About Air Quality Forecasting and a 2023 Air Quality Update

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MINNESOTA POLLUTION CONTROL AGENCY

Welcome!

This presentation will be 20 minutes and cover these topics:

- **Air Quality Index (AQI) Overview and Concepts**
- **Forecasting Air Quality**
- **Latest in Air Quality Information**
- **Shameless Self Promotion**

There will be time for questions - also feel free to ask as I go.
I don’t mind being interrupted.

Who Are We?

Minnesota Pollution Control Agency is the state of Minnesota's environmental regulatory agency.

The team is part of the Risk Evaluation and Air Modeling (REAM) Unit.

AQI forecasting is non-regulatory and unique at MPCA. WI, MI, ON have forecasting programs as well. IA has an alert program.

Team Members:

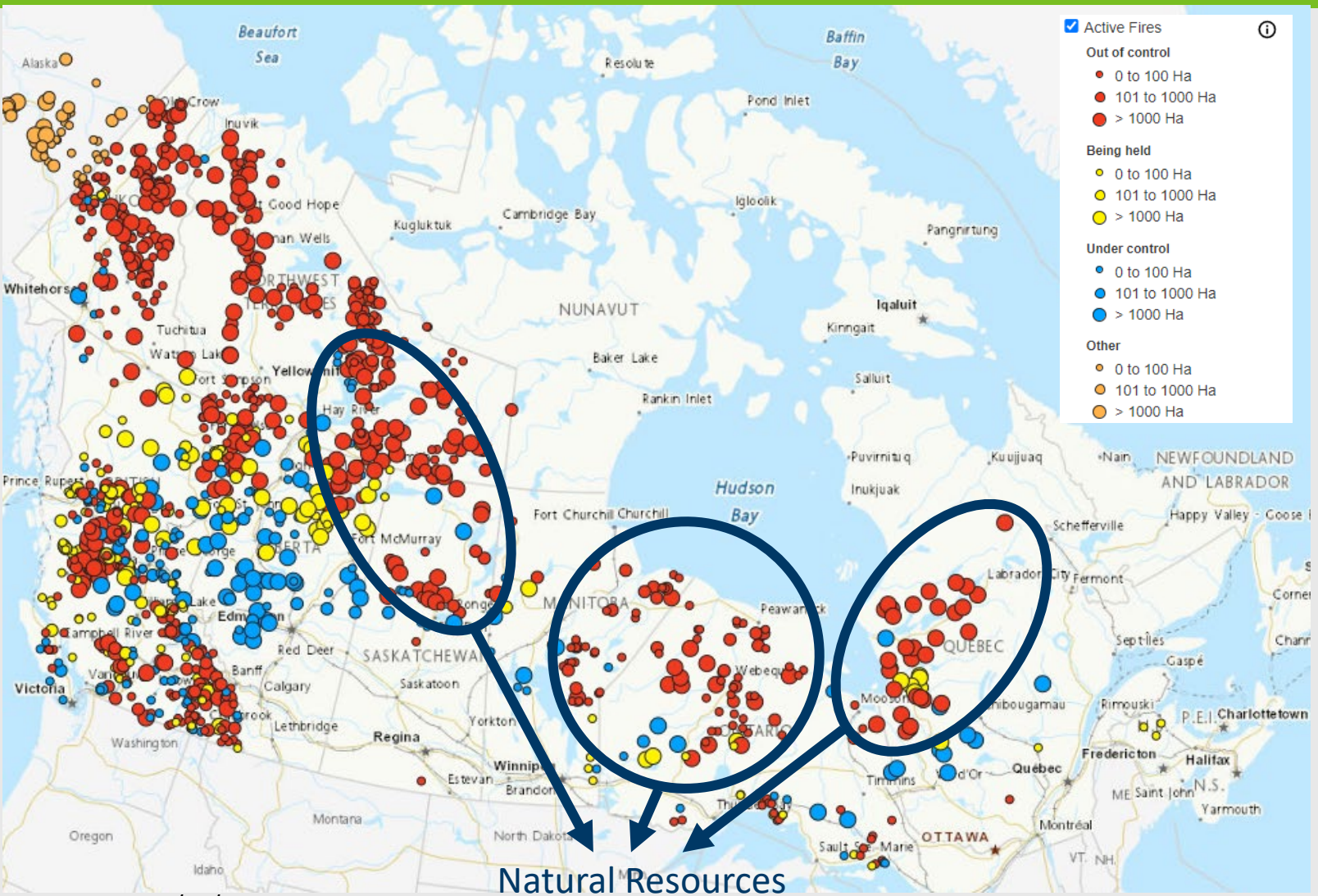
Matt Taraldsen (Supervisor)
David Brown (Forecaster)
Nick Witcraft (Forecaster)
Ryan Lueck (Forecaster)
Daniel Dix (Emergency Manager at MPCA)

The Air Quality Index (AQI)

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.

Air quality alert criteria is an AQI of 101 or higher

Why Has 2023 Been So Bad?



Natural Resources Canada 8/8/2023

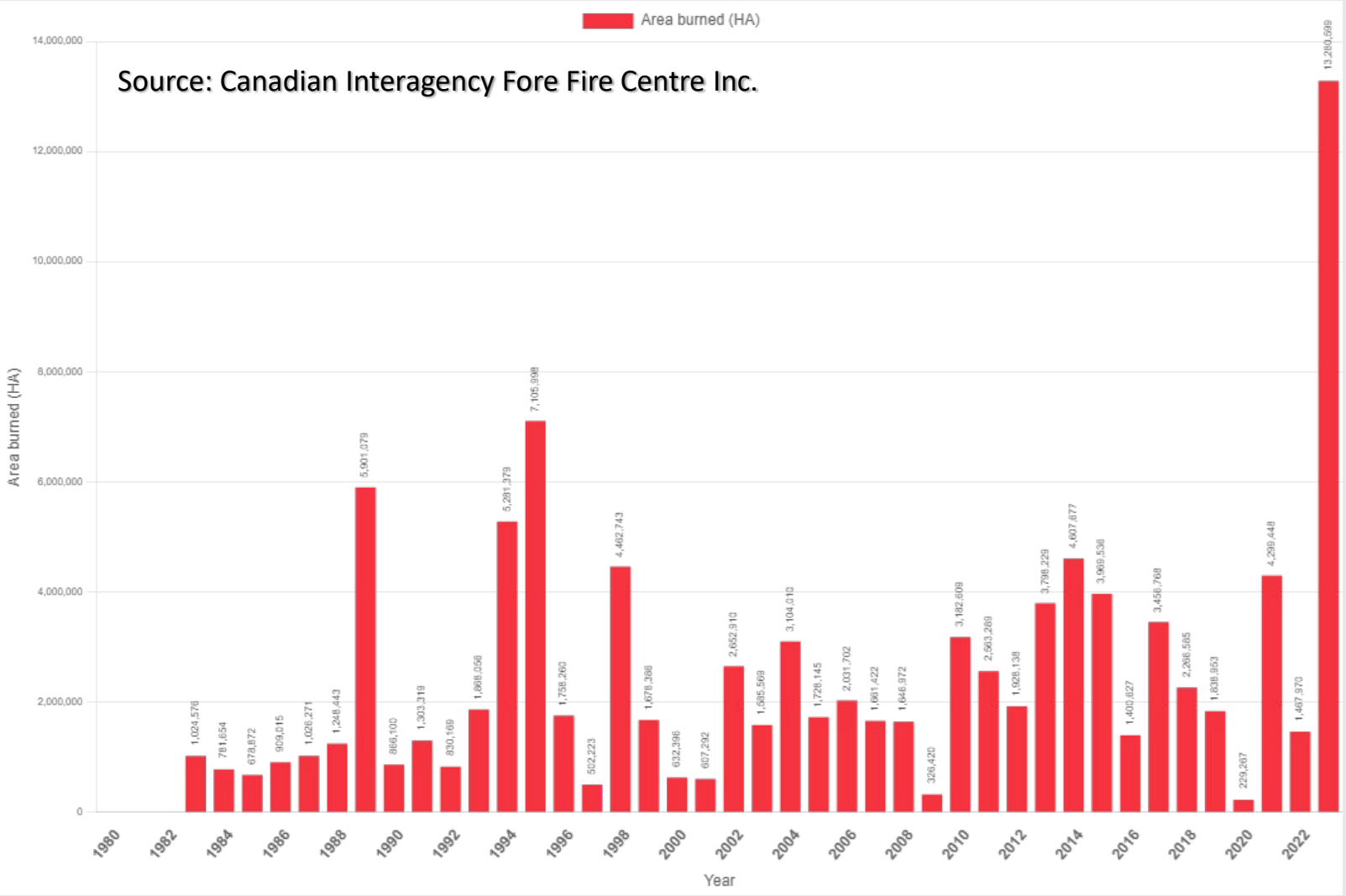
From Natural Resources Canada:
- 5,753 Fires to date (Near Annual Average)
- 33,799,474 acres burned (52,911 sq miles)

Area burned is almost 18x the entire seven county Twin Cities Metropolitan Area or about the size of the state of Arkansas. Twice previous area record set in 1995.

Source area of smoke impacting Minnesota has originated from:
- Quebec
- Ontario/Manitoba
- Alberta/British Columbia/Northwest Territory

Smoke in May and June full of Volatile Organic Compounds which lead to more ozone formation – not sure why.

How does 2023 rank historically?



2023

33,799,474 acres burned (52,911 sq miles)

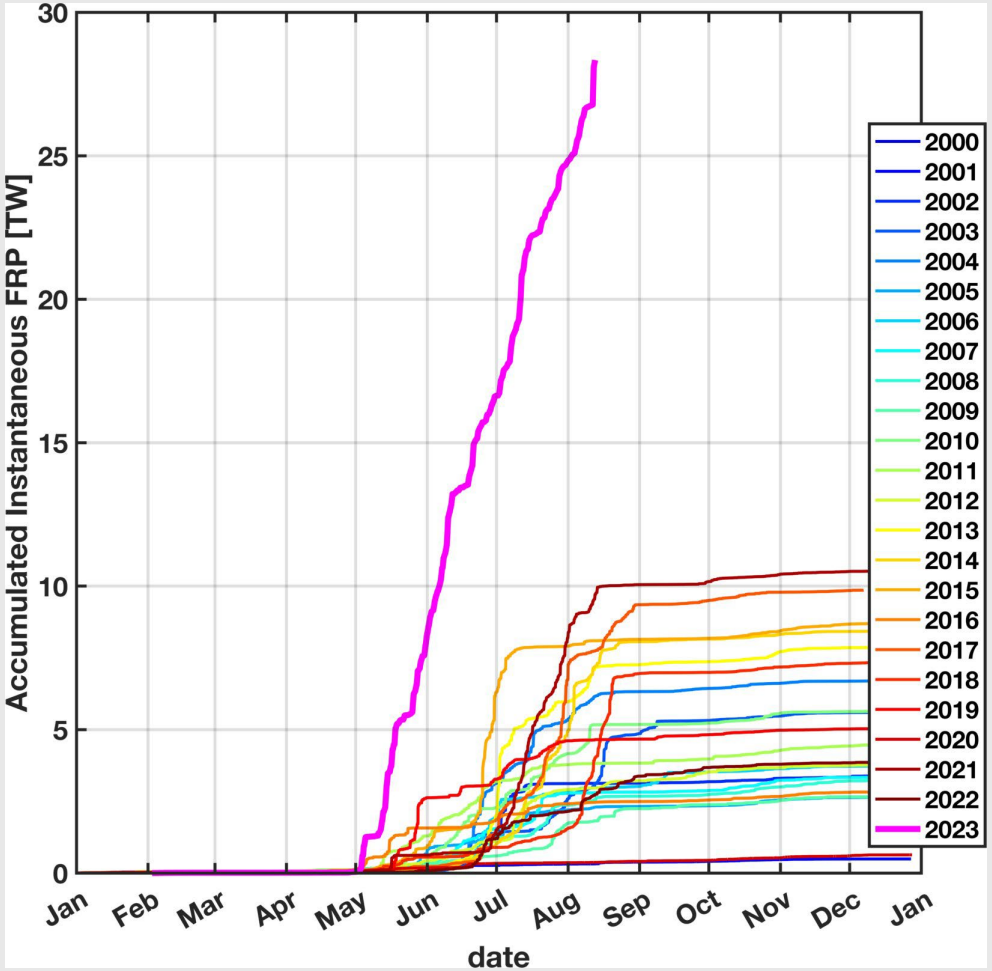
Previous Record (1995)

17,559,303 acres burned (27,436 sq miles)

The year 2021 was most impactful for MN. Large wildfires in Ontario were very close to MN border.

Annual area burned has been steadily increasing.

How does 2023 rank historically?



Source: @nplareau on Twitter

Fire Radiative Power (FRP) is the rate of emitted radiative energy (heat) of a wildfire, expressed in Watts. It represents the intensity of fires.

FRP is measured by satellites.

