Air Quality Sensors: US EPA Approach and Data Quality Considerations

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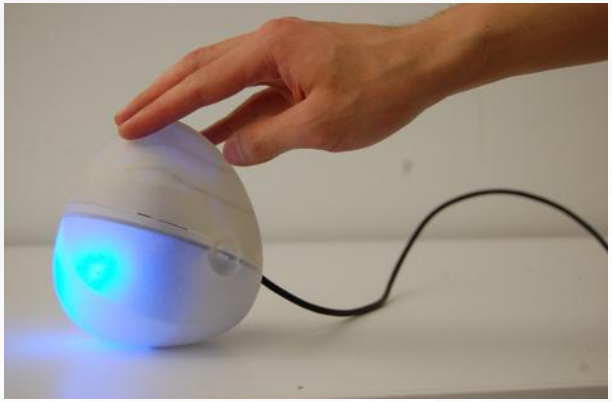
Outline*

- ✓ Why use air sensors?
  - ✓ New England example
- ✓ US EPA approach
- ✓ Sensor selection
- ✓ Sensor siting
- ✓ Interpreting sensor data
- ✓ Tools for data management
- ✓ Case study: Fire and Smoke Map

**Mention of trade names or commercial products in this talk does not constitute endorsement or recommendation for use.*

Why use simpler monitoring devices?



"Choose the air contaminants you want to measure. We customize your Egg with the necessary sensors to track any changes and automatically upload your data to the cloud."
– Air Quality Egg Website

"Our industry leading sensors are priced at a fraction of what you'd pay for a commercial sensor, are easy to install and connect seamlessly to your WIFI network."
– Purple Air Website

Why use sensors?

- To obtain personalized health information → Inform individuals, especially susceptible people, about their personal exposures to air pollutants
- To empower communities to gather information about exposures
- To raise awareness and educate communities about air pollution, and to inspire behavioral changes
- To supplement national, state, and local monitoring networks (e.g., western US wildfires)
- To identify pollution sources by monitoring near the suspected source(s)
- To detect air-pollution hotspots and predict pollution levels in a selected area (e.g., wood smoke in valleys)
- To locate leaks at industrial facilities
- To assist with daily forecasting / airshed management
- To site regulatory monitors
- As a research tool and for science education

Why use sensors?
New England example

- Continuous monitors have shown that there are elevated concentrations in parts of New England, especially $PM_{2.5}$ in valleys in winter.
- NH, VT, and ME conducted studies in valleys to investigate these elevated levels. This created a desire to put a system in place to monitor $PM_{2.5}$ more closely, focusing on woodsmoke in winter.
- Residential wood burning produces $PM_{2.5}$, carbon monoxide (CO), and generates hazardous air pollutants (HAPS) such as benzene and formaldehyde.
- EPA estimates that, nationwide, wood stoves, hydronic heaters, and fireplaces emit > 345,000 tons of $PM_{2.5}$ annually.

Strategies for Reducing Residential Wood Smoke

US EPA position: use of sensor data for NAAQS compliance

- For use in policy-making and regulatory decisions, sensors must meet sampling, siting, and QA requirements of CFR Parts of Title 40 (40 CFR Parts 50, 53, and 58)
  - Part 50 — National Primary And Secondary Ambient Air Quality Standards - https://ecfr.io/Title-40/Part-50
  - Part 53 - Ambient Air Monitoring Reference And Equivalent Methods - https://ecfr.io/Title-40/Part-53
  - Part 58 - Ambient Air Quality Surveillance - https://ecfr.io/Title-40/Part-58
- Sensor data that don't meet these requirements could still be useful in non-regulatory applications such as providing a better understanding of local air quality, helping in the siting of regulatory monitors, or identifying hot spots.

Memo on EPA's position on the use of air sensor data

US EPA position: use of sensor data (cont.)

- Key areas of focus for air sensors: Data quality, data interpretation, and data management
- Uncertainties related to these focus areas include:
  - Accuracy of measurements under various meteorological conditions
  - Appropriateness of data-algorithm assumptions
  - How well real-time measurements meet basic data quality indicators of performance" (e.g., precision, accuracy)
  - How well a device performs over time
  - How to interpret short-term values
  - Data privacy
  - Data ownership

US EPA position: use of sensor data (cont.)

