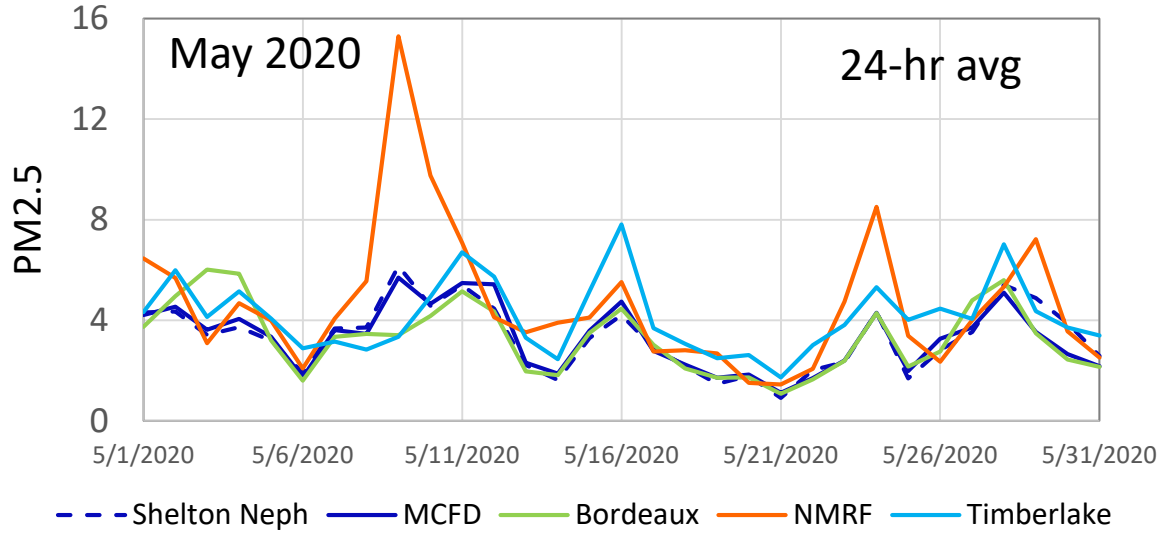


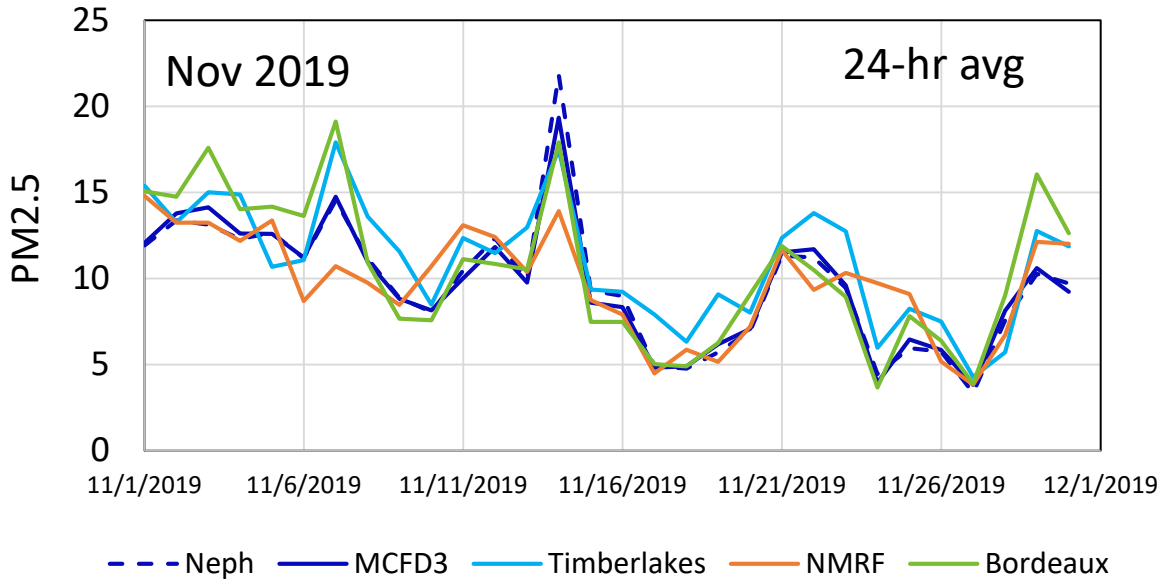
Non-linear response

- When comparing to a limited range of PM2.5 concentrations, relationship may appear linear
- Actual relationship with nephelometers is more sigmoidal
  - ➢ *Nephelometers have a non-linear response to FRM/FEM (gravimetric PM2.5 measurements)*



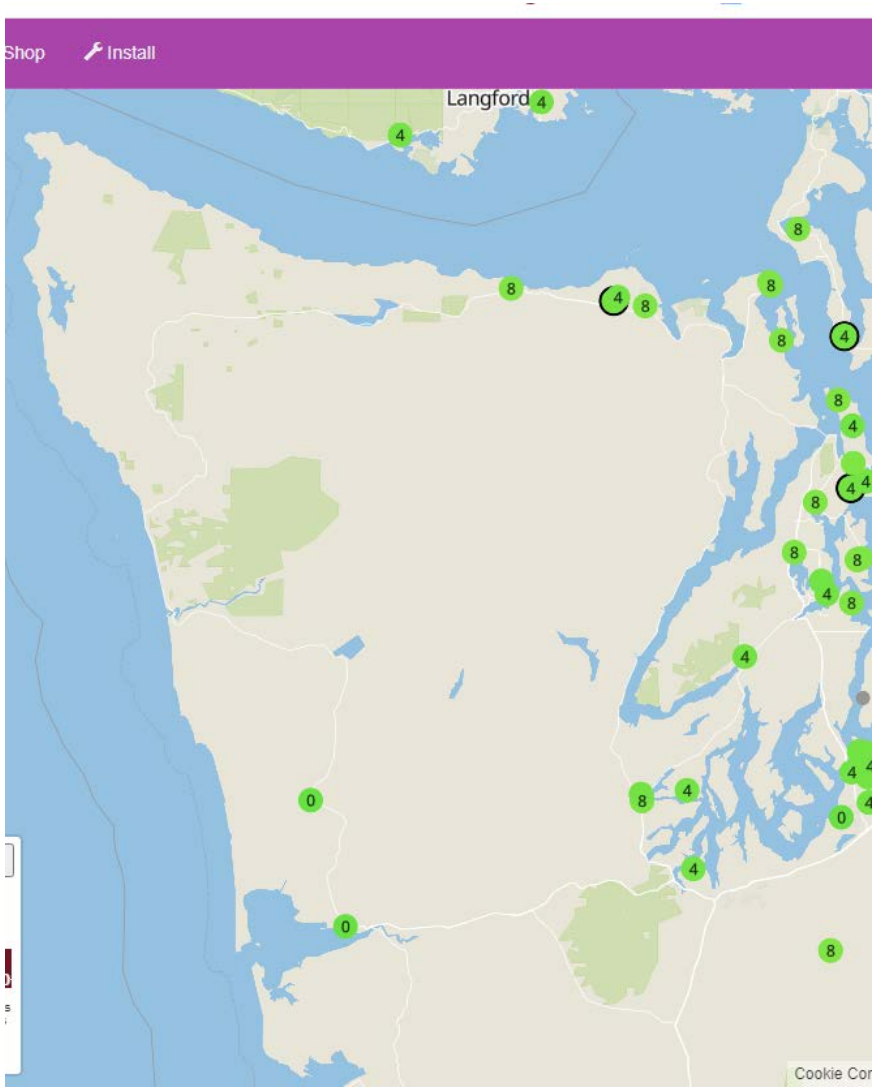
Evaluating Regional Air Quality





Future projects: a symbiotic relationship with the public

- Permanently install a Purple Air sensor at each of our air quality measurement sites
- Calculate correction factors monthly and post an automated calculator on our website *(still looking at the feasibility)*
- Crowd source public Purple Air sensor to replace saturation studies
  - ➢ Supplement county studies where there are gaps in the public sensor network
- Add new sensors as they become available
  - ➢ Looking at TSI Bluesky Air Monitor

