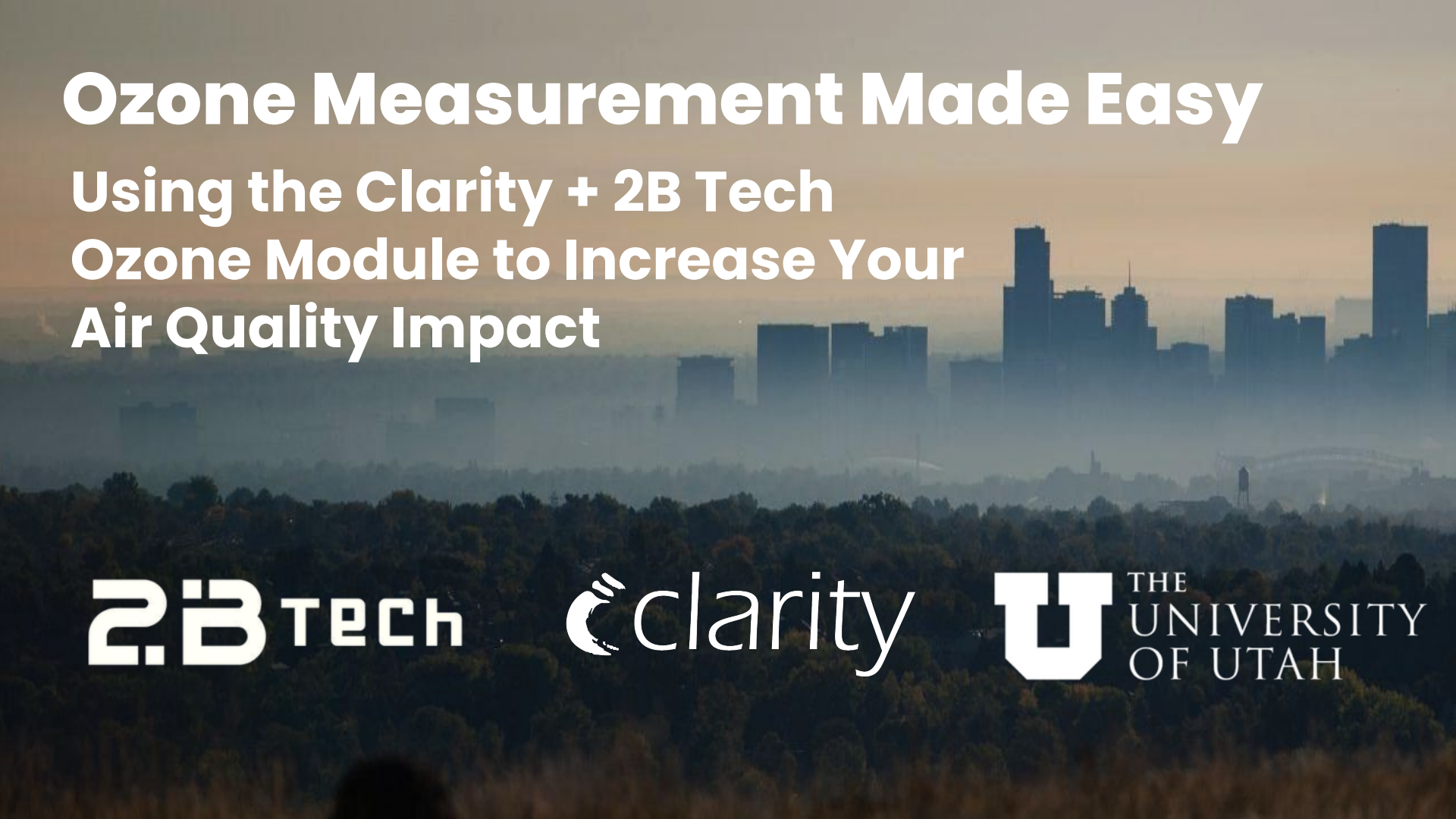
Ozone Measurement Made Easy

Using the Clarity + 2B Tech Ozone Module to Increase Your Air Quality Impact



Meet the panelists!

Daniel Mendoza

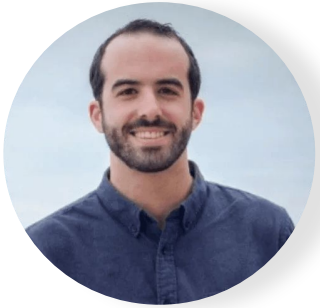
Research Assistant Professor,
Atmospheric Sciences
at University of Utah

Gordon Pierce

Outside Sales
2B Technologies

Hayden Aubermann

Sales & Marketing Manager
2B Technologies



Jack Kodros

Air Quality Data Scientist
Clarity Movement Co.

Paolo Micalizzi

Co-Founder & CTO
Clarity Movement Co.

clarity

Clarity Lab

Taking a scientific approach to enhancing sensor performance

Paolo Micalizzi

Co-founder & CTO

Jack Kodros

Air Quality Data Scientist

Levi Stanton

Solutions Engineering Lead

Clarity's in-house team of scientists

- ✓ Explore long-term scientific questions related to air quality sensing
- ✓ Understand how sensors perform in different environments (e.g., climate types, seasons, time of day)
- ✓ Improve sensor performance through calibration, hardware and software innovation

clarity

Overview:
Ozone Air Pollution

Jack Kodros
Air Quality Data Scientist

Most important things to remember:

1. **Ozone is toxic**. Bad for human health and plants.

2. **Ozone is not emitted directly**. It needs sunlight and precursor gases to form (photochemical reactions)

Topics for discussion:

1. **What ever happened to the ozone hole?**
   a. Common confusion: Ozone at *high altitudes* is good. Ozone at *the surface* is bad.
2. **What is ozone?**
   a. 3 oxygen atoms (O_3)
3. **Why do we care about surface ozone?**
   a. Bad for human health
   b. Bad for plants
   c. Important for atmospheric chemistry
4. **How does it form?**
   a. Needs sunlight and other pollutants to form
   b. Makes compliance difficult and complicated

Common source of confusion:
Isn't the ozone hole a bad thing?

- Ozone at **high elevations** in the atmosphere (stratosphere) is **a net positive.**
  - Blocks high-energy UV radiation
  - O_3 at this elevation forms naturally

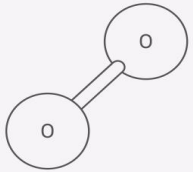
- Ozone **near the surface** of the atmosphere (i.e., where we can breathe it) is **a net negative**.
  - O_3 is toxic to humans and plants
  - Human emissions greatly increase O_3 concentrations at the surface

Image source: Air Central Texas' useful summary

What is Ozone?

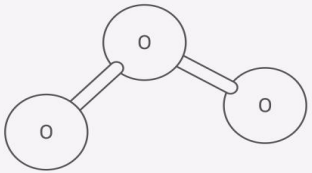
- **It is 3 oxygen atoms bonded together.**
  - The “oxygen” we breathe is O_2 (two oxygen atoms)
  - Extra oxygen atom makes it unstable and toxic
- **Written/spoken as “ozone” or “O_3”**
  - I usually say “oh three” when being technical and “ozone” when speaking of big picture topics.
- **We don’t typically “see” ozone pollution**
  - The smog we see is light scattering off of particles.
  - Bad ozone days aren’t as obvious as smoke days!

The air we breathe



The oxygen in the air that gives this planet life is made up of two oxygen atoms. Hence, the name O2.

Ozone



Ozone has an extra oxygen atom - O3. This extra atom makes ozone very unstable and harmful to breathe.

Why do we care about surface-level ozone?

1. Increases risk of disease for humans

2. Bad for crops (economic consequences)

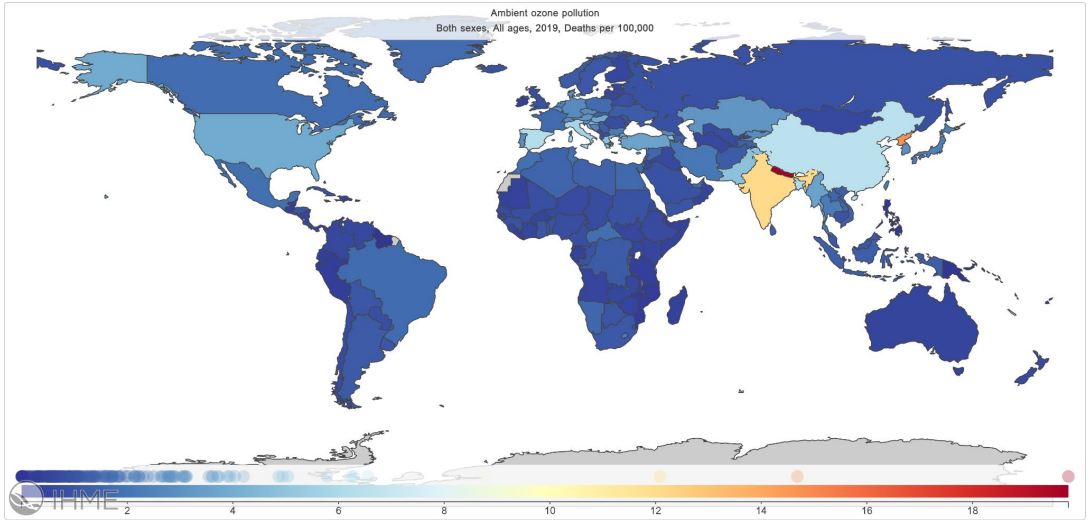
3. Important for atmospheric chemistry

The #1 reason we care about O_3 is human health!

"Like a sunburn on your lungs"

- Long-term ozone exposure is associated with **increased risk of Chronic Obstructive Pulmonary Disease** (COPD).
- In 2019, ozone accounted for:
  - **365,000 deaths** globally
  - **11% of all COPD deaths**
  - About 13,000 deaths were in the US (interactive map)
  - **3.7 million Disability Adjusted Life Years** (DALYs)

O_3 attributable deaths per 100,000 population



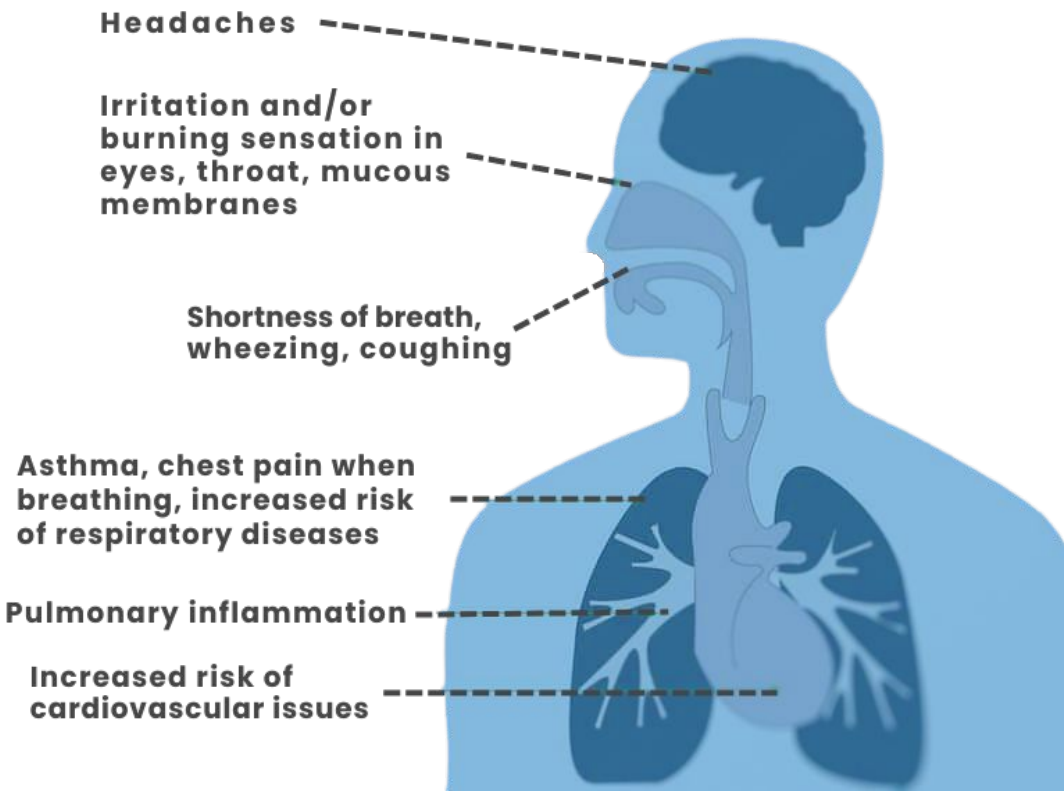
Source: Global Burden of Disease Study (2019)