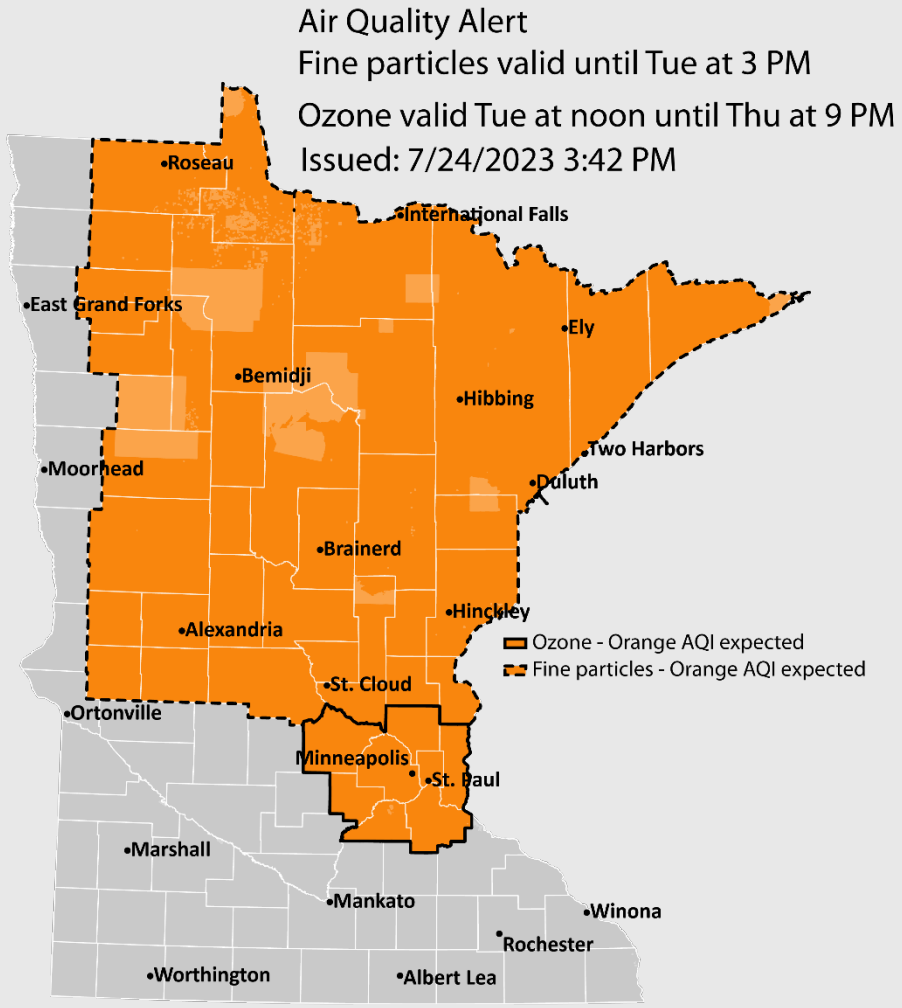
Adding FRP for all fires over time shows the overall wildfire intensity across a wildfire season.

Wildfire activity began two months earlier than normal in 2023. The record for total fire intensity was broken well before the official wildfire season beginning date (July 1).

Annual accumulated wildfire intensity has been increasing over time.

Pollutant emissions are related to FRP. The more intense the fire, the more pollution is emitted into the atmosphere.

Air Quality Alert Climatology



45 Alert Days so far in 2023
Previous Record – 42 Alert Days in 2021

18 Alerts in 2023
Previous Record - 13 Alerts in 2021

Discrepancies in numbers stem for the alerts in Cook/Lake counties surrounding the 2021 Greenwood Fire. Those alerts accounted for a majority of alert days in 2021.

Other statistics:

- Most ozone days since 1980s
- Most ozone alerts in one year in MN (5)
- First time we have had ozone and wildfire smoke alerts in effect at the same time.

Forecasting air quality

Forecasting the air quality index starts with forecasting weather.

Conditions that influence air quality:

Meteorology

Surface winds

Upper-level winds
Sky cover (cloud development)
Relative humidity
Mixing depth
Frontal positions
Low/high pressure system
Surface temperatures

Mid-level temperatures

Fire Weather Conditions

Atmospheric chemistry

Background volatile organic compounds (VOC) concentration

Nitrate Formation

Air mass source region characteristics

Proximity of particulate matter sources

Human behavior

Vehicle emissions

Wood fire emissions

Recreational Fires

Prescribed Burns

Mitigation Actions

The Air Quality Index (AQI)

- **We forecast the Air Quality Index (AQI)**
- **The AQI has two pollutants ground-level ozone and fine particle pollution (PM 2.5)**
- **Though ozone is in parts per billion (ppb) and fine particle pollution is in micrograms per cubic meter ($\mu g/m^3$) the AQI allows for describing the impact to people.**
- **101 or higher has impact (alert criteria).**
- **The AQI represents a 24 hour measure – and that creates a messaging challenge.**
- **Overall the weather has the largest impact to AQI – and we start there with our forecasting.**

Air Quality Event Setups in Minnesota

There are Three Main Air Quality Events that Impact Minnesota:

1) Ground-Level Ozone
   - In Minnesota – formed on warm sunny summer days

2) Fine Particle Pollution from Wildfire Smoke (PM 2.5)
   - Lofted by wildfires and transported hundreds/thousands of miles and pushed down into Minnesota via a front or high pressure area.
   - From fires <hundreds of miles from MN that becomes trapped at the surface and dragged into the state by a cold front.

3) Fine Particle Pollution from Stagnation (PM 2.5)
   - Build-up of local pollution and precursors caused by light wind and poor dispersion in the winter.

Forecasting Fine Particle Pollution

For Winter Stagnation and Secondary Formation:

1. Flow from the west across Minnesota
2. Temperatures around freezing
3. Relative humidity >80%
4. Low mixing heights/dispersion
5. Surface winds <10mph

For Wildfire Smoke:

1. A source region from a fire
2. Concentrated sinking motion (subsidence)
3. Limited rainfall
4. Terrain and marine interactions letting smoke linger or concentrate

Alert Process Diagram

Here are the alert decision steps along with primary dissemination routes

MPCA Duty Meteorologist Decides to Issue Alert

Heads-Up Given Internally + National Weather Service (NWS)

GIS Map and Alert Text Drafted

Press Release Drafted

Statement and Map Vetted by MPCA Communications

Alert Finalized and Ready to Transmit

Alert Text Transmitted to NWS offices to issue alert (AQA)

AQA Product From NWS

Out to Apps, Broadcasters, NWS Site

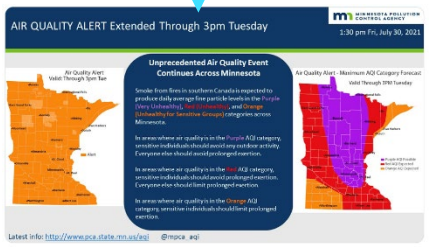
Alert Posted to @MPCA_AQI

MDH

MN DNR

MN DOT

Communications Sends Out Press Release to Media

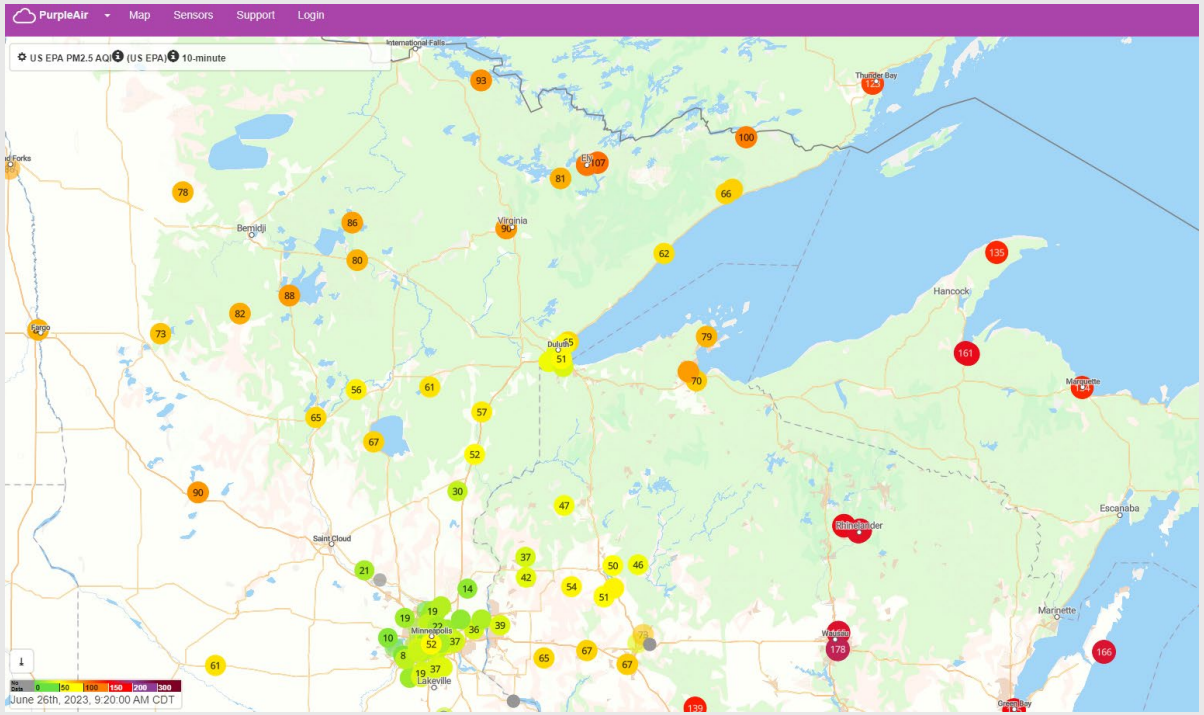


Transmitted to physicians and outdoor youth activity groups

Fire permits rescinded in affected counties/zones

Air Quality Observations

- Also keep an eye on air quality through Purple Air sensors as well as our regulatory monitors



Today's hourly monitoring data

Last updated Jun 26, 2023 08:44 CDT

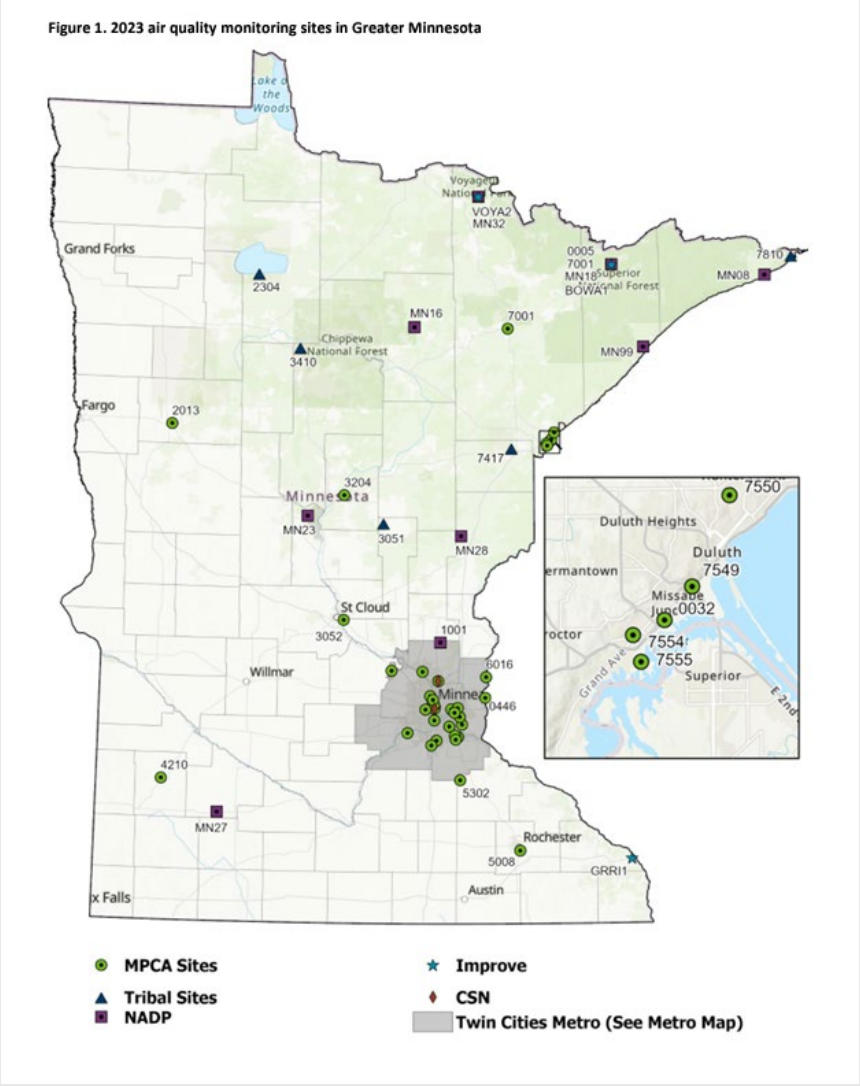
PM2.5 data | Ozone data

Concentrations in units of *ug/m*^{3}. Hours are the monitoring start hour.

