Developing an Early Warning Sensor for Chemical Anomalies in Wastewater Collection Systems

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Jan. 26, 2021

NEWEA Annual Meeting

Session 1: Collection Systems: Overcoming Operational Challenges: The Future Depends on What You Do Today

Motivation: Anomalies Happen

WATER ONLINE

Water | Wastewater | Industrial | Utility Management | Innovations

News | June 10, 2019

38 Companies Punished For Illegal Discharge Into Public Sewers

More than S$250,000 fine imposed on

Trade effluent that is illegally discharge
the environment. National water agency
prosecuted 38 companies between June
These companies were fined a total of S

Department of Justice

Office of Public Affairs

FOR IMMEDIATE RELEASE — Thursday, January 14, 2021

Owner of Oil Chem Inc. Pleads Guilty to Violating the Clean Water Act

The president and owner of Oil Chem Inc. pleaded guilty in federal court in Flint, Michigan, to a criminal charge of violating the Clean Water Act stemming from illegal discharges of landfill leachate — totaling more than 47 million gallons — into the city of Flint sanitary sewer system over an eight and a half year period.

Oil Chem owner accused of dumping nearly 50 million gallons of landfill liquid into Flint sewers

Updated Jan 14, 2021; Posted Jan 04, 2021

Oil Chem Inc., located at 711 W. 12th St. in Flint, is shown in this 2016 Flint Journal file photo.

2,872 shares

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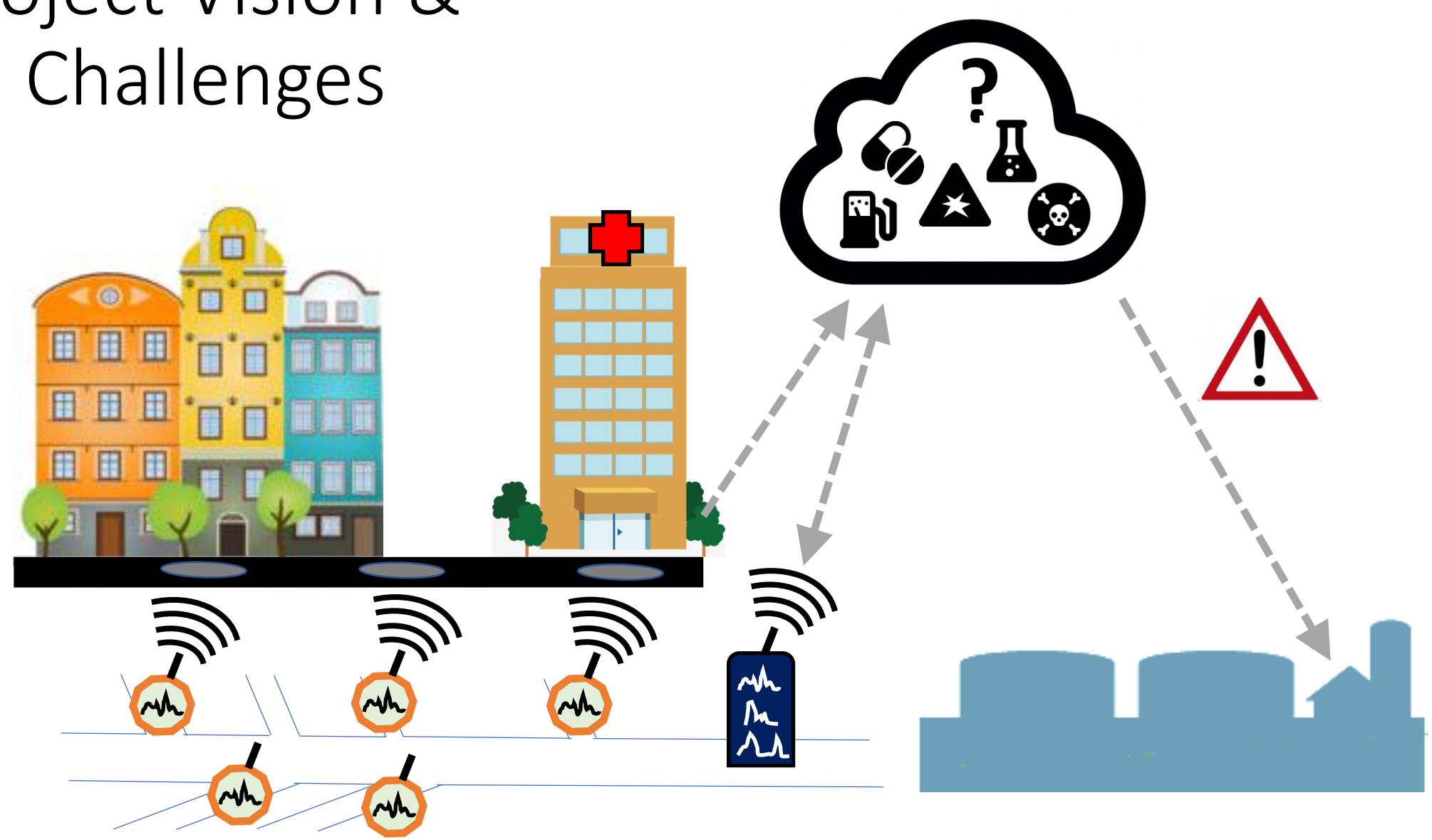
https://www.wateronline.com/doc/companies-punished-for-illegal-discharge-into-public-sewers-0001

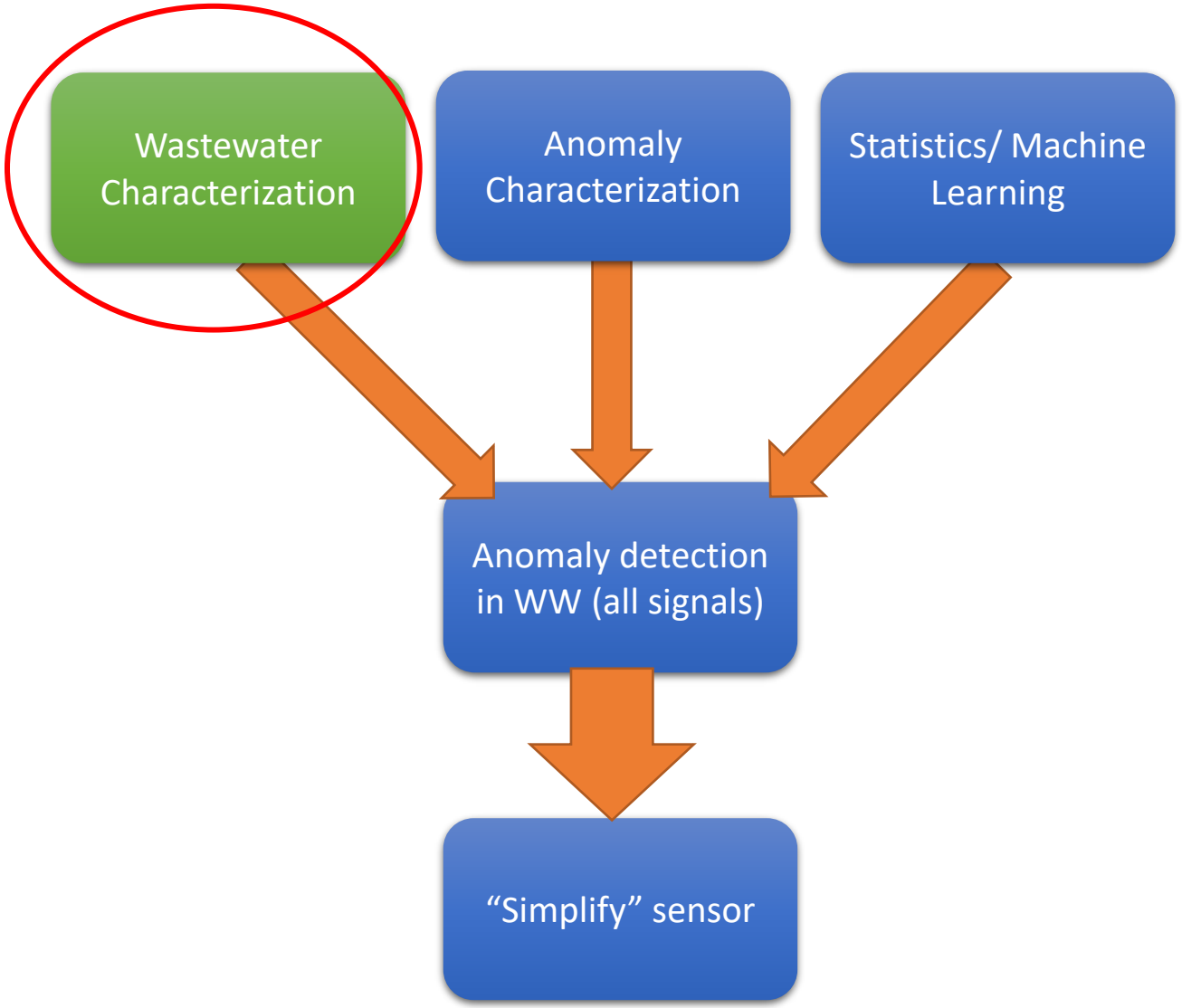
https://www.justice.gov/opa/pr/owner-oil-chem-inc-pleads-guilty-violating-clean-water-act

https://www.mlive.com/news/flint/2021/01/oil-chem-owner-accused-of-dumping-nearly-50-million-gallons-of-landfill-liquid-into-flint-sewers.html