The #1 reason we care about O_3 is human health

"Like a sunburn on your lungs"

- **Short-term ozone exposure is associated with**:
  - Coughing and scratchy throat
  - Difficulty breathing/harder to take deep breaths
  - Increased frequency and severity of asthma
  - Increases in hospital admissions and absences from school/work

- **Children, elderly, and people with respiratory issues are at a higher risk of health impacts due to ozone exposure.**



Reason #2:
Ozone is also bad for certain crops and vegetation

- Studies have shown that **increasing surface O_3 concentrations reduce crop yield** and are harmful to some plants.
  - One study found between **2% and 14% decreases in yields for maize, wheat, and soybean globally**
  - In 2000, **global crop production losses were the equivalent of $11 billion to $18 billion** (USD)
  - Study predicts that **global losses in 2030 will reach up to $35 billion due to** climate change and increasing ozone formation

- Evidence that sensitive crops are damaged at much lower concentrations (~40 ppb) than the EPA air standards

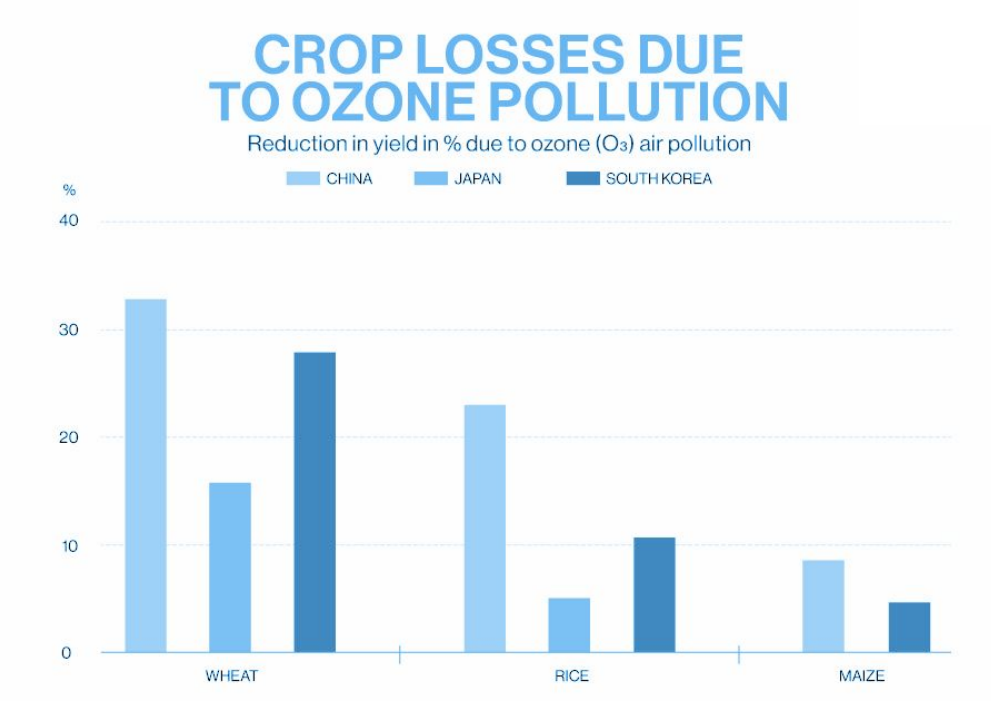


Image source: The Asean Post

Reason #3:
O_3 is important in atmospheric chemistry

Ozone reacts with many compounds in the atmosphere

- Reactions of ozone can **lead to formation of *even more* $PM_{2.5}$**.
- Ozone **also reacts with NO_2**. It is the reason we often see low NO2 concentrations in the summer (when O3 is high).
- **Ozone chemistry gets complicated fast.** This is an an active area of research for atmospheric chemists — **which is one reason we need measurements!**

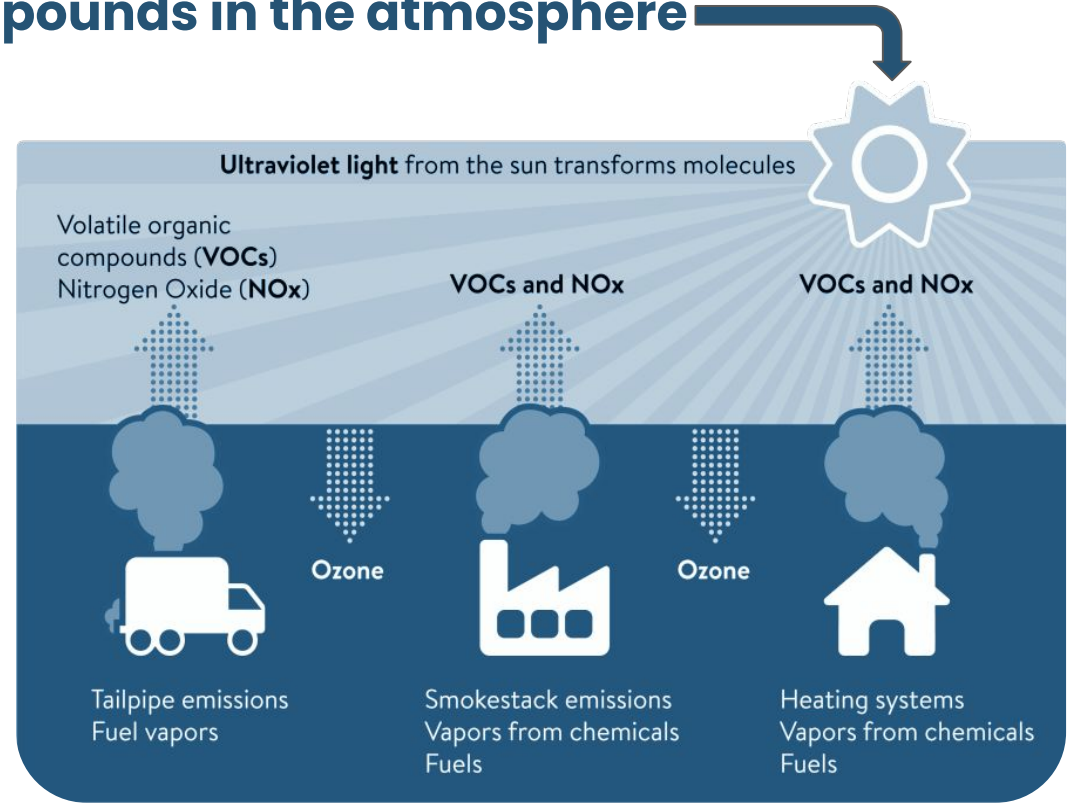


Image source: Minnesota Pollution Control Agency

How does surface-level ozone form?

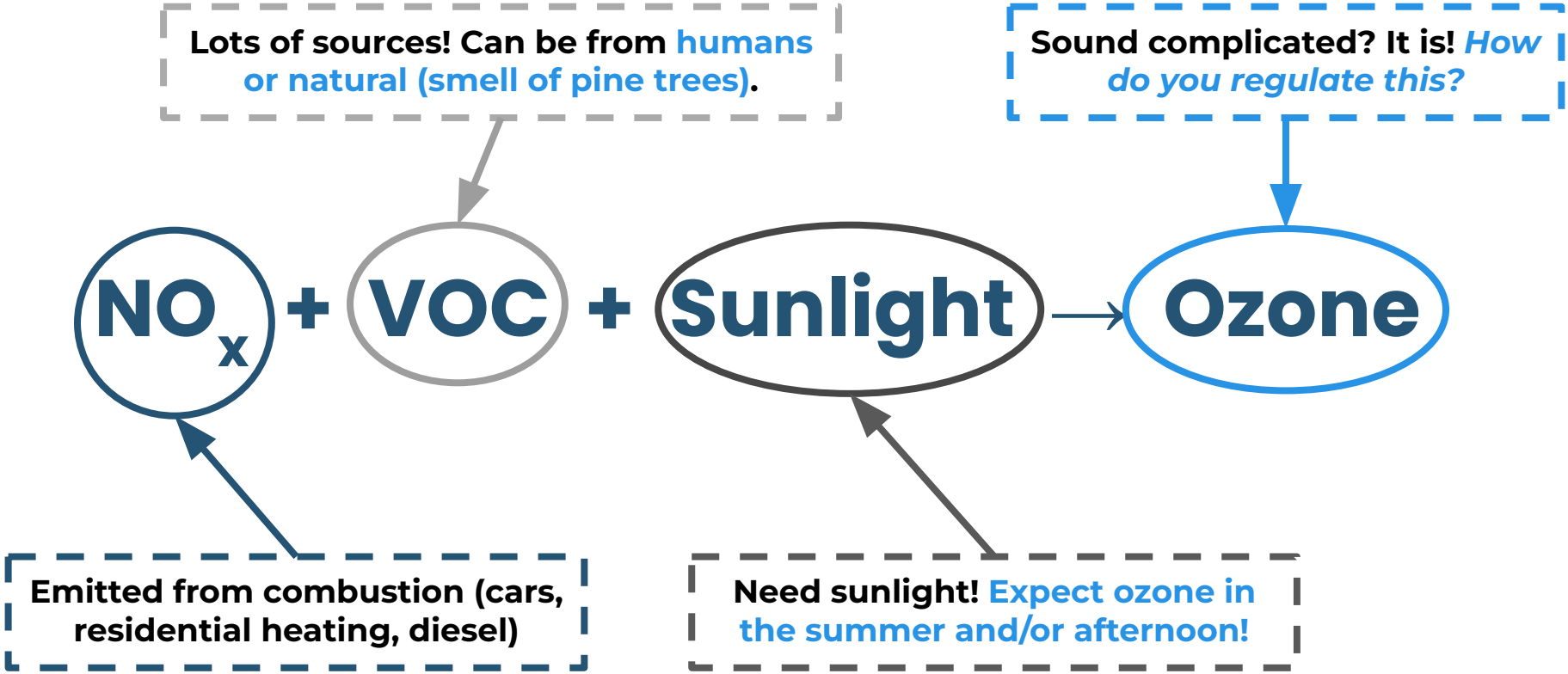
- Ozone is not emitted directly into the atmosphere! It is a "secondary" pollutant.
- Ozone forms in the atmosphere from chemical reactions involving NO_x and VOCs in the presence of sunlight.
- NO_x (NO and NO_2) and Volatile Organic Compounds (VOCs) are referred to as ozone "precursors".
- Ozone chemistry is complicated! *How can we regulate something that isn't directly emitted?*

$$NO_x + VOC + Sun \rightarrow Ozone$$

Ozone is not emitted directly into the atmosphere!

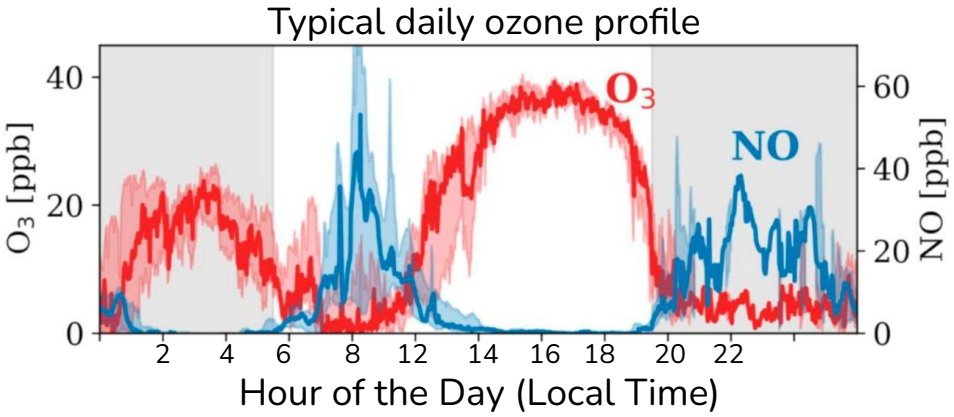
O_3 is a "secondary" pollutant

clarity



Ozone regulations:

- Ozone is one of the six criteria air pollutants the US EPA regulates as part of the Clean Air Act
- US EPA Standard (NAAQS): 70 ppb averaged over an 8 hour period
- The way ozone is formed makes regulation challenging:
  - Highest concentration may be downwind of urban emissions
  - Precursors can be a mix of human and natural emissions
  - Dependent on sunlight and meteorology



Most important things to remember:

1. **Ozone is toxic**. Bad for human health and plants.