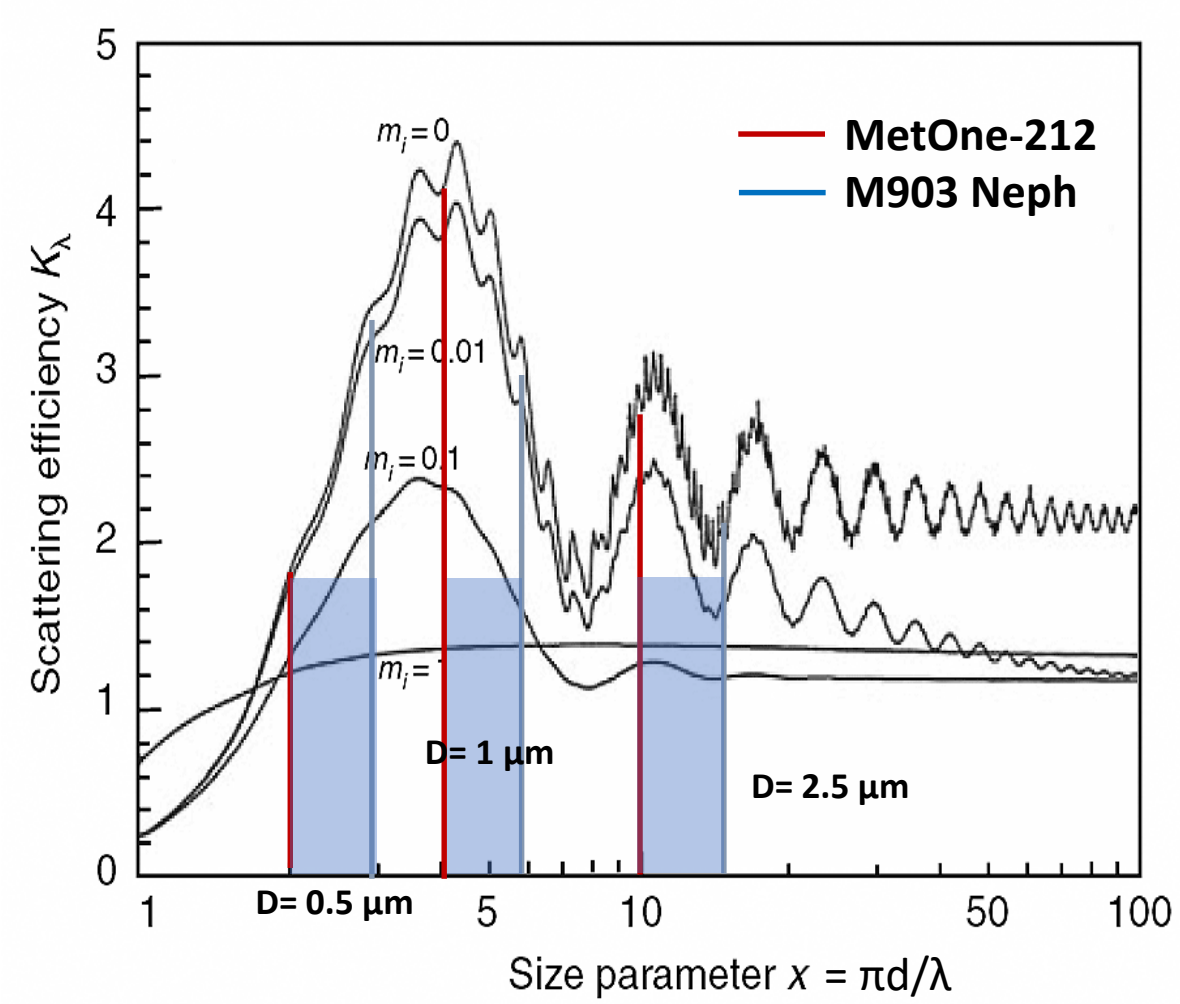


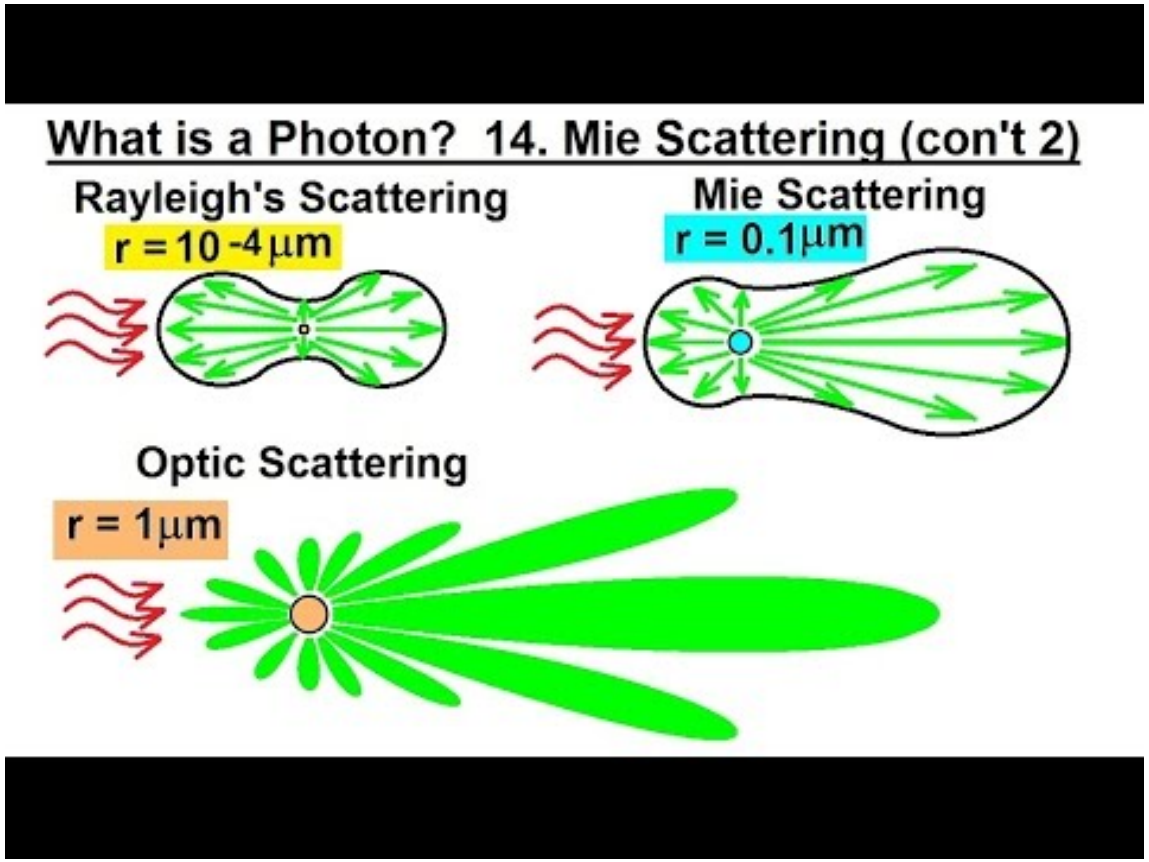
Last thoughts and things to consider

- How accurate do low cost sensors need to be?
  - ➢Training and evaluating model forecasts
  - ➢Consumption by the public for making personal health/activity decisions
  - ➢Evaluating regional air quality vs neighborhood scale air quality
- Complexity of the correction vs. usability
  - ➢ Incorporate a RH correction (Zheng et. al., 2018) https://www.atmos-meas-tech.net/11/4823/2018/amt-11-4823-2018.pdf
  - ➢ Linear vs. polynomial vs. ?
  - ➢ Adjust for concentration range