Project Vision & Challenges



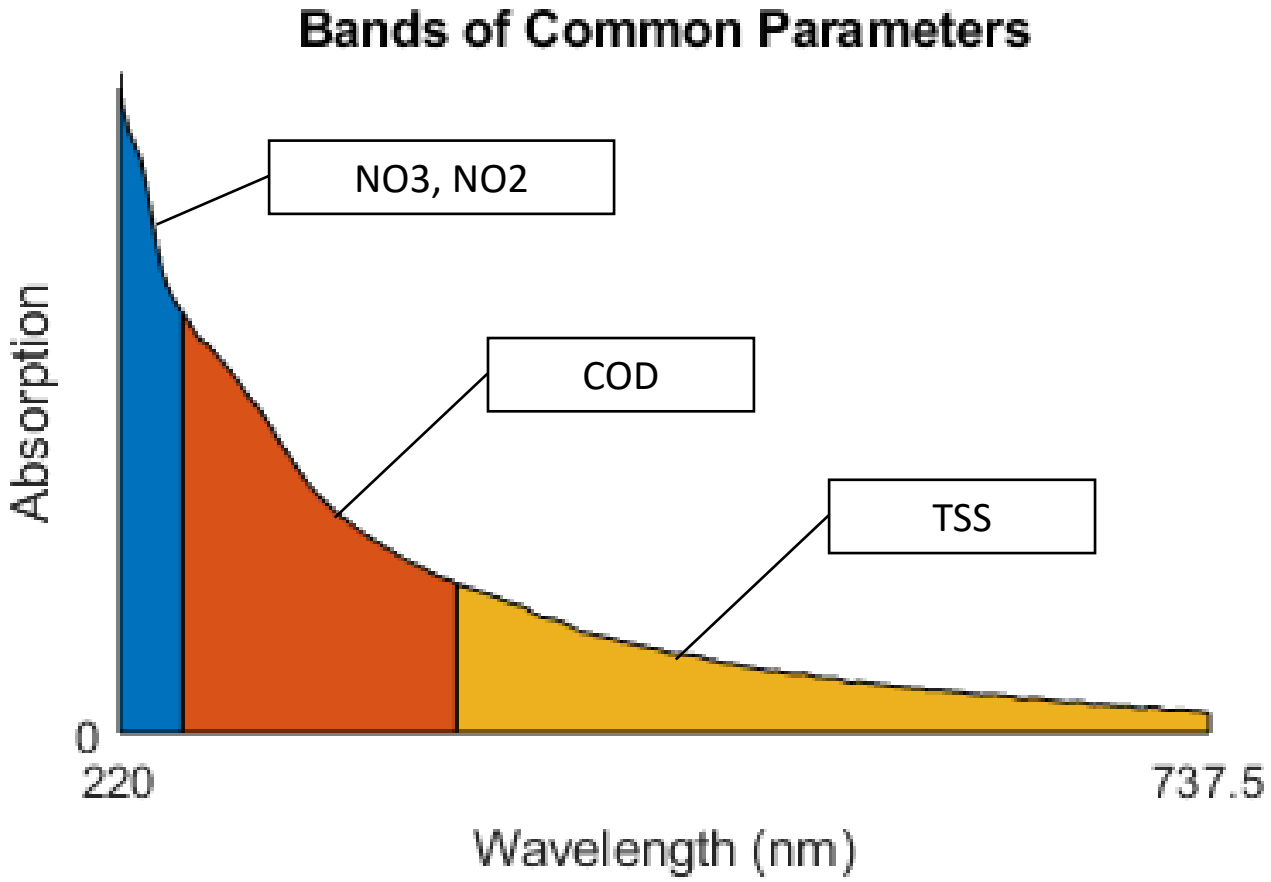
Research Objectives & Process

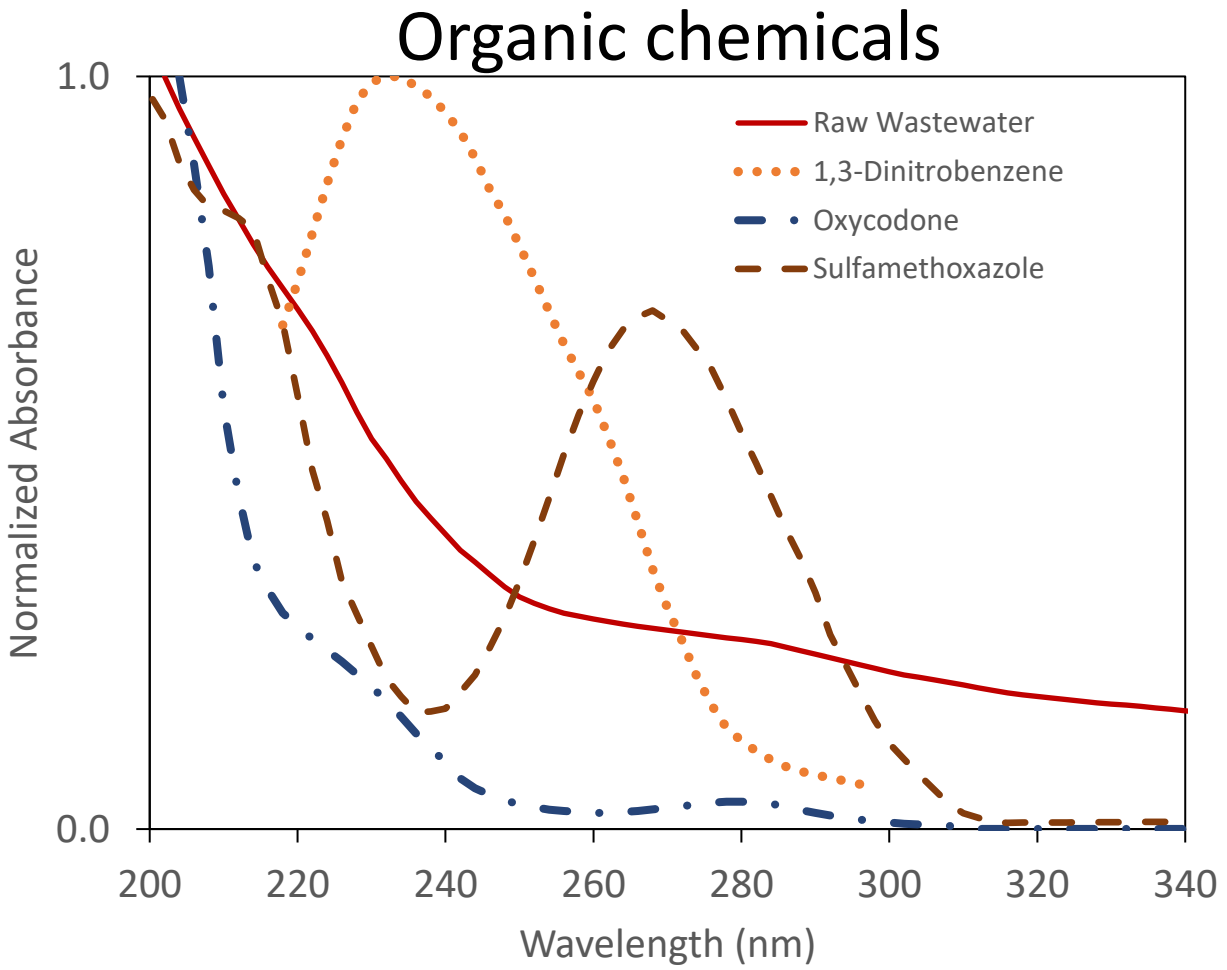


First steps:

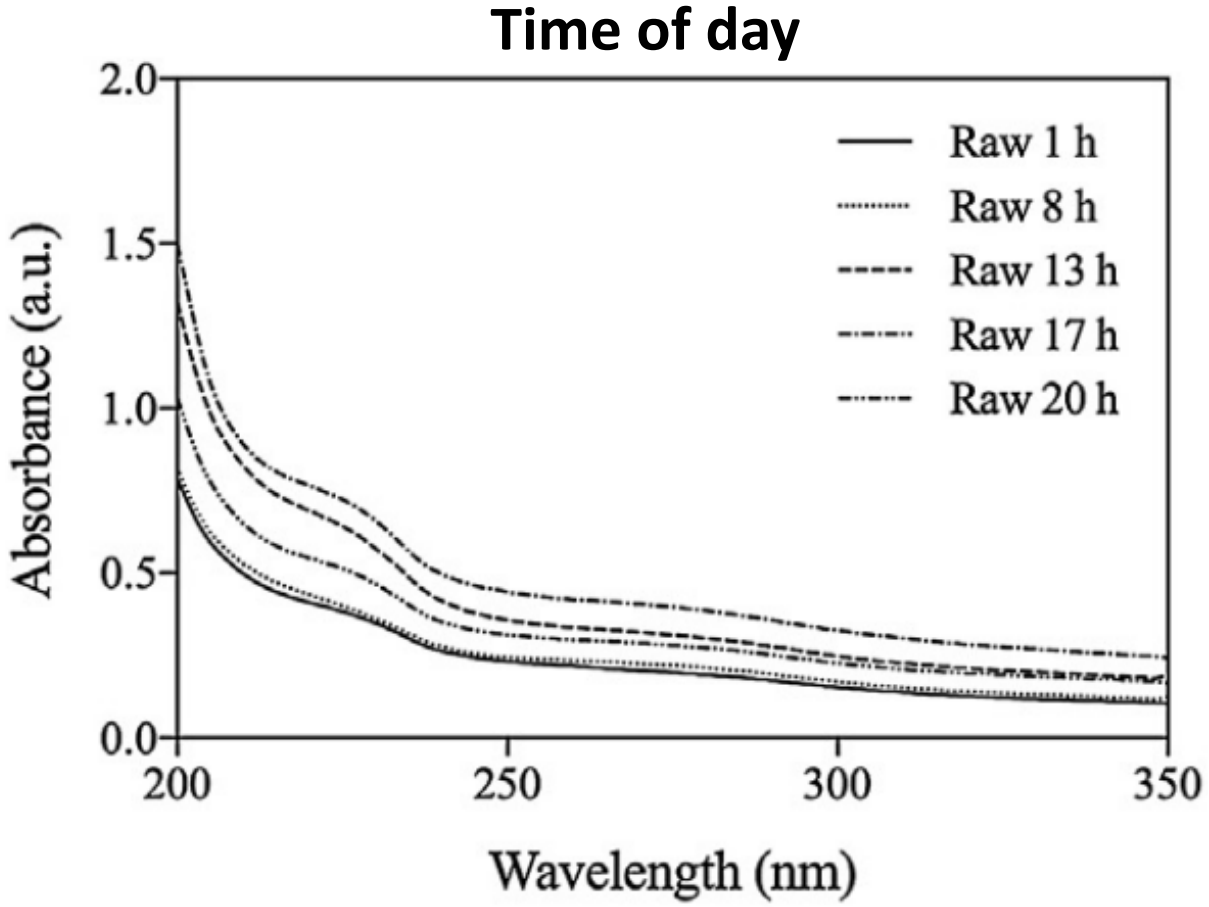
- Collection/analyze long-term dataset
- Determine simplest way to model (range of) “normal” for wastewater