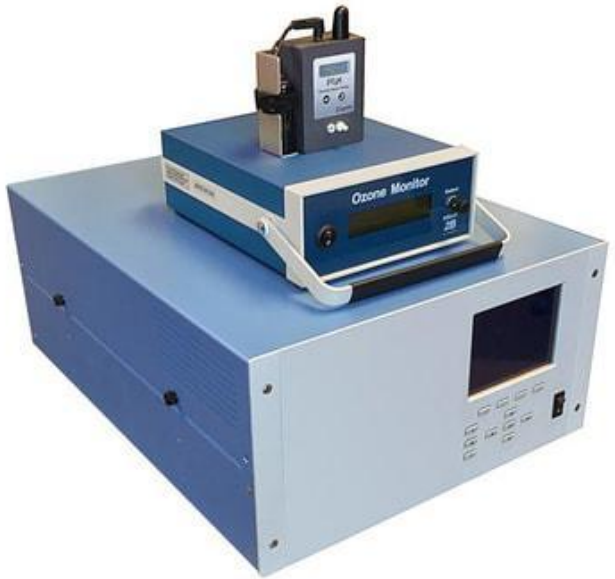
2. **Ozone is not emitted directly**. It needs sunlight and precursor gases to form (photochemical reactions)

Science behind 2B Tech's Ozone Monitors

Hayden Aubermann (Sales & Marketing Manager)

Background on 2B Technologies

- Company founded in 1998
- Made our name miniaturizing conventional ozone analyzers without compromising performance
- All of our ozone monitors are low-power (12V DC) and highly portable compared to the competition
- Ambient ozone monitors manufactured by 2B Technologies are US EPA certified as Federal Equivalent Methods (FEMs)



Measurement Principle: UV-Absorption

- 253.7 UV-light produced using a low pressure mercury lamp
- Based on the Beer Lambert Law, which is industry standard
- Highly accurate method of measuring in many applications, including ambient air
- Absolute measurement method requiring infrequent calibration
- Designed to run continuously with little to no maintenance

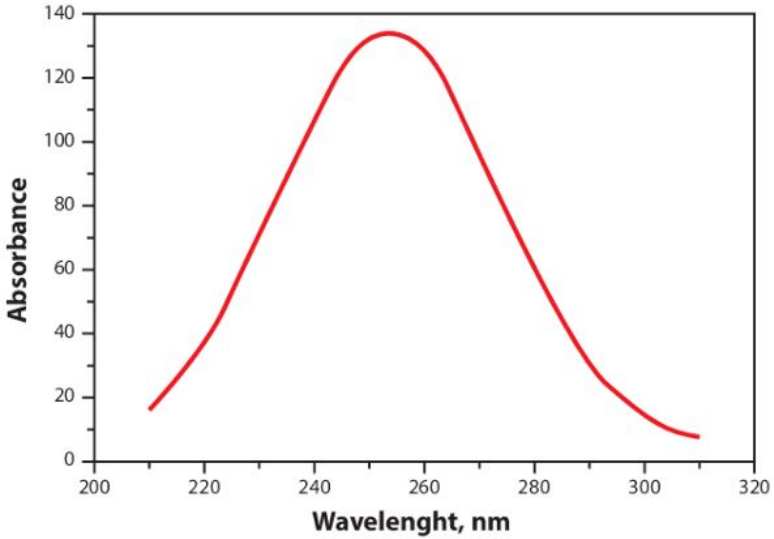
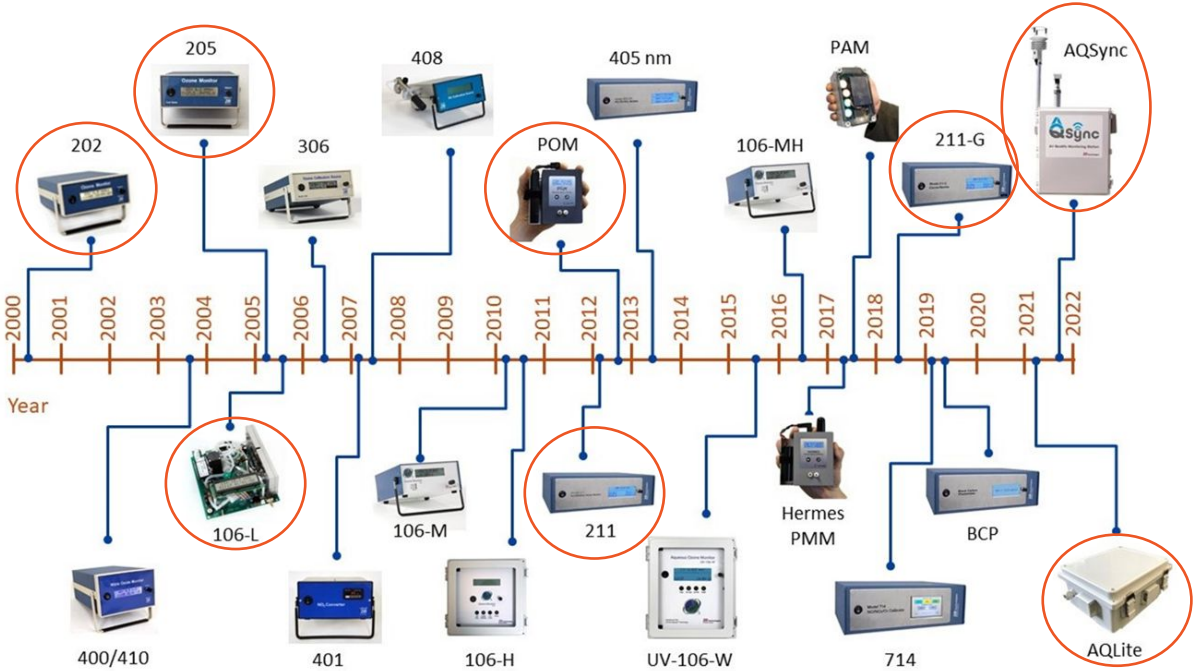


Fig.1: UV-Absorption Spectrum of O_3 with Maximum at 253.7 nm

Evolution of 2B Tech Products
Introduced ~1 New Instrument per Year



Applications Made Possible by 2B Tech Ozone Monitors

2B Tech

The Ozone Module: An Adaptation of 2B Tech's AQLite

Specs for Ozone Module/AQLite

Measurement Principle	UV Absorption (Single Beam)
Measurement Range	0-100 ppm (0-500 ppb for FEM)
Precision	Greater of 1.5 ppb or 2% of reading
Limit of Detection	3.0 ppb (10-second measurements)
FEM Designation Number	EQOA-0914-218
FEM-Approved Temperature Range	0-40 °C

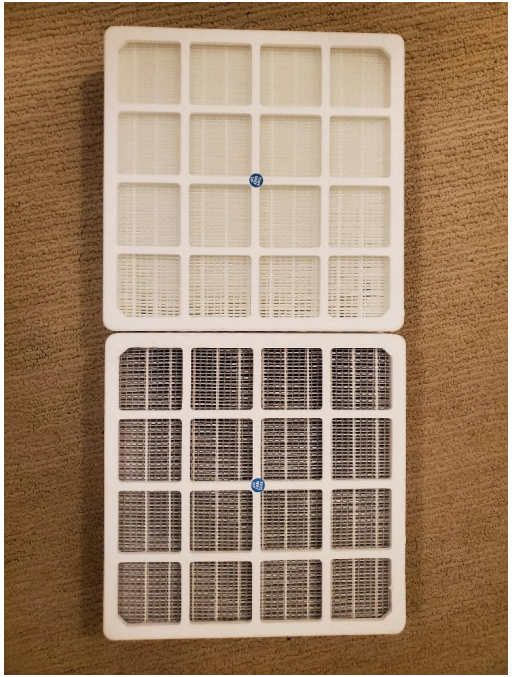
2B Tech

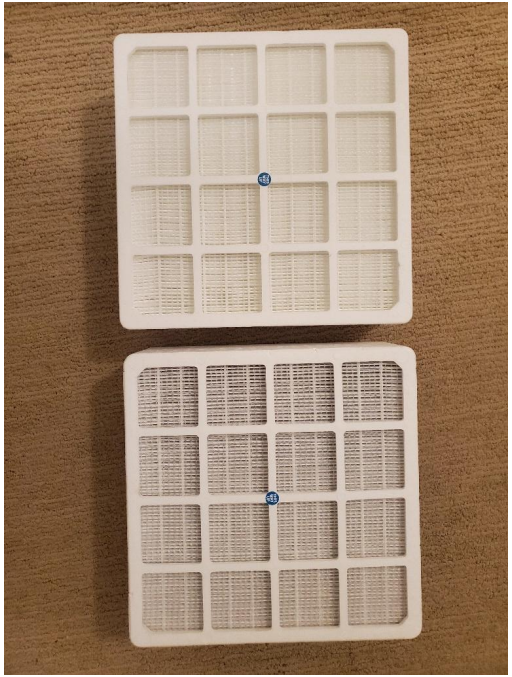
Air Quality Challenges and Solutions in Salt Lake County, Utah

Daniel Mendoza, PhD, *University of Utah*

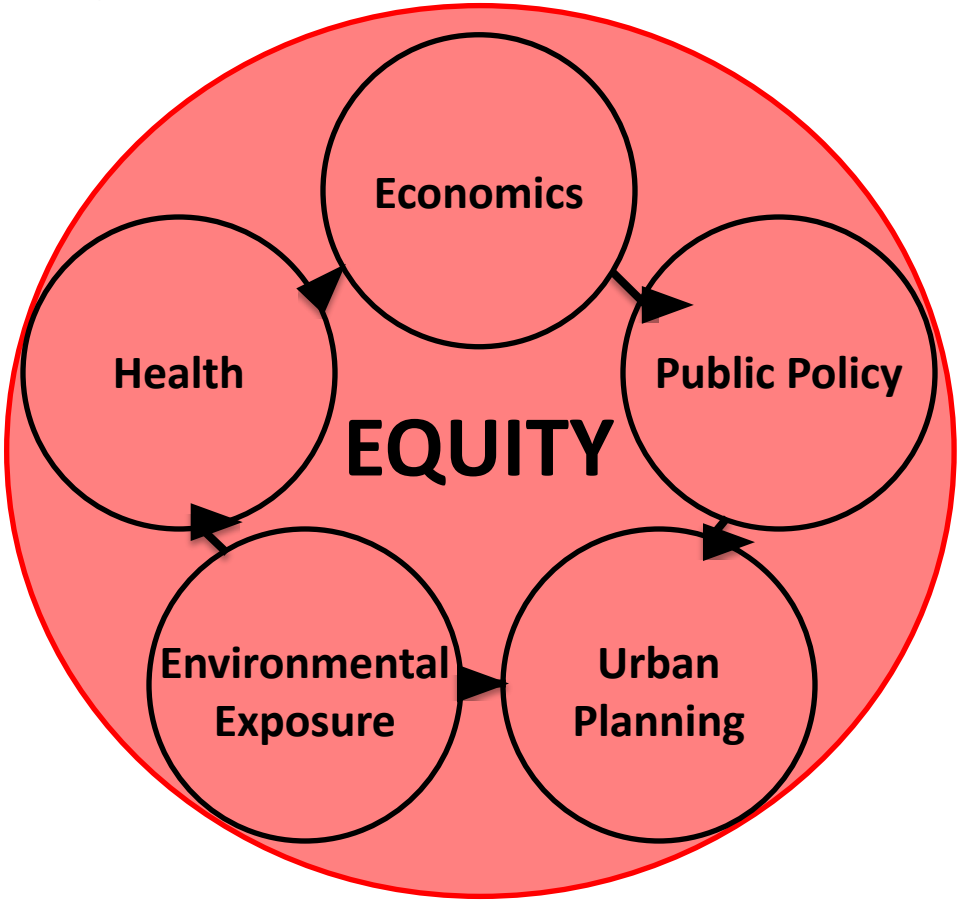
Ozone Measurement Made Easy:
Using the Clarity + 2B Tech Ozone Module to Increase Your Air Quality Impact
October 26th, 2023

Air Filter Change Day (01/18/22)