Site Name	Parameter	0	1	2	3	4	5	6	7		Daily Average	Rolling 24-hr Avg	NowCast AQI
Aberdeen	PM25	3	4.4	5.4	4.2	4.2	8.3	8.6	8.3	::	5.8	12.6	32
Apple Valley	PM25	12.8	8.1	6.9	8	9.2	8.1	6.3	8.4	::	8.5	7.1	32
Blaine	PM25	3	0	-3	1	0	-1	-3	-3	::	-0.8	0.6	0
Brainerd	PM25	4.4	3.7	3.7	4.2	5.7	8.7	15.9	20	::	8.3	9.5	58
Detroit Lakes	PM25	17.4	27.3	30	34	31.9	29.5	29.4	27.6	::	28.4	17.5	86
Duluth-WDSE	PM25	36.6	27.1	20.4	14.8	12.4	11.9	16.4	20	::	20	21.3	63
Ely	PM25	19.4	22.2	23.5	24.8	23	18.8	16.2	17.8	::	20.7	15.9	64
Emmetsburg, ILCC	PM25	9	15	16	17	17	20	21	18	::	16.6	9.9	65
Fargo NW	PM25	25.8	28.5	29.5	26.1	25.1	26.9	26.9	.	::	27	21.6	81
Fond du Lac	PM25	26.8	24.3	19.2	15.6	10.1	9.2	10.4	13.7	::	16.2	17.2	52
Grand Portage	PM25	33	27	29	27	29	35	38	34	::	31.5	22.7	97
LACROSSE DOT	PM25	16.4	18.1	18.2	20.3	22.2	25.9	27.8	32.2	::	22.6	12.1	86
Lakeville - Near Roa	PM25	12.9	12.7	9.3	9.7	8.4	6.7	5.2	6.6	::	8.9	6.9	27
Leech Lake Nation: C	PM25	6.7	8.9	12.6	15.7	16.9	24	32.2	32.4	::	18.7	13.6	87
Marshall	PM25	28.7	30.2	26.1	19.5	19.2	18.5	19.8	21.2	::	22.9	15.4	69
Minneapolis-Near Roa	PM25	9.1	9.3	8.1	8.8	8.5	7.6	7.5	11	::	8.7	8.2	38
Minneapolis-Phillips	PM25	8.8	7.6	7.8	8.4	7.8	6.7	6.9	11	::	8.1	7	36

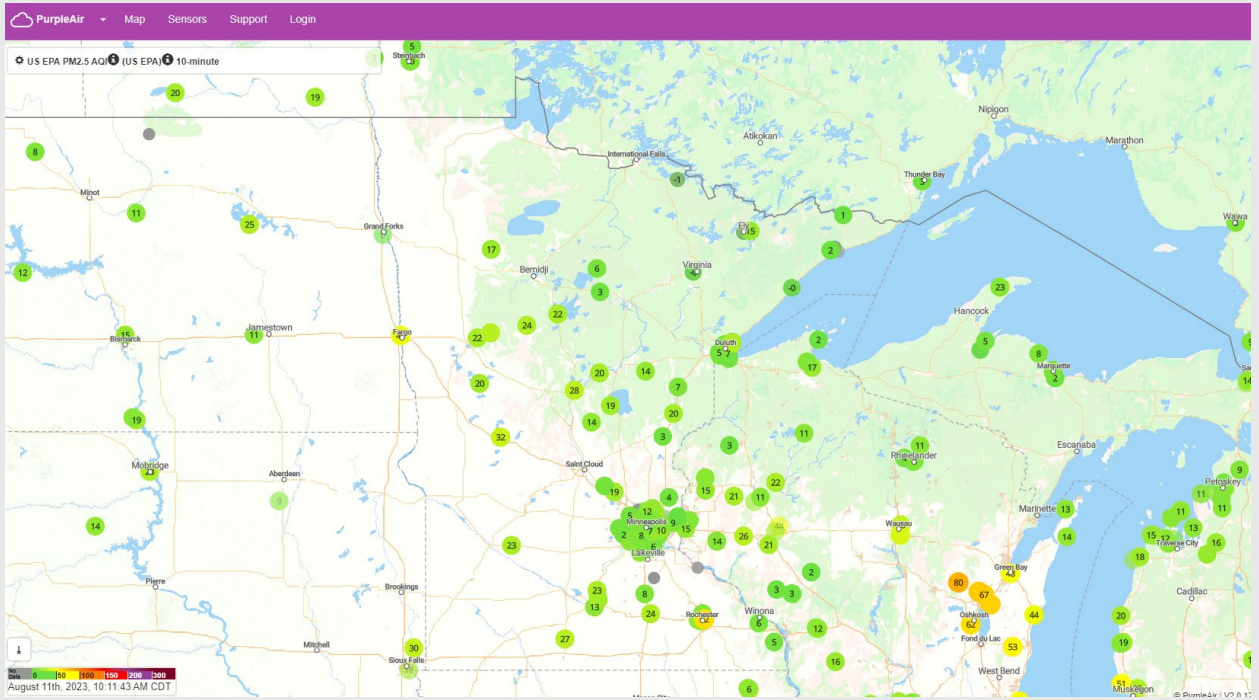
Regulatory Monitors

- Regulatory Monitors are monitors maintained by a state agency that meet EPA standards
- The density of the network is poor
- The monitors are continuously maintained and cross-validated with laboratory measurements at MPCA
- Data from these sites are used by EPA to determine if a state is in compliance with federal regulations



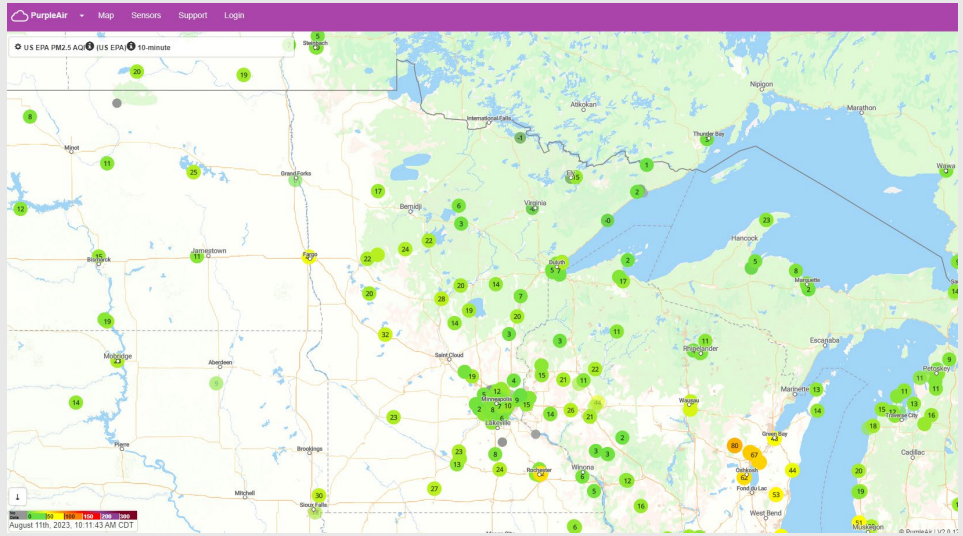
PurpleAir Monitors

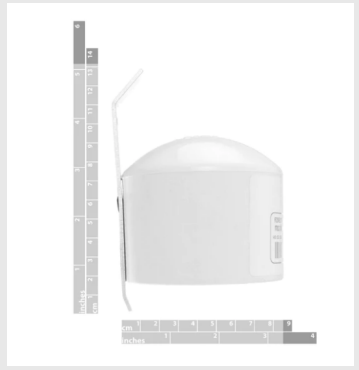
- Inexpensive citizen science type of sensor
- Show one minute data – and that confuses people
- Can apply EPA QA (top left)
- Surprisingly Accurate
- PurpleAir has siting guides – but not confident on that



Air Quality Monitor Changes

- The legislature has set aside funds for grants for community groups and local government to get air quality sensors.
- These sensors will sync up to an online portal currently being built at MPCA to host data.
- Data will then be available in near-real time on MPCA website.
- Already have a pilot project in Minneapolis – has been helpful!

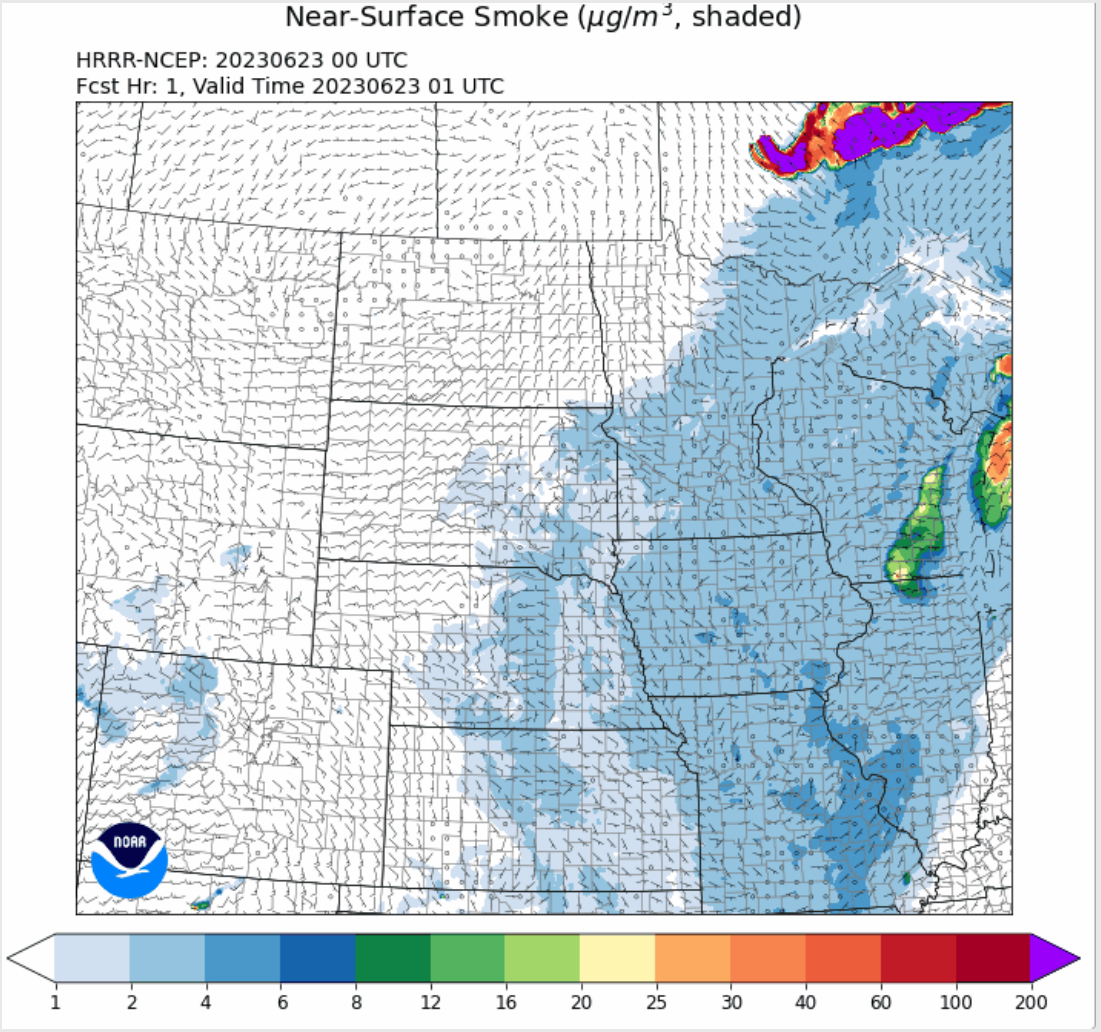




Air Quality Models

There are specialized models for forecasting air quality:

- Community Multiscale Air Quality Modeling System (CMAQ) model for ozone.
- High Resolution Rapid Refresh (HRRR) smoke for wildfire smoke.
- Rapid Refresh (RAP) Smoke
- Canadian Firework Model for Smoke
- Even internal tools (Dr. Robot)



Introducing Dr. Robot

Four python scripts are utilized to complete forecast process:

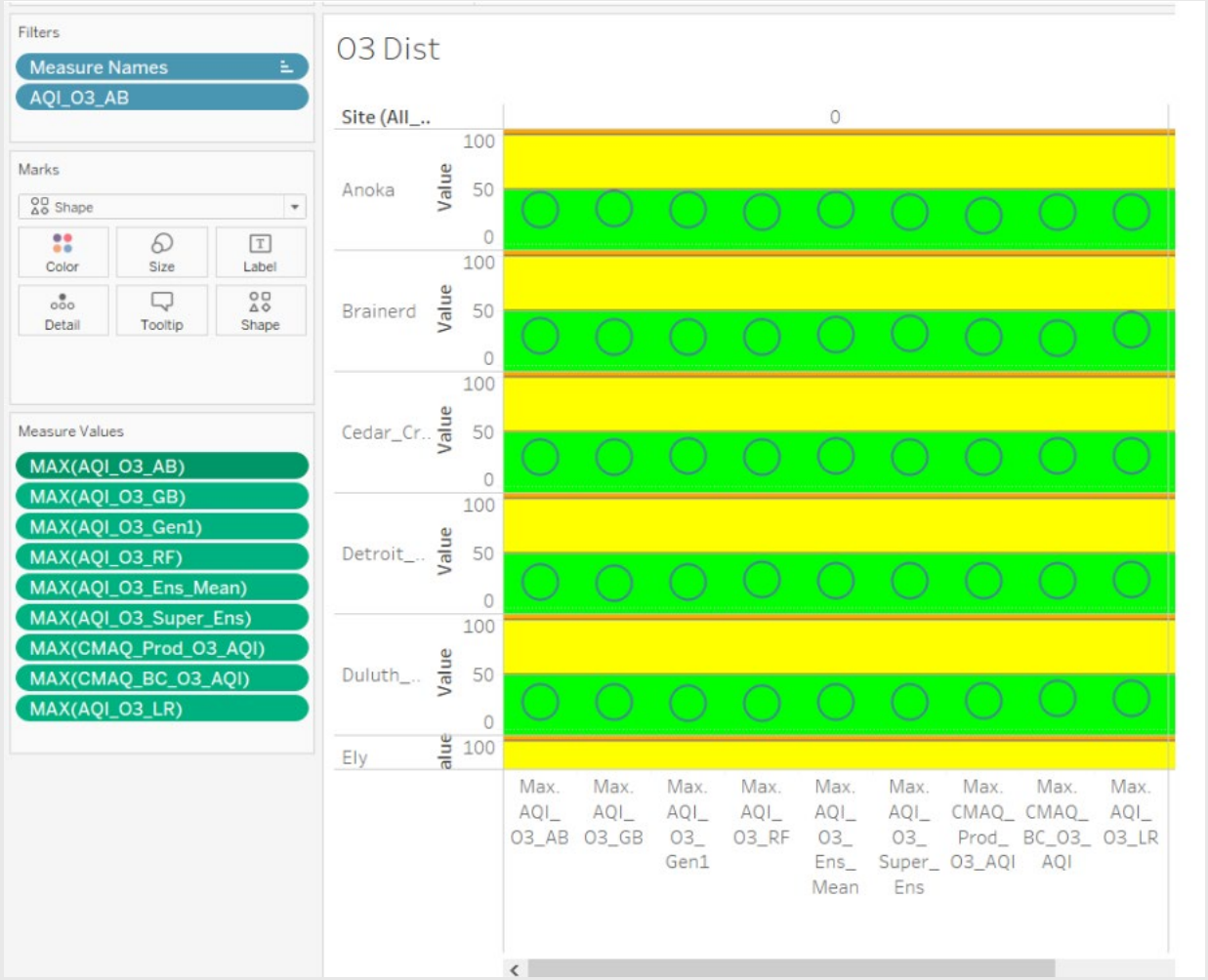
1) Scrapes Open-meteo API for surface and upper air data