UV-Vis Spectrometry: Wide Detection Capabilities





Previous wastewater studies

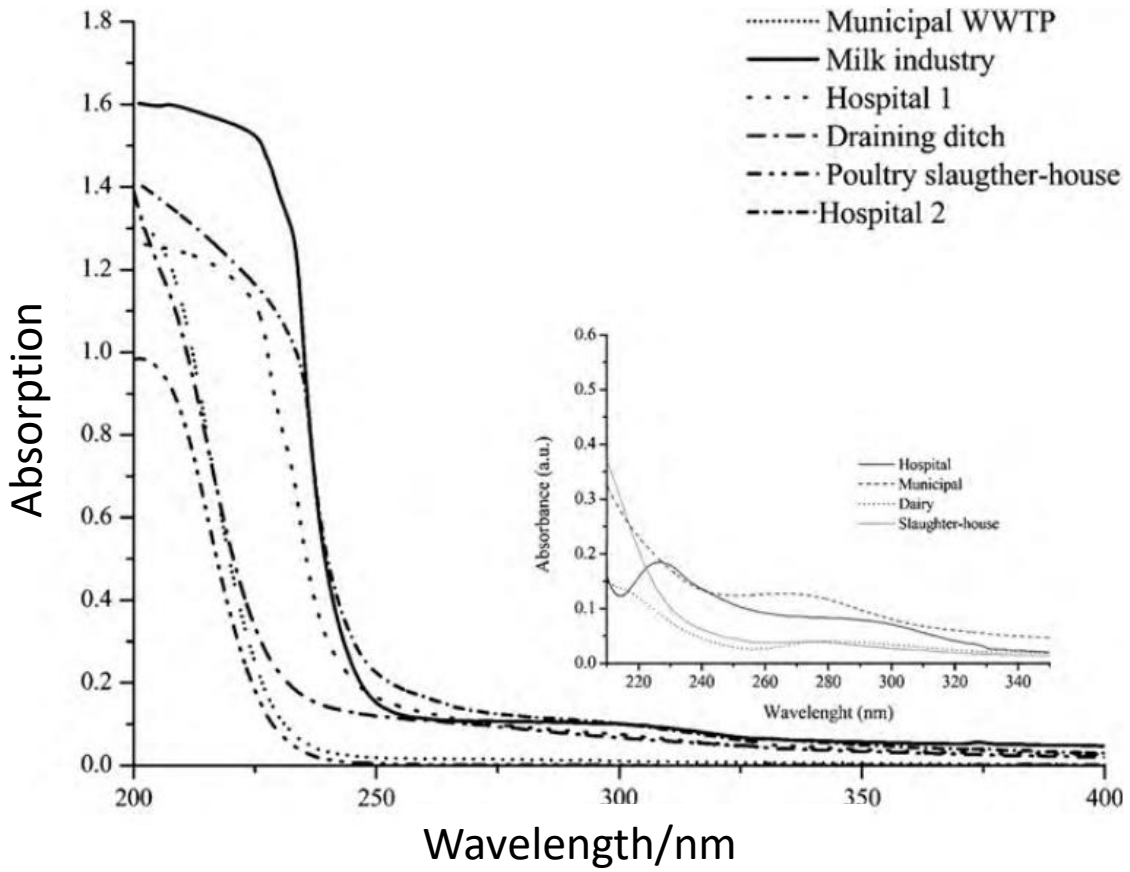


- Spectra grouped by hour
- Limited amount of data
- Does not show variability

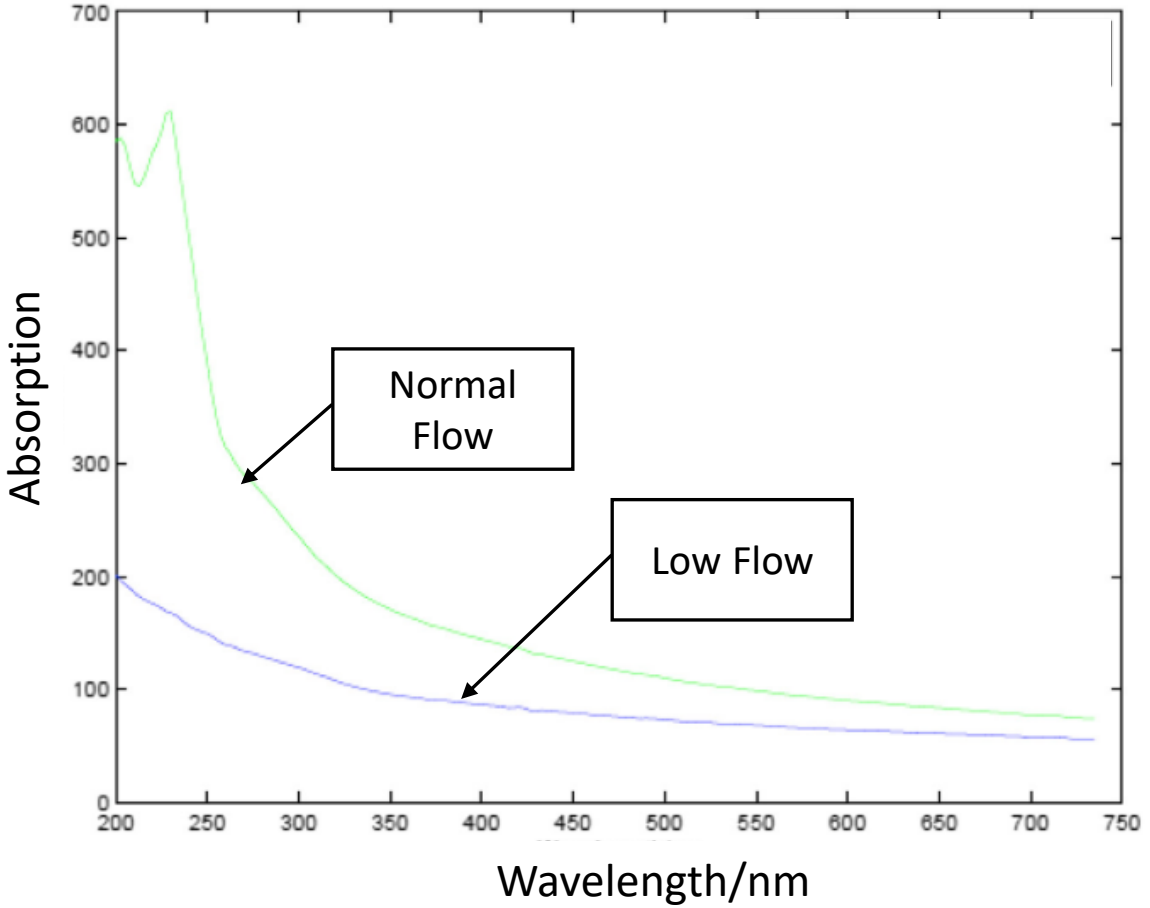
Thomas, M.-F. (2017). Chapter 9: Urban Wastewater. *UV-Visible Spectrophotometry of Water and Wastewater*, 281–315. https://doi.org/10.1016/B978-0-444-63897-7.00009-3

Previous wastewater studies

Origin



Flow rate



Tsoumanis, C. M., Giokas, D. L., & Vlessidis, A. G. (2010). Monitoring and classification of wastewater quality using supervised pattern recognition techniques and deterministic resolution of molecular absorption spectra based on multiwavelength UV spectra deconvolution. Talanta, 82(2), 575–581. https://doi.org/10.1016/j.talanta.2010.05.009

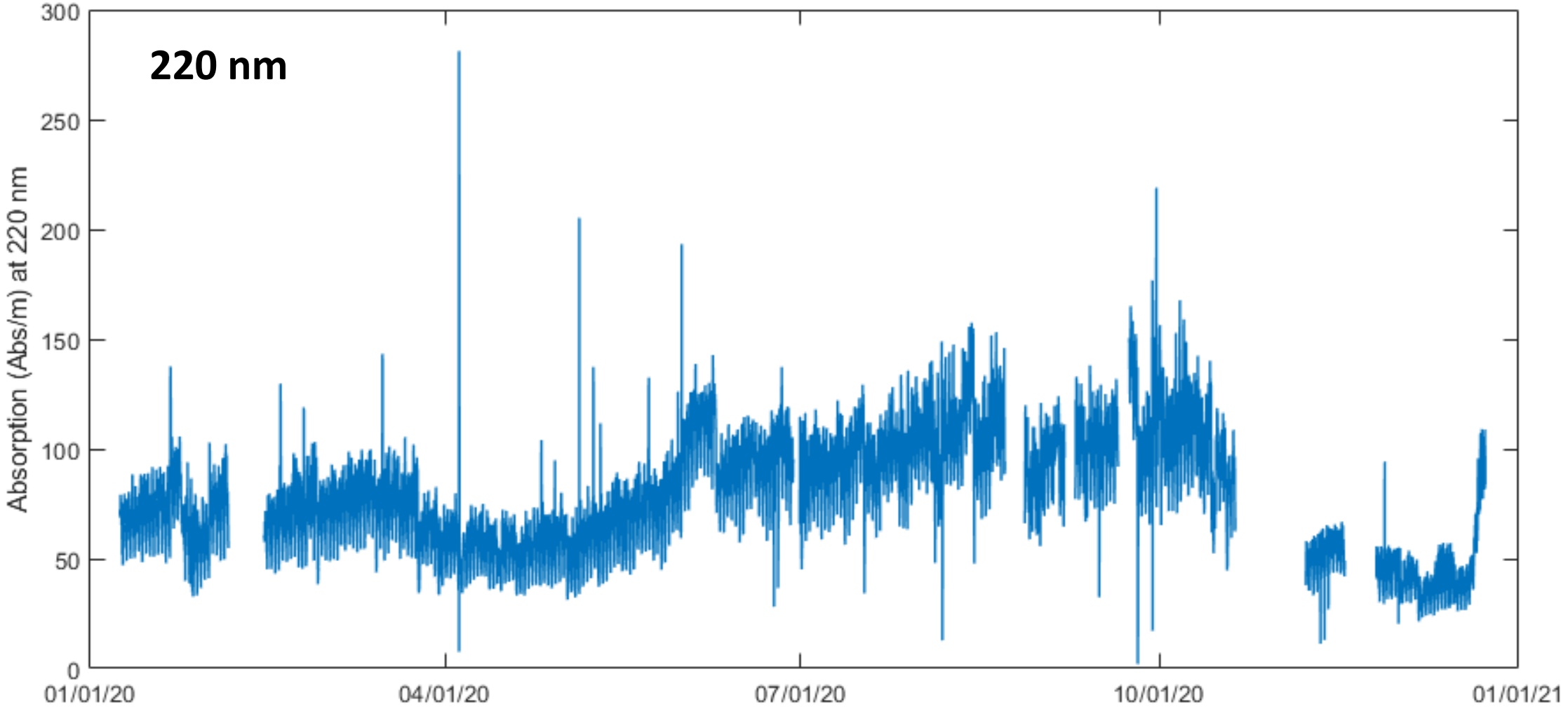
Chow, C. W. K., Liu, J., Li, J., Swain, N., Reid, K., & Saint, C. P. (2018). Development of smart data analytics tools to support wastewater treatment plant operation. *Chemometrics and Intelligent Laboratory Systems*, *177*, 140–150. https://doi.org/10.1016/J.CHEMOLAB.2018.03.006

Case Study: Upper Blackstone Clean Water

- Serves ~250,000 in the Worcester area (56 mgd)
- Spectrometer installed since July 2019
- Characterizing primary effluent

Analysis: 2020 calendar year

- 43,010 samples
- 208 wavelengths (220 - 737.5 nm)



Research Questions

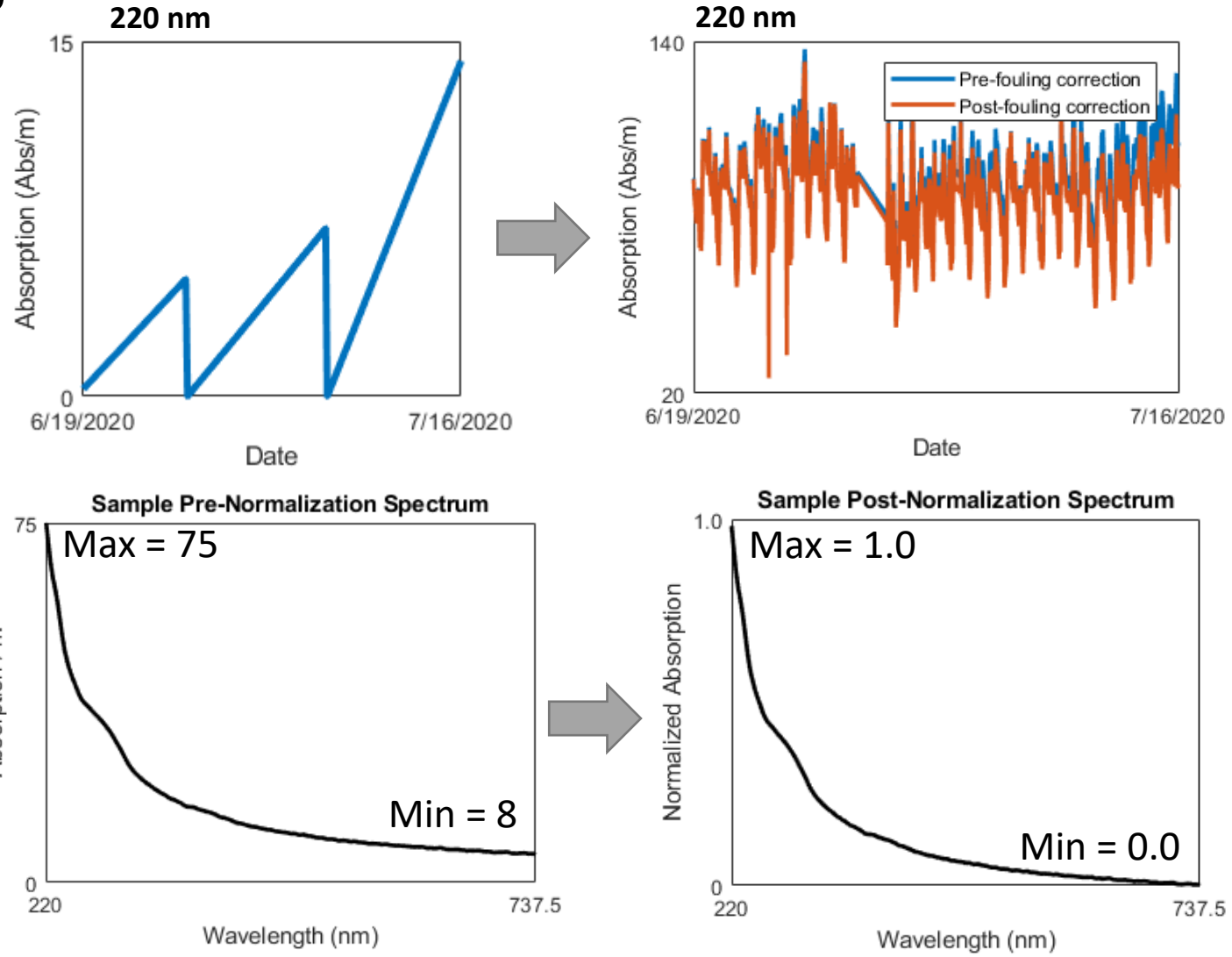
1. What new can be learned from high-res / long-term data?