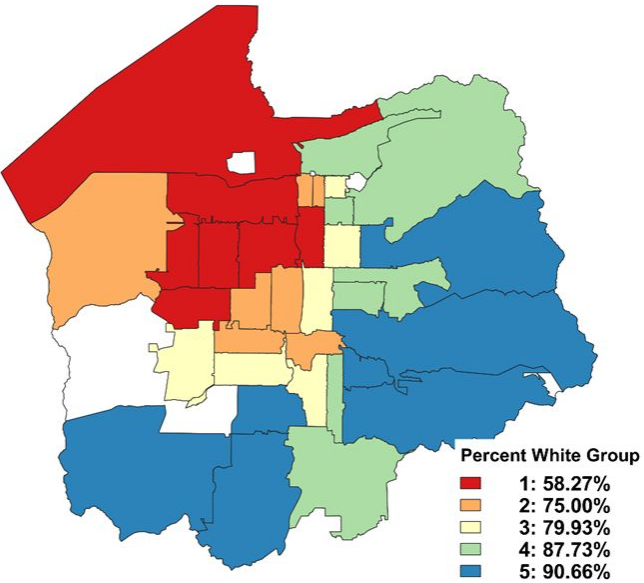


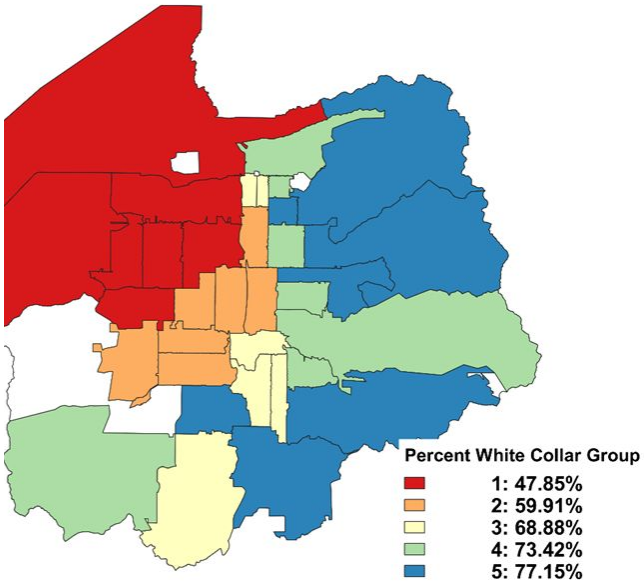


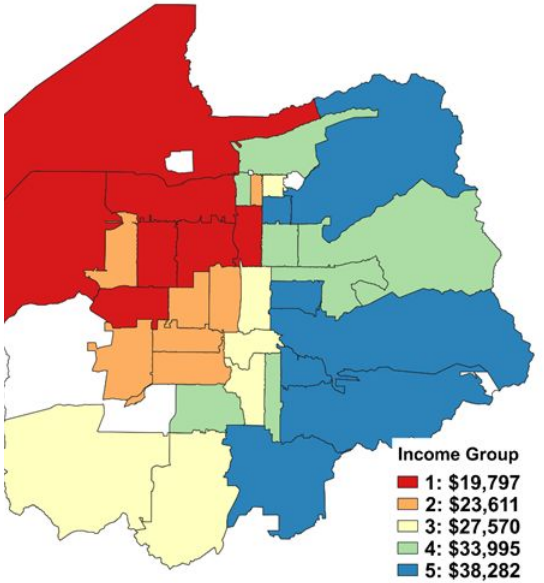
Developing Equitable and Inclusive Environments



Sociodemographic Distribution







A. Percent white population

B. Percent white-collar

C. Income group

The color scale ranges from red (lowest demographic values) to blue (highest demographic values). Excluded zip codes are shown in white.

Mendoza et al., 2020

Observational Studies Project

Open Access Article

The TRAX Light-Rail Train Air Quality Observation Project

by Daniel L. Mendoza [1,2,*], Erik T. Crosman [3], Logan E. Mitchell [1], Alexander A. Jacques [1], Benjamin Fasoli [1], Andrew M. Park [1], John C. Lin [1] and John D. Horel [1]

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(This article belongs to the Special Issue Technologies and Humanities for Smart Cities)

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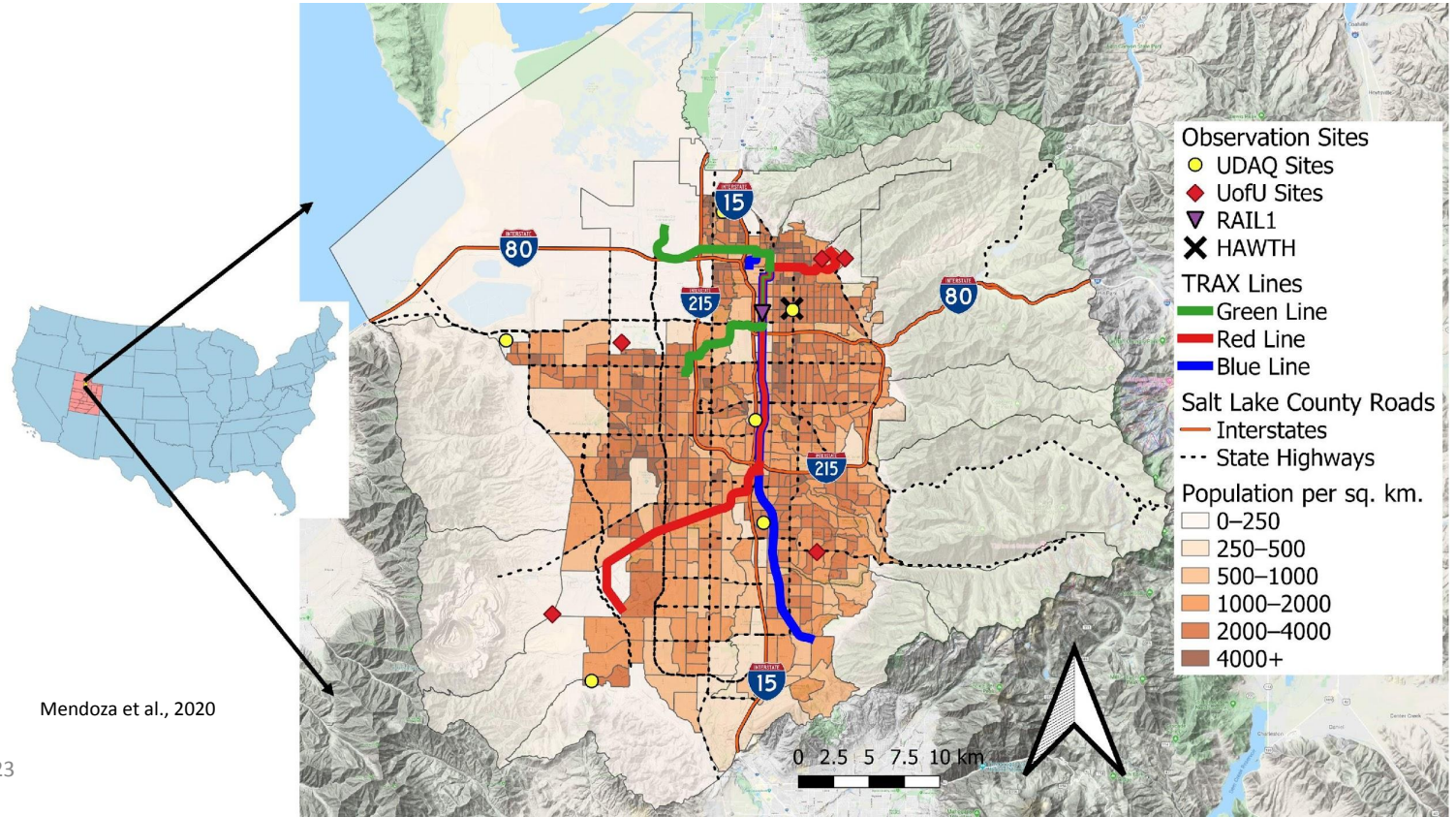
Air Quality Observation Network

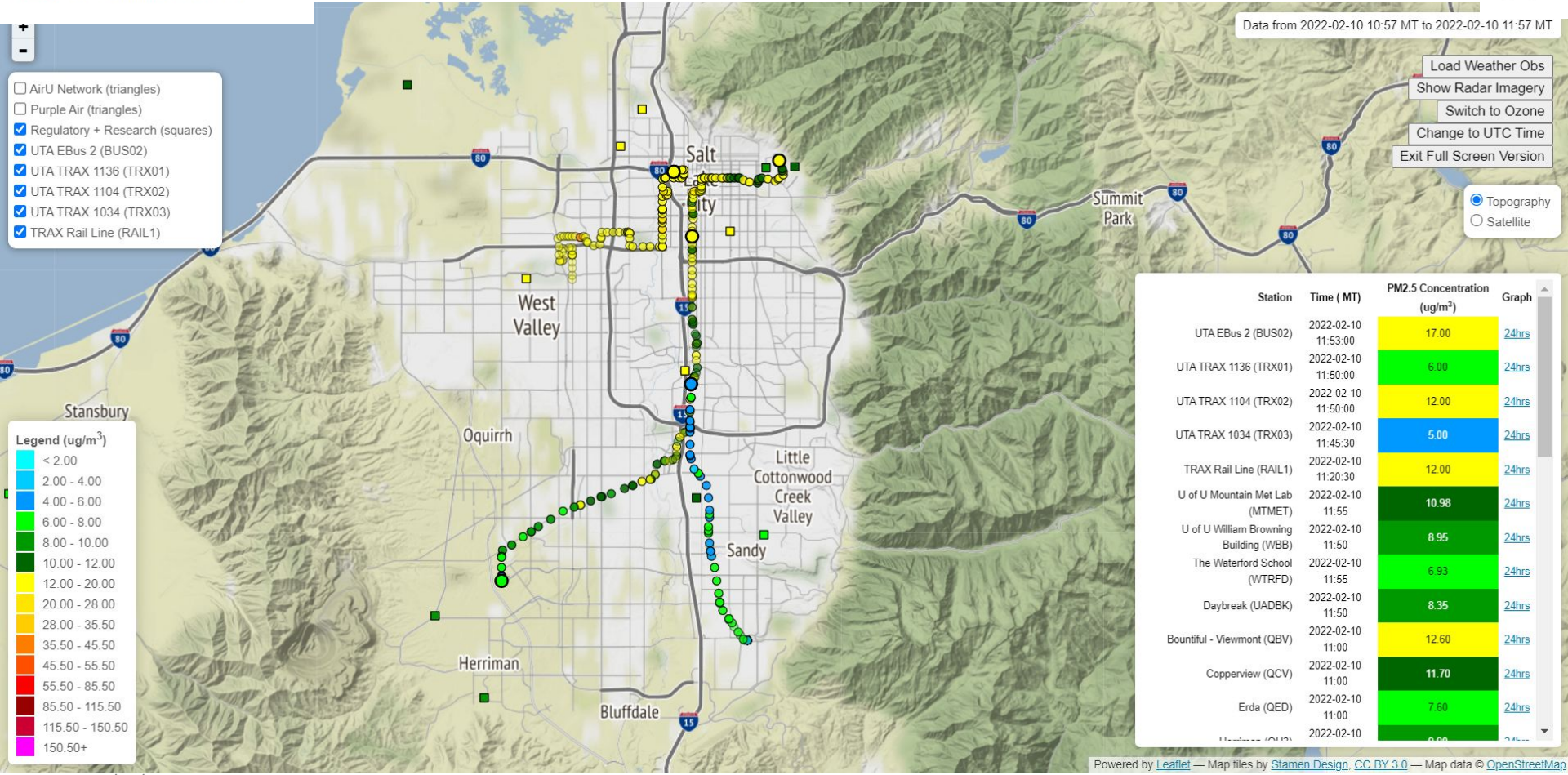


Mendoza et al., 2020

Bus Box

Benefits of Using 2B Tech Equipment

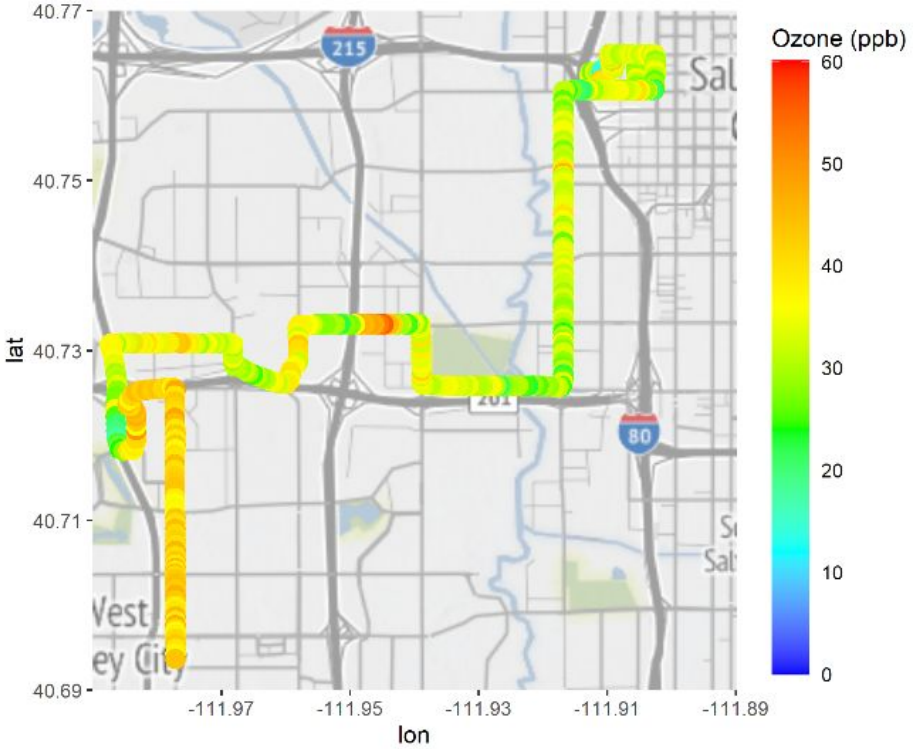
- High precision
- Low energy use
- Fast response
- Durable
- FEM
- Modular
- Easily serviceable