2) Random Forest AI Model Ensemble and verification come from Open-meteo data

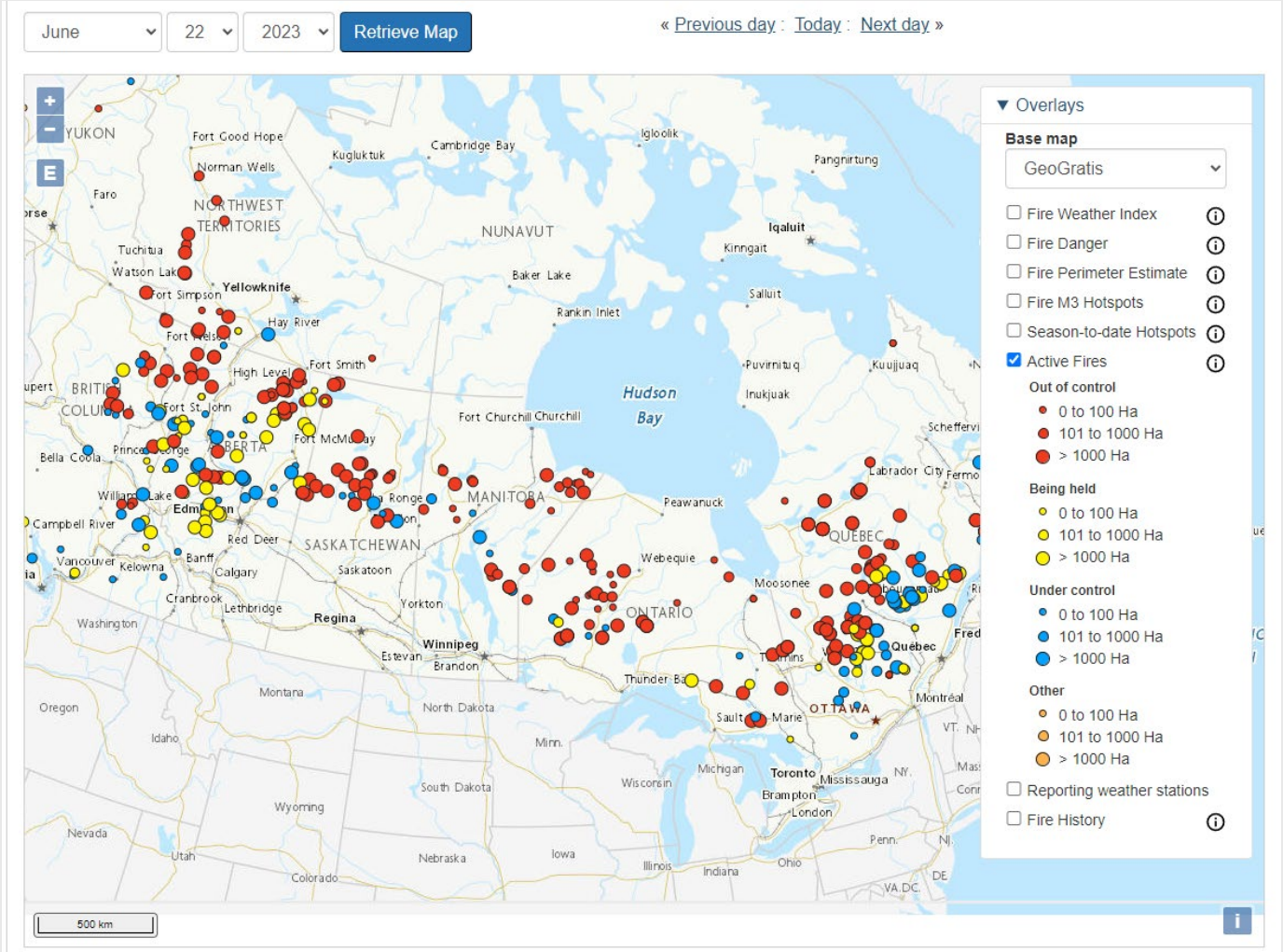
3) CMAQ GRIB files are queried and imported

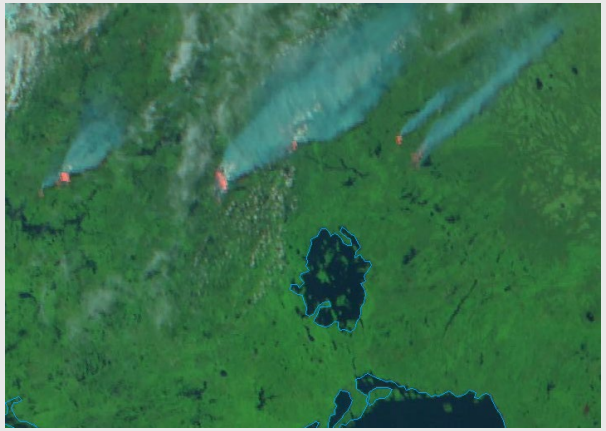
4) HRRR Smoke joined from GRIB files

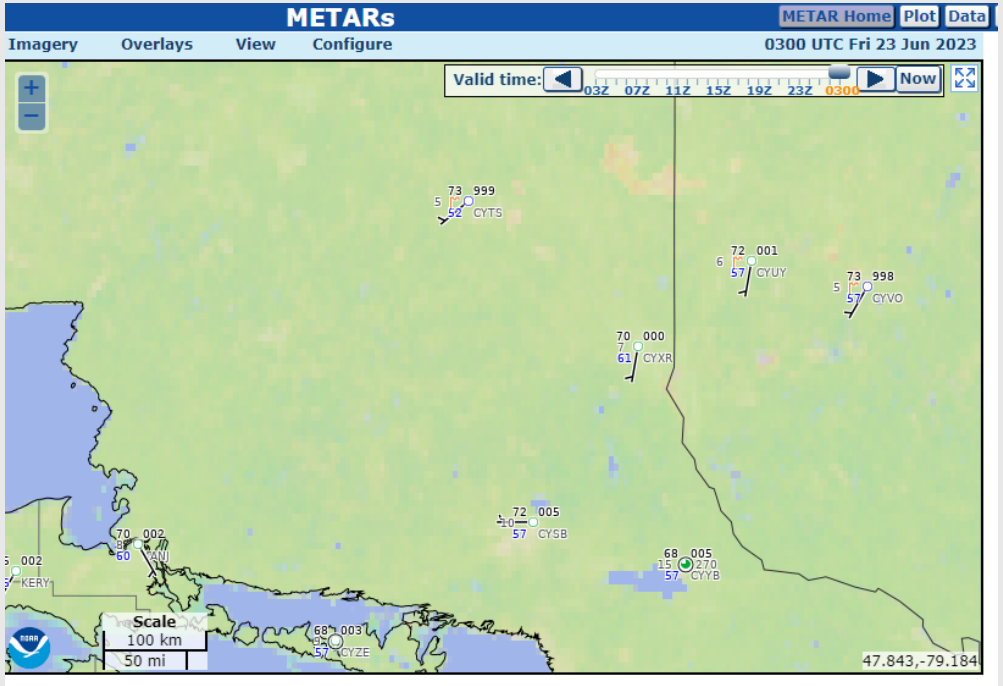
All data then loaded into Tableau to give guidance envelope