2. Is there a simpler method to define normal, and how might that be informative?

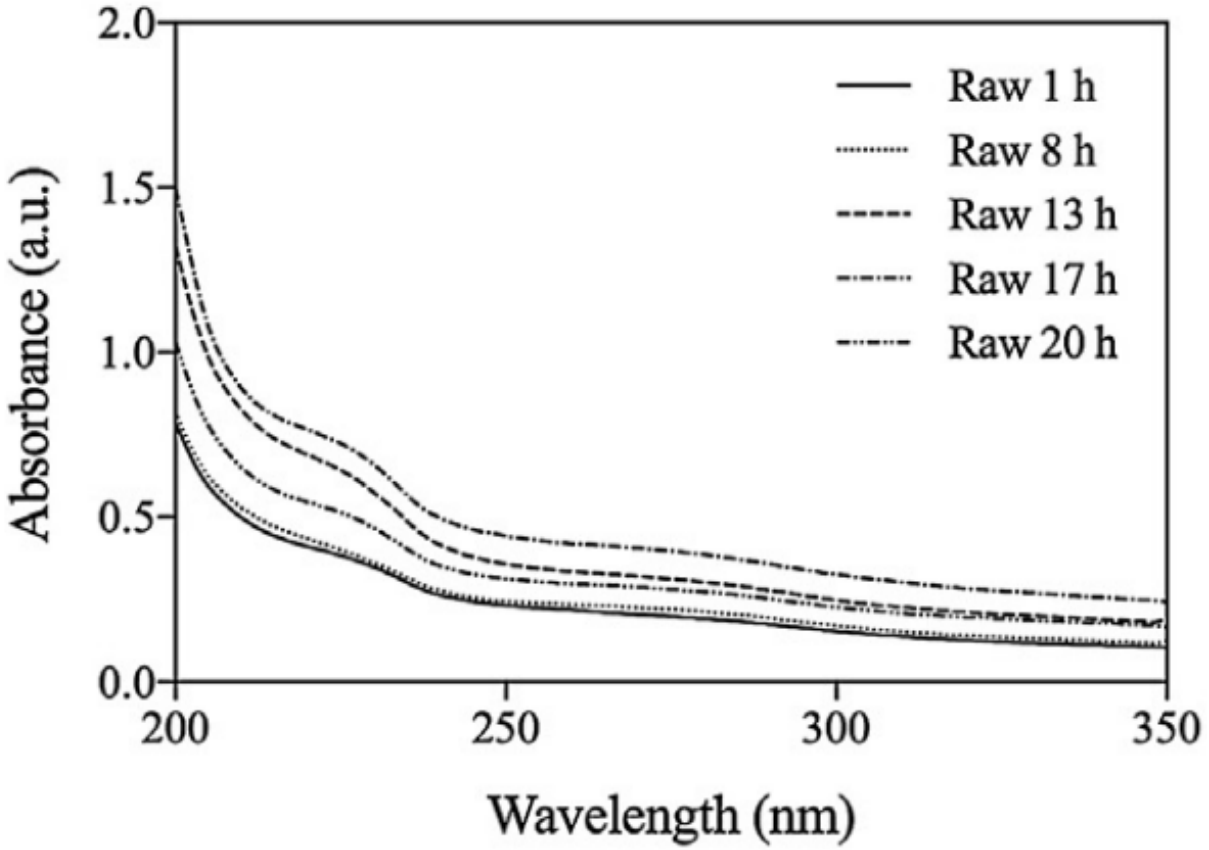
3. Can we observe the effects of government policy changes in 2020?

Data Preprocessing

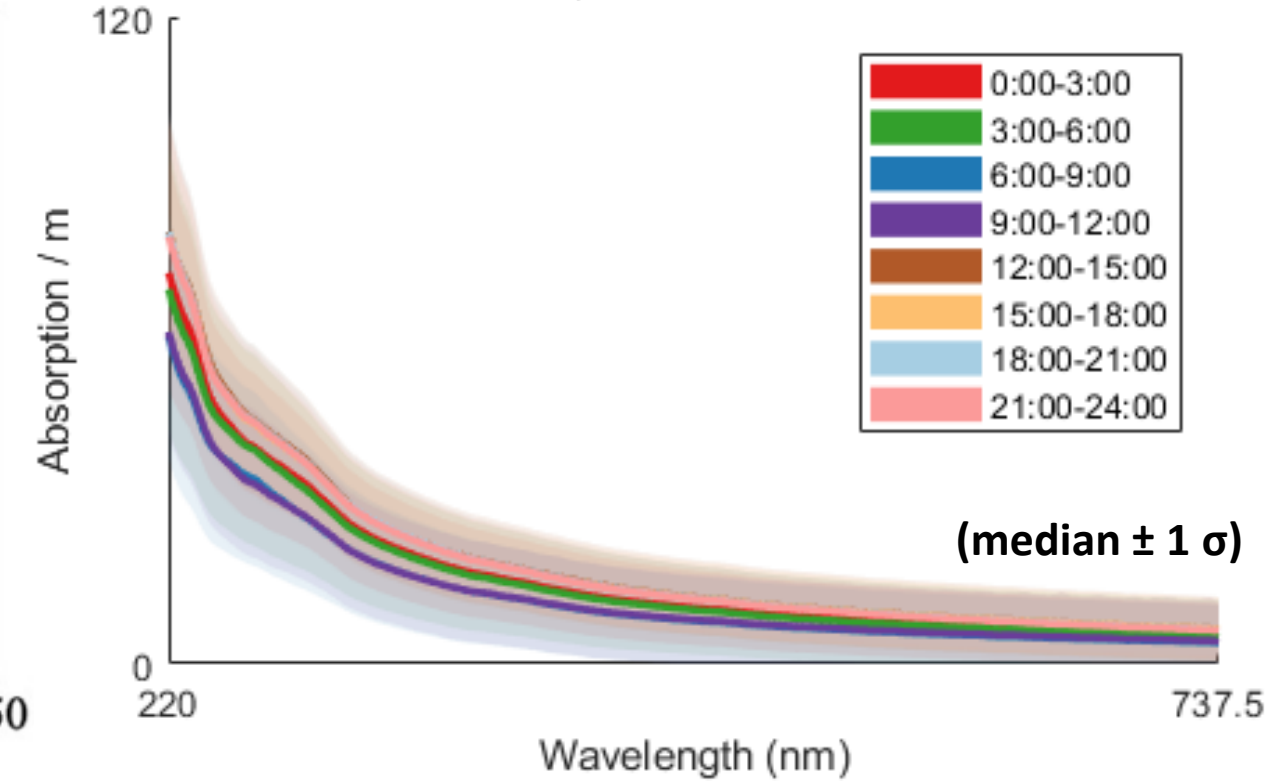
- **Lens Fouling**
  - Observe pre/post cleaning
  - Interpolate to quantify drift
  - Subtract from raw spectra
- **Normalization**
  - Simple scaling
  - Preserves shape
  - Reduces dilution effects



What Can We Learn?