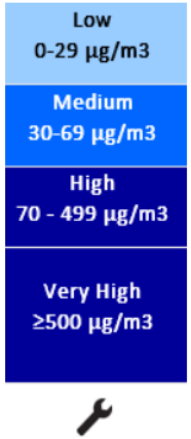
- To characterize air-sensor measurements, EPA is supporting research on sensor performance including:
  - Development of non-regulatory performance targets and testing protocols for monitoring applications that complement – but do not replace – existing regulatory programs.
  - Interpretation of real-time, non-regulatory sensor data

Sensor data: messaging

- EPA recognizes need for context and guidance related to interpretation and communication of real-time sensor data
- For example, sensor data may show episodic spikes in pollutant concentrations, but health science doesn't tell us what short-term (e.g., one minute) exposures mean for an individual

Pilot Version 1-minute particle pollution (PM2.5) readings (Not for regulatory purposes)

Pilot Scales	Message
Low 0-29 µg/m3	Enjoy your outdoor activities.
Medium 30-69 µg/m3	If medium readings continue (for an hour or more), use the Air Quality Index to plan outdoor activites.
High 70-499 µg/m3	You may be near a source of particle pollution like dust, smoke or exhaust. Check the air Quality Index to plan outdoor activities.
Very High >=500 µg/m3	You may be near a source of particle pollution like dust, smoke or exhaust. Check the Air Quality Index to find out if you should adjust outdoor activities. Very high readings may mean the sensor is not working properly.
🔧	Sensor may be offline. Check the Air Quality Index.



What do my sensor readings mean?

US EPA position: use of air-sensor data

- EPA is likely to be asked to use or respond to nonregulatory data and will continue to participate in discussions on issues identified above as well as others related to data ownership, standardized data formats, information security, privacy, and proprietary algorithms.

Particulate matter (PM) sensors

Sensor model	Detection approach	Operating details	Test Results... Test Environment
Alphasense OPC N2	Optical particle counting (0.38 to 17 microns). The cumulative particle counts across various size designations are converted to estimates of PM2.5 and PM10 particle mass concentrations.	Unit was integrated into a prototype United Nations multi-pollutant sensor pod. Designed as a stationary monitor; it recorded data as 1 minute averages in units of µg/m^3.	One month (November 2016) of continuous testing at an EPA testing platform in Research Triangle Park, NC
Shinyei	Volume scattering – particles (possibly including particles larger than 2.5 µm) entering the sensor scatter light from an internal light source. The scattered light signal	Designed as a stationary miniaturized monitor; can record data as fast as 1 second; data units in	Minimum 30 day testing period of duplicate or triplicate monitors at a state regulatory monitoring site in

[EPA Air Sensor Toolbox]

[Memo on EPA's position on the use of air sensor data]

Key points for using sensors

- Not a replacement for regulatory-grade monitors - <u>there are no US regulations that accept sensor data as official data</u>
- Must be selected to fit a purpose
- Requires human, institutional, and equipment systems
- Quality assurance (QA) is critical
- Partnerships and engagement with government, academia, and the public are important

Sensor considerations

- Most air quality sensors retail for $100 to $2500 (compared to ~ $20,000+ for a regulatory station)
- There may be only minimal technical support available
- Gas-phase sensors have limited life span (~ 6 months to 2 years)
- Particulate Matter (PM) sensors have longer lifespans (~1-3 years)
- Unforeseen costs (WiFi, cellular SIMs, vendor server costs) can exceed $200/year

Sensor considerations

- Low/ high temperatures (e.g.,104^{0}F / 40^{0}C) and high humidity (90%), may cause inaccurate readings
- Air sensors require field calibration
- Some air sensors need a physical enclosure
- Many air sensors do not display data in real-time. User may need to download data or view it on computer with specific software or an app.
- Many sensor manufacturers and sensor models do not have adequate specifications for operation & maintenance.
- Amount of data can be overwhelming – e.g., monitor operating 24 hours/day at 1-sec resolution for 1 week produces >600,000 data points!
- Research involving collocation of sensors with regulatory-grade monitors near sources is needed, especially for localized pollutant concerns

Sensor Selection:
What questions do we want to answer?

- Does this industrial facility pose a threat to public health?
- Where should I locate sensors to augment data from official monitors?
- Can we use sensors to determine spatial and temporal air-quality patterns to help support a particular air-pollution control policy?
- Do we need air-quality measurements every second? every minute? every 15 minutes? every hour?
- How long do we need to operate the sensors?
- Will we be able to use the raw data, or will we need to process the measurements?