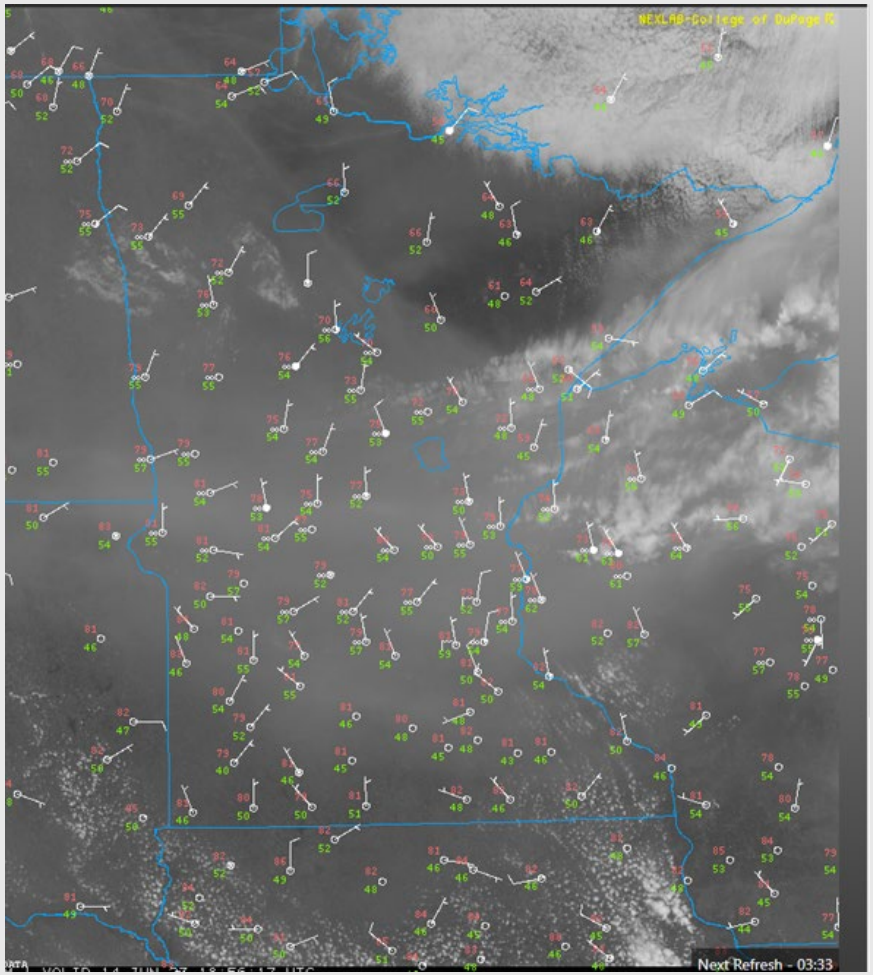
Forecasting Smoke – Detecting Fires

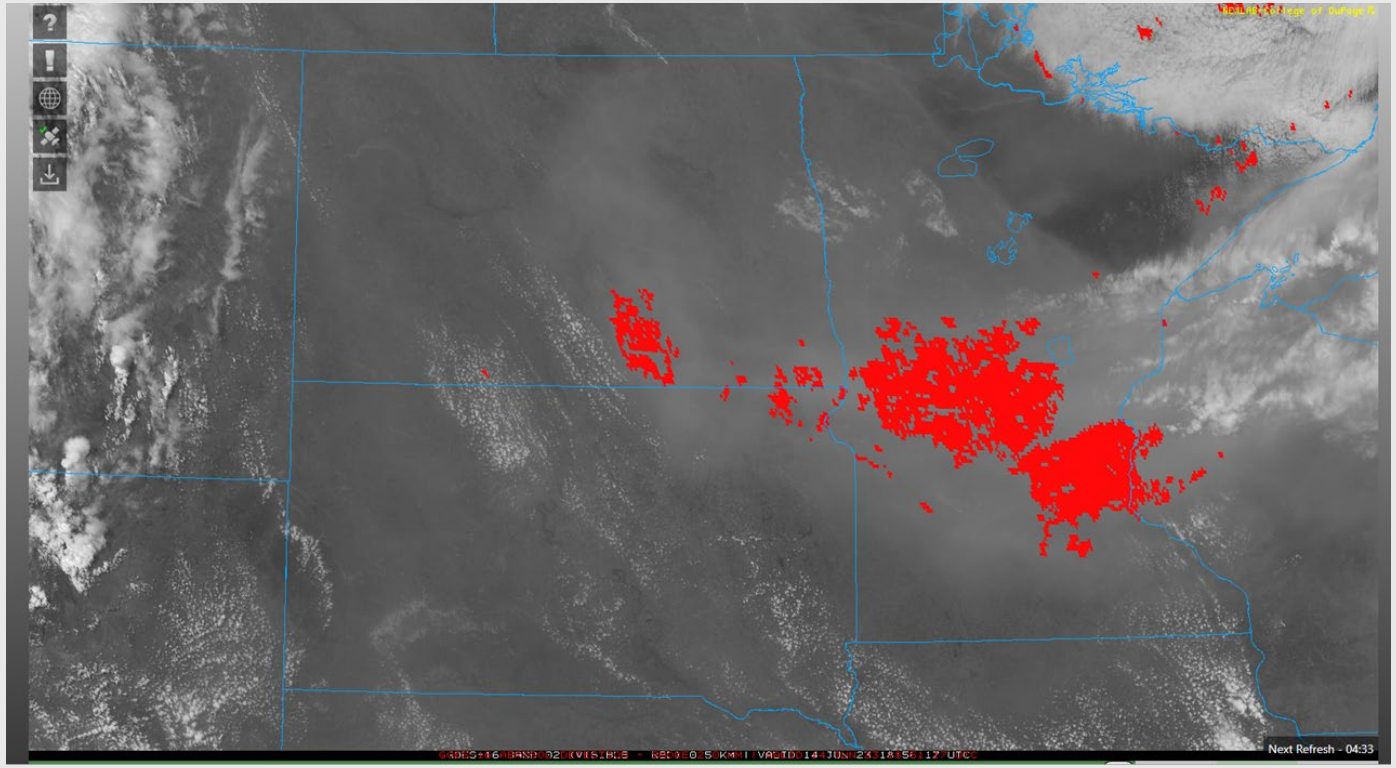




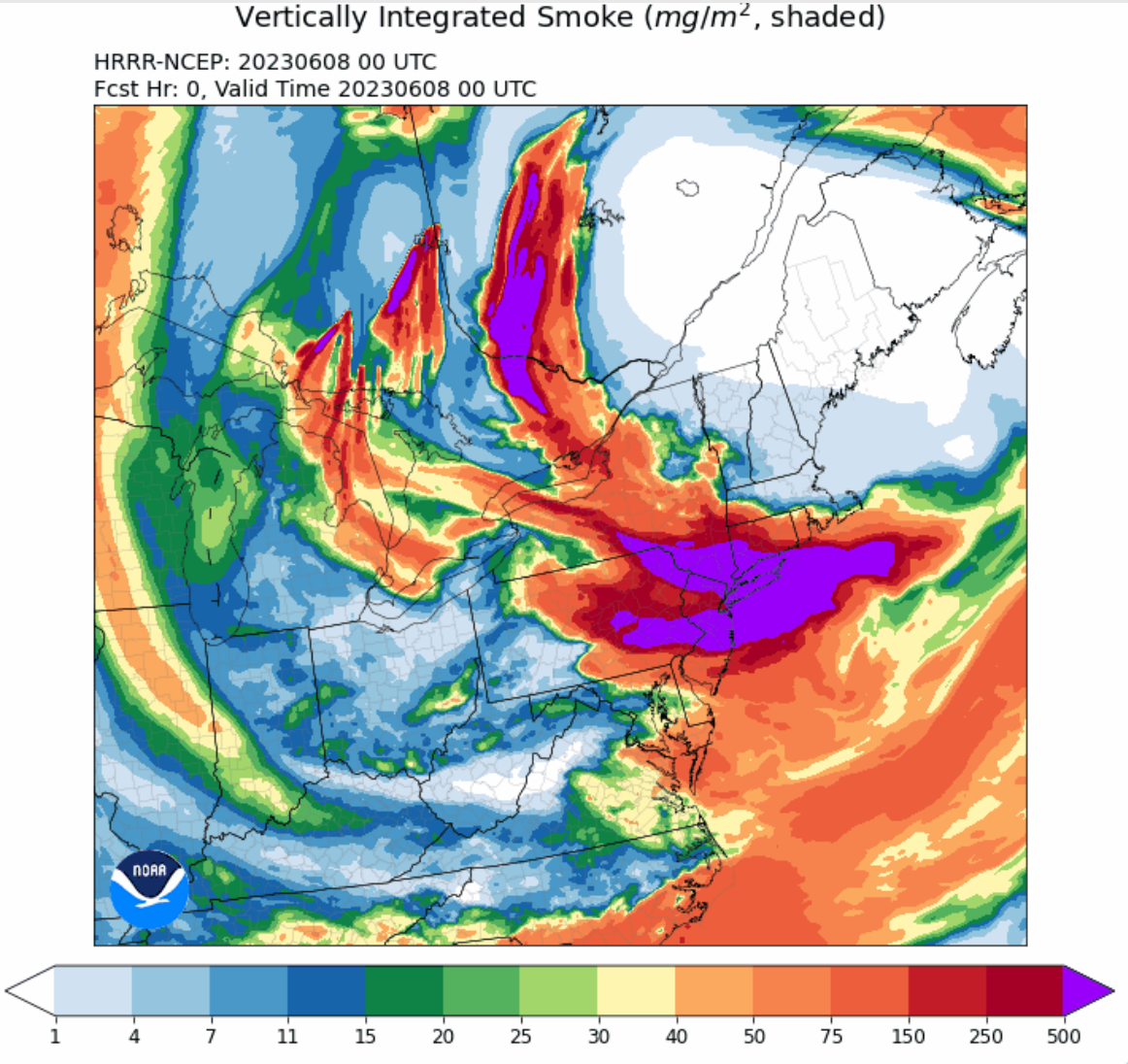


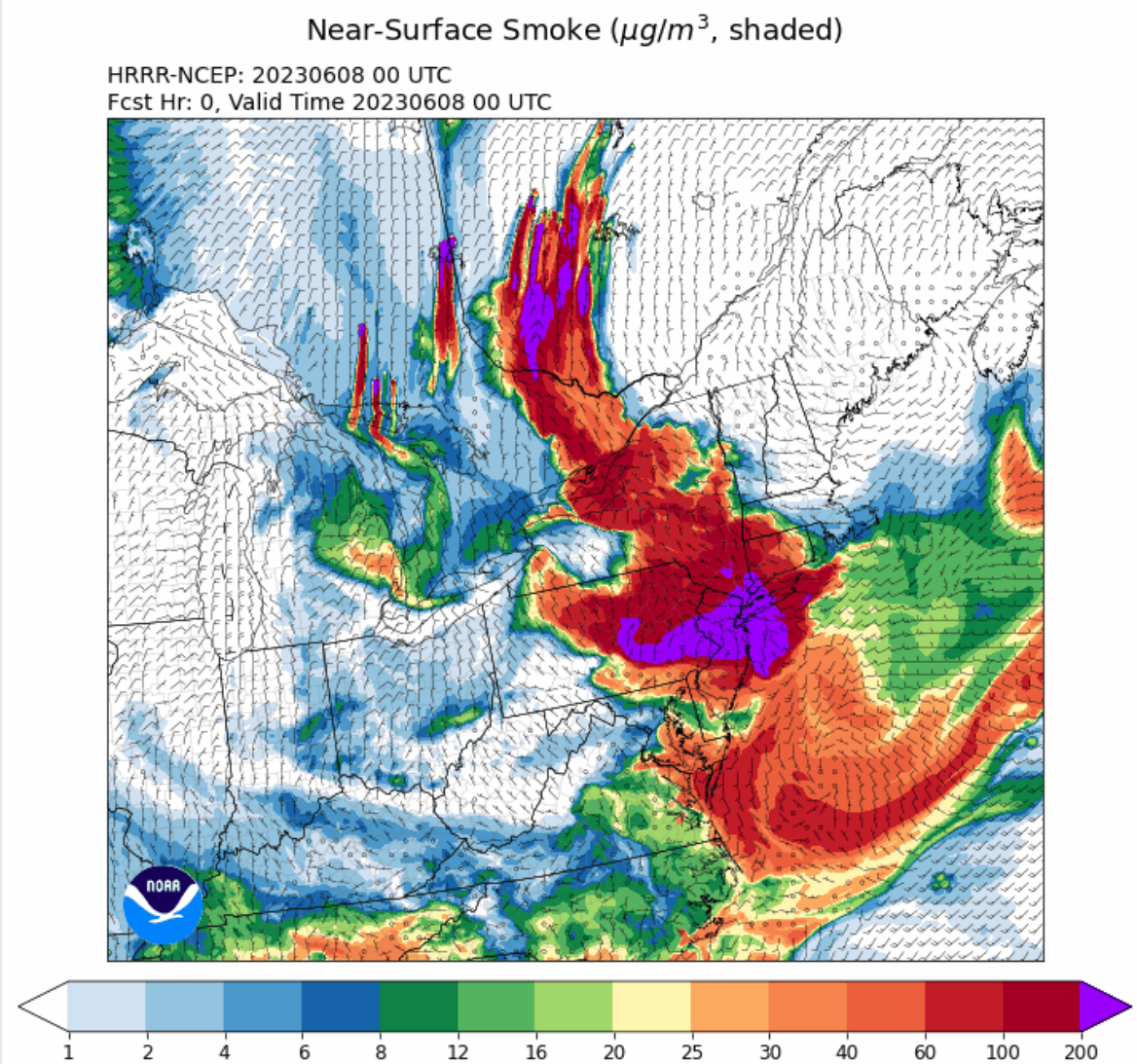
Forecasting Smoke – Detecting Smoke Plumes





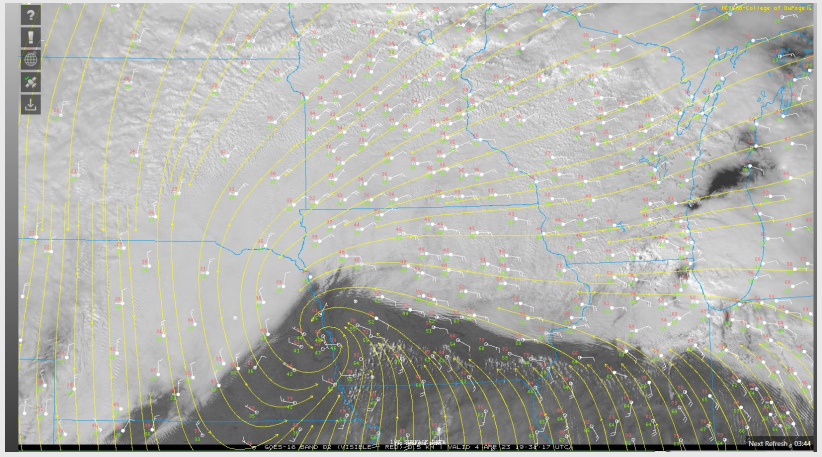
Smoke Modeling – Surface Vs Elevated



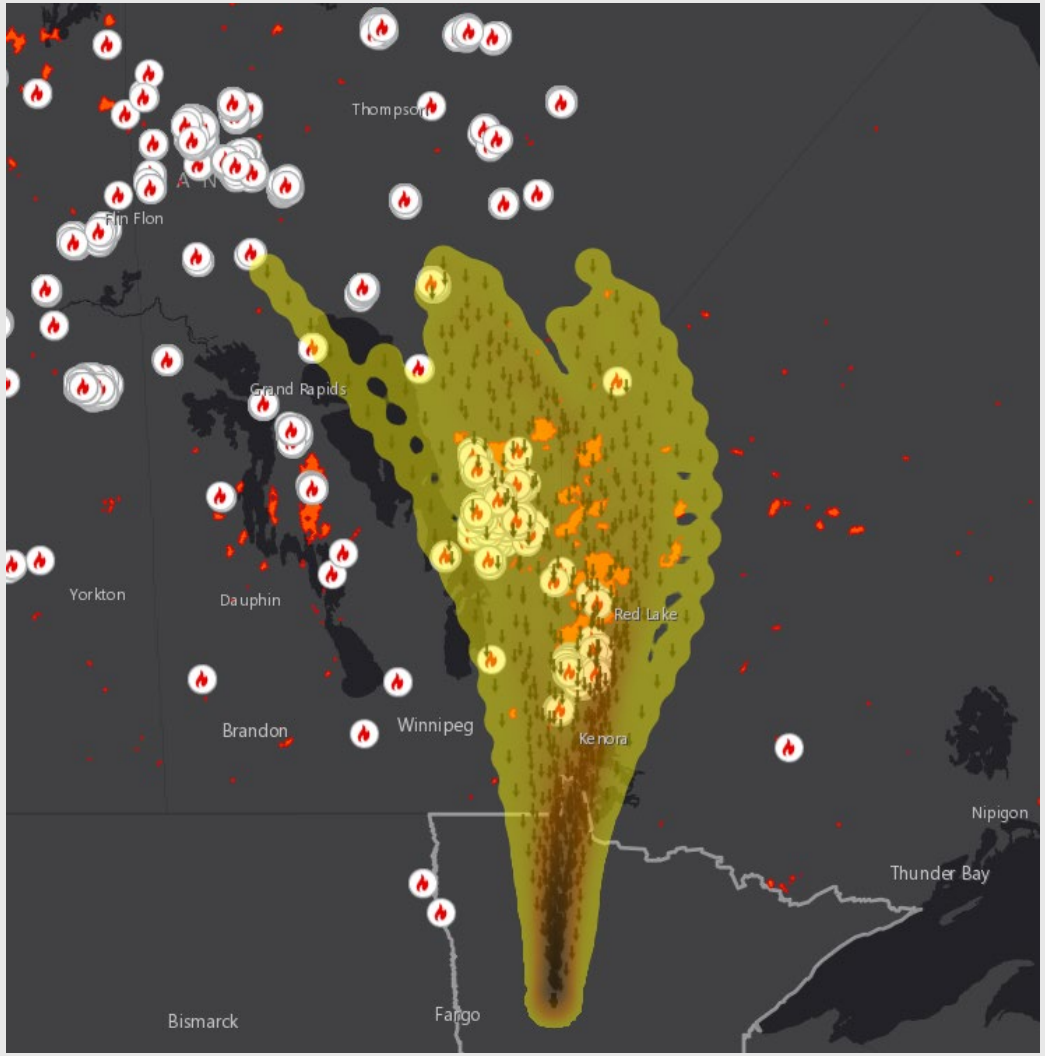


Smoke and Ozone – What Is the Source Area?