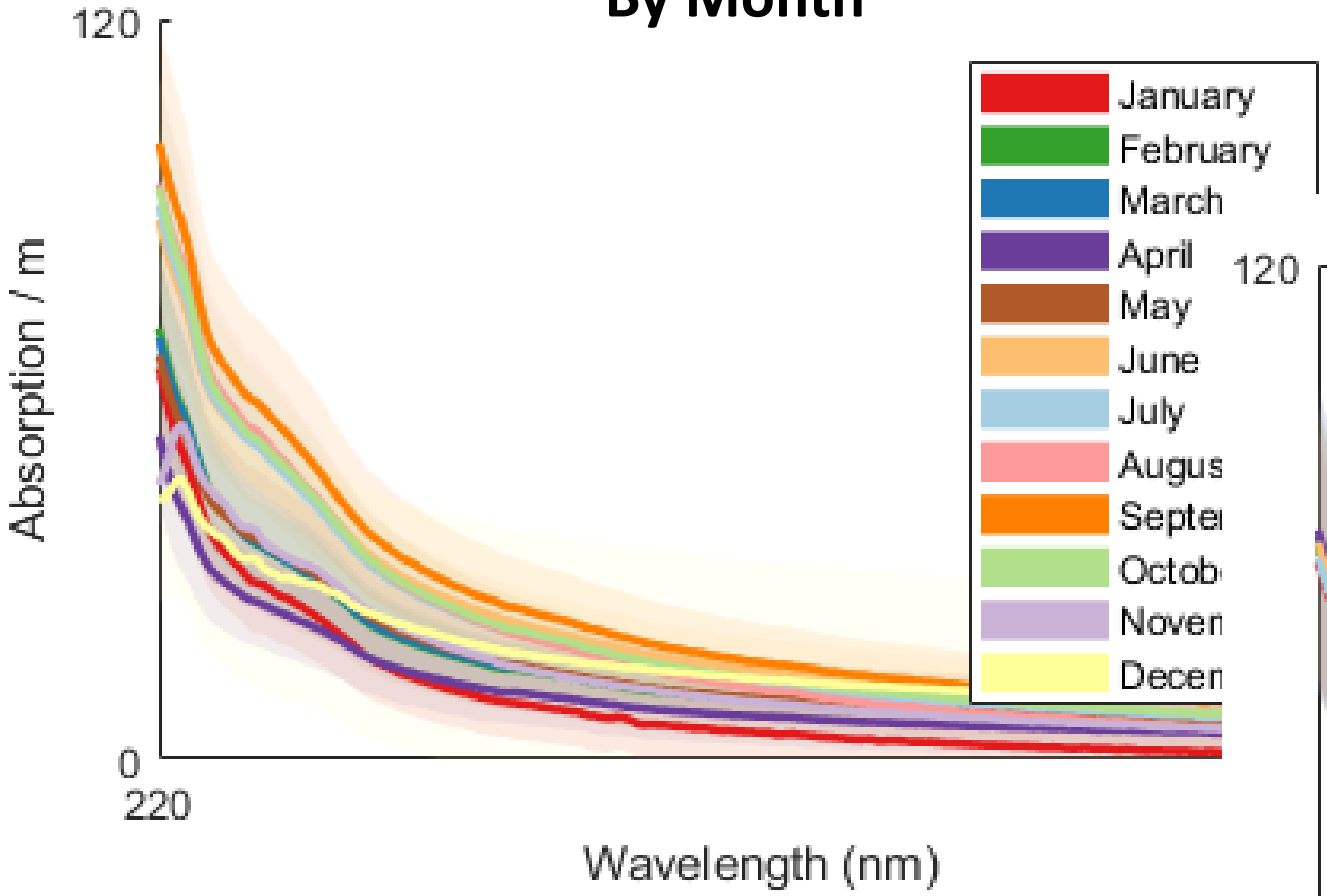
By 3-hr Bins



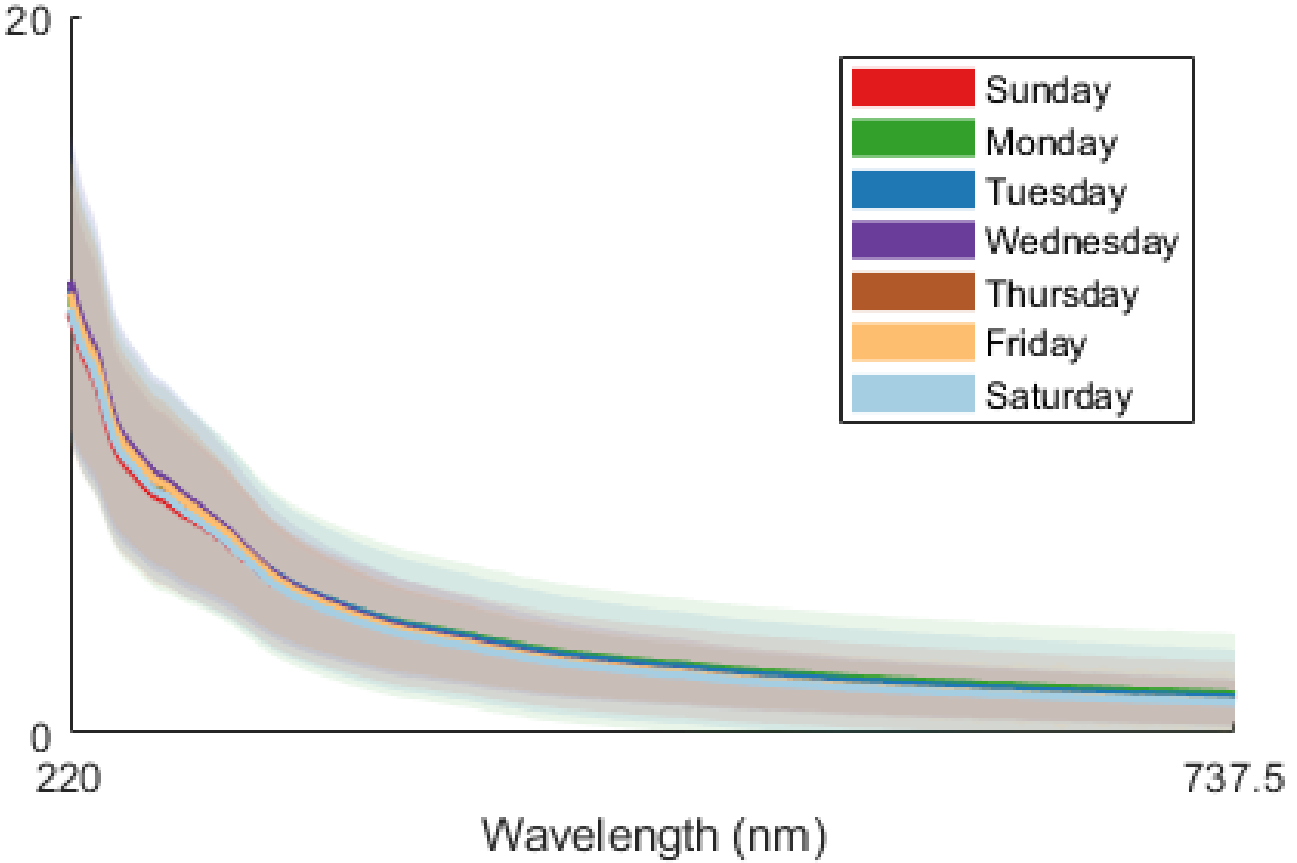
(median ± 1 σ)

What Can We Learn?

By Month

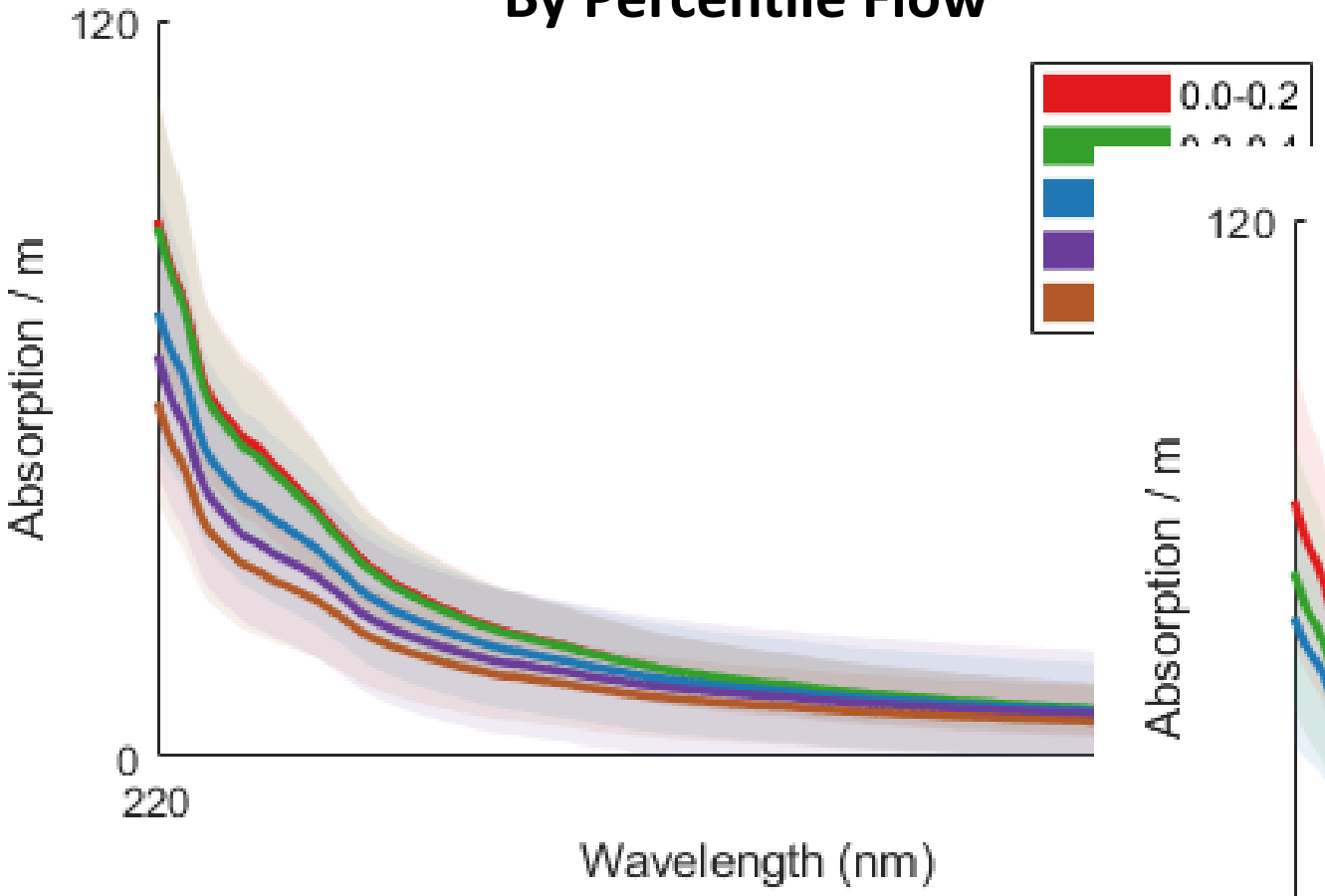


By Day of the Week

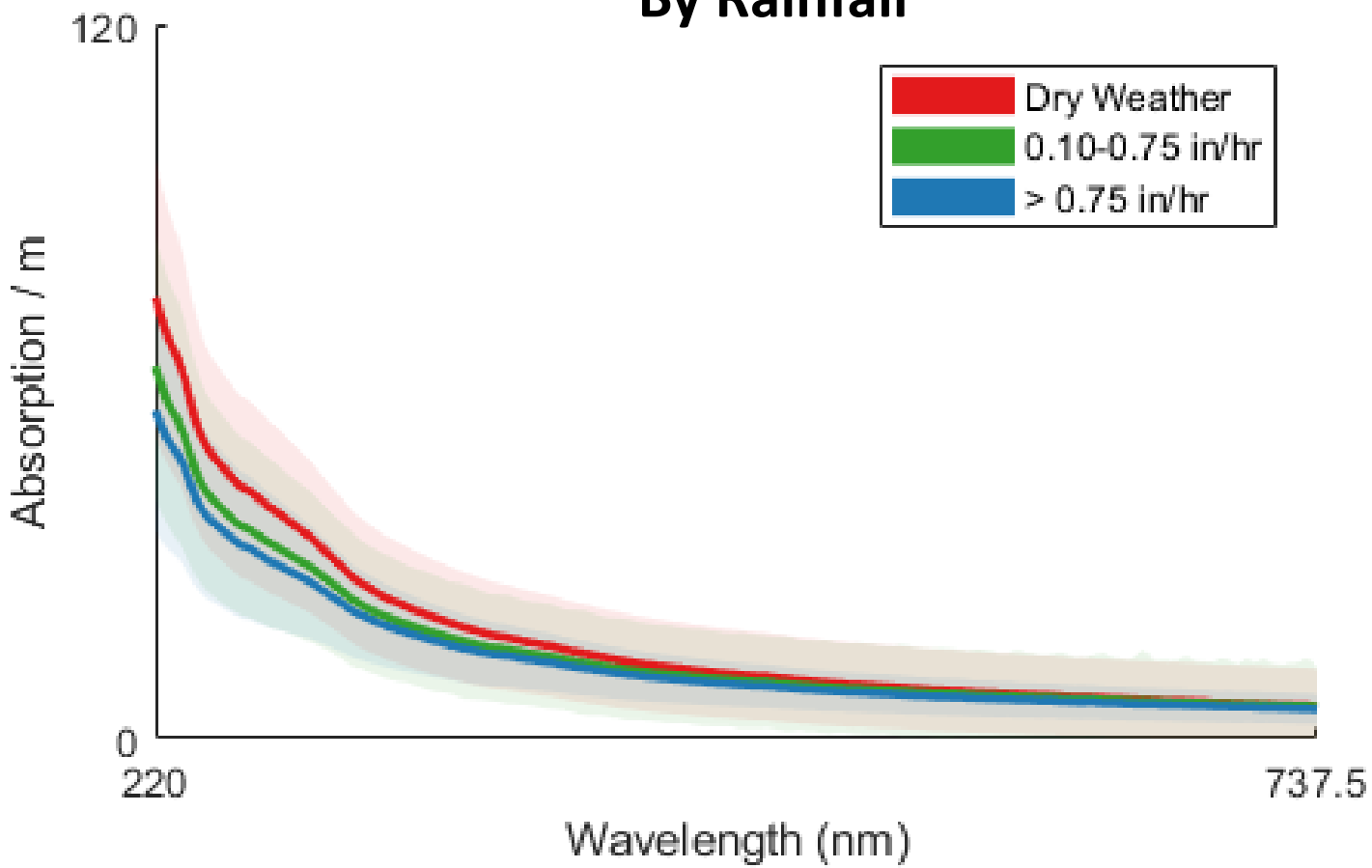


What Can We Learn?