Sensor selection – information needs

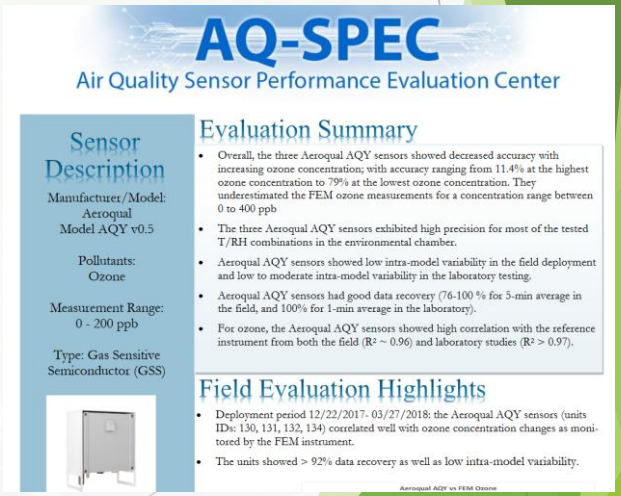
- What are the sources and pollutant(s) of interest?
- Are pollutant(s) primary or secondary (i.e., emitted directly or formed in the atmosphere)?
- Are existing measurements available? How might they be augmented?
- What field conditions are you likely to encounter?
- How might weather conditions influence pollution levels and data collection?
- What is the optimal frequency and duration of data collection?
- What are the intended uses of the data – spatial characterization? Air-quality trends? Exposure assessment? Source apportionment? Determine DQOs

Sensor Selection
Example: PurpleAir

- PurpleAir sensors use laser particle counters to measure smoke, dust, and other particulates
- All six New England states have used PurpleAir to supplement their air-monitoring networks
- ME, RI, NH are currently using EPA owned/loaned PurpleAir sensors
- The data is used for:
  - Valley study to potentially site FEM/FRM to monitor woodsmoke
  - Environmental Justice (EJ) study for potentially siting a FEM/FRM
  - To better understand PM levels at various elevations in same area
  - To investigate complaints of air pollution and elevated $PM_{2.5}$

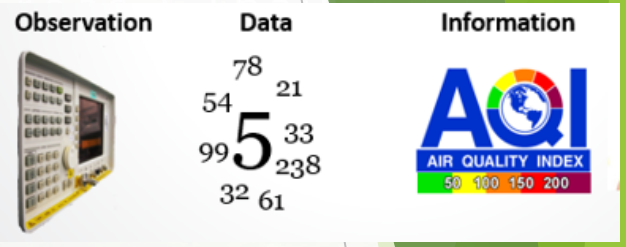
Sensor selection

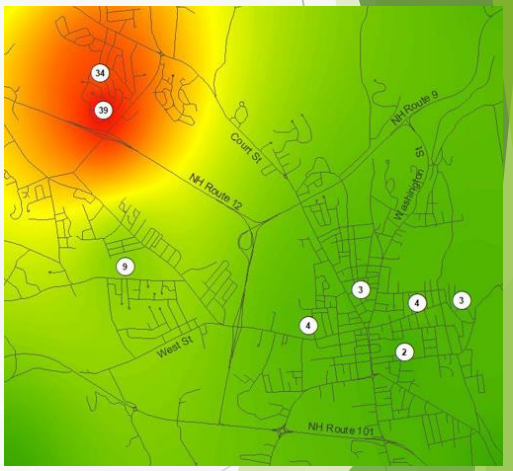
- US EPA Office of Research and Development (ORD) https://www.epa.gov/air-sensor-toolbox
- South Coast (California) AQMD - Air Quality Sensor Performance Evaluation Center (AQ-SPEC) - http://www.aqmd.gov/aq-spec
- Review of air sensors by other organizations (e.g., Europe' Joint Research Center https://www.epa.gov/air-sensor-toolbox/air-sensor-evaluations-conducted-other-organizations



Interpreting sensor data

- Data averaging
  - Data can be averaged to compare measurements to another instrument or a health-based benchmark such as the AQI or NAAQS
  - Data averaging can improve quality, usefulness, and manageability of data
- Averaging times vary depending on application
  - For trends of pollutant concentrations: 1-hour or 24-hour averages
  - To identify a pollution hotspot: shorter averaging periods (a few minutes) allows detection of high concentrations as sensor is moved around area of interest