Extra slide if needed

Light Scattering particle size and wavelength





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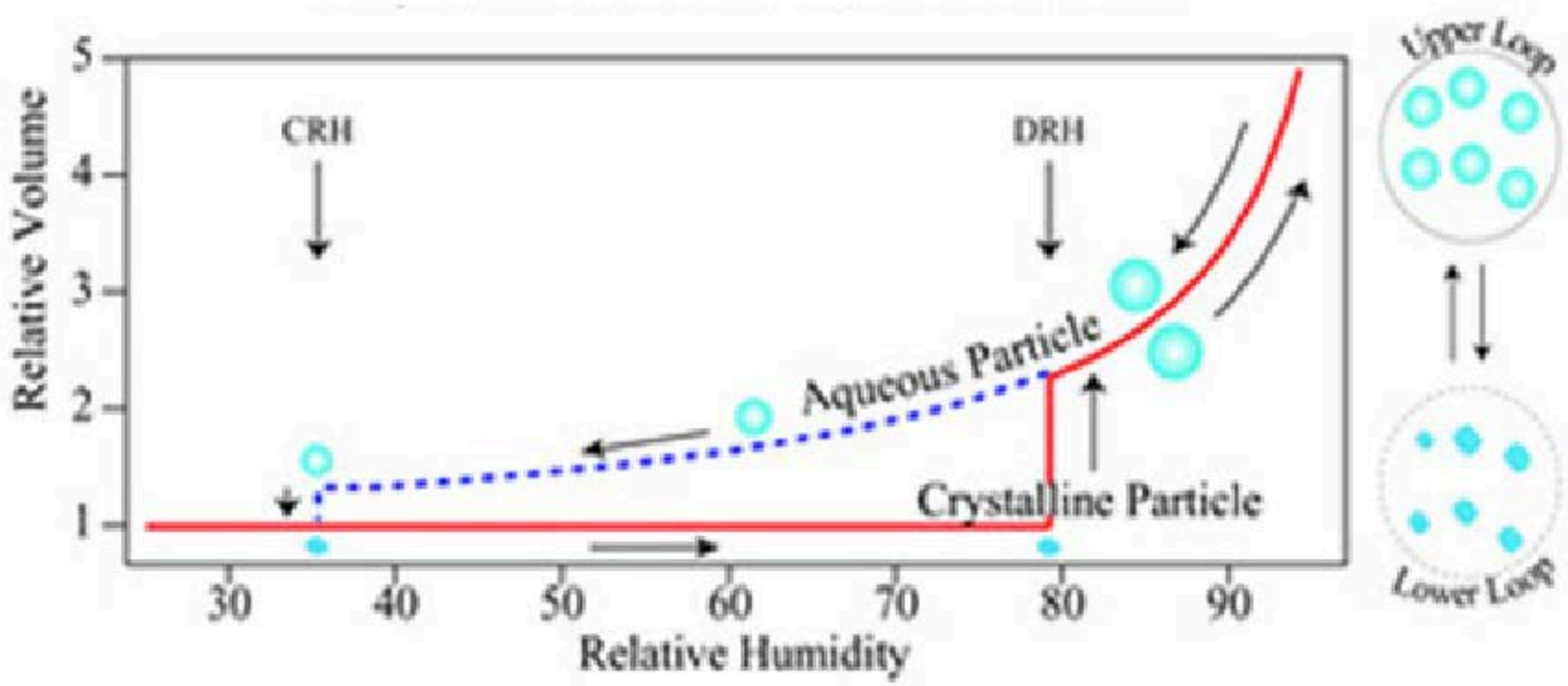
Hysteresis effect



From Kim and Yoo(2010), *J Korean Soc. For Atm. Env.* Vol 26 (2) P(202-218)
https://www.semanticscholar.org/paper/Numerical-Computation-of-the-Mass-Transfer-between-Kim-Yoo/b96984ec0b262137e6f049ec231bc6a5d0b207d6