- We utilize the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory)Model
- Model tracks trajectories – or where air is moving (below).
- We can run it in reverse and see where an airmass is coming from.
- July 28, 2021- Yellow is a heat map of parcel locations. Orange area is burnt area and white circles are active fires.
- We had a lot of smoke…

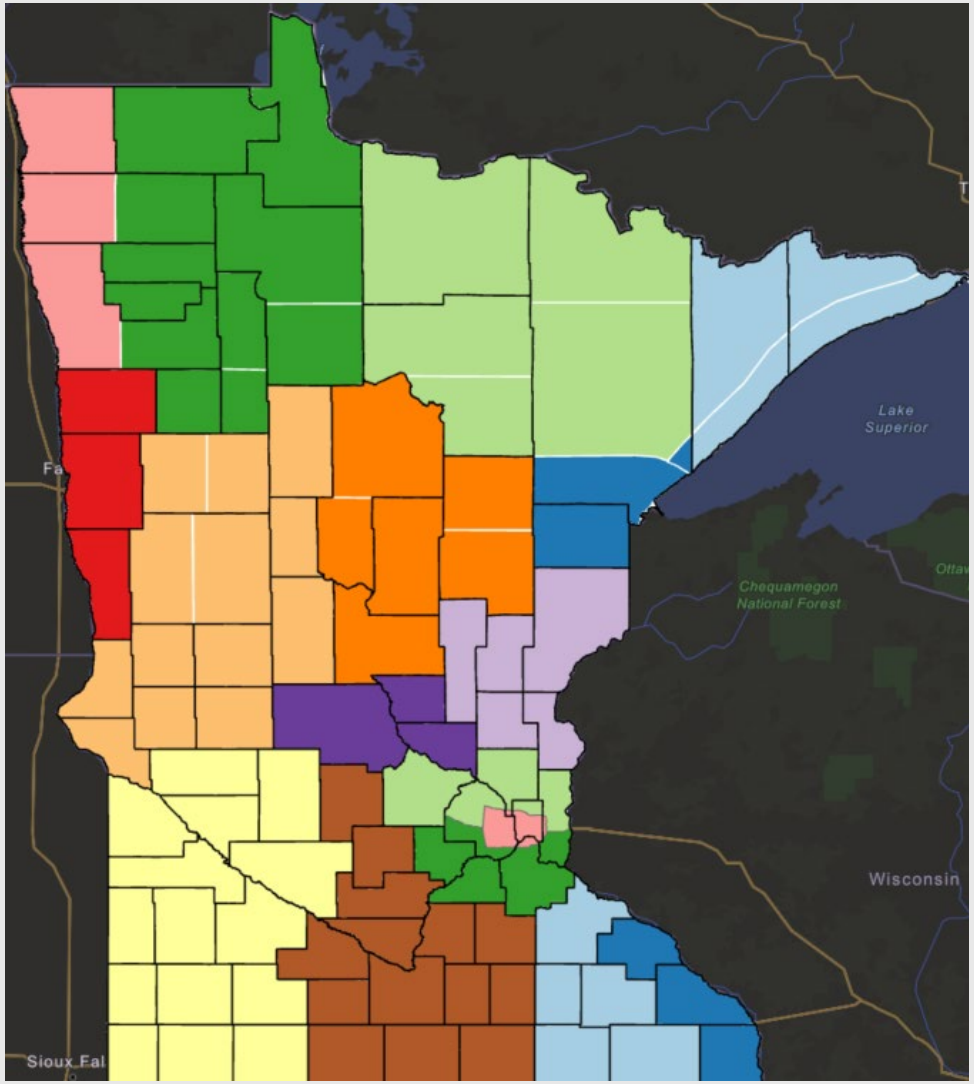


Example of streamlines in a model



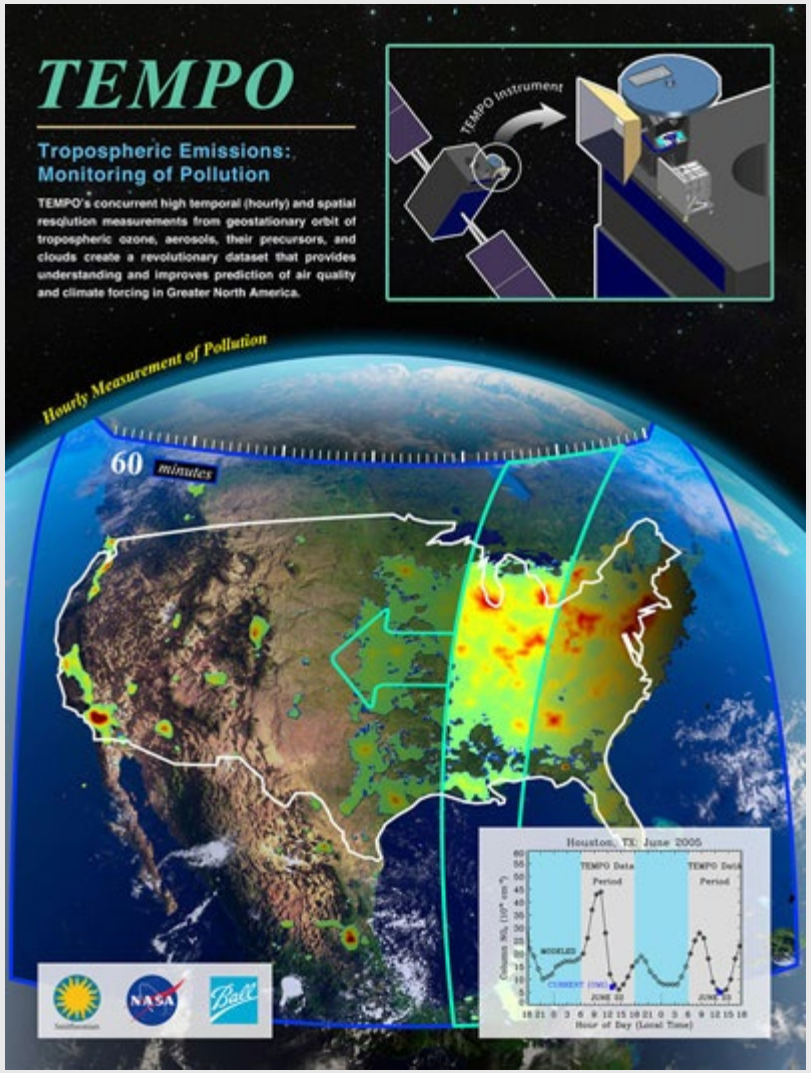
July 28, 2021

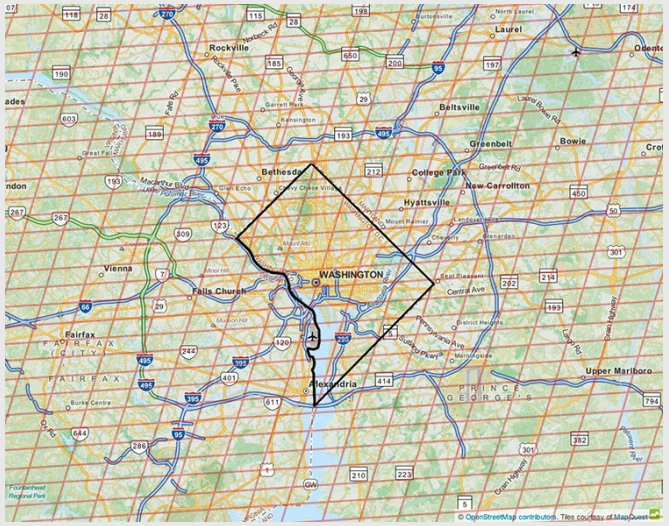
Switching From Point to Zone Forecasts



- New 17 Zones Replacing Twin Cities and Rochester Point Forecasts.
- White lines National Weather Service Zone Boundaries black lines Counties.
- Main changes from NWS/County borders are:
  - Removed sliver of lakeshore zone in St. Louis county
  - Split the Twin Cities Metro along Highway 212 and 694/494 Loop to account for suburbs vs Twin Cities proper.
- Zones based on similar background concentrations and landcover.
- Tried to stick to National Weather Service forecast office/Media Market boundaries – but Pine and Morrison are odd ones out

The Future – NASA Tempo





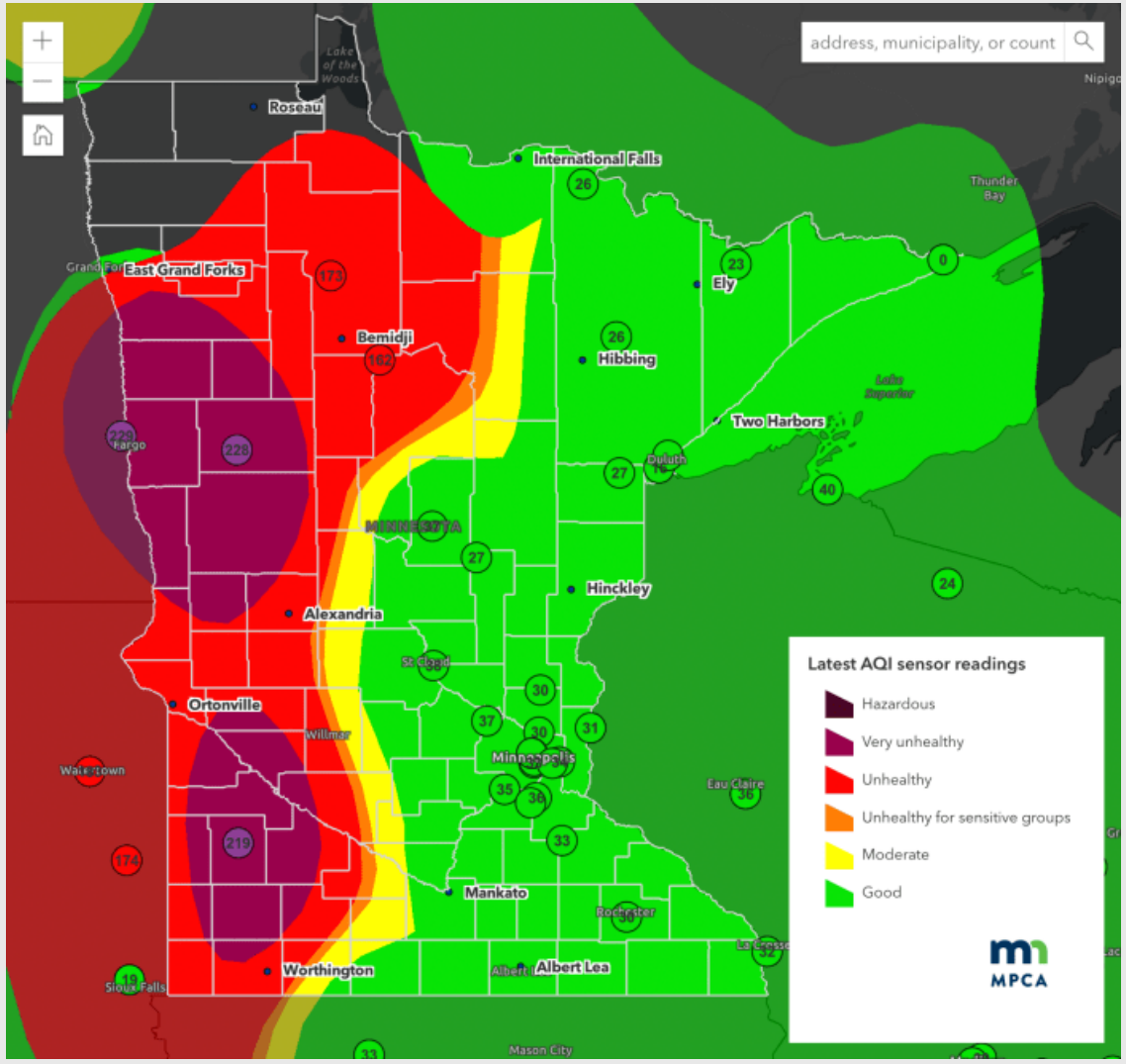
TEMPO will enable direct observation of source region characteristics

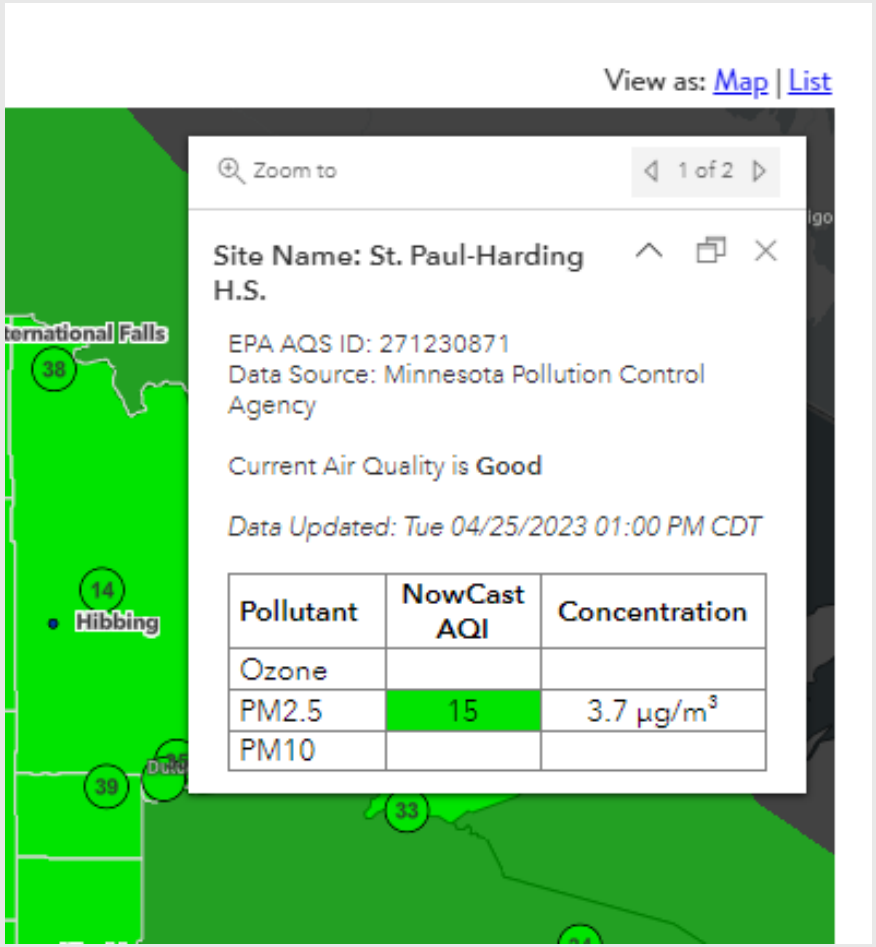
Will also allow measurement of smoke plumes from fires