Tools for data management

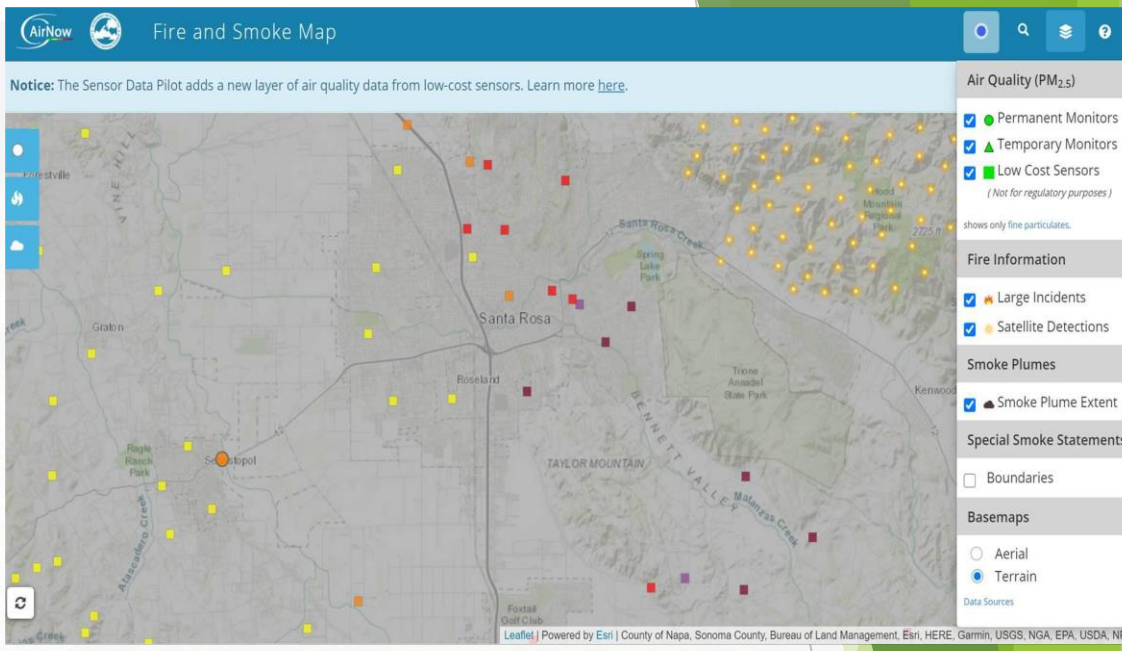
- Manufacturer
  - Usually a monthly fee; internet access
  - Varies in user-friendliness and customization options
- Tools/data platforms under development
  - Example: California Air Resources Board (CARB) data platforms for sensors

https://ww2.arb.ca.gov/capp-resource-center/community-air-monitoring/outline-of-measurement-technologies - scroll down to “Sensors and Sensor Networks”

Tools for data management

- US EPA's Real Time Geospatial Data Viewer (RETIGO)
  - Free, internet access
  - Includes tutorial
  - Can handle large datasets
- Spreadsheets – e.g., Excel
  - Commonly used
  - Cannot handle very large datasets
- Tableau Data Management (Tableau Data Management)
  - Monthly user fee
  - Handles very large datasets
- Quick-R R-shiny apps
  - Steep learning curve
  - Handles very large datasets

Case Study: using air sensors to monitor US Wildfires



- In 2020, EPA partnered with state, tribal and local air-monitoring groups and US Forest Service to add PurpleAir sensor data to the AirNow Fire and Smoke Map.