Station	Time (MT)	PM2.5 Concentration (ug/m3)	Graph
UTA EBus 2 (BUS02)	2022-02-10 11:53:00	17.00	24hrs
UTA TRAX 1136 (TRX01)	2022-02-10 11:50:00	6.00	24hrs
UTA TRAX 1104 (TRX02)	2022-02-10 11:50:00	12.00	24hrs
UTA TRAX 1034 (TRX03)	2022-02-10 11:45:30	5.00	24hrs
TRAX Rail Line (RAIL1)	2022-02-10 11:20:30	12.00	24hrs
U of U Mountain Met Lab (MTMET)	2022-02-10 11:55	10.98	24hrs
U of U William Browning Building (WBB)	2022-02-10 11:50	8.95	24hrs
The Waterford School (WTRFD)	2022-02-10 11:55	6.93	24hrs
Daybreak (UADBK)	2022-02-10 11:50	8.35	24hrs
Bountiful - Viewmont (QBV)	2022-02-10 11:00	12.60	24hrs
Copperview (QCV)	2022-02-10 11:00	11.70	24hrs
Erda (QED)	2022-02-10 11:00	7.60	24hrs
	2022-02-10		

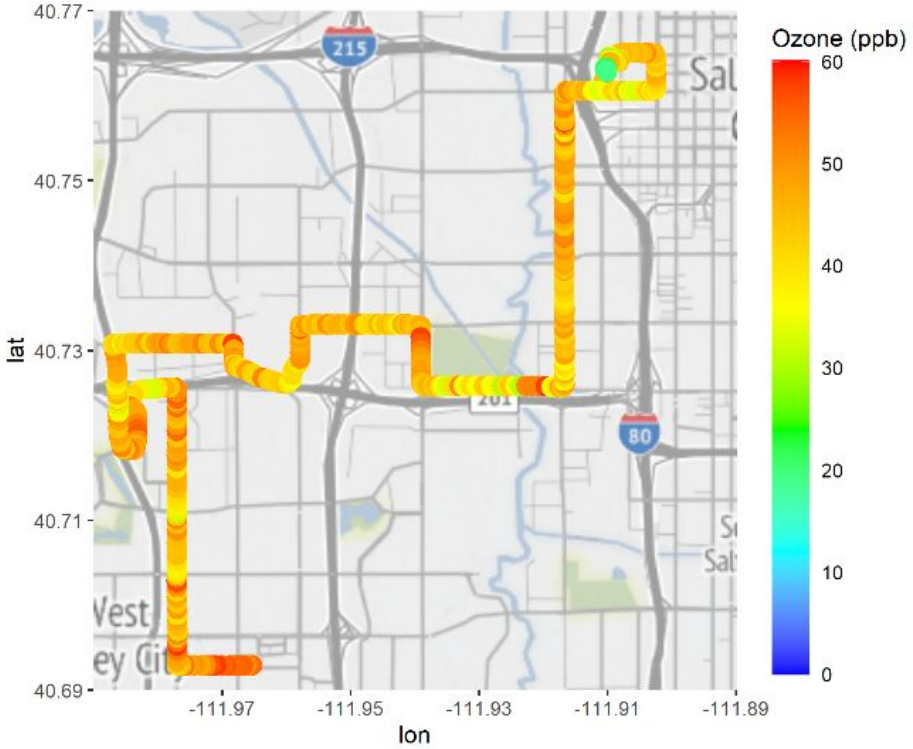
July 17 Heat Dome Event

Ozone readings at 9 AM



July 17 Heat Dome Event

Ozone readings at 1 PM



Air Quality and Educational Outcomes

Environmental Research Letters

ACCEPTED MANUSCRIPT • OPEN ACCESS

Impact of low-level fine particulate matter and ozone exposure on absences in K-12 students and economic consequences

Daniel L Mendoza[1], Cheryl S. Pirozzi[2], Erik T. Crosman[3], Theodore G. Liou[2], Yue Zhang[4], Jessica J. Cleeves[5], Stephen C. Bannister[6], William R L Anderegg[7] and Robert Paine III[1]

Accepted Manuscript online 8 October 2020 • © 2020 The Author(s). Published by IOP Publishing Ltd

Effects of $PM_{2.5}$ on Third Grade Students' Proficiency in Math and English Language Arts

by Casey Mullen [1] ✉, Sara E. Grineski [2,*] ✉, Timothy W. Collins [3] ✉ and Daniel L. Mendoza [4] ✉

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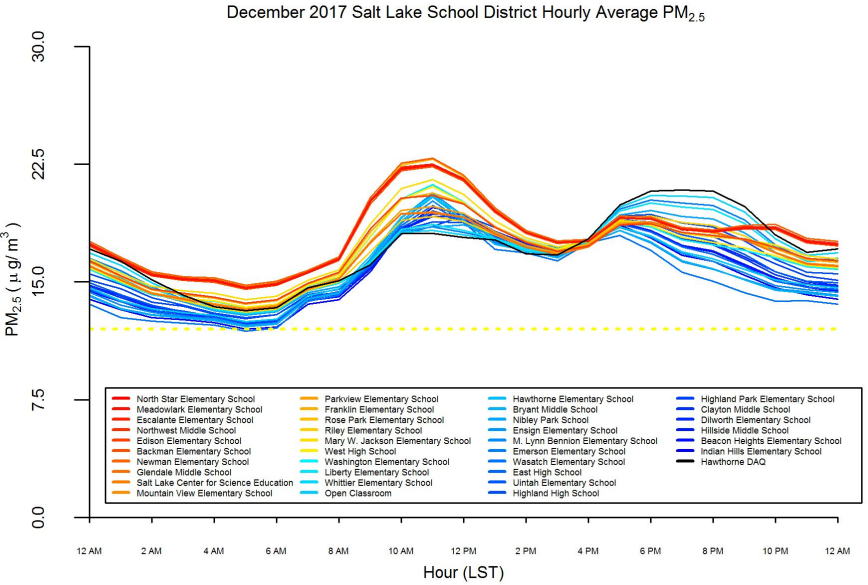
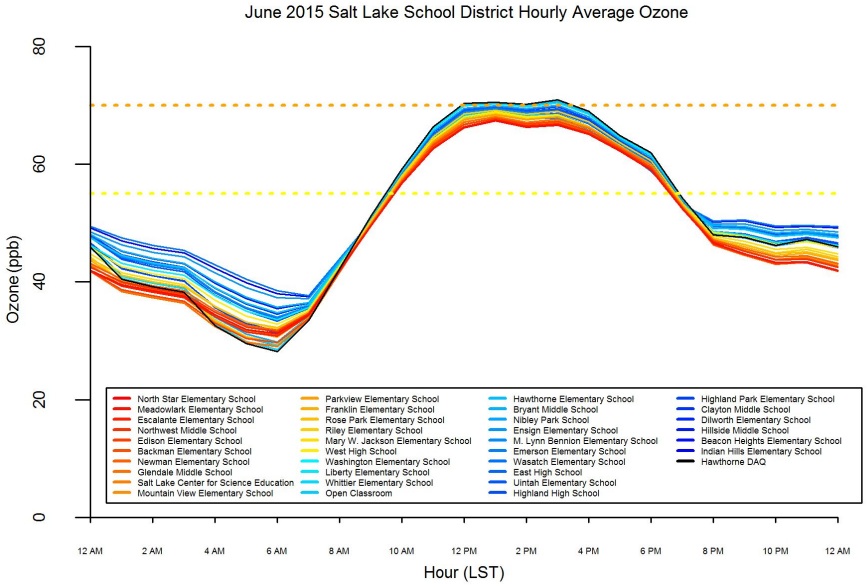
Int. J. Environ. Res. Public Health **2020**, *17*(18), 6931; https://doi.org/10.3390/ijerph17186931

Exposure Variability





Mendoza et al., 2020


West 2017-12-20 08:48:40
1997-2017 MESOWEST

Economic Impact of Air Pollution on Schoolchildren

- Three impacted groups
- Schools: ~$40/day/student
- Families:
  - Average wage: ~ $23/hr
  - 56% of students in SLCSD depend on free & reduced meals ~$5/day
- Economic multiplier: 2.5x
- Estimated impact: $452,000/year

Mendoza et al., 2020

atmosphere

MDPI

Article

Human Health and Economic Costs of Air Pollution in Utah: An Expert Assessment

Isabella M. Errigo [1,*], Benjamin W. Abbott [1,*], Daniel L. Mendoza [2,3], Logan Mitchell [3], Sayedeh Sara Sayedi [1], Jeffrey Glenn [4], Kerry E. Kelly [5], John D. Beard [4], Samuel Bratsman [1], Thom Carter [6], Robert A. Chaney [4], Andrew Follett [7], Andrew Freeman [2], Rebecca J. Frei [8], Mitchell Greenhalgh [1], Heather A. Holmes [5], Peter D. Howe [9], James D. Johnston [4], Leslie Lange [1], Randal Martin [10], Audrey Stacey [1], Trang Tran [11] and Derrek Wilson [12]

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Thank you!

Questions?

daniel.mendoza@utah.edu

Ozone studies using 2B Technologies analyzers

Gordon Pierce
(Outside Sales)

US Forest Service - Colorado

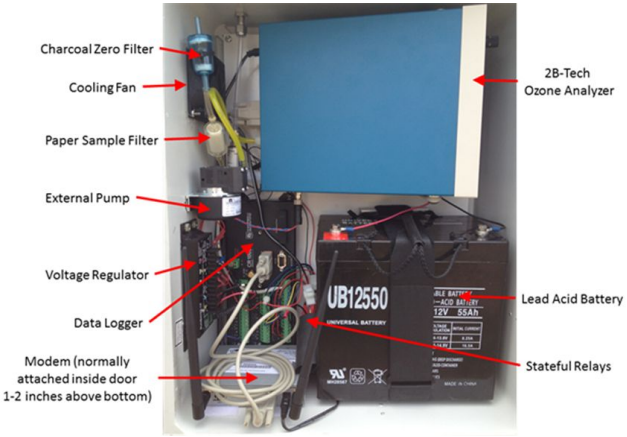
- Pre-AQLite
- Using Model 202 and Model 205 ozone analyzers with data logger and battery
- Equipment housed in a weatherproof box with solar panel
- Deployments commenced in 2006 at 3 sites
- Increased to over 20 sites, mostly in Colorado
- Originally designed to address potential secondary ozone standard and vegetative impacts
- Needed an analyzer that was low powered and solar-capable for remote deployments in National Forests

Pictures from USFS

Colorado Department of Public Health and Environment

COLORADO
Department of Public Health & Environment

- Pre-AQLite
- Using Model 205 dual-beam ozone analyzers with data logger and battery
- Equipment housed in a weatherproof box with solar panel
- Deployments commenced in 2015
- Focus primarily on un-monitored areas in Colorado and better defining areas where ozone is an issue
- Needed solar capability for short study deployments and remote areas



Pictures from CDPHE

2B Tech

Hitachi Rail – United Kingdom

HITACHI
Inspire the Next

- 3 AQLites
- Company goals:
  - Reduction of emissions and mitigation of climate change
  - Managing production processes by reducing emissions of substances able to affect the natural composition of the air and impact biodiversity, local communities and employee health
- Looking at emissions and air quality impacts to passengers and workers onboard trains

2B Tech

Pictures from Hitachi

US Environmental Protection Agency – Region 2

- 4 AQLites for sensor loan program
- These programs bring air sensor technology to the public for supplemental monitoring and educational purposes.
- designed to provide portable air monitoring equipment for use for responding to informational monitoring requests relating to air quality in New Jersey, New York, Puerto Rico, U.S. Virgin Islands, and eight Indian Nations

Pictures from EPA

Colorado State University

- 2 AQLites
- To fill in ambient monitoring gaps in northern Colorado
- Used as part of an EPA supported project to create better within-city air quality maps

Picture from 2B Tech

AQEarth – Fort Collins

- 1 AQLite
- AQEarth is a project that aims to work collaboratively with communities to help meet the air monitoring needs of five very different locations
- Pilot project to test an AQLite in a mobile environment
- Installed on top of school district van
- Similar system already used for 2B Tech PAM in CarTopper

Picture from 2B Tech

AQEarth – TriChapter Region of the Navajo Nation

- 4 AQLites
- AQEarth is a project that aims to work collaboratively with communities to help meet the air monitoring needs of five very different locations
- Counselor, Ojo Encino and Torreon Chapters
- Concerns on oil and gas development emissions in the area
- Used for filling regulatory monitoring gaps
- Very remote area

Picture from 2B Tech

University of Colorado / NOAA

- 1 AQLite
- Focusing on air quality in fire camps
- Assess the exposures for firefighters from particulates and ozone
- Research is ongoing
- Study includes other portable air monitors worn by firefighters

Picture from EPA

US Forest Service / California Air Resources Board

- 15 AQLites (currently in order process)
- Studies have shown that wildfires can increase ozone concentrations
- Paired with E-BAMs for wildfire response
- To look at ozone in fire camps and communities near wildfires
- Assess impacts to firefighters as well as local communities
- Data uploaded via satellite

Picture from CARB

clarity

Empowering the world to reduce air pollution

We are on a **mission** to empower the world to **reduce air pollution** by providing innovative air quality sensing solutions.