Output will be ~4km – can resolve parts of cities

MPCA is an early adopter – going to build a GIS workflow around it

Shameless Self Promotion – New Website





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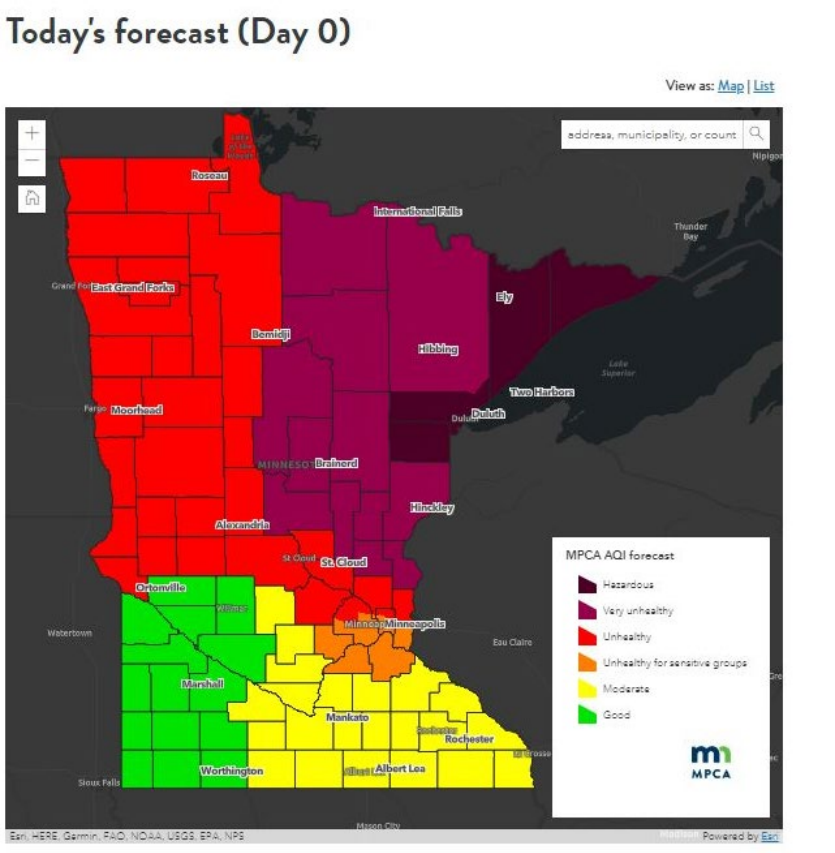
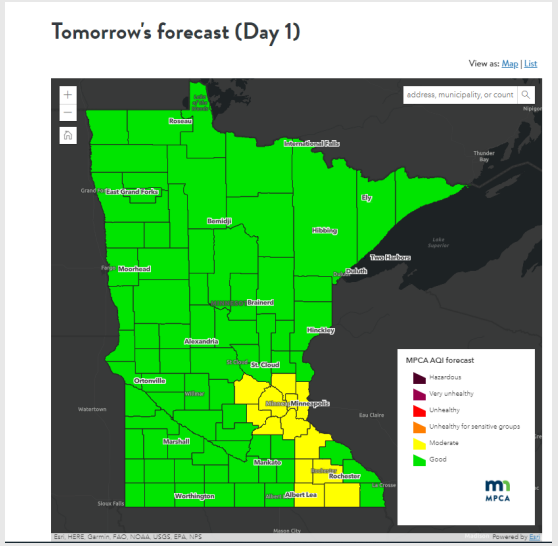
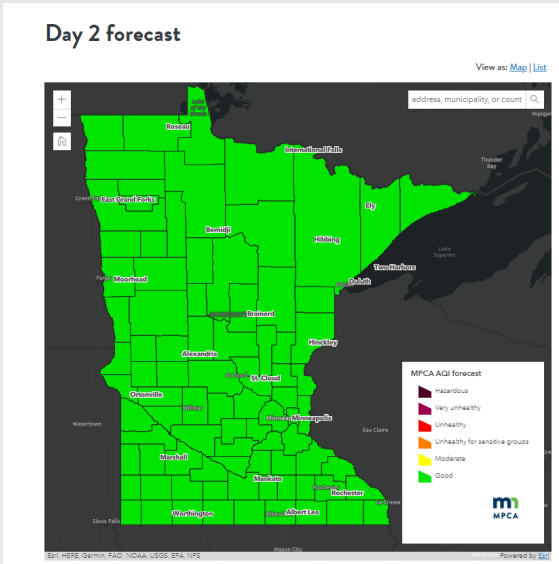
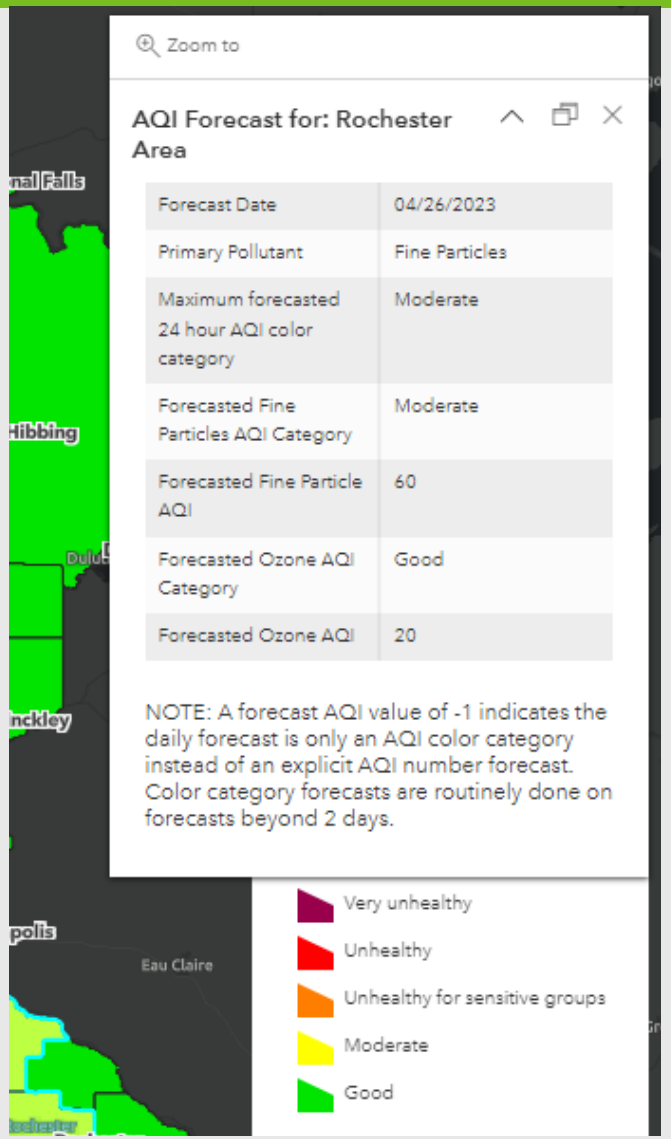
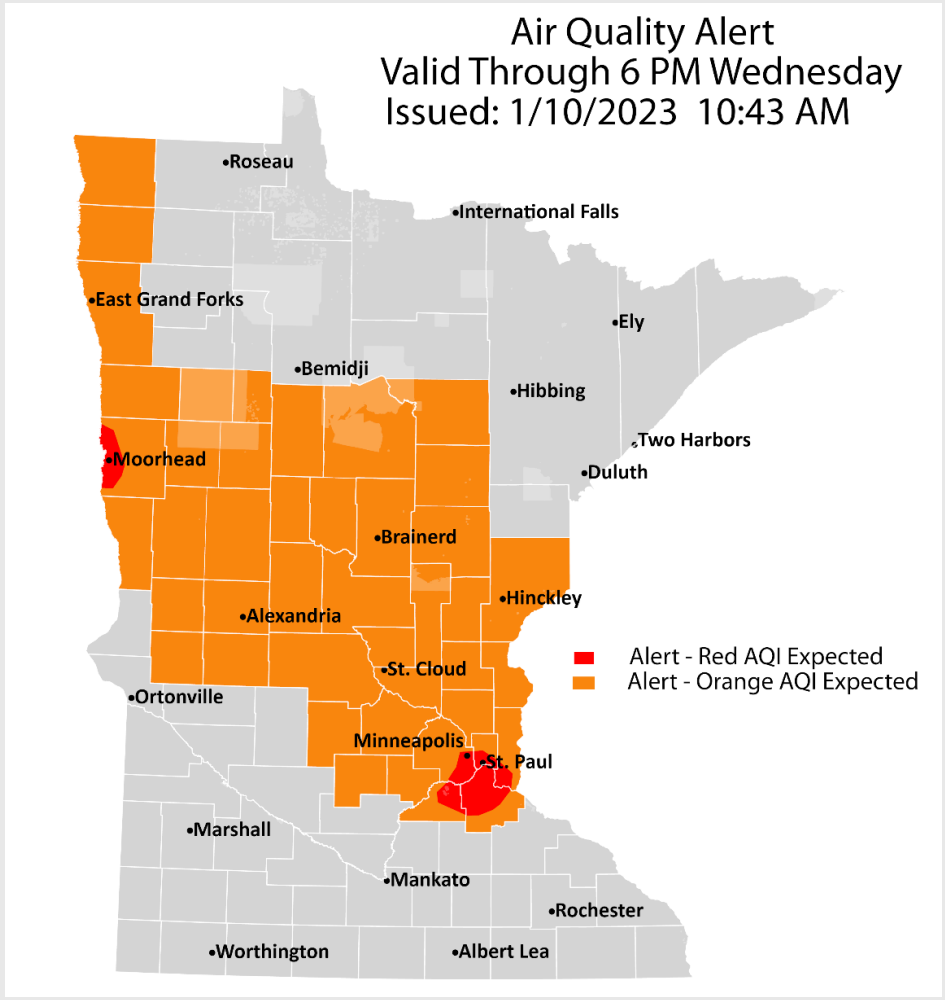




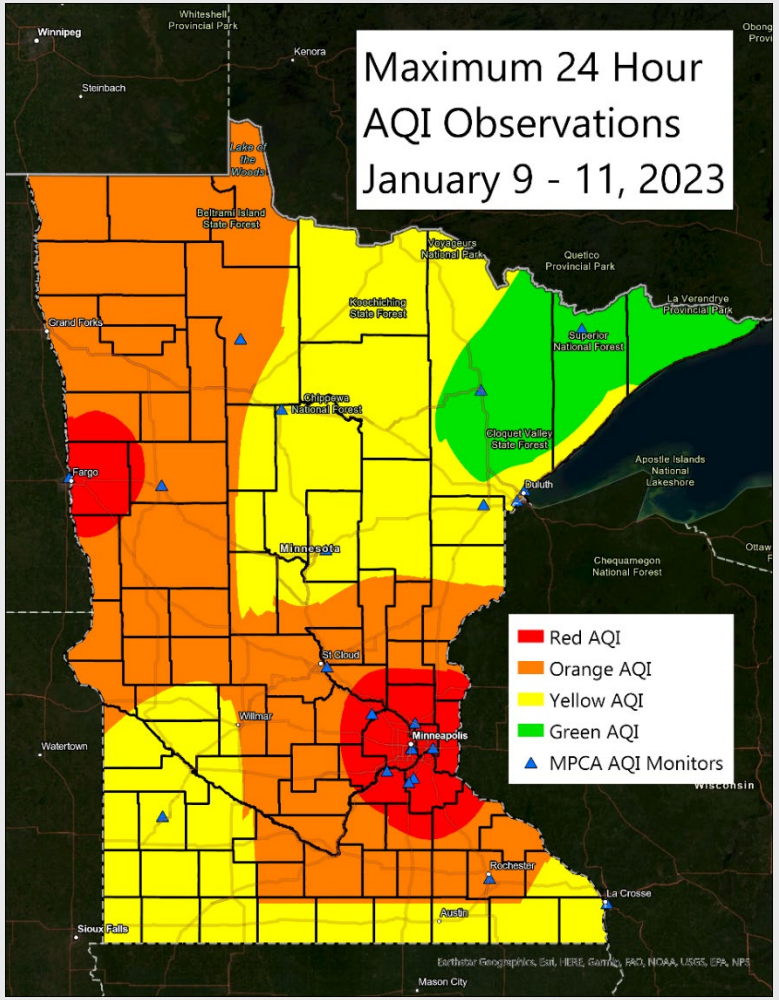




Shameless Self Promotion – GIS Maps



Forecasted



Final observations

Shameless Self Promotion – New Text Alerts

Air Quality Alert Message
Minnesota Pollution Control Agency
Relayed by National Weather Service Twin Cities/Chanhassen MN
115 PM CDT Wed Jun 14 2023

MNZ041>045-047>070-073>078-082>085-091>093-161100-
Anoka-Benton-Blue Earth-Brown-Carver-Chippewa-Chisago-Dakota-Douglas-Faribault-Freeborn-Goodhue-Hennepin-Isanti-Kanabec-Kandiyohi-Lac Qui Parle-Le Sueur-Martin-McLeod-Meeker-Mille Lacs-Morrison-Nicollet-Pope-Ramsey-Redwood-Renville-Rice-Scott-Sherburne-Sibley-Stearns-Steele-Stevens-Swift-Todd-Waseca-Washington-Watonwan-Wright-Yellow Medicine-
Including the tribal nations of Mille Lacs, Prairie Island, and Upper Sioux
Including the cities of Albert Lea, Alexandria, Apple Valley, Blaine, Bloomington, Brooklyn Park, Buffalo, Burnsville, Eagan, Eden Prairie, Farmington, Hastings, Mankato, Maple Grove, Minneapolis, Minnetonka, Northfield, Plymouth, Prior Lake, Ramsey, Rogers, Rosemount, Roseville, Shakopee, St. Cloud, St. Louis Park, St. Paul, Stillwater, Waconia, White Bear Lake, and Woodbury
115 PM CDT Wed Jun 14 2023

...AIR QUALITY ALERT NOW IN EFFECT THROUGH 6 AM CDT FRIDAY...