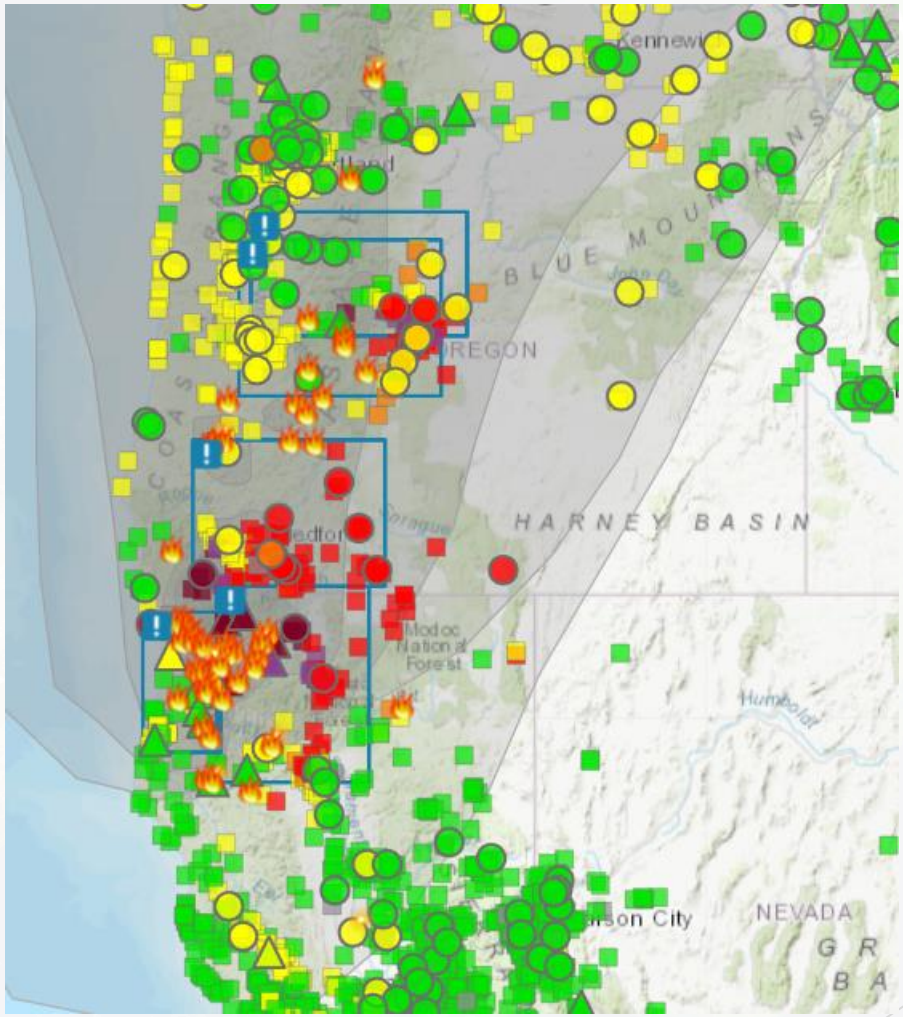
  https://fire.airnow.gov/

- Only Purple Air that are registered as "public outdoor sensors" show up on the map
- A correction equation for bias in PurpleAir data was developed so these data can be compared to monitors already on map.
- The correction allowed 1000s of new AQ observations to be added to map and visualized at the same scale.

  https://amt.copernicus.org/articles/14/4617/2021/

  $PM2.5 = 0.524 \times PAcf_1 - 0.0862 \times RH + 5.75$

Example of Fire and Smoke Map



Fire and Smoke Map

Questions?