By Percentile Flow



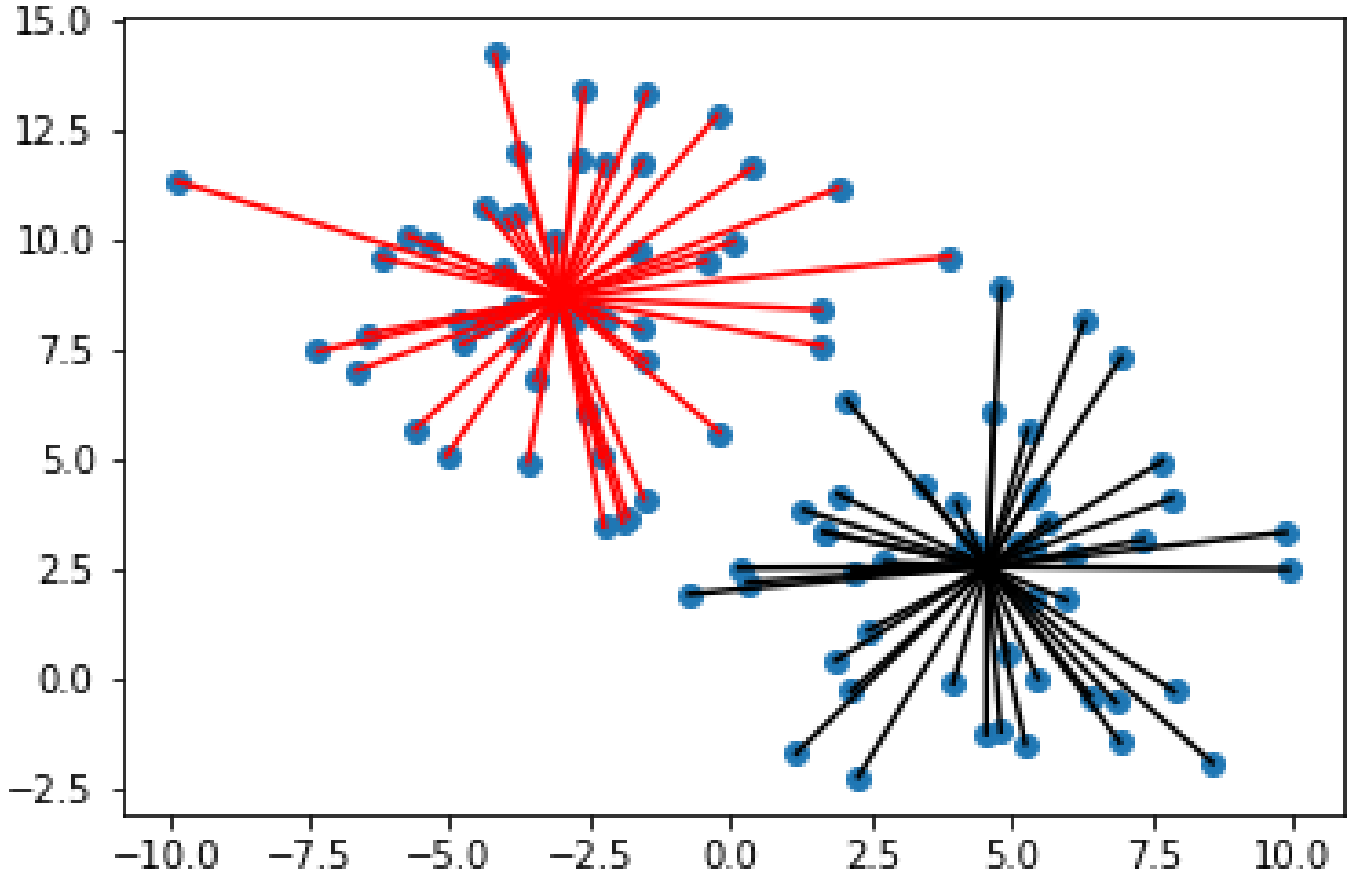
By Rainfall



Can we simplify definition of “normal”?

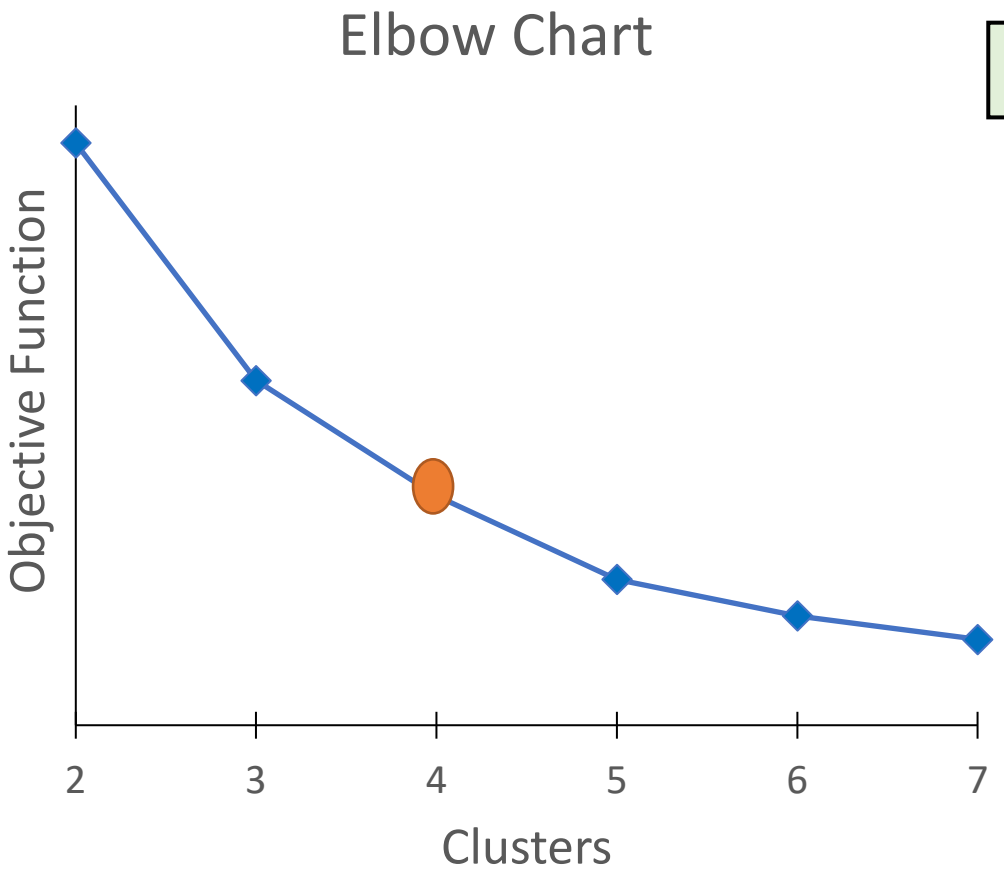
- **Objective**: Group spectra based on shape similarity

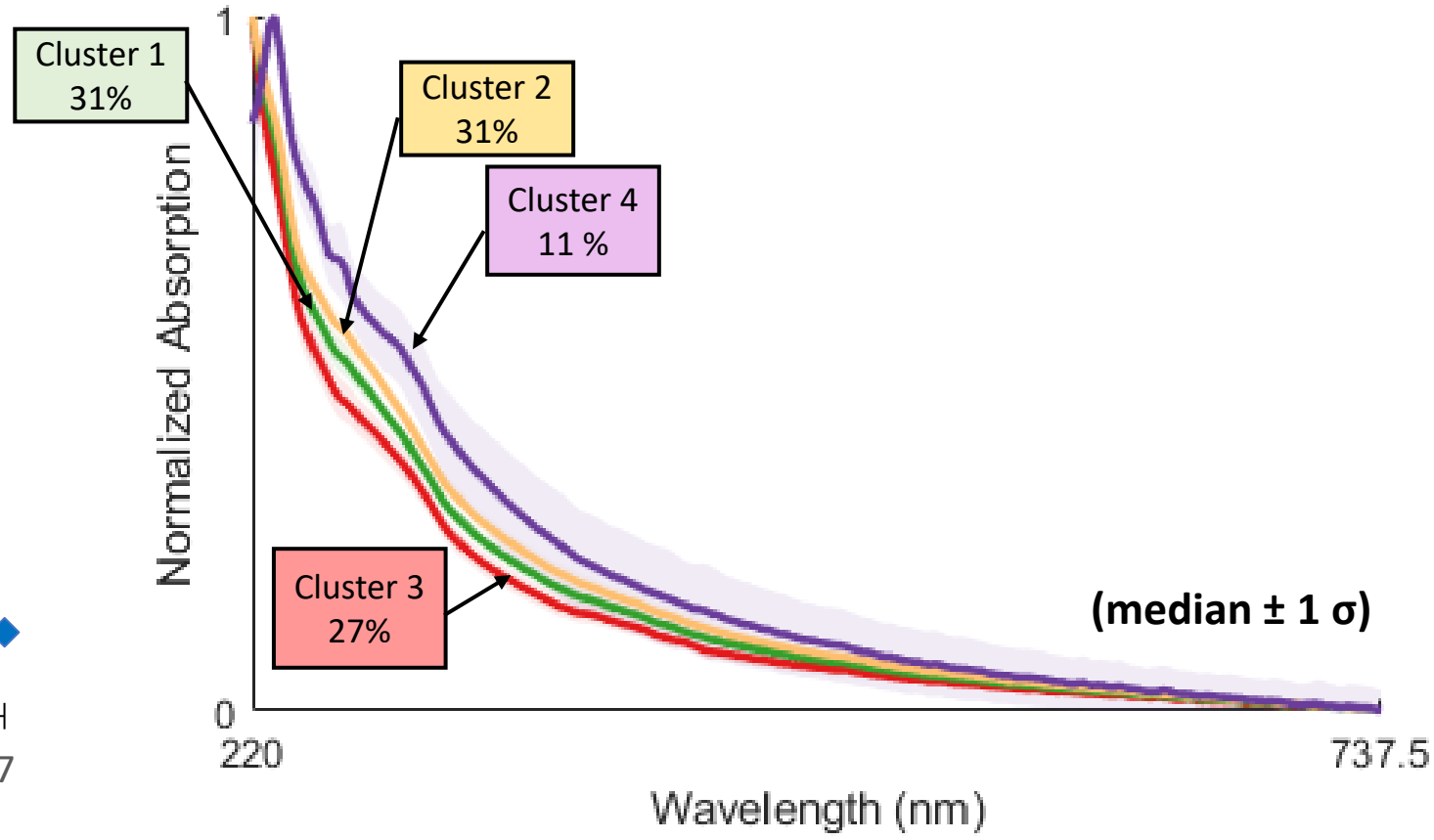
- **Method**: Fuzzy C-means Clustering
  - Unsupervised classification
  - Iterative, distance-based
  - No *a priori* constraints on clustering



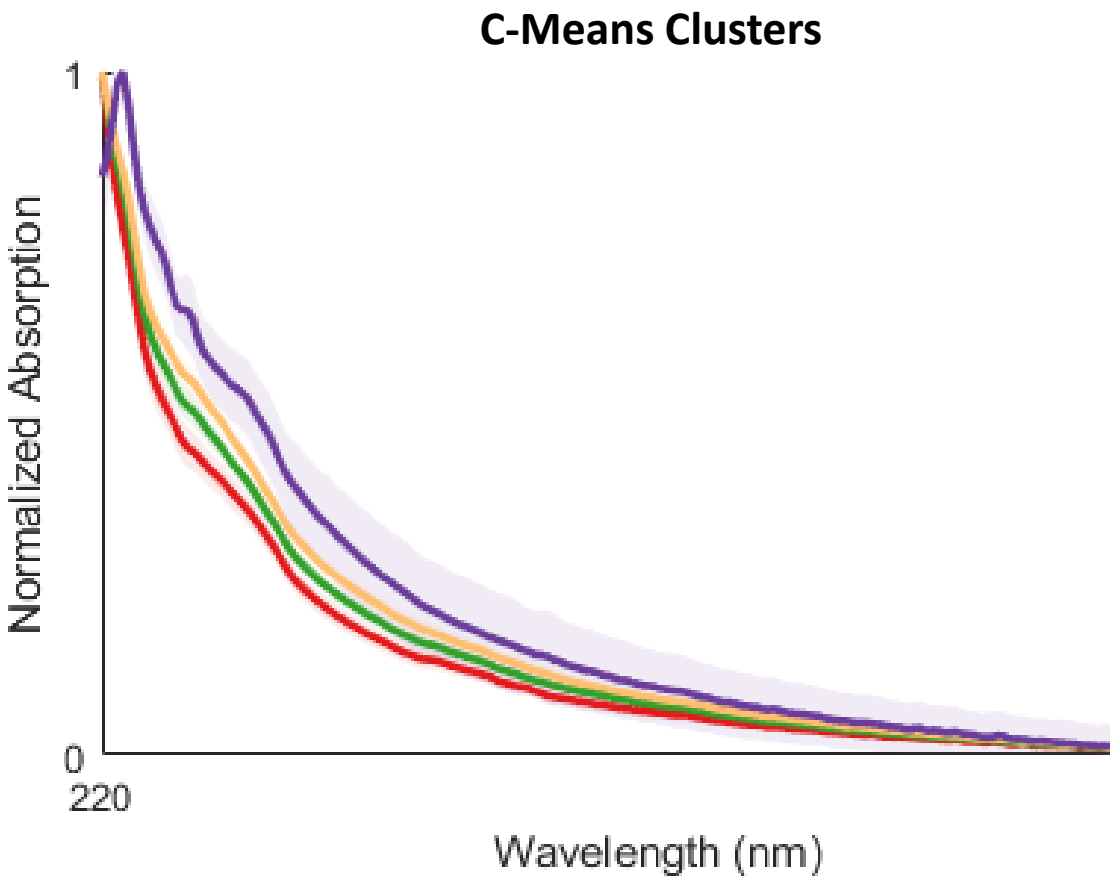
https://machinelearningjourney.com/index.php/2020/02/07/k-means-k-medians/