Clarity's Solution

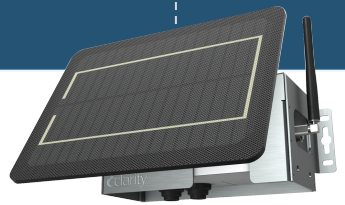
What we do?

We **enable organizations** to monitor air quality at **important sites** and **enhance** the existing regulatory monitoring network from **0-10 to hundreds** of monitoring sites per city.

No compromises on **data quality**.

Sensing-as-a-Service air quality monitoring

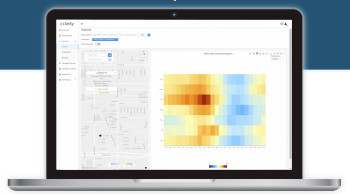
A fully integrated hardware, software, data and service offering



Clarity Nodes + Modules

Measures all key air pollutants

- Solar-powered
- Cellular-connected
- Easily installed within 5 minutes
- Integrates easily with Modules



Clarity Cloud

Cloud-based data analysis

- Natively-integrated IoT dashboard
- Secure data pipeline & storage
- Powerful APIs, analytics and visualization

Clarity Expert Support

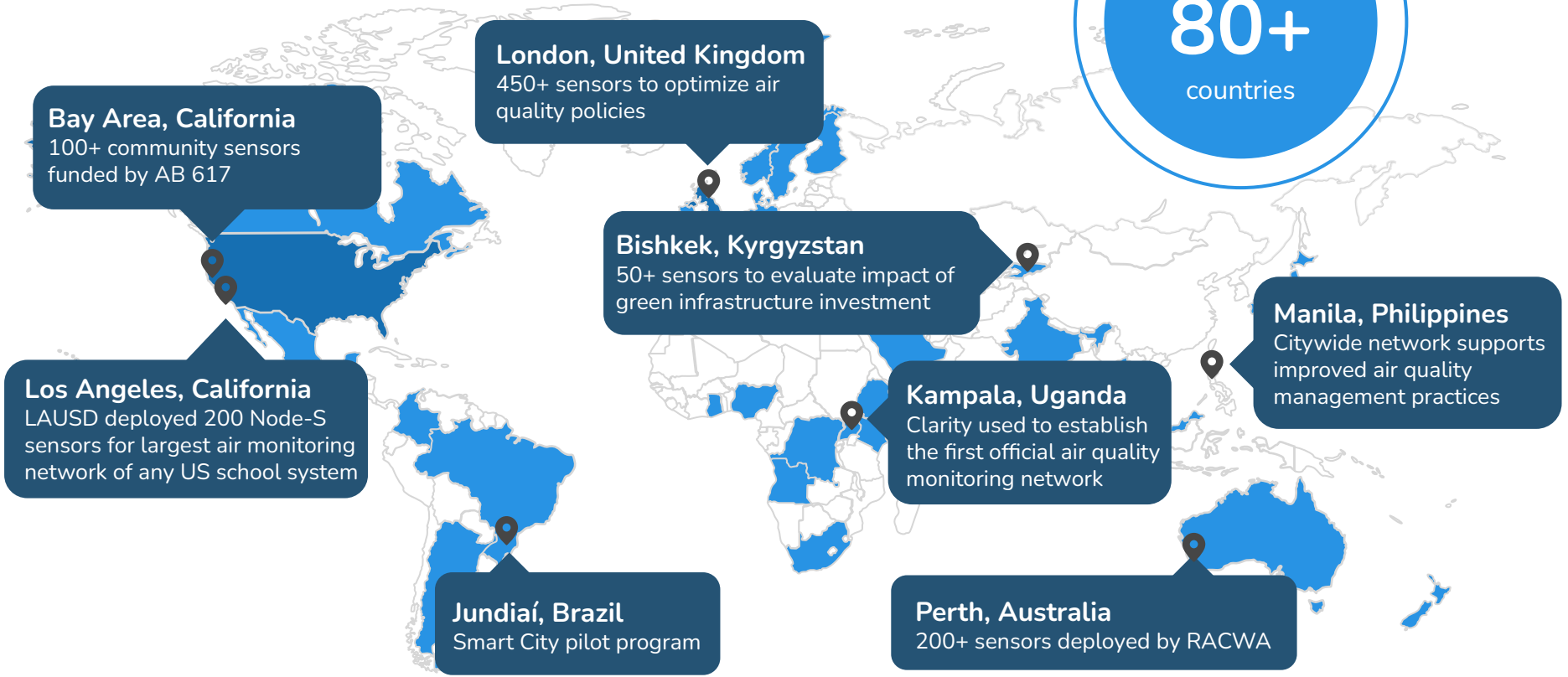
Scalable project support

- Highly qualified air quality experts
- Accurate and Reliable Data through remote-calibration
- Responsive project management enabled by modern software stack

Addressing a wide range of use cases

clarity

Deployed in **80+** countries



London, United Kingdom
450+ sensors to optimize air quality policies

Bay Area, California
100+ community sensors funded by AB 617

Bishkek, Kyrgyzstan
50+ sensors to evaluate impact of green infrastructure investment

Manila, Philippines
Citywide network supports improved air quality management practices

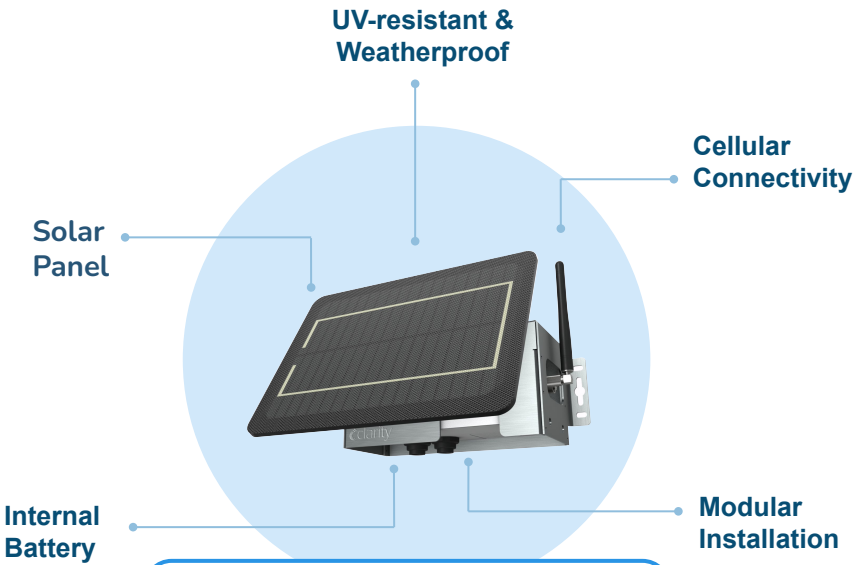
Los Angeles, California
LAUSD deployed 200 Node-S sensors for largest air monitoring network of any US school system

Kampala, Uganda
Clarity used to establish the first official air quality monitoring network

Jundiaí, Brazil
Smart City pilot program

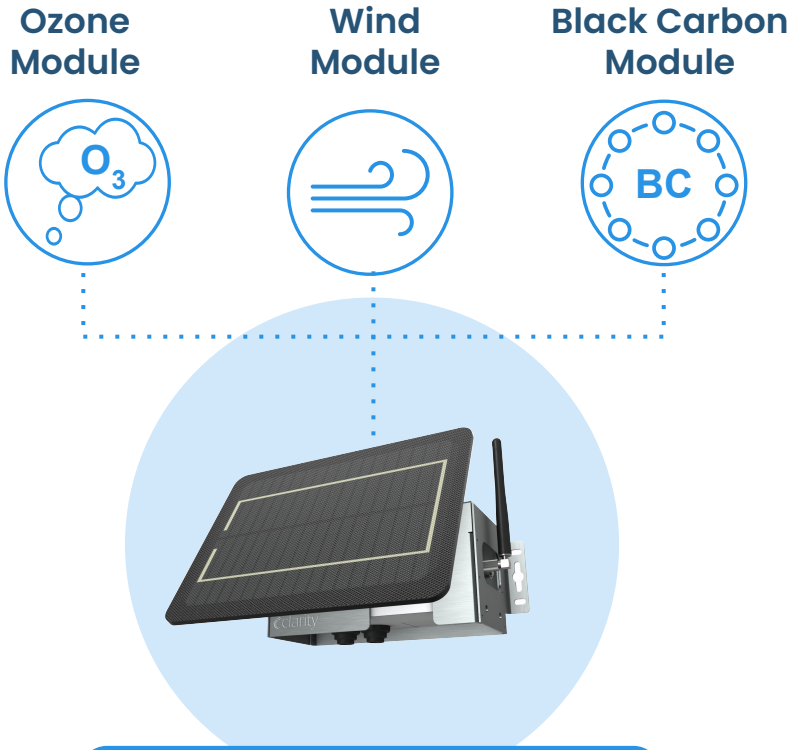
Perth, Australia
200+ sensors deployed by RACWA