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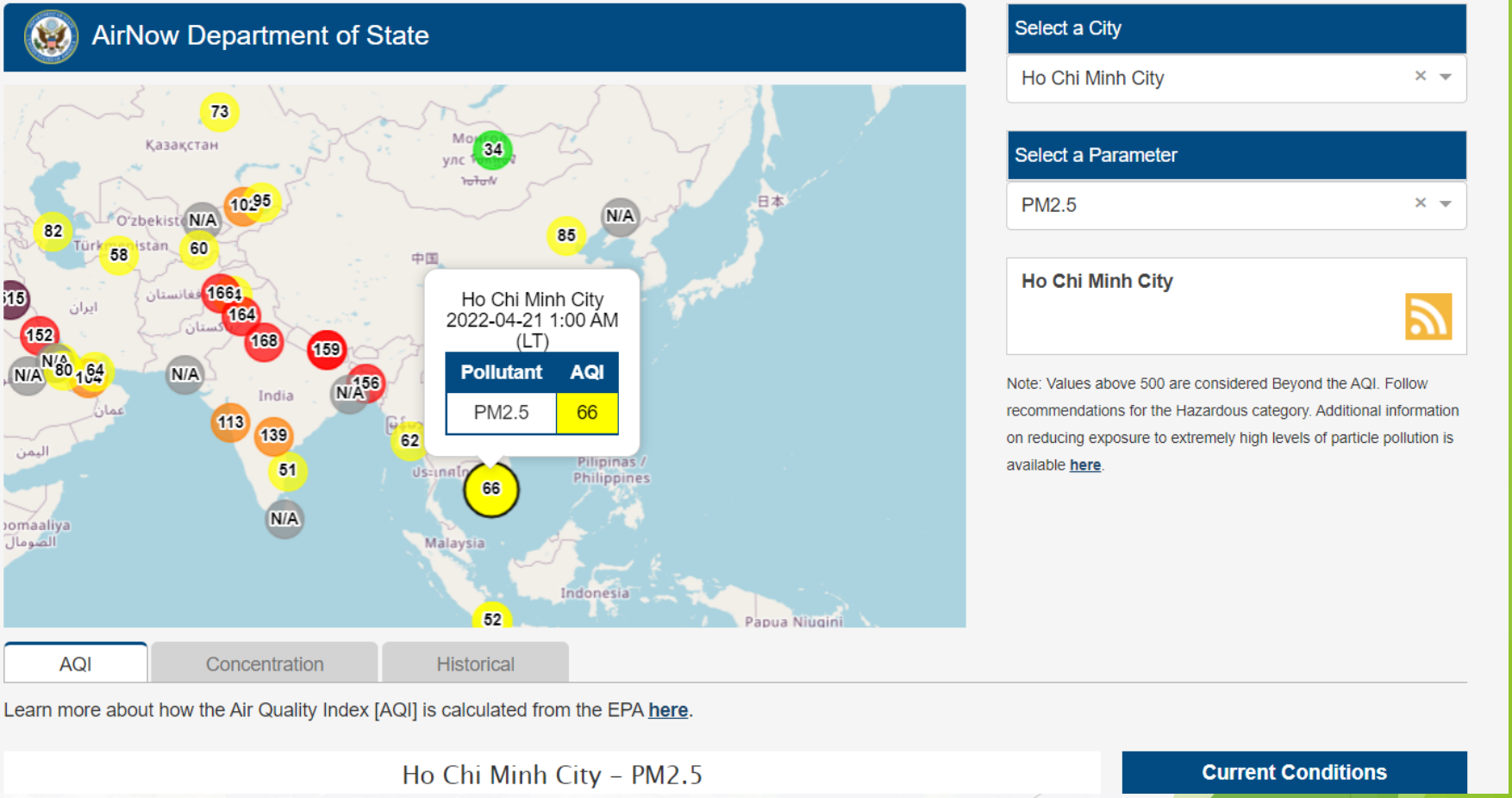
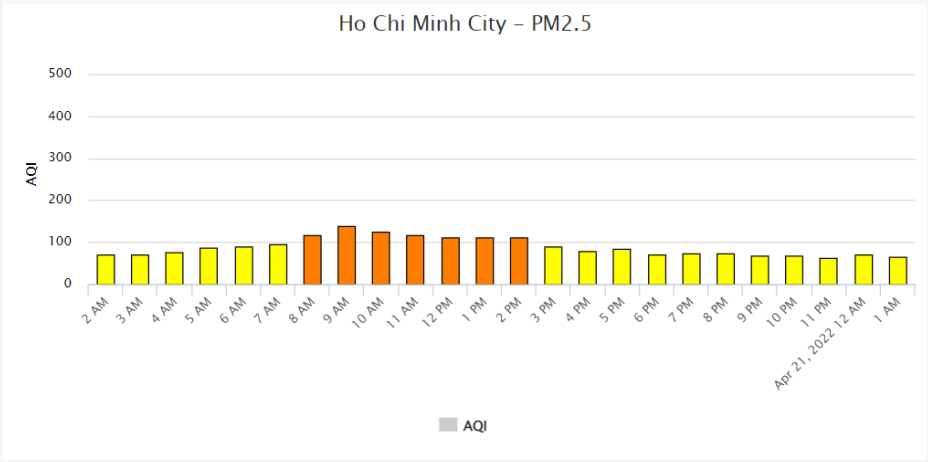
Extra slides

AirNow International at US Embassies



https://www.airnow.gov/international/us-embassies-and-consulates/



Current Conditions
observed at
Apr 21, 2022 1:00 AM (LT)

66 AQI
Moderate
PM2.5

Health Message

The AQI is between 51 and 100. Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.

Note: Values above 500 are considered Beyond the AQI. Follow recommendations for the Hazardous

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

See the Activity Guides to learn ways to protect your health when the AQI reaches unhealthy levels.

U.S. Embassies have “regulatory grade” monitors for ozone (O_3) and fine particulate matter ($PM_{2.5}$)