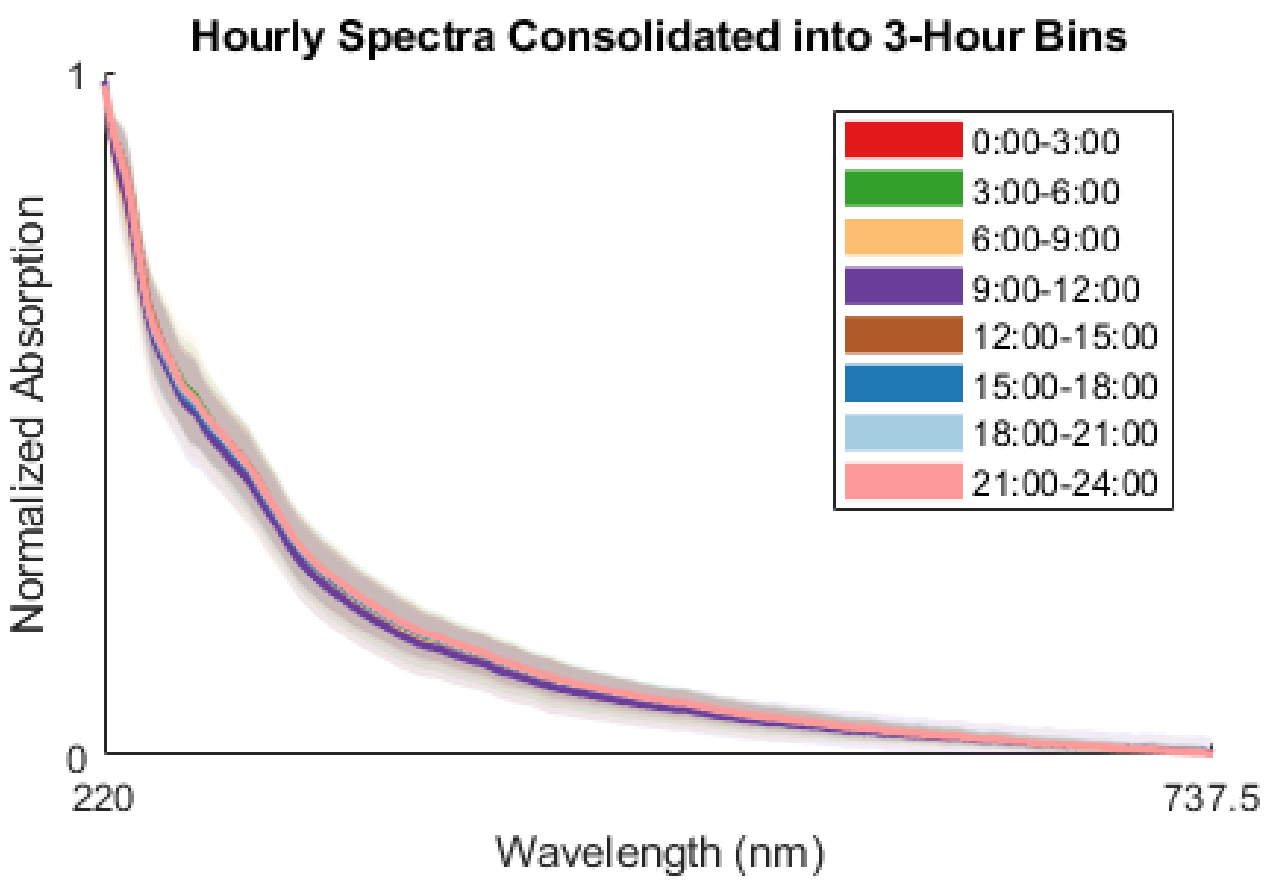
Clustering Results



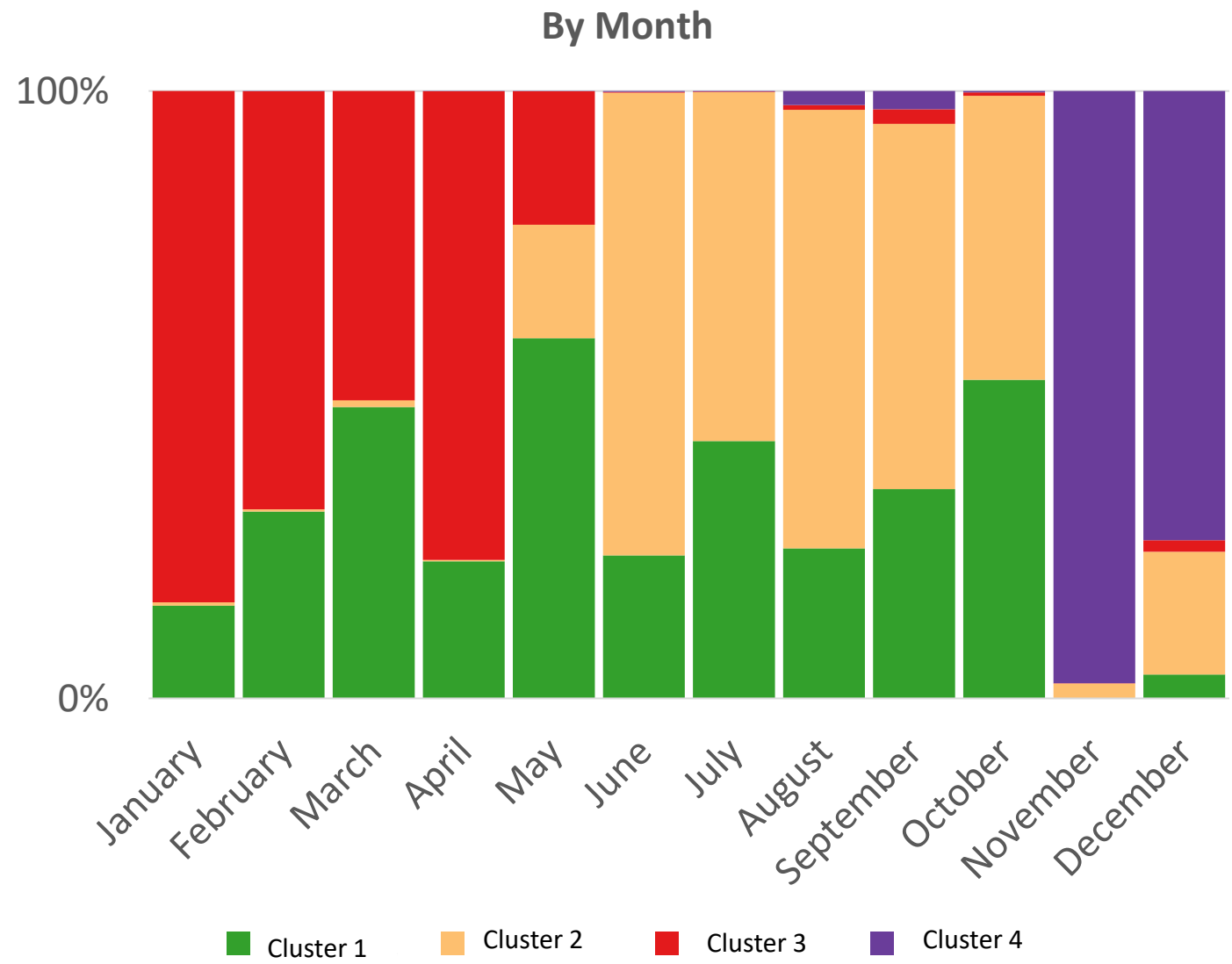


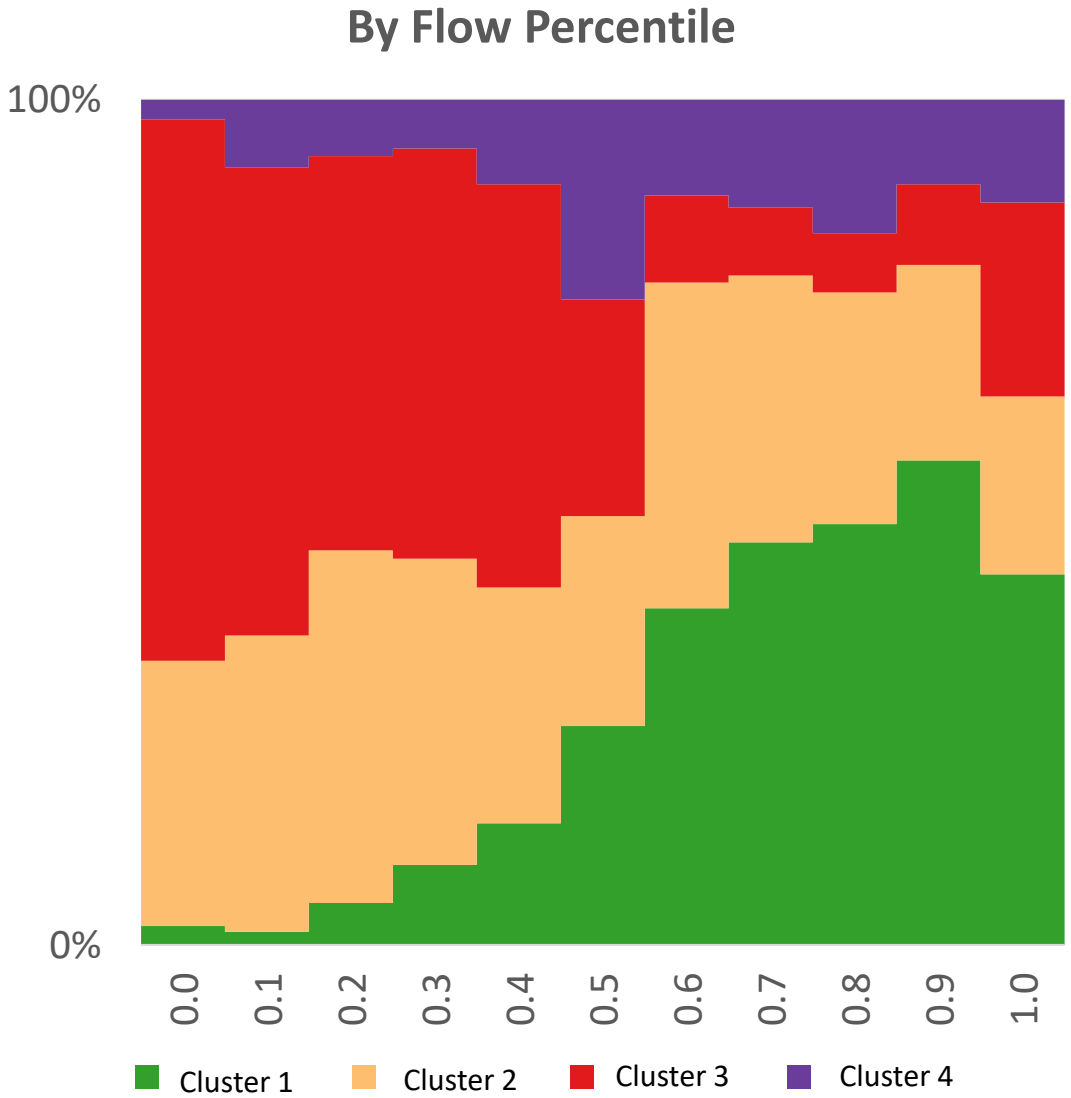
How do these compare with physics-based?





What do these clusters show?