* WHAT...The Minnesota Pollution Control Agency has expanded the Air Quality Alert for fine particle pollution. The Air Quality Index (AQI) is expected to reach the Red or Unhealthy category.

* WHERE...Central Minnesota.

* WHEN...Through 6 AM CDT Friday.

* IMPACTS...Some members of the general public may experience health effects. Sensitive groups, such as people with lung disease (including asthma), heart disease, and children and older adults, may experience health effects.

* ADDITIONAL DETAILS...Smoke from Canadian wildfires has settled across central Minnesota this afternoon. AQI observations are in in the Red (Unhealthy for Everybody) category across the alert area and will continue to be until at least Thursday morning. Smoke will gradually dissipate across the area Thursday - but may be slower to clear in the Minnesota and Mississippi River Valleys. Therefore the alert has been extended until Friday mornning.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

The general public should limit prolonged or heavy exertion.Sensitive groups, such as people with lung disease (including asthma), heart disease, and children and older adults, should avoid prolonged or heavy exertion.

Reduce or eliminate activities that contribute to air pollution, such as outdoor burning, and use of residential wood burning devices. Reduce vehicle trips and vehicle idling as much as possible.

Keep windows closed overnight to prevent smoke from getting indoors.

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For information on current air quality conditions in your area and to sign up for daily air quality forecasts and alert notifications by email, text message, phone, or the EPA AirNow mobile app, visit https://www.pca.state.mn.us/air-water-land-climate/current-air-quality-conditions. You can find additional information about health and air quality at https://www.pca.state.mn.us/air-water-land-climate/air-quality-and-health.

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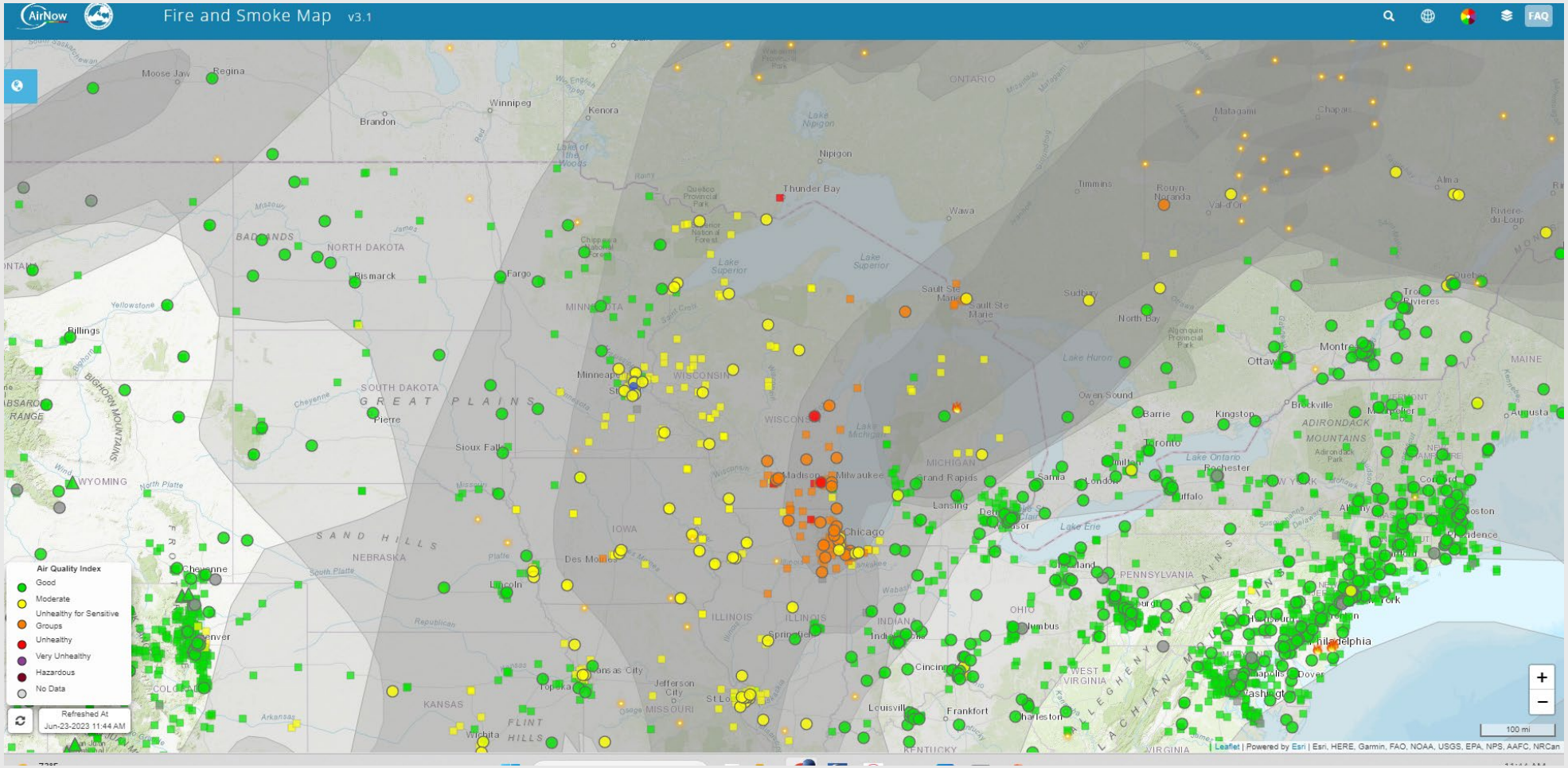
Taraldsen

Shameless Self Promotion – Air Now App

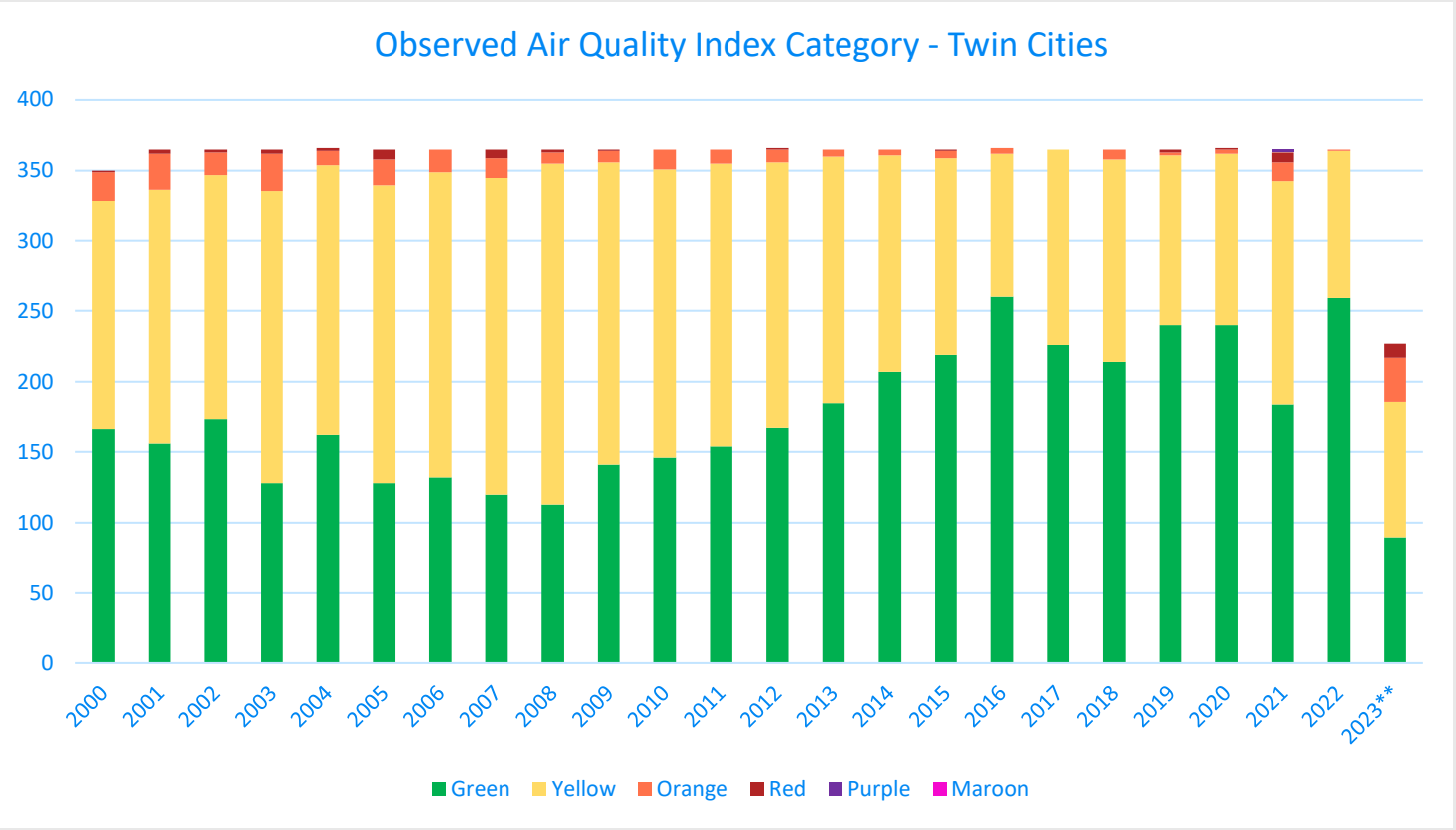
- MN Air App is Deprecated (RIP)
- Now using EPA Airnow App
- Will be alerting capabilities coming in 2023

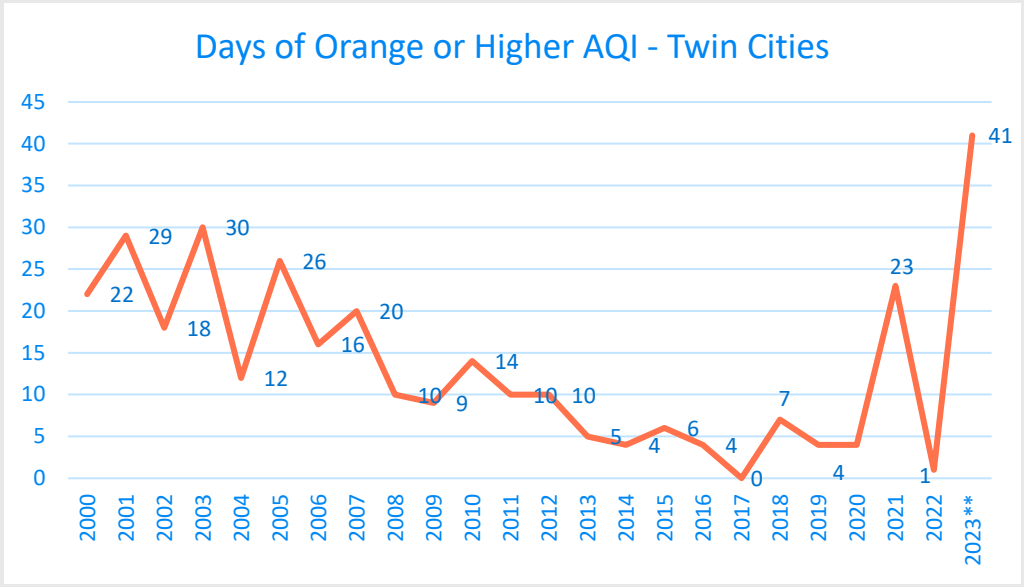


Air Quality Report Card

- Minnesota currently meets all federal heath standards for air pollution.
- Increase in air quality events has been caused by wildfires – both locally and in Canada.
- Will this trend continue – and how do we account for that?
- Ozone has continued to decrease – Evaluating how to incorporate 2023 data.
- Environmental Quality Board (EQB) currently calculating new report card – Will be posted on www.eqb.state.mn.us

AQI History


Observed Air Quality Index Category - Twin Cities
400
350
300
250
200
150
100
50
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023**
Green
Yellow
Orange
Red
Purple
Maroon


Days of Orange or Higher AQI - Twin Cities
45
40
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023**
22
29
18
30
12
26
16
20
10
9
14
10
10
5
4
6
4
0
7
4
23
1
41

Major Changes Coming in How We Do Regulatory Work!

2023 Legislative Session Brought About Major Changes

- MPCA will begin looking at Cumulative Impacts of Pollutants
- This will incorporate cross-media and non-chemical stressors
- Will result in multiple new positions on the team.
- Currently beginning rule make.
- Proposed rules will be on MPCA website (www.pca.state.mn.us)

- **Please comment on the proposed rules! Your feedback will help shape the future of this project.**

- Rules are anticipated to be completed by 2026

Thank you!
Questions?

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MINNESOTA POLLUTION CONTROL AGENCY