From sensor to platform



Sensor

Particulate Matter and Nitrogen Dioxide



Platform

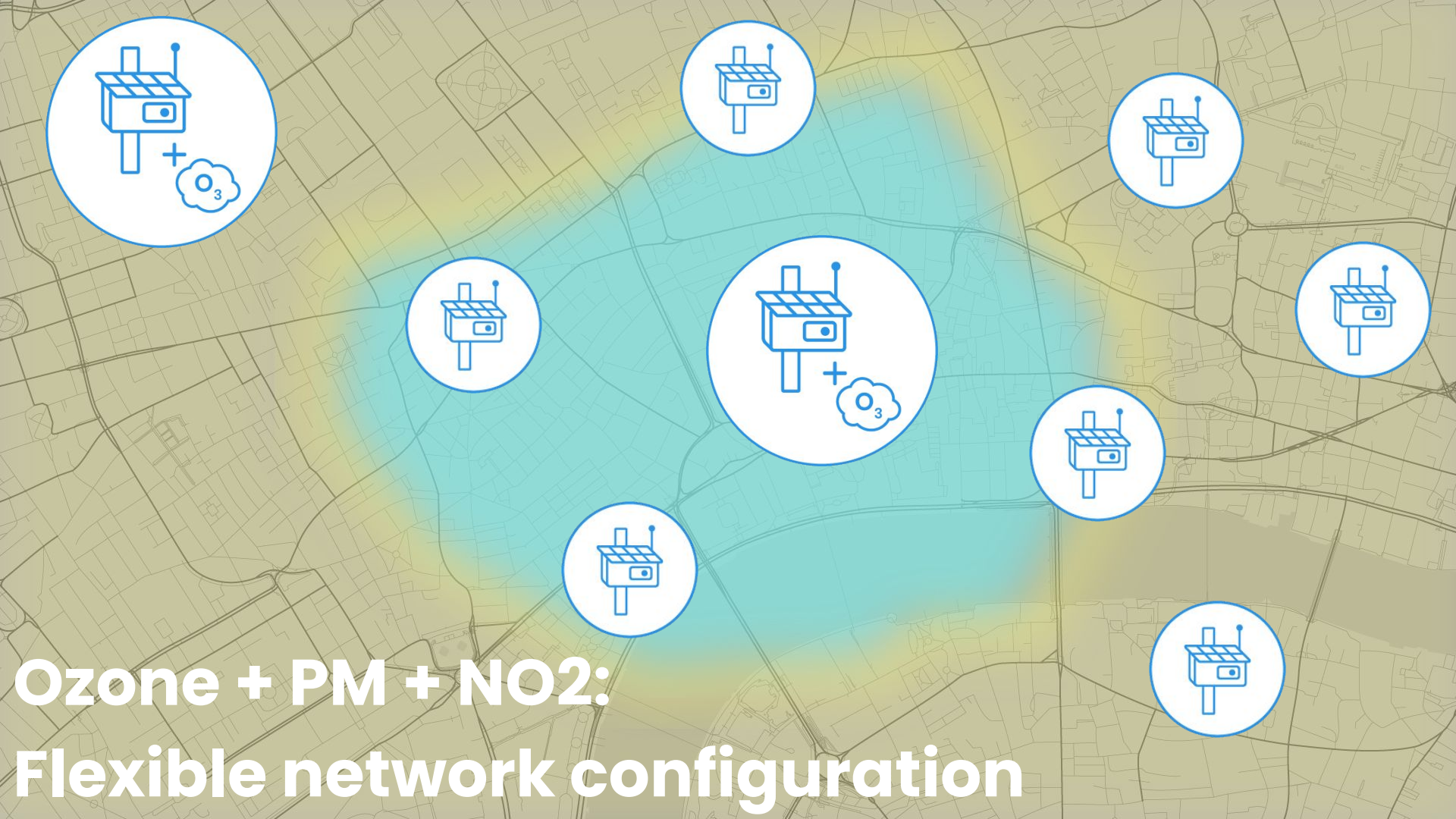
Scalable measurement of more pollutants

The Clarity Ozone Module

FEM-capable solution for ambient O_3 measurement

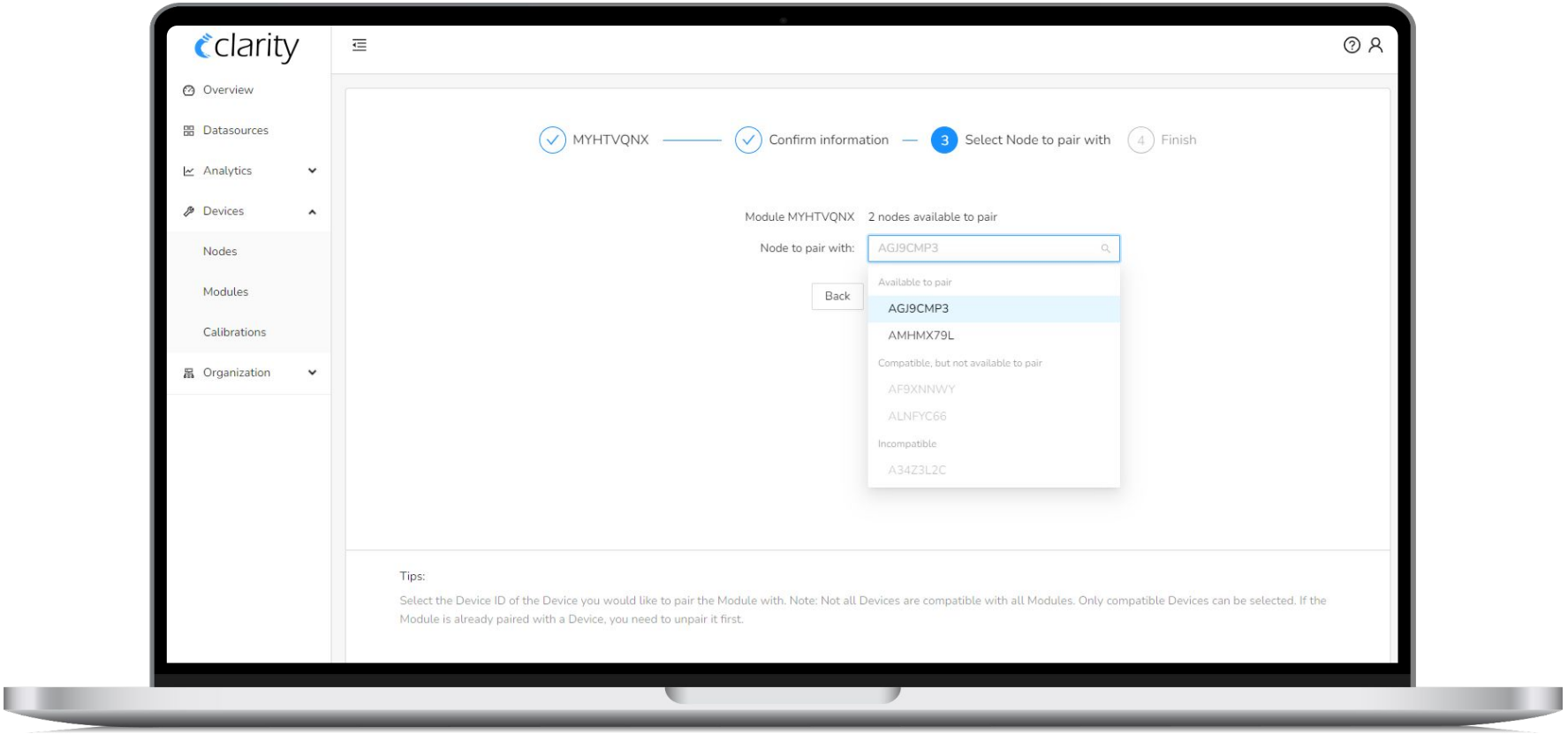
- **High-quality data** via 2B FEM technology complements Clarity's value prop of accurate data at scale
- **Ease of deployment and seamless data flow** to the Clarity Cloud for deployment at scale
- **Easily integrated with other Clarity** air quality measurements (PM, NO2, Wind, Black Carbon, etc.)
- **External solar power required** for Ozone Module (not powered by Node-S)