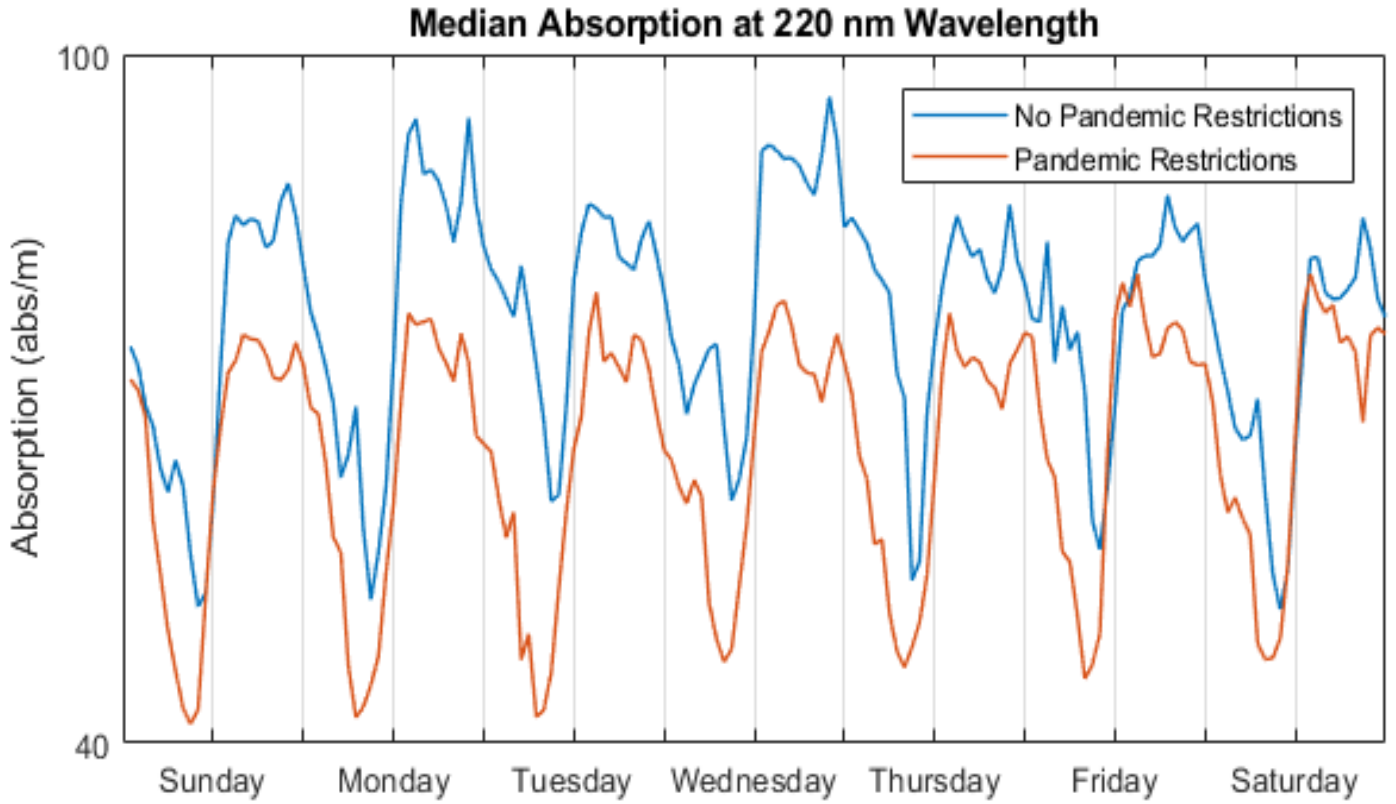




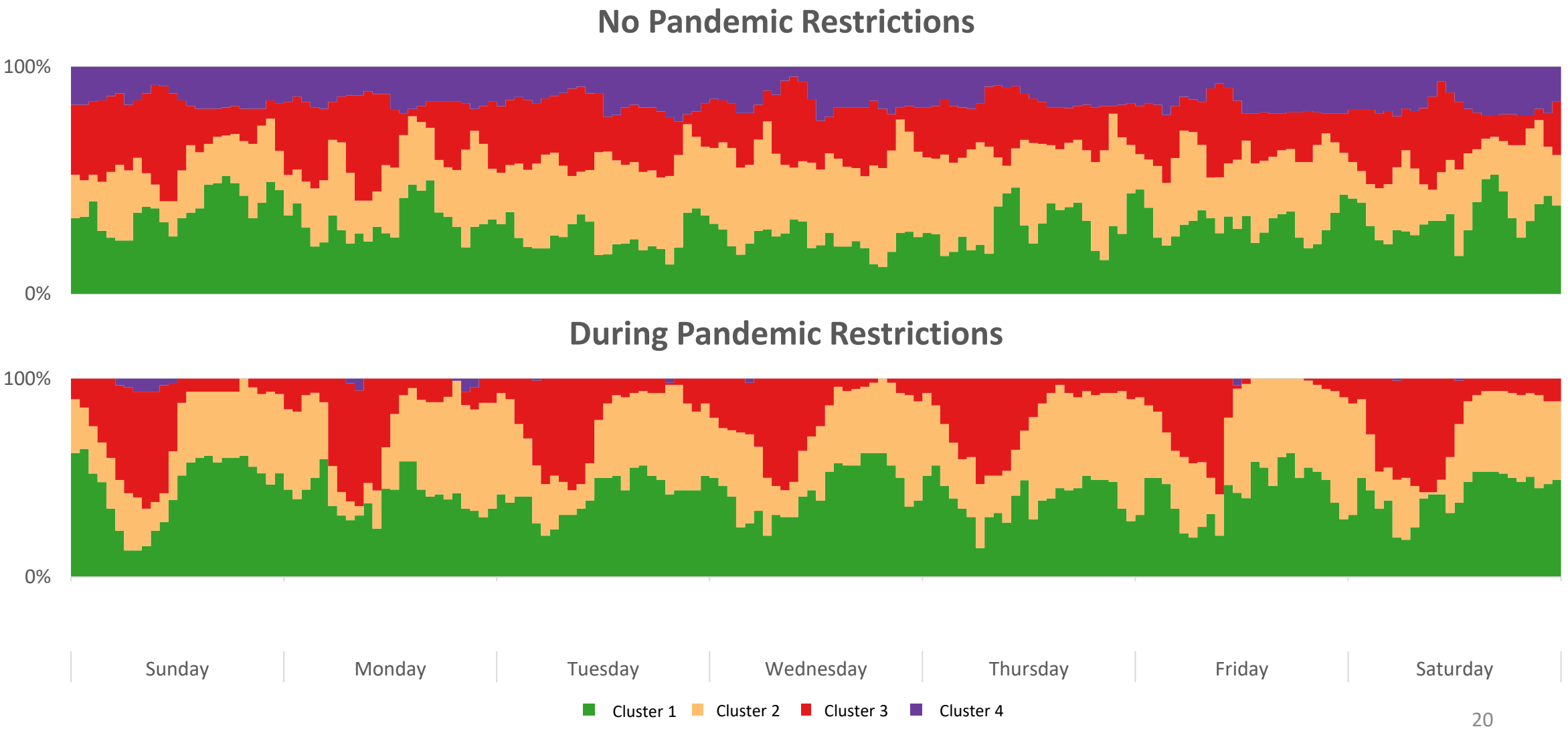
Case Study - Pandemic Restrictions

- **Start**: March 17, Gov. issues closure of schools, additional restrictions
- **End**: July 6, Gov. Baker announces start of Phase 3 reopening

	Median Flow (mgd)	% Wet Weather	Average 220 nm Absorption (abs/m)
No Restrictions	23.7	6%	77
Pandemic Restrictions	33.5 (+31%)	11%	65 (-15%)

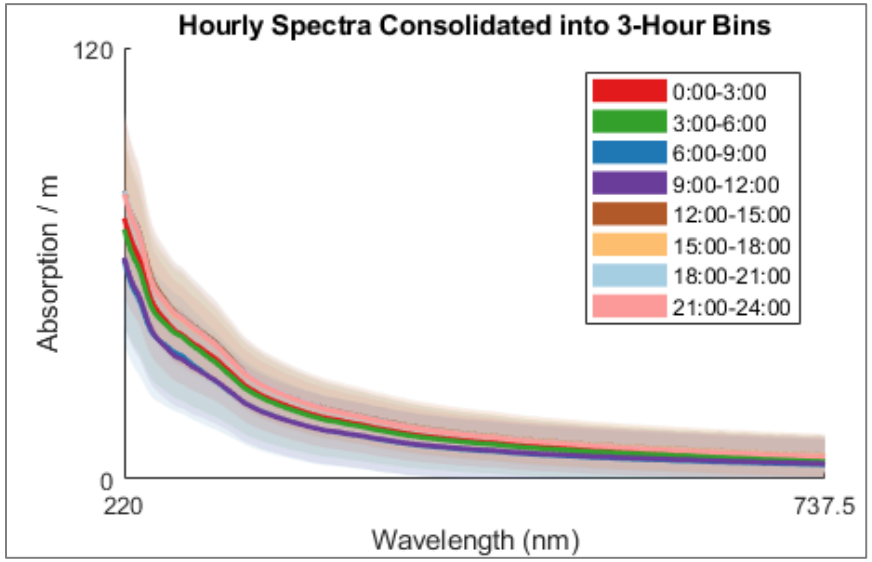


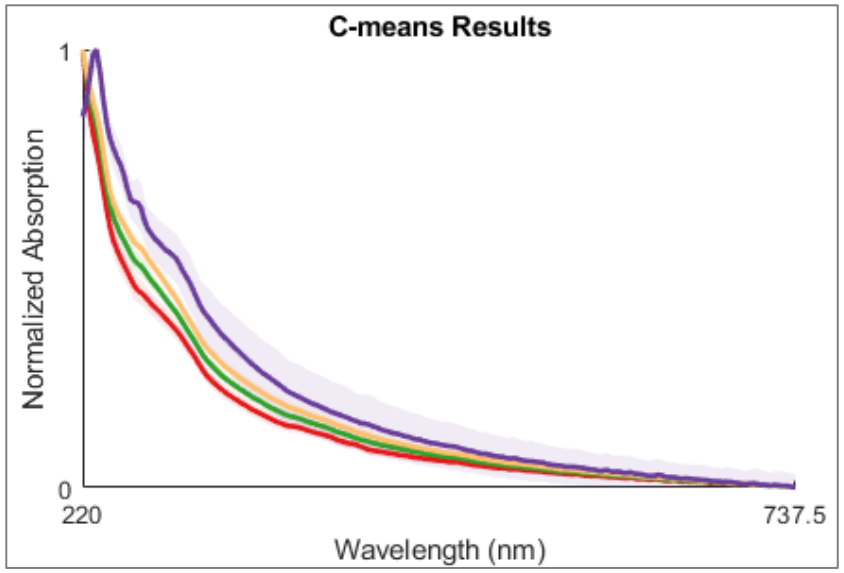
Day of Week/ Hour (C-Means Clusters)

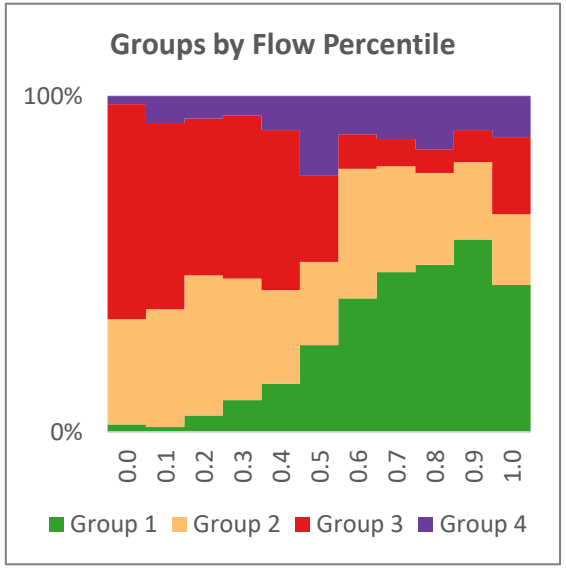


Conclusions

1. What have we learned?
2. Simply defining “normal”
3. Policy effects







Next steps: working toward <u>anomaly detection</u>

- Algorithm development (“normal” vs. not)
- Validation with field + lab data

Acknowledgements

- Upper Blackstone Clean Water
  - Edris Taher
  - Ken Pousland
- Funding - Northeastern University
- Environmental Sensors Lab
  - Professor Amy Mueller
  - Meyling Yi
  - Jose Saenz
  - Anna Pealock

Thank You!

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