2B TECH X clarity


Ozone + PM + NO2:
Flexible network configuration

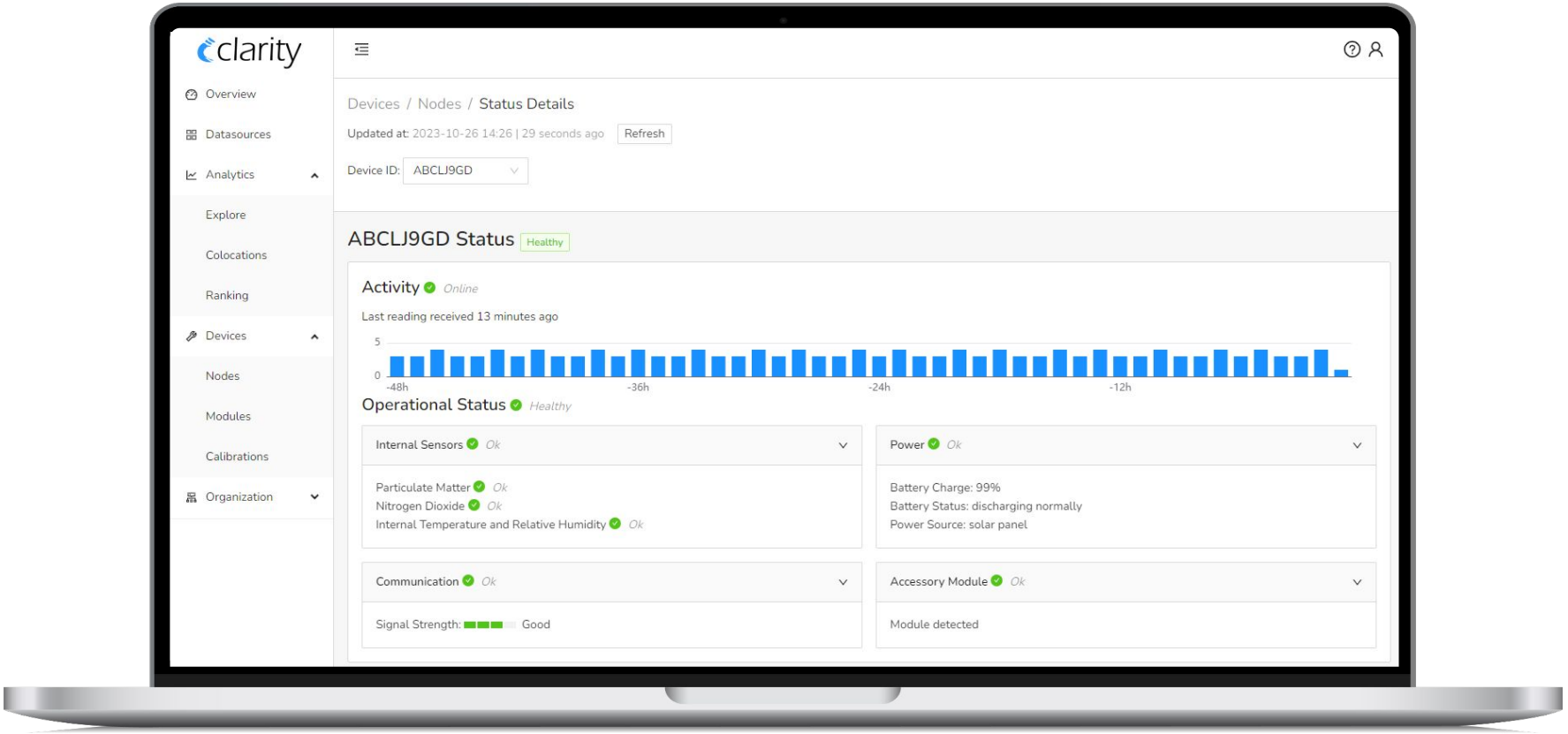
Ozone Module in the Clarity Dashboard

Easily pair the Ozone Module with a Clarity Node



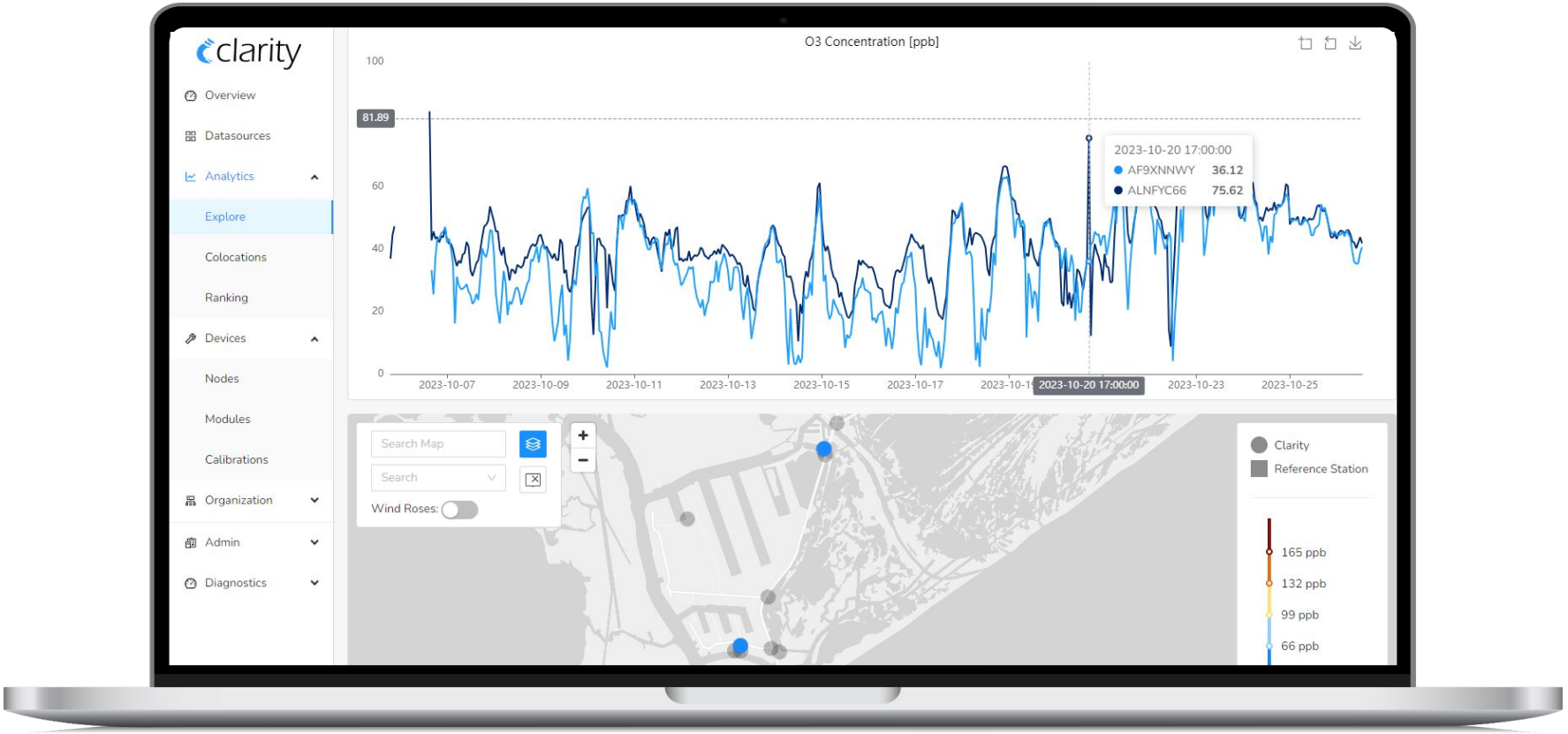
Ozone Module in the Clarity Dashboard

Monitor its operational status



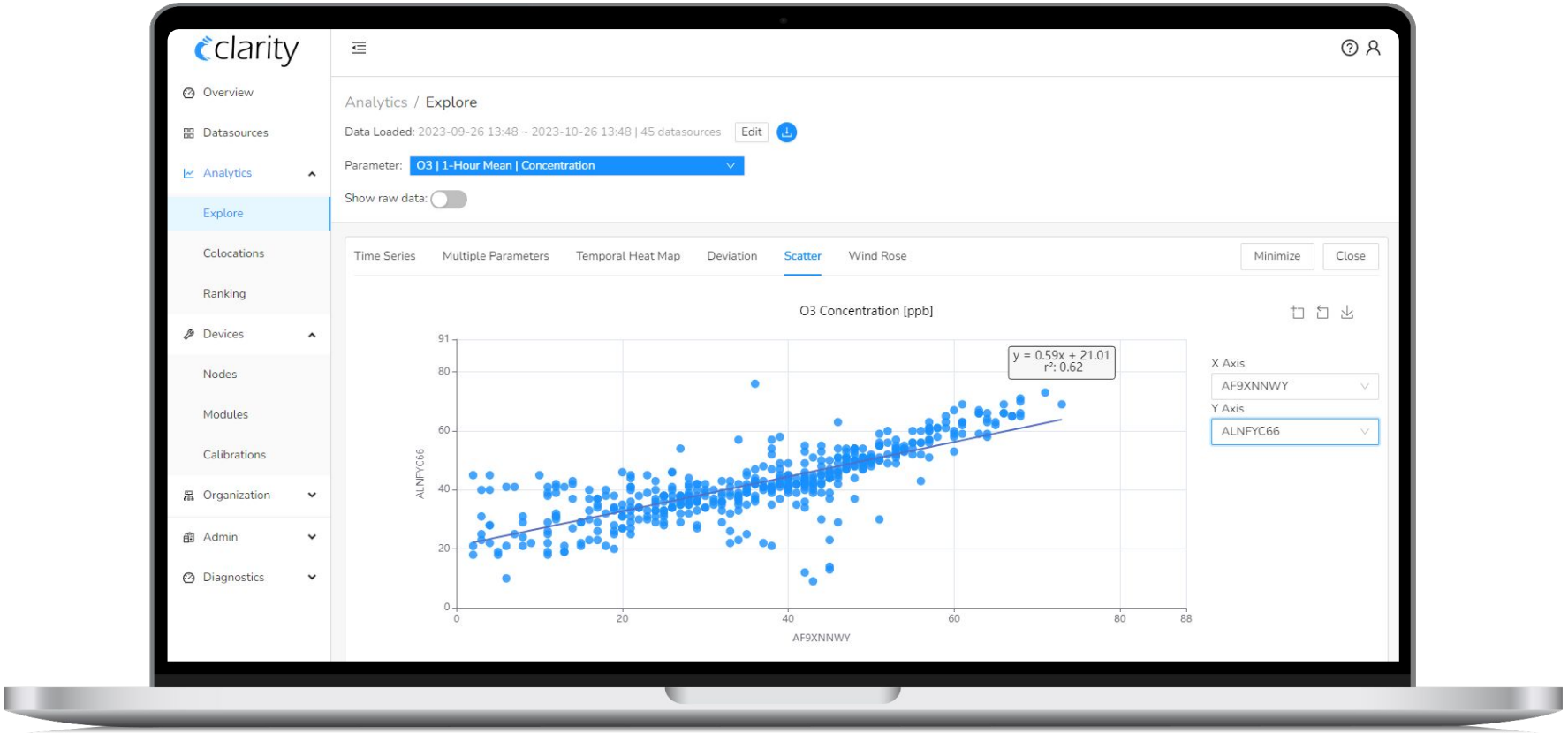
Ozone Module in the Clarity Dashboard

Compare measurements from different locations



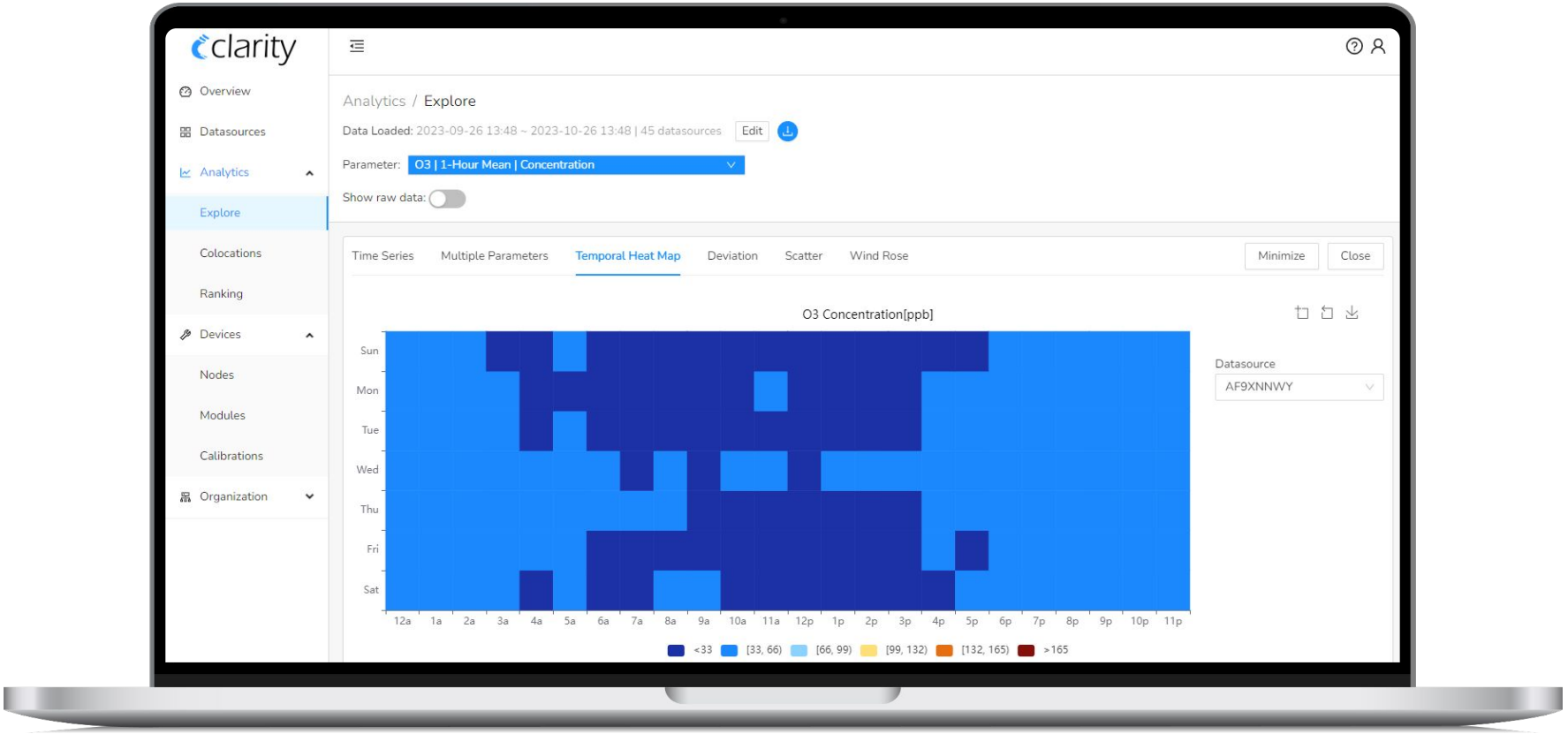
Ozone Module in the Clarity Dashboard

Correlate measurements from different modules



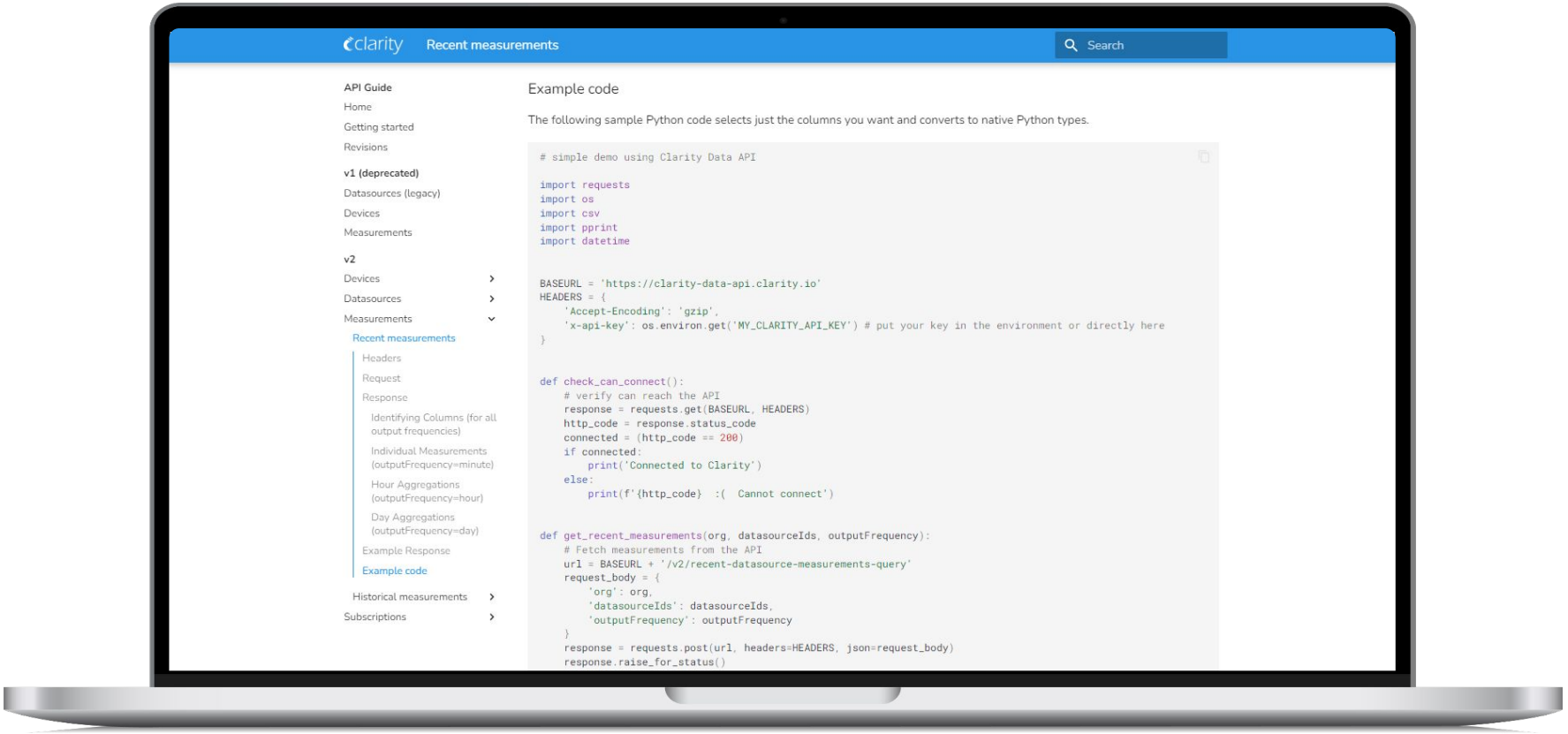
Ozone Module in the Clarity Dashboard

Visualize ozone pollution temporal patterns



Ozone Module in the Clarity Dashboard

Download data or integrate via API



Additional questions?

Contact us or visit the Clarity website

We're here to answer any questions!

hello@clarity.io

Learn more on the Clarity website

clarity.io

Get a quote for your desired configuration

clarity.io/build-your-solution